Current status and expected improvements of ionospheric reprocessing

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Motivation

- ✓ Reprocessing of IGS VTEC maps (GIMs) was officially solicited to Iono WG, five months ago.
- ✓ Different ionospheric analysis centers are upgrading their techniques in the last years (increase of temporal resolution –ESA-, combination of both physical models and data –JPL-, use of Kriging for interpolation –UPC-…)
- ✓ Both circumstances converts the IGS reprocessing campaign in a good opportunity to significantly improve the IGS ionospheric products.
- ✓ In this context:
  - We will show the first results of UPC reprocessing within the 3-months campaign during 2000.
  - We will show the possibility of improving the VTEC maps of **any center** by applying the Kriging technique in a simple and straightforward way.

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Kriging interpolation

- Kriging was developed in geostatistics for mining purposes.
- It takes into account the spatial correlation between the N known values in order to weight them to get an optimal interpolated estimate: potentially useful in regions with few available GPS data!

Interpolated value

$$Z_0^* = \sum_{i=1}^{N} \omega_i \cdot Z_i$$

Observations

Weight computed with Ordinary kriging

$$\sum_i \omega_i \gamma_{ij} + \lambda = \gamma_{i0}$$

Describes the correlation of data as a function of the distance

Semivariogram **between the given points**

Semivariogram **between the given and interpolated points**

Kriging interpolation

How to apply kriging to GIM estimation?

- The mean values and standard deviation of the data (VTEC residuals) should be independent of the location (for Ordinary Kriging equations).
- It is necessary to chose a suitable base model to compute residuals:
  - In particular the climatological IRI model behaves better than a plain planar fit as a VTEC background model.
  - And the GPS data driven model ("classical" VTEC maps in IONEX format) behaves better than the IRI one.

Obtaining TEC from IONEX

$$L_I = STEC + B_I$$

$$\hat{B}_I = < L_I - STEC_{IONEX} >$$

STEC IONEX used to compute the LI Bias (BI)

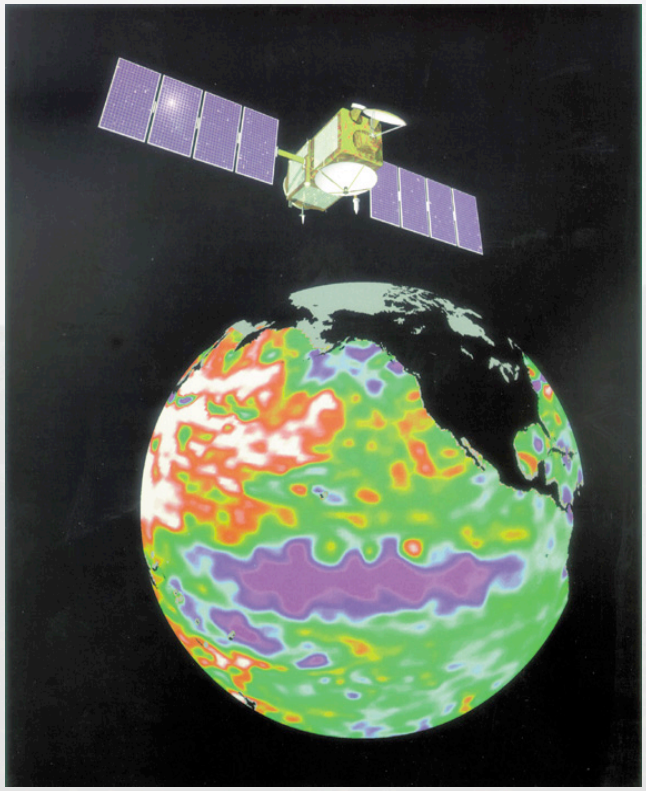
$$STEC_{IONEX\_aligned} = L_I - \hat{B}_I$$

$$TEC_{IONEX\_aligned} = STEC_{IONEX\_aligned} \cdot F_{IPP}^{-1}$$

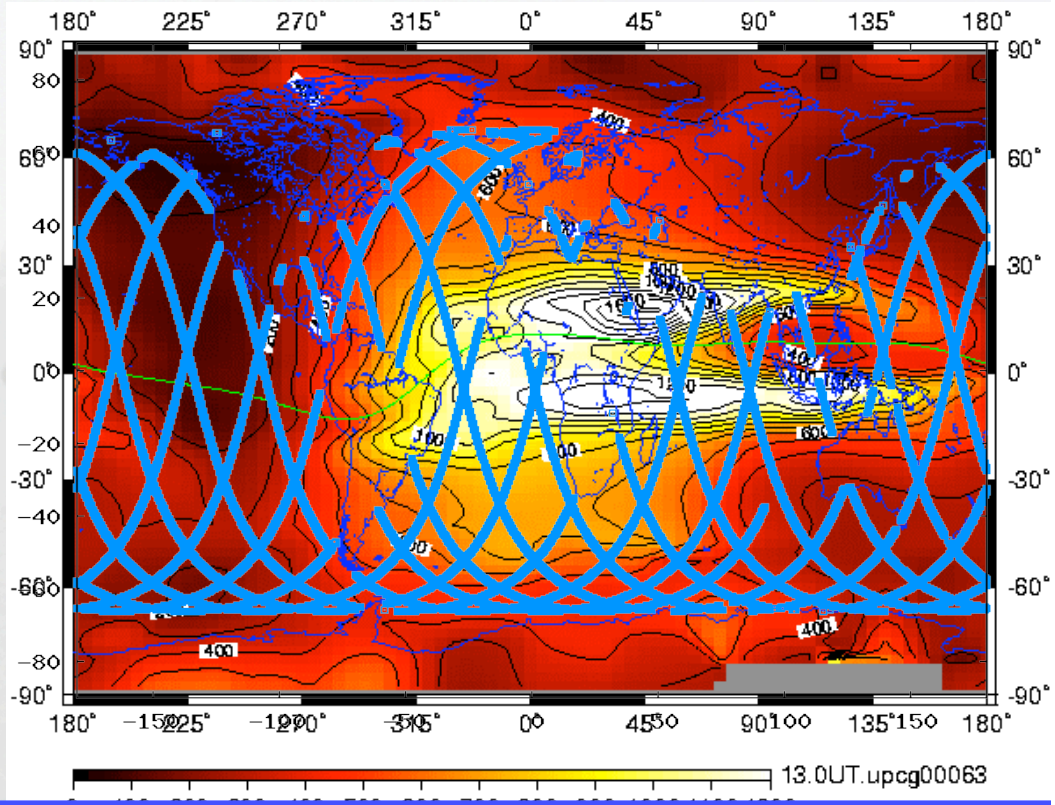
- The TEC is obtained from the STEC IONEX prediction ($STEC_{IONEX}$).
- It must be deprojected using an approximation of the mapping function (F_{IPP}).
- In this way the individual TEC estimates can be combined and interpolated by Kriging, from a global representative subset of ~150 receivers.

Testing the GIMs

Validation with VTEC observed by altimeters

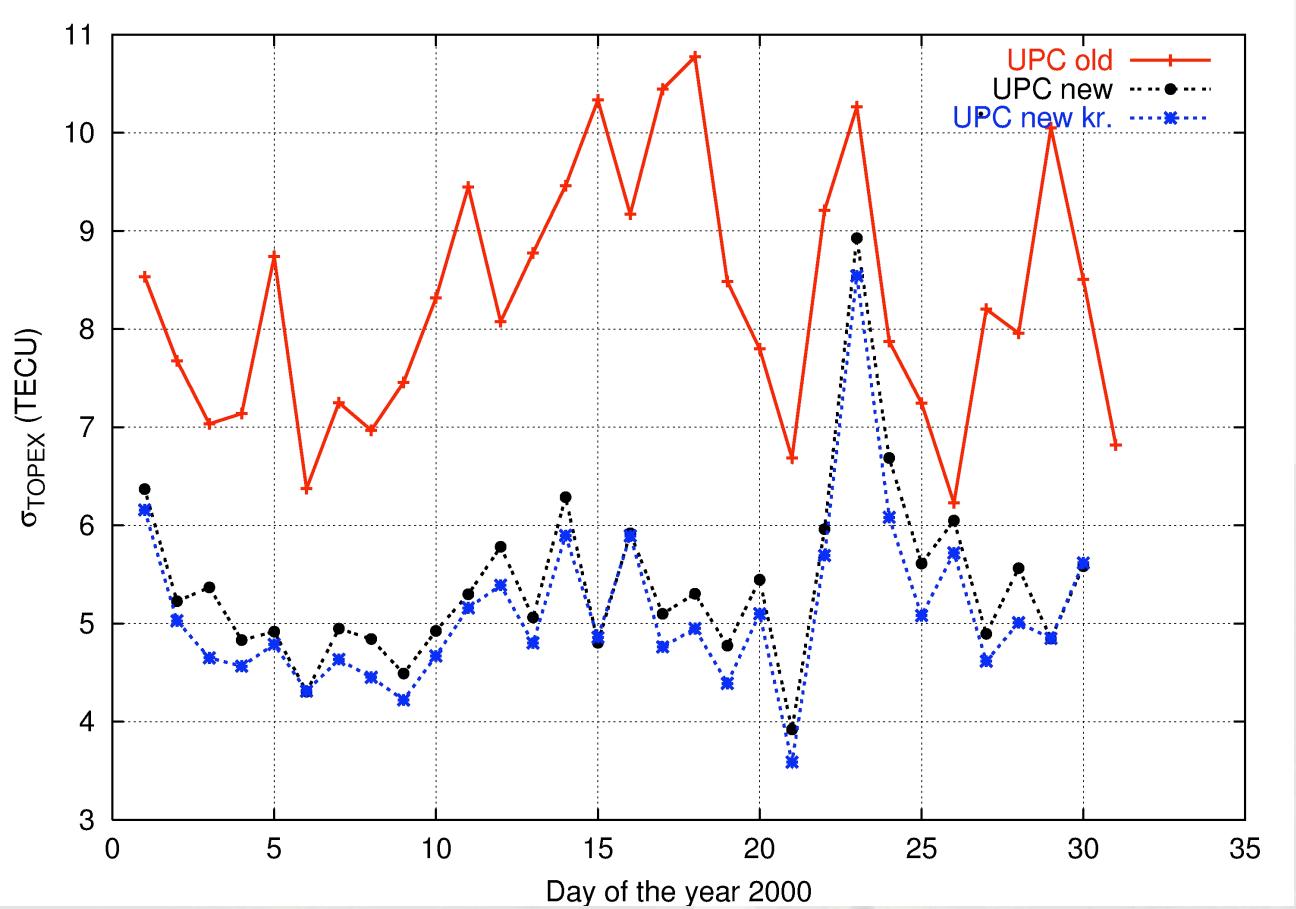


Day 063, 2000



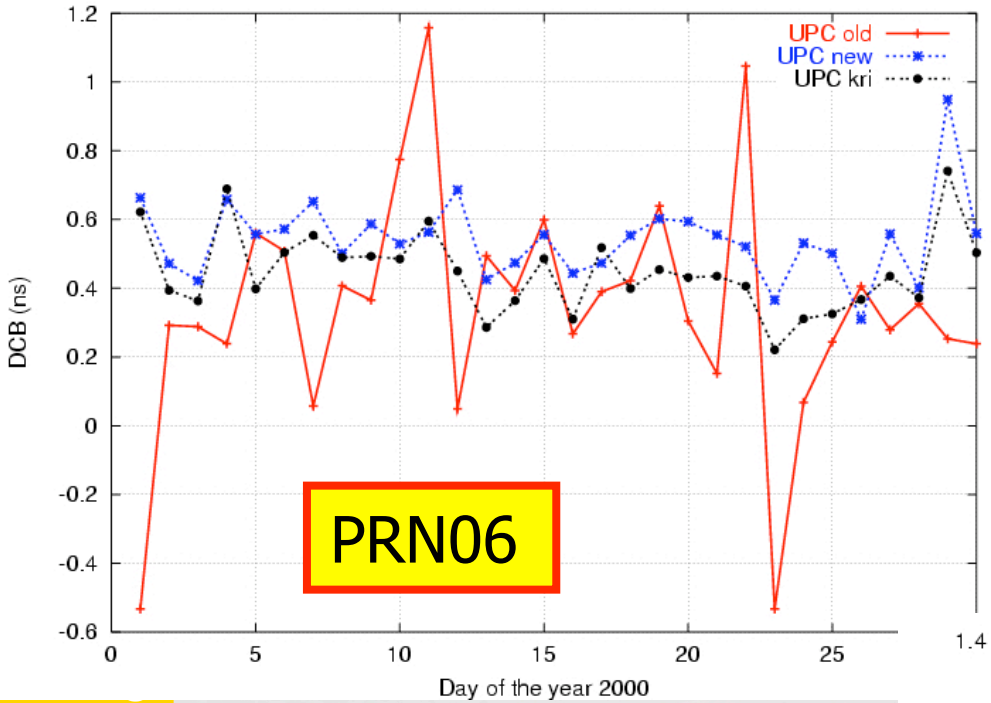
The direct VTEC measurements obtained from dual-frequency altimeters (TOPEX & JASON) over the oceans (typically far from GPS ground receivers) constitutes a good external data source of reference to characterize the iono maps accuracy in such "worst-case" scenario for GPS ionospheric maps.

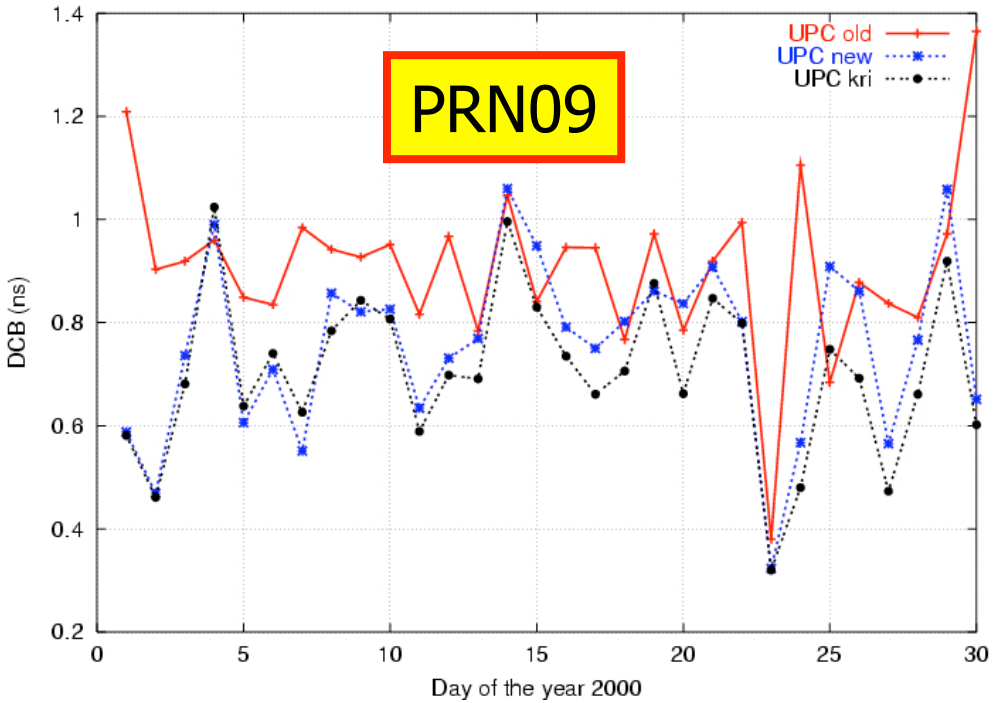
First UPC reprocessing results: VTEC compared vs. TOPEX (Std.Dev.)



Great improvement using the present UPC technique regarding to the available one during the last solar max, in 2000. An additional improvement is attained applying Kriging as well.

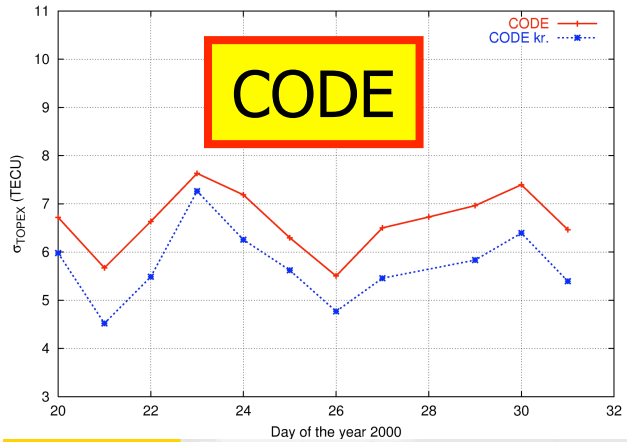
Reprocessing impact on Interfrequency biases (snapshot)

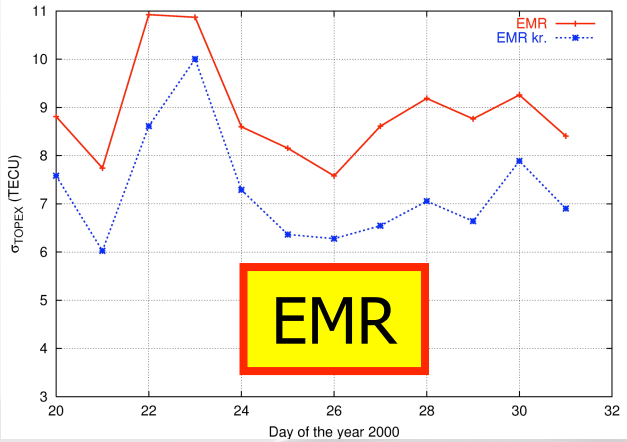


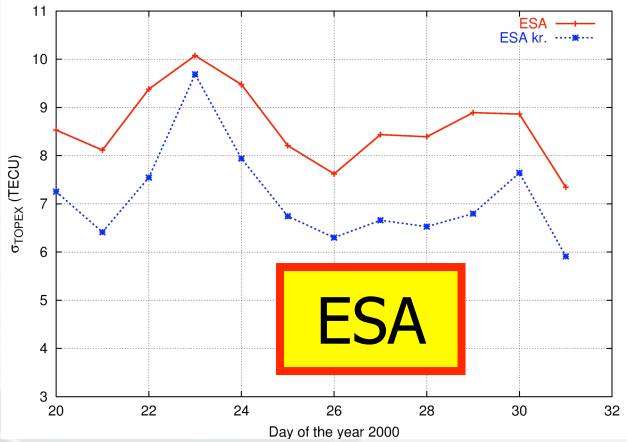


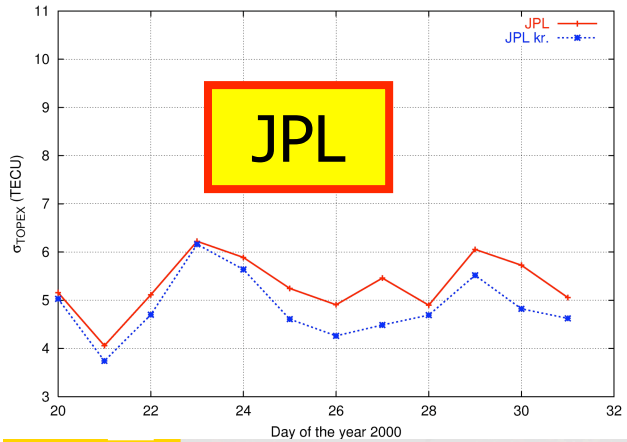
The DCBs computed as post-fit residual of PI regarding to the IONEX STEC, also benefits from the better performance of reprocessed VTEC maps (for instance DCB stability in top side plot)

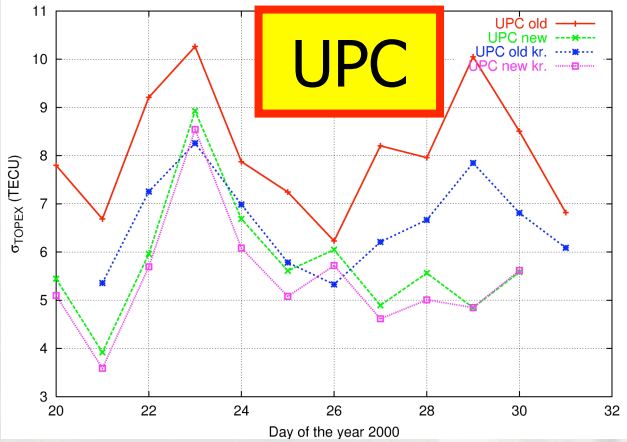
Applying the same approach to GIMS from other analysis centers

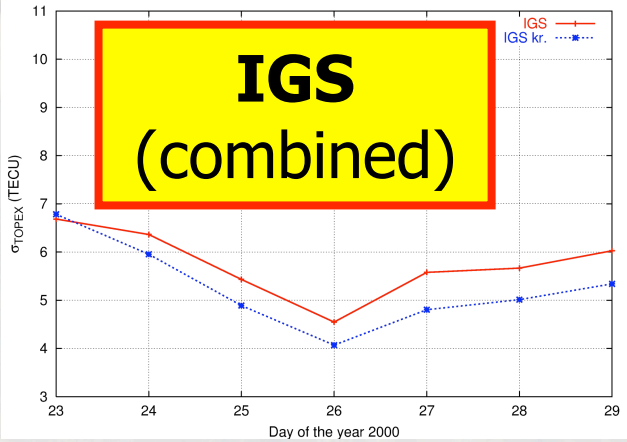






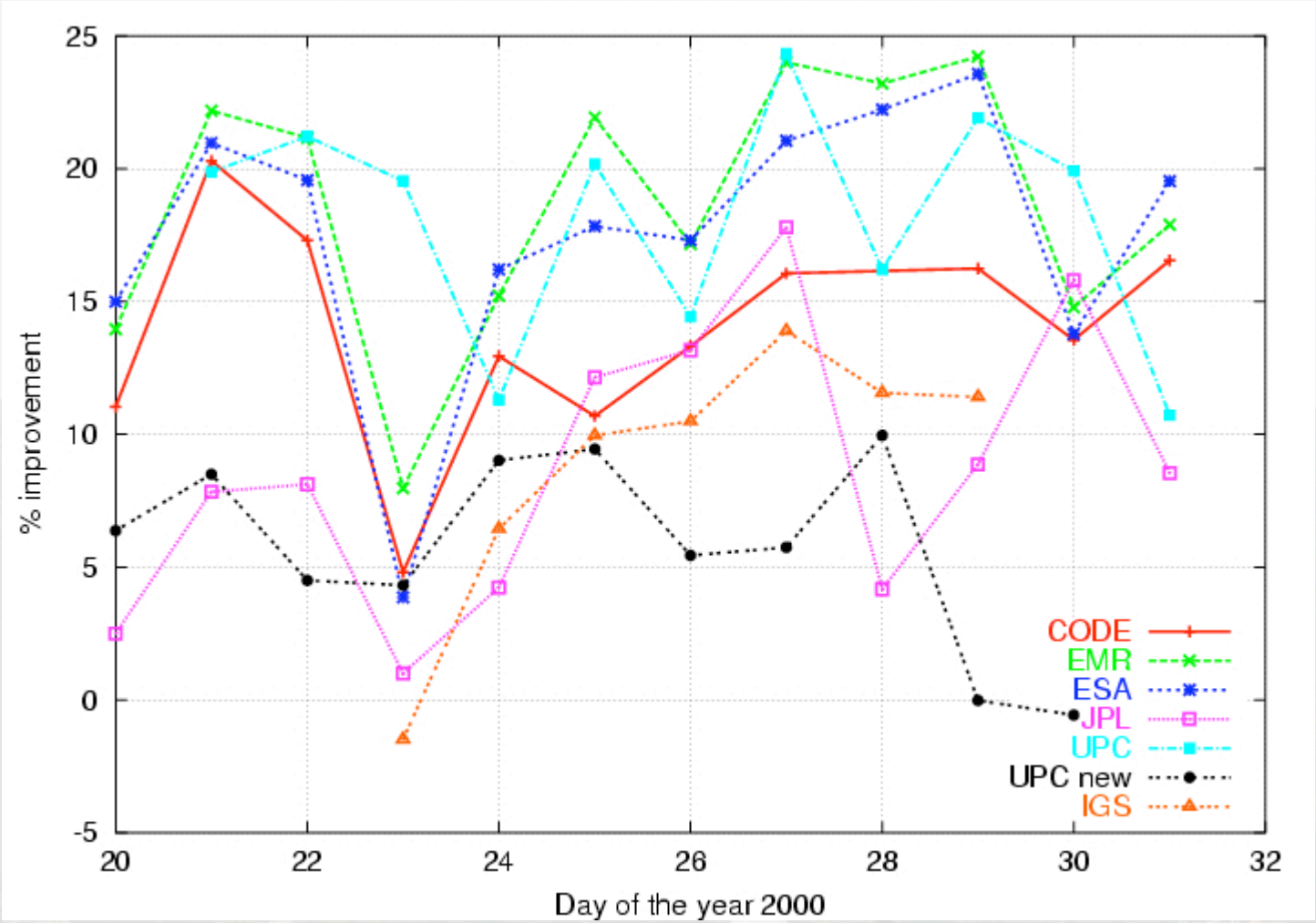






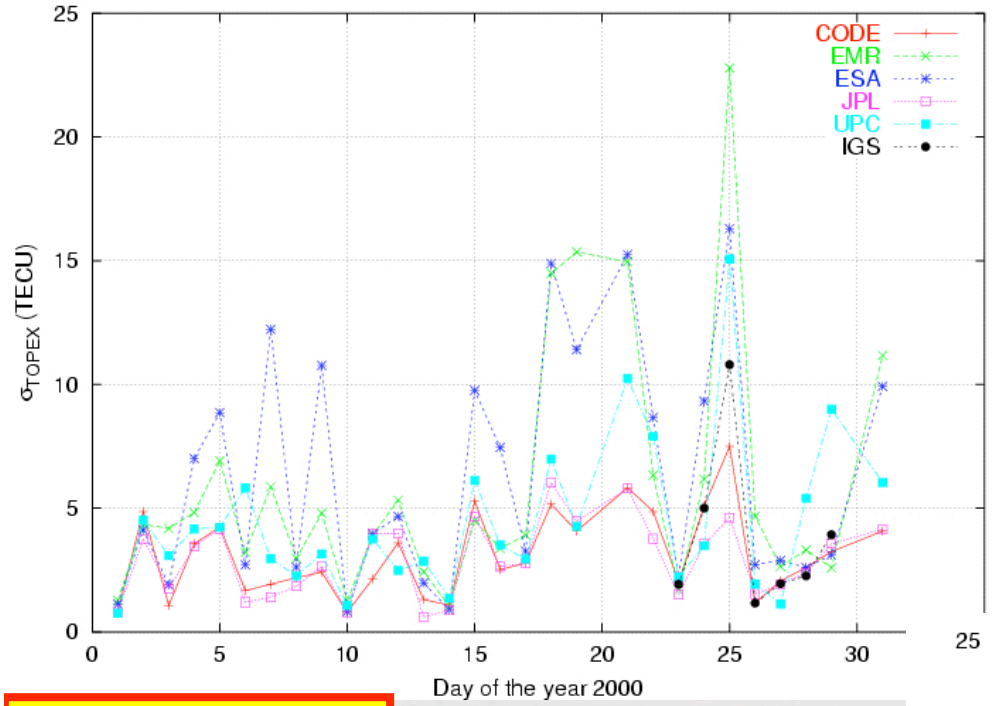
Systematic improvement applying the Kriging technique from ~0.5 to several TECU, for different GIM's center's as background models. A final improvement ~0.5 TECU on combined IGS GIM.

Relative improvement of Kriging reprocessing



Relative improvements range typically from 5 to 25%.

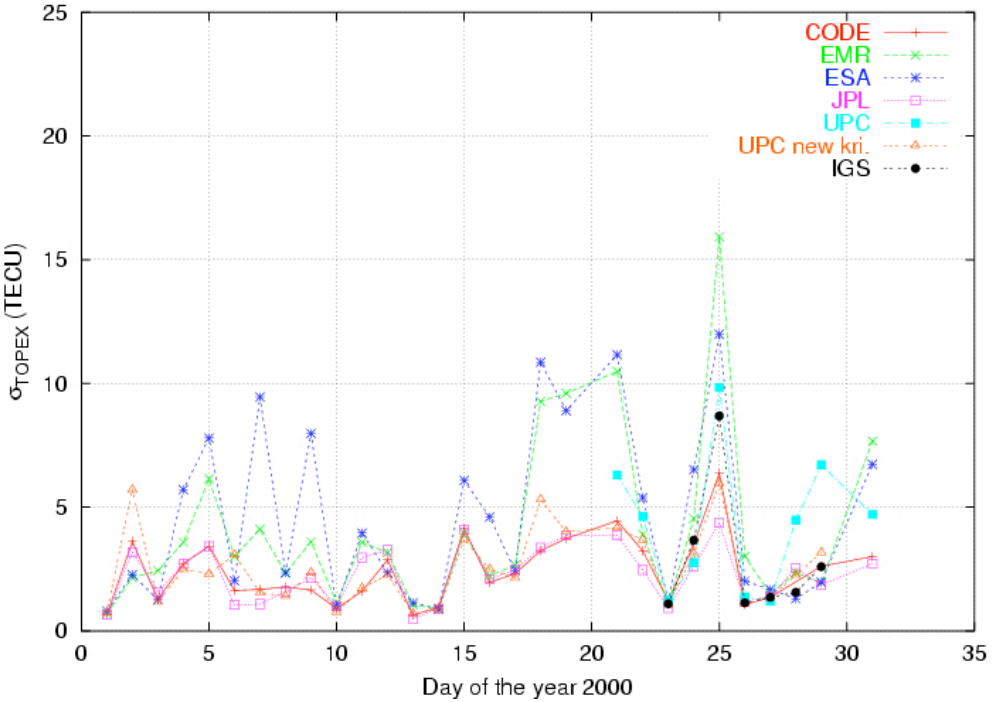
Low latitude improvement (Indonesia area)



Typical improvements up to 5 TECU (~1-3 TECU for IGS)

VTEC maps reprocessed with Kriging technique

Former (cddis) VTEC maps



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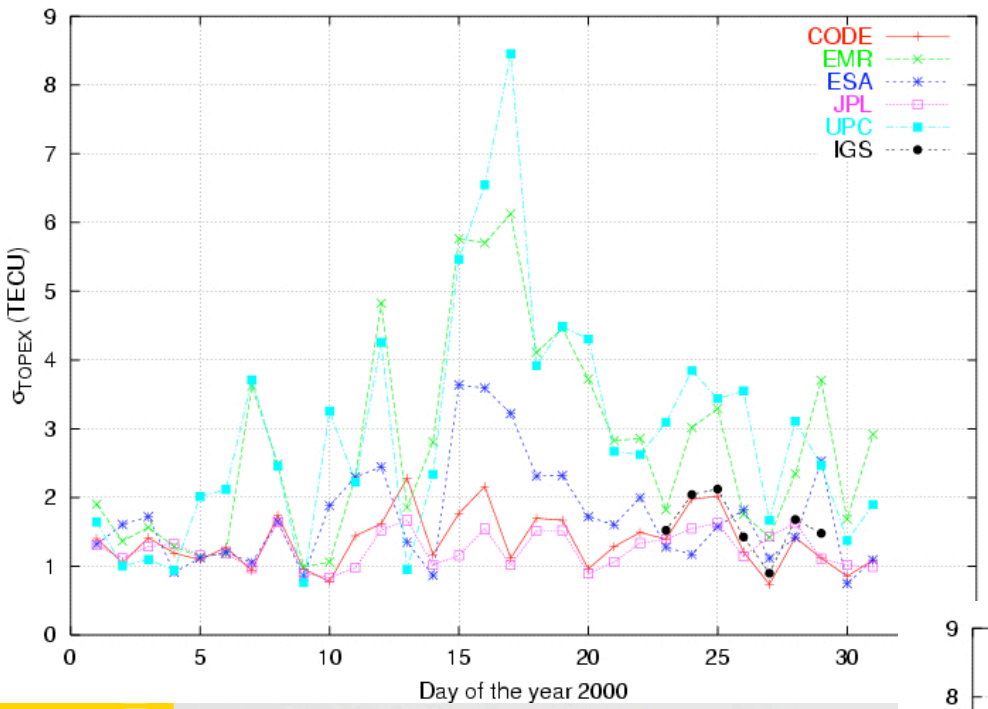
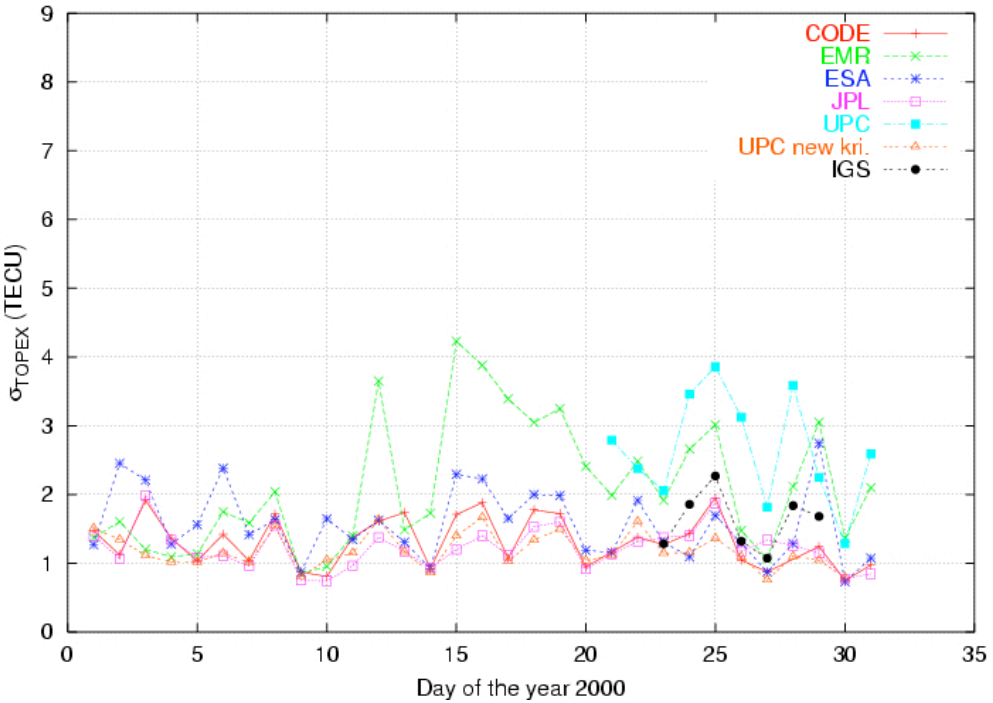
Mid latitude improvement (Mediterranean sea)



Typical improvements of 0.5-3 TECU or more

VTEC maps reprocessed with Kriging technique

Former (cddis) VTEC maps



Thank you! Conclusions

- ✓ UPC has started the reprocessing of its VTEC maps, in the context of the IGS reprocessing pilot project. An important improvement is being achieved.
- ✓ This has been done using a new technique, adapted from Kriging interpolation, and which takes into account the spatial correlations of the VTEC residuals, regarding a background model (the old VTEC map).
- ✓ Such technique is easily exportable, and significant improvements are also demonstrated for all the analysis centers taking its old VTEC maps as background model.
- ✓ Thus we encourage to the ionosphere IGS analysis centers to reprocess its VTEC maps with its new techniques (best option). Alternatively the Iono WG chairman could try to use the illustrated Kriging technique to reprocess and combine all of them (but there are presently serious threats of available manpower and resources).