Site-Dependent Effects in High-Accuracy Applications of GNSS

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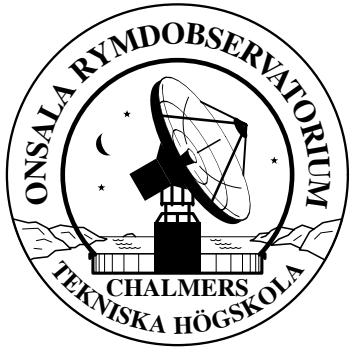


Presented by
Martin Lidberg
At the EUREF meeting, June 6-8 2007, London

Presentation Structure

The SWEPOS network
Site-dependent effects
Observable and Processing strategies
Investigation of site-dependent effects in SWEPOS
Calibration of GNSS stations
- statistical calibration method
- in-situ calibration method

Conclusions

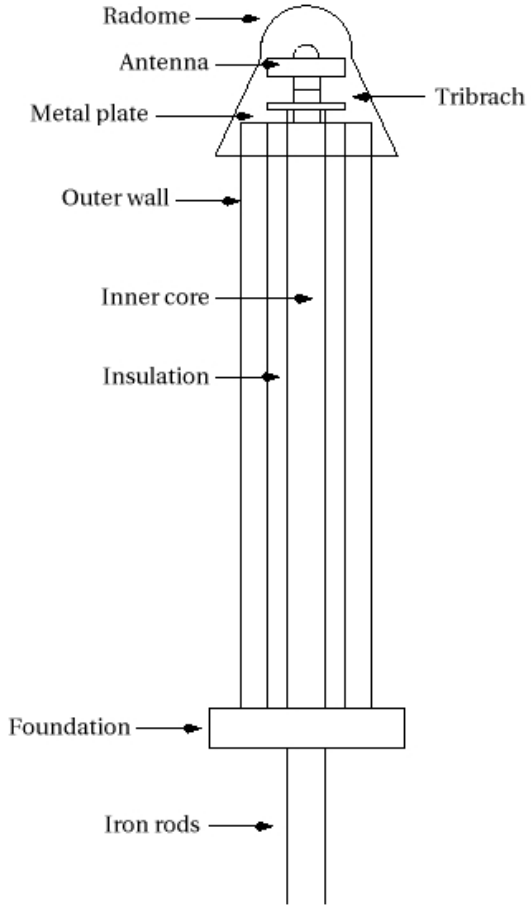
The Swedish Ground-Based GNSS Network SWEPOS

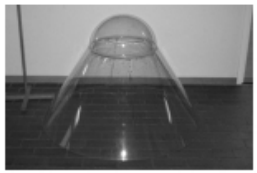
- Operated by the National Land Survey of Sweden.
- Collecting data since 1993
- 21 original stations and additional roof-top stations for RTK-applications.
- Original station separation ~200 km

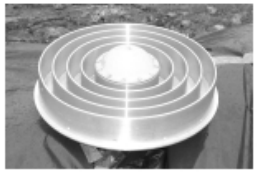
Original Station

Roof-top Station

The Design of the Original SWEPOS Station




Radome

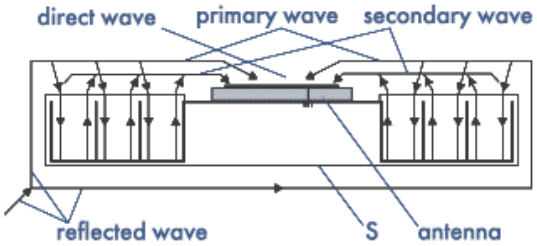

Antenna

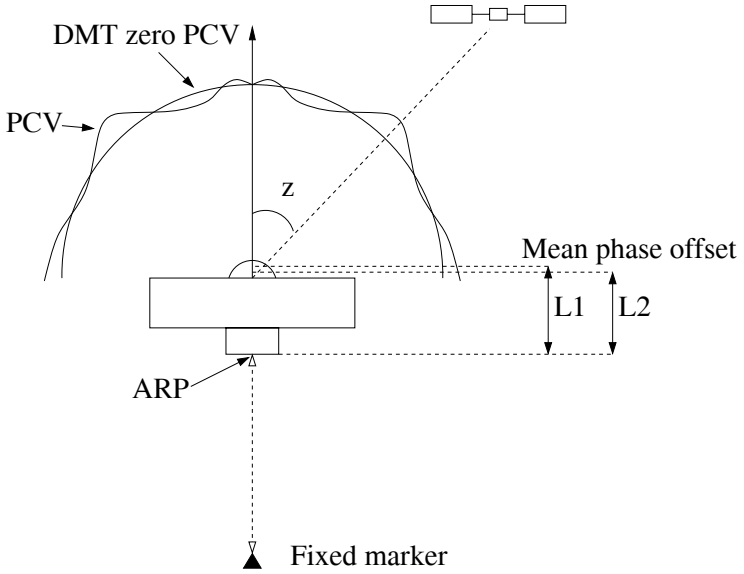

Tribrach


Metal plate

Antennas Used in Ground-Based GNSS

Dorne-Margolin antenna with choke ring ground plane





Phase Centre
The point in the antenna
that the solution is related to

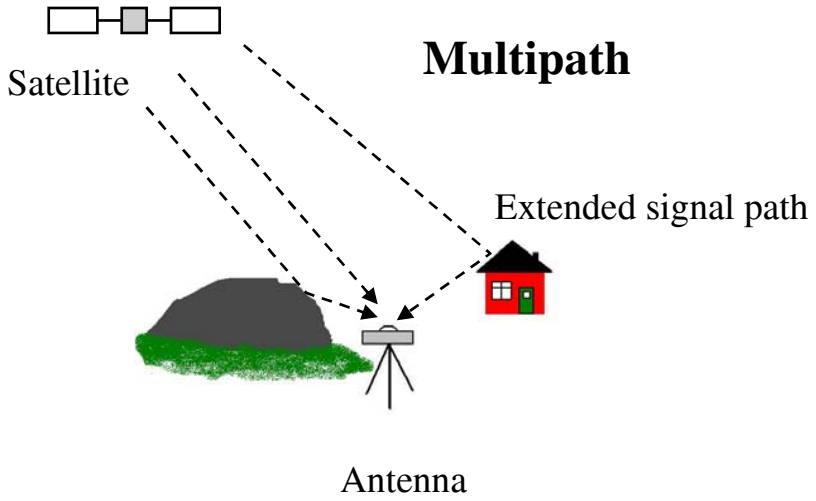
Where is it located?

The phase centre variations are to be accomplished for by the coming antenna specific calibration

Site-Dependent Effects

- Antenna type
- Pillar design
- Radome type
- Station environment

Snow on the antenna



Site-Dependent Effects in SWEPOS

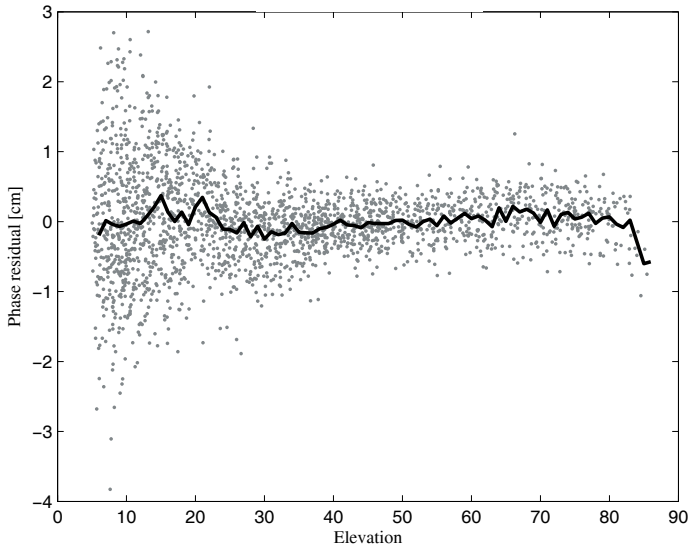
Purpose
To detect and investigate common and individual site dependent effects

- All original SWEPOS stations and some additional roof-top stations
- Precise Point Positioning (PPP) solution strategy using GIPSY-OASIS II
- Residual analysis
- Elevation cut-off angle set to 0 degrees
- 6 years of reprocessed data (1999-2004)

Analysis Method

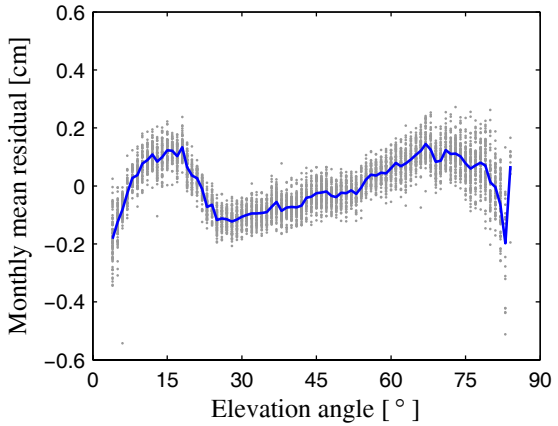
Each observation in the PPP analysis gives a residual

The direction in azimuth and elevation angles for the observations are known.

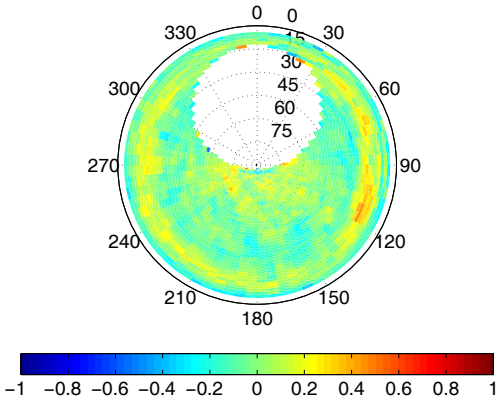


Daily residuals

Elevation dependent

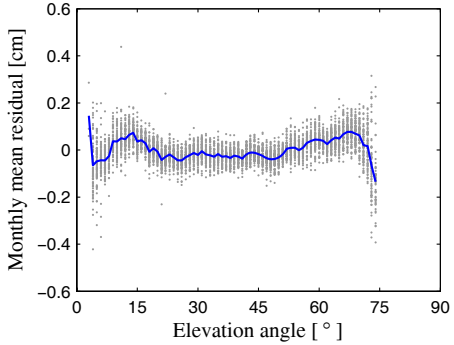


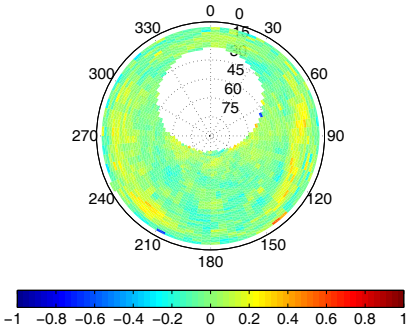
Azimuth and elevation dependent



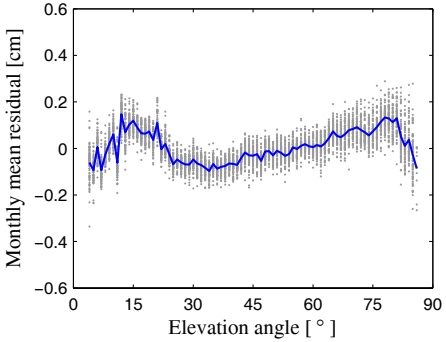
Investigation of Original SWEPOS Station

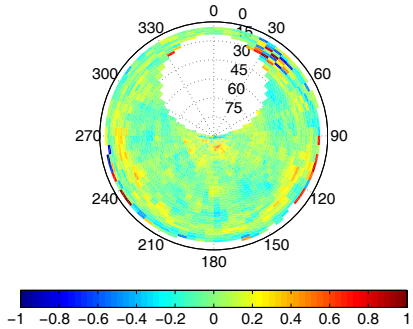
Arjeplog



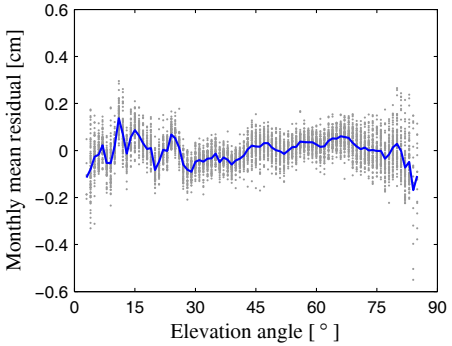


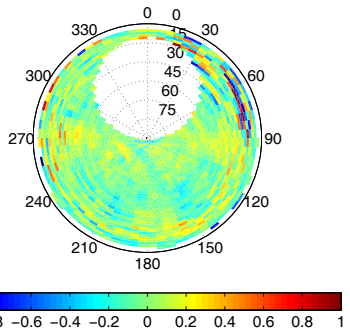
Hässleholm





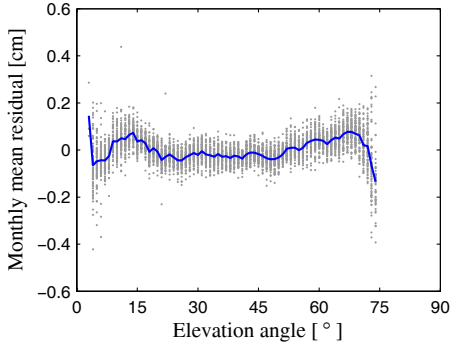
Onsala

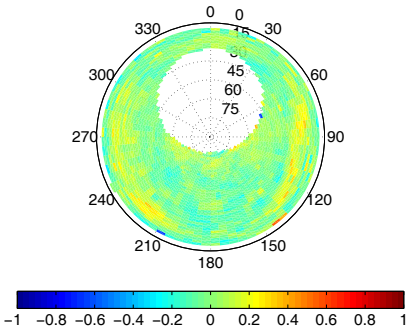




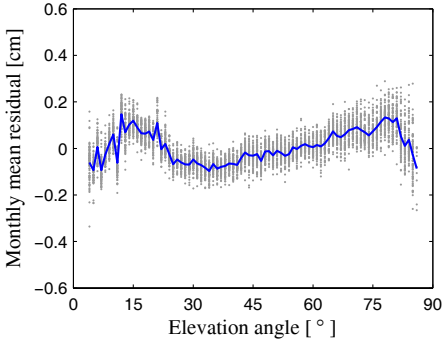
Investigation of Original SWEPOS Station

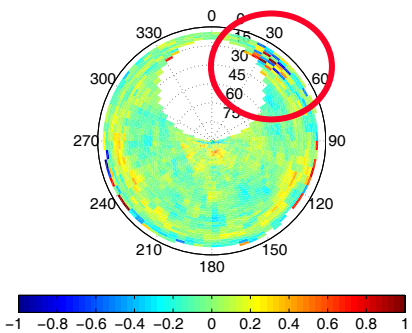
Arjeplog



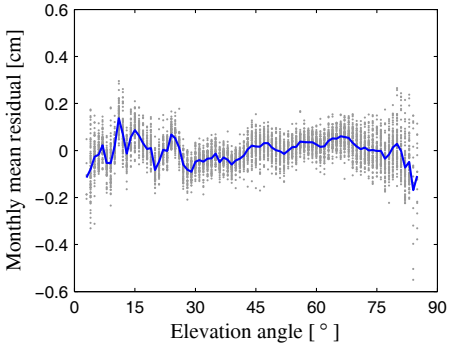


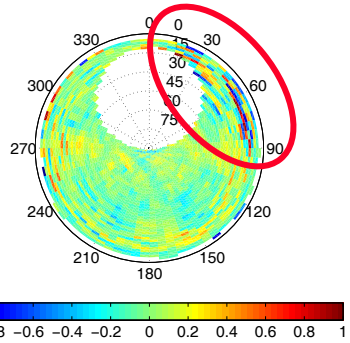
Hässleholm



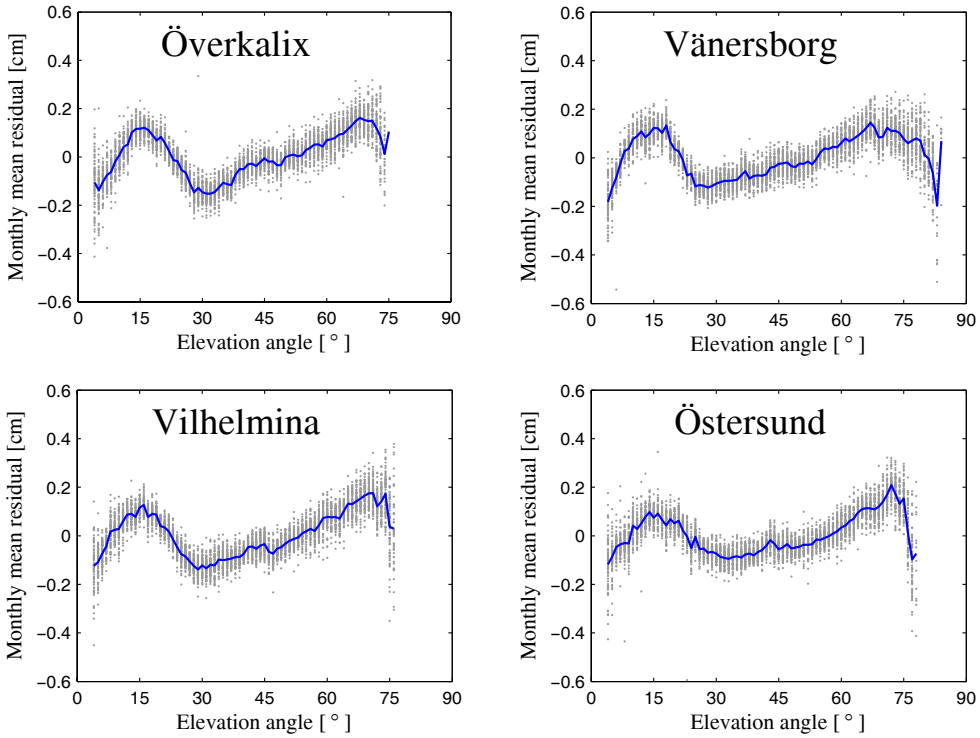


Onsala

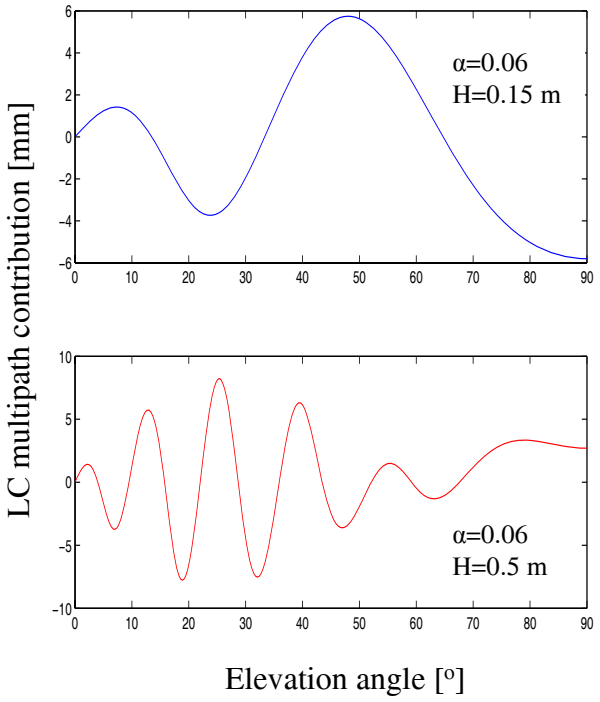




The typical SWEPOS pattern



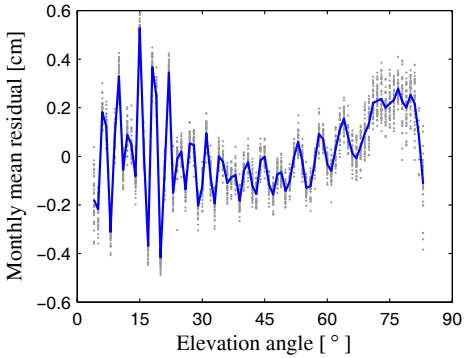
Simulation of multipath contribution following Jaldehag 1995.

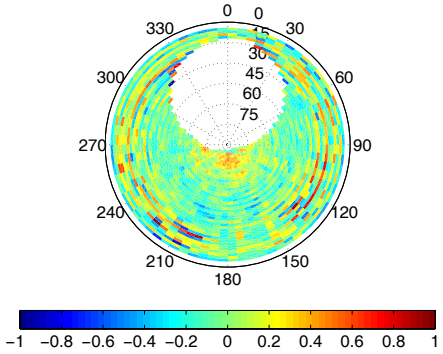


Our theory is that the similar pattern is due to the pillar-top design (concrete, metal plate etc.)

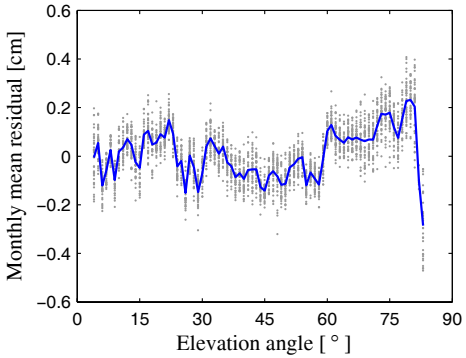
Investigation of Roof-Top Stations

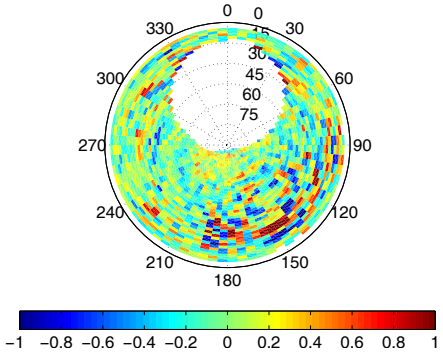
Nynäshamn



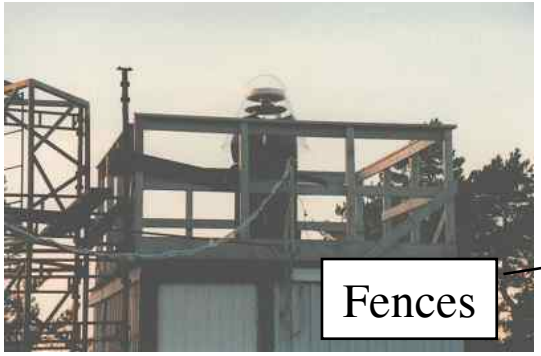


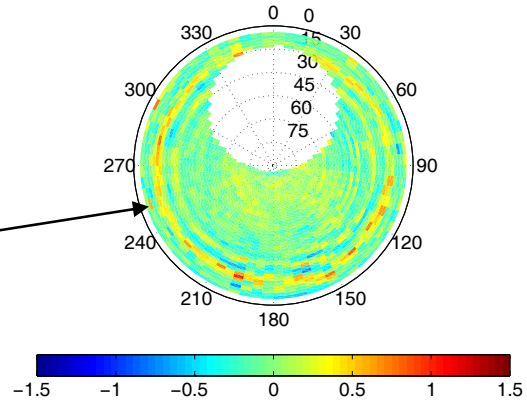
Stavsnäs

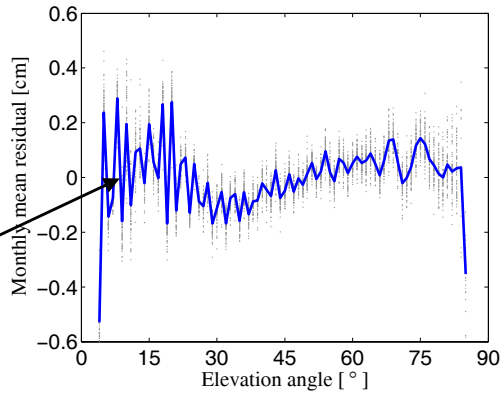


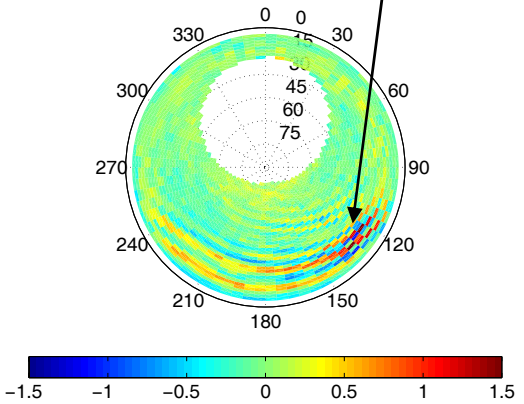


Special Effects and Possible Causes







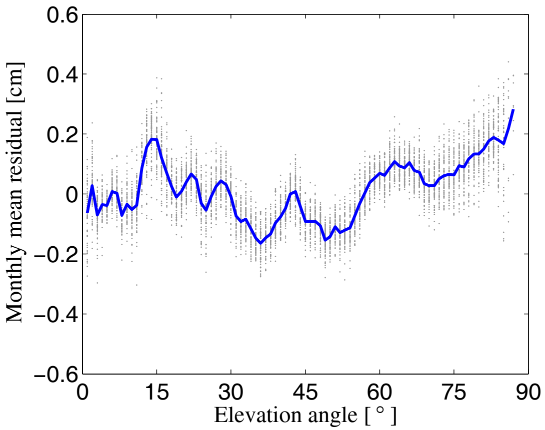


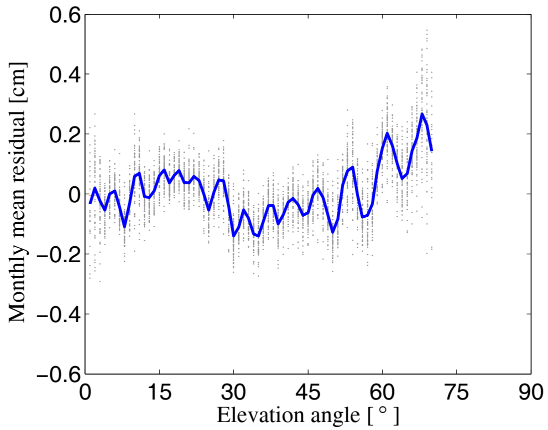
Different characteristics among IGS Stations

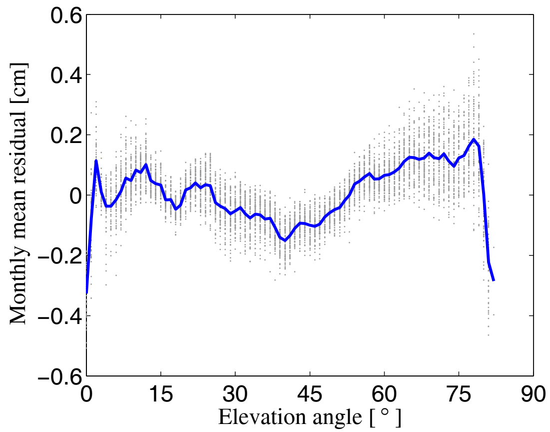
Wettzell

Tromsö

Metsähovi



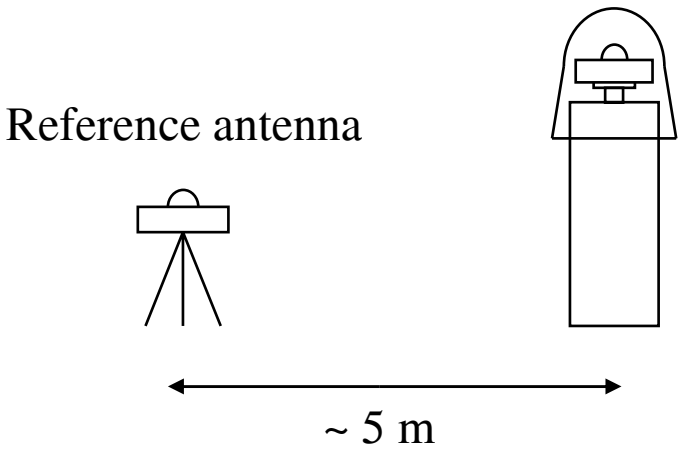




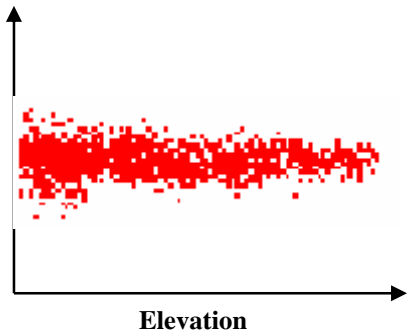
GNSS Station Calibration

Two methods of calibration where developed and evaluated for the Onsala SWEPOS/IGS site

1. In-situ



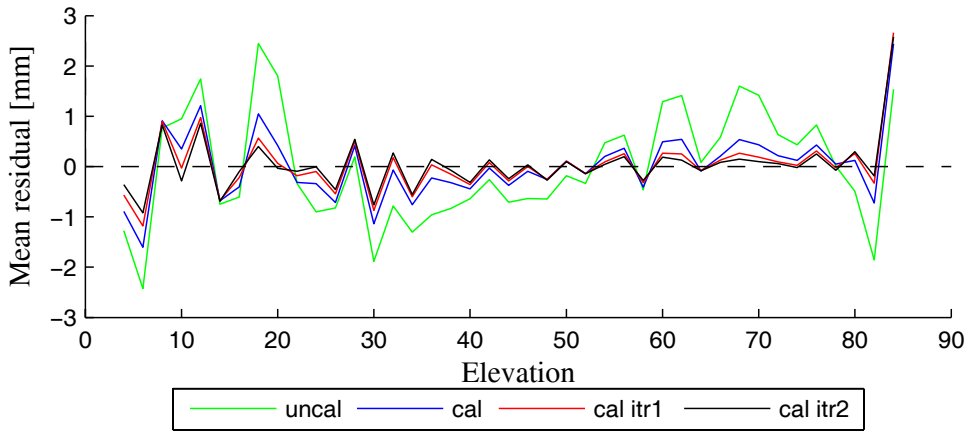
2. Statistical



Residual plots

Statistical Station Calibration

- Based on 6 years of post fit phase residuals from reprocessed data (1999-2004).
- Precise Point Positioning (PPP) processing strategy using GIPSY-OASIS software.
- Elevation cut-off angle set to 0 degrees
- Calibration matrix resolution 2x5 degrees in elevation and azimuth angles
- Residual outliers removed, empty grid boxes filled with nearest neighbouring averaging technique.
- Iterative approach used to absorb all systematic error sources in the calibration matrix
- Number of iteration steps is 2



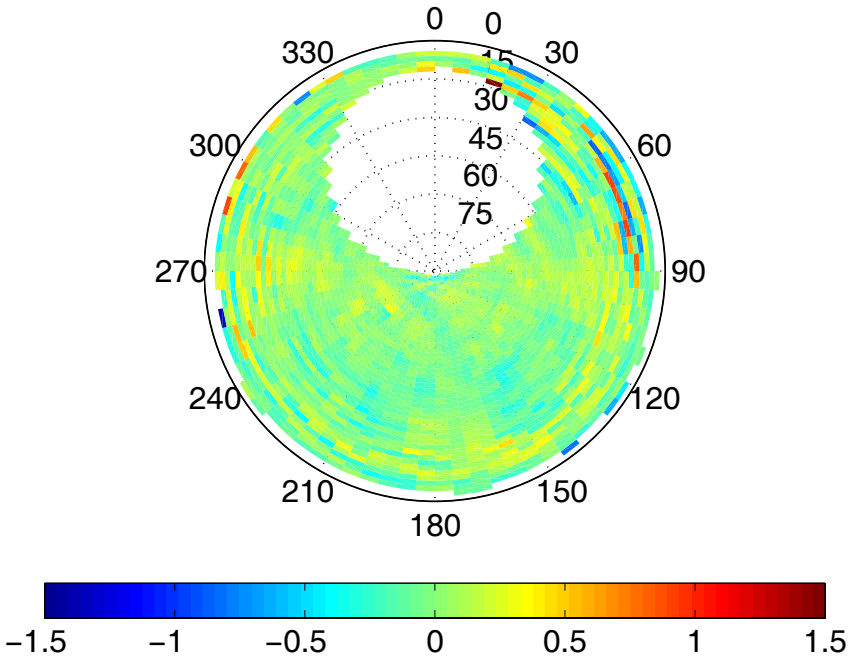
Example of residual pattern improvement due to iteration for the station Mårtsbo

The PPP post-fit phase residuals includes not only site dependent effects but all non modelled error sources

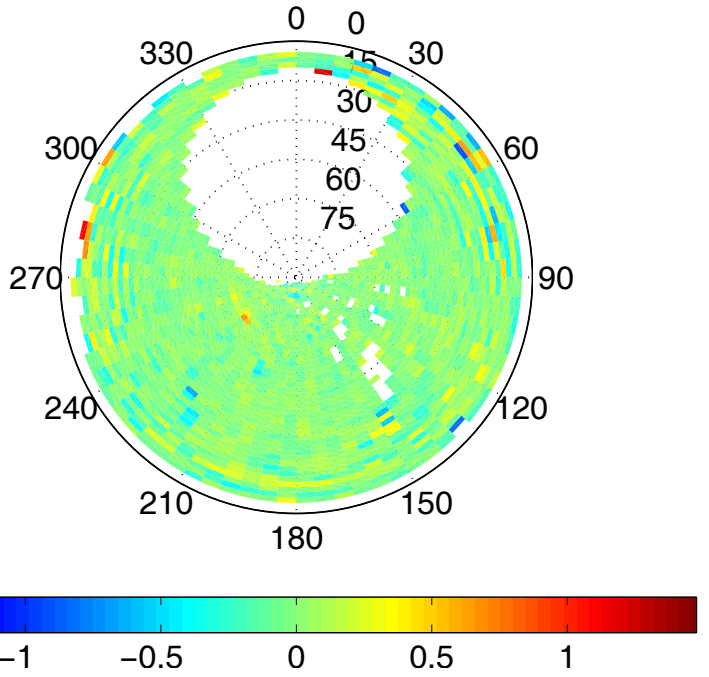
Statistical Station Calibration Results

Averaged PPP residuals for the Onsala station with and without calibration implemented

Uncalibrated based on 6 years data



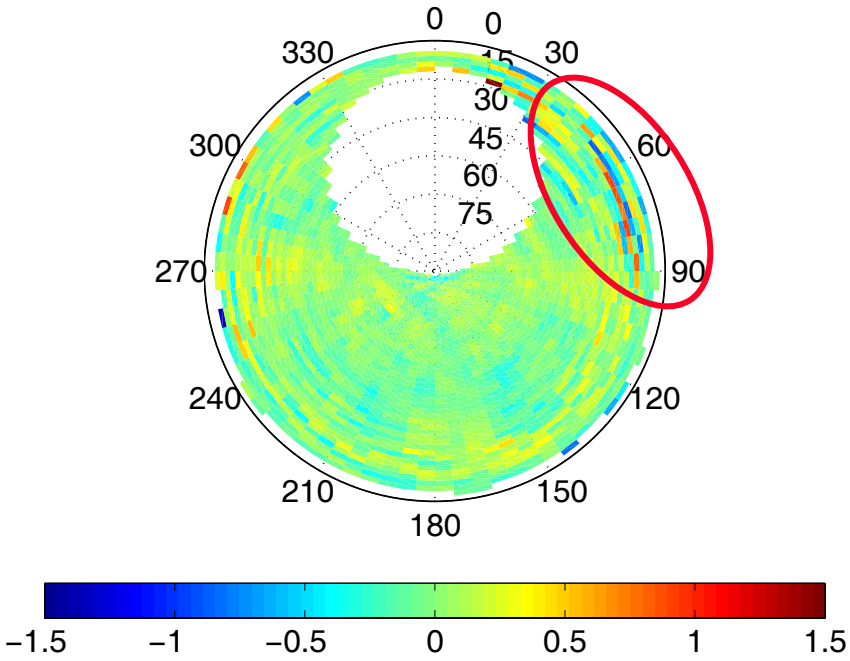
Calibrated based on 1 year data



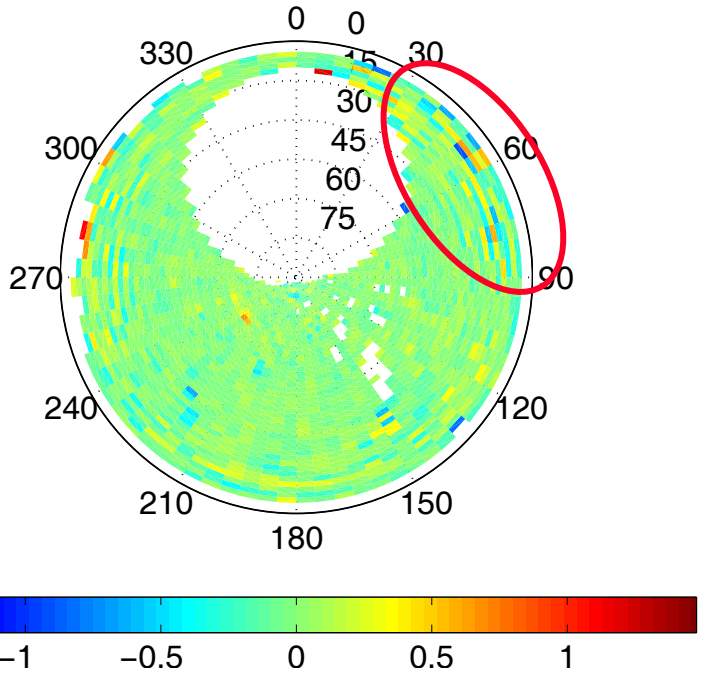
Statistical Station Calibration Results

Averaged PPP residuals for the Onsala station with and without calibration implemented

Uncalibrated based on 6 years data



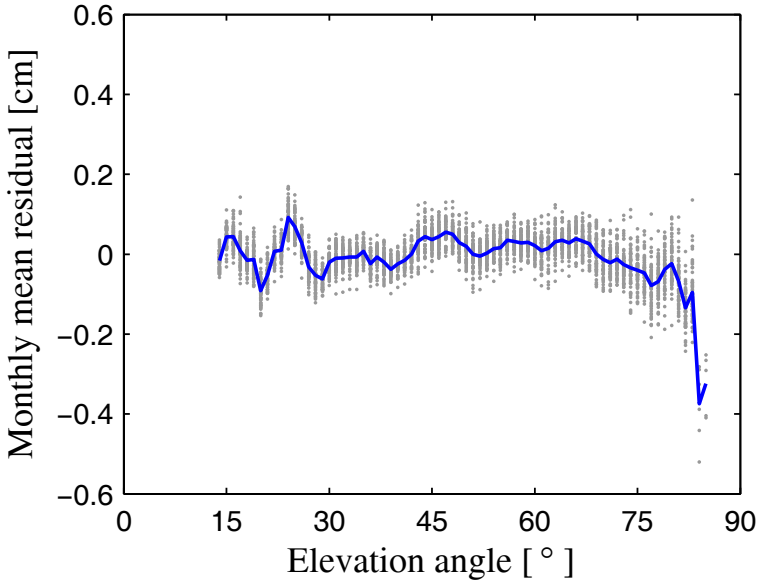
Calibrated based on 1 year data



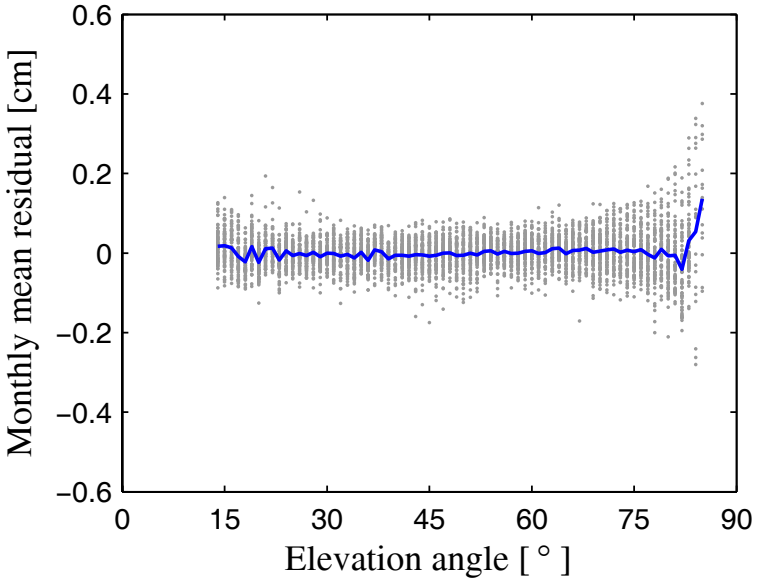
Statistical Station Calibration Results

Averaged PPP residuals over 6 years of data
for the Onsala station with and without calibration implemented
Elevation cut-off angle is 15 degrees

Uncalibrated



Statistical calibrated

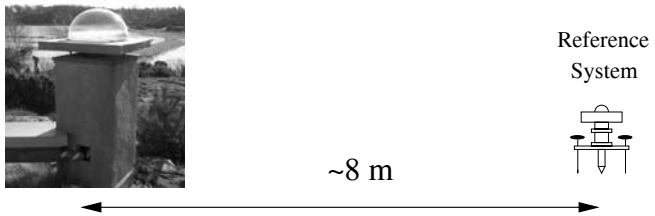


The residual pattern is straight for the calibrated case

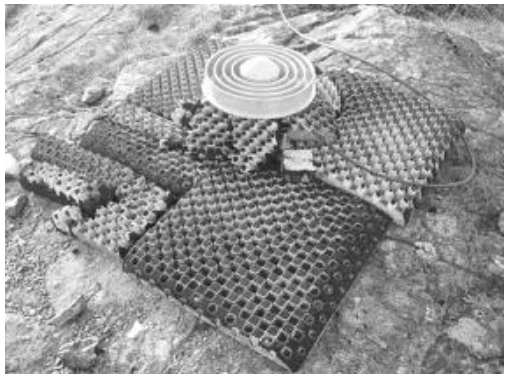
In-Situ Station Calibration

a relative calibration method

- Based on simultaneous acquired observations from the antenna to be calibrated and the assumed perfect reference antenna.
- The reference antenna was placed a few meters from the Onsala station and surrounded by microwave absorbing material.
- The field campaign was performed in March 2006.
- Only a few days of observation was used to produce the calibration matrix due to unpredicted snowfall and snow covered ground.



Reference antenna of type Dorn Margolin type T, together with used levelling device.

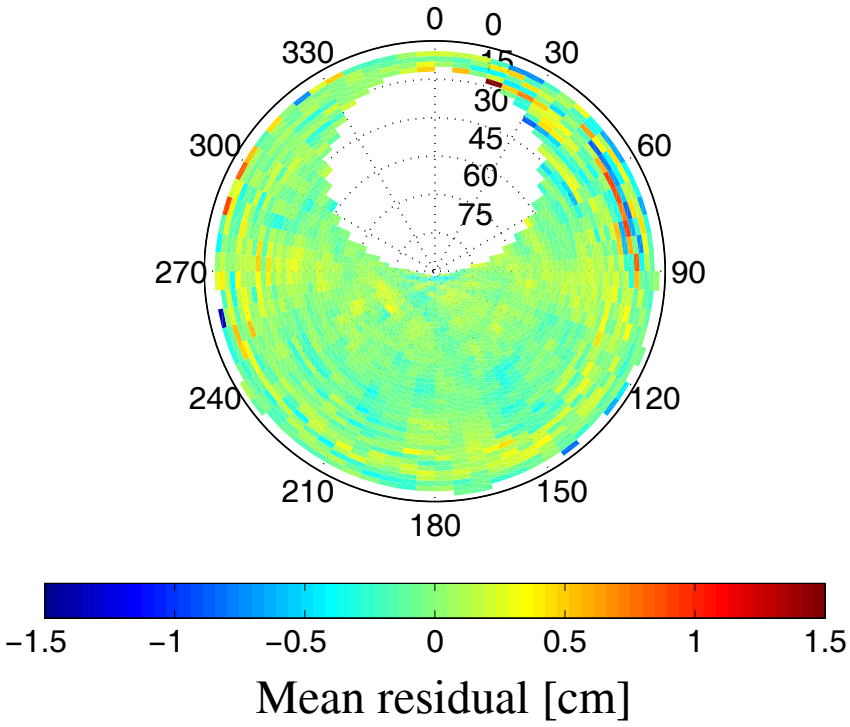


Reference antenna imbedded in ECCOSORB

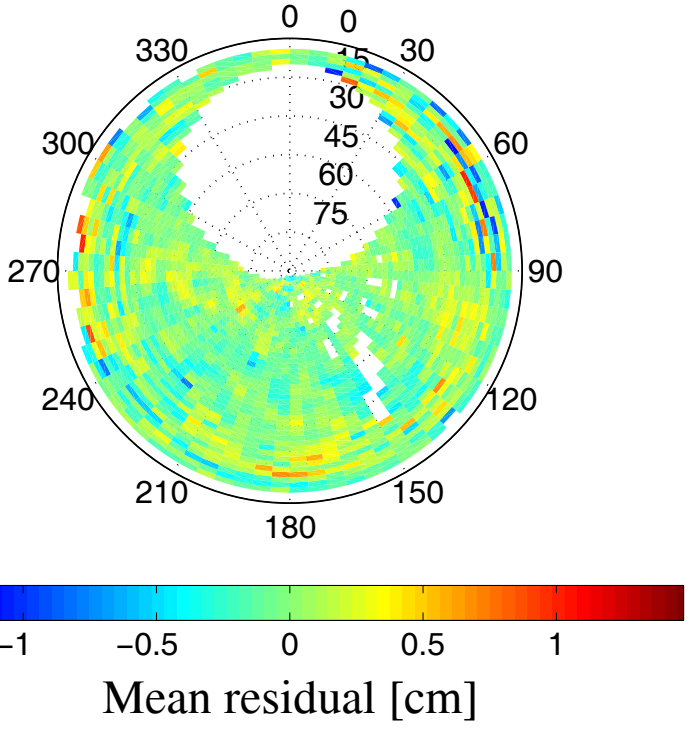
In-Situ Station Calibration Results

Averaged PPP residuals for the Onsala station with and without calibration implemented

Uncalibrated based on 6 years data



Calibrated based on 1 year data



Conclusions

Site-Dependent Effects in SWEPOS

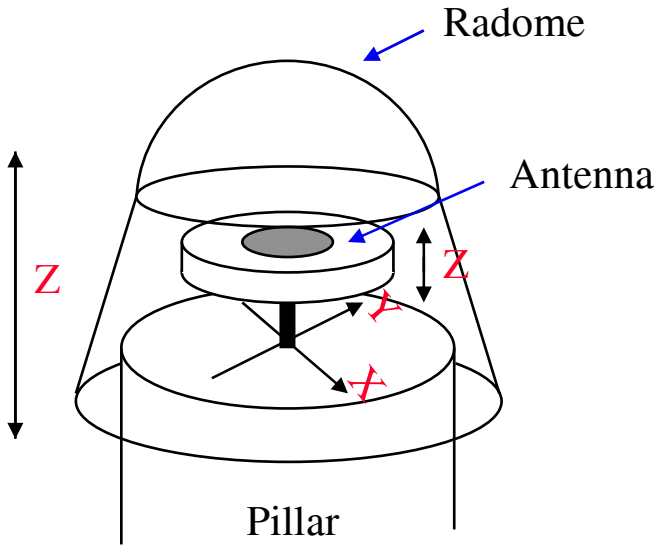
- Stations with similar design and equipment suffers from similar elevation dependent effects
- Surfaces and objects in the near-field of the station could cause disturbances in the post-fit phase residuals correlated to its distance to the antenna.
- The additional unique features in the residual patterns for each station is related to its local environment.
- Guidelines is to avoid reflecting surfaces close to the antenna and keep vegetation below the horizon mask.

GNSS station calibration

- Mitigation of site dependent effects is important in order to achieve higher accuracy in positioning. (but also for the estimation of the water vapour content in the atmosphere)
- Two calibration methods were tested and both were found to suppress site effects. However the methods are not directly comparable since they correct for different error sources.
- The reference antenna in the in-situ calibration needs to be well isolated from site-dependent error sources.

The New Calibration Station at Onsala

- Construction during fall 2005 at Onsala
- Antenna movable in X, Y and Z inside radome
- Radome movable in Z direction
- Eccosorb may be added



Investigation of effects from misalignment of antenna, radome and pillar

Preliminary results (1 month) show "SWEPOS-like" residual pattern