
Impact of Different Modeling Options on GPS-derived Station Heights



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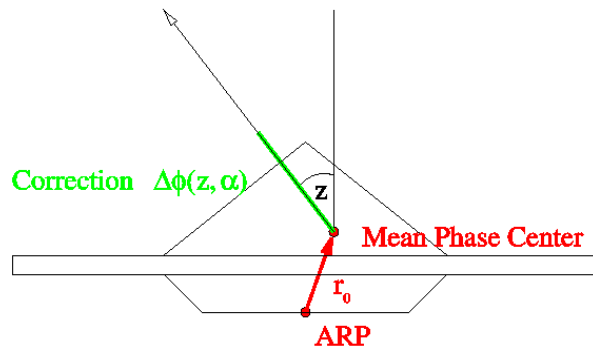
Astronomisches Institut der Universität Bern



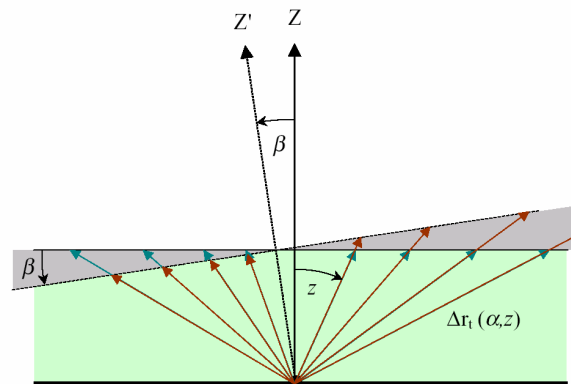
now at: European Space Operations Centre, Darmstadt

Motivation

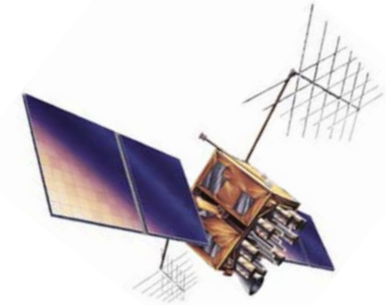
Several modeling options have a significant and systematic impact on estimated station heights



**Antenna Phase
Center Model**



**Troposphere
Modeling**



**Solar Radiation
Pressure**

1. Assess the order of magnitude by comparing long-term GPS solutions computed with different modeling options
2. Examples of time series and other systematic effects

GPS Reprocessing

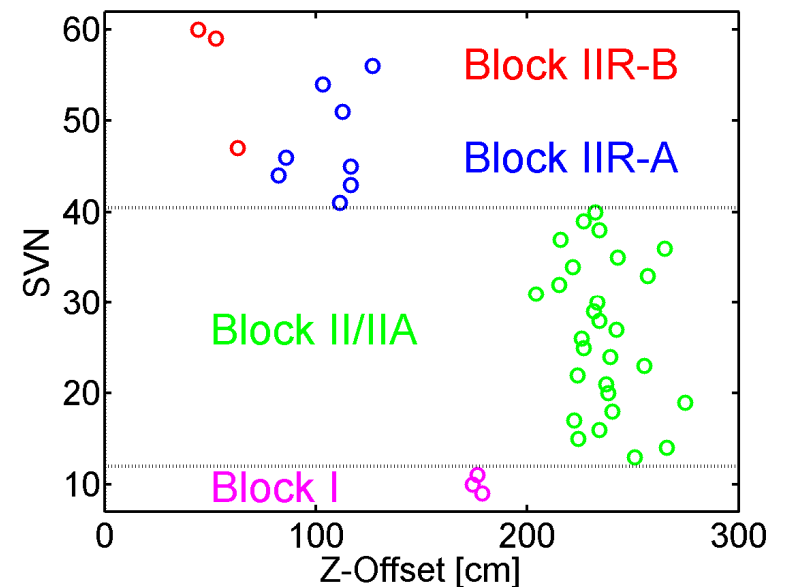
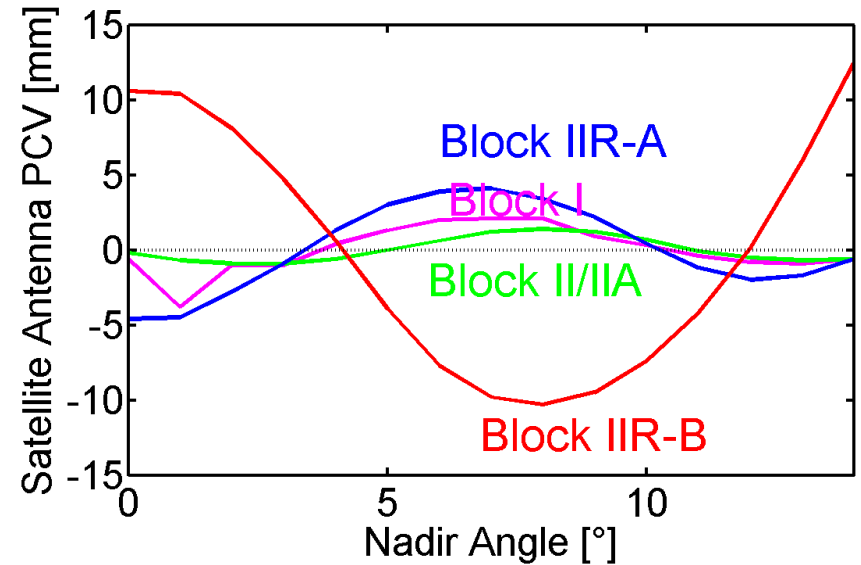
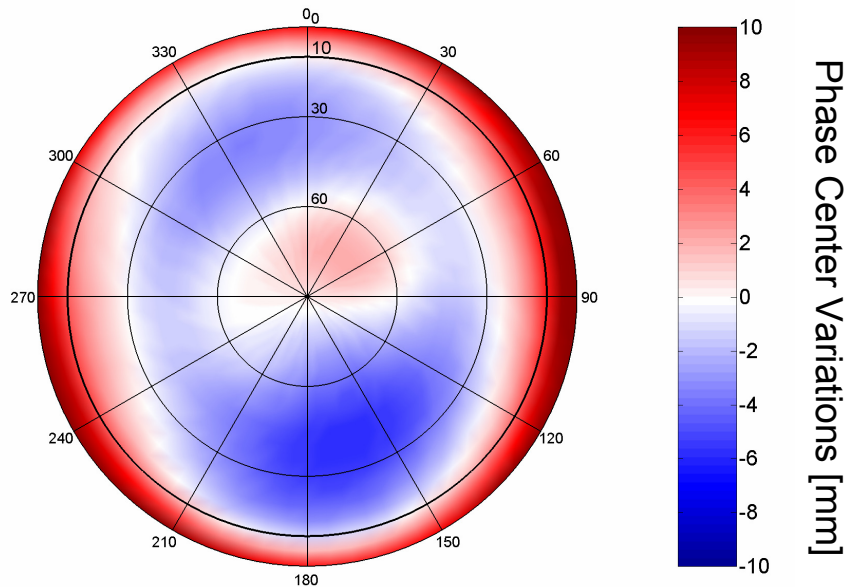
**Complete and homogeneous reprocessing by
TU München, TU Dresden and GFZ Potsdam**

- **Altogether 202 stations altogether, up to 160 per day**
- **Bernese GPS Software**
- **Datum stations: subset of 66 stable IGB00 stations**
- **Time interval: 1 January 1994 - 31 October 2005 (4322 days)**
- **Normal equations accumulated to reference frame (TRF) solutions**
- **Residuals of 14-parameter similarity transformations between two TRF solutions**

Antenna Phase Center Models

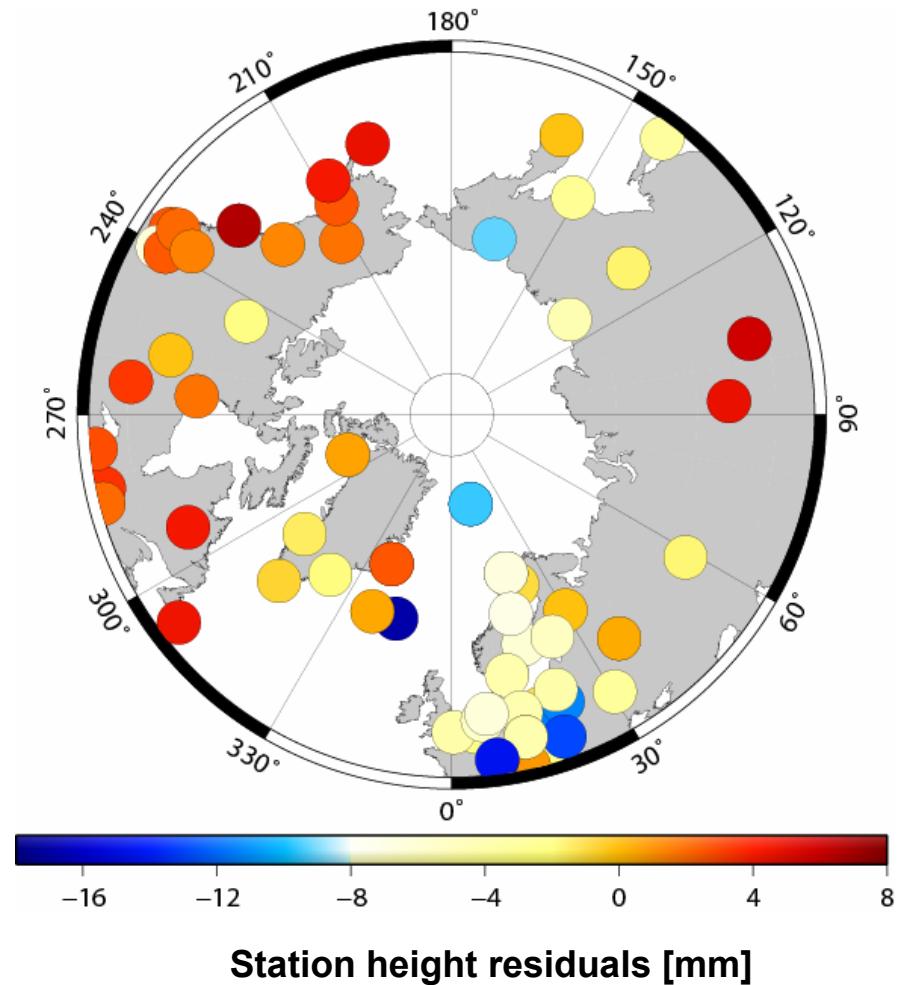
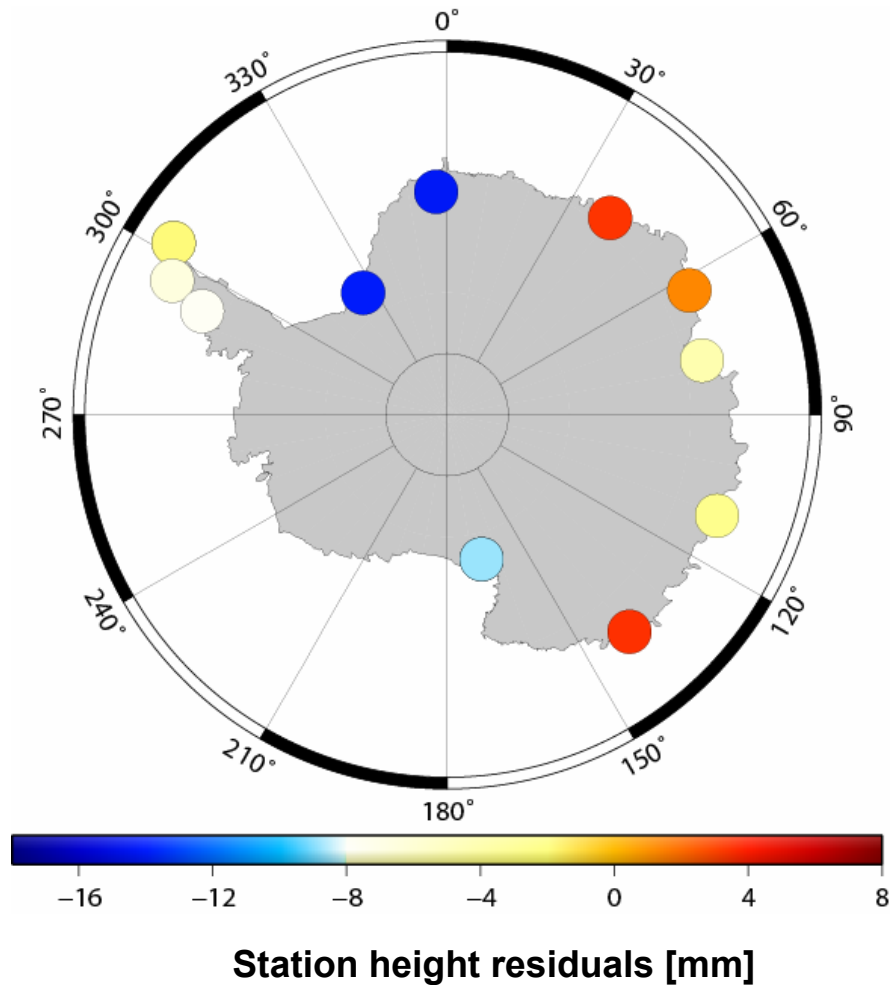
Antenna phase center variations (PCVs) and offsets (PCOs)

PCVs for **TRM14532.00** NONE



Absolute Model igs05 - Relative Model igs01

TRF scale difference: 0.84 ppb - 0.21 ppb/y



Troposphere Modeling (1)

$$\text{TD}(z) = f_h(z) \cdot \text{ZHD} + f_w(z) \cdot \text{ZWD}$$

TD	Total Delay
ZHD	Zenith Hydrostatic Delay
ZWD	Zenith Wet Delay
z	zenith angle
f_h	hydrostatic mapping function
f_w	wet mapping function

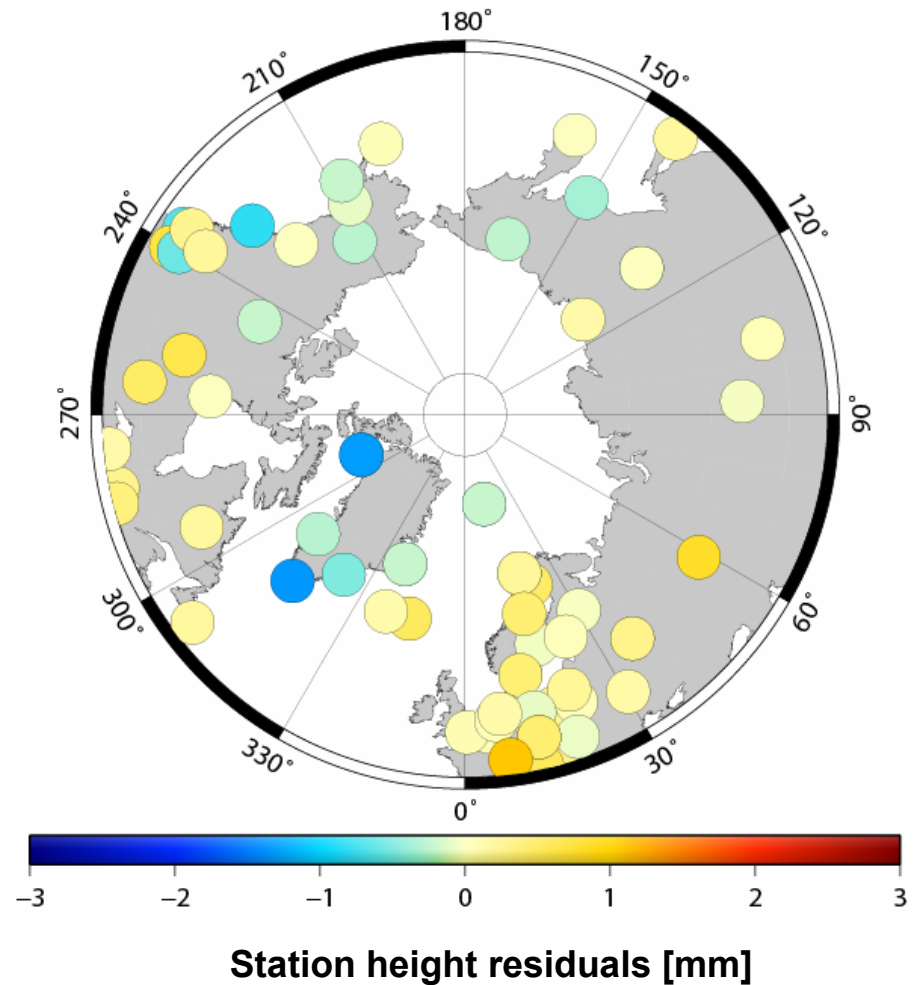
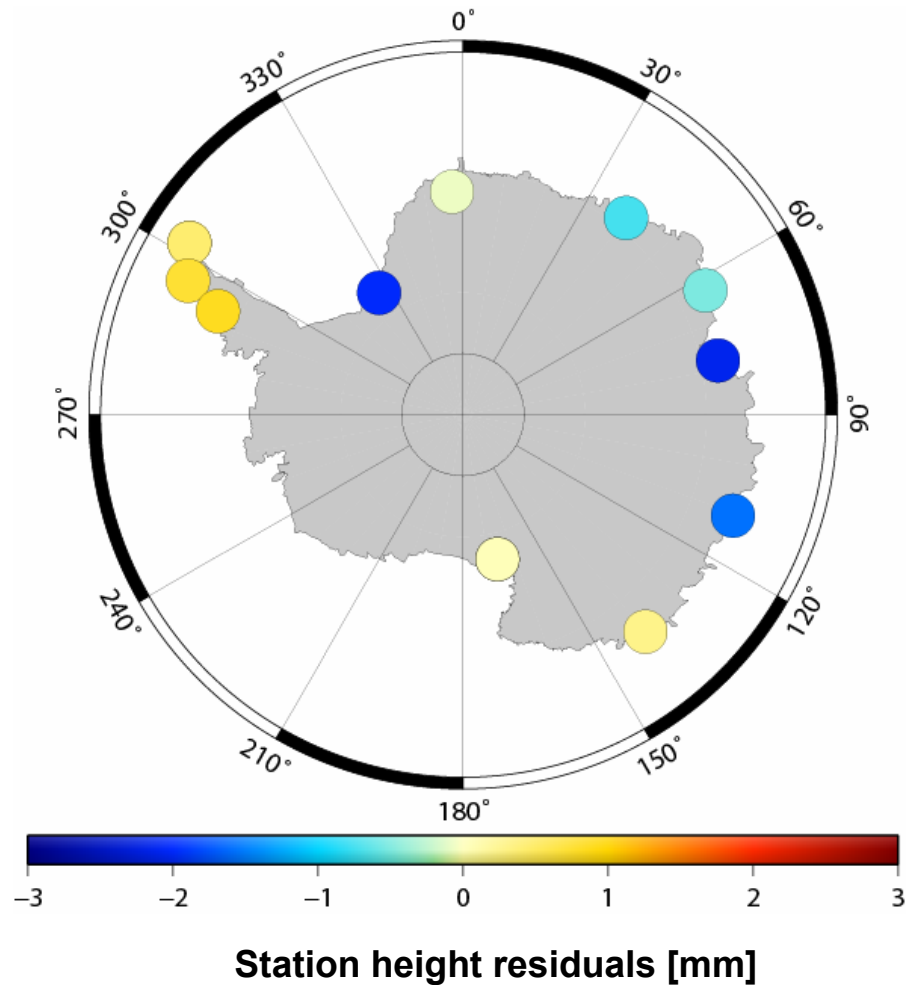
Troposphere Modeling (2)

Mapping Functions	
Outdated	Niell Mapping Function (NMF)
Empiric	Global Mapping Function (GMF)
Numerical Weather Model	Vienna Mapping Function 1 (VMF1)

Hydrostatic a Priori Delays	
Outdated	Constant (e.g., Berg)
Empiric	Global Pressure and Temperature Model (GPT)
Numerical Weather Model	European Centre for Medium-Range Weather Forecast (ECMWF)

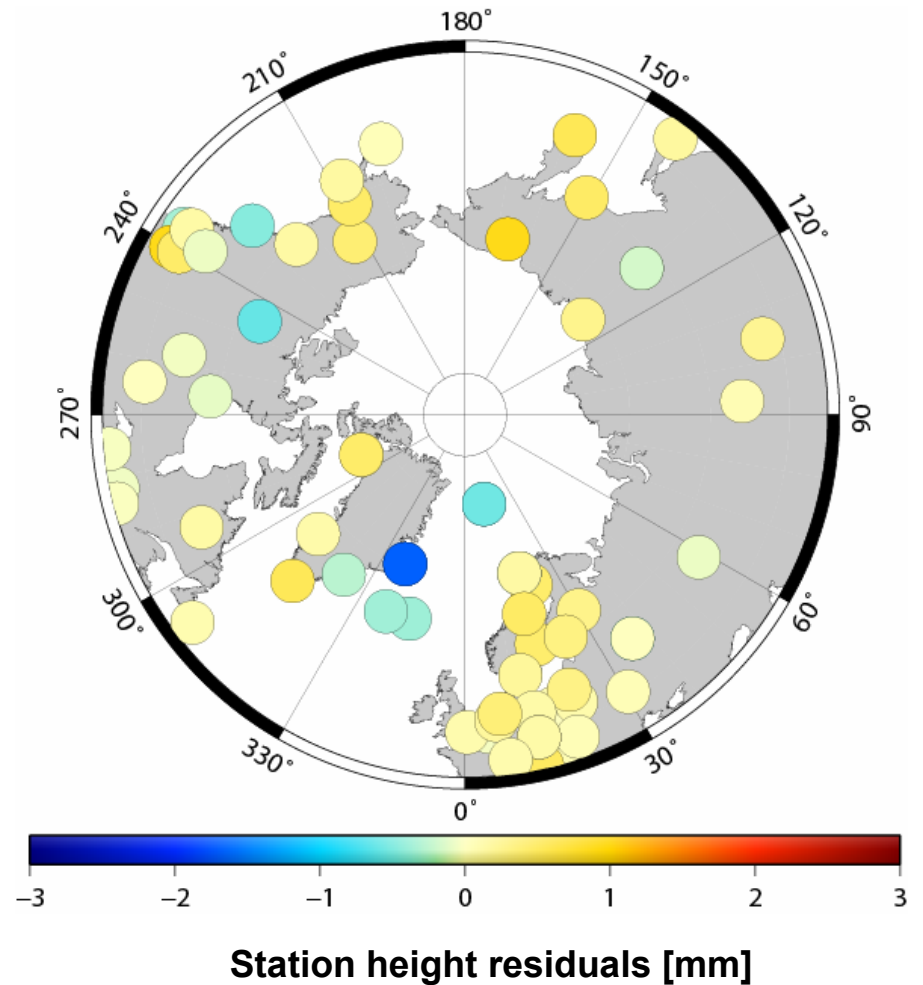
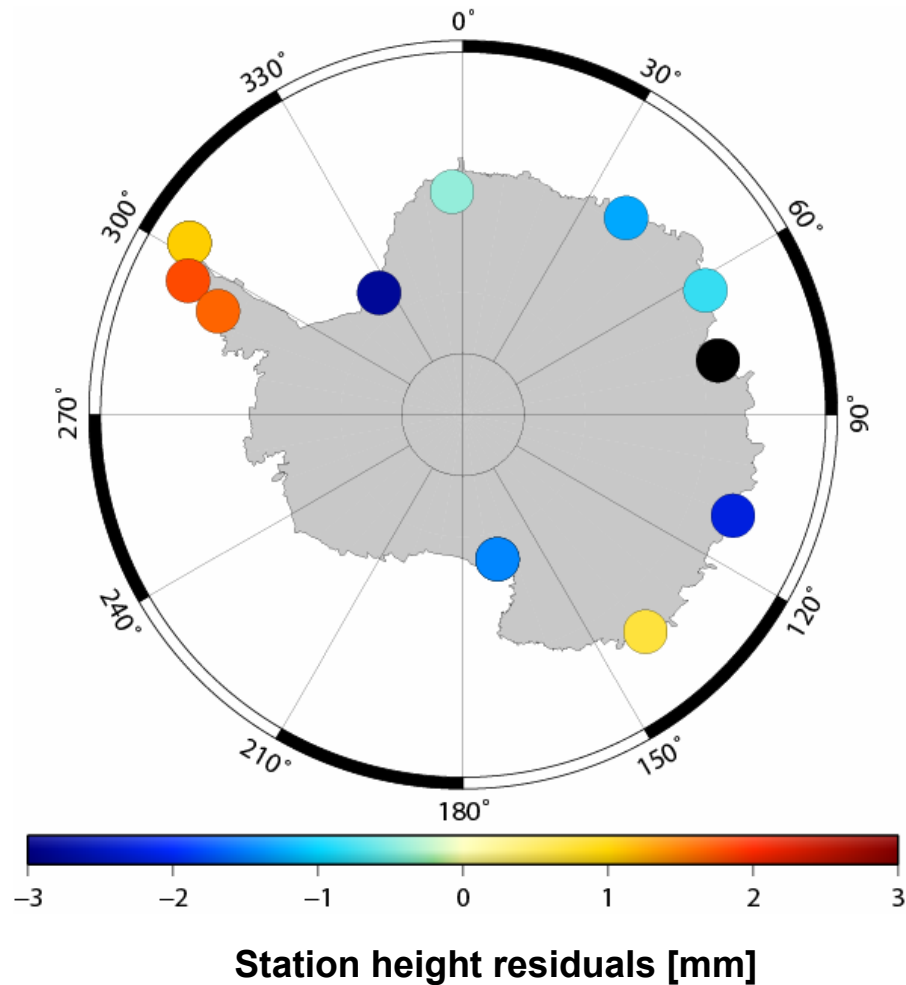
Mapping Functions

Vienna Mapping Function 1 (VMF1) – Global Mapping Function (GMF)



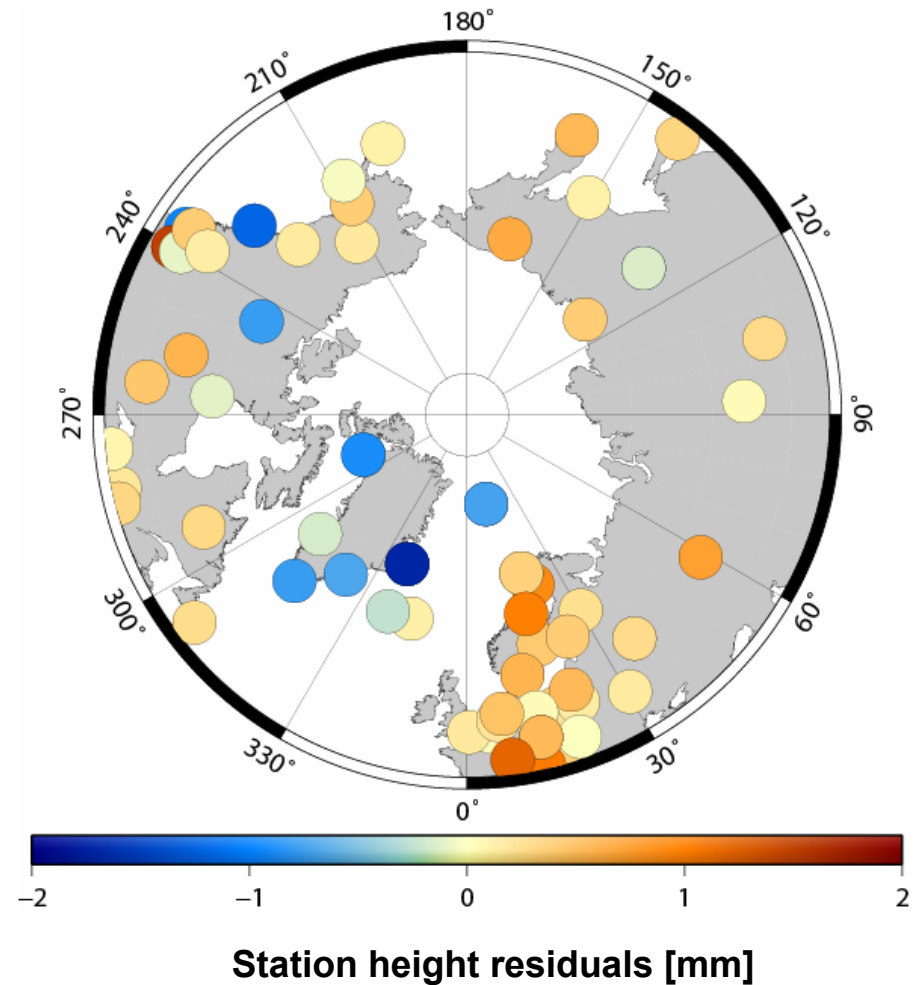
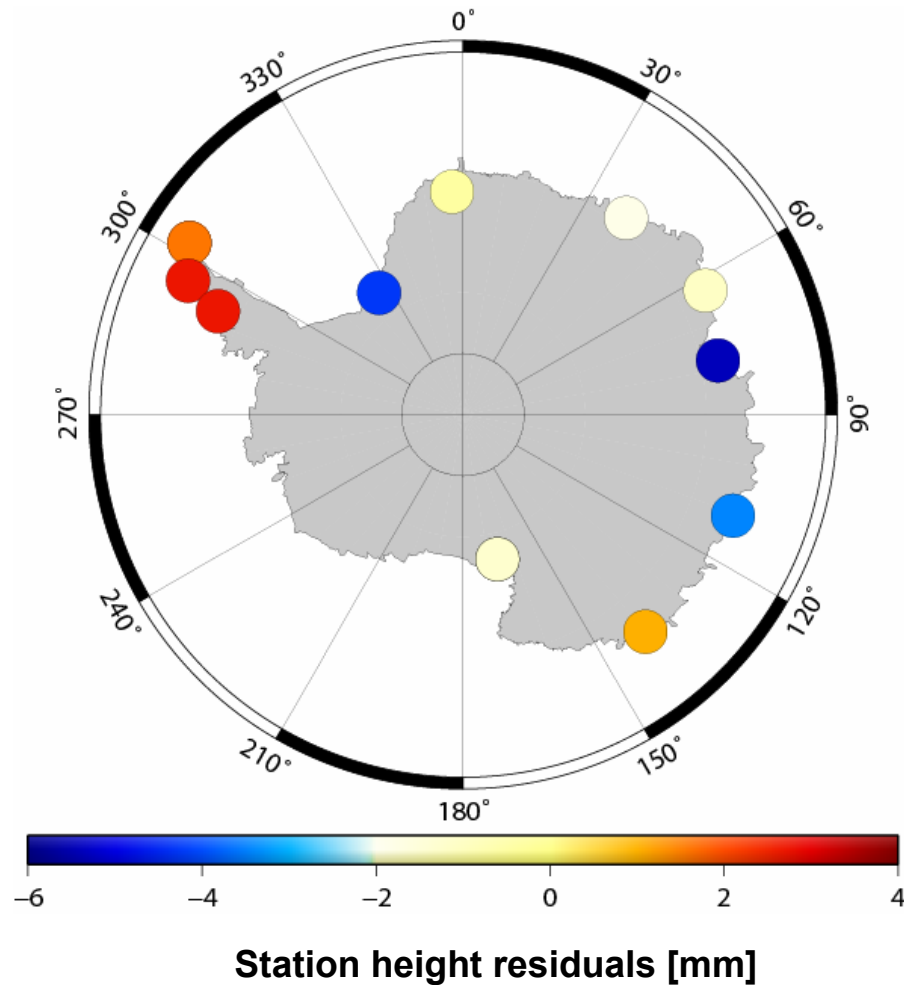
Hydrostatic a priori Delays

6^h ECMWF delays – Global Pressure and Temperature (GPT) model



Mapping Functions and a Priori Delays

VMF1/ECMWF – GMF/GPT



Impact of erroneous ZHD

Differences between the hydrostatic and wet mapping functions introduce a height error if an erroneous ZHD model is applied

- Zenith hydrostatic delay:

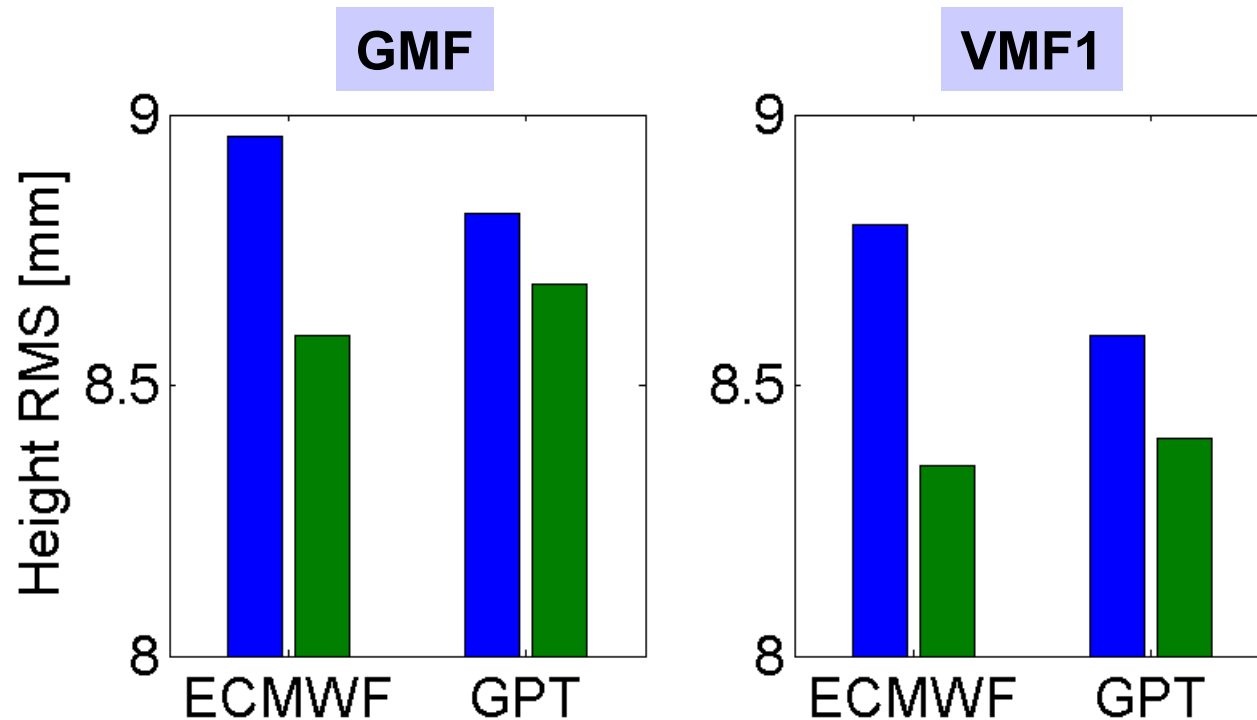
$$\text{ZHD} \approx 0.00227768 \cdot P_0$$

- Atmospheric loading effect on station height:

$$\Delta H_{AL} \approx -k \cdot (P_0 - P_{ref})$$

→ **Partial compensation of atmospheric loading**

Station Height Repeatabilities



183 stations **with** and **without** correction of atmospheric loading (Leonid Petrov*)

- Better repeatability **without** atmospheric loading corr. for **GPT**
- Better repeatability **with** atmospheric loading corr. for **ECMWF**

* <http://gemini.gsfc.nasa.gov/aplo/>

Solar Radiation Pressure Modeling (1)

Estimated orbit parameters:

- 6 Keplerian elements +
- 3 constant SRP parameters +
- 2 periodic SRP parameters in X-direction

A priori Solar Radiation Pressure (SRP) models:

ROCK SRP Model

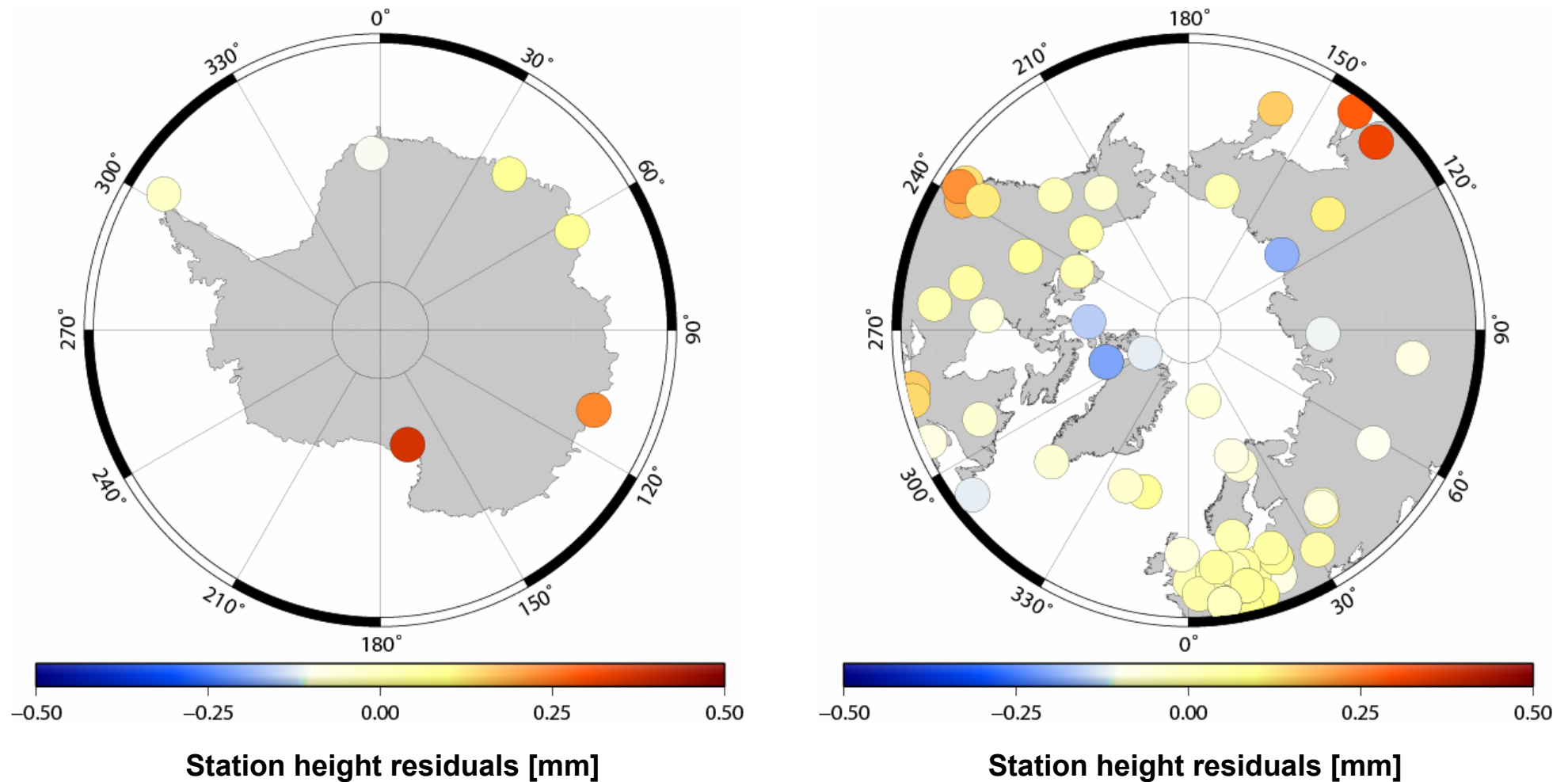
- Physical Model
- Fourier series for accelerations in x and z
- Angle between the direction to the Sun and the Z-axis

CODE SRP Model

- Empirical Model
- 4 constant terms and 8 periodic terms
- Elevation of the Sun above the orbital plane, argument of latitude of the satellite w.r.t. the Sun

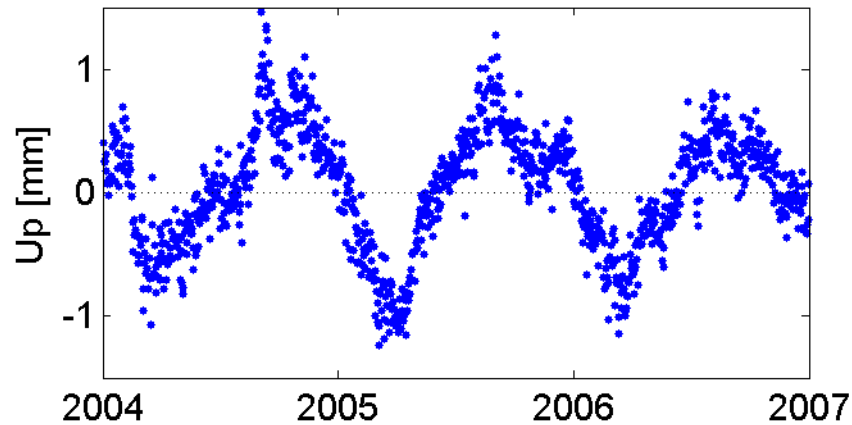
Solar Radiation Pressure Modeling (2)

Mean residual of 3-parameter similarity transformations
3 years of daily solutions with ROCK and CODE a priori SRP model

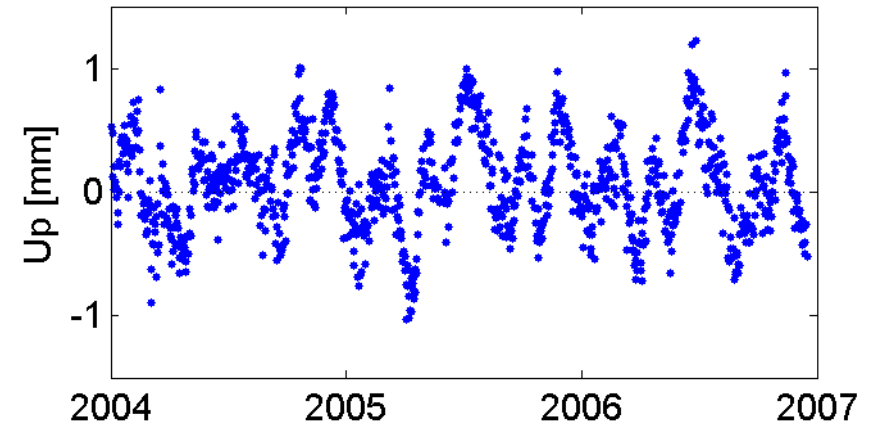


Residual Time Series: ROCK vs. CODE SRP

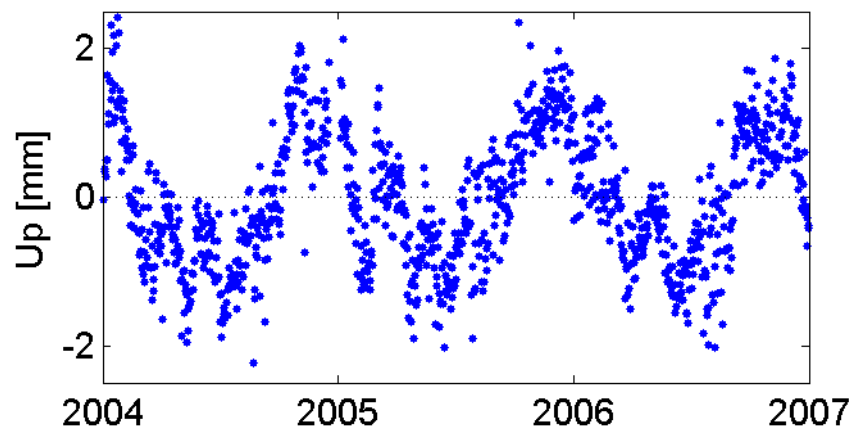
Onsala, Sweden



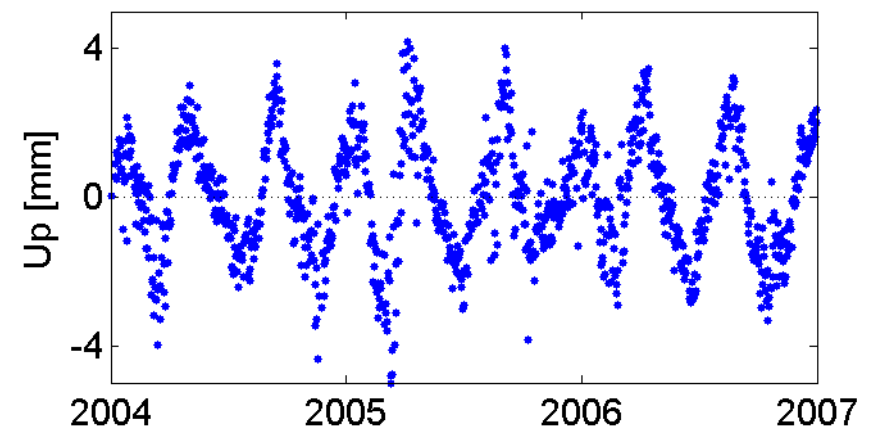
Wetzell, Germany



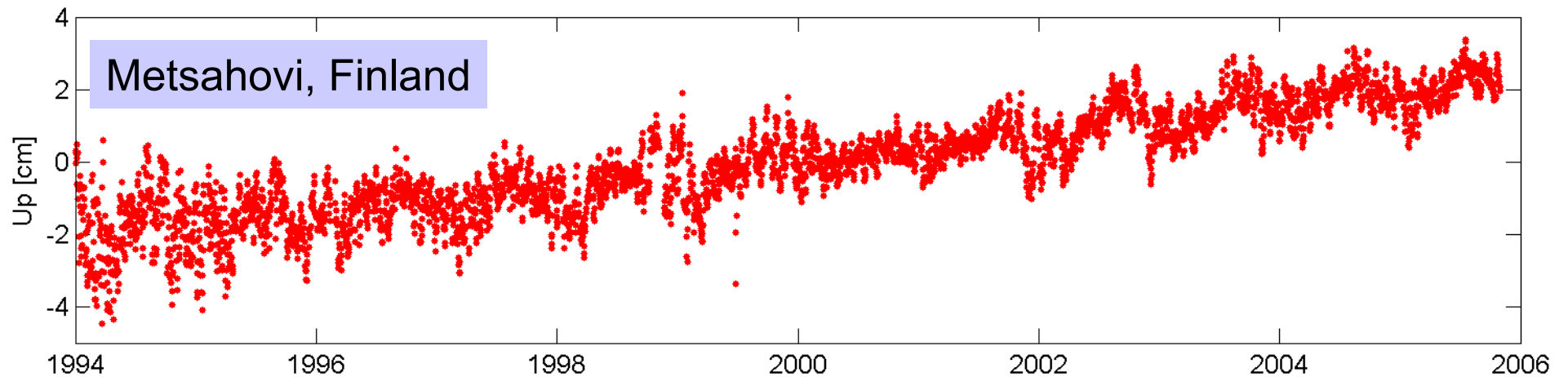
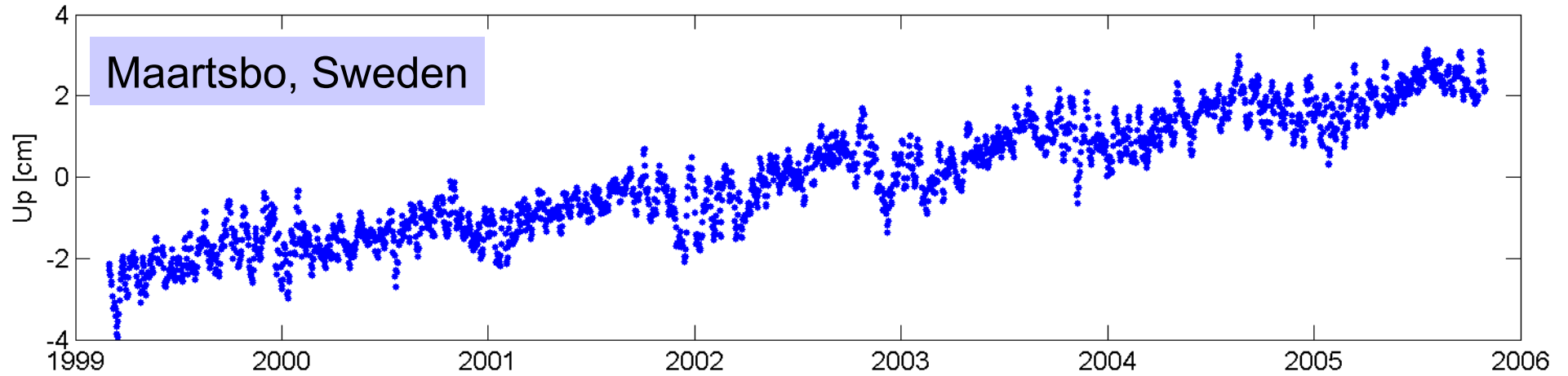
Fairbanks, Alaska



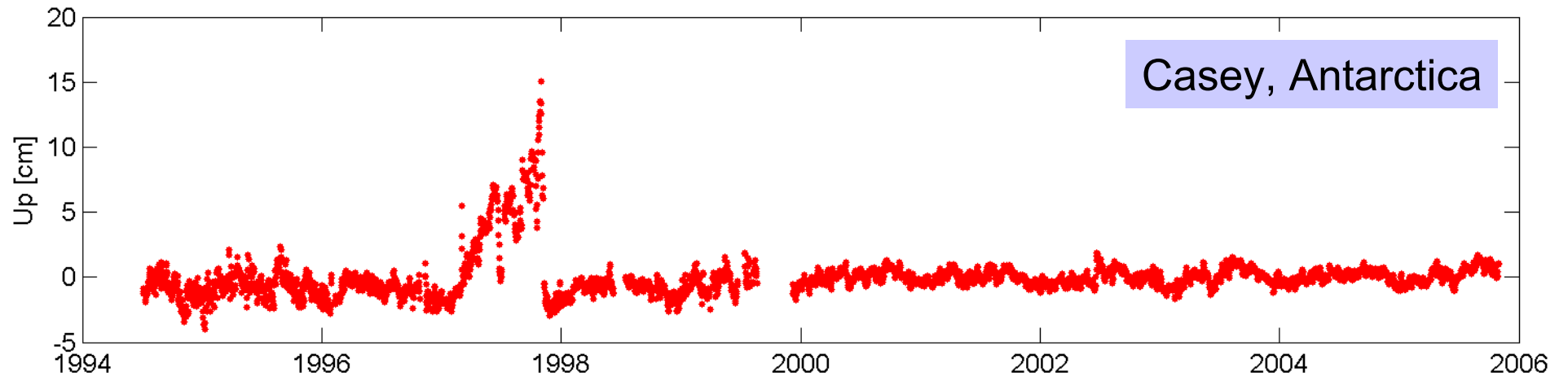
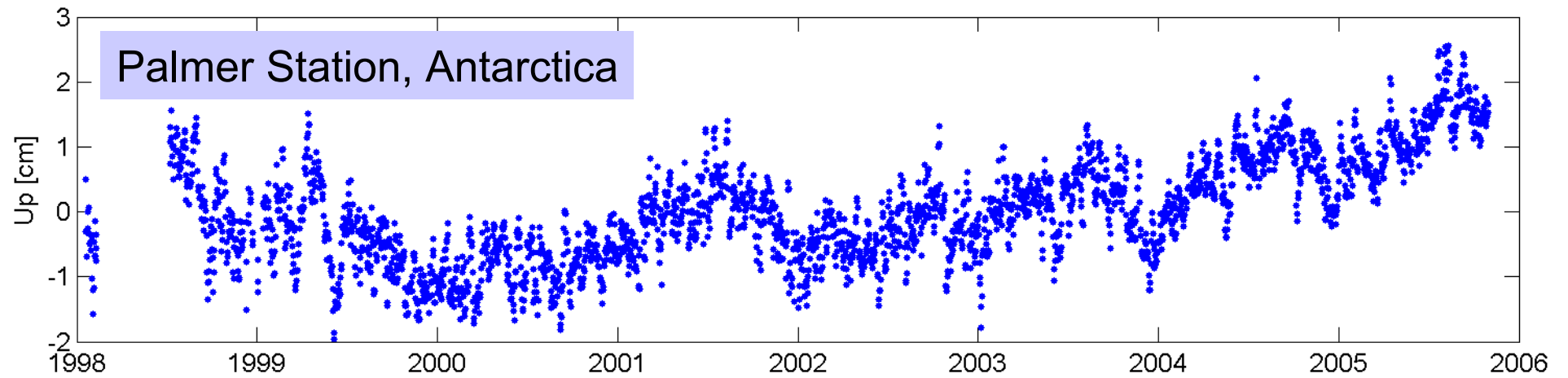
Perth, Australia



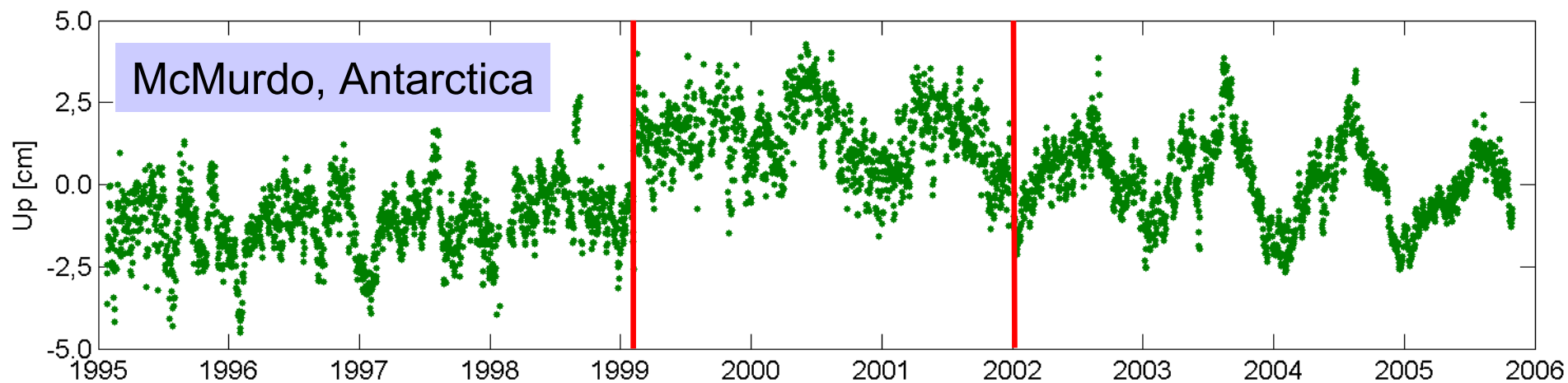
Station Height Time Series



Non-linear Velocities



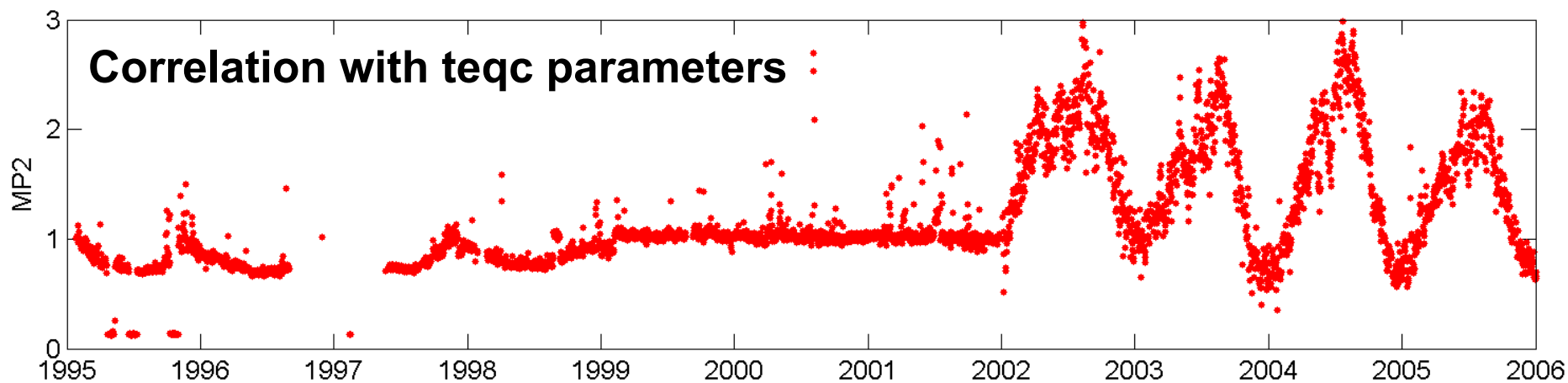
Data Problems



Discontinuities

Unknown

Receiver change



Conclusions

Homogeneous reprocessing essential for a proper interpretation of GPS-derived long-time series: IGS Reprocessing effort

Careful screening of the coordinate time series important before the estimation of reliable velocities

Antenna Phase Center Model:

- Robot-calibrations for **all** antenna/radome combinations
- **Consistent** and **complete** set of satellite antenna PCVs and PCOs based on the IGS reprocessing

Troposphere Modeling:

- Mapping functions and a priori delays based on **numerical weather models** should be used
- Erroneous ZHD modeling results in a **partial compensation of atmospheric loading**

A Priori Radiation Pressure Model:

- Impact on mean station heights very small but **pronounced periodic differences**