COST Action ES1206:
Advanced GNSS Tropospheric Products for Monitoring Severe Weather Events and Climate (GNSS4SWEC)

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Abstract

GNSS is a well established atmospheric observing system which can accurately sense water vapour, the most abundant greenhouse gas, accounting for 60-70% of atmospheric warming. Water vapour observations are currently under-sampled in operational meteorology and obtaining and exploiting additional high-quality humidity observations is essential to improve severe weather forecasting and climate monitoring. Inconsistencies introduced into long-term time series from improved GNSS processing algorithms make climate trend analysis challenging. Ongoing re-processing 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 will potentially be of great benefit to global and regional NWP reanalyses and climate model simulations (e.g. IPCC AR5).

COST Action ES1206

COST Action ES1206 is a 4-year project, running from 2013 to 2017, which addresses new and improved capabilities from concurrent developments in GNSS, meteorological and climate communities. For the first time, the synergy of multi-GNSS constellations will be used to develop new, more advanced tropospheric products, exploiting the full potential of multi-GNSS on a wide range of temporal and spatial scales - from real-time products monitoring and forecasting severe weather, to the highest quality post-processed products suitable for climate research. The Action will also promote the use of meteorological data as an input to real-time GNSS positioning, navigation, and timing services and will stimulate knowledge and data transfer throughout Europe and beyond.

The primary objectives of the Action are to:

- Establish a database to validate re-processed GNSS ZTD/IWV against reference quality data from a range of other instrumentation
- Determine the added value of re-processed GNSS tropospheric products to the current state-of-the-art climate research
- Assess the potential of new GNSS products for nowcasting and rapid NWP
- Stimulate the use of atmospheric data as an input to improve RT positioning
- Stimulate exchange of data and expertise in the field of GNSS Meteorology
- Coordinate the development of new multi-GNSS solutions
- Standardize the conversion of ZTD to IWV

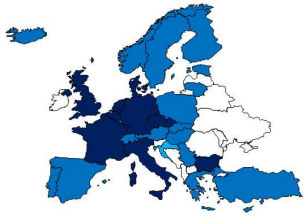


Figure 1: European participation in GNSS4SWEC

Participation

The Action consists of over 140 experts from around 40 countries, including collaboration/cooperation with several international programmes and organisations such as the IGS, EUREF, ECMWF, E-GVAP, GRUAN, HYMEX and EPOS also supports and integrates into a number of nationally funded research projects in the field of GNSS Meteorology.

In addition to the European members, a number of institutes from around the World are also involved in the Action from Canada, USA, Tunisia, Hong Kong, and Australia, and we encourage additional participation from all parts of the globe and from meteorological, geodetic and climate communities.

ES1206 website: http://gnss4swec.knmi.nl/

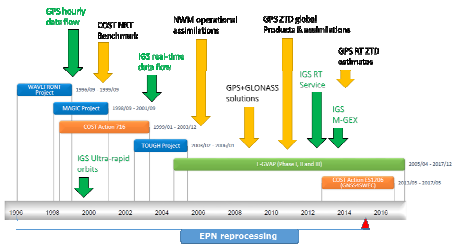


Figure 2: GNSS-Met Projects/Europe: Timelines, Links & Milestones

GNSS4SWEC Working Groups

WG1	Advanced GNSS processing techniques (AGNSS) Chair: **Dr Jan Dousa,** GOP (jan.dousa@pecny.cz) Co-chair: **Dr Galina Dick,** GFZ (galina.dick@gfz-potsdam.de)	1st scientific domain
WG2	GNSS for severe weather monitoring (GNSS4SW) Chair: **Dr Siebren de Haan**, KNMI (siebren.de.haan@knmi.nl Co-chair: **Dr Eric Pottiaux**, ROB (eric.pottiaux@oma.be)	2nd scientific domain
WG3	GNSS for climate monitoring (GNSS4C) Chair: **Dr Olivier Bock**, IGN (olivier.bock@ign.fr) Co-chair: **Dr Rosa Pacione**, ASI/CGS (rosa.pacione@e-geos.it)	3rd scientific domain

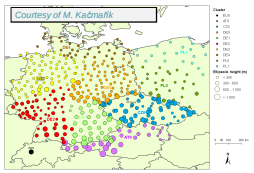
WG1 Goals and Achievements

The goals of the WG1 are defined in four domains:

- **Coordinating of development advanced tropospheric products in support of weather forecasting (ultra-fast products, asymmetry monitoring, tomography, multi-constellation processing)**
- **GNSS data reprocessing and assessment of involved models (to provide 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

WG1 main achievements:

- **Benchmark preparation: design, data collected, activity defined**
- **RT-Demonstration campaign** designed and started (in support WG2)
- **New analyses centres** setups, **new networks** included
- **EUREF re-analysis** almost finished (in support of WG3)
- Developed **tools for supporting use of NWM** data in positioning
- Initial tropospheric **asymmetry study**: focus on gradients
- **Multi-GNSS** tropospheric solutions and products



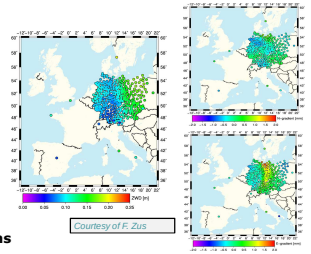


Figure 3: Benchmark GNSS Reference Stations

Figure 4: NWP-derived Tropospheric Parameters

WG2 Goals and Achievements

The goals of the WG2 are defined in five 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 geodetic and meteorological communities

WG2 main achievements:

- **Inventory of GNSS tools** for nowcasting and user requirements
- **Review of current meteo requirements** for GNSS-based and tomography products
- **Severe weather database** established at UKMO
- **Support in WG1 Benchmark definition period**
- **Several case studies** during intense precipitation events
- Towards using more data from ground-based GNSS

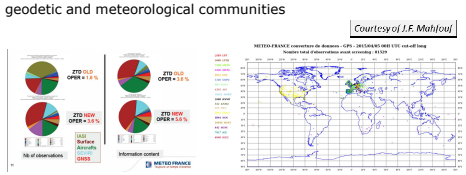


Figure 5: GNSS Data in operational ARPEGE Model

WG3 Goals and Achievements

The goals of the WG3 are defined in four 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…)

WG3 main achievements:

- **Inventory of re-processing GNSS products**
- **Tool preparation** and first GNSS re-processed **data screening**
- **Review of ZTD to IWV conversions**, initiated standardization
- **Data homogenization** tests
- Developing of **Tro-SINEX format** update
- **Global database** of tropo parameters/sources (GOP-TropDB)
- Collaboration with climate community initiated
- First studies with **climate** models
- Co-operation with **GRUAN** project

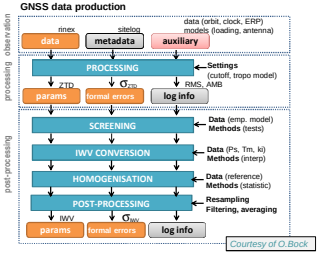


Figure 6: GNSS Standards and Methods for Climate

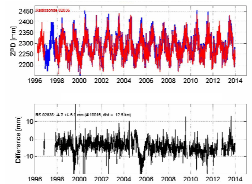


Figure 7: IWV/ZTD Inter-comparision at the EPN/GRUAN site in Sodankyla using homogeneously reprocessed data.