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THE OBJECTIVE DVORAK TECHNIQUE – HISTORICAL PERSPECTIVE

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1. INTRODUCTION

When satellite images first became available in the 1960's, identification and tracking of intense hurricanes became a trivial task due to the easily identifiable hurricane eye. However, tracking weaker tropical cyclones and finding a reliable way of estimating the intensity, were much more challenging problems. Scientists at NOAA/NESDIS led by Vern Dvorak, aided by the improving quality of geostationary satellite images in the 1970's, developed satellite applications specifically aimed at operational forecasting of tropical cyclones. By 1975, a methodology for estimating intensity based on cloud pattern evolution was published. That procedure came to be known as the Dvorak Technique and was supplemented by 1984 with the enhanced infrared (EIR) method for independently assigning hurricane intensity. The original objective Dvorak technique (ODT) was adapted from the EIR method and published by Dvorak in 1984. Since that time, applications development has continued within NESDIS and CIMSS, with modifications and enhancements to Dvorak's original objective IR measurements. The Dvorak technique continues to be widely used operationally throughout the world. This long term usage with better quality images and animation, along with improved validation measurements, have provided considerable insight on the strengths and weaknesses of the Dvorak technique. The present ODT algorithms continue to evolve and additional improvements are anticipated. Microwave observations from polar orbiters have shown the capability of providing independent intensity estimates to supplement the ODT, however they are limited by observation frequency and timeliness.

2. THE T-NUMBER

Dvorak (1975, 1984) introduced the concept of hurricane intensity and development trends in terms of a T-number. A T-number unit represents a typical one-day intensity change. The Dvorak technique gives intensities in terms of 0.5 T-no. increments while the ODT interpolates to finer resolution intensity. A standard table is used to convert T-No. to maximum 1-minute surface wind speed, and a pressure-wind relationship is also used to assign minimum sea-level pressure (MSLP). Very weak tropical disturbances during genesis stages are assigned T1. Minimal tropical storm intensity (35 kt) is T2.5. Minimal hurricane intensity (65 kt) is T4.0. T5 = 90 kt. T6 = 115 kt. T7 =140 kt. The seldom observed T8 = 170 kt is the top end of the scale.

The T-number approach was employed to provide a model of expected changes for assigning intensity within particular constraints and according to specific rules. This helps alleviate the problem of unreasonable intensity assignments due to poor quality images or unrepresentative image analysis.

The Dvorak T-number also provides an effective tool for normalizing intensity change according to intensity. For example, a 5 kt increase of maximum wind speed from 30 to 35 kt is an equivalent change in terms of T-No. to a 15 kt increase from 140 kt to 155 kt. Environmental forcing on intensity change may be better evaluated according to the associated normalized intensity change.

3. TWO INFRARED (IR) MEASUREMENTS

Dvorak (1984) describes the original version of the ODT, which was referred to as "analysis using digital IR data." The intensity as T-number to the nearest 0.1 is assigned from a table according to two IR temperature measurements, with an approach analogous to the enhanced infrared (EIR) Dvorak technique. The "eye temperature" and the "surrounding temperature" are the only measurements needed for an intensity estimate. The "eye temperature" is simply the warmest IR pixel with the eye. The "surrounding temperature" is defined as the warmest of the IR pixels on a hurricane centered circle. The warmer the "eye" and the colder the "surrounding temperature," the more intense is the hurricane. The typical ranges of the two temperatures and their sensitivity to the intensity, are quite different. For example, as the "surrounding temperature" decreases from -64C to -75C, the intensity increases 1.0 T-No., while an "eye" temperature increase from -45C to +15C is needed for a 1.0 T-No. increase. A computation circle of radius 55 km (one degree latitude diameter) is used with the original ODT.

With early applications and evaluation of ODT, it was clear that several modifications of the algorithm would improve results. (Zehr, 1989; Dvorak, 1995)

1. Multi-radius computation. Hurricanes with large eyes would sometimes give unrepresentative IR measurements of the "surrounding temperature" since the computation circle was well inside the coldest ring. Algorithms were modified to use computation circles through a range of sizes (R = approx. 25-125 km), and use the resulting coldest "surrounding temperature" for the T-No. assignment.

2. Time averaging. In some situations the ODT results were noisy with large differences among relatively short interval images. Averaging the computations over a time interval, in the 3-12 h range, produced realistic intensity trends.

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3. "Cold eye" and "no eye" scenes. The original Dvorak (1984) table needed to be expanded a bit to cover some "cold eye" cloud scenes, and an upper bound for "no eye" scenes needed to be incorporated into the look-up table. The table needs to give an intensity estimate using "surrounding temperature" alone when no eye (i.e. a pixel completely surrounded by colder pixels) is observed near the tropical cyclone center. In those cases, for the purposes of getting an estimate from the look-up table, the "eye temperature" will be equal to or colder than the "surrounding temperature."

4. EARLY TESTING WITH GMS IMAGES

The series of Geostationary Meteorological Satellites (GMS) operated by the Japan Meteorological Agency with satellite subpoint near longitude 140E have observed about half of the annual global total of tropical cyclones. In the late 1980's, the International Satellite Cloud Climatology Project (ISCCP) (WMO, 1985) provided archived GMS digital image data with 10 km spatial resolution at 3 h intervals. The 1983-1986 ISCCP GMS data along with aircraft reconnaissance observations of minimum sea level pressure (MSLP) of western North Pacific offered the opportunity to evaluate the Dvorak objective IR algorithm with western Pacific typhoons. The aircraft data were made available by William Gray's research project at Colorado State University. The author's work with the GMS tropical cyclone sample in collaboration with Vern Dvorak at NOAA/NESDIS, Washington, DC, gave results that were very similar to the Atlantic hurricane sample from which the technique was developed (Zehr,1989; Dvorak,1995). It was found that agreement of the GMS objective IR intensities with the MSLP observations of the western Pacific typhoon sample could be improved by making small adjustments to the original Dvorak look-up table.

5. NEW DEVELOPMENT WORK AND DATA SETS

Evaluation of the earlier ODT versions showed that it does not perform as well prior to IR eye formation. Development work at CIMSS (Cooperative Institute for Meteorological Satellite Studies, Madison, WI) in the 90s, addressed this issue and produced an improved version of the ODT (Velden et al 1998). Development of the AODT (Advanced ODT) and upgrades with operational implementation are continuing at CIMSS (Olander and Velden, 2004).

Data on hurricane structure and surface winds are now available in real time from a variety of satellite sensors to supplement the ODT. Microwave sounders, microwave imagers, scatterometer winds, and low-level satellite cloud motion vectors are the primary data sets.

With respect to intensity estimates, the AMSU (Advanced Microwave Sounder Unit) intensity algorithms (e.g. Demuth et al 2004) show particular skill with weak tropical cyclones, for which ODT algorithms may not be reliable. However, the ODT algorithms remain as the only data source capable of detecting rapid intensity change due to the high time resolution of geostationary viewing. Additional work is underway to explore the use of IR images for diagnosing radius of maximum wind, radial wind distribution, pressure-wind relationship, and onset of rapid intensification.

It seems clear that modernizing the Dvorak technique approach to tropical cyclones should retain the ODT and use it in combination with the newer data. This combined method should improve the intensity estimates, and also make it possible to produce reliable real-time analyses of the entire tropical cyclone surface wind field using remote sensors.

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