Test of a Center of Lateral Figure (CL) Reference Frame for a Global GPS Network

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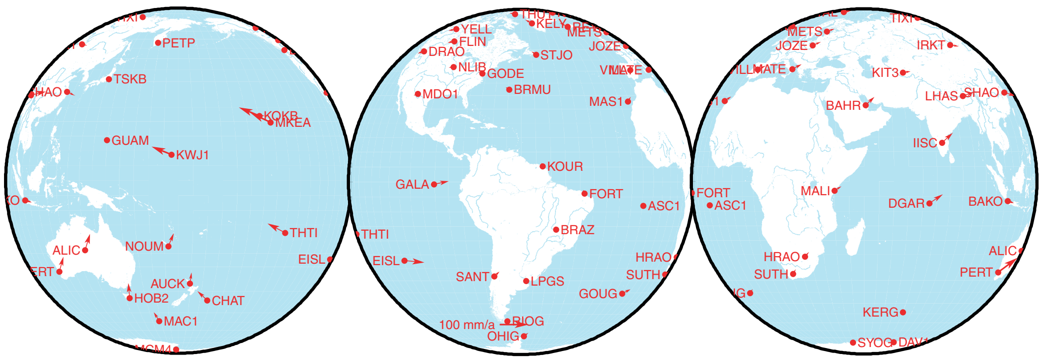
Seasonal degree-one deformation related to loading effects are a source of significant misfit between observed site coordinates and assumed positions that are based on a linear center of surface figure (CF) reference frame. This discrepancy is partly absorbed by apparent annual variations in the GPS "scale" parameter which, in turn, spreads annual deformation artifacts to sites elsewhere on the Earth's surface. In the presence of degree-one deformation, a suitable reference frame model should allow for non-linear site motion. The Center of Lateral Figure (CL) reference frame is one possible solution. With the CL model, station motions are constrained to move with constant horizontal velocities, and the vertical velocities are unconstrained. This confines degree-one deformation to the unconstrained vertical component. A CL reference frame model is demonstrated here using the results of a GIPSY/OASIS II fiducial-free analysis of over 700 globally distributed GPS sites. The reference frame model utilizes only the horizontal component of site positions and a GPS "scale" parameter is not included.

GPS Analysis and Reference Frame



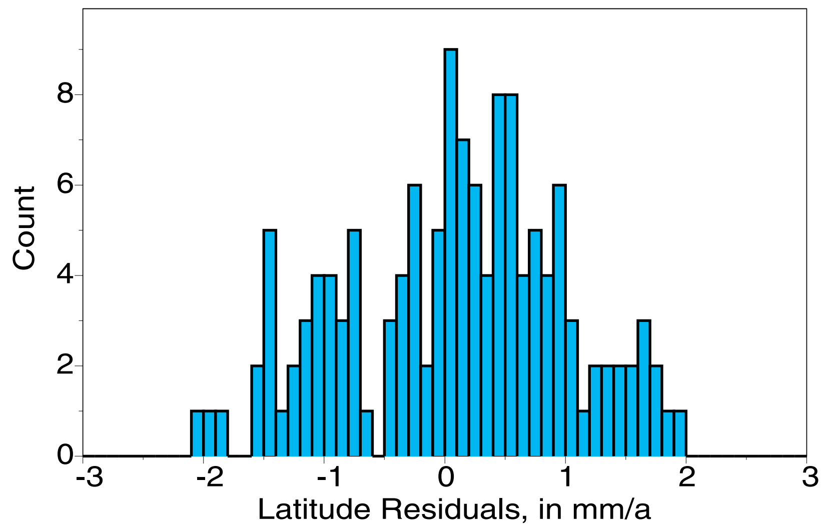
Approximately 800 GPS stations were analysed using GIPSY OASIS II software with JPL fiducial-free orbits and clocks. Ambiguity resolution was applied to the point-positioned daily solutions in 70 subnetworks and the network solutions were then combined to produce daily GPS positions in a common fiducial-free coordinate system. 58 sites shown in the figure above were selected for the reference frame. A Center of Lateral Figure (CL) reference frame model was chosen so that annual vertical motion due to degree-1 deformation would be confined to the vertical component. Briefly, only horizontal observations were utilized in determining the transformation parameters and the "scale" parameter was ignored. Otherwise, three translation and three rotation parameters were determined that best fit the daily observed horizontal positions with the linear reference frame velocity model. The bottom line is that vertical motion is "free" to move and does not enter into (or distort) the realization of the reference frame.

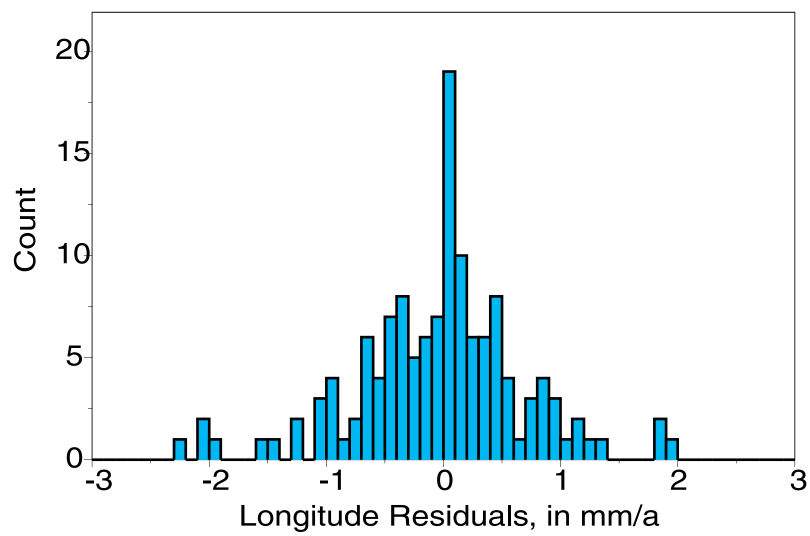
No further adjustments were done beyond the realization of the global CL reference frame. In other words, no local stabilization procdures were used. Here, we step directly to an analysis of the vertical signal for GPS sites on North America and determine a "stable" set of GPS sites on North America.

Velocities in a Global CL Reference Frame Plotted Relative to Stable North America

The 133 sites that were used to define North America motion are shown in RED. Other sites are shown in GREY. Velocities shown are from a global analysis that has been transformed into a Center of Lateral Figure (CL) reference frame using a globally-distributed set of reference sites. Motion of North America as a whole is estimated from velocites of 133 reference sites (shown in red). Velocites shown here are residuals after removal of modeled North America plate motion.

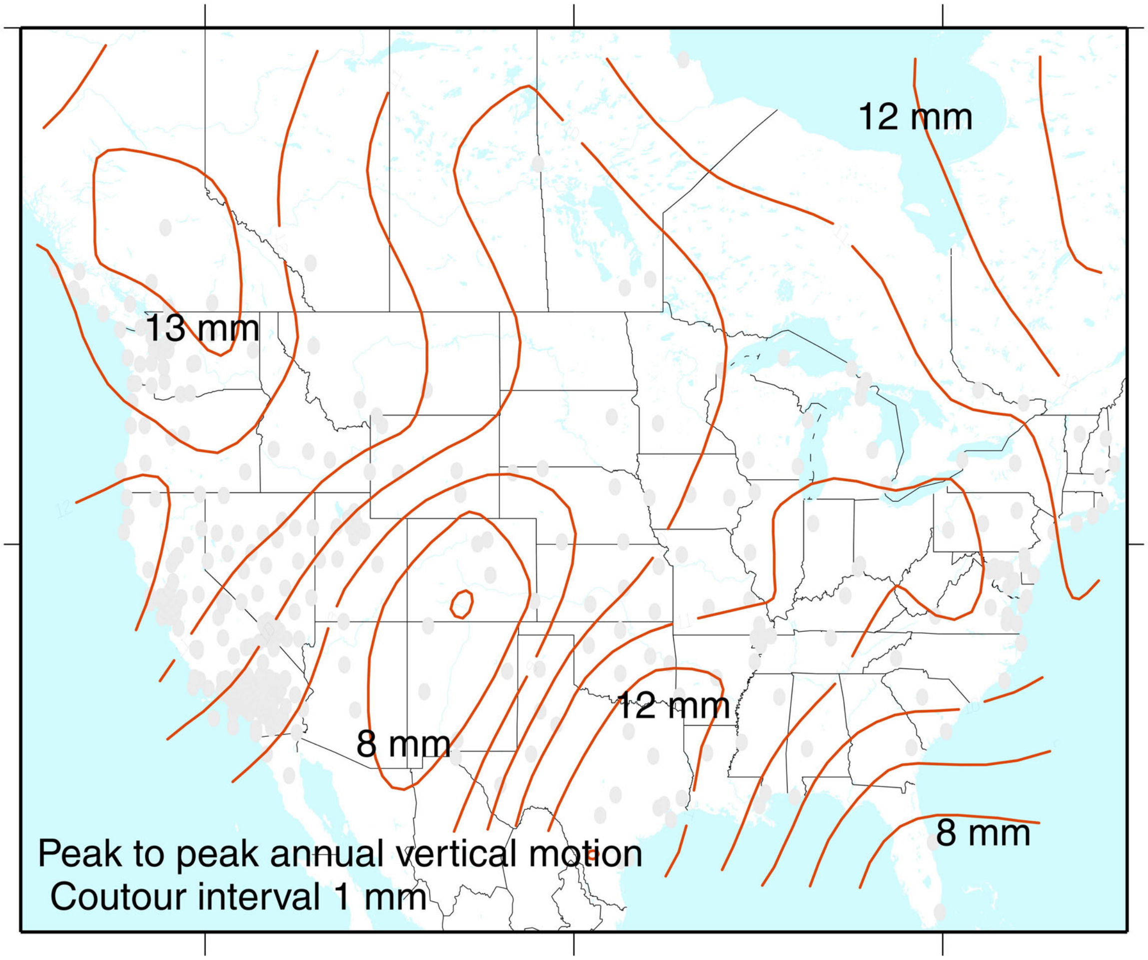
Residual Velocities at Sites Used to Define North America Motion





A total of 133 GPS sites within North America were selected to define plate motion of the "stable" portion of the continent. The primary criteria were 1) more than 2 years of observations and 2) motion in agreement (within 2 mm/year) with the model velocity. An iterative approach was used in selecting stations and solving NA motion. If we assume that the standard deviation of the residuals (0.7 mm/a longitude, 0.9 mm/a latitude) reflects the actual precision of GPS velocity measurements on a continental scale, then the 1-sigma uncertainties in the NA pole of rotation estimates are approximately ±1 degree latitude, ±0.3 degree longitude, and ±0.002 in angular rate.

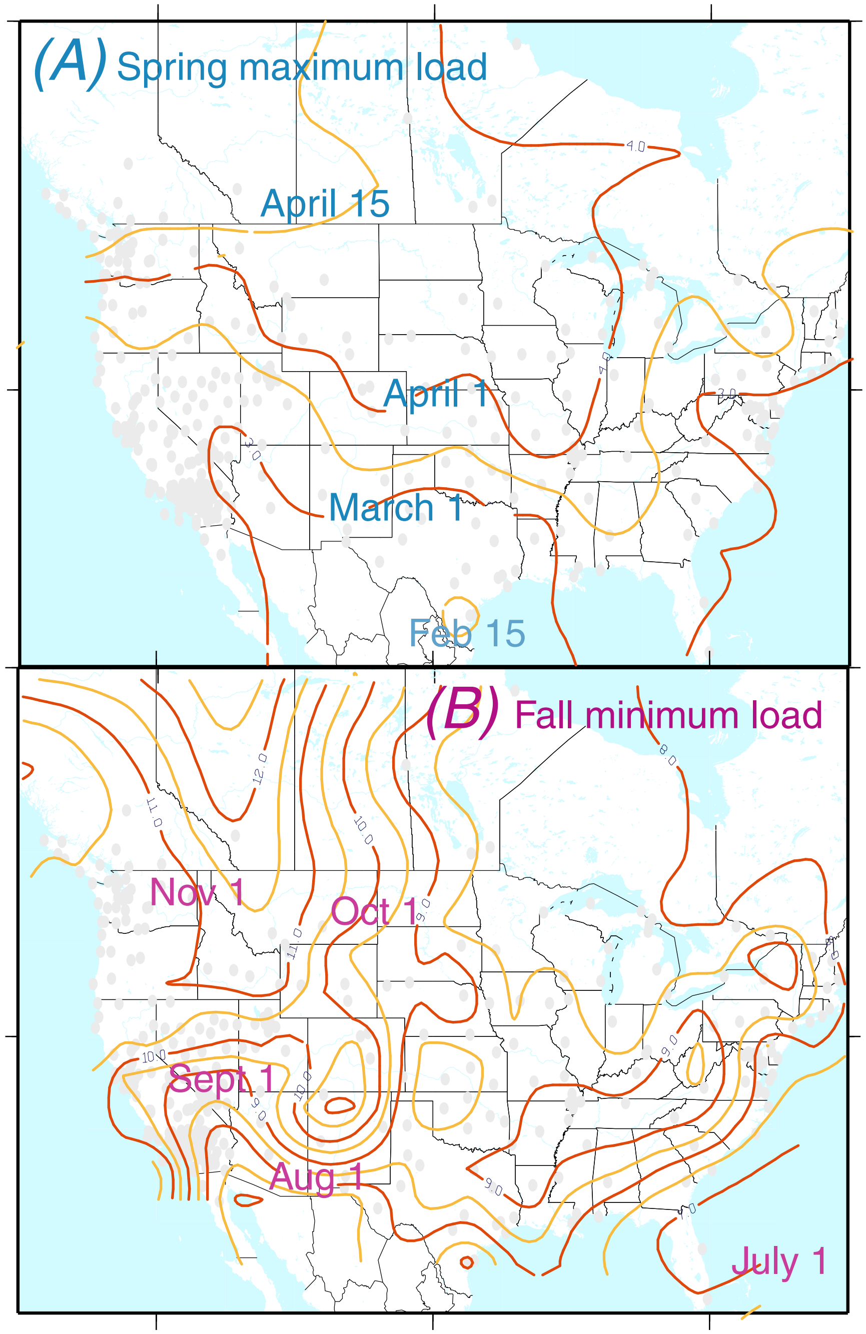
Seasonal Variation in Vertical Component
Amplitude of Annual Displacement



Peak to peak amplitudes of annual vertical motion in North America ranges from 4 mm to about 20 mm. Larger amplitudes are found in the Pacific Northwest and eastern Texas. Smaller ranges of vertical motion are found in the Southwest, MIdwest, and Florida. Values are derived from a global GPS solution transformed into a CL (center of lateral figure) reference frame. A CL frame (without use of a scale parameter) is utilized, which confines annual degree-1 deformation to the vertical component.

Seasonal Variation in Vertical Component

Date of annual maximum and minimum



Maximum downward displacements (top panel) in North America occur during spring months. In general, maximums in the south are earlier than the north by about 6 weeks. Upward displacements peak between early August and December (bottom panel), with sites located in the Northwest delayed relative to the south by about nine weeks. Values derived from global solution in CL reference frame.

Velocities in a Global CL Reference Frame Relative to Stable NA Defined by 133 Sites