GNSS analysis for weather applications based on IGS products

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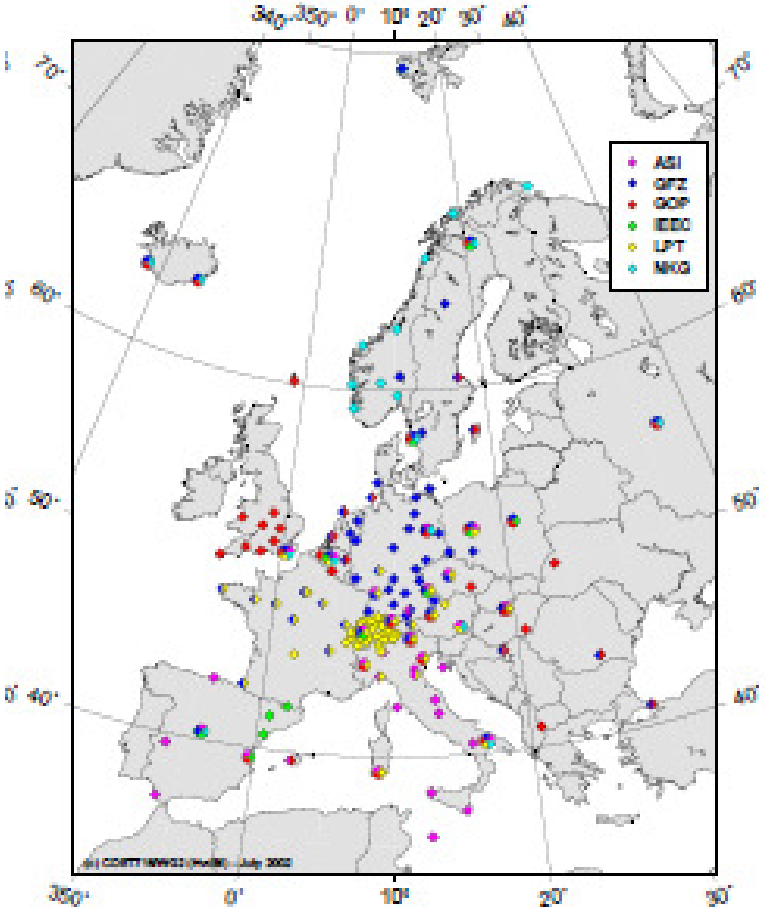
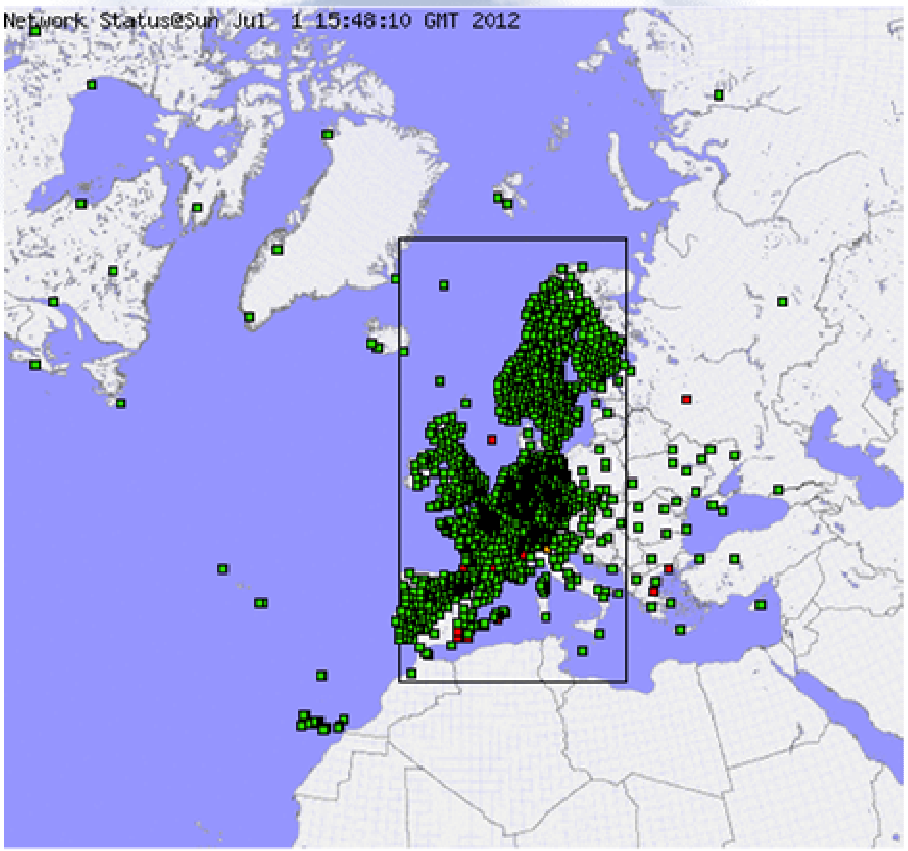
Outlook of the talk

- Current Status of GNSS-Met in Europe
- Meteorological Requirements
- Long Term Evaluation of Hourly ZTD
- New GNSS Developments:
  - from hourly to sub-hourly processing
  - from regional (Europe) to global processing
- IGS role in GNSS-Met Activities

10 years of GNSS-Met in Europe: July 2002 - July 2012





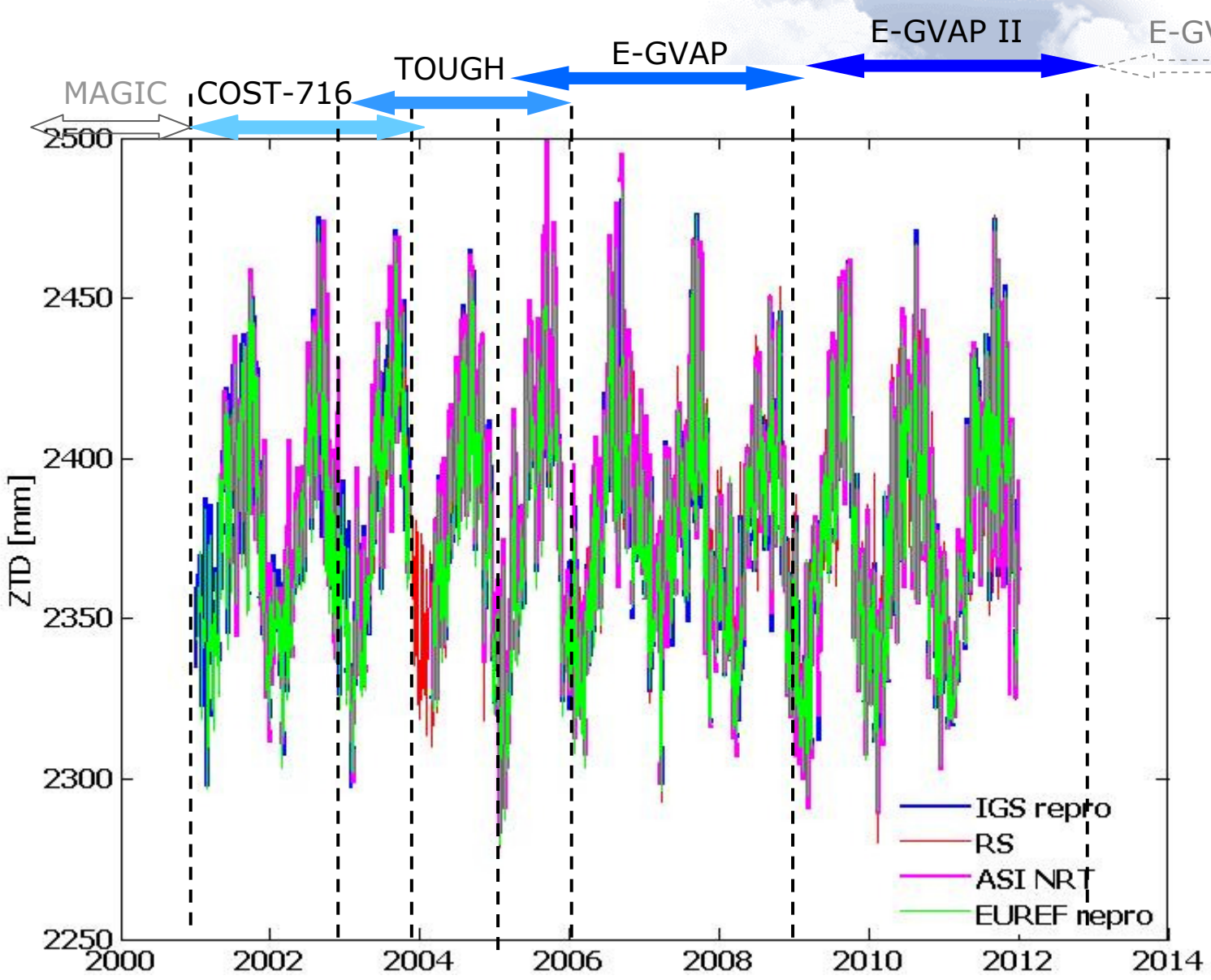
July 2002:

6 ACs and 150 stations

July 2012:

13 ACs and 1700 stations

Cagliari July 2001 - July 2012 Time Series

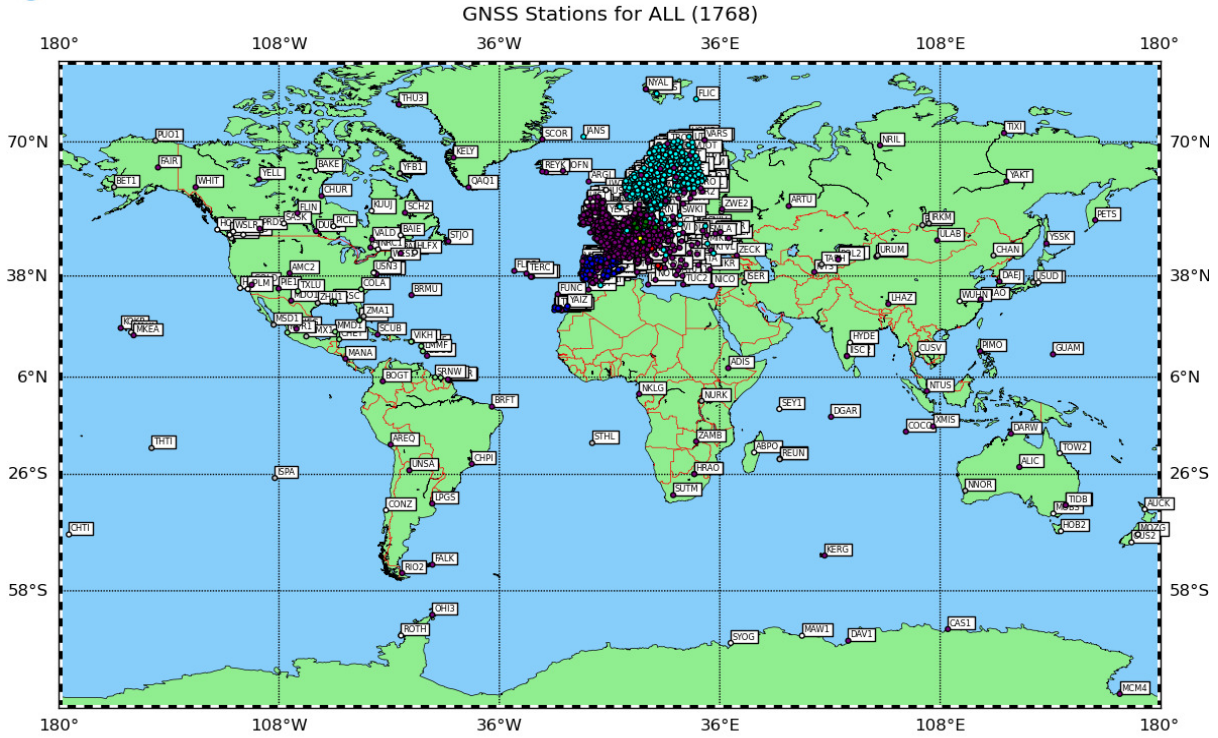


Current Status E-GVAP http://egvap.dmi.dk

EIG EUMETNET GNSS Water Vapour Programme.

EUMETNET
The Network of European Meteorological Services

- provide quality checked, ground based GNSS delay and integrated water vapour data (ZTDs and IWVs) in near real-time (NRT) for use in operational numerical weather prediction (NWP) models and in now-casting to the participating EUMETNET members.
- improve the NRT GNSS ZTD data quality and enlarge data coverage
- assist users in utilizing the data for weather forecasting.



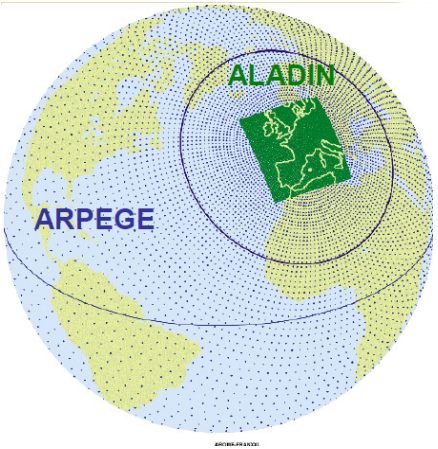
Operational status regarding GNSS use in NWP

Four Met institutes assimilate E-GVAP data in their operational models

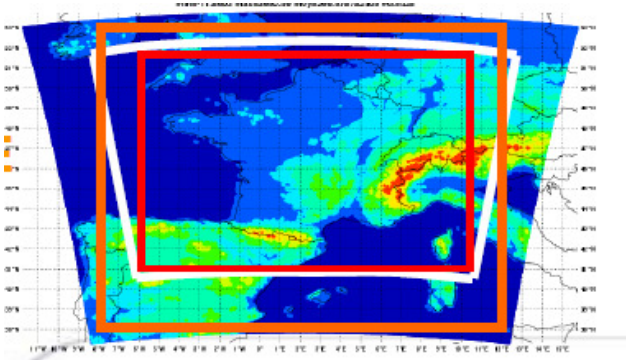
Météo France Arpege (global), Aladin (regional), Arome (mesoscale, at 2.5 km)

UK Metoffice NAE (regional) and UK4 (mesoscale, at 2.5 km), under trial in global model

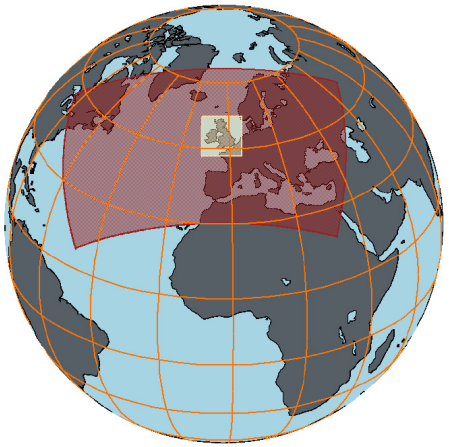
Météo France ARPEGE and ALADIN



Météo France AROME



UK Metoffice

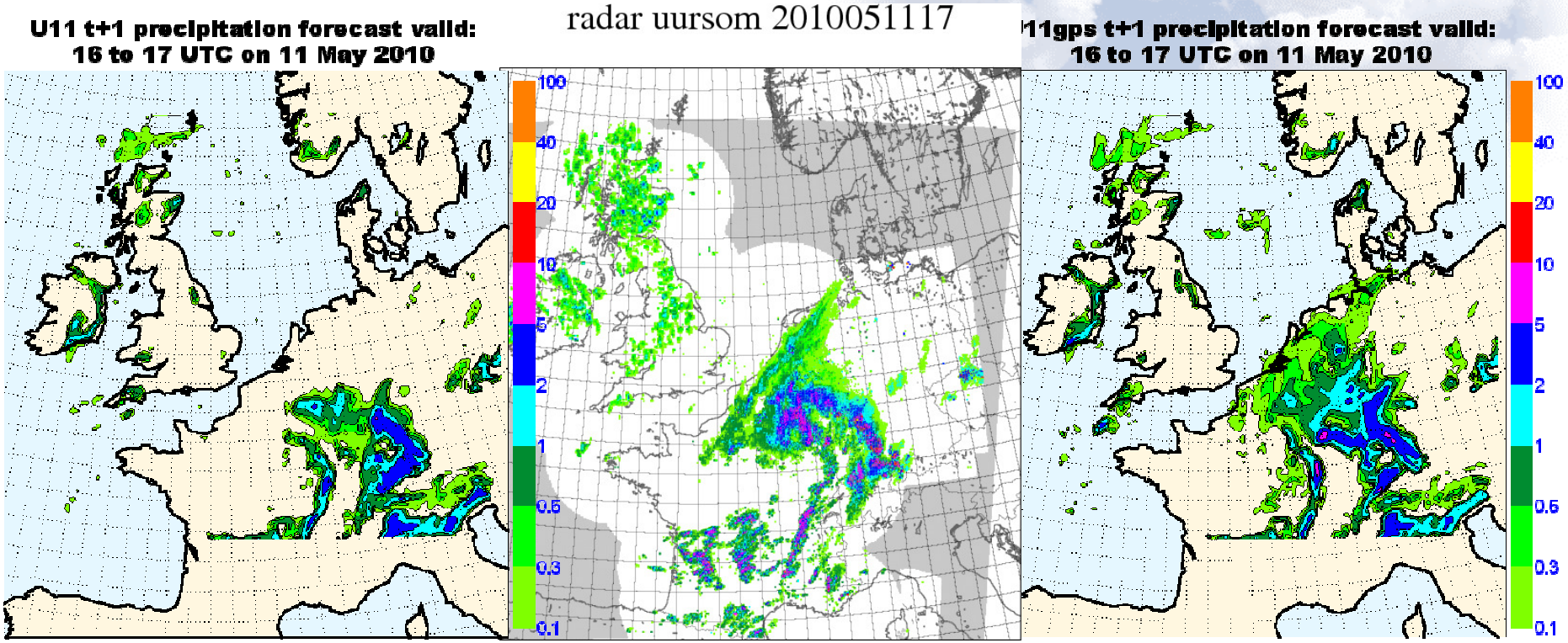


KNMI
DMI

Other Met Institutes (DWD, AEMET) are under trial.
A positive impact from the use of the E-GVAP data is reported.

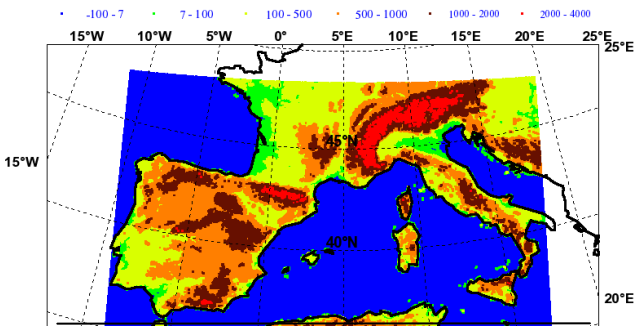
Rapid Update Cycle in NWP

(KNMI, Siebren De Haan)



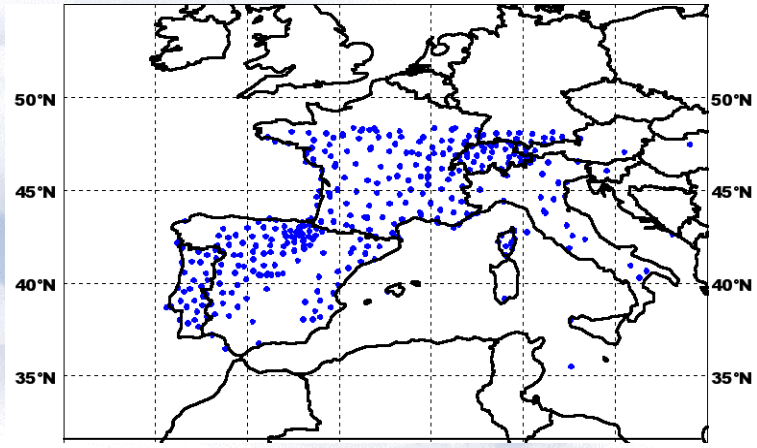
Validation of AROME-WMED

(Météo France, Mathieu Nuret)



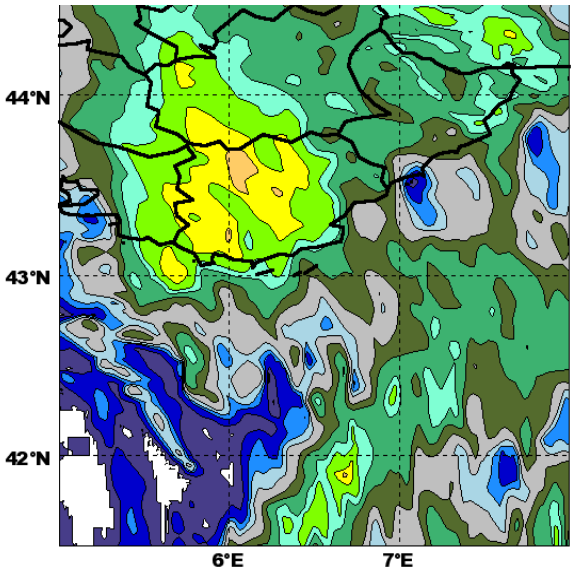
AROME WMED domain

15/06/2010 – 09UTC



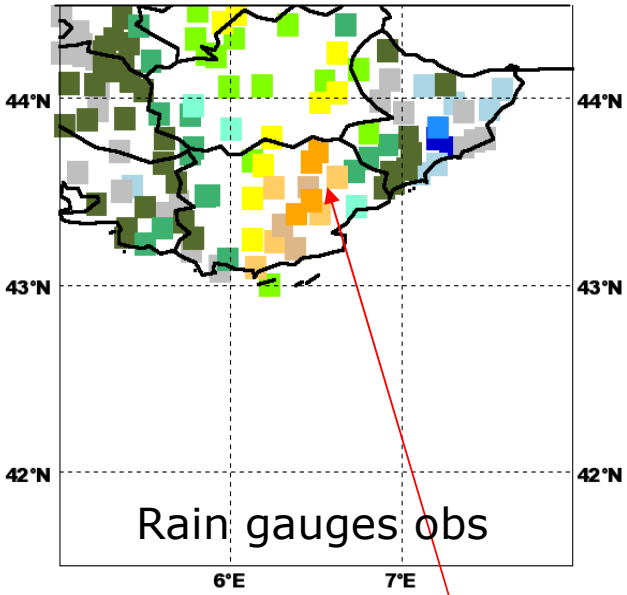
GPS data used

AROME_WMED (D031)

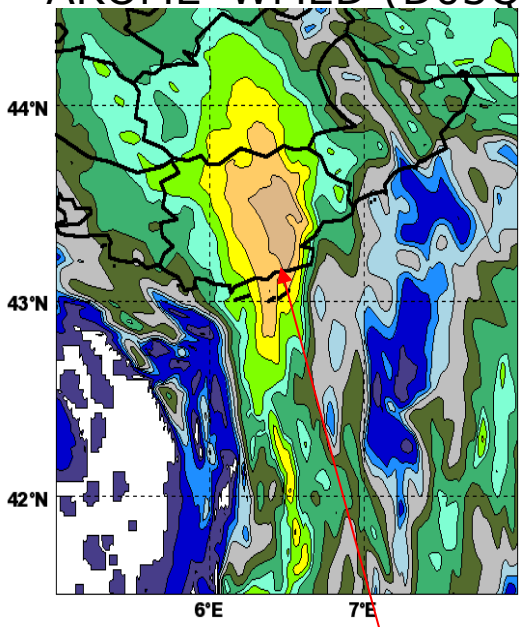


Old white list

OBS (6h Accumulation)



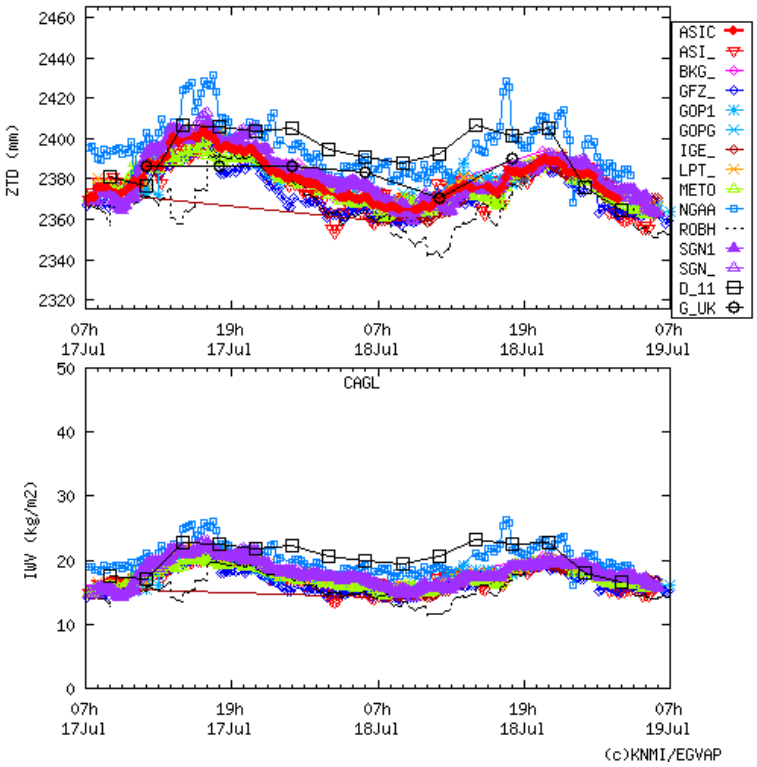
AROME_WMED (D03Q)

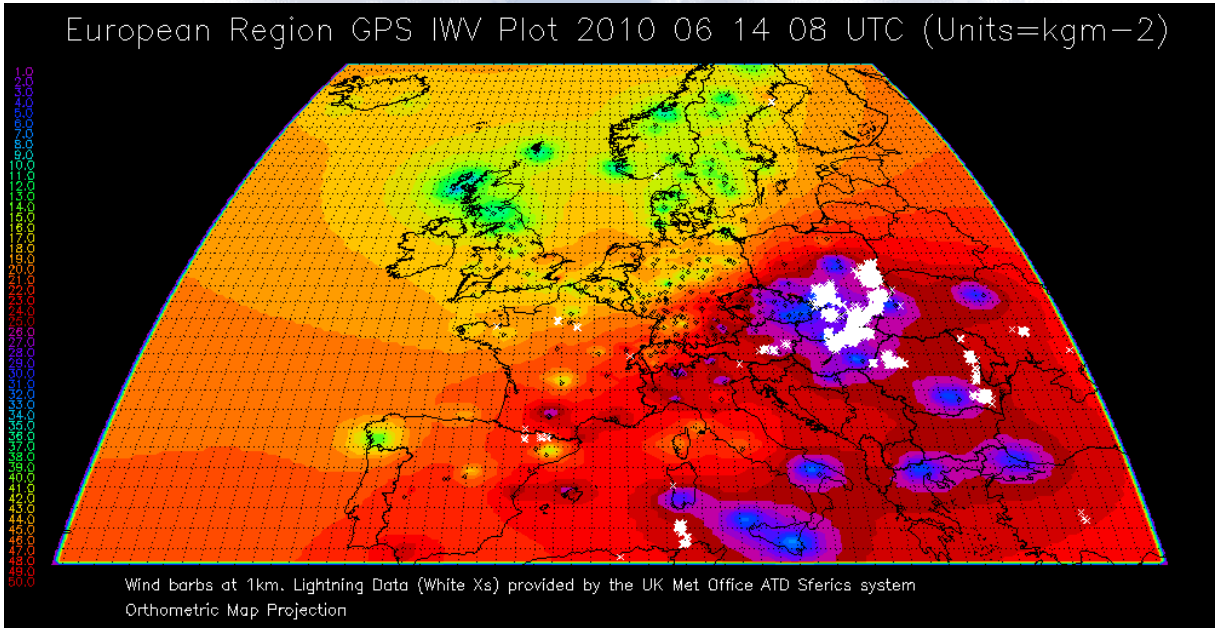


New white list

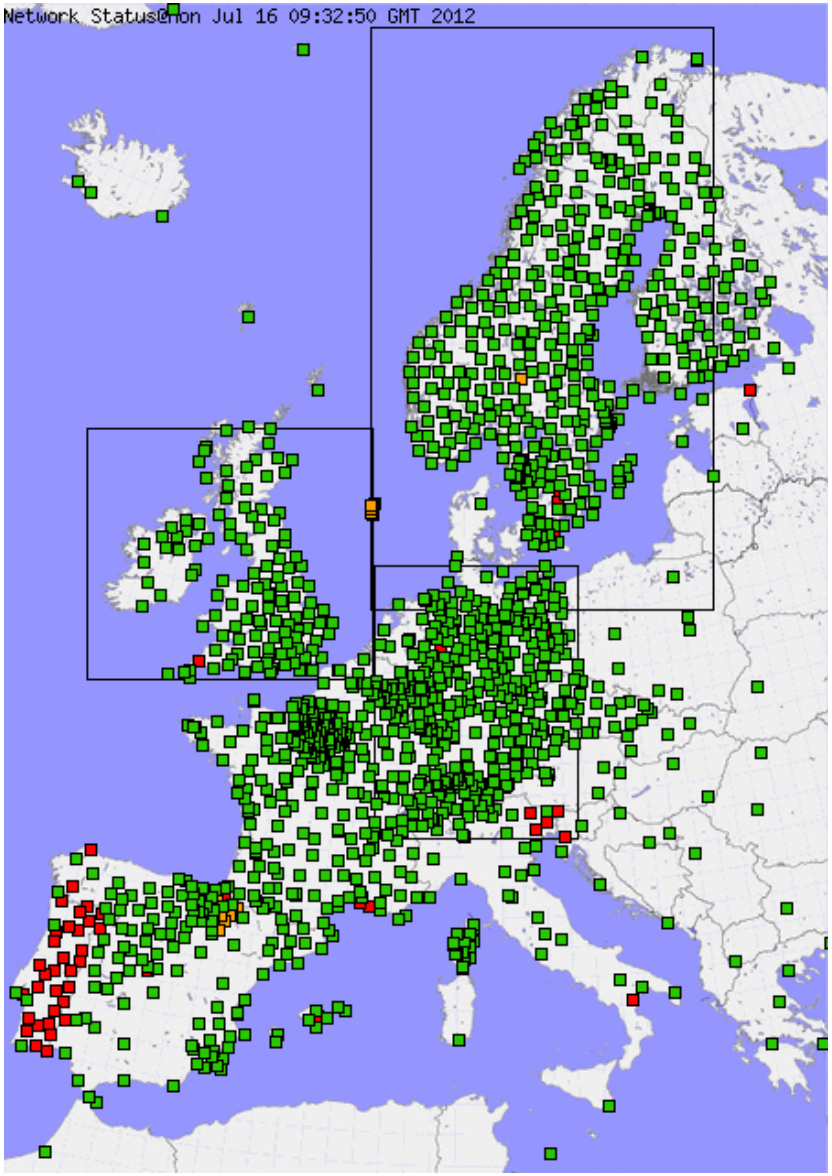
Integrated Water Vapour Map

ZTD estimates can be converted into IWV to create IWV map over Europe



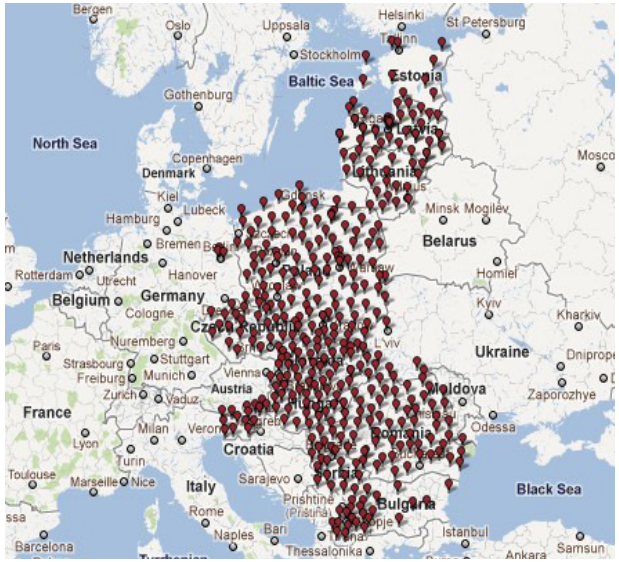


GNSS Water Vapour Network in Europe



~1700 unique GNSS sites world-wide delivering ~10M ZTDs per month.

Extensions expected in Eastern Europe and Scandinavia.
MoU between EUPOS and EUMETNET, opening for collaboration between individual EUPOS countries and institutes and E-GVAP.



EUPOS Network

E-GVAP products

Primary E-GVAP Product:

NRT ZTD of ~1700 world-wide (primarily European) sites
-Generation Frequency: Hourly, which automatically leads to ”aging” of some of the observations
-Applications & Users: Global and Regional NWP

……moving from regional towards global coverage

New products:

Sub-hourly ZTD
-Generation Frequency: Sub-Hourly
-Applications & Users: Local and Regional NWP, forecasters doing Now-casting

Hourly Slant and/or Gradients
-Generation Frequency: Hourly
-Applications & Users: potentially for use by Global, Regional and Local NWP, forecasters doing Now-casting

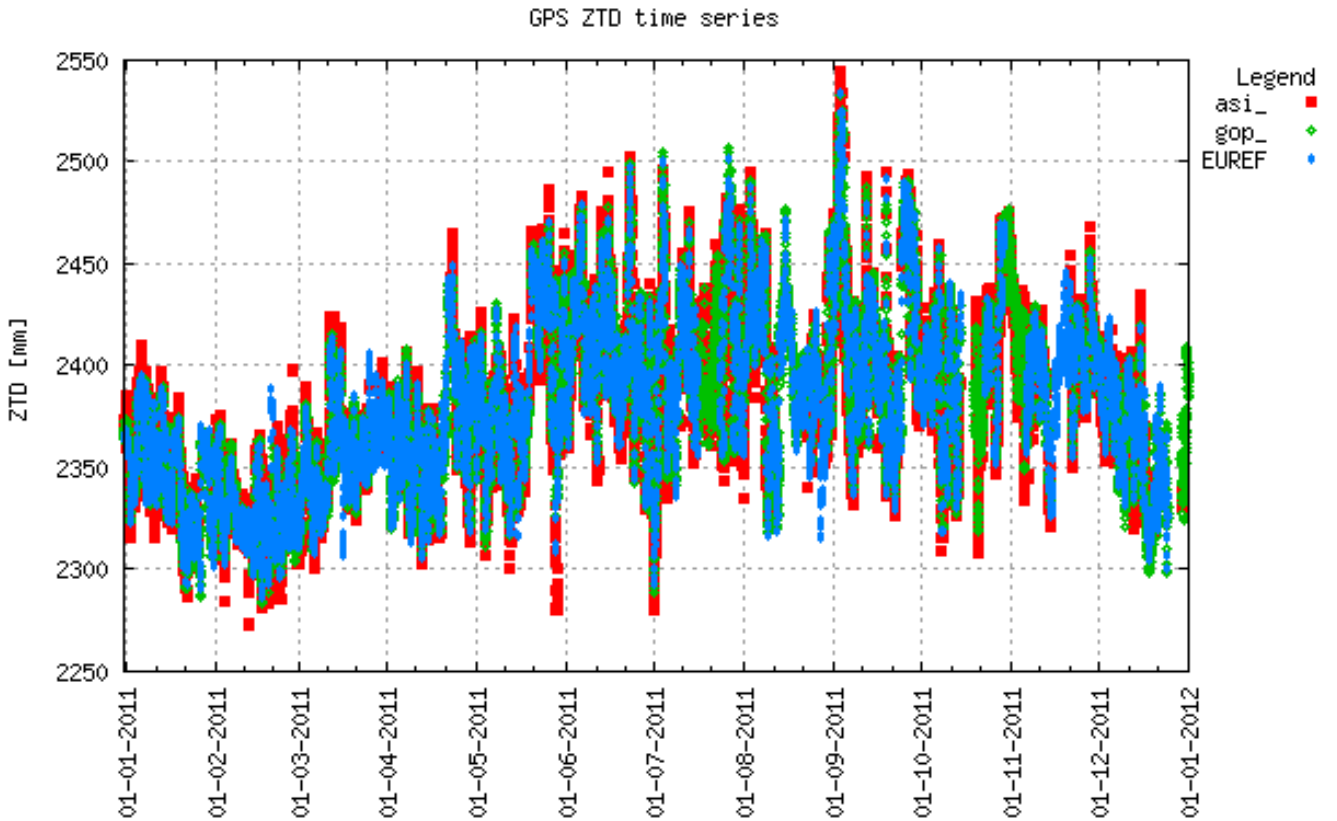
Long-Term Evaluation of ZTD Hourly Product

The long-term evaluation of ZTD hourly product is assessed via a comparison to reference post-processing solutions as

IGS tropospheric product in a global scope — ***PPP solution***

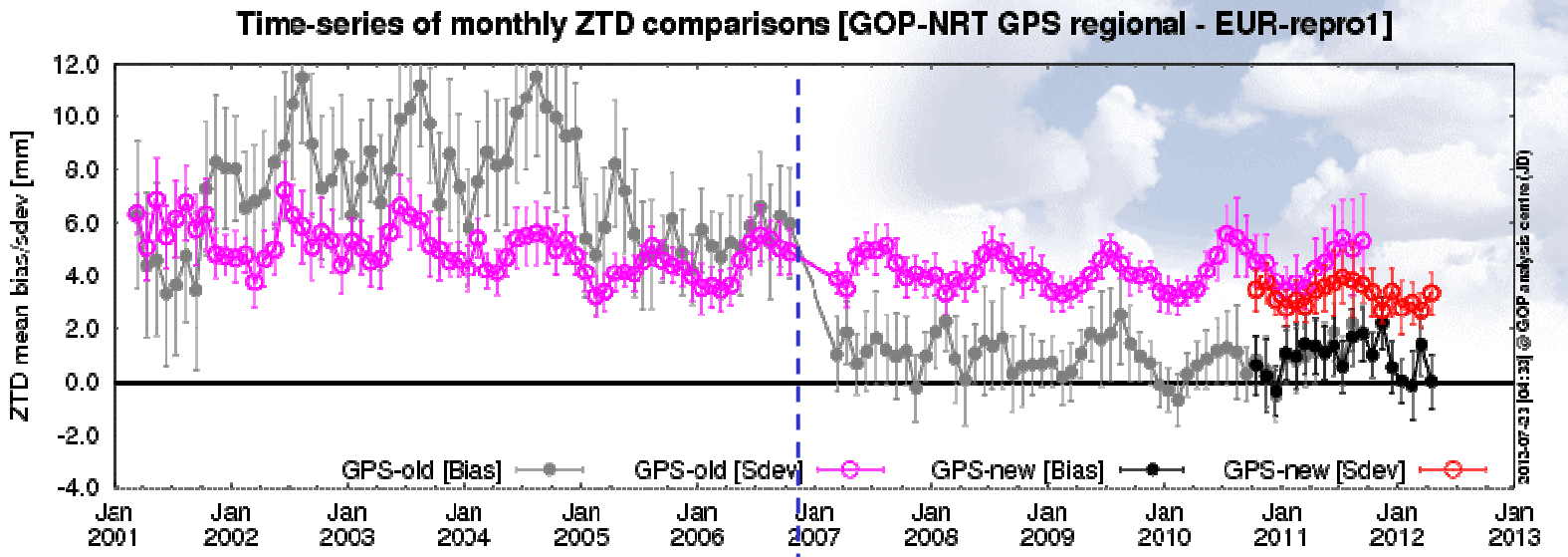
EUREF tropospheric product in a regional scope — ***Combination***

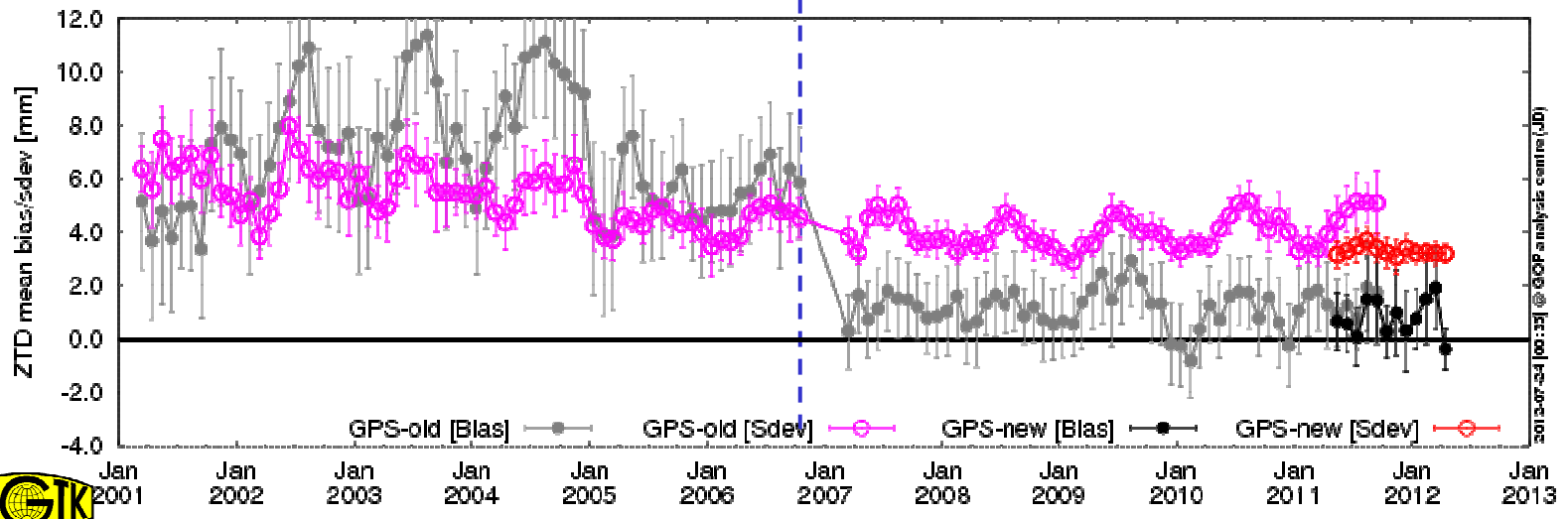
and independent technique as **radiosonde**



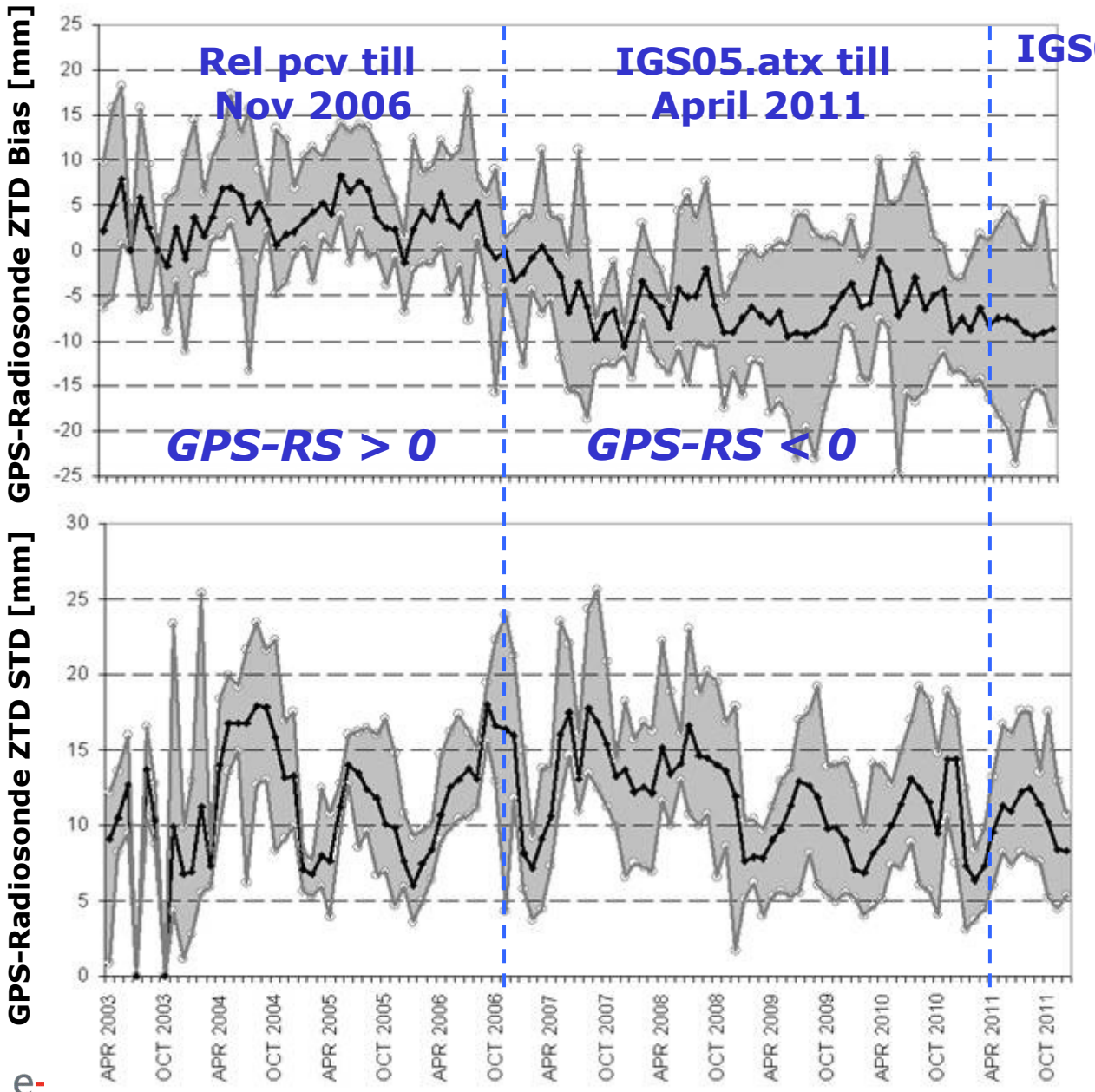
GOP ZTD Hourly Product: Long Term Evaluation

Monthly ZTD mean biases & std estimated from all common stations for GOP vs EUREF-repro1 and IGS-repro1

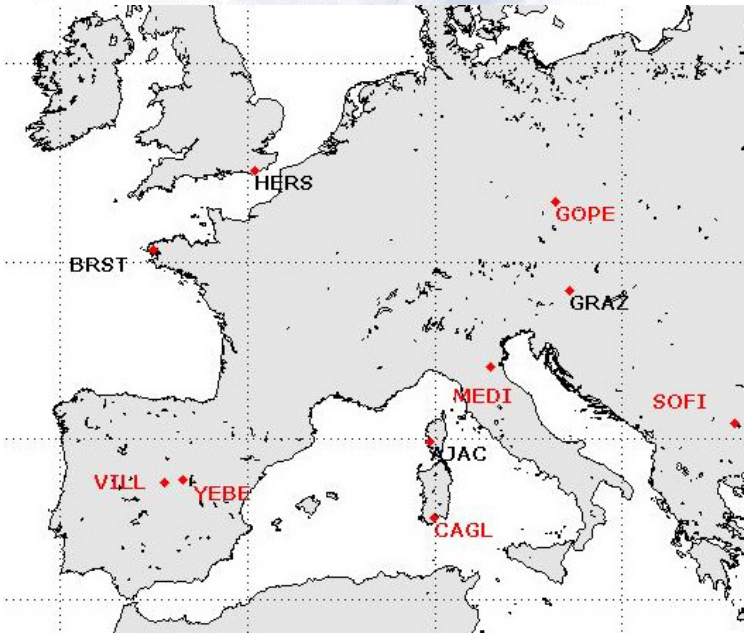




ASI ZTD Hourly Product: Long Term Evaluation



Monthly ZTD mean biases
& std for ASI vs RS



Site used for comparison
In red site used throughout the period

From Hourly to Sub-Hourly Processing

Moving toward NWP models with higher resolution and hourly cycling update, to improve forecasting of extreme precipitation.

To provide starting conditions for these models, observations with a high resolution in space and short delivery times, and related to humidity/rain/convergence are of particular interest.

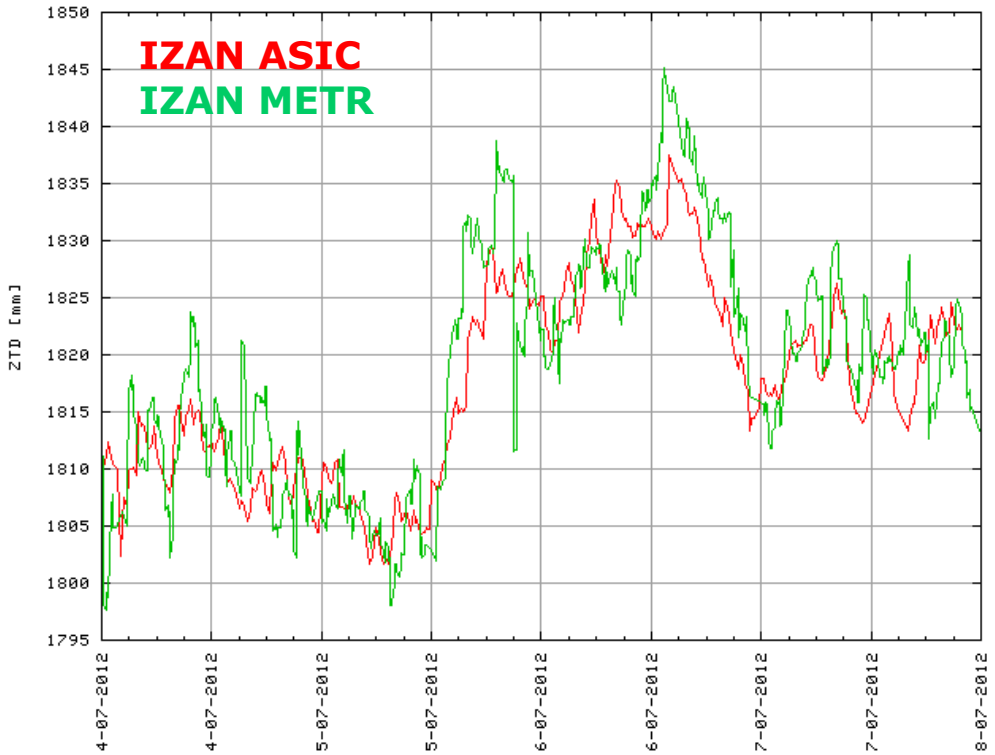
Ground-based GNSS delays are among the most promising observations in this regard.

Real-Time GNSS data streaming will allow to process GNSS data on sub-hourly basis, meaning that we will have more data for visualization, now-casting and assimilations into NWP Models.

RT Network

Sub-Hourly Data Processing

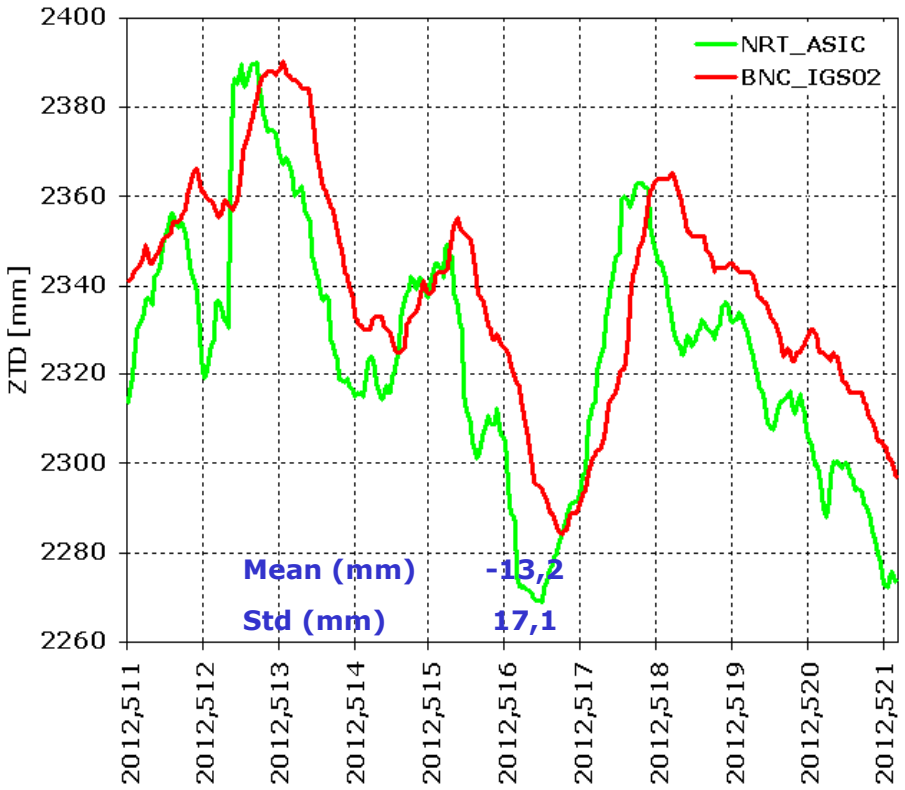
Data Processed every 15min
Observations converted from RT streaming to RINEX using BNC every 15min
New scheme for naming of the COST-format files uploaded to E-GVAP will be released enabling sub-hourly data uploads



The present availability of the IGS real-time precise orbit and clock service open the possibility of doing PPP solution, very promising for future efficient GNSS-Met.

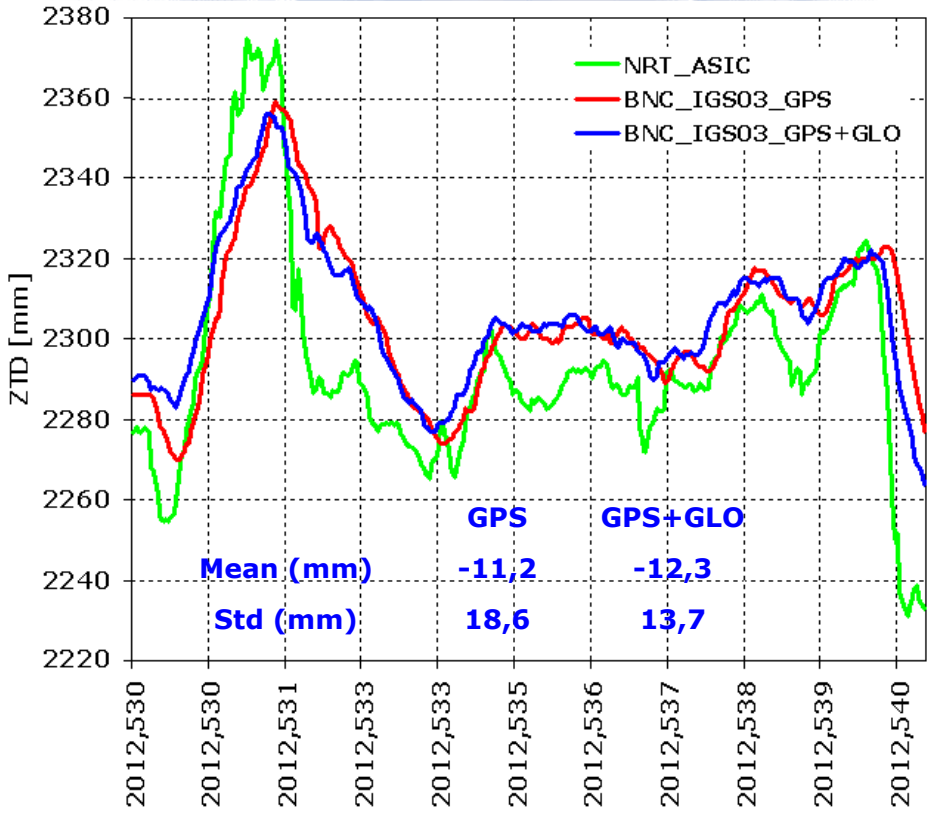
RT Processing with BKG BNC

Input Streams: MATE0 & IGS02
MATE0 coordinates fixed to Post Processed values
Reference Solution ASIC (NRT ZTD Combination)



05-08 July 2012

Input Streams: MATE0 & IGS03
MATE0 coordinates fixed to Post Processed values
2 Solutions: GPS, GPS+GLO
Reference Solution ASIC (NRT ZTD Combination)

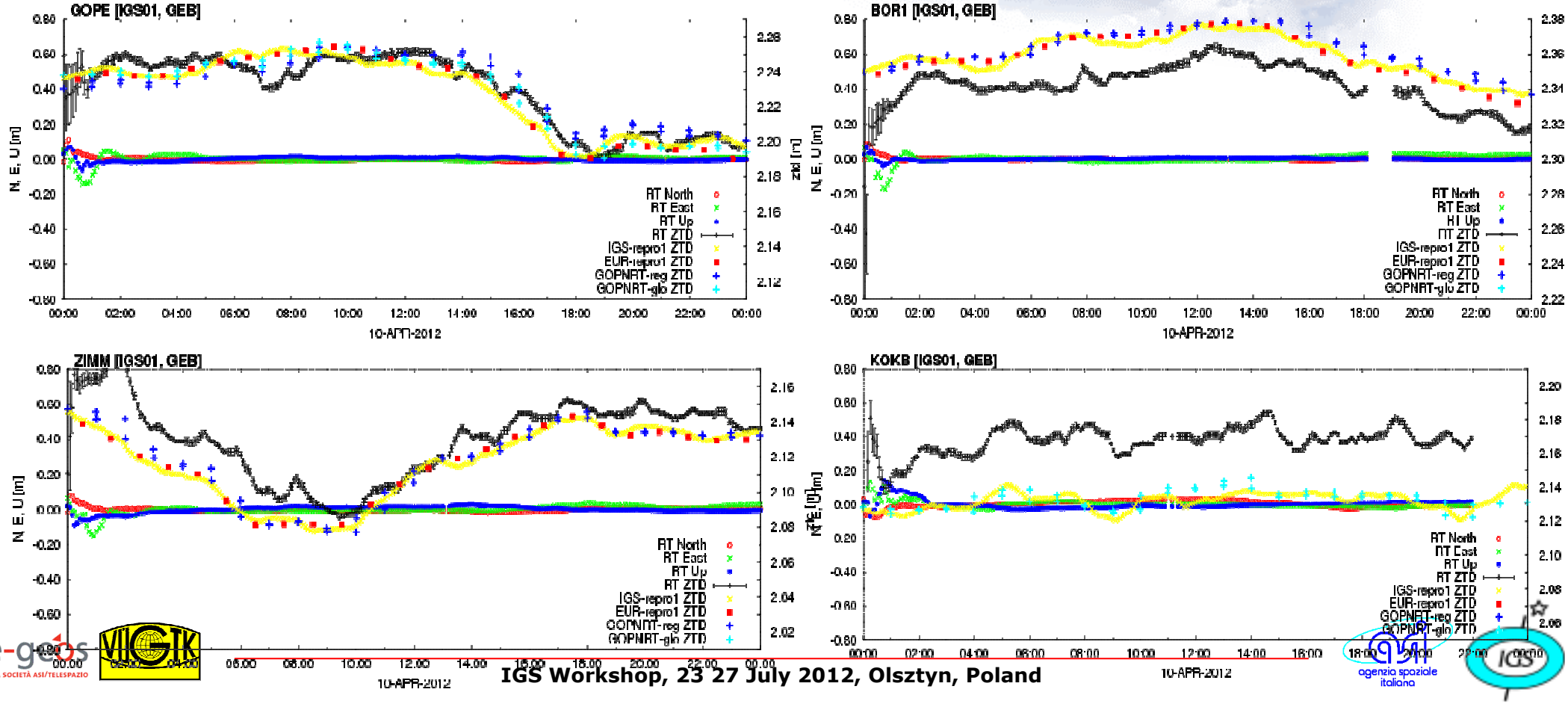


12-15 July 2012

RT Processing with G-NUT sw library (developed at GOP)

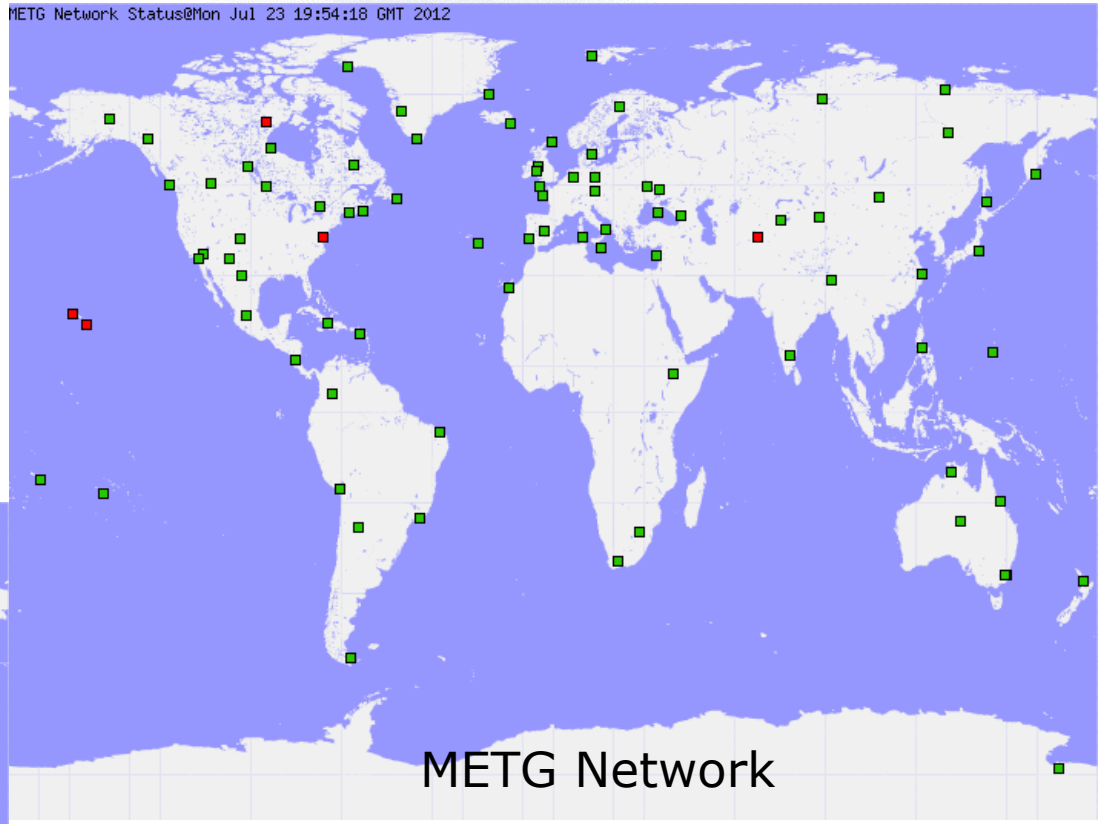
Real-time simulated with IGS01 corrections were estimated over 44 days (April-May 2012), plotted example for April-10, 2012

The tropospheric trends are well estimated even in real-time, however, various offsets are identified. Actually if they are stable at each stations this is not a serious problem, because NWPs are handling site bias on a monthly basis before the assimilation.

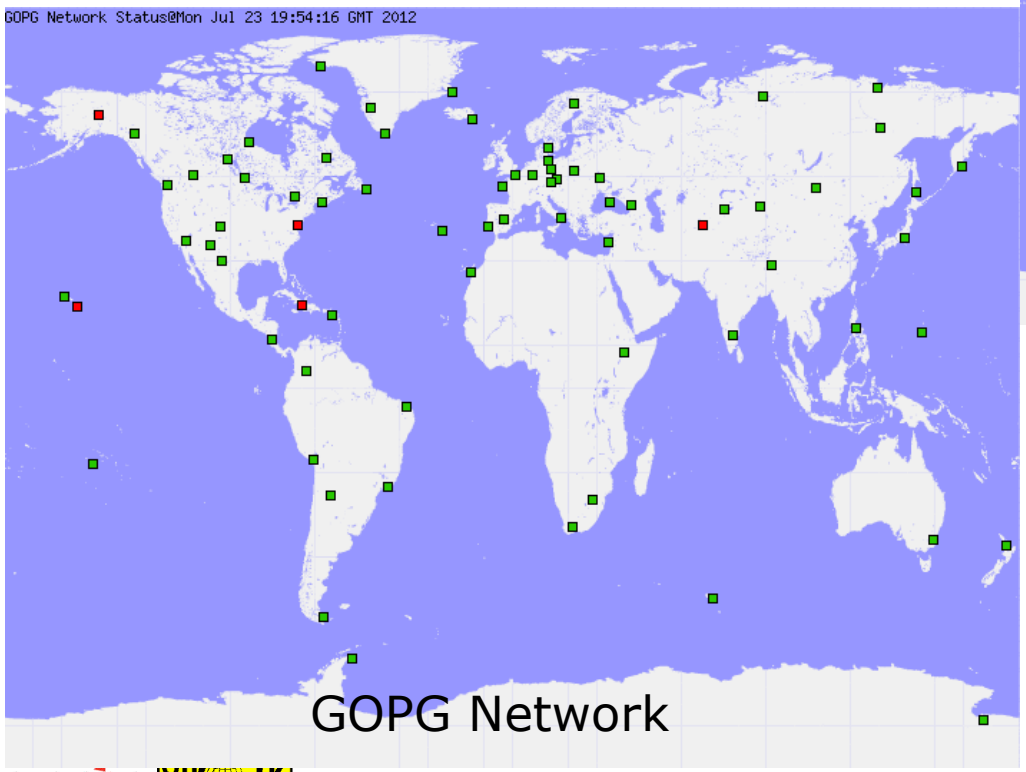


From Regional to Global Processing

UK MetOffice and Météo France run global NWP models and asked for world-wide homogeneously distributed GNSS ZTDs.



METG Network

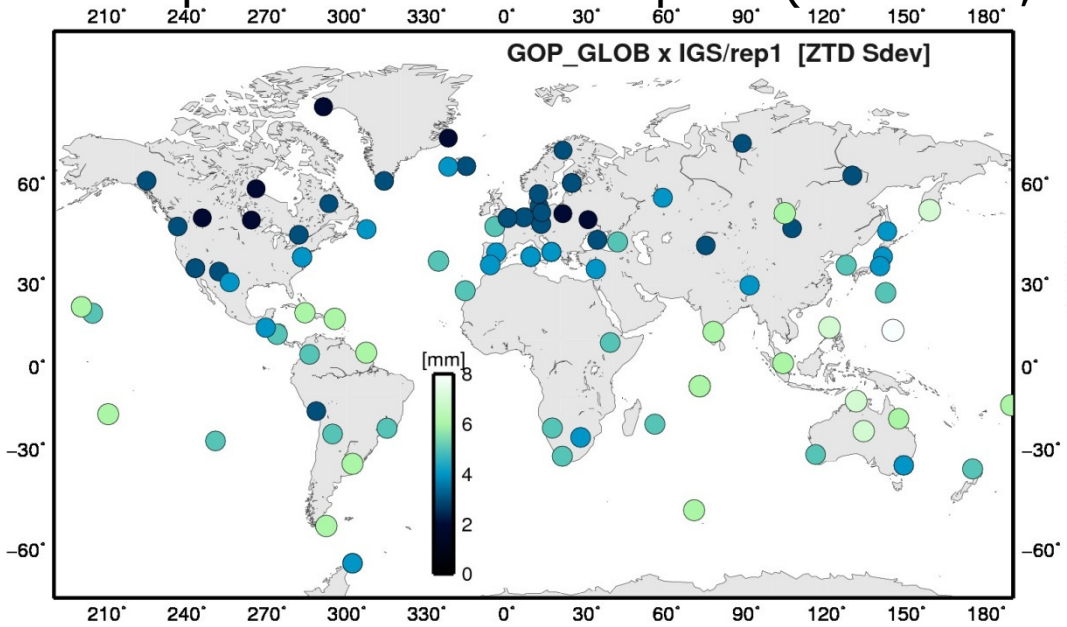


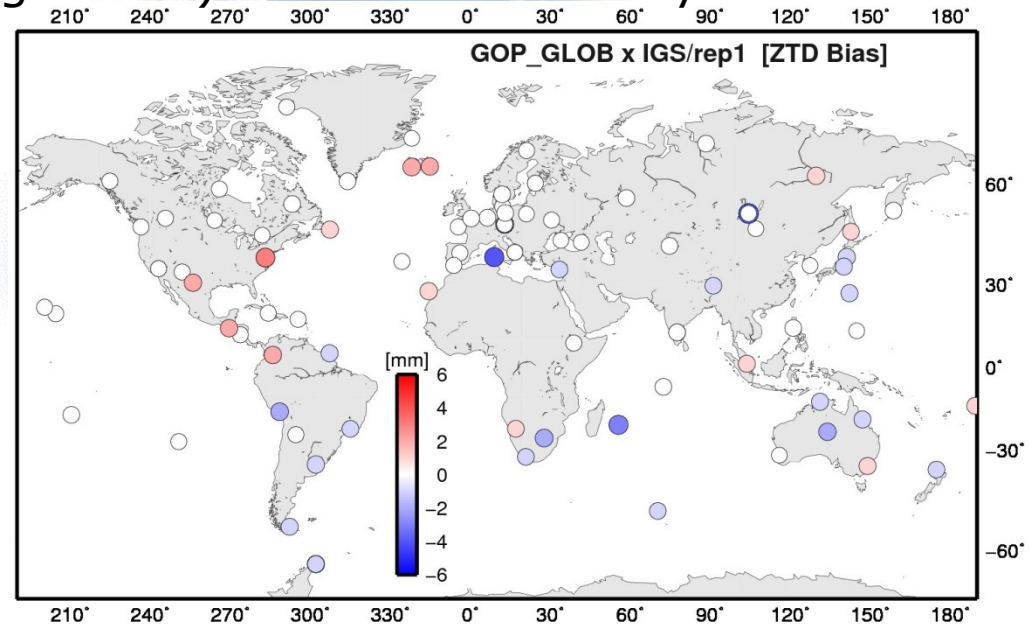
GOPG Network

In response, global processing have been implemented by METG and GOPG E-GVAP ACs.

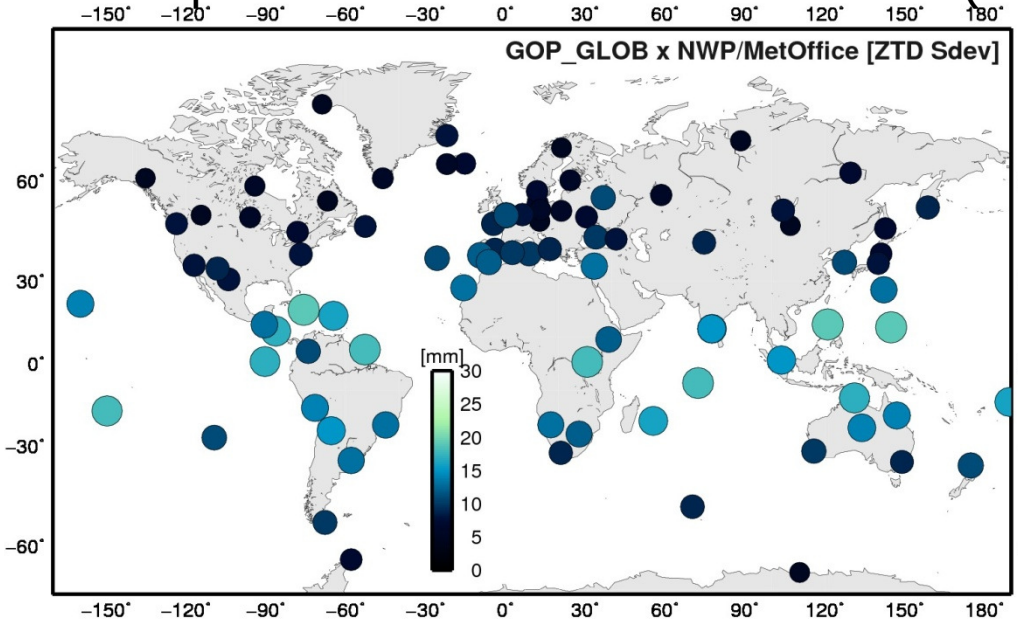
Global GOP hourly ZTD results vs IGS repro1 and NWP

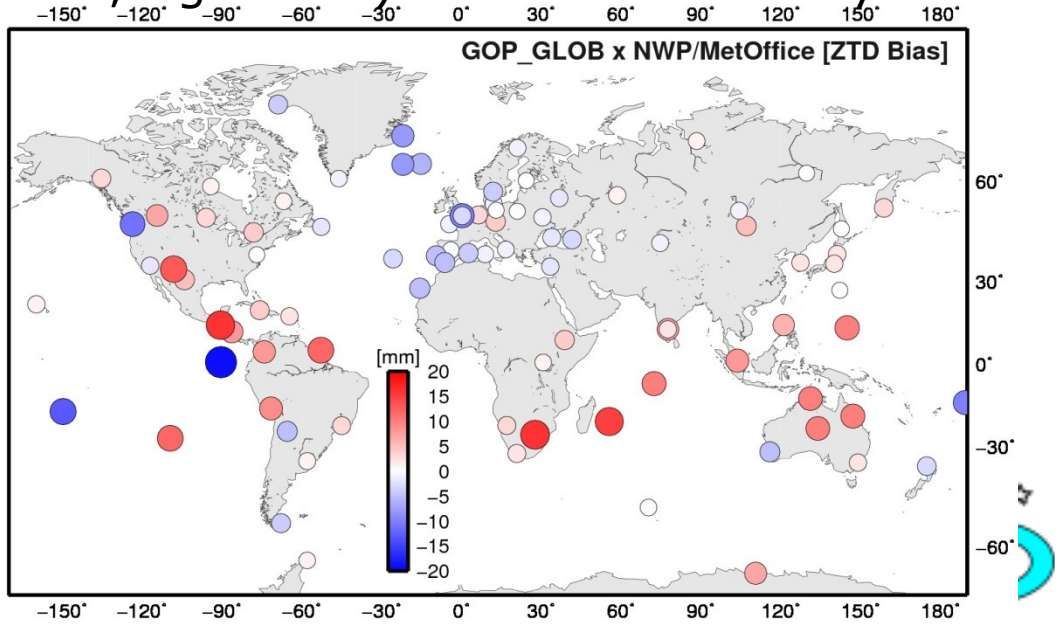
Comparison with IGS-repro1 (left Sdev, right Bias) over more than 1 year





Comparison with UK MetOffice NWP (left Sdev, right Bias) over more than 1 year





IGS role in GNSS Met Activities

- IGS is playing an important role by means of its products.
- Ultra-Rapid orbits are vital to NRT ZTDs and their robustness is very important for almost for all ACs, since only GFZ and NGAA use their own orbit products for clock estimation and utilization of PPP.
- Except GFZ and NGAA, all E-GVAP ACs use the network approach, since PPP (highly efficient technique for this purpose) is not supported by the IGS due to a lack of hourly precise clocks.
- IGS-RTPP clock product has the potential to support new sub-hourly (real-time or quasi real-time) and probably also near-real time solutions; thus PPP could be hopefully more used in future and make it more easy for further extensions.
- IGS Multi-GNSS analysis will support the development of multi-GNSS tropospheric products (GPS, GLONASS and prepare for Galileo inclusion) to study the impact of extra observations.
- IGS (and EUREF) provides reference ZTD product for various evaluations.

Conclusion

- GNSS-Met activities are very well established in North and West Europe and are an emerging R&D field in East and South-East Europe - GPS derived ZTDs are used operationally by 4 Met Services reporting positive impact.
- New project is being proposed to enhanced future GNSS-meteorology within European COST framework – see poster Jones et al.
- Development of new products from regional to global ZTD, GPS to multi-GNSS, hourly to sub-hourly or real-time, tropospheric gradients and slant delays (e.g for now-casting, severe weather monitoring etc.).
- E-GVAP is very thankful for the services that IGS provides – almost all E-GVAP ACs use IGS Ultra Rapid orbits for deriving NRT ZTDs in support of meteorology.

We acknowledge:
IGS and EUREF (and all contributors) for providing important products used for processing and evaluation; all E-GVAP ACs for providing the ZTD data used in this work and all the GNSS site owners for providing raw data for processing by the ACs.

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