A New GPS-based Climatology for the Total Electron Content in the Ionosphere

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Summary

A climatology was constructed from 2-hourly GPS-based maps of total electron content (TEC) as produced by JPL for the period of September 1998 through December 2007, covering nearly a full solar cycle. The climatology consists of a 5-dimensional grid with a spatial resolution of 5ºx2.5º, a temporal resolution of 2 hours and 1 month, and 2 levels of solar activity.

The global mean TEC (GTEC) is used as the forcing parameter. For periods prior to 1998 that value is based on TOPEX dual-frequency measurements or on solar radio flux ($F_{10.7}$).

Conclusions

The new TEC climatology is relatively easy to construct and easy to evaluate.

The modelled TEC comes close to the JPL GIM results, and performs much better than other climatologies, like IRI2007 and DORIS, as well as IRI95 and Bent (not shown).

The climatology can link the TOPEX dual-frequency altimeter measurements to correct the simultaneous ERS-1 and ERS-2.

When used to correct earlier altimeter missions, prior to the GPS era, the climatology significantly improves the mean sea level record.

References

Komjathy, A., and G. H. Born, GPS-based ionospheric corrections for single frequency radar altimetry, *J. Atmos. and Solar-Terrestial Phys.,* 61 (16), 1197–1203, 1999.

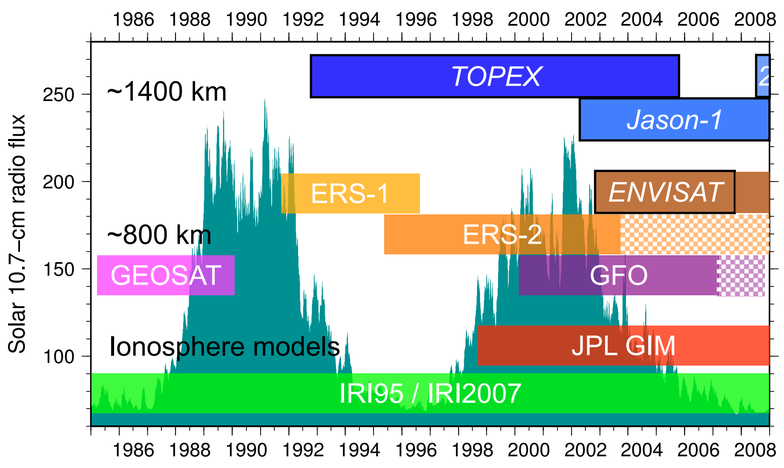
Bilitza, D., International Reference Ionosphere 2000, Radio Sci., 36 (2), 261–275, 2001.

Scharroo, R. ,W. H. F. Smith and J. L. Lillibridge, A new GPS-based climatology for the total electron content in the ionosphere, *in preparation.*

ftp://ibis.grdl.noaa.gov/pub/remko/nic08

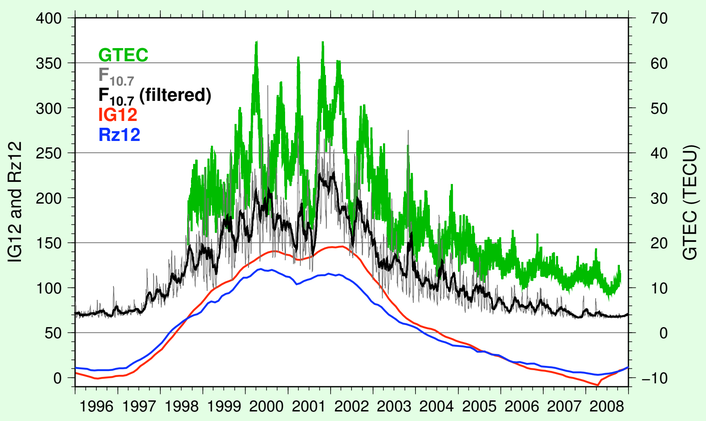
Motivation

- Single-frequency altimeters (Geosat, ERS-1, ERS-2, GFO, and recently, Envisat) require the use of a model to correct for the path delay which results from electrons in the ionosphere.
- The GPS-based JPL GIM (global ionosphere maps) suit well for this purpose, but start only in September 1998.
- Other climatologies (IRI95, IRI2007, Bent) are not sufficiently accurate.
- Hence, we attempt to build a climatology based on the JPL GIM maps.

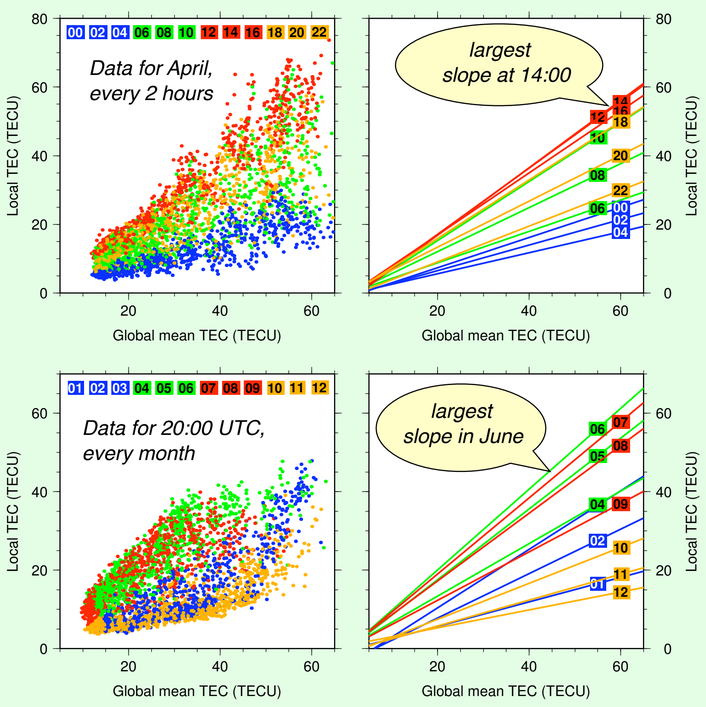


Modelling the TEC

- **Premise 1: Global mean TEC (GTEC) is a good proxy for the solar activity.**
- IRI uses the smoothed ionosphere index IG12 and sunspot number Rz12. Too smooth and does not follow rapid variations.
- GTEC leads to unbiased climatology, i.e. the mean result of the climatology is the same as the observed mean TEC.



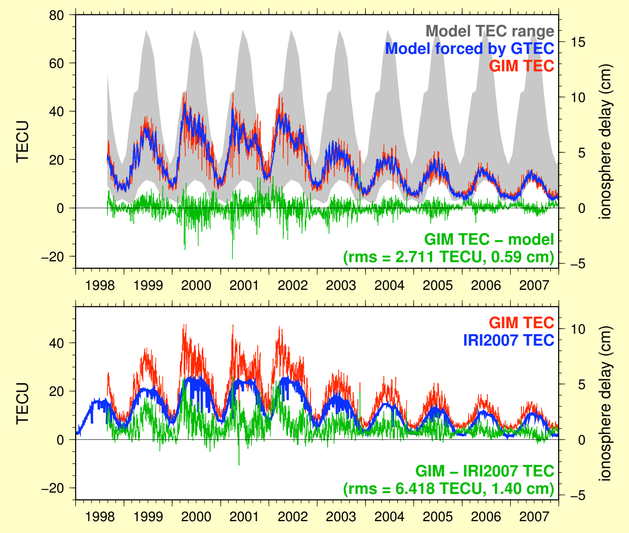
- **Premise 2: The TEC at any location depends linearly on GTEC.**
- Example: GIM grid node near Greenwich, England.
- GIM values distribute nicely depending on hour of day and month of year
- TEC most sensitive to GTEC around 14:00 UTC (also solar time) and in June.
- TEC varies little with GTEC around 04:00 UTC (solar time) and in December.
- Variation around day and year is not harmonic (as it is modelled in IRI). Use linear interpolation instead.



Local Comparison with GIM and IRI2007

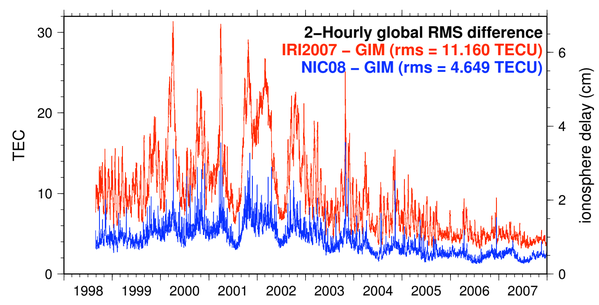
Comparison at Greenwich grid node:

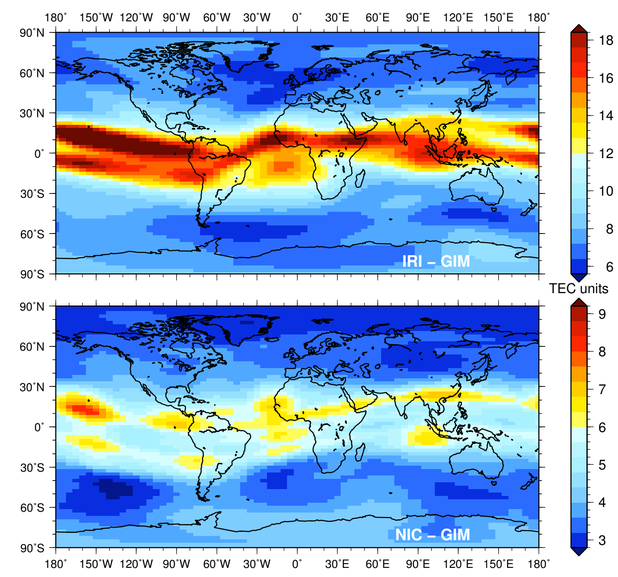
- **Grey area** indicates likely range of TEC.
  Upper limit: high solar activity
  Lower limit: low solar activity
- **Red** is GIM TEC
- **Blue** is climatology forced by GTEC
- **Green** is residual (2.7 TECU, 0.59 cm at Ku-band)
- **Blue** is TEC according to IRI2007
- **Green** is residual (6.4 TECU, 1.40 cm at Ku-band)



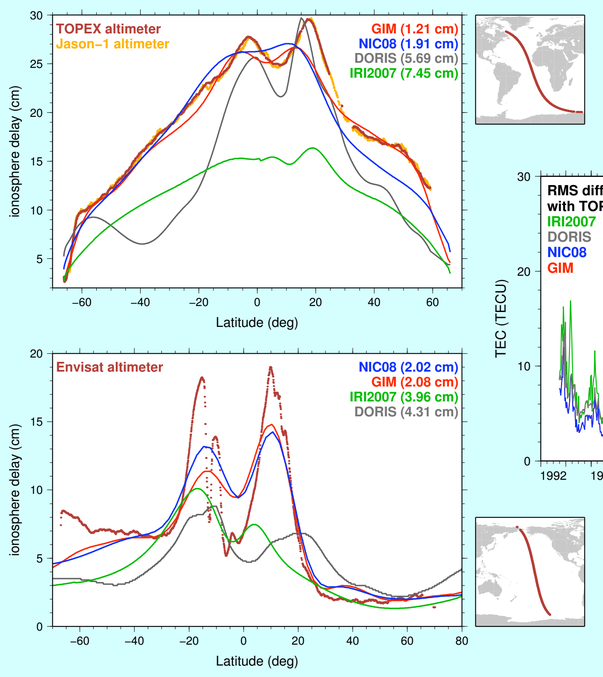
Global Comparison with GIM and IRI2007

- Note the factor 2 difference in the two colour bars.
- IRI2007 performs badly in the equatorial region and during high solar activity.

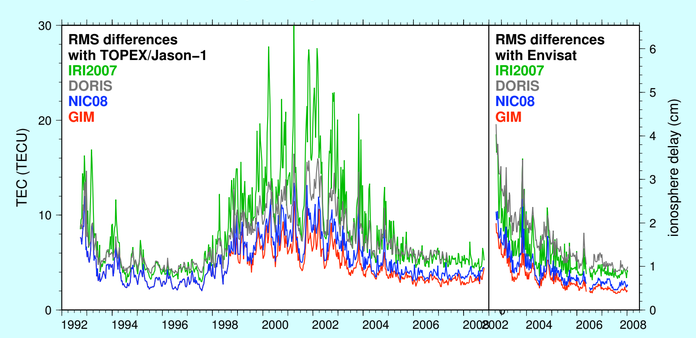




Comparisons with Dual-Frequency Altimeters



- Left: Individual altimeter passes of TOPEX/ Jason-1 (top) and Envisat (below)
- Below: Global RMS differences between dual-frequency altimeters and various models



- Even during high solar activity (2002) NIC08 performs well in comparison with dual-frequency altimeters; certainly much better than DORIS and IRI2007.

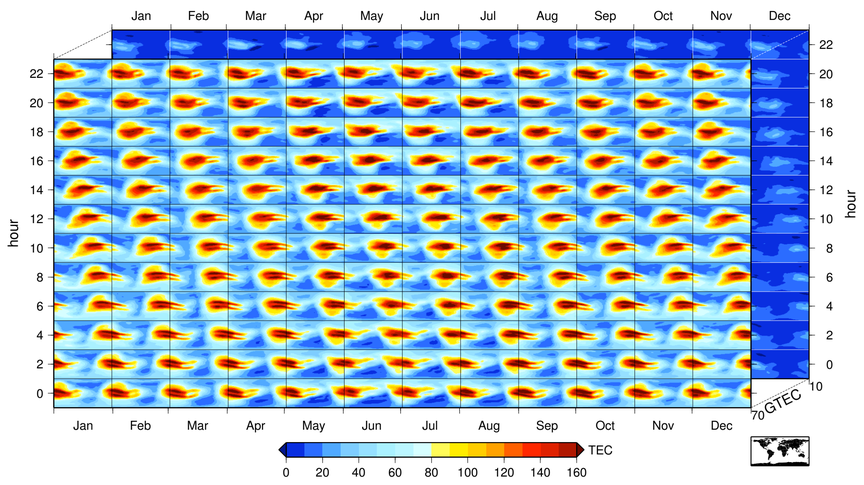
Climatology

- The climatology is a 5-dimensional array of TEC values. The coordinates are:

  Longitude: 5º, same as GIM, 73 nodes

  Latitude: 2.5º, same as GIM, poles added, 73 nodes

  Months: 12 monthly vertices determine piece-wise linear function



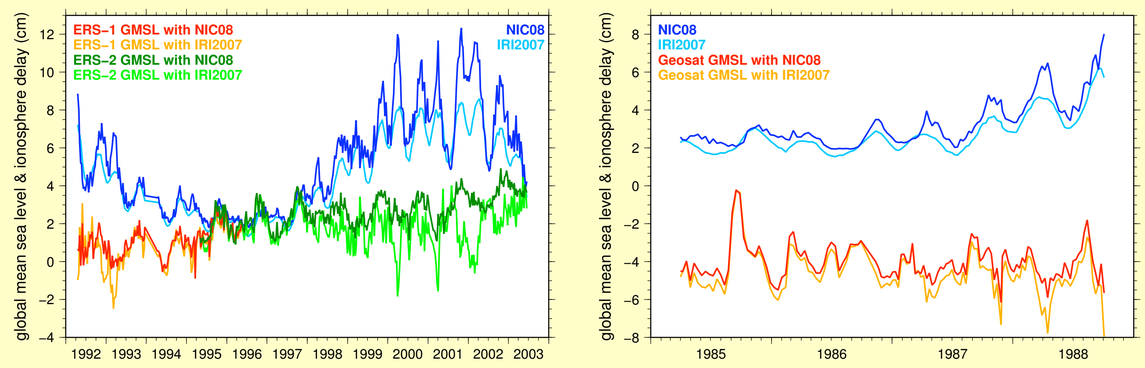
  Hours: 12 2-hourly vertices determine piece-wise linear function, even hours, same as GIM

  GTEC: 2 levels (10 and 70 TECU) to be interpolated linearly

- **72×71×12** independent solutions of **12×2** parameters: ***TEC (λ,ϕ,m,h,GTEC)***

Effect on Global Mean Sea Level

- NIC08 improves sea level time series. It removes peaks due to IRI2007 mean errors.



- Earlier GTEC can be determined from TOPEX dual-frequency altimeter measurements by inverting the climatology.
- Before that, GTEC is determined from solar flux values using a similar climatology: *GTEC(m,h,$F_{10.7}$).*