NEAR REAL TIME GPS ZENITH TOTAL DELAY ESTIMATION IN THE MEDITERRANEAN AREA: RESULTS OF 3 YEARS OF ROUTINE PROCESSING

Rosa Pacione

Telespazio S.p.A. - Centro di Geodesia Spaziale, Matera - Italy

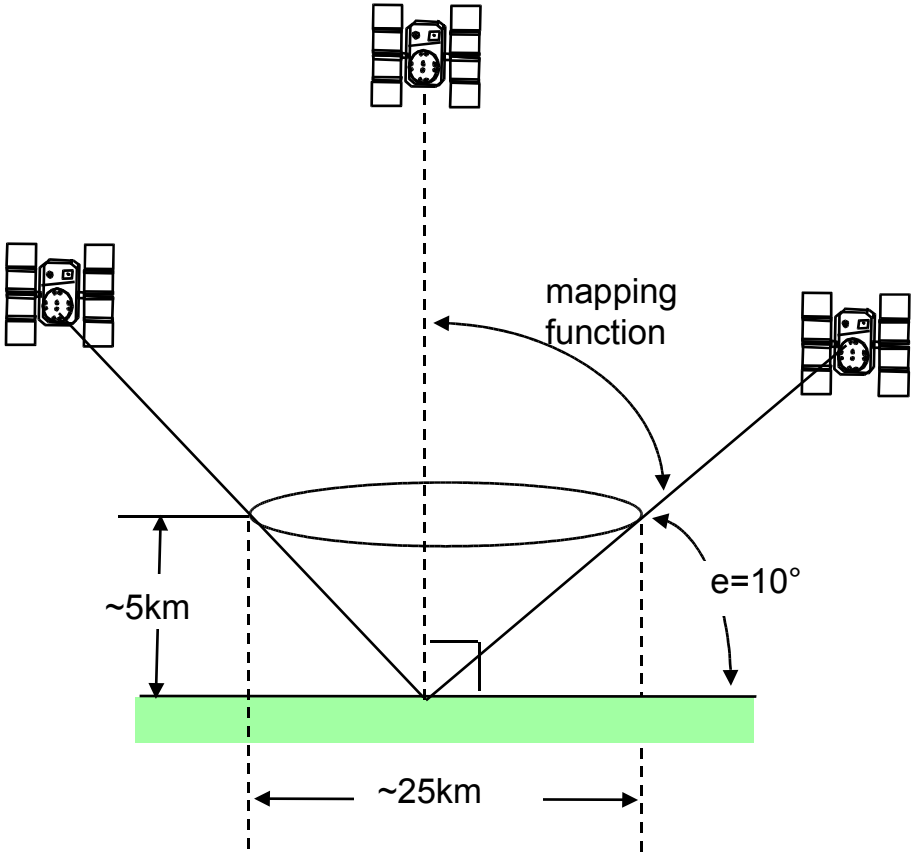
Francesco Vespe

Agenzia Spaziale Italiana - Centro di Geodesia Spaziale, Matera - Italy

Outlook of the talk

- Ground Based GPS Meteorology:
  - Fundamental Equation
  - Activities at CGS
- GPS processing strategies for ZTD estimation
- GPS ZTD validation
  - NRT versus “precise” Post Processed ZTD
  - NRT within COST-716 & TOUGH

Ground-Based GPS Meteorology



Fundamental Measurement

$$L_S = 10^{-6} \int N(s)\,ds$$

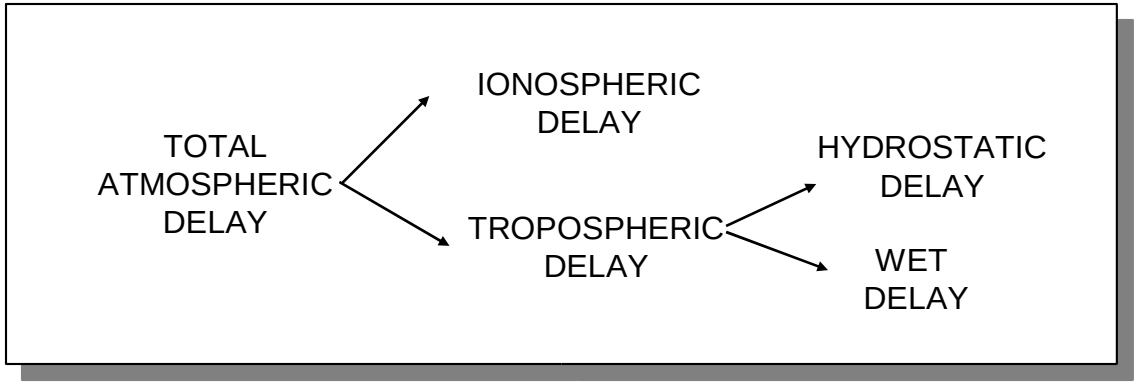
$$N = k_1 \cdot \left(\frac{P_d}{T}\right) + k_2 \cdot \left(\frac{e}{T}\right) + k_3 \cdot \left(\frac{e}{T^2}\right)$$

A mapping function is applied to determine how the signal delay changes with elevation angle.

The results are averaged over all the satellites to give the ZTD.

Tropospheric Delay

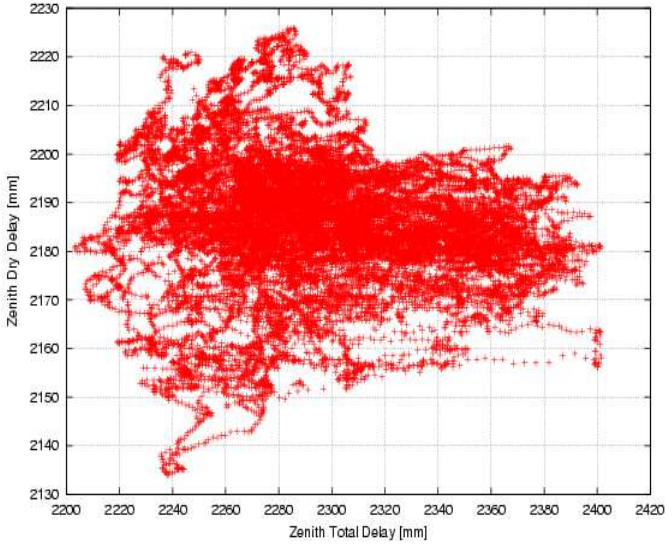
GPS Atmospheric Delay



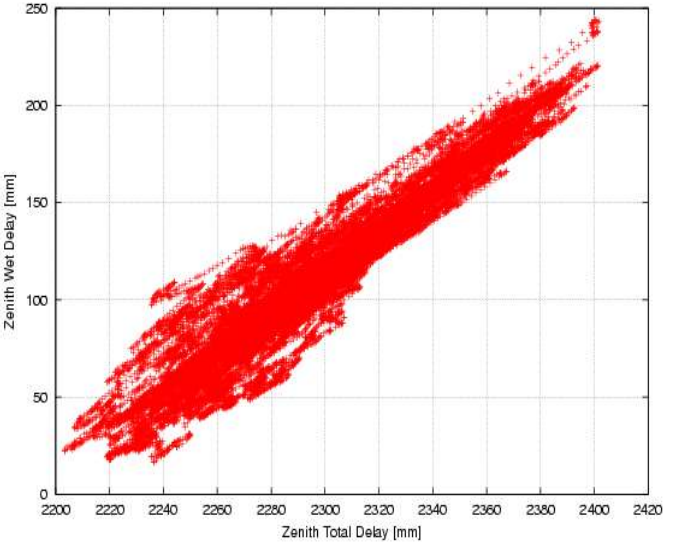
ZTD=ZHD+ZWD

Most of the variability in the ZTD is caused by water vapor in the lower troposphere

ZTD vs ZHD



ZTD vs ZWD



From GPS Observable to Meteo Forecast

GPS observable

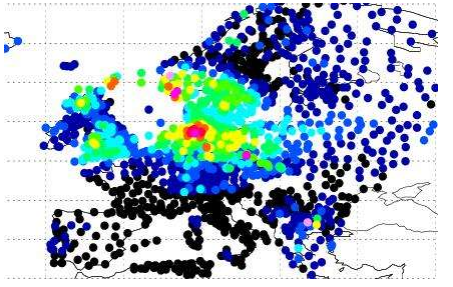
$$\lambda_i \phi_i = \rho + d_{clock} - d_{iono\,i} + d_{tropo} + \lambda_i N_i + \varepsilon_i$$

data reduction → ZTD

Noise for Geodesy
Signal for Meteorology

ZTD=ZHD+ZWD → IPWV

Forecast rain with GPS -DMI



assimilation → Meteo Forecasts

ASI Ground-Based GPS Met Activities

GPS RNX files

GPS Orbits
ERP
GPS sat. clocks

Post-Processing
Daily PPP solution
•ZTD
•Site Position

Near-Real Time
Network solution, SLW
•ZTD

IGU Orbits
ERP
Site Position

Nominal latency 15 days

Nominal latency 1h45min

GPS Met Products

January 1999

MAGIC

VALIDATION
•WVR
•RADIOSONDES
•VLBI
•NRT vs PPP
•NRT vs NRT

USERS
•NWP
•ENVISAT Sensor CAL/VAL

June 2001

COST 716

February 2003

TOUGH

Near Real Time Processing

Strategy	**Network Adjustment**
Data handling	**24h Sliding Window**
Sites	**40 European Sites**
Satellite Orbits	**Fixed to IGU**
ERP	**IGU**
Station coordinates	**Heavily constrained to previous month position aligned to IGS00**
'Bad' sat/sta detection	**Automatic detection and removal on post-fit phase residuals**
Cut-off elevation	**10deg**
Ocean Loading	**Applied (H.G.Scherneck)**
Mapping Function	**Neill (1996)**
Ant. phase center variation	**Applied following the IGS recommendations (Mader, 1999)**
Data sampling rate	**5min**
Estimated parameters	**Satellite & station clocks w.r.t a reference one** **Phase ambiguities (float)** **ZWD time resolution of 5min**
Output	**ZTD in COST V2 format** **4 scores per hourly solution every 15 min (at h:00, h:15, h:30, h:45)**

Ref. Pacione and Vespe, Journal of Atmospheric and Oceanic Technology, Vol.20, 1034-1042, 2003

Processing Schedule in Operation NRT Mode

-1h h

Data recording

h:15

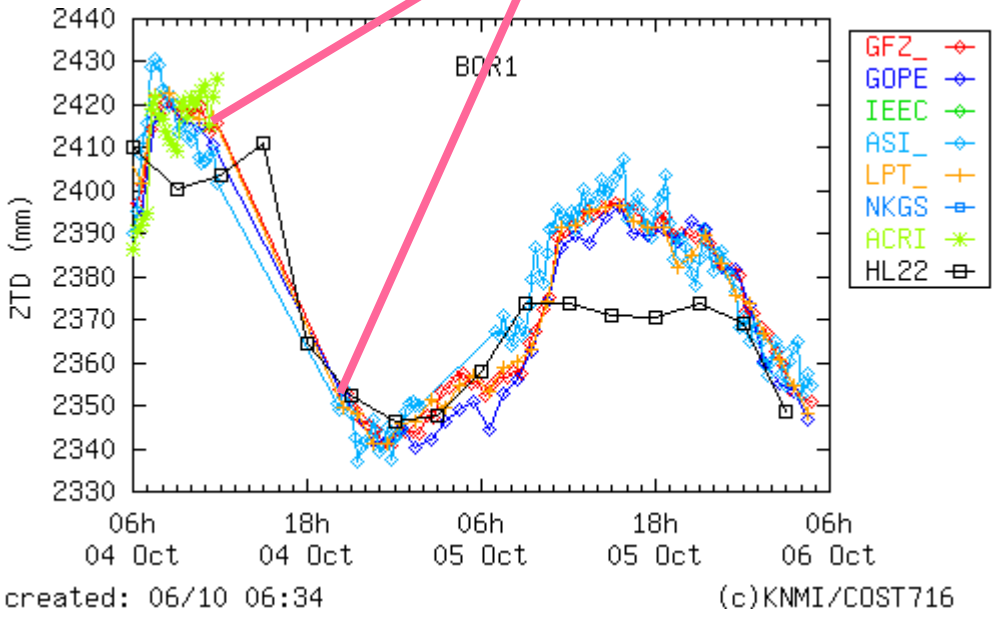
Waiting time

h:45

Data ftp and Processing

ZTD deliver to MetO

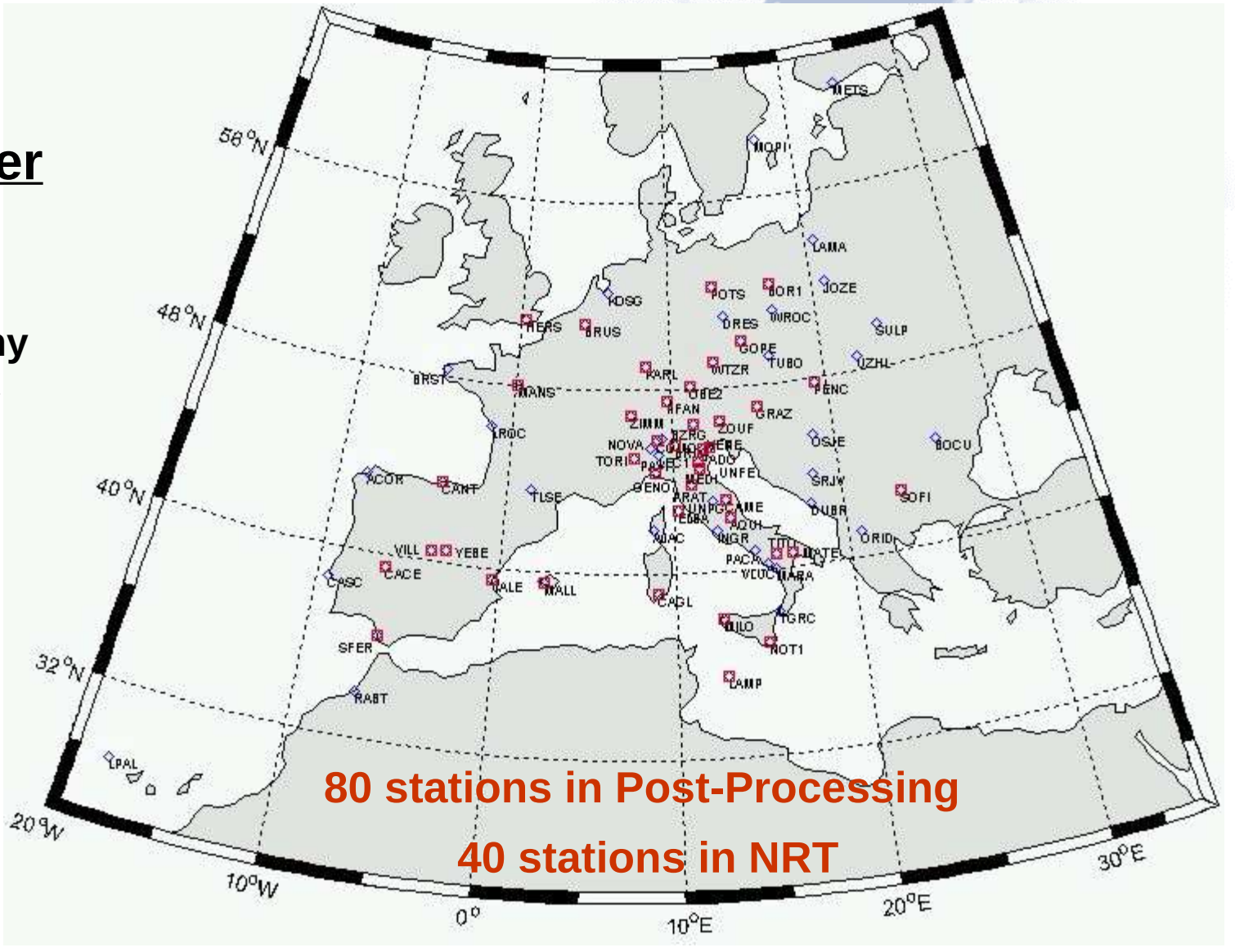
IGU obits not available



Ground-Based GPS Network

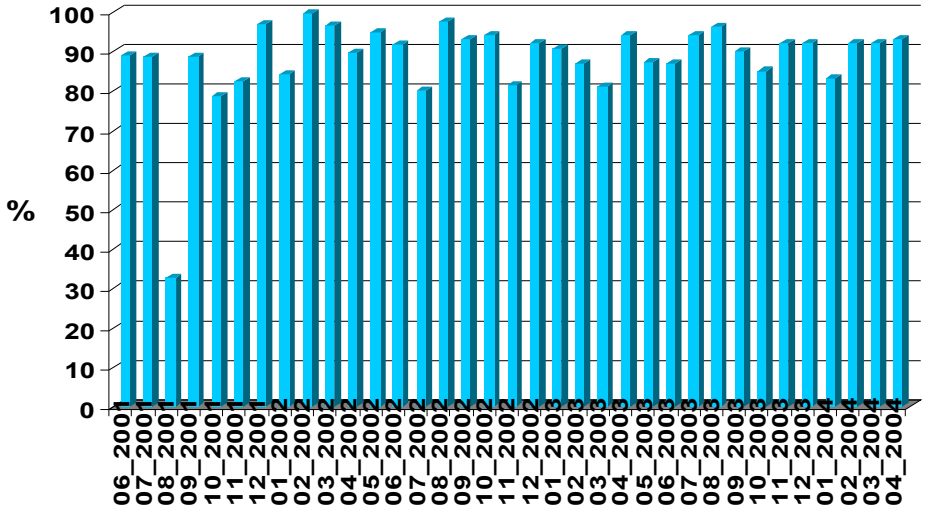
GPS Data Provider

ASI, EPN LDC, Italy
BKGE, EPN RDC, Germany
BKGI, IGS RDC, Germany
ESOC, Germany
IGNE, EPN LDC, France
IGNI, IGS GDC, France
OLG, EPN LDC, Austria

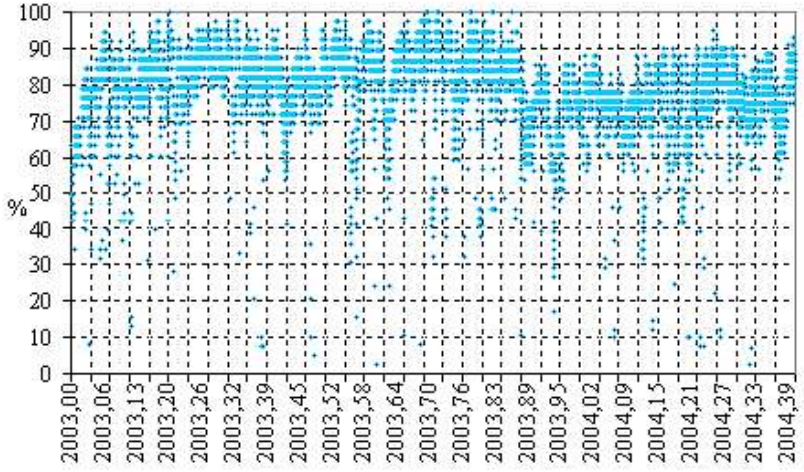


NRT Solution Statistics

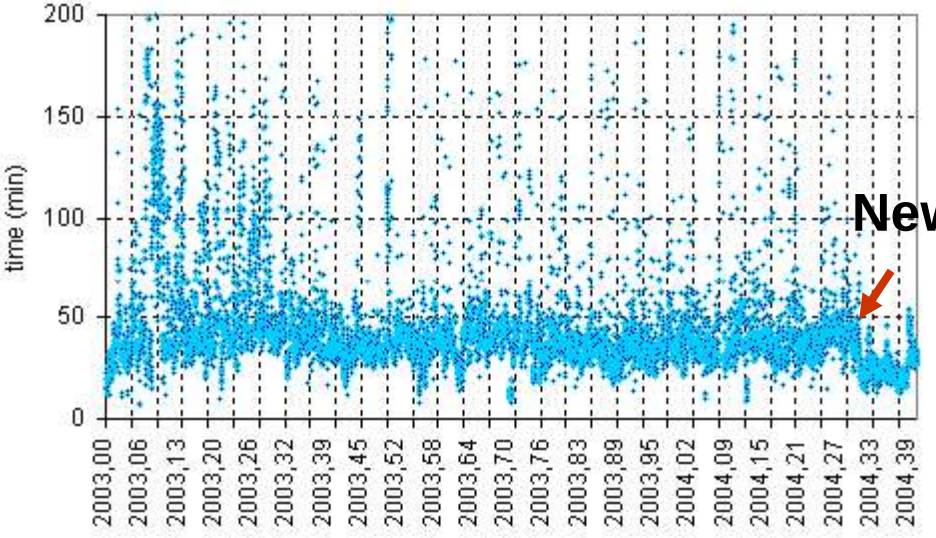
% hourly solutions - average 93%



% analyzed stations in each hourly solutions - average 78%

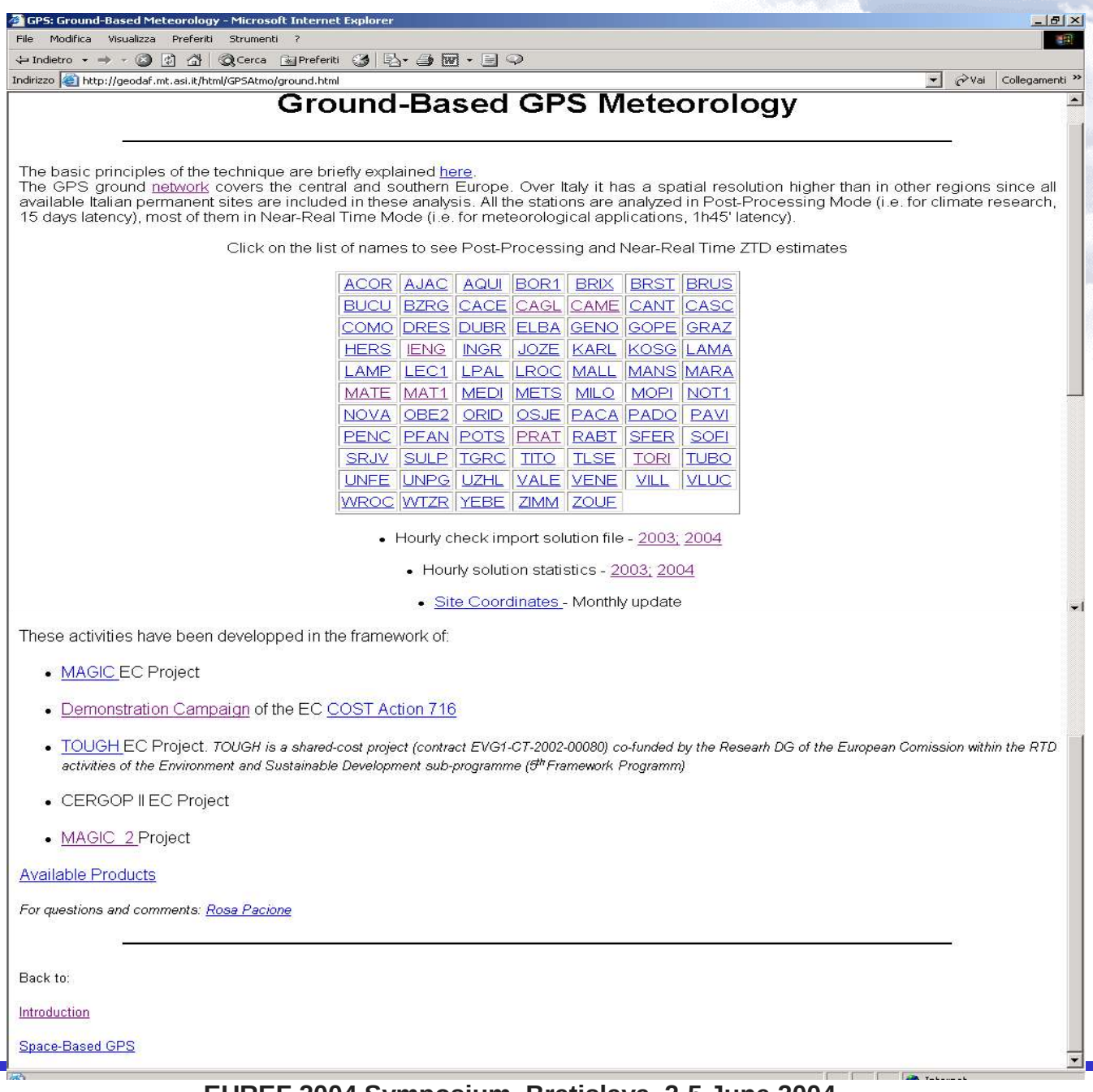


Processing time – average 48 min



New hw

http://geodaf.mt.asi.it/html/GPSAtmo/ground.html (1)



Ground-Based GPS Meteorology

The basic principles of the technique are briefly explained here.
The GPS ground network covers the central and southern Europe. Over Italy it has a spatial resolution higher than in other regions since all available Italian permanent sites are included in these analysis. All the stations are analyzed in Post-Processing Mode (i.e. for climate research, 15 days latency), most of them in Near-Real Time Mode (i.e. for meteorological applications, 1h45' latency).

Click on the list of names to see Post-Processing and Near-Real Time ZTD estimates

ACOR	AJAC	AQUI	BOR1	BRIX	BRST	BRUS
BUCU	BZRG	CACE	CAGL	CAME	CANT	CASC
COMO	DRES	DUBR	ELBA	GENO	GOPE	GRAZ
HERS	IENG	INGR	JOZE	KARL	KOSG	LAMA
LAMP	LEC1	LPAL	LROC	MALL	MANS	MARA
MATE	MAT1	MEDI	METS	MILO	MOPI	NOT1
NOVA	OBE2	ORID	OSJE	PACA	PADO	PAVI
PENC	PFAN	POTS	PRAT	RABT	SFER	SOFI
SRJV	SULP	TGRC	TITO	TLSE	TORI	TUBO
UNFE	UNPG	UZHL	VALE	VENE	VILL	VLUC
WROC	WTZR	YEBE	ZIMM	ZOUF		

- Hourly check import solution file - 2003; 2004
- Hourly solution statistics - 2003; 2004
- Site Coordinates - Monthly update

These activities have been developped in the framework of:

- MAGIC EC Project
- Demonstration Campaign of the EC COST Action 716
- TOUGH EC Project. *TOUGH is a shared-cost project (contract EVG1-CT-2002-00080) co-funded by the Research DG of the European Comission within the RTD activities of the Environment and Sustainable Development sub-programme (5th Framework Programm)*
- CERGOP II EC Project
- MAGIC 2 Project

Available Products

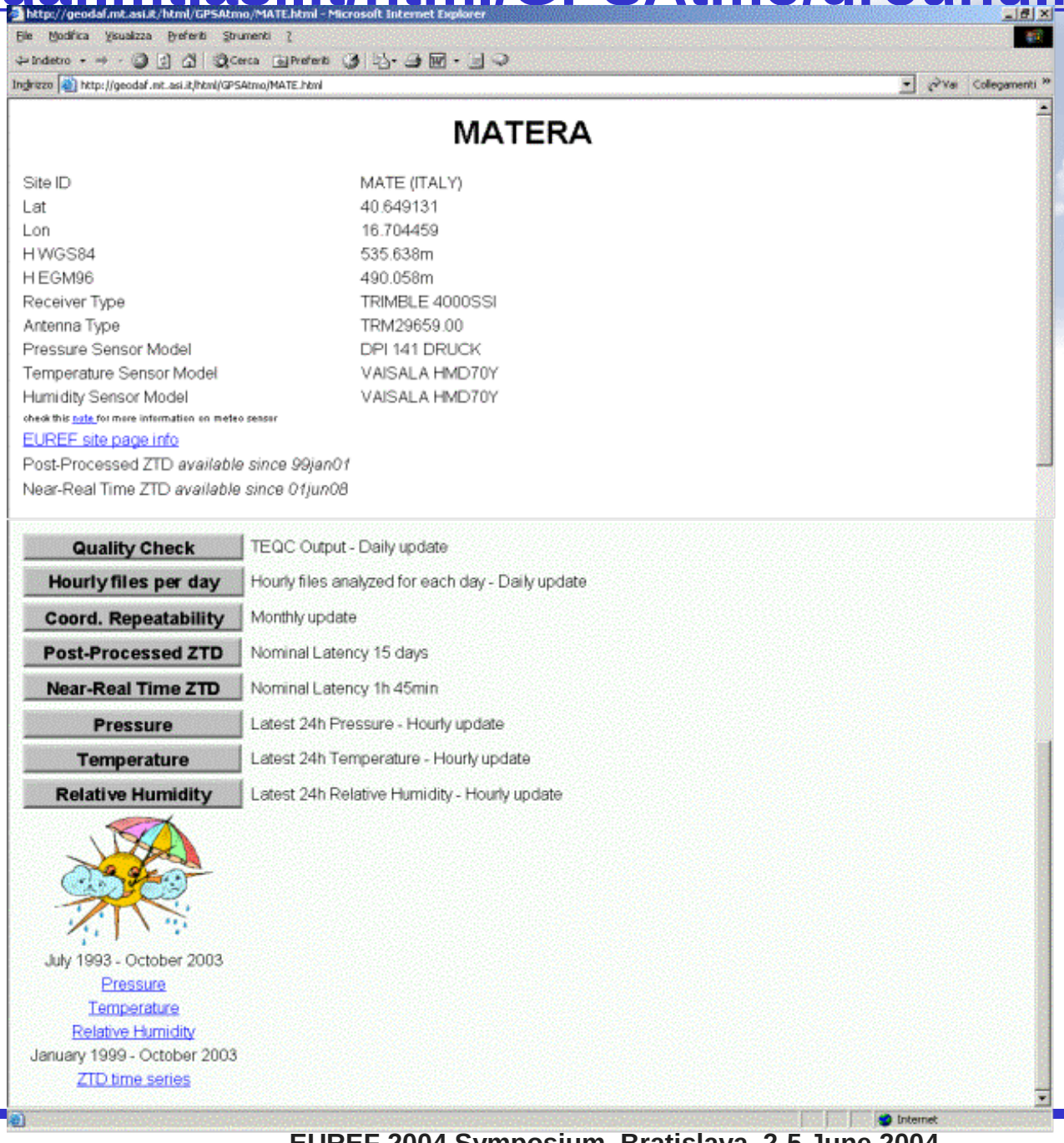
For questions and comments: Rosa Pacione

Back to:

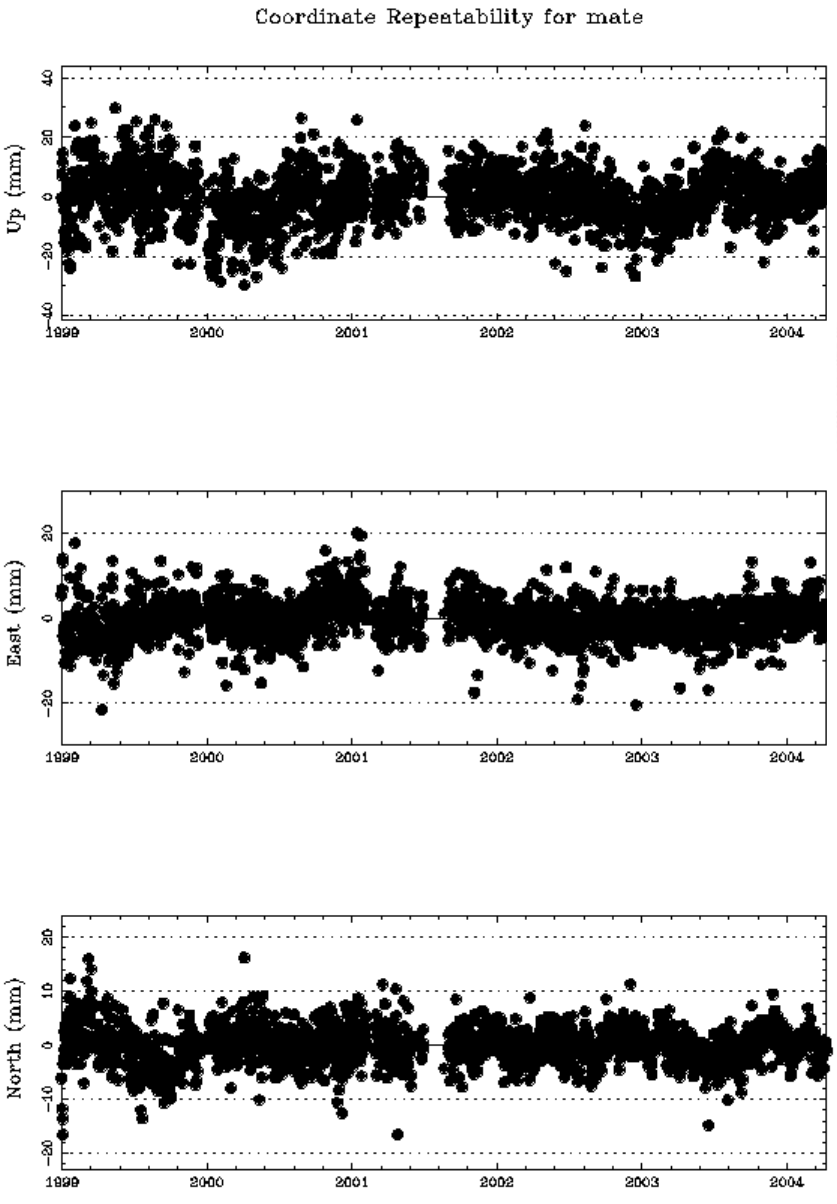
Introduction

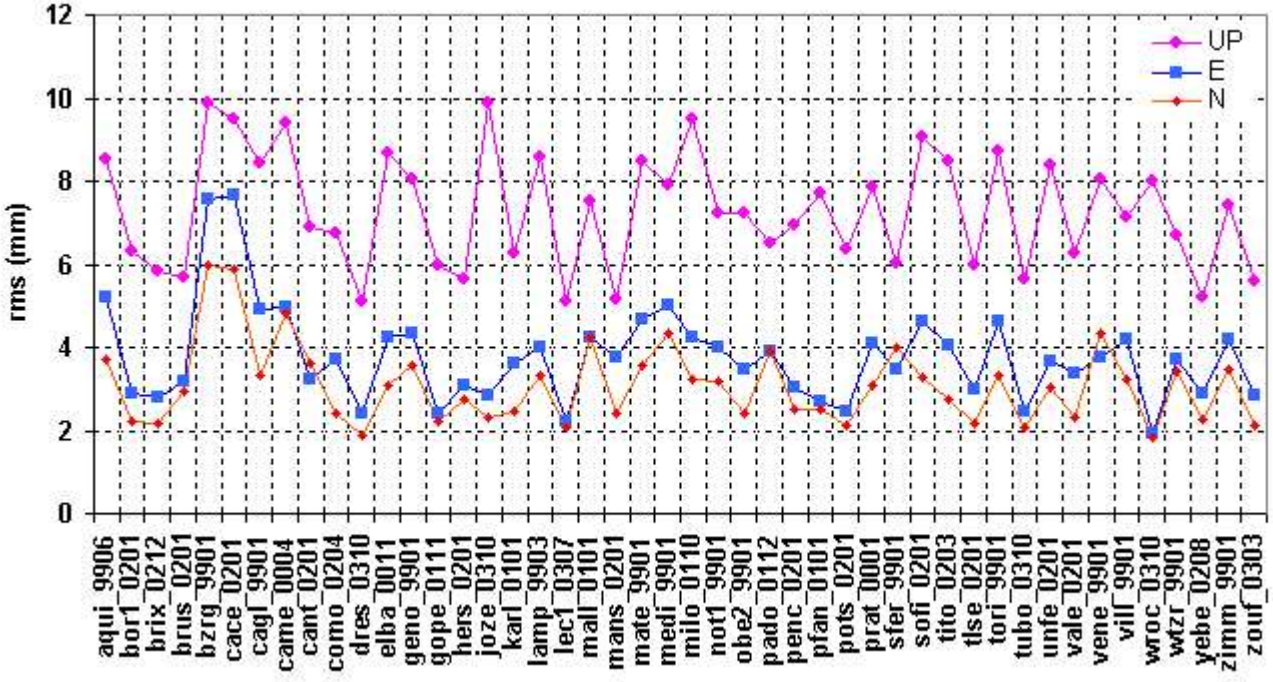
Space-Based GPS

http://geodaf.mt.asi.it/html/GPSAtmo/ground.html (2)



Station coordinate repeatability





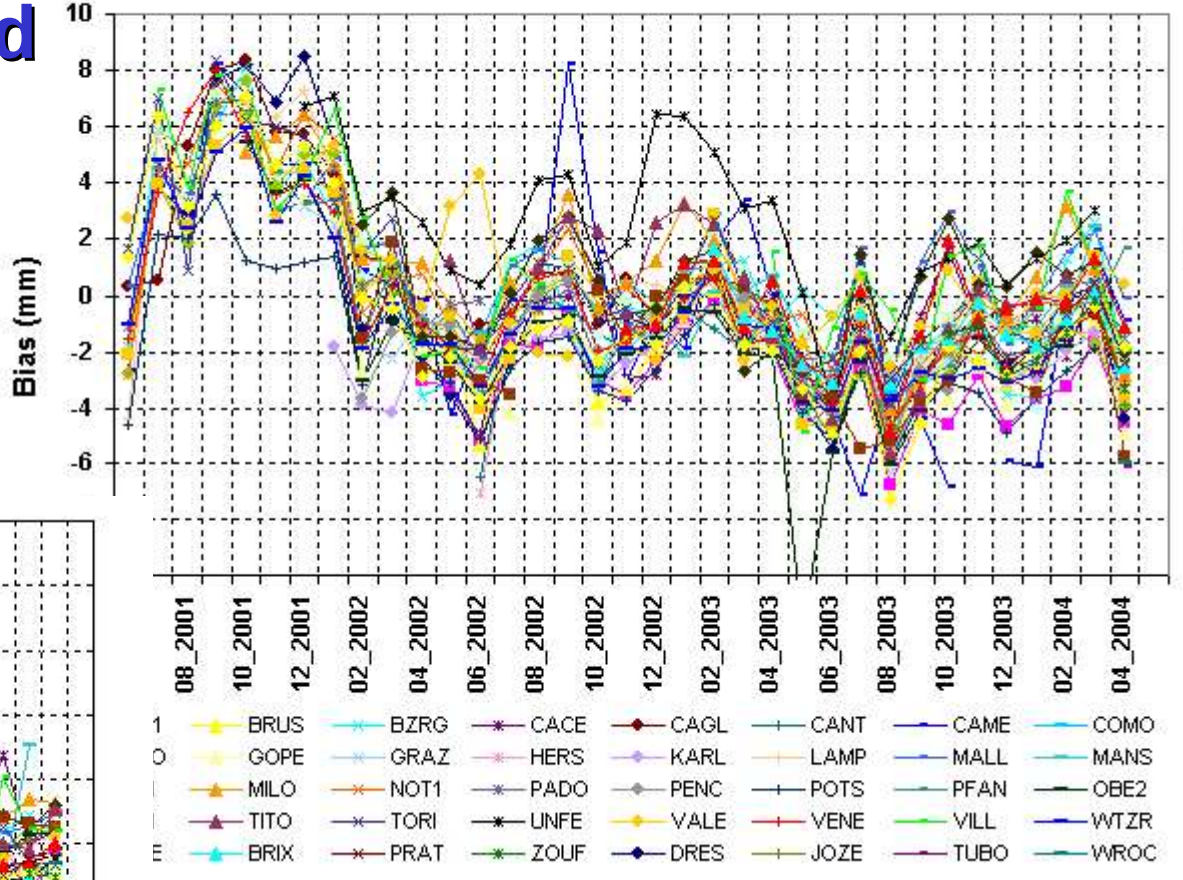
Heights coordinate repeatability as indicator for ZTD quality

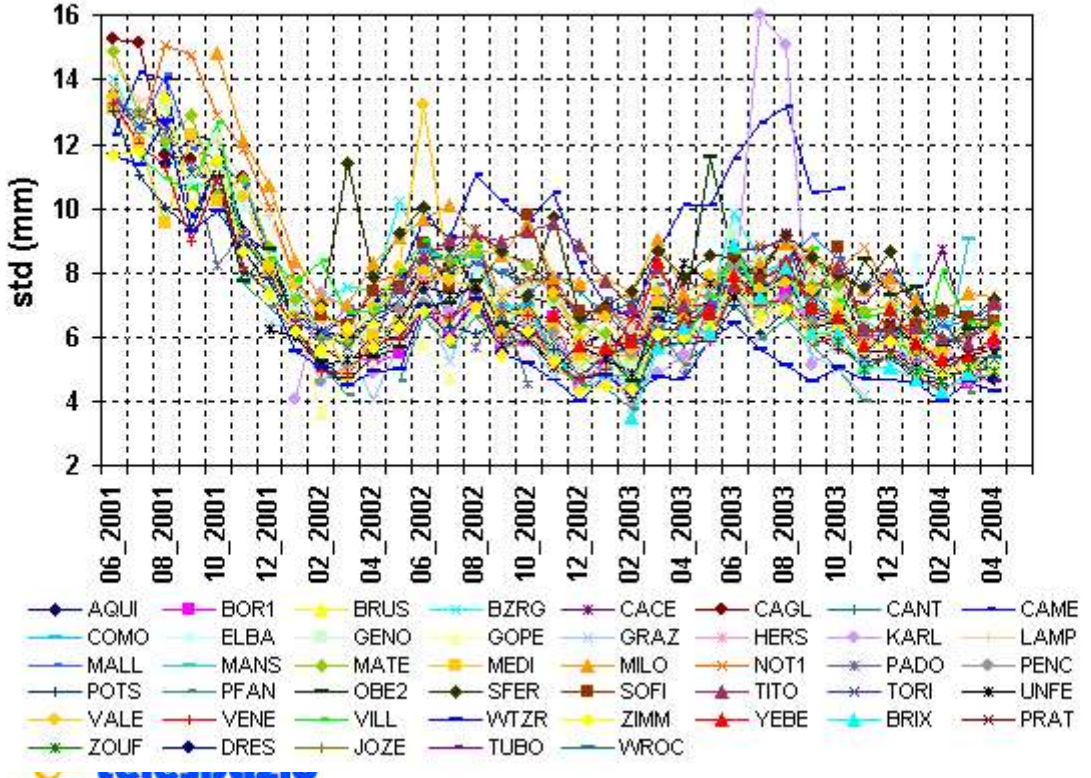
9mm H ⟶ 3mm ZTD ⟶ 0.45mm PW

NRT versus Post-Processed ZTD

Monthly mean bias and std

*June 2001-April 2004_*



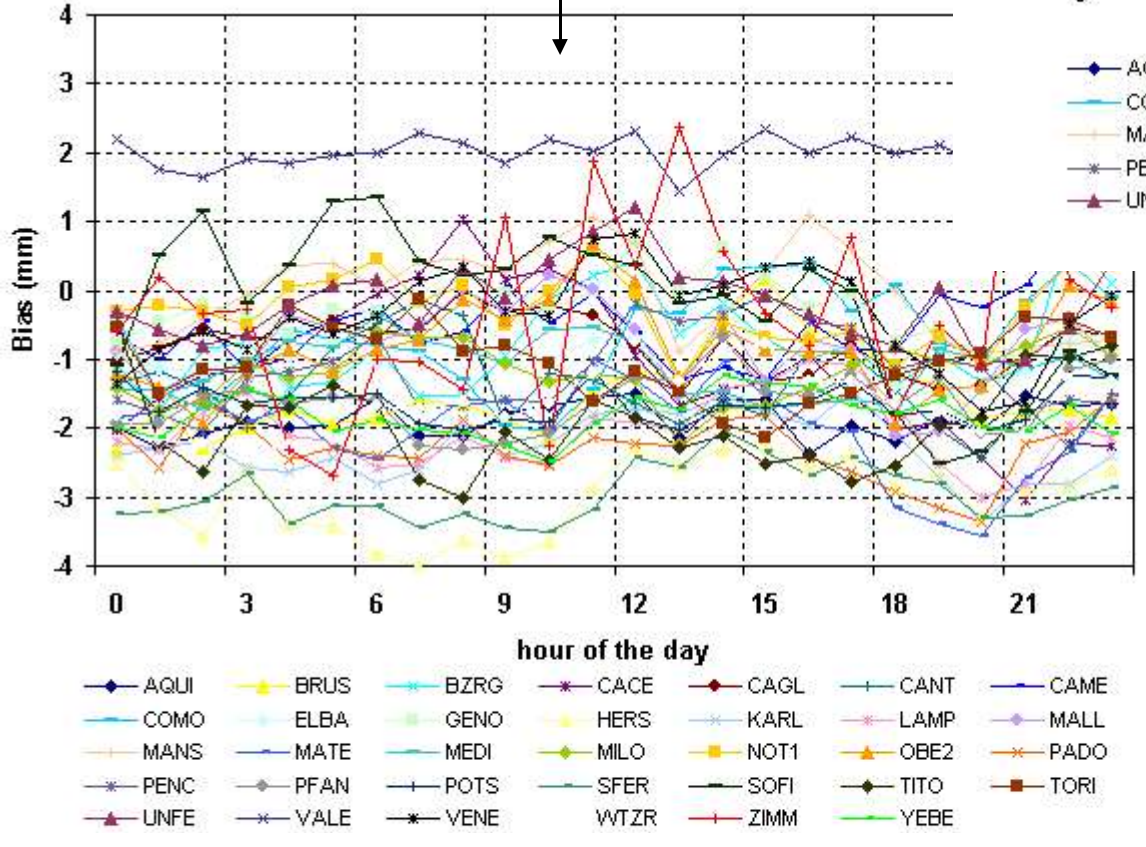


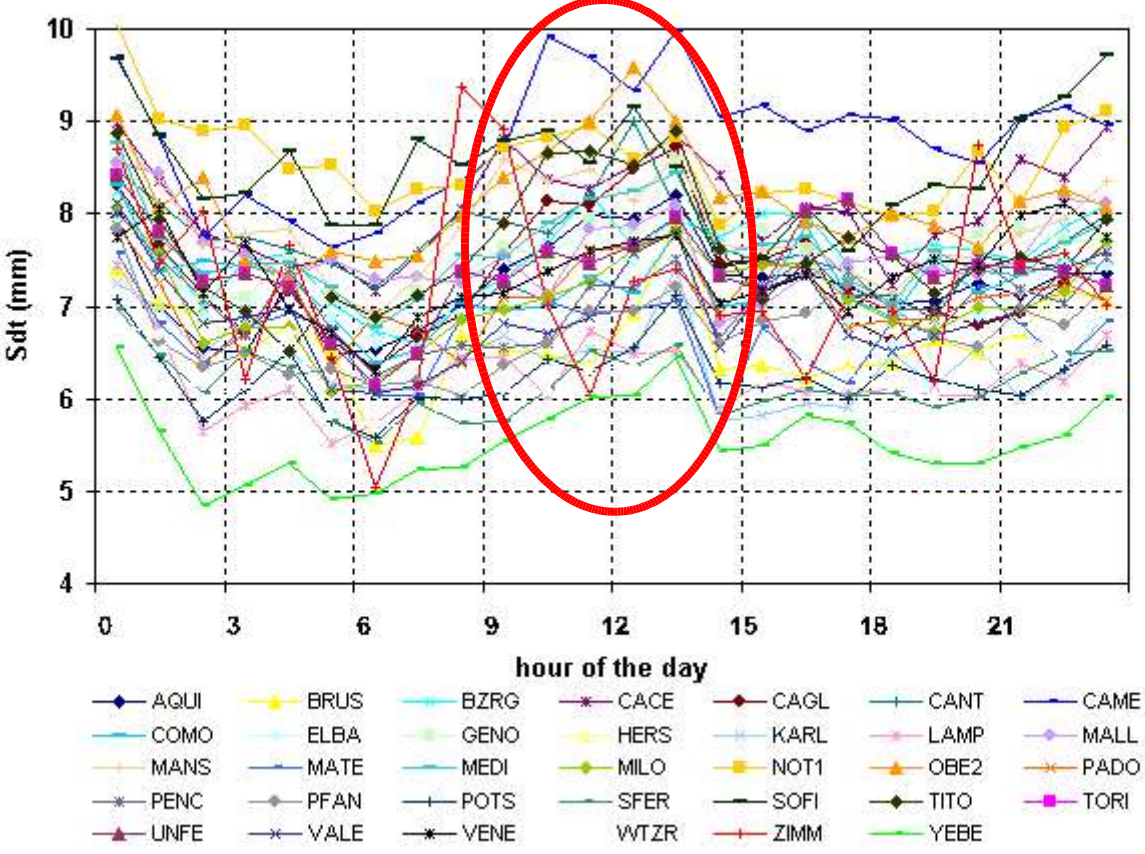
[6mm ZTD ≈ 1mm IPWV]

Daily ZTD variation w.r.t Post-Processed

2002-2003 bias and std

No daily cycle observed in ZTD bias

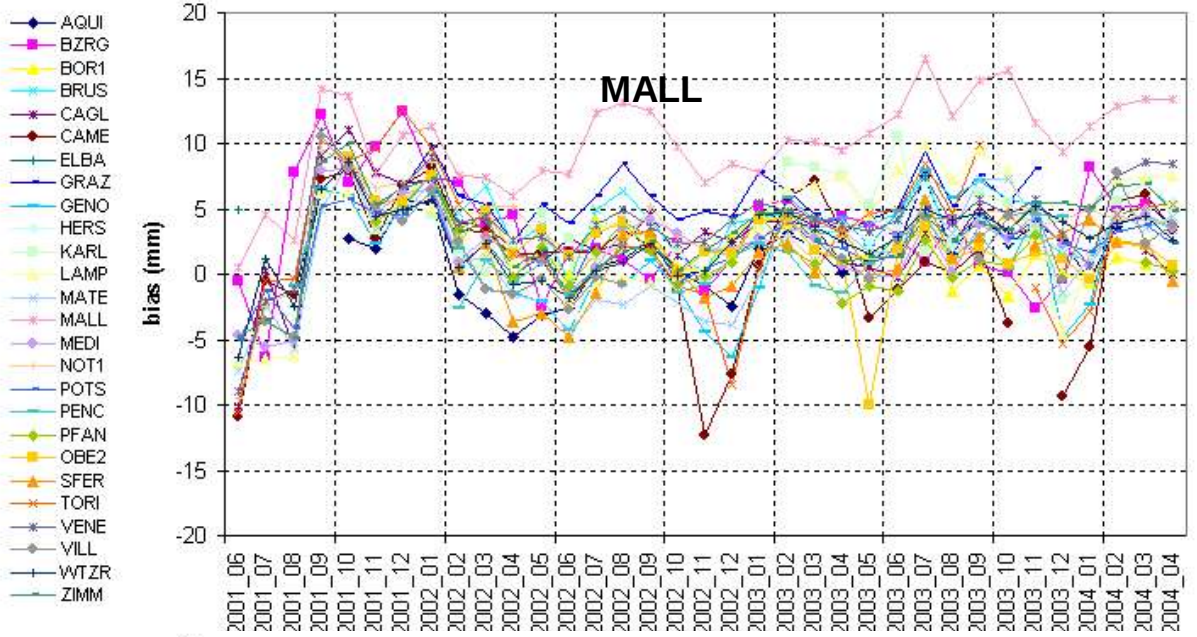


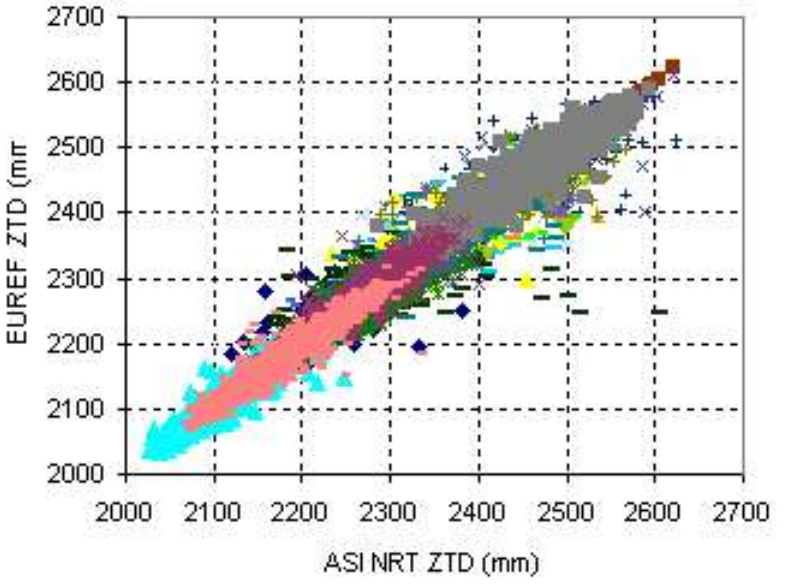


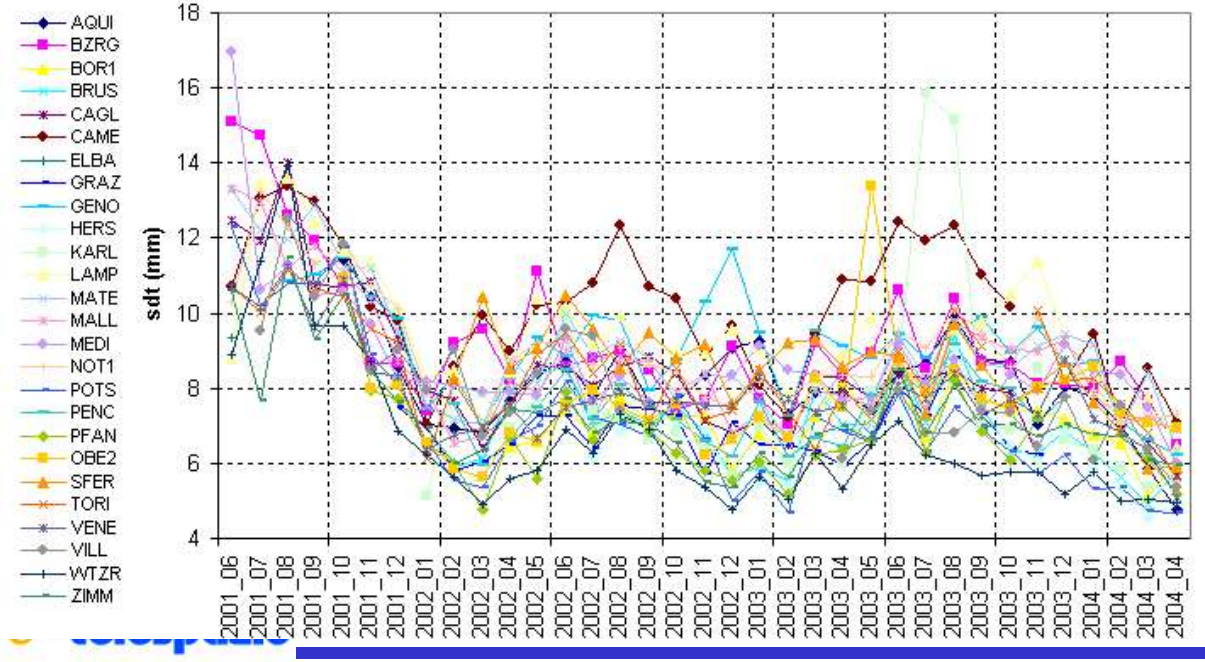
Slight increasing observed in ZTD std

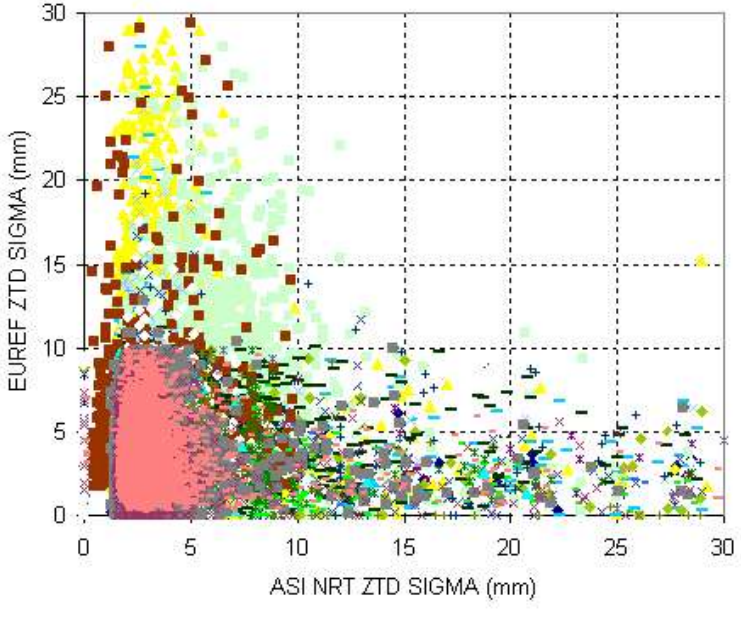
agenzia spaziale italiana

EUREF solutions vs NRT ZTD (*June 2001-April 2004*)

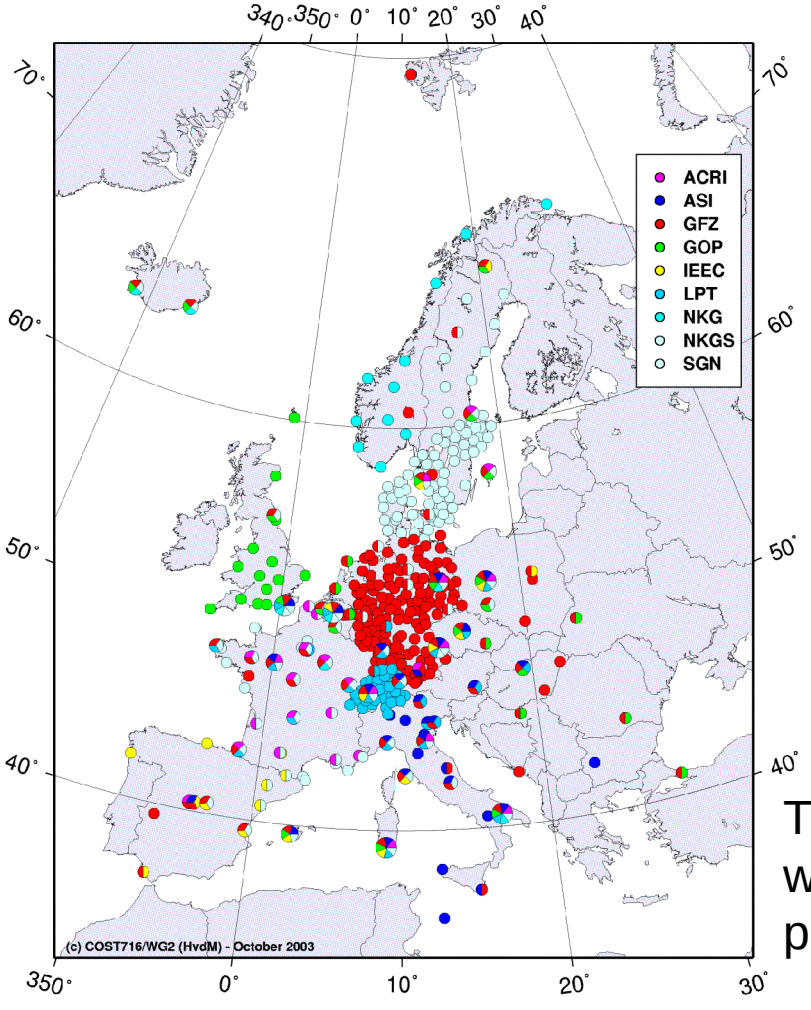






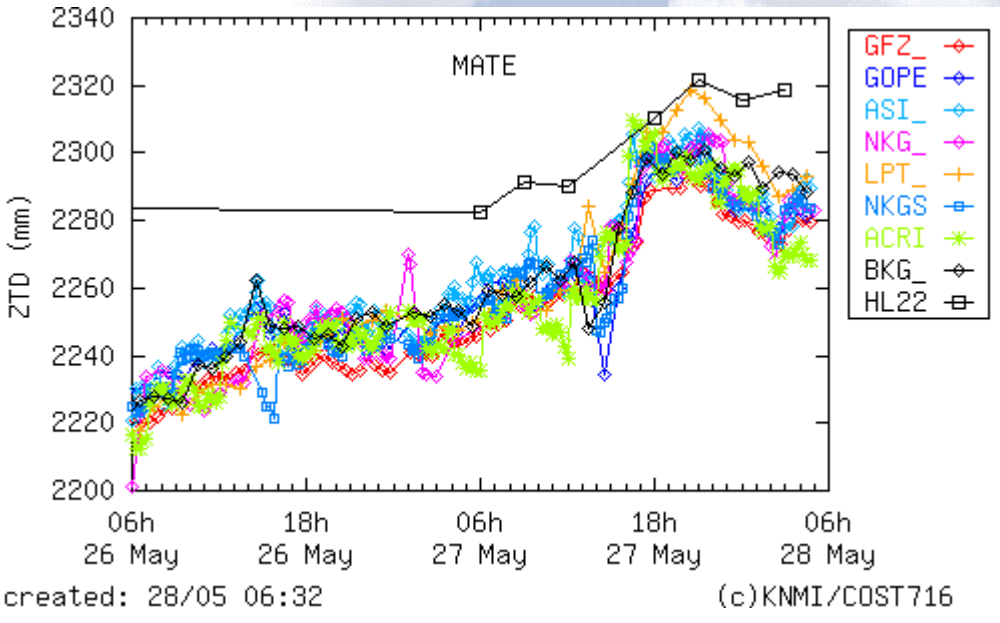


EC COST-716 Action & TOUGH Project



GPS stations in the near real-time network demonstration

http://www.knmi.nl/samenw/cost716/index.html

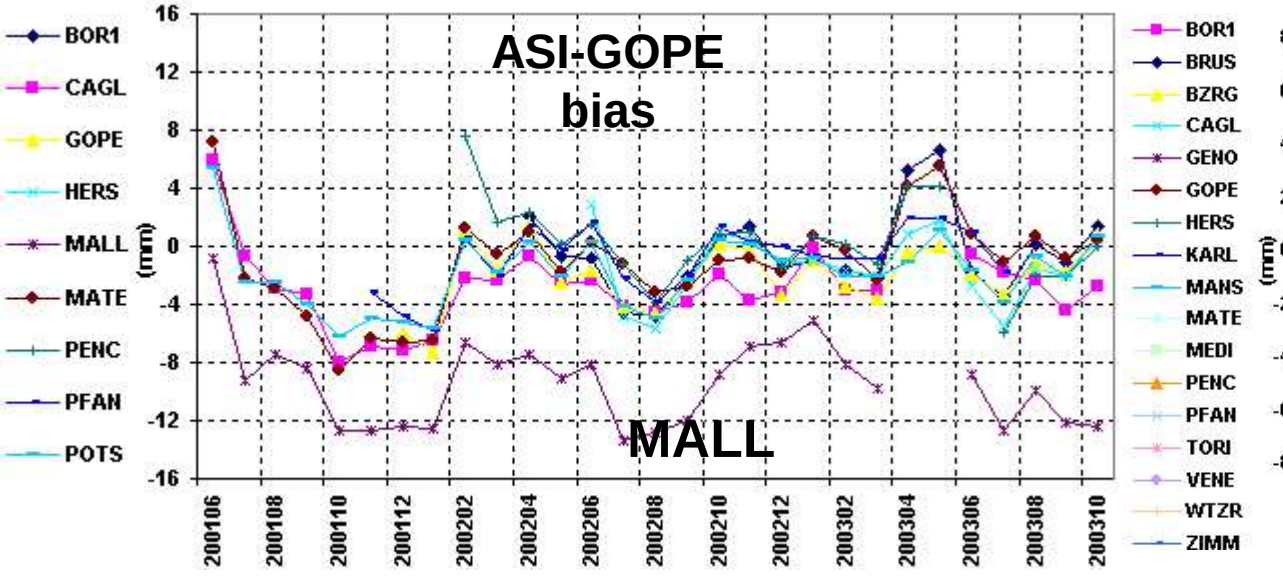


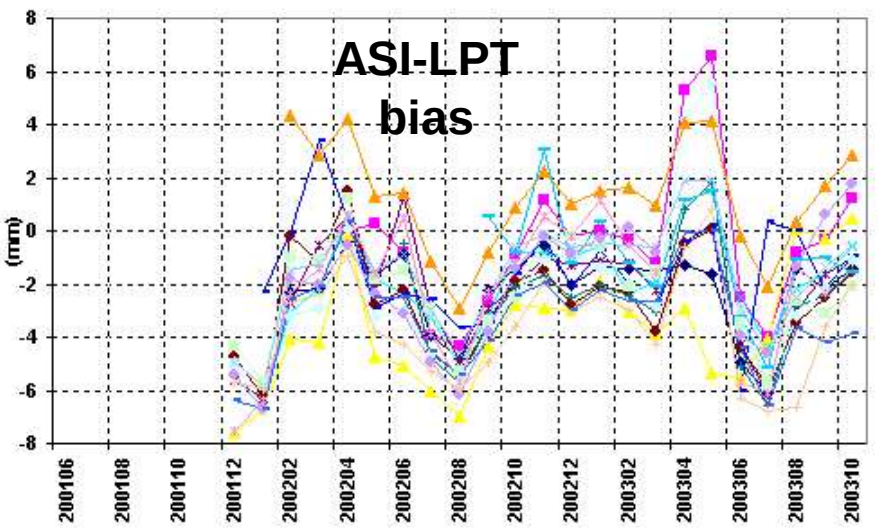
http://tough.dmi.dk

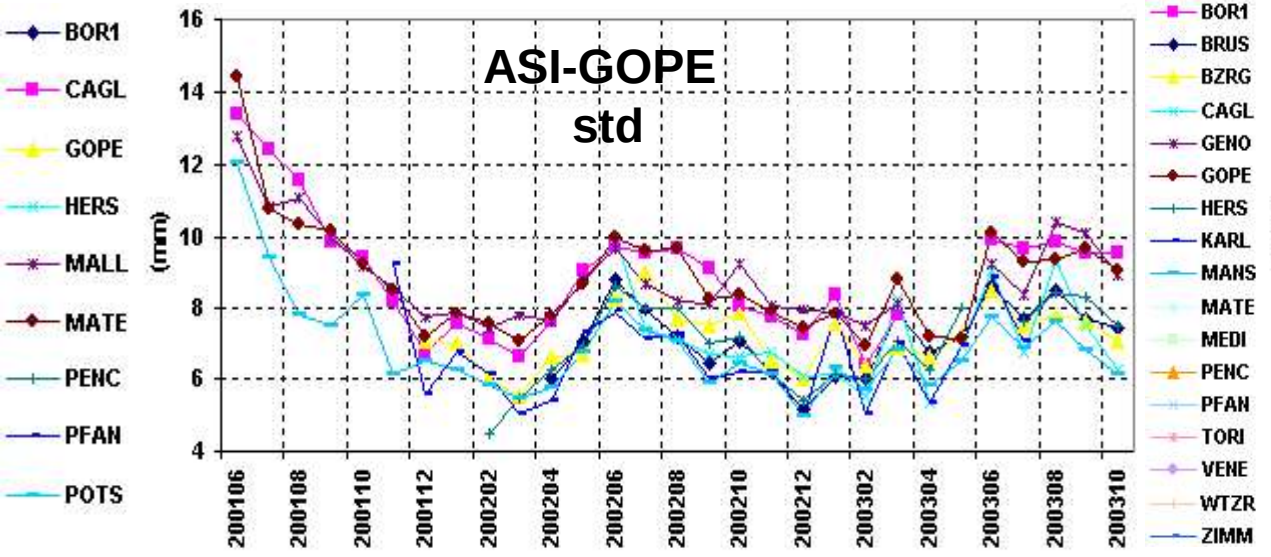
TOUGH is an interdisciplinary project between 15 institutes with expertise in the GPS system and numerical weather prediction. It runs from February 2003 to February 2006

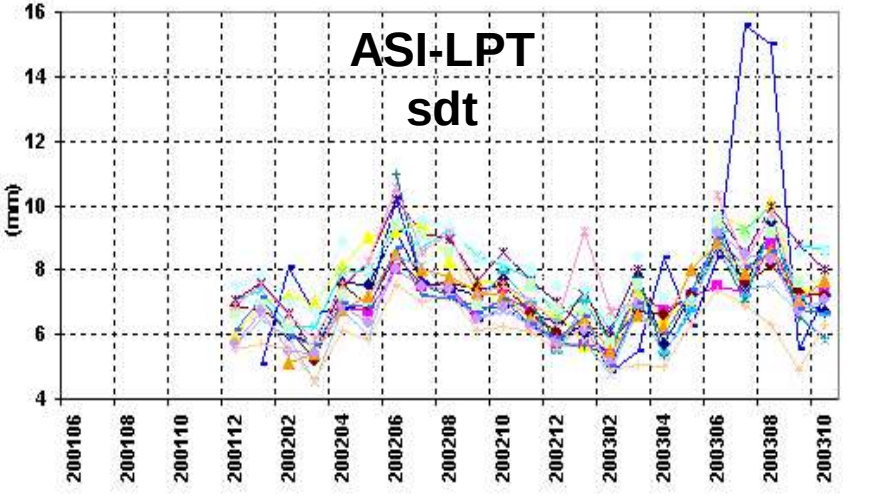
TOUGH is a shared-cost project (contract EVG1-CT-2002-00080) co-funded by the Research DG of the European Commission within the RTD activities of the Environment and Sustainable Development sub-programme (5'th Framework Programme).

NRT ZTD in TOUGH - Monthly bias & sdt

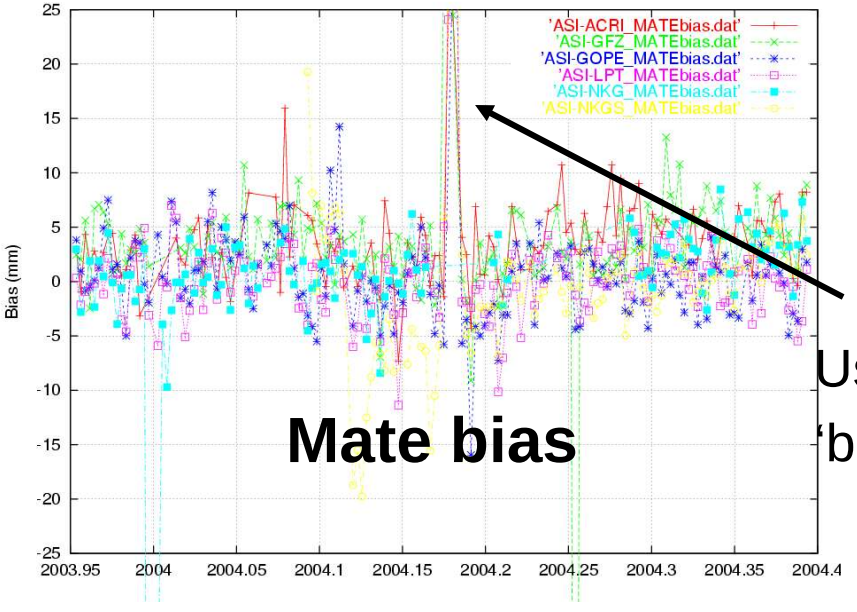




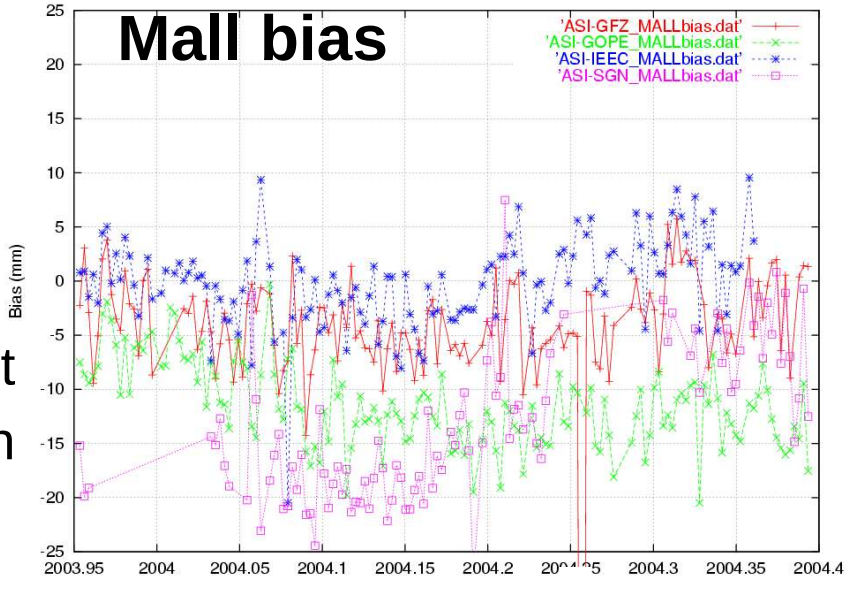


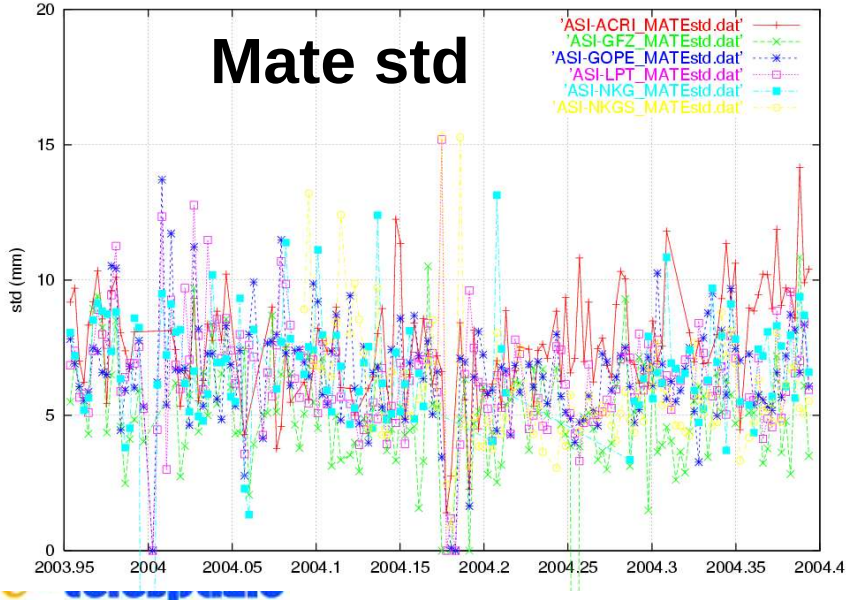


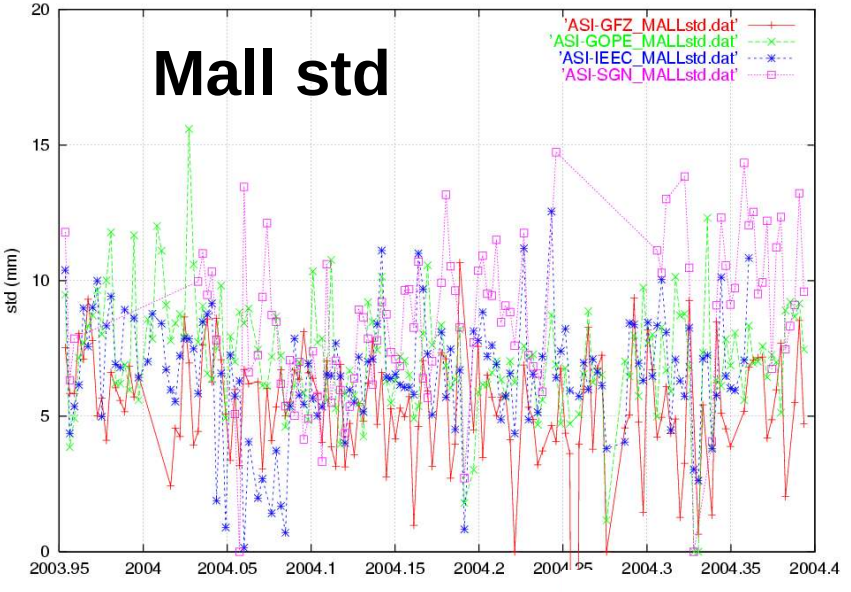
NRT ZTD in TOUGH – Daily bias & sdt



Useful to detect 'bad' daily solution

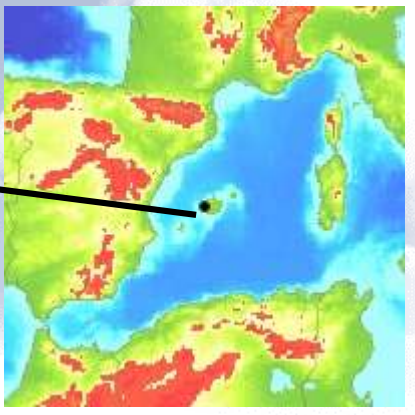






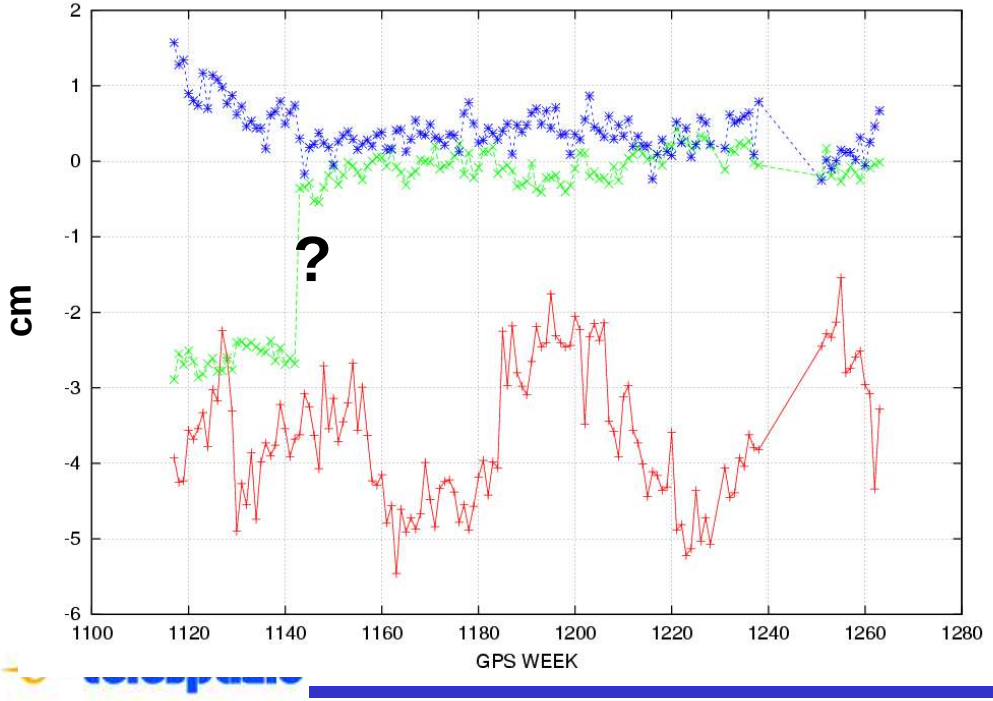
MALL station

Why are there ≈12mm ZTD bias w.r.t EUREF and GOPE?



Site coordinates (01jun03-04mar24)

Weekly Euref – Weekly PPP **N**, **E**, **U**



Station Equipment

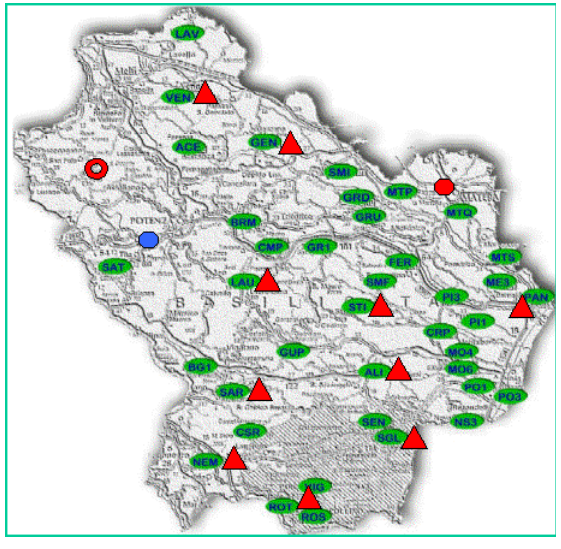
TRIMBLE 4000SSI+TRM29699.00Dome

1. Same phase center correction?
2. Different response of different sw (Bernese and Gipsy)?

Plans For The Future

-We will continue GPS data processing in NRT and PP within TOUGH & CERGOP2;

-We are establishing a regional network of permanent GPS receivers;



-We are studying new algorithms to integrate ground based GPS and RO.