# Observed Structure and Environment of Developing and Non-developing Tropical Cyclones in the Western North Pacific using Satellite Data

PI: Shuyi S. Chen
RSMAS/University of Miami, 4600 Rickenbacker Causeway, Miami, FL 33149
Phone: (305) 421-4048, FAX: (305) 421-4696, Email: schen@rsmas.miami.edu

Award Number: N00014-08-1-0258

http://orca.rsmas.miami.edu/TCS-08

## LONG-TERM GOALS

The long-term goal of this PI is to understand the physical processes of tropical convection, air-sea interaction and coupling of the atmosphere-ocean system in high-wind maritime regimes, with a particular emphasis on tropical cyclones. The ultimate goal is to better observe and predict tropical and subtropical weather systems.

## OBJECTIVES

This study aims to better understand the convective cloud systems and their interaction with the large-scale environment, which may be pre-cursors to the formation and development of tropical cyclones over the Western North Pacific. The main objectives of this research are 1) to compile a statistical data set for the tropical cyclones (TC) formation and structure as well as the storm environment for both developing and non-developing TCs, 2) to provide a valuable database for the Tropical Cyclone Structure 2008 (TCS-08) field campaign, and 3) to evaluate and validate post-field model simulations of TCs in the in-situ data sparse region of the Western North Pacific Ocean. It will provide a context of the observed TCs from TCS-08 field campaign against a broad range of distribution of TCs in the Western North Pacific.

## APPROACH

This research builds on results from the prior ONR, NSF, and NASA supported projects (e.g., CBLAST-Hurricane, RAINEX, and TRMM-TC) and the expertise of the PI on satellite data analysis of tropical convective systems over the western Pacific (Chen et al. 1996, Chen and Houze 1997a, 1997b). Dr. Chen has extensive experience with a number of major field campaigns, from the Tropical Ocean Global Atmosphere Coupled Ocean-Atmosphere Research Experiment (TOGA COARE) in 1992-93 to the recent CBLAST-Hurricane in 2003-04 and RAINEX in 2005. Other key personnel working on this project are Dr. Brandon Kerns, a post-doctoral associate working with Dr. Chen at

# Report Documentation Page

*Form Approved*
*OMB No. 0704-0188*



1. REPORT DATE
**2009**

2. REPORT TYPE

3. DATES COVERED
**00-00-2009 to 00-00-2009**

4. TITLE AND SUBTITLE
**Observed Structure And Environment Of Developing And Non-developing Tropical Cyclones In The Western North Pacific Using Satellite Data**

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)
**University of Miami/RSMAS,4600 Rickenbacker Causeway,Miami,FL,33149**

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

14. ABSTRACT
**The long-term goal of this PI is to understand the physical processes of tropical convection, air-sea interaction and coupling of the atmosphere-ocean system in high-wind maritime regimes, with a particular emphasis on tropical cyclones. The ultimate goal is to better observe and predict tropical and subtropical weather systems.**

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** | |

RSMAS, who is responsible for the cloud cluster analysis; Mr. Ed Ryan, a senior research associate who is responsible for processing satellite data and maintain a website for the cloud cluster tracking systems in real time (http://orca.rsmas.miami.edu/TCS-08).

In this study, we first define and identify cloud clusters using hourly IR imagery data from the Geostationary Meteorological Satellite (GMS). The method has been described in detail in Chen et al. (1996) and well-tested over the western Pacific warm pool region during TOGA COARE. The definition of a cloud cluster is an area > 5,000 $km^2$ with cloud top temperature < 208 K, which has been found to be correlated well with radar reflective of precipitating convective systems. We then track each cloud cluster in time, which include merging and splitting processes, from its formation to dissipation. The characteristics of the time clusters (e.g., size and duration) will be analyzed in relation to developing and non-developing tropical depressions (TD), tropical storms (TS), and typhoons.

To determine the factors controlling the formation of TCs, we then compare the characteristics of cloud clusters (e.g., size and duration) and large-scale environmental conditions (e.g., low-mid level vorticity, vertical wind shear, water vapor, and SST) for developing and non-developing TCs. The JTWC's best track data is used for TCs. Both global model analysis and satellite data including TRMM TMI are used for the TC environmental conditions such as environmental moisture using perceptible water vapor (PWV). The vertical shear surrounding TCs are from the Statistical Typhoon Intensity Prediction Scheme (STIPS, Knaff et al. 2005 and Chen et al. 2006).

The conditions identified as favorable for TC development based on cluster tracking results will be used to develop a new TC genesis prediction model that can be tested in real-time.

## WORK COMPLETED

We have completed the following data analysis:

- Cloud cluster analysis based on the method of cloud cluster analysis used during the TOGA COARE field program
- Track cloud clusters in time to TC or non-TC termination using hourly geostationary satellite IR and the Best Track data from 2004-2009
- Characterize the TC and non-TC surface winds using QuikSCAT data and global model analysis fields (including GFS, NOGAPS and CMC) to measure the low-level convergence/divergence and vorticity that may or may not favor for TC genesis
- Characterize the TC and non-TC environment moisture (dry or moist) using PWV data as a "favorability" index
- Characterize the TC and non-TC environmental vertical wind shear using the analysis used in STIPS and global model analysis field
- Analyses organized by monthly and individual TCs from 2004-2009

The finished analyses are available in real-time at: http://orca.rsmas.miami.edu/TCS-08/. In addition, more detailed analysis for each of the TCS-08 typhoon cases are available to privide a context for the 2008 season as well as a comparison for other typhoon seasons.

**RESULTS**

The scientific findings of this study are summarized in Kerns and Chen (2008, 2009) and will be followed in two other up coming manuscripts by Chen and Kerns. The most significant results of this study to date can be summarized as the following.

1) By tracking all cloud clusters, we are able to objectively determine both developing and non-developing TCs, which have been a one of the most difficult problem in understanding of formation (or genesis) of TCs in the past, especially the lack of objective method for determining non-developing TCs.

2) For most developing TCs, there are long-lasting clusters proceed the TC formation by more than 6-12 hr and some as long as more than 2-3 days. In addition, low-level vorticity were found to be enhanced associated with the long-lasting clusters (Fig. 1). The initial clusters usually are tracked long before the low-level vorticity centers, as shown in the case of Typhoons Sinlaku and Hagupit (2008), observed during the TCS-08 field program (Fig. 2).

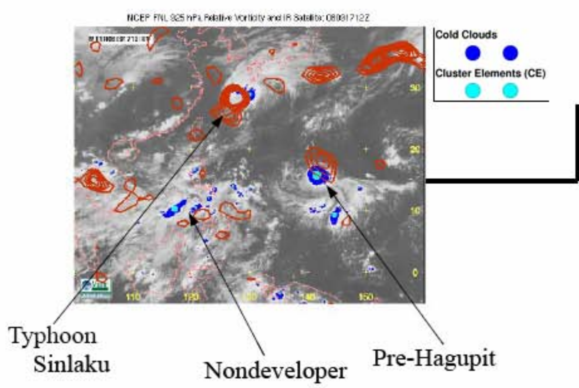


**Fig. 1.** GMS Infrared satellite image at 12Z 17 September 2008, overlayed with sub-208 K area (dark blue), cloud cluster locations (light blue) and NCEP FNL 925 hPa relative vorticity (red contours). Vorticity contours are every 20 from 30 to 150 X $10^{-6}$ $s^{-1}$.

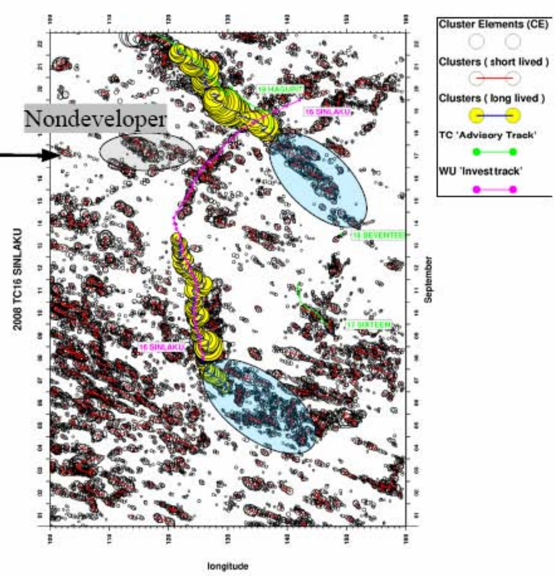


**Fig. 2.** Example of cloud cluster tracking during typhoons Sinlaku and Hagupit, 2008. The pre-genesis cloud clusters are highlighted in blue.

3) It is found that the most distinct characteristics of cloud clusters for developing TCs is the increase in duration that a cluster can be tracked from non-developing cases to tropical depressions (TD), tropical storms (TS), and typhoons (Fig. 3). The average lead time for a cluster proceed the TC formation is about 9-12 hrs. The maximum lead time arrange from 40-45 hrs.

4) Clusters proceeding TC formation can either a single traceable cluster or a group of long-lasting clusters. We refer the former as “pre-cursor” and the latter as “pre-conditioning” clusters.

5) There is very little sensitivity to SST from developing to non-developing TCs, whereas the vertical wind shear and moisture are found to be better predictors for TC formation in most cases.

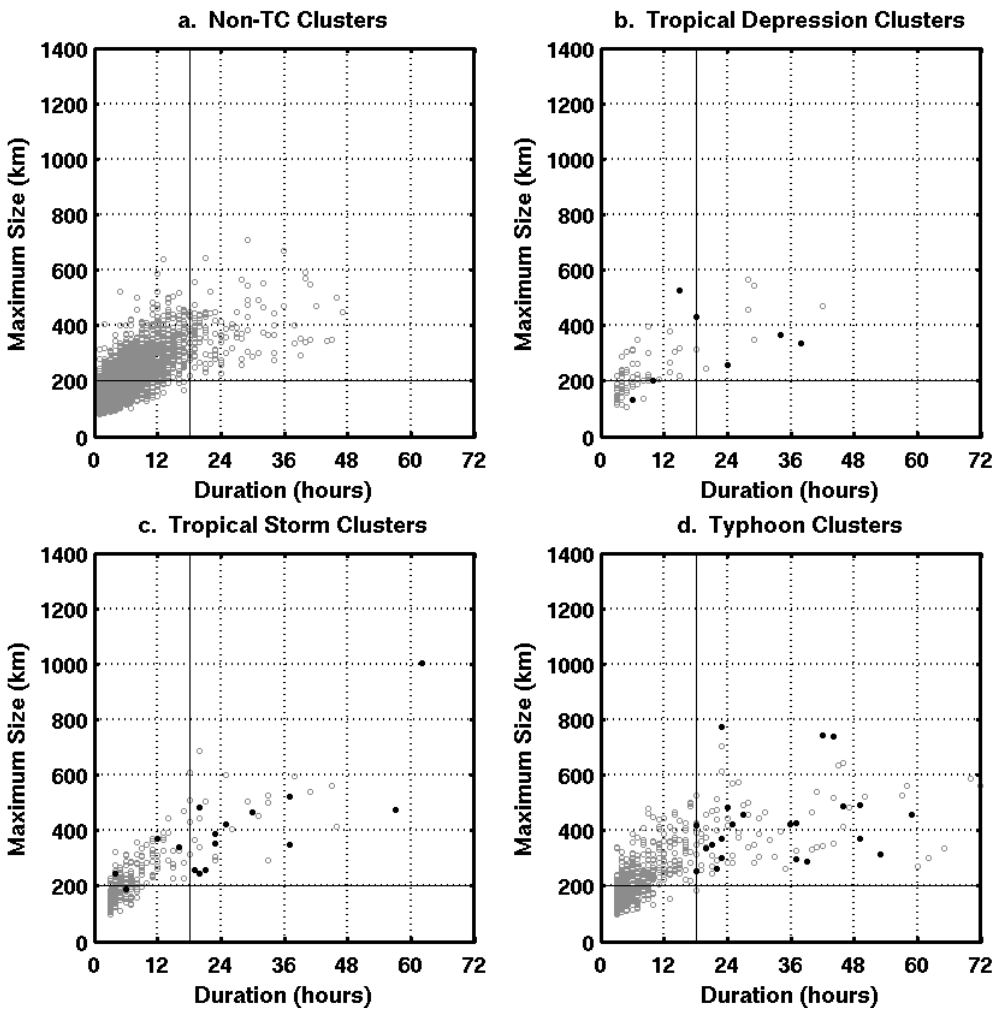


Figure 3 Maximum size (equivlent diameter of a cloud cluster in km) and duration for a) non-developing TC, b) TD, c) TS, and d) typhoons from 2004-2008.

## IMPACT/APPLICATIONS

The results from this study will have a significant impact on prediction of TC formation, specifically in the early stages. First, the coupling between the cloud cluster tracking and favorability indexes developed in this study can potentially lead to improvement in increase of lead time for TC genesis forecasting, which will be valuable for operational applications. Second, the characteristics of cloud clusters can be used as a new way of evaluate and verrfy numerical model simulations and forecasts of TC formation.

## RELATED PROJECTS

Drs. Chen and Kerns have been working with the Impact of Typhoons on Ocean over the Pacific (ITOP) science team using the method developed in this study to predict the early development of TCs over the West Pacific in 2009. The real-time cloud cluster analysis will be used for planning of ITOP missions during the field program in 2010.

## REFERENCES


Chen, S. S., and W. M. Frank, 1993: A numerical study of the genesis of extratropical convective mesovortices. Part I: Evolution and Dynamics. J. Atmos. Sci., **50**, 2401 - 2426.

Chen, S. S., R. A. Houze, Jr. and B. E. Mapes, 1996: Multiscale variability of deep convection in relation to large-scale circulation in TOGA COARE. *J. Atmos. Sci.*, **53**, 1380-1409.

Chen, S. S., and R. A. Houze, Jr., 1997a: Diurnal variation and lifecycle of deep convective systems over the tropical Pacific warm pool. *Quat. J. Roy. Meteor. Soc.*, **123**, 357-388.

Chen, S. S., and R. A. Houze, Jr., 1997b: Interannual variability of deep convection over the tropical warm pool. *J. Geophys. Res.*, **102**, 25,783-25,795.

Chen, S. S., J. Knaff, F. D. Marks, 2006: Effect of vertical wind shear and storm motion on tropical cyclone rainfall asymmetry deduced from TRMM. *Mon. Wea. Rev.,* **134**, 3190-3208.

Frank, W. M., Roundy, 2006: The role of tropical waves on tropical cyclogenesis. *Mon. Wea. Rev.*, **134**, 2397-2417.

Gray, W. M., 1988: Environmental influence on tropical cyclones. *Aus. Met. Mag.*, **36**, 127-139.

Knaff, J., C. R. Sampson, and M. DeMaria, 2005: An operational statistical typhoon intensity prediction scheme for the western North Pacific. *Wea. Forecasting*, **20**, 688-699.


## PUBLICATIONS


Kerns, B. W., and S. S. Chen 2008: Forecasting tropical cyclone genesis: An experimental cloud cluster tracking approach*, American Geological Union Fall Meeting 2008*, *San Francisco*, **A41G, 8.**

Kerns, B., and S. S. Chen, 2009: Long lived cloud clusters as precursors to tropical cyclone formation. *MWR*, submitted.