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ITCZ BREAKDOWN IN THREE DIMENSIONAL FLOWS

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1. Introduction and experimental design

The well defined Intertropical Convergence Zone (ITCZ) rarely stays the same. In satellite images, it has been observed to undulate and eventually break apart. This process is then referred to as "ITCZ breakdown". According to model simulations, the typical timescale of ITCZ breakdown is less than two weeks and it is suggested to happen most frequently in the tropical East Pacific. This may be one of the possible mechanisms of pooling vorticity so that tropical cyclogensis can take place. The suggested mechanism is the following: diabatic heating induces a positive (negative) potential vorticity (PV) anomaly below (above) the heating (eg. Hoskins 1991). The timescale for producing PV anomalies is a few days which is very efficient. Then, the meridional PV gradient changes sign on the poleward (equatorward) side of the heating in the lower (upper) troposphere. Thus, the flow satisfies the necessary conditions for combined barotropic/baroclinic instability. Nieto Ferreira and Schubert (1997, hereafter NFS) found this to be a valid mechanism in a barotropic model with no background flow. Here we extend their work to three dimensions and also consider the effects of background flow.

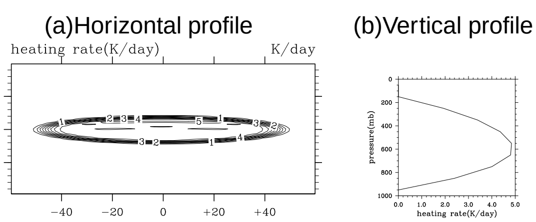

FIG. 1: (a)The horizontal profile of the prescribed ITCZ. The X-axis is relative longitude. (b) The vertical profile of the strength of the heating rate. The heating rate is strongest (about 4.8 K/day) at 600 hPa and decreases to zero at 150 hPa and 950 hPa.

Reading spectral primitive equation (PE) model is employed. The imposed heating (Fig.1(a)) has the same horizontal and temporal structure as n NFS. The vertical structure is designed by two parabolas connected at 600 hPa where the heating has its maximum in the vertical (shown in Fig.1(b)). The heating is applied for 5 days in the beginning of all simulations. Three experiments are considered: an experiment with no background flow, an experiment where the heating is imposed in an idealized trade-wind background flow, and thirdly, an experiment with the heating imposed in a climatological background flow. Both background flows are in steady state.

2. Results with no background flow

We have regenerated the results of NFS by using the Reading shallow water model. We then compared the result of our baroclinic experiment (shown in Fig.2) to that of our barotropic experiment. We found that the upper level PV anomaly is much weaker than its lower level counterpart and ITCZ breakdown remains rather barotropic.

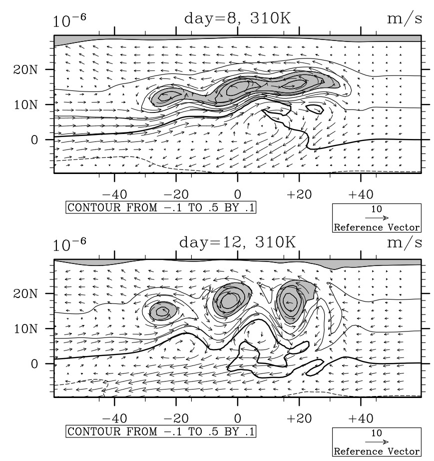

FIG. 2: No background flow. PV and winds on 310 K isentropical surface (about 800 hPa). Contours are PV (in PV units) and vectors are the corresponding wind field. Contour interval is 0.1 PV unit. Areas where PV is greater than 0.3 PV units are shaded.

3. Results with idealized trade winds

The idealized trade winds (shown in Fig.3) are generated by forcing the PE model with a zonally symmetric heat-

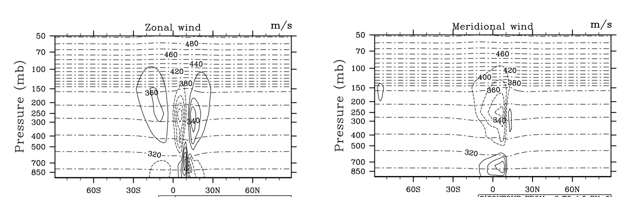

FIG. 3: The meridional cross section of the idealized trade winds. The contour interval for zonal wind is 2 m/s and 0.5 m/s for meridional wind. Dash-dotted contours are isentropic surfaces.

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ing whose width is 10° latitude centered at 10°N. The result (Fig.4) shows that the evolution of ITCZ breakdown is significantly accelerated by the background flow. It is of interest to see a vortex break off from the western end of the PV strip first. Then, the remaining part of the ITCZ continues breaking in sequence from the west and produces more disturbances. The same behavior was observed in an ITCZ breakdown event that occurred during 23 - 31 Aug. 2000 in the tropical East Pacific. The modeling result suggests that the background flow may play an important role.

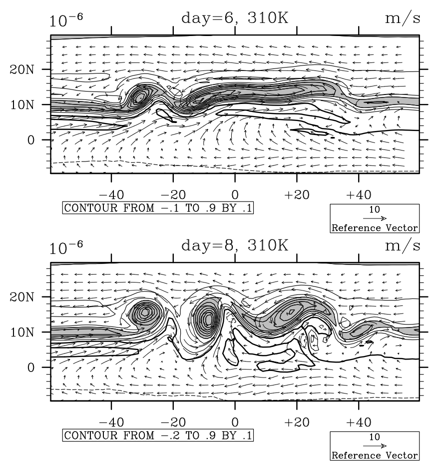

FIG. 4: PV and winds for idealized trade winds case.

4. Results with climatological flow

The zonally averaged climatological flow (shown in Fig.5) is derived from the NCEP high resolution global tropospheric analyses during the active season (August to October) of 2000 to 2002. Fig.6 shows results in the presence of this background flow. The westerly flow on the equatorward side of the PV strip has been influenced by the background flow. On day 8, the southeast cross-equatorial flow heavily distorts the eastern half of the PV strip and greatly weakens the development of the cyclonic flow of the easternmost disturbance. The lifetime of the produced disturbances tends to be shorter when climatological flow is present. This result may explain why the produced disturbances in the real atmosphere are not as readily observed as one might expect.

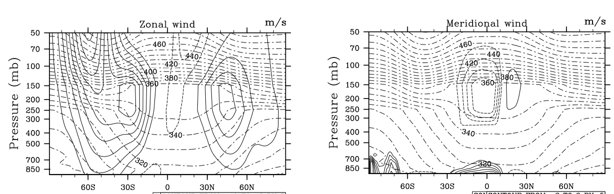

FIG. 5: The zonally symmetric climatological flow. The contour interval is 5 m/s and 0.5 m/s for zonal and meridional wind, respectively.

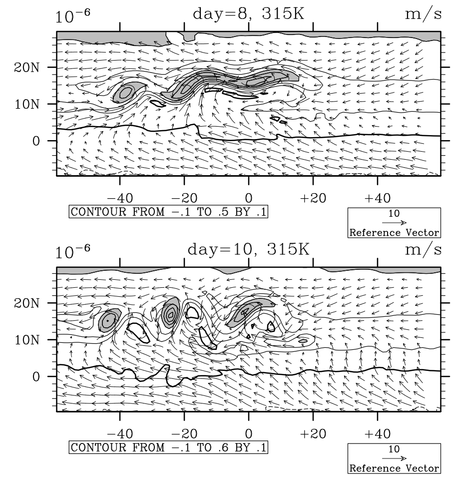

FIG. 6: PV and wind fields of the experiment with climatological background flow.

5. Conclusions

This research shows that the upper level negative PV anomaly is very weak and does not play a dynamical role in ITCZ breakdown. The evolution of the lower level PV anomaly shows no signficant difference with that of the barotropic experiment. Thus, we can conclude that ITCZ breakdown is primarily a barotropic process. The background flow plays an important role in the breakdown process. It may accelerate the process of breakdown and may exaggerate the breaking-off behavior at the western end of the ITCZ. The result of the third experiment shows that under the influence of the climatological background flow, the easternmost disturbance on the ITCZ is heavily distorted and it dissipates before axisymmetrizing. This result explains why ITCZ breakdown is not often observed as one might expect.

Acknowledgment

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