

The latest GOP upgrades for troposphere monitoring with GNSS

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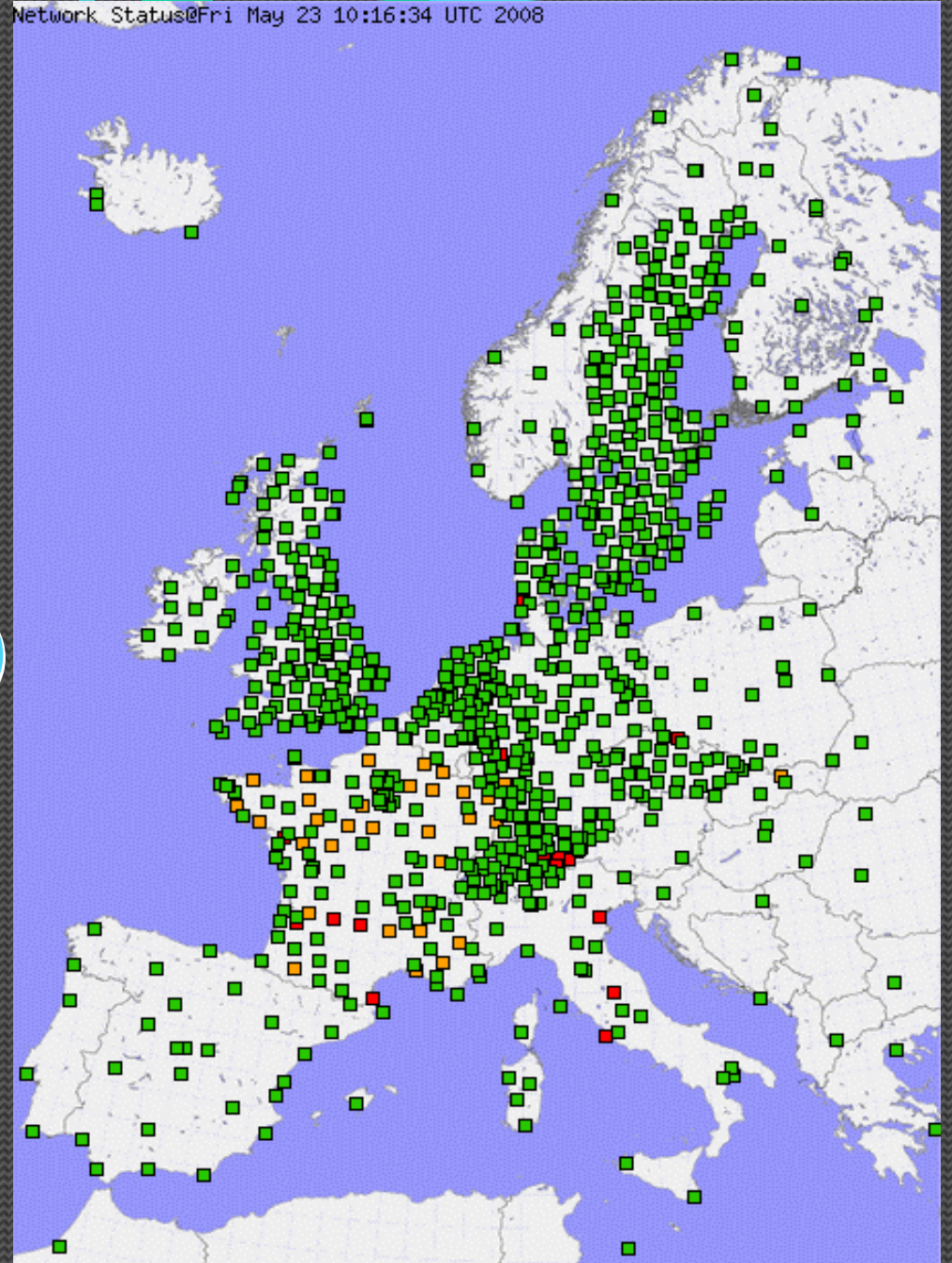


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 - multi-GNSS near real-time processing
 - global near real-time ZTD estimation
 - combination of regional/global ZTDs in NRT
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 - all available ZTD products compared

Introduction

- **GPS-meteorology (1998-...)**
(finished, MAGIC, COST-716, TOUGH, E-GVAP)
ongoing E-GVAP-II (2009-2012)
 - The EUMETNET Composite System
 - ~ 1200 stations in Europe
- **ZTD assimilation to NWP (2008-..)**
 - Meteo France
 - Met Office UK
 - ECMWF (?)**+ an interest for global ZTDs**
- **GOP contributes since 2001**
(~ 80 stations)



1999-2009 near real-time ZTD estimation strategy

Processing requirements:

- hourly GNSS data (IGS, EPN, national,...)
- precise orbits (IGS ultra-rapids, ...)

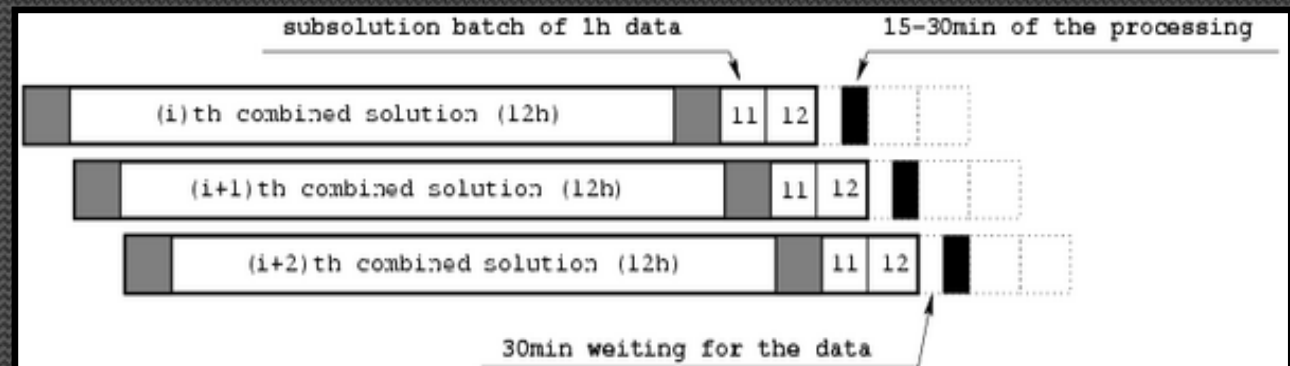
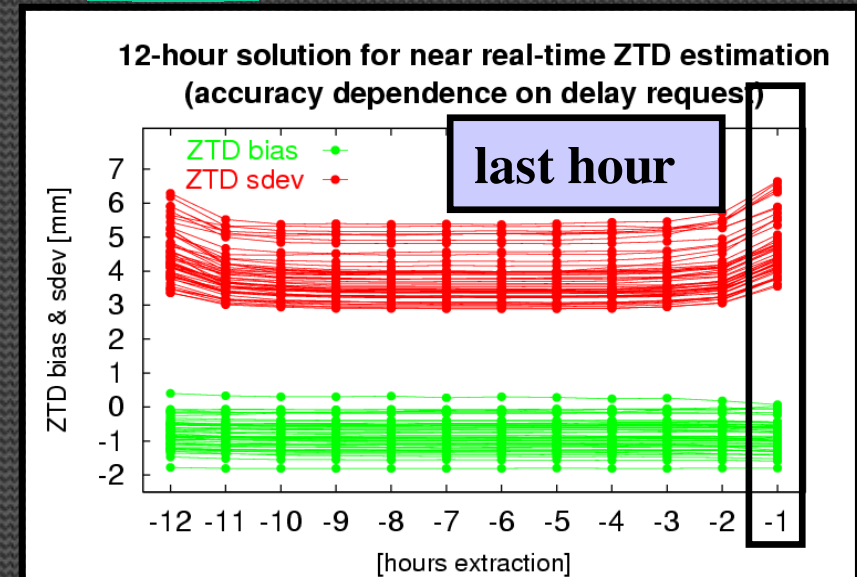
Processing features:

- processed every hour in HH:30
- pre-processing based on two-hours data batches
- hourly and two-hourly normal equations (NEQ) saved
- ZTD solution based on 12 hourly NEQ combination
- NRT coordinate solution based on 28 x 12 two-hourly NEQ combination (IGS05 reference frame)
- processing efficiently distributed in the clusters
- two-hourly ionosphere product for integer ambiguity resolution support

GOP ZTD characteristics:

- ZTD product (HH:00 – HH:59)
- Linear trend is between ZTDs
- ZTD product filtering:

- Sites with less than 4 hours of data in ZTD solution are excluded from the product
- Sites with less than 2 days of data in NRT coordinates solution are excluded from the product



Existing GOP near real-time systems

- **GOP near real-time troposphere**

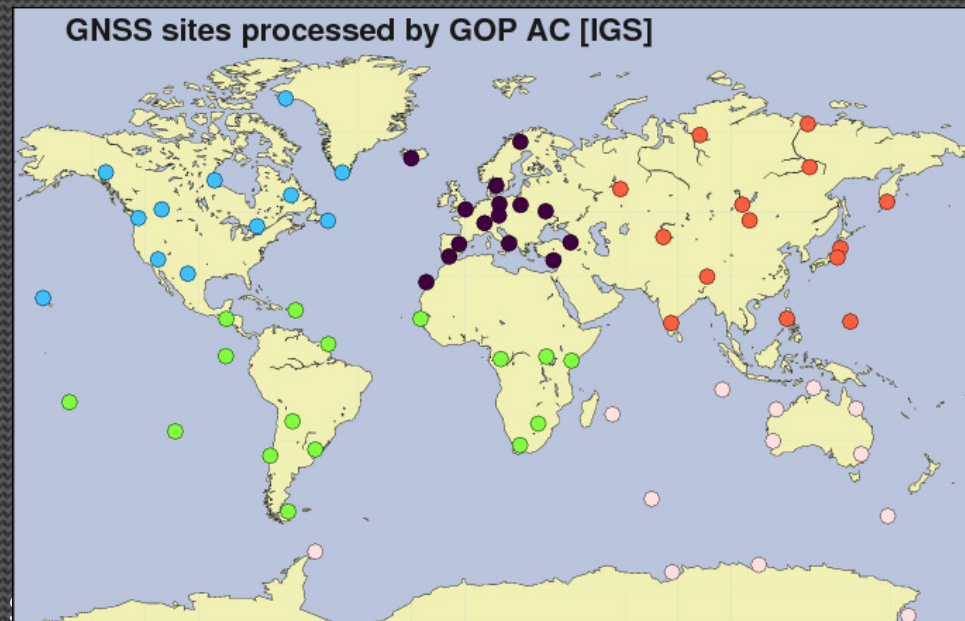
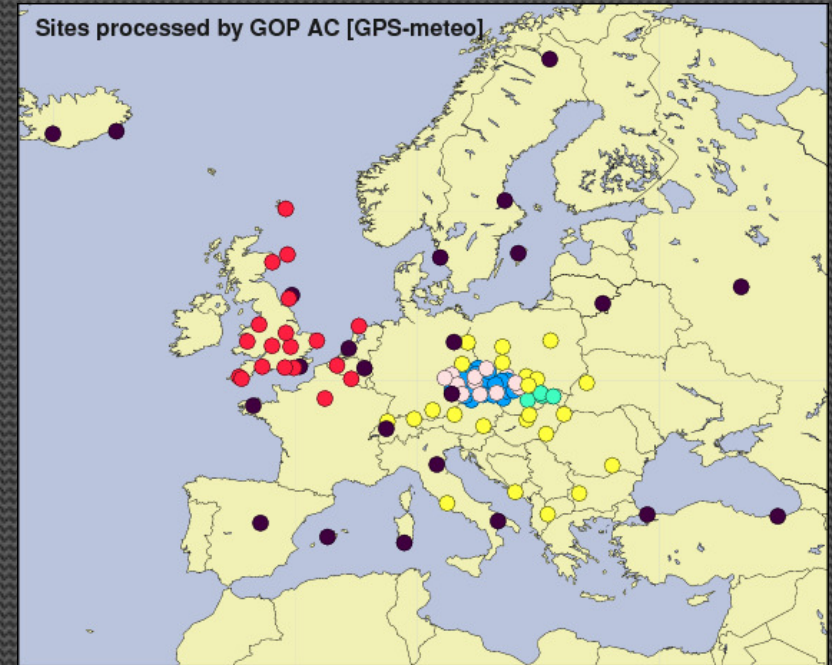
- ~ 80 stations in Europe
 - 1h/2h data batch
 - baselines max 2000 km
 - orbit & ERP fixed, checking the consistency
 - NRT coordinates estimated from last 28 days

- Contributes to E-GVAP-II project**

- **GOP near real-time orbits**

- ~ 80 stations in global distribution
 - 6h data batch
 - more sensitive to data gap problems
 - baselines up to 8000 km
 - redundant baselines
 - global distribution not always optimal
 - orbit & ERP iteratively estimated
 - NRT coordinates estimated

- Contributes to IGS ultra-rapid product**



Upgrades of GOP ZTD routine system

- **general**

- revised strategy based on 4-h sliding window
 - 4/8/12/24h stacking NEQs for troposphere estimation
 - overall processing optimization (troposphere/coordinates)

- **multi-GNSS**

- stand-alone GPS, GLONASS as well as combined GPS+GLONASS
 - simple switch between all by a single option in PCF file

- **global ZTD solution (hourly updated)**

- using fixed IGU orbits
 - NRT coordinates estimation

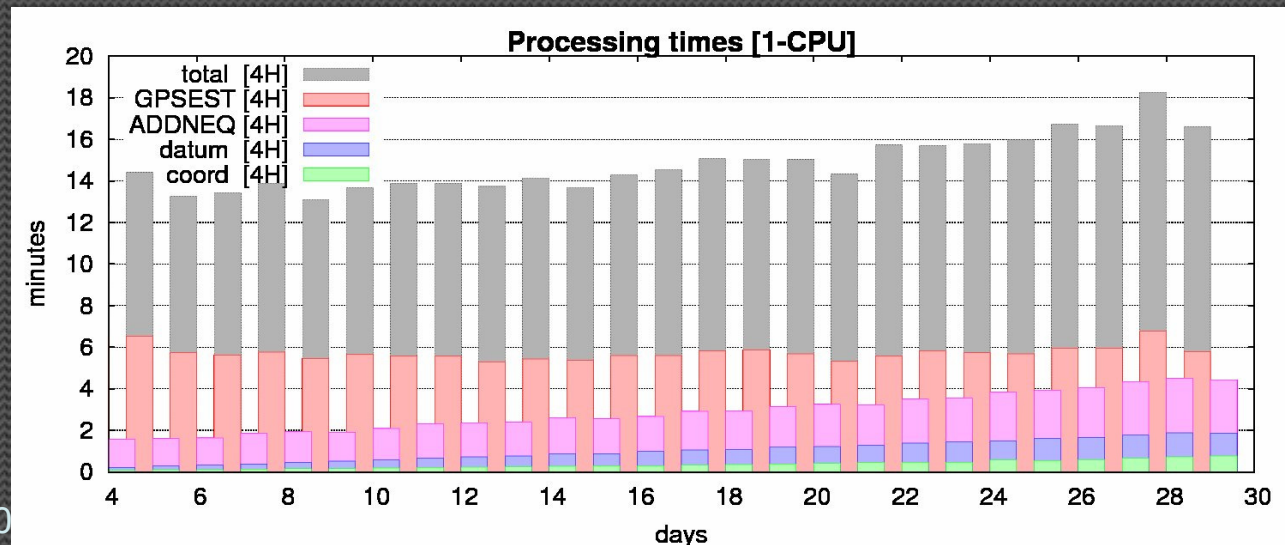
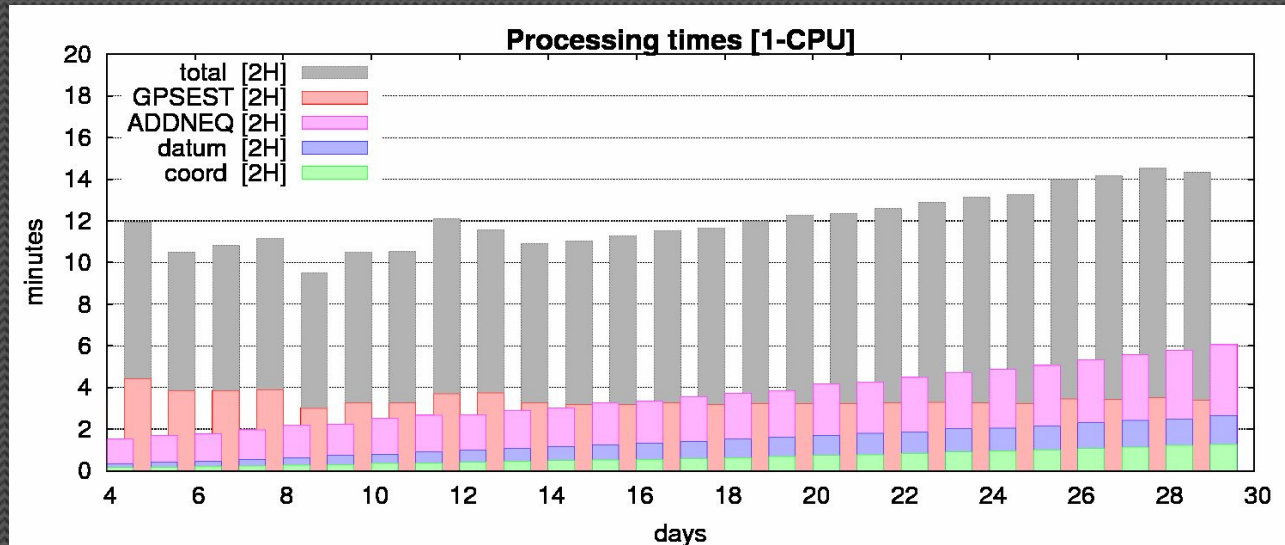
- **combined ZTD solution**

- regional solution
 - global solution
 - combined regional/global solution

NRT : Processing optimization !?

Necessary in near real-time mode,
but also interesting for large projects (EPN-repro)

- **processing scheme**
 - processing window – 1h/4h/...?
- **parallelization modes**
 - overheads x parallel run
 - fitting for available CPUs
 - cluster sizes, e.g.
 - ambiguity resolution
 - residual screening
 - ZTD/CRD estimation
 - etc.
- **program settings**
 - e.g. ADDNEQ2, GPSEST
 - efficient parameterization
 - parameter pre-elimination
- **HW/SW optimization**
 - Bernese compilation
 - routine system scripts
 - hardware
 - (HDD, system, swapping,...)



Flexibility of the GOP processing system

```

honza@janek: /home/honza/work/DB/cpu <2>
F10 key ==> File Edit Search Buffers Windows System Help
PID USER PASSWORD PARAM1 PARAM2 PARAM3 PARAM4 PARAM5 PARAM6 PARAM7 ...
3** 12***** 8***** 8***** 8***** 8***** 8***** 8***** 8***** ...

***
# Check Ref.Datum
#
55 DATUMPRE REF_FIX
56 COMB_CLU I=4R O=4R T=720:4
57 COMB_SEQ I=4R O=R4
58 CHK_REF NEXTJOB 057

***
# Coordinates amb-free/fix solution (24 days cumulated 360 x 4h_NE0s = 720h)
#
373 GPSESTAP _173_ STD:ORB A:FX,FR O:4W,4F W:-4+0 ELV:7
374 GPSEST_P PARALLEL _173_
375 CHK_EST
376 COMB_CLU I=4W O=4W T=720:4
377 COMB_SEQ I=4W O=W4
378 COMB_CLU I=4F O=4F T=720:4
379 COMB_SEQ I=4F O=F4

***
# Troposphere estimation for amb-free/fix
#
390 GPSTRPAP _390_ STD:ORB A:FX,FR O:OX,OW W:-4+0 C:W4
391 GPSTRP_P PARALLEL _390_
392 CONTINUE
393 COMB_CLU C=W4 I=OW O=OW T=24:4
394 COMB_SEQ C=W4 I=OW O=W0
395 COMB_CLU C=W4 I=OX O=OX T=24:4
396 COMB_SEQ C=W4 I=OX O=X0

***
VARIABLE DESCRIPTION DEFAULT
8***** 40***** 16*****
V_HINT 4
V_ORB A priori information IU
V_STLIST Station list file (+ext) METE0.SIT
***

-----+(Jed 0.99.18U) Emacs: PCF-EXAMPLE (Text) 10/36 3:06pm-----
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New database developments

towards better performance and higher generality

MySQL (2003-2009) → PostgreSQL (2009-...) database

multi-database → single database

data: ZTD, P/ZHD, ZWD/PWV, Tm, Ts, etc.

sources:

- GNSS, radiosonde, DORIS, WVR, NWM, VMF1, synoptic, in-situ, etc.
- grid data x site data applied

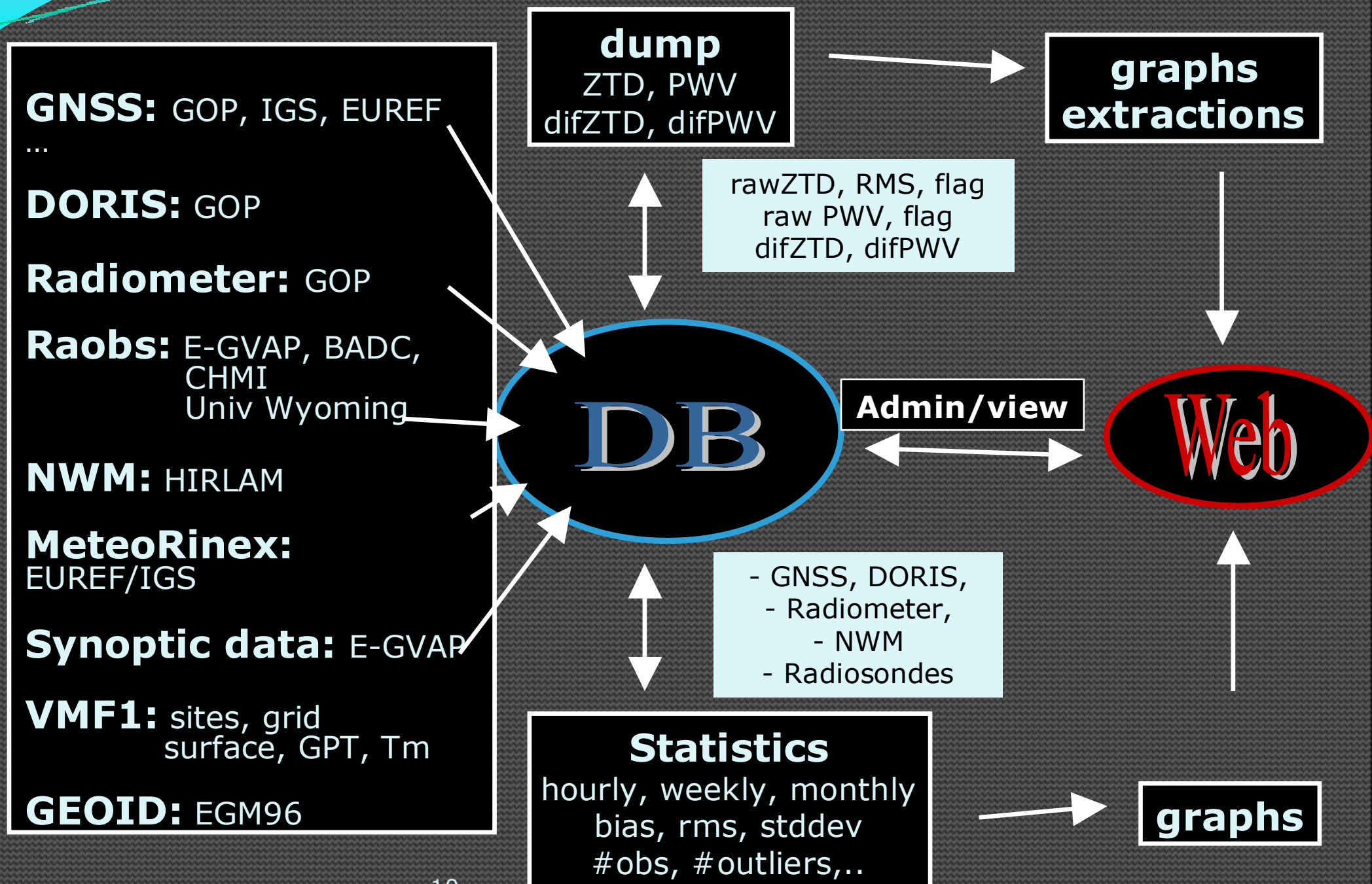
+ georeference information

- Longitude, Latitude, Height(elipsoid), Height(surface), geoid undulation

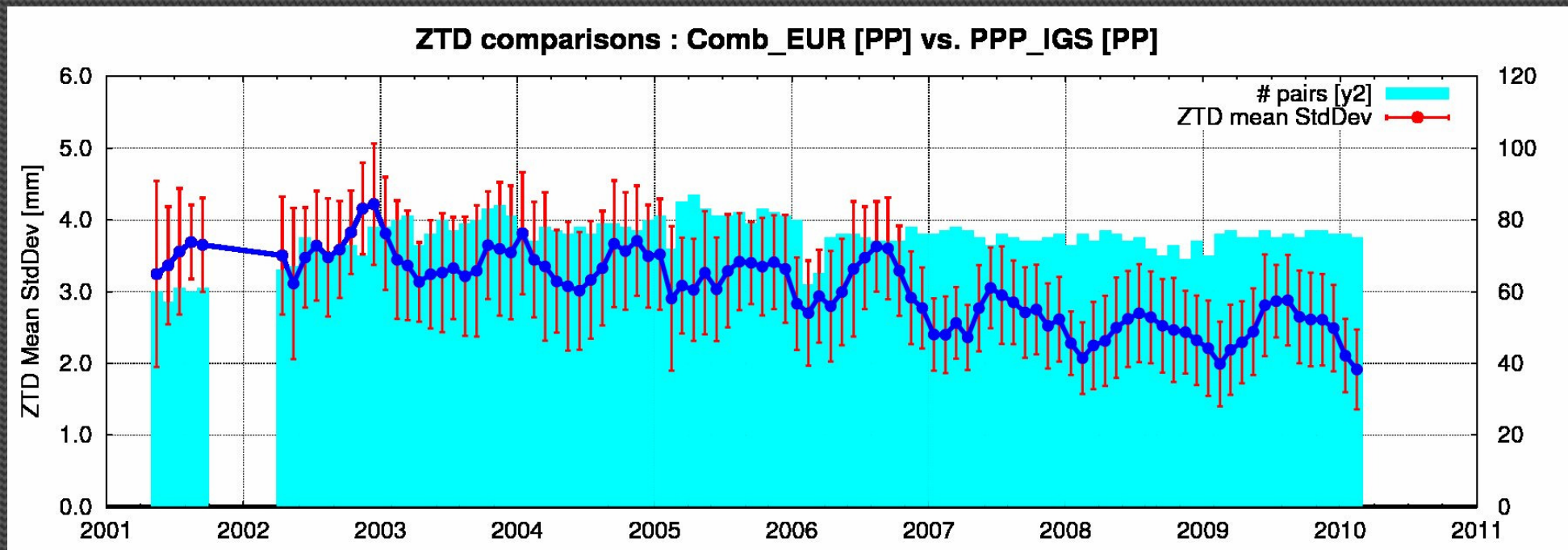
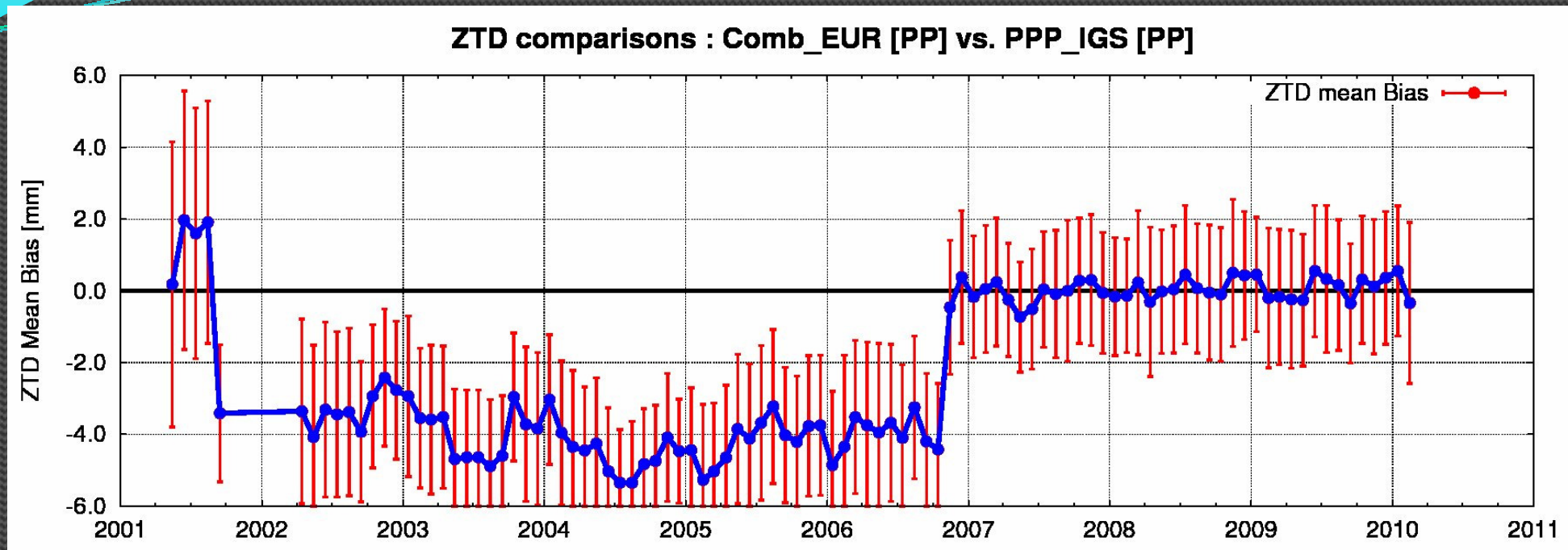
+ methods

- spatial interpolation, ..
- temporal interpolation, ..
- conversions, reductions, ..
- comparisons, search available pairs
- data statistics, extractions, plots, ..

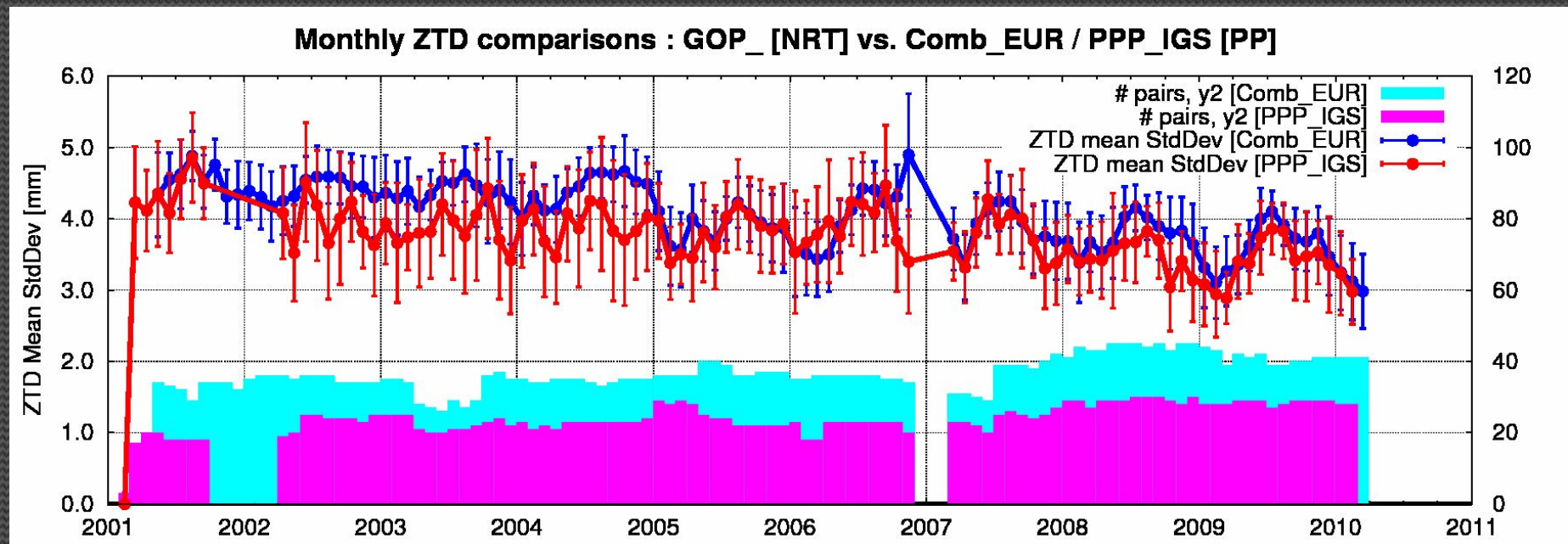
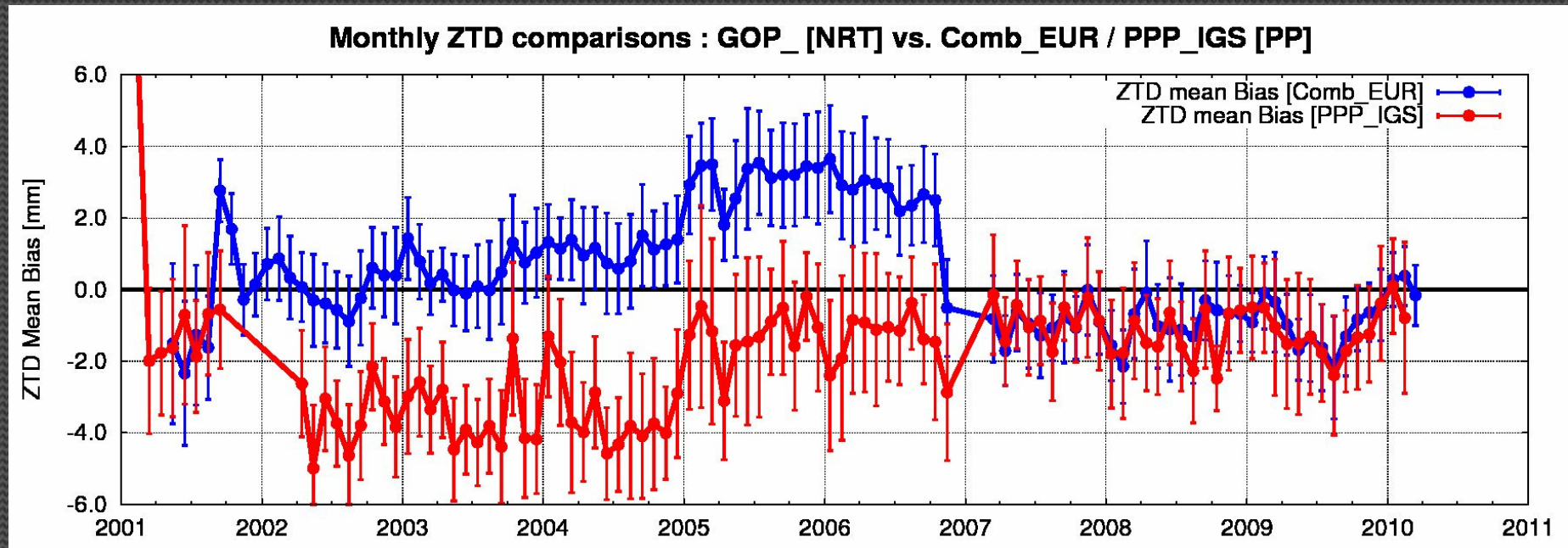
Database for troposphere evaluation



ZTD comparison : Comb-EUR x PPP-IGS

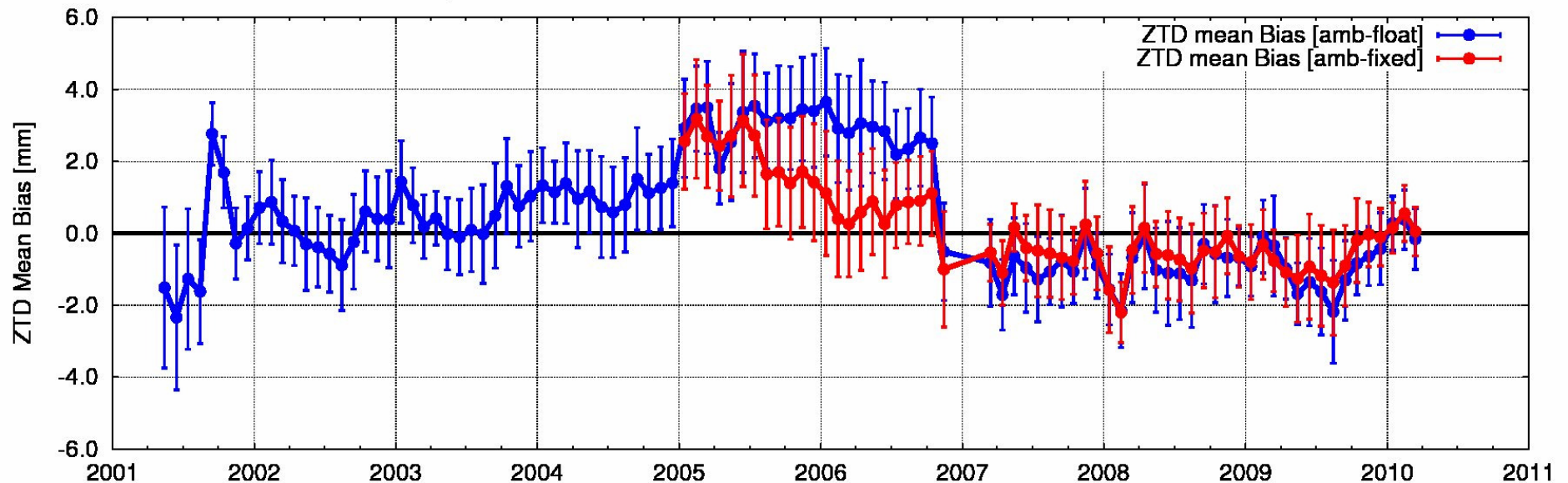


ZTD: NRT GOP x PPP-IGS / Comb-EUR

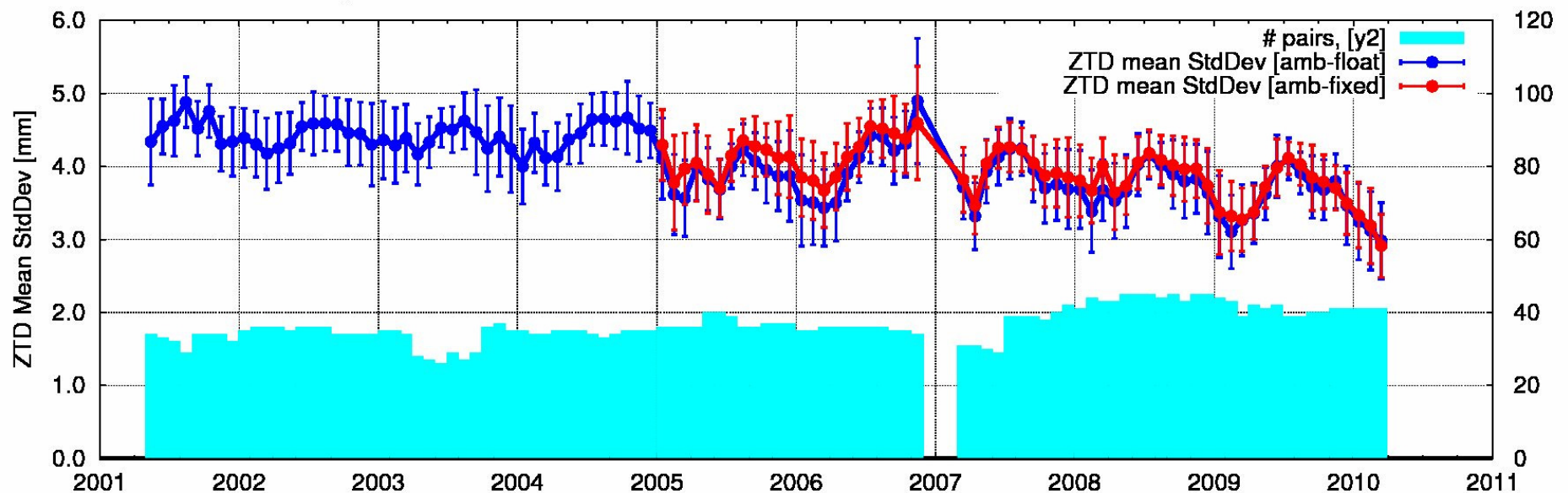


ZTD: NRT GOP x PPP-IGS / Comb-EUR

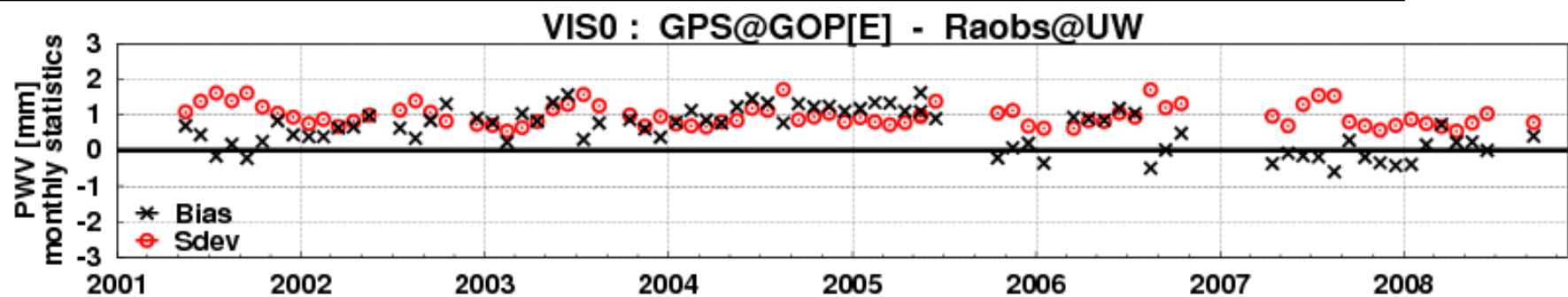
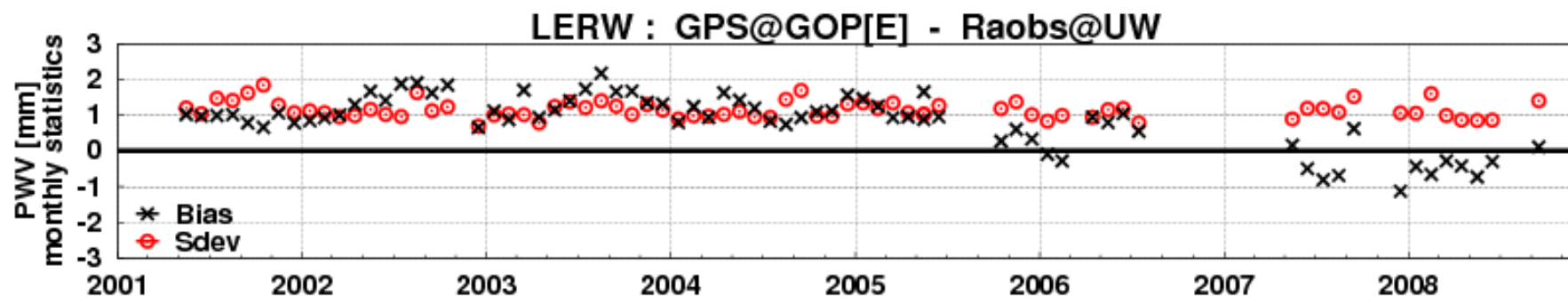
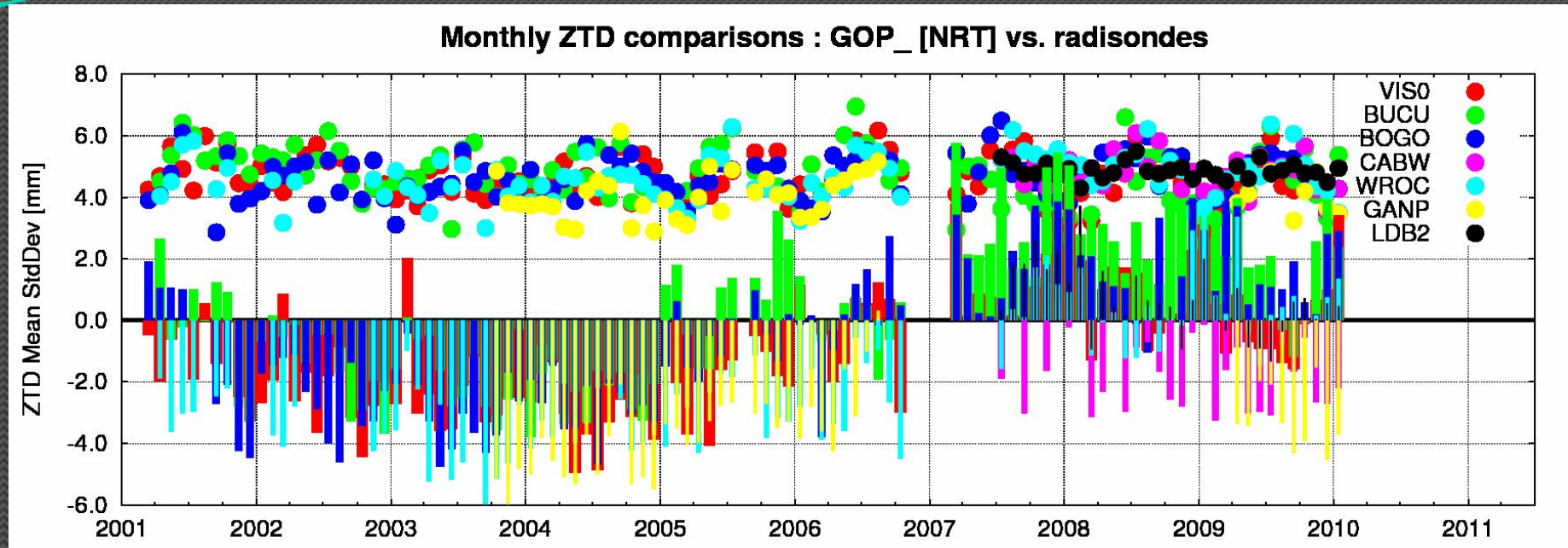
Monthly ZTD comparisons : GOP_/GOPX [NRT] vs. Comb_EUR [PP]



Monthly ZTD comparisons : GOP_/GOPX [NRT] vs. Comb_EUR / PPP_IGS [PP]

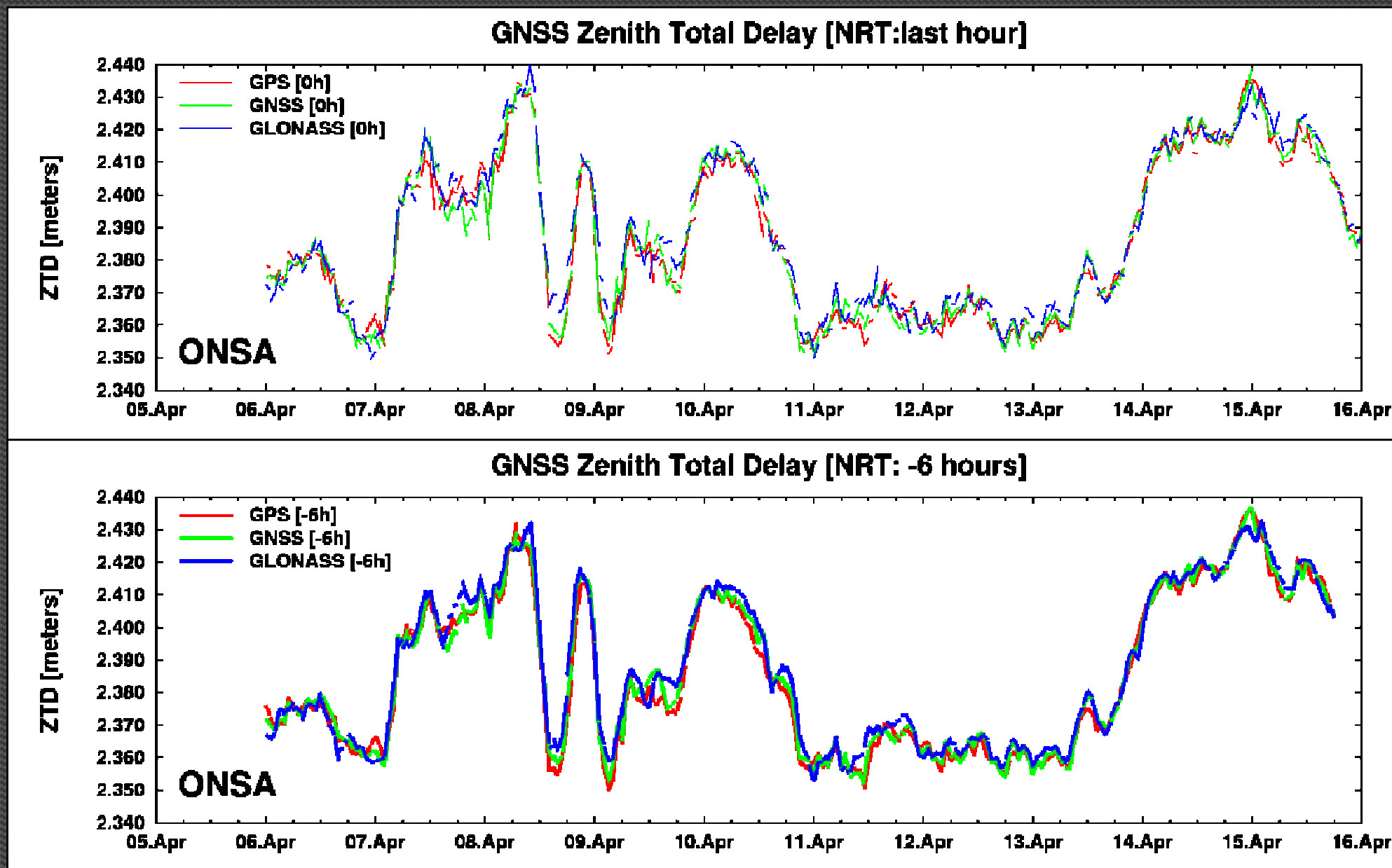


ZTD comparison : GOP x radiosondes

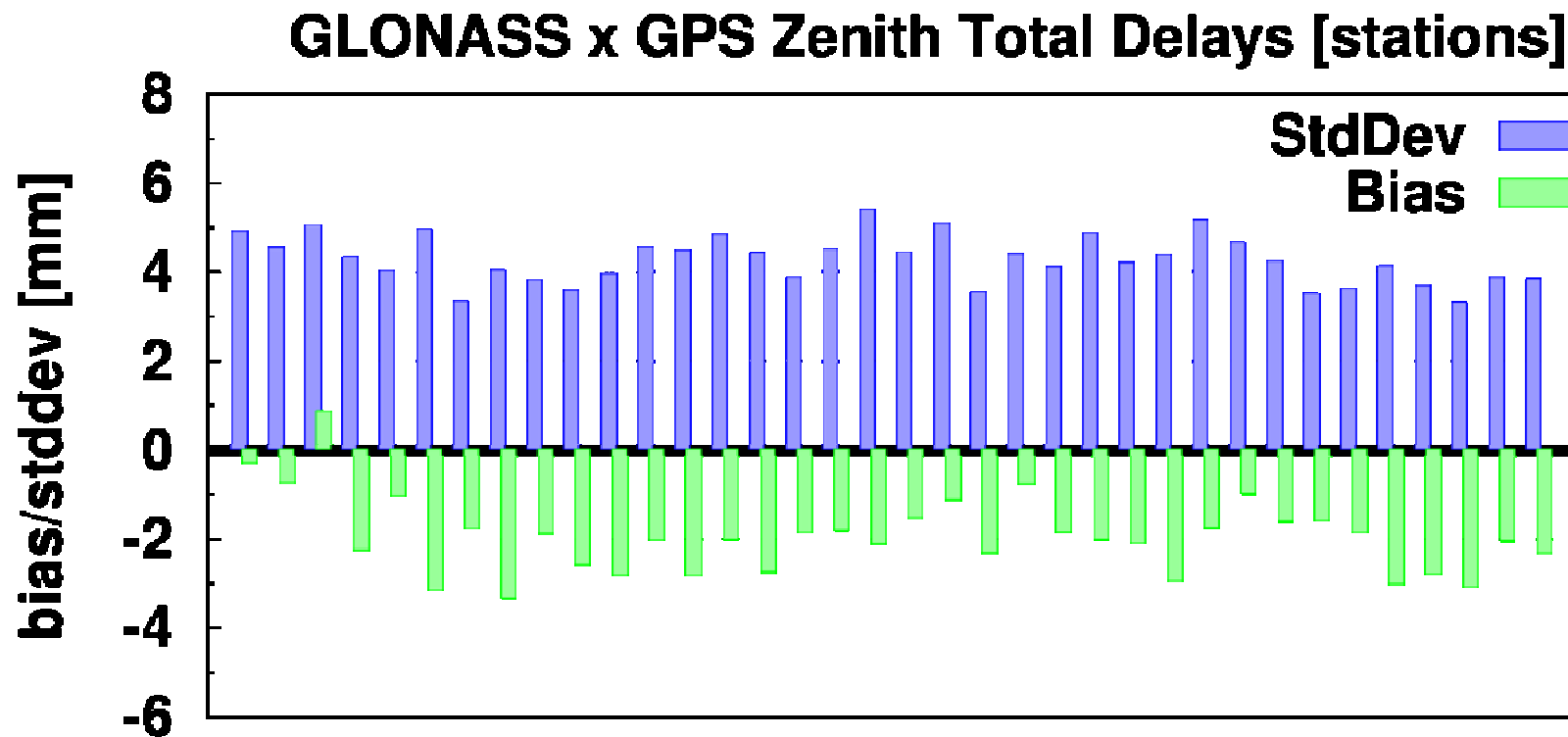
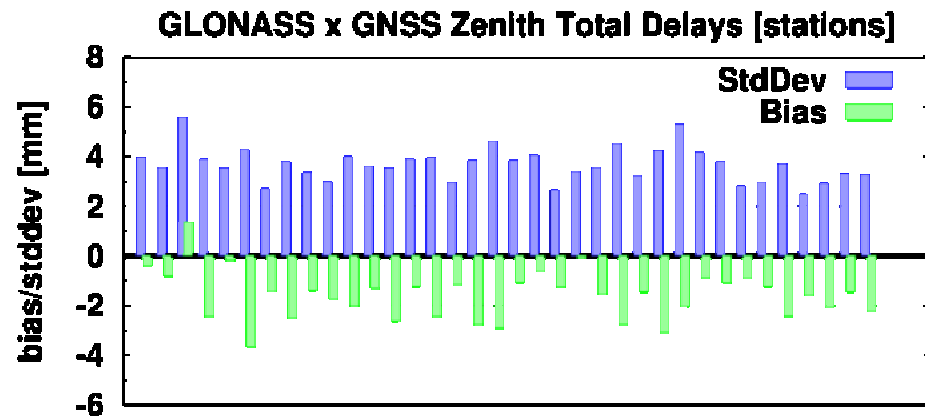
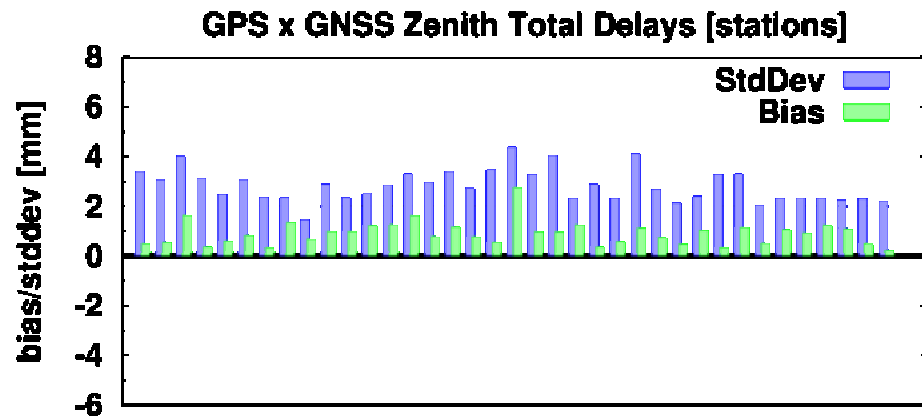


ZTD comparison - GPS, GNSS, GLONASS

ZTD from last hour, -1h, -6h (near real-time) solutions



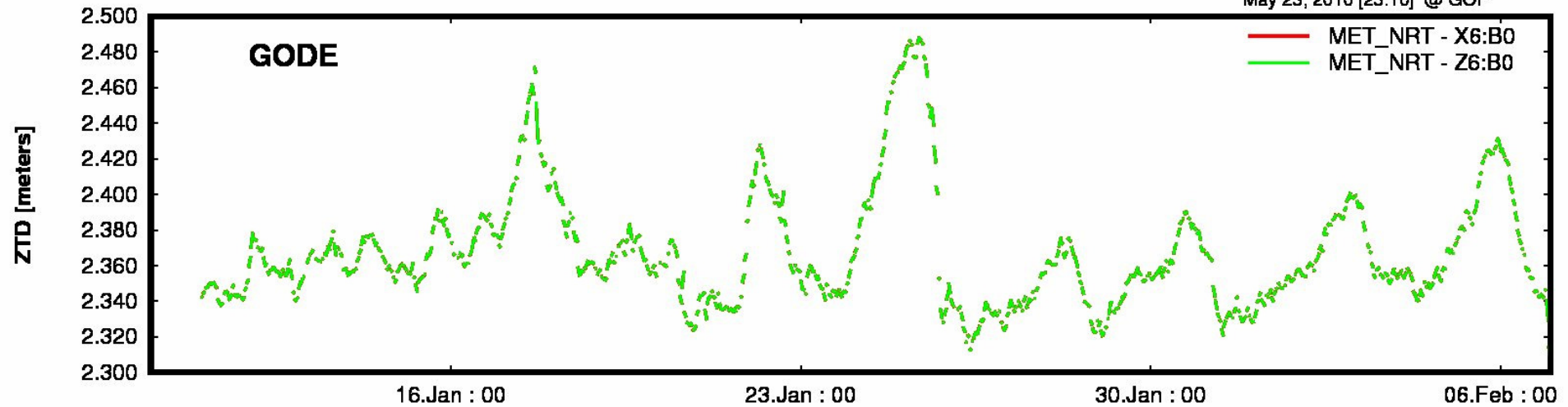
ZTD evaluation GPS x GLONASS



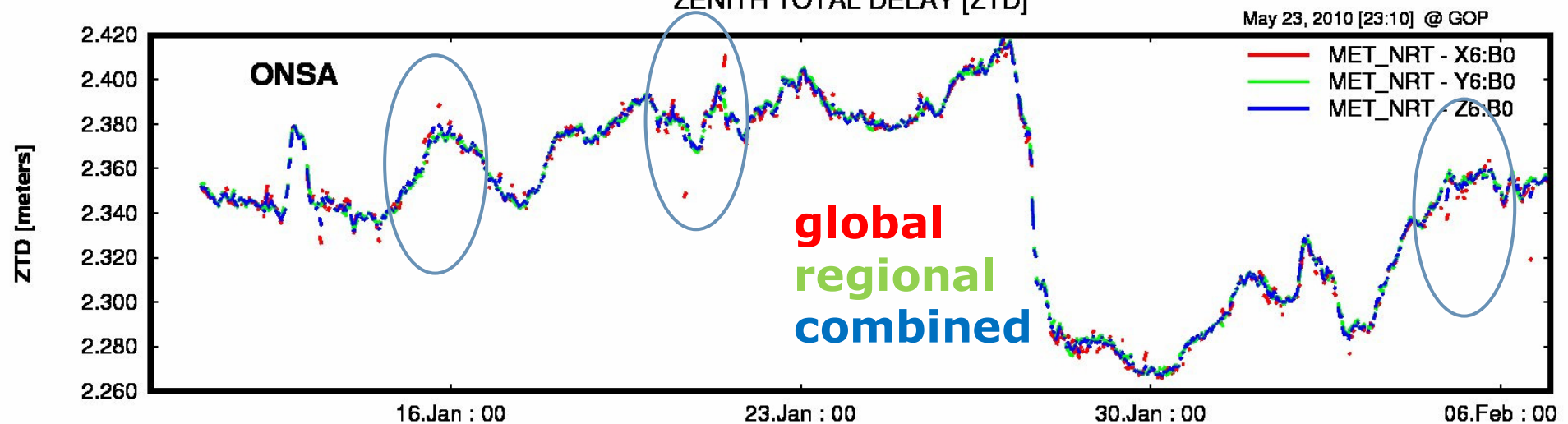
ZTD time-series for global stations

near real-time ZTDs for different stations in North America, Japan, Europe

ZENITH TOTAL DELAY [ZTD]



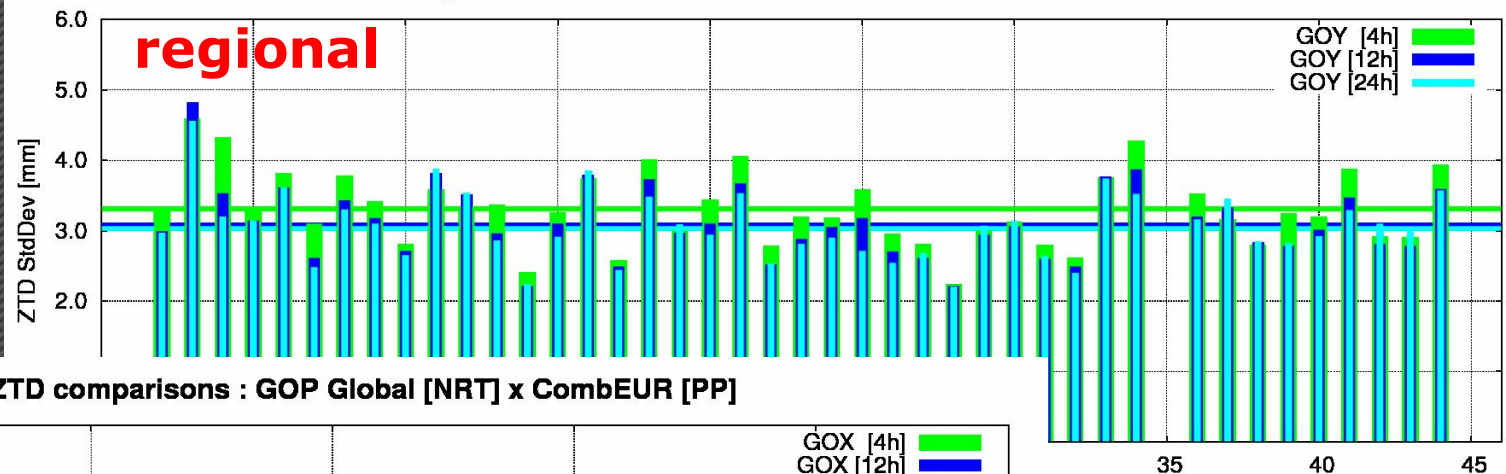
ZENITH TOTAL DELAY [ZTD]



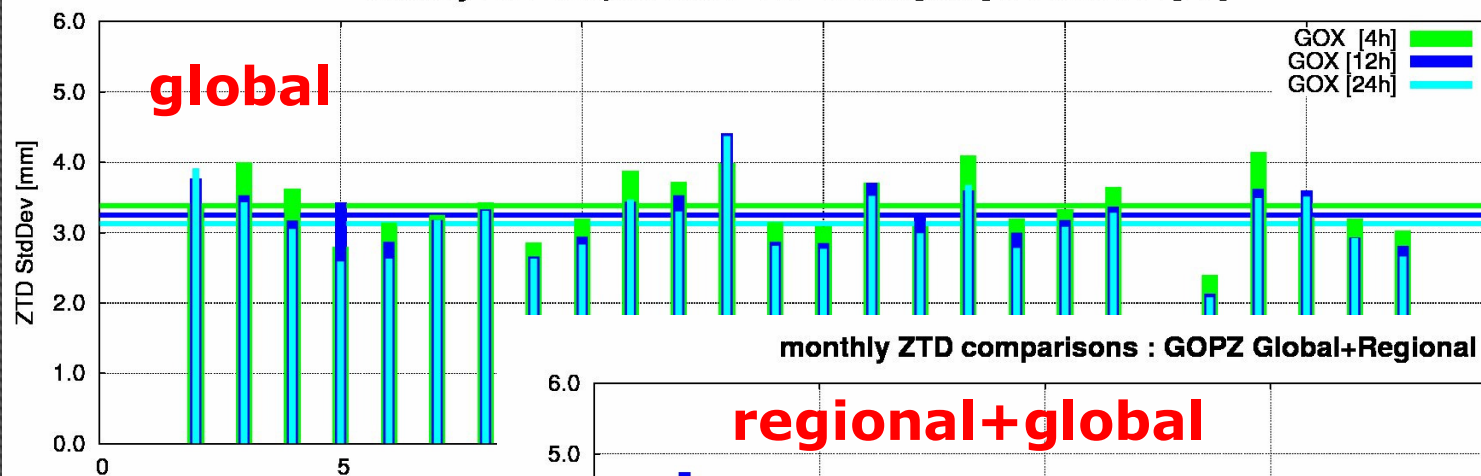
Comparisons of Global/Regional/Combined ZTDs

near real-time ZTDs from combination of last 4 hours, 12 hours and 24 hours

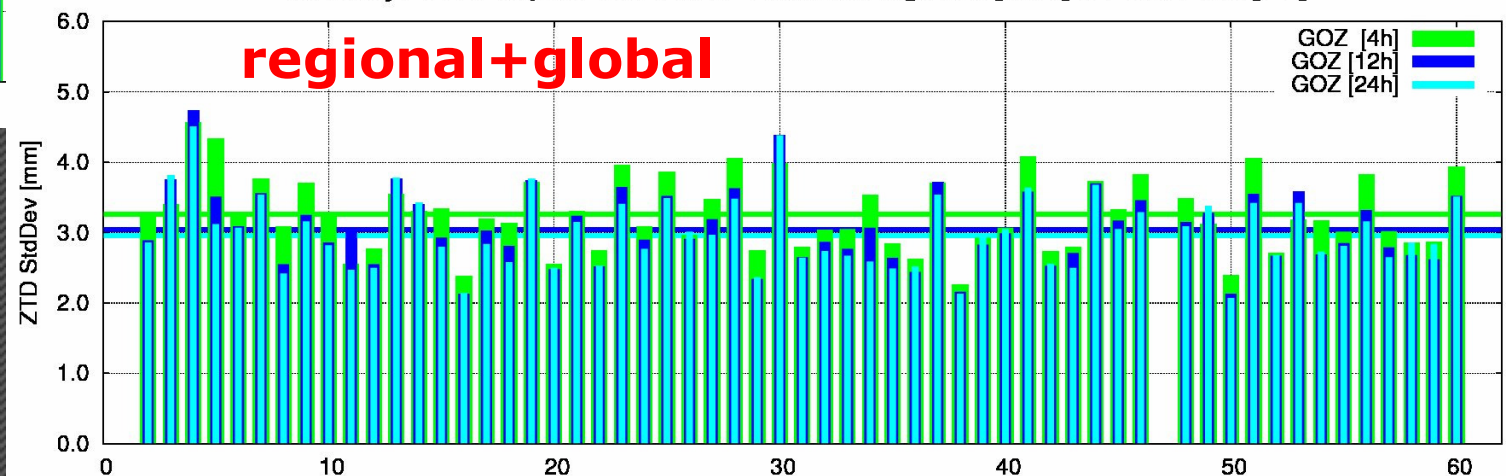
monthly ZTD comparisons : GOP Regional [NRT] x CombeUR [PP]



monthly ZTD comparisons : GOP Global [NRT] x CombeUR [PP]

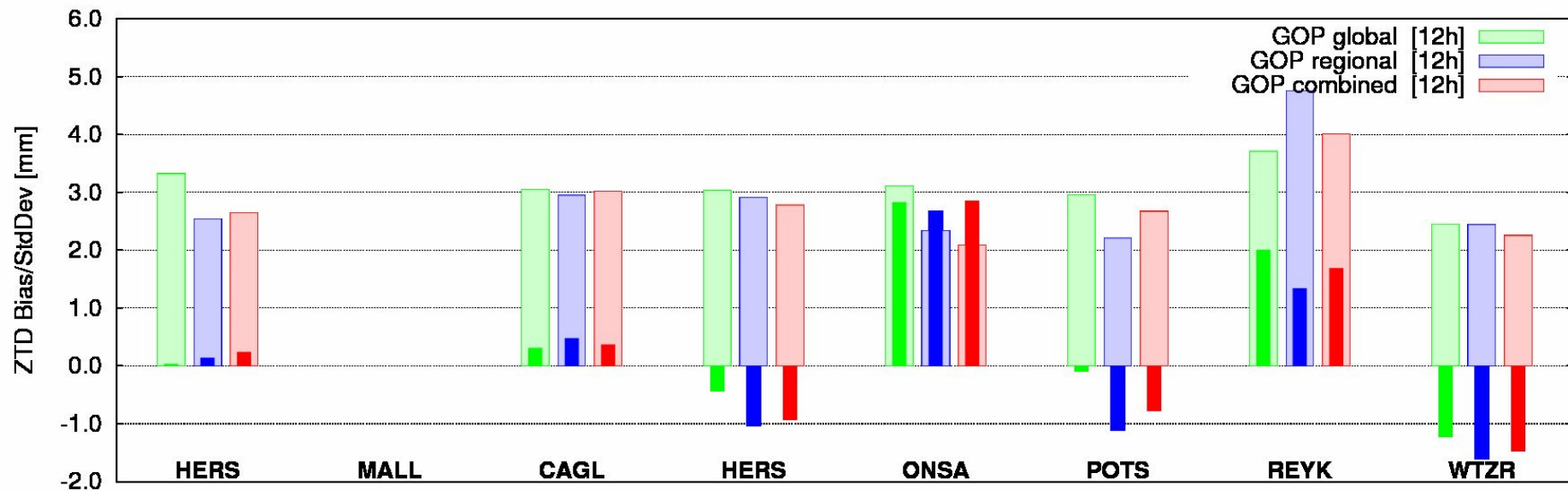


monthly ZTD comparisons : GOPZ Global+Regional [NRT] x CombeUR [PP]

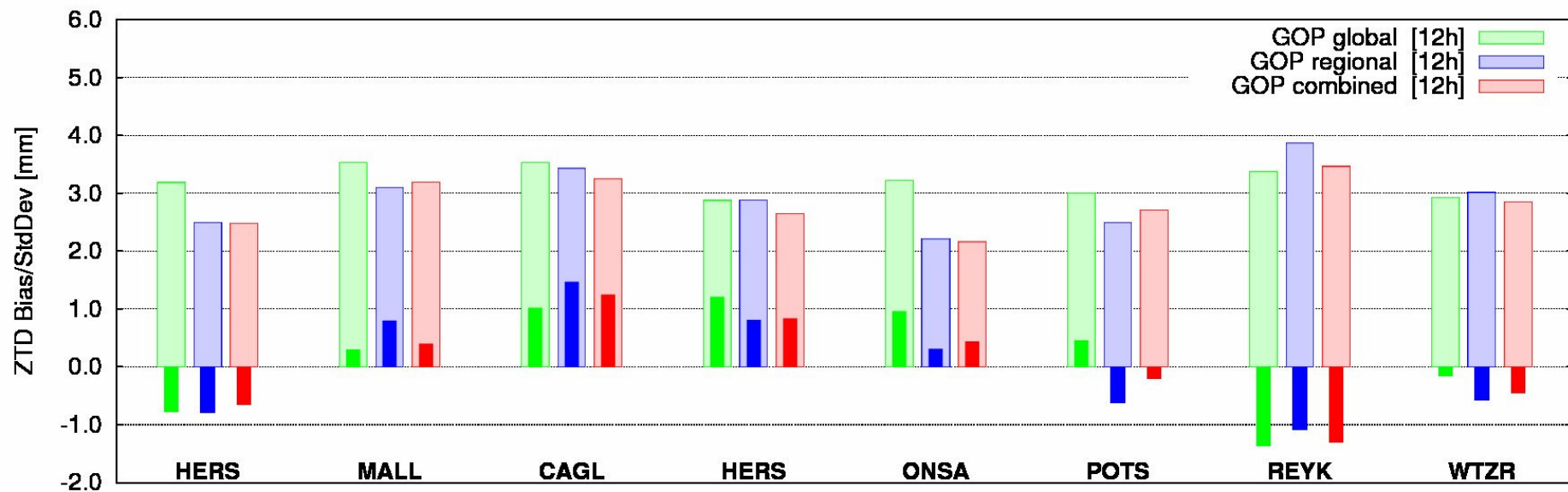


Combination of Global and Regional ZTDs

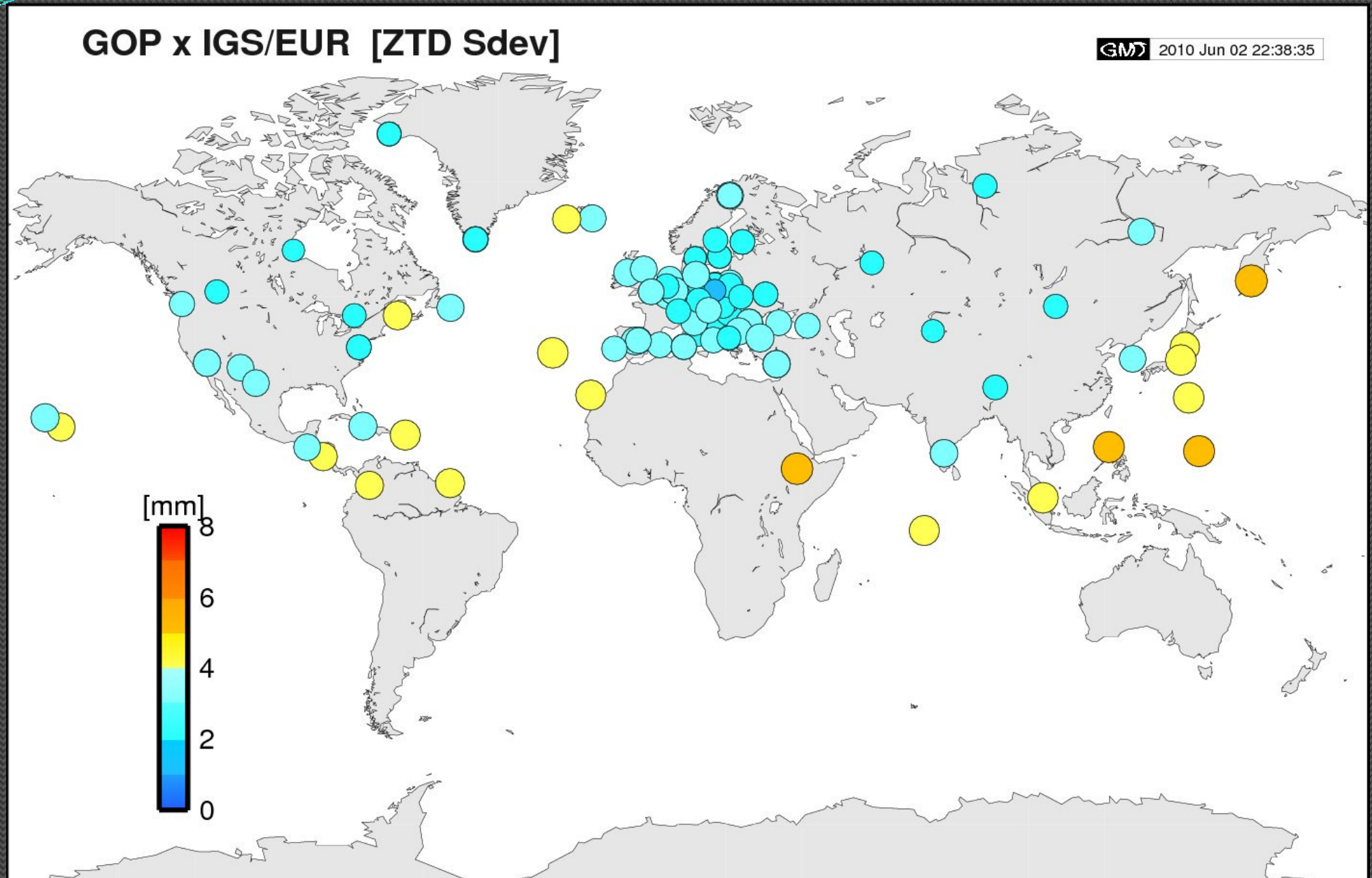
ZTD comparison : global/regional/combined [NRT] x ppp_IGS [PP]



ZTD comparison : global/regional/combined [NRT] x Comb_EUR [PP]



Global and combined ZTDs



Summary

We have revised our near real-time ZTD estimation strategy

- **Stand-alone GPS, GLONASS as well as combined GNSS implemented and processed**
- **Global hourly solution for ZTD implemented**
- **Combination of regional and global ZTD solution available**
- **New database for troposphere evaluation under development**
- **Evaluation of long-term combined EUREF and IGS PPP ZTDs**
- **Evaluation of GOP ZTD and all newly developed products**
- **Our contribution to E-GVAP is ready to be significantly extended**