7A.4 THE DVORAK TECHNIQUE THROUGH TIME

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I. INTRODUCTION

The Dvorak technique for estimating the intensity of tropical cyclones (TCs) from satellite-observed cloud patterns was introduced in 1972 (Dvorak 1972). While the technique has evolved since then, the basic premises of characteristic cloud patterns, 24-h trends, statistical rules, and output of T and other numbers have remained unchanged. This paper examines the evolution of selected aspects of the technique through time.

II. TECHNIQUE OUTPUT

Dvorak developed an (at the time) unique system of quantifying TC intensity. Cloud patterns were assigned T-numbers on a scale from 1.0 to 8.0 at 0.5 intervals; these were related empirically to a tentative maximum wind speed and minimum central pressure (Dvorak 1973). The T-numbers were related to the final intensity estimate of the cyclone through the current intensity (CI) number, which would equal or exceed the T-number depending on whether the TC was developing or weakening. This system remains in use today with only slight revision.

One aspect of the original technique was the concept of the TC central feature (CF) and external banding features (BF), both of which would be used to determine the intensity estimate. These numbers, which would be summed to produce a T-number, remain in use today.

Other parts of the technique have undergone significant revision. The T-number determined from the cloud pattern was originally called the 'preliminary' T-number, as it was subsequently processed through a set of rules before becoming 'final'. In the 1984 revision (Dvorak 1984, henceforth D84), this number became known as the data T-number (DT) - the number that came from the 'measurement' of the cyclone cloud pattern and was one of three numbers from which the final T-number (FT) was chosen.

III. CLOUD PATTERNS

The heart of the Dvorak technique is the relationship between satellite-observed cloud patterns and TC intensity. The original technique highlighted the evolution of the cloud patterns associated with stages of TC development in visible imagery (Fig. 1). Most emphasis was placed on size measurements of the central dense overcast (CDO) and eye patterns usually associated with stronger systems. Cloud patterns of weaker systems were treated more subjectively. The Dvorak (1975) revision made few changes, although there was some refinement of measurements for weaker systems.

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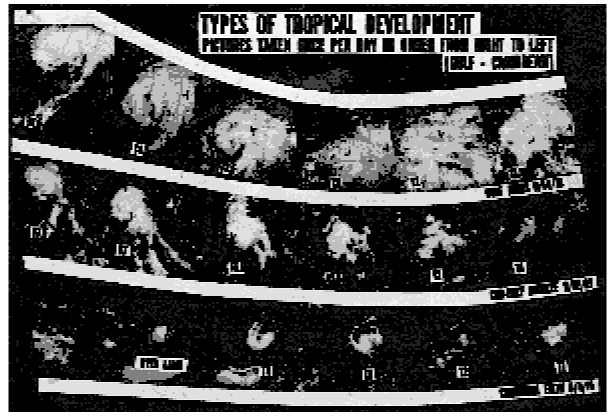

Figure 1. Examples of characteristic cloud patterns of developing TCs. From Dvorak (1973).

Major changes were introduced by D84. Firstly, two new cloud patterns were added - the curved band and shear patterns. This allowed for analyses of DT for non-CDO/eye TCs. Secondly, D84 included the use of infrared (IR) imagery for the first time. This brought about yet another pattern type - the embedded center or the IR equivalent to the CDO. Finally, this revision created the IR eye pattern, in which TC intensity is related to the cold cloud tops surrounding the center and the warm temperatures in the eye. This is the most objective of all Dvorak measurements and has led to the creation of objective intensity analyses (Velden et al., 1998).

Another major change was the concept of the pattern T-number (PT). While pattern matching/recognition was part of the original technique, the PT was introduced in 1975. It became formalized in D84, where it was the second of three possible FT. It was based on comparison of the overall cloud pattern to a table of known patterns, which were significantly revised between 1975 and 1984.

IV. 24-HOUR TRENDS

The technique is partly based on observed 24-h changes in cloud pattern and intensity. This was done to help filter out short-term changes that might be deceptive and/or unrepresentative (Dvorak 1975). Two images 24 h apart were used to determined if the TC had (D)eveloped, (W)eakened, or remained the (S)ame intensity based on a set of criteria of image interpretation. While the criteria have varied, this premise remains in use today.

The original technique included a first guess intensity estimate based on the previous day's estimate and the 24-h trend. In D84 this was more rigorously quantified into the model expected T-number (MET) - the third possible FT.

Dvorak (1975) developed the concepts of rates of TC development or weakening in terms of the technique: normal (1 T-number/day), rapid (1.5 T-number/day), and slow (0.5 T-number/day) trends. These trends were included as part of the calculation of the MET.

V. TECHNIQUE RULES

All versions of the Dvorak technique have featured a system of rules. Some of these dealt with determining 24-h trends from imagery, while others dealt with forecasting the intensity 24 h after the analysis. These rules have changed somewhat unsystematically between versions.

Other rules have evolved. The original technique had no set criteria on when a disturbance would be classifiable using the technique. Such criteria were introduced in 1975 and more rigorously quantified in D84. Similar changes have occurred to the rules relating the FT and CI [although these have not changed the basic premises of the original technique].

Perhaps the most controversial aspect of the technique has been the limits on intensity change over periods of 24-h or less. Such limits have inherently been part of the technique since the beginning. However, D84 quantified them in terms of maximum allowable 6, 12, 18, and 24-h changes in FT, with the maximum allowable 24-hr change of 2.5 T-numbers. Operational experience shows that rapidly intensifying TCs can change DT by 3.0 or more in 24 h, although it is unknown if the TCs actually intensified that quickly. Operational use today employs a somewhat relaxed set of constraints compared to D84.

VI. THE LEGACY OF THE TECHNIQUE

The Dvorak technique is now used at TC warning centers world-wide and so far has stood the test of time. New techniques using microwave data show promise in estimating TC intensity, and these techniques could in time supplant the Dvorak technique. However, microwave instruments are currently limited to low-earth-orbiting satellites that have issues of data availability and timeliness. The Dvorak technique, which can use abundantly available geostationary satellite imagery, will thus likely stay in use well into the 21st century.

Given the world-wide use, and the lack of TC ground truth in most areas, it is interesting to ask how accurate are the Dvorak estimates. Figure 2 shows error frequency distribution of Dvorak wind estimates compared to intensities derived from aerial reconnaissance data for Atlantic TCs between 1997-2001. This shows that half of the Dvorak technique errors were 7 kt or less, 65% were 10 kt or less (0.5 T-numbers at tropical storm intensities), and 90% were 20 kt or less. Thus, the Dvorak winds are on the whole quite good, although there are occasional large outliers as per Brown and Franklin (2002). Similar arguments can be made for the estimated pressures.

The Dvorak technique was a model for at least three other techniques. The most notable is the Hebert-Poteat technique for estimating the intensity of subtropical cyclones (Hebert and Poteat, 1975), which is similar to but less complex than the Dvorak technique. This has supplemented the Dvorak technique since being introduced.

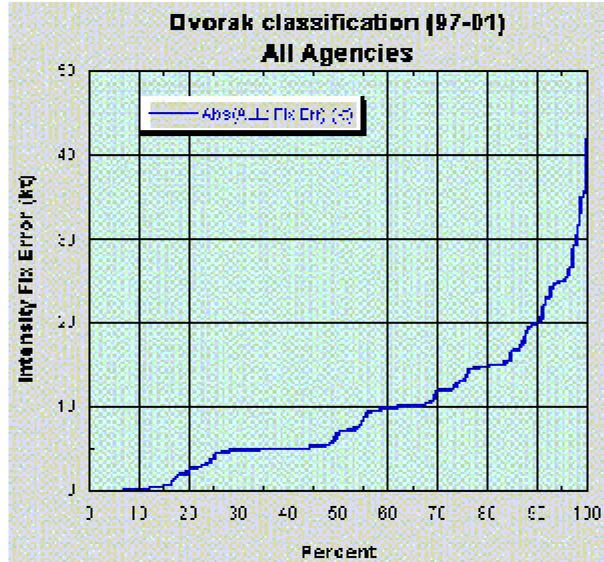

Figure 2. Error frequency distribution for Dvorak wind estimates compared to intensities from reconnaissance data for Atlantic TCs, 1997-2001. (From Franklin 2003)

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