15A.4 DEVELOPMENT OF THE ADVANCED OBJECTIVE DVORAK TECHNIQUE (AODT) – CURRENT PROGRESS AND FUTURE DIRECTIONS

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1. INTRODUCTION

An objective scheme to estimate tropical cyclone (TC) intensity using geostationary infrared satellite data has been developed at the University of Wisconsin-Madison, Cooperative Institute for Meteorological Satellite Studies (UW-CIMSS). This algorithm, the Objective Dvorak Technique (ODT) (Velden et al. 1998), utilizes many of the rules and guidelines described in the original, subjective Dvorak Technique (DT) (Dvorak, 1984). Comparisons between ODT estimates of minimum sea level pressure (MSLP) with aircraft reconnaissance measurements have shown the ODT to be on par with or slightly better than operational intensity estimates obtained using the subjective DT methodology (Velden et al. 1998). Field testing has isolated circumstances where further improvements to the existing ODT algorithm are needed to improve accuracy and applications over a wider variety of situations. This paper introduces the development of the Advanced Objective Dvorak Technique (AODT), which is based upon significant feedback from the ODT user community, and ongoing advances in satellite remote sensing technology.

2. OPERATIONAL USAGE AND FEEDBACK

The ODT algorithm has been utilized as a guidance tool at many TC forecasting centers worldwide for numerous years. These centers include the Satellite Analysis Branch (SAB) of NOAA/NESDIS, the Tropical Analysis and Forecast Branch (TAFB) of the Tropical Prediction Center, and the Joint Typhoon Warning Center (JTWC). Analyst feedback has led to various functionality upgrades and improvements. In addition, ODT performance reviews provided by SAB for the past three years have focused attention on primary areas of concern requiring further investigation.

An important concern is the accuracy of the ODT intensity estimates for storms outside the North Atlantic and East Pacific regions. The ODT was developed and tuned primarily in the Atlantic using aircraft reconnaissance *in situ* measurements of TC intensity. In the Northwestern Pacific, calibration was also performed utilizing aircraft reconnaissance measurements from the early-mid 1980s, however the corresponding satellite imagery back then had inferior spatial and temporal resolution compared with today's imagery and may not have been sufficient for precise ODT calibration in that region. Current use and comparisons with subjective DT estimates have generally shown the ODT provides slightly stronger intensity estimates in this region. But without Northwest Pacific aircraft reconnaissance, it is difficult to verify whether the ODT estimates are an improvement or not. This holds true for ODT applications in other TC basins as well.

Another ODT characteristic noted by the operational users is the occasional premature triggering of the "rapid intensification" flag. This is a unique aspect of the ODT and is enabled when two environmental eyewall temperature threshold values are exceeded. The rapid intensification option was installed into the ODT algorithm to adjust the time averaging scheme when rapid TC deepening is suggested. (e.g., Hurricane Opal of 1995). These threshold values were empirically determined by examining a limited set of satellite images during Atlantic TC events. Due to the inherent differences between Atlantic and Northwest Pacific TCs and the small number of Atlantic cases used to define the rapid intensification eyewall cloud temperature thresholds, the flag has been found to trigger too often in Northwest Pacific storms. This has led to significant storm intensity overestimation in certain cases. A reevaluation of this procedure for Northwest Pacific applications is now underway.

3. ADDITIONS AND IMPROVEMENTS TOWARD THE DEVELOPMENT OF THE AODT

In order to properly address the comments and concerns raised by the operational users during the past few years, certain routines within the ODT algorithm are currently being reexamined. These new research avenues not only will allow for a more robust algorithm, but will significantly enhance the current capabilities of the ODT and will lead to improved performance and a greater range of use.

A primary focus of current research is expanding the ODT range of use to include storm intensities of tropical storm and lesser strength utilizing methods defined in the original DT. This extension of functionality requires an enhancement of the current scene identification technique used to define eye and surrounding cloud region classifications. In the AODT, eye region characteristics are now specified, including such classifications as ragged, well-defined, and large eye scenes. Surrounding cloud region classifications are also more descriptive, ranging from uniform central dense overcast (CDO) to Curved Band (CB) patterns. The CB pattern identification routine allows for estimation of TC intensity at and below tropical storm strength. This routine utilizes an automated 10° log spiral analysis scheme to estimate the extent of the

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main band of convection, which is related to the current intensity of the storm as described in the DT technique. Although a complete statistical comparison between AODT CB estimated intensities and corresponding aircraft reconnaissance intensity measurements (or subjective intensity estimates from tropical forecasting centers) have not yet been performed as of this writing, preliminary comparisons have been promising.

Supplementary DT rules have also been incorporated with the introduction of the various new scene type classifications, as mentioned previously. These rules focus mainly on the appearance of the eye and their corresponding adjustments to the intensity estimate as outlined in the DT rules.

Additional statistical analyses of the eye and surrounding cloud region temperature histograms have been introduced to enhance the existing Fourier Transform analysis. The eye region analysis focuses on the spread and symmetry of the temperature measurements within the eye pixels. This helps to characterize eye clarity and size. The surrounding cloud region analysis concentrates on convective symmetry and extent characteristics, with emphasis on describing the organization and coverage of the convective cloud region in relation to the storm center. These new scene classification enhancements allow for incorporation of additional DT rules into the AODT algorithm, which in turn should lead to more accurate intensity estimates over a wider range of TC strengths.

Another upgrade regarding the AODT algorithm involves the actual programming code. Currently, the ODT must run within a McIDAS environment in order to obtain satellite navigation and calibration information. This environment, while powerful and flexible for use with many different satellite platforms and instruments, requires ODT users to possess or acquire McIDAS. In order to move the ODT towards a more “platform independent” version, the AODT algorithm now incorporates all necessary navigation and calibration routines within the ODT code library. This feature significantly increases the size of the algorithm library, but allows for easier implementation of a platform independent version. During this process, the code was rewritten and reorganized, which resulted in an algorithm that would allow for easier portability into non-McIDAS systems possessing their own navigation, calibration, and image handling library routines. This transition has been successfully demonstrated with the integration of the new code into the Navy TeraScan system for use at the JTWC. Additionally, the code is currently being ported into the SIDAS at the Air Force Weather Agency (AFWA) and into N-AWIPS for NOAA/TAFB. An X-Windows version is also under development.

4. FUTURE DIRECTIONS

As described in the previous section, development of the Advanced ODT (AODT) is underway. Current research efforts are focusing on extending the AODT applications over a wider range of TC intensities and basins, and addressing user concerns in specific cases. Future versions of the AODT will make use of supplementary geostationary satellite channels and unique information from polar orbiting platforms. Examples include the utilization of geostationary satellite water vapor channels to examine strong convection in tropical cyclones (Velden and Olander, 1998), polar-orbiting microwave sensors to examine tropical cyclone warm core structure (Brueske and Velden, 2000) and convective patterns (Cocks et. al. 1999; Edson 2000). Fusing information from these sensors in conjunction with the existing AODT algorithm should provide forecasters with an increasingly accurate state-of-the-art remote-sensing tool for estimating TC intensity.

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