Environmental Signals in GPS data: Crustal Loading due to Lake Water and Mountain Snow

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Two Global Positioning System (GPS) sites of the Basin and Range Geodetic network (BARGEN) are located ~30 km south of Great Salt Lake (GSL).
Lake-level records since mid-1996 indicate seasonal water elevation variations of ~0.3 m amplitude superimposed on a roughly "decadal" feature of amplitude ~0.6 m. Using an elastic Green's function and a simplified load geometry for GSL, we calculate that these variations translate into radial crustal loading signals of +-0.5 mm (seasonal) and +-1 mm (decadal).
The horizontal loading signals are a factor of ~2 smaller. Despite the small size of the expected loading signals, we conclude that we can observe them using GPS time series for the coordinates of these two sites. The observed amplitudes of the variations agree with the predicted decadal variations to <0.5 mm [Elosegui et al., 2003].

The crustal loading signature represents an error in the interpretation of the velocity in terms of tectonic processes. Currently, the leading contributions to the estimated velocity are <0.1 mm/yr for all components.
Velocity estimates with shorter time spans would have resulted in significant errors. For example, the vertical velocity error for the first ~4 years since BARGEN become operational was 0.7-0.9 mm/yr. The horizontal velocity error during that same time period was 0.2 mm/yr.

Unlike decadal variations, the observed and predicted annual variations disagree to >0.5mm. This difference may be caused by some combination of local precipitation-induced site motion, unmodeled loading from other nearby sources such as snow or global such as hydrology and atmospheric pressure, errors in the simplified GSL model, and atmospheric errors. We calculate three-dimensional loading signals due to seasonal snow depth variations in the BARGEN region using a gridded snow depth field of 0.5 degrees latitude by 0.5 degrees longitude resolution and sampled once daily. The largest radial displacement since the beginning of operations of BARGEN amounts to only ~0.3 mm. Horizontal displacements are a factor of ~3 smaller. There are some indications that snow depth field models, constructed using measurements from surface meteorological stations, may represent a lower bound on actual snow mass near mountain ranges in this region. Predicted snow-induced seasonal displacements at BARGEN sites may thus be underestimated. Accurate estimates of environmental effects will need to be incorporated into GPS data processing for precise geophysical applications.

References:

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Measurement of crustal loading using GPS near Great Salt Lake, Utah,
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