# TROPICAL CYCLONE MOTION STUDIES

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## LONG-TERM GOALS:

To improve tropical cyclone track and intensity prediction through a research program combining high resolution modeling and detailed observations to investigate physical processes by which the motion and structure of a tropical cyclone is modified.

## OBJECTIVES:

The objective of this project is to investigate the physical processes that occur as a tropical cyclone interacts with the environment such that motion and structure changes occur. Specific interactions being studied are with mesoscale convective systems (MCS) that have been hypothesized to impact the development, structure and motion of tropical cyclones, with baroclinic environments within the tropics and in the midlatitudes during extratropical transition, and with topography as a tropical storm makes landfall. As a storm makes landfall, significant asymmetries in the low-level wind structure are expected to develop with marked impact on precipitation and wind damage patterns. During extratropical transition, radical changes to the storm structure occur as the warm core is eroded by intruding cold, dry air from the midlatitudes. Re-intensification to a strong midlatitude system is possible, and to further complicate matters, passage over the Japan islands can also occur during this transitioning period. In cases where forecast models did poorly in predicting the motion and re-intensification of the storm during these transitional periods, better understanding of these processes should improve motion and intensity forecasts.

## APPROACH:

Due to the sparsity of detailed observations in regions where tropical cyclones develop and move, high-resolution, idealized modeling is combined with observations where available, in all

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studies described here. The degree of physical complexity included in current mesoscale models allows detailed examination of environmental and mesoscale convective system (MCS) impacts on the motion, structure, and intensity of tropical cyclones. However, caution must be taken when applying cause and effect arguments to describe the complex physical interactions that develop in these high-resolution models that may be a product of the model parameterizations rather than realistic physical processes. Thus a tiered approach is employed here in which understanding of basic processes comes first and is built upon by gradually adding to the complexity of the modelling system, isolating each physical process in turn. The U.S. Navy's coupled ocean-atmosphere mesoscale prediction system (COAMPS) is the primary model used in ongoing studies into landfall modifications and extratropical transition effects on tropical cyclone motion and structure. Where available, detailed observations such as those available from the ONR-sponsored TCM-92 and TCM-93 field experiments are used to verify processes examined in the model experiments.

## TECHNICAL RESULTS:

Results have been obtained with respect to the role that MCS played in the development of two tropical cyclones during TCM-92 and TOGA COARE. Interaction between MCSs and the large-scale environment was extremely important for these tropical cyclone developments. In both cases, pre-existing synoptic-scale, low-level vortices did not develop into tropical cyclones until development of, and interaction with, MCSs occurred. In one instance, (Ritchie and Holland 1997), multiple MCS developments over a few days within one of several low-level circulations resulted in the development of a tropical storm during a period when the large-scale environment in the western North Pacific was not conducive to storm development. In the other case (Simpson et al. 1997a; Simpson et al. 1997b), a series of monsoon lows moved off the Australian coast prior to the development of TC Oliver. The primary difference was the development and interaction of twin MCS within the monsoon low that rapidly resulted in a tropical cyclone.

The motion and structural development of tropical cyclones in a baroclinic vertical shear environment has also been numerically simulated (Frank and Ritchie 1997). Important results include the identification of persistent patterns of asymmetric convection and rainfall in the left quadrant of the storm. The rotational motion of the storm due to storm tilt that was identified in dry simulations is reduced in simulations that include parameterizations of convective processes since the tilt due to environmental shear is almost completely cancelled. In an environmental vertical wind shear of 3 m $s^{-1}$ over the entire troposphere, the storm advected at 1 m $s^{-1}$ with only a slight motion to the right of the storm track.

The first-order effects on the core of a tropical cyclone due to an asymmetric MCS have also been numerically simulated (Ritchie and Frank 1997). Initial results indicate that a storm will intensify in the presence of this asymmetric convection, but to a lesser extent than for symmetric forcing. These simulations differ from conventional wisdom that asymmetric convection or convection displaced from the center of a vortex results in non-intensification or even a weakening of the storm. The studies indicate that further investigation is needed to determine at what radius from the center the convection can be before detrimentally affecting the storm structure and intensity.

The COAMPS model was obtained from Naval Research Laboratory -- Monterey to investigate transitioning and landfalling tropical cyclones. An initial case study of a transitioning typhoon over Japan for which the NOGAPS model guidance was poor has been run to test various facets of the higher resolution modeling system. Although the predicted storm motion was slow for the COAMPS simulation, the path was very close to that observed, and rainfall patterns closely matched the SSM/I data. In general, the COAMPS system appeared to have captured the main aspects of the extratropical transition as well as the topographical interactions (Ritchie et al. 1997).

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