ODT – Objective Dvorak Technique
USERS GUIDE
(McIDAS Version 5.3)

Prepared by

Timothy L. Olander and Christopher S. Velden

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

March 2001

Table of Contents

1. Description of the ODT Algorithm

The Objective Dvorak Technique (ODT) algorithm is an computer based technique used to objectively determine tropical cyclone intensity using geostationary satellite infrared imagery. **The ODT is to be used only for storms at hurricane or typhoon strength or greater** (T# greater than 3.5, or pressures less than 994/984mb in the Atlantic/West Pacific), and should be applied immediately after the storm reaches this intensity in order for all rules to be applied properly.

The ODT is patterned after the Subjective Dvorak methodology (Dvorak, 1975, 1984) which makes use of various rules and pattern identification schemes in the determination of tropical cyclone intensity. Selected rules from this methodology have been implemented within the ODT in an effort to incorporate them into an objective algorithm.

The ODT was developed from prior objective satellite estimation algorithms developed at the University of Wisconsin/Space Science and Engineering Center (SSEC) and Colorado State University/Cooperative Institute for Research Applications (CIRA). Significant modifications and additions have been made during the development of the ODT, resulting in an algorithm that is substantially different from its forerunner 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 life cycle, a time averaging scheme, and the addition of various rules governing the variability of the intensity estimate values. These changes have led to more stable and less biased estimates of intensity.

For greater detail about the development process and statistical accuracies obtained with the ODT algorithm, please refer to Velden et al., 1998.

2. System Hardware and Software Requirements

The ODT was originally developed within the Man computer Interactive Data Access System (McIDAS) architecture. The algorithm utilizes McIDAS library routines to ingest infrared satellite data, display textual and graphical results, read input data files, and write various output files. The ODT was primarily developed utilizing McIDAS 7.5 on a Silicon Graphics, Inc. (SGI) Indigo2 running the UNIX–based IRIX 6.5 operating system. The routine has also been tested on a SUN Ultra–60 running Solaris 7.0.

3. ODT Acquisition and Installation

The ODT software package can be obtained via anonymous FTP from the University of Wisconsin/Cooperative Institute for Meteorological Satellite Studies (UW–CIMSS). All files required for the ODT are contained within a single UNIX tar file, and must be unpacked before installation. To obtain and install the ODT algorithm, follow the steps below :

cd <directory>	: move to the desired local directory
ftp 144.92.108.148	: FTP to cyclone.ssec.wisc.edu
anonymous	: login name (when prompted)
your e–mail address	: login password (when prompted)
cd pub/odt	: change to pub/odt directory
bin	: change FTP transfer mode to binary
get ODT–v5.3.tar.Z	: get compressed ODT (version 5.3) tar file
bye	: exit FTP
uncompress ODT–v5.3.tar.Z	: uncompress tar file (using UNIX command)
tar –xvf ODT–v5.3.tar	: unpack the ODT tar file

Once the ODT tar file has been unpacked successfully, it can be deleted from the local directory, if desired. After unpacking the tar file, all ODT–relevant files will be contained within the odt directory. The odt directory will contain many program files as well as subdirectories containing various routines, include files, and data files required by the main ODT routines. The README file contains information about ODT upgrades and modifications, additional information about the directory structure, and other ODT information.

To install the ODT algorithm, the following command is used :

odt–compile <compiler> <McIDAS version>

The ODT can be compiled using either the system compiler ***cc*** or the shareware compiler ***gcc*** (GNU C compiler). The C compiler used **must** be the same compiler utilized during the installation of McIDAS on the host machine. The version number refers to the current version of McIDAS being utilized on the host machine. For example, to install the ODT on a SGI Octane using McIDAS 7.6, the command "odt–compile gcc 7.6" would be used to compile the ODT software, since the gcc compiler was used to install McIDAS on the SGI host. Please refer to the McIDAS Users Guide for any questions involving installation of McIDAS.

The ODT utilizes various library files during compilation of many routines. Many ODT navigation and calibration routines were converted from FORTRAN to C using the **f2c** conversion program. The library file *libf2c.a* must be used to compile the ODT algorithm, and should either be linked to or a directly copied to the lib directory, depending on the UNIX shell being used with the odt–compile script. The file will most likely be located in the /usr/local/lib directory if **f2c** has been installed on the host machine, although the exact location will need to be determined by the user and entered into the odt–compile script prior to execution. The odt–compile script will then perform the link to/copy of the *libf2c.a* library file.

The McIDAS library file *libmcidas.a* must also be linked or copied to the lib directory using the odt–compile script. The file will be located in the ~mcidas/lib directory, with its location not need to be modified in the odt–compile script.

A third library file will be created by the odt–compile script. This library file will be called *libodtnav.a* and will contain a library of all of the routines found in the navcal directory. It will be placed in the lib directory during the compilation of the ODT algorithm.

Prior to compiling the ODT algorithm, the user should modify the following definitions in the odt.h include file :

```
#define HISTORYPATH "<path>"
#define TOPOPATH "<path>"
#define LOCALSERVER "<server>"
#define LOCALAREA <area>
```

The HISTORYPATH definition will specifically define the directory where all ODT history files will be stored. This directory definition must be enclosed with quotes, and will be appended to all history file names defined with the HISTORY= keyword. See Sections 4B and 4C for more information about history files and keyword usage.

The TOPOPATH variable defines the location of the high resolution topography file TOPOHRES. This file is used to determine the value for the land flag. For more information on the land flag, see Sections 4D3 and 5A.

4. Using the ODT

A. Introduction

The ODT algorithm operates within the McIDAS environment, utilizing the McIDAS text and graphics/image windows for command line and data input. Analysis output is displayed within the McIDAS text window, with graphical output displayed within the McIDAS graphics/image window. Activation and control of the ODT algorithm is performed using McIDAS command line structure.

ODT *<keywords>*

Keywords control text and graphical output, allow specific user interaction, and define ODT runtime operations. Each parameter and keyword associated with the ODT is defined below, with examples provided in Section 4C3.

B. History File

The ODT history file format has been changed from a binary file to an ASCII–format file due to user request. This file contains prior ODT intensity estimates, locations, and other information specific to each individual analysis for a particular storm. The history file is utilized in the time–averaging scheme for the determination of the Final T# values as well as for graphical and textual time–series displays.

History files are stored the directory defined with the HISTORYPATH definition in the odt.h file. This directory should be defined by the user prior to compiling the ODT algorithm. The line to modify in the odt.h file is :
#define HISTORYPATH <directory>

New ASCII–format history files will have the following format for each individual record stored (these values are discussed in greater detail in Appendix A) :

1998SEP21 31500 5.4 5.1 5.7 6 4 2 –62.06 –73.16 –77.04 17.04 61.43 2

Value 1	: date (YearMonDay format)
Value 2	: time (hhmmss format)
Value 3	: raw T#
Value 4	: final T# (time averaged value)
Value 5	: final CI
Value 6	: scene type
Value 7	: Rule 9 flag value
Value 8	: rapid intensification flag value
Value 9	: eye temperature
Value 10	: cloud top temperature
Value 11	: mean cloud region temperature
Value 12	: latitude
Value 13	: longitude
Value 14	: land flag (1=ocean/water; 2=land)

Entries within the default history file ODTDUMP.ODT will not have *valid* values for the Final T# value, the Final CI value, the Rule 9 flag, and the rapid strengthening flag, since previous history file values are required in the determination of these parameters.

Previous binary format history files can be converted to ASCII using an auxiliary program convertodthistory.c. Directions to obtain, compile, and utilize this algorithm are discussed in Appendix B.

C. Keywords

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

1. Description and Usage

HISTORY=filename (default=ODTDUMP.ODT)
History file containing previous ODT intensity estimates, locations, and other values for a particular storm. Values are explained in Section 4B and Appendix A.

LIST=YES/NO (default=NO)
List contents of history file within McIDAS text window. Can be used in conjunction with DATE, OUTPUT, DOMAIN, and WIND keywords. Pressure units in terms of millibars. ODT analysis will not be performed.

OUTPUT=SCREEN/FILE filename (default=SCREEN)
Direct LIST=YES keyword output to McIDAS text window or ASCII file *filename*. *filename* can include entire directory structure.

GRAPH=YES/NO (default=NO)
Plot intensity estimates from history file to McIDAS image window. Can be used in conjunction with DATE, PLOT, DOMAIN, and WIND keywords. Pressure units in terms of millibars. ODT analysis will not be performed.

PLOT=color1 color2 color3 (defaults=5 4 6; 0 to not display)
Defines graphic color level values for CI number, Final T#, and Raw T#, respectively. Color values can be modified using the McIDAS command GU. Graphics color level value of zero (0) will suppress plotting of desired intensity estimate value. Used in conjunction with GRAPH keyword.

DELETE=YES/NO (default=NO)
Allows for manual deletion of history file records. Must be used in conjunction with DATE keyword to define date/time limits to remove. See DATE keyword for default values associated with DELETE keyword.

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

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

date format : YearMonDay (e.g. 1998Oct17)
time format : HHMMSS (e.g. 131500)
Default values :

GRAPH and LIST	: date1/time1 : first record	
	date2/time2 : last record	
DELETE	: date1/time1 : no default, must specify	
	date2/time2 : date1/time1	

WIND=YES/NO (default=NO)

Intensity units given in terms of maximum wind speed (knots) instead of mean sea level pressure. Used in conjunction with LIST and GRAPH keywords or with ODT image intensity analysis. Speed and pressure values are related to CI number values using empirical relationship defined in Dvorak (1984).

DOMAIN=ATL/PAC (default=ATL)

Define oceanic domain which tropical cyclone resides. ATL should be used for storms within North Atlantic basin, while PAC should be used for storms within Western Pacific basin. Storms within Eastern Pacific basin can use either value, dependent upon where storm is located within this basin (left to user to decide which is correct). Keyword will control Raw T# intensity estimate determination and corresponding CI number pressure value (empirical CI number/pressure relationship (defined in Dvorak, 1984). Can be used with LIST and GRAPH keywords or with ODT image intensity analysis.

RULE48=ON/OFF (default=ON)

Activate/deactivate special ODT "first 48 hour" rule which subtracts 0.5 from Raw T# intensity estimate value during first 48 hours of analysis after storm reaches hurricane strength. This rule was added to account for overestimate bias during this time period of storm life cycle. Keyword will affect current ODT analysis only, and will not affect any values within history file. See Section 5G for more details.

AUTO=YES/NO type filename (defaults=NO 1 XXXX)

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

type = 1	: TPC WTNT4? (North Atlantic) or WTPZ3? (East Pacific) storm specific DISCUSSION files.
type = 2	: JTWC WTPN3? (Western North Pacific) TROPICAL CYCLONE WARNING file.
filename	: Name of input file. *filename* can include entire directory structure.

OVER=YES/NO (default=NO)

Allow user to manually override ODT scene identification and/or automated center positioning location. If used in conjunction with AUTO keyword, both override options will be presented to user to verify/change.

REMOTE=YES/NO <server name> <image number> (default=NO)

Allow use of imagery stored on remote server instead of stored on local machine. Server name can be full McIDAS group/descriptor or alias name for local ADDE dataset. Image number is position within local ADDE dataset to copy subsection of remotely displayed image, and is also suffix for name using McIDAS image file naming convention AREA####, where #### is the image number. Defaults for the server name and image number are provided in the odt.h file using the LOCALSERVER and LOCALAREA parameters, respectively.

2. Special Keyword Notes

If no history file is provided by the user, the ODT intensity analysis will be added to the default ODTDUMP.ODT history file. In addition, runtime (see Section 4D2) will be abbreviated, providing the user with only one intensity estimate value and no intensity flag values. The intensity value will be listed as the CI number in the McIDAS text window output, but actually represents the Raw T# intensity estimate.

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

The DELETE keyword cannot be used in conjunction with the LIST and/or GRAPH keywords. If this is attempted, the DELETE keyword will work normally but the LIST and/or GRAPH output will be unmeaningful.

The REMOTE keyword will allow the user to utilize remotely stored data imagery instead of locally stored imagery. The program will copy a subsection (480 x 640) of the remotely stored data (centered at the user– or automatically–defined center location) to the local workstation. The McIDAS group/descriptor or a corresponding alias can be used for the local server name parameter, with its position defined using the image number parameter. The image range for the local group/descriptor dataset should be defined as 1–9999 (or some other number greater than one) in order to properly name the locally stored AREA. If the data file number is defined as 80, the remote data will be copied to group/descriptor.80, which must correspond to AREA0080 on the local server (in the $HOME/mcidas/data directory). The extra 0's will be automatically added to the image number for those values less than 1000.

The local server and image number default values are defined in the odt.h include file using the LOCALSERVER and LOCALAREA define statements. The LOCALSERVER definition should be enclosed with quotes since it is a character string. The LOCALAREA value can be any integer between 1 and 9999 as long as it is within the range definition of the LOCALSERVER.

3. Examples

– ODT

Perform ODT analysis on current image and add record to default history file ODTDUMP.DAT. NOTE : no time averaging or application of any rules (Step 9, rapid deepening, first 48 hour rule) will be performed, and only the final CI number (corresponding to the raw T#) will be output.

– ODT HISTORY=OPAL.ODT

Perform ODT analysis and add record to history file OPAL.ODT. All rules will be applied as necessary.

– ODT HISTORY=OPAL.ODT OVER=YES

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

– ODT HISTORY=OPAL.ODT RULE48=NO

Perform ODT analysis and add record to history file OPAL.ODT. All rules will be applied as necessary EXCEPT the First 48 hour rule subtracting 0.5 from Raw T# intensity estimate.

– ODT HISTORY=OPAL.ODT GRAPH=YES PLOT=3 4 0

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

– ODT HISTORY=OPAL.ODT LIST=YES

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

– ODT HISTORY=OPAL.ODT LIST=YES OUTPUT=FILE /home/odt/OPAL.TXT

Do NOT perform ODT analysis; provide listing of history file OPAL.ODT to output file OPAL.TXT within /home/odt directory.

– ODT HISTORY=OPAL.ODT DELETE=YES DATE=1995OCT03 151500

Delete the 1995OCT03/151500UTC record from the history file OPAL.ODT.

– ODT HISTORY=OPAL.ODT DELETE=YES DATE=1995OCT03 151500 1995OCT03 191500

Delete all records between 1995OCT03/151500UTC and 1995OCT03/191500 UTC from the history file OPAL.ODT.

– ODT HISTORY=OPAL.ODT LIST=YES DATE=1995OCT03 1500

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

– ODT HISTORY=OPAL.ODT LIST=YES DATE=X X 1995OCT03 31500

List all records between the beginning of the history file OPAL.ODT and 1995OCT03/31500UTC.

– ODT OPAL.ODT AUTO=YES 1 /home/odt/storm/AAL1795.DAT

Perform automated ODT analysis and add record to history file OPAL.ODT. ODT will read NHC internal file AAL1795.DAT for forecast and prior position information, and is located in the /home/odt/storm directory. The storm center location will be automatically determined and utilized by the ODT in the analysis of the storm intensity.

– ODT HISTORY=OPAL.ODT AUTO=YES 3 /home/odt/jtwc/wp2698web.txt OVER=YES

Perform automated ODT analysis and add record to history file OPAL.ODT. ODT will read JTWC Tropical Cyclone Warning file wp2698web.txt for forecast information, and is located in the /home/odt/jtwc directory. Prior position location information will be extracted from the OPAL.ODT history file. Once the ODT has automatically determined the storm center location, the user will be prompted to either agree with the cursor location or to reposition the cursor manually. Once the center location is determined, the user will be presented with the ODT evaluated Scene Type and asked to either accept or change it. Once the user selects the scene type, the ODT will determine the intensity estimate for the tropical cyclone being evaluated.

– ODT HISTORY=OPAL.ODT REMOTE=YES LOCALDATA/ODT 100
Perform ODT analysis on remotely stored image. Image is displayed in McIDAS window, and storm center location is selected by user, as normal. As command line is entered, a subsection of the remotely stored image will be copied (using McIDAS IMGCOPY command) from the remote server to local server (LOCALDATA/ODT) at position 100 (AREA0100). The ODT analysis will then proceed as normal.

– ODT HISTORY=OPAL.ODT REMOTE=YES
Perform ODT analysis on remotely stored image, as with above example. Remotely stored image is copied to local server and position as defined in odt.h file using LOCALSERVER and LOCALAREA definitions from #define statements.

D. Runtime Messages

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

1. Normal Operation

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

```
Reading history file OPAL.ODT
USER FIX Position : Latitude  =    25.07
                    Longitude =    89.91
Beginning Image Data transfer, bytes= 28768

Starting OBJECTIVE DVORAK TECHNIQUE analysis

Appending ODT to end of history file OPAL.ODT

          **************************************************
                         UW - CIMSS
                 Objective Dvorak Technique (ODT)
               Tropical Cyclone Intensity Algorithm

          Current Analysis -- Date: OCT  4    Time:  21500UTC
                Lat:  26:14:48 N       Lon:  89:06:41 W

               CI No./Pressure    T-No.(ave)    T-No.(raw)
                 6.5 / 935.0         6.5            7.0

          Eye Temp : -54.7 C       Surrounding Temp : -80.8 C
                               Distance from center :  44 km
          Scene Type : EMB C

          Rule Flags:     STEP 9: OFF    RAPID DEEPENING:   ON

          **************************************************
```

```
Completed OBJECTIVE DVORAK TECHNIQUE analysis
```

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

```
Appending ODT to end of history file OPAL.ODT
```

This message will appear most frequently since the ODT will usually be applied to the latest available image for the storm being investigated. If, however, the user decides to reanalyze an image or analyze an image that was not previously examined, the following messages will be displayed, respectively :

```
Replacing record  38 in history file OPAL.ODT

Inserting ODT within history file OPAL.ODT
```

Within the intensity estimate section of the text output, all vital information relating to the current image analysis will be displayed. The date, time, and location are presented first. The three intensity estimate are then displayed, providing the user with the current Raw T#, Final T#, and CI number with corresponding pressure/wind value. The "T–No.(raw)" value provides the user with the current intensity of the storm at that specific moment in time. The "T–No.(ave)" represents the time averaged intensity of the storm. The time averaging scheme is explained in greater detail in Section 5D. Finally, the "CI No." value represents the time averaged value after various rules governing its variability have been applied. For more details on these rules, see Sections 5E–G. Adjacent to the "CI No." value the corresponding pressure/wind value, as defined in Dvorak (1984), is provided, dependent upon the use of the keywords DOMAIN and WIND. These keywords are described in Section 4C1.

The bottom half of the intensity estimate output text contains information about the scene being analyzed and various rule flag values which affect the intensity estimate calculations. The eye and surrounding cloud top temperature values, described in Section 5H, are listed next to the "Eye Temp" and "Surrounding Temp" labels. The distance from the center where the surrounding cloud top temperature was found is provided adjacent to the "Distance from center" label. Beneath the eye temperature the objectively determined scene type is given. Objective scene type determination is described in Section 5C. This value can be changed by the ODT operator using the OVER keyword option, and will be described in Section 4C1. Finally, the two rule flag values are displayed at the bottom of the output text field. These flags, described in Sections 5E–F, notify the user if either of these rules, governing the determination of the Final T# and/or the CI number, are currently being applied.

2. No History File

When running the ODT without specifying a history file, an abbreviated text output will be displayed in place of the normal intensity estimate output text. Much of the output is the same, but there are a few minor changes. First, the name of the output history file will be ODTDUMP.ODT. Second, the intensity estimate will consist of only one value. This value is listed at the "CI No." in the text output, but actually represents the Raw T# intensity estimate. Since no rules or time averaging are applied in the calculation of the Raw T# value, the two "Rule Flags" values are not presented. A typical output for this ODT operation would be :

```
Reading history file ODTDUMP.ODT
USER FIX Position : Latitude  =    25.07
                    Longitude =    89.91
Beginning Image Data transfer, bytes= 28768

Starting OBJECTIVE DVORAK TECHNIQUE analysis

Appending ODT to end of history file ODTDUMP.ODT

          **************************************************
                          UW - CIMSS
                Objective Dvorak Technique (ODT)
              Tropical Cyclone Intensity Algorithm

          Current Analysis -- Date: OCT  4    Time:   21500UTC
                Lat:  26:14:48 N       Lon:  89:06:41 W

                         CI No./Pressure
                           7.0 / 921.0

          Eye Temp : -54.7 C        Surrounding Temp : -80.8 C
                              Distance from center :  44 km
          Scene Type : EMB C

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

Completed OBJECTIVE DVORAK TECHNIQUE analysis
```

3. Land Interaction

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

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

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

4. 48–Hour Rule

During the first 48 hours after the tropical cyclone being analyzed reaches hurricane/typhoon status, a special rule is applied in the calculation of the Raw T# value.

Application of this rule can be controlled utilizing the RULE48 keyword. If this rule is applied to the Raw T# intensity estimate, the following warning will be displayed in the runtime message section (also see Section 5G for more information) :

```
***APPLYING 48-HOUR RULE***
```

5. Automated Storm Center Determination

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

The automatic cursor position (AUTO FIX Position) can be determined in one of four ways; 1.) Quadratic Interpolation, 2.) Laplacian Analysis, 3.) 10° Log Spiral Analysis, or 4.) Linear Extrapolation. The first estimate position is calculated using a quadratic interpolation scheme utilizing NHC or JTWC forecast products. When calculating this position the following message will be displayed to indicate that the ODT is performing this task :

```
calculating AUTO FIX position... please wait
```

Once the position is determined, the data points used in the quadratic interpolation procedure and the interpolated position will be presented. An following example is for a forecast at 08:15UTC on October 4, 1995 :

```
Reading history file OPAL.ODT
T1 -   1995/10/ 3    600Z          22.10       92.10
T2 -   1995/10/ 3   1800Z          23.40       91.00
T3 -   1995/10/ 4    600Z          25.80       89.50
T4 -   1995/10/ 4   1800Z          28.70       88.00
T5 -   1995/10/ 5    600Z          31.50       87.10
NHC Interpolated Forecast LAT/LON=    26.35144         89.18359
Beginning Image Data transfer, bytes= 33408
AUTO FIX Position  : Latitude   =    26.35
                   : Longitude =    89.18
AUTO FIX Position determined using NHC Interpolation
```

If the quadratic interpolation methodology is successful in calculating a center fix position, this location can be modified using either the Laplacian Analysis or 10° Log Spiral Analysis, as described in Section 5C. If either of these methods are used, the AUTO FIX Position Latitude/Longitude values will differ from the "NHC Interpolated Forecast LAT/LON" position, and one of two messages will appear below the position values :

```
AUTO FIX Position determined using Laplacian Analysis
```

or

```
AUTO FIX Position determined using 10^ Log Spiral Analysis
```

If the quadratic interpolation scheme fails, a simple linear extrapolation of the previous storm center locations, stored within the history file, will be performed. No data points will be presented, and the "NHC Interpolated Forecast LAT/LON" banner will be replaced with the following lines :

```
Bad NHC interpolated position
Linear Extrapolated Forecast LAT/LON=    xx.xxxx       yy.yyyy
```
(xx.xxxx and yy.yyyy will contain actual values)

In addition, the following line will be displayed below the AUTO FIX Position lines (if the Laplacian and 10° Log Spiral Analysis fail to modify the location) :

```
AUTO FIX Position determined using Linear Extrapolation
```

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

```
Must use USER INPUT cursor position
```

The user will then be prompted to manually position the cursor and enter the new storm center location. The final position will then be displayed within the runtime message output as :

```
USER FIX Position : Latitude  =   xx.xx
                  : Longitude =   yy.yy
```
(xx.xx and yy.yy will contain actual values)

6. User Scene Type and Cursor Position Override

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

User cursor position modification is handled immediately after the automatic storm center location is determined (see Section 5C). The AUTO FIX position will be displayed along with the method used to determine the location. The user will then be asked if he/she agrees with the position. If the user agrees the algorithm will continue as normal, otherwise the user will be asked to reposition the cursor. For example, if the user agrees with the storm center location, the runtime text output will be the following :

```
Reading history file OPAL.ODT
T1 -  1995/10/ 3    600Z          22.10     92.10
T2 -  1995/10/ 3   1800Z          23.40     91.00
T3 -  1995/10/ 4    600Z          25.80     89.50
T4 -  1995/10/ 4   1800Z          28.70     88.00
T5 -  1995/10/ 5    600Z          31.50     87.10
NHC Interpolated Forecast LAT/LON=    26.35144       89.18359
Beginning Image Data transfer, bytes= 33408

AUTO FIX Position : Latitude  =   26.35
                  : Longitude =   89.18
AUTO FIX Position determined using NHC Interpolation
```

```
Do you agree with this position?
YES: Press RIGHT mouse button
NO : Position cursor at desired location
     and press MIDDLE mouse button
  <user presses RIGHT mouse button>
YES - will use AUTO FIX Position
Beginning Image Data transfer, bytes= 28768
```

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

```
  <user presses MIDDLE mouse button>
NO  - will use USER FIX Position
USER FIX Position : Latitude  =   26.77
                    Longitude =   89.22
Beginning Image Data transfer, bytes= 28768
```

User scene type modification is presented either immediately after the ODT is initiated or after the automatic cursor position is accepted/modified. The ODT will display the objectively determined scene type and ask the user to either accept or modify the value. If the user chooses to modify the scene type, a sequence of scene type classifications will be presented to the user. Once the desired scene type is displayed, the scene type is entered and the program proceeds as normal in its determination of the current storm intensity estimate. Two example sessions are below :

The user agrees with the scene type :

```
Reading history file OPAL.ODT
USER FIX Position : Latitude  =   25.07
                    Longitude =   89.91
Beginning Image Data transfer, bytes= 28768

Starting OBJECTIVE DVORAK TECHNIQUE analysis
ODT has classified the scene as EMB C
Do you agree with this classification?
TOGGLE : Press MIDDLE mouse button
ACCEPT : Press RIGHT  mouse button
  <user presses RIGHT mouse button>
Scene type has not been changed
```

The user does not agree with the scene type :

```
Reading history file OPAL.ODT
USER FIX Position : Latitude  =   25.07
                    Longitude =   89.91
Beginning Image Data transfer, bytes= 28768

Starting OBJECTIVE DVORAK TECHNIQUE analysis
ODT has classified the scene as EMB C
Do you agree with this classification?
TOGGLE : Press MIDDLE mouse button
ACCEPT : Press RIGHT  mouse button
```

```
  <user presses MIDDLE mouse button>
Change to CDO
  <user presses MIDDLE mouse button>
Change to SHEAR
  <user presses MIDDLE mouse button>
Change to EYE
  <user presses RIGHT mouse button>
Scene type has been changed to  EYE
```

E. History File Output

1. Text Output

Text output of the history file contents can be displayed using the LIST, DATE, and OUTPUT keywords. Using the OUTPUT=SCREEN keyword displays the contents of the history file within the McIDAS text window. An example is given below for Hurricane Opal :

Reading history file OPAL.ODT

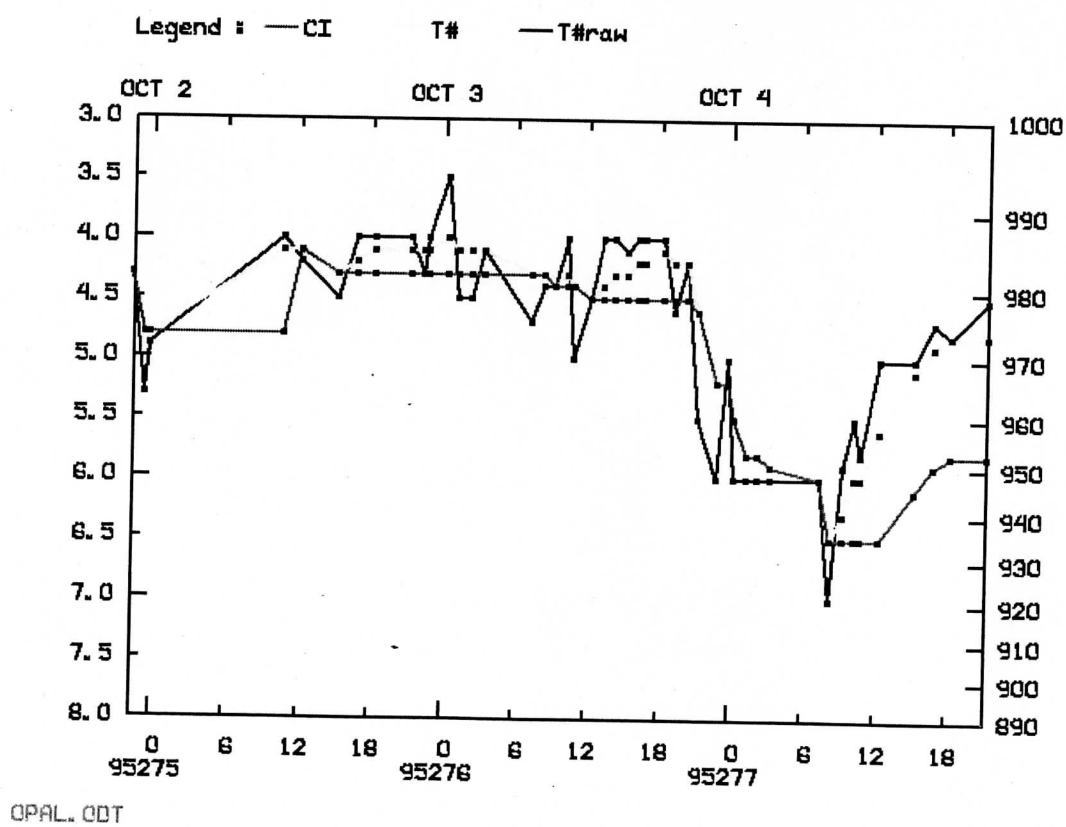
		Intensity		T-No		Temperatures(C)		Scene	Step9	Rapid
Date	Time	CI	MSLP	Avg	Raw	Eye	Cloud	Type	Flag	Flag
1995OCT01	221500	4.3	982.2	4.3	4.3	-57.1	-62.9	EMB	OFF	OFF
1995OCT01	231500	4.8	973.6	4.8	5.3	-54.1	-75.2	EMB	OFF	OFF
1995OCT01	234500	4.8	973.6	4.8	4.9	-74.2	-79.5	CDO	OFF	OFF
1995OCT02	104500	4.8	973.6	4.1	4.0	-41.6	-55.7	EMB	OFF	OFF
1995OCT02	121500	4.1	985.4	4.1	4.2	-54.1	-61.7	EMB	OFF	OFF
1995OCT02	151500	4.3	982.2	4.3	4.5	-37.1	-57.7	EYE	OFF	OFF
1995OCT02	164500	4.3	982.2	4.2	4.0	-67.3	-70.4	CDO	OFF	OFF
1995OCT02	181500	4.3	982.2	4.1	4.0	-61.7	-66.5	CDO	OFF	OFF
1995OCT02	211500	4.3	982.2	4.1	4.0	-60.6	-65.6	CDO	OFF	OFF
1995OCT02	221500	4.3	982.2	4.1	4.3	-51.8	-62.5	EMB	OFF	OFF
1995OCT02	224500	4.3	982.2	4.1	4.0	-48.8	-63.3	CDO	OFF	OFF
1995OCT03	1500	4.3	982.2	4.0	3.5	-36.9	-46.8	EYE	OFF	OFF
1995OCT03	11500	4.3	982.2	4.1	4.5	-63.6	-67.7	EMB	OFF	OFF
1995OCT03	21500	4.3	982.2	4.1	4.5	-62.1	-71.8	EMB	OFF	OFF
1995OCT03	31500	4.3	982.2	4.1	4.1	-52.1	-60.2	EMB	OFF	OFF
1995OCT03	71500	4.3	982.2	4.3	4.7	-74.2	-78.4	CDO	OFF	OFF
1995OCT03	81500	4.3	982.2	4.3	4.4	-72.7	-76.7	CDO	OFF	OFF
1995OCT03	91500	4.4	980.6	4.4	4.4	-75.2	-76.7	CDO	OFF	OFF
1995OCT03	101500	4.4	980.6	4.3	4.0	-66.9	-71.3	CDO	OFF	OFF
1995OCT03	104500	4.4	980.6	4.4	5.0	-57.1	-72.2	EMB	OFF	OFF
1995OCT03	121500	4.5	979.0	4.5	4.5	-62.9	-69.9	EMB	OFF	OFF
1995OCT03	131500	4.5	979.0	4.4	4.0	-67.3	-69.9	CDO	OFF	OFF
1995OCT03	141500	4.5	979.0	4.3	4.0	-63.6	-67.3	CDO	OFF	OFF
1995OCT03	151500	4.5	979.0	4.3	4.1	-55.4	-59.9	EMB	OFF	OFF
1995OCT03	161500	4.5	979.0	4.2	4.0	-67.3	-68.6	CDO	OFF	OFF
1995OCT03	164500	4.5	979.0	4.2	4.0	-63.6	-65.6	CDO	OFF	OFF
1995OCT03	181500	4.5	979.0	4.1	4.0	-62.9	-68.6	CDO	OFF	OFF
1995OCT03	191500	4.5	979.0	4.2	4.6	-67.7	-72.7	EMB	OFF	OFF
1995OCT03	201500	4.5	979.0	4.2	4.2	-70.8	-73.7	CDO	OFF	OFF
1995OCT03	211500	4.6	977.2	4.6	5.5	-69.0	-80.8	CDO	OFF	ON
1995OCT03	224500	5.2	966.0	5.2	6.0	-70.8	-81.0	CDO	OFF	ON
1995OCT03	234500	5.2	966.0	5.2	5.0	-71.3	-77.1	CDO	OFF	ON
1995OCT04	1500	5.5	960.0	5.5	6.0	-69.0	-83.0	CDO	OFF	ON
1995OCT04	11500	5.8	952.8	5.8	6.0	-71.8	-81.1	CDO	OFF	ON
1995OCT04	21500	5.8	952.8	5.8	6.0	-69.5	-80.7	CDO	OFF	ON
1995OCT04	31500	5.9	950.4	5.9	6.0	-66.1	-80.7	CDO	OFF	ON
1995OCT04	71500	6.0	948.0	6.0	6.0	-66.5	-80.9	CDO	OFF	ON
1995OCT04	81500	6.5	935.0	6.5	7.0	-54.7	-80.8	EMB	OFF	ON
1995OCT04	91500	6.5	935.0	6.3	5.9	-63.3	-76.8	EMB	ON	ON
1995OCT04	101500	6.5	935.0	6.0	5.5	-63.3	-77.0	CDO	ON	ON
1995OCT04	104500	6.5	935.0	6.0	5.8	-62.9	-78.9	CDO	ON	ON
1995OCT04	121500	6.5	935.0	5.6	5.0	-69.0	-77.1	CDO	ON	ON
1995OCT04	151500	6.1	945.4	5.1	5.0	-59.5	-67.7	EMB	ON	ON
1995OCT04	164500	5.9	950.4	4.9	4.7	-69.9	-73.7	CDO	ON	ON
1995OCT04	181500	5.8	952.8	4.8	4.8	-70.4	-74.8	CDO	ON	ON
1995OCT04	211500	5.8	952.8	4.8	4.5	-21.5	-43.2	EYE*	ON	OFF

The text output displays time, date, intensities (CI with corresponding pressure/wind value, Final T#, and Raw T#), eye and cloud top temperatures, scene type, Dvorak Step 9 flag value, and rapid intensification flag value. In addition, if the storm center is located over a land feature at the time listed, a "*" will be listed next to the scene type. When listing the contents of the default history file, only the date, time, CI and corresponding pressure/wind value, eye and cloud top temperatures, and the scene type (with land flag) will be displayed.

If the user would rather write the LIST output to an ASCII instead of to the screen, the OUTPUT=FILE <filename> keyword can be used in conjunction with the LIST keyword. This option provides the same contents as the "OUTPUT=SCREEN" option, however the storm center latitude and longitude position will be appended at the end of each line.

2. Graphical Output

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



The intensity estimate values are plotted along the ordinate; T# values along the left hand side and its corresponding pressure/wind along the right side. Time is plotted along the abscissa, with Julian date and time (UTC) plotted at the bottom and the corresponding calendar day (month and day) plotted along the top of the graph. The history file used is displayed in the bottom–left hand corner of the graph. A legend of the displayed variables is presented along the top of the graphics window. In the example above, the CI number (CI), Final T# (T#), and Raw T# (T#raw) are all displayed, but any combination of the three values can be plotted using the PLOT keyword. Any portion of the history file can be plotted using the DATE keyword.

5. Background Information

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

A. Land Flag

Tropical cyclone land interaction is determined utilizing a high resolution topography map named TOPOHRES. The location of this file is defined using the TOPOPATH definition statement in the odt.h include file. This directory should be defined prior to compiling the ODT algorithm. The resolution of the map file is 0.1° X 0.1° latitude/longitude. If the tropical cyclone storm center position is located over a land region, the land flag is set to true for that analysis. Land interaction does not modify the determination of any of the intensity estimate values directly, however if the storm is located over a land mass continuously for 12 hours the application of the Rule 9 adjustment, if currently being applied, is turned off.

B. Scene Classification

Objective scene identification is performed using Fast Fourier Transform (FFT) analysis, histogram analysis, and several empirically defined temperature values. Scene classifications are currently limited to four main categories :

EYE	: Eye (also 'EYE L', 'EYE S', 'EYE R', 'DRY R')
EMB C	: Embedded Center or Warm Spot
CDO	: Central Dense Overcast
SHEAR.	: Shear

The eye classification actually consists of several additional sub–classifications, such as small/pinhole eye ('EYE S'), ragged eye ('EYE R'), large eye ('EYE L'), and dry region ('DRY R'). These classifications do not provide any additional information to the intensity estimate calculation, but are distinguished for possible future intensity estimate adjustments utilizing Dvorak EIR and/or Visible Rules.

Scene type is determined by performing FFT and histogram analysis on the eye region (0–40km) and surrounding cloud region (24–136km). By examining the number and size of the eye region FFT harmonics, histogram temperatures for the eye and cloud regions, various temperature differences, and threshold temperatures, scene type can be inferred. The threshold values were defined empirically through comparison of a large sample of FFT analysis with their corresponding manually determined scene type. Thresholds were defined where natural FFT harmonic and histogram divisions/groupings existed. Obviously, when utilizing empirically defined threshold limits in classification schemes, certain scenes will be, in the user's opinion, misclassified. The user is given the opportunity to reclassify the scene using the OVER keyword.

Once the scene type has been automatically or manually resolved, the value is passed to the intensity estimation routines, along with eye and surrounding cloud top temperature information, to define the intensity estimate for the scene being examined.

C. Automatic Storm Center Location

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

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

1. NHC Tropical Storm/Hurricane Discussion files (WTNT4? or WTPZ4?)
2. JTWC Tropical Cyclone Warning files (WTPN3?)

File type number one contains forecast positions and prior storm positions (12 and 24 hours previous), while files two and three only contain forecast positions, thus requiring storm locations previously stored within the ODT history file for the interpolation routine.

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

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

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

D. Time Averaging Scheme

The Final T# value is calculated using a linear–weighted time averaging scheme, which places greater weight on the current intensity estimate value and less weight upon each preceding intensity estimate. The time averaging scheme uses the current Raw T# value and all available Raw T# values obtained within the last 12 hours. The current value is given a weight of 12.0, with all other values given weights directly proportional to their time difference from the current analysis time.

E. Rapid Deepening

The rapid deepening flag is based purely upon two cloud top convection temperatures. If the cloud top temperature value is less than –70°C and the mean cloud top histogram temperature is less than –75°C for more than two continuous hours, it is determined that rapid intensification is underway. These values were empirically determined by examining the performance of the ODT in relation to actual reconnaissance intensity measurements, and noting how various cloud top region temperatures related to storms that rapidly deepened.

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

F. Dvorak EIR Step 9 Rule

The Dvorak Rules EIR Step 9 (see Dvorak, 1984) is used in the determination of the CI number after a storm has reached its maximum intensity and is weakening. This rule holds the CI number to values up to 1.0 T# higher in value than the current Final T# value (the time averaged intensity estimate value). Subjective application of this rule (e.g. how and when to apply it) varies from forecaster to forecaster, and is the focal point of much debate. The value 1.0 was chosen for the ODT since it provided the best fit for the estimated intensity values when compared with reconnaissance pressure measurements.

In the ODT algorithm, application of this rule is performed when the storm has undergone a "significant strengthening event". This is identified by computing a least squares fit to the current and all Final T# values within the past 24. If the slope of this fit is less than or equal to –1.0 (decreasing 1.0 T# in the last 24 hours), a "significant strengthening event" is said to be occurring, and a flag is set. When the Final T# stops increasing the Dvorak Rule 9 is initiated, influencing the Final CI number calculation.

An additional rule within the ODT affects the calculation of the Final T# and CI number. This rule is as follows; "Always hold the CI to the highest Final T# in the last 12 hours (but never greater than 1.0 for the CI number) in all cases". This rule will hold the CI number to the highest Final T# obtained during the last 12 hours, regardless of where the storm is in its life cycle. For example, if the T# (and CI number) increase to a 5.2, then the T# begins to decrease, the CI number value will be held at 5.2 until the T# either increases and exceeds 5.2 or 12 hours passes.

G. 48–Hour Rule

An adjustment to the Raw T# determination may be applied during the first 48 hours after the ODT analysis is initiated on a storm. This adjustment is controlled with the RULE48 keyword, with application of this rule set to "on" as the default condition.

The impetus for this rule stems from the ODT overestimate bias noted in statistical analysis during this time period of the storm life cycle. It is believed that during initial storm development the intensity values provided by the ODT and original Dvorak EIR rules may represent values that more closely depict those obtained during more advanced stages of a tropical cyclone life cycle. During the first 48 hours after hurricane/ typhoon status is reached, the low–level vortex (and MSLP) still responding to the convective forcing and secondary circulations. CDO, EMB C, and EYE scene types defined during this time period probably represent more advanced tropical cyclone stages, and therefore overestimate MSLP intensity. Due to direct comparisons between ODT intensity estimates and aircraft reconnaissance measurements of developing storms, the implementation of a rule to account for this bias was initiated.

When applied, the 48 hour rule will subtract up to 0.5 T# from the Raw T# value for any scene type except shear prior to the storm entering a "significant strengthening cycle". This value is weighted, dependent upon the time difference from the start of the analysis to the current time period. The weighting factor is :

$$0.5\ T\#\ X\ ((48hrs. - \Delta t)/48hrs.)$$

where Δt is the time difference between the start of the analysis and the current time, in hours. At the start of the analysis this T–number adjustment will be 0.5, and will decrease to 0.0 after 48 hours. Once this adjustment is applied to the Raw T# and the ODT completes successfully, the value will be entered into the history file. By using the keyword RULE48=OFF, only the current image will be affected, with other records in the history file being unaffected. It is highly recommended that application of this rule should be consistent throughout the entire life cycle of the storm being analyzed.

H. Determination of the Temperatures Values

Determination of the eye region temperature is relatively straightforward. This value is the warmest pixel within a 40 km radius from the user or automated storm center location. Proper determination of the storm center is paramount to correct determination of the storm intensity because the retrieval of an accurate eye temperature is heavily dependent on cursor location.

The surrounding cloud top region temperature determination is a little more complicated. The cloud top region analyzed is centered at the storm center location and lies between 24 and 136 km from the center location, and represents the eyewall and main convective area of the storm. 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. For more information about this value, see Velden et al. (1998) and Zehr (1989).

The mean cloud top region temperature is used in the determination of rapid deepening and in the intensity estimation during rapid deepening events. This value is actually the temperature at the maximum of the coldest Gaussian distribution estimated from the histogram of cloud region temperature measurements. This value provides a good estimate for the overall structure of the surrounding cloud top region, and is used in conjunction with the derived cloud top region "coldest–warmest" temperature to determine rapid deepening events.

I. Cursor Position Sensitivity Reduction

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

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

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

6. Acknowledgments

We gratefully acknowledge the support of our research sponsors, the Office of Naval Research, Program Element (PE–060243) and the Space and Naval Warfare Systems Command, PMW–185 (PE–0603207N).

We also wish to thank the following people for their input in the development of the ODT 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; Mark DeMaria of the Cooperative Institute for Research in the Atmosphere for the quadratic interpolation code; Mike Turk, Otto Karst, and Roney Sorenson at the Satellite Analysis Branch, and Richard Pasch, Jack Beven, Max Mayfield, and Jiann–Gwo Jiing at the National Hurricane Center/Tropical Prediction Center for their evaluation of the ODT algorithm and for countless suggestions on improving the ODT; and Roger Edson and Frank Wells, formerly at the Joint Typhoon Warning Center, for their evaluation and comments regarding the ODT when utilized in the West Pacific.

7. References

Coakley, J.A. and F. Bretherton, 1982 : Cloud cover from high resolution scanner data: detecting and allowing for partially filled fields of view. *J. Geophys. Res.*, **87**, 4917–4932.

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.]

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. *Weather and 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.

Appendix A. ASCII format history file flag values

When examining the ASCII history file, certain integer values are used to designate various ODT parameters for each analysis. These values are defined below for each particular parameter in question.

1. Rule 9 flag
   - 0 – First record in history file. No value assigned
   - 1 – No significant strengthening event noted.
   - 2 – Significant strengthening event noted; Final T# values still increasing or steady.
   - 3 – Applying Rule 9 adjustment to CI value; Final T# decreasing.
   - 4 – Final T# value increasing during Rule 9 application; holding CI value until Final T# value converges with CI value.
   - 5 – Another significant strengthening event noted; CI value and Final T# value have converged; will increase CI value until onset of weakening; will apply Rule 9 again.

2. Scene type
   - 0 – EYE : clear eye region
   - 1 – EYE L : very large, clear eye region
   - 2 – EYE S : very small, "pinhole" eye region
   - 3 – EYE R : cloud filled, "ragged" eye region
   - 4 – DRY R : dry intrusion into eye region
   - 5 – EMB C : embedded center (warm spot, but no eye)
   - 6 – CDO : central dense overcast (uniform cloud region over center)
   - 9 – SHEAR : cyclone being sheared

   Note : values 0 – 3 result in no change in analysis at this time. A possible intensity value adjustment may be applied for each different value in the future (as stated in Dvorak Rules) for EIR and VISIBLE satellite image analysis.

3. Rapid deepening
   - 0 – No rapid deepening event noted.
   - 1 – Onset of rapid deepening event; watch for 2 hours.
   - 2 – Rapid deepening event in progress; apply rules.
   - 3 – Rapid deepening event concluded; holding Final T#
4. Land flag
   - 1 – Cyclone center over water/ocean.
   - 2 – Cyclone center over land.

Appendix B. Binary format history files and conversion

Previous versions of the ODT utilized binary format history files. The change to ASCII format files was done in response to ODT user request. The data stored in the ASCII file has changed slightly to add the mean cloud top temperature value, which is used in the determination of the rapid intensification flag and intensity estimate values.

During the development of the ODT algorithm, the structure of the history file has changed slightly. The most recent versions of the ODT (versions 4.1+) used a 15 word/record format, with each data record containing values stored as four byte integers (instead of floating point values, as with the new ODT version 5.3). Below is the storage structure of a typical binary record :

Value 1	: date (Julian date format YYYYDDD)
Value 2	: time (hhmmss format)
Value 3	: raw T# (value X 1000) + land/ocean flag
Value 4	: final T# (value X 10)
Value 5	: final CI number (value X 10)
Value 6	: eye temperature (value X 10)
Value 7	: cloud top temperature (value X 10)
Value 8	: scene type (integer value)
Value 9	: strengthening/weakening flag (value X 10) + rapid strengthening flag
Value 10	: storm center latitude (value X 10000)
Value 11	: storm center longitude (value X 10000)
Value 12–15	: future use

The program *convertodthistory.c* will convert old binary–format ODT history files to new ASCII–format history files. This program can be obtained via anonymous FTP from cyclone.ssec.wisc.edu in a similar manner as explained in Section 3 to obtain the ODT algorithm.

Instead of : **get ODT–v5.3.tar.Z**
replace with : **get convertodthistory.c**

The program can be compiled with either the **cc** or **gcc** compilers using the following command :

```
<compiler> –o convertodthistory convertodthistory.c
```

This program will convert the old binary formats into ASCII files. Since the old binary files do not contain values for the mean cloud top temperature, these will be replaced with a value of –999.99. Other values may or may not be available, such as the land flag and latitude/longitude positions. A missing value for the land flag will be 0, while the missing flags for the position elements will be –99.99 and –999.99, respectively.