BIFROST Project: Observing the postglacial rebound in Fennoscandia using continuous GPS

Hans-Georg Scherneck *

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Abstract. This short paper reports of loading effects considered in the continuous GPS project BIFROST (Baseline Inferences from Fennoscandian Rebound Observations, Sealevel and Tectonics). Effects due to ocean, atmosphere and hydrology are considered. We regularly find admittance of the modelled effects at less than fifty pecent of the full effect. We thinks that the finding relates to a difficult noise situation at all periods, and that a satisfying model for the dominating noise source has not been found yet. An additional reason for low admittance is found in the mapping process of the nonfiducial network solution into a conventional reference frame.

1 Introduction

The BIFROST project was created in 1993 to measure postglacial isostatic adjustment in Fennoscandia with continuous GPS in all three spatial dimensions. The project aims at inference of absolute sea level change by combination of the vertical rates with tide gauge derived relative sea level rates. The project also expects to reveal horizntal motion, and possible perturbation due to other sources of stress, generally covered under the term of neotectonics or intraplate tectonics.

Several publications are available or under way, BIFROST project (1996), Scherneck et al. (1998), Milne et al. (2000), Scherneck et al. (2001), Johansson et al. (2002), and Scherneck et al. (2002), that center on the measurement and its interpretation in terms of models for deglaciation history, earth isostatic adjustment response, and the sea level problem. In the present, short communication the following problem is considered.

The standard BIFROST model for motion of a station consists of a constant rate and of biases that are introduced when antenna configuration or receiving conditions have been changed; these signals are conceived as embedded in Gauss-Markov noise. In the standard solution we also reduce the time series for loading effects due to air pressure and fit sinusoidal harmonics with annual and sub-annual signatures, as these effects are both straight-forward to model and discernable visually in the resulting time series. At various degrees of sophistication several stations have obtained extended site motion models. For instance, near the Baltic Sea coast, loading due to the varying water level of the sea is considered. Using an Empirical Orthogonal Function (EOF) approach, we also consider a stochastic portion of motion to be more or less in common at all stations in an area. The 3D-rates determined with the EOF-method where possible (elsewhere a solution that includes automated outlier editing using a criterion of five standard deviations is used) is shown in Fig. 1.

2 Loading effects

Recently, global hydrological data was used by van Dam et al. (2001) to predict loading induced displacements of the earth surface. Since loading effects in the frequency domain covered by the project can be considered as quasi-static we consider only one, in-phase admittance coefficient for each of the perturbing effects. Now, the atmospheric load and the hydrological load compete at annual frequencies, while the atmospheric load—quite uniquely—has substantial variations also on a weekly scale. In this range of periods we think that, besides barometrically and tidally incurred displacement, only atmospheric perturbations of signal propagation and multipath would affect the GPS derived positions.

* Chalmers University of Technology
Onsala Space Observatory
SE-439 92 Onsala
mailto:hgs@oso.chalmers.se

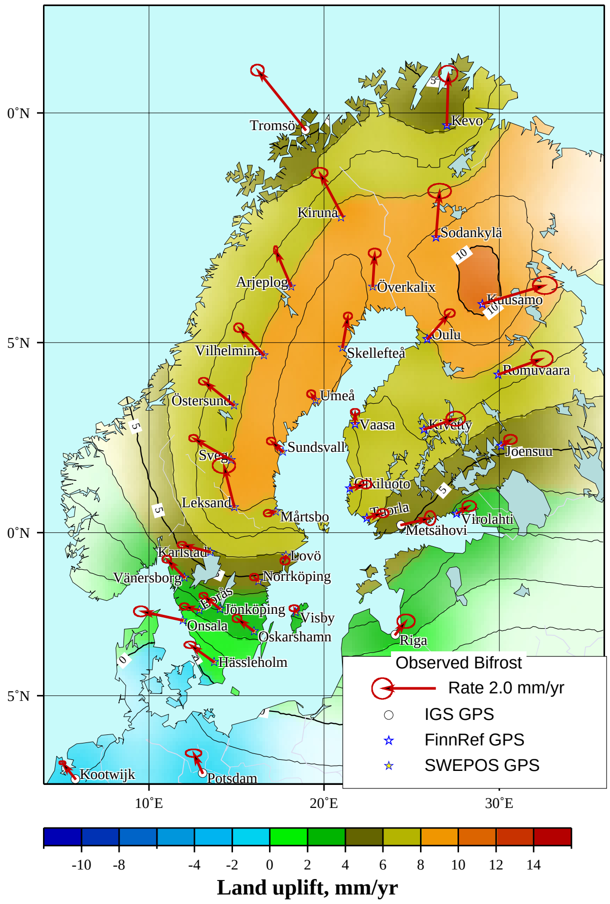

Figure 1: Three-dimensional rates, vertical plotted as colours, horizontal as arrows with error ellipse (one standard deviation). The vertical standard deviation is tyically 0.25 to 0.35 mm/yr in Sweden; the somewhat shorter obervation time span in Finland causes error limits near 0.5 mm/yr.

A typical result for atmospheric loading that we have found before hydrological loading was considered ranges between 0.2 and 0.35 for the ratio between the the observed and the predicted effect. Using hydrological loading predictions according to van Dam et al. (2001), we also find quite typically admittance coefficients below unity (cf. Table 1). As an alternative we have used soil moisture data from climatic stations operated by the Swedish Metorological and Hydrological Institute (SMHI). For these time series typically very low admittance is found. In each case we explain the deficiency as follows in the discussion.

3 Discussion

The loading signals are spatially coherent over large distances. The GPS network solution uses a seven-parameter transform in order to map the daily position solutions into a conventional, International Terrestrial Reference Frame (ITRF). At the stage of mapping the loading model has not been applied (except for global tide and ocean tide loading). The mapping is a time-consuming task with a space-consuming product. At the same time the mapping attenuates the local displacements slightly because of its being over-determined. A clue supporting this notion comes from the observation that the barometric loading admittance that is found at the sites that control the mapping is regularly very low (cf. Fig. 2, especially METS, Metsähovi).

Now, if both effects are realistically modelled and the data is affected by both of these effects and else only contains uncorrolated perturbations, the admittance coefficients for both effects should become larger. The observation that we tend to conclude, however, is that long-period loading due to hydrology is admitted by trading off the more wide-band barometric loading. This is the more surprising as spatial coherence of atmospheric variations is expected to be more narrow, and thus each station would move in more unique patterns, while hydrological loading would generate signals that are in common over wider distances.

Table 1: GPS vertical position variations, admittance coefficients for predicited hydrological loading effects according to van Dam et al. (2001).

Site	Coeff.	Std.dev.	comment
ARJE	.974	.098	
JONK	.408	.133	
KIRU	.005	.092	LOW
MART	.304	.120	
OSKA	-.234	.215	CONTRA
OVER	.664	.107	
SUND	.565	.114	
SVEG	.723	.089	
UMEA	1.016	.101	
VANE	.577	.157	
VILH	.909	.088	

The low admittance in the SMHI soil moisture case is probably because the data variation is dominated by the snow. The effect of snow on the electrical characteristic of the antennas is an uplift of the phase centre, opposite to the loading effect and an order of magnitude greater. The correlation of snow on an antenna and snow on the ground at a station several 10's of kilometer apart does not correlate perfectly either. In the snow-free parts of the year, the loading effect might prevail.

Visby (VISB) on the island of Gotland presents an interesting case in Figure 2. When the loading is combined from air pressure and sea level, giving approximately a sea bottom pressure, the remaining air pressure loading effect is found at insignificant amplitude. The effect to be admitted is supposed to consist of the pressure acting on the island only, which is nexpected to cause only little additional deformation.

4 Conclusions

Loaidng effects of different kinds, air pressure, sea level and hydrology, appear to be resolvable in BIFROST GPS data. In all cases the admittance coefficients found are small on the average, smaller than the modelled deformation. The situation for hydrology is especially complicated since the effect of snow on the GPS antennas is twofold, depression due to loading of the crust, and an uplift due to electrical effects.

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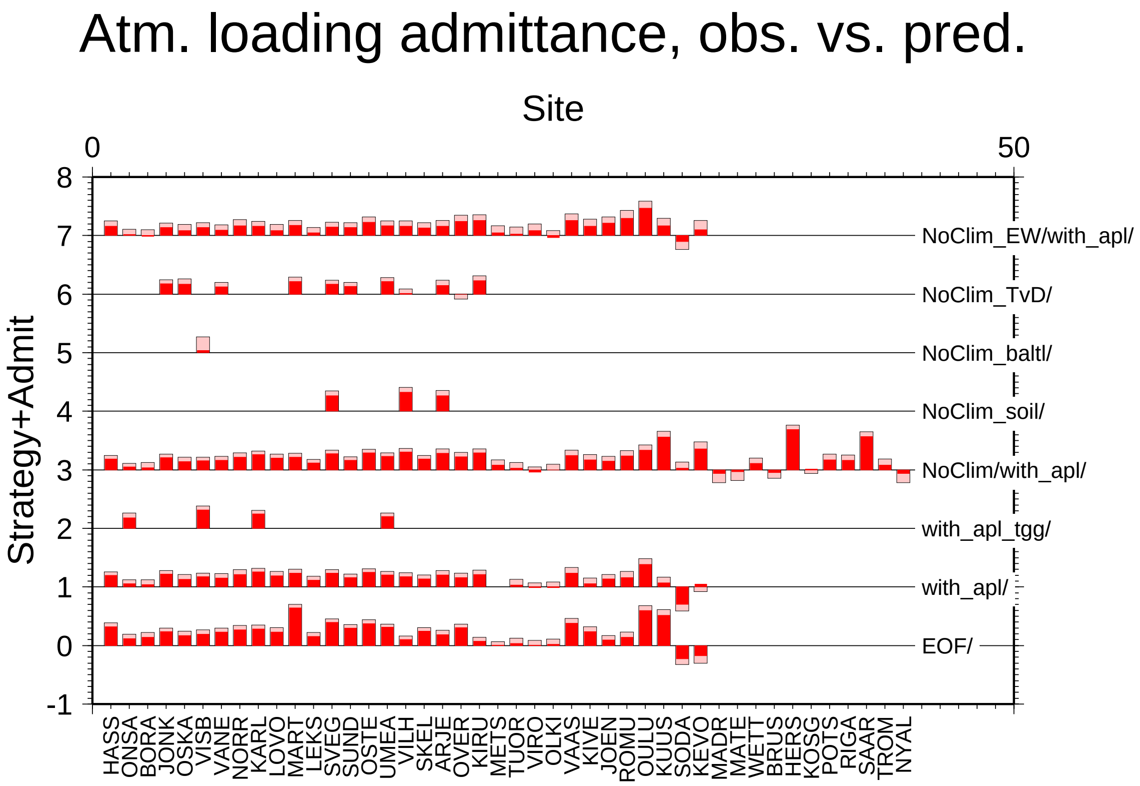

Figure 2: Air pressure loading, admittance coefficients found for each station in a range of processing variants. The different processing options, linear regression of different kinds of environmental parameters, are denoted as follows: NoClim - No seasonal cycles estimated (default is that they are); with_apl - biases and rates; _tgg - with tide gauge; _baltl - with combined air pressure and sea level; _soil - with SMHI soil moisture; _TvD - with hydrology according to van Dam et al. (2001); _EW - data during winter months are suppressed. The admittance coefficient is represented by the vertical dark-red bar. The standard deviation is indicated by the height of the light-coloured cap.

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