

Comment on "A Semi-Empirical Approach to Projecting Future Sea-Level Rise"

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Rahmstorf (Reports, 19 January 2007, p. 368) presented an approach for predicting sea-level rise based on a proposed linear relationship between global mean surface temperature and the rate of global mean sea-level change. We find no such linear relationship. Although we agree that there is considerable uncertainty in the prediction of future sea-level rise, this approach does not meaningfully contribute to quantifying that uncertainty.

Rahmstorf (*1*) proposed a relationship between global mean surface temperatures (*2, 3*) and the rate of global mean sea-level change (*4*). The approach assumes that "the rate of sea-level rise is roughly proportional to the magnitude of warming above the temperatures of the pre-Industrial Age" (*1*). On this basis, sea level is predicted to rise 0.5 to 1.4 m above the 1990 level by 2100. These estimates are considerably higher than those published in the Third Assessment Report of the Intergovernmental Panel on Climate Change (*5*) and therefore require closer inspection.

The calculation of the linear relationship between temperature and the rate of sea-level change (*1*) did not explore whether the calculated proportionality constant of 3.4 mm/year per °C applies to the time scales of most relevance to anthropogenic warming (i.e., decades to centuries). Figure 1A replicates figure 2 in (*1*). As in (*1*), both the temperature and sea-level time series are smoothed with the Monte Carlo singular spectrum analysis method (MC-SSA) (*6*) to remove energy with periods of less than 15 years. However, we split the data into four epochs that approximately relate to the four dominant periods of the temperature record (Fig. 1B), and we did not apply the 5-year binning procedure as in (*1*), because that further reduces the degrees of freedom. Figure 1A clearly demonstrates that no linear relationship exists on a 50-year time scale, which is 50% of the 100-year period for which predictions were made in (*1*).

We note that using the model $dH/dt = a(T - T_0)$ (where a is the proportionality constant, T is the global mean temperature, and T_0 is the previous equilibrium temperature value), with the quoted values of $a = 3.4$ mm/year per °C and $T_0 = -0.5$ °C (*1*), gives $dH/dt = 1.7$ mm/year with zero (average) change in temperature (i.e., with

$T = 0$). This shows that the mean rate obtained from this model over the past century agrees well with other estimates of sea-level rise over the past

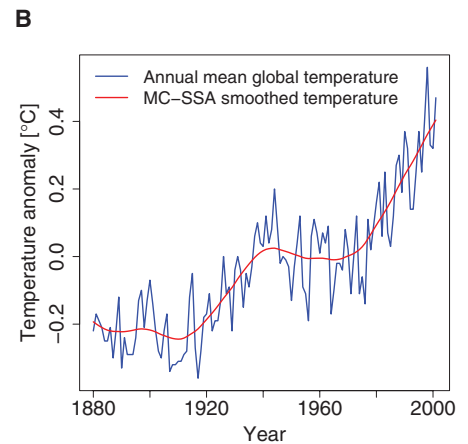
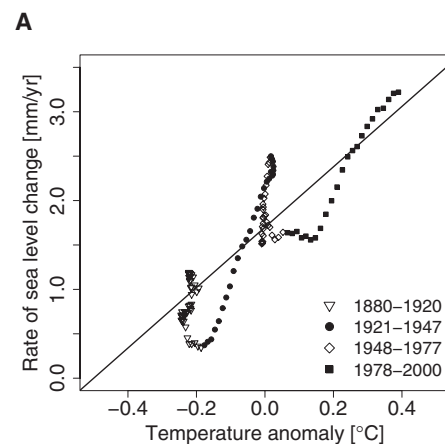
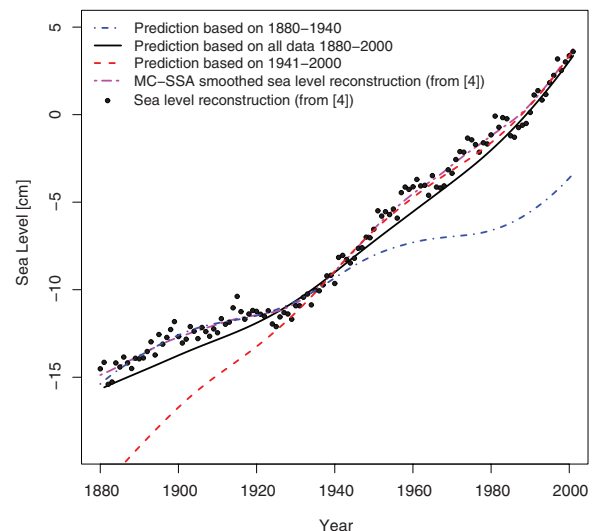


Fig. 1. (A) The relationship of the rate of global mean sea-level rise (*4*) to global mean surface temperature (*2, 3*) with the data divided into four epochs, each showing a different relationship between the variables. This figure is similar to figure 2 in (*1*) but without the binning into 5-year averages so as to better illustrate the data clustering. **(B)** The global mean surface temperature record (*2, 3*), annual data and data smoothed using the MC-SSA method (*6*). The four epochs described in (*A*) relate to the four sections of the temperature record that can be clearly seen.

Fig. 2. Hindcasts of the global mean sea level based on linear rates calculated from the full data set as in (*1*) and based on rates calculated from the first and second halves of the reconstructed sea-level record (*4*). The mean rate of sea-level rise is 0.86 mm/year based on the first half of the record and 1.98 mm/year based on the second half of the record. The mean rate for the 1887 to 1994 period based on the sea-level reconstruction (*4*) is 1.49 mm/year.



100 years [e.g., (*4, 7*)]. However, the issue is whether this model can provide information at shorter periods than the century scale and be used to predict global sea levels some decades into the future.

A reasonable test of the strength of a model is its ability to predict observations that are not already included in its formulation. To illustrate the nonlinearity of the temperature/sea-level change relationship, we calculated linear coefficients for the first half of the observational record and then proceeded to predict the remaining observations. We also used the second half of the data set to hindcast sea levels during the earlier part of the record. To make this testing sensitive to changes on time scales of decades, which are of most interest for prediction, we detrended both the smoothed surface temperatures and the smoothed sea levels for the first and second halves of the data before calculating the annual rates of sea-level change (detrending improves the results but does not change their character). We then calcu-

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lated the linear regression coefficients for the two halves of the data (a_1, a_2) along with the equivalent values of T_0 (i.e., T_{01}, T_{02}). Finally, to obtain the full dH/dt , we added back the linear trend, which had been subtracted from the sea levels. From the above regression, we obtain $a_1 = 8.26$ mm/year per °C and $T_{01} = -0.12$ °C for the first half of the data and $a_2 = 6.60$ mm/year per °C and $T_{02} = -0.32$ °C for the second half, compared with $a = 3.4$ mm/year per °C and $T_0 = -0.5$ °C from fitting the whole data set. The root mean square error is 0.21 mm over the first half of the record to which the data are fitted and 0.35 mm over the second half of the record when the data are fitted to that. This is in comparison with 0.62 mm for the model when fitted to all the data, illustrating that we do indeed obtain a better fit to the data included in the model over shorter time periods. The results of this analysis are shown in Fig. 2, which shows

that at the 50- to 100-year time scale, the linear relationship has little skill in predicting the observations not included in the original model formulation. Using the coefficients obtained from the first half of the data, a trend in sea level of 0.86 mm/year is predicted for the entire 122-year period, whereas using the second half of the data, a trend of 1.98 mm/year is calculated. These compare with a trend of 1.49 mm/year for the sea-level reconstruction (4) to the time period over which the model is formulated.

In conclusion, although we agree that there is considerable uncertainty in future projections of sea-level change and that model predictions currently appear to underestimate observations, we do not agree that simplistic projections of the nature presented in (1) substantially contribute to our understanding of the uncertainties in the nonlinear relationships of the climate system.

References and Notes

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