

**ADT – Advanced Dvorak Technique  
USERS’ GUIDE  
(McIDAS Version 8.1.2)**

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## **1.) Description of the ADT Algorithm**

The Advanced Dvorak Technique (ADT) 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 ADT can be used to classify storm intensity beginning from storm formation from development to dissipation.

The ADT is patterned after the Subjective Dvorak Enhanced Infrared ‘EIR’ Technique (SDT) (Dvorak, 1975, 1984) which made use of various pattern identification schemes and rules to determine tropical cyclone intensity. The ADT has been developed to closely mimic the SDT methodology in terms of intensity determination protocol and the incorporation of various rules and analysis methods. Some of the original SDT rules have been modified in the ADT as determined by in depth statistical analysis of ADT performance during application of these rules. Additionally, some intensity relationships have been modified within the ADT using regression based methods, further advancing the ADT beyond the scope of the SDT and previous versions of the ADT (ODT and AODT).

The ADT 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 ADT, 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, the implementation of various SDT rules governing the variability of the intensity estimates, and the modification of various intensity estimates away from the SDT methodologies towards the use of several regression-based equations utilizing various measured environmental parameters. 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/ADT algorithm, please refer to Velden et al. (1998), Olander et al. (2004, 2002), and Olander and Velden (2007).

## **2.) System Requirements**

The ADT 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 ADT has been tested and operated on a wide variety of UNIX/LINUX operating systems. 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.

The ADT code libraries can be ported into various systems utilizing the various API (application programming interface) routines provided within the tar file (as described in Section 3 below). Non-McIDAS systems can replace the McIDAS-specific functions with their own system functions to access the satellite imagery and provide their own graphical user interface (GUI) to replace the McIDAS command line and image display interface.

### 3.) ADT Acquisition and Installation

The current version (8.1.2) of the ADT algorithm can be obtained via the UW-CIMSS ADT web page, along with the Users' Guide. The ADT overview web page is located at:

**<http://cimss.ssec.wisc.edu/tropic2/misc/adt>**

A new registration process has been implemented to obtain the ADT code. In order to obtain the ADT code from the webpage it is now required that a License Agreement is signed along with filling out the online registration form. The new download website, containing instructions on how to download the ADT, can be found at:

**<http://cimss.ssec.wisc.edu/tropic2/misc/adt/download>**

Once the registration process has been approved and the ADT tar file is obtained, the tar file can be uncompressed and unpacked using the following command:

```
gunzip ADTV8.1.2.tar.gz  
tar -xvf ADTV8.1.2.tar
```

The resulting subdirectory "ADTV8.1.2" will contain the following:

- history : directory - output history files (suggested)
- inc : directory - include files
- lib : directory - library files
- odtapi : directory - application program interface (API) routines
- odtappl : directory - main application routine
- odtext : directory - external data handing routines
- odtplib : directory - ADT library routines
- odtmcidas : directory - McIDAS specific routines
- test : directory - test files for ADT installation check
- adtenv : file - environment argument setup file (Section 4E)
- compileall : file - compile script
- Makefile : file - UNIX makefile (for compileall script)
- digelev\_hires\_le.map : file - high resolution topography file

The ADT directory is structured in a function library format that not only allows for quicker installation of ADT updates, but also improves integration of the ADT code within non-McIDAS graphical interface platforms. Interface between the ADT library functions and any GUI are controlled by the odtapi functions.

Prior to installation of the ADT, the current libmcidas.a library file must be located and linked to within the lib directory. The ADT 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 "compileall" script using the variable MCLIB to define the location of the libmcidas.a file. The MCLIB

variable should be modified in this file to reflect its location on the machine where the ADT is being installed. Note 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 ADT algorithm can be compiled using the “compileall” script file using the following command (to assure that the ADT is compiled with all necessary McIDAS dependencies):

**compileall mcidas**

Please refer to Section 5P for information about compiling outside of the McIDAS environment.

## 4.) Using the ADT

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

### A.) Command Line Structure and Keywords

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

**ADT** *<parameters>* *<keywords>*

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

#### 1.) Description of Use

ADT -- Advance Dvorak Technique

ADT *<keywords>*

ADT history\_file *<keywords>*

ADT history\_file DATSET=src\_dataset local\_dataset *<keywords>*

ADT AUTO format fcst\_file history\_file *<keywords>*

ADT DEL history\_file DATE=

ADT EDIT history\_file date time "comment"

ADT LIST history\_file *<keywords>*

ADT PLOT history\_file *<keywords>*

Parameters:

**AUTO** Allows for automated ADT estimate to objectively determine position of storm center (see Section 5.J.2)

**DEL** Deletes history file record; Must be used with DATE= keyword to define date/time limits

**LIST** Lists contents of history file (see Remarks)

**PLOT** Plots intensity estimates from history file (see Remarks)

**history\_file** History file to be used (def=path defined in environmental variable ODT\_HISTORY)

**format** Format of forecast file valid options (see examples in Section 5.I.1):  
 ATCF – Automated Tropical Cyclone Forecast record format  
 DISC – TPC WTNT4\* or WTPZ3\* storm specific discussions  
 PACWARN – JTWC WTPN3\* tropical cyclone warning  
 RMSC – RMSC ICAO format (FK?? or WT??) format  
 ICAO – WTIO30 FMEE (MeteoFrance) format  
 TCWC – Tropical Cyclone Warning Center tech bulletin (AXAU\*) format  
 GENERIC - see remarks for example format  
 (def=ATCF)

**fcst\_file** File name containing forecast information for AUTO option; directory location defined by environmental variable ODTAUTO (no AUTOFIX)

**day** Adds comment to specified day in history file (no default)

**time** Adds comment to specified time in history file (no default)

**comment** Comment to add to history file for specified day and time (no default)

Keywords:

**ATCF=stormID sourceID rawT finalT**

Produces ATCF formatted listing for current ADT estimate or entire history file (or portion of file using DATE= keyword). See remarks.

- stormID=annual tropical cyclone number/basin value; valid basin values:

L=Atlantic

E=East Pacific

C=Central Pacific

W=West Pacific

A=North Indian Ocean

B=South Indian Ocean

S=Australian Region (90E-135E)

P=Australian Region (east of 135E)

- sourceID = WMO identifier (e.g., NHC, PGTW, etc.)

- rawT = flag determining raw T number output:

0=adjusted raw T number; 1=unadjusted raw T number

- finalT = flag determining final T number output:

0=3-hour linear average

(def=-1 XXXX 0 0)

**COLor=CI MSLP FinalT Adj-RawT UnAdj-RawT outline text**

Defines graphic color levels of plotted parameters (def=1 2 0 0 0 6 7; 0 to not display)

**DATE=beg\_day beg\_time end\_day end\_time**

Defines range of dates and times for LIST, PLOT and DEL options; can be any valid McIDAS date/time format or ADT date format

yyyy/mm/dd, yyyy-mm-dd, dd/mon/yyyy, dd-mon-yyyy, yyyymond

yyyy=year, dd=date (1-31)

mm=integer month (1-12), mon=character month (min 3 characters)



**DATaset=src\_dataset local\_dataset**

- src\_dataset = ADDE dataset name and position; specific alias.position or group/descriptor.position format must be used, a position number greater than zero represents an absolute position in the dataset, and zero or a negative number represents a relative position in the dataset based on image time, with 0 being the most recent, -1 the second most recent, etc.; no default value for this parameter.
- local\_dataset = ADDE dataset name and position or specific McIDAS area file name (AREAxxxx, where xxxx is area file number; path determined from ODTDATA environmental variable); specific position value must be used if ADDE format; lat/lon image center location is determined using cursor position or forecast interpolation; area file is 480x640 pixels; no default value for this parameter.

(See Section 4D6 for more information)

**DOMain=ATL/PAC**

Defines domain for CI to MSLP conversion; valid options: ATL or PAC, see Remarks (def=computed)

**KZ=YES gale\_radius pressure\_env**

Utilize Knaff/Zehr wind speed/pressure derivation technique to determine mean sea level pressure estimate value. Must input 34-knot wind/gale radius value (in km) and environmental pressure value (in mb). (def=NO)

**LAND=NO**

Applies ADT land interaction rule (def=YES)

**MW=score date time**

Passive Microwave eye score value input. See section X.X for more details on this process. Date must be in YYYYmonDD format (YYYY=year, mon=three letter ID for month, DD-day), time is in HHMMSS format.

**MAXWradius=value**

Manually defines maximum wind radius (in km). If the ADT estimate has determined an eye scene and the MAXW of less than 5 km is specified, the scene type will be changed to PINHOLE EYE. If a value of MAXW of greater than or equal to 38 km is specified, the scene type will be changed to LARGE EYE (no default).

**OUTput=loc filename**

Defines location of LIST option output; valid option T, FILE or TFILE, where T, sends the LIST output to the current text window, FILE, sends the output to a file (def=ODTDUMP.ASC) where the directory is defined

by the environmental variable ODTOUTPUT or TFILE, where the output is sent to both the window and a file (def=T)

**OVERride=YES**

Allows a user to interactively override the automated scene type; cannot be used with AUTO option (def=NO)

**RMW=value**

Manual input value for radius of maximum wind distance (in km). Value is used in order to override automated RMW determination technique and aid in pinhole eye determination (no default). Positive value will indicate usage of value.

**RAWT=init\_rawt**

Allows a user to over ride the initial raw T intensity value as defined by the subjective Dvorak rules; see Remarks (def=1.0)

**SEARCh=NO**

Performs search for maximum curved band location if ADT estimate has determined a CURVED BAND scene (def=YES).

**VOU=ONE/TEN**

List either one or ten minute averaged wind speed value in bulletin or storm history listing output.) Ten minute wind speed is equal to 0.88 \* one-minute wind speed value. (def=ONE)

**WIND=YES**

Lists intensity as maximum wind speed (knots) instead of MSLP. Speed and MSLP values are derived from the empirical relationship to CI number defined in Dvorak (1984) and Shwechuck and Weir (1980). (def=NO)

Remarks:

The units for pressure/wind are shown in millibars/knots for both the LIST and PLOT options. If the LIST option is used with ATCF keyword, the output file will be in fixed DVTO format.

When using the DOMAIN= keyword, ATL should be used for storms within the North Atlantic basin, while PAC should be used for storms within the Western Pacific basin. Domain selection will affect Raw T intensity estimates and corresponding CI pressure values (empirical CI number/pressure relationship).

If the value for RAW= keyword is set to 0.0, the derived Raw T will be displayed. If using ATCF keyword during an ADT estimate, an output file is created in the directory

defined by the environmental variable ODTOUTPUT using the following naming convention:

CIMSS\_DVTO\_yyyymmddhhmm\_ssbasin\_FIX

where: yyyy - year

mmdd - month (01-12) and day (01-31)

hhmm - UTC time (12:15 UTC = 1215)

ss - stormID

basin - sub basin

## 2.) Examples

### *ADT*

Perform abbreviated ADT 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.

### *ADT OPAL.ODT*

Perform ADT 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.

### *ADT OPAL.ODT RAWT=2.5*

Perform ADT 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.

### *ADT OPAL.ODT ATCF=13L NHC 0 1*

Perform ADT analysis and add record to history file OPAL.ODT. All rules will be applied as necessary. Output file containing intensity estimate for current analysis in ATCF format will be created with annual tropical cyclone ID of 13L, Fix Center of NHC, Adjusted Raw T# value, and 3-hour linear averaged Final T# value displayed.

### *ADT OPAL.ODT OVER=YES*

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

### *ADT PLOT OPAL.ODT COLOR=3 4 5 1 2 XX*

Display graph of contents of history file OPAL.ODT in current graphic image using color level 3, 4, 5, 1, and 2 for the CI#, Adjusted MSLP, Final T#, Adjusted Raw T#, and Unadjusted Raw T# plots, respectively. Graph boundary and wording will utilize the default values. No intensity analysis is performed.

### *ADT LIST OPAL.ODT*

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

### *ADT LIST OPAL.ODT ATCF=13L NHC 0 1*

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

### *ADT LIST OPAL.ODT OUTPUT=FILE OPAL.TXT*

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

*ADT DEL OPAL DATE=1995/10/03 151500*

Delete only the 3 October 1995 at 15:15:00UTC 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.

*ADT DEL OPAL DATE=03/OCT/1995 15:15:00 03/MAR/1995 19:15:00*

Delete all records between 3 October 1995 at 15:15:00UTC and 3 October 1995 at 19:15:00UTC 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.

*ADT LIST HISTORY=OPAL DATE=03-Oct-1995 1500*

List all records between 3 October 1995 at 00:15:00UTC and the end of the history file OPAL.ODT. No intensity analysis is performed.

*ADT LIST OPAL DATE=X X 1995OCT03 3:15:00*

List all records between the beginning of the history file OPAL.ODT and 3 October 1995 at 3:15:00UTC. No intensity analysis is performed.

*ADT AUTO PACWARN wp2698.txt OPAL.ODT*

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

*ADT OPAL.ODT DATASET=EASTS/NH.-1 ALL.9990*

Perform manual ADT analysis on the second most recent image position in the ADDE remote dataset server group EASTS/NH. A subset of the displayed image will be copied to the ADDE local dataset server group (alias) ALL in the 9990 position. See Sections 4C and 4D6 for more details.

*ADT OPAL.ODT KZ=YES 85 1002*

Perform manual ADT analysis utilizing the Knaff/Zehr wind speed/pressure relationship to derive MSLP estimate using 85 km as the 34 knot/gale radius and 1002mb as the environmental pressure value.

*ADT EDIT OPAL.ODT 1995OCT03 81500 "Great Estimate*

The comment "Great Estimate" will be added to the 1995OCT03/08150 UTC intensity analysis record in the OPAL.ODT history file.

## B.) History File

The ADT history file is an ASCII format file containing ADT intensity estimates, locations, and other specific information for each image analysis. The ADT 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 (3-hour average)
Value 7	: final CI# value
Value 8	: eye region temperature (°C)
Value 9	: mean cloud region temperature (°C) – movable annulus
Value 10	: mean cloud region temperature (°C) – set region (old method)
Value 11	: “coldest-warmest” cloud region temperature (°C)
Value 12	: storm center latitude (+/- = North/South Hemisphere)
Value 13	: storm center longitude (+/- = West/East Hemisphere)
Value 14	: eye diameter, CDO size, or shear distance (in km)
Value 15	: eye region temperature standard deviation value
Value 16	: cloud region symmetry value
Value 17	: satellite ID value
Value 18	: eye region scene type (original value)
Value 19	: cloud region scene type (original value)
Value 20	: eye region scene type (original value if user override performed)
Value 21	: cloud region scene type (original value if user override performed)
Value 22	: Dvorak Weakening (Dvorak EIR Rule 9) flag
Value 23	: Dvorak Constraint Limits (Dvorak EIR Rule 8) flag
Value 24	: latitude bias application flag
Value 25	: rapid dissipation flag (east pacific only)
Value 26	: land/ocean flag
Value 27	: eye region FFT value
Value 28	: cloud region FFT value
Value 29	: curved band analysis – BD curve gray scale value
Value 30	: curved band analysis – convection curvature amount (out of 25)
Value 31	: distance from center to “coldest-warmest” temperature value
Value 32	: automated center determination flag
Value 33	: MSLP latitude bias adjustment value
Value 34	: radius of maximum wind (in km)
Value 35	: external passive microwave (PMW) “eye score” value
Value 36	: input 34 knot wind/gale radius value (in km)
Value 37	: input environmental pressure value (in mb)
Value 38	: user comment – 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 ADT command line entry with select keywords, such as DELETE and DATE, in order to assure correct modification to the remaining history file entries.

### C.) UNIX Environment Variables

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

<u>Variable</u>	<u>Description</u>
ODTTOPO	Directory where TOPOHRES topography file is located
ODTHISTORY	Directory where ADT history files are stored
ODTAUTO	Directory for forecast files for ADT auto mode
ODTOUTPUT	Directory for LIST/ATCF output
ODTSST	Directory for the external SST input file ( <i>usage disabled</i> )
ODTDATA	Directory where local AREA files are stored

The default location for the base directory is defined using the \$ODTHOME parameter, which is defined on line one of the *adtenv* file. The default location of this variable is the top directory of the ADT directory tree. If any of the variable names are not defined in the *adtenv* file explicitly, the value will default to the \$HOME environment variable value.

The ODTDATA variable is the directory location where the McIDAS AREA files are stored on the local machine (e.g. \$HOME/mcidas/data). This value will be used with the local\_dataset value with the DATASET keyword to define where the downloaded image will be stored.

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

```
. adtenv
```

## D.) Algorithm Output

During ADT 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 ADT Analysis

Full ADT analysis of an image requires the use of a history file and may use various combinations of specific keywords. Below is sample intensity bulletin output:

```
Utilizing history file /home/adt/history/TEST.ODT
Performing full ADT analysis
Using USER-SELECTED center position : LAT: 22.99 LON: 66.21
Ocean basin automatically selected as ATLANTIC
Utilizing image data file /home/adt/mcidas/data/AREA2010
```

```
*****
```

```
                UW - CIMSS
            ADVANCED DVORAK TECHNIQUE
                ADT - Version 8.1.2
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
```

```
Final T#  Adj T#  Raw T#
6.4       6.5    7.1
```

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

```
Estimated radius of max. wind base on IR : 31.4km
```

```
Center Temp : 18.6C   Cloud Region Temp : -74.2C
```

```
Scene Type : EYE
```

```
Positioning Method : MANUAL
```

```
Ocean Basin : ATLANTIC
Dvorak CI > MSLP Conversion Used : ATLANTIC
```

```
Tno/CI Rules : Constraint Limits : 1.5T/6hr
                Weakening Flag : OFF
                Rapid Dissipation Flag : OFF
```

```
*****
```

```
ADDED RECORD TO END OF HISTORY FILE /home/adt/history/TEST.ODT
WROTE 66 RECORDS TO HISTORY FILE /home/adt/history/TEST.ODT
Successfully completed ADT analysis
```

The first section of the ADT intensity bulletin 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 ADT analysis will be performed on the image. This will be indicated by the following message:

```
Performing full ADT analysis
```

The path and file name of the current image file being analyzed will be listed prior to the intensity estimate bulletin. 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.

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 unadjusted Raw T#, adjusted Raw T#, Final T# (3-hour average), and CI#.

The “Raw T#” value is the unadjusted Raw “DT” number determined using the current scene type and measured environmental parameters (Section 5B and 5C) for the selected scene type (cloud curvature, eye/cloud temperatures, etc.). The “Adj T#” value represents the current intensity of the storm after any Constraint Limit (Dvorak “Rule 8”) rules have been applied (see Section 5F). The “Final T#” value is the average of the current and previous three hour analyses values (see Section 5D). Finally, the “CI#” value represents the 3-hour averaged value after various ADT rules and constraints governing its variability, listed next to the Constraint Limits and Weakening Flag labels at the end of the intensity bulletin, have been applied. For more details on these rules, see Sections 5E, 5F, and 5G.

Adjacent to the “CI#” value are the corresponding estimated mean sea level pressure (MSLP) and maximum wind (Vmax) values (see Sections 5I and 5O). The MSLP value displayed for the derived CI# intensity estimate may have 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 any adjustment will be listed below the CI#/Pressure/Vmax information next to the “Latitude Bias Adjustment to MSLP” label (see Section 5L). A positive/negative adjustment will increase/decrease the MSLP value obtained from the specific CI#/MSLP relationship for the scene being investigated. Please see Sections 5I, 5L, and 5O for more information on these adjustments.

Following the eye and cloud temperature information (Section 5C), the specific Scene Type and Positioning Method information is listed. The example above obtained a CLEAR EYE scene for a manually selected storm center location. The storm center selection method is provided in both the intensity bulletin and the preceding runtime messages section. A discussion of an automatically selected storm center location will be



provided in Sections 4D4 and 5J. The scene type will be determined automatically using various image analysis methods (see Section 5B). Manual selection of the storm scene type can be performed using the OVER keyword described in Section 4A1.

If the scene type of the current analysis is an EYE, PINHOLE EYE, or a LARGE EYE, an estimate of the Radius of Maximum Wind (RMW) will be provided under the Latitude Bias Adjustment line in the intensity bulletin. For more information on the derivation of the RMW value see Section 5M.

The ocean basin in which the storm is located will be displayed next. This value will either be ATLANTIC, PACIFIC, or INDIAN. Following the ocean basin designation, the empirical T# to MSLP relationship method used to determine the MSLP value for the given T#/CI# is presented. This value will either be listed as ATLANTIC or PACIFIC, indicating the Atlantic or West Pacific empirical relationship conversion is used. The conversion will automatically be determined unless manually overridden using the DOMAIN keyword. See Section 5I for more information on the automatic ocean basin determination process and T# to MSLP conversion relationship.

The final three “Tno/CI Rules” entries inform the user whether the SDT “Rule 8” and/or “Rule 9” T#/CI# adjustments are being utilized. Constraint Limits will list which Raw T# constraint limit (T# change per time period) is being applied, if it has been exceeded, to derived the Adjusted Raw T# value (see Section 5F). The Weakening Flag indicates will be either OFF, WKN, or ON, indicating which CI# determination scheme is being followed (see Section 5E). Finally, the Rapid Dissipation Flag value will either be ON or OFF, indicating a further adjustment to the Weakening Flag application. This adjustment is only applied in the East Pacific basin (see Section 5G)

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 TEST.ODT and was the last of 66 records written to the history file.

Most frequently an intensity analysis will be performed on the most current image available. 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:

```
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>  
  
OR  
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>
```

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

## 2.) Abbreviated ADT Analysis

If a history file is not specified on the command line when utilizing the ADT, 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 ADT analysis
Using USER-SELECTED center position : LAT: 22.99 LON: 66.21
Ocean basin automatically selected as ATLANTIC
Utilizing image data file /home/ad/mcidas/data/AREA2010
```

```
*****
```

```
                UW - CIMSS
            ADVANCED DVORAK TECHNIQUE
                ADT - Version 8.1.2
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
7.1 / 917.8mb/143.0kt
```

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

```
Estimated radius of max. wind base on IR : 31.4km
```

```
Center Temp : 18.6C   Cloud Region Temp : -74.2C
```

```
Scene Type : EYE
```

```
Positioning Method : MANUAL
```

```
Ocean Basin : ATLANTIC
```

```
Dvorak CI > MSLP Conversion Used : ATLANTIC
```

```
*****
```

```
Successfully completed ADT 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:

```
Performing abbreviated ADT analysis
Using USER-SELECTED center position : LAT: 22.93 LON: 66.04
Ocean basin automatically selected as ATLANTIC
Utilizing image data file /home/adt/mcidas/data/AREA2010
Tropical cyclone is over land
```

\*\*\*\*\*

```
                UW - CIMSS
            ADVANCED DVORAK TECHNIQUE
                ADT - Version 8.1.2
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 ADT ANALYSIS AVAILABLE
```

\*\*\*\*\*

### 4.) Automated Storm Center Determination

The ADT algorithm can be executed in a completely automated mode, utilizing an interpolated tropical cyclone forecast and three storm center determination analysis techniques to obtain a completely objective storm intensity estimate. See Section 5J for specific information on the formats allowed for the input forecast files.

The automated storm center location is determined using one of the following methods; polynomial interpolation of a forecast, linear extrapolation of previous history file positions, or a combination analysis approach using a Spiral Centering (SC) or eye Ring Fitting (RF) scheme to determine the best storm center location. 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, JTWC, or RSMC forecast (in ATCF, discussion/warning text, or ICAO format) 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 the Final T# value for the previous entry in the history file is greater than 3.5 and either the interpolation or extrapolation methods are successful, a full objective analysis search for the storm center location is performed using a combination of three image analysis routines. The first method is a Spiral Centering analysis centered at the

interpolation/extrapolation position. Once completed, an eye Ring Fitting analysis, which attempts to fit different size rings to cloud temperature gradients, is performed. Once both methods have been completed, an empirically based determination scheme selects the center point from the two methods (or a combination of the SC and RF routines). For a more detailed discussion of the entire auto-location methodology, refer to Section 5J2.

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. In this example a strong eye region was not found, but the Spiral Centering routine was able to find a center point successfully:

```
Accessing forecast file /home/adt/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
Utilizing image data file /home/adt/mcidas/data/AREA2030
Warmest pixel temperature of 12.6C at LAT: 18.34 LON: 87.55
Will utilize SPIRAL 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, will be used as the first guess for the three auto-centering techniques:

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

If both the polynomial interpolation and linear extrapolation schemes fail, the three auto-centering techniques will not be attempted and the ADT will quit and the user will be notified in the runtime message output section with the following message:

```
Error with autopositioning
Exiting ADT
```

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 ADT 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:

```
ADT has classified the EYE SCENE as EYE
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:

```
ADT has classified the EYE SCENE as EYE
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 PINHOLE
<user presses MIDDLE mouse button>
Change eye scene to LARGE
<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 ADT 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 ADT has the ability to utilize remotely stored and displayed McIDAS imagery. The ADT will assume the data is stored locally unless the keyword DATASET is used. The DATASET keyword utilizes two entries to describe the remote and local McIDAS ADDE dataset server names and images. The dataset names can be listed using a group/descriptor.position or alias.position format.

If a remotely stored McIDAS image is analyzed by the ADT, a subsection of the image displayed within the McIDAS image display window will be copied to the local machine. The keyword entry must describe the remote dataset server name within the first variable in the DATASET keyword, and it must be in ADDE format. The second variable in the DATASET keyword will be used to define the location and name where the image will be copied and should also be in McIDAS ADDE format. The size of the image copied will be 480x640 pixels and will be centered at the user-selected (manual mode; cursor position) or forecast interpolated (automated mode) storm center position. An example output text message when using the DATASET keyword follows:

```
DOWNLOADING REMOTE IMAGE EAST/NH.5 TO LOCAL IMAGE ALL.7777
WITHIN LOCAL DIRECTORY AT /home/adt/mcidas/data/AREA7777
Utilizing image data file /home/adt/mcidas/data/AREA7777
```

In the example above, the ADT 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 (alias) of "ALL" into position 7777. The local ADDE image in this example was saved in the /home/adt/mcidas/data directory in the file AREA7777. The directory where the ADT will copy the local image to is defined using the ODTDATA environmental parameter in the *adtenv* file. The ADT algorithm then utilized this image in the derivation of the intensity estimate. See Section N. for more information about the DATASET keyword using non-McIDAS compile option.

#### 7.) ATCF Record Output

An ATCF Fix File format record can be produced for each individual intensity estimate using the ATCF keyword. The output file location will be automatically determined using the ODTOUTPUT environmental variable. The file name will also be automatically determined using the date and time information of the image being investigated. See Section 4A1 for more information about the file naming structure. If an ATCF file is produced, an information message such as the following will be displayed:

WROTE ATCF OUTPUT TO FILE /home/adt/output/CIMSS\_DVTO\_199909102115\_08L\_FIX

Any or all records of a history file can be displayed in ATCF format, which is a format various TCFCs utilize and are accustomed to. The ADT utilizes the ATCF Version 3.3 “Fix File” data format and the “DVTO Fix Type” for its output ATCF files. Specific information about the ATCF and these formats can be found at:

[http://www.nrlmry.navy.mil/atcf\\_web/docs/database/new/database.html](http://www.nrlmry.navy.mil/atcf_web/docs/database/new/database.html)

This capability is considered part of the product tailoring effort that the GOES-R Program is undertaking independently of the GOES-R Ground Segment Project. The output can be displayed in the standard output window or sent to an output file. A sample ATCF format file is displayed below:

===== ADT-Version 8.1.2 =====

```
AL, 08, 199909081515, 20, DVTO, I, , 1581N, 5006W, , 3, 45, 2, 1000, 2, DVRK, , , , , , , , , , , NHC, AUT, I,
30, 2, 30, 6, T, 30, -158, -276, SHER, , GOES8, T,
AL, 08, 199909081615, 20, DVTO, I, , 1585N, 5027W, , 3, 45, 2, 1000, 2, DVRK, , , , , , , , , , , NHC, AUT, I,
30, 2, 30, 6, T, 31, -61, -288, SHER, R8, GOES8, T,
AL, 08, 199909081715, 20, DVTO, I, , 1590N, 5050W, , 2, 45, 2, 1000, 2, DVRK, , , , , , , , , , , NHC, AUT, I,
30, 2, 30, 6, T, 30, -55, -338, ICDO, R8, GOES8, T,
AL, 08, 199909081815, 20, DVTO, I, , 1596N, 5072W, , 2, 45, 2, 1000, 2, DVRK, , , , , , , , , , , NHC, AUT, I,
30, 2, 29, 6, T, 29, -199, -365, ICDO, R8, GOES8, T,
AL, 08, 199909081915, 20, DVTO, I, , 1602N, 5095W, , 3, 45, 2, 1000, 2, DVRK, , , , , , , , , , , NHC, AUT, I,
30, 2, 29, 6, T, 30, -415, -340, CBND, , GOES8, T,
AL, 08, 199909082015, 20, DVTO, I, , 1606N, 5118W, , 2, 45, 2, 1000, 2, DVRK, , , , , , , , , , , NHC, AUT, I,
30, 2, 29, 6, T, 29, -293, -354, ICDO, R8, GOES8, T,
AL, 08, 199909082115, 20, DVTO, I, , 1662N, 5175W, , 3, 45, 2, 1000, 2, DVRK, , , , , , , , , , , NHC, AUT, I,
30, 2, 29, 6, T, 30, -349, -451, CBND, R8, GOES8, T,
<records deleted from listing>
AL, 08, 199909101445, 20, DVTO, I, , 1956N, 5963W, , 2, 77, 2, 975, 2, DVRK, , , , , , , , , , , NHC, AUT, I,
45, 2, 45, 6, T, 45, -651, -685, CDO, , GOES8, T,
AL, 08, 199909101545, 20, DVTO, I, , 1950N, 5947W, , 2, 77, 2, 975, 2, DVRK, , , , , , , , , , , NHC, AUT, I,
45, 2, 45, 6, T, 45, -601, -648, EMBC, , GOES8, T,
AL, 08, 199909101645, 20, DVTO, I, , 1965N, 6004W, , 2, 77, 2, 975, 2, DVRK, , , , , , , , , , , NHC, AUT, I,
45, 2, 45, 6, T, 45, -655, -646, CDO, , GOES8, T,
AL, 08, 199909101745, 20, DVTO, I, , 1993N, 5988W, , 2, 77, 2, 976, 2, DVRK, , , , , , , , , , , NHC, AUT, I,
45, 2, 44, 6, T, 45, -664, -656, CDO, , GOES8, T,
AL, 08, 199909101815, 20, DVTO, I, , 1986N, 5984W, , 2, 77, 2, 975, 2, DVRK, , , , , , , , , , , NHC, AUT, I,
45, 2, 45, 6, T, 46, -612, -658, EMBC, , GOES8, T,
<records deleted from listing>
AL, 08, 199909131015, 20, DVTO, I, , 2400N, 7105W, , 1, 127, 1, 935, 1, DVRK, , , , , , , , , , , NHC, AUT, I,
65, 1, 65, 6, T, 65, 194, -704, EYE, , GOES8, T,
AL, 08, 199909131115, 20, DVTO, I, , 2404N, 7127W, , 1, 127, 1, 935, 1, DVRK, , , , , , , , , , , NHC, AUT, I,
65, 1, 64, 6, T, 64, 191, -698, EYE, , GOES8, T,
AL, 08, 199909131215, 20, DVTO, I, , 2407N, 7151W, , 1, 127, 1, 935, 1, DVRK, , , , , , , , , , , NHC, AUT, I,
65, 1, 64, 6, T, 63, 194, -683, EYE, R9, GOES8, T,
AL, 08, 199909131315, 20, DVTO, I, , 2412N, 7173W, , 1, 127, 1, 935, 1, DVRK, , , , , , , , , , , NHC, AUT, I,
65, 1, 63, 6, T, 61, 191, -658, EYE, R9, GOES8, T,
AL, 08, 199909131415, 20, DVTO, I, , 2417N, 7194W, , 1, 127, 1, 935, 1, DVRK, , , , , , , , , , , NHC, AUT, I,
65, 1, 62, 6, T, 61, 187, -654, EYE, R9, GOES8, T,
<records deleted from listing>
AL, 08, 199909152245, 20, DVTO, I, , 3179N, 7841W, , 1, 109, 1, 960, 1, DVRK, , , , , , , , , , , NHC, AUT, I,
58, 1, 54, 6, T, 56, 28, -607, EYE, R9, GOES8, T,
AL, 08, 199909152345, 20, DVTO, I, , 3209N, 7837W, , 1, 109, 1, 960, 1, DVRK, , , , , , , , , , , NHC, AUT, I,
58, 1, 54, 6, T, 56, 20, -602, EYE, R9, GOES8, T,
AL, 08, 199909160015, 20, DVTO, I, , 3234N, 7833W, , 1, 109, 1, 960, 1, DVRK, , , , , , , , , , , NHC, AUT, I,
58, 1, 53, 6, T, 49, -77, -608, EYE, R9, GOES8, T,
AL, 08, 199909160145, 20, DVTO, I, , 3279N, 7826W, , 1, 109, 1, 961, 1, DVRK, , , , , , , , , , , NHC, AUT, I,
58, 1, 51, 6, T, 48, -72, -602, EYE, R9, GOES8, T,
```

## E.) History File Output

### 1.) Text Output

#### a.) Original Format Listing

A listing of the history file contents can be displayed within the McIDAS text display window or written to an output file using the LIST parameter with the DATE and OUTPUT keywords. An example of an original format listing is provided below:

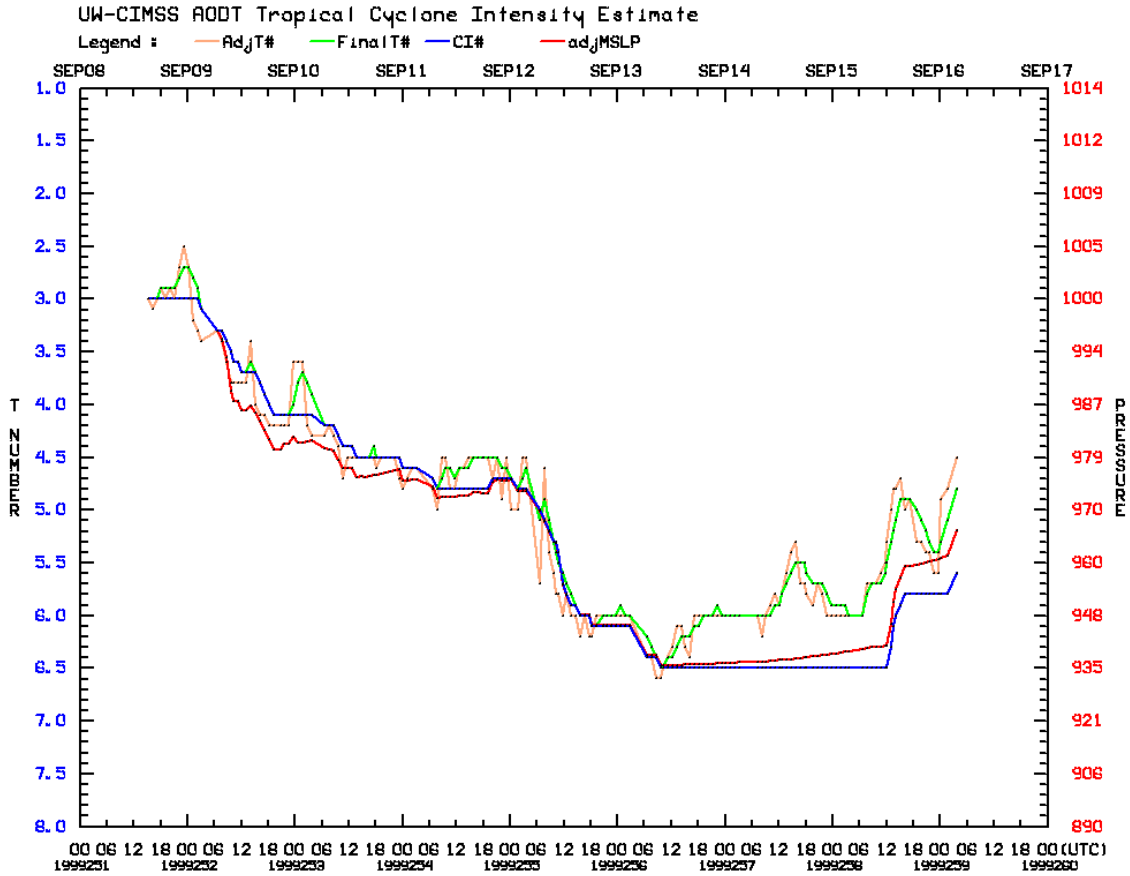
```
==== ADT-Version 8.1.2 =====
-----Intensity----- -Tno Values-- ---Tno/CI Rules--- --Temperature--
Date      Time      Final/MSLP/BiasAdj/(kts)  Pnl Adj Inl  Cnstrnt  Wkng Rpd  Cntr  Mean  Scene  EstRMW  MW  Storm Location  Fix  Mthd  Comments
(UTC)    CI      MSLP /BiasAdj/(kts)    Tno Raw Raw  Limit  Flag Wkng Region  Cloud Type (km)  Score  Lat  Lon
1999SEP08 151500  3.0 1000.0/ +0.0 / 45.0  3.0 3.0 3.0  NO LIMIT  OFF  OFF  -15.86 -27.61 SHEAR  N/A -0.00 15.81 50.06
1999SEP08 161500  3.0 1000.0/ +0.0 / 45.0  3.0 3.0 3.1  0.1T/hour  OFF  OFF  -6.16 -28.89 SHEAR  N/A -0.00 15.86 50.28 FCST
1999SEP08 171500  3.0 1000.0/ +0.0 / 45.0  3.0 3.0 2.5  0.1T/hour  OFF  OFF  -5.56 -33.82 IRRCD0 N/A -0.00 15.91 50.51 FCST
1999SEP08 181500  3.0 1000.0/ +0.0 / 45.0  2.9 2.9 2.5  0.1T/hour  WKN  OFF  -19.96 -36.52 IRRCD0 N/A -0.00 15.96 50.73 FCST
1999SEP08 191500  3.0 1000.0/ +0.0 / 45.0  2.9 3.0 3.0  NO LIMIT  WKN  OFF  -41.56 -34.03 CRVBND N/A -0.00 16.02 50.96 FCST
1999SEP08 201500  3.0 1000.0/ +0.0 / 45.0  2.9 2.9 2.5  0.1T/hour  WKN  OFF  -29.36 -35.45 IRRCD0 N/A -0.00 16.07 51.18 FCST
1999SEP08 211500  3.0 1000.0/ +0.0 / 45.0  2.9 3.0 3.7  0.1T/hour  WKN  OFF  -34.96 -45.12 CRVBND N/A -0.00 16.62 51.76 FCST
1999SEP08 221500  3.0 1000.0/ +0.0 / 45.0  2.8 2.7 2.7  NO LIMIT  WKN  OFF  -15.16 -42.83 CRVBND N/A -0.00 16.71 52.01 FCST
1999SEP08 231500  3.0 1000.0/ +0.0 / 45.0  2.7 2.5 2.2  0.5T/6hr  WKN  OFF  -0.66 -41.90 CRVBND N/A -0.00 16.80 52.26 FCST
1999SEP09 001500  3.0 1000.0/ +0.0 / 45.0  2.7 2.7 2.7  NO LIMIT  WKN  OFF  -14.16 -42.70 CRVBND N/A  N/A 16.89 52.50 FCST
1999SEP09 011500  3.0 1000.0/ +0.0 / 45.0  2.8 3.2 4.1  0.5T/hour  WKN  OFF  -68.96 -44.97 UNIFRM N/A  N/A 16.98 52.73 FCST
1999SEP09 021500  3.0 1000.0/ +0.0 / 45.0  2.9 3.3 4.3  0.5T/hour  WKN  OFF  -66.06 -49.50 UNIFRM N/A  N/A 17.06 52.96 FCST
1999SEP09 031500  3.1 998.4/ +0.0 / 47.0  3.1 3.4 4.5  0.5T/hour  OFF  OFF  -65.16 -56.73 UNIFRM N/A  N/A 16.71 53.66 FCST
1999SEP09 064600  3.3 996.4/ -0.0 / 51.0  3.3 3.3 4.5  0.5T/6hr  OFF  OFF  -60.16 -69.20 UNIFRM N/A  N/A 16.94 54.46 FCST
<records deleted from listings>
1999SEP11 031500  4.6 975.2/ -2.0 / 79.6  4.6 4.6 4.6  NO LIMIT  OFF  OFF  -58.76 -71.83 UNIFRM N/A 15.98 20.97 60.56 SPRL
1999SEP11 064500  4.7 974.0/ -1.5 / 82.2  4.7 4.8 4.8  NO LIMIT  OFF  OFF  -47.06 -68.08 EMBC  N/A 15.98 21.66 60.42 SPRL
1999SEP11 074500  4.8 972.0/ -1.6 / 84.8  4.8 5.0 5.0  NO LIMIT  OFF  OFF  -59.86 -70.36 EMBC  N/A 14.99 21.49 61.20 SPRL
1999SEP11 084500  4.8 972.2/ -1.4 / 84.8  4.7 4.5 4.5  NO LIMIT  WKN  OFF  -46.46 -69.65 UNIFRM N/A 14.99 21.76 61.17 SPRL
1999SEP11 094500  4.8 972.1/ -1.5 / 84.8  4.6 4.5 4.5  NO LIMIT  WKN  OFF  -62.46 -69.24 UNIFRM N/A 14.99 21.61 61.52 SPRL
1999SEP11 104500  4.8 972.2/ -1.4 / 84.8  4.6 4.8 4.8  NO LIMIT  WKN  OFF  -64.36 -68.35 EMBC  N/A 14.99 21.69 61.53 SPRL
1999SEP11 114500  4.8 972.2/ -1.4 / 84.8  4.7 4.8 4.8  NO LIMIT  WKN  OFF  -60.96 -67.65 EMBC  N/A 19.09 21.77 61.65 SPRL
<records deleted from listings>
1999SEP12 094500  5.3 963.9/ -0.1 / 97.2  5.3 5.6 6.4  0.5T/hour  OFF  OFF  0.74 -69.96 EYE  22 IR 55.77 23.15 65.87 COMBO
1999SEP12 101500  5.3 963.8/ +0.2 / 97.2  5.4 5.8 6.3  0.5T/hour  OFF  OFF  9.04 -71.14 EYE  26 IR 55.77 23.05 65.86 COMBO
1999SEP12 104500  5.4 961.9/ -0.1 / 99.6  5.5 5.8 6.3  0.5T/hour  OFF  OFF  12.44 -68.40 EYE  25 IR 55.77 23.15 66.16 COMBO
1999SEP12 114500  5.7 954.9/ -0.3 /107.2  5.6 6.0 7.0  0.5T/hour  OFF  OFF  11.54 -73.20 EYE  23 IR 68.92 22.96 66.13 COMBO
1999SEP12 124500  5.8 952.5/ -0.3 /109.8  5.7 5.8 5.8  NO LIMIT  OFF  OFF  -0.06 -69.34 EYE  30 IR 69.22 22.96 66.21 COMBO
1999SEP12 134500  5.9 950.4/ -0.0 /112.4  5.8 6.0 6.0  NO LIMIT  OFF  OFF  0.14 -67.35 EYE  33 IR 69.22 23.27 66.51 COMBO
1999SEP12 144500  5.9 950.3/ -0.1 /112.4  5.9 6.0 6.0  NO LIMIT  OFF  OFF  12.94 -66.10 EYE  32 IR 69.22 23.19 66.70 COMBO
1999SEP12 154500  6.0 948.1/ +0.1 /115.0  6.0 6.2 6.2  NO LIMIT  OFF  OFF  7.24 -66.61 EYE  26 IR 69.22 23.36 66.76 COMBO
1999SEP12 164500  6.0 948.1/ +0.1 /115.0  6.0 6.0 6.0  NO LIMIT  OFF  OFF  12.14 -67.45 EYE  34 IR 69.22 23.38 67.13 COMBO
1999SEP12 174500  6.0 948.2/ +0.2 /115.0  6.0 6.2 6.2  NO LIMIT  OFF  OFF  13.64 -67.15 EYE  24 IR 55.12 23.50 67.28 COMBO
1999SEP12 181500  6.1 945.5/ +0.1 /117.4  6.1 6.2 6.2  NO LIMIT  OFF  OFF  11.14 -66.92 EYE  30 IR 55.12 23.40 67.58 COMBO
1999SEP12 191500  6.1 945.6/ +0.2 /117.4  6.1 6.0 6.0  NO LIMIT  ON  OFF  16.54 -68.66 EYE  34 IR 55.12 23.53 67.63 COMBO
1999SEP12 204500  6.1 945.7/ +0.3 /117.4  6.0 6.0 6.0  NO LIMIT  ON  OFF  16.74 -72.05 EYE  34 IR 55.12 23.66 68.00 COMBO
1999SEP12 214500  6.1 945.7/ +0.2 /117.4  6.0 6.0 6.0  NO LIMIT  ON  OFF  19.14 -67.50 EYE  36 IR 52.44 23.58 68.19 COMBO
1999SEP12 224500  6.1 945.6/ +0.2 /117.4  6.0 6.0 6.0  NO LIMIT  ON  OFF  19.24 -70.46 EYE  35 IR 52.44 23.52 68.29 COMBO
1999SEP12 234500  6.1 945.6/ +0.2 /117.4  6.0 6.0 6.0  NO LIMIT  ON  OFF  19.24 -69.12 EYE  33 IR 52.44 23.57 68.61 COMBO
1999SEP13 004500  6.1 945.7/ +0.3 /117.4  6.0 6.0 6.0  NO LIMIT  ON  OFF  19.74 -71.65 EYE  33 IR 51.12 23.61 68.82 COMBO
1999SEP13 014500  6.1 945.7/ +0.3 /117.4  6.0 6.0 6.0  NO LIMIT  ON  OFF  20.54 -68.90 EYE  34 IR 51.12 23.62 69.03 COMBO
1999SEP13 024500  6.1 945.7/ +0.3 /117.4  6.0 6.0 6.0  NO LIMIT  ON  OFF  21.44 -69.21 EYE  33 IR 51.12 23.60 69.25 COMBO
1999SEP13 064500  6.4 938.1/ +0.5 /124.6  6.2 6.4 6.4  NO LIMIT  OFF  OFF  19.14 -69.40 EYE  28 IR 51.12 23.86 70.09 COMBO
1999SEP13 074500  6.4 938.1/ +0.5 /124.6  6.3 6.4 6.4  NO LIMIT  OFF  OFF  18.84 -69.23 EYE  29 IR 51.12 23.91 70.31 COMBO
1999SEP13 084500  6.4 938.2/ +0.6 /124.6  6.4 6.6 6.6  NO LIMIT  OFF  OFF  19.44 -70.73 EYE  28 IR 48.45 23.97 70.54 COMBO
1999SEP13 094500  6.5 935.6/ +0.6 /127.0  6.5 6.6 6.6  NO LIMIT  OFF  OFF  19.34 -71.15 EYE  28 IR 48.45 23.98 70.83 COMBO
1999SEP13 101500  6.5 935.6/ +0.6 /127.0  6.5 6.5 6.5  NO LIMIT  OFF  OFF  19.44 -70.40 EYE  28 IR 42.44 24.00 71.05 COMBO
1999SEP13 111500  6.5 935.7/ +0.7 /127.0  6.4 6.4 6.4  NO LIMIT  OFF  OFF  19.14 -69.82 EYE  27 IR 42.44 24.04 71.28 COMBO
1999SEP13 121500  6.5 935.7/ +0.7 /127.0  6.4 6.3 6.3  NO LIMIT  ON  OFF  19.44 -68.37 EYE  29 IR 42.44 24.08 71.51 COMBO
<records deleted from listings>
1999SEP14 124500  6.5 937.0/ +2.0 /127.0  5.8 5.8 5.8  NO LIMIT  ON  OFF  15.04 -62.88 EYE  30 IR 75.44 25.55 76.20 COMBO
1999SEP14 134500  6.5 937.1/ +2.1 /127.0  5.7 5.6 5.6  NO LIMIT  ON  OFF  13.34 -60.23 EYE  33 IR 75.44 25.66 76.38 COMBO
1999SEP14 144500  6.5 937.2/ +2.2 /127.0  5.6 5.4 5.4  NO LIMIT  ON  OFF  13.84 -58.17 EYE  31 IR 74.36 25.78 76.56 COMBO
1999SEP14 154500  6.5 937.3/ +2.3 /127.0  5.5 5.3 5.3  NO LIMIT  ON  OFF  14.14 -57.54 EYE  36 IR 74.36 25.91 76.68 COMBO
1999SEP14 164500  6.5 937.5/ +2.5 /127.0  5.5 5.7 5.7  NO LIMIT  ON  OFF  14.34 -61.15 EYE  29 IR 74.36 26.08 76.78 COMBO
1999SEP14 174500  6.5 937.5/ +2.5 /127.0  5.5 5.7 5.7  NO LIMIT  ON  OFF  11.14 -61.61 EYE  26 IR 74.36 26.16 76.87 COMBO
1999SEP14 181500  6.5 937.7/ +2.7 /127.0  5.6 5.8 5.8  NO LIMIT  ON  OFF  8.64 -62.38 EYE  28 IR 74.36 26.31 76.97 COMBO
1999SEP14 194500  6.5 937.9/ +2.9 /127.0  5.7 5.9 5.9  NO LIMIT  ON  OFF  9.84 -63.94 EYE  28 IR 74.36 26.54 77.03 COMBO
1999SEP14 204500  6.5 938.0/ +3.0 /127.0  5.7 5.7 5.7  NO LIMIT  ON  OFF  10.24 -61.50 EYE  31 IR 74.36 26.73 77.11 COMBO
1999SEP14 214500  6.5 938.2/ +3.2 /127.0  5.7 5.8 5.8  NO LIMIT  ON  OFF  10.44 -62.85 EYE  36 IR 74.36 26.89 77.31 COMBO
1999SEP14 224500  6.5 938.3/ +3.3 /127.0  5.8 6.0 6.0  NO LIMIT  ON  OFF  11.04 -64.52 EYE  37 IR 74.36 27.06 77.31 COMBO
1999SEP14 234500  6.5 938.6/ +3.6 /127.0  5.9 6.0 6.0  NO LIMIT  ON  OFF  12.54 -65.74 EYE  36 IR 74.36 27.33 77.42 COMBO
1999SEP15 004500  6.5 938.6/ +3.6 /127.0  6.0 6.0 6.0  NO LIMIT  ON  OFF  13.04 -65.17 EYE  33 IR 74.36 27.41 77.54 COMBO
1999SEP15 014500  6.5 938.9/ +3.9 /127.0  6.0 6.0 6.0  NO LIMIT  ON  OFF  12.94 -65.93 EYE  32 IR 74.36 27.70 77.66 COMBO
1999SEP15 024500  6.5 939.1/ +4.1 /127.0  6.0 6.0 6.0  NO LIMIT  ON  OFF  12.84 -67.52 EYE  33 IR 72.23 27.89 77.89 COMBO
1999SEP15 034500  6.5 939.1/ +4.1 /127.0  6.0 6.0 6.0  NO LIMIT  ON  OFF  13.44 -68.25 EYE  33 IR 72.23 27.95 78.08 COMBO
1999SEP15 064500  6.5 939.7/ +4.7 /127.0  6.0 6.0 6.0  NO LIMIT  ON  OFF  10.74 -64.22 EYE  31 IR 72.23 28.56 78.29 COMBO
1999SEP15 074500  6.5 939.9/ +4.9 /127.0  5.8 5.7 5.7  NO LIMIT  ON  OFF  12.54 -61.87 EYE  34 IR 72.23 28.80 78.64 COMBO
1999SEP15 084500  6.5 940.1/ +5.1 /127.0  5.7 5.7 5.7  NO LIMIT  ON  OFF  11.04 -61.84 EYE  31 IR 72.23 29.05 78.64 COMBO
1999SEP15 094500  6.5 940.1/ +5.1 /127.0  5.7 5.7 5.7  NO LIMIT  ON  OFF  11.54 -61.29 EYE  35 IR 72.23 29.08 78.68 COMBO
1999SEP15 104500  6.5 940.3/ +5.3 /127.0  5.7 5.6 5.6  NO LIMIT  ON  OFF  10.24 -60.71 EYE  34 IR 68.43 29.26 78.62 COMBO
1999SEP15 114500  6.5 940.4/ +5.4 /127.0  5.6 5.5 5.5  NO LIMIT  ON  OFF  11.54 -59.24 EYE  35 IR 68.43 29.44 78.68 COMBO
1999SEP15 121500  6.5 940.5/ +5.5 /127.0  5.5 5.3 5.3  NO LIMIT  ON  OFF  12.14 -57.99 EYE  40 IR 67.44 29.53 78.82 COMBO
1999SEP15 131500  6.3 945.9/ +5.7 /122.2  5.3 5.0 4.9  0.5T/hour  ON  OFF  11.54 -51.90 EYE  38 IR 67.44 29.72 78.87 COMBO
1999SEP15 134500  6.1 951.2/ +5.8 /117.4  5.2 4.8 4.8  NO LIMIT  ON  OFF  11.94 -49.46 EYE  37 IR 67.44 29.81 78.89 COMBO
1999SEP15 141500  6.0 953.9/ +5.9 /115.0  5.1 4.8 4.8  NO LIMIT  ON  OFF  11.04 -50.45 EYE  42 IR 67.44 30.01 78.91 COMBO
1999SEP15 151500  5.9 956.5/ +6.1 /112.4  4.9 4.7 4.7  NO LIMIT  ON  OFF  9.44 -47.91 EYE  40 IR 34.33 30.22 78.86 COMBO
1999SEP15 161500  5.8 959.1/ +6.3 /109.8  4.9 5.0 5.0  NO LIMIT  ON  OFF  10.84 -54.18 EYE  34 IR 34.33 30.38 78.98 COMBO
1999SEP15 171500  5.8 959.2/ +6.4 /109.8  4.9 4.9 4.9  NO LIMIT  ON  OFF  10.84 -51.62 EYE  32 IR 34.33 30.54 79.08 COMBO
1999SEP15 184500  5.8 959.5/ +6.7 /109.8  5.0 5.3 5.3  NO LIMIT  ON  OFF  12.04 -57.59 EYE  31 IR 32.11 30.83 78.86 COMBO
1999SEP15 194500  5.8 959.8/ +7.0 /109.8  5.1 5.3 5.3  NO LIMIT  ON  OFF  6.94 -57.76 EYE  32 IR 32.11 31.19 78.81 COMBO
1999SEP15 204500  5.8 959.9/ +7.1 /109.8  5.2 5.4 5.4  NO LIMIT  ON  OFF  9.94 -58.59 EYE  32 IR 25.55 31.34 78.75 COMBO
1999SEP15 214500  5.8 960.1/ +7.3 /109.8  5.3 5.4 5.4  NO LIMIT  ON  OFF  1.14 -58.88 EYE  30 IR 25.55 31.59 78.68 COMBO
1999SEP15 224500  5.7 960.3/ +7.5 /109.8  5.4 5.6 5.6  NO LIMIT  ON  OFF  2.84 -60.75 EYE  30 IR 25.55 31.80 78.41 COMBO
1999SEP15 234500  5.8 960.6/ +7.8 /109.8  5.4 5.6 5.6  NO LIMIT  ON  OFF  2.04 -60.25 EYE  35 IR 21.52 32.10 78.37 COMBO
1999SEP16 001500  5.8 960.8/ +8.0 /109.8  5.3 4.9 4.8  0.5T/hour  ON  OFF  -7.76 -60.86 EYE  N/A 21.52 32.35 78.34 COMBO
1999SEP16 014500  5.8 961.2/ +8.4 /109.8  5.1 4.8 4.8  NO LIMIT  ON  OFF  -7.26 -60.25 EYE  N/A 11.44 32.79 78.26 COMBO
1999SEP16 034500  5.6 966.2/ +8.6 /104.6  4.8 4.5 4.5  NO LIMIT  ON  OFF  -20.16 -54.90 EYE  N/A 11.44 32.98 78.14 N/A
1999SEP16 074500  0.0 0.0/ +0.0 / 0.0  0.0 0.0 0.0  N/A  N/A 99.99 99.99 LAND  N/A 12.54 34.62 77.57 N/A
Utilizing history file /home/adt/history/FLOYD.ODT
Successfully completed listing
```





## 2.) Graphical Output

A time series graph of intensity estimates and environmental temperature values stored within history files can be displayed within the McIDAS image/graphics window. Graphic capabilities are controlled using the ADT parameter PLOT along with the keywords COLOR, DOMAIN, WIND, and DATE.



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Figure 1: Example ADT graphical time-series output of a history file.

In the example shown in Figure 1, the CI#, 3-hour averaged Final T# (FinalT#), Adjusted Raw T# (AdjT#), and the latitude bias-adjusted MSLP value (adjMSLP) are all displayed. Any combination of the seven intensity estimate values can be plotted using the COLOR 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 legend of the displayed variables presented along the top of the graphics window. The various environmental temperature values calculated and used by the ADT in the intensity estimate calculations can also be graphed.

### **3.) Background Information**

#### **A.) Land Flag**

TC land interaction will be determined utilizing the high-resolution digital elevation map *digilev\_hires\_le.map* provided in the ADT package. The file supplied with the ADT package uses an 8-km surface elevation map, adopted from the GEOCAT library, which was originally derived from the USGS GTOPO30 dataset available on the USGS website at: <http://edcdaac.usgs.gov/gtopo30/gtopo30.html>.

To determine if a storm is over land, the following logic is utilized. If a 10 X 10 pixel grid box, centered at the current storm location, possesses 85% or more (85 out of 100 pixels) of its area as a land feature, 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. Typically the automated ADT will continue to attempt intensity estimates while the storm is over land until either the official TCFC forecasts are discontinued or the TC reemerges over the open ocean again and has not dissipated while over the land surface. The date and time(s), latitude, longitude, land flag, internal ADT satellite ID, and automated centering method values will contain their assigned values, however the values for the intensity estimates and the remaining parameters will be assigned a “missing value”. All values will contain zero for their missing values except the four temperature values (99.50), the radius of maximum wind value (-99.5), and microwave eye score value (-99.5). 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). It is assumed that the entire 10 X 10 grid box will fall within the image being examined.

#### **B.) Scene Classification**

The original “decision tree” methodology of scene type determination patterned after the subjective Dvorak Technique has been replaced with a “scene score” determination scheme. This methodology helps alleviate the occasional rapid and unrealistic scene type variability in the ADT output between consecutive image analyses by replacing the “branches” in the decision tree methodology with natural threshold divisions (scores).

The scene score is a sum of selected environmental parameters measured from the satellite imagery for both the eye (when an eye is present, 0-24 km from the determined center position) and cloud region (24-136km from the center position) of the TC. These scores are used to objectively determine the storm scene type. Each parameter in the scene score derivation was originally a “branch” in the initial decision-tree methodology and is weighted by an empirically-determined value, shown in the equations listed below, chosen to closely mirror the influence of the parameter in the original determination methodology.

The eye region scene score is derived with the following equation:

$$\text{Eye score} = \text{FFT}_{\text{Eye}} + \text{BD}_{\text{Eye}} + \text{PrevEye} + \Delta\text{T}_{\text{Eye-Cloud}} + \text{Adj}_{\text{T-12hr}}$$

$\text{FFT}_{\text{Eye}}$  : Number of harmonics in eye region Fast Fourier Transform  
 $1.0 - ((\text{EyeHarmonicValue} - 2) * 0.1)$

$\text{BD}_{\text{Eye}}$  : BD-enhancement category of eye region temperature  
 $-1.0 * (\text{EyeBDCat} * 0.5)$

$\text{PrevEye}$  : Adjustment for previous record eye scene  
 $+0.25$

$\Delta\text{T}_{\text{Eye-Cloud}}$  : Difference between eye and cloud region BD-enh. categories  
 $(0.25 * (\text{CloudBDCat} - \text{EyeBDCat})) +$   
 $(0.50 * (\text{CloudCWBDCat} - \text{EyeBDCat}))$

$\text{Adj}_{\text{T-12hr}}$  : Adjustment for 12-hour previous record T# strength  
 $\text{MAX}(-1.0, \text{T\#Value}_{\text{T-12hrs}} - 4.5)$

The cloud region scene score is derived with the following equation:

$$\text{Cloud score} = \text{BD}_{\text{CloudCW}} + \text{BD}_{\text{Cloud}} + \text{FFT}_{\text{Cloud}} + \text{PrevScene} + \text{Adj}_{\text{T-12hr}}$$

$\text{BD}_{\text{CloudCW}}$  : BD-enh. category of “coldest-warmest” cloud region temp.  
 $\text{CloudCWBDCat} * 0.25$

$\text{BD}_{\text{Cloud}}$  : BD-enhancement category of eye region temperature  
 $\text{CloudBDCat} * 0.25$

$\text{FFT}_{\text{Cloud}}$  : Adj. based on harmonics in cloud region Fast Fourier Trans.  
 $\text{If}(\text{CloudHarmonicValue} \leq 2) \text{value} = \text{MIN}(1.5, \text{BD}_{\text{CloudCW}} * 0.25)$

$\text{PrevScene}$  : Adjustment for previous record cloud scene  
 $-0.50$  if curved band or shear scene

$\text{Adj}_{\text{T-12hr}}$  : Adjustment for 12-hour previous record T# strength  
 $\text{MIN}(1.0, \text{T\#Value}_{\text{T-12hrs}} - 2.5)$

More specific definitions and measurement details of utilized temperature categories and values, such as the “coldest-warmest” cloud region temperature value and BD enhancement category, are discussed here and in the following sections of this document.

- EyeHarmonicValue: Count of the number of times the harmonic values in the Fast Fourier Transform analysis increases over the previous value. Each harmonic value corresponds to a single cosine wave, at different frequencies, used to approximate the temperature histogram for the image region being investigated. More changes in the values indicate more harmonics and a less uniform temperature scene in the eye region.
- CloudHarmonicValue: Same as EyeHarmonicValue, but with cloud region.
- EyeBDCat: Gray scale category within the BD-curve enhancement of the eye region temperature value. The BD-curve enhancement is shown in Figure 3, with Table 1 listing the temperature breakdown values for each gray scale range.
- CloudBDCat: Same as EyeBDCat, but with cloud region temperature value.
- CloudCWBDcat: Same as EyeBDCat, but with cloud region “coldest warmest” temperature value.
- T#Value<sub>T-12hrs</sub>: Final T# value at time 12 hours previous of current time.

The Fast Fourier Transform (FFT) analysis is a well established and documented mathematical function to determine the variability of a “signal” over its range of values. In this case, the signal is the temperature histogram over a set temperature range. The FFT attempts to approximate this signal using a combination of a number of cosine waves with different frequency. A histogram with containing a large number of values in a small number of bins can be estimated with a low frequency cosine wave, while more chaotic histograms with more temperature value bins containing data can be approximated by the combination of several cosine waves at different frequencies.

Additional environmental variables are used in several specific checks to further refine eye and cloud scene types after the individual scene score values have been derived, such as the cloud symmetry value (discussed in Section 5H) to help determine an ‘Irregular CDO’ scene, or eye radius size to define a ‘Large Eye’ scene.

The three eye region scene types and five cloud region scene types are described below:

<u>Eye Region Scene Type</u>	<u>Description</u>
EYE	Any eye type (clear, ragged, and obscured)
PINHOLE	Very small eye/pronounced warm spot
LARGE	Clear, well-defined eye with radius $\geq 38$ km
<u>Cloud Region 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

## Examples of ADT Eye Region Scene Types

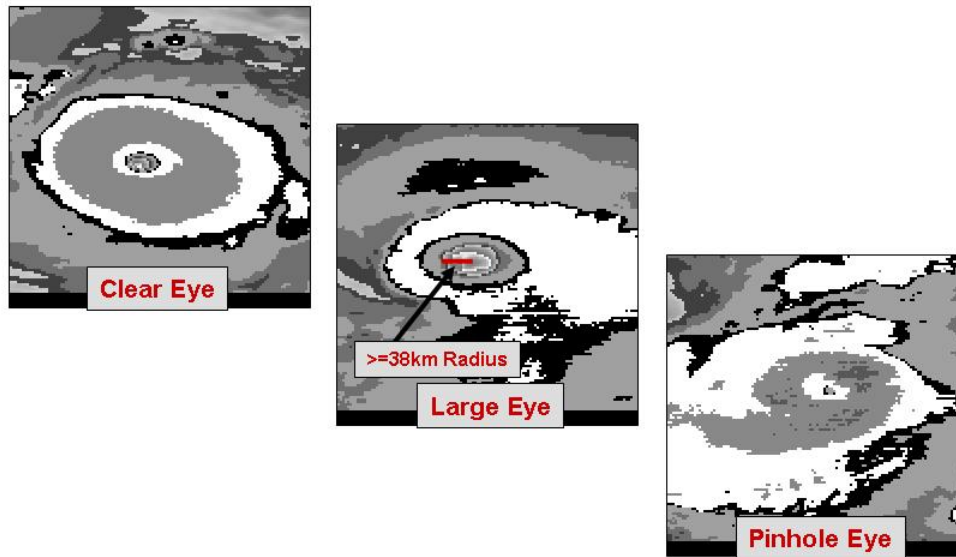


Figure 2: Examples of three ADT Eye Region scene types.

Examples of the three eye scene types are shown in Figure 2. Eye size is derived by measuring the distance across the eye between BD-curve “Dark Gray” temperature range edges (Figure 3). Table 1 lists the temperature ranges and the corresponding “gray scale” color values. Distances are measured at 90° angles outward from the auto-selected center location and are averaged to give an approximate eye size.

Temperature Range	Gray Scale Category/Comment
> +9°C	No enhancement – Low clouds
+9°C to -30°C	Off White – Cirrus Outflow Pattern
-30°C to -42°C	Dark Gray
-42°C to -54°C	Medium Gray
-54°C to -64°C	Light Gray
-64°C to -70°C	Black
-70°C to -76°C	White
-76°C to -80°C	Top Medium Gray
< -80°C	Top Dark Gray

Table 1: BD-curve enhancement temperature and corresponding gray scale values.

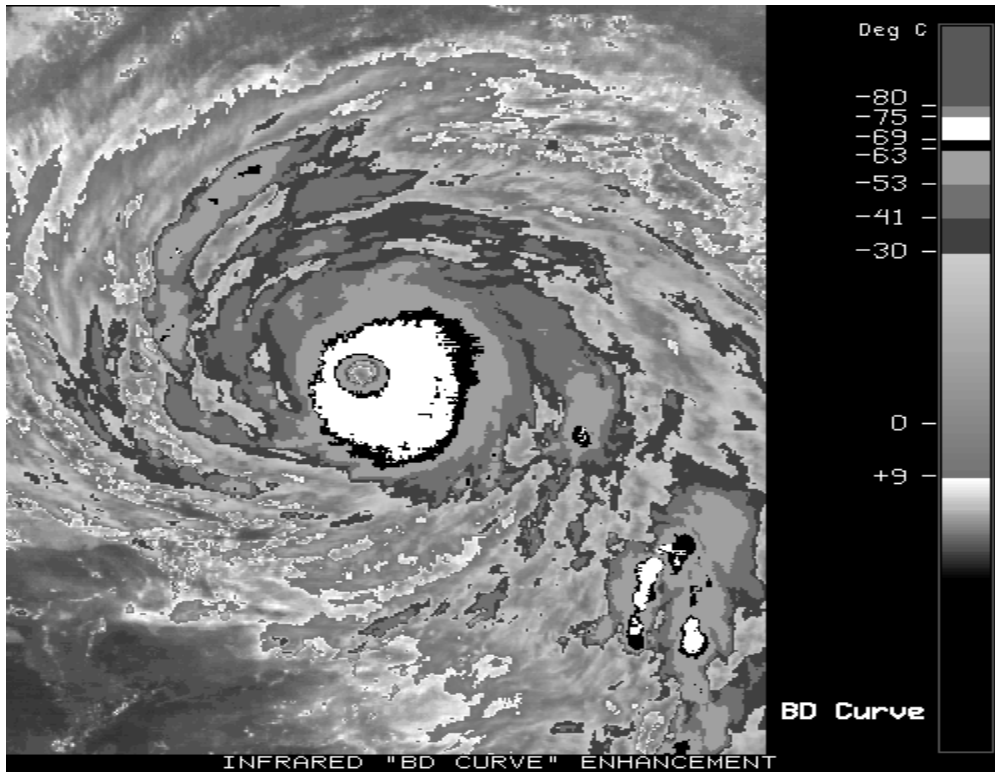


Figure 3: BD-curve Enhancement displayed on a longwave IR window channel image.

### Examples of ADT Cloud Region Scene Types

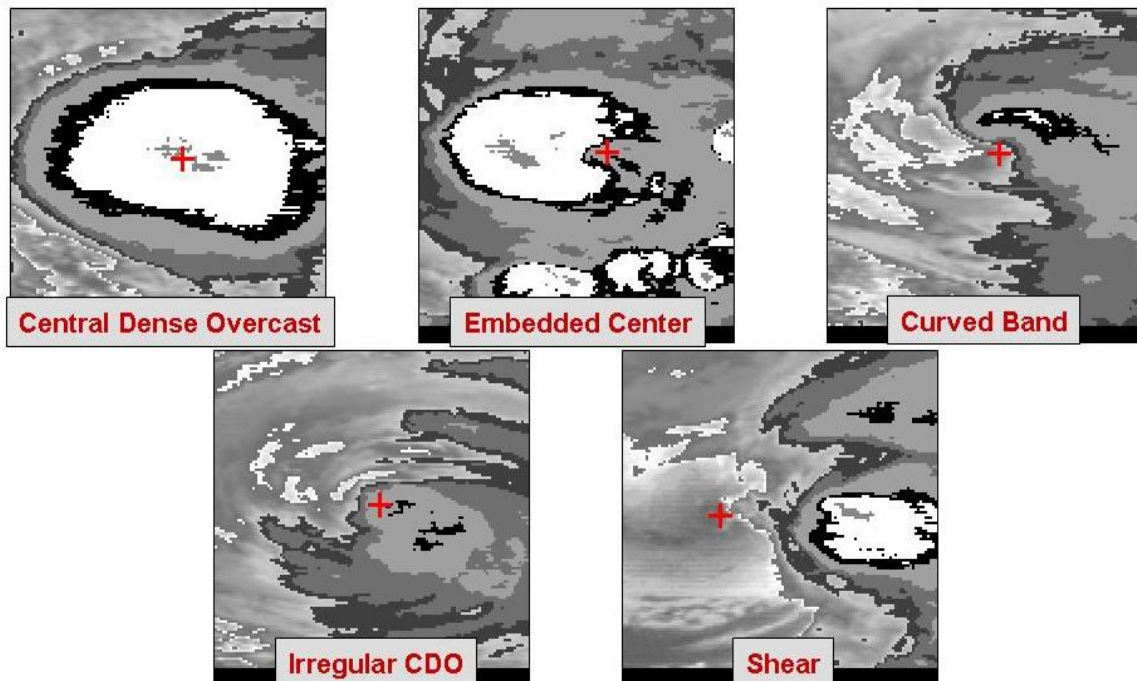


Figure 4: Examples of the five ADT Cloud Region scene types.

Examples of the five cloud region scene types are shown in Figure 4. If the cloud scene is determined 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 (described in greater detail in Section 5H2). The amount of curvature depends on the BD-Curve Gray Scale (Table 1) being used. The algorithm will first target the “Light Gray” gray scale range to define the convective region of the curved band area. If this temperature region is devoid of significant activity or completely surrounds the selected storm center position in this gray scale range, analysis of warmer/colder ranges BD-curve temperature levels will be performed. Once a Curved Band gray scale and curvature amount at the provided storm center location is determined, an additional search will be performed to look for another possible storm center location that yields a greater amount of curvature in the cloud region, and thus a higher intensity estimate. This maximum curvature search value is supplied only as a reference to the ADT user and is not utilized in any way by the ADT algorithm or stored in the history file for future use/reference. It is supplied at the request of ADT users to help assess the accuracy of the curved band intensity calculation and to aid TCFC forecasters in the TC storm center determination process for possible storm center location adjustment. The location and associated amount of maximum cloud curvature can vary greatly from image to image, so interpretation of its value is left to the user to assess.

Once the scene type has been determined the intensity estimate for the derived scene type will be calculated using various environmental values such as the eye and surrounding cloud top temperatures, convective symmetry, eye and cloud region sizes, and other measured or derived values stored in the history file using various methods described in the following sections.

### **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. The CloudCW value is still utilized within the ADT scene selection process as described above, so the calculation of the value still remains within the ADT algorithm and the derived parameters are saved in the ADT history files.

#### **D.) Time Averaging Scheme**

Time-averaging of ADT intensity outputs is employed to smooth the “noise” inherent in individual estimates, which as mentioned above can result from objectively changing scene types and crossing value thresholds in consecutive analysis times. The time-averaging scheme uses the current Raw T# and all available Raw T# values obtained within the last 3 hours. The time-average is a straight non-weighted mean of these estimates. The 3-hr time window for the averaging is based on empirical analysis noted above, and user preference input. The ADT Final T# at any current analysis time reflects this time-averaged value.

#### **E.) Weakening Flag (Dvorak EIR Rule 9)**

The ADT Weakening Flag is modeled after the STD EIR Rule 9 (Dvorak, 1984), but also utilizes a modification to the original STD EIR Rule 9 that is applied at some operational TC forecasting centers. The “original” STD EIR Rule 9 rule is used in the determination of the CI# after a storm has reached its maximum intensity and is

weakening during the dissipation stage of the TC lifecycle (e.g. extra-tropical transition, moving over cold waters, interacting with severe atmospheric shear, etc). The EIR Rule 9 will hold the CI# at values 0.5 to 1.0 higher in value than the current Final T# (Raw T# after adjustments and time-averaging). Subjective application of this rule (e.g. how and when to apply it) varies between forecasters and is the focal point of much debate. The value of 1.0 is utilized in the ADT since it provides the most statistically accurate estimates of storm intensity when compared with actual reconnaissance observations.

The “modified” Weakening Flag rule logic affects the calculation of the CI# during the formation/strengthening stage of the storm prior to maximum TC intensity (where the “original” Rule 9 rule will be invoked) as follows: “Always hold the CI# to the highest Final T# over the last 6/12 hours, but never greater than 1.0, in all cases”. This rule will hold the ADT CI# equal to the highest Final T# obtained during the previous 12 hours in all ocean basins EXCEPT in the East Pacific where it will be held to the highest value over the past 6 hours. For example, if the Final T# value had previously obtained a value of 5.2 in an Atlantic storm, but now is decreasing, the CI# value will be held at 5.2 for up to 12 hours or until the Final T# falls below 4.2. This rule is dis-invoked if the TC re-strengthens to the held CI# and greater intensity values.

#### **F.) Constraint Limits (Dvorak EIR Rule 8)**

The ADT limits the magnitude of intensity change between estimates based on a modification to the SDT EIR Rule 8 which constrains the rate of increase or decrease of the Raw T# intensity estimate (value initially determined by the scene type and/or regression analyses, and before any rules or adjustments are applied) based upon specified rates of change over designated time periods. The rate of change checks are performed against the Final T# (after rule adjustments and time averaging described later) values stored in the history file for times prior to the current analysis time. The rate of change allowance is dependent upon the current intensity of the storm, as defined in the Dvorak EIR technique (Dvorak 1984). The Final T# value of the record immediately prior to the current analysis time is used as the current intensity estimate. When the intensity of the storm is less than T4.0, the current Raw T# rate of change cannot exceed  $\pm 0.5$  T# over 6 hours. If greater or equal to T4.0, 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.

The ADT also employs a modified version of this rule based upon the current scene type analyzed: The allowable rate of change is reduced by 0.5 during most non-Eye scene types (Curved Band, CDO, Embedded Center), so that the amount of change is limited to 0.5/1.0/1.5/2.0 T# over 6/12/18/24 hours. For Eye scenes the amount of allowed change is increased by 0.5 to 1.5/2.0/2.5/3.0 T# over 6/12/18/24 hours. The latter modification allows the Final T#/CI# to increase at a quick enough and realistic rate during “rapid intensification” events. For Shear scenes, the rate of change rule is unmodified from the original SDT EIR Rule 8.

If one of the criteria is exceeded, the Adjusted Raw T# (value after all rules/adjustments, but before time-averaging) will be assigned the maximum/minimum value allowed by the above criteria, and will be used in the determination of the corresponding Final T# and CI# values. Note: The unadjusted Raw T# value, before any adjustments have been made, is always stored in the history file for reference.

As a final “gross error check” for the Raw T# values derived by the ADT, a supplementary Rule 8 rule has been added to the constraint limits 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 ADT during “scene type transitions”, especially between eye and non-eye cases. Due to the completely objective nature of the scene determination scheme, and the discrete 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 produces estimates that are reasonable when these types of scene changes occur, but will not allow the Raw T# values to change at a rate greater than observed in nature.

Implementation of this modified rule has allowed for the Final T# calculation to be changed from a time-weighted 6-hour average to a 3-hour average (discussed in the next section). By utilizing the 3-hour scheme, the admissible rate of change of the Final T# value is greater than with the 6-hour scheme, making for more allowable rapid increases in intensity over short time periods that can be associated with storms undergoing rapid intensity changes.

#### **G.) Rapid Weakening Flag**

It is commonly observed that TCs can dissipate at a very rapid rate as they move over colder waters. However, the Dvorak Technique Rule 8 and Rule 9 constrain the rate of dissipation and it is believed that these rules do not allow for the rapid dissipation rates commonly observed in the East Pacific region (and periodically noted in other regions).

In order to alleviate this limitation, the Dvorak EIR Weakening Rule 9 has been modified to allow the CI# intensity estimate to reflect this commonly observed phenomenon. The ADT Rapid Weakening Flag relaxes the application of the original Rule 9 intensity adjustment to the Final T# when determining the CI#. Normally, up to 1.0 T# is added to the current Final T# value to come up with the CI#. In cases where rapid weakening is determined, the additive value is modified to 0.5. To be identified as a possible rapid weakening event, the Adjusted Raw T# values over the previous six hours are evaluated. If the slope of these values is less than  $-0.5/6$  hours the weakening flag is tripped and subsequently observed for an additional six hours. If over a second six hour period the slope does not increase over the threshold, the rapid weakening flag is turned on and the CI# additive constant is adjusted from 1.0 to 0.5. The rapid weakening flag is held on until the slope of the Adjusted T# values over six hours becomes greater than  $-0.37/6$  hours. If this condition is exceeded for a continuous period of six hours, the rapid weakening flag is then turned off and the additive value returns to 1.0.

## H.) Intensity Estimate Derivation Methods

As discussed in the Algorithm Overview in Section 1, the ADT is originally based upon the operationally-utilized Subjective Dvorak Enhanced Infrared ‘EIR’ Technique (SDT). Several deviations from the original SDT have been included into the ADT in order to improve upon the initial implementation of logic from the SDT into the ADT. The primary advancement involves the utilization of linear regression equations relating various cloud parameters to TC intensity. These equations were implemented for all eye scenes and several of the cloud scenes. The remaining scene types not utilizing regression-based methods have also been improved to better correlate their specific cloud parameter measurements to TC intensity.

### 1.) Regression-based Intensity Estimates

As mentioned previously, a regression-based analysis scheme was implemented in order to better correlate ADT eye and cloud region temperature measurement values with observed intensity. Measured values such as maximum eye region and minimum cloud region temperatures have been used historically in the SDT and early versions of the ADT to estimate TC intensity in all eye scene types as well as the CDO (and Irregular CDO) and Embedded Center cloud scene types. These parameters worked well in most cases, but additional methods were explored to better assess the TC intensity. Using linear regression analysis, additional parameters were found to aid significantly in the process of estimating TC intensity using infrared window imagery. A schematic representation of the regression-based parameters used in the ADT is provided in Figure 5.

The cloud symmetry value measures the temperature difference between opposing sides of the storm to assess the structure of the convection surrounding the eyewall region of the TC. Storms possessing a more symmetric convective structure (smaller temperature differences between opposing sections of the storm eyewall cloud region) are typically more intense than storms with asymmetric convection. This parameter is actually indirectly included in the SDT EIR technique via measurements of the width of the various BD-enhancement gray shades surrounding the storm center position as well in the “climatological” pattern-T# comparison diagrams. The cloud symmetry value is obtained by determining the average cloud top temperature value within the 24 sectors defined earlier (15-degree arcs, 80-km wide annulus from storm center with distance from eye pre-determined by warmest-coldest ring value). Opposing sector values (180-degree rotation) are differenced and summed around the storm center. These twelve values are then averaged to determine the final cloud symmetry value.

Another important parameter is the size of the central dense overcast, or CDO scene type, region in a non-eye situation. This parameter mimics the SDT which also makes use of a CDO size parameter to help assess the current strength of the storm. The impact of this value itself is not large, but it was found to be a significant contributor to estimating intensity in these situations when combined with the other parameters. The value is derived by simply averaging the diameter measurements of the storm CDO along

four axes centered on the storm center position. The CDO edge is defined as the boundary between the Light Gray and Medium Gray shades in the BD-enhancement shown in Figure 3 and listed in Table 1.

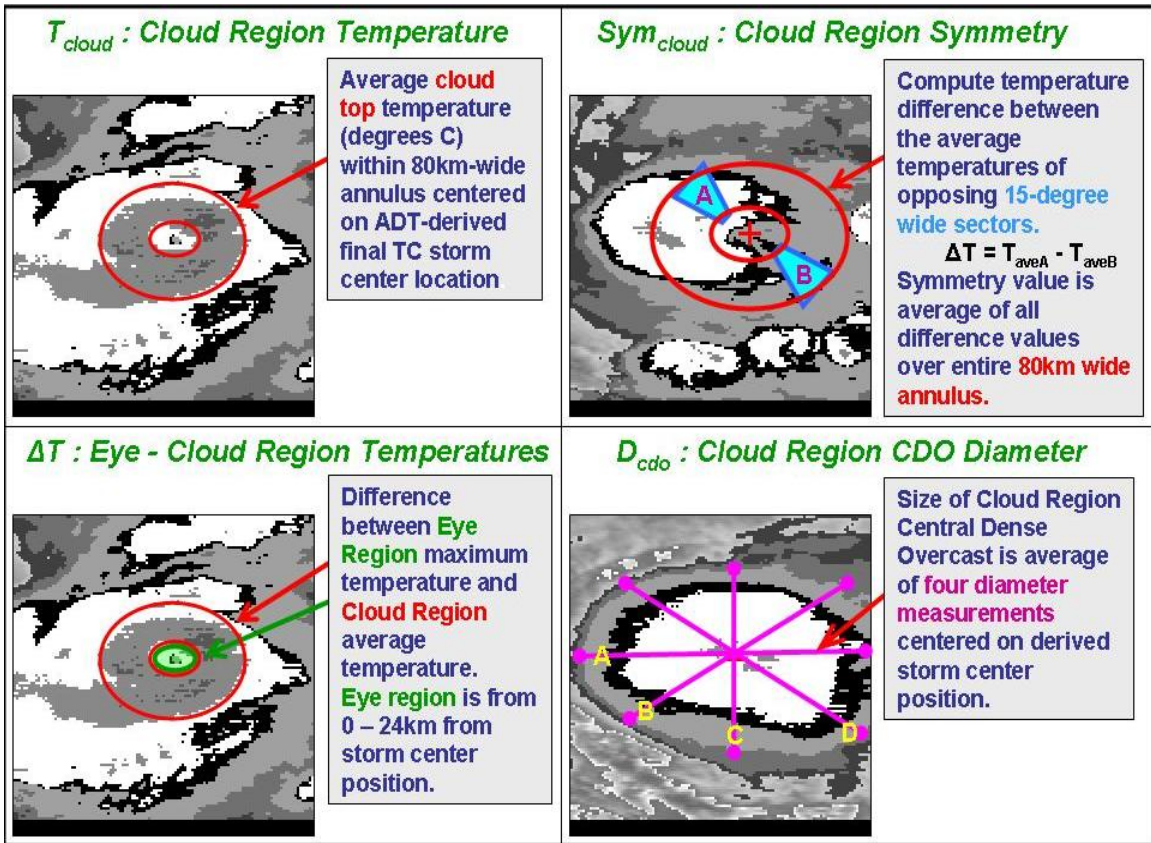


Figure 5: Schematic representation of the four regression equation parameters.

Two separate regression equations are used in the ADT; one equation for the eye scene types and one equation for the cloud scene types. The equations yield intensity estimates in terms of T# values which can be converted to MSLP or Maximum Wind Speed (as discussed in Sections 5I and 5O):

$$\text{Eye Scenes: Intensity} = 1.10 - 0.070 * T_{\text{cloud}} + 0.011 * \Delta T - 0.015 * \text{Sym}_{\text{cloud}}$$

$$\text{Cloud Scenes: Intensity} = 2.60 - 0.020 * T_{\text{cloud}} + 0.002 * D_{\text{cdo}} - 0.030 * \text{Sym}_{\text{cloud}}$$

- $T_{\text{cloud}}$  : Cloud region average temperature (deg C)
- $\Delta T$  : Eye (max) – cloud (ave) region temperatures (deg C)
- $\text{Sym}_{\text{cloud}}$  : Cloud region temperature symmetry (deg C)
- $D_{\text{cdo}}$  : Cloud region CDO size (km)

Significant correlation improvements between ADT intensity estimates and aircraft reconnaissance intensity observations were realized with the implementation of the new regression equations over the previous intensity estimation techniques. The cloud scene correlations improved from 0.28 to 0.50, while the eye scenes improved from

0.62 to 0.70. The improvement in the cloud scene correlation is most significant since the CDO scene type still remains the most troublesome area within the ADT algorithm and one that continues to merit research attention.

## 2.) Non-regression-based Intensity Estimates

The remaining cloud scene types that do not utilize a regression-based intensity estimation scheme are the Curved Band and Shear scenes. Intensity estimates for these two scenes rely on techniques based on the original SDT. The Shear scene type measures the distance between the determined storm center position (usually the interpolated forecast position) and the leading edge of the main convective region defined as the minimum distance to the “Dark Gray” BD-curve Gray Scale temperature range (Table 1). The value of this distance is then related to intensity; the greater the distance the weaker the storm intensity. A distance of 140km or greater will correspond to a T# intensity of 1.5, with an increase in intensity of 0.5 for every 30km distance reduction (except for the following two exceptions; 1.) At 80km, the intensity is 2.25; and 2.) Between 0 and 35km, the T# intensity is at its maximum value of 3.5). Subsequent modifications have improved the identification of the edge of the main cloud region, leading to superior intensity results for this scene type.

The Curved Band scene type utilizes a methodology similar to the one used in the automated storm center determination scheme described in Section 5J2. This technique utilizes a 10-degree log spiral to measure the amount of convection and determines the amount of curvature, in terms of 15° segments, in the cloud region surrounding the storm center. The technique to compute the curvature measures the cloud top temperature at each point on the log spiral in 15° steps along the spiral. The measured temperature must be colder than the specific threshold temperature value being checked to be classified as convective cloud. The specific threshold temperature values correspond to the maximum temperature values within each gray scale temperature range listed in Table 1. The gray scale ranges between the Dark Gray and White enhancement ranges, inclusive are utilized in this process. Each point on the log spiral arc are checked at 15° increments, with a count of “consecutive cloud segments” retained to find the maximum number of consecutive segments in each gray scale range, if available. Consecutive cloud segments are counted on this arc to determine the amount of curvature (24 segments would correspond to 360-degrees of curvature).

The Light Gray temperature range is checked first, with warmer ranges checked if the number of consecutive segments does not exceed seven segments. If a gray range is not found in these three ranges, the scene type is assumed to be a shear scene. If the Light Gray region is found to possess more than 25 consecutive segments, the routine will then check the curvature of the Black and White temperature ranges. If each number of consecutive segments in the Black and White ranges are also greater than 25, the scene type will be assigned a CDO/Embedded Center scene type, otherwise the scene will be assigned a Curved Band scene type. The amount of curvature is then related to a T# intensity value based upon the original Dvorak Technique (with an additional adjustment provided for curved bands measure from the Black and White temperature ranges). For

less than 20% curvature the T# intensity will be equal to 1.5. Between 20% and 40% curvature, the T# range will increase from 1.5 to 2.5. Above 40% curvature the T# intensity will increase by 0.5, starting at 2.5 for 40% to 4.0 for 100% (and up to 4.5 for 120% curvature). T# values are interpolated to the nearest 0.1 increment between the curvature threshold values listed.

The storm center utilized for the Curved Band scene is primarily the interpolated official forecast since the storm strength is typically too low for the auto-centering techniques to be used. The 10-degree log spiral is rotated in 10-degree increments around the storm center to find the maximum cloud curvature amount at the selected center position. A search for the storm center position that yields the highest value is also conducted and output to the user for reference if it does not correspond to the original, interpolated forecast position.

#### **I.) T# to MSLP Conversion Relationship Auto Determination**

The ADT intensity estimates are derived in terms of T# and CI#, which are a holdover from the SDT, where higher values correspond to stronger, more intense tropical cyclones. The T# is short for “Tropical Number”, and is defined in the SDT in relation to storm strength categories of mean sea level pressure (MSLP) and maximum sustained surface wind speeds (Dvorak 1984). The T# represents the “current” intensity of the storm. There are three T# values derived by the ADT; the Raw T#, the Adjusted Raw T#, and the Final T# values. These are explained in Section 5F.

The Current Intensity (CI#) is derived from the ADT Final T# value after a final set of time-based intensity constraint rules/adjustments are applied after the storm has stopped (temporarily?) strengthening, and represents the final intensity estimate output by the ADT. The three T# and CI# values can differ depending on the current intensity status of the storm and how it has changed over a given period of time (the constraint rules can vary over different time periods), but each value provides information about the current storm status and evolution.

The empirically-derived relationship between the CI# and storm intensity categories is given in Table 2 for the Atlantic TC basin (after Dvorak, 1984). The Northwest Pacific basin relationships (Shewchuck and Weir, 1980) differ slightly (not shown). Thus, proper identification of the correct relationship to use is essential for conversion of the CI# to intensity. The ADT can automatically determine the conversion method “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 designated as Atlantic basin (in consultation with users).

It should be noted that for T#/CI# values greater than 8.0 or less than 2.0 in Table 2, the MSLP estimates were not provided by the original Dvorak study, and are thus extrapolated in the ADT by using MSLP gradients from preceding/following categories

in the conversion table. These values include those found between 1.0 and 2.0 and between 8.0 and 8.5.

<b>Classification (approx)</b>	<b>CI# Value</b>	<b>Wind (kts)</b>	<b>Speed</b>	<b>MSLP (hPa)</b>
	1.0	25.0		1014.0
	1.5	25.0		1012.0
	2.0	30.0		1009.0
Tropical Storm	2.5	35.0		1005.0
	3.0	45.0		1000.0
	3.5	55.0		994.0
Hurricane – Cat 1	4.0	65.0		987.0
	4.5	77.0		979.0
Hurricane – Cat. 2	4.7	82.2		975.4
	5.0	90.0		970.0
Hurricane – Cat 3	5.2	94.8		966.0
	5.5	102.0		960.0
Hurricane – Cat 4	6.0	115.0		948.0
	6.5	127.0		935.0
Hurricane – Cat 5	6.8	134.8		926.6
	7.0	140.0		921.0
	7.5	155.0		906.0
	8.0	170.0		890.0
	8.5	185.0		873.0

Table 2: Relationships between ADT-derived CI# values and TC maximum sustained surface wind speed and mean sea level pressure (MSLP) values for Atlantic basin storms.

## **J.) Automatic Storm Center Determination and Input File Formats**

The ADT automated storm center location algorithm approximates TC position using three methods: polynomial interpolation of TCFC forecasts, linear extrapolation of the history file positions or with an advanced dual methodology examining the TC cloud top spiral features and circular feature (ring) search discussed in Section 5J2.

As a first guess, the forecast positions from TCFC forecast, with its file name and directory location passed to the ADT algorithm via algorithm inputs (command line, GUI values, or environmental variables, depending on the implantation of the algorithm), are read within the ADT algorithm to obtain the current position using a polynomial interpolation routine. This interpolation routine uses three forecast positions (current, 12 hour, and 24 hour positions) defined in the forecast file to interpolate the current position defined by the time of the image being examined. If the image time falls within the time period defined within the forecast file positions/times, a valid interpolated forecast position will be used within the algorithm, otherwise an extrapolation of the previous history file positions will be used.



The ADT algorithm will typically be utilized from the time of the first TCFC forecast is provided for the storm in question until the storm either dissipates over land, becomes extratropical, or weakens to below tropical depression status, resulting in the TCFC to issue a final forecast for the storm being analyzed. The ADT can be terminated at any point after the final forecast is issued. An upper limit of 24 hour beyond the “initial” time in the final forecast is typically used to end the ADT processing. The five types of acceptable input file formats are:

- ATCF Forecast Record file
- NHC/CPHC Discussion/Warning files  
(WMO headers: “WTNT4? KNHC” or “WTPZ4? KNHC” or “WTPA4?” PHFO)
- JTWC Tropical Cyclone Warning files  
(WMO header: “WTPN3? PGTW”)
- Other Regional Specialized Meteorological Center (RSMC) Formats
  - ICAO format files from:
    - RSMC Nadi (Fiji): FKPS01-02 NFFN
    - RSMC New Delhi (India): FKIN20 VIDP
    - RSMC Tokyo (Japan): FKPQ30-34 RJTD
  - Tropical Cyclone Warning Centers (TCFC) Technical Bulletins: Australia
    - TCWC Perth: AXAU01-02 APRF
    - TCWC Darwin: AXAU01-02 ADRM
    - TCWC Brisbane: AXAU21 ABRF
  - RSMC La Reunion, MeteoFrance Warning files  
(WMO header: WTIO30 FMEE)
- Generic Entry file

## 1.) Forecast File Examples

### ATCF Forecast Record Format

Information about the ATCF format can be found in Sections 4E1b and 4D7. The ADT will skip redundant forecast positions (for each critical radii report).

```
AL, 13, 2002092400, 03, OFCL, 0, 127N, 620W, 50, 1006, TS, 34, AAA, 0, 0, 0, 0, 0, 0, 0, 60,
0, 0, BRJ, 275, 16,
AL, 13, 2002092400, 03, OFCL, 3, 127N, 627W, 50, 1006, TS, 34, NEQ, 90, 30, 50, 90, 0, 0, 0, 60,
0, 0, BRJ, 275, 15, 12, NEQ, 100, 0, 50, 100,
AL, 13, 2002092400, 03, OFCL, 3, 127N, 627W, 50, 1006, TS, 50, NEQ, 20, 0, 0, 20, 0, 0, 0, 60,
0, 0, BRJ, 275, 15, 12, NEQ, 100, 0, 50, 100,
AL, 13, 2002092400, 03, OFCL, 12, 138N, 648W, 55, 1006, TS, 34, NEQ, 100, 30, 50, 100, 0, 0, 0, 65,
0, 0, BRJ, 300, 15,
AL, 13, 2002092400, 03, OFCL, 12, 138N, 648W, 55, 1006, TS, 50, NEQ, 20, 0, 0, 20, 0, 0, 0, 65,
0, 0, BRJ, 300, 15,
AL, 13, 2002092400, 03, OFCL, 24, 150N, 671W, 60, 1006, TS, 34, NEQ, 100, 50, 50, 100, 0, 0, 0, 75,
0, 0, BRJ, 300, 13,
AL, 13, 2002092400, 03, OFCL, 24, 150N, 671W, 60, 1006, TS, 50, NEQ, 30, 20, 20, 30, 0, 0, 0, 75,
0, 0, BRJ, 300, 13,
AL, 13, 2002092400, 03, OFCL, 36, 161N, 690W, 70, 1006, TS, 34, NEQ, 100, 60, 60, 100, 0, 0, 0, 85,
0, 0, BRJ, 300, 11,
AL, 13, 2002092400, 03, OFCL, 36, 161N, 690W, 70, 1006, TS, 50, NEQ, 50, 30, 30, 50, 0, 0, 0, 85,
0, 0, BRJ, 300, 11,
AL, 13, 2002092400, 03, OFCL, 36, 161N, 690W, 70, 1006, TS, 64, NEQ, 30, 20, 20, 30, 0, 0, 0, 85,
0, 0, BRJ, 300, 11,
AL, 13, 2002092400, 03, OFCL, 48, 170N, 705W, 75, 1006, TS, 34, NEQ, 120, 80, 80, 120, 0, 0, 0, 90,
0, 0, BRJ, 300, 8,
AL, 13, 2002092400, 03, OFCL, 48, 170N, 705W, 75, 1006, TS, 50, NEQ, 50, 30, 30, 50, 0, 0, 0, 90,
0, 0, BRJ, 300, 8,
AL, 13, 2002092400, 03, OFCL, 72, 190N, 730W, 70, 1006, TS, 34, NEQ, 100, 60, 60, 100, 0, 0, 0, 85,
0, 0, BRJ, 310, 8,
AL, 13, 2002092400, 03, OFCL, 72, 190N, 730W, 70, 1006, TS, 50, NEQ, 50, 30, 30, 50, 0, 0, 0, 85,
0, 0, BRJ, 310, 8,
AL, 13, 2002092400, 03, OFCL, 96, 225N, 750W, 80, 1006, TS, 34, AAA, 0, 0, 0, 0, 0, 0, 0, 100,
0, 0, BRJ, 330, 10,
AL, 13, 2002092400, 03, OFCL, 120, 260N, 770W, 90, 1006, TS, 34, AAA, 0, 0, 0, 0, 0, 0, 0, 110,
0, 0, BRJ, 335, 10,
```

## NHC Discussion Format

These files can be obtained easily from various internet sources. The WMO header will change for each active storm (up to five active storms at a time) and each basin covered by the NHC and/or CPHC (Atlantic, East and Central Pacific).

WTNT42 KNHC 281454 2005240 1454  
TCDAT2

HURRICANE KATRINA DISCUSSION NUMBER 23  
NWS TPC/NATIONAL HURRICANE CENTER MIAMI FL  
11 AM EDT SUN AUG 28 2005  
THE AIR FORCE HURRICANE HUNTERS JUST MEASURED A 166 KT FLIGHT LEVEL WIND IN THE NORTHEAST EYEWALL...WHICH REQUIRES AN ADDITIONAL UPWARD ADJUSTMENT OF THE CURRENT INTENSITY TO 150 KT. A DROP IN THE EYE GAVE A CENTRAL PRESSURE OF 907 MB. KATRINA IS COMPARABLE IN INTENSITY TO HURRICANE CAMILLE OF 1969...ONLY LARGER. GPS DROPSONDE DATA FROM THE NOAA G-IV MISSION EARLIER TODAY SHOWED KATRINA'S INTENSE CYCLONIC CIRCULATION EXTENDING THROUGH THE 200 MB LEVEL...WITH THE FLOW SPIRALING ANTICYCLONICALLY OUTWARD IN A WELL-DEVELOPED UPPER-LEVEL OUTFLOW PATTERN BEYOND A COUPLE HUNDRED N MI FROM THE CENTER. FLUCTUATIONS IN STRENGTH...DUE TO INTERNAL STRUCTURAL CHANGES...ARE LIKELY PRIOR TO LANDFALL. HURRICANES RARELY SUSTAIN SUCH EXTREME WINDS FOR MUCH TIME. HOWEVER WE SEE NO OBVIOUS LARGE-SCALE EFFECTS TO CAUSE A SUBSTANTIAL WEAKENING THE SYSTEM...AND IT IS EXPECTED THAT THE HURRICANE WILL BE OF CATEGORY 4 OR 5 INTENSITY WHEN IT REACHES THE COAST.

THERE IS NO CHANGE TO THE TRACK FORECAST. KATRINA SHOULD GRADUALLY TURN TOWARD THE NORTH...INTO A WEAKNESS IN THE SUBTROPICAL RIDGE ASSOCIATED WITH A LARGE MID-LATITUDE CYCLONE OVER THE NORTHERN UNITED STATES AND SOUTHERN CANADA. THE OFFICIAL FORECAST TRACK IS ABOUT IN THE MIDDLE OF THE DYNAMICAL GUIDANCE MODELS...WHICH ARE RATHER TIGHTLY CLUSTERED. RECALLING THAT THE AVERAGE NHC 24-HOUR TRACK FORECAST ERROR IS ABOUT 80 N MI...THE ACTUAL LANDFALL POINT COULD STILL BE ANYWHERE FROM SOUTHEASTERN LOUISIANA TO THE MISSISSIPPI COAST. ALSO...WE MUST CONTINUE TO STRESS THAT THE HURRICANE IS NOT JUST A POINT ON THE MAP...BECAUSE DESTRUCTIVE WINDS...TORRENTIAL RAINS...STORM SURGE...AND DANGEROUS WAVES EXTEND WELL AWAY FROM THE EYE. IT IS IMPOSSIBLE TO SPECIFY WHICH COUNTY OR PARISH WILL EXPERIENCE THE WORST WEATHER.

THIS ADVISORY SHOWS AN ADDITIONAL EXPANSION OF THE WIND FIELD OVER THE EASTERN SEMICIRCLE BASED ON AIRCRAFT AND SURFACE OBSERVATIONS. HURRICANE FORCE WINDS ARE FORECAST TO SPREAD AT LEAST 150 N MI INLAND ALONG THE PATH OF KATRINA. CONSULT INLAND WARNINGS ISSUED BY NATIONAL WEATHER SERVICE FORECAST OFFICES.

FORECASTER PASCH

### FORECAST POSITIONS AND MAX WINDS

INITIAL	28/1500Z	26.0N	88.1W	150 KT
12HR VT	29/0000Z	27.2N	88.9W	145 KT
24HR VT	29/1200Z	29.1N	89.6W	140 KT
36HR VT	30/0000Z	31.4N	89.5W	85 KT...INLAND
48HR VT	30/1200Z	34.5N	88.5W	45 KT...INLAND
72HR VT	31/1200Z	40.0N	84.0W	30 KT...INLAND
96HR VT	01/1200Z	45.0N	77.0W	25 KT...EXTRATROPICAL
120HR VT	02/1200Z	52.0N	69.0W	25 KT...EXTRATROPICAL

## JTWC Tropical Cyclone Warning Format

As with NHC Discussions, these forecasts can be readily obtained from the internet, and will have a separate WMO header for each storm and each basin covered by the Joint Typhoon Warning Center.

WTPN32 PGTW 291500  
MSGID/GENADMIN/NAVPACMETOCEN PEARL HARBOR HI/JTWC//  
SUBJ/TROPICAL CYCLONE WARNING//  
RMKS/

2004242 1417

1. TYPHOON 19W (CHABA) WARNING NR 044  
02 ACTIVE TROPICAL CYCLONES IN NORTHWESTPAC  
MAX SUSTAINED WINDS BASED ON ONE-MINUTE AVERAGE  
---  
WARNING POSITION:  
291200Z4 --- NEAR 29.4N5 130.0E4  
MOVEMENT PAST SIX HOURS - 325 DEGREES AT 07 KTS  
POSITION ACCURATE TO WITHIN 040 NM  
POSITION BASED ON CENTER LOCATED BY A COMBINATION OF  
SATELLITE AND RADAR  
PRESENT WIND DISTRIBUTION:  
MAX SUSTAINED WINDS - 095 KT, GUSTS 115 KT  
RADIUS OF 064 KT WINDS - 050 NM NORTHEAST QUADRANT  
050 NM SOUTHEAST QUADRANT  
050 NM SOUTHWEST QUADRANT  
050 NM NORTHWEST QUADRANT  
RADIUS OF 050 KT WINDS - 080 NM NORTHEAST QUADRANT  
080 NM SOUTHEAST QUADRANT  
080 NM SOUTHWEST QUADRANT  
080 NM NORTHWEST QUADRANT  
RADIUS OF 034 KT WINDS - 200 NM NORTHEAST QUADRANT  
OVER WATER  
180 NM SOUTHEAST QUADRANT  
180 NM SOUTHWEST QUADRANT  
180 NM NORTHWEST QUADRANT  
REPEAT POSIT: 29.4N5 130.0E4  
---

FORECASTS:  
12 HRS, VALID AT:  
300000Z3 --- 31.6N0 130.3E7  
MAX SUSTAINED WINDS - 080 KT, GUSTS 100 KT  
RADIUS OF 064 KT WINDS - 050 NM OVER WATER  
RADIUS OF 050 KT WINDS - 080 NM OVER WATER  
RADIUS OF 034 KT WINDS - 200 NM NORTHEAST QUADRANT  
OVER WATER  
180 NM SOUTHEAST QUADRANT  
OVER WATER  
180 NM SOUTHWEST QUADRANT  
170 NM NORTHWEST QUADRANT  
OVER WATER  
VECTOR TO 24 HR POSIT: 030 DEG/ 19 KTS  
---

24 HRS, VALID AT:  
301200Z6 --- 34.9N6 132.7E3  
MAX SUSTAINED WINDS - 060 KT, GUSTS 075 KT  
RADIUS OF 050 KT WINDS - 070 NM OVER WATER  
RADIUS OF 034 KT WINDS - 180 NM NORTHEAST QUADRANT  
OVER WATER  
170 NM SOUTHEAST QUADRANT  
OVER WATER  
170 NM SOUTHWEST QUADRANT  
OVER WATER  
160 NM NORTHWEST QUADRANT  
VECTOR TO 36 HR POSIT: 040 DEG/ 30 KTS  
---

36 HRS, VALID AT:  
310000Z4 --- 39.5N7 137.4E5  
MAX SUSTAINED WINDS - 045 KT, GUSTS 055 KT  
BECOMING EXTRATROPICAL  
RADIUS OF 034 KT WINDS - 170 NM NORTHEAST QUADRANT  
OVER WATER  
130 NM SOUTHEAST QUADRANT  
OVER WATER  
160 NM SOUTHWEST QUADRANT  
130 NM NORTHWEST QUADRANT  
VECTOR TO 48 HR POSIT: 035 DEG/ 34 KTS  
---

EXTENDED OUTLOOK:  
48 HRS, VALID AT:  
311200Z7 --- 44.9N7 142.8E5  
MAX SUSTAINED WINDS - 035 KT, GUSTS 045 KT  
EXTRATROPICAL  
---

REMARKS:  
291500Z7 POSITION NEAR 30.0N3 130.1E5.  
TYPHOON (TY) 19W (CHABA), LOCATED APPROXIMATELY 215 NM SOUTH  
OF SASEBO, JAPAN, HAS TRACKED NORTHWESTWARD AT 07 KNOTS OVER  
THE PAST 06 HOURS. THE WARNING POSITION IS BASED ON 291130Z6  
ENHANCED INFRARED SATELLITE IMAGERY. THE WARNING INTENSITY  
IS BASED ON SATELLITE CURRENT INTENSITY ESTIMATES OF 90 AND  
102 KNOTS. NEXT WARNINGS AT 292100Z4, 300300Z6, 300900Z2 AND  
301500Z9. REFER TO TYPHOON 22W (SONGDA) WARNINGS (WTPN33 PGTW)  
FOR SIX-HOURLY UPDATES.//

## RMSC Formats

The WMO RSMC sites produce forecast products in several formats for an individual storm. The ADT algorithm can read most of these formats; however, subtle differences between site formats may lead to errors. If one forecast format fails, another format may be available from the RSMC providing the forecast. The formats listed below are the suggested forecast product formats to use for the different RSMC sites.

*ICAO Format:* Unfortunately the ICAO format is not uniform across all RMSC forecast centers. The ADT, however, attempts to account for the current differences and should successfully read all ICAO format forecasts unless they change.

```
FKPS01 NFFN 060300                                2008037 0307
TC ADVISORY
DTG:                20080206/0300Z
TCAC:               DARWIN
TC:                 GENE
NR:                 35
PSN:                S2854 W17748
MOV:                ESE 15KT
C:                  972HPA
MAX WIND:           65KT
FCST PSN +12HR:     11/1200 S3042 W17418
FCST MAX WIND +12HR: 55KT
FCST PSN +18HR:     12/0000 S3118 W17230
FCST MAX WIND +18HR: 50KT
FCST PSN +24HR:     12/1200 S3200 W17030
FCST MAX WIND +24HR: 45KT
NXT MSG:            20080206/0800Z
WXTLIST: done
```

*Australian TCWC Format:* This warning format is produced by the Australian TCWCs and is utilized over the ICAO format due to the inclusion of the Identifier tag in the forecast body, allowing for greater ease in automated processing for obtaining and parsing the product information.

```
AXAU01 APRF 260705
IDW27600
TROPICAL CYCLONE TECHNICAL BULLETIN: AUSTRALIA - WESTERN REGION
Issued by PERTH TROPICAL CYCLONE WARNING CENTRE
at: 0704 UTC 26/01/2009
Name: Tropical Cyclone Dominic
Identifier: 12U
Data At: 0600 UTC
Latitude: 20.1S
Longitude: 115.6E
Location Accuracy: within 25 nm [46 km]
Movement Towards: south southwest [207 deg]
Speed of Movement: 8 knots [15 km/h]
Maximum 10-Minute Wind: 45 knots [85 km/h]
Maximum 3-Second Wind Gust: 65 knots [120 km/h]
Central Pressure: 987 hPa
Radius of 34-knot winds NE quadrant: 60 nm [110 km]
Radius of 34-knot winds SE quadrant: 60 nm [110 km]
Radius of 34-knot winds SW quadrant: 60 nm [110 km]
Radius of 34-knot winds NW quadrant: 60 nm [110 km]
Radius of 48-knot winds NE quadrant:
Radius of 48-knot winds SE quadrant:
Radius of 48-knot winds SW quadrant:
Radius of 48-knot winds NW quadrant:
Radius of 64-knot winds:
Radius of Maximum Winds:
Dvorak Intensity Code: T3.0/3.0/D1.0/24HRS
Pressure of outermost isobar: 1002 hPa
Radius of outermost closed isobar: 75 nm [140 km]
```

Storm Depth: Deep  
 FORECAST DATA  
 Date/Time : Location : Loc. Accuracy: Max Wind : Central Pressure  
 [UTC] : degrees : nm [km]: knots[km/h]: hPa  
 +12: 26/1800: 21.4S 115.3E: 055 [100]: 050 [095]: 982  
 +24: 27/0600: 22.8S 115.6E: 085 [155]: 030 [055]: 996  
 +36: 27/1800: 24.2S 116.4E: 120 [220]: 025 [045]: 999  
 +48: 28/0600: 25.4S 117.6E: 160 [295]: 025 [045]: 998  
 +60: 28/1800: 26.7S 118.6E: 210 [390]: 020 [035]: 1000  
 +72: 29/0600: 28.2S 119.7E: 250 [465]: 020 [035]: 1000  
 REMARKS:  
 TC Dominic was named at 03Z.

*WTIO30 FMEE Format:* This format is primarily used from the MeteoFrance site at La Reunion Island in the Southern Indian Ocean.

WTIO30 FMEE 071800

2008038 1802

RSMC / TROPICAL CYCLONE CENTRE / LA REUNION  
 TROPICAL CYCLONE FORECAST WARNING (SOUTH-WEST INDIAN OCEAN)  
 0.A WARNING NUMBER : 15/10/20072008  
 1.A VERY INTENSE TROPICAL CYCLONE 10 (HONDO)  
 2.A POSITION 2008/02/05 AT 1800 UTC :  
 15.0S / 82.9E  
 (FIFTEEN DECIMAL ZERO DEGREES SOUTH AND EIGHTY TWO DECIMAL NINE DEGREES EAST)  
 3.A DVORAK ANALYSIS : 6.5/7.0 /D 1.0/18 H  
 4.A CENTRAL PRESSURE : 906 HPA  
 5.A MAX AVERAGE WIND SPEED (10 MN) : 120 KT  
 6.A EXTENSION OF WINDS BY QUADRANTS (KM):  
 30 KT NE: 160 SE: 160 SO: 260 NO: 200  
 50 KT NE: 060 SE: 040 SO: 080 NO: 080  
 7.A FIRST CLOSED ISOBARE (PRESSURE / AVERAGE DIAM): 1004 HPA / 800 KM  
 8.A VERTICAL EXTENSION OF CYCLONE CIRCULATION: DEEP  
 1.B FORECASTS:  
 12H: 2008/02/06 06 UTC: 15.3S/83.3E, MAX WIND=110KT, INTENSE TROP. CYCL..  
 24H: 2008/02/06 18 UTC: 15.6S/83.7E, MAX WIND=100KT, INTENSE TROP. CYCL..  
 36H: 2008/02/07 06 UTC: 16.4S/84.6E, MAX WIND=090KT, INTENSE TROP. CYCL..  
 48H: 2008/02/07 18 UTC: 17.6S/85.5E, MAX WIND=080KT, TROPICAL CYCLONE.  
 60H: 2008/02/08 06 UTC: 18.9S/86.2E, MAX WIND=060KT, SEVERE TROP. STORM.  
 72H: 2008/02/08 18 UTC: 20.1S/86.4E, MAX WIND=050KT, SEVERE TROP. STORM.  
 2.B OTHER INFORMATIONS:  
 T=6.5+, CI=7.0  
 HONDO SHOWS AN ANNULAR PATTERN (YET SLIGHTLY ERODED IN THE SOUTHEASTERN PART) . THE ENVIRONMENT IS FAVORABLE ; LOW LEVELS INFLOWS ARE WELL ESTABLISHED, WINDSHEAR IS WEAK AND UPPER LEVEL DIVERGENCE RATHER GOOD. HOWEVER THE SYSTEM HAS A RATHER SMALL SIZE (CF MICROWAVE IMAGERY) AND SHOULD THEN QUICKLY REACT TO MODIFICATIONS IN THE ENVIRONMENTAL CONDITIONS.  
 HONDO IS LOCATED BETWEEN TWO COMPETING STEERING FLOWS; SUBTROPICAL HIGH PRESSURES IN THE SOUTHWEST AND EQUATORIAL UPPER LEVEL RIDGE THAT REMAINS THE DOMINANT STEERING FLOW. HONDO IS THEN EXPECTED TO KEEP ON TRACKING SLOWLY SOUTHEASTWARDS, THEN QUICKER BEYOND 36 HOURS TOWARDS A WEAKNESS IN THE SUBTROPICAL RIDGE IN THE SOUTHEAST.  
 WEAKENING IS EXPECTED TO BE STRONGER BEYOND 48 TO 60 HOURS ON COOLER SEA SURFACE TEMPERATURES.

## Generic Format

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:

<b>dd mm yyyy tttt aa.a bbb.b</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.

## 2.) ADT Auto-Centering Methodology

The ADT automated storm center determination process utilizes an interpolation of an official TCFC short-term track forecast as a first guess for the storm center position. Official forecasts can be obtained from various World Meteorological Organization (WMO) sanctioned Regional Specialized Meteorological Center (RSMC), such as the NOAA National Hurricane Center (NHC) for the Atlantic Ocean, Caribbean Sea, and Eastern Pacific Ocean and the Central Pacific Hurricane Center (CPHC) for the Central Pacific Ocean (to dateline). A list and examples of all RSMC valid forecast products is provided in Section 5J1. Forecasts are typically provided from NHC and CPHC every six hours for active TCs at or above Tropical Depression classification. These forecast positions are given every 12 hours, and the ADT normally uses the initial position and the first 12-hour forecast point for its interpolated values to the current analysis time.

The ADT will interpolate the provided TC position forecast to the current satellite image time using a polynomial interpolation of the storm forecast positions. If the forecast interpolation fails for any reason, a linear extrapolation of storm positions from 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 (explained later in the document) of the record immediately preceding the current analysis time in the history file is 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 thorough analysis of the image is conducted to determine if a potentially better storm center location can be employed.

Two techniques are used in the auto-centering scheme (Wimmers and Velden, 2004). These methods are quite computationally intensive and may take a significant amount of time to complete, since the routines require the satellite image being investigated to be remapped into a rectilinear projection before proceeding. The computation issue has been somewhat alleviated with the introduction of several mathematical shortcuts within the routine and with the implementation of the ADT algorithm on more state-of-the-art computers possessing greater computational power. Both processes are always performed during the auto-centering process.

The remapping to rectilinear projection process involves transforming satellite data, most likely in the original satellite projection (but it could be in any other non-linearly displayed projection such as Mercator), into a grid layout with equal spacing between the different grid points in both latitude and longitude locations. In order to do this, each point on the rectilinear projected grid must be interpolated from the original data points in the satellite image being analyzed. In order to speed up this process, a spline-fitting routine can be used to estimate certain values instead of interpolating each point directly from the satellite data. This process involves directly interpolating only a set number of points in the rectilinear projected grid (defined within the program) and then it will fit a cubic spline between the interpolated points to estimate the values between the interpolated points. The ADT will directly interpolate every third point on the rectilinear grid and then fit the two remaining points between each grid point (in the x and y direction). This process can drastically speed up the performance of the remapping process but will result in a remapped file that is very similar to the one that would be produced by a direct interpolation of each point. The routines that perform the cubic spline interpolation process were originally provided by Dave Santek of the Space Science and Engineering Center in Madison, WI, and were converted from the original FORTRAN code to C for the ADT algorithm.

The first technique, the Spiral Centering (SC) routine, determines a center point in the image where there is a maximum alignment between the image cloud top temperature gradient and the 5-degree log spiral vector emanating from the center point within each different analysis region (at different points within the remapped rectilinear grid, as described below). The equation for the 5-degree log spiral is:

$$R(\Theta) = A * e^{(B * \Theta)}$$

$R(\Theta)$  = radial distance from origin (center point of SC analysis regions)

A = starting position distance of spiral from origin

B = angle between spiral tangent and radial line at point  $(R, \Theta)$  ( $5^\circ$  in this case)

$\Theta$  = angle from the x-axis

The log spiral must be converted to Cartesian coordinates in order to determine the vector at each point within the cloud top temperature grid field. If the origin of the

analysis grid is center location located at (0,0), any point on the log spiral can be defined as:

$$\begin{aligned} X(\Theta) &= R(\Theta) * \cos(\Theta) \\ Y(\Theta) &= R(\Theta) * \sin(\Theta) \end{aligned}$$

In the northern hemisphere, the X axis would increase positive moving east and the Y axis would increase positive moving north. In the southern hemisphere, the X axis would be the same, but the Y axis would increase positive moving south. This will assure the log spiral will spiral outwards in the correct direction for each hemisphere to match the cyclonic curvature of the storm rotation.

This analysis is a two step procedure consisting of two analysis processes. The size and resolution of the different analysis grids are hardcoded within the ADT algorithm, with a fine-resolution analysis grid embedded within a course-resolution grid. The first step is a “course-resolution” analysis, where the temperature gradient and log spiral analysis vectors are calculated at individual grid points (the origin point  $R(\Theta)$  in the log spiral equation) within a  $1.75^\circ$ -radius circular analysis region at a “course” resolution of  $0.2^\circ$ . Once an intermediate maximum alignment center position is determined using the cross-product analysis, a second “fine resolution” analysis is performed in a rectangular region surrounding the initial center position at a  $0.1^\circ$  “fine scale” resolution to find the final spiral center determined position.

The resolutions of the course and fine scale analysis grids were chosen in order to try and optimize the computation time of the SC routine versus the ability of the routine to capture the rotational features of the image being examined. Since the routine is processing the image over an image of size  $N \times N$  at each point within the analysis region at different analysis resolutions, any increase in analysis resolution will result in an increase in processing for each pixel on the order of  $N^4$ . As computing power improves, an increase of the analysis resolutions can be considered (to eventually match the resolutions of the imagery being investigated), but currently the values utilized are optimized to allow for efficient and accurate processing.

The alignment is calculated by summing the cross-products of the image temperature gradient vector with an overlaid spiral unit vector field (Figure 6). The equation for the cross product is:

$$\mathbf{a} \times \mathbf{b} = a * b * \sin\Theta * \mathbf{n}$$

a and b = magnitudes of vectors **a** and **b**

$\Theta$  = smaller angle between vectors **a** and **b**

**n** = unit vector perpendicular to the plane containing vectors **a** and **b**

As can be seen, the cross product value between the temperature gradient vector and the spiral vector will be maximized where the angle between the vectors is  $90^\circ$ . The vectors **a** and **b** can be defined as either the temperature gradient or the spiral vector field, but for this discussion, **a** is assigned to the temperature gradient vector and **b** is the spiral vector.



The initial SC analysis field normally takes shape as a “bull’s eye” pattern around the TC’s center of rotation. An additional “distance penalty function” field (a weak “bull’s eye” pattern centered on the first guess forecast position) is added to the initial spiral center analysis field to guide the storm center determination process away from the edges of the spiral center analysis region. The final “enhanced” spiral analysis field results. This approach has the advantage of using the composition of the whole image instead of just the orientation of the spiral bands. Also, by using only the curvature of the image, the algorithm is not drawn to high-temperature “moats”, but rather uses their curved shape as a guide to the optimal center. The technique closely mimics the method used by experienced meteorologists to determine a center of rotation because it naturally assigns appropriate weights to the rotation-induced gradients of all sizes. However, the algorithm can be quite sensitive to the effects of upper-level shear in IR imagery, leading to center estimates driven by patterns in the asymmetric cirrus clouds rather than low-level clouds defining the center.

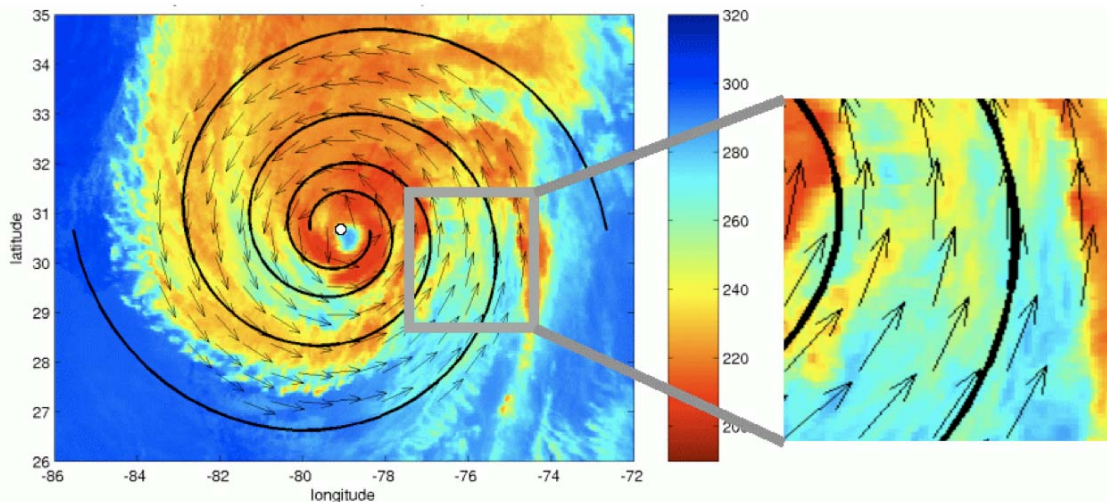


Figure 6: Example of a 5-degree log spiral field vector field. Black lines represent two spirals emanating from test center point (white dot). Arrows represent vector of log spiral at various points in analysis region.

Further calculation beyond the SC method is needed to resolve the exact center of rotation in storms which possess a well-defined eye (if one is present in the image being analyzed). Although finding the eye of a storm is a simple task for the meteorologist to perform subjectively, it is made objectively and computationally difficult by partial obscurations and nearby, oddly shaped high-temperature moats. To address this issue, the second technique is attempted at the completion of the SC process. The Eye Ring Fitting (RF) analysis method performs a search around the enhanced spiral analysis center point for the most intense gradients in a small ring-shaped area defining the storm eyewall. The dot product of the gradient field is summed for each point on each individual ring and center point, with the maximum value indicating the determined center point and TC eyewall size (Figure 7). The dot product equation is the following:

$$\mathbf{a} \cdot \mathbf{b} = |\mathbf{a}| * |\mathbf{b}| * \cos\Theta$$

$$\Theta = \text{angle between a and b vectors}$$

In the RF routine, **a** would be the temperature gradient vector at a specific point on the ring and **b** would be the “position” unit vector from the center point to the ring at the point being analyzed.. When the vectors are in the same direction, the angle will be near zero, maximizing the product of the vector magnitudes. This process is performed over a circle of radius 0.75° from the center position corresponding to the spiral analysis center point determined in the SC routine. The resulting field is the final RF analysis score field.

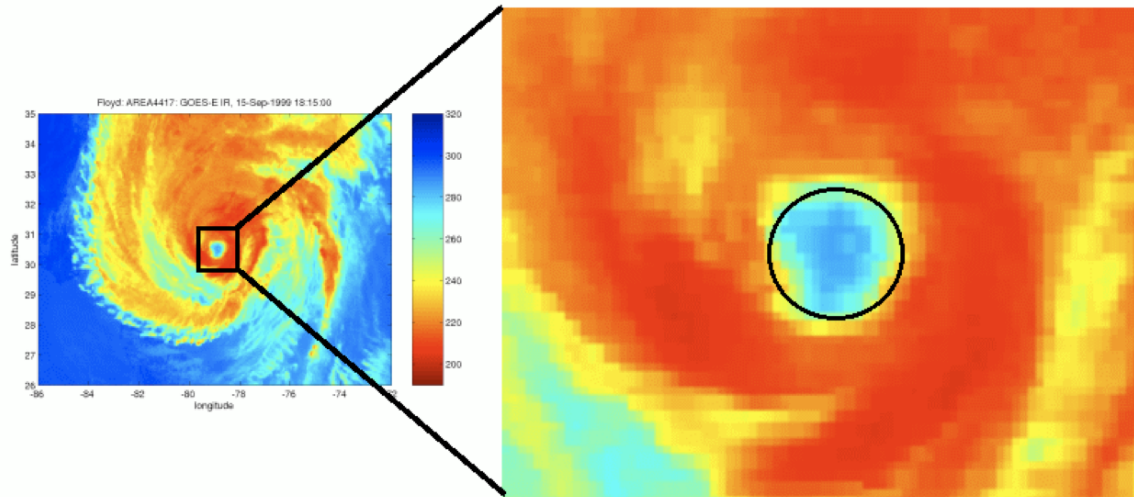


Figure 7: Example of eye ring analysis (black circle) which best matches temperature gradients of the eyewall feature in the tropical cyclone.

Once both analyses techniques have successfully completed, their derived center points and corresponding confidence factors are used to determine the “best” storm position for the scene being analyzed. The confidence factors score derivation process is performed in two steps. For each point an Enhanced Spiral Part (ESP) confidence score is derived by determining the minimum value of the sum of two weighted spiral values, as shown in the following equation:

$$\text{ESP score} = \text{Distance Penalty (DP)} + \text{Spiral Part score (SP)}$$

$$\text{DP} = \text{constant} * \text{distance of point from First Guess position}$$

$$\text{SP} = 10 * (\text{spiral score at point} - \text{maximum spiral score})$$

Where “spiral score at point” is equal to the spiral score (from the SC routine process described previously) at each point in the analysis and “region maximum spiral score” is the maximum spiral score value within the analysis region. Basically this value is just the difference between the spiral score value at each individual point in the analysis region from the maximum spiral score value within the entire region.

If the position of the maximum ESP value (least negative) is outside of a set radii distance threshold (the maximum allowable displacement value of  $1.15^\circ$ ) from the first guess position (forecast interpolation position), the ESP confidence factor will only be derived and the position of the ESP maximum will be used as the storm center position by the ADT algorithm. This will result in the “Spiral Centering” automated storm centering method type being used (ID value of 4 for parameter 32 in the history file listed in Section 4B) and identified as “SPRL” in the History File Listing shown in Section 4E1a.

If the position of the maximum ESP value (least negative) is within the set radius threshold of  $1.15^\circ$ , however, a second “distance weighted” Enhanced Spiral Part (ESPd) confidence score will be derived, adding the “Distance Bonus (DB)” value to the initial ESP value. The DB value is a constant value (equal to 4.5) which will further weight all ESP score values within  $0.25^\circ$  of the derived Spiral Center position derived previously. This is done to further weight the scores in the calculation described next towards the previously calculated Spiral Center position.

A third confidence factor will be also be derived utilizing the RF routine analysis values. This value is simply a sum of the ESPd value and the ring fit analysis score value at the position being analyzed. This value is called the Combined Confidence (CC) factor value. If the maximum CC factor value is greater than an empirically determined value of 15.0, the position of the maximum CC factor will be used as the final automatically-derived storm center position. This will result in the “Combination Ring/Spiral” automated storm centering method type being used (ID value of 5 for parameter 32 in the history file listed in Section 4B) and identified as “COMBO” in the History File Listing shown in Section 4E1a.

An example of an actual TC storm center selection process is shown in Figure 8. If the previous Final T# intensity was between 3.5 and 4.5, the Spiral Centering and Eye Ring Analysis positions will be used if three or more eye or embedded center scene types have been identified for previous intensity estimates prior to the current analysis date/time. This will ensure that the storm organization is sufficient for the different techniques to work properly and correctly estimate the storm center location. If less than three eye/embedded center scenes have been found, the forecast interpolation position will only be utilized. Once the Final T# value has exceeded 4.5, both auto-centering techniques will be attempted.

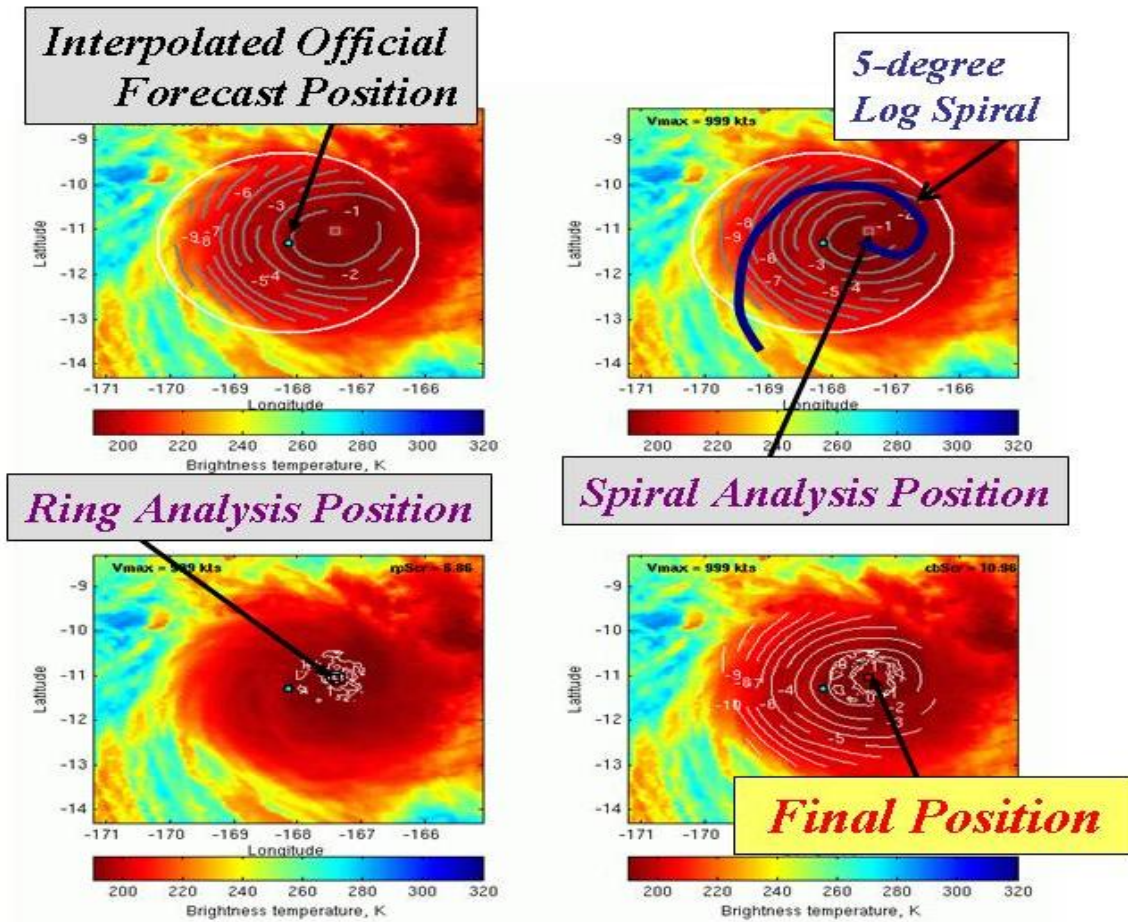


Figure 8: Four-panel image showing various steps, and resultant analysis for each step, in the automated storm centering routine. Upper two images show the initial and enhanced Spiral Centering (SC) contour analyses fields. The white oval represents the computation boundary of the SC analysis. Upper left is initial spiral analysis gradient field, with the enhanced SC in upper right (an example 5-degree log spiral is shown with blue line). Lower left shows contour field associated with Ring Fitting (RF) analysis. Lower right is combined SC and RF analysis contour field. Initial forecast position (blue dot) and subsequent intermediate and final center positions (red dots) are indicated.

### K.) 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 and should only be used as a suggestion.

#### **L.) Latitude Bias Adjustment**

If the Knaff/Zehr pressure/wind relationship is not utilized by the ADT (Section 5O), the MSLP value output by the ADT will include an adjustment based on the latitude of the storm, designed to eliminate a bias noted by Kossin and Velden (2003) in the ADT-derived MSLP values and underlying Dvorak Technique. The equation used for this adjustment is:

$$CI\#_{adj} = CI\#_{orig} + (7.325 - (0.302)*ABS(latitude))$$

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

The MSLP bias adjustment is only applied to scene types that utilize eye and cloud temperature values to determine the strength of the storm since the bias is related to corresponding temperatures associated with a higher/lower tropopause height. In order for the adjustment to be turned “on”, six hours of continuous “EIR-type” scenes must be present. These types of scenes are CDO, Embedded Center, and Eye scenes, while non-EIR scenes include Shear, Curved Band, and Irregular CDO. Once the scene criterion is met, the bias adjustment is blended into use over the next six hours using a time-weighted multiplication factor, ranging from 0.0 at the initial time to 1.0 at the six hour time period, with the determined latitude bias adjustment value.

For more specific information about the 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](http://www.ssec.wisc.edu/~kossin/articles/kossin_velden_MWR.pdf)

#### **M.) Estimate of Radius of Maximum Wind (RMW)**

The ADT invokes a subroutine after each intensity estimate to approximate the radius of maximum wind (RMW). This subroutine calculates the RMW using a regression equation derived from historical comparisons between IR imagery cloud top temperature fields and collocated in-situ reconnaissance aircraft radius of maximum wind measurements. If the derived ADT cloud region temperature (described in Section 5C) is colder than  $-50^{\circ}\text{C}$ , the distance from the storm center to the  $-45^{\circ}\text{C}$  cloud top temperature



isotherm is measured in four directions and averaged to produce a final distance measurement. The RMW location (in kilometers from the storm center position) is then determined from this distance using the equation:

$$\text{RMW} = 2.8068 + (0.8361 * \text{dist})$$

If the ADT derived cloud top temperature value is warmer than  $-50^{\circ}\text{C}$ , the distance to the isotherm defined by the equation  $(\text{ERT} + 2.0 * \text{CRT}) / 3.0$ , where ERT is the eye (center) temperature and CRT is the cloud region temperature, is used in the above equation to determine the RMW value.

#### **N.) Passive Microwave (PMW) Eye Score**

In order to try and alleviate a long standing issue with obtaining accurate intensity estimates with the ADT during Central Dense Overcast (CDO) scene types, an external routine, using passive microwave (PMW) imagery, is used to derive an “eye score” value that the ADT can use to obtain a more accurate intensity estimate than can be obtained with the IRW imagery alone. The process of how the PMW eye score is derived will be detailed in a yet to be written document.

Once the eye score is derived, the score and the PMW scan date and time information is passed into the ADT algorithm. Typically the eye score information is delayed from the current IR analysis time by anywhere from one hour to longer delay periods. This does not pose a problem for the ADT.

Utilization of the PMW eye score value will only be allowed prior to three consecutive, automated “eye” scene type determinations by the ADT algorithm. Once three consecutive eye scene types have been found using the IR imagery alone, the PMW “eye score” information will be ignored no matter what its value may be.

Before the three eye scenes are found, the PMW eye score value will be used to determine the intensity of the storm at the time of the PMW eye score value (it will actually be assigned to the time record in the existing storm history file that exists immediately after the date/time of the PMW eye score record). There are two threshold eye score values that are utilized in the PMW eye score routine, each corresponding to a different T# intensity value to be assigned in the ADT algorithm for the intensity. If the eye score value is equal to or greater than 20.0, but less than 60.0, the ADT will reassign the Raw T# intensity score of the existing record in the ADT history file to be 4.3. If the eye score value is greater than or equal to 60.0, the Raw T# value for this record will be assigned to a 5.0. If no records exist in the ADT history file after the PMW eye score record time, the intensity estimate for the current IR image being analyzed will be modified to one of these two values.

In order to try and alleviate an artificial “jump” in the ADT history file records once the PMW eye score value exceeds one of the threshold values, all of the CI# values, as well as the adjusted Raw T# and Final T# values, in each record up to 12 hours prior to

the PMW eye score record time will be adjusted linearly to a value between the “current” PMW eye score intensity value and the CI# value of the 12-hour previous record. The history file records will be physically changed within the history file, but the “historical” values (obtained prior to the application of the PMW eye score adjustment) will be kept in the history file comment section for each record.

For example, if the PMW eye score value of 26.2 occurred at 20:56UTC, the following record in the history file (most likely at 21:15UTC) will have its Adjusted Raw T#, Final T#, and CI# values all changed to 4.3. Looking back 12 hours from the 21:15UTC record shows the 9:15UTC record with an intensity value (CI#) of 3.4. Thus, all records between 9:15 and 21:15 will have their Adjusted Raw T#, Final T#, and CI# values changed to the corresponding linear interpretation value between 3.4 and 4.3 (depending on the time between the two end times). The original values will be stored for each of these times in their corresponding comment section in the history file.

The same adjustment 12 hour previous record adjustment will be applied if the PMW eye score values change from the first threshold range (between 20.0 and 59.9) to the second (60.0 and above). For example, if the MW eye score exceeds 60.0 at 14:45UTC, all records back to 2:45UTC will be linearly adjusted between the 5.0 value at 14:45 and the CI# value at 2:45UTC.

The PMW eye score adjustment will continue to be applied as long as two conditions are not met. The first, as mentioned previously, occurs when three consecutive, automatically determined scene types are determined from the IR imagery to be “eye” scene types. The second occurs when the PMW eye score value drops below the 20.0 threshold value for more than 12 hours. Once either of these situations occurs, the PMW eye score adjustment will be terminated. If the first situation occurs, the PMW eye score adjustment can never be applied during the remainder of the storm’s lifecycle. If the second situation occurs, the PMW adjustment can once again be applied if a PMW eye score value once again exceeds a threshold value.

During the application of the PMW eye score adjustment, the Rule 8 flag value in each history file record will be modified to store a descriptive value for each situation during the PMW eye score adjustment period. These values will be displayed in the History file Listing described in Section 4E1a. The value will be “MW ON” when the eye score values are 20.0 and above, “MW Adj.” for the 12 hour period prior to the first eye score values exceeding 20.0, and “MW Off” for either of the two conditions where the eye score adjustment is turned off (the records 12 hours previous to the “MW Off” will be assigned “MW Hold” in the second condition described in the above paragraph). The records modified during the initial 12-hour adjustment periods (either with the first eye score value above 20.0 or with the transition between the 20.0 and 60.0 values) will all have their comment section appended with the information “MWinit=A.A/B.B/C.C”, where A.A, B.B, and C.C are the initial Adjusted Raw T#, Final T#, and CI# values, respectively (prior to the MW adjustment).

## **O.) Knaff/Zehr Wind-Pressure Relationship**

A new relationship between the TC wind and MSLP values has been implemented into the ADT using the methodology outlined in Knaff and Zehr, 2007. This technique utilizes several environmental TC parameters to convert the T# value obtained by the ADT to wind speed (using the relationship shown in Table 2) and then to an estimate of MSLP, and is far too complex to describe in detail in this document.

The environmental parameters needed by the ADT to calculate the MSLP estimate are the environmental MSLP and the gale radius (the 34 knot wind radius) of the TC being examined. The environmental MSLP value can be obtained by determining the outermost closed isobar and adding 2 hPa, while the gale radius can be derived by averaging all available quadrant 34 knot wind radii estimate values. These values are obtained from the ATCF Best Track/Objective Aid/Wind Radii format files using the observational comprehensive archive (CARQ) record values. The ATCF homepage is provided in Section 4D7. The environmental MSLP/last closed isobar value is the “RADP” value, while the 34 knot radii values (value of 34 in the RAD column) will be stored in the RAD1 through RAD4 values.

## **P.) Non-McIDAS Environment Compilation**

If the ADT code is to be run in an environment where McIDAS is not installed, the ADT can be compiled completely free of the McIDAS core environment using a special keyword during the use of the “compileall” script file. To compile the ADT code in non-McIDAS fashion, use the following command:

**compileall nomcidas**

This command will eliminate the symbolic link to the libmcidas.a library file within the compileall script. In addition, it will run the Makefile within the odtappl using a special parameter to eliminate the inclusion of the McIDAS library file (so as to not cause an error during compilation).

The resulting executable will not be able to be run in any sort of interactive mode, so a storm center position will need to be passed to the ADT routine using a “hidden” functionality with the OVER keyword or by utilizing the automated center determination methodology as described in Section I above. Also, the user will need to explicitly define the name of the McIDAS AREA image file to be used with the DATASET keyword.

If a “manual” position is to be entered into the ADT, the OVER=YES keyword should be utilized. The latitude and longitude values must be entered after the “YES” to provide the ADT with a “manual” storm center position. In addition, if the user wishes to “manually” override the scene type determined within the ADT, a fourth option can be entered after the latitude and longitude values to signify the “manually” selected scene type to be used by the ADT. A few examples are listed below to show how the “manual”



operation of the ADT in non-McIDAS mode can be correctly executed. Please note the image file directory location is defined by the ODTDATA environmental parameter in the aodtenv file.

*ADT AUTO DISC opal.wrn23.txt OPAL.ODT DATASET=X AREA1234*

The ADT will run in “automated mode” using the NHC discussion file opal.wrn23.txt to provide the initial storm center position. The image file AREA1234 will be utilized by the ADT algorithm, with the output being written to the history file OPAL.ODT.

*ADT OPAL.ODT DATASET=X AREA1234 OVER=YES 25.5 90.2*

The ADT will run in “manual mode” using the manually defined storm center position at 25.5N/90.2W. The image file AREA1234 will be utilized, with the output being written to the OPAL.ODT history file.

*ADT AUTO DISC opal.wrn23.txt DATASET=X AREA1234 OVER=YES X X EYE*

The ADT will run in “automated mode” using the NHC discussion file opal.wrn23.txt to provide the initial storm center position. The image file AREA1234 will be utilized by the ADT algorithm. The automated scene type selection value will be overridden with the manually entered value of “EYE” when determining the TC intensity.

Valid options for the “manual” scene type override are:

EYE	- Clear eye
PINHOLE	- Pinhole eye
LARGE	- Large eye
UNIFORM	- Uniform CDO
EMBEDDED	- Embedded Center
IRREGULAR	- Irregular CDO
CURVED	- Curved band
SHEAR	- Shear

The ADT parameter PLOT, which graphically displays the ADT history file, will not be available when compiling the ADT in non-McIDAS mode. An error message will result to remind the user of this restriction.

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