Advanced GNSS Tropospheric Products for the Monitoring of Severe Weather Events and Climate (GNSS4SWEC)

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Abstract

Global Navigation Satellite Systems (GNSS) have revolutionised positioning, navigation and timing (PNT), becoming a common part of our everyday life. Aside from PNT applications, GNSS have proved to be an accurate sensor of atmospheric water vapour, the most abundant greenhouse gas, accounting for 60-70% of global warming, and of obvious importance in weather forecasting. Atmospheric humidity is one of the most variable and important parameters for forecasting extreme weather events and monitoring climate change, but is under sampled in current operational meteorological and climate observing systems.

The proposed EU COST Action (http://www.cost.eu) will address new and improved capabilities from concurrent developments in both GNSS and atmospheric communities to improve (short-range) weather forecasts and climate projections. For the first time, the synergy of the three GNSS systems, GPS, GLONASS and Galileo, will be used to develop new, advanced tropospheric products, stimulating the full potential exploitation of multi-GNSS water vapour estimates on a wide range of temporal and spatial scales, from real-time monitoring and forecasting of severe weather to climate research. The Action will also stimulate knowledge transfer and data sharing throughout Europe, particularly from West to East, and will promote the use of atmospheric data in satellite-based navigation services.

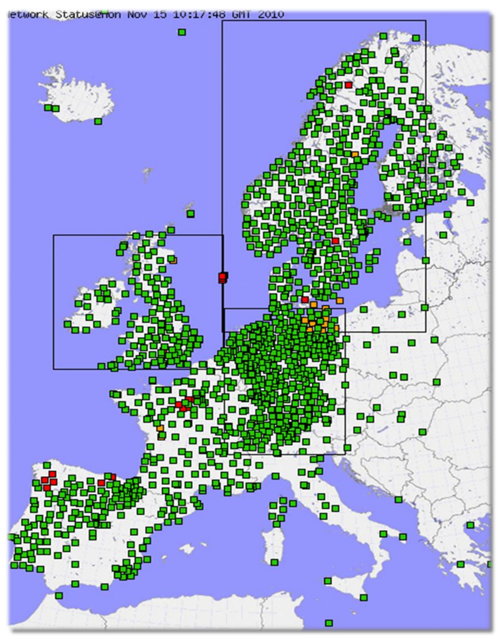

Figure 1: The E-GVAP GNSS network

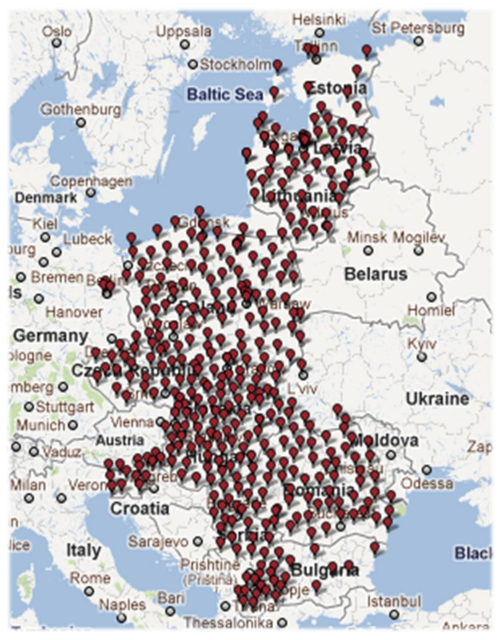

Figure 2: The EUPOS GNSS network

Background

Application of GNSS for Numerical Weather Prediction (NWP) was the focus of previous European projects (COST-716, TOUGH, E-GVAP…), and the use of meteorological GNSS products in NWP is now an established technique. At the present time, EUMETNET supports the operational exploitation of more than 1,600 continuously operating GNSS receivers in the framework of the E-GVAP project (http://egvap.dmi.dk) with assimilation of hourly-updated Zenith Tropospheric Delays (ZTD) into NWP.

Advancements in NWP models (such as the U.K. Met Office 1.5 km model) require GNSS observations with improved timeliness and (spatial and temporal) resolution than are currently available. The potential of GNSS observations to meet these new requirements, and also for use in very short-range forecasting (typically of severe weather events), has improved considerably in the last few years due to improved GNSS raw data timeliness (real-time data streaming), improved GNSS network coverage and improved GNSS processing techniques (e.g. real-time processing).

Additionally, the synergy between GNSS and NWP is mutually beneficial: GNSS ZTD estimates are assimilated into NWP models, whilst at the same time it can be beneficial to use NWP data as an input into GNSS processing schemes to improve the modelling of atmospheric signal propagation, which could significantly improve future real-time positioning accuracy.

Finally, inconsistencies introduced into long-term time series from improved GNSS processing algorithms make climate trend analysis challenging. Ongoing reprocessing efforts using state-of-the-art models are underway which will provide consistent time series of tropospheric data, using 15+ years of GNSS observations and from over 600 stations worldwide. These datasets will enable validation of systematic biases from a range of instrumentation, improve the knowledge of climatic trends of atmospheric water vapour, and also be of benefit to global and regional NWP reanalyses and climate model simulations (e.g. IPCC AR5)

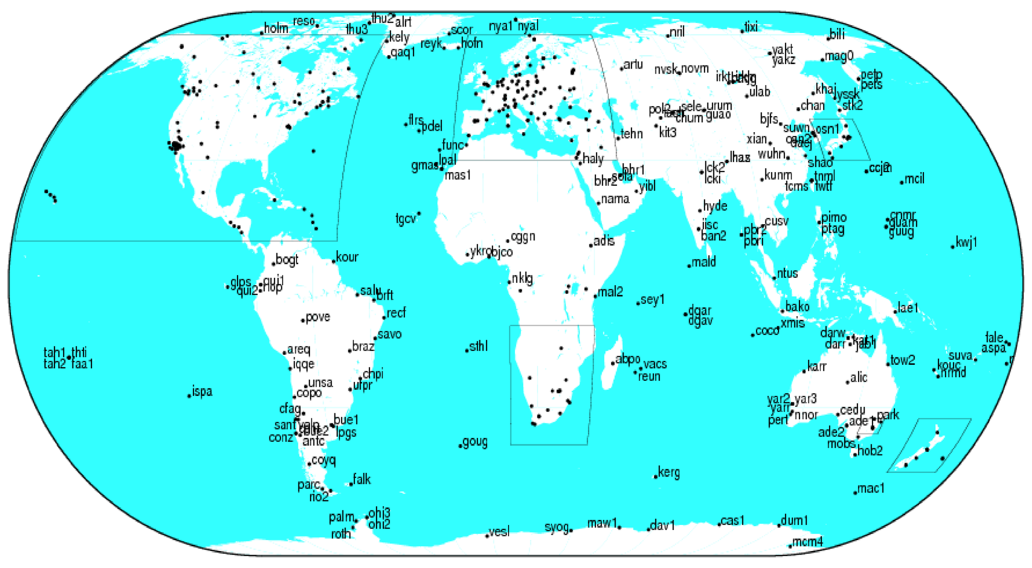

Figure 3: The Global IGS GNSS network

Scientific Programme

The key questions to be addressed by the proposed EU COST Action are:

- What is the impact of combining observations from several GNSS (GPS, GLONASS, Galileo) on the tropospheric products?
- What new GNSS processing techniques are capable of delivering advanced tropospheric products suitable for nowcasting and the new generation of NWP models?
- How far can new GNSS tropospheric products improve nowcasting of severe weather events?
- What is the added value of reprocessed (currently GPS-only) tropospheric products to the current state-of-the-art climate research? (water vapour trends/variability, reanalysis products e.g. ERA-CLIM, IPCC AR5 models etc.).
- How much can multi-GNSS tropospheric products improve climate analysis, particularly in sensitive regions? (e.g. high latitudes and Mediterranean).
- How can atmospheric data improve real-time satellite-based PNT products?

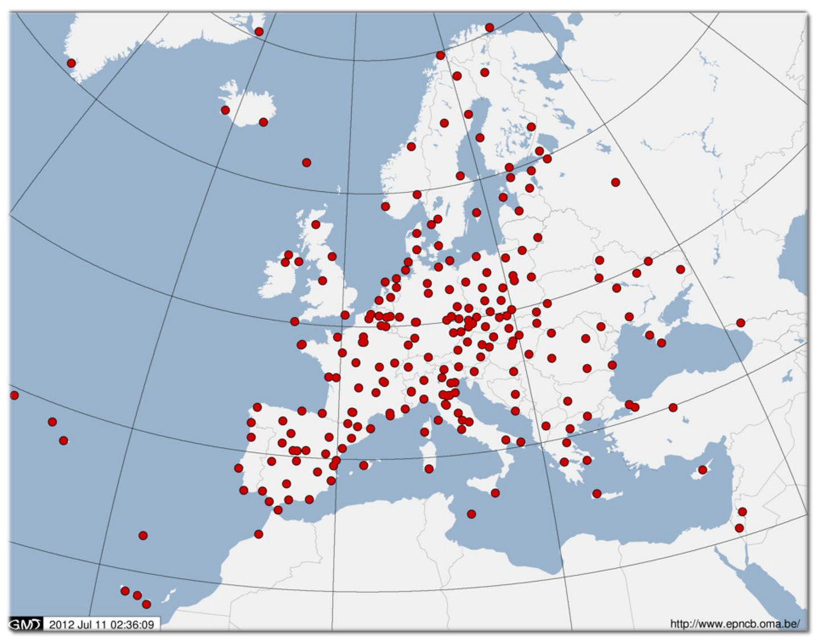

Figure 4: The EUREF Permanent network

Deliverables

The proposed EU COST Action would:

- Cross-validate and quantify systematic instrument biases of atmospheric water vapour observations (GNSS, VLBI, DORIS, radiosonde, WVR, lidar, sun photometers, SSM/I...) over climatic time scales.
- Establish a database of reference tropospheric solutions and stimulate the collection/archiving of raw GNSS data from various sources (EUPOS, national positioning services, GNSS campaigns...).
- Enhance the production of multi-GNSS products, check consistency and assess the benefit of multi-GNSS products (tropospheric delays, gradients, slant delays…).
- Develop new GNSS products (gradients, slant delays…) and assess their potential for use in severe weather nowcasting and high-resolution rapid-cycle NWP.
- Standardize conversions from GNSS tropospheric delay (ZTD) to atmospheric water vapour (IWV)
- Promote dialogue between GNSS tropospheric product providers and end-users.
- Stimulate the awareness/exploitation of atmospheric data in GNSS processing, particularly for real-time GNSS services.

Benefits

The proposed EU COST Action would:

- Coordinate R&D on a European scale, improving cross-border data and knowledge/expertise transfer in the fields of GNSS data processing, meteorology and climate monitoring.
- Improve understanding of atmospheric processes resulting in more accurate nowcasting of severe weather leading to improved hazard management, thereby lowering the risk of loss of life and the risk to national infrastructure.
- Promote the use of reprocessed long-term GNSS tropospheric datasets for climate research. This will in turn lead to improved satellite-based PNT products through improved signal propagation modelling.
- Develop new multi-GNSS processing techniques, using observations from all satellite constellations leading to new/more advanced tropospheric products with improved accuracy and reliability.
- The Action will link to the activities of the tropospheric working groups of the International GNSS Service (IGS) and the International Association of Geodesy Reference Frame Sub-commission for Europe (EUREF) and work in support of the operational goals of the E-GVAP project.
- Direct the exploitation of GNSS and meteorological data for the mutual benefit of both communities, leading to a consolidation of collaborating groups resulting in more focused working practices.

Organisation

The proposed Action Team consists of experts from 41 institutions in 28 countries, including collaboration/cooperation with a large number of international programmes and organisations such as the IGS, EUREF, ECMWF, E-GVAP and EUPOS as well as extensive links to others such as the Galileo programme, GEO, GEOSS, IPCC AR5, WMO-GRUAN, GMES, HYMEX and EPOS. It will be organized in three Working Groups (WG) with strong working relationship between each groups:

- WG 1: Advanced GNSS processing techniques
- WG 2: GNSS for severe weather monitoring
- WG 3: GNSS for climate monitoring

The Action will also integrate a number of nationally funded research projects in the field of GNSS meteorology (Belgium, Bulgaria, the Czech Republic, Denmark, France, Germany, Greenland, Hungary, Italy, Luxembourg, Norway, Poland, Portugal, Spain, Sweden, Switzerland, The Netherlands, the United Kingdom…).

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