

Combination of GPS Near Real-Time tropospheric parameters

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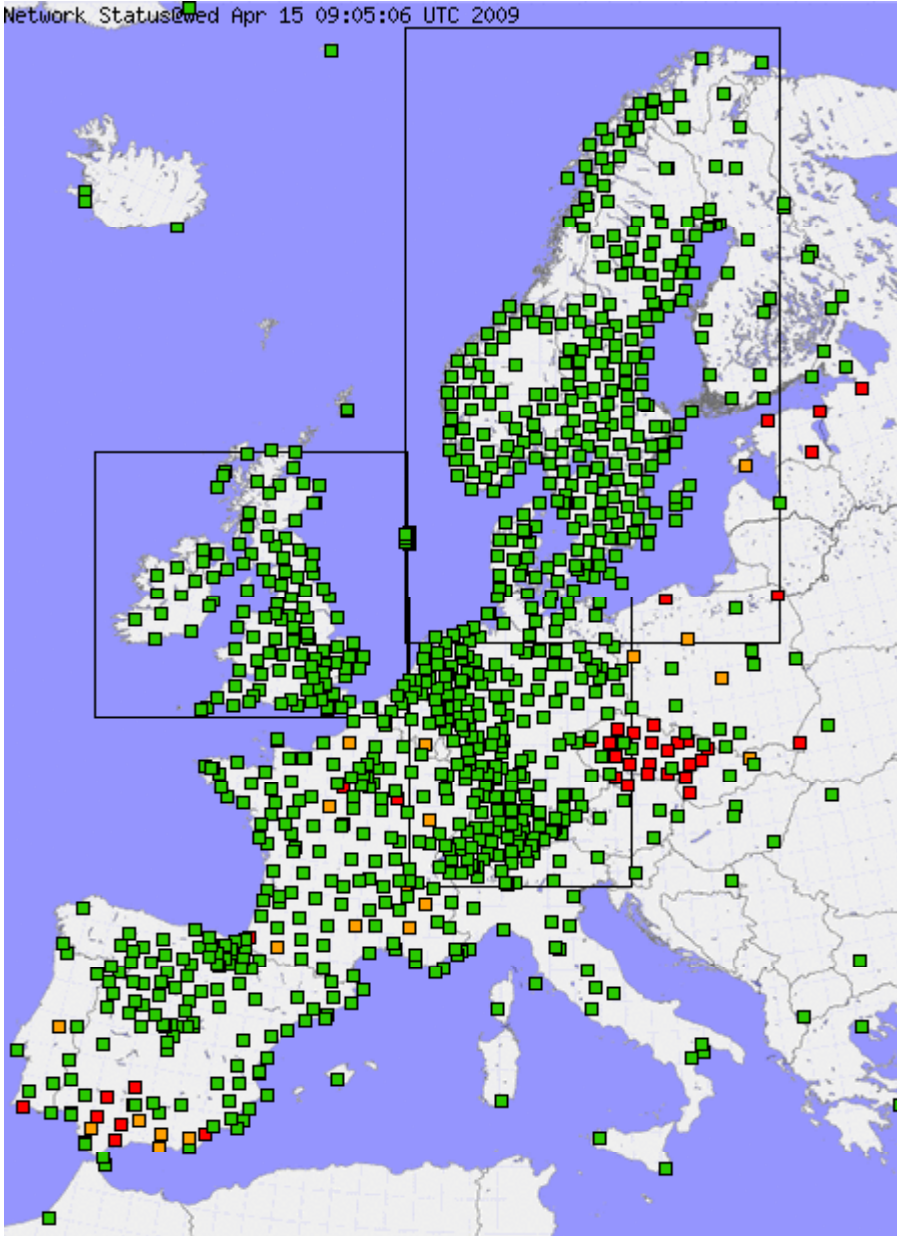


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- A large, soft-focus image of a blue sky with white clouds, serving as a background for the list of topics.
- E-GVAP (The EUMETMET GPS Water Vapour Programme) Scenario
 - NRT ZTD Combination Strategy
 - NRT Combined E-GVAP Network
 - NRT Combined ZTD validation
(w.r.t. Radiosonde and EUREF Solutions)
 - NRT Combined Solutions as Quality Control Tool

Operational E-GVAP Network



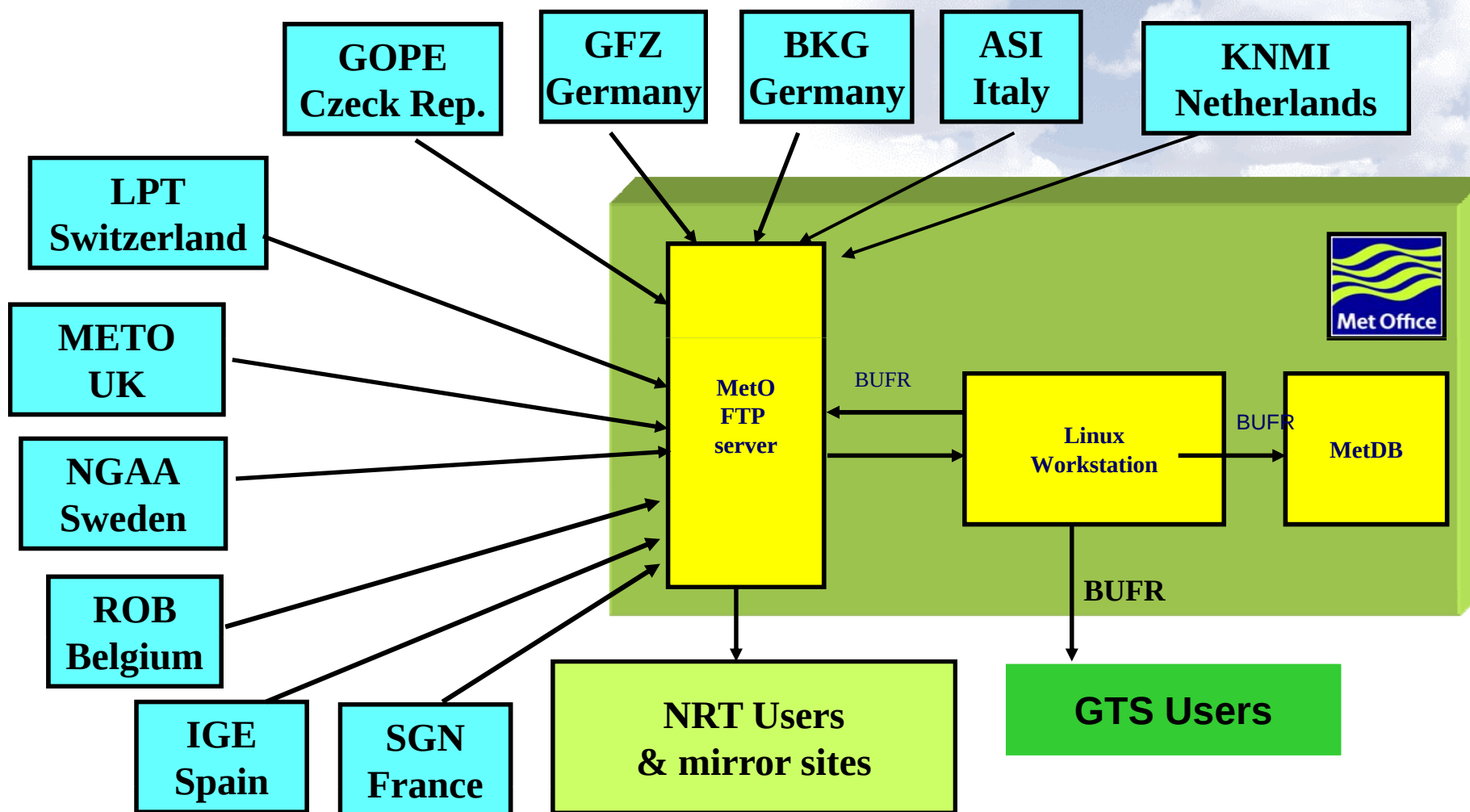
Network Status Wed Apr 15 09:05:06 UTC 2009



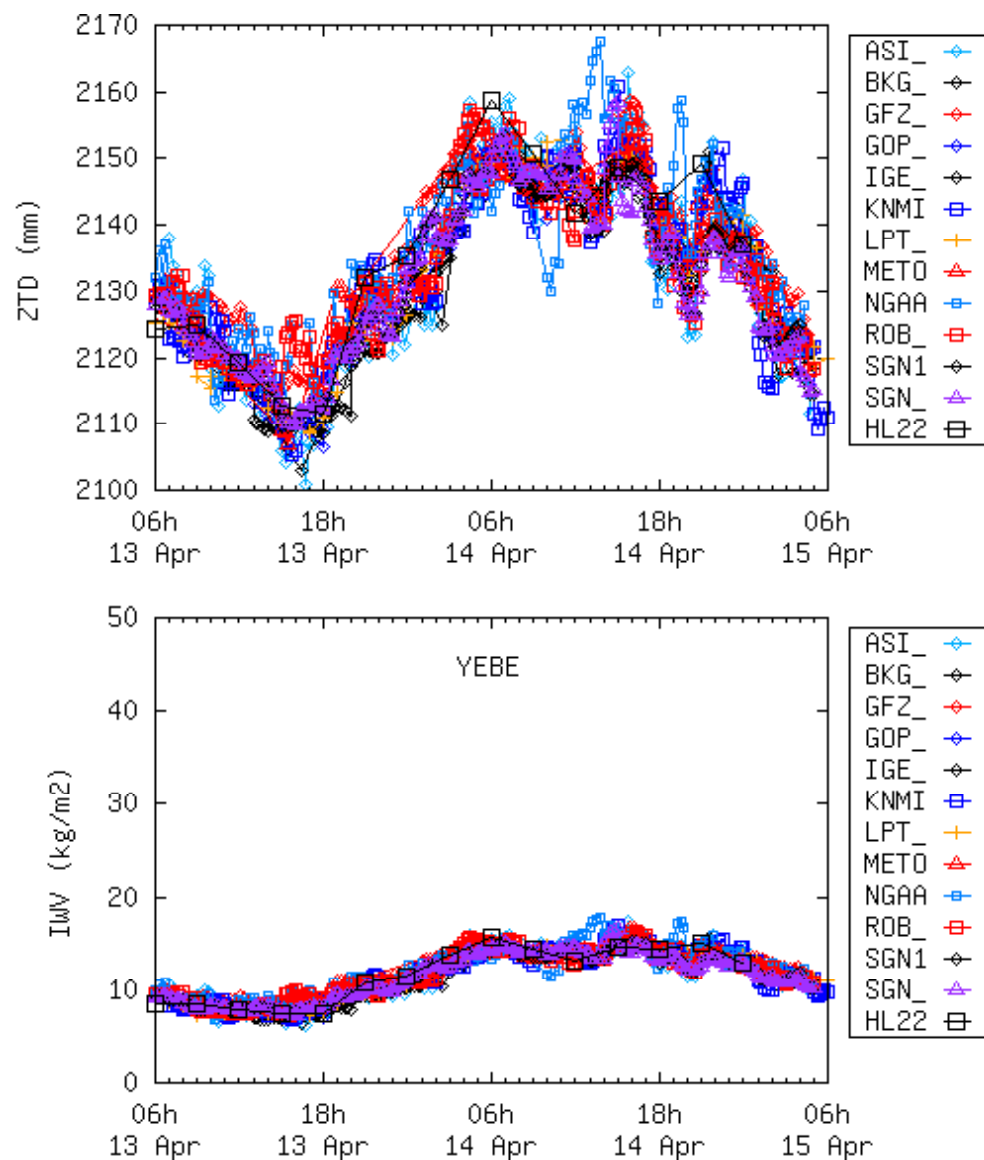
- 13 Institutions
- 11 ACs
- ~1000 GPS sites
- ~200 analyzed by 2 ACs
- ~150 analyzed at least by 3 ACs

<http://egvap.dmi.dk>

E-GVAP NRT Processed Data Flow



Motivation



created: 15/04 06:32

(c) KNMI/EGVAP

This study is motivated by the need of having an internally consistent Zenith Total Delay (ZTD) product on the basis of several individual troposphere solutions, obtained from Near Real-Time processing.

Combining these solutions can reveal problems in the processing and can provide a reliable quality indicator.

For a single site ZTD is modeled as:

$$y_n^k = Y_n + b^k + e_n^k$$

$n = 1, \dots, N$ time epochs
 $k = 1, \dots, K$ analysis centers

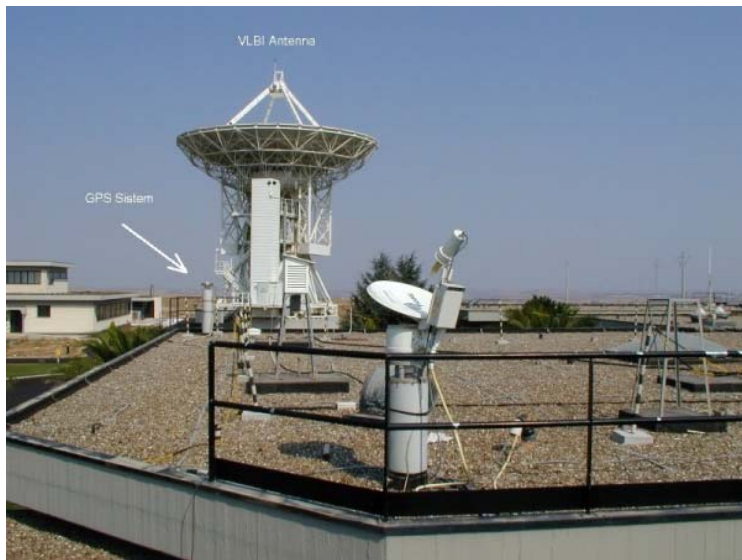
where Y_n is the 'true' ZTD at epoch t_n , b^k is the analysis center bias and e_n^k is the residual between Y_n and y_n^k .

The linear function model which can be solved in the generalized least square sense by adding the following constrain equation:

$$\sum_k b^k = 0$$

The method provides:

- combined NRT ZTD estimates and their standard deviation,
- site and analysis centre specific bias and weight.



In collocated sites, the method can be used to combine atmospheric parameters retrieved from various geodetic techniques as GPS and VLBI.

The bias will be the sum of: **site and analysis centre bias + technique bias.**

Combination steps



The first step in the combination process is reading and checking the cost files. At this stage, gross errors (ZTD sigma $\geq$ 30mm) are detected and removed.



Data or processing problems are suddenly detected and e-mails send to the ACs.

Then, **a first combination** is performed to compute proper weights for **the final combined solution** which will provide combined NRT ZTD estimates, their standard deviation and site/analysis centre specific bias.

Input for NRT ZTD Combination

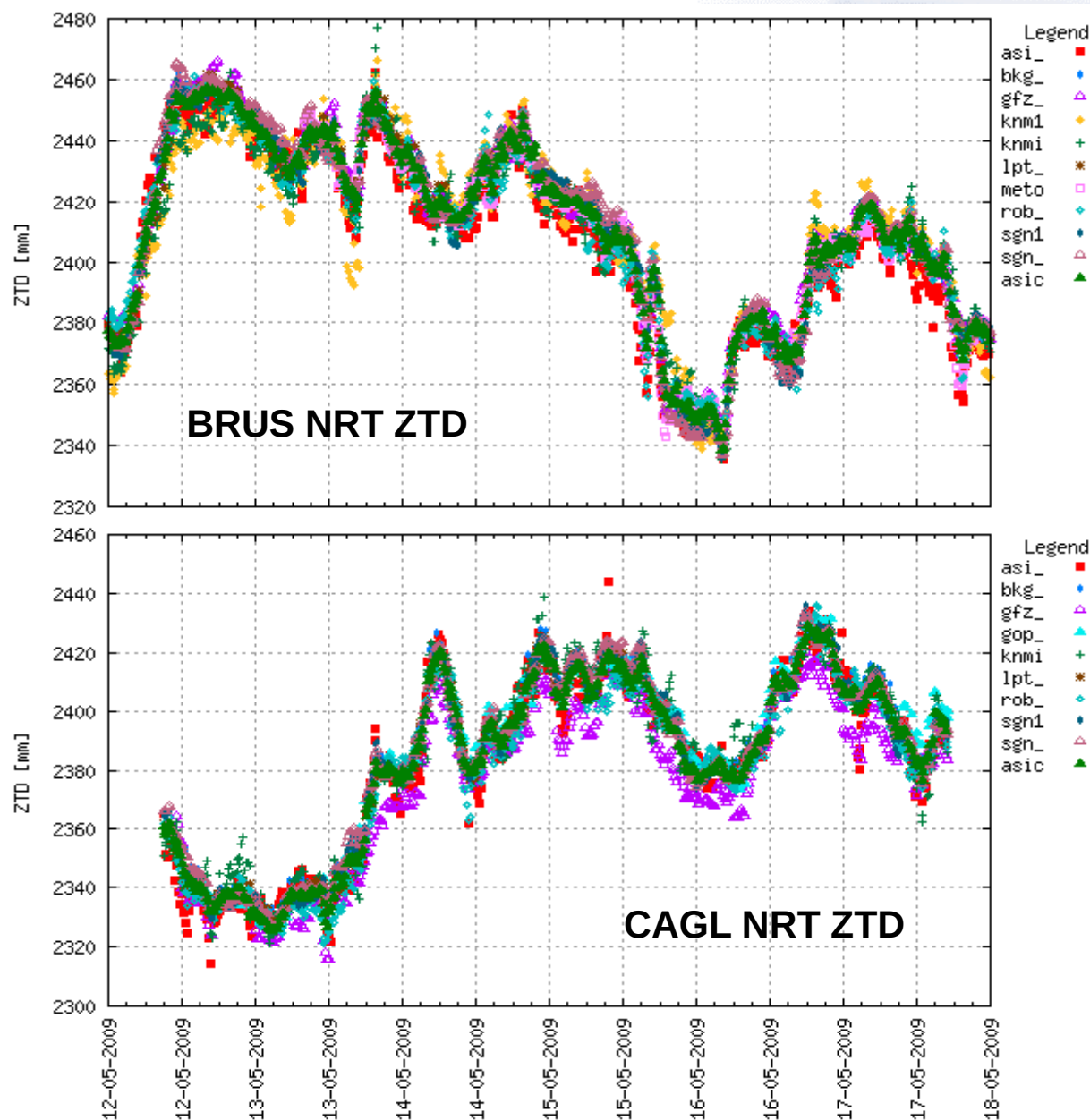


We consider the time series of GPS ZTD estimates obtained by different ACs for the same GPS site. Ideally the time series within each batch should have the same length and sampling interval but in practice

AC	# samples	@
ASI	4	00-15-30-45
BKG	1	30
GFZ	4	07,30-22,30-37,30-52,30
GOP	2	00-59
IGE	5	00-15-30-45-59
KNMI	5	00-14-29-44-59
KNM1	5	00-14-29-44-59
LPT	2	00-59
LPTR	11	02-07-12-17-22-27-32-37-42-47-52
METO	5	00-15-30-45-59
NGAA	4	00-15-30-45
ROB	5	00-15-30-45-59
SGN	5	00-15-30-45-59
SGN1	5	00-15-30-45-59

..... there is the need to specify a set of equidistant time moments at which to perform time series combination (@ 00 – 15 – 30 - 45).

5 Day NRT ZTD Time Series



The performance of the method has been tested on a 10-month (**July 2008 – April 2009**) dataset, by comparing NRT ZTD combined estimates

- Radiosonde ZTD,
 - EUREF Post-Processing combined solutions
- on the **Super Site Network**.

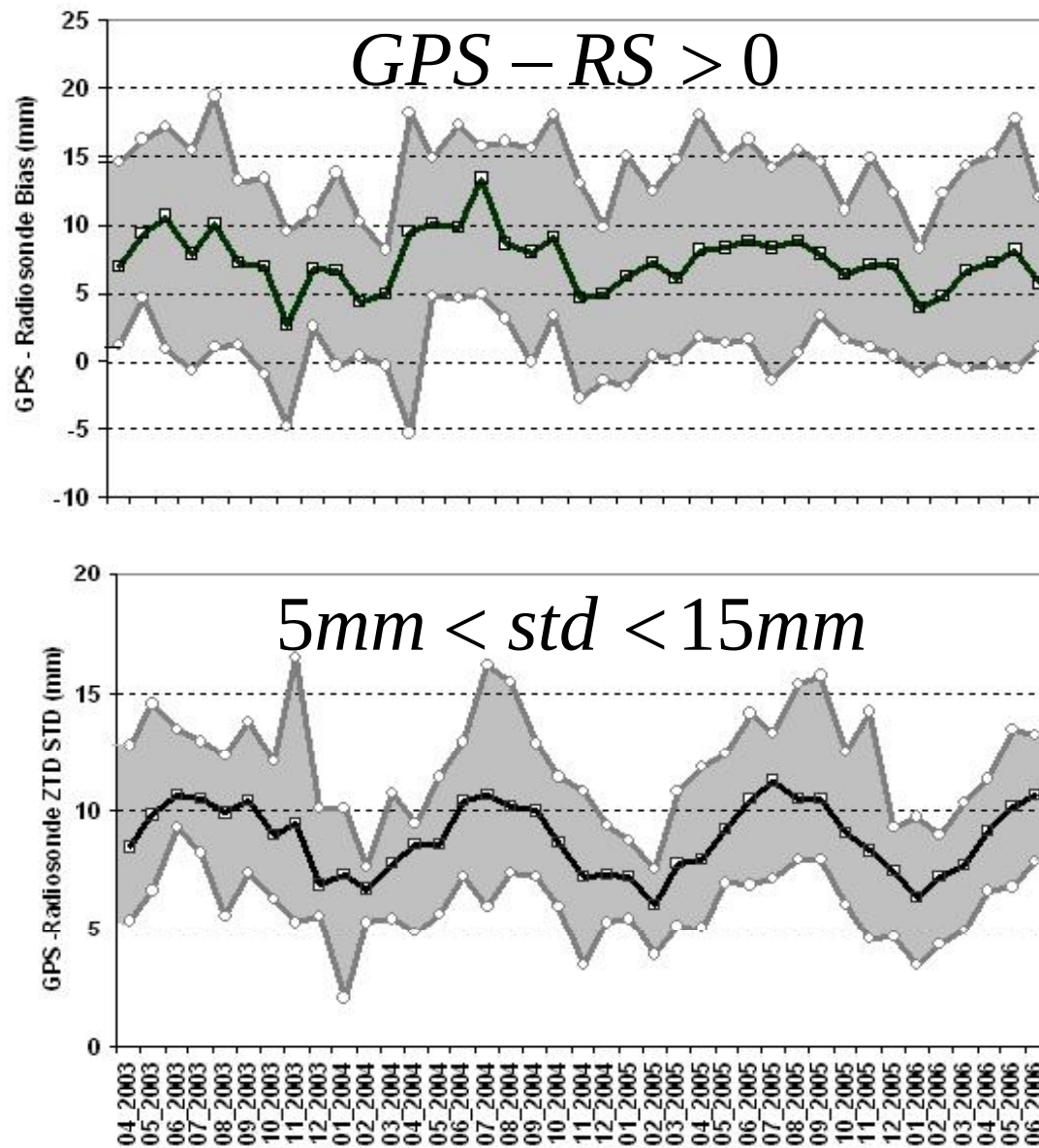


E-GVAP Super Site Network

A **network of Super Sites** covering Europe has been identified on the base of:

- RINEX data should be available at least in 20 minutes after the full hour,
- the site should be geodetically stable and with high installation standards,
- the site should be collocated with meteorological equipment (radiosonde and/or water Vapour radiometer) for validation.

Site	Riceiver	Antenna & Radome	RS Code	Distance (Km)	(GPS-RS) height (m)
	(april 2009)	(april 2009)			
BRST	LEICA GRX1200GGPRO	LEIAT504 NONE	07110	10	-85
CABW	TRIMBLE 5700	TRM41249.00 NONE	NA	NA	NA
CAGL	TRIMBLE 4700	TRM29659.00 NONE	16560	15	187
CAMB	ASHTECH UZ-12	ASH700936D_M SNOW	03808	0,6	0
GOPE	ASHTECH Z-18	TPSCR3_GGD CONE	11520	29	181
LDB2	JPS LEGACY	TPSCR3_GGD CONE	10393	5	5
MILO	TRIMBLE 4000SSI	TRM29659.00 NONE	16429	12	35
M0SE	LEICA GRX1200GGPRO	LEIAT504GG LEIS	16245	27	40
MEDI	TRIMBLE 4000SSI	TRM29659.00 NONE	16144	15	-1
ONSA	JPS E_GGD	AOAD/M_B OSOD	NA	NA	NA
PAYE	TRIMBLE NETR5	TRM55971.00 NONE	06610	8	8
SMNE	LEICA GRX1200GGPRO	LEIAT504GG NONE	07145	32	-86
YEBE	TRIMBLE NETRS	TRM29659.00 NONE	08221	45	288
ZIMM	TRIMBLE NETRS	TRM29659.00 NONE	06610	40	417



ASI GPS solutions – TOUGH project

Monthly variation in ZTD bias (top) and std (bottom) of GPS versus radiosonde for 13 stations (black line).

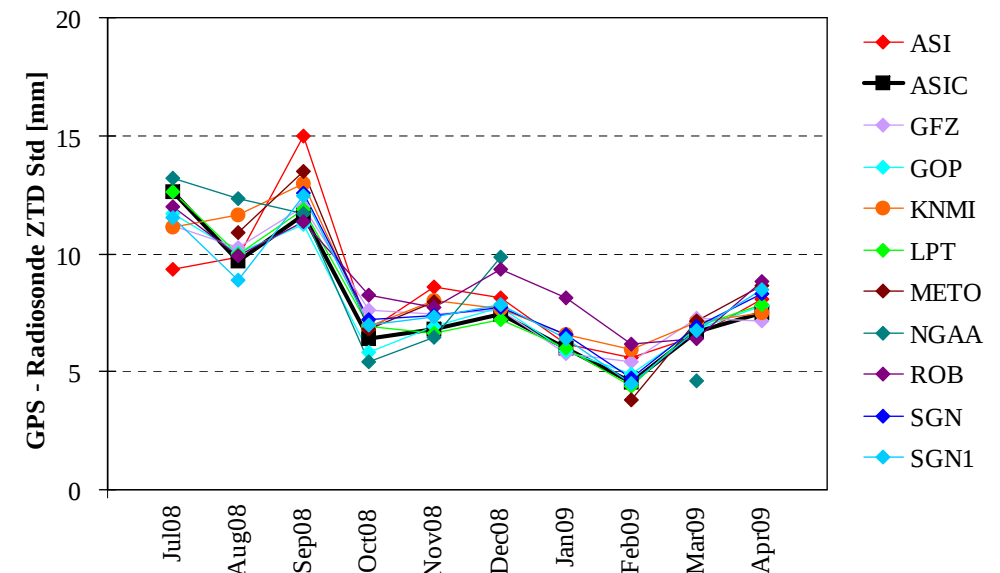
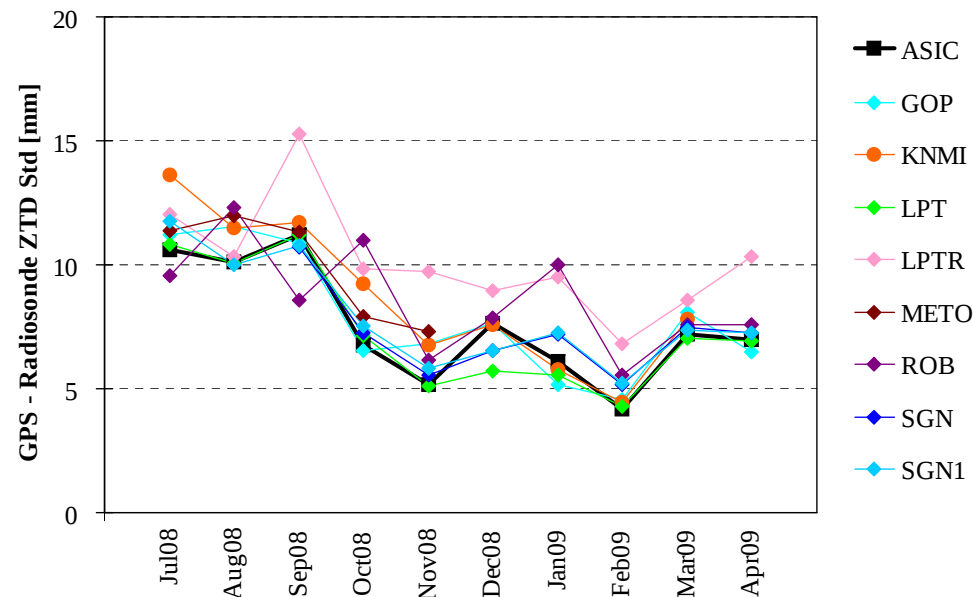
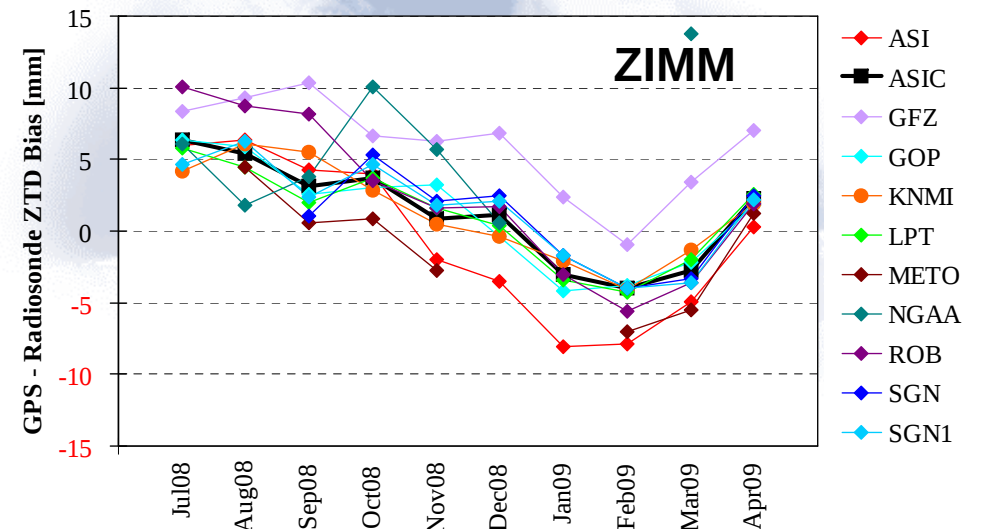
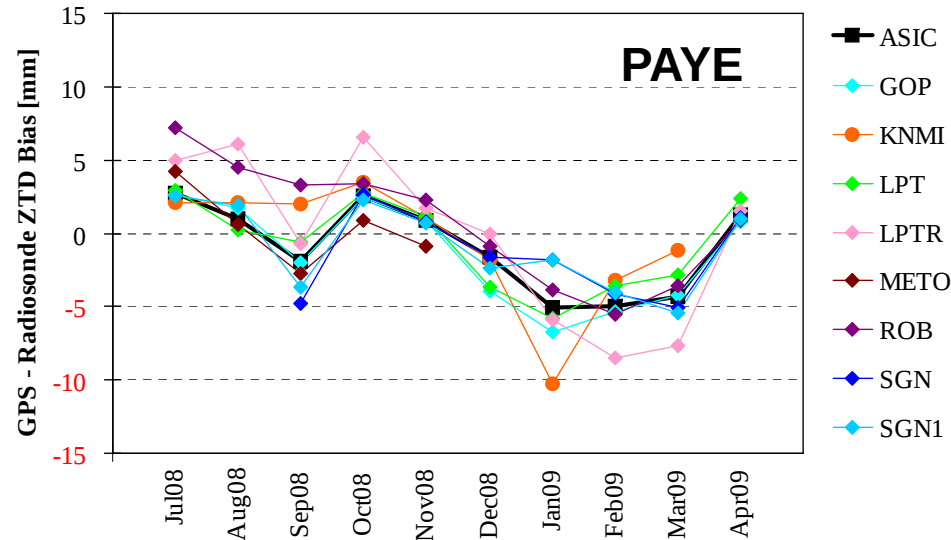
The gray area lies between the minimum and maximum values ([Pacione and Vespe, JTECHA, Vol. 25, No. 5, pages 701–714](#)).

Radiosonde seems to be drier than GPS and the std seems to follow the thermal cycle of the atmosphere.

PAYE and ZIMM versus Radiosonde



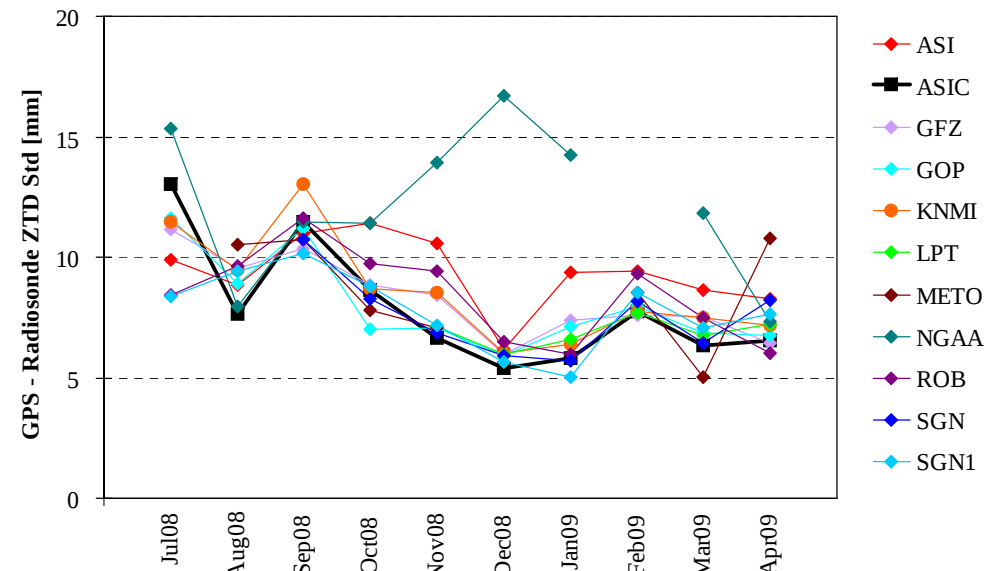
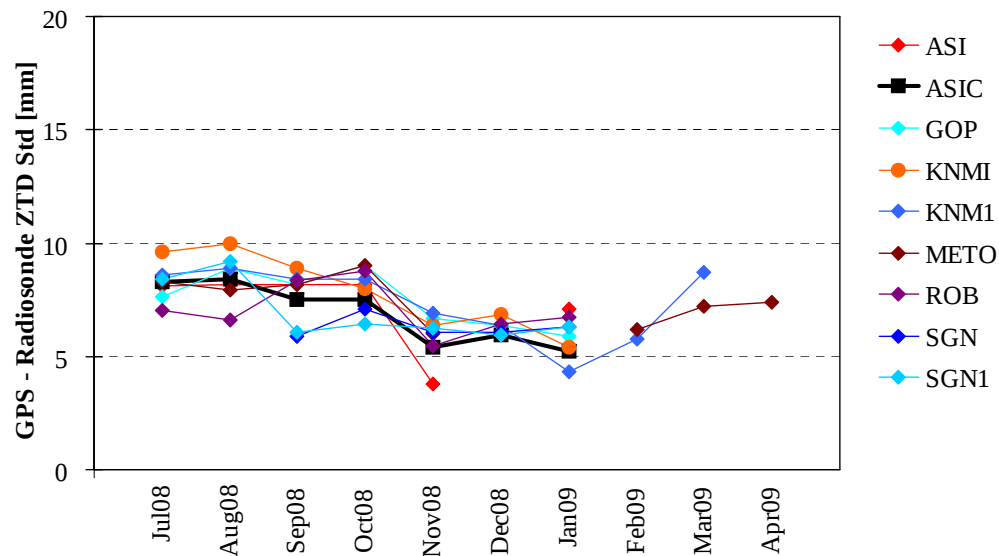
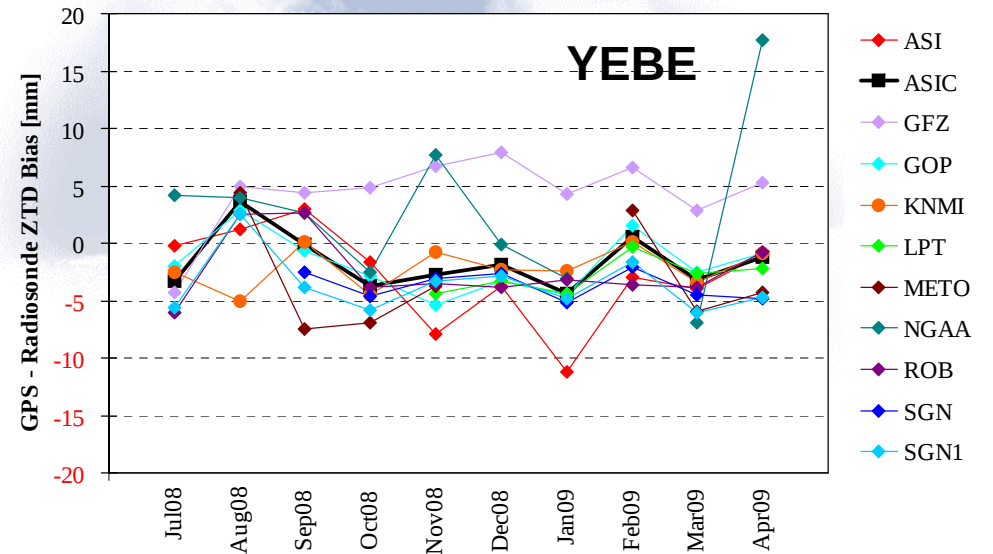
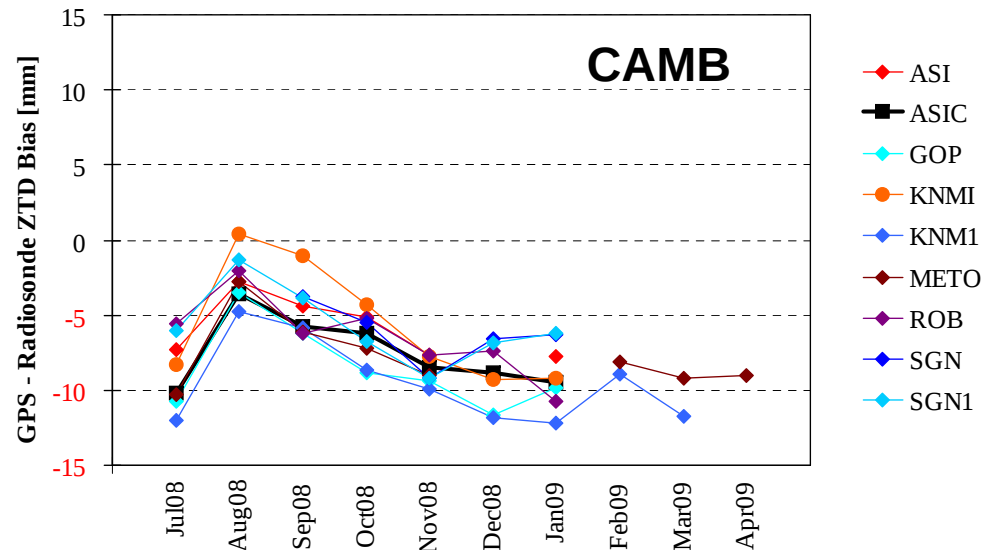
Same radiosonde (06610) but PAYE closer to the radiosonde launching site than ZIMM



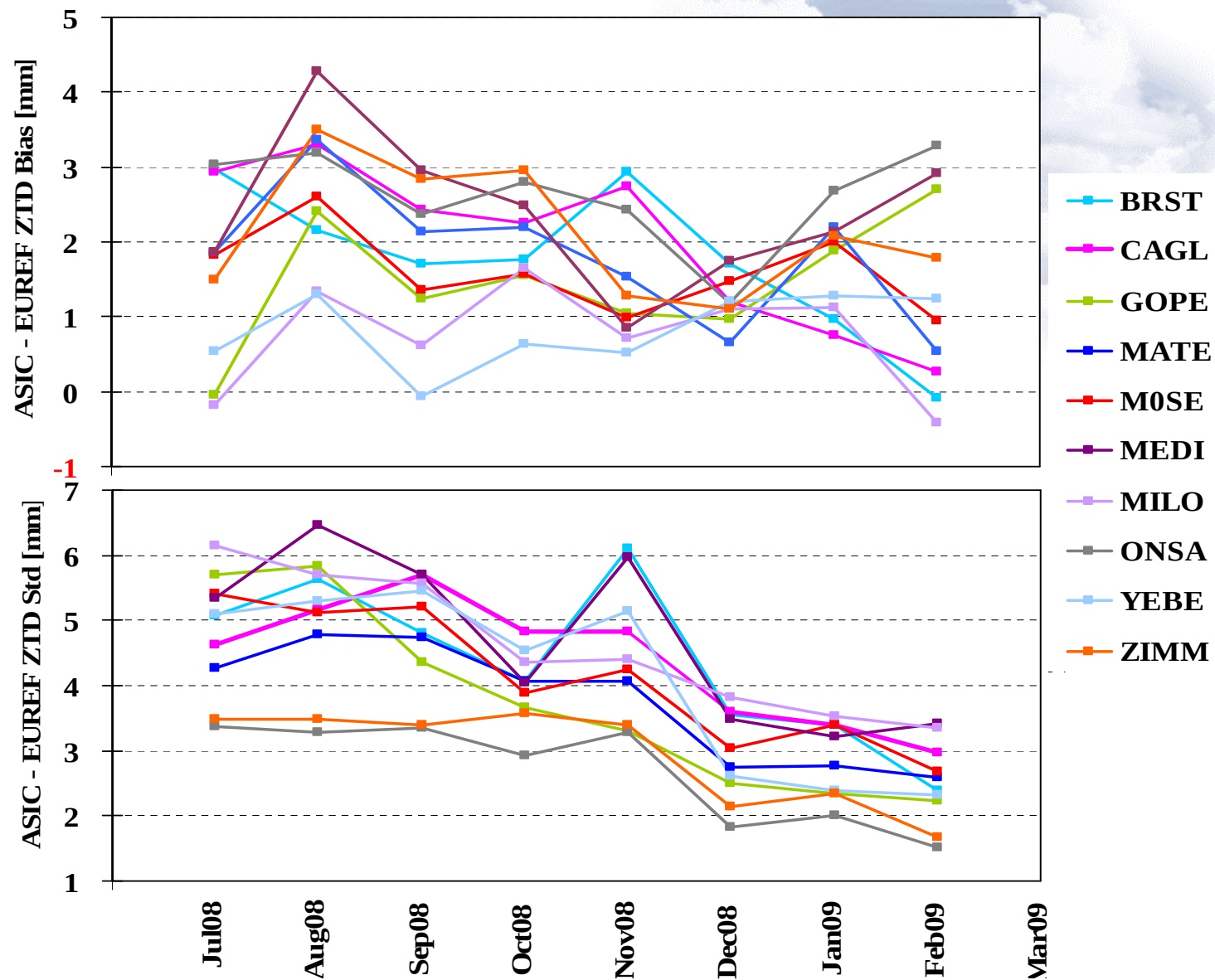
CAMB and YEBE versus Radiosonde



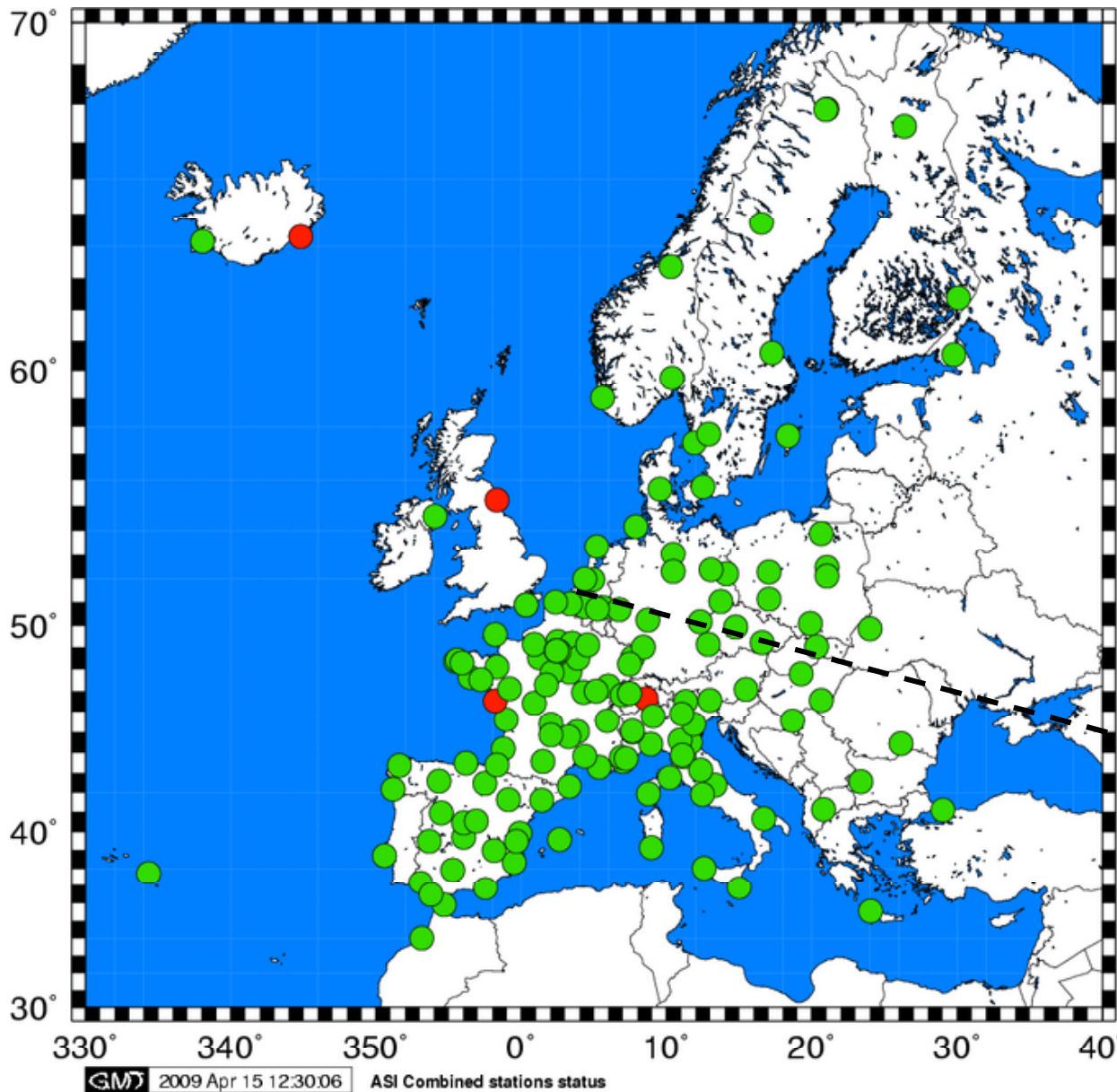
Among the Super Sites, CAMB is the closest while YEBE is the furthest site w.r.t. the radiosonde launching site



Combined NRT vs EUREF Post-Processed solutions – Monthly basis



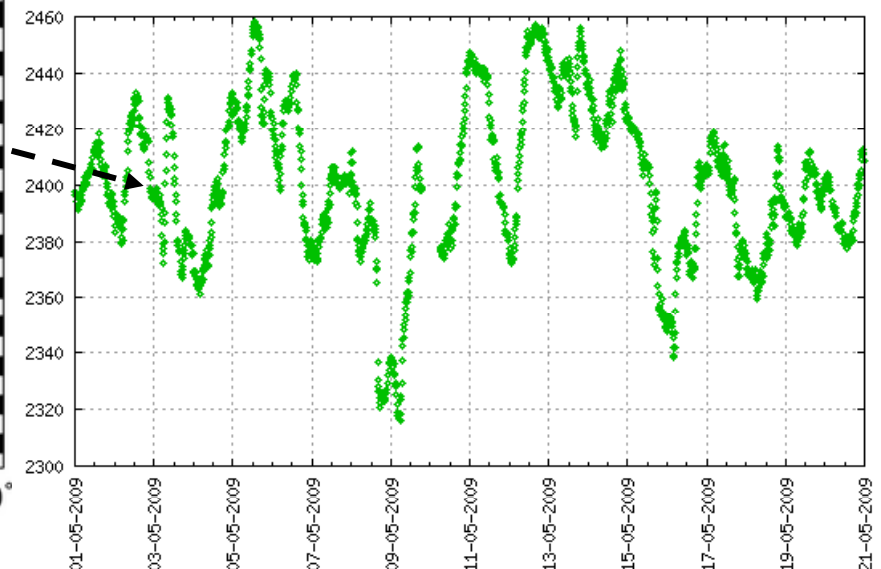
ASI Combined E-GVAP Network



Every hour the contributing solutions are fetched from UKMeto and the ZTD combination performed.

The combination of ~150 sites takes a couple of min.

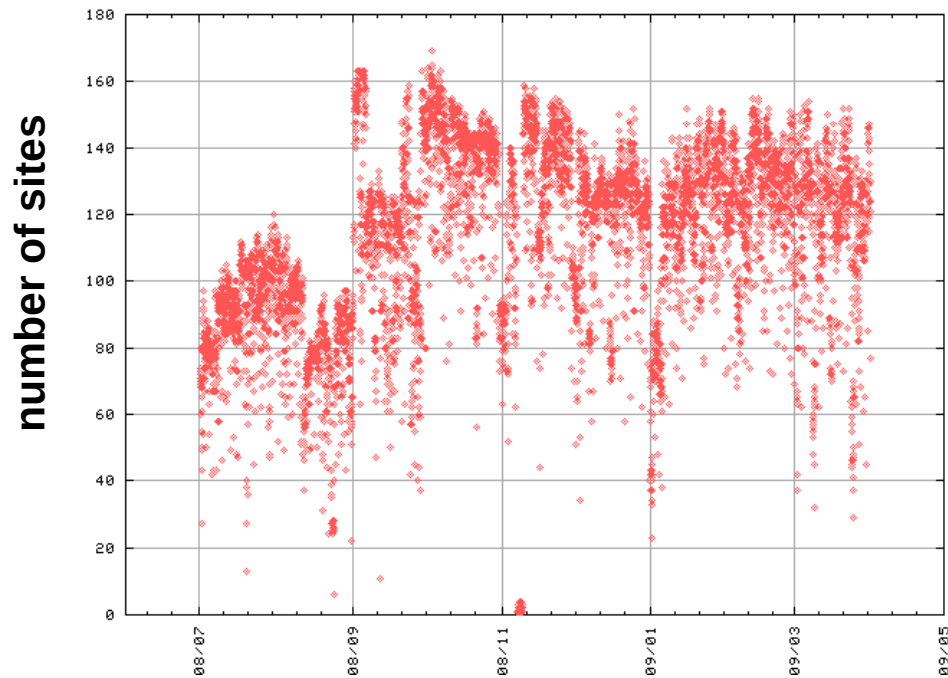
BRUS combined NRT ZTD



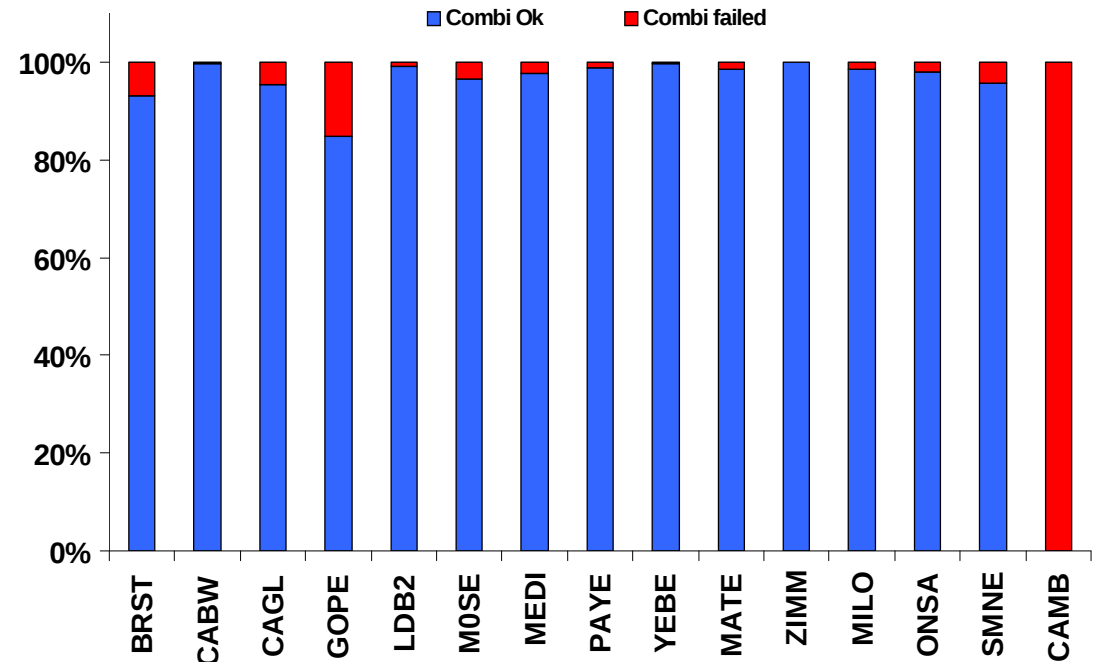
Combined Solution Statistics



From June 2008 to April 2009



March-April 2009

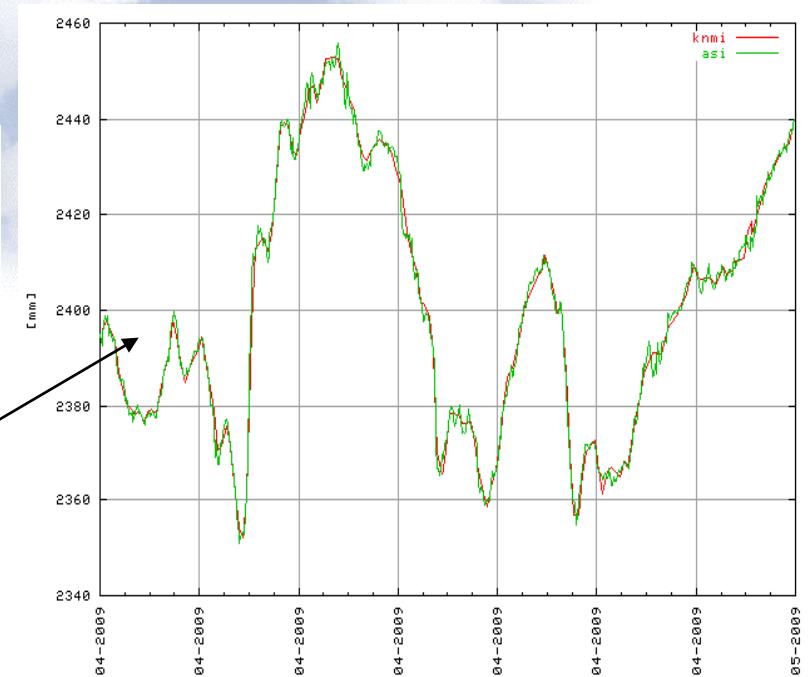
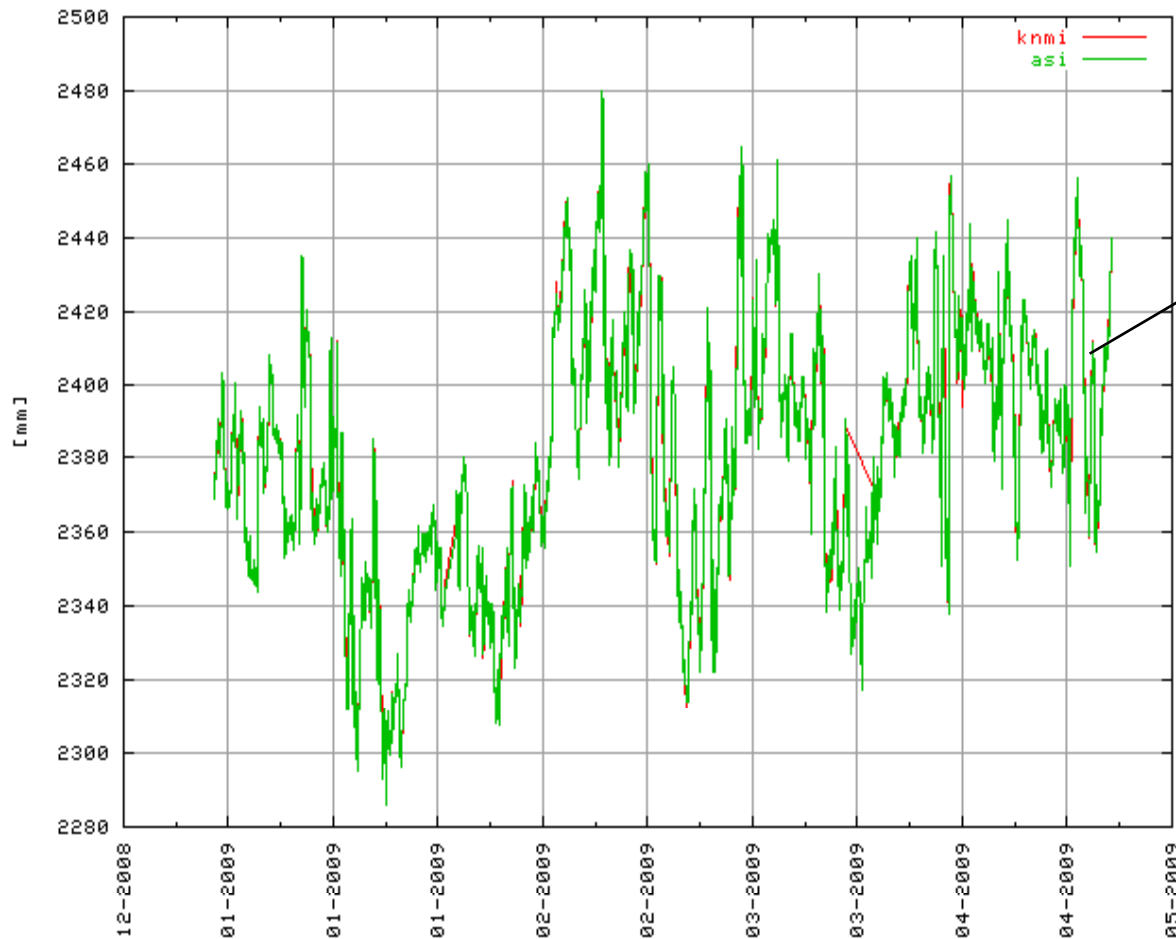


- The combination fails if after the first combination level the ACs get < 3 .
- @ GOPE: 15% of failure mainly due to the lack of contributing solutions.
- No combination @ CAMB (only 1-2 ACs).

ASI and KNMI Combination

Within E-GVAP @KNMI another combination is performed, only on Super Site data, based on the Kalman filtering procedure.

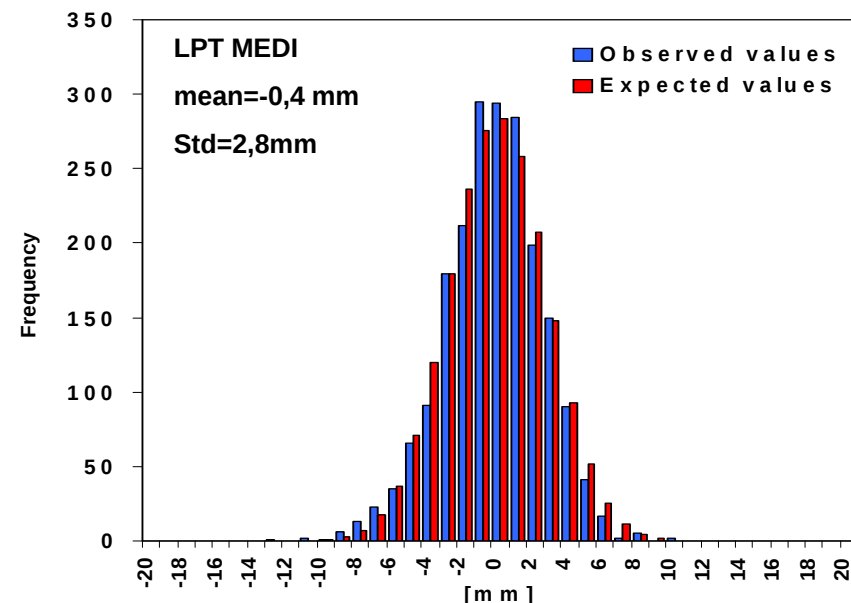
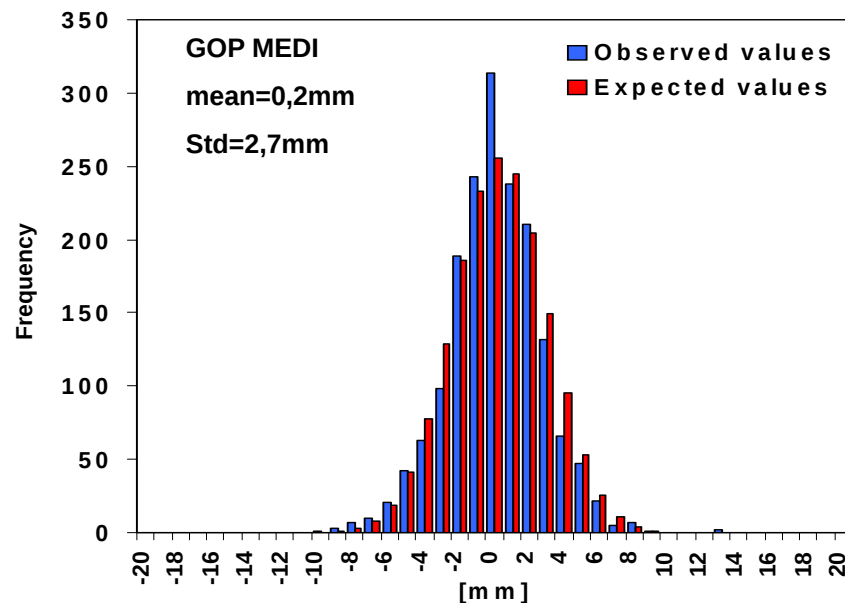
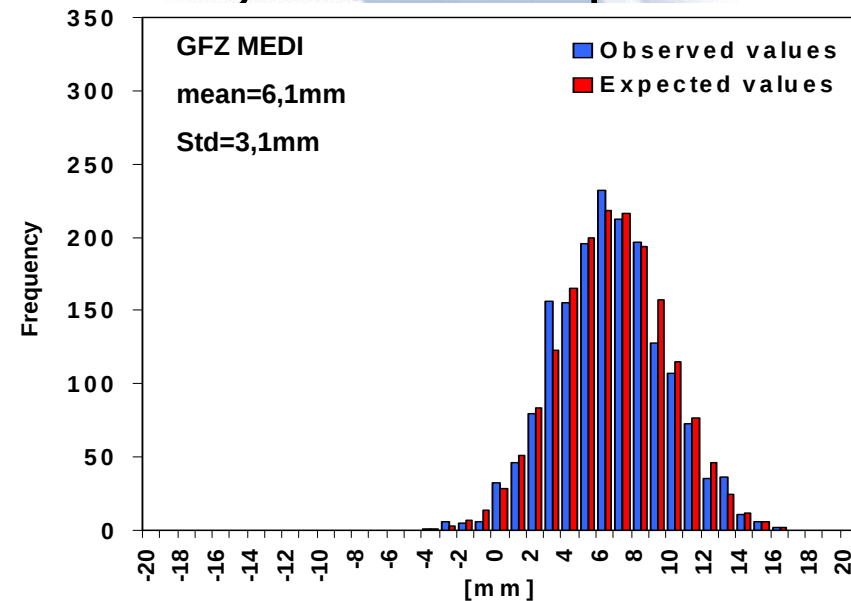
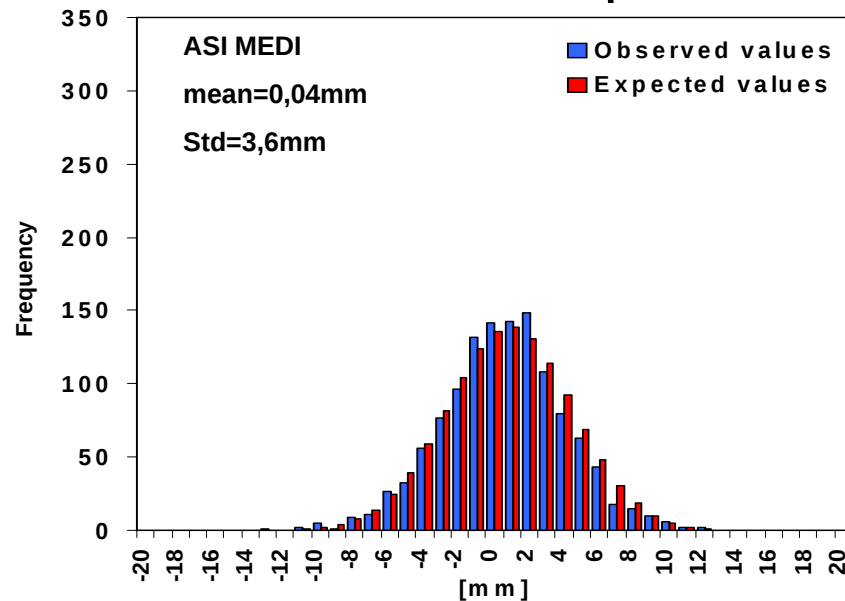
CABW Jan-Apr 2009



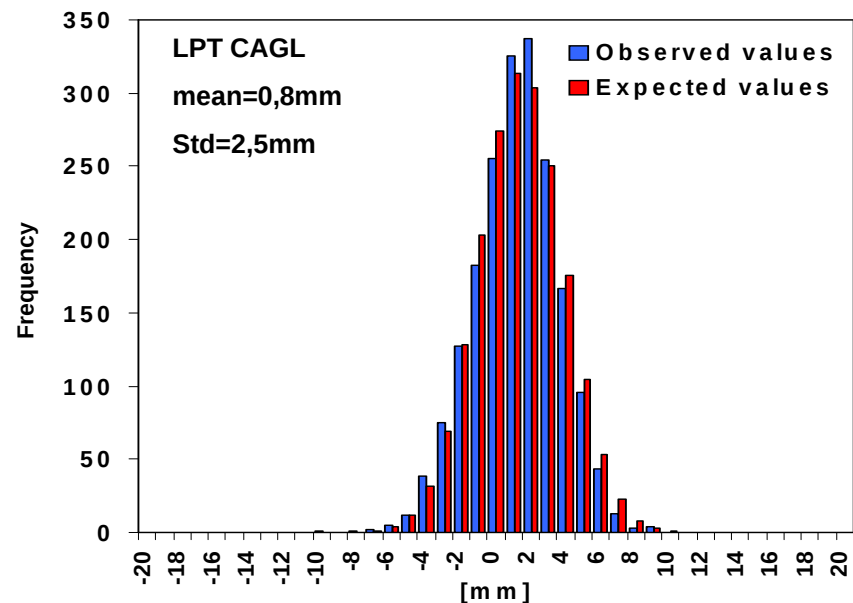
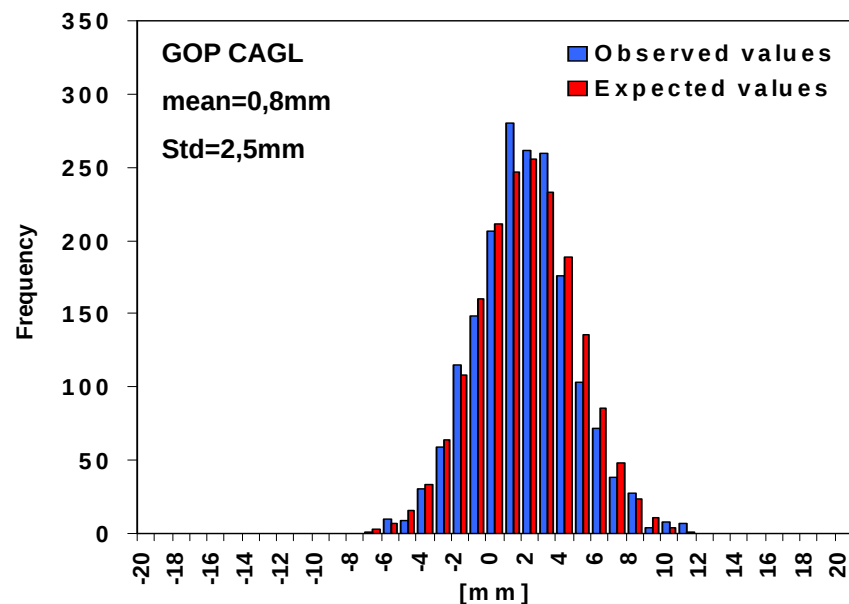
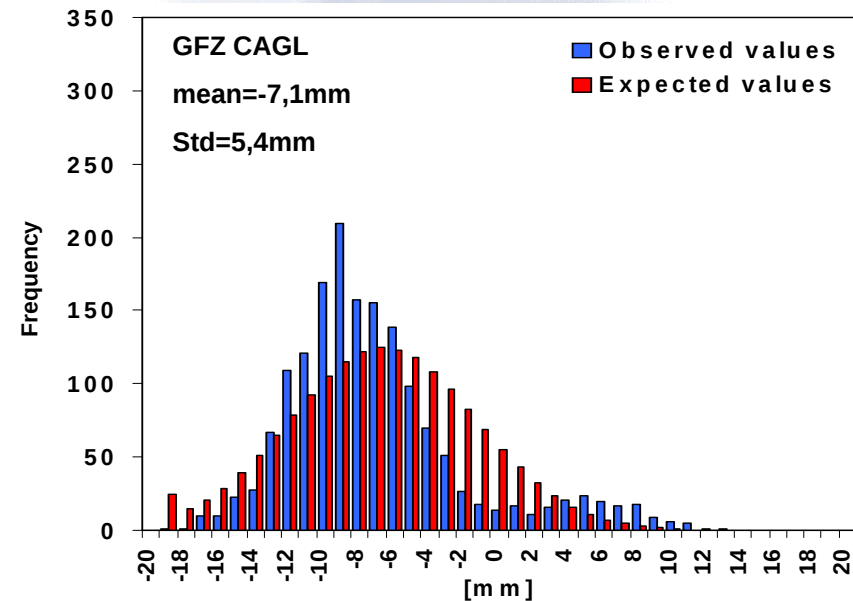
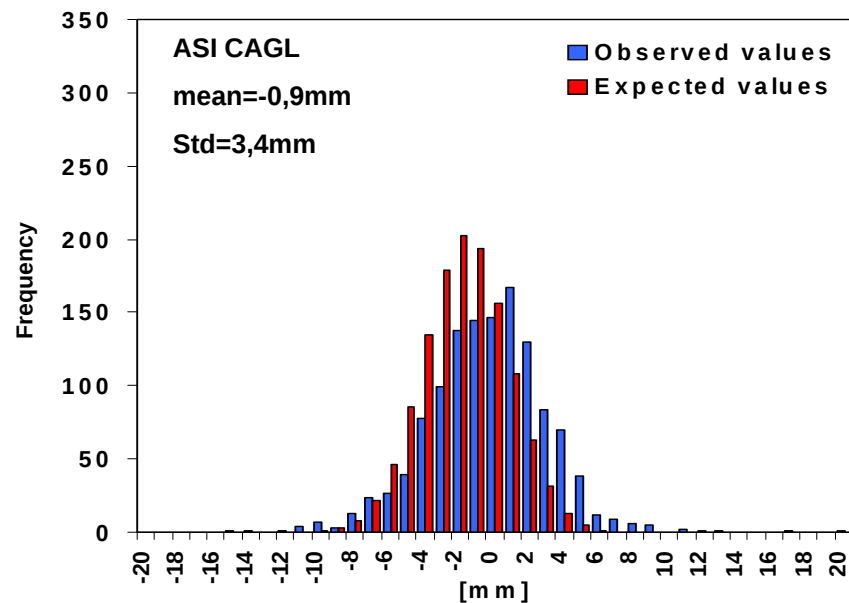
6-day zoom

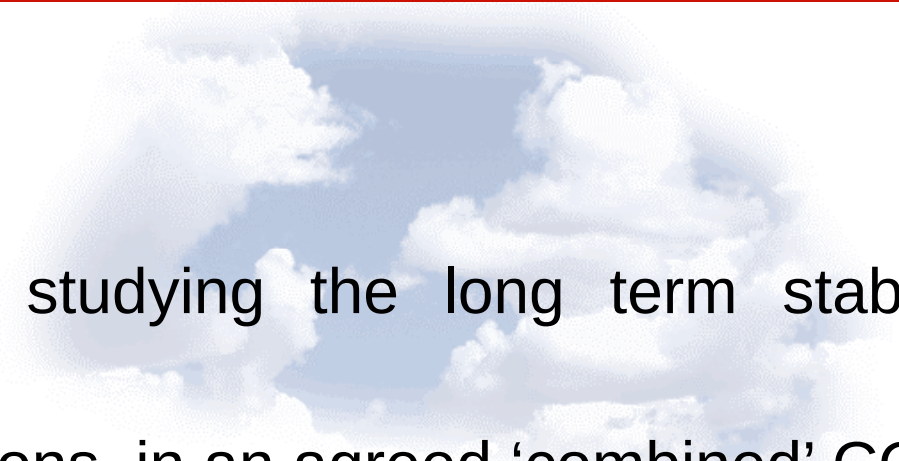
We thanks S. de Haan for providing KNMI 'combined' ZTDs at CABW

The combination method provides site/analysis centre specific bias.



Bias Time Series - CAGL



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- A large, semi-transparent image of a blue sky with white, fluffy clouds serves as a background for the text.
- To continue the validation for studying the long term stability. HIRLAM data will be considered.
 - To send the combined ZTD solutions, in an agreed 'combined' COST format, to the E-GVAP database. These solutions could be useful for checking and monitoring the contributing NRT ZTD data from the individual ACs.
 - To combine GPS and VLBI retrieved atmospheric parameters.
 - To make ZTD maps over Europe.

- We describe a **method for combining NRT GPS derived ZTDs** applied routinely to the solutions delivered within E-GVAP and how it is used for detecting problems in data processing.
- The **validation w.r.t. radiosonde** observations over 9-month dataset shows that GPS is now 'too dry'. It was vice versa when relative PCVs were applied.
- The **intra-technique validation** (GPS combined NRT and GPS EUREF combined Post-Processed) shows a small (2-4mm) but visible for all the stations bias.
- The combination of ~150 sites takes a couple of min. The only limitation is that at least **three different solutions** should be available for the combination.

Acknowledgments

We acknowledge all E-GVAP analysis centres.