Testing Winds Against Other Variables from COADS

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Introduction

Several investigators have noted and commented on the appearance of multidecadal secular trends in surface wind speed records from COADS summaries (as well as the data sets from which these summaries are derived) for various eras and areas. Most commonly, secular increases have been reported (Ramage, 1987; Wright, 1988; Cardone et al., 1990; Isemer and Hasse, 1991), and are dismissed as artifacts of the observing system, In some cases secular decreases have been reported (Cardone et al., 1990; Ward, 1992). Some investigators also interpret the apparent trends as indicative of real changes in air-sea interaction processes (Bunker, 1980; Whysall et al., 1987; Flohn and Kapala, 1989).

In applying the COADS for the North Atlantic Ocean from the period 1951-1987 to investigations for the NOAA Atlantic Climate Change Program, we too noticed a prevalence of secular increase over much of the region for this period. The secular increase is most evident in the monthly mean scalar wind speeds. Figure 1 shows the monthly time series of wind speed from the COADS summary for an exemplary two-degree square in the central subtropical Atlantic, and the secular trend line derived of a linear least square fit to the time series of monthly mean speeds. We decided to investigate more closely the prevalence and reality of this apparent secular increase of winds.

Approach

We chose to revisit, within the confines of the COADS summaries, the question of whether the apparent increase of wind speed in the COADS summaries is indicative of a true climate variation or an artifact of the observing system, by applying consistency tests to other variables contained in the COADS summaries. We selected data from the COADS trimmed file covering the North Atlantic region illustrated in Fig. 2. These 359 two-degree by two-degree squares from COADS were chosen for completeness of the monthly mean time series during the 37-year period 1951-1987. They also are sufficiently distant from coasts to enable computation of sea level pressure gradients across each, in anticipation that these gradients will be an important ancillary variable. To provide some regional discrimination, we divided the data into high, middle, and low latitude zones for analyses, using cuts at 30°N and 40°N.

Linear least square fits to the monthly mean wind speed data, as exemplified by Fig. 1, were made for all of the 359 two-degree by two-degree squares. The secular trend of wind speed was positive in 97 percent of the two-degree squares of latitude greater than 40°N, and 99 percent of those of less than 40°N. For samples the size of those from our three regions, the non-parametric sign test indicates a median value greater than zero at 95 percent or higher confidence level for 58 percent or more positive values. A secular increase evidently is essentially ubiquitous in data from the region shown in Fig. 2. The exemplary illustration of Fig. 1 shows the median value, 2.6 cm s^{-1} yr^{-1}, for the entire region.

The most important ancillary variable obtainable from the COADS summaries is the sea level pressure gradient, from which an often fictitious but useful variable, the sea level geostrophic wind, can be computed. As the geostrophic wind computed from the monthly mean sea level pressure from the COADS summaries is intrinsically a vector average, it must be compared to the average component winds, or their modulus, from COADS. These vector averages can, of course, be quite different from the scalar average wind speed. The ratio of the modulus of the vector-averaged wind to the scalar average wind speed, sometimes called the directional steadiness, provides a convenient measure of their similarity or dissimilarity. This information is coded into Fig. 2. The large area with directional steadiness less than 0.55 indicates considerable dissimilarity between the scalar and vector-averaged winds, and possibly also their secular trends. The linear least square fit procedure was applied also to the time series of moduli of the vector-averaged winds. The ranges of secular changes found for the vector-average winds were very similar to those found for scalar wind speed. In the high and low latitude bands, moreover, there is again a preponderance of positive values, 91 and 96 percent, respectively. The median values of the secular increase of vector winds are only one-half and one-third those of the scalar wind speed but they are significantly non-zero. In the mid-latitude band, however, the values of secular change of vector average wind are almost equally divided between positive and negative, for a median near zero. In this region the secular increase of wind speed does not carry over into the vector mean winds.

To seek support for the reality of the secular increase of vector-averaged wind, we defined estimators

$$\frac{\partial}{\partial t}w_v = \frac{\partial W_v}{\partial G}\frac{\partial G}{\partial t} + \frac{\partial W_v}{\partial \theta}\frac{\partial \theta}{\partial t} \tag{1}$$

and

$$\frac{\partial}{\partial t}\alpha = \frac{\partial \alpha}{\partial G}\frac{\partial G}{\partial t} + \frac{\partial \alpha}{\partial W_v}\frac{\partial W_v}{\partial t} + \frac{\partial \alpha}{\partial \theta}\frac{\partial \theta}{\partial t} \tag{2}$$

in which W_v and G denote the monthly vector averaged and geostrophic wind moduli, a, the angle between the observed vector averaged and the geostrophic wind, and q, the airsea difference of virtual potential temperatures. Functional forms for $\partial W_v / \partial G$, etc., were derived from a combination of the models of Rossby and Montgomery (193 5) and Luthardt and Hasse (1981), and evaluated using regional mean values from the COADS summaries. Equations 1 and 2 were then evaluated for each two degree square using values of $\partial G/\partial t$, $\partial\theta/\partial t$, etc. obtained by the same linear least square fit procedure as was used for Fig. 1, etc.

Results

The procedure outlined above provides a set of estimations of wind changes consistent with changes in related variables that were compared to the COADS summaries of observations. The results were generally negative. Median values of the secular trend of vector-averaged winds estimated using (1) were different (less than) from their observed counterparts in the COADS at a 95 percent confidence level in both the high and low latitude bands. In fact, neither was different from zero with 95 percent confidence. The estimation of the secular change of geostrophic departure angle, with the apparent secular increase of vector average wind included among the estimators, was found to be significantly different from that observed in the northern band, but not significantly different in the southern band. In both cases, however, the secular trend of the geostrophic departure angles for the wind observations are not significantly different from zero.

Thus, we failed to find support among the other variables in the COADS summaries for the reality of the secular increase of the vector averaged winds and, by implication, the even larger increases of the scalar wind speeds during the past four decades. A primary conclusion is that considerable caution is advised in application of the COADS summaries to problems of decadal and longer-term climate studies. Furthermore, within the confines of the COADS summaries, possibilities for improving the data appear to be very limited. During the past decade most progress has been made by investigators working with data sets antecedent to COADS. More such efforts could be encouraged by making the carefully edited data from which the COADS summaries were made available in convenient form. Periodic reissues of the summaries should be made in step with progress in improving the quality of the historical data to support research on real climate variations.

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Figure 1: Monthly mean values of surface wind speed in COADS summary for two-degree square having its southwest corner located at 26°N, 46°W. Speed values are in cm s^{-1} for the years 1951-1987. Dark line denotes result of linear least square fit to data with slope 2.6 cm s^{-1} yr^{-1}.

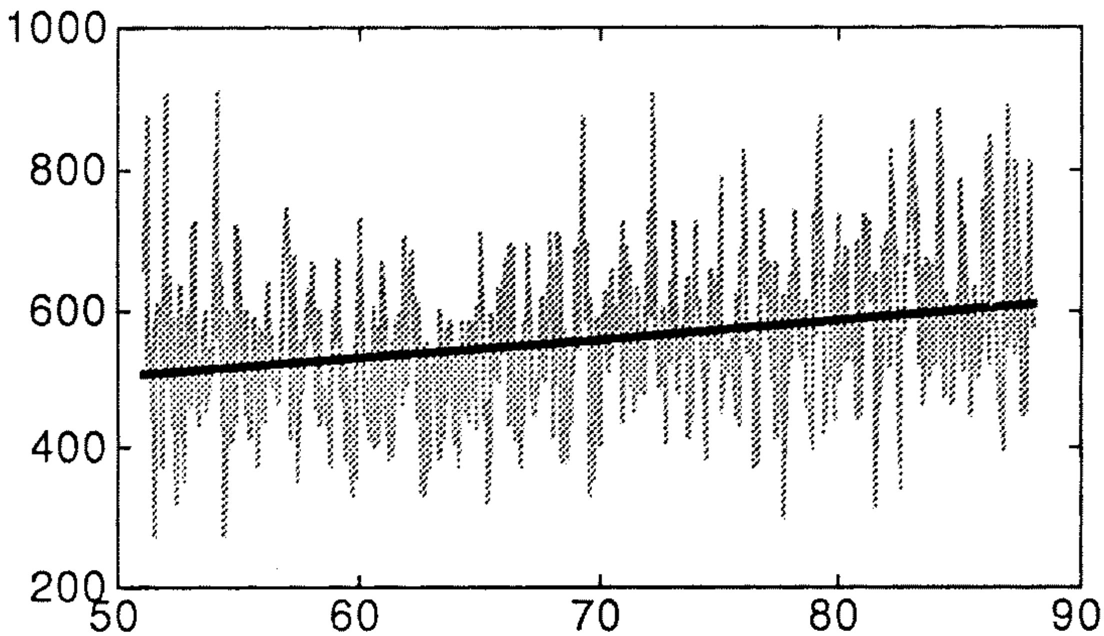

Figure 2: Map of two-degree squares from which COADS data were used in this investigation. Gray tones indicate intervals of directional steadiness, W_V/S: dark gray, .95-.75; intermediate gray, .75-.55; light gray, .55-.35.