Proceedings of the Fourteenth Annual Climate Diagnostics Workshop
NTIS, Us. Dept. of Commerce, Springfield, VA pp 256-259.

Zero Potential Vorticity Gradient Basic States in the Neighborhood of the Equator

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In this talk we investigate zonally averaged basic states for linearized stationary wave models, where the basic state zonal winds have been modified in the neighborhood of the equator in such a manner as to eliminate meridional gradients in the pseudo-potential vorticity near the equator. The unmodified basic states commonly used (i.e., Jacqmin and Lindzen, 1985, Nigam and Lindzen, 1989) in linear models typically have large potential vorticity gradients near the equator ($\sim \beta$). There are two related aims to this study:

1. To see whether the modified basic states differ from the unmodified basic states to a *measurable* extent; and
2. To see whether the response to stationary forcing (especially to tropical heating) would be affected by the modification to the basic state.

The motivation for the study comes from a common shortcoming in linearized stationary wave models: namely, although the response to tropical forcing in geopotential height appears superficially reasonable, the associated wind fields are generally excessive. Large values of friction are used in the neighborhood of the equator in order to bring the wind fields down to reasonable values. Now, to the extent that the forced waves are Rossby wave-like, their potential vorticity comes from the potential vorticity gradients in the basic state (Lindzen and Schoeberl, 1982). It therefore seemed possible that eliminating such gradients near the equator might reduce the response to stationary forcing. In addition, regions of zero potential vorticity gradient might also affect stationary waves by causing the reflection of stationary waves (Lindzen and Tung, 1977). It has been noted by Nigam, *et al* (1986), that nonlinear GCM's do not have this problem at the equator. A possible reason for this might be that wave-mean flow interactions in the GCM might act to iron out the basic state gradients in potential vorticity. However, to the extent that basic states are based on observations, we would hardly be justified in replacing them with states that differ pronouncedly from those that are observed; hence item 1 above.

We have, thus far, only completed item 1 above[1]. Our procedure is to replace zonal winds within a distance, a, of the equator with winds satisfying the following equation (essentially the equation for zero pseudo-potential vorticity gradient on an equatorial beta-plane):

$$\frac{\partial^2 \bar{u}(y,z)}{\partial y^2} + \left(\frac{2\Omega}{N}\frac{y}{a}\right)^2 \frac{1}{\rho}\frac{\partial}{\partial z}\left(\rho \frac{\partial \bar{u}}{\partial z}\right) \tag{1}$$

where $y = a\phi$, ϕ =latitude, and where $u(\pm a)$ is set equal to the unmodified values. We also smooth the fields in the neighborhood of $y = \pm a$ in order to eliminate kinks in the velocity field.

[1] Since the meeting, work towards answering item 2, above, has been done; pronounced changes in the stationary wave response have been found – including both amplitude reductions and increased reflectivity.

Figure 1a shows the unmodified basic state zonal wind and its associated distribution of potential vorticity gradients. Figure 1b shows the same for a modified basic state where a corresponds to 5°; Figure 1c shows the same where a corresponds to 10°. A comparison of Figures 1a and 1c shows that the modified u-field is noticeably different from the original; however, a comparison of Figures 1a and 1b shows that the modified u-field is virtually undistinguishable from the original. Thus, within about 5° of the equator, observed zonally averaged zonal winds are compatible with *radically* different distributions of potential vorticity gradient. The situation is even more vexing with temperature. Figure 2 compares the zonally averaged temperature and zonal wind fields for modified basic states with a corresponding to 10° and 20°. (The temperatures are in cyclostrophic balance with the wind fields.) The zonal winds are very different, but the temperature field shows almost no discernible differences. We are left with the uncomfortable situation where a variable which appears to be of fundamental importance to dynamics (namely, potential vorticity gradient) does not seem to be readily determined from existing data – at least in the immediate neighborhood of the equator. Nevertheless, if our modelling studies demonstrate that response is more accurate for zero potential vorticity gradients at the equator, then this might provide compelling reason to use this value regardless.

Acknowledgements

This research was supported by NSF Grant ATM 84-14660, and NASA Grant NAGW-525 at M.I.T., and by NSF Grant xxxx at the University of Maryland.

Figure Legends

Figure 1 (a) $y - z$ cross sections of $\bar{u}$ and potential vorticity gradient for unmodified basic state, (b) same for modified basic state with $a = 10°$, (c) same for modified basic state with $a = 5°$.

Figure 2 Modified basic states for $a = 10°$ and $a = 20°$. Wind is in m/s and temperature is in deg K.

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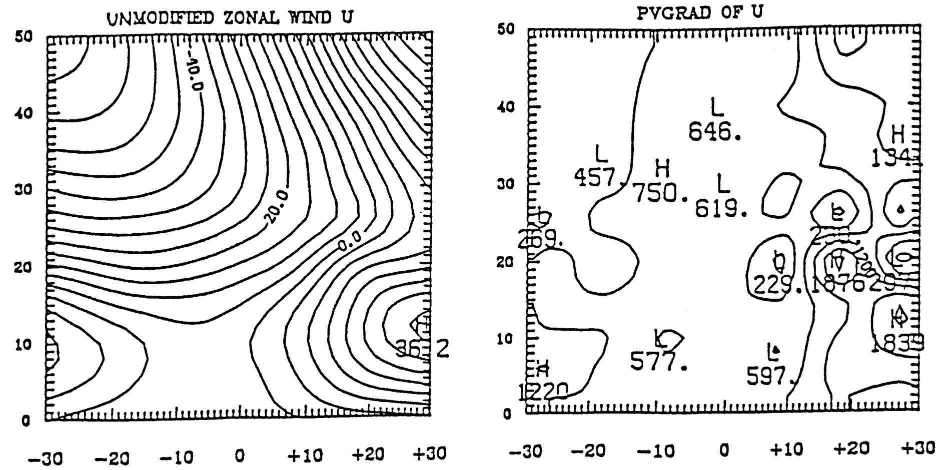
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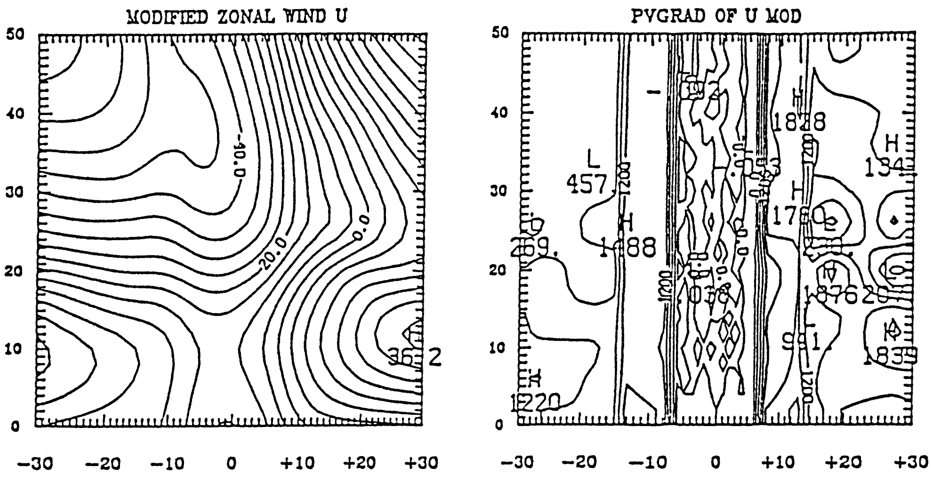
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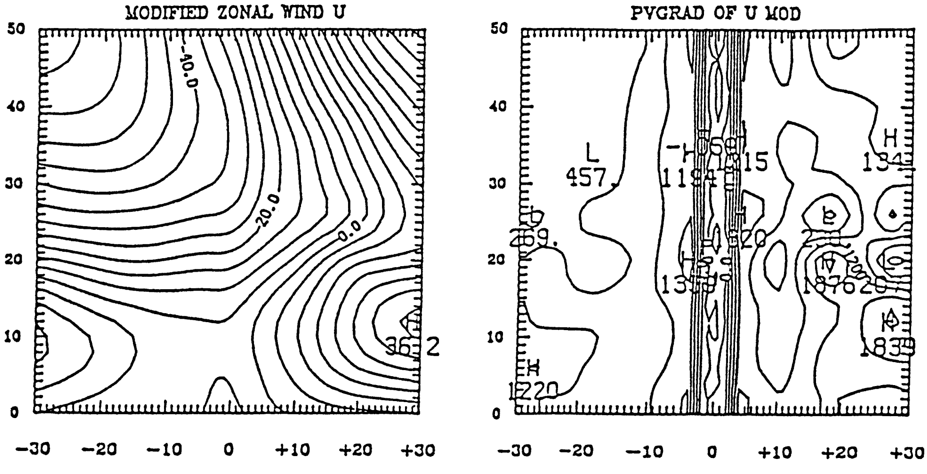
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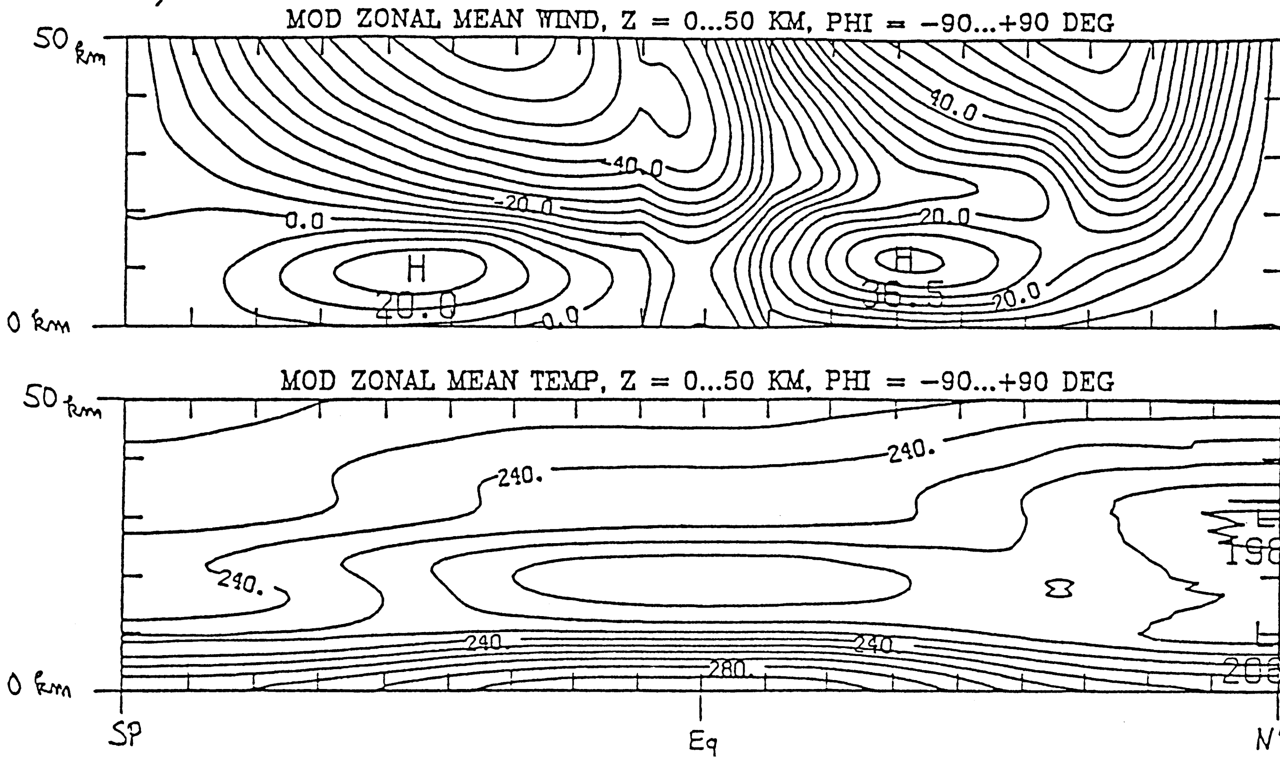
Figure 1

a)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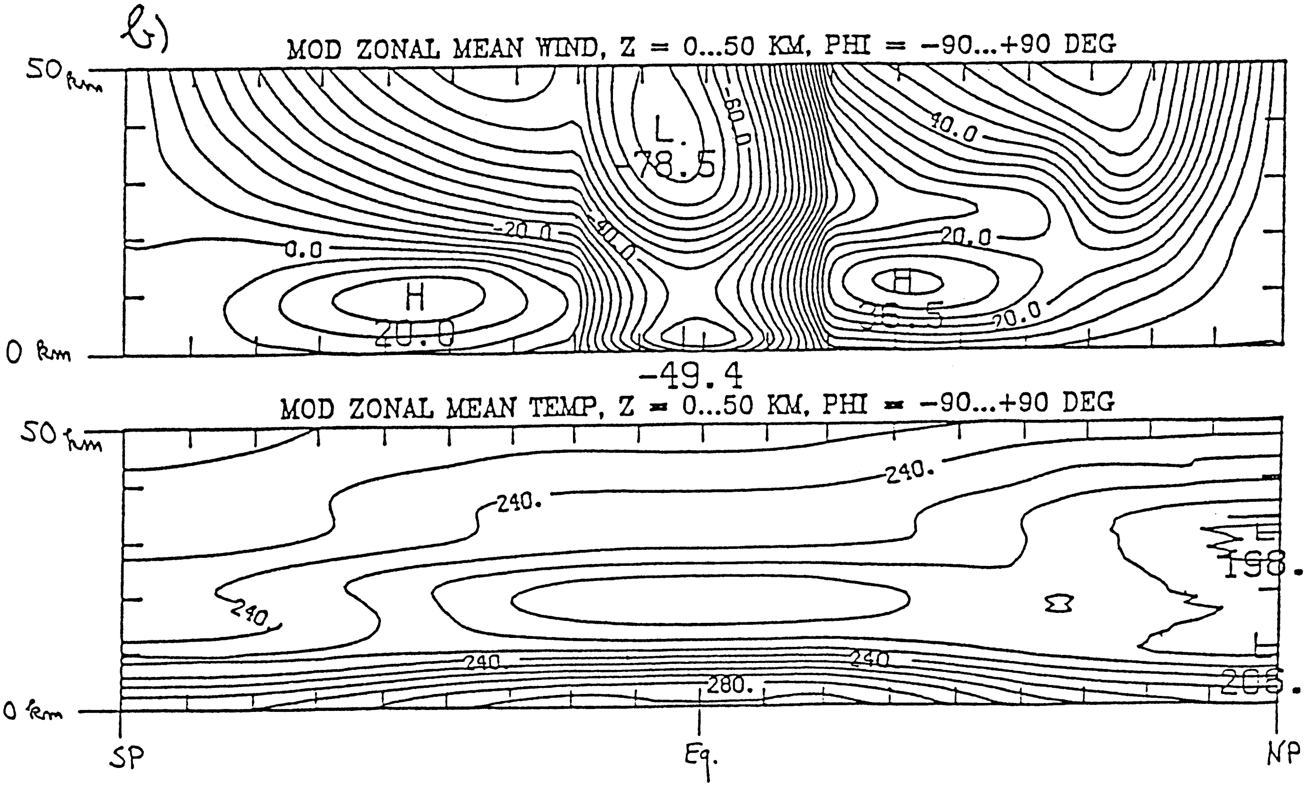
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-49.4
MOD ZONAL MEAN TEMP, Z = 0...50 KM, PHI = -90...+90 DEG
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