Reply to comment by F. Feser et al. on 'Improved global maps and 54-year history of wind-work on ocean inertial motions'

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[1] In their comment, *Feser et al.* [2003] argue that the NCEP Reanalysis surface winds used by *Alford* [2003; henceforth A03] are artificially high at high frequencies due to temporal aliasing. This possibility is investigated here by direct comparison with buoy winds in the northeastern Atlantic. As in a previous more extensive buoy comparison in the Pacific [*Alford*, 2001; henceforth A01], no evidence for aliasing of NCEP winds is found. *INDEX TERMS:* 3337 Meteorology and Atmospheric Dynamics: Numerical modeling and data assimilation; 3339 Meteorology and Atmospheric Dynamics: Ocean/atmosphere interactions (0312, 4504); 4544 Oceanography: Physical: Internal and inertial waves. **Citation:** Alford, M. H., Reply to comment by F. Feser et al. on 'Improved global maps and 54-year history of wind-work on ocean inertial motions,' *Geophys. Res. Lett.*, *30*(22), 2166, doi:10.1029/2003GL018543, 2003.

[2] The goal of A03 was to improve upon the initial estimate by A01 of the global distribution of work done by the wind on the ocean mixed-layer using National Center for Environmental Prediction (NCEP) Reanalysis winds [*Kalnay et al.*, 1996]. Because the ocean's response is strongly peaked at the local inertial frequency (f $\equiv$ 2 sin [latitude] cycles per day), the NCEP winds' 4x-daily sampling frequency is satisfactory at low latitude, but barely adequate at high latitudes. (For example, at the poles, the inertial frequency and the NCEP winds' Nyquist frequency are equal at 2 cpd.) To quantitatively address the effects of finite temporal resolution on the study, a high-resolution regional model of the northeast Atlantic (REMO, *Feser et al.* [2001]), whose hourly sampling is more than adequate, was used as a benchmark.

[3] In the comparison, whose details are given in A03, it was found that the REMO and NCEP winds always agreed well at low frequency, but for frequencies > 0.5 cpd, the REMO spectra were lower than the NCEP spectra (by a latitude-independent factor of $1.32^2 = 1.74$ at a frequency of 1.3 cpd). Based on excellent agreement between 18 National Data Buoy Center (NDBC) buoys and the NCEP winds over 4 years from latitudes 40–60N in the Pacific, A01 concluded that the NCEP winds were bias-free.

[4] In their comment, *Feser et al.* [2003] write that temporal aliasing artificially elevates high-frequency NCEP spectra above REMO. To support their interpretation, they sub-sample the REMO winds at 6-hourly intervals to match the NCEP winds, noting that their sub-sampled REMO spectra are closer to the NCEP spectra. However, this only demonstrates the effect of subsampling on the REMO spectra, offering no information on aliasing in the NCEP spectra.

[5] Much preferable to model-model comparisons are direct comparisons with buoy wind measurements, which have long provided vital validation for models and remote sensing techniques, and are the best available ground-truth. In the short time available for this reply, the National Climatic Data Center (NCDC) has provided me with archived time series from two UK meteorological buoys in the REMO domain (both near 51N, 15W), one from 1988 (the year of the REMO winds used in A03) and one from 2002 (Figure 1). Power spectra from 1988 (panel a) confirm that buoy (black) and NCEP spectra (blue) agree well with each other, and exceed the REMO spectra at the same location (red) at high frequency. By plotting the spectral ratios (panel c) of NCEP/buoy (blue) and REMO/buoy (red), the attenuation of the REMO wind spectra by O(1/1.74) for frequencies >0.5 cpd is clear. Furthermore, the REMO spectra were not significantly raised by sub-sampling at 6-hour intervals as *Feser et al.* [2003] did (panel b, green line). The steep slope ("redness") of the true spectrum prevents aliasing from significantly raising the portion of the spectrum below 1/(6 hour). It is difficult to reconcile this observation with *Feser et al.* [2003]'s finding that the REMO spectrum was elevated when subsampled, since their highest plotted frequency is 2 cpd, even though the REMO Nyquist frequency is 12 cpd. In addition, the location they chose for the comparison was very close to the domain's edge, where NCEP winds are applied as a boundary condition, so agreement there is forced. It is not clear what effects this has on their results. (A03 excluded this boundary region from his analysis.)

[6] REMO data from 2002 are not presently available to me, but the NCEP and buoy spectra agree extremely well at that location and year, too (Figure 1, d–e). The 6-hour-subsampled buoy spectrum (green line) is not significantly elevated above the 1-hour quantity, again indicating the ineffectiveness of aliasing at elevating the resolved portion of the spectrum. This also confirms that the 1988 winds, which were unfortunately only archived at 3-hour intervals, are not affected by aliasing.

[7] This note has shown that NCEP surface wind spectra near 50N, 15W agree well with those of directly measured, ground-truth buoy measurements (as seen before at 18 buoys in the North Pacific), while spectra of the REMO winds fall below both of them by a factor of 1.7 for frequencies >0.5 cpd. It is not intended to rule out the possibility of aliasing in NCEP winds at other locations and times, which *is* conceivable due to unresolved scales and processes in the NCEP model [W. Ebis (NCEP), pers. comm.]. However, neither a search of the literature, an

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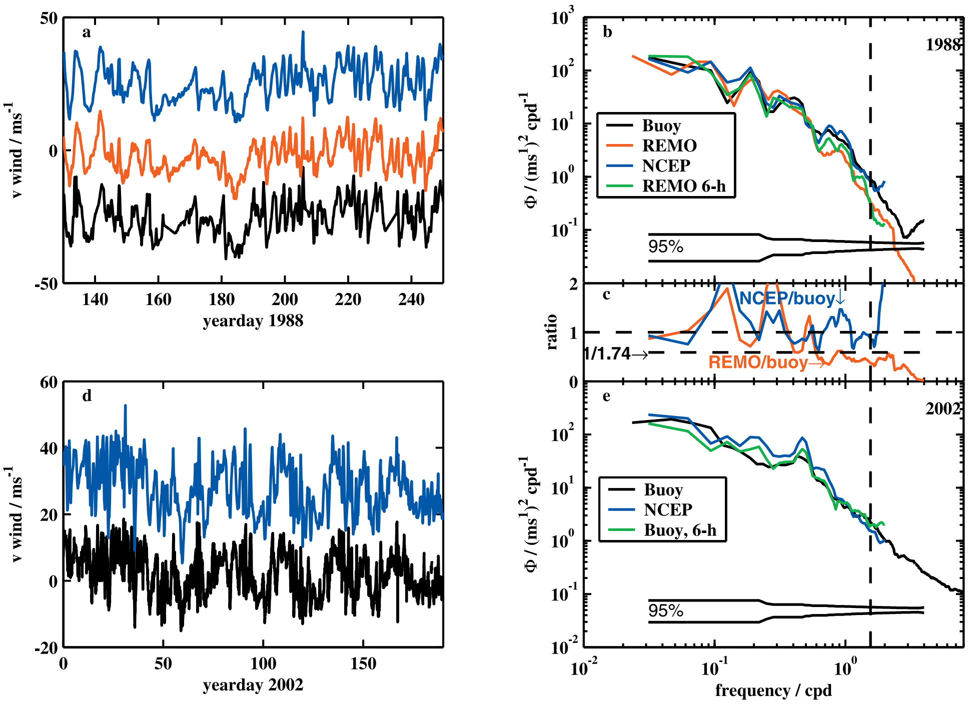

Figure 1. (a) Time series of 1988 meridional wind from UK meteorological buoy 62006 (51.1N, 14.1W, black), REMO (51N, 14W, red), and NCEP (50N, 15W, blue). Traces are offset by 25 m s^{-1}. (b) Corresponding power spectra. Spectra are computed using Welch's method from overlapping 60-day segments of wind from the period shown at left. Each segment is demeaned, detrended and Hanned before Fourier transforming and averaging together. The buoy (black) and NCEP spectra (blue) agree well, but the REMO data (red) are a factor of 1.7 below both of them. The spectrum of 6-hour subsampled REMO data (green) is also well below the buoy and NCEP spectra. The dotted line is the inertial frequency, f $\approx$ 1.6 cpd. (c) Spectral ratios: NCEP/buoy (blue) and REMO/buoy (red). (d) Time series of 2002 meridional wind from UK buoy 62081 (51.0N, 13.3W, black) and NCEP (50N, 15W, blue). (e) Corresponding power spectra. Green line is the buoy wind subsampled to 6-hour intervals.

18-buoy, 4-year buoy/NCEP comparison in the Pacific, nor the present small Atlantic study has revealed any evidence for it.

[8] Neither is this note meant to undermine the validity of the REMO model; to the contrary, the low-frequency REMO winds appear extremely accurate. High-frequency coherence between REMO and NCEP is also high - application of a small latitude-indendent spectral correction factor (Figure 1c) renders the REMO winds extremely valuable over all resolved frequencies. This was the reason for using the REMO winds as a benchmark in the first place.

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