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Combining tide-gauge observations with estimates of spatial sea-level variability to improve reconstructions and to close the contemporary global and regional sea-level budget

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All processes that affect sea level show distinct regional patterns, and therefore, sea-level changes show considerable spatial variability. This spatial variability forms a challenge when reconstructing global and regional sea-level changes from tide gauges, which are only available at a limited number of locations and are mostly located along coasts in the northern hemisphere.

We can improve estimates of global and regional sea-level changes from tide-gauge records by explicitly taking the expected spatial variability into account. From estimates of global ice mass loss and land water storage changes, spatial sea-level fingerprints can be computed, which identify whether sea-level changes at specific tide-gauge locations are expected to be representative for global-mean or basin-mean sea-level changes. Furthermore, developments in altimetry and GPS now allow for reliable estimates of local vertical land motion (VLM) at an increased number of tide gauges.

We reconstruct global and regional sea-level changes since 1958 by combining the expected sea-level fingerprints with observations from tide gauges and GPS stations. The spatial sea-level fingerprints associated with glacial isostatic adjustment (GIA) and present-day ice mass loss and land water storage are used to detect and correct possible biases due to the uneven spatial sampling of the tide-gauge observations. The fingerprints that emerge from GIA and present-day mass redistribution have an earth-deformation component, which is also observed as VLM. Hence, care must be taken when combining spatial sea-level fingerprints with VLM observations to avoid double-counting of solid-earth deformation. By separating observed land motion into known and unknown sources, this double-counting is avoided.

For most ocean basins, the reconstructed sea-level changes can be explained by the combined effects of GIA, present-day mass redistribution, and ocean density effects. A substantial part of the observed decadal variability can be explained by ocean density variations, while trends and accelerations are mostly driven by ice and land water storage changes. The only exception is the South Atlantic Ocean. In this basin, reconstructed sea level cannot be reconciled with the underlying processes, which is probably related to the sparse tide-gauge coverage in this region.

When the regional sea-level estimates are merged into a global-mean estimate, we find a GMSL trend of 1.5 $\pm$ 0.2 mm/yr, and an acceleration of 0.07 $\pm$ 0.02 mm/yr^2. Both the global-mean trend and the acceleration can be explained by the sum of contributing processes, and hence, the global sea-level budget since 1958 can be considered closed without requiring a contribution of deep-ocean thermal expansion or pre-1990 Antarctic mass loss, although substantial uncertainty remains due to the sparsely-observed South Atlantic Ocean.