Estimating Zenith Total Delay Fields by using Ground-Based GPS network

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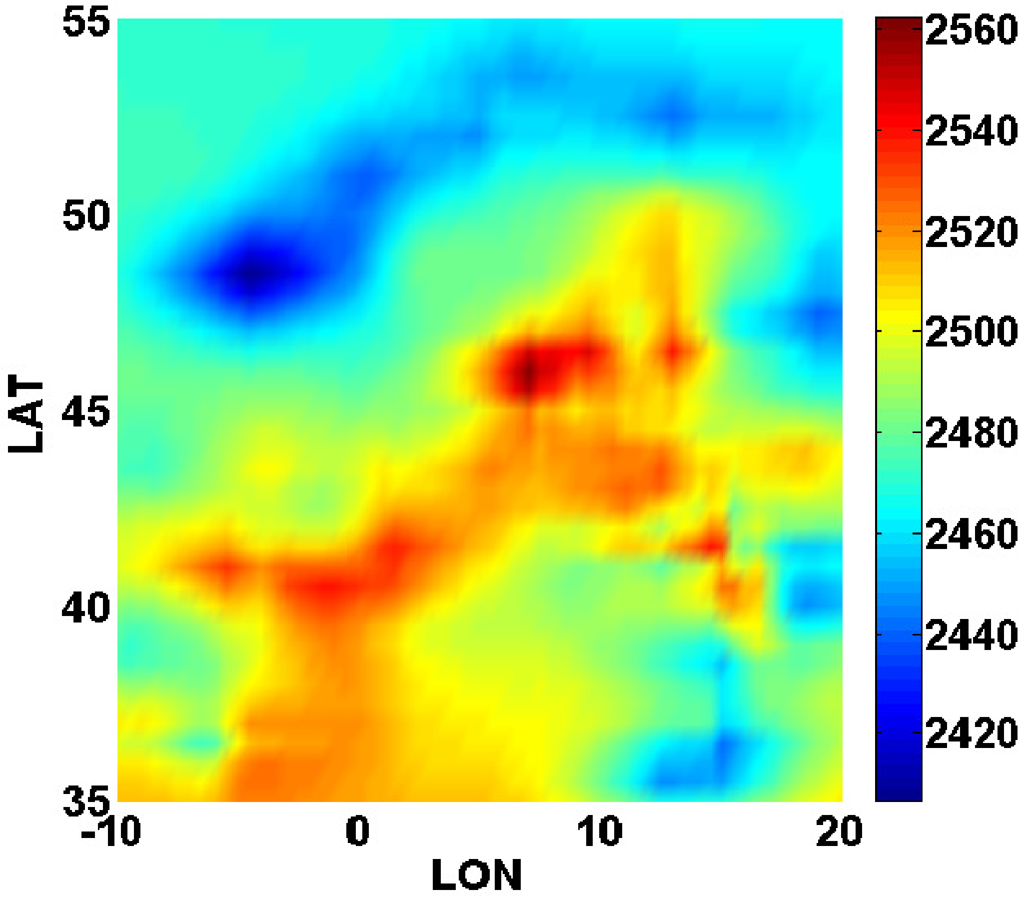
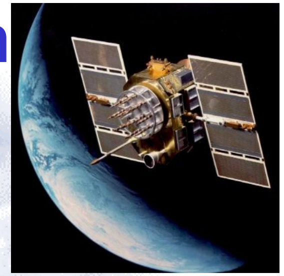
Outlook of the talk

- Why do we need ZTD fields?
- How these fields can be derived from point wise ZTD estimates?
- Experimental data
- Future activities

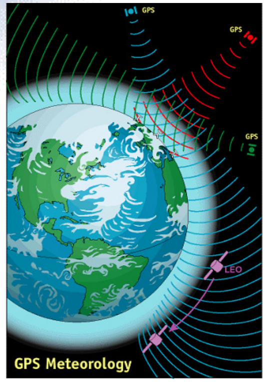
ZTD field exploitation



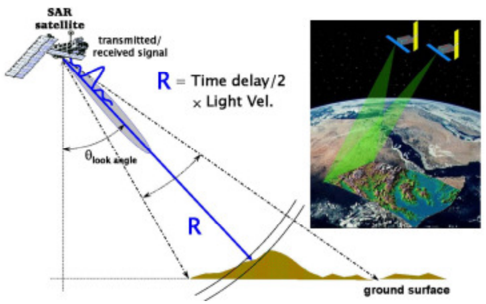
GNSS Navigation



GNSS Ground-Based & Space-Based Met.



SAR product geolocation



GNSS Navigation

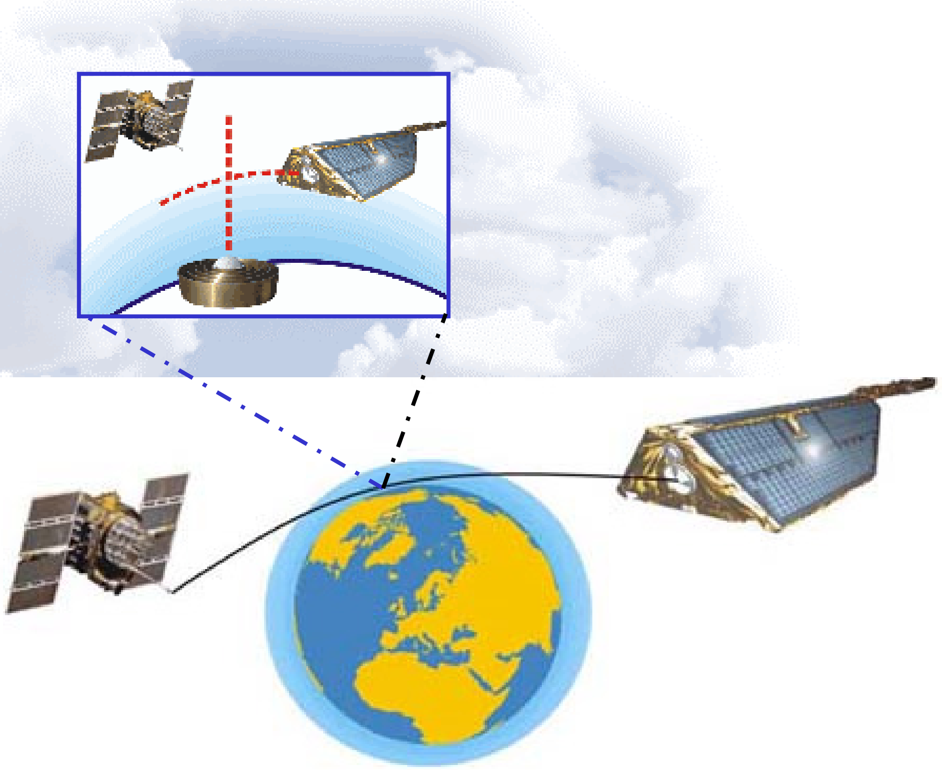
ZTD field in a region of interest may serve to derive tropospheric correction, to be removed from the GNSS signal, at the desired user location for positioning services.

The effectiveness of such a correction resides mainly on the density of the available GNSS network and on the possibility of a fast GNSS data processing to minimize the latency between the ZTD field delivery and the time of the requested correction.

SCUTUM (www.scutumgnss.eu) introduces EGNOS (European Geostationary Navigation Overlay Service) in the dangerous goods transports for Europe. The SCUTUM project is managed by the European GNSS Supervisory Authority (GSA) through EU 7FP funds.

GNSS Ground-based and Space-based Meteorology

RO is not a stand-alone technique since to get pressure, temperature and water vapour pressure from refractivity profile external information (ECMWF/NCEP) are needed.



$$N(h) = a_1 \frac{P(h)}{T(h)} + a_2 \frac{P_{wet}(h)}{T^2(h)}$$

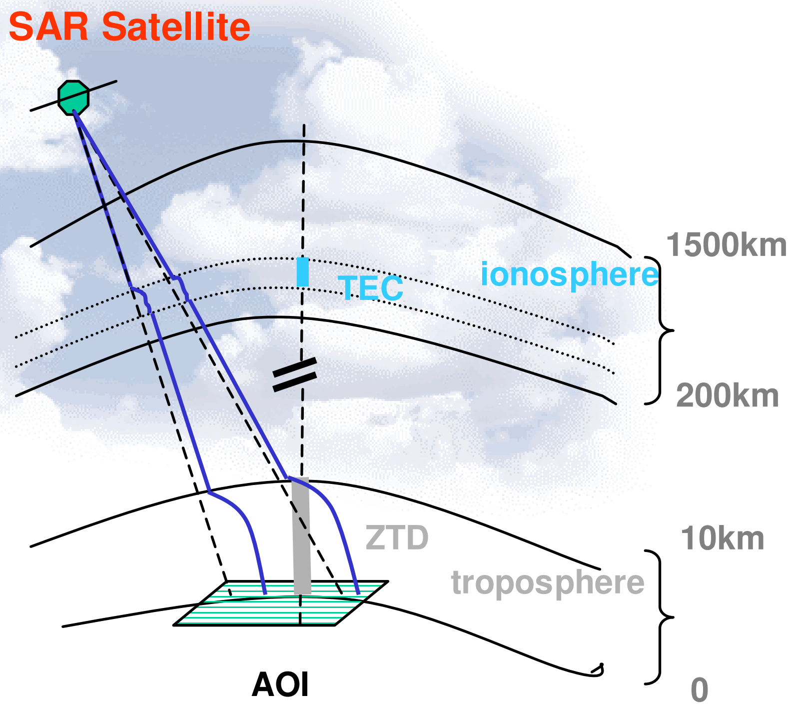
$$\frac{dP}{dh} = -\frac{g m_{dry}}{a_1 R} N + \frac{a_3 g m_{dry}}{a_1 R} \frac{P_{wet}}{T^2} + \frac{g\left(m_{dry} - m_{wet}\right)}{R} \frac{P_{wet}}{T}$$

$$ZTD = 10^{-6} \int_{ground-GPS}^{\infty} N(h)dh = 10^{-6} \int_{ground-GPS}^{\infty} (a_1 \frac{P}{T} + a_2 \frac{P_w}{T^2})dh$$

The availability of reliable ZTD fields in the area of the occultation event let us to use the ZTD as additional data in the lower troposphere.

Synthetic Aperture Radar (SAR) product geolocation

Atmospheric effects are no more negligible in accurate geolocation (at 1-m level) of the products generated by the most advanced SAR satellite missions, as Cosmo-SKYMed (ASI) and Terrasar-X (DLR).



COSMO-SkyMed Fiumicino Airport, Rome, Italy

Even if a routine correction at a global scale of the SAR images can be more easily implemented by means of a tropospheric model, specific and refined applications for a given area may profit from the experimental GNSS ZTD fields.

Tropospheric models: UNB3m and GPT&SAASTAMOINEN (1/2)

➢ **UNB3m computes the hydrostatic and wet zenith delays according to:**

- Saastamoinen model

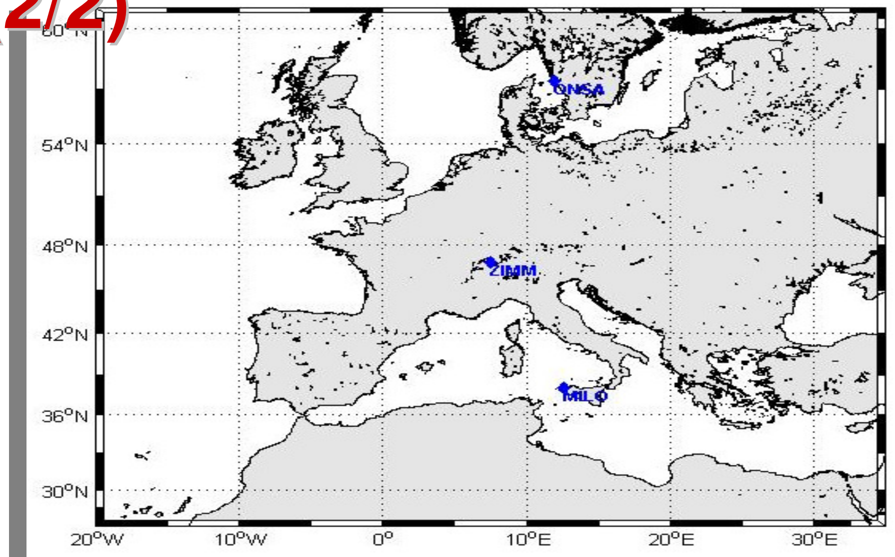
- prediction of the meteorological parameters with annual mean and amplitude for temperature, pressure and relative humidity.

➢ **GPT&SAASTAMOINEN computes the hydrostatic and wet zenith delays according to:**

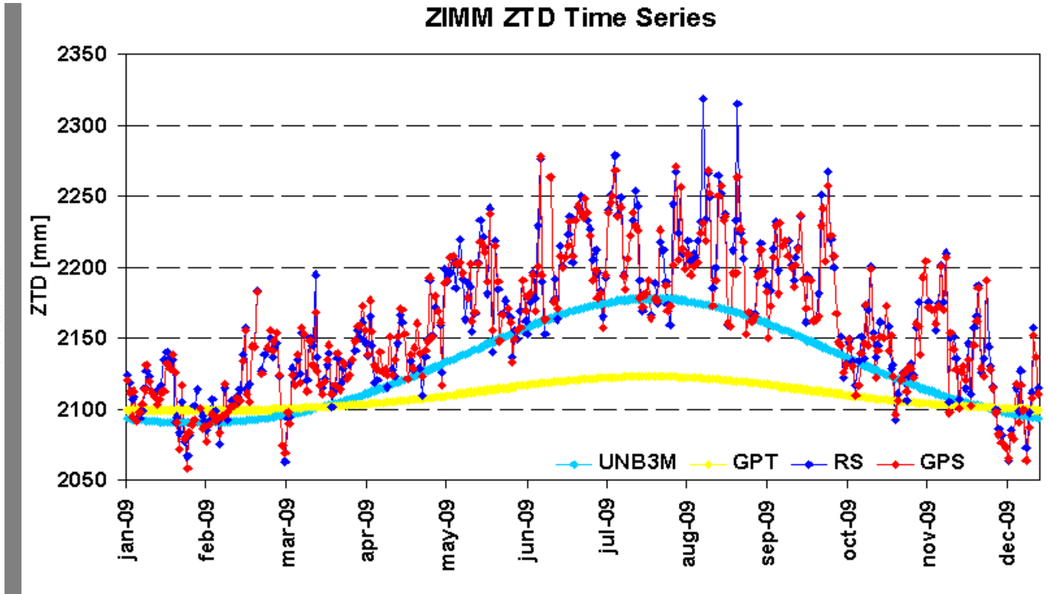
- Saastamoinen model

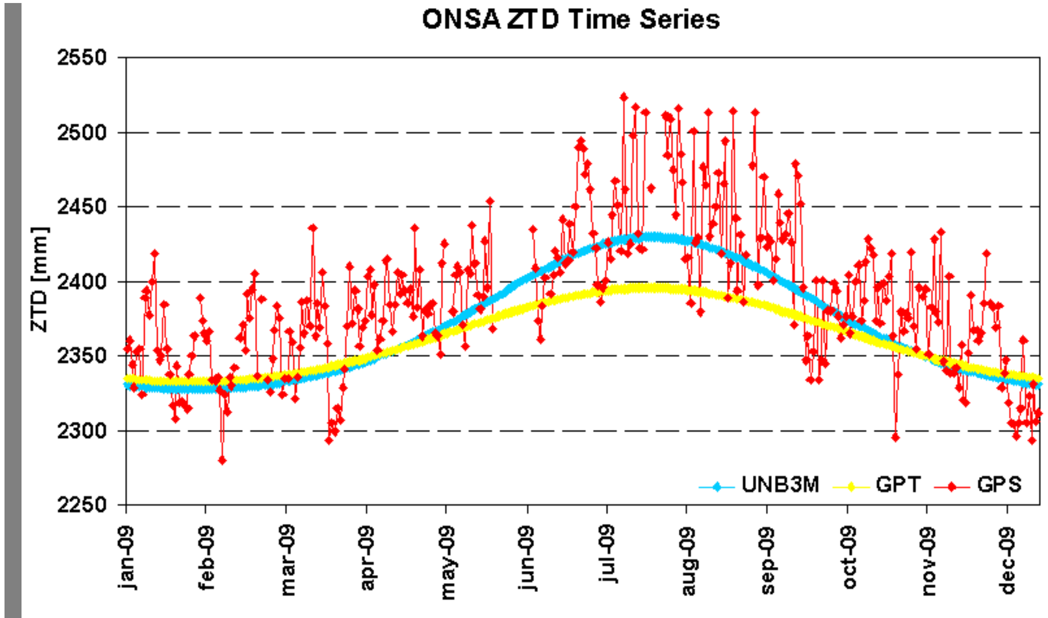
- GPT model (based on a spherical harmonic expansion).

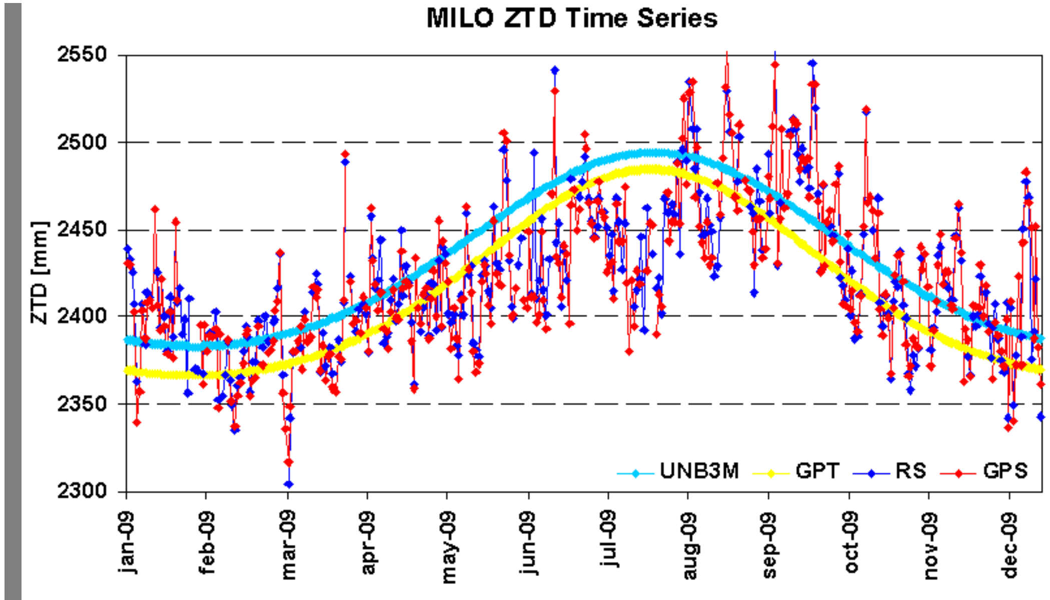
Tropospheric models: UNB3m and GPT&SAASTAMOINEN (2/2)



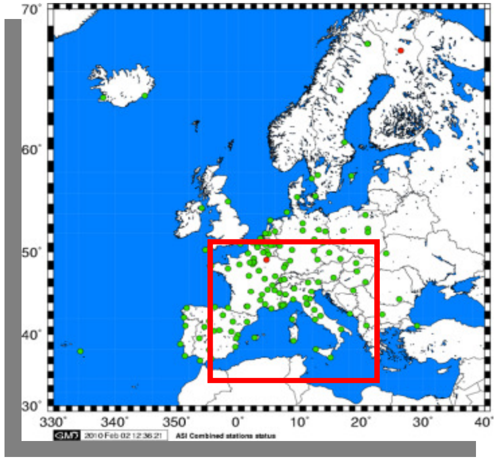
ONSA, ZIMM and MILO geographical location

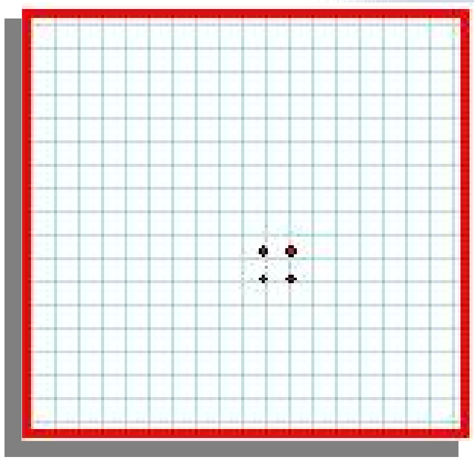


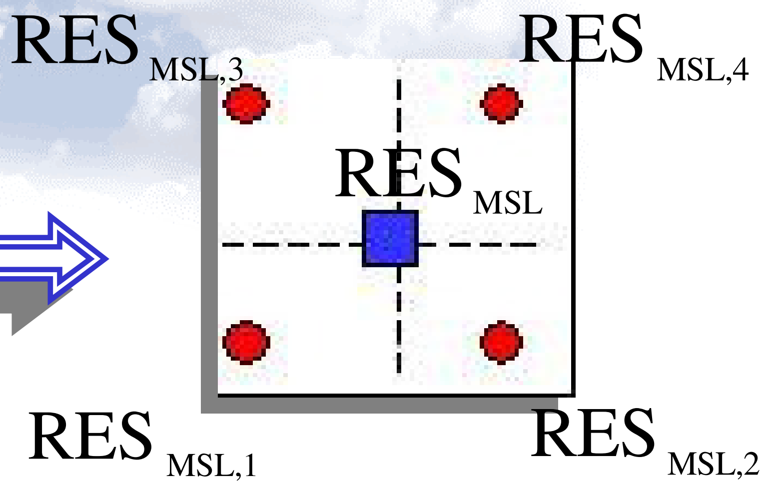




From point wise ZTD estimates to the ZTD Fields







First Step:

ZTD residuals

Second Step:

residual grids

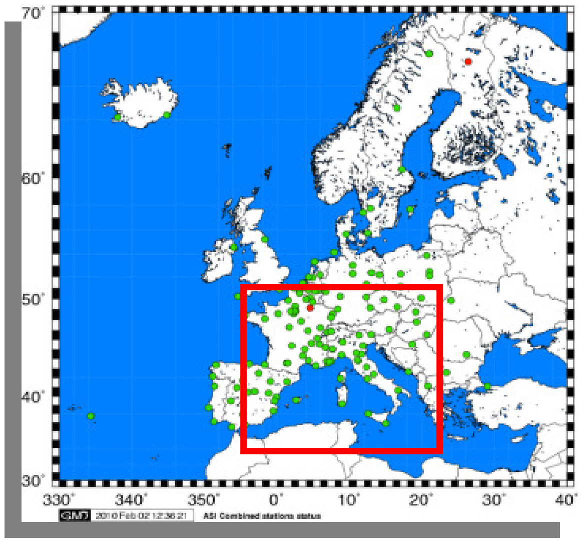
Third Step:

ZTD at a given location

From point wise ZTD estimates to the ZTD Fields: First Step

To obtain residuals ZTD at mean sea level, we need estimated and modelled ZTD values.

Following UNB3m and its look-up table barometric pressure (P), temperature (T), relative humidity (RH), temperature lapse rate (λ) and water vapour pressure height factor (β) are determinated for a given latitude and day of the year.

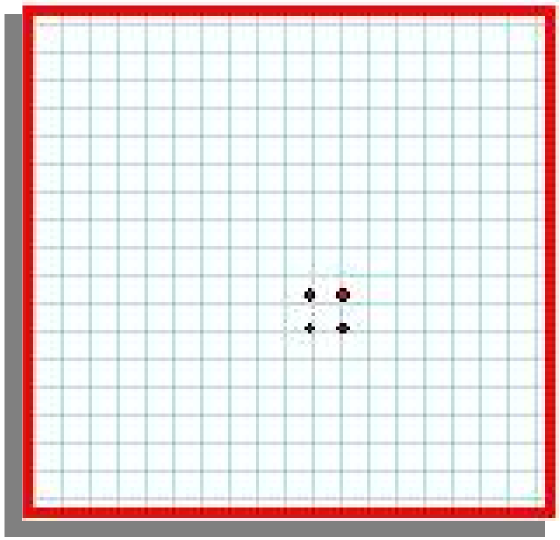


$$RES_{MSL} = ZWD_{MSL} - ZWD_{MOD,\, MSL}$$

From point wise ZTD estimates to the ZTD Fields: Second Step

We get gridded residuals at mean sea level using Ordinary Kriging interpolation.

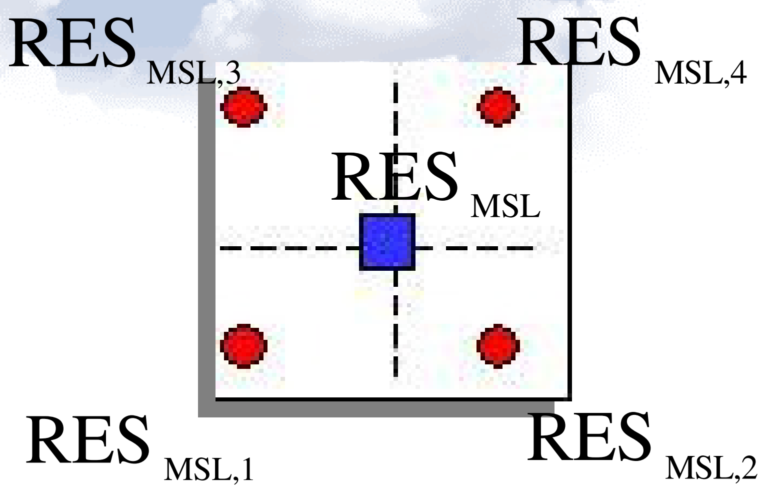
The outputs are 0.5^0x0.5^0 residual grids.



From point wise ZTD estimates to the ZTD Fields: Third Step

To get the residual at a given location, we perform a bi-linear interpolation with the four nearest points surrounding it:

$$\mathrm{RES}_{\mathrm{MSL}} = \sum_{\mathrm{i}=1}^{4} \omega_i RES_{MSL,i}$$

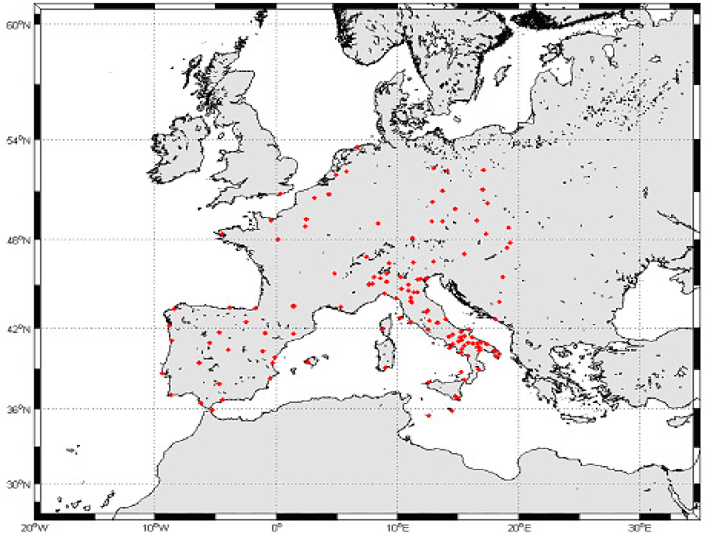


where the general weight function is:

$$\omega(x, y) = x^2 y^2 (9 - 6x - 6y + 4xy)$$

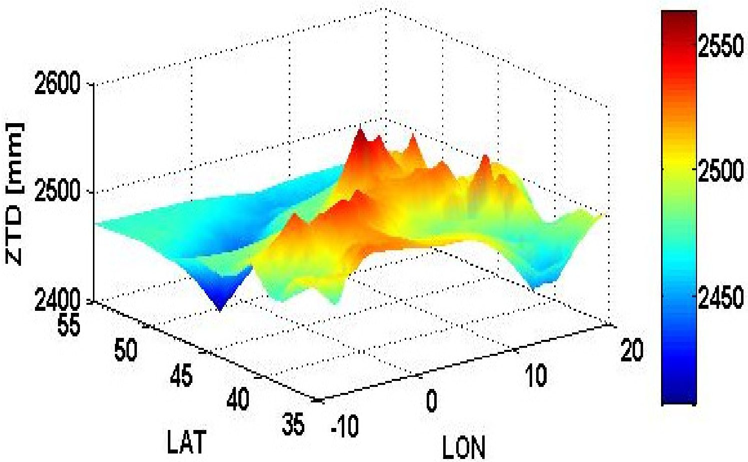
for $0 \le x \le 1$**,** $0 \le y \le 1$**.**

Experimental data

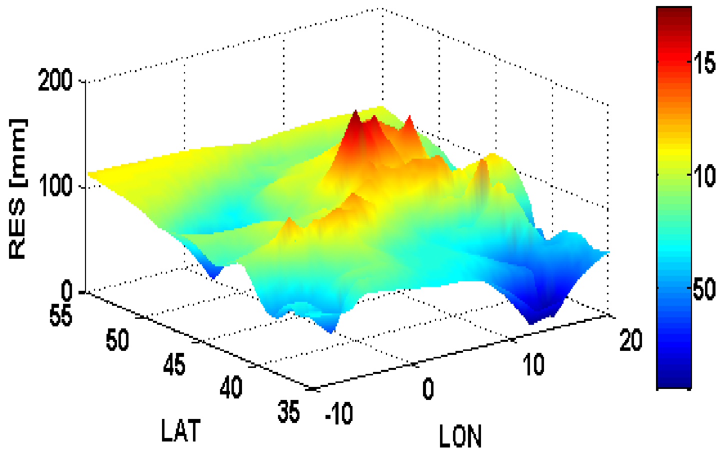


We test our procedure over 1 week (from 10MAR14 to 10MAR20) of ZTD estimates coming from 130 European GPS stations mostly belonging to the EPN Network.

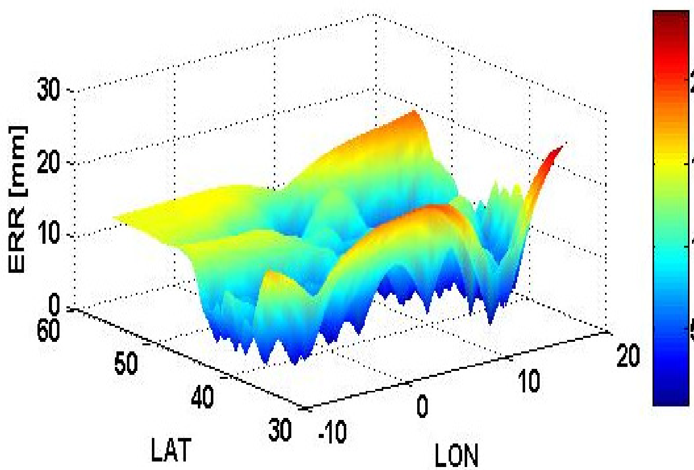
GPS ground-based network



a) Residual field



b) ZTD field

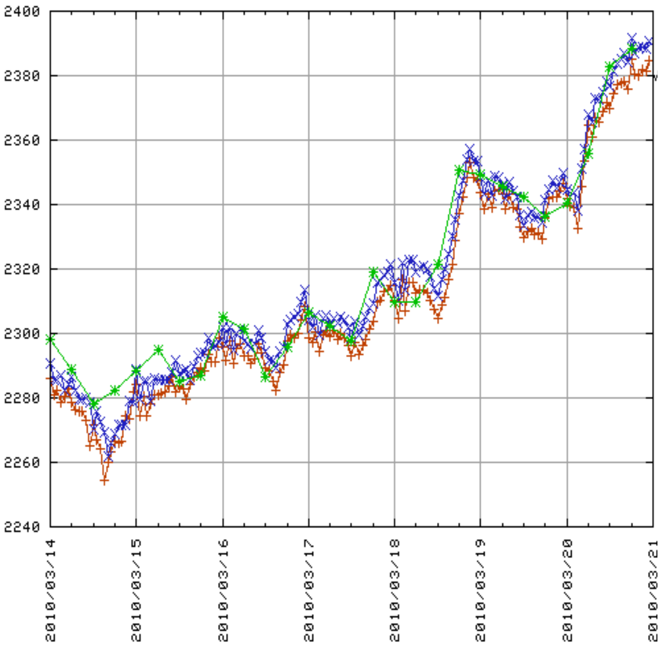


c) Error field

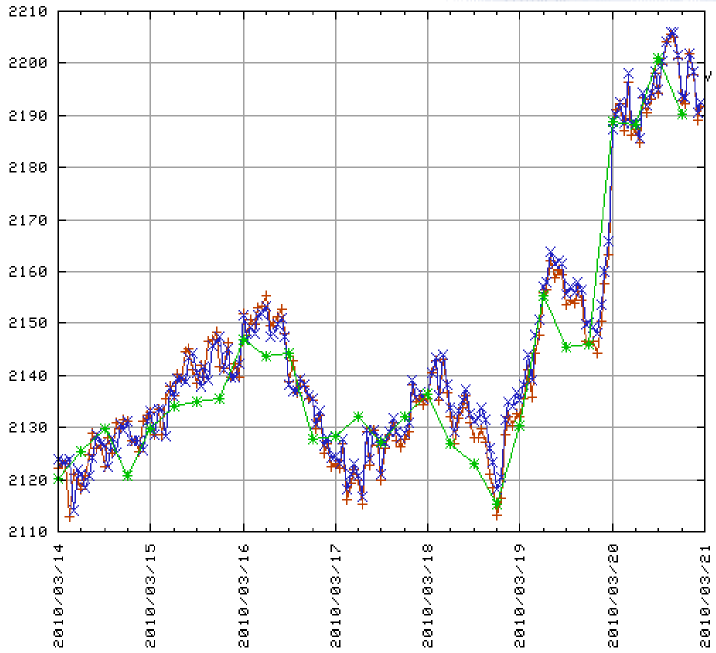
ZTD Field Validation (1/2)

ZTD[mm]

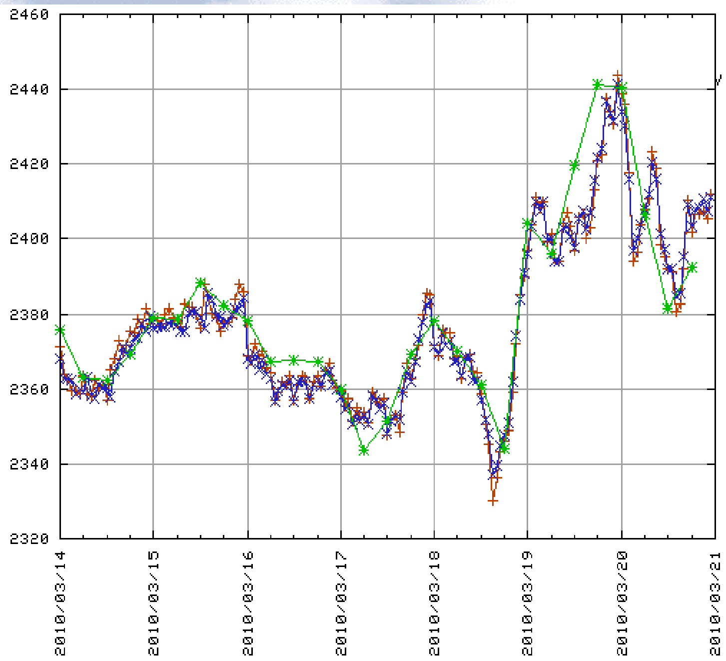
BZRG ZTD time-series



ZIMM ZTD time-series



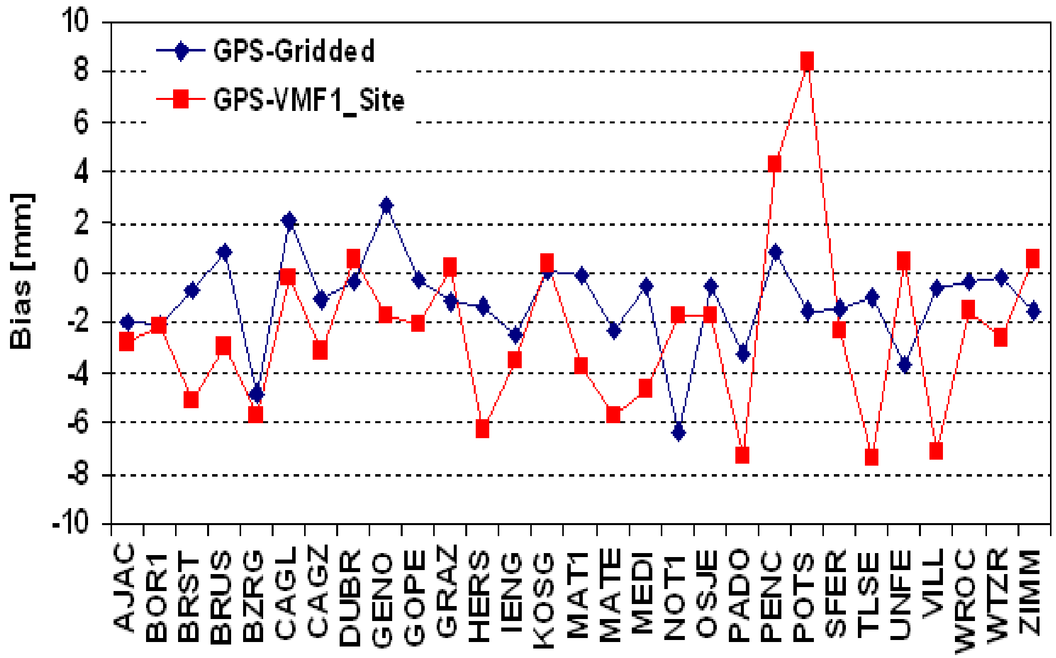
BRUS ZTD time-series

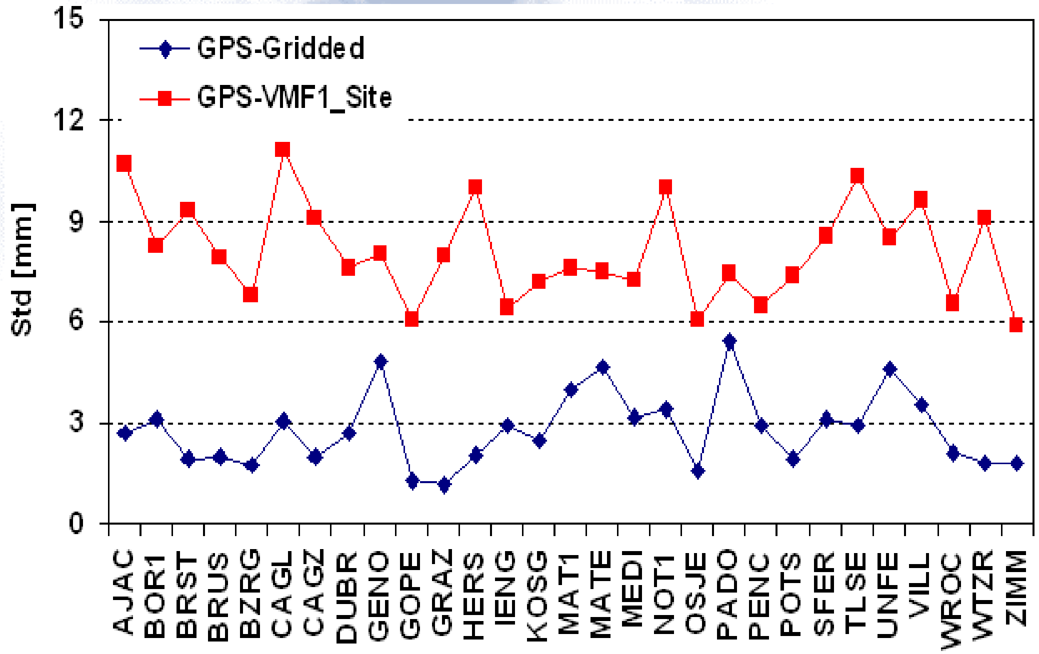


- **in red GPS-derived,**
- **in blue Gridded,**
- **in green VMF1_Site**

(http://ggosatm.hg.tuwien.ac.at/DELAY/readme.html)

ZTD Field Validation (2/2)





	MEAN [mm]	STD [mm]	CC
GPS-Gridded	-1,1	2,8	0,99
GPS-VMF1_site	-2,3	8,1	0,93

The agreement of "*GPS vs Gridded*" is better than "*GPS vs VMF1_Site*" and it is partly to be expected since GPS-derived ZTDs are the input data for computing the ZTD fields.

Summary & future activities

- We present a method for estimating ZTD fields by using ground-based GPS network and we foresee some fields of applications.
- More sites will be included in the GPS network in order to have a denser and more homogenous coverage.
- The validation activities will continue by considering a longer time series and other ZTD fields as those provided by the University of Technology of Vienna.
- Improve the ZTD residuals computation by considering the tropospheric gradients.

References

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