Solar-Terrestrial Centre of Excellence

Activity Report 2010

The Solar-Terrestrial Centre of Excellence, STCE is a scientific collaboration that focuses on the Sun, through interplanetary space, up to the Earth and its atmosphere and includes a Space Weather application and service centre.

The solid base of the STCE is the experience that exists in the Royal Observatory of Belgium, the Royal Meterological Institute and the Belgian Institute for Space Aeronomy. The STCE focusses on fundamental solar, terrestrial and atmospheric physics research, is involved in earth-based observations and space missions, offers a broad variety of services (mainly linked to space weather and space climate) and operates a fully established space weather application centre. The scientists act at different levels within the frame of internal, national and international collaborations of scientific and industrial partners. The STCE benefits also from the platforms of interaction offered through the ESA (SWWT, SWENET), EU (COST, FP7) and others (e.g. ISES).

The STCE's strengths are based on know-how, sharing knowledge, manpower, infrastructure and a reliable network in the Sun-Space-Earth interconnection.

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PART 1

A. Common Public Outreach and Science Communication

A.1. Objectives

With the 'Educational and Public Outreach', EPO – section we want to communicate and disseminate the content of the projects of the operational directorate solar physics and space weather. The target groups are

- **A.** The broad public,
- **B.** Students
- **C.** Scientists of the space weather community,
- **D.** Governmental/Commercial entities.

Each group is defined based on their background and interest.

The broad public is defined as the general public with no scientific background, people with no professional scientific interest in space weather, e.g. amateur astronomers and private solar observers, local institutes, schools... We address them in their own language with a non-scientific and understandable vocabulary, avoiding and explaining the jargon.

In the group 'students', we target undergraduate and PhD students. They should be addressed with a specific content. More scientific jargon and language is possible. With this group, we go further then only providing basic information. We target education in depth.

Group 'C' consists of researchers, scientists involved in instrumentation, observatories and applications.

The fourth group gathers the people, companies and institutes who are defined as end users. E.g. satellite operators have a commercial interest in space weather applications such as space weather monitoring and forecasts. Space tourism is another stake holder: space travel companies, space port operators, insurance companies.

The EPO project is a necessary and important activity as it strengthens the coordination role of the general manager. It is our task to point to the added value of the STCE's activities towards the whole society. The EPO project should raise the visibility of the activities of the STCE and raise awareness of the issues at hand, e.g. the implications of solar activity and space weather.

The EPO section offers also a platform for internal communication across the project boundaries.

A.2. Progress and results

We describe the content and define the target group of our actions undertaking within the EPO project.

A.2.1. Internal communication

Good internal communication is a necessary condition for a smoothly running group. It reflects on the external communication and strengthens our position in the scientific community.

The website is one of the tools to disseminate news among the STCE-community. The series of seminars are another way to establish contacts and exchange knowledge.

The highlight of internal communication is our annual STCE meeting: June 03, 2010. For the 2010 edition, we focussed on the collaborative nature of the STCE. We left plenty of room for discussion. In the plenary session, three STCE members zoomed in on the contribution of all the involved projects to three general topics:

1) Research and Modeling, by A. Zhukov,
2) Applications, Services, Data storage and exploitation, by D. Moreau,
3) Instrumentation by H. De Backer.

All work packages contributed to these overviews.

The afternoon was open for discussion in 4 parallel splinter sessions. In the splinter session, the session convenors focussed on a particular topic with relevance for the majority of the STCE-community. Participants were encouraged to present new insights, new collaborations, and added values. The 4 splinters were

- Space Science and Weather, chaired by J. De Keyser and F. Clette,
- Radiation and Earth Atmosphere, chaired by S. Dewitte and M. Van Roozendael,
- Ionosphere, chaired by R. Warnant and N. Bergeot,
- Radio Science, chaired by C. Marqué and H. Lamy.

All chairpersons gave a wrap up in plenary session.

The Radio Science Day of Oct 14, 2010 is a follow-up of the Radio Science splinter. During the splinter, the participants expressed their need to put up a common policy concerning Radio Science performed at the Space Pole. Sharing expertise, hardware and software between users of various radio experiments conducted on the plateau was perceived to be useful. During a half-day session people with an interest in Radio Science or in sharing the hardware/software facilities got the opportunity to introduce their work and express their needs towards the Radio Science Community at the plateau.

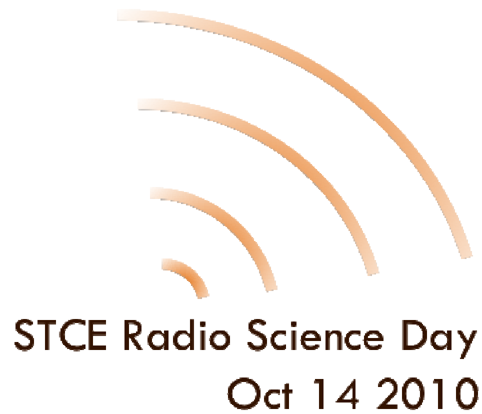


Figure 1: The Radio Science Day of Oct 14 is a follow up of the Radio Science Splinter at the annual STCE meeting. A next Radio Science Day is planned in May 2011.

A.2.2. Communication with the general public:

A.2.2.1. *Solar dome visits*

Visits to the USET dome were a key element of many public group visits to the SIDC by showing live observations of the Sun (weather permitting!) and a direct contact with a solar observing facility in operation.

A.2.2.2. *Amateur astronomers*

Despite the low solar activity, the communication towards the general public about solar activity and space weather continued proactively. Contacts set during press events or in previous years lead to questions to give information sessions to groups of interested people or to write articles in more popular journals intended for the general public or for journal with a public interested in astronomy and science. This results in publications in Science Connection, Guidestar, Solar Novus Today and the ESA-website and to series of seminars given in amateur astronomer clubs throughout Belgium.

A.2.2.3. *Course 'Collège Belgique'*

At the initiative of the the general STCE coordinator a proposal was introduced for a lecture series on Space Weather at the Académie Royale des Sciences in the framework of the "Collège Belgique" cycle. Frederic Clette (KSB) and Johan Dekeyser (BISA) presented a short course on Solar activity and space weather [249].

A.2.2.4.*Students: Dreamday*

The Dreamday is organized by ICHEC to help students to better know different jobs in different companies.The 18th of March 2010, a class of 5th secondary came to the Space Pole to meet scientists from the 3 institutes. They had the opportunity to ask questions about the job of scientist and to discuss about their curriculum to reach the job they have today.

A.2.2.5.*I love my Sun*

“I Love my sun” is an international project supported by COST Action ES0803, to create some awareness on space weather among the school children in Europe. We went in a class of 6 year old children to explain them what aurora is and how it is created. With a simple and illustrated presentation, they were given a lot of information about the Sun and the consequences of its activity on the Earth.
Some weeks after the presentation, the children are asked to draw the Sun. Results showed that children had well integrated the way the Sun was presented to them and the drawings showed the Sun in activity, with eruptions and not the Sun as they used to draw it before.

A.2.2.6.*Teachers: PROBA2@school*

We collaborated with the Vliebergh-Senciecentrum (VSC), an entity within the ‘Academisch Vormingscentrum voor Leraren’ of the KULeuven. The centre offers teachers and representatives of educational studies the opportunity to follow continuing-education courses. These courses have the goal to keep up with the development in the field of academic education and scientific research. Another goal is to develop a research critical mind and to bring in new didactical insights into the daily class practice.

The PROBA2 project is called: ‘Ruimteweer waarnemen met een Belgische satelliet’. The goal is to capture the attention of teachers. In a second step, we will work together with the interested teachers to develop concrete courses and exercises for students of the third grade ASO, TSO and KSO. Several applications are possible in statistics, mathematics, physics, and geography.

E. D’Huys and P. Vanlommel participated in several meetings on the organization and content of the educative PROBA2@school project.

The PROBA2 introductory course for teachers was given on March 24, 2010. Teachers got a written PROBA2 bundle. The teachers were D. Berghmans, E. D’Huys and P. Vanlommel.

Several schools showed interest: Paridaens Leuven, K.A. Berchem, Sancta Maria Leuven, H. Drievuldigheidscollege Leuven, St. Lutgardinstituut Beringen, Koninklijk Atheneum Landen, Klein Seminarie Hoogstraten, Stedelijk Humaniora Dilzen.

The first actual interaction between us and school students was undertaken in November. The school of Dilzen visited the PROBA2 Science Center and the RWC Belgium.

A.2.3. Communication with the press and governmental entities

A.2.3.1.*PROBA2*

The PROBA2 satellite is one of the key elements of the Belgian participation to Europe’s efforts towards monitoring solar variability and its effect on Space Weather. Benefiting from major co-funding from other sources, the data distribution and the integration in the operational space weather forecasting and monitoring is one of the key themes in the STCE.

The purpose and importance of the PROBA2 project was communicated towards the press and the broad public on several occasions.

In 2009, we had a press conference on 1 July concerning the shipping. The launch of PROBA2 was put into the picture during a champagne breakfast-press event on 2 November 2009. Third in this series of press conferences, we had a large event on 26 January 2010 about the first achievements and images. The European Space Agency and the Solar-Terrestrial Centre of Excellence invited the press and interested respresentatives from industrial and political environments. The the Royal Observatory of Belgium hosted the event. We focused on three points:

1. PROBA2 is the result of a successful European collaboration with major participation of Belgian industry,
2. The objective of the mission is to test new spacecraft and instrument technology in space,
3. The satellite is equipped with a quartet of new science instruments focusing on solar and space weather observations. For the two 'state of the art' solar telescopes SWAP and LYRA, the scientific responsibility lies in Belgium. The Czech Republic for the scientific experiments TPMU and DSLP.

We welcomed the Belgian Minister of Science S. Laruelle, and ESA Directors Mr Courtois and Mr Southwood. After the general part, a representative of Verhaert Space illustrated the technical successes. The principal investigators of SWAP and LYRA, B. Berghmans and J-F Hochedez, in collaboration with a TPMU/DSLP scientist commented on the first scientific achievements. Here, SWAP has the advantage that it visualizes the dynamic Sun. On Jan 15, 2010, SWAP witnessed an annular eclipse. Beside nice images, this gives also the possibility to study the black regions (shadow of the moon) in relation with diffracted light.

Figure 2: SWAP witnesses an annular eclipse on Jan 15. The results were presented to the press.

The formal part was concluded with a Questions & Answers session.

Following persons were available for interviews:

Mr Courtois ,	ESA Director of Technical and Quality Management
Mr Southwood,	ESA Director of Science and Robotic Exploration
Mr Strauch,	ESA PROBA2 project manager
Mr Teston,	ESA PROBA Programme Manager
Mr Berghmans,	Principal Investigator SWAP, scientist at ROB
Mr Hochedez,	Principal Investigator LYRA, scientist at ROB
Mr Defise,	Principal Investigator SWAP, General Manager CSL
Mr Preud'homme,	Commercial Director Verhaert Space
Mr Schmutz,	Director PMOD/WRC
Ms Wagner,	Belgian Federal Science Policy
Mr Stverak,	Scientist DSLP
Mr Bloomfield	Trinity College Dublin

Media response

Both written press and television broadcasters took the opportunity to target several people. A digital press map was distributed.

The media response was enormous:

1. Weerbericht één-television (BE)
2. De Standaard (BE)
3. Le Soir (BE)
4. RTE - Irish TV (IE)
5. Independant (IE)
6. Tagblatt (CH)
7. BBC (UK)
8. TV Oost (BE)
9. TV Bruxelles (BE)
10. SDA/ATS - Swiss news agency (CH)
11. Czech Radio (CZ)
12. Agence Belga - Belgian news agency (BE)
13. United Press International
14. Metrotime (BE)
15. Astronews (DE)
16. Nu (NL)
17. Skynews (Belga) (BE)
18. Nieuws (Belga) (BE)
19. Europa Press (ES)
20. Hirado (HU)
21. National Geographic (JP)
22. Omskinform (RU)
23. RND (RU)
24. Science Daily (US)
25. Physorg.com (US)
26. Alpha Galileo (UK)
27. …

The corresponding links can be found on http://proba2.sidc.be/index.html/gallery/breve/proba2-press-event-26-january-2010

ESA-TV made a commercial to promote the ROB contribution to the PROBA2 project. This commercial was intended for broadcasters to be picked up. Frank Deboosere, VRT, weather journal, used a part of it for his weather talk on 'één'. A broadcast like this, reaches a large part of the people in Vlaanderen.

Figure 3: J.F. Hochedez is being interviewed by the visual press on Jan 26 as the Principal Investigator of LYRA.

Figure 4: We see the scale model built by the ROB in collaboration with the STCE as it was presented on the Jan 26 press event.

PROBA2 scale model

The ROB technical workshop built a scale model of PROBA2 that was shown at the 26 January press event. The model hit the bull's eye. PMOD/WRC and Spacebel expressed their interest to order and pay for a scale model. Special arrangements were taken for the request of PMOD WRC to put a replica of LYRA into scale model of PROBA2. Two other replica were made for own use. At the European Space Weather Week 7 in Brugge, PROBA2 was shown at the Space Weather fair. The scale model is used to illustrate our information sessions given in the frame of PROBA2@school or seminars for the broad public.

General conclusions

The collaboration with ESA and the international partners gave an extra boost to the prestige of the event and accordingly to the ROB and the STCE. The organization went very smooth even if it was quite a challenge to preserve a reasonable balance between all partners and the organization. With the help of several ROB staff and the cell 'Event Support', the outcome was very professional.

A.2.4. Communication with scientists

A.2.4.1. *Organizing conferences: 2010 CESRA Meeting*

CESRA is the Community of European Solar Radio Astronomers, which convenes every 3 years for a meeting discussing the last developments in the field of solar radio physics. During the 2007 CESRA meeting, C. Marqué proposed that the next CESRA meeting could be organized in Belgium. In 2009, the CESRA board allocated to the STCE/ROB the task to organize the meeting after reviewing a proposal made by C. Marqué and A. Vandersyppe. The Floreal Club, a vacation center in the city of La Roche en Ardenne was chosen as venue.

Local and Scientific Organizing Committee

The role of the LOC was to organize all practical matters linked to the meeting: looking for sponsors, renting the venue, taking option on hotel rooms, selecting the conference diner site, organizing the social activity, organizing transportation, managing the registration of participants and abstract submissions, composing & printing booklets, managing invitation letters for visa applications, setting up of the meeting.

The Scientific Organizing Committee established the scientific program of the meeting (contributed talks, invited speakers, sponsored participants etc…)

Meeting organization

The 2010 CESRA meeting adopted the format of previous workshops of this organization; plenary sessions in the morning where contributed and invited talks were presented, and splinter sessions in the afternoon where all participants could present and discuss their results.

Poster sessions were scheduled the whole week. Posters were on display in the room where coffee breaks and cosy corners were installed, allowing participants to discuss.

The meeting took place from June 15th to June 19th. A welcome reception was organized in the evening of June 14th. The social activity took place in the afternoon of June 16th. The conference dinner was organized in the evening of June 17th.

Scientific program and organization

The SOC choose the general theme of the meeting to be: *Energy storage and release through the solar activity cycle - models meet radio observations* and it defined five plenary and posters sessions:

1. Quiet sun and plasma diagnostics of the solar atmosphere
2. Pre-flare and pre-CME activity

3. Particle acceleration in solar flares
4. Large-scale disturbances
5. Solar activity cycle

A morning session was devoted to instruments, database and reports of radio observatories.
Plenary session programs were made of contributed talks, selected from the submitted abstracts and of the following invited talks:

- Bob Bentley (London): "Virtual Observatory Projects"
- Eduard Kontar (Glasgow): "Electron acceleration and propagation in solar flares"
- Salvatore Mancuso (Torino): "SoHO UV & white light diagnostics of coronal shock waves"
- Kiyoto Shibasaki (Nobeyama): "The quiet Sun at radio wavelengths"
- Manuela Temmer (Graz): "Coronal mass ejections"
- Manolis Georgoulis (Athens): "Pre-flare and pre-CME configurations"

The splinter sessions were devoted to:

- Quiet Sun
- Pre-flare & pre-CME activity
- Particle acceleration in flares
- Large-scale disturbances and shocks

Eighty-nine abstracts were submitted for presentations.

A full program and overview can be found on the website http://sidc.be/CESRA2010.

Members of the SOC

- C. Marqué (STCE, co-chair)
- H. Aurass (Potsdam)
- K. –L. Klein (Meudon)
- MacKinnon (Glasgow)
- V. Melnikov (Nizhnyi Novgorod)
- A. Nindos (Ioannina, co-chair)
- S. Poedts (Leuven; European Solar Phys Div of EPS)
- S. Pohjolainen (Turku)

List of local contributors

- Vandersyppe (ROB)
- O. Boulvin (ROB)
- E. D'Huys (STCE)
- O. Lemaître (ROB)
- Ph. Motte (ROB)
- P. Vanlommel (STCE)
- R. Van der Linden (STCE/ROB)
- The technical service of ROB
- The rest of the SIDC team

A.2.4.2.*Organizing conference: Turbulence and Multifractals*

From 09 to 11 June 2011, a conference 'Turbulence and Multifractals in Geophysics and Space' was organized. M. Echim, H. Lamy and J. De Keyser were members of the scientific committee and took care of the local organization. The conference was organized on the occasion of Professor's Tom Chang visit at the Belgian Institute for Space Aeronomy.

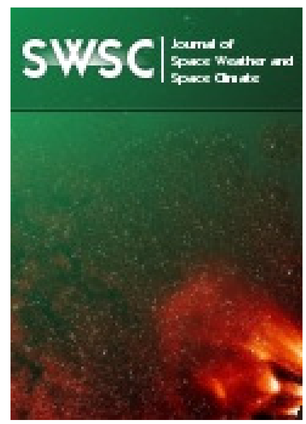
A.2.4.3.*Space Weather and Space Climate Journal (SWSC)*

The STCE has taken charge of the editorial office a new European journal for Space Weather: the *Journal of Space Weather and Space Climate* (SWSC) is an international multi-disciplinary and interdisciplinary open access journal set up under the auspices of the COST Action ES0803. Besides providing the secretarial support to the editorial office, the STCE provides several members to the Editorial Board of the Journal.

See http://www.swsc-journal.org

The SWSC Journal publishes papers on all aspects of space weather and space climate including but not limited to

- fundamental and applied scientific research including theory, observation, modeling and prediction
- technical applications and engineering solutions
- impact on humans and technology in space, in the air, at sea and on land
- societal and economic implications
- educational and dissemination concepts and experiences
- development of user-targeted products and services
- scientific, technical, political and commercial initiatives



The SWSC accepts manuscripts related to space weather and space climate from a broad range of fields including solar physics, space plasma physics, aeronomy, planetology, radio science, geophysics, biology, medicine, astronautic, aeronautic and electrical engineering, meteorology, climatology, mathematics, economy and informatics. JSWC publishes regular research articles, short communications, invited reviews, technical and observational reports, strategic and educational articles and concise project reports. All manuscripts are peer reviewed. Accepted papers are published in electronic form only, taking advantage of the extensive opportunities offered by electronic media.

The SWSC is an open access journal

A.2.4.4.*Participation to Summer School in Trieste*

The STCE actively participated in the International Advanced School on Space Weather Modelling and Applications held in Trieste, Italy for PhD students. The science and data exploitation of PROBA2, our space weather monitoring and forecast activities were the subject of 3 half day sessions. The teachers were D. Berghmans, D. Seaton and P. Vanlommel. From the STCE E. D'Huys participated as students. The school brought in total 86 people together.

A.2.4.5.*The Seventh European Space Weather Week, ESWW7*

A highlight for the space weather community is the annual European Space Weather Week. It was for the fifth time organised in Belgium by the Solar-Terrestrial Centre of Excellence. We welcomed 250 participants from all over the world.

Ronald Van der Linden and Petra Vanlommel are members of the Programme Committee responsible for the scientific program. The SIDC and communication cell of the STCE is responsible for the local organisation and the exploitation of the site. This year's ESWW was held in Brugge.

A report

Space Weather got a boost thanks to the significant investments for example by the EU FrameWork 7 and by the Space Situational Awareness (SSA) Program of ESA. The European community working in the field of space weather has a natural focus on the Space Weather part of the SSA. This ESA program supports new and existing initiatives that meet the requirements of a broad group of users of space weather applications and products. At the ESWW it became clear that SSA is an opportunity for Europe to strengthen its skills and play an important role in the space scenery.

From this increasing number of space weather programs, one could conclude that space weather is overall getting worse. It's not, but our vulnerability is increasing as our technology is getting more advanced. Thus, the space weather effects on spacecraft and its environment are a hot issue. Post-analysis of space weather radiation events causing hazardous effects in spacecraft, helps to handle future events. It becomes more and more critical for space craft engineers to be one step ahead of the Sun. More in-depth research, modelling and forecasting can help. Data input is crucial for performing this task.

Figure 5: For the seventh edition, we developed this poster. The focus lies on the spacecraft and spacecraft environment.

The ESWW showed again clearly and amply that we are at the beginning of a new era, with enormous data flows coming in, e.g. from the NASA SDO mission or from dedicated space weather monitors such as PROBA2. To handle all that data we need new machinery such as virtual observatories, online quicklook viewers and automatically generated data and event catalogs. Space weather products and services, following naturally as the output of research and modelling activities evolve rapidly. We are progressing to more mature, worldwide, American and European application centres. But there are limitations to our space weather capabilities, including the sparsity of certain experiments, e.g. coronographs. Efforts are done, however, to assimilate data into models and implement these models into a usable platform. Bridging the gap between models and applications is an issue relevant for all physical layers, from the Sun and the corona, through the heliosphere and the magnetosphere, across the radiation belts, over the earth poles, the ionosphere, to the Earth's surface. This diversity of scales and processes is difficult to control, but several groups try.

Beside these hard core issues, other side-events are also on the ESWW-menu contributing to a lively and dynamic conference:

- The space weather tutorial served as an ice-breaker and helped the people in the field to get into the subject.
- The keynote lecture dragged us into the world of Birkeland and aurora's. Birkeland's life teaches us the need to communicate with non-experts and to build a firm bridge between pure science and applications.
- The debate put the question about space exploration on the foreground: 'What is the rationale behind the decision to send humans to space?' It's in the human nature to explore, how small or grown up you are. Children's biggest fantasy is about dinosaurs and ... space, the past and the future.
- Further, the possibilities of a scientific market were explored during a fair: the Matroshka phantom drew our attention to the received radiation dose while traveling through space, the aurora and the Sun were visible in 3D, a huge radio receiver was mounted in the exhibition hall and the planeterrella experiment was also demonstrated.
- And of course, the students did their best to deliver a nice oral or poster presentation. Two nominees left home with a small but nice present in their bags.

The European Space Weather Week offers the platform to meet in a formal and informal environment, during the plenary sessions, the numerous splinters and a whole bunch of side events like the tutorial, the space weather fair, the debate-evening. Many, scientists, engineers, space weather product developers, students, national delegates, ... take this opportunity.

<u>STCE presence at ESWW7</u>

The STCE was very well represented at the ESWW7: organisation of the event, poster contributions, participating at the space weather fair. We list the contributions of the STCE to the fair.

- ➢ H. Lamy presented BRAMS, a new radio observing facility to detect and characterize meteors. The principle of meteor detection with radio techniques was explained and illustrated with an impressive receiving station set up.
- ➢ D. Berghmans presented a PROBA2 stand. Publicity was made for the Guest Investigator Program which offers visiting scientists the opportunity to work at the PROBA2 Science Centre and explore the science in SWAP and LYRA. Selected investigators spend one or a few months with the Principal

Investigator (PI) teams to obtain expert knowledge on the instruments LYRA and SWAP. The scientists can actively participate in the daily commanding of SWAP and LYRA. The ESWW7 indeed offers a good opportunity to get this initiative known in the space weather community. Another focus of the stand lied on the scientific outcome of the past research done with SWAP and LYRA data. Special attention was given to the fact that PROBA2 is 1 year in space since the launch on November 02, 2009.

- S. Raynal and P. Vanlommel presented the STCE. A movie displayed the science, applications and services, and policy of the STCE.

Here under, we list the tasks and events for which the coordination cell of the STCE was responsible.

Scientific side events

- Space Weather Tutorial and quiz,
- Space Weather Fair
- Contest: The Best of

Local Organization

- Suitable site and set up
- Creation of an esww poster
- Website: creation and instantaneous update
- Social events: welcome reception, conference dinner, beer tasting, coffee breaks, sandwich lunches
- welcome pack: booklet, USB-stick, relevant touristic material
- Promotion material: invitation for event, fair, keynote, debate
- Sponsoring
- Information desk
- Cosy corner
- Wired and wifi connection
- Daily briefings for participants
- Instantaneous display of photos on HD screen with a software-tool developed by O. Lemaître
- Photographs
- …

Actions towards the Press and Public

- E-Invitation for the debate sent to the press, the public and amateur astronomers
- E-Invitation for the keynote lecture and the welcome reception for VIPS.
- Press conference, 30 minutes before the start of the debate.

A.2.4.6. *The eHEROES project*

The STCE is a partner in a submitted FP7 proposal '*Environment for Human Exploration and RObotic Experimentation in Space', eHEROES.* KULeuven is the main proposer. Giovanni Lapenta is the coordinating person. The proposal contains 4 scientific packages: Value-added data on solar sources, Solar and Space Events and their Evolution, Exploring Space in Time, Impact on Space Exploration. The EPO-officers of the STCE are especially involved the package 'Dissemination, exploitation and management of intellectual property'. We defined the target groups, the work structures and tool, and the content for dissemination. The STCE will take the lead in this package.

A.2.4.7. *Participation in COST ES0803 action*

Since November 2010, P. Vanlommel is work group leader of WG3 'Exploitation – Dissemination - Education – Outreach' of the COST ES0803 action. The most challenging in this task is to set up a structure

in which all the actions of the WG3 fit. Up to now, the deliverables were actions standing on their own without any connection: a bunch of listed items. A well defined frame and policy was absent.
The space weather portal could act as a central point to store all the deliverables and services of and offered by the COST-members. From this central point, the dissemination process can start. To be successful in this process, the space weather portal should include an easy guidance for our target groups which we defined in B.2.1. Each group looks for specific information in a specific language/jargon. The space weather portal should be more then only a technical deliverable. It should act as a portal guiding visitor towards the information they need.
The active participation of the EPO officer in this COST action can result in a benefit for the STCE since the goal of this COST WG is the same.

A.3. Perspective for next years

The internal communication needs an upgrade. Information should flow top-down but especially horizontal between the different projects. Efforts have been done in the past to improve the horizontal communication, e.g. the annual meeting. The EPO section should make an even larger effort to initiate horizontal communication.

We will proceed with the project PROBA2@school. Once we visited all the participating schools, we will have an evaluation meeting. We want to know what sort of efforts the schools did, where we can fine-tune our input given to the schools, which parts of the offered program can be worked out more into depth, how do we proceed for the next school year?

We will participate at Le Bourget 2011. This is a chance for us to identify more member users of our STCE services in the commercial area. As a scientific group offering space weather and aeronomy applications, we should enlarge the group of users. Space Weather and aeronomy is still a new field of which the boundaries of interest are not yet discovered.

A.4. Partnerships

List of international collaborators having actively contributed to the project in the last year

- PROBA2 consortium
- SOTERIA consortium
- SDO consortium

List of national partners collaborators having actively contributed to the project in the last year

- Katrien Bonte, KULeuven
- Vliebergh-Censie, lerarenopleiding KULeuven

A.5. Missions

Assemblies, symposia, conferences:
- SOTERIA annual meeting, Davos, Swiss, January 18-20, 2010
- PROBA2 SWT, La Roche, Belgium, June 14-16, 2010
- CESRA, La Roche, Belgium, June 15-19, 2010
- ESWW7, Brugge, Belgium, November 15-19, 2010

Commissions, working groups:
- PC-meeting esww7, Brussels, Belgium, January 26, 2010
- PC-meeting esww7, Rome, Italy, May 27-18, 2010
- PC-meeting esww7, Brussels, Belgium, October 06-07, 2010
- PROBA2@school, Leuven, Belgium, February 23, 2010
- PROBA2@school, Leuven, Belgium, May 05, 2010

Visits to

- SES-Astra, Betzdorf, Luxembourg, August 18, 2010

Informative Visits of ROB-RWC-PROBA2 Science Center

- Studente 6de Middelbaar, February 11, 2010
- Stedelijke Humaniora Dilzen, November 23, 2010
- Lessius Hogeschool Mechelen, contactpersoon Adriaan Tirry, October 29, 2010

Interview

- In the frame of a Master thesis 'wetenschapsvoorlichting en vertrouwen', Wijsbegeerte en moraalwetenschappen, promotor prof dr. Gustaaf C. Cornelis, Vrije Universiteit Brussel, Etterbeek

Informative sessions

- Studiekeuze-beroepen, Sint-Jozefs Instituut Betekom, March 08, 2010
- Workshop wetenschap KULeuven, Belgium, March 16, 2010
- Kick-off PROBA2@school, Leuven, Belgium, March 24, 2010
- Volkssterrenwacht Beisbroek, Brugge, Belgium, May 05, 2010
- Jaarvergadering VVS, werkgroep Zon, Genk, Belgium, September 18
- Werkgroep Aardrijkskunde Brabant, Heilig Hart Instituut, Leuven, Belgium, September 28
- Sint-Jozefsf College, 4de leerjaar, Aarschot, Belgium, December 13, 2010

Field missions:

- Brugge, Belgium, esww7-site

B. Visiting Fellows program

- Janos Lichtenberger and Csaba Ferencz (Hungary) visited us on 2-3 March in the context of VLF measurements of whistlers.
- Dr. Ingmar Sandberg, National Observatory of Athens, Athens, Greece, visited us during 6 weeks to work with us on Solar Energetic Particle (SEP) Events in May-June, under the supervision of N. Crosby. He gave a seminar on his processing of ESA/SREM data.
- M. Echim and H. Lamy hosted a visit of Prof. Tom Chang (MIT, USA) to the Institute in early June.
- M. Echim, H. Lamy, and J. De Keyser organized an international workshop devoted to "Turbulence and Multifractals" at the Space Pole on 9-11 June 2010, with the support of the STCE. There were 18 presentations and lively discussions on future work and cooperation. E. Gamby created and managed a website devoted to the event.
- On 17 June 2010 N. Crosby hosted a Space Weather Working Team (SWWT) Steering Board meeting at BIRA-IASB and on 18 June 2010 a SWWT Plenary at ROB.
- A SEP Data Workshop was organized at BIRA-IASB on 15-17 Sept. 2010 by N. Crosby.
    - Dr. Rikho Nymmik, Moscow State University, Moscow, Russia, gave the STCE seminar "Modeling Solar Energetic Particle Fluxes: Some Key Problems", 14 Sept. 2010.
    - Other participants in the workshop included Ingmar Sandberg (Greece), James Adams (USA) and Steve Gabriel (U.K.), as well as various other members of the SEPEM consortium and ESA.
- Dr. Anton Artemyev (IKI, Moscow) visited the Institute on 25-26 November to work with J. De Keyser on empirical reconstruction techniques and magnetotail physics. He gave a seminar on Friday 26 November, entitled "Thin current sheet in Earth's magnetotail: Cluster observations and analytical model".
- Dr. Mirela Voiculescu (Univ. Dunarea de Jos, Galati, Romania) visited the Institute on 29 November - 11 December to work with V. Pierrard and F. Darrouzet on the trough and with J. De Keyser on

subauroral ion drift. She gave a seminar “Characteristics of ionospheric troughs observed in the premidnight sector; relationship with inner magnetosphere and interplanetary conditions” on 9 December.

PART 2: RESEARCH & MODELLING

A. Energetic events in the Solar Atmosphere

A.1. Physics of coronal mass ejections – 3D dynamics

A.1.1. Description

The Solar Terrestrial Relations Observatory (STEREO) spacecrafts were launched with the objective of obtaining stereoscopic observations of the Sun from a near-Earth orbit. A large number of events characterised by distinctive border regions and clear facets have been the stereoscopically reconstructed including CMEs in the plane of sky view, and EUV observations of magnetic loops or active. In contrast, a variety of studies on EUV waves have been carried out using STEREO/EUVI data without the stereoscopic reconstruction of the diffusive wave fronts due to the inherent difficulties of the points identification in diffusive and almost homogeneous regions. However, the reliable reconstruction of the 3-D parameters of EUV waves is essential and critical for the understanding of their nature.

A.1.2. Progress and results

Two advanced methods have been developed to deal with the stereoscopic reconstruction of diffuse homogeneous objects such as EUV wave fronts and dimming. The methods permit the 3D reconstruction of the evolving complete structure of an EUV wave - observed by SECCHI EUV telescopes (see Figure 6*)*. The first one deals with the reconstruction of on-disk diffusive events during the initial stage of their development when the pair images from STEREO-A and STEREO-B spacecrafts differ. In this case techniques of epipolar geometry to reconstruct the 3D parameters of event are applicable.

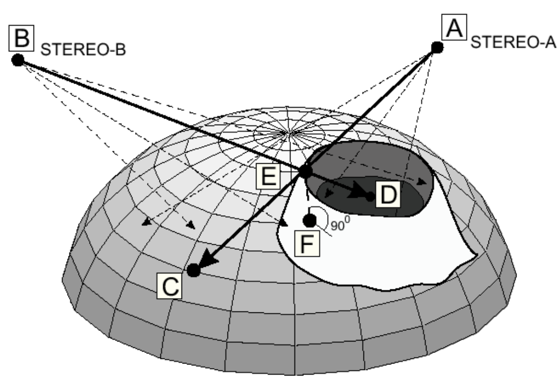


Figure 6: 3D parameters reconstruction of EUV waves - Statement of the problem.

The other method deals with the stereoscopic reconstraction of diffusive events at their latter stage when the images of STEREO A and B are similar to each other and it is impossible to match singular points.We use a robust method to identify automatically the segments of the diffuse front on STEREO. Despite the complexity of the methods they are both applicable for similar structures with non-distinct borders.

In general, the problem of point matching needs a very careful elaboration. We have shown that there are always exist regions where stereoscopic tools can not be applied at all for some segments of diffusive objects as the problem becomes ill-posed and solutions unstable.

A.1.2.1.*Main results*

Full 3D parameter of EUV wave dynamics have been reconstructed, such as the 3D spatial coordinates of the wave front crest, the inner front and outer boundaries, and the vertical and horizontal speeds (see Table 1).

	Eastern Wave Front				Western Wave Front			
Time	Height [Mm]	Distance from inner border to Ec [Mm]	Distance from outer border to Ec[Mm]	Wave front width [Mm]	Height (Mm)	Distance from inner border to Ec [Mm]	Distance from outer border to Ec[Mm]	Wave front width [Mm]
4:25 UT	18	--	--	--	35.5	--	--	--
4:35 UT	93	75	195	120	109	55	--	--
4:45 UT	14.5	185	385	200	<14.5	155	345	190
4:55 UT	14	275	555	280	<14	235	>445	>210
5:05 UT	<14	375	--	--	<14	295	>445	--

Table 1. Characteristics describing evolution of 3D structure of the eastern and western wave front during time interval 4:25 UT - 5.05 UT (in units of 1Mm).

Furthermore, we have identified unumbigously regions of dimming, low coronal extension of CME and different parts of the wavefronts (crest and borders). It has been rigorously demonstrated that:

- The EUV wave initiates at a certain height from the solar surface.
- The EUV wave undergoes phases of growth and declining.
- The velocity of the CME bubble border coincides with the speed of the inner front boundary.
- The borders of wavefront coincide with the borders of CME bubble.
- The considered EUV wave event was triggering by the lower extention of the CME bubble during the whole observation time of event. This is an important result that gives evidence on the type of the triggered mode and solves a long standing debate in the literature.

These results are published in: O. Podladchikova “Three-Dimensional Structure Evolution of an EUV Wave”, submitted to Astrophys Journal, 2011.

A.1.3. Perspective for the next years

The main perspective for next year on this activity is to present the full 3D evolution of the EUV eruptive events including also the dimmings and eruption centers. We hope to develop and use a semi-automatic stereoscopic technique to analyse the 3D structure for a set of events in order to provide some generalized characteristics and conclusions for such events.

B. Solar Atmosphere

B.1. Solar activity

B.1.1. Description

The ultimate goal of our investigations of the solar activity is to understand the structure and variability of the solar atmosphere. This has important implications for several unsolved problems of solar physics, in particular coronal heating and the mechanism of solar eruptions – flares and coronal mass ejections (CMEs) – that have a potential influence on space weather.

A particular attention is paid to the investigation of the structure of CMEs, of Interplanetary CMEs (ICMEs), their relationship and link with disturbed space weather conditions at Earth, using the data from SOHO, ACE, STEREO, Hinode, PROBA-2 and SDO missions. Our studies therefore address all stages of the CME evolution, starting from the pre-eruptive coronal configuration (streamers, active regions), continuing with CME signatures in the low corona (dimmings, EIT waves, erupting filaments), the CME structure and dynamics in three dimensions, properties and propagation of corresponding structures (ICMEs) in the interplanetary medium, and finishing with their potential geoeffectiveness.

B.1.2. Progress and results

B.1.2.1. *Interpretation of the coronal spectral line broadening in coronal dimmings*

Spectroscopic UV and EUV observations of the solar transition region and corona, such as the ones provided by SOHO/SUMER and Hinode/EIS, are highly suited to study flows of mass and energy in the solar atmosphere. They provide diagnostics on plasma thermal and nonthermal velocities and are thereby important for studies of coronal heating, solar wind acceleration and eruptive solar phenomena.

A spectroscopic investigation of solar eruptive phenomena in the low corona was undertaken, in paticular a study of the coronal line profile distortion in dimmings using Hinode/EIS. It was demonstrated earlier that coronal dimmings are the most frequent extreme-ultraviolet (EUV) signature of CMEs. However, the spectroscopic diagnostics of their plasma is difficult due to scarce observations. Fe XII (195.12 Å) line profiles observed by Hinode/EIS in a coronal dimming after an X-class flare on December 13, 2006 were analyzed. Line profile distortions were quantified with empirical coefficients (asymmetry and peakedness) that compare the fitted Gaussian to the data. It was found that the apparent line broadenings reported in previous studies are likely to be caused by inhomogeneities of flow velocities along the line of sight, or at scales smaller than the resolution scale, or by velocity fluctuations during the exposure time (Figure 7). The increase in the amplitude of Alfvén waves cannot alone explain the observed features, contrary to statements in the literature. A double-Gaussian fit of the line profiles shows that, both for dimmings and active region loops, one component is nearly at rest while the second component presents a larger Doppler shift than that derived from a single-Gaussian fit.

B.1.2.2. *EIT wave studies*

EIT waves are large-scale bright fronts propagating in the solar corona in association with CMEs. An invited review paper on EIT waves was prepared. An overview of the observed properties of large-scale wave-like fronts in the solar atmosphere (Moreton waves, EIT waves and similar phenomena observed in other wavelengths) was presented. The models proposed to explain these phenomena were reviewed. A particular emphasis was put on the recent EIT wave observations made by the STEREO mission. New key observational results and their implications for EIT wave models were discussed. It was concluded that no single model could account for the large variety of observed EIT wave properties. Prospects for future investigations of this complex phenomenon were outlined.

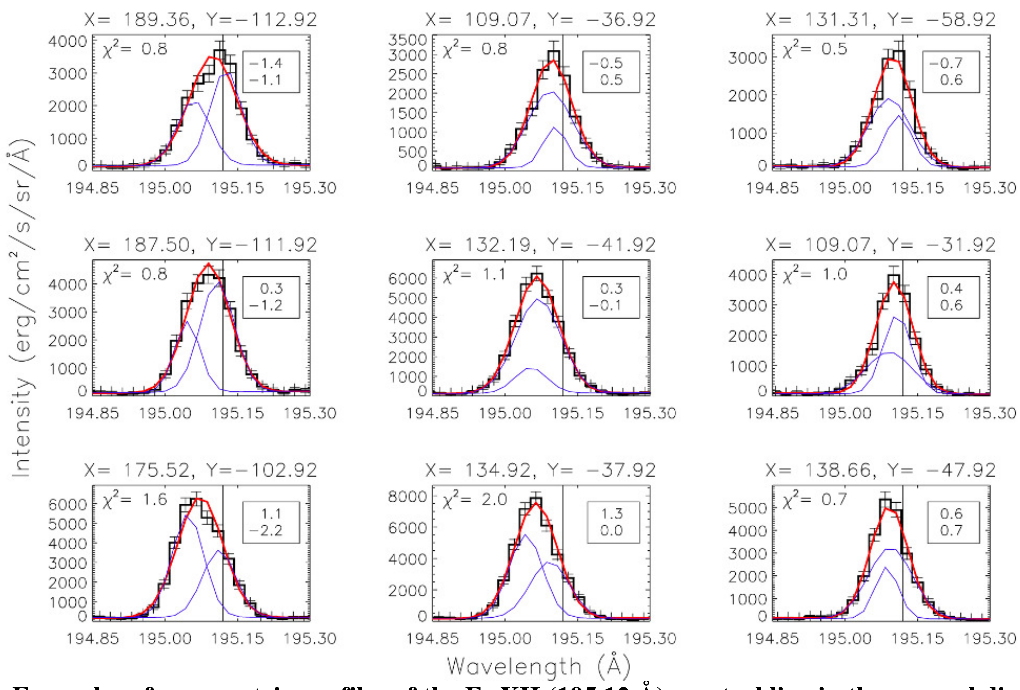


Figure 7: Examples of asymmetric profiles of the Fe XII (195.12 Å) spectral line in the coronal dimming associated with a CME on December 13, 2006. The red curve is the single-Gaussian fit, which does not account fully for the profiles. The blue curves show two components of the double-Gaussian fit that better describes asymmetric line profiles. This indicates that Alfvén waves alone cannot explain the observed broad line profiles and flow inhomogeneities or velocity fluctuations are involved. From Dolla and Zhukov (2011).

One of the first EIT wave events that were observed by STEREO/SECCHI from widely separated viewpoints was studied. It was found that EIT wave is a bimodal phenomenon. The wave mode represents a wave-like propagating disturbance, probably a fast magnetosonic wave. The convective mode is the lateral bulk mass motion of coronal plasma due to the restructuring of the coronal magnetic field during the CME lift-off. The convective mode also allows us to explain stationary EIT wave fronts that are sometimes reported. Both modes are coupled during the EIT wave propagation in the corona. The bimodal physical nature of EIT waves may explain the inability of existing models to explain all EIT waves in the framework of a single physical mechanism.

There is strong evidence that some of EIT waves might be fast magnetosonic waves, or at least have a fast magnetosonic wave component. By making measurements of the wave speed, coronal density and temperature, it is possible to calculate the quiet Sun coronal magnetic field strength using coronal seismology. An EIT wave observed on February 13, 2009 by the SECCHI/EUVI instruments onboard the STEREO spacecraft was investigated. The two spacecraft were situated in quadrature, i.e. with the angular separation of 90 degrees. The wave epicenter was observed at disk center as seen from the STEREO B satellite. The background coronal density was derived through Hinode/EIS observations of the quiet Sun, and the temperature was estimated through the narrow temperature response of EUVI bandpasses. The density, temperature and speed measurements allowed us to estimate the quiet Sun coronal magnetic field strength to be around 0.7±0.7 G.

B.1.2.3. *CME initiation in the low corona observed by SWAP and SECCHI*

A study of the CME initiation observed on April 3, 2010 by SWAP onboard PROBA2 and SECCHI onboard STEREO was performed. A three-dimensional reconstruction of the eruption was made (Figure 8). It was found that the event unfolded in two parts: an initial flow of cooler material confined to a height low in the corona, followed by a flux rope eruption higher in the corona. It was concluded that mass offloading from the first part triggered a rise and, subsequently, catastrophic loss of equilibrium of the flux rope.

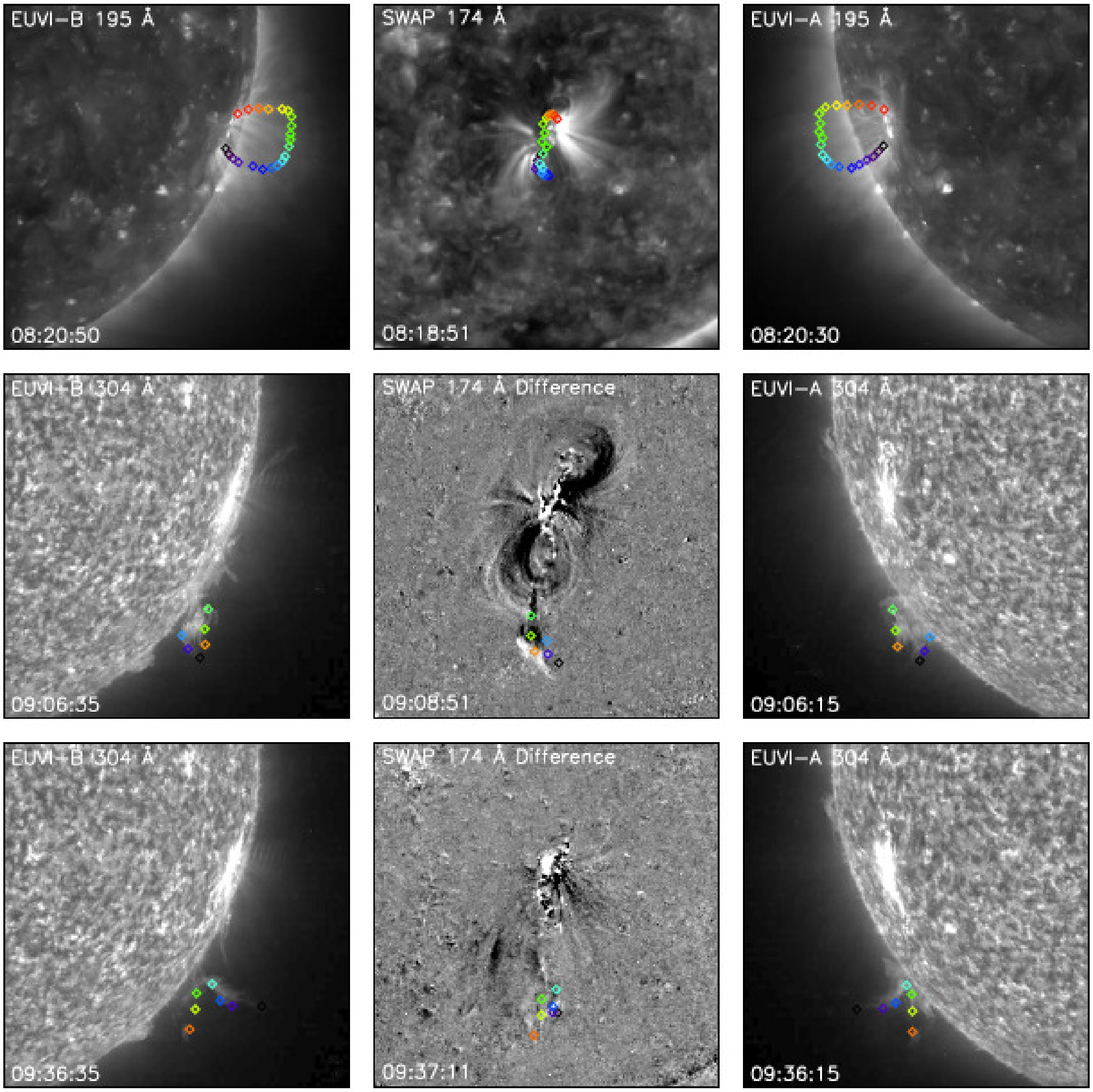


Figure 8: The initiation of a CME on April 3, 2010 observed by SECCHI/EUVI onboard STEREO A and B (right and left columns respectively) and SWAP onboard PROBA2 (middle column). Reconstructions of three different structures seen during the eruption are shown. The first row shows a reconstruction of a large, loop-like structure. The second row shows the initial mass flow that triggered the eruption as it moves southward. The final row shows a reconstruction of the final flow of the eruption. The color helps to identify individual reconstructed points in projections from each point of view.

B.1.2.4. *Coronal shock waves and their relation to flares and CMEs*

The origin of coronal shock waves is a subject of a long-standing debate. Coronal shocks can be either flare-generated freely propagating blast waves, or CME-driven shocks. Since CMEs and flares are usually closely synchronized, it is hard to give a conclusive answer. A multi-wavelength study of large-scale coronal disturbances associated with several CME/flare events was performed. The study was focused on the events in which the flare energy release, and not the associated CME, is the most probable source of the shock wave. Therefore, events associated with rather slow CMEs were selected. To ensure minimal projection effects on the CME speed measurements, only events related to flares situated close to the solar limb were included in the study. Radio dynamic spectra and positions of radio sources were used together with LASCO and EIT observations. The kinematics of the shock wave signatures, type II radio bursts, was analyzed and compared with the flare evolution and the CME kinematics. It was found that velocities of the shock waves were significantly higher, up to one order of magnitude, than the contemporaneous CME velocities. On the other hand, shock waves were in a close temporal association with the flare energy release that was very impulsive in all events. This suggests that the impulsive increase of the pressure in the flare was the source of the shock wave.

B.1.2.5. *CMEs and their interplanetary counterparts*

Classically, CMEs are observed using coronagraphs, so the coronagraphic data play a crucial role in understanding the structure and evolution of CMEs. The data from SECCHI COR1 and COR2 coronagraphs onboard STEREO can be used to reconstruct reliably the 3D structure of CMEs (Figure 9). Their structure, direction of propagation and speed in three dimensions remain key parameters in CME science. A review paper was prepared, where the state-of-the-art techniques used to reconstruct the aforementioned parameters were analyzed, while at the same time the difficulties of stereoscopic reconstruction of optically thin plasma were highlighted. Using the same techniques, several case studies of CMEs were analyzed in detail. Four methods were applied for reconstructing CMEs: (1) forward modeling technique, (2) local correlation tracking method, (3) center of mass tracking, and (4) polarization ratio technique. It was found that every method provides an important insight on the 3D structure of CMEs, but they also display the difficulties of stereoscopic reconstruction of optically thin plasma.

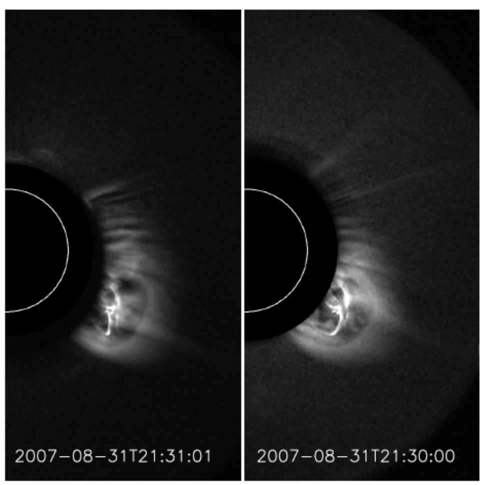


Figure 9: A CME on August 31, 2007 observed by SECCHI/COR1 coronagraph onboard STEREO A (right column) and STEREO B (left column) spacecraft. The visible solar disc is represented by the white circle, while the larger dark disc shows the coronagraph occulter. These two images show the difference in the CME appearance as observed from two different vantage points and allow us to make a 3D reconstruction of the CME structure. Adapted from Mierla et al. (2010).

Once the 3D structure and propagation direction of CMEs are calculated, they should be tested to assess the correctness of the model. A study was performed that compared the 3D parameters calculated using STEREO COR2 observations of CMEs at the Sun with their counterparts measured in situ in the interplanetary space (ICMEs). The study was based on a model to reconstruct the direction of propagation and angular widths of CMEs, allowing the eventual radial propagation up to 1 AU and analysis of their theoretical impact on a given spacecraft. To do so, data from the Advanced Composition Explorer (ACE) and the Wind spacecraft, located at the L1 point between the Sun and the Earth, and STEREO in situ data, were used. Then, by having the 3D geometry and direction of propagation for each CME, the CME parameters could be extrapolated to 1 AU to infer if they should have been detected in situ. The results of this analysis showed that, in general, the models and estimations done with the STEREO data to infer 3D properties of CMEs are valid.

For one of the studied CMEs, it was found that the results of the 3D reconstruction were showing unexpected values. The emission measured in the core of this CME was incompatible with the usual Thomson scattering process that dominates the white-light images used in the study. It was demonstrated that the observations could be explained by the Hα radiation. If this is also the case for other CMEs, their mass estimations may have to be revised.

B.1.3. Perspective for the next years

Investigations of solar eruptive events, their interplanetary counterparts and geomagnetic consequences will be pursued further. In particular, the geoeffectiveness of limb full halo CMEs will be studied. Another important track of research is the possibility to link directly solar and interplanetary observations using STEREO data, including the information obtained by novel Heliospheric Imagers (HI) onboard STEREO. The investigation of solar radio bursts will be continued, and a particular attention will be paid to distinguishing between flare-associated and CME-associated radio bursts.

C. The Earth's Atmosphere

C.1. Atmospheric Effects on GNSS Applications

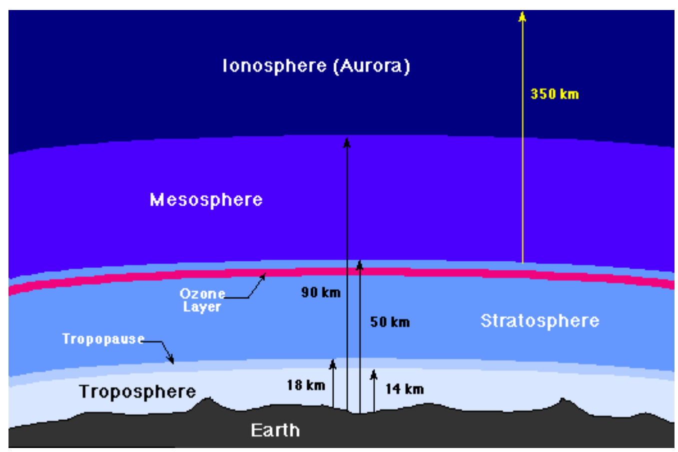


Figure 10: Subdivision of the Earth's atmosphere in different layers

When travelling from GNSS (Global Navigation Satellite System) satellites to receiving antennas located on the Earth, the radio-frequency signals emitted by Global Navigation Satellite Systems (such as GPS, GLONASS and Galileo) interact with the Earth's atmosphere. The two atmospheric layers that influence the most the propagation of these GNSS signals are the troposphere and the ionosphere (see Figure 10). The troposphere is the lowermost atmospheric shell and it is the seat of all meteorological phenomena's (clouds, rain, hydrometeors...). It contains approximately 75% of the atmosphere's mass and 99% of its water vapour and aerosols. The ionosphere is stretching from a height of about 50 km to more than 1000 km; it is named so because it is ionized by the Sun's ultra-violet light. The ionosphere is thus a shell of free electrons, electrically charged atoms and molecules that surrounds the Earth. As most of the space weather starts at the Sun, also the Earth's ionosphere is undergoing the effects of space weather.

Both the ionosphere and the troposphere refract the GNSS satellite signals and are error sources for GNSS applications. Tropospheric refraction causes errors of about 2-50 m on GNSS signals, while the errors caused by the ionospheric refraction can reach up to 50-150 m.

C.1.1. Objectives

To assess and mitigate the influence of the Earth's atmosphere on high precision GNSS applications taking advantage of new GNSS satellite signals.

GNSS allows computing positions on the Earth with precisions ranging from several meters down to a few mm, depending on the sophistication of the hardware and software used. When high-precision GNSS applications are targeted, the Earth's atmosphere becomes a predominant error source. The effect of the tropospheric refraction on the propagation of GNSS signals can be corrected using several a priori models which satisfy the less demanding GNSS applications, like dm-m level GNSS positioning and navigation. For high-precision applications where mm accuracy is desired, the tropospheric error is precisely parameterised and estimated with the final position solution. As the ionosphere is a dispersive medium, GNSS applications can be corrected for first-order ionospheric effects by combining two different GNSS signals having different frequencies.

Within the next years, existing Global Navigation Satellite Systems like GPS and GLONASS will launch new types of satellites and provide additional signals (on additional frequencies) to deliver better accuracy, reliability and availability of positioning. Moreover, according to a 2007 Russian presidential decree, GLONASS will offer in the near future a full 24-satellite constellation. In 2010, the upcoming GALILEO system plans to launch 3 or 4 test satellites which will be very similar to the final satellites. And finally, in the years 2011-2013, the remaining 26 satellites should be launched. Full Operational Capability of the GALILEO system is expected by end 2013. All these signals have the potential to allow more precise observations of the Earth's atmosphere.

C.1.2. Progress and results

C.1.2.1. *Usage of new precise E5 code from Galileo*

- STCE scientists, together with a consortium led by the Universität der Bundeswehr (München), participated to the FP7 project SX5 (Scientific Service Support based on Galileo E5 Receivers) which aims at developing a software application for precise positioning based on an E5 Galileo. The Galileo E5 broadband signal features an ultimately low code range noise and the lowest possible multipath errors compared to all other signals of all other GNSS. By combining the code range and carrier phase measurements on this high-performance navigation signal, a new technique has been developed to mitigate the ionospheric error. The role of ROB in the consortium is to evaluate the scientific potential of the Galileo E5 receivers within the fields of the position, position changes, and time transfer. As a first step, STCE scientists wrote the SX5 requirement document for the position, position changes, and time transfer in 2010.

- We investigated the possibilities of the precise E5AltBOC code of the future Galileo constellation for ionosphere studies and for time transfer accuracy. The idea proposed here is to use the Code-Minus-Carrier (CMC) and Code-plus-Phase (CPC) combinations. CMC contains only ionosphere but is contaminated by a constant hardware delay and ambiguities (constant for each satellite track). CPC is an ionosphere-free pseudorange, but also contains hardware delays and carrier phase ambiguities. Both combinations have the same noise level as the E5AltBOC signal, i.e. about 10 times lower than the present GNSS pseudoranges on each frequency, or 25 times less than the dual-frequency ionosphere-free combination of pseudoranges..

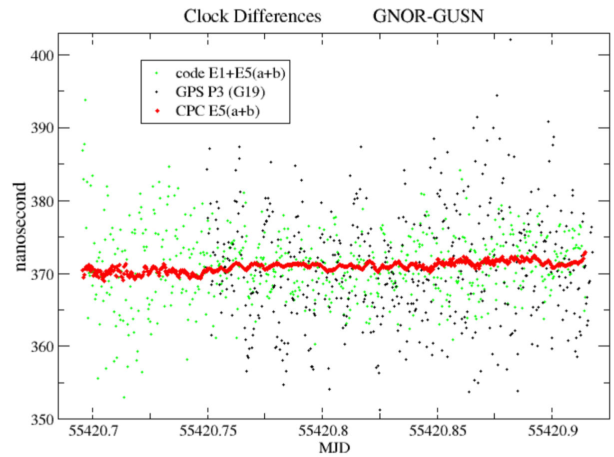


Figure 11: Comparison between the clock solutions obtained with either dual-frequency ionosphere-free combination of pseudoranges, or the CPC combination.

  Using CPC and CMC in a combined approach should allow retrieving with high precision the ionosphere Total Electron Content (TEC) and the receiver clock synchronization error. Figure 11 shows the precision of the clock solution obtained with CPC from E5, compared with the precision of the dual-frequency ionosphere-free combination of P1 and P2 currently used with GPS for time transfer. The next step of this research will be the determination of the ambiguities in order to retrieve the ionospheric and the accurate clock synchronization error.

C.1.3. Perspective for next years

- Extend the ROB software to perform Precise Point Positioning (PPP), Atomium, to allow the estimation of site positions in a kinematic mode and investigate the impact of the ionosphere on this kinematic positioning;
- Study the use of Atomium for tropospheric delay estimation, more particularly in the context of E-GVAP;
- Study the second-order ionospheric delays and improve their modeling taking advantage of new GNSS satellite signals.

C.2. Modelling the Earth's Atmosphere using GNSS

C.2.1. Objectives

To improve our knowledge of the spatial and temporal variations in the Earth's atmosphere (troposphere and ionosphere) and its physical processes with emphasis on Europe and Antarctica (WP ROB B.1).

As GNSS signals travel through the Earth's atmosphere, they contain information on the state of the ionosphere and the troposphere. To extract this information from GNSS signals, networks of continuously observing GNSS stations, with well-known positions, are used. For that purpose, members of the ROB "GNSS project" maintain a network of continuously observing GNSS stations and contribute actively to the elaboration and extension of the European GNSS network, known as the EUREF Permanent Network (EPN). In a second step, the GNSS data from these networks are used to compute information on the state of the Earth's ionosphere and troposphere.

C.2.2. Progress and results

C.2.2.1. *Development of GNSS Observation Networks*

- STCE scientists are in charge of the daily management of the EUREF Permanent GNSS network (EPN), see Figure 12. Within that framework, they maintain and continuously update the EPN Central Bureau (CB) web site (http://epncb.oma.be/, see Figure 13). In 2010, the site received almost 2.5 million hits and 20 new stations have been included in the network bringing the total number of EPN stations at 245.
- The quality of the ionospheric and tropospheric monitoring will improve if more satellite signals traversing the Earth's atmosphere will become available. For that purpose, encouraging EPN stations to switch from GPS-only to GPS+GLONASS (Russian counterpart of GPS) or GPS+GLONASS+Galileo (future European navigation system) is one of our top priorities. As a result, 58% of the EPN GNSS receivers track now GLONASS satellites in addition to GPS which is a 10% increase within the last year. Furthermore, over the last year, almost 90% of the new antennas introduced in the EPN have GPS/GLONASS or GPS/GLONASS/Galileo tracking capabilities.
- In support of the need for multi-GNSS tracking capabilities, a new software, Qualcheck, was developed in order to check the quality of the GNSS data of the ROB and EPN GNSS stations. The new software keeps the existing functionalities of the old one, but allows now in addition generating statistics over the new GPS frequencies. This software is already used for the snapshots of satellite tracking on the EPN Central Bureau website (see Figure 14). Moreover, the design of this software has been

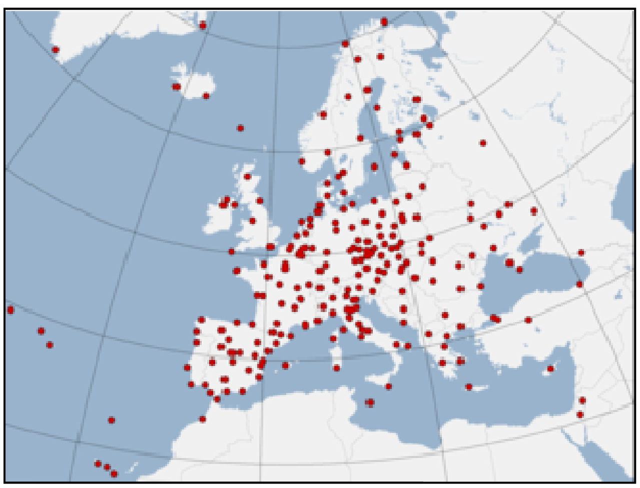


Figure 12: Map of the continuously observing GNSS stations in the EPN (Status: March 2010)

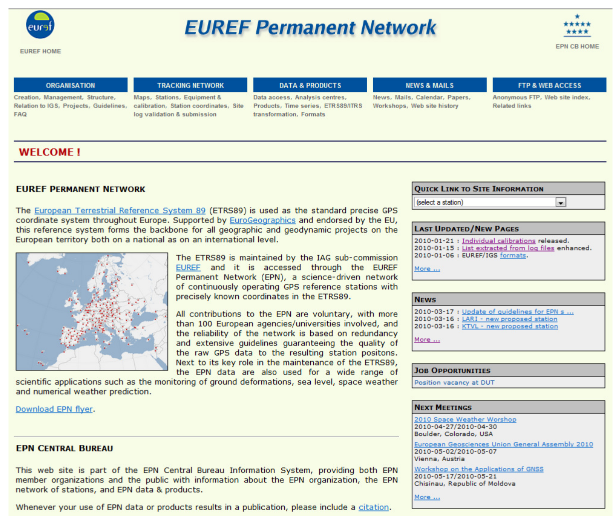


Figure 13: http://epncb.oma.be/ web site of the Central Bureau of the EPN hosted by the ROB

optimized to facilitate future developments, including the quality check on the future Galileo data.

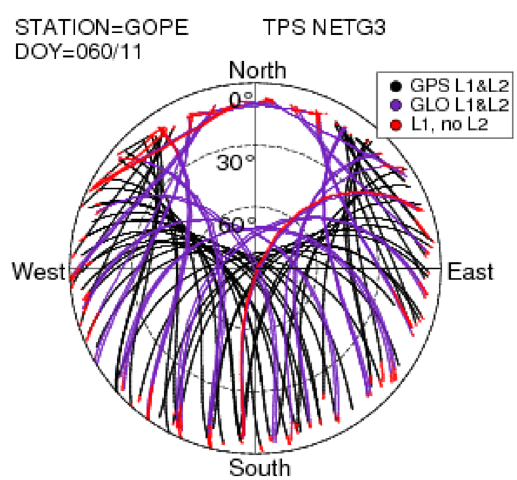


Figure 14: Snapshot of the tracking for the station GOPE showing the skyplot for a particular day.

- ➢ In order to be able to generate long-term statistics on ionospheric and tropospheric phenomena over Europe, we continued to extend our GNSS data center to contain all historical EPN data as well as data from national GNSS densification networks installed in Belgium, France, the Netherland, UK, and Germany. The oldest data go back to 1996.
- ➢ In order to support the (future) generation of near real-time or real-time ionospheric maps and tropospheric products, STCE team members maintain an EPN broadcaster providing real-time access to more than half of the EPN data. In 2010, more streams and users were added to the Networked Transport of RTCM via Internet Protocol (NTRIP) relay caster that was installed at the end of last year. Over time this relay caster is gradually evolving into a (redundant) top caster. The number of streams relayed from the NTRIP caster at Bundesamt für Kartographie und Geodäsie (BKG) is continuously decreasing as the streams are now accessed directly from their source instead of via the caster of BKG. In addition, STCE team members has developed the necessary procedures and programs to provide real-time access to IGS observations (about 50 stations), to the French GNSS permanent network (RGP) observations (17 stations) and to real-time IGS orbits and clocks.
- ➢ As part of our effort to also modernise the ROB GPS network, several multi-GNSS receivers and antennas have been tested. Within that framework, two new GPS+GLONASS+Galileo test receivers have been installed at ROB and scientists of the STCE team already started working with GLONASS and GIOVE A/B data.

C.2.2.2. *GNSS at the Princess Elisabeth base in Antarctica*

Site installation

The STCE team remotely assisted the crew in Antarctica for the installation and maintenance of the GPS equipment at the polar station in Antarctica (Figure 15).

In addition a box with communication and power distribution, common to all teams using the E. Danco shelter, was designed and built by the STCE team. This consumed however a considerable amount of time, inhibiting us from designing and building a new box for the GPS/GNSS equipment. This GNSS box will hopefully be ready for November 2011 and can then be shipped to Antarctica for next scientific season (2011-2012).

Figure 15: GPS antenna installed at the Princess Elisabeth base in Antarctica

Results

The data from ELIS receiver at the Princess Elisabeth (PE) base in Antarctica has been processed. The data were used to test the best way to estimate the Vertical Total Electron Content (VTEC) over the base each 15 minutes. The comparison with CODE Global Ionospheric Maps (GIMs), which deliver each 2 hour a global 2.5°x5° grid, shows differences of 0.1±1.7 TECU for a full day. It demonstrates that the VTEC estimated each 15 minutes from the ELIS data only is not biased and is reliable compared to GIMs (Figure 16) and allow to deliver VTEC with a higher sampling rate than global models.

C.2.2.3. *Monitoring of the Earth's troposphere*

- The STCE team has continued to develop and ensure the daily maintenance of the ROB near real-time "EUMETNET EIG GNSS water VApour Program" (E-GVAP) II analysis centre. This service uses state-of-the-art estimation techniques to provide European meteorological institutes with near real-time (NRT) GNSS-based tropospheric Zenith Path Delay (ZPD) estimates for assimilation in the Numerical Weather Prediction (NWP) models and for nowcasting applications.
- The STCE team used GNSS data from the Belgian dense network (ROB GNSS stations+FLEPOS+WALCORS+GPSBru) to compute the integrated water vapour (IWV) to monitor the location, movement and variability of small-scale atmospheric water vapour structures. The different gridding methods have been tested for the generation of the IWV maps. The different method show already a good agreement, but there is still room for potential improvements using variational techniques. The results showed that the GNSS network densification is mandatory to sense the small-scale structures and to provide valuable information for weather forecasting and nowcasting applications (Figure 17). Several improvements to the method were pointed out, notably in terms of sampling rate of the tropospheric delay estimations.

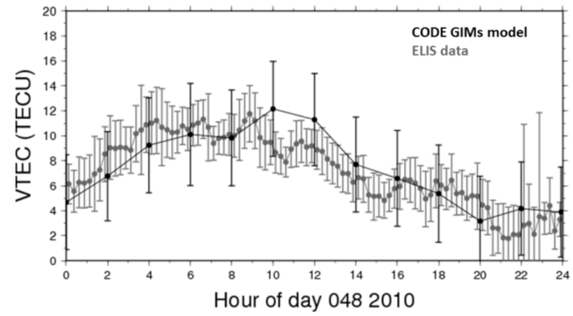


Figure 16: Vertical Total Electron (VTEC) above the Princess Elisabeth base estimated each 15 minutes from ELIS GNSS station.
Gray: VTEC from ELIS GNSS station
Black: VTEC from Global Ionospheric Maps (GIMs) from the CODE analysis Centre.

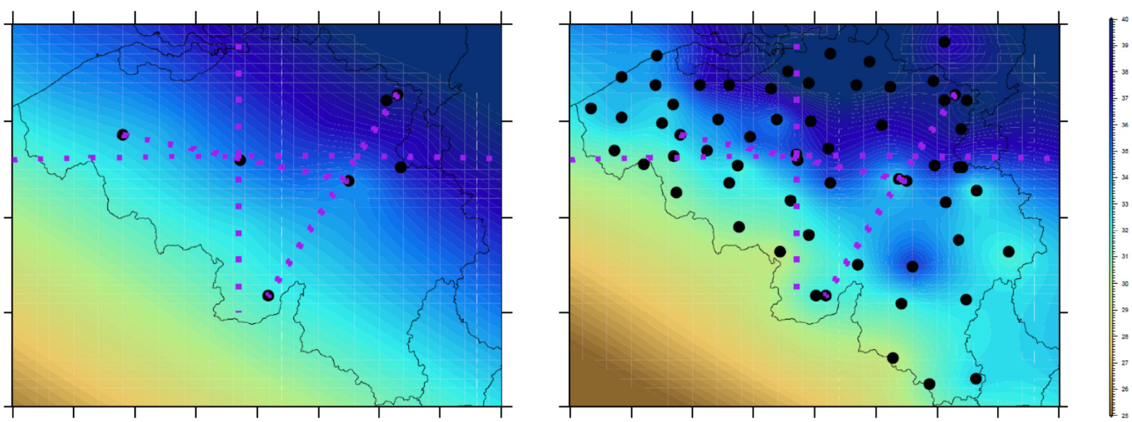


Figure 17: IWV fields reconstructed from GNSS observations during a thunderstorm burst that occurred in Belgium (night between the 28th and the 29th June 2005 at 00:00 UTC - the vertical scales correspond to IWV values in millimeters). Left: using a solely the GNSS data from the EPN ; Right: same network but augmented by the Belgian GNSS densification network

C.2.2.4. *Monitoring of the Earth's Ionosphere*

- STCE team members investigated a method to deliver VTEC maps in near-real time over Europe from the EPN data. Different parameters, data input, and interpolation methods has been tested in order to produce in near-real time, 0.5°x0.5° grid of VTEC maps and maps of the VTEC variance over Europe each 15 minutes. The results showed that the most adapted interpolation for such a product is the spline interpolation. These VTEC maps were compared with Global Ionospheric Maps (GIMs) and showed good agreement with a mean differences lower than 1 TECU ($1TECU=10^{16}e^{-}.m^{-2}$, except during stormy days when GIMs seem to underperform (Figure 18). Consequently, the VTEC maps and its variance estimated each 15 minutes over Europe will be a useful product for applications using radio signal especially to notify users of abnormal events (e.g. ionospheric storm).

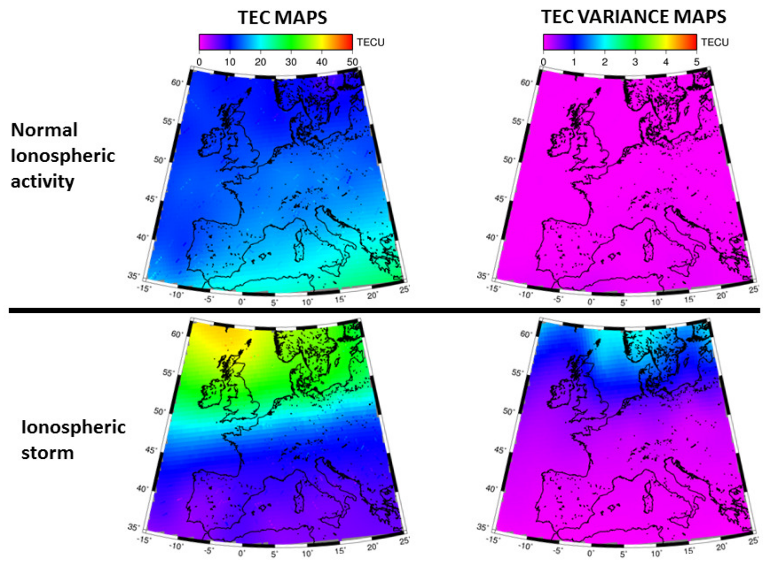


Figure 18: 0.5°x0.5° TEC maps over Europe estimated each 15 minutes from EPN data in a near-real time approach.
TEC maps over Europe (left) and its variance (right) in TECU estimated over 15 minutes in a near-real time approach, for normal ionospheric activity (top , DOY 303 2003, 12:30-12:45 UT) and during an ionospheric storm (DOY 303 2003 , 22:30-22:45).

- The variation of the daily mean VTEC over Europe and its correlation with geomagnetic Kp and Dst indexes has been investigated for different ionospheric states : (1) stormy state in 2003 (October Halloween Storm) and 2010 (August storm) and (2) normal state in 2008 (minimum Solar activity). The daily mean VTEC over Europe decreases up to 4 TECU in response to high geomagnetic activity. Moreover, the time of recovery to normal daily mean VTEC is close to 2-3 days after the main geomagnetic disturbance (
- Figure **19**). This is a good indicator to detect changes in the background VTEC over Europe due to geomagnetic storms.

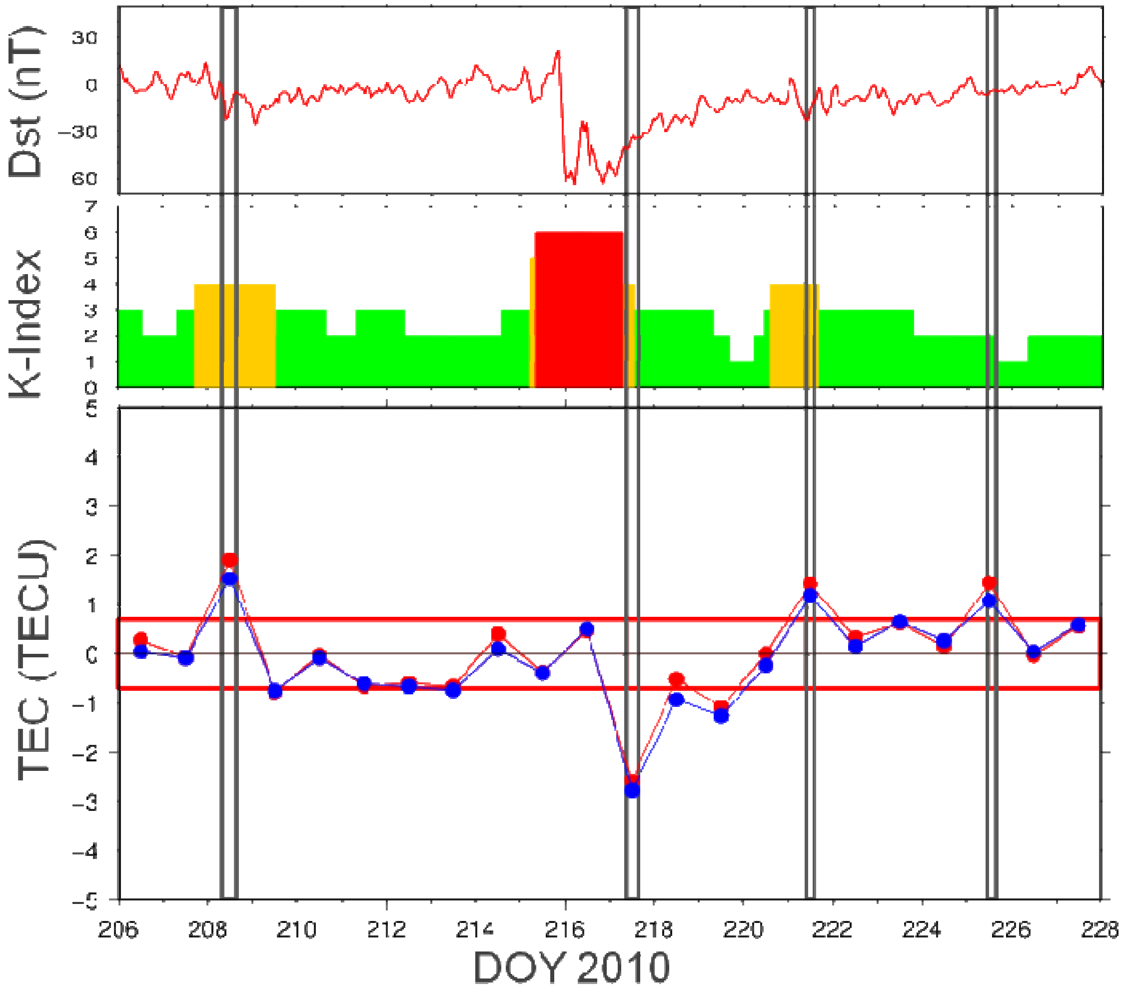


Figure 19: 22 days around the August 2010 stormy period (CME impact DOY 215).
Bottom: Daily mean (blue) and median (red) VTEC after removing the mean/median value for the entire period. The red rectangle corresponds to the maximum error due to parameter estimation from equation presented in section 1.
Middle: Planetary Kp Index estimated every 3 hours (KP index from NOAA Space Weather Centre). Green: No storm (Kp≤ 4); orange: minor storm (Kp= 5); red: moderate (Kp= 6) to extreme (Kp= 9) geomagnetic storm.
Top: Disturbance storm time Index (Dst index from the World Data Centre for Geomagnetism, Kyoto) estimated each hour in nT. Rq: The Dst scale is not the same for 2003 compared to 2008 and 2010.
The black rectangles underline the days when significant daily TEC variation is detected (w.r.t. to the 22 days periods).

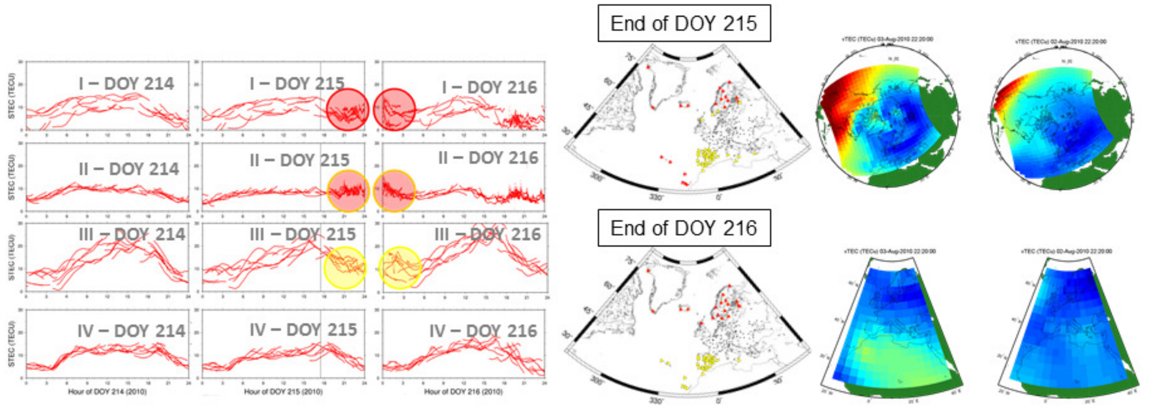


Figure 20: Ionospheric disturbances due to 3rd August 2010 CME impact.
Left: STEC times-series during 3 days around the August 2010 storm (DOY 215). Four typical STEC times series from 4 EPN stations are presented here (patterns I, II, III, IV). The black line corresponds to the time of the CME impact (17:30 UT, DOY 215). The colored circles are the different patterns detected. IV shows an example of station where no perturbation is observed.
Middle: Maps of stations where ionospheric disturbances are detected. Top: End of DOY 215 (20:30 to 00:00 UT); Bottom: beginning of DOY 216 (00:00 to 05:00 UT). Red and yellow triangles correspond to pattern I-II and III respectively. Black triangles correspond to GPS stations where no disturbances are detected (pattern IV on Figure on the left).
Right: MIDAS reconstruction of the VTEC above North-Africa/Europe (bottom) and Polar regions (top). These VTEC maps are presented at the same hour (22:20 UT) for different days in August 2010. Left: DOY 215, which is the day of the CME impact (3rd August 2010). Right: DOY 214 for comparison (day before the storm).

- Ionospheric disturbances caused by a CME impact have been investigated. The Slant Total Electron Content (STEC) variation along each GPS signal path between each EPN ground stations (more than 240 sites) and the GPS satellites has been checked to detect small variations in the ionosphere during the 2010 August storm period in response to a CME impact. The disturbances for this geomagnetic storm present an amplitude of 3 to more than 7 TECU and an apparent periodicity of 30 minutes. The origin of these disturbances, deduced from reconstructions based on the MIDAS tomographic algorithm are due to: (1) auroral or caused by polar-cap plasma patches in Northern Europe and (2) the extreme eastern edge of a Storm Enhanced Density structure in Southern Europe (Figure 20). In the future, this will be useful to study the ionosphere physics during stormy events.
- STCE team members have started to test the MIDAS software for performing ionospheric tomography over Europe. They assessed the reliability of the Gradient-drift and Kelvin-Helmholtz Waves observed into the MIDAS ionospheric images obtained from GPS data. It was demonstrated that zones of gradient drift located in France, contrary to zones of Kelvin Helmholtz Waves located in the North of Sweden and Finland, were well probed by the GPS signals and hence that a good reliability of the MIDAS imaging could be expected in gradient drift zones. In addition, STCE team members tested the optimal spatial resolution of the MIDAS imaging when using the large amount of GNSS data available in Europe. First results showed that the MIDAS algorithm tends to under-estimate the vTEC and that fine grids lead to greater resolution of ionospheric structures but also increase likelihood of artifacts in the reconstruction. The 2°x2° grid offers the best trade-off between these problems.
- In collaboration with Dr. K. I. Hodges of the University of Reading, STCE team members developed a polar-cap patch identification and tracking algorithm. Dr. Hodges has developed a “feature-tracking” algorithm that has been extensively applied to meteorological storm studies. Adaptation of this algorithm to the problem of tracking polar-cap patches has proved feasible; however some optimisation to remove “false-positive” identifications is yet to be completed.

C.2.2.5. *Added-value of new satellite signals (modernized GPS, GLONASS & Galileo) for monitoring the Earth's atmosphere*

STCE members evaluated the distribution of present and future GNSS signals for probing the Earth's atmosphere when using

a) GLONASS and simulated Galileo data in addition to GPS,
b) dense GNSS networks (in Belgium, France, Germany, Sweden and UK) in addition to the EUREF Permanent Network (EPN) ,

It has been shown that:

- In the case of the troposphere, the use of dense GNSS tracking networks insures a coverage of 73% compared to 14% in the case of EPN only. Moreover, the use of multi-GNSS data increases the GNSS signal distribution by a factor of 2.
- In the case of the ionosphere, the use of dense GNSS networks allows to reduce the number of empty voxels by 17% and improves the coverage especially in the north. But, this densification induces inhomogeneities in the GNSS signal distribution and therefore mainly densification stations located in the UK and Scandinavia (homogenizing the overall inter-station distances) will provide a real added value. The use of multi-GNSS data improves the GNSS signal coverage along the day by a factor of 2.

a) b)

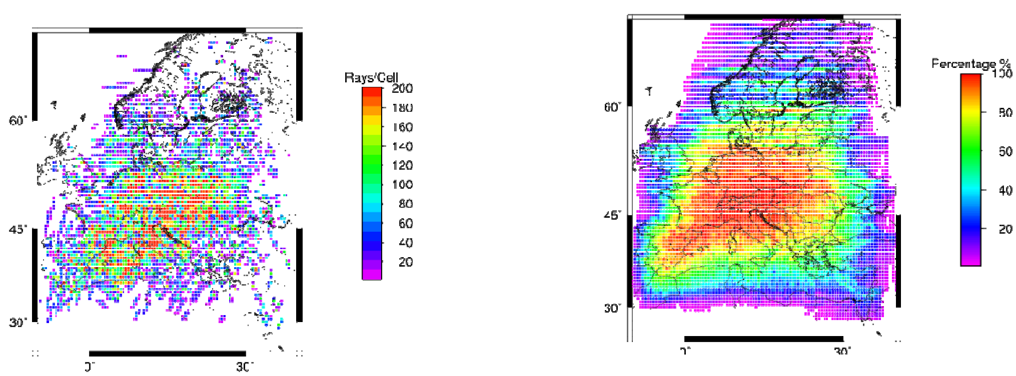


Figure 21: GPS signal distribution at an altitude of 300km in a grid of 0.5°x0.5°x30km using EPN: a) number of GPS rays per voxel, from 10h00 to 10h20, b) percentage of epochs during one day for which voxels are traversed by at least 5 rays.

C.2.3. Perspective for next years

- Upgrade the ROB network of permanent GPS stations to a multi-GNSS network
- Continue to maintain, extend and improve the EUREF Permanent tracking network
- Continue to contribute to the GIANT project at the Belgian Antarctic Base
- Continue to monitor the European ionosphere by concentrating on the automation of the generation of TEC maps
- Continue to develop methods for ionospheric physics studies
- Continue to perform on-demand studies of the ionosphere for radio communication users when they detect problem.
- Continue to monitor the troposphere by developing and maintaining the ROB E-GVAP II service
- Continue to exploit the Belgian dense GPS network to improve the knowledge of spatial and temporal variations of the atmosphere
- Further develop and maintain the real-time access to GNSS observations, orbits and products

D. Earth Environment – Magnetosphere

D.1. Observations and models of the Earth's magnetosphere

D.1.1. Description

Science-based prediction of the effects of the solar wind on the Earth's magnetosphere requires both visualization of observations and numerical simulation of magnetospheric dynamics based on a physical model.

D.1.1.1.*Numerical simulation of magnetospheric processes*

Magnetospheric processes are inherently kinetic in nature. It is therefore our goal to develop kinetic simulation capabilities.
H. Gunell is developing computer codes for Vlasov simulations, together with E. Gamby and J. De Keyser. The underlying idea is to simulate the Vlasov (or Boltzmann) equations directly, coupled to Maxwell's equations. This is basically a hyperbolic problem in 7 dimensions (3 coordinates in space, 3 coordinates in velocity space, and time). It is clear that a number of simplifications have to be made to make such problems tractable.
We have worked on a 1d2v (one dimension in space and two dimensions in velocity) model. This initial model has been tested thoroughly to validate the approach. This code describes the plasma velocity distribution as a function of the velocity component parallel to the magnetic field and of the magnetic moment. The code benefits from the magnetic moment being invariant, but it is also able to treat cases where it is not. The simulations have been able to reproduce the electrostatic potential profile in a double layer experiment in a magnetic mirror configuration.
The model has then been put to use to study the physics of an auroral flux tube. The auroral region spans a wide range of densities and magnetic fields, and that makes it necessary to simultaneously resolve both large and small scales. The aim is to obtain the electrostatic potential as a function of the spatial coordinate along the magnetic field. The current-voltage relationship can also be studied in this way. We offer the possibility of treating certain particle species relativistically. Particularly electrons from the magnetosphere can be accelerated to high speeds in cases when the auroral potential drop reaches tens of kilovolts.

D.1.1.2.*Observations and models: Data interpretation*

We are continuously improving MIM, our Matlab-based software package for data interpretation. This package allows the comparison of data originating from ground- or space-based observing platforms, as well as data produced by models. The confrontation of both is, obviously, very important.

D.1.1.3.*Related activities*

The DSIM code has been used to study nanodust propagation (work done by J. De Keyser together with I. Mann). The idea is that the nanodust propagation problem can be formulated as a kinetic problem, basically a modified convection-diffusion problem, which can be tackled quite easily with DSIM.

D.1.2. Progress and results

D.1.2.1.*Numerical simulation of magnetospheric processes*

We have contributed to a review of kinetic and multi-fluid approaches for plasma simulation (in the context of solar wind models).
The 1d2v Vlasov model was finished first. It has been validated with results from laboratory experiments. The code has been tested; good agreement was found between the Vlasov simulation results and previous

results from particle in cell simulations of a beam plasma interaction experiment. First results were presented at the EGU General assembly in May.
The model subsequently has been applied to auroral flux tubes. The main challenge is the computationally demanding nature of the computations. We have progressively improved the speed of the computations in by the following means:

- We introduce an artificially higher dielectric constant in the simulation, so that it can run on a coarser spatial grid and with a longer time step. In this way an approximate solution can be found quickly. That solution is then refined by progressively decreasing the dielectric constant to realistic values. Thus, we arrive at a solution without relying on assumptions about the distribution function in the interior of the simulation region.
- Recent improvements include use of a non-uniform mesh in configuration space to enable us to simulate the whole flux tube while still resolving small-scale phenomena near the ionosphere.
- For cases with lower potential drops the relativistic treatment of (some) particle populations can be switched off to improve the computational performance.
- The code is parallelized and has been run on 36 parallel processors on the plato computer. Efforts have been made to speed up the computations as much as possible.

This work on the auroral physics problem is closely related to our studies of the auroral electric circuit.

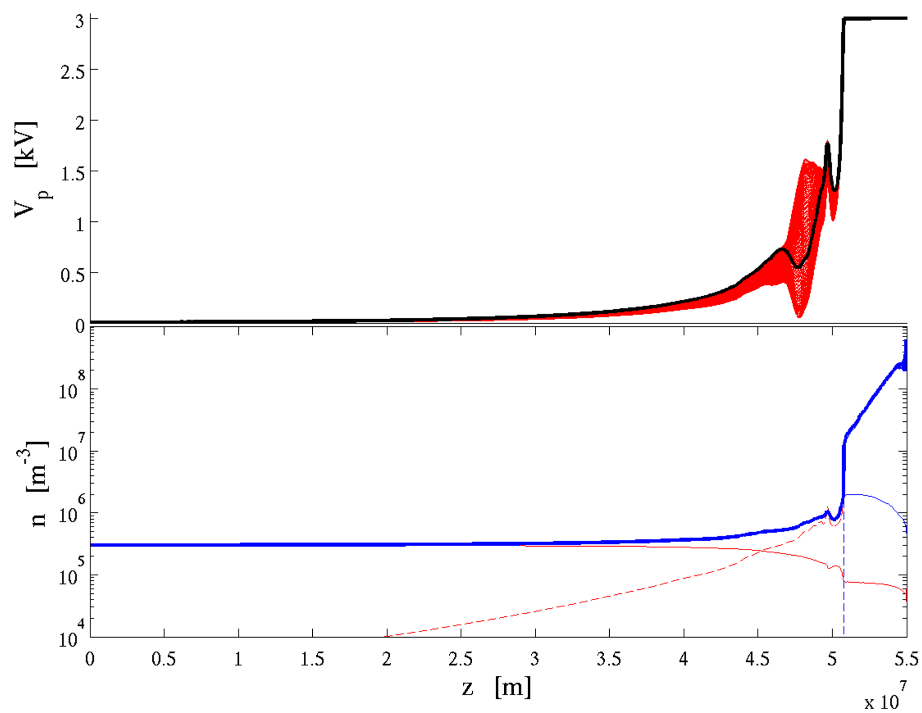


Figure 22: Plasma and electric field structure in an auroral flux tube; z indicates the distance along the flux tube, with the magnetospheric equator at z = 0 (to the left) and the ionosphere at z = 55000 km (to the right). Upper panel: Simulated plasma potential along an auroral field line. The black curve shows the potential at one instant in time; the red area shows its variability during 0.1 s. Half of the potential drop is concentrated in a thin double layer just below one Earth radius altitude. The rest of the potential drop is distributed over a distance of a few Earth radii at higher altitude. The latter region exhibits large oscillations, whereas the double layer remains stable. Lower panel: The thick blue curve shows the corresponding plasma density. The thin solid curves show protons (red) and electrons (blue) from the magnetospheric end of the system. The dashed curves show protons (red) and electrons (blue) originating from the ionosphere. A steep density gradient develops at the position of the double layer.

In a related effort on kinetic simulation, M. Echim has continued to work with Gabriel Voitcu from ISS Bucharest on developing particle simulations for plasma interfaces. An interesting poster was presented by G. Voitcu during the Cluster workshop in Romania in May. R. Maggiolo has been looking for CIS plasma distributions that resemble some of the features simulated by G. Voitcu. M. Echim, together with G. Voitcu (ISS Bucarest, Romania) and prof. R. Marchand (Univ. Of Alberta, Edmonton, Canada) have investigated the formation of non-gyrotropic electron and proton velocity distribution functions at the edges of plasma structures interacting with non-uniform distribution of the electromagnetic field. The direct and the inverse test-kinetic methods have been used and the results have been compared.

D.1.2.2.*Observations and models: Data interpretation*

The MIM software has been subject to continuous maintenance, including bug fixes and efficiency improvements (E. Gamby, J. De Keyser). The following steps have been taken:

- Efficiency improvements have been implemented in several of MIM's numerical solvers (solution of stiff ODE problems; solution of DAE problems; optimization techniques).
- J. De Keyser has extended and optimized the parameter scanning functionality in the TD module for computing equilibrium configurations of tangential plasma discontinuities.
- E. Gamby has updated the demonstration script for magnetopause reconstruction using formatted data from THEMIS.
- E. Gamby enhanced the functionality of the Dataset Formatter module:
    - Add a new feature to automatically ingest the formatting information from a Cluster Active Archive (CAA) file.
    - Parameterize the extraction of CDF variables using regular expressions. This allows using the same formatting database for the four Cluster spacecraft.
    - E. Gamby has updated the formatting database for the CAA archive to use Calibrated Parameters (CP) instead of Preliminary parameters (PP).
    - This now leads to a seamless way of importing data from the CAA into a MIM data analysis, which goes beyond the typical tasks of a Virtual Observatory.
- Further work has been done by J. De Keyser on data interpretation algorithms for multi-spacecraft constellations (gradient computation, magnetospheric boundary reconstruction, field-aligned density in the plasmasphere).

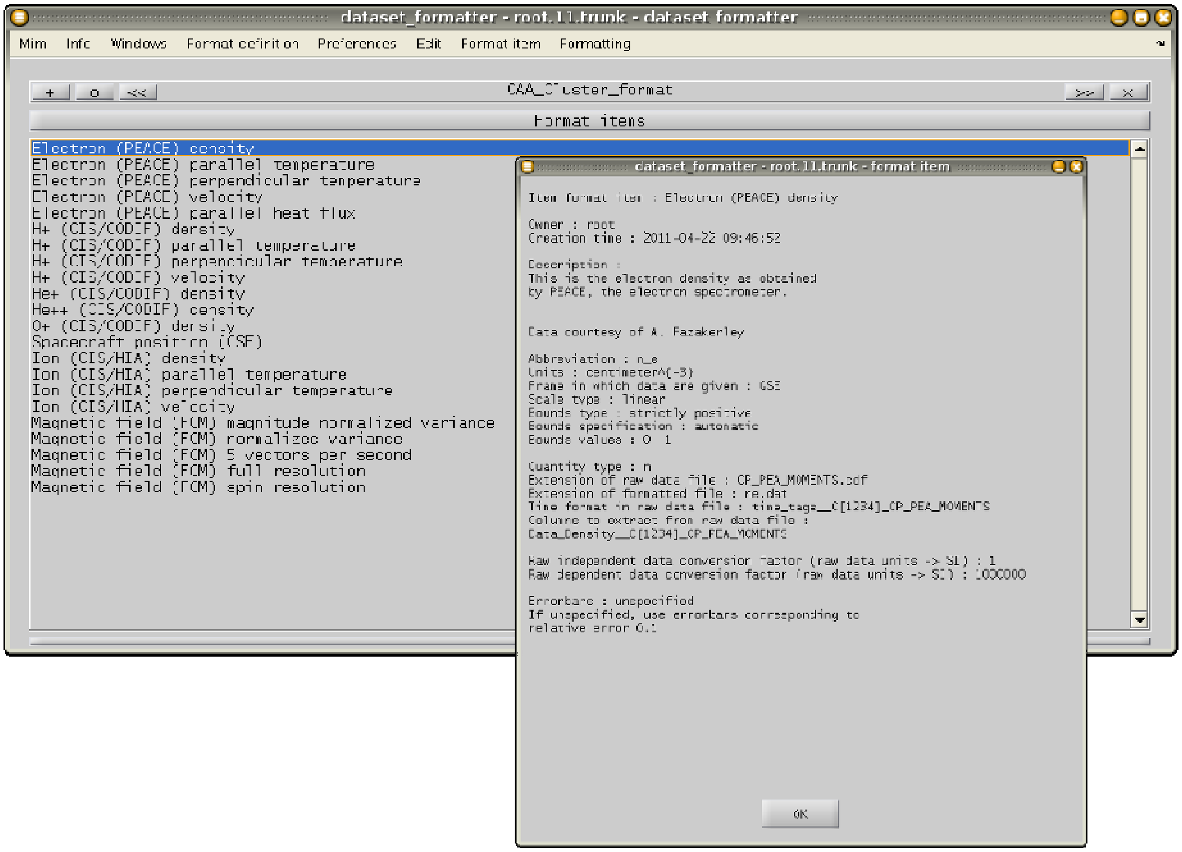


Figure 23: MIM dialog boxes illustrating the properties of data that can be imported from the Cluster Active Archive (CAA). These properties are automatically derived from the meta-data dictionary of the CAA. They are used to convert data downloaded over the Internet on-the-fly so as to import them in a MIM analysis.

D.1.2.3.*Related activities*

Some initial DSIM nanodust simulations with simplified physics have been carried out. E. Gamby has created/adapted makefiles so that DSIM now compiles and runs on the kronos servers. In this context, he has contributed a wiki page that explains how to configure and run MPI applications at BIRA-IASB.

D.1.3. Perspective for the next years

D.1.3.1.*Numerical simulation of magnetospheric processes*

We have succeeded in our intention to produce a proof of principle simulation, indicating that Vlasov simulations are indeed a valuable tool for addressing problems in magnetospheric plasma physics. At the same time, however, it is very clear that the plasma problems that we want to address are computationally challenging.

In the coming years, we want to further explore the auroral physics simulation that has been implemented. A survey of the parameter space will give us more insight in the physics of the problem. In another line of research, we would like to parameterize the current-voltage relations obtained with these simulations, and use them as building blocks in overall simulations of the auroral current system, to complement earlier work that we have done on this subject. It would be interesting to confront that with recent Cluster observations of the auroral acceleration region.

D.1.3.2. *Observations and models: Data interpretation*

Confronting observational data and model results is a constant need. We therefore intend to maintain the MIM software (bug tracking, regular updates), but also to extend its functionality by adding new modules to it. The modular design of the MIM environment allows us to do that fairly easily.

In the coming years, we foresee a need for the visualization of multi-dimensional data sets. A major action therefore is a re-design of the plotting system within MIM to allow a more flexible organization of the plotting mechanism. Such a revision of the plotting mechanisms in MIM is actually underway (E. Gamby, J. De Keyser). A new framework has been devised and a crude prototype implementation is ready, which follows a more modular and object-oriented approach (E. Gamby, J. De Keyser). Much work remains to be done, however, to arrive at an operational system.

Several additions to MIM will be made in the context of other activities of the space physics division. MIM should provide generic supporting functionality whenever that is needed. Major additions and/or modifications are expected in the following areas:

- comet science (in support of ESA/Rosetta);
- multi-spacecraft data interpretation tools (in particular multi-point gradient calculation in support of ESA/Cluster);
- modeling of auroral current systems.

D.1.3.3. *Related activities*

We hope to continue the work on nanodust particle propagation. The idea is to select a sensible set of starting positions and velocities, and to determine the fate of such particles.

PART 3: APPLICATIONS, SERVICES, DATA STORAGE AND EXPLOITATION

A. Space Weather

A.1. Solar Activity and Space Weather Operations Centre

A.1.1. Objectives

The Operations Center consists of the *World Data Centre* (WDC) for the Sunspot Index since 1981 and the *Regional Warning Centre Belgium* (RWC Belgium) of the *International Space Environment Service* (ISES) since 2000. Our core activity is the monitoring of the solar activity and space weather on time-scales that range from several years (sunspot cycle) down to hours (real-time activity monitoring). Our long-term goals are

- to remain the focal point for the international sunspot calculations;
- to continuously monitor and improve the quality of the indices and forecasts we produce
- to study the sunspot time series since its origins, its possible expansion by parallel advanced sunspot indices and its future extension by another modern non-visual index.
- to grow, together with our partners at BISA and RMI, into a European equivalent of the Space Weather Prediction Center operated by NOAA, with complementary and/or improved services;
- to play a prominent role in ESA's *Space Situational Awareness Program* (SSA);
- to improve our knowledge on the Sun-Earth connection.

To reach these objectives we have built up considerable IT infrastructure for the monitoring of solar activity, the automated detection of solar events, the logistic handling of incoming/outgoing space weather messages over the ISES network and the collection of sunspot observations from stations worldwide.

A.1.2. Progress and results

A.1.2.1.*International Sunspot index*

Throughout the year, the routine production of the International Sunspot Index was continued. This includes

- Total, hemispheric and central zone sunspot number
- Monthly provisional index
- Daily Estimated International Sunspot Index (EISN)
- Definitive sunspot index (quarterly)
- Additional indices: PPSI, sunspot areas
- Mid-term forecasts of the total sunspot number (Waldmeier and Cugnon-Denkmeier methods)

Forecast improvement

Concerning the mid-term forecast of the smoothed monthly averaged sunspot number, a new technique was implemented by T. Podladchikova to improve these forecasts. This new technique is based on a Kalman filter application. It can be applied to improve the results of any already existing forecast technique (such as those used at SIDC, or the Lincoln-McNish method used elsewhere). It was demonstrated that significant improvements (5-57%) can be established. We have implemented this technique in an automated way for a first test phase. The improved predictions are available on http://sidc.be/products/kalfil/.

This research was presented at the Seventh European Space Weather Week (15-19 November, 2010 - Brugge, Belgium) and at the Plazma Physics in Solar System (14-18 February, 2011 - Moscow, Russia).

Quality Control

F.Clette initiated the investigation of a possible drift of the sunspot index after the year 1998, suggested by discrepancies between the sunspot index and other solar indices over the declining phase of the last solar cycle. A presentation of such a study was presented by Dr. L. Svalgaard in a seminar given at the ROB in September. Subsequently, multiple exchanges took place with the observers of the pilot station of the sunspot network at Locarno in order to collect evidence of any possible trend. We also contacted K.Mursula (Univ. Oulu), the Solar Section of the AAVSO as well as Dr. A. Koeckelenbergh, former Director of the SIDC. Various data were exchanged with the Locarno team in view of a visit of that team to the ROB in early 2011.

Observers' participation

The numbers of observers using the Wolf interface http://sidc.be/WOLF/ has increased. Five observers have been registered during this year; two from United States, one from Brazil, one from Peru and one from Italy. Now 93 observers use the WOLF interface, they are located in 33 different countries, 18 countries are not in Europe (Figure 24). The countries with more than one observer are indicated in the figure.

Every first of month, we have more than 50 stations who have encoded their data. The number of stations inserting their data for the current day (typically 12:30 UT) is stable, these stations are used for the estimated index sunspot number (EISN) distributed in our space weather bulletins.

Five observers still continue to send e-mails and don't use the WOLF interface: HE40 (Helwan, Egypt), SM85 (San Miguel, Argentina), KS52 (Kislovodsk, Russia), PR203 (Prostejov, Czech Republ), CB127 (Camaguey, Cuba)

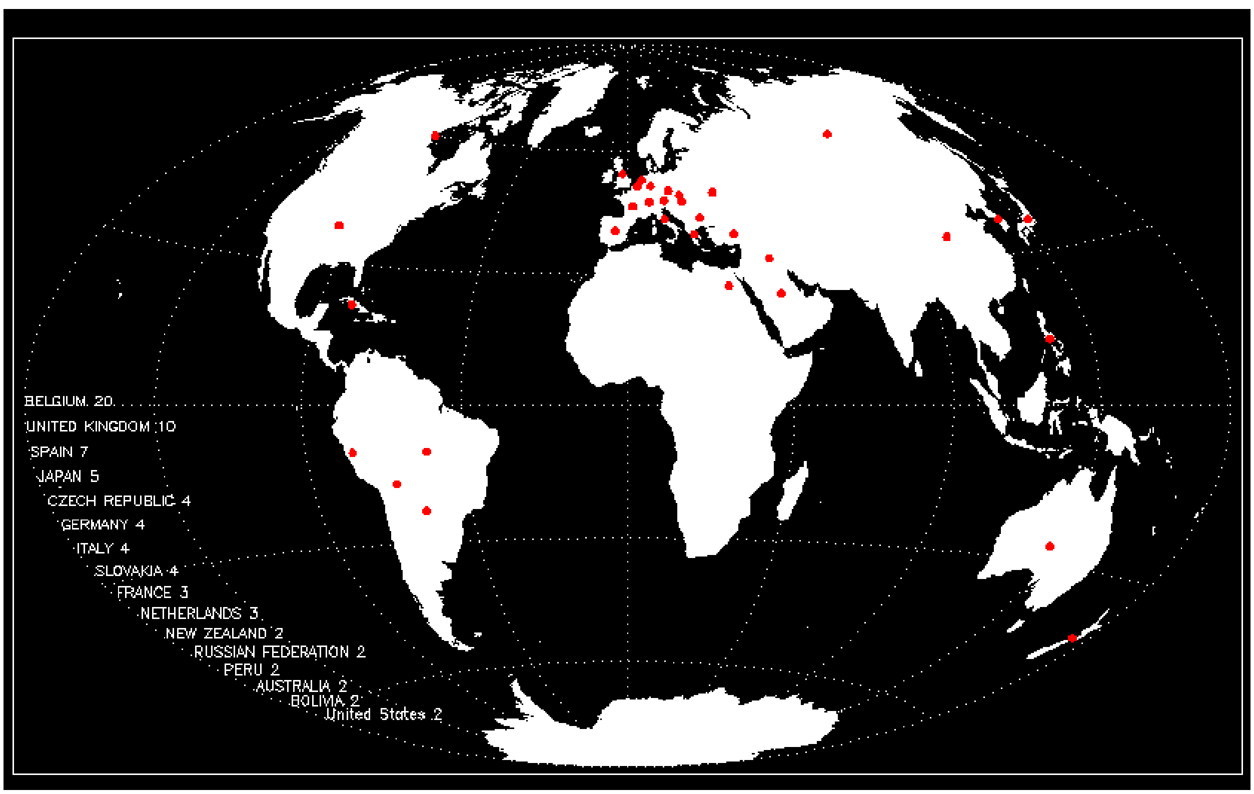


Figure 24: Localization of WDC observers

Sunspot index (Ri) computation

Laurence Wauters has finalized the MySQL/PHP programmation for the computation of the sunspot index using directly data from the DATA_SIDC database. In this program, a set of parameters can be chosen: the Pilot Station, the period (number of days/month/year) taken into account and the fixed final date of the period used for the computation. This programmation will permit the study of the impact of this parameters set on the Ri values.

A.1.2.2.*PreviMaster and PreviWeb Upgrade*

- Eva Robbrecht took over the lead of the RWC in the summer of 2010. As a start she has organised two meetings discussing the future of the RWC and the technical details and a brainstorming session with the forecasters to receive input on their requirements for the new system. The goal of the RWC is to provide operational services and information concerning space weather. In principle any service or information produced within the STCE could be "federated" in the RWC.
- We have started preparatory work for the upgrade of the PreviMaster and PreviWeb software, which is mainly performed by Sarah Willems and Elke D'Huys. The aim of the upgrade is to modernize and improve the whole system. In 2010 we started to make an inventory of the whole system, listing all routines with their functionalities. We have started collecting requirements for the new system, which will result in a RWC requirements document. The progress and problems that emerge are discussed in weekly follow-up meetings.

A.1.2.3.*Forecaster activities*

- The solar weather forecaster team in 2010 consisted of David Berghmans, Frederic Clette, Elke D'Huys, Christophe Marqué, Eva Robbrecht, Luciano Rodriguez, Petra Vanlommel and Andrei Zhukov. They each took several cycles of forecaster duty, which is organized, in weekly cycles running from Monday to Sunday. The forecaster duty includes writing a daily space weather bulletin [51] that contains a forecast on flaring activity, geomagnetic activity and the probability for SEP events. The bulletin is issued daily at 12h30 UT. Apart from writing the bulletin, the forecaster is expected to monitor the Sun during daytime, including the weekends. Whenever necessary the forecaster can issue a "presto" alert. At the end of the week the forecaster summarizes the solar and geomagnetic activity in a weekly bulletin [52]. The SIDC issues a Monthly Bulletin [53] at the end of each month (in PDF format) summarizing solar and geomagnetic activity and providing details on sunspot numbers.
- We have revived the weekly briefings, organized every Friday, to discuss the solar activity during the previous week. We have made a new generic email address: swforecaster@sidc.be, to make it easier to communicate with the forecaster team. This address is also communicated to some of our users. They may use it to request additional information from the forecasters. We have restructured the RWCWDC wiki and have extended the available information so that it's ready for use again.
- Sarah Willems and Laurence Wauters performed a statistical study of the accuracy of real and forecasted data for the geomagnetic index K for day1, day2 and day3. The results of the study will be presented to the forecaster team in May 2011.

A.1.2.4.*Development of automated detection algorithms and supporting software*

- FLARE DETECION: The GOES X-ray flare alert is made operational again and it has since then sent out several successful email alerts.
- CACTUS: We have created a new version of the CACTus LASCO CME catalog, using the updated CACTus algorithm. The previous version of the catalog was not extendible after 2007 and did not contain movies. The new version of the catalog is available online at http://sidc.oma.be/cactus/catalog.php. The catalog is extended automatically when new data becomes available. A number of enhanced products are also made available based on the CACTus output: monthly CME rate in graphical format (see Figure 25), ASCII and XML. This will makes it easier to share our data with people who want to use it for publications. Just like the sunspot number, also the

CME rate has increased since 2009. This again shows that the CME rate is in close relationship to the sunspot number. Additionally we have seen that while the sunspot number was near 0, CME activity never receded completely. We have imported the CACTus detections in the HEK database (Helio Events Knowledge database) managed by the SDO team at LMSAL, California. Several problems remain to be resolved.

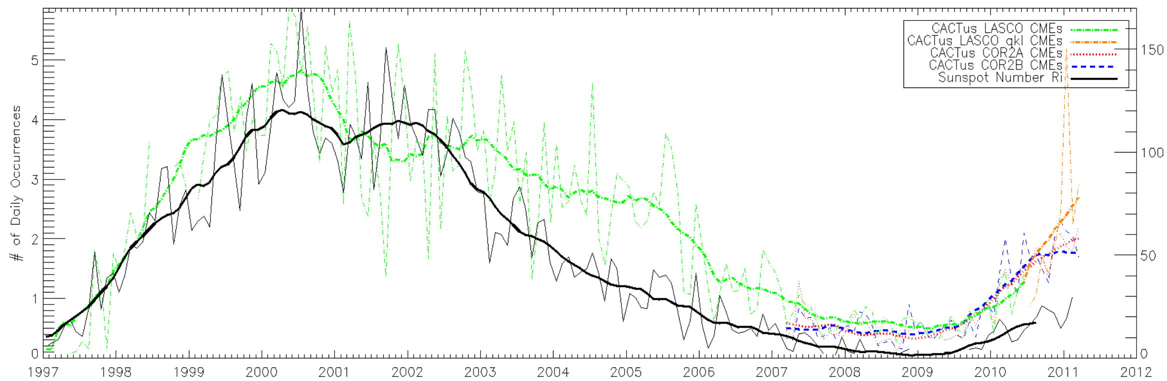


Figure 25: CACTus LASCO, SECCHI-A and SECCHI-B CME rate versus the Sunspot number.

- NEMO: In 2010, several critical updates were applied to the NEMO. The enhanced performance of NEMO includes the ability to extract limb-dimmings and the detection of small-scale events. Furthermore, the catalogues of solar eruptive events that can be constructed by NEMO may now include larger number of physical parameters associated to the dimming regions. The application on SECCHI/STEREO data encountered a series of difficulties for event detection due to the appearance characteristics in the data attributed to the new instrument and the early stages of the mission. However, application of NEMO on the high resolution SECCHI data led to the discovery of EUV Micro-Eruptions in the solar corona. The new algorithm was able to detect such small-scale eruptive events that did not present any signatures of bursts in the total EUV intensity curve or even in the derived moments of pixel distribution of the consecutive images. These algorithms underwent extensive tests with STEREO data during 2010. The production of the first eruptive events catalog for STEREO was also initiated, it is available online at http://sidc.be/nemo/catalog/. Additionally, the software was further improved with several new useful features like true dimming area computation, cluster analysis technique of dimming extraction and angular measure of intensity. A new approach was introduced: detect regions of interest out of the full disk images and check their statistical parameters. This approach improved the event discrimination and permitted the detection of smaller events as well. Remarkably, less parameters are used which makes the algorithm easier to adapt for other types of data.
- SWB: The Solar Weather Browser (SWB) is an open-source software tool that makes it easy to display and combine solar images from different observatories together with solar metadata, without the need of data processing on the users computer. For the forecast team, the SWB offers an easy tool to browse through solar data while performing the forecast and monitoring the sun.

A.1.2.5.*Space Situational Awareness Program – Precursor services*

"The overall aim of ESA's SSA Preparatory Programme is to support the European independent utilisation of and access to space for research or services, through providing timely and quality data, information, services and knowledge regarding the environment, the threats and the sustainable exploitation of the outer space surrounding our planet Earth." The projects below fit in the preparatory phase of the SSA program and are focused on the Space Weather element.

- SN-I project: The work includes activities SN-SWE-001 "analysis and evaluation of existing SWE assets" and SN-SWE-003 "Definition and detailed design of space weather services prototypes". The RWC team has participated in writing the SN-1 proposal primed by Rhea system (Louvain-La-

Neuve) that was delivered to ESA on May 18 2010. After negotiation, the proposal was selected by ESA and the project officially started on Nov 1st 2010 with duration of 1 year. The main roles for the RWC in the SN1 project are: being the solar expert service centre (ESC solar), leading the space weather assets and services review and leading the assessment of the service concepts and user feedback in an operational environment (Task 5, 2011). Figure 26 shows a snapshot of the online database that was developed within the consortium.

- SN-II proposal: The work includes activities SN-SWE-002 "Implementation design of Space Weather instruments". The RWC team participated in the proposal writing lead by CSL. The proposal was not

Figure 26: Screenshot of the ESA asset DB constructed in the SN-1 project.

selected by ESA.

- CO-1 project: This project is part of the "core element". The work includes the definition of the customer requirements for the SSA system and the definition of underlying governance and data policy. The RWC team was part of a winning proposal and it has participated in the revision of the customer requirements document.

A.1.2.6. *SODA: The Soteria Data Archive*

SOTERIA is a collaborative network funded by the European commission under the Framework Programme 7 for the collection, organisation and use (via theory and simulation) of space physics data aimed at better understanding space weather. Soteria involves 16 centres in 11 European countries and is coordinated by Giovanni Lapenta of the Katholieke Universiteit Leuven (Belgium).

The work package 6 is devoted to the assimilation and the dissemination of the data archive. This means that the data's from each partner that are part of the Soteria project will be made easily accessible through the Soteria Community and to the public.

To do so, we developed and deployed virtual observatory called SODA. SODA provides a single frontend to access the datas provided by the Soteria partners.

Its mains objectives are:

- Provide an uniform way to access data spead across different locations
- Provide a simple and user friendly way to query for data with specific properties

SODA is composed of 3 independent parts:

- *Client*: Web interface allowing the user to enter queries and displatying the results
- *Server*: Manages the available data providers and track information coming from them
- *Data providers*: Provide an interface to the local catalogs of data.

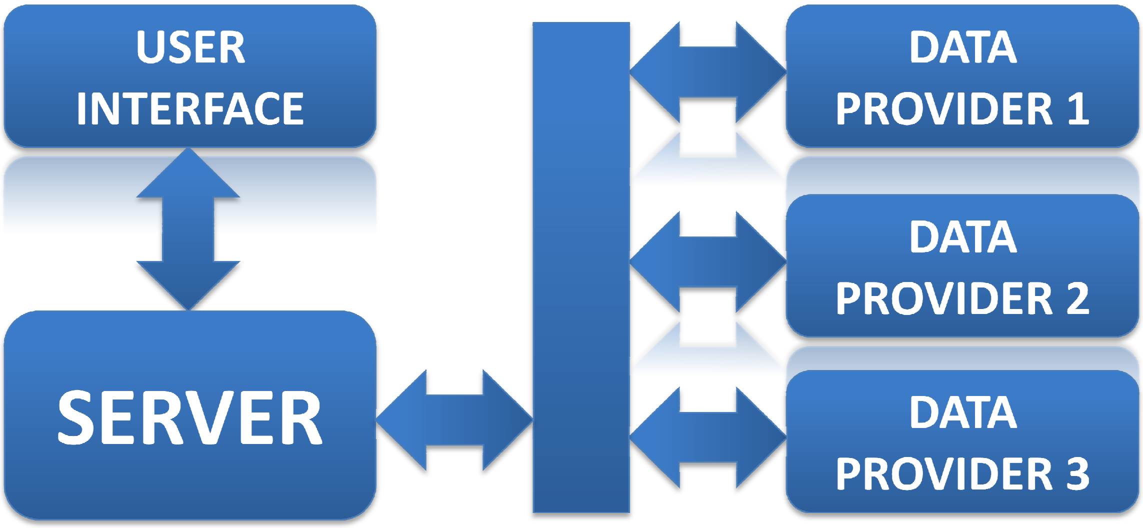


Figure 27: General structure of SoDA

Soda is running since September at the Royal Observatory of Belgium

Uset Data provider

A Data provider serving the Uset H-Alpha and White-light datasets was developped and is up and running at the observatory. It allows access to the images produced on a daily basis.

UniGraz data provider

A Data provider serving the DrawX dataset was developped and is up and running at the UniGraz institute in Austria. Benoit Callebaut made deployment and testing with the collaboration of Wolfgang Maierhofer from the UniGraz institute. It allows access to the DrawX images produced on a daily basis.

Crawling Meta Data Provider

The crawling data provider presents itself as a standard data provider but it is not linked to a specific set of data.

Instead, a user interface allows the user to register web sites or more generally network accessible resources like FTP servers to be analyzed for data files, and to build from the detected files a database of available set of datas.

This approach is necessary for institues that are not able or do not want to run a data provider at their own side.

It has the drawback of lacking of automatic update capability since it takes snapshots of the state of a remote data repository and to retrieve data files attributes present in those files only.

It has been successfully tested on the Level 0 files of the Sphinx dataset.

Installation and deployment

A server was installed and configured beginning of year 2010 in order to be able to run the the SoDA virtual observatory.

SoDA client for the Interactive Data Language

A client for IDL (Interactive Data Language) was developped. It allows running queries directly from an IDL program. It has the same level of functionality as the web interface with the added feature of directly decoding the file into IDL specific structures.

Data provider development tools

In order to make the development of Data provider by third parties, a software package was developed to generate the necessary data provider code and descriptions files interactively. The generated data provider is guaranteed to be correct, relieving the developer and the SoDA server administrator from tedious tests and debugging.

A.1.2.7.*Synergy with the FP-7 projects COMESEP and AFFECTS*

- The COMESEP proposal was submitted to EU in Dec 2009, which resulted in negotiations during 2010. The project has been accepted and has officially started on Feb 1st 2011 (duration: 3 years). The COMESEP project is lead by Norma Crosby (BIRA) and enables an international collaboration betwee partners from Belgium (ROB, BIRA), Austria (UNIGRAZ), Denmark (DTU), Greece (NOA), Croatia (HVAR), UK (UCLan) and non-EU participation from the USA and India. The project contains a CME and a SEP research section and an operational development section to set up an automated risk alert system for space weather. ROB is involved in searching for solar data corresponding to historical large space weather events recorded in geomagnetic indices, The CME – ICME study, the advancement of automated alerts and the set-up of the risk-alert system.
- The FP7 project AFFECTS ("Advanced Forecast For Ensuring Communications Through Space") is a collaboration between members of the solar, geomagnetic and ionospheric scientific communities, which started officially on March 1st 2011. It is lead by Volker Bothmer from the University of Göttingen and involves partners from Belgium (ROB), Germany (UGOE, FHG, DLR, ASTRIUM ST), Norway (UoT), and Ukraine (SRI NASU-NSAU), as well as non-EU participation from the USA. One of the main goals of the project revolves around setting up an operational chain of models to provide early warnings for space weather events (with special emphasis on those events that impact the ionosphere), operational integration into the SIDC Regional Warning Center, and subsequent quality control and feedback.
- The purpose is to integrate the results of both projects in the RWC activities in 2013-2014.

A.1.2.8.*Network activities*

- The SIDC/STCE was responsible for the local organization of the *Seventh European Space Weather Week* (ESWW7), which took place in November 2010 in Bruges and the CESRA worskshop for European Radio Astronomers, which took place in June 2010 in La-Roche-en-Ardenne.
- We have visited one of the customers of the RWC to have a better mutual understanding of each other's activities.
- As consultant, F. Clette has provided guidance about key space-weather related solar observations needed for a L1 mission proposal to Bernard Boullet (CNES, Toulouse). This mini-mission proposal was finally not selected by CNES (Nov. 2010)
- Eva Robbrecht and Ronald Van der Linden have participated in the COST ES0803 workshop held in Paris (March 2010).
- Colleagues from Locarno (Switzerland), who are one of the most important contributors to the sunspot number, have visited us to discuss sunspot procedures.
- Eva Robbrecht presented the RWC activities at an internal space weather workshop in Meudon, Paris (Dec 2010).

A.1.3. Perspective for next years

- A number of technical improvements are foreseen for the Ri calculation:

- Migrate the last five observers who still send e-mail with sunspot data to the WOLF web interface.
- Check the impact of the set parameters like the pilot station in on the Ri sunspot index and continue to check the impact of K factors.
- Computation of the sunspot index before 1981 with the currently used method.
- Try to include hemispheric computation in MySQL/PHP code.
- Check the impact of the time of observation on the Sunspot index computation.
- Include localisation of the sunspot group in the Wolf interface.

➢ E. Robbrecht will continue to lead the RWC during 2011. We plan to finish the upgrade of the RWC and to work on the upgrade of the previweb pages according to the forecasters needs. We will organize monthly forecaster meetings during which we discuss in more detail a space weather subject to improve the quality of our predictions. We will also prepare a learning-track to train new forecasters. E. Robbrecht will represent the RWC at the ISES meeting and the Space Weather Workshop, both in Boulder, April 2011. The RWC activities will be coordinated with our contributions to the FP-7 projects (COMESEP and AFFECTS).

➢ F.Clette will take over the lead of the WDS "sunspot". The investigation of the post-1998 drift of the sunspot index will be continued in collaboration with the Locarno station and also by exploiting by-products of the solar index research developed for the SoTerIA project. We will codify the methods implemented in the base software still in use nowadays. Various validation tests will be implemented on this database to fully qualify the new software (using database applications). This should result in the publication of a full description of the methods used for sunspot calculations and predictions (technical manual and scientific paper). This new software could then replace the old one, offering a higher robustness and also a more flexible use for quality control and diagnostics and for future adaptations.

➢ The Kalman filter technique introduced by T. Podladchikova to improve the sunspot index forecasts will be applied operationally and monitored for its performance.

➢ We will continue working on the SN-I project and participate in upcoming SSA proposals, our goal is to maintain the Belgian lead in space weather operations in Europe

➢ SIDC/STCE will be the local organizer for the eight ESWW, which will be held in Namur, Belgium during 28/11 – 2/12 2011.

➢ The Soteria project ends in October 2011 and no funding is allocated for further development of SODA for the last 4 months of the project at the Royal Observatory. Fortunately, AFFECTS will re-use and enhance the actual SoDA infrastructure. SoDA will be maintained on a best effort basis unless more funding are allocated to it.In the mean time, we intend to continue to work on a few points:
    - *Integrating more datasets*: ongoing work is focused on the SphinX dataset and data from Oulu University. Integration of SWAP and LYRA datasets are also targeted. More coud be added depending on community feedback.
    - *Enhancing the web interface*: some remarks were done at the last Capacity Building Workshop and we will try to take them into account
    - *Enhancement of clients*: enhancements have to be made to the IDL client. A client with a lot more visualisation and data management functionalities could provide a big added value for the user.

➢ Eva Robbrecht and Cis Verbeeck have registered for the course "project management" organised by SELOR.

A.1.4. Partnerships

List of international collaborators having actively contributed to the project in the last year

➢ Dr. Norbert Jakowski and Michael Danielides, German Aerospace Center (Germany)

- Prof. Truls Lynne Hansen, Tromso Geophysical Observatory (Norway),
- Prof. Eija Tanskanen, Finnish Meteorological Institute
- Dr. Astrid Veronig, UNIGRAZ (Austria),
- Dr. Peter Beck, Austrian institute of Technology
- S. Cortesi, M. Cagnotti, Specola Solare Ticinese, Locarno (Switzerland)
- M. Bianda, R. Ramelli, IRSOL, Locarno (Switzerland)
- J. Poncy, Thales-Alenia (France)
- Wolfgang Maierhofer, Manuela Temmer, Roland Maderbacher, UniGraz (Austria)
- Dr. Tania Podladchikova, Moscow State University (Russia)
- The network of SIDC solar observers.

List of national collaborators having actively contributed to the project in the last year

- Michel Kruglanski, Norma Crosby, Erwin De Donder and Stijn Calders, BIRA
- Andre Sincennes, Simon Reid, Rhea System NV

Grant(s)/Project(s) used for this research/service

- Contract SN1 – ESA
- STCE
- SOTERIA (project n° 218816) from European Commission's Seventh Framework Programme (FP7/2007-2013)

A.1.5. Scientific outreach

Wikis and Websites

- SN-1 asset database: http://catalogue.ssa-sn1.eu/
- RWCWDC wiki (intranet): http://sol042.oma.be:8000/RWCWDC/wiki
- Forecasting pages on the SIDC website, e.g. http://sidc.oma.be/LatestSWData/LatestSWData.php
- ESWW7 website: http://www.sidc.be/esww7/
- CESRA website: http://sidc.be/CESRA2010/index.php

Commissions, working groups:

- COST ES0803 workshop, Paris, March 2010
- F.Clette was invited to join the COST project ES1005 "Towards a more complete assessment of the impact of solar variability on the Earth's climate" initiated by T. Dudok de Wit of the LPC2E at the Université d'Orléans. Dedicated to the study of long-term proxies relevant to the Sun-Earth and climate relations, this project was selected by the end of 2010. Its actual start is scheduled for mid-2011.
- SN-1 kick-off meeting at ROB, Nov 5, 2010
- Space Weather workshop at Meudon, Paris, Dec 6-7 2010
- Second Soteria Annual Meeting, 5-7 October 2010, Debrecen
- ESWW7, 17 – 19 November 2010, Brugge
- Soteria Summer School, 17-29 October 2010, Trieste ICTP

A.2. NEMO Operational Development

A.2.1. Description

The recent developments in space instrumentation for solar observations and telemetry have caused the necessity of advanced pattern recognition tools for the different classes of solar events. The Extreme ultraviolet Imaging Telescope (EIT) of solar corona on-board SOHO spacecraft has uncovered a new class of eruptive events which are often identified as signatures of Coronal Mass Ejection (CME) initiations on solar disk. It is evident that a crucial task is the development of an automatic detection tool of CMEs precursors. The Novel EIT wave Machine Observing (NEMO) code is an operational tool that detects automatically solar eruptions using EIT image sequences. NEMO applies techniques based on the general statistical properties of the underlying physical mechanisms of eruptive events on the solar disc.

The NEMO version that was in operation till August 1, 2010 consists of two main steps, namely the event detection and the eruptive dimming recognition. The event detection is based on the detection of bursts in the high order moments of the image while the eruptive dimming extraction is based on a sequence of filtering techniques applied in the pixel distributions of image sequences (see Figure 28).

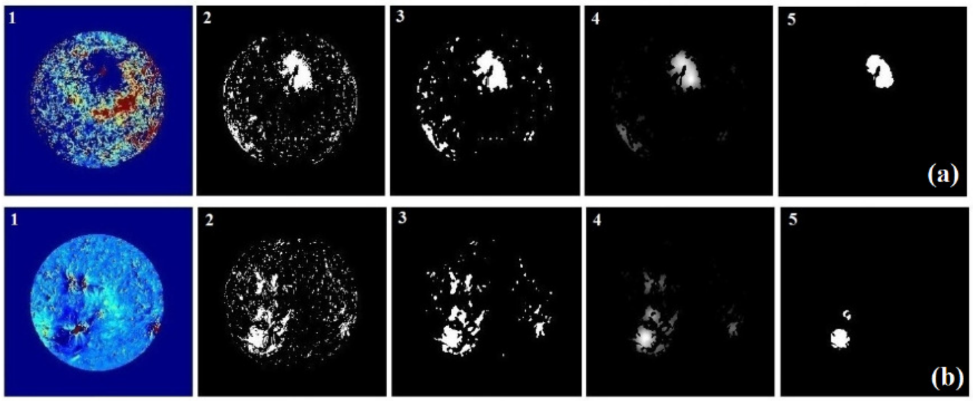


Figure 28: steps of dimming extraction form EUV/SOHO 195 A EUV corona image. (a) – 12 May 1997 at 05:07 UT; (b) –07 April,1997 at 14:22 UT.

A.2.2. Progress and results

In 2010, several critical updates were applied in NEMO algorithms that resulted to a significant increase of the recognition efficiency of solar eruptions linked to CMEs. The increased efficiency of NEMO has resulted to the ability of extraction of dimmings observed near the solar limb and to the detection of small-scale events as well. Furthermore, the catalogues of solar eruptive events that can be constructed by NEMO may now include larger number of physical parameters associated to the dimming regions.

A.2.2.1.*Detection of Solar Eruption Characteristics*

The NEMO updates provide calculations of the surface of the dimming region, implement novel clustering technique for the dimmings and set new criteria to flag the eruptive dimming based on their complex characteristics. The surface of the dimming area is computed now directly in terms of physical variables (square kilometers) by taking rigorously into account that EIT images correspond to solar sphere projections. The clustering of dark regions is achieved through circle vicinity clustering. Furthermore, the novel methods for the eruptive dimming extraction - based on the volume metric of the dimming - increased the detection efficiency and the accuracy of the associated extracted parameters. Figure 29 depicts the extracted structures from the differences images using the basic (Figure 29a) and the modified algorithm (Figure 29b).

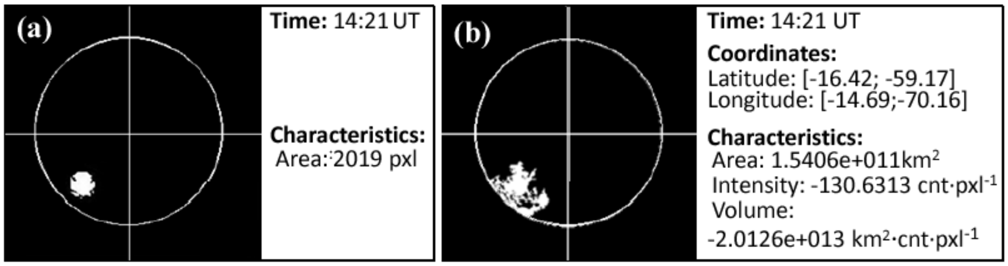


Figure 29. More precise extraction of the dimming of 7 April ,1997 EIT/SOHO event by modified algorithm with respect to the dimming extracted by the basic NEMO method – (a). (b) –More dimming characteristics are provided by modi fied extraction algorithm.

As it is shown, the modified algorithm demonstrates considerably more precise definition of the dimming shape.The surface of the dimming is given in km^2 instead of pixels while a number of additional parameters is also provided. Using a series of examples, we have shown that the modified version of NEMO tool presents indeed significantly higher temporal and spatial efficiency on the automatic detection of CME precursors. In particular, small eruptive events located near the solar limb can be detected now while major events can be detected at earlier times than before.

A.2.3. Perspective for the next years

The NEMO tool will incorporate the optimized new algorithms and it is expected to provide early warnings for CMEs precursors and automatically construct new catalogs with enhanced and more accurate information about the detected solar eruptive events.

B. Earth Atmosphere

B.1. Synergy between GNSS-based and other SW products

B.1.1. Objectives

To use STCE products (e.g. SIDC records, GNSS-based ionospheric and tropospheric monitoring) monitoring to

- learn more about the interaction and correlation between the Sun and the Earth's atmosphere,
- find opportunities to apply these products for other applications,
- indentify the synergies in the frame of the STCE.

B.1.2. Progress and results

B.1.2.1. *Correlation between solar parameters and ionospheric TEC values*

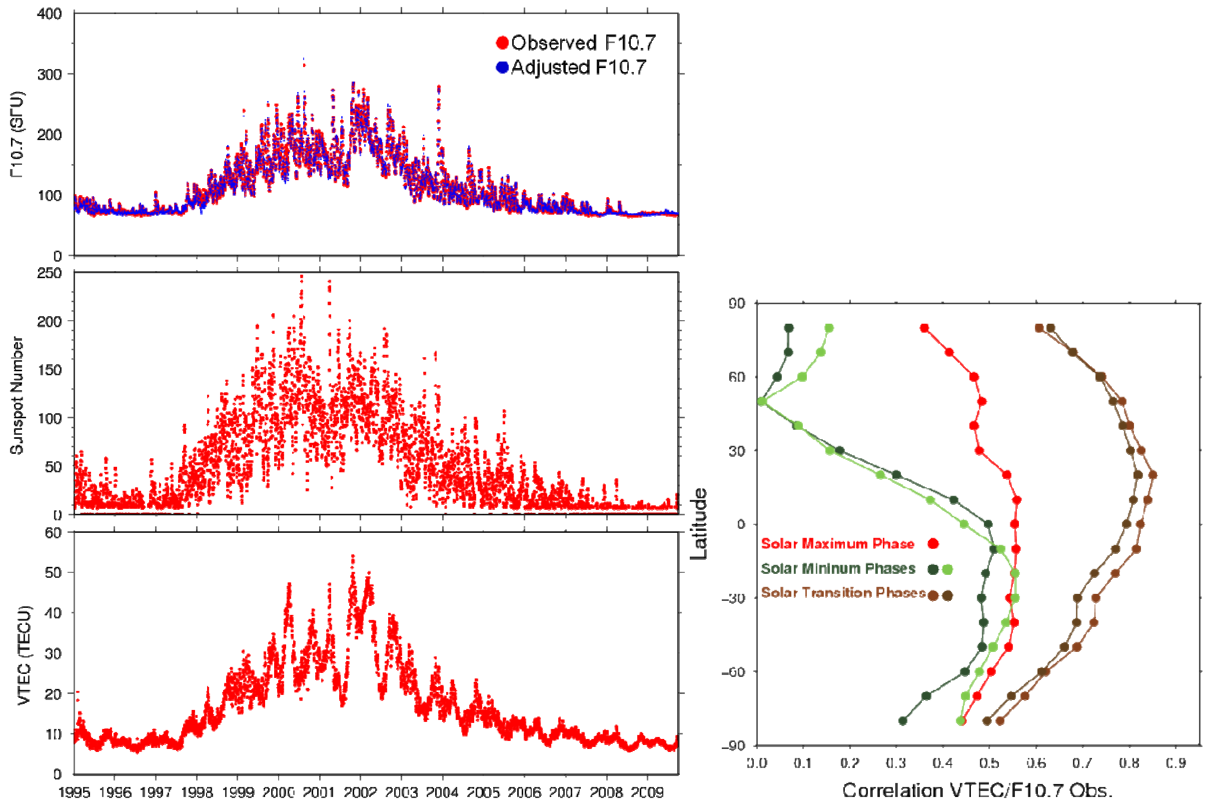


Figure 30: Latitudinal dependency of the VTEC/F10.7o correlation with respect to the Solar Cycle Phases. Left: Ionospheric and Solar data during the 23rd Solar Cycle. Bottom : daily mean global VTEC in TECU. Middle : Sunspot Number as delivered by SIDC. Top : F10.7 flux observed and adjusted from Penticton radio telescope.
Right: Correlation between the F10.7 flux observed and the VTEC each 10° of geomagnetic latitude for different Solar cycle phases.

The correlation between the solar activity and the daily mean Vertical Total Electron Content (VTEC) of the Earth ionosphere discretized each 10° of latitude continued to be investigated. The best correlation is found for the F10.7 observed flux (index corresponding to the solar radio flux per unit frequency at a wavelength of 10.7 cm), when VTEC is expressed in geomagnetic coordinates. Moreover, the maximum correlation (R=0.94) is close to S30° latitude during winter while the minimum (R=0.74) occurs during summer period close to the South Pole. Finally the correlation is larger during the phases of Solar transition activity (R=0.71±0.09) and decreases during maximum (R=0.49±0.05) and minimum (R=0.32±0.19) phases with a complete de-correlation at N50° during Solar minimum. This implies a different response of the ionization in the ionosphere with respect to the Solar cycle phases (Figure 30).

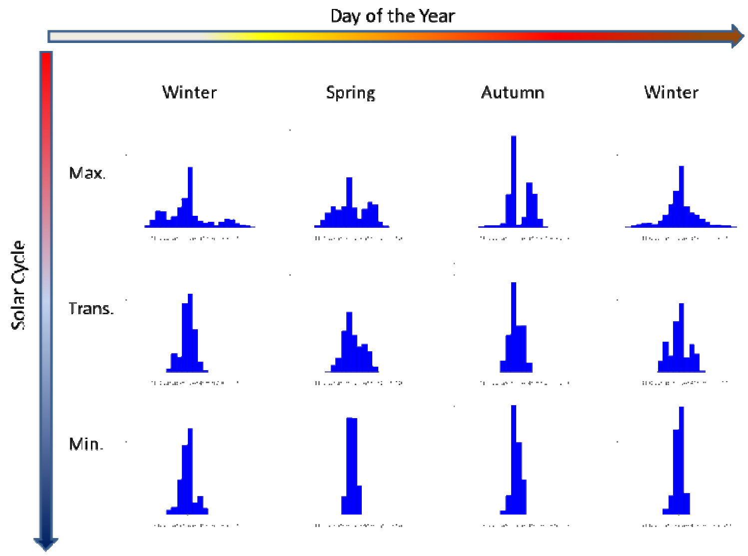


Figure 31: TEC variations in a 45 minutes time span close to the Goldstone complex (California, US) with respect to the seasons (horizontal axis) and to the Solar cycle phases (vertical axis).

B.1.2.2. *Radioscience*

Radioscience deals with radio signals in S-, X-, and Ka-bands, which are perturbed by the plasma between the spacecraft and the antenna on Earth tracking the spacecraft (at the NASA DSN (Deep Space Network) or the ESA tracking stations ESTRACK).

- At the Earth side of the line-of-sight, the Slant Total Electron Content (STEC) gradients during 45 minutes close to the Goldstone complex (California, US, Longitude: 243°06'37.66245"; Latitude: 35°25'33.24354") have been estimated targeting radio science applications. For an elevation angle from 25° to 60°, the STEC varies from 3 to 10 TECU depending on the solar cycle phases and the seasons during the year. This tool will permit to correct radio signals for radio sciences applications.
- The radio-wave is also perturbed while propagating through the solar plasma. STCE members have compared the prediction of the time delay of the radio-wave propagation between a spacecraft around Mars and the Earth due to the electron density of the solar corona and interplanetary plasma [220]. The steady-state radial electron density profiles proposed in the literature permit to predict the total electron density along the propagation path between the spacecraft and Earth's based tracking stations, and in turn the associated time delay of the radio-signal propagation that can be expressed in range delay and Doppler contribution (solid blue and red curves in Figure 32). This predicted time delay permits to explain the periodic variations in the observed range biases. However, the solar plasma is not spherically symmetric and the radial models may not correctly account for the true total electron content along the propagation path. Then outputs of a time-dependent 3D Magneto-

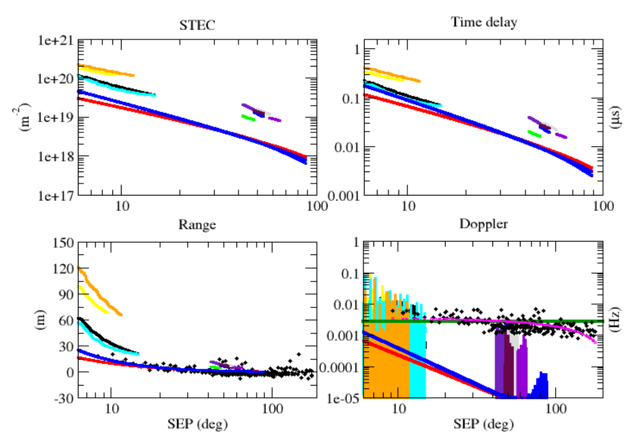


Figure 32: Time Delay, Range and Doppler induced by Slant Total Electron Content from steady-state radial models (red and blue solid lines) and 3D models (others colored lines). Black dots are range biases and Doppler residuals from MEX data.

Hydro-Dynamic code of the heliosphere provided by the Community Coordinated Modeling Center (CCMC) services has been used to re-compute the associated time delay on an Earth-Mars radio-wave link. Larger values than predicted by the radial profile models have been obtained. The comparison with the estimated range bias values is represented in Figure 32. This work is still in progress.

B.1.3. Perspective for next years

- Continue to study the correlations between solar parameters and ionospheric total electron content
- Choose the optimum parameters and process to predict electron concentration from solar data in input
- Continue to provide electron content from on-demand radio sciences users.

B.2. Monitoring, modeling and forecasting the ionospheric activity

Nowadays, our modern society relies on many operational technological systems based on the use of radio waves: ground-to-ground and ground-to-satellite telecommunications, radars, Global Navigation Satellite Systems (GNSS) such as GPS or Galileo, … Free electrons in the ionosphere perturb the propagation of radio waves. Indeed, the ionosphere is defined as "the atmospheric layer where the free electron concentration is sufficient to affect radio wave propagation". In practice, Space Weather phenomena are often the origin of disturbed ionospheric activity conditions which can strongly affect the performances of technological systems based on radio waves. Therefore, it is indispensable to monitor, to model and to forecast the ionospheric activity and its effects on these technological systems.

B.2.1. Objectives

The goal of this WP is to develop techniques allowing to monitor, to model and to forecast ionospheric and Space Weather activity "parameters" which have an influence on the performances of technological systems based on radio waves (electron concentration, Total Electron Content (TEC), geomagnetic activity, …).

The electron concentration in space and time is the main parameter which describes the state of the ionosphere. The ionospheric activity strongly depends on Solar activity. Indeed, extreme UV and X rays emitted by the Sun are the main source of ionization in the ionosphere. For this reason, Space Weather is the main driver of ionospheric disturbances. In particular, geomagnetic storms are often the cause of strong variability in the ionosphere electron concentration.

The ionosphere Total Electron Content or TEC is another parameter of interest. Indeed, the influence of the ionosphere on GNSS measurements depends on GNSS wave frequency and on TEC. The TEC is the integral of the electron concentration on the GNSS receiver-to-satellite path. It is measured in TEC Units (TECU): 1 TECU=10^{16} electrons m^{-2}.

B.2.2. Progress and results

In 2010, the goals of this WP were :

- To analyze the added value of dual frequency GPS (L1/L5) and Galileo (E1/E5a) data for TEC reconstruction.
- To further validate the triple frequency Galileo (E1/E5a/E5b) TEC reconstruction technique.
- To develop an improved K nowcast and a more reliable geomagnetic storm alert service (improved quality control).
- To develop a Dst geomagnetic nowcast technique based on ACE data.
- To develop improved Local Ionospheric Electron Density (LIEDR) at Dourbes

B.2.2.1. *TEC reconstruction using dual frequency GPS (L1/L5) and Galileo (E1/E5a) data*

In collaboration with the University of Liège (ULg), two SEPTENTRIO POLARX3EG GNSS receivers have been installed in November 2009 at the Geophysical Observatory of Dourbes. These two dual frequency GNSS receivers are able to track simultaneously GPS L1/L5 and Galileo E1/E5a signals.

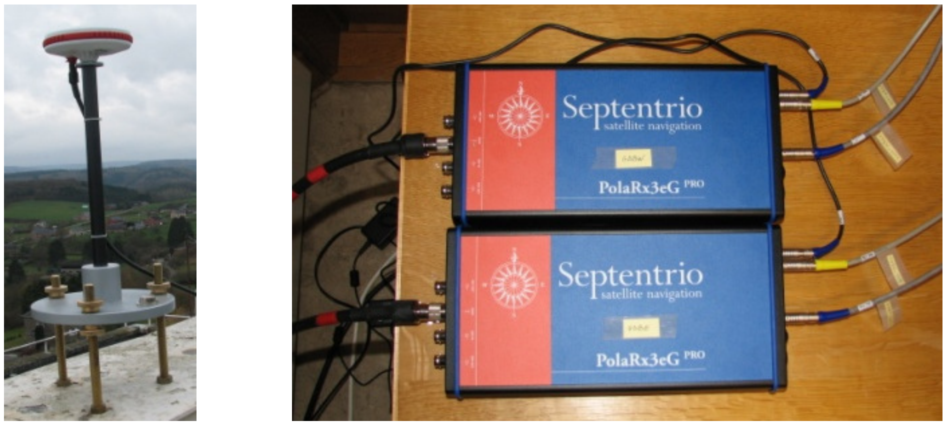


Figure 33: GNSS equipment in Dourbes

In a first step, preprocessing software has been developed. This software detects cycle slips and analyzes the quality of new GNSS signals: resistance to multipath, measurement noise, inter-frequency hardware biases, … Usual cycle slip detection methods can be strongly affected during periods of disturbed ionospheric activity. Therefore, as the measurements will be used for ionosphere monitoring, the “testing quantities” (combinations of code and carrier phase measurements) implemented in our software have been chosen in such a way that cycle slip detection is not influenced by the ionospheric activity. Our pre-processing software has been tested with success on a few case studies. Further validation is ongoing using all the data collected by our receivers which are in continuous operation since November 2009.

B.2.2.2. *Validation of the triple frequency Galileo (E1/E5a/E5b) TEC reconstruction technique*

The availability of triple frequency measurements makes it possible to improve the ambiguity resolution process by the use of Geometric-Free and Ionosphere-Free linear combinations. Instead of resolving Geometric-Free ambiguities directly, the procedure aims to resolve the original phase ambiguities N_{L1}, N_{L2}, N_{L5}, and then reconstruct the Geometric-Free ambiguities and TEC. Our improved method has been validated on measurements made on E1, E5a and E5b signals emitted by the two experimental Galileo satellites, Giove-A and Giove-B. Those measurements were provided by four stations belonging to the Galileo Experimental Sensor Stations (GESS) network. In the text which follows, L1 stands for Galileo E1 signal, L2 for E5b and L5 for E5a.

Ambiguity resolution

Our enhanced ambiguity resolution process has three main steps:

- First, the Extra-Widelane-Narrowlane combination, which is Geometric-Free and Ionosphere-Free, is used to resolve **Extra-Widelane (EWL) ambiguities** (N_{L5}-N_{L2}). This combination gives the integer ambiguities plus a residual term, which is mainly constituted by code/phase hardware delays, multi-path delays and measurement noise. It is critical that this term be less than 0.5 cycle (i.e. approximately 5 m), which leaves room for residual errors.

  Theoretically, considering a 99% level of confidence, the error will not be greater than 0.31 cycle, which means that we are able to resolve the EWL ambiguities. The variability level of the EWL combination (due to multipath and noise) has been confirmed by analyzing Giove-A and Giove–B data. Furthermore, as we have mathematically demonstrated that an error on the EWL ambiguities would cause a huge error on the obtained TEC values, we can confirm that we have fixed the ambiguities at their correct integer values.

- Secondly, the Widelane-Narrowlane combination, which is Geometric-Free and Ionosphere-Free, is used to estimate the Widelane ambiguities; the Differenced Widelane combination, which is Geometric-Free, can also be used to estimate the **Widelane (WL) ambiguities** (N_{L2}-N_{L1}). Those combinations give the integer ambiguities plus a residual term. As it is larger than 0.5 cycle, both Widelane-Narrowlane and Differenced-Widelane residual terms prevent us from resolving WL ambiguities.

  The Widelane-Narrowlane and Differenced-Widelane combinations actually give quite different approximated values of Widelane ambiguities. As code measurements are used to compute the former but not the latter one, it helps us – together with the analysis of Geometric-Free code combination (see Figure 2) – to conclude that L1 code hardware biases are rather large, while L2 and L5 rather small. Other researches (Mayer et al., 2011) also studied the behavior of code hardware delays. In agreement with our results, they show that Giove-A and Giove-B differential satellite and receiver code hardware delays (IFB L1-L2) are around -2300 TECU, that is two orders of magnitude more than GPS ones. Moreover, IFB of Giove-A and Giove-B seems to be stable (+/- 3 TECU or 1 ns over one month period).

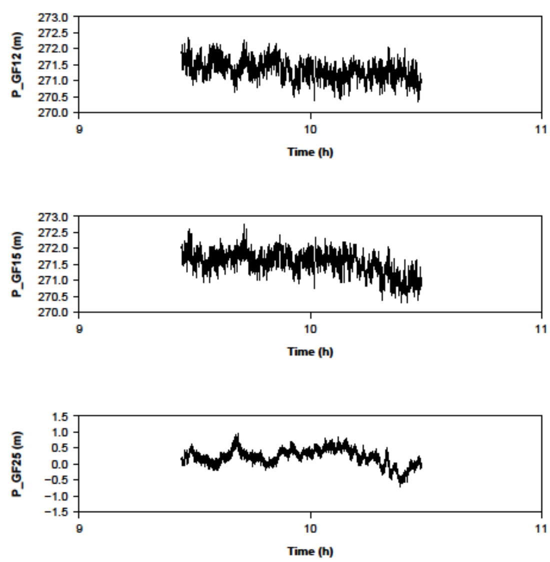


Figure 34: Geometric-Free code combination for station GMIZ Day of Year 341 in 2008 – Both L1/L2 and L1/L5 combinations vary around 270 m, whereas L2/L5 vary around 0 m. We found out that it could be explained if L2 and L5 code hardware delays are rather small, while L1 ones rather large.

- Finally, a triple frequency phase combination is used together with approximated TEC values to resolve the **original phase ambiguities**. This combination only depends on the ambiguities N_{L1}, N_{L2}, N_{L5} and on phase delays (residual term). If we introduce the values of EWL and WL ambiguities obtained from previous steps in this triple frequency phase combination, we can obtain N_{L2} (and then N_{L1} and N_{L5}).

  We have shown that the presence of phase hardware delays could lead to an error of 4 cycles on the ambiguities, which corresponds to an error of 2-3 TECU on TEC values.

TEC reconstruction

As we have computed the original phase ambiguities N_{L1}, N_{L2}, N_{L5}, we are able to reconstruct Geometric-Free ambiguities L1/L2, L1/L5 and L2/L5. Then, **TEC** can be obtained from all three Geometric-Free combinations. However, it has been proved that the best way to compute TEC is to use frequencies as far apart as possible (which minimize the error budget), so that we will not compute TEC using L2/L5. The two other combinations have the same level of precision (see Figure 35). Finally, it has been shown that the total error on TEC – caused by the ambiguity resolution and phase delays – would reach about 2-3 TECU.

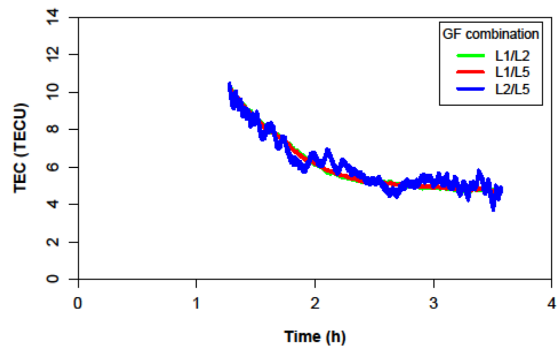


Figure 35: TEC values for station GNOR Day of Year 013 in 2008: TEC_{25} is less precise than TEC_{12} and TEC_{15}.

B.2.2.3. *Development of an improved K nowcast and a more reliable geomagnetic storm alert service*

A nowcast system (K-LOGIC) for operational estimation of a proxy, K-type, geomagnetic index was developed. The system is based on a fully automated computer procedure for real-time digital magnetogram data acquisition, screening the dataset and removing the outliers, estimating the solar regular (S_R) variation of the geomagnetic field, calculating the K index, and issuing an alert if storm-level activity is indicated.

In 2010, a new procedure was developed for estimation of the solar regular variations curve and consequently implemented into K-LOGIC. Implemented also was an improved real-time data/processing quality control following the detailed statistical analysis of magnetic data from previous years. The reliability of the alert module was also improved by incorporating a Dst index nowcast that allowed a double check on the current geomagnetic activity levels. Last but not least, the data quality control matrix was further elaborated and includes the assessment of the recent nowcast accuracy, based on comparison with the "close to definitive" K value as soon as this value becomes available.

Status: operational.

Website: updated: (http://swans.meteo.be/geomagnetism/ground_K_dourbes).

B.2.2.4. *development of a Dst geomagnetic nowcast technique based on ACE data.*

A new procedure based on the Lund neural network model has been implemented. This product has been incorporated into the K-LOGIC system to improve reliability of the alert service.

Status: operational.

Website: updated: (http://swans.meteo.be/geomagnetism/Dst)

B.2.2.5. *Development of an improved Local Ionospheric Electron Density (LIEDR) at Dourbes*

The purpose of the LIEDR (Local Ionospheric Electron Density profile Reconstruction) system is to acquire and process data from simultaneous ground-based total electron content (TEC) and digital ionosonde measurements, and subsequently to deduce the vertical electron density distribution above the ionosonde's location. LIEDR is primarily designed to operate in real time for service applications and, for research applications and further development of the system, in a post-processing mode. The system is suitable for use at any site where collocated TEC and digital ionosonde measurements are available.

In 2010, the operation of LIEDR was unproblematic most of the time, with only a few exceptions when the digisonde failed to deliver autoscaled values or the TEC values were missing (or far too low) to produce realistic ionospheric electron density profiles. These problems are clearly due to the rather old ionosonde (in operation since the early 1980's) and the sometimes unreliable computer network connections in Dourbes. The O+/H+ ion transition model which was upgraded to account for the changing solar activity, now incorporates solar activity index nowcast from NOAA. The LIEDR algorithm was improved, now having the option of selecting between three different ionospheric density profilers. The imaging was also improved and now plots the ionospheric plasma frequency. An additional derivative product, associated with LIEDR, includes an ionospheric slab thickness monitor. The ionospheric slab thickness, the ratio between the ionospheric electron content to the peak ionospheric density, offers substantial information on the neutral and ionospheric temperatures/gradients and the ionospheric composition and dynamics in general. It is a very useful product, complementing the plasma frequency monitor, as it gives an immediate quantitative information on the dynamics of the local ionosphere (for example, during geomagnetic storms, the slab thickness changes drastically, with storm time values often increasing more than 100-150% above the normal values).

Status: operational.

Website: updated: (http://swans.meteo.be/ionosphere/liedr).

B.2.3. Perspective for next years

In 2011, the goals of this WP are:

- To exploit new GNSS signals for ionosphere monitoring.
- To explore the new RMI DPS-4D ionosonde capabilities in terms of operational use for monitoring and modeling purposes
- To further improve LIEDR system (in particular, implementation of an improved O+/H+ transition level model and calculation of the topside ionospheric plasma scale height)
- To forecast ionospheric parameters (in particular, the response of local ionospheric characteristics to changing solar/geomagnetic activity)

B.2.4. External funding sources

Part of the 2010 activities reported above and part of the activities foreseen in 2011 have been or will be funded by external sources:

- SWANS (2010-2011), ESA/PRODEX 9, contract C90390.
- Modélisation de l'erreur ionosphérique qui affecte les systèmes de positionnement par satellites (2007-2010), Belspo/Action 2.

B.3. Development of products and services for the users of real time GNSS applications

B.3.1. Objectives

Nowadays, Global Navigation Satellite Systems are widely used to measure positions in real time with a few cm precision. Such a level of precision can be obtained in "differential mode". In this positioning mode, mobile users make use of so-called "differential" corrections broadcast by reference stations in order to improve their positioning precision. At the present time, the ionospheric effect on GNSS radio signals remains the main factor which limits the accuracy and the reliability of differential positioning. Indeed, GNSS differential applications are based on the assumption that the measurements made by the reference station and by the mobile user are affected in the same way by the different error sources, in particular, by the ionospheric effect. The validity of this assumption depends on the distance between the user and the reference station which is called "baseline": on shorter baselines, ionospheric residual effects are smaller than on larger baselines. In practice, these applications will not be affected by the "absolute" TEC but by gradients in TEC between the reference station and the user. For this reason, local variability in the ionospheric plasma can be the origin of strong degradations in positioning precision. Strong variability in the ionospheric electron concentration (and in TEC) is mainly due to Space Weather events such as geomagnetic storms. GNSS real time users who undergo degradations of their measurement accuracy are not necessarily aware about this problem: this is an important limitation to the reliability of GNSS, in particular, in the frame of so-called "safety-of life" applications such as landings of planes. Therefore, it is important to develop services allowing to monitor GNSS "integrity" with respect to ionospheric threats and to warn GNSS users against such events.

Therefore, the goals of this WP are:

- To develop operational techniques to assess, to model and to forecast Space Weather effects on real time GNSS applications;
- To develop a web site which provides information about Space Weather activity and about Space Weather effects on real time GNSS applications.

B.3.2. Progress and results

In 2010, the goals were:

- To further validate SoDIPE-RTK software on the Active Geodetic Network under more active ionospheric conditions.
- To develop an empirical model to forecast the occurrence of ionospheric disturbances.
- To further develop the SWANS web site using the output of WP RMI-C1 (improved K and alerts, Dst, LIEDR, …)

B.3.2.1. *Validation of SoDIPE-RTK software on the Active Geodetic Network*

The SoDIPE-RTK software has been described in detail in the STCE report 2009 and the main results are presented in Lejeune et al., 2011. This software extracts the part of the positioning error which is only due to the ionosphere. Such software needs to be permanently updated to take into account changes in network characteristics (receiver and antenna types, number and maintenance of stations, etc.).

SoDIPE is applied to the whole Belgian dense network (called Active Geodetic Network, or AGN) which is composed of more than 60 GPS stations: FLEPOS (Flemish part, 40 stations) and WALCORS (Walloon part, 23 stations); the ROB permanent GPS stations are also used in our data processing. The equipment used in the different GPS stations of the network is not homogeneous. Indeed, in 2010, FLEPOS began to change the receivers and antennas of their permanent stations which in addition to GPS satellites can now acquire GLONASS signals. This has firstly implications for the handling of RINEX files within the software. Secondly, the computation of the double differences (DD) for two stations with different types of antenna needs to be corrected by taking into account the Phase Offset (PO) and the Phase Centre Variation (PCV) of the antennas. Figure 4 illustrates results obtained for a baseline with different antenna types (LEIAT504 for BRUG and LEIAR25.R3 for PITT): the user positioning error given by SoDIPE software is lower after careful antenna calibration.

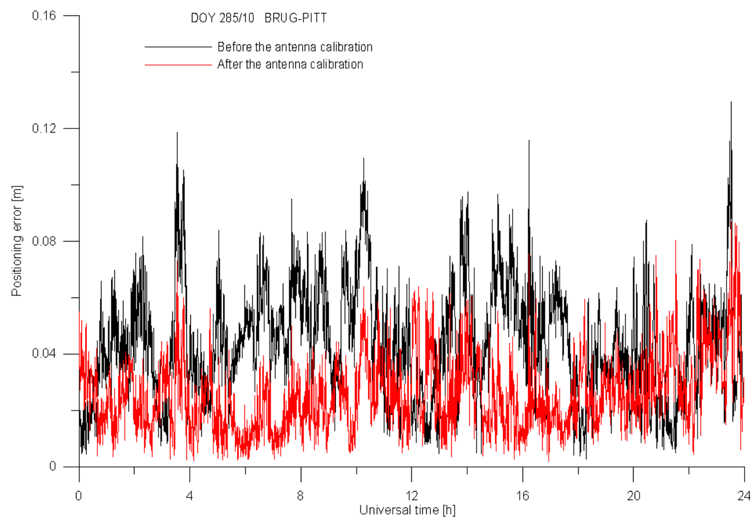


Figure 36: Positioning error given by SoDIPE software for the baseline Bruges (BRUG) – Pittem (PITT) before (black line) and after (red line) the antenna calibration for DOY 285/10

Another step realized this year is that SoDIPE is operational on our website. The final SoDIPE product is a map where all AGN baselines are plotted using a colour code ranging from green (nominal conditions) to red (extreme conditions) which depends on the ionospheric error which affects the considered baseline. The ionospheric error is computed on 15 minute periods.

In order to analyze the effects of baseline orientation, we also produce polar plots, where σ of the ΔD component is plotted as a function of baseline azimuth. Since we want to compare all baselines with each other, it is necessary to eliminate the length effect. Therefore, $\sigma_{\Delta D}$ has been normalized by the baseline length. Each polar diagram depicts the normalized ionospheric error as a function of baseline azimuth. As for the previous final SoDIPE product, polar plots contain all AGN baselines and can be obtained every 15 minutes. They describe in an understandable way the impact of the TID propagation and of geomagnetic storms, in terms of structures and gradients.

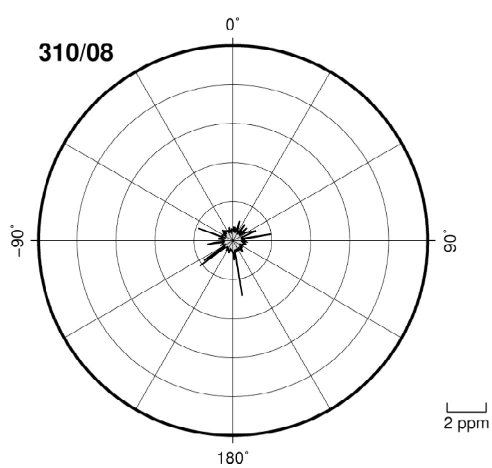


Figure 37: Polar diagram in Belgian AGN for DOY 310/08

A.2.2.2. Development of an empirical model to forecast the occurrence of ionospheric disturbances

The developments of the forecasting model done in 2010 concern the long-term component of the model: the Travelling Ionospheric Disturbances (TID's) probability of occurrence as a function of time for a GPS station in Belgium.

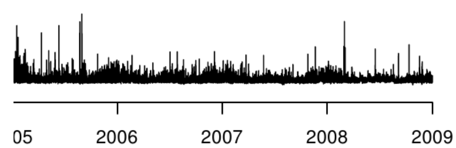


Figure 38: Temporal series of SDRoTEC, averaged over 3 GPS stations. Peaks correspond to strong ionospheric activity due to powerful geomagnetic storms.

Instead of using an ordinal variable like the number of ionospheric events (see STCE report 2009), we decided to use a continuous variable in the forecasting model. The parameter chosen is the standard deviation of the Rate of TEC within 15 minute time intervals, averaged over all satellites in view for a given station: SDRoTEC. Finally, values relative to three permanent GPS stations form the ROB (Brussels (BRUS), Dourbes (DOUR) and Dentergem (DENT)) were merged to get a reliable temporal series over Belgium, without any data gap. The series, which is depicted in Figure 38, covers 7 years of data corresponding to the declining phase of Solar cycle 23: January 2002 to December 2008. Except for the peaks due to active geomagnetic conditions, we can observe that SDRoTEC is larger during autumn and winter, while minimum values usually occur during summertime.

The structure of the model uses a Principal Component Analysis (PCA) on the temporal series; such a technique allows to extract the recurring patterns induced by seasonal and local-time dependence of the ionospheric variability. PCA consists in computing eigenvalues and eigenvectors (called Principal Components, or PCs) of the correlation matrix between the different variables. In our case, the original variables are the 2557 days lying between 2002 and 2008. The observations consist in 96 values of SDRoTEC (one for each 15 minute time interval) projected on the 2557 variables.

Once the PCA computed, we can present PCs by decreasing part of total variance explained, as shown in Table 2: First ten PCs and their associated eigenvalues(λ), part of variance explained (σ^2) and cumulative part of variance explained ($\Sigma\sigma^2$).

PC	λ	σ^2[%]	$\sum\sigma^2$[%]
1	607.43016	23.76	23.76
2	320.12448	12.52	36.28
3	139.49432	5.46	41.73
4	132.93514	5.20	46.93
5	91.34319	3.57	50.50
6	71.31565	2.79	53.29
7	64.95176	2.54	55.830
8	61.00836	2.39	58.22
9	50.45713	1.97	60.19
10	47.57601	1.86	62.05

Table 2: First ten PCs and their associated eigenvalues(λ), part of variance explained (σ^2) and cumulative part of variance explained ($\Sigma\sigma^2$).

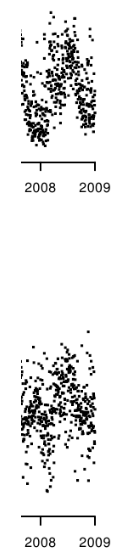


Figure 39: First two PCs; scores (left); loadings (right)

We can observe that we need the first five PCs to explain half of the total variance contained in the correlation matrix. Figure 39 represents the first two PCs where projections of the 96 observations on the PC (called *scores*) are represented on the left part. The *loadings*, which correspond to the correlations between the PC and the original variables (the 2557 days) are represented on the right side of Figure 39.

We can interpret the first two PCs as follows:

- PC1 illustrates the rise of ionospheric activity (local variability) during daytime in winter, where large negative values of the correlations are observed (around -1). During nighttime, ionospheric variability is very low and stable. During summer, correlations are positive and around 0.5, what means that there is also ionospheric activity during daytime but it is not as strong as during winter. This PC, responsible for about 25% of the total variance, corresponds to the winter daytime MSTID's occurrence observed in the former statistics (see STCE report 2009).
- PC2 shows an asymmetric profile with respect to PC1. Correlations reach 0.7 during summer while they are close to zero in winter. This PC is related to summer nighttime MSTID's occurrence, as described in the previous statistics (see also STCE report 2009).

The interpretation of next PCs is more difficult as loadings and scores patterns are not as clear as they are for PC1 and PC2. However, we have to include these following PCs in the next step of our data processing, which consists in catching the bulk of total variance by selecting only a subset of PCs. The number of PCs to be selected depends on the percentage of variance to explain; in this study we will fix this parameter at 95%. The analysis of the cumulative part of variance explained ($\Sigma\sigma^2$) leads us to select the first 64 PCs. By doing this, we exclude all PCs relative to transient events like “ionospheric noise” induced by active geomagnetic conditions. We are now able to re-project the data in the original data space by using only 64 PCs. Then we get a new temporal series of SDRoTEC that we call “model” and that we can compare to the original data to validate our procedure. Figure 8 shows for the year 2004 the difference between the original data and the model coming from the reconstruction technique. We can observe that residuals are generally smaller during summer than during winter, where large values can appear. Moreover, some of these discrepancies are due to geomagnetic events which generate unmodeled ionospheric activity. As an example, the large ionospheric residuals observed during the night of 9-10

November 2004 were due to an extreme geomagnetic storm, with an associated DST value of -289nT. These transient events are not part of our model, what explains large residuals.

Figure 40: Residuals between observed and modeled values of SDRoTEC in 2004.

The goal of the next step is to build an annual model of ionospheric variability, based on PCA analysis and the reconstruction technique. In other words, we have to find a temporal series of SDRoTEC for a “mean year” with a 15 min. time resolution. Therefore, we have to merge the different years within one mean year. As shown in Figure 40: Residuals between observed and modeled values of SDRoTEC in 2004., loadings do not seem to depend on solar cycle and remain stable over the period analyzed. Therefore, the computation of the mean year is achieved by averaging the eigenvectors corresponding to the same day. Then, we reduce the number of PCs to 64 and we are finally able to re-project the data in the original data space to get the model.
The building of this model uses data from 2002 to 2007 and the model is validated on the year 2008 (see below). Figure 41Figure 40: Residuals between observed and modeled values of SDRoTEC in 2004. depicts both original data and the model during equinoxes and solstices. We can observe that the regular pattern of MSTID's is correctly modeled: a slight rise of the ionospheric activity during nighttime in summer and a large one around noon in winter. However, we have to point out some large discrepancies, especially during high solar activity periods like in 2002 or 2003.

Validation of this model has been made based on 2008 values. RMS of residuals (model - observations) are plotted in Figure 42. We can see that RMS values are generally larger during autumn and winter, what confirms the results shown in Figure 41. Relative RMS values are twice larger during these months than during summer, with a mean value of about 15%.

In the future, we have to improve the modeling of the behavior of ionospheric variability during autumn and winter. Such a model might include some proxies of ionospheric disturbances like the Total Electron Content.

Figure 41: Model assessment during equinoxes and solstices.

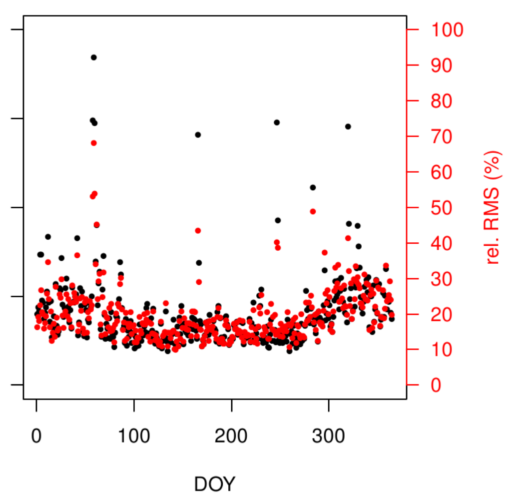


Figure 42: Absolute and relative values of the Root Mean Square (RMS) of residuals "model-observations" over the year 2008.

B.3.2.2. *Development of the SWANS web site using the output of WP RMI-C1 (improved K and alerts, Dst, LIEDR, improved TEC reconstruction, …)*

A new version of the K-LOGIC system was implemented on the SWANS website (http://swans.meteo.be/geomagnetism/ground_K_dourbes) following the inclusion of an improved module for the estimation of the solar regular variation (Sr) curve. Also, a Dst index nowcast, using the Lund Regional Warning Center model, has been implemented and an image is displayed in the registered-users area of the SWANS website (http://swans.meteo.be/geomagnetism/Dst). As a result, the alert's reliability has been raised - based now on both the ground-based estimation of K and the Dst nowcast.

Figure 43 shows a screenshot for the K-LOGIC system operation during the storm on 3-5 August 2010. Note the refined estimation of the K index (top panel) and the high-quality (QF>6) of the data input/processing.

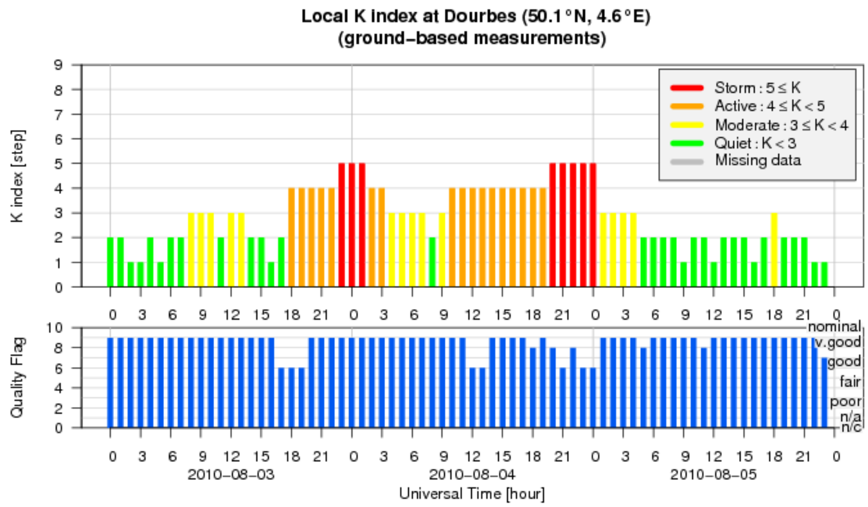


Figure 43: screenshot for the K-LOGIC system operation during the storm on 3-5 August 2010

LIEDR has also been updated and the website (http://swans.meteo.be/ionosphere/liedr) now offers current as well as historical plots and data in better screen resolution and additional information, including the slab thickness monitoring.

Figure 44 shows a screenshot for the LIEDR system operation during the storm on 4-7 April 2010. Note the periods of enhanced ionospheric density on 05 April followed by a period of depleted ionosphere the following day which is a typical behaviour during geomagnetic storms.

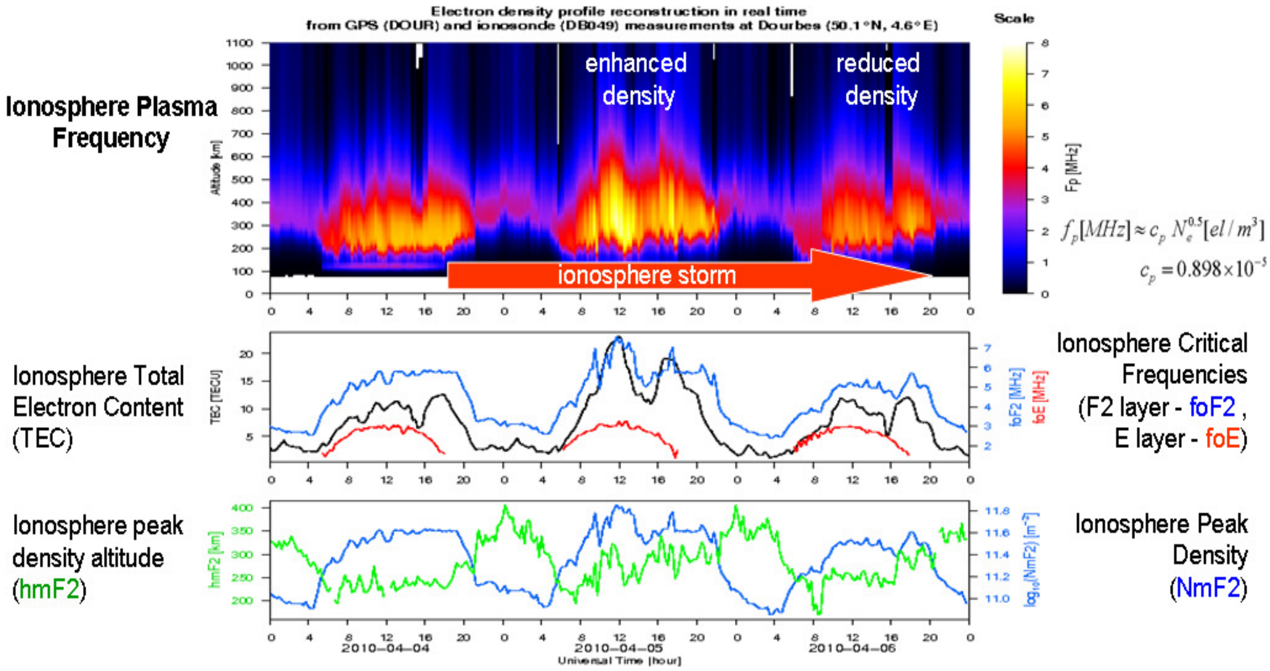


Figure 44: screenshot for the LIEDR system operation during the storm on 4-7 April 2010

Figure 45 shows a screenshot for the ionospheric slab thickness monitor (a product associated with LIEDR) during the storm on 4-7 April 2010. Again, note the substantial increase (top panel, values about 150% above normal) in the slab thickness during the storm, which is in concordance with the LIEDR results.

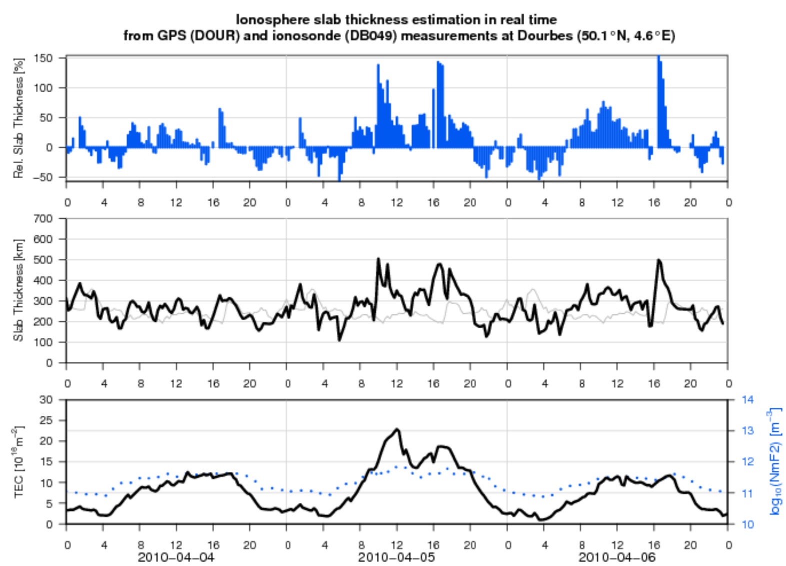


Figure 45: screenshot for the ionospheric slab thickness monitor

Several other services have been added to the registered-users area of the website for performance evaluation: SoDIPE-RTK Polar Plot image and animation, real-time cosmic ray image, ionosonde measurement image, F10.7 solar radio flux image and file download, real time geomagnetic field image. Various small modifications have been made to the website (extra buttons, parameters, plot panels, ...), to improve the usability, along with refactoring of various programs to keep the codebase maintainable. An image was added to show the data available in the database.

B.3.3. Perspective for next years

In 2011, the goals of this WP are:

- To further validate SoDIPE-RTK software on the Active Geodetic Network under more active ionospheric conditions.
- To further develop the SWANS web site.

PART 4: INSTRUMENTATION AND OBSERVATIONS

A. Solar ground-based observations

A.1. Optical - USET and radio - Humain

The “Solar ground-based observations” within the STCE deals with the development or refurbishing of current ground-based solar instruments in the optical and the radio range. Two sites are concerned, Uccle, with the USET instruments and Humain, near Marche-en-Famenne, with radiospectrographs. The main reason for developing such a suite of instruments is the monitoring of the solar activity for research (flare, CME, long term cycle studies, see Figure 46) and operational activities such as the WDC Sunspots or the RWC Brussels.

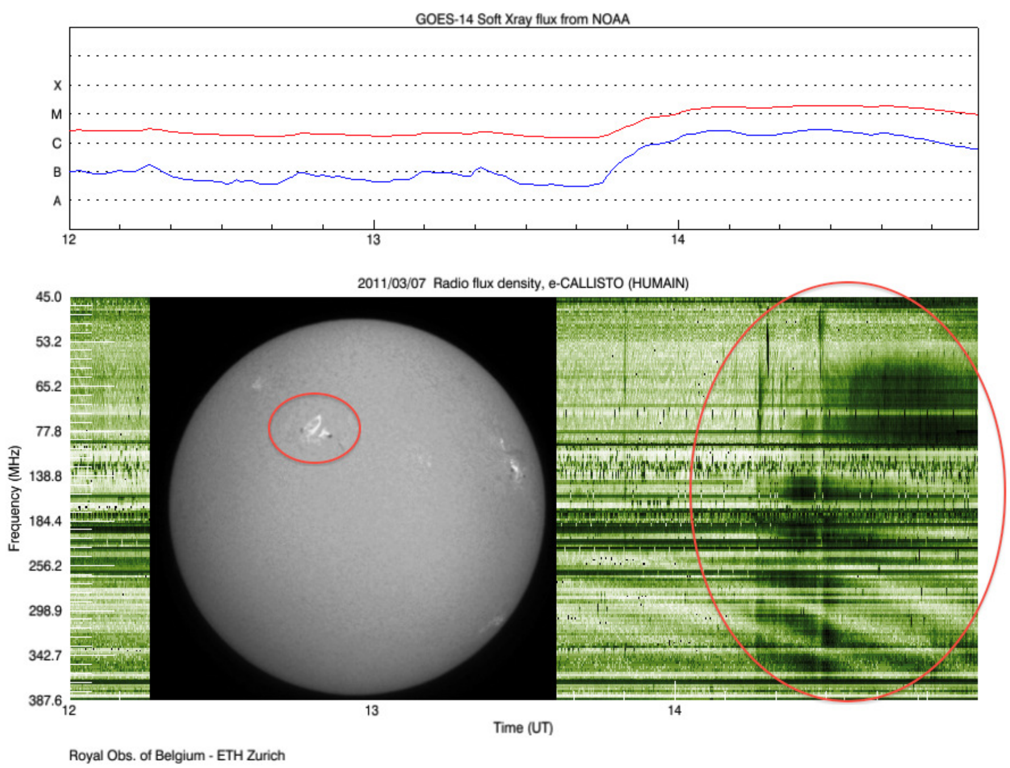


Figure 46 M flare of March 7 2011, observed in Halpha by USET, left, red circle, and by Callisto in Humain (right, red circle)

A.1.1. Description

A.1.1.1. *USET*

General objectives

Data collection and services

The optical USET instruments are providing visual observations since 1940 in support to the SIDC sun-spot index determination, as one of the reference stations in the worldwide "sunspot" network. Since

2002, the USET also produces CCD images in support of real-time solar activity monitoring and forecasting, as well as for fundamental solar research. Those long-term observations provide a continuous characterization of the solar activity and of the sources of irradiance variations. The introduction of white-light and Hα CCD imagers, now in routine use, are also part of a wider ongoing effort to improve and better understand existing solar activity indices and to study new quantitative ground-based solar indices based on modern electronic imaging techniques. This work includes also coordination with other similar solar facilities in Europe and beyond.

The USET activities thus follow two base axes:

- Optical observations of the Sun and characterization of its activity: sunspot drawing, imaging of the photosphere (white light), imaging of the chromosphere (H-alpha, CaII-K)
- Digitization and processing of the visual sunspot observations of the Uccle station, and publication in the SIDC Bulletin of additional indices for this reference station.

<u>Instrument operations, maintenance and upgrade</u>

In order to ensure the continuous operations of the USET instruments and also in order to improve and to extend the capabilities of the Uccle solar optical facilities, we develop new instruments and we upgrade existing ones by introducing new techniques at the level of optics, mechanics or image detectors. As USET telescopes work in the visible light domain, the systems can mostly be built from existing commercial components and do not require specific industrial development. Instead, the new instruments involve primarily the study and development of unique custom solutions, adapting or combining newly available technologies for the specific requirements of modern solar imaging. This work thus relies on internal ROB workshops (mechanics, electronics) and it contributed to the development of a unique internal expertise in optical instrumentation at the ROB.

The USET instrumentation objectives currently involve the following developments:

- Digital imaging system in white-light (photosphere)
- Digital imaging system in the Hα line (chromosphere)
- Digital imaging system in the CaII-K line (chromosphere)
- Telescope pointing system
- Telescope and dome automatization

The funding for these activities comes from the Observatory (salaries & daily observations operations), FP7 projects such as SOTERIA (digitization), and STCE (hardware development).

A.1.1.2. *Humain*

The Humain project started in 2008 as the radio component of "Solar ground-based observations". As such, it is fully funded (salaries and equipment) through the STCE. The idea is to take opportunity of the existing facilities in Humain: parabola on equatorial mounts, laboratories, and on-site personal, to redevelop a small set of solar dedicated radio telescopes. Compared to the past observations operated at Humain, which involved in particular the maintenance of a 48-antenna interferometer, the new observations do not deal with radio imaging but rather with the monitoring of solar activity through wide-band spectral observations (decimetric-metric band related to CMEs and flare activities) and flux measurements at selected individual frequencies (flare physics and irradiance). It involves therefore a smaller set of radiotelescopes. The scientific goals of the project fit very well with the other projects of the Solar Physics department, in particular with the Proba-2 instruments SWAP and LYRA, USET, and an Action 1 project about radio signatures of shock waves (J. Magdalenić). In addition, the project is aimed at supporting the SIDC space weather forecast activities as well as perpetuating the long-term solar radio observations in Belgium.

A.1.2. Progress and results

A.1.2.1. *USET*

Improvements to the white-light CCD telescope

The new ND4 full aperture filter ordered from the Lichtenknecker Company in December 2009 was installed in February 2010. Initial tests showed that the attenuation of the filter was lower than the specifications. After the manufacturer provided an additional ND0.9 to be placed near the focal plane, new tests proved to be satisfactory except for a weak ghost image.

As the optical performance of the 2-lens 0.94x focal reducer installed in 2009 proved to be insufficient (off-axis image degradation), a new design was done, leading to the installation of a single long-focus lens (F=4 m) with excellent results.

Thanks to the two above upgrades, the image quality was considerably improved. The image resolution is now close to the theoretical value for the telescope aperture (~1 arcsec) and only limited by the CCD pixel size and the atmospheric turbulence.

By the end of 2010, the study of the optical rail support for this telescope was started. For this design, the large size and mass of the optical assembly, compared to the other two telescopes, must be taken into account.

Improvements to the Hα telescope

The Hα telescope continued to serve as a test bed for the installation of a common optical rail (installed in June 2009) and independent motorized controls (pointing and focusing). The experience acquired on this telescope can then be quickly transposed to the other two telescopes.

In August 2010, we proceeded with the installation of the "Z" micrometric translation stage providing motorized fine control of the focusing. In manual mode, this brought already a significant improvement on the accuracy and ease of focusing.

Development of a new CaII-K CCD telescope

The first months of the year were devoted to the ordering process of the custom lenses required for the telecentric Barlow system feeding the narrow-band filter. A survey of manufacturer was carried out and three offers were obtained. The first offer made already in 2009 by Molenaar Optics was finally selected. After a final design review, the lenses were ordered in June 2010 and finally delivered in October 2010.

F.Clette also searched for and found a heat-rejection filter compatible with this application, i.e. with transmittance in the violet near 393 nm. This optical filter was also delivered in the fall of 2010.

In parallel, the electronic and mechanical design was started for the CaII-K filter enclosure and thermal regulation. The control electronics were defined and a breadboard system was tested. Mechanical drawings were prepared and the selection of appropriate materials (Invar rods, insulation) was undertaken. By lack of manpower, the progress was slow and this work will only be completed in 2011.

Upgrade of the telescope and dome

Except for the study of the mechanical accommodation and type of rotational encoders on the USET telescope mount, not much progress could be done for the automation of the instrument.

In view of the increased automatization, webcams are required to provide a view of the inside of the dome and of the overall sky conditions. For the latter, a camera with Ethernet link and 180° wide-angle lens were selected and purchased by mid 2010. The design of a watertight and insulated enclosure for this exterior whole-sky monitoring webcam was completed by late 2010. The construction and installation is foreseen in 2011.

Software developments

In 2010, most of the efforts were concentrated on the rewriting almost from scratch of an entirely new version of the SunCap camera control and image acquisition software. This included the re-definition and commissioning: graphical user interface, expanded capabilities, more advanced automatic image acquisition modes, expandability of the software in view of the future inclusion of focus and pointing controls. Initial benchtop tests were made with success for the motion control of the OWIS micro-positioning stages. The interfacing is thus ready and only software development remains to be done.

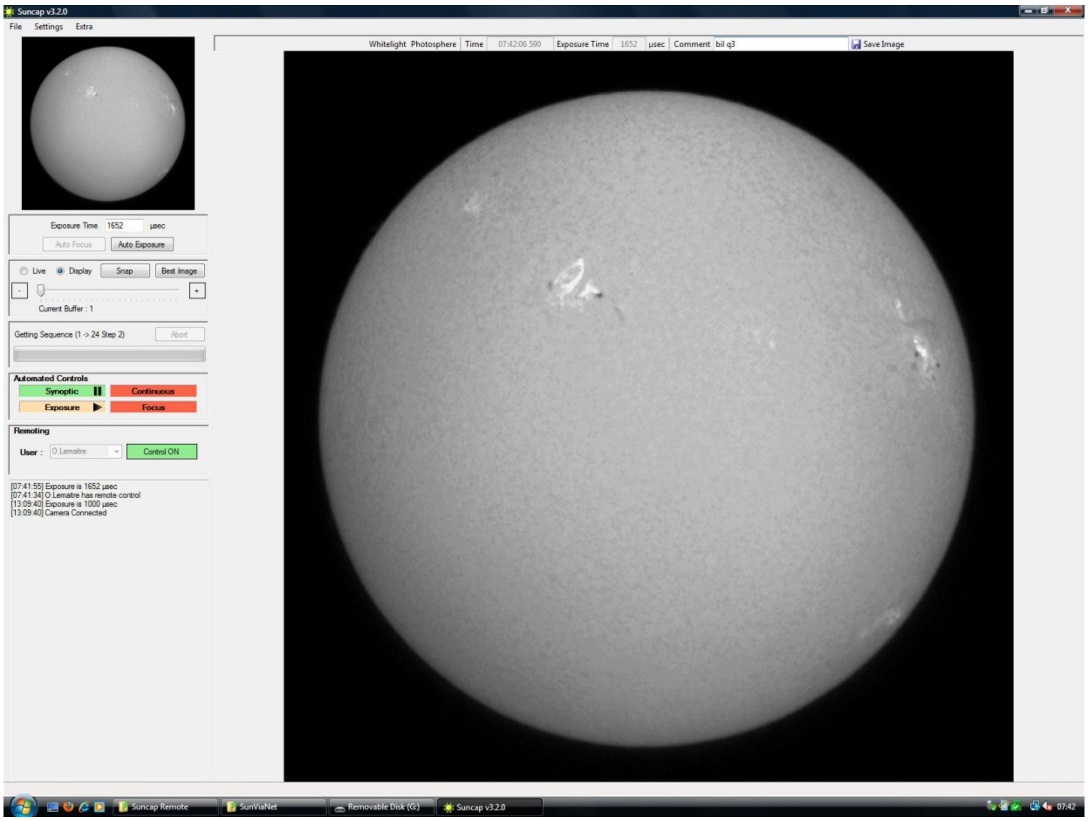


Figure 47: Screenshot of the new streamlined SunCap graphical user interface. The new program features improved and extended capabilities for automated image acquisition and is ready-built for future extensions (remote control of pointing and focus, etc.).

A basic version of image browsing and selection software, SunGlasses, was also created. At this stage it is still missing more advanced capabilities required for working with high-cadence image sequences. Given the lack of time and the low solar activity, this key element of the planned USET data pipeline was not further developed in 2010.

In the framework of the training period, a student from the ESI (Ecole Supérieure d'Informatique de Bruxelles), Greogry Vangroeningen, developed a **web-based logbook for the USET operations**. This application is accessible from any PC in the ROB domain. It allows recording all events and circumstances of the USET observations (actions, observing modes, weather, observer identification). The information is saved in a database, allowing a wide range of later use for recovering specific information or statistics. The recorded information includes both manual entries by the instrument operators and automatic records of camera and telescope status including all images captured by the USET cameras, providing all metadata associated with the image archive. After a 6-month commissioning period, this application should entirely replace the paper logbook used until now.

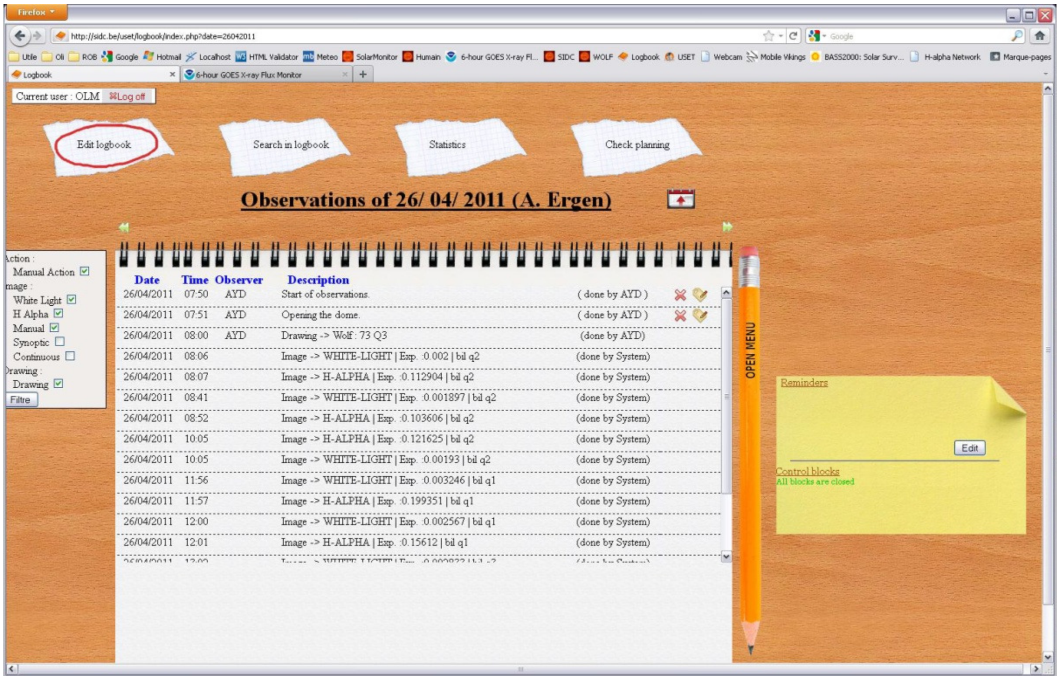


Figure 48: Screenshot of the new on-line USET electronic logbook, which replaces and extends the traditional paper logbook used until now. It is associated with a database that merges the observing log itself with the complete list of images produced automatically by the different USET CCD cameras.

Daily solar observations and data distribution

In 2010, due to particularly bad weather conditions in November and December, the count of observing days was a bit below average, totalling 246 days. An overview of the 2010 observations is given in the tables below.

Instrument	**Nb. Images**	**Comment**
Sunspot drawing	293	Visual observation
CCD Photosphere	936	White-light channel
CCD Chromosphere	1911	H-alpha channel
Total	**3140**	

Table 3: USET data statistics for 2010

USET data distribution:

- The design of the USET web pages was further improved. In particular, a **full technical instrument description** was added, with an interactive user interface using new pictures of the USET and its various components. A brief history of the Uccle solar optical instruments was also included.
- In preparation ofr the wider export of USET images to external data portals, a **new logo** was created by O. Lemaître combining a USET image with a drawing of the instrument.

As the Hα telescope is now fully operational and provides high-quality images, final arrangements were made with two **global solar data portals:** the Global H-alpha High-resolution Network (GHAN) managed by the New Jersey Institute of Technology and BASS2000 led by the Observatory of Paris-Meudon. The final steps were made in the preparation of the appropriate images files (format, metadata) and of the data transfer protocols.

Figure 49: New USET logo used in all data publications and distributed images.

Digitization of the Uccle sunspot drawing collection (SoTerIA)

The global digitization and encoding of sunspot group parameters from the 70-year Uccle sunspot drawings collection continued without interruption in 2010, with measurements carried out mainly by two operators (O. Lemaître and A.-M. Hernando). Drawings for the year 1957, which were still missing and almost thought to be lost, were finally recovered, thereby fully completing the drawing archive. In summer, temporary job students were hired to also continue the bulk scanning of the drawings.

By the end of 2010, about 80% of the drawings had been digitized (60 years) and about 65% of the drawings had been measured (46 years). The table below shows how the progress is distributed.

Year	0	1	2	3	4	5	6	7	8	9
1940	-	-	-	-	-	-	-	D	-	D
1950	D	-	-	-	-	D	D	D	D	D
1960	D	D	D	D	D	D	X	P	X	X
1970	X	X	X	P	X	X	P	X	X	X
1980	X	X	X	X	X	P	P	P	X	P
1990	X	X	X	X	X	P	X	X	X	X
2000	P	X	X	X	X	X	X	P	P	P
2010	X	X								

Table 4: Progress of the Uccle sunspot drawing digitization by late 2010
(D: digitized; P: partly measured; X= completed)

Due to limited manpower, the **quality control** was so far limited to a few years (1985-1990). Further improvements were brought to the **DigiSun software** by S. Vanraes, primarily to take into account actual results of the measurements (addition of new entries in the sunspot group classification grids). The software was fully documented with an updated DigiSun manual.

In the Fall of 2010, in the framework of a professional training period for ACTIRIS-Bruxelles Formation, a **WEB-based application** was created by J.Nutin under supervision of F.Clette **for providing public access to the future Uccle digitized drawing collection and associated sunspot group database**. Making use of Web services, this application allows a visual interaction combining group parameters and clickable scanned images. The application could not be fully completed over the short duration of the training period and futher work is needed in 2011 to complete it.

A.1.2.2.*Humain*

Spectral Observations

Callisto

Spectral observations are performed in Humain using a broadband log periodic antenna, plugged to a small Callisto spectrometer built by the ETH institute in Zürich (Switzerland). This instrument allows a monitoring of the solar activity in the frequency range 45-870 MHz (i.e. in the corona), which is in practice reduced to the band 45-387 MHz (a compromise between time accuracy and sensitivity). Callisto is both an instrument and a network. Several identical receivers are installed around the world, to provide a nearly 24-hour coverage of the solar activity in radio. The network is managed by C. Monstein (ETH).

Solar activity has been rather low since the set up of this instrument in Humain in the mid-2008. As shown in Figure 50, 2010 marks the real start of the new solar cycle in terms of radio burst activity. The number of bursts is increasing, roughly following the rise of the solar activity as revealed by the sunspot number. The figure shows the number of bursts per month in Humain collected by C. Monstein. Only the main bursts are listed there. Since August 2010, C. Marqué is maintaining, in parallel, a local version of the burst catalog that will be made public after cross validation. It is obvious from this figure that the local catalog contains much more bursts (mostly fainter bursts) that the one maintained by C. Monstein. In 2011, it is expected that each Callisto station around the world will maintain its own catalog. During this transition phase, objective selection criteria need to be defined. In order to create such a catalog, C. Marqué developed an IDL tool to display, manually detect and create such an event list.

Callisto observations are being used for the space weather forecasts of the SIDC as an early warning tool of flares or CMEs: shock waves (seen as type II bursts), energy release during flares (type III bursts), or post-eruptive magnetic reconfiguration (type IV bursts). Whenever possible or needed, C. Marqué or J. Magdalenić check the daily observations regularly and provide to the forecaster on duty extra information on the radio burst which is observed. C. Marqué developed a quicklook display of the last 3 hours of observations combined with Xray light curves from the GOES satellite. This gives an easier way in associating a given radio burst and with a peculiar solar flare.

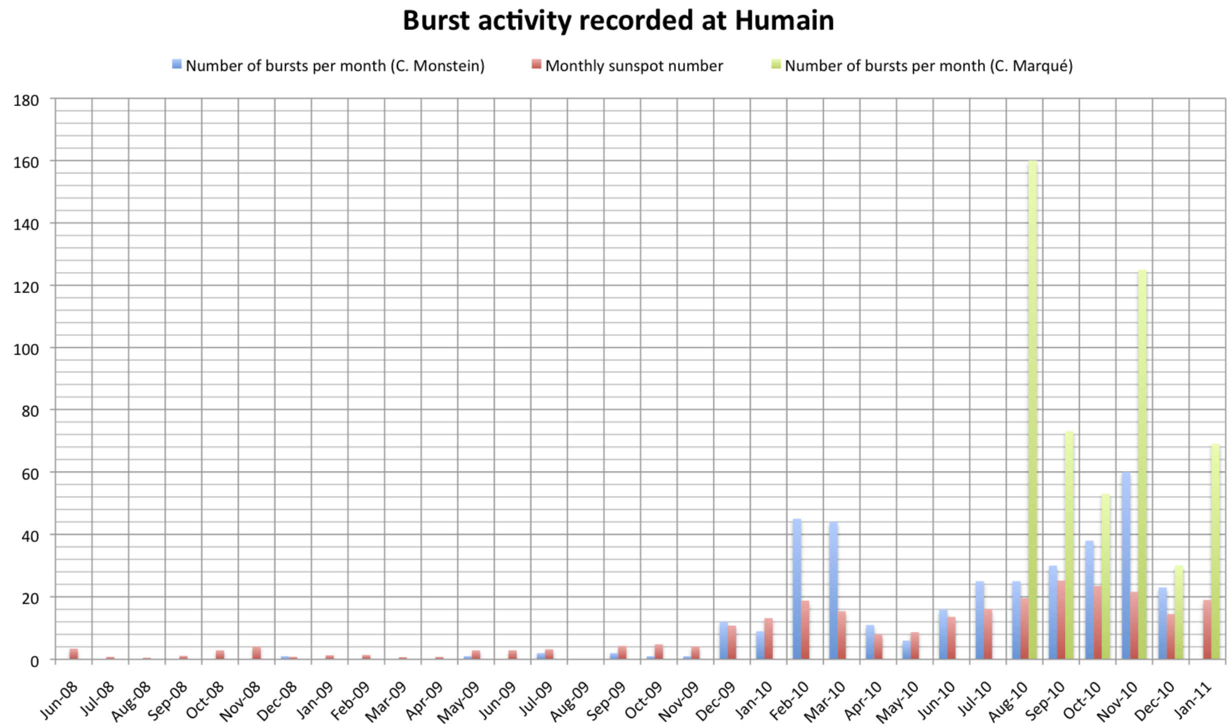


Figure 50 Number of radio burst per month recorded in Humain (blue and green bars) compared to the sun-spot number (red bars)

Phoenix2

The ETH Zürich institute, which is an invaluable partner of the Humain refurbishment project since the beginning, has strongly reduced its observing and scientific activities linked to solar radio astronomy. The reason is the retirement of the chief scientist of the project, Pr. A. Benz. In this context, the ROB was contacted by ETH during the spring of 2010 to transfer some instruments from ETH to ROB. After some discussion, it was decided that ROB would receive and operate a second spectrograph, called Phoenix2 that can monitor the solar activity from the metric to the centimetric range (100 MHz – 4 GHz).

In August 2010, C. Marqué, J. –L. Dufond and J. –P. Noël went to Switzerland to discuss the technical details of this instrument and its transfer. The instrument was effectively brought to ROB in September 2010.

The instrument will be put on the same radio telescope (6-m dish) that is currently used for the Callisto observations. C. Marqué purchased a new receiving antenna, with 2 orthogonal polarizations. It will be put at the focal plane of the dish, which requires a support structure to be designed and built. J. –L. Dufond made a design proposal that has been adapted and discussed with the mechanical workshop of the Observatory. J. –P. Noël worked on a new Focal Plane Unit containing the pre-reception HF part. Its role is to produce from the two incoming linear polarizations, two circular polarizations and two redundant intensity inputs for the Phoenix2 receiver.

Flux-Monitoring

The flux-monitoring project is made in cooperation with Canadian colleagues from DRAO (K. Tapping) and NRCan (D. Botteler). The idea is to build a new generation of solar flux monitors in the microwave range, that would be ran on both sides of the Atlantic ocean to provide a large time coverage of the solar activity. The main frequency target is 2.8 GHz (10.7 cm of wavelength), which is very important for the space weather forecasts of SIDC. Our Canadian partners make the core design of the receiver. They received at the very end of 2010 an extra support from a university engineering team that has brought the level of details in the design to a high standard.

On the Belgian side, most efforts were put in the refurbishing of the radio telescope mount that will host the receiver. The chosen telescope is one of the 48 parabolic dishes constituting the decommissioned solar interferometer of Humain, located on the North-South branch of the array, near the intersection with the EW array. In 2009, a company from Nivelle, Zimmer TMT was chosen to make the mechanical refurbishment. The antenna was dismantled in February 2010 and put back about a month later.

After discussion with C. Marqué and J. –L. Dufond, the technical service of the Observatory performed some heavy work (trenches, new electric board) to bring power and network infrastructures from the entry point in the station to the refurbished antenna.

C. Marqué purchased a new parabolic dish suitable for the microwave observations at the end of 2010 and investigated some suitable receiving antenna to be put at the focus.

J. –P. Noël and J. –L. Dufond worked on the design of a new control system, including the choice of the hardware.

It was decided that the refurbishment of the next 2 antenna mounts would be done at the mechanical workshop of the Observatory. The technical service dismantled with J. –L Dufond 2 antenna on site and brought them back to the observatory in November 2010.

A.1.3. Perspective for the next years

A.1.3.1. *USET*

The priorities for 2011 in terms of development will be:

- Instrument development (hardware):
    - Mechanical construction, installation and commissioning of the CaII-K telescope internal optics in connection with the Observatory of Rome (PSPT).
    - Construction and commissioning of the thermally-controlled enclosure of the CaII-K filter.
    - Design and construction of the motor-actuated mechanical support and focus systems for all three telescopes.
    - Completion of the solar pointer: this will involve a study phase in order to optimize the system to the actual properties of image turbulence at the Uccle site.
- Instrument development (software):
    - Development of new programs (SunGlasses) for the selection and pre-processing of high-cadence images from the 3 new camera systems.
    - Implementation of systematic procedures for the determination of the camera dark level and flat-field, which will be used in the routine observations of the new cameras.
    - Data provision to external solar portals (Global Hα Network, BASS2000)
    - Development and testing of the solar pointer control software
    - Implementation of a remote USET commanding interface allowing telescope and camera control from any workstation in the ROB through the Ethernet.
- Sunspot data digitization and long-term sunspot data exploitation in the context of the SOTERIA project:
    - Completion of the systematic digitization and encoding of the Uccle sunspot drawing collection.
    - Systematic data quality control and validation of the new Uccle sunspot catalog
    - Development of a new program for the group tracking, in replacement of the existing SOLKOP program.

A.1.3.2. *Humain*

In 2011 the following tasks will be performed.

- Callisto: The burst list will be made public on the Humain website; the main bursts (the more relevant for space weather) will be included in the monthly bulletin of the SIDC.
- Phoenix2: The support structure for the receiving antenna will be built by the mechanical workshop and installed in Humain. The focal plane unit will be fully tested at ROB before being set up. The installation of the Phoenix2 receiver in Humain is expected in the spring of 2011.
- Control of the antenna: An engineer programmer, Bram Bourgoignie, will join the team in January 2011. His first task will be to design a control software that will be used for the 6m radiotelescope (hosting Callisto and Phoenix2) and the smaller 4m dish for the flux-monitoring project. J. –L. Dufond and J. –P. Noël will finalize the control system on the hardware side.

The new dish will need to be adapted for the existing mount and a new support structure for the horn-receiving antenna will be designed.

It is hoped that by the end of 2011, the control system will be fully operational. On the receiver side, the front-end unit of the flux-receiving system will be assembled. Time permitting, a prototype of one channel of the receiver will be tested.

A.1.4. Collaborators

A.1.4.1. *USET*

- Manuela Temmer, Astrid Veronig, Kanzelhöhe Observatory, Austria: H-alpha instrument development. (SoTerIA project, HaSteNet project)
- Jean-Marie Malherbe, Observatoire de Paris-Meudon, France (HaSTeNet project)
- Francesca Zuccarello, Osservatorio di Catania, Italy (HaSTeNet project)
- S. Cortesi, M. Cagnotti (Specola Solare Ticinese, Locarno, Switzerland): pilot station of the sunpot network
- M. Bianda, R. Ramelli (IRSOL, Locarno, Switzerland): support to the Specola Solare

A.1.4.2. *Humain*

- C. Monstein, ETH Zürich, Switzerland
- K. Tapping, DRAO, Canada,
- D. Botteler, NRCan, Canada

B. Space Based Solar Observations

B.1. Development of new solar instrumentation

B.1.1. Description

Technology is an important driver in space science. Future missions for space astronomy and solar research require the development of critical optical components for improved UV solar observations. The selected technologies are imaging and non-imaging UV detectors, UV filters and onboard data image processing. Present technologies exhibit serious limitations in performance, technology complexity and lifetime stability. For the future space missions planned to study the Sun, new developments technologies capable of operating at high temperatures and in harsh environments are investigated. For those fields, it is not sufficient to merely watch the industry progress. It has been a successful tradition in solar terrestrial physics to trigger or to perform specific technological development. At STCE/ROB, we have identified and developed a specific expertise in two technological disciplines: UV light detection and image processing. For both, a voluntarist way has proven beneficial in order to meet the needs with the possibilities in a timely manner.

B.1.2. Progress and results

B.1.2.1.*APSOLUTE and BOLD*

In 2010, Ali BenMoussa participated in the APSOLUTE teleconference and/or progress meetings at CMOSIS (Belgium). He participated in the design review meeting. The purpose of this meeting was to describe the APSOLUTE image sensor together with its functional properties and the additional goal of giving the go-ahead for tape-out of the design. For APSOLUTE, two image sensors are being developed: -1- 256x256 sensor containing 16 test pixel variants, organized in blocks of 64x64 pixels, -2- 1024x1024 sensor, containing the 'best guess pixel' variant. A calibration test plan was issued by Ali BenMoussa on 15/12/2010 (Issue2, rev1) [106]. This document provides a detailed description and methodology of all tests to be performed with a description of the measurement setups. The output of the different test campaigns are expected to allow the evaluation of the APSOLUTE sensors as well as to select a preferred pixel design with recommendation for the Flight Model (FM) detectors for EUI project onboard Solar Orbiter.

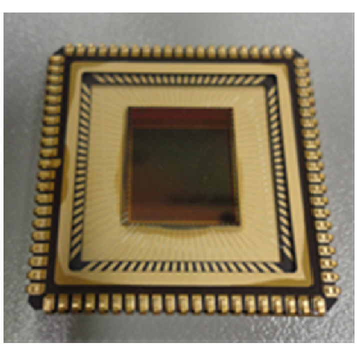


Figure 51: APSOLUTE detector

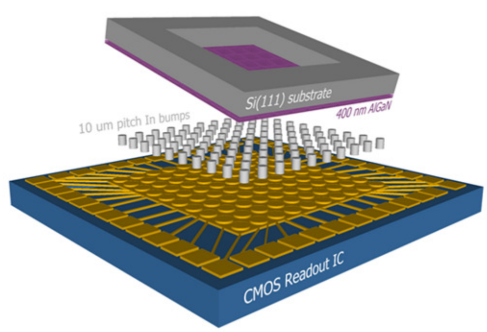


Figure 52: BOLD prototype design

In complement of the APSOLUTE project, the BOLD project was extended to 21/01/2011 (CCN3). Ali BenMoussa (as WPs Manager) is actively involved on the conceptual pixel design study and on the (E)UV optical testing [118][101]. During 2010, the effort was focused on the technology predevelopment and on the integration of the 2D demonstrator. 2D AlGaN arrays were integrated with the CMOS ROICs (read out electronics). Two BOLD calibration campaigns were carried out in June and November 2010 at the PTB-Bessy II synchrotron. First integrations (detector flip-chip bonded to ROIC) were tested at DeMeLab (ROB) on 21/04/2010. Few cross checking of characterization results between IMEC and ROB laboratories have been performed. The two teams are in close collaboration and exchanges of samples and data are still on-going. The results are encouraging with some part of the BOLD imager responding to the light excitation [77][17]. A technical note (TN4) of the BOLD project was issued on 18/08/2010 (Issue2, rev0) by Ali BenMoussa and Boris Giordanengo [101]. This TN described the (E)UV testing activities, a description of the samples including priority list and preliminary measurements analysis, as well as the tackling of the photoemission problem.

Ali BenMoussa followed a 2 days CMOS APS characterization training course in Barcelona (E) on November 2010 by Prof. A. Theuwissen. The course aimed to give an in-depth knowledge about the characterization solid-state imaging devices. This was done by means of hands-on measurements and evaluation of an existing camera. In this context Ali BenMoussa started to test the signal and noise performance of the EUV HAS imager sensor (spare from SWAP) in collaboration with Dr L. Duvet from ESTEC. A complete optical characterization of the HAS sensor is reported in the thesis of Eng. A. Mekaoui who performed a six months training (until May 2010) at ROB under the supervision of Ali BenMoussa [119].

The detector development activities (APSOLUTE and BOLD) have been presented by Ali BenMoussa during different meetings (see [133][134][135][137][139]).

B.1.2.2. *UV detectors developments (single pixel)*

Recent results on deep-ultraviolet solar-blind photodiodes based on high-quality AlN films grown on sapphire substrates were simulated and fabricated [1]. New cBN and diamond detectors were also reported [15][54] as well as new results on LYRA photodetectors [89]. In parallel, and in preparation for the eventual testing of the UV detectors and filters prototypes, the Detector Measurements Laboratory (DeMeLab) at STCE/ROB premises was further developed by Ali BenMoussa and reviewed by external experts (Spectra Physics) on 09/03/2010, in good accordance with the development plan for the detector prototypes.

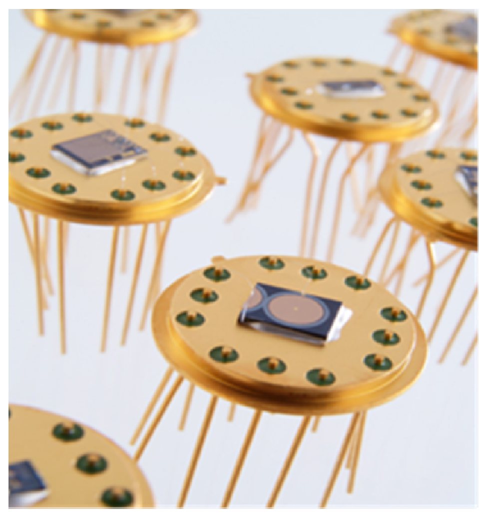


Figure 53: Single UV photodiodes (IMEC)

The LYRA radiometric model i.e. the Si-AXUV detectors' responsivity, was updated thanks to new measurements performed by Ali BenMoussa at DeMeLab facilities (see Figure 54). Ali BenMoussa has also participated to the ESIO proposal (UV flux monitor) [102] and he took formal responsibility with ETRI institute in South Korea [103] for the collaboration on the developement of future Solar UV flux monitor (LYRA successor on K-star project) [104]. The detector development activities (including LYRA) have been presented by Ali BenMoussa during different international conferences (see [131][132][136][138]).

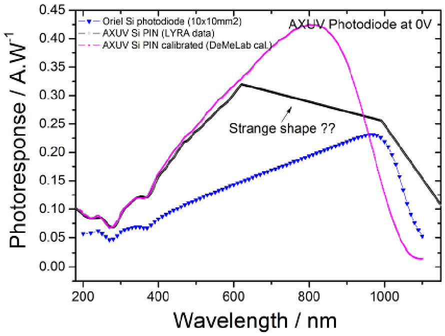


Figure 54: Response of a Si-AXUV @ DeMeLab

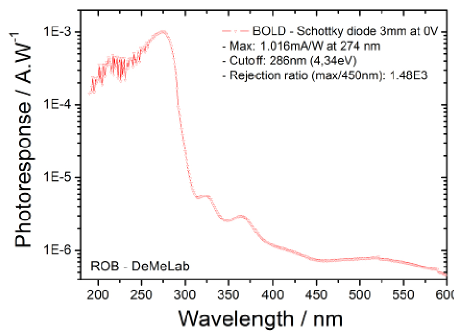


Figure 55: Response of an AlGaN diode @ DeMeLab

B.1.2.3. *UV filters developments*

In combination with the above, Ali BenMoussa participated in many test activities related to the multi-layers UV filters characterizations. In accordance to the support activity foreseen for the specification of the UV filters onboard EUI (see section future space missions), Ali BenMoussa has coordinated and participated in the activity of filters measurements at DeMeLab and at PTB-Bessy II on Novembre 2010. A filter test and calibration plan was issued by Ali BenMoussa on 05/11/2010 (Issue1, rev0) [110].

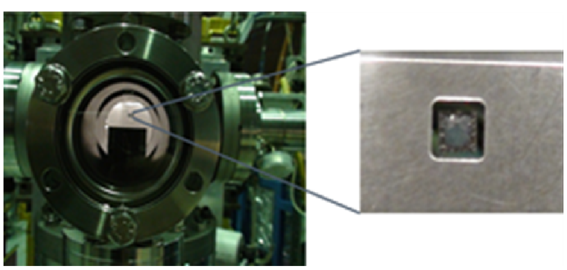


Figure 56: Filters calibration @ PTB

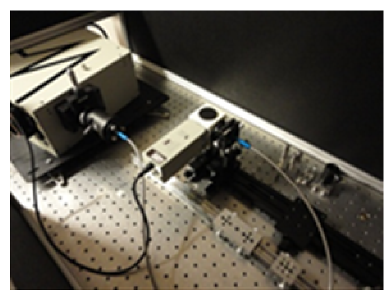


Figure 57: Filters measurement @ DeMeLab

B.1.2.4. *Extreme ultraviolet Onboard Compression System (EOCS)*

After the closing of the EOCS1 project, a discussion has been initiated between Ali BenMoussa and Samuel Gissot and the EUI consortium partners (CSL, MSSL) in order to define the possible continuation of the EOCS project and what should be its objectives and deliverables. The results led to the initiation of the EOCS project 2 for which a statement of work (SoW) was issued by Ali BenMoussa and Samuel Gissot and submitted to ESA on 22nd July 2010 [100]. Samuel Gissot presented the results of the EOCS1 project and EOCS2 goals at the 2nd international workshop on On-board Payload Data Compression (OBPDC 2010) conference in Toulouse on 29th October 2010 [42]. The EOCS2 project has also been presented by Ali BenMoussa during the EUI compression meeting at ROB (04/10/2010).

B.1.3. Perspective for the next years

A last (closed) meeting of the BOLD project shall be held on 21st January 2011 at ESA (NL). The tests campaign of the APSOLUTE prototypes shall start in February 2011. A test planning was issued on 14/12/2010 (Issue1, rev3) by Ali BenMoussa [108]. This document describes the tests activities planning for the APSOLUTE sensors (1st batch), which started in November 2010 at CMOSIS and should finish before the EUI PDR (fall 2011). This document is intended to guide the measurement campaign that will be performed in various facilities i.e. CMOSIS, DeMeLab (STCE/ROB), PTB-Bessy II (Berlin), CRC (Louvain-La-Neuve) and CSL on a relative short time scale. Measurements of multilayers UV filters and development of new solarblind detectors (AlN, cBN and diamond) are also planned in 2011.

B.2. Future space missions: Solar Orbiter

B.2.1. Description

One of the main future space missions is the Solar Orbiter which is anticipated to be the major solar and heliophysics ESA space mission after SOHO. Solar Orbiter is the next solar–heliospheric mission currently in the competition in the Cosmic Vision programme of ESA. It is devoted to solar and heliospheric physics and will provide unprecedented close-up and high-latitude observations of the Sun. The Extreme Ultraviolet Imager (EUI) onboard Solar Orbiter consists of a suite of two high-resolution imagers (HRI) and one dual-band full Sun imager (FSI) that will provide EUV and Lyman-α images of the solar atmospheric layers above the photosphere.The EUI instrument is based on a set of challenging new technologies allowing to reach the scientific objectives and to cope with the hard space environment of the Solar Orbiter mission.

Several STCE scientists are involved in the Extreme-Ultraviolet Imager (EUI) team at ROB that is a Co-PI institution for the EUI.

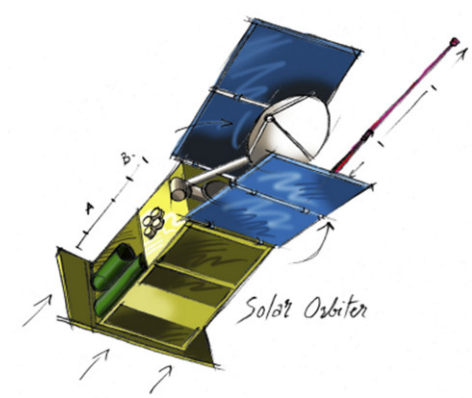


Figure 58: Artistic view of Solar Orbiter

B.2.2. Progress and results

B.2.2.1. *Extreme Ultraviolet Imager (EUI) / Solar Orbiter (S.O.)*

PI & STCE/ROB Project Management activities

Since January 2010, Ali BenMoussa has taken over the EUI-STCE/ROB Institute Project Management (IPM) and the EUI-PRODEX Principal Investigator at Belgian level (BPI) activities in place of Erik Pylyser who is on extended sick leave. Ali BenMoussa updated the EUI STCE/ROB PEA proposal which takes into account the extension of the project until end of 2011. Ali BenMoussa updated also the STCE/ROB-EUI detailed work packages descriptions (version 2.0, 09/02/2010) [95]. He continued the follow-up of the agreed STCE/ROB activities [116] and participated actively in the set-up of the statement of work (SoW) for the EUI Onboard Compression System (EOCS-2) project [100]. He took formal responsibility with PTB (Berlin, D) [109] and CRC (Louvain-La-Neuve, Be) for the collaboration on the detectors and multilayer UV filters tests [110] and calibration campaigns.

On-board science data processing software requirements

A preliminary report of the EUI science algorithms (pre- and post-processing) was issued and delivered to the EUI consortium on 29 June 2010. It presents several procedure that could be included on-board EUI, their objectives and requirements. These functions include on-board calibration, pre-processing prior to compression, prioritization and image selection, triggering on particular events. A final version (Issue2, rev0) was issued on 23/06/2010 taking into account what was discussed and agreed after the 3rd EUI consortium meeting [114]. Ali BenMoussa participated in many activites summarized in the EIDB interface document [115].

Compression, data prioritization and filtering, autonomy

In complement, Ali BenMoussa is deeply involved in different EUI working group (WG) activities which affect strongly the data compression system, the detector activities and also the science algorithms development [114]. Two EUI electronics meetings were held at STCE/ROB with the objectives to agree on the Common Electronics Box (CEB) and the Front End Electronics (FEE) needs and concepts to start specifications and preliminary design [146]. A TN related to the science data requirement with impact on the FEE-CEB design was issued on 05/11/2010 by Ali BenMoussa in collaboration with David Berghmans, Samuel Gissot and Bogdan Nicula [105]. It provides an overview of the issue due to the current design of the FEE-CEB (e.g. impact on the image cadence, image quality and telemetry) and the sensor architecture (e.g. image artifacts that could occur due to the rolling shutter mechanism of the EUI sensor). The aim of this document is to clarify how the science data requirements could be achieved. Recommendations and possible technical options are introduced.

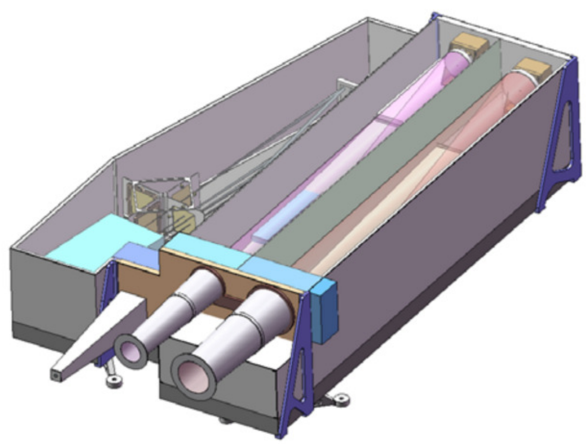


Figure 59: 3D view of the EUI optical bench (CEB not shown)

B.2.3. Perspective for next years

Solar Orbiter is retained in the competition for ESA's Cosmic Vision programme. STCE will continue to participate in the EUI project (in particular in maintaining the scientific requirements and descope and augmentation analysis). Science support to the EUI PI will be continued. Solar Orbiter is planned to be launched in 2017 or 2018.

Ali BenMoussa will carry on project duties and research in consistency with ESA plans and with the EUI collaborative partnership. ESA milestones are the second and final Cosmic Vision mission selections (fall 2011) as well as the next review for EUI, the Instrument Preliminary Design Review (IPDR) which is planned to be held in the second half of 2011 (mid Oct. for EUI) and to be completed by January 2012. Upon final selection of Solar Orbiter in the Cosmic Vision program, then, from 2011 and throughout 2012-2013, the various instrument models (structural and thermal model, Engineering model, Qualification and Flight Model) will be built by the consortium and delivered to ESA. Ali BenMoussa's main responsibilities on the longer term lie specifically in the management and technical activities.

B.3. Future space solar missions: PROBA3/ASPICS

B.3.1. Description

PROBA-3 is an ESA's experimental mission devoted to the in-orbit demonstration of formation flying techniques and technologies. The mission will be implemented with a pair of small spacecraft, which together form a coronagraph. One spacecraft will carry the main optical bench and associated detectors, electronics, etc., while the second spacecraft will carry the occulter. STCE scientists participate in the project of the coronagraph for the PROBA-3 mission, ASPIICS (Association de Satellites Pour l'Imagerie et l'Interférométrie de la Couronne Solaire), led by Laboratoire d'Astrophysique de Marseille (France). ASPIICS heralds the next generation of coronagraphs for solar research, exploiting formation flying to gain access to the inner corona under eclipse-like conditions (field of view from 1.04 to 3 solar radii) for long periods of time. ASPIICS will make a giant step in our knowledge of the solar corona by providing observations that will lead to the insights necessary for understanding key physical processes and for the prediction of space weather in the Sun – Earth system. The ASPIICS unprecedented field of view makes it uniquely suited for studies of the solar corona, as it will fill the crucial observational gap between the fields of view of low-corona EUV imagers and usual space coronagraphs.

B.3.2. Progress and results

Scientific support was also provided to the ASPIICS consortium, by contributing to two conference papers describing the ASPIICS coronagraph, as well as to the investigation of ASPIICS descope options.

B.3.3. Perspective for the next years

PROBA-3/ASPIICS activities will be continued as the ASPIICS selection was announced in January 2010 and the kickoff of the project is expected in 2011. The launch of PROBA-3 is expected around 2015.

B.4. ALTIUS – ROSINA - Nomad Instruments

These instruments perform atmospheric observations. The project covers 1 full-time equivalent located within the engineering department of BIRA-IASB to work on equipment for the meaurement of atmospheric compositions.
The goal is two-fold: subscription in programmes for observing the Earth atmosphere and providing support for instrument development.

B.4.1. Description

B.4.1.1. *ALTIUS*

ALTIUS is a limb sounding spectral imager for observation of the Earth's atmosphere. It uses the limb scattering technique, besides the sun, star or moon occultation technique. Different sunrays will enter the atmosphere and will be scattered toward the instrument, being partially absorbed or scattered along their respective optical paths.

It is possible to perform a measurement at any time when the satellite, a PROBA-like microsatellite, is on the dayside. If this is done from an almost polar orbit, one can achieve a very efficient coverage of the globe over a few days.

B.4.1.2. *ROSINA*

BIRA-IASB contributed to the construction of the DFMS detector, part of the ROSINA mass spectrometer complement on ESA/Rosetta, for measuring the composition of a cometary coma. As the mission is presently underway, the project supports testing of the hardware to decide on instrument operation scenarios, and participation in instrument reviews, calibration, and preparation of the scientific modes of operation.

B.4.1.3. *NOMAD*

The ExoMars Trace Gas Orbiter (TGO) mission fits in the Joint Mars Exploration Programme of ESA and NASA. It will demonstrate key flight and in situ enabling technologies for future exploration missions and will accomplish scientific investigations fundamental to the exploration of Mars. It will also act as a data communications relay for other future ESA/NASA missions.

NOMAD is a 3-channel spectrometer on board ExoMars TGO. 2 channels (SO and LNO) work in the infra-red and build upon the expertise of BIRA-IASB's successful SOIR-instrument. The 3rd channel (UVIS) works in the ultraviolet-visible range and builds upon a UVIS instrument that was developed for the ExoMars Lander.

B.4.2. Progress and results

B.4.2.1. *ALTIUS*

The work performed in the STCE contract is a part time support to the instrument development team, situated mainly in the documentation and knowledge management domain. Data and document structures are set up and maintained. Active participitions to meetings (notulating) and reporting.

B.4.2.2. *ROSINA*

In the framework of STCE one person works part time in testing of the detector section of the spare model. Two types of tests were conducted, one aiming a better understanding of thermal behavior of the detector, assessing a possible switch on of the instrument at low temperatures; Another test was carried out after a hardware failure occurred during tests in the PI institute (Bern). Reporting on all tests was performed.

B.4.2.3. *NOMAD*

BIRA-IASB manages all of the tasks carried out across the European consortium and maintains the documentation necessary for ESA and NASA. They also take care of the planetary protection (PP) aspects necessary for missions going to Mars, alongside their project management responsibilities.

In the framework of the STCE one person works part time on NOMAD documentation, planetary protection support and education and public outreach (EPO). A website for the project has been developed (http://mars.aeronomie.be/en/exomars).

B.4.3. Perspective for the next years

B.4.3.1.*ALTIUS*

Launch date for ALTIUS is not fixed. A tentative date is 2014. Phase B will start shortly and throughout this phase continuation of managerial support has to be consolidated.

B.4.3.2.*ROSINA*

Arrival of Rosetta at the target comet is foreseen in 2014. Till then support will be given in order to clarify and guarantee the good behavior of the instrument, from tests on the spare parts and spare model on the ground.

B.4.3.3. *NOMAD*

The spacecraft will be launched in January 2016 by a NASA-provided Atlas V 421 class launcher. Arrival at Mars is foreseen nine months later, in October 2016. Up till then administrative support will be further needed. Activities in the PP and EPO fields will be carried out.

B.5. Solar Irradiance

B.5.1. Objectives

The climate on earth is directly determined by the amount of energy that the earth receives from the sun. This energy is transmitted from the sun to the earth in the form of light, or Total Solar Irradiance (TSI).

B.5.2. Progress and Results

The measurement from space of the TSI is a long term specialisation of the RMIB, as can be seen from the space missions summarised in Table 5.

Name	**Misson/Agency**	**Year**	
Solcon	Spacelab-1 NASA	1983	
	Atlas-1 STS-45 NASA	1992	
Sova 1	**Eureca ESA STS-46 NASA**	**1992**	**Brought back to earth**
Solcon	Atlas-2 STS-56 NASA	1993	
Solcon	Atlas-3 STS-66 NASA	1994	
TAS	TAS STS-85 NASA	1997	
IEH-3	IEH-3 STS-95 NASA	1998	
Freestar	Freestar STS-107 NASA	2003	
Currently in space :			
Diarad/Virgo	**SOHO ESA**	**1996**	**Still running**
Diarad/Sovim	**Columbus/ISS ESA**	**2008**	**Most accurate**
Sovap	**Picard CNES**	**2010**	

Table 5: RMIB space missions dedicated to the measurement of the TSI from space.

The space missions which are important for current or future activities within the STCE are indicated in bold in table 1. These missions are:

- the SOVA instrument which flew in space on the Eureca satellite in 1992, and which, thanks to the unique capabilities of the NASA space shuttle, has been brought back to earth. Future on-ground laboratory analysis of this instrument will allow to improve our knowledge of the absolute value of the TSI. This absolute value of the TSI, or Solar Constant, is a matter of controversy since the launch of the Tim/Sorce instrument in 2003.
- The Diarad/Virgo instrument is our most successfull long term measuring TSI instrument so far. Long term TSI variations are directly relevant for the quantification of the solar influence on climate change on earth. Diarad/Virgo has measured over a complete solar cycle, and has significantly contributed to our understanding of long term TSI variations.
- The Diarad/Sovim instrument on the ISS is our most accurate instrument in space so far. Particular attention has been paid to its absolute level since it was launched after Tim/Sorce.
- The Sovap/Picard instrument which was launched successfully on 15 June 2010 is meant to provide continuity for the ageing Diarad/Virgo instrument and to possibly reconstruct the TSI level 300 years ago during the so-called little ice age, which was probably due to a dimmer sun than we know today.

During 2010 the Sovap/Picard instrument was launched and taken into operation successfully. Figure 60 shows the different independent long term TSI measurements by independent groups, with one color per group. The RMIB measurements are shown in red, including the time series of SOVA1, DIARAD/VIRGO and DIARAD/SOVIM, see also table 1. The Sovap/Picard results are not yet shown as they are still under validation. Prior to the launch of TIM/SORCE, indicated in purple in fig. 1, all the recent independent instruments agreed with each other within their stated accuracy of the order of +/- 1 W/m². The TIM/SORCE instrument, launched in 2003, measures about 5 W/m² lower than the other radiometers, while it has a stated accuracy better than +/- 1 W/m². Thus, clearly, there is a problem of stated versus real accuracy, which needs to be resolved. Every instrument group needs to critically reexamin its absolute acuracy. On the RMIB side, we did this by making an extra effort to characterise the DIARAD/SOVIM radiometer, and currently we are thoroughly validating the Sovap/Picard TSI results.

In 2010 we also continued the processing and analysis of the DIARAD/VIRGO measurements, and its comparison with other TSI time series. 2009 was a particularly interesting year, since it was the end of an unusual long solar minimum, and for characterising the long term behaviour of the sun it is interesting to

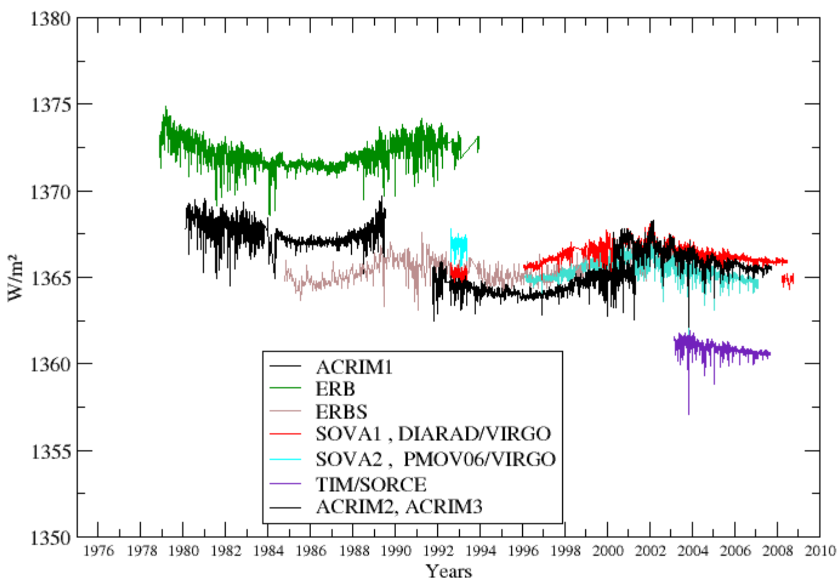


Figure 60: Independent space measurements of TSI. The measurements from the RMIB are given in red, including the new measurements from DIARAD/SOVIM.

know if after this solar minimum a lower TSI was reached compared to the previous minimum (reached in 1996).

Figure 61 shows the measurements of DIARAD/VIRGO over the complete solar cycle 23. The red curve gives the measurements of the left channel, which is exposed to the sun continuously. Under the effect of the solar UV radiation the channel is ageing. The blue crosses are the measurements of the right channel, which is only exposed to the sun for about one hour every month. Since the right channel exposure is sufficiently low, we know it does not age significantly, and so the blue crosses give the true long term behaviour of the TSI. The green line shows the ageing corrected left channel measurement series, which has the long term behaviour of the right channel and the short time behaviour of the left channel.

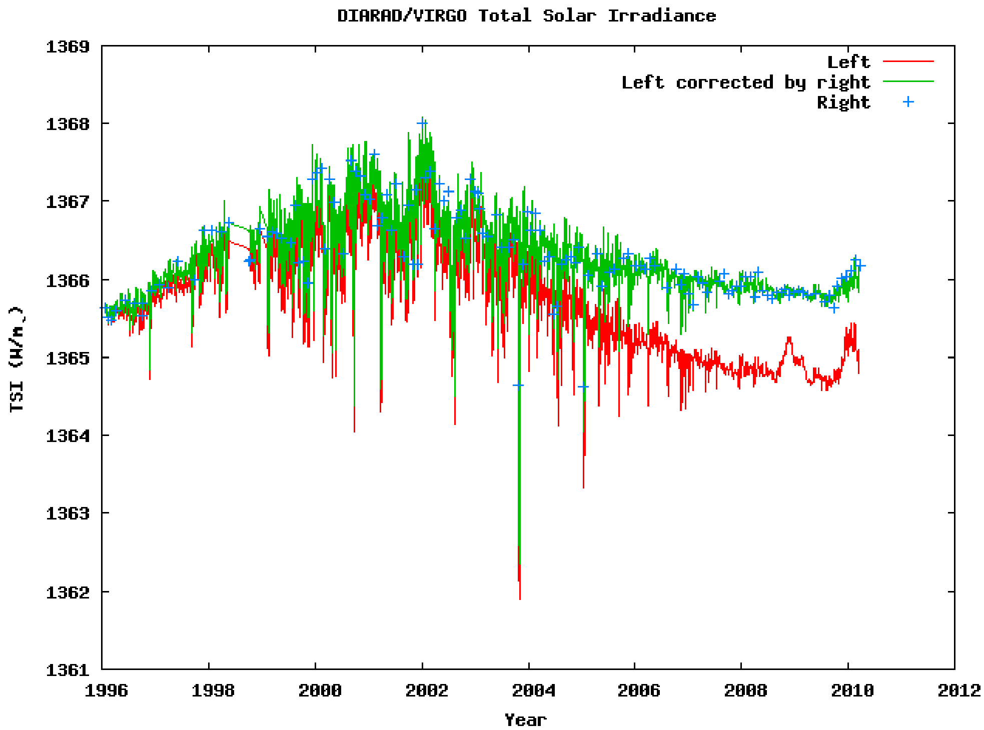


Figure 61: Measurements of DIARAD/VIRGO

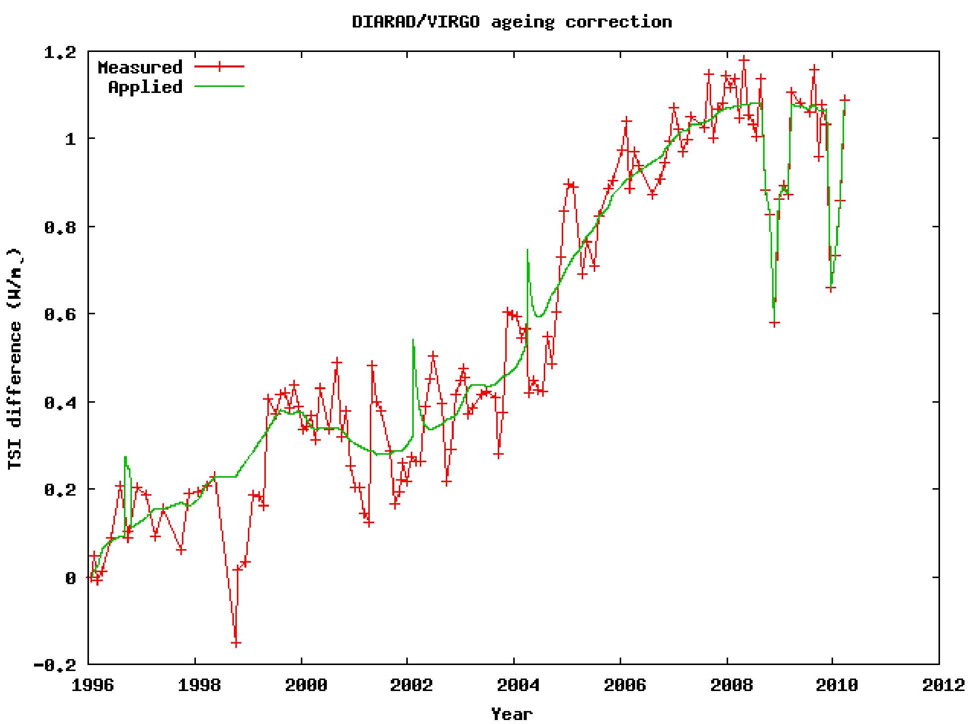


Figure 62: DIARAD/VIRGO ageing correction.

Figure 62 shows the difference between the right and left channel measurements (red crosses), and a smoothed curve (green line) running trough it. As the left channel ages, it becomes less sensitive with

time, and the right minus left difference increases. The ageing correction of the left channel is done by adding the green curve to the left channel measurements. The two downward spikes twoards the end of the curve in figure 3 appear to be an anomaly of the left channel, which fortunately is not present in the right channel, and is therefore removed by the ageing correction procedure.
The long term variation of the TSI needs to be known as accurately as possible to quantify the influence of the sun on the climate change on earth. For the variation over a solar cycle, the most important question is whether the TSI level changes in between solar minima. For the last solar cycle, DIARAD/VIRGO provides one of the four independent time series shown in red on figure 4, the other time series are provided by PMO6/VIRGO (in green), by the combination of ERBS (in blue) and TIM (in purple), and by the combination of ACRIM 2 (in light blue) and ACRIM 3 (in orange/brown). By comparing these time series, it can be assessed in an objective way that the first three time series agree well and give the true solar behaviour, while the ACRIM 3 shows some more deviations. Compared to the previous version of this graph the agreement of ACRIM3 with the other time series has been strongly improved by shifting it upwards by 0.25 W/m². Now ACRIM3 agrees well with the second maximum in 2002, while before it agreed well during the first maximum in 2001.Apparently, during its first year of operation, ACRIM3 had an early ageing of 0.25 W/m².

Our best estimate of the measured TSI variation is the average of all available measurements. This is shown as the red curve in Figure 63. Alternative composite measurements are provided by the PMOD

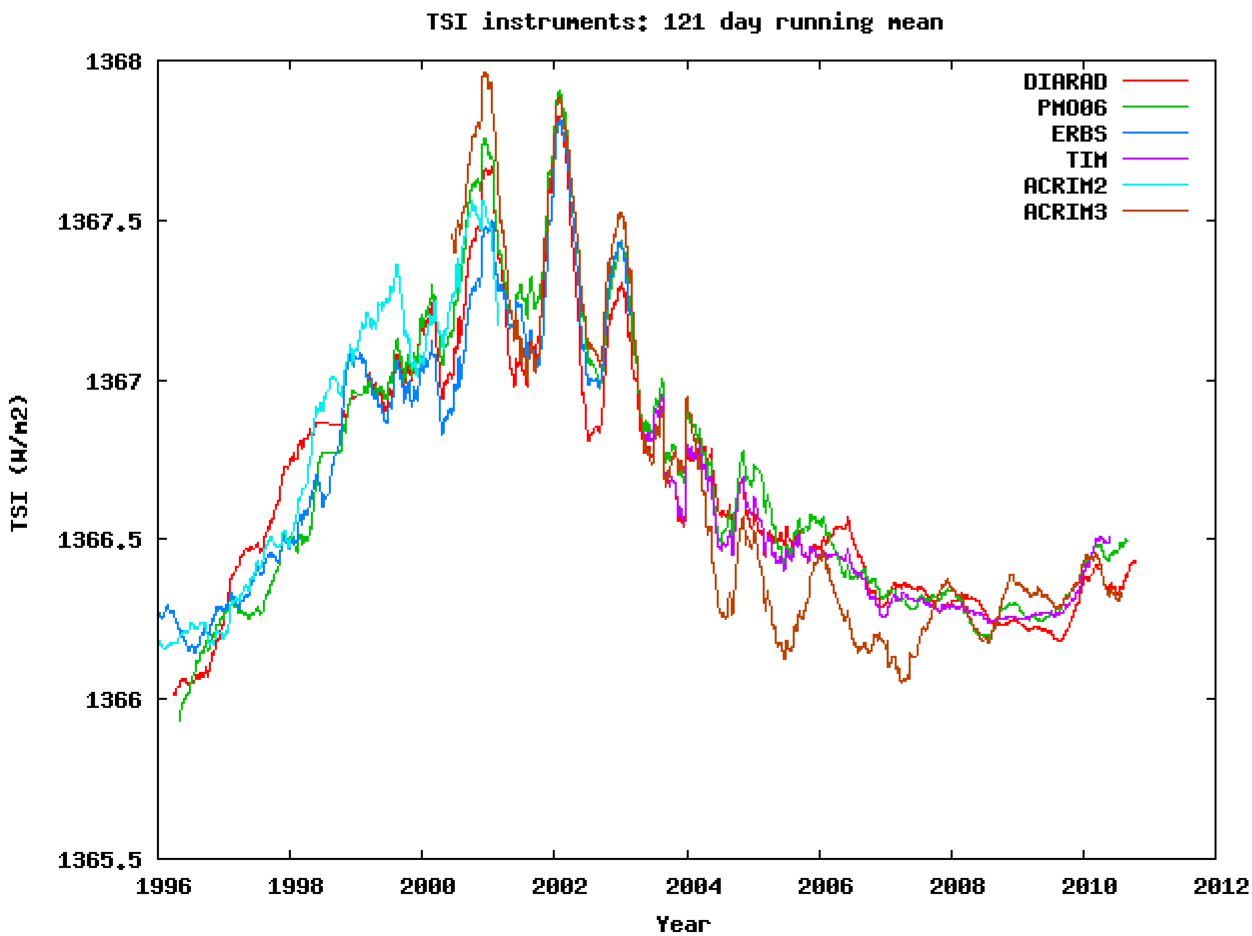


Figure 63: Independent time series of TSI variation over cycle 23.

group (green curve in Figure 64) and the ACRIM group (blue curve in Figure 64). A regression model fitted to our composite measurements is shown as the purple curve. For solar cycle 23, we have a good agreement between our composite measurements and our model, which gives us a high confidence in their correctness. We find no significant change in the TSI level of the two minima, contrary to the other composite measurement series.

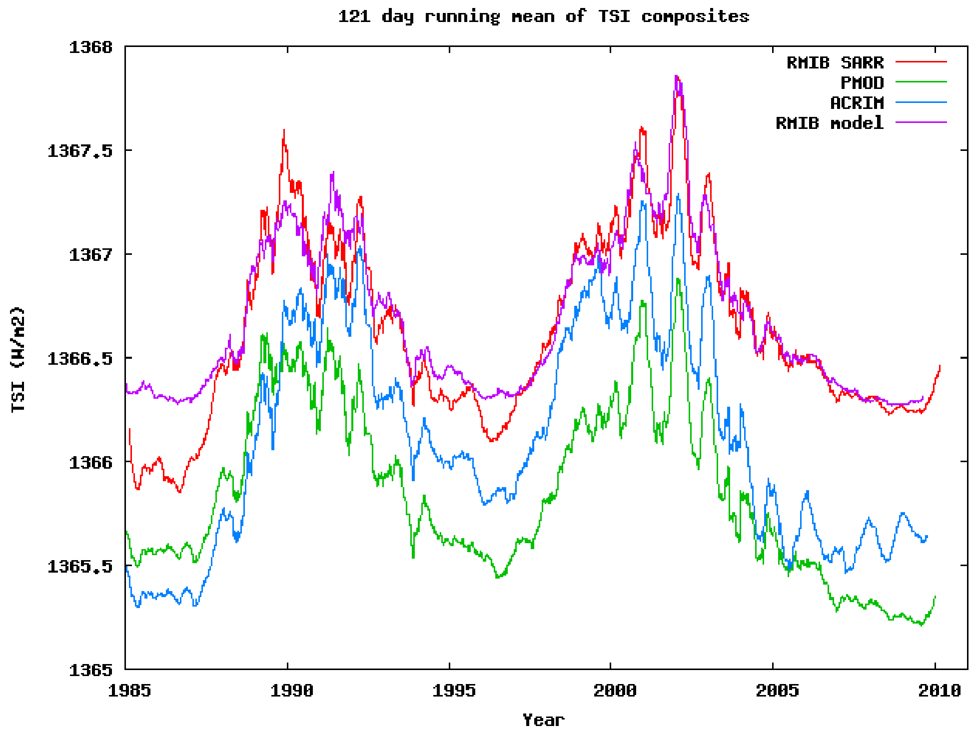


Figure 64: Different composites and regression model of TSI variation over solar cycles 22 and 23.

Our TSI regression model is based on Mount Willson magnetograms. An example of such a magnetogram is shown in figure 6. A dipole of strong magnetic fields is visible as the green and the yellow dot in the lower right quarter of the image. The strong magnetic fields correspond to sunspots, which are dark and hence cause a decrease in TSI. With time the strong magnetic fields are diffused over the solar disc, and become intermediate strength magnetic fields, visible in the blue and red colors in Figure 65. These intermediate mangetic fields correspond to facula, which are bright, and hence cause an increase of the TSI.

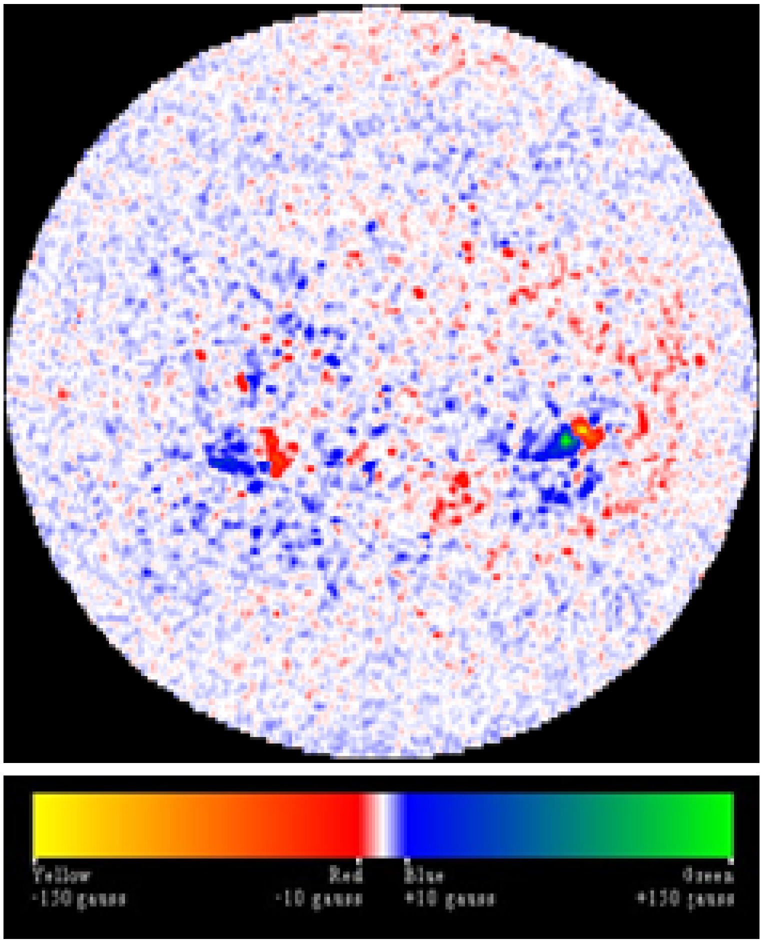


Figure 65 Example of Mount Willson magnetogram used for characterising sunpots and facula.

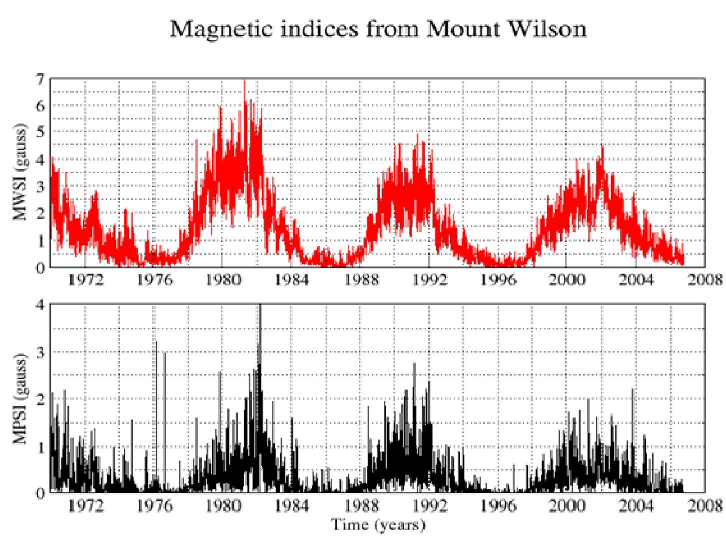


Figure 66: **Time series of Mount Willson MPSI and MWSI indices**

Sunspots are characterised by the so called Mount Wilson Sunpsot Index (MWSI), which is defined as the average field strength over the magnetogram pixels with a field strength higher than 100 gauss. Facula are characterised by the so called Mount Wilson Plage strength Index (MPSI), which is defined as the the average field strength over the magnetogram pixels with a field strength between 10 and 100 gauss. The time series of these indices is shown in Figure 66. Both indices show an 11 year solar cycle. In general, within a solar cycle, the maximum of the MWSI is reached earlier than the maximum in MPSI, which can be understood since the medium field strength facula are generated from a diffusion of the high field strength sunspots.

Our regression model (the purple curve in figure 5) is obtained from the magnetic indices from figure 7 trough a simple linear regression, TSI= a + b MPSI + c MWSI.

Figure 67 shows the evolution in time of the difference between our composite measurements and the model. In time, we see a clear improvement of the agreement between both, this is due to the increase in the number and quality of TSI instruments. For the last 5 years, we reach an excellent agreement within +/- 0.1 W/m².

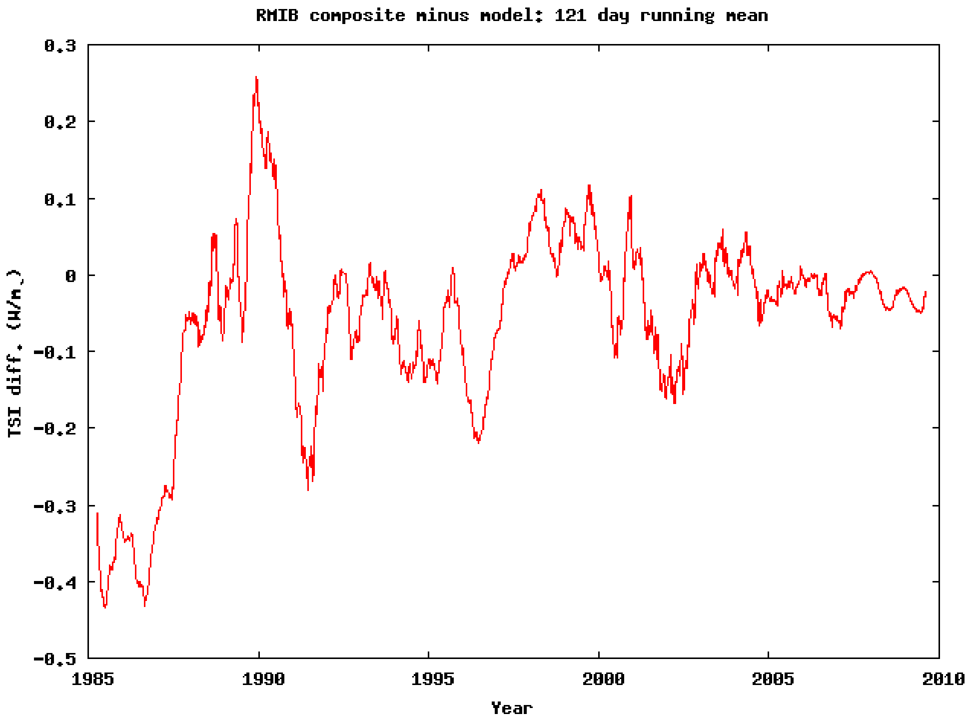


Figure 67: Time series of RMIB TSI composite minus model

The goal of the new Picard mission is to measure the fast TSI increase expected at the beginning of solar cycle 24 and to establish a possible correlation between solar irradiance and diameter variations. Figure 68shows the measured TSI variation in 2009 (red curve) and a prediction for the TSI increase at the start of solar cycle 24 (purple curve). As can be seen, the TSI increase of solar cycle 24 started already at the end of 2009, so a launch of Picard in 2010 became very urgent.

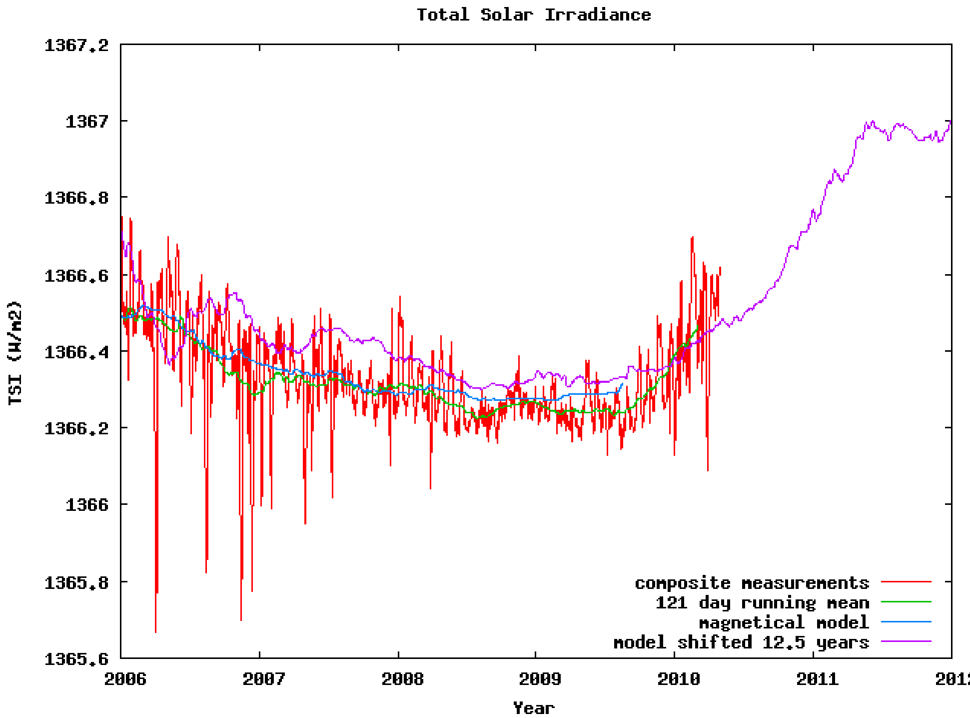


Figure 68: TSI variation at end solar cycle 23, start solar cycle 24.

The launch of Picard was first planned in March 2010. In the first week of March we participated to the testing of the commanding and data analysis of the operations at the CCC in Toulouse and the CMSP at BUSOC in Brussels. The testing was done with the prototype hardware in the so-called Avionics banc.

The Sovap instrument was switched on on 28/6. The first measurements indicated that its right shutter was opened during launch. This possibility had been anticipated beforehand in the command planning. The shutter was closed in order to have a minimal contimination during outgassing. During the first week we were present at the CCC with contact with RMIB trough the CMSP for the validation of the good functioning of the instrument. Everything was nominal.

The Sovap instrument started its regular solar measurements on 21/7, the Belgian national holiday.

The first days everything was nominal, on 26/7 a problem started to occur for the right shutter, which had the tendency to remain apparently blocked in closed position. A detailed analysis showed that the shutter did actually move from close to open, when it was commanded to do so, but that it received too much energy, and bounced back to the closed position. In order to safeguard the primary mission to measure the long term variation of the Total Solar Irradiance the left channel – which functions without anomalies – was, and is still exposed to solar radiation once every month. With this low exposure, the channel does not age, and therefore measures the corect long term TSI variation.

At the end of the commissioning period, we participated to the Revue de Recete en Vol (RRV) in Toulouse on 12-13 Oct. 2010. At this occasion, we defined a new strategy for the use of the right shutter. We decided to try to reopen the right shutter and when this succeeded to keep it open continuously. After several attempts the permanent opening of the right shutter succeeded on 18/11. Possibly the success of this attempt was due to the temperature change during the eclipse season.

We visited LASP on 8/12 and we participated to the TSI radiometer expert workshop in San Francisco on 11-12/12. The workshop was organised by NASA HQ in order to make progress in the determination of the true value of the solar constant. An important new tool to make ground measurements is the LASP TRF facility where TSI instruments can be compared to a cryogenic radiometer using programmable beam configurations. We plan to test some of our radiometers at this facility in 2010.

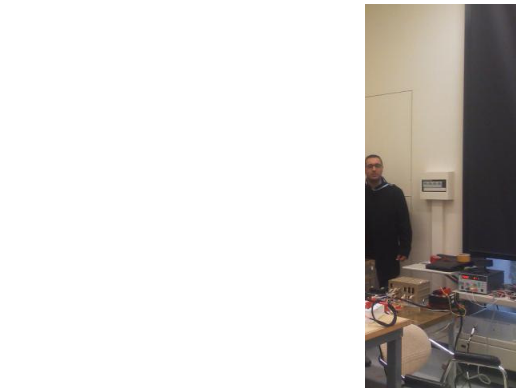


Figure 69: The Picard avionics banc prototype hardware used during the CCC testing in March 2010.

A first evaluation of the Sovap Tsi was made but not yet communicated externally.
We participated to the International Pyrheliometric Comparisons in Davos from 27/9 to 15/10. In order to do this we had to refurbish our travel radiometer 'CR9'.

B.5.3. Perspectives for the next year

Figure 70: The Picard satellite launched from Yasni on 15 June 2010.

For 2011, the publication of the absolute level of Sovap/Picard is the first priority. The first results will be published for the classical shutter operation. The processing of the new mode with the permanently opened right shutter will be elaborated later on.
A continuing analysis of Diarad/Virgo and the other available TSI instruments is also foreseen.
At instrument level the priority will be the refurbishment of the SOVA instrument which flew in space in 1992, the characterisation of the SOVA, SOVAP MQ and CR9 instruments and the testing at LASP TRF.

B.6. Sun-Earth Radiation Imbalance

B.6.1. Objectives

The sustained funding of the STCE allows developing new space instruments. Building on the experience we have gained with the measurement of the TSI, we want to develop the Sun-earth IMBAlance (SIMBA) radiometer which can measure both the radiation coming from the sun and from the earth. A first application is the continuation of the TSI time series with an improved instrument. A second application is a calibration of the earth emitted radiation with the sun as best possible calibration source. A third application is the first ever direct measurement of the net radiation entering the earth (incoming solar minus nearly equal outgoing terrestrial radiation), which is the driver for climate change on earth.

In 2010, a new eningeering master thesis from the University of Liege was started with the aim to improve the first Simba instrument design.

A reprocessing of the historical NASA Wide Field Of View radiometers for the period from 1978 to 1999 was done - described hereafter - in order to demonstrate the feasability of the Simba data processing.

Climatologists require long, uninterrupted time series of high quality in order to study climate change. The sum of longwave radiation emitted and shortwave radiation reflected at the top of the atmosphere is a particularly important quantity that determines the net amount of energy that is absorbed by the Earth.

Our aim is to build long time series with high spatial resolution of monthly-mean, top-of-atmosphere radiation, with global coverage. This should enable studies at global and at regional scale of the monthly averages. Compared with former work, we want to improve the accuracy of the monthly averages by using state-of-the-art models and processing techniques.

B.6.2. Progress and Results

B.6.2.1. *Building long time series of total TOA radiation maps*

The first data that have successfully been used for this study have been obtained from an accurate but low-resolution instrument, the wide-field-of-view (WFOV) radiometer, that flew on several spacecraft in the past. This slightly undervalued instrument, much more robust than the early scanners which were hosted on the same spacecraft, has proven very valuable in constructing long time series, due to its long life span and limited degradation. It is a broadband radiometer with only two channels: a channel for shortwave radiation and one for total radiation (longwave plus shortwave radiation). Although the total channel has proven very stable, the shortwave channel exhibited nonuniform ageing over time. The main drawback of the WFOV radiometer is the low spatial resolution: at a typical altitude of 600 – 800 km, the field of view from limb to limb is several tens of degrees latitude and longitude. A single measurement thus covers many thousands of square kilometers.

The spacecraft carrying the WFOV radiometer were of different type, providing different ways of sampling the Earth's radiation budget. Most spacecraft are sun-synchronous, observing a given latitude at the same local time of day at every overpass, and yielding two measurements per day. Overpasses occurring at local noon yield accurate estimates of the monthly mean. Overpasses occurring at dawn or dusk, though, are likely to introduce significant error in the monthly mean estimate. Spacecraft in sun-synchronous orbits have excellent coverage of the Earth, going to latitudes of 80 degrees and more. One spacecraft so far (ERBS) was inserted in a low-altitude, precessing orbit, yielding good diurnal sampling with multiple measurements per day, although the coverage is reduced with respect to sun-synchronous satellites. The maximum latitude reached by the ERBS satellite is 57 degrees.

The different satellites thus cause different sampling strategies and spatial coverage. They also cover different time spans. By combining the information form multiple satellites, both global coverage and good diurnal sampling can be obtained over a long time period. The instantaneous data from the satellites are binned in rectangular boxes and fitted to an empirical diurnal model in order to produce monthly means. The empirical diurnal model models the total radiation flux as a function of the position of the sun; it is currently a rather simple model with a uniform night-time flux, and a day-time flux modelled by a half-cosine function.

The figures below show the monthly mean maps for the months March, June, September and December of the year 1987, when the four spacecraft Nimbus-7, NOAA-9, NOAA-10 and ERBS were simultaneously operational. The yearly seasonal cycle is clearly visible in the maps. Also clearly visible is the effect of the land–sea distribution on the radiation, and some particular land areas such as the Sahara desert and the interior of Australia. The figures are part of a dataset containing monthly mean data from November 1978 to September 1999, a period of nearly 21 years. This dataset is a first success in the construction of a long time series of

TOA radiation, by reviving old WFOV measurements. The next paragraph describes how we intend to improve this dataset.

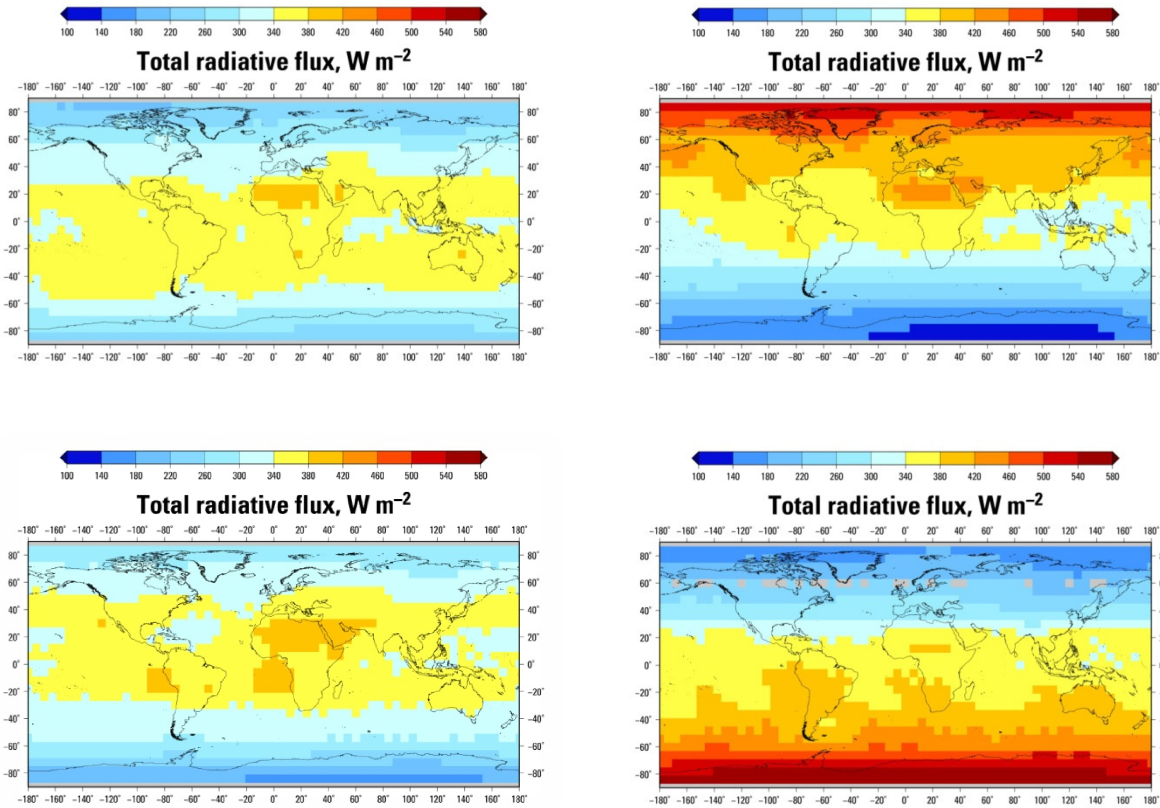


Figure 71: ***Total radiation maps for the four seasons of the year 1987. Top left: March 1987. Top right: June 1987. Bottom left: September 1987. Bottom right: December 1987.***

B.6.2.2. *Improving the time series*

The monthly means derived from the WFOV measurements, as shown in the figures, exhibit a spatial structure which agrees with climatological means and measurements from narrow field-of-view instruments (not shown). However, the resolution is below what is expected from modern climatological data. We can improve the resolution of the measurements by collocating the measurements with reanalyses. The idea is to combine the high-resolution reanalysis data, which is known with lesser accuracy, with the WFOV measurements, which are very reliable. This will allow to improve the resolution to 2.5 degrees.

Slow changes of the Earth-emitted and reflected radiation must show up as trends in time series constructed from the monthly means. However, changes in longwave and shortwave radiation tend to offset each other, such that the trend in total radiation may be weaker than the trend in the separate longwave and shortwave bands. We will therefore separate the longwave and shortwave contributions to the total radiation.

Adding data from after 1999, from broadband instruments on board Meteosat, Terra, and Aqua, would add value to the time series. We intend to add data from these platforms to extend the data range to present. The excellent diurnal sampling provided by the Geostationary Earth Radiation Budget instrument (GERB) on board Meteosat is particularly valuable in this respect.

Another problem with the monthly means as presently calculated is that the accuracy is not sufficient to detect a radiation imbalance at the top of the atmosphere, as expected if global climate change occurs. One reason is the empirical diurnal model, which is too simple for certain scene types, such as ocean or snow-covered surfaces. Another reason is the poor diurnal sampling which may happen at certain times and latitudes. Yet another reason is the lack of knowledge of cloud cover and cloud properties in the field of view of the instrument. At present, we do not know the relative importance of each of these reasons. Therefore, we will explore the magnitude of the error caused by these reasons, starting with the diurnal sampling.

B.6.3. Perspectives for the next year

Acontinuation of the master thesis for the improvement of the Simba instrument design is foreseen.

C. Space Experiments

C.1. The Xylophone Bar Magnetometer (XBM)

C.1.1. Objectives

The short-term goal is to study the feasibility of developing a resonating XBM suited to miniaturization using MEMS technology. The long-term goals is to embark a set of such miniature magnetometers onboard a fleet of micro/pico-satellites to carry out simultaneous measurements of the small- and large-scale structures of the Earth's magnetic field. In particular the study of the structure of the current sheet regions above auroral regions would be of great interest. Depending on the launching date, the XBM could be considered as a potential payload for one of the Belgian cubesat in the QB50 project led by the Von-Karman Institute.

For this project, BISA works in collaboration with the CSL (Dr. Pierre Rochus), IMEC (Dr. Véronique Rochus and Dr. Xavier Rottenberg), the Microwave Laboratory at UCL (Dr. Laurent Francis and Prof. Eric Raskin) and Open Engineering (Pascal de Vincenzo, Stéphane Paquay).

C.1.2. Progress and results

During this year, the project has continued nominally with several new designs that have been simulated in order to obtain the highest possible sensitivity for the magnetometer.

With the acquisition of a licence for the Oofelie Finite Element Software, Dr. Sylvain Ranvier has been able to model new designs of the MEMS XBM:

a) Using the commercial low-cost SOIMUMPS technology, the results indicate that, the traditional vibrating bar configuration does not lead to measureable displacements.
b) A design using piezoelectric material and a new configuration for the electrodes exhibits much higher sensitivity than with the traditional configuration. Contacts have been taken with Paul Kirby (Cranfield University) for possible collaboration in manufacturing MEMS XBM with piezoelectric material. Additional developments will require external funds.
c) Several designs based on capacitive detection, which will be manufactured by IMEC with their SiGeMEMS process at the beginning of 2011.

Several meetings were organized with the various partners:

- Meeting at CSL on 12/02 to discuss about strong electro-thermal and thermo-mechanical couplings in the bar, abstract for the IAC, GSTP funding, participation to QB50.
- Meeting at CSL on 23/04 to discuss about further simulations, Master Thesis of Sébastien Requier and to send the corrected version of the article of Lamy et al. to Acta Astronautica
- Meeting at UCL on 12/05 to discuss about other possible design and/or processes (such as SOIMUMPS) to build the XBM. A student from UCL will be involved in the project to design the electronics and insert it in the current design of the XBM.
- Meeting at BISA on 07/10 to discuss various options for continuing work on the XBM. Collaboration with the University of Cranfield was considered. The GSTP option seemed not to be a viable way.
- H. Lamy and S. Ranvier went to Open Engineering on 22/10 to discuss about the multi-physics results of the work of Sébastien Requier that shall be included in the paper for the EuroSim IEEE conference. Some results are very doubtful so it was decided that Stéphane Paquay will run some of the simulations again.
- H. Lamy and S. Ranvier have visited IMEC on 23/11 to meet Xavier Rottenberg and Véronique Rochus. IMEC will be an important partner in our project. Discussions were held about the possibilities to design our XBM with the new and controlled SiGeMEMS process available at IMEC. Sylvain Ranvier has made Oofelie simulations of this design and Véronique Rochus will submit a run in early 2011.

Sylvain Ranvier participated in the measurements on the prototypes which were designed by Innocent Niyonzima and realized at UCL in 2009. This was done in collaboration with the LTAS laboratory at ULg to use their PolyTec. The goal was to acquire some experience with the measurements of the bar frequency as well as to have an estimate of the bar displacement. In principle, the results could have been compared to the simulations carried out with Oofelie both with and without multiphysics, but unfortunately, the prototypes were too damaged and/or not "clean enough" to obtain meaningful data.

Several students from ULg and UCL have collaborated to this project. In particular, H. Lamy followed the master thesis of Sébastien Requier (ULg), and was member of his jury at the defense on 05/09. The title of the master thesis was "Harmonic simulation of a MEMS Xylophone Bar Magnetometer: multiphysics couplings and validation of electrokinetic thermoelastic elements in Oofelie".

C.1.3. Perspective for next years

The biggest problem we had to face in 2010 was the lack of additional funding for this project. Despite the current economical and political situation in Belgium, we intend to submit a GSTP proposal after the delivery by IMEC of the XBM prototypes made with their SiGeMEMS process.

Additional simulations of the SiGeMEMS prototypes will be carried out. The influence of strong couplings between the various fields (electrical, thermal and mechanical) will be studied in the case of the XBM made with SOI and the results will be presented at the EuroSimE meeting held in Linz, Austria in April 2011.

Simulations of a "smart magnetometer" (i.e. a set of magnetometers placed inside and outside a spacecraft) will be carried out for nano/pico-satellites. The idea is to simulate various electromagnetic perturbations due to the spacecraft payload and to prove that this smart magnetometer can accurately retrieve the signal from the background external magnetic field, without using a long external boom. A French engineer student from “L’école des mines de Alès” will come to BISA for a 3 months period training. She will initiate this work.

We will also continue considering a possible collaboration with the development of Belgian cubesat in the framework of the QB50 project led by the Von Karman Institute.

C.2. Meteors: the BRAMS network

C.2.1. Objectives

The goal is to build a network of radio receiving stations using forward scattering techniques to detect and characterize meteors. The project is called BRAMS for Belgian RAdio Meteor Stations. A dedicated beacon is used as the transmitter and there are many receiving stations spread all over Belgium. One of them is located at BISA, one is located in Humain and has interferometric capabilities, and all other receiving stations are hosted by radioamateurs or groups of amateur astronomers. Some of the scientific goals of this project are to calculate flux densities and mass indexes for both meteor showers and sporadic meteors, retrieve meteoroid trajectories from multi-station observations, and determine physical parameters such as ionization, mass and velocity whenever possible. BRAMS will help us to better characterize the mass, velocity, temporal and spatial distributions of meteor showers and sporadic meteors.

This project is done in collaboration with ROB, RMI, with radioamateurs or groups of amateur astronomers.

C.2.2. Progress and results

- Beacon in Dourbes:
  - ➢ BISA has obtained a license from IBPT/BIPT to emit a power of 150 W at a frequency of 49.970 MHz for the beacon.
  - ➢ A signal generator and a power amplifier have been procured.
  - ➢ Discussions have been held with R. Warnant and Mr. Rasson, Director of the “Centre de Geophysique du Globe”, concerning the installation of our beacon in Dourbes. An agreement was found to operate the beacon there, provided that it does not perturb the other equipment in Dourbes. A first visit of the site was made on June 24 to look for the best location to install the beacon.
  - ➢ The radio beacon started emitting on 21/09. During the first weeks of operation, no interference with other equipment in Dourbes was detected. Meteor reflections from the radio beacon are seen by observers as far as the north of The Netherlands and the south of Paris.
  - ➢ The gain of the beacon antenna has been measured in the horizontal direction, and the measurements are in good agreement with the simulation results.
  - ➢ Future plans include installing a 6 m x 6 m grid as reflector below the antenna to remove the direct signal propagating along the ground as much as possible. S. Ranvier has simulated several antenna designs with large ground shielding planes in order to increase the gain towards the zenith and reduce radiation at low elevation angle of the beacon antenna. The wire-netting to be used for the grid has been ordered. It will be installed during the first months of 2011. It will decrease the size of the antenna lobes and therefore the number of reflections on planes. Also it will strongly attenuate the power of the direct signal (currently seen by all receiving stations located in Belgium). If really needed, a more complicated structure will be added later on. The complexity/performance ratio of this additional structure is, however, rather low.
  - ➢ An UPS will be ordered soon because in case of electrical breakdown, the signal generator does not restart with the correct frequency and a manual restart is therefore necessary.

- Receiving station in BISA:
  - We came to an official agreement with RMI to install our receiving station in the park next to BISA. Works for digging tranches and install power cables have been done in June. The whole system was installed in July/August and was fully operational for the Perseids in August.
  - A prototype 3-element Yagi antenna has been successfully built at the BISA workshop. We have measured its impedance and adapted it to 50Ω. Its sensitivity is similar to the commercial one bought at HF Electronics in 2009. Another crossed 3 elements Yagi antenna has also been built at the workshop to measure both polarizations.
  - We have installed the 2 antennas in the RMI meteorological park next to BISA at the Space Pole: a simple basic station (just like the ones that will be deployed elsewhere) that listens to the Ypres beacon at 49.99 MHz and a station using both polarizations that listens to the Dourbes beacon at 49.97 MHz. So far the two polarizations have been recorded separately with 2 ICOM-R75 receivers. Work has been carried out with an USRP2 receiver which would allow combining both polarizations. However, due to a much smaller sensitivity of the USRP2, low noise amplifiers have been procured. A small shelter to house the receiver equipment has been outfitted by the BISA workshop. It is equipped with an appropriate fan, a thermostat and a heater in order to maintain the adequate temperature in the shelter. An UPS has been installed to provide emergency power in case of electrical breakdown.

- Other receiving stations:
  - We have currently 24 radio-amateurs or groups of amateur astronomers interested to host one receiving station and be part of the BRAMS network.
  - We have obtained suitable commercial receivers (ICOM-R75) at a good compromise between cost and performance. 20 of these receivers are now being procured.
  - We have struggled to find a good and cheap GPS receiver for providing time synchronization of all the stations. E. Gamby did some tests to see how GPS timing information can be read out, but the difficulty is to find a cheap GPS receiver that provides the pps output signal. E. Gamby has tested a Garmin GPS to see how well the GPS timing information can be read out. He also made various tests to better understand the NTP protocol and the degree of synchronization that can be obtained with it. This led to a more precise specification for the BRAMS GPS receiver:
    - It must provide PPS output.
    - It must interface with a serial port.
    - Its antenna must have a clear view of the sky.
  - 3-elements Yagi antennas with a robust mast system to select the desired inclination of the antenna have been built at the BISA workshop. Tests with a prototype were very satisfactory.

- Interferometer station in Humain:
  - The goal is to build a 5-antenna interferometer at the radioastronomical site of Humain. For that, we came to an agreement with Ronald Vanderlinden, the ROB director. There are a number of very good reasons to install our interferometer there: excellent radioastronomical site with little noise, existing facilities (power, internet, and man power), lots of space, no reflections on metallic surfaces in the surroundings, etc… The scientific goal of the interferometer is to obtain a good accuracy on the echo direction with no ambiguity. One antenna will be a crossed 3-elements Yagi antenna like the one used at the BISA receiving station.
  - The trenches for the cables and the concrete foundations for the antennas have been made by an external company. The supports of the antenna have been fixed in the concrete blocks by the staff from the BISA workshop.

- The five antennas and a shelter to house the receiving equipment have been built at the BIRA workshop and will be installed in 2011. Nylon wires have been ordered to ensure a better resistance of the antennas against the wind.
- S. Ranvier wrote a Matlab implementation of the direction finding algorithm for the interferometer.

- Radar system:
  - S. Ranvier started to investigate different possibilities for developing a radar to enhance BRAMS capabilities.
  - A project related to BRAMS has been included in the ANTARES (Antarctic Telescience Atmospheric Research for the Exploration of Space) proposal which was submitted by D. Moreau in the Research Programme SSD "Polar Research, Climate and Atmosphere". The project is called PRAMS for Polar RAdio Meteor Stations and aims at installing a meteor radar at the Belgian Princess Elisabeth Station in Antarctica. This proposal, however, has not been successful.

- BRAMS ICT system:
  - The BRAMS website (http://brams.aeronomie.be) has been created by E. Gamby and is maintained by E. Gamby and H. Lamy. E. Gamby created a svn repository for the site. Detailed pages have been added about the Dourbes beacon, the BIRA-IASB station, the interferometer... A system has been created for managing the geolocations of the future stations. One can now easily edit parameters such as longitude and latitude, the official operator of the station, and auxiliary information. A similar system has been set up for managing the beacons. One can edit parameters such as longitude, latitude, frequency, power... The network map is automatically updated with the coordinates provided above.
  - A first version of the BRAMS archiver has been created by E. Gamby. This application is responsible for copying the data files from the external hard disks to the central archive. This version focuses on checking the consistency of the file naming conventions, and copying files at the right place inside the archiving tree.
  - Emmanuel Gamby and Stijn Calders work on data acquisition software; they have created a first prototype for acquiring the audio signal from the soundcard.
  - H. Lamy, E. Gamby and S. Calders work on the development of a Matlab code for automatic detection of meteors in spectrograms. More sophisticated methods are currently considered to detect and remove echoes due to planes.

- Student involvement:
  - A meeting was held on 15 March 2010 with Pierre Ernotte and two of his students of EPHEC on the subject of the development of an automatic method of detection and discrimination of meteor echoes on spectrograms. This work is done in the framework of their master thesis at EPHEC.
  - In August, E. Gamby worked with a student from EPHEC on the algorithm for detecting meteors. The conclusion is that the algorithm is not good enough when the spectrogram becomes a little bit complicated. In particular, the ability to remove airplane reflections from the spectrogram is a key issue. H. Lamy, S. Calders and E. Gamby have begun to look at curve fitting techniques that are used for road recognition from aerial images.
  - On 27/09, Hervé Lamy gave a short presentation of the BRAMS network and proposed ideas of trainings for EPHEC students. Two students are interested, one to work on the code for automatic detection of meteors, one to implement a method developed in Steyaert et al (2010) to determine approximate velocity and trajectory of a meteoroid from multi-stations observations of a head echo. These two projects are done in collaboration with Pierre Ernotte, teacher at EPHEC.
  - Hervé Lamy proposed the subject "Réflexion d'ondes VHF monochromatiques sur les avions survolant un émetteur" as a possible training for engineer students of ULB in the PROJ-H-403

framework. A student is interested and will work on this subject in the first semester of 2011. Marc Haelterman from ULB will be co-promotor of the project.

- J. De Keyser proposed the subject "Radio meteor detection: Data processing and scientific interpretation" as the subject for a possible Master's thesis (Master in Space Sciences) at the K.U.Leuven. The co-promotor would have been G. Lapenta. No student was interested.

- Funding:

- Hervé Lamy has submitted an Action 1 proposal called "Radio Meteor Studies using the Belgian RAdio Meteor Stations (BRAMS) network" to hire a scientist for 4 years. The proposal has not been selected.

C.2.3. Perspectives for next years:

In 2011, we will have a kick-off meeting at the Planetarium of Brussels in February 2011 with all amateur astronomers interested to host a BRAMS receiving station. Each participant will receive identical material, i.e. a ICOM-R75 receiver, coaxial cables, a 3-elements Yagi antenna and a GPS clock. BISA will install most of these stations and will check other installations. All antennas will be matched with the network analyser available at BISA. We expect approximately 20 stations to be fully operational in July. Data from each individual station will be collected with external USB sticks with a storage capacity of 64 Gb. They will be sent regularly to BISA by using the Belgian post. The data will be stored at BISA and further analyzed.

The 5 antennas for the interferometer will be installed in Humain in March 2011. Once the receivers will be received, initial tests will be carried out. We expect the interferometer to be operational in July.

Work is also planned to decrease the power of the direct signal coming from the Dourbes beacon.

We will also develop a radar system to complement the BRAMS facilities. This system will be very useful to compare the performances of back scatter and forward scatter systems, something that has never been done before. We will also acquire experience with the development of a radar system in case the project PRAMS (Polar RAdio Meteor Stations) is funded in 2011.

C.3. Study of the polarization

C.3.1. Objectives

The initial goal of BISA is to use the polarization of some auroral emission lines to better understand the ionosphere/magnetosphere coupling and the physics of the ionosphere. Space weather applications are also envisaged. We are also interested in polarization measurements in other planetary atmospheres like for example Mercury or Jupiter. We also plan to develop a European network of scientists specialized in all aspects of polarization, i.e. observations, theory, modeling, instrumentation and laboratory measurements.

C.3.2. Progress and results:

- In order to obtain more information about the polarization of thermospheric emission lines, C. Simon and H. Lamy work together with J. Lilensten and M. Barthélemy from the IPAG, Grenoble, on the implementation of a spectropolarimeter attached to a Cassegrain telescope. BIRA-IASB has participated to its construction by providing the optical components (Wollaston prism, half-wave plate) as well as the associated mountings and the engine to rotate the plate. IPAG will provide the LHIRES spectrometer, the CCD and the telescope. Development and mounting of the instrument is realized in Grenoble.

- Despite some good reviews and an average score of 17.42/20, the COST proposal oc-2010-1-6549, « Polarization to study the solar system and beyond », is not among the 10 top-ranked proposals in the domain "Materials, Physical and Nanosciences". Given the positive feedback we received, we intend to submit an improved version of this proposal for the next call in September.
- After some modifications, we have re-submitted the COST proposal oc-2010-2-8667 "Polarization to study the solar system and beyond" in the domain "Materials, Physical and Nanosciences". This time it has been selected and we have been invited to submit a Full Proposal. Deadline for submission is 14 of January.

C.3.3. Perspectives for next years

A COST Full Proposal will be introduced in January 2011. More than 100 European scientists have already agreed to join the network.
We will continue the development of the spectropolarimeter with IPAG. Hopefully some tests onsite (in Svalbard) could be done in winter time at the end of 2011.
Some tests for the polarization capabilities of the ALIS cameras will be done by the ALIS team in 2011. After discussion with the group of Utrecht during the workshop in 2009, it was suggested to use modulators in front of the polarizing lenses instead of a rotating filter. We will consider this option.
H. Lamy and C. Simon will be associated to observations of the polarization of Na lines in Mercury's exosphere carried out by Arturo Lopez-Ariste with the THEMIS instrument on the Solar Telescope in Tenerife. The goal is to estimate the magnetic field strength and/or direction from the Hanle effect. The exospheric Na densities can also possibly be retrieved.

C.4. Optics laboratory facilities

C.4.1. Description

The optics laboratory of BIRA-IASB provides facilities for the radiometric characterization and calibration of optical instruments generally dedicated to the measurements of the solar radiation and atmospheric trace species. Such characterizations are performed on commercial instruments designed for ground-based measurements or space qualified instruments developed in the frame of space projects.

Within the spectral range 185 – 900 nm actually available, the tasks are typically:

- The determination of wavelength scales using various spectral light sources.
- The absolute calibration of spectroradiometer using standards of spectral irradiance
- The characterization of various sub-systems as optical diffuser (entrance optics), filters, lamps …
- The production of a monochromatic and tunable light source for the characterization of the diffuse light of spectrographs, the transmission of filters, or the measurement of detector response. It can be achieve by using a solar simulator coupled to a monochromator

The goal of this work package is to maintain the available facilities as a service for the UV-VIS, to extend the spectral range down to 100 nm or below for vacuum radiometry and to provide an upgrade for the NIR (up to 2.5 μm) for which less equipment is actually available. The objective consists of bringing this infrastructure up-to-date as a service for possible external collaborations (ROB, universities …).

For space projects (SOLSPEC, LYRA, BOLD …), some optical components have to be tested under vacuum. The detectors should be characterized for wavelength below the cut-off of the atmospheric pressure (~185 nm). There is a demand for a VUV facility that can be achieve by the refurbishment of the B225 (McPherson Inc, USA) spectrometer of BIRA-IASB. Connected to a cell, the facility can also offer an opportunity for absorption cross section measurements of molecule in the VUV (SO_2 ...). For the NIR, an upgrade of an existing UV-VIS instrument is proposed (Bentham, UK).

C.4.2. Progress and results

Many tasks have been performed during the last years in the frame of European projects (for example: biological dosimetry, calibration of radiometers and spectrometers for comparison campaigns …). Also, for space activities, the experiment SOLSPEC (UV-VIS-IR spectroradiometer as part of the SOLAR payload onboard ISS) was developed at BIRA-IASB (joined project with LATMOS, France and ZAH, Germany). Before and after the integration, a wide range of tasks were performed in the laboratory: check-up of detector response, selection of flight model of internal lamps, vacuum tests, adjustment of filters, followed by the complete characterization (linearity measurements, angular response, wavelength scale, …).

Actually, the works in the optics laboratory are dedicated to:

- The maintenance of the radiometers and spectroradiometers operational on the Belgian network for UV-VIS monitoring of the global solar irradiance (angular response, absolute calibrations …).
- Synergies between different teams at BIRA-IASB: characterization (for internal diffuse light) of spectrographs dedicated to the measurements of atmospheric trace species (NO_x, O_3 …).

Needs for the NIR spectral range

Less laboratory equipement was available for the NIR spectral range despite of the important role of this radiation on the Earth radiative budget (thermal structure and dynamics) due to the wavelength dependent atmospheric absorption (H_2O, CO_2) and the absorption by the upper layer of ocean water. In 2010, a new Bentham double monochromator (PbS detector and phase sensitive detection) was delivered for upgrating our laboratory facility or performing solar measurements. The dedicated spectral range of this instrument is 600-2500 nm. It is now used for developing a validation campaign for SOLSPEC in the IR.

Needs for a VUV facilities (mainly for space project)

Up to now, a thermal vacuum chamber of IASB is available for radiometry below 200 nm. A new facility is proposed. It is based on the the refurbishment of a B225 McPherson VUV spectrometer using the following equipment:

- Light sources: a hollow cathode lamp and deuterium lamp coupled to an energy optimizer.
- Detector: solar blind PMT (vacuum PMT housing).
- A predispersor will be connected to the B225. The complete system will provide a level of performance similar to a double monochromator.
- Without the detector, the system is able to provide of a monochromatic and tuneable light beam.

The tests of individual components are in progress. Some mechanical works are still required for assembling the sub-systems.

C.4.3. Perspective for next years

To have the VUV facility tested and ready-to-use. To develop some collaboration with the DEMALab facility (ROB).

PART 5: PERSONNEL

We give an overview of the people that contributed to an STCE work package. We indicate the payroll and the work involved.

- R. Abjij, BISA-IASB staff: Data & Mission Center
- W. Aerts, STCE: Time laboratory and new GNSS signals
- Q. Baire, STCE: Development of Atomium
- J. Bartholomees, permanent RMI staff: technical assistant for the ozone sounding preparation and launch
- A. Benmoussa, PRODEX: detector specialist and PI Demelab
- N. Bergeot, STCE: Monitoring of the ionosphere on GNSS positioning
- D. Berghmans, permanent ROB staff: Space Weather Services, PROBA2/SWAP PI
- D. Bolsée, BISA-IASB staff: Earth observations
- O. Boulvin, permanent ROB staff: technical expert and observer for the USET project.
- C. Bruyninx, permanent ROB staff: PI “GNSS” project
- J. Bulcke, permanent BISA-IASB staff: HPC and ITC support
- R. Burston, STCE: Ionospheric physics
- S. Calders, BISA-IASB staff: space weather services
- J.-M. Chevalier, STCE: Monitoring of the ionosphere
- F. Clette: Solar physics scientists, research on the observation of the Sun with optical instruments for the monitoring of the solar activity on short and long time scales. PI of the USET project.
- H. De Backer, permanent RMI staff: project management, PI for the STCE workpackage
- V. De Bock, external contribution: UV radiation and UV index forecast, retrieval of aerosol properties (AOD) from Brewer sunphotometer measurements
- E. De Donder, BISA-IASB staff
- P. Defraigne, permanent ROB staff: PI “Time and time transfer” project
- E. D’Huys, STCE: Space Weather Services, EPO, SWAP & LYRA software testing
- J. De Keyser, permanent BISA-IASB staff: PI Observations and models of the Earth’s magnetosphere, PI participating in experiments
- M. Demazière, permanent BISA-IASB staff: PI Radiative transfer
- S. Delanoye, BISA-IASB staff: Observations of the Earth’s atmosphere
- A. Delcoo, external contribution: validation of satellite observations of ozone and AOD
- V. Dehant, permanent ROB staff: Radioscience experiment coordinator
- S. Dewitte, permanent RMI staff: PI Solar Irradiance & Sun-Earth Radiation Imbalance
- L. Dolla, STCE: spectroscopic diagnostics of the solar atmosphere
- M. Dominique, PRODEX: PI LYRA (second half 2010)
- J.–L. Dufond, permanent ROB staff: Electronic engineer for USET and Humain.
- A. Ergen, permanent ROB staff: Electronic technician for the USET and Humain project. Observer in the USET project.
- E. Gamby, BISA-IASB staff: Observations and models of the Earth’s magnetosphere, participating in experiments
- D. Gillotay, permanent BISA-IASB staff: Measurement of solar irradiance and UV index
- S. Gissot, PRODEX: analysis of EUV images of the solar corona
- H. Gunel, BISA-IASB: Observations and models of the Earth’s magnetosphere
- L. Hetey, BISA-IASB staff: Data & Mission Center
- J.F. Hochedez, permanent ROB staff: PI Solar Orbiter PI and LYRA (first half 2010)
- S. Kotchenova, BISA-IASB staff: energetic events in the solar corona: coronal heating
- M. Kruglanski, permanent BISA-IASB staff: Space Weather Services

- H. Lamy, permanent BISA-IASB staff: Space environment monitoring
- J. Legrand, ROB staff: GNSS applications
- S. Lejeune, STCE: Ionosphere and GNSS applications
- S. Le Maistre, PRODEX: Radioscience experiment data analysis
- O. Lemaître, permanent ROB staff: Technical assistant and observer for the USET project.
- V. Letocart, BISA-IASB staff: Data & Mission Center
- K. Litefti, BISA-IASB staff: Data & Mission Center
- P. Lisnichenko, STCE: Energetic events in the solar corona
- J. Magdalenić, BELSPO Action 1: solar radio data analysis
- A. Mangold, external contribution: aerosol analysis, installation and analysis of the aerosol, UV and ozone instruments at the Belgian Base Princess Elisabeth in Antarctica
- C. Marqué, STCE: Solar physics scientists, research on radio observations of the solar corona, PI of the Humain project
- D. Mesmaker, ROB staff: maintenance and development of observation of GNSS networks
- N. Messios, BISA-IASB staff: Data & Mission Center
- A. Michel, BISA-IASB: Data & Mission Center
- M. Mierla, PRODEX: 3D reconstruction of CMEs
- M. Mitrovic, PRODEX: Radioscience error budget
- D. Moreau, B.USOC: PI Data & Mission Center
- A. Moyaert, ROB staff: maintenance and development of observation GNSS networks
- E. Neefs, permanent BISA-IASB staff: Atmosphere observations – engineering
- B. Nicula, STCE : Energetic events in the solar corona
- C. Nkono, PRODEX: Plasma effect on radioscience
- V. Pierrard, permanent BISA-IASB staff: fundamental processes of space environment
- J. –P. Noël, STCE: Electronic technician for the Humain project
- E. Podladchikova, STCE: Energetic events in the solar corona
- E. Pottiaux, STCE: Monitoring of the troposphere, influence of the atmosphere on GNSS positioning
- S. Ranvier, BISA-IASB staff: participating in experiments
- O. Rasson, BISA-IASB staff: Data & Mission Center
- S. Raynal, STCE: Common activities
- E. Robbrecht, permanent ROB staff: space weather activities, lead RWC Belgium
- L. Rodriguez, PRODEX: interplanetary plasma and magnetic field and STEREO data analysis
- P. Rosenblatt, PRODEX: Radioscience experiment data analysis
- D. Seaton, PRODEX: PROBA2/SWAP data analysis
- S. Stankov, STCE: Ionosphere and GNSS applications
- K. Stegen, STCE. Ionosphere and GNSS applications
- J. Spits, PRODEX: Ionosphere and GNSS applications
- R. Van der Linden, permanent ROB staff : general manager, Space Weather Services, Energetic events in the solar corona
- A. Vander Syppe, ROB staff: organization of conference, press events, meetings
- P. Vanlommel, STCE: Common activities, Space Weather Services
- R. Van Malderen, STCE : time series analysis of ozone and ozone-related phenomena, intercomparison and trends analysis of water vapour measurements
- S. Vanraes, permanent ROB staff: programmer and observer for the USET project.
- N. Vermeulen, STCE: Solar Irradiance, Sun-Earth Radiation Imbalance
- Y. Voitenko, BIRA-IASB staff: fundamental science
- S. Willems, staff ROB: IT support for SWAP-LYRA, Space Weather Activities
- R. Warnant, permanent RMI staff: PI Ionosphere and GNSS applications
- D. Wattez, permanent RMI staff: technical assistant for the ozone sounding preparation and launch
- G. Wautelet, Belspo/Action 2: Ionosphere and GNSS applications
- L. Wauters, STCE: the WDC for the sunspot index and Space Weather Activities

- M. West, PRODEX: STEREO data analysis
- A. Zhukov, STCE: Solar activity and plasma modelling, studies of the solar atmosphere

PART 6: PUBLICATIONS

1. Publications with peer review

[1] H. A. Barkad, A. Soltani, M. Mattalah, J-C. Gerbedoen, M. Rousseau, J-C. De Jaeger, A. BenMoussa, V. Mortet, K. Haenen, B. Benbakhti, M. Moreau, R. Dupuis and A. Ougazzaden
Design, fabrication and physical analysis of TiN/AlN deep UV photodiodes
J. Phys. D: Appl. Phys. 43 465104, 2010

[2] Bergeot N., Bruyninx C., Defraigne P., Pireaux S., Legrand J., Pottiaux E., and Baire Q.
Impact of the Halloween 2003 Ionospheric Storm on Kinematic GPS Positioning in Europe
GPS Solutions, Springer, 2010-08-27, 1-10, doi: 10.1007/s10291-010-0181-9

[3] Bidaine B., Warnant R.
Assessment of the NeQuick model at mid-latitudes using GNSS TEC and ionosonde data
Adv. Space Research, 45, pp. 1122-1128, doi:10.1016/j.asr.2009.10.010, 2010

[4] Bidaine B., Warnant R.
Ionosphere modeling for Galileo single frequency users: illustration of the combination of the NeQuick model and GNSS data ingestion
Adv. Space Research., 47, pp. 312-322, doi:10.1016/j.asr.2010.09.001, 2010.

[5] De Bock, Veerle, H. De Backer, A. Mangold, and A. Delcloo
Aerosol Optical Depth measurements at 340 nm with a Brewer spectrophotometer and comparison with Cimel observations at Uccle, Belgium
Atmos. Meas. Tech., 3, 1577-1588, doi:10.5194/amt-3-1577-2010, 2010

[6] J. De Keyser and M. Echim
Auroral and subauroral phenomena: An electrostatic picture,
Ann. Geophys., 28, 633-650, 2010.

[7] J. De Keyser, R. Maggiolo, and E. Echim,
Monopolar and bipolar auroral electric fields and their effects.
Ann. Geophys., 28, 2027-2046, 2010.

[8] J. De Keyser, R. Maggiolo, M. Echim and I. Dandouras.
Wave signatures and electrostatic phenomena above aurora: Cluster observations and modeling of plasma properties and electric and magnetic fields at the plasma sheet boundary,
J. Geophys. Res., 2011

[9] M. Echim, J. Lemaire and O. Lie-Svendsen,
A review on solar wind modeling: kinetic and fluid aspects,
Surveys in Geophysics, Volume 32, Issue 1, pp.1-70, 2011.

[10] Z. Ever and I.N. Pakskes
Tools for a random report generater,
Models for an Easy Life, half Vol. 1, 233-238, 2010.

[11] E.V. Faricheva, M.A. Kiyan, V.N. Podladchikov, O. Podladchikova
Cluster Analysis for NEMO tool improvement,
New Technologies 28, 149-153, 2010.

[12] S.E. Gibson, T.A. Kucera, D. Rastawicki, J. Dove, G. de Toma, J. Hao, S. Hill, H.S. Hudson, C. Marqué, P.S. McIntosh, L. Rachmeler, K. K. Reeves, B. Schmieder, D.J. Schmit, D.B. Seaton, A. Sterling, D. Tripathi, D.R. Williams, M. Zhang
Three-dimensional Morphology of a Coronal Prominence Cavity
ApJ, 724, pp.1133-1146, 2010

[13] Jonson, Jan Eiof, A. Stohl, M.M. Fiore, P. Hess, S. Szopa, O. Wild, G. Zeng, F.J. Dentener, A. Lupu, M.G. Schulz, B.N. Duncan, K. Sudo, P. Wind, M. Schultz, E. Marmer, C. Cuvelier, T.J. Keating, A. Zuber, A. Valdebenito, V. Dorokhov, H. De Backer, J. Davies, G.H. Chen, B. Johnson, D.W. Tarasick , R. Stübi, M.J. Newchurch, P. von der Gathen, W. Steinbrecht, and H. Claude
A multi-model analysis of vertical ozone profiles
Atmos. Chem. Phys., 10, 5759-5783, doi:10.5194/acp-10-5759-2010, 2010

[14] Keim, Corneli, M. Eremenko, J. Orphal, G. Dufour, J.-M. Flaud, M. Höpfner, A. Boynard, C. Clerbaux, S. Payan, P.-F. Coheur, D. Hurtmans, H. Claude, H. De Backer, H. Dier, B. Johnson, H. Kelder, R. Kivi, T. Koide, M. López Bartolomé, K. Lambkin, D. Moore, F. J. Schmidlin, and R. Stübi
Tropospheric ozone from IASI: comparison of different inversion algorithms and validation with ozone sondes in the northern middle latitudes
Atmos. Chem. Phys., 10, 6345-6345, doi:10.5194/acp-10-6345-2010, 2010

[15] N. F. Kleimeie, T. Haarlammert, H. Witte, U. Schühle, J-F Hochedez, A. BenMoussa and H. Zacharias
Autocorrelation and phase retrieval in the UV using two-photon absorption in diamond pin photodiodes
Optics Express, Vol. 18, Issue 7, pp. 6945-6956 (2010)

[16] Lamy H., Nyonzima I., Rochus P., Rochus V.,
A Xylophone Bar Magnetometer for micro/pico satellites
Acta Astronautica, 67, 793-809, 2010.

[17] P. E. Malinowski, J-Y Duboz, P. De Moor, J. John, K. Minoglou, S. Martin Horcajo, F. Semond, E. Frayssinet, B. Giordanengo, A. BenMoussa, R. Mertens and C. Van Hoof
Extreme Ultraviolet Detection using AlGaN-on-Si inverted Schottky photodiodes
Applied Physics Letter, Vol. 98, 2011, pp. 141104 (2011)

[18] Martinez M. C. and Defraigne P.
Combination of TWSTFT and GPS data for time transfer
Metrologia, 47 (3), 305-319, 2010

[19] J. Magdalenic, C. Marqué, A.N. Zhukov, B. Vrsnak, T. Zic
Origin of Coronal Shock Waves Associated with Slow Coronal Mass Ejections
Astrophysical Journal, 718, pp.266-278, 2010

[20] Mekaoui, S., S. Dewitte, C. Conscience, A. Chevalier,
Total Solar Irradiance absolute level from DIARAD/SOVIM on the International Space Station
Adv. Space Res., Vol. 45, pp . 1393-1406, 2010.

[21] M. Mierla, B. Inhester, A. Antunes, Y. Boursier, J. P. Byrne, R. Colaninno, Joe Davila, C. A. de Koning, P.T. Gallagher, S. Gissot, R.A. Howard, T. A. Howard, M. Kramer, P. Lamy, P. Liewer, S. Maloney, C. Marqué, R.T.J. McAteer, T. Moran, L. Rodriguez, N. Srivastava, O.C.St. Cyr, G. Stenborg, M. Temmer, A. Thernisien, A. Vourlidas, M. West, B. E. Wood, A.N. Zhukov
On the 3-D reconstruction of Coronal Mass Ejections using coronagraph data
Annales Geophysicae, 28, pp.203-215, 2010

[22] V. Pierrard,
The kinetic approach to model space plasmas,
Numerical Modeling of Space Plasma Flows, Astronum 2009 Proceedings, ASP Conference series, Vol. 429, 233-238, 2010.

[23] Pireaux S., Defraigne P., Wauters L., Bergeot N., Baire Q., and Bruyninx C.
Influence of ionosphere perturbations in GPS time and frequency transfer

Journal of Advances in Space Research, doi:10.1016/j.asr.2009.07.011, vol 45 (9), pp. 1101-1112, 2010

[24] Pireaux S., Defraigne P., Wauters L., Bergeot N., Baire Q., and Bruyninx C.
Higher-order ionospheric effects in GPS time and frequency transfer
GPS solutions, 14(3), 267-277, 2010

[25] O. Podladchikova, A. Vourlidas, R.A.M. Van der Linden, J.-P. Wuelser, S. Patsourakos
EUV Observations and Analysis of Micro-Eruptions and Their Associated Coronal Waves,
Astrophysical Journal 709, 369-376, 2010.

[26] Spits J., Warnant R.
Total Electron Content Monitoring using triple frequency GNSS: results with Giove-A/-B data
Adv. Space Research, 47, pp. 296-303, doi:10.1016/j.asr.2010.08.027, 2011

[27] Staiger, Henning, J. Kaurola and H. De Backer
Merged daily gridded European fields of bias corrected ERA-40 and solar cloud modification factors derived from pyranometer observations
J. Geophys. Res, 115, D21109, doi:10.1029/2009JD013718,, 2010

[28] Stankov S., Stegen K., Warnant R.
Seasonal variations of storm-time TEC at European middle latitudes
Adv. Space Research, 46, pp. 1318-1325, doi:10.1016/j.asr.2010.07.017, 2010

[29] Stankov S., Stegen K., Muhtarov P., Warnant R.
Local ionospheric electron density profile reconstruction in real time from simultaneous ground-based GNSS and ionosonde measurements
Adv. Space Research, 47, pp. 1172-1180, doi:10.1016/j.asr.2010.11.039, 2011

[30] Van Malderen, R. and H. De Backer
A drop in upper tropospheric humidity in autumn 2001, as derived from radiosonde measurements at Uccle, Belgium
J. Geophys. Res., 115, D20114, doi:10.1029/2009JD013587

2. Publications without peer review

[31] Aerts W., Bruyninx C., and Defraigne P.
Bandwidth and Sample Frequency Effects in GPS Receiver Correlators
NAVITEC 2010 (on CDrom)

[32] Bergeot N., Bruyninx C., Aerts W., Legrand J., and Moyaert A.
GPS en Antarctique: Mieux comprendre la fonte de la calotte polaire à la Station Princesse Elisabeth.
Science Connection n°29, Avril-Mai 2010

[33] Bergeot N., Bruyninx C., Aerts W., Legrand J., and Moyaert A.
GPS in Antarctica: Voor een beter begrip van het smelten van de poolkap bij het Prinses Elisabethstation.
Science Connection n°29, April-Mei 2010

[34] Bidaine B., Nava B., Stankov S., Warnant R.
M-Ingestion: simultaneous ingestion of ionosonde and GNSS data into the NeQuick ionospheric model
In P. Doherty, M. Hernandez-Pajares, J.-M. Juan, J. Sanz, A. Aragon-Angel (Eds.), The International Beacon Satellite Symposium 2010, June 7-11 2010, Barcelona, Spain, 2010

[35] Bruyninx C. and EUREF Technical Working Group

Maintenance of the ETRS89 using EUREF's Permanent GNSS Service
Proc. Int. Symp. on GNSS, Space-based and Ground-based Augmentation Systems and Applications, 28-29 Nov. 2010, Brussels, pp. 17-20

[36] Burston R., Bergeot N., Bruyninx C., and Chevalier J.-M.
A Two-stage Mid-latitude Instability Process: Gradient-drift and Kelvin-Helmholtz Waves?
Proc. Beacon Satellites Symposium 2010, June 7-10, 2010, Barcelona (on USB)

[37] Burston R., Hodges K., Astin I., Chevalier J.-M., Bergeot N., and Bruyninx C.
Using Ionospheric Imaging Combined with Feature Tracking to Automate Identification and Tracking of Polar-cap Plasma Patches
Proc. Institute of Navigation GNSS Technical Meeting, p 343-348, September 21-24, 2010, Portland, Oregon, USA

[38] Defraigne P., Petit G., Uhrich P., and Aerts W.
Requirements on GNSS receivers from the perspective of timing applications
in: Proc. EFTF, CD-rom, 2010

[39] Defraigne P., Martinez M.C., Mudrak A., and Binda S.
Galileo Common View: format, processing and tests with GIOVE
in: Proc. 42th PTTI, CD-rom, 2010

[40] Defraigne P., Baire Q., and Harmegnies A.
Time and frequency transfer combining GLONASS and GPS data
in: Proc. 42th PTTI, CD-rom, 2010

[41] Defraigne P.
JD6: Time and Astronomy
Highlights of Astronomy, Vol. 15, XXVIIth IAU General Assembly, Aug. 2009, doi: 10.1017/S174392113100877X, 2010

[42] S. Gissot, G. Rouvroy and A. BenMoussa
Preliminary design of the Extreme Ultraviolet Imager (EUI) compression system on-board the Solar Orbiter mission
2nd International Workshop on On-Board Payload Data Compression-OBPDC 2010, Toulouse, France (28-29/10/2010)

[43] J-P Halain, F. Auchère, P. Rochus, L. Jacques, K. Fleury, L. Rossi, E. Renotte, J-M Defise, D. Berghmans, J-F Hochedez, A. Zukhov, A. BenMoussa, U. Schühle, L. Harra, T. Appourchaux
The technical challenges of the Solar-Orbiter EUI instrument
SPIE 2010, Proc. SPIE, Vol. 7732, 77320R (29/07/2010)

[44] Lamy P., Vives S., Curdt W., Dame L., Davila J., Defise J. M., Fineschi S., Heinzel P., Kuzin S., Schmutz W., Tsinganos K., Turck-Chieze S., Zhukov A.
Towards a new formation flying solar coronagraph
In: Proceedings of the 9th International Conference of the Hellenic Astronomical Society, K. Tsinganos, D. Hatzidimitriou, and T. Matsakos (eds.), San Francisco: Astronomical Society of the Pacific, vol. 424, pp. 15–18 (2010)

[45] Lamy P., Damé L., Vivès S., Zhukov A.
ASPIICS: a giant coronagraph for the ESA/PROBA-3 formation flying mission
In: Space Telescopes and Instrumentation 2010: Optical, Infrared, and Millimeter Wave. Edited by Oschmann, Jacobus M., Jr.; Clampin, Mark C.; MacEwen, Howard A. Proc. SPIE, Vol. 7731, pp. 773118–773118-12 (2010), doi:10.1117/12.858247.

[46] Ihde J., Bruyninx C., Söhne W., and Weber G.
Evolution of the EPN resources toward real-time GNSS

Proc. Int. Symp. on GNSS, Space-Based and Ground-Based Augmentation Systems and Applications, Berlin, 30 Nov-2 Dec 2009, Germany, pp 44-45

[47] L. Jalabert, T. Sato, M. Kumemura, D. Bolsee, C. Hermans, A. BenMoussa, H. Fujita
Embedding vertical nanosheets into PDMS with a reusable template engineering
Proc. 23rd IEEE International Conference on Micro Electro Mechanical Systems (MEMS 2010), Hong-Kong pp 384-387 ISSN 1084-6999 (24-28/01/2010)

[48] Sharma S. and Defraigne P.
New Time scale algorithm at the Royal Observatory of Belgium
in: Proc. EFTF, CD-rom, 2010

[49] SIDC team
Provisional sunspot numbers, Monthly solar indices, Monthly Summary of Solar and Geomagnetic activity
SIDC sunspot bulletin (12 monthly issues)

[50] SIDC team
Definitive sunpot numbers
SIDC-News (4 quarterly issues)

[51] SIDC RWC Belgium
Daily bulletin on Solar and Geomagnetic activity
http://www.sidc.be/products/meu/index.php

[52] SIDC RWC Belgium
Weekly bulletin on Solar and Geomagnetic activity
http://www.sidc.be/products/bul/index.php

[53] SIDC RWC Belgium
Monthly Bulletin on Solar and Geomagnetic activity
http://www.sidc.be/products/mobu/index.php

[54] A. Soltani, A. Talbi, V. Mortet, A. BenMoussa, W.J. Zhang, J-C Gerbedoen, J-C De Jaeger, A. Gokarna and K. Haenen
Diamond and Cubic Boron Nitride: Properties, Growth and Applications
Proceedings of the E-MRS Symposium* F*, Volume 1292, Issue 1 pp. 191-196 (Nov 2010)

[55] Spits J., Warnant R.
Total Electron Content monitoring using triple frequency GNSS: Results with GIOVE-A/-B data
In P. Doherty, M. Hernandez-Pajares, J.-M. Juan, J. Sanz, A. Aragon-Angel (Eds.), The International Beacon Satellite Symposium 2010, June 7-11 2010, Barcelona, Spain, 2010

[56] Stankov S, Stegen S., Wautelet G., Warnant R.
On the local operational geomagnetic index K calculation
Geophysical Research Abstracts, 12, Abs. No EGU2010-7228 (Proc. EGU General Assembly 2010, Vienna, 02-07 May 2010

[57] Stankov S., Stegen K., Warnant R.
A statistical study of the TEC storm-time response at European middle latitudes for use in ionospheric nowcast and forecast
In P. Doherty, M. Hernandez-Pajares, J.-M. Juan, J. Sanz, A. Aragon-Angel (Eds.), The International Beacon Satellite Symposium 2010, June 7-11 2010, Barcelona, Spain, 2010

[58] Wautelet G., Lejeune S., Warnant R.
Monitoring the ionospheric positioning error with a GNSS dense network

Geophysical Research Abstracts, 12, Abs. No EGU2010-4791 (Proc. EGU General Assembly 2010, Vienna, 02-07 May 2010.

[59] Wautelet G., Lejeune S., Stankov S., Aquino M., Warnant R.
Understanding the occurrence of mid-latitude ionospheric irregularities by using GPS, ionosonde and geomagnetic measurements
In P. Doherty, M. Hernandez-Pajares, J.-M. Juan, J. Sanz, A. Aragon-Angel (Eds.), The International Beacon Satellite Symposium 2010, June 7-11 2010, Barcelona, Spain, 2010

3. Publications in press, submitted

But not yet accepted

[60] Aerts W., Baire Q., Bergeot N., Bruyninx C., Burston R., Chevalier J.-M., Defraigne P., Legrand J., Pottiaux E., and Roosbeek F.
EUREF Annual Report
Proc. of Symposium of the IAG Subcommission for Europe (EUREF), May-June 2010, Gävle, Sweden, in press

[61] Baire Q., Bergeot N., Bruyninx C., Defraigne P., Legrand J., Pottiaux E., Roosbeek F., and Voet P.,
National report of Belgium
Proceedings of the EUREF Symposium 2009, 26-30 August 2009, Florence, Italy, in press

[62] Baire Q., Bruyninx C., Defraigne P., and Legrand J.
Precise Point Positioning with Atomium using IGS Orbit and Clock Products: First Results,
Accepted to Bulletin of Geodesy and Geomatics, May 2010.

[63] Bergeot N., Bruyninx C., Legrand J., Pottiaux E., Roosbeek F., and Voet P.
National Report of Belgium
Proc. of Symposium of the IAG Subcommission for Europe (EUREF), July 2008, Brussels, in press

[64] Bergeot N., Bruyninx C., Pireaux S., Defraigne P., Legrand J., Baire Q., and Pottiaux E.
Using the EUREF Permanent Network to monitor the ionosphere
Proceedings of the EUREF Symposium 2009, 26-30 August 2009, Florence, Italy, in press

[65] Bergeot N., Bruyninx C., Pottiaux E., Pireaux S., Defraigne P., and Legrand J.
Detection of abnormal ionospheric activity from the EPN and impact on kinematic GPS positioning
Proceedings EUREF 2008 Symposium, June 2008, Brussels, Belgium.

[66] Bruyninx C., Aerts W., and Legrand J.
GPS Data Acquisition and Analysis
Encyclopedia of Solid Earth Geophysics, Springer, in press

[67] Bruyninx C., Baire Q., Legrand J. and Aerts W.

The EPN Infrastructure: Status, Monitoring and Plans
Proc. of Symposium of the IAG Subcommission for Europe (EUREF), June 2010, Gävle, in press

[68] Bruyninx C., Habrich H., Söhne W., Kenyeres A., Stangl G., and Völksen C.
Enhancement of the EUREF Permanent Network Services and Products
"Geodesy for Planet Earth", IAG Symposia Series, in press

[69] Bruyninx C., Legrand J., and Roosbeek F.
Status and Performance of the EUREF Permanent Tracking Network
Proc. of Symposium of the IAG Subcommission for Europe (EUREF), June 2008, Brussels, Belgium, in press

[70] Chevalier J.-M., Bruyninx C., Legrand J., Bergeot N., and Burston R.
Sounding the Atmosphere: Improvement of the Ray Geometry Using Dense European GNSS Networks and Multi-GNSS Signals
Proc. of Symposium of the IAG Subcommission for Europe (EUREF), May-June 2010, Gävle, Sweden, in press

[71] Clette, F.
Past and future sunspot indices: New goals for SoTerIA
Journal of Atmospheric and Solar-Terrestrial Physics, Volume 73, Issue 2-3, 2011, in press.

[72] Defraigne P. and Baire Q.
Combining GPS and GLONASS for Time and Frequency Transfer,
Journal of Advances in Space Research, accepted (June 2010), doi: 10.1016/j.asr.2010.07.003.

[73] J. De Keyser,
Least squares gradient calculation for moving structures,
Submitted to Annales Geophysicae, 2011.

[74] L. Dolla, A. N. Zhukov
On the nature of the spectral line broadening in solar coronal dimmings
Astrophysical Journal, 730, 113 (14pp), 2011

[75] H. Lamy, S. Ranvier, J. De Keyser, S. Calders, E. Gamby, and C. Verbeeck,
BRAMS, the Belgian RAdio Meteor Stations,
Proceedings of the Meteoroids 2010 conference, 2010, submitted.

[76] Lejeune S., Wautelet G., Warnant R. (2011)
Ionospheric effects on relative positioning within GPS dense network
GPS Solutions, doi:10.1007/s10291-011-0212-1, in press.

[77] P. E. Malinowski, J-Y Duboz, P. De Moor, J. John, K. Minoglou, P. Srivastava, Y. Creten, T. Torfs, J. Putzeys, H. Osman, F. Semond, E. Frayssinet, B. Giordanengo, A. BenMoussa, J-F Hochedez, C. Van Hoof, R. Mertens
10 µm pixel-to-pixel pitch hybrid backside illuminated AlGaN-on-Si imagers for solar blind EUV radiation detection
Submitted to IEEE International Electron Devices

[78] M. Mierla, I. Chifu, B. Inhester, L. Rodriguez, A. N. Zhukov
Low polarised emission from the core of the 31 August 2007 CME
Astron. Astrophys. 530, L1, 2011

[79] M. Mierla, B. Inhester, L. Rodriguez, S. Gissot, A. N. Zhukov, N. Srivastava
On 3D reconstruction of coronal mass ejections: II. Longitudinal and latitudinal width analysis of 31 August 2007 event
J. Atmos. Sol.-Terr. Phys. (in press 2010)

[80] R. Miteva, H. Önel, J. Magdalenic, C. Marqué
Particle acceleration at shock waves in the solar corona and interplanetary space
Solar Physics (Submitted in 2010)

[81] O. Podladchikova, A. Vuets, P. Leontiev, R. A. M. Van der Linden,
Recent Developments of NEMO: Detection of Solar Eruptions Characteristics,
submitted to Solar Physics

[82] O. Podladchikova,
Three-Dimensional Structure Evolution of an EUV Wave,
submitted to Astrophys Journal

[83] Pottiaux E.
GNSS Near Real-Time Zenith Path Delay Estimations at ROB: Methodology and Quality Monitoring
Bulletin of Geodesy and Geomatics, in press

[84] Pottiaux E.
Detecting Small-Scale Tropospheric Phenomena Using GNSS Observations from Dense National Networks
Proceedings of the EUREF Symposium 2008, 17-20 June 2008, Brussels, Belgium, in press

[85] S. Ranvier, V. Rochus, S. Druart, H. Lamy, P. Rochus, L. Francis,
A MEMS-based Xylophone Bar Magnetometer for pico satellites
Acta Astronautica.

[86] L. Rodriguez, M. Mierla, A. N. Zhukov, M. West, E. Kilpua
Linking remote-sensing and in situ observations of coronal mass ejections using STEREO
Solar Physics (submitted 2010)

[87] D. B. Seaton, M. Mierla, D. Berghmans, A. N. Zhukov, L. Dolla
SWAP–SECCHI observations of a mass-loading type solar eruption
Astrophysical Journal, 727, L10 (5pp), 2011

[88] Stankov S., Stegen K., Warnant R.
Geomagnetic activity index K nowcast with data quality control
Annals of Geophysics, accepted.

[89] Y. Stockman, A. BenMoussa, I. Dammasch, J.-M. Defise, M. Dominique, J.-P Halain, J.-F. Hochedez, S. Koller, W. Schmutz, U. Schühle
In-flight performance of the solar UV radiometer LYRA / PROBA-2
International Conference on Space Optics, ICSO 2010, Rhodes, Greece (4-8/10/2010)

[90] Voet P., Bergeot N., Bruyninx C., Legrand J., Pottiaux E., and Roosbeek F.
National Report of Belgium,
Proceedings of the EUREF Symposium 2008, 17-20 June 2008, Brussels, Belgium, in press

[91] M. West, A. N. Zhukov, L. Dolla, L. Rodriguez
Coronal seismology using EIT waves: estimation of the coronal magnetic field strength in the quiet Sun
Astrophysical Journal, 730, 122 (10pp), 2011

[92] A. N. Zhukov
EIT wave observations and modeling in the STEREO era
J. Atmos. Sol.-Terr. Phys. (in press 2010)

[93] A. N. Zhukov, M. West, L. Rodriguez, I. S. Veselovsky
Bimodal physical nature of EIT waves in the solar corona

Astron. Astrophys. (submitted 2010)

4. Reports, Thesis, etc

[94] A. BenMoussa
EUI PRODEX proposal (version 6.1 and 6.2)
PRODEX EUI PEA Report

[95] A. BenMoussa
ROB Detailed Work Package Descriptions
EUI project document

[96] A. BenMoussa
EUI_MonthlyProgressReport_ROB_Jan-Mar_2010
EUI project document

[97] A. BenMoussa
EUI_MonthlyProgressReport_ROB_April-May_2010
EUI project document

[98] A. BenMoussa
Minutes of EUI Monthly Telecon January 2010
EUI project document

[99] A. BenMoussa
Minutes of EUI Electronics meeting at ROB 25/02/2010
EUI project document

[100] A. BenMoussa and S. Gissot
EUI On-board Compression System project – EOCS2 (Statement of Work)
EUI project document

[101] A. BenMoussa and B. Giordanengo
BOLD TN4: BOLD Calibration Plan
BOLD project document

[102] A. BenMoussa
Contribution to the ESIO UV flux monitor
ESIO project document

[103] A. BenMoussa
ETRI-ROB agreement collaboration
K-Star project document

[104] A. BenMoussa
K-Star UV flux monitor
K-Star project document

[105] A. BenMoussa, D. Berghmans, S. Gissot and B. Nicula
Science data requirement – impact on the FEE-CEB design
EUI project document

[106] A. BenMoussa
EUI detector calibration test plan
EUI project document

[107] A. BenMoussa

EUI detector radiation test plan
EUI project document

[108] A. BenMoussa and J-P Halain
EUI Test and calibration planning
EUI project document

[109] A. BenMoussa and A. Gottwald
PTB-ROB agreement collaboration
EUI project document

[110] A. BenMoussa and X. Zhang
EUI multilayer filters calibration plan
EUI project document

[111] Bruyninx C., Legrand J., Bergeot N., Baire Q., Defraigne P., and Aerts W.
User Requirements – Precise Positioning, Position Change and Time Transfer
Requirements document for FP7project SX5

[112] Dehant V. et al., among them C. Bruyninx, N. Bergeot, E. Pottiaux, P. Rosenblatt, M. Mitrovic, Ö. Karatekin, R. Van der Linden, A. Zhukov, E. Podladchikova, L. Rodriguez
Atmospheric, ionospheric, and interplanetary plasma propagation corrections on Earth-Mars RAdio Link (EMRAL)
Proposal in response to FP7-SPACE-2010-1 and SPA.2010.2.1-03 ‘Exploitation of science and exploration data’, Collaborative project, 97 pages.

[113] Dehant V. et al., among them P. Rosenblatt, M. Mitrovic, S. Le Maistre, R. Van der Linden, A. Zhukov, E. Podladchikova, L. Rodriguez
Propagation corrections of spacecraft Radio links for improving planetary Ephemerides (EPRORAD)
Proposal in response to FP7-SPACE-2011-1 and SPA.2011.2.1-01 ‘Exploitation of science and exploration data’, Collaborative project, 74 pages.

[114] V. Delouille, S. Gissot, D. Berghmans, B. Nicula and A. BenMoussa
EUI Science Algorithm WG preliminary report
EUI project document

[115] J-P Halain, A. BenMoussa and the EUI Team
EUI EID-B
EUI project document

[116] J-P Halain, A. BenMoussa et al. (EUI Team)
EUI Management Plan
EUI project document

[117] Hernandez et al., among them N. Bergeot and P. Defraigne
Ionospheric Delay Corrections in GNSS Signals for High Precision Applications
Proposal in response to ESA ITT ESA ITT AO/1-6311/2010/F/WE.

[118] P. E. Malinowski, A. BenMoussa et al. (BOLD Team)
BOLD TN7: Characterization Test results
BOLD project document

[119] A. Mekaoui, A. BenMoussa, K. Hamrouni and W. Fradi
Characterization of the extreme ultraviolet imager onboard the SWAP Telescope
Thesis from ESPRIT (Ecole Superieure Privee d’Ingenierie et de Technologies) Tunisian republic

[120] Pottiaux E.

Sounding the Earth's Atmospheric Water Vapour Using Signals Emmitted by Global Navigation Satellite Systems
Ph.D. thesis published at the Université Catholique de Louvain, June 2010

[121] Pottiaux E., Bruyninx C., and Defraigne P.
E-GVAP Management Report 2010
ROB Internal publication

[122] Stankov S., Stegen K., Warnant R.
Local Operational Geomagnetic Index K Calculation (K-LOGIC) from digital ground-based magnetic measurements
Technical Report, Solar-Terrestrial Centre of Excellence, Royal Meteorological Institute of Belgium.

[123] Stankov S., Stegen K., Warnant R.
RMI-Dourbes ionosonde database – Status 2010
Technical Report, Solar-Terrestrial Centre of Excellence, Royal Meteorological Institute of Belgium.

[124] R. Van der Linden and the SIDC team.
Annual report 2010 to the International Space Environment Service.
ISES Annual Report

[125] P. Vanlommel and the PC esww6
The sixth European Space Weather Week: the final result
Work report, published in SWEN, 14 pages

[126] Warnant R., Bidaine B., Brenot H., Lejeune S., Stankov S., Stegen K., Spits J., Wautelet G.
SIDC Telescience
PRODEX project performance report, contract C90317

5. Meeting presentations

[127] Aerts W., Baire Q., Bergeot N., Bruyninx C., Burston R., Chevalier J.-M., Defraigne P., Legrand J., Pottiaux E., and Roosbeek F.
EUREF Annual Report
Symposium of the IAG Subcommission for Europe (EUREF), 02-05 June 2010, Gävle, Sweden

[128] Aerts W., Bruyninx C., and Defraigne P.
Bandwidth and Sample Frequency Effects in GPS Receiver Correlator
NAVITEC 2010, December 8-10, 2010, Noordwijk, Nederlands

[129] E. Baudrez, I. Decoster, N. Clerbaux, P.-J. Baeck, S. Dewitte, A. Ipe, S. Nevens, A. Velázquez,
Extending TOA Radiation Back to 1978 Using Wide Field-of-View Data
Earth Radiation Budget Workshop 2010, Paris, France, September 13–16, 2010.

[130] E. Baudrez, I. Decoster, N. Clerbaux, P.-J. Baeck, S. Dewitte, A. Ipe, S. Nevens, A. Velázquez,
Extending TOA Radiation Back to 1978 Using Wide Field-of-View and Geostationary Data
Third CM-SAF User Workshop, Rostock, Germany, September 6–8, 2010.

[131] A. BenMoussa
LYRA onboard PROBA2
SBDDXV cultuurcentrum Hasselt (Cultural Centre), Hasselt, Belgium, 22-24/02/2010

[132] A. BenMoussa, A. Soltani and J-C De Jaeger
Developments of wide-bandgap semiconductor photodetectors for space applications

The 37th International Symposium on Compound Semiconductors – ISCS – Kagawa, Japan, 31/05 – 04/06/ 2010

[133] A. BenMoussa (invited talk)
Space Weather monitoring at the Royal Observatory of Belgium – introduction to EUI
International Conference on Space Environment, Jeju, Korea, 13-15/10/2010

[134] A. BenMoussa
ROB contribution to BOLD activities
BOLD progress meeting at IMEC (B) - 05/02/2010

[135] A. BenMoussa
EUI Detector activities
EUI Electronics meeting at ROB - 25/02/2010

[136] A. BenMoussa
ROB contribution to UV detectors development
ROB-LPC2E meeting at ROB – 18-19/03/2010

[137] A. BenMoussa
EUI on Solar Orbiter and its detector
3rd Consortium meeting at MPS – 25-26/04/2010

[138] A. BenMoussa
Advanced technologies for solar observations
K-star meeting at ROB – 21/06/2010

[139] A. BenMoussa
Current APS implementation
EUI Electronics WG meeting at ROB - 22/11/2010

[140] A. BenMoussa
EUI/Solar Orbiter updates
BOLD progress meeting at IMEC (B) - 05/02/2010

[141] A. BenMoussa
ROB EUI activities updates
EUI internal meeting at ROB – 09/02/2010

[142] A. BenMoussa
ROB EUI activities updates
EUI internal meeting at ROB – 31/03/2010

[143] A. BenMoussa
EUI ROB activities
3rd Consortium meeting at MPS – 25-26/04/2010

[144] A. BenMoussa
3rd EUI consortium meeting – Debriefing
EUI ROB internal meeting at ROB – 05/06/2010

[145] A. BenMoussa
ROB EUI activities updates
EUI ROB internal meeting at ROB – 30/06/2010

[146] A. BenMoussa
EUI onboard compression system EOCS2 project
EUI Compression WG meeting at ROB - 04/10/2010

[147] Bergeot, N.; Legrand, J.; Burston, R.; Bruyninx, C.; Defraigne, P.; Chevalier, J.; Clette, F.; Marqué, C.; Lefevre, L.
Correlation between solar activity and Earth's ionospheric electron content during the 23rd solar cycle
Session SA33B "Response of the Atmosphere and Ionosphere to Solar Extreme Ultraviolet Variability", American Geophysical Union, Fall Meeting 2010, Poster-abstract #SA33B-1774, 12/2010

[148] Bergeot N., Burston R., Legrand J., Chevalier J.-M., Bruyninx C., Defraigne P., Baire Q., and Pottiaux E.
TEC Variations and Ionospheric Disturbances over Europe during the August 2010 Storm Event
Seventh European Space Weather Week, 15-19 November 2010, Brugge, Belgium

[149] Bergeot N., Bruyninx C., Aerts W., Lombardi D., Camelbeeck T., Van Camp M., Legrand J., and Moyaert A.
Installation of a GPS station at the Princess Elisabeth base to monitor crustal motions due to ice mass variations
Belgian IPY Symposium, 26 May 2010, Brussels, Belgium

[150] Bergeot N., Legrand J., Burston R., Bruyninx C., Defraigne P., Chevalier J.-M., Clette F., Marque C., and Lefevre L.
Correlation Between Solar Activity and Earth's Ionospheric Electron Content During the 23rd Solar Cycle
AGU Fall Meeting 2010, 12-17/12/2010, San Francisco, USA

[151] D. Berghmans
Tracking Solar Activity with Online Facilities
International Advanced School on Space Weather Modelling and Applications, Trieste, Italy, 18-29 October, 2010

[152] Bruyninx C., Baire Q., Legrand J. and Aerts W.
The EPN Infrastructure: Status, Monitoring and Plans
Symposium of the IAG Subcommission for Europe (EUREF), May-June 2010, Gävle, Sweden

[153] Bruyninx C., Baire Q., Legrand J., and Pottiaux E.
Efforts Towards an Improved Long-term Monitoring of the EUREF Permanent Network
IGS Analysis Workshop and Vertical Rates Symposium, 28 June – 02 July 2010, Newcastle, UK

[154] Bruyninx C., Habrich H., Kenyeres A., Söhne W., Stangl G., and Völksen C.
The EUREF Permanent Network and its GNSS-based Services and Products as a European Standard
IGS Analysis Workshop and Vertical Rates Symposium, 28 June – 02 July, 2010, Newcastle, UK

[155] Bruyninx C., Baire Q., Legrand J., Aerts W., and Pottiaux E.
Modernization of the EPN tracking network and introduction of IRTF2008/IGS08
EPN LAC Workshop 2010, 18-19 November 2010, Warsaw, Poland

[156] Bruyninx C.
Maintenance of the ETRS89 using EUREF's Permanent GNSS Service
International Symposium, on GNSS, Space-Based and Ground-Based Augmentation Systems and Applications, 29-30 November 2010, Brussels, Belgium

[157] Burston R., Hodges K., Astin I., Bergeot N., Chevalier J.-M., and Bruyninx C.
Combining Ionospheric Imaging with Feature Tracking to Automate Identification and Tracking of Polar-cap Plasma Patches
Space Weather Workshop 2010, 27-30 April 2010, Boulder, US

[158] Burston R., Bergeot N., Bruyninx C., and Chevalier J.-M.

A Two-stage Mid-latitude Instability Process: Gradient-drift and Kelvin-Helmholtz Waves?
Beacon Satellite Symposium 2010, 07-11 June 2010, Barcelona, Spain

[159] B. Callebaut, D. Berghmans
SoDA: The Soteria Data Archive
ESWW7, 2010-11-18, Brugge

[160] B.Callebaut, D. Berghmans
SoDA: The Soteria Data Archive
Second Soteria Annual Meeting, 2010-10-6, Debrecen

[161] Chevalier J.-M., Bruyninx C., Legrand J., Bergeot N., and Burston, R.
Sounding the Atmosphere: Improvement of the Ray Geometry Using Dense European GNSS Networks and Multi-GNSS Signals
Symposium of the IAG Subcommission for Europe (EUREF), May-June 2010, Gävle, Sweden

[162] Chevalier J.-M., Bruyninx C., Legrand J., Bergeot N., and Burston R.
Impact of Dense GNSS Networks and Multi-GNSS on Trans-ionospheric Ray Path Distribution for Tomographic Applications
Beacon Satellite Symposium 2010, 07-11 June 2010, Barcelona, Spain

[163] Chevalier J.-M., Bruyninx C., Legrand J., Bergeot N., and Burston R.
Assessing the added-value of dense GNSS networks and multi-GNSS observations for tomographic applications
EGU, May 2010, Vienna, Austria, Geophysical Research Abstracts, Vol. 12, EGU2010-10538)

[164] Chevalier J.-M., Benoit L., Bergeot N., Bruyninx C., Legrand J., Burston R., Defraigne P., Pottiaux E., and Baire Q.
Near Real Time GPS-Based Ionospheric Models: Application to Belgium
AGU Fall Meeting 2010, 12-17 December 2010, San Francisco, USA

[165] Cid C., Aran A., Cerrato Y., Chandra R., Cremades H., Dasso S., Jacobs C., Lathuillere C., Mandrini C., Menvielle M., Poedts S., Rodriguez L., Saiz E., Sanahuja B., Schmieder B., Zhukov A. N. and Aguado J.
Could a full-halo CME coming from the limb be geoeffective? (oral presentation)
SCOSTEP's Symposium STP12, Berlin, Germany, July 12–16

[166] F. Darrouzet, J. De Keyser, and V. Pierrard,
Plasma density profiles in the plasmasphere for space weather applications.
European Space Weather Week 7, Bruges, Belgium, 15-19 November 2010.

[167] V. De Bock, H. De Backer, A. Mangold, and A. Delcloo
Aerosol Optical Depth measurements at 340 nm with a Brewer spectrophotometer and comparison with Cimel sunphotometer observations at Uccle, Belgium
3rd MeteoClim PhD Symposium on Meteorology and Climatology, Uccle, Belgium, November 5, 2010

[168] Defraigne P., Petit G., Uhrich P., Aerts W.
Requirements on GNSS receivers from the perspective of timing applications
EFTF, 12-16 April 2010, Noordwijk, Netherlands

[169] Defraigne P.
Galileo Time Service Provider, Architecture and Operations
Meeting of the Galileo Timing Interface Working Group, 11-12 November 2010, Torino, Italy

[170] Defraigne P., Martinez M.C., Mudrak A., Binda S.
Galileo Common View: format, processing and tests with GIOV"

Precise Time and Time Interval, 15-18 November 2010, Washington, USA

[171] Defraigne P., Baire Q., Harmegnies A.
Time and frequency transfer combining GLONASS and GPS data
Precise Time and Time Interval, 15-18 November 2010, Washington, USA

[172] J. De Keyser.
Multi-spacecraft gradient techniques: Applicability for studying magnetosphere-ionosphere coupling.
19th Cluster workshop, Poiana-Brasov, Romania, 18-21 May 2010. (Invited)

[173] J. De Keyser, R. Maggiolo, and M. Roth.
Magnetopause reconstruction techniques.
Workshop on magnetospheric processes, Toulouse, France, 8-10 June 2010.

[174] J. De Keyser, R. Maggiolo, and F. Darrouzet,
Why are we still working on multi-spacecraft methods 10 years into the Cluster mission?, Understanding the solar wind – magnetosphere interaction at multiple scales with Cluster, THEMIS, and Double Star,
Cluster 10th Anniversary Workshop, Corfu, Greece, 27 Sep – 1 Oct 2010. (Invited)

[175] J. De Keyser, R. Maggiolo, and M. Echim.
Monopolar and bipolar auroral electric fields and their ionospheric signature.
19th Cluster workshop, Poiana-Brasov, Romania, 18-21 May 2010.

[176] J. De Keyser, R. Maggiolo, and M. Echim,
Monopolar and bipolar auroral electric fields, Understanding the solar wind--magnetosphere interaction at multiple scales with Cluster, THEMIS, and Double Star,
Cluster 10th Anniversary Workshop, Corfu, Greece, 27 Sep – 1 Oct 2010.

[177] Dolla L., Zhukov A. N.
On the nature of the spectral line broadening in solar coronal dimmings (oral presentation)
COSPAR 38th Scientific Assembly, Bremen, Germany, July 18–25

[178] Dolla L., Zhukov A. N.
On the nature of the spectral line broadening in solar coronal dimmings (oral presentation)
Solar Plasma Spectroscopy: Achievements and Future Challenges, September 13–15, Cambridge, United Kingdom

[179] Dolla L., Zhukov A. N.
On the nature of the spectral line broadening in solar coronal dimmings (poster)
Hinode 4: unsolved problems and recent insights, October 11–15, Mondello, Italy

[180] M. Dominique and A. BenMoussa
Lyra new Technology and Status
PROBA-2 worshop, ESTEC NL, 22/06/2010

[181] M. Dominique, D. Berghmans, M. Kruglanski, L. Dolla, E. De Donder, A. BenMoussa and W. Schumtz
Impact of the particle environment on SWAP and LYRA data
European space weather week (ESWW7), Bruges, B, 16-20/11/2010

[182] M. Echim, R. Maggiolo, J. De Keyser, M. Roth.
Advances in modeling and understanding in-situ observations and coupling of the magnetosphere and the auroral ionosphere during Cluster-DMSP conjunctions.
19th Cluster workshop, Poiana-Brasov, Romania, 18-21 May 2010.

[183] M. Echim, J. De Keyser, and R. Maggiolo,

Magnetospheric interfaces/generators with convergent and divergent electric fields at auroral latitudes: modeling and experimental evidence.
38th COSPAR Scientific Assembly, Bremen, Germany, 18 – 25 July 2010.

[184] M. Echim, R. Maggiolo, J. De Keyser, F. Darrouzet, S. Wing, and J. Johnson,
Multiscale coupling between a solar wind driven magnetospheric generator and dayside aurora,
AGU Meeting of the Americas, Iguaçu Falls, Brazil, 8 – 12 August 2010.

[185] R. Endeer, L. Apland & S. Claus
What about the salmon?
Presented at 2010 Inside Joke Conference, 13-17 December 2010.

[186] S. Gissot G. Rouvroy and A. BenMoussa
Preliminary design of the Extreme Ultraviolet Imager compression system on-board the Solar Orbiter mission
2nd Int. Workshop on On-Board Payload Data Compression-OBPDC, Toulouse, CNES, France, 28-29/10/2010

[187] H. Gunell, J. De Keyser, and E. Gamby,
Magnetic field aligned potential drops in the magnetosphere, in the laboratory, and in Vlasov simulations,
EGU General Assembly, Vienna, Austria, 2-7 May, 2010.

[188] Habrich H., Altiner Y., Bruyninx C., Ihde J., Mervart L., Söhne W., and Weber G.
Development of the EUREF GNSS services and reference networks
United Nations/Moldova/United States of America Workshop on the Applications of Global Navigation Satellite Systems, May 17-21 2010, Chisinau, Moldova

[189] H. Lamy and S. Ranvier
BRAMS, a meteor radio receiving station
Poster and Fair stand, European Space Weather Week 6, Bruges, November 17, 2010

[190] H. Lamy, S. Ranvier, J. De Keyser, S. Calders and E. Gamby,
"BRAMS: the Belgian RAdio Meteor Stations",
poster displayed at the Meteoroids 2010 conference in Breckenridge, Colorado, USA, 24-28 May 2010.

[191] H. Lamy, S. Ranvier, J. De Keyser, S. Calders and E. Gamby,
BRAMS, the Belgian RAdio Meteor Stations, a Pro-Am collaboration,
JENAM 2010 Conference, SPS8 session "Amateurs and professional astronomers", Lisbon, Portugal, 06-10 September 2010. (Invited)

[192] H. Lamy, S. Ranvier, J. De Keyser, S. Calders and E. Gamby,
BRAMS, the Belgian RAdio Meteor Stations, a Pro-Am collaboration,
International Meteor Conference, Armagh, Ireland, 16-19 September 2010.

[193] H. Lamy, C. Simon, M. Echim, J. De Keyser, B. Gustavsson, T. Sergienko, U. Brandström, I. Sandahl,
Characterizing magnetospheric electrons from ALIS observations of discrete auroral arcs and quasi-stationary modeling of auroral acceleration.
AGU Fall Meeting, San Francisco, CA, USA, 13-17 December 2010.

[194] Lamy P., Damé L., Curdt W., Davila J., Defise J. M., Fineschi S., Heinzel P., Howard R., Kuzin S., Schmutz W., Tsinganos K., Turck-Chièze S., Zhukov A.
ASPIICS / PROBA-3: a formation flying externally-occulted giant coronagraph mission (poster)
COSPAR 38th Scientific Assembly, Bremen, Germany, July 18–25

[195] J. A. Logan, J. Staehelin, J.-P. Cammas, V. Thouret, H. Claude, H. De Backer, C. Hueglin, H. E. Scheel, R. Stübi, and R. Derwent
Long-term changes in ozone over Europe since the early 1990s – analysis of ozone measurements from sondes, regular aircraft (MOZAIC) and alpine surface sites
11th Science Conference of the International Global Atmosphere Chemistry (IGAC) Project, Halifax, Canada, July 11-16, 2010

[196] Lombardi D., Bergeot N., Bruyninx C.,Camelbeeck T., Francis O., Rapagnani G., Van Camp M., and van Dam T.
Installation and preliminary data analysis of a permanent geodetic and seismic station at the new Belgian Princess Elisabeth Station in East Antarctica
International Polar Year Oslo Science Conference, 8-12 June 2010, Oslo, Norway

[197] W. Maenhaut, W. Wang, X. Chi, N. Raes, J. Cafmeyer, A. Cheymol, A. Delcloo, V. De Bock, and H. De Backer
Measurements on Atmospheric Aerosols and of the Aerosol Optical Depth during 2006 at Uccle, Belgium
11th Science Conference of the International Global Atmosphere Chemistry (IGAC) Project, Halifax, Canada, July 11-16, 2010

[198] J. Magdalenić, C. Marqué, J. –L. Dufond, J. –P. Noël
Solar Radio Observations in Humain
Radio Science Days, ROB, Brussels (Belgium), October 14th 2010

[199] Magdalenić J., Marqué C., Zhukov A. N., Berghmans D., Seaton D. B., Dammasch I., D'Huys E.
Type II burst recorded at Humain associated with the CME/flare event on 18 March 2010 (oral presentation)
CESRA 2010 meeting, La Roche-en-Ardenne, Belgium, June 13–19

[200] Magdalenić J., Marqué C., Zhukov A. N., Veronig A., Vršnak B.
Flare-generated coronal shock on 14 November 2005 (oral presentation)
COSPAR 38th Scientific Assembly, Bremen, Germany, July 18–25

[201] C. Marqué, J. –L. Dufond, A. Ergen, J. Magdalenić, J. –P. Noël
Solar radio observations in Belgium (Poster)
2010 CESRA Meeting, La Roche en Ardenne (Belgium), June 15th-19th 2010

[202] C. Marqué, in name of CRAF
Protecting the access to the radio sky: an overview of CRAF activities (Poster)
2010 CESRA Meeting, La Roche en Ardenne (Belgium), June 15th-19th 2010

[203] C. Marqué
Radio Spectrographic observations in Belgium
4th LOFAR Solar KSP workshop, Postdam (Germany), November 8th-9th 2010

[204] Mierla M., Inhester B., Rodriguez L., Zhukov A. N., Srivastava N. and Gissot S.
On 3D reconstruction of coronal mass ejections: Study of 31 August 2007 event (oral presentation)
STEREO Science Working Group 21, Dublin, Ireland, March 22–26

[205] Mierla M., Rodriguez L., Berghmans D., Besliu-Ionescu D., Chifu I., Dammasch I., de Groof A., Demetrescu C., Dobrica V., Gissot S., Hochedez J.-F., Inhester B., Magdalenic J., Maris G., Nitoiu D., Seaton D., Srivastava N., West M. and Zhukov A. N.
Multispacecraft observations of 3 and 8 April 2010 Coronal Mass Ejections (poster)
CESRA 2010 meeting, La Roche-en-Ardenne, Belgium, June 15–19

[206] Mierla M., Rodriguez L., Berghmans D., Besliu-Ionescu D., Chifu I., Dammasch I., de Groof A., Demetrescu C., Dobrica V., Gissot S., Hochedez J.-F., Inhester B., Magdalenic J., Maris G., Nitoiu D., Seaton D., Srivastava N., West M. J. and Zhukov A. N.
Multispacecraft observations of 3 and 8 April 2010 Coronal Mass Ejections (oral presentation)
European Space Weather Week 7, Brugge, Belgium, November 15–19

[207] P. M. Miller, M. E. Koepke, and H. Gunell,
Experimental verification of dynamics modulation in a periodically-driven neon glow discharge plasma,
52nd Annual Meeting of the APS Division of Plasma Physics, Chicago, Illinois, 8-12 November, 2010.

[208] O.Podladchikova
Three-Dimensional Structure of an EUV Wave
Isradynamics 2010, Israel, Dead Sea, April 14-20

[209] O. Podladchikova
TwoMethods for Stereoscopic Reconstruction of Diffusive Solar Objects
LPC2E-CNRS, Orleans, France, 28 July, 2010

[210] O. Podladchikova, A. Vourlidas, R.A.M. Van der Linden, J.-P. Wuelser, S. Patsourakos,
EUV Observations and Analysis of Micro-Eruptions and Their Associated Coronal Waves.
CESRA, La Roche en Ardenne, June 14 - 19, 2010, Belgium

[211] O. Podladchikova, A. Vourlidas, R.A.M. Van der Linden, J.-P. Wuelser, S. Patsourakos,
Recent Developments of NEMO: Detection of Solar Eruptions Characteristics
ESWW7, Brugge, November 15 - 19, 2010, Belgium

[212] Pottiaux E., and Bruyninx C.
National Report of Belgium (ROB) to the E-GVAP II Joint Expert Team Meeting 2010
E-GVAP II Joint Expert Teams meeting 2010, 23-24 September 2010, Oslo, Norway

[213] Pottiaux E., Bruyninx C., and Defraigne P.
Sounding the Earth's Atmospheric Water Vapour Using Signals Emitted by Global Navigation Satellite Systems
METEOCLIM Symposium 2010, 5 November 2010, Uccle, Belgium

[214] Pottiaux E., Aerts W., Baire Q., Bergeot N., Bruyninx C., Burston R., Chevalier J.-M., Defraigne P., and Legrand, J.
EPN-related Activities and Research at ROB (LAC)
EPN LAC Workshop 2010, 18-19 November 2010, Warsaw, Poland

[215] Pottiaux E.
Sounding the Earth's Atmospheric Water Vapour Using Signals Emitted by Global Navigation Satellite Systems
Ph.D. private defense, Université Catholique de Louvain (UCL), Louvain-La-Neuve, Belgium

[216] S. Ranvier, V. Rochus, S. Druart, H. Lamy, P. Rochus, L. Francis,
A MEMS-based Xylophone Bar Magnetometer for pico satellites,
talk at the International Astronautics Congress 2010, Prague, Chech Republic, 27 Sep – 1 Oct 2010.

[217] E. Robbrecht and the RWC team
Regional Warning centre Belgium
Space Weather workshop Meudon, Paris, 6-7 Dec 2010

[218] Rodriguez L., Zhukov A. N. and West M. J.
STEREO-B as a space weather monitor at the L5 point: a practical example (oral presentation)

STEREO Science Working Group, Trinity College Dublin, Ireland, March 22–26

[219] Rodriguez L., Zhukov A. N., Mierla M., Kilpua E. and West M. J.
Linking remote-sensing and in situ observations of CMEs observed by STEREO (oral presentation)
COSPAR 38th Scientific Assembly, Bremen, Germany, July 18–25

[220] Rosenblatt P., Nkono C., Dehant V., Zhukov A., Bird M., Le Maistre S., Mitrovic M.
Quantification of solar corona effects on radio-signals using radial electron profiles
MaRS meeting, Bonn, Germany, March 18th 2010.

[221] Schmieder B., Dasso S., Mandrini C., Demoulin P., Zhukov A. N., Aran A., Cerrato Y., Cid C., Cremades H., Menvielle M., Poedts S., Rodriguez L., Saiz E.
Tracking intense geomagnetic storms to the interplanetary medium and solar sources. A case study (oral presentation)
SCOSTEP's Symposium STP12, Berlin, Germany, July 12–16

[222] D. Seaton
Downloading and Handling Solar Data from Satellites
International Advanced School on Space Weather Modelling and Applications, Trieste, Italy, 18-29 October, 2010

[223] Sharma S., Defraigne P.
New Time Scale at the Royal Observatory of Belgium
EFTF, 12-16 April 2010, Noordwijk, Netherlands

[224] Söhne W., Iocovone D., Aerts W., Bruyninx C., Pacione R., and Weber G.
EPN Regional Broadcasters for Real-time GNSS Data Dissemination
EUREF Symposium 2010, June 2-4 2010, Gävle, Sweden

[225] Van der Linden, R., Ben Moussa, A., Berghmans, D., Boulvin, O., Boyes, D., Cabanas Parada, C., Callebaut, B., Clette, F., Dammasch, I., Delouille, V., D'Huys, E., Dolla, L., Dominique, M., Dufond, J.-L., Ergen, A., Giordanengo, B., Gissot, S., Goryaev, F., Hochedez, J.-F., Lemaître, O., Lisnichenko, P., Magdalenic, J., Mampaey, B., Marqué, C., Nicula, B., Podladchikova, E., Pylyser, E., Raynal, S., Rodriguez, L., Seaton, D., Vandersyppe, A., Vanlommel, P., Vanraes, S.,Verbeeck, C., Verdini, A., Wauters, L., West, M., Willems, S., Zhukov, A.
Space Weather data and services at SIDC / RWC Belgium
Symposium PSW, session 1, paper number PSW1-0052-10 (Poster, Nr. Tue-287), 38th COSPAR Scientific Assembly, 18-15 July 2010, Bremen, Germany, p.2, 2010

[226] R. Van der Linden and the RWC team
Regional Warning centre Belgium
COST ES0803 workshop, Paris, March 2010

[227] R.Van der Linden and the RWC/WDC team
Space Weather data and services at SIDC / RWC Belgium
COSPAR, Bremen, Germany, 15-18 July 2010

[228] R.Van der Linden and the RWC/WDC team
ISES meeting
COSPAR, Bremen, Germany, July 2010

[229] P. Vanlommel
August 2010 events
SES-Astra, Betzdorf, Luxemburg, August 18, 2010

[230] P. Vanlommel
Monitoring and Predicting SpW in the Heliosphere: Operational Services - Science & Exercises

International Advanced School on Space Weather Modelling and Applications, Trieste, Italy, 18-29 October, 2010

[231] R. Van Malderen and H. De Backer
A drop in UT humidity in autumn 2001, as derived from radiosonde measurements at Uccle, Belgium
3rd MeteoClim PhD Symposium on Meteorology and Climatology, Uccle, Belgium, November 5, 2010

[232] N. Vermeulen
PICARD-SOVAP: Het ultieme wapen tegen een onzeker klimaat
RMIB newsletter, last trimester 2010.

[233] G. Voitcu and M. Echim,
Test-kinetic simulation of ion energy-dispersed structures and of non-gyrotropic distribution functions formed at the traversal of a plasma interface: two-dimensional solutions.
19th Cluster workshop, Poiana-Brasov, Romania, 18-21 May 2010.

[234] G. Voitcu and M. M. Echim,
Test-kinetic simulation of non-gyrotropic velocity distribution functions for particles injected into a sheared electromagnetic field distribution,
38th COSPAR Scientific Assembly, Bremen, Germany, 18 – 25 July 2010.

[235] Warnant R., Lejeune S., Wautelet G., Spits J., Stegen K., Stankov S.
The RMI Space Weather and Navigation Systems (SWANS) project
Presented at 38th COSPAR Scientific Assembly, Bremen, Germany, 18-25 July 2010.

[236] Wautelet G., Lejeune S., Warnant R.
A GPS/GNSS dense network used to monitor ionospheric positioning error
Presented at 2010 AGU Fall Meeting, 13-17 December 2010.

[237] Wauters L. and the WDC team
Solar sub-cycle (poster)
CESRA, 15-18 juin 2010, La Roche-en-Ardennes

[238] West M. J., Zhukov A. N., Dolla L. and Rodriguez L.
Using EIT waves for coronal seismology (oral presentation)
STEREO Science Working Group, Trinity College Dublin, Ireland, March 22–26

[239] Zhukov A. N.
Solar-terrestrial research and modeling at the STCE (oral presentation)
STCE 2010 meeting, Brussels, Belgium, June 3

[240] Zhukov A. N.
Global coronal mass ejections (oral presentation)
CESRA 2010 meeting, La Roche-en-Ardenne, Belgium, June 15–19

[241] Zhukov A. N., West M. J., Rodriguez L. and Veselovsky I. S.
Bimodal physical nature of EIT waves revealed by STEREO observations (oral presentation)
COSPAR 38th Scientific Assembly, Bremen, Germany, July 18–25

[242] Zhukov A. N.
Solar and interplanetary weather forecasting: Observational and statistical methods (invited presentation)
COSPAR 38th Scientific Assembly, Bremen, Germany, July 18–25

6. Public Presentations

[243] D. Berghmans
PROBA2 – een Belgische missie
PROBA2@school, Vliebergh-Sencie, Leuven, March 24, 2010

[244] K. Bonte, A. DeGroof, E. D'Huys and P. Vanlommel
De Zon, Ruimteweer en PROBA2
Bezoek Middelbare school Dilzen, ROB, November 23, 2010

[245] S. Calders
BRAMS: meteor detection
annual meeting of the "werkgroep radioastronomie" of the VVS, November 2010.

[246] F. Clette
Un Soleil plein d'activité ... pour bientôt ?
January 29, 2010, Société Astronomique de Liège

[247] F. Clette
En connexion directe avec le Soleil: de l'espace jusqu'à … nous tous
August 12, 2010, Euro Space Center, Redu, Nuit des Etoiles

[248] F. Clette
Petite climatologie illustrée du Soleil: un cycle bien peu cyclique
October 15, 2010, Cercle Astronomique de Bruxelles

[249] F.Clette & J. Dekeyser (BISA)
Activité et cycle solaires: causes et conséquences, surveillance et prévision
December 9, 2010, Collège Belgique, Acédémie Royale des Sciences de Belgique

[250] Clette, F.
Our inconstant Sun: Solar Activity and Flares
Solar Novus Today, Electronic journal of the photovoltaïc industry, 23/9/2010 [http://www.solarnovus.com/index.php?option=com_content&view=article&id=1374:our-inconstant-sun-solar-activity-and-flares&catid=38:application-tech-features&Itemid=246]

[251] Clette, F.
Particle Beams: Danger in space
Solar Novus Today, Electronic journal of the photovoltaïc industry, 19/10/2010 [http://www.solarnovus.com/index.php?option=com_content&view=article&id=1524:particle-beams-danger-in-space&catid=38:application-tech-features&Itemid=246]

[252] Clette, F.
Understanding Solar Wind: Consequences on Earth
Solar Novus Today, Electronic journal of the photovoltaïc industry, 16/11/2010 [http://www.solarnovus.com/index.php?option=com_content&view=article&id=1687:understanding-solar-wind-consequences-on-earth&catid=38:application-tech-features&Itemid=246]

[253] Clette, F.
Down to the Ground: Space weather in our daily lives
Solar Novus Today, Electronic journal of the photovoltaïc industry, 9/12/2010 [http://www.solarnovus.com/index.php?option=com_content&view=article&id=1812:down-to-the-ground-space-weather-in-our-daily-lives&catid=38:application-tech-features&Itemid=246]

[254] A. DeGroof
PROBA2: Ontwikkeling, lancering en exploitatie
Werkgroep Aardrijkskunde Brabant, Leuven, September 28, 2010

[255] E. D'Huys
PROBA2: gegevens van SWAP en LYRA
Werkgroep Aardrijkskunde Brabant, Leuven, September 28, 2010

[256] ESA and the PROBA2 team
PROBA2 – the first results
Press Conference, ROB, January 26, 2010

[257] C. Marqué
Lecture on solar radio astronomy in Belgium for Belgian radio amateurs
October 23, 2010. Royal Observatory of Belgium

[258] O. Podladchikova
Recent achievements in solar physics
International Astrophysical Conference, YSC-17, Kiev National University, 27 April-1 May, 2010

[259] O. Podladchikova
Evolution of the solar-type stars
AACIMP-2010, Kiev, Ukraine, 9-20 August, 2010

[260] O. Podladchikova
Tutorial: Sand-piles models for turbulent plasma
AACIMP-2010, Kiev, Ukraine, 9-20 August, 2010

[261] C. Verbeeck and the SDO-team
SDO – the first data
Press Conference, ROB, April 22, 2010

[262] R. Van der Linden and P. Vanlommel
Human exploration of Space: challenges, risks and benefits
Press Conference during esww7, Oud-Sint Jan, Brugge, November 16, 2010

[263] P. Vanlommel
Wetenschapper-fysicus
Oriëntatie 2de jaar, Sint-Jozefs Instituut Betekom, March 08, 2010

[264] P. Vanlommel
Ruimteweervoorspeller in 50 minuten
Workshop KULeuven, Leuven, March 16, 2010

[265] P. Vanlommel
Ruimteweer
PROBA2@school, Vliebergh-Sencie, Leuven, March 24, 2010

[266] P. Vanlommel
PROBA2: een nieuwe visie op ruimteweer en de Zon
Volkssterrenwacht Beisbroek, Brugge, May 05, 2010

[267] P. Vanlommel
PROBA2: een nieuwe visie opruimteweer – eerste resultaten
VVS, werkgroep zon, Genk, September 18, 2010

[268] P. Vanlommel
De Zon – de energetische drijver van het ruimteweer
Werkgroep Aardrijkskunde Brabant, Leuven, September 28, 2010

[269] P. Vanlommel
Space Weather in 20 questions – the Quiz

ESWW7, Brugge, Belgium, November 15, 2010

[270] P. Vanlommel
Onze Zon en PROBA2, onze satelliet
Sint-Jozefs College, 4de leerjaar, Aarschot, December 13, 2010

[271] Warnant R.
Galileo ? Bien plus qu'un système de positionnement !
Space Commission of Belgian Senate on 09/02/2010.

7. Public Outreach publications

[272] P. Vanlommel
Looking back at ESWW7
http://www.sidc.be/news/131/welcome.html, December 01, 2010.

[273] P. Vanlommel
New Product: COMBISWAP
http://www.sidc.be/news/130/welcome.html, November 26, 2010.

[274] P. Vanlommel
Aug 2010 event – fully screened
http://www.sidc.be/news/129/welcome.html, September 07, 2010.

[275] P. Vanlommel, W. Vander Putten and the esww7 PC
7th European Space Weather Week – poster release
http://www.sidc.be/news/128/welcome.html, August 17, 2010.

[276] P. Vanlommel
PROBA2: an eye on space weather events
http://www.sidc.be/news/124/welcome.html, April 19, 2010.

[277] P. Vanlommel and the PROBA2 Science Team
PROBA2: Belgian scientists keep an eye on the Sun – the Royal Observatory of Belgium in an orbit around Earth
http://www.sidc.be/news/120/welcome.html, January 21, 2010.

[278] PROBA2 Science Team
SWAP & LYRA data release – PROBA2 Guest Investigator Program
http://www.sidc.be/news/126/welcome.html, May 04, 2010.

[279] PROBA2 Science Team
PROBA2 witnesses an annular eclipse
http://proba2.sidc.be/index.html/outreach/documentation/article/proba2-witnesses-an-annular, February 02, 2010.

8. Press releases

[280] PROBA2 consortium
Press text: Technology-testing PROBA2 opens new eye on the Sun
http://www.esa.int/SPECIALS/Proba/SEMYNUKOP4G_0.html, January 31, 2010.

[281] SDO Team
Press release: SDO – First Light
http://www.sidc.be/news/125/welcome.html, April 20, 2010.

[282] P. Vanlommel
Press text: PROBA2 1 year – Dutch, French, English
http://www.sidc.be/PROBA2anniversary/, November 02, 2010.

[283] P. Vanlommel and C. Marqué
Press text: CESRA - Strategic interest of Radio Observations – Dutch, French, English
http://www.sidc.be/news/127/welcome.html, June 11, 2010.

[284] P. Vanlommel and the SDO Team
Press release: SDO launch
http://www.sidc.be/news/123/welcome.html, February 09, 11, 2010.

9. Publications in popular journals

[285] E. D'Huys and P. Vanlommel
Ruimteweer waarnemen met een Belgische satelliet
Information brochure for high school teachers on PROBA2, the Sun and Space Weather, published by Vliebergh-Sencie, KULeuven, 47p, March, 2010
http://sidc.oma.be/Leerkrachten/PROBA2@school_20101001.pdf

[286] P. Vanlommel and E. D'Huys, translation by S. Raynal
De Koninklijke Sterrenwacht van België aan boord van PROBA2- een blik op de toekomst
Science Connection, nr 29, april-mei 2010.

[287] P. Vanlommel, translation by S. Raynal
PROBA2: Belgische wetenschappers zetten de Zon in haar blootje
Science Connection, nr 28, februari-maart 2010.

[288] P. Vanlommel and E. D'Huys
Ruimteweer waarnemen met een Belgische satelliet
Series in Guidestar (Newsletter Astro Event Group Oostende), August 2010, p 38
http://www.digilife.be/aeg/nieuwsbrief/Guidestar08-2010.pdf
Series in Guidestar (Newsletter Astro Event Group Oostende), September 2010, p 38
http://www.digilife.be/aeg/nieuwsbrief/Guidestar09-2010.pdf
Series in Guidestar (Newsletter Astro Event Group Oostende), October 2010, p 38
http://www.digilife.be/aeg/nieuwsbrief/Guidestar10-2010.pdf
Series in Guidestar (Newsletter Astro Event Group Oostende), November 2010, p 38
http://www.digilife.be/aeg/nieuwsbrief/Guidestar11-2010.pdf
Series in Guidestar (Newsletter Astro Event Group Oostende), December 2010, p 38
http://www.digilife.be/aeg/nieuwsbrief/Guidestar12-2010.pdf

[289] P. Vanlommel and E. D'Huys
De Koninklijke Sterrenwacht aan boord van PROBA2
Guidestar (Newsletter Astro Event Group Oostende), July 2010, p 38
http://www.digilife.be/aeg/nieuwsbrief/Guidestar07-2010.pdf