The EISCAT_3D Science Case

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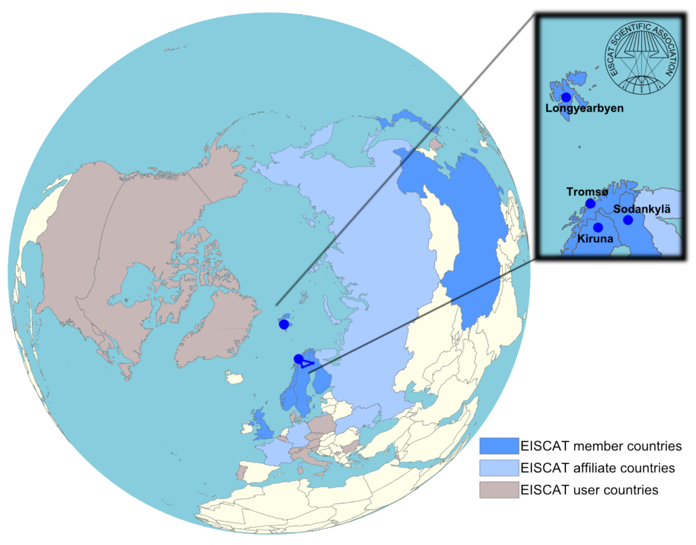


EISCAT Scientific Association

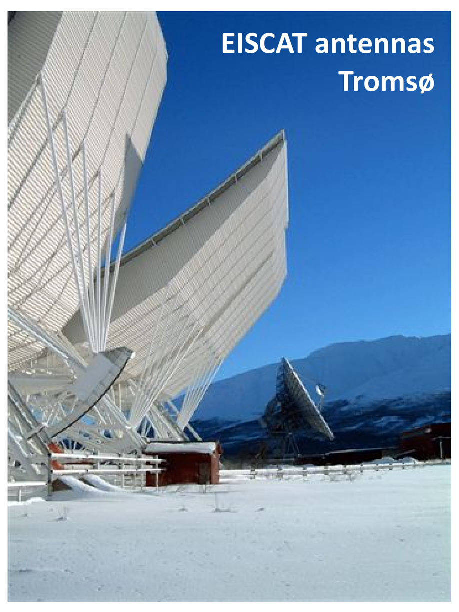
EISCAT is an international research organisation, conducting fundamental research into solar-terrestrial physics and atmospheric science.

EISCAT was founded in 1976 and the first EISCAT data were obtained in 1981.

EISCAT operates three incoherent scatter radar systems (224 MHz, 500 MHz, 931 MHz) in northern Fenno-Scandinavia and on Svalbard.

The EISCAT systems are located in Tromsø (Norway), Kiruna (Sweden), Sodankylä (Finland) and Longyearbyen (Svalbard).

EISCAT also operates an ionospheric heater and supporting instruments such as dynasondes.



EISCAT is at the present funded by seven member organisations from six countries:

- Suomen Akatemia, Finland
- Solar Terrestrial Environment Laboratory, Nagoya, Japan
- National Institute of Polar Research, Japan
- China Research Institute of Radiowave Propagation, China
- Norges Forskningsråd, Norway
- National Environment Research Council, UK
- Vetenskapsrådet, Sweden

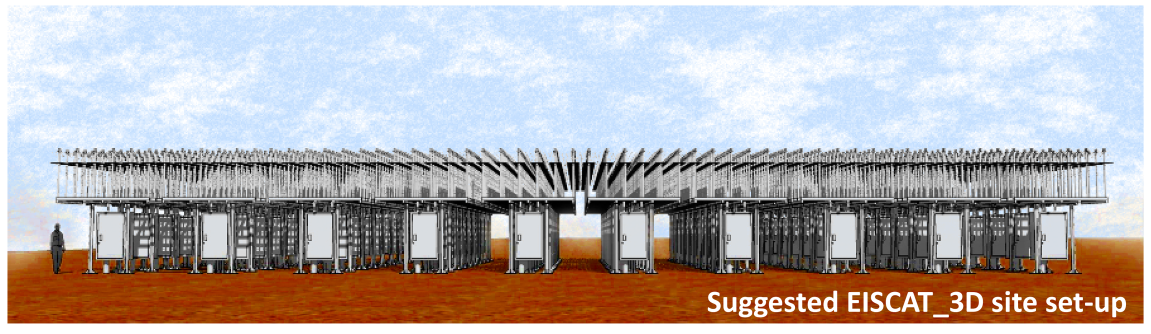
EISCAT receives additional funding from Russia, France, Ukraine and the EU.

EISCAT_3D

EISCAT, with international partners, is preparing to construct the next generation radar: EISCAT_3D. It will consist of multiple phased arrays and use state-of-the-art signal processing and beam-forming techniques to become the world's most sophisticated research radar. The five key capabilities of EISCAT_3D are:

- Resolution of space-time ambiguity.
- 3D volumetric capability.
- Sub-beam width measurements.
- Continuous monitoring of solar variability on terrestrial atmosphere and climate.
- Model validation for space weather and global change.

This is a unique set of capabilities of one single facility.

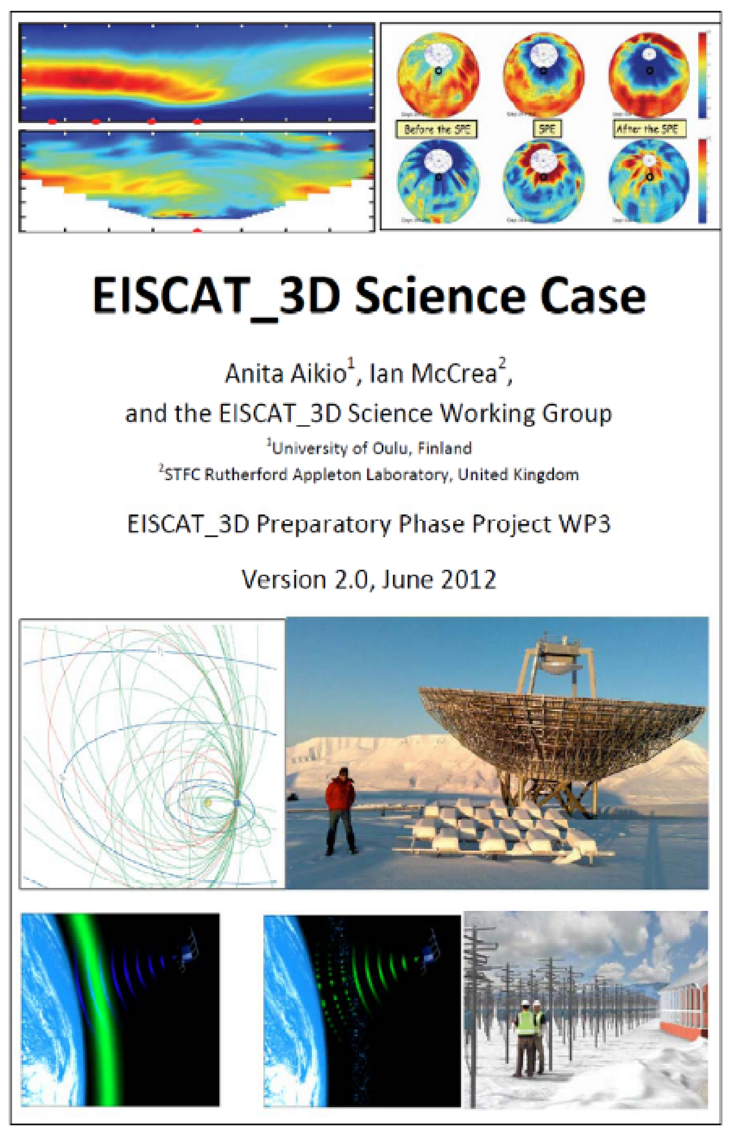


The planned time-line for the EISCAT_3D system is:

2005 – 2009	FP6 Design Study (completed)
2010 – 2014	FP7 Preparatory Phase (ongoing)
2014 – 2021	Implementation Phase
2014 – 2016	*Preparation*
2016 – 2019	*Construction (in stages)*
2019 – 2021	*Commissioning (in stages)*

The EISCAT_3D Preparatory Phase started 1 October 2010. The aim is to ensure that the EISCAT_3D project is sufficiently mature with respect to technical issues, legal matters and finances.

EISCAT_3D Preparatory Phase is Funded by the European Commission under the call FP7-INFRASTRUCTURES-2010-1 *"Construction of new infrastructures: providing catalytic and leveraging support for the construction of new research infrastructures".*


EISCAT_3D Science Case

Anita Aikio[1], Ian McCrea[2], and the EISCAT_3D Science Working Group

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EISCAT_3D Preparatory Phase Project WP3

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www.eiscat3d.se/project/fp7/science-case

The EISCAT_3D Science Case

The EISCAT_3D Science Case is prepared as part of the Preparatory Phase. It is regularly updated with new releases, and it aims at being a common document for the whole future EISCAT_3D user community.

The material presented here comes from two science working groups during the two first project years. In addition to the science working groups, contributions have been obtained from other members of the scientific community, both present EISCAT users and potential EISCAT_3D users.

The Science Case aims at being a common document of the whole future EISCAT_3D user community. Therefore, we welcome input and suggestions for improvements of the document.

The Science Case is divided into five main areas, as presented here.

Atmospheric Physics and Global Change

Research questions:

Where do upgoing atmospheric gravity waves break into turbulence and how do they affect the temperature and global circulation?

Do solar energetic particle events deplete ozone in the stratosphere?

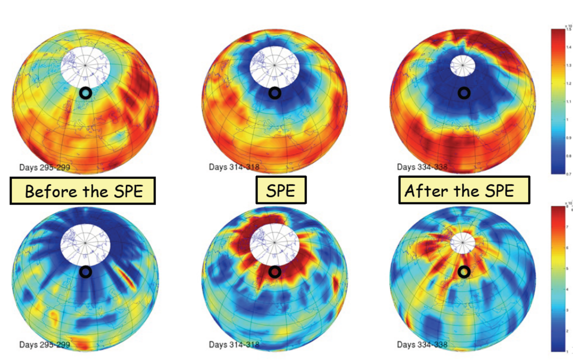
What processes link the the variations in surface temperature to geomagnetic activity of solar origin, as suggested in some recent studies?

Are mesospheric thin layers and noctilucent clouds signs of global change, connected to human activity?

How do stratospheric warming events affect the dynamics of the mesosphere and thermosphere?

Is greenhouse warming of the lower atmosphere resulting in long-term cooling of the middle and upper atmosphere?

Noctilucent clouds.Photo: Peter Dalin



Variations in ozone density (top) and nitric oxide density (bottom) at 46 km altitude, as observed by the GOMOS instrument on ENVISAT, following the intense solar particle events (SPEs) during the Halloween superstorm of 2003 *(Seppälä et al., 2004)*.

Space and Plasma Physics

Research questions:

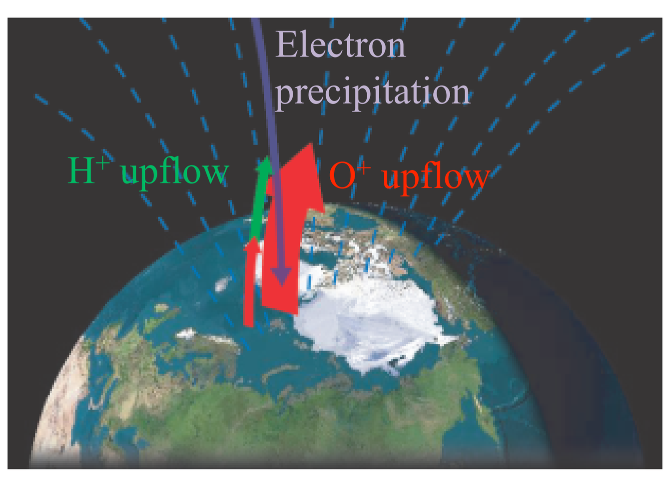
How much energy originating from the Sun and near-Earth space is deposited in the thermosphere during substorms and what effect does it have on the various atmospheric regions?

Which are the most important generation mechanisms of ion outflows and what kind of effect do those have on substorm onset?

What is the plasma physics behind auroral arcs, small-scale structures, naturally enhanced ion acoustic waves and artificial aurora induced by ionospheric heater facilities?

How is plasma convection structured on different scales and what implications does this have for large-scale global models which average over hundreds of km?

Under which situations do the inductive electric fields, that are created due to the temporal variations of ionospheric currents, become significant and how do they affect the magnetosphere and the ground?



Both hydrogen ion (H^+) and oxygen ion (O^+) upflows in the topside polar ionosphere were recently observed with the EISCAT Svalbard radar (ESR) in the vicinity of the cusp (*Ogawa et al., 2009*).

Solar System Research

Research questions:

What is the meteoroid mass flux into the Earth's atmosphere and what is its temporal variation?

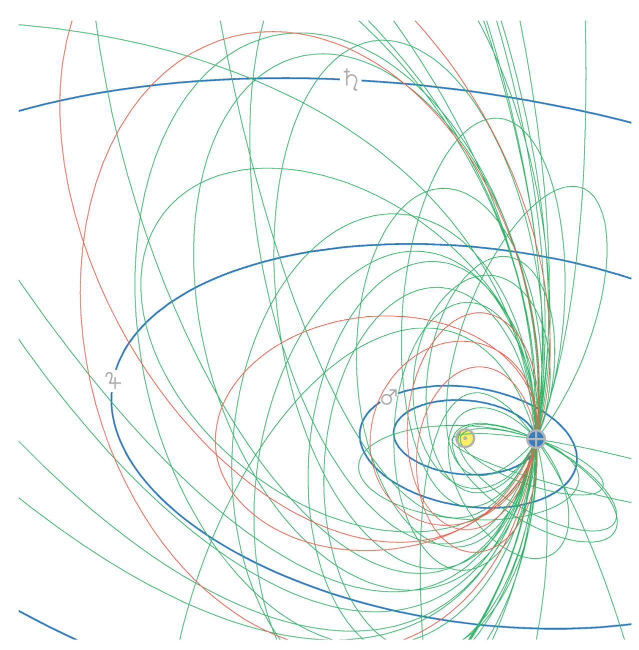
What kind of orbits do meteoroids have and what do they tell us about meteoroid dynamics and cometary dynamics?

What is the mechanism behind the meteor head echoes?

What is the role of meteoric dust in the chemistry and heat balance of the middle atmosphere?

What kind of sub-surface geochemical properties do planets and asteroids have and what can they tell us about the formation of our planetary system?

How is the solar wind accelerated and what is the distribution of solar wind velocities as a function of solar latitude and distance during different solar conditions?



Meteoroid orbits calculated from tristatic EISCAT UHF measurements. Sun (yellow), Earth (blue) and prograde (green) and retrograde (red) meteoroid orbits (*Szasz, 2008*).

Space Weather and Service Applications

Key goals for EISCAT_3D:

Identification and study of the ionospheric irregularity structures capable of affecting communications and position-finding techniques.

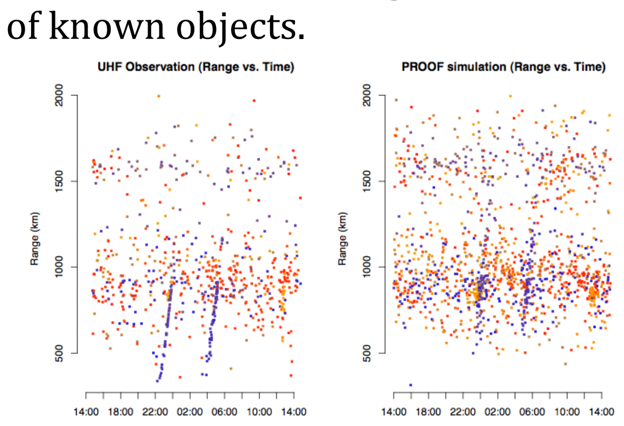
Use of EISCAT_3D data for now-casting of ionospheric conditions, validation and constraint of ionospheric models, combined use of data and modelling for ionospheric forecasting and as a tool to initiate and respond to space weather alerts.

Development of inter-operable data products and their demonstration in multi-instrument comparison and model assimilation.

Providing ionospheric observations to be used together with satellite measurements to study the physical processes in the ionosphere-atmosphere system caused by space weather phenomena.

Monitoring of the space debris environment for the verification of current space debris models.

Identification of new space debris objects and quantification of space weather induced changes in the orbits of known objects.



Comparison between measurements of the space debris environment as observed by the EISCAT UHF radar (left) and the predictions of the ESA PROOF model (right) (*Markkanen et al, 2009*). The clouds of vertically-distributed points correspond to debris fragments from the Cosmos-Iridium collision.

Radar Techniques, Coding and Analysis

Key goals for EISCAT_3D:

Development of optimised observing strategies for large-scale and small-scale imaging of upper atmosphere processes, under a range of different geophysical conditions.

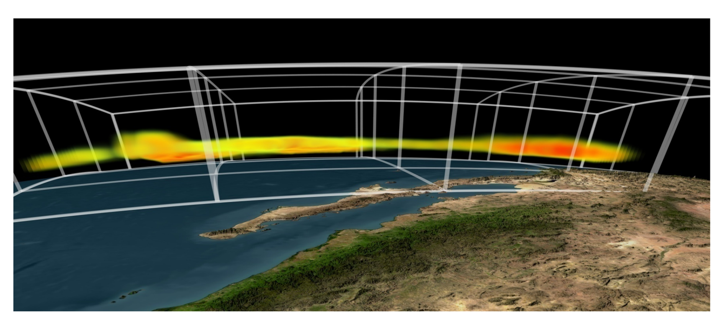
Development of beam- and phase front-shaping techniques to optimise the radar for use in different regions of the atmosphere.

Development of automated strategies to identify and track different types of events/objects.

Development of intelligent techniques to control the scheduling and interleaving of EISCAT_3D experiments.

Demonstration of new coding techniques, including "perfect codes" and amplitude modulation codes, to maximise the temporal and spatial resolution of the new radar.

Testing of antenna coding techniques, e.g. for the purpose of investigation ionospheric vorticity structures via the use of orbital angular momentum.



Schematic representation showing the volumetric imaging of an ionospheric layer by EISCAT_3D.

More information

About EISCAT: *www.eiscat.se*

About EISCAT_3D: *www.eiscat3d.se*