Role of Vortex Rossby Waves on Tropical Cyclone Intensity

Melinda S. Peng
Naval Research Laboratory
Monterey CA 93943-5502
phone: (831) 656-4704 fax: (831) 656-4769 e-mail: melinda.peng@nrlmry.navy.mil

Award Number: N0001407WX20651

LONG-TERM GOALS

The long-term goal of this project is to improve the prediction of tropical cyclone (TC) genesis and intensity changes through improved understanding of the fundamental mechanisms involved. Accurate prediction of TC intensity change is critical to Navy missions and civilian activities in coastal areas. Significant gains have been made in the TC track prediction over the past three decades. The intensity forecast, however, has shown very little progress during the same period. A main factor contributing to the lack of skill in the prediction of TC intensity is the inadequate understanding of the complicated mechanisms that are involved. These mechanisms include internal dynamic and thermodynamic processes, external forcing, and scale interactions. Only after we understand these processes, will we then be able to tackle the weaknesses in model simulations and forecasts.

OBJECTIVES

The objective of this project is to understand how asymmetric disturbances, often generated by local convection, affect TC structure and intensity change. Two focus areas of the study include: 1) the effect of different characteristics of externally exposed asymmetries on the axisymmetrization of TCs, and 2) the evolution of stable and unstable waves and their impacts on the basic vortex.

APPROACH

For the first part of the study listed under the objectives, our approach is to use an idealized TC model to investigate vortex axisymmetrization for different basic vortex profiles and different asymmetries. The model developed can be used as a barotropic or a baroclinic model. Idealized vortices resembling realistic TC radial profile and asymmetries representing disturbances from convection will be prescribed. Diagnostic tools will be developed to analyze results from model integrations. For the second part of the study, wind profiles with radial shear instability in the inner part, the outer part, or both, will be investigated to understand the growth and decay of vortex Rossby modes with different wave numbers. To investigate the instability characteristics of TC wind profiles, an eigenvector analysis system for the barotropic vorticity equation will be built, and stable and unstable eigenvalues and eigenmodes will be investigated.

WORK COMPLETED

Following the axisymmetrization study in a barotropic framework, we have completed new work on the axisymmetrization in baroclinic models. The results are discussed in the following section. In addition, we have completed construction of an eigenvector analysis system for the barotropic vorticity

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
30 SEP 2007	**Annual**	**00-00-2007 to 00-00-2007**

4. TITLE AND SUBTITLE	
Role Of Vortex Rossby Waves On Tropical Cyclone Intensity	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Research Laboratory,Monterey,CA,93943-5**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S)
	11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
code 1 only

14. ABSTRACT
The long-term goal of this project is to improve the prediction of tropical cyclone (TC) genesis and intensity changes through improved understanding of the fundamental mechanisms involved. Accurate prediction of TC intensity change is critical to Navy missions and civilian activities in coastal areas. Significant gains have been made in the TC track prediction over the past three decades. The intensity forecast, however, has shown very little progress during the same period. A main factor contributing to the lack of skill in the prediction of TC intensity is the inadequate understanding of the complicated mechanisms that are involved. These mechanisms include internal dynamic and thermodynamic processes, external forcing, and scale interactions. Only after we understand these processes, will we then be able to tackle the weaknesses in model simulations and forecasts.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**5**	

equation and investigated the eigenmodes with the largest growth for different unstable basic-state profiles. The time evolutions of unstable disturbances in linear and nonlinear barotropic models are investigated.

RESULTS

Previous studies on vortex axisymmetrization indicate that asymmetries imposed near the radius of maximum wind can lose their energy to the symmetric static state while propagating outward due to differential rotation of the basic vortex. In our study, we find that the impacts of disturbances on the symmetric vortex through axisymmetrization can be explained by the phase tilt of the asymmetries in the early stage, and that their phase tilts are determined by the characteristics of the asymmetries, such as their positions, radial profiles, and azimuthal wave numbers. The further an initial asymmetry is away from the core, the smaller the upshear tilt is. In addition, the efficiency of differential rotation on changing the phase tilt from an upshear to a downshear tilt also depends on the initial position of the asymmetries and the further the asymmetry is away from the core, the slower the process is. These two factors act oppose each other such that an optimal radius can be obtained, such that when an asymmetry is placed initially, the energy transfer between the asymmetry and the basic state will be largest. For several different basic-state profiles investigated, the optimal radius is about 1.5 to 2 time the radius of the maximum wind. The concept of the optimal radius is illustrated in Fig. 1.

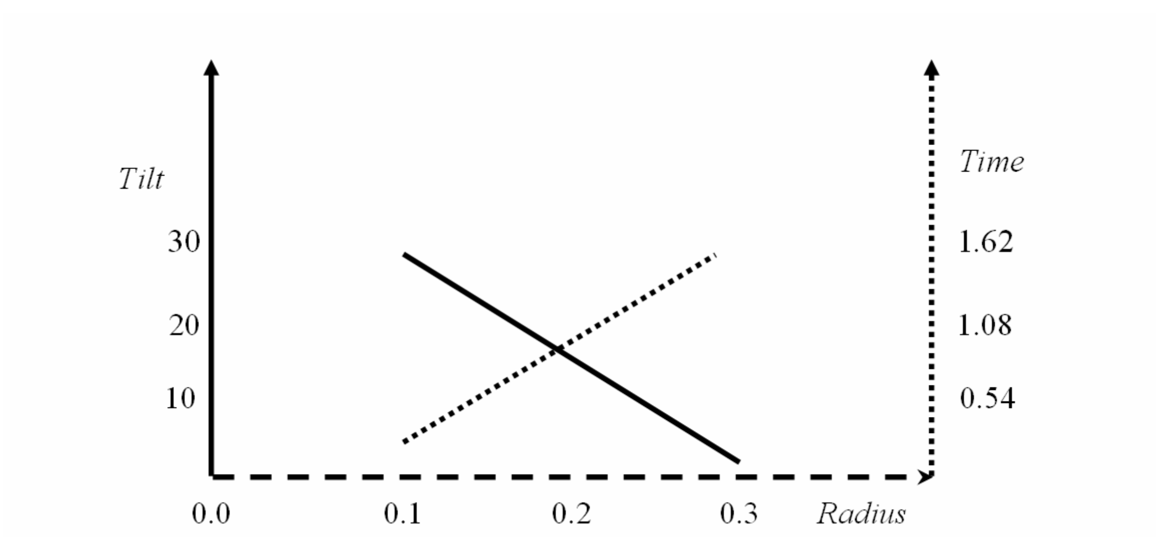

Fig. 1. The left axis show the tilt of the asymmetry as a function of the initial position of the asymmetry while the right axis is the time it takes for the asymmetric tilt to be restored to neutral. The cross point represents the existence of an optimal radius where the asymmetry would have the largest energy exchange with the basic state.

As an asymmetry is placed further away from the core, the basic-state vortex can obtain a double-wind peak, or change its outer wind profile (Fig 2). This suggests that axisymmetrization can be a mechanism for the formation of the double eyewall. The manuscript documenting the general result of barotropic vortex axisymmetrization has been submitted to QJRMS and is currently under review. Another manuscript documenting the results on the double eye wall structure is completed and submitted to a special book issue for the Asian Oceanic Geosciences Society (AOGS).

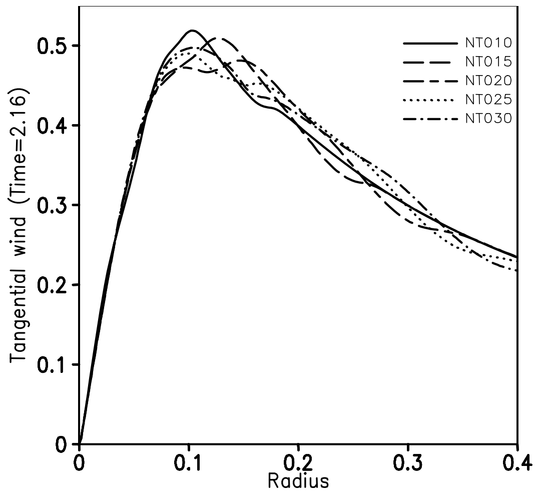

Fig. 2. Final state of the basic state wind profile after axisymmetrization for asymmetries placed at different positions in nonlinear simulations. Notice the existence of double wind maxima and different variations of the outer wind profile. Even though the change of the basic state is small, they represent only one single asymmetry. In reality, asymmetries are generated all the time and their impacts to the basic-state symmetric wind are cumulative.

We completed the study of axisymmetrization (through Rossby wave propagation) in a baroclinic framework. The main finding is that the baroclinic vortex Rossby wave propagates outward at a slower speed than the corresponding barotropic vortex Rossby wave, resulting in a slower linear axisymmetrization for baroclinic asymmetric disturbances. Therefore, more baroclinic asymmetric KE can be transferred locally to the barotropic symmetric circulation than that from barotropic asymmetric disturbances. The warm (cold) advection by the barotropic mean flow in the linear baroclinic experiment induces a phase shift between the baroclinic asymmetric divergence and vorticity, therefore the baroclinic disturbance divergence modifies the energy propagation of the baroclinic vortex Rossby wave and makes the vortex axisymmetrization evolve slower in the linear baroclinic case than the corresponding barotropic case. A manuscript is under preparation.

The stability of a hurricane-like vortex is investigated through eigenvector analysis and nonlinear simulations in a barotropic framework. The focus is on the outer unstable profiles that have been observed in NOGAPS analyses of tropical cyclones. The eigenvector analysis shows that the most unable mode is the wavenumber-two mode. When this type of mode is included in the nonlinear simulation, the growth of the initial disturbances located near where the vorticity gradient changes sign induces strong asymmetries in the inner core, and causes large energy exchange between the asymmetry and the basic state. These unstable modes, in general, reduce the maximum intensity of the basic-state vortex, and change the outer structure of the vortex (Fig. 3). Research work continues in this area.

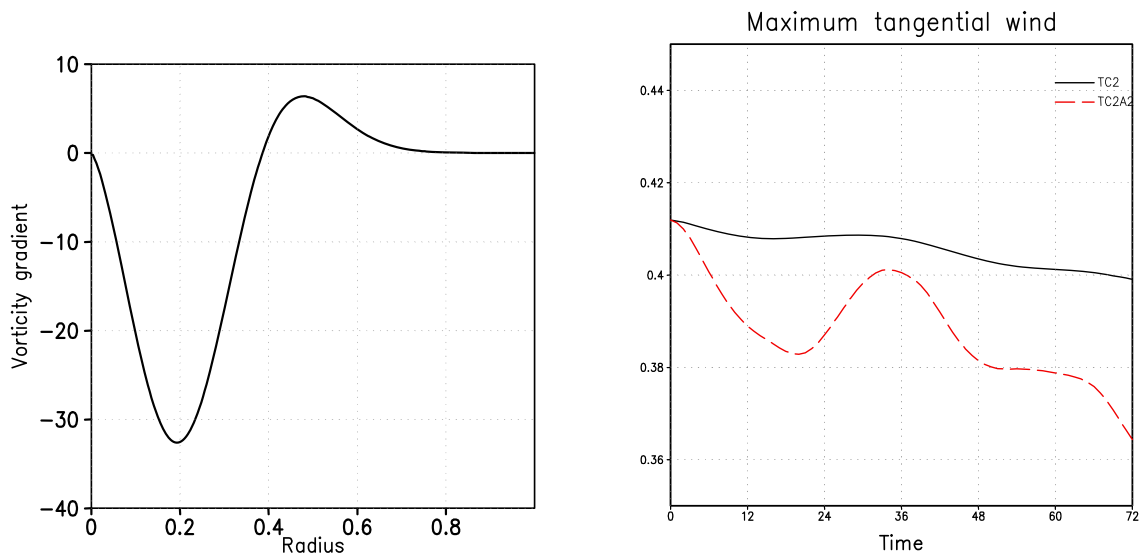

Fig 3. The left panel is the vorticity gradient of a basic-state wind profile where it changes sign at outer radius, indicating barotropic instability. The right panel shows the time evolution of the maximum wind speed of the basic state. The black solid line has no initial disturbance while the red dashed line is the maximum symmetric wind intensity with an initial asymmetry that has the structure of the most unstable wavenumber-two structure. Note that the vortex intensity decreases significantly with the unstable mode.

IMPACT/APPLICATIONS

The understanding of how a hurricane-like vortex can gain or lose energy to and from asymmetric disturbances is critical to improve our predictions of TC genesis and TC intensity change.

TRANSITIONS

Results from this study that lead to modeling improvements in the ability of NOGAPS to predict tropical cyclones will transition to 6.4 projects within PE 0603207N (SPAWAR, PMW-180) that focus on the transition of NOGAPS to FNMOC.

RELATED PROJECTS

This project is closely related to the NRL 6.2 funding on "Predicting tropical cyclone genesis using NOGAPS". Knowledge gained from this project will help to improve the prediction of tropical cyclone genesis.

PUBLICATIONS

Peng, J.-Y., M. S. Peng, and T. Li, 2007: Dependence of vortex axisymmetrization on the characteristics of the asymmetry. *QJRMS*, (Submitted).

Peng, J.-Y., T. Li, M. S. Peng, 2007: Formation of tropical cyclone concentric eyewalls by wave-mean interactions. *AOGS,* (submitted).

PRESENTATIONS

Peng, M. S. Jiayi Peng, and T. Li, 2007: Dependence of vortex axisymmetrization on the characteristics of the asymmetry. IAMAP, 2-13 July 2007, Perugia, Italy. (Invited talk).