

**ADT – Advanced Dvorak Technique  
USERS’ GUIDE  
(McIDAS Version 7.2)**

Prepared by

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on behalf of

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# ADT – Advanced Dvorak Technique

## Users’ Guide

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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 (2006).

## **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 (7.2) of the ADT algorithm can be obtained via the UW-CIMSS ADT web page, along with the Users' Guide. The ADT web page is located at :  
**<http://cimss.ssec.wisc.edu/tropic/adt/adt.html>**

Please note a login name and password is required to obtain the ADT code from the ADT webpage. Please contact Tim Olander ([timo@ssec.wisc.edu](mailto:timo@ssec.wisc.edu)) for this information.

The downloaded ADT tar file for Version 7.2.x can be uncompressed and unpacked using the following command (x represents the latest update available within the 7.2 release series):

```
gunzip NADT-V7.2.x.tar.gz  
tar -xvf NADT-V7.2.x.tar
```

The resulting subdirectory "ADTV7.2.x" will contain the following :

- docs : directory - documentation
- 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
- odtmlcid : directory - McIDAS specific routines
- aodtenv : file - environment argument setup file (Section 4E)
- compileall : file - compile script
- Makefile : file - UNIX makefile (for compileall script)
- TOPOHRES : 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.

## 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** <*keywords*> {*comment*}

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

#### 1.) Description of Use

**HISTORY=filename** (default=none)

History file used for the ADT analysis. If no history file is specified, no history file will be created/appended. History file names will be appended with an “.ODT” suffix if not explicitly defined in the “filename” definition. The directory where the history files are written to is defined with the ODTISTORY environment argument. See Special Keyword Notes in Section 4A2 and Section 4B for additional information about the ADT history file.

**LIST=YES/NO** (default=NO)

List contents of history file within McIDAS text window. Keyword can be used in conjunction with DATE, OUTPUT, and DOMAIN keywords. Pressure/wind units in terms of millibars/knots. If utilized in conjunction with the ATCF keyword, the listing produced will be in ATCF Fix File/DVTO format. ADT analysis will not be performed.

**OUTPUT=SCREEN/FILE filename** (default=SCREEN)

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

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

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

**PLOT=c1 c2 c3 c4 c5 c6 c7 c8 c9 c10** (default=1 2 0 0 0 0 0 6 7;0 to not display)  
Defines graphic color level values for CI#, Adjusted MSLP, Final T# (6-hr time-weighted), Final T# (3-hr average), Adjusted Raw T#, Unadjusted Raw T#, 12-hour Average TIE Model value, Current TIE Model value, graphics boundaries, and graphics wording, respectively. The TIE Model values have been disabled for this version. If TEM keyword is used with GRAPH keyword, the color levels will be for the eye region temperature, cloud region temperature, and “coldest-warmest” cloud region temperature, respectively (the other four values will not be used). Graphics color level value of zero (0) will suppress plotting of desired intensity estimate value. Use in conjunction with GRAPH keyword.

**DELETE=YES/NO** (default=NO)  
Allow for manual deletion of history file records. Keyword must be used in conjunction with DATE keyword to define date/time limits to remove. Any records existing in history file after deletion of unwanted records will be updated as necessary (Final T# and CI values will be recalculated). See DATE keyword for default values associated with DELETE keyword. ADT analysis will not be performed.

**DATE=date1 time1 date2 time2** (default=see below)  
Defines range of dates and times for LIST, GRAPH, and DELETE keywords. Format for date and time values are the same as those given within the text listing (LIST=YES option) :  
date format : YearMonDy (e.g. 1998OCT17)  
time format : HHMMSS (e.g. 131500)  
Default values :  
GRAPH and LIST : date1/time1 : first record  
date2/time2 : last record  
DELETE : date1/time1 : no default, must specify  
date2/time2 : date1/time1

**WIND=YES/NO** (default=NO)  
Provide intensity units in terms of maximum wind speed (knots) instead of mean sea level pressure. Keyword used in conjunction with GRAPH keyword to plot intensity estimates in terms of wind speed. Speed and pressure values are related to CI number values using empirical relationships defined in Dvorak (1984) and (Shewchuck and Weir, 1980).

**DOMAIN=ATL/PAC** (default=auto determination)

Define relationship “domain” for CI# to MSLP conversion. ATL should be used for storms within North Atlantic basin, while PAC should be used for storms within Western Pacific basin. If the oceanic basin is not explicitly defined with this keyword, a basin will be selected automatically (see Section 5H). Domain selection will affect Raw T# intensity estimate determination and corresponding CI number pressure value (empirical CI number/pressure relationship). Keyword can be used with LIST and GRAPH keywords or with ADT analysis.

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

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

**Keyword cannot be used with OVER keyword.**

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

**OVER=YES/NO** (default=NO)

Allow user to manually override ADT scene identification. **Keyword cannot be used in conjunction with AUTO keyword.** See Section 4D5 for more information.

**IC=value** (default=1.0)

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

**REMOTE=YES/NO localserver localarea** (default=NO ODTLSERVE ODTLDATA)

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

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



- LAND=YES/NO** (default=YES)  
Apply ADT land interaction rule. See Section 4D5 and 5A for more information.
- RMW=radius** (default=-99)  
Allow user to input radius of maximum wind radius (in km) manually. If radius is less than 5km or greater than 45km, scene type will be changed to PINHOLE EYE or LARGE EYE, respectively, if an eye scene is determined.
- SEARCH=YES/NO** (default=YES)  
Perform search for maximum curved band location if Curved Band scene type was automatically determined or manually selected. See Section 5J for more information.
- COMM=YES/NO** (default=NO)  
Add comment field to history file at specified date/time (using DATE keyword). Comment can be up to 50 characters in length and must be enclosed within braces “{“ and “}” on the command line.
- ATCF=stormID sourceID rawT finalT** (default=-1 XXXX 0 0)  
Produce ATCF format output listing for a current intensity estimate record or an entire history file listing. If ATCF keyword is used in conjunction with LIST keyword, output will consist of all records defined with DATE keyword. If ATCF keyword is defined when producing a tropical cyclone intensity estimate, an output file will be produced (in the directory defined with the ODTOUTPUT environmental variable) containing the ATCF format output for the current record. The naming convention for the output file is defined in Section 4A2.
- stormID : Annual tropical cyclone number and basin value (e.g. 10W, 06L)  
sourceID : Fix site/WMO Identifier character string (e.g. NHC, PGTW, etc.)  
rawT : Flag value indicating output of the Adjusted Raw T# (0) or Unadjusted Raw T# (1) value into the ATCF DVTO “T num (raw)” parameter output slot.  
finalT : Flag value indicating output of the 6-hour weighted average Final T# (0) or 3-hour straight linear Final T# (1) value into the ATCF DVTO “T num (average)” parameter output slot.

## 2.) Special Keyword Notes

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

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

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

The ATCF keyword can be utilized during an ADT intensity estimate analysis or in conjunction with the LIST keyword to output an ATCF Fix File format output (instead of the standard history file listing). If an ATCF format listing is desired with an intensity analysis, an output file will be created in the directory defined with the ODTOUTPUT environmental variable (Section 4C). The naming convention of this output file will be :

**CIMSS\_DVTO\_yyyymmddhhhh\_ssA\_FIX**

yyyy - year  
mm - month (01-12)  
dd - day (01-31)  
hhhh - UTC time (12:15UTC = 1215)  
ss - annual tropical cyclone number (input on command line)  
A - sub-basin ID : L-Atlantic, E-East Pacific, C-Central Pacific,  
W-West Pacific, A-No. Indian Ocean, B-So. Indian Ocean,  
S-Australia Region (90E-135E), P-Australia Region (135E east)

**3.) 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 HISTORY=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 HISTORY=OPAL.ODT IC=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 HISTORY=OPAL.ODT ATCF=13 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 cyclone number of 13, Fix Center of "NHC, Adjusted Raw T# value, and 3-hour linear averaged Final T# value displayed.

*ADT HISTORY=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 HISTORY=OPAL.ODT GRAPH=YES PLOT=3 4 5 0 1 2*

Display graph of contents of history file OPAL.ODT in current graphic image using color level 3, 4, 5, 0, 1, and 2 for the CI#, Adjusted MSLP, Final T# (6-hr average), Final T# (3-hr), Adjusted Raw T#, and Unadjusted Raw T# plots, respectively. TIE Model output will not be displayed. Graph boundary and wording will utilize the default values. No intensity analysis is performed.

*ADT HISTORY=OPAL.ODT LIST=YES*

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

*ADT HISTORY=OPAL.ODT LIST=YES 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 HISTORY=OPAL.ODT LIST=YES 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 HISTORY=OPAL DELETE=YES DATE=1995OCT03 151500*

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

*ADT HISTORY=OPAL DELETE=YES DATE=1995OCT03 151500 1995OCT03 191500*

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

*ADT HISTORY=OPAL LIST=YES DATE=1995OCT03 1500*

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

*ADT HISTORY=OPAL LIST=YES DATE=X X 1995OCT03 31500*

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

*ADT HISTORY=OPAL.ODT AUTO=YES 2 wp2698.txt*

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 HISTORY=OPAL.ODT REMOTE=YES*

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

*ADT HISTORY=OPAL.ODT DATE=1995OCT03 81500 COMM=YES {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 (6-hour time-weighted average)
Value 7	: final T# value (3-hour average)
Value 8	: final CI# value
Value 9	: eye region temperature (°C)
Value 10	: mean cloud region temperature (°C) – movable annulus
Value 11	: mean cloud region temperature (°C) – set region (old method)
Value 12	: “coldest-warmest” cloud region temperature (°C)
Value 13	: storm center latitude (+/- = North/South Hemisphere)
Value 14	: storm center longitude (+/- = West/East Hemisphere)
Value 15	: eye diameter, CDO size, or shear distance (in km)
Value 16	: eye region temperature standard deviation value
Value 17	: cloud region symmetry value
Value 18	: satellite ID value
Value 19	: eye region scene type (original value)
Value 20	: cloud region scene type (original value)
Value 21	: eye region scene type (original value if user override performed)
Value 22	: cloud region scene type (original value if user override performed)
Value 23	: Dvorak Weakening (Dvorak EIR Rule 9) flag
Value 24	: Dvorak Constraint Limits (Dvorak EIR Rule 8) flag
Value 25	: latitude bias application flag
Value 26	: rapid dissipation flag (east pacific only)
Value 27	: land/ocean flag
Value 28	: eye region FFT value
Value 29	: cloud region FFT value
Value 30	: curved band analysis – BD curve gray scale value
Value 31	: curved band analysis – convection curvature amount (out of 25)
Value 32	: distance from center to “coldest-warmest” temperature value
Value 33	: automated center determination flag
Value 34	: MSLP latitude bias adjustment value
Value 35	: radius of maximum wind (in km)
Value 36	: 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 Arguments

In order to provide more control regarding various ADT input/output file and directory definitions, the ADT utilizes seven 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> )
ODTLSERVER	Name of local ADDE server dataset name
ODTLAREA	ID number of local ADDE server dataset position

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

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

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

```
. aodtENV
```

## 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 7.2.1
    Tropical Cyclone Intensity Algorithm
```

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

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

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

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

```
6hr-Avg T#   3hr-Avg T#   Adj T#   Raw T#
   6.3         6.4         6.5       7.1
```

```
Eye 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# (6-hour time-weighted average), 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 5M) 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 “6hr-Avg T#” value is the 6-hour time-weighted averaged intensity of the storm. The time averaging scheme is explained in greater detail in Section 5D. The “3hr-Avg T#” value is the average of the current and previous three hour analyses values. Finally, the “CI#” value represents the 6-hour time-weighted averaged value after various 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 and F.

Adjacent to the “CI#” value are the corresponding estimated mean sea level pressure (MSLP) and maximum wind (Vmax) values. 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. 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 5H and 5K for more information on this adjustment.

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 section 4D4. The scene type will be determined automatically using various image analysis methods (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 will be provided under the Latitude Bias Adjustment line in the intensity bulletin. For more information on the derivation of this maximum wind value see Section 5L.

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 5H 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/adt/mcidas/data/AREA2010
```

```
*****
```

```
                UW - CIMSS
            ADVANCED DVORAK TECHNIQUE
                ADT - Version 7.2.1
    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
```

```
Eye 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
Utilizing topography file /home/adt/TOPOHRES
Tropical cyclone is over land
```

\*\*\*\*\*

```
                UW - CIMSS
          ADVANCED DVORAK TECHNIQUE
            ADT - Version 7.2.1
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 5I 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 or JTWC forecast in conjunction with two previous positions from the history file (6 and 12 hour old positions), if available. If the forecast interpolation scheme fails, a linear extrapolation of the previous 12 hours of storm positions stored in the history is determined.

If 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 5H.

In the following examples, a TPC/NHC forecast was used in the polynomial interpolation scheme. The data points used in the polynomial interpolation scheme are displayed prior to the interpolated position. 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 REMOTE is used. The REMOTE keyword utilizes two ADT environment arguments to describe the name and location of the data file being examined. These variables can be defined in the aodtenv file (Section 4C) or with two REMOTE keyword entries (Section 4A1).

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

```
DOWNLOADING REMOTE IMAGE EAST/NH.5 TO LOCAL IMAGE LOCAL/IMAGES.7777
  WITHIN LOCAL DIRECTORY AT /home/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 of “LOCAL/IMAGES” into position 7777. The local ADDE image in this example was located in the /home/adt/mcidas/data directory in the file AREA7777. The ADT algorithm then utilized this locally stored image in the derivation of the intensity estimate for the storm image being examined.

#### 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 4A2 for more information about the file naming structure.

If an ATCF file is produced, an information message will be displayed at the end of the intensity bulletin indicating the location and name of the file created :

```
WROTE ATCF OUTPUT TO FILE /home/adt/output/CIMSS_DVTO_199909102115_08L_FIX
```

## 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, DATE, and OUTPUT keywords. An example of an original format listing is provided below :

```

===== ADT-Version 7.2.1 =====
-----Intensity----- ---Tno Values--- ---Tno/CI Rules--- -Temperature-
Date      Time      Final/MSL/Plat/Vmax 6hr 3hr Adj Inl  Cnstrnt  Wkng Rpd  Cntr  Mean  Scene  EstRMW  Storm  Location  Fix  Comments
  (UTC)    CI      MSLP/BiasAdj/(kts) Ave Ave Raw Raw  Limit  Flag Wkng Region Cloud Type (km)  Lat  Lon  Mhd
1999SEP08 151500  3.0 1000.0/ +0.0 / 45.0  3.0 3.0 3.0 3.0  NO LIMIT  OFF  OFF  -15.86 -27.61  SHEAR  N/A  15.81  50.06  FCST
1999SEP08 161500  3.0 1000.0/ +0.0 / 45.0  3.0 3.0 3.1 3.3  0.1T/hour  OFF  OFF  -6.16 -28.89  SHEAR  N/A  15.86  50.28  FCST
1999SEP08 171500  3.0 1000.0/ +0.0 / 45.0  3.0 3.0 3.0 2.5  0.1T/hour  OFF  OFF  -5.56 -33.82  IRRCD0  N/A  15.91  50.51  FCST
1999SEP08 181500  3.0 1000.0/ +0.0 / 45.0  2.9 3.0 2.9 2.5  0.1T/hour  WKN  OFF  -19.96 -36.52  IRRCD0  N/A  15.96  50.73  FCST
1999SEP08 191500  3.0 1000.0/ +0.0 / 45.0  2.9 3.0 3.0 3.0  NO LIMIT  WKN  OFF  -41.56 -34.03  CRVBND  N/A  16.02  50.96  FCST
1999SEP08 201500  3.0 1000.0/ +0.0 / 45.0  2.9 2.9 2.9 2.5  0.1T/hour  WKN  OFF  -29.36 -35.45  IRRCD0  N/A  16.07  51.18  FCST
1999SEP08 211500  3.0 1000.0/ +0.0 / 45.0  2.9 2.9 3.0 3.7  0.1T/hour  WKN  OFF  -34.96 -45.12  CRVBND  N/A  16.62  51.76  FCST
1999SEP08 221500  3.0 1000.0/ +0.0 / 45.0  2.8 2.8 2.7 2.7  NO LIMIT  WKN  OFF  -15.16 -42.83  CRVBND  N/A  16.71  52.01  FCST
1999SEP08 231500  3.0 1000.0/ +0.0 / 45.0  2.7 2.7 2.5 2.2  0.5T/6hr  WKN  OFF  -0.66 -41.90  CRVBND  N/A  16.80  52.26  FCST
1999SEP09 001500  3.0 1000.0/ +0.0 / 45.0  2.7 2.7 2.7 2.7  NO LIMIT  WKN  OFF  -14.16 -42.70  CRVBND  N/A  16.89  52.50  FCST
1999SEP09 011500  3.0 1000.0/ +0.0 / 45.0  2.8 2.8 3.2 4.1  0.5T/hour  WKN  OFF  -68.96 -44.97  UNIFRM  N/A  16.98  52.73  FCST
1999SEP09 021500  3.0 1000.0/ +0.0 / 45.0  2.9 2.9 3.3 4.3  0.5T/hour  WKN  OFF  -66.06 -49.50  UNIFRM  N/A  17.06  52.96  FCST
1999SEP09 031500  3.1 998.8/ +0.0 / 47.0  3.1 3.3 3.4 4.5  0.5T/hour  OFF  OFF  -65.16 -56.73  UNIFRM  N/A  16.71  53.66  FCST
1999SEP09 064600  3.3 996.4/ -0.0 / 51.0  3.3 3.3 3.3 4.5  0.5T/6hr  OFF  OFF  -60.16 -69.20  UNIFRM  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 4.6  NO LIMIT  OFF  OFF  -58.76 -71.83  UNIFRM  N/A  20.97  60.56  SPRL
1999SEP11 064500  4.7 974.0/ -1.5 / 82.2  4.7 4.8 4.8 4.8  NO LIMIT  OFF  OFF  -47.06 -68.08  EMBC  N/A  21.66  60.42  SPRL
1999SEP11 074500  4.8 972.0/ -1.6 / 84.8  4.8 4.9 5.0 5.0  NO LIMIT  OFF  OFF  -59.86 -70.36  EMBC  N/A  21.49  61.20  SPRL
1999SEP11 084500  4.8 972.2/ -1.4 / 84.8  4.7 4.7 4.5 4.5  NO LIMIT  WKN  OFF  -46.46 -69.65  UNIFRM  N/A  21.76  61.17  SPRL
1999SEP11 094500  4.8 972.1/ -1.5 / 84.8  4.6 4.7 4.5 4.5  NO LIMIT  WKN  OFF  -62.46 -69.24  UNIFRM  N/A  21.61  61.52  SPRL
1999SEP11 104500  4.8 972.2/ -1.4 / 84.8  4.6 4.7 4.8 4.8  NO LIMIT  WKN  OFF  -64.36 -68.35  EMBC  N/A  21.69  61.53  SPRL
1999SEP11 114500  4.8 972.2/ -1.4 / 84.8  4.7 4.6 4.8 4.8  NO LIMIT  WKN  OFF  -60.96 -67.65  EMBC  N/A  21.77  61.65  SPRL
-records deleted from listings-
1999SEP12 094500  5.3 963.9/ -0.1 / 97.2  5.3 5.3 5.6 6.4  0.5T/hour  OFF  OFF  0.74 -69.96  EYE  22  IR  23.15  65.87  COMBO
1999SEP12 101500  5.3 963.8/ +0.2 / 97.2  5.4 5.3 5.8 6.6  0.5T/hour  OFF  OFF  9.04 -71.14  EYE  26  IR  23.05  65.86  COMBO
1999SEP12 104500  5.4 961.9/ -0.1 / 99.6  5.5 5.4 5.8 6.3  0.5T/hour  OFF  OFF  12.44 -68.40  EYE  25  IR  23.15  66.16  COMBO
1999SEP12 114500  5.7 954.9/ -0.3 /107.2  5.6 5.7 6.0 7.0  0.5T/hour  OFF  OFF  11.54 -73.20  EYE  23  IR  22.96  66.13  COMBO
1999SEP12 124500  5.8 952.5/ -0.3 /109.8  5.7 5.8 5.8 5.8  NO LIMIT  OFF  OFF  -0.06 -69.34  EYE  30  IR  22.96  66.21  COMBO
1999SEP12 134500  5.9 950.4/ -0.0 /112.4  5.8 5.9 6.0 6.0  NO LIMIT  OFF  OFF  0.14 -67.35  EYE  33  IR  23.27  66.51  COMBO
1999SEP12 144500  5.9 950.3/ -0.1 /112.4  5.9 5.9 6.0 6.0  NO LIMIT  OFF  OFF  12.94 -66.10  EYE  32  IR  23.19  66.70  COMBO
1999SEP12 154500  6.0 948.1/ +0.1 /115.0  6.0 6.0 6.2 6.2  NO LIMIT  OFF  OFF  7.24 -66.61  EYE  26  IR  23.36  66.76  COMBO
1999SEP12 164500  6.0 948.1/ +0.1 /115.0  6.0 6.0 6.0 6.0  NO LIMIT  OFF  OFF  12.14 -67.45  EYE  34  IR  23.38  67.13  COMBO
1999SEP12 174500  6.0 948.2/ +0.2 /115.0  6.0 6.0 6.2 6.2  NO LIMIT  OFF  OFF  13.64 -67.15  EYE  24  IR  23.50  67.28  COMBO
1999SEP12 181500  6.1 945.5/ +0.1 /117.4  6.1 6.1 6.2 6.2  NO LIMIT  OFF  OFF  11.14 -66.92  EYE  30  IR  23.40  67.58  COMBO
1999SEP12 191500  6.1 945.6/ +0.2 /117.4  6.1 6.0 6.0 6.0  NO LIMIT  ON  OFF  16.54 -68.66  EYE  34  IR  23.53  67.63  COMBO
1999SEP12 204500  6.1 945.7/ +0.3 /117.4  6.0 6.0 6.0 6.0  NO LIMIT  ON  OFF  16.74 -72.05  EYE  34  IR  23.66  68.00  COMBO
1999SEP12 214500  6.1 945.7/ +0.2 /117.4  6.0 6.0 6.0 6.0  NO LIMIT  ON  OFF  19.14 -67.50  EYE  36  IR  23.58  68.19  COMBO
1999SEP12 224500  6.1 945.6/ +0.2 /117.4  6.0 6.0 6.0 6.0  NO LIMIT  ON  OFF  19.24 -70.46  EYE  35  IR  23.52  68.29  COMBO
1999SEP12 234500  6.1 945.6/ +0.2 /117.4  6.0 6.0 6.0 6.0  NO LIMIT  ON  OFF  19.24 -69.12  EYE  33  IR  23.57  68.61  COMBO
1999SEP13 004500  6.1 945.7/ +0.3 /117.4  5.9 6.0 6.0 6.0  NO LIMIT  ON  OFF  19.74 -71.65  EYE  33  IR  23.61  68.82  COMBO
1999SEP13 014500  6.1 945.7/ +0.3 /117.4  6.4 6.0 6.0 6.0  NO LIMIT  ON  OFF  20.54 -68.80  EYE  34  IR  23.66  69.03  COMBO
1999SEP13 024500  6.1 945.7/ +0.3 /117.4  6.0 6.0 6.0 6.0  NO LIMIT  ON  OFF  21.44 -69.21  EYE  33  IR  23.60  69.25  COMBO
1999SEP13 064500  6.4 938.1/ +0.5 /124.6  6.2 6.4 6.4 6.4  NO LIMIT  OFF  OFF  19.14 -69.40  EYE  28  IR  23.86  70.09  COMBO
1999SEP13 074500  6.4 938.1/ +0.5 /124.6  6.3 6.4 6.4 6.4  NO LIMIT  OFF  OFF  18.84 -69.23  EYE  29  IR  23.91  70.31  COMBO
1999SEP13 084500  6.4 938.2/ +0.6 /124.6  6.4 6.4 6.6 6.6  NO LIMIT  OFF  OFF  19.44 -70.73  EYE  28  IR  23.97  70.54  COMBO
1999SEP13 094500  6.5 935.6/ +0.6 /127.0  6.5 6.5 6.6 6.6  NO LIMIT  OFF  OFF  19.34 -71.15  EYE  28  IR  23.98  70.83  COMBO
1999SEP13 101500  6.5 935.6/ +0.6 /127.0  6.5 6.5 6.5 6.5  NO LIMIT  OFF  OFF  19.44 -70.40  EYE  28  IR  24.00  71.05  COMBO
1999SEP13 111500  6.5 935.7/ +0.7 /127.0  6.4 6.5 6.4 6.4  NO LIMIT  OFF  OFF  19.14 -69.82  EYE  27  IR  24.04  71.28  COMBO
1999SEP13 121500  6.5 935.7/ +0.7 /127.0  6.4 6.4 6.3 6.3  NO LIMIT  ON  OFF  19.44 -68.37  EYE  29  IR  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 5.8  NO LIMIT  ON  OFF  15.04 -62.88  EYE  30  IR  25.55  76.20  COMBO
1999SEP14 134500  6.5 937.1/ +2.1 /127.0  5.7 5.7 5.6 5.6  NO LIMIT  ON  OFF  13.34 -60.23  EYE  33  IR  25.66  76.38  COMBO
1999SEP14 144500  6.5 937.2/ +2.2 /127.0  5.6 5.6 5.4 5.4  NO LIMIT  ON  OFF  13.84 -58.17  EYE  31  IR  25.78  76.56  COMBO
1999SEP14 154500  6.5 937.3/ +2.3 /127.0  5.5 5.5 5.3 5.3  NO LIMIT  ON  OFF  14.14 -57.54  EYE  36  IR  25.91  76.68  COMBO
1999SEP14 164500  6.5 937.5/ +2.5 /127.0  5.5 5.5 5.7 5.7  NO LIMIT  ON  OFF  14.34 -61.15  EYE  29  IR  26.08  76.78  COMBO
1999SEP14 174500  6.5 937.5/ +2.5 /127.0  5.5 5.5 5.7 5.7  NO LIMIT  ON  OFF  11.14 -61.61  EYE  26  IR  26.16  76.87  COMBO
1999SEP14 181500  6.5 937.7/ +2.7 /127.0  5.6 5.6 5.8 5.8  NO LIMIT  ON  OFF  8.64 -62.38  EYE  28  IR  26.31  76.97  COMBO
1999SEP14 194500  6.5 937.9/ +2.9 /127.0  5.7 5.7 5.9 5.9  NO LIMIT  ON  OFF  9.84 -63.94  EYE  28  IR  26.54  77.03  COMBO
1999SEP14 204500  6.5 938.0/ +3.0 /127.0  5.7 5.7 5.7 5.7  NO LIMIT  ON  OFF  10.24 -61.50  EYE  31  IR  26.73  77.11  COMBO
1999SEP14 214500  6.5 938.2/ +3.2 /127.0  5.7 5.8 5.8 5.8  NO LIMIT  ON  OFF  10.44 -62.85  EYE  36  IR  26.89  77.31  COMBO
1999SEP14 224500  6.5 938.3/ +3.3 /127.0  5.8 5.8 6.0 6.0  NO LIMIT  ON  OFF  11.04 -64.52  EYE  37  IR  27.06  77.31  COMBO
1999SEP14 234500  6.5 938.6/ +3.6 /127.0  5.9 5.8 6.0 6.0  NO LIMIT  ON  OFF  12.54 -65.74  EYE  36  IR  27.33  77.42  COMBO
1999SEP15 004500  6.5 938.6/ +3.6 /127.0  5.9 5.9 6.0 6.0  NO LIMIT  ON  OFF  13.04 -65.17  EYE  33  IR  27.41  77.54  COMBO
1999SEP15 014500  6.5 938.9/ +3.9 /127.0  5.9 6.0 6.0 6.0  NO LIMIT  ON  OFF  12.94 -65.93  EYE  32  IR  27.70  77.66  COMBO
1999SEP15 024500  6.5 939.1/ +4.1 /127.0  5.9 6.0 6.0 6.0  NO LIMIT  ON  OFF  12.84 -67.52  EYE  33  IR  27.89  77.89  COMBO
1999SEP15 034500  6.5 939.1/ +4.1 /127.0  6.0 6.0 6.0 6.0  NO LIMIT  ON  OFF  13.44 -68.25  EYE  33  IR  27.95  78.08  COMBO
1999SEP15 064500  6.5 939.7/ +4.7 /127.0  6.0 6.0 6.0 6.0  NO LIMIT  ON  OFF  10.74 -64.22  EYE  31  IR  28.56  78.29  COMBO
1999SEP15 074500  6.5 939.9/ +4.9 /127.0  5.8 5.8 5.7 5.7  NO LIMIT  ON  OFF  12.54 -61.87  EYE  34  IR  28.80  78.64  COMBO
1999SEP15 084500  6.5 940.1/ +5.1 /127.0  5.7 5.7 5.7 5.7  NO LIMIT  ON  OFF  11.04 -61.84  EYE  31  IR  29.05  78.64  COMBO
1999SEP15 094500  6.5 940.1/ +5.1 /127.0  5.7 5.7 5.7 5.7  NO LIMIT  ON  OFF  11.54 -61.29  EYE  35  IR  29.08  78.68  COMBO
1999SEP15 104500  6.5 940.3/ +5.3 /127.0  5.7 5.6 5.6 5.6  NO LIMIT  ON  OFF  10.24 -60.71  EYE  34  IR  29.26  78.62  COMBO
1999SEP15 114500  6.5 940.4/ +5.4 /127.0  5.6 5.6 5.5 5.5  NO LIMIT  ON  OFF  11.54 -59.24  EYE  35  IR  29.44  78.68  COMBO
1999SEP15 121500  6.5 940.5/ +5.5 /127.0  5.5 5.5 5.3 5.3  NO LIMIT  ON  OFF  12.14 -57.99  EYE  40  IR  29.53  78.82  COMBO
1999SEP15 131500  6.3 945.9/ +5.7 /122.2  5.3 5.3 5.0 4.9  0.5T/hour  ON  OFF  11.54 -51.90  EYE  38  IR  29.72  78.87  COMBO
1999SEP15 134500  6.1 951.2/ +5.8 /117.4  5.2 5.1 4.8 4.8  NO LIMIT  ON  OFF  11.94 -49.46  EYE  37  IR  29.81  78.89  COMBO
1999SEP15 141500  6.0 953.9/ +5.9 /115.0  5.1 5.0 4.8 4.8  NO LIMIT  ON  OFF  11.04 -50.45  EYE  42  IR  30.01  78.91  COMBO
1999SEP15 151500  5.9 956.5/ +6.1 /112.4  4.9 4.9 4.7 4.7  NO LIMIT  ON  OFF  9.44 -47.91  EYE  40  IR  30.22  78.86  COMBO
1999SEP15 161500  5.8 959.1/ +6.3 /109.8  4.9 4.8 5.0 5.0  NO LIMIT  ON  OFF  10.84 -54.18  EYE  34  IR  30.38  78.98  COMBO
1999SEP15 171500  5.8 959.2/ +6.4 /109.8  4.9 4.8 4.9 4.9  NO LIMIT  ON  OFF  10.84 -51.62  EYE  32  IR  30.54  79.08  COMBO
1999SEP15 184500  5.8 959.5/ +6.7 /109.8  5.0 5.0 5.3 5.3  NO LIMIT  ON  OFF  12.04 -57.59  EYE  31  IR  30.83  78.86  COMBO
1999SEP15 194500  5.8 959.8/ +7.0 /109.8  5.1 5.1 5.3 5.3  NO LIMIT  ON  OFF  6.94 -57.76  EYE  32  IR  31.19  78.81  COMBO
1999SEP15 204500  5.8 959.9/ +7.1 /109.8  5.2 5.3 5.4 5.4  NO LIMIT  ON  OFF  9.94 -58.59  EYE  32  IR  31.34  78.75  COMBO
1999SEP15 214500  5.8 960.1/ +7.3 /109.8  5.3 5.3 5.4 5.4  NO LIMIT  ON  OFF  1.14 -58.88  EYE  30  IR  31.59  78.68  COMBO
1999SEP15 224500  5.8 960.3/ +7.5 /109.8  5.4 5.4 5.6 5.6  NO LIMIT  ON  OFF  2.84 -69.75  EYE  30  IR  31.80  78.41  COMBO
1999SEP15 234500  5.8 960.6/ +7.8 /109.8  5.4 5.5 5.6 5.6  NO LIMIT  ON  OFF  2.04 -60.25  EYE  35  IR  32.10  78.37  COMBO
1999SEP16 001500  5.8 960.8/ +8.0 /109.8  5.3 5.3 4.9 4.8  0.5T/hour  ON  OFF  -7.76 -60.86  EYE  N/A  32.35  78.34  COMBO
1999SEP16 014500  5.8 961.2/ +8.4 /109.8  5.1 5.2 4.8 4.8  NO LIMIT  ON  OFF  -7.26 -60.25  EYE  N/A  32.79  78.26  COMBO
1999SEP16 034500  5.6 966.2/ +8.6 /104.6  4.8 4.6 4.5 4.5  NO LIMIT  ON  OFF  -20.16 -54.90  EYE  N/A  32.98  78.14  N/A
1999SEP16 074500  0.0 0.0/ +0.0 / 0.0  0.0 0.0 0.0 0.0  N/A  OFF  99.99 99.99  LAND  N/A  34.62  77.57  N/A

```

Utilizing history file /home/adt/history/FLOYD.ODT  
Successfully completed listing







## 5.) Background Information

### A.) Land Flag

Tropical cyclone land interaction is determined utilizing the low-resolution topography map TOPOhRES provided. The resolution of the map file is 0.1° X 0.1° latitude/longitude. If a 1.0 X 1.0 degree 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. The latitude, longitude, and land flag parameters will contain their assigned values, however the values for the intensity estimates and the remaining parameters will be assigned a “missing value” (mostly 0’s). Calculation of both Final T# values and the CI# value will exclude all “over land” entries once the storm resumes movement over open water (non-land grid points).

### B.) Scene Classification

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

#### Eye Region

<u>Scene Type</u>	<u>Description</u>
EYE	Any eye type (clear, ragged, obscured)
PINHOLE	Very small eye/pronounced warm spot
LARGE	Clear, well-defined eye greater than 45 km in diameter
NONE	No eye

#### Cloud Region

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

Eye scene types are derived by examining the eye region FFT harmonics, variability of temperature values in the eye region, and “BD enhancement curve” categorical differences between the eye and surrounding cloud region temperature values. Eye size is derived by measuring the distance across the eye between BD-curve “Dark

Gray” temperature range edges. Distances are measured at 90° angles outward from the manual/auto-selected center location and are averaged to give an approximate eye size.

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

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

### **C.) Eye and Surrounding Cloud Region Temperature Determination**

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

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

Calculations of the two surrounding cloud region temperature values are a bit more complicated than for the eye temperature. The first cloud region temperature value computed is centered at the storm center location and lies between 24 and 136 km from the center location. Individual analysis rings are selected, and are dependent upon the resolution of the satellite imagery. Thus for a 4 km resolution infrared image, there will be  $(136 - 24)/4 = 28$  rings. On each ring the warmest temperature will be found. The coldest of these values will be used as the cloud top temperature value. This value is referred to as the “coldest-warmest” temperature, and it is used only in the determination process for the cloud region scene type. The ring number (CWRN) distance (in km from the storm center location) on which the “coldest-warmest” temperature value is located is

used in the determination of the “mean” cloud region temperature discussed below. For more information about this value, see Velden et al. (1998) and Zehr (1989).

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

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

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

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

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

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

The ADT Weakening Flag is modeled after the Dvorak EIR Rule 9 (Dvorak, 1984), but also utilizes a modification that is applied at some operational TC forecasting centers. This rule is used in the determination of the CI# after a storm has reached its maximum intensity and is weakening. The EIR Rule 9 will hold the CI# at values 0.5 to 1.0 higher in value than the current Final T#. 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 reconnaissance pressure measurements.

The current weakening flag rule logic affects the calculation of the CI# during the entire lifecycle of the TC being examined. This rule is as follows: “Always hold the CI# to the highest Final T# in the last 12 hours, but never greater than 1.0, in all cases”. This rule will hold the CI# equal to the highest Final T# obtained during the previous 12 hours. For example, if the Final T# value had previously obtained a value of 5.2, 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. The “Weakening” flag indicator in intensity estimate bulletin (Section 4D1) will display “ON” during the application of this rule.

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

The ADT Constraint Limits is a modification of the Dvorak EIR Rule 8 which constrains the rate of increase or decrease of the Raw T# intensity estimate value based upon specified rates of change over specific time periods. The rate of change comparisons are performed against the Final T# (6-hour average) values stored in the history file at various times prior to the current analysis time, with the rate of change constraints being dependent upon the “current” intensity of the storm, as defined in the Dvorak EIR technique. The Final T# (6-hour average) value of the record immediately prior to the current analysis time is used as a proxy for the “current” intensity estimate. When current intensity of the storm is less than 4.0, the current Raw T# rate of change cannot exceed  $\pm 0.5$  T# over 6 hours. If the current intensity estimate value is greater or equal to 4.0, the rate of change of the Raw T# value cannot exceed the following rates : 1.0 over 6 hours, 1.5 over 12 hours, 2.0 over 18 hours, and/or 2.5 over 24 hours.

The ADT employs a modified version of this rule based upon the current scene type analyzed. This modification was developed from extensive statistical analysis of ADT performance of over 3500 individual intensity estimates. The rate of change is constrained/increased by 0.5 during all scene types of non-shear/eye scenes for all time periods. For a non-shear/eye scenes (such as Curved Band, CDO, Embedded Center) the amount of change is limited to 0.5/1.0/1.5/2.0 T# over 6/12/18/24 hours, while for eye scenes the amount of allowed change is increased to 1.5/2.0/2.5/3.0 T# over 6/12/18/24 hours. The latter modification will allow the Final T#/CI# to increase at a quick enough and realistic rate during “rapid intensification” events. For shear scenes only, the rate of change rule is unmodified from the original Dvorak EIR Rule 8.

If one of the criteria is exceeded, the Adjusted Raw T# will be assigned the maximum/minimum value allowed by the criteria in question and will be used in the determination of the corresponding Final T#/CI# values. The unadjusted Raw T# value is also 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 threshold values that are used to define the different scene types, changes between scene types can result in unrealistic jumps in Raw T# values from one intensity estimate to another. The addition of this rule will produce estimates that are reasonable when these types of scene changes occur, but still will allow the Raw T# values to change at a rate greater than observed in nature. The largest MSLP change we found in our test data set was with Hurricane Opal, which had a decrease in observed MSLP (from reconnaissance aircraft) of 17mb (933mb to 916mb) over about two and a half hours (07:20UTC to 09:45UTC). This corresponds to a change of about 0.6 T# (933mb  $\approx$  6.6 T#; 916mb  $\approx$  7.2 T#) in 2.5 hours, or approximately 0.25 T#/hour.

Implementation of this modified rule has allowed for the time-weighted Final T# calculation to be changed from 12 hours to 6 hours, with the 6-hour weighted average proving to be slightly more accurate statistically than the previous 12-hour methodology. By utilizing the 6-hour scheme, the rate of change of the time-weighted Final T# value is greater than with the 12-hour scheme, allowing for more rapid increase in intensity over time, especially in conjunction with the modified constraint limit rules for eye scenes, and has resulted in more realistic intensity changes and estimates over time.

#### **G.) Rapid Weakening Flag (East Pacific region only)**

In the East Pacific basin only, it is commonly observed that tropical cyclones dissipate at a very rapid rate as they move over colder waters. The Dvorak Technique Rule 8 and Rule 9 constrain the rate of dissipation and modify the current Final T# in the calculation of the CI# intensity estimate value. It is believed that these rules constrain the dissipation rate to those that are not realistic for the East Pacific region and do not allow for the rapid dissipation rates commonly observed. In order to alleviate this problem, the Dvorak Technique Weakening Rule 9 (as discussed in Section E above) has been modified to allow the CI# intensity estimate to reflect this commonly observed phenomena.

The Rapid Weakening Flag will relax the application of the original Rule 9 intensity adjustment to the Final T# when determining the CI#. Typically, 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 points is less than  $-0.5/6$  hours the weakening flag is tripped and subsequently observed for an additional six hours. If over the second six hour period the slope does not increase over the threshold, the rapid weakening flag will be turned on and the CI# additive constant will be 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 flag is then turned off and the additive value will return to 1.0.

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

The ADT intensity estimates are presented in terms of T#/CI#, mean sea level pressure (MSLP), and wind speed values. The pressure values are derived from one of two empirical conversions relating CI# to MSLP for the North Atlantic (Dvorak, 1984) and Northwest Pacific (Shewchuck and Weir, 1980) ocean basins. Also, proper determination of the initial Raw T# is dependent upon use of the correct storm basin conversion relationship. Thus, proper identification of the correct relationship to use is essential for conversion of T# to MSLP, especially outside of the Atlantic and West Pacific regions. 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 ( $180^\circ$  E/W) and east of the Prime Meridian ( $0^\circ$  E/W) is designated as a Northwest Pacific storm (regardless of N/S hemisphere), with all other storms designated as an Atlantic storm. The user can override this automated determination process with the DOMAIN keyword if desired.

The division point in the Pacific Ocean was chosen to match the “areas of responsibility” for the Joint Typhoon Warning Center and Central Pacific Hurricane Center. Use of either CI#/pressure conversion in the Eastern Pacific Ocean is a topic for debate since specific rules defining the use of one of the conversions for this or other regions, such as Indian Ocean or Southern Pacific Ocean, have not been documented.

It must be noted that for T#/CI# values greater than 8.0 or less than 2.0 the MSLP estimates have been extrapolated using MSLP gradients similar to those found in the preceding/following regions of the accepted T# to MSLP conversion tables. These values include those found between 1.0 and 2.0 and between 8.0 and 8.5.

## I.) Automatic Storm Center Determination and Input File Formats

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

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

- ATCF Forecast Record file
- NHC Tropical Storm/Hurricane Discussion files (WTNT4? or WTPZ4?)
- JTWC Tropical Cyclone Warning files (WTPN3?)
- Generic Entry file (see below for 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.

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

The two methods utilized are new additions to the auto-centering scheme. The methods were developed at UW-CIMSS by Anthony Wimmers to aid in determining the storm center position when the previous ADT techniques were less reliable. These methods are quite labor intensive and may take a significant amount of time to complete, especially if the satellite image being investigated is not in a rectilinear projection and needs to be remapped to this projection internally before proceeding.

The first technique, the Spiral Centering routine, determines a center point in the image where there is a maximum alignment between the image gradient field and a 5-degree log spiral vector emanating from the center point. 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 is quite sensitive to the effects of upper-level shear in IR imagery, leading to center estimates driven by patterns in the cirrus clouds rather than low-level clouds.

Further calculation beyond the Spiral Centering method is needed to resolve the exact center of rotation in storms with a well-defined eye. 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 employed. The Eye Ring Fitting analysis method performs a search around the spiral center point for the most intense gradients in a small ring-shaped area defining the storm eyewall.

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. 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, only the forecast interpolation position will be utilized. Once the Final T# value has exceeded 4.5, both auto-centering techniques will be attempted.

## **J.) Maximum Curved Band Location Search**

If a Curved Band scene type has been determined automatically, or was selected manually during a scene override, an additional search will be performed to locate a storm center position possessing a greater cloud curvature measurement than obtained at the original selected storm center location. The search will examine the same BD-curve temperature range as obtained with the automatic scene type determination scheme. A 2° latitude/longitude box, centered at the originally selected storm center location, will be



examined at a 0.2° spacing between search points. At each search point, the 10° Log Spiral will be examined to determine the maximum arc length of the BD-curve temperature range being targeted. The spiral will then be rotated 15° and the measurement is performed again. Once the spiral has been rotated 360°, the spiral is moved to the next search point and the process is repeated. The search point possessing the maximum arc length measurement will then be shown in the intensity analysis output.

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

#### **K.) Latitude Bias Adjustment**

The MSLP value displayed in the ADT intensity estimate bulletin is adjusted using a linear regression-based adjustment equation. This equation is designed to eliminate a pronounced intensity estimate bias noted in the derived CI# value of the ADT 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#<sub>orig</sub> value to be entered in units of pressure (millibars). Since the ADT produces estimates in terms of T# values, the CI#<sub>orig</sub> value must be converted to millibars before the adjustment equation is applied. The pressure adjustment value is stored in a history file.

The latitude bias adjustment is only applied to scene types that utilize eye and cloud temperature values to determine the strength of the storm since the adjustment is related to tropopause height and the corresponding temperature changes 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 criteria has been met, the lat-bias adjustment will be blended into use over the next six hours using a time-weighted multiplication factor 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)

#### L.) Estimate of Radius of Maximum Wind (RMW)

An estimate of RMW using geostationary IR data was derived using a simple linear regression analysis of cloud temperature fields and collocated reconnaissance aircraft radius of maximum wind measurements. If the derived ADT cloud top temperature is determined to be 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 temperature and CRT is the cloud top temperature, is used in the above equation to determine the RMW value.

#### M.) Eye and Cloud Scene Intensity Determination

The determination of the Raw T# intensity estimates for EYE and CDO scene types has been modified from previous versions of the ADT. Previous versions utilized methods mimicking those found in the SDT relating cloud temperature (and eye temperature for EYE scene types) to a Raw T# intensity estimate value. The ADT has implemented a new scheme to estimate the Raw T# intensity which utilizes regression-based formulae for both the EYE and CDO scene types. These scene types still utilize the cloud region temperature values, however new intensity predictors have been implemented, resulting in intensity estimates that are significantly improved over the previous methods.

The equations for the Atlantic Basin EYE and CDO scene types are as follow:

$$\text{EYE Raw T\#} = 1.10 - 0.070 * T_{\text{cloud}} + 0.011 * \Delta T - 0.015 * \text{Sym}_{\text{cloud}}$$

$$\text{CDO Raw T\#} = 2.60 - 0.020 * T_{\text{cloud}} + 0.002 * D_{\text{CDO}} - 0.030 * \text{Sym}_{\text{cloud}}$$

where :

$T_{\text{cloud}}$	- cloud region temperature
$\Delta T$	- eye minus cloud region temperature difference
$\text{Sym}_{\text{cloud}}$	- cloud region symmetry value
$D_{\text{CDO}}$	- diameter of CDO region (Dark Gray) (in km)

The Eye Raw T# equation has also been slightly modified in the extreme cold cloud region temperature values ( $< -80^{\circ}\text{C}$ ).

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