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Improving Ionospheric determinations at UPC: Kriging and Wide Area RTK techniques

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Improving Ionospheric determinations at UPC: Kriging and Wide Area RTK techniques

Outline

1. GIM improvement by using Kriging
2. Improvement in ionospheric determination for Wide Area RTK
3. Conclusions

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Kriging interpolation to GIM

- It takes into account the spatial correlation of the data.
- The residuals of the IPP TEC over the UPC GIM are interpolated.

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

Interpolated value → Z_0^{*}

Observations → Z_i

Weight computed with Ordinary kriging → ω_i

$$\sum_{i} \omega_i \gamma_{ij} + \lambda = \gamma_{i0}$$

Semivariogram **between the given points** → γ_{ij}

Semivariogram **between the given and interpolated points** → γ_{i0}

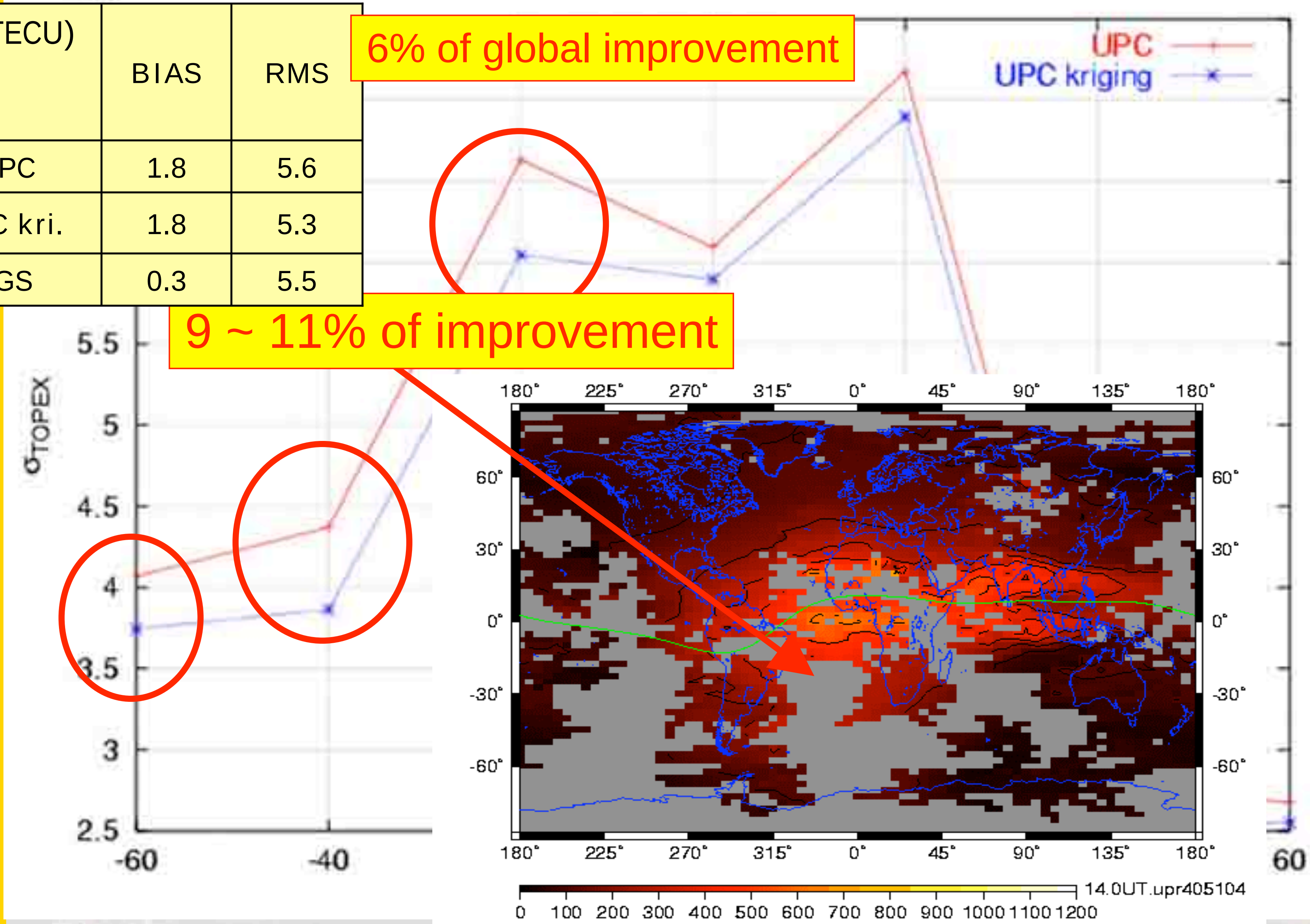
Describes the correlation of data as a function of the distance → *Semivariogram*

TOPEX vs GPS VTEC comparison for year 2002 (1,248,020 obs.)

(in TECU)	BIAS	RMS
UPC	1.8	5.6
UPC kri.	1.8	5.3
IGS	0.3	5.5

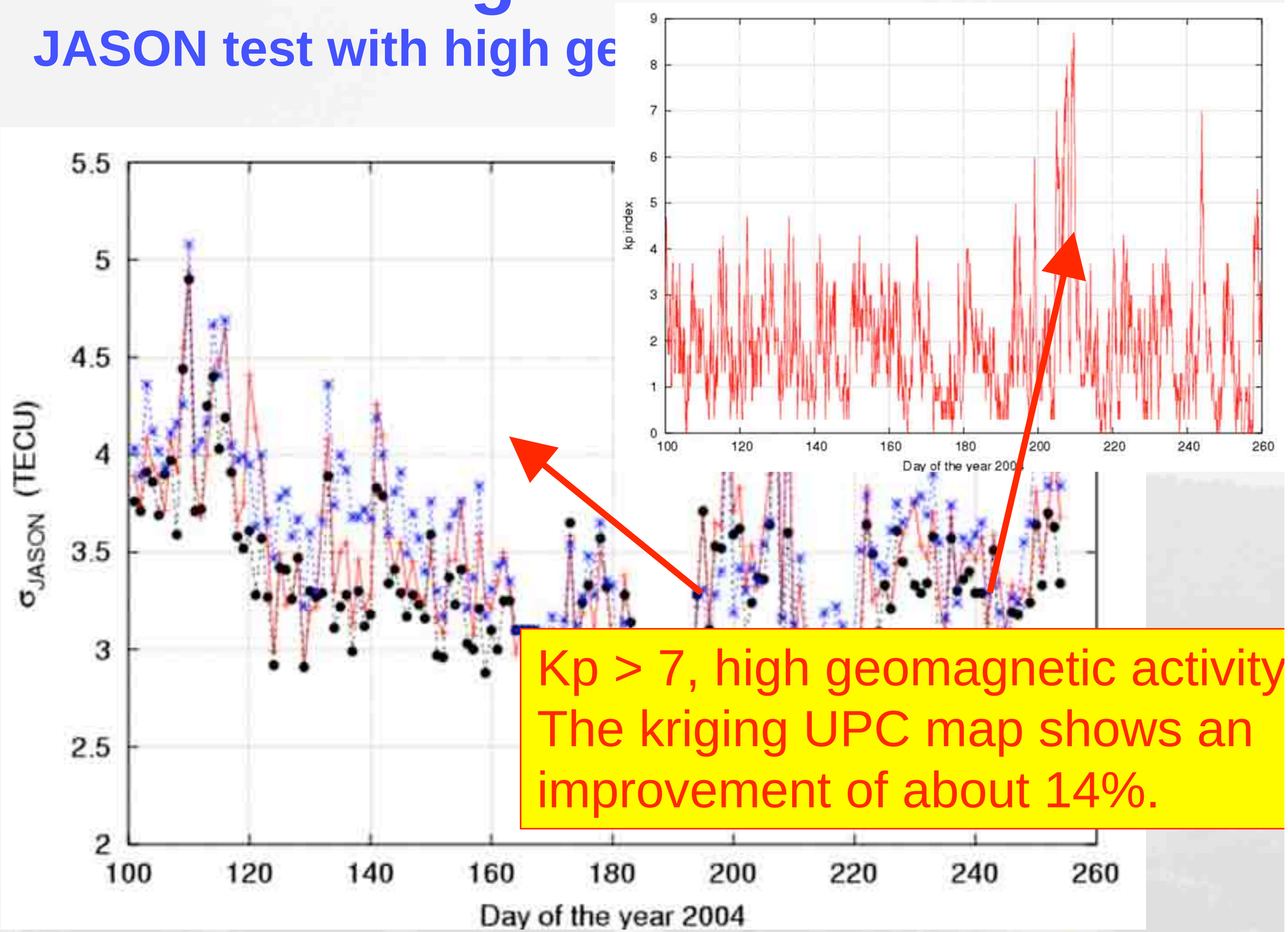
6% of global improvement

9 ~ 11% of improvement



Testing the GIMs

JASON test with high ge



Kp > 7, high geomagnetic activity
The kriging UPC map shows an improvement of about 14%.

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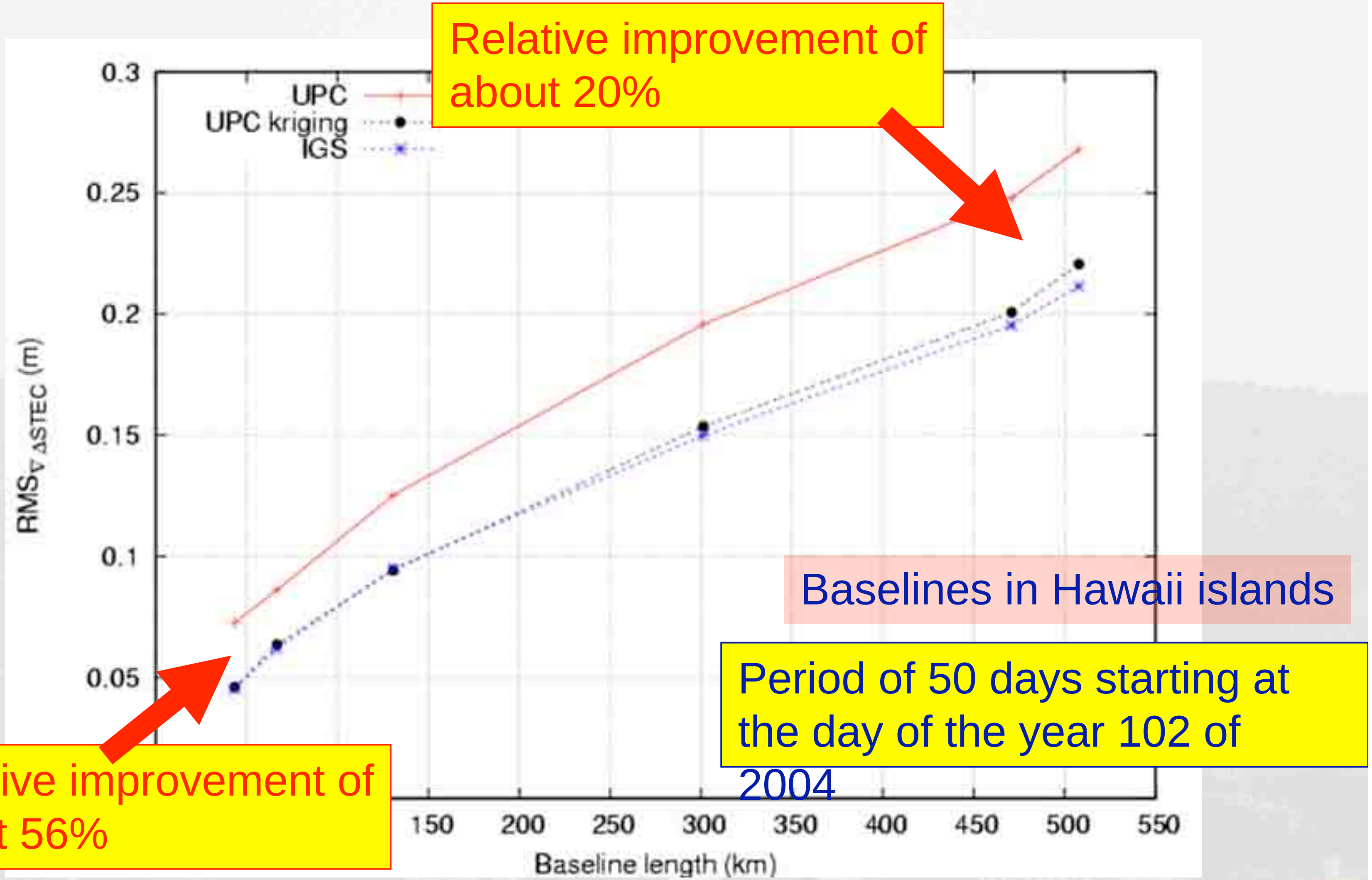
Testing the GIMs

∇ΔSTEC test



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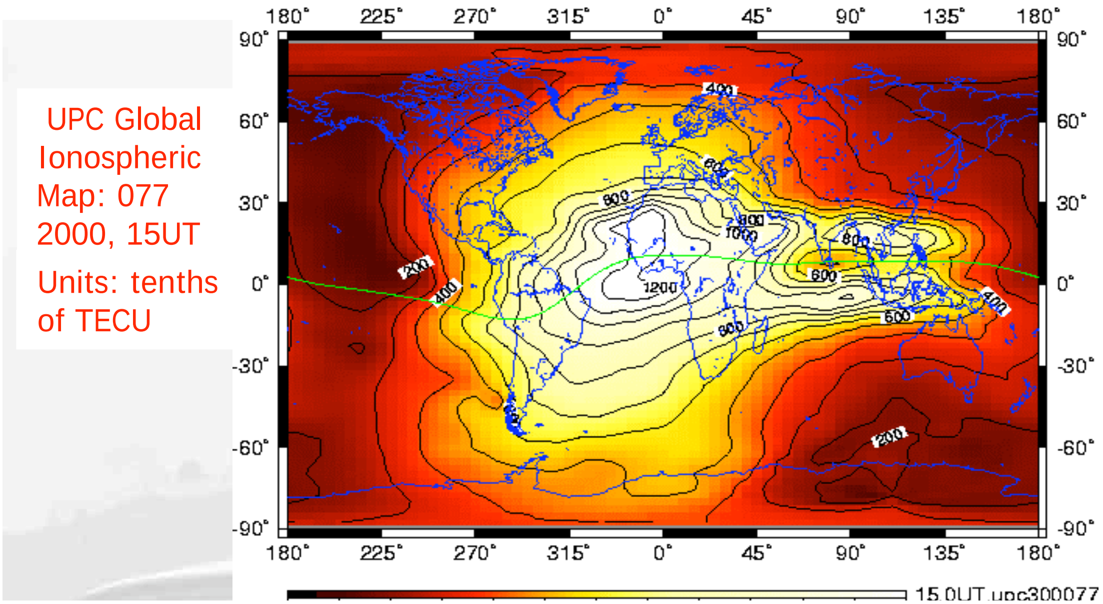
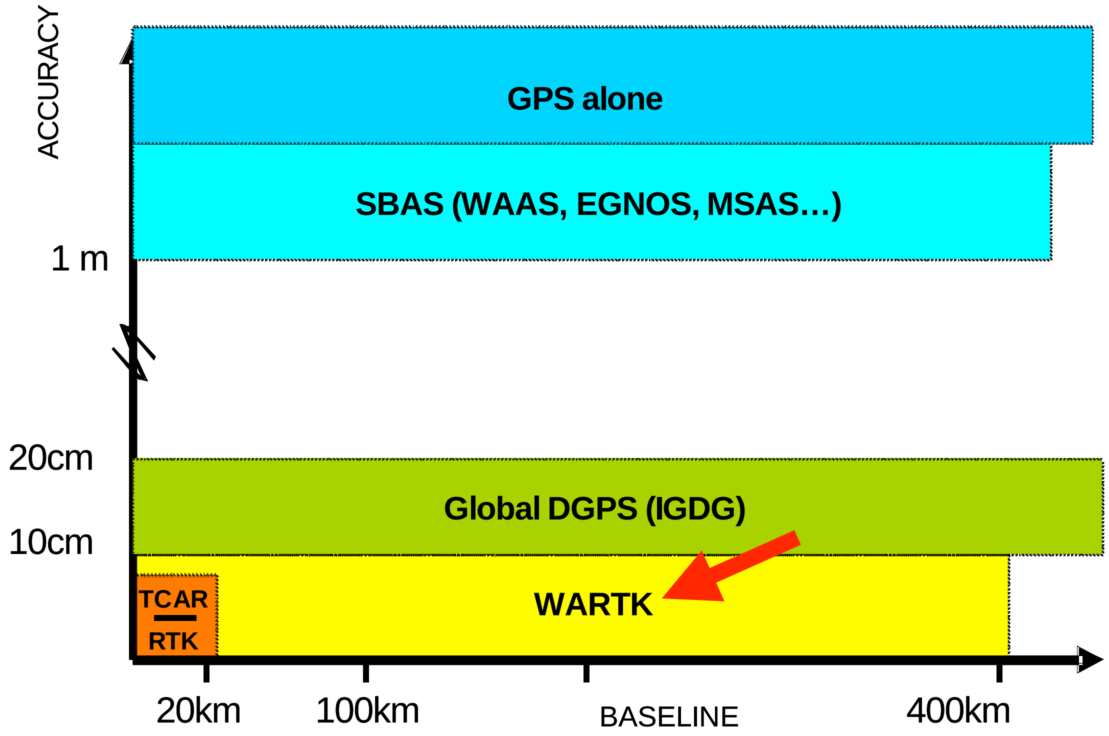
WARTK: subdecimeter-error navigation at hundreds km away

he differential ionospheric refraction typically limits the real-time ambiguity fixing (and the corresponding navigation with sub-decimeter errors) to baselines of few tens of km in different approaches in both two and three-frequency systems (RTK, LAMBDA, TCAR, CIR, ITCAR, FMCAR).

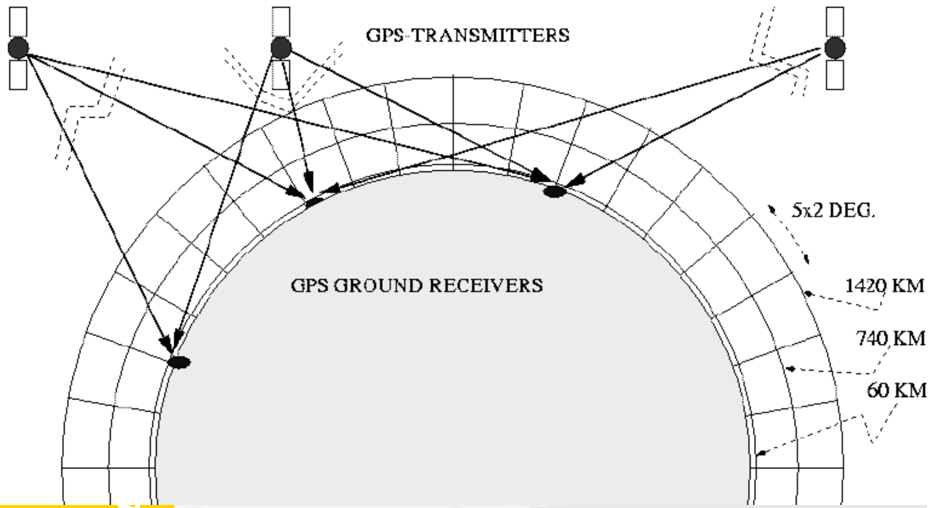


ide Area RTK (WARTK) overcome this problem incorporating an accurate real-time ionospheric model: (1) in two-frequency systems (GPS: WARTK), and (2) in three-frequency systems (Galileo and Modernized GPS: WARTK-3, which allows the extension of the Local Area Galileo services to continental scales).

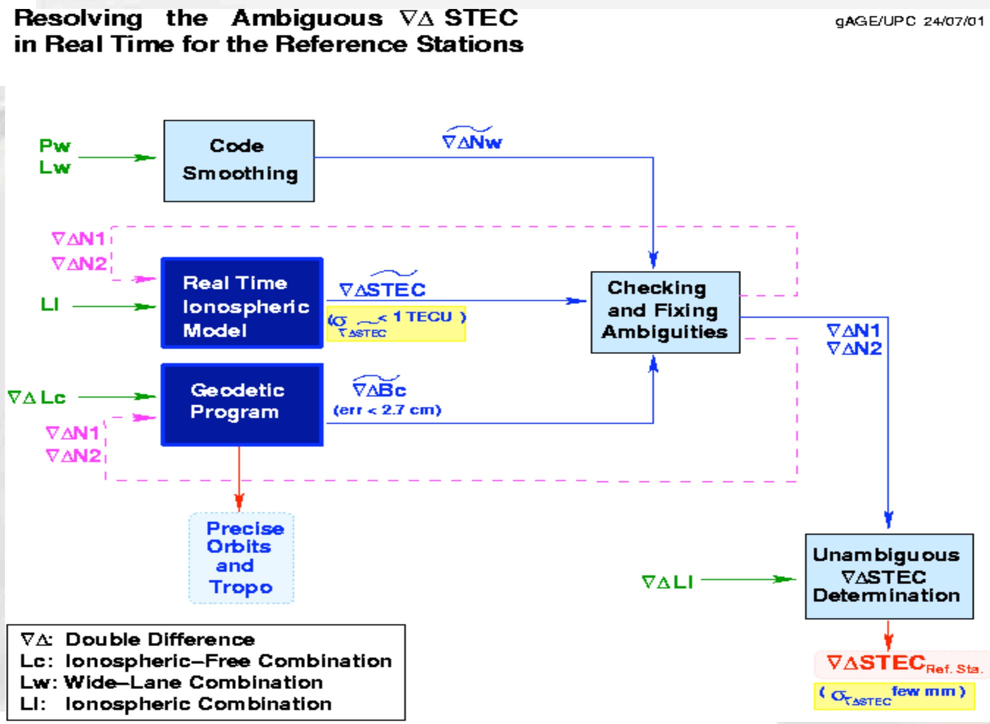


oth approaches (WARTK and WARTK-3) were presented in previous papers and demonstrated in many

The real-time ionospheric model



The ionospheric electron density distribution is decomposed in voxels (see equation solved by continuous Kalman filtering) in the GNSS data driven real-time model.

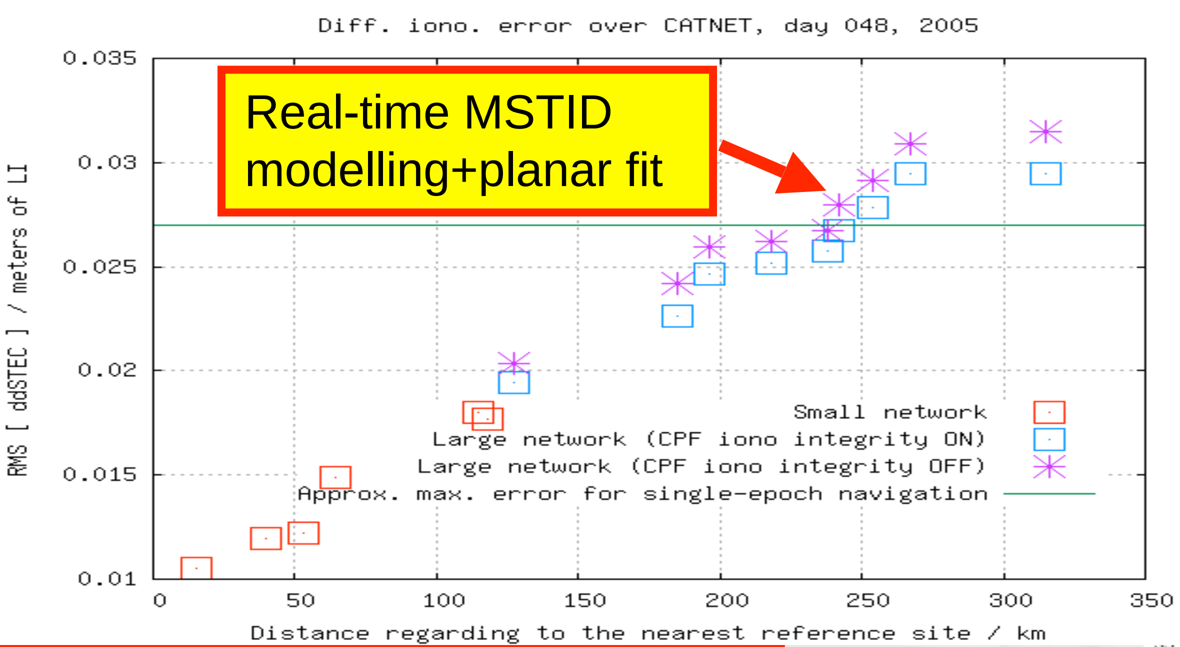


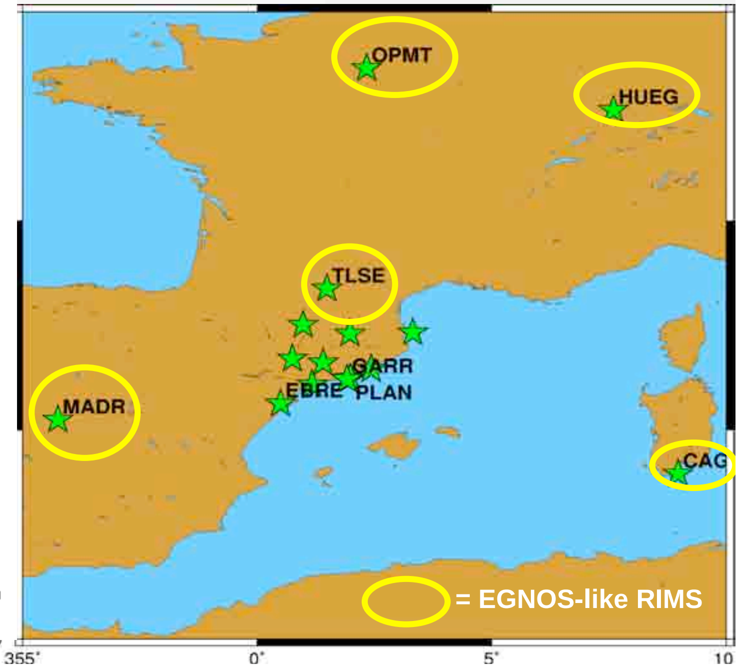
Both models, ionospheric and geodetic, are combined continuosly in a forward filter running in real-time, improving the estimation and fixing of L1, L2 carrier phase ambiguities. From the unambiguous L1-L2, an accurate double differenced STEC (~0.1 TECU) can be obtained and broadcast to the users.

$$L_I = STEC + B_I = \int_{REC}^{SAT} N_e\,dl + B_I = \sum_i \sum_j \sum_k (N_e)_{i,j,k}\,\Delta s_{i,j,k} + B_I$$

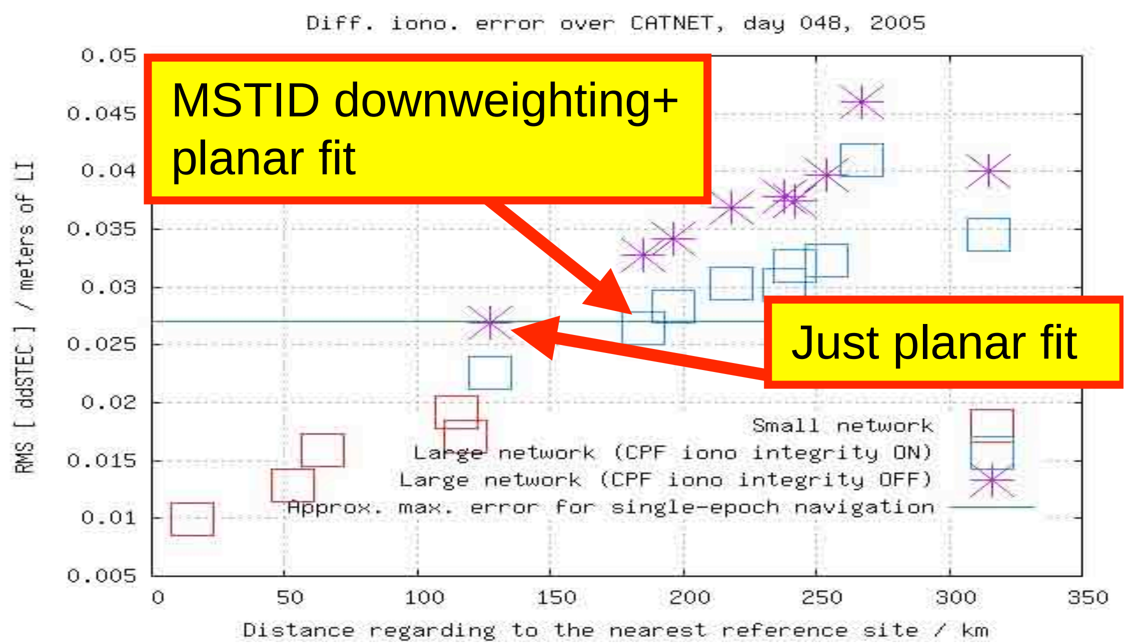
ianz

WARTK-EGAL: Service area improvement

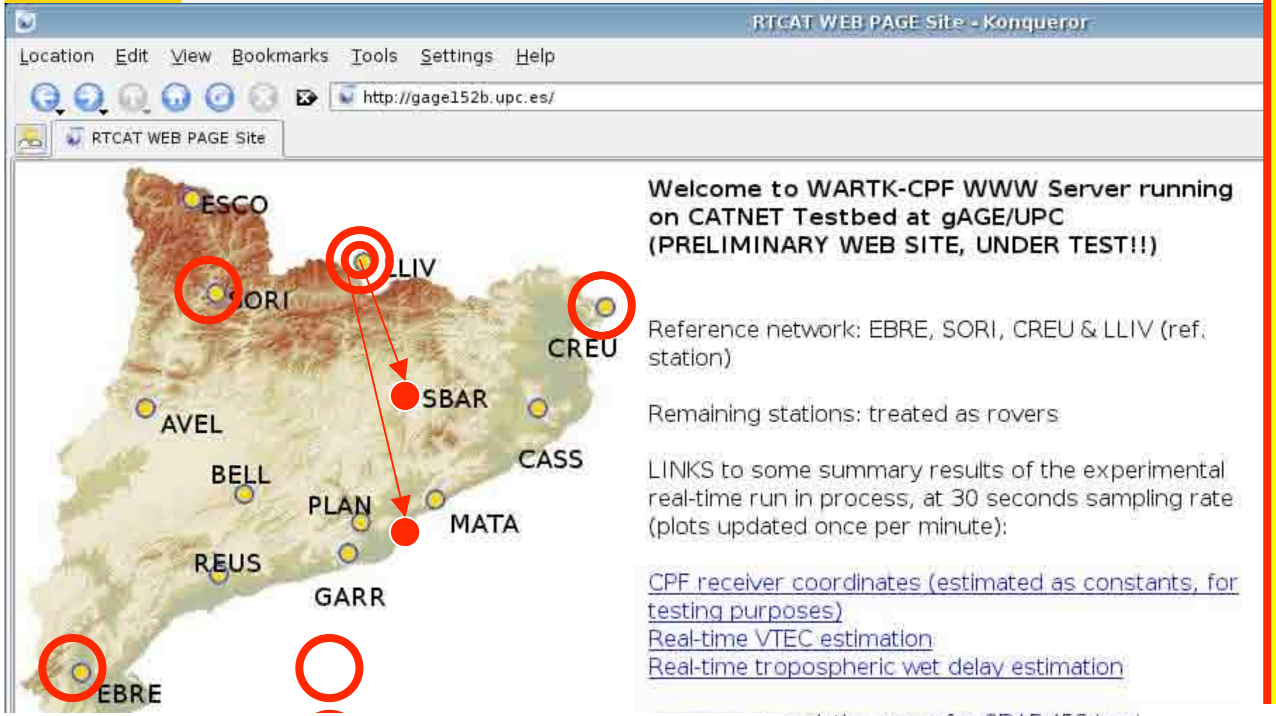




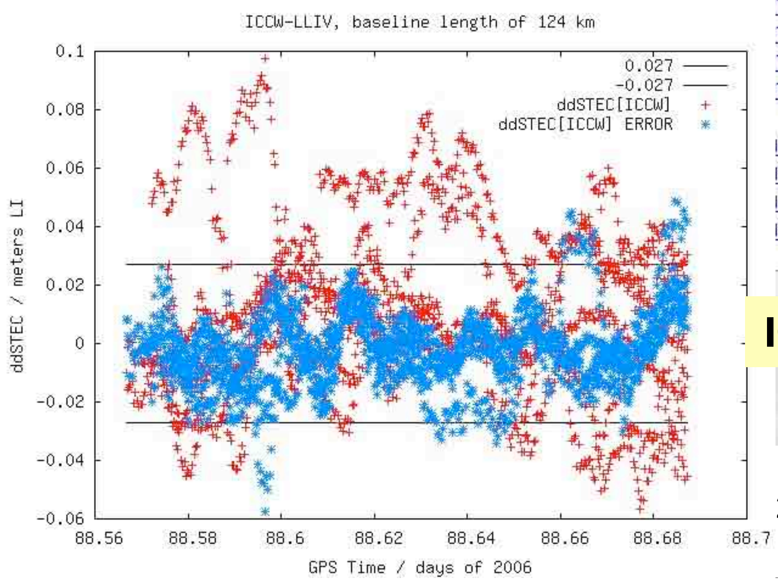
Using a simple real-time MSTID model (planar wave with climatological parameters) the WARTK service area is doubled (up to 250 km) regarding to a simple MSTID downweighting of MSTID-affected satellites (up to 190 km), and is four times regarding to using just a simple planar fit of slant ionospheric corrections per satellite (~125 km).



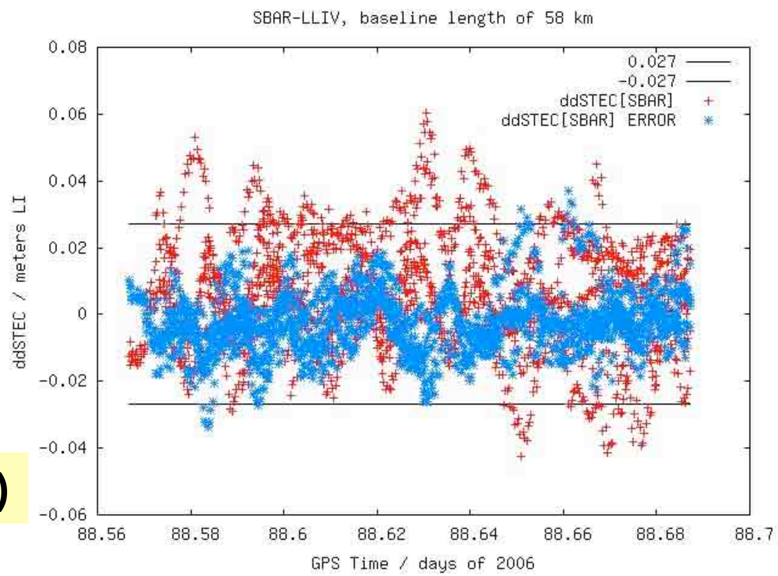
WARTK-EGAL: Preliminary WARTK CPF based on CATNET



Real-time experiment contemplated in WARTK-EGAL: from the available 13 CATNET datastreams (corresponding to the 13 permanent sites), several external receivers will be used as CPF WARTK reference sites. The remaining sites are treated as roving users.



ICCW (124km)



2006

SBAR (58km)

GALILEO: WARTK3 [gAGE-ESA patent,2002]

allows INSTANTANEOUS (single epoch) ambiguity fixing at hundreds of Km far from the ref. station

EGNOS-like permanent stations networks have the potential for supporting centimeter Navigation over Europe.

WARTK-EGAL: Centimeter Navigation over Europe: Funded Galileo Join Undertaking FP6-2nd, being gAGE/UPC leader of the Int. Consortium.

Applications of GNSS navigation at centimeter level over Europe: extending the present applications of RTK (civil engineering, precise farming, transport...), as far as new applications, such as real-time GPS meteorology, single GNSS receivers as orientation sensors capabilities, real-time mapping, Tsunami detection, accurate navigation on deep waters,...

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Conclusions

• The Kriging algorithm has been adapted to the problem of interpolation in the Global VTEC map generation, behaving better than previous technique.

• The UPC GIMs improvements due to the kriging are specially important in south hemisphere (few data available), low latitudes (high TEC gradients), Solar Maximum conditions, reaching up to 11% of improvement, and high geomagnetic activity (14% of improvement).

• Such improvements are also extended to the potential use of GIMs to predict double differences of ionospheric corrections for geodetic applications.

• Enhancement of EGNOS/Galileo service is feasible over Europe: from meter-level to centimeter-level accuracy with WARTK

• Many new applications can be feasible with WARTK

Thank you!

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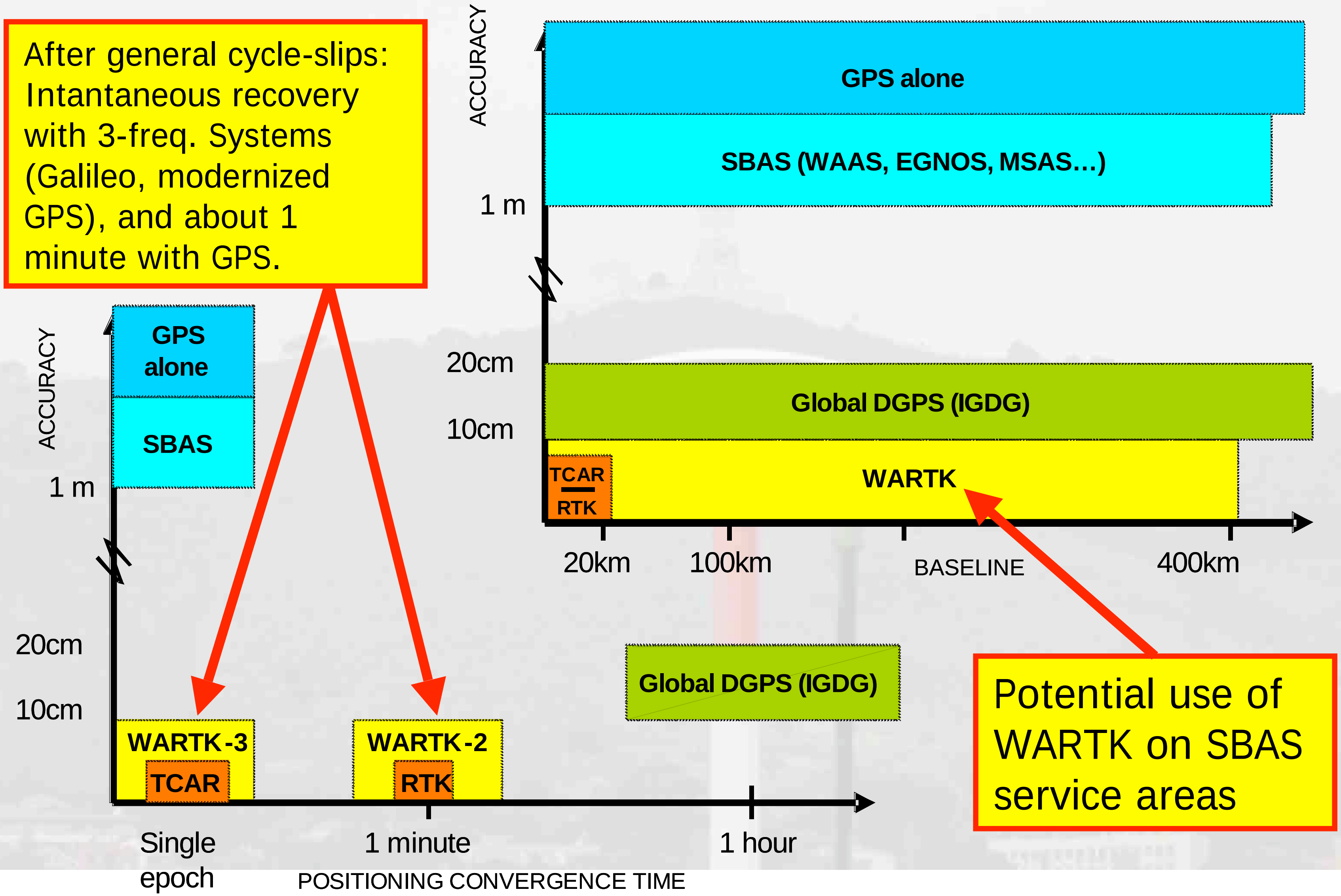
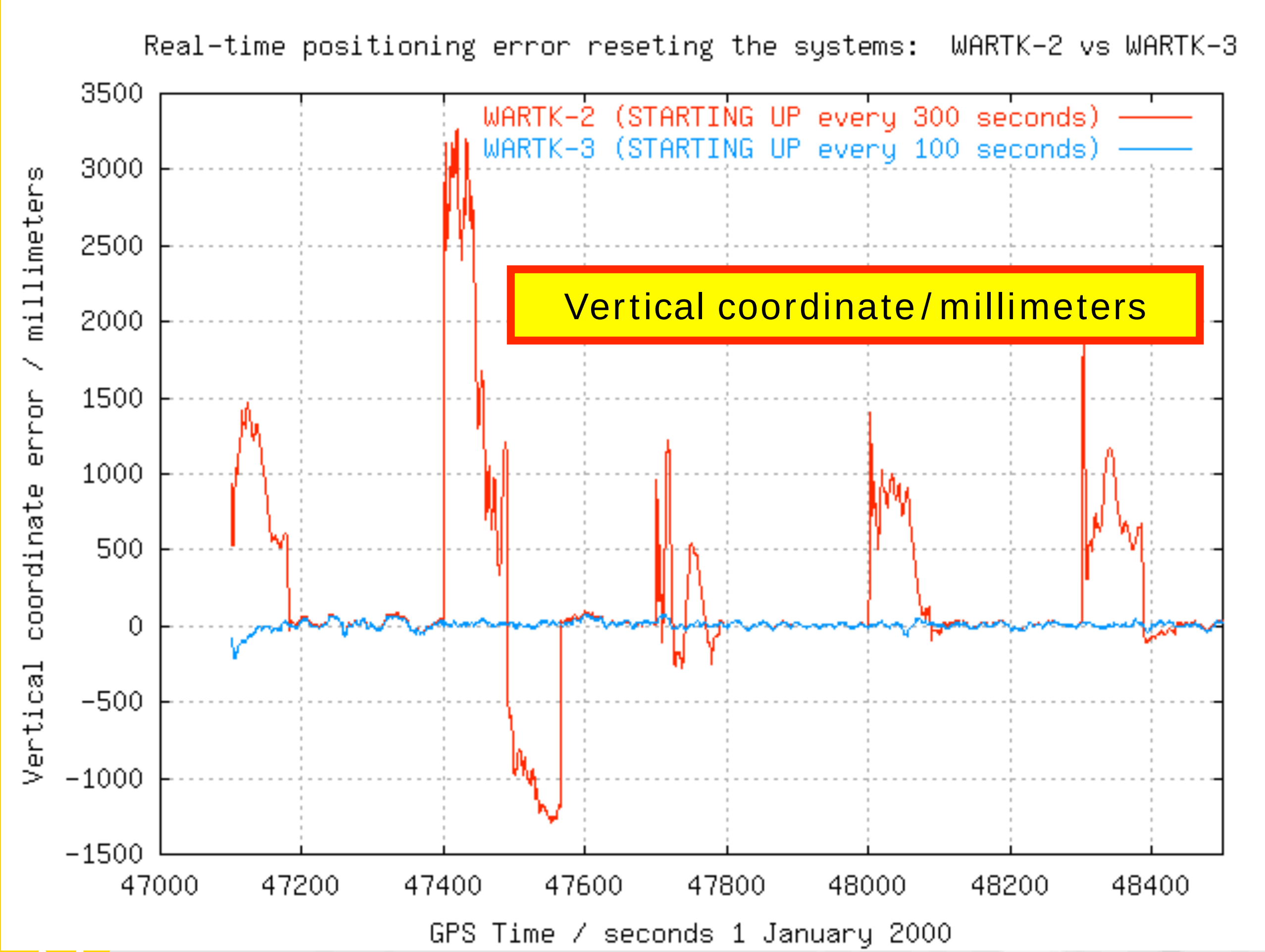
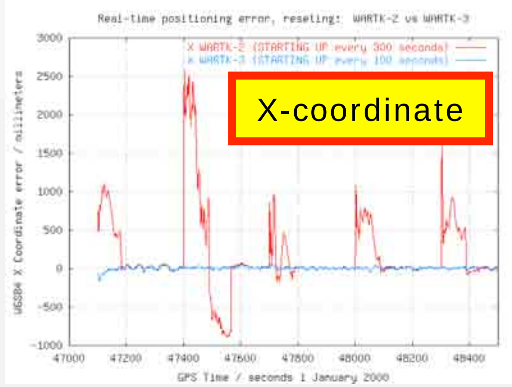
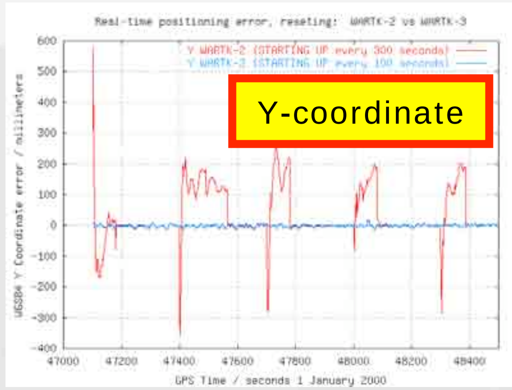
WARTK: subdecimeter-error navigation at hundreds km away, and in single-epoch with 3-frequency systems

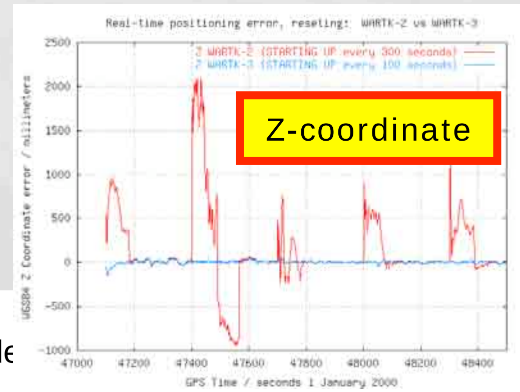


ROVE: WARTK3 vs WARTK2 (starting up everything each 100/300 sec., including tropo.)



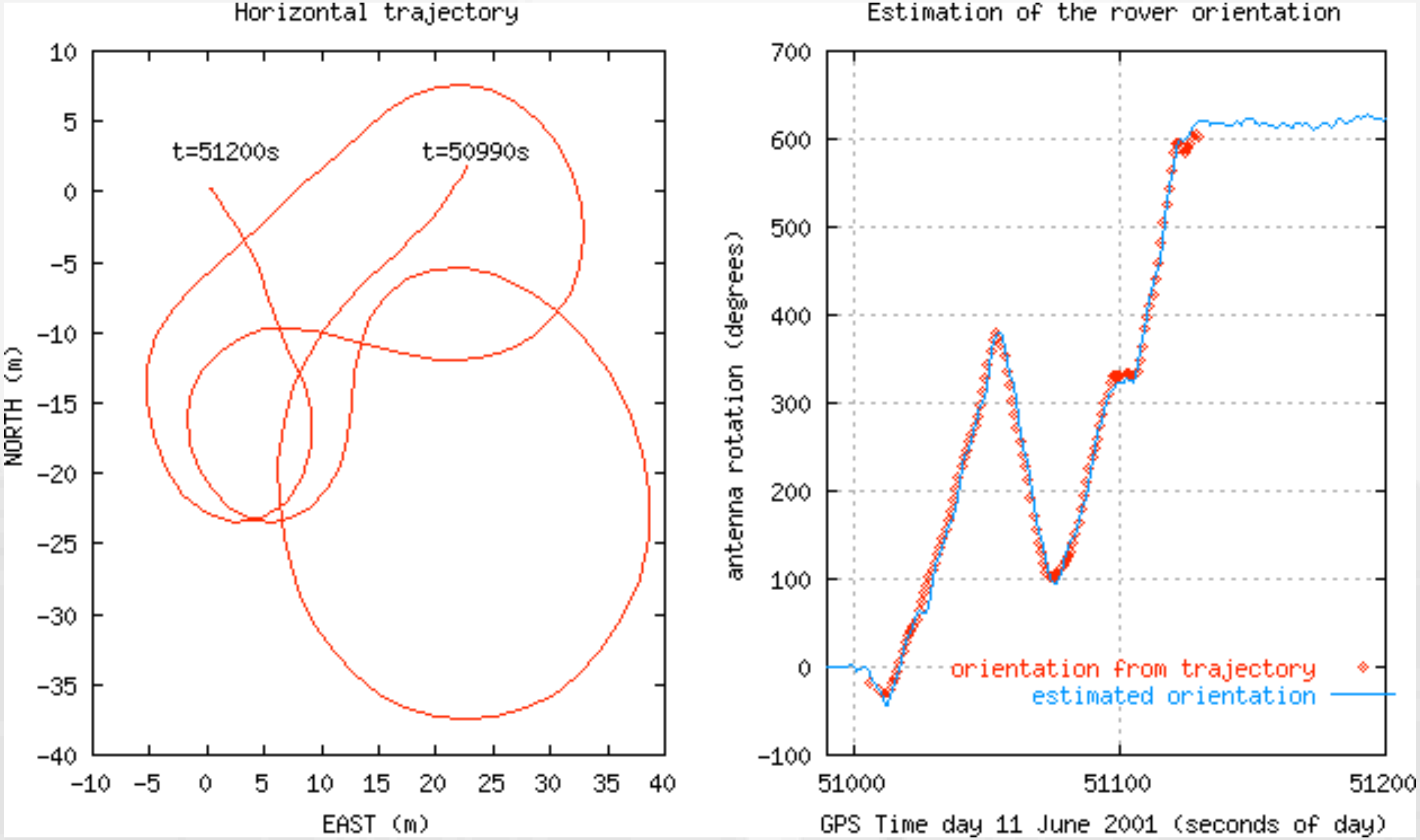






Starting-up everything: WARTK-2 (i.e. with GPS data) provides equivalent results to WARTK-3 (RMS of 2 cm and 100 % amb. fixed), but after a convergence time of ~100 sec. (instead of instantaneously).

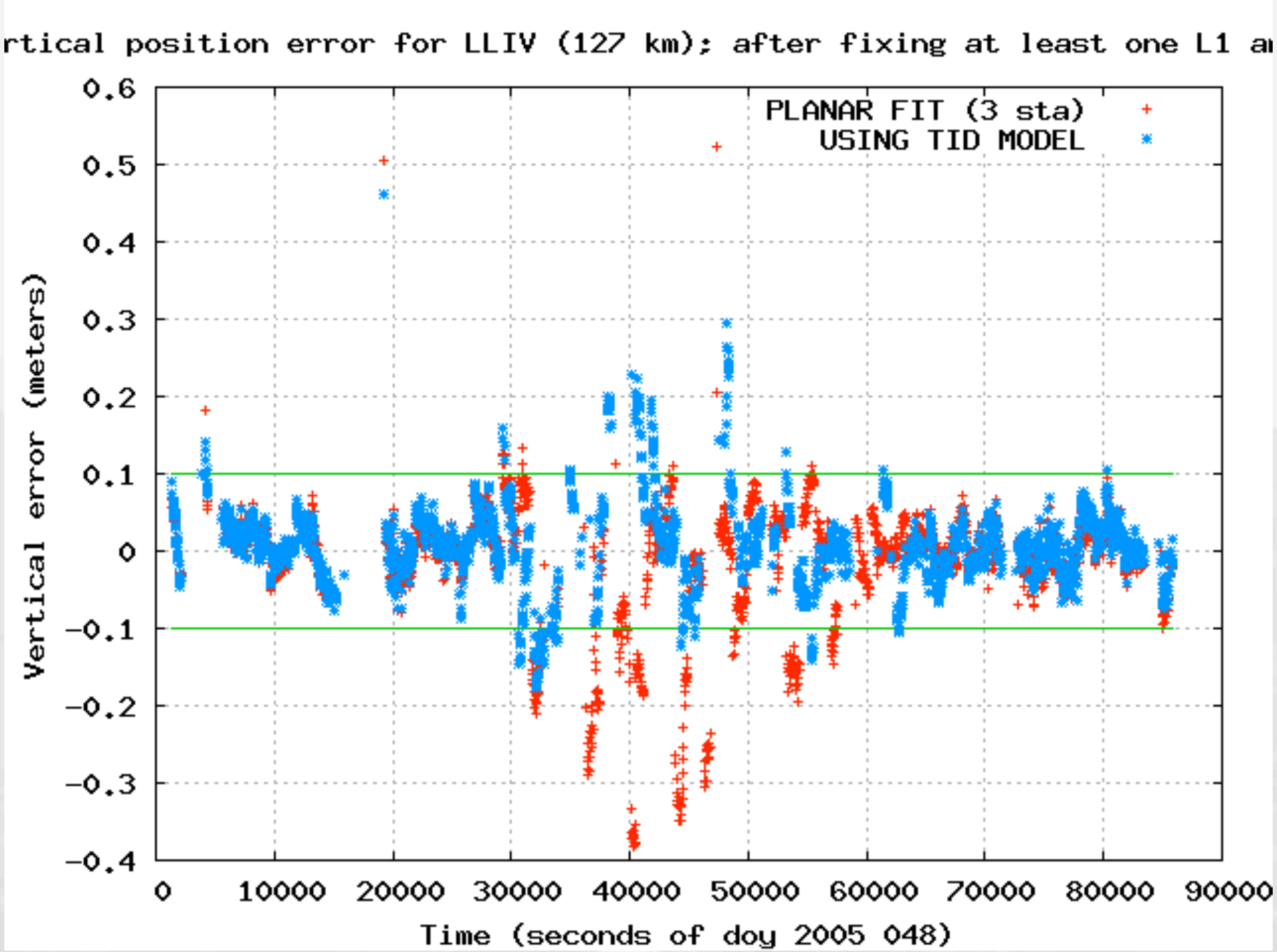
Real-time single antenna orientation estimation



The single antenna rotation estimated with the updated WARTK is compatible at the level of few degrees with the antenna rotation deduced from both the car trajectory (right hand plot), and the second antenna on the car roof.

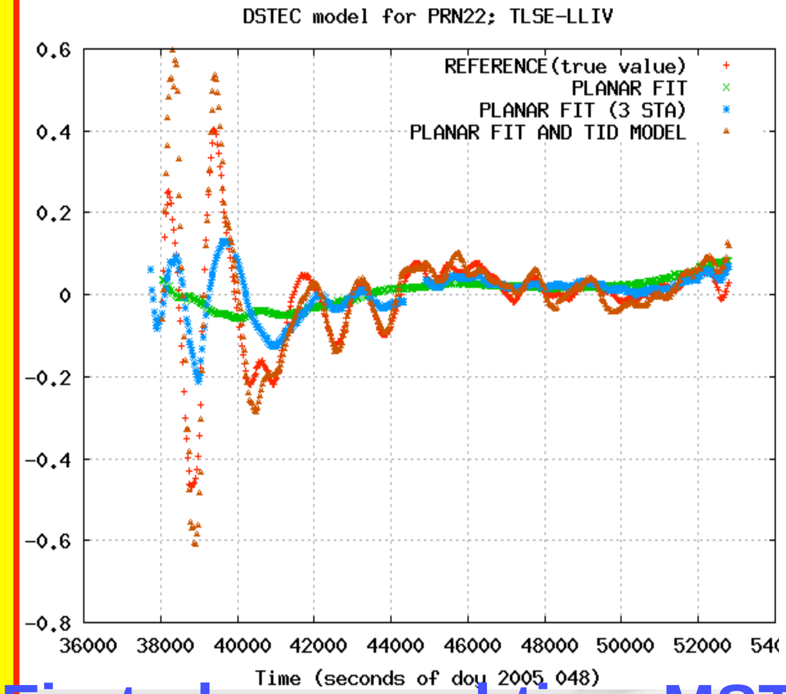
Navigation impact of real-time MSTID model

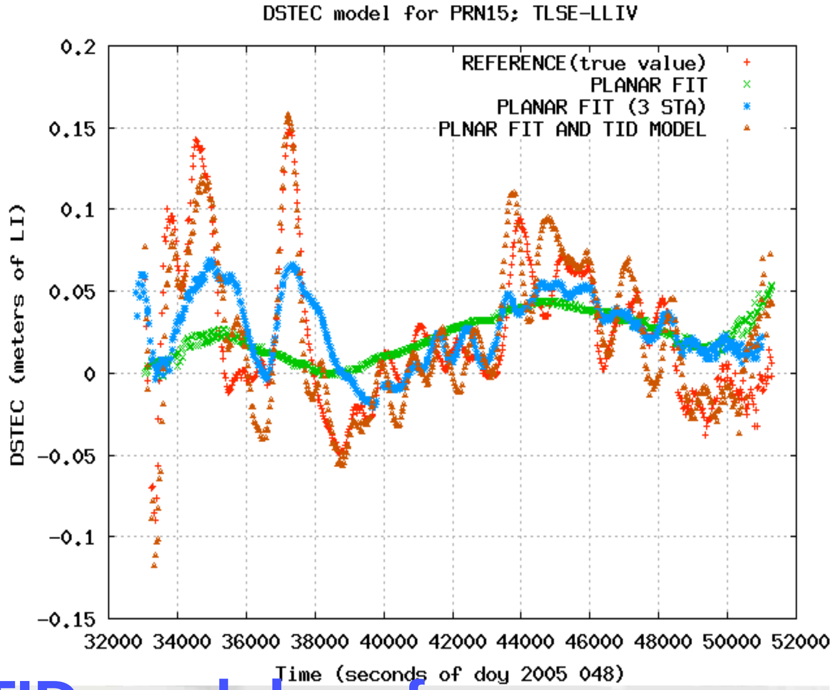
Navigation accuracy comparison between using or not the new real-time MSTID model (blue and red points) for LLIV treated as rover (127 km baseline).

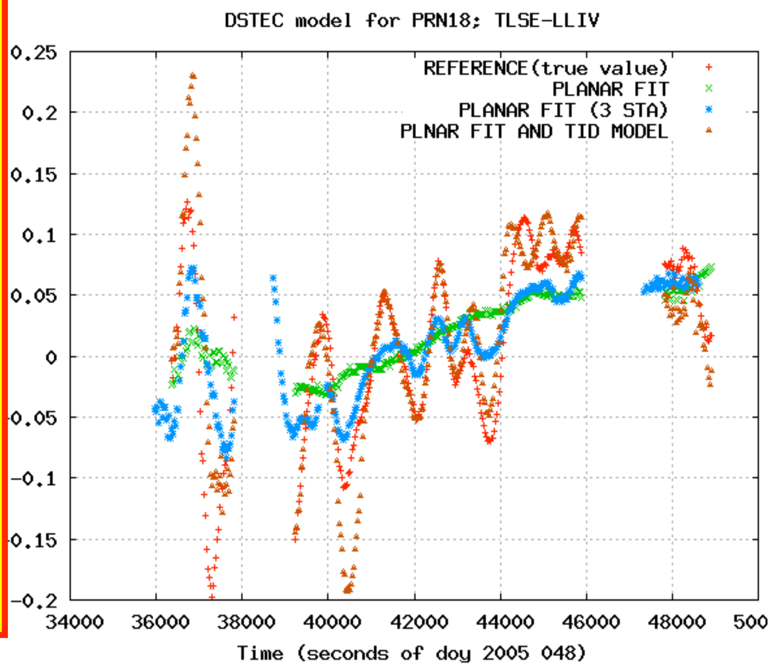


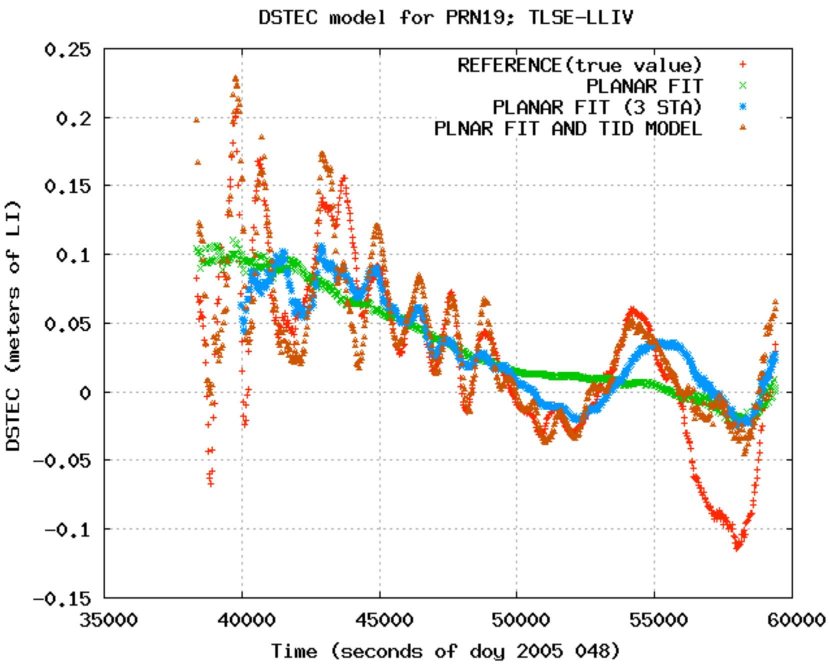
First glance real-time MSTID model performance

Comparison of the real-time TID model (brown points), the simple planar fit with just 3 or more reference stations (blue and green points respectively), versus the reference values (red points), all of them for the between-satellites Slant TEC single difference (sat. PRN 22, 15, 18 &19 respectively, during day 48, 2005).





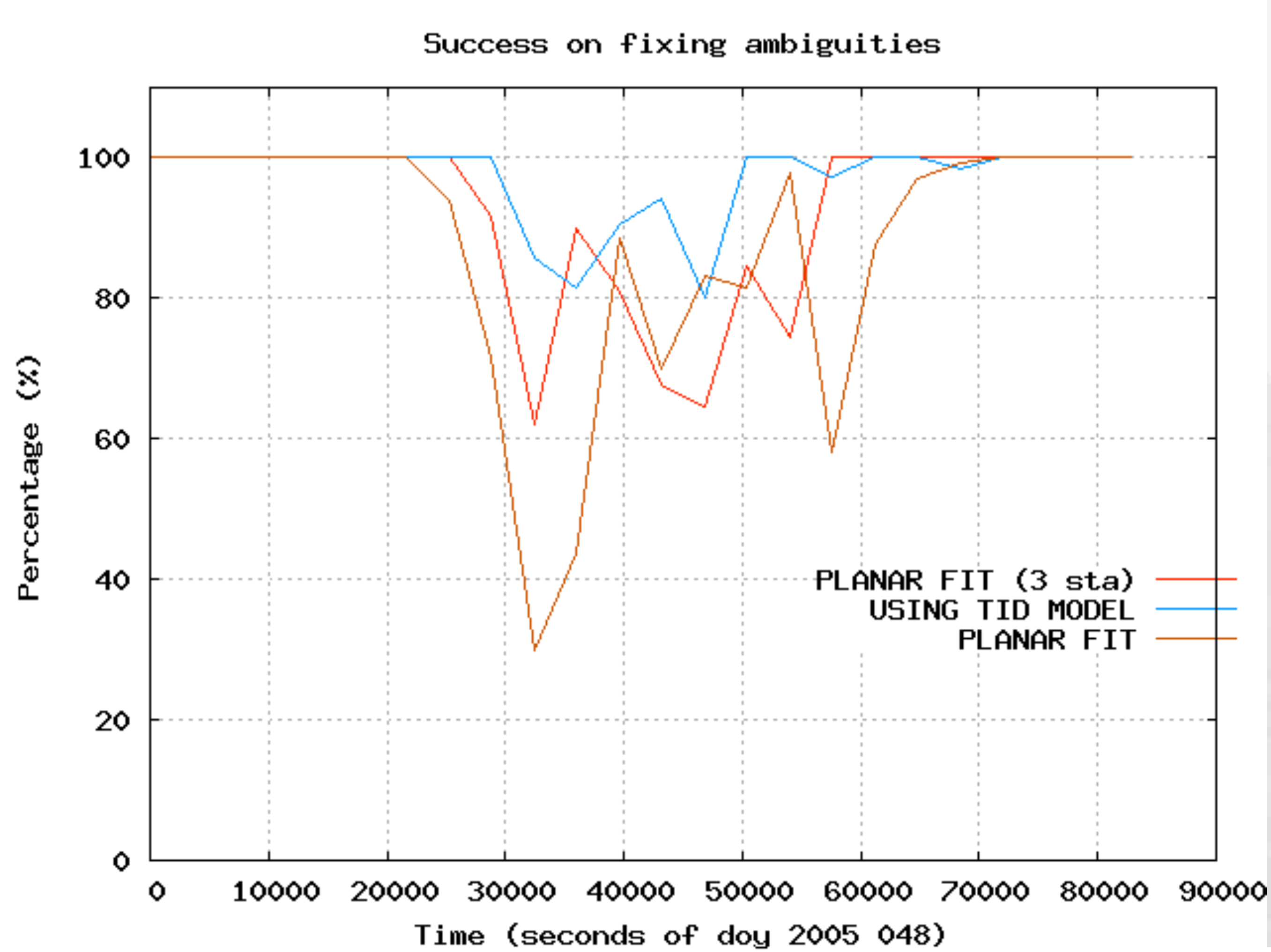




Ambiguity fixing improvement using real-time MSTID model

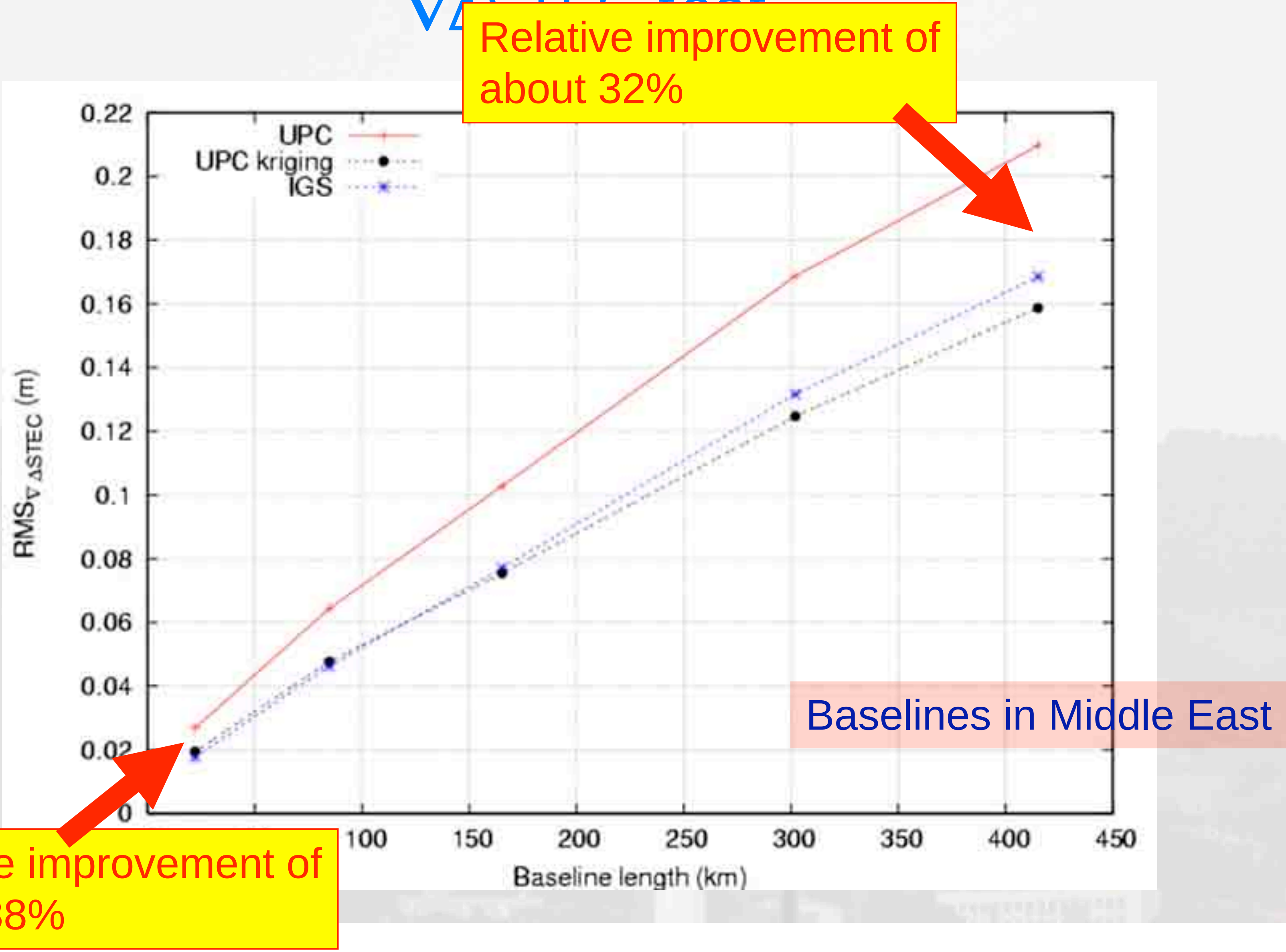
omatics

Comparison of the ambiguity fixing rate for receiver LLIV treated as rover (127 km baseline) between using linear (planar) fit (red and brown with 3 and more reference receivers) and adding the MSTID model (blue line), day 048, 2005.



Testing the GIMs

∇ΔSTEC test



The kriging technique

Semivariogram

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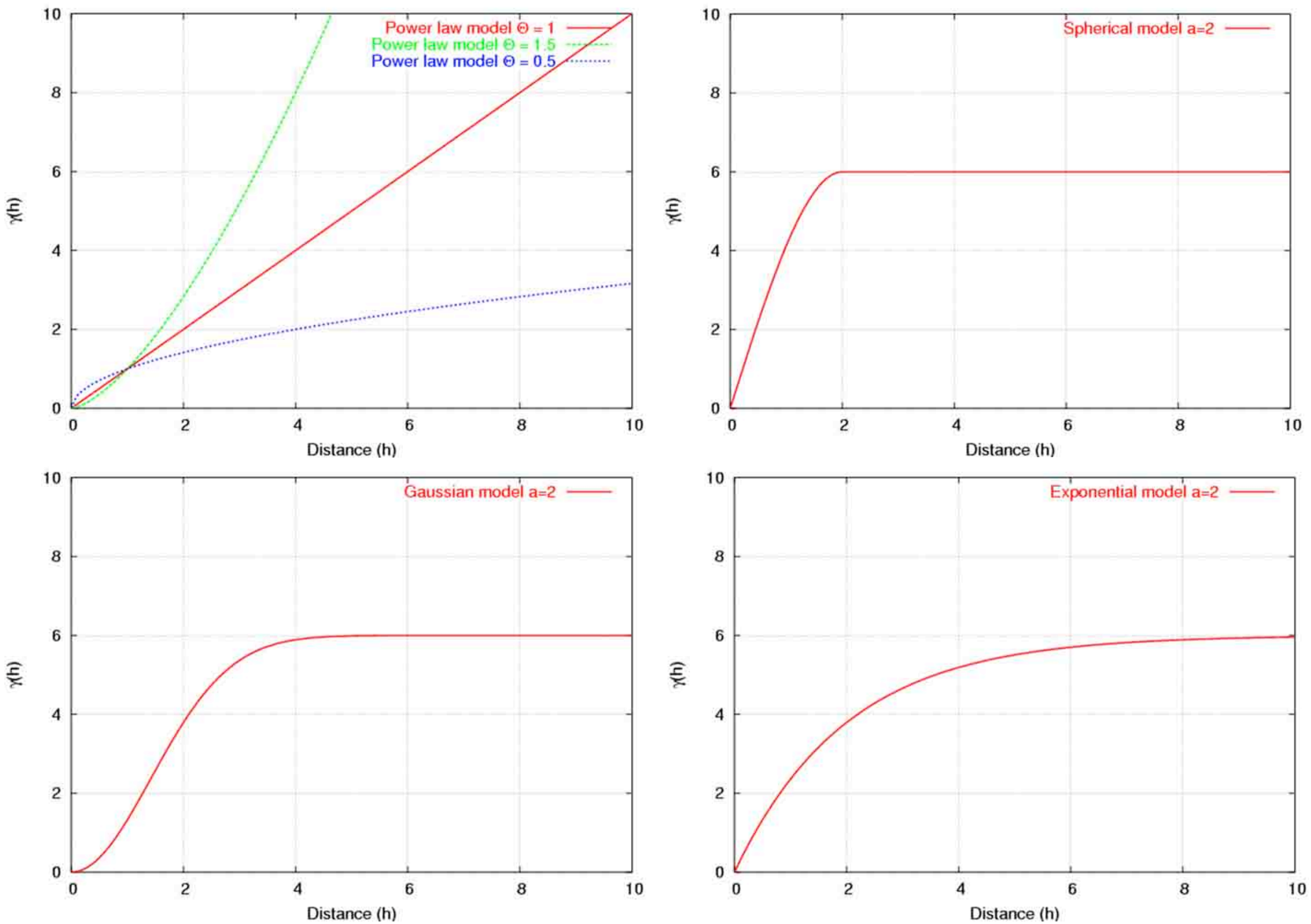

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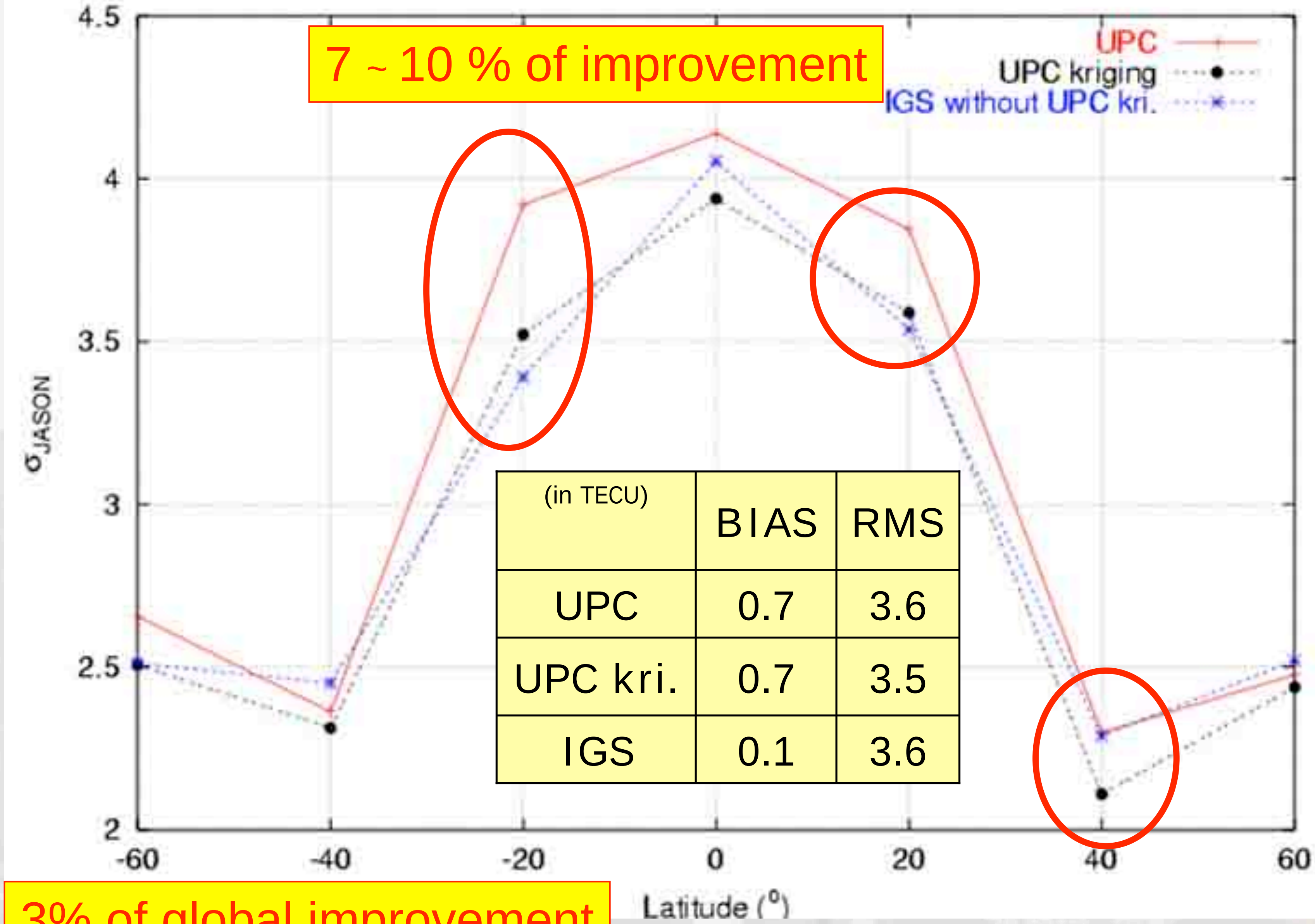
JASON comparison for year 2004 (6,455,801 obs.)



(in TECU)	BIAS	RMS
UPC	0.7	3.6
UPC kri.	0.7	3.5
IGS	0.1	3.6

3% of global improvement