Supplementary information

1. Determination of ice mass losses and their spatial pattern.

For Greenland we used a recent estimate of mass balance for the ice sheet derived from GRACE and mass budget calculations that provides annually resolved values with a detailed determination of the regional, basin-scale distribution of losses (van den Broeke et al., 2009). The mass balance data cover the entire period, 2000-2008 (fig S3, (van den Broeke et al., 2009)), so no interpolation in time was required. For Antarctica, we used a recent assessment of basin-scale losses/gains from mass budget calculations for the years 1996, 2000 and 2006 (Rignot et al., 2008). We fitted a degree-two polynomial to these data and an updated estimate for the Amundsen Sea Embayment for 2007 (Rignot, 2008), which resulted in a mean of 175 Gt/yr. The mass changes for each basin have been distributed over the main outlet glaciers (glaciers with balance velocities larger than 25 m/yr (Bamber et al., 2000)). As mentioned in the main text, this value was reduced by 40 Gt/yr in the Abbots-Ferrigno sector of West Antarctica. It is important to note that the estimates are means for a nine year period and because of the time-varying losses from both ice sheets, the values will be different for a different epoch. It should be noted, however, that GRACE data support a roughly similar acceleration in mass loss for both ice sheets for the period 2002-2009 (Velicogna, 2009). We believe, therefore, that the regional variations in RSL, shown in Fig 3, are robust for a ~decadal timescale at least and certainly while Greenland and Antarctica dominate the contribution to eustatic SLR in roughly equal measure.

For mountain glaciers and ice caps (MG&IC) we used a variety of sources including the compilation for the period 1995-2005, which, although noisy, indicates a likely increase in loss during this period (Meier et al., 2007). We use their linear fit to extrapolate to 2008 and then scale the values for each region listed in Table 1, where we have distributed the mass changes over areas with elevation above 2000 m. The relative regional contributions were obtained by reference to the original sources and a new estimate of the contribution of MG&IC (Dyurgerov and Meier, 2005;Hock et al., 2009;Kaser et al., 2006;Rignot et al., 2003). For Alaska, we used our own estimate for the period 2003-09 from the EOF-CSR fields. For Patagonia and Svalbard we used published estimates from GRACE (Chen et al., 2007;Wouters et al., 2008). We did not include the Himalayas and Karakorum in the total (~40 Gt/yr) as there is uncertainty about whether the glacier losses reach the ocean or whether they contribute to land water storage. These recent observations of ice sheet and MG&IC provide a relatively detailed distribution of ice mass loss, which was used in our calculation of changes in the gravity field, and which are shown in Fig 1.

2. Calculation of relative sea level.

We compute changes in relative sea-level by solving the sea-level equation (Farrell&Clark,1976), which accounts for the fact that surface mass transport, solid Earth deformation and sea-level changes are coupled through gravity. The sea-level equation is solved following a pseudo-spectral approach (Mitrovica and Peltier, 1991), including the effect of migrating coastlines (Milne and Mitrovica, 1998a) and of changes in the Earth rotation (Milne and Mitrovica, 1998b).

The elastic response of the solid Earth has been computed for a radially stratified and compressible Earth based on the Preliminary Reference Earth Model (PREM) (Dziewonsky and Anderson, 1981).

3. Effects of GIA and ice mass distribution

In addition to ice mass changes, steric and ocean circulation effects, GIA also has an impact on RSL through both vertical motion of the Earth's surface and its effect on the gravity field. The largest GIA signals are confined, however, close to those land masses that have experienced the largest changes in ice loading and, in particular, North America (Fig S1). The low latitude impact of GIA on RSL, where the ice melt signal is largest, is close to zero (Fig S1). Thus, it is of little importance for the areas of maximum RSL rise shown in Figure 2. It is a first-order effect, however, when attempting to match the fingerprint of ice melt with observations of sea level from altimetry or tide gauge data (Mitrovica et al., 2001). In this case, uncertainties in the modelled GIA signal, due to incomplete knowledge of ice load history, mantle viscosity and lithospheric thickness, are a serious limitation.

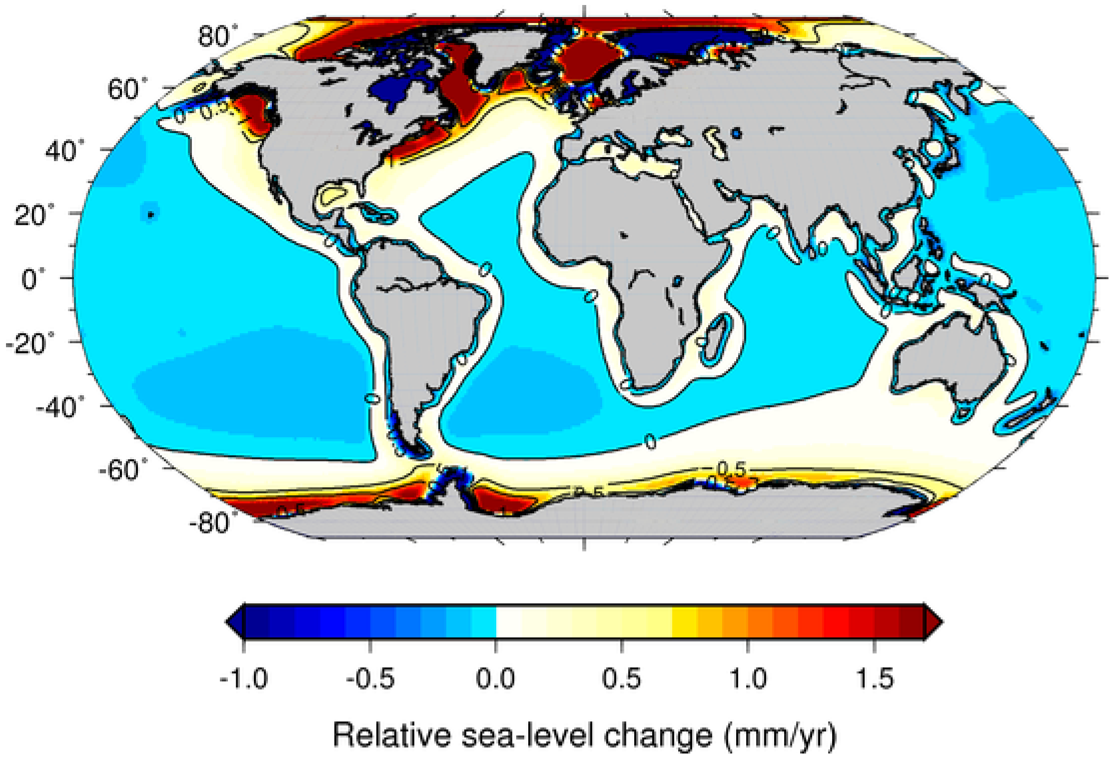

Figure S1. The effect of GIA only on RSL based on ICE-5G (VM2) (Peltier, 2004).

It is apparent from Figure S1 that the effect of GIA on RSL for latitudes above about 40° N is the same order of magnitude (or larger) as the signature of present-day ice melt. In Fig S2, we show the combined pattern of RSL due to both GIA and ice melt. As explained above, the low-latitude pattern is similar to Figure 4. For the North Atlantic and Arctic Oceans, the pattern is, however, markedly different and sensitive to the GIA model used. The fingerprint of ice melt in this region is not the dominant signal. GIA, over decadal timescales is, however, constant while the ice melt signal is not. As the ice melt volume increases, it begins to emerge as the dominant component of the RSL pattern. We illustrate this point for an extreme ice melt scenario where we have quadrupled the flux from 1.7 mm/yr to 6.8 mm/yr (Fig S3). In the Baltic Ocean and Hudson Bay, GIA is still a dominant signal but now, the RSL reduction around Greenland and the gradient across the North Atlantic and around the European coastline more closely resembles the pattern in Figure 4 for ice melt only. The uncertainties in GIA, steric changes, ocean circulation variability and water impoundment make the fingerprinting of ice melt contributions to sea level particularly challenging. Inclusion of complementary geodetic data such as vertical velocities from GPS (Bevis et al., 2009;Wu et al., 2010) and observations of orbital variations (Marcus et al., 2009) would help toward achieving this objective.

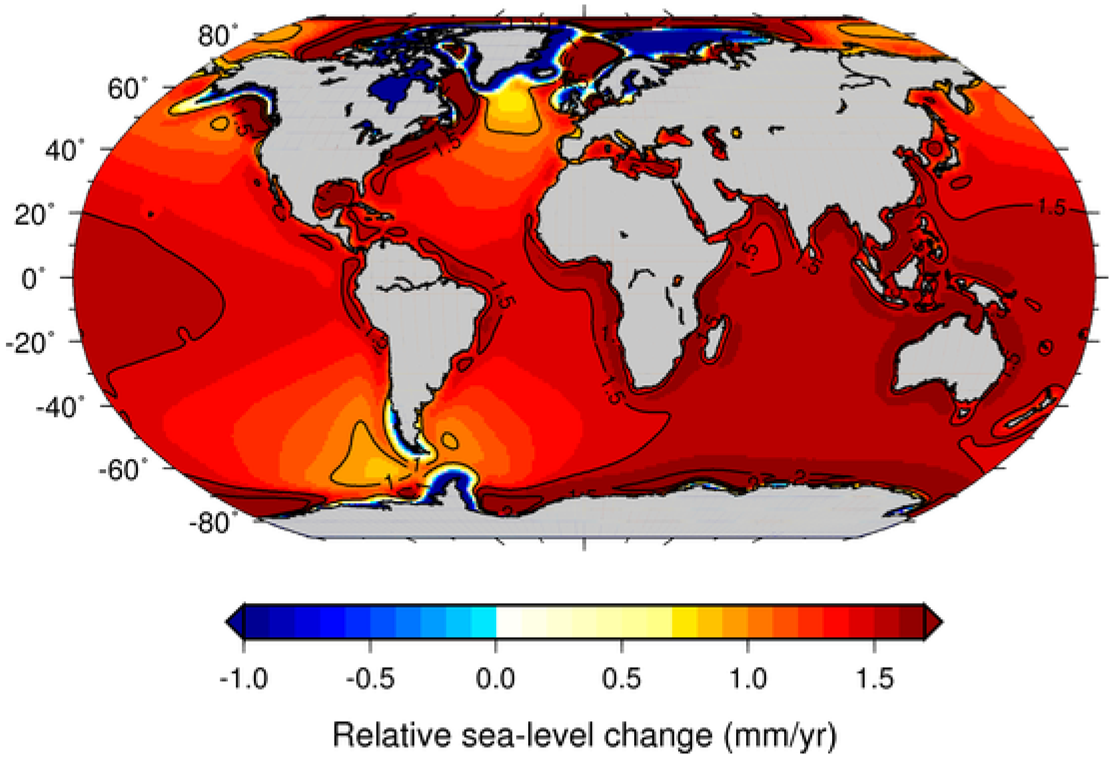

Figure S2. The combined effect of GIA and ice melt on RSL based on ICE-5G (VM2) and the spatial distribution of melting shown in Figure 1.

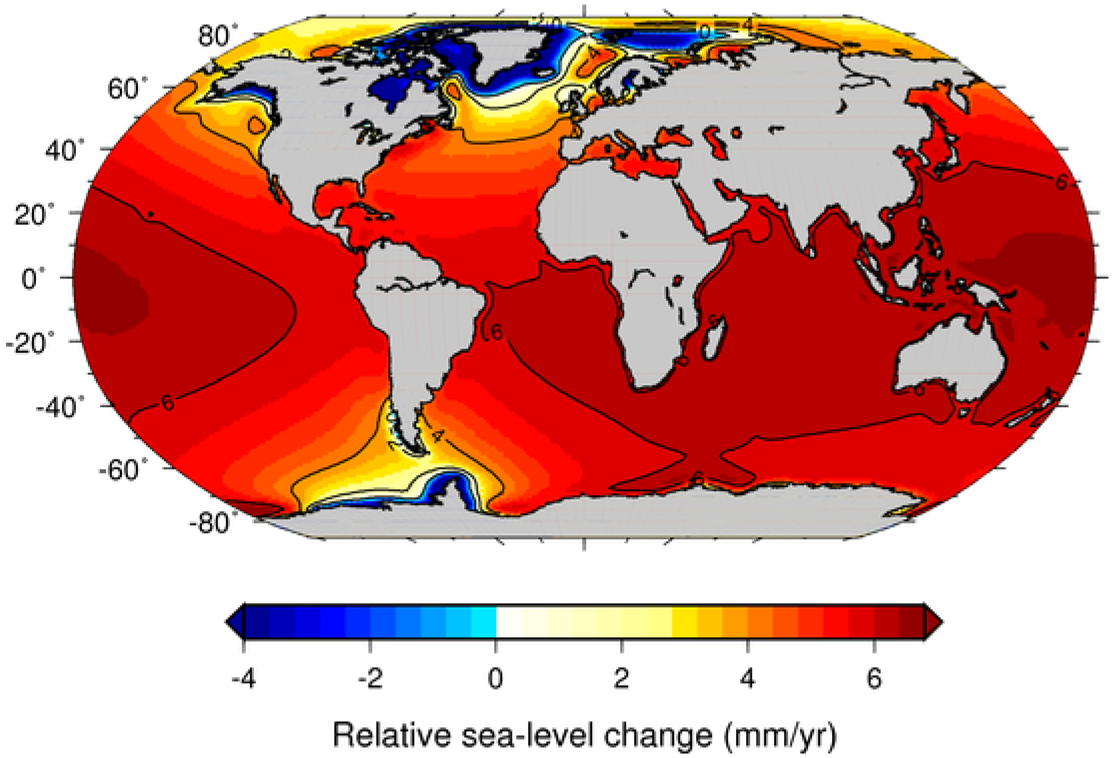

Figure S3. As for Figure S2 but with the ice melt contribution multiplied by a factor 4 for all sources.

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