

**ADT – Advanced Dvorak Technique
USERS’ GUIDE
(McIDAS Version 7.2.3)**

Prepared by

Timothy L. Olander and Christopher S. Velden

on behalf of

The Cooperative Institute for Meteorological Satellite Studies
Space Science and Engineering Center
University of Wisconsin-Madison
1225 West Dayton Street
Madison, WI 53706

March 2008

Table of Contents

1.)	Description of the ADT Algorithm	1
2.)	System Requirements	2
3.)	ADT Acquisition and Installation	3
4.)	Using the ADT	4
A.)	Command Line Structure and Keywords	4
1.)	Description of Use	4
2.)	Examples	7
B.)	History File	9
C.)	UNIX Environment Arguments	10
D.)	Algorithm Output	11
1.)	Full ADT Analysis	11
2.)	Abbreviated ADT Analysis	14
3.)	Land Interaction	15
4.)	Automated Storm Center Determination	15
5.)	User Override Function	17
6.)	Remote Server Data Access	18
7.)	ATCF Record Output	18
E.)	History File Output	19
1.)	Text Output	19
a.)	Original Format Listing	19
b.)	ATCF Format Listing	20
2.)	Graphical Output	21
5.)	Background Information	22
A.)	Land Flag	22
B.)	Scene Classification	22
C.)	Eye and Surrounding Cloud Region Temperature Determination	23
D.)	Time Averaging Scheme	24
E.)	Weakening Flag (Dvorak EIR Rule 9)	25
F.)	Constraint Limits (Dvorak EIR Rule 8)	25
G.)	Rapid Weakening Flag (East Pacific only)	26
H.)	T# to MSLP Conversion Relationship Auto Determination	27
I.)	Automatic Storm Center Determination and Input File Formats	28
1.)	Forecast File Examples	28
2.)	ADT Auto-Centering Methodology	32
J.)	Maximum Curved Band Location Search	33
K.)	Latitude Bias Adjustment	34
L.)	Estimate of Radius of Maximum Wind	34
M.)	Eye and Cloud Scene Intensity Determination	35
N.)	Non-McIDAS Environment Compilation	35
6.)	Acknowledgments	37
7.)	References	38

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 (7.2.3) 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/tropic2/misc/adt>

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

The downloaded ADT tar file for Version 7.2.3 can be uncompressed and unpacked using the following command:

```
gunzip ADTV7.2.3.tar.gz  
tar -xvf ADTV7.2.3.tar
```

The resulting subdirectory "ADTV7.2.3" 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
- 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)
- 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. Please see Section N 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.I.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 ODTISTORY)

format Format of forecast file valid options (see examples in Section 5.I.1):
 ATCF - tropical cyclone forecast records
 DISC - TPC WTNT4* or WTPZ3* storm specific discussions
 PACWARN - JTWC WTPN3* tropical cyclone warning
 RMSC – RMSC ICAO or WTIO30 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 , yyyymondd

 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 N for more information)

DOMain=ATL/PAC

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

LAND=NO

Applies ADT land interaction rule (def=YES)

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 45 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)

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).

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 X X

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 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 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	: 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 7.2.3
Tropical Cyclone Intensity Algorithm
```

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

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

```
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# (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 “Final T#” value is the average of the current and previous three hour analyses values. 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 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/ad/mcidas/data/AREA2010
```

```
*****
```

```
                UW - CIMSS
            ADVANCED DVORAK TECHNIQUE
                ADT - Version 7.2.3
Tropical Cyclone Intensity Algorithm
```

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

```
CI# /Pressure/ Vmax
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
Utilizing topography file /home/adt/TOPOHRES
Tropical cyclone is over land
```

```
                UW - CIMSS
      ADVANCED DVORAK TECHNIQUE
            ADT - Version 7.2.3
Tropical Cyclone Intensity Algorithm
```

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

```
TROPICAL CYCLONE OVER LAND
NO 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, 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 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 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/ad/mcidas/data/AREA7777
Utilizing image data file /home/ad/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/ad/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 4A2 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/ad/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 parameter with the DATE and OUTPUT keywords. An example of an original format listing is provided below:

```
===== ADT-Version 7.2.3 =====
-----Intensity----- -Tno Values--- ---Tno/CI Rules--- --Temperature--
Date      Time      Final/MSLP/BiasAdj/(kts)  Pnl Adj Inl  Cnstrmt  Wkng Rpd  Cntr  Mean  Scene  EstrMW  Storm  Location  Fix  Comments
      (UTC)      CI      MSLP / BiasAdj / (kts)  Tno Raw Raw   Limit  Flag Wkng Region  Cloud Type (km)  Lat  Lon  Mchd
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  15.81 50.06 FCST
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  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  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  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  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  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  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  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  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  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  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  17.06 52.96 FCST
1999SEP09 031500  3.1 998.8/ +0.0 / 47.0  3.1 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 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  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  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 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 4.5 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 4.5 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 4.8 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 4.8 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 5.6 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 5.8 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 5.8 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 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  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 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 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 6.2 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  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 6.2 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 6.2 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  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  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  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  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  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  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  6.0 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  NO LIMIT  ON  OFF 21.14 -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  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  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 6.6 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 6.6 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  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 6.4 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 6.3 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  NO LIMIT  ON  OFF 15.04 -63.88 EYE  30 IR  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  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  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  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  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  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  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  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  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  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  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  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  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  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  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  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  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  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  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  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  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  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  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  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  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  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  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  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  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  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  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  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  31.59 78.68 COMBO
1999SEP15 224500  5.8 960.3/ +7.5 /109.8  5.4 5.6 5.6  NO LIMIT  ON  OFF  2.84 -60.75 EYE  30 IR  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  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  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  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  32.98 78.14 N/A
1999SEP16 074500  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
```

The text output displays time, date, all intensity values (CI# with corresponding adjusted MSLP and wind values, Final T#, and the Adjusted and Initial/Unadjusted Raw T# values), T#/CI# constraint and weakening rules, eye and cloud region temperatures, scene type, estimated radius of maximum wind value, storm position, and storm center fix method (manual or automated technique). Any comments that have been entered will be displayed at the end of each history file entry.

If an external ASCII output file is desired, the ADT keyword command “OUTPUT=FILE <filename>“ is used. The directory location where the output text file is written is defined with the ADT environment argument ODTOUTPUT. For example, an output file defined as “listing.txt” will produce the following output message:

History file listing written to ASCII file /home/adt/output/listing.txt

b.) ATCF Format Listing

Any or all records a history file can be displayed in ATCF format using the ATCF keyword in conjunction with the LIST parameter. The output will be displayed in the text output window unless specifically requested to be stored in an output file using the OUTPUT keyword. A sample ATCF format file is displayed below:

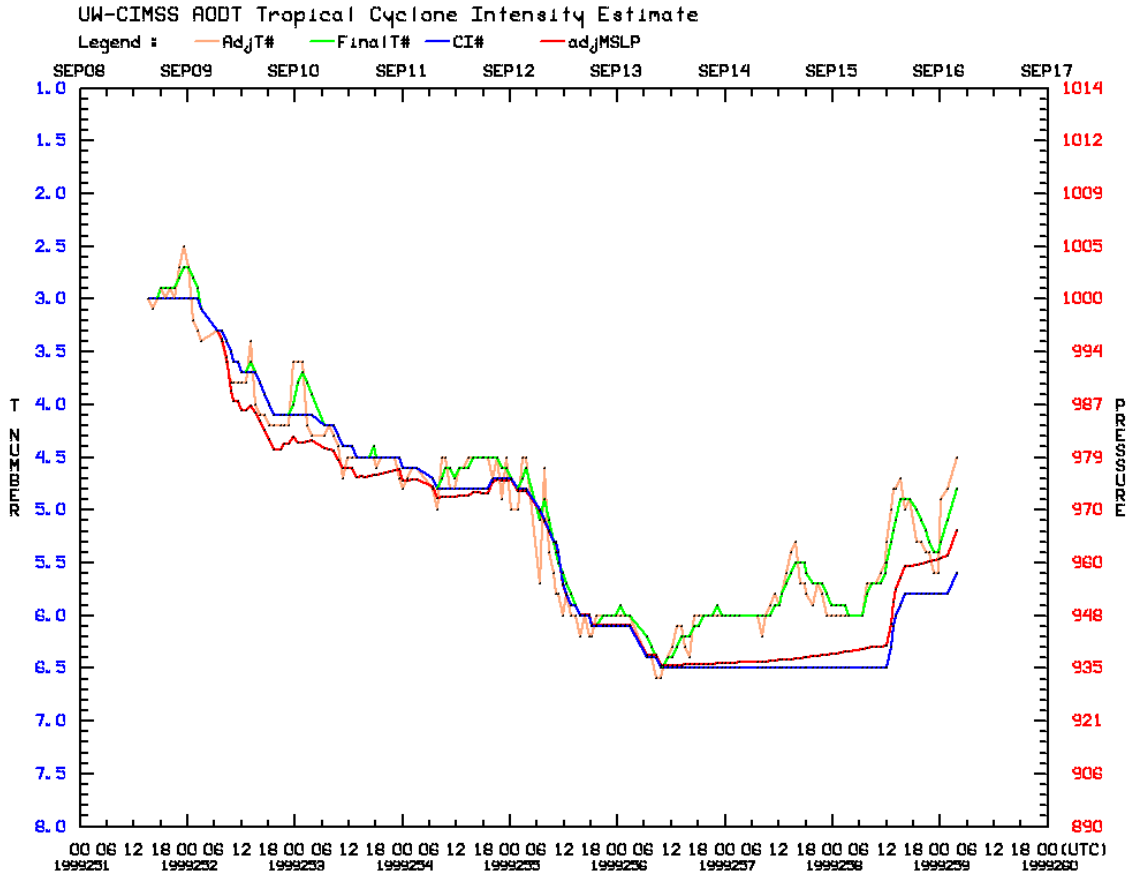
```

===== ADT-Version 7.2.3 =====
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, , GOESS, 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, GOESS, 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, GOESS, 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, GOESS, 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, , GOESS, 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, GOESS, 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, GOESS, 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, , GOESS, 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, , GOESS, 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, , GOESS, 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, , GOESS, 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, , GOESS, 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, , GOESS, 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, , GOESS, 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, GOESS, 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, GOESS, 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, GOESS, 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, GOESS, 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, GOESS, 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, GOESS, 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, GOESS, T,
Utilizing history file /home/adt/output/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. Below is an example:



18

In the example above, 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.

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 three 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 with greater than 45 km radius
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 determination of the Final T# value is now calculated differently than in previous versions. The time averaging scheme uses the current Raw T# value and all available Raw T# values obtained within the last 3 hours. The average is a straight non-weighted average instead of the original 6-hour weighted value used in previous versions of the ADT.

Use of the 3-hour non-weighted time averaged value for the Final T# was decided upon for a number of reasons. Primarily, statistical comparisons between use of the 3-hour and 6-hour weighted average values and corresponding aircraft reconnaissance intensity measurements demonstrated slightly improved accuracy using the 3-hour value. This most likely resulted from the improved use of the various “Rule 8” T# constraint rules coupled with the fact that using the 3-hour allows for more rapid intensification/weakening of the Final T# values during such events, reducing the possibility of the ADT estimates from “lagging behind” the intensity change of the TC being examined. Also, it allowed various rules coupled to the determination of the CI# to be removed and simplified.

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# (3-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# value of the record immediately prior to the current analysis time is used as a proxy for the “current” intensity estimate. When current intensity of the storm is less than 4.0, the current Raw T# rate of change cannot exceed ± 0.5 T# over 6 hours. If the current intensity estimate value is greater or equal to 4.0, the rate of change of the Raw T# value cannot exceed the following rates : 1.0 over 6 hours, 1.5 over 12 hours, 2.0 over 18 hours, and/or 2.5 over 24 hours.

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 will be decreased/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 Final T# calculation to be changed from a time-weighted 6 hour average to a 3 hour average. By utilizing the 3-hour scheme, the rate of change of the Final T# value is greater than with the 6-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

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° 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 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 three methods: polynomial interpolation of NHC/JTWC forecasts, warmest linear extrapolation of the history file positions, or a more advanced, dual methodology examining the TC cloud top spiral features and circular feature (ring) search.

As a first guess, the forecast positions from NHC, JTWC, or RSMC bulletins 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 five types of input file formats are:

- ATCF Forecast Record file
- NHC Discussion files (WTNT4? or WTPZ4?)
- JTWC Tropical Cyclone Warning files (WTPN3?)
- RMSC ICAO (FK??) or WTIO30 formats
- Generic Entry file

1.) Forecast File Examples

ATCF Forecast Record Format

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

ICAO Format : Unfortunately the ICAO format is not uniform across all RMSC forecast centers. The ADT, however, has accounted for many of the differences and should successfully read all ICAO format forecasts.

```
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
```

WTIO Format : This format is also not perfectly uniform (or available) from all of the RMSC forecast centers, but the ADT should read all correctly.

```
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 SUBTRO
PICAL 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:

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

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

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

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

2.) ADT Auto-Centering Methodology

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, the forecast interpolation position will only 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 and should only be used as a suggestion.

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#_{orig} value to be entered in units of pressure (millibars). 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 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

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°C, the distance from the storm center to the -45°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:

$$RMW = 2.8068 + (0.8361*dist)$$

If the ADT derived cloud top temperature value is warmer than -50°C, the distance to the isotherm defined by the equation $(ERT + 2.0*CRT)/3.0$, 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_{cloud}	- cloud region temperature
ΔT	- eye minus cloud region temperature difference
$\text{Sym}_{\text{cloud}}$	- cloud region symmetry value
D_{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°C).

N.) 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.

6.) Acknowledgments

We gratefully acknowledge the support of our research sponsors, the Office of Naval Research, Program Element (PE-0602435N) along with the Oceanographer of the Navy through the program office at the PEO C4I&Space/PMW-180 (PE-0603207N) and the Joint Hurricane Testbed under the NOAA/USWRP grant NA030AR4310177.

We also wish to thank the following people for their input in the development of the ADT algorithm: Jeff Hawkins at the Naval Research Laboratory, Monterey for his support and collaboration; Ray Zehr at the Regional and Mesoscale Meteorology Branch of NOAA/NESDIS for the original digital Dvorak code and many ideas; Mike Turk and Gregg Gallina at the Satellite Analysis Branch, and Richard Pasch, Jack Beven, Max Mayfield, Hugh Cobb, Ed Rappaport, Daniel Brown, James Franklin, and Chris Sisko at the National Hurricane Center/Tropical Prediction Center for their evaluation of and comments on the ADT algorithm; Roger Edson and Frank Wells, formerly of the Joint Typhoon Warning Center, for their evaluation and comments regarding the ADT and its application in the West Pacific; Mark Connor at the Air Force Weather Agency for various coding issues and questions; and Bonnie Granzow at SeaSpace, Corp. for proofreading previous ADT Users' Guides.

7.) References

- Dvorak, V., 1975: Tropical cyclone intensity analysis and forecasting from satellite imagery. *Mon. Wea. Rev.*, **103**, 420-430.
- Dvorak, V., 1984: Tropical cyclone intensity analysis using satellite data. NOAA Tech. Rep. NESDIS 11, 47 pp. [Available from NOAA/NESDIS, 5200 Auth Rd., Washington, DC 20233.]
- Kossin, J.P and C.S. Velden, 2003: A pronounced bias in tropical cyclone intensity estimation based on the Dvorak Technique, *Mon. Wea. Rev.*, **132**, 165-173.
- Olander, T.L, and C.S. Velden, 2007: The Advanced Dvorak Technique (ADT) – Continued development of an objective scheme to estimate tropical cyclone intensity using geostationary infrared satellite data. *Wea. Forecasting.*, **22**, 287-298.
- Olander, T.L, C.S. Velden, and J.P. Kossin, 2004: The Advanced Objective Dvorak Technique (AODT) – Latest upgrades and future directions. *26th Conference on Hurricanes and Tropical Meteorology*, Miami, FL, Amer. Meteor. Soc., 294-295.
- Olander, T.L, C.S. Velden, and M.A. Turk, 2002: Development of the Advanced Objective Dvorak Technique (AODT) – Current progress and future directions. *25th Conference on Hurricanes and Tropical Meteorology*, San Diego, CA, Amer. Meteor. Soc., 585-586.
- Shewchuck, J.D. and R.C. Weir, 1980: An evaluation of the Dvorak technique for estimating tropical cyclone intensity from satellite imagery. NOCC/JTWC 80-2, USNOCC, JTWC, Comnavmarinas, Box 17, San Francisco, CA, 96630, 25 pp.
- Velden, C.S, T.L. Olander and R. Zehr, 1998: Development of an objective scheme to estimate tropical cyclone intensity from digital geostationary satellite infrared imagery. *Wea. Forecasting*, **13**, 172-186.
- Zehr, R., 1989: Improving objective satellite estimates of tropical cyclone intensity. *Extended Abstracts, 18th Conf. on Hurricanes and Tropical Meteorology*, San Diego, CA, Amer. Meteor. Soc., J25-J28.