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GRAPE, GNSS Research and Application for Polar Environment, Expert Group of SCAR. Edited by Giorgiana De Franceschi and Maurizio Candidi.

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PREFACE

ARTICLES

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PREFACE

GRAPE, Solar Terrestrial Physics in an operational environment

Brief historical outline

The Scientific Committee for Antarctic Research (SCAR) Action Group GPS for Weather and Space Weather Forecast (GWSWF) was established in Saint Petersburg in July 2008, as a joint group that links the Standing Scientific Groups of Physical Sciences (SSG/PS) and Geosciences (SSG/GS). This happened in response to the invitation of the SCAR Secretariat that initiatives should be encouraged to create cross-disciplinary groups to address new advanced scientific objectives.

As detailed on the original webpage for the group, http://www.gwswf.scar.org/, the scientific framework for the operation of GWSWF was designed to address the issue of lack of Global Navigation Satellite System (GNSS) high-rate sampling receiver coverage over the polar regions, and particularly in Antarctica. The aims of the Action Group are to contribute to answering the questions that are still open within the Sun-Earth interactions studies. Some of the issues of particular interest in the scientific international debate were:

1. Characterization of the cause-effect mechanisms driving the formation and evolution of ionospheric irregularities;
2. Distribution and evolution of precipitable water vapor in the polar regions that has a key role in the characterization and evolution of the global climate of the Earth.

The group is to address the following scientific objectives:

1. Encourage the establishment of a permanent network of GNSS receivers for multi-purposes investigations over the Arctic and Antarctica.
2. Stimulate international collaboration in bi-polar investigations, particularly in conjugate regions.

The objectives that were indicated as cross-linking the activities of SSG/PS and SSG/GS included:

1. Ionospheric imaging over Antarctica.
2. Exchange of data and expertise for the application of tomography to other fields of interest for both communities (e.g., three-dimensional water vapor reconstruction).
3. Exchange of technologies to install and manage remote global positioning system (GPS) stations.
4. Possibility to host instruments in the polar stations that the two communities manage.

The XXXI SCAR Delegates Meeting in Buenos Aires, Argentina (August 9-11, 2010) encouraged the Action Group GWSWF to explore synergies with the Geodetic Infrastructure for Antarctica (GIANT) and International Polar Earth Observation Network (POLENET) groups of SSG-GS. The Inter-hemispheric Conjugacy Effects in Solar-Terrestrial and Aeronomy Research (ICESTAR) was reported to be considering ways to interact with GWSWF, generating joint scientific objectives.

At the SCAR 4th Cross Linkages Meeting, May 5-6, 2011, in Ottawa, Canada, the Chief Officer of SSG-GS, reported that the Action Group GWSWF intended to upgrade to an Expert Group, with revised Terms of Reference. It was noted that the new Terms of Reference overlapped with those of the ICESTAR Expert Group, such that the two groups should discuss the best way forward. An ACTION was established with SSG-PS and the chairs of the ICESTAR EG to determine the way forward with regards to the new Terms of Reference of the GWSWF, and to address the question whether they should be merged into a single Expert Group.

In Portland, USA, from July 23-25, 2012, at the XXXII SCAR SSG/PS and SSG/GS Meeting, the Delegates approved the conversion of the Action Group GWSWF to the Expert Group GNSS Research and Application for Polar Environment and Weather and Space Weather Forecast (GRAPE/WSWF). On that occasion, GRAPE was also included in the framework of the new SSG/GS Scientific Research Program Solid Earth Response and influence on Cryosphere Evolution (SERCE) (http://www.scar.org/researchgroups/progplanning/SERCE_Proposal_Apr2012.pdf), that states: *The SERCE and GRAPE (www.grape.scar.org) groups will work collaboratively to apply GNSS data to better understand the cause-effect mechanisms driving the formation and evolution of ionospheric irregularities, to improve mapping of the distribution and evolution of precipitable water vapour in polar regions, and to encourage both use of current GNSS data for multidisciplinary studies and to encourage establishment of a co-located network of high-rate GNSS receivers specifically for research on climate and space weather phenomena.*

The current terms of reference for the Expert Group can be found at www.grape.scar.org.

Research framework

According to the statement in the SCAR Strategic Plan (http://www.scar.org/strategicplan2011/SCAR_Strat_Plan_2011-16.pdf): *Antarctica also serves as a unique vantage point to look outwards from our planet to observe near-Earth space, our solar system and beyond*. In this statement, SCAR defines the motivation for research from Antarctica concerning Solar-Terrestrial effects, and for the operation of the GRAPE group.

The physics of polar ionospheric phenomena was studied classically in the XX century, with passive remote observations made by dedicated instrumentation, both ground-based and satellite-borne auroral imagers, and riometer stations. Active instrumentation was introduced with the ionospheric sounders. Sporadic flights of sounding rockets have provided sparse *in-situ* data in this region that is not accessible to satellite *in-situ* observations. More recently, extended arrays of ionospheric radars (SuperDARN) have been established, and these are being deployed to cover the southern polar region in full.

Although maybe designed for other uses that are generally of commercial interest, a new tool has been recently made available with the development of satellite services, providing data as a side product of the GPS infrastructure (GNSS in perspective). GPS signals propagate from the GPS satellite sources to the receivers, most of which are ground based. The signals traverse the ionospheric layers situated along the geometrical path between source and receiver. The ionospheric plasma is highly inhomogeneous and dynamical, it can show the presence of small-scale structures or irregularities embedded in the large-scale ambient plasma. These irregularities can produce short-term phase and amplitude fluctuations in the carrier frequency of the radio waves which pass through them, which are commonly called ionospheric phase and amplitude scintillations. These fluctuations can be analyzed to investigate the physical processes causing them, and conversely, to understand how and when the operational capabilities of GNSS receivers are affected, in order to develop countermeasures to improve their performance against the ionospheric threats.

The Special Issue

The collection of papers that forms this special issue represents the whole amplitude of research that is being conducted in the framework of GRAPE, while also connecting to other initiatives that address the same objectives in regions outside the polar regions, and worldwide, such as the Training Research and Applications Network to Support the Mitigation of Ionospheric Threats (TRANSMIT; www.transmitionosphere.net), a Seventh Framework Programme (FP7) Marie Curie Initial Training Network that is focused on the study of ionospheric phenomena and their effects on systems embedded in our daily life, Near-Earth Space Data Infrastructure for e-Science (ESPAS), an FP7-funded project that aims to provide the e-Infrastructure necessary to support the access to observations, for the modeling and prediction of the near-Earth Space environment, Concept for Ionospheric Scintillation Mitigation for Professional GNSS in Latin America (CIGALA) and its follow-up and extension

Countering GNSS High-Accuracy Applications Limitations due to Ionospheric Disturbances in Brazil (CALIBRA), both of which are funded by the European Commission in the frame of FP7, for facing the equatorial ionosphere and its impact on GNSS.

The main objective of the present Special Issue of Annals of Geophysics is to collect recent reports on work performed in the polar regions and on the datasets collected in time by the instrumentation deployed across various countries. This collection will set the starting point for further research in the field, especially in the perspective of the new and very advanced space system that will be available in the next few years. In the following, papers will be found that describe the initiatives to deploy instrumental arrays to observe the ionospheric scintillation phenomenon (Romano et al., *Measuring GNSS...*); to build hardware/ software structures to store the relevant data and to make it available in appropriate formats (Romano et al., *eSWua: a tool...*; and Romano et al., *The IDIPOS project...,* in the national context of the Italian Antarctic Programme). Other papers deal with more proper scientific analyses of the available data, ranging from the analysis of the relation between scintillation and conditions in the interplanetary medium, and originally on the Sun (Prykril et al.), also in their bipolar conjugate manifestation (Prykril et al.), to the evaluation of the effects taking place in the near Earth regions, in the inner magnetosphere (Fernandez et al.), and in the statistical representation of ionospheric conditions (Correia et al.); a climatological description of a scintillation scenario is given both for the polar regions and for the mid-latitudes (Spogli et al.); a different, but no less relevant, analysis is given with respect to the water vapor content and its effects at tropospheric levels (Sarti et al.).
According to the content of the various papers, they belong to the GRAPE work packages, as follows:

Work Packages

1. S-T interactions and ionospheric effects in the current solar-cycle
Multi-instruments investigation of the upper atmosphere plasma dynamics and scintillation generation (SuperDARN, GNSS, ionosondes, VLF, etc.).

– Paul Prikryl, Yongliang Zhang, Yusuke Ebihara, Reza Ghoddousi-Fard, Periyadan T. Jayachandran, Joe Kinrade, Cathryn N. Mitchell, Allan T. Weatherwax, Gary Bust, Pierre J. Cilliers, Luca Spogli, Lucilla Alfonsi, Vincenzo Romano, Baiqi Ning, Guozhu Li, Martin J. Jarvis, Donald W. Danskin, Emma Spanswick, Eric Donovan, Mike Terkildsen, *An interhemispheric comparison of GPS phase scintillation with auroral emission observed at the South Pole and from the DMSP satellite*.

– Emília Correia, Amanda Junqueira Paz, Mauricio A. Gende, *Characterization of GPS total electron content (GPS-TEC) in Antarctica from 2004 to 2011*.

– José Henrique Fernandez, Emília Correia, *Electron precipitation events in the lower ionosphere and the geospace conditions*.

– Vincenzo Romano, Giovanni Macelloni, Luca Spogli, Marco Brogioni, Giuditta Marinaro, Cathryn N. Mitchell, *Measuring GNSS ionospheric total electron content at Concordia, and application to L-band radiometers*.

Scintillation climatology, TEC fluctuations, structure scale, C/N statistics, etc.

– Luca Spogli, Lucilla Alfonsi, Pierre Cilliers, Emilia Correia, Giorgiana De Franceschi, Cathryn N. Mitchell, Vincenzo Romano, Joe Kinrade, Miguel Angel Cabrera, *GPS scintillations and total electron content climatology in the southern low, middle and high latitude regions*.

2. Lower atmosphere delay in GNSS-based systems (water vapor reconstruction, etc.)
– Pierguido Sarti, Monia Negusini, Claudio Tomasi, Boyan H. Petkov, Alessandro Capra, *Thirteen years of integrated precipitable water derived by GPS at Mario Zucchelli Station, Antarctica*.

3. Modelling and models testing
– Paul Prikryl, Veettil Sreeja, Marcio Aquino, Periyadan T. Jayachandran, *Probabilistic forecasting of ionospheric scintillation and GNSS receiver signal tracking performance at high latitudes*.

4. Data management strategy
– Vincenzo Romano, Silvia Pau, Michael Pezzopane, Luca Spogli, Enrico Zuccheretti, Marcio Aquino, Craig M. Hancock, *eSWua: a tool to manage and access GNSS ionospheric data from mid-to-high latitudes*.

– Vincenzo Romano, Luca Spogli, Alberto Salvati, Claudio Rafanelli, Lili Cafarella, *The IDIPOS project: is a multidisciplinary data infrastructure for weather and space weather feasible?*

5. Coordination with other programmes inside and outside SCAR (e.g. URSI, CAWSES II, SuperDARN, EISCAT 3D)
This very introduction to the special issue details the framework of international cooperation in which GRAPE is to be considered.

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