GPS time series and sea level

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Abstract. Time series of IGS, EUREF and FinnRef GPS networks show in most cases periodicity both in station coordinates and inter-station distances. In regional networks also a secular trend of the scale can be seen, and the rate depends on how the sites are selected. Sea and atmospheric loading are contributing in the GPS error budget when determining vertical motions.

Our goal is to study the accuracy in determining the temporal variation of the sea surface using the combined information of GPS and tide gauges. Our work will contribute to the IGS TIGA project (GPS Tide Gauge Benchmark Monitoring Project).

Periodicity in GPS Time Series

We use Finnish permanent GPS network for geodynamics studies (i.e. postglacial rebound). The time series resulting from our weekly GPS solutions show periodic variation, which was noticed for almost all baseline components of the FinnRef® network. These results have been reported in Poutanen *et al.,* (2002). In a picture is shown the height component of the baseline METS-SODA and it's Lomb periodogram showing obvious periodical behavior.

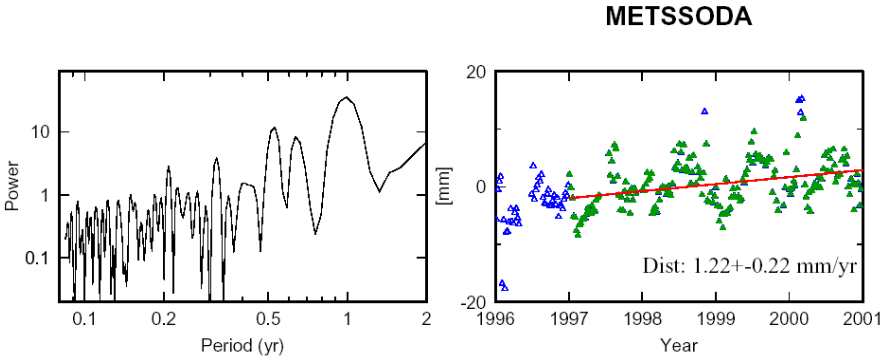

Fig. 1. Annual variation of Metsähovi-Sodankylä distance shown in FinnRef® network time series and its Lomb periodogram.

Scale Variation

We solved for the 7-parameter Helmert transformations between the weekly solutions of the FinnRef® coordinates. The scale factors show an annual variation and a secular increase of 1.4 ppb/year on scale. The amplitude of the annual period is 4 ppb, it corresponds 4 mm change at a 1000 km long baseline, i.e. the length of Finland.

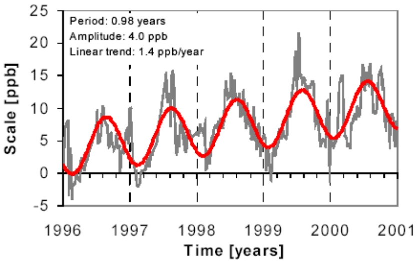

Fig. 2. Scale variation of the FinnRef® network.

The FinnRef® annual scale variation is in the same phase as the variation of the DORIS positioning system in Metsähovi observatory (Mangiarotti *et al*. 2000). The IGS GPS time series show the same effect, both in radial component and inter-station distances (Fig. 3). The scale in the IGS network is quite constant globally (topmost panel). However, in the Fennoscandian area (middle panel), there is a secular change of the same magnitude, as is seen in FinnRef® data, too. Six North European stations show much smaller trend (bottom). This supports our interpretation that the postglacial rebound is the reason for the secular change. One should be aware of this when IGS or other time series are used in interpretation of secular trends.

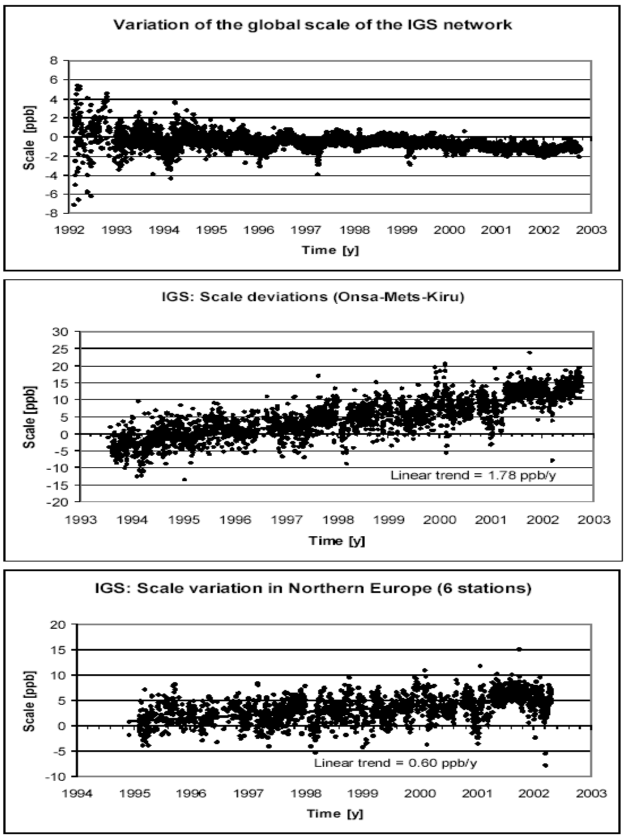

Fig. 3. Variation of scale of the IGS network. The scale depends on the region selected; topmost panel – global; middle panel – Fennoscandian only; lowermost panel – North Europe.

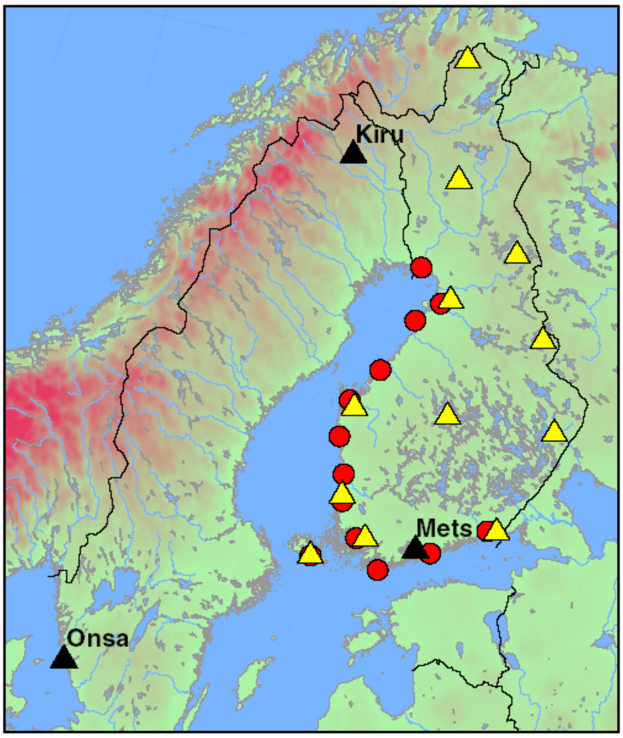

Fig. 4. Study area. Permanent GPS stations of the FinnRef® are shown with yellow triangles, Finnish tide gauges with red circles, and mentioned IGS stations with black triangles.

Local Disturbances

Some of the seasonal effects can be local effects, specific on that particular station only. An example of the local seasonal variation is shown in upper figure, where the height of the Sodankylä station is changed 20-40 mm during the winter time. This was soon addressed to the accumulation of snow ontop of the antenna radome. The details are discussed e.g. in Johansson *et al.* (2002), Poutanen *et al.,* (2002) and Mäkinen *et al.* (2003).

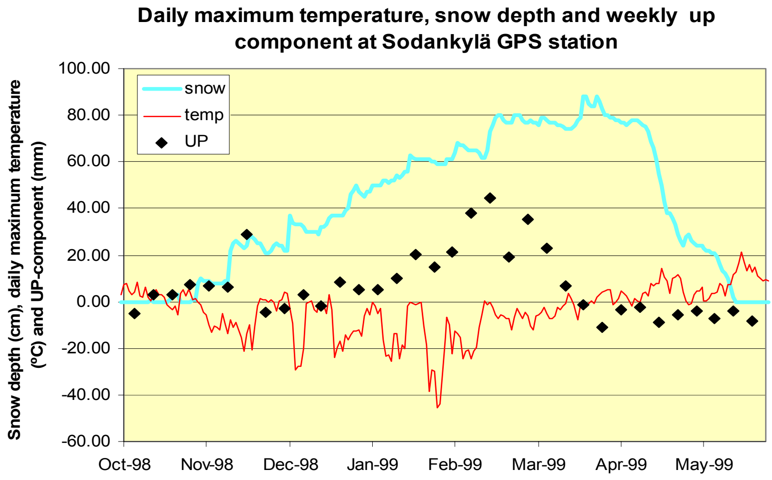

Fig. 5. Seasonal variation due to the snow accumulation.

GPS Time Series, Loading and Sea Level

The air pressure variation in Metsähovi [hPa] during one year (top), and the sea level variation at the Helsinki tide gauge, about 30 km from the station (middle). The loading computed from this data (bottom, red) and the vertical component of the IGS GPS solution (bottom, green) show high correlation in general trends.

In connection with the data reduction of the Metsähovi superconducting gravimeter GWR T020, we have calculated the atmospheric loading from HIRLAM (High Resolution Limited Area Model) air pressure data and sea loading from tide gauge data. Loading calculations of the Baltic Sea show that 1 m of uniform layer of water corresponds 31 nm s^{-2} in gravity and 10 mm in height. (Poutanen *et al.,* (2004).

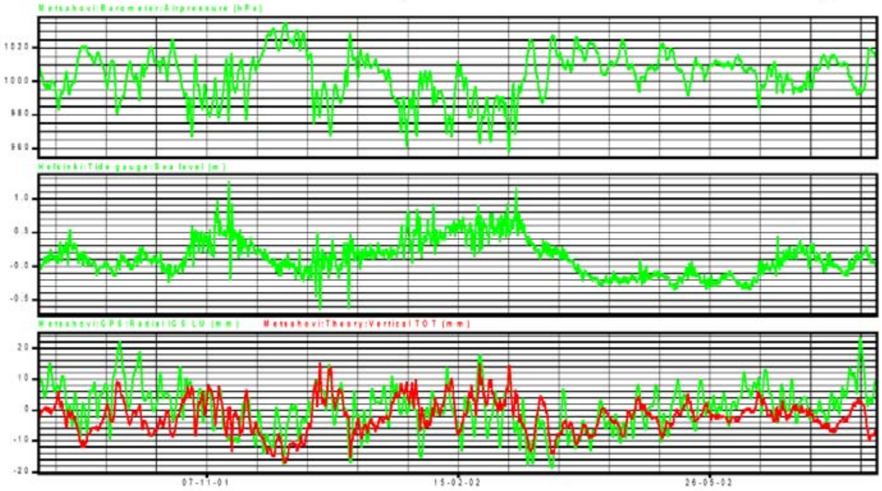

Fig. 6. Air pressure variation (top) in Metsähovi and sea level variation (middle) at Helsinki tide gauge. Loading at Metsähovi (bottom, red) and the GPS vertical component (green).

Ongoing GPS/Sea Level Project

We have an ongoing project where we analyze both tide gauge data and long GPS time series from the GPS stations in vicinity of tide gauges. Our goals are to be able to monitor the absolute sea level change in well-defined reference frame (ITRF). On the other hand we may monitor the stability of the tide gauge itself. Figure shows the results from the test where we changed the height of the antenna and tried monitor changes with GPS. Distance to the control station was 10 km. The results show that we are able to see changes of several millimeters only.

We have a plan to continue analysis in the following areas most of which contribute to TIGA:

- GPS time series analysis, including effect of troposphere, snow and other environmental disturbances on accuracy of solution. This will improve the quality of time series, especially in that part of the network where snow accumulation will degrade the data quality in wintertime.
- Combining GPS and superconducting gravimeter data set. In Metsähovi we have tested analysis of gravity data together with tide gauge and GPS data. Both atmospheric loading and sea loading can be seen in gravity data. Separation of various effects requires data of different instruments.
- Analysis of postglacial rebound and sea level variability from GPS, tide gauge, levelling, satellite altimetry and gravity data.

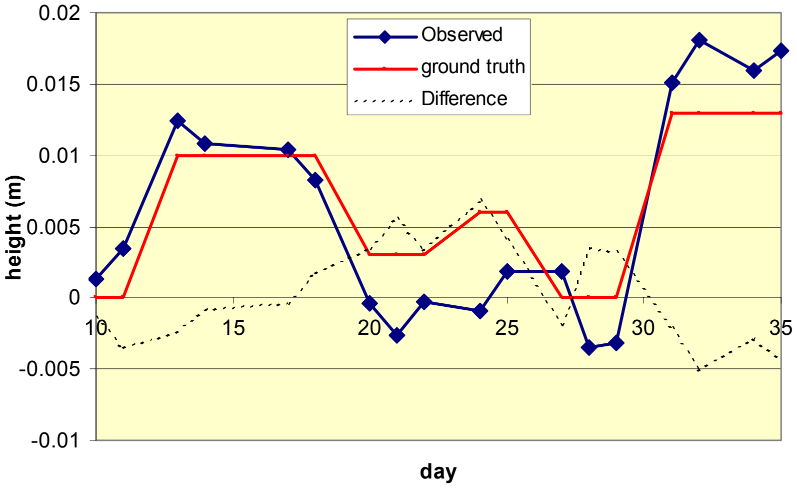

Fig. 7. Change of height in test baseline.

Conclusion

Monitoring stability of tide gauges or detecting temporal variation of sea level with GPS is degraded by several effects. We have discussed some of them, showing also the magnitude of the effect. The goal is to improve the resolution and reliability of GPS time series.

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