

Evolution of Tropical Cyclone Characteristics

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LONG-TERM GOALS

The long-term goals are to understand how variabilities in the large-scale atmospheric environment and the internal tropical cyclone structure influence tropical cyclone track, structure, and intensity characteristics and define how these influences differ between developing, mature, and decaying tropical cyclones. During the initial stages of tropical cyclone development, structure and track characteristics can exhibit large variabilities that pose difficult forecast situations. Because decaying tropical cyclones often transition to fast-moving and rapidly developing extratropical cyclones that may contain gale-, storm-, or hurricane-force winds, there is a need to improve understanding and prediction of the extratropical transition (ET) phase of a decaying tropical cyclone. Therefore, a tropical cyclone throughout its life cycle has the potential for impacting many fleet units.

OBJECTIVES

Recent research has concentrated on two primary objectives. Extended periods of increased and reduced tropical cyclone activity occur several times during a typical tropical cyclone season (Harr and Elsberry 1995a,b). An objective of this project is to identify the physical mechanisms in the large-scale circulation that act to initiate, maintain, and terminate periods of enhanced or reduced tropical cyclone activity. If reliable forecasts of extended periods of increased or reduced tropical cyclone activity could be made, maritime operations could be coordinated appropriately.

A second objective has been to begin identification of operational global model forecast characteristics with respect to ET. The goal is to determine which aspects of ET are least predictable by examining forecast characteristics that are most inconsistent among multiple integrations of the Navy Operational Global Atmospheric Prediction System (NOGAPS) and among members of the NOGAPS and Global Forecast System (GFS) ensemble forecast systems.

APPROACH

The interannual variability in temporal clustering of tropical cyclone activity and inactivity over the western North Pacific basin during northern summer is established. To explain the variation in temporal clustering due to primary large-scale, slowly-varying atmospheric circulation patterns, a hierarchical framework of global-scale intraseasonal circulations and regional-scale monsoon trough variability is defined. Low-level wind fields and outgoing longwave radiation (OLR) characteristics are then partitioned into contributions from the various modes. Relationships between the two modes are examined to identify factors that explain variability in tropical cyclone activity/inactivity.

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Operational global model forecasts of ET cases are examined to catalog consistent features among models and among repeated integrations of individual models.

WORK COMPLETED

A temporal clustering algorithm was applied to time series of tropical cyclone activity over the western North Pacific during May-November 1958-1998. A wavelet analysis of 850 hPa zonal wind was completed to identify dominant periods of variability in large-scale circulations over the western North Pacific. A singular value decomposition (SVD) analysis of 10-25 day filtered 850 hPa and 200 hPa winds and OLR was completed to complement a similar analysis of 30-60 day circulations that was completed in the previous year. Variabilities in low- and upper-level winds and OLR were related to periods of tropical cyclone activity and inactivity.

To examine the capability of operational numerical models with respect to ET, an algorithm that is designed to track circulations throughout a forecast sequence and catalogue various analyzed and forecast parameters has been applied to several cases of ET during the 2003 tropical cyclone season over the western North Pacific and North Atlantic basins. Furthermore, several long-term integrations of NOGAPS have been examined to identify variability in forecasts of ET. A review of the current understanding of ET and its impacts was completed (Jones et al. 2003). Finally, a review of the topics of tropical cyclone formation and extratropical transition was completed (Harr 2002) for the Fifth International Workshop on Tropical Cyclones.

RESULTS

Previous results (Harr and Elsberry 1995a,b) have related tropical cyclone activity over the western North Pacific with the sign of zonal wind anomalies associated with the monsoon trough. Positive (westerly) anomalies are associated with an active monsoon trough and with enhanced tropical cyclone activity. Negative (easterly) anomalies define an inactive monsoon trough and reduced tropical cyclone activity. Based on a SVD analysis, intraseasonal modes related to the Madden-Julian Oscillation (MJO) were identified with an enhanced or reduced monsoon trough. The time coefficients of the SVD analysis were used to define periods of significant MJO activity into four periods defined with respect to the monsoon trough as; i) beginning active; ii) active; iii) beginning inactive; and iv) inactive. Although tropical cyclone activity in the monsoon trough increased during the MJO active period (Table 1), there were more tropical cyclones during the inactive portion of the MJO than would be expected by chance. Because of the number of tropical cyclones during the inactive portions of the MJO, prediction of intraseasonal tropical cyclone variability over the western North Pacific based solely on the MJO would not have sufficient skill.

To account for a larger portion of the variance in tropical cyclone activity, a SVD analysis of filtered 850 hPa (Fig. 1) and 200 hPa (not shown) winds, and OLR is used to identify principal circulation patterns over a period of 10-25 days, which is identified with variability in the monsoon trough (MT). A significant feature in the 10-25 day correlation patterns is a cross-equatorial flow from (to) the Southern Hemisphere during periods of an enhanced (reduced) monsoon trough. Furthermore, the correlation maps define circulation anomalies that propagate from southeast to northwest throughout the monsoon trough region of the western North Pacific. The time coefficients associated with the SVD analysis of 10-25 day variability were used in a manner similar to that defined with respect to the 30-60

	MJO Beginning Active	MJO Active	MJO Beginning Inactive	MJO Inactive
South China Sea	4	15	7	1
Monsoon Trough	19	45	16	17
East of Monsoon Trough	5	13	5	11
North of Monsoon Trough	9	4	3	17

Table 1 Frequency of tropical cyclone occurrence over the regions of the western North Pacific during June-October 1979-1998 based on MJO classifications defined by time coefficients of a SVD analysis of 850 hPa winds and OLR. Table rows define sub-regions of the western North Pacific as South China Sea (Eq.-20N, 100-120E), Monsoon Trough (Eq.-20N, 120-150E), East of the Monsoon Trough (Eq.-20N, 150-180E), and North of the Monsoon Trough (20-30N, 110-160E).

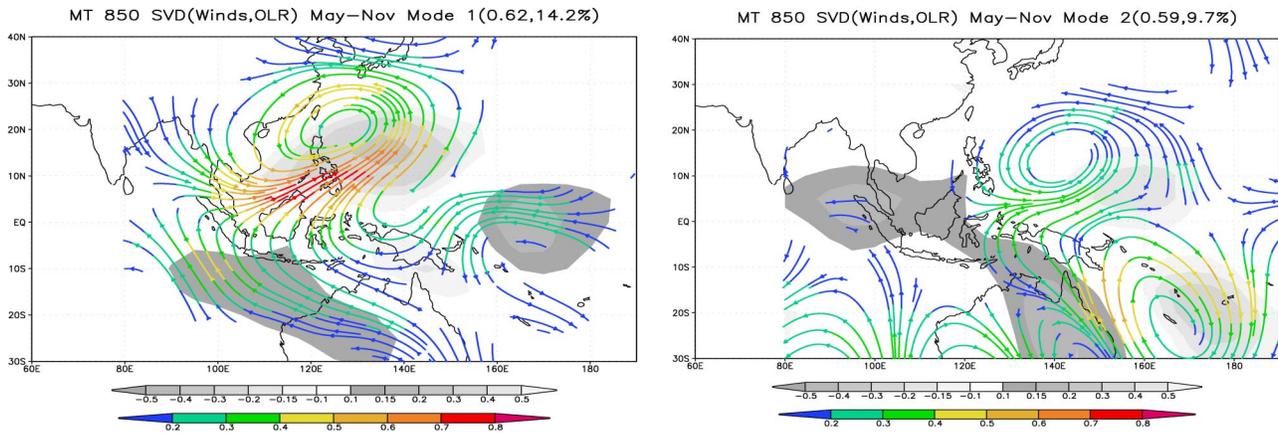


Figure 1. Heterogeneous correlation maps (left: mode 1, right: mode 2) defined from the SVD analysis of 850 hPa wind anomalies and OLR anomalies between May-November 1979-1998. Gray-shaded areas define OLR correlations such that light-to-dark defines enhanced convection and dark-to-light defines reduced convection. Wind correlations are depicted by color-coded streamlines such that westerly anomalies would be associated with positive correlations. The total correlation and percent covariability associated with each mode are defined in the parentheses above each panel.

day variability to define four classifications associated with propagation and activity of the monsoon trough (Table 2). Of the 17 tropical cyclones that formed in the monsoon trough during the MJO inactive period (Table 1), 16 occurred when the 10-25 day mode defined an active monsoon trough. Therefore, a combination of the two modes is required to explain a significant portion of the tropical cyclone activity. Tropical cyclone activity during periods when the MJO is in the inactive phase over the western North Pacific occurs when the 10-25 day mode dominates the MJO (Fig. 2). Comparison with 200 hPa SVD patterns and coefficients suggest that the presence of the MT mode is linked to midlatitude wave activity in both Southern and Northern Hemispheres. Furthermore, track types during periods of significant MT variability tend to cluster such that recurving tracks are more prevalent during the beginning inactive and inactive MT periods.

	MT Beginning Active	MT Active	MT Beginning Inactive	MT Inactive	No MT Mode
South China Sea	0	1	0	0	0
Monsoon Trough	6	10	0	1	0
East of Monsoon Trough	3	4	1	1	2
North of Monsoon Trough	1	3	3	1	9

Table 2. The frequency of tropical cyclones that formed during the MJO inactive period (defined in Table 1) with respect to the phase of the 10-25 day monsoon trough (MT) mode. The regions of the western North Pacific defined in each row are as defined in Table 1. The right-most column contains instances of tropical cyclone formation when the MT mode was not present as defined by the SVD coefficients.

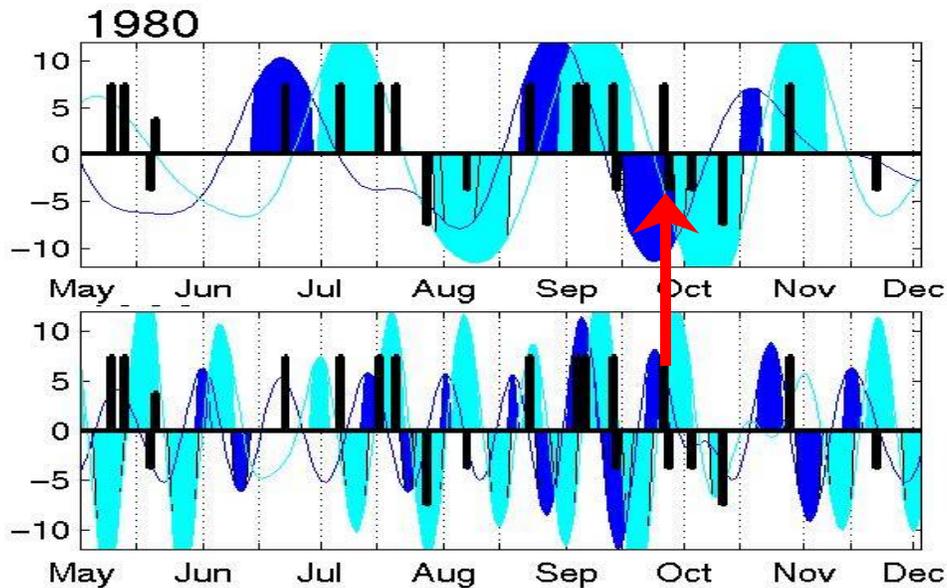


Figure 2. SVD time coefficients for MJO modes (top) and MT modes (bottom) during 1980. Upward (downward) pointing bars represent tropical cyclones that formed in (out) of the monsoon trough. Positive (negative) coefficients represent the active (inactive) phases of each mode. The red arrow highlights a tropical cyclone that formed in the western North Pacific monsoon trough during the inactive phase of the MJO when the MT mode was active.

IMPACT/APPLICATIONS

Identification of the interactions between various modes of tropical circulation variability will lead to a statistical forecast scheme of extended periods of tropical cyclone activity/inactivity. If reliable forecasts of extended periods of inactivity (i.e., at least 20 days with no tropical cyclones) could be made, maritime operations could be coordinated to take advantage of the period of reduced threat from tropical cyclones.

As characteristics and identification of the predictability associated with operational forecast model characteristics with respect to ET become identified, guidance to operational forecasters will be available such that increased value from numerical products will be realized.

TRANSITIONS

It is anticipated that an operational forecast scheme of intraseasonal variability in tropical cyclone activity will be based on the research results from this project. An assessment of the potential for accurate forecasts with respect to ET circulations will be available to operational forecasters.

RELATED PROJECTS

This project is related to the project titled “Predicting Tropical Cyclone Formation and Structure Change” under Principal Investigators R. L. Elsberry and P. A. Harr. Research conducted under the project described in this summary will be applied to the development of a knowledge-based expert system to allow Joint Typhoon Warning Center (JTWC) forecasters to make more accurate and consistent forecasts of tropical cyclone formation and structure.

SUMMARY

During the next year, results from the examination of the interaction between modes of tropical circulation variability will provide a sound forecast system for assessment of tropical cyclone activity that may be expected over ranges between 10-25 days. Finally, the assessment of the capability of each operational numerical model to predict various components of ET will provide operational forecasters with information to efficiently assess model guidance.

REFERENCES

- Harr, P. A., and R. L. Elsberry, 1995a: Large-scale circulation variability over the tropical western North Pacific. Part I: Spatial patterns and tropical cyclone characteristics. *Mon. Wea. Rev.*, **123**, 1225-1246.
- Harr, P. A., and R. L. Elsberry, 1995b: Large-scale circulation variability over the tropical western North Pacific. Part II: Persistence and transition characteristics. *Mon. Wea. Rev.*, **123**, 1247-1268.

PUBLICATIONS

- Harr, Patrick A., 2002: Tropical cyclone formation and extratropical transition. Topic Chairman and Rapporteur Reports of the Fifth International Workshop on Tropical Cyclones (IWTC-V), WMO/TD No. 1136, WMO, Geneva, Switzerland.
- Jones, S. C., P. A. Harr, J. Abraham, L. F. Bosart, P. J. Bowyer, J. L. Evans, D. E. Hanley, B. N. Hanstrum, R. E. Hart, F. LaLaurette, M. R. Sinclair, R. K. Smith, and C. Thorncroft, 2003: The extratropical transition of tropical cyclones: Forecast challenges, current understanding and future directions. *Weather and Forecasting*, in press.