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MONSOON DEPRESSIONS, MONSOON GYRES, MIDGET TROPICAL CYCLONES, TUTT CELLS, AND HIGH INTENSITY AFTER RECURVATURE: LESSONS LEARNED FROM USE OF DVORAK'S TECHNIQUES IN THE WORLD'S MOST PROLIFIC TROPICAL-CYCLONE BASIN.

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1. INTRODUCTION

Vern Dvorak first published his techniques for estimating tropical cyclone (TC) intensity from visible satellite imagery in 1975 (Dvorak 1975). It is an astonishing testimony to the solidarity of the techniques that 30 years later, they are still being used world-wide in their original form. The single largest adjustment to Dvorak's techniques was his own addition of rules for estimating TC intensity from Enhanced Infrared (EIR) satellite imagery that was published as a technical report in 1984 (Dvorak 1984). Since then, no one has put forth any substantial alterations (or alternatives) to Dvorak's techniques that have supplanted the world-wide usage of the original techniques. Hebert and Poteat (1975) developed techniques for estimating the intensity of subtropical cyclones from satellite imagery that mesh with Dvorak classification when the cyclone acquires persistent centrally located deep convection. Recent attempts have been made to use microwave imagery to ascertain the intensity of TCs, but techniques developed so far only complement (but do not replace) the Dvorak techniques (*cf*. Edson, in this Preprint Volume). To-date, no method using any suite of new remote sensing technology (from scatterometry to the many channels of MI imagery) can be used in a stand-alone mode to improve on Dvorak's original methods. The only major enhancement to Dvorak's original techniques is their automation (e.g., the Objective Dvorak Technique of Velden, et al., 1998).

As a user and on-site observer (at the Joint Typhoon Warning Center, Guam) of the operational use of Dvorak's techniques during the past 25 years, there are only a handful of instances when certain phenomena seemed to be problematic for the techniques (and for users of the techniques). Some of the difficulties faced by users of Dvorak's techniques in the western Pacific are discussed in this presentation.

2. DVORAK MEETS THE WESTERN PACIFIC

Dvorak's techniques for estimating TC intensity from satellite imagery were developed largely from the study of TCs in the North Atlantic where there was readily available data from aircraft reconnaissance to fine-tune the techniques. The large scale circulation of the North Atlantic, however, is really quite a bit different from that of the western Pacific (and the Indian Ocean). Two major differences are the presence of a monsoon trough in the western Pacific (Fig. 1) and also a colder tropopause there. Phenomena occur in the western Pacific (and in the Indian Ocean) that are rarely seen in the North Atlantic: Monsoon Depressions, and Monsoon Gyres (Lander 1994). Other factors that have caused problems for intensity estimation include very small TC size and extratropical transition.

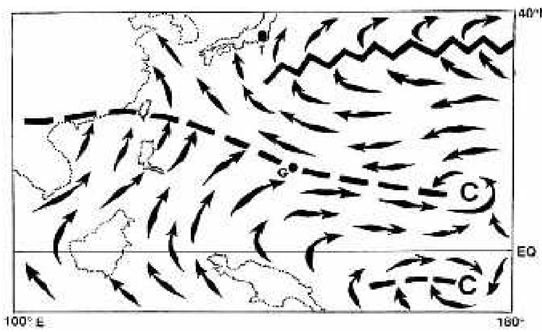

Figure 1. A schematic illustration of a commonly observed flow pattern of the low-level circulation in the monsoon trough during the northern summer in the western North Pacific.

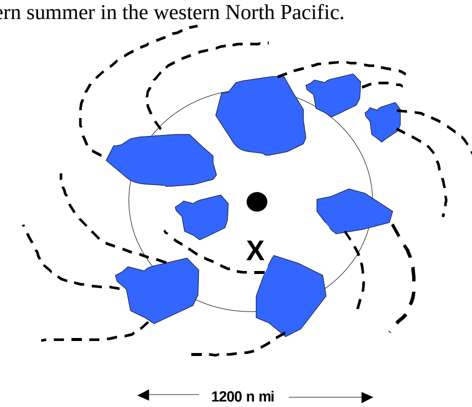

Figure 2. A schematic illustration of a typical monsoon depression in the western North Pacific. Several mesoscale convective systems are distributed in a large area (the circle diameter is 1200 n mi). Cirrus outflow from the deep convection forms a well-defined anticyclonic pattern. The center of symmetry of the cirrus outflow (black dot) is often displaced to the north of the low-level circulation center (X).

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a) Monsoon Depressions

Although originating as a term to describe cyclonic vortexes that form at the head of the Bay of Bengal in the Boreal summer, the term monsoon depression is now also used to describe the large tropical cyclonic vortexes that form along the monsoon trough in the western North Pacific. Approximately two-thirds of that basin's named TCs derive from monsoon depressions. Because of the large size of monsoon depressions, and the initial lack of deep convection close to the center, analysts either avoid using Dvorak's techniques to classify these systems, or else give them "T" numbers that equate to wind speeds that are too low. As soon as monsoon depressions acquire persistent central deep convection, they may already have extensive areas of gales, and are often classified as tropical storms on the first warning.

b) Subtropical Cyclones

Because of the prevalence of cut-off lows in the north Atlantic in the summer and fall, there are far more genuine subtropical cyclones there than in the western North Pacific. Trying to determine when a subtropical cyclone becomes a tropical cyclone has been a problem for Atlantic TC forecasters for many years. At the NHC, there was a recent decision made to name (in normal succession) any subtropical cyclone that forms in the Atlantic. Then the problem of having "instant" named tropical storms (or even hurricanes) is avoided. In Hebert and Poteat, the only factor for the differential diagnosis of subtropical versus tropical is the presence or absence of persistent deep convection near the cyclone center.

c) Cold Tropopause

The tropopause temperature and convective cloud-top temperatures in the tropics of the western North Pacific are typically much colder than their Atlantic counterparts. Eye wall cloud-top temperatures colder than -81°C (in a complete ring) are a common occurrence in the western Pacific, but rare in the Atlantic. This is too cold to appear on the table used for the eye adjustment in Dvorak's EIR techniques. In an early paper, Shewchuk and Weir (1980) adjusted for the colder outflow temps by introducing a modified relationship between the Dvorak "T" number and wind speed. Kossin (personal communication) found that colder cloud tops do not correlate well with greater intensity if the colder cloud tops are due to variations in tropopause height. Emanuel (personal communication) notes that intensity is weakly correlated with ambient (but not local) tropopause temperature, while the rate of intensification might correlate with the difference between cloud-top temperature and (unperturbed) tropopause temperature. The effects on TC intensity of these factors are not fully understood.

d) Extratropical Transition

When TCs begin to lose their deep convection as they undergo extratropical transition, the intensity estimates using Dvorak's techniques often fall to unrealistically low values. In the case of Typhoon Seth moving northward towards Korea (JTWC 1994), the satellite intensity estimates were as much as three "T" numbers (35 kt) below the ship- and land-verified intensity. At the time, JTWC satellite analysts experimented with using the subtropical techniques of Hebert and Poteat to derive the intensity for Seth. This still resulted in "ST" numbers equating to intensities that were far too low. The attempt to use Hebert and Poteat's classification system on TCs that are becoming extratropical is probably a misapplication. The JTWC analysists also tried to apply to the recurving Typhoon Seth a technique for estimating the intensity of mid-latitude cyclones from satellite imagery (Smigielski and Mogil 1992). Again it was difficult to derive intensities high enough. The last attempt to overcome this problem was the development of the XT technique (Miller and Lander 1997) for use specifically to derive from satellite imagery the intensity of TCs that are undergoing extratropical transition.

e) Midget Tropical Cyclones

The intensity of "midget", or very small tropical cyclones, is often underestimated (especially in the early stages). See for example the discussion on midget Typhoon Ellie in JTWC (1991). The problem here seems to one of recognizing the phenomenon as it unfolds. There may be some problems in the actual measurements of very small typhoons for purposes of intensity estimation, because the intensity is based on the embedded distance of the eye within its wall cloud.

3. CONCLUSIONS

Dvorak's techniques for estimating TC intensity from satellite imagery have been used operationally around the world for nearly 30 years. They have not been superceded or substantially modified in all that time. Largely developed from data on Atlantic TCs, users of the techniques in other basins have encountered a few minor problems. Some problems such as extratropical transition are common to all basins. New remote-sensing data and techniques such as the XT technique should nicely complement Dvorak's techniques and fill-in the fringe areas.

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