Reply to: Rahmstorf, S. and Vermeer, M., 2011. Discussion of: Houston, J.R. and Dean, R.G., 2011. Sea-Level Acceleration Based on U.S. Tide Gauges and Extensions of Previous Global-Gauge Analyses. Journal of Coastal Research, 27(3), 409–417

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REPLY

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Rahmstorf and Vermeer (RV) argue that modeling sea level as a function of temperature using their semi-empirical approach as presented by Rahmstorf (2007) and Vermeer and Rahmstorf (2009) is superior to the standard approach of analyzing sea-level rise as a function of time used by Houston and Dean (2011). Their criticism applies not only to this paper, but also to the work of eminent sea-level experts such as Douglas, Holgate, Woodworth, and others who have used the same standard approach we use. In making this claim, RV present their Figure 1 as the key evidence supporting the efficacy of their model. Figure 1 purports to show good agreement between accelerations based on their modeling and accelerations based on the data of Church and White (2006). However, it is easily seen that the portion of Figure 1 where the agreement is "good" compares their modeling versus increasingly meaningless data, and they have been selective in showing only data that appear to match their modeling and not the data that strongly disagree.

Houston and Dean (2011) considered only tide-gauge records with lengths greater than 60 years, noting that shorter record lengths are "corrupted" by decadal fluctuations. Douglas (1992) shows that as a result of decadal fluctuations, as record lengths become increasingly shorter than approximately 50–60 years, about half of tide-gauge records display increasingly large positive accelerations, while the other half displays increasingly large negative accelerations. These positive and negative accelerations are uncorrelated to accelerations based on record lengths greater than approximately 50–60 years. Note in Figure 1 that as the record length becomes shorter, the 2-sigma range becomes increasingly large so that for most of the right-hand side of Figure 1 it is not possible to know whether the accelerations are positive or negative, making comparisons increasingly meaningless.

In Figure 1, RV show only the data that agree with their model. On the x axis of Figure 1, record lengths are shorter than 60 years for starting years after around 1940. It happens that at around 1940 the acceleration shown is approximately zero. Thus, as seen in Figure 2, the record from 1940 to 2001 has a strong linear trend with decadal fluctuations but approximately no acceleration. If the record from 1940 to 2001 has zero acceleration, how is it then possible that all shorter records (starting years after 1940) shown in Figure 1 have positive accelerations that increase as record lengths shorten? It is not possible. Again, RV only plot the data as long as they agree with their model. If the plot is extended, *e.g.,* to the starting year of 1985, the acceleration is -0.044 mm/y^2, more than twice the range shown for negative accelerations in Figure 1. If the plot is extended further, the folly of analyzing records shorter than approximately 60 years becomes increasingly obvious. The acceleration for a starting year of 1995 is -0.51 mm/y^2, about 25 times the range shown for negative accelerations in Figure 1. RV compare their model to data as long as there are positive accelerations and do not continue the plot when accelerations become negative, which must happen for the overall record from 1940 to 2001 to have an acceleration of approximately zero. Their rationale for stopping at a starting time of 1970 is that after 1970 "… short-term noise dominates the calculations and results oscillate strongly" (p. 789). But Douglas (1992) shows, *e.g.,* that 30–40-year record lengths (starting times 1960 and 1970 in Figure 1) show positive and negative accelerations 10–20 times larger than accelerations determined from 80-year records. Yet RV criticize our analysis of 80-year records from 1930 to 2010 as being too short. The fact is that decadal fluctuations begin to dominate records shorter

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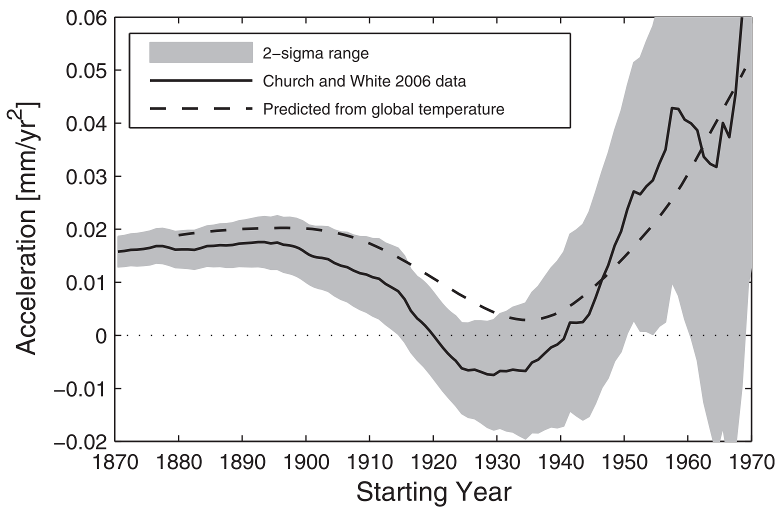

Figure 1. From Comment by Rahmstorf and Vermeer.

than about 60 years, and accelerations become increasingly meaningless for starting years in Figure 1 greater than about 1940. Moreover, positive accelerations peak some time after the starting time of 1970 and eventually plunge to very large negative values. In summary, RV compare their model results to meaningless data after the starting year of about 1940 and are selective in only showing data with positive accelerations after 1940.

Church *et al.* (2004) correctly analyze the same data set (their own) that RV incorrectly analyze and conclude that "Decadal variability in sea level is observed but to date there is no detectable secular increase in the rate of sea level rise over the period 1950–2000" (p. 2624). This conclusion is evident from Figure 2 and in stark contrast to the claims of RV and the acceleration they show in Figure 1 for a starting year of 1950.

RV link sea-level rise with temperature using a simple linear relationship with two free variables of opposite signs that allow them to "fit" any smooth data set. However, they are curve fitting, not modeling physics, so the approach cannot be used to predict future sea level. *Holgate et al.* (2007) criticized RV's assumption of a linear relationship between global mean surface temperature and the rate of global mean sea-level change and concluded, "We find no such linear relationship" (p. 1866b). Further they concluded, "… 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" (p. 1866b). A recent workshop of the Intergovernmental Panel on Climate Change (IPCC, 2010) considered the semi-empirical approaches of Rahmstorf (2007), Vermeer and Rahmstorf (2009), and others and concluded, "No physically-based information is contained in such models …" (p. 2) and "The physical basis for the large estimates from these semi-empirical models is therefore currently lacking" (p. 2).

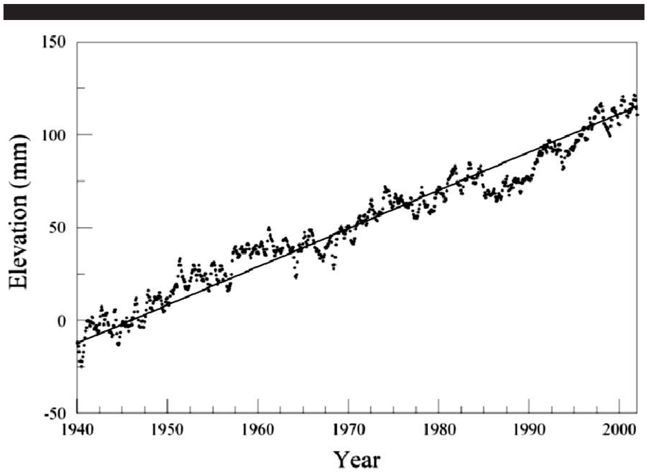

Figure 2. Church and White (2006) data from 1940–2001.

RV also present less fundamental criticisms of Houston and Dean (2010). For example, they note that data considered by Houston and Dean are biased to the northern hemisphere. This criticism would apply to any study of sea-level rise and is attributable to the lack of historical tide-gauge data in the southern hemisphere. In fact, it applies to the historical temperature that RV use in their analysis. However, we note that Watson (2011) published an analysis of sea level in Australia and obtained small decelerations very similar to those of our study.

RV argue that impoundment by dams decreased the rate of sea-level rise after around 1960. They say that our paper claims that groundwater mining would offset this impoundment, and they then argue that this mining is relatively small. They neglect to mention that groundwater mining is only one of the offsetting factors given in Houston and Dean. Houston and Dean (2011) state, "However, in the IPCC, Bindoff et al. (2007) note that the reservoir impoundment is largely offset by other anthropogenic activities that accelerated since 1930, such as groundwater extraction, shrinkage of large lakes, wetland loss, and deforestation" (p. 415). Houston and Dean further state that "Huntington (2008) showed ranges of the contribution of each term of the land–water interchange determined in several studies and concluded that the net effect of all the contributions was to increase the sea-level trend" (p. 415). This conclusion is in direct opposition to the claim of RV that impoundment by dams significantly decreased the rate of sea-level rise.

The important conclusion of our study is not that the data sets we analyze display small sea-level decelerations, but that accelerations, whether negative or positive (we reference studies that found small positive accelerations), are quite small. To reach the multimeter levels projected for 2100 by RV requires large positive accelerations that are one to two orders of magnitude greater than those yet observed in sea-level data.

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