

Model Initialization and Preprocessing

8.1. Introduction

The ARPS model has a variety of initialization options, which can tailor the model to a specific application. The simplest initialization option involves a horizontally homogeneous base state and an initial thermal bubble with no terrain. Apart from a single sounding, this configuration requires no external data. For applications that require real terrain and surface data properties, preprocessors ARPSTERN or ARPSTRN as well as ARPSSFC are available to generate the needed fields from databases. A program, EXT2ARPS, that interpolates external data sets to ARPS grid, and generates data sets for 3-D initialization of ARPS is also provided. This chapter describes each of these preprocessors in Sections 8.2, 8.3 and 8.5. In addition, Section 8.4 discusses the options for the horizontally homogeneous initial state and Section 8.6 describes the use of external boundary conditions.

8.2. Terrain Data Preprocessor

This section describes two separate methods that may be used to generate an analyzed terrain field for use in ARPS. ARPSTERN uses a Barnes scheme to analyze the terrain data, which allows the user a degree of flexibility in determining the smoothness of the resultant terrain field. ARPSTERN, however, is able to process global data of a resolution only down to 5 minutes and U.S. data no finer than 30 seconds. ARPSTRN uses either a bi-linear or bi-quadratic interpolation scheme to analyze global data of 30 second resolution and U.S. as well as European¹ data of 3 second resolution.

¹ Support for 3 second European terrain data was added by external users and it is still not fully tested. See notes in the template input file for ARPSTRN for instructions.

8.2.1. ARPS Terrain Data Preprocessor: ARPSTERN

Program ARPSTERN (in file *src/arpstern/arpstern.f90*) performs the analysis of terrain data on ARPS model grid. The current version has provision for one analysis scheme, the Barnes multi-pass technique. This scheme allows for flexible user control over the analyzed terrain field (e.g. cutoff wavelength). In addition, the analysis scheme can be applied to an irregularly spaced database.

The following sections contain a description of the terrain database, the terrain processing programs and the Barnes analysis scheme. A more detailed description of the database can be found in Appendix C.

At present, ARPSTERN supports three data sets:

- 1) $1^\circ \times 1^\circ$ ($\sim 110 \times 110 \text{ km}^2$) data covering the entire globe,
 - 2) $5' \times 5'$ ($\sim 10 \times 10 \text{ km}^2$) data covering North America and Europe,
- and

3) $30'' \times 30''$ ($\sim 1 \times 1 \text{ km}^2$) data covering the Continental United States. The data are available in the data files *elev.dat* ($5'$ and 1° data) and *dma_elev.dat* ($30''$ data), which are made available by the National Center for Atmospheric Research (NCAR) and may be downloaded directly from the CAPS anonymous ftp site according to the instructions as given in Section 3.8.

The first step of ARPS terrain preprocessing converts these original ASCII files into unformatted binary direct-access files. These files are then used by the analysis program ARPSTERN to create the final smoothed terrain field. The direct-access files are platform-dependent (e.g. IBM RISC/6000, Intel Linux or Cray), and require the conversion and analysis programs to be run on the same platform. In general, the conversion has to be done only once for each computer system.

a) ASCII to binary data conversion

The following files are required to convert the ASCII data sets into direct access files, and should be found either in the ARPS root directory or the specified subdirectory

<i>src/arpstern/dir1deg.f90</i>	Program DIR1DEG for 1° data conversion
<i>src/arpstern/dir5min.f90</i>	Program DIR5MIN for $5'$ data conversion
<i>src/arpstern/dir30sec.f90</i>	Program DIR30SEC for $30''$ data conversion

<i>src/arpstern/Makefile</i>	Makefile for ARPSTERN system
<i>input/arpstern.input</i>	Control input parameters for all three programs as well as ARPSTERN
<i>makearps</i> <i>Makefile</i>	Shell script for general make control for ARPS Makefile for the ARPS system
<i>elev.dat</i> <i>dma_elev.dat</i>	NCAR 5' and 1° ASCII data file NCAR 30" ASCII data file

The data files, *elev.dat* and *dma_elev.dat*, must reside in the subdirectory as specified by the parameter *terndir* in *arpstern.input*.

To compile and link DIR1DEG, DIR5MIN and DIR30SEC, enter the commands from the ARPS root directory

```
makearps dir1deg
makearps dir5min
makearps dir30sec.
```

The executables will be placed in the *bin* subdirectory.

Before executing these three programs, several parameters must be set in *arpstern.input*, which is a NAMELIST format input file that is also used by the analysis program ARPSTERN. These parameters include *comtype*, a flag for computer type, *terndir*, a string specifying the directory containing the ASCII data files, and *tdatadir*, the name of the directory into which the output data files will be written. After the parameters are set, programs DIR1DEG, DIR5MIN and DIR30SEC are executed by entering:

```
bin/dir1deg < input/arpstern.input > dir1deg.out
bin/dir5min < input/arpstern.input > dir5min.out
bin/dir30sec < input/arpstern.input > dir30sec.out
```

where **dir1deg**, **dir5min** and **dir30sec** are the executable commands produced in the compilation and link step. The standard output files (*.out) contain the diagnostic information from the programs.

The following data files are produced (in directory *tdatadir*) by the conversion programs:

<i>dir1deg.dat</i>	1° direct-access data set
<i>dir1deg.hdr</i>	Header file containing the record numbers of <i>dir1deg.dat</i>
<i>dir5min.dat</i>	5' direct-access data set

<i>dir5min.hdr</i>	Header file containing the record numbers of <i>dir5min.dat</i>
<i>dir30sec.dat</i>	30" direct-access data set
<i>dir30sec.hdr</i>	Header file containing the record numbers of <i>dir30sec.dat</i> .

It is important to note that, depending on the location and the resolution of the model domain, one, two or all three of these data sets may be required by the analysis program ARPSTERN. Therefore all three data sets should be converted.

b) Analysis of terrain data to ARPS grid - ARPSTERN

The main program (ARPSTERN) for ARPS terrain analysis, *arpstern.f90* is located in the *src/arpstern* subdirectory, and the input file, *arpstern.input*, in the *input* subdirectory. To compile and run the program (after the direct access data sets have been created), enter the following commands from the ARPS root directory

```
makearps -ncarg arpstern  
bin/arpstern < input/arpstern.input > arpstern.output
```

Option *-ncarg* is provided in the *makearps* command so that the NCAR Graphics library is linked for ARPSTERN to plot the analyzed terrain fields. This option should be omitted when NCAR Graphics is not available.

The file *arpstern.input* must be edited to set the control parameters properly before the execution of **arpstern**. The definitions of these parameters are explained in detail in the next subsection.

The terrain file generated by ARPSTERN for ARPS is called *arpstern.dat*, which is placed in the ARPS root directory

ARPSTERN includes subroutines that set up the analysis and terrain grids, obtain the required terrain data, perform the desired analysis on the initial terrain field, calculate and plot the response function, and produce contour plots of the terrain fields. The calling tree of ARPSTERN is:

```
ARPSTERN--STRLNTH  
      +- {OPNGKS}  
      +-SETGRID--SETMAPR  
      |           +-LLTOXY  
      |           +-XYTOLL  
      |           +-RESPONSE-- {AGSETC}  
      |                               +- {AGSETI}  
      |                               +- {EZXY}  
      +-GETTER--READTER  
      +-BARNES
```

```

+-PLOT (1) +- {SET}
              +- {WTSTR}
              +- {SUPMAP}
              +- {CONREC}
              +- {FRAME}
+-RMSDIF--PLOT see 1
+- {CLSGKS}

```

In the program, subroutine SETGRID sets up the terrain and analysis grids. Subroutine GETTER retrieves, by calling READTER, the terrain data from the data base, and if necessary interpolates data from coarser sets to finer resolution data points for use in the analysis program. Subroutine BARNES performs the actual data analysis. The definitions of the other ARPSTERN related subroutines can be found in the subroutine glossary section of Chapter 5.

The terrain data read by GETTER are a function of the geographical location of the analysis grid and of the type of terrain resolution desired by the user. If the header file of the desired resolution contains the needed 30" \times 30" latitude / longitude block, the record number and file name are passed to READTER and the data are read and added to the initial terrain array. If no match is found the next coarsest resolution data set is searched until the desired data block is found. In the case that no match occurs (this is possible) the program will print a stop message and terminate. Note that the program is designed to search in the direction of increasing terrain data spacing.

c) Control parameters description for ARPSTERN

This section provides a guide for setting the control parameters in the input file *arpstern.input*, which is used by both the ASCII-to-binary conversion programs and the analysis program ARPSTERN. The default values are given for the example case in the latter part of this section.

Control Parameters for Terrain Preprocessors (set in *input/arpstern.input*)

<u>Parameter</u>	<u>Definition/Purpose</u>	<u>Options/Suggested Values</u>
<i>nx</i>	Number (non-dimensional, ND) of ARPS grid points in the ξ (or x) direction.	Same as in <i>arps.input</i> set for ARPS. Default = 67.
<i>ny</i>	Number (ND) of ARPS grid points (ND) in the η (or y) direction.	Same as in <i>arps.input</i> set for ARPS. Default = 67.

<i>dx</i>	ARPS grid spacing (m) in <i>x</i> -direction.	Same as in <i>arps.input</i> as is set for ARPS (see Chapter 4). Default = 1000.0.
<i>dy</i>	ARPS grid spacing (m) in <i>y</i> -direction.	Same as in <i>arps.input</i> as is set for ARPS (see Chapter 4). Default = 1000.0.
<i>ctrlat</i>	The latitude location (degrees north) of the center of model domain.	Same as in <i>arps.input</i> as is set for ARPS (see Chapter 4). Default = 40.7.
<i>ctrlon</i>	The longitude (degrees east) location of the center of model domain.	Same as in <i>arps.input</i> as is set for ARPS (see Chapter 4). Default = 248.0
<i>analtype</i>	Option (ND) for the terrain data analysis schemes.	1 = Barnes analysis, 2 = Bilinear interpolation with smoothing. (available only in ARPSTRN) Default = 1.
<i>mapproj</i>	Map projection option (ND) used by ARPS model.	Same as in <i>arps.input</i> as is set for ARPS (see Chapter 4). Default = 1.
<i>trulat1</i> <i>trulat2</i>	1st true latitude (degrees north) of map projection. 2nd true latitude (degrees north) of map projection.	Same as in <i>arps.input</i> as is set for ARPS. Default = 40.7.
<i>trulon</i>	True longitude (degrees east) of map projection.	Same as in <i>arps.input</i> as is set for ARPS. Default = 248.0.
<i>sclfct</i>	Scaling factor (ND) for map projection.	Same as in <i>arps.input</i> as is set for ARPS. Default = 1.0.

<i>itertype</i>	Type (ND) of maximum resolution terrain data desired by the user.	<p>1 = 30" data (on the order of 1 km; available on for the U.S.).</p> <p>2 = 5' data (on the order of 10 km).</p> <p>3 = 1° data (on the order of 110 km).</p> <p>Ideally, the resolution of the selected data is slightly higher than the model grid resolution.</p> <p>Default = 1.</p>
<i>rmsopt</i>	Option (ND) to calculate the <i>r.m.s.</i> differences for a one or multi-pass scheme. Note: <i>r.m.s.</i> differences will be calculated automatically for multi-pass analyses.	<p>0 = <i>r.m.s.</i> calculated.</p> <p>1 = no <i>r.m.s.</i> calculation.</p> <p>Default = 0.</p>
<i>comtype</i>	Flag for the type of computer used to run the terrain data preprocessors and analysis.	<p>1= IBM and other computers supporting integer *2 arrays.</p> <p>4 = CRAY and other computers supporting a minimum of 8 byte integers.</p> <p>Default = 1.</p>
<i>tdatadir</i>	Path name of the directory that contains the direct access data and header files. Character <i>tdatadir</i> *80.	<p>Character string in quotes. Not to exceed 80 characters in length. Default = '<i>arpstern.data</i>'.</p>
<i>terndir</i>	Path name of the directory containing the original ASCII data files <i>elev.dat</i> and <i>dma_elev.dat</i> . Character <i>terndir</i> *80.	<p>Character string in quotes. Not to exceed 80 characters in length. Default = '<i>/work/official/arpstern.data</i>'.</p>

<i>knot</i>	<p>Shape factor (ND) used in denominator of the Barnes weight function (k_0).</p>	<p>0.0 = determined by program, > 0.0, any positive value. Recommended value = average grid-to-closest-data point spacing squared. Default = 0.0.</p>
<i>gamma</i>	<p>Convergence factor (ND) used in the multiple pass analysis (γ).</p>	<p>Positive values between $0.2 < \gamma < 1.0$. Value 1.0 recommended for retaining long wavelength structures and minimizing the return of wavelength features. Default = 1.0.</p>
<i>ipass</i>	<p>Number (ND) of iterations through the Barnes analysis scheme.</p>	<p>1 = single pass. >1 = multiple pass. Multiple pass analyses produce steeper response functions at the cutoff wavelength. Default = 4.</p>
<i>tol</i>	<p>Lower limit (ND) of the weight function/response considered to be significant. Values below this level are neglected. Used to determine <i>knot</i>.</p>	<p>Small number on the order of 10^{-7} (smaller values force larger number of data points to be included in the computational box) Default = 10^{-7}.</p>
<i>wdn</i>	<p>Wavelength in terms of the analysis (ARPS) grid spacing used with the desired initial response <i>rdnot</i>.</p>	<p>Any positive number. Value 2 recommended for the removal of small scale features. Default = 2.0.</p>
<i>rdnot</i>	<p>Desired response (ND) of waves of length <i>wdn</i> by the first pass of the Barnes analysis.</p>	<p>$0 < rdnot < 1$. $rdnot < 0.05$ recommended. Default = 0.006.</p>

d) Barnes analysis scheme

The primary goal of a terrain preprocessor is to generate a numerically smoothed yet realistic terrain data set suitable for use by ARPS. The current terrain analysis program for ARPS utilizes the Barnes (1964) method. To avoid introducing small scale noise near the analysis (model) grid boundary, a buffered data area surrounding the analysis grid is employed. This buffer zone supplies data outside the analysis area for use in the Barnes analysis.

The Barnes analysis scheme iteratively applies a Gaussian shaped weight function, w , to the input data. This analysis technique has the form:

$$g^n(i,j) = g^{n-1}(i,j) + \frac{\sum_{m=1}^M [w_m (f_o(x,y) - g^{n-1}(x,y))]}{\sum_{m=1}^M w_m} \quad (8.2.1)$$

where,

$$\begin{aligned} g^n(i,j) &= \text{the analysis value at the analysis point } (i,j), \\ g^{n-1}(i,j) &= \text{a background field or value of the previous pass at} \\ &\quad \text{the analysis point,} \\ f_o(x,y) &= \text{the data value at a data point } (x,y), \\ g^{n-1}(x,y) &= \text{the previous pass analysis at a data point.} \end{aligned}$$

The weight function for the Barnes scheme is:

$$w_m = \exp\left(-\frac{r_m^2}{\gamma k_1}\right) \quad (8.2.2)$$

where,

$$\begin{aligned} r_m &= \text{distance between the analysis point and the data point,} \\ k_o &= \text{shape or influence factor,} \\ k_1 &= \gamma k_o, \\ \gamma &= \text{convergence factor with } \gamma = 1 \text{ for an one pass scheme and} \\ &\quad 0.2 \leq \gamma \leq 1.0 \text{ for a multiple pass scheme.} \end{aligned}$$

w is the weight of each terrain data point a distance r from the analysis point for a predetermined shape factor k_o . For a multiple pass application, a small γ on the order of 0.2 will revive smaller scale structures removed by the initial pass. The shape factor k_o can be specified by the user or determined by the program. This method allows the user to define a low response at the

Nyquist wavelength and for other small-scale structures in the analyzed field. The response of the first pass in spectral space is:

$$D^o = \exp(-k_o \left(\frac{\pi}{\lambda}\right)^2) \quad (8.2.3)$$

where,

$$\begin{aligned} D^o &= \text{initial response of wavelength } (\lambda) \\ \lambda &= \text{wavelength in terms of } wdn \text{ times the maximum grid spacing} \\ &\quad \text{in } x \text{ and } y \text{ directions,} \\ k_o &= \text{shape factor.} \end{aligned}$$

Solving (8.2.3) for k_o , we have

$$k_o = -\ln(D^o) \left(\frac{\lambda}{\pi}\right)^2 \quad (8.2.4)$$

The use of maximum data spacing in the x and y directions ensures the removal of smaller scale features due to data spacing variation. The Barnes analysis incorporates a tolerance or cut-off radius to improve the program efficiency. The tolerance parameter (tol) and shape factor k_o define the size of the computational box surrounding each analysis point. The computational box is described in the next subsection.

e) Initial terrain data area requirements

When the user selects the multiple pass option ($ipass > 1$), the analysis program requires a larger initial terrain area than would be required for a single pass analysis. This is due to the fact, referencing equation (8.2.3), that the second pass adds to the background field (the first pass analysis at the analysis points) the Barnes analysis applied to the difference field between the initial terrain data and the first Barnes analysis at the terrain points. Additional points are required outside the analysis grid area in order to perform an analysis that converges and is free of edge effects.

For this particular application, the analysis at the analysis / model grid points are performed at the same locations for each pass. The analysis at the terrain points is conducted over a smaller and smaller area with each pass.

Before the terrain domain size requirements are defined, a number of intermediate variables need to be determined. The number of data points required for the Barnes scheme to converge to within a pre-set tolerance limit is calculated by the following relations (x and y directions, respectively):

$$nbufx = \left(\frac{\ln(tol) * k_o}{\text{min. terrain spacing x dir.}} \right)^{\frac{1}{2}} + 1, \quad (8.2.5)$$

$$nbufy = \left(\frac{\ln(tol) * k_o}{\text{min. terrain spacing y dir.}} \right)^{\frac{1}{2}} + 1. \quad (8.2.6)$$

The computational box size is defined by $2*nbuf(x,y) + 1$ data points. Figure 8.1 depicts the area around each analysis point required to obtain a convergent analysis.

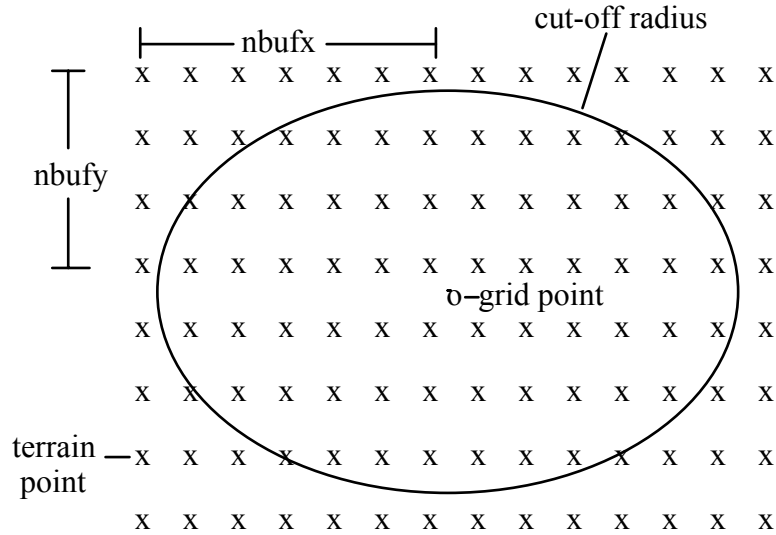


Figure 8.1 Computational box indicating grid points, terrain/data points and the cut-off radius (area of influence) according to a prescribed tolerance level.

After the Barnes shape factor k_o , tolerance, $nbufx$ and $nbufy$ are determined, an estimate of the number of terrain data points ($nptx$, $npty$) required to complete the analysis can be made using the following relations:

$$nptx = 1.3*((ipass+1)*2*nbufx + \text{analysis area (degrees lon.)} * ndx) \quad (8.2.7)$$

$$npty = 1.3*((ipass+1)*2*nbufy + \text{analysis area (degrees lat.)} * ndy) \quad (8.2.8)$$

Parameters $nptx$ and $npty$ define the minimum number of terrain data points required in the x and y directions respectively. Parameters ndx and ndy prescribe the number of data points per 1 degree block and are set automatically according to the selected $itertype$:

$itertype = 1$ (30 second data), then $ndx = ndy = 120$;

$itertype = 2$ (5 minute data), then $ndx = ndy = 12$;

$itertype = 3$ (1 degree data), then $ndx = ndy = 2$.

f) Barnes response function

The response function for a specific n-pass analysis is calculated and plotted by ARPSTERN. For a single pass scheme D^o is obtained through the use of Eq. (8.2.3):

$$D^o = \exp(-k_o * (\frac{\pi}{\lambda})^2). \quad (8.2.9)$$

For a two-pass scheme ($ipass = 2$):

$$D^{1*} = D^o + (1 - D^o) * D^1 \quad (8.2.10)$$

where, $D^1 = (D^o)^\gamma$.

For multiple pass schemes ($ipass > 2$):

$$D^{n*} = D^o + (1 - D^o)(D^1 + \varphi^n) \quad (8.2.11)$$

where,

$$\varphi^n = \sum_{i=1}^{i=n} D^i * \prod_{j=2}^i (1 - D^{j-1}), \quad \text{for } 2 < n < \infty \text{ and } n = 2 \text{ is for the third}$$

pass (Koch *et al.*, 1985).

g) Example of a multi-pass analysis

An example is given for a 4-pass analysis over Northern Utah. This area is highly variable in terrain elevation and illustrates the characteristics of the multiple pass Barnes scheme. This example used the 30" Continental US data set which, at the latitude of Northern Utah, has an approximate resolution of 700 by 900 meters in the longitudinal and latitudinal directions, respectively. The parameters used by this example are:

In *arpstern.input*, $nx=61$, $ny=61$, $dx=1000.0$ m, $dy=1000.0$ m, $mapproj=1$, $trulat1=40.7$, $trulon=248.0$, $scfct=1.0$, $itertype=1$, $rmsopt=1$, $comtype=1$, $tdataidir='arpstern.data'$, $terndir='arpstern.data'$, $knot=0.0$, $gamma=1.0$, $ipass=4$, $tol=0.0000001$, $wdn=2.00$, $rdnot=0.006$.

The final terrain field of the analysis is shown in Figure 8.2. The example area includes a flat basin represented by the Great Salt Lake, gentle valleys, and steep mountainous terrain.

The computational requirements of the terrain preprocessor vary with the number of passes, grid sizes and desired response function characteristics. On an IBM RISC 590 workstation, approximately 30 CPU seconds was required to complete this 4-pass example. When determining which data sets to apply, the user should be aware of the analysis grid spacing to terrain data resolution ratio. Ratios of order 2 will provide a useful analysis field without excess computations. Ratios on the order of 10, for example, require significant amounts of CPU time and memory, without much improvement in the final product.

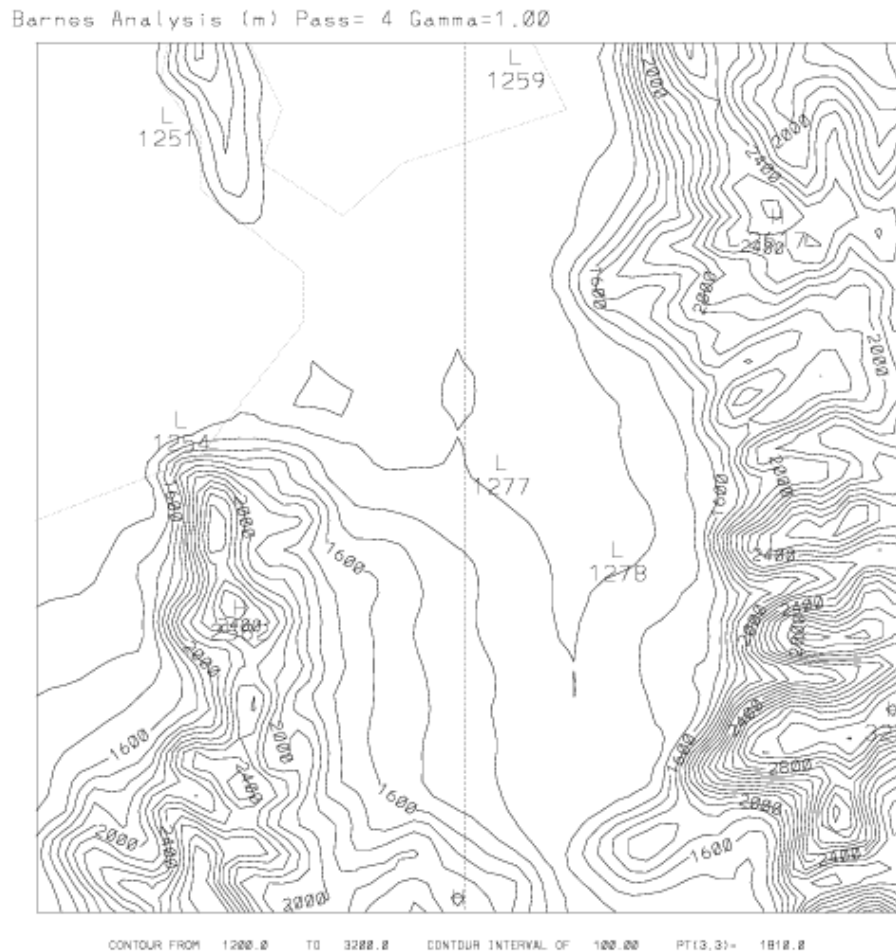


Figure 8.2. Analyzed terrain contours (contour interval = 100 m) on a 60x60 km grid.

8.2.2. ARPS Terrain Data Preprocessor: ARPSTRN

a) Preparation of datasets

The global 5 min terrain data is available on the CAPS ftp server. The commands are:

```

cd data           [move to the data subdirectory]
ftp caps.ou.edu   [connect to the CAPS anonymous ftp server]
cd pub/ARPS/ARPS.data/arpstern.data
                    [go to the terrain subdirectory]
get tbase_global_5min.data.gz [retrieve the terrain data base]
gunzip tbase_global_5min.data.gz [uncompress terrain datafiles]

```

If using 30 second or finer resolution data, **arpstrn** will automatically download the necessary data files from a CAPS ftp server². It is necessary, however, that you have a fast internet connection and also that certain permissions are specified by your system to allow for the remote transfer of these files. To allow for automated connection to the remote server(s), create a *.netrc* file in your home directory that contains this line:

```
machine caps.ou.edu login anonymous password [your email address]
```

The *.netrc* file should be set such that it is only readable by you. Do **chmod go-rwx .cshrc** to remove read/write/execute permission for all others beside yourself.

You can also choose to pre-download the 30 second data or 3 second US data files to your own local directory. The 30 second data is located at <ftp://caps.ou.edu/pub/ARPS/ARPS.data/arpstopo30.data> and the 3 second US data is located at <ftp://caps.ou.edu/pub/ARPS/ARPS.data/demtopo3.data>³. You can also get the whole directory in one tar file as, *arpstopo30.data.tar.gz* for 30 second data or *demtopo3.data.tar.gz* for 3 second US data. The steps are:

```

cd data           [move to the data subdirectory]
ftp caps.ou.edu   [connect to the CAPS anonymous ftp server]
cd pub/ARPS/ARPS.data/ [go to the data subdirectory]
get arpstopo30.data.tar.gz [retrieve the terrain data base]
tar xzvf arpstopo30.data.tar.gz [untar terrain datafiles]

```

² CAPS ftp server name is correct up to the time while this document is creating. It may be changed later, please refer to the comments inside *arpstrn.input* for up-to-date instructions.

³ Users do not have to download the data from CAPS ftp server. They can also download it directly from USGS servers. It is provided for users' convenience.

b) *Analysis of terrain data to ARPS grid – ARPSTRN*

The main module for ARPSTRN, *arpstrn.f90*, is found in the subdirectory *src/arpstrn* and the input file is located at *input/arpstrn.input*. In order to generate the *arpstrn* executable, from the ARPS root directory perform the following:

```
makearps -zxncar arpstrn or
makearps -zxpost arpstrn
```

The *-zxncar/-zxpost* flag invokes a link for either the NCAR Graphics library or the ZXPLLOT Graphics library, which allows for the plotting of the analyzed terrain fields upon execution of *arpstrn*. Option *-zxncar* can be used only when NCAR Graphics is installed.

To execute the module ARPSTRN set the list of parameters in the *arpstrn.input* file as are described in the next section. From the ARPS root directory perform the following:

```
bin/arpstrn < input/arpstrn.input > arpstrn.out &
```

A *.*trndata* terrain file is produced in the main directory and named with a prefix according to *runname* specified in *arpstrn.input*.

c) *Control parameters description for ARPSTRN*

This section provides a guide for setting the control parameters in the input file *arpstrn.input*, which is used by the analysis program ARPSTRN.

Control Parameters for Terrain Preprocessors (set in *arpstrn.input*)

<u>Parameter</u>	<u>Definition/Purpose</u>	<u>Options/Suggested Values</u>
<i>nx</i>	Number (non-dimensional, ND) of ARPS grid points in the ξ (or <i>x</i>) direction.	Same as in <i>arps.input</i> set for ARPS. Default = 67.
<i>ny</i>	Number of ARPS grid points (ND) in the η (or <i>y</i>) direction.	Same as in <i>arps.input</i> set for ARPS. Default = 67.

<i>dx</i>	ARPS grid spacing (m) in <i>x</i> -direction.	Same as in <i>arps.input</i> as is set for ARPS (see Chapter 4). Default = 1000.0.
<i>dy</i>	ARPS grid spacing (m) in <i>y</i> -direction.	Same as in <i>arps.input</i> as is set for ARPS (see Chapter 4). Default = 1000.0.
<i>ctrlat</i>	The latitude location (degrees north) of the center of model domain.	Same as in <i>arps.input</i> as is set for ARPS (see Chapter 4). Default = 35.0.
<i>ctrlon</i>	The longitude (degrees east) location of the center of model domain.	Same as in <i>arps.input</i> as is set for ARPS (see Chapter 4). Default = -100.0
<i>mapproj</i>	Map projection option (ND) used by ARPS model.	Same as in <i>arps.input</i> as is set for ARPS (see Chapter 4). Default = 0.
<i>trulat1</i> <i>trulat2</i>	1st true latitude (degrees north) of map projection. 2nd true latitude (degrees north) of map projection.	Same as in <i>arps.input</i> as is set for ARPS. Default = 30.0, 60.0
<i>trulon</i>	True longitude (degrees east) of map projection.	Same as in <i>arps.input</i> as is set for ARPS. Default = -100.0.
<i>sclfct</i>	Scaling factor (ND) for map projection.	Same as in <i>arps.input</i> as is set for ARPS. Default = 1.0.
<i>trnanxopt</i>	Option (ND) for the terrain data analysis schemes.	1 = Bilinear interpolation 2 = Biquadratic interpolation Default = 1.

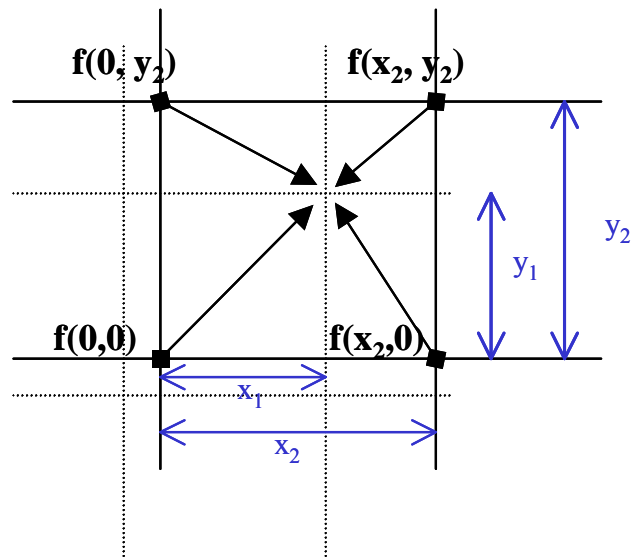
<i>trndataopt</i>	Type (ND) of maximum resolution terrain data desired by the user.	<p>1 = 1° global data (not implemented)</p> <p>2 = 5' global data (on the order of 10 km).</p> <p>3 = 30" global data (on the order of 1 km)</p> <p>4 = 3' data for contiguous U.S. states and Alaska</p> <p>Ideally, the resolution of the selected data is slightly higher than the model grid resolution.</p> <p>Default = 4.</p>
<i>fn_trndata</i>	File name of terrain data base file(s). (Not used by 3" or 30" data).	Character string in quotes. Not to exceed 80 characters in length.
<i>dir_trndata</i>	Directory of terrain data base file(s) to which the 30" and 3" terrain data are downloaded via ftp from the external site.	Character string in quotes. Not to exceed 80 characters in length.
<i>usgs_dem_index_fn</i>	The file containing the file name index of 3" USGS terrain data patches	(usually names <i>usgs_dem.index</i> or <i>europa_dem.index</i> and found in <i>src/arpstrn</i> directory)
<i>europa</i>	Flag to indicate whether the provided 3 second terrain data is over Europe or United States. Only valid for trndataopt = 4.	Integer flag. (See comments in file <i>arpstrn.input</i> for detail instructions.) = 0, 3s terrain data is over U.S. states and Alaska = 1, 3s terrain data is over Europe Default = 0.

<i>nsmth</i>	Number of times 9-point smoother is applied.	<p>[Note: comments on effect of number of smoothing passes? Is there an optimal number of passes?]</p> <p>Default = 1.</p>
<i>lat_sample, lon_sample</i>	Data sampling interval in latitude and longitude directions (arc seconds).	<p>The sampling interval should be comparable to the ARPS grid resolution.</p> <p>30" on lat. circle $\approx 920\text{m}$ 30" on long. circle $\approx 920 * \cos(\text{lat})$ [m]</p> <p>Default: lat_sample = 30 [m] lon_sample = 30 [m]</p>
<i>hctrinc</i>	Contour interval for the terrain height (in meters)	Default = 250m
<i>latgrid, longrid</i>	Plotting intervals between latitude and longitude grid lines.	<p>= 0.0, internally determined < 0.0, no grid lines > 0.0, interval number Default = 10. (lat. and long. lines are plotted every 10 degrees)</p>
<i>nmapfile</i>	Number of mapfiles used to provide political boundaries on terrain plots.	Detail of political maps (such as state or county boundaries) to be plotted depends on size of the physical domain.
<i>mapfile()</i>	File name of map data (e.g., <i>usstate.mapdata</i> , <i>spcounty.mapdata</i> , <i>worldcoast.mapdata</i>)	(map datasets are found in the <i>data/arpstpl</i> directory)
<i>terndmp</i>	Flag to dump ARPS terrain data file.	<p>0 = no terrain data file 1 = unformatted binary 3 = HDF4 (uncompressed) 7 = NetCDF format</p>

d) *Data analysis using bilinear and biquadratic interpolation*

ARPSTRN provides the choice of using either bilinear or biquadratic interpolation to analyze the terrain data to a given grid configuration and physical domain as defined by the user.

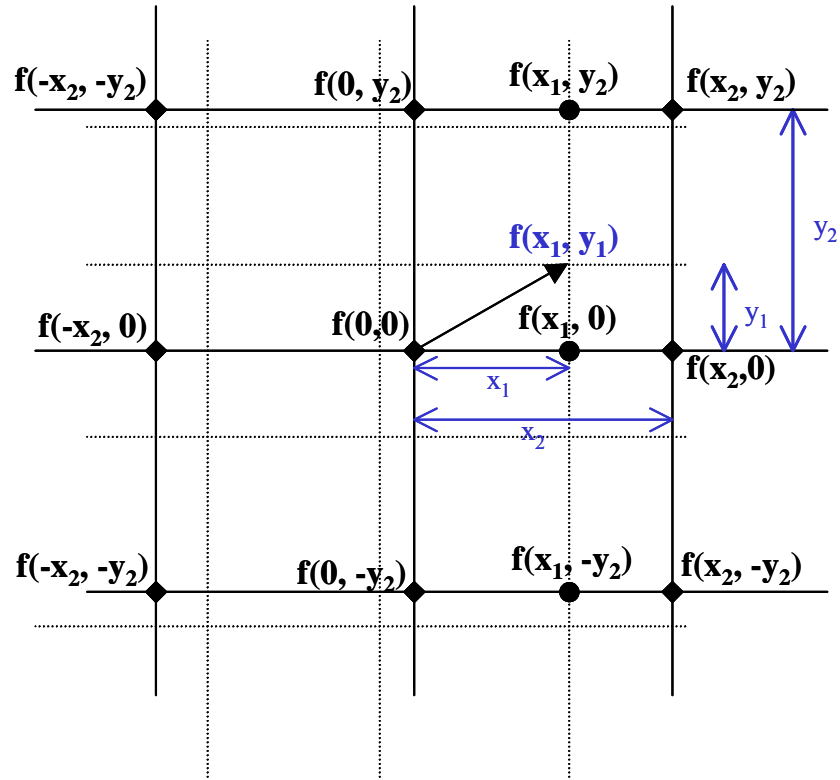
1. bilinear interpolation



Bilinear interpolation derives the value of terrain elevation for a gridpoint on the new grid by using a distance-weighted average of elevation for the four closest gridpoints from the original grid:

$$f(x_1, y_1) = \left(1 - \frac{x_1}{x_2}\right) \left(1 - \frac{y_1}{y_2}\right) f(0,0) + \frac{x_1}{x_2} \left(1 - \frac{y_1}{y_2}\right) f(x_2,0) + \frac{y_1}{y_2} \left(1 - \frac{x_1}{x_2}\right) f(0, y_2) + \frac{x_1}{x_2} \frac{y_1}{y_2} f(x_2, y_2)$$

2. Biquadratic interpolation



Biquadratic interpolation uses a distance-weighted average that considers the values of 9 neighboring gridpoints. The nearest gridpoint from the original grid, $f(0,0)$ is identified and used as the central reference point by which the following functions are defined:

$$f(x_1, y_2) = f(0, y_2) + \frac{1}{2} [f(x_2, y_2) - f(-x_2, y_2)] \left(\frac{x_1}{x_2} \right) + \frac{1}{2} [f(-x_2, y_2) - 2f(0, y_2) + f(x_2, y_2)] \left(\frac{x_1}{x_2} \right)^2$$

$$f(x_1, 0) = f(0, 0) + \frac{1}{2} [f(x_2, 0) - f(-x_2, 0)] \left(\frac{x_1}{x_2} \right) + \frac{1}{2} [f(-x_2, 0) - 2f(0, 0) + f(x_2, 0)] \left(\frac{x_1}{x_2} \right)^2$$

$$f(x_1, -y_2) = f(0, -y_2) + \frac{1}{2} [f(x_2, -y_2) - f(-x_2, -y_2)] \left(\frac{x_1}{x_2} \right) + \frac{1}{2} [f(-x_2, -y_2) - 2f(0, -y_2) + f(x_2, -y_2)] \left(\frac{x_1}{x_2} \right)^2$$

$$f(x_1, y_1) = f(x_1, 0) + \frac{1}{2} [f(x_1, -y_2) - f(x_1, y_2)] \left(\frac{y_1}{y_2} \right) + \frac{1}{2} [f(x_1, y_2) - 2f(x_1, 0) + f(x_1, -y_2)] \left(\frac{y_1}{y_2} \right)^2$$

[Note: the derivation of the above equations for biquadratic interpolation follows that as found at: <http://www.fho-emden.de/~hoffmann/bicubic03042002.pdf>]

8.3. Surface Characteristics Preprocessor

8.3.1. Introduction

The preprocessor program, ARPSSFC, prepares the surface characteristics data set for use in ARPS. The data are retrieved from a surface characteristics database and mapped to ARPS grid. The output parameters for ARPS include soil type, vegetation type, leaf area index and surface roughness.

8.3.2. Surface Characteristics Data Base

The original soil and vegetation data were obtained from the Global Ecosystems Database (GED) Version 1.0 on CD-ROM. The original data sets are in IBM PC format and were converted into ASCII integer files for use by ARPSSFC. The ASCII files were created using the following format:

```
integer colmn, rows      ! Columns and Rows
integer proj             ! Map projection type??
real resl               ! Resolution (degree??)
integer data(colmn,rows) ! Data array

WRITE(20, '(a20,i8,i8,e20.10,i8)')
&      title,colmn,rows,resl,proj
WRITE(20, '(20i4)')
&      ((data(i,j),i=1,colmn),j=1,rows)
```

The original data sets can be ordered from:

*National Geophysical Data Center
NOAA EGC/I
325 Broadway
Boulder, CO 80303-3328
Phone:(303) 497-6277*

email: ngdc.seginf@noaa.gov

<http://www.ngdc.noaa.gov>

The surface data in ASCII format as appropriate for use by ARPSSFC may be downloaded directly from the CAPS anonymous ftp site <ftp://caps.ou.edu/pub/ARPS/ARPS.data/arpssfc.data>. The following files are available:

soil type data

whsoil.data.gz - the data set is based on Wilson and Henderson-Sellers (1985) soil type classification. It has a spatial resolution of $1^\circ \times 1^\circ$ with global coverage.

soil_1km.data.gz - the State Soil Geographic (STATSGO) data are based on a digital soil association map developed by the National Cooperative Soil Survey and distributed by the National Resources Conservation Service of the U.S. Department of Agriculture. The data are of 1-km resolution and cover the contiguous U.S. states.

30s global top layer soil type data^{4,5} - Since ARPS5.2.2, the implementation for $30'' \times 30''$ global top layer soil type data set was added. It uses the same data set as WRFSI for soil types.

vegetation type data

owe14d.data.Z- the vegetation type data set is based on Olson *et al.* (1985) world ecosystems classification. It also has a spatial resolution of $1^\circ \times 1^\circ$ with global coverage.

naoge1_01l_1km.img.gz – a vegetation type data set that originates from the USGS North American 1-km data (1990). The original data were compiled from NOAA AVHRR satellite imagery by a joint collaboration among the USGS EROS Data Center and the Center for Advanced Land Management Information Technologies (CALMIT) at the University of Nebraska-Lincoln.

⁴ The implementation was provided by an outside user.

⁵ CAPS ftp server does not host this data set. It is available from ftp://aftp.fsl.noaa.gov/divisions/frd-laps/WRFSI/Geog_Data/soiltype_top_30s/ at the time of writing.

30s USGS global landuse data set⁶ – this data set was also added since ARPS5.2.2. It has a spatial resolution of 30" × 30" with global coverage and it is also used by WRFSI as vegetation types.

Normalized Difference Vegetation Index (NDVI)

ndviymm_10min.data.Z - Kidwell (1990) monthly NDVI data. *yymm* in the file name indicates the year and month of the data, e.g., *ndvi9006.data* is for June, 1990. The data covers a period from Jan., 1985 to Dec., 1990. The spatial resolution is 10' × 10' and is global in coverage.

nammmyndl_1km.img.gz – the USGS 1-km monthly data. The files are distinguished by month '*mmm*' (e.g., *jun* stands for June) and year '*yy*'.

vegetation fraction data

mm.gvegfract.gz – vegetation fraction data from NESDIS as derived from NDVI data using the methodology by Gutman and Ignatov (1998)

The files ending in *.gz must be unzipped using “gunzip”. The files ending in *.Z must be uncompressed using the UNIX command “uncompress”.

The above data sets are used by ARPSSFC to derive *soiltyp*, the soil type, *vegtyp*, the vegetation type, *lai*, the leaf area index and *roufns*, the surface roughness length. ARPSSFC first converts the soil and vegetation data into the categories consistent with ARPS. The soil and vegetation types and NDVI from the latitude / longitude grid are mapped onto the ARPS grid, by selecting values from the nearest data point (because the type classification is discrete). The leaf area index and surface roughness are derived from the vegetation type and NDVI on the ARPS grid then smoothed by a 25-point filter. In the following tables, the conversions from the original classification to the categories used in ARPS are given.

⁶ It is available from ftp://aftp.fsl.noaa.gov/divisions/frd-laps/WRFSI/Geog_Data/landuse_30s/ at the time of writing.

Table 8.1. Conversion of Soil Types from Wilson and Henderson-Sellers (1985) (1 degree) Soil Classes

USDA Soil Type Classes used by ARPS	Definition	W&H Soil cases
01	Sand	
02	Loamy sand	11 17 23
03	Sandy loam	14 20 26 27
04	Silt loam	
05	Loam	12 18 24
06	Sandy clay loam	15 21 28
07	Silty clay loam	
08	Clay loam	13
09	Sandy clay	19 25
10	Silty clay	16 22
11	Clay	29 30 31
12	Ice	34
13	Water	00

Table 8.2. Conversion of Soil Types from USGS STATSGO (1 km) Soil Classes

USDA Soil Type Classes used by ARPS	Definition	STATSGO Classes
01	Sand	
02	Loamy sand	
03	Sandy loam	
04	Silt loam	5 13
05	Loam	6
06	Sandy clay loam	7
07	Silty clay loam	8
08	Clay loam	9
09	Sandy clay	10
10	Silty clay	11
11	Clay	12 15 16
12	Ice	
13	Water	14

Table 8.3. Conversion of Soil Types from
30s 17-category USGS top layer Soil Classes⁷

USDA Soil Type Classes used by ARPS	Definition	17-category Soil Categories
01	Sand	1
02	Loamy sand	2
03	Sandy loam	3
04	Silt loam	4, 5
05	Loam	6, 13
06	Sandy clay loam	7
07	Silty clay loam	8
08	Clay loam	9
09	Sandy clay	10
10	Silty clay	11
11	Clay	12
12	Ice	15, 16
13	Water	14

⁷ Currently implementation, may be changed later. See comments in *src/arpssfclib.f90* for up-to-date information.

Table 8.4. Conversion to ARPS Vegetation Type from (1 degree) Olson World Ecosystem Classes

Vegetation Type	Definition	Olson World Ecosystem Classes	Grass/tree	Roughness
01	Desert	01 08 50 69 71	grass	0.002
02	Tundra	42 53	grass	0.020
03	Grassland	16 30 37 40 52	grass	0.010
04	Grassland with shrub cover	02 41 43 49	tree	0.100
05	Grassland with tree cover	58	tree	0.150
06	Deciduous forest	24 25 26 27 29 56 61	tree	0.750
07	Evergreen forest	06 20 21 22 23 46 47 48 57 60 62	tree	1.000
08	Rain forest	32 33 54	tree	2.000
09	Ice	17 70	grass	0.005
10	Cultivation	28 31 36 38 39 55	grass	0.020
11	Bog or marsh	44 45	grass	0.020
12	Dwarf shrub	59 63 64	grass	0.060
13	Semidesert	51	grass	0.040
14	Water	00 65 66 67 68 72 73	grass	0.001

Table 8.5. Conversion to ARPS Vegetation Type from (1 km) USGS Classes

Vegetation Type	Definition	USGS Classes	Grass/tree	Roughness
01	Desert	01 08 50 69 71	grass	0.002
02	Tundra	09 42 53	grass	0.020
03	Grassland	16 30 37 40 10 52 76 76 93	grass	0.010
04	Grassland with shrub cover	02 41 43 49 07 82 83 85 87 94	tree	0.100
05	Grassland with tree cover	18 58 91	tree	0.150
06	Deciduous forest	03 04 05 19 24-27 29 56 61 78 88 89	tree	0.750
07	Evergreen forest	06 20-23 34 46-48 57 60 62 77	tree	1.000
08	Rain forest	32 33 54 79 86 90	tree	2.000
09	Ice	17 70	grass	0.005
10	Cultivation	28 31 35 36 38 39 55 92	grass	0.020
11	Bog or marsh	13 44 45 74 75 80	grass	0.020
12	Dwarf shrub	12 59 63 64	grass	0.060
13	Semidesert	11 51 81 84	grass	0.040
14	Water	00 14 15 65-68 72 73	grass	0.001

Table 8.6. Conversion to ARPS Vegetation Type from 25-category USGS Classes (30")⁸

Vegetation Type	Definition	USGS index	Categories
01	Desert	23	Bare Grnd. Tundra
02	Tundra	20	Herb. Tundra
		21	Wooden Tundra
		22	Mixed Tundra
03	Gassland	5	Crop./Grs. Mosaic
		7	Grassland
04	Grassland with shrub cover	9	Mix Shrb./Grs.
		10	Savanna
05	Grassland with tree cover	6	Crop./Wood Mosc
06	Deciduous forest	11	Decids. Broadlf.
		12	Decids. Needlf.
		15	Mixed Forest
07	Evergreen forest	13	Evergrn. Braodlf.
		14	Evergrn. Needlf.
08	Rain forest		
09	Ice	24	Snow or Ice
10	Cultivation	2	Drylnd Crop. Past.
		3	Irrg. Crop. Past.
		4	Mix. Dry/Irrg. C.P.
11	Bog or marsh	17	Herb. Wetland
		18	Wooded wetland
12	Dwarf shrub	8	Shrubland
13	Semidesert	1	Urban
		19	Bar. Sparse Veg.
14	Water	16	Water Bodies

The Leaf Area Index, *lai*, is calculated from NDVI for herbaceous vegetation and trees, respectively. The relations between the NDVI and LAI for herbaceous vegetation (Asrar *et al.*, 1984) are:

⁸ Current implementation, may be changed later. See comments in *src/arpssfc/lib.f90* for up-to-date information.

$$lai = - \ln[1-NDVI / 0.915] / 0.83] / 0.96$$

and for trees (Nemani and Running, 1989):

$$lai = 1.625 \exp(NDVI / 0.34)$$

8.3.3. Description of ARPSSFC Program

The driver program for ARPSSFC is contained in file *arpssfc.f90* of the *src/arpssfc* directory. ARPSSFC shares with ARPS a number of utility subroutines and the compilation and linking are controlled by the same shell script *makearps* and the makefile *Makefile*. The calling tree of ARPSSFC is:

```

ARPSSFC +- INITPARA  +-+ GTLFNKEY
          |           +-+ JULDAY
          |           +-+ STRLNTH
          |           +-+ PRTLOG +-+ STRLNTH
          |                   +-+ RETUNIT
          +- SETGRD  +-+ SETMAPR
          |           +-+ LLTOXY
          |           +-+ SETORIG +-+ XYTOLL
          |                   +-+ LLTOXY
          +- XYTOLL
          +- GTSFCDT +-+ STRLNTH
          |           +-+ GETUNIT
          |           +-+ RETUNIT
          +- GTSOILTYP
          +- GTSFCDT
          +- GTVEGTYP
          +- GTSFCDT
          +- GTNDVI
          +- GTLAI
          +- SMOOTH25P
          +- GTRFNS
          +- SMOOTH25P
          +- WRTSFCP +-+ STRLNTH
          |           +-+ GETUNIT
          |           +-+ RETUNIT
          +- {OPNGKS}
          +- PLOT  +-+ {SET}
          |         +-+ {WTSTR}
          |         +-+ {SUPMAP}
          |         +-+ {CONREC}
          |         +-+ {FRAME}
          +- {CLSGKS}

```

Subroutines INITPARA and SETGRD are used to read in the input parameters from *arps.input* and set up ARPS computational grid.

To compile and run program ARPSSFC, enter the following:

```
makearps -ncarg arpsfc
bin/arpsfc < arps.input > arpsfc.output
```

where **makearps** is the general ARPS make shell script. Script **makearps** creates executable file *bin/arpsfc*.

A number of NCAR Graphics routines are called (those in {} in the calling tree) to generate graphic plotting of the surface property fields. When NCAR Graphics is not available, *-ncarg* option should be omitted in the **makearps** command. In this case, no graphic output will be generated.

Before the compilation and execution, a set of parameters must be set properly. They are described in the following subsection.

8.3.4. Control Parameters for ARPSSFC

The control parameters used by ARPSSFC are set in *arpsfc.inc* and *arps.input*. Table 8.3 describes the setting of these parameters. A complete definitions for those parameters is found in Chapter 4.

Parameters set in *arpsfc.inc* (Normally, it is not needed to be changed except that you know what you are doing).

<i>nsoiltyp</i>	Number of soil types. (The ARPS is currently set to use 13 soil categories).	Default=13
<i>nvegtyp</i>	Number of vegetation types. (The ARPS is currently set to use 14 vegetation categories).	Default=14
<i>gvnx</i>	Number of NESDIS green vegetation data points (east-west direction).	Default=2500
<i>gvny</i>	Number of NESDIS green vegetation data points (north-south direction).	Default=904

Table 8.3. Control Parameters for the Surface Property Data Preprocessor - ARPSSFC

Parameter	Definition	Options/Default setting
<i>nx</i>	Number of ARPS grid points in x direction	As for ARPS
<i>ny</i>	Number of ARPS grid points in y direction	As for ARPS
<i>dx</i>	Grid spacing (m) in ξ -direction.	As for ARPS
<i>dy</i>	Grid spacing (m) in η -direction.	As for ARPS
<i>ctrlat</i>	The latitude (degrees north) of the center of model domain.	As for ARPS
<i>ctrlon</i>	The longitude (degrees east) of the center of model domain.	As for ARPS
<i>mapproj</i>	Map projection option	As for ARPS
<i>trulat1</i> <i>trulat2</i>	True latitudes of map projection	As for ARPS
<i>trulon</i>	True longitude of map projection.	As for ARPS
<i>scfct</i>	Scaling factor for map projection	As for ARPS
<i>stypout</i>	Output flag for soil type data	1 = yes, 0=no
<i>vtypout</i>	Output flag for vegetation type data	1 = yes, 0=no
<i>laiout</i>	Output flag for leaf area index	1 = yes, 0=no
<i>rfnout</i>	Output flag for surface roughness	1 = yes, 0=no
<i>vegout</i>	Output flag for vegetation fraction	1 = yes, 0=no
<i>ndviout</i>	Output flag for NDVI	1 = yes, 0=no
<i>schmopt</i>	schemes for specifying soil and vegetation data	0 - 4
<i>sdatopt</i>	Option for selecting soil texture data sets	1 - 3
<i>vdatopt</i>	Option for selecting vegetation type data sets	1 - 3
<i>ndatopt</i>	Option for selecting NDVI data sets	1 - 2
<i>vfrcopt</i>	Option for selecting vegetation fraction data set	0 - 1
<i>nsmthsl</i>	Number of smoothing passes applied to <i>veg</i> , <i>ln</i> (roufhs) and <i>lai</i>	3
<i>drawval</i>	Option for NCARG to draw integer value at each grid point	1 = yes, 0=no
<i>fgbgni</i> , <i>fgendi</i> <i>fgbgnj</i> , <i>fgendj</i>	Beginning and ending indices in x-direction/y-direction to specify the foreground region when <i>schmopt</i> = 1, 2.	User specified

<i>fgstyp, fgvtyp</i> <i>fglai, fgrfns,</i> <i>fgveg,</i>	Constant values for the foreground when <i>schmopt</i> = 1, 2.	User specified
<i>bgstyp, bgvtyp,</i> <i>bglai, bgrfns,</i> <i>bfveg</i>	Constant values for the background when <i>schmopt</i> = 0, 1,	User specified
<i>fstypfl/bstypfl</i>	File name of vegetation class data	' <i>whsoil.data</i> '
<i>fvtypfl/bvtypfl</i>	File name of vegetation class data	' <i>owe14d.data</i> '
<i>fndvifl/bvtypfl</i>	File name of NDVI data	' <i>ndvi.data</i> '
<i>vfrcdr</i>	Directory name for vegetation fraction data set	
<i>lkupfl</i>	File name of look-up table (for <i>schmopt</i> = 4).	' <i>sfc_winter.tbl</i> '
<i>sfcdtfl</i>	File name of output surface property data for ARPS	' <i>arpssfcdt.data</i> '
<i>sfcfmt</i>	Data file format	1 = binary format 3 = HDF 4 format 7 = NetCDF format

8.4. Horizontally Homogeneous Model Initial State

ARPS can be initialized with a horizontally homogeneous initial state or a three-dimensionally varying analysis. In the horizontally homogeneous case (*initopt* = 1), six options are available. They are: initialization using an external sounding, specification of an isentropic atmosphere, an isothermal atmosphere, an atmosphere with constant static stability, the Weisman and Klemp (1982) analytic moist thermodynamic sounding, and an atmosphere with constant density & potential temperature and hydrostatic base state. The horizontally homogeneous options are described in detail in the following subsections and the corresponding code can be found in subroutine INIBASE. The three dimensional initialization procedure is presented in Section 8.5.

8.4.1. Initialization using external sounding (*inibasopt=1*)

A single column sounding file for ARPS contains the values of thermodynamic quantities, moisture and wind at either height or pressure levels. The data do not have to be equally spaced or defined at the model grid levels. When the data are not at the model grid levels, they are linearly (in height) interpolated to the model grid levels. It is important to note that the sounding data must cover the entire extent of the physical model domain.

Otherwise, extrapolation will be performed that might yield spurious results. It is recommended that the user check the sounding data after the interpolation. The printout of these data can be found in the standard output file or a separate sounding file (named *runname.sound*). The latter can be fed into your favorite sounding plotting program (*e.g.* Skew-T plot or Tephigram). Coming with the ARPS package, a program called KEWT is included to do Skew-T plot using either NCARG or ZXPLLOT plotting tools.

a) Example sounding

A sample input sounding file (provided in the ARPS release as *may20.snd*) is shown below (those inside [] are annotations). A sounding file must have exactly the same format as the example.

Sounding Input for ARPS					[header line, not used by model]
supercell storm					[description of sounding]
15:00:00 CST					[time of sounding]
20 May, 1977					[date of sounding]
FT. SILL, OK					[location of sounding]
'height' 'pot. temp.' 'rel. humidity' 'uv'					[data types (see below)]
0.0 0.965e5					[height (m) and pressure (pa) at ground level]
33					[number of data levels in sounding: lvlsnd]
Z, THETA, RH, U, V					[data column labels not used by ARPS]
16250.000	406.000	0.00000	14.000	-5.100	
15750.000	398.000	0.00000	15.000	-5.400	
15250.000	390.000	0.00000	16.000	-5.700	
14750.000	382.000	0.00000	17.000	-6.000	
14250.000	374.000	0.00000	18.000	-6.300	
13750.000	366.000	0.00000	19.000	-6.800	
13250.000	358.000	0.00000	20.000	-7.600	
12750.000	351.000	0.00000	21.000	-8.800	
12250.000	346.000	0.00000	21.800	-10.200	
11750.000	343.600	0.00000	22.600	-11.200	
11250.000	341.000	0.00000	23.400	-11.700	
10750.000	338.500	0.00000	24.000	-11.800	
10250.000	336.000	0.34960	24.400	-11.000	
9750.000	333.500	0.53010	24.300	-10.000	
9250.000	331.000	0.58590	23.700	-8.500	
8750.000	329.000	0.57420	22.400	-6.000	
8250.000	327.500	0.56300	20.400	-3.000	
7750.000	326.000	0.63030	18.400	1.000	
7250.000	324.600	0.63160	16.000	6.600	
6750.000	323.200	0.60140	13.400	11.400	
6250.000	321.800	0.64950	11.000	13.500	
5750.000	320.500	0.71920	8.600	14.100	
5250.000	319.000	0.77210	6.100	13.700	
4750.000	317.500	0.78080	3.600	12.500	
4250.000	315.500	0.76890	1.500	10.800	
3750.000	313.500	0.74610	-0.500	9.600	
3250.000	311.200	0.82920	-3.500	8.800	
2750.000	309.000	0.87740	-4.400	8.000	
2250.000	307.000	0.89300	-6.200	7.000	
1750.000	305.000	0.86640	-7.800	6.000	
1250.000	304.000	0.85490	-9.200	4.700	
750.000	303.000	0.80820	-10.400	2.000	
250.000	303.000	0.71020	-12.000	-3.000	
0.000	303.000	0.71020	-12.000	-3.000	

In the above example, the data are specified at 500 m increments. Their formats are described next. Please note that the data have to be given in the order of decreasing height or increasing pressure.

b) Sounding data types (see also subroutine SOUNDG):

In the sounding data file, the temperature and moisture variables can be specified at either height or pressure levels and in several types. The types are designated by character strings in the sixth record of the file. Only the first character of each string is examined (case insensitive), and for this reason the first character should not be left blank. The data types for height/pressure, temperature, moisture and winds, respectively, are:

Height AGL (meters, default)

Pressure (Pa)

Potential Temperature (K, default)

Temperature (K)

Specific Humidity (mixing ratio) (kg/kg, default)

Relative Humidity (nondimensional, ranging from 0 - 1).

Dew Point temperature (K)

X-y components (m/s)

Direction-speed (degree, m/s)

Knot-direction-speed(degree, knot).

In the example given, the base state is specified by potential temperature and relative humidity at height levels. The horizontal winds are given in their x and y velocity components. When the winds are given as direction and speed, the direction is the angle between the north and the direction from which the wind comes from (e.g., a $(u, v) = (10, 0)$ m/s wind will be given as direction = 270° , speed = 10 m/s). Pressure at height levels is diagnosed from the hydrostatic relation.

8.4.2. Isentropic Atmosphere (*inibasopt* = 2)

For an isentropic atmosphere with constant potential temperature θ_0 , other base state variables can be expressed as functions of height using the hydrostatic relation:

$$C_p \theta_0 \frac{\partial \bar{\pi}}{\partial \bar{z}} = -g$$

$$\bar{p} = p_0 \bar{\pi}^{-C_p/R}$$

$$\bar{\rho} = \frac{\bar{p}}{R_d \theta_0 \bar{\pi}}$$

Here the overbar indicates the base state variables. For this option, \bar{q}_v is set to zero and \bar{u} and \bar{v} are set according to the value of option *viniopt*. $\theta_0 = 300$ K is hardwired in the code (subroutine INIBASE).

8.4.3. Isothermal Atmosphere (*inibasopt* = 3)

For an isothermal atmosphere with constant temperature T_0 , we have the formulations for the other state variables as follows:

$$\bar{p} = p_0 \exp\left(-\frac{gz}{R_d T_0}\right),$$

$$\bar{\pi} = \left(\frac{\bar{p}}{p_0}\right)^\kappa,$$

$$\bar{\theta} = T_0 / \bar{\pi},$$

$$\bar{\rho} = \bar{p} / (R_d T_0),$$

where $p_0 = 10^5$ Pa. In the program, $\bar{q}_v = 0$ and \bar{u} and \bar{v} are set according to the value of option *viniopt*. $T_0 = 250$ K is hardwired in subroutine INIBASE.

8.4.4. Constant Static Stability Atmosphere (*inibasopt* = 4)

The state variables of a constant static stability ($N = \text{constant}$) atmosphere are given by

$$\bar{\theta} = \theta_0 \exp\left(\frac{N^2 z}{g}\right),$$

$$\frac{\partial \bar{\pi}}{\partial z} = -g / (C_p \bar{\theta}),$$

$$\bar{p} = p_0 \bar{\pi}^{1/\kappa},$$

$$\bar{\rho} = \bar{p} / (R_d \theta_0 \bar{\pi}),$$

where $N = 0.01 \text{ s}^{-1}$ and $\theta_0 = 300$ K.

8.4.5. Analytic Moist Thermodynamic Sounding (*inibasopt* = 5)

An analytic moist thermodynamic sounding after Weisman and Klemp (1982) is supported by ARPS. The potential temperature, and relative humidity are given in the following.

Define z_{tr} as the tropopause height, T_{tr} and θ_{tr} as the temperature and potential temperature at the tropopause level, respectively, and θ_0 as the surface potential temperature. Then, the vertical base state profiles of potential temperature $\bar{\theta}(z)$ and relative humidity $\bar{RH}(z)$ are given by:

$$\begin{aligned}\bar{\theta}(z) &= \theta_0 + (\theta_{tr} - \theta_0) \left(\frac{z}{z_{tr}} \right)^{5/4} && \text{if } z \leq z_{tr}. \\ \bar{\theta}(z) &= \theta_{tr} \exp \left[\frac{g}{C_p T_{tr}} (z - z_{tr}) \right] && \text{if } z > z_{tr}.\end{aligned}$$

and

$$\begin{aligned}\bar{RH}(z) &= 1 - \frac{3}{4} \left(\frac{z}{z_{tr}} \right)^{5/4} && \text{if } z \leq z_{tr}. \\ \bar{RH}(z) &= 0.25 && \text{if } z > z_{tr}.\end{aligned}$$

where $z_{tr} = 1.2 \times 10^4$ m, $T_{tr} = 213$ K, $\theta_{tr} = 343$ K, $\theta_0 = 300$ K can be reset using namelist parameters *htrop*, *ttrop*, *pttrop*, *ptground* respectively. A user can reset these values for a particular application. Finally, the water vapor mixing ratio below 1200 m (assumed mixed layer top, *mixtop*) is reset to 0.015 kg/kg (*qvmixed*). Again, the wind is set according to *viniopt*.

8.4.6. Hydrostatic base state with constant density and potential temperature (*inibasopt* = 6)

[*Need description here.*](#)

8.5. Initialization Using 3-D Analysis _____

8.5.1. Generalized data interpolator

Program EXT2ARPS interpolates data from a user-supplied 3-D analysis grid to ARPS grid. The user-supplied external data are typically read in from a file, which supplies the fields on the user's grid. These fields are must provide the ARPS variables (described below) and arrays of latitude and longitude coordinates of the user-supplied grid. The user-supplied data must cover a volume (horizontal and vertical extent) at least as large as the ARPS model. The interpolator will use linear, quadratic or cubic interpolation based

on user specification in both horizontal and vertical directions to properly place the data on the staggered ARPS grid and initialize the base state and perturbation fields. A smoother is applied to the ARPS fields to eliminate any noise due to the interpolation.

After the external data are interpolated to ARPS grid, the wind fields are adjusted to ensure that the anelastic mass continuity equation is satisfied. This has been found to be important in reducing the initial oscillations in the mass (pressure) field.

Currently supported external data sets are

ARPS data – The data from a coarse resolution run of ARPS. This option realizes a one-way nesting of ARPS runs and ARPS data can be in any ARPS supported data format. The program support MPI mode for this data source.

NMC NAM data – The data from NCEP NAM model in GRIBV1 format, *i.e.* the former ETA model outputs. EXT2ARPS can ingest several data sets from this data source.

Grid #212 – 40km resolution data defined over NCEP grid #212. A message passing mode of the program (**ext2arps_mpi**) for this data source has been implemented and tested.

Grid #218 – 12km resolution tiled data defined over NCEP grid #218. The tile information can be found at <http://www.emc.ncep.noaa.gov/mmb/research/tiles.218.html>. The program will determine the tiles to be read automatically.

NMC RUC data – The data from NCEP RUC model in GRIBV1 format. Several data sets from this source are supported:

Grid #87 – NMC RUC hybrid-B data defined over grid #87

Grid #211 – NMC RUC AWIPS data in grid #211

Grid #236 – NCEP native coordinate RUC2 data in grid #236 or NCEP isobaric RUC2 data in grid #236

NCEP GFS global data – The data from NCEP GFS global model, *i.e.* the former AVN global data in GRIBV1 format. Again several data sets from this source are supported:

Grid #2 – NCEP GFS global data in grid #2 ($2.5^{\circ} \times 2.5^{\circ}$)

Grid #3 – NCEP GFS global data in grid #3 ($1^{\circ} \times 1^{\circ}$). The program is also implemented to read data over a sub-region retrieved

from NOMADS (NOAA Operational Model Archive Distribution System).

NCEP/NCAR reanalysis data – NCEP/NCAR T62 reanalysis 1 data on Gaussian grid in GRIBV1 format.

NCEP-DOE global reanalysis 2 data – defined over grid #2 in GRIBV1 format.
See <http://www.cdc.noaa.gov/cdc/data.ncep.reanalysis2.html>.

NARR Regional reanalysis data – This is NARR 32km resolution reanalysis data defined over grid #221 and it covers North American region. The program reads "A" series data in GRIBV1. The static field, such as terrain heights, land cover etc, has to be read from an extra fixed field file, "AWIP32.fixed" which is defined over the same grid.

Other data sources – These data sources were implemented with earlier version of **EXT2ARPS** and they are still not tested with ARPS5.2. Users should use with care.

- OLAPS data
- GEMPAK RUC data
- GEMPAK ETA data
- COAMPS data
- GEMPAK RUC-2 data
- GEMPAK ETA data, grid #104

The steps required to process an external file are outlined below.

*a) Create executable **ext2arps***

Enter the command: **makearps ext2arps** or
makearps ext2arps_mpi

b) Modify ARPS input file

Before running **ext2arps**, ARPS input file must be edited for the ARPS run you are preparing. The grid set up, map projection parameters, and control parameters for history data dump of the model run are used by **ext2arps** as well as **arps**.

If you want to use **ext2arps** to generate boundary conditions for ARPS, in addition to the history files that can be used to initialize the model,

set the variable *exbcdmp* to 1 in the NAMELIST block *output*. Before running **arps** you will likely want to reset *exbcdmp* to 0.

The NAMELIST block *extdfil* contains variables that describe the directory of the input file, the external file's names and the valid time of the data in the files. These parameters are used to specify your external data sets and will be passed to the specific data reader. Their definitions can be found in Chapter 4.

c) Run *ext2arps*

Finally, issue command

ext2arps < *arps.input* >! *ext2arps.out*

to execute program EXT2ARPS.

The program will create one or a set of history files (depending on how many external data sets you specify in *arps.input* - the value of *nextdfil*). These files can be used to initialize the model (for initialization option *initopt* = 3) at the desired time. The format and directory of the history file are set in *arps.input*. If *exbcdmp* = 1, external boundary condition file(s) are created at the same time.

8.5.2. Control parameters for EXT2ARPS

This section provides a guide for setting the control parameters in the input file *arps.input*, which is used by the data interpolation program EXT2ARPS. There are two parts for these control parameters. The first part is those that are shared with the program *arps*. The second part is those specific parameters used only by program *ext2arps*. Summary of those two parts are provided in Table 8.4 and Table 8.5 respectively. The detailed definitions can be found in Chapter 4.

Table 8.4. Common Control Parameters for both
ARPS and EXT2ARPS in *arps.input*

Parameter	Definition	Options/Default setting
<i>nx</i>	Number of ARPS grid points in x direction	As for ARPS
<i>ny</i>	Number of ARPS grid points in y direction	As for ARPS
<i>nz</i>	Number of ARPS grid points in z direction	As for ARPS
<i>nocmnt</i>	Number of comment lines	As for ARPS
<i>cmnt</i>	Comments for ARPS data files	As for ARPS
<i>runname</i>	String containing the pertinent information for this run	As for ARPS
<i>runmod</i>	Option for configuring the model geometry	1 = 3-D run
<i>initime</i>	String corresponding to the model time zero. This is usually the first external data file time.	'19977-05-20.21:00:00'
<i>ternopt</i>	Model terrain option. Set <i>exttrnopt</i> below.	2 = read in from file
<i>terndta</i>	Name of the terrain data file for <i>ternopt</i> = 2	'arpstern.dat'
<i>ternfmt</i>	Format of the terrain data file	1 = Fortran unformatted 2 = HDF4 (uncompressed) 3 = NetCDF format
<i>dx</i>	Grid spacing (m) in ξ -direction.	As for ARPS
<i>dy</i>	Grid spacing (m) in η -direction.	As for ARPS
<i>dz</i>	Grid spacing (m) in ζ -direction.	As for ARPS
<i>strhopt</i>	Option for vertical grid stretching	As for ARPS
<i>dzmin</i>	Minimum grid spacing (m) in the vertical direction	As for ARPS
<i>zrefsfc</i>	Reference: height (m) of the model bottom boundary	As for ARPS
<i>dlayer1 /dlayer2</i>	The depth of layer 1 and layer 2 for vertical stretching	As for ARPS
<i>strhtune</i>	Tuning factor for stretching option 2	As for ARPS

<i>zflat</i>	The height (m) at which grid levels become flat	As for ARPS
<i>ctrlat</i>	The latitude (degrees north) of the center of model domain.	As for ARPS
<i>ctrlon</i>	The longitude (degrees east) of the center of model domain.	As for ARPS
<i>mapproj</i>	Map projection option	As for ARPS
<i>trulat1</i> <i>trulat2</i>	True latitudes of map projection	As for ARPS
<i>trulon</i>	True longitude of map projection.	As for ARPS
<i>sclfact</i>	Scaling factor for map projection	As for ARPS
<i>tbc/bbc</i>	Option for the top and bottom boundary	As for ARPS
<i>fftopt</i>	Fast Fourier Transform method for use as <i>tbc</i> = 4	As for ARPS
<i>soilmodel_option</i>	Option for soil model scheme	As for ARPS
<i>nzsoil</i>	Number of soil layers for <i>soilmodel_option</i> = 2	As for ARPS
<i>dzsoil</i>	Averaged vertical grid spacing for <i>soilmodel_option</i> = 2	As for ARPS
<i>nstyp</i>	Number of soil types per grid point	As for ARPS
<i>dmp_out_joined</i>	Flag indicating the final ARPS output file form. Used only in MPI mode.	0 = ARPS output files in split files 1 = ARPS output files in one large joined file
<i>hdmpfmt</i>	Option for history data file format	As for ARPS
<i>hdfcompr</i>	Option for HDF4 compression	As for ARPS
<i>dirname</i>	Name of directory into which output files are written	As for ARPS
<i>exbcdmp</i>	Option to dump ARPS external boundary data files	As for ARPS
<i>exbhdfcompr</i>	HDF4 compression option for <i>exbcdmp</i> = 3	As for ARPS
<i>filcmprs</i>	Option to compress the history dumping files	As for ARPS
<i>readyfl</i>	Option for a marker file to indicate that writing of the history file has done	As for ARPS
<i>grdout</i>	Option for grid output	1 = yes, 0 = no
<i>basout</i>	Output option for base state fields	1 = yes, 0 = no
<i>varout</i>	Output option for perturbation fields	1 = yes, 0 = no
<i>mstout</i>	Output option for moist variables	1 = yes, 0 = no
<i>iceout</i>	Output option for ice variables	1 = yes, 0 = no
<i>tkeout</i>	Output option for TKE	1 = yes, 0 = no
<i>trbout</i>	Output option for turbulence field (km)	1 = yes, 0 = no
<i>rainout</i>	Output option for surface accumulated rainfall	1 = yes, 0 = no
<i>sfcout</i>	Output option for soil model variables	1 = yes, 0 = no

<i>landout</i>	Output option for soil and vegetation property arrays	1 = yes, 0 = no
<i>prcout</i>	Output option for precipitation rates	1 = yes, 0 = no
<i>radout</i>	Output option for radiation arrays	1 = yes, 0 = no
<i>flxout</i>	Output option for surface fluxes	1 = yes, 0 = no
<i>qcexout</i>	Output option for <i>qc</i> array in EXBC file	1 = yes, 0 = no
<i>qrexout</i>	Output option for <i>qr</i> array in EXBC file	1 = yes, 0 = no
<i>qiexout</i>	Output option for <i>qi</i> array in EXBC file	1 = yes, 0 = no
<i>qsexout</i>	Output option for <i>qs</i> array in EXBC file	1 = yes, 0 = no
<i>qhexit</i>	Output option for <i>qh</i> array in EXBC file	1 = yes, 0 = no
<i>soildmp</i>	Flag to dump ARPS soil data files	0 = no soil data files; 1 = Fortran unformatted; 3 = HDF 4 dumps; 7 = NetCDF format
<i>terndmp</i>	Flag to dump ARPS terrain data file	As for <i>soildmp</i>

Table 8.5. Control Parameters used only by program **EXT2ARPS** in *arps.input*

Parameter	Definition	Options/Default setting
<i>extdopt</i>	Option for external data sources	0
<i>extdfmt</i>	Format for external data sources (valid only when <i>extdopt</i> =0)	As for <i>hdmpfmt</i>
<i>nextdfil</i>	Number of external data file to be processed	Problem dependent
<i>extdtime</i>	Time string corresponding to each external data file	'1977-05-20.21:00:00+03:00:00'
<i>iorder</i>	Option for polynomial interpolation schemes	1-3, 3 is recommended
<i>intropt</i>	Number of ARPS grid points in y direction	1-2, 1 is default
<i>nsmooth</i>	Number of smoothing passes after interpolation	1 is default
<i>ext_lbc</i>	Option to apply lateral boundary conditions to the winds	1 = yes, 0 = no
<i>ext_vbc</i>	Option to apply vertical boundary conditions to w	1 = yes, 0 = no
<i>exttrnopt</i>	Option for terrain in the ARPS grid	0-2, 0 is default
<i>extsfcopt</i>	Option for near surface interpolation	0-1, 1 is recommended
<i>extntmrg</i>	Terrain merge zone in number of grid points when <i>exttrnopt</i> = 2	7
<i>dir_extd</i>	Name of directory which contains the external data file to be processed	'./'
<i>extdname</i>	Prefix string of external file names	'may20'
<i>grdbasopt</i>	Flag for grid and base file outputs for ARPS history files. It was added recently for I/O efficiency of large problem.	0

8.5.3. Using Other External Data Sets in EXT2ARPS

Program **EXT2ARPS** is capable of being extended to support any user-supplied 3-D data as long as certain conditions are met (as outlined below). In this section, steps for decoding GRIBV1 format files are outlined. For any other data formats, users should either write their own decoders or link the existing decoders to the program. For this purpose, the C shell script *makearps* should be modified to add any new libraries to the library list (**LIBS**) if they have not already been there.

The steps required to add an external file support are outlined below.

a) *Prepare include/gribcst.inc*

The file *gribcst.inc* defines the GRIB dimension parameters and the external fields that will be read and processed by the GRIB dataset decoder. It is used in file *getextd3d.f90*. Each external grid is defined in one block. You can add one extra block for the specific grid based on any existing ones in that file.

b) *Prepare getextd3d.f90*

A new subroutine should be created based on any of the existing ones, such as subroutine *getnmceta212*, subroutine *getnmcru211* or subroutine *getnarr221* etc. in the file *getextd3d.f90*. The purpose of this new subroutine is to read from the desired database and fill the output arrays with the read-in data. All these subroutines first construct the external data file name using the namelist specifications, which are passed in from the main program *ext2arps*. Then it calls *rdnmcgrb*, the GRIBV1 decoder, to decode the provided files. At last, the output arrays are filled from the extracted 2-D data set *var_grb2d* or the extracted 3-D data set *var_grb3d*. The data must be returned on an unstaggered grid, so some interpolation of the original data may be necessary. The units of your input data may need to be changed to match the ARPS units, which are specified below:

<i>p_ext</i>	Pressure (Pascal)
<i>hgt_ext</i>	Height (m)
<i>t_ext</i>	Temperature (K)
<i>qv_ext</i>	Mixing ratio (kg kg ⁻¹)
<i>u_ext</i>	Eastward wind velocity (ms ⁻¹)
<i>v_ext</i>	Northward wind component (ms ⁻¹)
<i>qc_ext</i>	Cloud water mixing ratio (kg kg ⁻¹)
<i>qr_ext</i>	Rain water mixing ratio (kg kg ⁻¹)
<i>qi_ext</i>	Ice mixing ratio (kg kg ⁻¹)
<i>qs_ext</i>	Snow mixing ratio (kg kg ⁻¹)

<i>qh_ext</i>	Hail mixing ratio (kg kg ⁻¹).
<i>tsoil_ext</i>	Soil temperature (K)
<i>qsoil_ext</i>	Soil moisture (m ³ m ⁻³)
<i>wetcanp_ext</i>	Water content on canopy (kg m ⁻²)
<i>snowdpth_ext</i>	Snow depth (m)
<i>trn_ext</i>	Terrain height (m)
<i>psfc_ext</i>	Surface pressure (Pascal)
<i>soiltyp_ext</i>	Soil type in categories
<i>t_2m_ext</i>	Temperature at 2m AGL (K)
<i>qv_2m_ext</i>	Specific humidity at 2m AGL(kg kg ⁻¹)
<i>u_10m_ext</i>	East wind velocity at 10m AGL (m s ⁻¹)
<i>v_10m_ext</i>	North wind velocity at 10m AGL (m s ⁻¹)

NOTES:

1) The winds should be earth relative (that is eastward and northward, which may not be the same as *u* and *v* relative to the *x* and *y* coordinates of the source grid).

2) If the cloud, rain, ice, snow or hail mixing ratios are not available they should be set to -999., and EXT2ARPS will set them to zero in the ARPS file. Filling the arrays with zero in RDEXTFIL will achieve the same effect, but less efficiently.

3) If the surface fields are available, such as *t_2m_ext*, *qv_2m_ext*, *u_10m_ext* and *v_10m_ext*, you can set *extsfcopt* = 1 to get more accurate surface interpolations. Otherwise *extsfcopt* must be 0.

Map projection information for the external grid should also be provided as described by the following variables:

<i>iproj_ext</i>	Projection number of external grid
<i>trlon_ext</i>	True longitude of external map projection (degrees east) (longitude line parallel to the - <i>y</i> coordinate)
<i>latnot_ext(2)</i>	Latitude(s) where projection is true, that is where the projection surface intersects the sphere, (<i>latnot_ext(2)</i> is only used when <i>iproj_ext</i> = 2 or -2)
<i>x0_ext</i>	<i>x</i> coordinate of origin for external grid (m)
<i>y0_ext</i>	<i>y</i> coordinate of origin for external grid (m)

c) Prepare *src/ext2arps/ext2arps.f90*

In file *src/ext2arps/ext2arps.f90*, there are two *SELECT* statements with *extdopt* as parameters. You should add one new *CASE* block into each of the *SELECT* block. The first added *CASE* block just sets the dimensions of the external grid. The second *CASE* block should call the new subroutine added

above just as all other *CASE* blocks have done. Of course, you should assign an unused case number for parameter *extdopt*. Then you can use this sequential number to represent your new source grid to set the control parameter *extdopt* in the namelist file when running *ext2arps*.

d) *Modify makearps and src/ext2arps/Makefile*

You may need to add references to your database libraries or other routines needed for successful linking. Add any subroutines to the compilation list and the link list (E2AOBJS1) inside *src/ext2arps/Makefile*, and add any new libraries to the library list (LIBS) in *makearps*.

e) *Compile and run ext2arps as usual*

At last, you can compile and run *ext2arps* just as what you have done before with any other supported data sources. Just remember to set the control parameter *extdopt* to the newly added number.

8.6. Time-Dependent Boundary Conditions

ARPS has the capability of forcing the lateral boundary solutions using an external data set. The external data may come from another model or from a coarser resolution run of ARPS. The latter practice can be referred to as one-way interactive nesting, which will be discussed more in next subsection.

A relaxation boundary condition similar to that discussed by Davies (1983) is employed in ARPS. With this scheme an extra forcing term of the form

$$\frac{\partial \bar{\rho}\phi}{\partial t} = -K_b \bar{\rho}(\phi - \phi_e) \quad (8.6.1)$$

is added to the right hand side of u, v, θ, p and water/ice variable equations. In Eq. (8.6.1), ϕ represents a prognostic variable and ϕ_e is the corresponding external data value. In ARPS, ϕ_e is a value linearly interpolated between two times when external boundary condition data are available.

The relaxation coefficient K_b is defined as,

$$K_b = \frac{K_{b0}}{1 + [2(i - i_b) / (n_b - 1)]^2} \quad \text{for } |i - i_b| \leq n_b - 1$$

or $K_b = 0.0 \quad \text{for } |i - i_b| > n_b - 1 \quad (8.6.2)$

where K_{b0} is the maximum relaxation coefficient at the boundary, n_b the width of the relaxation zone in terms of the number of grid points, i the grid index and i_b the index of boundary grid point. Apparently K_b is non-zero only within a zone near the lateral boundaries, and decreases from its maximum value at the boundary to 1/5 of this value at the inner edge of this zone. This relaxation procedure forces the model boundary solution towards the external value.

To control noise that might be produced by the inconsistency between the interior model solution and the externally forced value, enhanced computational mixing can be added in the boundary zone. This mixing has the same formation as the second order horizontal computational mixing as described in Section 6.4, and is given by:

$$\frac{\partial \bar{\rho}\phi}{\partial t} = K_c \left[\frac{\partial^2 \bar{\rho}(\phi - \phi_e)}{\partial \xi^2} + \frac{\partial^2 \bar{\rho}(\phi - \phi_e)}{\partial \eta^2} \right] \quad (8.6.3)$$

The coefficient K_c has the same form as K_b given in (8.6.2). Chapter 4 provides the suggested values for K_{b0} , K_{c0} and n_b . It also describes the way to specify external boundary condition files. The external boundary condition files can be produced at the same time as history data are written by DTADUMP. A data conversion program, EXT2ARPS, that prepares the external boundary condition files for ARPS from external data sets is described in Section 8.5.

Given that ARPS has the capability of using time-dependent external boundary conditions, as discussed in Section 8.6, it is straightforward to run ARPS in a self-nested mode. This is discussed in Section 7.5.