PAST AND FUTURE CHANGES OF SEA LEVEL ALONG THE EAST COAST OF THE UNITED STATES OF AMERICA

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Introduction

We seek to quantify future changes of sea level along the Eastern coast of North America with particular emphasis on heavily populated areas. There are several processes that will contribute to the sea level signal and each needs to be considered in order to produce accurate projections[1]. The primary component signals are: changes in sea surface height due to ocean steric changes and the associated dynamic signal, changes in relative sea level due to melting of land ice (ice caps, glaciers and ice sheets), changes in relative sea level due to glacial isostatic adjustment (GIA) associated, mainly, with the melting of the now absent North American ice sheet (NAIS). This poster focuses improving estimates of the latter while including the signal of other processes listed.

Method & Results

There are two key model inputs for the GIA model: Earth rheology and density model and an ice history model. The latter is described in the section "Ice Models". The Earth model includes density and elastic structure as defined by the seismic PREM[2]. The viscosity structure is defined by three parameters which are varied over a wide range (Fig. 1). These parameters are: lithosphere thickness (high viscosity region), upper mantle viscosity (base of lithosphere to 660 km), lower mantle viscosity (660 to Core-Mantle boundary). We compute RSL using the theory and algorithm described in Mitrovica and Milne[3] and Kendall et. al[4]. We compare modelled RSL values to observations from the database of Engelhart and Horton[5]. The quality of the data-model fit for a selection of model parameters in shown in Figure 2. The Engelhart and Horton[5] database contains approximately 500 index points distributed between Maine and Southern Carolina (Figure 5). In total we considered over 360 Earth models and 35 ice models to give more than 12000 model runs.

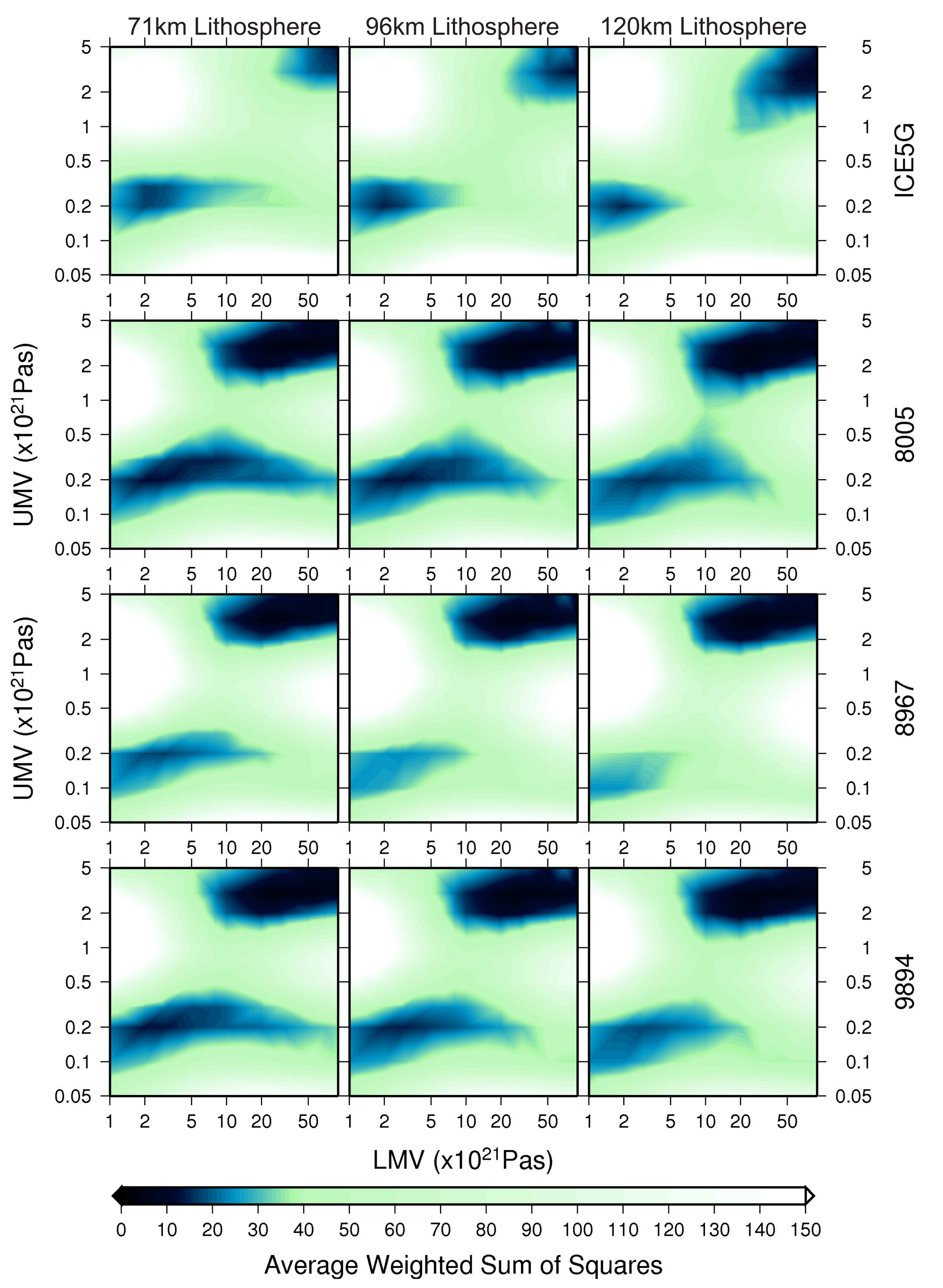

Figure 1: Phase space plots showing the quality of fit as a function of upper and lower mantle viscosity, lithosphere thickness and ice model. Results for the three best fitting NAIS models of Tarasov et. al[6] are shown as well as those for ICE5G.

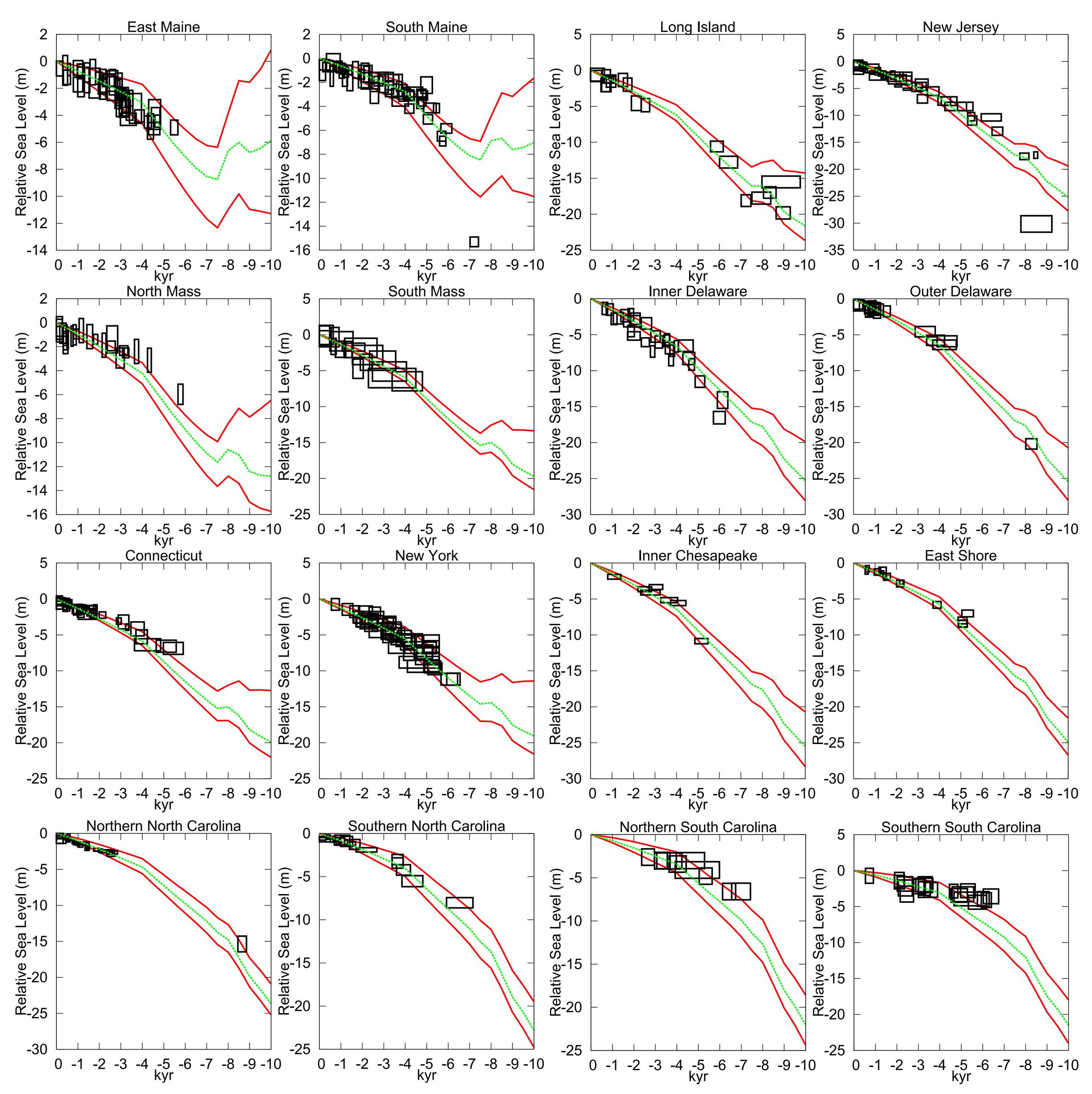

Figure 2: RSL curves of the best fitting model(green), the maximum and minimum values over the best ~50 runs(red). Sea–level index points from Engelhart and Horton[5] are shown with uncertainty in black.

References

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[3]Mitrovica, J.X. and G.A. Milne, 2003. On Post-Glacial Sea Level: I. General Theory, Geophys. J. Int., 154, 253-267.
[4]Kendall, R., J.X. Mitrovica, and G.A. Milne, 2005. On Post Glacial Sea-Level: II. Numerical Formulation and Comparative Results on Spherically-Symmetric Earth Models, Geophysical J. Int., 161, 679-706.
[5] Engelhart, S.E., Horton, B.P., Quaternary Science Reviews, 54, 12-25 (2011)
[6] Tarasov et. al., Earth and Planetary Science Letters, 315-316, 30-40 (2012)

Ice Models

Below are maps of ice thickness for the best fitting input NAIS model from the study of Tarasov et. al.[6] as well as ICE5G[7] of Peltier, presented at 21ka BP. In this study only the North American component model is varied, surface ice over the rest of the Earth is provided by ICE5G[7].

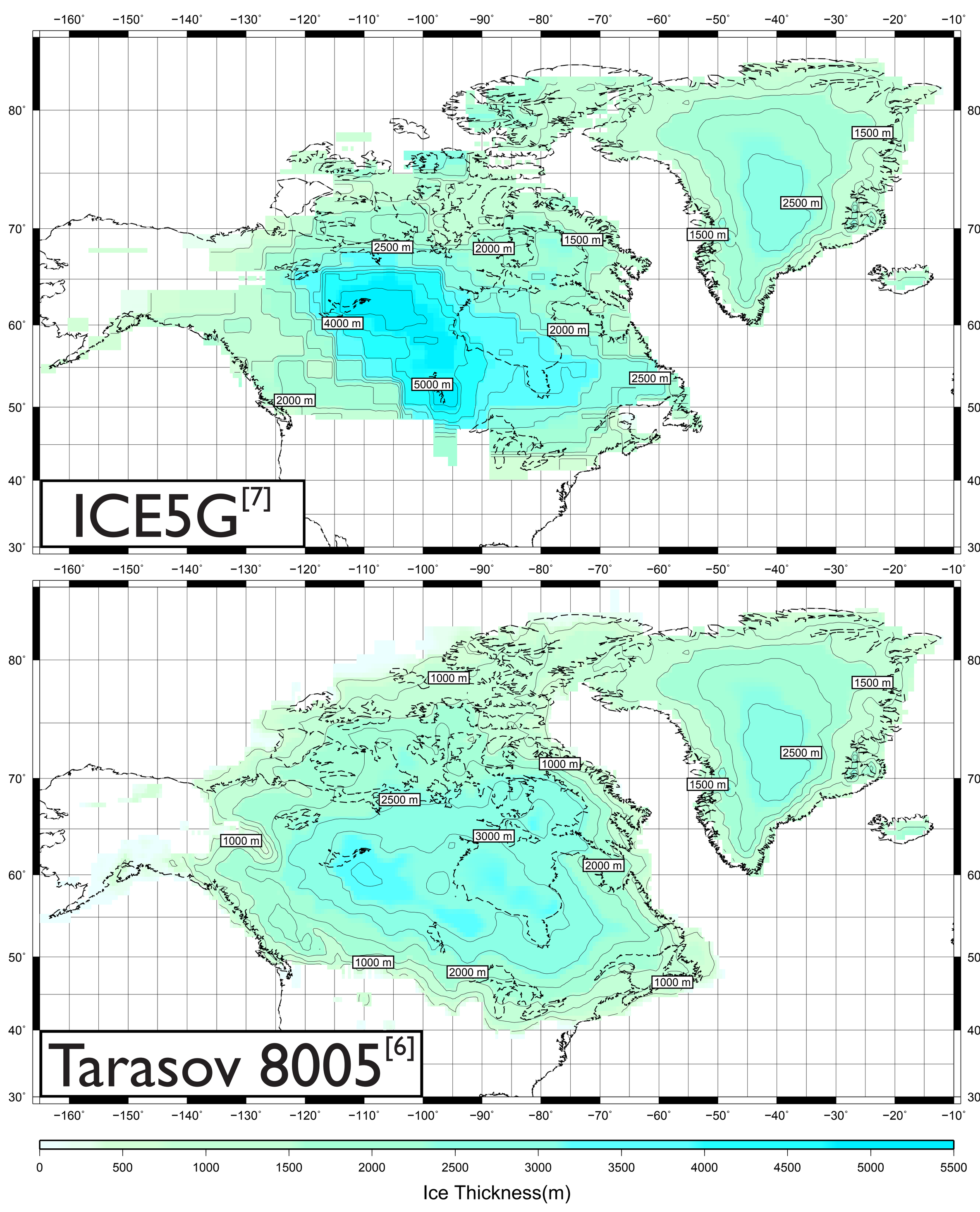

Figure 3: Plots of input ice thickness for a model of Tarasov and ICE5G[7] of Peltier at 21ka BP. Only the North American ice sheet is varied between models. All other ice sheets (e.g. Greenland) are as defined in ICE5G[7].

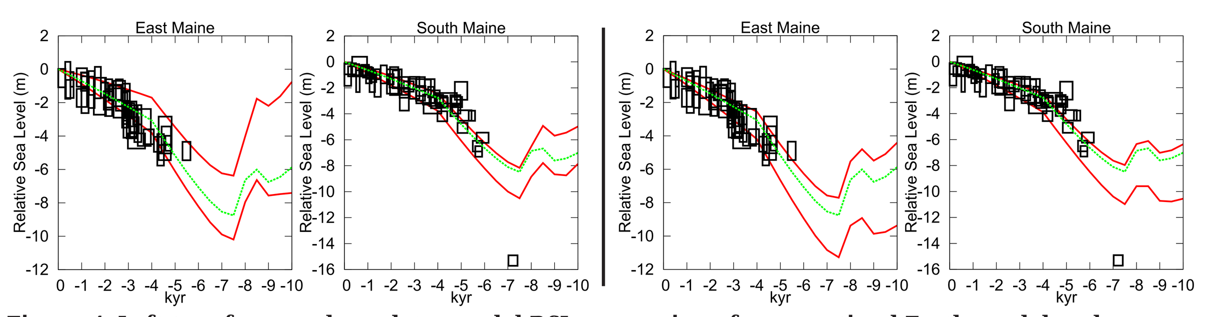

Figure 4: Left two frames show data–model RSL comparison for an optimal Earth model and a range of ice models. Right two frames show data–model comparison for an optimal ice model (9894) and a range of Earth models. Curves are as follows: best fitting model(green), the maximum and minimum values(red).

The models of Tarasov[6] are calibrated, using a Bayesian methodology, to a range of data sets including, for example, RSL histories, ice margin chronology (see [6] for more information). Input ice thickness near the last glacial maximum for the best fitting model of Tarasov et. al[6], 9894 and ICE5G[7] of Peltier are shown above in Figure 3.

Of note is that the ice models of Tarasov et al.[6] were calibrated using the Earth model VM5a[6]. This model is characterised by viscosity values that are significantly less than those found to provide optimal fits to the US east coast RSL data set considered here. Revisiting the calibrations of Tarasov et al.[6] with the extension of considering a range of Earth viscosity models is therefore a clear avenue to extend this work.

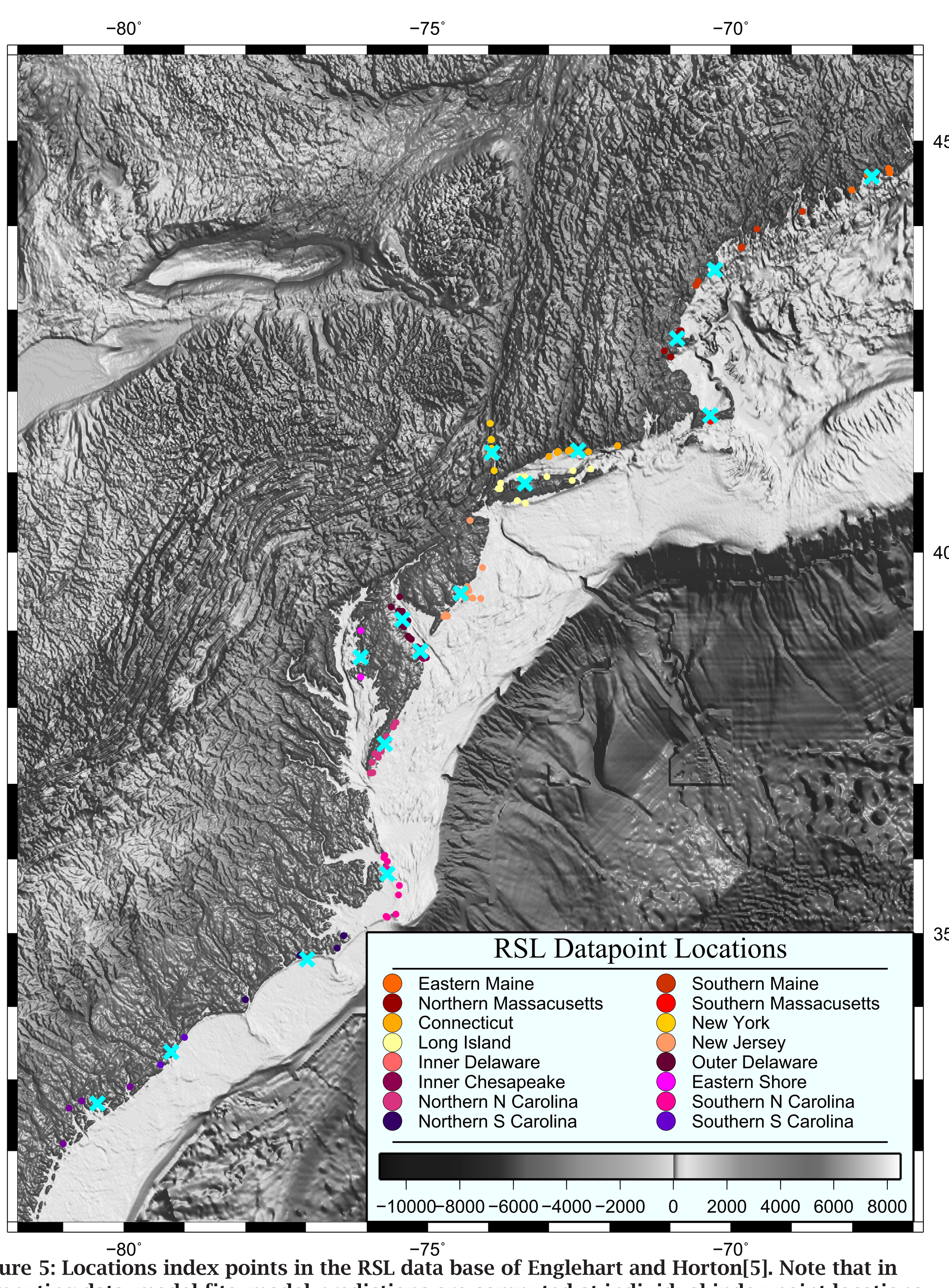

Figure 5: Locations index points in the RSL data base of Englehart and Horton[5]. Note that in computing data–model fits, model predictions are computed at individual index point locations. However, when comparing to data and model as RSL curves (Fig. 2) the model is run for a location that is the weighted mean of the index points for that area.

[7]Peltier, W.R., Global glacial isostasy and the surface of the ice-age Earth: the ICE-5G (VM2) model and GRACE. Annual Review of Earth and Planetary Sciences, May 2004, Vol 32, 111-149.
[8] Arendt, A., et. al. 2012, Randolph Glacier Inventory [v2.0]: A Dataset of Global Glacier Outlines. Global Land Ice Measurements from Space, Boulder Colorado, USA. Digital Media.
[9] CMIP5 multi-model ensemble archive(2012)
[10] B. Marzeion, et. al, Past and future sea-level change from the surface mass balance of glaciers. The Cryosphere, 6, 1295–1322, 2012

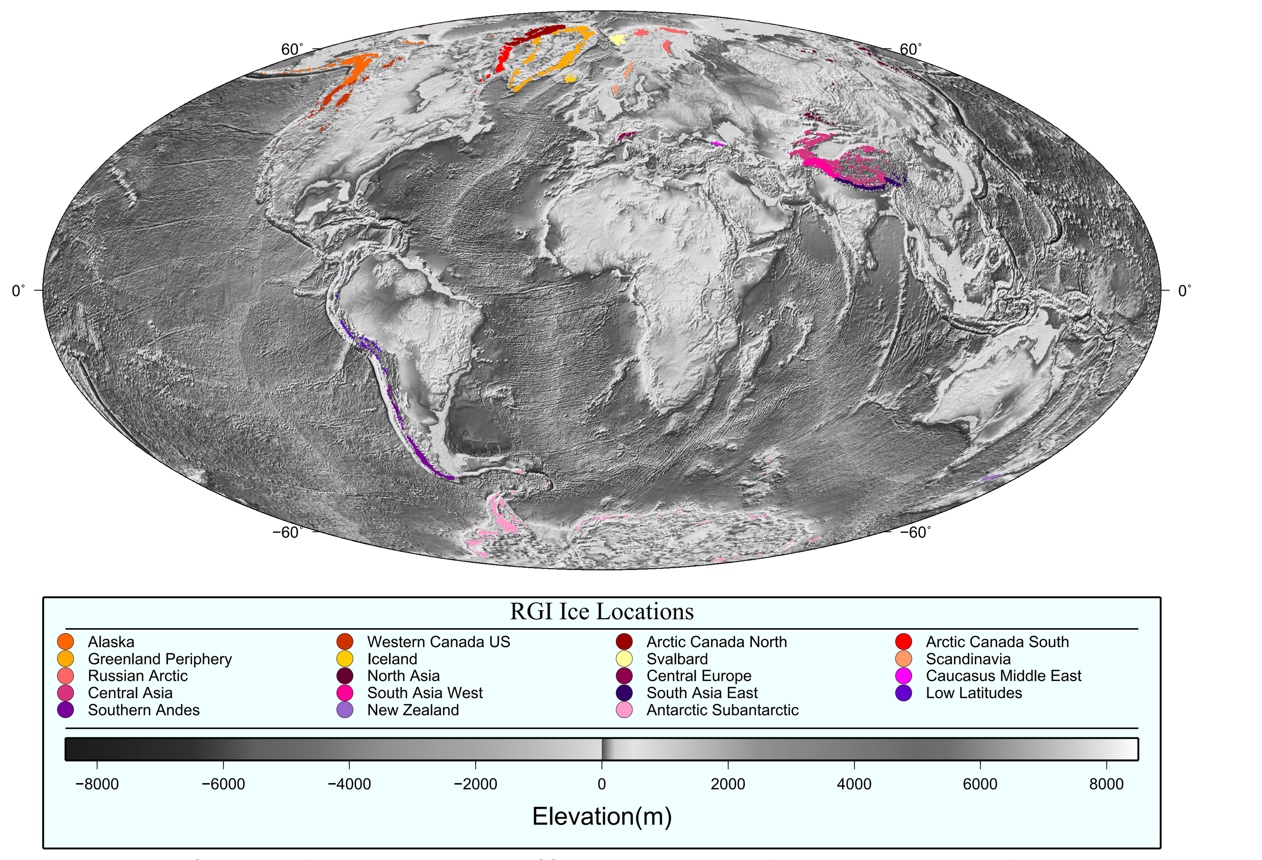

Figure 6: Map of Randolph Glacier Inventory[8] outlines, subdivided into their individual groupings as provided. Glacier outlines were used to approximate ice volume for sea–level fingerprinting.

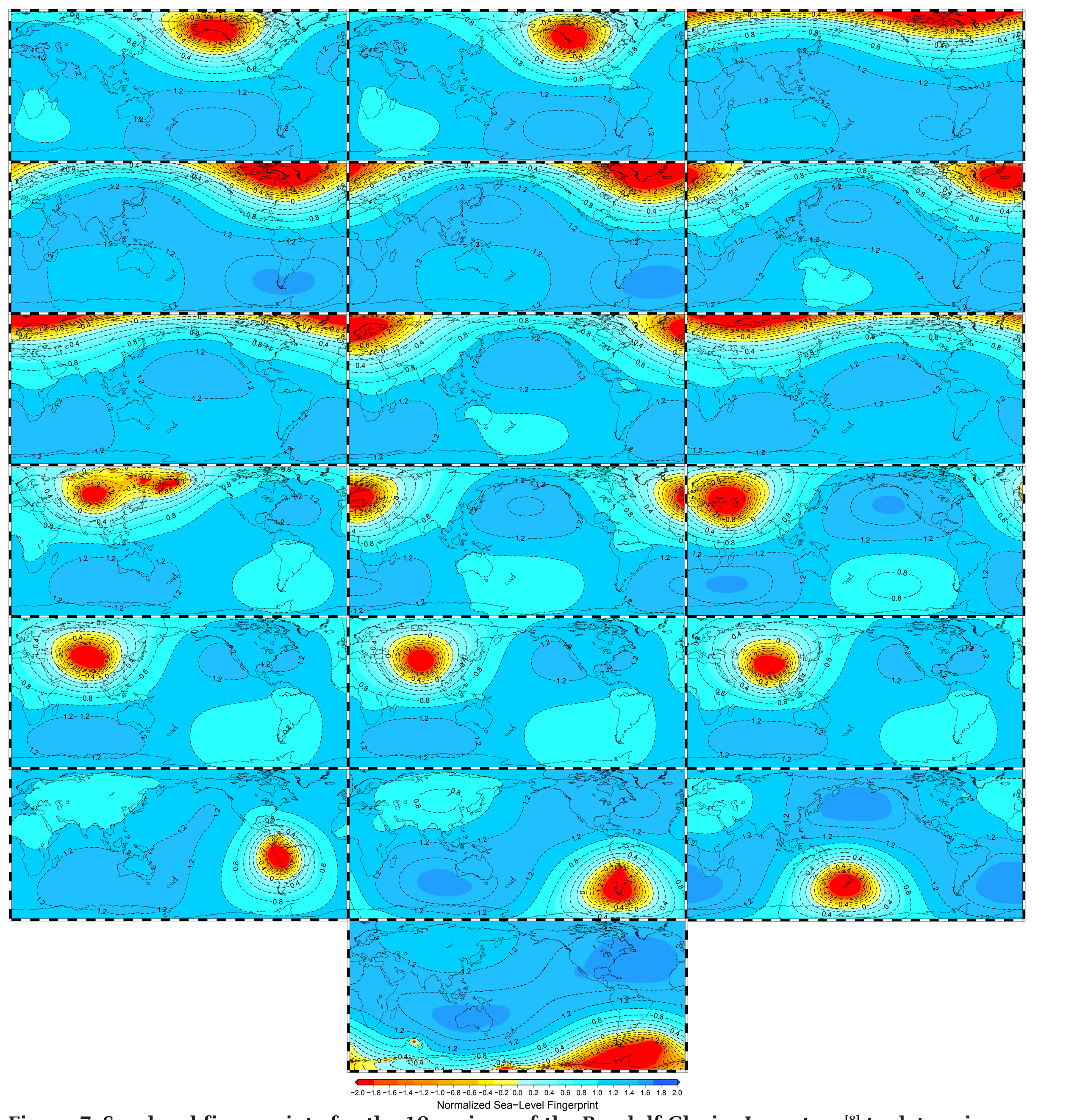

Figure 7: Sea–level fingerprints for the 19 regions of the Randolf Glaciar Inventory[8] to determine contributions of each site to local sea–level rise according to the results of Marzion et. al.[10]

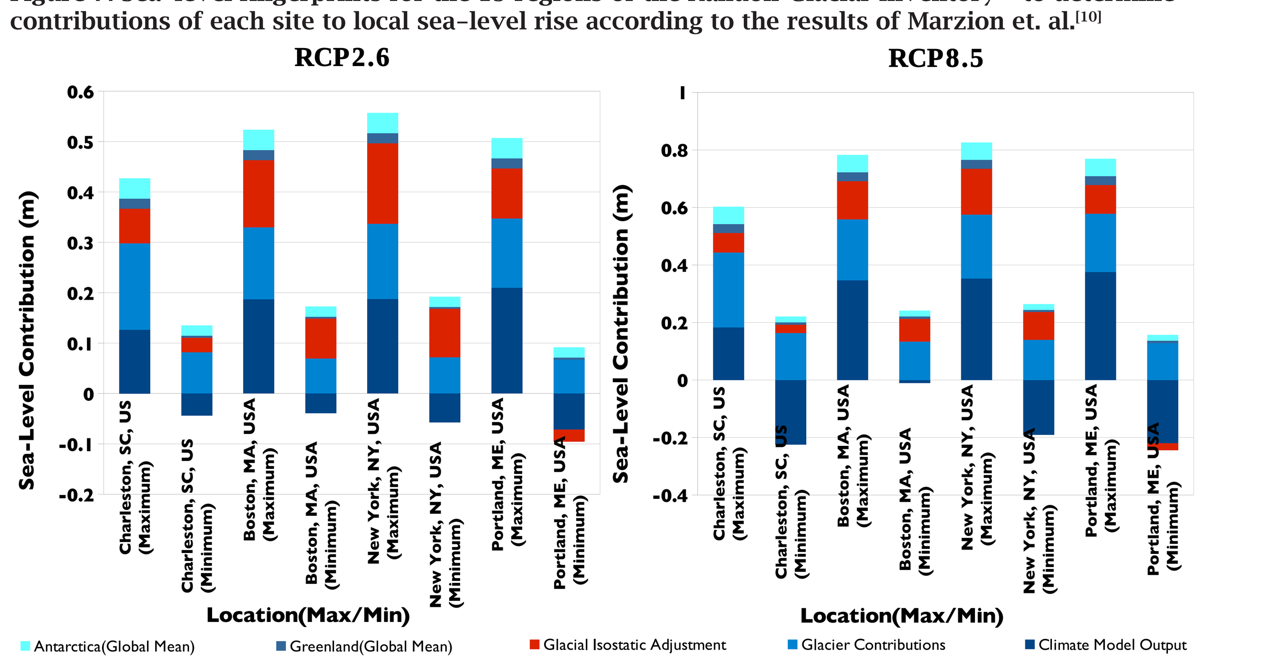

Figure 8: Maximum and minimum sea–level contributions at 2100 from steric changes, ice melting and GIA for four largely populated cities along the East Coast of the United States.[9][10][11][12] Maximum bars are composed of the maximum value of the dataset for each component while minimum bars are composed of the minimum value of the dataset for each component.

Sea–Level At 2100

In order to obtain values for sea-level change at 2100 we investigated the contributions of each signal to the total. To elucidate the contribution of glaciers we conducted sea-level fingerprinting experiments to determine the spatial pattern of the melt water redistribution. Combining this information with the results of Marzion et. al.[10] we are able to obtain a suite of values for each location. To determine local sea-level changes due to steric effects model output from the CMIP5 archives was utilized. Figure 8 show the difference between the average sea-level change value from 2090-2100 and 2005-2015. Values presented for the contributions due to the Greenland and Antarctic ice-sheets are obtained from the latest IPCC report and presented as their global mean sea-level values. Fingerprinting experiments for the GrIS and AIS are the next stage in this investigation.

Conclusions

Our results indicate that high viscosity values for the upper and lower mantle best fit the RSL history provided by the study of Engelhart and Horton[5]. The best fitting model had the following parameters, 71km lithosphere, $3 \cdot 10^{21}$Pa•s for upper mantle viscosity, $70 \cdot 10^{21}$Pa•s for lower mantle and featured the 9894 NAIS model. Using our improved GIA model predictions we are then able to combine this data with that from the CMIP5[9] and various other studies concerning contributors to sea-level change to obtain a maximum and minimum range of values at various localities along the east coast of the United States. For example, using the RCP8.5 climate scenario, Boston's range of values was from ~23cm to ~78cm at 2100 from these processes alone and we note that the GIA contribution to the total signal ranges from ~7% to ~31% for the locations considered in Fig.8.

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