Critique of the methods used to project global sea-level rise from global temperature

Based on previous work (1), Vermeer and Rahmstorf (2) proposed a model to link global surface temperature (T) and sea level (H) (Eq. 1):

$$dH/dt = a(T - T_0) + b dT/dt \quad [1]$$

where a , T_0 , and b are parameters that were estimated for both synthetic and real data. The model was fitted to global sea-level (3) and surface-temperature time series (4), combining an iterative procedure with simple linear regression, and it was used to project future sea-level rise.

All these machinery called our attention, given that the model can be fitted directly using the explicit form of the equation above (Eq. 2)

$$H_t = H_0 + a \sum_0^t T_i - aT_0(t - t_0) + b(T_t - T_{t_0}) \quad [2]$$

where sea level at year t depends on a mean level (H_0) and terms representing presumed linear relationships with (i) the cumulated sum of temperature anomalies up to year t , (ii) the number of years since the first date considered, and (iii) the temperature during year t with respect to the temperature during the first year. When this equation is fitted to smoothed and binned observations, parameter estimates and projections of future sea-level rise are, as expected, similar to those presented in ref. 2. However, updated parameter estimates improved the ability of the Rahmstorf (1) model to fit the data and resulted in projections of sea-level rise similar to those produced by the extended version of the model (2) (Table 1).

Nevertheless, our main concern with the study by Vermeer and Rahmstorf (2) is the inconsistent inclusion of the terms representing the effect of temperature on sea-level rise. The

terms on the right-hand side of Eq. 1 and Eq. 2 are highly correlated. This results in confounded estimates of model parameters because, given the data (Fig. 1), we will instead expect a negative, probably spurious, effect for $\sum_0^t T_i$ and a positive relationship between H_t and T_t . This last effect would indeed provide a better representation of observations (e.g., T and H are both increasing, although T is increasing slightly more rapidly). The observed negative correlation between $\sum_0^t T_i$ and t (Fig. 1) turns positive when temperatures from the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR4) (5) are used to project sea level. In these situations, the effects of collinearity become dangerous (e.g., model parameters are based on a population of observations with a correlation structure quite different from that of the data used in projections). The change in the sign of the net effect of the term, including $\sum_0^t T_i$, between the two periods considered points in this direction (Table 1).

We want to stress that this is only a critique to the methods used in refs. 1 and 2. These studies highlight the pressing need for accurate projections of future sea-level rise, one of the main concerns associated with climate change. Although we do not agree with their current approach, we hope the ideas they pursued would help inspire better approaches to solve this critical concern (5).

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Equation	Period	Contribution to sea-level rise (cm)			Sea-level increase (cm)
		$a \sum_0^t T_i$	$-aT_0(t-t_0)$	$b(T_i - T_{t_0})$	
$H_t = H_0 + a \sum_0^t T_i - aT_0(t-t_0)$	1880–2000	−3.16	24.3	—	21
$H_t = H_0 + a \sum_0^t T_i - aT_0(t-t_0)$	2000–2100	100 (80, 115)	20.3	—	121 (100, 135)
$H_t = H_0 + a \sum_0^t T_i - aT_0(t-t_0) + b(T_i - T_{t_0})$	1880–2000	−3.67	28.7	−4.04	21
$H_t = H_0 + a \sum_0^t T_i - aT_0(t-t_0) + b(T_i - T_{t_0})$	2000–2100	117 (93, 134)	23.9	−18.1 (−21.7, −13.1)	122 (103, 137)

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