Science AAAS

# Comment on "Global Trends in Wind Speed and Wave Height"

Frank J. Wentz and Lucrezia Ricciardulli

*Science* **334**, 905 (2011);
DOI: 10.1126/science.1210317

# Comment on "Global Trends in Wind Speed and Wave Height"

**Frank J. Wentz* and Lucrezia Ricciardulli**

Young *et al*. (Reports, 22 April 2011, p. 451) reported trends in global mean wind speed much larger than found by other investigators. Their report fails to reference these other investigations and does not discuss the consequences that such large wind trends would have on global evaporation and precipitation. The difference between their altimeter and buoy trends suggests a relatively large trend error.

Surface wind is an important driver of oceanic and atmospheric circulation. Even small wind trends can have a large impact on atmospheric and ocean dynamics, on air-sea fluxes, and on the hydrological cycle (*1*–*3*). An excellent review of global wind trends is given by Tokinaga and Xie (*4*).

Young *et al*. (*5*) appear to be unaware of these other investigations. Their statement that "the radar altimeter provides by far the longest-duration record" of wind speed suggests that they are also unaware of the multitude of satellite microwave (MW) radiometers and scatterometers that have been launched since 1987, all of which provide highly accurate ocean measurements of wind speed. For example, one series of MW radiometers, the SSM/Is (special sensor microwave/imagers), has been in continuous operation without interruption for 25 years, which is longer than the continuous operation of altimeters. Furthermore, the spatial sampling of the MW radiometers and scatterometers is greatly superior to the altimeters because they have swath widths of 1000 to 1400 km, as compared with the altimeter swath width of about 5 km. The paper has no references to any of the wind results coming from these other satellite sensors.

More important, the reported wind trends in the paper are 2.5 to 5 times higher than those reported by other investigators (*2*, *4*). Using SSM/I winds, Wentz *et al*. (*2*) report a 1987 to 2006 global trend over the oceans of 0.08 m $s^{-1}$ $decade^{-1}$ (1.0% $decade^{-1}$) and also provide a wind trend map for this period. By adjusting ship-based anemometer readings to agree with wave observations, Tokinaga and Xie (*4*) estimated the 1988 to 2008 global wind trend to be 0.084 m $s^{-1}$ $decade^{-1}$ (1.1% $decade^{-1}$). Their paper reviewed wind trends reported by other investigators and from several reanalysis data sets. Excluding an uncorrected ship-based data set, which was known to be spurious, the global wind trend estimates that exceed the 99% confidence level ranged from 0.9% to 1.8% $decade^{-1}$. Their estimate of the SSM/I wind trend in the ship-sampled regions for 1988 to 2008 is 0.134 m $s^{-1}$ $decade^{-1}$ (1.7% $decade^{-1}$), which is 0.05 m $s^{-1}$ $decade^{-1}$ higher than the ship value. This difference is within the error bar reported by (*2*). They also found a very high correlation of their monthly winds with the SSM/I retrievals, exceeding 0.98 in most areas. In contrast to these previous investigations, Young *et al*. (*5*) report a global trend over the oceans of 2.5% to 5% per decade for the 1991 to 2008 period.

Perhaps the strongest argument against such high wind trends is the effect this would have on global evaporation. About 86% of the world's evaporation comes from the oceans, and evaporation is directly proportional to wind speed. Evaporation also depends on the surface relative humidity (RH) (*6*), but current climate modeling predicts a relatively stable RH, and no substantial RH trend has been observed (*7*). If RH remains constant, a 2.5% (5%) $decade^{-1}$ increase in winds would result in a 5% (10%) increase in evaporation and precipitation over 20 years. This is an enormous increase and would certainly have been observed by precipitation-measuring satellites. It has not been (*2*, *8*).

To further put this into perspective, both climate models and satellite observations agree that the total water in the atmosphere increases at the Clausius-Clapeyron (CC) rate of 6.5%/K as the climate warms (*2*). However, most climate models predict a muted response of evaporation and precipitation to warming, on the order of 2.5%/K. This muted response is due to radiative constraints on the surface energy budget (*3*, *9*, *10*). Changes in forcing mechanisms like cloud cover and type or aerosols can increase this muted response, but the CC rate of 6.5%/K is a reasonable upper bound. During the past two decades, the surface and lower troposphere warmed at a rate near 0.2K $decade^{-1}$ (*2*). Hence, the expected increase in evaporation is between 1% (radiative cooling constraint) and 2.6% (upper CC limit). The increase of 5% to 10% in evaporation implied by the large wind trends (*5*) is far above even the upper limit.

Most climate models do not predict a significant increase of global surface winds in response to anthropogenic forcing. Rather, a robust prediction of the models seems to be a weakening of the tropical circulation (*11*). The observational data also suggest a weakening of the trade winds over the past decades (*12*–*14*). Young *et al*. (*5*) wind trends are positive almost everywhere.

Young *et al*. (*5*) give no error estimates on their results, but an error can be inferred from their table 1, which compares altimeter-derived trends with buoy trends. Our Fig. 1 gives the root mean square (RMS) difference and correlation of

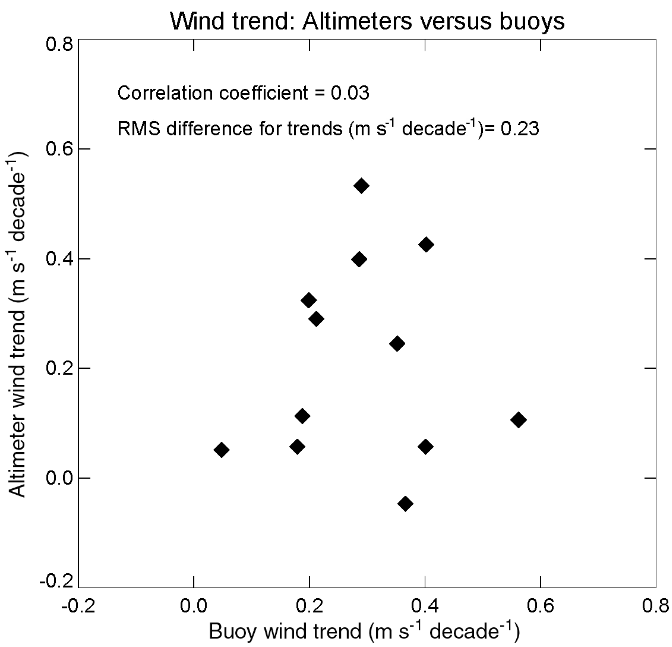


**Fig. 1.** Plot of altimeter versus buoy wind trends (m $s^{-1}$ $decade^{-1}$) for the 12 selected buoys, as given in table 1 of Young *et al*. (*5*). The figure includes the correlation coefficient and the RMS difference for buoy minus altimeter wind trends. For a mean global wind of 7.5 m/s, the RMS corresponds to 3.1% $decade^{-1}$.

Remote Sensing Systems, 444 10th Street, Santa Rosa, CA 95401, USA.

*To whom correspondence should be addressed. E-mail: frank.wentz@remss.com

the mean altimeter and buoy trends. The RMS difference is 3.1% decade$^{-1}$, which is of the same order as the estimated mean trend.

Young *et al*. (*5*) present a trend map of the NCEP/NCAR (National Centers for Environmental Prediction/National Center for Atmospheric Research) reanalysis winds and say that it is "qualitatively consistent" with the altimeter but do not provide any statistics. When we look at the two maps [Figure 1 and fig. S6 in (*5*)], we see very different patterns, such as large basin-wide areas in the Atlantic and Indian Ocean where NCEP/NCAR is showing negative trends and the altimeter is showing positive trends.

Thus far, our comments have been related to the mean trends found by Young *et al*. (*5*), not their 90th and 99th percentile results. Considering the very small sample size, the altimeter versus buoy error for the mean results, the decrease in radar sensitivity at high winds, and the inherent difficulty in constructing precision time series from multiple satellites, we find it hard to place much credence on the claim that high winds have increased by 15% over the past 20 years. A recent study (*15*) using wide-swath satellite radiometer wind retrievals show the opposite effect: a decrease in the frequency of tropical high-wind events.

In summary, we question the validity of global wind trends at the 2.5 to 5% decade$^{-1}$ level. Such a large increase disagrees with wind retrievals from wide-swath satellite radiometers and scatterometers over the past 25 years. Furthermore, the associated increase in global evaporation and precipitation that would have occurred is unreasonably high. Finally, the difference of 3.1% decade$^{-1}$ between the altimeter wind trends and those from the collocated buoys is probably indicative of the inherent error in the wind trends reported in this paper.

**References**

1. L. Yu, *J. Clim.* **20**, 5376 (2007).
2. F. J. Wentz, L. Ricciardulli, K. Hilburn, C. Mears, *Science* **317**, 233 (2007).
3. I. M. Held, B. J. Soden, *J. Clim.* **19**, 5686 (2006).
4. H. Tokinaga, S.-P. Xie, *J. Clim.* **24**, 267 (2011).
5. I. R. Young, S. Zieger, A. V. Babanin, *Science* **332**, 451 (2011).
6. T. Schneider, P. A. O'Gorman, X. Levine, *Rev. Geophys.* **48**, RG3001 (2010).
7. A. Dai, *J. Clim.* **19**, 3589 (2006).
8. R. F. Adler *et al*., *J. Geophys. Res.* **113** (D22), D22104 (2008).
9. M. R. Allen, W. J. Ingram, *Nature* **419**, 224 (2002).
10. G. L. Stephens, T. D. Ellis, *J. Clim.* **21**, 6141 (2008).
11. G. A. Vecchi, B. J. Soden, *J. Clim.* **20**, 4316 (2007).
12. S. K. Gulev, V. Grigorieva, *Geophys. Res. Lett.* **31**, L24302 (2004).
13. G. A. Vecchi *et al*., *Nature* **441**, 73 (2006).
14. H. Tokinaga, S.-P. Xie, *Nat. Geosci.* **4**, 222 (2011).
15. G. Gastineau, B. Soden, *Geophys. Res. Lett.* **38**, L09706 (2011).

24 June 2011; accepted 19 October 2011
10.1126/science.1210317