

Convection and Shear Flow in TC Development and Intensification

C.-P. Chang
Department of Meteorology
Naval Postgraduate School, Code MR/Cp
Monterey, CA 93943
Telephone 831-656-2840, e-mail cpchang@nps.edu

H.C. Kuo
Department of Meteorology
Naval Postgraduate School, Code MR/Cp
Monterey, CA 93943
Telephone 831-656-2840, e-mail kuo@as.ntu.edu.tw

C. H. Liu
Department of Meteorology
Naval Postgraduate School, Code MR/Cp
Monterey, CA 93943
Telephone 831-656-2840, e-mail ching_hwang@yahoo.com

Award # N0001410WX20619

LONG TERM GOALS

To study the dynamic processes of tropical cyclone (TC) development in the western North Pacific through field observational data and theoretical modeling.

OBJECTIVES

The objectives are: (1) to study the convection and vorticity generations in the vortex environment that may lead to the development and intensification of TC; (2) to study the development and evolution of deep moist mesoscale convective system subject to strain effect due to the horizontal shear associated with the vortex rotation; (3) to study the offsetting between (1) and (2); (4) to study nonlinear interactions that may lead to additional strain effects that may impact on the convection in ways that are not yet known.

APPROACH

TCS-08 offers a unique opportunity to collect high resolution data of kinematic and thermodynamic fields to determine the filamentation time, which is a function of total deformations and vorticity. The NRL P-3 aircraft with ELDORA airborne radar made it possible to directly compute the filamentation time at the convection scale, allowing an investigation into the effect of filamentation of the re-

Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE 30 SEP 2011		2. REPORT TYPE		3. DATES COVERED 00-00-2011 to 00-00-2011	
4. TITLE AND SUBTITLE Convection and Shear Flow in TC Development and Intensification				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 Postgraduate School, Department of Meteorology, Code MR/Cp, Monterey, CA, 93943				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					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 6	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

intensification stage of Typhoon Sinlaku (2008). In 2010, we concentrate on the differentiation of the stratiform convection and cumulus convection from the Eldora radar data for Typhoon Sinlaku (2008) in the re-intensifying stage.

RESULTS

Our effort this year was to better understand the filamentation dynamics on different types of the convection in a re-intensifying stage of typhoon. We classified the convections in Typhoon Sinlaku (2008) into cumulus and stratiform forms. Figure 1 shows the east-west (Fig. 1a) and north-south (Fig. 1b) cross sections through the typhoon center. The high reflectivity extending to over 9 km height about 20km from the center characterized the inner core of the eyewall, and a stratiform area is identified in the south side of the typhoon (Fig 1b) with a 20 dBZ echo-top around 5km height. The hatched area plotted in Fig. 1 is the region of filamentation time smaller than 20 min, which is identified as the rapid filamentation zone and is clearly overlapped with convection.

To classify the reflectivity into convective and stratiform regimes, we adapted the method proposed by Steiner et al. (1995) with some modifications. The classification of deep cumulus convection of their method is simple and straightforward, and is based on either 1) the reflectivity greater than 40dBZ, or 2) the difference between a grid point and its 11km background is greater than some threshold, then this grid point is classified as cumulus convection. Any reflectivity less than 10 dBZ is excluded. All the other grid points are classified as stratiform convection. Neither the horizontal gradient nor the vertical structure of the reflectivity was considered in their method. An improvement of this method has been proposed by Biggerstaff and Listemaa (2000). Several detailed reflectivity structures, such as horizontal and vertical gradients and bright-band characteristics (Rosenfeld et al. 1995) were incorporated in their scheme. These investigators used NEXRAD data in their study. Note that the NEXRAD data suffers coarse resolution in range and limited elevations in the vertical direction. During TCS08, the ELDORA radar was able to provide better resolution in both horizontal and vertical directions. On the other hand, the ELDORA radar, as a X-band radar, suffers more attenuation than the S-band type of radar such as NEXRAD. To apply the radar convection classification scheme to the ELDORA radar data, some parameter adjustments is required. Therefore, we set the convective threshold to 30 dBZ instead of 40 dBZ and the background reflectivity range to 9km instead of 11 km used by Steiner et al. (1995). The convection types are determined from the “working level”, which was 1.5 km height near the radar and 3 km height away from radar in Steiner et al. (1995). In the present study we choose the 2.5km level as our working level. This level is lower than the 5 km bright-band region (Fig. 1b) to avoid the bright-band contamination, and also sufficiently above the sea surface to avoid ground clutter contamination. Figure 2 shows the convective and stratiform regions classified at 2.5 km. The convective area identified is closely co-located with rainband structure and with stratiform convection next to it. Figure 2 clearly indicates the limited coverage of deep cumulus convective in the typhoon core region.

Figure 3 shows the frequency distribution of the filamentation time (minute) for cumulus convection (strong convection) and stratiform convection (in general weak convection) between 2 km and 4 km heights. It suggests that in the eyewall region with intense convective forcing the suppression of vortex strain effect may be small but still systematic and conspicuous. The demarcation occurs at filamentation time ~ 19 min. In the spiral band region 200 km from the TC center, the suppression by the vortex straining effect and filamentation is quite effective so that deep cumulus strong convection

occurs much less frequently than the stratiform weak convection for filamentation time smaller than 24 min.

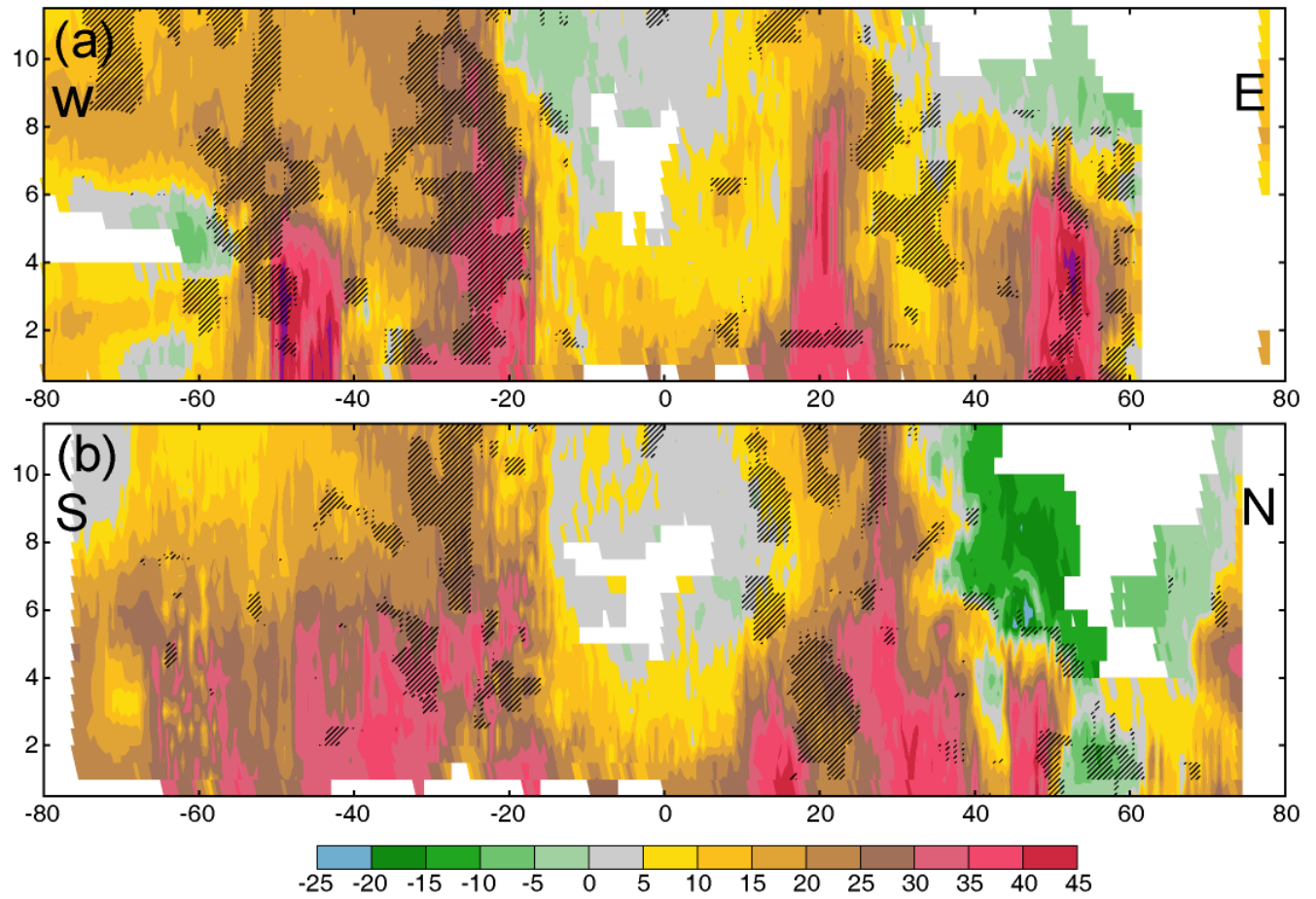


Figure 1: The E-W (a) and N-S (b) reflectivity vertical cross sections through the center of Typhoon Sinlaku. The color bar shows the reflectivity values. The hatched area is the regions with filamentation time smaller than 20 min (rapid filamentation zone).

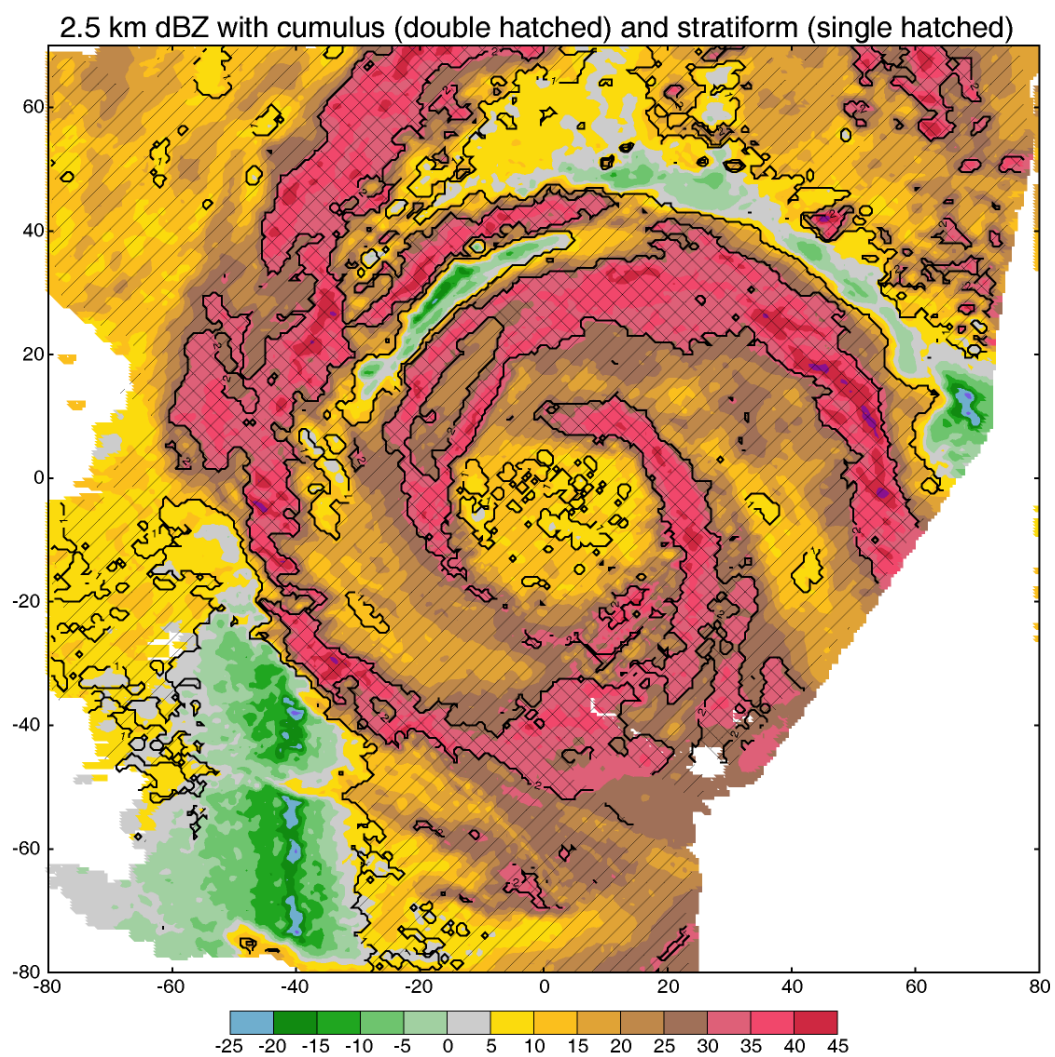


Figure 2: Reflectivity at 2.5km with cumulus (double hatched) and stratiform (single hatched) area..

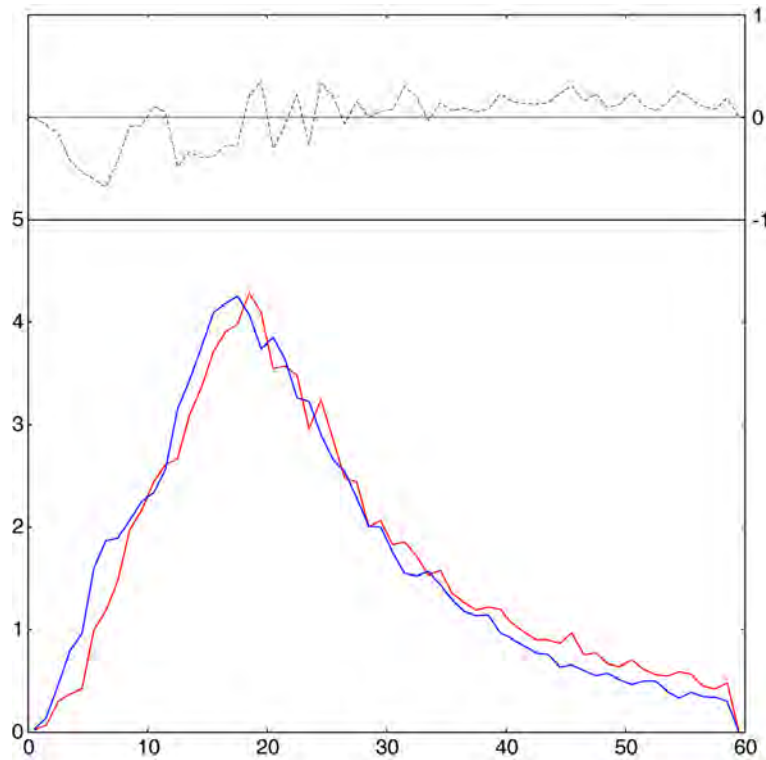


Figure 3: The frequency distribution of filamentation time (minute) for the convective (red) and stratiform (blue) reflectivity near the eye core region between 2 km and 4 km heights. The dashed line in the upper panel is the difference between the two. The unit is the same as the lower panel but the scale is shown at the upper right of the frame.

IMPACT

The vorticity generation by the convective systems and the upscale transfer of energy in the storm environment are important in TC genesis and intensification. The horizontal strain in the storm environment may enhance the cloud entrainment and organize the convection into banded structure. Previous analyses of filamentation dynamics were on strong TCs and many with concentric eyewalls. Our results are from high resolution aircraft data and applied to a weak but developing typhoon. Thus these results offer information on the mechanisms governing convection in the early stage of a TC, which is crucial in the study of TC intensifications.

RELATED PROJECTS

TCS08 projects led by Professors Russ Elsberry, Pat Harr and Michael Montgomery at NPS.

SUMMARY

The TCS-08 P3 radar data were used to identify the cumulus/stratiform convections and to compute the filamentation time scale in both the core region as well as the outer spiral rainband region in Typhoon

Sinlaku 2008. The results indicate that the filamentation process may suppress cumulus form deep convection more than the stratiform convection. This is especially pronounced in the outer spiral band region, which is 200 km from the center. The suppression is much more effective such that strong cumulus convection occurs about 50% less frequent than weak stratiform convection for filamentation time shorter than 24 min. The situation is reversed for filamentation time greater than 24 min. In the eyewall region where intense convective forcing is present, the effect of filamentation suppression on cumulus deep convection is about 10% and is systematic and conspicuous for filamentation times shorter than 19 min.

REFERENCES

- Biggerstaff, M. I., and S. A. Listemaa 2000: An improved scheme for convective/stratiform echo classification using radar reflectivity. *J. Appl. Meteor.*, **39**, 2129-2150.
- Rosenfeld, D., E. Amitai, and D. B. Wolff, 1995: Classification of rain regimes by the three-dimensional properties of reflectivity fields. *J. Appl. Meteor.*, **34**, 198–211.
- Rozoff, M. C., W. H. Schubert, B. D. McNoldy, and J. P. Kossin, 2006: Rapid filamentation zones in intense tropical cyclones. *J. Atmos. Sci.*, **63**, 325-340.
- Steiner, M., R. A. Houze Jr., and S. E. Yuter, 1995: Climatological characterization of three-dimensional storm structure from operational radar and rain gauge data. *J. Appl. Meteor.*, **34**, 1978–2007.

PUBLICATION

- Kuo, H.-C., C.-P. Chang, and C.-H. Liu, 2011: Convection and Shear Flow in Typhoon Development and Intensification: An Observation of Typhoon Silaku during TCS-08. *Mon. Wea. Rev.* (under revision).