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

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## 1. INTRODUCTION

42% of all the hurricanes that developed over the Atlantic Ocean between 1899 and 1996 underwent extratropical transition (Hart and Evans, 2001). Such extropical cyclones may cause strong winds 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.

An important factor in extratropical transition is the interaction of a hurricane with a pre-existing baroclinic wave. Thorncroft and Jones (2000) investigated the extratropical transition of Hurricane Iris (1995). Iris was steered northward by the flow associated with an upper-level positive potential vorticity (PV) anomaly. Subsequently the upper-level PV wrapped up cyclonically in the manner of the LC2 baroclinic life cycle described in Thorncroft *et. al.* (1993). The low-level remnants of Iris were advected around into the center of the LC2-type development giving a strong low-level low pressure system.

In this paper idealized numerical experiments are described which investigate the interaction of a hurricane-like vortex with an LC2-type baroclinic wave.

## 2. INITIAL CONDITIONS

Calculations are carried out using a three-dimensional, nonlinear, primitive equation limited area model (Jones and Thorpe., 1992), but with the full variation of the Coriolis parameter with latitude. The model is initialized with a zonal jet (Wernli *et. al*., 1999) which has a maximum just below the tropopause and at a latitude of 52° (y=0). 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 an LC2-type baroclinic wave develops. A horizontal cross-section of the PV of the baroclinic wave at 144h is shown in Fig. 1. Two extratropical cyclones have developed. The PV shows the cyclonic wrap-up which is characteristic for the LC2 life cycle.

A hurricane-like vortex is inserted and the integration is recommenced. The maximum tangential wind speed of the vortex is 34 $ms^{-1}$ and the radius of gale force winds is 270 km. The tangential wind speed is maximum at the surface and decreases to zero at the tropopause. The insertion is carried out at different integration times corresponding to different stages of maturity of the baroclinic wave and at different positions relative to the baroclinic wave.

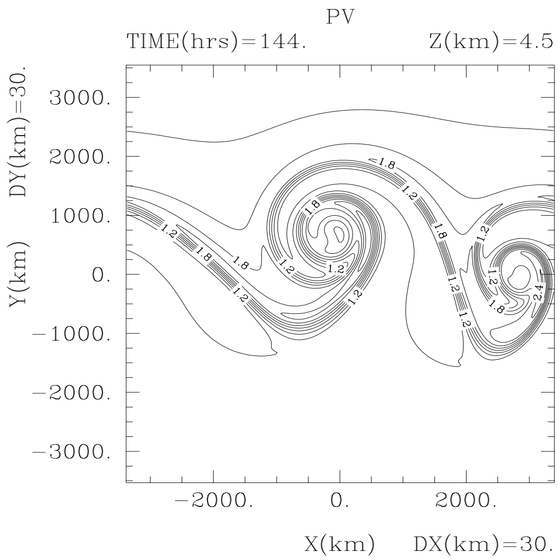


**Fig. 1: 'No Storm':** Horizontal cross-section of the PV after 144 h integration time at a height of 4.5 km with no hurricane-like vortex inserted.

## 3. CALCULATIONS WITH HURRICANE

Results shown in this abstract concentrate on two cases to investigate the sensitivity of the evolution to the initial location of the hurricane-like vortex relative to the baroclinic wave. For this purpose the hurricane is inserted at the same longitude, but at different latitudes. In case 'Storm South' the initial location of the vortex is 500 km further south than in case 'Storm North'. In both cases the hurricane-like vortex is inserted at the beginning of the integration time.

In the initial stages of the calculation (not shown) 'Storm North' moves southwards whereas 'Storm South' remains stationary. This can be attributed to the

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PV-gradient associated with the mid-latitude jet. In the case of ‘Storm South’ the hurricane-like vortex is located in a region where the PV-gradient associated with the jet approximately cancels that associated with the beta effect. Thus no “PV-gyres” develop and the vortex does not move. In the case of ‘Storm North’ there is a negative meridional PV-gradient to the north of the vortex. The interaction between the vortex and the PV-gradient leads to the development of “PV-gyres”, so that the vortex is steered southwards.

The influence of the vortex on the baroclinic wave can be seen by comparing Figs. 2 and 3 with Fig. 1. The insertion of ‘Storm South’ does not influence the development of the baroclinic wave noticeably, whereas

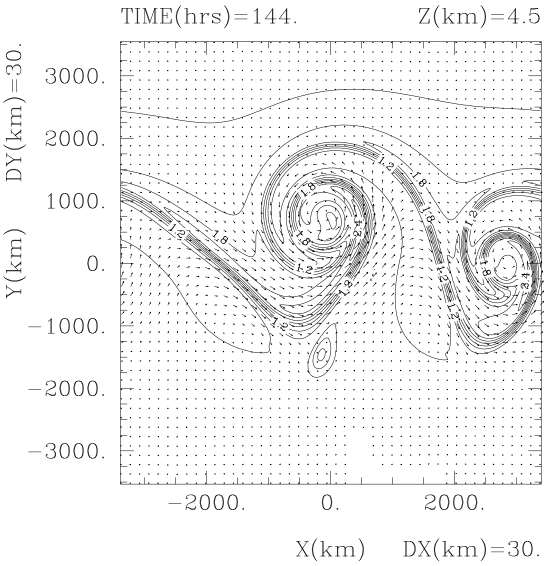


**Fig. 2: ‘Storm South’**: Horizontal cross-section of the PV and horizontal wind vector after 144 h integration time at a height of 4.5 km. Initial vortex location x:= -500km, y:= -1550km

the insertion of ‘Storm North’ results in the development of a third low-pressure system characterized by high values of PV. We suggest that the circulation of ‘Storm North’, which impinges on the baroclinic zone at the initial time, perturbs the zonal, baroclinically unstable flow leading to the development of a third extratropical system. Further experiments are in progress to test this hypothesis.

In the case of ‘Storm South’ the extratropical system seen at the center of the domain in Fig. 2 approaches the vortex. The PV of the vortex is distorted by the the horizontally sheared flow ahead of the trough. In the case of ‘Storm North’ the extratropical system passes well to the north of the vortex and the latter remains in the tropics. The closer approach of the extratropical system and the vortex in ‘Storm South’ than in ‘Storm North’ can be attributed to two factors. Firstly, the position of the hurricane in the case ‘Storm South’ is further to the north (due to the southward motion of the vortex in ‘Storm North’). Secondly the meridional extension of the baroclinic flow in ‘Storm South’ is much bigger than in ‘Storm North’. Thus, the baroclinic flow has stronger influence on the vortex. ‘Storm North’ may undergo extratropical transition at a later integration time, because in another case (not shown), where the storm is located more to the southeast, the first extratropical system passes by and advects the storm southwards, whereas the interaction with the second extratropical system results in an extratropical transition event.

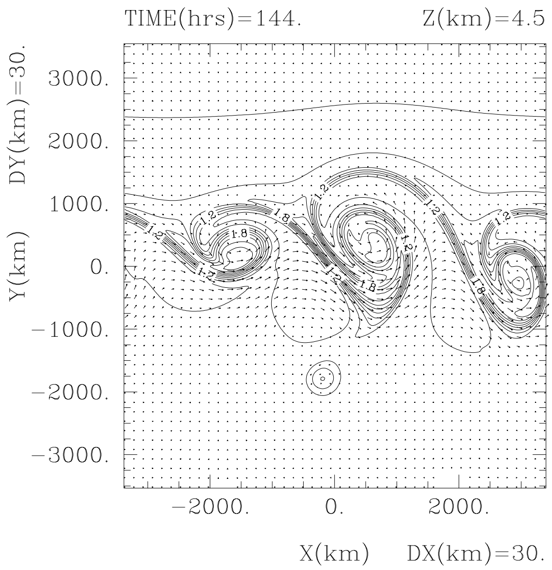


**Fig. 3: ‘Storm North’:** Horizontal cross-section of the PV and horizontal wind vector after 144 h integration time at a height of 4.5 km. Initial vortex location x:=-500km, y:= -1050km

## 4. ACKNOWLEDGEMENTS

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