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NUMERICAL EXPERIMENTS ON THE INTERACTION OF A HURRICANE-LIKE VORTEX WITH A BAROCLINIC WAVE

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1. INTRODUCTION

The extratropical transition of tropical cyclones may cause strong storms and heavy rainfall in the mid-latitudes. Therefore accurate prediction of a transition event is of the utmost importance. A better understanding of the dynamics of extratropical transition may help to improve the numerical forecasts of these events.

Here a series of idealized numerical experiments are carried out to investigate how the initial position of the hurricane relative to different types of baroclinic waves influences the future evolution of both systems.

2. INITIAL CONDITIONS AND SETUP OF EXPERIMENTS

Calculations are carried out using a three-dimensional, nonlinear, primitive equation limited area model including the full variation of the Coriolis parameter with latitude. The model is initialized with a zonal jet which has a maximum just below the tropopause and at the center of the domain in the meridional direction. The initial conditions are in thermal wind balance giving a strong meridional temperature gradient in the troposphere

When this basic state is perturbed near the tropopause a baroclinic wave develops, in which the upper-level PV anomalies wrap up cyclonically (LC2 case from Thorncroft et. al., 1993) When a barotropic wind shear is added to the basic zonal flow the baroclinic wave development is characterized by upper-level PV anomalies that thin meridionally and bend back anticyclonically (LC1 case).

After 72 h integration time a hurricane-like vortex with a maximum wind speed of 34 ms^{-1} is inserted and the integration is recommenced. The tangential wind speed of the vortex is maximum at the surface and decreases to zero at the tropopause. Nine different model runs are carried out for each baroclinic lifecycle to test the sensitivity of the flow evolution to the initial position of the hurricane. In each model run one hurricane is inserted at a different position relative to the baroclinic wave. These different positions are zonally and meridionally arranged in three rows, as illustrated in Fig. 1. In the zonal direction the distance between two rows is 500 km, in the meridional direction it is 250 km.

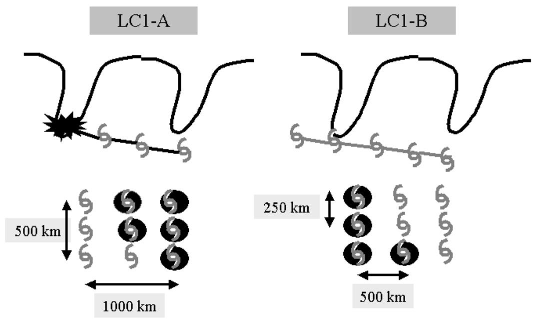

Fig. 1: Schematic illustration of hurricane tracks for case LC1. The initial hurricane positions highlighted in black resulted in the track illustrated above

3. RESULTS

The different tracks of the hurricanes in the case of LC1 are shown in the schematic illustration in Fig. 1. The tracks of the hurricanes fall into two categories. In both cases the hurricane starts to move to the northwest due to the beta drift and the steering flow associated with the barotropic wind shear. In the cases where the initial position of the hurricane is more to the west or southwest (LC1-B), the vortex reaches the western trough at a time when the baroclinic wave is not mature. In consequence the meridional extent of the wave is relatively small, so that the vortex can pass the trough and as the trough extends meridionally with time, the hurricane is steered to the south (Fig. 2a). The vortex weakens steadily and no extratropical transition takes place. Because of the periodic boundary conditions in our model setup, the hurricane leaves the domain at the western boundaries and moves back in at the eastern boundaries.

In contrast, the hurricanes which are initially further to the east and northeast (LC1-A) cannot pass the western trough. Furthermore, because of their more northern position these hurricanes are more strongly influenced by the southwesterly flow ahead at the western trough and, consequently, are steered even further to the north. In the case shown in Fig. 2b the hurricane is located directly to the east of the high upper-level PV, and as they interact with each other the ex-hurricane intensifies, which is evident in the surface geopotential (not shown here).

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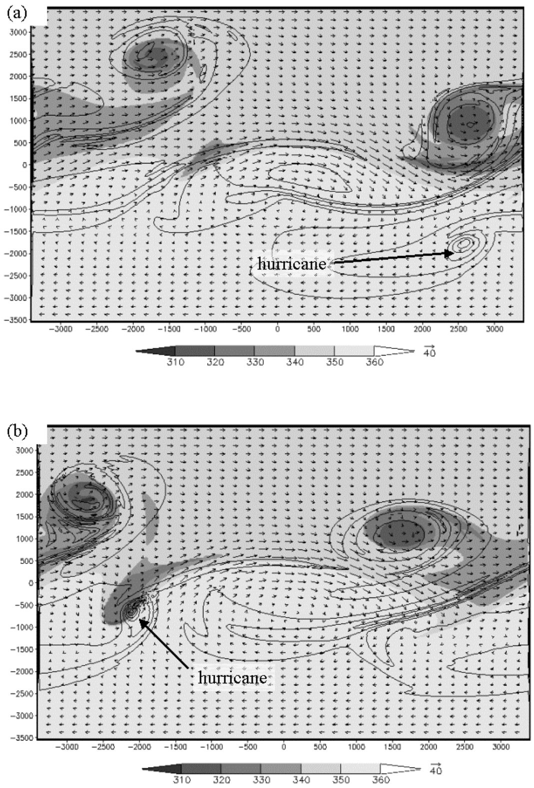

Fig. 2: Typical example of LC1-A (upper) and LC1-B (lower). Plots show low-level PV (contours) and potential temperature (shaded) and horizontal wind vectors on

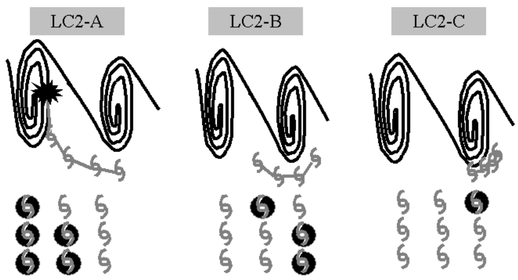

Fig. 3: As Fig. 1 for LC2

In the LC2 case there are three major types of hurricane tracks shown in Fig. 3. The hurricanes which are initially located further to the southwest or the west move to the northwest primarily due to the beta-drift and hit the western trough (LC2-A). The merging of the PV associated with the front and the PV associated with the hurricane (Fig. 4a) results in the development a frontal wave and a deepening of the resulting system. The timing of this merging seems to be critical for the deepening. In one case (not shown here), in which the hurricane hits the frontal zone some hours later, the deepening is not as dramatic as in the case shown in Fig. 4a.

The LC2-C that is located furthest to the northeast cannot pass the eastern trough and as this trough evolves and moves to the east, the hurricane is also steered eastwards (see Fig. 4b). As a consequence this hurricane ends up about 2000 km further to the east than the LC2-B case which was initially located just 250 km further to the south. The LC2-B cases form the intermediate group of hurricane tracks, as these hurricanes are able to pass the eastern trough, but do not interact with the western trough.

The results show that the hurricane track is very sensitive to its initial position. A deviation of just 250 km in its initial position leads to a completely different hurricane motion. This difference can determine whether extratropical transition occurs or not. But the hurricane is not only influenced by the baroclinic wave, the development of the wave is also influenced by the hurricane, for example, when the hurricane induces a wave on the frontal zone. Even though these differences are not as striking as the differences in the hurricane track, they can be significant for the future development of both systems.

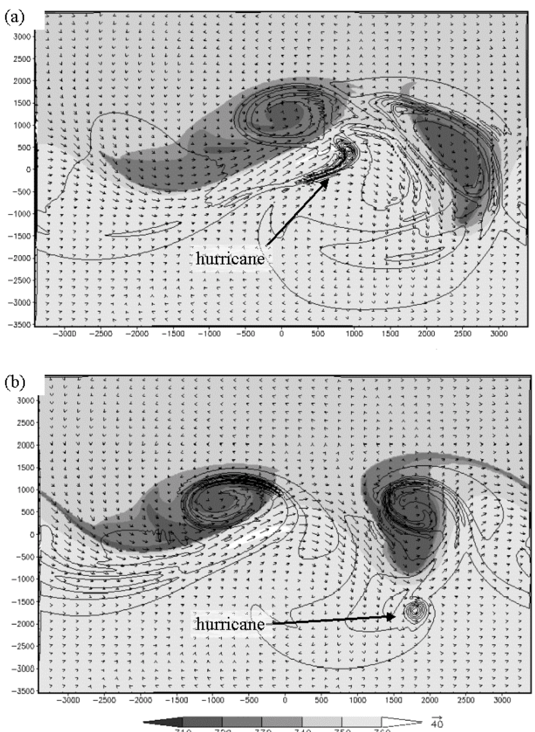

Fig. 4: As Fig. 2 for LC2-A (upper) and LC2-C (lower).

4. ACKNOWLEDGEMENTS

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5. REFERENCES

Thorncroft, C. D., B. J. Hoskins, M. E. McIntyre, 1993: Two paradigms of baroclinic-wave life-cycle behaviour. *Quart. J. Roy. Meteor. Soc.*, **119**, 17-55