

Effects of Convective Heating and Air-Sea Interaction on Tropical Cyclone Motion

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LONG-TERM GOALS

The long-term goal is to advance our understanding of the dynamics of tropical cyclone (TC) motion. Of particular interests are the origin of the non-steering component of TC motion and the impacts of baroclinic processes (vertical environmental shear, vertical structure, and diabatic heating) on TC motion.

SCIENTIFIC OBJECTIVES

The specific scientific objective of this study is to understand how the convective heating and interaction between the TC and upper ocean influence the motion and vertical coupling of baroclinic TCs.

APPROACH

Design and perform controlled numerical experiments with a realistic hurricane model (Wang 1998) and a coupled hurricane-ocean model to identify major processes determining baroclinic TC motion in the presence of convective heating and/or air-sea interaction. We develop, test, and apply a new diagnostic framework, the potential vorticity tendency (PVT) analysis, for quantifying contributions of various physical processes to TC motion.

WORK COMPLETED

We have put forward a novel diagnostic approach, the PVT analysis, for quantitatively assessing contributions of various physical processes to baroclinic TC motion.

Investigation of the physical processes by which diabatic heating affects the beta drift of a baroclinic TC and the motion under the influence of environmental vertical shears have been completed.

A numerical study of the influence of TC-ocean interaction on the baroclinic TC motion has been carried out, results will be written up shortly.

Report Documentation Page

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14. ABSTRACT The long-term goal is to advance our understanding of the dynamics of tropical cyclone (TC) motion. Of particular interests are the origin of the non-steering component of TC motion and the impacts of baroclinic processes (vertical environmental shear, vertical structure, and diabatic heating) on TC motion.					
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RESULTS

We have proposed and demonstrated with numerical experiments that a baroclinic TC moves toward an area of maximum potential vorticity tendency (PVT) (Wu and Wang 2000). PV advection and diabatic heating are the primary contributors to PVT. The PV advection process consists of advection of symmetric PV by asymmetric flow (which includes environmental "steering flow" and beta-induced "ventilation flow") and the advection of asymmetric PV (which includes beta gyres and contribution from asymmetric heating) by symmetric flows. We discovered that the change of PVT by the diabatic heating process depends on the vertical gradient of the convective heating and the coupling between the vertical shear and the horizontal gradient of convective heating.

We have revealed that in the presence of convective heating, the motion of baroclinic TCs has a considerable non-steering component. The movement of a TC can be better accounted for by a combination of two primary processes: advection of the symmetric PV by the asymmetric flow (the steering component) and the direct influence of the asymmetric diabatic heating (the non-steering component) (Fig. 1). Even in the presence of heating, a steering level can still be found at which the TC moves approximately with the asymmetric flow weighted by the horizontal symmetric PV gradient. Such a steering level is located at the height where the vertical gradient of the asymmetric heating vanishes, rather than at the level of the mass center of the TC. It is also found that the steering effect is determined by the horizontal symmetric PV gradient, thus, the asymmetric flows in the core region, rather than outer regions is most effective in controlling TC translation.

How does the air-sea coupling affect the TC motion? Comparison of the track differences between the coupled and uncoupled numerical experiments indicates that the difference is sometimes significant while other times rather moderate, especially for fast-moving tropical cyclones. Why? The response of ocean surface temperature to the surface wind stress is remarkably asymmetric, thus the convective heating is also asymmetric due to oceanic feedback. The asymmetric convective heating affects the TC motion by two processes: generation of asymmetric flows, which may alter advection of symmetric PV, and modification of the PVT tendency, which may deflect the TC toward the maximum PVT area. It seems that the track difference depends on how these two processes compete with each other.

IMPACT/APPLICATIONS

The PVT analysis approach provides a revealing tool for understanding baroclinic tropical cyclone motion in general and the non-steering processes of the TC motion in particular. It has the potential to be applied to real observational analysis and to diagnoses of the outputs from complex numerical models.

TRANSITIONS

Our PVT analysis technique has been applied to observed data by Johnny Chan's group at the City University of Hong Kong (Chan 2000, Lei and Chan 200, Ko and Chan 2000). The data used to validate the PVT approach and determine the relative contribution of various processes to the overall PVT include the UK Meteorological Office operational analyses, satellite-derived temperature profiles from high-resolution geosynchronous satellite images for individual TCs, and the analyses from Tropical

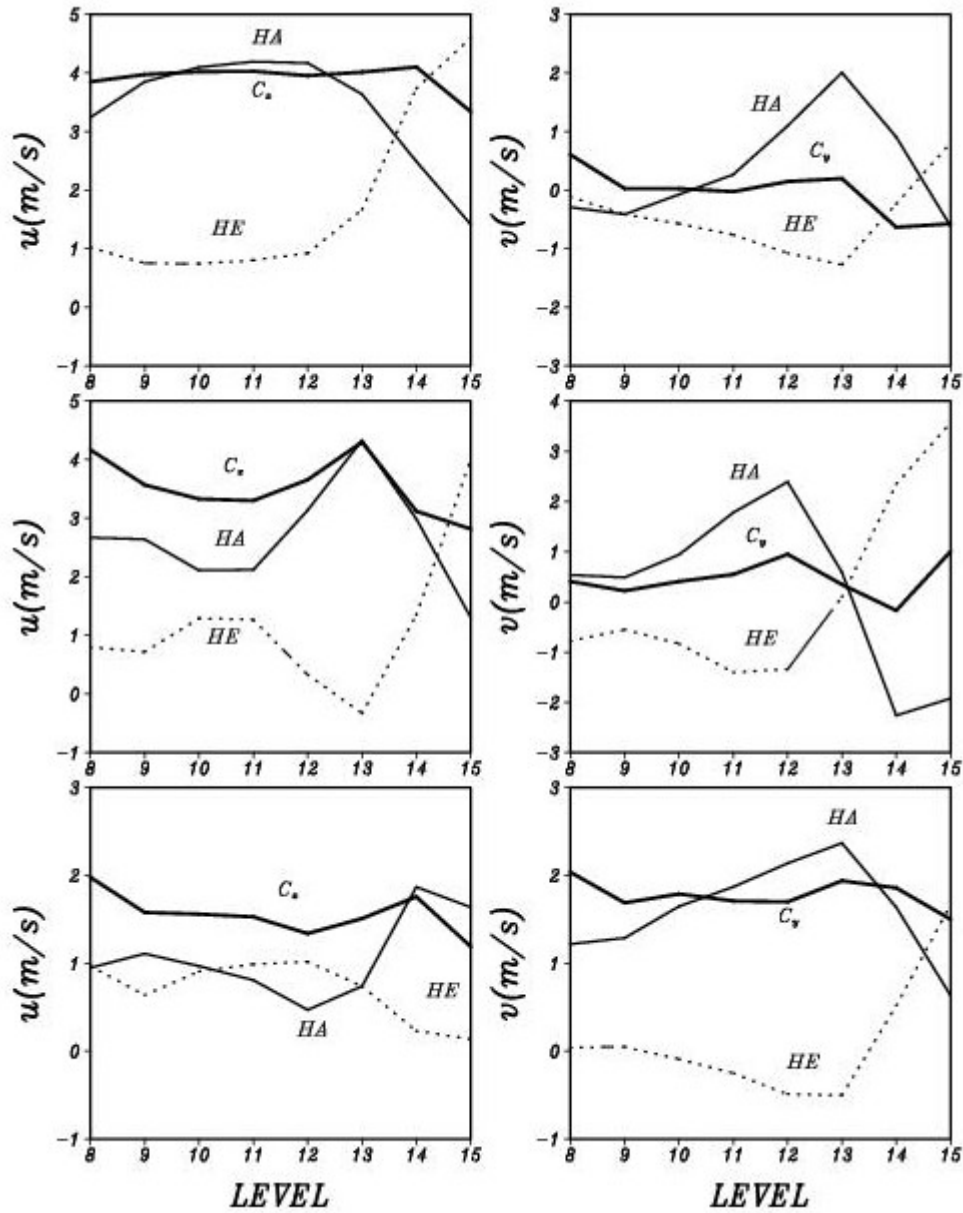


Figure 1 Time mean contributions of horizontal advection (HA) and diabatic heating (HE) to the zonal (left panels) and meridional (right panels) of TC motion (C) in the experiments with uniform zonal environmental flow on an f -plane (upper), vertically sheared environmental flow (middle) on an f -plane and resting environment on a beta plane (bottom), respectively. These results indicate that the HA and HE are primary contributors to the TC motion.

Cyclone Motion Experiment TCM-90. The observations firmly support the concept and premise of the PVT approach, which opens a new avenue for explaining non-steering processes of TC motion.

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PUBLICATIONS

The following publications during FY 2000 are supported or partially supported by this grant.

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Dissertation

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