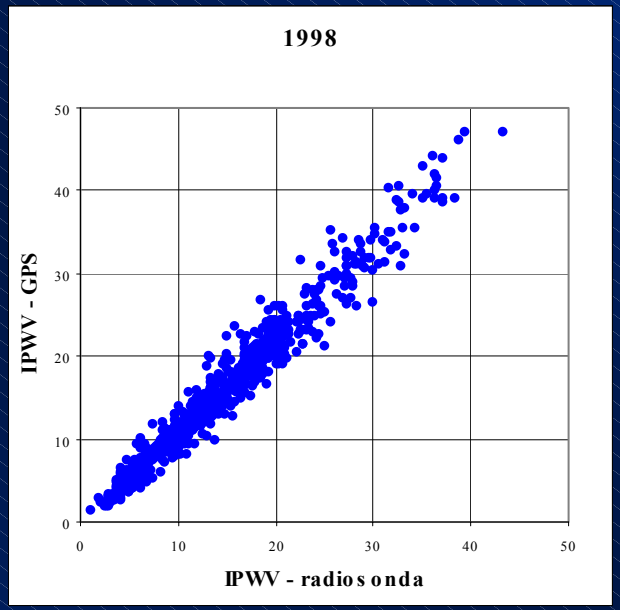
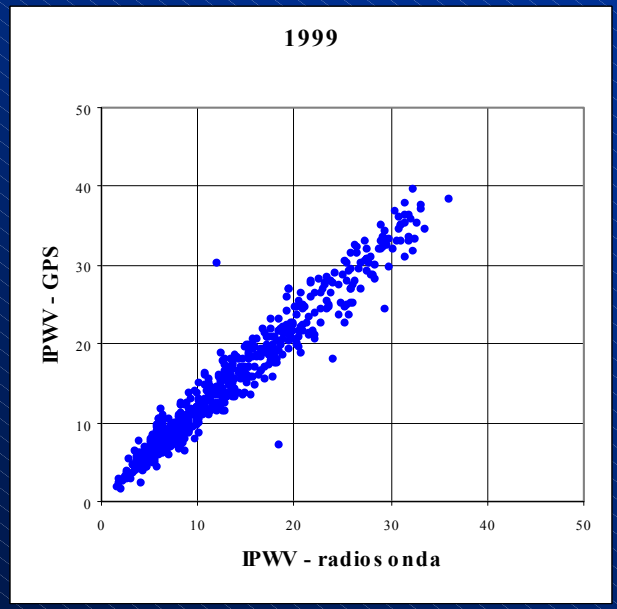
Warsaw Uniwersity of Technology
Institute of Geodesy & Geodetic Astronomy
kruczyk@gik.pw.edu.pl, +4822 660-77-54

Michał Kruczyk, Tomasz Liwosz, Jerzy B. Rogowski

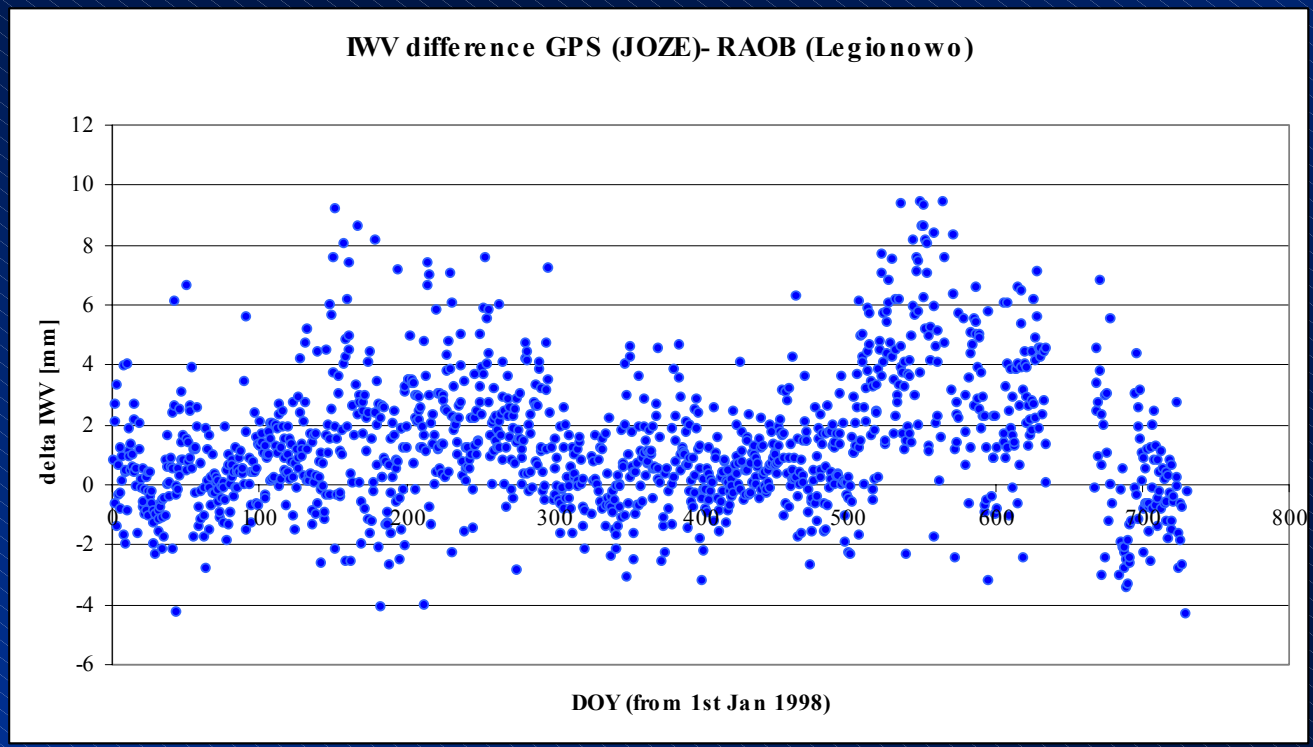
Selected Remarks on GPS Tropospheric Delay Obtaining, Quality, Behavior and Utility

4th EPN Local Analysis Centres Workshop
Graz, 18-19 September 2003



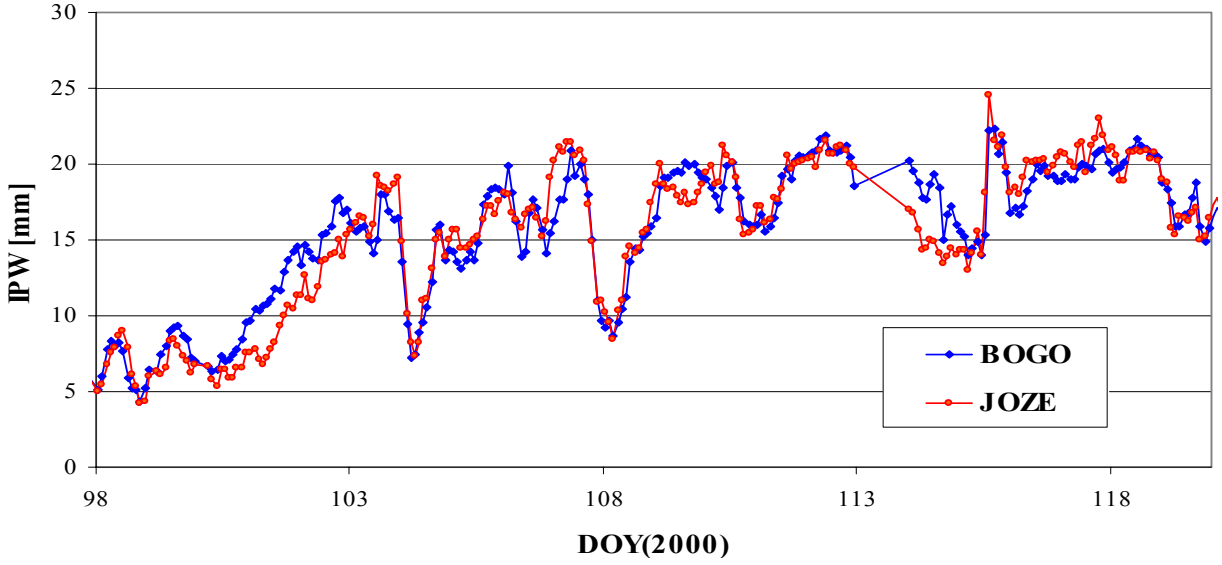


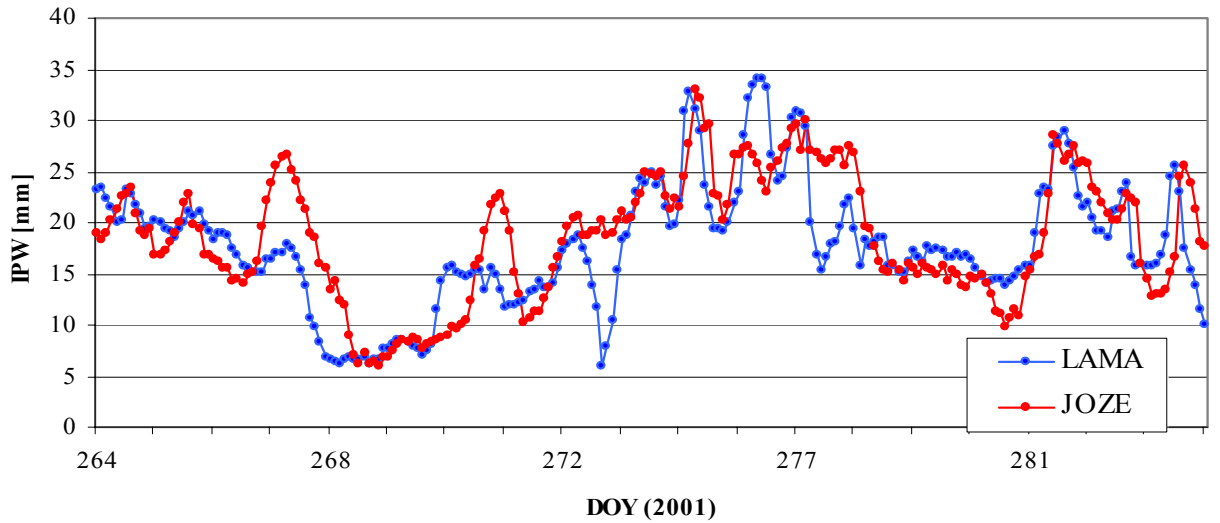
Positive bias IPW from GPS: (dependent on season)



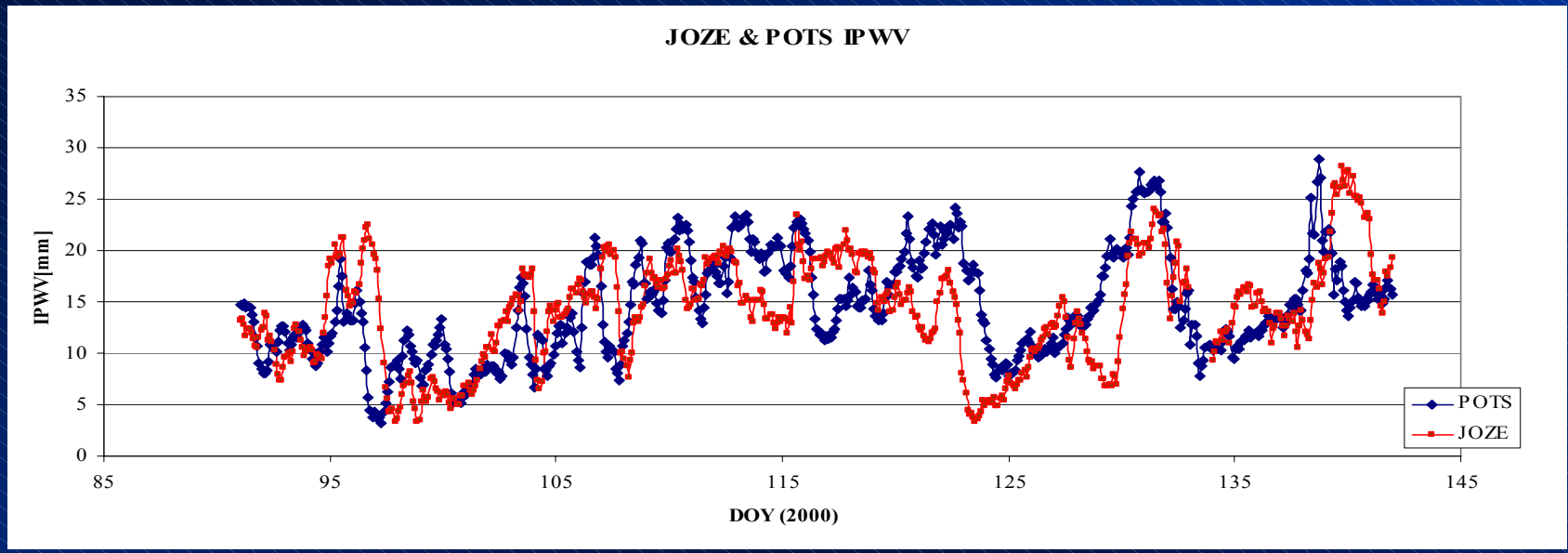
IPW values of two permanent stations show some similarities depending on spatial separation (distance and baseline azimuth)

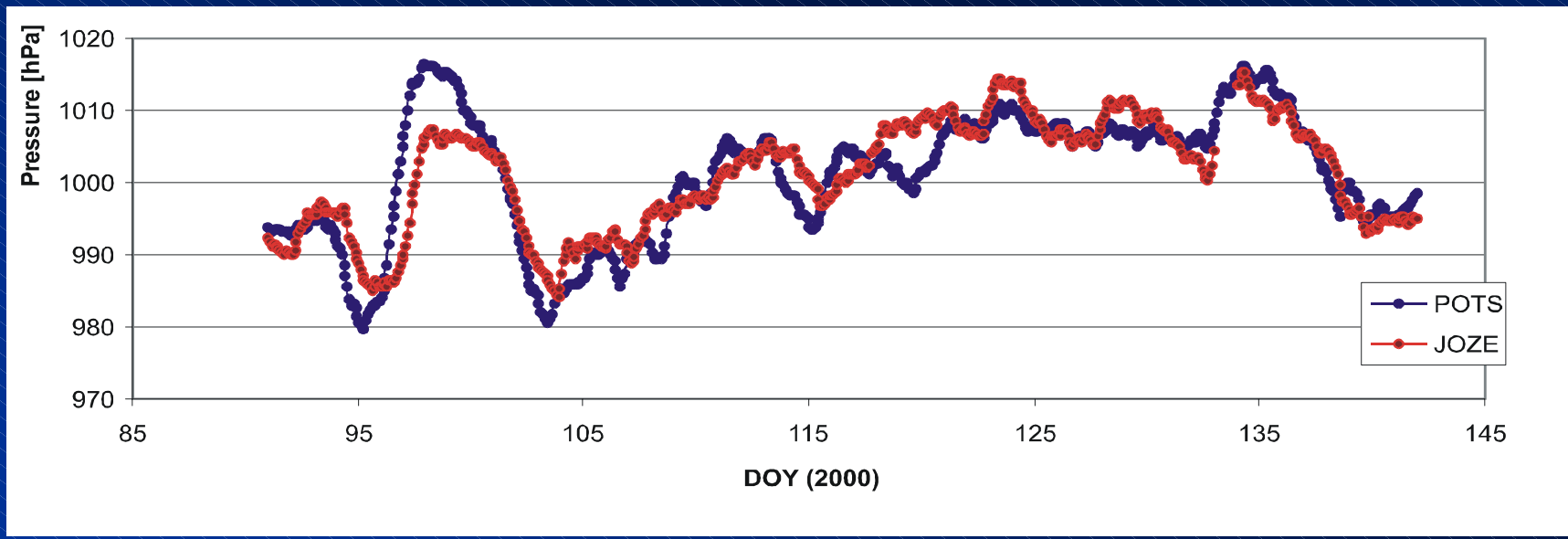
1. **BOGO and JOZE – Warsaw vicinity, 42 km distance, 0.96 correlation**
2. **LAMA and JOZE – about 180 km distance, 0.74 correlation**

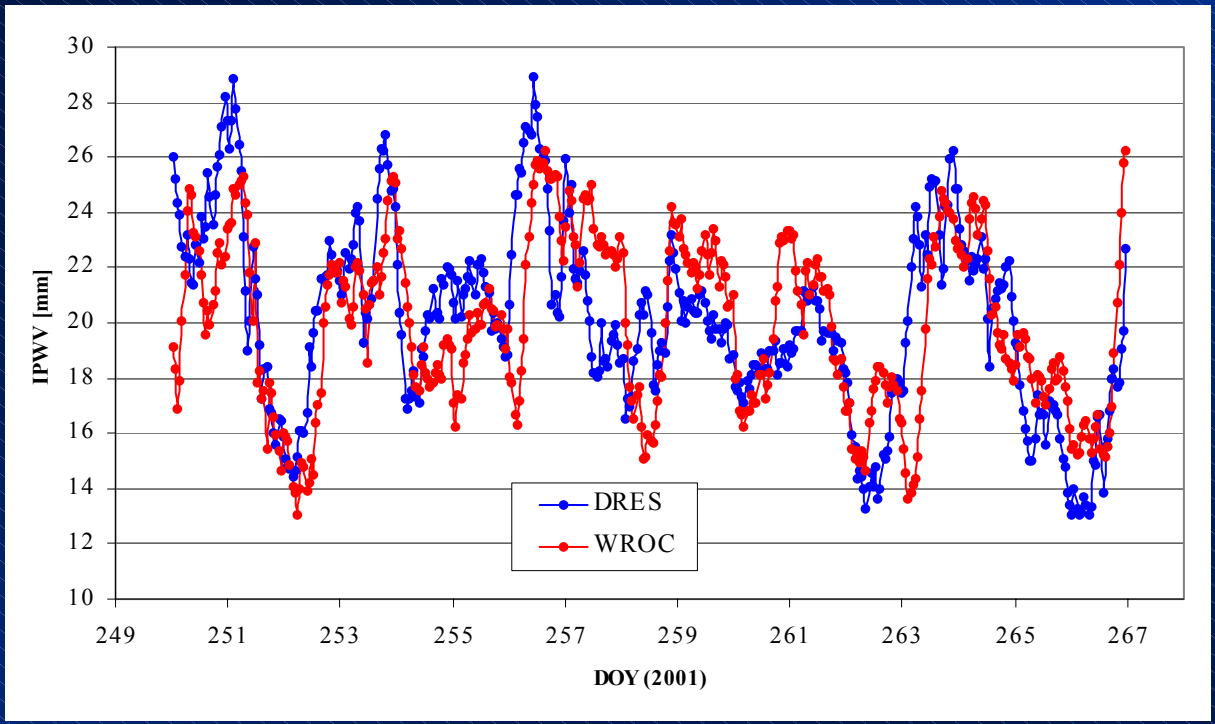




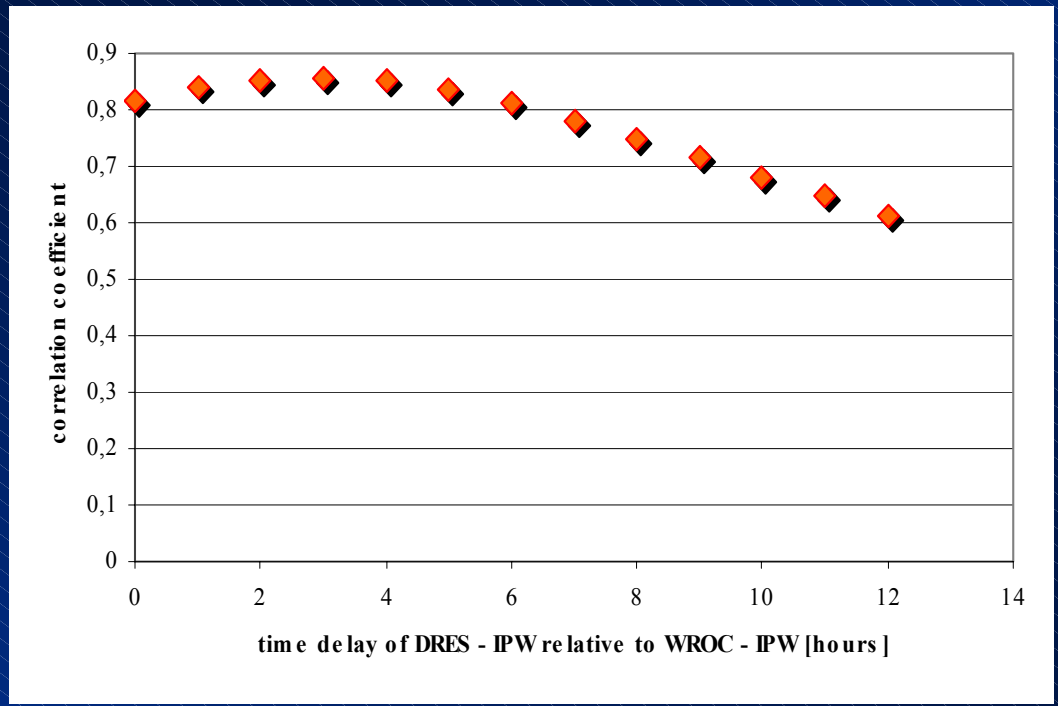
Setting aside parameters for two stations with the same latitude we can discern time similar IPW changes shifted in time. Also we see anticorrelation between IPW and atmospheric pressure on surface. We illustrate it below for POTS – Potsdam, and JOZE – Jozefoslaw near Warsaw.





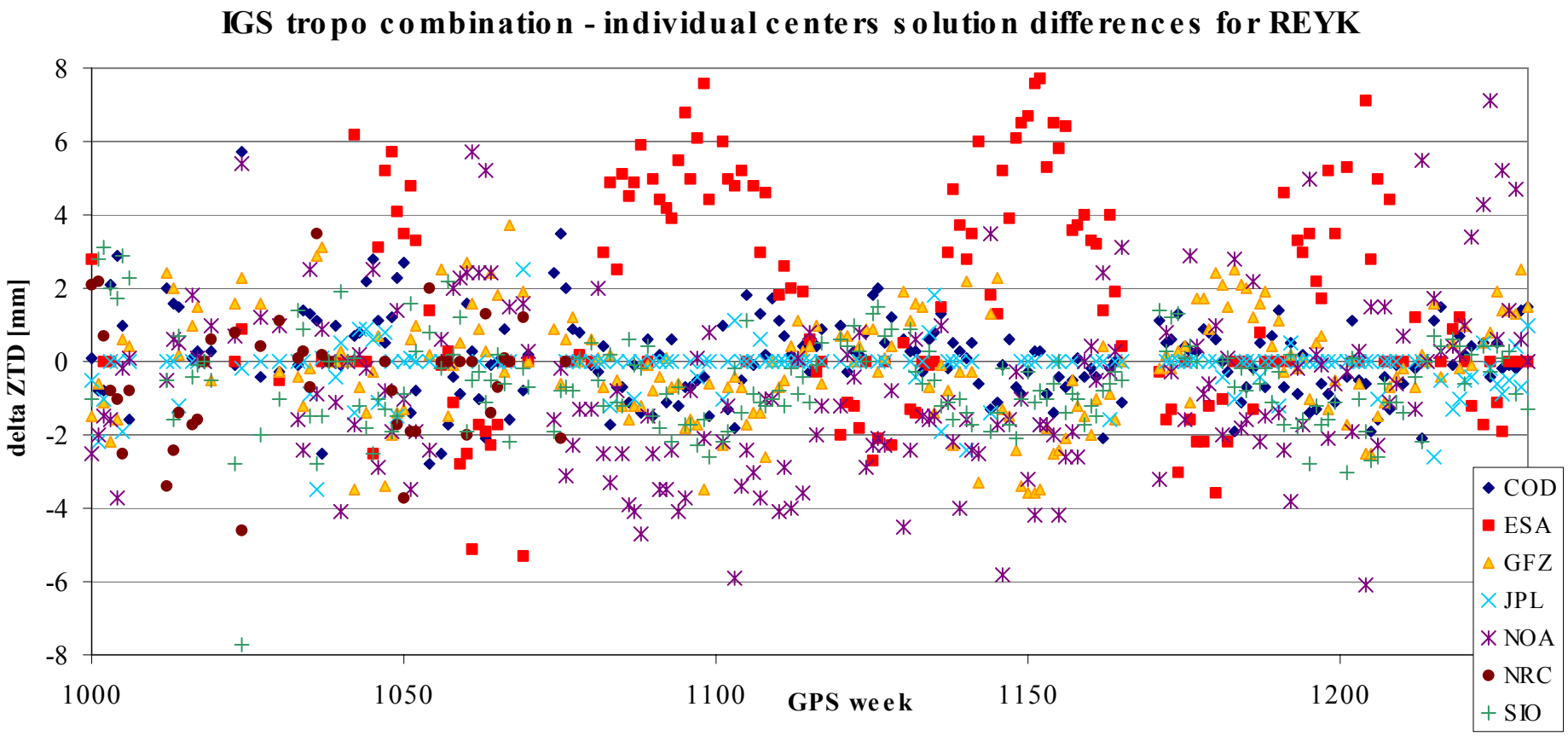


IPWV for DRES and WROC (220 km distance, same latitude), correlation coefficient of this series with time delay step used (below)



Available tropospheric combined product:

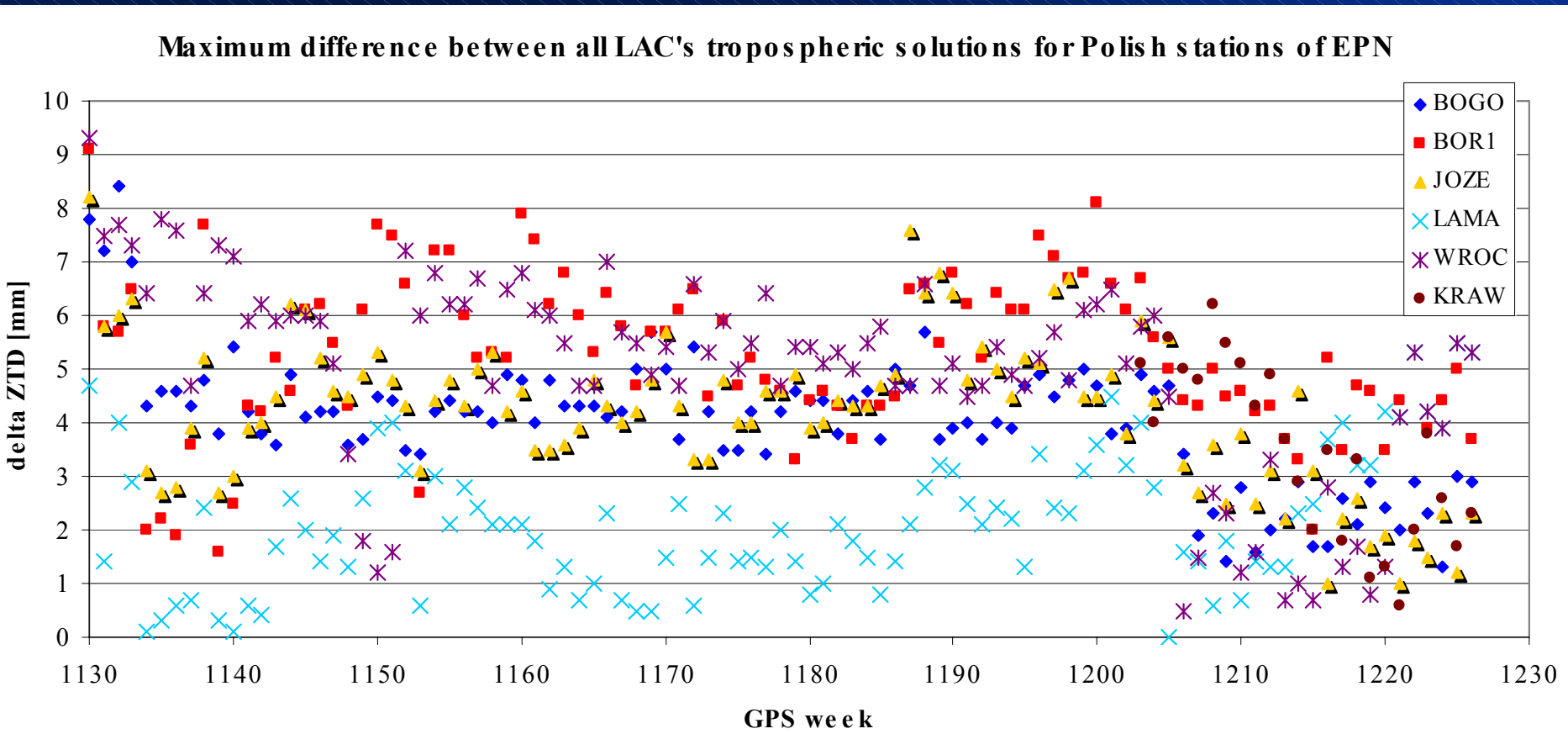
- IGS ('ZPD' format) – GFZ beginning from GPS week: 890
- EPN (mod. SINEX) beginning from GPS week: 1110
  BKG, GFZ from 1130 (1 hour interval)



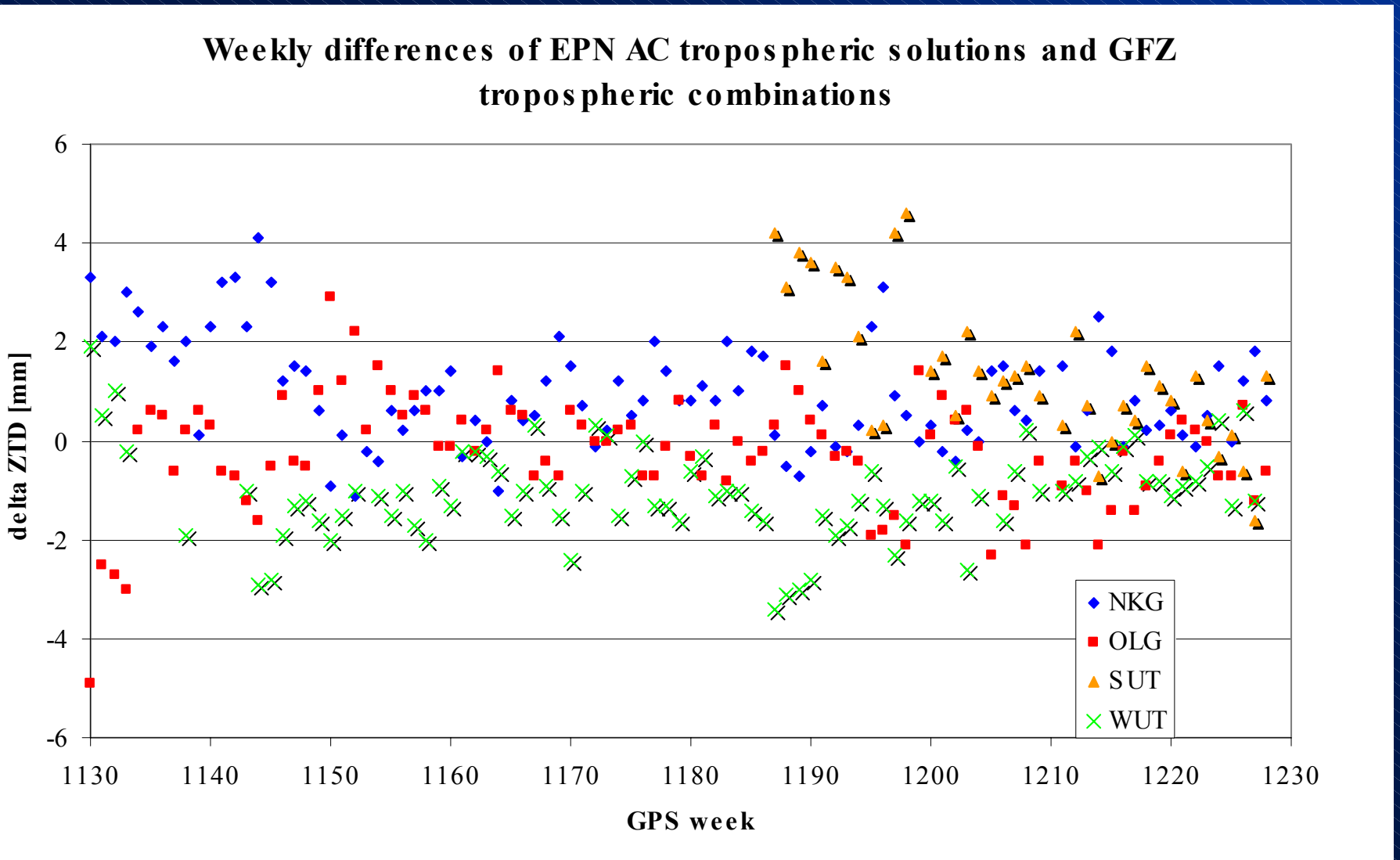
Differences between individual IGS Analysis Centers solutions and IGS tropospheric combination for REYK

Closer look at some statistical aspects of separate Analysis Centers solutions and combinations for various stations can disclose many interesting regularities.

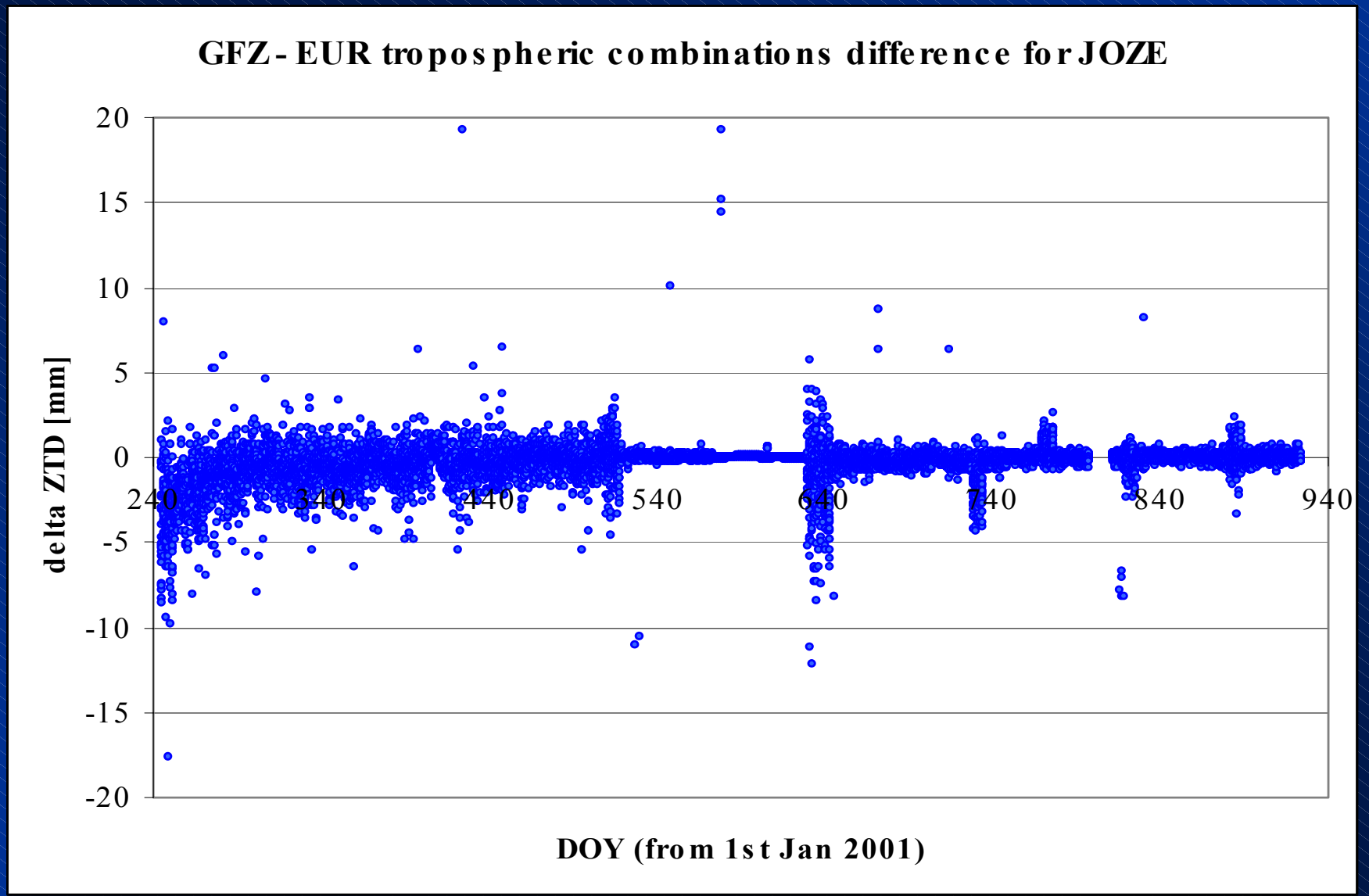
Quality of EPN LAC's tropo solutions seems to improve!



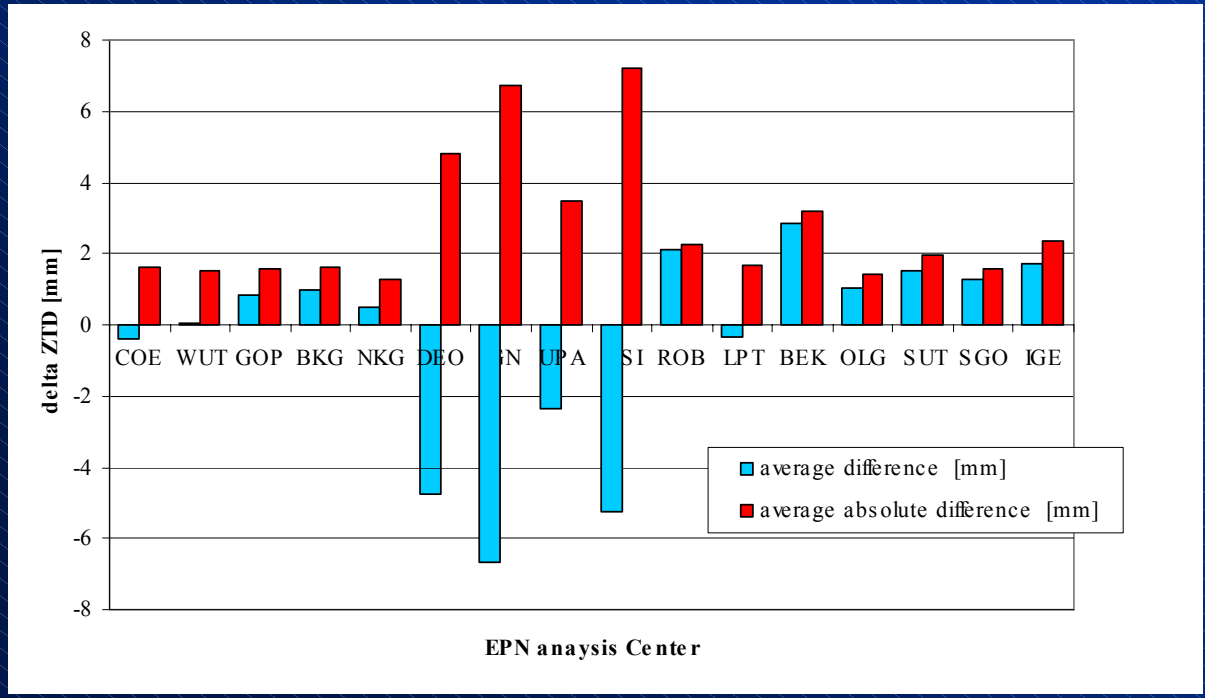
JOZE average (weekly) AC solutions – EPN (by GFZ) combination differences for JOZE



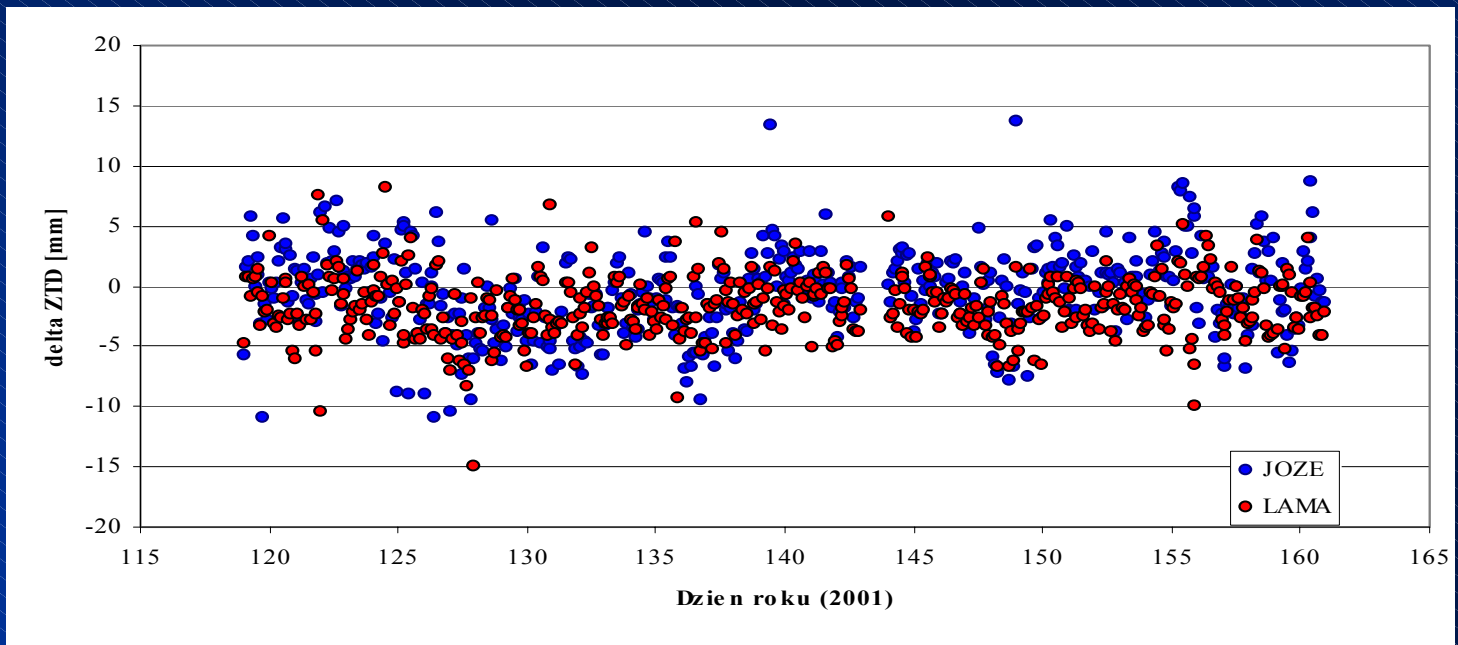
Difference between GFZ and EUR depends on week and diminishes
GPS weeks : 1130-1226



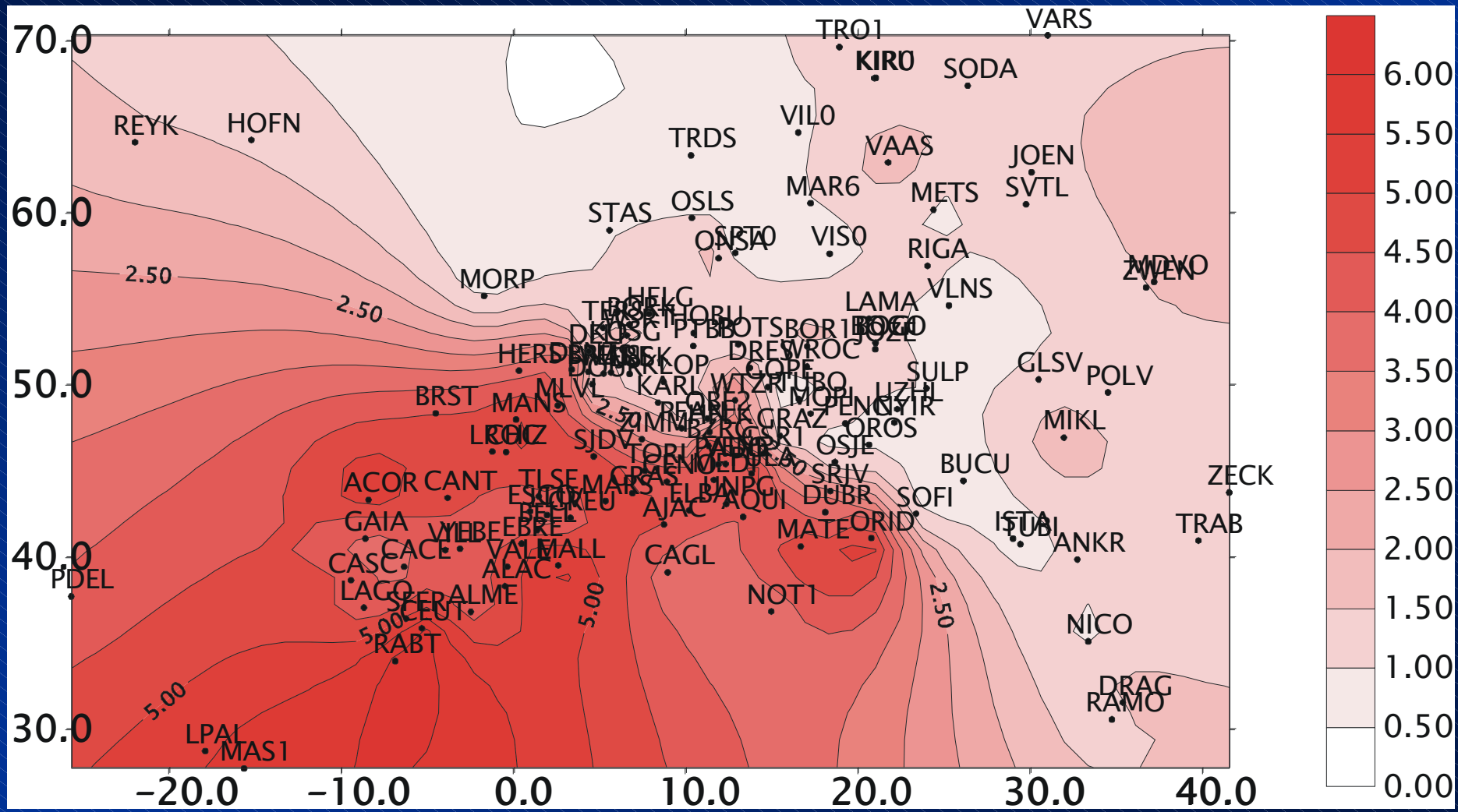
Mean and mean absolute differences EPN AC solutions and EPN tropospheric combinations GPS week 1130-1204



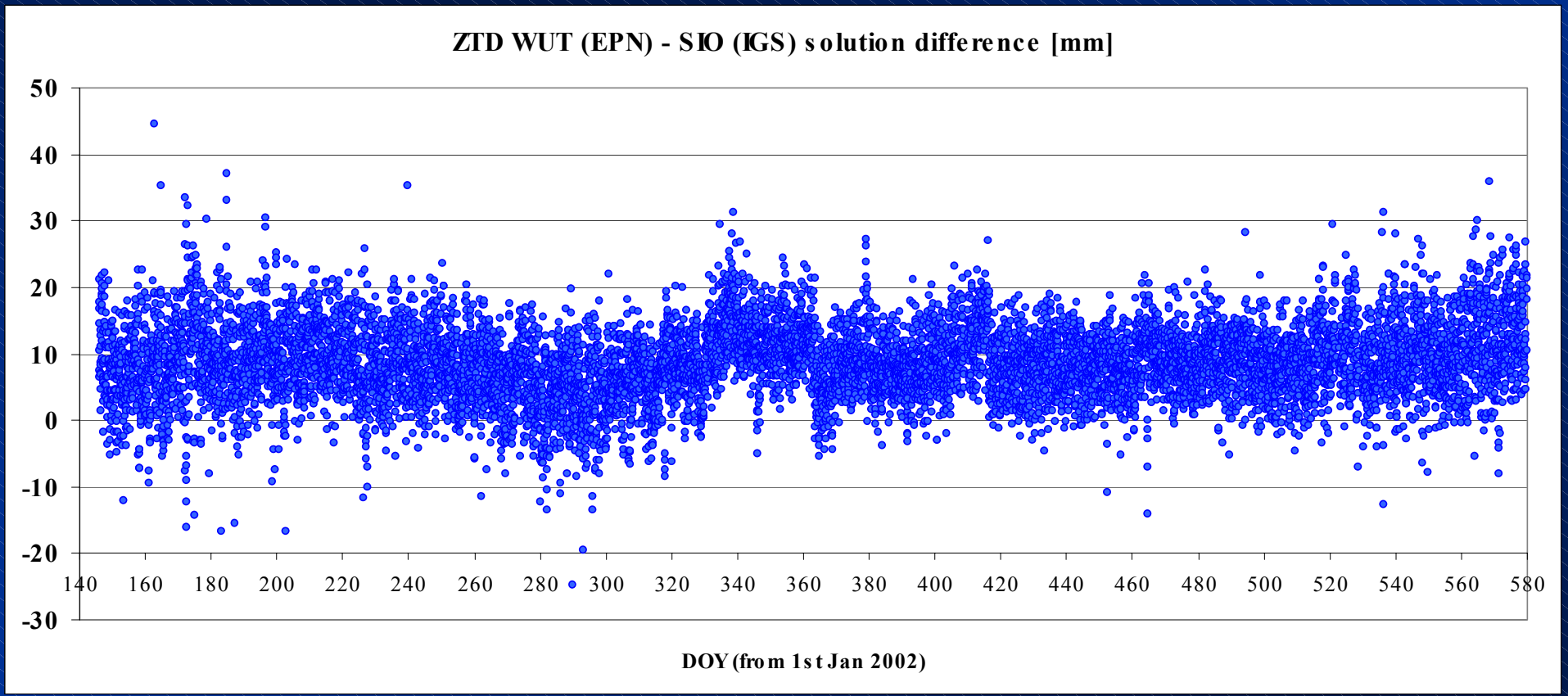
Differences of IGS and EPN ZTD combinations for two permanent stations in Poland



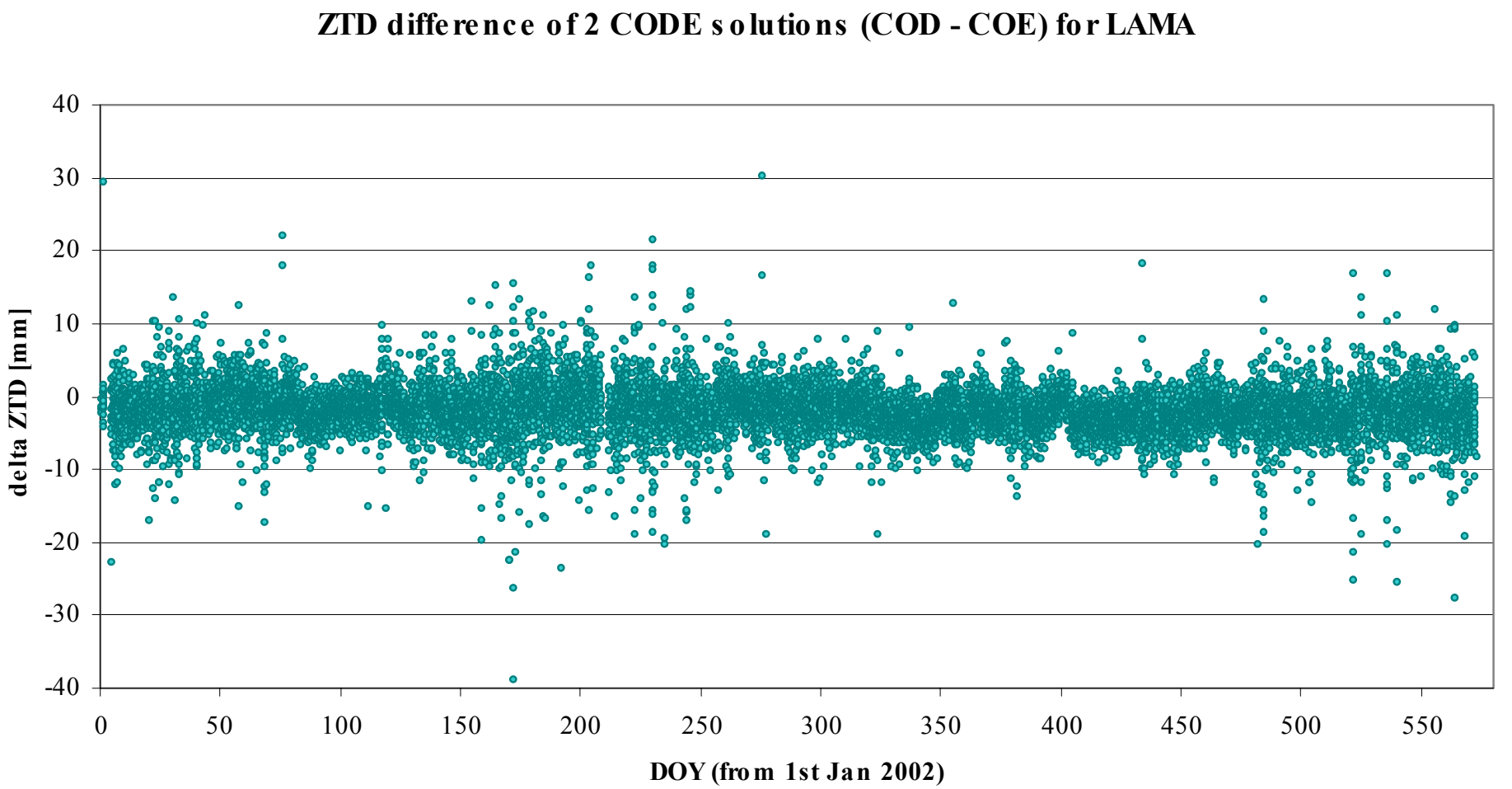
Mean absolute differences of all EPN AC tropospheric solutions and EPN combination [mm]. Averaged in time all AC solutions for each station GPS week 1130-1204



Comparing EPN and IGS solutions we find bias changing with time and scatter changing with season
Below difference of SIO and WUT solutions for JOZE

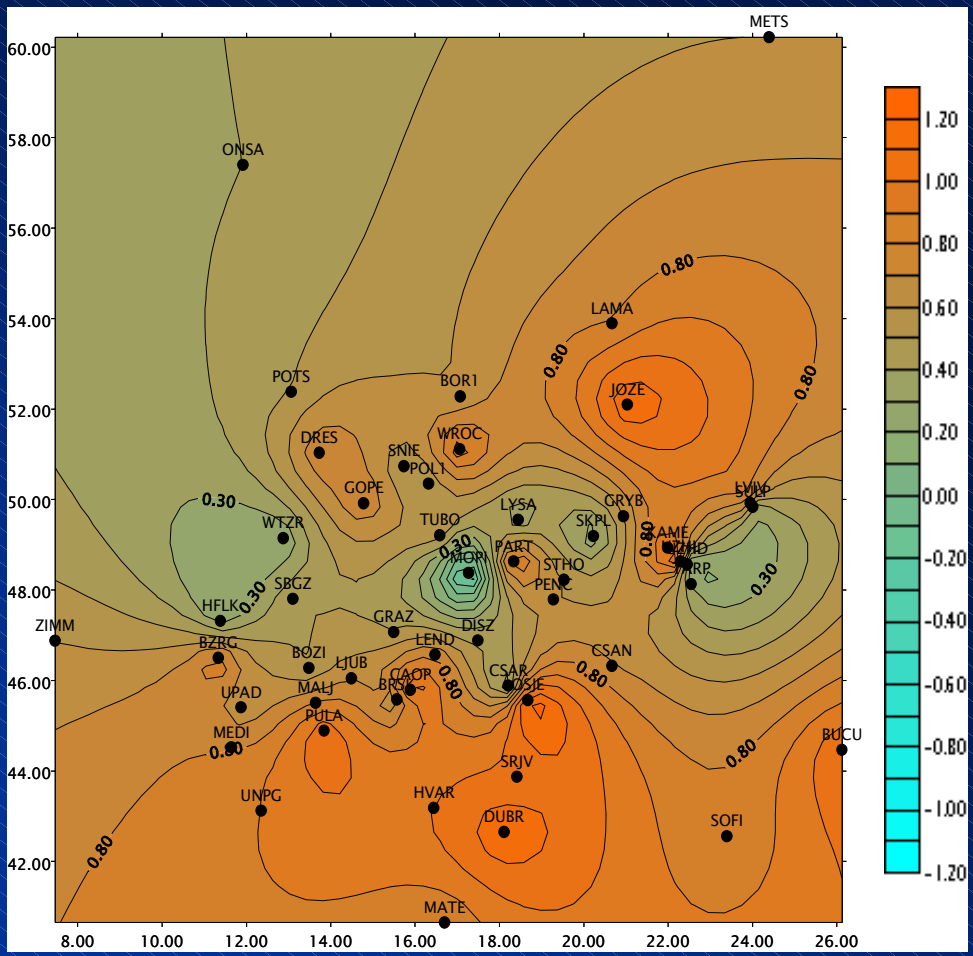


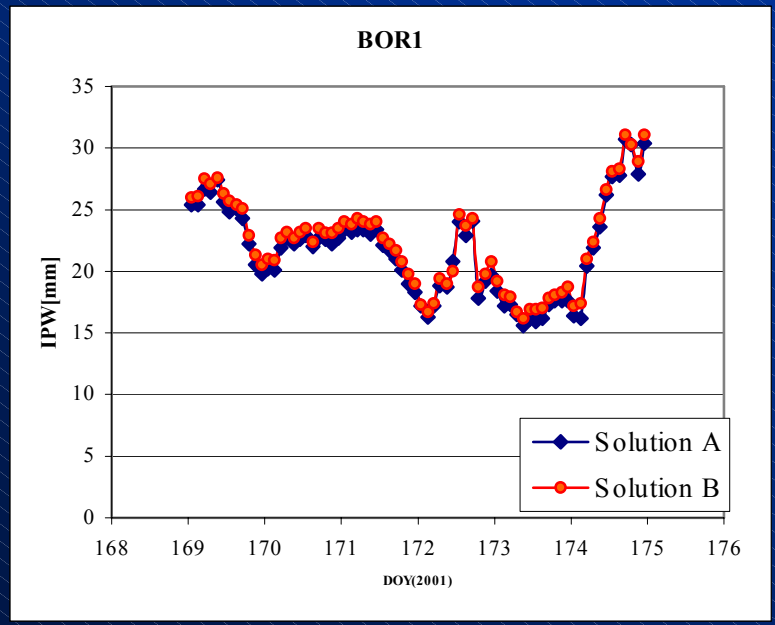
Below difference of 2 CODE solutions (COD – COE) for LAMA

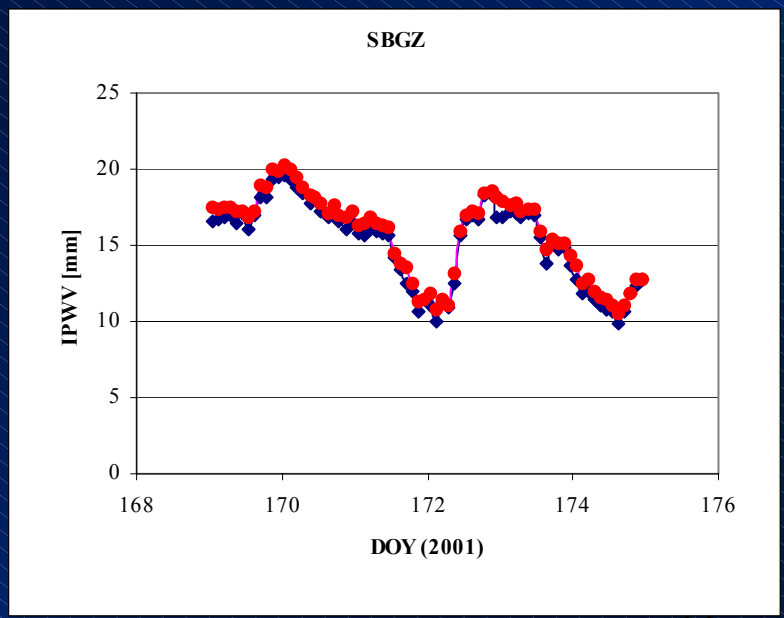


Bias = -2.5 mm, difference STDEV = 3 mm

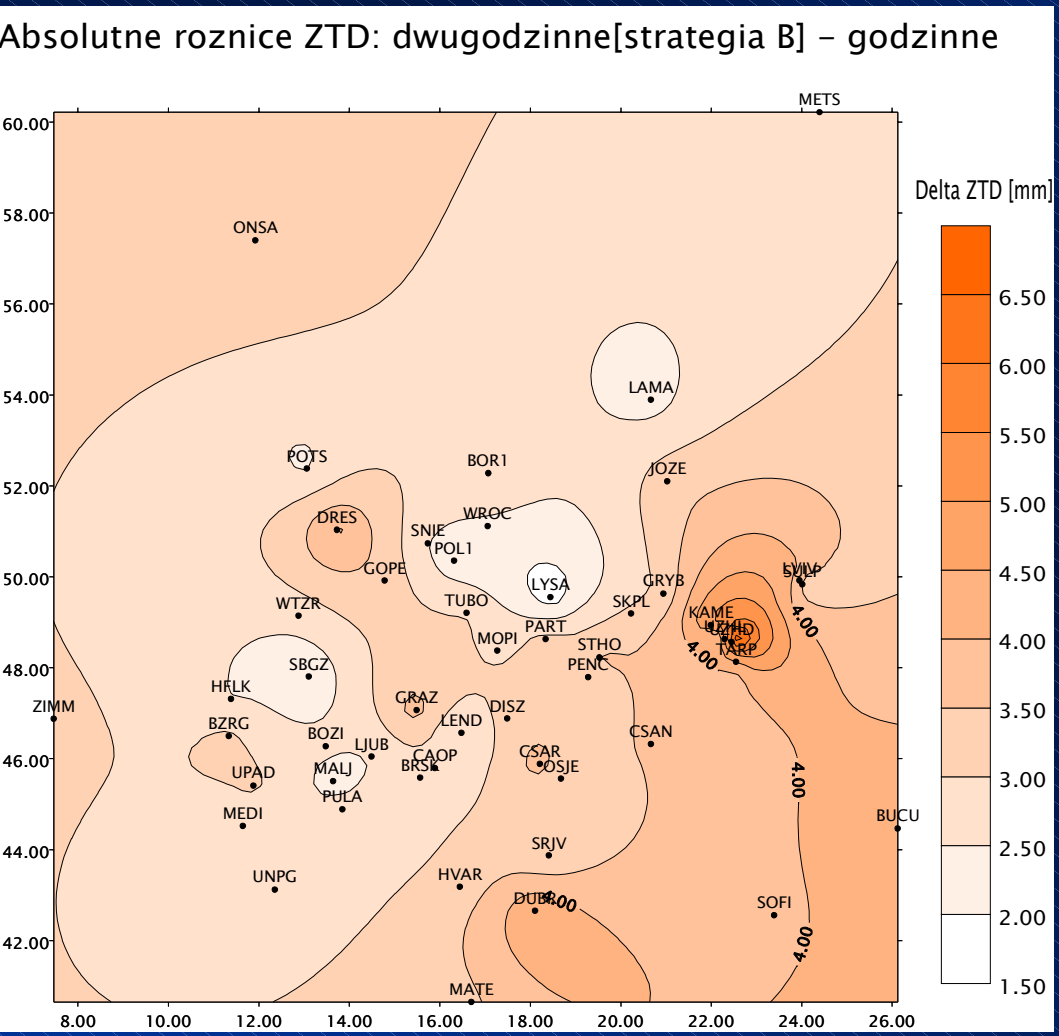
The map of average IPW differences between two CERGOP-2 2001 tropospheric solutions. First (A solution)utilizes Saastamoinen mapping function, without elevation dependent weighting, the second (B solution) includes weighting, and dry Niell MF. We got IPW average difference 0.7 mm (51 stations, the whole campaign length).

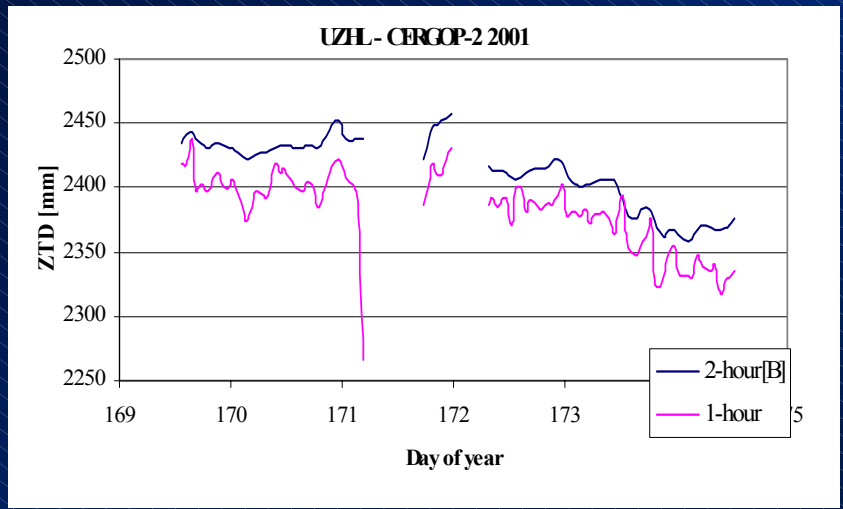




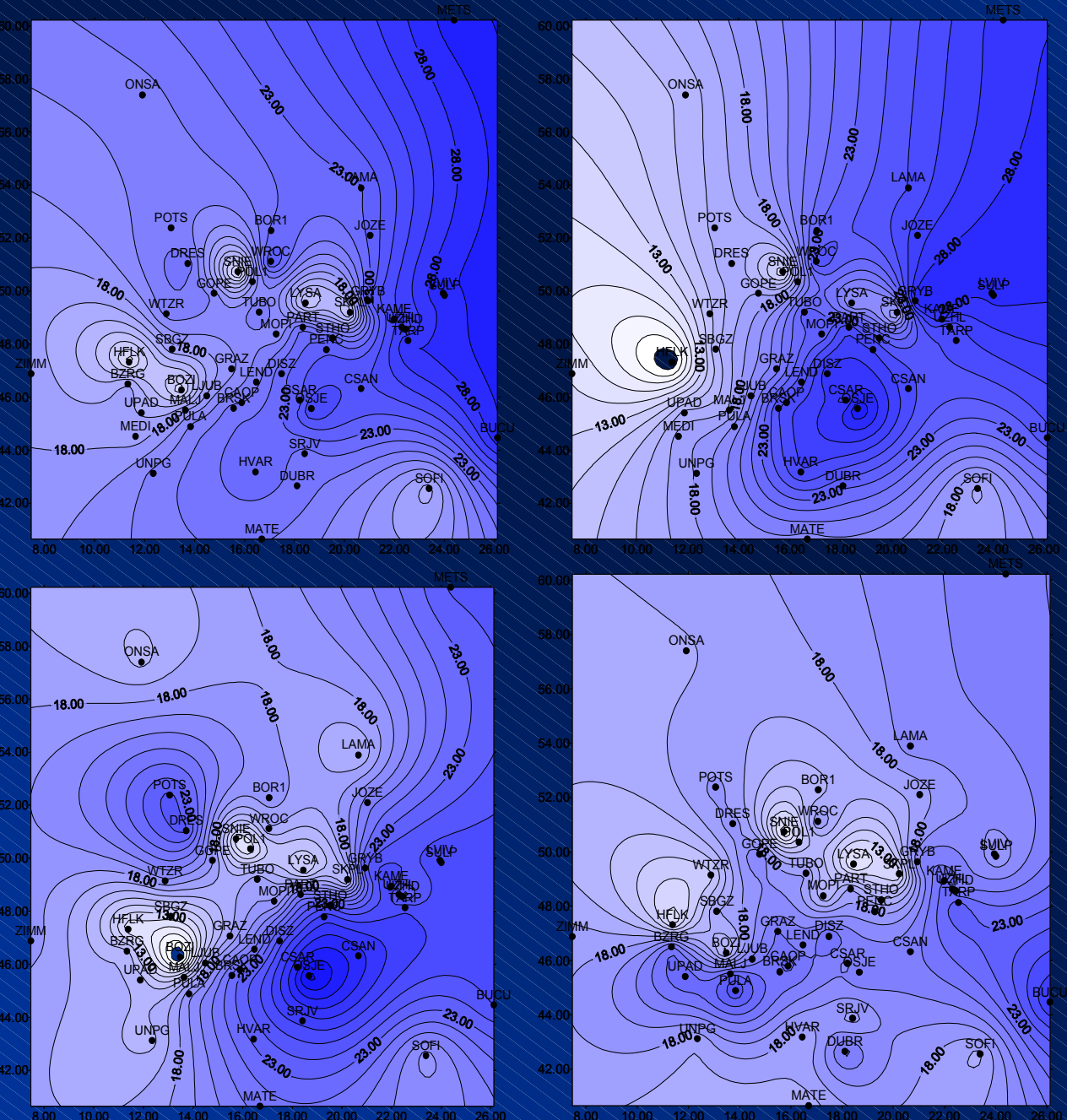


Map of the differences between 1-hour (B-solution) , and 2-hour ZTD solution of CERGOP-2 campaign (next: JOZE and UZHL – least stable station)





IPWV maps CERGOP-2 2001 – surface pressure (standard atmosphere)



Four consecutive days 11.00 TU

170 171
172 173

Our NRT ZTD estimation project

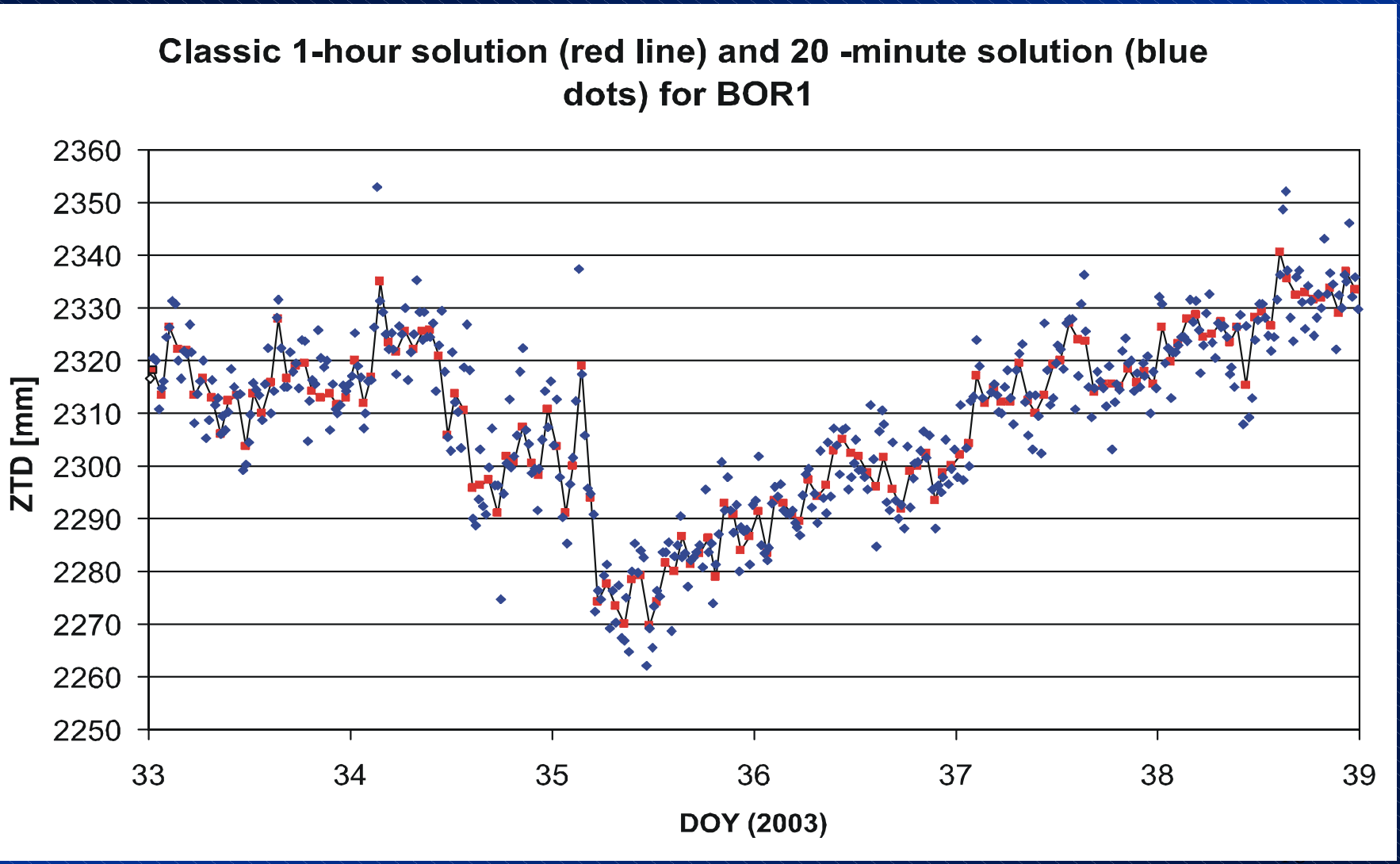
Project phases:

1. **Establishing dedicated Linux server (FTP, WWW) and local data base**
2. **Software installation: BPE (+ GAMIT?), perl, bash, Fortran LF95**
3. **Plannned strategy:**

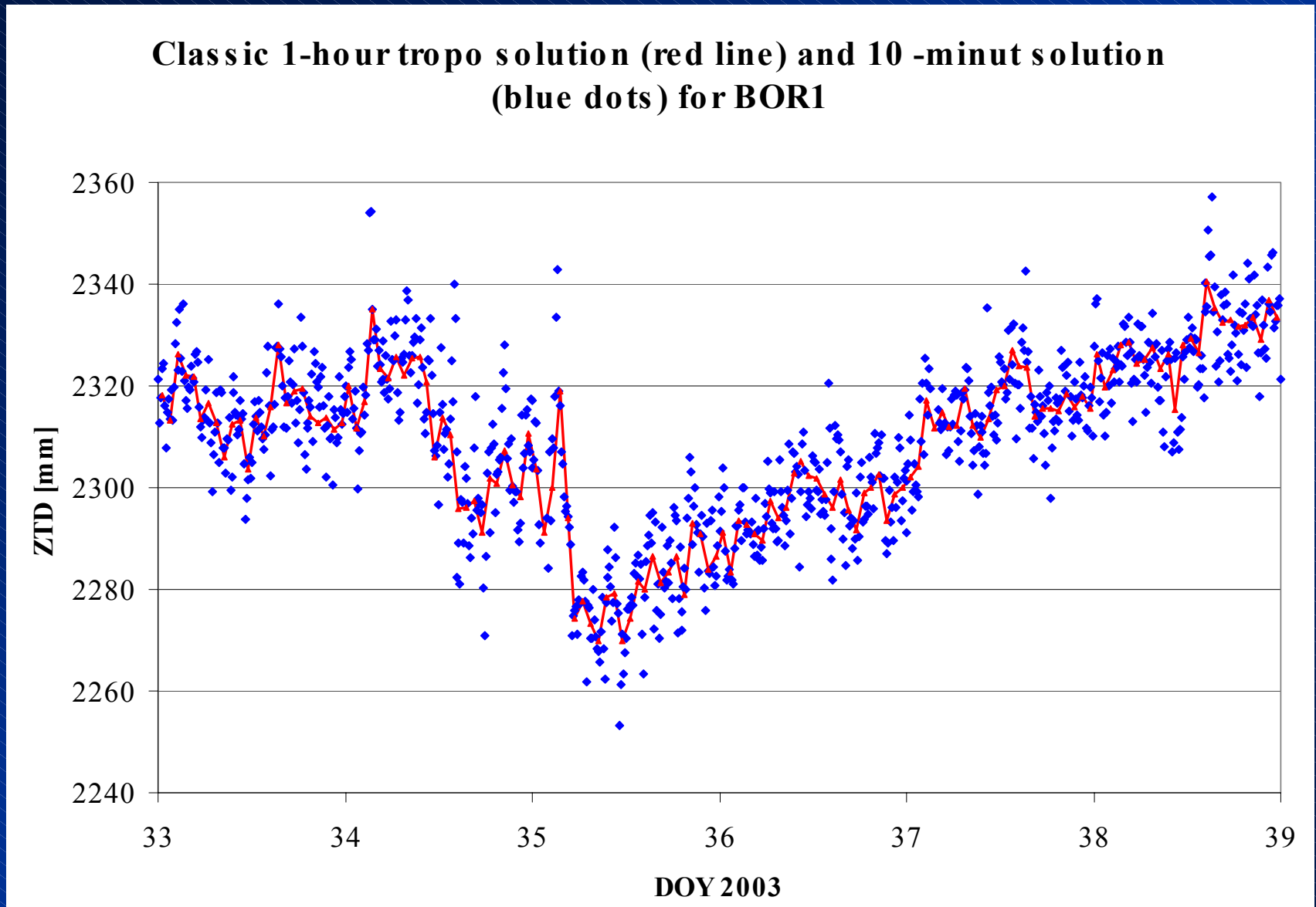
- **Ultra Rapid IGS orbits and precise IGS orbits (for comparison) + broadcast clocks; satellite exclusion procedure, own orbit quality weighting index (or GOP hourly)**
- **1 hour (typical) or 30-20 min estimation step**
- **Coordinate 'fixed' to weekly EPN SINEX**
- **Dry Niell mapping; elevation cutoff : 10º or less; cos(z) observation weighting**
- **careful handling of other parameters:'ocean loading', gravity model, planetary EPH etc.**
- **Quality check, multipath modeling ?**
- **Float ambiguity, QIF – L3, 12-7 last hours NEQ combination, or *sliding window* (RINEX concatenation) ?**

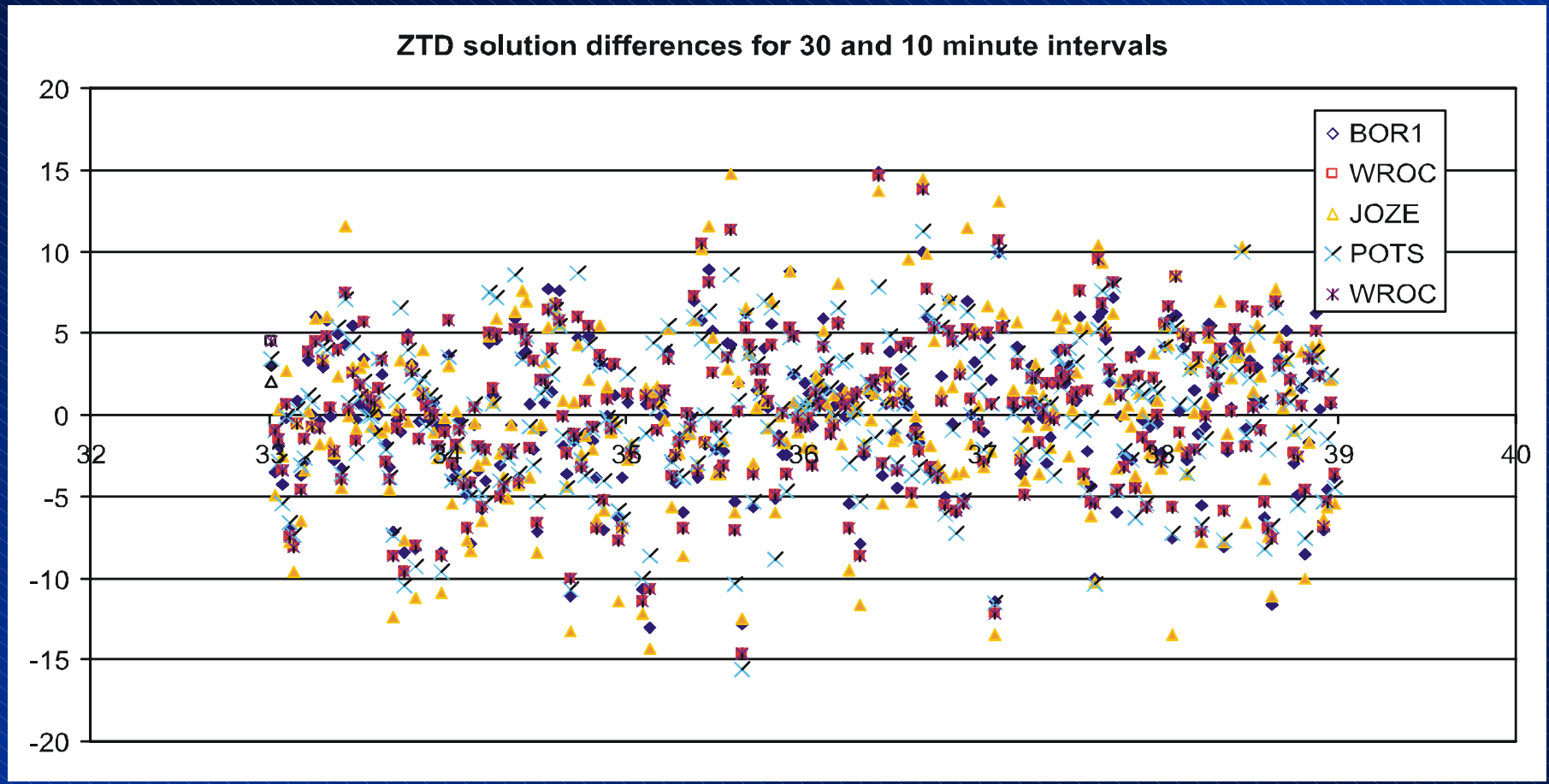
5. **Paralel daily post-processing for solution quality control**
6. **Comparison with NWP model post-analysis fields (UMPL + inne ?)**
7. **Visualisation subfield (gnuplot, gri, ConVis, GMT ?)**
8. **Output format: COST (BUFR?)**
9. **Output recepients: KNMI (COST), Met Office, in Poland –IMGW, ICM**

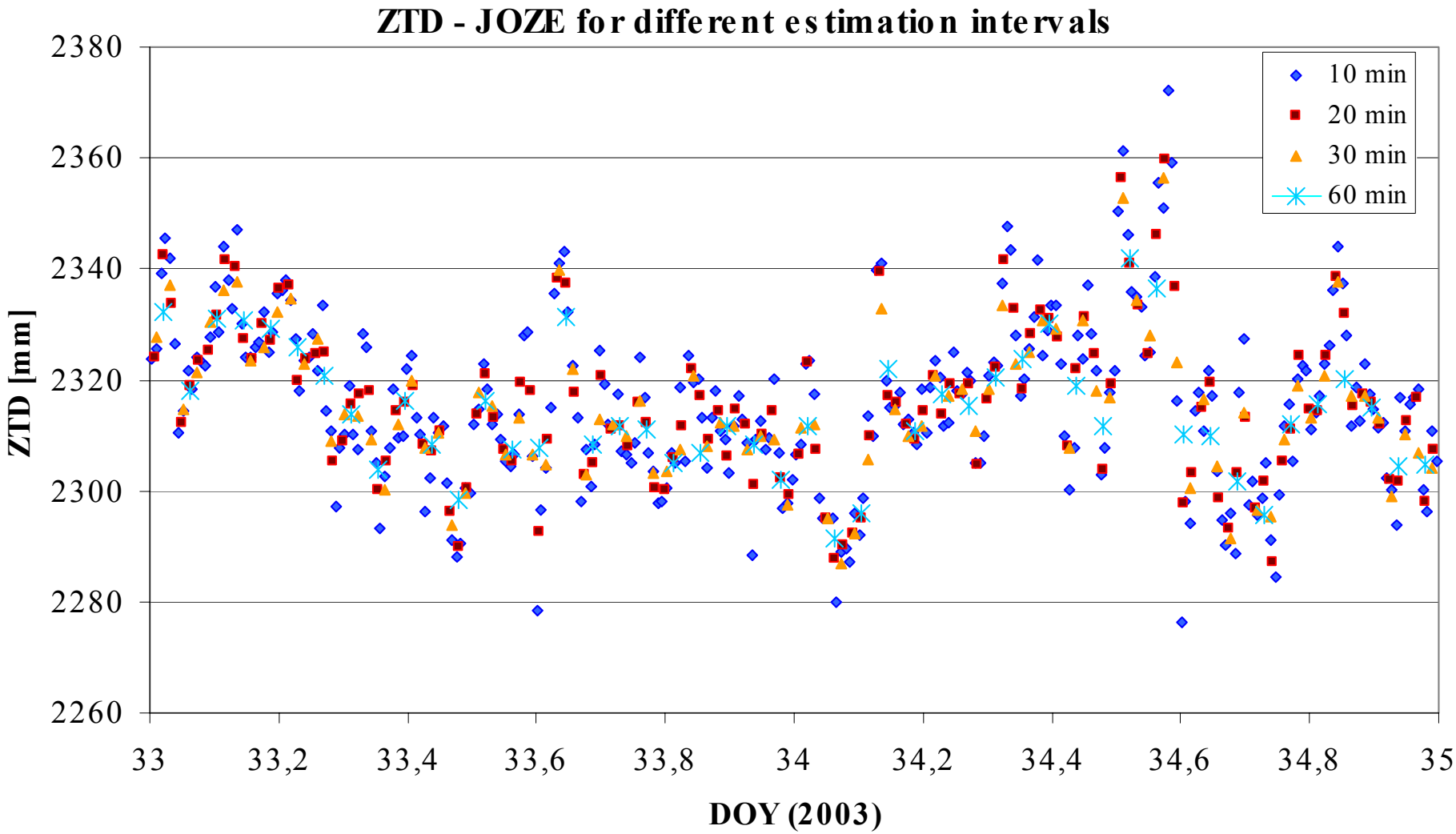
Question of time resolution (time step) of ZTD estimates:
We compared ZTD calculated in 1 Hour and 20 minutes intervals
Obtained for small 6-station network



The same for 1 – hour and 10 –minute solutions

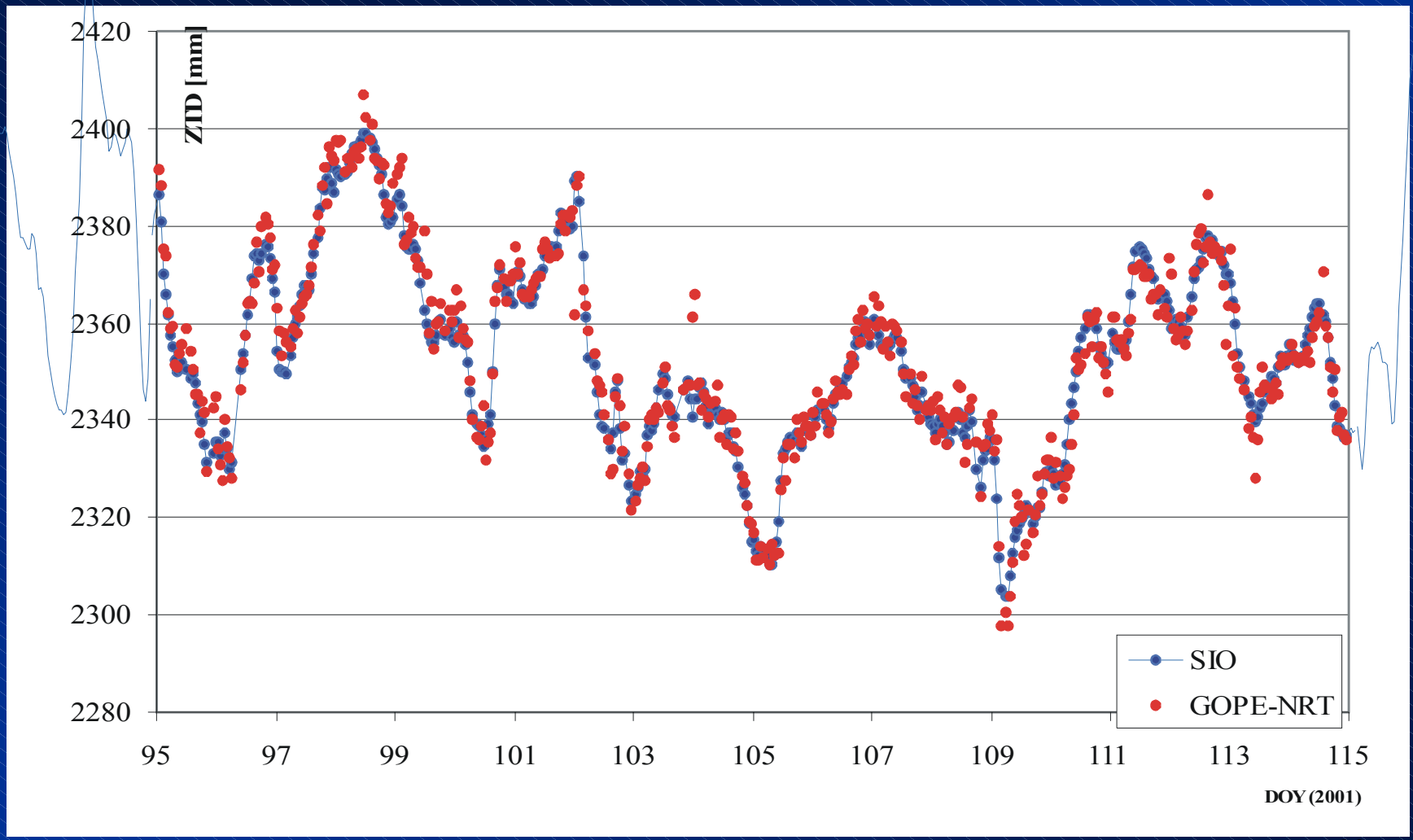



ZTD solution differences for 30 and 10 minute intervals
20
15
10
5
0
-5
-10
-15
-20
32
33
34
35
36
37
38
39
40
BOR1
WROC
JOZE
POTS
WROC



Mean absolute difference between solutions clearly bigger than solution stdev - proof of 'sub-hour' information potential of ZTD

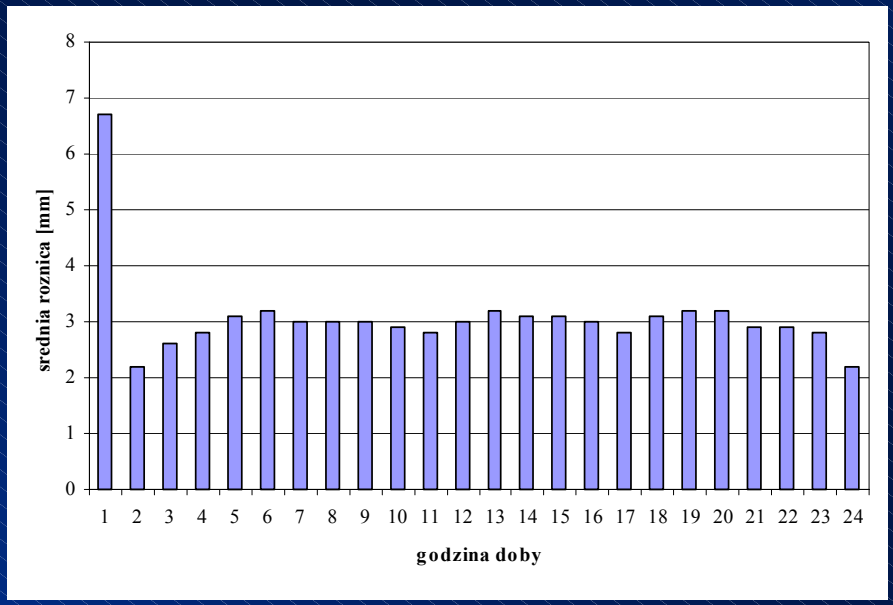
Exemplary NRT solution for COST-716 action of GOP EPN Analysis Center compared to daily SIO solutions (solution by J. Dousa)
The difference of ZTD over BOR1 final IGS SIO solution and NRT COST-716 GOP AC



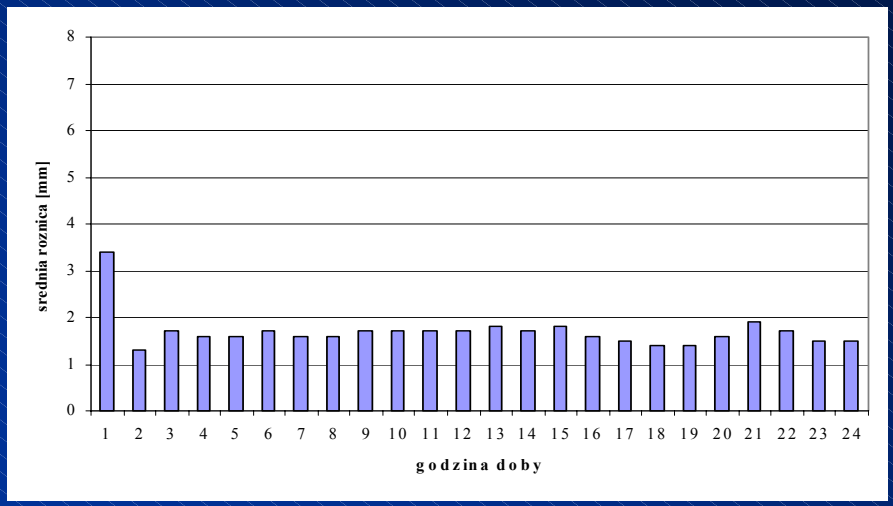
Difference stdev on 4-6 mm level and bias smaller than 1 mm!

Pattern of differences between subsequent hour estimates (some kind of derivative)

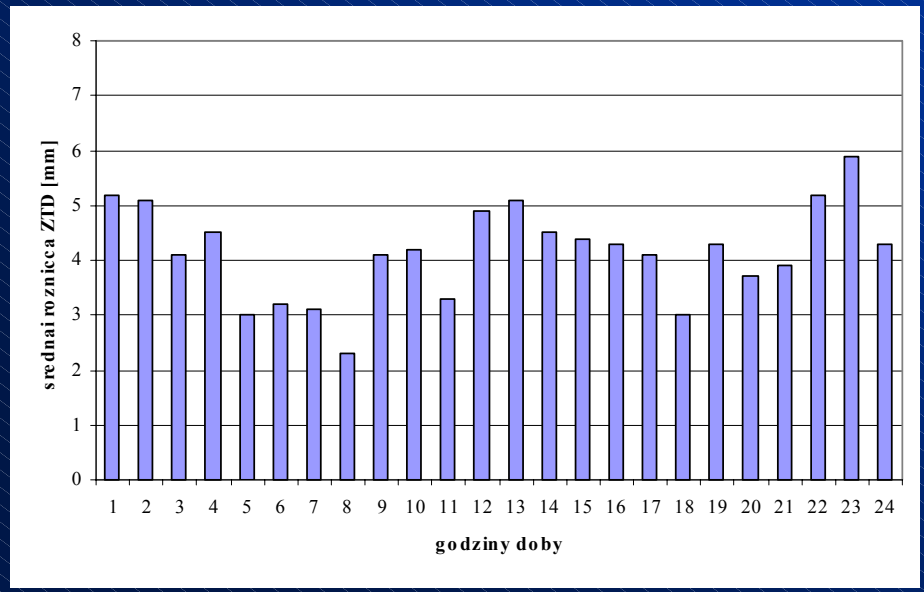
Daily (SIO): JOZE



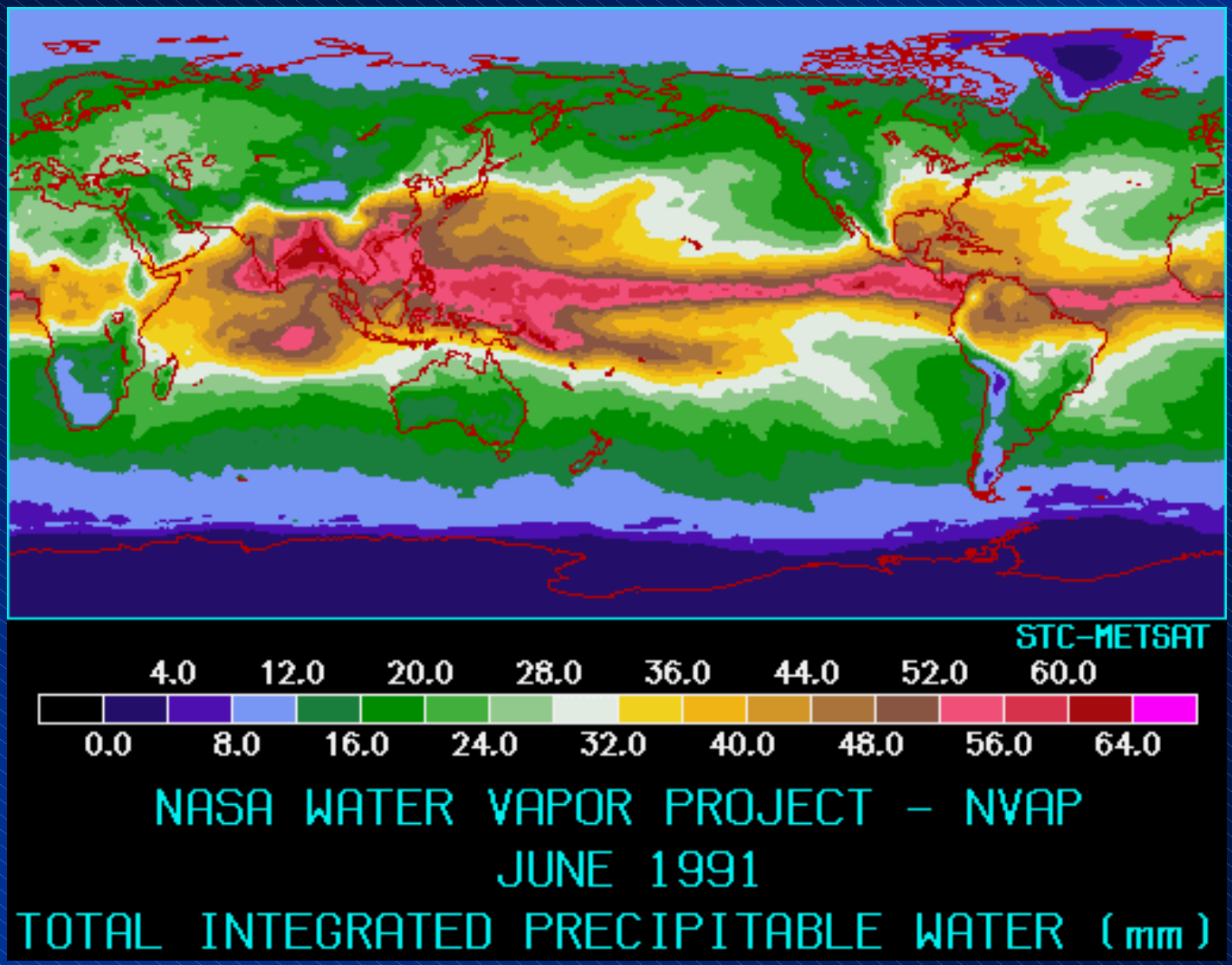
NYA1



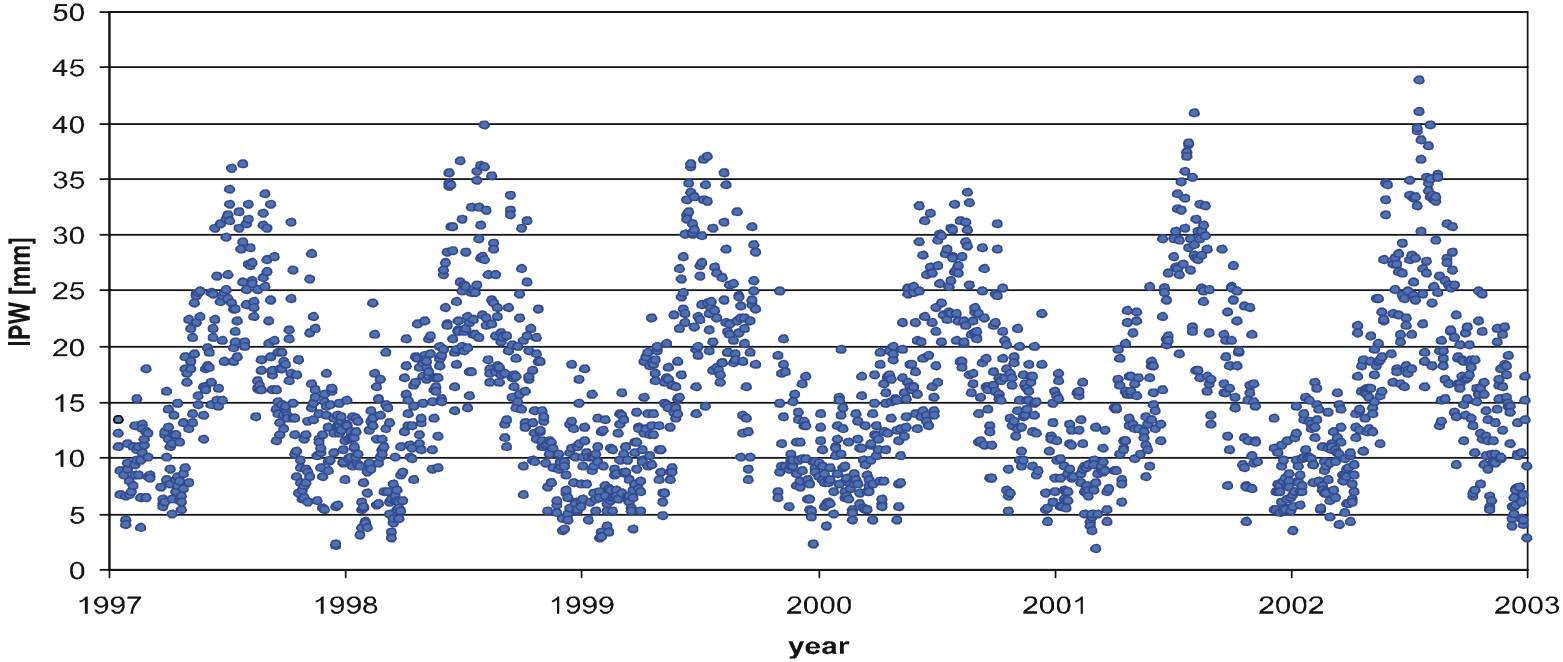
Hourly (GOP): BOGO



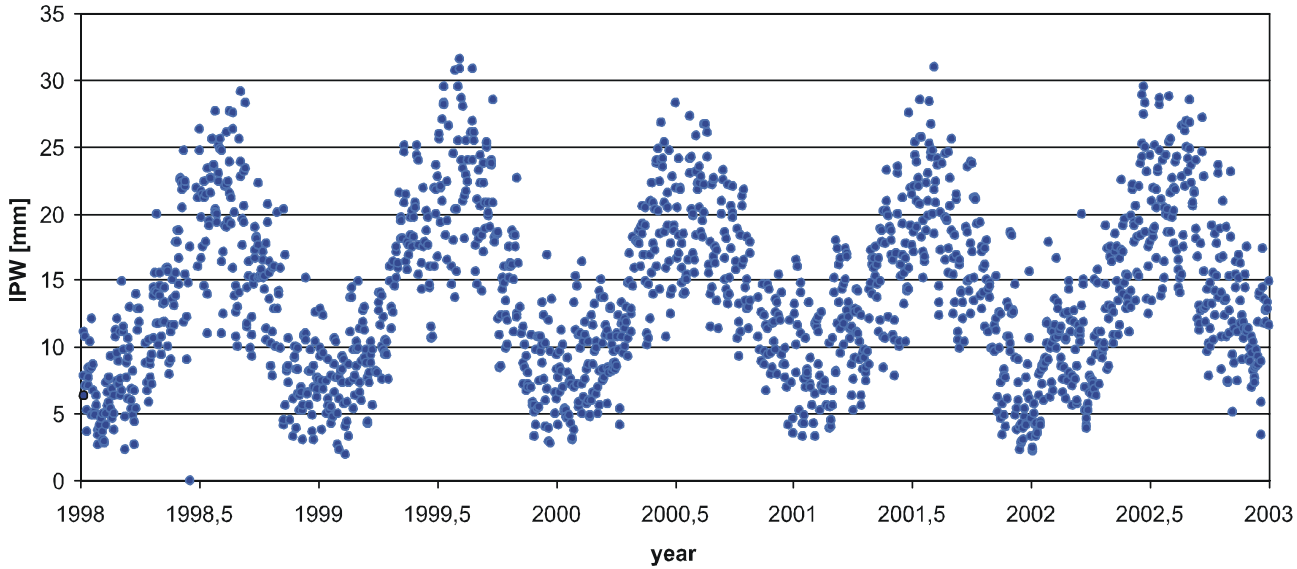
IPWV in climatology

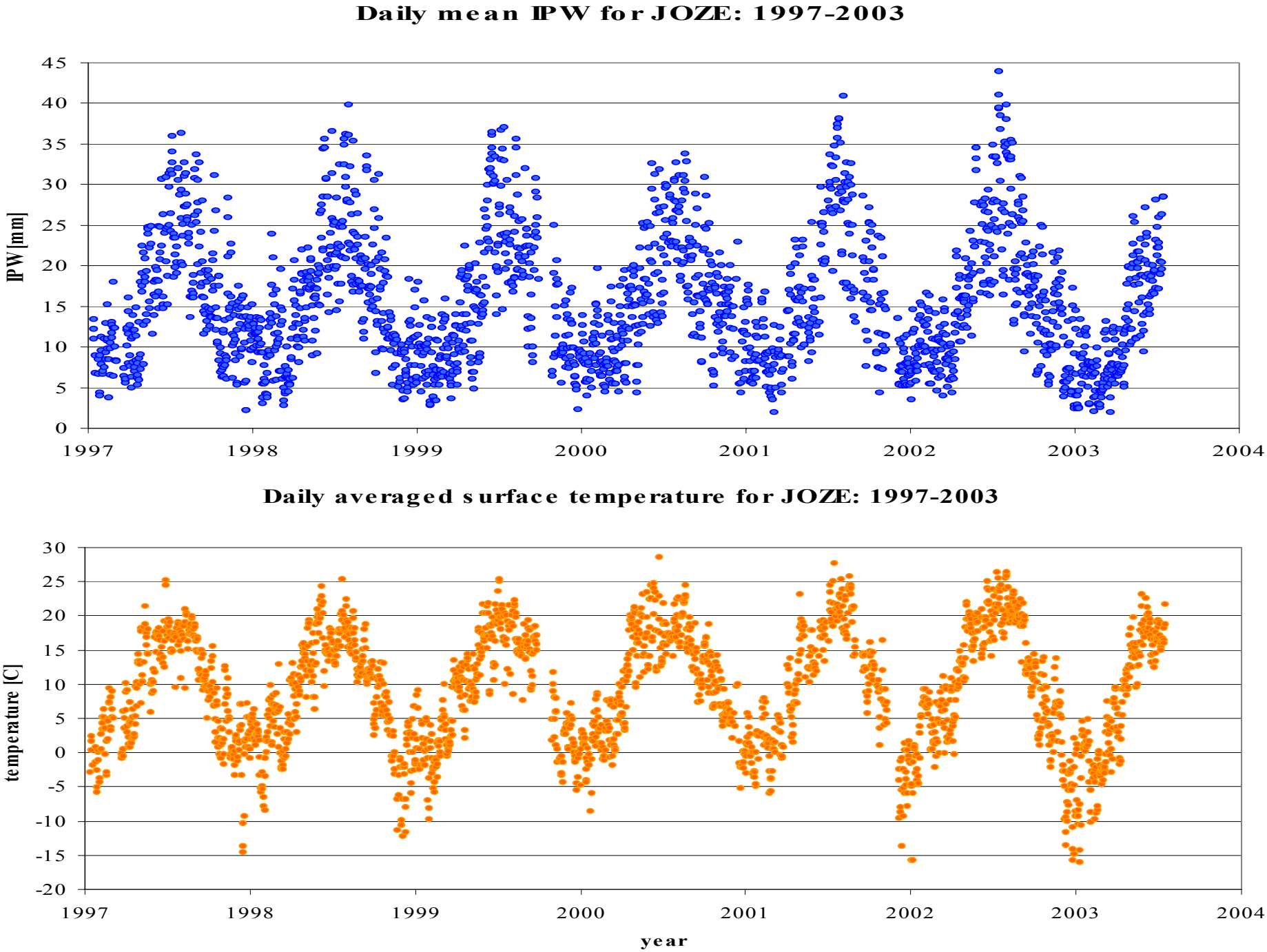


Daily mean IPW for JOZE: 1997-2002



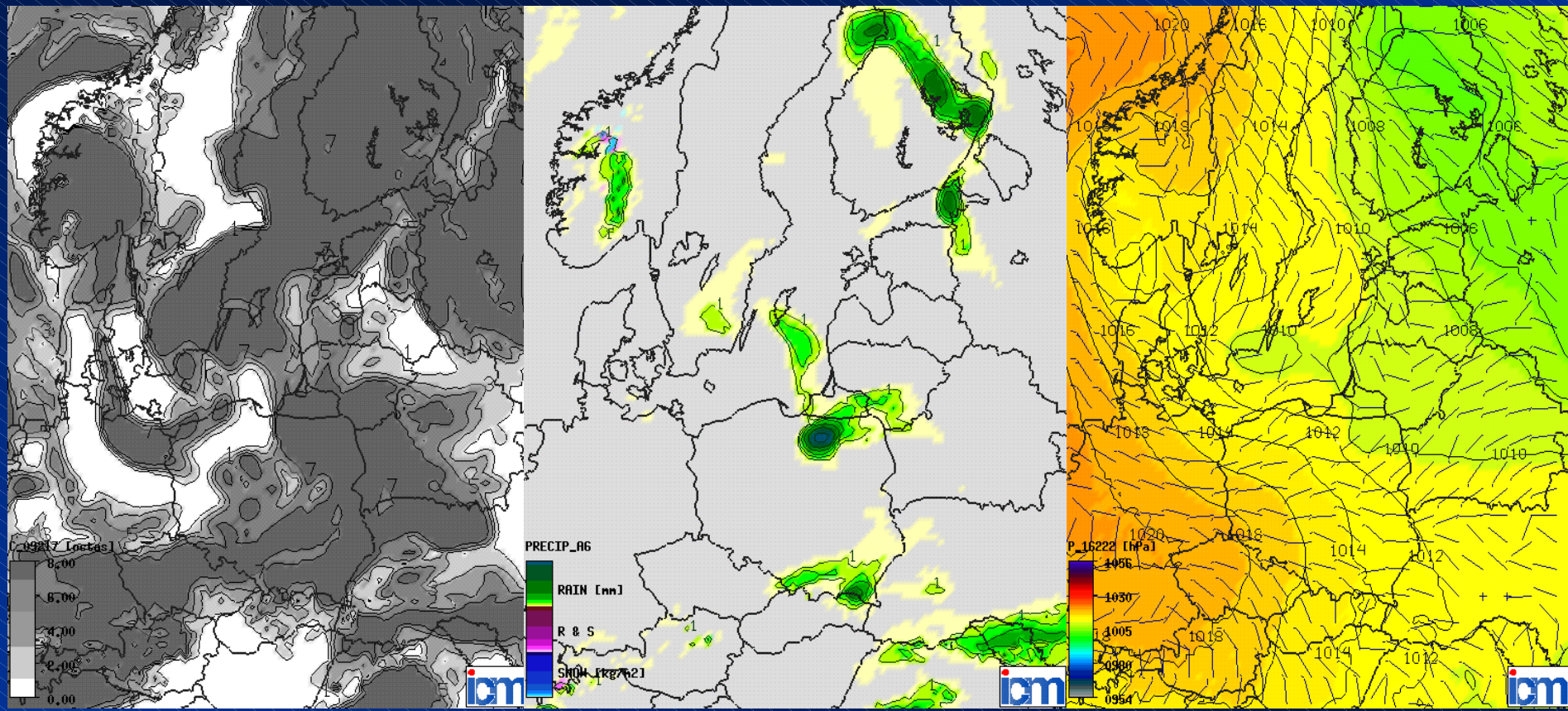
Daily averaged IPW values for ZIMM: 1998-2002




Daily mean IPW for JOZE: 1997-2003
IPW [mm]
45
40
35
30
25
20
15
10
5
0
1997
1998
1999
2000
2001
2002
2003
2004
Daily averaged surface temperature for JOZE: 1997-2003
temperature [C]
30
25
20
15
10
5
0
-5
-10
-15
-20
1997
1998
1999
2000
2001
2002
2003
2004
year

UMPL (ICM Warsaw University): 17 km - grid, 31 levels

Unified Model (Meteo Office, UK) clone

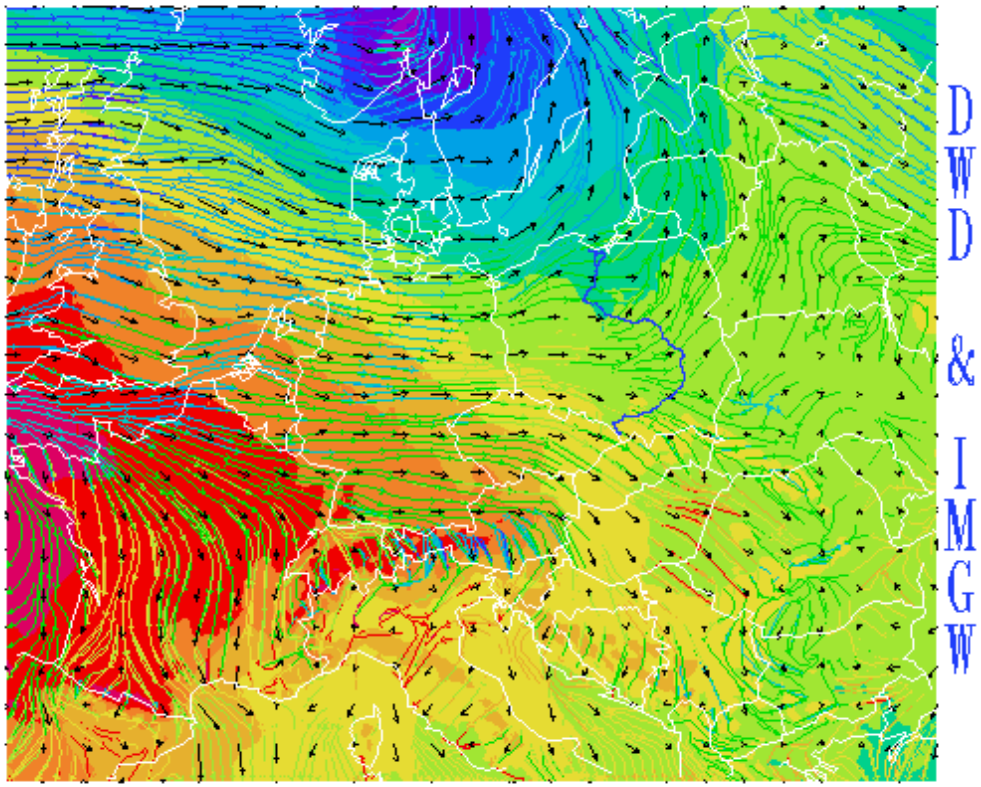


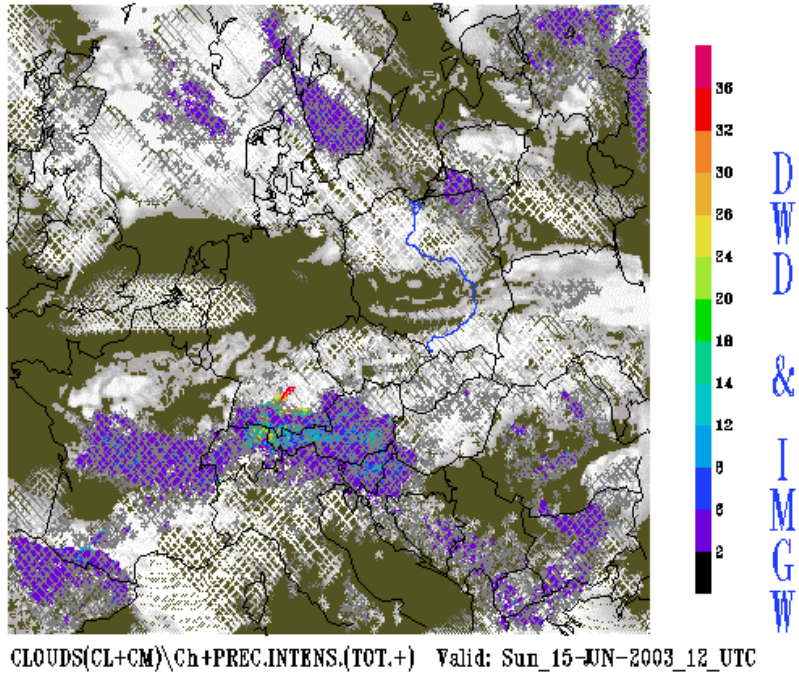
COAMPS model (Navy Research Lab. , USA) under testing in ICM

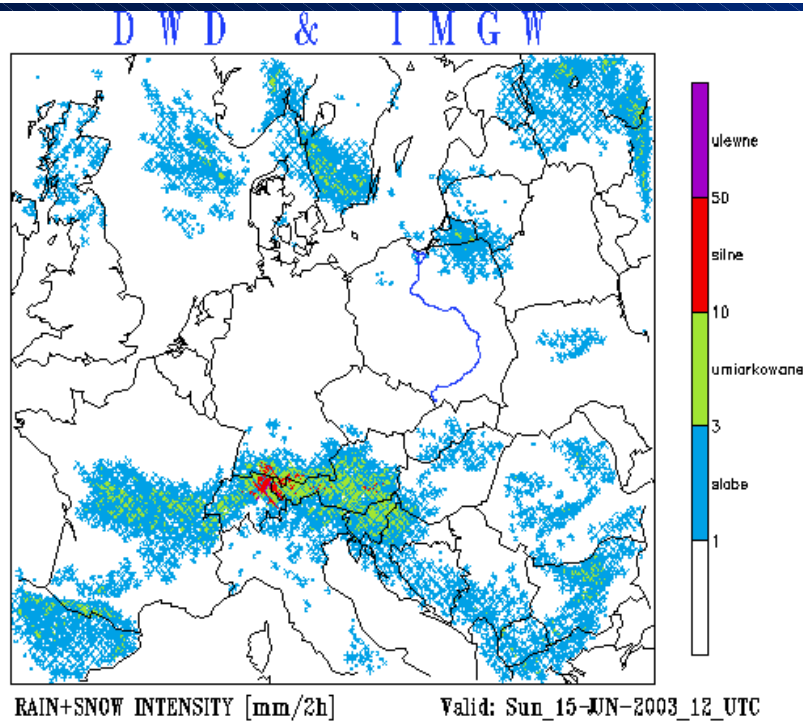
Mesoscale model IMGW/DWD (9 km resolution)

Selected fields visualisation:

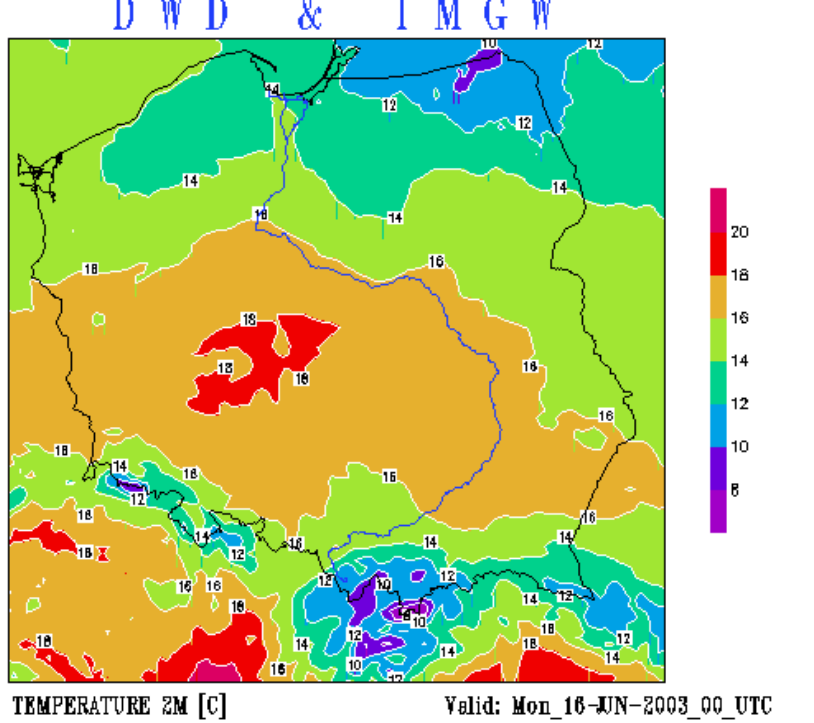
- wind and pressure
- clouds
- precipitation

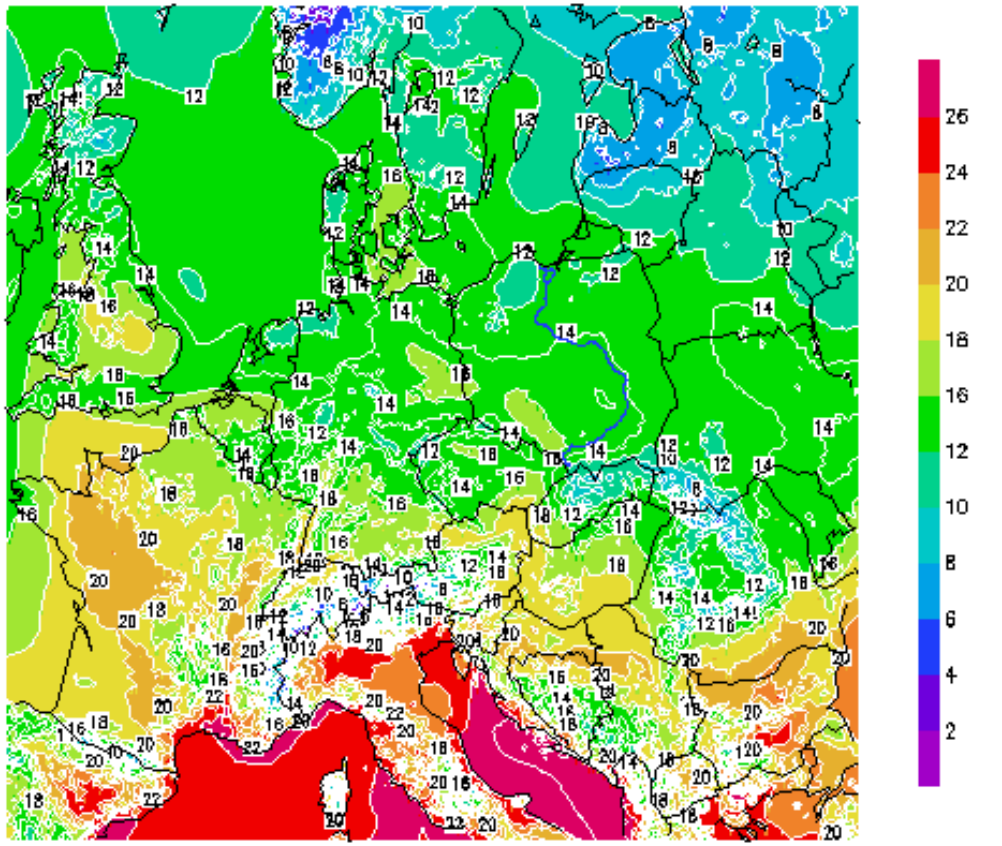




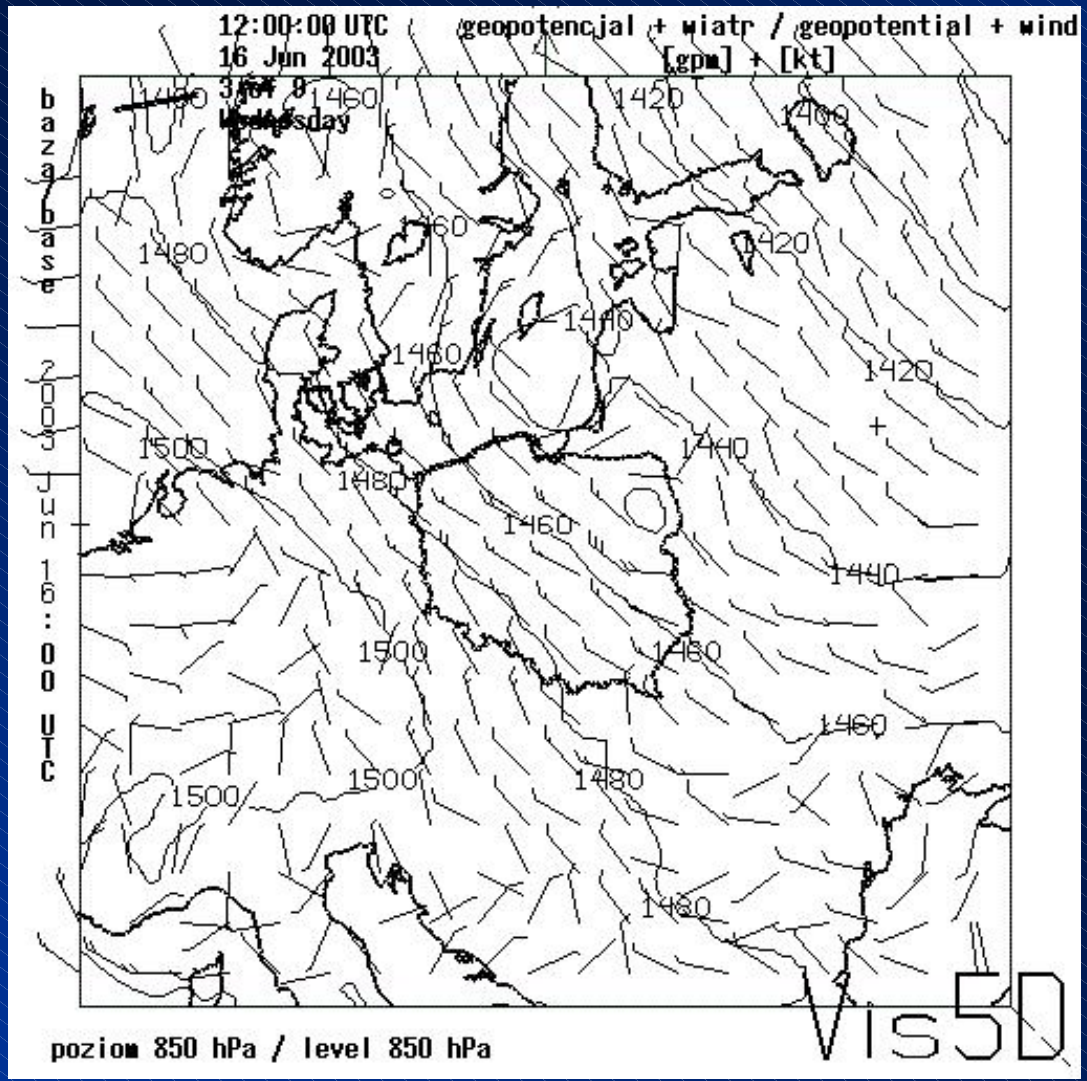


Temperature



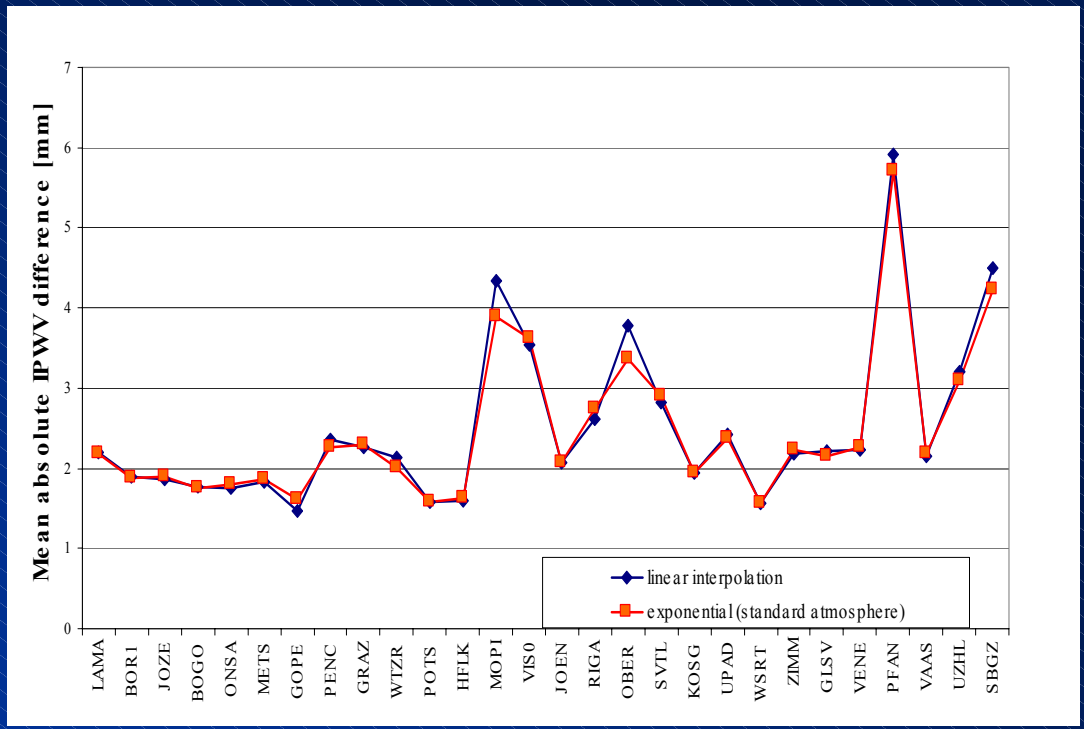


Aladin model (Meteo France) – IMGW Kraków

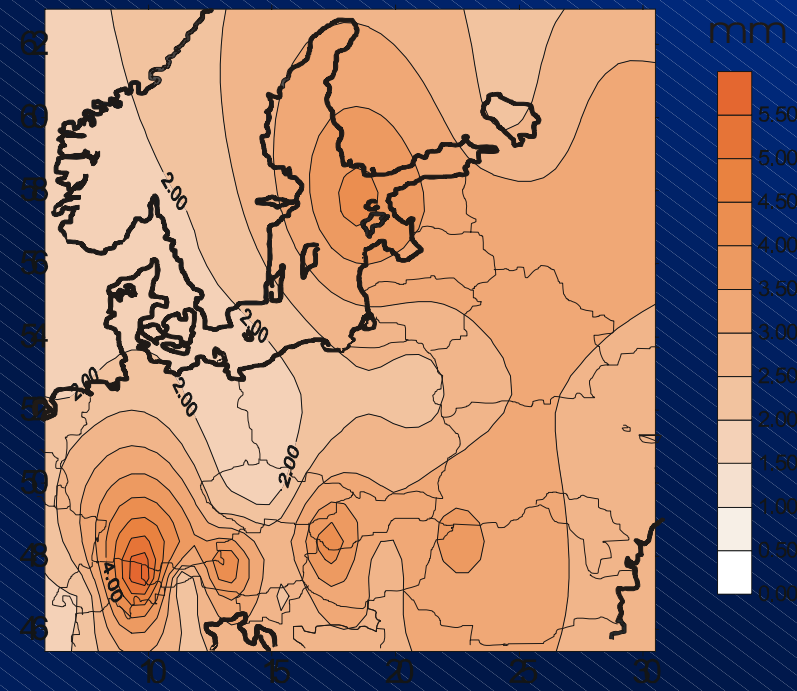


Comparing GPS IPW and IPW from UMPL Numerical Weather Prediction model (T=0 prognosis step, after assimilation; using time and space interpolation from model grid to station position) we get mostly negative biases, average absolute difference depends upon solution quality (both EUREF & IGS stations smaller then merely EUREF) and other factors. Some stations show distinctly greater difference (see below: comparisons for 4 individual stations and map of average differences during 5 warm months in 1999).

IPW differences UMPL vs. GPS

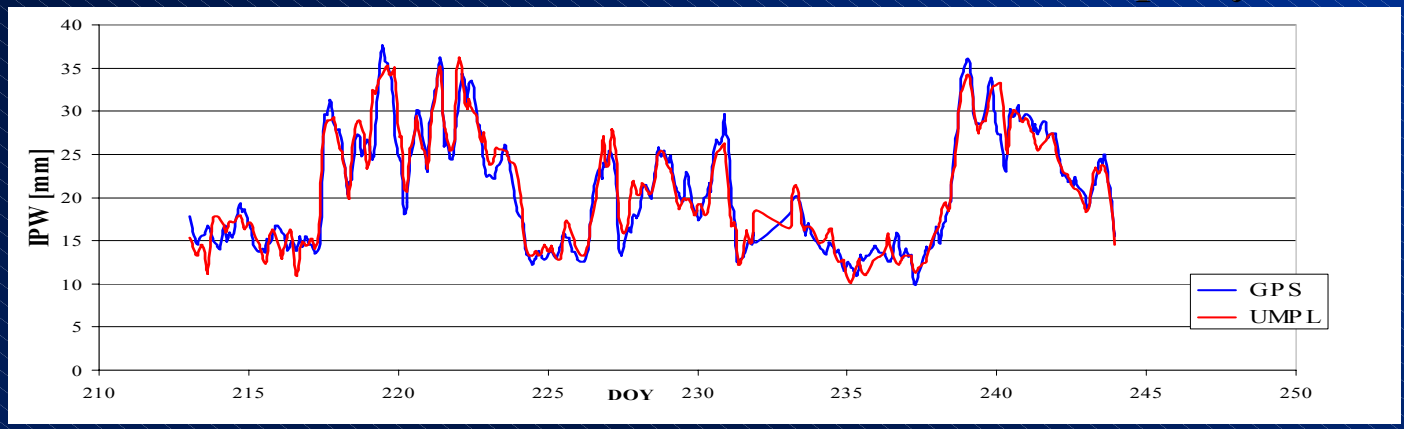


Height interpolation methode impact on differences



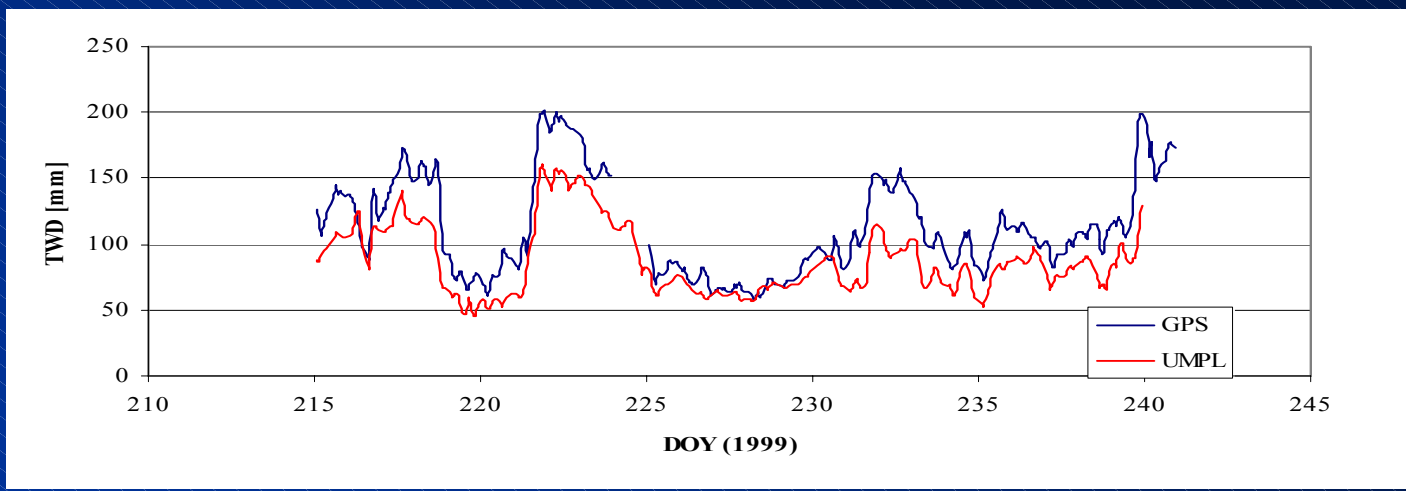
Average differences map

GPS and UMPL model derived IPW for exemplary stations

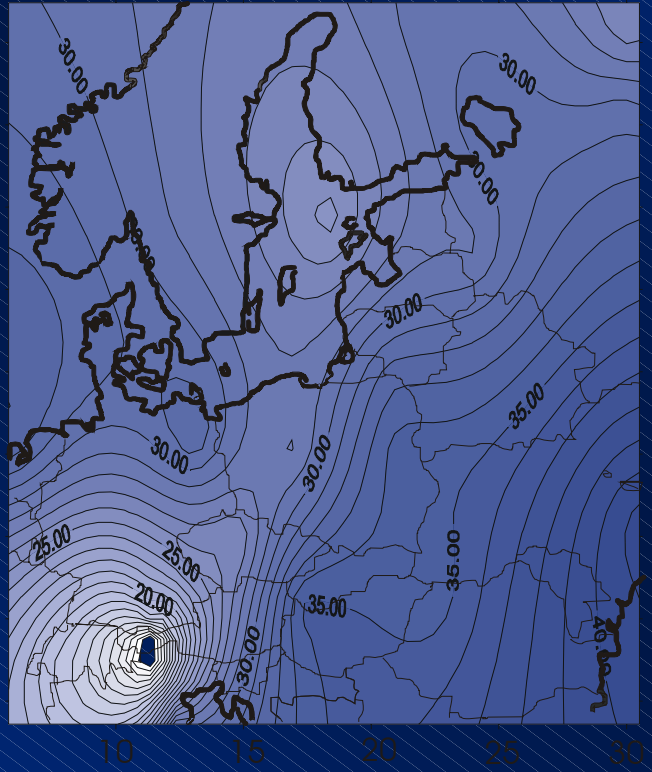


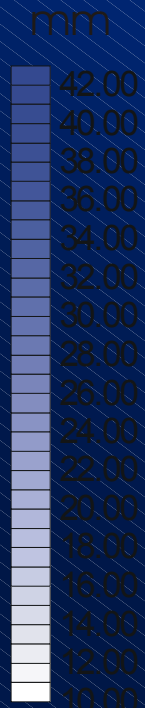
IPW - JOZE
Aug 1999

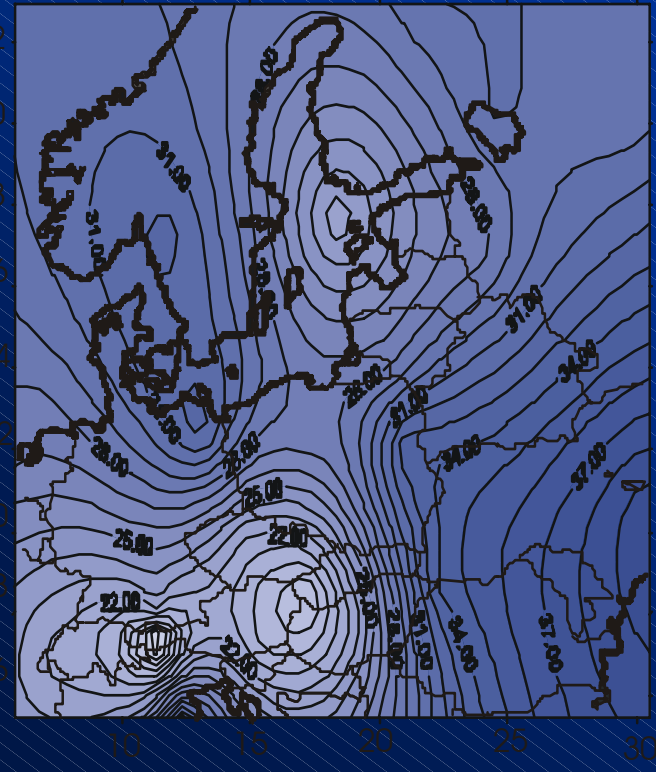
IPW – BOR1
Sept 1999



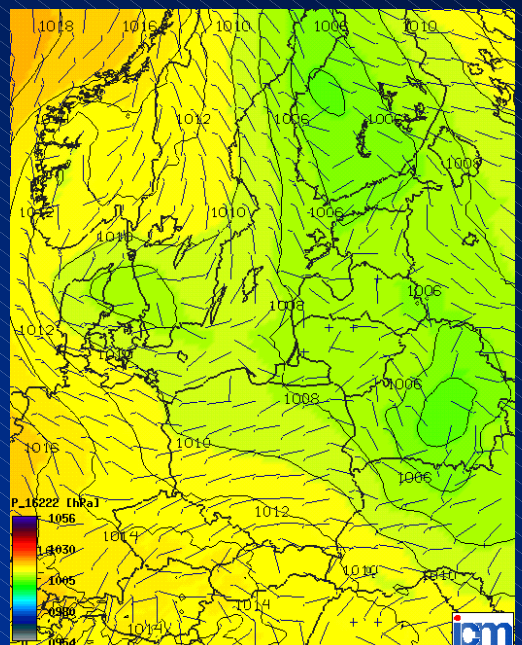
ZWD - METS
Aug 1999

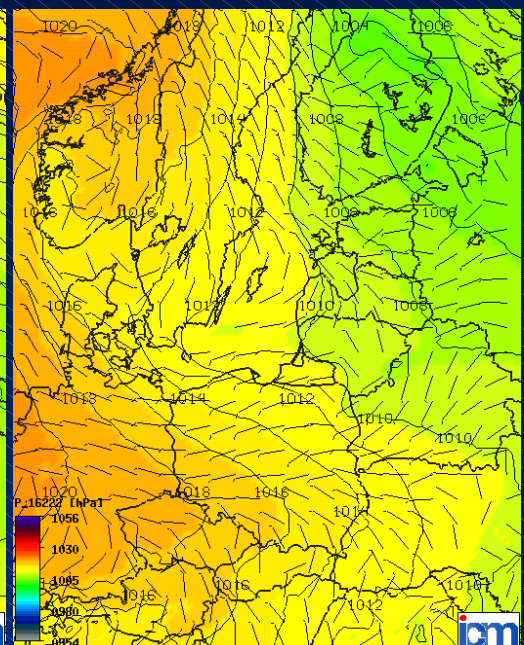






15.00 TU





23.00 TU

Densification of the Permanent Network in Poland

Dense GPS net concept cenceived in 2000: Utilisation of Polish national meteorology institute (IMGW) points national geophysical instrument concept could be implemented

Meteorological stations (small black dots) operate Internet connection and are managed by qualified staff so they can be additionally equiped with GPS receiver

Acknowledgements:

- **dr Bogumił Jakubiak (ICM) – UMPL NWP model data**
- **doc. Zenobia Lityńska (IMGW) – radiosounding data**
- **KBN – grants 8 T12E 008 20 and**
  'OPRACOWANIE I WDROŻENIE SYSTEMU WYZNACZANIA ZAWARTOŚCI PARY WODNEJ W CZASIE PRAWIE RZECZYWISTYM NA PODSTAWIE OBSERWACJI PERMANENTNYCH GPS'