GNSS meteorology

Jaroslaw BOSY

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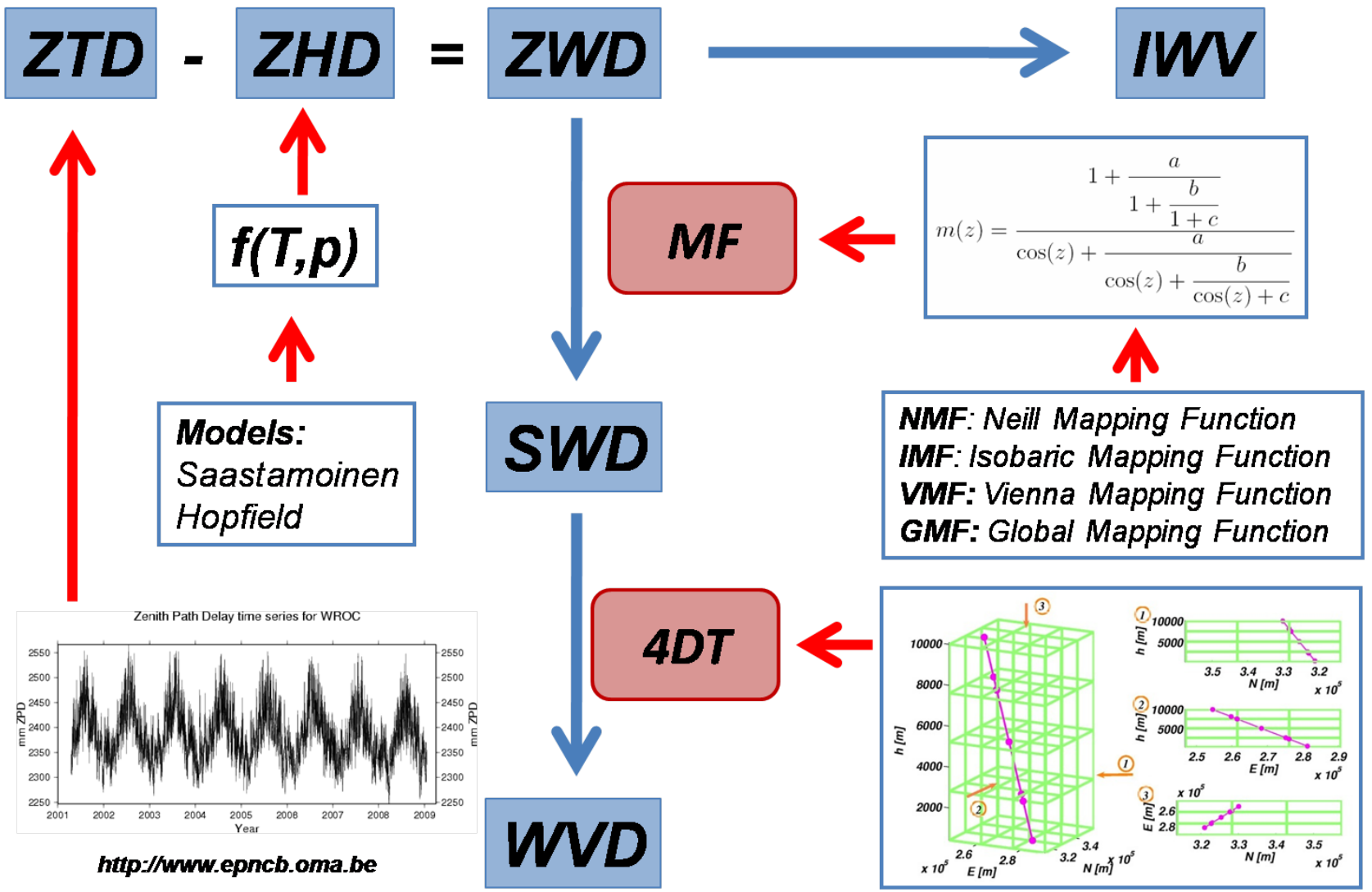
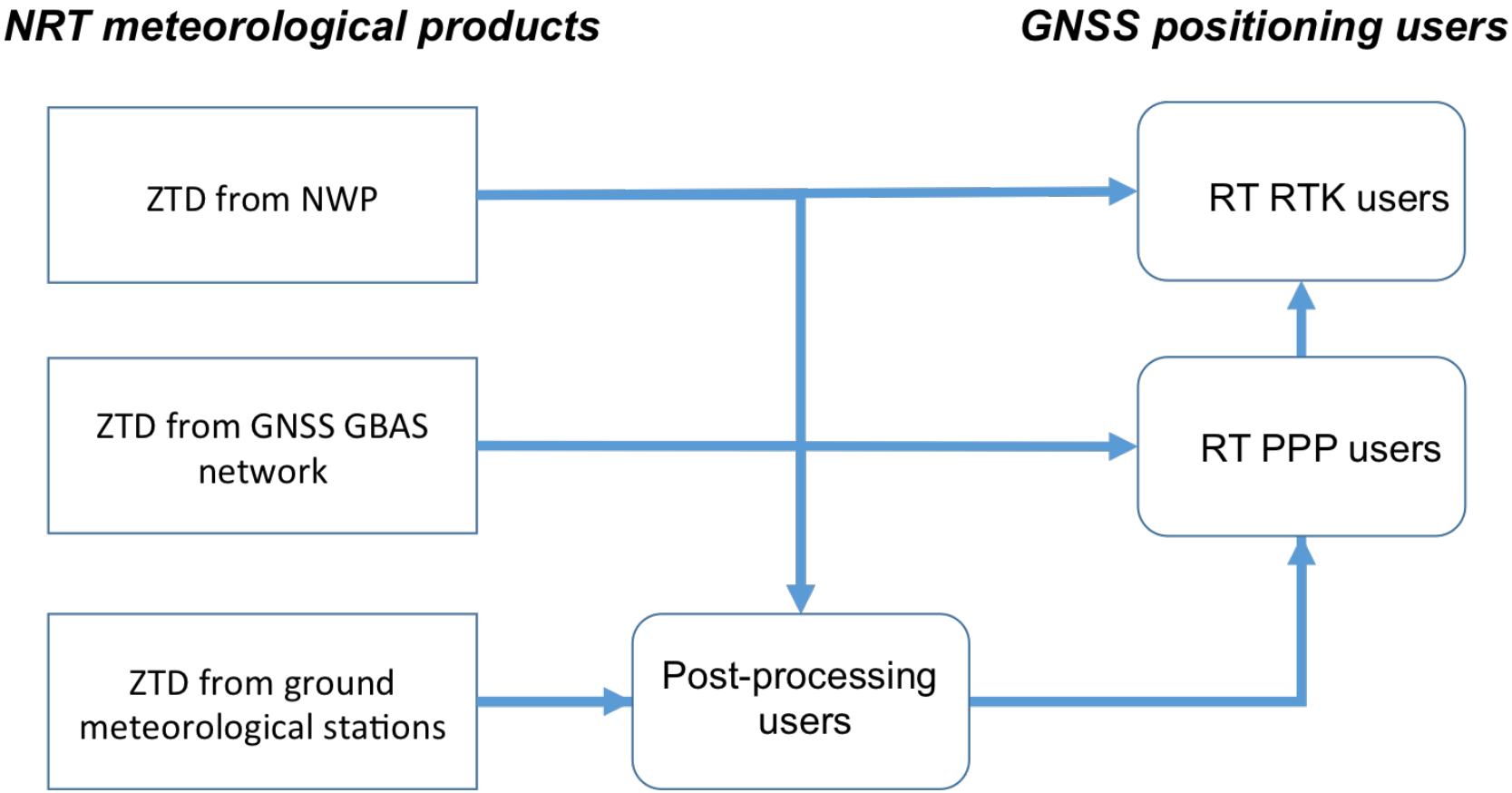
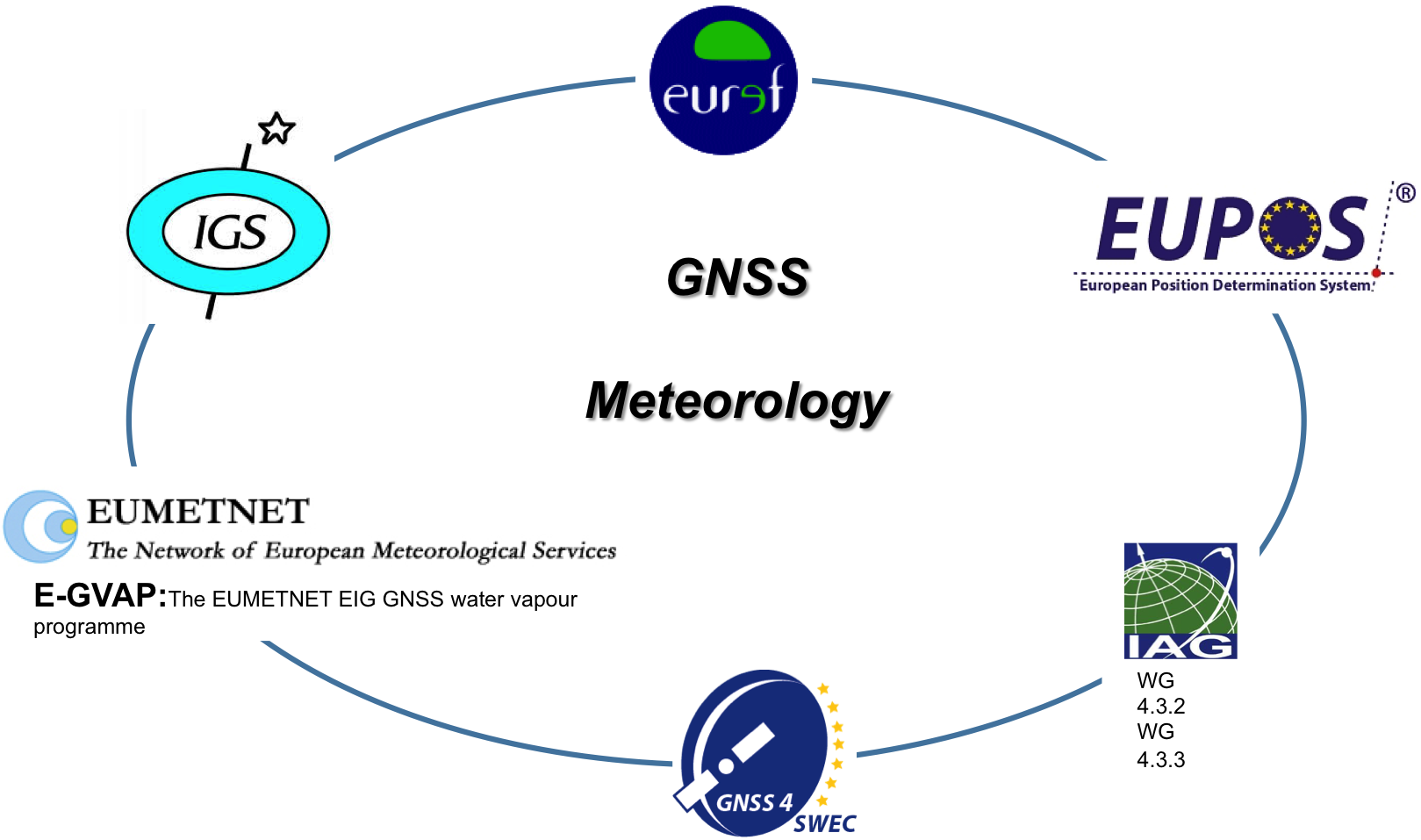


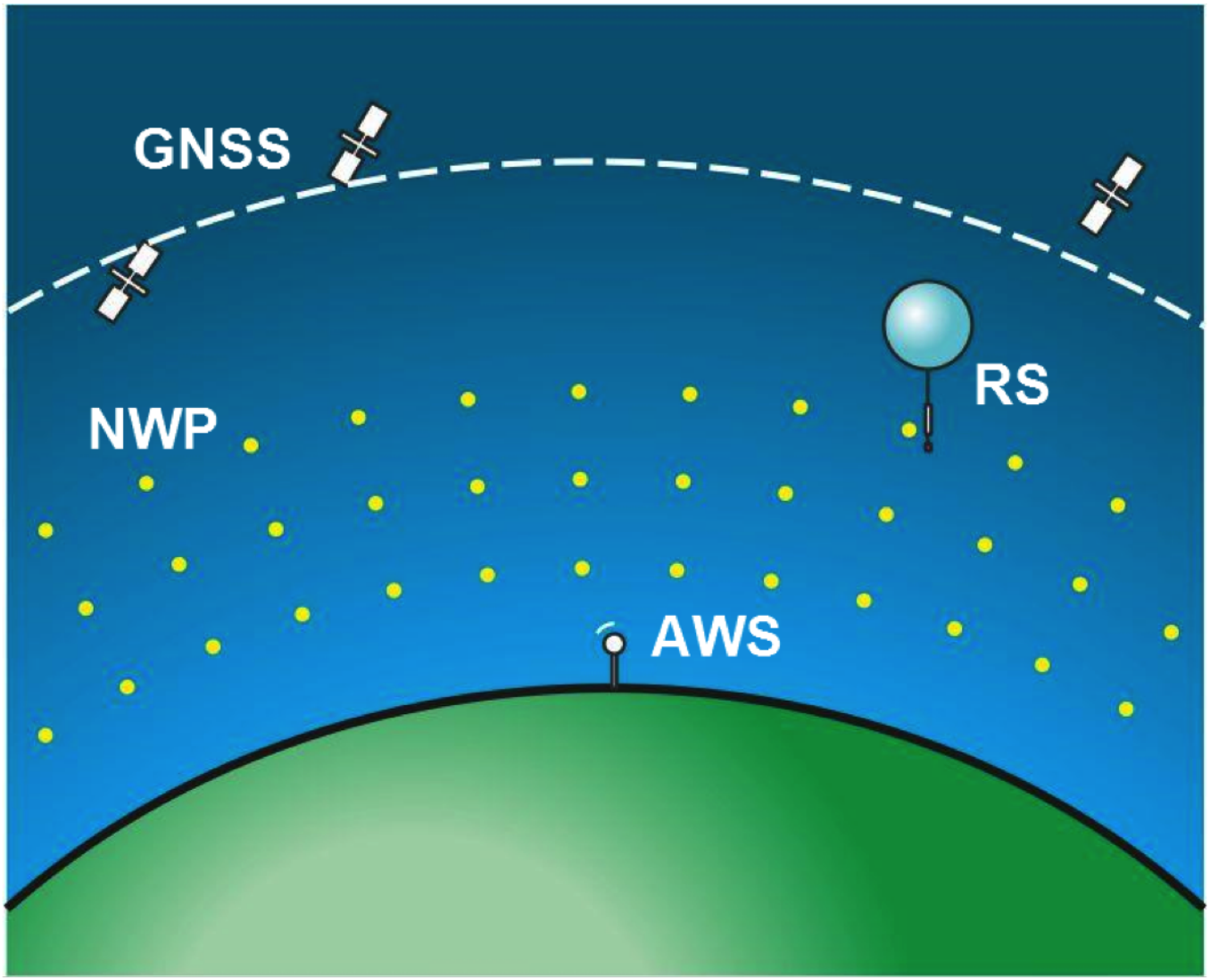
GNSS - METEO motivation



GNSS and METEO comunity



GNSS and METEO data

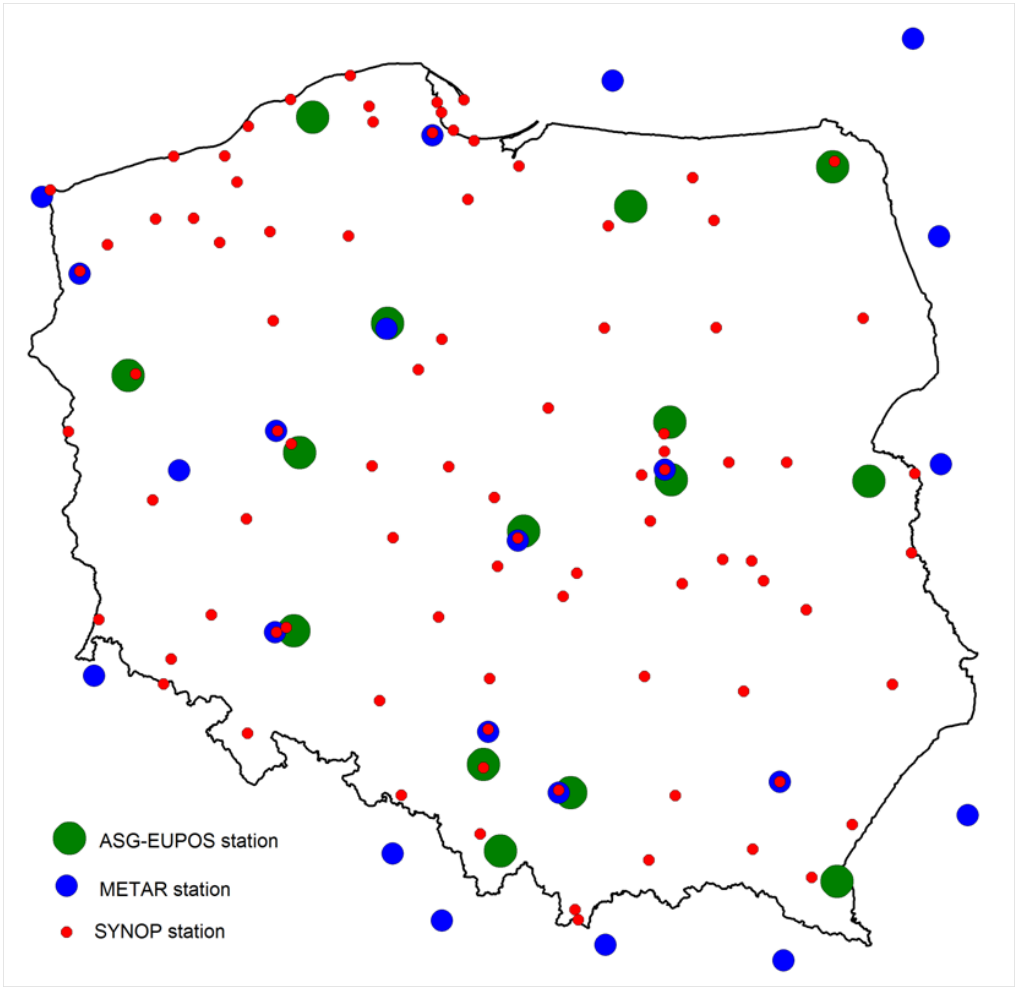


GBAS - **Active GeodeticNetwork ASG-EUPOS**

ASG-EUPOS - 2014:

- 50 Polish GPS reference stations;
- 52 Polish GPS/GLONASS reference stations;
- 23 Foreign EUPOS reference stations;
- 16 Polish reference stations included in the network EUREF Permanent Network.

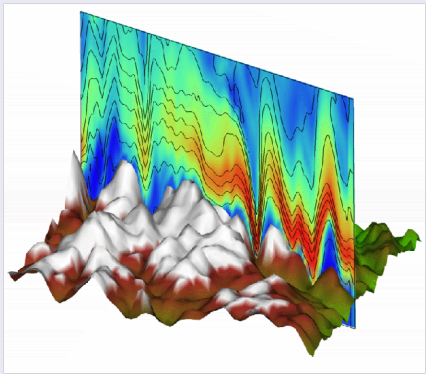
Ground meteorological data - 3



NWP models

COAMPS model

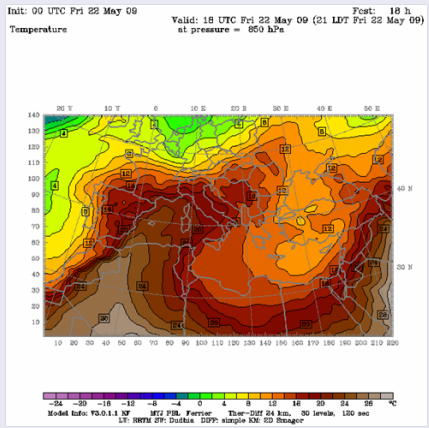
The Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS) has been developed by the Marine Meteorology Division (MMD) of the Naval Research Laboratory (NRL). The atmospheric components of COAMPS, described below, are used operationally by the U.S. Navy for short-term numerical weather prediction for various regions around the world.



A three-dimensional depiction of a severe localized windstorm in an isolated valley within the Alpine mountains *(http://www.nrlmry.navy.mil/coamps-web/web/home)*

WRF model

The Weather Research and Forecasting (WRF) Model is a next generation mesoscale model, designed to serve both operational forecasting and atmospheric research needs. WRF has been collaboratively developed by NCAR, NCEP, FSL, AFWA, NRL, OU and FAA.



WRF in National Observatory of Athens: 850 hPa temperature over Europe
(http://cirrus.meteo.noa.gr/forecast/wrf/index.htm)

GNSS meteorology

The ground based GNSS meteorology is based on the tropospheric delay, one of the results of GNSS data processing . The tropospheric delay is represented by the Zenith Total Delay ZTD. The ZTD can be split into hydrostatic ZHD and wet ZWD component of the delay:

$$ZTD = ZHD + ZWD$$

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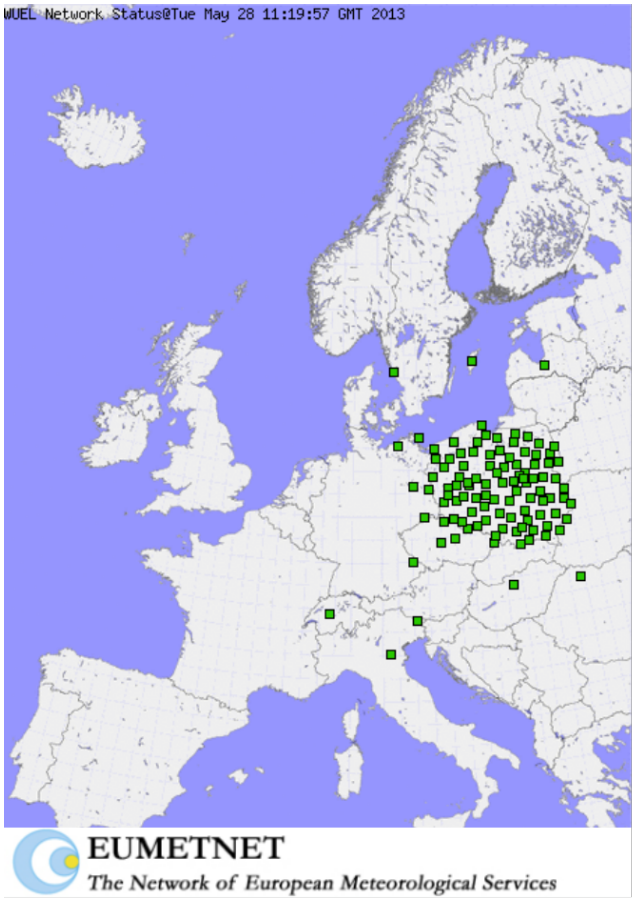
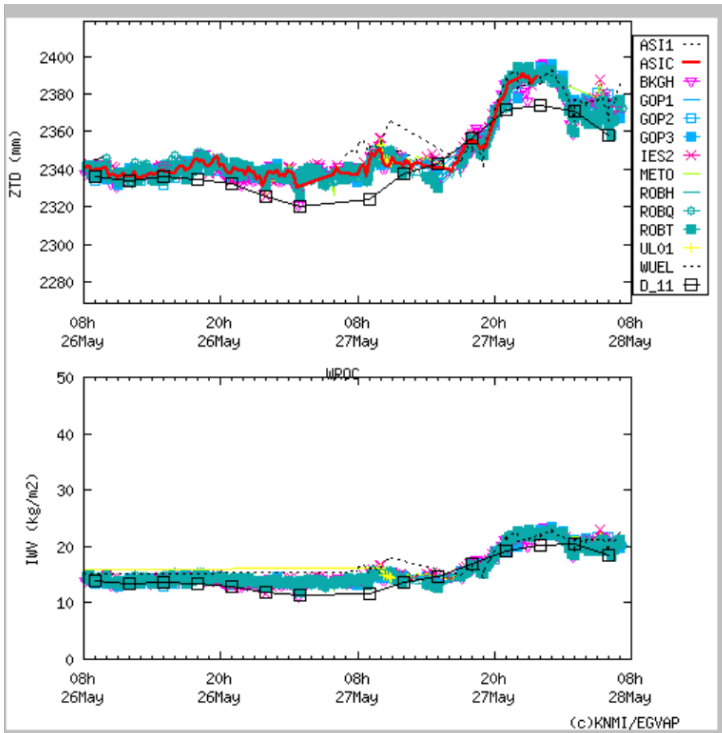
The wet component of Zenith Tropospheric Delay ZWD is the foundation for computing of water vapor content in the atmosphere. The relation between ZWD and the water vapor content in atmosphere is expressed by IWV (Integrated Water Vapor) and given by the equation:

$$IWV = \frac{ZWD}{10^{-6} \cdot R_w} \left(k_2' + \frac{k_3}{T_M} \right)^{-1}$$

where R_w is the specific gas constant for water vapor, k_2', k_3 are refraction constants and T_M is weighted mean water vapor temperature of the atmosphere.

E-GVAP The EUMETNET EIG GNSS water vapour programme





HIRLAM(KNMI) AN - GPS ZTD

7day stat. 2013/05/19 - 2013/05/27

AC	num	bias	RMS	stddev
ASIC	54	6.8	10.4	7.9
GOP1	54	6.2	10.3	8.2
METO	54	6.5	11.1	9.0
ROBH	54	7.9	11.7	8.7
TEST				
ASI1	54	6.6	10.6	8.3
BKGH	54	4.9	10.6	9.4
GOP2	54	5.8	10.6	8.9
GOP3	54	6.5	10.8	8.7
IES2	50	6.5	11.1	9.0
ROBQ	54	10.6	14.6	10.1
ROBT	54	9.0	14.4	11.2
UL01	39	2.2	14.5	14.3
WUEL	46	6.2	11.8	10.0

Notes

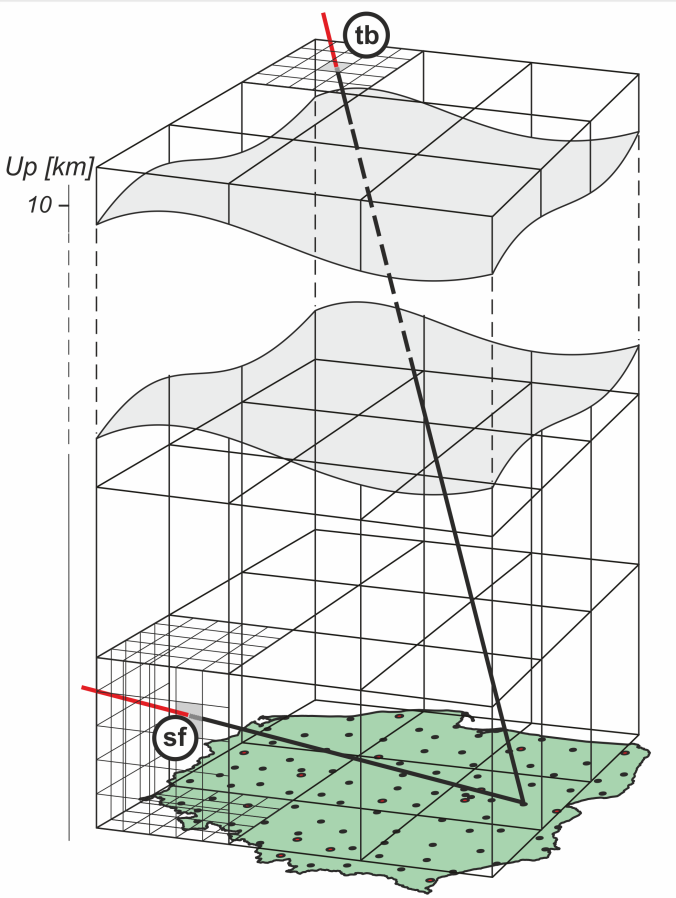
- Statistics are updated daily
- GPS ZTD are interpolated to NWP analysis time

Graphical location of the site

latitude	51.11330
longitude	17.06200
altitude	140.54

http://egvap.dmi.dk/

3D WV WUELS GNSS tomography model



The ray path in consecutive voxels. Two cases are cons idered, the first when the ray is coming out of the model?s side face (sf), and the second, when ray is coming out of the model top boundary (tb)

- **Model A: Constrained GNSS troposphere tomography model**

$$N_w = (A^T \cdot P \cdot A)^+ \cdot A^T \cdot P \cdot SWD$$
$$(A^T \cdot P \cdot A)^+ = V \cdot S^+ \cdot U^T$$

where the $P = {C_{SWD}}^{-1}$ is a weighting matrix.

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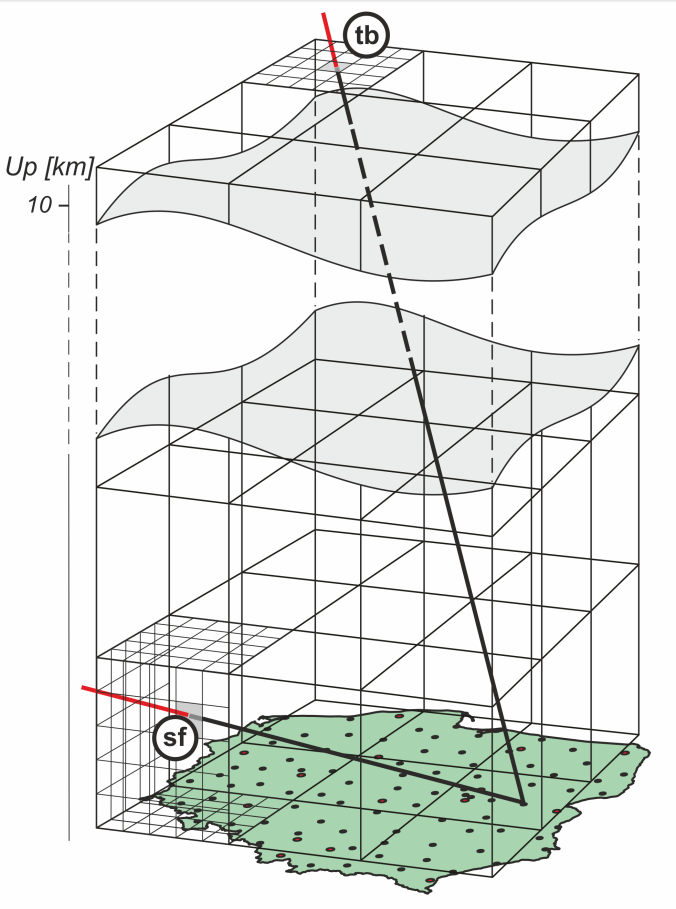

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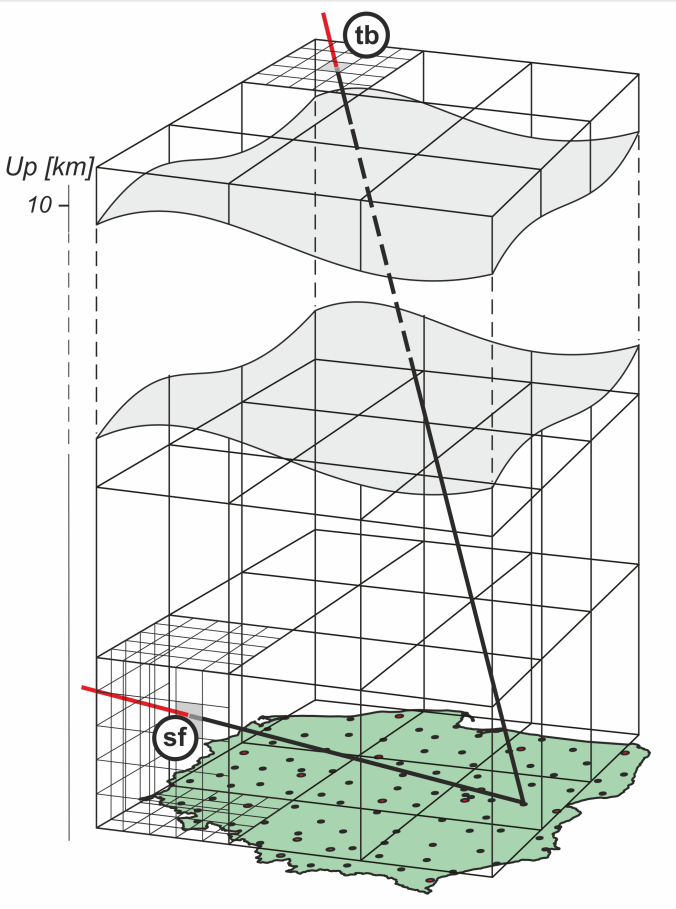
- **Model B: Unconstrained GNSS troposphere tomography model**

$$\Delta N_w = (A^T \cdot A)^+ \cdot A^T \cdot \Delta SWD$$
$$(A^T \cdot A)^+ = V \cdot S^+ \cdot U^T$$
$$N_w = N_{wapriori} + \Delta N_w$$

3D WV WUELS GNSS tomography model



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$$(A^T \cdot A)^+ = V \cdot S^+ \cdot U^T$$
$$N_w = N_{wapriori} + \Delta N_w$$

- **Model C: Unconstrained robust Kalman filtering GNSS troposphere tomography model**

ECOST Action ES1206 - GNSS4SWEC - http://gnss4swec.knmi.nl

http://gnss4swec.knmi.nl

COST Action ES1206 - ***Advanced Global Navigation Satellite Systems tropospheric products for monitoring severe weather events and climate*** (***GNSS4SWEC***)

17 May 2013 – 16 May 2017

chair Dr. Jonathan Jones
vice-chair Dr. Guergana Guerova

Working Group 1: ***Advanced Processing Techniques***

Working Group 2: ***Use of GNSS tropospheric products for high resolution NWP and sever weather forecasting***

Working Group 3: ***Use of GNSS tropospheric products for climate monitoring***

Established the Wroclaw University of Environmental and Life Sciences (WUELS) GNSS GNSS & METEO group (http://www.igig.up.wroc.pl/igg)

GNSS

dr. J. Kapłon

prof. J. Bosy

METEO

dr. W. Rohm

PhD students

T. Hadaś

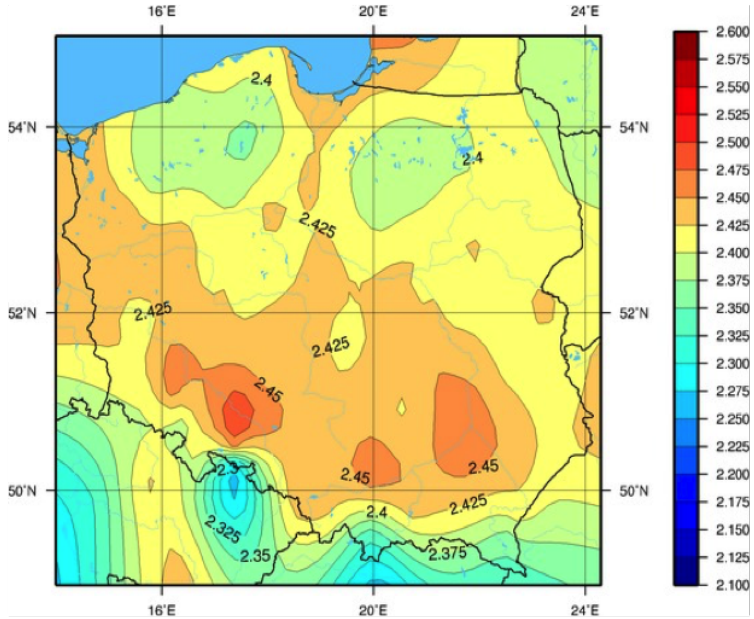
K. Kaźmierski

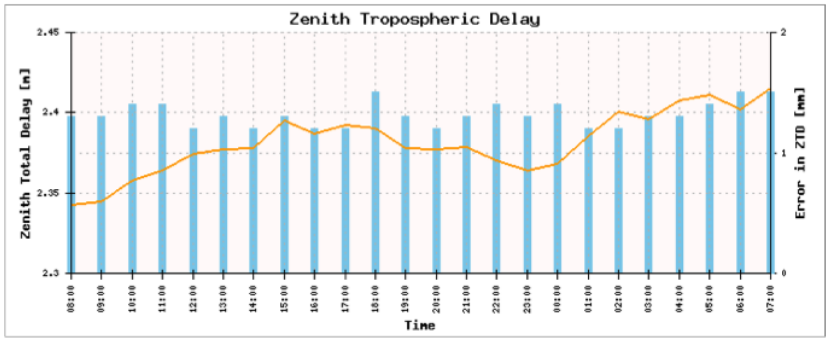
J. Sierny

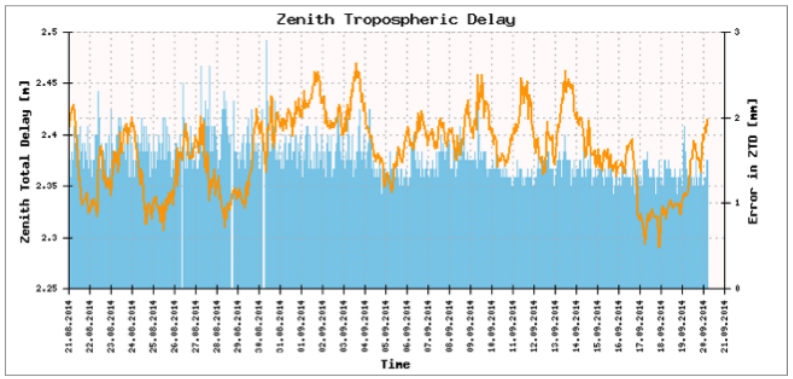
K. Wilgan

P. Hordyniec

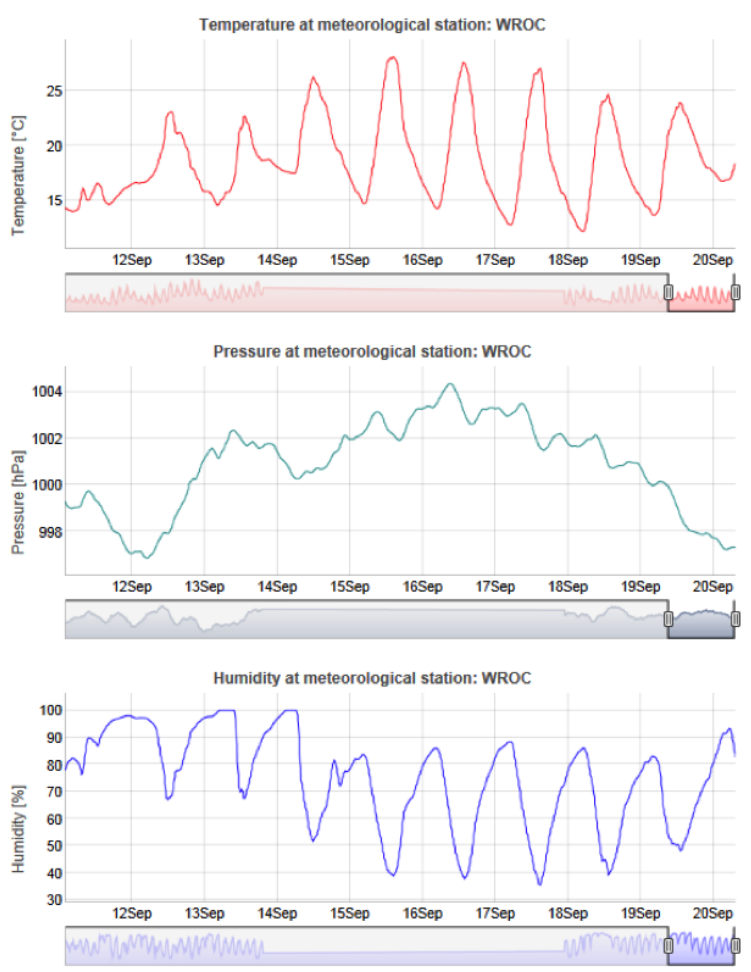
IGGHZ-G:
http://www.igig.up.wroc.pl/igg/?menu=GNSS&submenu=Products



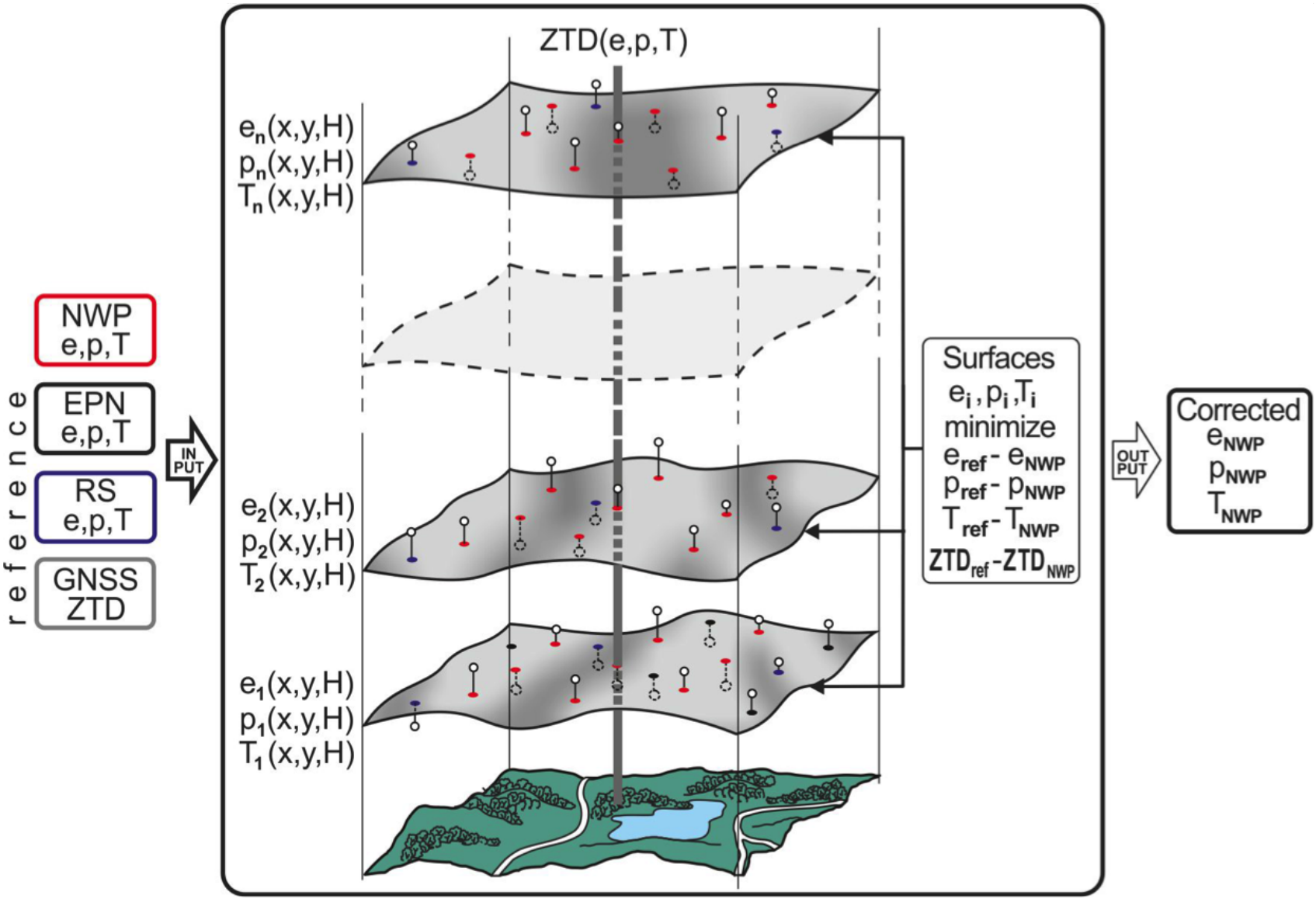




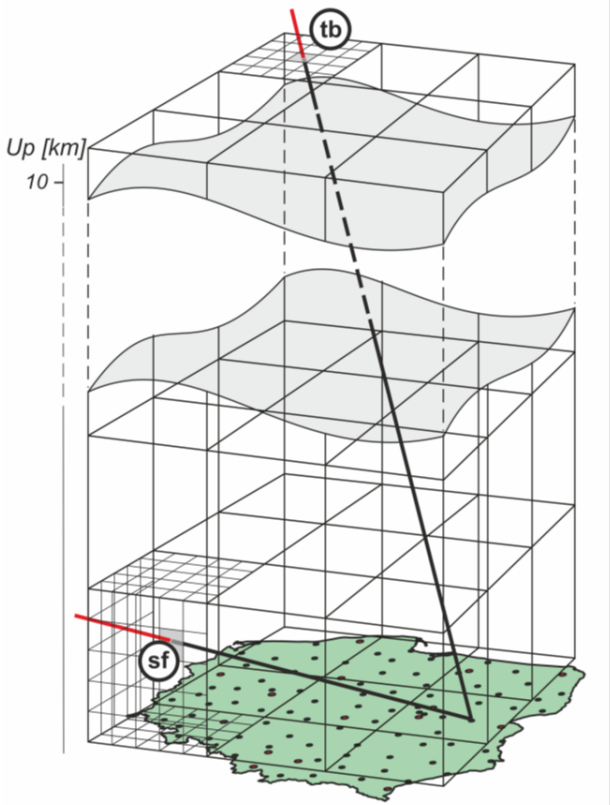
IGGHZ-M:
http://www.igig.up.wroc.pl/igg/?menu=METEO&submenu=Products

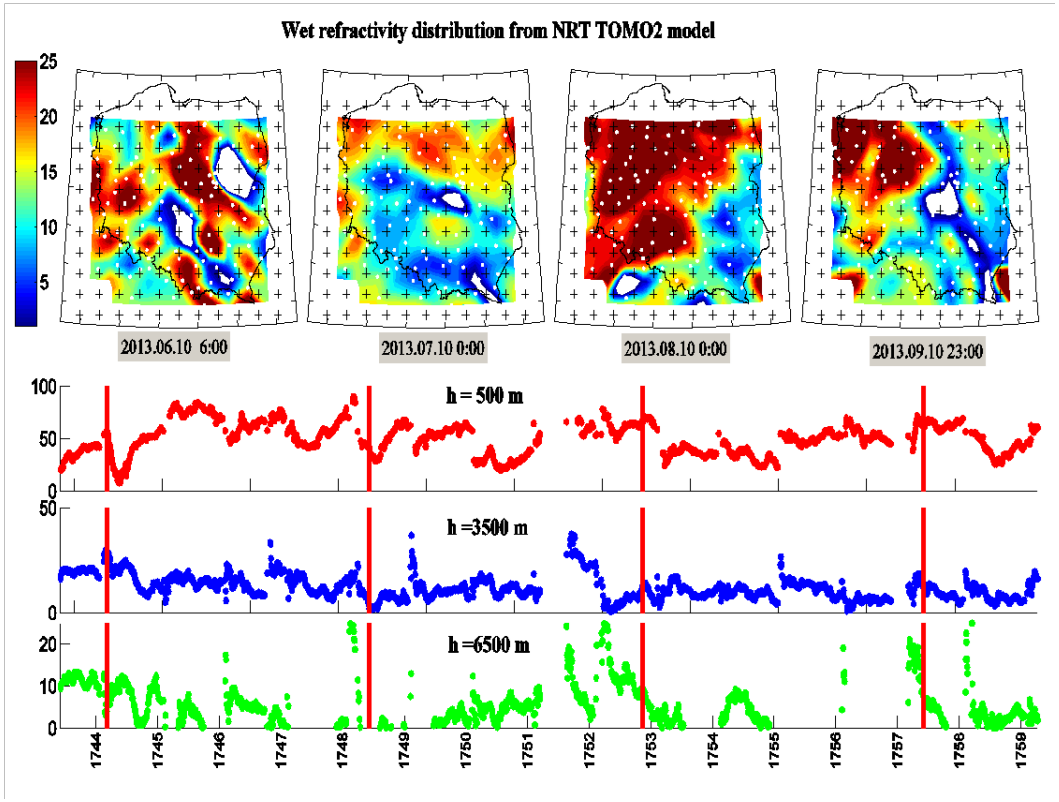


Integrated troposphere model



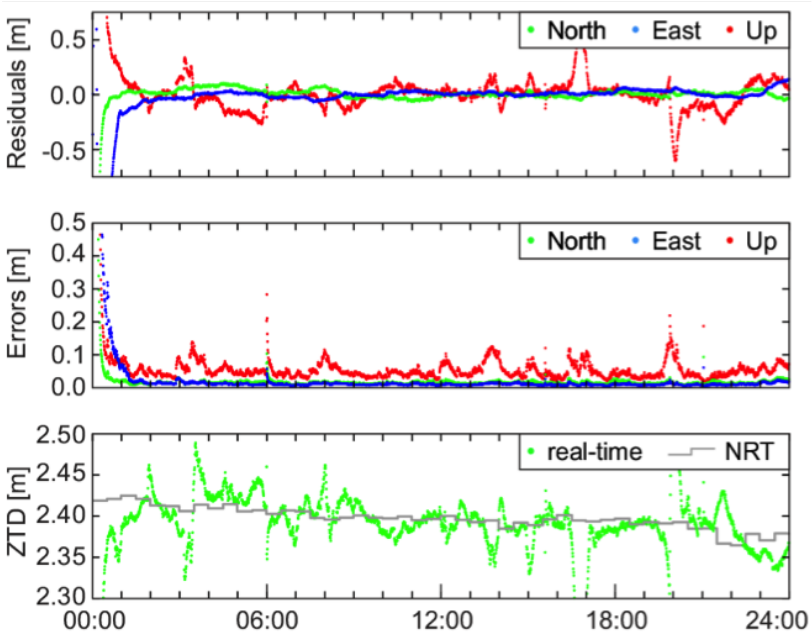
TOMO2: 3D NRT GNSS tomography model for area of Poland



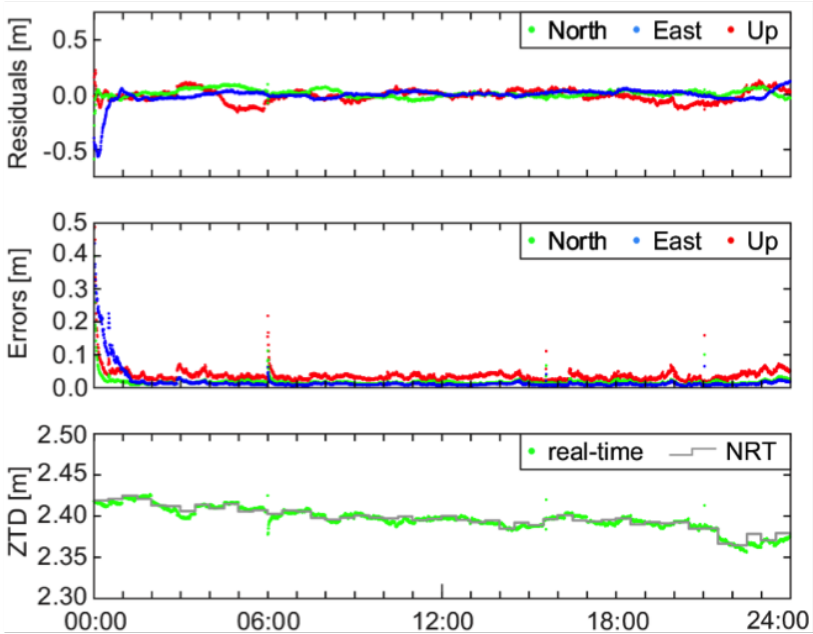


Preliminary tests using of NRT ZTD as an input in GNSS-WARP software

Solution with ZTD estimation



Solution with NRT ZTD input



Current projects:

- **National Science Centre grant PRELIDIUM UMO-2012/07/N/ST10/03716** "*Improving the methods of real-time GNSS satellite precise positioning*" 2013-2015 (Tomasz Hadas);

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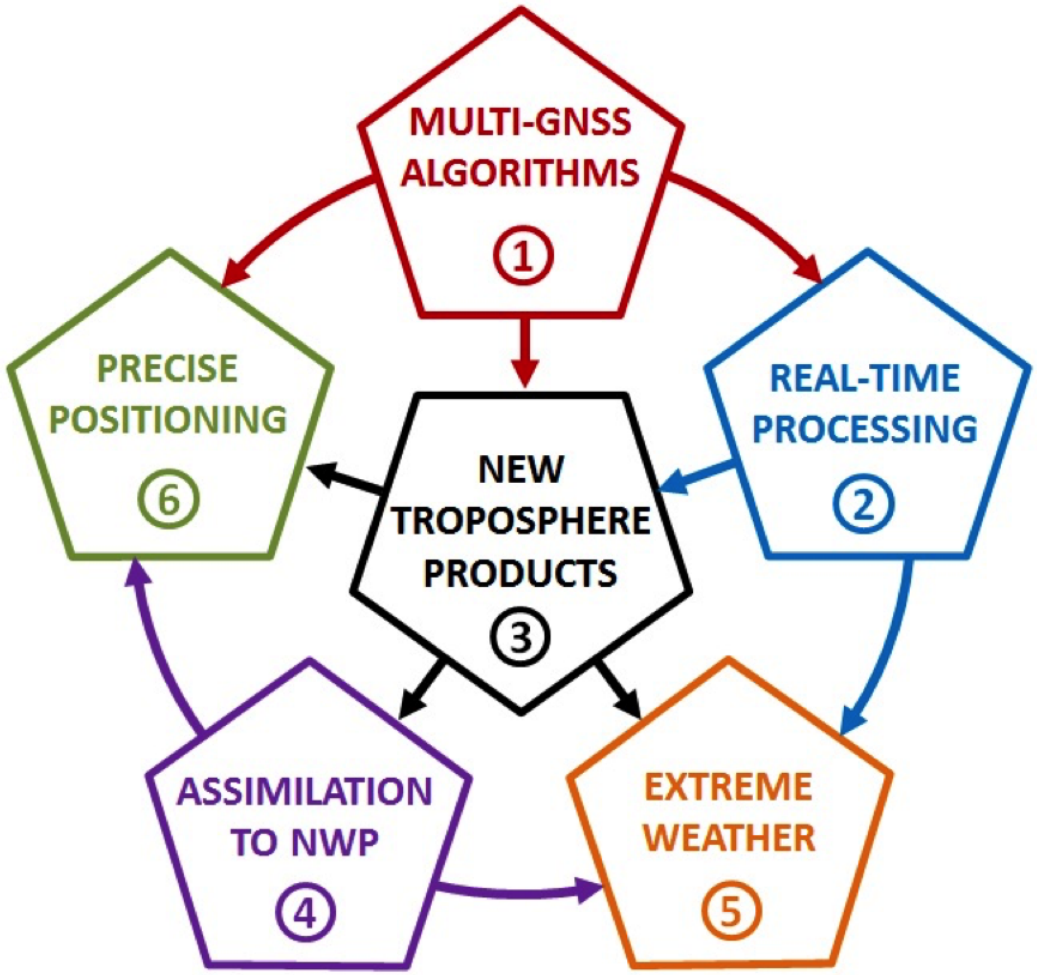
- **ESA Contract No. ESA ITT AO/1-7824/14/NL/CBi** "*Higher Order Ionospheric modelling campaigns for precise GNSS applications (HORION)*" 2014-2016 (Jaroslaw Bosy, Jan Kaplon, Tomasz Hadas, Kamil Kazmierski);

Harmony Project Advanced GNSS Tropospheric Products for monitoring Severe Weather Events and Climate (*GNSS4SWEC*)



Project ITN-EJD

European Joint Doctorate programme in Marie Skłodowska-Curie action:

Multi-GNSS applications for Earth System monitoring (mGNSS-4ES)

Leader - WUELS Wroclaw, Poland (Jarosław Bosy, Witold Rohm)
Participants (level 1):
UWM Olsztyn, UPC-IonSAT Barcelona, TU Berlin, TU Munich/DGFI, TU Vienna, AU Thessaloniki, U Newcastle, U Sofia, U Luxembourg, Chalmers University of Technology
Partners (level 2): UNB, OSU, RMIT, ROB, NCU Taiwan, GFZ, MetOffice, U Wroclaw, U Wuhan

Major research and study topics :

- Troposphere sensing and modelling (e.g. real-time troposphere retrievals for nowcasting and rapid update cycle forecasting, multi-GNSS troposphere tomography; boundary layer RO retrievals),
- Ionosphere sensing and modelling (e.g. real-time monitoring; 3D/4D modelling; ionosphere corrections for positioning),
- Geodesy and geodynamics (e.g. ionosphere and troposphere corrected multi-GNSS PPP and relative positioning),
- Ocean studies (e.g. wind and ocean current studies using reflectometry).

Thanks for your attention

jaroslaw.bosy@up.wroc.pl