Scientific questions and algorithm development in the CALIBRA project

Alfonsi Lucilla[1], Spogli Luca[1], Aquino Marcio[2], Bougard Bruno[3], Cesaroni Claudio[1], De Franceschi Giorgiana[1], Dodson Alan[2], Monico J. F. Galera[4], Marcin Grzesiak[5], Yang Lei[2], Park Jihye[2], Romano Vincenzo[1]

[1]Istituto Nazionale de Geofisica e Vulcanologia, ITALY; [2]Nottingham Geospatial Institute, The University of Nottingham, UK; [3]Septentrio Satellite Navigation NV, BELGIUM; [4]Universidade Estadual Paulista, BRAZIL; [5]SRC PAS, POLAND

Contact Email: lucilla.alfonsi@ingv.it

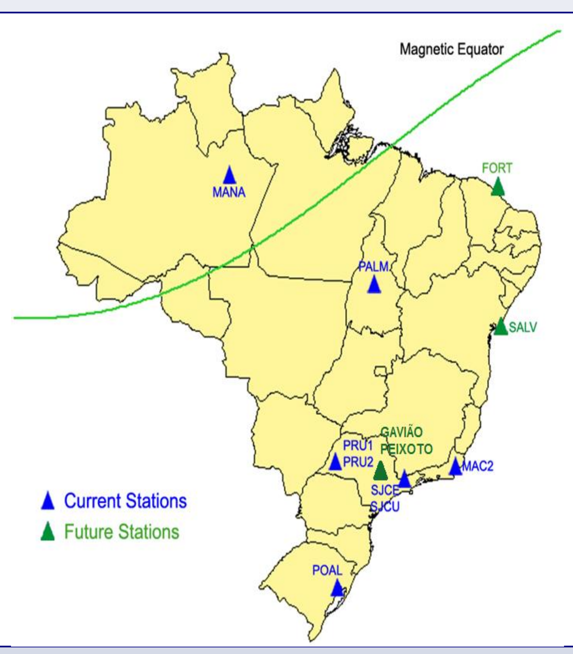
INTRODUCTION

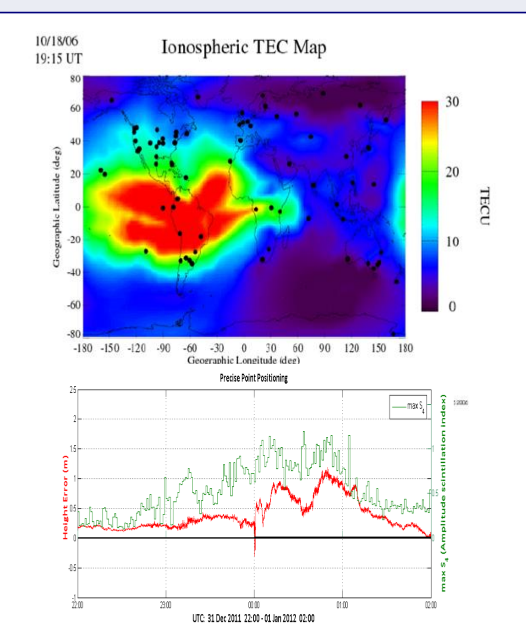
CALIBRA (**C**ountering GNSS high **A**ccuracy applications **L**imitations due to **I**onospheric disturbances in **BRA**zil) is a project funded under the EC Seventh Framework Program and is carried out in the Galileo FP7 R&D program supervised by the GSA. Started in November 2012, the project is focused on the development of algorithms to be applied to the highly precise GNSS carrier phase observable, which will be implemented in GNSS receivers in order to counter adverse ionospheric effects, especially ionosphere scintillation, over the Brazilian territory. This poster includes the project objectives and the results of our work in progress, with focus on the scientific and computational challenges that must be tackled to translate the assessment of temporal and spatial TEC gradients typical of the perturbed equatorial ionosphere into tools that can support the development of algorithms capable to effectively counter the space weather threats to GNSS high accuracy positioning.

Website: ***http://www.calibra-ionosphere.net***

MAIN OBJECTIVES

- identify and describe vulnerabilities of GNSS carrier phase based techniques and reliant services/applications to ionospheric disturbances;
- establish metric and characterise ionosphere related effects degrading positioning algorithms (RTK and PPP), in terms of accuracy, integrity and availability;
- develop local empirical models for TEC climatology and scintillation;
- develop new algorithms for a ‘cleaner’ observable to enable improved positioning performance;
- implement algorithms on Septentrio receivers;
- carry out application specific field tests, e.g. static, dynamic, offshore, etc.;
- validate and fine tune algorithms.





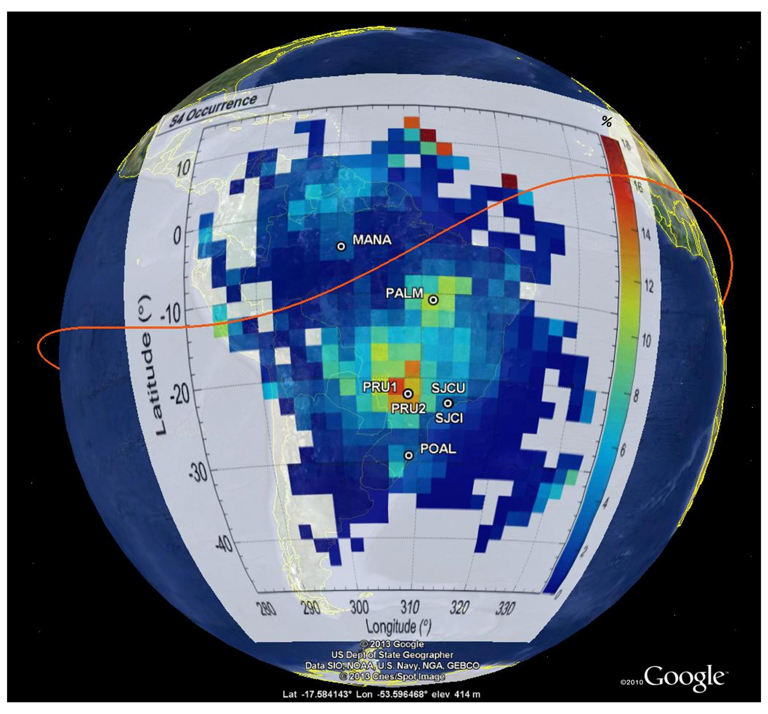
WORK IN PROGRESS

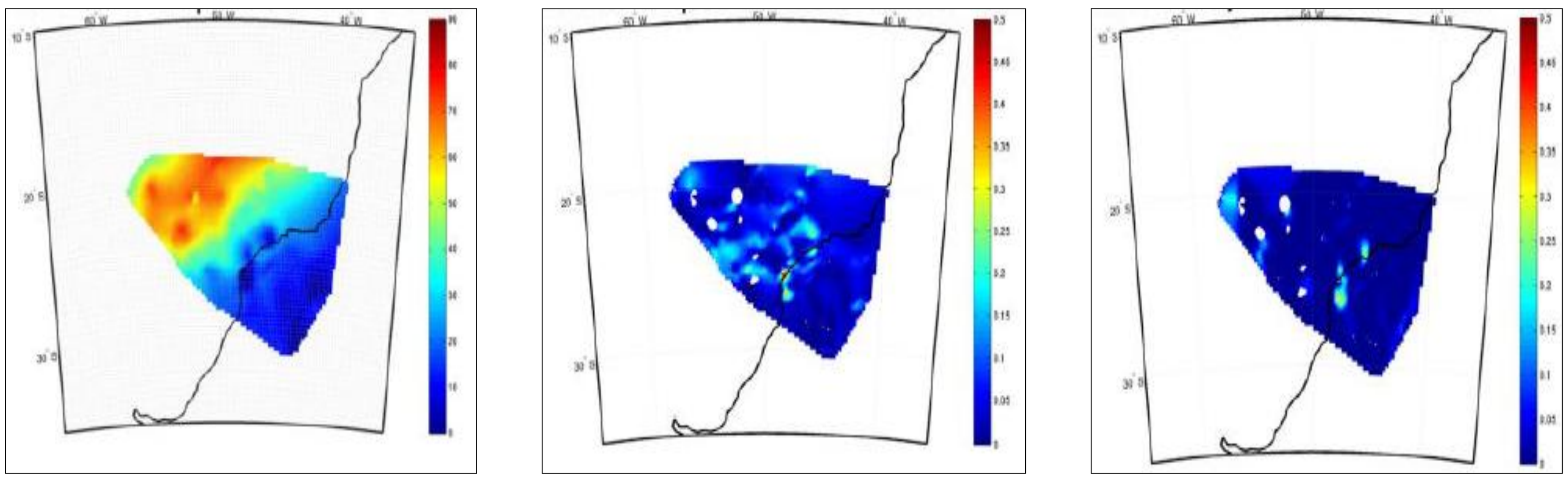
CIGALA AND URTKN DATA ANALYSIS

The CIGALA network is used to characterize the Brazilian ionosphere at a global scale. The URTKN network is deployed in the São Paulo State and it is used to characterize the calibrated TEC and its gradients in correspondence with the scintillation measurement made by the CIGALA receivers covering the same region.

On the left a map describes the percentage of occurrence of S4 above 0.25 in geographic coordinates (GPS + GLONASS, L1 frequency) in the UT range 22-04 UT over the year 2012. The most affected regions are those in the latitudinal range between 30°S and 10°N and in correspondence with longitudes between 300°E and 330°E, over São Paulo and Tocantins States and northward of Manaus (MANA) due to the presence of the EIA crests.

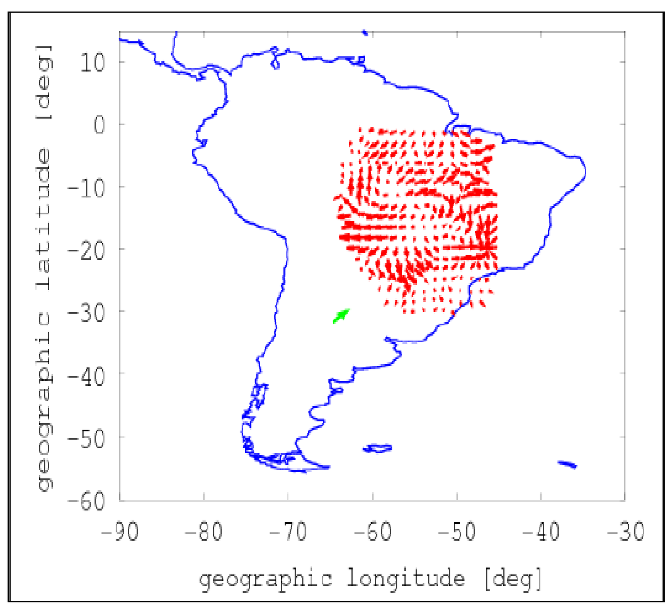
The figure on the right shows TEC (left, TECU), TEC N-S gradients (middle, TECU/km), TEC E-W gradients (TECU/km, right) and scintillation conditions (white dots) on 2 February 2012 between 2:00 UT and 2:10 UT (LT=UT-3). As expected, scintillations are often associated to plasma bubbles (TEC depletions), more visible in the N-S gradients mapping.

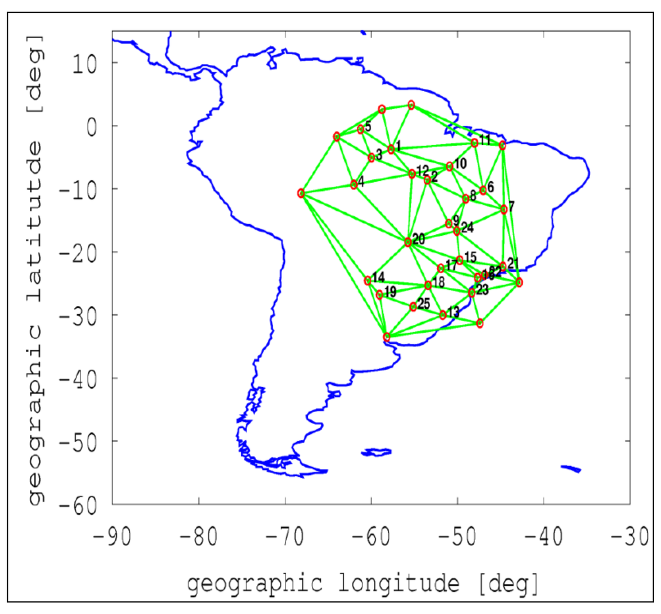


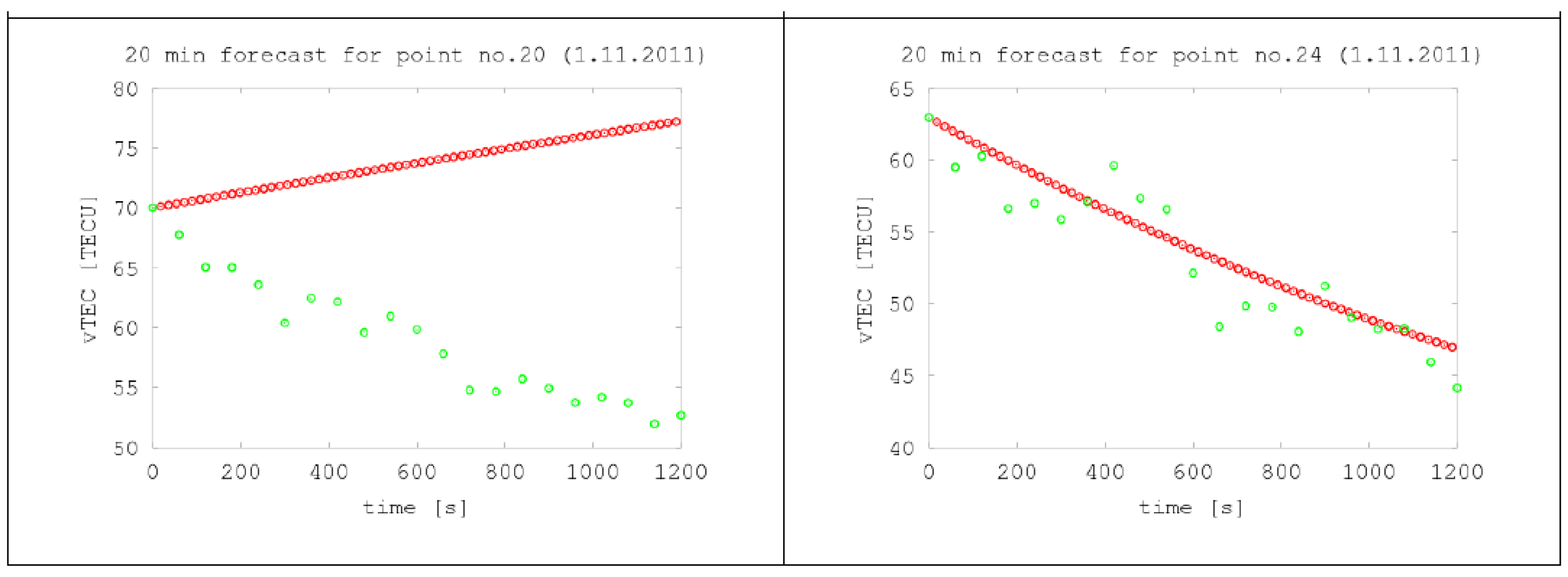


PRELIMINARY EMPIRICAL MODEL

The project includes the realization of a local empirical model able to describe the dynamics of the electron density gradients affecting the Brazilian region under strong scintillation regime. The preliminary version of the model is based on incorporating spatial TEC gradients into TEC temporal changes by assuming that the temporal gradient is a function of the spatial gradient and of the drift velocity. Experimental TEC data from the CIGALA network are used to reconstruct **v**, the field velocity of the electron fluid integrated along the line of sight, for a given epoch (figure bottom-left). The transport theory is applied to evolve the velocity field with desired time resolution using an appropriate numerical integration scheme. The figure in the middle describes the computational domain with internal points numbering. Figure on the right shows an example of the first results of VTEC forecasting on 1 November 2011.



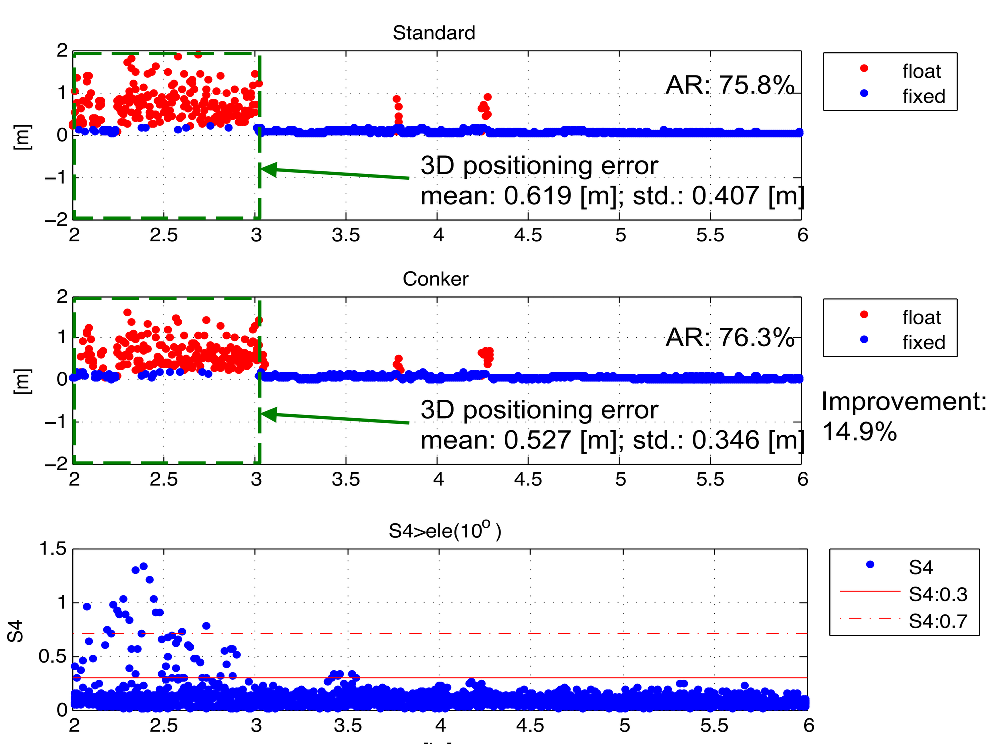




PRELIMINARY ALGORITHM DEVELOPMENT: IMPROVED STOCHASTIC MODEL

To mitigate the impact of scintillation on GNSS positioning, the Least Squares stochastic model can be improved by assigning weights to the observations based on tracking errors estimated by a model that is sensitive to scintillation conditions. As a preliminary algorithm, we adopted the Conker Model to compute these tracking errors for each observation based on the S4 index. The figure on the right compares the 3D positioning results of single baseline RTK (10km baseline) using the standard stochastic model (top), which uses a constant weight for all observations of the same type, and the improved stochastic model using the Conker output (middle). The S4 index (bottom) is also shown. In the first two plots, the red dots indicate the solutions where the ambiguity resolution (AR) were failed and flagged as “float” and the blue dots are ambiguity fixed solution and flagged as “fixed”. The label “AR” inside each plot presents the ambiguity success rate.

During the strong scintillation period (2-3 UTC hour; green dashed box), the improved stochastic model increased the positioning accuracy in terms of 3D positioning error (mean and standard deviation). The improvement of positioning error during this period is 14.9%.



ACKNOWLEDGEMENTS

The authors would like to express their sincere thanks to the EC and GSA, for their funding and supporting to this research.