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The causes of sea-level rise since 1900

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Global-mean sea level (GMSL) has been rising unsteadily by about 1.5 mm/yr since 1900, but the underlying causes of this trend and the multi-decadal variations are still poorly understood. Over the last few years, updated estimates of the underlying contributing processes have become available, notably for the contributions from glaciers, terrestrial water storage, the Greenland Ice Sheet, and thermal expansion. In parallel, 20th-century GMSL estimates have been revised downward as a result of improved reconstruction approaches, spatial bias correction schemes, and the inclusion of estimates of local vertical land motion at tide-gauge locations. Together, both developments now necessitate the re-evaluation of the GMSL budget to determine whether the observed sea-level rise since 1900 can be reconciled with the estimated sum of contributing processes.

Here we present a probabilistic framework to reconstruct and budget sea level with independent observations considering their inherent uncertainties. We find that the sum of thermal expansion, ice-mass loss and terrestrial water storage changes is consistent with the trends and multi-decadal variability in observed sea level on both global and basin scales, which we reconstruct from tide-gauge records.

Glacier-dominated cryospheric mass loss has caused twice as much sea-level rise as thermal expansion since 1900. Glacier and Greenland Ice Sheet mass loss well explains the high rates typically seen in global sea-level reconstructions during the 1930s, while a sharp increase in water impoundment by artificial reservoirs has been the dominant contributor to lower-than-average rates during the 1970s. The acceleration since the 1970s is caused by both thermal expansion and increased Greenland mass loss. No additional large-scale deep ocean warming or additional mass

loss from Antarctica are needed to explain 20th-century changes in global-mean sea level. This assessment reconciles the magnitude of observed global-mean sea-level rise since 1900 with estimates of underlying processes.