Vertical motion observed with GPS:

What can we learn about regional geophysical signals, Earth structure, and rheology?

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Introduction

Tectonic studies entail observations of surface displacements from GPS are based predominantly on observations of horizontal displacements, while vertical displacements mostly provide constraints for loading-related geophysical processes. A main reason for this disjoint use of GPS observations is that tectonic signals often are larger in the horizontal component while loading signals dominantly are contained in the vertical component. Moreover, the horizontal components of GPS-determined displacements have a precision about three times that of the vertical component.

Considering the growing number of PBO stations with records potentially long enough to determine reliable secular trends, it is worthwhile to ask the question to what extent vertical displacement time series can be used to constrain tectonic processes, Earth structure, and rheology. In order to answer this question, we study the anatomy of time series of vertical displacements determined from regional and local GPS networks in North America and derive the spatio-temporal pattern of vertical crustal motion as so far by these networks.

The Data

We use the vertical motion observations for North American stations from the publicly available archives at UNAVCO, SORPAC, and CORS as well as our own MAGNET archive (Figure 1). The focus of our studies is the Southwest part of the U.S., and three station distribution is almost (Figure 1).

All the GPS data were homogeneously processed with the GPS/VASSIS II (GPS/V) software package of A Propulsion Laboratory (JPL) using the Precise Point Positioning (PPP) method (Zumberge et al., 1997) to determine daily coordinates, with ambiguity resolution applied across the entire network by an automatic solution of the ionospheric- plus tropospheric-wind-field method (Blum, 1995). Satellite orbit and clock parameters were provided by IERS. Ionosphere-free combinations of carrier phase and pseudorange were processed every 5 minutes. To account for atmospheric effects that can bias the inference of the antenna phase center height we solve simultaneously for station height, satellite delay and atmospheric delay gradient parameters. We processed the data with a satellite elevation cutoff angle of 15° in order to minimize the effects of atmospheric refraction and multipath. Compared to lower cutoff elevations, this results, on the one hand, in less data used and, hence, more uncertainty in individual data positions, and, on the other hand, in lower bias of station coordinates as associated with atmospheric refraction of the GPS signal, which is a product for satellites at low elevation. Ambiguity resolution was carried out on the complete North American network.

All time series were determined in ITRF2000. Time series of daily station displacements are computed with respect to the coordinate system at epoch 2000.1. No spatial filtering has been applied to reduce noise or to homogenize time series. These time series were then used to determine vertical rates taking into account annual and semi-annual harmonic constituents. For time series analysis, the time window from 2000/02/01 to 2006/10/31 was used in order to avoid effects due to the transitions of ITRF, from ITRF2000 to ITRF2005.

Figure 2: Time series of vertical displacements. Left: two diagrams. Stations distributed from 30° to 60° N. Right: two diagrams. Stations in the Basin and Range Province. In each panel, the time series of vertical displacements are shown in the left diagram, while the right diagram shows for each station the difference to the time series at the bottom. The offset around Nov. 5, 2006 is due to the transition of ITRF to ITRF2005.

Secular Trends.

Generally, at interannual periods, the GPS time series of vertical displacements show significant nonlinear components potentially contaminating the derived secular velocity field (see Figure 2). Determining reliable secular trends for time series with variations at interannual to decadal and longer time scales requires time series longer than those scales. This is well known from studies of climatological and oceanographic time series, where often 20 to 50 years are considered the minimum record length for trend estimation. However, in the case of climate and oceanography, the signals are mainly due to the Earth system processes, which can be modeled to a large extent. For vertical GPS time series, a significant portion may come from the observation system and data analysis, thus complicating the situation considerably. Nevertheless, the spatial pattern of the vertical secular velocity field displays patterns potentially related to geophysical processes, including tectonics (Figure 6). In particular, the Basin and Range Province shows mainly significant uplift, which is contrary to the expectation of an extensional basin driven by intertropical potential energy.

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References


Figure 3: Spectrum of selected time series. Stations are from top left to bottom right: YELL, WHIT, CHUR, STRA, NAU, FRED, PEI, APEX.