P1.20 IMPACT OF HIGH FREQUENCY WINDS ON THE DETERMINATION OF MEAN AND SEASONAL STRESSES OVER THE OCEAN

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1. INTRODUCTION

Studies of the axial atmospheric angular momentum and torque balance have revealed large uncertainties in the estimated seasonal variability of zonal wind stress over the ocean (Ponte et al. 2003). The zonal stress is given by

$$\tau = \rho C_d U u$$

where ρ is air density, C_d is the drag coefficient, U is the wind amplitude, and u is the zonal wind speed. Because of the nonlinear dependence of τ on the wind, variability at weekly and shorter periods can have an important effect in determining the mean and seasonal cycle in surface stresses (e.g., Hanawa and Toba 1987; Simmonds and Keay 2002). Using available operational and satellite-derived wind products, we explore here the potential for uncertainties in high frequency winds to contribute to errors in the seasonal variability in τ. Focus is on the seasonal cycle of zonal stress fields, as they relate to our original interest on the zonal torques involved in the seasonal axial AAM balance.

2. DATA AND METHODOLOGY

Atlas et al. (1996) have created a multiyear wind dataset by merging European Centre for Medium-Range Weather Forecasts (ECMWF) operational products with satellite observations from the Special Sensor Microwave Imager (SSMI). Here we use both the original ECMWF winds and the Atlas et al. satellite-enhanced winds (hereafter referred to as SSMI) to calculate zonal wind stresses based on the bulk formulation of Large and Pond (1982), as described in detail by Ponte et al. (2003). Both wind products were available on a 1x1 degree grid at 6-h sampling for the period 1988-99.

The average stress over any period can be written as

$$<\tau> = \tau_{\mathrm{M}} + \tau'$$

where brackets denote time averaging, $\tau_{\mathrm{M}} = <\rho><C_d><U><u>$ denotes the contributions from the mean terms, and τ' includes all the covariance terms (e.g., $<\rho><C_d><U'u'>$) that incorporate the effects of nonlinearities in the stress relation. By comparing $<\tau>$ values based on 6-h quantities with values based on quantities that have been averaged over different periods, we can quantify the importance of τ' on the seasonal and mean stress values as a function of temporal resolution. In addition, using the difference in ECMWF and SSMI winds as a crude proxy for error, we can compare respective τ values to assess the effects of errors as a function of timescale.

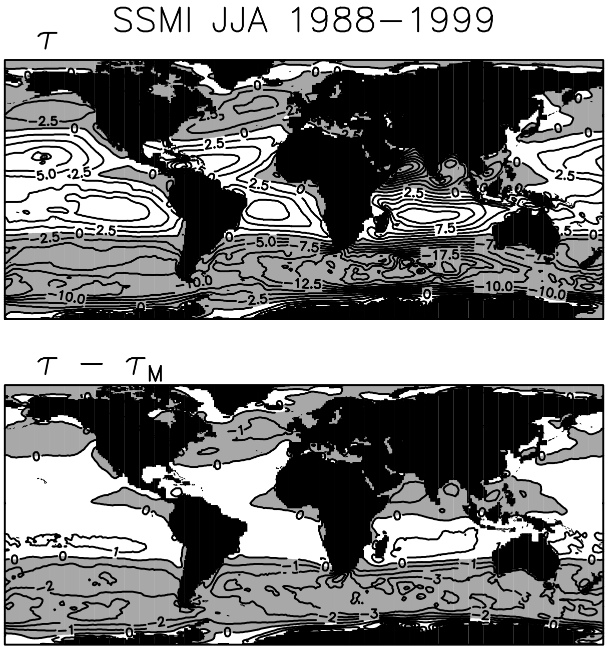

Fig. 1. Values of zonal stress on the atmosphere (positive for surface easterlies) using SSMI winds averaged over JJA season (top) and respective τ' contributions (bottom). Contour interval is 2.5 (top) and 1 (bottom) in units of N m^{-2}. Light shading denotes negative values.

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3. CONTRIBUTION OF HIGH FREQUENCIES TO $<\tau>$

Figure 1 shows values of $<\tau>$ based on 6-h quantities for the austral winter months of June-July-August (JJA), together with respective contributions from τ'. The latter terms are small but not negligible; typical amplitudes are approximately 10 to 20% of $<\tau>$ values. Important contributions by τ' are observed in most of the Southern Ocean, where strong synoptic winter variability is expected, and also in some tropical areas and the northern North Atlantic.

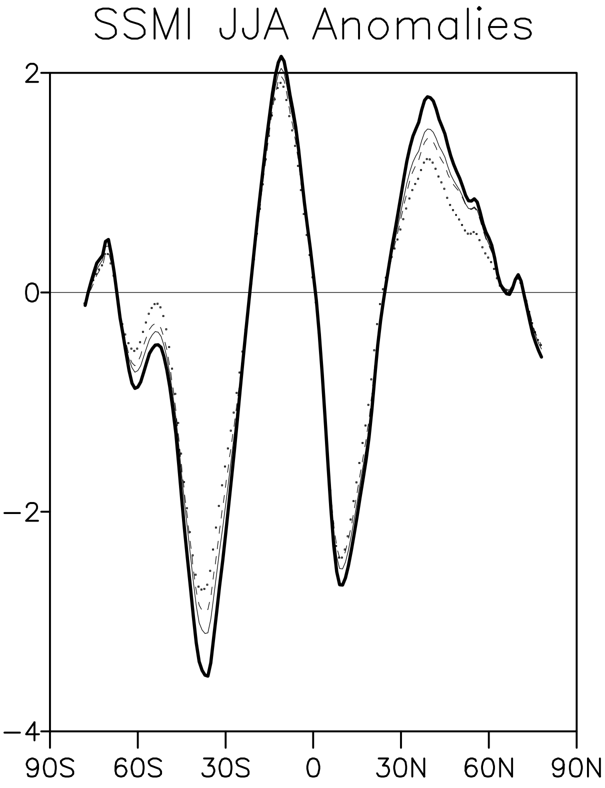

Fig. 2. Zonally averaged stress values (N m^{-2}) based on SSMI winds. Seasonal anomalies for JJA are shown based on 6-h (heavy solid), 3-d (thin solid) and 7-d (dashed) averaged quantities. The dotted line represents values of the mean term τ_M.

Results in Fig. 1 include the effects on τ' of all wind variability at periods longer than 12 h. To examine the importance of the highest frequencies, we calculate JJA stresses based on 3-d and 7-d averaged quantities (Fig. 2). Zonally averaged stress anomalies from the annual mean are shown to focus on the seasonal cycle. The 3-d results indicate that variability at subweekly periods provides a substantial contribution to the JJA stress anomalies, particularly at mid latitudes. Comparison with the values of τ_M confirms the importance of τ' contributions to $<\tau>$ found in Fig. 1 when only seasonal anomalies are examined.

4. EFFECTS OF HIGH FREQUENCY ERRORS

Given the importance of relatively short period variability in the determination of seasonal and mean zonal stresses, we explore the effects of possible errors in the wind field at these time scales by forming differences between the various τ curves shown in Fig. 2 for SSMI wind fields and their counterparts based on ECMWF winds. These differences (Fig. 3) are taken here to represent a crude measure of the uncertainty in the zonally averaged stress estimates.

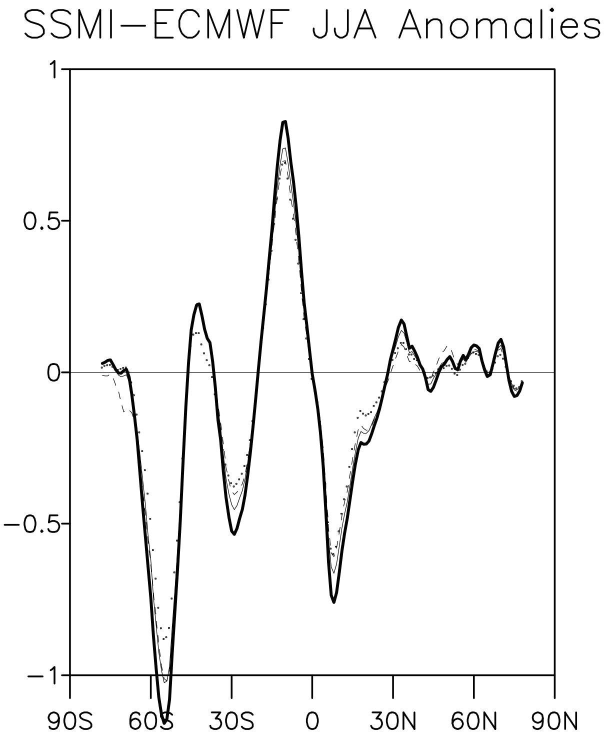

Fig. 3. As in Fig. 2 but curves are the differences between SSMI and ECMWF stresses.

Most of the differences in JJA stress anomalies in Fig. 3 are attributable to errors in the τ_M term, but errors in τ' are not negligible. For example, in the region of maximum difference near 50S-60S, τ' contributions are around 25% of the total difference in the ECMWF and SSMI fields. As seen from the 3-d curve, half of that signal comes from changes in wind fields at period shorter than 6 days.

Our original motivation stemmed from the uncertainty in the available estimates of the seasonal zonal torque *T* over the ocean, where *T* is the integral over the ocean surface of $(r \cos\phi)\,\tau$, with *r* being the radius of Earth and ϕ the latitude. The uncertainty introduced by possible high frequency errors in wind fields is assessed in Fig. 4 for the annual cycle.

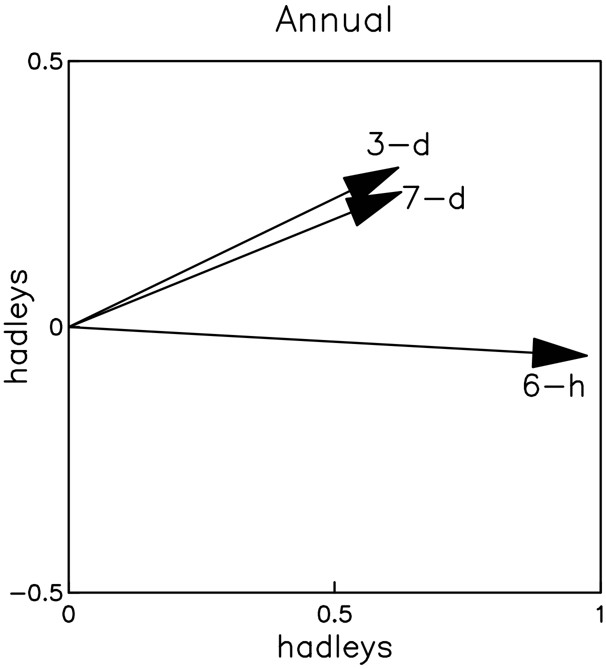

Fig. 4. Annual amplitude and phase of the difference in *T* values based on SSMI and ECMWF fields, in units of Hadleys (1 Hadley=10^{18} kg m^2 s^{-2}). Different vectors are for values derived from 6-h, 3-d, and 7-d quantities. Phase is plotted counterclockwise with 90° corresponding to a vector pointing straight upward. A phase of 0° corresponds to no phase difference between SSMI and ECMWF values.

Values of *T* for SSMI and ECMWF based on 6-h quantities differ in amplitude by 1 Hadley, with little difference in phase. Differences obtained for *T* series based on 3-d stress quantities are comparatively smaller and also show some phase shifting. Results for 3-d and 7-d quantities are very similar. These findings indicate that errors in subweekly wind fields contribute substantially to the differences between the annual cycles of *T* estimated from SSMI and ECMWF products.

5. SUMMARY

By comparing two different wind products and respective stress fields derived from them, we have shown that weekly and shorter period variability in surface winds affects the mean and seasonal cycle of zonal stress over the ocean, and that uncertainties at subweekly periods can lead to substantial errors in the latter. Results point to the need for determining subweekly wind variability as well as possible, both to model the seasonal variability in the ocean circulation and to close the seasonal torque balance of the atmosphere. Satellite wind observations with daily or better temporal resolution thus seem to be important for minimizing uncertainties in stress fields on seasonal timescales.

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