GNSS Data Processing at GFZ

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GRUAN ICM-9 Meeting

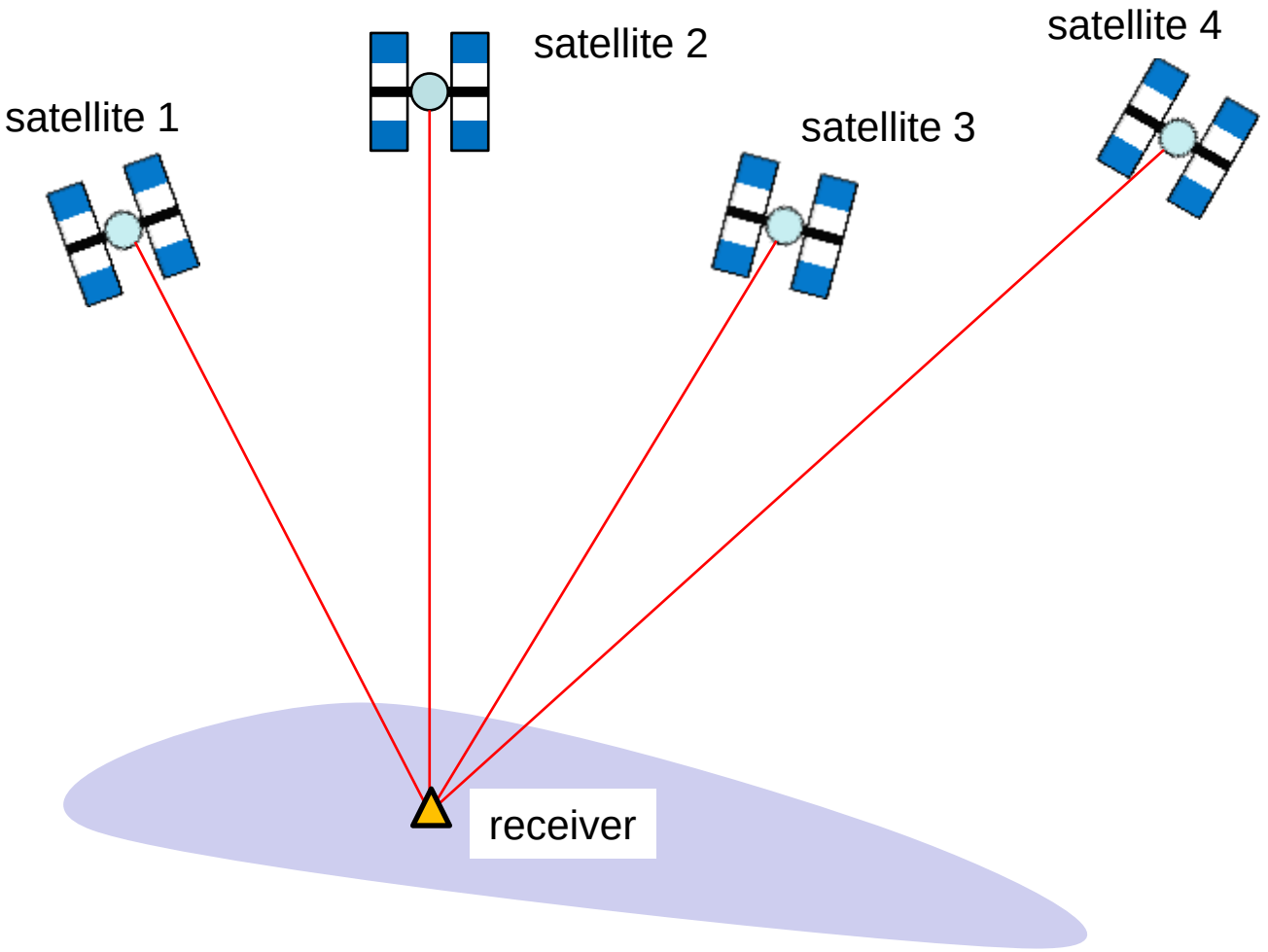
12-16 June 2017, FMI, Helsinki, Finland

GFZ Helmholtz-Zentrum Potsdam

HELMHOLTZ GEMEINSCHAFT

Global Navigation Satellite Systems (GNSS)

Position determination by range measurements to each satellite:

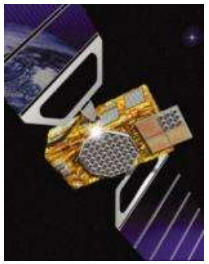


Global Navigation Satellite Systems

GPS (USA): 31 satellites,
fully operational

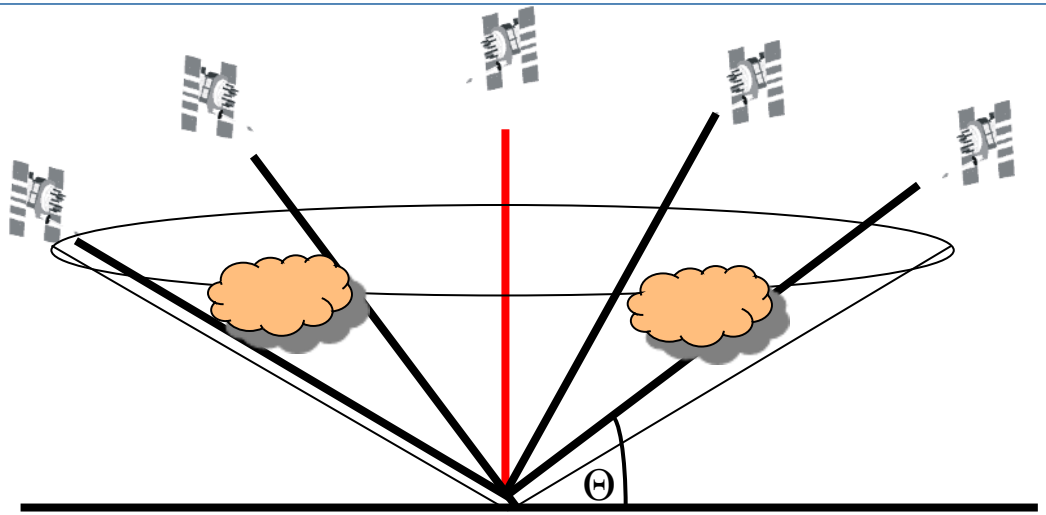
GLONASS (Russia): 24 satellites,
fully operational

Galileo (EU): currently 18 satellites,
13 operational satellites



BeiDou (China): currently 21 satellites
(3 MEO satellites)

Atmosphere Sounding with ground-based GNSS



Isotropic water vapor distribution & known mapping function (~1/sin Θ)

Additional: pressure and temperature at the station for conversion of ZTD to IWV

Result of GNSS data analysis: Zenith Total Delay (ZTD) with mm-accuracy

dry, hydrostatic wet

$$ZTD = ZHD + ZWD$$

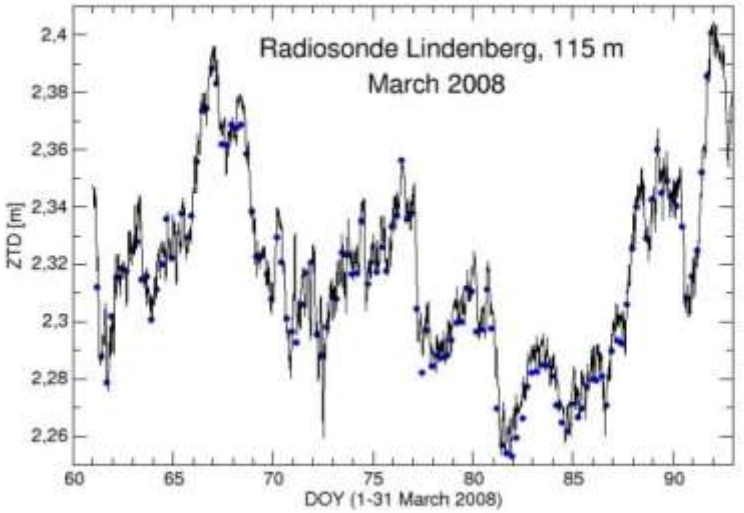
$$ZHD = f(\text{pressure})\ [\pm 1\ \text{mm accuracy}]$$

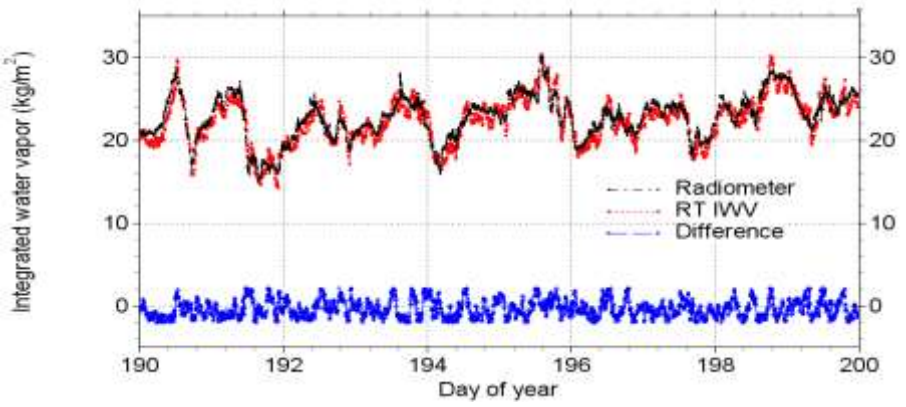
$$PWV = \Pi(T_m) \bullet ZWD$$

Converted Precipitable Water Vapor (PWV)

Why GNSS-derived PWV?

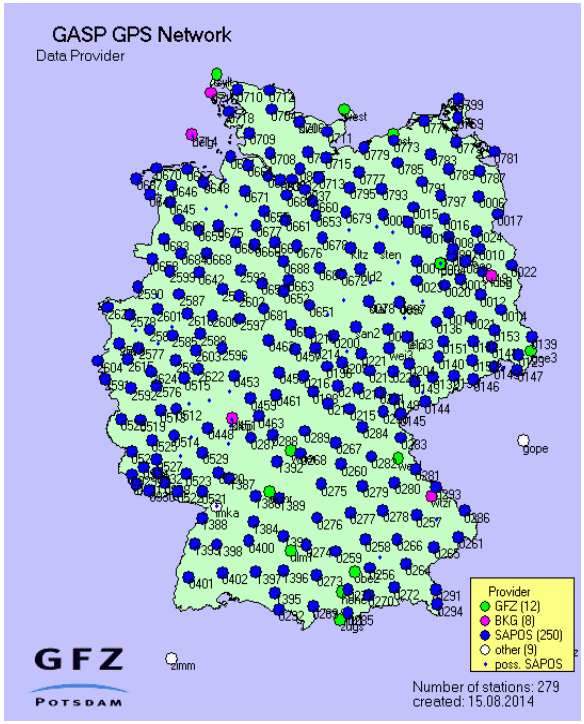
- locally high resolution in space and time
- all-weather capability
- high accuracy (1-2 mm PWV): comparable with meteorological instrumental measurements, like RS, WVR
- long-term stability, continuous time series (for climate research)



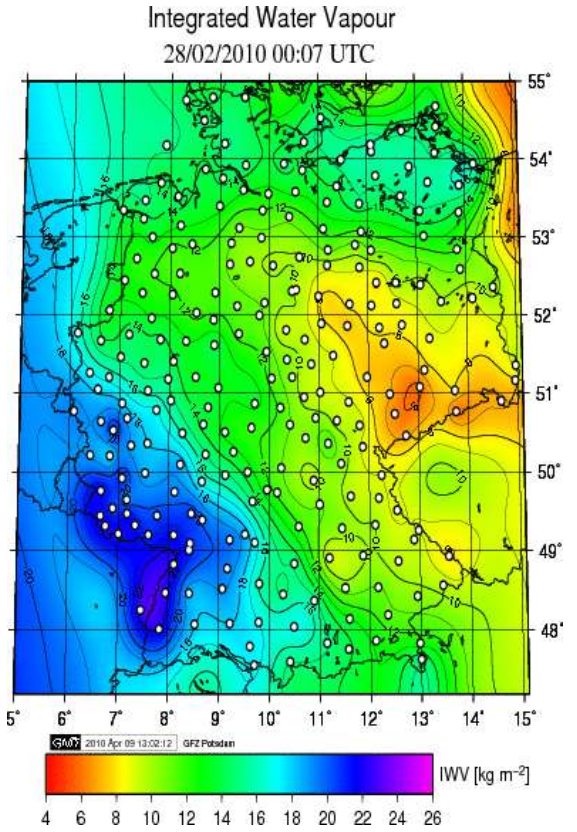


Operational Water Vapor Monitoring at GFZ

- Automatically processing of hourly GNSS with GFZ EPOS Software since 2000
- ~ 500 stations in NRT processing in (German SAPOS + EUREF + global IGS)
- ZTD/PWV with 15 min. time resolution
- STD with 2.5 min. time resolution

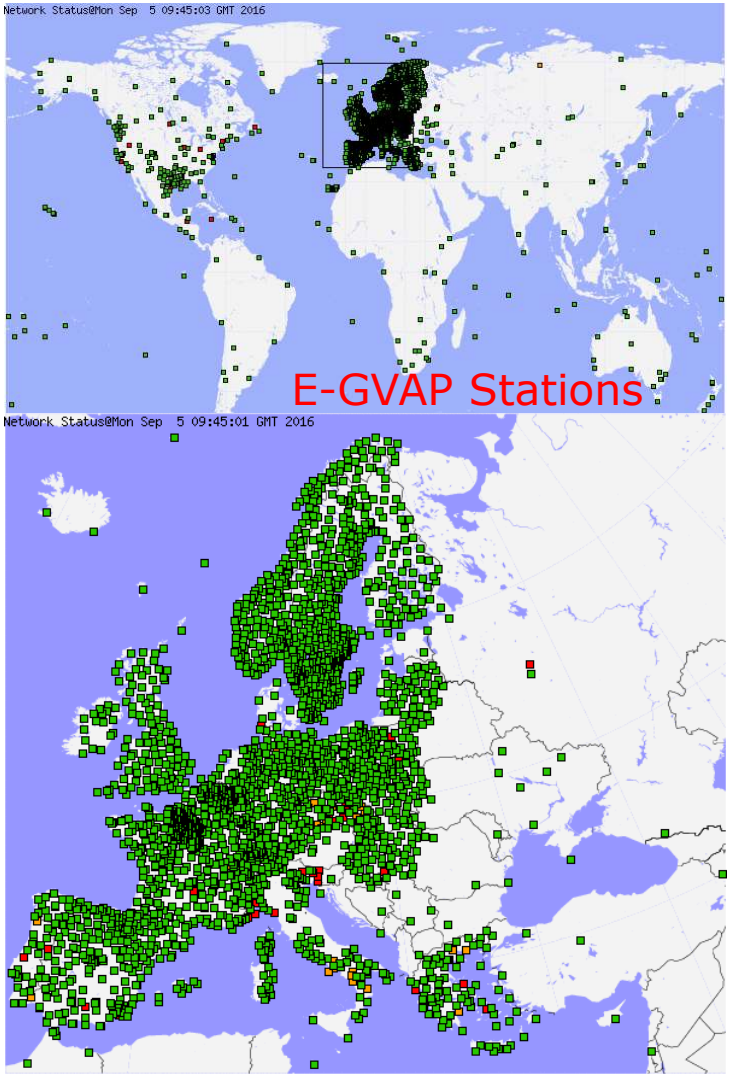


Zenith Total Delay,
Precipitable Water Vapor,
Slant Total Delay Gradients



Operational use of GFZ ZTD data by several European meteo services for weather forecast (e.g. MeteoFrance, UKMet Office)

GFZ Participation in European Meteo Projects



E-GVAP I,II,III (2006 - 2018)

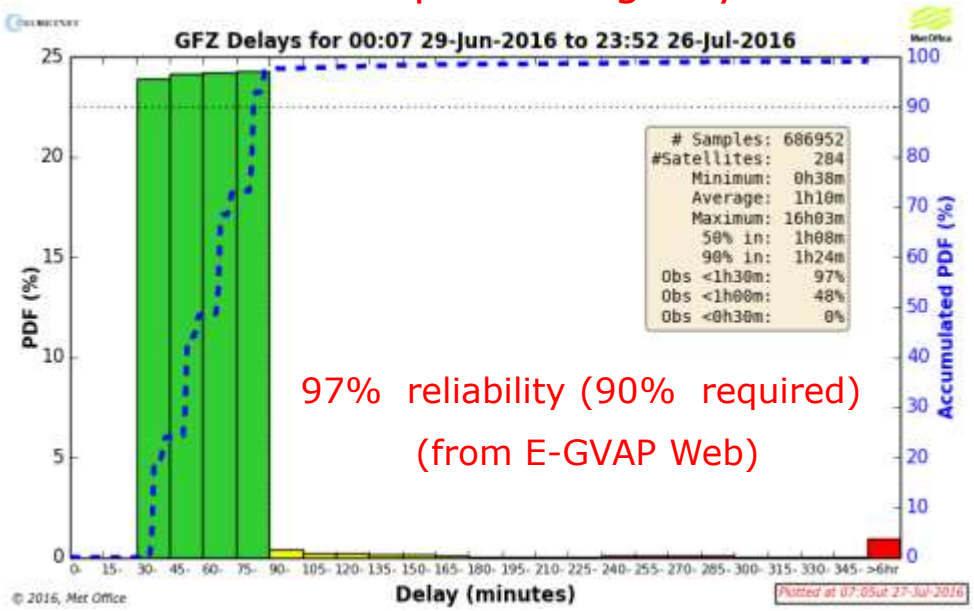
EUMETNET GPS Water Vapor Programme

20 Analysis Centres in Europa

(10 operational)

More than 4000 GNSS stations

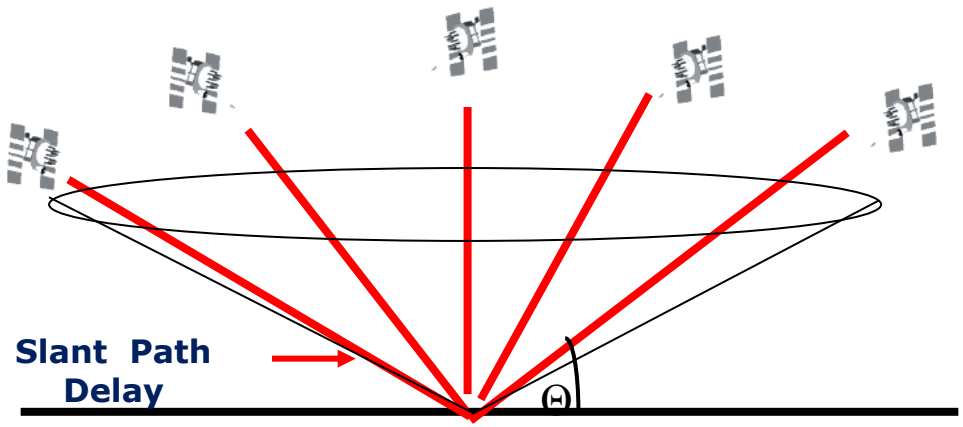
Statistics GFZ processing July 2016



97% reliability (90% required)

(from E-GVAP Web)

Operational “Slant Delays” Processing



EPOS software feature:
automatic processing of ~100000 “slants” per hour (in case of “global” solution with ~500 stations)

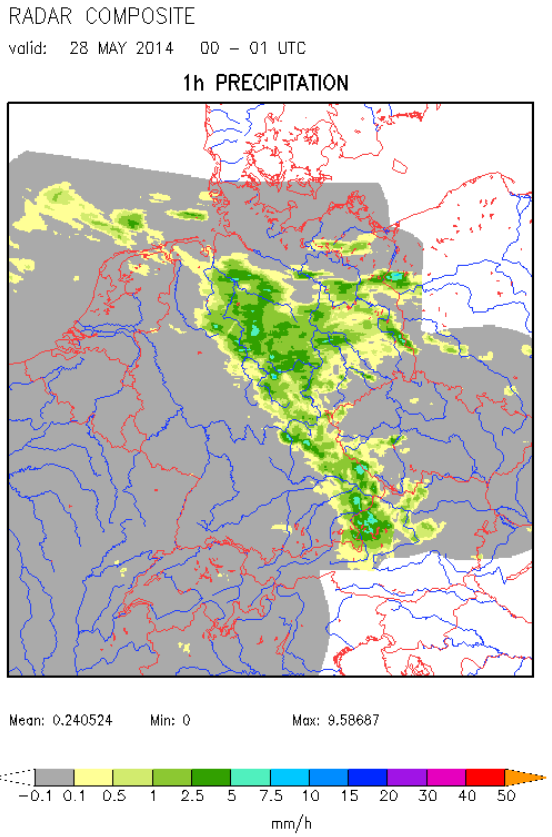
Delivering to DWD for the assimilation tests for NWP

“Slant delays”, derived from German SAPOS network

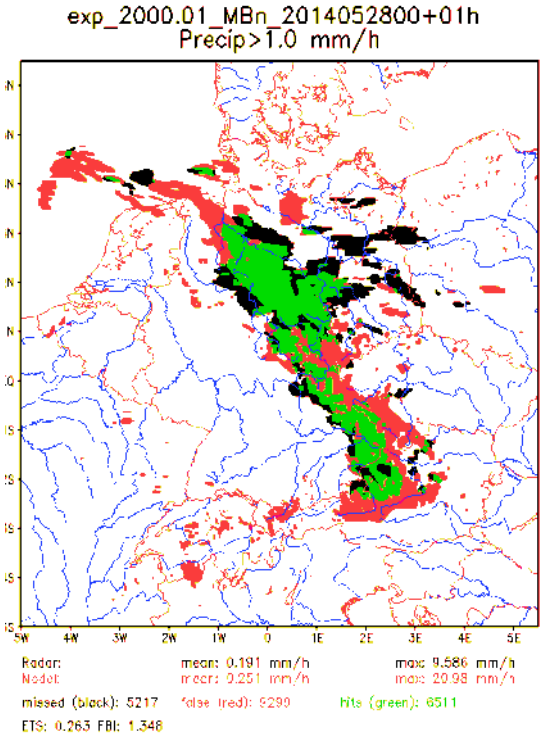
Positive Impact of Slants Assimilation on Rain Forecast

DWD results for 28 May 2014, 1:00 UTC, 0:00 UTC forecast, 1 mm/h threshold

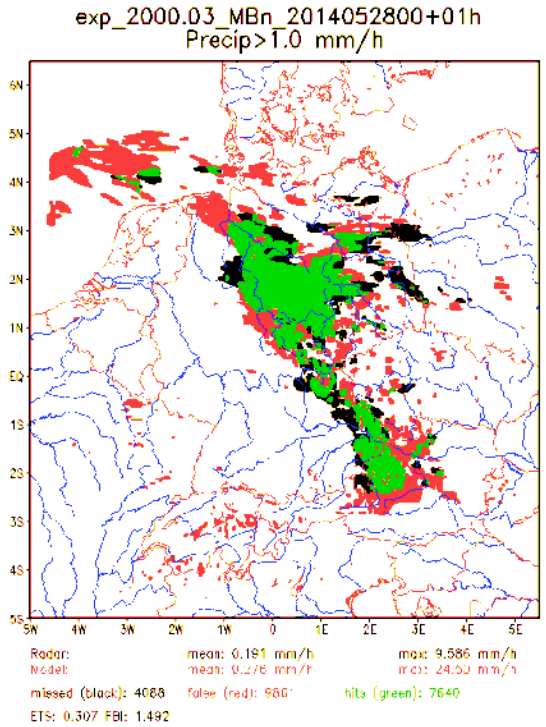
radar observations



control experiment



'slants' assimilation



Courtesy: M. Bender (DWD)

	hit	miss	false	ETS
control experiment	**6511**	**5217**	**9299**	**0.283**
'slants' assimilation	**7640**	**4088**	**9861**	**0.307**

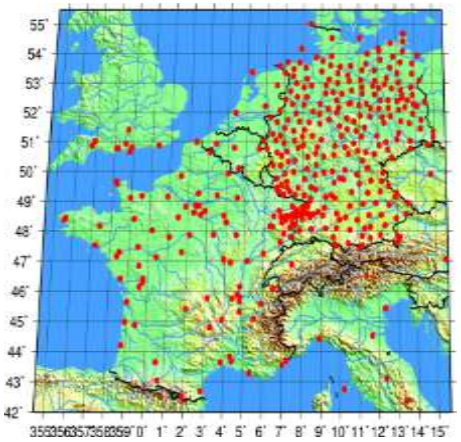
GFZ Helmholtz Centre Potsdam

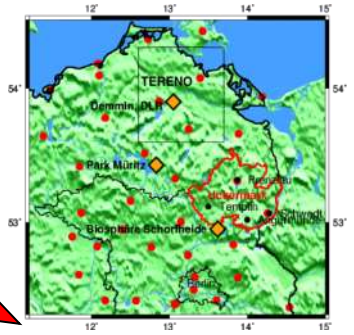
HELMHOLTZ ASSOCIATION

GNSS-derived PWV: GFZ Activities/Projects

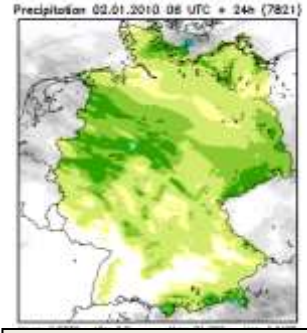
E-GVAP (EUMETNET GPS Water Vapor)
EU-COST Action: GNSS4SWEC

Monitoring network

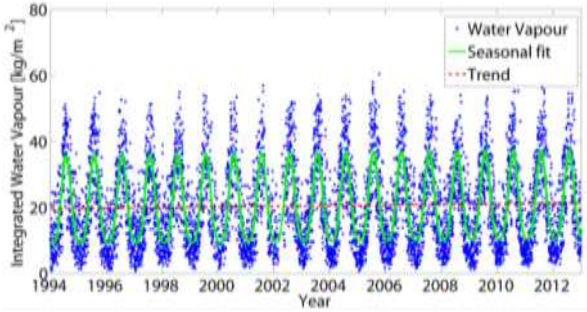




GFZ TERENO:
TERrestrial
ENvironmental
Observatories

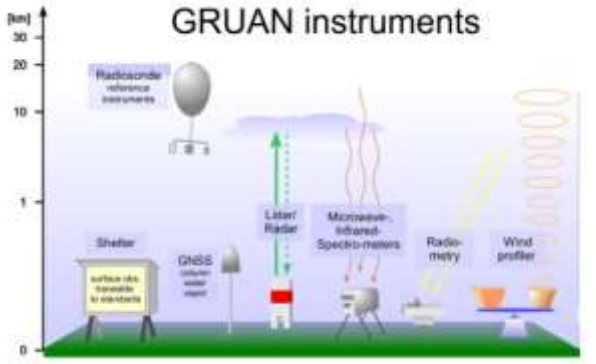


Assimilation in the numerical weather models



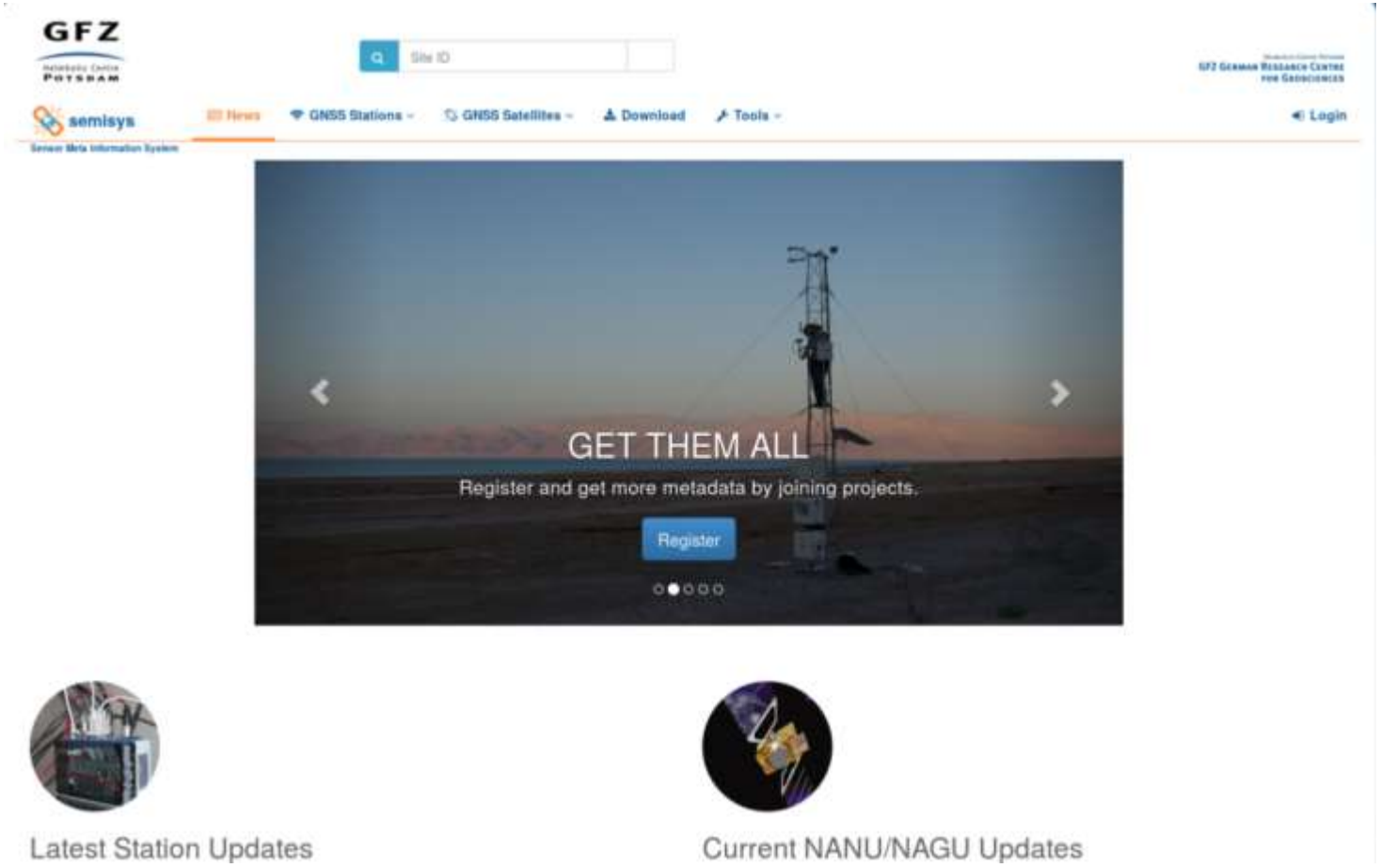
IWV trends for climate research

Meteo Campaigns:
DESERVE
(atmospheric and climate research)



GRUAN:
GCOS Upper Air Network
(climate research)

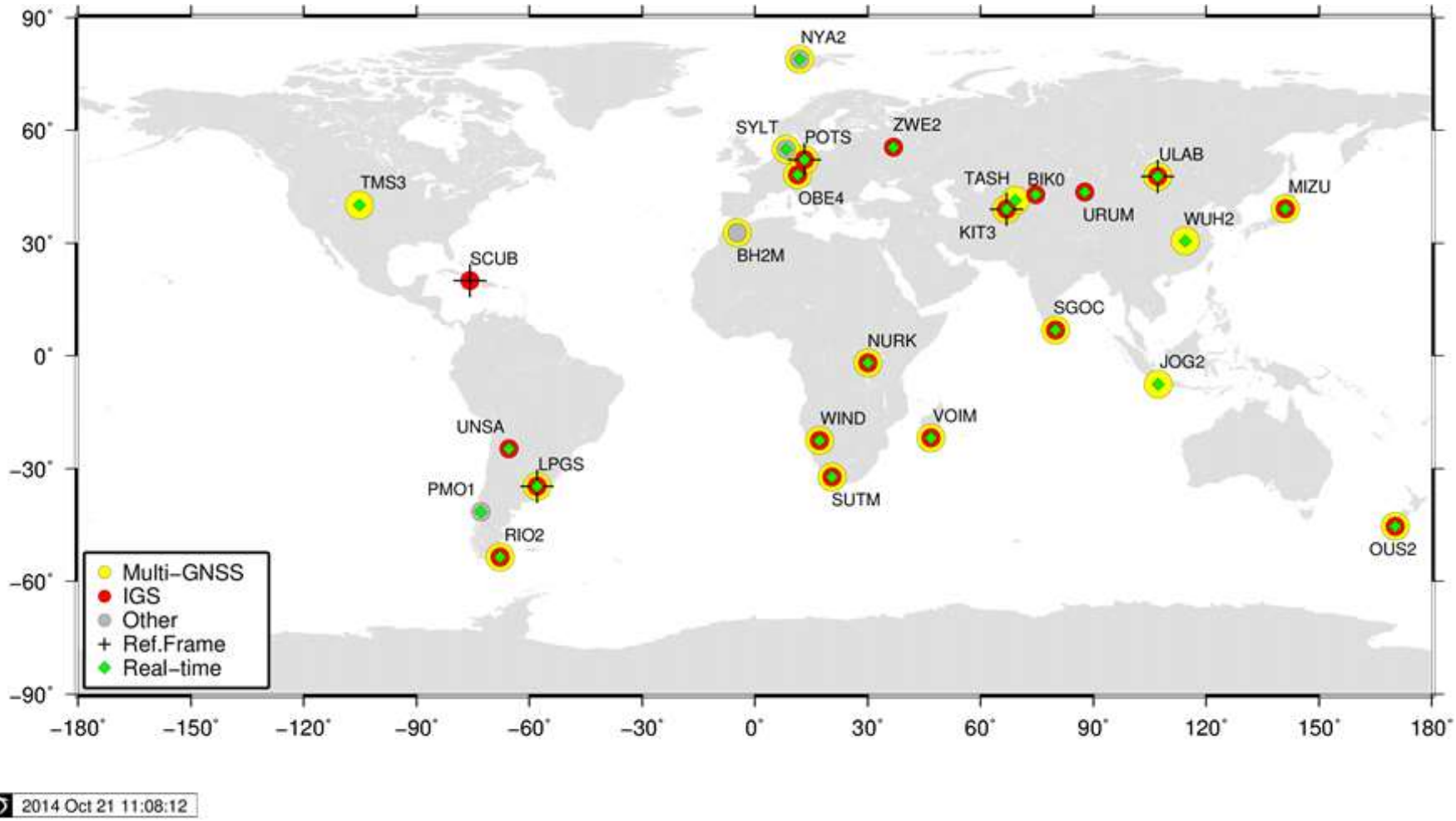
GNSS Data Handling at GFZ



GFZ Sensor Meta Information System (SEMISYS, M. Bradke): http://semisys.gfz-potsdam.de

GFZRNX toolbox (Th. Nischan): metadata/data editing, splicing, splitting, converting

GFZ GNSS Global Network

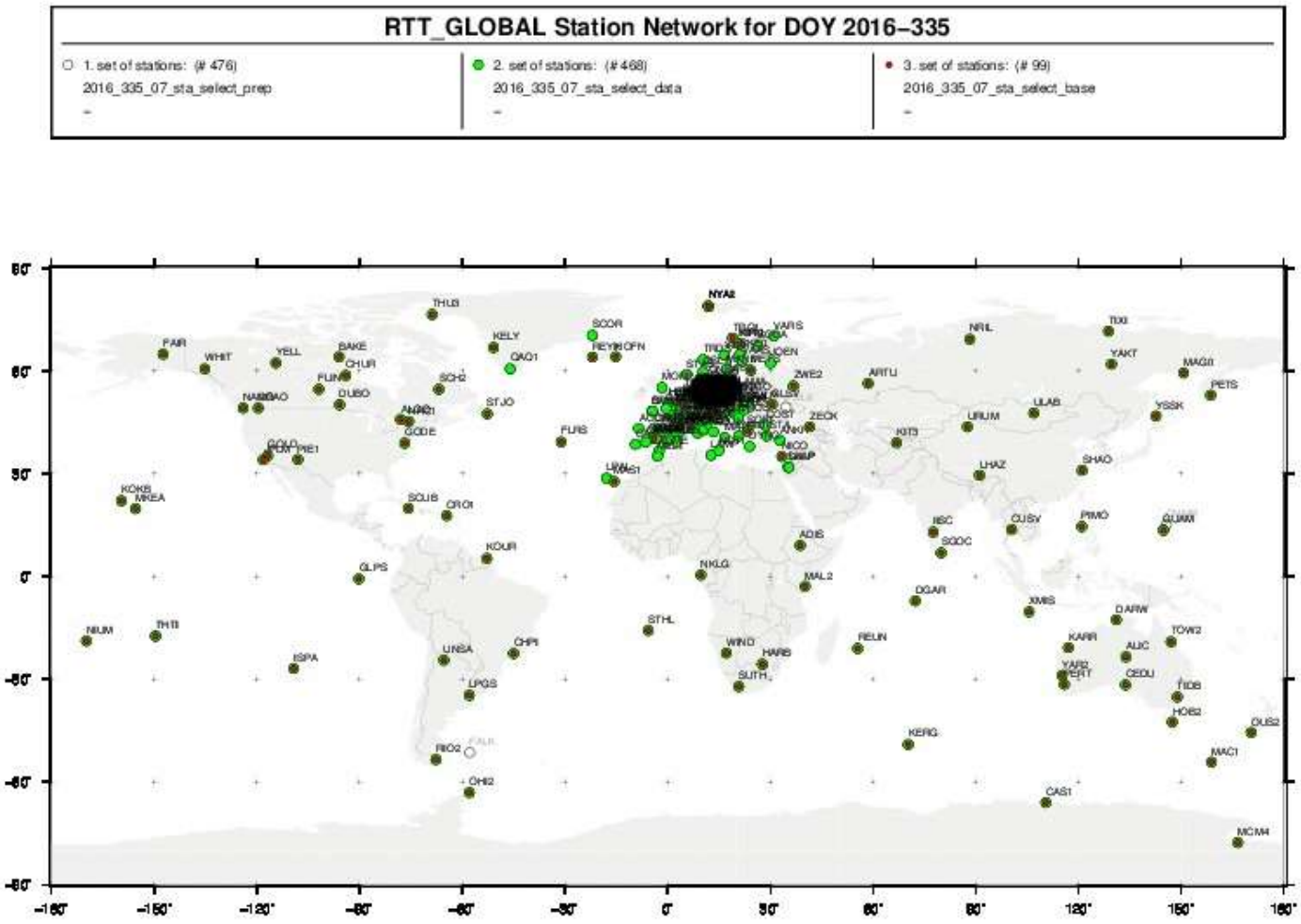


GFZ GNSS Operational Data Centre

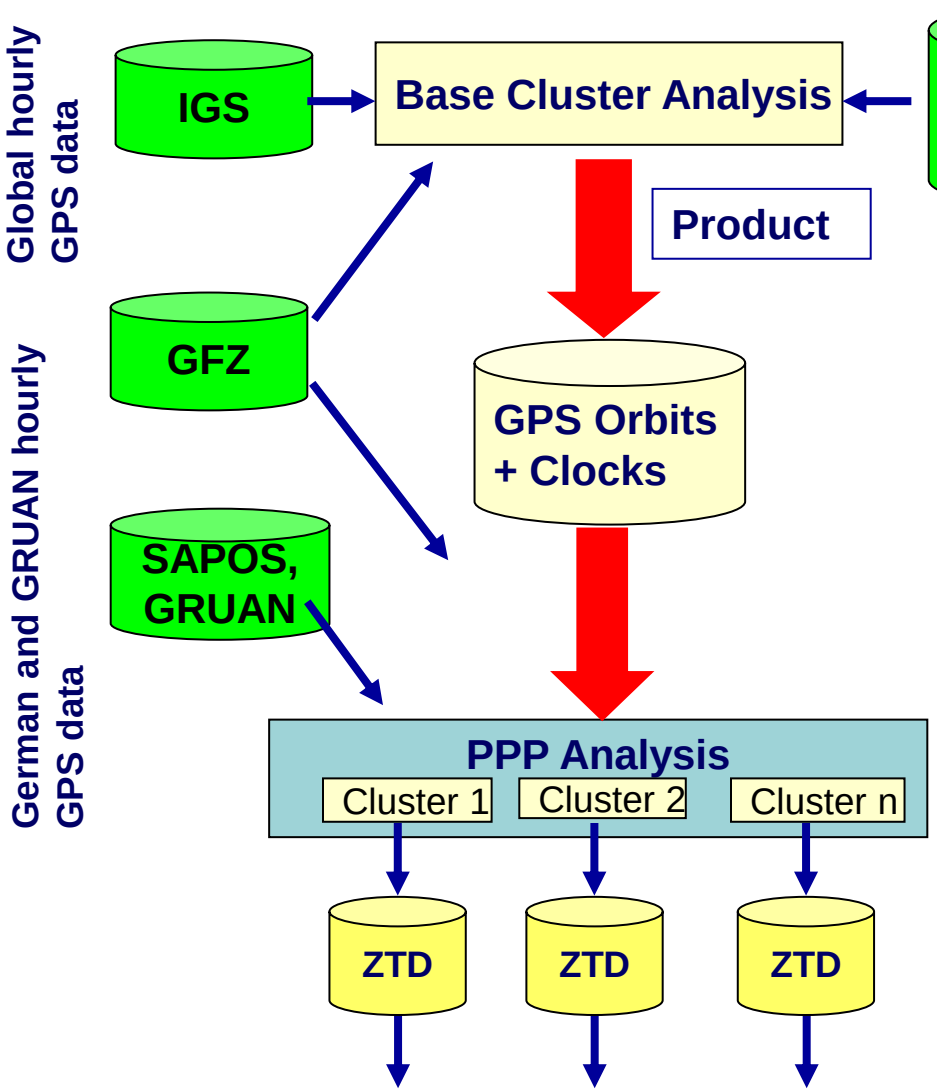
GNSS sites operated by GFZ

- 21 stations @ **IGS** International GNSS Service, 6 core stations
- 20 stations @ **MGEX** Multi-GNSS EXperiment
- 15 stations @ **GRAS** GNSS Receiver for Atmospheric Sounding within MetOp
- 02 stations @ **EPN** EUREF Permanent Network
- 04 stations @ **ESA** European Space Agency: Galileo Experimental Sensor Stations
- 05 stations @ **GRUAN** GCOS Reference Upper Air Network

Global GNSS Network in NRT Processing for PWV



GNSS Processing with GFZ EPOS Software (PPP strategy)



GFZ EPOS Software (PPP strategy):

Part 1 - Network orbit improvement:

- Adjustment of precise orbits & clocks
- Global network: ~80 IGS + German sites
- Input orbits: GFZ 3h Ultra Rapid (pred.)

Part 2 - PPP Analysis:

- Estimation of trop. parameters
- Large set of parameters possible: high sampling rate, ZTD/PWV/STD/Gradi

Processing time (LINUX PC):

<15 min for more than 500 sta

Product generation (conversion to PWV)
Product distribution

Overview of GNSS Processing at GFZ for PWV

NRT processing:

- GF1R "rapid" solution for E-GVAP (about 360 stations)
- GF1G "global" solution for E-GVAP (about 460 stations)
- GRUAN processing (delay > 1h)

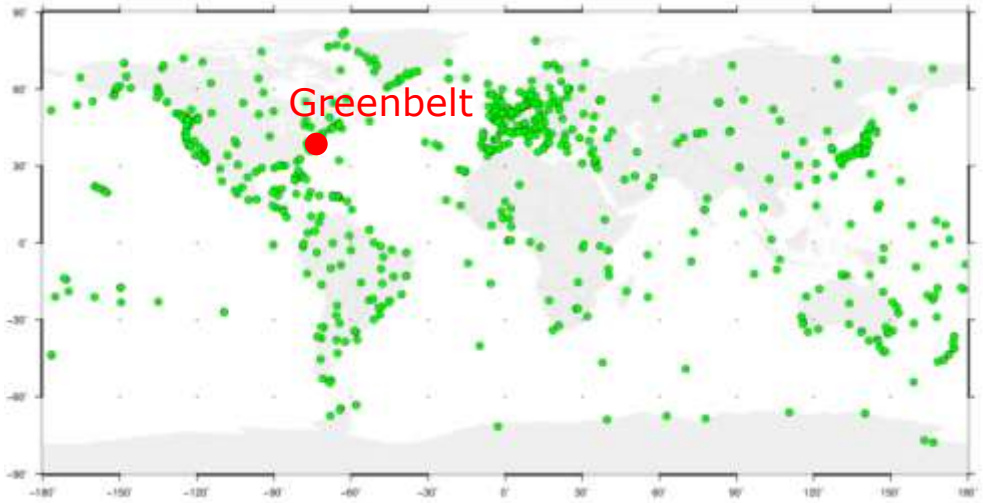
TIGA reprocessing project of IGS (finished):

- about 800 globally distributed TIGA stations
- 19 years data span
- ZTD products are available at GFZ ftp

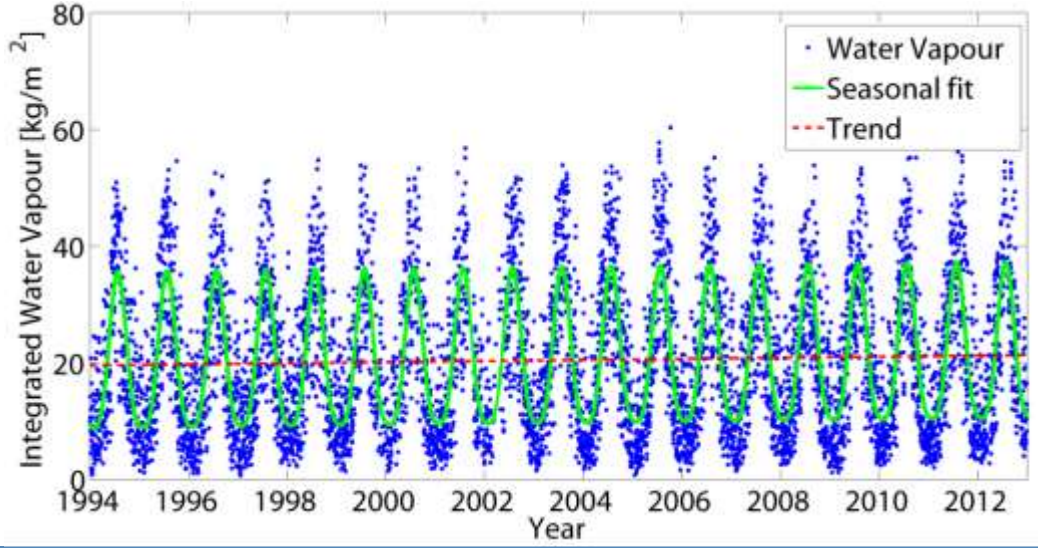
Reprocessing for climate applications (on-going):

- German SAPOS + global IGS + GRUAN network
- about 600 stations in processing
- more than 15 years data span
- ZTD/PWV products both in COST and TRO-SINEX format, available at GFZ ftp
- other products are also available: gradients, slants

Long term water vapor trends



- Recent consistent reprocessing
- ~800 stations
- 19 years of data (1994 - 2013)



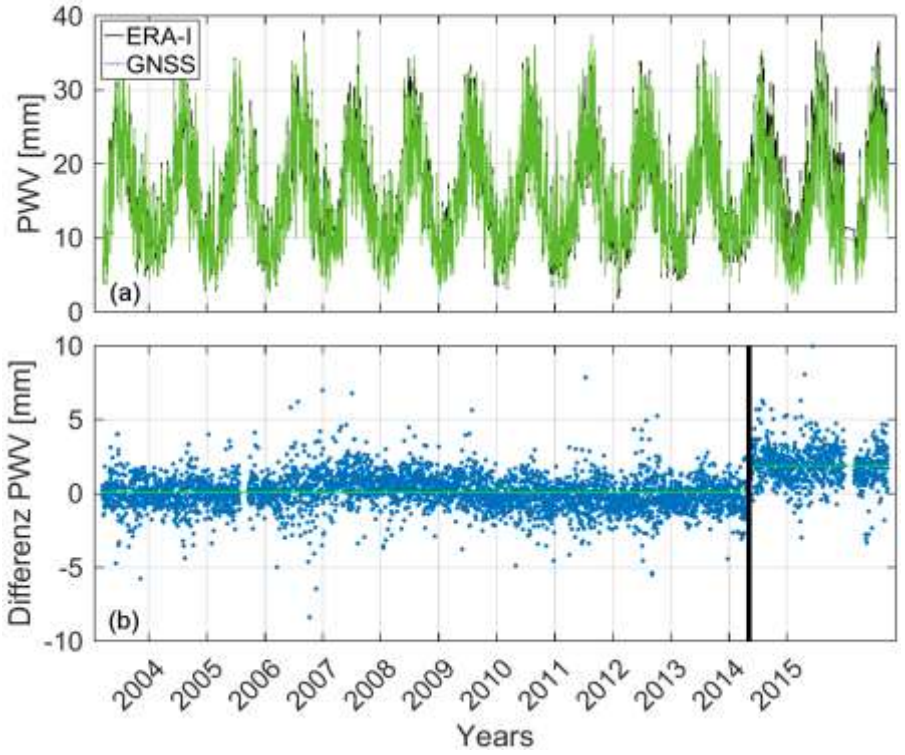
- Example:

  Greenbelt (+0.94 mm/decade)
- Quality of the entire data set currently evaluated

Homogenization of PWV Time Series

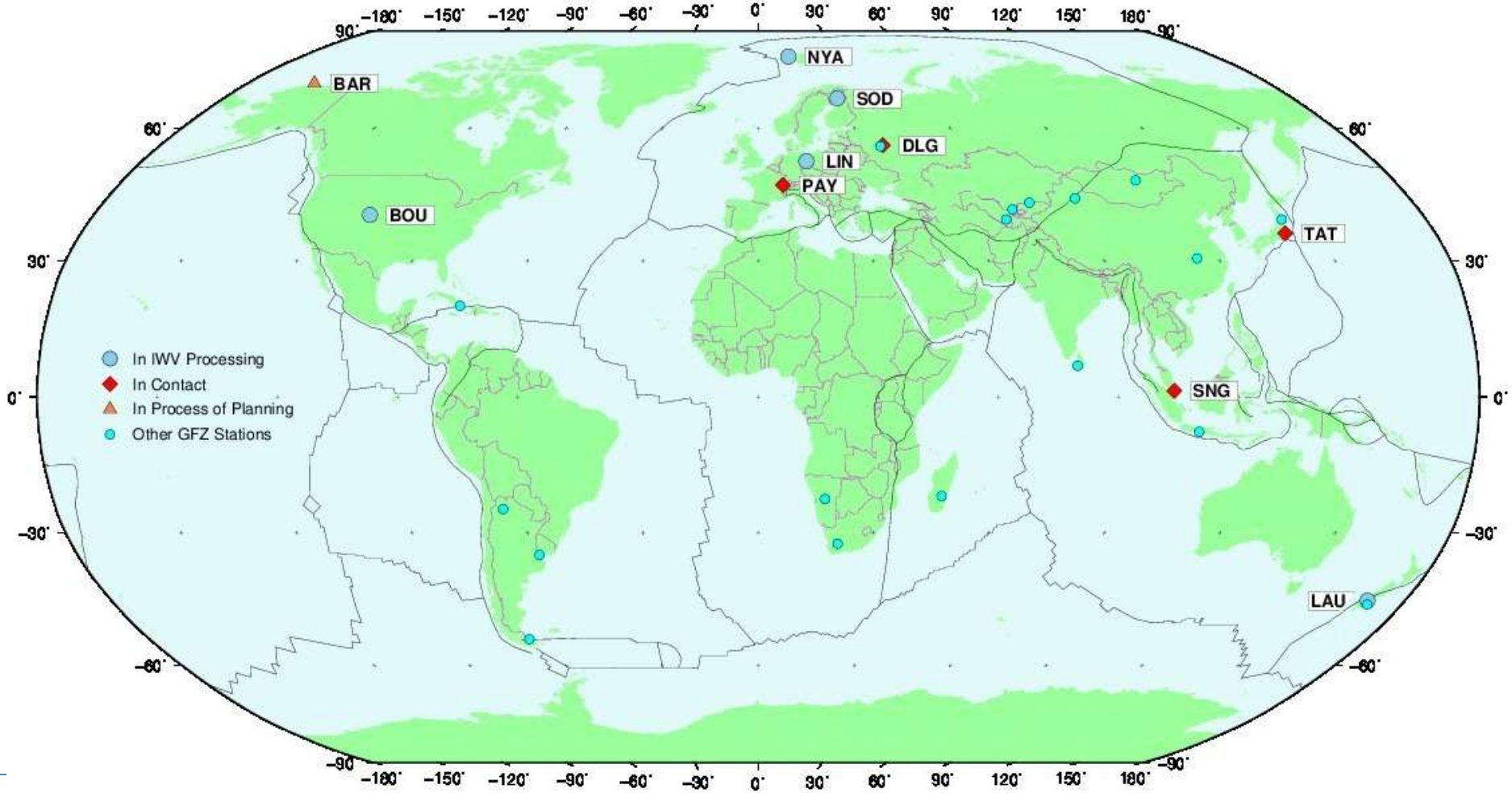
- Required for detecting climatic trends

- Inconsistencies in time series:
  - change processing setup
    → avoidable by reprocessing
  - change hardware or software of GNSS stations
    → not avoidable!
    → homogeneity check



- Uncertainty estimation → detect and correct inhomogeneity

GRUAN GNSS Network



GRUAN GNSS Site Lindenberg (Germany)

- GFZ site LDB0, installed 2007
- GNSS data available since 2007
- PWV NRT products available starting from 2007
- Reprocessing on-going
- Automatically hourly GNSS raw data flow and NRT analysis
- Co-located GNSS site LDB2 (operated by BKG)

GRUAN GNSS Site Ny-Alesund (Norway)

- GFZ site NYA2, installed 2011
- GNSS data available since end of 2011
- PWV products available starting from 2011
- Reprocessing on-going
- Automatically hourly GNSS raw data flow and NRT analysis
- IGS sites NYAL and NYA1 (close to NYA2)

GRUAN GNSS Site 'Table Mountain' Boulder (USA)

- GFZ site TMS3, installed 2014
- GNSS data available since end of 2016
- ZTD NRT products available starting from Jan 2017
- Re-processing will be done
- Automatically hourly GNSS raw data flow and NRT analysis

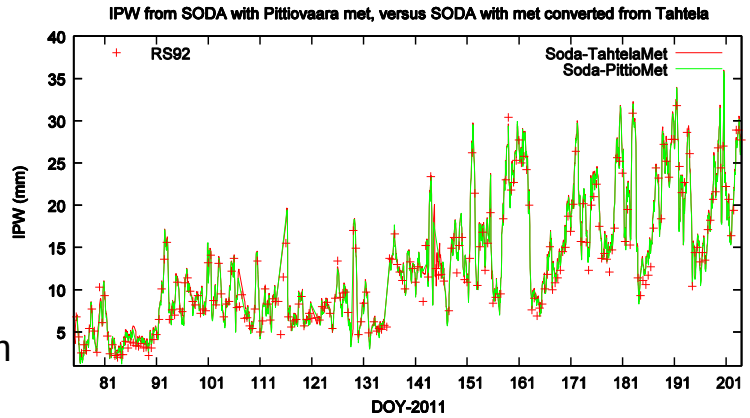
GRUAN GNSS Site Sodankyla (Finland)

- FMI/GFZ site SODF, installed Feb 2015, GFZ site software
- GNSS data available since 2015
- PWV NRT products available starting from 2017
- Reprocessing will be done
- Automatically hourly GNSS raw data flow and NRT analysis
- Another GNSS site SODA

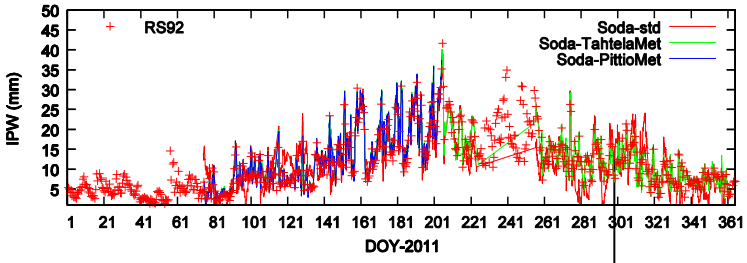
Courtesy: Rigel Kivi (FMI)

Pittiövaara

97 m



Sodankylä



20 km

Courtesy: Rigel Kivi (FMI)

GRUAN GNSS Site Lauder (New Zealand)

- GNSS site LDRZ
- installed 2012
- GNSS data available since 2012
- PWV products available only in reprocessing mode
- Reprocessing on-going
- NO automatically hourly GNSS raw data flow and NRT analysis

Future Work

GNSS data processing:

- Reprocessing 2000-2016 (about 600 sites, including GRUAN)
- PWV time series homogenisation and trend analysis
- PWV uncertainty estimation

GRUAN sites:

- GNSS site in NSA-C1 site of Barrow: installation of GNSS test equipment (July 2017)
- Payerne (Switzerland), Cabauw (Netherlands) and Potenza (Italy): GNSS data flow and processing at GFZ (in progress)
- Dolgoprudny (Russia): negotiations on GNSS data flow and processing via GFZ
- Singapore (Singapore) and Tateno (Japan): GFZ contacted these sites

Contacts

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Many thanks for your attention!