Effects of self-attraction and loading on sea level at monthly and longer time scales

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Outline

Problem:

Self-attraction and loading (SAL) effects associated with the Earth's constantly changing mass field can influence sea level variability on all time scales. Do we need to take these effects into consideration when interpreting and using altimeter surface height measurements?

Approach:

- Use “sea level equation” to determine monthly and longer period SAL effects on absolute sea level

- Investigate SAL effects related to variable loads from land hydrology and ice, atmospheric pressure, and ocean bottom pressure

- Relevant references for more details: Tamisiea et al. (2010, *J. Geophys. Res.*) and Vinogradova et al. (2010, *J. Geophys. Res.*)

Summary:

SAL effects are not easily parameterized and need to be calculated using the full physics of SAL. Loads from hydrology, atmosphere, and ocean can all be important, depending on time scale and region. Observed altimeter trends and other sea level variability can be measurably affected by SAL effects.

Self-attraction and loading

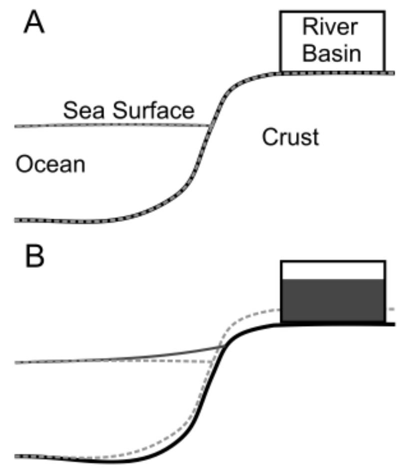

Fig. 1. Schematic of SAL effects on sea level from changes in water storage in a river basin. (A) Initial configuration of the sea surface and crust prior to loading. (B) Sea surface and crust after increase in river basin water storage (initial positions shown by the dashed lines).

- Under elastic assumption, sea surface and crust return to original positions after load is removed

- Similar adjustments occur under loads from atmospheric pressure or ice over land and from bottom pressure changes related to ocean dynamics

Parameterizing SAL?

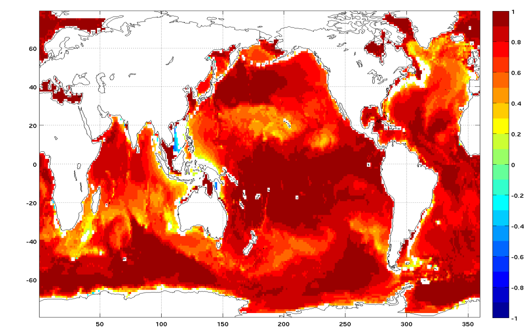

Fig. 2. Correlation between dynamic ocean bottom pressure loads and corresponding SAL perturbations calculated using the “sea level equation”. Only significant correlations are shaded.

- Correlation is highly variable in space and far from perfect in large areas

- Errors in using simple SAL parameterizations based on a constant proportionality factor are not negligible

- For most accurate results need to solve “sea level equation” as done here

- In addition no simple parameterizations are available to derive hydrology and atmospheric pressure SAL perturbations

Decadal trends from ice losses

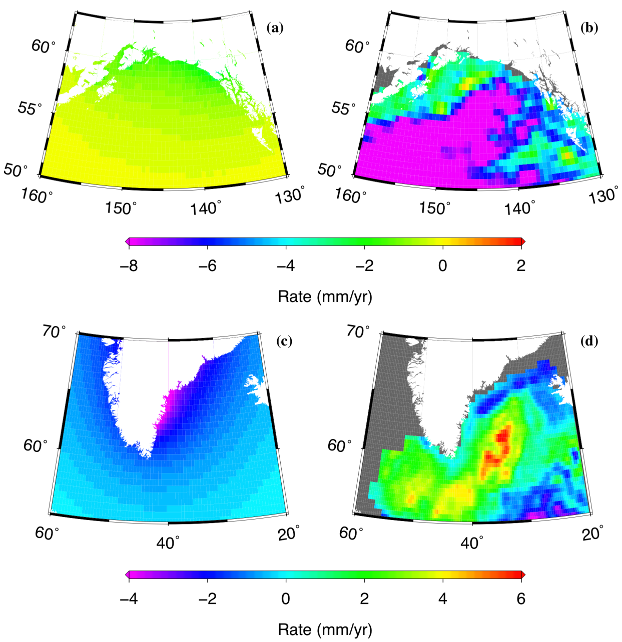

Fig. 3. Decadal trends in absolute sea level from SAL effects caused by estimated ice mass losses in **(a)** Alaska and **(c)** Greenland and respective altimeter sea level trends in **(b)** and **(d)**.

- Near-field trends caused by SAL amount to a few mm/yr and are an order of magnitude larger than the implicit global mean sea level trends from respective ice losses (~0.2 mm/yr for Alaska and ~0.3 mm/yr for Greenland)

- Magnitude of SAL effects on regional sea level trends is comparable to observed trends and can produce significant spatial gradients in the amplitude of the trends

- Proper interpretation of altimeter-observed trend patterns need to take into account the effects of SAL

Effects from hydrology, atmospheric pressure and bottom pressure

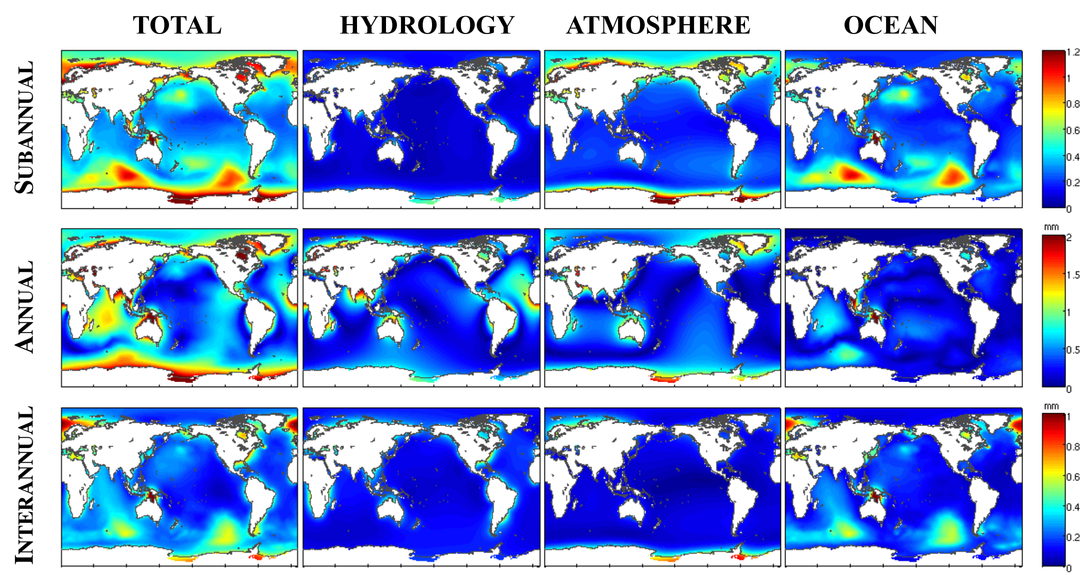

Fig. 4. Standard deviation in mm of SAL effects at (1st row) subannual, (2nd row) annual and (3rd row) interannual time scales estimated over 2002-2008. Combined effects and separate contributions from land hydrology, atmosphere and ocean dynamics are shown from left to right. Spatial mean values and a local trend are removed from each monthly field before calculation of standard deviations.

- Hydrology loads tend to have the largest effects on annual time scales, with ocean bottom pressure effects being more important at sub-annual and interannual time scales

- Atmospheric and hydrologic variations are largest closest to some continental boundaries

- Joint effects of all loads amount to typical magnitudes on sea level variations from the global average of at most a few mm

- Consideration of SAL effects for altimeter data analysis can be important in regions of weak barotropic variability (e.g., high southern latitudes)

- Different conclusions apply if one is interested in relative sea level or bottom pressure measurements (see Tamisiea et al. 2010 and Vinogradova et al. 2010)