Convection and Shear Flow in TC Development and Intensification

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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 reintensification 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 then 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 Bigerstaff 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.

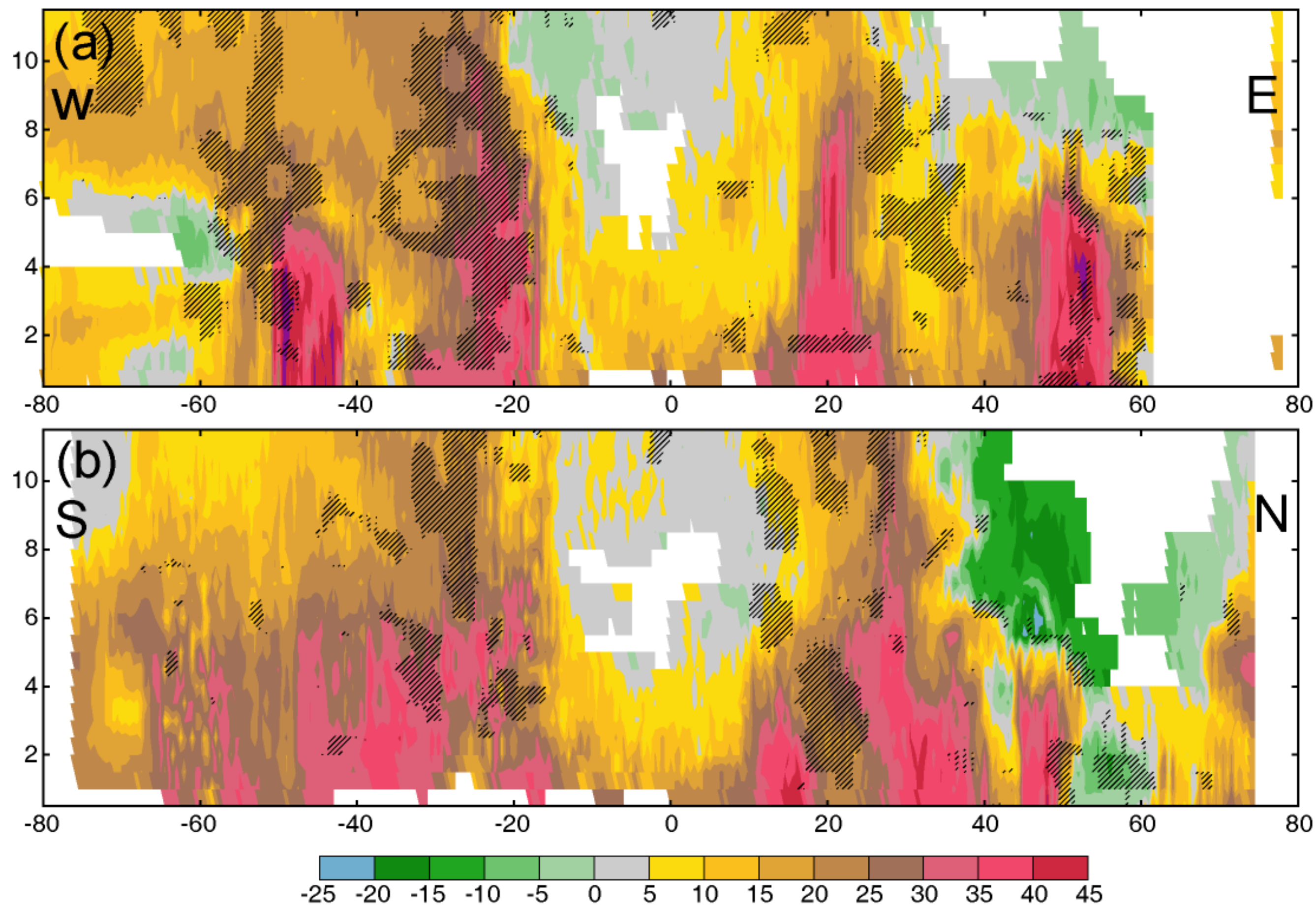

Figure 1: The E-W (a) and N-S (b) reflectivity vertical cross sections through the center of Typhoon Sinlaku. The color bar shows the reflectivity values. The hatched area is the regions with filamentation time smaller than 20 min (rapid filamentation zone).

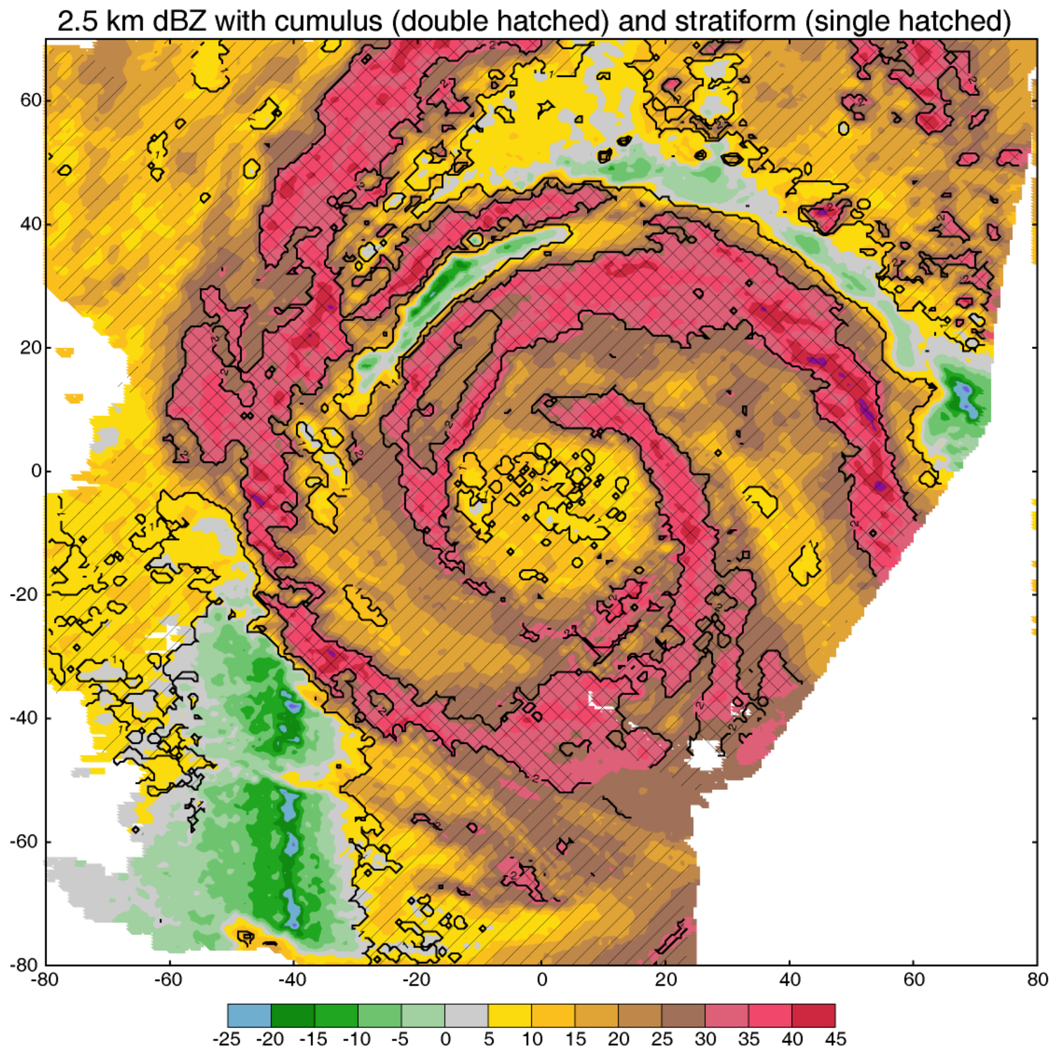

Figure 2: Reflectivity at 2.5km with cumulus (double hatched) and stratiform (single hatched) area..

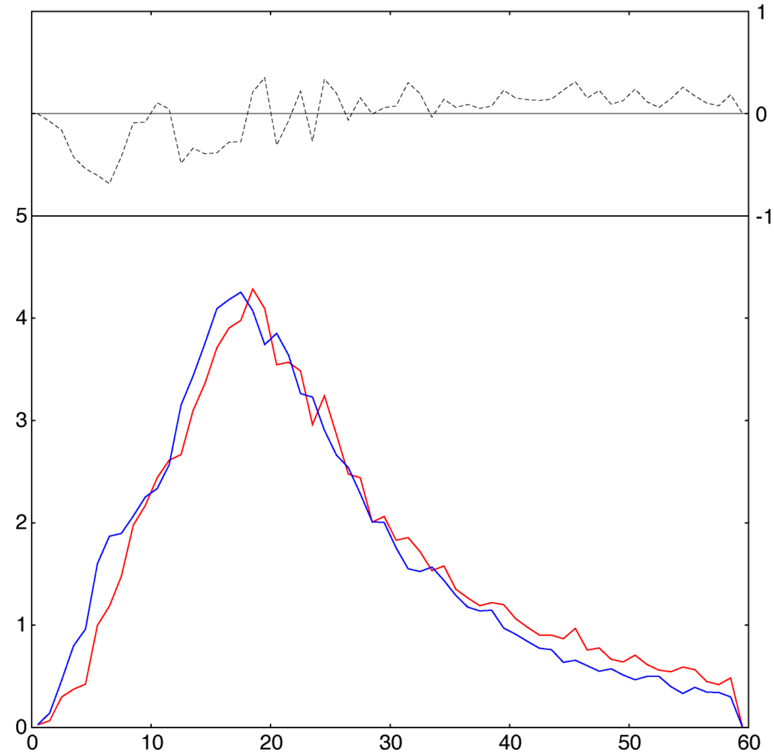

Figure 3: The frequency distribution of filamentation time (minute) for the convective (red) and stratiform (blue) reflectivity near the eye core region between 2 km and 4 km heights. The dashed line in the upper panel is the difference between the two. The unit is the same as the lower panel but the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

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PUBLICATION

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