UW−CIMSS
Satellite−Derived Wind Algorithm

USER'S GUIDE
(version 1.n)

Prepared by

Timothy L. Olander

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

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1. Introduction

A. Historical Background

The satellite winds derivation algorithm has been under development at the University of Wisconsin−Madison/Cooperative Institute for Meteorological Satellite Studies (UW−CIMSS) and the National Oceanic and Atmospheric Administration/National Environmental Satellite, Data and Information Service (NOAA/NESDIS) for about 20 years. Initial efforts required human interaction to target and track cloud features in satellite imagery displayed with the Man computer Interactive Data Access System (McIDAS), developed by the Space Science and Engineering Center (SSEC) at the University of Wisconsin. These methods were very labor−intensive and extremely subjective, thus preventing the algorithm from being used operationally.

Since the late 1980s, automated tracking (Hayden and Stewart, 1987; Merrill, 1989; Merrill et. al., 1991; Velden, 1993; Holmlund, 1993) and quality control techniques (Hayden and Pursor, 1988; Hayden and Velden, 1991; Holmlund, 1998; Holmlund et. al., 2001) were developed and advanced to the level where significant impact within global forecast models has been achieved (Velden et. al., 1992; Velden, 1996; Velden et. al., 1998; Goerss et. al., 1998; Soden et. al., 2001). Winds derived from this algorithm are now being utilized quantitatively in various forms within many global models worldwide. Wind data are currently produced operationally at NOAA/NESDIS and pseudo−operationally at UW−CIMSS for use in various global and regional scale models. Forecast and research meteorologists qualitatively use the data to aid in analysis of various weather systems (Velden et. al., 1997; Bosart et. al., 1999).

Many improvements have been implemented through collaborative research efforts at UW−CIMSS and NOAA/NESDIS, impacting processing strategies and algorithm functionality. Algorithms have been introduced by collaborating meteorological agencies over the years, providing important additions to the existing set of algorithms developed at UW−CIMSS and NOAA/NESDIS. Such efforts have improved two aspects continually being investigated to provide the highest quality and most accurate satellite−derived wind vectors: automated height assignment and quality control. Routines have been provided by the Australian Bureau of Meteorology (ABoM) and European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), for use within the winds derivation algorithm and will be discussed in greater detail in this guide. These additions, coupled with the ongoing research efforts at NOAA/NESDIS and UW−CIMSS, have resulted in a "state of the art" satellite−derived winds algorithm that has impacted many different areas of forecast and research meteorology.

The winds algorithm historically has been operated within the McIDAS architecture, operating recently within an UNIX environment. In order to create an algorithm that could be more freely shared with other interested parties wishing to derive their own satellite wind vector data sets, a "McIDAS−independent" version of the winds algorithm has been initiated (Olander et. al., 2000). The algorithm will still utilize McIDAS data structure formats and McIDAS navigation/ calibration routines, but does not require the McIDAS software package to be installed.

The current version of the winds algorithm described in this guide can analyze satellite imagery from the GMS−5, Meteosat−5, and Meteosat−7 geostationary satellites. Expansion of the algorithm for use of imagery from the GOES platforms is under development, and will be introduced in a future release of the code. Ability to utilize future geostationary and polar−

orbiting platforms are planned and will also be included in later releases of the code. Finally, the ability to use imagery from select prior geostationary satellites for retro−processing will also be incorporated in coming versions.

The winds algorithm is command line driven, utilizing numerous keywords which provide the ability to customize the functionality of the various commands. Development of a graphical user interface (GUI) is planned to allow for easier "mouse−driven" X−Windows−type interaction. This GUI will provide a platform for display of input and output files, such as satellite imagery, wind vectors, and analysis grid fields derived from the wind and/or model forecast fields.

B. Processing Overview

The satellite winds derivation process involves the execution of a sequence of commands. Each command is presented in greater detail in the following sections. A general overview of the command sequence is presented in Figure 1. This flowchart highlights the main satellite winds derivation processes : image registration, image targeting and target height assignment, wind vector determination, and wind vector editing and quality control. Additional routines compliment these applications, performing specific tasks targeting select satellite wind data subsets. These routines are also discussed in later sections.

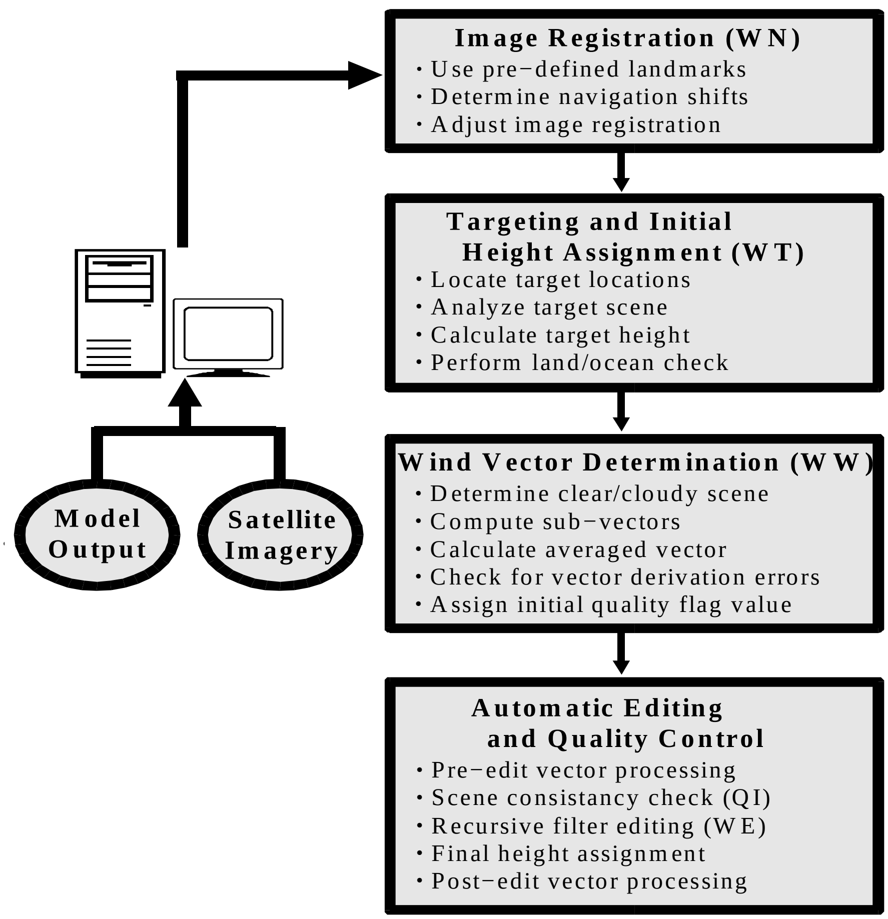

Figure 1. Overview of the satellite winds derivation algorithm.

Prior to execution of the winds derivation process, two input data sets must be collected and staged. The first set is a sequence of three or more satellite images (up to five) and height assignment image(s). The optimal time resolutions, for specific channel numbers, are presented in Table 11 in Section 11A. A constant time resolution for each image pair being processed is recommended, however, the winds algorithm will work successfully for a non−uniform time resolution between image pairs. The satellite images must be in McIDAS Image format. Image format converters are provided to convert from SDSH "simple" format to McIDAS Image format (see Section 10A and 10B). The second data set is a numerical model forecast. The model forecast must be valid for the image times being processed, up to nine hours difference between the forecast time and the first image time of the data set being processed. An error will occur in the main processing routines if this time difference is exceeded. The model data must be in GRIB format and must consist of separate data files for each parameter, pressure level, and forecast time period required (see Section 3B).

Once the input data are properly staged, satellite wind processing can begin. The first step involves the examination of the registration information for each satellite image. This is done to correct any possible navigation shifts observed in any data set image. The routine utilizes a list of pre−determined landmark points to track between the different images. The location of each available landmark point in the first image is determined and searched for in the remaining images using a correlation analysis scheme. An average shift from the first image is then calculated from all landmark points located in each successive image. Any calculated shift, in lines and/or elements, can then be applied to the image using a separate application. See Section 4 for more details.

Once any navigation shifts have been corrected, wind vector targets can then be determined. Targets are identified using a maximum gradient searching routine coupled with a Coakley−Bretherton analysis scheme (Coakley and Bretherton, 1982). The search area size is user−defined and is satellite and channel dependent (see Table 12 in Section 11C). Targets are either cloud edges, defined cloud features, or gradients in water vapor imagery. Initial height assignment values are calculated using any or all of five different methods (see Appendix A), depending upon the target and height assignment imagery utilized. Each target is assigned a land or ocean flag value, depending upon the surface characteristic at the target location. See Section 5 for more details.

Wind vector derivation is conducted after the targeting routine. Calculations are performed at each target location. Targets are tracked between successive image pairs, using a numerical model forecast wind field as a first guess for tracking cloud features or water vapor gradients between images. The tracking area size is user−defined, and is satellite and channel dependent (see Table 12 in Section 11C). Guess departures and acceleration checks between successive image pair sub−vector values are computed and indicated using a series of additive error flag values (see Appendix B). If the image registration routine is not performed prior to the wind targeting routine, any navigation shift may be interpreted as a wind vector acceleration, resulting in a large number of flagged winds. Thus, proper image registration is vital in the production of accurate wind vectors. See Section 6 for more details.

Wind vector values that possess non−critical error flag values (FLAG <=3) are passed into two independent wind vector editing and quality control routines. These routines check the overall coherence of the wind vector field and the fit of each individual vector to a background numerical model guess wind field. The first routine is the EUMETSAT Quality Indicator routine (QI). The QI routine examines each wind vector in relation to its surrounding "buddy" vectors and computes a value which conveys its "fit" to the surrounding satellite wind vector field. The second routine is the two−stage, three−dimensional Recursive Filter (RF) objective analysis routine (WE). The first stage of the initial RF analysis involves comparing each wind vector to the background numerical model wind field. In addition, the initial height assignment value for each wind vector is examined and may be reassigned using a variational penalty function relating the wind analysis to the model forecast wind, temperature, and pressure fields. A second RF analysis is then performed, comparing this modified field with the initial wind field prior to modification. Various quality flag values are assigned from this analysis to each wind vector examined. See Section 7 for more details.

In addition to the main wind derivation processes, various specific applications are run prior to and following the quality control and editing routines. These routines will modify or edit various wind vector parameters, such as wind speed, direction, pressure height, and error FLAG values based upon the wind vector type being examined. The routines will examine potentially misanalyzed wind vectors and may either reassign or remove vectors based upon various criteria defined in the routines. Application of these routines are very specific and focus on a select sub−set of wind vectors within the derived wind vector field. See Section 8 for more details.

2. Algorithm Acquisition and Installation

The high−density, geostationary satellite winds derivation algorithm can be obtained directly from UW−CIMSS via anonymous FTP transfer. To obtain the location of the winds algorithm download file and current version being distributed, please contact either Chris Velden or Gail Dengel at UW−CIMSS via e−mail at the addresses listed in the Contact Information section (Section 13).

Two files will be obtained from UW−CIMSS :
- windcoX.XX.tar.Z (X.XX is the version number, e.g. 1.62)
- build_windco

The entire winds algorithm will be contained within the compressed "tar" file. The macro file "build_windco" is used to uncompress and expand the "windcoX.XX.tar.Z" file, create all subdirectories, extract all programs and library files, and install the winds derivation algorithm. To execute this macro file, type the following command on the UNIX command line :

build_windco

Once the macro file has successfully completed, the current directory will contain the following files and directories :

Files :

README	− text file containing information about the winds algorithm
changesXX.X.txt	− log of changes to code for version X.XX
Makefile	− top level Makefile
build_windco	− macro file used to extract and build winds code
windcoX.xx.tar	− UNIX tar file containing winds code

Directories :

bin	− executable command binary files
cmd	− command program routines
data	− various data files (Section 3)
inc	− winds software include files
lib	− winds software library file and routines
lib/navcal	− image navigation and calibration routines
libf2c	− F2C library file and routines
reppix	− image replication routines (Section 10C)
simplegms	− GMS−5 image format conversion routines (Section 10A)
simplemsat	− Meteosat−5 and −7 image format conversion routines (Section 10B)

To install a new version of the winds derivation code, the old version must first be removed. To do this, type the following command on the UNIX command line within the top level directory :

make clean

After the old version has been removed, the new version can be installed as discussed above.

3. Context File

Parameters used by wind vector derivation routines are defined within the context file. This file allows the user to define runtime elements specific to the current wind set, such as input/output files, path names, and analysis control parameters which are used repeatedly instead of using command line keywords. Separate context files can be defined for specific wind derivation processing domains and/or instruments, which allow for simultaneous processing of wind sets within individual accounts or customization for particular data set analysis.

Context files are specified for the processing routines using the TEXT keyword. Context files can be specified with an absolute or relative path and file name for the file. If the context file name only is specified, it must be located in the current directory.

There are five main sections within each context file : PATHS, GRIBS, FILES, VALUES, and MISCELLANEOUS. These topics are discussed in detail in the following five sections.

A. PATHS

The PATHS input values are the complete path names for the directories in which the different winds algorithm input/output files are stored. The first parameter on each line is the descriptor name, the second parameter is the absolute path to the directory containing the file(s), and the third is a short description/comment. The path names can be up to 80 characters long. Table 1 summarizes the contents of the PATHS input values.

Descriptor Name	Description/Comment
GRIBPATH	Model guess files (GRIB format).
IMAGEPATH	Satellite data set and height assignment images.
WINDPATH	Wind vector output file, in McIDAS MD format.
GRIDPATH	Wind vector output file in McIDAS GRID format.
SCHEMAPATH	Wind vector format file "SCHEMA".
RTCFPATH	Radiative transfer coefficient files.
TOPOPATH	High−resolution topography file "TOPOHRES".

Table 1 : Path name descriptors defined in the context file.

B. GRIBS

The files defined in the GRIBS section are the individual GRIB format files containing the numerical model output for each separate parameter and level. The GRIB file names can be up to 100 characters long and must be contained in the GRIBPATH directory defined in the context file. A list of GRIB file descriptors are presented in Table 2. The first parameter is the data field type. The second parameter is the file name for the particular GRIB file described by the third parameter which describes the GRIB file type and level.

Type	Description
TEMP	Air temperature at 13 levels
DEWP	Dew point depression at 6 levels (1000 to 300 hPa)
HEIGHT	1000 hPa heights
MSLP	Mean sea level pressure at surface
U	Wind u−component at 10 levels (1000 to 100 hPa)
V	Wind v−component at 10 levels (1000 to 100 hPa)

Table 2 : GRIB name descriptors defined in the context file.

There must not be more than NLEVELS number of levels for each data field type, where NLEVELS is defined within the GridHdr.h include file. Currently, there are 13 numerical model levels expected (in hPa) :

Level Number	Pressure Levels (hPa)
1	1050 (surface)
2	1000
3	850
4	700
5	500
6	400
7	300
8	250
9	200
10	150
11	100
12	70
13	50

Table 3 : Numerical model input data pressure levels.

Values are read and stored in arrays for each data field type. The temperature, dew point depression, and U and V component arrays can contain up to NLEVELS levels of data, although dew point depressions usually are not defined above 300 hPa. Two additional GRIB files containing 1000 hPa heights and mean sea level pressure are also needed in order to estimate the surface parameter types for the radiative transfer calculations. Missing GRIB files will be filled with "missing data" values.

Model forecast time period for the GRIB files must coincide with the imagery being used to derive the wind vectors. Any forecast period may be used as the background field for the targeting and wind vector determination routines, but the time at which the forecast fields are valid must be within +/− 9 hours of the first image time. This function can be overridden using the command line keyword ORT in these routines (see Sections 5E and 6E).

C. FILES

The FILES section contain the names of the input satellite data files, the output wind vector file, and the grid file output during execution of the Recursive Filter wind editing routine, if desired. For entries that are not available or used, the value "MISG" should be entered. These file names can also be overridden using command line keyword entries in various winds algorithm routines, however it is recommended that a context file is utilized to minimize errors and maximize continuity among the various routines. These file names are listed in Table 4.

Up to five images can be used in the derivation of the wind vectors, however three images are normally used in order to shorten the wind derivation process time. Operationally, the time difference between consecutive images is either 30 or 60 minutes for winds derived using water vapor and/or infrared imagery (depending on satellite), 15 minutes for visible imagery (seven or less if rapid−scan data are available), and 60 minutes for GOES sounder imagery. These are the optimal time differences, and are discussed in Section 11.

Two height assignment images can be specified for derivation of the wind vector pressure heights. Height assignment methods are described in Appendix A.

For more detailed information about each of the following data formats (satellite imagery, wind vector files, and gridded output files), see the McIDAS Programmers Manual, Chapters 6 and 7 (Accessing Data and Format of the Data Files), at the following internet address : http://www.ssec.wisc.edu/mug.

Parameter	Description
ARA1	First image in wind vector image set.
ARA2	Second image in wind vector image set.
ARA3	Third image in wind vector image set.
ARA4	Fourth image in wind vector image set (if applicable).
ARA5	Fifth image in wind vector image set (if applicable).
HARA1	First height assignment image (infrared image)
HARA2	Second height assignment area (water vapor image, if used).
MDF	Wind vector output file.
GRID	Grid output file from Recursive Filter editing routine WE.

Table 4 : Input and output data file names defined in the context file.

D. VALUES

The parameters in the VALUES section define run−time control variables utilized during the wind vector derivation process. They can be modified for specific satellites and channels in order to optimize various functions of the individual winds algorithm routines. All of these parameters can be overridden using command line keywords, but it is recommended that the context file values are used when calculating a set of wind vectors in order to retain continuity among the different winds algorithm routines. Definitions and usage of these parameters are described in greater detail in Sections 5 thru 7.

Parameter	Description
LLAG	Line size for target tracking search area.
ELAG	Element size for target tracking search area.
LSIZ	Line size for target selector/analysis box.
ESIZ	Element size for target selector/analysis box.
QCU	U−component quality control criterion (m/s difference).
QCV	V−component quality control criterion (m/s difference)
LATN	Northern latitude extent of target/wind vector derivation.
LATS	Southern latitude extent of target/wind vector derivation.
LONW	Western longitude extent of target/wind vector derivation.
LONE	Eastern longitude extent of target/wind vector derivation.
PMAX	Maximum pressure of cloud height assignment.
PMIN	Minimum pressure of cloud height assignment.
MAXB	Maximum acceptable image brightness temperature.
MINB	Minimum acceptable image brightness temperature.
ROW	Input/output row number within wind vector file (MDF).

Table 5 : Run−time control variables defined in the context file.

E. MISCELLANEOUS

The parameters in the Miscellaneous section control selected run−time input/output functions for various wind vector derivation routines. Many of these parameters can also be overridden using command line keyword entries. See Sections 5 thru 7 for more details.

Parameter	Definition
ALL	Obtain all possible targets within image.
OUT	Output vector information at end of job to screen.
INIT	Initialize output wind file/row (used for reanalysis).

Table 6 : Miscellaneous variables defined in the context file.

4. Automatic Image Registration (WN)

A. Introduction

In order to ensure proper registration of imagery navigation utilized in the automatic wind vector derivation process, an automatic image registration routine is provided. The winds navigation (WN) routine corrects registration errors in consecutive images utilizing cross correlation and minimum lag coefficient analysis at user selected landmark points.

The automatic image registration routine is currently used operationally in the adjustment of infrared and water vapor imagery only. Analysis is performed utilizing brightness counts, which are transformed from the original satellite raw counts for each field of view (based upon the number of bits used to store the data for each satellite) to values between 0 and 255.

B. Flowchart

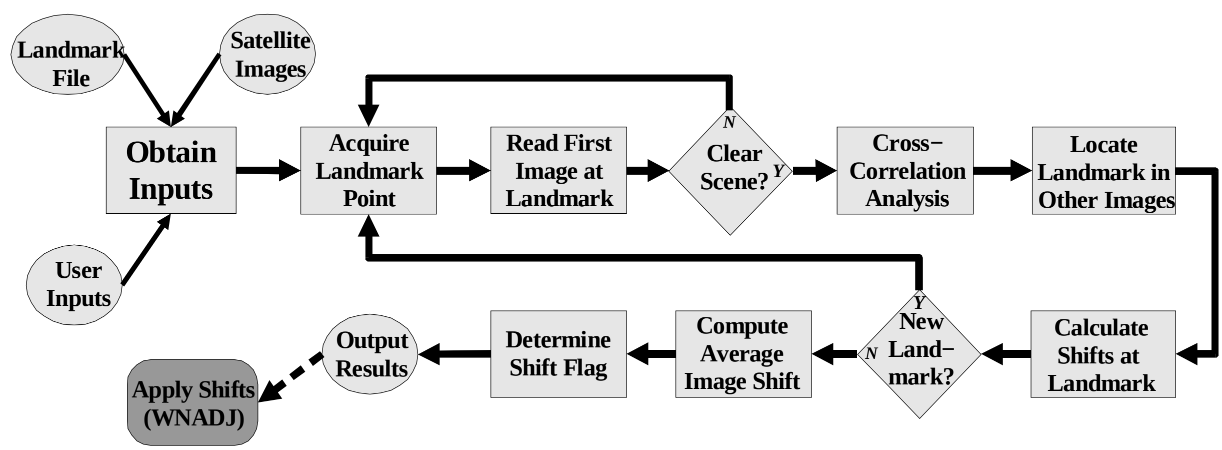

Figure 2 : Overview of the automatic image registration routine.

C. Methodology

Automatic image registration is performed using 11 µm (micron) infrared window imagery since landmarks can be identified at the surface using this channel. Adjustments to water vapor images are determined using the adjustments obtained separately from analysis of the infrared imagery. Registration modifications to 3.9 µm infrared imagery could also be adjusted using analysis of 11 µm images.

Images used in the autoregistration process should be single band images. Multi−band images containing two or more channels can be used, however the highest channel number will be chosen by the algorithm as the channel to be navigated. Use of the BAND keyword will allow for direct assignment of the proper channel by the user (see Section 3E).

Landmark locations are predetermined by the user, with latitude and longitude locations stored in an ASCII file. The format of this file is :

<latitude> <longitude> <point #>

Latitude values have positive/negative values for northern/southern hemisphere. Longitude values have positive/negative value for western/eastern hemisphere (this is opposite from most systems, but reflects those used by McIDAS). The point # values are simply a sequential numbering of each landmark point. The values on each line must be separated with either a tab or a space. The file JAPAN is provided and contains landmark database for the northwest Pacific Ocean. A global landmark data file will be provided with later versions of the winds processing algorithm. Landmark files for different regions of the world can be created by the user to suit their specific needs, using the format provided above.

Cloud−free landmarks are sought and identified within the first infrared image of the image set. The algorithm will automatically determine landmarks that are cloud covered by utilizing the Coakley−Bretherton analysis routine (Coakley and Bretherton, 1982). The size of the landmark search box is controlled by the user (see Section 4E).

Once all cloud−free landmarks have been identified, matching landmarks are searched for in the remaining infrared images in the image set. Images with 10% or more bad/unusable data are skipped. Matching landmarks are found in successive images by computing the minimum correlation error (lag correlation) between the landmark point from the first image and all other points within the search area within the remaining images in the image set. The point which obtains the minimum correlation error is retained as the matching point, from which line/element differences are calculated. A larger search box allows for more extreme shifts in navigation to be corrected, but also increases the probability for incorrect correlation matches between two images.

If the line/element shifts for a particular landmark are less than user−defined threshold values, it is counted as an initial good landmark (NMARK). Average line/element shifts for all good landmarks for all images are then computed, with differences between each good landmark and the computed average shift calculated. If these differences are below a user−defined threshold distance, the point is then retained as a final good landmark (OMARK).

Four final quality checks are performed to determine if the line and element shifts should be applied to the images. Error values are assigned for each quality check, and are displayed in the FLAG column of the routine output :

Value	Meaning
1	Successful navigation check; shift is applied.
−1	Number of OMARK landmarks < user−defined value (MARKS).
−2	Line/element standard deviation > user−defined value (SD).
−3	Absolute value of line/element mean < user−defined value (MIN).
−4	Ratio of NMARK/OMARK < user−defined value (RATIO).

Table 7 : Image registration algorithm error values.

D. Routine Output

The following presents a sample screen output display obtained while running the auto navigation routine WN. Three GMS−5 infrared images were navigated, using the navigation file JAPAN, located in the directory defined in the context file TESTCNTX.

The context file TESTCNTX was used, having the following FILE values defined :

ARA1	AREA1300	first WV image in image set.
ARA2	AREA1301	second WV image in image set.
ARA3	AREA1301	third WV image in image set.

```
> wn MIN=2 ERR=7 BAND=2 FILE=JAPAN TEXT=TESTCNTX

 ***** STARTING AUTO-REGISTRATION *****
Read in 13 Temperature GRIB file names successfully
Read in  6 Dewpt. Dep. GRIB file names successfully
Read in 10 U-Component GRIB file names successfully
Read in 10 V-Component GRIB file names successfully
Read in  7 path names successfully
Read in  9 file names successfully
Read in 15 wind processing variables successfully
Read in  4 miscellaneous variables successfully
Read in context file successfully
 first area name = /home/tlo/windco/windco/data/AREA1310
 second area name = /home/tlo/windco/windco/data/AREA1311
 third area name = /home/tlo/windco/windco/data/AREA1312
main: number of input areas 3.
 Landmark file = /home/tlo/windco/windco/data/JAPAN
MARK: no imagery for landmark box ...
 Useable landmarks found  189
    LMARK        LAT      LON      2        3        4        5
       1       37.51 -137.11     1        4        1        1
       2       41.46 -139.96     2        2        2        2
       3       41.83 -140.98     3        7        3        6
       5       41.32 -141.35     4        7        4        5
       6       41.18 -140.27     5        3        5        2
       7       38.36 -141.41     5       16        5       18
       8       42.08 -143.19     5       41        5       46
 <lines deleted>
     175       39.34 -139.88    30        1       31        0
     176       40.71 -139.95    31        1       32        1
     178       38.08 -140.89    31        9       32        8
     179       36.95 -140.82    32        2       33        5
     180       34.60 -137.97    33        4       34        2
     181       34.60 -137.18    33       12       34       20
     189       42.34 -140.89    33       13       34       15
Image  1 = /home/tlo/windco/windco/data/AREA1311
Image  2 = /home/tlo/windco/windco/data/AREA1312


IMAGE  -----LINE-----  -----ELEM-----  LCOR  ECOR  LCOR  ECOR  NMARK  OMARK  FLAG
SECOND      2.51   0.95   -1.15   0.93  3237 10701  3234 10701    33     27     1
THIRD       1.31   0.78   -1.97   1.25  3237 10701  3237 10701    34     31    -3
```

The first part of the routine output confirms the input of the context file information. The next set of output defines the imagery data files, the landmark file, and the number of valid landmarks found within the imagery boundaries. Following the file and landmark information, the landmark correlation output is displayed. This output shows the landmark point position, the NMARK counter, and its minimum lag coefficient error value for each image being navigated (see ERR keyword in Section 3E). The final statistics output contains information about the line/element shift statistics (mean and standard deviation), the line/element information before and after the shifts are applied, the initial and final number of landmarks, and the final quality flag.

The first column indicates which image is being compared to the first image. The columns under LINE provide the line mean and standard deviation shift of the final good landmarks. The columns under ELEMENT are the element mean and standard deviation shifts. The first LCOR and ECOR columns show the initial line and element of the upper left corner of the image in satellite coordinates. The second LCOR and ECOR columns show the final line and element after the shift has been calculated, in satellite coordinates. The number of initial and final good landmarks found in each image are given under the NMARK and OMARK columns, respectively. Finally, the FLAG column displays the final quality flag for each image being examined.

This example shows the results of the autoregistration process for three infrared images. Notice the FLAG values for the two images. The second image has a FLAG value of 1 indicating that all quality control thresholds were met and a shift was applied. It exceeded the MIN value for its line shift value and also passed all of the other final quality threshold checks, thus an adjustment could be calculated and applied to the imagery, which is noted by the LCOR change from 3237 to 3234 (three lines). The third image failed one of the final quality control checks, indicated by the FLAG value of −3. Looking closer the output line for the third image, both the line and element mean shift were less than MIN value provided within the command line entry (MIN=2), thus the final quality threshold checks failed for this image and no adjustments were made to the final LCOR/ECOR values.

The values obtained for the line and element shifts can be applied to corresponding images from different bands on the same satellite having the same horizontal resolutions using the WNADJ command. Usage of the WNADJ program is discussed in Section 4F.

E. Usage

The following keywords can be entered on the command line at the initiation of the automatic image registration routine WN :

Format : wn *keywords*

Online help listing is available by entering ***wn*** or ***wn help*** on the command line.

keywords

AREA =*<image 1> <image 2> <image 3> <image 4> <image 5>*

Image files to be autonavigated. Landmarks will be determined within the first image, with calculations and adjustments being made to the second through fifth images in relation to the first image.
<image 1> : First image; serves as template for navigation adjustments. (default=ARA1 value in context file)
<image 2> : Second image. (default=ARA2 value in context file)
<image 3> : Third image. (default=ARA3 value in context file)
<image 4> : Fourth image, if necessary. (default=ARA4 value in context file)
<image 5> : Fifth image, if necessary. (default=ARA5 value in context file)

BAND =*<channel>*

Satellite channel number to be used in determination of landmarks. This function is only used if input images are multi−channeled.
<channel> : Satellite channel number to use in landmark determination process. (default=highest channel number in multi−channel image)

CORR=*<method>*

Correlation coefficient analysis methodology used for determining landmark locations. Valid types are CROSS (cross−correlation) or EUCL (Euclidian norm with radiance correction).
<method> : Correlation methodology for landmark tracking. (default=CROSS)

ERR =*<threshold>*

Threshold value for comparison to minimum lag correlation coefficient error value for each landmark point found in landmark search field of views. If error value is less than the threshold value, the landmark point is counted as a good initial landmark (NMARK). Value in brightness counts.
<threshold> : Maximum brightness count threshold value found in cross correlation analysis for use as good landmark. (default=10)

FILT =*<threshold>*

Threshold value for difference between each individual line/element shift and average line/element shift of all initial good landmark values (NMARK), used in the determination of the final good landmarks (OMARK). If line and element shifts are greater than threshold value, landmark is not counted as a good final landmark.
<threshold> : Maximum difference from average shift threshold value for use as a final good landmark. (default=2.0)

ICUT =*<threshold>*
<threshold> : Maximum threshold value of minimum correlation coefficient values for landmarks found in field of views. Landmarks with values greater than threshold value will be thrown out. Value in terms of brightness counts.
<threshold> : Maximum coefficient value for landmark. (default=20)

LAGE =*<lag>*
Element lag value for starting point search element in landmark search field of views. Also used to check maximum distance shift of landmark in search field of views. Landmarks with shift values greater than threshold are thrown out.
<lag> : Starting element lag value for landmark search. (default=LAGL)

LAGL =*<lag>*
Line lag value for starting point search line in landmark search field of views. Also used to check maximum distance shift of landmark in search field of views. Landmarks with shift values greater than threshold are thrown out.
<lag> : Starting line lag value for landmark search. (default=20)

MARKS=*<threshold>*
Threshold value of number of final good marks (OMARK) used in final quality control process. If number of marks is less than threshold value, FLAG=−1.
<threshold> : Quality control value vs. OMARK value. (default=5)

MIN =*<threshold>*
Threshold value for average distance shift of final good marks (OMARK) used in final quality control process. If average shift is less than threshold value, FLAG=−3.
<threshold> : Quality control minimum value vs. OMARK average shift. (default=2.0)

RATIO=*<threshold>*
Threshold ratio of initial good landmarks (NMARK)to final good landmarks (OMARK) used in final quality control process. If ratio falls below threshold value, FLAG=−4.
<threshold> : Quality control ratio vs. NMARK/OMARK value. (default=0.4)

SD =*<threshold>*
Threshold value for line/element distance shift standard deviation of final good marks (OMARK) used in final quality control process. If standard deviation is greater than threshold value, FLAG=−2.
<threshold> : Quality control shift value vs. OMARK standard deviation. (default=1.5)

SIZE =*<box>*
Box size used in correlation analysis to find navigation landmarks.
<box> : Box size around landmark point, in lines/elements. (default=15)

TEXT = *<context file>*
Context file to be used by routine. File name should include path name as well as file name, and can be provided as an absolute or relative path/file name definition.
<context file> : Context file path/file name. (default=AUTOWINX)

F. WNADJ

The WNADJ routine will modify the navigation of an existing image using the adjustments obtained for a corresponding image (time/date/resolution) from the WN routine run previously. The method type used to adjust the navigation is determined by user preference, and can either be an absolute LCOR/ECOR value adjustment or an incremental adjustment to these values. See Section 4A−E for more discussion of the autoregistration/navigation process.

The WNADJ routine should only be used when a navigation error is reported by the WN routine (see image registration error flags defined in Table 7 in Section 4C).

Format : wnadj <image> *keyword*
<image> : Image of which navigation will be adjusted. (default=none)

Online help listing is available by entering ***wnadj*** or ***wnadj help*** on the command line.

keyword :
METHOD = <*type*> <*line*> <*element*>

Method type and line/element values to adjust image navigation by. Values are obtained with the WN program using infrared data.

<*type*> : INC/ABS; INC will adjust by incremental line/element shift, ABS will adjust using absolute LCOR/ECOR values. (default=INC)

<*line*> : Line adjustment to apply to navigation. Either incremental value or absolute LCOR value. (default=0 (INC) or original LCOR value (ABS))

<*element*> : Element adjustment to apply to navigation. Either incremental value or absolute ECOR value. (default=0 (INC) or original ECOR value (ABS))

5. Targeting and Initial Height Assignment (WT)

A. Introduction

Target selection and initial height assignments for potential wind vectors are performed using the WT program. Command line keyword entries allow the user to modify various aspects, including target and height assignment region sizes and several height assignment threshold values. These are discussed in Section 5E. A schematic flowchart of the routine is presented in Section 5B, with a brief description of the methodology provided in Section 5C. The various height assignment routines utilized in WT are discussed in detail in Appendix A.

B. Flowchart

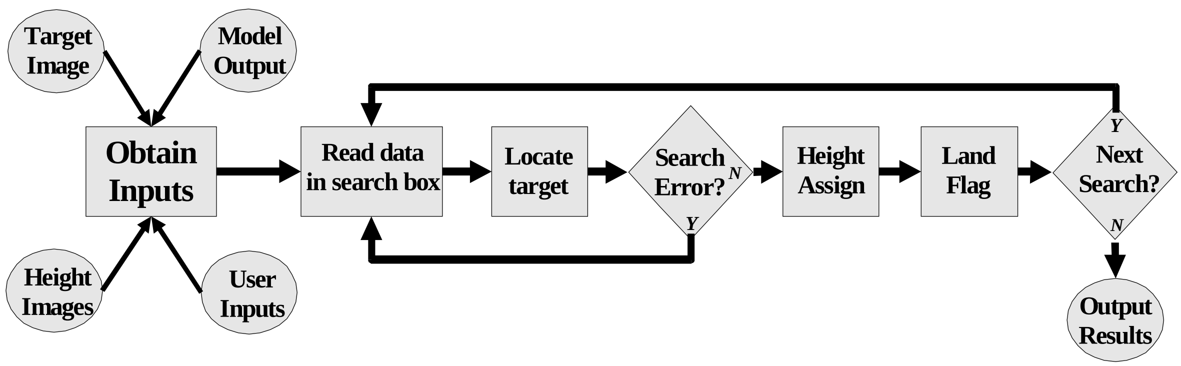

Figure 3 : Overview of the targeting and initial height assignment routine.

C. Methodology

Three images are used in the targeting and height assignment routine. The first image is the ARA1 image, defined in the context file or keyword entry, and is used as the targeting image. The second and third images are the two height assignment images, as defined with the HARA1 and HARA2 values in the context file or keyword entries. The targeting and height assignment images must be of the same time and spatial resolution. The routine REPPIX is provided to replicate pixels in lower resolution files to match the targeting image resolution (see Section 10C).

For infrared and water vapor imagery targeting, the first height assignment image is an infrared image, with the second height assignment image being the corresponding water vapor image. For a visible target image, the first height assignment image is a corresponding infrared image at the same spatial resolution and view (coverage) of the visible image, using REPPIX to replicate the image to the visible resolution, if necessary. The second height assignment image is not needed. Table 8 presents a quick summary of the imagery type used for targeting and height assignment of different satellite channels :

ARA1	HARA1	HARA2
IR	IR	WV
WV	IR	WV
VIS	IR (at same resolution)	not needed

Table 8 : Summary of targeting and height assignment image usage.

The target selection process is performed within the search region latitude/longitude boundaries, as defined within the context file or by command line keyword. The target box size can be set by a command line entry (for a square search box), or by context file entry (for a square or rectangular box) using the LSIZ/ESIZ keywords/context file parameters, which define the line and element extents, respectively.

Once the size of the target box is defined, the program will loop through the targeting image, searching each target box for a potential target. Two loops will control the flow of this process, a "line" loop and an "element " loop. At the beginning of each line loop, starting at the northern latitude boundary, a block of data (LSIZ number of lines) is read from the image. Starting at the western longitude boundary, a target box of LSIZ by ESIZ is examined for a potential wind target. The method used to locate a target within the target box depends on the targeting imagery type. Once a target box has been examined, as described below, the next target box will be read and examined. After crossing the eastern boundary or image edge, the next block of lines are read and the process is repeated until the southern boundary or image bottom is exceeded.

For infrared and visible "cloud drift" tracking, local bidirectional brightness temperature gradients are calculated within the target box and compared with user−defined threshold values. By identifying the lowest (coldest) brightness temperature features with maximum gradients and sufficient variability, a target can be identified (Merrill, 1989). For water vapor targeting analysis, examination of cloud free regions is performed. Bidirectional brightness temperature gradients are again computed, but potential targets are not confined to the coldest values. Instead, the region within the targeting box with the greatest variability exceeding user−defined thresholds is identified as a target (Velden et. al., 1997).

Keywords allow the user to explicitly define the sensitivity of the bidirectional analysis. The DVAL keyword allows the user to set the temperature gradient threshold value. The default value for infrared and visible targeting is 15° K, since cloud edges are being targeted. For water vapor, the default value is set to 1° K, since small gradients in upper−level water vapor structure are being analyzed. Other command line keywords, such as COAK, allow the user to control various target selection process parameters. These are discussed in Section 5D.

Once a target area has been examined and a potential target has been selected (which does not fail various quality control tests, such as brightness temperature threshold tests and scene gradient/coherence checks), the height of the target is calculated using up to five different height determination methodologies, appropriate for the targeting image and the nature of the feature (e.g. BASE would not be applied to cirrus target) being examined. The five different height estimate methods are :

1. H_2O−Intercept Method (H_2O)
2. Infrared Window (IRW) Channel Method (WIN)
3. CO_2 Slicing (or CO_2−IRW) Method (CO_2) (not yet available)
4. Water Vapor Histogram Method (HIST))
5. Cloud Base Method (BASE)

These methods are described in detail in Appendix A. All methods are performed for water vapor, infrared, and GOES−sounder imagery, while only methods 2, 3 (when available), and 5 are performed for visible imagery since a water vapor image is not used as a height assignment image.

All height assignment techniques depend on numerical model forecast temperature, moisture, and/or pressure fields to convert satellite brightness temperature measurements into pressure height estimates. Model guess forecast fields must be valid for a time period within nine hours of the satellite imagery being used by the targeting routine. An error will occur during processing if these times are not in agreement. Use of model forecast files is discussed in Section 3B.

Satellite brightness temperature values are calculated directly from the satellite imagery radiance measurements in the height assignment determination process of the WT routine. These conversions are satellite−dependent, and rely on the specific radiative transfer coefficient files provided with the winds derivation algorithm package. Use of these coefficient files is discussed in Section 3B.

Each different height determination is saved for each target, along with a quality control value noting the quality of the height estimate value. The final "best height" for the target is determined by the wind vector derivation routine (WW) discussed in Section 6.

D. Routine Output

The following example presents a typical screen output displayed by the WT routine. The example presented was obtained during a processing run using three GMS−5 water vapor images.

The context file TESTCNTX was used, having the following pertinent values defined :

ARA1	AREA1300	first WV image in image set.
HARA1	AREA1310	IR height assignment image (same time as ARA1).
HARA2	AREA1300	WV height assignment image (same image as ARA1).
MDX	MDXX9990	Output wind file.
ROW	1	Row number to write derived wind targets/vectors.

```
> wt S 15 15 TEXT=TESTCNTX

 ***** STARTING WINDS TARGETING *****
Read in 13 Temperature GRIB file names successfully
Read in  6 Dewpt. Dep. GRIB file names successfully
Read in 10 U-Component GRIB file names successfully
Read in 10 V-Component GRIB file names successfully
Read in  7 path names successfully
Read in  9 file names successfully
Read in 15 wind processing variables successfully
```

```
Read in  4 miscellaneous variables successfully
Read in context file successfully
opened first height assignment area /home/tlo/windco/windco/data/AREA1310
opened second height assignment area /home/tlo/windco/windco/data/AREA1300
 CO2 BAND NOT FOUND
opened target area /home/tlo/windco/windco/data/AREA1300
Image date and time: 100311, 162500
 max number of bytes   300000 number of lines   15 bytes per data element    1
 ELEMENT BOUNDS    0 2000  500 2000
Schema name is GWIN
Total number of keys 120
Missing data value -2139062144
Text description for MD file
 Opening MD file /home/tlo/windco/windco/data/MDXX9990.
 value of MISG -2139062144.
read  GRIB file >/home/tlo/windco/nogaps/01200_000020air_temp<
Name of gridded variable is      T   .
Level of gridded variable is     1397113632.
Day  100311,    time  0,        forecast time 12.
unpk: row and col in GRIB=14 5.
gribx12 ended normally
  <many lines deleted>
read  GRIB file >/home/tlo/windco/nogaps/01200_001000wnd_vcmp<
Name of gridded variable is      V   .Level of gridded variable is     100.
Day  100311,    time  0,        forecast time 12.
unpk: row and col in GRIB=14 5.
unpk: at level 100.000000, V-comp=-78.
gribx12 ended normally
 Guess time/date :   100311   120000
 Wind Image time/date :   100311   180000
 Guess and image times/dates agree
 BEGINNING TARGET SELECTION AFTER IVAL=     0

-----------------------------------------------------------------
  COL    HST     5:8     8:A     WIN     CLB      LAT       LON
-----------------------------------------------------------------
    1   515.3 -9999.0 -9999.0   645.4 -9999.0  49.4141 -114.6350
    2   478.4 -9999.0 -9999.0   644.3 -9999.0  49.4651 -115.2736
    3   486.6 -9999.0 -9999.0   614.3 -9999.0  49.3087 -120.1622
 CLOUD CONTAMINATED SCENE
    4   481.3 -9999.0   109.8   611.6 -9999.0  49.1121 -122.9156
    5   526.9 -9999.0  -500.0   745.4 -9999.0  49.1801 -126.2616
    6   509.2 -9999.0 -9999.0   689.7 -9999.0  48.9649 -135.0643
    7   489.7 -9999.0 -9999.0   662.6 -9999.0  48.9161 -140.9517
    8   469.2 -9999.0 -9999.0   605.0 -9999.0  49.1123 -142.3377
 CLOUD CONTAMINATED SCENE
    9   420.8 -9999.0   373.5   577.2 -9999.0  49.1178 -142.6295
   10   501.1 -9999.0  -500.0   737.1 -9999.0  49.2058 -148.8082
 <many lines deleted>
 3541   280.2 -9999.0   137.0   586.6 -9999.0   0.3004 -145.1715
 3542   287.1 -9999.0 -9999.0   530.3 -9999.0   0.2603 -145.6706
 CLOUD CONTAMINATED SCENE
 3543   262.9 -9999.0   186.4   380.9 -9999.0   0.3154 -146.6237
 CLOUD CONTAMINATED SCENE
 3544   231.5 -9999.0   177.9   269.4 -9999.0   0.3631 -146.8507
 CLOUD CONTAMINATED SCENE
 3545   289.8 -9999.0   271.0   491.4 -9999.0   0.3711 -147.6254
 CLOUD CONTAMINATED SCENE
 3546   276.1 -9999.0   242.9   549.6 -9999.0   0.3338 -148.4027
 CLOUD CONTAMINATED SCENE
 3547   268.0 -9999.0   280.7   413.3 -9999.0   0.1112 -148.8175
 CLOUD CONTAMINATED SCENE
 3548   258.2 -9999.0   239.5   390.2 -9999.0   0.3943 -149.8715
 DONE with target calculation
**********************************************************************
 Specifications for this target selector run :
 Target selector size : 15 lines by 15 elements
 Area /home/tlo/windco/windco/data/AREA1300 at 100311/162500   band=  4 res= 4
```

```
 Brightness range from  20 to 250
 Select all possible targets? :  YES

 *** ERROR TOTALS FOR TARGET REJECTION FOLLOW ***

  Total number of attempts                     : 13204
  Error #1  - Gradient is too flat             :   585 rejections
  Error #2  - Max gradient is on boundary      :     0 rejections
  Error #3  - Input grid is too small          :     0 rejections
  Error #4  - Min Brightness fails threshold   :     0 rejections
  Error #5  - Max Brightness fails threshold   :     0 rejections
  Error #6  - Target spacing failure           :     0 rejections
  Error #7  - Target outside lat/lon bounds    :  8040 rejections
  Error #8  - Target outside height assgn area :     0 rejections
  Error #9  -                                  :     0 rejections
  Error #10 -                                  :     0 rejections
  Error #11 -                                  :     0 rejections
  Error #12 -                                  :     0 rejections
  Error #13 -                                  :     0 rejections
 Total number of rejections                    :  8625
 Total number of targets selected              :  3549
 Summary of heights successfully created
  HST      5:8     8:A     WIN    BASE
  3550       0    1572    3550       0

 ****  Cloud Base Height Assignment Summary  ****

 Mean difference in pressure assignments       : 0
 Successful cloud base heights                 : 0
**********************************************************************

COMPLETED TARGET SELECTION ROUTINE SUCCESSFULLY
```

The following output is an example of the final summary output for an image set consisting of three infrared images. The main point of interest regards the cloud base height assignment methodology output.

```
> wt S 15 15 TEXT=TEXTCNTX

< routine output lines deleted >

**********************************************************************
 Specifications for this target selector run :
 Target selector size : 15 lines by 15 elements
 Area /home/tlo/windco/windco/data/AREA1310 at 100311/162500   band=  2 res= 4
 Brightness range from  20 to 250
 Select all possible targets? :  YES

 *** ERROR TOTALS FOR TARGET REJECTION FOLLOW ***

  Total number of attempts                     : 13485
  Error #1  - Gradient is too flat             :     0 rejections
  Error #2  - Max gradient is on boundary      :     0 rejections
  Error #3  - Input grid is too small          :     0 rejections
  Error #4  - Min Brightness fails threshold   :     0 rejections
  Error #5  - Max Brightness fails threshold   :   225 rejections
  Error #6  - Target spacing failure           :     0 rejections
  Error #7  - Target outside lat/lon bounds    :  8050 rejections
  Error #8  - Target outside height assgn area :     0 rejections
  Error #9  -                                  :     0 rejections
  Error #10 -                                  :   541 rejections
  Error #11 -                                  :     0 rejections
  Error #12 -                                  :     0 rejections
  Error #13 -                                  :     0 rejections
```

```
 Total number of rejections                    :  8816
 Total number of targets selected              :  3305
 Summary of heights successfully created
  HST      5:8     8:A     WIN    BASE
  3306       0    1612    3306     503

 ****  Cloud Base Height Assignment Summary  ****

 Mean difference in pressure assignments       : -49
 Successful cloud base heights                 : 503
**********************************************************************

COMPLETED TARGET SELECTION ROUTINE SUCCESSFULLY
```

The first section of the output concerns the reading of the input context file TESTCNTX. Once this has been completed successfully, the identification of the different input target height assignment images is performed. The input guess (model forecast) GRIB files are then read and stored for use in the routine.

Once all of the above preparatory work is completed, the targeting and height assignment routines are started. For an individual target, one or more different height assignment values will be calculated using the different height assignment routines valid for each type of image and feature being examined. The routine output will list the five values obtained for each target, as well as the target latitude and longitude position. The output will be of the following format :

```
-----------------------------------------------------------------
  COL    HST     5:8     8:A     WIN     CLB      LAT       LON
-----------------------------------------------------------------
    4  481.3 -9999.0   109.8   611.6 -9999.0  49.1121 -122.9156
```

The first column is the target number. The next five columns are the different height assignment values obtained from the different methodologies. The order of the output values is : Water Vapor Histogram, CO_2 Slicing, H_2O Intercept, Infrared Window Channel, and Cloud Base. A value of −9999.0 indicates a height assignment using the particular methodology either failed or was not attempted. The final two columns are the latitude and longitude position of the target, respectively. The sign convention for latitude is positive for Northern Hemisphere and negative for Southern Hemisphere. For longitude, the sign convention is positive for Western Hemisphere and negative for Eastern Hemisphere.

If a target is determined to be "cloud contaminated" (a cloud target in a water vapor image), a message "CLOUD CONTAMINATED SCENE" will appear above the target line output, and will occur only when the H_2O Intercept method is used, as explained in Appendix A.

The final routine output is the summary statistics section, which will highlight the many different error types obtained during target processing for the entire scene. Such values include the number of targets attempted, rejected, and accepted, and the different height assignment methods used for all of the targets in the scene.

The routine output will be similar for WV and IR image processing, except for IR images the output will contain height assignment values and summary statistics for the cloud base height assignment method. The routine output for sounder imagery (from the GOES satellites) will also be very similar to the WV image output since the valid sounder channels are two WV sounder channels (Band 10 (7.4 μm) and Band 11 (7.0 μm)). For visible image processing, the routine output will be similar to that obtained from IR imagery, however there will be no Water Vapor Histogram or H_2O Intercept method heights since a water vapor image is not currently used as a height assignment image. Only Infrared Window Channel and Cloud Base heights will be produced from visible imagery.

E. Usage

The following keywords can be entered on the command line at the initiation of the targeting and initial height assignment routine WT :

Format : wt <height mode> <height box> <target box> *keywords*

<height mode> : Height assignment methodology.
A=Averaging or S=Sampling. (default=A)

<height box> : Height assignment box size. (default=LLAG value in context file)

<target box> : Target selector box size. (defaults : line=LSIZ, element=ESIZ values in context file)

An abbreviated online help listing is available by entering ***wt*** or ***wt help*** on the command line. Additional help can be obtained using ***wt help more***.

keywords :

ADD =<*flag*>

Flag to add new records to end of row in an existing wind vector output file. Cannot be used in conjunction with MOD keyword. (MOD will override)

<*flag*> : YES/NO flag for adding records to end of existing row. (default=NO)

ARA1 =<*image*>

Satellite image from which initial wind vector targets are determined. This is also the first image of the image set.

<*image*> : Wind vector targeting image. (default=ARA1 value in context file)

COAK=<*value*> <*threshold*> <*coherence*>

Perform additional Coakley−Bretherton analysis filtering within target selection routine. Will identify and filter out three deck and coherent scenes from analysis in addition to normal gradient/threshold value comparisons.

<*value*> : 1=Performs additional Coakley−Bretherton analysis, 0=Only performs gradient/threshold comparisons. (default=0)

<*threshold*> : Percentage of target box analysis samples which must be contained in either the warm or cold Coakley/Bretherton filtered sample clusters analysis. A percentage of analysis samples less than this threshold value indicates a multi−deck scene. (default=80)

<*coherence*> : Percentage of target box analysis samples which are contained entirely in either the warm or the cold Coakley/Bretherton filtered sample clusters. A percentage of analysis samples greater than this threshold value indicates a scene which is too coherent. (default=80)

DVAL =*<gradient>*

Minimum acceptable brightness temperature gradient for target selection. The default value is 1 for all wind types except for infrared image winds, which has a default of 15.
<gradient> : Minimum brightness temperature gradient. (default=1 or 15)

HARA1=*<image>*

Primary satellite image used in initial target height assignment.
<image> : First height assignment image. (default=HARA1 value in context file)

HARA2=*<image>*

Secondary satellite image used in initial target height assignment, if necessary.
<image> : Second height assignment image. (default=HARA2 value in context file)

LAT =*<minimum> <maximum>*

Latitude bounds for analysis ((+)=north, (−)=south hemisphere). Also see LON.
<minimum> : Southern extent of analysis. (default=LATS value in context file)
<maximum> : Northern extent of analysis. (default=LATN value in context file)

LON =*<minimum> <maximum>*

Longitude bounds for analysis ((+)=west, (−)=east hemisphere). Also see LAT.
<minimum> : Eastern extent of analysis. (default=LONE value in context file)
<maximum> : Western extent of analysis. (default=LONW value in context file)

MAXB=*<max Tb>*

Maximum valid brightness temperature from image to be used in height assignment and targeting routines. Also see MINB.
<max Tb> : Maximum brightness temperature. (default=MAXB value in context file)

MDF =*<wind file>*

Output wind vector file name (path determined from context file).
<wind file> : Wind vector file name. (default=MDF value in context file)

MINB =*<min Tb>*

Minimum valid brightness temperature from image to be used in height assignment and targeting routines. Also see MAXB.
<min Tb> : Minimum brightness temperature. (default=MINB value in context file)

NVAL =*<grid points>*

The number of grid points used in the determination of the maximum gradient in Coakley−Bretherton Analysis.
<grid points> : Number of grid points. (default=5)

ORT = <*flag*>

Override for time check between images and model guess forecast fields. Time check threshold is +/− 9 hours from time of first image.
<*flag*> : YES=Override time check, allow any model forecast time, NO=Utilize 9 hour default time check. (default=NO)

PCT =*<rate %> <skin %>*

Percentages used in determination of warmest cluster and surface skin temperature determination in sampling height assignment methodology (see <height mode>).

<rate %> : Upper percentile used define warmest cluster within height box/field of view. (default=250 (value x 10))

<skin %> : Upper percentile used in the determination of the surface skin temperature utilizing sampling of histogram within field of view. (default=50 (value x 10))

ROW =*<row>*

Row number within wind vector file to write target information.

<row> : Row number in wind vector file. (default=ROW value in context file)

TEXT = <*context file*>

Context file to be used by targeting routine. File name should include path name as well as file name, and can be provided as an absolute or relative path/file name definition.

<*context file*> : Context file path/file name. (default=AUTOWINX)

6. Wind Vector Derivation (WW)

A. Introduction

Wind vector determination from a sequence of consecutive satellite images is performed using the WW routine. Numerous command line keyword entries allow the user to modify various thresholds and control algorithm execution. Many command line keywords for the wind vector derivation routine are similar to those used in the targeting routine. The keywords used in this routine are discussed in Section E. A schematic flowchart of the algorithm is provided in Section B, with a brief description of the methodology provided in Section C. Sample routine output is provided in Section D.

B. Flow Chart

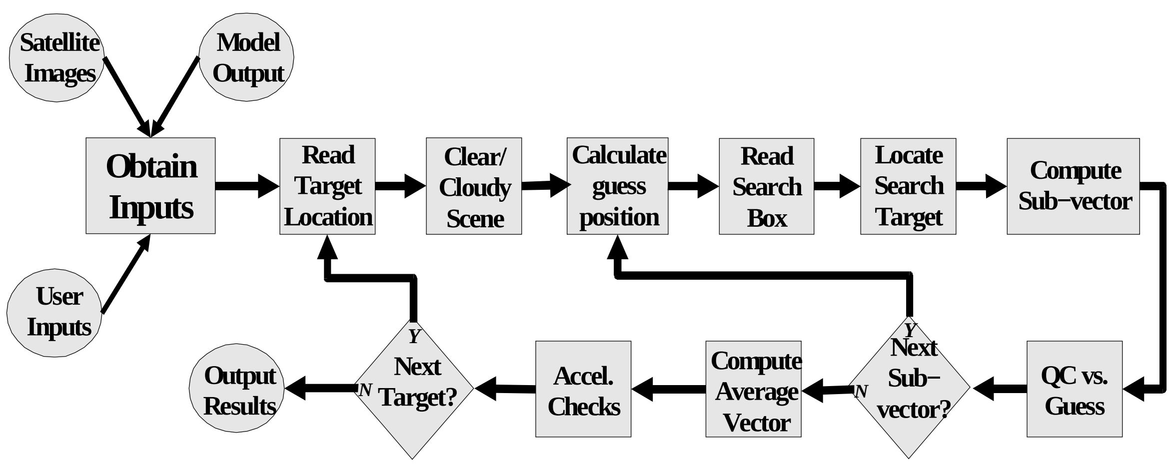

Figure 4 : Overview of the wind vector derivation routine.

C. Methodology

Wind vector determination currently utilizes a sequence of images possessing a preferred time resolution, dependent upon the satellite channel being interrogated. Optimal time resolutions for different satellite channels are provided in Section 11A, Table 11. Wind vector calculations can be performed using two to five sequential images. Time differences between all images does not have to be constant, but must be sequential.

Initial target locations must be determined using WT (see Section 5) prior to the use of this routine. The initial targets are then investigated one by one, with wind vector calculations attempted at each target position within the user−defined analysis region (as defined with the LATN/S and LONE/W keywords from the context file or command line). A zenith angle check is performed, calculating the difference between the current target location and the satellite sub−point. If this difference is greater than 75°, wind vector determination is halted for the target in question. A corresponding error flag value is assigned to the FLAG data value for either the out of analysis bounds or zenith errors. The program then proceeds with the next target search box. Error FLAG data values are listed in Appendix B.

Prior to wind vector determination for each target, the "best" height assignment value is selected from the five potential height values calculated in the targeting routine. The height selection process is dependent upon the satellite channel being investigated. Infrared wind vector heights will be determined from one of four height values (see Appendix A): IR Window (WIN), H_2O−Intercept (H_2O), CO_2 Slicing (CO_2), or Cloud Base (BASE). Visible wind vector heights will be chosen from the same set as the infrared winds, however the H_2O height will not be available. Water vapor wind vectors are chosen from either H_2O or Water Vapor Histogram (HIST) height values. The lowest pressure (highest altitude) value of all of the calculated height values is used as the final wind vector pressure height assignment value. If the final infrared or visible channel height is WIN and a valid Cloud Base (BASE) height is available, the BASE height will be used for the best height assignment value.

For each water vapor channel target, a cloud contamination flag value (MASK) is determined to identify clear or cloud contaminated WV signals. This process first checks to make sure the target has valid WIN and HIST height values. If true, the process will check for a valid H_2O height. If this height is valid, the HIST pressure height value is subtracted from the lower pressure (higher altitude) value between the H_2O and WIN height values, otherwise the HIST height is subtracted from the WIN value. If this difference is greater than the threshold value (default of 75 hPa), the scene is said to be "clear", otherwise the WV scene is said to be "cloud contaminated".

Once the best height and cloud contamination values are determined, the wind vector calculation for the target begins. A first guess wind vector is interpolated from the model forecast wind field at the location and height of the initial target. This guess is used to calculate the center location of the search area in the second image. The search area size is user−defined using the LLAG/ELAG keywords/context file parameters, and will have a height of LLAG+LSIZ and a width of ELAG+ESIZ (L/ESIZ are the target area box size, as defined by keyword/context file parameters). The image data within the target and search box regions are read, checking for any data errors. Once successfully read, statistical analysis of both regions is conducted, locating the highest correlated point between the initial target location (in the target box) and the search box region. The vector displacement (or sub−vector) between these two points is calculated and quality control parameters for the data pair are determined. This process is then repeated for the next image pair, with the selected search region location used as the initial target location for the sub−vector calculation (and so on if more than three images are used).

Once the intermediate wind sub−vectors are determined, acceleration checks are conducted. The average vector speed and direction are produced from the intermediate sub−vectors, with the average location derived from the initial target and subsequent search locations. The averaged vector is then compared to an interpolated model forecast wind vector at the newly determined location and height. Large accelerations and departures from the guess vector are flagged for each wind vector, with their corresponding error FLAG data values (see Appendix B) assigned to the FLAG value in the output wind file. The threshold values for these tests are user−defined using the QCU/QCV keyword/context file parameters.

A final "possible land feature" error FLAG value is set for vectors located over land (the land/water flag value is determined in the targeting routine) possessing pressure values greater than 300 hPa (altitude lower than 300 hPa) and speeds less than 3.25 m/s. Land and water surfaces are determined using the high−resolution topography map file TOPOHRES. The resolution of this map is 0.1° latitude by 0.1° longitude, and provides an average physical surface classification for each grid box. Bodies of water are given the value of 2, with all other physical surface types given the value of 1.

D. Routine Output

The following is an example of the output obtained while running the wind vector calculation routine WW. The example presented was obtained during a processing run using three GMS−5 water vapor images. Initial target locations were obtained using the targeting routine WT described in Section 5.

The context file TESTCNTX was used, having the following pertinent values defined :

ARA1	AREA1300	first WV image in image set.
ARA2	AREA1301	second WV image in image set.
ARA3	AREA1301	third WV image in image set.
HARA1	AREA1310	IR height assignment image (same time as ARA1)
MDX	MDXX9990	Output wind file
ROW	2	Row number to write derived wind targets/vectors

```
> ww TEXT=TESTCNTX

 ***** STARTING WINDS CALCULATION *****
Read in 13 Temperature GRIB file names successfully
Read in  6 Dewpt. Dep. GRIB file names successfully
Read in 10 U-Component GRIB file names successfully
Read in 10 V-Component GRIB file names successfully
Read in  7 path names successfully
Read in  9 file names successfully
Read in 15 wind processing variables successfully
Read in  4 miscellaneous variables successfully
Read in context file successfully
3 images in winds loop
Schema name is GWIN
Total number of keys 120
Missing data value -2139062144
Text description for MD file
 Opening MD file /home/tlo/windco/windco/data/MDXX9990.
 Number of targets in MD file is   3549
Date and time of area 0: 100311, 162500.
Band number for area 0: 4.
main: area bounds, image coords  1853 457 5533 8457.
main: area bounds, area coords  0 0 920 2000.
Date and time of area 1: 100311, 170200.
Band number for area 1: 4.
main: area bounds, image coords  1869 457 5549 8457.
main: area bounds, area coords  0 0 920 2000.
Date and time of area 2: 100311, 173200.
Band number for area 2: 4.
main: area bounds, image coords  1885 453 5565 8453.
main: area bounds, area coords  0 0 920 2000.
Band number for height assignment area /home/tl: 4.
read  GRIB file >/home/tlo/windco/nogaps/01200_000020air_temp<
Name of gridded variable is      T   .
Level of gridded variable is     1397113632.
Day  100311,    time  0,        forecast time 12.
unpk: row and col in GRIB=14 5.
gribx12 ended normally
```

```
 <many lines deleted>
read  GRIB file >/home/tlo/windco/nogaps/01200_001000wnd_vcmp<
Name of gridded variable is      V   .
Level of gridded variable is     100.
Day  100311,    time  0,        forecast time 12.
unpk: row and col in GRIB=14 5.
unpk: at level 100.000000, V-comp=-78.
gribx12 ended normally
 Guess time/date :   100311   120000
 Wind Image time/date :   100311   180000
 Guess and image times/dates agree

 Begin wind calculation in MD file MDXX9990
 Begin in row  2 at column     1

 Slow vectors over land will be flagged
 Tracking box size 15 lines by 15 elements
 Match area offset 20 lines by 36 elements
 Latitude  range from  60 to   0
 Longitude range from -150 to -100
 Pressure  range from  100 to 1000 mb
 Area AREA1300 at 100311/162500 at  res= 4  band= 4
 Area AREA1301 at 100311/170200 at  res= 4  band= 4
 Area AREA1302 at 100311/173200 at  res= 4  band= 4

----------------------------------------------------------
  COL FLAG    LAT    LON    PW   DIR   SPD       U       V
----------------------------------------------------------
   16   33   48.5 -106.5   532    96    29  -29.21    3.00 HIS
   17   32   49.6 -106.2   509   346    28    6.70  -27.06 HIS
   22   13   49.2 -113.2   559   298    64   56.50  -30.10 HIS
   27    1   48.0 -120.9   427   359     5    0.08   -4.88 HIS
   28    1   48.1 -121.0   428   358     5    0.13   -4.92 HIS
   29   11   48.3 -122.5   395   312     4    3.17   -2.87 H2O
   33   32   48.1 -126.7   472   313    24   17.55  -16.20 HIS
   35   11   47.4 -129.6   512   264    46   45.83    5.08 HIS
   36   23   48.0 -130.0   492   349    11    2.07  -10.74 HIS
   37   33   47.6 -131.4   369   270    15   15.39    0.03 H2O
 <many lines deleted>
 3509    2    0.8 -145.8   103   160    12   -4.21   11.72 H2O
 3510    2    0.7 -146.1   122   161    12   -4.02   11.78 H2O
 3511   20    0.7 -147.2   145   180     4   -0.02    3.84 H2O
 3512    0    0.9 -147.3   129   177     6   -0.31    6.36 H2O
 3513   23    0.9 -148.6   250   154    21   -9.22   18.93 H2O
 3514    1    0.5 -148.8   263   147    17   -9.29   14.34 H2O
 <many lines deleted>
 3543    0    0.3 -145.7   287   164    12   -3.23   11.38 HISREDARA ERROR:
invalid line number = 920
 +++ Pixel Brightness Error
REDARA ERROR: invalid line number = 920
 +++ Pixel Brightness Error

 3546   20    0.4 -147.6   270   224     2    1.30    1.36 H2O
 3547    0    0.3 -148.4   242   154    16   -6.74   13.97 H2OREDARA ERROR:
invalid line number = 920
 +++ Pixel Brightness Error

 3549   11    0.4 -149.9   239   106    18  -17.20    5.08 H2O

 DONE with wind calculation
**********************************************************************
 Number of initial targets                             :  3549
 Number of old winds                                   :     0

 Number of deleted winds                               :     0
 Number of targets outside area of interest            :     0

 Winds without errors                                  :  1009
```

```
 U and/or V guess reproducibility errors          :  1238
 U and/or V reproducibility errors                :  1335
 Possible land feature errors                     :    11

 TOTAL WINDS GENERATED                            :  2678

 Bad wind guess retrievals                        :     0
 Tracer correlation failures                      :   815
 Search box off edge of area                      :     0
 Target box off edge of area                      :     0
 Target/search box off edge of buffer             :    32
 Pixel brightness out of bounds                   :    24
 Pixel brightness minimum                         :    20
 Pixel brightness maximum                         :   250
 TOTAL WIND FAILURES                              :   871


 Height assignment summary -- number of uses of method
    5:8   8:A   HST   WIN   CLM  BASE
      0  1214  2340     1     0     0

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

COMPLETED WINDS CALCULATION ROUTINE SUCCESSFULLY
```

The initial routine output for the wind vector routine is similar to the output obtained with the winds targeting routine. The context file and the model forecast GRIB files are read prior to determination of wind vectors.

For each valid target location determination of a wind vector is obtained using a set of images as defined in the context file TESTCNTX. The context file has remained unchanged from the targeting routine except the ROW parameter has been changed to 2 from 1 (after copying the values from row 1 to row 2 using the SCOPY command, described in Section 9B). The ROW parameter can also be set using the command line keyword.

Each target which obtains a valid wind vector will have various properties displayed. Target locations where a wind vector cannot be determined (where the target cannot be tracked successfully over the image set) will not be displayed. The output display for each vector will be of the following format :

```
-------------------------------------------------------------------
  COL FLAG      LAT       LON       PW   DIR   SPD       U       V HGT
-------------------------------------------------------------------
   16   33  48.5205 -106.5992   532    96    29  -29.21    3.00 HIS
```

The first column is the column number of the vector within the output wind file. The FLAG is listed in column two (see Appendix B). For this example, the FLAG of 33 indicates that an acceleration in both U and V components has been noted between the two sub−vector values. The third and fourth columns are the latitude and longitude of the wind vector respectively and represent the average position of the three target/search locations found in the three images. The fifth column is the "best" height assignment value selected using the selection process discussed in Section 6C. The sixth and seventh columns are the wind direction and speed, with their corresponding U and V components listed in columns eight and nine. These values are the obtained by averaging the sub−vectors calculated for the image set. The final column is the height assignment method used to determine the pressure value listed in column five.

The final section of the routine output lists the total number of different errors obtained during the execution of the wind vector calculation routine, as well totals for the five height assignment methods used for the "best" height assignment pressure values.

E. Usage

The following keywords can be entered on the command line at the initiation of the wind vector derivation routine WW. Many of the keywords override values defined within the context file. Please note that certain keywords defined in this routine are also defined in the winds targeting routine WT (in Section 5E), but may perform different tasks :

Format : ww *keywords*

An abbreviated online help listing is available by entering ***ww*** or ***ww help*** on the command line. Additional help can be obtained using ***ww help more***.

keywords :

ARA1 =<*image*>
First image in series of consecutive satellite images.
<*image*> : First satellite image. (default=ARA1 value in context file)

ARA2 =<*image*>
Second image in series of consecutive satellite images.
<*image*> : Second satellite image. (default=ARA2 value in context file)

ARA3 =<*image*>
Third image in series of consecutive satellite images.
<*image*> : Third satellite image. (default=ARA3 value in context file)

ARA4 =<*image*>
Fourth image in series of consecutive satellite images. If only three images are used in the derivation of wind vectors, this image is defined as missing (MISG) in context file.
<*image*> : Fourth satellite image. (default=ARA4 value in context file)

ARA5 =<*image*>
Fifth image in series of consecutive satellite images. If, only three images are used in the derivation of wind vectors, this image is defined as missing (MISG) in context file.
<*image*> : Fifth satellite image. (default=ARA5 value in context file)

COL =<*start*> <*end*>
Minimum and maximum column boundaries within wind vector file to perform wind vector calculations. Default values are first and last record within row. See also ROW.
<*start*> : First record for wind vector calculation. (default=1)
<*end*> : Last record for wind vector calculation. (default=last record/CMAX)

ELAG =*<elements>*

Number of elements larger than target area for search area (element size of search area equals ELAG+ESIZ). Also see LLAG.

<size> : Number of elements. (default=ELAG value in context file)

ESIZ =*<elements>*

Number of elements in target selector area. Also see LSIZ.

<elements> : Number of elements. (default=LSIZ value in context file)

HARA1=*<image>*

Primary satellite image used in initial target height assignment.

<image> : First height assignment image. (default=HARA1 value in context file)

LAND =*<land flag>*

Slow vectors will be flagged if over land since wind vector may be a land feature instead of a cloud/water vapor feature, and will be assigned the "possible land feature" error FLAG data value.

<land flag> : YES=Flag possible land features. (default=YES)

LAT =*<minimum> <maximum>*

Latitude bounds for analysis ((+)=north, (−)=south hemisphere). Also see LON.

<minimum> : Southern extent of analysis. (default=LATS value in context file)

<maximum> : Northern extent of analysis. (default=LATN value in context file)

LLAG =*<lines>*

Number of lines larger than target area for search area (line size of search area equals LLAG+LSIZ). Also see ELAG.

<size> : Number of lines. (default=LLAG value in context file)

LON =*<minimum> <maximum>*

Longitude bounds for analysis ((+)=west, (−)=east hemisphere). Also see LAT.

<minimum> : Eastern extent of analysis. (default=LONE value in context file)

<maximum> : Western extent of analysis. (default=LONW value in context file)

LSIZ =*<lines>*

Number of lines in target selector area. Also see ESIZ.

<lines> : Number of lines. (default=LSIZ value in context file)

MASK=*<cutoff>*

Threshold value used in determination of cloud contamination flag (see Section 6C).

<cutoff> : Cloud contamination threshold value, in hPa. (default=75)

MAXB=*<max Tb>*

Maximum valid brightness value from image to be used in height assignment and targeting routines. Also see MINB.

<max Tb> : Maximum brightness value. (default=MAXB value in context file)

MDF =*<wind file>*
Output wind vector file name (path determined from context file).
<wind file> : Wind vector file name. (default=MDF value in context file)

MINB =*<min Tb>*
Minimum valid brightness value from image to be used in height assignment and targeting routines. Also see MAXB.
<min Tb> : Minimum brightness value. (default=MINB value in context file)

ORT = <*flag*>
Override for time check between images and model guess forecast fields. Time check threshold is +/− 9 hours from time of first image.
<*flag*> : YES=Override time check, allow any model forecast time, NO=Utilize 9 hour default time check. (default=NO)

OUT =*<output flag>*
Wind vector information output flag.
<output flag> : YES=Output wind vector information during execution of program. (default=OUT value in context file)

QCU =*<threshold>*
Wind vector U−component quality control threshold. If derived U−component of the wind vector is greater than threshold value, a "U departure from guess" error FLAG data value will be assigned to wind vector. Also see QCV.
<threshold> : Threshold value (in m/s) for U−component deviation from guess. (default=QCU value in context file)

QCV =*<threshold>*
Wind vector V−component quality control threshold. If derived V−component of the wind vector is greater than threshold value, a "V departure from guess" error FLAG data value will be assigned to wind vector. Also see QCU.
<threshold> : Threshold value (in m/s) for V−component deviation from guess. (default=QCV value in context file)

PMAX=*<max pressure>*
Maximum pressure level for wind height assignment. Wind vectors with height assignment pressures greater than maximum will be assigned a "Target outside of pressure pmax/pmin range" error FLAG data value. Also see PMIN.
<max pressure> : Maximum pressure for wind vector height assignment (in hPa). (default=PMAX value in context file)

PMIN =*<min pressure>*
Minimum pressure level for wind height assignment. Wind vectors with height assignment pressures less than minimum will be assigned a "Target outside of pressure pmax/pmin range" error FLAG data value. Also see PMAX.
<max pressure> : Minimum pressure for wind vector height assignment (in hPa). (default=PMIN value in context file)

REDO =<*redo flag*>

Allow reanalysis of wind vector file if wind vectors have previously been calculated. Will recalculate wind speed, direction, and error flag values.

<redo flag> : YES will reanalyze previously computed wind vectors. (default=NO)

ROW =<*row*>

Row number within wind vector file to write target information. Also see COL.

<row> : Row number in wind vector file. (default=ROW value in context file)

TEXT = <*context file*>

Context file to be used by wind vector determination routine. File name should include path name as well as file name, and can be provided as an absolute or relative path/file name definition.

<*context file*> : Context file path/file name. (default=AUTOWINX)

7. Automatic Editing and Quality Control

A. Introduction

There are currently two independent routines used for automatic quality control (AQC) of satellite−derived winds. The first quality control routine, named QI, involves the utilization of statistical properties in the derivation of a quality indicator (QI) value for each wind vector through various consistency tests with surrounding vectors. The second routine, named WE, is a two stage, three−dimensional objective analysis, based upon recursive filter (RF) analysis, which utilizes numerical model information as a background field. Wind vector heights are also reassigned in this process through a minimization of a simple variational penalty function.

Each AQC routine possesses numerous command line keyword options, allowing considerable user control of each routine, permitting the AQC routines to be tuned for specific needs, such as rapid scan cycles, different satellite channels, and nested wind vector editing. All keywords for each routine will be described in detail in each of the following sections, with suggested settings for different analysis situations provided in Section 11B.

B. EUMETSAT Statistical Quality Indicator Analysis (QI)

1. Flowchart

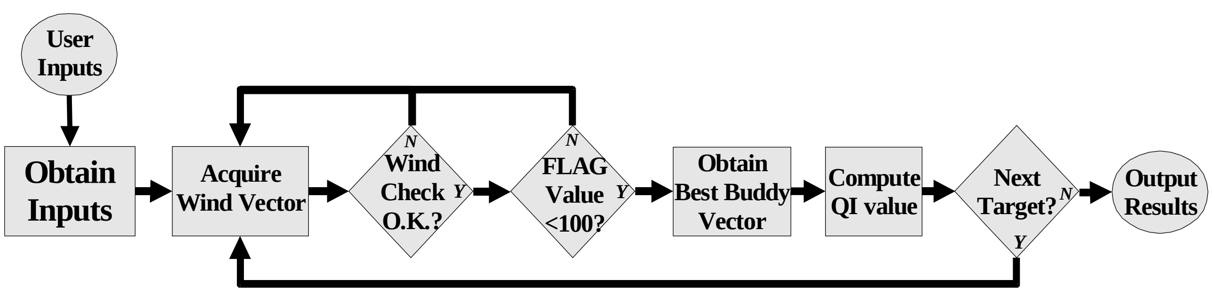

Figure 5 : Overview of the EUMETSAT Quality Indicator quality control routine.

2. Methodology

The statistical Quality Indicator (QI) analysis routine QI, developed at EUMETSAT and the European Space Operations Center and based on the EUMETSAT approach for automatic quality control, estimates the reliability of each derived vector based on several quality control tests (Holmlund, 1998). These tests not only analyze the consistency in space and time of each wind's vector components, but also the height and temperature of the tracers used in the vector determination, the symmetry of vector pair(s) (achieved from tracking tracers between consecutive images), differences with surrounding vectors, and difference from a forecast guess. All values used within the QI routine are stored within the input wind file, so auxiliary data inputs, such as numerical model forecasts, are not needed.

Currently, seven tests are included in the QI analysis scheme. A weighted average value is computed for the final quality test function value $f_i(x)$ for each vector :

Direction :	$\lvert D_2(x,y)-D_1(x,y)\rvert/(d_1*\exp^{-((V2(x,y)+V1(x,y))/20)+10})$	
Speed :	$\lvert V_2(x,y)-V_1(x,y)\rvert/(s_1*(V_2(x,y)+(V_1(x,y))+s_2)$	
Vector :	$\lvert \mathbf{S_2}(x,y)-\mathbf{S_1}(x,y)\rvert/(v_1*(\lvert \mathbf{S_2}(x,y)+(\mathbf{S_1}(x,y)\rvert)+v_2)$	
Spatial :	$\lvert \mathbf{S}(x,y)-\mathbf{S}(x-i,y-j)\rvert/(p_1*(\lvert \mathbf{S_2}(x,y)+(\mathbf{S_1}(x-i,y-j)\rvert)+p_2)$	(1)
Forecast :	$\lvert \mathbf{S_2}(x,y)-\mathbf{F_1}(x,y)\rvert/(f_1*(\lvert \mathbf{S_2}(x,y)+(\mathbf{F_1}(x,y)\rvert)+f_2)$	
U−component:	$\lvert u_2(x,y)-u_1(x,y)\rvert/(x_1*(\lvert u_2(x,y)+(u_1(x,y)\rvert)+x_2)$	
V−component:	$\lvert v_2(x,y)-v_1(x,y)\rvert/(y_1*(\lvert v_2(x,y)+(v_1(x,y)\rvert)+y_2)$	

where $D_i(x,y)$, $V_i(x,y)$, $S_i(x,y)$, $u_i(x,y)$, and $v_i(x,y)$ are the direction, vector, speed, u−component, and v−component derived from the *i*th image pair of an image triplet at location (x,y), respectively. $S(x,y) = S_1(x,y) + S_2(x,y)$; $S(x-i,y-j)$ refers to the vectors in the surrounding locations in the EUMETSAT segment coordinates (Bulher and Holmlund, 1994). $F(x,y)$ is the interpolated forecast vector. In order to combine the results of the different test functions listed in Equation 1, each result must be normalized into a specific range. This is done using a simple tanh−based function (see Holmlund, 1998 for greater detail) :

$$\Phi_i(x) = 1 - \tanh\{\ [f_i(x)]\ \}^{a_i} \qquad (2)$$

The spatial test is only applied to vectors within a predefined pressure range centered at the height of the vector $S(x,y)$ in question. Deviations obtained from these tests do not result in vector rejection, but instead only lowers the value of the quality indicator associated with each vector in the wind output file. This quality indicator can then be used in conjunction with the WE editing routine to accept or reject a vector. Keywords can be used to adjust many of the parameters involved in the testing processes. These keywords are described in Section 7B4, with suggested settings and examples of use provided in section 11B. A detailed look at the QI routine is provided in Holmlund, 1998.

3. Routine Output

The following is an example of the output obtained with the QI program. Initial target locations and height assignments were obtained using the targeting routine WT. Wind vector determination, as well and the initial quality control values for the FLAG data value, were calculated in the wind vector derivation routine WW. This program, if used, should be run prior to execution of the RF editing routine WE, explained in Section 7C.

The context file TESTCNTX was used, having the following pertinent values defined :

MDX	MDXX9990	Output wind file
ROW	3	Row number to write edited wind vectors

```
> qi MDXX9990 3 TEXT=TESTCNTX
Read in 13 Temperature GRIB file names successfully
Read in  6 Dewpt. Dep. GRIB file names successfully
Read in 10 U-Component GRIB file names successfully
Read in 10 V-Component GRIB file names successfully
Read in  7 path names successfully
Read in  9 file names successfully
Read in 15 wind processing variables successfully
Read in  4 miscellaneous variables successfully
Read in context file successfully
Schema name is GWIN
Total number of keys 120
Missing data value -2139062144
```

```
Text description for MD file
 OPENED MD FILE /home/tlo/windco/windco/data/MDXX9990.
 Minimum speed :    0.00
  Weights :
   spd   dir   vec    u     v   buddy  fcst
   1.00  1.00  1.00  0.00  0.00  2.00  1.00
 Speed check params    :    0.20    1.00    3.00
 Direction check       :   20.00   10.00   10.00    4.00
 Vector check params   :    0.20    1.00    3.00
 Max pressure diff     :   50.00
 Max lat/lon diff      :    1.00
 Buddy check params    :    0.20    1.00    3.00
 Forecast check params :    0.40    1.00    2.00
 u -component params   :    1.00    1.00    2.00
 v -component params   :    1.00    1.00    2.00
 Max number of columns :    3549
 Calling sorting routine
 Finished sorting routine
 Total number of targets processed : 3549
 Total number of winds             : 2678
 Total number of channels          : 1
 Channel WV   : Number of targets :     2678  winds :     2678  with QI >    0
:     2519
 ----- DONE QI -----
```

At the start of the QI routine, the parameters used within the routine are listed after successfully reading the context file. These values can be modified by the user using several command line keywords described in Section 7B4. After reading the input wind vector file, all vectors are sorted by latitude to improve the efficiency of the buddy−checking routine. Once sorted, each individual quality indicator value is calculated, with a final quality indicator value derived using Equation 1, as explained in Section 7B2. This final quality value is stored in the TEM1 data value for each wind vector (see Appendix C) and can then be used in conjunction with the WE editing routine for editing of the wind vector field. This data value will be renamed in the future when the new GWIN format structure is defined.

4. Usage

The following keywords can be entered on the command line at the initiation of the QI routine :

Format : qi <wind file> <row> *keywords*
<wind file> : Input/output wind file (default=MDF value in context file)
<row> : Row number in wind file (default=ROW value in context file).

An abbreviated online help listing is available by entering ***qi*** or ***qi help*** on the command line. Additional help can be obtained using ***qi help more***.

keywords :

AQC = <*speed*> <*direction*> <*vector*> <*u−comp*> <*v−comp*> <*buddy*> <*forecast*>
Quality control weights for the derivation of the final, weighted quality flag value.
(defaults=1.0, 1.0, 1.0, 0.0, 0.0, 2.0, 1.0)

BOX = <*area*>
Define collocation box area size for vector buddy checking, in degrees latitude/longitude.
<*area*> : Box size. (default=1.0, in degrees)

DIR = <*dependency*> <*fraction*> <*offset*> <*norm. exp.*>
Wind vector direction test parameters used in determination of direction quality flag.
<*dependency*> : Exponential dependency (d_1 in Equation 1). (default=20.0)
<*fraction*> : Direction fraction (d_2 in Equation 1). (default=10.0)
<*offset*> : Direction offset. (default=10.0 m/s)
<*norm. exp.*> : TANH normalization exponential (a_i in Equation 2). (default=4.0)

FOR = <*fraction*> <*offset*> <*norm. exp.*>
Wind vector forecast test parameters used in determination of forecast quality flag.
<*fraction*> : Forecast fraction (f_1 in Equation 1). (default=0.4)
<*offset*> : Forecast offset (f_2 in Equation 1). (default=1.0 m/s)
<*norm. exp.*> : TANH normalization exponential (a_i in Equation 2). (default=2.0)

LOC = <*fraction*> <*offset*> <*norm. exp.*>
Wind vector location (buddy check) test parameters used in determination of spatial quality flag.
<*fraction*> : Spatial fraction (p_1 in Equation 1). (default=0.2)
<*offset*> : Spatial offset (p_2 in Equation 1). (default=1.0 m/s)
<*norm. exp.*> : TANH normalization exponential (a_i in Equation 2). (default=3.0)

QI = <*threshold*>
Threshold value for output statistics only.
<*threshold*> : Threshold value. (default=0)

PDIF = <*threshold*>
Maximum pressure difference allowed for buddy checking. Wind vectors with difference greater than threshold are skipped in buddy checking routine.
<*threshold*> : Pressure difference threshold limit, in hPa. (default=50.0)

SLOW= <*threshold*>
Minimum wind speed allowed for QI determination. Wind vectors with speeds less than threshold have QI value set to 0.0.
<*threshold*> : Wind speed minimum threshold, in m/s. (default=0.0)

SPD = <*fraction*> <*offset*> <*norm. exp.*>
Wind vector speed check parameters used in determination of speed quality flag.
<*fraction*> : Speed fraction (s_1 in Equation 1). (default=0.2)
<*offset*> : Speed offset (s_2 in Equation 1). (default=1.0 m/s)
<*norm. exp.*> : TANH normalization exponential (a_i in Equation 2). (default=3.0)

TEXT = <*context file*>
Context file to be used by QI routine. File name should include path name as well as file name, and can be provided as an absolute or relative path/file name definition.
<*context file*> : Context file path/file name. (default=AUTOWINX)

UC = <*fraction*> <*offset*> <*norm. exp.*>
Wind vector u−component check parameters used in determination of u−component quality flag.
<*fraction*> : U−component fraction (x_1 in Equation 1). (default=1.0)
<*offset*> : U−component offset (x_2 in Equation 1). (default=1.0 m/s)
<*norm. exp.*> : TANH normalization exponential (a_i in Equation 2). (default=2.0)

VC = <*fraction*> <*offset*> <*norm. exp.*>
Wind vector v−component check parameters used in determination of v−component quality flag.
<*fraction*> : V−component fraction (y_1 in Equation 1). (default=1.0)
<*offset*> : V−component offset (y_2 in Equation 1). (default=1.0 m/s)
<*norm. exp.*> : TANH normalization exponential (a_i in Equation 2). (default=2.0)

VEC = <*fraction*> <*offset*> <*norm. exp.*>
Wind vector vector check parameters used in determination of vector quality flag.
<*fraction*> : Vector fraction (v_1 in Equation 1). (default=0.2)
<*offset*> : Vector offset (v_2 in Equation 1). (default=1.0 m/s)
<*norm. exp.*> : TANH normalization exponential (a_i in Equation 2). (default=3.0)

VIS = <*flag*>
Visible wind processing flag.
<*flag*> : YES=process ONLY visible wind vectors, NO=process all but visible wind vectors. (default=NO)

C. Recursive Filter Analysis (WE)

1. Flowchart

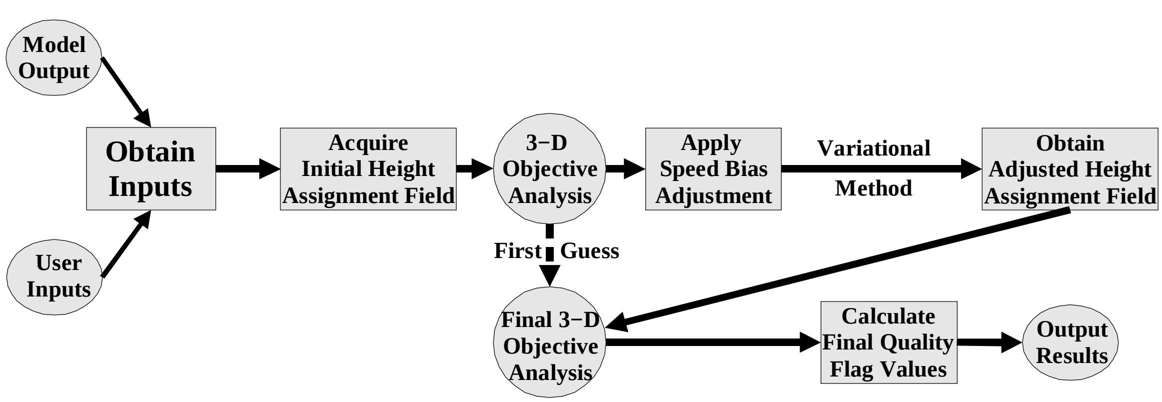

Figure 6 : Overview of the Recursive Filter automatic editing and quality control routine.

2. Methodology

Quality control of the wind vectors using the Recursive Filter analysis routine WE is a two step process involving the reassignment of pressure heights and assignment of a quality flag to each vector. This process involves a two stage, three−dimensional objective analysis (Hayden and Pursor, 1995) of the wind field using background information from a numerical forecast. The objective analysis scheme is an adaptation of the Recursive Filter analysis described in Hayden and Pursor (1988).

The first stage of the objective analysis provides a preliminary analysis using the satellite data at their initially assigned pressure height and pseudo data from the numerical model forecast (typically the 12− or 18−hour forecast field of temperature and wind). After applying a speed bias to certain winds (a slow−bias is observed with upper−tropospheric cloud drift winds), pressure altitudes of the wind vectors are adjusted by minimizing a variational penalty function evaluated using the initial wind vector analysis and the numerical model forecast field for various atmospheric parameters. The penalty function equation is :

$$B_{m,k} = \left(\frac{V_m - V_{i,j,k}}{F_v}\right)^2 + \left(\frac{T_m - T_{i,j,k}}{F_t}\right)^2 + \left(\frac{P_m - P_{i,j,k}}{F_p}\right)^2 + \left(\frac{dd_m - dd_{i,j,k}}{F_{dd}}\right)^2 + \left(\frac{s_m - s_{i,j,k}}{F_s}\right)^2 \qquad (3)$$

where V=velocity, T=Temperature, P=pressure, dd=direction, s=speed, F=weighting factors (see VAR keyword in Section 7C4), m=measurement, i,j=horizontal dimensions of model guess field, and k=vertical dimension of model guess field.

Before the penalty function is calculated, gross error checks are performed on the five parameters listed in Equation 3. If any of the error checks fail, the penalty function is not calculated for the wind vector in question. The values for the error checks are modified using various command line keywords such as FIT and VAR.

$$\begin{array}{lll}
(V_m - V_{i,j,k}) & < M_v F_v S & : M_v = 7.0 \\
(T_m - T_{i,j,k}) & < M_t F_t & : M_t = 2.0 \\
(P_m - P_{i,j,k}) & < M_p F_p & : M_p = 1.5 \\
(dd_m - dd_{i,j,k}) & < M_{dd} F_{dd} / S & : M_{dd} = 2.0 \\
(s_m - s_{i,j,k}) & < M_s F_s S & : M_s = 7.0 \\
S = s/30 & & : 0.5 < S < 2.0
\end{array} \qquad (4)$$

The M values listed in Equation 4 are the default gross error limit weighing factor values, which are assigned/modified by the FIT keyword. The F values represent the penalty function weighting factors, and are assigned/modified with the VAR keyword. Considerable care should be taken when modifying the various M or F values, since modifying one or both of the values will significantly change the gross error limit threshold values for the particular parameter being modified. For example, if the influence of the vector error in Equation 3 is reduced by increasing the weighting factor F_v, the gross error tolerance will be increased in Equation 4 unless the gross error limit weight factor M_v is reduced to compensate for this increase.

The velocity M_v value performs an additional function of defining the maximum permitted value of the penalty function. This value is determined by the following equation :

$$B_{max} = 0.75S(M_v)^2 \qquad (5)$$

An initial quality flag is assigned to the vector at the reassigned height at this stage of the processing. This value represents the quality of the reassigned wind vector in relation to the model forecast analysis field at the vector height and location. This quality flag value is stored in the RFI data value and is calculated with the following equation :

$$RFI = 1.0 - Bm/Bmax \qquad (6)$$

The second stage of the procedure applies the full RF analysis utilizing the initial objective analysis vectors as a first guess and the reassigned pressure altitude vectors from the penalty function evaluation. This second objective analysis provides a final quality estimate for each vector based on the local quality of the analysis and the fit of the observation to that analysis. Vectors that do not obtain a final quality value exceeding an empirically defined threshold are flagged and rejected. This final quality value is stored within the output wind file in the RFF data value value. The relationship between the RFI and RFF values can be used to tune various keyword settings if too many or too few vectors are rejected during the editing process.

The final quality threshold value can be modified through the use of command line keywords. The current operational threshold value and related keyword settings utilized at NOAA/NESDIS are conservative, having been based upon error analysis against collocated rawinsonde information. The threshold is not optimal for situations which vary strongly from the numerical model background field (meteorological situations which are difficult to model, such as upper−level hurricane outflow and strong extratropical events), leading to a high number of wind vectors being rejected. Keywords are available to regulate the analysis (Hayden and Purser, 1995), the penalty function, and the final quality estimates. These keywords are described in Section 7C4, with examples of suggested use provided in Section 11. A more detailed explanation of the automated RF quality control scheme is provided in Hayden and Nieman, 1996, and Velden et al., 1997, 1998.

3. Routine Output

The following is an example of the output obtained during execution of the recursive filter wind vector editing routine WE. Initial target locations and height assignments values were obtained by the targeting routine WT (see Section 5). Wind vector determination, selection of the "best" height assignment value, and the initial values for the FLAG data value were determined in the wind vector determination routine WW (see Section 6). If utilized, the QI routine should be run prior to the execution of the WE routine. The QI routine is explained in Section 7B.

The context file TESTCNTX was used, having the following pertinent values defined :

MDX	MDXX9990	Output wind file
ROW	3	Row number to write edited wind vectors

```
> we INC=10 QP=2 RF=.7 GINC=2 BFAC=.08 SLOW=4 VAR=7 X X 100000 100000 WGS=.15
RJECT=X 1.0 ZMET=2000 OGRD=1 GRDF=GRID1234

 ***** STARTING AUTOEDITOR *****
Read in 13 Temperature GRIB file names successfully
Read in  6 Dewpt. Dep. GRIB file names successfully
Read in 10 U-Component GRIB file names successfully
Read in 10 V-Component GRIB file names successfully
Read in  7 path names successfully
Read in  9 file names successfully
Read in 15 wind processing variables successfully
Read in  4 miscellaneous variables successfully
Read in context file successfully
read  GRIB file >/home/tlo/windco/nogaps/01200_000020air_temp<
Name of gridded variable is      T   .
Level of gridded variable is     1397113632.
Day  100311,    time  0,        forecast time 12.
unpk: row and col in GRIB=14 5.
gribx12 ended normally
 <stuff deleted>
read  GRIB file >/home/tlo/windco/nogaps/01200_001000wnd_vcmp<
Name of gridded variable is      V   .
Level of gridded variable is     100.
Day  100311,    time  0,        forecast time 12.
unpk: row and col in GRIB=14 5.
unpk: at level 100.000000, V-comp=-78.
gribx12 ended normally
 GUESS TIME/DATE :   100311        0
NUMBER OF REPORTS FROM GUESS IS 1556
ADD MDF,ROW MDXX9990 3
Schema name is GWIN
Total number of keys 120
Missing data value -2139062144
Text description for MD file
 OPENED MD FILE /home/tlo/windco/windco/data/MDXX9990
 <many lines deleted>
WIND VECTOR QI LESS THAN THRESHOLD VALUE OF 60 : 239
 ACCELERATION ERROR RESORTED FOR REPORT 240
 <many lines deleted>
FINAL GUESS WEIGHT IS 0.150000
BEGIN INITIAL ANALYSIS
BEGIN ITERATION NUMBER 1
TOTAL NUMBER OF REPORTS IS 2358
TOTAL NUMBER OF DATA POINTS IS 20228
BEGIN ITERATION NUMBER 1
BEGIN ITERATION NUMBER 2
BEGIN ITERATION NUMBER 3
BEGIN ITERATION NUMBER 4
BEGIN ITERATION NUMBER 5
TOTAL NUMBER OF REPORTS IS 2358
BEGIN ITERATION NUMBER 1
BEGIN ITERATION NUMBER 2
BEGIN ITERATION NUMBER 3
BEGIN ITERATION NUMBER 4
BEGIN ITERATION NUMBER 5
adjust height assignments of cmw using first analysis
NEW HEIGHT ASSIGNMENTS  NG,NB  1557  2358
BEGIN ITERATION NUMBER 1
BEGIN ITERATION NUMBER 2
BEGIN ITERATION NUMBER 3
BEGIN ITERATION NUMBER 4
BEGIN ITERATION NUMBER 5
BEGIN ITERATION NUMBER 6
 Opened GRID file /home/tlo/windco/windco/data/GRID1234
ADD MDF,ROW MDXX9990 3

THE AUTOEDITOR IS FINISHED
```

As with the targeting and wind vector calculation routines the first portion of routine output includes the context file and model forecast GRIB reading routine outputs.

The first portion of the RF editing routine output lists those vectors which fail to meet one of two threshold values. The first group are those vectors which possess a quality indicator value less than the threshold value, assuming the QI routine was run prior to the WE routine. All vectors failing this test have their FLAG data value reassigned to 6666 and are ignored during the RF editing routine. The second group are those vectors which possess a FLAG value between 10 and 33, indicating a possible acceleration error noted in the wind vector derivation routine. These vectors are reanalyzed in the WE routine. Vectors possessing an acceleration value below an empirically set threshold value have their FLAG data value reset to 0 and are passed, along with all other vectors with previously assigned a FLAG data value less than or equal to 3, to the WE routine.

Completion of each RF iteration is output to the screen. If requested with the command line keyword OGRD, a grid file is produced at completion of the editing routine. This grid file will contain either the initial model forecast field or the final wind field meshed with the initial forecast field, depending on the keyword value controlling the grid file output. The grid file will contain wind vector U and V component values at each pressure level listed in Table 9 at the same spatial resolution as the initial GRIB−format model forecast fields.

Level Number	Pressure Levels (hPa)
1	925
2	850
3	775
4	700
5	600
6	500
7	400
8	350
9	300
10	250
11	200
12	150
13	100

Table 9 : Default pressure levels for RF quality control and output GRID files.

4. Usage

The following keywords can be entered on the command line at the initiation of the RF analysis editing routine WE.

Format : we *keywords*

An abbreviated online help listing is available by entering ***we*** or ***we help*** on the command line. Additional help can be obtained using ***we help more***.

keywords :

BFAC =<*speed factor*> <*mean bias*> <*height reassignment flag*>

Permits bias correction to be applied to each vector.
<*speed factor*> : Factor to be multiplied by the speed value of each derived vector. The result is added to the speed of the vector. (default=0.0)
<*mean bias*> : Mean bias (in m/s) to be added to the speed of the vector. (default=0.0)
<*height reassignment flag*> : Value > 0.0 allows for height reassignment before first phase of the objective analysis is completed to allow for the new speed bias adjustment. (default=0.0)

EROW=<*row number*>

Initial row, as listed in ROW keyword, for height reassignment to begin at.
<*row number*> : Starting row number index to be reanalyzed (as listed in ROW keyword). (default=1; meaning start with the first row listed with ROW keyword)

ERR =<*error value*>

Quality gross error check value for each level in analysis.
<*error value*> : Default quality gross error check value. (default=5.0 m/s)

FIT =<*velocity*> <*temperature*> <*pressure*> <*direction*> <*speed*>

Gross error limit weighting factor (M values in Equation 4) for each parameter used prior to computing the penalty function. Note that FIT and VAR keywords are closely related in Equation 4, and strategies for optimal adjustment to either/both keywords may not be obvious. See discussion in Section 7C2. Also see VAR.
<*velocity*> : Weighting factor for vector velocity. (default=7.0)
<*temperature*> : Weighting factor for temperature. (default=2.0)
<*pressure*> : Weighting factor for pressure. (default=1.5).
<*direction*> : Weighting factor for direction. (default=2.0)
<*speed*> : Weighting factor for speed. (default=7.0)

GINC =<*increment*>

Controls the horizontal density of the model grid forecast field observations.
<*increment*> : Model grid sampling increment. (default=4 (this will pick up every fourth horizontal grid point in both X and Y directions))

GRDF =<*grid file*>

File name for grid format output file. Also see OGRD and WGT.
<*grid file*> : File name for output grid file. (default=GRD value in context file)

INC =*<increment>*

Assigns the horizontal increment for the objective analysis. The analysis system has been designed to be relatively insensitive to the size of the grid increment, except for the feature that the density of pseudo reports, the forecast background fields, is affected. A reduction of INC by a factor of 2 will increase the number of pseudo reports by a factor of 4. This will improve the representation of the background, but will not increase its influence relative to the wind vectors. Internally, a factor controlling the weight of the pseudo observations is downweighted to offset the increased density.
<increment> : Horizontal increment in units of degrees*10. (default=10 (= 1 degree))

LAT =*<minimum> <maximum>*

Latitude bounds for analysis.
<minimum> : Southern extent of analysis. (default=LATS value in context file)
<maximum> : Northern extent of analysis. (default=LATN value in context file)

LON =*<minimum> <maximum>*

Longitude bounds for analysis.
<minimum> : Eastern extent of analysis. (default=LONE value in context file)
<maximum> : Western extent of analysis. (default=LONW value in context file)

MDF =*<input/output file> <additional file(s)>*

File name(s) for input/output wind vector file(s). See also ROW keyword.
<input/output file> : File name for input/output file. (default=MDF value in context file)
<additional file(s)> : Additional file name(s) which contain data to be edited thru quality control scheme. (default=same file as *<input/output file>*)

NZ =*<lower level> <upper level>*

Override default level numbers used in analysis (see Table 9).
<lower level> : Lower level in range. (default=1)
<upper level> : Upper level in range. (default=13)

OGRD=*<grid type flag>*

Flag to produce grid format output file and to declare its contents. Also see GRDF and WGT.
<grid type flag> : Value=0 does not produce output grid file, Value=1 produces final analysis field, Value>1 produces background guess field. (default=0)

PL =*<levels>*

Override default pressure levels in Table 9. Range of values are as defined in NZ.
<levels> : Pressures, in hPa. (default=see Table 9)

QI = <threshold>

EUMETSAT QI threshold value. Vectors with QI values less than threshold value will not be analyzed within RF analysis.
<threshold> : Threshold value for inclusion of vector in RF analysis. (default=60)

RANG=*<first record> <last record>*

Allow user to explicitly define wind vector records to analyze/edit.
<first record> : First record to edit in wind file. (default=1)
<last record> : Last record to edit in wind file. (default=total number of records (value stored in CMAX data value))

REDO=*<reanalyze flag>*

Allow reanalysis of data points previously quality controlled and flagged. All wind vectors are reinstated, with vector information taken from the "original" data locations within wind output file. Original quality flag values are lost.
<reanalyze flag> : Value=0 does not perform reanalysis, Value≠0 restores value to original OPW data values. (default=0)

RF =*<data fit>*

Control the fit of the model guess to the wind data. Note that the quality flag attached to each wind vector will be influenced by this keyword.
<data fit> : Analysis fit parameter. Smaller values request a looser fit. (default=1.0)

RJECT=*<rejection threshold> <modification flag>*

Quality control threshold value and modification flag. Reject (and flag) records with RFF data value less than rejection threshold. If modification flag in not equal to zero, adjust rejection threshold value by an amount determined by speed, height, and wind type (water vapor, cloud drift, or sounder wind).
<rejection threshold> : Quality indicator threshold. (default=0.5)
<modification flag> : Value≠0 applies adjustment, Value=0 does not apply adjustments. (default=0)

ROW =*<input/output row> <additional row(s)>*

Row number(s) in wind vector file(s) to which wind vectors are written. Row(s) will be overwritten. See also MDF keyword.
<input/output row> : Row number in output wind vector file to be read/written. (default=ROW value in context file)
<additional row(s)> : Additional row(s) in MD file(s) that contain data to be edited. (default=0; meaning read/write only *input/output row*>).

SLOW=*<threshold value>*

Wind vector speeds below defined threshold are flagged.
<threshold value> : Speed threshold value (value in m/s). (default=0)

TEXT = *<context file>*

Context file to be used by RF editing routine. File name should include path name as well as file name, and can be provided as an absolute or relative path/file name definition.
<context file> : Context file path/file name. (default=AUTOWINX)

VAR =*<velocity> <temperature> <pressure> <direction> <speed>*

Controls the weighting factors within the penalty function equation (F terms in equations 3 and 4) for each of the five parameters used in the assignment of the level of best fit for pressure reassignment. Increasing value of weighting factor downweights the "worth" of that parameter in the computation. Default values will give equal "worth" to a 2 m/s velocity discrepancy, a 10 °C discrepancy, or a 100 hPa discrepancy. The default values for direction and speed will remove these parameters from the computation of the penalty function. Also see notes on FIT keyword.

<velocity> : Weighting factor for velocity. (default=2.0 m/s)
<temperature> : Weighting factor for temperature. (default=10.0 °C)
<pressure> : Weighting factor for pressure. (default=100.0 hPa)
<direction> : Weighting factor for direction. (default=1000.0 degrees)
<speed> : Weighting factor for speed. (default=1000.0 m/s)

WGS =*<weighting factor>*

In order to ensure that the pseudo observations (model forecast field data) do not overwhelm the real observations (wind vectors), a weighting factor is applied to the reliability of the pseudo observations based on the density. This value is : WGS=((GINC*INC/10)**2)/32; for GINC=2 and INC=20, WGS=0.5.

<weighting factor> : Weighting factor for reliability. (default is dependent upon input GINC and INC values)

WGT =*<weights grid output flag>*

Write observation weights to a grid file (output file defined with GRDF keyword).

<weights grid output flag> : Value≠0 outputs grid file with weights, Value=0 outputs grid file without weights (default=0)

WRIT =*<output flag>*

Write quality flag values, and any other values modified during objective analysis routine, to wind vector output file.

<output flag> : Value=YES will output final quality flags, Value=NO will not output values. (default=YES)

ZMET=*<vertical coupling>*

Control of the vertical coupling of the analysis. A lower number means more vertical coupling (less independence for data at individual levels). Increasing the vertical coupling would give a single level wind more "buddy checking" in the vertical.

<vertical coupling> : Vertical coupling control variable. (default=750)

8. Post−Processing Routines

A. CKCIRRUS

The CKCIRRUS routine was designed to modify the heights of wind vectors in two cloud−deck scenes which originally assigned high level semi−transparent cirrus clouds to mid level heights. Reassignment is performed by comparing these questionable wind vectors with surrounding "buddy" vectors having similar properties but possessing more reasonable height assignments. Typically, wind vectors requiring adjustment will possess a much greater wind speed than surrounding wind vectors at or near the same level. This error is due to failure of the H_2O−IRW Intercept Method in correctly assign a valid height to the target in question because the upper−level water vapor (ice/cirrus cloud) feature was too transparent to provide an accurate height.

A wind vector with a height value derived from either the Infrared Window Channel (WIN), Water Vapor Histogram (HIST), or Cloud Base (BASE) method with a pressure less than 500 hPa (altitude greater than 500 hPa) is compared with surrounding wind vectors within a user−defined search box (INC keyword). Only wind vectors with pressures less than 300 hPa (altitudes greater than 300 hPa), derived using the H_2O method, and within 30% of the wind speed of the vector will be used as buddy vectors. The height of the wind vector in question will be reassigned to the height of the closest buddy wind vector meeting the selection criteria. The old, incorrect vector height will be retained within the LINE data value value for each reassigned wind vector, since this data value is not currently used by the wind processing algorithm. A new data value will be defined for proper storage of this value in future GWIN wind file format structure versions.

Format : ckcirrus <wind file> <row> *keywords*
<wind file> : Wind input/output file name. (default=MDF value in context file)
<row> : Row number in wind file to examine. (default=ROW value in context file)

Online help listing is available by entering ***ckcirrus*** or ***ckcirrus help*** on the command line.

keywords :
INC = <*box size*>
<*box size*> : Size of box side, in degrees x 10. (default=30 (= 3.0 degrees))
TEXT = <*context file*>
File name should include path name as well as file name, and can be provided as an absolute or relative path/file name definition.
<*context file*> : Context file path/file name. (default=AUTOWINX)

```
> ckcirrus MDXX9990 2 TEXT=TESTCNTX

  *****  STARTING CKCIRRUS  *****

Read in 13 Temperature GRIB file names successfully
Read in  6 Dewpt. Dep. GRIB file names successfully
Read in 10 U-Component GRIB file names successfully
Read in 10 V-Component GRIB file names successfully
Read in  7 path names successfully
Read in  9 file names successfully
Read in 15 wind processing variables successfully
Read in  4 miscellaneous variables successfully
Read in context file successfully
```

```
McIDAS MD file name is /home/tlo/windco/windco/data/MDXX9990.
Using row no. 2.
Schema name is GWIN
Total number of keys 120
Missing data value -2139062144
Text description for MD file
 Opening file /home/tlo/windco/windco/data/MDXX9990.
Vector :  3543 old height =  287 new height =  122 (  3510)
Vector :  3505 old height =  295 new height =  272 (  3506)
Vector :  3417 old height =  262 new height =  239 (  3484)
Vector :  3393 old height =  246 new height =  230 (  3326)
Vector :  3447 old height =  312 new height =  204 (  3446)
Vector :  3330 old height =  155 new height =  125 (  3331)
Vector :  3350 old height =  248 new height =  239 (  3349)
 <lines deleted>
Vector :   801 old height =  260 new height =  263 (   800)
Vector :   790 old height =  220 new height =  216 (   735)
Vector :   686 old height =  270 new height =  244 (   739)
Vector :   687 old height =  263 new height =  211 (   633)
Vector :   626 old height =  383 new height =  156 (   625)
Vector :   576 old height =  316 new height =  202 (   577)
CKCIRRUS DONE ....
- Modified     77 winds out of   1309 total vectors
```

B. SLOWCK

The SLOWCK routine was designed to check for and flag mid−level water vapor wind vectors being incorrectly tracked and height assigned. Radiation from low−level cloud tops contaminates the clear−sky water vapor signal, resulting in brightness temperatures that lead to height assignments too high in altitude and wind speeds that are too slow for their assigned pressure levels.

All wind vectors having a TYPE value of WV (also WV10 and WV11 for GOES sounder wind vectors), in addition to TYPE=IR winds with height values derived using the H_2O−IRW Intercept Method, will be evaluated by this routine. Mid−level wind vectors between 300 and 700 hPa with a vector speeds minus guess speeds of greater than or equal to 5 m/s will be flagged. These winds will be assigned a FLAG data value value of 6666. The SLOWCK routine should be run twice during the winds derivation process; once prior to execution of the automatic editing and quality control routines, and once after completion of the RF and/or QI routines. An example of this processing logic is presented in Section 12.

Format: slowck <wind file> <row> *keyword*
<wind file> : Wind input/output file name. (default=MDF value in context file)
<row> : Row number in wind file to examine. (default=ROW value in context file)

Online help listing is available by entering ***slowck*** or ***slowck help*** on the command line.

keyword :
TEXT = <*context file*>
File name should include path name as well as file name, and can be provided as an absolute or relative path/file name definition.
<*context file*> : Context file path/file name. (default=AUTOWINX)

```
> slowck MDXX9990 3 TEXT=TESTCNTX
  *****  STARTING SLOWCK  *****

Read in 13 Temperature GRIB file names successfully
Read in  6 Dewpt. Dep. GRIB file names successfully
Read in 10 U-Component GRIB file names successfully
Read in 10 V-Component GRIB file names successfully
Read in  7 path names successfully
Read in  9 file names successfully
Read in 15 wind processing variables successfully
Read in  4 miscellaneous variables successfully
Read in context file successfully
McIDAS MD file name is /home/tlo/windco/windco/data/MDXX9990.
Using row no. 3.

SLOWCK BEGIN .....

COMMAND LINE PARAMETERS

WIND FILE =  /home/tlo/windco/windco/data/MDXX9990,      ROW = 3.
Schema name is GWIN
Total number of keys 120
Missing data value -2139062144
Text description for MD file
 Opening file /home/tlo/windco/windco/data/MDXX9990.
DAY1 from row header =  2000311.
HMS1 from row header =  180000.
CMAX from row header =  3549.

  SLOWCK - Modified 219 records.

  *****  FINISHED SLOWCK  *****
```

C. CKIRWIN

The CKIRWIN routine was designed as a gross−error check to flag low− to mid−level wind vectors that differ significantly from their corresponding guess (model forecast) vectors in speed and direction. Only wind vectors with a data value TYPE equal to IR will be considered.

Wind vectors with pressures greater than 500 hPa (altitudes less than 500 hPa) will be compared with their guess wind vector estimates. If the wind vector direction differs by more than 50 degrees from the guess wind direction, and the wind vector speed differs from the guess wind speed by at least 0.5 m/s, the vector will be flagged. If the wind vector passes the direction check, its wind speed difference is examined. A wind vector with a speed greater than or equal to 11.0 m/s and greater than 8 m/s faster than the guess wind speed will be flagged with error FLAG value 6666.

Format: ckirwin <wind file> <row> *keyword*
<wind file> : Wind input/output file name. (default=MDF value in context file)
<row> : Row number in wind file to examine. (default=ROW value in context file)

Online help listing is available by entering ***ckirwin*** or ***ckirwin help*** on the command line.

keyword :
TEXT = <*context file*>
File name should include path name as well as file name, and can be provided as an absolute or relative path/file name definition.
<*context file*> : Context file path/file name. (default=AUTOWINX)

```
> ckirwin MDXX9990 6

  *****  STARTING CKIRWIN  *****

Read in 13 Temperature GRIB file names successfully
Read in  6 Dewpt. Dep. GRIB file names successfully
Read in 10 U-Component GRIB file names successfully
Read in 10 V-Component GRIB file names successfully
Read in  7 path names successfully
Read in  9 file names successfully
Read in 15 wind processing variables successfully
Read in  4 miscellaneous variables successfully
Read in context file successfully
McIDAS MD file name is /home/tlo/windco/windco/data/MDXX9990.
Using row no. 6.
Schema name is GWIN
Total number of keys 120
Missing data value -2139062144
Text description for MD file
 Opening file /home/tlo/windco/windco/data/MDXX9990.
DAY1 from row header =  2000311.
HMS1 from row header =  180000.
CMAX from row header =  3305.
reassigning FLAG=6666 : 31,     -- DIRECTION ERROR.
reassigning FLAG=6666 : 32,     -- DIRECTION ERROR.
reassigning FLAG=6666 : 35,     -- DIRECTION ERROR.
reassigning FLAG=6666 : 36,     -- DIRECTION ERROR.
reassigning FLAG=6666 : 37,     -- DIRECTION ERROR.
reassigning FLAG=6666 : 48,     -- DIRECTION ERROR.
reassigning FLAG=6666 : 52,     -- DIRECTION ERROR.
reassigning FLAG=6666 : 53,     -- DIRECTION ERROR.
reassigning FLAG=6666 : 59,     -- DIRECTION ERROR.
reassigning FLAG=6666 : 60,     -- DIRECTION ERROR.
reassigning FLAG=6666 : 76,     -- SPEED ERROR.
reassigning FLAG=6666 : 77,     -- DIRECTION ERROR.
reassigning FLAG=6666 : 91,     -- DIRECTION ERROR.
reassigning FLAG=6666 : 93,     -- SPEED ERROR.
 <many lines deleted>
reassigning FLAG=6666 : 3200,     -- DIRECTION ERROR.
reassigning FLAG=6666 : 3208,     -- DIRECTION ERROR.
reassigning FLAG=6666 : 3213,     -- DIRECTION ERROR.
reassigning FLAG=6666 : 3237,     -- DIRECTION ERROR.
reassigning FLAG=6666 : 3256,     -- DIRECTION ERROR.
reassigning FLAG=6666 : 3261,     -- DIRECTION ERROR.
reassigning FLAG=6666 : 3262,     -- DIRECTION ERROR.
reassigning FLAG=6666 : 3298,     -- DIRECTION ERROR.

  CKIRWIN - Deleted 766 winds

  *****  FINISHED CKIRWIN  *****
```

D. CKVIWIN and CKVIWIN1KM

The CKVIWIN and CKVIWIN1KM routines are very similar to the CKIRWIN routine, however they only examine and modify winds having a data value TYPE equal to VIS. The ckviwin program should be used with 4km full disk visible imagery, while the ckviwin1km program should be used with 1km or rapid scan imagery (from GOES satellites, for example).

Wind vectors differing by 90° (70°) from the wind guess direction will be flagged in CKVIWIN (CKVIWIN1KM). Unlike CKIRWIN, there is no speed check with these routines. All vectors failing the directional check will be assigned a FLAG data value value of 6666.

Format: ckviwin/ckviwin1km <wind file> <row> *keyword*
<wind file> : Wind input/output file name. (default=MDF value in context file)
<row> : Row number in wind file to examine. (default=ROW value in context file)

Online help listing is available by entering ***ckviwin/ckviwin1km*** or ***ckviwin/ckviwin1km help*** on the command line.

keyword :
TEXT = <*context file*>

File name should include path name as well as file name, and can be provided as an absolute or relative path/file name definition.

<*context file*> : Context file path/file name. (default=AUTOWINX)

E. JETCK

The JETCK program was designed to identify wind vectors within strong, high−level jet regions which differ significantly from the model guess wind field. These vectors were flagged by the RF editor since the wind speed of the satellite wind was much faster, but in the same direction, as the model guess wind vector at the same location, thus leading to a critical error FLAG data value (FLAG > 3).

An edited (FLAG > 3) wind vector with a TYPE data value of WV or IR, between pressure heights of 100 hPa and 300 hPa, possessing a derived speed between 60 and 130 m/s, within 90 degrees from the guess wind vector direction, and greater in speed than the guess wind vector will be reassigned a FLAG data value of 3 and a RFF data value of 50.

Format: jetck <wind file> <row> *keyword*
<wind file> : wind input/output file name. (default=MDF value in context file)
<row> : row number in wind file to examine. (default=ROW value in context file)

Online help listing is available by entering ***jetck*** or ***jetck help*** on the command line.

keyword :
TEXT = <*context file*>

File name should include path name as well as file name, and can be provided as an absolute or relative path/file name definition.

<*context file*> : Context file path/file name. (default=AUTOWINX)

9. Other Routines

A. MDCREATE

The MDCREATE routine will create a wind output file. The file will be in McIDAS "point data" file format, formatted according to the GWIN template (default condition of command line entry described below). A description of this layout is provided in Appendix C. The file will be created in the directory defined by the WINDPATH variable in the context file defined using the TEXT keyword (see Section 3A).

The maximum number of columns that can be allocated in a wind vector file 80000. There is no limit to the number of rows that can be allocated.

Format : mdcreate <wind file> <template> <# rows> <# columns> <text ID> *keyword*

<wind file> : Wind input/output file name. (default=MDF value in context file)

<template> : Template file name (default='GWIN')

<# rows> : Number of rows in wind file being created. (default=1)

<# columns> : Number of columns in wind file being created. (default=5000)

<text ID> : Text identification string. (default=none)

Online help listing is available by entering ***mdcreate*** or ***mdcreate help*** on the command line.

keyword :

TEXT = <*context file*>

File name should include path name as well as file name, and can be provided as an absolute or relative path/file name definition.

<*context file*> : Context file path/file name. (default=AUTOWINX)

```
> mdcreate MDXX9990 GWIN 6 40000

Read in 13 Temperature GRIB file names successfully
Read in  6 Dewpt. Dep. GRIB file names successfully
Read in 10 U-Component GRIB file names successfully
Read in 10 V-Component GRIB file names successfully
Read in  7 path names successfully
Read in  9 file names successfully
Read in 15 wind processing variables successfully
Read in  4 miscellaneous variables successfully
Read in context file successfully

 File may not exist.
 Creating open file /home/tlo/windco/windco/data/MDXX9990.

 ***** Successfully created file /home/tlo/windco/windco/data/MDXX9990
```

B. SCOPY

The SCOPY routine copies wind vector information between different rows of a single wind file or between rows of two separate wind files. Different rows can be concatenated into a single row using the ADD keyword, which appends a selected row to the end of an existing row of wind vector records.

Selection of records by wind file data values can be performed using the CK1/CV1 keywords for those data values which are character based (see Appendix C), and the NK1/NV1 keywords for integer based keywords. For character data values specified with the CK1 keyword, only those vectors with a data value matching the value specified with the CV1 keyword will be copied. For integer data values specified with the NV1 keyword, only wind vectors with data values between the minimum and maximum values specified with the NV1 keyword will be copied to the output row in the output wind file .

Format : scopy <input file> <output file> <input row> <output row> *keywords*
<input file> : Wind file to be copied from (relative or absolute path name). (default=none)
<output file> : Wind file to be copied to (relative or absolute path name). (default=none)
<input row> : Row number in input file to be copied. (default=1)
<output row>: Row number in output file to be copied to. (default=1)

Online help listing is available by entering ***scopy*** or ***scopy help*** on the command line.

keywords :
ADD = <*flag*>

Flag which specifies to add copied records to the end of an existing group of records in a wind file row or to start at the beginning of the row (column 1). NOTE : any wind vector records existing in the wind file will be overwritten unless ADD=YES command is used.
<*flag*> : YES will copy (add) records to the end of existing records, NO will copy starting at column 1 (will overwrite any existing records). (default=NO)

CK1 =<*element 1*> ... <*element n*>

Character data selection criteria. Only wind vectors with data values(s) of CK1 having value(s) of CV1 will be copied to output wind file. Up to 10 element variables can be specified.
<*element x*> : Character data element names. Value(s) will be defined with CV1 keyword(s).

CV1 = <*value 1*> ... <*value n*>

Character data selection criteria values, corresponding to element type(s) defined with CK1, will be copied. Up to 10 element types can be specified, one for each data value type defined with CK1 keyword.
<*value x*> : Character selection criteria values.

NK1 = <*element 1*> ... <*element n*>

Integer data selection criteria. Only wind vectors with value(s) between the minimum and maximum values defined with the NV1 keyword(s) will be copied to the output file. Up to 10 element variables can be specified.
<element x> : Integer data element names. Value range(s) will be defined with NV1 keyword.

NV1 = *<min 1> <max 1> ... <min n> <max n>*

Integer data selection value(s) within the range(s) defined by minimum and maximum values, corresponding to the element type(s) define with NV1, will be copied. Up to 10 min/max pairs can be specified, one for each data value type defined with NV1 keyword.

<min x> : Minimum value of data selection criteria.

<max x> : Maximum value of data selection criteria.

Examples :

− scopy MDXX8888 MDXX8888 1 2

Will copy all records from row 1 to row 2 within wind file MDXX8888 beginning at column 1 (existing records in row 2 will be overwritten).

− scopy MDXX8888 MDXX9999 1 1

Will copy all records from row 1 in wind file MDXX8888 to row 1 in wind file MDXX9999 beginning at column 1 (existing records will be overwritten)

− scopy MDXX8888 MDXX9999 1 2 ADD=YES

Will append row 1 from wind file MDXX8888 to the end of any existing records in row 2 of wind file MDXX9999.

− scopy MDXX8888 MDXX8888 3 4 CK1=TYPE CH CV1=WV H2O

Will copy only vectors from row 3 of wind file MDXX8888 having a data value TYPE of WV (water vapor) and CH of H2O (H_2O−Intercept method) to row 4 of the same file beginning at column 1 (existing records will be overwritten).

− scopy MDXX8888 MDXX9999 1 4 NV1=LAT LON NV1=20 50 −150 −120

Will copy only vectors from row 1 of wind file MDXX8888 between 20N and 50N latitude and 120E and 150E longitude (negative longitudes are east hemisphere winds) to row 4 of wind file MDXX9999 beginning at column 1 (existing records will be overwritten).

```
     ***** SAME WIND FILE EXAMPLE *****
> scopy ../data/MDXX9990 ../data/MDXX9990 1 2
Schema name is GWIN
Total number of keys 120
Missing data value -2139062144
Text description for MD file
 OPENING SOURCE MD FILE ../data/MDXX9990
 SOURCE AND TARGET MD FILE ARE THE SAME
 EXISTING WINDS IN TARGET MD FILE IN ROW 2
   STARTING WRITE AT RECORD 1

SCOPY WROTE 3549 VECTORS TO TARGET WIND FILE

     ***** DIFFERENT WIND FILE EXAMPLE *****
> scopy ../data/MDXX9990 ../data/MDXX9991 3 1
Schema name is GWIN
Total number of keys 120
Missing data value -2139062144
Text description for MD file
 OPENING SOURCE MD FILE ../data/MDXX9990
Schema name is GWIN
Total number of keys 120
Missing data value -2139062144
Text description for MD file
 OPENING TARGET MD FILE ../data/MDXX9991
mdread: read error!
 NO WINDS IN TARGET MD FILE IN ROW 1...
   STARTING WRITE AT RECORD 1

SCOPY WROTE 3549 VECTORS TO TARGET WIND FILE
```

```
     ***** ADD OPTION EXAMPLE *****
> scopy ../data/MDXX9990 ../data/MDXX9990 4 2 ADD=YES
Schema name is GWIN
Total number of keys 120
Missing data value -2139062144
Text description for MD file
 OPENING SOURCE MD FILE ../data/MDXX9990
 SOURCE AND TARGET MD FILE ARE THE SAME
 EXISTING WINDS IN TARGET MD FILE IN ROW 2
   STARTING WRITE AT RECORD 3550

SCOPY ADDED 3305 VECTORS TO TARGET WIND FILE
```

C. MDOX

The MDOX routine allows the user to list the contents of a specific wind file record. The user should specify the row and column using the ROW and COL keywords. An error will occur if the column number is greater than the total number of wind vectors in the row being examined.

Format : mdox <input file> *keywords*
<input file> : Wind file relative or absolute path name. (default=none)

Online help listing is available by entering ***mdox*** or ***mdox help*** on the command line.

keywords :
ROW = <*row #*>
Row number of wind file record to be output.
<*row #*> : Row number. (default=1)

COL = <*column #*>
Column number of wind file record to be output.
<*column #*> : Column number. (default=1)

```
> mdox ../data/MDXX9990 ROW=3 COL=2539

Schema name is GWIN
Total number of keys 120
Missing data value -2139062144
Text description for MD file
 OPENING FILE ../data/MDXX9990


     WIND VECTOR  --  FILE = ../data/MDXX9990 : ROW = 3 COL = 2539

| DAY1 =   2000311 SYD | HMS1 =    180000 HMS | CMAX =       3549     |
| SATD =      GMS5     | PROD =      WV       | SID  =          2     |
| PDCR =      USA      | MOD  =         0     | FLAG =          0     |
| TYPE =      WV       | LAT  =     10.32 DEG | LON  =    -121.08 DEG |
| DIR  =       106 DEG | SPD  =     18.90 MPS | PW   =        137 MB  |
| TC   =    201.70 K   | CH   =      H2O     | QC58 =      -9999     |
| PW8A =       130 MB  | TC8A =    201.70 K   | QC8A =          7     |
| PWHI =       250 MB  | TCHI =    232.80 K   | QCHI =          1     |
| PWWI =       464 MB  | TCWI =    264.50 K   | QCWI =          1     |
| WM   =        LP     | DIRG =       109 DEG | SPDG =      14.20 MPS |
| DDIR =        94 DEG | DSPD =      4.80 MPS | ODIR =        106 DEG |
| OSPD =     17.50 MPS | OPW  =       137 MB  | TSIZ =         15     |
| TLAG =        20     | RFI  =     97.67     | RFF  =      82.87     |
| ODDG =       110 DEG | OSPG =     13.40 MPS | STDV =       3.80     |
| GRAD =     19.00     | LAND =         2     | MASK =          2     |
| ZEN  =     24.95 DEG | TEM1 =        63     | TEM2 =          0     |
| TEM3 =         0     | IDAY =    100311 SYD | ITIM =     162500 HMS |
| TLAT =     10.26 DEG | TLON =   -121.32 DEG | TDIR =        107 DEG |
| TSPD =     13.10 MPS | CORR =      0.94     | ERR  =          0     |
| TAVG =    181.50     | TRAN =     21.00     | TSTD =       3.80     |
| TGRA =     19.00     | IDAY =    100311 SYD | ITIM =     170200 HMS |
| TLAT =     10.33 DEG | TLON =   -121.06 DEG | TDIR =        105 DEG |
| TSPD =     12.80 MPS | CORR =      0.91     | ERR  =          0     |
| TAVG =    181.50     | TRAN =     21.00     | TSTD =       3.80     |
| TGRA =     19.00     |
```

D. ASCI

The ASCI routine will write an ASCII−format text file from a single row of a wind file. The text file will contain the following information :

<u>Value</u>	<u>Description</u>
type	Wind vector type (WV, IR, VIS, WV10, WV11), from TYPE data value.
day	Wind vector date, in YYYYMMDD format.
satellite	Satellite type (GMS5, GOES8, etc.), from SATD data value.
time	Wind vector time (middle image in image triplet), in UTC.
lat	Wind vector latitude location (negative=south hemisphere).
lon	Wind vector longitude location (negative=east hemisphere).
pre	Wind vector pressure, in hPa.
spd	Wind vector speed, in m/s.
dir	Wind vector direction, (0=north, 90=east, 180=south, 270=west).
mask (opt.)	Cloud mask flag value (1=clear sky, 2=cloud contaminated).

Table 10 : ASCII text file value order and descriptions.

The TYPE and LAND keywords allow the user to list only vectors with certain characteristics to a text file. The TYPE keyword will list only vectors with the user−defined type to the output file. The LAND keyword will list only those vectors with location over a land mass, a body of water, or both, as determined using the high−resolution topography map TOPOHRES.

The MASK keyword will allow output of the MASK data value to the output file, in addition to the other wind information provided. This value will be appended at the end of each line within the ASCII file. This data value provides information on the type of target being tracked by the program: a cloud feature (value=2) or a clear sky, water vapor gradient (value=1).

Format :   asci <wind file> <row> *keywords*
<wind file>   : Wind input/output file name (relative or absolute path name) (default=none)
<row>   : Row number in wind file to examine (default=1)

Online help listing is available by entering ***asci*** or ***asci help*** on the command line.

keywords :
TYPE = <*wind type*>
Wind vector type to output to ASCII file. Can only specify one type individually or all types in file.
<*wind type*> : 1=IR, 2=VIS, 3=WV, 4=WV11, 5=WV10, 6=ALL types. (default=6)

LAND = <*flag*>
Output flag to specify land and/or ocean vectors for output to ASCII file. Only wind vectors located over land and/or water will be output.
<*flag*> : 1=land only, 2=water only, 3=all winds. (default=3)
MASK = <*flag*>
Flag to specify output of cloud mask flag value to ASCII file.
<flag> : YES will output cloud mask vector to ASCII file, NO will not. (default=NO)

FILE = <*file*>
Output file name to which ASCII output is written.
<*file*> : Output ASCII file name. (default=ASCIFILE)

```
> asci ../data/MDXX9990 3 FILE=GMS-2000311.18z
Schema name is GWIN
Total number of keys 120
Missing data value -2139062144
Text description for MD file
 OPENED MD FILE ../data/MDXX9990.
OUTPUT ALL LAND & WATER WINDS TO ASCII FILE
OUTPUT ASCII FILE : GMS-2000311.18z
 type   sat      day      hms     lat     lon     pre   spd   dir
 WV    GMS5    20001106  1800   47.06  -144.72   325  43.60  269
 WV    GMS5    20001106  1800   46.95  -145.22   350  34.00  271
 WV    GMS5    20001106  1800   46.91  -145.81   375  29.60  272
 <many lines deleted>
 WV    GMS5    20001106  1800    0.60  -143.34   275   4.30  242
 WV    GMS5    20001106  1800    1.03  -145.76   137  18.50  160
 WV    GMS5    20001106  1800    0.94  -146.01   137  18.40  161
 WV    GMS5    20001106  1800    0.32  -130.03   237   6.60  169
 WV    GMS5    20001106  1800    0.60  -148.26   200  22.70  154

Number of winds = 716
```

E. GWIN2BUFR2

The GWIN2BUFR2 program will read a row from a wind file and output a BUFR file. The BUFR table files must be located in the directory explicitly defined in the environmental variable BUFR_TABLES. Modification of the variable is dependent upon the UNIX shell environment used. For Korn shell the following command example will define the /home/windco/bufr directory as the location of the BUFR table files :

export BUFR_TABLES='/home/windco/bufr/'

Note : a slash ("/") must be placed at the end of the directory definition.

Format : gwin2bufr2 −i <input file> −o <output file> −r <wind row>

<input file> : Input wind file for conversion (relative or absolute path name). (default=none)

<output file> : Output BUFR−format file (relative or absolute path name). (default=none)

<wind row> : Row number of the input wind file to be read and converted.

Note : The "−i", "−o", and "−r" must precede the input file, output file, and input file row number definitions, respectively.

```
> gwin2bufr2 -i ../data/MDXX9991 -o BUFR2000311.18z

 MD   input  file:    ../data/MDXX9991
 BUFR output file:    BUFR2000311.18z
ENV b
                   ECMWF

      BUFR ENCODING SOFTWARE VERSION -  3.6
             25 NOV 1997.

 Your path for Bufr tables is :
 /home/tlo/bufr
 BUFR Tables to be loaded B0000980601,D0000980601
 No strange records warnings    :   0
 No records with missing DIR/SPD:   871
 No records extracted           :   2678
  end GWIN2BUFR
```

10. Image Format Conversion

The winds processing algorithm requires input satellite image files to be in McIDAS image format. The current version of the software provides two image conversion routines to reformat image files from SDSH "simple" format to McIDAS image format. These routines will work with GMS−5, Meteosat−5, and Meteosat−7 imagery.

A. SIMPLEGMS

The GMS−5 image conversion routine is found in the simplegms directory. The <band flag> parameter controls the output of the different infrared (non−visible) channels. The default will output all non−visible channels to one image file. Setting the band flag to one will output non−visible channels to three separate image files. AREA0001 will contain the visible channel in McIDAS image file format. Using <band flag>=1 will extract the remaining three infrared channels and reformat them into one multi−channel McIDAS image file AREA0002. Using <band flag>=0 will extract the three infrared channels into three separate McIDAS image files named AREA0002, AREA0003, and AREA0004. These files will contain the 11.0 μm infrared, the 12.0 μm infrared, and the 6.8 μm water vapor channels, respectively.

Format : simplegms <input file> <nav file> <cal file> <band flag>
<input file> : Input "simple" format GMS multi−channel image. (default=none)
<nav file> : Input calibration table file. (default=none)
<cal file> : Input navigation table file. (default=none)
<band flag> : Infrared image output method flag. 1=extract IR channels into separate files, 0=extract IR channels into one file. (default=0)

B. SIMPLEMSAT

The Meteosat−5 and Meteosat−7 image conversion routine can be found in the simplemsat directory. The <interp file> parameter defines the interpretation file supplied with the simple image data which defines the navigation and calibration parameters of the input image file. This information is extracted and written to the converted output image file. Image data will be written to files with name formats of AREA####, where #### is an integer value defined using the <output #> command line keyword. Visible data will be written to this file, with the infrared and water vapor band images written to value+1 and value+2, respectively, if stored in the same image file. For example, if <output #>=800, the visible output image will be written to a file named AREA0800 (note the 0 is appended to the beginning of the numerical value to create a name containing eight characters). The infrared and water vapor channels, if available, will be written to images AREA0801 and AREA0802, respectively.

Format : simplemsat <interp file> <input file> <output #>
<interp file> : Interpretation file for reading calibration block, date, and time from image. (default=none)
<input file> : Input "simple" format Meteosat image file. (default=none)
<output #> : AREA number to write the extracted output visible data file to. Number plus one will be IR channel (if present) and number plus two will be WV channel (if present). (default=none)

C. REPPIX

The REPPIX routine will replicate pixels of a low−resolution image to spatially match a higher resolution image. Images can only be scaled up in resolution (pixel replication). The primary use for this program is to align 4 km infrared imagery to 1 km resolution for use as a height assignment area (HARA1) when processing wind vectors from full resolution visible imagery. This algorithm will produce an image that will allow pixel−by−pixel matching to be conducted during the target height assignment processes.

Format : reppix <input file> <output file> <mag>

<input file> : Input file. File name must include relative or absolute path names. (default=none)

<output file> : Output file. File name must include relative or absolute path names. (default=none)

<mag> : Magnification factor to remap input file by to produce output file. (default=none, but input must be an integer greater than 1)

11. Processing Strategies

A. Image Resolutions

Image temporal and spatial resolutions are dependent upon the geostationary satellite and channel being used. Resolutions used at CIMSS and NOAA/NESDIS for different channels and satellites are provided in Table 11 :

Satellite Name	Satellite Sensor	Central Wavelength (μm)	Spatial Resolution (km)	Temporal Resolution (minutes)
GOES−8/10	Imager	10.7 (IR)	4	30
		6.8 (WV)	8	60
		3.9 (SWIR)	4	30
		0.65 (VIS)	4 (full disk)	30
		0.65 (VIS)	1 (CONUS)	15 or 7
	Sounder	7.4 (WV10)	8	60
		7.0 (WV11)	8	60
GMS−5	Imager	11.0 (IR)	5	30
		6.8 (WV)	5	30
		0.63 (VIS)	1.25	30 or 15
Meteosat−5/7	Imager	11.5 (IR)	5	30
		6.9 (WV)	5	30
		0.75 (VIS)	2.5	30

Table 11 : Current spatial and temporal resolutions for different satellites and channels (as of 2001).

B. Suggested Use for Routines

Many of the commands used at UW−CIMSS for the different wind vector derivation routines are presented as a guide. These commands have been used for many years to derive operational wind products, so any major deviation from the commands listed here should be done with great care. Any questions about these commands or proposed command modifications should be directed to one of the people listed in the Contact Information section (Section 13).

All commands listed below will assume the TEXT keyword is used, if necessary. Context files used should be tuned specifically by the user for each satellite and imagery channel being processed. The ROW keyword may also need to be used with each routine below, dependent upon the processing strategies used for retaining different routine output values in different rows of the wind vector file.

It is recommended that output from each main wind processing routine is stored in separate wind file rows for possible post−processing and wind vector examination. This strategy will require a significant increase in data storage requirements. The user is urged to determine the best processing strategy to fit their processing needs and data storage availability.

Image registration

For autonavigation of an image set, the following command will invoke the automatic image registration routine WN to calculate any navigation shifts contained within the image set :
> wn MIN=2 ERR=7 BAND=4 FILE=GLOBAL

The values for BAND, FILE, and TEXT will be user−dependent, based upon the satellite channel number of the imagery being navigated, the landmark file being read, and the context file used, respectively. The MIN value can be adjusted to set the minimum threshold for an adjustment to be applied. The ERR keyword adjusts the sensitivity of the lag correlation. The SIZE keyword can be modified to adjust the search box size for correlating landmarks between images. Increasing this value will allow for larger navigation shifts to be identified, but will also lead to greater probability that false landmark correlations will be found.

Targeting

The targeting routine WT typically uses many of the default command line keyword values when executed, with only the target size box being adjusted for different satellites and channels. For water vapor and infrared channel (11 µm and 3.9 µm) image processing, the following command is used :
> wt S 15 15

The COAK keyword can also be used when processing infrared channel image targets. This keyword will help identify and remove targets in multi−deck scenes and coherent scenes by performing a Coakley−Bretherton analysis on the target scene. The following command incorporates the Coakley−Bretherton analysis :
> wt S 15 15 COAK=1 95 95

The second and third variables of the COAK keyword control the percentage threshold values for the multi−deck and coherence checks, and are very stringent. Lowering these values will allow more targets to be identified in a scene, but will decrease the quality of the targets being chosen.

Processing of water vapor sounder channels from GOES−8 and GOES−10 is very similar to that used for water vapor imager data, except the size of the targeting box is reduced due to the reduction of spatial resolution :
> wt S 15 7

For visible image processing, the following commands are used (dependent upon the spatial resolution of the visible image being used) :
> wt S 15 35 DVAL=30 : for 1km resolution data (GOES CONUS data, for example)
> wt S 15 15 : for 4 km resolution data

The DVAL keyword will adjust the minimum brightness temperature gradient value, and will help target cloud edge features instead of land/water gradients and other non−cloud edge features. Typically for infrared channel imagery, DVAL is 15 (while water vapor channel imagery uses a DVAL of 1).

Wind vector derivation

The typical command for all satellites and channels for the wind vector derivation routine WW will use all command default values :
> ww

Most default values used in this routine are supplied by the context file, and are not typically changed between satellites. Many of these values are listed in Section 11C, Table 12.
Automatic editing

Real−time editing strategies for satellite−derived wind vectors at UW−CIMSS vary between satellites and channels. For water vapor and infrared channel wind vector processing over oceanic regions, a "dual pass" RF editing strategy is employed in order to capture the circulation in and around tropical cyclones. This dual pass editing process involves editing the scene twice. The first pass applies a "tight" RF editing scheme to the entire wind vector field. The second pass is focused on a square region, 30° on a side, centered on the current location of the tropical cyclone selected by the user. This second pass utilizes a "loose" RF editing scheme, and allows wind vectors which vary more from the model than the "tight" RF editing scheme to be retained. The loose editing pass will allow a few more "questionable" vectors to be kept, but it retains many more good vectors in high−curvature regions in the inflow and outflow regions of the tropical storm that would have been discarded due to inconsistencies with the guess field.

Below are the RF editing routine WE commands used operationally at UW−CIMSS for processing water vapor and infrared channel wind vectors using the dual−pass editing strategy :
<u>GMS−5</u>
− *TIGHT*
> we INC=10 QP=2 RF=.7 GINC=2 BFAC=.08 SLOW=4 VAR=7 X X 100000 100000 WGS=.15 RJECT=X 1.0 ZMET=2000
− *LOOSE*
> we INC=10 QP=2 RF=.5 GINC=2 BFAC=.08 SLOW=4 VAR=5 X X 100000 100000 WGS=.10 RJECT=X 1.0 ZMET=2000

<u>GOES−8/10</u>
− *TIGHT*
> we INC=10 QP=2 RF=.8 GINC=2 BFAC=.085 SLOW=5 VAR=5 X X 100000 100000 WGS=.50 RJECT=X 1.0 ZMET=2000
− *LOOSE*
> we INC=10 QP=2 RF=.7 GINC=2 BFAC=.085 SLOW=4 VAR=7 X X 100000 100000 WGS=.15 RJECT=X 1.0 ZMET=2000

<u>Meteosat−5/7</u>
− *TIGHT*
> we INC=10 QP=2 RF=.8 GINC=2 BFAC=.08 SLOW=4 VAR=7 X X 100000 100000 WGS=.30 RJECT=X 1.0 ZMET=2000
− *LOOSE*
> we INC=10 QP=2 RF=.5 GINC=2 BFAC=.08 SLOW=4 VAR=5 X X 100000 100000 WGS=.10 RJECT=X 1.0 ZMET=2000

The main differences between tight and loose RF editing schemes are the RF, VAR, and WGS keywords. The RF and WGS keywords, explained in Section 7C2 and 7C4, control the influence of the model forecast fields on the wind vector field analysis. By lowering these values, the influence of the model forecast fields is reduced, thus allowing more wind vectors to pass through the editing routine as good vectors.

The VAR keyword difference is only with the first variable, the velocity field in the penalty function. By lowering/raising this value, more/less influence will be given to the velocity field in the derivation of the penalty function (Equation 3) for each wind vector. However, notice that by lowering/raising the VAR wind vector value, which correspond to the F_v value in Equations 3 and 4, the gross error limit for the wind vector is also lowered/raised.

For visible channel wind vector RF editing using the WE routine, the following commands are used for the different geostationary satellites :

GMS−5

> we INC=10 QP=2 RF=.9 GINC=2 SLOW=4 VAR=5 X X 100000 100000 WGS=.3

GOES−8/10

> we INC=10 QP=2 RF=.9 GINC=2 SLOW=3 VAR=6 X X 100000 100000 WGS=.5

Meteosat−5/7

> we INC=10 QP=2 RF=.9 GINC=2 SLOW=3 VAR=6 X X 100000 100000 WGS=.5

Please note that the keyword values used have been empirically derived through extensive analysis for each satellite and channel. These values should only be adjusted ***with great care***.

For the EUMETSAT Quality Indicator routine QI, the following command is used for water vapor and infrared wind vector editing :

> qi

For visible wind processing, the command will be :

> qi VIS=YES

The QI routine should utilize the default keyword parameter values, since these values have been empirically derived for use by EUMETSAT scientists and researchers. As with the WE routine, modification of these values should be done ***with great care***.

C. Context File Parameters

When using a context file with the different winds algorithm routines, many of the parameters contained within the context file will be the same regardless of the satellite or channel being processed. Listed below are the values that change within the different UW−CIMSS context files for different context file parameters :

Variable	value
QCU	10
QCV	10
LLAG	21
ELAG	37
LSIZ	15
ESIZ	15
PMAX	1000
PMIN	100 for wv/ir, 600 for vis*
MAXB	250
MINB	20 for wv/ir, 5 for visible

* Use 500 for GMS−5 visible, 600 for GOES and Meteosat visible

Table 12 : Non−standard context file variables for different satellites and imagery types.

12. Background Processing

Execution of the wind derivation routines can be performed using UNIX crontab files and the crontab scheduling process. The entire wind derivation process at UW−CIMSS uses single script files which control the execution of each individual routine for each different satellite and channel being processed. Utilization of script files allows for easy modification of wind processing strategies for different satellites and channels, as well as easier crontab entry. Also, they allow for the inclusion of additional auxiliary scripts, use of command line arguments from the script file, and use of text file parsing commands, such as *sed* and *awk*.

A crontab file can be written in any UNIX shell. The Korn Shell (ksh) is used at UW−CIMSS, utilizing several functions and commands unique to ksh. Below is a condensed ksh script file used at UW−CIMSS in the processing of water vapor and infrared channel winds using the dual−pass RF editing strategy. Certain variables, such as tropical cyclone position, are obtained via auxiliary scripts designed to parse data files for specified tropical cyclone information. Note that different context files are used in the targeting and wind vector derivation routines for water vapor and infrared channel processing. These files will only differ by their definitions of the image set, height assignment images, and row numbers (due to slight differences in processing strategies, as discussed in Section 11).

```
#!/bin/ksh
  if [[ $# −lt 2 || $# −gt 3 ]]
   then
    echo
    echo ’>>> PLEASE ENTER CORRECT NUMBER OF ARGUMENTS’
    echo ’>>>  usage : windswvir.scr <time> <focus> <storm#>’
    echo ’>>>            <focus> : 1−storm,2−fixed,3−Guam’
    echo
    exit
  fi
#−−−−−
# pre−processing set up
#−−−−−
  export PATH=/bin:/usr/bin:/usr/bsd:/etc:/usr/ucb:/usr/bin/X11:/usr/lpp/X11/Xamples/bin:$HOME/bin:.
  let day=‘date +%y%j‘
  let dayxx=‘date +%y%m%d‘
  let time=$1
  let focus=$2
  if [ $# −eq 3 ]
   then
    let storm=$3
  fi
#−−−−−
# Define file names and other variables based on time
#−−−−−
  if [ $time −eq 0 ]
   then
    ctime=00
    wva1=AREA1000
    wva2=AREA1001
    wva3=AREA1002
    ira1=AREA1010
    ira2=AREA1011
    ira3=AREA1012
```

```
    wind=MDXX1005
    outgrd1=GRID1005
    outgrd2=GRID1006
  elif [ $time −eq 6 ]
   then
  <lines deleted>
  else
    echo TIME IS INVALID... EXITING
    exit 1
    EOF
    date
    exit
  fi
#−−−−−
# obtain tropical cyclone storm position
#−−−−−
  if [ $focus −eq 1 ]
   then
    $HOME/scripts/hurricane.scr $storm | read lat lon
      if [ $lat ]
       then
        echo GOOD LAT/LON
      else
        echo NULL LAT/LON
        read lat lon < $HOME/scripts/tcloc−guam
        echo GETTING STORM CENTER FROM tcloc−guam
      fi
  elif [ $focus −eq 2 ]
   then
    read lat lon <$HOME/scripts/tcloc−fix
  else
    read lat lon <$HOME/scripts/tcloc−guam
  fi
#−−−−−
# determine loose auto−editing box around storm location
#−−−−−
  $HOME/scripts/determineNSEW.scr $lat $lon | read $latn $lats $lonw $lone
  echo
  echo latitude  = $lat
  echo longitude = $lon
  echo latitude bounds = $latn $lats
  echo longitude bounds = $lonw $lone
  echo
#−−−−−
# Run navigation check using WN command
#−−−−−
  wn MIN=2 ERR=7 BAND=2 FILE=GLOBAL TEXT=GMS5IR$ctime'Z'
#−−−−−
# obtain navigation shifts from WN output using sed/awk in aux. script file
#−−−−−
  getnavshifts.scr | read $lineshift2 $eleshift2 $lineshift3 $eleshift3
  wnadj $wva2 METHOD=ABS $lineshift2 $eleshift2
  wnadj $wva3 METHOD=ABS $lineshift3 $eleshift3
#−−−−−
# Create the winds md file
#−−−−−
  mdcreate $wind GWIN 6 40000 wv−ir−winds−$day−$time
```

```
#−−−−−
# Run the targeting job − WV winds
#−−−−−
  wt S 15 15 ROW=1 TEXT=GMS5WV$ctime'Z'
#−−−−−
# Run the winds job − WV winds
#−−−−−
  ww ROW=1 TEXT=GMS5WV$ctime'Z'
#−−−−−
# Run the targeting job − IR winds
#−−−−−
  wt S 15 15 ROW=2 TEXT=GMS5IR$ctime'Z'
#−−−−−
# Run the winds job − IR winds
#−−−−−
  ww ROW=2 TEXT=GMS5IR$ctime'Z'
#−−−−−
# Combine WV and IR into row 3
#−−−−−
  scopy $wind $wind 1 3
  scopy $wind $wind 2 3 ADD=YES
#−−−−−
# Do cirrus check
#−−−−−
  ckcirrus $wind 3 TEXT=GMS5WV$ctime'Z'
#−−−−−
# Add check to IR winds to limit the amount of mislabeled IR winds
#   below 500 mb which are really upper−level WV winds
#   Bad wind will have flag set to 6666
#−−−−−
  ckirwin $wind 3 TEXT=GMS5WV$ctime'Z'
#−−−−−
# Add check to WV winds to delete those which are really cloud drift winds
#  above 450 mb, but are labeled as WV gradient winds.  Leads to slow
#  bias in WV wind field.
#  Bad wind will have flag set to 6666
#−−−−−
  slowck $wind 3 TEXT=GMS5WV$ctime'Z'
#−−−−−
# Move row 3 into row 4 for TIGHT auto−editing
#−−−−−
  scopy $wind $wind 3 4
#−−−−−
# Run QI editing routine
#−−−−−
  qi $wind 4 TEXT=GMS5WV$ctime'Z'
#−−−−−
# **** TIGHT autoediting
#−−−−−
  we INC=10 QP=2 RF=.7 GINC=2 BFAC=.08 SLOW=4 VAR=7 X X 100000 100000 WGS=.15 RJECT=X 1.0
ZMET=2000 ROW=4 OGRD=1 GRDF=$outgrd1 TEXT=GMS5WV$ctime'Z'
#−−−−−
# Move row 3 into row 5 for LOOSE auto−editing
#−−−−−
  scopy $wind $wind 3 5 NK1=LAT LON NV1=$lats $latn $lone $lonw
```

```
#−−−−−
# **** LOOSE autoediting
#−−−−−
  we INC=10 QP=2 RF=.5 GINC=2 BFAC=.08 SLOW=4 VAR=5 X X 100000 100000 WGS=.10 RJECT=X 1.0
ZMET=2000 ROW=5 OGRD=1 GRDF=$outgrd2 TEXT=GMS5WV$ctime'Z'
# −−−−−
# Copy row 4 and row 5 into row 6 for "nested" final wind field
#   use all winds from row 5 and all winds but those within the
#   30x30 box around the storm in row 4
#−−−−−
  scopy $wind $wind 5 6
  scopy $wind $wind 4 6 NK1=LAT LON NV1=$latn 60    −179  −70  ADD=YES
  scopy $wind $wind 4 6 NK1=LAT LON NV1=0     $lats −179  −70  ADD=YES
  scopy $wind $wind 4 6 NK1=LAT LON NV1=$lats $latn $lonw −70  ADD=YES
  scopy $wind $wind 4 6 NK1=LAT LON NV1=$lats $latn −179 $lone ADD=YES
#−−−−−
# Rerun SLOWCK
#−−−−−
  slowck $wind 6 TEXT=GMS5WV$ctime'Z'
#−−−−−
# end script
#−−−−−
  exit
#−−−−−
```

13. Contact Information

The satellite winds derivation algorithm was developed at the UW−CIMSS. Much of the code was derived from the original Fortran version of the code, currently being used operationally at UW−CIMSS and NOAA/NESDIS. The image navigation and calibration routines were derived from McIDAS routines, and were either converted from Fortran to C for this version of the winds algorithm, or were directly imported from McIDAS source code developed at SSEC.

Routines developed outside of UW−CIMSS, NOAA/NESDIS, and SSEC were incorporated with approval of the organizations which developed them. These routines were either directly converted to C from Fortran by these organizations, or were converted by programmers at UW−CIMSS with their approval.

All contacts for the winds derivation algorithm are located within the UW−CIMSS.

Cooperative Institute for Meteorological Satellite Studies
University of Wisconsin−Madison
1225 West Dayton Street
Madison, WI 53706

For all scientific and algorithm access questions or comments regarding the winds algorithm, please contact :

Chris Velden e−mail : chris.velden@ssec.wisc.edu

For all questions regarding McIDAS file formats, architecture, or other McIDAS−specific topics, please contact :

Dave Santek e−mail : dave.santek@ssec.wisc.edu

For all programming questions, program bug reports, or other general winds algorithm questions, please contact :

Gail Dengel e−mail : gail.dengel@ssec.wisc.edu
or
Tim Olander e−mail : tim.olander@ssec.wisc.edu

For all questions regarding the EUMETSAT Statistical Quality Indicator editing routine, please contact :

Kenneth Holmlund e−mail : holmlund@eumetsat.de
EUMETSAT
Am Kavalleriesand 31
64295 Darmstadt Germany

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Chris Velden, Gail Dengel, Tim Olander, and Dave Santek
UW−CIMSS development team

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APPENDIX A − Height Assignment Methodologies

1. Infrared Window Channel (WIN) and Water Vapor Histogram Methods (HIST)

Height assignment using singular satellite bands can be made by comparing either infrared window (11 μm) or water vapor (6.7 μm) brightness temperature values with numerical model forecast temperature profiles. Cloud heights are determined by interpolating the cloud temperature, which is an averaged value over a set number of pixels, to the interpolated model guess field at a certain location.

This method works well with opaque clouds, however movement of opaque clouds usually does not accurately represent atmospheric motion at the assigned level (Nieman et al., 1993), resulting in a lower derived wind speed than observed. Semitransparent clouds or subpixel clouds give a more accurate representation of the actual movement of the atmosphere at a particular level. Estimation of this level is very difficult in these cases since determination of the cloud top brightness temperature is affected by an unknown cloud emissivity or the percentage of cloud versus clear sky, respectively. The brightness temperatures are warmer than observed in these cases, thus leading to estimated cloud heights that are too high in pressure (too low in altitude), typically resulting in an overestimation of the wind speed at the estimated cloud height.

2. Water Vapor−Infrared Window Intercept Method (H_2O)

Height assignments derived with this method are based upon the fact that radiances from two different spectral bands are linearly related for different cloud amounts within the field of view at a specified height. Observed radiance measurements are a function of clear sky and opaque cloud radiances. Opaque cloud radiance can be calculated from :

$$R_{bcd}(N,P_c)=R_{c1}(N)-\int_{Pc}^{Ps} t(N,p)(dB[N,T(p)]/dp)dp. \qquad (7)$$

where R_{bcd} is the opaque ("black") cloud radiance, R_{c1} is the clear−sky radiance, *t(N,p)* is the fractional transmittance of radiation of spectral band *N* emitted from the atmospheric pressure *p* arriving at the top of the atmosphere (p=0), *Ps* is the surface pressure, *Pc* is the cloud pressure, and *B[N,T(p)]* is the Planck radiance of the spectral band *N* for a temperature *T(p)*.

The second part of Equation 7 represents the radiance decrease from clear sky conditions introduced by an opaque cloud at a pressure level *p*. This calculation is dependent upon an "accurate" estimation of the current atmospheric temperature and moisture structure, which are provided by a guess (model forecast) profile. By comparing the observed radiances with the calculated radiances (for an observed atmosphere defined by the guess profiles), an estimation of the cloud height can be derived for a completely opaque cloud.

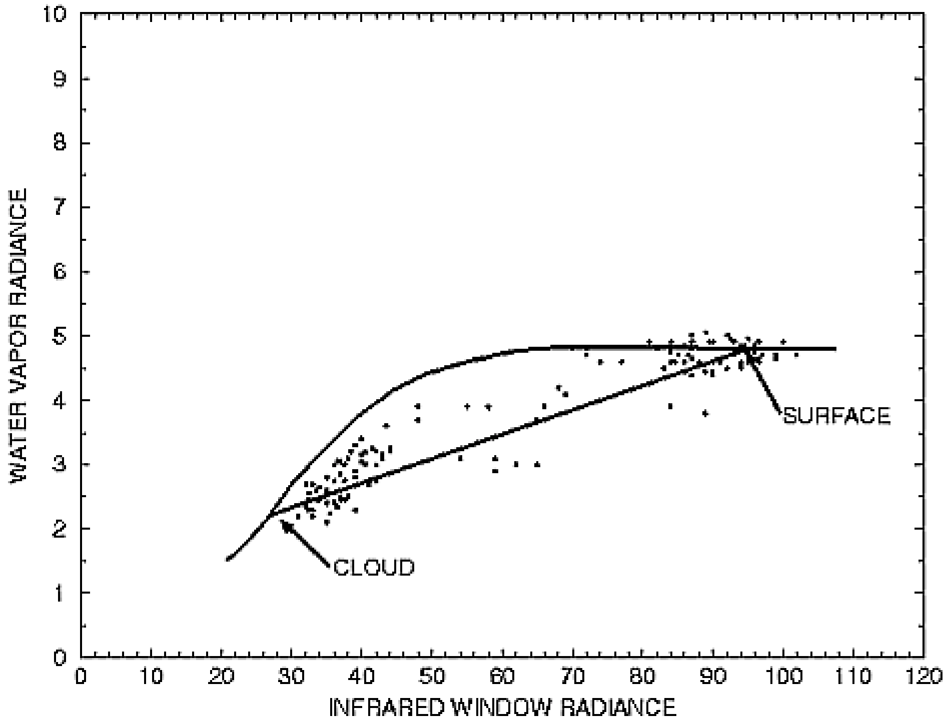

Figure 7 : Measured radiances (mW m^{-2} sr^{-1} cm) for fields of view partially filled with clouds.

In Figure 7, observed WV and IR radiances at each FOV (points) are plotted with the calculated radiances at different heights for opaque clouds in the atmosphere (curved line). The straight line connects the center points of the warmest and coldest clusters, which approximate the observed surface and cloud conditions. By extrapolating this line to intersect the calculated radiance curve, where the cloud amount is one (representing an opaque cloud), the cloud top temperature/pressure can be determined.

The cluster determination algorithm used is a modified version of the bivariate asymmetric Gaussian histogram analysis (Rossow et al., 1985; Tomassini, 1981), and involves ten steps. These steps are outlined in detail in Nieman et. al., 1993.

Calculated water vapor radiances can be in error due to incorrect guess (model forecast) profiles. This error would lead to calculated radiances being systematically higher or lower than observed radiances. When the calculated radiances are systematically lower, an adjustment is applied to the radiances obtained via Equation 7. When the calculated radiances are greater than observed radiances, no adjustment is applied since it is assumed that the lower measured radiance is due to cloud contamination.

The accuracy of this method can be affected by the amount of water vapor in the atmosphere (Spinoso, 1997). Dry atmospheric conditions lead to a steeper slope between the IR and WV radiances, leading to an overestimate in the target height (lower pressure value).

3. CO_2−Infrared Window Ratio Method (CO_2) (*not implemented yet*)

Unlike previous methods discussed above, the CO_2−Infrared Window Ratio technique, also called the CO_2 Slicing method, can work with semi−transparent cloud effectively. This is due to the fact that the emissivities of ice clouds and the cloud fractions for the Infrared Window and CO_2 Channels are roughly the same (Nieman et. al., 1993).

Height assignment based upon this method are determined using the following equation :

$$\frac{R(CO_2) - R_{c1}(CO_2)}{R(IRW) - R_{c1}(IRW)} = \frac{nE(CO_2)[R_{cbd}(CO_2,P_c) - R_{c1}(CO_2)]}{nE(IRW)[R_{cbd}(IRW,P_c) - R_{c1}(IRW)]} \quad (8)$$

where *n* is the fraction of field of view covered by cloud and *E* is the cloud emissivity.

The ratio of the measured radiance difference between cloudy and clear sky for the CO_2 and Infrared Window (IRW) channels is calculated (left side of Equation 8). This ratio is compared to a series of possible solutions computed at incremental pressure values. The pressure value which produces a result most closely matching the ratio value on the left side is used as the pressure of the cloud. The radiance values on the right−hand side require a first guess (model forecast) field, as with the H_2O−Infrared Window Intercept method, in order to properly estimate the atmospheric profile at the target location.

Typically, the 11 μm infrared window channel and the 13 μm CO_2 channel are used with this method (Eyre and Menzel, 1989), however any two channels can be used provided their weighting functions (molecular absorption characteristics) are sufficiently dissimilar while the effective cloud amount is the same for the two channels (Spinoso, 1997).

This method can fail when the observed and clear radiance difference falls below the instrument noise for either channel used in Equation 8, such as low broken cloud or very thin cirrus scenes. Also, when the scene contains two cloud layers, the CO_2 slicing method will produce a height somewhere between the two heights (Menzel et al., 1992). Finally, with very high opaque clouds, this method will fail since the clear−cloudy difference will be near zero. In such cases the window channel method will work sufficiently (Nieman et. al., 1993).

4. Cloud Base Method (BASE)

Wind speeds for low level cumulus clouds (cloud top pressures greater than 600 hPa (altitudes lower than 600 hPa)) have been found to be best represented by the movement at the cloud base level instead of the mid or upper levels of the cloud (Hasler et al., 1979). A method was developed at the Australian Bureau of Meteorology (LeMarshall, 1993; Spinoso, 1997) to estimate this height using the Infrared Window channel.

This method first obtains a histogram of the brightness temperature values over a selected region surrounding the cloud target being examined. This histogram is then smoothed and Hermite polynomials are fitted to the histogram to separate the distribution into two components; a cloudy and clear sky region.

Assuming the distributions are normal, the cloud base height can be estimated. The mid−cloud temperature, also called the modal cloud temperature, is determined by examining the second−derivative histogram of the cloudy distribution, while the cloud top temperature is estimated to be located at the coldest 5% of the cloudy distribution. The cloud base temperature is estimated to be located the same distance from the modal cloud temperature as the cloud top temperature. The calculated cloud base temperature is converted to a pressure using a guess (model) field interpolated to the target location.

As mentioned previously, this height assignment method is only applied to those targets which are calculated to have a cloud top pressure of greater than 600 hPa (altitude lower than 600 hPa). This "initial" target cloud top height is provided by one of the previous Infrared Window height assignment methods. The Cloud Base method is used to adjust only these winds, and is not utilized for water vapor winds or winds with pressures less than 600 hPa (altitudes higher than 600 hPa).

APPENDIX B − FLAG values

FLAG	Error description
Wind targeting and tracking errors (cumulative)	
0	No error
1	U−component departure from guess
2	V−component departure from guess
3	U and V−component departure from guess
10	U−component acceleration
20	V−component acceleration
30	U and V−component acceleration
40	Possible land feature
Wind targeting and tracking errors (non−cumulative)	
100	Band wind guess
200	Correlation error
300	Search box off top/bottom of image
400	Target box off edge of image
500	Pixel brightness out of bounds (noisy lines)
600	Bad image navigation
700	Target box off top/bottom of image
800	Search box off edge of image
1000	Target outside of latitude/longitude boundaries
1500	Zenith angle failure
2000	Target outside of pressure minimum/maximum
Wind editing and post−processing errors (non−cumulative)	
3000	Resultant wind outside of lat/lon limits
4000	Slow vectors
5000	RF analysis flagged winds
6666	Postprocessing error
7777	QI value below threshold

APPENDIX C − GWIN format structure

The GWIN format structure defines the storage layout of each wind vector contained within the wind vector file.

The GWIN format structure contains 120 data elements. These values are stored in two distinct blocks. The first block contains the row header values. These seven values are shared among all wind vectors in a particular row. The second block contains the data records. There are 113 individual values stored for every wind vector derived. The first 61 elements are the vector information values, with the remaining 52 values representing four repeat groups. The repeat groups represent the values obtained when calculating wind vectors between image pairs (up to four different pairs can be stored).

All data values are stored in the format structure as an integer or long. Character values are converted to integer values when stored and back to character values when read from the wind vector file.

Units Legend :

CYD	− yyyyddd (yyyy=year, ddd=Julian date)
HMS	− hhmmss (hh=hour, mm=minutes, ss=seconds)
DEG	− degrees (compass heading (north=0, west=270) or map coordinate location)
MPS	− meters/second
MB	− hPa or millibars
K	− degrees Kelvin

(Scale) values are 10^{x}, and represent the floating point value stored as an integer. Scale values are contained within the GWIN format structure file.

Row Header

Value	Format	Units (scale)	Description
DAY1	Integer	CYD	Julian date
HMS1	Integer	HMS	Time (UTC)
CMAX	Integer		Total number of vectors in row
SATD	Character		Satellite ID name
PROD	Character		Wind vector product (WV or CDFT)
SID	Integer		Satellite ID number
PDCR	Character		Wind set producer country

Data Record

Vector Information

Value	Format	Units (scale)	Description
MOD			*not used*
FLAG	Integer		Error flag
TYPE	Character		Wind type (sensor/band)
LAT	Long	DEG (4)	Latitude location
LON	Long	DEG (4)	Longitude location
DIR	Integer	DEG	Final wind direction
SPD	Integer	MPS	Final wind speed

PW	Integer	MB	Final height assignment
TC	Integer	K (2)	Cloud temperature at final height
CE			*not used*
CH	Character		Height assignment method
PW58	Integer	MB	CO_2 Slicing height assignment
TC58	Integer	K (2)	CO_2 Slicing temperature
CE58			*not used*
QC58	Integer		CO_2 Slicing quality control
PW8A	Integer	MB	H_2O Intercept height assignment
TC8A	Integer	K (2)	H_2O Intercept temperature
CE8A			*not used*
QC8A	Integer		H_2O Intercept quality control
PWHI	Integer	MB	WV histogram height assignment
TCHI	Integer	K (2)	WV histogram temperature
CEHI			*not used*
QCHI	Integer		WV histogram quality control
PWWI	Integer	MB	IR window height assignment
TCWI	Integer	K (2)	IR window temperature
CEWI			*not used*
QCWI	Integer		IR window quality control
TCOL			*not used*
WM	Integer		Cloud tracking metric
DIRG	Integer	DEG	Final guess wind direction (from WE)
SPDG	Integer	MPS (1)	Final guess wind speed (from WE)
GTYP			*not used*
DDIR	Integer	DEG	DIR−DIRG vector difference
DSPD	Integer	MPS (1)	SPD−SPDG vector difference
SGRD			*not used*
SGSP			*not used*
SDEL			*not used*
ODIR	Integer	DEG	Original wind direction (from WW)
OSPD	Integer	MPS (1)	Original wind speed (from WW)
OPW	Integer	MB	Original height assignment (from WT)
TSIZ	Integer		Target box size
TLAG	Integer		Search box size
RFI	Integer	(2)	Initial Recursive Filter quality flag
RFF	Integer	(2)	Final Recursive Filter quality flag
ODDG	Integer	DEG	Original guess vector (from WW)
OSPG	Integer	MPS (1)	Original guess vector (from WW)
STDV	Integer	(1)	Target box BT standard deviation
GRAD	Integer	(1)	Target box BT gradient
LINE	Integer	MB	Height assignment (from CKCIRRUS)
ELE	Integer		Target element (LINE was target line)
LAND	Integer		Land flag (1=land, 2=water)
MASK	Integer		Cloud flag (1=clear sky, 2=cloud view)
ZEN	Long	DEG (4)	Zenith angle from satellite subpoint
PWT			*not used*
PWB			*not used*

TLT			*not used*
TLB			*not used*
TEM1	Integer		Temporary − QI value
TEM2	Integer		Temporary − Cloud Base height
TEM3	Integer		Temporary − Cloud Base temperature
TEM4			*not used*

Repeat Group

These values repeat for each pair of images used to track wind sub−vectors. For a typical group of three images, there will be two repeat groups. First repeat group contains the sub−vector values determined with images one and two, while the second contains the sub−vector values for images two and three.

Value	Format	Units (scale)	Description
IDAY	Integer	SYD	Date of first image in pair
ITIM	Integer	HMS	Date of first image in pair
TLAT	Long	DEG (4)	Latitude of sub−vector
TLON	Long	DEG (4)	Longitude of sub−vector
TDIR	Integer	DEG	Direction of sub−vector
TSPD	Integer	MPS (1)	Speed of sub−vector
CORR	Integer	(2)	Target correlation of sub−vector
ERR	Integer		Acceleration error flag of sub−vector
TAVG	Integer	(1)	Sub−vector target box average
TRAN	Integer	(1)	Sub−vector target box range
TSTD	Integer	(1)	Sub−vector target box standard deviation
TGRA	Integer	(1)	Sub−vector target box gradient
COLD			*not used*