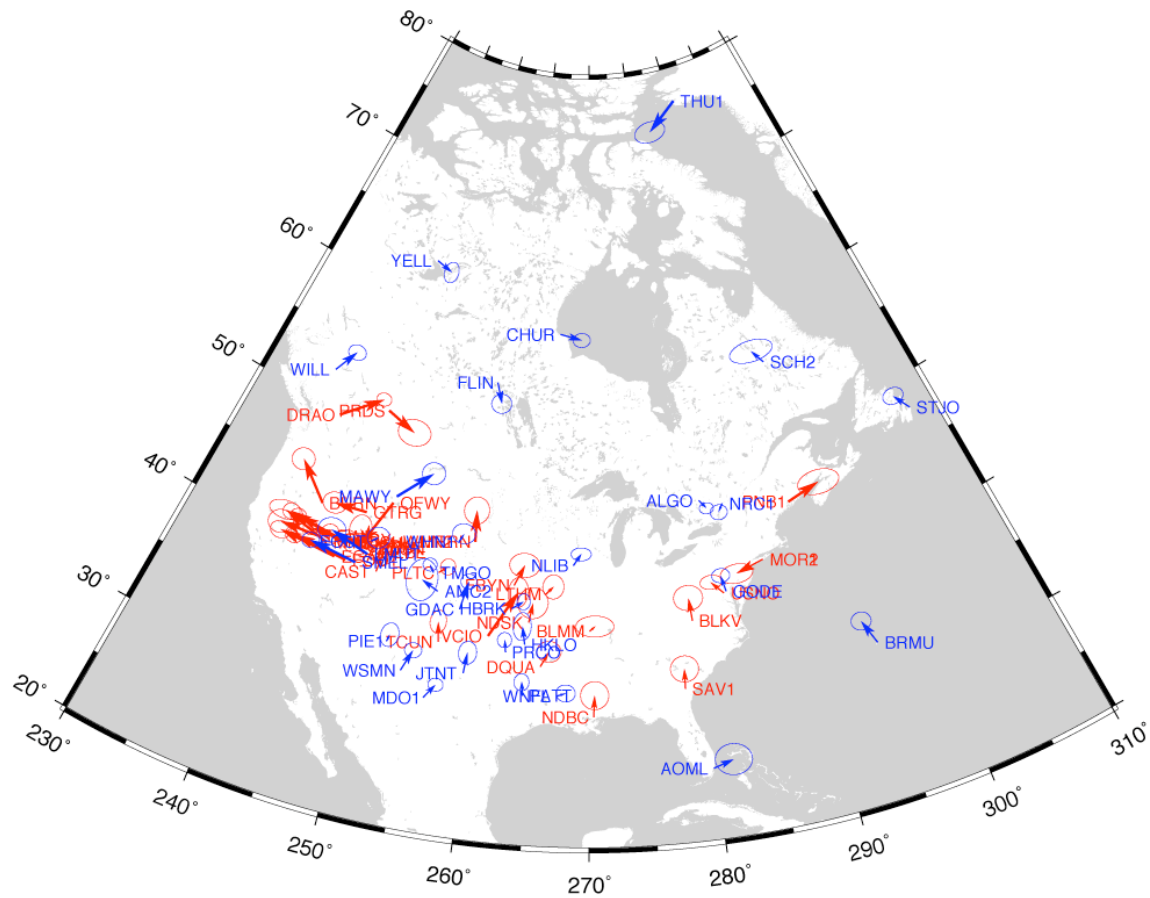
Brief Report on SNARF Activities:
Horizontal GIA Velocities and Reference-Frame Determination

J. L. Davis and M. E. Tamisiea
Harvard-Smithsonian Center for Astrophysics

Tom Herring
Massachusetts Institute of Technology

In this report, we lay present some preliminary results and conclusions from our work on glacial isostatic adjustment (GIA) and reference-frame determination. In particular, we investigated how the process of North American reference-frame determination is influenced by GIA, and the extent to which NA-relative velocities can be interpreted as GIA.

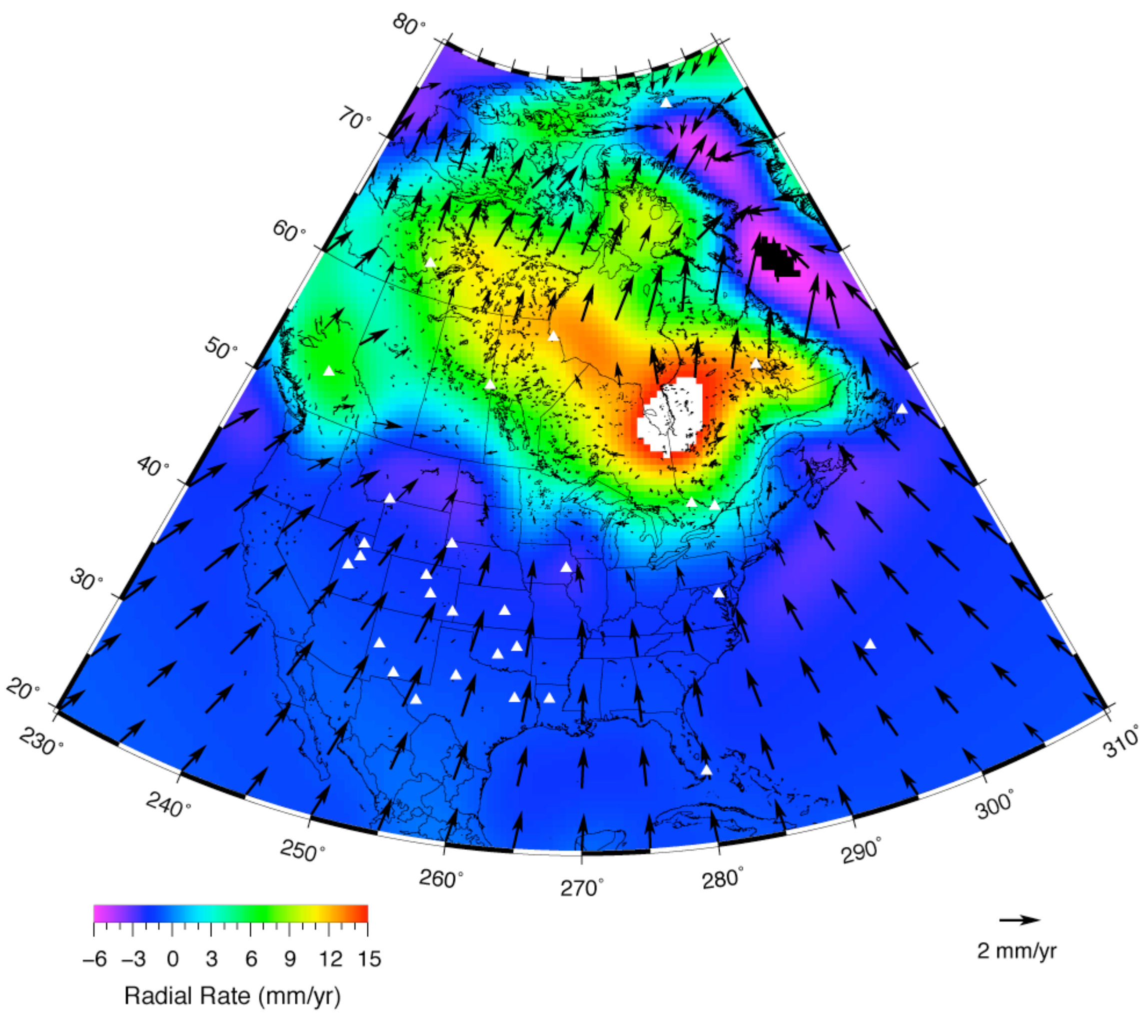
GPS Solution snarf_96_0204_gia.vel (σ < 0.5 mm/yr; v < 3 mm/yr)



Our data consisted of a subset of the solution snarf_96_0204_gia.vel produced by Tom Herring using GLOBK. (This solution used SIO h-files.) This solution is shown above. In plotting, we limited velocities to those less than 3 mm/yr and those with horizontal uncertainties of less than 0.5 mm/yr. Sites used by Herring to establish the North American reference frame (NARF) are shown in blue. No velocity scale is shown on the previous figure, but it is the same as those for the figures that follow.

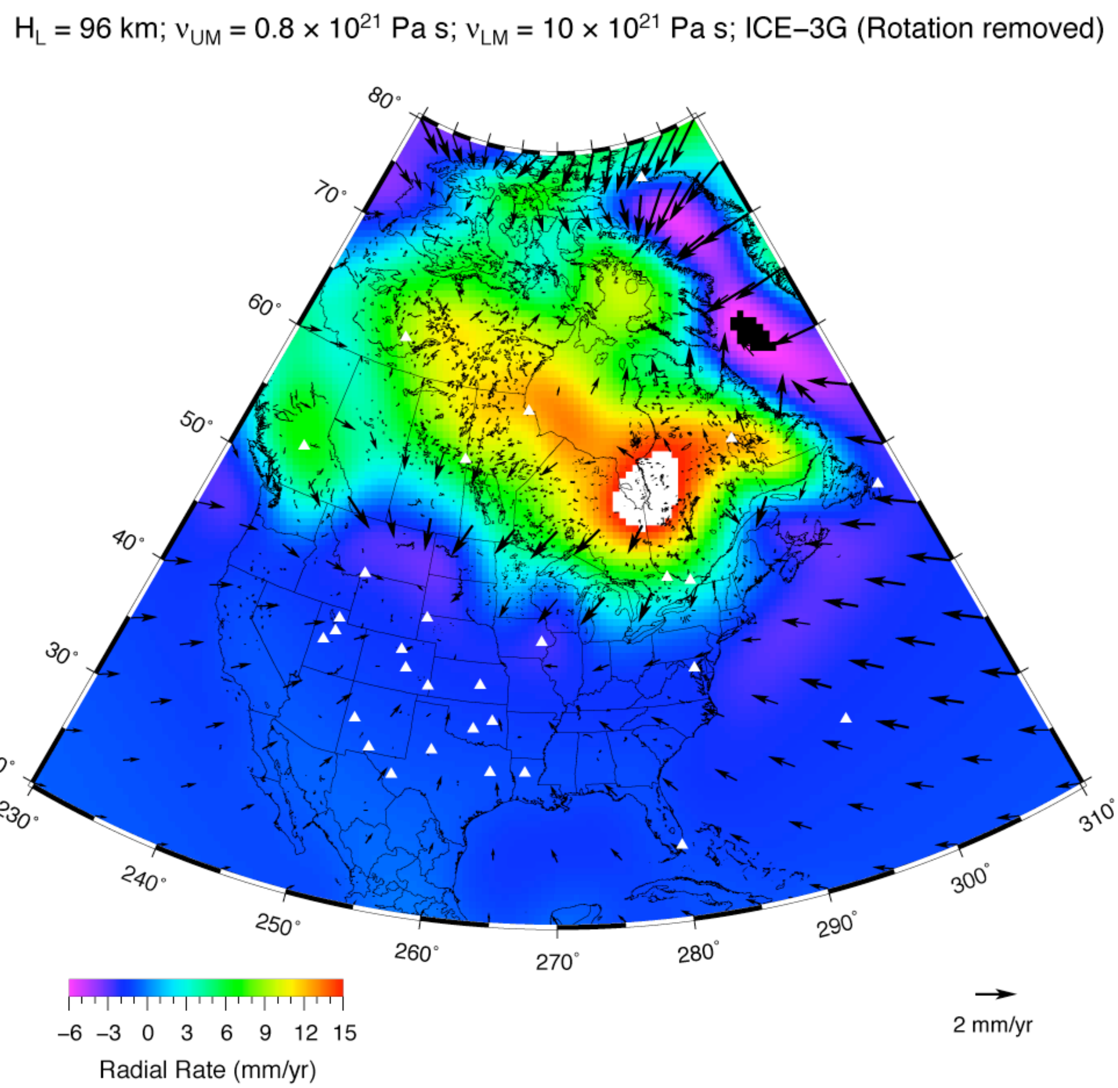
In the next figure, we show predictions of the GIA motions for this region for a three-layer spherical Earth model (calculated by Jerry Mitrovica and Glenn Milne) that is reasonable for Fennoscandia [see *Milne et al.,* 2001].

H_L = 96 km; $\nu_{UM} = 0.8 \times 10^{21}$ Pa s; $\nu_{LM} = 10 \times 10^{21}$ Pa s; ICE–3G



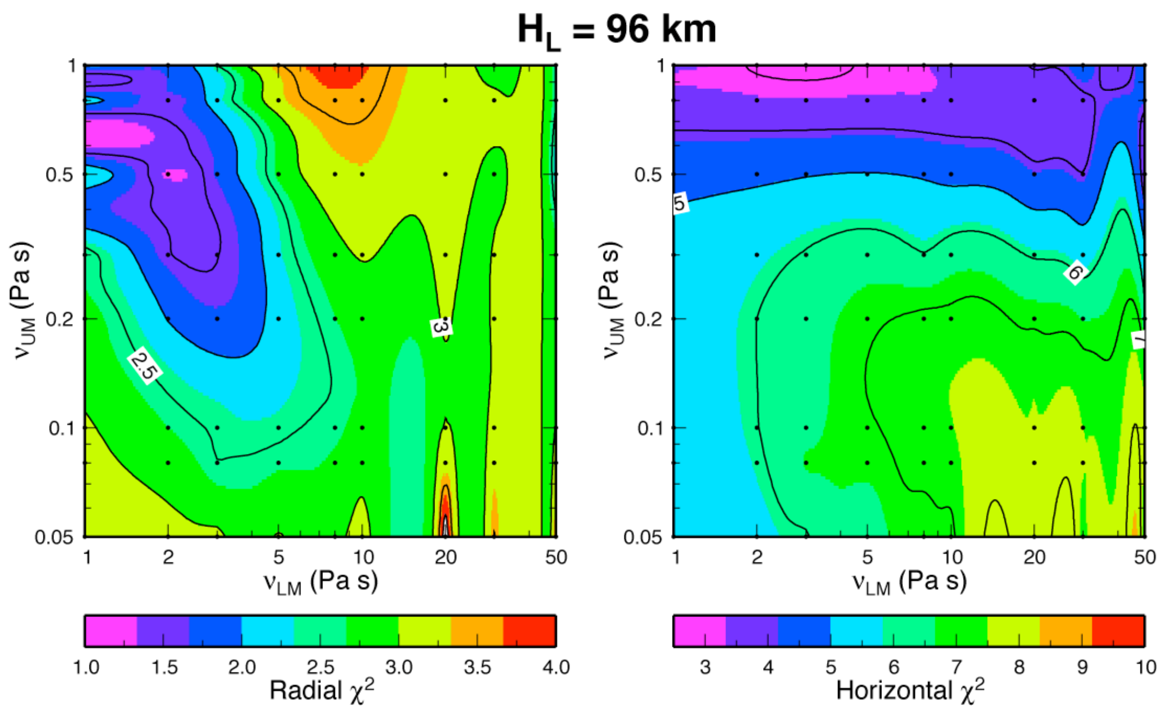
The locations of the sites used to define NARF are shown as white triangles. It is somewhat typical for such calculations to yield the far-field velocities seen above. The GPS solution, however, was produced under the constraint that defined the NARF. Generally, this constraint consists in part of estimating the best-fit rotation that describes the loosely constrained solution for the sites that define the NARF. (See also *Argus et al.* [1999].)

We therefore calculated model values at the locations of the reference sites and estimated a best-fit rotation. We assumed a diagonal covariance matrix with the variances of the horizontal GPS velocities. For this model, the amplitude of the rotation vector was 1.5 mm/yr. The next figure shows the GIA field with this best-fit rotation removed.



Several observations can be made regarding this result. Since most of the GPS sites that are used to determine the reference frame are in areas that have relatively low deformation due to GIA, the solution has greater weight in this region and the residual GIA velocities here are nearly zero. Moreover, the residual GIA velocities are only significant in regions where the tangential gradient of the radial GIA motion is large, and where, unfortunately, there are few GPS sites in the solution. Moreover, these are the regions where ice-model errors will have the greatest impact. There are also significant velocities at the “eastern edge” of the GIA field, at three GPS sites (BRMJ, STJO, and THU1).

The following figure shows the results for a suite of models with the same lithospheric thickness. For these calculations, the χ^2 statistic was calculated after adjustment of the model field by the best-fit rotation. (This affects the horizontal results only.) Furthermore, four GPS sites (SMEL, LMUT, MAWY, and WILL) were not used since they dominated the horizontal χ^2 statistics, presumably due to their being located in less tectonically stable areas. The dots indicate the viscosity pairs that were used.



At this point, we conclude the following:

(1) GIA may introduce a systematic error in the determination of poles of rotation for plate models determined from geodetic data at the level of ~1 mm/yr.
(2) A greater density of GPS sites would be required in areas where GIA predicts deformation to discriminate GIA models based on horizontal motions. However, these sites would be very sensitive to ice-model errors, and no unique ice model can be determined.
(3) Radial motions could play a more significant role, but we still require a greater site density in these areas, and in areas where subsidence is occurring (to better constrain the viscosity of the lower mantle).
(4) We can also investigate the effects of translations. A quick study done almost a decade ago indicated that this procedure would remove a great deal of information unless a good site distribution is available.
(5) We need to extend the suite of Earth models for which we have calculated the viscoelastic Green's functions.
(6) We probably need to make the "site cutoff" for SNARF farther east than for this particular solution.