EIG EUMETNET GNSS Water Vapour Programme

E-GVAP

E-GVAP and the use of ground based GNSS data in meteorology

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Menu

- **Examples of current ground based GNSS data that are useful in meteorology and climate monitoring.**
- **About the processing, collection and usage of NRT GNSS ZTDs taking place in regi of E-GVAP, and the impact upon weather forecasts.**
- **Are GNSS ZTDs good enough? E-GVAP active quality control.**
- **Future.**

Current and near future ground based GNSS data useful in meteorology and climate monitoring

- **Climate monitoring: IWV (integrated water vapour) and/or ZTD from post processed, possibly combined, solutions. [ZTD is at least as good as IWV regarding sensitivity to climate change, but ”climate people” are not familiar with ZTD]. It is important that ”climate people” are pointed to homogeneous, reprocessed datasets of the highest quality, and discouraged from using data of lower quality.**

- **Weather forecasting: NRT (near real-time = max 90 min) ZTDs for assimilation into NWP (numerical weather prediction) models, for weather forecasting on global and regional scale. Operational today.**

- **Weather forecasting: Real-time (5-15 minutes) ZTDs for assimilation in high resolution, rapid update, local NWP models. And 2D IWV fields for ”now-casting” [=assisting weather forecasters in assessemnt of current weather situation]. Will become very important.**

What is E-GVAP?

- EIG EUMETNET GNSS Water Vapour Programme.
- EUMETNET = organisation of European national meteorological offices (West European + number of East European, enlarging).
- E-GVAP is a separate observing programme under EUMETNET. Not all EUMETNET members are members of E-GVAP (currently 15). It is those members that finance E-GVAP.

Purpose of E-GVAP

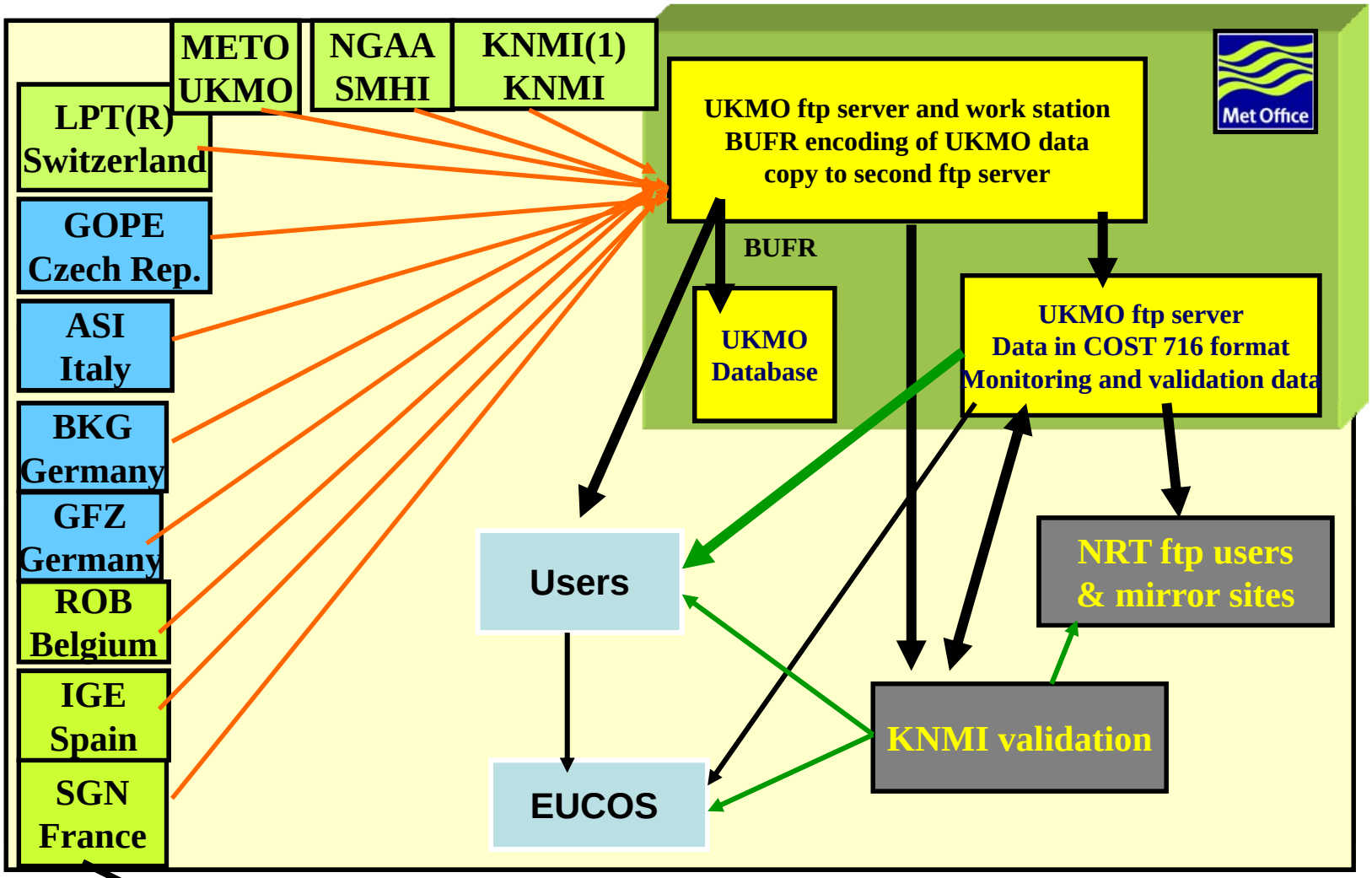
- To provide quality checked, ground based GNSS zenith total delay and integrated water vapour data (ZTDs and IWVs) in near real-time (NRT) for use in operational numerical weather prediction (NWP) models and in now-casting to the participating EUMETNET members.
- To improve on the NRT GNSS ZTD data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

Method

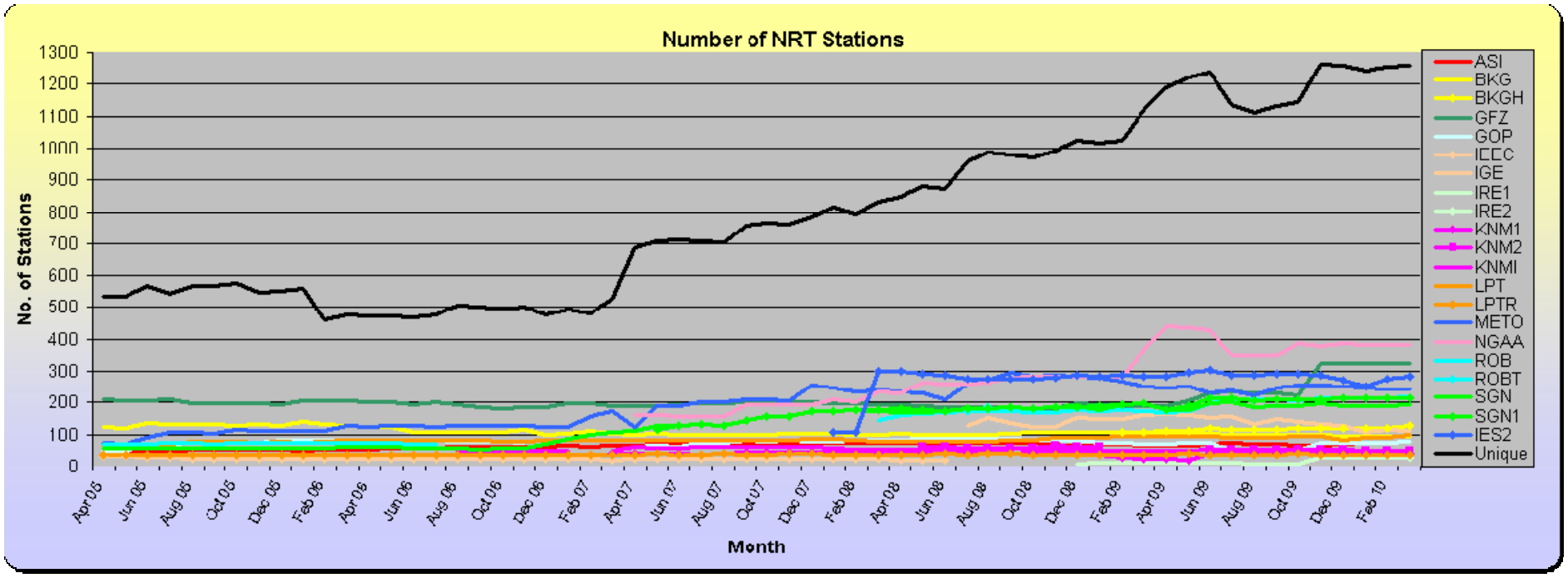
Collaboration with geodesy. Through EUREF and on national level. Examples:

- Exchange of data.
- Exchange of knowhow
- Collaboration in national and international cross dicipline projects. From joint article level to EU projects.
- Sharing of facilities.

NRT GNSS ZTD data flow Today



Analysis centres (ACs), each processing raw GNSS data from many sites.
In many cases only national AC can get access to the raw data.

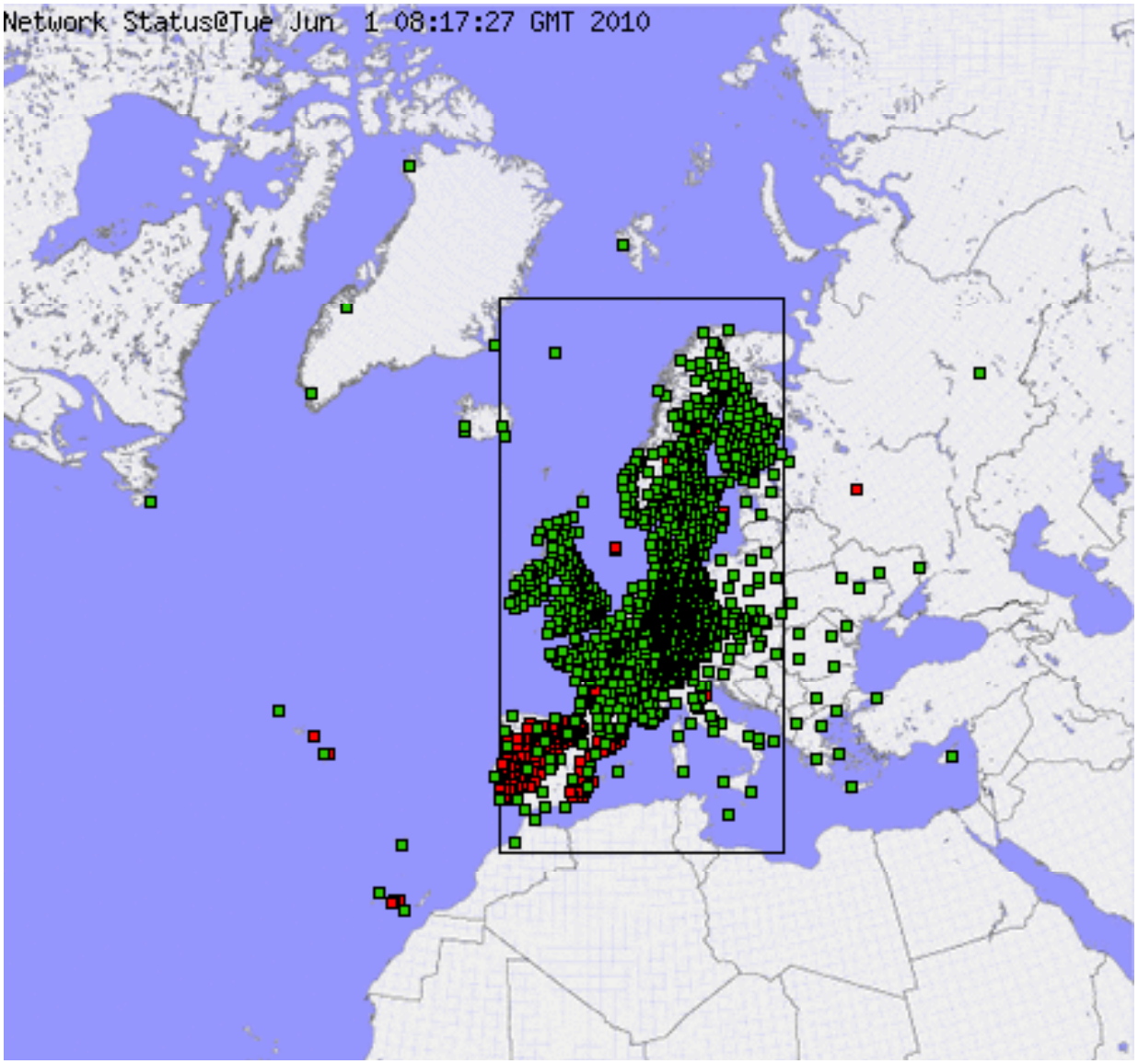


Number of GNSS sites versus time.
About 1250 unique GNSS sites end of 2009.
Increase from about 1000 during 2009.

DATA COVERAGE

Negotiating access to global NRT ZTD data, on request of members.

Hope to gain access to North American NRT ZTD data during this year.



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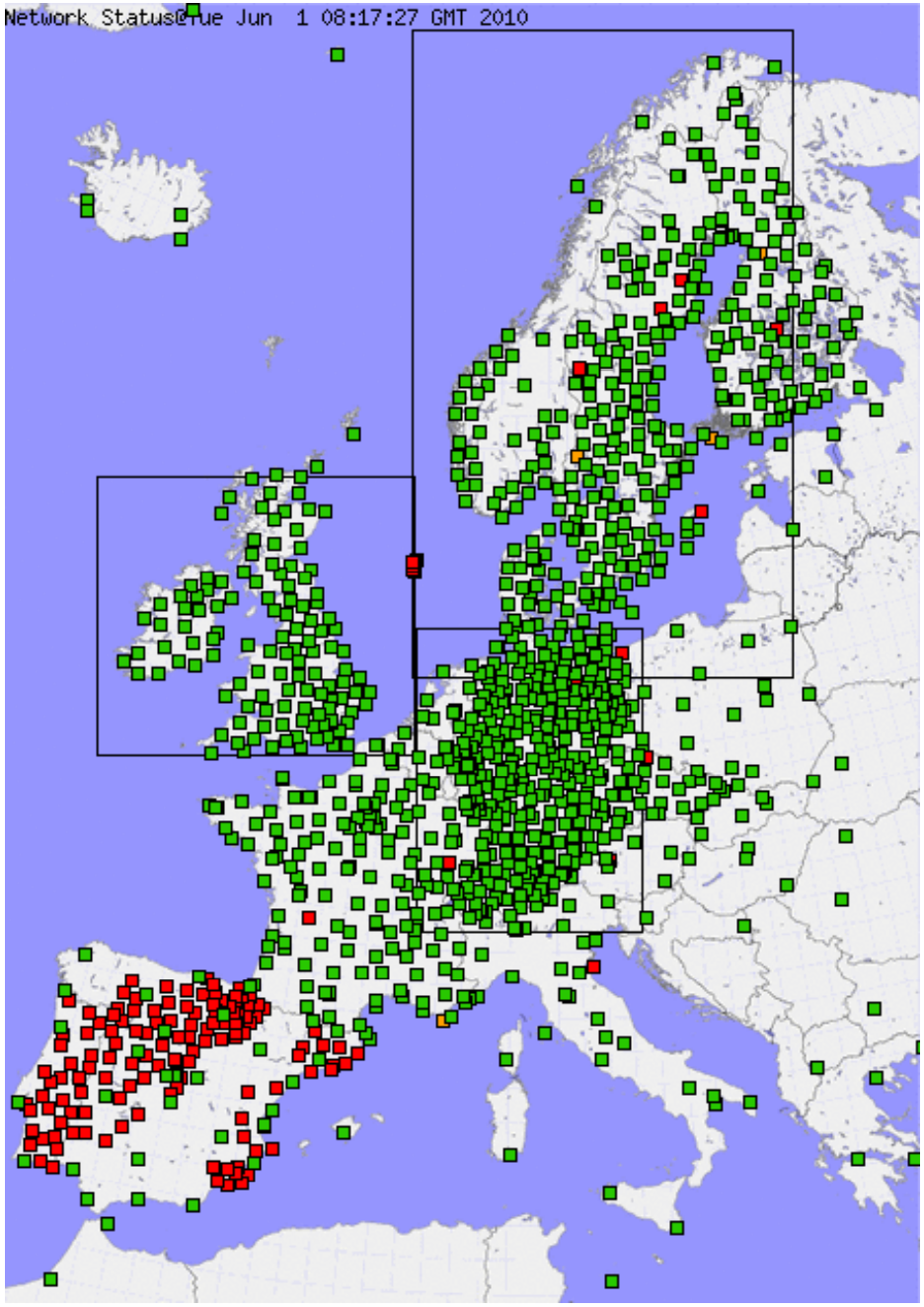
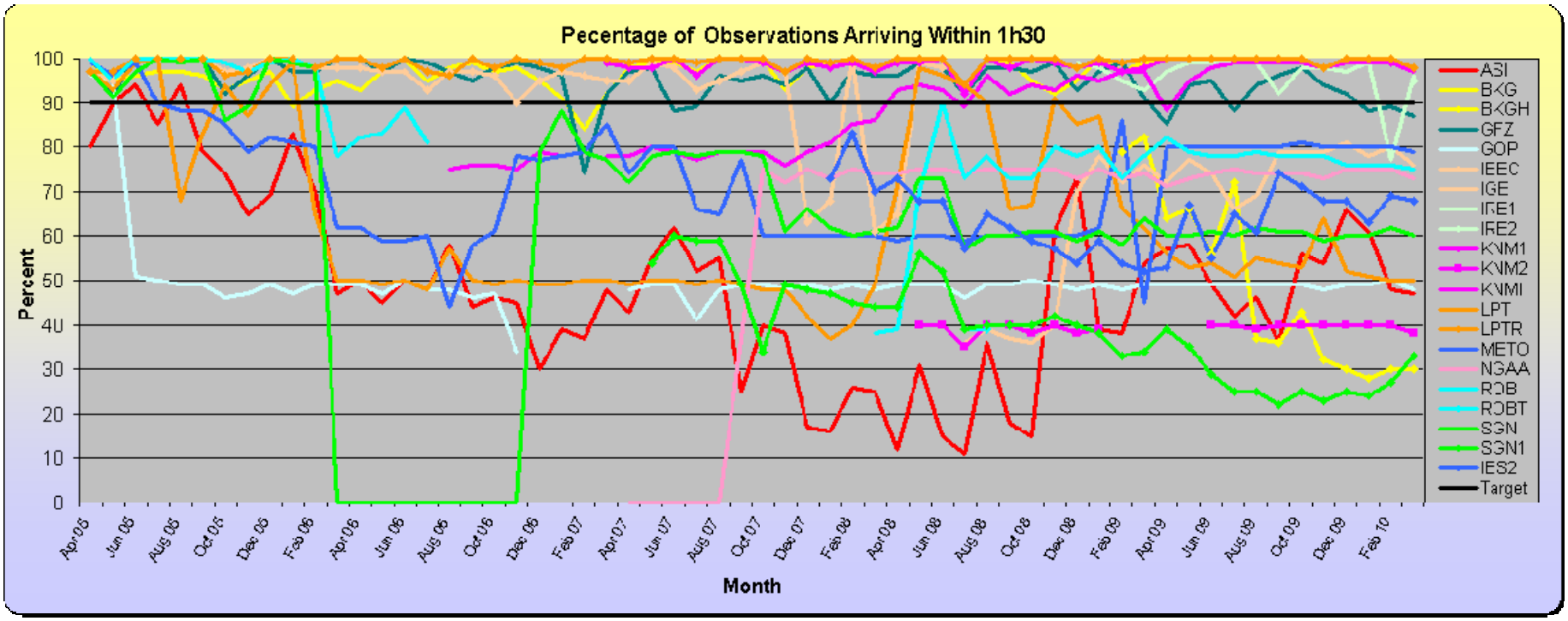
DATA COVERAGE, Europe

Colour according to latency.

Validation statistics and graphs are created automatically and shown via click at each square representing a GNSS site.

Available via homepage, egvap.dmi.dk item validation





Timeliness. Percentage of NRT ZTD data arriving within 90 minutes of their valid time.

Current cut-off times for NWP regional data assimilation are of the order 90 – 150 min. For the future high resolution rapid update local NWP models, producing new short range forecasts every hour, cut-off times will become significantly shorter.

Use of NRT GNSS data in meteorology

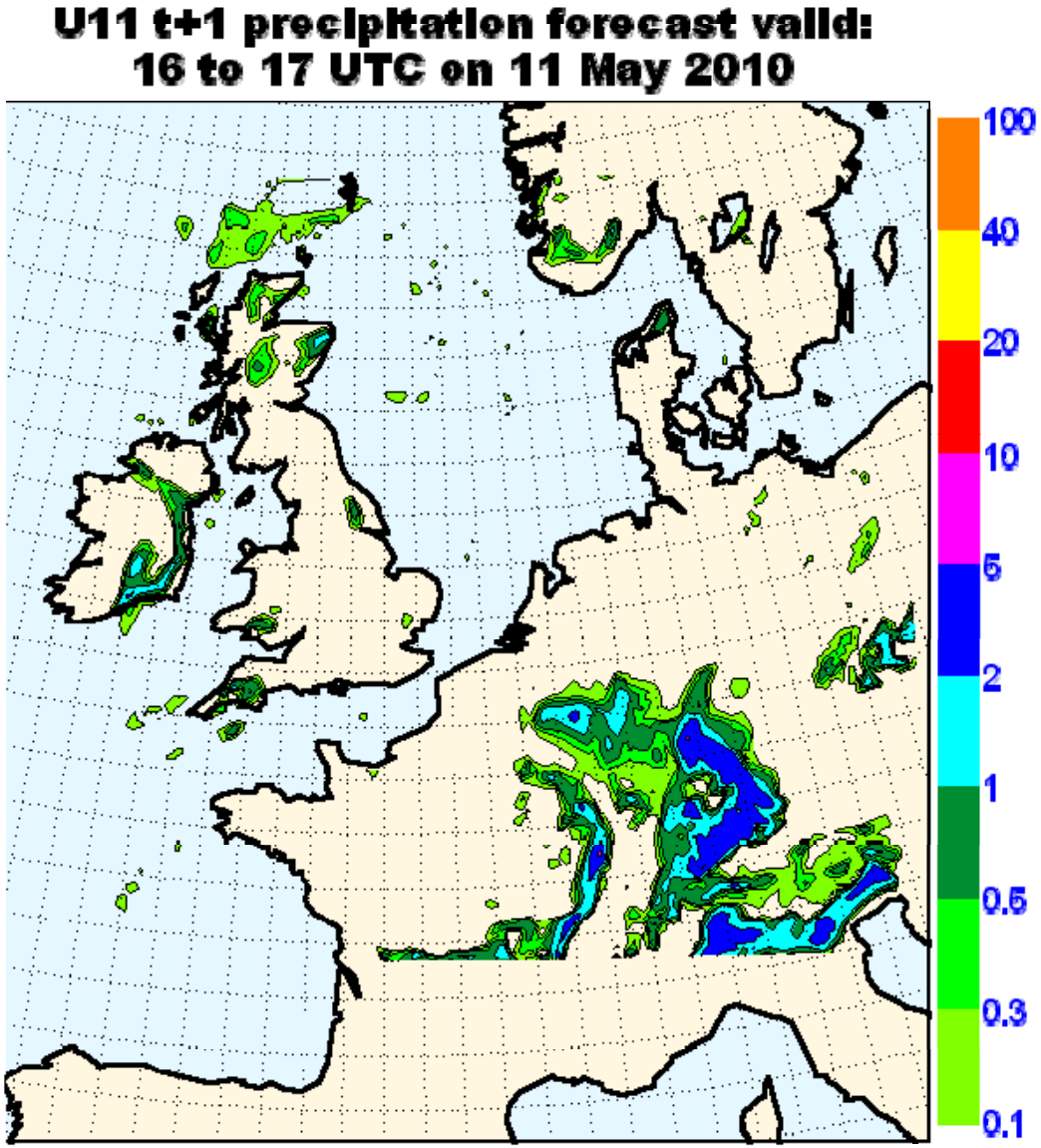
- Two European institutes, Météo France and UK Metoffice, use NRT ZTDs in their numerical weather predictions operations today.
- Both report a possitive impact from the usage of ground based GNSS delay data.
- A number of met institutes are expected to follow with assimilation of NRT ZTDs this year, in particular those using the ”HIRLAM” and ”HARMONIE” model setups.

Impact study from KNMI (the Netherlands)

by Siebren de Haan

Precipitation in KNMI HIRLAM with hourly assimilation cycle, so-called *rapid update cycle.*

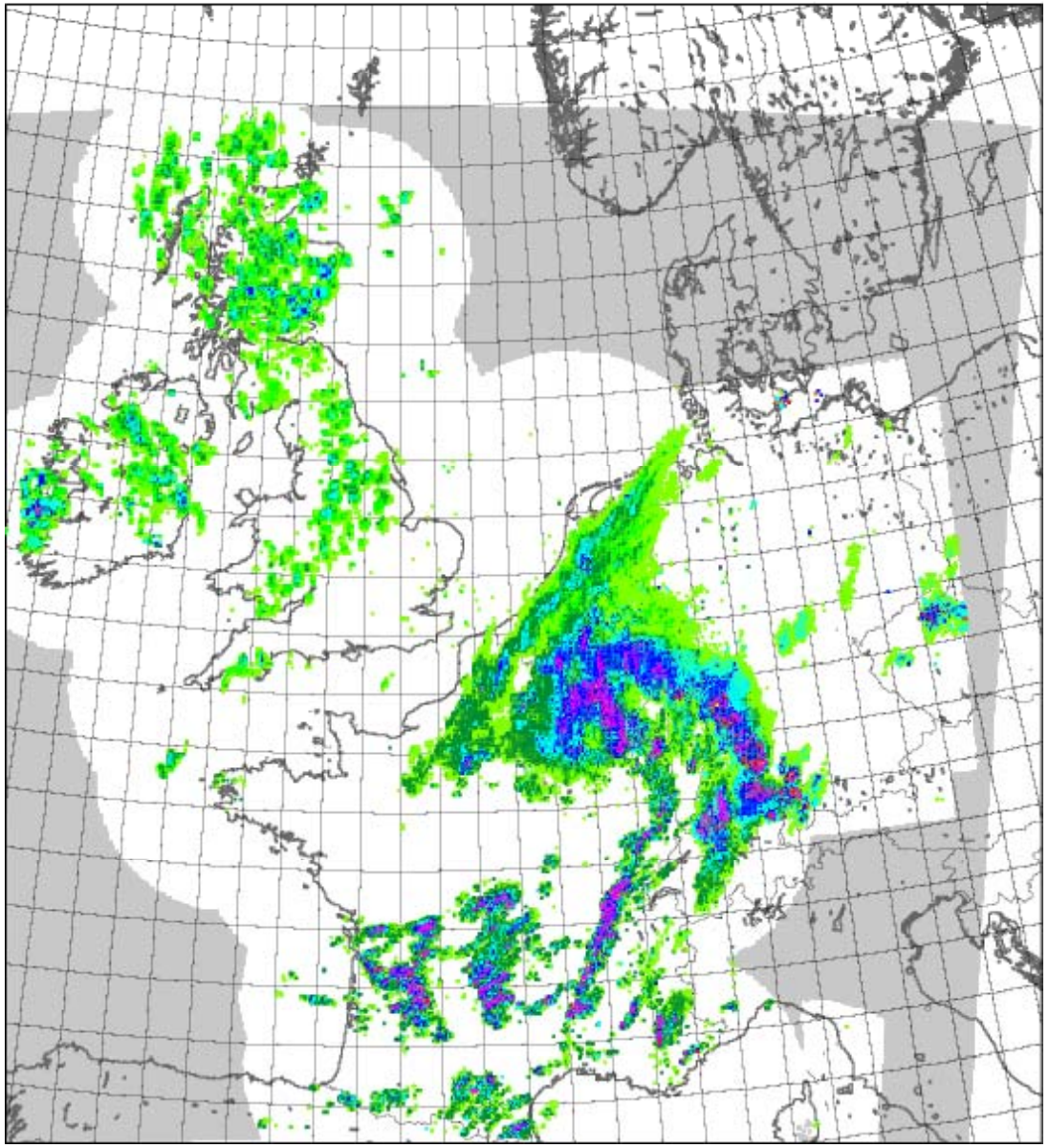
Surface pressure, and profiles of temperature and wind from landing and ascenting aircraft in Schipol are assimilated.
No GNSS data



radar uursom 2010051117

Precipitation measured by radar.

From Siebren de Haan.



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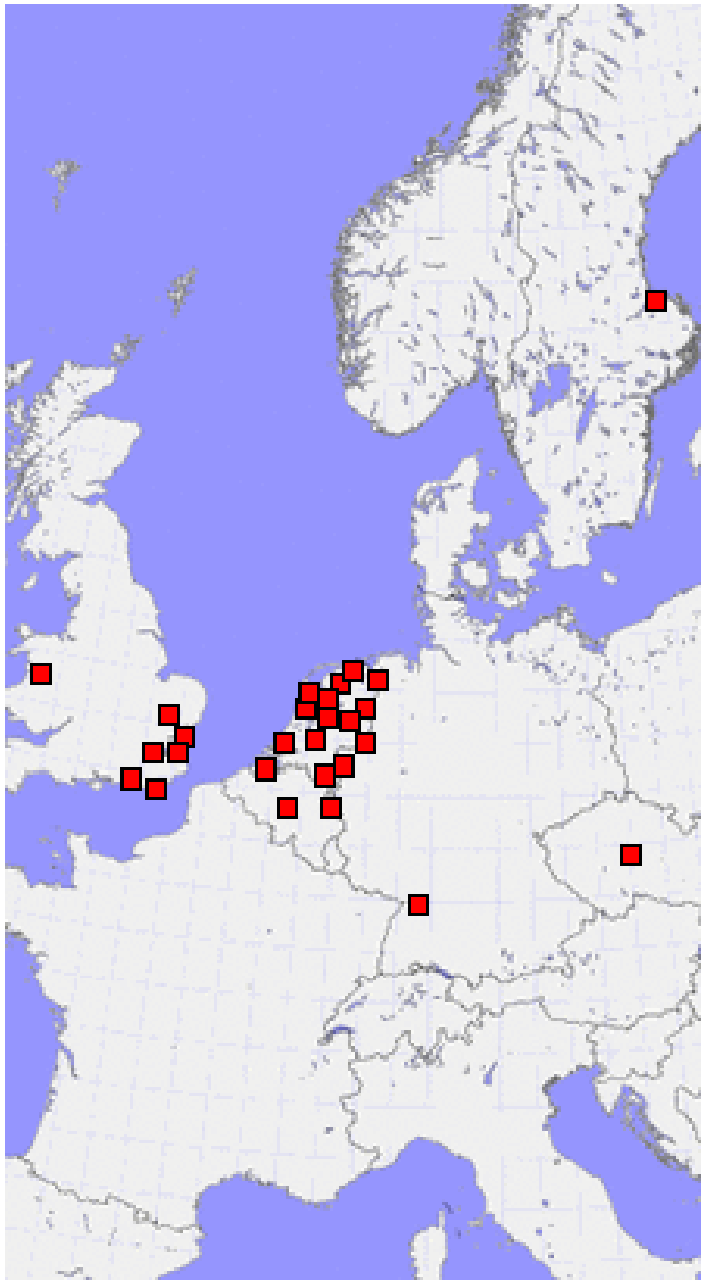
Included ZTDs from shown sites in data assimilation

Surface pressure and profiles of temperature and wind still assimilated

From Siebren de Haan.



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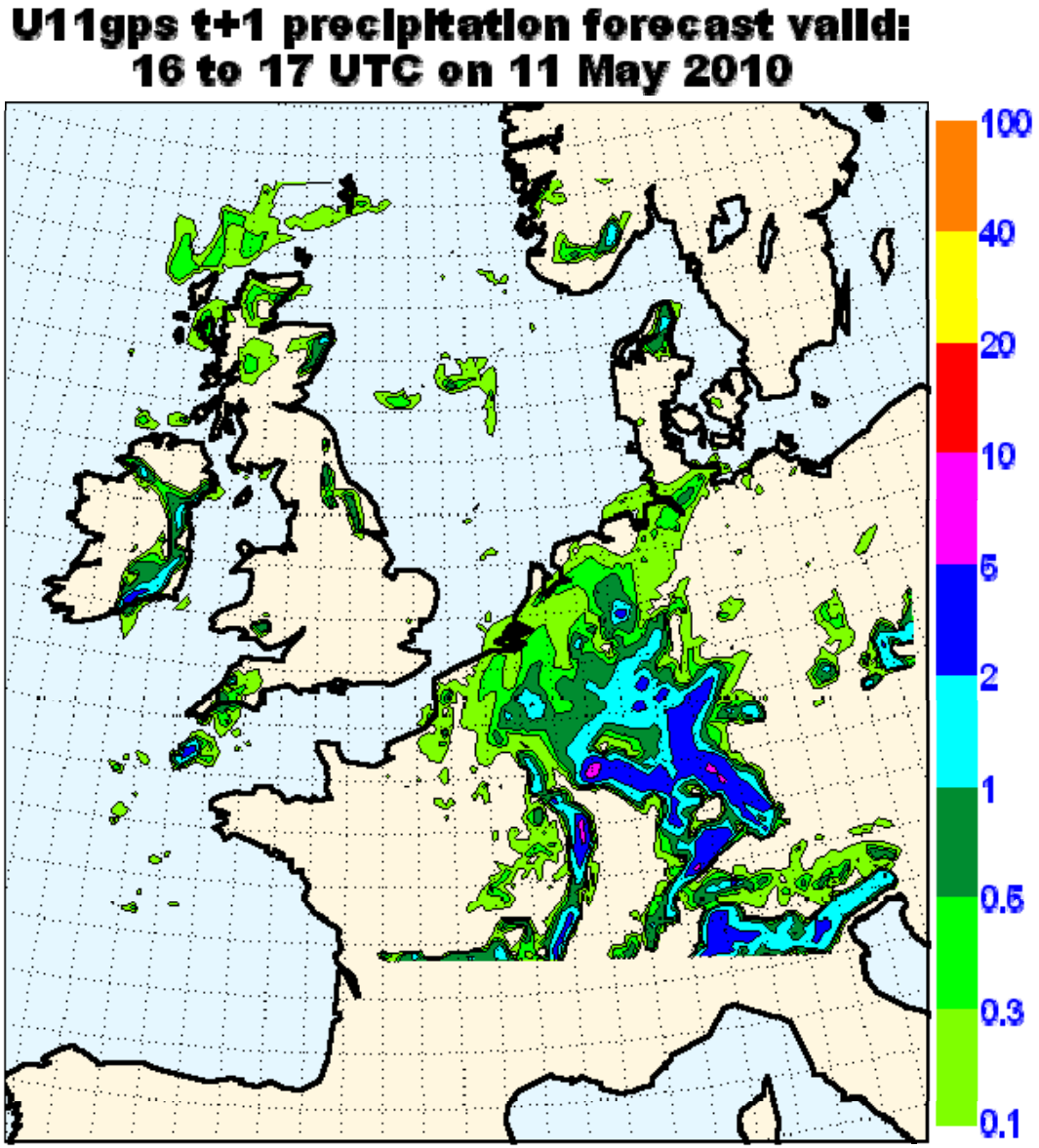
Precipitation in KNMI HIRLAM with hourly assimilation cycle

Surface pressure and profiles of temperature and wind from landing and ascenting aircraft assimilated, but now with NRT GNSS ZTDs from mainly Dutch sites included.

Notice improvement over Dutch area

From Siebren de Haan.

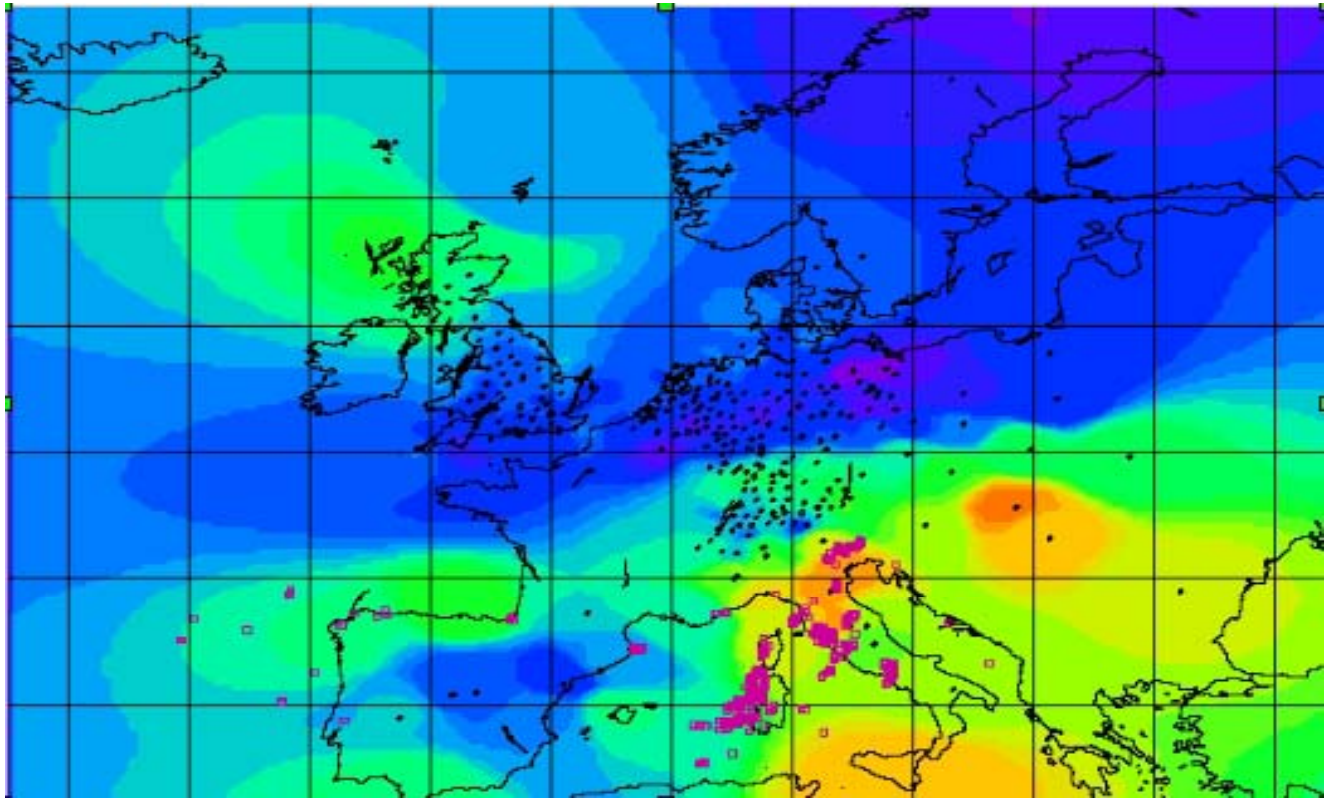


X. Yan et al, *The benefit of GPS zenith delay assimilation to high-resolution quantitative precipitation forecasts: A case-study from COPS IOP 9,* Quarterly Journal of the Royal Met. Soc., 2009, vol 135, p 1788 – 1800. "Clear positive effect on short-range quantitative precipitation forecasts." "Assimilation of ZTD induces changes in the low-to-middle tropospheric water vapour vertical structure that are consistent with water vapour measurements from radiosonde and lidar."

Reima Eresmaa, *Impact of ground-based GPS ZTD data assimilation in HIRLAM: 3D-var analyses and forecasts,* HIRLAM Newsletter, 2009, no 55, p 29 -36. "Small impact on standard verification scores.. ..without bias correction there is a systematic moistening impact. and increase in temperatures and upper tropospheric geopotential height." "Impact appear most positive in the regions of Europe where GPS station density is highest."

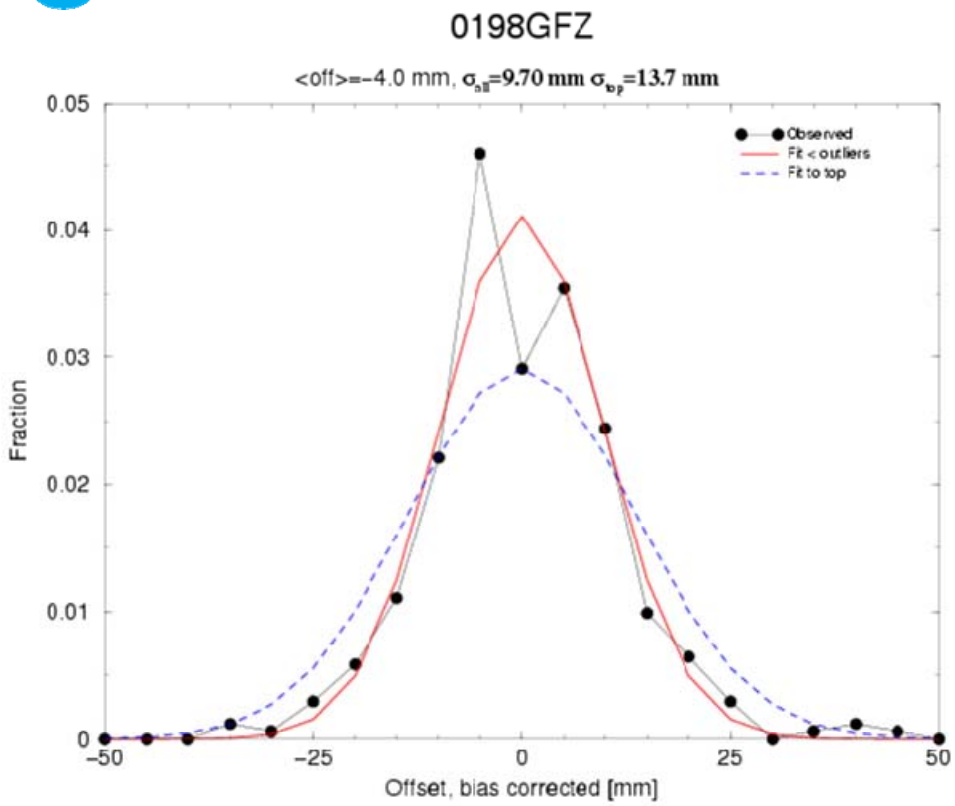
2D IWV maps

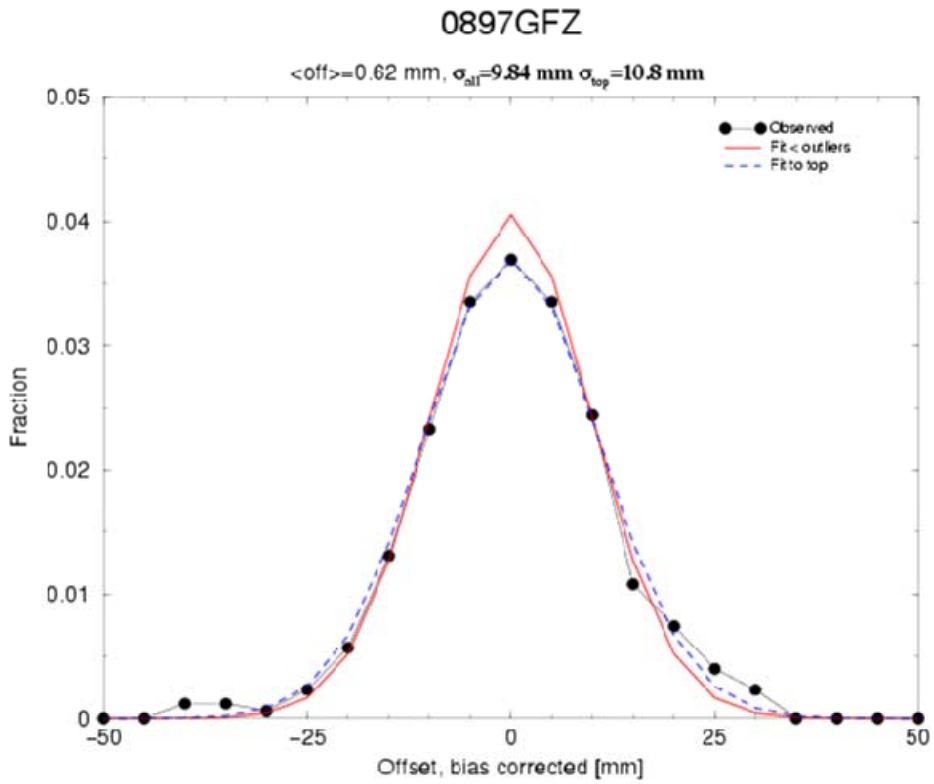
Based on the ZTDs and additional pressure and temperature information maps of integrated water vapour (IWV) are made. Such maps are useful in meteorological now-casting, where they can help foresee rain events.



Purple marks on map are lightning observations

Example of met. institute statistical data monitoring of ZTD offsets



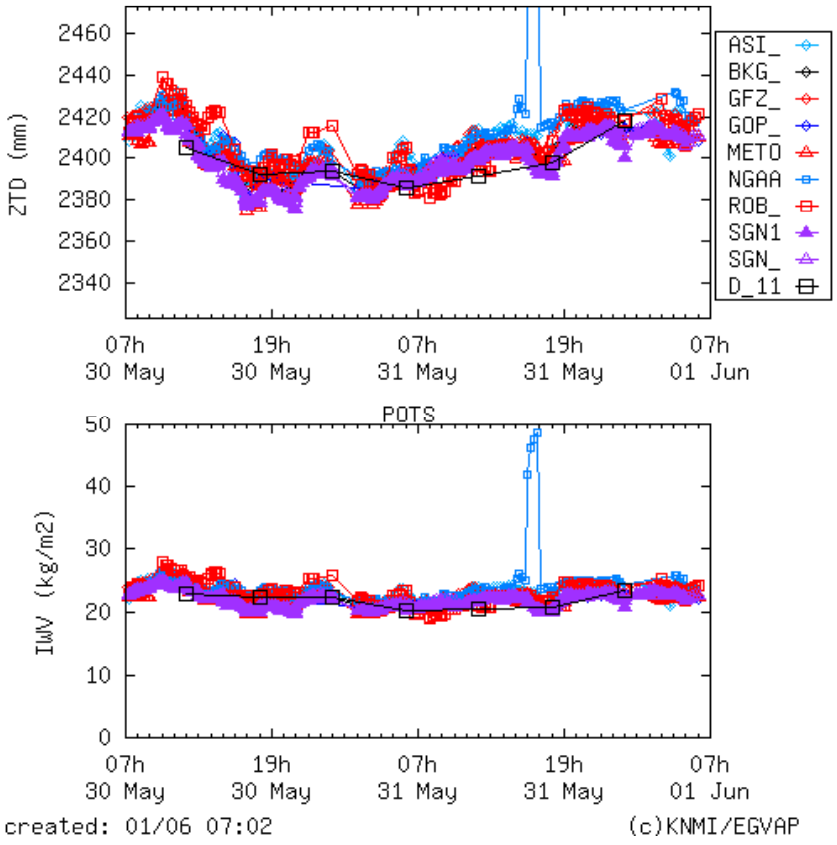


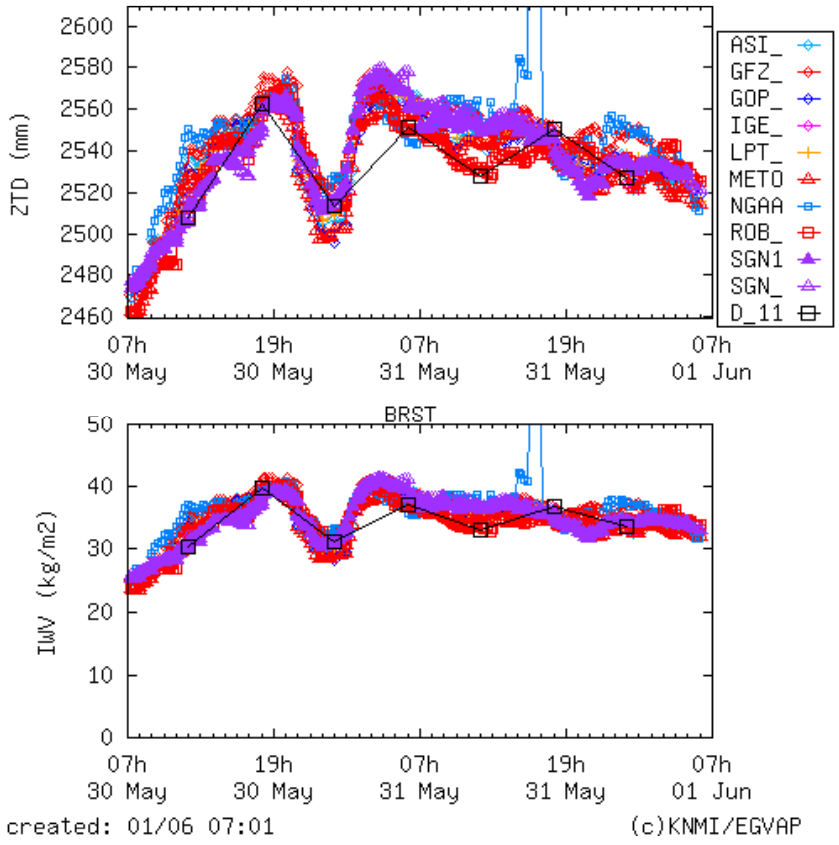
NWP data assimilation is based on the assumption that offsets have a Gaussian distribution. Tests of this reduce the number of useful NRT GNSS ZTD sites significantly. The cause of the non Gaussian behaviour is not understood, not even whether it is on GNSS, NWP, or both sides.

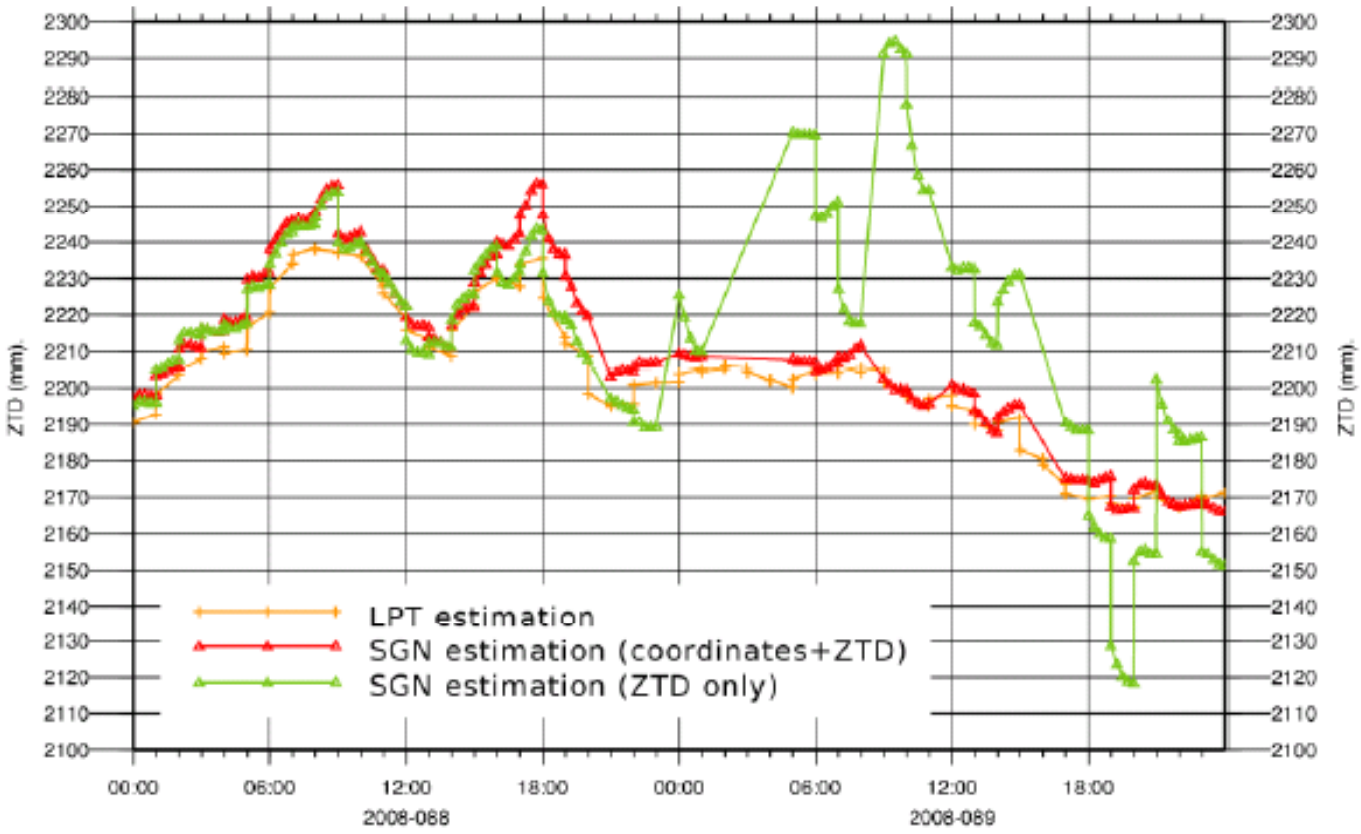
In addition NWP data assimilation is based on the assumption that observation errors are not correlated.

Examples of NRT processing problems

Intermittent problem with an AC solution (based on ppp processing).





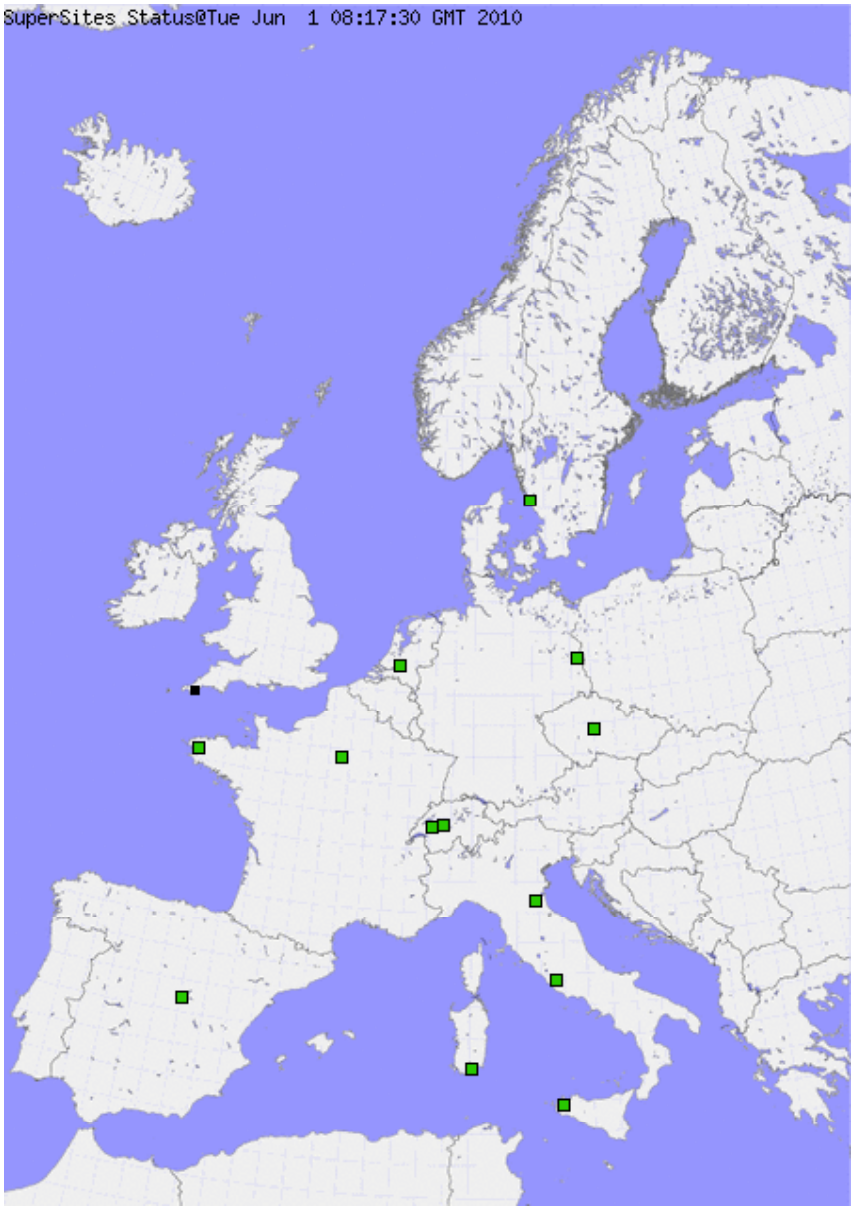


Problem in network SGN solution due the movement of a site by a site owner, without the AC knowning in proper advance.

AQC, active quality control

- While the vast majority of the NRT ZTDs are of high quality, there is from time to time a few which contain significant errors.
- Due to the intrinsics of the GNSS system and processing these errors are in many cases strongly correlated.
- Correlated errors in observations are poisonous to numerical weather prediction models.
- Because NWP models are not very good at humidity, it is not robust to rely only on NWP identification of multi GNSS site errors from an AC
- To identify such events, on the fly, E-GVAP is setting up AQC, in which NRT ZTD data from super-sites, and other GNSS sites processed by many ACs, are inter compared.
- If ZTDs from one AC deviates simultaneously at many sites, it is a strong warning signal, and the ACs data of the time will be flagged accordingly

The supersites



To be processed by all ACs.

At the supersites auxiliary measurements are available, e.g. from radiosonde or WVR. This is useful in validation studies, for both meteorology and geodesy.

In addition to the above, a lot of meteorological measurements of surface pressure, temperature and humidity, as well as radiosonde data from other sites are made available via E-GVAP and the EUREF EUMETNET MoU for use by geodesist in their scientific work.

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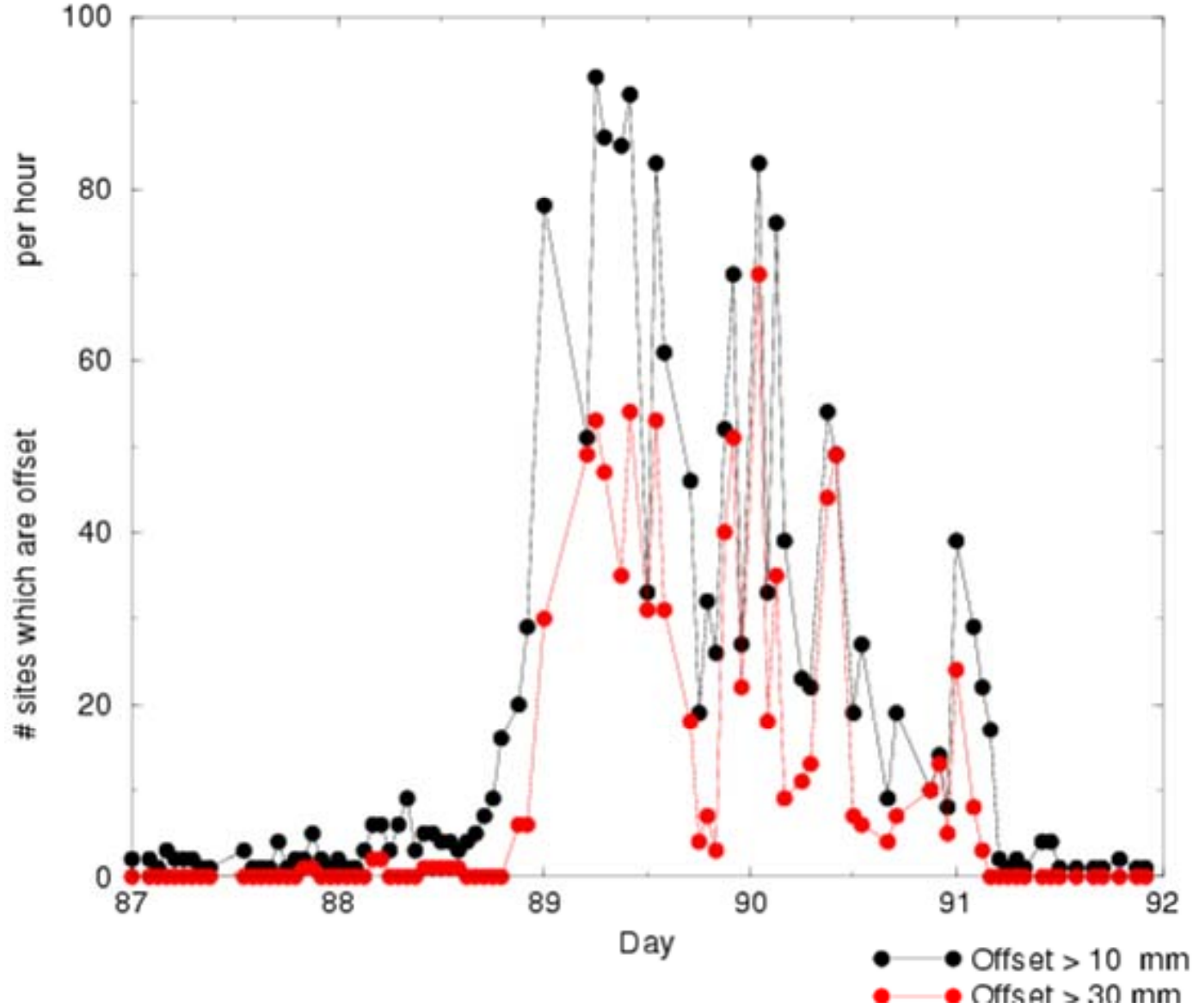
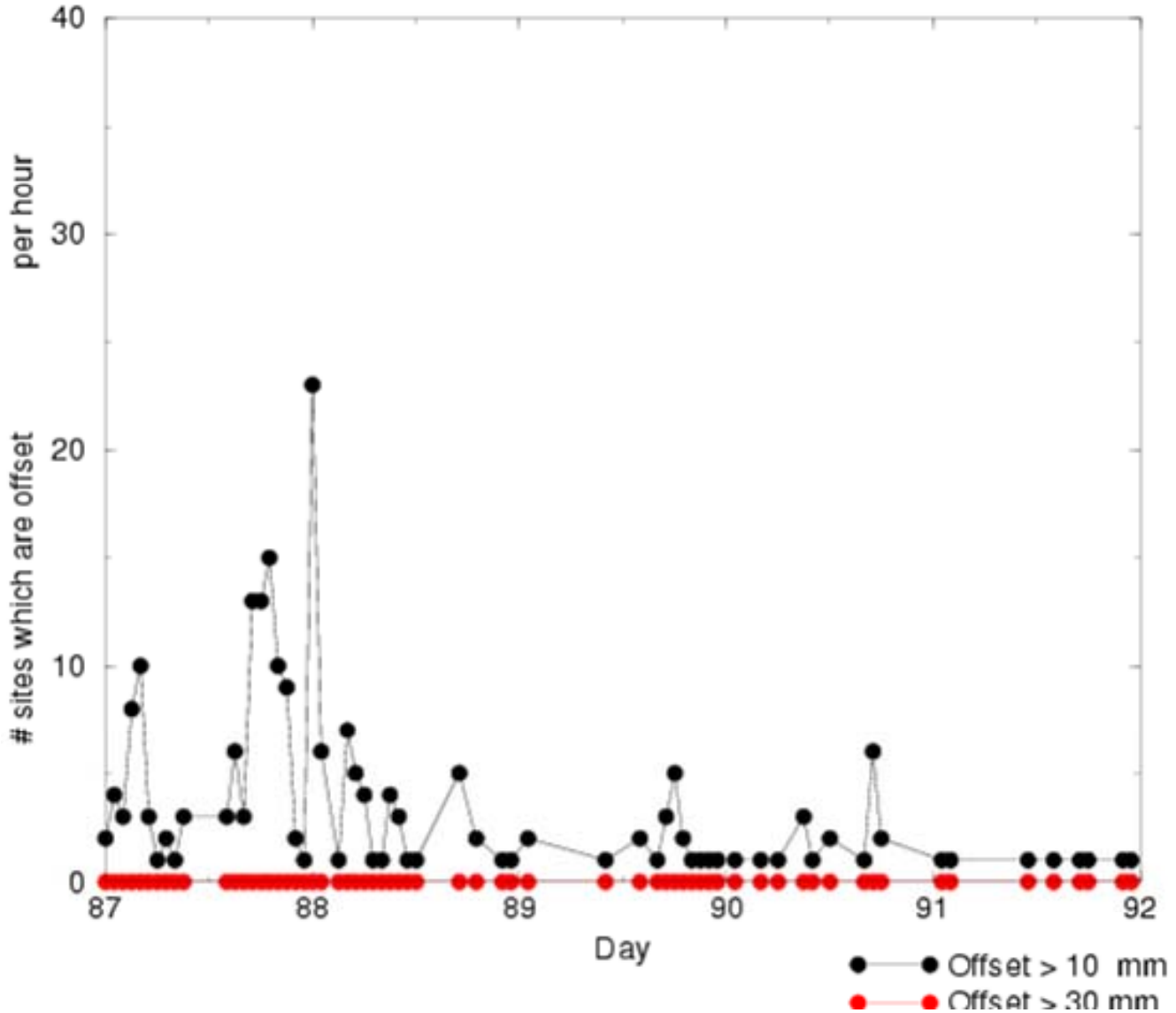
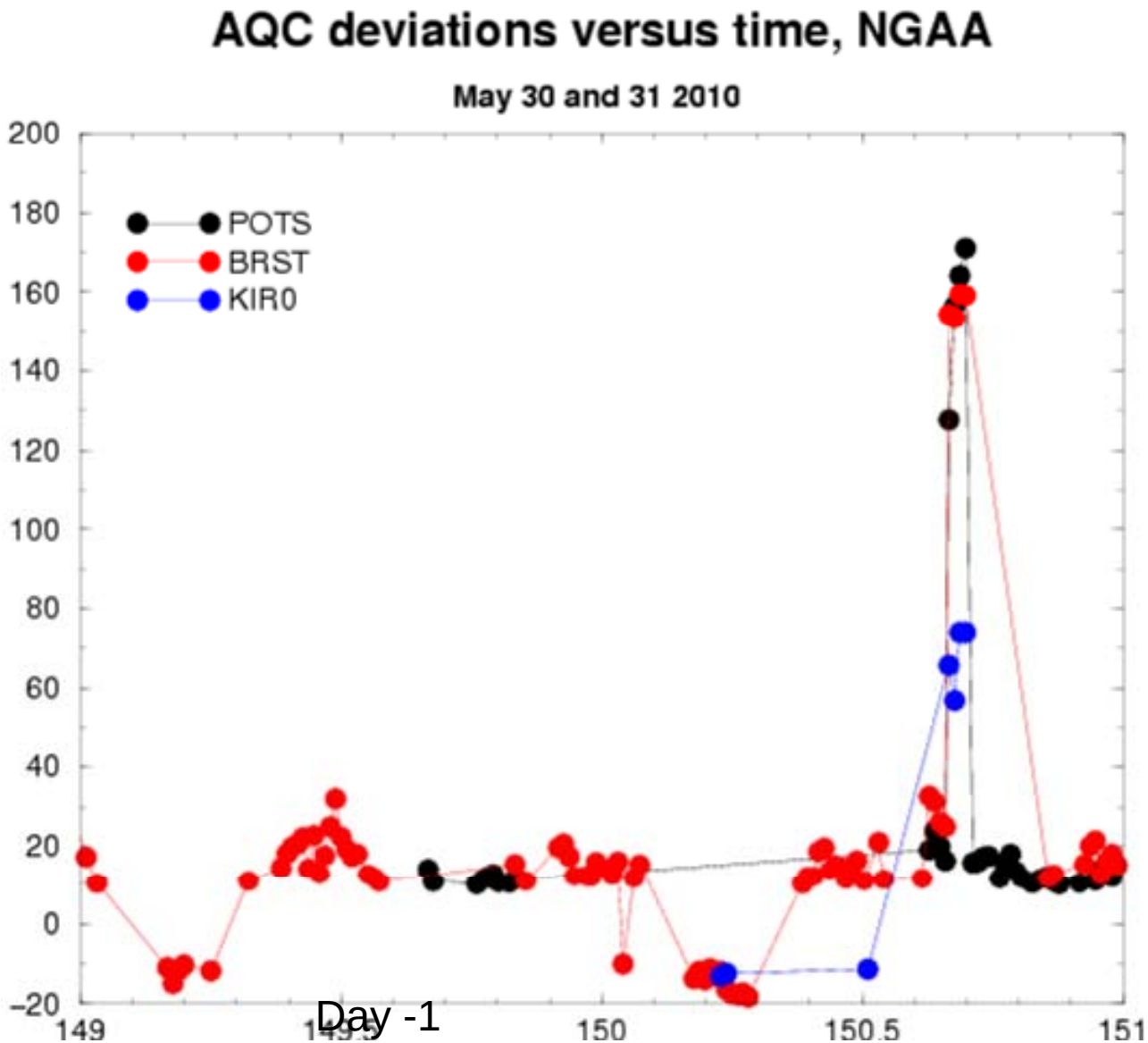
For SGN 2008. Days 87 to 92.



For GFZ 2008. Days 87 to 92.



Deviations larger than 10 mm with respect to median of medians of ACs. Unit is mm.



Clearly the AQC is effective in picking out the correlated large offsets in the afternoon of May 31.

- Clearly this type of multiple error detection will be useful in NWP and in notifying ACs in case of errors.
- The plan is to include also other types of offsets (with respect to NWP forecasts, e.g.) and make real-time flagging of AC performance available to users.

- It certainly shows the strength of having different ACs processing common sites using slightly different methods.

- Is this type of early inter comparison and multiple error detection of NRT ZTD data useful also on the geodesy side?

- In addition **combined NRT solutions** will be made available by ASI and KNMI, based on two different combination methods. Rosa Pacione described the ASI approach at this meeting. Those will be used in the quality control.

Future

1 Making the NRT GNSS observing network:

- Global and denser.
- Faster access to delay data.
- Improving on the fly quality control.
- Access to an operationaly real-time orbit and clocks product, enabling widespread usage of PPP derivation of delays will be very important in this regard. Usage of low price, single frequency recievers appears promising.

2 More GNSS data delivered per site

- Gradients. Appears very promising as the next step, in particular with more satellites becoming available. Requires research and development on both GNSS and met. side.
- Slant/residuals. Also promissing. But not clear how fast noise can be reduced.

3 Combining GNSS site data to new products.

- Tomography [3D water vapour fields via inversion of GNSS delays, constrained other atmospheric data]. Highly useful in now-casting, and in some NWP models, if good quality. More research and possibly densification of networks necessary.

Future

4 Expanded use of met. and other data in GNSS data validation.

5 Usage of met. data in GNSS processing. For example.

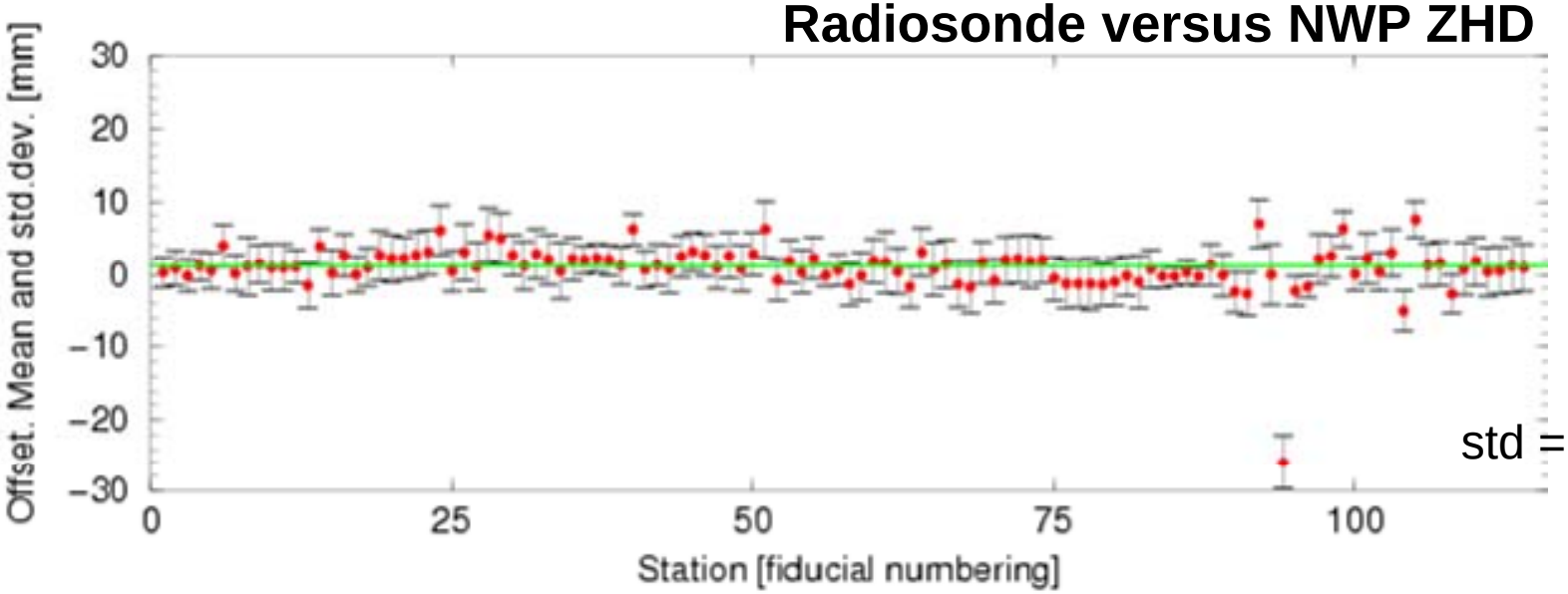
- Actual pressure data (meassure or NWP) instead of climatology in ZHD assessment.
- Colaboration in understanding of ”difficult sites”. Is it NWP or/and GNSS which have a problem?

6 Site sharing where beneficial. Either for economical reasons or for validation purposes.

7 Usage of single frequency receivers to densify network.

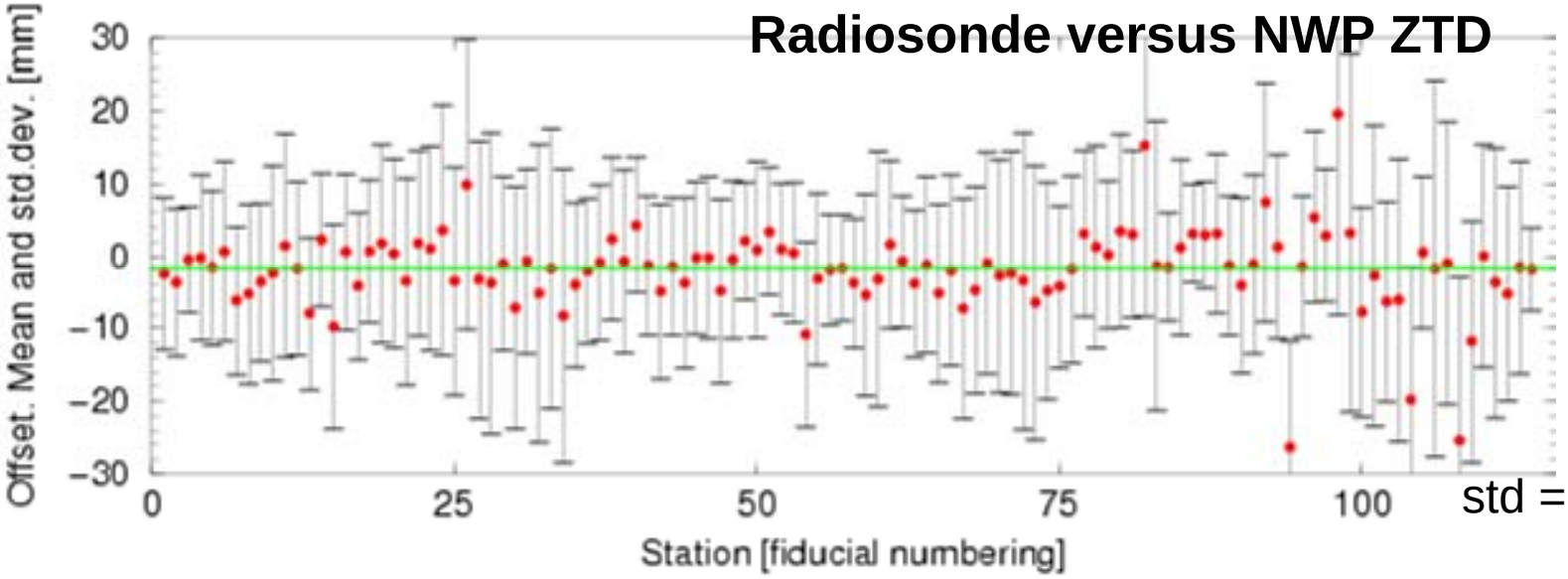
8 Unique GNSS site names. Please!

Radiosonde versus NWP ZHD



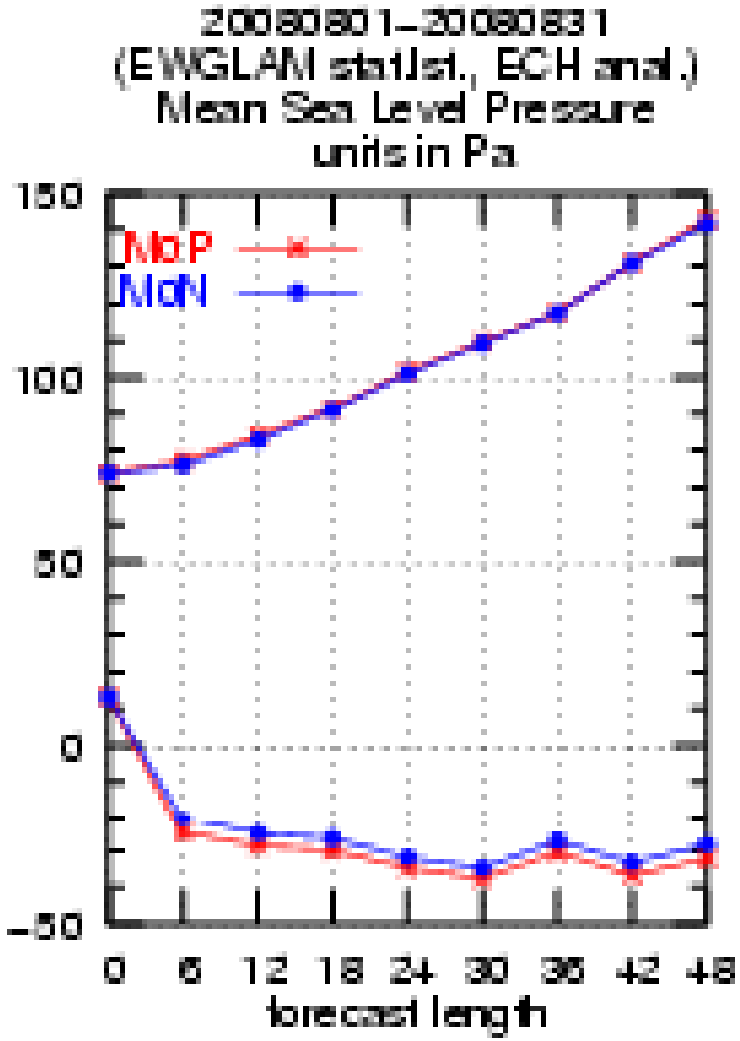
std = 3.7 mm

Radiosonde versus NWP ZTD



std = 14.7 mm

Example of NWP HIRLAM offsets in mean sea level pressure against observations.
X-axis. Forecast length in hours.
Y-axis. Bias and RMS of NWP versus observed pressure offsets, unit is pascal (divide by 100 to get millibars).



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An example of data quality and validation problems