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PRELIMINARY UPC VTEC FORECAST MODEL BASED ON IGS GIMs

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Short Outline

- Introduction to IGS Global Ionospheric Maps
- Prediction of IGS GIMs: UPC approach
- Results
- Conclusions and future steps

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IGS Global Ionospheric Maps

- The **IGS Iono-WG** was created in 1998 with the goal to generate reliable vertical TEC Global Ionospheric Maps (**GIMs**) using IGS network.
- Individual GIMs are computed by the IAACs: **CODE, ESA, JPL** and **UPC**.
- Evaluation and combination to create the IGS global VTEC products (**IGSG** and **IGRG**).
- All products in **IONEX** format, at 2h resolution and 2.5º/5º in longitude/ latitude resolution.
- Latencies of **9-16 days** for final GIMs and **1-2 days** for rapid GIMs.
- Long time series of GIMs available.
- More details can be found for instance in Hernández-Pajares et al. 2009.

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UPC prediction approach

· Short-term VTEC prediction model developed in the frame of IGS iono-WG.

· Preliminary **2-days** ahead VTEC forecast product developed and being automatically distributed through **CDDIS** FTP server on a daily basis.

· Interest for a wide variety of scientific and technological applications.

· Moreover, a preliminary combined product with ESA forecast product is being automatically generated and distributed as well.

· Current UPC approach based on taking long time series of UPC GIMs as input data and the use of **L**inear **R**egression combined with the **D**iscrete **C**osine **T**ransform (**LRDCT** method).

UPC prediction approach

- DCT coefficients as vertical and horizontal spatial frequency components.
- Spatial information of the whole image in each coefficient.
- Representation of data with a set of parameters of a generative model (DCT).

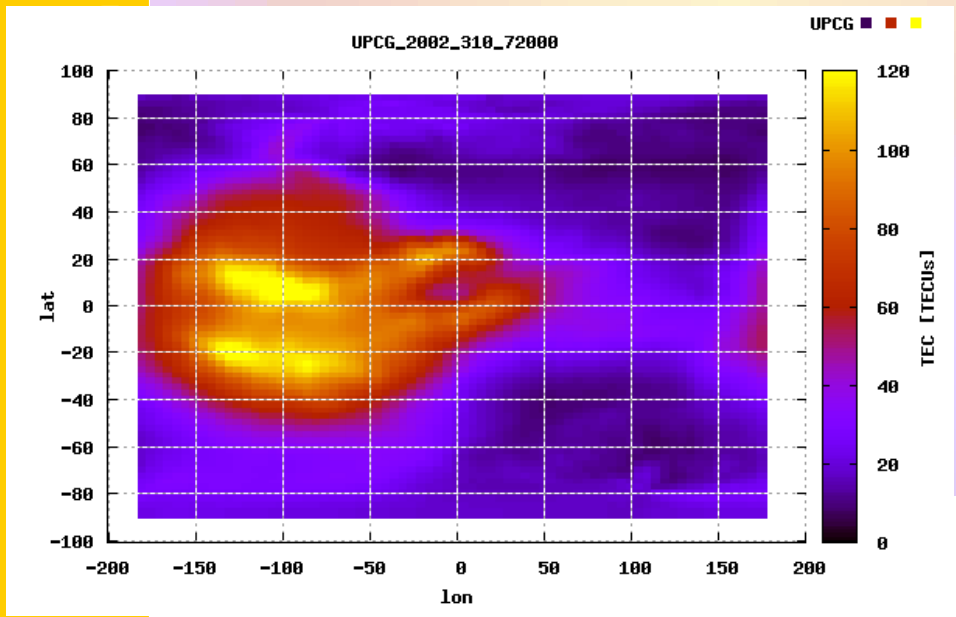
NxM samples are generated with a subset of $C_{p,q}$ (lower dimensional representation of the map)

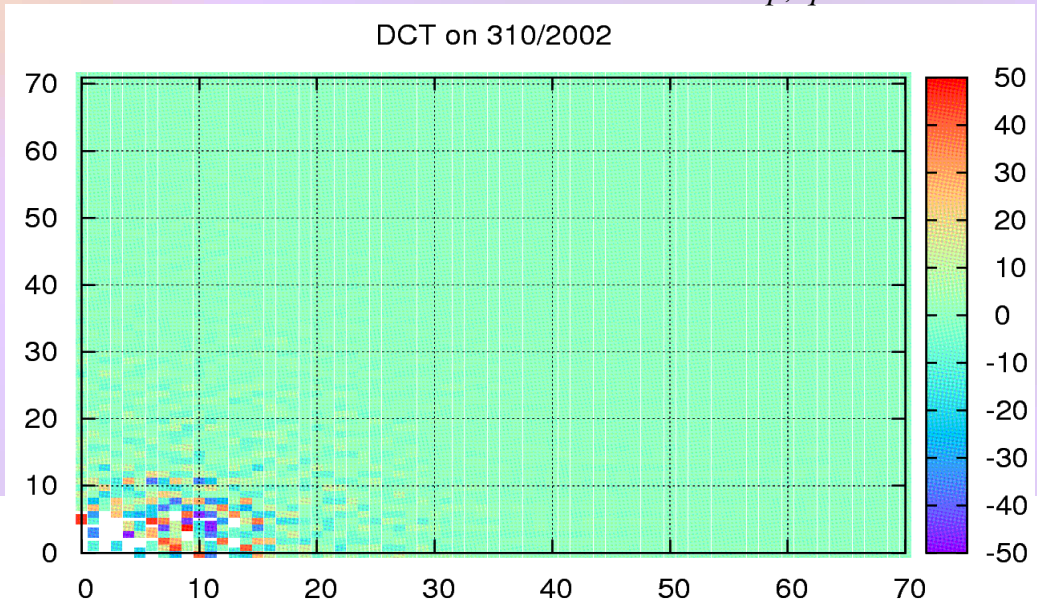
- Not evolution of a pixel but of the frequency components that generate the map (more robust).

$$C_{p,q} = \alpha_p \alpha_q \sum_{m=0}^{M-1} \sum_{n=0}^{N-1} x_{m,n} \cos \frac{\pi(2m+1)p}{2M} \cos \frac{\pi(2n+1)q}{2N}$$

Original image MxN: $\chi_{m,n}$

DCT image PxQ: $C_{p,q}$





UPC prediction approach

Training

- The model is trained using a **training dataset** of one year of final (best) available UPC GIMs (13 independent models per day).
- Every single GIM in the training dataset is transformed in a Sun fixed reference frame using the **DCT**.
- A **L**inear **R**egression is applied to each of the DCT coefficients → the prediction is done on the DCT coefficients.

$$\widehat{C_{p,q}}[t_0 + v] = \omega_0 + \sum_{u=1}^{U} \omega_u \cdot C_{p,q}[t_0 - u + 1]$$

where ω_0 and ω_u are the **regression coefficients** to be adjusted with the training set.

- Adjustment by finding the relation between all the training subsets of seven days and their corresponding known reference values.
- Additional information may be added so that regression coefficients will also be adjusted to it.

UPC prediction approach

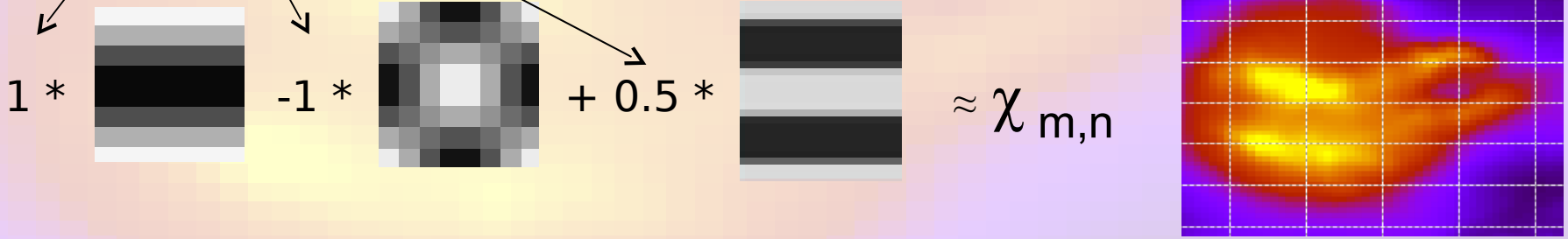
Prediction

- The model is applied to the **model's input dataset**, i.e. the available UPC GIMs for last seven days.
- Every single GIM in the training dataset is transformed in a Sun fixed reference frame using the **DCT**.
- Applying the adjusted regression coefficients to model's input set to obtain the DCT coefficients that will generate the predicted map.
- Inverse DCT, and convert to longitude/latitude before encapsulating in IONEX format.

UPC prediction approach

Intuitive idea behind the method

$$C_{p,q} = \alpha_p \alpha_q \sum_{m=0}^{M-1} \sum_{n=0}^{N-1} x_{m,n} \cos \frac{\pi(2m+1)p}{2M} \cos \frac{\pi(2n+1)q}{2N}$$



Building blocks analogy: The image/map is constructed from a series of building blocks (DCT basis functions)

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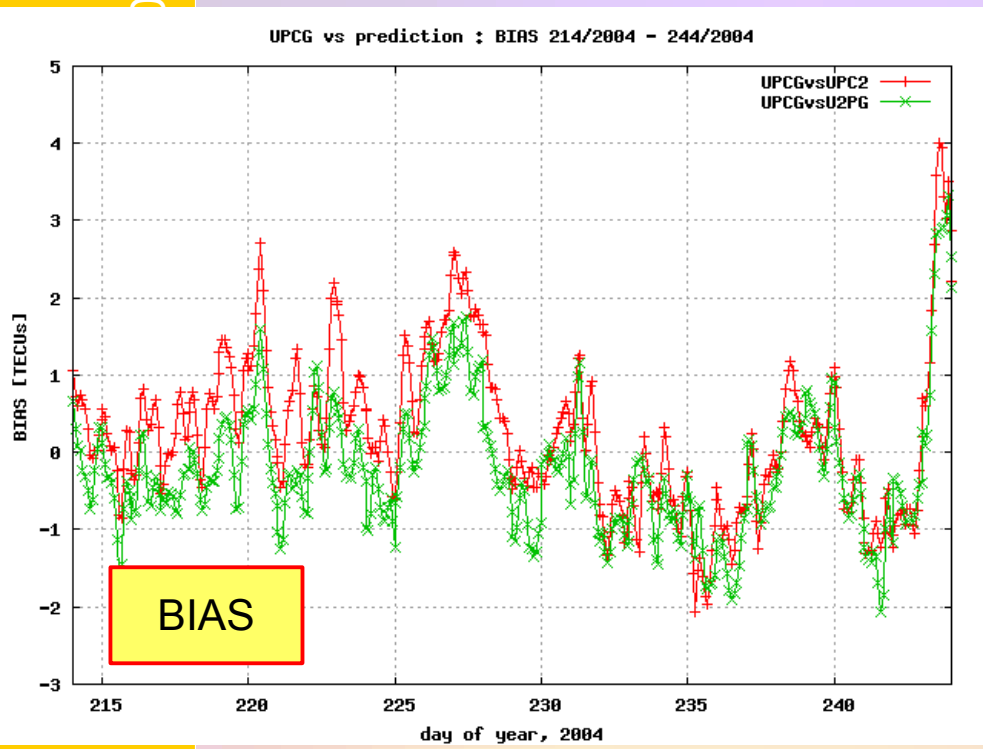
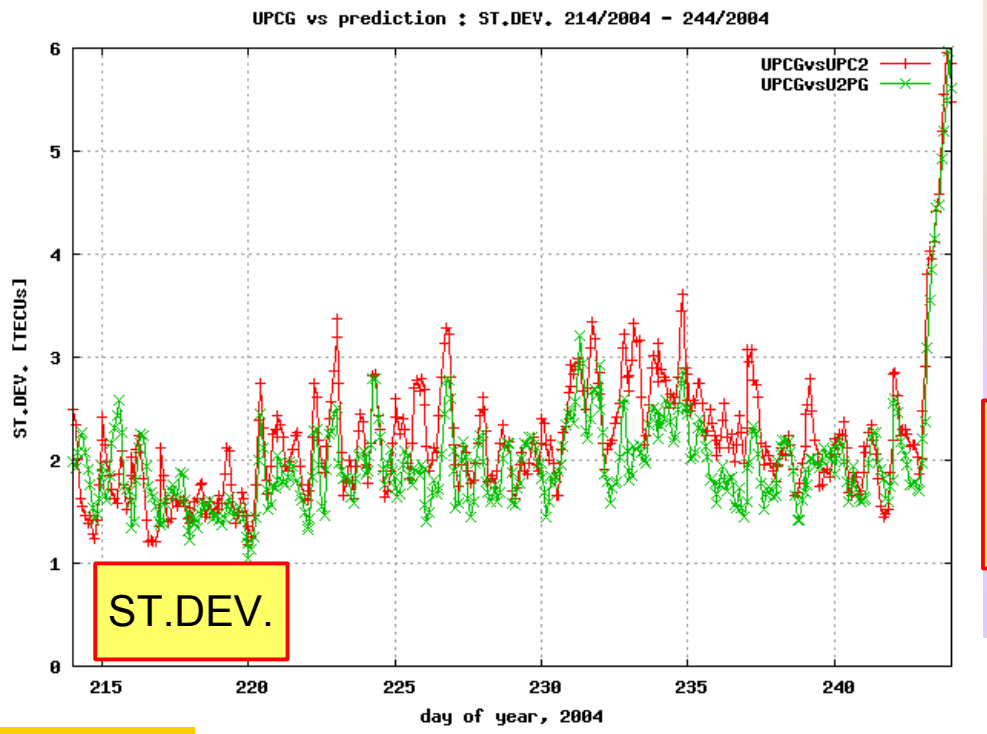
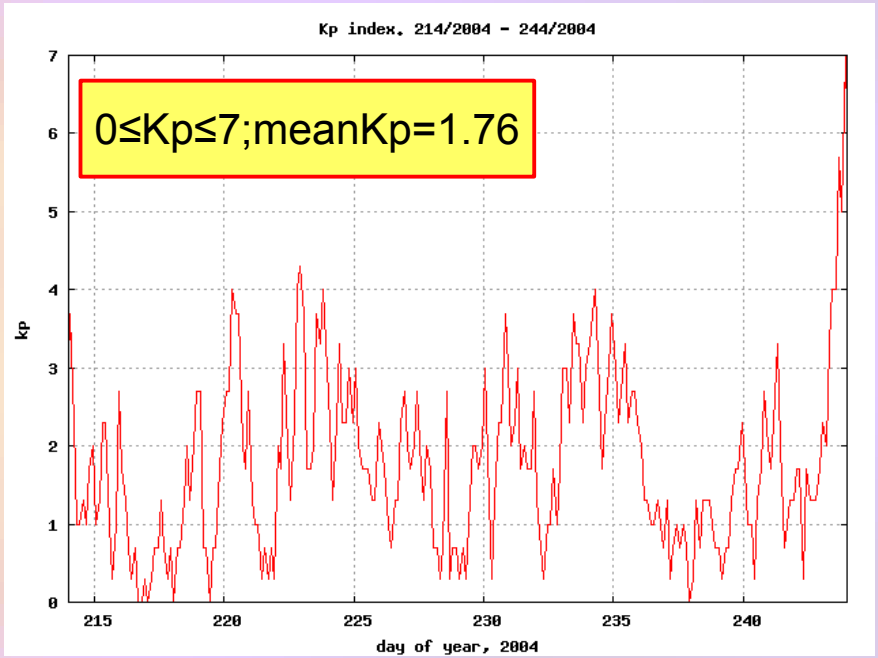
Validation with Final UPCG GIMs

One month period
214 – 244, 2004



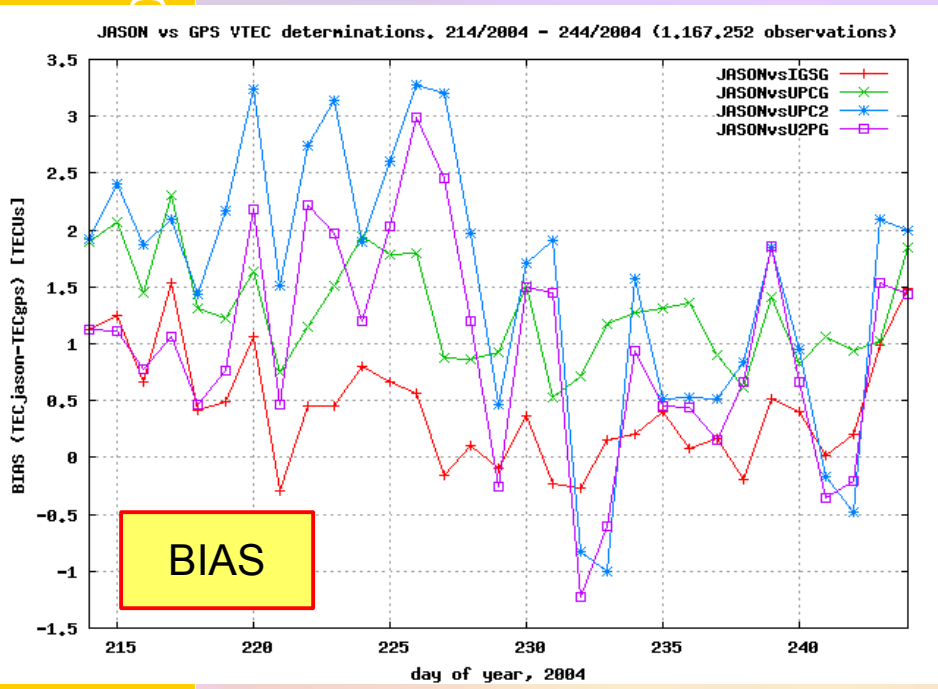




- UPCGvsU2PG overall RMS results show an RMS improvement of 10.9 % with respect to UPCGvsUPC2 .
- X-class flare on 226 and 231 (GOES).

External validation: JASON VTEC

One month period
214 – 244, 2004



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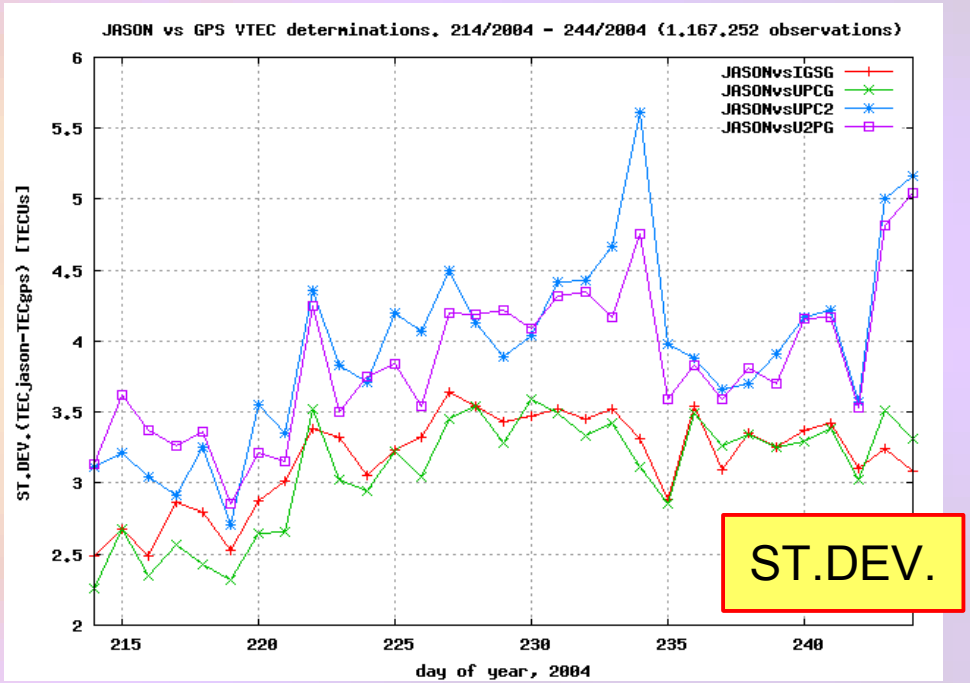

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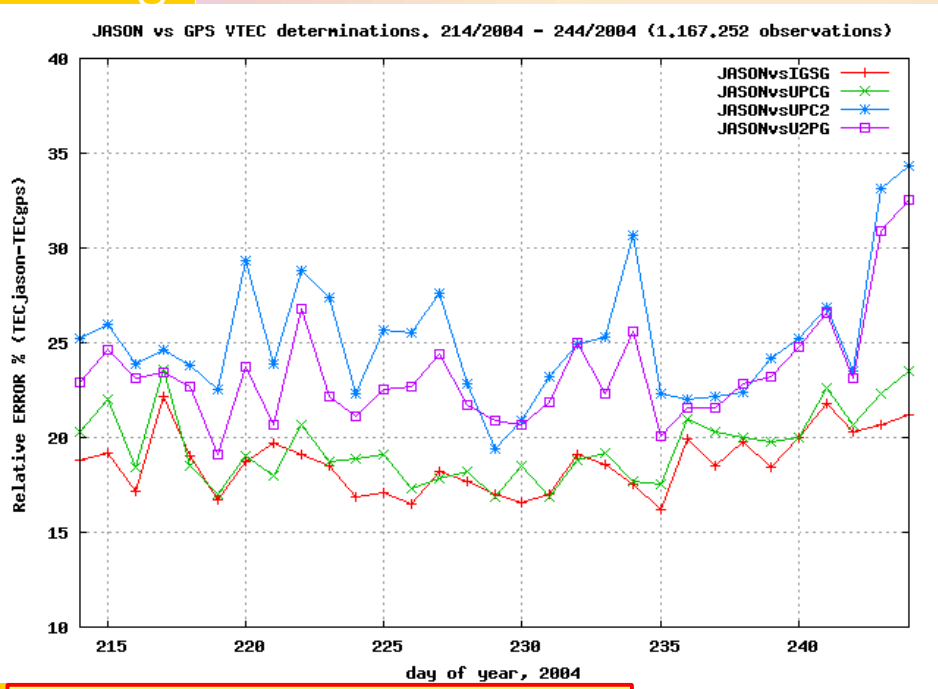
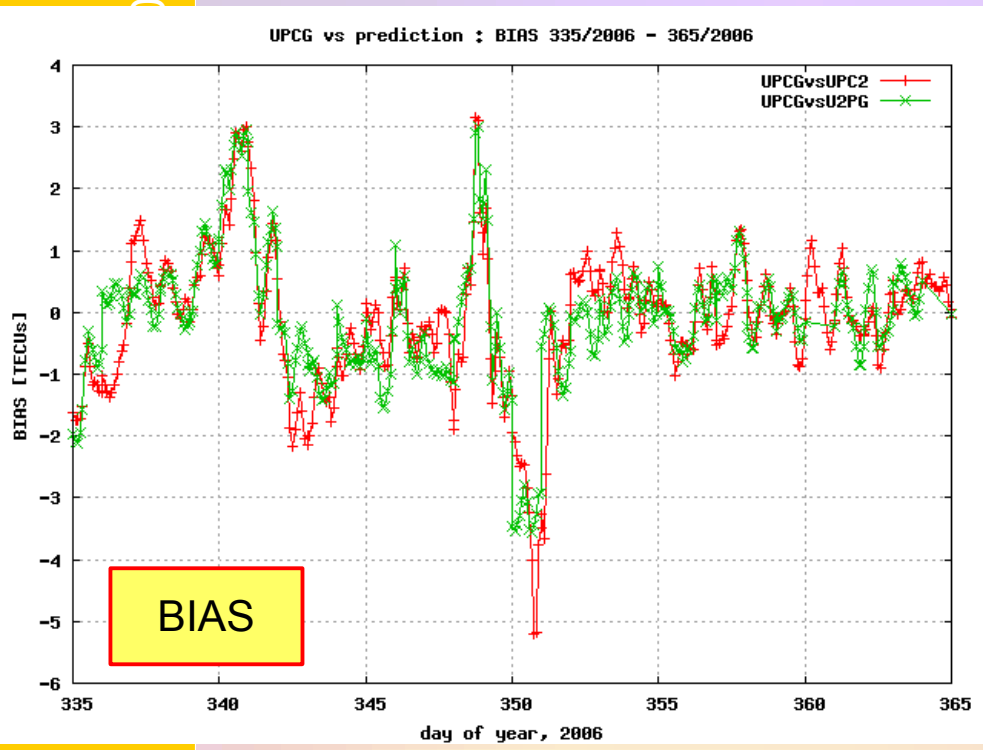


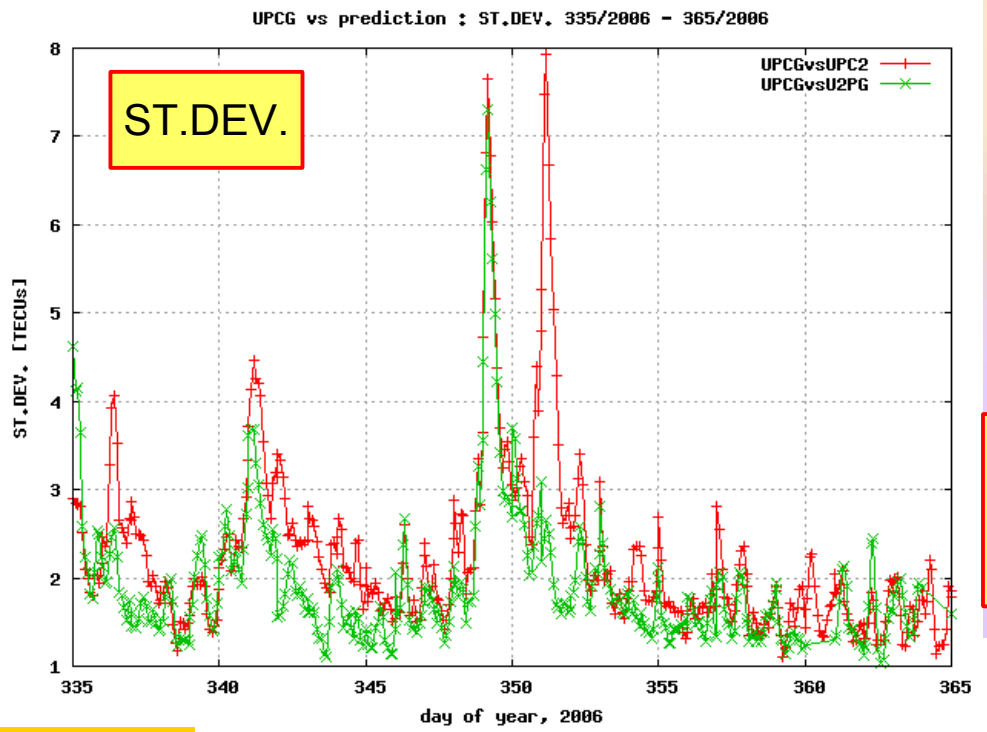
ERROR % (RMS/meanVTEC)

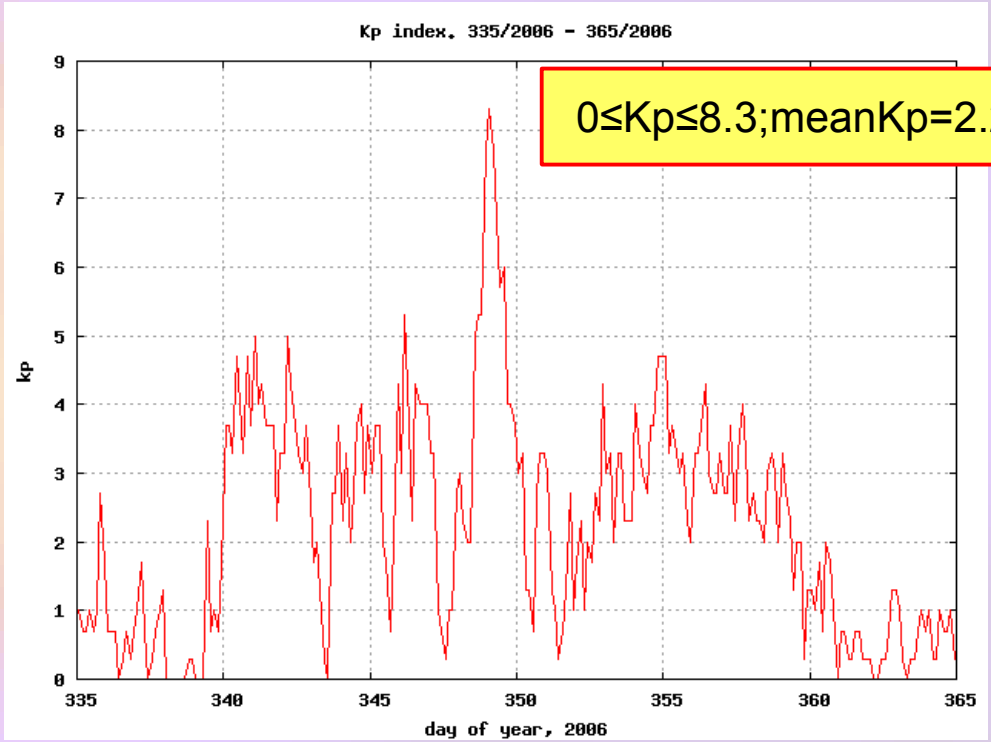
- U2PG overall RMS results are 22.1% worse than UPCG ones and UPC2 are 32.5% worse.

Validation with Final UPCG GIMs

One month period
335 – 365, 2006



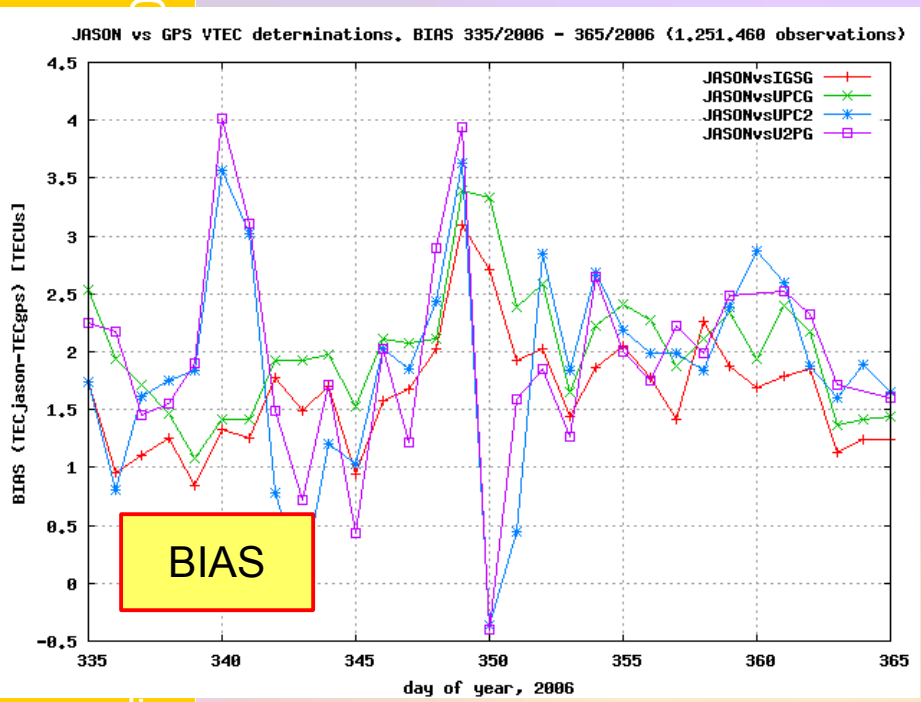




- UPCGvsU2PG overall RMS results show an RMS improvement of 16.6 % with respect to UPCGvsUPC2 .
- X-class flares on 340, 347 and 348 (recorded by GOES). Geomagnetic storm on 348.

External validation: JASON VTEC

One month period
335 – 365, 2006



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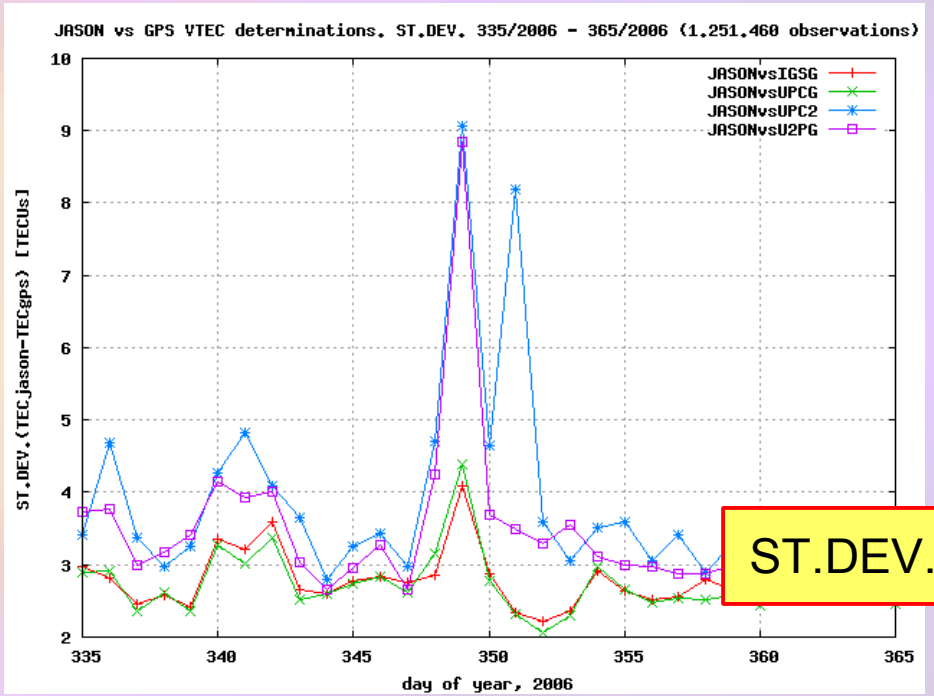

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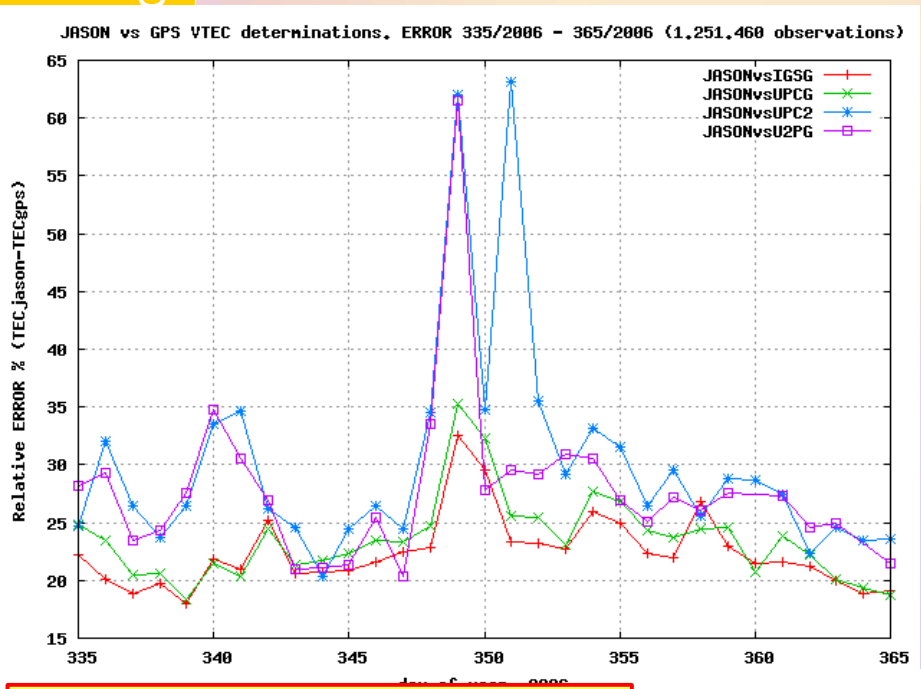
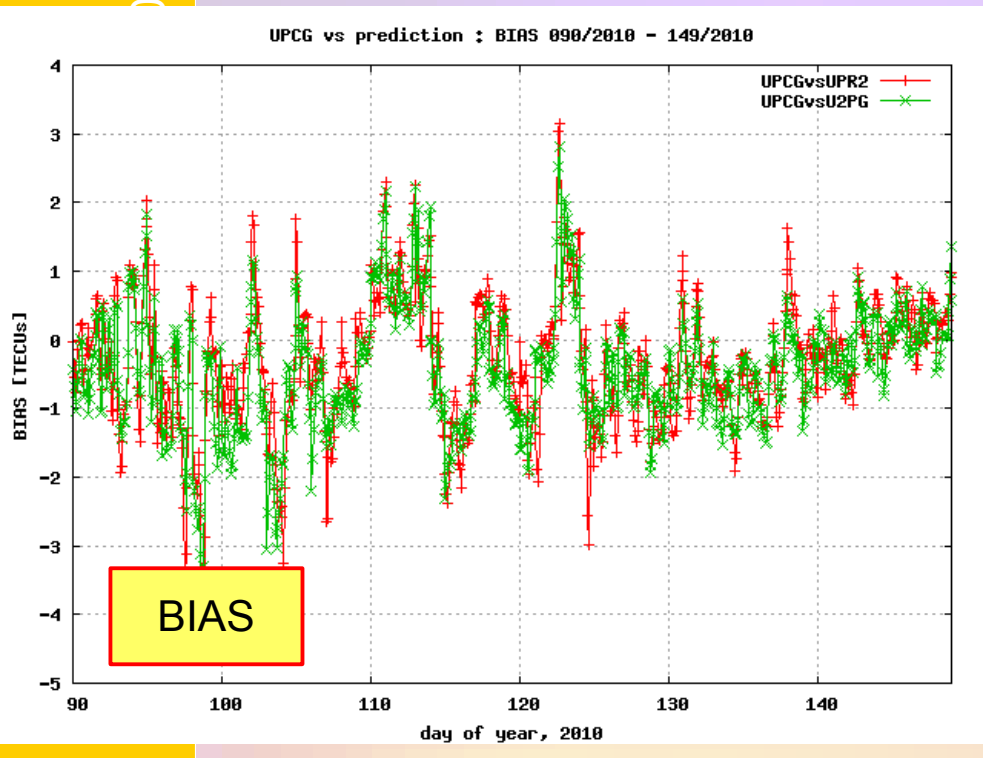


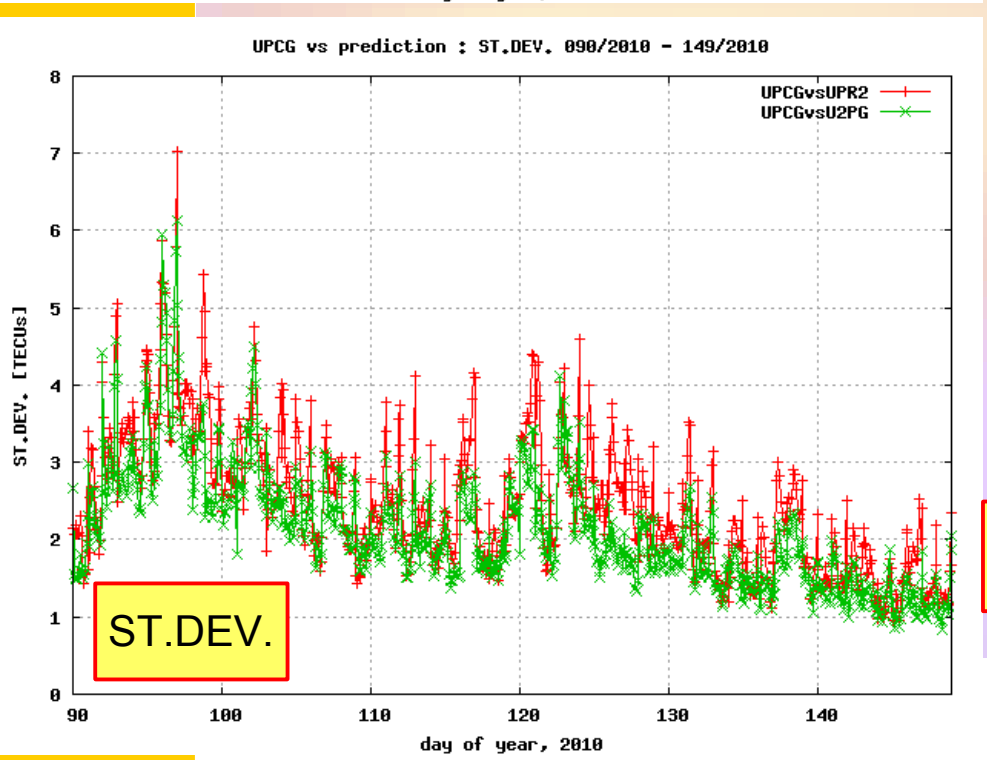
ERROR % (RMS/meanVTEC)

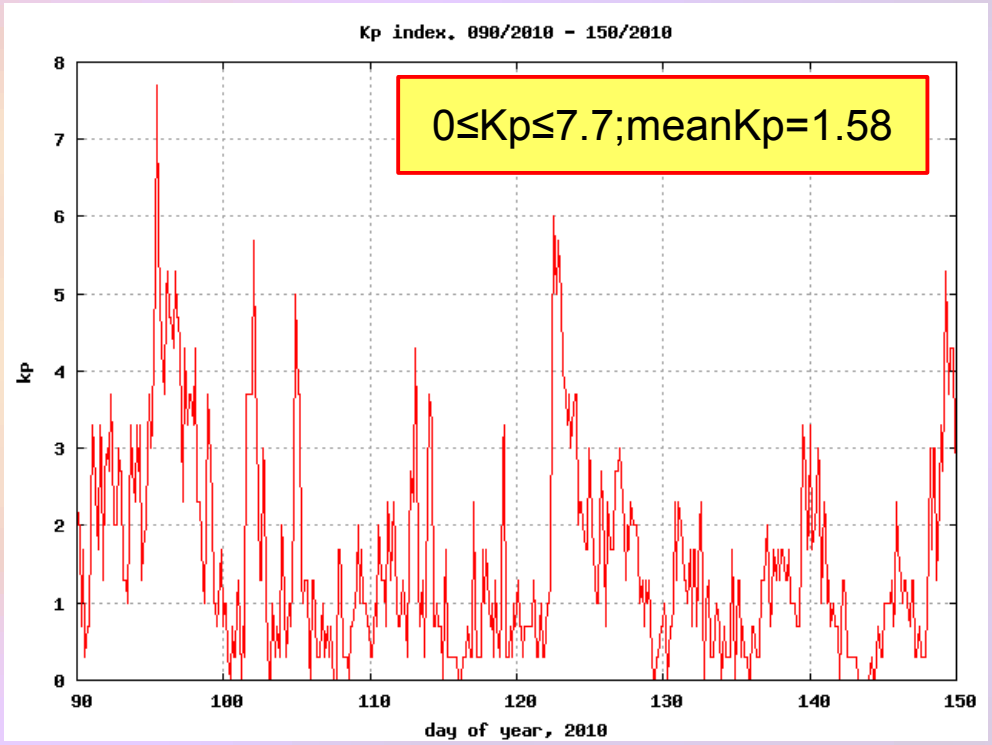
- U2PG overall RMS results are 21.1% worse than UPCG ones and UPC2 are 30.6% worse.

Validation with Final UPCG GIMs

Last two months period
90 – 149, 2010



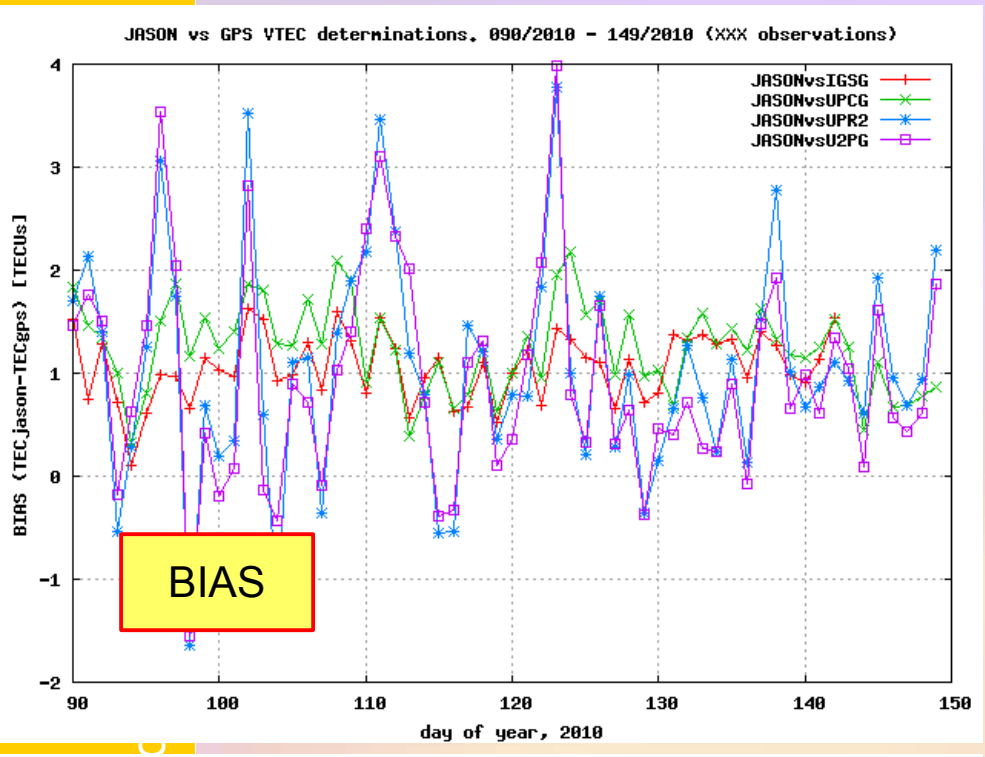




•UPCGvsU2PG overall RMS results show an RMS improvement of 13.3 % with respect to UPCGvsUPR2 .

External validation: JASON VTEC

Last two months period
90 – 149, 2010



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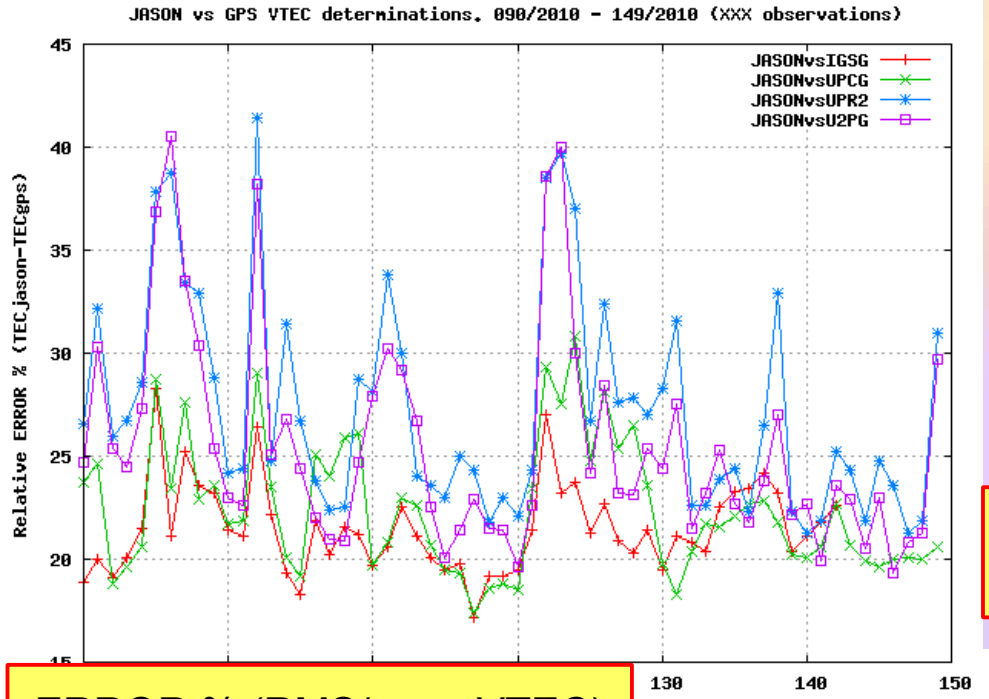
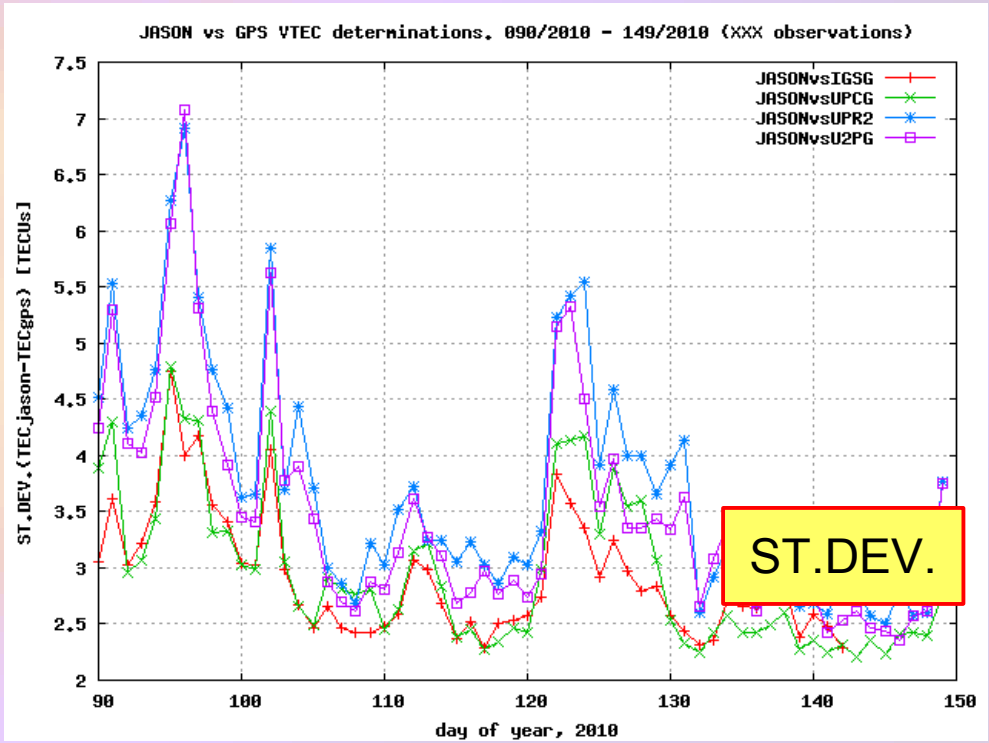


ERROR % (RMS/meanVTEC)



ST.DEV.

•U2PG overall RMS results are 17.4% worse than UPCG ones and UPC2 are 24.7% worse.

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Conclusions & future steps

- UPC current prediction model provides better results for the selected periods than non-variant ionosphere with similar results to predicted global VTEC maps from other IAACs.
- UPC forecast product generated in test mode for more than one year without major problems.
- Moving from a preliminar to an official UPC IGS forecast product seems feasible in less than one year.

Future steps

- Improvement of the LRDCT model under different geomagnetic/solar conditions
- Comparison with other prediction methods such as Neural Networks.
- Assessment on the use of different models or parameters in function of the geomagnetic/solar activity.
- Tests with additional physical information (Solar Flux, Kp, etc).

Acknowledgements

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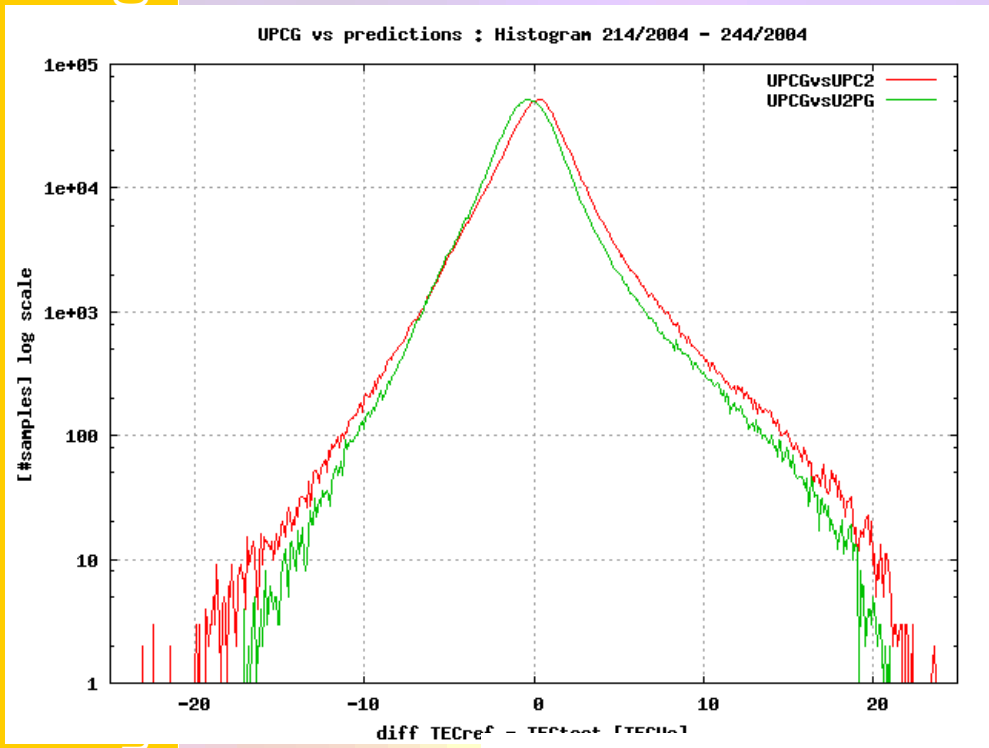
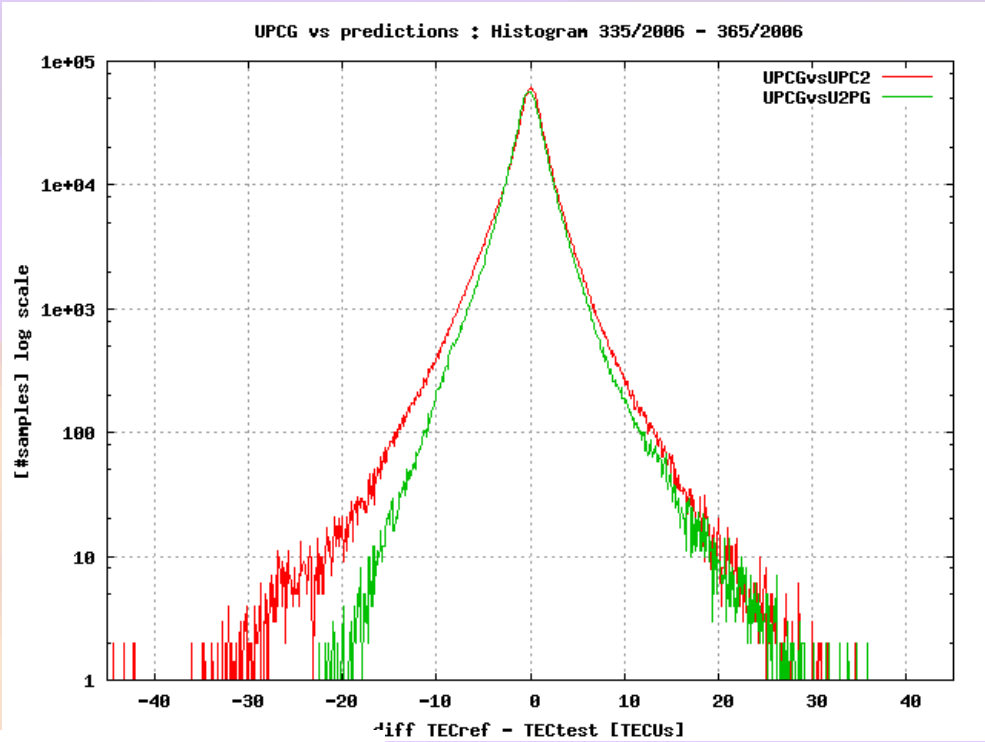
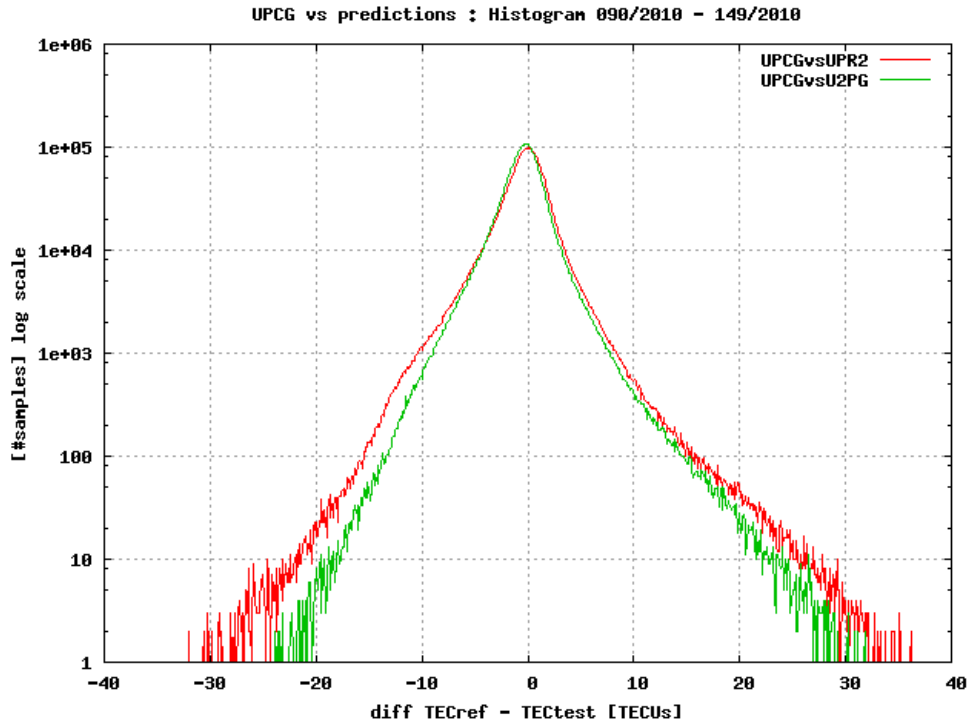
Thanks a lot!

Histograms







BEACON Satellite