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RELATIONSHIP BETWEEN INTRASEASONAL OSCILLATION AND SUBTROPICAL WIND MAXIMA OVER THE SOUTH PACIFIC OCEAN

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1. INTRODUCTION

The significance of tropical heat sources on higher latitude jet streams has been examined by numerous investigators. Hurrell and Vincent (1990) provide a summary of many of these investigations in their observational case study of the relationship between tropical heating and subtropical wind maxima in the Southern Hemisphere during SOP-1, FGGE. Their paper, together with subsequent observational and modeling investigations of the same case study (Hurrell and Vincent, 1991a, b), provided the main impetus for the present study. They showed that the divergent outflow from tropical heating associated with the South Pacific convergence zone (SPCZ), acted on by the coriolis force, was an important factor in maintaining the subtropical jet on the poleward side of the SPCZ during the period, 6-20 January 1979. They found a similar, but weaker relationship, over the southern Indian Ocean from 3-17 February 1979, a period when the SPCZ heating was greatly reduced and the jet was essentially non-existent. Since their findings were based on a case study and involved the use of the highly-specialized FGGE data set, the natural questions which arose were, "Is this relationship a regular feature of the circulation over the South Pacific?", and, "If so, can it be detected with a routine data set?". Another question posed by Hurrell and Vincent in their papers was, "How important was the intraseasonal oscillation in causing the enhanced heating and divergent outflow in the Pacific Ocean in January and southern Indian Ocean in February?".

The purpose of the present paper is to address the answer to these three questions. To accomplish this, some circulation features for an entire warm season in the Southern Hemisphere were examined. The year selected was 1984-85, and the warm season consisted of the 6-month period, 1 November 1984 - 30 April 1985. This period was chosen because there were numerous cases of the westerly wind maxima over the South Pacific and the intraseasonal oscillation was well documented (Vincent et al., 1991).

The primary data set used in this study was essentially the same as that used by Vincent et al. (1991). Briefly, it consists of the ECMWF analyses in spherical harmonics, with a triangular truncation of T63, but these data were transformed to a 3° latitude by 5° longitude grid. The analyses were available at 00 UTC each day at standard pressure levels up to 30 mb and contained geopotential height, temperature, relative vorticity, horizontal divergence, vertical velocity, and relative humidity. Horizontal wind components were computed from vorticity and divergence, and velocity potential from divergence. Since the analyses were global, no boundary conditions were required for the computation of velocity potential. The variables used in the present study are the zonal (u) component of the wind, velocity potential (χ) and the meridional component of velocity potential (v_χ). The level used to depict the relationship between episodes of enhanced tropical divergent outflow and subtropical westerly wind maxima is 200 mb. Vincent et al. (1991) showed a high correlation between tropical heat sources, as indicated by outgoing longwave radiation (OLR), and χ at 200 mb.

2. RESULTS AND DISCUSSION

A Hovmoeller diagram of the zonal wind at 200 mb, averaged from 21-36°S, for the 6-month period noted in Section 1, is shown in Fig. 1. Values greater 30 m/s (in some cases, 25 m/s) have been shaded to highlight regions and times of local wind maxima. It is obvious that numerous cases of wind maxima occurred within the Southern Hemisphere subtropics during their summer season. Particularly noticeable are those over the western and central South Pacific Ocean and South America. Since the present study is interested in examining the potential relationship between tropical heat sources in the South Pacific and their corresponding subtropical wind maxima, several cases of distinct episodes of the latter were identified. Eight of these cases, between early December 1984 and mid-April 1985, are depicted in Fig. 1. It is seen that the wind maximum in each case persisted for 1-2 weeks, and, with one or two exceptions, tended to propagate eastward. It is important to state that in all 8 cases the subtropical wind maxima were distinct from the higher latitude jet stream which meandered between latitudes, 40-55°S.

Figure 2 shows a Hovmoeller diagram of the meridional component of the divergent wind, v_χ, at 200 mb, averaged between latitudes, 12-24°S. Values of poleward-moving air greater than 2 m/s have been shaded. It is seen in most cases

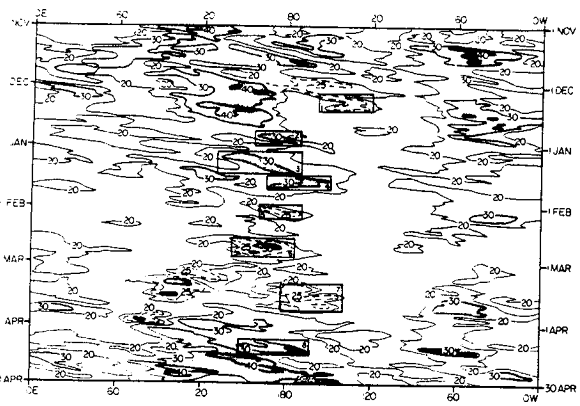

Fig. 1. Hovmoeller plot of the daily zonal wind at 200 mb in m/s averaged from 21-36S for 1 Nov 84 - 30 Apr 85. Values ≥ 25 or 30 are shaded and 8 cases of wind maxima are identified.

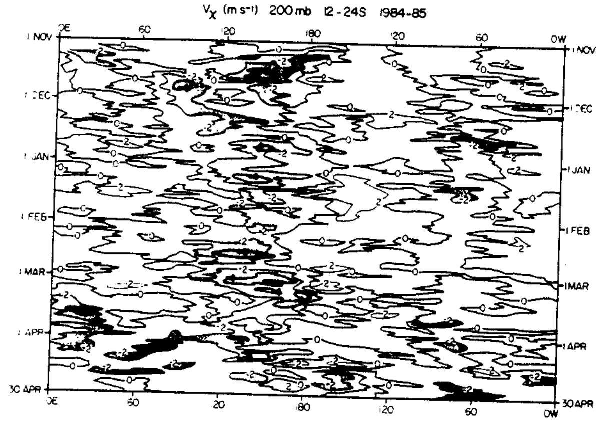

Fig. 2. As in Fig. 1, except for the divergent component of the meridional wind in m/s averaged from 12-24S. Values ≤ -2 are shaded.

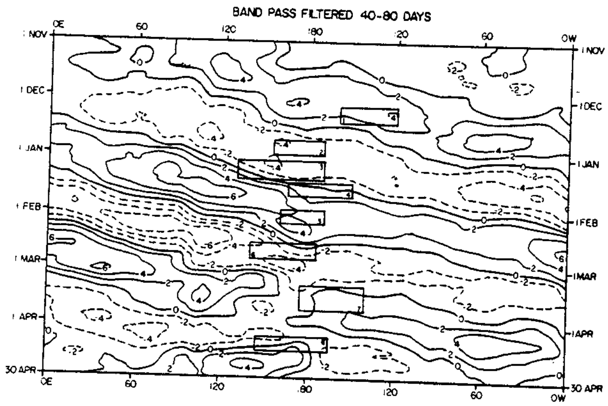

Fig. 3. As in Fig. 1, except for bandpass filtered (40-80 days) values of velocity potential in 10^6 m^2/s averaged from 0-15S.

(those selected, as well as those which were not) that the divergent outflow from the tropics tends to maximize near the entrance region of the individual subtropical wind maxima. This suggests that the outflow from the tropics, under the influence of the coriolis force, is a factor in acting to enhance and maintain subtropical "jets" in the Southern Hemisphere. It should be noted that in all 8 cases, as well as others, enhanced values of velocity potential in the tropics were associated with the maxima of v_χ and u (not shown). It's also important to emphasize that divergent out-flow from the tropics may not be the sole source for the development and maintenance of the observed wind maxima. Hurrell and Vincent (1991a) and others (e.g., Trenberth, 1986, 1987) have used the E-P flux equations to show that transient eddies can also play an important role. More will be said concerning this later.

Next, we examine the role of the intra-seasonal oscillation as a stimulator of divergent outflow from the tropics during periods of enhanced subtropical wind maxima. Figure 3 shows a Hovmoeller diagram of the velocity potential at 200 mb which has been zonally-averaged from 0-15°S and band passed filtered for a period of 40-80 days using the recursive filter technique described by Murakami (1979). Before the data were filtered, they were statistically tested and it was determined that the significant spectral peaks were between 50 and 67 days. For details regarding these results, the reader is referred to Vincent et al. (1991). Also shown in Fig. 3 are the boxes which outline the locations and times of the 8 cases referred to in Fig. 1. It appears that the tropical oscillation might be important in 4 of the 8 cases. Table 1 gives the details concerning each case and shows, as stated earlier, that each wind maximum lasts from 1-2 weeks. It appears that the subtropical winds in cases 2, 3, 6 and 8 might have been enhanced by divergent outflow from the tropics due to the passage of the intraseasonal oscillation. The remaining cases occurred during the non-convective stage of the oscillation, as indicated by the positive anomalies seen in the filtered velocity potential.

To conserve space, only 2 of the 8 cases are illustrated and discussed; however, it should be noted that the results which follow were common to all 8 cases. Maps of total χ (not

Table 1. Dates and longitudinal extent of 8 cases of subtropical wind maxima located between latitudes 21-36S. Also indicated is whether or not a case appears to be influenced by the intraseasonal oscillation.

Case No.	Dates	Longitudinal Extent	Oscillation
1	5 Dec - 14 Dec	160W - 120W	No
2	24 Dec - 1 Jan	155E - 170W	Yes
3	4 Jan - 15 Jan	130E - 170W	Yes
4	16 Jan - 23 Jan	165E - 150W	No
5	31 Jan - 7 Feb	160E - 170W	No
6	17 Feb - 26 Feb	140E - 175W	Yes
7	12 Mar - 25 Mar	175E - 140W	No
8	8 Apr - 16 Apr	145E - 165W	Yes

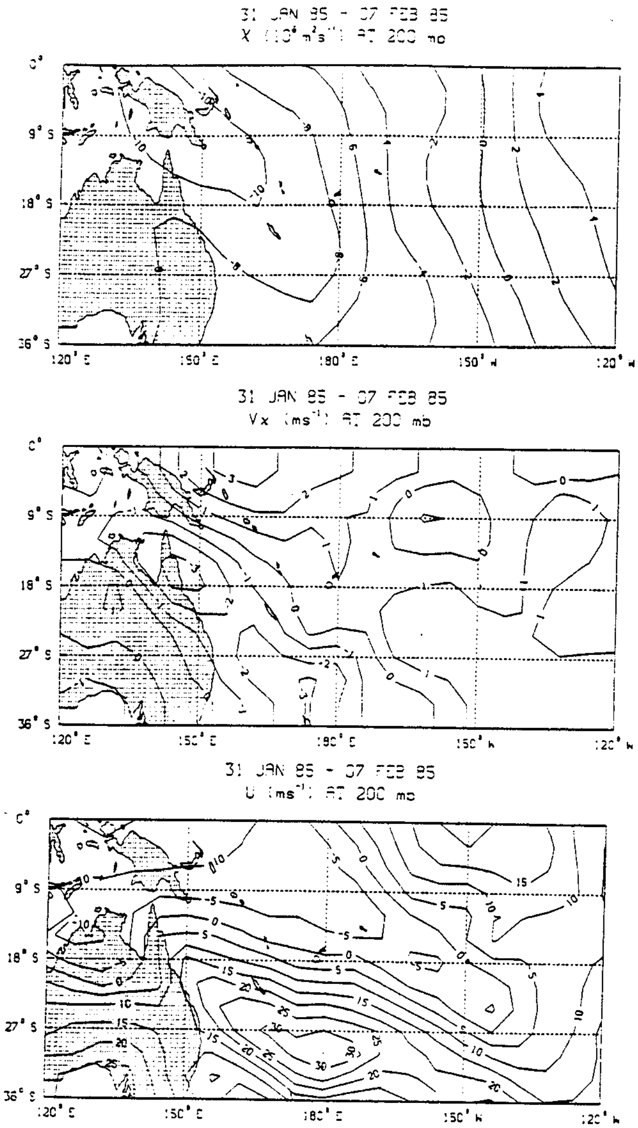

Fig. 4. Time averaged horizontal distributions of χ, v_χ and u at 200 mb for Case 5, 31 Jan 85 - 7 Feb 85.

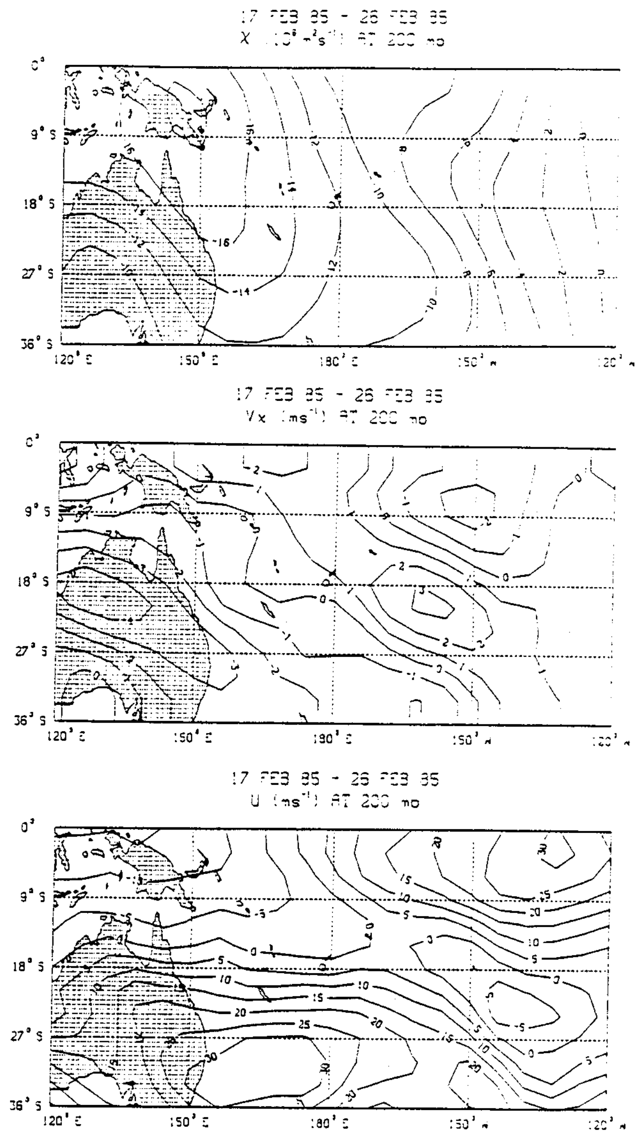

Fig. 5. As in Fig. 4, except for Case 6, 17 Feb 85 - 26 Feb 85.

band-passed), v_χ and u at 200 mb, which have been time-averaged over the life cycle of the subtropical wind maximum for case 5, are shown in Fig. 4. Recall that this case is one where the intraseasonal oscillation is not considered to be an important factor in causing divergent outflow from the tropics. It is seen that the minimum value of χ (about -11 x 10^6 m^2s^{-1}) is located over Borneo. Maximum poleward divergent flow occurs over northeastern Australia and the axis of maximum (negative) values stretches from there to the northern tip of New Zealand. Furthermore, this axis is located in the entrance region of the subtropical jet which is centered near the Dateline with a maximum value of 30-35 ms^{-1}. For comparison, Fig. 5 shows the same three variables for case 6, a period when the intraseasonal oscillation was suspected of being an important factor in causing the divergent outflow associated with initiating and maintaining the observed subtropical wind maximum. The patterns of χ and v_χ are similar to those in Fig. 4, but the magnitudes of both are much greater in Fig. 5. This is not surprising since case 6 involves the oscillation. Also, as in case 5, case 6 shows that the axis of maximum poleward divergent flow is located in the entrance region of the subtropical wind maximum. Perhaps the most surprising fact in comparing Figs. 4 and 5 is that the maximum value of u is essentially the same in both cases. This implies that other factors may be responsible for decelerating the wind in the entrance region of maximum u, particularly in case 6. Hurrell and Vincent (1991a), using the localized E-P flux equations of Trenberth (1986), found that transports of heat and momentum (both horizontal and vertical) were responsible for decelerating the subtropical wind maximum associated with the SPCZ in its entrance region. However, the effect of the eddy fluxes was not as great as the Hadley-type forcing discussed in this paper, thus the net effect of these two mechanisms was to enhance the subtropical jet.

A comparison of the averages for some of the key features between the four oscillation and four non-oscillation cases is given in Table 2. As expected, the average maximum negative value of χ for the four oscillation cases was greater than that for the cases when the oscillation was not present. Also, as expected, the average speed of the poleward divergent flow was greater for the oscillation cases. There is no apparent difference in the duration of wind maxima between oscillation and non-oscillation cases, and it appears that the mean distances in latitude among the three variables being considered are not significantly different; however, the average locations of each variable is farther poleward for the non-oscillation cases. A somewhat surprising result, however, is that the average speed of the maximum zonal wind for the oscillation cases was less than that for the non-oscillation cases. Of course, the 8 cases examined do not represent a sufficient number from which to draw any definite conclusions regarding this "unexpected" result. Furthermore, as suggested earlier, it's possible that middle latitude wave dynamics (i.e., E-P fluxes) are more important (e.g., to decelerate the wind) when forcing from the tropical oscillation is occurring. Additional cases need to be compiled, and perhaps composited, in order to address the question concerning the significance of tropical versus middle latitude forcing during episodes of subtropical wind maxima in the Southern Hemisphere.

Finally, what the present study has shown, in response to the three questions posed in the Introduction, is: (1) poleward divergent outflow from tropical heat sources was an important factor in causing and maintaining subtropical wind maxima over the South Pacific Ocean; (2) this relationship occurs quite frequently and can be detected from routine analyses; and (3) the intraseasonal oscillation was an important factor in perturbing the divergent outflow, but perturbations in the tropical heating field on other temporal scales appear to be equally important.

Table 2. Averages of some key variables at 200 mb for the 8 cases of subtropical wind maxima.

Variable	4 oscillation cases	4 non-oscillation cases
χ (max)	-16×10^6 m^2 s^{-1}	-10×10^6 m^2 s^{-1}
v_χ (max)	-5 ms^{-1}	-3 ms^{-1}
u (max)	36 ms^{-1}	38 ms^{-1}
lat χ (max)	8°S	13°S
lat v_χ (max)	20°S	22°S
lat u (max)	28°S	30°S
duration	10 days	10 days

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