# JHT Final Report

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## *Implementation of the UW-CIMSS Advanced Objective Dvorak Technique (AODT)*


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**Recap of Project Goals:** The primary goal of this project was the implementation and evaluation of an objective algorithm for estimating tropical cyclone (TC) intensity from geostationary satellite data developed at UW-CIMSS, into the Tropical Prediction Center (TPC) operational data analysis platform N-AWIPS. The Advanced Objective Dvorak Technique (AODT) was developed primarily at UW-CIMSS on McIDAS, and is a state-of-the-art method designed to objectively estimate TC intensity from IR imagery. This project was aimed at 1) implementing the AODT into the fully-operational TPC computing environment, 2) helping to evaluate and maintain the algorithm performance, and 3) providing subsequent updates to the N-AWIPS code when new and successful research modifications were demonstrated. The detailed plan for the integration of the AODT into N-AWIPS as agreed upon by the NOAA/Computing Development Branch (CDB), TPC and UW-CIMSS was attached as an Appendix in the Year1 report.

**Summary of First Year Achievements/Milestones:** We were successful in achieving all of our proposed milestones for the first year of this project (exception: see the note at the end of the report on the TIE model). The accomplishments:

1) The AODT code was rewritten so that it fits into the CDB N-AWIPS architecture as specified by CDB staff, with a final delivery in March 2004 (about two weeks ahead of schedule). For this release, we included all required code specified by the CDB programmers along with a Programmer's requested by CDB.
2) Integration of the AODT algorithm into NMAP at CDB occurred in April 2004. Successful testing and evaluation by CDB and TPC resulted in the formal delivery of the NMAP-AODT to TPC within N-AWIPS v5.7.3 in time for the 2004 TC season.

**Summary of Second Year Achievements/Milestones**: Since the prototype version of the AODT was successfully implemented onto the TPC N-AWIPS in the first year, the focus in the second year was on goals 2 and 3 as stated above. During the 2004 Atlantic and East Pacific TC season, the AODT was run in TAFB at TPC. Despite some early bugs, AODT estimates were produced in real time for most of the storm cases in 2004. CIMSS fielded questions from the analysts and forecasters during the events, mainly related to certain AODT behavior or output interpretation. Towards the end of the season, limited feedback via personal communication from TPC was received at CIMSS on the overall AODT performance. In addition, CIMSS conducted an internal evaluation of the performance during this season. The combined evaluation was used to modify, test and implement upgrades to the existing AODT version.

The following are a list of AODT modifications based on statistical or empirical analysis:

LATITUDE BIAS ADJUSTMENT TO MSLP OUTPUT

- The Dvorak method was found to contain a significant latitude bias in regards to the estimated MSLP (Kossin and Velden, 2004). An adjustment for this was implemented into the prototype NAWIPS version of the AODT. However, the adjustment should only be invoked when certain scene types have been identified. These scenes are those that use the cloud region temperature value to determine storm intensity (CDO, Embedded Center, and Eye scenes... and not ‘pattern-type” scenes such as Curved Band, Irregular CDO, and Shear). New logic has been implemented to determine if an EIR-type scene type is available for six hours continuously. If so, a latitude-dependent bias adjustment to the estimated output MSLP value will be "blended in" over the next six hours (adjustment value is multiplied by a value between 0.0 and 1.0 depending on time within six hour blending period). The adjustment will also be "blended out" if non-EIR-type scene types are identified for a continuous six-hour period.

CHANGES TO HOW DVORAK RULE 8 IS APPLIED

- Added an "Initiation Rule" to limit growth/decay by 0.1Tnum/hour in first 6 hours after a storm file has been initialized. This was based on a systematic tendency for the AODT to over-develop storms in the formative stages.
- Added new Raw T# intensity constraint boundaries based on scene types. New rule constraint changes were implemented for shear, eye, and “other” scene types. Shear scene type constraints match those in original Dvorak Rules. "Other" scene type constraints subtract 0.5 T# from allowed T# variability over time (e.g., 1.5T#/12hr reduced to 1.0T#/12hr), while eye scenes add 0.5 T# to allowed T# variability (e.g., 1.5T#/12hr increased to 2.0T#/12hr). These modifications were based on AODT performance when the error statistics are broken down by scene type.
- Added new rule for shear scenes after land interaction. 0.5 is added to Raw T# if land interaction was greater than 6 hours and scene type after storm re-emergence over water is a shear scene. This adjustment for shear scene is based on statistical analysis of post-land events, and is turned off once another scene type is encountered.

CHANGE TO HOW DVORAK RULE 9 IS APPLIED

- Removed 0.5 subtraction to CI# value if storm has weakened and now is in "steady state". During weakening, AODT will now always hold CI# up to 1.0 greater than max Final T# in past 12 hours. The old rule was put in based on TPC feedback, however, we found it hurt the statistical performance of the AODT. This will be revisited in the future.

CHANGE TO CI CALCULATION IN EYE SITUATIONS

- If the scene type is an eye, the CI# will be based upon the three-hour averaged Final T# instead of the six-hour weighted average Final T#. This will allow the intensity of a storm during eye cycles to vary faster than the previously-employed 6-hour average, for CI# determination.

NEW CENTER FINDING ROUTINES

- Implemented new automated center finding methods that consist of a Spiral Fitting routine that attempts to fit a log-spiral to the cloud shield, and a Ring Fitting routine that searches for circular, high-gradient regions (eyewall) in the cloud shield. Logic was also added to determine a quality flag value for the combined results of each of the two methods. The quality flag value obtained via one or both of these techniques is used in conjunction with previously existing techniques to determine the best centering point for the storm in question. The auto center location positions are only used if the current final T# is greater or equal to 4.5 in formative stages, and 3.5 thereafter, otherwise the interpolated storm forecast position is used as the storm center location (as done in the previous AODT version).

ESTIMATE OF RADIUS OF MAXIMUM WIND (RMW) IN STORMS WITH EYES

- Added radius of maximum wind determination logic based on recent work with IR data. This works for storms with clear eyes as determined by AODT scene type, and for the full range of mean cloud region temperature values. The routine calculates eye size by identifying the interface between the eye and eyewall, and then estimates the RMW through a simple linear regression. In preliminary testing we have found that this algorithm explains 60% of the variance of the RMW. The output from this algorithm will also serve as an important input parameter for the CIMSS AMSU TC intensity algorithm presently being run at TPC.

NEW HISTORY FILE LISTINGS

- Added or modified wording on history file listing parameters:
  * Reorganized parameters being listed
  * Reworded MSLP Lat Bias Adjustment column header (next to Final MSLP value associated with CI# value). Final MSLP value listed is after MSLP Lat Bias adjustment has been applied.
  * Lists Raw, Adj, and time-averaged T# values
  * Relabeled ‘Rule 8’ and ‘Rule 9’ flags as ‘Constraint Limits’ and ‘Wkng Flag’, respectively
  * Added estimated Radius of Maximum Wind (RMW) value, if available
  * Added storm positioning "Fix" method (manual or auto-location method)
- Added ability to add comments (up to 50 characters) to history file record via command line input.

OTHER MODIFICATIONS

- Eye size is now determined within the new RMW routine. Eye size is used to determine ‘LARGE EYE’ scene types.
- Modified code to better manage memory used during execution of algorithm. Memory is dynamically allocated and de-allocated as needed instead of "hard coding" all arrays when compiling the code. This cuts down on the amount of memory up front during the execution of the algorithm.
- CVS repository was created for storage of code and eventual use/modification by a number of potential AODT programmers/researchers. The repository was initialized using final AODT Version 6.3 submitted to NOAA/CDB for inclusion within NAWIPS (the redesigned code using the AODT as a library for the NMAP application).

LATEST AODT VERSION (6.4.2)

The statistics below represent the latest AODT performance based on a dependent sample. We used Atlantic cases in 2004 as an "independent" sample to test the new AODT version to further evaluate its performance. We investigated the causes of remaining systematic errors in an attempt to physically understand and correct for them (other than simple statistical bias adjustments). Based on this work, version 6.4.2 was packaged and released. This version was made available in spring to NOAA/CDB for inclusion within NAWIPS/NMAP. It is expected that TPC will have it available for evaluation before the end of the 2005 TC season.

**Performance of the new AODT Version 6.4**

+/- bias indicates under/overestimate of intensity (MSLP in hPa) by the AODT versus reconnaissance (within +/- one hour of AODT observation). TAC = Average of all Tropical Analysis Centers subjective estimates coincident with the AODT estimates. Sample of cases (num) is homogeneous for all three methods, and is derived from 56 storms (1995-2003).

| OVERALL | bias | rmse | aae | num |
|---|---|---|---|---|
| vers6.3 (old) | 0.57 | 10.48 | 8.02 | 3459 |
| vers6.4 (new) | -0.17 | 9.65 | 7.44 | 3459 |
| TAC | 0.72 | 9.72 | 7.24 | 3459 |

| FORMATIVE (PRE-EYE) | bias | rmse | aae | num |
|---|---|---|---|---|
| vers6.3 (old) | -1.50 | 10.52 | 7.94 | 2039 |
| vers6.4 (new) | - 0.43 | 9.08 | 6.78 | 2039 |
| TAC | -0.92 | 7.79 | 5.79 | 2039 |

| MATURE | bias | rmse | aae | num |
|---|---|---|---|---|
| vers6.3 (old) | 2.41 | 9.89 | 7.71 | 724 |
| vers6.4 (new) | -0.37 | 10.26 | 8.25 | 724 |
| TAC | 2.04 | 10.25 | 7.69 | 724 |

| WEAKENING (POST-EYE) | bias | rmse | aae | num |
|---|---|---|---|---|
| vers6.3 (old) | 3.84 | 10.85 | 8.46 | 696 |
| vers6.4 (new) | 0.19 | 10.22 | 8.18 | 696 |
| TAC | 4.48 | 13.37 | 10.64 | 696 |

***It should be stressed that the statistics above reflect the performance of the AODT as run in a purely automated mode. No manual center fixing or intervention. The performance metrics above clearly show the modifications listed earlier have led to significant improvements in the AODT. It should also be noted that the AODT comparison with TAC represents a stringent test. The TAC we compare to at any given time is a consensus value, which is normally better than the individual analysis center values. In addition, the Atlantic recon information may at times play into the TAC decision-making on subjective Dvorak estimates.***

**A note on the status of the TIE Model:** When we instituted the auto-center-fix algorithm during our in-house testing phase in the first year, we saw a dramatic loss of initial accuracy in the TIE-model during the initial weak TC phase. This is because the TIE-model does not consider scene-type, and relies solely on central and surrounding brightness temperatures; so brightness temperature inaccuracies due to center-fix errors can apparently significantly affect the TIE estimates. The AODT doesn't suffer from this because during the initial weak phase, scene types such as Curved Band or Shear are not sensitive to brightness temperature.

Because of these initially large inaccuracies, we decided to suspend the TIE-model output. Note that the TIE-model is included in the algorithm package that we delivered to CDB, so all the hooks are in place, but it's output has simply been disabled. We should also point out that a part of the TIE-model - specifically the latitude dependence - has already been directly incorporated into the AODT, so the AODT/TIE-model construct is now implicit in the AODT algorithm we have implemented onto N-AWIPS. We found that it was the latitude-dependent bias correction inherent in the TIE-model that allowed it to compare so favorable to the AODT in initial testing. By incorporating a bias adjustment into the AODT, the TIE-model was found to no longer compete as well against it. The development of the TIE-model also directly led to other modifications in the AODT algorithm, particularly in response to behavior and error characteristics as a function of scene type. To summarize, the notion of the TIE-model as a stand-alone algorithm has for now been abandoned in lieu of its contribution and assimilation into the AODT algorithm.