Analysis of sea-level reconstruction techniques for the Arctic Ocean

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For reconstructing historical sea levels in the Arctic area, lack of data presents a major challenge. We attempt to adapt the model by Church et al. (2004), examining inclusion criteria for tide gauges in the area. The tide gauge records are taken from the PSMSL database.

The reconstruction model is based on spatial, stationary patterns of variability extracted from a calibration period, usually satellite data; however, for this exercise, we are using data from the Drakkar ocean model, covering the period 1950–2000 with monthly data. These patterns are determined as empirical orthogonal functions (EOFs). The model determines, for each point in time, an appropriately weighted sum of these, constrained locally by tide gauge records and regularized per Kaplan et al. (1997).

The leverage of each tide gauge is a statistical measure of its influence on the result. This way, we can readily identify possible outliers among the tide gauge records in a procedural, objective way.

We use the model described by Kaplan et al. (1997), i.e. minimizing the cost function

\[(H\alpha - G)R^{-1}(H\alpha - G) + a' A^{-1}a,\]

where \(E\) are the raw eigenfunctions from a calibration period, \(G\) are the tide gauge records, \(H\) an indicator matrix, \(R\) describes the error covariance, and \(A\) contains the retained eigenvalues. We solve for \(a\), giving coefficients for the eigenfunctions at each time step. To capture any overall trend in the data, the eigenfunction basis is augmented with an “EOF0” (a spatially uniform pattern). As in Church et al. (2004), we use first differences of the tide gauge time series, avoiding the need for a consistent vertical datum for the tide gauges, something that is hard to provide in gauge time series.

The reconstruction period 1950–2010 is as the only period where a reasonable amount of tide gauge data seems available. The calibration sea-level dataset is from the Drakkar ocean model (Barnier et al., 2006); it is intended to replace this with satellite altimetry in the long run.

Conclusions

The reconstructed development in Arctic mean sea level (above 68°N) shows an increasing trend of about 0.9 mm/yr for the 1950–2010 period. Although this is somewhat lower coastal MSL findings by Henry et al. (2012) (1.6 ± 0.11 mm/yr for the Norwegian and Russian sectors), the qualitative development is similar, with a positive trend of about 4 mm/yr between 1998 and 2010. Also, the lack of IB correction in our reconstruction (on the order of 0.3 mm/yr) may affect the results. While leverage is often used to identify dubious observations and outliers, in this case they might indicate appropriately influential gauges; by far the most variance in the area is explained by the uniform EOF0 and the practically uniform EOF1, and forcing these will introduce large changes to the reconstruction.

References