Sources of uncertainty in relative sea-level change projections from a probabilistic point of view.

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1. Motivation

As global average sea-level (GSL) rises in the early part of this century (Nerem et al. 2010) there is great interest in how much global and regional (relative) sea level (RSL) will change in the forthcoming decades. Recent work indicates GSL will rise up to 120 cm by 2100 relative to 2000 (Kopp et al. 2014). However, at each stage of making sea-level projections there are assumptions that will alter the uncertainty of the final result. These include drift corrections, spatial patterns of land-ice/water mass loss and glacial isostatic adjustment (GIA). Here we assess the cumulative effect of uncertainty in the resulting RSL projections to 2100.

2. Method of RSL projection

We consider three scenarios, RCP 4.5, RCP 8.5 (Moss et al. 2010) and an upper limit based on Jevrejeva et al. 2014. We aggregate spatial projections of individual sea-level components, which are themselves sampled from continuous probability density functions. By combining realisations from the individual components, we derive a total uncertainty that varies in space (θ,ϕ) and time (t),

$$RSL(\theta,\phi,t) = F_{SAT}(\theta,\phi)\cdot[STR(t)+DSL(\theta,\phi,t)] + F_{GLA}(\theta,\phi)\cdot GLA(t) + F_{GRE}(\theta,\phi)\cdot GRE(t) + F_{ANT}(\theta.\phi)\cdot ANT(t) + F_{LW}(\theta,\phi)\cdot LAN(t) + F_{GIA}(\theta,\phi)\cdot t$$

where SAT is the impact of self-attraction of the ocean upon itself due to the long term alteration of ocean density changes, STR is the globally averaged steric sea-level rise, DSL is the dynamic sea-level change, GLA are glaciers, GRE is the Greenland ice sheet, ANT is the Antarctic ice sheet, LAN is Land-water storage and GIA (aforementioned). The function $F(\theta,\phi)$ refers to the unique normalised spatial pattern (fingerprint) associated with the ocean response to the mass redistribution of the given component.

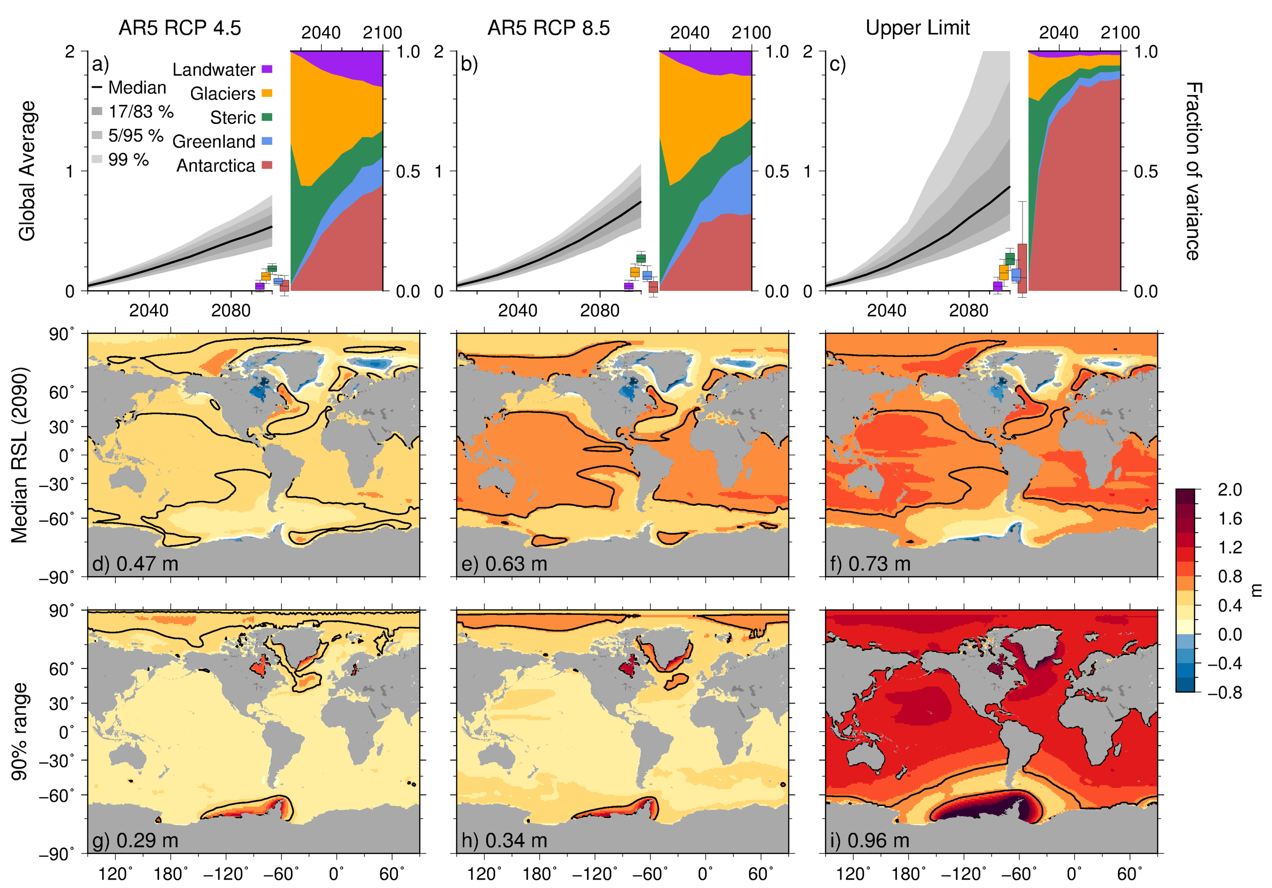


Figure 1: (a-c) GSL projections, GSL components at 2090 (box-whisker) and fraction of variance of individual components (DSL and GIA not global). (d-f) Total RSL projections at 50th percentile relative to 1986-2005 average at 2090. (g-i) 90% range (5th-95th percentile) of total RSL projection at 2090. Black contour is GSL (d-i, also labelled). White contour is zero.

3. Steric and DSL uncertainties

Steric and DSL projections are multi-model ensemble means (MEM) from CMIP5 (Taylor et al. 2012). We correct the 1850-2100 period of each model by the linear, quadratic and cubic polynomials of full/partial pre-industrial control runs. For steric (Figure 2), differences in MEM are less than 0.5 cm (1850-2100) though the ensemble ranges up to 4 cm. For DSL (Figure 3), differences in MEM (linear-quadratic) are up to ±0.4 cm. Individual models vary by 10's cm over the century and within the ensemble little spatial agreement exists.

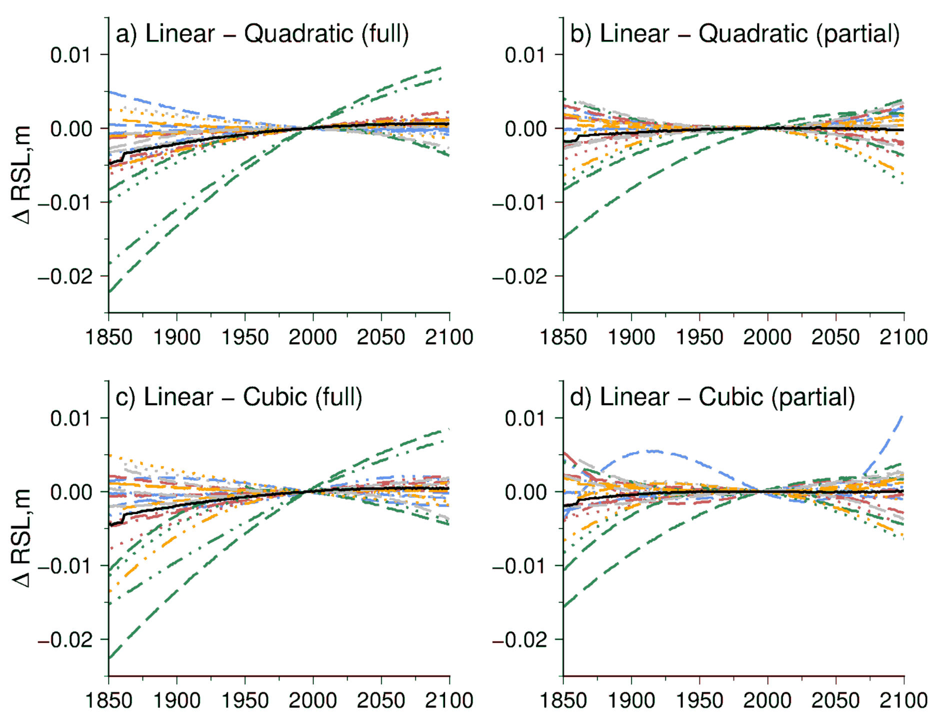
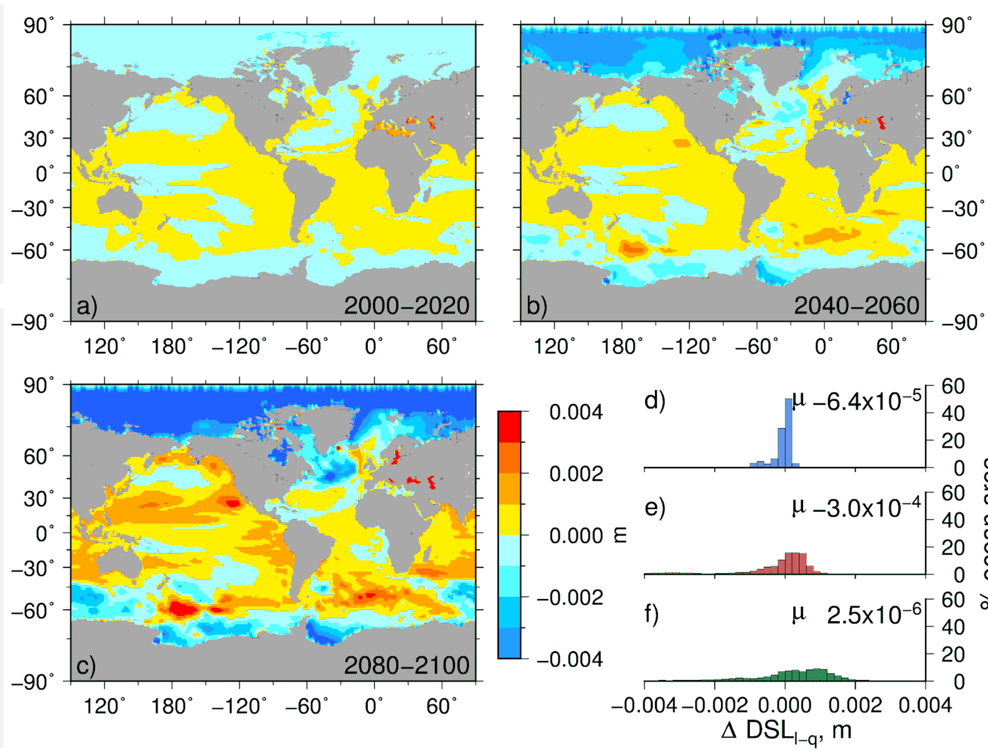


Figure 2 (left): Difference between steric sea-level (models: coloured, MEM: black) corrected by linear, quadratic, cubic polynomials.

Figure 3 (right): Difference between DSL MEM for linear and quadratic drift corrections using full pre-industrial control runs at 2010, 2050 and 2090 relative to 1986-2005 (a-c) and histograms (d-f). Global average, μ.



4. DSL uncertainty continued

In certain locations, the ensemble of projected DSL does not conform to a normal distribution (Figure 4). This implies that DSL may be skewed along the West Coastlines of USA, South America and Africa).

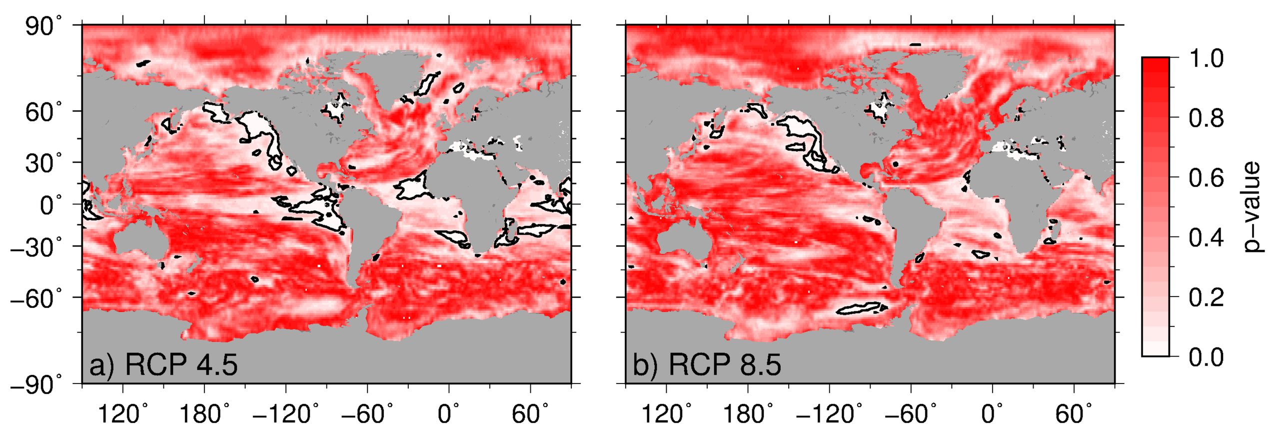


Figure 4: p-values of DSL MEM calculated by normality test for RCP 4.5 and RCP 8.5 at 2090. Area within black contour: null-hypothesis is rejected at 95% confidence limit (p = 0.05).

5. GIA and ice-sheets

Differences between GIA models (Figure 5a,d) results in projected RSL change by 2100 differing by less than 2 cm for the bulk of the global oceans, though up to -70 cm and +60 cm along the North Canadian, Scandinavian and Antarctic coastlines (Figure 5g).

Assuming the spatial distribution of projected ice-sheet mass loss lies between that observed presently (Figure 5b,c: Bamber & Riva, 2010) and one that is uniform (Figure 5e,f), median projected RSL change in 2100 could differ by up to -45 cm in South America and +50 cm in the Southern Ocean, though the bulk of the global oceans differ by ±5 cm (Figure 6d-f). Spatial pattern of mass loss will strongly affect RSL projection near to source of mass, even for 5th percentile.

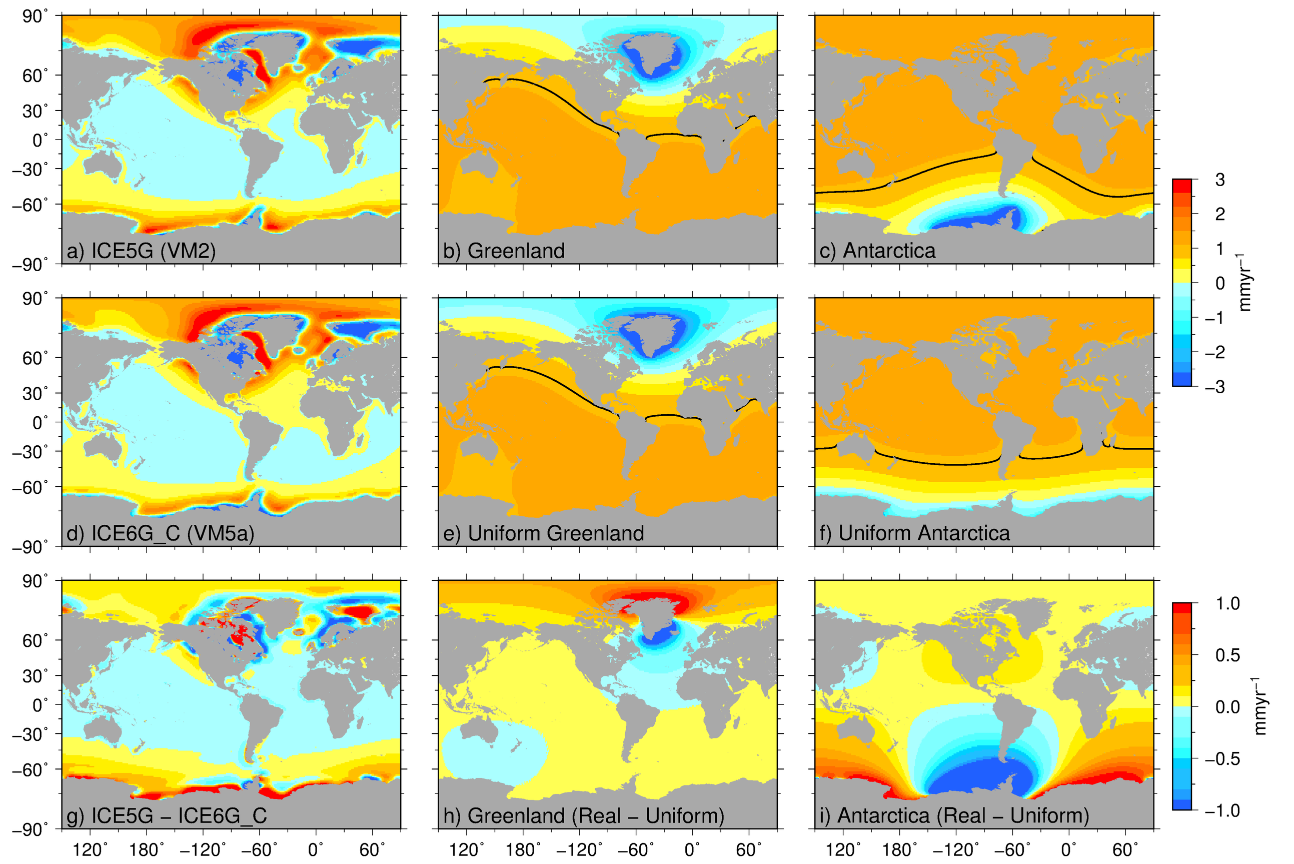


Figure 5: Spatial patterns of RSL due to GIA (left), Greenland (middle) and Antarctic (right) ice sheets. GIA models are ICE5G (VM2) (Peltier, 2004) and ICE6G_C (VM5a) (Peltier et al. 2015) whilst Greenland and Antarctic ice sheets show normalised, realistic (modern) and uniform patterns of mass loss (Bamber & Riva, 2010). Bottom panels show the differences between the fingerprints of respective components.

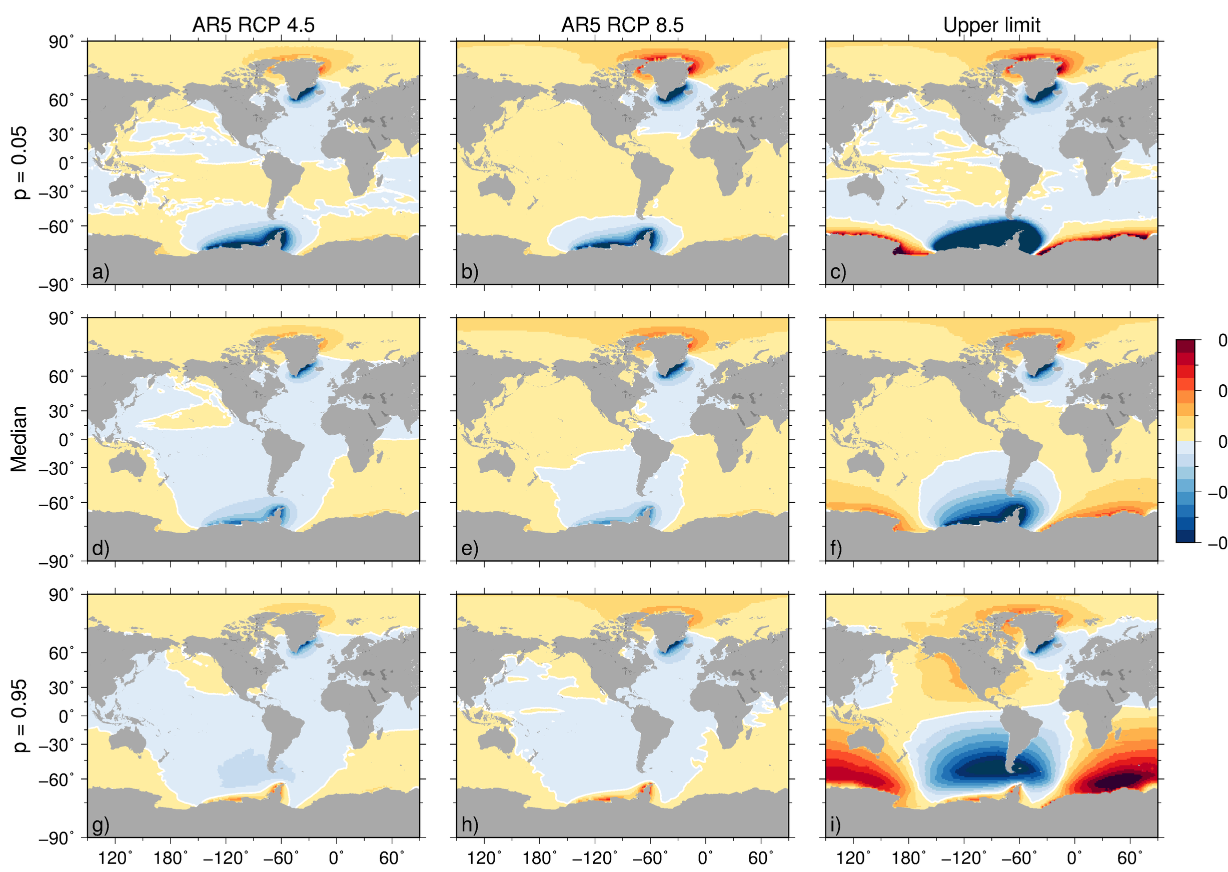


Figure 6 (left): Difference between RSL projections at 2090 using spatial patterns of realistic and uniform ice mass loss from Antarctica and Greenland. a-c, d-f, g-i: 5th, 50th and 95th percentiles. White contour is $\Delta RSL_t = 0$.

6. Summary

Drift corrections are important for ensemble members of STR and DSL. The MEM is largely unaffected by the selection of polynomial that one uses, as long as one is used.

The choice of GIA model or GRE/ANT mass loss pattern results in small projected RSL differences for low-mid latitudes by 2100. For all scenarios, the location of large differences in RSL (due to GRE/ANT loss pattern) moves from source of loss towards the equator and becomes diffuse as the GSL percentiles are traversed.

7. Acknowledgements

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8. References

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