P 1.7 TROPICAL CYCLONE MULTIPLE EYEWALL CHARACTERISTICS

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1. INTRODUCTION

Tropical cyclones (TCs) reaching a maximum sustained wind speed greater than or equal to 120 kts often form double or concentric eyewalls as revealed by passive microwave imagery. These intense TCs can create one small diameter eyewall followed by the formation of a secondary eyewall at larger radii. The outer eyewall usually constricts the inflow of moisture, mass and momentum into the inner eyewall and the inner eye weakens and/or dies completely. The outer eyewall becomes the primary eyewall and begins to shrink in size while the storm regains strength. This process can continue several times if environmental conditions are favorable. Mapping this eyewall replacement cycle (ERC) is vital to understanding inner storm dynamics, short-term intensity trends, modeling simulations and upgrading land falling warnings.

Visible and Infrared (vis/IR) imagery cannot penetrate the frequent upper-level clouds shielding a storm's internal structure (eye, eyewall and rainbands), but non-raining clouds have little impact on passive microwave frequencies. 85 GHz brightness temperatures are dramatically lowered by large frozen hydrometeors associated with vigorous convection and updrafts. Thus, rainbands and eyewalls stand out in stark contrast to the relatively "warm" ocean background. TC positions and storm structure can then be viewed with more clarity than many vis/IR images.

The Naval Research Laboratory's Marine Meteorology Division in Monterey, CA (NRL-MRY) has successfully demonstrated the utility of passive microwave products for global tropical cyclone (TC) monitoring (Hawkins et. al., 2001). Near real-time data from the Special Sensor Microwave/Imager (SSM/I), Tropical Rainfall Measuring Mission (TRMM) Microwave Imager (TMI) and Advanced Microwave Sounding Unit (AMSU-B) can identify double eyewalls not seen in coincident vis/IR geostationary imagery. Temporal changes from one pass to another then provide short-term structural/intensity updates by recognizing organizational evolution.

2. DATA SETS AND PROCESSING

NRL-MRY ingests data from three operational SSM/Is sensors (F-13, 14 and 15), the NASA TMI, two operational AMSU-Bs and more recently the AMSR-E (Hawkins et al., this volume). The 85 or 89 GHz brightness temperature data are mapped to a storm-centered image with resolution commensurate to the satellite sensors (5-16 km). These data sets are posted via the NRL TC web page within 1-3 hours of satellite acquisition. The NRL TC web page data set extends from 1997 to the present and covers the vast majority of intense storms within this study.

In addition, the SSM/I data was processed using the method of Poe (1990) to create high-resolution (1-2km) images tailored to extract TC structure. The data set uses the official SSM/I data archive at NRL-DC going back to 1987. SSM/I data for most of the intense storms since 1997 have been processed to create a special data set known as TROPX. TROPX nicely supplements the real-time TC web page since some passes are missed due to communication issues or processing problems.

3. CONCENTRIC EYEWALL FREQUENCY

Best track 1-minute maximum sustained wind speeds were used from the National Hurricane Center (NHC, Miami) for the Atlantic and East Pacific and from the Joint Typhoon Warning Center (JTWC, Pearl Harbor) for the western Pacific (WPAC), Indian Ocean (IO) and southern hemisphere (SHEM). Each storm with best track winds greater than or equal to 120 kt (62 m/s, referred to as "intense" for this study) was then reviewed to determine if double or concentric eyewalls existed anytime during their lifetime.

85 GHz imagery from the SSM/I and 85 GHz/ 37 GHz imagery from TMI were the main tools used to determine the existence of double eyewalls. Many TCs begin wrapping secondary bands once a small strong inner eye forms. However, only a select group finishes the process resulting in complete concentric eyewalls. The criteria to identify double eyewalls focused on qualitatively identifying two distinct significantly lowered brightness temperature rings encircling the storm center. The 100% complete rings are likely indicative of double wind maximums as noted by some Atlantic aircraft penetrations. The

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eyewalls were mostly circular in nature, but some took on several shapes (note the 5-16 km resolution inherent in 85 GHz sampling).

Many storms meeting the 120 kt criteria exhibited partial secondary outer eyewalls. Only those systems with 100% encirclement of both inner and outer eyewalls were labeled as concentric eyewall cases. Figure 1 lists the number of TCs meeting the intensity threshold for the Atlantic, EPAC, WPAC and SHEM respectively, each starting in 1997.

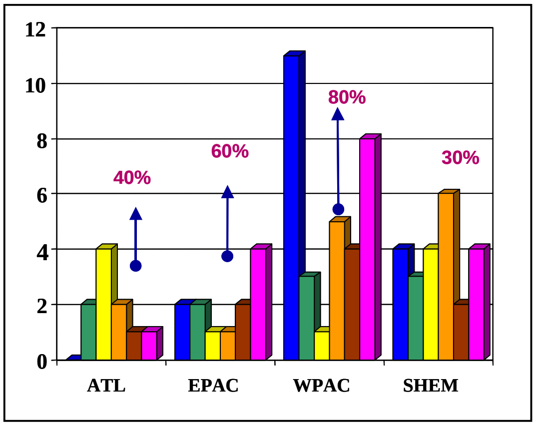

Figure 1: Number of TCs reaching best track intensities of 120 kt and above during 1997-2002 for four ocean basins. The percent of the six-year total found to exhibit concentric eyewalls is displayed above each basin.

As expected, the western Pacific experiences more intense storms, sometimes brewing up to 11 TCs per year. The WPAC also has more long-lived intense storms due to a combination of genesis regions far out to sea and more “room to grow” before encountering landfall or unfavorable environmental conditions.

The Atlantic and EPAC typically produce 1-2 120 kt or higher storms per year. Approximately 40% of the Atlantic and 60% of the EPAC intense storms reached concentric or double eyewall status. Both basins have specific reasons why more storms do not reach this unique status. Many major Atlantic storms do not reach 120 kts until they are well west and are then subject to upper-level troughs and shear in addition to landfall among many islands or North America.

Many folks perceive EPAC storms as weak since a large percentage either landfall quickly into Mexico or spend considerable time decaying over cool waters as nothing but a low-cloud swirl. However, “intense” EPAC storms do exist and they have shown the ability to form “classic” double eyewall structure. Some EPAC Category V storms have exhibited almost three (3) concentric eyewalls simultaneously.

The western pacific basin contains not only the highest number of “intense” storms, but also the largest percentage attaining concentric eyewall status. Roughly 80% of the TCs over 6 years had double eyes as viewed via passive microwave imagery. Note that although the number of “intense” storms fluctuates greatly from year to year, the % with double eyes stayed relatively high throughout the study period (not shown). WPAC storms often obtained max winds well in excess of 120 kts, with many reaching 140 and 150 kts in the best track data set.

The southern hemisphere typically had 3-4 “intense” storms/year, but only ~ 30% attained double eyewalls. The low % is due to the fact many SHEM storms did not maintain 120 kts for long and frequent shear cut short the process of forming concentric eyewalls. In several cases a secondary eyewall was underway, only to be stopped by rapid TC decay and weakening.

4. SUMMARY AND FUTURE POTENTIAL

Passive microwave data has shown that double or concentric eyewalls exist in a much larger % of TCs than previously indicated. Poor internal storm structure mapping by cloud obscured vis/IR sensors has masked important inner storm dynamics now demonstrated with a constellation of polar orbiting passive microwave sensors. Further study matching this and larger data bases with limited Atlantic recon aircraft radar will enable the community to comprehend the complex evolution of storm dynamics and how this knowledge will assist not only our real-time warnings, but also advances in numerical modeling simulations and multi-day forecasts.

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