The CORS network and improved understanding of "Stable North America"

G. F. Sella, R. Snay, M. Cline, and D. Haw

National Geodetic Survey, NOAA, 1315 East-West Highway, Silver Spring, MD 20910, giovanni.sella@noaa.gov

G21B-0499

Abstract

The National Geodetic Survey in 1994 created the Continuously Operating Reference Station (CORS) network as a partnership with site operators of continuously operating GPS (CGPS) sites who were willing to share their data with the public. The network currently contains ~1,200 stations located mostly in the United States and is growing at ~ 200 stations a year. In North America most tectonic studies of deformation using GPS have concentrated on the active plate boundary of the western US and have related observed motions to the stable eastern part of the plate. Initially limited attention was paid to the robustness of the definition of the stable part of the plate as it was assumed to have little to no motion. As the resolution of GPS analysis has improved increasing attention is now focused on understanding the stable part of the plate. This new focus has made extensive use of CORS data as it contains most of the available CGPS data east of the Rocky Mountains. Perhaps the most dramatic conclusion of these studies has been that glacial isostatic adjustment is the largest motion affecting the stable part of the North American plate. Quantifying the extent and magnitude of this motion is critical to ensure that it does not bias interpretations at the millimeter to sub-millimeter. For NGS the need to improve both the accuracy and access to the National Spatial Reference System (NSRS) and its continued move to dominantly space geodetic techniques these studies are important. NGS is significantly improving the CORS infrastructure in collaboration with its partners desire for millimeter level accuracy and the rapid expansion of CGPS stations to support real-time networks. Although the legal binding reference frame for North America is the non-geocentric NAD83 the Plate Boundary Observatory's Stable North American Reference Frame (SNARF) provides a key step in its eventual replacement/update.

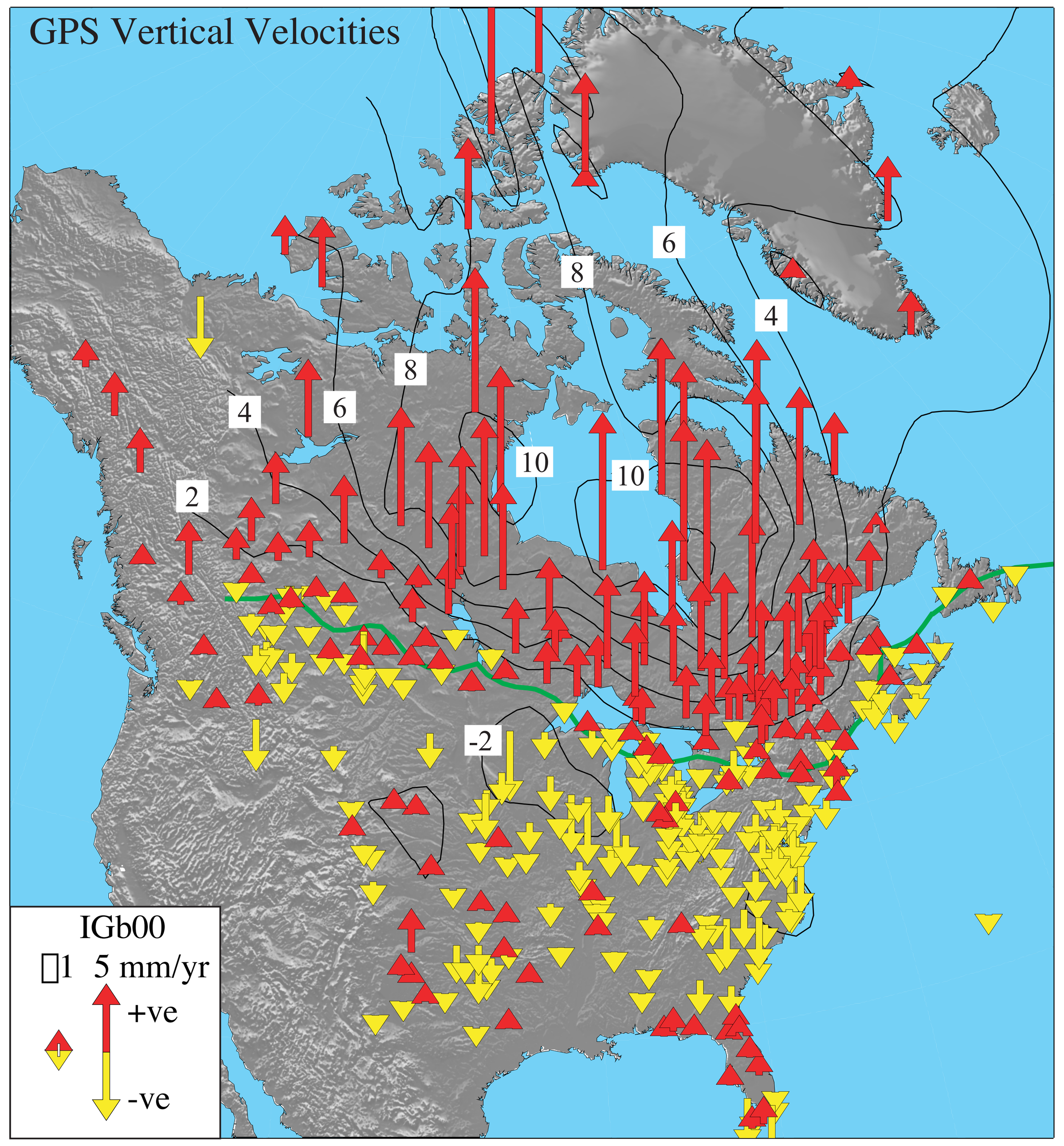
CORS Network Evolution

In the late 1980's NGS helped form the core of the Cooperative International GPS Network (CIGNET). CIGNET, which had been augmented by other international partners, formed the initial IGS Network in 1991 and NGS founded in 1994 NGS the Continuously Operating Reference Station (CORS) Network focused in the United States. This network established partnerships with operators of continuously operating GPS sites (CGPS) who agreed to share their data with NGS. NGS took the shared data and distributed it via a single server and computed official coordinates consistent with the National Spatial Reference System (NSRS). Participating operators include, federal, state and local agencies, university groups and private companies and a small number of stations in foreign countries also participate.

In 2001 two additions were made to the CORS program: 1) User Friendly CORS (UFCORS) an interactive web based utility that allowed a user to customize her/his data requests; 2) the Online User Positioning Service (OPUS) that permitted users to submit their own GPS data to NGS for processing via the web from anywhere in the US and receive back via e-mail a coordinate in both ITRF and NAD83. Their rapid adoption/success, especially of OPUS (in 2007 submissions averaged 20,000/month), revolutionized the use of CORS.

Currently the CORS network contains approximately 1,200 stations and a further 300 are anticipated to be included by early next year. The increased participation in CORS is being driven, largely, by the need for CGPS to support real-time applications. Site operators are keen to have their stations included in CORS to ensure that the coordinates they provide to real-time users are consistent with the NSRS.

Despite the fact that many of the CORS sites were not built to meet the most rigorous standards of the geophysical community they have used CORS sites extensively to better understand crustal deformation across the United States. Since the network is most dense in the eastern United States it has been used to define the stable part of the North American plate. Beginning in the mid 90's researchers began using CORS data to quantify the rigidity of North America and this has evolved into trying to quantify the amount and extent of the glacial isostatic adjustment (GIA) caused by the ice loading during the last glaciation.



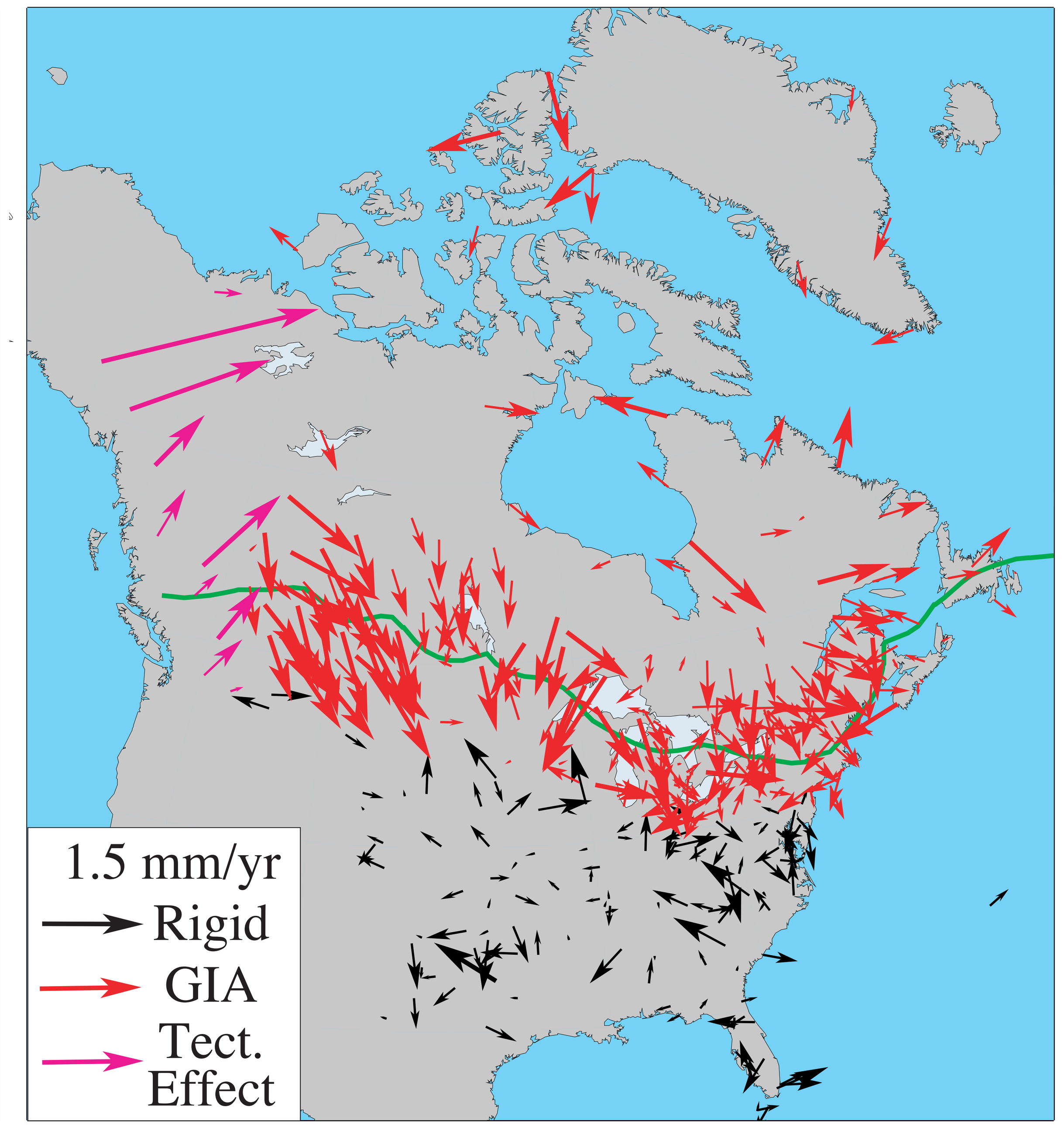


Figure 1. Left: Vertical GPS site motions with respect to IGb00. Green line shows interpolated "hinge line" separating uplift from subsidence. Right: Horizontal motion site residuals after subtracting best fit rigid plate rotation model defined by sites shown with black arrows. Red vectors represent sites primarily affected by GIA. Purple vectors represent sites that include tectonic effects.

Recent Analysis of CORS and Canadian Base Network (CBN) data

Processing Strategy:

Sella et al., [2007] (Geophysical Research Letters 34, L02306, doi:10.1029/2006GL027081) used GIPSY/OASIS II, Release 5.0 software developed at the Jet Propulsion Laboratory. Offset parameters were estimated at the date of each change of antenna height or model or dome model. Daily position estimates were generated with loose constraints, and then transformed to IGb00. Velocity estimates were based on a weighted least squares line fit to the daily position estimates, including the offset parameters described above. The velocity error estimates account for white (uncorrelated) and colored (time-correlated) noise and random walk noise following Mao et al. [1999]. They exploited the correlation between WRMS (the weighted root mean square scatter of the daily position estimates about a best fit straight line) and white and flicker noise amplitudes observed in the data of Mao et al. [1999], as outlined in Dixon et al. [2000].

Data interpretation:

A cubic spline was fit to the IGb00 vertical velocities, and the regional zero velocity line (hinge line) (Fig. 1 Left) was identified. They interpreted that sites north and within ~ 200 km south of this line may be significantly affected by glacial isostatic adjustment (GIA - sites with red arrows). The remaining site velocity data were inverted to derive best-fit angular velocity for the plate, minimizing the weighted, least squares misfit to the data, as described by Ward [1990]. Applying their error model to their data set of 124 rigid site velocities yielded a χ^2 per degree of freedom (χ_v^2) of 1.0 for the rigid plate model, close to the expected value of 1.0. This suggests that their error model was reasonable and that the region sampled by these data can be assumed rigid within data uncertainty. If they included the 115 CGPS sites that may be significantly affected by GIA, 239 site solution, gives a larger $\chi_v^2 = 1.5$ suggesting that the plate can no longer be assumed to be rigid.

Observed GPS Velocities

The vertical velocities (Fig. 1 left) show fast rebound (~10mm/yr) near Hudson Bay, the site of thickest ice at the last glacial maximum, which changes to slower subsidence (1-2 mm/yr) south of the Great Lakes). This pattern is illustrated by the "hinge line" separating uplift from subsidence, which is consistent with water level gauges along the Great Lakes. In addition two lobes of fast uplift rate east and northwest of Hudson Bay appear to correspond with two lobes of maximum ice thickness proposed in ICE-5G [Peltier, 1998].

The horizontal velocities are more scattered but show motions directed outward from Hudson Bay and secondary ice maxima in western Canada (Fig. 1 right). In addition, the motions show a pattern of south-southeast directed flow in southwestern Canada. Some of the horizontal scatter is presumably a combination of local site effects and intraplate tectonic signal, but the pattern in the far field (beyond the GIA) is not clear.

Conclusions

Observed GPS velocities reflect unambiguously that the largest signal across stable North America is that caused by GIA although some GPS residual velocities still contain a small amount of non-GIA related motion that is local and/or regional in origin.

Table 1: Comparison of angular velocity for North America:

Lat	Lon	Omega deg/My	Source	No. of sites	Frame
-5.67 N	-84.75 E	0.196	Sella et al., 2007	124	IGb00
-7.37 N	-84.36 E	0.188	SNARF 1.0		IGb00
-2.7 N	-84.6 E	0.202	Calais et al., 2006	119	ITRF00
-5.04 N	-83.14 E	0.194	Altamimi et al., 2002		ITRF00
-2.39 N	-79.08 E	0.199	Sella et al. 2002	68	ITRF97
1.4 N	-83.8 E	0.183	Dixon et al, 1999	4	ITRF94

CORS Network Changes and Future

2006:

Required a set of specific guidelines for all new CORS stations.
www.ngs.noaa.gov/CORS_Establish_Operate_CORS.html

In particular all building monumented sites had to be masonry buildings

All antennas had to be attached to monument with a force centering device. Many/most CORS stations prior to 2006 were simply spun to refusal on a threaded rod. This created two problems antenna not oriented so the phase center correction was incorrectly applied and height changes often occurred when antennas were replaced. For example 2 small <3.5" diameter force centering devices have been developed recently that work well for small non-choke ring antennas. For choke ring antennas the SCIGN force centering device remains common.

www.surveying.com
(P/N 2072)

McRoberts Machine Shop
303-776-2397 (Ask for Judy)

All site operators must provide a suite of pictures of their equipment and monumentation so a visual description of the site exists. Additional verbal description of the site is included in the site logs

2007:

Review of all metadata associated with all CORS, log files standerdized and revised based on missing or incomplete data. Still not fully finished.

If any users are aware of missing information or of undocumented offsets please e-mail NGS we may be able to identify information

2008:

Complete check of all data holdings and reconciliation with off line storage

Complete metadata reconciliations

Reanalyze all CORS data holdings since 1994 in conjunction with IGS orbit reanalysis. New processing will be done with NGS developed double difference software PAGES that over the last two years has undergone major revisions to comply with all current IERS convention recommended processing modules. The CORS network solution will include ambiguity resolution.

All solutions will be submitted to NRCAN for a NAREF combination

2009:

Complete reanalysis of all CORS data and publish new coordinates and velocities for all sites

Update NAD83 CORS epoch

Consider and implement changes to NAD83 definition

CORS network at 3000 stations?