TROPICAL CYCLONE MOTION STUDIES

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LONG-TERM GOALS:

Globally, tropical cyclone characteristics such as activity, genesis location, and track types have been observed to vary over space and time scales that range from seasonal to that of an individual cyclone. Because of this hierarchical structure to the variability in tropical cyclone characteristics, the long-term goal of this research is to define a synthesized view of the large-scale, synoptic-scale, and mesoscale components that contribute to the variability in tropical cyclone characteristics. Over large space scales and long time scales, the long-term goal is to improve forecast accuracy of tropical cyclone characteristics into the medium range beyond 72 h. At the opposite end of the space and time spectrum, the goal is to improve understanding of the potential effects of mesoscale variabilities in tropical cyclone structure on the short-term motion, formation, intensification, and structure change of a tropical cyclone. Additionally, a long-term goal is to understand how variabilities in the environment and tropical cyclone structure differ between developing, mature, and decaying tropical cyclones. Because decaying tropical cyclones often transition to fast-moving and rapidly-developing extratropical cyclones that may contain gale- or storm-force winds, special attention is given to improving understanding and prediction of the extratropical transition phase of a decaying tropical cyclone.

OBJECTIVES:

Observations from two ONR sponsored field programs (TCM-92, TCM-93) suggest that the outer wind structure of the mature tropical cyclone, which is important to understanding its motion over shorter time scales, is dependent on the growth, evolution, and decay characteristics of mesoscale convective systems (MCSs) and associated midlevel vortices. The objectives for this reporting period have concentrated on improved understanding of factors that control MCS evolution in the tropical cyclone environment and the relationships between the MCS development and the large-scale environment. Furthermore, the effect of mesoscale structure changes on tropical cyclone characteristics are to be defined for various stages of tropical cyclone development, which includes developing, mature, decaying, and extratropical transition.

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Results from the TCM-93 field program (Harr and Elsberry 1996; Harr et al. 1996a,b) may be used as a basis for examination of the relationships between MCS evolution associated with a tropical cyclone and the variability of the large-scale circulation. At one extreme, which resulted in a small tropical cyclone moving in a broad steering current, the role of mesoscale features in determining tropical cyclone characteristics was to form an initial concentration of vorticity about which the tropical cyclone formed (Harr et al. 1996a). At the other extreme, the role of mesoscale features contributed to the total organization of a larger circulation system (Harr et al. 1996b). Although this large tropical cyclone continued to contain MCS development that contributed to large structural asymmetries, the influence on a subsequent track change was unclear (Harr and Elsberry 1996). Based on these results, it is hypothesized that the structure of a mature tropical cyclone, which may affect its motion, may be determined by conditions at the time of formation. This hypothesis implies that tropical cyclone wind structure changes as the system intensifies evolve from conditions at formation time and that these developments (excluding drastic external influences) are small compared to structural differences that are established during formation.

Because detailed observations such as those taken during TCM-93 are not routinely available, relationships between the evolution of the mesoscale characteristics and the large-scale circulation during various stages of the tropical cyclone development are based on an extensive data base (Finta 1997) that consists of hourly geostationary satellite imagery and corresponding environmental fields from 12-h analyses produced by the Navy Operational Global Atmospheric Prediction System (NOGAPS). Extension to the extratropical transition stage is accomplished through a multivariate statistical approach (Harr et al. 1996c) that relates the tropical cyclone transition and the large-scale environment (Klein et al. 1997, Klein 1997).

WORK COMPLETED:

High-resolution satellite imagery is used in conjunction with NOGAPS analyses to examine the interaction between MCS evolution, tropical cyclone characteristics, and the large-scale environment. The relative importance of MCS activity to TC development and eventual mature structure is described by a conceptual model. The model is examined through objective determination of MCS activity for a variety of tropical cyclone evolutions. Examination of cases of extratropical transition that occurred between 1990-1996 extend the analysis and lead to description of a separate conceptual model that describes the structural modifications that occur during transition.

RESULTS:

Based on analyses of MCS and tropical cyclone evolution during TCM-93 (Harr et al. 1996a,b), two conceptual models were developed to define the variability in structure and structure changes of a mature tropical cyclone. The conceptual model defined the relative roles of MCS activity in increasing the organization of a developing tropical cyclone. A first type, labeled "mesoscale type," was defined as a tropical disturbance in which increasing low-level cyclonic vorticity was caused primarily by a centrally located MCS in a thermodynamically favored environment. A second type, labeled "synoptic type," was based on a hypothesis that strong synoptic-scale dynamic forcing (rather than MCS forcing) is the primary mechanism for increasing low-level vorticity. Extension of the analysis (Finta 1997) by examination of additional cases using high-resolution satellite imagery and NOGAPS analyses resulted in a refinement of the conceptual model that bases the variability in tropical cyclone structure as a variation on the same theme: the interaction of mesoscale and synoptic scale processes in a thermodynamically favorable environment. Based on this analysis, it was demonstrated that tropical cyclones that formed primarily by vigorous sustained MCS activity tend to be smaller than those that develop primarily through synoptic-scale processes. This result implies that processes that operate during the tropical cyclone development have a lasting influence on the structure, and hence the motion, of the mature tropical cyclone.

A more quantitative means of defining the MCS and synoptic environment was introduced by Harr et al. (1997). Although based on a limited sample, this study verified that MCS size and duration could be related to each conceptual model type and these characteristics were then also related to the eventual mature tropical cyclone structure. Furthermore, this study defined the means by which MCS evolution associated with tropical cyclone activity could be examined with respect to general MCS activity throughout the tropical western North Pacific environment.

Klein et al. (1997) and Klein (1997) extended the analysis of Harr et al. (1996c) by continuing the examination of structural modifications during the transition from a tropical cyclone to an extratropical midlatitude cyclone. From these studies, it was learned that characteristics of extratropical transition could be defined in a framework of midlatitude circulation variability. Although tropical cyclone track and structure during the mature to decaying stages, may be related to the subtropical environment through which it is moving, the midlatitude circulation into which the decaying tropical cyclone moves exerts more influence on the transition and the type of midlatitude cyclone that would result from the transition. Klein (1997) defines a single conceptual model of the cloud signatures and their relation to the structure of all transitioning tropical cyclones in the sample period of study. This model defines transition as a two-stage process that involves transformation of the warm-core tropical cyclone to a cold-core system, and then re-intensification of the cold-core system into a mature extratropical cyclone. Furthermore, it was documented that NOGAPS forecast performance could be related to the stages defined in the conceptual model.

IMPACTS:

The conceptual models based on the TCM-93 results and the subsequent satellite analysis by Finta (1997) and Harr et al. (1997) impact the diagnosis and forecasting of tropical cyclone structure and structure changes, which also influence motion. Establishment of the importance of MCS evolution in determining the tropical cyclone structure leads the forecasters to analyze MCS characteristics in satellite imagery. The work of Finta (1997) was designed to establish the utility of high-resolution satellite imagery in deducing MCS and tropical cyclone evolution. A "systematic-approach technique" may provide a more complete categorization in terms of various large-scale and MCS parameters that can eventually be used to predict future wind structure based on the characteristics of the large-scale and mesoscale environment.

In response to optimum-track and least-cost ship routing factors, summer and early autumn trans-ocean maritime activity is often conducted at higher latitudes to take advantage of the climatologically favorable warm season wind and wave height conditions and significantly shorter route distances. Therefore, accurate forecasts of the intensity and movement of transitioning tropical cyclones is critical. Results of Harr et al. (1996), Klein et al. (1997), and

Klein (1997) that indicate the NOGAPS forecast accuracy depends on the type of transition, and the character of the midlatitude circulation into which the transitioning cyclone is moving, which will assist the operational forecaster in the interpretation of the numerical guidance.

TRANSITIONS:

It is expected that the integrated results of this investigation into the hierarchical structure of variability in tropical cyclone characteristics will be transitioned into a forecast system that JTWC will use to synthesize the contribution of MCS, tropical cyclone structure and motion characteristics, and the variability of the large-scale circulation.

REFERENCES:

Finta, C. A., 1997: Observations of mesoscale convective systems during tropical cyclone genesis. M. S. Thesis, Naval Postgraduate School, 80 pp.

Harr, P. A., and R. L. Elsberry, 1996: Structure of a mesoscale convective system embedded in Typhoon Robyn during TCM-93. *Mon. Wea. Rev.*, **124**, 634-652.

Harr, P. A., M. S. Kalafsky, and R. L. Elsberry, 1996a: Environmental conditions prior to formation of a midget tropical cyclone during TCM-93. *Mon. Wea. Rev.*, **124**, 1693-1710.

Harr, P. A., R. L. Elsberry, and J. C.-L. Chan, 1996b: Transformation of a large monsoon depression to a tropical storm during TCM-93. *Mon. Wea. Rev.*, **124**, 2625-2643.

Harr, P. A., R. L. Elsberry, P. M. Klein, T. F. Hogan, and W. M. Clune, 1996c: Impacts of the extratropical transition of tropical cyclones on midlatitude circulation systems. Preprints, *Fifteenth Conf. on Wea. Analysis and Forecasting*, Amer. Meteor. Soc., Boston, MA 02108, 509-512.

Harr, P. A., C. A. Finta, and R. L. Elsberry, 1997: Role of mesoscale convective vortices in determining the circulation structure during tropical cyclone formation. Preprints, *Twenty-second Conf. and Hurricanes and Tropical Meteorology*, Amer. Meteor. Soc., Boston, MA 02108, 193-194.

Klein, P. M., 1997: Extratropical transition of western North Pacific tropical cyclones. M.S. Thesis, Naval Postgraduate School, 101pp.

Klein, P. M., P. A. Harr, and R. L. Elsberry, 1997: Extratropical transition of western North Pacific tropical cyclones. Preprints, *Twenty-second Conf. and Hurricanes and Tropical Meteorology*, Amer. Meteor. Soc., Boston, MA 02108, 364-365.