

THE INTERNATIONAL GPS SERVICE (IGS) IONOSPHERE WORKING GROUP ACTIVITIES

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- on behalf of the IGS Ionosphere Working Group -

presented by

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ABSTRACT

The International GPS Service (IGS) Ionosphere Working Group (Iono_WG) is active since June 1998. The working group's main task is the routine provision of ionosphere Total Electron Content (TEC) maps with a 2-hours time resolution and of daily sets of GPS satellite and receiver hardware delays (DCBs). The computation of these TEC maps and hardware delays sets is based on the routine evaluation of GPS dual-frequency tracking data recorded with the global IGS tracking network. Currently five IGS Ionosphere Associate Analysis Centers (IAACs) cooperate in the Iono_WG activities.

In the medium- and long-term, the working group intends to develop more sophisticated ionosphere models and to realize near-real-time availability of IGS ionosphere products.

Beyond the routine provision of ionosphere products, the Iono_WG intends to support the ionosphere community also with other activities, e.g. by using the IGS global tracking network and capabilities to run high-rate data campaigns during events being of special relevance for the ionosphere. A first such campaign was organized during the total solar eclipse on 11 August 1999, and a solar maximum campaign, called "HIRAC/Solarmax", did run from 23 to 29 April 2001. The intent of such campaigns is to establish high-rate tracking databases for ionosphere scientists and other interested researchers, which can be the subject of ionospheric analyses over the years. The high-rate data are made available through the Crustal Dynamics Data Information System (CDDIS) IGS Global Data Center.

It is the intent of this presentation to give an overview over the Iono_WG activities, also with regard to possible common interests of the Iono_WG and SCAR/WG-GGI.

1 INTRODUCTION

The Working Group started its routine activities in June 1998: Several so called Ionosphere Associate Analysis Centers (IAACs) provide per day twelve global TEC maps with a 2-hours time resolution and a daily set of GPS satellite DCBs in IONEX format files (Schaer et al., 1997). The routine provision of daily ground station DCBs is under preparation. Currently five IAACs contribute with ionosphere products:

- CODE, Center for Orbit Determination in Europe, Astronomical Institute, University of Berne, Switzerland.
- ESOC, European Space Operations Centre of ESA, Darmstadt, Germany.
- JPL, Jet Propulsion Laboratory, Pasadena, California, U.S.A.
- NRCan, National Resources Canada, Ottawa, Ontario, Canada.
- UPC, Polytechnical University of Catalonia, Barcelona, Spain.

The mathematical approaches used by the distinct IAACs to establish their TEC maps are quite different. Details about the individual IAACs modeling can be found in e.g. (Schaer 1999; Feltens, 1998; Mannucci et al., 1998; Gao et al.; Hernandez-Pajares M. et al., 1999).

2 MAIN ACTIVITY

Once per week the ionosphere products from the different IAACs are compared at the Ionosphere Associate Comparison Center (IACC) at ESOC. These comparisons are based on a preliminary version of a dedicated comparison/combination algorithm, being based on weighted and unweighted means. Analyses of the residuals of the different IAACs TEC maps with respect to the outcoming “mean” TEC maps allow for the establishment of statistics about the IAACs TEC maps agreement. The same procedure is principally also done for the of DCBs.

However, as already mentioned above, the IAACs use very different approaches to establish their TEC maps, which results in very different temporal and spatial resolutions. These circumstances reflect also in the comparison results; the weighting scheme in the comparison algorithm must be improved. Software upgrades for an improved weighting scheme are currently under work. The new weighting scheme for the comparison/combination algorithm will use the output of two self-consistency methods proposed by NRCan and UPC (Heroux, 1999; Hernandez-Pajares, 2000). Both methods are in principle based on the analysis of residuals resulting from the comparison of directly from GPS-observables derived TEC values with corresponding TEC values interpolated from the IAACs TEC maps, in order to assess the quality of the distinct IAACs TEC maps. This is done with GPS data collected at ground stations equally distributed in a global geographic grid in order to achieve a geographic-dependent weighting.

Beyond that, the Iono_WG intends to perform other kinds of validation, which are in short:

- Comparison of IAACs models vertical TEC values with TEC values derived from TOPEX (and Envisat, once launched) altimeter data.

- Validation with ionosondes data.
- Validation by verifying the different IAACs models ability to adapt to International Reference Ionosphere (IRI) TEC values. - The IRI is considered in this test simply as a pure mathematical reference.
- Analyses of ERS/Envisat orbit determination statistics resulting from the usage of the different IAACs-models for correcting ionospheric delays.

As an example of results obtained with the preliminary comparison algorithm, Figure 1 shows the sequence “mean” TEC maps of 28 March 2000, a day during a period in the current solar maximum, when the TEC level was very high.

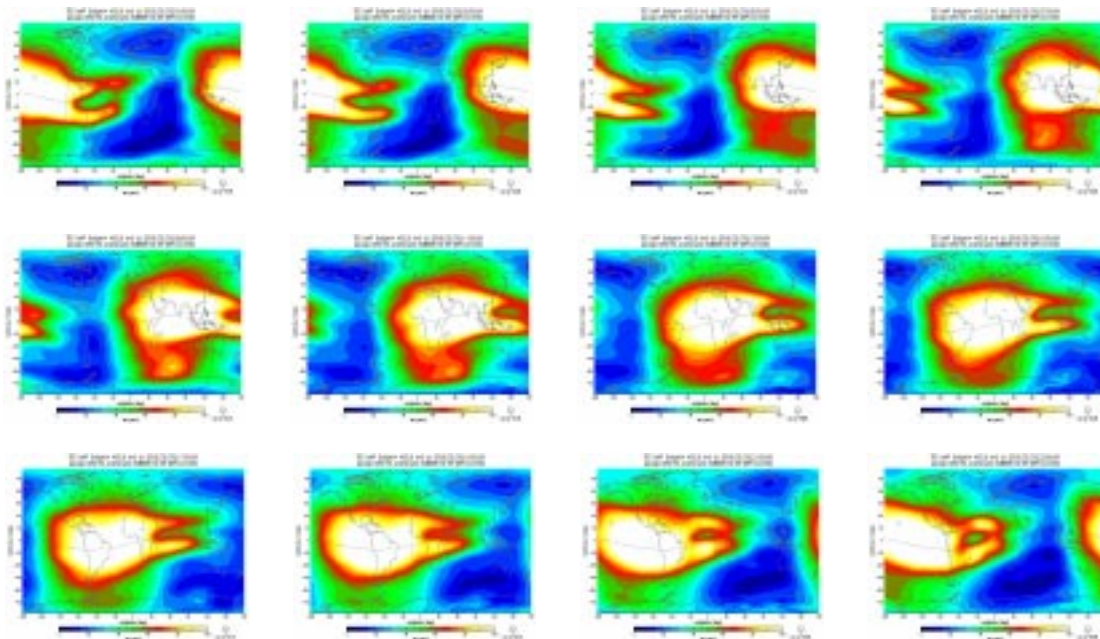


Figure 1: The IGS “weighted mean” TEC maps of 28 March 2000 in [TECU]
 (1st row: 1^h, 3^h, 5^h, 7^h; 2nd row: 9^h, 11^h, 13^h, 15^h; 3rd row: 17^h, 19^h, 21^h, 23^h).

The other important subject of comparisons are the DCBs. When directly comparing the DCB-series of the different IAACs, one can see an overall agreement in the order of about **0.3 ns**. According to a presentation of S. Schaer at the IGS Workshop, 27 - 29 September 2000, Washington, mean IAAC satellite DCB series show an agreement of about **0.1 ns**, while the day-by-day variations are significantly higher.

3 SPECIAL ACTIVITIES

On the occasion of the solar eclipse on 11 August 1999 the Iono_WG organized and coordinated a special observation campaign. This event was a unique opportunity to demonstrate the power of the GPS technique in monitoring the ionospheric ionization. As the zone of totality crossed Europe, the rather dense portion of the IGS network provided excellent conditions for

monitoring the eclipse: ca. 60 IGS ground stations along the eclipse path from North America over Europe to the Middle East recorded on that day high-rate dual-frequency GPS-data (1 sec resp. 3 sec). These solar eclipse data were archived at the Crustal Dynamics Data Information System (CDDIS) NASA/GSFC U.S.A. and can be accessed for analyses via *anonymous ftp* at [cddisa.gsfc.nasa.gov](ftp://cddisa.gsfc.nasa.gov) in directory */gps/99eclipse* (Feltens and Noll, 1999). Figure 2 below presents an example for the detection of Travelling Ionospheric Disturbances (TIDs) from high-rate GPS measurements at two swedish stations, recorded during the solar eclipse on 11 August 1999. See also Jakowski et al., 1999a and Jakowski et al., 1999b for the Solar Eclipse Campaign.

vil0: Vilhelmina / Sweden
mar6: Maartsbo / Sweden

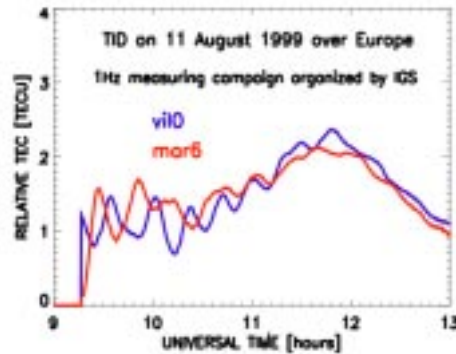


Figure 2: Travelling Ionospheric Disturbances (TIDs) detected from high-rate GPS data at two swedish stations on 11 August 1999.

The current solar maximum represents another unique chance to establish such a high-rate tracking database for ionosphere analyses. The two regions of major interest are in this case:

1. the polar regions and
2. low latitudes including the crest regions at both sides of the geomagnetic equator.

The “HIRAC/SolarMax” campaign was thus organized by the Iono_WG and lasted from 23 - 29 April 2001. On 26 April a large solar flare was observed which impacted the ionosphere on 28 April. A list of the stations and a map can be accessed as pdf files via

ftp://cddisa.gsfc.nasa.gov/pub/gps/01solarmax/solarmax_table.pdf

ftp://cddisa.gsfc.nasa.gov/pub/gps/01solarmax/solarmax_map.pdf

(Figure 3 below shows this map)

In order to obtain a comprehensive view of the geomagnetic and ionospheric state, the IGS activity within HIRAC/SolarMax was coordinated with other ionospheric observation programs or measurement campaigns, especially with the European action COST 271: “Effects of the upper atmosphere on terrestrial and earth-space communications”: More than 20 people participating in COST 271 have supported this campaign by a number of coordinated well-qualified observations. In particular the global ionosphere impact on signal propagation in space based communication and navigation systems shall be studied. These coordinated measurements included:

- Vertical Sounding,
- GPS based TEC monitoring over Europe,
- NNSS measurements along tomography chains,
- Geomagnetic Activity,
- Electric field measurements,

- EISCAT,
- Space based GPS onboard CHAMP,
- HF Radar measurements.

The high-rate GPS and GLONASS data are also archived at the CDDIS and are available through *anonymous* ftp at *cddisa.gsfc.nasa.gov* in directory */gps/01solarmax* (Feltens, Jakowski and Noll, 2001). The high-rate tracking data of more than 100 IGS stations were delivered to the CDDIS so far (status at 18 June 2001).

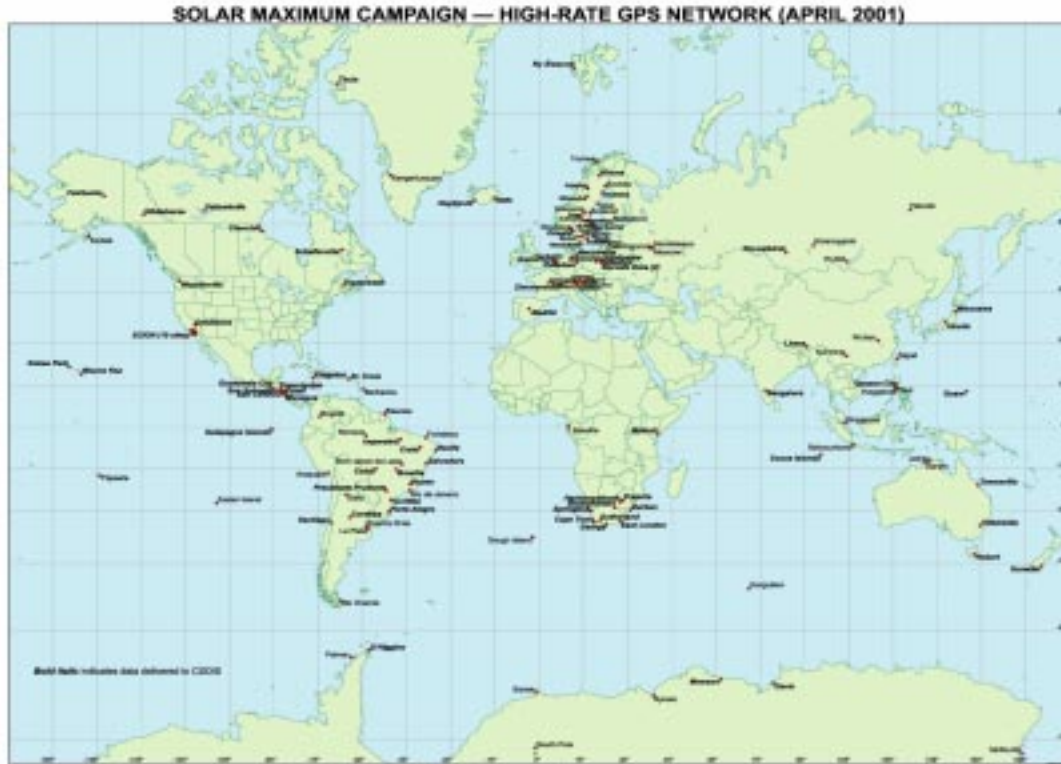


Figure 3: Global Map of IGS stations which were proposed to participate at the “HIRAC/SolarMax” campaign. Of these stations over 100 delivered their data to the CDDIS so far.

Similar campaigns are also planned for the future.

4 POSSIBLE INVOLVEMENT OF THE IONO_WG INTO SCAR/WG-GGI ACTIVITIES

Ionospheric behavior is often a complicated one, especially around the equator and over the polar regions - this was also the main reason why the HIRAC/SolarMax campaign was initiated. The Iono_WG has thus a vital interest to become involved into activities like antarctic research. Generally the IGS could contribute to the antarctic research activities with high-rate GPS tracking data, since quite a lot of IGS sites are located in the Antarctica, and many of these sites are already involved into the SCAR/WG-GGI activities. The IGS Iono_WG could especially contribute with routine TEC information over the antarctic region. Dedicated tracking campaigns, similar to HIRAC/SolarMax, could be organized to get a better understanding of high atmos-

phere behavior over the Antarctica. The Iono_WG could also use its contacts to the ionosphere community to encourage ionosphere people to contribute with other non-GPS data to such campaigns too. Further fields of cooperation might be possible ...

5 CONCLUSIONS AND LOOK INTO THE FUTURE

The IGS Ionosphere Working (Iono_WG) commenced its activities in June 1998. Main task is the routine establishment and provision of ionosphere products using IGS global GPS tracking data. The worldwide IGS GPS and GLONASS ground stations network (about 180 sites) provides the unique opportunity for a global ionosphere monitoring on routine base. Currently five so called Ionosphere Associate Analysis Centers (IAACs) contribute to this routine processing. Once the current comparison/combination algorithm is upgraded with a new weighting scheme, the Iono_WG intends to start with the routine delivery of an official IGS ionosphere product.

The next important task will be a significant reduction of the time interval between the recording of the GPS observables and the delivery of ionosphere products derived from these GPS data; currently these are 11 days.

In the medium and long-term the Iono_WG models shall be extended and improved, e. g. with regard to special models for certain regional and local areas (e.g. for the Antarctica), or at the IAACs the development of more complex mathematical ionosphere models. Final target should then be an independent IGS ionosphere model.

With regard to the SCAR/WG-GGI activities, it could be of benefit for the Iono_WG also to become involved into antarctic research.

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