# Atmospheric VLBI: A Method to Validate Long Time Series of Water Vapour Content

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# Structure of presentation

- Why monitor water vapour in the atmosphere?
- Ground-based GPS observations provide high temporal and spatial resolution, but suffer from some systematic effects
- VLBI-data suffer from some other (less important?) systematic effects
- Status report on long-term comparisons between VLBI, GPS, and radiosonde data
- Conclusions

(For more details on trends and stabilty in the GPS results: Nilsson and Elgered, JGR Atmospheres, 2008)

# Why monitor the atmospheric water vapour content?

What is the relation between variations in temperature and Integrated Water Vapour (IWV)?

Following the Clausius-Clapeyron relation assuming conservation of relative humidity [Trenberth et al., Bull. Am. Meteorol. Soc., 2003]) we obtain for the IWV ~ 6 [%/K]. How correct is this assumption?

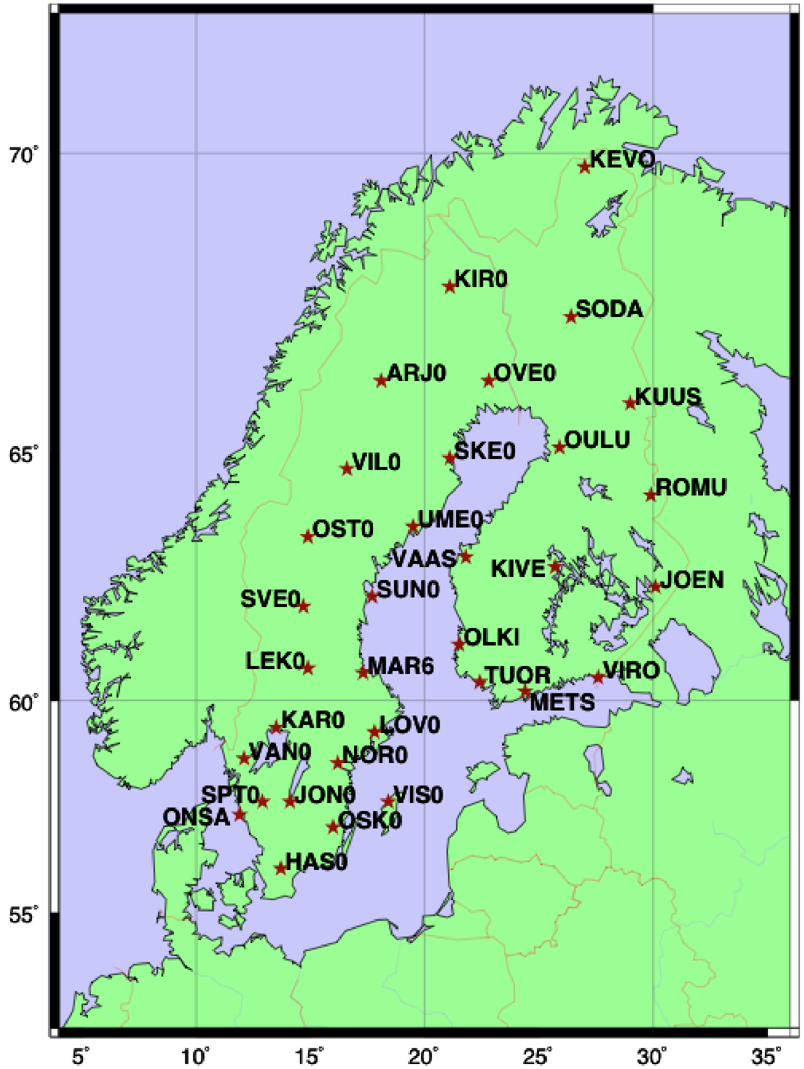
The global IWV mean is 24.9 kg/m$^2$ [Trenberth & Smith, J. of Climate, 2005]

The ERA40 model shows [Bengtsson et al. JGR, 2004]:
+0.11 K/decade in global temperature 1979–2001
+0.36 kg/m$^2$/decade in IWV 1979–2001
(0.11 K/decade * 6%/K · 24.9 kg/m$^2$ = 0.16 kg/m$^2$/decade),
which is argued to be due to artifacts in the global observing system.

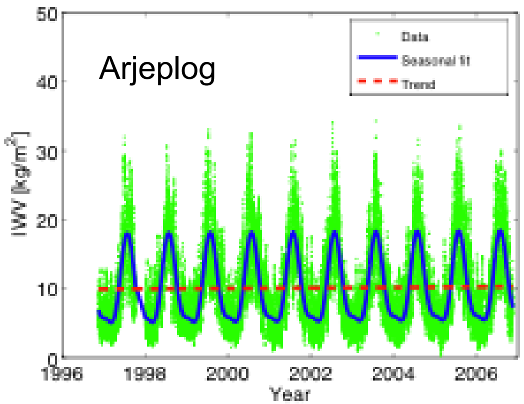
Accurate observations of the IWV and temperature are therefore important

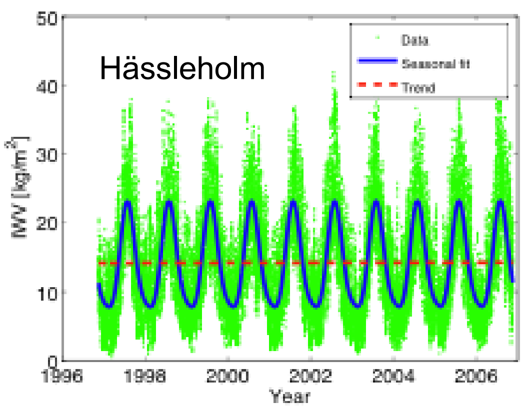
# Available GPS data from Sweden and Finland

- Swedish network SWEPOS started in late 1993
- Finnish network FinnRef started in late 1996
- Many (>100) additional stations have been added thereafter
- Here we use data from November 16, 1996 to November 15, 2006



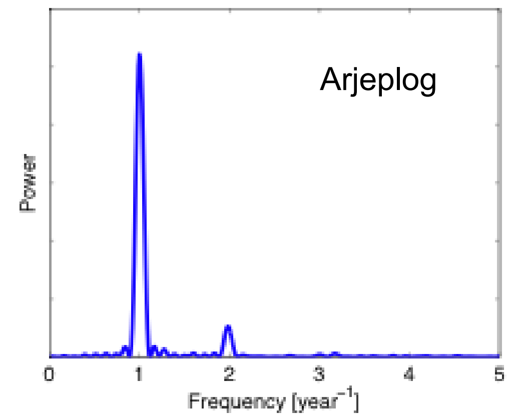
# Estimating IWV trends

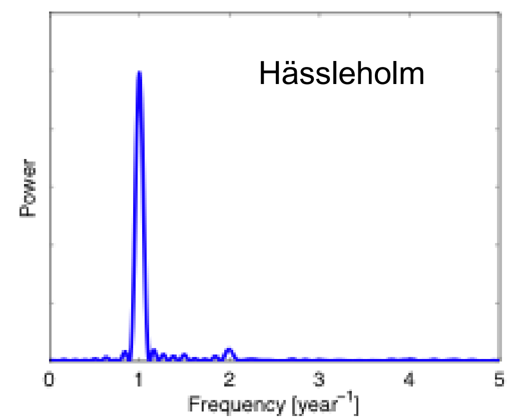



Both annual and semi-annual terms are used to describe the seasonal variations.

This is motivated from the Lomb-Scargle periodograms:

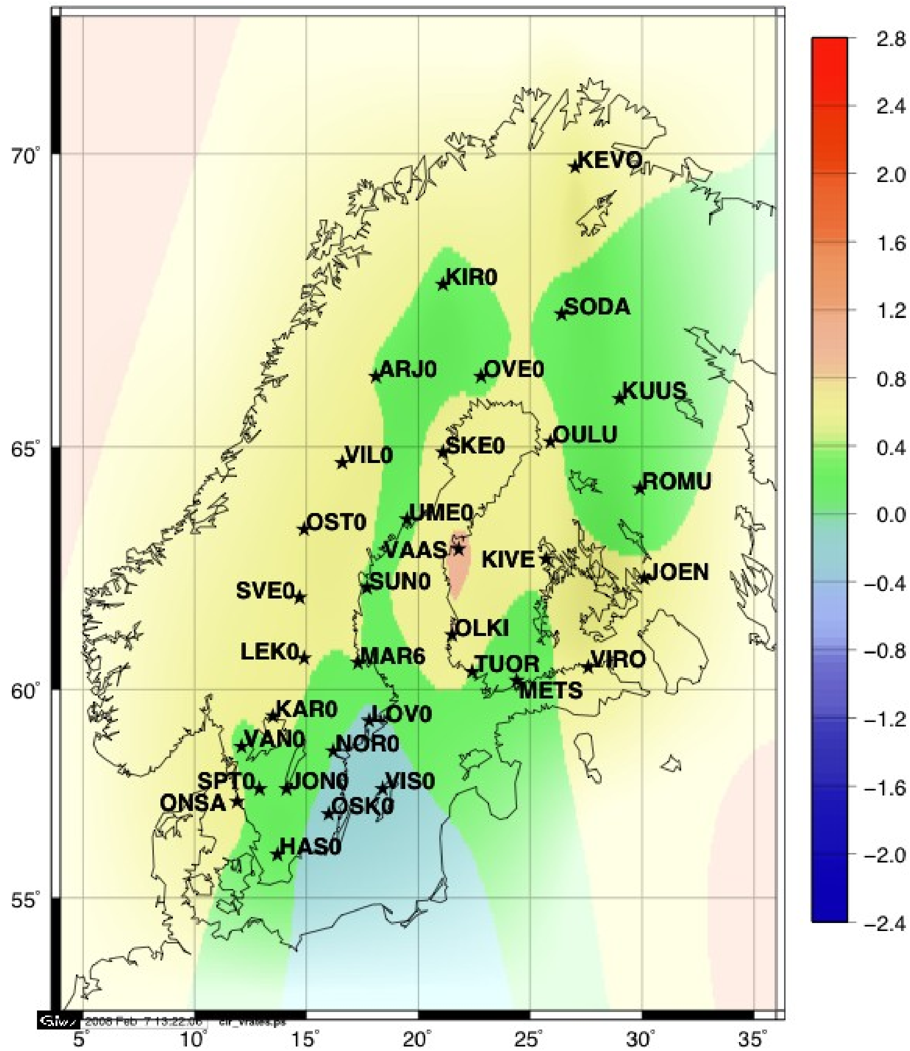



The IWV data are fitted to the model:

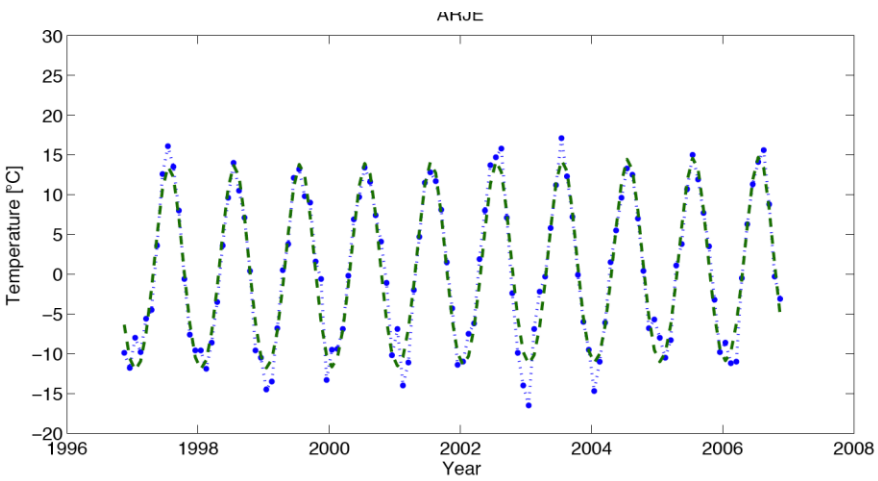
where $t$ is the time in years and the coefficients $I_0$, $A$, $B$, $C$, $D$, $E$ are estimated.

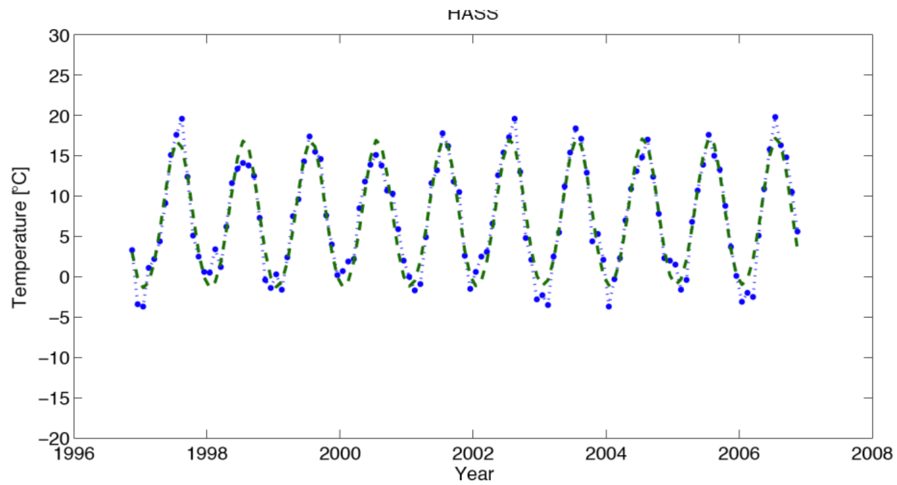
# IWV trends over Sweden and Finland




- Analysis period: 10 years, November 16, 1996 – November 15, 2006
- IWV trends varies from –0.5 to +1.5 kg/m$^2$/decade
- Uncertainties in the trends are ~0.4 kg/m$^2$/decade (taking temporal correlations into account)

# Estimating trends in ground temperature from observed monthly means — close to Swedish sites

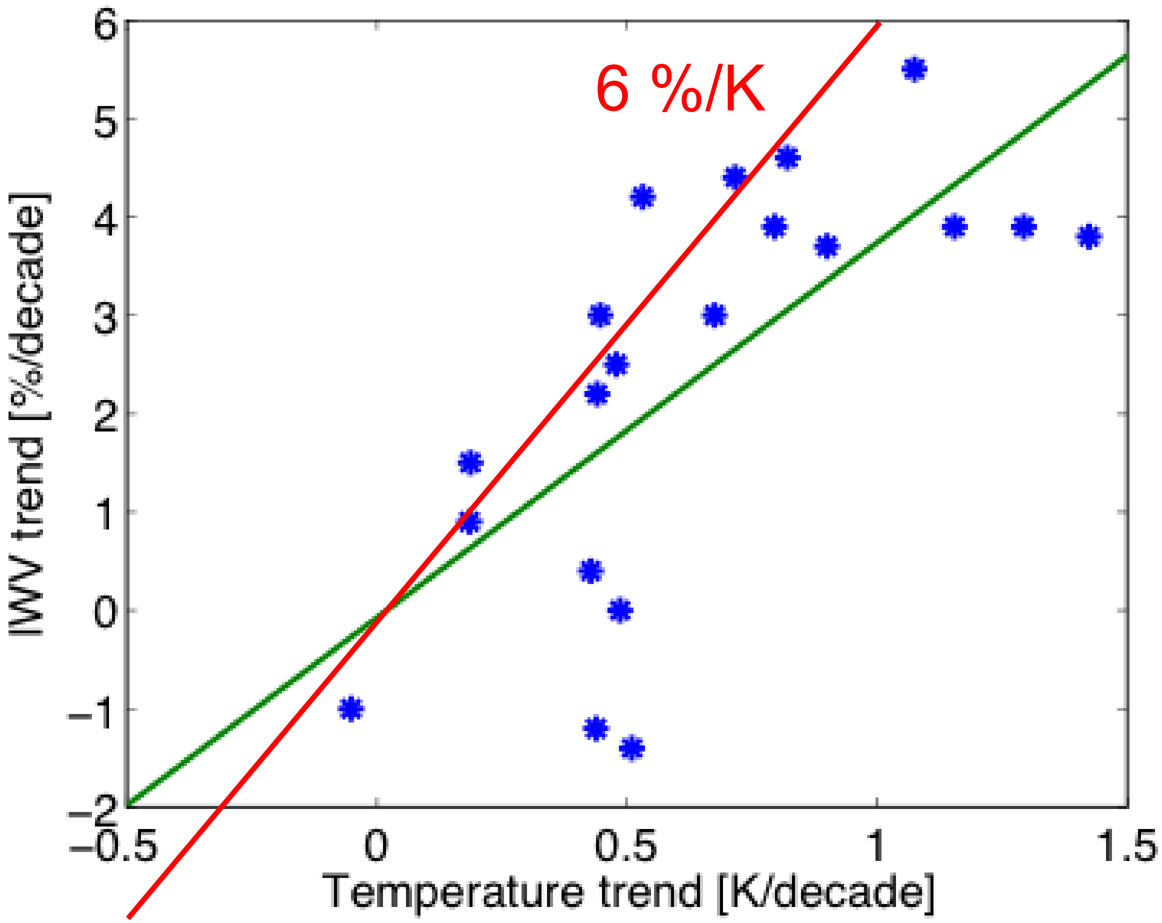



The temperature data are fitted to the same type of model:

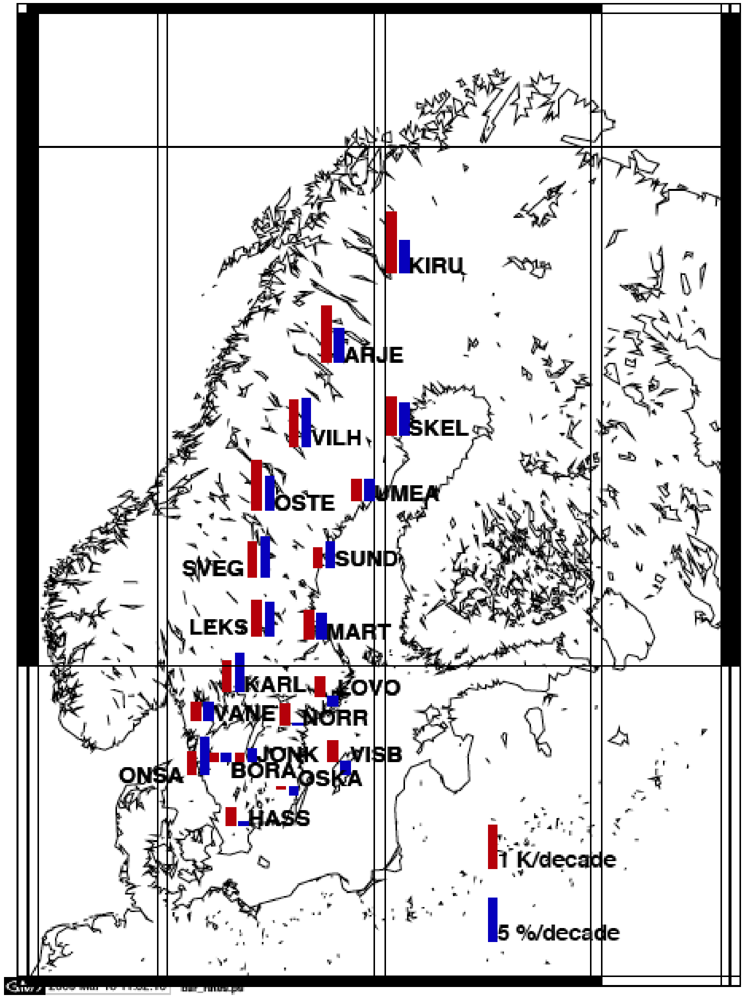
where *t* is the time in years and the coefficients $T_0$, *A, B, C, D, E* are estimated.

# Correlation between trends in ground temperature and IWV over Sweden

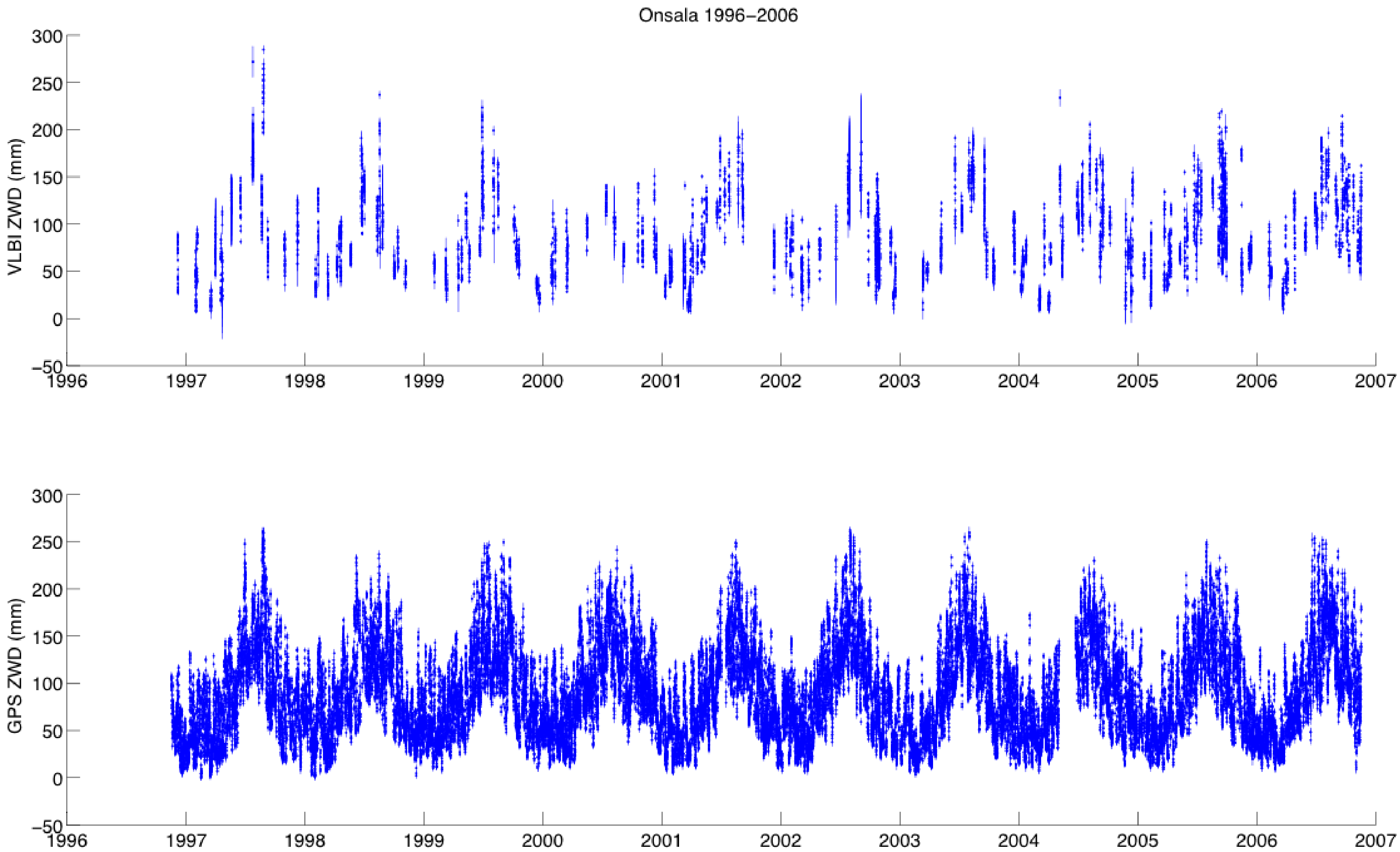



- Correlation coefficient: 0.69
- Slope: 3.8 %/K

# Temperature and IWV trends over Sweden



# Validating the GPS results using VLBI data

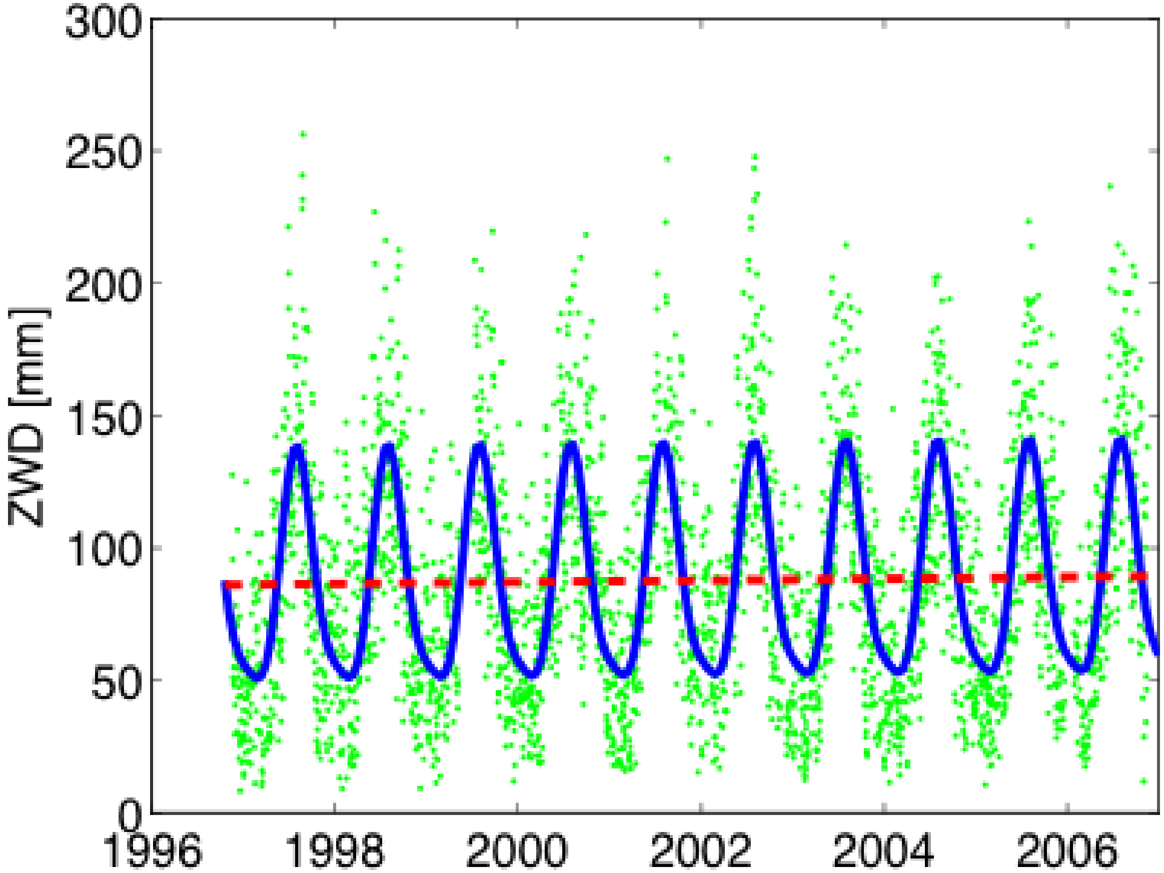


# Linear trends in ZWD inferred from GPS and VLBI data

| | |
|---|---|
| GPS trend using all data 1996–2006: | 0.4 mm/yr |
| VLBI trend (NMF): | 0.6 mm/yr |
| VLBI trend (VMF): | 0.7 mm/yr |
| GPS trend data from VLBI periods: | 1.0 mm/yr |

| | |
|---|---|
| VLBI trend (NMF) all data 1983-2009 | 0.4 mm/yr |
| VLBI trend (VMF) all data 1983-2009 | 0.4 mm/yr |

# Validating the GPS results using radiosonde data




Radiosonde trend: 0.32 mm/yr

GPS trend (as before):0.37 mm/yr

# RMS differences in the ZWD inferred from GPS, VLBI and radiosonde data

GPS – radiosonde (1996 – 2006): 10 mm

VLBI (NMF) – radiosonde: 11 mm
VLBI (VMF) – radiosonde: 11 mm
VLBI (VMF) – GPS: 7 mm

GPS – radiosonde (using data from VLBI periods only): 13 mm

# Conclusions

- The use of GPS for monitoring of the wet atmosphere is promising/meaningful/reasonable.
- Correlation observed between trends in ground temperature and water vapour content are also reasonable
- VLBI data are too sparse at Onsala in order to validate trends in water vapour / zenith wet delay.
- Validation using Onsala VLBI data must therefore presently focus on studies of RMS differences.