

AODT – Advanced Objective Dvorak Technique
USERS' GUIDE
(McIDAS Version 6.3)

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AODT – Advanced Objective Dvorak Technique

Users’ Guide

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1.) Description of the AODT Algorithm

The Advanced Objective Dvorak Technique (AODT) algorithm is a computer based technique, developed at the University of Wisconsin-Madison/Cooperative Institute for Meteorological Satellite Studies (UW/CIMSS), to objectively determine tropical cyclone intensity using geostationary satellite infrared imagery. The AODT can be used to classify storm intensity beginning from storm formation through development and dissipation. Previous versions of the ODT could only classify intensities once the storm being examined reached hurricane strength or greater (T# 3.5 or approximately 994/984mb in the Atlantic/Western Pacific).

The AODT is patterned after the Subjective Dvorak Enhanced Infrared 'EIR' Technique (SD) (Dvorak, 1975, 1984) which made use of various pattern identification schemes and rules to determine tropical cyclone intensity. The AODT has been developed to closely mimic the SD methodology in terms of intensity determination protocol and the incorporation of various rules and analysis methods.

The AODT was originally derived from previous objective satellite estimation algorithms developed at the University of Wisconsin/Space Science and Engineering Center and Colorado State University/Cooperative Institute for Research Applications. Significant modifications and additions have been made to the AODT, resulting in an algorithm that bears little if any resemblance to its forerunners in terms of methodology, functionality, and content. The primary modifications from previous digital Dvorak methods include the addition of a history file (containing previous intensity estimates obtained during a storm lifecycle), utilization of a time-weighted averaging scheme, new definitions and determinations of various environmental temperature values, and the use of various SD rules governing the variability of the intensity estimate values. These changes have led to more stable and statistically sound estimates of intensity.

For greater detail about the development process and statistical accuracy obtained with the current and previous ODT/AODT algorithm, please refer to Velden et al. (1998) and Olander et. al. (2002).

2.) System Hardware and Software Requirements

The AODT was originally developed within the Man computer Interactive Data Access System (McIDAS) architecture. The algorithm utilizes McIDAS library functions and routines to ingest infrared satellite data, display textual and graphical results, read various input data files, and write various output files. The AODT was primarily developed utilizing McIDAS 7.6 on a Silicon Graphics, Inc. Indigo2 running the UNIX-based IRIX 6.4 operating system. The AODT has been tested and operated on additional UNIX operating systems, including HP and Sun platforms. Integration within LINUX systems has also been successfully performed. Use of the GCC C-compiler is recommended, but the local system C-compiler can be used if the Makefile files in the two navcal directories are modified correctly.

3.) AODT Acquisition and Installation

The current version of the AODT algorithm can be obtained via the UW-CIMSS AODT web page, along with the Users' Guide. All files required for installation of the AODT are contained within a single compressed UNIX tar file. The AODT can be obtained from the following URL address :

<http://cimss.ssec.wisc.edu/tropic/aodt/aodt.html>

Once the AODT tar file has been downloaded, it can be uncompressed and unpacked using the following command :

```
gunzip AODT-v6.3.tar.gz  
tar -xvf AODT-v6.3.tar
```

Once completed, an "aodt-v6.3" directory should contain all of the files necessary to compile and create the AODT executable. The contents of the aodt-v6.3 directory are:

- NOTES : AODT notes and instructions
- odt.c odtauto.c odtdata.c odfft.c odthistory.c odtintensity.c odtmcidas.c
odtmcinput.c odtoutput.c odtsct.c : AODT C programs
- odt.h,odtsst.h : AODT include files
- TOPOLRES : Low resolution topography file
- aodt-compile : AODT compile script
- aodtenv : AODT environment argument setup file (Section 4.E)
- bin/ : directory containing binary files created during compilation
- history/ : directory containing output history files (suggested location)
- lib/ : directory containing library files
- navcal/ : directory containing navigation/calibration files and F2C files
- sst/ : directory containing current sea surface temperature files
- samples/ : directory containing test script and data and sample forecast files

Prior to installation of the AODT, the current libmcidas.a library file must be located and linked to within the aodt-v6.3/lib directory. The AODT requires this file for all text and graphical output within the McIDAS user interface windows. This file should reside in the ~mcidas/lib directory. The actual linking is performed within the "aodt-compile" script using the variable MCLIB to define the location of the libmcidas.a file. The MCLIB variable should be modified to reflect the location of the file on the machine where the AODT is being installed. Note that the entire path name must be used instead of the "~mcidas/lib" designation (e.g. /home/mcidas/lib). Once the MCLIB variable has been defined, the AODT algorithm can be compiled using the following syntax :

```
aodt-install <gcc/cc>  
<gcc/cc> - designates use of the system C-compiler (CC) or the GNU C  
compiler. GCC is recommended, but should be the same compiler  
used to compile the McIDAS code.
```

4.) Using the AODT

The AODT algorithm operates within the McIDAS architecture, utilizing the McIDAS text and graphics/image windows for command line input, data access, and image analysis. Runtime status and final analysis text output are displayed within the McIDAS text window, with image display and graphical output displayed within the McIDAS graphics/image window.

Use of the AODT algorithm is initiated via the McIDAS command line structure using a selection of keywords to control various functions of the AODT algorithm. All AODT keywords are defined in Section 4A1, with examples provided in Section 4A3.

A.) Command Line Structure and Keywords

The AODT is initiated and controlled with the following command line structure :

AODT <*keywords*>

Various keywords control different aspects of the AODT algorithm, many of which can be used in combination with other keywords to perform specific tasks. A short description of use for each keyword, along with several examples, will be presented in the following sections.

1.) Description of Use

HISTORY=filename (default=none)

History file used for the AODT analysis. If no history file is specified, no history file will be created/appended. History file names can be up to twelve total characters in length, including the suffix “.ODT”, which will be added to the end of all history file names. The directory where the history files are written to is defined with the ODHISTORY environment argument. See Special Keyword Notes in Section 4A2 and Section 4B for additional information about the AODT history file.

LIST=YES/NO (default=NO)

List contents of history file within McIDAS text window. Can be used in conjunction with DATE, OUTPUT, and DOMAIN keywords. Pressure/wind units in terms of millibars/knots. AODT analysis will not be performed.

OUTPUT=SCREEN/FILE filename (default=SCREEN)

Direct LIST=YES keyword output to McIDAS text window or ASCII file *filename*. The default output filename is ODTDUMP.ASC. The directory where the FILE output is written is defined with the ODTOUTPUT environment argument (see Section 4C).

GRAPH=YES/NO/TEM (default=NO)

Plot intensity estimates from history file to McIDAS image window. Can be used in conjunction with DATE, PLOT, DOMAIN, and WIND keywords. Pressure/wind units in terms of millibars/knots. TEM value plots eye region, cloud region, and “coldest-warmest” cloud region temperatures, respectively. Temperature units in terms of degrees Celsius/Fahrenheit. AODT analysis will not be performed.

PLOT=c1 c2 c3 c4 c5 c6 c7 c8 c9 (defaults=1 2 0 0 0 6 0 1 7; 0 to not display)

Defines graphic color level values for CI#, Adjusted MSLP, Final T# (6-hr time-weighted), Final T# (3-hr average), Raw T#, 12-hour Average TIE Model value, Current TIE Model value, graphics boundaries, and graphics wording, respectively. If TEM keyword is used with GRAPH keyword, the color levels will be for the eye region temperature, cloud region temperature, and “coldest-warmest” cloud region temperature, respectively (the other four values will not be used). Color values can be modified using the McIDAS command GU. Graphics color level value of zero (0) will suppress plotting of desired intensity estimate value. Used in conjunction with GRAPH keyword.

DELETE=YES/NO (default=NO)

Allows for manual deletion of history file records. Must be used in conjunction with DATE keyword to define date/time limits to remove. Any records existing in history file after deletion of unwanted records will be updated as necessary (Final T# and CI values will be recalculated). See DATE keyword for default values associated with DELETE keyword. AODT analysis will not be performed.

DATE=date1 time1 date2 time2 (default=see below)

Defines range of dates and times for LIST, GRAPH, and DELETE keywords. Format for date and time values are the same as those given within the text listing (LIST=YES option) :

date format : YearMonDy (e.g. 1998OCT17)

time format : HHMMSS (e.g. 131500)

Default values :

GRAPH and LIST : date1/time1 : first record
date2/time2 : last record

DELETE : date1/time1 : no default, must specify
date2/time2 : date1/time1

WIND=YES/NO (default=NO)

Intensity units given in terms of maximum wind speed (knots) instead of mean sea level pressure. Used in conjunction with GRAPH keyword to plot intensity estimates in terms of wind speed. Speed and pressure values are related to CI number values using empirical relationships defined in Dvorak (1984) and (Shewchuck and Weir, 1980).

DOMAIN=ATL/PAC (default=auto determination)

Define oceanic domain where tropical cyclone resides. ATL should be used for storms within North Atlantic basin, while PAC should be used for storms within Western Pacific basin. If the oceanic basin is not explicitly defined with this keyword, a basin will be selected automatically (see Section 5G). Domain selection will affect Raw T# intensity estimate determination and corresponding CI number pressure value (empirical CI number/pressure relationship). Can be used with LIST and GRAPH keywords or with AODT analysis.

AUTO=YES/NO type filename atctype (defaults=NO 0 AUTOFIX OFCL)

Allow for completely automated operation of AODT, utilizing NHC/JTWC forecasts and Laplacian Analysis to objectively determine storm center position.

Cannot be used with OVER keyword.

type = 0 : ATCF Tropical Cyclone Forecast Record files.
type = 1 : TPC WTNT4? (North Atlantic) or WTPZ3? (East Pacific) storm specific DISCUSSION files.
type = 2 : JTWC WTPN3? (Western North Pacific) TROPICAL CYCLONE WARNING file.
type = 3 : Generic format (see Section 5H for format/example)
filename : Name of input file. The directory where the input files is located is defined with the ODTAUTO environment argument.
atctype : ATCF objective technique acronym (default is official forecast)

OVER=YES/NO (default=NO)

Allow user to manually override AODT scene identification. *Cannot be used with AUTO keyword.* See Section 4D5 for more information.

IC=value (default=1.0)

Allow user to override the initial Raw T# intensity classification value, as defined in the Subjective Dvorak Rules. The initial Raw T# classification value will be set to 1.0 unless explicitly defined by the user as another value. This keyword should only be used when analysis of a tropical cyclone is initiated at a time later than initial formation (storm has a Raw T# value greater than 1.0). If value is set to 0.0, this function will be turned off for the analysis, allowing for the AODT derived value to be displayed as the Raw T#.

REMOTE=YES/NO localserver localarea (default=NO ODTLERVE ODTLDATA)

Utilize a remotely displayed/stored McIDAS image for AODT analysis. Subset of data image will be copied to the local server as defined by the *localserver* and *localarea* UNIX environment arguments. See Section 4C for more information.

localserver : ADDE dataset name (group/descriptor format or alias name). The default is the environment argument ODTLERVE.
localarea : ADDE dataset position (within local group/descriptor). The default value is the environment argument ODTLDATA.

LAND=YES/NO (default=YES)
Apply AODT land interaction rule. See Section 4D5 and 5A for more information.

SST=filename (default=SST.DAT)
Name of file containing SST information for TIE Model. Directory where SST file is located is defined using ODTSSST environmental variable. See Section 5K for more information.

SEARCH=YES/NO (default=YES)
Perform search for maximum curved band location if Curved Band scene type was automatically determined or manually selected. See Section 5J for more information.

2.) Special Keyword Notes

If no history file is provided, the AODT intensity bulletin and runtime output (see Section 4D) will be abbreviated, providing the user with only the intensity estimate value at the current time. No analysis flag values will be listed, and no history file will be created or modified.

If the GRAPH, LIST, or DELETE keywords are used, an AODT intensity analysis will not be performed. These functions are used to only investigate and modify the contents of the history file.

The AUTO and OVER keywords cannot be used in the command line at the same time. No user interaction is allowed during the automated operation of the AODT. If these keywords are used in the same command line entry, the override capability will be disabled, and an error message will alert the user of this fact.

3.) Examples

AODT
Perform abbreviated AODT analysis on current image. Only the current Raw T# will be displayed, with no time averaging or application of any being performed. Output will not be written to any history file.

AODT HISTORY=OPAL.ODT
Perform AODT analysis and add record to history file OPAL.ODT. All rules will be applied as necessary. If this is the first analysis in the OPAL.ODT history file, the initial Raw T# value classification will be set to 1.0.

AODT HISTORY=OPAL.ODT IC=2.5
Perform AODT analysis on the first record within the OPAL.ODT history file, however the initial intensity estimate (first record in history file) within the history file will be set to 2.5.

AODT HISTORY=OPAL.ODT OVER=YES

Perform AODT analysis and add record to history file OPAL.ODT. User will be presented with the evaluated AODT Scene Type and prompted to accept or change this value.

AODT HISTORY=OPAL.ODT GRAPH=YES PLOT=3 4 0 1 2

Display graph of contents of history file OPAL.ODT in current graphic image using color level 3, 4, 1, and 2 for the CI, Final T# (6-hr average), Raw T#, and TIE model estimate plots, respectively. The Final T# (3-hr average) values will not be displayed. Graph boundary and wording will utilize the default values. No intensity analysis is performed.

AODT HISTORY=OPAL.ODT LIST=YES

List contents of history file OPAL.ODT within McIDAS text window. No intensity analysis is performed.

AODT HISTORY=OPAL.ODT LIST=YES OUTPUT=FILE OPAL.TXT

Do NOT perform AODT analysis; provide listing of history file OPAL.ODT to output file OPAL.TXT within directory defined with the ODTOUTPUT environment argument.

AODT HISTORY=OPAL DELETE=YES DATE=1995OCT03 151500

Delete only the 1995OCT03/151500UTC record from the history file OPAL.ODT. No intensity analysis is performed, but all subsequent records in the history file are modified following the deleted record.

AODT HISTORY=OPAL DELETE=YES DATE=1995OCT03 151500 1995OCT03 191500

Delete all records between 1995OCT03/151500UTC and 1995OCT03/191500 UTC from the history file OPAL.ODT, inclusive. No intensity analysis is performed, but all subsequent records in the history file are modified following the deleted records.

AODT HISTORY=OPAL LIST=YES DATE=1995OCT03 1500

List all records between 1995OCT03/001500UTC and the end of the history file OPAL.ODT. No intensity analysis is performed.

AODT HISTORY=OPAL LIST=YES DATE=X X 1995OCT03 31500

List all records between the beginning of the history file OPAL.ODT and 1995OCT03/31500UTC. No intensity analysis is performed.

AODT HISTORY=OPAL.ODT AUTO=YES 2 wp2698.txt

Perform automated AODT analysis and add record to history file OPAL.ODT. AODT will read JTWC Tropical Cyclone Warning file wp2698.txt for forecast information, and is located in the directory defined by the ODTAUTO environment argument.

AODT HISTORY=OPAL.ODT REMOTE=YES

Perform AODT analysis on the remotely stored image currently displayed in the McIDAS image display window. A subset of the displayed image will be copied to the local server on the user's machine in a location defined using the environment arguments ODTLSERVER and ODTLDATA. See Sections 4C and 4D6 for more details.

B.) History File

The AODT history file is an ASCII format file containing AODT intensity estimates, locations, and other specific information for each image analysis. The AODT algorithm utilizes records in the history file for the determination of the intensity estimate values as well as the application of various rules utilized within the intensity estimate routines. Each analysis stored in the history file will contain the following values :

Value 1	: date (YYYYMMDD format : YYYY=year, MM=month, DD=day)
Value 2	: time (hhmmss format)
Value 3	: Julian day and partial day
Value 4	: raw T# unadjusted
Value 5	: raw T# adjusted by Rule 8 rules
Value 6	: final T# value (6-hour time-weighted average)
Value 7	: final T# value (3-hour average)
Value 8	: final CI# value
Value 9	: eye region temperature (°C)
Value 10	: mean cloud region temperature (°C) – movable annulus
Value 11	: mean cloud region temperature (°C) – set region (old method)
Value 12	: “coldest-warmest” cloud region temperature (°C)
Value 13	: storm center latitude (+/- = North/South Hemisphere)
Value 14	: storm center longitude (+/- = West/East Hemisphere)
Value 15	: eye diameter or shear distance (in km)
Value 16	: eye region temperature standard deviation value
Value 17	: cloud region symmetry value
Value 18	: eye region scene type (original value)
Value 19	: cloud region scene type (original value)
Value 20	: eye region scene type (user override value)
Value 21	: cloud region scene type (user override value)
Value 22	: Dvorak Weakening flag
Value 23	: Dvorak Rule 8 flag
Value 24	: land/ocean flag
Value 25	: eye region FFT value
Value 26	: cloud region FFT value
Value 27	: curved band analysis – BD curve gray scale value
Value 28	: curved band analysis – convection curvature amount (out of 25)
Value 29	: distance from center to “coldest-warmest” temperature value
Value 30	: automated center determination flag
Value 31	: MSLP pressure value using latitude bias adjustment
Value 32	: TIE Model output flag
Value 33	: TIE Model current pressure value – if SST value available
Value 34	: TIE Model 12-hour averaged pressure value – if SST value available
Value 35	: sea surface temperature value (°C) – if available

History files should not be modified directly. Any modifications, such as reanalysis or removal of individual records, should only be done using the AODT command line entry with select keywords, such as DELETE and DATE, in order to assure correct modification to the remaining history file entries.

Due to McIDAS keyword entry constraints, with origins dating back to the initial DOS-based systems, history file names are limited to 12 characters in total length, including the “.ODT” suffix. History file names provided in the command line without the “.ODT” suffix will have it appended automatically, with the prefix name truncated to eight characters if necessary. For example, the command line entered history file name of JOSEPHINE will result in a file name of “JOSEPHIN.ODT”, while “OPAL.ODT” or “OPAL” will result in “OPAL.ODT”. The directory location of the history files is defined with the ODTHISTORY environment variable.

C.) UNIX Environment Arguments

In order to provide more control regarding various AODT input/output file and directory definitions, the AODT utilizes UNIX environment arguments to define specific variables used within the AODT algorithm. This provides the user greater ability to personalize the AODT to the local machine on which it is operating.

Seven environment arguments are defined within the aodtENV file :

<u>Variable</u>	<u>Description</u>
ODTTOPO	Directory where TOPOHRES topography file is located
ODTHISTORY	Directory where AODT history files are stored
ODTAUTO	Directory for forecast files for AODT auto mode
ODTOUTPUT	Directory for LIST output
ODTSST	Directory for the external SST input file
ODTLSERVER	Name of local ADDE server dataset name
ODTLAREA	ID number of local ADDE server dataset position

ODTTOPO, ODTHISTORY, ODTAUTO, ODTOUTPUT, and ODTSST are directory names. The default value for the base directory for these variables is defined using the \$ODTHOME environmental variable, which is defined on line one of the aodtENV file. If any of these variable names are not defined in the aodtENV file explicitly, the value will default to the \$HOME environment variable value.

The ODTLSERVER and ODTLAREA variables will copy a remotely stored image to the local server using the standard McIDAS ADDE dataset name and position identification scheme. ODTLSERVER is the dataset name, in either *group/descriptor* format or an ADDE alias name (using AKA), with ODTLAREA being the *position* variable. Please refer to the McIDAS Users’ Guide for details on specific McIDAS ADDE server definitions and topics.

To install these variables within the UNIX environment, use the following command on the UNIX command line :

. aodtENV

Once entered in the UNIX environment, any McIDAS session initiated will utilize the seven AODT environment arguments. The UNIX “env” command can be used to verify the values assigned to each of the variables.

D.) Algorithm Output

During AODT operation the algorithm will display various text outputs within the McIDAS text window, consisting of various runtime information and error messages, interactive prompts for user override options, and the final intensity estimate bulletin.

1.) Full AODT Analysis

Full AODT analysis of an image requires the use of a history file and may use various combinations of specific keywords. Below is sample output obtained during analysis of an image for Hurricane Floyd :

```
Utilizing history file /home/odt/aodt-v6.3/history/FLOYD.ODT
Performing full AODT analysis
Utilizing image data file /home/odt/mcidas/data/AREA2010
Using USER-SELECTED center position : LAT: 22.99 LON: 66.21
SST value of 18.6C at cursor location
Ocean basin automatically selected as ATLANTIC
Warmest pixel temperature of -0.1C at LAT: 23.99 LON: 66.21
ADDED RECORD TO END OF HISTORY FILE
WROTE 66 RECORDS TO HISTORY FILE /home/odt/aodt-v6.3/history/FLOYD.ODT
*****
```

```
                UW - CIMSS
      ADVANCED OBJECTIVE DVORAK TECHNIQUE
                AODT - Version 6.3
Tropical Cyclone Intensity Algorithm
```

```
      ----- Current Analysis -----
Date : 12 SEP 1999      Time : 124500 UTC
Lat  : 22:59:26 N      Lon  : 66:12:49 W
```

```
      CI# /Pressure/ Vmax
      6.5 / 934.8mb/127.0kt
```

```
Latitude bias adjustment to MSLP : -0.2mb
```

```
      6hr-Avg T#      3hr-Avg T#      Raw T#
      6.3              6.4              6.5
```

```
Eye Temp : -0.1C      Cloud Region Temp : -70.2C
Scene Type : CLEAR EYE
Ocean Basin : ATLANTIC
Flags : Rule 8 : NO LIMIT      Weakening : OFF
```

```
                UW - CIMSS
TROPICAL CYCLONE INTENSITY ESTIMATE MODEL
      TIE MODEL - Version 0.0A Beta
```

```
      Sea Surface Temperature=18.6C
      Current Pressure/Vmax : 920.0mb/140.4kt
      12hr-Avg Pressure/Vmax : 923.8mb/137.4kt
```

```
*****
Successfully completed AODT analysis
```

The first section of the AODT output includes the runtime messages, which provide general information about the history file being used and various other parameters used in the derivation of the current intensity estimate. The history file utilized will be displayed first, and thus a full AODT analysis will be performed on the image. This will be indicated by the following message :

```
Performing full AODT analysis
```

The path and file name of the current image file being analyzed will be listed next. In this example the locally stored image file is named AREA2010. The path to this image is defined by the \$MCPATH environment variable, and is defined in the local “.mcenv” file. For an example of remotely stored data, and its corresponding output messages, see Section 4D6.

The location of the storm center selected for the current intensity analysis will then be shown. The example above used a manually selected storm center location, indicated by the USER-SELECTED message containing the storm center coordinates. A discussion of an automatically selected storm center location will be provided in section 4D4. The ocean basin in which the storm is located will be displayed next. This value will either be ATLANTIC or PACIFIC, indicating the MSLP-T# relationship used for the output pressure value in the intensity bulletin and history file listing. The basin will automatically be determined unless manually overridden using the BASIN keyword. See Section 5G for more information on the ocean basin determination.

Once the intensity analysis has completed, the current analysis information will be written to the history file. In this example the current analysis was appended at the end of the history file, and was indicated by the message :

```
Added record to end of history file
```

The above message will appear most frequently since the AODT will usually be executed utilizing the latest available image for the storm being investigated. If analysis of a missed image or reanalysis of a previously examined image is performed, one of the following message groups will be displayed, respectively :

```
Overwrote record X in history file <history file>  
Modified X subsequent records in history file <history file>  
Wrote X record(s) to history file <history file>
```

or

```
Inserting record X in history file <history file>  
Modified X subsequent records in history file <history file>  
Wrote X record(s) to history file <history file>
```

When a record is overwritten or inserted into an existing history file, all records after the current analysis will be automatically recalculated, as needed, using the new records information.

Within the intensity estimate bulletin, all vital information relating to the current image analysis will be displayed. The date, time, and location are presented first, followed by the four intensity estimate values; the current Raw T#, Final T# (6-hour time-weighted average), Final T# (3-hour average), and CI#. The “Raw T#” value represents the current intensity of the storm, and is the value obtained after the Dvorak Rule 8 rules have been applied (see Section XX). The “6hr-Avg T#” value is the 6-hour time-weighted averaged intensity of the storm. The time averaging scheme is explained in greater detail in Section 5D. The “3hr-Avg T#” value is the average of the current and previous three hour analyses values. Finally, the “CI#” value represents the 6-hour time-weighted averaged value after various subjective Dvorak EIR rules governing its variability, Rule 8 and Rule 9 have been applied. For more details on these rules, see Sections 5E and F. Adjacent to the “CI#” value are the corresponding estimated mean sea level pressure (MSLP) and maximum wind (Vmax) values. These values are based upon specific relationships between T# and MSLP for different oceanic basins (see Section 5G)

The MSLP value displayed for the derived CI# intensity estimate has been modified by a latitude bias adjustment, which is a linear regression-based equation which adjusts the original CI# based upon the current storm latitude. The amount of the adjustment is listed under the CI#/MSLP/Vmax information in the intensity estimate bulletin. A positive/negative adjustment will increase/decrease the MSLP value obtained from the specific CI#/MSLP relationship for the scene being investigated. Please see Section 5K for more information on this adjustment.

The next section of the intensity estimate bulletin contains information about the scene being analyzed and various rule flag values affecting the current intensity estimate calculation. First, the eye and surrounding cloud region temperature values, described in Section 5C, are provided first. Beneath the eye temperature, the objectively determined scene type is listed. This classification can be manually defined by the user, if desired, using the OVER manual override keyword. Objective scene type determination is described in Section 5B. Next, the current oceanic basin is provided, and will be automatically determined unless explicitly defined by the user with the DOMAIN keyword, and is described in Section 5G. Finally, two Dvorak EIR Rule flag values are displayed. These flags, described in Sections 5E and 5F, notify the user whether these rules, which govern the determination of the Final T# and CI# values, have been applied during the current intensity estimation analysis.

The final section of the intensity estimate bulletin is the experimental Tropical Cyclone Intensity Estimate (TIE) Model output. An estimate will not appear if a valid sea surface temperature (SST) (Section 5K) cannot be obtained from an external data file. Also, the TIE Model estimate will not be displayed until the TIE Model estimate and AODT estimate difference is less than or equal to 0.5 T#. A message in the intensity estimate bulleting will be displayed indicating this condition has not been met. Once this condition has been met, all subsequent TIE Model estimates will be displayed within the intensity estimate bulletin and available for output with the LIST and GRAPH options.

See the TIE Model Users' Guide, available on the AODT homepage, for more specific information about the TIE Model.

2.) Abbreviated AODT Analysis

If a history file is not specified on the command line when utilizing the AODT, an abbreviated analysis will be performed. Much of the output will be the same, however a few modifications to the runtime messages and intensity bulletin will exist. First, the intensity bulletin will contain only one intensity estimate value. This estimate will be listed at the "CI#", representing the intensity estimate at the analysis time only. Second, the two "Rule Flags" values will not be listed since they are only utilized when a history file is present. A sample abbreviated output is presented below :

```
Performing abbreviated AODT analysis
Utilizing image data file /home/odt/mcidas/data/AREA2010
Using USER-SELECTED center position : LAT: 22.99 LON: 66.21
SST value of 18.6C at cursor location
Ocean basin automatically selected as ATLANTIC
Warmest pixel temperature of -0.1C at LAT: 23.99 LON: 66.21
```

```
                UW - CIMSS
      ADVANCED OBJECTIVE DVORAK TECHNIQUE
                AODT - Version 6.3
Tropical Cyclone Intensity Algorithm
```

```
      ----- Current Analysis -----
Date : 12 SEP 1999      Time : 124500 UTC
Lat  : 22:59:26 N      Lon  : 66:12:49 W
```

```
      CI# /Pressure/ Vmax
      6.5 / 934.8mb/127.0kt
```

```
Latitude bias adjustment to MSLP : -0.2mb
```

```
Eye Temp : -0.1C      Cloud Region Temp : -70.2C
Scene Type : CLEAR EYE
Ocean Basin : ATLANTIC
```

```
                UW-CIMSS
TROPICAL CYCLONE INTENSITY ESTIMATE MODEL
                TIE MODEL - Version 0.0A Beta
```

```
      Sea Surface Temperature=18.6C
      Current Pressure/Vmax : 920.0mb/140.4kt
      12hr-Avg Pressure/Vmax : 923.8mb/137.4kt
```

Successfully completed AODT analysis

3.) Land Interaction

If the storm center is over a land region (as defined in Section 5A), a warning will be presented in the runtime output and intensity bulletin. No intensity estimate will be calculated unless explicitly requested by the user with the LAND keyword. A sample output for a storm center over land is presented below :

```
Tropical cyclone is over land

*****

                UW - CIMSS
          ADVANCED OBJECTIVE DVORAK TECHNIQUE
                AODT - Version 6.3
    Tropical Cyclone Intensity Algorithm

        ----- Current Analysis -----
Date : 12 SEP 1999      Time : 124500 UTC
Lat  : 22:56:18 N      Lon  : 66:02:56 W

                TROPICAL CYCLONE OVER LAND
                NO AODT ANALYSIS AVAILABLE

*****
```

4.) Automated Storm Center Determination

The AODT algorithm can be run in a completely automated mode, utilizing interpolated tropical cyclone forecasts and a Laplacian-based storm center determination routine to obtain a completely objective storm intensity estimate. See Section 5H for specific information on the formats allowed for the input forecast files.

The automated storm center location is determined using one of three techniques; polynomial interpolation of a forecast, Laplacian analysis of the current image, or linear extrapolation of previous history file positions. The polynomial interpolation scheme determines the current position of the storm using three positions (the current, 12 hour, and 24 hour forecast positions) from a TPC/NHC or JTWC forecast in conjunction with two previous positions from the history file (6 and 12 hour old positions), if available. If the forecast interpolation scheme fails, a linear extrapolation of the previous 12 hours of storm positions stored in the history is determined.

If either the interpolation or extrapolation methods are successful, a Laplacian analysis of the cloud top temperature field will be performed. This analysis scheme will search for large cloud top temperature gradients concentrated in small regions (e.g. eye regions). If the previous Final T# stored in the history file is greater or equal to 3.5, an examination of the Laplacian analysis will be performed to determine if the location chosen by this technique should be used. If this technique fails, but a definite “warm spot” location can be identified and is sufficiently close to the interpolated forecast position, the location of this feature will be utilized. For a more detailed discussion of the autolocation technique, please see Section 5H.

In the following examples, a TPC/NHC forecast was used in the polynomial interpolation scheme. The data points used in the polynomial interpolation scheme are displayed prior to the interpolated position. The Laplacian analysis is then performed using the interpolated position as the center point of the analysis region. Since an eye region was found, the Laplacian analysis position was used.

```
Accessing forecast file /home/aodt-v6.3/forecasts/storm01-15.txt
CURRENT ANALYSIS TIME : 01/OCT/2000 0715UTC
      DATE      TIME      LAT      LON
T0 01/OCT/2000 0300UTC   18.10   87.10
T1 02/OCT/2000 1200UTC   18.30   87.40
T2 02/OCT/2000 0000UTC   19.00   87.50
FORECAST INTERPOLATION successful -- LAT: 18.16 LON: 87.27
Will utilize LAPLACIAN ANALYSIS position -- LAT: 17.96 LON: 87.28
```

If the polynomial interpolation scheme fails, and the linear extrapolation of the previous 12 hour storm center locations, stored within the history file, is used as the first guess for the Laplacian analysis.

```
Accessing forecast file /home/aodt-v6.3/forecasts/storm01-15.txt
Error accessing forecast file /home/aodt-v6.3/forecasts/storm01-15.txt
FORECAST INTERPOLATION failed
LINERAR EXTRAPOLATION successful - LAT: 18.09 LON: 87.22
Will utilize LAPLACIAN ANALYSIS position - LAT: 17.96 LON: 87.28
```

If both the polynomial interpolation and linear extrapolation schemes fail, the Laplacian analysis will not be performed and the AODT will quit and the user will be notified in the runtime message output section with the following message :

```
Error with autopositioning
Exiting AODT
```

As mentioned previously, the automated center determination scheme cannot be used in conjunction with the manual override capability (see next section). If both the AUTO and OVER keywords are entered on the same command line, the override capability will be disabled, and the following message will be presented :

```
OVER and AUTO keywords cannot be used at same time
Disabling override ability
```

5.) User Override Function

The user override function allows the user to modify the automatically determined scene type classification prior to the AODT storm intensity estimate calculation. This is performed utilizing mouse button inputs to toggle through the various scene types. After the scene type has been automatically determined, the user will be prompted either accept or modify the scene type. If the user desires to modify the scene type, a sequence of scene type classifications will be presented to the user. Once the desired scene type is chosen, the program will proceed with the determination of the current storm intensity estimate using the user-selected scene type. Two example sessions are below :

The user agrees with the scene type :

```
AODT has classified the EYE SCENE as CLEAR
Do you agree with this scene classification?
TOGGLE : Press MIDDLE mouse button
ACCEPT : Press RIGHT mouse button
  <user presses RIGHT mouse button>
CLOUD AND EYE SCENES have not been changed
User accepted scene type
```

The user does not agree with the scene type :

```
AODT has classified the EYE SCENE as RAGGED
Do you agree with this scene classification?
TOGGLE : Press MIDDLE mouse button
ACCEPT : Press RIGHT mouse button
  <user presses MIDDLE mouse button>
Change eye scene to OBSCURED
  <user presses MIDDLE mouse button>
Change eye scene to NONE
  <user presses RIGHT mouse button>
Change cloud scene to UNIFORM CDO
  <user presses MIDDLE mouse button>
Change cloud scene to EMBEDDED CENTER
  <user presses RIGHT mouse button>
CLOUD SCENE has been changed to EMBEDDED CENTER
User modified scene type
```

In the second example, the user selected NONE for the eye scene. The scene types switched from eye scene to cloud (no-eye) scenes, and the user resumed scrolling through the different cloud scene type options until the desired scene was presented. The opposite switch can be performed, from cloud to eye scene types, by selecting the cloud scene type of EYE during the override process.

Note that the original and user override values for the scene type are both stored in the history file for the storm being analyzed. The override values will be used, if the scene was manually changed for the specific history file record, in any history file listings or intensity estimate recalculations if previous record(s) is/are modified/inserted/deleted.

The capability to override the automatically determined storm center location has been disallowed since it defeats the purpose of executing the AODT in fully automatic mode (without manual intervention). Thus, the concurrent use of the OVER and AUTO keywords is not allowed, resulting in a runtime text error message and the disabling of the override capability for the analysis being performed.

6.) Remote Server Data Access

The AODT has the ability to utilize remotely stored and displayed McIDAS imagery. The AODT will assume the data is stored locally unless the keyword REMOTE is used. The REMOTE keyword utilizes two AODT environment arguments to describe the name and location of the data file being examined. These variables can be defined in the aodtENV file (see Section 4C) or with two REMOTE keyword entries (see Section 4A1).

If a remotely stored McIDAS image is investigated by the AODT, a subsection of the image displayed within the McIDAS image display window will be copied to the local machine. The McIDAS server dataset and position variables, defined with the ODTLSERVER and ODTLAREA AODT environment arguments, will be used to define the location and name where the image will be copied. The variable ODTLSERVER defines the ADDE *group/descriptor* name (or alias name) while ODTLDATA defines the *position* number within the *group/descriptor*. The size of the image copied will be 480x640 pixels and will be centered at the user-selected storm center position. An example output text message when using the REMOTE keyword follows :

```
DOWNLOADING REMOTE IMAGE EAST/NH.5 TO LOCAL IMAGE LOCAL/IMAGES.7777
  WITHIN LOCAL DIRECTORY AT /home/aodt-v6.3/mcidas/data/AREA7777
Utilizing image data file /home/aodt-v6.3/mcidas/data/AREA7777
```

In the example above, the AODT user was investigating a remotely stored image within the ADDE dataset name of “EAST/NH” at position “5”. It was copied to the local server defined with the ADDE dataset name of “LOCAL/IMAGES” into position 7777. The local ADDE image in this example was located in the /home/aodt-v6.3/mcidas/data directory in the file AREA7777. The AODT algorithm then utilized this locally stored image in the derivation of the intensity estimate for the storm image being examined.

E.) History File Output

1.) Text Output

An abbreviated listing of the history file contents can be displayed within the McIDAS text display window or written to an output file using the LIST, DATE, and OUTPUT keywords. An example of a text window listing is provided below for Hurricane Isabel:

Utilizing history file /home/aodtv6.3/history/ISABEL.ODT

Date	Time	CI	MSLP	Adjst/Vmax	6hr	3hr	Raw	Raw	12hr	Eye	Cloud	Type	Wkng	Rule8	Storm	Location
			-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
2003SEP06	133000	2.0	1017.2	+8.2/ 30.0	2.0	2.0	2.0	0.0	0.0	0.0	-34.06	-48.78	CRVBND	OFF	No Limit	14.00 34.10
2003SEP06	140000	2.1	1016.4	+8.2/ 31.0	2.1	2.1	2.2	0.0	0.0	-46.06	-48.29	CRVBND	OFF	No Limit	14.00 34.20	
2003SEP06	143000	2.2	1015.6	+8.2/ 32.0	2.2	2.2	2.5	0.0	0.0	-43.26	-48.09	IRRCDO	OFF	No Limit	14.00 34.30	
2003SEP06	150000	2.3	1014.8	+8.2/ 33.0	2.3	2.3	2.5	0.0	0.0	-42.36	-48.24	IRRCDO	OFF	No Limit	14.00 34.40	
2003SEP06	153000	2.4	1014.4	+8.6/ 34.0	2.4	2.3	2.7	0.0	0.0	-69.96	-61.53	UNIFRM	OFF	0.5/hour	13.60 34.60	
2003SEP06	160000	2.4	1014.4	+8.6/ 34.0	2.4	2.4	2.8	0.0	0.0	-71.46	-63.88	UNIFRM	OFF	0.5/hour	13.61 34.71	
2003SEP06	163000	2.5	1013.6	+8.6/ 35.0	2.5	2.5	2.9	0.0	0.0	-69.96	-65.25	UNIFRM	OFF	0.5/hour	13.61 34.81	
2003SEP06	170000	2.6	1012.6	+8.6/ 37.0	2.6	2.6	2.9	0.0	0.0	-69.96	-65.25	UNIFRM	OFF	0.5/hour	13.61 34.92	
2003SEP06	173000	2.7	1011.6	+8.6/ 39.0	2.7	2.7	3.0	0.0	0.0	-68.56	-65.31	UNIFRM	OFF	0.5/hour	13.62 35.02	
<lines deleted from listing>																
2003SEP07	143000	3.7	999.7	+8.5/ 59.0	3.7	3.7	4.0	0.0	0.0	-58.46	-58.88	UNIFRM	OFF	1.0/6hr	13.69 37.91	
2003SEP07	150000	3.7	999.0	+7.8/ 59.0	3.7	3.7	4.0	0.0	0.0	-58.46	-63.06	UNIFRM	OFF	1.0/6hr	14.50 37.70	
2003SEP07	153000	3.8	997.5	+7.8/ 61.0	3.8	3.7	4.1	978.0	983.2	-70.06	-64.70	UNIFRM	OFF	1.0/6hr	14.54 37.78	
2003SEP07	160000	3.8	996.9	+7.1/ 61.0	3.8	3.9	4.1	970.8	982.7	-36.36	-65.60	EMBC	OFF	1.0/6hr	15.24 38.19	
2003SEP07	163000	3.9	996.1	+7.7/ 63.0	3.9	3.9	4.3	975.4	982.3	-74.46	-67.50	UNIFRM	OFF	0.5/hour	14.60 37.95	
2003SEP07	170000	4.0	994.7	+7.7/ 65.0	4.0	4.0	4.3	975.5	982.1	-74.46	-68.28	UNIFRM	OFF	0.5/hour	14.64 38.03	
2003SEP07	173000	4.0	993.8	+6.8/ 65.0	4.0	4.1	4.4	965.5	981.4	-43.26	-67.41	EMBC	OFF	0.5/hour	15.56 38.63	
2003SEP07	180000	4.1	993.0	+7.6/ 67.4	4.1	4.2	4.5	974.8	981.1	-71.46	-67.80	UNIFRM	OFF	No Limit	14.71 38.19	
2003SEP07	183000	4.2	991.4	+7.6/ 69.8	4.2	4.3	4.4	976.3	980.8	-69.96	-65.67	UNIFRM	OFF	1.0/6hr	14.74 38.28	
2003SEP07	190000	4.2	991.3	+7.5/ 69.8	4.2	4.3	4.5	977.4	980.5	-67.16	-63.97	UNIFRM	OFF	No Limit	14.77 38.36	
2003SEP07	201500	4.4	987.7	+7.1/ 74.6	4.4	4.5	4.7	961.9	979.9	-13.66	-60.05	EYE/R	OFF	1.0/6hr	15.24 39.04	
2003SEP07	204500	4.4	987.7	+7.1/ 74.6	4.3	4.4	3.9	961.4	979.0	-10.96	-61.52	CRVBND	WKN	0.5/hour	15.32 39.10	
2003SEP07	211500	4.4	987.5	+7.0/ 74.6	4.2	4.2	3.9	957.6	977.8	-5.56	-63.80	CRVBND	WKN	0.5/hour	15.44 39.21	
2003SEP07	214500	4.4	987.5	+6.9/ 74.6	4.3	4.3	4.8	953.5	976.2	-3.06	-64.25	EYE/R	WKN	1.0/6hr	15.56 39.35	
<lines deleted from listing>																
2003SEP08	161500	6.0	953.1	+5.1/115.0	6.0	5.9	6.2	944.7	944.6	14.04	-66.46	EYE/C	OFF	No Limit	17.53 42.87	
2003SEP08	164500	6.0	953.1	+5.1/115.0	6.0	6.0	6.1	944.8	944.6	15.54	-66.32	EYE/C	OFF	No Limit	17.56 42.97	
2003SEP08	171500	6.0	953.0	+5.0/115.0	6.0	6.0	6.0	945.4	944.7	16.74	-64.83	EYE/C	OFF	No Limit	17.62 43.01	
2003SEP08	174500	6.0	953.0	+5.0/115.0	6.0	6.0	6.0	945.7	944.7	16.74	-64.79	EYE/C	ON	No Limit	17.65 43.12	
2003SEP08	181500	6.0	952.9	+4.9/115.0	6.0	6.0	6.0	945.9	944.9	15.94	-64.98	EYE/C	ON	No Limit	17.76 43.12	
2003SEP08	184500	6.0	952.8	+4.8/115.0	6.0	6.0	6.1	945.8	944.9	15.94	-65.36	EYE/C	ON	No Limit	17.81 43.18	
2003SEP08	191500	6.0	952.8	+4.8/115.0	6.0	6.0	6.0	945.4	945.0	15.94	-64.63	EYE/C	ON	No Limit	17.86 43.26	
2003SEP08	194500	6.0	952.8	+4.8/115.0	6.0	6.0	6.0	944.2	945.0	14.74	-64.82	EYE/C	ON	No Limit	17.85 43.36	
2003SEP08	201500	6.0	952.8	+4.8/115.0	6.0	6.0	6.0	943.7	945.0	14.34	-65.03	EYE/C	ON	No Limit	17.88 43.44	
2003SEP08	204500	6.0	952.7	+4.7/115.0	6.0	6.0	6.1	945.1	944.9	14.34	-65.37	EYE/C	ON	No Limit	18.01 43.50	
2003SEP08	211500	6.0	952.6	+4.6/115.0	6.0	6.0	6.0	946.6	944.7	15.84	-64.93	EYE/C	ON	No Limit	18.14 43.60	
2003SEP08	214500	6.0	952.6	+4.6/115.0	6.0	6.0	6.1	941.8	944.6	15.44	-66.34	EYE/C	ON	No Limit	18.12 43.63	
<lines deleted from listing>																
2003SEP11	144500	6.7	931.0	+1.6/132.2	6.7	6.7	6.9	936.1	941.1	18.84	-72.54	EYE/C	ON	No Limit	21.44 54.45	
2003SEP11	151500	6.7	931.1	+1.7/132.2	6.7	6.7	6.9	936.1	939.8	19.64	-72.55	EYE/C	ON	No Limit	21.37 54.52	
2003SEP11	154500	6.8	928.3	+1.7/134.8	6.8	6.7	7.0	935.8	939.6	19.04	-73.01	EYE/C	ON	No Limit	21.37 54.61	
2003SEP11	161500	6.8	928.3	+1.7/134.8	6.8	6.8	6.9	935.2	939.0	19.54	-72.79	EYE/C	ON	No Limit	21.40 54.70	
2003SEP11	164500	6.8	928.2	+1.7/134.8	6.8	6.8	7.0	935.1	938.8	18.54	-73.41	EYE/C	ON	No Limit	21.43 54.74	
2003SEP11	171500	6.8	928.3	+1.7/134.8	6.8	6.9	7.0	935.3	938.6	19.54	-73.36	EYE/C	ON	No Limit	21.42 54.81	
2003SEP11	174500	6.9	925.4	+1.6/137.4	6.9	6.9	7.1	935.1	938.5	19.14	-73.72	EYE/C	ON	No Limit	21.44 54.89	
2003SEP11	181500	6.9	925.4	+1.6/137.4	6.9	6.9	7.0	935.0	938.1	18.94	-73.41	EYE/C	ON	No Limit	21.46 54.97	
2003SEP11	184500	6.9	925.5	+1.7/137.4	6.9	7.0	7.0	935.4	938.0	18.94	-73.58	EYE/C	ON	No Limit	21.43 54.99	
2003SEP11	191500	6.9	925.5	+1.7/137.4	6.9	7.0	7.0	935.0	937.8	19.94	-73.57	EYE/C	ON	No Limit	21.44 55.05	
2003SEP11	194500	6.9	925.4	+1.6/137.4	6.9	7.0	7.0	935.3	937.3	19.14	-73.38	EYE/C	ON	No Limit	21.46 55.11	
2003SEP11	201500	7.0	922.6	+1.6/140.0	7.0	7.0	7.1	936.0	937.3	18.64	-73.64	EYE/C	ON	No Limit	21.46 55.17	
2003SEP11	204500	7.0	922.6	+1.6/140.0	7.0	7.0	7.0	935.6	937.0	19.74	-73.32	EYE/C	ON	No Limit	21.48 55.26	
2003SEP11	211500	7.0	922.6	+1.6/140.0	6.9	6.9	6.8	936.3	936.6	19.54	-72.12	EYE/C	ON	No Limit	21.46 55.33	
2003SEP11	214500	7.0	922.6	+1.6/140.0	6.9	6.9	6.8	936.6	936.6	19.14	-72.19	EYE/C	ON	No Limit	21.49 55.37	
2003SEP11	221500	7.0	922.6	+1.6/140.0	6.9	6.9	6.7	936.5	936.4	19.04	-71.73	EYE/C	ON	No Limit	21.49 55.43	
2003SEP11	224500	7.0	922.6	+1.6/140.0	6.8	6.8	6.8	937.8	936.3	18.44	-71.85	EYE/C	ON	No Limit	21.47 55.51	
<lines deleted from listing>																
2003SEP13	004500	7.0	922.3	+1.3/140.0	6.1	6.1	6.0	945.0	941.3	15.94	-64.34	EYE/C	ON	No Limit	21.78 59.13	
2003SEP13	011500	7.0	922.3	+1.3/140.0	6.1	6.0	6.1	944.9	941.5	15.74	-65.24	EYE/C	ON	No Limit	21.77 59.24	
2003SEP13	014500	7.0	922.3	+1.3/140.0	6.0	6.0	5.9	946.5	941.7	14.94	-63.96	EYE/C	ON	No Limit	21.78 59.34	
2003SEP13	021500	7.0	922.3	+1.3/140.0	6.0	6.0	6.0	946.8	942.0	15.54	-64.40	EYE/C	ON	No Limit	21.79 59.41	
2003SEP13	024500	7.0	922.2	+1.2/140.0	6.0	5.9	5.9	950.0	942.5	15.44	-63.03	EYE/C	ON	No Limit	21.96 59.41	
2003SEP13	031500	6.9	925.0	+1.2/137.4	5.9	5.9	5.8	951.9	942.9	14.54	-62.98	EYE/C	ON	No Limit	21.95 59.59	
2003SEP13	034500	6.9	925.0	+1.2/137.4	5.9	5.9	5.8	949.3	943.2	13.94	-62.64	EYE/C	ON	No Limit	21.93 59.65	
2003SEP13	061500	6.9	924.8	+1.0/137.4	6.0	5.9	6.3	944.8	943.9	12.34	-68.36	EYE/C	ON	No Limit	22.14 60.03	
2003SEP13	064500	6.9	924.9	+1.1/137.4	6.0	6.1	6.3	945.3	944.1	9.64	-67.68	EYE/C	ON	No Limit	22.10 60.19	
2003SEP13	071500	6.9	924.9	+1.1/137.4	6.1	6.3	6.4	945.7	944.6	9.74	-69.90	EYE/C	ON	No Limit	22.04 60.29	
2003SEP13	081500	6.9	925.0	+1.2/137.4	6.2	6.3	6.4	942.6	944.7	12.64	-69.97	EYE/C	ON	No Limit	21.99 60.37	
2003SEP13	084500	6.9	924.9	+1.1/137.4	6.4	6.4	6.7	941.6	945.1	12.14	-71.48	EYE/C	ON	No Limit	22.10 60.44	
2003SEP13	091500	6.9	924.8	+1.0/137.4	6.4	6.4	6.7	941.8	944.9	12.24	-71.42	EYE/C	ON	No Limit	22.16 60.58	
2003SEP13	094500	6.9	924.8	+1.0/137.4	6.5	6.5	6.7	942.4	945.0	10.54	-71.46	EYE/C	ON	No Limit	22.16 60.65	
2003SEP13	101500	6.9	924.8	+1.0/137.4	6.5	6.5	6.6	942.7	945.2	12.14	-70.73	EYE/C	ON	No Limit	22.17 60.70	
2																

In the example above, the CI#, 6-hour time-weighted average Final T# (T#6hr), Raw T# (T#raw), TIE Model 12-hour averaged value (TIEavg), and the latitude bias-adjusted MSLP values are all displayed. Any combination of the seven intensity estimate values can be plotted using the PLOT keyword (Section 4A1).

The intensity estimate values are plotted along the ordinate; CI#/T# values along the left hand side and corresponding pressure/wind values along the right side. Time is plotted along the abscissa, with Julian date and time (UTC) displayed at the bottom and the corresponding calendar day (month and day) plotted along the top of the graph. Any portion of the history file can be plotted using the DATE keyword. The complete history file name is displayed in the bottom-left hand corner of the graph, with a legend of the displayed variables presented along the top of the graphics window. The various environmental temperature values calculated and used by the AODT in the intensity estimate calculations can also be graphed.

5.) Background Information

A.) Land Flag

Tropical cyclone land interaction is determined utilizing the low-resolution topography map TOPOLRES provided. The resolution of the map file is 1.0° X 1.0° latitude/longitude. If the storm center is positioned over a grid box with an average height greater than sea level (and more than 50% covered by land), the land flag will be triggered. If the land flag is triggered, no intensity estimate will be produced unless specifically requested by the user using the LAND keyword. The history file will still include an entry for any intensity estimate attempted while over land. The latitude, longitude, and land flag parameters will contain their assigned values, however the values for the intensity estimates and the remaining parameters will be assigned a “missing value” (mostly 0’s). Calculation of both Final T# values and the CI# value will exclude all “over land” entries once the storm resumes movement over open water (non-land grid points).

B.) Scene Classification

Objective scene identification is performed using Fast Fourier Transform (FFT) analysis, 10° log spiral analysis, and/or other statistical analysis techniques. Scene classifications are performed separately for the eye (0-24km from storm center) and surround cloud (24-136km) regions. Determinations of certain scene types are dependent upon past intensity estimates stored in the history file of a particular storm, closely mirroring the thresholds defined in the subjective Dvorak EIR technique. The six eye region scene types and five cloud region scene types are described below :

Eye Region

<u>Scene Type</u>	<u>Description</u>
CLEAR	Clear, well-defined eye
PINHOLE	Very small eye/pronounced warm spot
LARGE CLEAR	Clear, well-defined eye greater than 40 km diameter
LARGE RAGGED	Ill-defined eye region greater than 40 km diameter
RAGGED	Ill-defined (cloudy or oblong) eye region
OBSCURED	Very cloudy/cloud covered warm region
NONE	No eye

Cloud Region

<u>Scene Type</u>	<u>Description</u>
UNIFORM CDO	Overcast cloud region with uniform temperature structure
EMBEDDED CENTER	Arc of convection within central overcast cloud region
IRREGULAR CDO	Cloud region over storm center, but large shift in coverage
CURVED BAND	Curved cloud region surrounding circulation center
SHEAR	Displaced convection and exposed circulation center

Eye scene types are derived by examining the eye region FFT harmonics, variability of temperature values in the eye region, and “BD enhancement curve” categorical differences between the eye and surrounding cloud region temperature values. Eye size is derived by measuring the distance across the eye between BD-curve “Dark Gray” temperature range edges. Distances are measured at 90° angles outward from the user or auto-selected storm center location, and are averaged to give an approximate eye size.

Cloud region scene types are determined by examination of the entire cloud region FFT harmonics, the average difference between opposing 15° arc average temperatures (convective symmetry value), and by differencing the average and “coldest-warmest” cloud region temperature values. If the cloud scene is thought to be a “Curved Band” type scene, a 10° Log Spiral analysis will be performed to determine the curvature extent of the convective cloud region around the selected center position. The algorithm will first target the BD-curve “Light Gray” temperature range to define the convective region of the curved band area. If this temperature region is devoid of significant activity/completely surrounds the selected storm center position, analysis of warmer/colder ranges BD-curve temperature levels will be performed. Once a Curved Band scene is determined, an additional search will be performed to look for a location that yields a greater amount of curvature in the cloud region, and thus a higher intensity estimate (Section 5I). If the scene is determined to be a “Shear” scene, the distance between the center position and the closest BD-curve “Dark Gray” temperature range pixel will be determined.

Once the scene type has been automatically or manually determined, the value is used in conjunction with the eye and surrounding cloud top temperatures, oceanic basin type, and other history file information to calculate the intensity estimate for the image being investigated.

C.) Eye and Surrounding Cloud Region Temperature Determination

Proper determination of the storm center is paramount for an accurate storm intensity estimate since the eye and cloud region temperature value calculations are heavily dependent on this location.

Determination of the eye region temperature is straightforward. This temperature is assigned the value of the warmest pixel within a 24 km radius from the user or automated storm center location. Since an incorrect eye temperature can lead to an incorrect intensity estimate, proper selection of the storm center location is essential.

Calculations of the two surrounding cloud region temperature values are a bit more complicated than for the eye temperature. The first cloud region temperature value computed is centered at the storm center location and lies between 24 and 136 km from the center location. Individual analysis rings are selected, and are dependent upon the resolution of the satellite imagery. Thus for a 4 km resolution infrared image, there will

be $(136 - 24)/4 = 28$ rings. On each ring the warmest temperature will be found. The coldest of these values will be used as the cloud top temperature value. This value is referred to as the “coldest-warmest” temperature, and it is used only in the determination process for the cloud region scene type. The ring number (CWRN) distance (in km from the storm center location) on which the “coldest-warmest” temperature value is located is used in the determination of the “mean” cloud region temperature discussed below. For more information about this value, see Velden et al. (1998) and Zehr (1989).

The second cloud region temperature computed is the “mean” cloud region temperature value, and is the actual value that is assigned as the cloud region temperature. First, an annulus region is determined around the storm center location. The annulus will be a total of 80 km wide and is centered on the CWRN distance explained above. The minimum inner/maximum outer radius of the annulus will be the CWRN distance minus/plus 40 km. The minimum inner radius cannot be less than 24 km from the storm center location, but there is no maximum limit on the outer radius distance. For example, if the CWRN distance is 48 km, the inner distance will be a minimum of 24 km (not 8 km), and the outer distance will be 104km. Once the annulus is defined, it is divided into 24 arc regions (15° each) and the average temperature of each arc is calculated. The average of the 24 average arc temperature values is computed and assigned to the “mean” cloud region temperature value.

The “coldest-warmest” temperature value was replaced with the “mean” temperature value after close examination of both values, and their respective Raw T# intensity values, in relation to aircraft reconnaissance intensity measurements. The “coldest-warmest” temperature value varied significantly more than the “mean” values, and their corresponding intensity estimates. The intensity estimate values computed using the coldest-warmest temperature values were found to be inferior to the intensity estimates using the mean temperature values, thus the change was implemented.

D.) Time Averaging Scheme

The Final T# (6-hour average) value is calculated using a linear-weighted time averaging scheme, which places greater weight on the current intensity estimate value and less weight upon each preceding intensity estimate. The time averaging scheme uses the current Raw T# value and all available Raw T# values obtained within the last 6 hours. The current value is given a weight of 6.0, with all other values given weights directly proportional to their time difference from the current analysis time.

Determination of the time-weighted Final T# value previously utilized a 12-hour time period, but it was found that by changing the analysis period to 6 hours coupled with the use of the Dvorak EIR Rule 8 (see Section 5F) provided a statistically superior intensity estimate. In addition, utilizing a 6-hour time averaging period eliminates the need for the Rapid Deepening flag and corresponding time-averaging period change (from 12 hours to 3 hours). The rapid deepening flag had been a documented source of error in the analysis of some tropical cyclones where it had been (incorrectly?) triggered.

E.) Dvorak EIR Rule 9/Weakening Rule

The Dvorak EIR Rule 9/Weakening Rule (Dvorak, 1984) is used in the determination of the CI# after a storm has reached its maximum intensity and is weakening. This rule holds the CI# values 0.5 to 1.0 T# higher in value than the current Final T#. Subjective application of this rule (e.g. how and when to apply it) varies from forecaster to forecaster and is the focal point of much debate. The value of 1.0 is utilized in the AODT algorithm since it provides the most statistically accurate estimates of storm intensity when compared with reconnaissance pressure measurements.

In the AODT algorithm, application of this rule is performed when the storm has undergone a “significant strengthening event”. This event is identified by computing a least squares fit to the current and all Final T# values during the past 24. If the slope of this fit is greater than or equal to 1.0 (increasing 1.0 T# in the last 24 hours), a significant strengthening event is said to be occurring. Once the Final T# (6-hour average) begins to decrease, the Rule 9 guidelines are applied to calculate the CI#.

An additional criteria check can modify the Rule 9 “additive” constant of 1.0 if the storm CI# values becomes “constant” (does not vary by more than 0.5) for a continuous 24-hour period. If this condition is met, the additive value will be reduced to 0.5 while the storm maintains its steady state condition. Once this steady-state condition has ended, the additive constant will return to the maximum value of 1.0.

An additional rule within the AODT affects the calculation of the Final T# and CI# prior to weakening after a “significant strengthening event” (e.g. during the formation stages). This rule is as follows: “Always hold the CI# to the highest Final T# in the last 12 hours (but never greater than 1.0 for the CI#) in all cases”. This rule will hold the CI# equal to the highest Final T# (6-hour averaged) obtained during the previous 12 hours. For example, if the Final T# value increased to 5.2 then decreases in intensity, the CI# value will be held at 5.2 for 12 hours unless the T# exceeds 5.2 during that time period. If this rule is invoked, the “Weakening” flag indicator in intensity estimate bulletin (Section 4D1) will display “WEAK” (as opposed to “OFF” or “ON” when the Dvorak EIR Rule 9 discussed above is being applied).

F.) Dvorak EIR Rule 8

The Dvorak EIR Rule 8 constrains the rate of increase or decrease of the Raw T# intensity estimate value based upon specified rates of change over specific time periods. The rate of change comparisons are performed against the Final T# (6-hour average) values stored in the history file at various times prior to the current analysis time, with the rate of change constraints being dependent upon the “current” intensity of the storm, as defined in the Dvorak EIR technique. The Final T# (6-hour average) value of the record immediately prior to the current analysis time is used as a proxy for the “current” intensity estimate. When “current” intensity of the storm is less than 4.0, the current Raw T# rate of change cannot exceed ± 0.5 T# over 6 hours. If the “current” intensity estimate

value is greater or equal to 4.0, the rate of change of the Raw T# value cannot exceed the following rates : 1.0 over 6 hours, 1.5 over 12 hours, 2.0 over 18 hours, and/or 2.5 over 24 hours. If one of the criteria is/are exceeded, the Raw T# will be assigned the maximum/minimum value that does not exceed the criteria in question.

As a final “gross error check” for the Raw T# values derived by the AODT, a supplementary Rule 8 rule has been added to the Dvorak Rule 8 rules listed above. This additional rule will limit the growth of the Raw T# value by 0.5 over 1 hour. Implementation of this rule was found to be necessary due to the inherent variability of the AODT during “scene type transitions”, especially between eye and non-eye cases. Due to the completely objective nature of the scene determination scheme, and the threshold values that are used to define the different scene types, changes between scene types can result in unrealistic jumps in Raw T# values from one intensity estimate to another. The addition of this rule will produce estimates that are reasonable when these types of scene changes occur, but still will allow the Raw T# values to change at a rate greater than observed in nature. The largest MSLP change we found in our test data set was with Hurricane Opal, which had a decrease in observed MSLP (from reconnaissance aircraft) of 17mb (933mb to 916mb) over about two and a half hours (07:20UTC to 09:45UTC). This corresponds to a change of about 0.6 T# (933mb \approx 6.6 T#; 916mb \approx 7.2 T#) in 2.5 hours, or approximately 0.25 T#/hour.

Implementation of this rule has allowed for a modification of the time-weighted Final T# calculation from 12 hours to 6 hours, with the 6-hour weighted average proving to be slightly more accurate statistically than the previous 12-hour methodology. By utilizing the 6-hour scheme, the rate of change of the time-weighted Final T# value is typically more than with the 12-hour scheme, allowing for greater rapid increases in intensity over time than previously found. Introduction of the Dvorak EIR Rule 8 limits this growth realistically, and has allowed for the rapid flag determination scheme to be removed from the AODT. The rapid flag was found to work in certain cases, but often led to significant overestimates of intensity in other cases, due to the time-weighted averaging scheme changing from 12 hours to 3 hours. The integration of the Dvorak EIR Rule 8 in conjunction with the new 6-hour time-weighted average Final T# scheme has resulted in more realistic intensity estimates and changes over time.

G.) Oceanic Domain Auto Determination

The AODT intensity estimates are dependent upon the ocean basin in which the storm being examined is located. This is a result of using separate empirical relationships between CI# and minimum sea level pressure (MSLP) for the North Atlantic (Dvorak, 1984) and Northwest Pacific (Shewchuck and Weir, 1980) basins. Also, a different Raw T# may result for a particular eye and cloud region temperature pair, depending upon which basin is designated.

Previous versions of the ODT relied on the user to manually designate the ocean basin using the DOMAIN keyword. The AODT can automatically determine the ocean

basin based upon the longitude value of the selected storm center location. A storm west of the international dateline (180° E/W) and east of the Prime Meridian (0° E/W) is designated as a Northwest Pacific storm (regardless of N/S hemisphere), with all other storms (longitude-wise) designated as Atlantic. The user can override this determination process with the DOMAIN keyword, if desired.

The division point in the Pacific Ocean was chosen to match the “areas of responsibility” for the Joint Typhoon Warning Center and Central Pacific Hurricane Center. Use of either CI#/pressure relationship in the Eastern Pacific Ocean is a topic for debate, but no specific rules defining the use of one of the relationships for this or other regions, such as Indian Ocean or Southern Pacific Ocean, have been documented, so it is left to the user to decide which is the proper relationship in these regions.

H.) Automatic Storm Center Determination

The automated storm center location algorithm approximates tropical storm position using four methods : polynomial interpolation of NHC/JTWC forecasts, warmest pixel search, Laplacian Analysis of the cloud region temperature values, and linear extrapolation of the history file positions.

As a first guess, the forecast positions from NHC or JTWC are used in conjunction with previous storm locations in the polynomial interpolation routine. This routine interpolates the position at the time desired using three forecast positions (current, 12 hour, and 24 hour positions). The four types of input file formats are :

- ATCF Forecast Record file (“OFCL” forecast is default)
- NHC Tropical Storm/Hurricane Discussion files (WTNT4? or WTPZ4?)
- JTWC Tropical Cyclone Warning files (WTPN3?)
- Generic Entry file (see below for format)

If the forecast interpolation fails, a linear extrapolation of storm positions for the previous 12 hours (stored in the history file) is attempted. Once a valid interpolated forecast or extrapolated history file position is obtained, the Final T# intensity estimate of the record immediately preceding the current analysis time in the history file found. If this value is less than 3.5, the interpolated/extrapolated point is used as the final automated storm position. However, if this value is greater or equal to 3.5, a more thorough analysis of the image is conducted to determine a better storm center location.

The analysis begins by searching for the warmest satellite image pixel within 75km of the forecast interpolated/history file extrapolated point. A Laplacian Analysis is then performed over a 90km radius analysis region, which identifies temperature gradients exceeding various threshold values. The gradient threshold fields are then statistically analyzed, with an empirically defined “confidence factor” derived based upon the scatter and cohesiveness of the gradient points for each of the thresholds.

If this confidence factor is greater than an empirically defined threshold “A”, a well-defined and spatially confined cloud feature with strong temperature gradients has been located (e.g. an eye). The average position of the Laplacian Analysis gradient threshold field points determined for the storm center location will be used as the center point position in this case unless this distance is greater than 80km from the initial warmest pixel location. This last check will assure that a non-eye cloud feature at the edge of the Laplacian Analysis region is not incorrectly analyzed as an eye feature due to the small number of points being examined at this distance.

If the confidence factor is below “A” but above “B”, a less well-defined feature has been identified. This type of feature may be a large but clear eye (less spatially confined), a forming, obscured, or ragged eye (spatially confined, but less of a temperature gradient to examine), a strong, centralized feature in the cloud top temperature field, but without an eye feature (e.g. embedded center cloud pattern), or even an organized curved band-type pattern. As with the “A” case above, the average position of the Laplacian Analysis gradient field points will proxy as the storm center point position.

If the confidence factor is below “B” but above “C”, a feature has been located, but it is a broadly defined spatial feature without a strong, centralized gradient to identify (e.g. a warm spot/forming eye feature). The location of the warm spot is provided as the storm center location if this location is within 40km of the initial interpolated/extrapolated position and is significantly warmer than the cloud top temperature at the interpolated/extrapolated position.

Any feature with a confidence factor below “C” will use the forecast interpolated /extrapolated history file position as the storm center location.

Each line in the Generic Entry file contains either the initial/current position of the storm or a forecast position at 12-hours or 24-hours, and are formatted as follows :

dd mm yyyy tttt aa.a bbb.b

<u>parameter</u>	<u>value</u>	<u>format</u>
dd	date	two digit integer
mm	month	two digit integer
yyyy	year	four digit integer
tttt	UTC time	HHMM format : HH-hour MM-minute
aa.a	latitude	floating point (+/- : north/south)
bbb.b	longitude	floating point (+/- : west/east)

An example file for Floyd using the 12 September 1999/03:00UTC forecast product :

```
12 09 1999 0300 22.7 64.5
12 09 1999 1200 22.9 66.0
13 09 1999 0000 23.2 68.3
```

The first line contains the “initial” position, with the second and third lines containing the 12-hour and 24-hour forecast positions. Use of a forecast file older than 24 hours will result in a failure with the auto-positioning routine.

I.) Maximum Curved Band Location Search

If a Curved Band scene type has been determined automatically, or was selected manually during a scene override, an additional search will be performed to locate a storm center position possessing a greater cloud curvature measurement than obtained at the original selected storm center location. The search will examine the same BD-curve temperature range as obtained with the automatic scene type determination scheme. A 2° latitude/longitude box, centered at the originally selected storm center location, will be examined at a 0.2° spacing between search points. At each search point, the 10° Log Spiral will be examined to determine the maximum arc length of the BD-curve temperature range being targeted. The spiral will then be rotated 15° and the measurement is performed again. Once the spiral has been rotated 360°, the spiral is moved to the next search point and the process is repeated. The search point possessing the maximum arc length measurement will then be shown in the intensity analysis output.

This feature was incorporated, in response to user feedback, due to the high degree of subjectivity inherent to the curved band analysis technique. It was added to provide an objectively determined location with the greatest curvature, however this location may or may not be the best location, due to limitations inherent to the technique. The storm center location produced by this method should be used as a suggestion, and should be examined closely to determine its applicability to the current scene analysis over the original storm center location.

J.) Sea Surface Temperature Information

The sea surface temperature (SST) information is used in conjunction with various parameters in the AODT history file in the determination of the TIE Model intensity estimate for the current scene being analyzed. Details on the usage of the SST values and the derivation of the TIE-Model intensity estimates are discussed in the TIE Model User’s Guide, obtained at the following website:

<http://cimss.ssec.wisc.edu/tropic/aodt>

The SST data used for the TIE Model intensity estimate within the AODT package can be obtained from various FTP sites listed on the following website :

<http://polar.wwb.noaa.gov/sst/>

The SST files obtained from the above website are real-time, global, one-degree resolution GRIB format files (RTG_SST) distributed by the National Centers for Environmental Prediction/Marine Modeling and Analysis Branch (NCEP/MMAB). Significant detail on the derivation process for the RTG_SST files can also be found at the above website.

Once obtained, the SST files should be placed in the directory defined in the “aodtenv” file with the ODTSSST environmental variable. The name of the file to be used is obtained by the AODT algorithm using the SST keyword, as described in Section 4A1. If the SST file is available, the TIE Model intensity estimate will be appended to the end of the AODT intensity estimate bulletin after the first clear eye scene has been identified. An example of the TIE Model intensity estimate is shown in Section 4D1.

K.) Latitude Bias Adjustment

The MSLP value displayed in the AODT intensity estimate bulletin is adjusted using a linear regression-based adjustment equation. This equation is designed to eliminate a pronounced intensity estimate bias noted in the derived CI# value of the AODT and underlying Dvorak Technique. The equation used for this adjustment is as follows :

$$CI\#_{adj} = CI\#_{orig} - (-20.60822 + (0.88463)*ABS(latitude))$$

This equation requires the CI#_{orig} value to be entered in units of pressure (millibars). Since the AODT produces estimates in terms of T# values, the CI#_{orig} value must be converted to millibars before the adjustment equation is applied. This pressure value is stored in a history file.

For more specific information about the derivation and reasoning behind this latitude bias adjustment, please refer to the following online document (Kossin and Velden, 2003) at :

http://www.ssec.wisc.edu/~kossin/articles/kossin_velden_MWR.pdf

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