McIDAS

Man computer Interactive Data Access System

TOVS Processing

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This document tells you how to compute vertical profiles of temperature and moisture from TIROS-N Operational Vertical Sounder (TOVS) radiance data with the IBM-based McIDAS. You should be familiar with McIDAS commands and procedures used in GOES-VAS retrieval generation (Chapter 14 of the *McIDAS Reference Manual*). The steps required to transfer the raw TIROS-N Information Processor (TIP) data into vertical profiles of temperature and moisture are:

- **identifying the TOVS radiance data to process**
- **preprocessing the TIP data**
- **preprocessing archived data**
- **adjusting the calibration reference parameters**
- **previewing the data to process**
- **deriving ancillary data**
- **generating TOVS temperature/moisture retrievals**
- **editing or quality control**
- **tuning the database**

These steps are described below.

Identifying the TOVS Radiance Data to Process

NOAA weather satellites are near polar orbiting platforms in a sun-synchronous orbit. The period is 110 minutes. The satellite does not pass over the same earth location from orbit to orbit, but appears to move westward about 25 degrees of longitude at the equator each orbit (actually, the earth is rotating this amount). The orbit is called a precessing orbit. This means that relative to a position on earth, the earth location of the TIROS-N satellite appears to be moving eastward from one day to the next. Therefore, to process TOVS radiances for a given day you must know the location of the satellite track.

Suborbital tracks are displayed on McIDAS using commands USAORB and MAPORB. USAORB plots orbital tracks over North America. MAPORB displays tracks from a user selected geographical region of the Earth on a Mercator map. Both commands give the location of the satellite at a given location, day and time. Make sure that you note the beginning and ending times of the satellite track over the geographical area you want to process. You will need them for future processing. Also be aware that the default coverage is between 70 North and 65 South latitude, due to the unusual nature of polar air masses.

A sample MAPORB command sequence is given below. The italicized words are parameter variables; the bolded numbers and letters are actual keyboard entries.

MAPORB *ss date ulat ulon llat llon*
MAPORB 61 89059 70 20 -10 -90

This entry draws a Mercator map roughly covering eastern Europe, plotting the suborbital tracks of NOAA-11 for 28 February 1989. USAORB follows a similar format, except that the map boundaries are fixed to cover North America.

Preprocessing the TIP Data

Once you know the satellite number and time window for the desired temperature/moisture retrieval locations, you must preprocess the appropriate TIP data. The TIP data must be located in one of the digital areas on disk. Locate the TIP data with command LA, recalling that the orbital period is 110 minutes. The location of this data is system dependent.

When you locate the data, use command TIPTI to preprocess it. This procedure includes locating the High resolution InfraRed Sounder (HIRS) and Microwave Sounding Unit (MSU) radiance measurements in the TIP data, and transforming these HIRS and MSU radiances into a 20-channel HIRS area and a 4-channel MSU area. An example is given below.

LA ***barea earea***
TIPTI ***inarea hirsarea msuarea [keywords]***

LA 6701 6710
TIPTI 6704 2511 2512 TIME=12:00 12:10

From the TIP data located in area 6704, this entry writes HIRS and MSU radiances into areas 2511 and 2512 respectively for the time window 12:00 to 12:10 UTC. This example assumes that the time window is a subset of the much larger TIP area 6704.

Preprocessing Archived Data

Most non-real time (i.e., historical) HIRS and MSU radiance data exists in tape format known as 1B data tape. 1B data is reformatted, calibrated and earth located. You will need to run a series of commands to make it look like a TIP area. Once it is a TIP area, you can use command TIPTI.

Since the data is on tape, you must list or inventory the tape before you begin (unless, of course, someone has already done this). To inventory the tape, use the background job UBLIST1B, indicating the tape name and the number of files required for the listing. The system provides an inventory of the 1B tape. Because UBLIST1B is a background job, you will have to use an editor terminal to update a series of data statements. See the example below. Update these six lines of code located at the end of the program.

```
LOGON AJ 3330
PROG TOVS1B



//VOL = SER = TOVS1B
```

The first statement gives the user's logon initials and project number to charge. Line two gives the tape name (TOVS1B) so the operator knows which tape to mount. The final line also defines the name of the tape. Be sure the tape names in the second and last lines are identical.

After you change these lines, update and submit program UBLIST1B. When the program is finished, you can check the appropriate editor spool file and print the list of all HIRS and MSU files (up to 999).

Next, you can select the desired HIRS and MSU files to process, and transfer the data from tape to disk. This can also be performed by a background job called UBGETT1B which transfers the desired tape files to two LW files (one HIRS and one MSU) on disk called HIRSIBIN and MSUSIBIN. See the example on the next page.

Call up program UBGETT1B from an editor terminal and change the following lines, which are located near the end of the program.

```
LOGON AJ 3330
PROG 2 3 174800 175800
.
.
.
//VOL=SER=TOVS1B
```

The second line is unique from the previous example. The first parameter (2) is the HIRS file number. The second parameter (3) is the MSU file number. The third and fourth parameters are the beginning and ending times of the portions of the overpass to be processed in HHMMSS UTC.

If the HIRS and MSU are not located on the same tape, this background job must be executed twice. The data statement then looks like this:

```
PROG -1 3 174800 175800
```

This program transfers only the MSU radiance data from tape file 3 to LW file MSUSIBIN. Change the data statement to:

```
PROG 2 -1 174800 175800
```

Running UBGETT1B a second time with the above statement transfers the HIRS information from tape file 2 to LW file HIRSIBIN. This accomplishes in two steps what it took one run of program UBGETT1B to accomplish.

When the data is transferred from tape to disk, you must run the TOVS1B program to reformat the data from the original LW files into a TIP HIRS and MSU area. See the example below.

TOVS1B ***hirs filename msu filename tip area***
TOVS1B HIRSIBIN MSUSIBIN 2480

In this example, the respective LW files containing HIRS and MSU radiance information (HIRSIBIN and MSUSIBIN) are reformatted to look like a HIRS and MSU TIP area (2480). If you want to format either a HIRS or MSU file but not both, enter the letter X for the appropriate missing file.

At this point, you can enter the previously described TIPTI command.

TIPTI ***inarea hirsarea msuarea [keywords]***
TIPTI 2480 2481 2482 TIME=17:48 17:58

This entry preprocesses the HIRS and MSU TIP area in 2480 and transforms it into a 20-channel HIRS area (2481) and a 4-channel MSU area located in 2482. The TIPTI command preprocesses radiance data for the time window 17:48 to 17:58 UTC. When you run TIPTI to ingest either a HIRS TIP or a MSU TIP area, remember that preprocessing the HIRS TIP area (MSU TIP area) requires you to place a zero in the *msuarea* (*hirsarea*) so that the program runs correctly to completion. From this point, the HIRS and MSU areas are identical in appearance to the areas described in the previous section and you can proceed as normal.

Adjusting the Calibration Reference Parameters

TIPTI, the TOVS TIP processor, uses several Calibration Reference Parameters (CRPs). These include coefficients employed in various transformations (i.e., the conversion of resistance to temperature for the platinum resistance thermometers (PRT) associated with the HIRS calibration blackbodies and linearization of MSU measurements), as well as nominal values for several parameters used in data quality control.

Each sensor stores parameters in two files named HIRSCRPF and MSUSCRPF. Each spacecraft in the TIROS-N/NOAA series has one record. The HIRS instruments in this series have been remarkably stable and consistent. On several spacecraft, however, the MSU has undergone changes that required certain parameters to be adjusted to avoid discarding good data. As a result, a mechanism has been established that recognizes the need for a change and updates the parameter file to accommodate the new data characteristics. The affected MSU parameters are:

- CAVG - the average counts in each of the four channels; for blackbody and space (calibration targets) views
- CSIG - the standard deviations about CAVG
- CLIM - the upper and lower limits for each target view
- TARG - the nominal blackbody target temperature

Nominal values for the instrument are determined during ground testing and spacecraft integration. Once in orbit, actual measurements of these quantities may change. When TIPTI encounters an out-of-range condition for any of these critical items, it issues a warning message, suggesting that one or more of the above parameters may need adjusting. Command IUMCRP modifies the parameters, resulting in the addition of a new, date-stamped record for the particular satellite to the CRP file. See page 14-18.1 in the *McIDAS Reference Manual* for more information about IUMCRP.

The software that reads the CRP files depends on the chronological order of the entries. After you make changes, command TSCRPF resorts the file by date. It is automatically invoked at the conclusion of IUMCRP unless it is overridden by keyword SORT. TSCRPF can also inventory the file. Below is the HELP for TSCRPF:

```
C ? TSCRPF -- Time-sort calibration-reference-parameter file (BTR)
C ?   Keyin:  sensor
C ?   Parameter:
C ?       sensor | hirs or msu (Default = msu)
```

If any NULL records (see the IUMCRP documentation) are present, TSCRPF deletes them. Since the HIRS instruments have been quite stable, no CRPs have been modified. However, the file structure and access software are analogous to those for MSU. If problems arise that necessitate a capability to adjust parameters, a command similar to IUMCRP will be developed.

Previewing the Data to Process

Once the radiance information is located in the digital areas with command TIPTI, you should display one or more of the bands (channels) on a McIDAS image frame. Besides displaying the weather as seen from that part of the spectrum, the image also provides a quick quality check of the channel data.

You can display the data in several ways. The most direct method is to display a HIRS or MSU channel with the DF command. Unfortunately, depending on the orientation of the orbit, this imagery is flipped (ascending orbit) or reversed left to right (descending orbit). Additionally, at this point the radiance data is not limb-corrected. Limb-correcting eliminates the effects of a local zenith angle when viewing MSU radiances. To limb-correct the MSU radiances, use command MSUL. It writes a new limb-corrected area from the nonlimb-corrected area.

The HIRS and MSU areas generated by TIPTI, which have the radiance data flipped or reversed for image display, can be reformatted into polar stereographic or Mercator projection using command AAMAP, which remaps one band at a time. For example, band 8 of the HIRS (11 micrometer window) is often displayed to see cloud or surface temperatures. Use a resolution factor of 10 for both HIRS and MSU to approximately fill the image frame with the remapped image. An example of the above sequence (limb correction, remapping and displaying a selected TOVS channel), is described below.

MSUL *inarea outarea*
MSUL 2512 2513

From the input MSU area 2512, which is nonlimb-corrected, the above command generates a limb-corrected MSU area and stores it in area 2513. This area or a HIRS area is then remapped. Display it directly with AAMAP or use command DF.

AAMAP *inarea outarea frame proj clat clong mag* **BAND=**
AAMAP 2511 2514 1 PS 40 -35 1 BAND=8

From the 20 HIRS channels in area 2511, the 11 micrometer window channel (band 8) is remapped into a polar stereographic projection and displayed at a center of 40 North latitude and 35 East longitude.

Deriving Ancillary Data

To generate TOVS temperature and moisture profiles, specify an atmospheric first guess. Use surface observation fields of pressure/geopotential, temperature and moisture for greater retrieval accuracy. The TOVS retrieval algorithm uses the appropriate atmospheric first guess, surface information, and the HIRS and MSU radiances to generate the temperature and moisture retrievals.

First Guess

The initial estimate (guess) of vertical temperature and moisture structure can be derived from any of the three following types of information:

- climatology
- regression statistics based on TOVS/radiosonde comparisons
- numerical model output

Climatology (the poorest quality initial conditions) and regression (of higher quality) can be specified directly in the retrieval program using appropriate keywords, and need no further technical elaboration. However, if you have access to high quality numerical model output, which is potentially the best initial estimate, you need to perform several steps to restructure this data into a proper form.

MDU MAKE *gmdf* RGSS
GSVA *ggridf grid gmdf llnw llse inc* SOURCE=TOVS

MDU MAKE 2511 RGSS
GSVA 2101 1 2511 70350 20270 10 SOURCE=TOVS

These entries generate MD file 2511 with a RGSS schema. Then GSVA transforms a grid file of model output, located in grid file 2101 with the first grid to be used located in grid 1, into a field of atmospheric profiles. Guess MD file 2511 covers an area from 20N to 70N and 10E to 90E at a resolution of 1.0 degree lat/lon. The grids included in the grid file must be fields of temperature for the mandatory levels from 1000mb to 10mb, dewpoint from 1000mb to 300mb, and the 1000mb geopotential height field. These grids may originate from a numerical model analysis, forecast, or a time interpolation of these grids. This sequence is identical to the procedure followed in GOES/VAS processing, except the context file has been eliminated necessitating the keyword SOURCE=TOVS.

Surface Fields

The procedure to generate surface information for retrieval processing also follows the VAS methodology. Keep in mind that the context file is not used for TOVS processing. Surface observations are transferred from their permanent operational file (schema SVCA) to an editable surface file (schema RSVC). Next, three analyses defining surface conditions are derived from the RSVC file and a background guess field, if one is available. These analyses are:

- 1000mb geopotential height
- sea level temperature
- sea level dewpoint depression

The following set of commands demonstrates these steps.

MDU MAKE *smdf* RSVC
CSVA *smdf* TIME= MDF= LAT= LON= SOURCE=TOVS
IGU MAKE *sgridf*
SFVA *parm* *sgridf* SMDF= ROW= GSS= GMDF= LAT= LON=

MDU MAKE 2512 RSVC
CSVA 25 12 MDF=5 TIME=12 LAT=20 70 LON=-90 -10 SOURCE=TOVS
IGU MAKE 2512
SFVA Z100 2512 SMDF=2512 ROW=12 LAT=20 70 LON=-90 -10
SFVA TSL 2512 SMDF=2512 ROW=12 LAT=20 70 LON=-90 -10
SFVA DD 2512 SMDF=2512 ROW=12 LAT=20 70 LON=-90 -10

CSVA transforms operational surface reports at 12 UTC for an area covering 20N to 70N and 10E to 90E from an SVCA type MD file into "editable" surface report MD file (2512) with an RSVC schema.

The surface information required by the retrieval algorithm is:

- 1000mb geopotential height
- sea level temperature
- sea level dewpoint depression

SFVA creates gridded analyses of these three surface parameters and stores them in grid file 2512. Since not all the keywords are included in this example, experiment with the others, especially for command SFVA.

Generating TOVS Temperature/Moisture Retrievals

Once the first guess profiles and surface analyses are defined, you are ready to generate temperature/moisture retrievals. The retrieval algorithm is a single command, although the numerous positional parameters and keywords can be confusing. A typical example is given below. The third line is indented to show that it is a continuation of the second line.

MDU MAKE *mdf* TRET
TOVRET *hara mara mdf row gmdf sgridf zgrid tgrid dgrid* BEG= SIZ=
GSS= PLT= IRF=

MDU MAKE 2513 TRET
TOVRET 2511 2512 2513 1 2511 2512 1 2 3 BEG=3 2 SIZ=100 54
GSS=G PLT=Z IRF=1

After generating the MD file which will contain the derived atmospheric profiles, the command TOVRET is invoked. TOVRET incorporates the HIRS and MSU radiances (located in areas 2511 and 2512, respectively), the atmospheric guess profiles (MD file 2512), and the surface analyses (grid file 2512; grids 1, 2, 3) to produce the satellite-derived retrievals.

The keywords in the above example define:

- where to begin (line 3, element 2)
- how large an area to process (100 lines by 54 elements)
- the source of first guess information (produced from a grid analysis)
- what product to plot on the image frame (500mb geopotential heights)
- the MD retrieval file to initialize before adding any of the new temperature/moisture soundings

As you become more familiar with this retrieval algorithm, you will find the algorithm's versatility can generate retrievals in other ways than described above. A thorough description of the retrieval science and a detailed examination of the TOVS retrieval algorithm may be found in *The Technical Proceedings of the Second International TOVS Study Conference* (Menzel (ed), 1985).

Editing or Quality Control

Upon completion of TOVRET, you must edit the file of temperature/ moisture retrievals to eliminate poor quality soundings. Certain profiles may be of less-than-desirable quality. Problems can occur because of contaminated radiances, bad surface information, or the inability of the algorithm to correctly identify the complex meteorological structure. Quality control is achieved through an automatic editor. It can also be performed manually.

Retrieval editing requires a combination of meteorological sense and experience. An editing session often uses the good neighbor policy which compares retrieval values to those nearby, and frequently takes on a personal approach. The commands to perform the interactive form of editing are discussed below.

PLVA ***parm lev*** **MDF= ROW= LAT= LON=**
XRVA MDF= ROW=

PLVA TDIF 850 MDF=2513 ROW=1 LAT=20 70 LON=-90 -10
XRVA MDF=2513 ROW=1

With the satellite image displayed on the monitor screen (if desired), the differences between the satellite derived and the first guess 850mb temperatures (actually, satellite - guess) are plotted over the specified area using PLVA. The differences are displayed in degrees Celsius (or Kelvin) times 10. You can plot other mandatory levels of differences by changing the second positional parameter in PLVA to the level desired.

XRVA is the editing command. Use the joystick or mouse to position the cursor over the errant retrieval and press the space bar to place a box, whose size depends on the size of the cursor, on the graphic screen marking the questionable sounding. Repeat this process as many times as you find bad retrievals in the field. When the editing for that particular level is finished,

Type: **R**
Press: **Enter**

XRVA begins flagging the marked satellite soundings in the MD file. Keep two things in mind at this point. First, the retrievals are not physically deleted from the file, they are only flagged. Second, when a sounding is edited at one level it is edited at all levels. You can repeat the editing procedure for as many levels and different parameters as you want. Delete or edit soundings that do not agree well with their neighbors, taking into account the atmospheric structure.

Meteorologists often develop a personal technique of selecting fields for quality control. However, it is safe to assume that looking at first order differences or calculations at several mandatory levels provides the most comprehensive editing session. For example, you might edit the fields TDIF (satellite - first guess) and T (level temperature) for the mandatory levels (850, 700, 500, 300 mb) and also the total precipitable water vapor (WV). Since geopotential height is a second order calculation derived from temperatures, it is usually not selected for editing unless geopotential fields are an important final product.

Tuning the Database

The physical algorithm employed in the retrieval of atmospheric temperature and moisture profiles involves the computation of weighting functions and synthetic radiometric data for the HIRS and MSU channels. The algorithm is essentially a perturbation method in which guess profiles of temperature and moisture are adjusted on the basis of the differences between calculated and observed radiances, or equivalent blackbody or brightness temperatures. Ideally, these differences should arise solely from the difference between the true atmospheric state, which is what we are trying to retrieve, and the initial guess. However, there are known shortcomings in the radiative transfer models which can lead to differences which adversely affect the quality of the retrievals.

The fast statistical transmittance models employed in the retrieval process are based on state-of-the-art, line-by-line transmittance calculations. The latter, in turn, depend on specifications of the spectroscopic properties of the absorbing gases. For the infrared (HIRS), these include carbon dioxide, water vapor, and trace gases such as ozone, methane, and oxides of nitrogen. In the microwave region (MSU), oxygen and water vapor are the gases of concern. The spectroscopic parameters are based on a combination of theory and laboratory measurements.

When the calculations are applied to a real instrument sensing the real atmosphere, discrepancies are bound to occur. The tuning procedure is an attempt to ameliorate the effects of these shortcomings. The output of the process is a set of three parameters for each channel:

- GAMMA adjusts the calculated transmittances
- BIAS accounts for that portion of the radiance or brightness temperature difference not explained by the GAMMA adjustment
- RMSE is an estimate of the total measurement noise; it scales the weighting function, thereby allowing each channel to influence the solution to a degree proportional to its reliability

Through analysis of NOAA/NESDIS's global satellite radiosonde matchup databases, the sets of GAMMAs, RMSEs and regression equations for obtaining BIASes dynamically during the profile-retrieval process have been determined for NOAA-10 and NOAA-11 (the current operational spacecraft). The parameters reside in a single file accessed by the retrieval programs, with one record per spacecraft. For TIROS-N through NOAA-9, the file contains static tuning parameters which will be upgraded with archives of matchup data. As future spacecraft in the TIROS-N/NOAA series comes on-line, the analysis will be performed and the tuning file updated.

The tuning parameters are nominally fixed for the lifetime of each spacecraft unless significant changes occur in the operating characteristics of one or more channels. If this happens, a future upgrade will embody a time dependent file structure analogous to that developed for the Calibration Reference Parameters.