The use of ITRF velocity field in testing GIA models

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Introduction

Glacial isostatic adjustment (GIA) causes lateral and vertical movements of the Earth's surface, and is hard to distinguish from the deformational response to decadal and longer term changes in continental water storage and the mass of glaciers and ice sheets. It is necessary to know the distribution of GIA to properly interpret sea-level change and ice-sheet mass balance from gravity and altimetry data. GNSS measurements can give valuable constraints on GIA models.

This work tests a suite of GIA models against the ITRF velocity field to choose a smaller subset of GIA models for further investigation. The subset will subsequently be tested against a more abundant surface velocity field developed from IGS data and other similarly reprocessed GNSS datasets using the TANYA software for reference frame combination developed at Newcastle University.

The initial surface velocity field consists of ITRF2008 [1] sites located in low strain areas.

Plate motion

The ITRF sites were assigned to plates using the plate boundaries published by P. Bird [3]. Bird divided the Earth into 52 tectonic plates (PB2002 plate motion model), whereas the ITRF 2008 plate motion model [2] consists of 14 plates.
We used ITRF2008 PMM for the majority of sites.

However, there are sites that are located on PB2002 plates that do not have a direct equivalent in ITRF2008 PMM. Thus, they were assigned to plates from PB2002 plate motion model (Tonga, Okhotsk, Okinawa, Mariana, Shetland, Aegan Sea, Yangtze and North Bismarck). We also replaced the plates defined in ITRF2008 PMM by < 3 sites, and those where the errors are more than 0.1 mas/a, with plates from PB2002 plate motion model (Arabian, Caribbean, Sundaland).

ITRF residuals

We calculated the ITRF residuals by subtracting tectonic plate motion from measured ITRF sites' velocities. After subtracting plate motion from the ITRF velocity sites, we eliminated a number of sites using the following criteria:

- sites with multiple measurements where the velocities differ from each other by more than 0.01 mm/yr

- for sites with multiple measurements with small differences in velocities, only the velocities with the smallest standard error for that site were taken into consideration.

- sites where East and North component were larger than 1 cm/yr and up component larger than 3 cm/yr (these corresponded to the sites with large formal errors)

ITRF sites

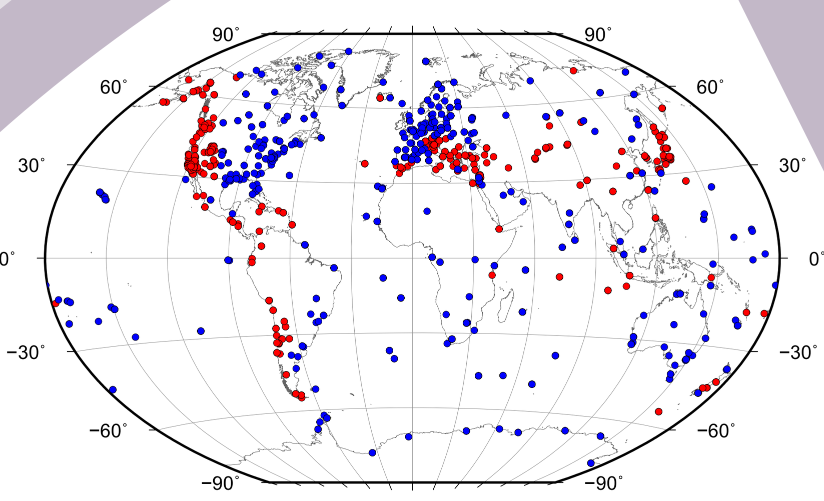


Figure shows ITRF 2008 sites in high strain areas (red) and low strain areas (blue) according to Global Quake Model [4]

Plate motion

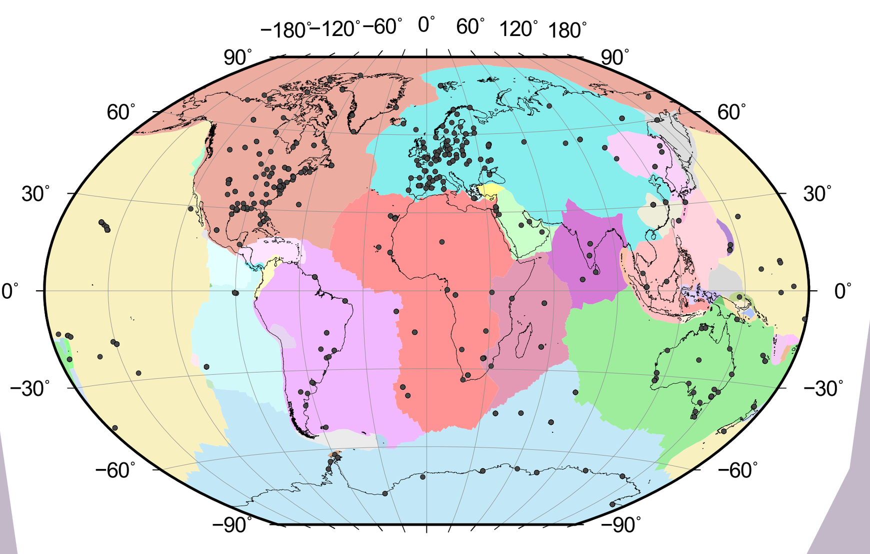
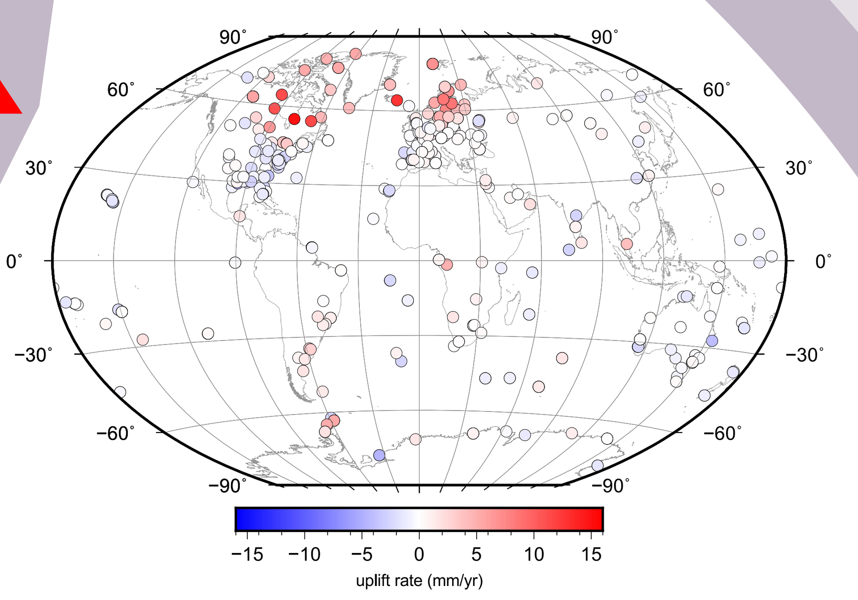
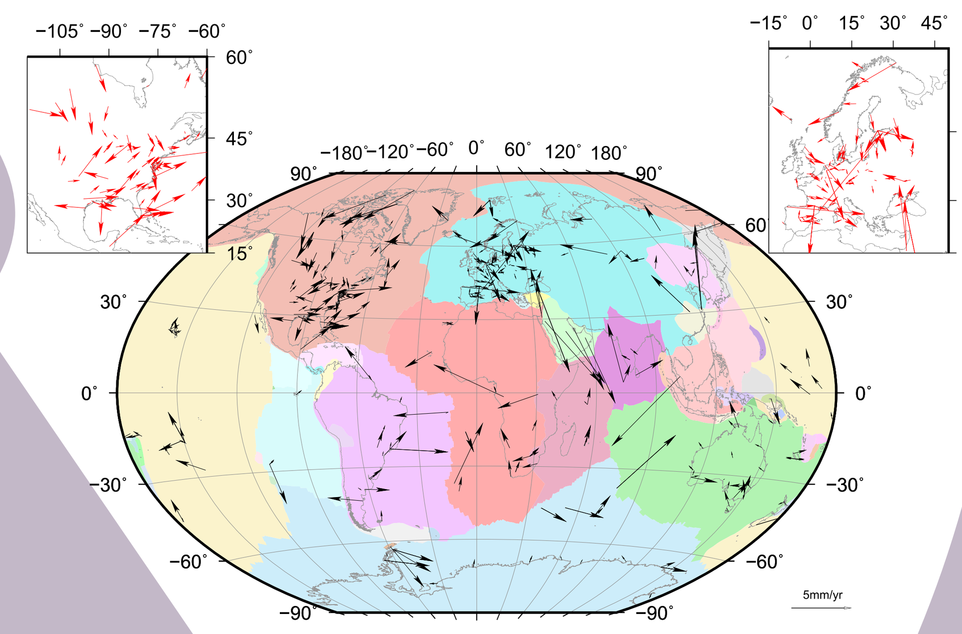


Figure shows tectonic plate boundaries according to [3] and ITRF 2008 sites in low strain areas.

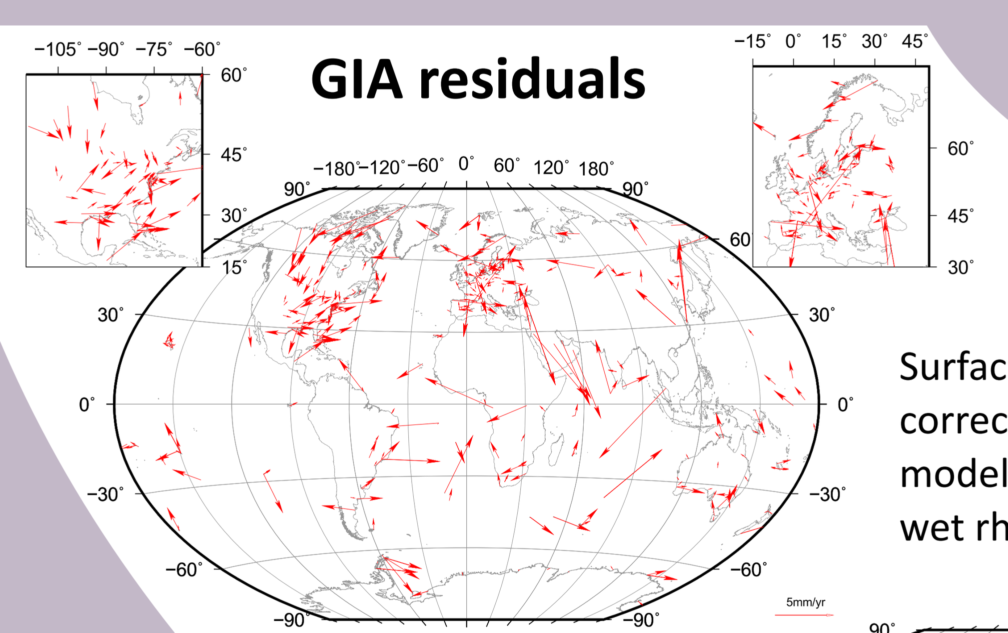
ITRF residuals



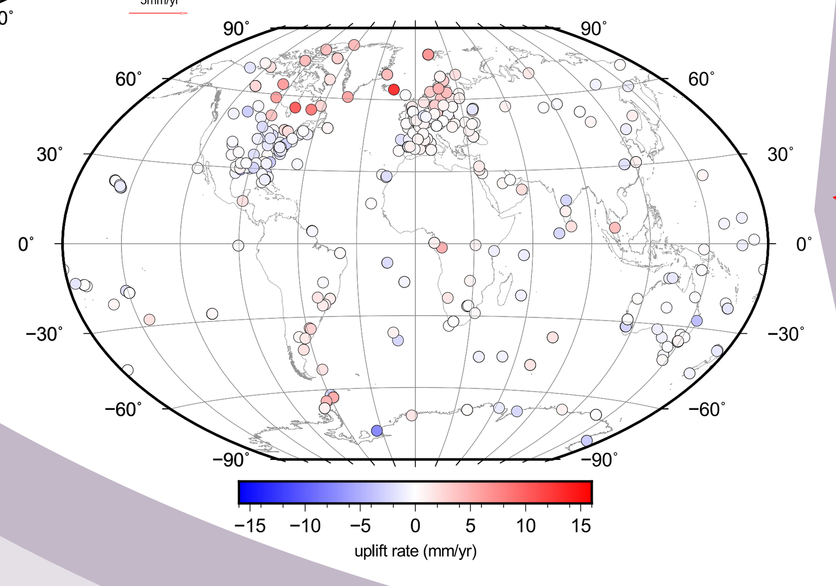


Vertical and horizontal surface velocity field after subtracting plate motion

GIA residuals



Surface velocity residual field after correcting with ICE5G + SL Earth model with 4 mm grain size and wet rheology



GIA models

105 GIA models are used. Three different ice models [5],[6],[10] are combined with a range of rheological models that represent 1D and 3D Earth structure.

1D Earth models: - viscosity varies only radially
-Earth models with varying lithosphere thickness, upper mantle viscosity and lower mantle viscosity.

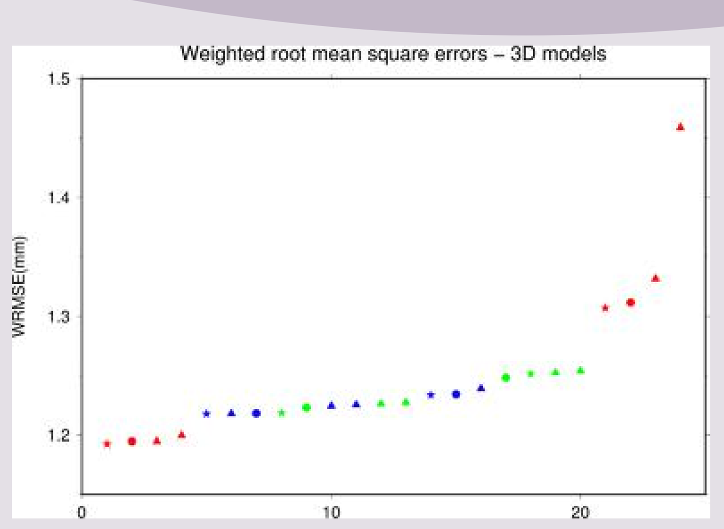
3D Earth models:
-the mantle viscosity varies radially and laterally and depends on the ice history due to our use of power law rheology.
-Earth models are based on one of two seismic models, SL[8] and S40RTS [7]; mantle grain size and water content can be varied.

GIA residuals

We subtracted the GIA surface velocity fields from the ITRF residuals and calculated the weighted root mean square errors (WRMSE). The WRMSE for GIA residuals (i.e. the residual field after subtracting GIA velocities from ITRF residuals, where plate motion had been removed) are shown in Figure A.

Results

- ICE6G models show to be the best fits, which can be due to the fact that this ice model is tuned to fit GPS measurements
- results also imply that correcting for GIA in horizontal sense with 1D GIA models does not make an improvement, whereas for 3D models, there is an improvement after correcting for GIA



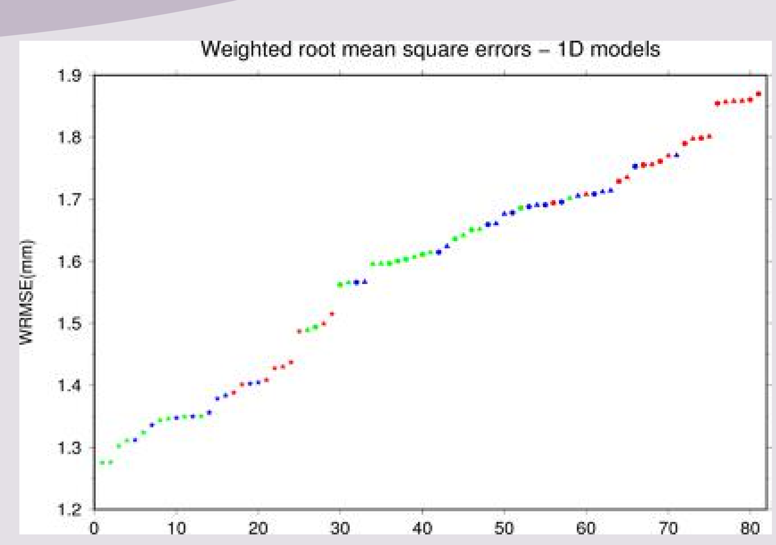


Figure A: WRMSE for 1D and 3D GIA models. Stars represent ICE6G ice models, circles ICE5G and triangles W12. On the right (1D models) red stands for 71 km lithosphere thickness, blue 96 km, green 120 km and on the left (3D models) red stands for 1 mm grain size, blue 4 mm and green 10mm.

References:
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