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Using DORIS measurements for ionosphere modeling

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Introduction

Nowadays, most of the ionosphere models used in geodesy are based on terrestrial GNSS measurements and describe the Vertical Total Electron Content (VTEC) depending on longitude, latitude, and time. These VTEC maps are based on the assumption of a single-layer ionosphere. The accuracy of the VTEC maps is different for different regions of the Earth, because the GNSS stations are unevenly distributed over the globe and some regions (especially the ocean areas) are not very well covered by observations.

To overcome this unsatisfying measurement geometry of the terrestrial GNSS measurements and to take advantage of the different sensitivities of other space-geodetic observation techniques, we work on the development of multi-dimensional models of the ionosphere from the combination of modern space-geodetic satellite techniques. Currently, we test the capability of DORIS observations to derive ionospheric parameters such as VTEC.

DGFI VTEC model

The DGFI approach consists of a given background model $VTEC_{back}$ (e.g. NIC09) and an unknown correction part $\Delta VTEC$ expanded in terms of B-spline functions. For the global approach we use trigonometric B-Splines T for modeling the longitude dependency and normalized quadratic polynomial B-Splines P for the description of latitude and time dependency *[Schmidt et al. (2011)]*. Three one-dimensional B-Splines are combined to describe the VTEC in three dimensions:

$$VTEC(\varphi,\lambda,t) = VTEC_{back}(\varphi,\lambda,t) + \sum_{k_1=0}^{K_1-1}\sum_{k_2=0}^{K_2-1}\sum_{k_3=0}^{K_3-1} d_{k_1,k_2,k_3}^{j_1,j_2,j_3} \cdot P_{k_1}^{j_1}(\varphi) T_{k_2}^{j_2}(\lambda)\, P_{k_3}^{j_3}(t)$$

The model resolution is defined by the level j_i for each dimension i. The characteristics of the functions can be seen in Fig. 1.

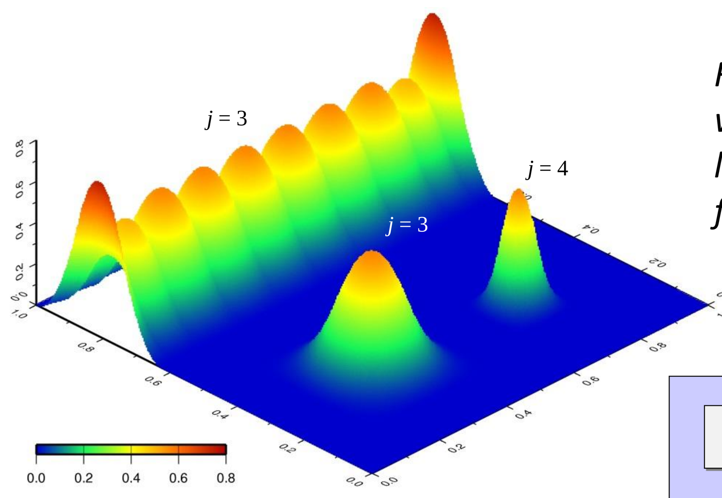

Fig.1: Two-dimensional B-splines used for the modeling with different level j. They are compactly supported and located on a regular grid. The coefficient d of each function is estimated within an adjustment procedure.

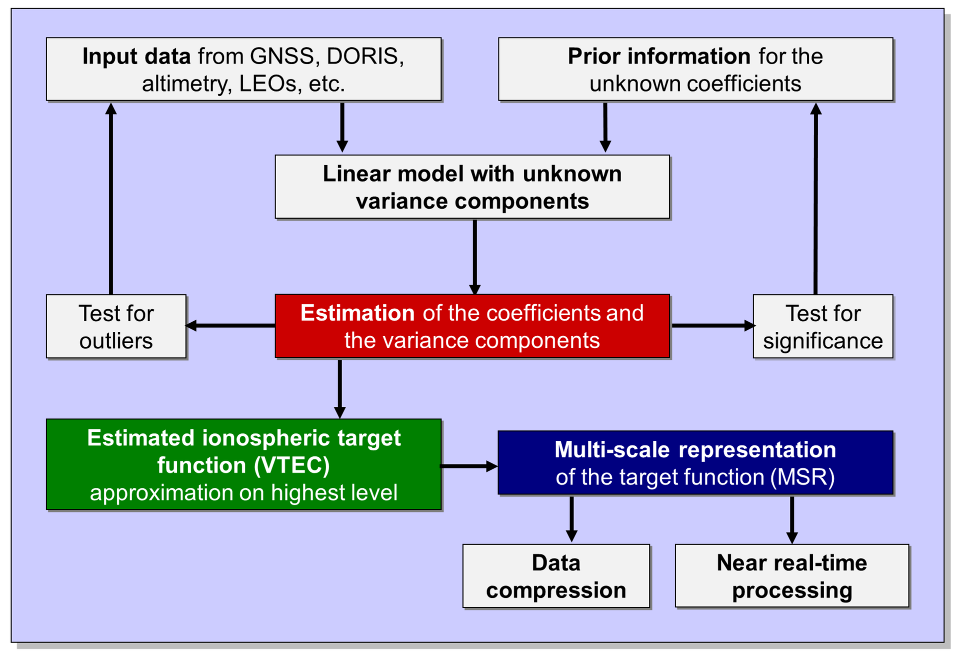

Fig.2: Flowchart of the procedure to estimate the VTEC model by the combination of data from different observation techniques or missions.

Different space-geodetic measurements are used to estimate the unknown model coefficients. In order to take into account the different accuracy levels of the observations, a fast Monte-Carlo implementation of the iterative maximum-likelihood Variance Component Estimation (VCE) is applied, see *Koch and Kusche, (2002)*. Fig. 2 shows the main steps of the procedure.

DORIS Observations

Observations from all active DORIS beacons received by the DGXX receiver on board of Jason-2 were used in this study. Within the time period under investigation (CONT08: Aug. 12-25, 2008), measurements from 52 beacons are available.

Fig. 3 shows the data distribution for 24 hours (48 beacons). Obviously, the observations are not equally distributed over the globe. However, since many DORIS beacons are located on islands, the station coverage is better than for GNSS.

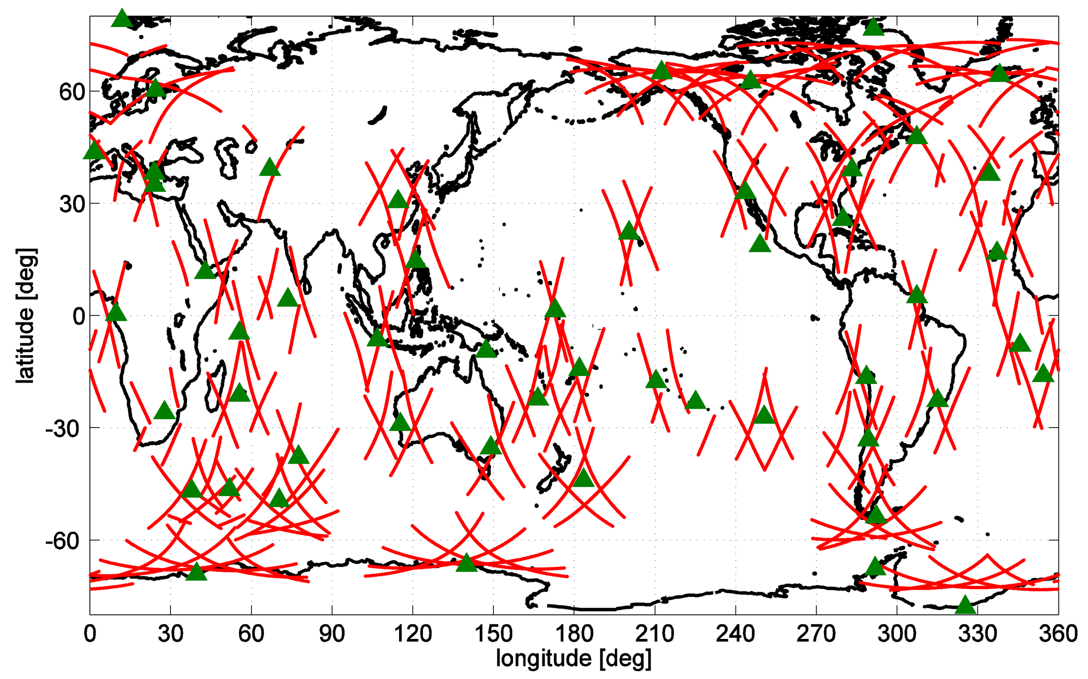

Fig. 3: Location of VTEC observations (red dots) from 48 DORIS beacons (green triangles) for 24 hours (12-08-2008) with 10° elevation mask, mission Jason-2.

DORIS VTEC Preprocessing

In order to derive VTEC measurements from the phase observations given in the DGXX RINEX files the following preprocessing steps have to be conducted:

- Computation of ionospheric delay d_{ion} in [m], biased
- Computation of STEC in [TECU], biased
- Estimation of STEC biases (from comparison with IGS GIMs) and computation of unbiased STEC
- Mapping of STEC to VTEC
- Extension/reduction of VTEC from Jason-2 orbit height to other height (in this case to GPS orbit height), only if indicated

More information on the preprocessing is given in *Dettmering et al. (2012)*.

VTEC comparisons

The computed DORIS VTEC values show differences up to 2 TECU RMS w.r.t. IGS GIMs, mainly in equatorial regions and probably related to higher absolute VTEC values in these areas. Differences to other models (i.e. NIC09 and IRI-07) reach up to 4 TECU RMS.

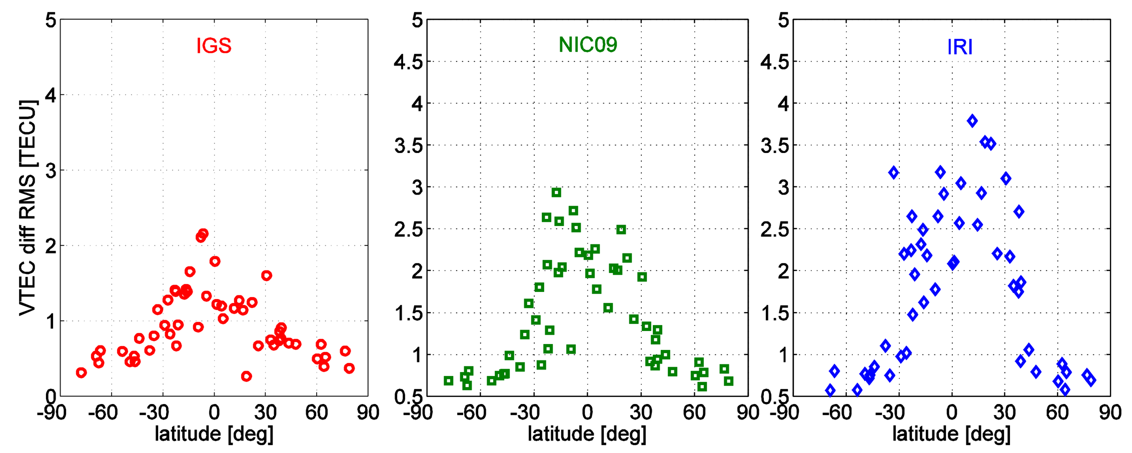

Fig. 4: VTEC differences between DORIS and three global models; RMS for CONT08 time period per station in [TECU]; ordered by station latitude.

References

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Schmidt M., Dettmering D., Mößmer M., Wang Y., Zhang J. (2011): Comparison of spherical harmonic and B spline models for the vertical total electron content. Radio Science, 46, RS0D11, doi:10.1029/2010RS004609

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Global VTEC Maps

The DORIS VTEC observations are used to compute global VTEC maps (j_2=2 , j_1=j_3=3) for Aug. 12 2008. In addition the following measurements are included in the processing:

- VTEC Observations from 67 GPS permanent stations
- Altimetry-based VTEC from mission Jason-2
- VTEC derived from Radio Occultation measurements (COSMIC and Champ)
- Background model: NIC09

Figure 5 shows the mean Variance Components (VC) for all data groups computed by the VCE. DORIS observations get the lowest VC (corresponding to highest weights). In contrast to GPS the VC and therefore the accuracy of the adjusted observations depend on the DORIS station latitude (Fig. 6).

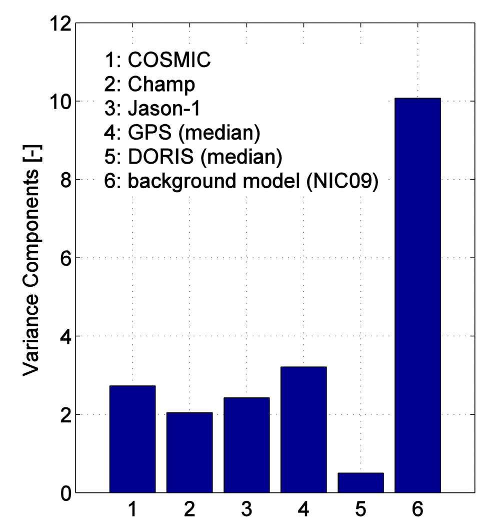

Fig. 5: Variance Components for the different observation groups

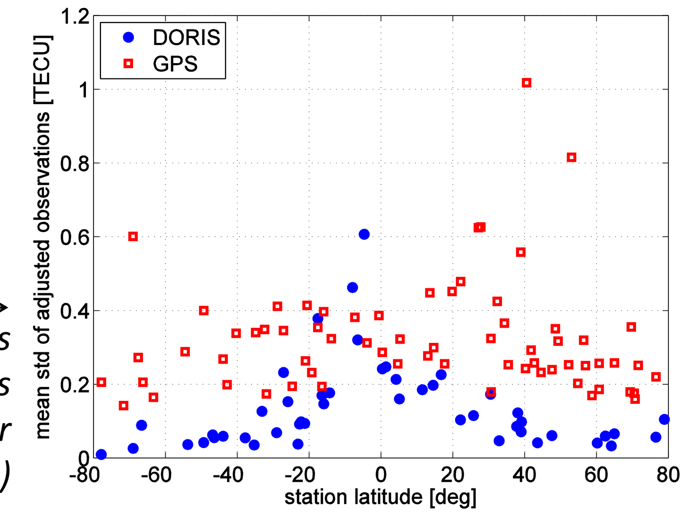

Fig. 6: Standard deviations of adjusted observations (average per station) for GPS (red) and DORIS (blue)

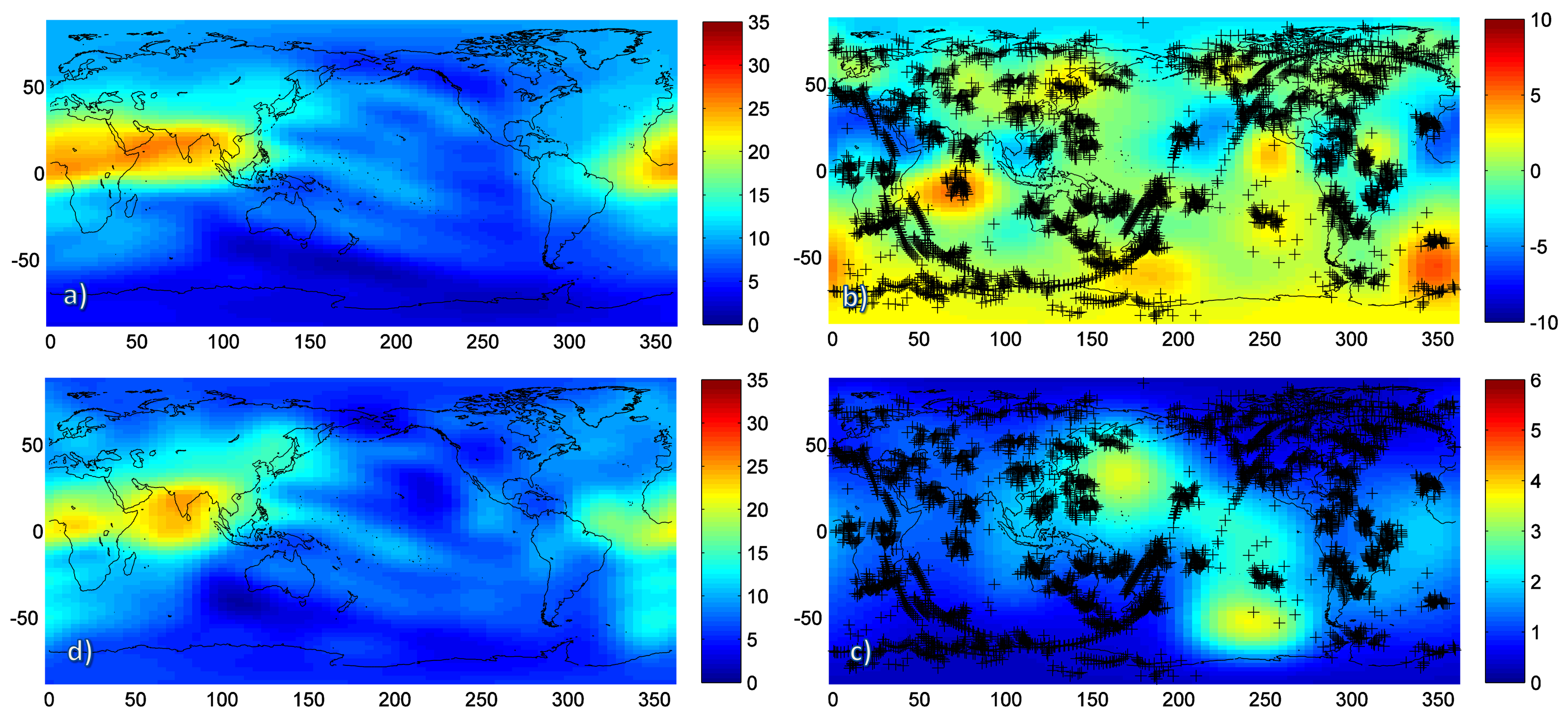

Fig. 7: Global VTEC map (in [TECU]) for 2008-08-12 12h UTC based on all observations.
a) Background model NIC09; b) estimated ΔVTEC; c) formal errors of ΔVTEC; d) DGFI VTEC model
Observation locations are marked by black crosses.

Using only GPS measurements increases the mean formal errors (from 1.5 to 3.0 TECU) as well as the differences to external models (IGS GIM, from ±5.4 to ±7.8 TECU) significantly.

Conclusions

DORIS measurements from DGXX receivers can easily be used as input for ionospheric modeling. After fixing the absolute level of VTEC by means of external information, DORIS VTEC matches well to models, especially to IGS. The main improvements for VTEC modeling are the high sensitivity (depending on the DORIS frequencies) and the data coverage.

Moreover, DORIS seems very promising for 4-dimensional modeling of electron density.

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