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THE ADVANCED OBJECTIVE DVORAK TECHNIQUE (AODT) – CONTINUING THE JOURNEY

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1. INTRODUCTION

In the early 1970's, scientists at NOAA/NESDIS pioneered a technique to estimate tropical cyclone (TC) intensity using geostationary satellite data. These efforts were led by Vern Dvorak whom continued to advance the technique in the 1980's (Dvorak 1984). The method of equating satellite cloud signatures and brightness temperature values to TC intensity became know as the Dvorak Technique (DT). The DT has been used at TC forecast centers worldwide since that time, and is the primary tool for determining TC intensity where aircraft reconnaissance measurements are not available (a large majority of global TC basins).

The main shortcoming of the DT is the inherent subjectivity stemming from the experience and judgment of the TC forecaster using it. In the late 1980's, Zehr (1989) developed an objective technique using enhanced infrared satellite data. This "digital Dvorak (DD)" method laid the foundation for the development of the Advanced Objective Dvorak Technique (AODT) algorithm that exists today.

2. MOTIVATION AND INITIAL EFFORTS

The primary motivation for developing an automated, objective intensity estimation scheme was to remove the analyst judgment from the DT. This subjectivity was most prominent in certain analysis situations that involved cloud pattern typing. The availability of higher-resolution global infrared satellite data, and computer processing resources to provide sufficient analysis capabilities, both provided the incentive to develop an objective method.

The initial development of the ODT (prior version of the AODT) first required a careful identification of the strengths and weaknesses of the objective DD algorithm available at that time. The DD technique worked only for cases when the TC was well organized and possessing an intensity at or greater than minimum hurricane/typhoon. This allowed for reasonably accurate intensity estimates at or near peak intensity when the storm possessed an eye structure. But it lacked skill in other situations and could not be applied to weaker TCs.

The ODT Incorporated the concept of DT "scene type" designations and this provided greater accuracy in the intensity estimates. A procedure was developed which performed a Fourier Transform Analysis of the eye and surrounding cloud top regions in the IR imagery to determine scene types. This scheme eventually defined four primary scene types: Eye, Central Dense Overcast (CDO), Embedded Center (EMBC), and Shear. By using these four scene type designations, a proper "branch" in the DT logic tree could be followed to more accurately produce an objective intensity estimate.

The creation of a "history file" allowed for previous intensity estimates, and their related analysis parameters, to be stored and utilized by subsequent image interrogations by the ODT algorithm. A time-averaged T-number replaced the Data-T number, and was effective in removing much of the fictitious short-term variability in the intensity estimates. In addition, specific DT rules, such as the "EIR Rule 9" controlling the weakening rate of a TC after maximum intensity, were implemented to more closely follow the DT principles.

Statistically, the ODT was shown to be competitive with TC intensity estimate accuracies obtained with the subjective DT at operational forecast centers (OFC) such as the Satellite Analysis Branch (SAB) of NOAA/NESDIS in Washington DC, the Tropical Analysis and Forecast Branch (TAFB) of NOAA/NCEP at the Tropical Prediction Center in Miami, FL, and the Air Force Weather Agency (AFWA) at Offutt AFB in Omaha, NE. These statistics were only valid for Atlantic Ocean and Caribbean Sea TCs since aircraft reconnaissance MSLP measurements in these basins were used in assessing ODT performance. An attempt to tune the ODT for the Northwest Pacific TCs was conducted using TC cases in the 1980's when aircraft validation was available. Even though the IR imagery available at that time was of inferior quality, some WPAC threshold adjustments were implemented. See Velden et al. (1998) for further details on the ODT.

The original goal of the ODT was to achieve the accuracy of the DT using computer-based, objective methodology. This goal was accomplished, however, important limitations still existed. The ODT still could only function on storms that possessed an intensity at, or greater than, minimal hurricane/ typhoon. Also, the location of the storm center needed for the ODT analysis still required manual selection prior to algorithm execution. These issues were the primary motivation for the continued development of the ODT.

3. THE ADVANCED ODT (AODT)

The advancement of the ODT into the realm of infrared satellite data interpretation and pattern recognition was initially met with skepticism. The DT Curved Band (CB) analysis technique is the primary tool used by analysts to interrogate pre-hurricane/

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typhoon strength TCs. This method relates TC intensity to the amount of curved cloud cover surrounding the storm center. This amount is measured using a 10° log spiral, which is manually rotated to determine the extent of the spiral covered and the actual center of the storm circulation. The technique is very subjective due to image interpretation regarding the definition of the cloud field region over which the spiral is placed, hence the initial skepticism over automating such an approach. However, after fruitful discussions with numerous TC forecasters, and a lengthy trial and error process, an objective scheme was derived and incorporated into the AODT algorithm.

Another major advancement to the ODT was the elimination of the final remaining subjective element: the manual determination/positioning of the TC center location. This is proving to perhaps be the most challenging aspect of the AODT transition. A method was developed to utilize an OFC short-term track forecast as a first guess for the storm center location at a given analysis time. Once derived, a Laplacian Analysis technique is employed to search for strong, localized gradients in the image brightness temperature (BT) field surrounding the interpolated forecast position. Such BT gradient fields are typically associated with TC eyes, but can also be applied to EMBC and some CB scene types. If the Laplacian Analysis scheme locates a region that exceeds empirically determined threshold conditions, the region center is used as the AODT storm center location. Statistically, the AODT intensity estimates produced using the automated center location routine are only slightly degraded compared to those obtained using manual storm center location placements (Olander et. al., 2004). More sophisticated center-determination schemes are being developed for future AODT applications (Wimmers and Velden, 2004).

Additional DT rules were also incorporated into the AODT in order to further stabilize the intensity estimates over time. For example, the DT Rule 8 was implemented, which constrains the TC intensity estimate growth/decay rate over set time periods. The inclusion of this rule led to a modification of the AODT time-averaged intensity value calculation, reducing the averaging period from 12 to 6 hours.

Finally, the AODT now includes an adjustment to the final estimate of TC MSLP. The adjustment was implemented following the discovery by Kossin and Velden (2004) of a latitude-dependent bias in the DT estimates of MSLP. It was found that this bias is related to the slope of the tropopause (and corresponding infrared channel cloud top temperature measurements) with latitude. The inclusion of this bias adjustment into the AODT resulted in a 10% reduction in MSLP estimate errors compared to aircraft reconnaissance measurements.

4. FUTURE DIRECTIONS

The AODT research efforts have centered on optimizing the utilization of geostationary satellite infrared imagery to operate over the full range of tropical cyclone intensities. While this technique provides forecasters with a robust objective tool, the use of supplementary spectral information may advance the technique even further. For example, polar-orbiting microwave sensors are being used to denote tropical cyclone structure and to infer intensity (Herndon and Velden, 2004; Edson, 2000). Employment of these instruments/methods in conjunction with the existing AODT when intelligently combined into an integrated algorithm should provide analysts with a powerful tool for estimating tropical cyclone intensity (Velden et. al., 2004).

5. REFERENCES

Dvorak, V., 1984: Tropical cyclone intensity analysis using satellite data. NOAA Tech. Rep. NESDIS11, 47pp., NOAA/NESDIS, 5200 Auth Rd., Washington, DC 20233.

Edson, R.T., 2000: Evaluation of TRMM and SSM/I imagery in the early development of tropical cyclones. Proc. of the 24th Conf. on Hurr. and Trop. Meteor., Ft. Lauderdale, FL, 254-255.

Herndon, D. and C. Velden, 2004: Upgrades to the UW-CIMSS AMSU-based TC intensity algorithm, (this volume).

Kossin, J.P. and C.S. Velden, 2004: A pronounced bias in tropical cyclone minimum sea-level pressure estimation based on the Dvorak technique. *Mon. Wea. Rev.*, 132, 165-173.

Olander, T.L., C.S. Velden, and J.P. Kossin, 2004: The Advanced Objective Dvorak Technique (AODT)-Latest Upgrades and Future Directions, (this volume).

Velden, C.S., T.L. Olander, and R.M. Zehr, 1998: Development of an objective scheme to estimate tropical cyclone intensity from digital geostationary satellite infrared imagery. *Wea. and Forecasting*, **13**, 172-186.

Velden, C.S., J. Kossin, T. Olander, D. Herdon, T. Wimmers, R. Wacker, K. Brueske, B. Kabat, J. Hawkins, R. Edson, and M. DeMaria, 2004: Toward an objective satellite-based algorithm to provide real-time estimates of TC Intensity using integrated multispectral (IR and MW) observations, (this volume).

Wimmers, A. and C. Velden, 2004: Satellite-based center-fixing of TCs: New automated approaches, (this volume)

Zehr, R., 1989: Improving objective satellite estimates of tropical cyclone intensity. Extended abstracts, 18th Conf. On Hurricanes and Tropical Meteorology, San Diego, CA, *Amer. Meteor. Soc.,* J25-J28.