GRUAN ICM-7
Collaborations in GNSS sphere with other projects

E-GVAP, COST Action GNSS4SWEC and EUREF

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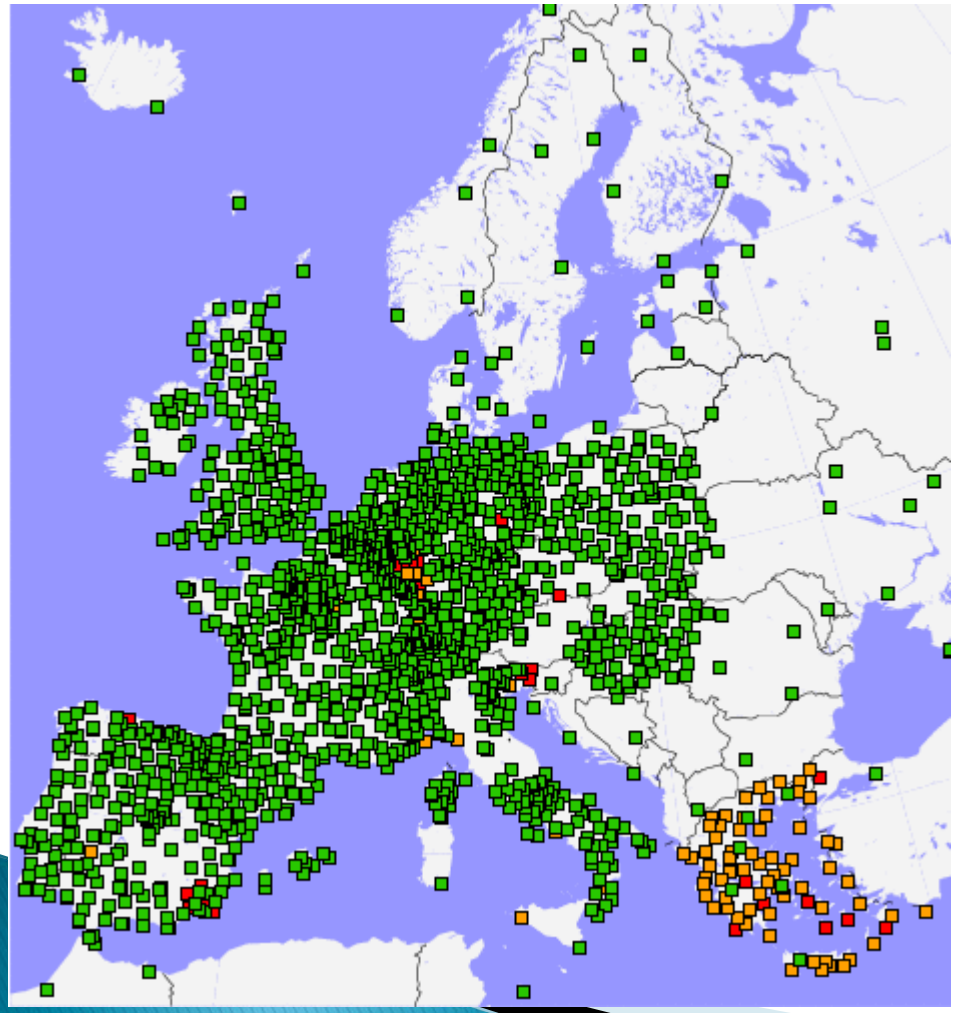
Timeline of European GNSS-Met Projects

Current Status (E-GVAP)

EUMETNET

The Network of European Meteorological Services



- *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

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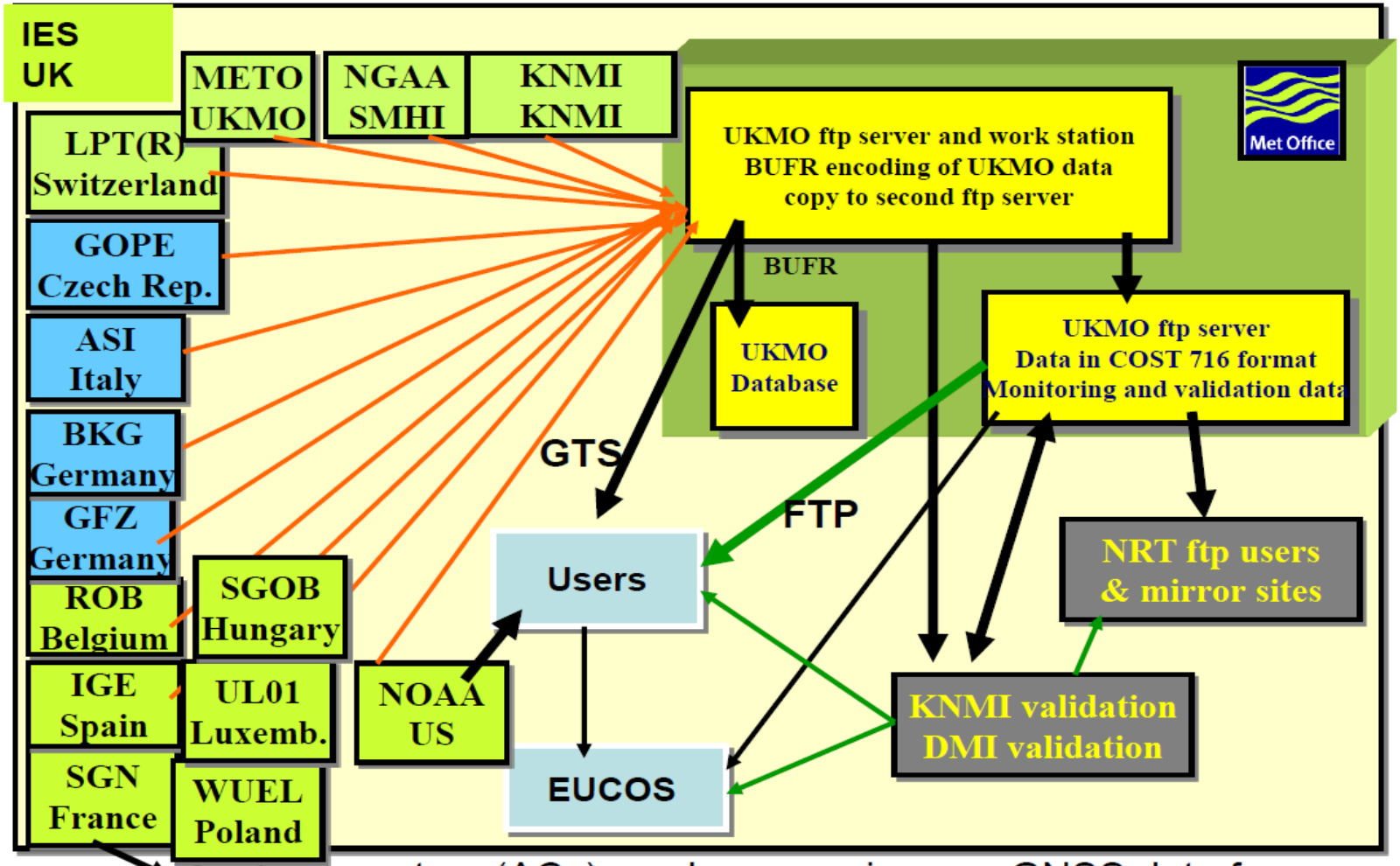
E-GVAP data flow

EUMETNET

OBS system overview

NRT GNSS ZTD data flow Today



Analysis centres (ACs), each processing raw GNSS data from many sites. In many cases only national AC can get access to the raw data.

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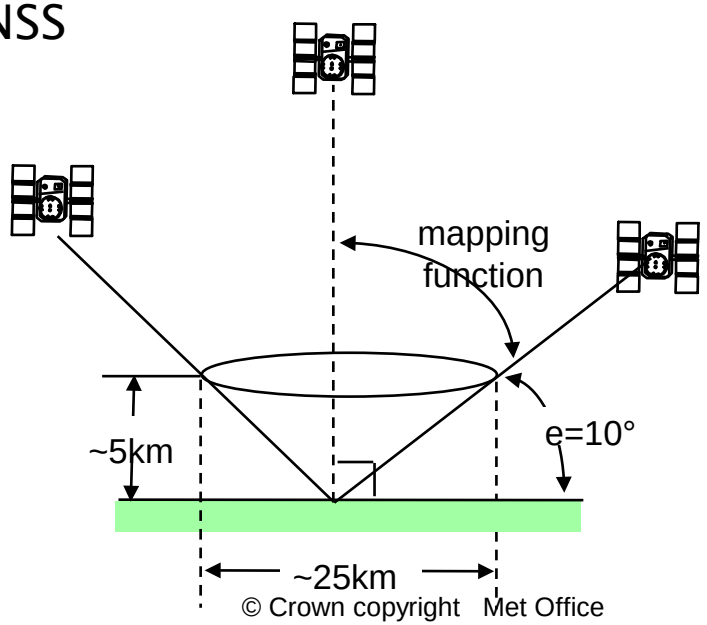
Developing Met. Requirements

- 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 (e.g. Hadley Centre)



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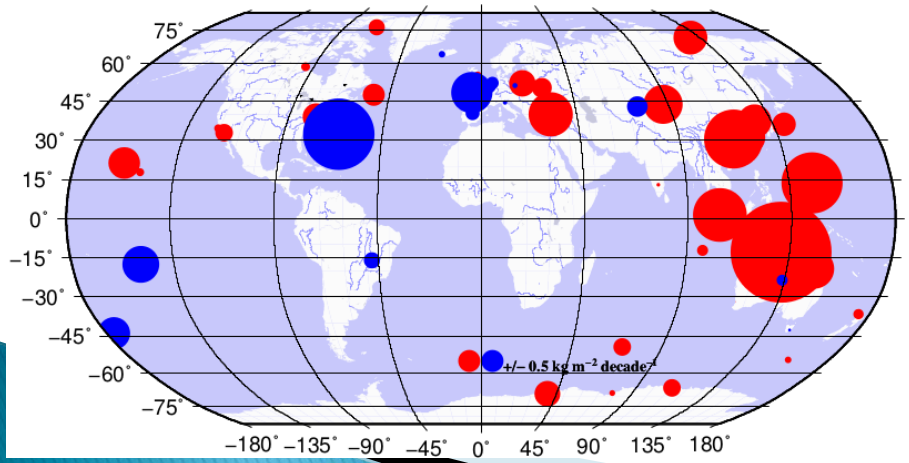
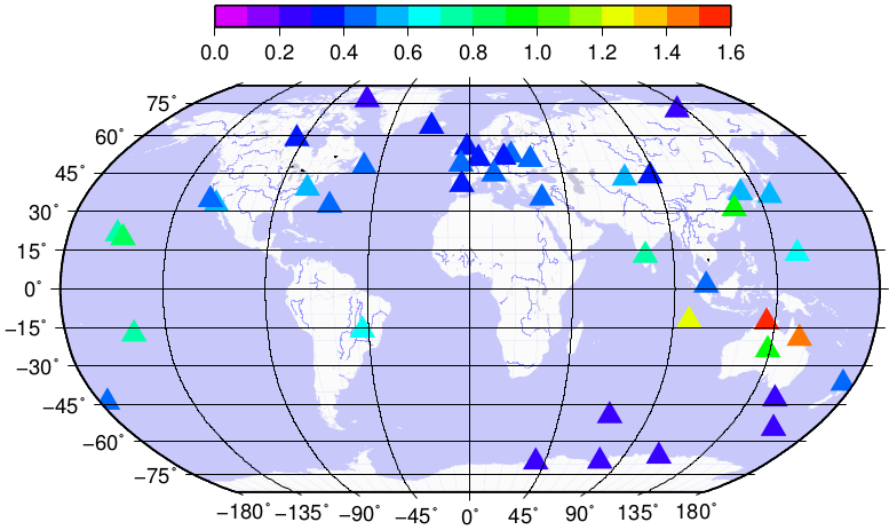
Climatic Water Vapour Trends

- **Long term model validation**
  - NCEP model – good seasonal and inter-annual variations but underestimation of IWV of <40% in tropics and <25% in Antarctica
- **Liner IWV trends**
  - Global trend: -1.65 to +2.32 kg/m^2 per decade
  - Global trend uncertainty: 0.21 to +1.52 kg/m^2 per decade

Ning 2012, GPS Meteorology with focus on Climate Applications

http://publications.lib.chalmers.se/records/fulltext/157389.pdf





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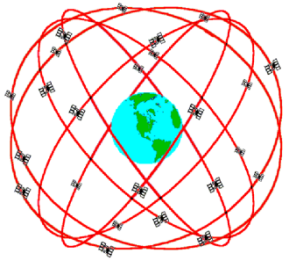
GNSS Developments



- 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 (from moving platforms?)
- Single frequency processing
- Long-term, homogenised GPS products available (EPN/IGS/CODE/others), valuable for climate analysis?

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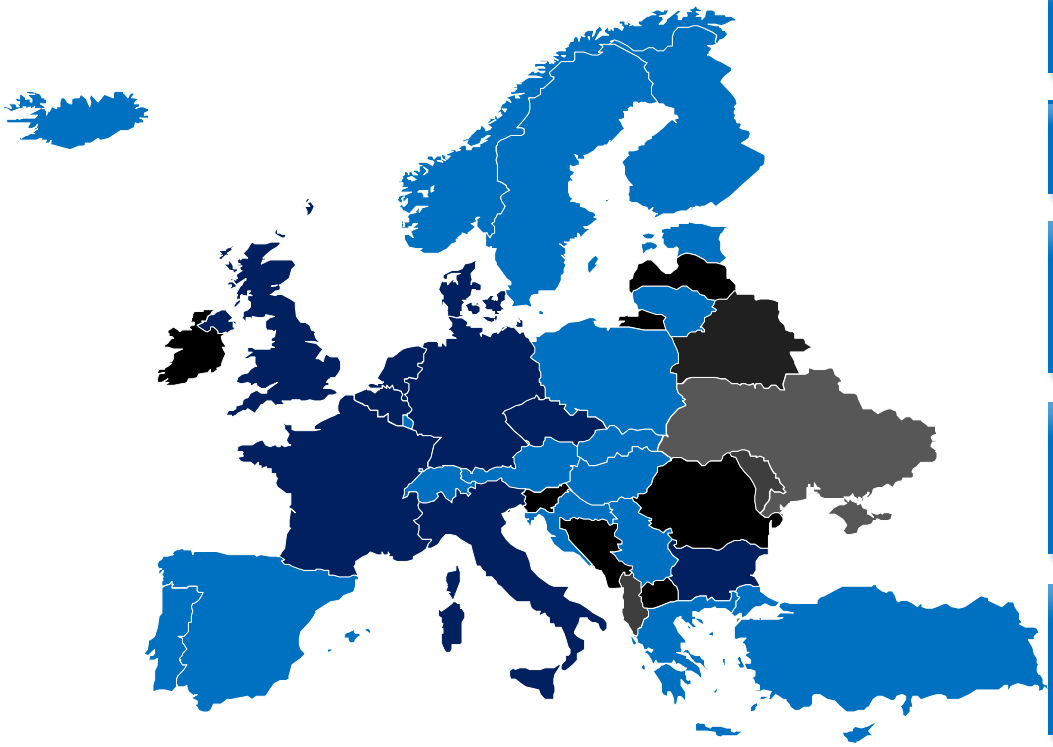
COST ACTION ES1206 GNSS4SWEC



- 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

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

GNSS4SWEC Working Groups

WG1	*Advanced GNSS processing techniques (AGNSS)*
WG2	*GNSS for severe weather monitoring (GNSS4SW)*
WG3	*GNSS for climate monitoring (GNSS4C)*

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Main Aims of the Action

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.*

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GNSS Integrated Water Vapour (IWV) assessment and intercomparisons

COST Action GNSS4SWEC
WG3 (GNSS for climate monitoring)

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IWV intercomparison studies w.r.t. GNSS in literature:

Instrument	bias [mm]	stdev [mm]	slope	offset [mm]
RS	-3.78 – 8.00	0.21 – 3.87	0.82 – 1.47	-25.95 – 11.66
MWR	-1.66 – 0.50	1.02 – 4.18	0.82 – 1.21	-1.46 – 4.60
sun photometer	-3.58 – 5.90	0.80 – 2.90	0.63 – 1.03	-3.37 – 5.70
FTIR	-0.09 – 0.61	0.73 – 1.02	0.95 – 1.06	-0.78 – 0.40
satellite	-7.05 – 1.50	0.35 – 7.04	0.75 – 2.33	-2.92 – 8.89
models	-8.70 – 5.30	0.64 – 8.08	0.66 – 2.00	-31.90 – 9.70

➔ wide ranges!

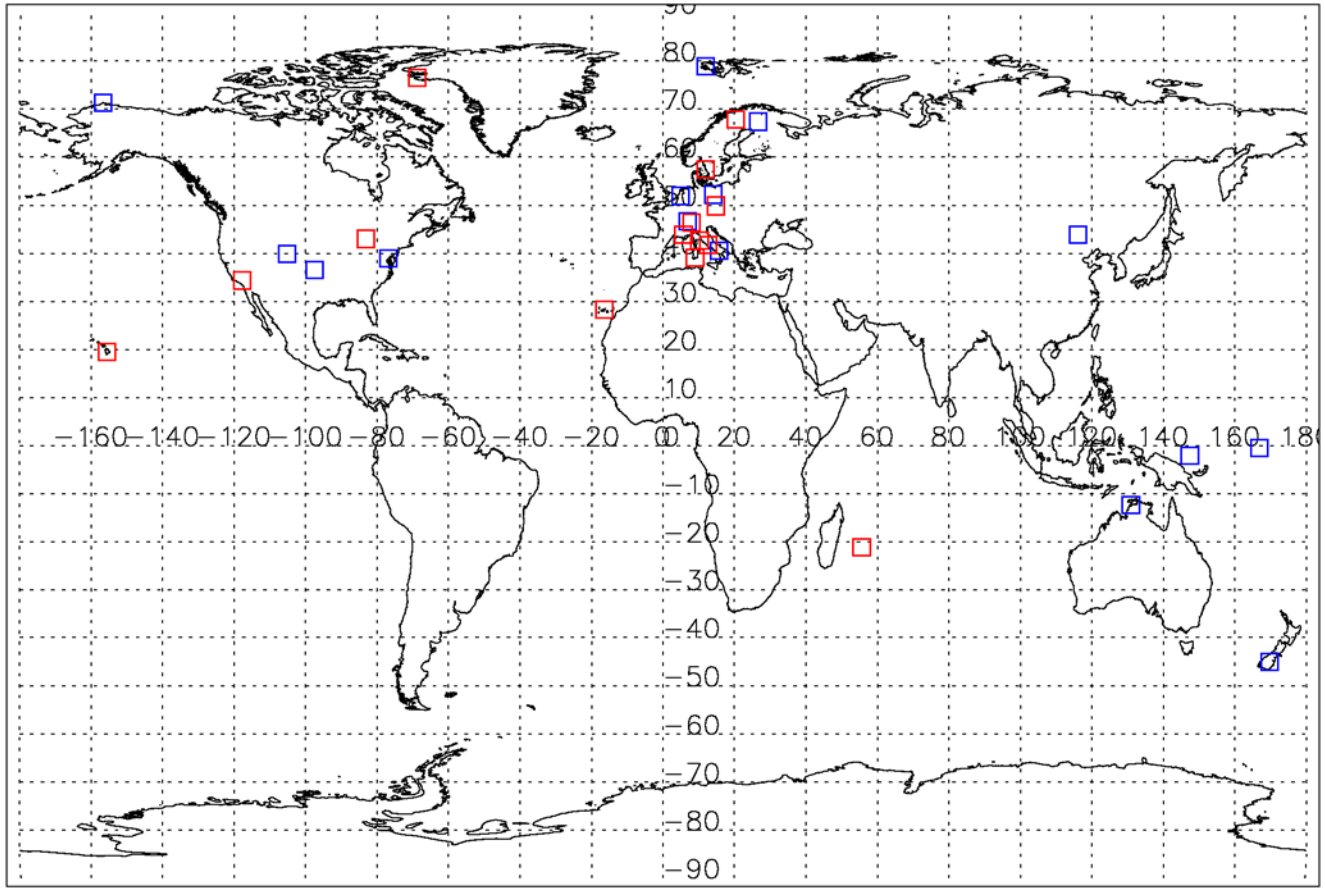
- different **types** of instruments are compared with GNSS (e.g. different RS types)
- different **data retrieval algorithms** for a given instrument at different sites
- **inhomogeneous** data records at many sites
- different studies apply different **methodologies** (different co-location and coincidence criteria, different definitions of statistical parameters, etc.)

GNSS IWV assessments & intercomparisons

- objectives:
  - evaluate the precision and accuracy of the GNSS IWV estimates
    → sensitivity studies (impact of GNSS data processing procedure)
    → intercomparisons with reference data (campaign data over short periods)
  - assess homogeneity of long GNSS time series
    → develop homogenisation methods taking beneif of the multiple parameters available from GPS data processings (ZTD, formal errors, positions...)
    → compare GPS ZTD/IWV to ZTD/IWV data from other instruments that are homogeneous/homogenized on long term

- work plan (2015-2016):
  - apply uniform methodology on data of "**supersites**" (> 3 instruments measuring IWV)
  - with **consistency in data quality** of similar instruments at different sites
  - with known data **accuracy/precision** and comprehensive metadata
    - => seeking for cooperation with GRUAN and NDACC

Identified “supersites”



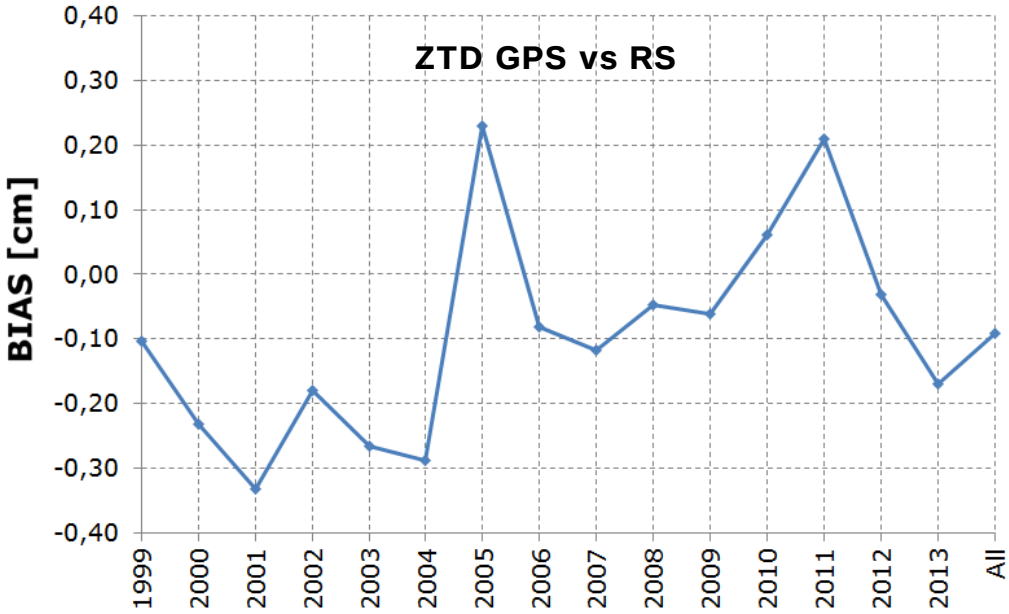
□ : GRUAN sites

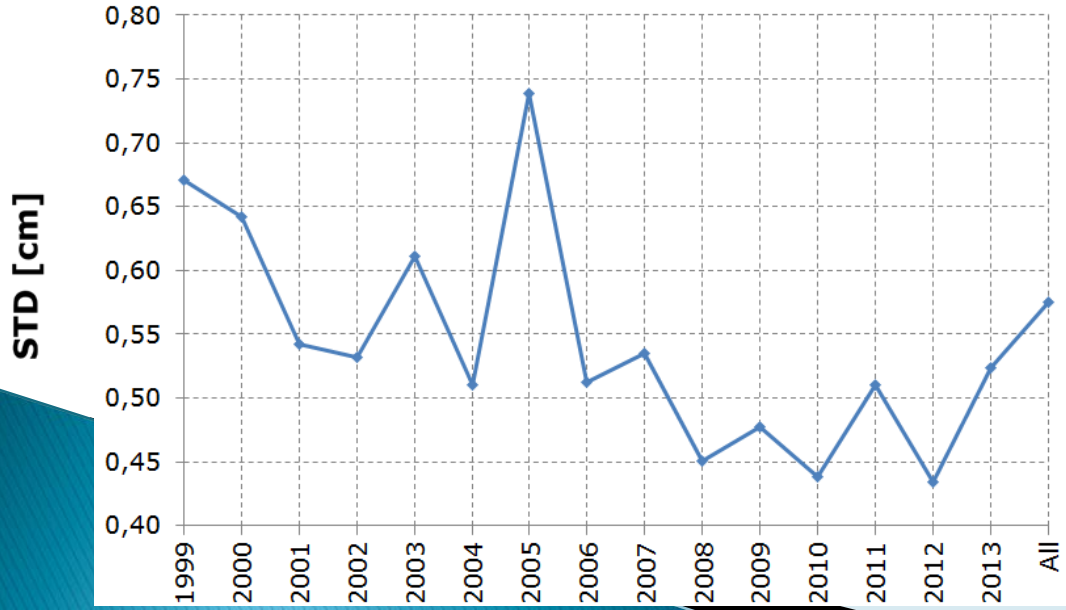
□ : NDACC & other sites

Proposed collaboration between GNSS4SWEC and GRUAN

- GRUAN aims at providing
  - High quality datasets of IWV and other meteo variables
  - Validated metedata for instruments on GRUAN sites
- GNSS4SWEC aims at providing
  - High quality, screened, homogenized, GNSS data (in cooperation with EPN Repro2)
  - Validated metedata for instruments on GNSS sites
- IWV intercomparison exercise
  - Intercompare IWV data on a few sites and assess inter-system biases
  - are absolute measurements feasible?
  - Is a calibration transferable between instruments?
  - Note: questions such as absolute accuracy of GNSS IWV (and of other instruments) are central for GNSS4SWEC => special issue perspective

Sodankyla: GRUAN, EPN and E-GVAP site





- In the framework of EPN Repro2, GNSS data collected at Sodankyla has been homogeneously reprocessed
- In the framework of GNSS4SWEC WG3 Sodankyla ZTD data have been compared w.r.t. RS data

Comparison Table for the period 2008-2013
AS0: Reprocessed Solution
ASIC: E-GVAP combined Solution

	AS0	ASIC
Bias [cm]	0.052	0.292
STD [cm]	0.539	0.552
CC	0.9937	0.9931

Contribution from
E. Fionda Fondazione Bordoni, Rome

European Permanent Network (EPN)- Repro2

R. Pacione
on behalf of the EPN Repro2 Working Group

EPN Repro-2: Goals

EPN-Repro2 is the second reprocessing campaign organized under the umbrella of EUREF

(*International Association of Geodesy Sub-commission 1.3 - Regional Reference Frames for Europe*)

Goals:

- Will be a continuation of the EPN-Repro1 campaign (but now IGS08)
- Response to the planned IGS repro2 campaign
- Generate consistent coordinates, velocities and troposphere parameters (ZTD+Grad) in one reference frame
- Support the densification of the ITRF2013

European Permanent Network

http://www.epncb.oma.be/

NYA1 and SODA EPN and GRUAN stations

EPN Repro-2: Organization

- Three LACs analysed the entire EPN back to 1996
  - ASI - Centro di Geodesia Spaziale (GIPSY 6.2)
  - GOP – Geodetic Observatory Pecný (Bernese 5.2)
  - MUT - Military University of Technology (GAMIT 10.50)
- Analysis of sub-regional network of the EPN
  - LPT – Swisstopo (Bernese 5.2)
  - IGE – Instituto Geográfico Nacional España (Bernese 5.2)
- Analysis strategy agrees with the „Guidelines for EPN Analysis Centres (released Nov. 2013)

Status:

- **all individual solutions delivered**
- **ZTD combination effort in progress**
- **ZTD evaluation foreseen**