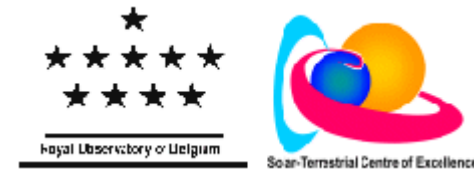


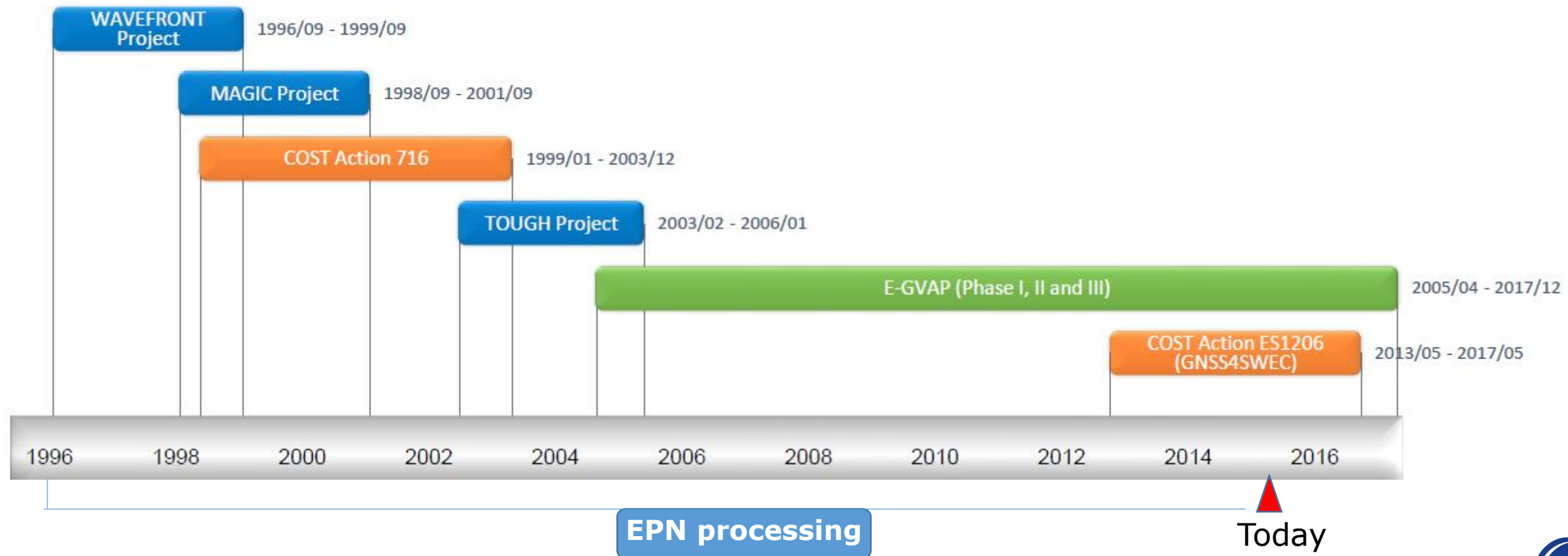
## **COST Action ES1206**

### ***Advanced Global Navigation Satellite Systems tropospheric products for monitoring severe weather events and climate (GNSS4SWEC)***

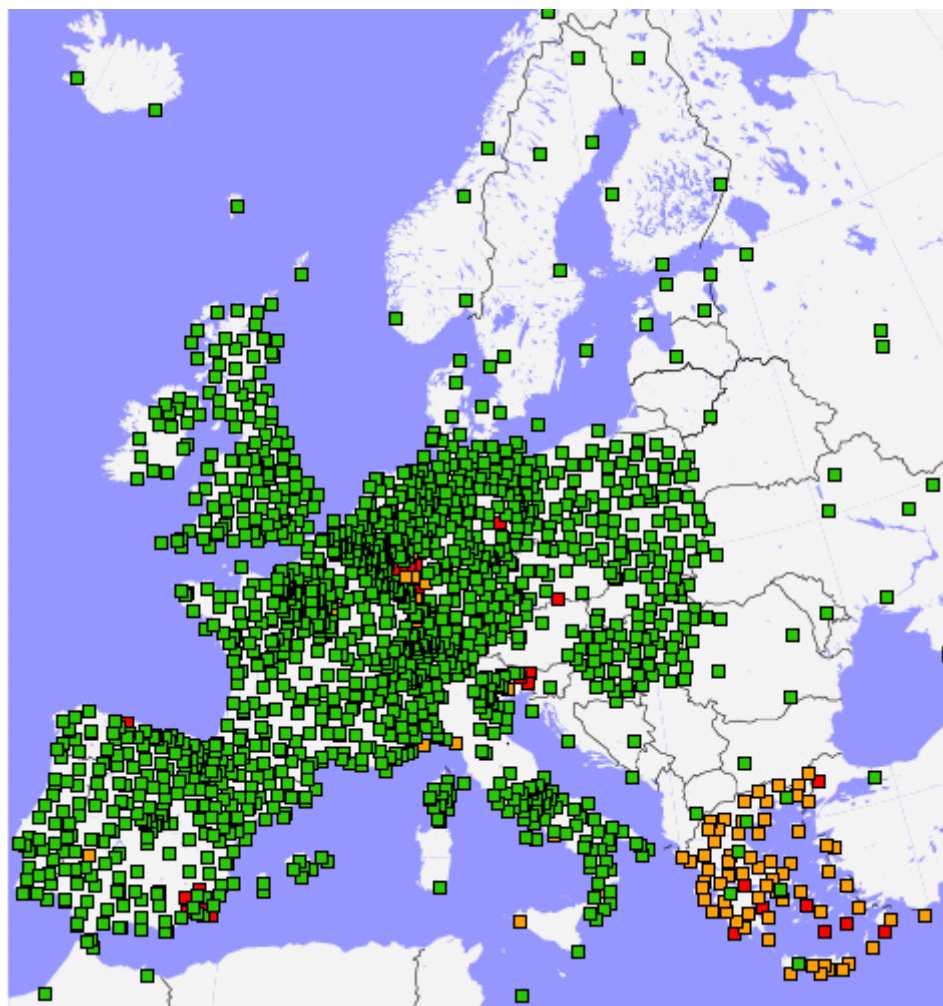
R. Pacione, J. Jones, G. Guerova, J. Dousa, G. Dick, S. De Haan, E. Pottiaux, O. Bock, G. Elgered, H. Vedel



# Timeline of European GNSS-Met Projects



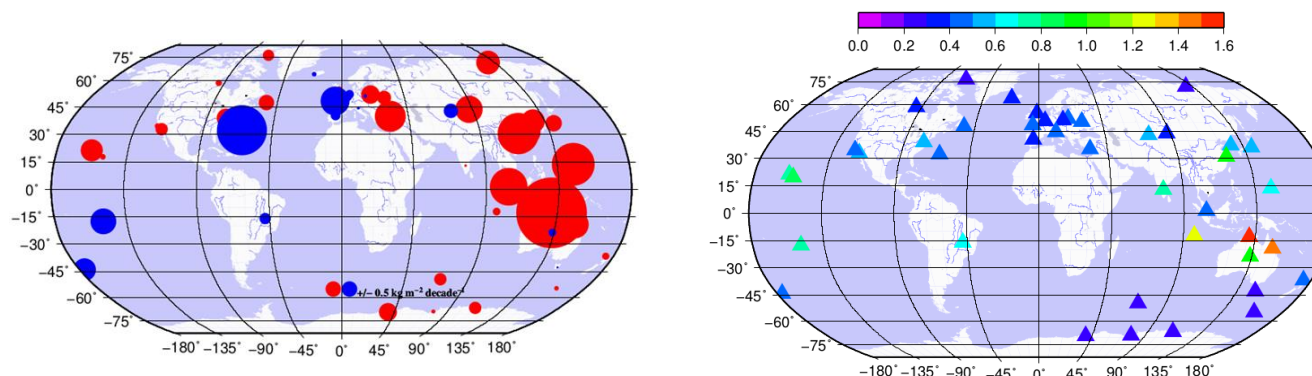
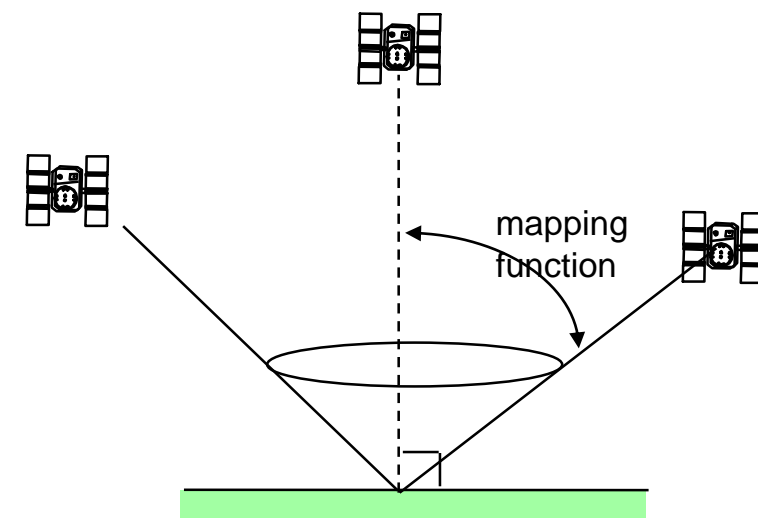
# Current Status E-GVAP

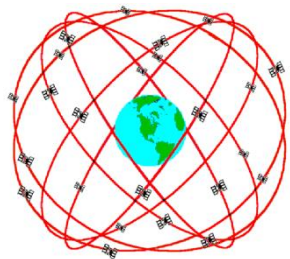


- *EIG EUMETNET Project coordinating the **near real-time** delivery of data from ~2400 GPS sites delivering > **14M ZTDs pcm***
- Focus is on GPS-only **hourly processing**, delivering only ZTD **in 90mins**
- **Operational assimilation** at a few European National Met Services, many others under testing.
- Use of E-GVAP ZTDs has proven positive impact on NWP forecast skill
- Surface T and P used for conversion to Integrated precipitable Water Vapour (**IWV**)
- Active Quality Control (**AQC**) in place
- **MoUs** in place with **EUREF** and **EUPOS**

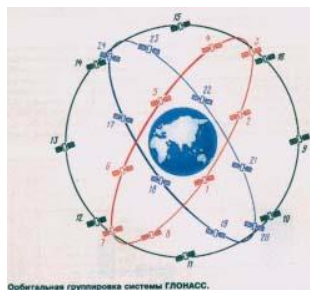
# Developing Meteorological Requirements

- ZTD only gives you integrated column total measurement from 'cone of observation'
- New hi-resolution NWP models require ZTD with **improved timeliness** and greater spatial and temporal resolutions than are currently available (e.g. Met Office UKV 1.5km)
- Observations providing additional information concerning tropospheric water vapour are desired (i.e. **vertical resolution and azimuthal anisotropy**)
- **Sub-hourly processing** greatly increases the usefulness of GNSS products for nowcasting and IWV displays
- **Climate community** only now starting to use GNSS tropospheric products



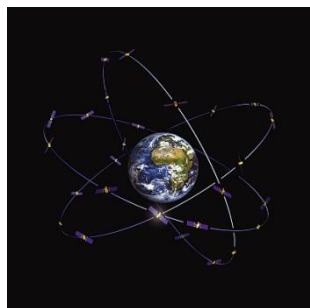


**Multi-GNSS constellations** (GPS + GLONASS, Galileo etc...) = new SV geometries, new frequencies, increased number of observations



Continued R&D working towards more **advanced tropospheric products** (slants, gradients, tomography)

NTRIP **real-time** raw data streaming

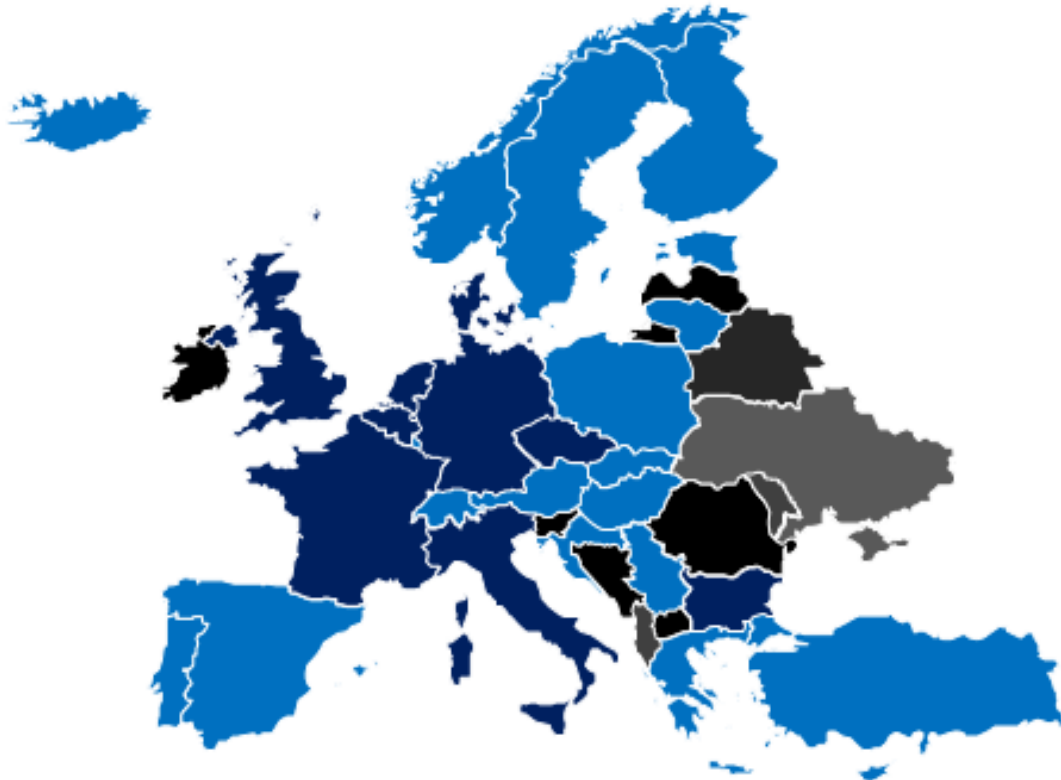


Real time PPP processing

Single frequency processing

**Long-term, homogenised GPS tropospheric products available** (EPN/IGS/CODE/others)

# COST ACTION ES1206 GNSS4SWEC



*Dark Blue: Countries involved in Management Team*  
*Blue: Countries participating in the Action*

4 year Action (2013 – 2017)

29 COST Countries

5 non-EU Countries (USA,  
Canada, Aus, HK, TN)

Over 100 participants from  
60+ institutions

COST funds networking  
activities, not R&D





1

*Coordinate the development of new, multi-GNSS techniques and products.*

2

*Improve the understanding of short-term atmospheric processes.*

3

*Promote the use of, and determine the impact of, re-processed long-term GNSS tropospheric datasets for climate.*

4

*Link its activities to the IGS and EUREF, and work in support of E-GVAP.*

5

*Coordinate the exploitation of GNSS and meteorological data for mutual benefit.*

6

*Lead to a consolidation of collaborating groups.*

**WG1**

*Advanced GNSS processing techniques (AGNSS)*

**WG2**

*GNSS for severe weather monitoring (GNSS4SW)*

**WG3**

*GNSS for climate monitoring (GNSS4C)*





# Working Group 1: Main Goals

## The main goals of the WG1 are defined in four main domains:

- Coordinating of development advanced tropospheric products in support of weather forecasting (ultra-fast products, asymmetry monitoring, tomography, multi constellation processing)
- Reprocessing and model assessment in consistent tropospheric products for climatology
- Exploiting numerical weather data in precise GNSS positioning (mapping functions, a priori ZHD modeling, tropospheric gradients, tropospheric models for real-time positioning, parameter conversions)
- Stimulating transfer of knowledge, tools and data exchange in support of new analysis centres and new networks setup
- **Sub-WG1:** 10 specific activity domains and leaders appointed
- **WG1 members:** 70 members / 25 countries / 4 non-EU partners

# Working Group 1: New

*Goals: Support transfer of knowledge, data exchange for improving coverage of tropospheric products in Europe*

## New ACs

- SGO – Satellite Geodetic Observatory, Penc, Hungary (Bernese)
- KTU – Karadeniz Technical University in Trabzon, Turkey (TropNET)
- AUT – Aristotle University in Thessaloniki, Greece (TropNET)
- BEU – Bulent Ecevit University in Zonguldak, Turkey (TropNET)
- *MUT – Military university of Technology, Warsaw, Poland (TropNET)*
- *SUG – Sophia University, Bulgaria (Uni Luxembourg)*
- + others coming.

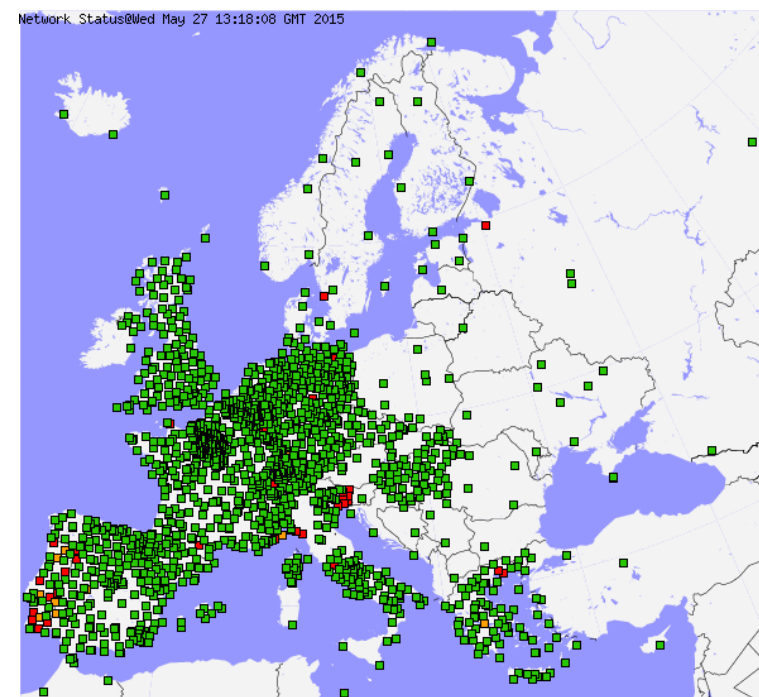
## Supported by:

- GOP - TropNET processing package (Bernese)
- Uni Luxembourg – troposphere example campaign

## New networks for E-GVAP

- Greece, Hungary, Austria (soon), Italy(+)
- + other coming

**TropNET info: <http://www.pecny.cz/> ( Trop-NET )**



# Working Group 1: Bench

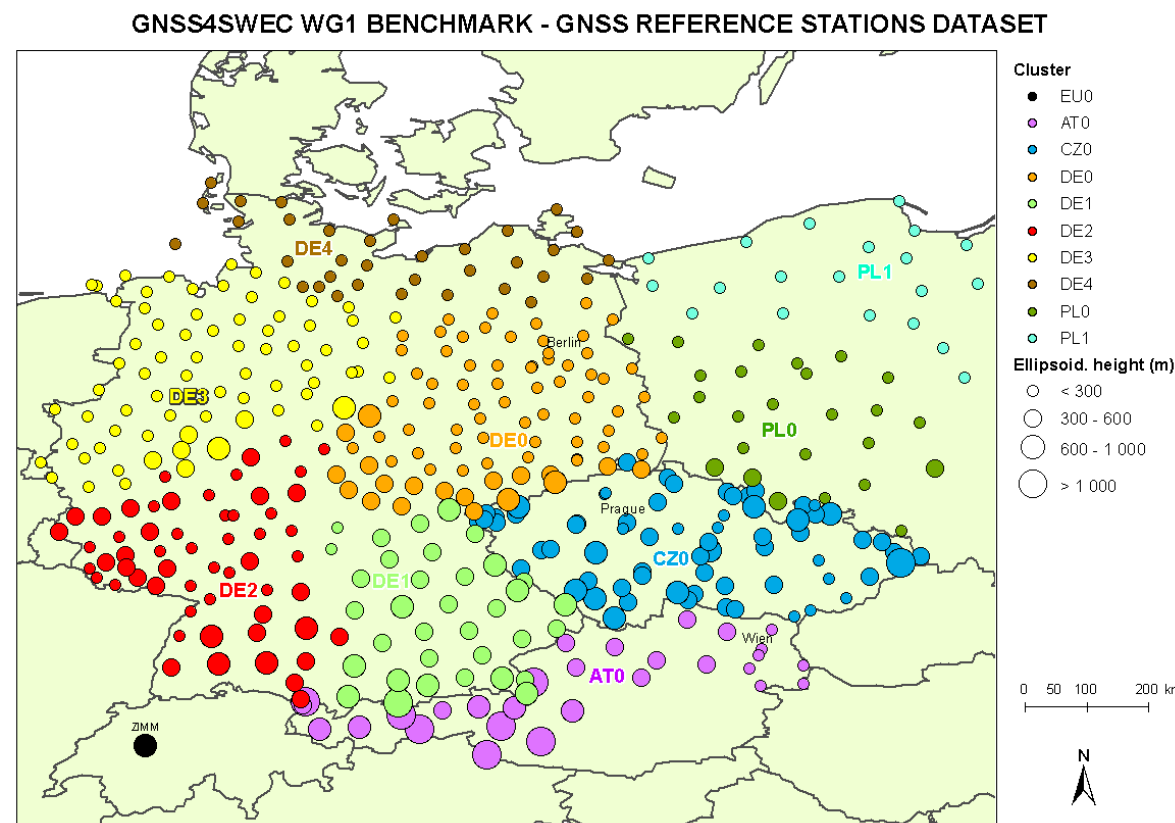
*Goal: Design a common data set for advanced GNSS product and strategy developments, their evaluation and inter-comparisons*

## 1<sup>st</sup> half of the COST Action (achievements)

- ☺ inventory and benchmark design
- ☺ data set almost completed
- Jun-Jul 2013 floods of Danube
- GNSS: ~500 stations
- SYNOP: ~300 stations
- NWM: global, regional
- WVR: Potsdam, Lindenberg

## 2<sup>nd</sup> half of the COST Action

- Contributions & evaluation
- Feedback & interpretations



# Working Group 1: Real Time Demonstration Campaign

*Goal: Develop and assess ultra-fast tropospheric product for NWP nowcasting*

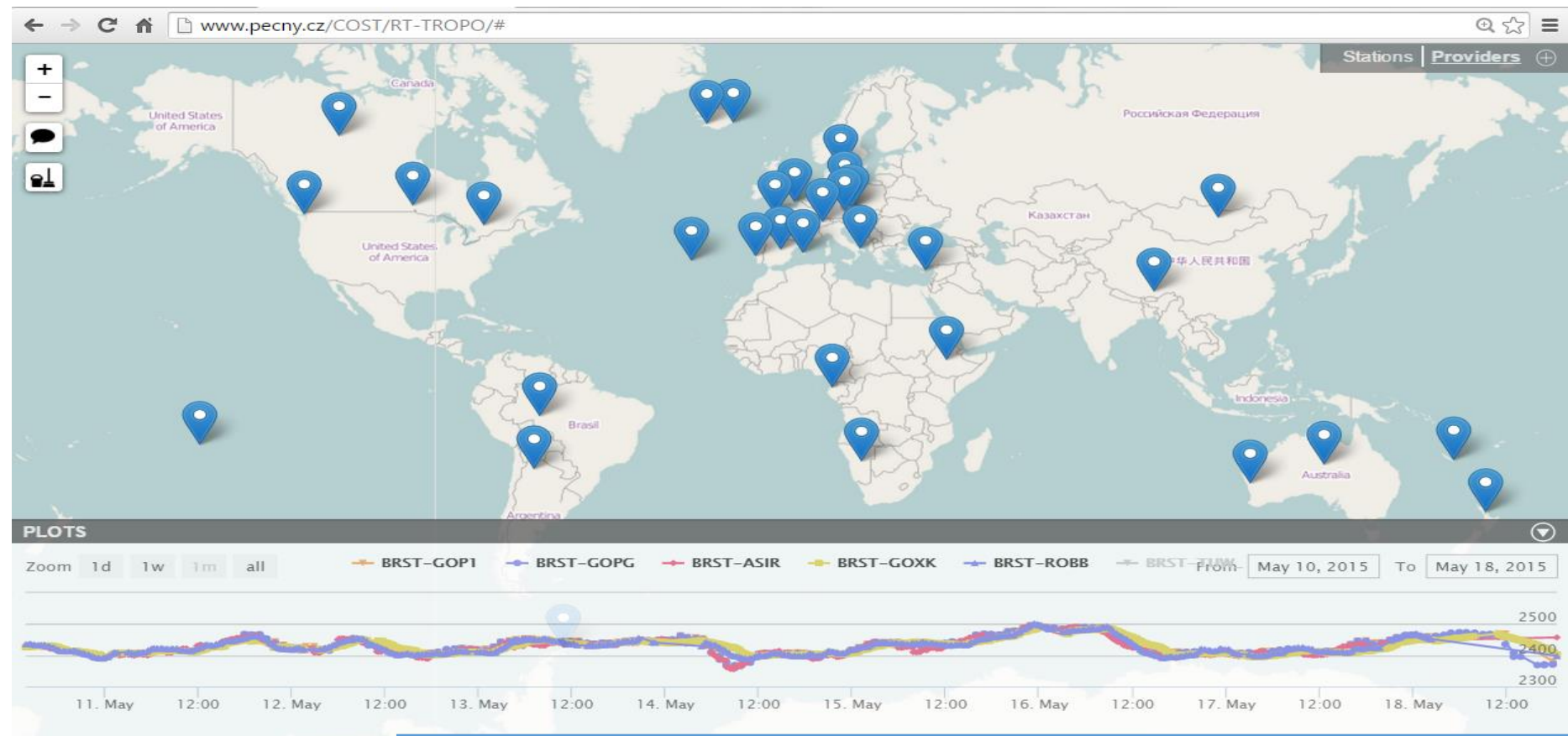
- ☺ Development and assessment of real-time or sub-hourly tropospheric solutions (new software and strategies), testing & assessing IGS RTS products
- ☺ April 1, 2015 - RT demonstration campaign for real-time (European & global)

## 4 ACs:

- ASI
- GOP
- ROB
- TUW

## Status:

22.5.2015



Monitoring at: <http://www.pecny.cz/COST/RT-TROPO>

# Working Group 2: Main Goals

## The main goals of the WG2 are defined in five main domains:

- Coordinate the development and standardization of methods and data formats for using current, new and enhanced (operational) GNSS tropospheric products for use in nowcasting and data assimilation in NWP.
- Promote the usage of GNSS tropospheric products in weather forecasting (NWP + nowcasting).
- Establish benchmark datasets and case studies for tests, assessment and validation (for each method/product).
- Update/Produce requirements for current, new, and enhanced GNSS tropospheric products and produce recommendations and methods for operational GNSS nowcasting tools.
- Stimulating transfer of knowledge, tools and data exchange and strengthening the link between the geodesy and meteorological community.
- **Sub-WG2:** 7 specific activity domains and leaders appointed
- **WG2 members:** 44 members / 21 countries / 1 non-EU partner

# Working Group 2: Main Achievements

- The databases for benchmark, severe weather case studies and real-time GNSS processing (output of NWP for use in GNSS processing) was setup. It will be fed in the next years.
- Data Assimilation in NWP:
  - New analysis centres (stimulated by WG1) provides GNSS products to E-GVAP and are now ready for assimilation.
  - Initialisation of NWP models: the developments of a VarBC (instead of a static bias correction) is well progressing in Harmonie (NWP).
  - Rapid-cycle (every 30 min) data assimilation in NWP demonstrated to significantly improve the information content for the forecasts.
  - Development of operators for data assimilation of slant tropospheric delays and horizontal gradients is in progress.
- Tomography: initiation of a comparison campaign between different tomography software in order to study best setup based on synthetic and real data.
- Nowcasting: A review of possible GNSS-derived products (ZTD, gradients, fluxes, water vapour maps, alarms/alerts...) for non numerical nowcasting was carried out and it was demonstrated that GNSS can be used to study the fog formation and dynamics.



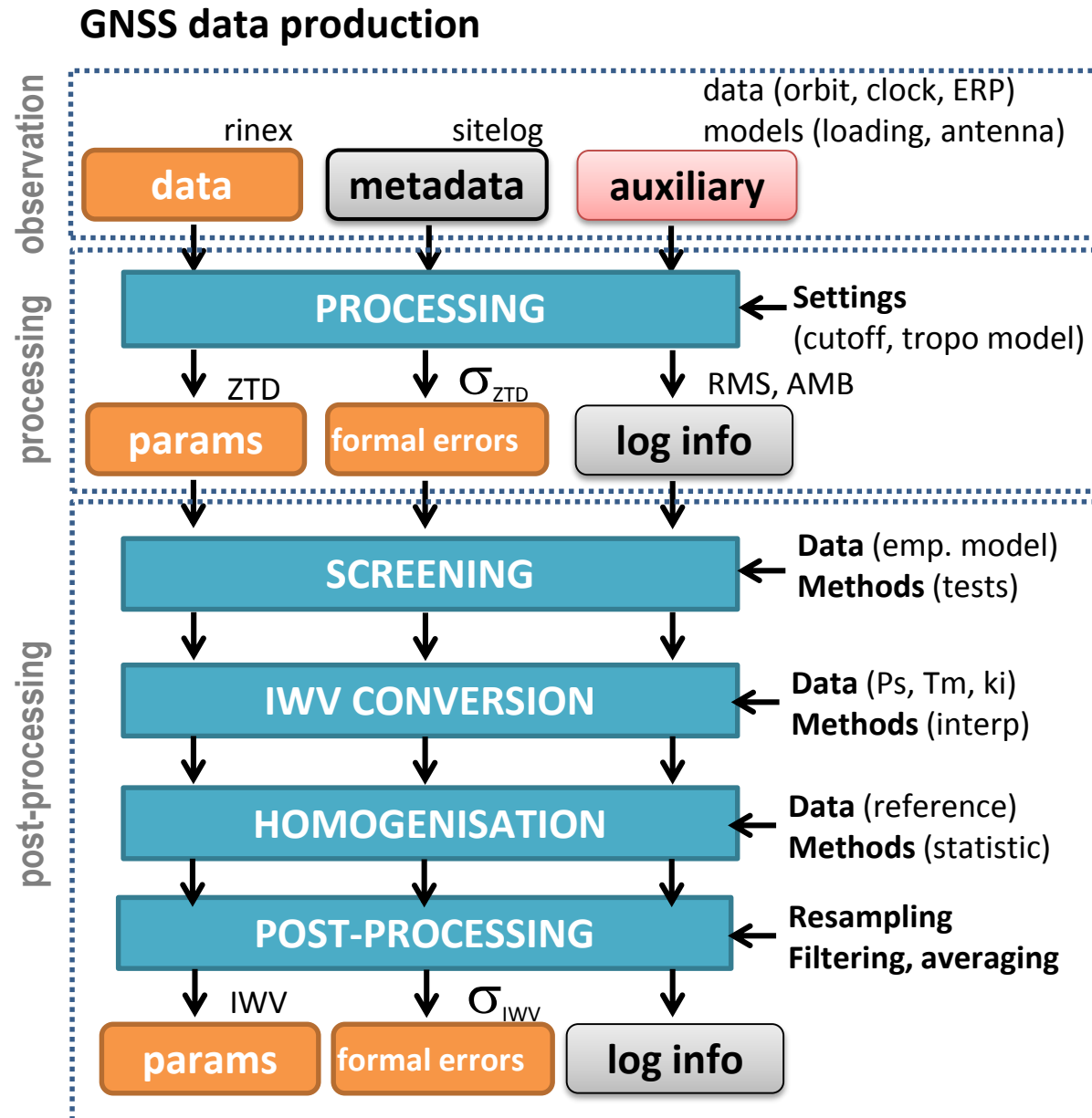
# Working Group 3: Main Goals

## The main goals of the WG3 are defined in four main domains:

- GNSS data (re-) processing methods and validation of long tropospheric parameter series for climate applications.
- establish tropospheric parameter post-processing standards and methods for climate applications.
- evaluate the uncertainty of GPS IWV in terms of GPS internal uncertainty, accuracy (biases of GPS IWV vs. reference measurements) and long term stability
- Assess the benefit of GPS ZTD and IWV long time series for climate research to document climate trends and variability and to evaluate climate models (CMIP, CORDEX, EC-Earth, GEWEX, HYMEX...).
- **Sub-WG3:** 5 specific activity domains and leaders appointed
- **WG3 members:** 52 members / 17 countries / 1 non-EU partner



# Working Group 3: Standards and Methods for Climate



**Standards**

**WG3**

**IGS**

(obs)

**IERS**

(for geodesy)

**X**

(for climate)

**X**

**X**

**X**

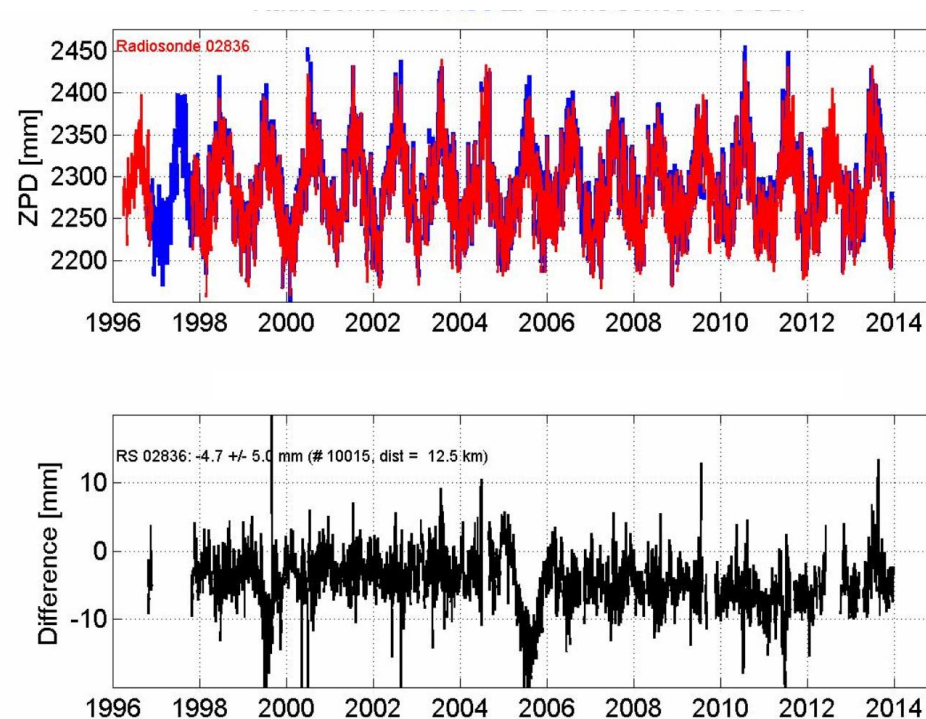
**X**

(depend on application)

# Working Group 3: IWV inter-comparison

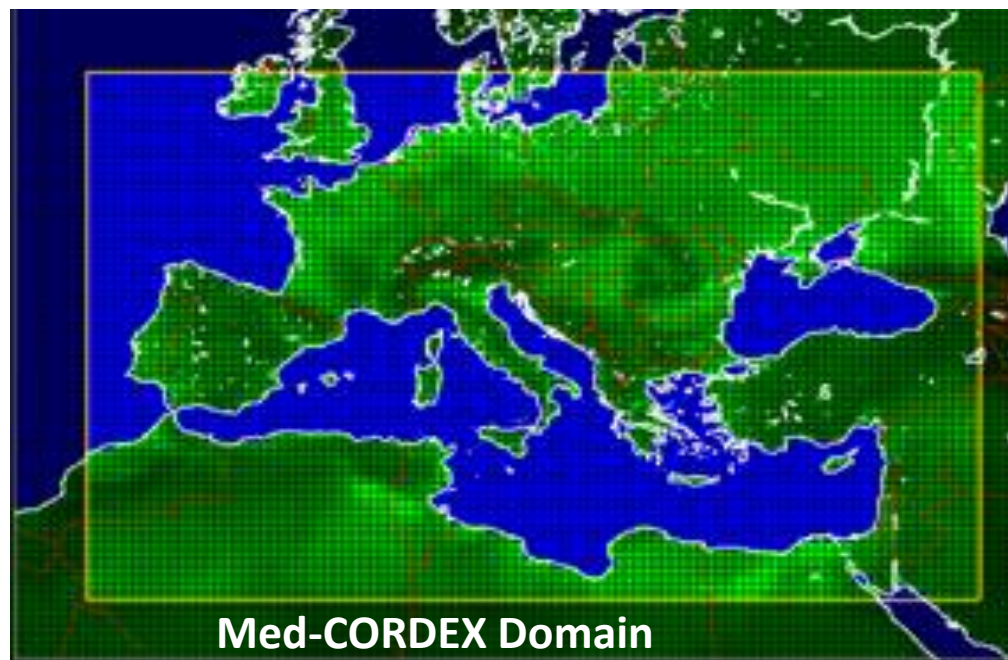
*Goal: improve the knowledge of the various error sources in the GNSS data arising from data processing, ZTD to IWV conversion, and other factors*

Several studies are underway at the **EPN/GRUAN site in Sodankylä** using homogeneously reprocessed data.



ZTW/IWV time series, although homogeneously reprocessed, are not free of discontinuities. So statistical homogenisation methods have been developed and an inter-comparison exercise will be organized.

# Working Group 3: IWV trends and variability



- Assessment of Med-CORDEX, Euro-CORDEX climate model simulation using GNSS IWV long time series
- IGS Repro1 (1996-2010) used as reference reprocessed GPS solution.

**Data after 2010 are required!**

- The climate groups expressed the need for more spatially dense GPS ZTD/IWV data over Europe.

**EPN repro2 is expected.**



# Summary

- GNSS data recorded within EPN are crucial for meteorology in Europe, particularly for their high reliability and standards.
- Products build over EPN hourly data (e.g. ZTD provided to E-GVAP) are used. There is lack of data and NRT ZTD in Eastern Europe.
- The European climate community is waiting for EPN Repro2 as a reference data set over EUROPE.
- EUREF is acknowledged for its data, products and services.
- IGS is acknowledged for its products and the activities carried out in the RT, MGEX, Tropo WGs.

