GFZ
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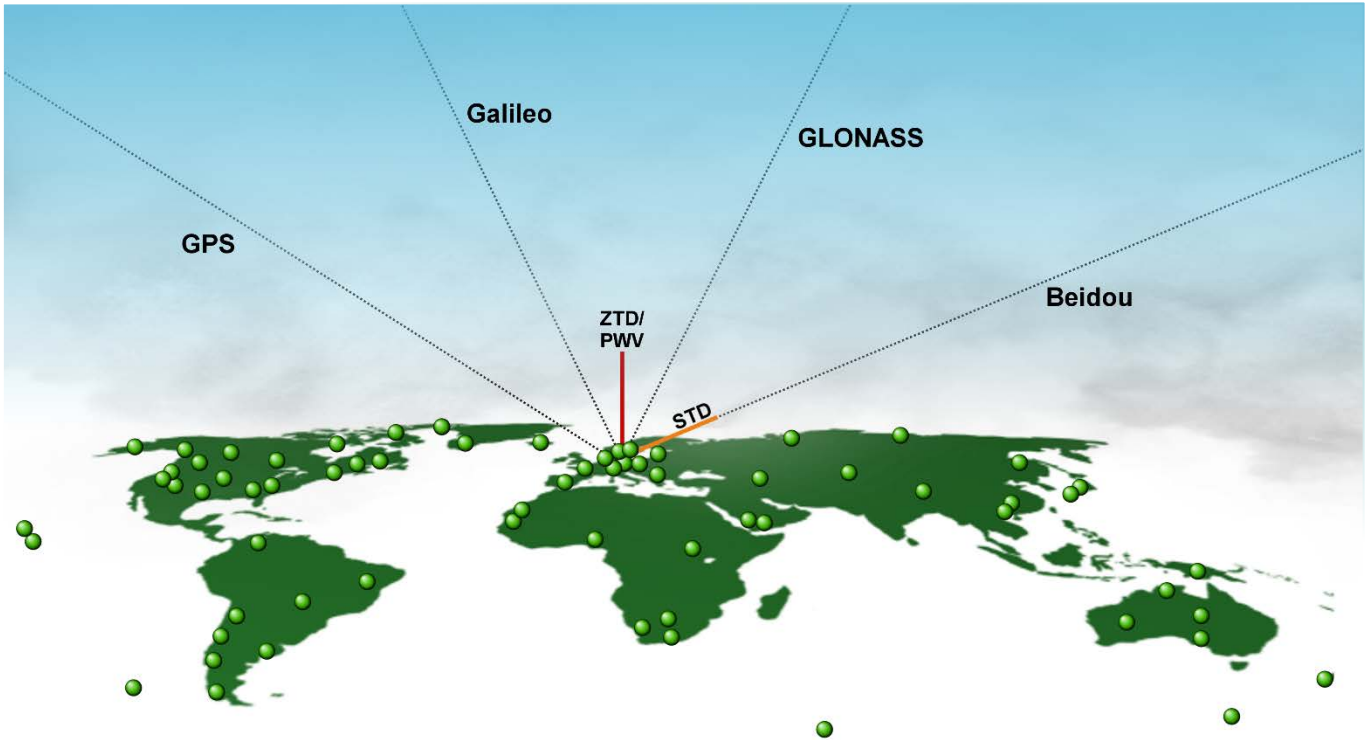
On the statistical significance of climatic trends estimated from GRUAN tropospheric time series

Fadwa Alshawaf, Galina Dick, Jens Wickert

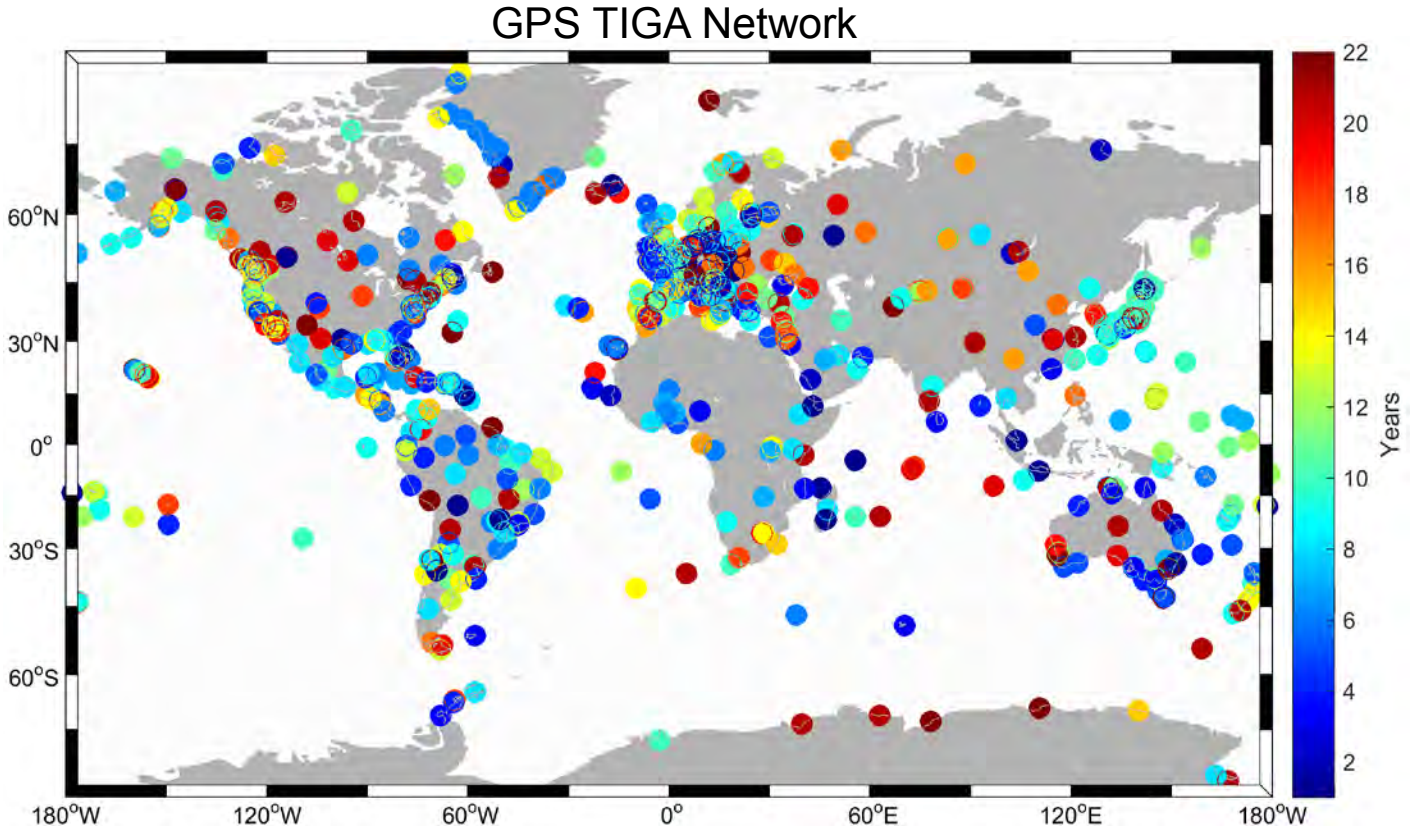
Overview



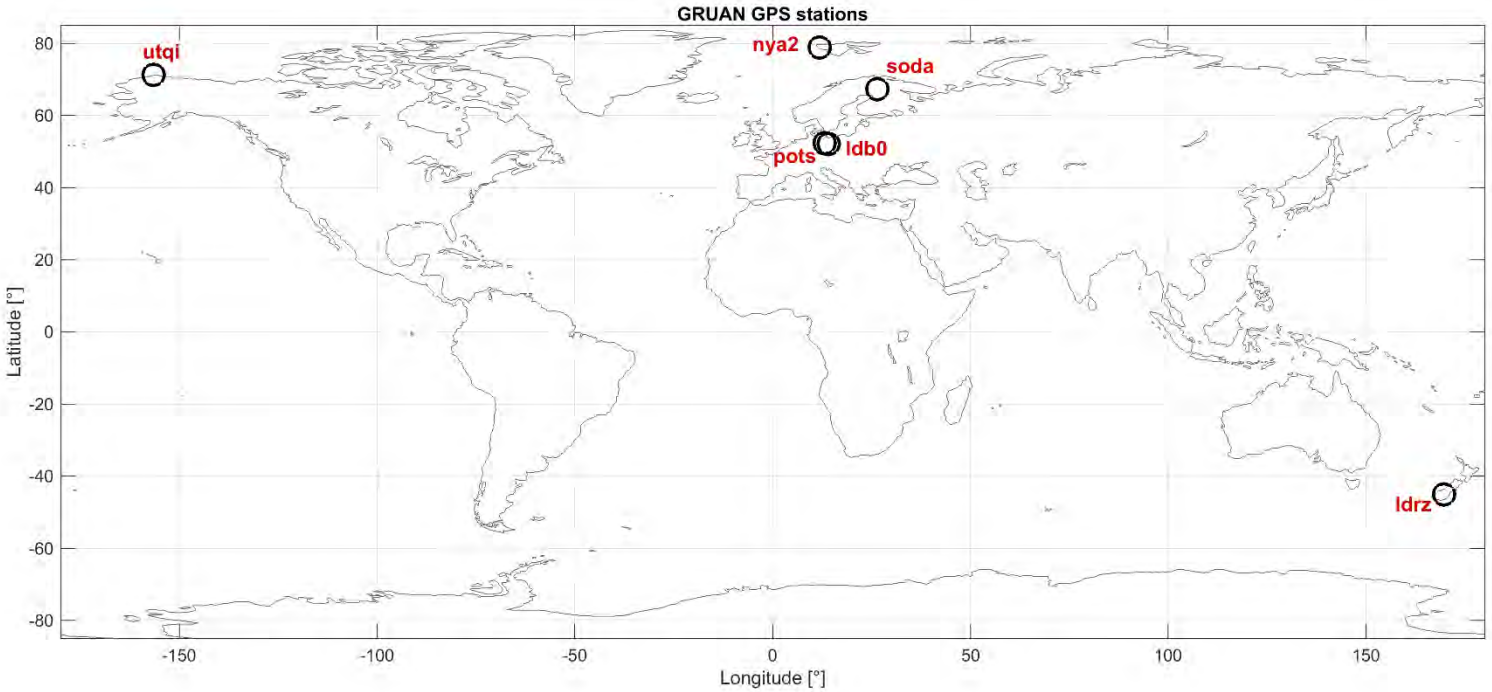
Climate norms 30 years → GNSS time series question of time

Overview

- TIGA: Tide Guage Benchmark Monitoring
- Reprocessing of data,1995–2015
- 750 sites
- 371 > 10 years



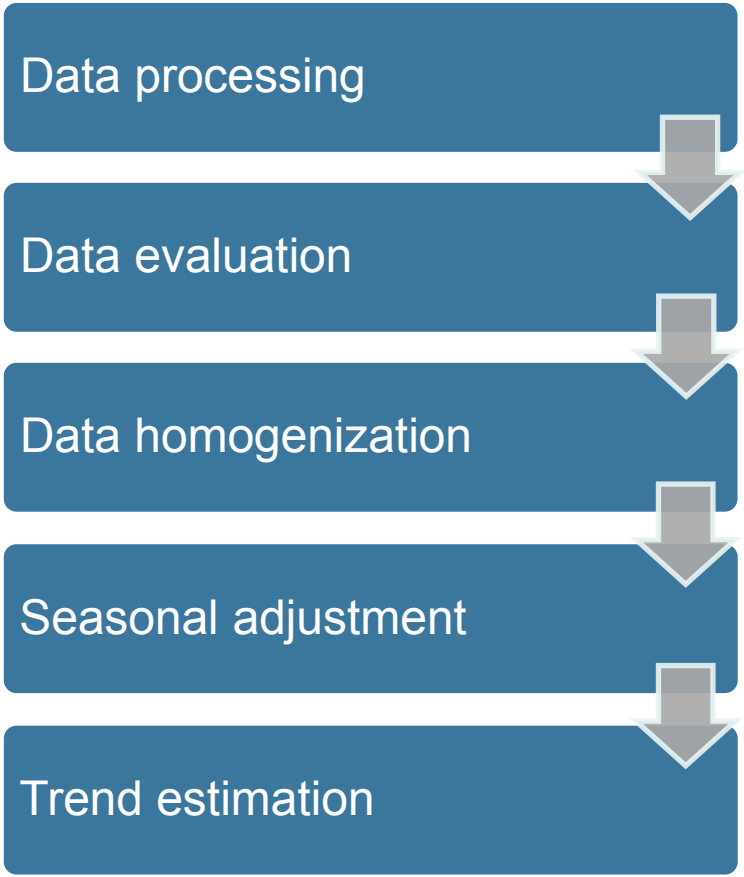
GRUAN GPS stations



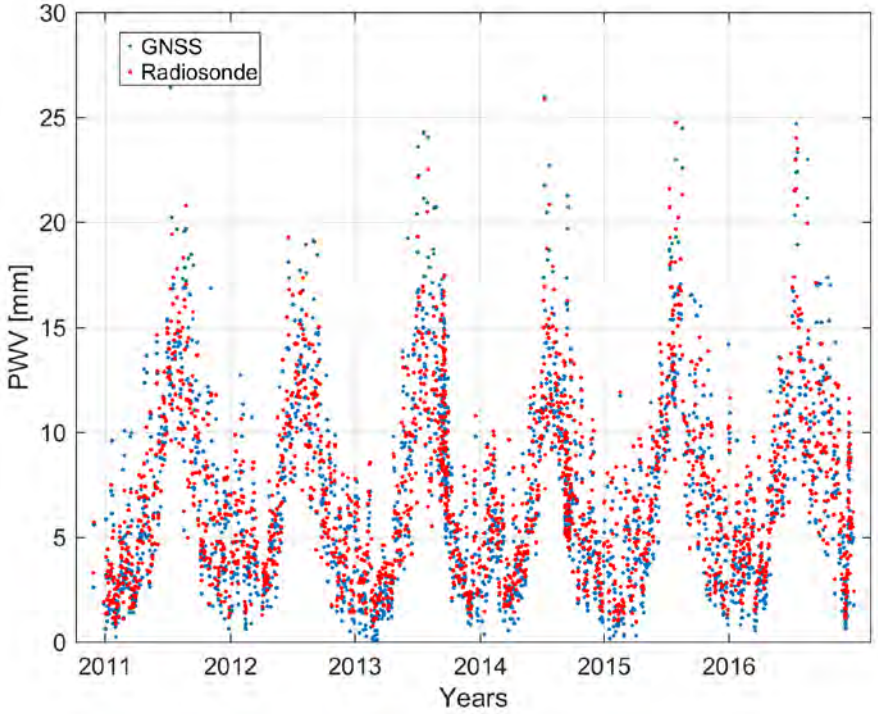
GRUAN GPS stations

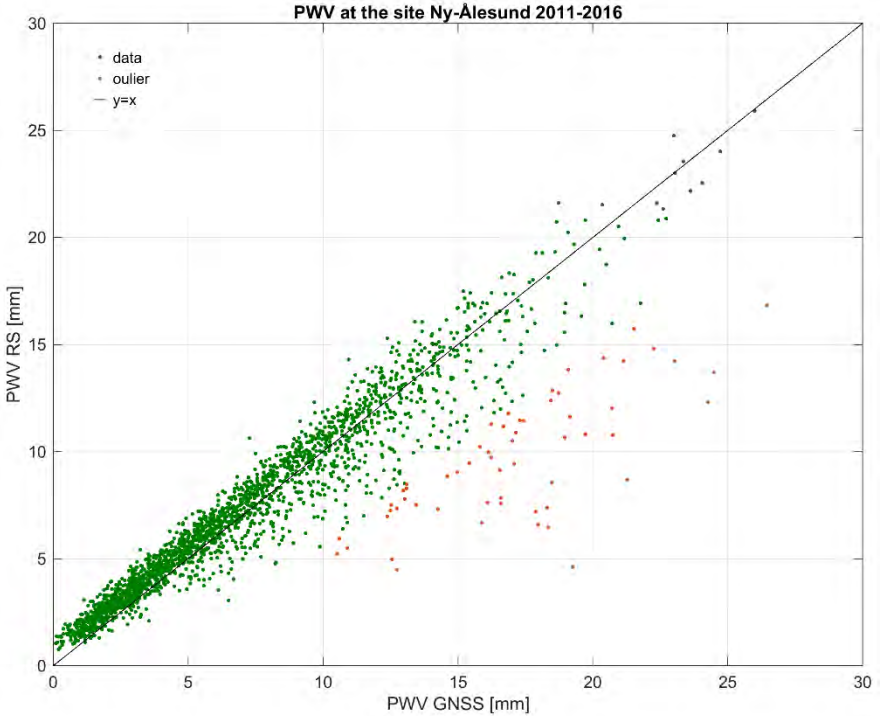
2011–2017

Workflow


Data processing
Data evaluation
Data homogenization
Seasonal adjustment
Trend estimation

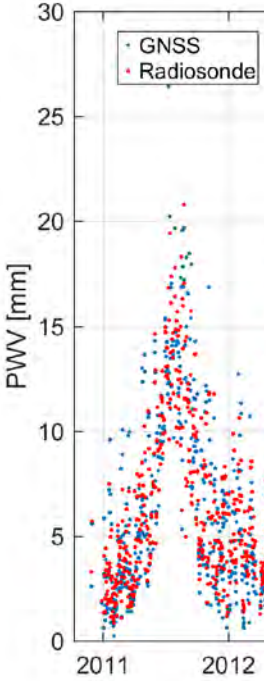
PWV at NyAlesund

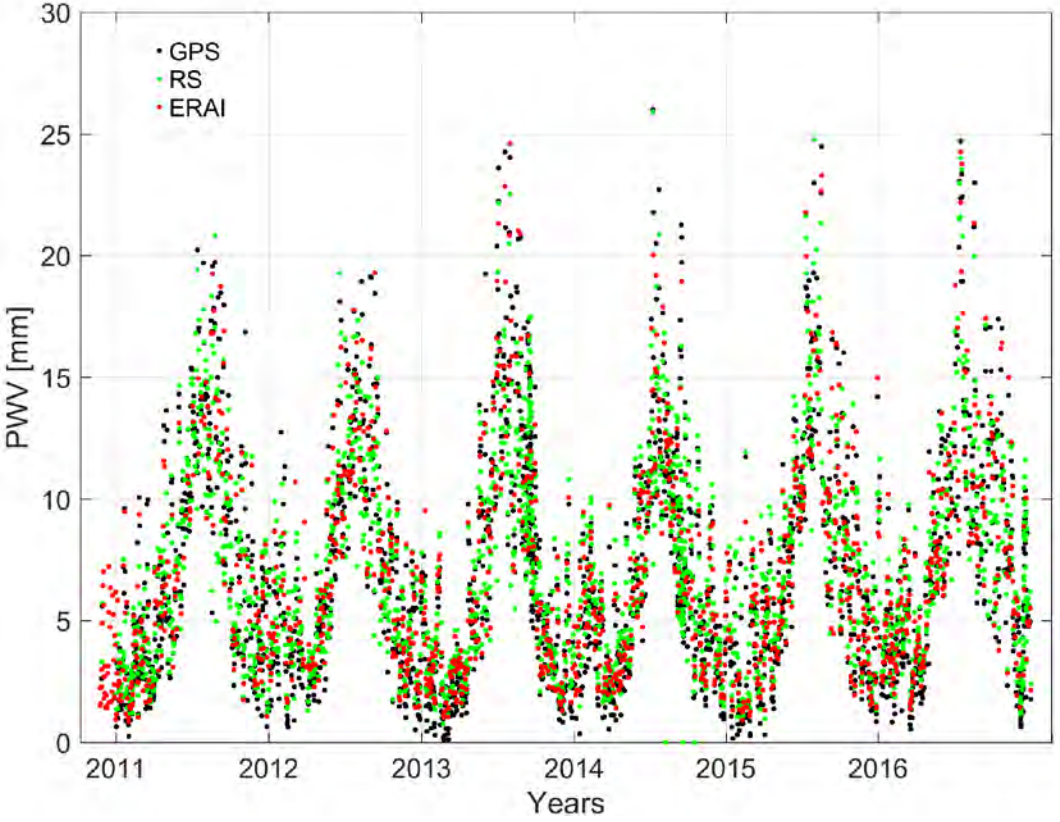


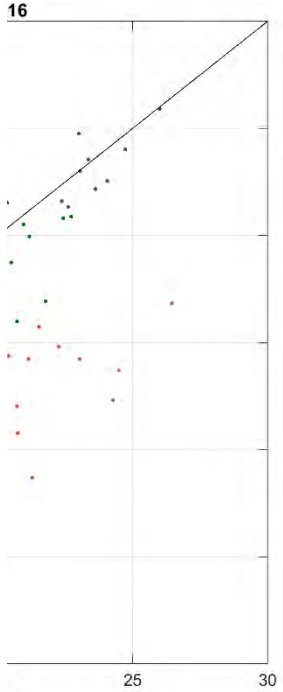


RS data from M. Maturilli

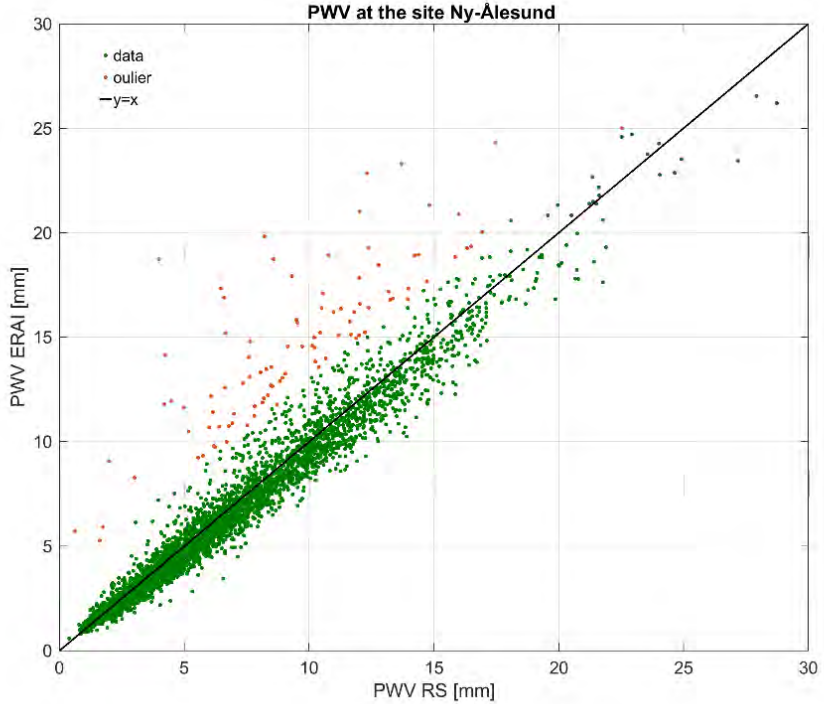
PWV at NyAlesund

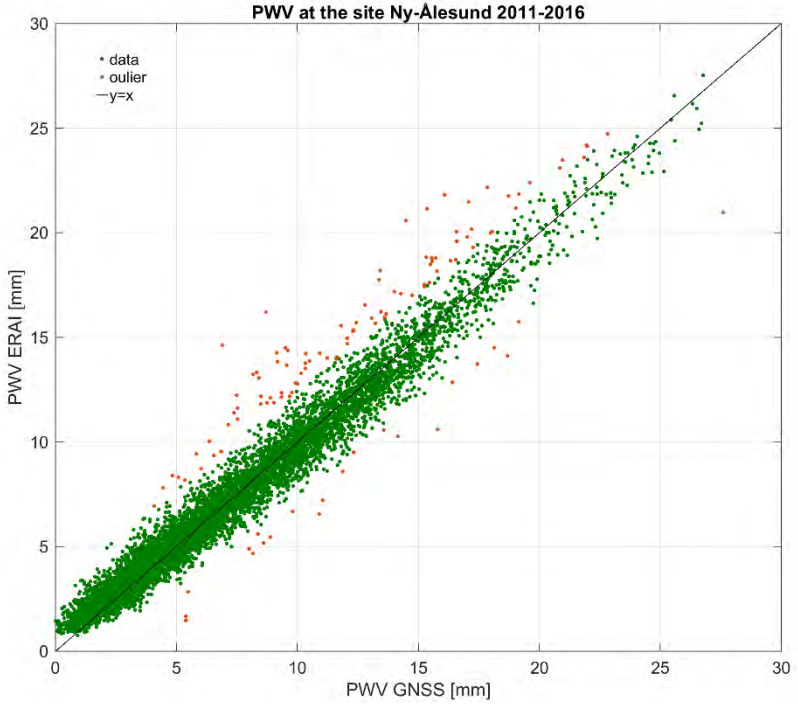






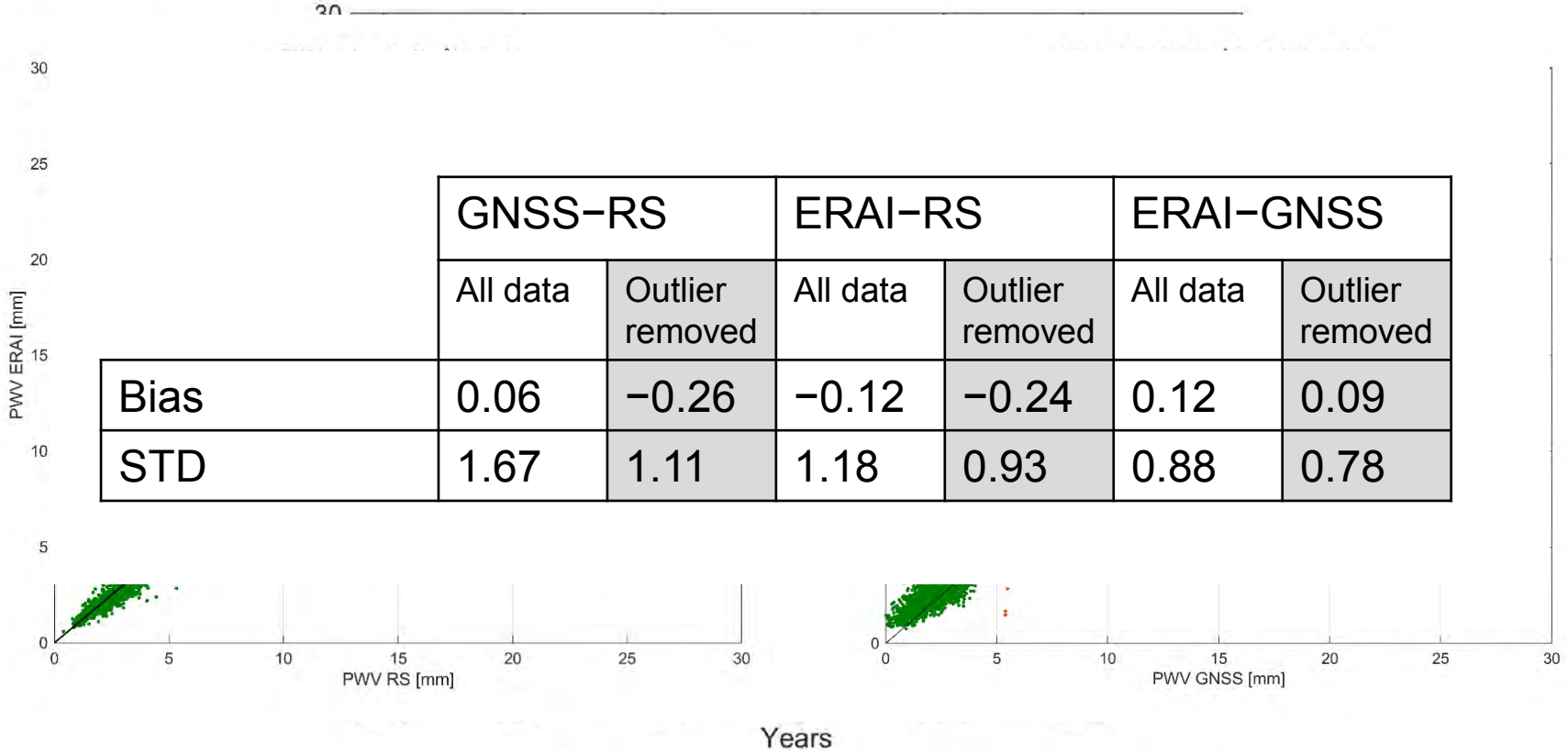
PWV at NyAlesund





Years

PWV at NyÅlesund

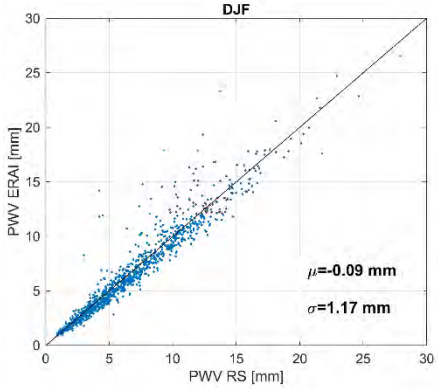


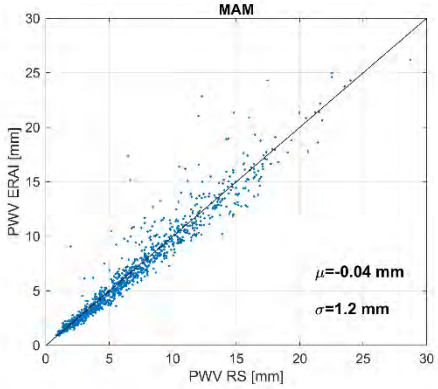
	GNSS−RS		ERAI−RS		ERAI−GNSS	
	All data	Outlier removed	All data	Outlier removed	All data	Outlier removed
Bias	0.06	−0.26	−0.12	−0.24	0.12	0.09
STD	1.67	1.11	1.18	0.93	0.88	0.78

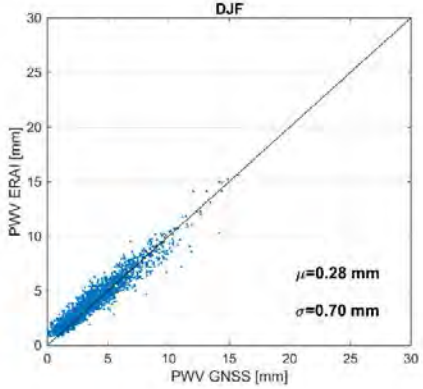
PWV at NyAlesund

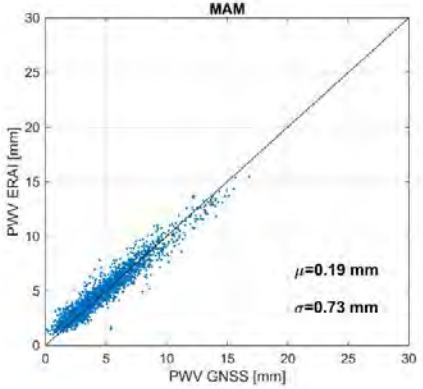
ERAI vs.RS

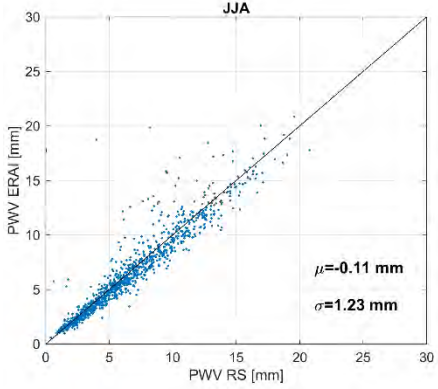
ERAI vs.GPS

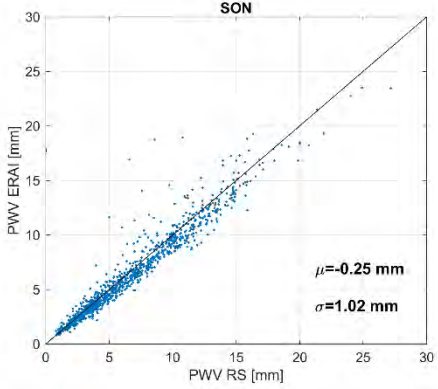


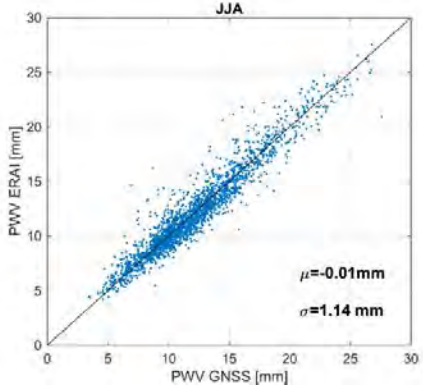


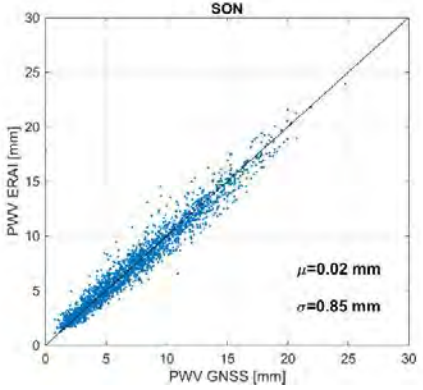




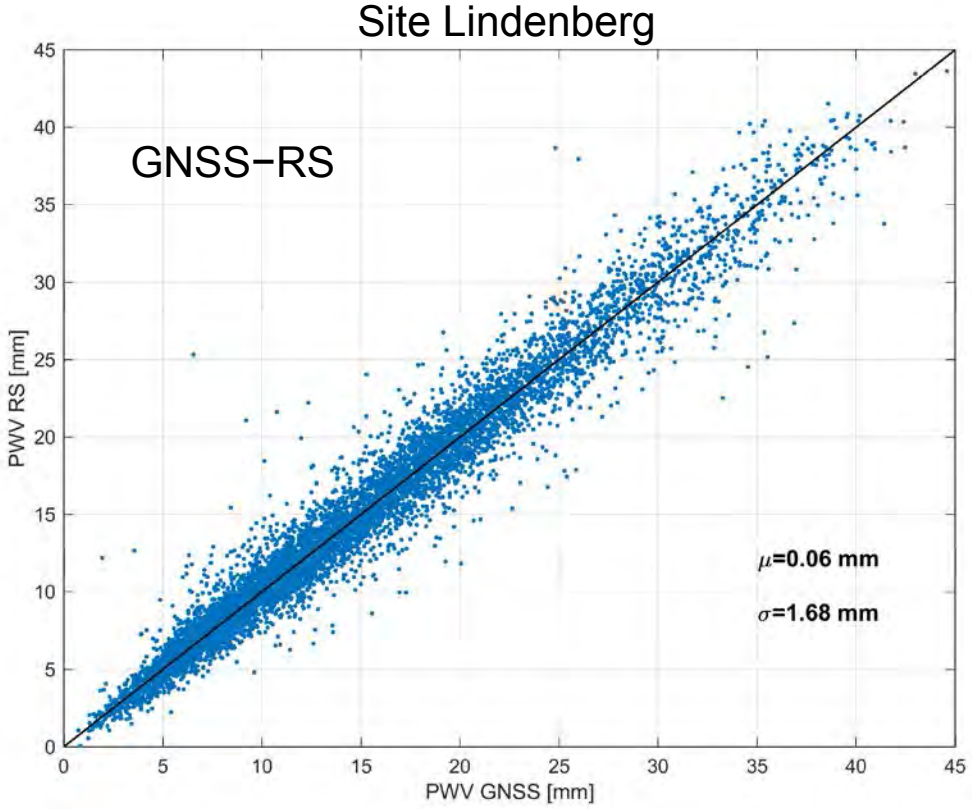








Overview

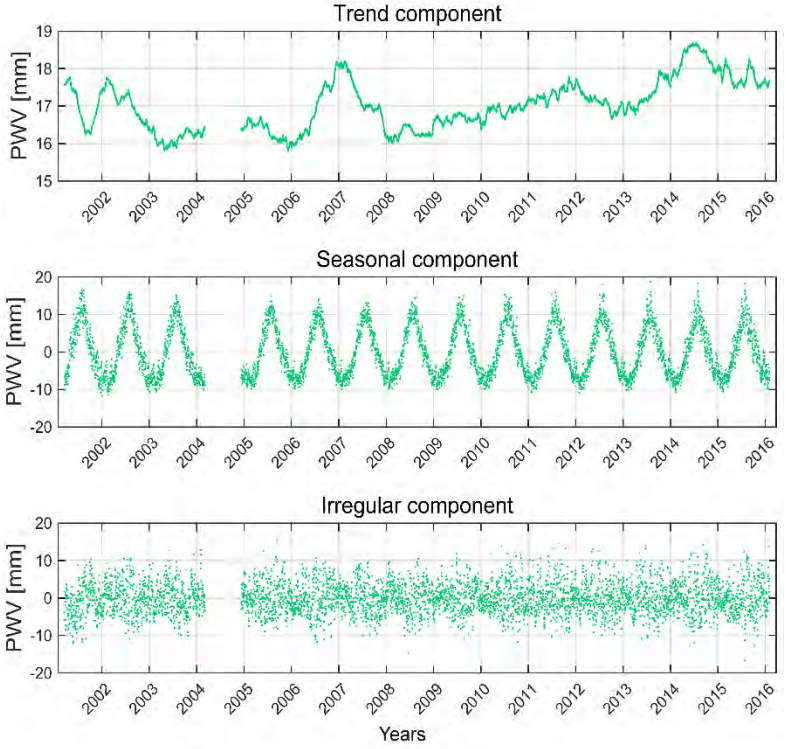


RS data from M. Sommer

Trend Estimation

Important are:

- the time span of the time series
- the presence of gaps
  (the start and the end of the time series)
- the presence of noise, its magnitude
  compared to the expected trend
- the autocorrelation in the time series
- homogeneity



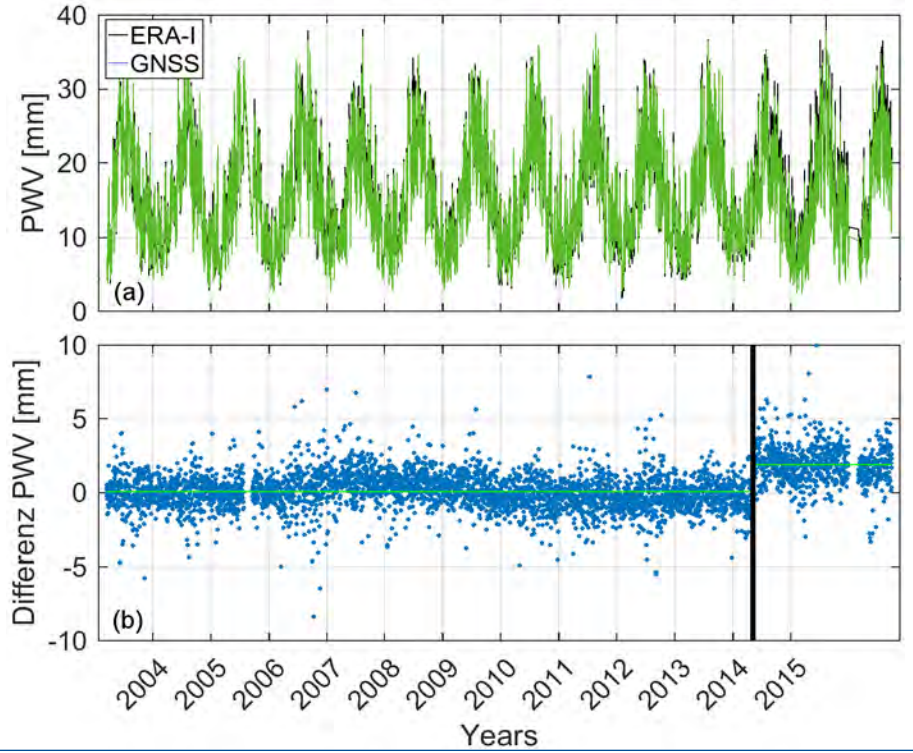
Trend Estimation

- **Data Homogeneity** → prerequisite for detecting climatic trends
- Inconsistencies in time series:

  o change processing setup
  → avoidable by Reprocessing,
  One model setup for the whole time window

  o change hardware or software of GNSS stations
  → not avoidable!
  → Homogeneity check

- Singular spectrum analysis



Trend Estimation

- Trend
- Seasonal
- Irregular

$$Y = T + S + N$$

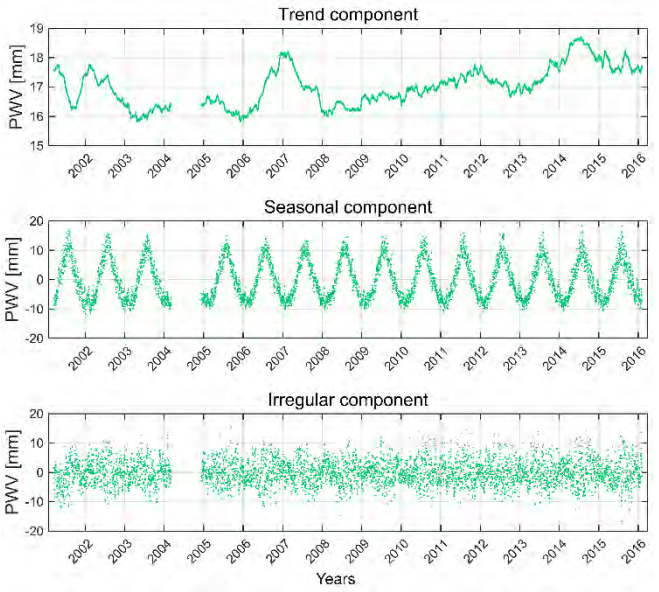
$$T = a + bt$$

magnitude

$$\sigma_b = \frac{\sigma_N}{\sqrt{\sum (t - \bar{t})^2}} \cdot \sqrt{\frac{1 + r}{1 - r}}$$

standard error

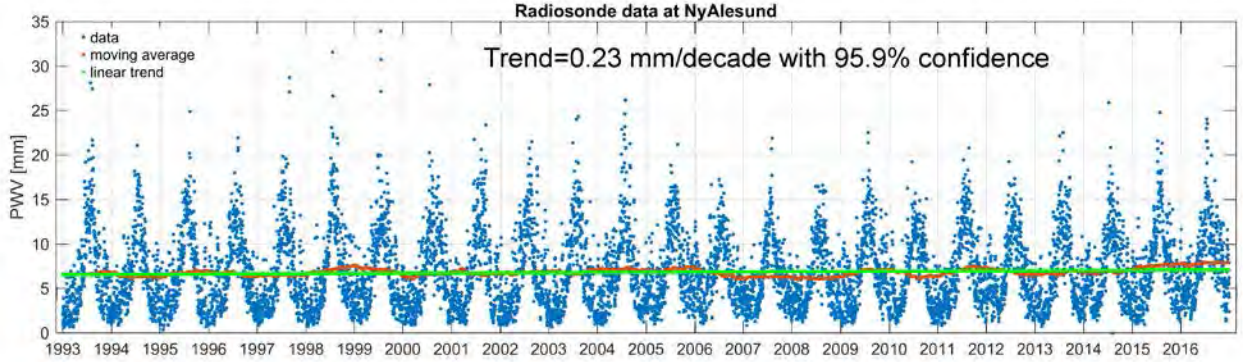
r 1-lag autocorrelation



When $|b| / \sigma_b > 2$, confidence >95% → significant

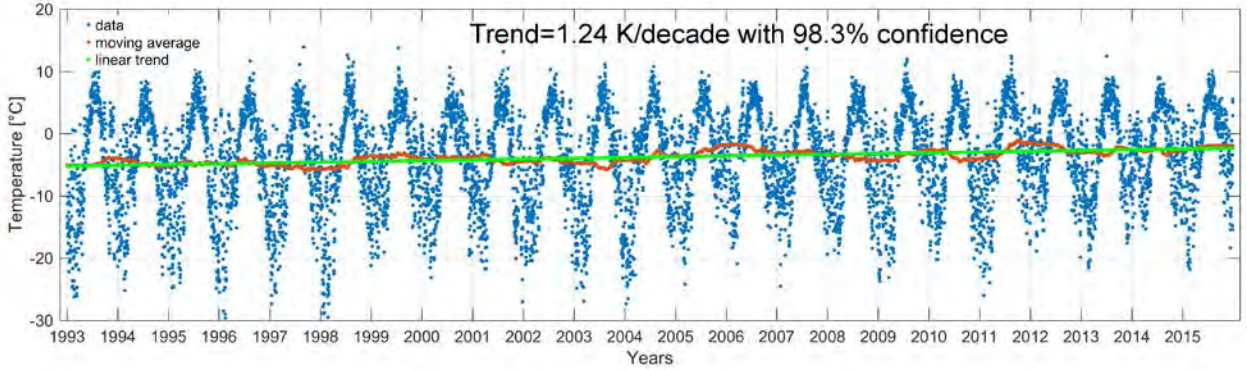
Results: Radiosonde data Ny-Ålesund

Significant ✓



24 years

Significant ✓



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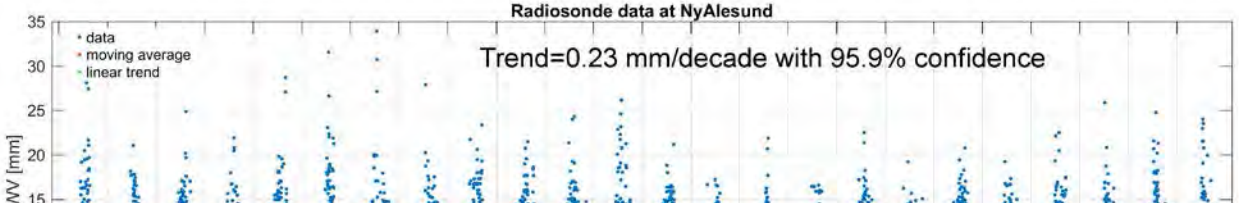
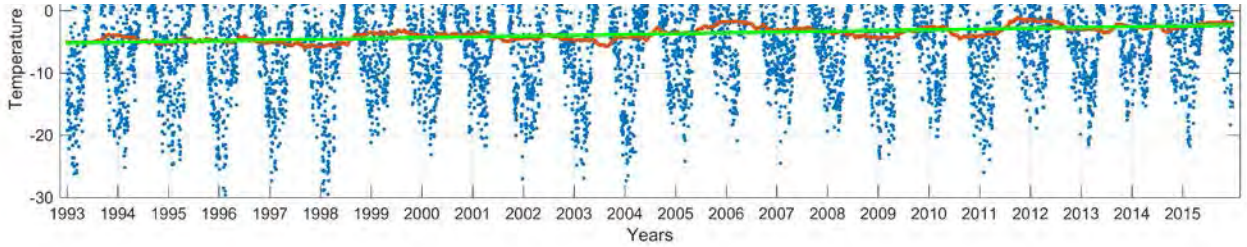
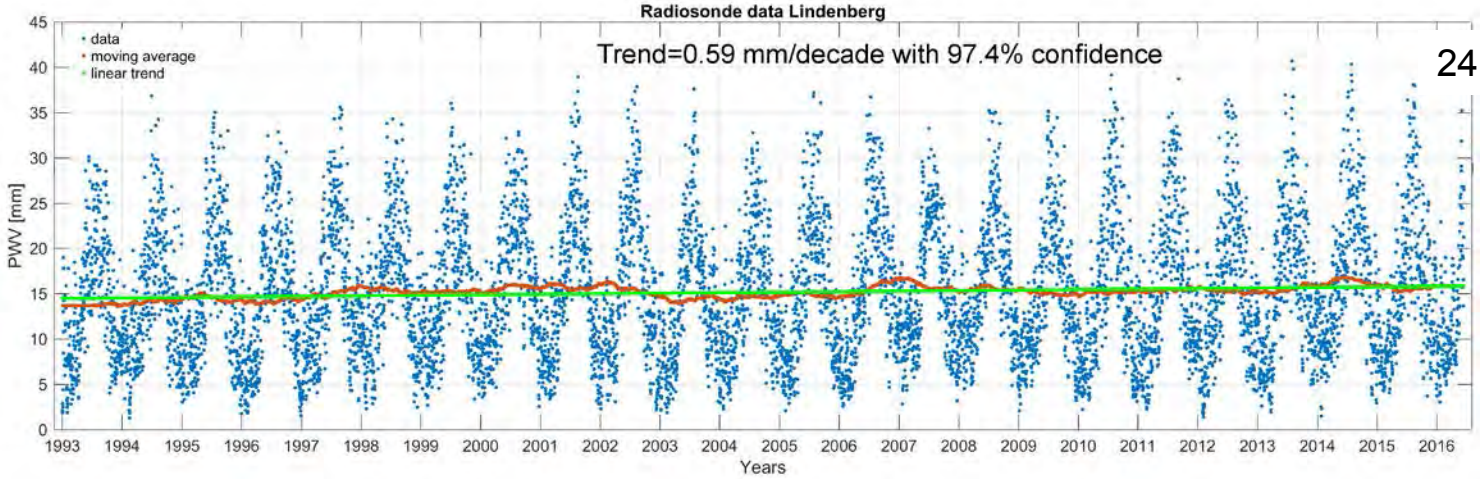


6.97% increase in PWV per a degree Celsius increase in temperature
→ Agreement to Clausius-Clapeyron equation

Significant ✓



Results: Radiosonde data Lindenberg



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standard error

r 1-lag autocorrelation

Required data size

For a trend magnitude b_o and 90% confidence level

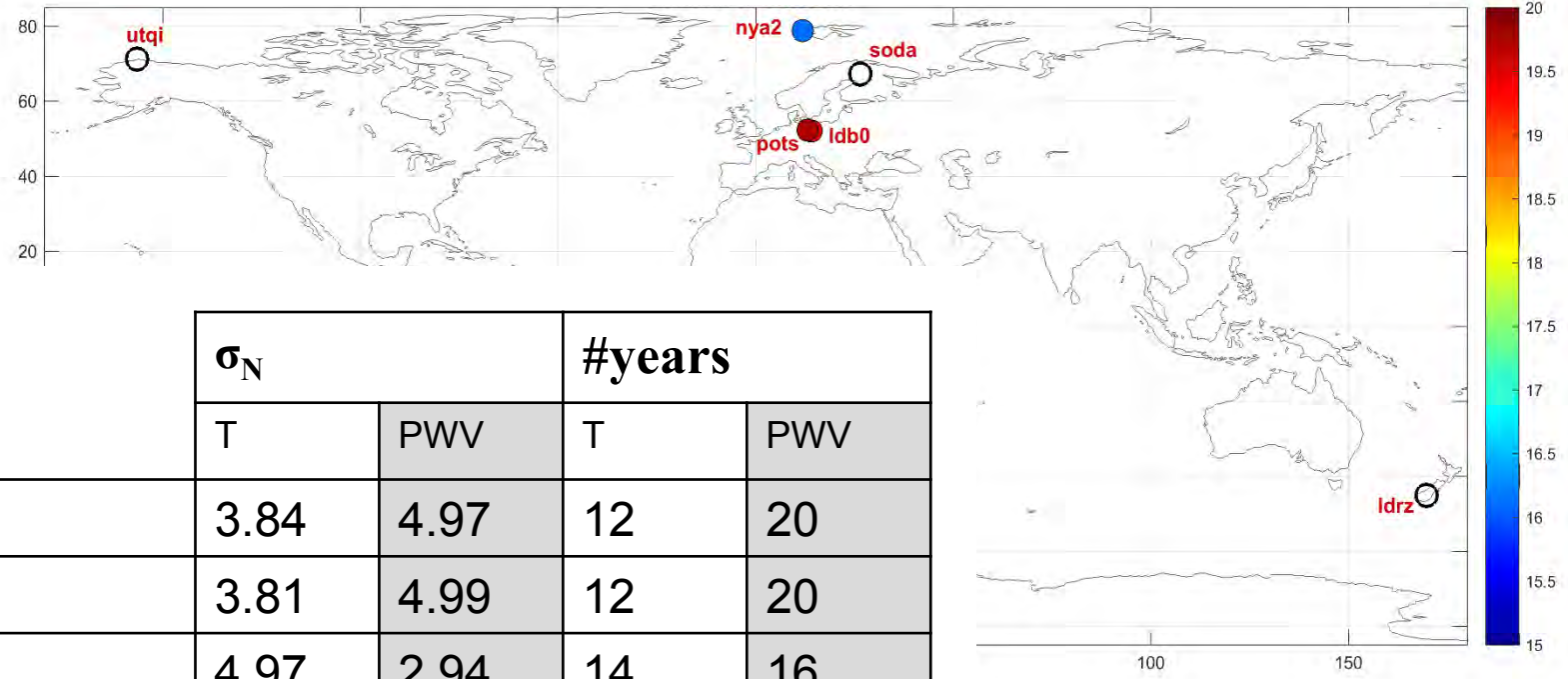
$$n_{req} = \left[3.3 \frac{\sqrt{12}}{\sqrt{365.25}} \frac{\sigma_N}{|b_o|} \sqrt{\frac{1 + r}{1 - r}} \right]^{2/3}$$

- Higher r, σ_N
- Smaller b_o

→ longer dataset is required

Required Length of PWV time series

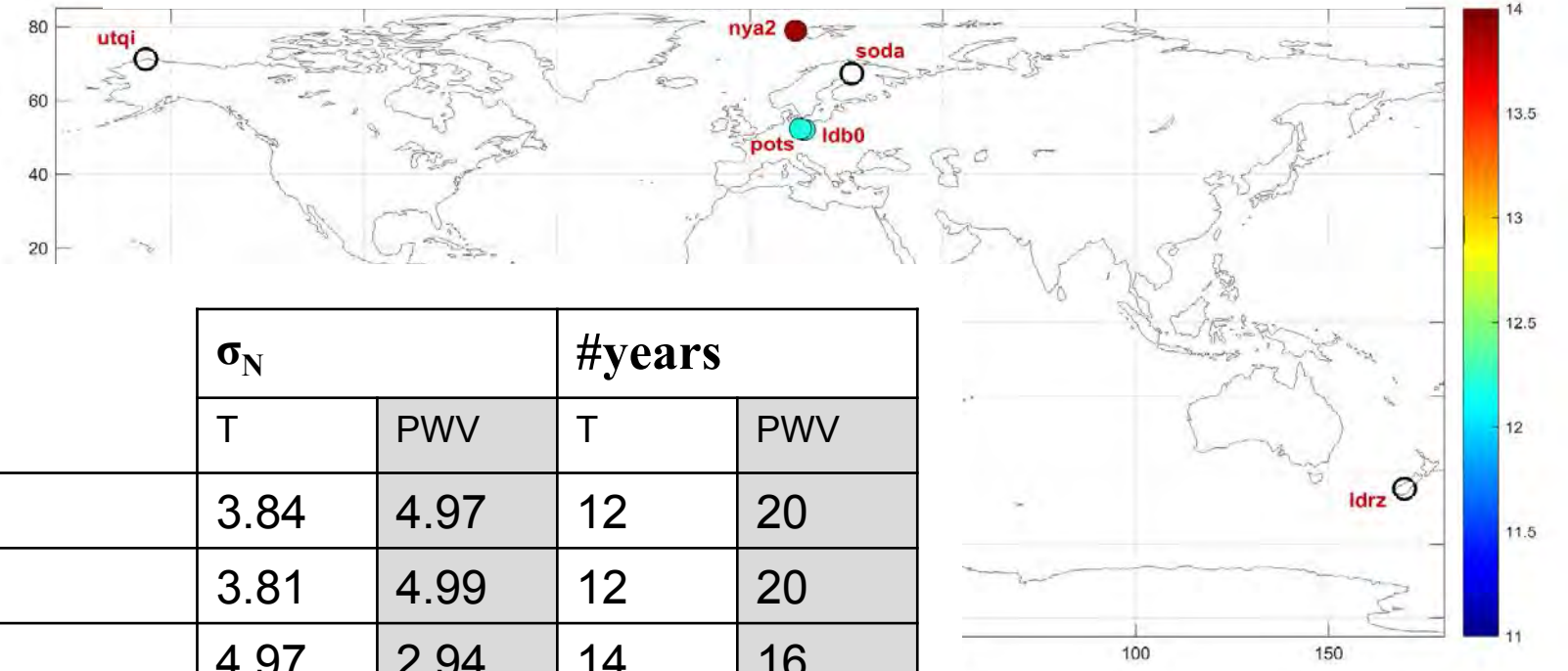
Required length to detect a PWV trend of 0.4 mm/decade



	σ_N		#years	
	T	PWV	T	PWV
LDB0	3.84	4.97	12	20
POTS	3.81	4.99	12	20
NYA2	4.97	2.94	14	16

Required Length of temperature time series

Required length to detect a T trend of 1 K/decade



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Summary

- PWV trend estimation using
  - GPS
  - Radiosonde
  - ERA-Interim

- The trends are statistically significant for adequately long time series

- Time series longer than 15 years are required to estimate significant trends

Alshawaf et al., 2017: Estimating trends in atmospheric water vapor and temperature time series over Germany, Atmos. Meas. Tech., 10, 3117-3132, https://doi.org/10.5194/amt-10-3117-2017.

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