SIGNATURE OF TROPICAL CYCLONE INTENSIFICATION: AN ASSESSMENT OF FROZEN

13C.4 HYDROMETERS IN NUMERICAL SIMULATIONS

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1. INTRODUCTION

The evolution of TC intensity is controlled by both environmental effects (DeMaria and Kaplan 1994; Emanuel et al. 2004) and inner core dynamics (Montgomery and Kallenbach 1997; Schubert et al. 1999). Therefore, improving our understanding in TC inner core dynamics is one of a key factor to advance the TC intensity forecasting.

CloudSat equipped with Cloud Profiling Radar scans high resolution profiles of liquid and ice water content (IWC) (125 levels in 30 km in vertical and ~14 km in horizontal), and 10-year accumulated measurements provide ~1500 swathes that pass through TCs within 300 km of the storm center (Tourville et al. 2015). These CloudSat measurements indicated that the storms with elevated amount of IWC tend to intensify in the next 6 hours (Wu and Soden 2017). However, the temporal discontinuity and limited spatial coverage in CloudSat observations hinder the investigation for the reason why intensifying storms have generally higher amount of IWC than weakening storms.

WRF (Weather Research and Forecasting model) idealized TC simulation has the ability to reproduce the TC evolution in the configuration without any ambient effect, and such implement can compensate for the deficiencies in the CloudSat measurements. Miyamoto and Nolan (2018, accepted) executed 225 simulations in WRF with idealized settings by varying the initial field such as maximum tangential wind, the strength of wind shear, storm size and storm translation velocity, creating the diverse TC evolutions.

This study aims to figure out the source of elevated IWC in the intensifying storms by analyzing the WRF idealized TC simulations and comparing the results to CloudSat measurements.

2. METHODOLOGY

The WRF 3.7 with idealized settings is adopted to execute series of simulations with 40 vertical layers with the finest horizontal resolution of 2 km. To evaluate its performance, numbers of cross-section with various distance of the storm center (within 300 km) were sliced out for the comparison with CloudSat measurements to validate the genuineness of its reproducibility. Another slicing method, the cross-section is always through the storm center, is adopted to identify the reason for the higher amount of IWC in the intensifying storms. The TC intensity is defined as the maximum azimuthal-averaged tangential wind at the height of 2 km, and the TC intensity change is defined by the intensity difference at the time of the cross-section and 6 hours later. If the intensity gets stronger (weaker) more than 2 m/s, we defined it as intensifying (weakening) storms. The details about the model configurations refer to Miyamoto and Nolan (2018).

3. RESULTS

Robust signal of TC intensification in the CloudSat measurements of Cloud IWC was shown by Wu and Soden (2017). Herein, we performed the same analyses for the model simulations and then aimed to identify the source responsible for the difference in the cloud IWC between intensifying and weakening storms.

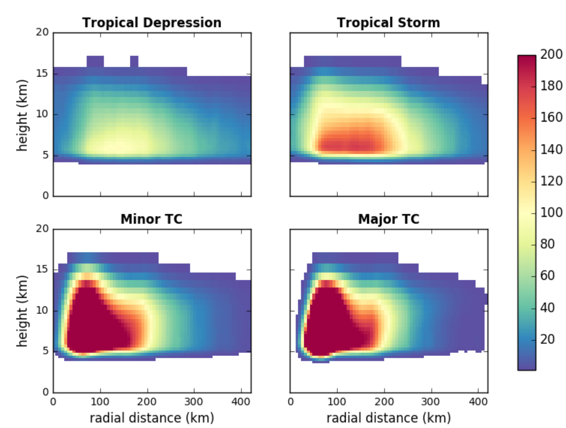

Fig 1. The composites of IWC in intensifying TCs from model simulations for four intensity categories. The shading is the amount of IWC in mg/m3. The x axis is radius in km and the y axis is the height in km.

3.1 FROZEN HYDROMETERS

The composites of IWC from model simulations were calculated for intensifying and weakening storms, respectively (Fig. 1). Both composites for intensifying and weakening storms demonstrated similar distribution of IWC that the closer to the TC center the greater the amount, yet the difference between composites of intensifying and weakening storms becomes larger as the one moves closer to the TC center (Fig. 2). These characteristics are identical to those from CloudSat measurements in Wu and Soden (2017), validating the value of using the data from model for the investigation.

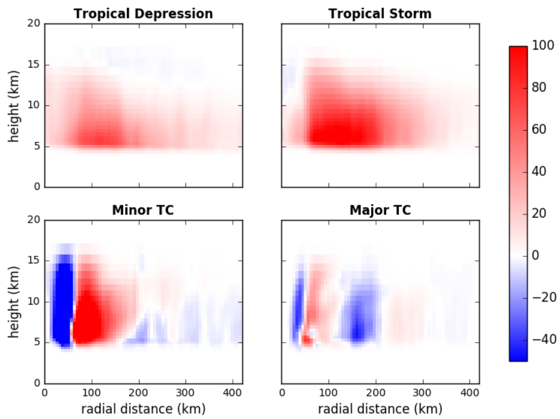

Fig 2. The difference between intensifying and weakening TCs (intensifying TCs – weakening TCs) in IWC from model simulations for four intensity categories. The shading is the amount of IWC in mg/m3. The x axis is radius in km and the y axis is the height in km.

3.2 TC INTENSITY CHANGE AND CONDITIONS

The convective heating is the major energy source for TC intensification and intensity maintenance, and the IWC usually forms as the convective heating releases at mid- to high-troposphere, where the high energy transform efficiency is located (Nolan et al. 2007). Since the signature of TC intensification has been found in IWC, apparent differences between intensifying and weakening storms in the diabatic heating, which is highly correlated with the production of IWC, are expected.

The differences in diabatic heating between composites of intensifying and weakening storms are calculated for different intensity categories (Fig. 3). The intensifying storms have less diabatic heating than the weakening storms at the TC center, while as the one moves outward to the eyewall region the diabatic heating in the intensifying storms becomes greater than that in weakening storms except for the intensity category of tropical depression, whose diabatic heating is larger almost everywhere in the intensifying storms.

We also perform the same analysis for the transverse circulation (vertical and radial velocity) for four intensity categories. Intensifying storms have more upward-motion component than weakening storms near the eyewall region in all four intensity categories, while they have less upward-motion component than weakening storms at the TC center in tropical storm, minor and major TC. Since the strength of upward motion is highly correlated with the amount of convective heating release, it is not surprising that such distribution coincides with the latent heating difference.

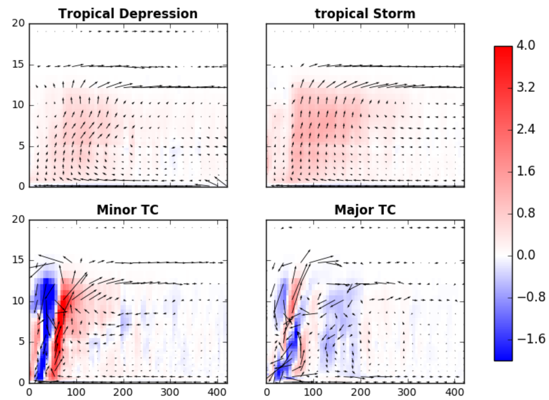

Fig 3. The difference between intensifying and weakening TCs in composites of diabatic heating and transverse circulation from model simulations for four intensity categories. The shading is the diabatic heating in K per hour. The vector qualitatively represents the transverse circulation. The x axis is radius in km and the y axis is the height in km.

4. DISCUSSION

In this study, we aim to find the reason for the elevated IWC in the intensifying TCs using WRF simulations. After the validation of model's ability in reproducing the distribution of IWC in TCs, the difference in diabatic heating and transverse circulation between intensifying and weakening TCs are calculated.

The difference in diabatic heating and vertical motion between intensifying and weakening TCs are significant and coincides with each other. The intensifying TCs have generally greater diabatic heating than weakening TCs, especially near the eyewall region, and the upward motion in the intensifying TCs is stronger at the same region, implying that the elevated amount of IWC at eyewall could be produced by active convections. However, the outer region, where the intensifying TCs also have greater amount of IWC, doesn't demonstrate the same signal as what have shown in eyewall region. Thus, the source for elevated IWC at outer region in intensifying TCs remains unclear and requires further investigation.

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