# User's Guide for the UPOS Product
# Atmospheric Profile Generator

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## I. Overview

The Atmospheric Profile Generator (APG) is a script written in the Interactive Data Language (IDL) which provides an interface between the Airforce Weather Agency's (AFWA) Mesoscale Model (MM5) and Modtran4 for a wide range of potential applications. Our current approach is to produce atmospheric profiles and target to sensor spectral transmittance in seconds for true target radiance determination over any MM5 theater area. The atmospheric and cloud profiles within a specified path are a combination of MM5 analysis/forecasts and Modtran4 climatology.

We have, in fact, developed separate codes for two general scenarios, namely the ground sensor scenario and the airborne sensor scenario, shown in Slides 2 and 3. For each case, minimal input entered via a graphical user interface (GUI) is required from field operators. A pair of theater area displays allows users to pinpoint the sensor and target location of interest with their mouse. Output atmospheric profiles are displayed on a single window for easy comparison and interpretation, while spectral transmittance is displayed on a second window. The output data are also saved in a convenient format for easy importability into other applications if desired.

The following sections give a general description of the codes and their many features. A flowchart of the APG product is given in Slide 4.

## II. Graphical User Interface

A graphical user interface window appears when either the program 'profgen4a' (ground sensor scenario) or 'profgen4b' (airborne sensor scenario) is called from the IDL command line. The '4' after 'profgen' indicates that these programs are compatible with Modtran4. The developed widget-based GUI for these codes consists of lists which the user must select 1 item from, fields which the user must fill in, and buttons which perform specific operations. A sample GUI window for each scenario type is presented in Slide 5.

### (a) Theater Area List

The theater area list allows the user to choose the specific MM5 theater area of interest. Currently, only the coarse theater areas are listed as options, but the finer nested theaters could be added if desired. The current list of MM5 theater areas along with their properties (grid size, grid resolution, and map projection) is presented in Table 1.

Table 1: Theater Areas and Properties

| Theater Number | Theater Name | Grid Size | Grid Resolution | Map Projection |
|---|---|---|---|---|
| T01 | Alaska | 115 x 96 | 45 km | Polar Stereographic |
| T02 | Conus | 192 x 139 | 45 km | Lambert Conformal |
| T03 | Europe | 119 x 104 | 45 km | Lambert Conformal |
| T04 | Southwest Asia | 149 x 139 | 45 km | Lambert Conformal |
| T05 | South America | 168 x 142 | 45 km | Mercator |
| T06 | West Pacific | 199 x 149 | 45 km | Lambert Conformal |
| T07 | China | 149 x 119 | 45 km | Lambert Conformal |
| T08 | Atlantic | * | * | * |
| T09 | Africa | 210 x 120 | 45 km | Mercator |
| T10 | New Zealand | 159 x 119 | 45 km | Mercator |
| T11 | East Pacific | * | * | * |
| T12 | Indonesia | * | * | * |
| T13 | Antarctic | * | * | * |
| T14 | Russia | 115 x 96 | 45 km | Polar Stereographic |

* Theater data not currently available

**(b) Cycle Time List**

The cycle time denotes the UTC date and time when the AFWA MM5 analysis run was performed. Analysis runs are carried out every 6 hours for some theaters and every 12 hours for others. Upon executing the 'profgen4' script, the current date will appear in this list along with the option to choose between the 00, 06, 12, or 18 hour runs. The date of April 20, 2000 is shown as the cycle date in the example in Slide 5 for demonstration purposes.

**(c) Forecast Hour List**

AFWA produces forecasts from 3 hours out to 72 hours in advance relative to the cycle time, in 3 hour increments. This list allows the user to choose the forecast hour of interest. A 00 hour forecast indicates that the analysis run for the chosen cycle time will be used.

***- File Naming Convention***

The theater area, cycle time, and forecast hour lists are needed only for the purpose of identifying which MM5 slimgrib data file is to be accessed. The term 'slimgrib' refers to the fact that the MM5 data files we receive each day from AFWA have a select number of parameters. The files vary in size from 5 to 16 Metabytes. The AFWA naming convention for these files is as follows:

MM5 data file label = us057 g1 010 t AA N CC00 0FF00 .

The label ‘us057’ is the AFWA WMO identifier and ‘g1’ indicates that the data is in GRIB edition 1 format. The numbers ‘010’ refer to the process or model ID, namely MM5, and the letter ‘t’ represents the word ‘theater’. The letters ‘AA’ represent the theater area number from the first column of Table 1. The letter ‘N’, representing the theater nest, will be either a ‘w’, ‘y’, or ‘z’ for the slimgrib data. The APG currently picks out the 45 by 45 km course grid MM5 data files. The letters ‘CC’ represent the UTC cycle time hour and the 2 zeros that always follow the cycle time minute. The letters ‘FF’ represent the forecast hour and the 2 zeros that always follow the forecast minute. Note that AFWA does not include the date in their naming labels. That information is contained in the header of the MM5 data file.

The following lists and fields contain information needed for the execution of Modtran4.

### (d) Observer Visibility List

One of the important contributors to the atmospheric spectral transmittance is the boundary layer aerosol type and concentration. While the aerosol type is determined by the user based on the sensor and target location (described below), its concentration is based on the meteorological range, which approximately equals 1.3 times the observer surface visibility. Modtran4 uses default values for the meteorological range which depend on the aerosol type. Table 2 summarizes the aerosol types, associated color codes, and default meteorological ranges.

Table 2: Aerosol Types and Properties

| Aerosol Type | Color Code | Default Meteorological Range |
|---|---|---|
| Navy Maritime (Sea) | blue | determined from surf wind speed |
| Rural | green | 23 km |
| Snow / Ice | white | 23 km |
| Desert / Barren | orange | determined from surf wind speed |
| Urban | red | 5 km |

The observer visibility list gives the user the option to choose the default value or to override it with a different visibility, ranging from 3 to 30 km in 3 km increments.

### (e) Zenith Angle List (Ground Sensor Scenario only)

For the ground sensor scenario, the spectral transmittance is computed by Modtran4 from the ground to the final pressure level provided in the MM5 data, namely 50 mbars or approximately 20.8 km above sea level. The observer zenith angle (listed in 5 deg increments ranging from 0 deg or directly upward to 90 deg or directly horizontal) must be specified to define the specific path over which the spectral transmittance is calculated. Note that if you have both a sensor and target below 20.8 km above sea level, you should use the airborne sensor scenario code even if you happen to have a sensor on the ground.

**(f) Sensor and Target Height Fields (Airborne Sensor Scenario only)**

For the airborne sensor scenario, the sensor and target heights in kilometers must be entered by the user. Note that these heights are relative to the ground. The surface elevation information is included in the MM5 data files.

**(g) Spectral Band List**

The spectral band list allows the user to choose which spectral band Modtran4 computes the transmittance over. The current choices, shown in Slide 5, are the 3-5 micron and 8-12 micron bands. Additional bands can be added if desired. The 3-5 and 8-12 micron bin sizes are 2 $cm^{-1}$ and 1 $cm^{-1}$ respectively while the 3-5 and 8-12 micron FWHM's at each wavelength are 4 $cm^{-1}$ and 2 $cm^{-1}$ respectively.

**(h) Extract Button**

Pressing the EXTRACT button instructs the code to call upon the external executable program 'wgrib-afwa' to extract data from the MM5 data file which has been selected based on the information provided in the first 3 GUI lists. Now if the selected file is not currently available, a pop-up window appears to indicate that and asks that a different file be selected. If the file is available, a pop-up window appears to inform the user that the extraction process is taking place. The following data are extracted over the entire theater area:

- Latitude and Longitude
- Surface Elevation (above sea level)
- Surface Pressure, Temp, and Relative Humidity
- Surface Wind Speed (u and v components)
- Surface Terrain Type (sea, rural, ice, barren, urban)
- Precipitation Type (no precip, rain)
- Geopotential Height Profiles (versus pressure)
- Temperature Profiles (versus pressure)
- Relative Humidity Profiles (versus pressure)

The process takes approximately 10-15 seconds to complete. The pop-up window also indicates when the extraction is complete and instructs the user to click the RUN button to display the theater area.

**(i) Run Button**

Pressing the RUN button initiates the execution of the main body of the program. The first order of business is to determine the sensor and target latitude and longitude. This starts with a window display of the entire theater area. Slide 6 shows four examples of the theater area displays for Conus, Europe, South West Asia, and West Pacific.

Note that each 45 by 45 km grid point is color coded based on the surface terrain / aerosol type as given in Table 2. As the user moves the mouse around the display, the latitude and longitude numbers on the lower left-hand corner change accordingly. Once the general region of interest is determined, a click of the mouse by the user will produce a new window displaying a zoom in of that region. The size of the zoomed in region is 40 deg longitude by 20 deg latitude. At this resolution, the MM5 grid points are easily distinguishable from one another and the user can home in on the specific area of interest. A sample zoom display is given on Slide 7 for a Middle East region in the South West Asia theater.

For the ground sensor scenario, a second click of the mouse highlights the chosen grid point both on the zoomed in and theater area display. The color of the highlighted grid point coincides with the surface terrain / aerosol type color code. The final lat and lon are also indicated on the lower left-hand corner of each window. If an area is clicked in between or outside of the grid points, the closest MM5 grid point is chosen. Again, for this scenario, the ground sensor is assumed to be viewing a target at or above the defined atmosphere, namely 50 mbars, in the direction of the specified zenith angle.

For the airborne sensor scenario, two clicks of the mouse are required. The first click (using the left mouse button) indicates the location of the sensor and the second click (using the right mouse button) indicates the target location. The scrolling lat/lon numbers at the bottom of the display also specify which location is being requested. It should be noted that the sensor/target positions do not have to land on an MM5 grid point. Once both positions are selected, the closest MM5 grid point to the midpoint between the sensor and target is determined and highlighted. The surface quantities and atmospheric profiles from the designated grid point are used as the intermediate environment between the sensor and target.

The program next reads in the specific parameters for the selected grid point. This is followed by the production of a formatted input file named ‘tape5’ which is read into Modtran4. The generation of this input file is based on user selections from the GUI lists and fields, the MM5 data file header content, and the specific grid point parameters. A call to the Modtran4 executable then runs the code, and typically after a few seconds, output files are produced. The output file ‘tape6’ contains, among other things, the atmospheric profiles for the MM5 grid point. This information is read in and a new window appears to display the results. An example of this window is presented on Slide 8. Note first that the window title includes the cycle time, forecast hour, and MM5 grid point lat and lon.

On the Profiles window, the first row of plots (pressure, temp, water vapor density, and relative humidity) essentially reproduces the MM5 atmospheric profiles, while the second row of profiles (ozone, aerosol, and clouds) are produced from the Modtran4 climatology, which depends on season, location, and atmospheric state. Note that the altitude along the y-axis is relative to the ground level, not necessarily to the sea level. Clouds are detected when the relative humidity reaches 100%. The type of cloud (lower: nimbostratus, stratus, strato cumulus, cumulus, altostratus or ice: cirrus) is determined by the height and thickness of the identified cloud. Modtran4 then provides the density structure for each cloud type. Precipitation is recognized by the presence of a lower cloud and by a positive indication from the MM5 precipitation parameter. In this case, the lower right-hand corner plot would be labeled ‘Rain Cloud Profile’ instead of ‘Lower Cloud Profile’ to indicate the presence of precipitation.

Once the user clicks the Profiles window to continue, the output file ‘tape6’ is checked to determine whether or not a path exists between the defined sensor and target endpoints. For the ground sensor scenario, a path will always exist. For the airborne sensor scenario, though, a path may not exist due to the curvature of the earth. If this is the case, a pop-up window appears to indicate that no path could be found and thus there is zero transmittance. Additionally, for the airborne sensor scenario, if both the sensor and the target are above the defined atmosphere, a pop-up window appears indicating this and that the transmittance is unity by default. If a path exists where at least one endpoint is below the defined atmosphere, a final window appears displaying the spectral transmittance, which is read from a second output file named ‘pltout’.

Two examples of the Transmittance window for the airborne sensor scenario showing the 3-5 and 8-12 micron bands are given in Slide 11. Note that for this scenario, the window title includes the zenith angle as well as the target to sensor range. For the ground sensor scenario, just the zenith angle is given. Typically, the spectral transmittance decreases with higher zenith angle, longer paths, and lower visibility. Moreover, the identification of any thick lower clouds sends the spectral transmittance to zero over most bands. This is not true, though, for thin lower clouds or for the higher cirrus ice clouds, where low but detectable transmittances are measured.

### (j) Close Button

Pressing the CLOSE button will close all windows including the GUI interface and return the user to the IDL command line. If the user wishes to pick a different path instead of closing, the user can simply press the RUN button again and the program will reinitiate, starting with the current theater area display. The user can also opt to change the visibility, zenith angle, sensor/target heights, and/or spectral band before pressing RUN. If the user, though, wishes to change the theater area, cycle time, and/or forecast hour, the EXTRACT button must be pressed (to extract data from a new MM5 file) before pressing the RUN button.

## III. Output Files

Table 3: Output File Names and Formats

| | | | | |
|---|---|---|---|---|
| Name: profiles1.dat | | Source: data from first row of Profiles Window | | |
| Data File Format | | | | |
| Altitude Above Ground (km) | Pressure (mbars) | Temperature (Kelvin) | Water Vapor Density (g/m$^3$) | Relative Humidity (percent) |
| Name: profiles2.dat | | Source: data from second row of Profiles Window | | |
| Data File Format | | | | |
| Altitude Above Ground (km) | Ozone Abundance (ppbv) | Aerosol 550 nm Extinction (km$^{-1}$) | Cirrus Cloud 550 nm Extinction (km$^{-1}$) | Lower Cloud Density (g/m$^3$) |
| Name: spectra.dat | | Source: data from Transmittance Window | | |
| Data File Format | | | | |
| Wavelength (microns) | | Transmittance (range: 0 – 1) | | |

The output data from the Profiles and Transmittance windows are also saved in the route directory where IDL is run. The names and formats of the three output files are given in Table 3. Samples of the 'profiles1.dat' and 'profiles2.dat' files from the results in Slide 8 are given in Appendix A. The header information from Table 3, while shown in Appendix A, is not included in the output files to allow for easy importability into other applications if desired.

***- Comparison with Radiosondes***

As a qualitative measure of performance for the APG results, temperature and relative humidity analysis profiles were compared with radiosonde data obtained from the NOAA Forecast Systems Laboratory's RAOB online database. Shown in Slides 9 and 10 are two examples from the RAOB stations in Detroit, MI and in Osan, Korea. While the temperature profiles are quite accurate, the relative humidity profiles do show some differences at particular altitudes. This may be caused by water vapor variability throughout the 45 km square MM5 grid point.

## IV. Requirements

### (a) Operating System

While the IDL script and supporting codes can run on both UNIX and Windows systems, it is recommended for MM5 data acquisition purposes that it be run on a UNIX system (such as an SGI, SUN, or HP) which can be accessed either from a workstation or from a PC through an X-terminal software such as XVision or Exceed.

### (b) Software

The two codes 'profgen4a' (ground sensor scenario) and 'profgen4b' (airborne sensor scenario) which are discussed in this User's Guide are compatible with Modtran4 and IDL 5.4 (or higher). We do have another code available called 'profgen3' which is compatible with Modtran3 and IDL 5.4 (or higher). It provides the ground sensor scenario of the APG, but lacks the ability to customize the cloud base height and thickness based on the relative humidity profile. Please note that the Modtran executable is machine sensitive and the appropriate compiled version must be used. Finally, the MM5 portable data extractor 'wgrib' or 'wgrib-afwa' must be accessible.

### (c) Disk Space

The largest consumers of disk space are the actual MM5 data files themselves which can vary in size from 5 to 16 Metabytes. It is thus recommended that a server with at least 500 Mb of available disk space be used.

## V. References

1) A. Berk, L. S. Bernstein, and D. C. Robertson. MODTRAN: A Moderate Resolution Model for LOWTRAN7, GL-TR-89-0122, 1989.

2) PLEXUS User's Manual, Version 2.1, Geophysics Directorate, Phillips Laboratory, U.S. Air Force, Hanscom AFB, MA., 1996.

3) C. H. Dey. GRIB, Edition 1, NCEP Central Operations, National Weather Service, NOAA, U.S. Dept. of Commerce, Office Note 388, 1998.

4) A. Berk, G. P. Anderson, P. K. Acharya, J. H. Chetwynd, L. S. Bernstein, E. P. Shettle, M. W. Matthew, and S. M. Adler-Golden. MODTRAN4 User's Manual, AFRL, Space Vehicles Directorate, Air Force Materiel Command, Hanscom AFB, MA, 1999.

5) W. Ebisuzaki. Portable GRIB Decoder, Version 1.6, ftp://wesley.wwb.noaa.gov/pub/wgrib.

6) NOAA FSL RAOB Database Access, http://raob.fsl.noaa.gov.

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## Appendix A

## UPOS Atmospheric Profile Generator Sample Output Files

| Profiles1 Output Data File | | | | |
|---|---|---|---|---|
| Altitude Above Ground (km) | Pressure (mbars) | Temperature (Kelvin) | Water Vapor Density (g/m$^3$) | Relative Humidity (percent) |
| 0.00000 | 996.30000 | 278.50000 | 5.47885 | 79.00000 |
| 0.17900 | 975.00000 | 279.60000 | 5.24624 | 70.00000 |
| 0.39200 | 950.00000 | 279.10000 | 5.34801 | 74.00000 |
| 0.61000 | 925.00000 | 277.70000 | 5.33685 | 81.00000 |
| 0.83300 | 900.00000 | 276.90000 | 5.38208 | 86.00000 |
| 1.06200 | 875.00000 | 276.10000 | 5.31689 | 90.00000 |
| 1.29600 | 850.00000 | 275.30000 | 5.22435 | 93.00000 |
| 1.55080 | 823.62500 | 274.50000 | 5.14678 | 96.58000 |
| 1.78600 | 800.00000 | 273.80000 | 5.06125 | 100.00000 |
| 2.02840 | 776.25000 | 273.80000 | 5.08051 | 100.00000 |
| 2.30500 | 750.00000 | 273.90000 | 5.11420 | 100.00000 |
| 2.38480 | 742.60000 | 273.90000 | 5.08078 | 100.00000 |
| 2.74120 | 710.41600 | 273.70000 | 5.03293 | 100.00000 |
| 2.86000 | 700.00000 | 273.60000 | 5.00571 | 100.00000 |
| 3.02630 | 685.62600 | 272.70000 | 4.69966 | 100.00000 |
| 3.24020 | 667.57500 | 271.60000 | 4.37266 | 100.00000 |
| 3.45400 | 650.00000 | 270.50000 | 4.03929 | 100.00000 |
| 3.81040 | 621.31200 | 268.10000 | 3.03694 | 90.03000 |
| 4.08600 | 600.00000 | 266.20000 | 2.45185 | 83.00000 |
| 4.76100 | 550.00000 | 262.20000 | 1.07897 | 49.00000 |
| 5.48800 | 500.00000 | 257.20000 | 0.66762 | 45.00000 |
| 6.27400 | 450.00000 | 251.00000 | 0.47679 | 53.00000 |
| 7.12900 | 400.00000 | 244.20000 | 0.37941 | 76.00000 |
| 8.07500 | 350.00000 | 237.30000 | 0.18732 | 71.00000 |
| 9.13000 | 300.00000 | 228.60000 | 0.07191 | 65.00000 |
| 10.33200 | 250.00000 | 221.00000 | 0.02960 | 61.00000 |
| 11.76600 | 200.00000 | 216.70000 | 0.01503 | 51.00000 |
| 13.59300 | 150.00000 | 215.20000 | 0.00444 | 18.00000 |
| 16.16200 | 100.00000 | 215.50000 | 0.00180 | 7.00000 |
| 20.57000 | 50.00000 | 216.20000 | 0.00168 | 6.00000 |

| Profiles2 Output Data File | | | | |
|---|---|---|---|---|
| Altitude Above Ground (km) | Ozone Abundance (ppbv) | Aerosol 550 nm Extinction ($km^{-1}$) | Cirrus Cloud 550 nm Extinction ($km^{-1}$) | Lower Cloud Density ($g/m^3$) |
| 0.00000 | 30.62570 | 0.09724 | 0.00000 | 0.00000 |
| 0.17900 | 31.35000 | 0.08916 | 0.00000 | 0.00000 |
| 0.39200 | 31.89430 | 0.08042 | 0.00000 | 0.00000 |
| 0.61000 | 32.57290 | 0.07236 | 0.00000 | 0.00000 |
| 0.83300 | 33.46280 | 0.06495 | 0.00000 | 0.00000 |
| 1.06200 | 34.09390 | 0.05815 | 0.00000 | 0.00000 |
| 1.29600 | 34.95340 | 0.05195 | 0.00000 | 0.00000 |
| 1.55080 | 35.86390 | 0.04595 | 0.00000 | 0.00000 |
| 1.78600 | 36.73330 | 0.04103 | 0.00000 | 0.20000 |
| 2.02840 | 37.88130 | 0.03617 | 0.00000 | 0.35000 |
| 2.30500 | 39.35710 | 0.03062 | 0.00000 | 0.85500 |
| 2.38480 | 39.75100 | 0.02919 | 0.00000 | 1.00000 |
| 2.74120 | 41.80000 | 0.02358 | 0.00000 | 1.00000 |
| 2.86000 | 42.52570 | 0.02196 | 0.00000 | 1.00000 |
| 3.02630 | 43.27180 | 0.02014 | 0.00000 | 1.00000 |
| 3.24020 | 44.82900 | 0.01803 | 0.00000 | 0.30000 |
| 3.45400 | 45.98000 | 0.01614 | 0.00000 | 0.15000 |
| 3.81040 | 48.02210 | 0.01372 | 0.00000 | 0.00000 |
| 4.08600 | 49.86380 | 0.01210 | 0.00000 | 0.00000 |
| 4.76100 | 54.72970 | 0.00961 | 0.00000 | 0.00000 |
| 5.48800 | 60.42000 | 0.00823 | 0.00000 | 0.00000 |
| 6.27400 | 69.94260 | 0.00700 | 0.00000 | 0.00000 |
| 7.12900 | 81.51680 | 0.00516 | 0.00000 | 0.00000 |
| 8.07500 | 95.82310 | 0.00289 | 0.00000 | 0.00000 |
| 9.13000 | 115.67100 | 0.00158 | 0.00000 | 0.00000 |
| 10.33200 | 153.87900 | 0.00095 | 0.00000 | 0.00000 |
| 11.76600 | 219.85200 | 0.00065 | 0.00000 | 0.00000 |
| 13.59300 | 409.49100 | 0.00046 | 0.00000 | 0.00000 |
| 16.16200 | 624.59800 | 0.00040 | 0.00000 | 0.00000 |
| 20.57000 | 2299.00000 | 0.00052 | 0.00000 | 0.00000 |