AODT – Advanced Objective Dvorak Technique
USERS' GUIDE
(McIDAS Version 6.0)

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1.) Description of the AODT Algorithm

The Advanced Objective Dvorak Technique (AODT) algorithm is an computer based technique, developed at the University of Wisconsin-Madison/Cooperative Institute for Meteorological Satellite Studies (UW-CIMSS), used to objectively determine tropical cyclone intensity using geostationary satellite infrared imagery. The AODT can be used to classify storm intensity beginning from storm formation stages through development and dissipation stages. Previous versions of the AODT 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 (SD) methodology (Dvorak, 1975, 1984) which makes use of various rules and pattern identification schemes in the determination of tropical cyclone intensity. The AODT has been developed to closely mimic the Subjective Dvorak methodology in terms of intensity determination protocol and the incorporation of various rules and analysis methods.

The AODT was developed from prior 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 during the development of the AODT, resulting in an algorithm that is substantially different from 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, a time averaging scheme, definition and determination of the various environmental temperature values, and various SD rules governing the variability of the intensity estimate values. These changes have led to more stable and less biased estimates of intensity.

For greater detail about the development process and statistical accuracy obtained with the 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 software to ingest infrared satellite data, display textual and graphical results, read 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, with integration within LINUX being conducted.

3.) AODT Acquisition and Installation

The AODT software package can be obtained via anonymous FTP from the UW-CIMSS. All files required for the AODT are contained within a single UNIX tar file, and must be unpacked before installation. To obtain and unpack the AODT algorithm, follow the steps below :

cd $HOME/<aodt-dir>	: move to the local AODT directory
ftp 128.104.108.35	: FTP to cyclone.ssec.wisc.edu at UW-CIMSS
anonymous	: login name (when prompted)
your e-mail address	: login password (when prompted)
cd AODT	: change to AODT directory
bin	: change FTP transfer mode to binary (from ASCII)
get AODT-v6.0.tar	: get current AODT tar file
bye	: exit FTP
tar -xvf AODT-v6.0.tar	: unpack the AODT tar file

The AODT can also be obtained with a web browser by pointing to the URL address :
http://cimss.ssec.wisc.edu/tropic/aodt/aodt.html

After unpacking the tar file, an "aodt-v6.0" directory should exist, containing all of the files necessary to compile and create the AODT executable file. Within the aodt-v6.0 directory, the following files and directories will exist :

- odt.c odtauto.c odtcoakley.c odtdata.c odtfft.c odthistory.c odtintensity.c odtmcidas.c odtmcinput.c odtmedstats.c odtoutput.c odtscene.c : AODT C programs
- NOTES : AODT notes and instructions
- TOPOHRES : High 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
- test/ : directory containing test script and data and sample forecast files

Prior to installation of the AODT, the current libmcidas.a file must be located and linked to within the <aodt-lib>/aodt-v6.0/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 "odt-compile" script using the variable MCLIB to define the location of the libmcidas.a file. The MCLIB variable should be checked and modified, if necessary, prior to compiling the AODT. Note that the entire path name must be used instead of the "~mcidas/lib" designation (e.g. /home/mcidas/lib).

Once the AODT has been successfully unpacked and the MCLIB variable set correctly in the odt-compile script, 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. Various make files are used in the two navcal subdirectories dependent upon machine and/or c compiler used.

4.) Using the AODT

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

Utilization and control of the AODT algorithm is performed via the McIDAS command line structure. Various keywords control text and graphical output options, allow specific user interaction, and define AODT runtime operations. 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*>

Each keyword controls various aspects of the AODT algorithm, many of which can be used in conjunction with other keywords to perform specific tasks. Examples of how to use each keyword will be provided within each section and at the end of the section.

1.) Description and Usage

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 ODTHISTORY environment argument. See Special Keyword Notes 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, DOMAIN, and WIND keywords. Pressure units in terms of millibars. 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 directory where the FILE output is written is defined with the ODTOUTPUT environment argument (see Section 4C).

GRAPH=YES/NO (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 units in terms of millibars. AODT analysis will not be performed.

PLOT=color1 color2 color3 (defaults=5 4 6; 0 to not display)

Defines graphic color level values for CI number, Final T#, and Raw T#, respectively. 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 LIST and GRAPH keywords or with AODT image intensity analysis. Speed and pressure values are related to CI number values using empirical relationship defined in Dvorak (1984).

DOMAIN=ATL/PAC (default=auto determination)

Define oceanic domain which 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 oceanic basin is not explicitly defined with this keyword, a basin will 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 (defaults=NO 0 AUTOFIX)

Allow for completely automated operation of AODT, utilizing NHC/JTWC forecast files and Laplacian/10° Log Spiral Analysis to objectively determine storm center position. Can be used with OVER keyword to allow user to override automated cursor selection position, if desired.

type = 0 : TPC WTNT4? (North Atlantic) or WTPZ3? (East Pacific) storm specific DISCUSSION files.

type = 1 : JTWC WTPN3? (Western North Pacific) TROPICAL CYCLONE WARNING file.

filename : Name of input file. The directory where the input files is located is defined with the ODTAUTO environment argument.

OVER=YES/NO (default=NO)

Allow user to manually override AODT scene identification and/or automated center positioning location. See Section 4D5 for more information.

NHC=YES/NO (default=NO)

Output a three hour average Final T# value within the screen text output. This value is the average of all available Raw T# values stored in the history file for the three hour time period previous to the image analysis time being examined. This value is not a time weighted average of the Raw T# values, as is the normal Final T# value).

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 ODTLSERVE 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 ODTLSERVE.

localarea : ADDE dataset position (within local group/descriptor). The default value is the environment argument ODTLDATA.

2.) Special Keyword Notes

If no history file is provided by the user, AODT runtime output (see Section 4D) will be abbreviated, providing the user with only the current "Raw T#" intensity estimate value. No analysis flag values will be listed, and no history file is written to. This has changed from previous versions of the ODT, where a default history file was written to.

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

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 NHC=YES

Perform AODT analysis on current image, with screen output containing an average of all records during the past three hours.

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

Do NOT perform AODT analysis; display graph of contents of history file OPAL.ODT in current graphic image using color level 3 and 4 for the CI and T# plots, respectively. Raw T# values will not be displayed.

AODT HISTORY=OPAL.ODT LIST=YES

Do NOT perform AODT analysis; provide listing of history file OPAL.ODT within McIDAS text window.

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.

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.

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

List all records between 1995OCT03/001500UTC and the end of the history file OPAL.ODT.

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.

AODT HISTORY=OPAL.ODT AUTO=YES 1 wp2698.txt OVER=YES

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. Once the AODT has automatically determined the storm center location, the user will be prompted to either agree with the storm center location or to reposition the center location manually. Once the location is determined, the user will be presented with the AODT evaluated Scene Type and asked to either accept or change it. Once the user selects the scene type, the AODT will determine the intensity estimate for the tropical cyclone being evaluated.

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 file which contains previous AODT intensity estimates, locations, and other information specific to a particular storm. The history file is utilized in the time-averaging scheme for the determination of the Final T# values as well as for graphical and textual time-series displays.

Due to McIDAS constraints, with origins dating back to DOS-based McIDAS operation, history file names are limited to 12 characters. AODT history files will have the suffix ".ODT" appended to the file name if it does not exist in the command line entry. File names over eight characters in length will be truncated and appended with the ".ODT" suffix. For example, the history file named JOSEPHINE will result in a history file named JOSEPHIN.ODT, while the file name OPAL.ODT will be left as OPAL.ODT (an additional .ODT will not be appended). The directory location for the history file is defined using the ODTHISTORY environment argument.

Each individual AODT analysis is written to a history files containing 26 specific analysis values, and are stored in the following manner :

Value 1	: date (YYYYMMDD format : YYYY=year, MM=month, DD=day)
Value 2	: time (hhmmss format)
Value 3	: raw T# value
Value 4	: final T# value
Value 5	: final CI value
Value 6	: eye region temperature (°C)
Value 7	: mean cloud region temperature (°C)
Value 8	: "coldest-warmest" cloud region temperature (°C)
Value 9	: storm center latitude (+/- = North/South Hemisphere)
Value 10	: storm center longitude (+/- = West/East Hemisphere)
Value 11	: eye diameter or shear distance (in km)
Value 12	: eye region temperature standard deviation value
Value 13	: cloud region symmetry value
Value 14	: eye region scene type (original value)
Value 15	: cloud region scene type (original value)
Value 16	: eye region scene type (user override value)
Value 17	: cloud region scene type (user override value)
Value 18	: current strengthening flag
Value 19	: rapid intensification flag
Value 20	: land/ocean flag
Value 21	: eye region FFT value
Value 22	: cloud region FFT value
Value 23	: ring analysis – last full ring category on BD curve
Value 24	: ring analysis – last partial ring category on BD curve
Value 25	: curved band analysis – BD curve category used for analysis
Value 26	: curved band analysis – number of arcs spiral passed through (out of 24)

History files should not be modified directly. Any modifications, such as overwriting/reanalysis or removal of individual records should be done using AODT keywords, such as the DELETE keyword, in order to assure correct modification to the remaining history file entries.

C.) UNIX Environment Arguments

In order to provide more control regarding AODT input/output file and directory definitions, the AODT now utilizes UNIX environment arguments to define specific variables used within the AODT algorithm. This allows the user to modify these values previously hardcoded into the AODT algorithm, requiring the AODT to be recompiled when changes were required.

Six environment arguments are defined within the file aodtenv :

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

ODTTOPO, ODTHISTORY, ODTAUTO, and ODTOUTPUT are directory names, and ***must not*** end with a "/" (this is appended to the end of the directory name within the code). The default values for these directories are the $HOME directory.

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, on the command line type the following :

. aodtenv

Once entered, any McIDAS session initiated will utilize the six AODT environment arguments defined in the aodtenv file. To verify that these values have been assigned to their corresponding environment arguments, use the UNIX "env" command.

D.) Runtime Messages

When obtaining a current intensity estimate, the AODT algorithm will display messages, interactive prompts, and results in the McIDAS text window. The display will depend on the keywords utilized and the type of analysis being performed.

1.) Normal Operation

During normal operation of the AODT, using a history file and with or without utilizing specific keywords in the command line, the general text output will be displayed within the McIDAS text window. Below is a sample output during Hurricane Floyd :

```
CURRENT HISTORY FILE = FLOYD.ODT

SUCCESSFULLY READ 61 RECORD(S) FROM HISTORY FILE
AUTOMATICALLY SELECTED OCEAN BASIN OF ATLANTIC
ADDING RECORD TO END OF HISTORY FILE
SUCCESSFULLY WROTE 62 RECORD(S) TO HISTORY FILE

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

      CI-No./Pressure   T-No.(ave)   T-No.(raw)
        6.1 / 945.4mb      6.1          6.8

 Eye Temp :  -0.7 C     Cloud Region Temp : -68.6 C
 Scene Type : CLEAR EYE
 Basin : ATLANTIC

 Flags :   Rule 9 : OFF  Rapid : OFF

****************************************************

         *** Finished with ODT Analysis ***
```

The text output generated by the AODT for this example is separated into two parts, the runtime messages and the intensity estimate output. The runtime messages provide the user with general information about the history file being used and how the current analysis is being placed within the history file. In this example, the current analysis is being appended at the end of the current history file, and is indicated by the message :

```
ADDING RECORD TO END OF HISTORY FILE
```

This message will appear most frequently since the AODT will usually be executed using the latest available image for the storm being investigated. If, however, the user decides to analyze a missed image or reanalyze an image previously examined, the following messages will be displayed, respectively :

```
OVERWRITING RECORD xx IN HISTORY FILE

 or

INSERTING RECORD WITHIN HISTORY FILE
MODIFIED yy SUBSEQUENT RECORDS IN HISTORY FILE
```

Within the intensity estimate section of the text output, all vital information relating to the current image analysis will be displayed. The date, time, and location are presented first. The three intensity estimate values are then displayed, providing the user with the current Raw T#, Final T#, and CI number with corresponding pressure/wind value. The "T-No.(raw)" value provides the user with the current intensity of the storm at that specific moment in time. The "T-No.(ave)" represents the time averaged intensity of the storm. The time averaging scheme is explained in greater detail in Section 5D. Finally, the "CI No." value represents the time averaged value after various rules governing its variability have been applied. For more details on these CI No. rules, see Section 5F. Adjacent to the "CI No." value the corresponding pressure/wind value, as defined in Dvorak (1984), is provided, dependent upon the use of the keywords DOMAIN and WIND. If the NHC keyword is utilized, a three hour average Raw T# intensity value will also be displayed, along with its corresponding pressure/wind value. Keywords are described in Section 4A1.

The bottom half of the intensity estimate output text contains information about the scene being analyzed and various rule flag values which affect the intensity estimate calculations. The eye and surrounding cloud region temperature values, described in Section 5C, are listed next to the "Eye Temp" and "Cloud Region Temp" labels. Beneath the eye temperature the objectively determined scene type is provided. Objective scene type determination is described in Section 5B. This value can be modified using the OVER keyword, and is described in Section 4A1. The current oceanic basin will be provided next to the "Basin" label. This value will be automatically determined unless explicitly defined using the DOMAIN keyword, and is described in Section 5G. Finally, two rule flag values are displayed at the bottom of the output text field. These flags, described in Sections 5E and 5F, notify the user if either of these rules, governing the determination of the Final T# and/or the CI number, are currently being applied.

2.) Abbreviated Operation

When running the AODT without specifying a history file, an abbreviated text output will be displayed in place of the normal intensity estimate output text. Much of the output is the same, but a few minor changes exist. First, the intensity estimate will consist of only one value. This value is listed at the "T-No." in the text output, which represents the Raw T# intensity estimate. Second, the "Rule Flags" values are not used or displayed since the Final T# and CI values are not calculated. A typical abbreviated output would be :

```
RUNNING ABBREVIATED ODT ANALYSIS
AUTOMATICALLY SELECTED OCEAN BASIN OF ATLANTIC

****************************************************

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         Tropical Cyclone Intensity Algorithm

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

                   T-No./Pressure
                    6.3 / 940.2mb

 Eye Temp :  -0.7 C     Cloud Region Temp : -68.6 C
 Scene Type : CLEAR EYE
 Basin : ATLANTIC

****************************************************

         *** Finished with ODT Analysis ***
```

3.) Land Interaction

If the storm center is over a land region (as defined in Section 5A), a warning will be presented in both the runtime messages and the intensity estimate output. The user will be notified in the runtime message section by the following notification :

```
***** TROPICAL CYCLONE IS OVER LAND *****
```

Within the intensity estimate output section, the flag "OVER LAND" will be presented directly below the "Basin" label.

4.) Automated Storm Center Determination

When running the AODT, using the AUTO keyword to initiate the objective determination of the storm center location, minor additions to the runtime message output will be displayed. See Section 5H for more information about the automatic storm center location scheme.

The automatic cursor position can be determined using one of four techniques; 1.) Quadratic Interpolation, 2.) Laplacian Analysis, 3.) 10° Log Spiral Analysis, or 4.) Linear Extrapolation. The first estimate position is calculated using a quadratic interpolation scheme utilizing NHC or JTWC forecast products. The second and third techniques determine a possible adjustment to the Quadratic Interpolation routine position. The final technique is a linear extrapolation of the history file positions previously determined, and is only used if the Quadratic Interpolation routine fails. The following message will indicate the implementation of the automated storm center determination scheme :

```
*** Utilizing automatic center finding algorithm ***
```

For the following example, a NHC format forecast/discussion file is used for the quadratic interpolation process. The file name will be displayed with the data points used in the quadratic interpolation procedure and the final interpolated position, which is then used in the Laplacian and 10° Log Spiral analysis. An example output session is :

```
READING FORECAST FILE /home/odt/forecasts/storm01-15.txt
CURRENT ANALYSIS TIME :  4/JUN/2001   845UTC
T1   3/JUN/2001   600Z        24.20    53.10
T2   3/JUN/2001  1800Z        25.30    55.90
T3   4/JUN/2001   600Z        26.50    58.60
T4   4/JUN/2001  1800Z        27.60    61.50
T5   5/JUN/2001   600Z        28.00    65.10

Interpolated forecast position : LAT = 26.75  LON=59.26
Performing Laplacian Analysis
Performing 10^ Log Spiral Analysis

Utilizing LAPLACIAN ANALYSIS position : LAT= 26.69 LON=58.95
```

If the quadratic interpolation methodology is successful in calculating a center fix position, this location may be adjusted using either the Laplacian Analysis or 10° Log Spiral Analysis schemes, as described in Section 5H. If either of these methods are used, the method and new forecast position location coordinates will be displayed and used as the center location position for the AODT analysis.

If the quadratic interpolation scheme fails, a simple linear extrapolation of the previous storm center locations, stored within the history file, will be performed with the following example output :

```
ERROR WITH QUADRATIC INTERPOLATION
ATTEMPTING LINEAR EXTRAPOLATION WITH HISTORY FILE LOCATIONS
Linear Extrapolated Position : LAT=  xx.xx LON=  yy.yy
```

(xx.xxxx and yy.yyyy will contain actual values)

If the linear extrapolation methodology also fails to produce a valid data point, the following message will be presented, prompting the user to define the storm center location manually :

```
Autopositioning failed… Must use USER INPUT
```

The user will then be prompted to manually select the storm center location.

5.) User Override Function

The user override function, initiated with the OVER keyword, allows the user to change the automatic scene type classification and/or the automated storm center location before calculation of the AODT storm intensity estimate. This is handled utilizing mouse positioning and button inputs.

a.) Scene Type Override

The AODT will display the objectively determined scene type and ask the user to either accept or modify the value. If the user chooses to modify the scene type, a sequence of scene type classifications will be presented to the user. Once the desired scene type is displayed, the program proceeds in its determination of the current storm intensity estimate using the selected scene type. Two example sessions are below :

The user agrees with the scene type :

```
CURRENT HISTORY FILE = /home/odt/history/OPAL.ODT

SUCCESSFULLY READ 10 RECORD(S) FROM HISTORY FILE
AUTOMATICALLY SELECTED OCEAN BASIN OF ATLANTIC
AODT has classified the EYE SCENE as RAGGED
Do you agree with this classification?
TOGGLE : Press MIDDLE mouse button
ACCEPT : Press RIGHT  mouse button
  <user presses RIGHT mouse button>
CLOUD AND EYE SCENES have not been changed
```

The user does not agree with the scene type :

```
CURRENT HISTORY FILE = /home/odt/history/OPAL.ODT

SUCCESSFULLY READ 10 RECORD(S) FROM HISTORY FILE
AUTOMATICALLY SELECTED OCEAN BASIN OF ATLANTIC
AODT has classified the EYE SCENE as RAGGED
```

```
Do you agree with this 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 EMBD CNTR
  <user presses RIGHT mouse button>

CLOUD SCENE has been changed to EMBD CNTR
```

In the second example, the user selected NONE for the eye scene. The OVER function then switched the selection options from eye scenes to cloud scenes, and scrolled through the different cloud scene options until the desired scene was selected. When this switch is performed, the eye scene written to the history file will automatically be entered as an eye type "None", as defined in Section 5B. The opposite switch can be performed, from cloud to eye scene, by selecting the cloud scene type of EYE during the override process. If this switch is performed, the cloud scene will be defined as a cloud type "Uniform".

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 listed, if available, with any storm text listings (LIST keyword) or with any recalculations of intensity if a record is modified/reanalyzed or record(s) are inserted or deleted.

b.) Cursor Position Override

The ability to manually override the automatically determined storm position can be set using the OVER keyword. The automated storm center position will be displayed along with the method used to determine the location. The user will then prompted to agree with the automated position or select a new position. If the user agrees the algorithm will continue, otherwise the user will be asked to reposition the cursor. For example, if the user agrees with the storm center location, the runtime text output will be the following :

```
Do you agree with this position?
YES: Press RIGHT mouse button
NO : Position cursor at desired location
     and press MIDDLE mouse button
  <user presses RIGHT mouse button>
YES - will use AUTO FIX Position
```

If the user does not agree with the position, the following message will appear after the mouse is repositioned and the MIDDLE mouse button is pressed :

```
Do you agree with this position?
YES: Press RIGHT mouse button
NO : Position cursor at desired location
     and press MIDDLE mouse button
   <user presses MIDDLE mouse button>
NO  - will use USER FIX Position
NEW STORM CENTER : LAT=xxxx.xx LON=yyyy.yy
```

6.) Remote Server Data Access

The AODT has the ability to utilize remotely stored and displayed McIDAS imagery in addition to locally stored images. The AODT assumes the data is stored locally unless the keyword REMOTE is used. The REMOTE keyword makes use of two UNIX environment arguments, as described in Section 4C, but can be overridden with REMOTE keyword entries, as described in Section 4A1.

If a remotely stored McIDAS image is displayed within the McIDAS image display window, the AODT will copy a subsection of the displayed remote image to the local machine using the local McIDAS server dataset and position definitions defined with the ODTLSERVER and ODTLAREA environment arguments. The variable ODTLSERVER defines the ADDE *group/descriptor* name (or alias name) while ODTLDATA defines the *position* number within the *group/descriptor*. The image copied will be 480x640, and will overwrite any existing image on the local server at the address defined with these variables.

When the REMOTE keyword is used, a message similar to the example below will be output :

DOWNLOADING REMOTE IMAGE EAST/NH.5 TO LOCAL IMAGE ALL.7777
WITHIN LOCAL DIRECTORY AT /home/odt/mcidas/data/AREA7777

This example examines a remotely stored image within the ADDE dataset name of "EAST/NH" at position "5". It is copied to the local server defined with the ADDE alias (AKA command) dataset name of "ALL" into position 7777. This local ADDE image is located in the /home/odt/mcidas/data directory in the file AREA7777. This local area is then queried by the AODT algorithm to estimate the storm intensity for the image in question.

E.) History File Output

1.) Text Output

A text 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 Bertha :

```
CURRENT HISTORY FILE = /home/odt/history/BERTHA.ODT

SUCCESSFULLY READ 76 RECORD(S) FROM HISTORY FILE
                  Intensity      T-No    Temperatures(C)   Scene  Rule9  Rapid
   Date     Time  CI   MSLP     Avg  Raw    Eye   Cloud    Type   Flag   Flag
1996JUL09 141500  5.0  970.0    5.0  5.0  -22.06 -58.22    EYE/R  OFF    OFF
1996JUL09 151500  5.0  970.0    4.8  4.8  -24.36 -56.34    EYE/R  OFF    OFF
1996JUL09 161500  5.0  970.0    4.8  4.8  -13.26 -55.03    EYE/R  OFF    OFF
1996JUL09 171500  5.0  970.0    4.8  4.9   -3.66 -53.28    EYE/C  OFF    OFF
1996JUL09 181500  5.0  970.0    4.8  4.7  -19.96 -54.48    EYE/R  OFF    OFF
1996JUL09 191500  5.0  970.0    4.7  4.5  -48.46 -57.13    UNIFRM OFF    OFF
1996JUL09 201500  5.0  970.0    4.7  4.7  -56.66 -58.39    EMBC   OFF    OFF
1996JUL09 211500  5.0  970.0    4.6  4.5  -66.46 -61.50    UNIFRM OFF    OFF
<records not shown>
1996JUL10 121500  4.6  977.2    4.6  5.0  -60.56 -65.68    EMBC   OFF    OFF
1996JUL10 131500  4.6  977.2    4.6  4.5  -55.96 -57.76    UNIFRM OFF    OFF
1996JUL10 141500  4.6  977.2    4.6  4.5  -61.26 -47.54    UNIFRM OFF    OFF
1996JUL10 151500  4.6  977.2    4.4  3.5  -60.56 -50.20    IRRCDO OFF    OFF
1996JUL10 161500  4.6  977.2    4.3  3.5  -40.86 -53.62    IRRCDO OFF    OFF
1996JUL10 171500  4.6  977.2    4.3  5.0  -24.96 -59.22    EYE/R  OFF    OFF
1996JUL10 181500  4.6  977.2    4.4  4.9  -56.66 -63.34    EMBC   OFF    OFF
1996JUL10 191500  4.6  977.2    4.4  4.5  -53.66 -60.15    UNIFRM OFF    OFF
<records not shown>
1996JUL11 101500  4.5  979.0    4.3  4.5  -64.36 -50.39    UNIFRM OFF    OFF
1996JUL11 111500  4.5  979.0    4.2  3.5  -44.76 -52.24    IRRCDO OFF    OFF
1996JUL11 141500  4.5  979.0    3.8  2.7    5.04 -29.49    CRVBND OFF    OFF
1996JUL11 151500  4.5  979.0    3.5  2.5   12.04 -24.26    CRVBND OFF    OFF
1996JUL11 161500  4.2  983.8    3.2  2.2   11.54 -22.74    CRVBND OFF    OFF
1996JUL11 171500  3.8  989.8    2.8  1.7   15.74 -18.44    CRVBND OFF    OFF
1996JUL11 181500  3.8  989.8    2.8  3.5    2.74  -8.27    SHEAR  OFF    OFF
1996JUL11 191500  3.9  988.4    2.9  3.5    4.84 -11.56    SHEAR  OFF    OFF
1996JUL11 201500  3.9  988.4    2.9  3.5   13.64 -11.33    SHEAR  OFF    OFF
1996JUL11 211500  3.9  988.4    2.9  3.0   20.74 -11.70    SHEAR  OFF    OFF
<records not shown>
1996JUL12  81500  3.3  996.4    3.3  3.5   20.44 -24.40    SHEAR  OFF    OFF
1996JUL12  91500  3.3  996.4    3.3  3.5   17.64 -27.06    SHEAR  OFF    OFF
1996JUL12 101500  3.4  995.2    3.4  3.5   -6.46 -32.23    SHEAR  OFF    OFF
1996JUL12 111500  3.4  995.2    3.3  3.0  -55.66 -40.92    IRRCDO OFF    OFF
1996JUL12 121500  3.5  994.0    3.5  4.5  -69.46 -53.79    UNIFRM OFF    OFF
1996JUL12 131500  3.7  991.2    3.7  5.0  -65.16 -66.22    EMBC   OFF    OFF
1996JUL12 141500  3.9  988.4    3.9  5.0  -61.26 -64.73    EMBC   OFF    OFF
1996JUL12 151500  4.1  985.4    4.1  4.6  -50.86 -57.70    EMBC   OFF    OFF
1996JUL12 161500  4.1  985.4    4.0  3.4   -0.46 -48.08    CRVBND OFF    OFF
1996JUL12 171500  4.1  985.4    3.9  3.4    8.34 -39.55    CRVBND OFF    OFF
1996JUL12 181500  4.1  985.4    3.8  3.0   10.74 -36.52    CRVBND OFF    OFF
1996JUL12 191500  4.1  985.4    3.7  3.0   -2.56 -35.08    CRVBND OFF    OFF
1996JUL12 201500  4.1  985.4    3.6  3.2    5.84 -35.38    CRVBND OFF    OFF
         *** Finished with ODT Analysis ***
```

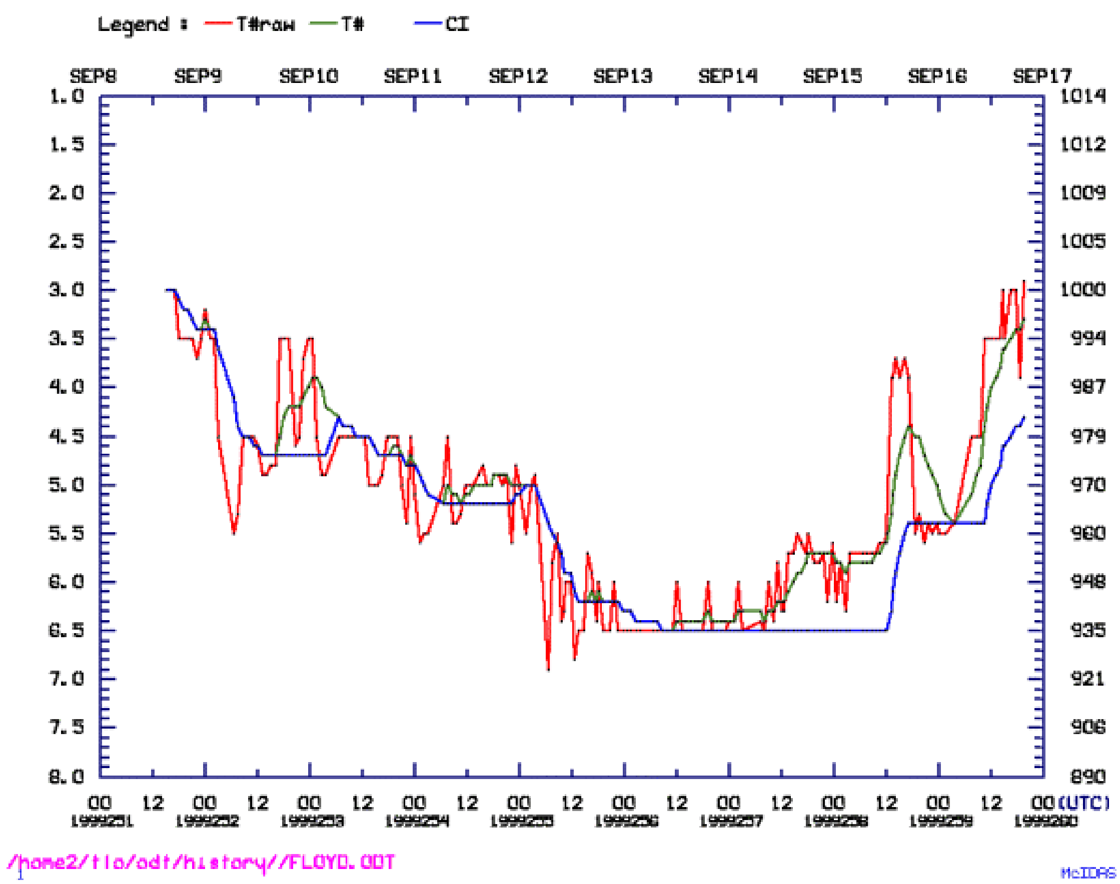
The text output displays time, date, intensities (CI with corresponding pressure/wind value, Final T#, and Raw T#), eye and cloud region temperatures, scene type, Dvorak Rule 9 flag value, and rapid intensification flag value. In addition, if the storm center is located over a land feature at the time listed, a "*" will be listed prior to the scene type.

If it is desired to write the output of the history file to an external ASCII file, the AODT keyword command “OUTPUT=FILE <filename>“ can be used. This option provides the same contents as the “OUTPUT=SCREEN” option, however the storm center latitude and longitude position are appended at the end of each line. The directory location where this file is written is defined using the environment argument. An example to write the contents of the history file BERTHA.ODT to an output ASCII file “odtout.txt” would be :

AODT HISTORY=BERTHA.ODT LIST=YES OUTPUT=FILE odtout.txt

2.) Graphical Output

Time series graphs of intensity estimates stored within history files can be displayed within the McIDAS image/graphics window. The plots are controlled with the AODT keywords GRAPH, PLOT, and DATE. Below is an example for Hurricane Floyd:



The intensity estimate values are plotted along the ordinate; T# values along the left hand side and its corresponding pressure/wind along the right side. Time is plotted along the abscissa, with Julian date and time (UTC) plotted at the bottom and the corresponding calendar day (month and day) plotted along the top of the graph. The complete history file name is displayed in the bottom-left hand corner of the graph. A legend of the displayed variables is presented along the top of the graphics window.

In the example above, the CI number (CI), Final T# (T#), and Raw T# (T#raw) are all displayed, but any combination of the three values can be plotted using the PLOT keyword. Any portion of the history file can be plotted using the DATE keyword.

5.) Background Information

Many of the algorithms unique to the AODT have been previously described in Velden et. al., (1998). This section will provide additional information about these processes and describe new algorithms developed since the release of that paper.

A.) Land Flag

Tropical cyclone land interaction is determined utilizing a low resolution topography map named TOPOHRES. The resolution of the map file is 0.1° X 0.1° latitude/longitude. If the storm center is positioned over a land mass of some sort, the land flag will be triggered. Land interaction does not modify the determination of any of the intensity estimate values directly, however if the storm is located over a land mass continuously for 12 hours, the Rule 9 adjustment, if currently being applied, is turned off.

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 and surround cloud regions, with use of one or both scene types in determination of the current storm intensity estimate.

Eye Region

Scene Type	Description
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

Scene Type	Description
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

Scene types are determined separately for the eye (0-24km) and surrounding cloud (24-136km) regions. 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, 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, 10° Log Spiral Analysis is performed to determine the extent of the convective cloud region around the selected center position. If the scene is a "Shear" type scene, the distance between the center position and the closest BD-curve "Light Gray" temperature range pixel is determined.

Once the scene type has been automatically or manually resolved, the value is passed to the intensity estimation routines, along with eye and surrounding cloud top temperatures, oceanic basin type, and rapid intensification information, to define the Raw T# intensity estimate for the scene being examined.

C.) Eye and Surrounding Cloud Region Temperature Determination

Determination of the eye region temperature is relatively straightforward. This value is the warmest pixel within a 24 km radius from the user or automated storm center location. Proper determination of the storm center is paramount to correct determination of the storm intensity because the retrieval of an accurate eye temperature is heavily dependent on cursor location.

The surrounding cloud region temperature value determinations are a bit more complicated. Two values are computed, although only one is utilized in the determination of the storm intensity and output to the history file. The first cloud region value computed is the "mean" cloud region temperature value, and is computed in the following manner. The storm is divided into 24 arc regions of 15° each. The average temperature of each arc is determined. The average of all 24 average values are then averaged to provide the "mean" cloud region temperature value.

The second 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. For more information about this value, see Velden et al. (1998) and Zehr (1989).

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 larger fluctuations of intensity values using the coldest-warmest temperature values do not correlate as well qualitatively with the aircraft reconnaissance intensity measurements as the intensity estimates using the mean temperature value, thus the modification was implemented.

D.) Time Averaging Scheme

The Final T# 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 12 hours. The current value is given a weight of 12.0, with all other values given weights directly proportional to their time difference from the current analysis time.

E.) Rapid Deepening

The rapid deepening flag had been based purely upon cloud region temperature values in previous ODT versions. In order to reduce the number of false alarms noted during the past few years, three new environmental checks have been implemented for the AODT. First, the eye region scene type must be of type CLEAR or PINHOLE. Second, the surrounding cloud region must be of type UNIFORM. Third, the cloud region must consist of a continuous ring of temperature values less than or equal to –70°C ("White" in the BD Enhancement Curve). These values were empirically determined by examining the performance of the AODT in relation to actual reconnaissance intensity measurements, and noting how these values related to storms that rapidly deepened.

If the rapid deepening flag is set, the time averaging scheme will utilize only the previous three hours of Raw T# intensity estimates, as opposed to twelve in normal operation. The time averaging weights will be adjusted accordingly, with the current Raw T# estimate given a weight of 3.0, and all other Raw T# values being weighted accordingly. Once either or both of the temperature thresholds are not exceeded, the rapid flag will be applied for 12 hours and then turned off.

F.) Subjective Dvorak EIR Rule 9

The SD EIR Rule 9 (see Dvorak, 1984) is used in the determination of the CI number after a storm has reached its maximum intensity and is weakening. This rule holds the CI number to values up to 1.0 T# higher in value than the current Final T# value (the time averaged intensity estimate value). 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 1.0 was chosen for the AODT since it provided the best fit for the estimated intensity values 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 is identified by computing a least squares fit to the current and all Final T# values within the past 24. If the slope of this fit is less than or equal to -1.0 (decreasing 1.0 T# in the last 24 hours), a “significant strengthening event” is said to be occurring, and a flag is set. When the Final T# stops increasing the SD Rule 9 is initiated, influencing the Final CI number calculation.

An additional rule within the AODT affects the calculation of the Final T# and CI number prior to the application of Rule 9. 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 number) in all cases”. This rule will hold the CI number to the highest Final T# obtained during the last 12 hours. For example, if the T# (and CI number) increase to a 5.2, then the T# begins to decrease, the CI number value will be held at 5.2 until the T# either increases and exceeds 5.2 or 12 hours passes.

Once the significant strengthening event is noted, and the storms begins to weaken, an additional check will modify the Rule 9 “additive” value of 1.0 if the storm CI values hold “constant” (do 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. Once this condition is broken, the additive value will again increase to a maximum of 1.0.

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, for a particular eye and cloud region temperature pair, a different Raw T# may be derived depending upon which basin is designated for the storm image in question.

Previous versions of the ODT relied on the user to designate the ocean basin using the DOMAIN keyword. This keyword can still be used, but the default basin for a particular storm is now derived using the storms position instead of using a fixed, default basin value. The basin is chosen based upon the storm longitude only. 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 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 specific rule(s) defining use of one specific relationship for this region (or other regions, such as Indian Ocean or Southern Pacific Ocean) have not been documented, so it is left to user judgement as to which basin to use with the AODT in this/these region(s).

H.) Automatic Storm Center Determination

The automated storm center location algorithm estimates tropical storm position using four methods : interpolation of NHC/JTWC forecasts, Laplacian Analysis, an automated 10° Log Spiral positioning routine, and linear extrapolation.

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

- NHC Tropical Storm/Hurricane Discussion files (WTNT4? or WTPZ4?)

or

- JTWC Tropical Cyclone Warning files (WTPN3?)

Once the interpolated position is determined, it is used as the storm center location for the Laplacian Analysis and automated 10° Log Spiral positioning schemes. The Laplacian Analysis scheme identifies temperature gradients within the analysis area (150 by 150 km box centered at interpolation point). Statistical analysis of these gradients is conducted, with an empirically defined "confidence factor" formulated based upon the number and scatter of the Laplacian gradients.

After performing the Laplacian Analysis, an automated 10° Log Spiral Analysis is conducted. This algorithm consists of placing a 10° Log Spiral at various points centered around the initial guess position and determining the extent of the largest curved band within the cloud top region. The target band is determine by performing a Coakley-Bretherton analysis (Coakley et al., 1982) on the region of interest. This method defines the target region (temperature range) for the curved band analysis. Once the target region is defined, the spiral is placed at every pixel within the search area, and the extent of the curved band which lies along the 10° Log Spiral is determined. In addition, the curved band is rotated at 30° intervals at each point in order to search for the proper orientation of the analysis spiral. The spiral that contains the most continuous target region points is selected as the center position. A "confidence factor" is formulated based upon the extent of the curved band analysis.

Once the confidence factors are produced for the Laplacian and 10° Log Spiral Analysis, they are compared to the NHC/JTWC interpolated forecast position confidence factor, which is based upon time difference from the initial forecast position. The location corresponding to the largest confidence factor is used in the AODT analysis, unless the user manually overrides the position.

I.) Cursor Position Sensitivity Reduction

In order to reduce the sensitivity of cursor placement when manually determining the storm center location, a routine has been added to the AODT algorithm to compare intensity estimate at the user defined location with selected surrounding points. Surrounding cloud top region temperature analysis will be performed at the user selected storm center location. In addition, similar analysis will be performed at four points surrounding the user selected center location. These points will be located at +/- 2 pixels in both the x and y image coordinates (not latitude and longitude), and are located in the following manner :

```
              _________X                + (0,-2)
Image         |
Coordinates   |           (-2,0)  +       X       + (+2,0)     X =   user selected
              |                                                      cursor location
              |                         + (0,+2)
              Y
```

At each of the five positions, surrounding cloud top region temperature analysis will be performed. The point which provides the coldest cloud top region temperature value will be used in the determination of the intensity estimate.

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