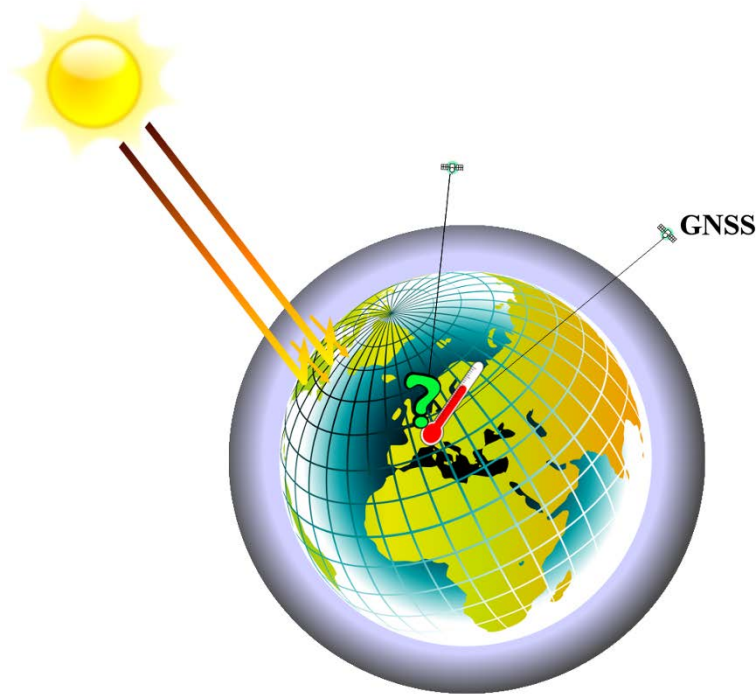


Analysis of long-term temporal variations in atmospheric water vapor time series

F. Alshawaf, G. Dick, S. Heise, T. Simeonov, S. Vey, T. Schmidt, and J. Wickert

German Research Center for Geosciences GFZ

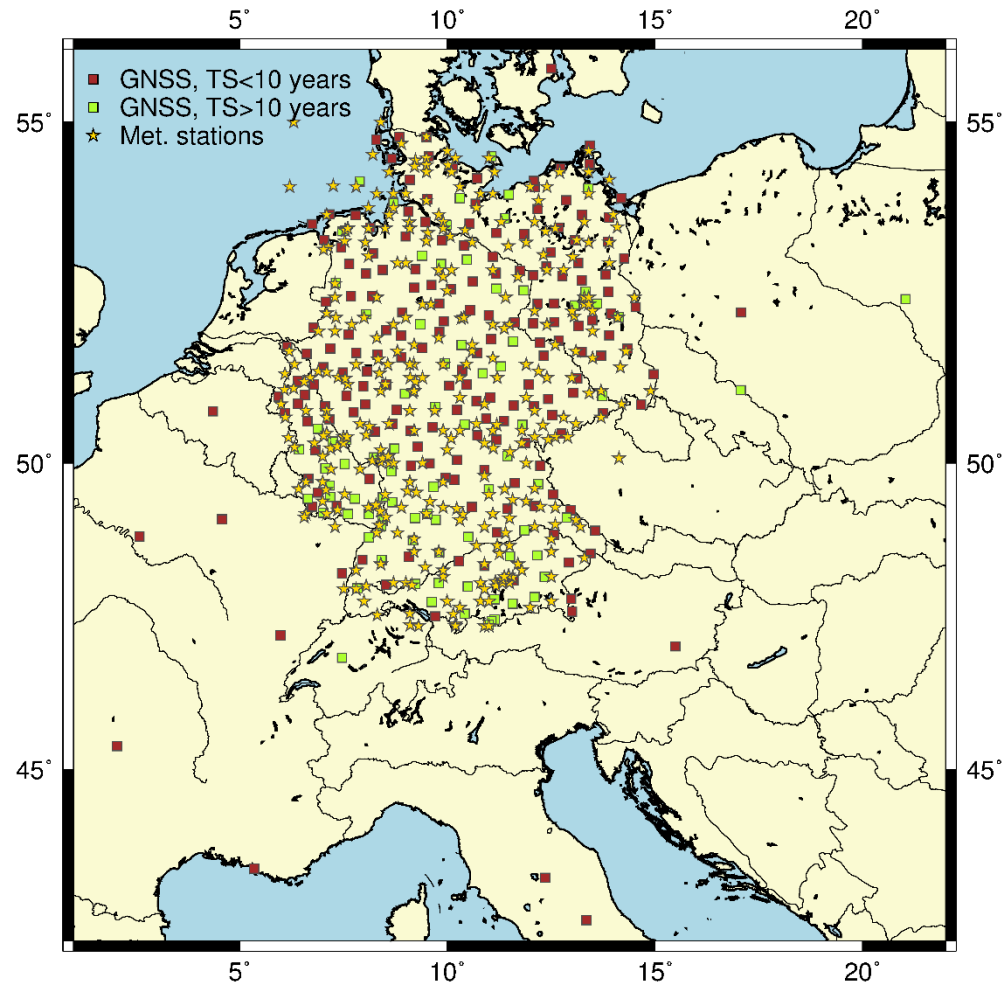


Motivation

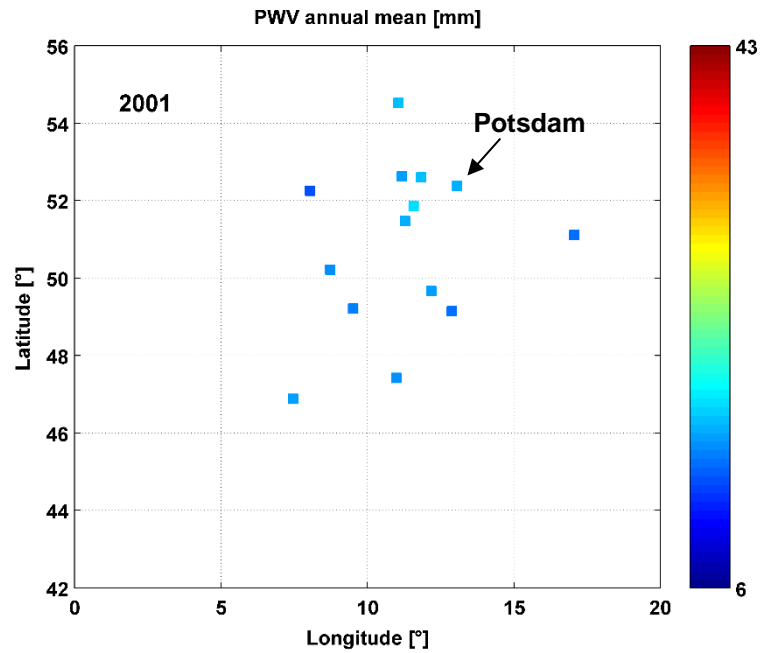
- Improving the assessment of past and projected impacts of climate change
- Monitoring atmospheric variables:
 - Temperature
 - Precipitable water vapor
 - Precipitation
 - Ice and snow
- GNSS are not sufficient and time series are not long enough
- Meteorological data, Radiosonde, Reanalysis and model data
- Data homogenization

Data sets

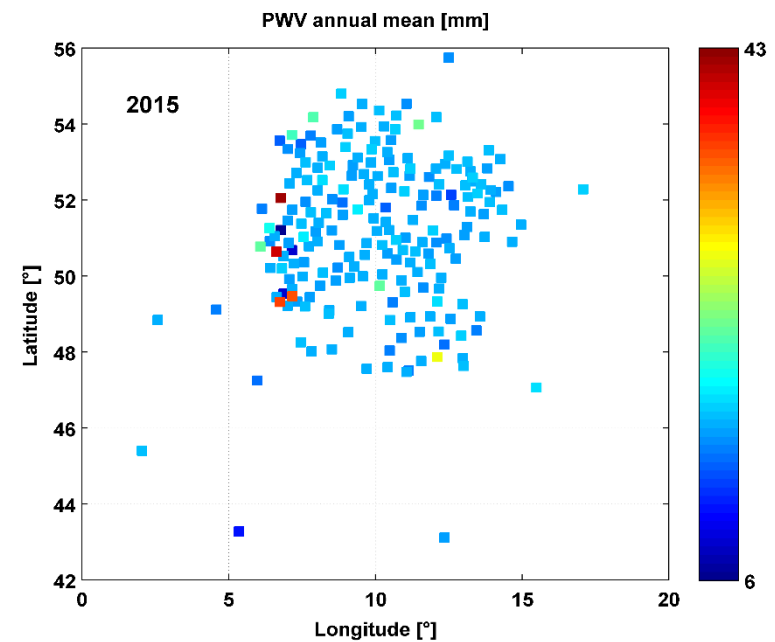
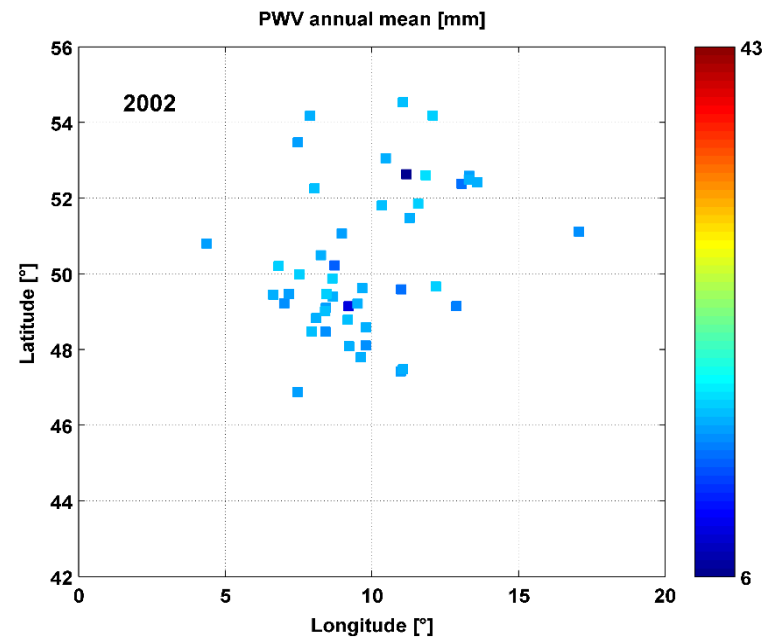
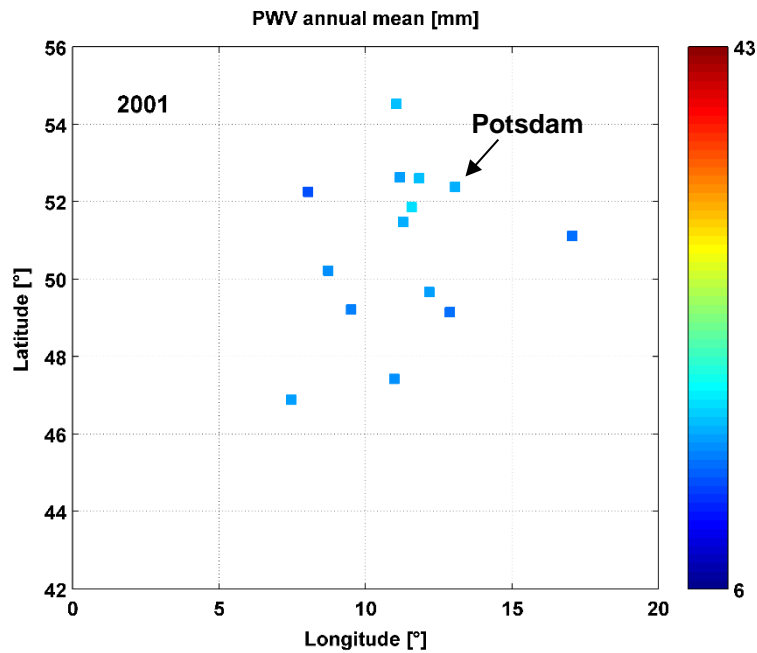
- GPS-based PWV, ZTD, ZWD, at 15 minutes
- 278 sites
- 84 sites with time series > 10 years



Data sets

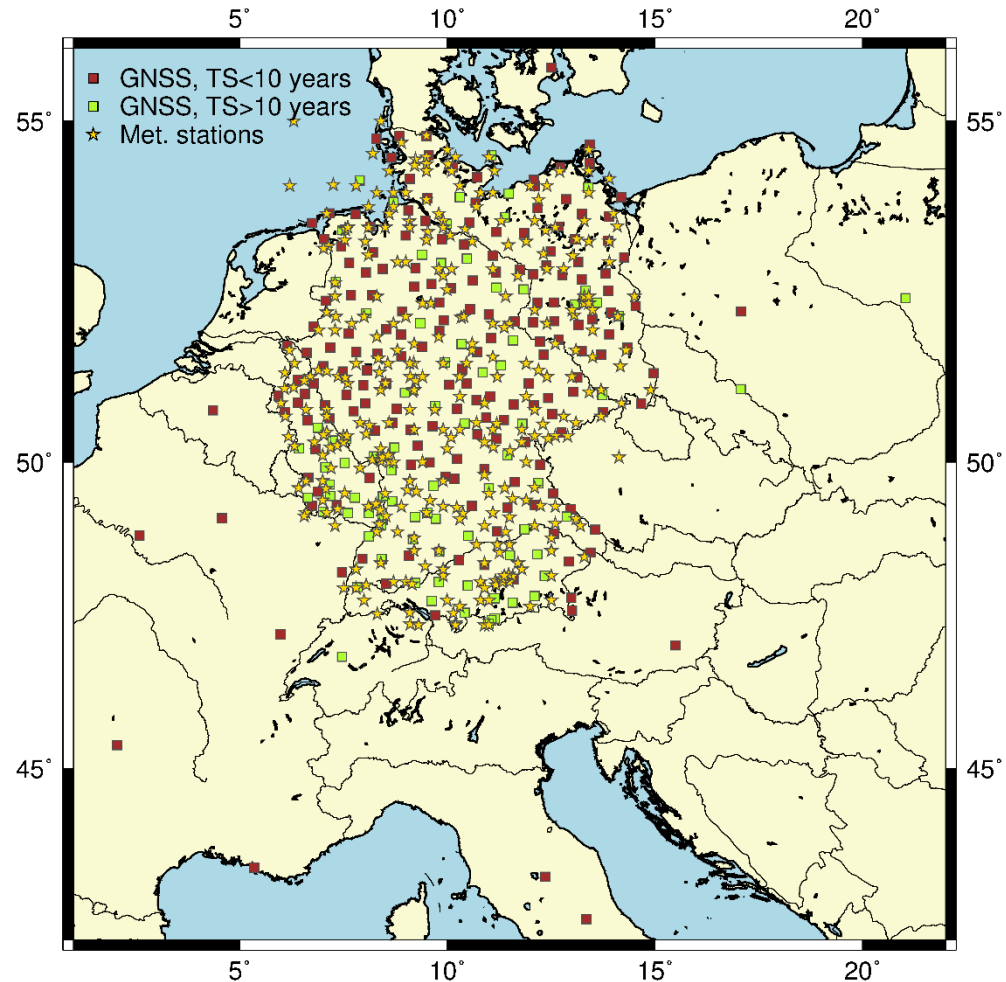


Data sets



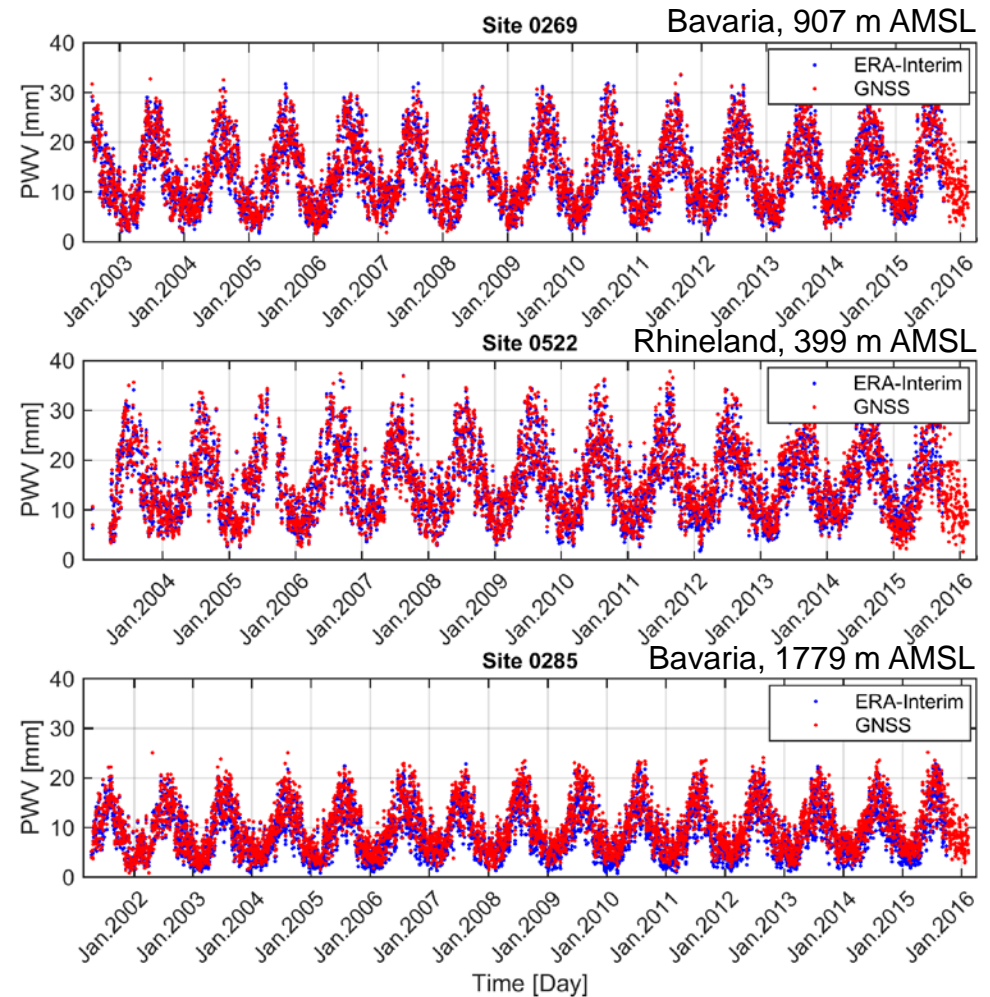
Data sets

- GPS-based PWV, ZTD, ZWD, at 15 minutes
- 278 sites
- 84 sites with time series > 10 years
- 326 meteorological stations from the German weather service (DWD) Climate Data Center (CDC)
<ftp://ftp-cdc.dwd.de/pub/CDC/>
Hourly observations of P, T, RH, etc.
- Radiosonde, 2 measurements/day
- ERA-Interim at 6 hours and 60 km × 60 km, since 1979



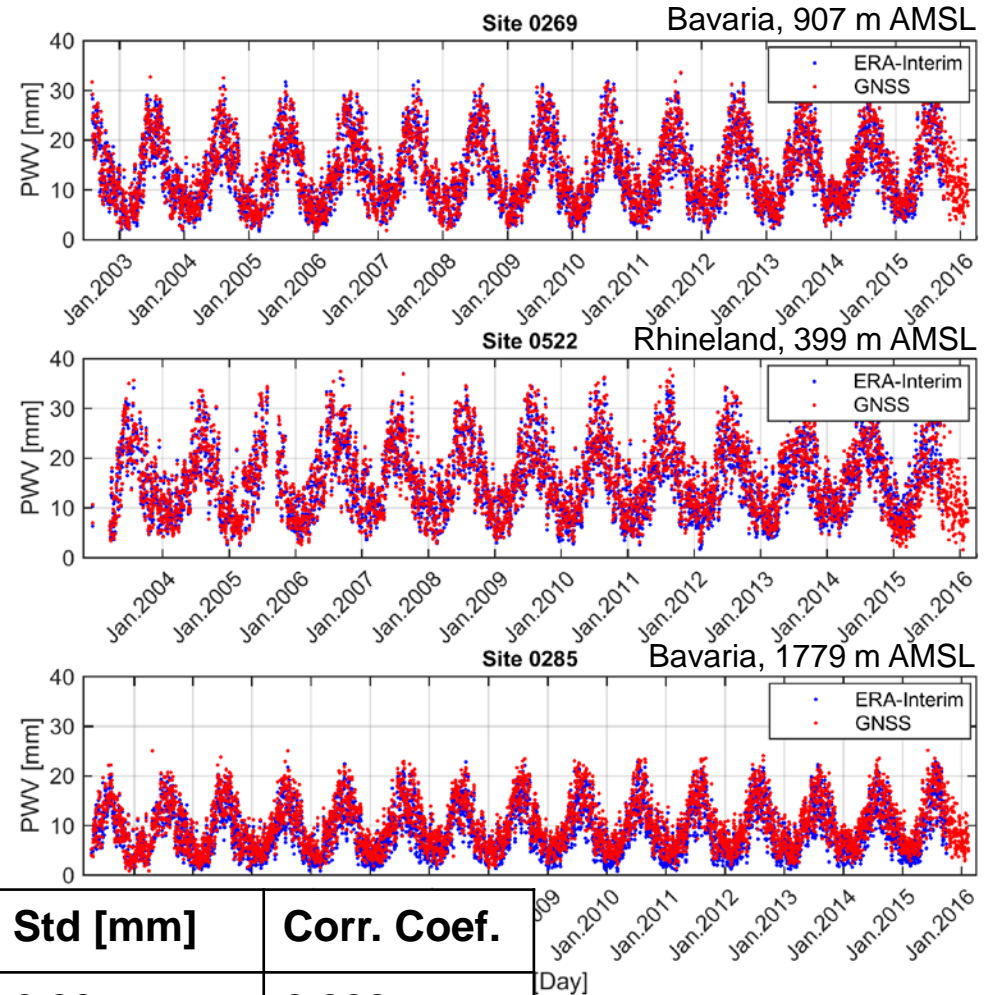
GNSS and ERA-Interim

- Downscaling
- Vertical interpolation
- Daily mean values



GNSS and ERA-Interim

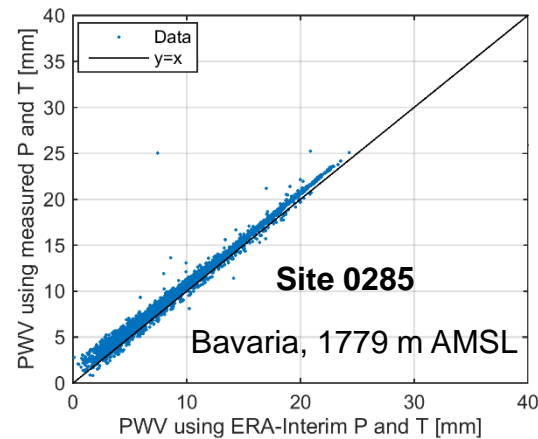
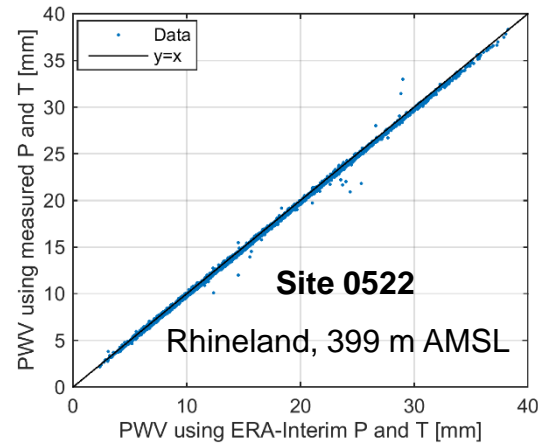
- Downscaling
- Vertical interpolation
- Daily mean values



	Mean [mm]	Std [mm]	Corr. Coef.
Site 0269 (Bavaria)	-0.275	0.33	0.998
Site 0522 (Rhinland)	0.205	0.189	0.999
Site 0285 (Bavaria)	-0.598	0.492	0.983

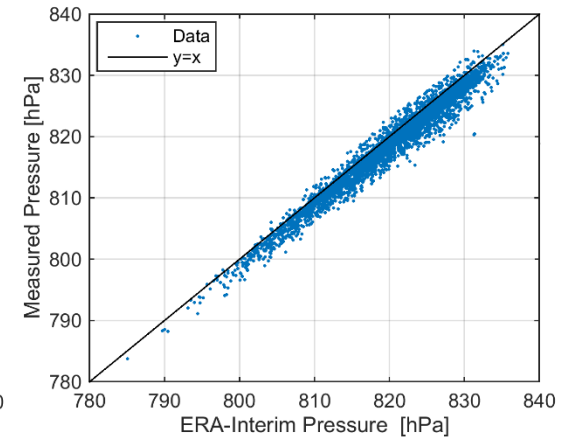
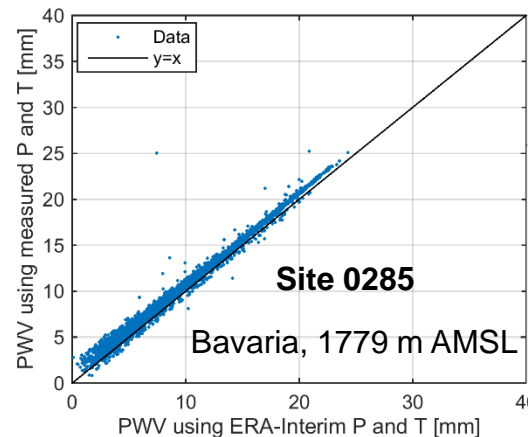
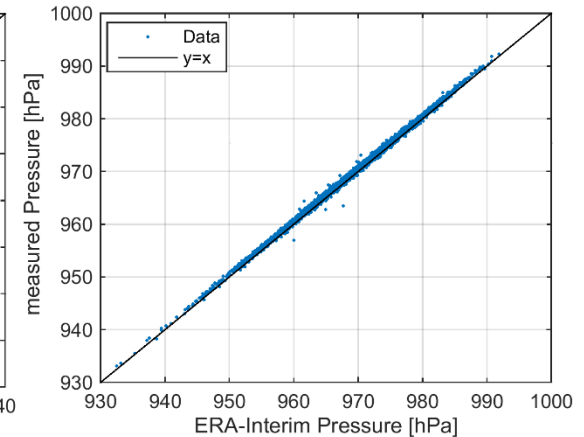
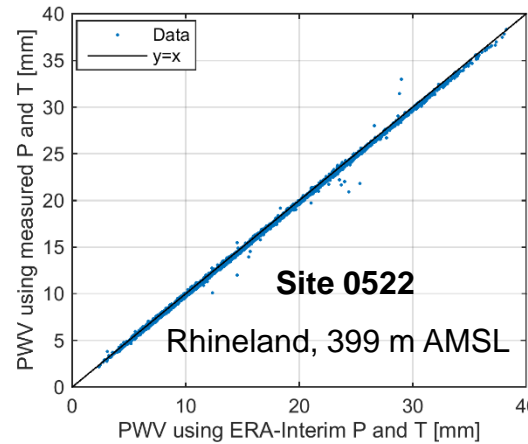
GNSS and ERA-Interim

- Using ERA-Interim pressure and temperature
- Downscaling and vertical interpolation



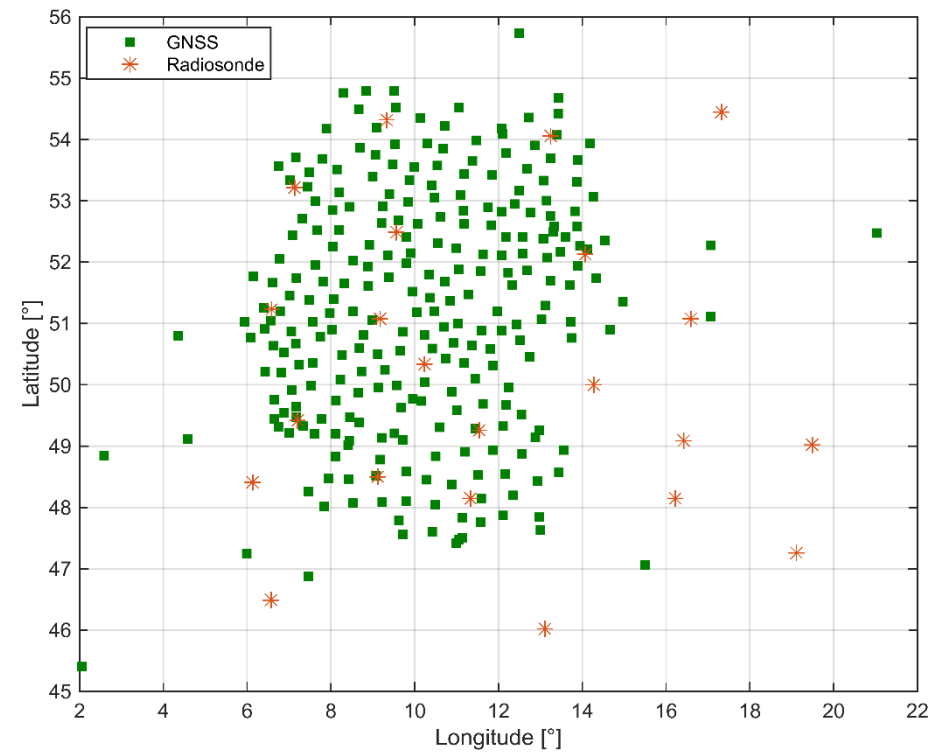
GNSS and ERA-Interim

- Using ERA-Interim pressure and temperature
- Downscaling and vertical interpolation
- ERA-Interim data are good replacement for synoptic data

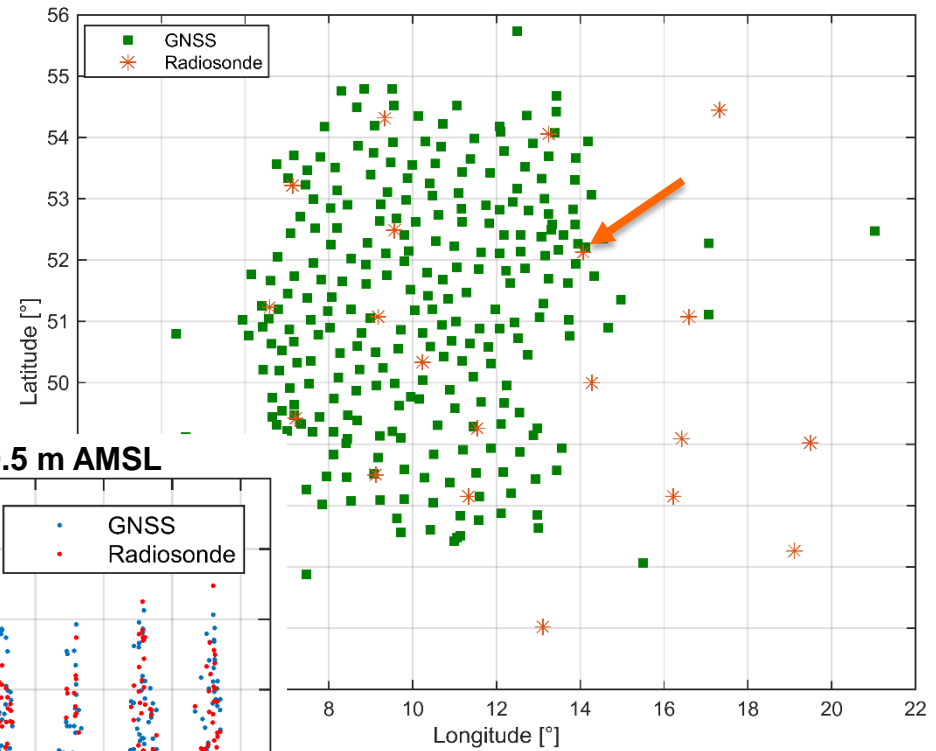
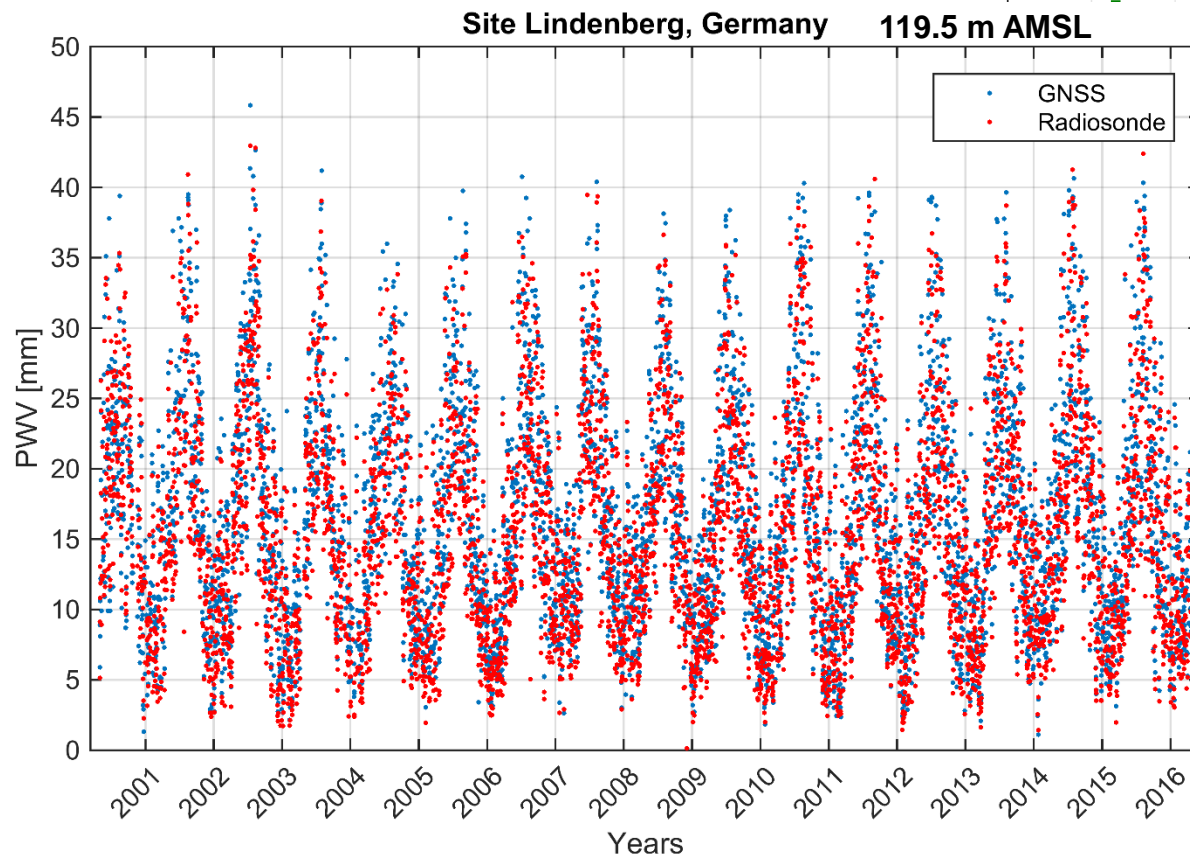


	Mean [hPa]	Std [hPa]	Corr. Coef.
Site 0522	-0.59	0.36	0.999
Site 0285	1.3	1.32	0.983

GNSS and Radiosonde



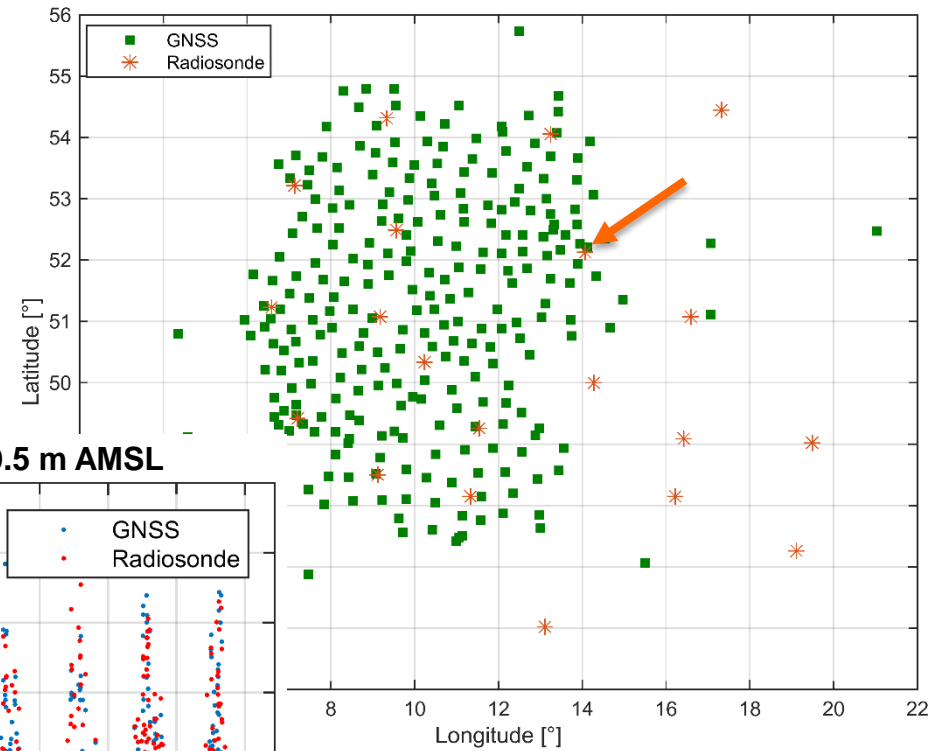
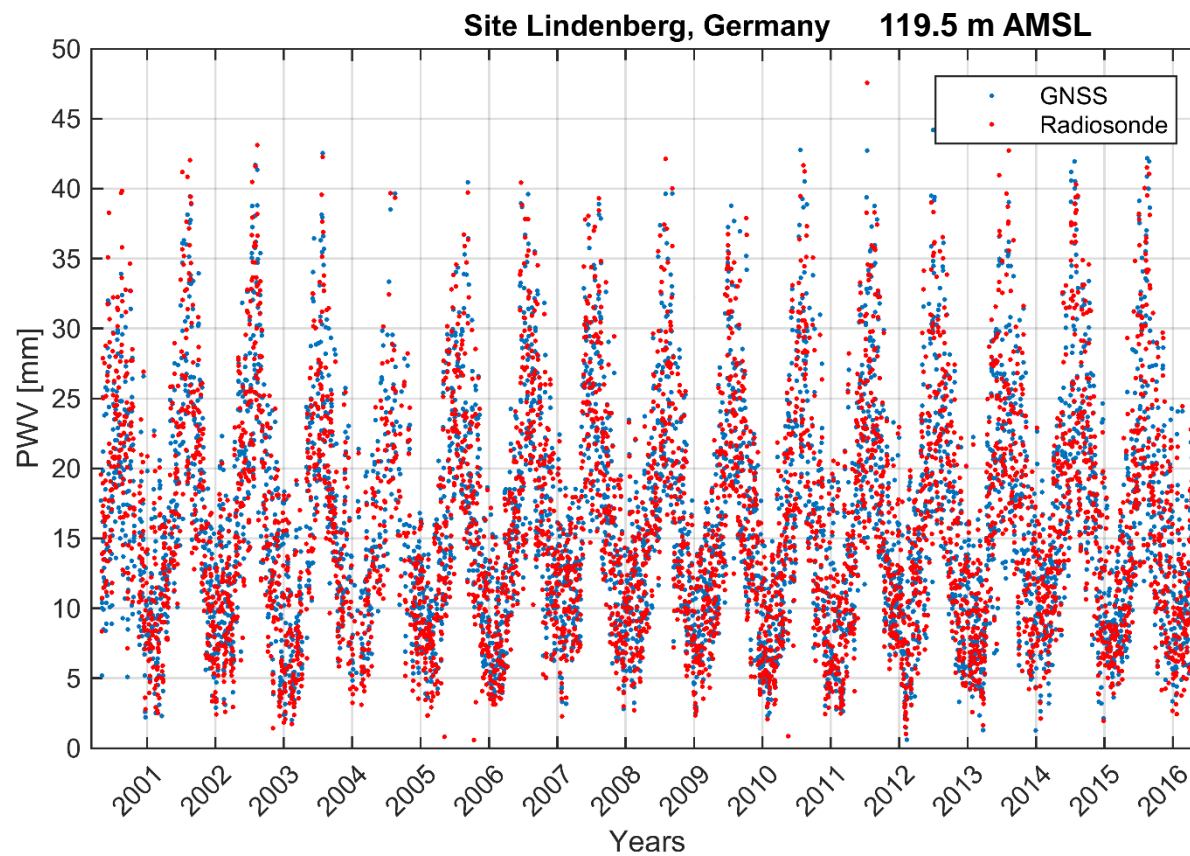
GNSS and Radiosonde



12 UTC

Corr. Coef.	0.98
Mean [mm]	1.17
Std [mm]	1.57

GNSS and Radiosonde

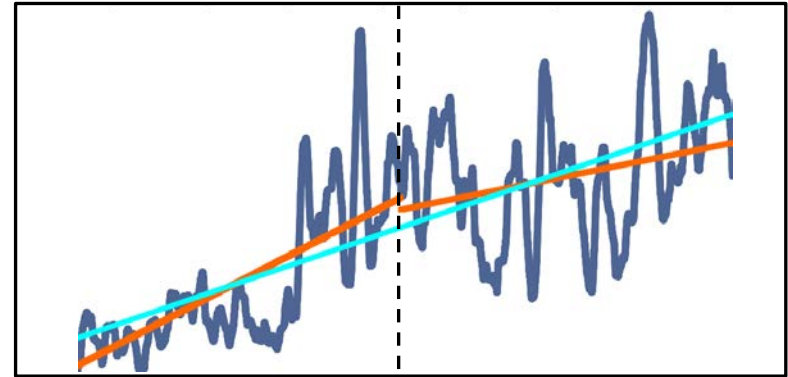


00 UTC

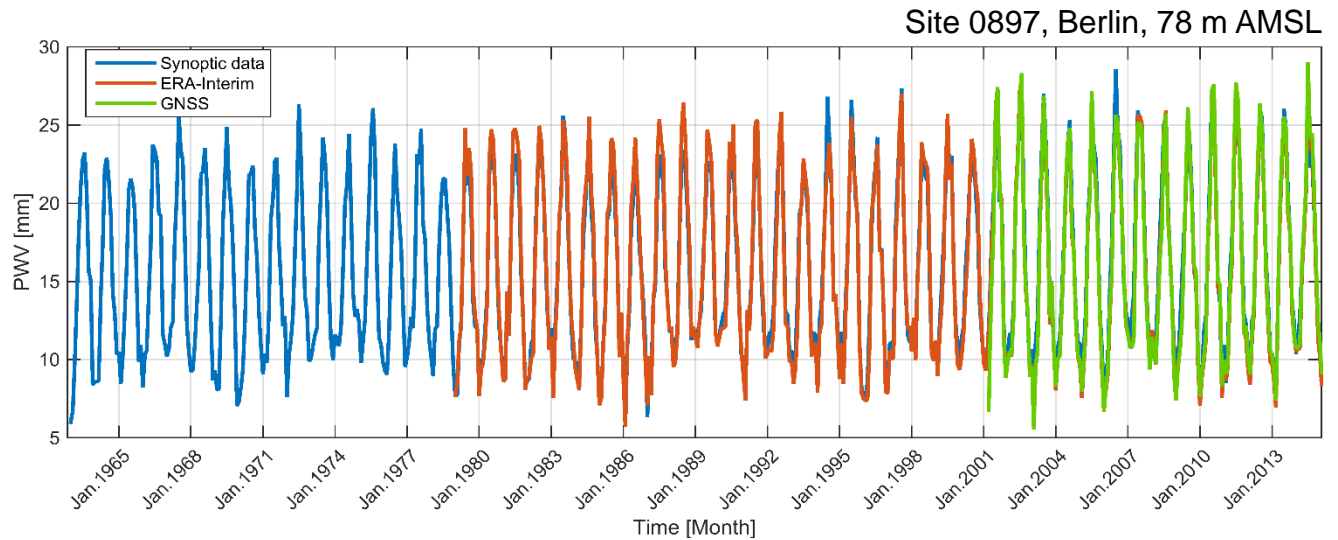
Corr. Coef.	0.98
Mean [mm]	0.19
Std [mm]	1.79

PWV from GNSS, ERA-Interim and Synoptic data

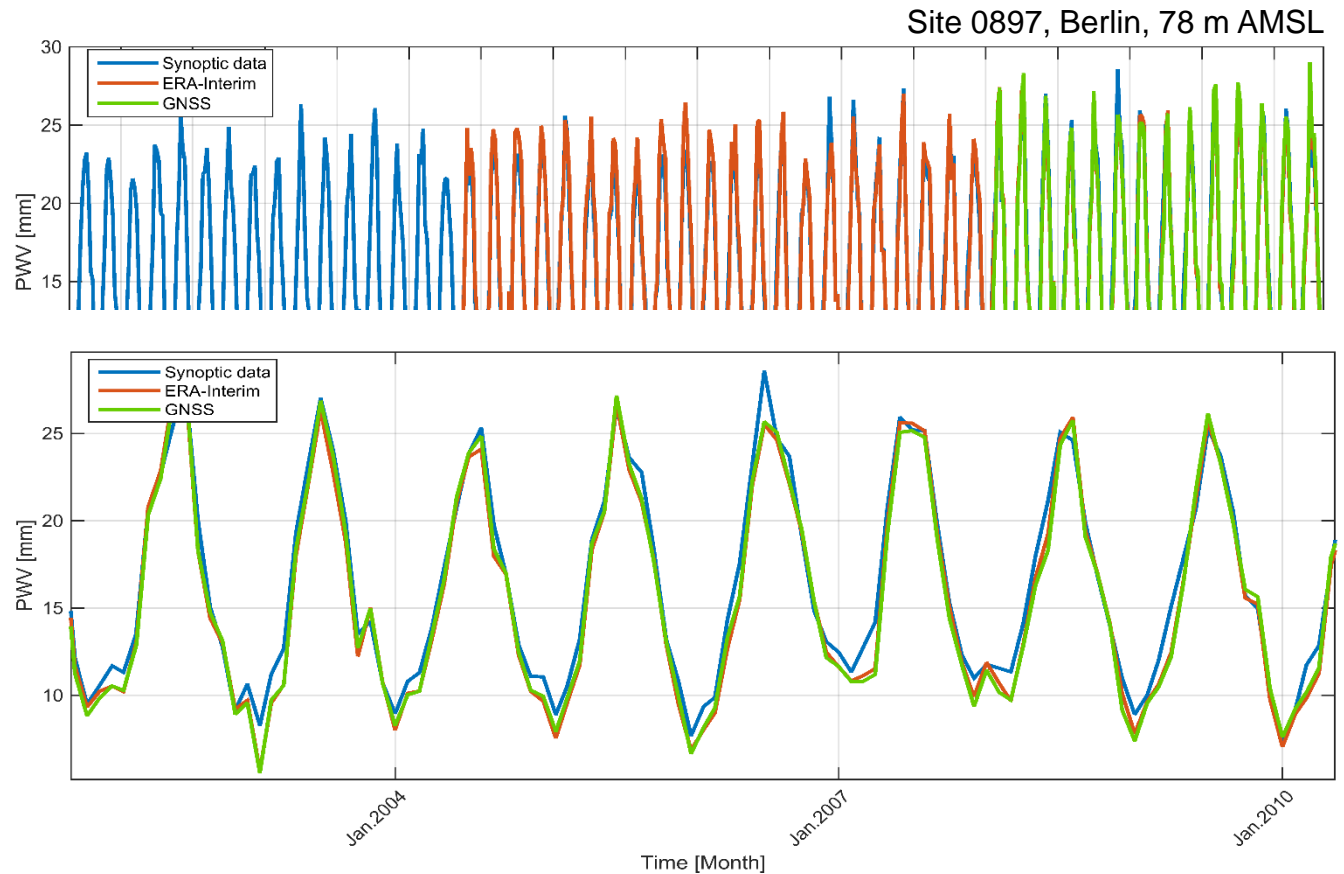
- Trend analysis
- For climatology, 15 years is too short!
- Other long-term data sets:
 - ERA-Interim reanalysis data
 - Synoptic data
- Using the Reitan relation:
 - $\ln PWV = a T_d - b$
 - $a = 1.288, 1.249, 0.981$
 - $b = 0.0384, 0.0427, 0.0341$ for hourly, daily, and monthly data, repec.
 - $T_d = T - \frac{(100-RH)}{5}$



PWV from GNSS, ERA-Interim and Synoptic data

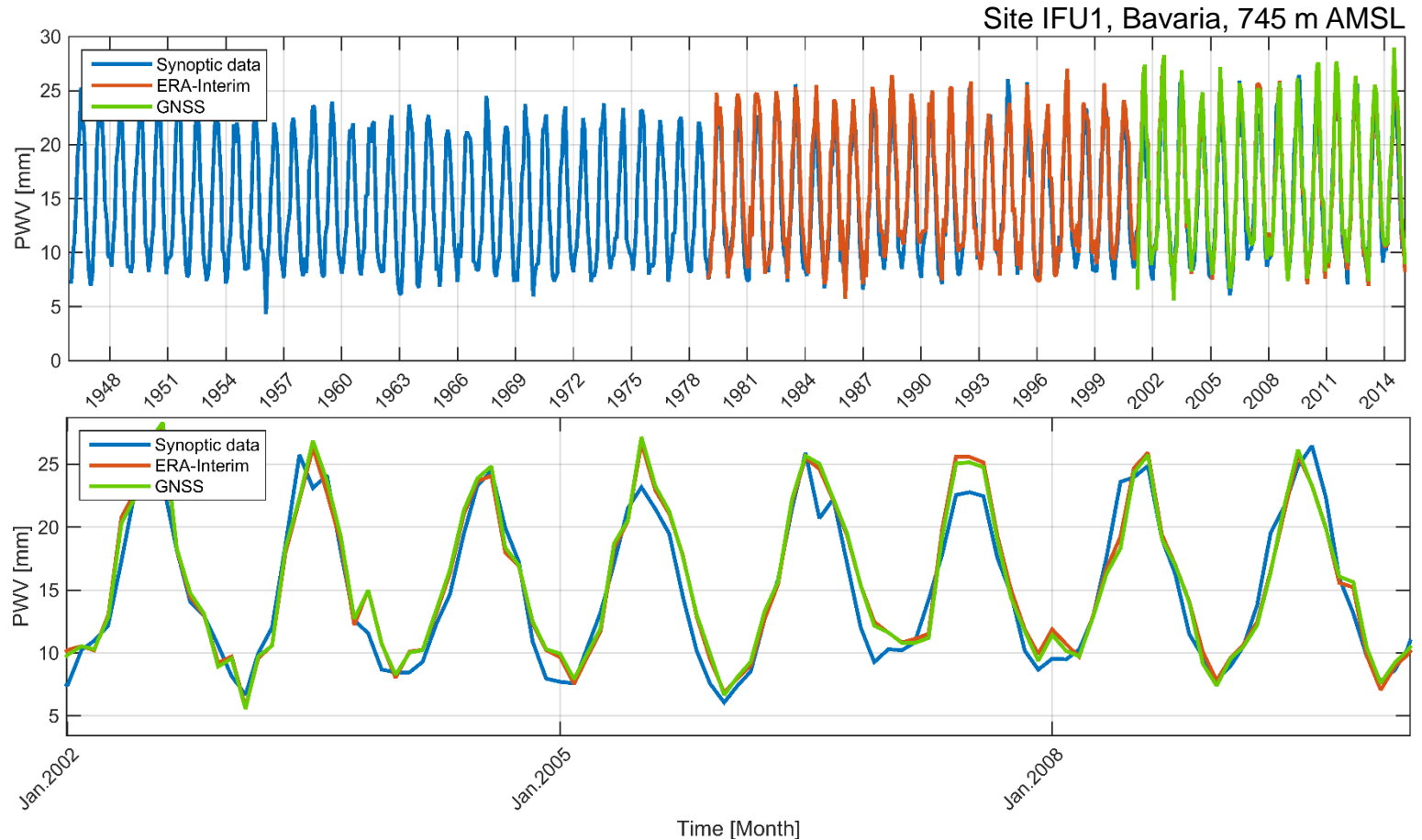


PWV from GNSS, ERA-Interim and Synoptic data



	Mean [mm]	Std [mm]	CC
ERA-Interim/GNSS	-0.184	0.539	0.996
ERA-Interim/Synoptic	-0.1933	0.9745	0.987

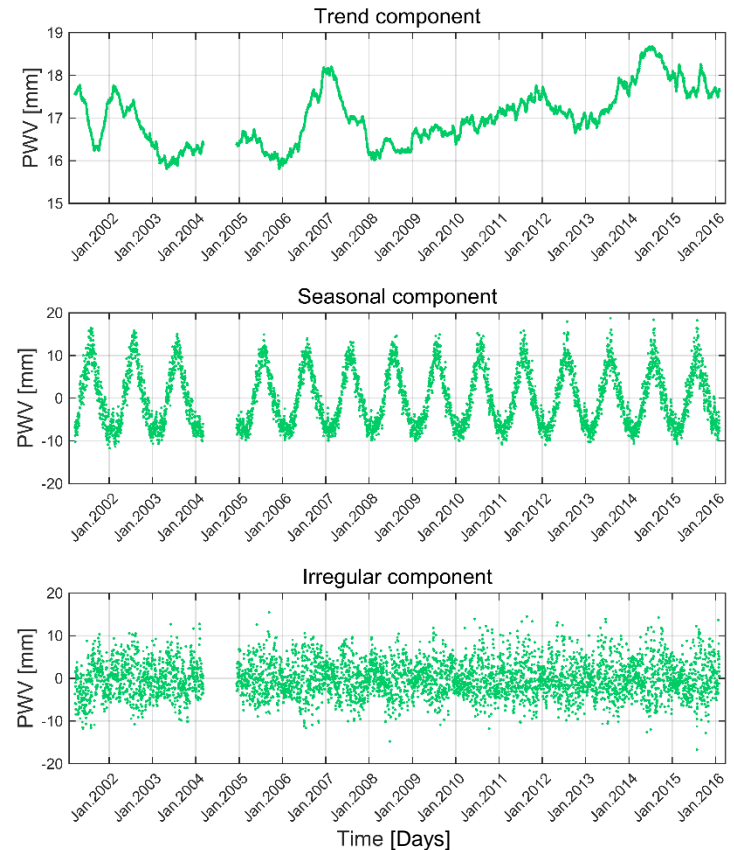
PWV from GNSS, ERA-Interim and Synoptic data



	Mean [mm]	Std [mm]	CC
ERA-Interim/GNSS	-0.184	0.539	0.996
ERA-Interim/Synoptic	-0.835	1.53	0.965

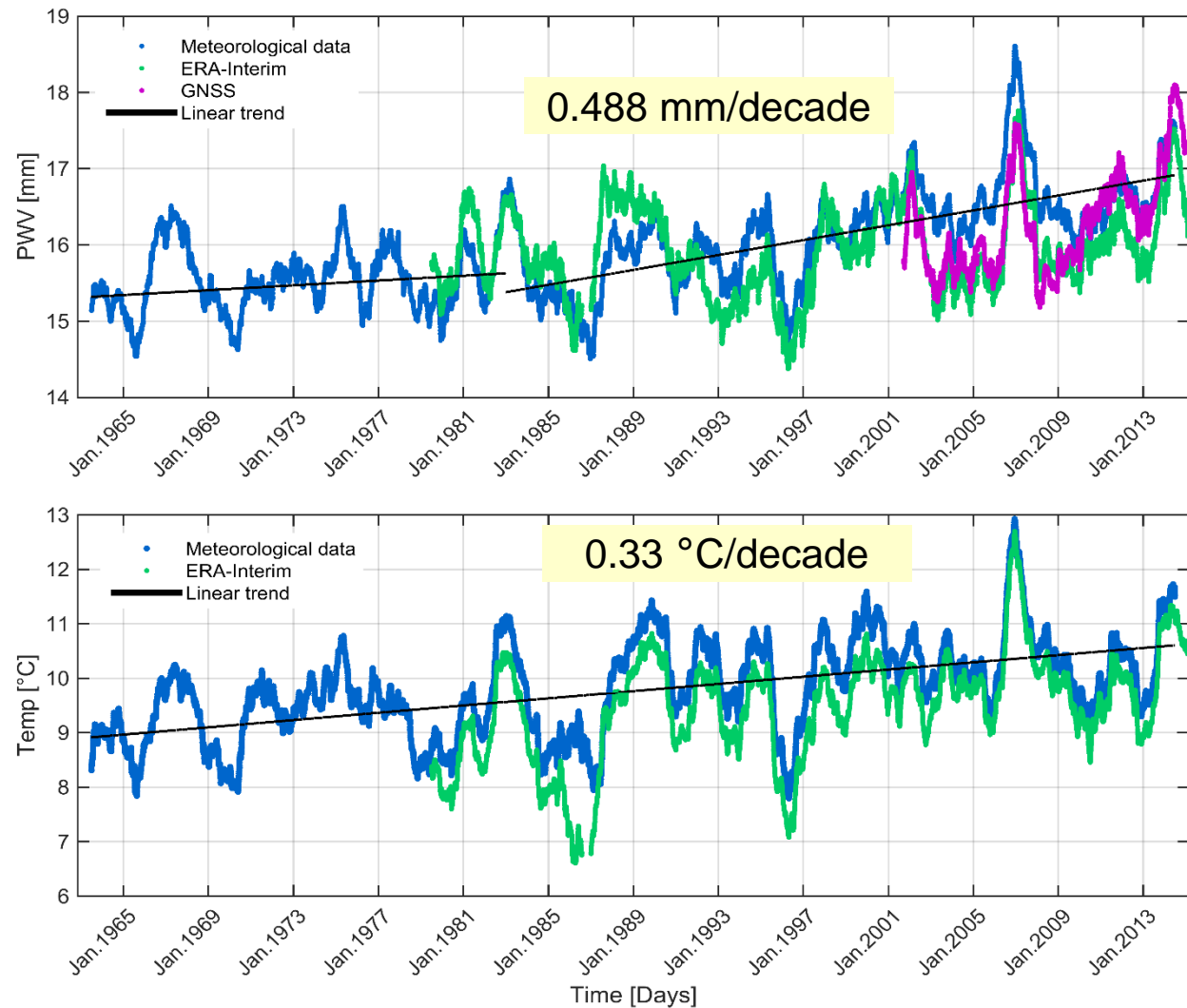
Determination of Decadal variations

- PWV and temperature time series have:
 - Trend component
 - Seasonal component
 - Irregular component
- Trend estimation with moving average filter
- Estimation of the seasonal signal from the detrended signal
- Iterative solution

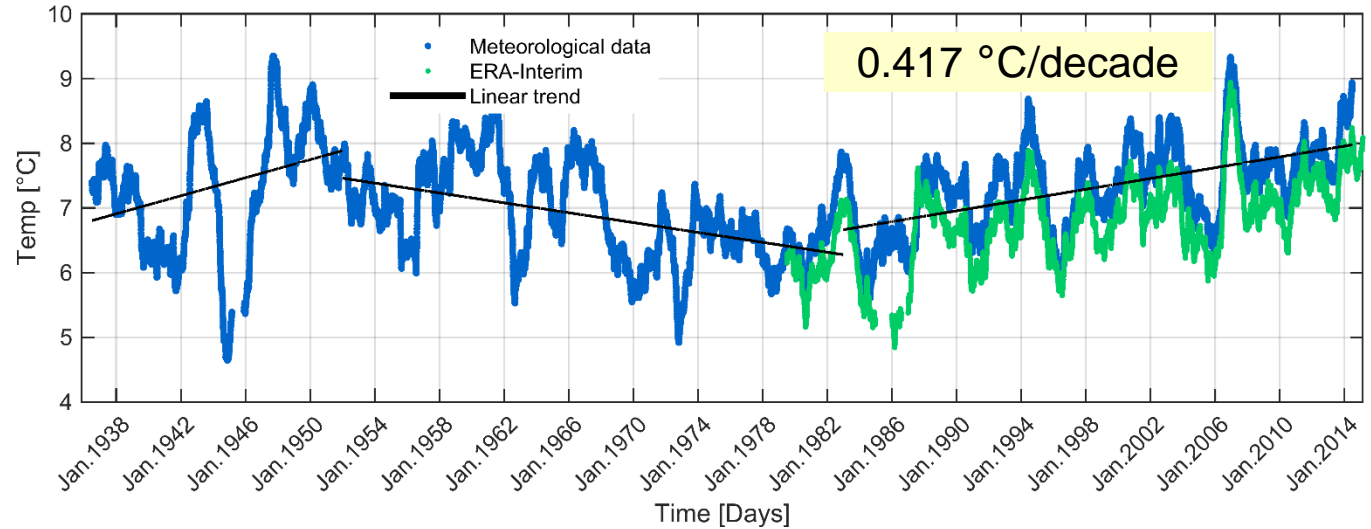
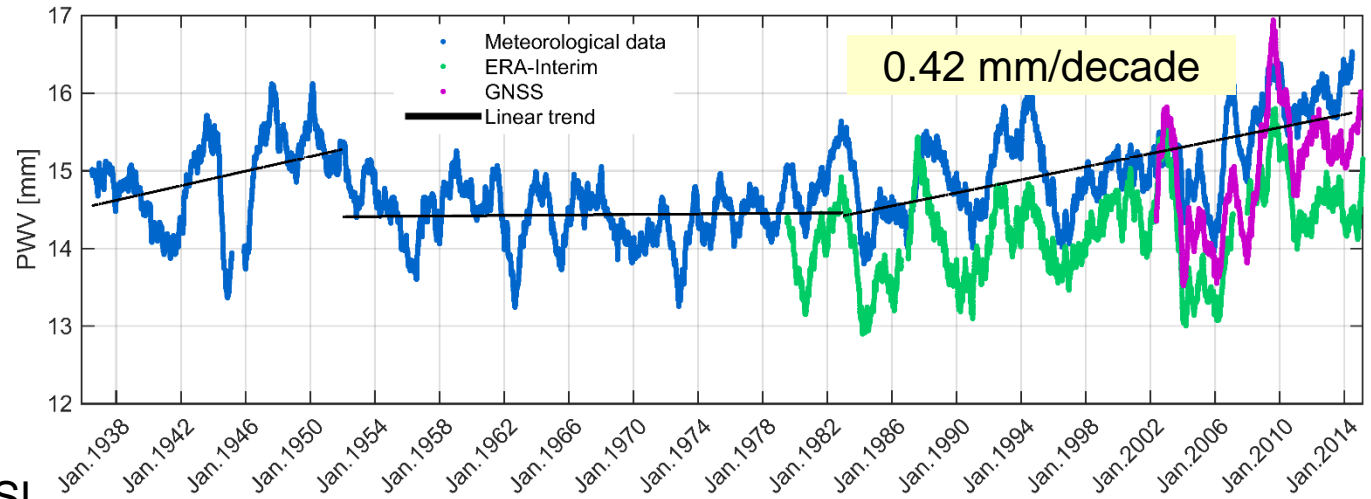


Determination of Decadal variations

Site 0897,
Berlin, 78 m AMSL

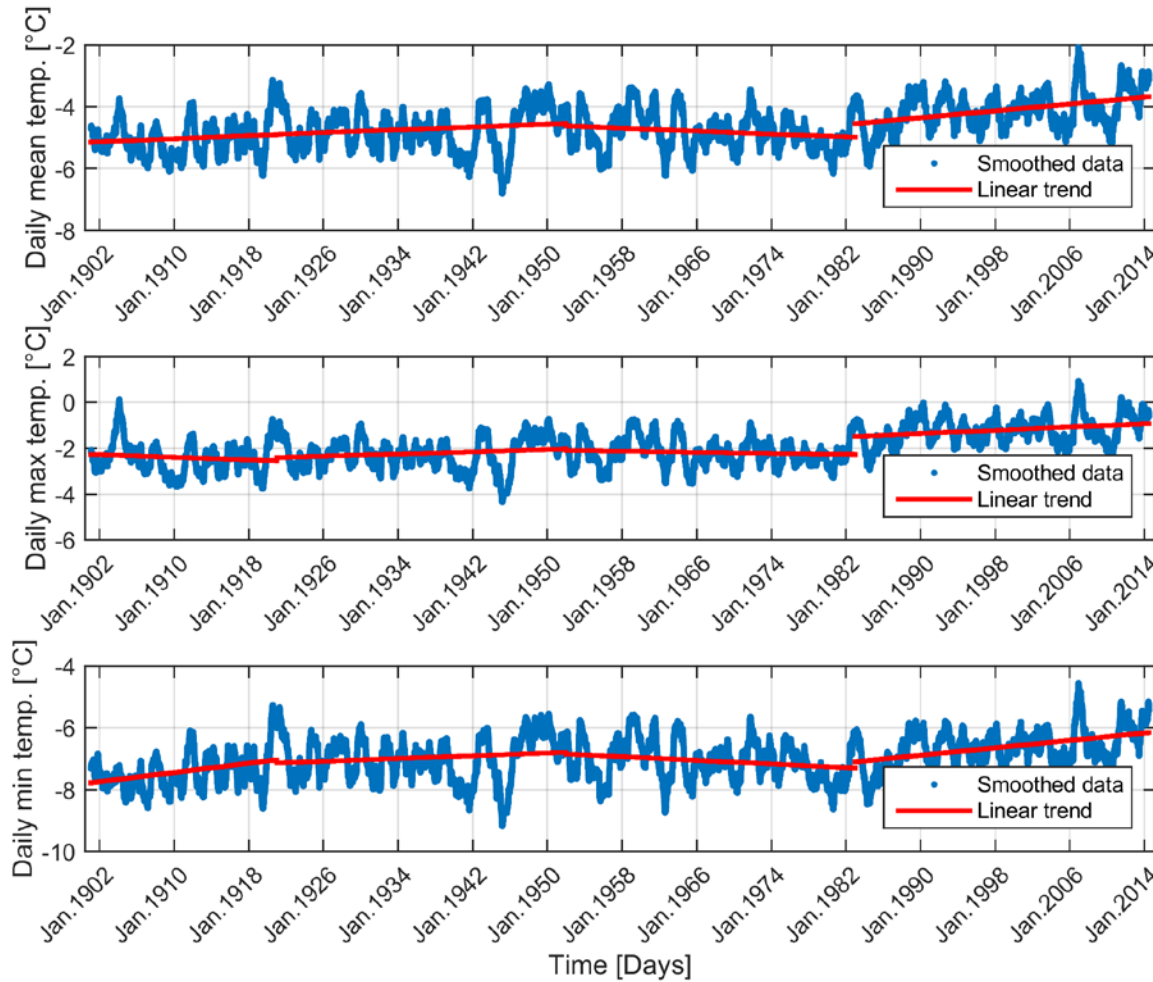


Determination of Decadal variations



Determination of decadal variations – Temperature

Site ZUGS,
Bavaria,
2963 m AMSL



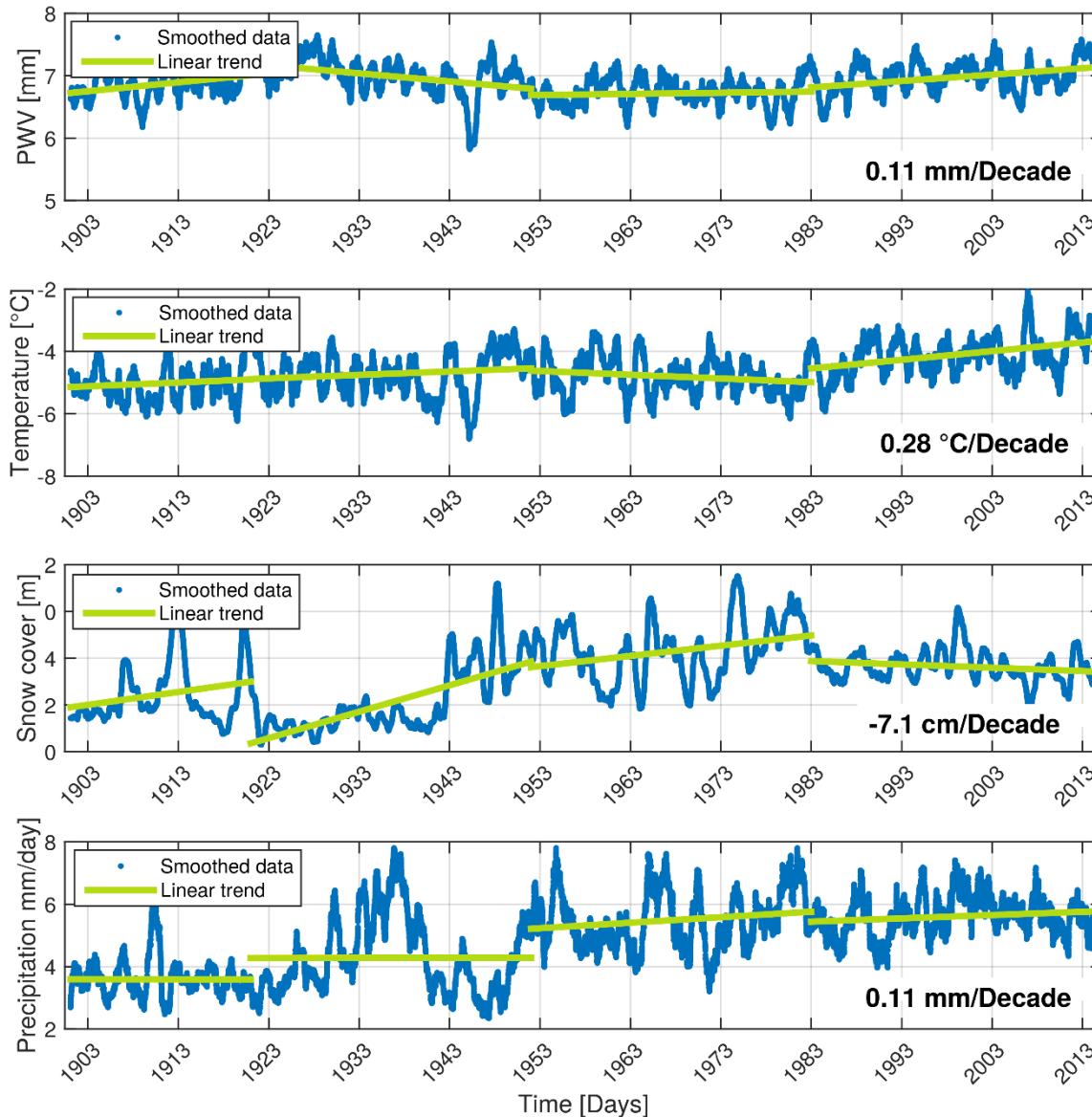
0.28°C/decade

0.18°C/decade

0.3°C/decade

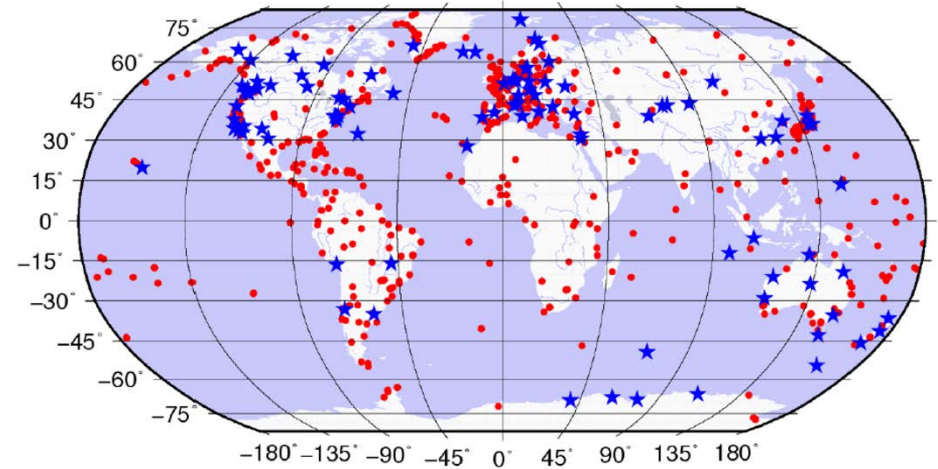
Determination of decadal variations – Precipitation and snow

Site ZUGS,
Bavaria,
2963 m AMSL



Data homogenization

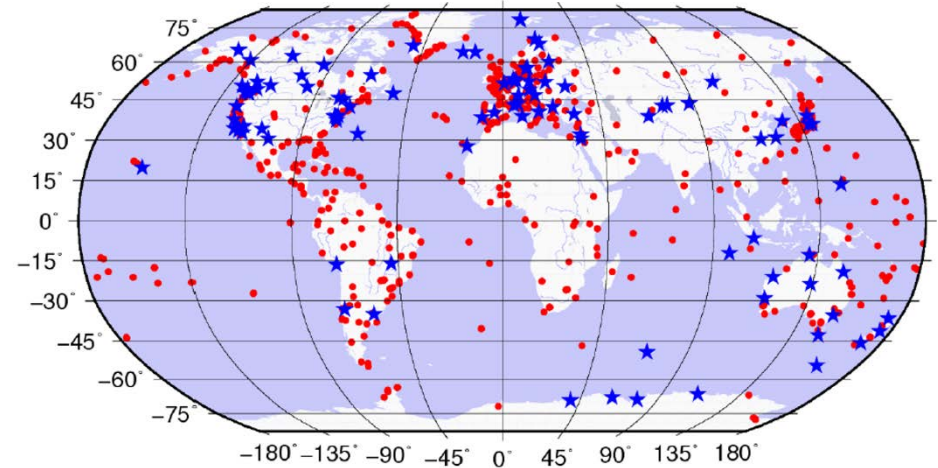
- 101 GPS stations
- 47 contain change points
- Mainly due to inconsistencies in PWV time series made by hardware replacement and installation
- ERA-Interim, also showed change points
- The radiosonde RH measurements are not homogenized before assimilated into ERA-Interim



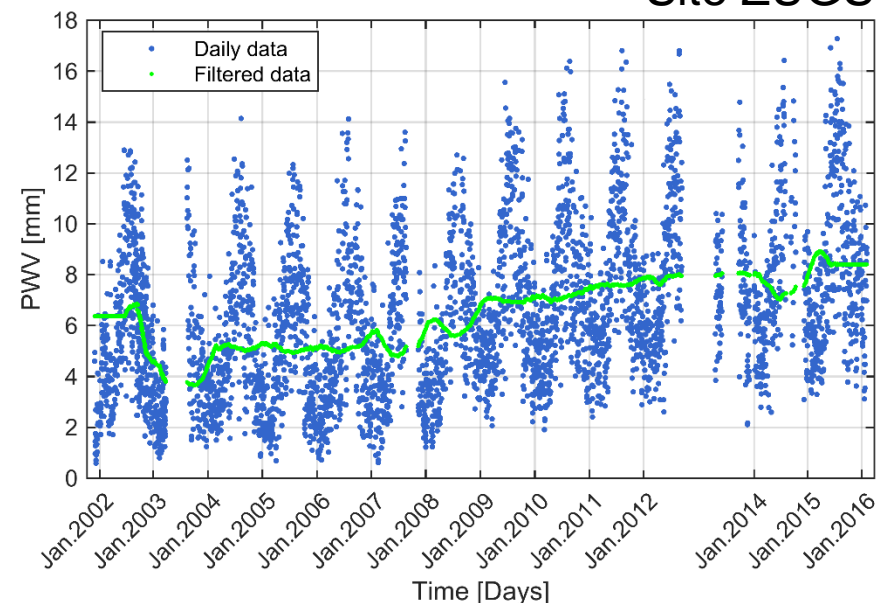
Ning, T., J. Wickert, Z. Deng, S. Heise, G. Dick, S. Vey, and T. Schöne, 2016:
Homogenized time series of the atmospheric water vapor content obtained from the GNSS
reprocessed data. J. Climate. doi:10.1175/JCLI-D-15-0158.1, in press

Data homogenization

- 101 GPS stations
- 47 contain change points
- Mainly due to inconsistencies in PWV time series made by hardware replacement and installation
- ERA-Interim, also showed change point
- GAPS in the PWV time series
- Lack of meteorological data
- Delay in raw data transfer



Site ZUGS



Outlook

- Produce sequence of 2D maps of PWV, Temp, ...etc, for the region of Germany over long time periods
- Study their temporal evolution on regional scale
- Compare with model data (WRF, spatial resolution of 2 km × 2 km)
- Involve climate models

Outlook

- Produce sequence of 2D maps of PWV, Temp, ...etc, for the region of Germany over long time periods
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Thank you very much