14.4 A GRAPHICAL USER INTERFACE TO PREPARE THE STANDARD INITIALIZATION FOR WRF

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1. INTRODUCTION

The Weather Research and Forecasting (WRF) model is slated to be the next operational meso-scale weather forecast model for the U.S. The Forecast Systems Laboratory (FSL) has developed the WRF Standard Initialization (SI), an important and necessary first step in setting up WRF. The SI provides three mandatory functions: 1) to define and localize a three-dimensional grid, 2) to specify the 'static' surface characteristics of land, water, and vegetation, and 3) to provide the initial and lateral boundary condition files by interpolating larger scale model data to the domain.

These are complicated processes that have been greatly simplified by the development of a WRF graphical user interface (GUI).

The primary objective of this paper is to describe the WRF GUI and provide an understanding of its functionality. The GUI helps the user run all SI processes to generate domains, process initial and lateral boundary condition data, and create display graphics. Details of the GUI software and directory structure are presented in section 2. Section 3 describes the design and layout and gives an example for setting up and localizing a domain over Australia, including a discussion about creating initial and lateral boundary condition data. Future work is discussed in section 4. A brief summary is found in section 5.

The design of this GUI was influenced by applications that FSL evaluated during this development, including: the Air Force Weather Agency (AFWA) System GUI and the National Center for Atmospheric Research (NCAR/ARMY) MM5 GUI.

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2. SOFTWARE

To build the WRF GUI, download the WRF SI tar file via the WRF web site: http://wrf-model.org/si, compile, and install. Installation is accomplished by manually running a script that is provided. The installation requires some understanding of the SI system design that is detailed in the information file called README found in the tar file.

2.1 *Selecting Perl/Tk*

Perl is the language used to configure WRF scripts. Configuration requires environment and file variables to be set prior to being run as well as setting many command-line arguments. Setting all these parameters can be a complex task. To assist the user, a GUI was developed. Many languages and tools were considered to develop the GUI and were evaluated.

Perl/Tk was the tool selected because:

- compatibility with the existing SI Perl scripts
- portability to Unix and Windows platforms
- ease in building GUI using rich widget set
- ability to work with web language (CGI, etc.)
- open source, well supported.

2.2 *Required software*

Required software for the GUI is: C, Perl, Perl/Tk, and NCAR Graphics. The projection mapping software, key to determining a model domain, is written in C. The C compiled software allows for faster code than would be possible in Perl since it is, generally, interpreted code.

The Tk extension to Perl does not come with the standard Perl distribution. If this is not already on your system, it is recommended that your system administrator install Perl/Tk.

Required software for the SI (run by the GUI) is: Fortran, C, and Perl. The SI software is written in Fortran, Fortran90, and C. It is fully dynamic by vir-

tue of the Fortran namelist files containing variables such as entries for domain size, etc. Much of the software comes from the FSL Local Analysis and Prediction System (LAPS). LAPS has been in existence for many years, and the grid localization software is particularly robust. This software is used by many researchers and operational weather centers. It has been tested on numerous computer platforms and tested for domains that cover the poles and cross the dateline.

2.3 *Directory Structure*

The SI is designed to allow significant flexibility achieved using three primary directory structures: one for the source software, one for the installed executables, and one for the output data. This is implemented using environment variables where the source software directory is called SOURCE_ROOT, the executable files directory is called INSTALLROOT, and the data directory is called DATAROOT. In a typical SI implementation, the SOURCE_ROOT and INSTALLROOT share the same directory. Users should ensure that there is ample disk space in DATAROOT to accommodate localization output which can be quite large.

3. GUI LAYOUT AND DESIGN

The GUI described here is customized for WRF, and a banner image is displayed upon start-up as shown in Fig. 1. The GUI automatically determines a WRF realization through a simple evaluation of the system. We allow this capability because other weather analysis and forecasting systems can use this GUI to configure and localize domains (e.g. LAPS).

3.1 *Application Layout*

The overall GUI design includes suppressing detail and complexity until the user needs it. As such, some controls are disabled and others are not displayed until they are relevant to the user accomplishing a task. Tool tips (small information boxes) are also displayed when the user places the cursor on certain widgets within the application.

Displaying a lot of information in a small space is a big challenge in a GUI application. The tabbed panel approach, where tabs are located across the top of each panel, simplifies the overall layout. It allows the application to have many panels of information, but allows only one to be shown at a time. An additional advantage of the tabbed panel approach is sequential navigation.

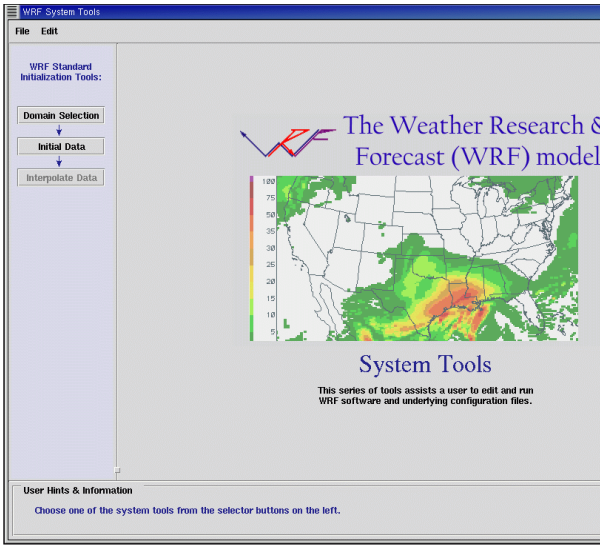

Figure 1. Display of WRF GUI application at start-up.

The GUI is designed to present graphical tools that can completely run all of the SI processes in a robust manner that makes sense to the users of the application. Users can bypass very complicated procedures, especially for those unfamiliar with scripting.The GUI provides a set of default values to simplify the user interaction. Users can get useful results setting up WRF without otherwise knowing how to proceed from scratch.

The application's GUI window layout consists of process buttons from the *tool selector* to the left of the window and a display containing the *editing tool* interface to the right of the window. Always present in the GUI window is the standard menubar at the top of the window. The user can exit the application or query the help pages and version information by selecting options found on the **File** and **Help** buttons of the menu bar. At the bottom of the GUI window a **Hints & Information** area sometimes suggests steps to be taken, and other times summarizes the success status of the step that has recently been completed (Fig. 1).

There are several components to the SI and a specific sequence of steps that need to take place. The buttons of the tool selector (Figs. 1 and 15) with arrows direct the user in moving through these steps. The steps are: **Domain Selection**, **Initial Data**, and **Interpolate Data**. When a user presses a button from the *tool selector*, a corre-

sponding *editing tool* interface is displayed (to the right).

Domain localization and creation of the static surface characteristics file are realized in the **Domain Selection** editing tool interface (sec. 3.2). The creation of initial and lateral boundary condition files is achieved in a two-part task; the first part, acquiring data, is realized with the **Initial Data** editing tool interface (sec. 3.3), and the second part, interpolating data to the domain, is accomplished with the **Interpolate Data** editing tool interface (sec. 3.4).

3.2 *Domain Selection Interface*

The phrase *domain localization* with respect to WRF SI means to complete the following tasks:

- Prepare the directory structure where the SI data will be written.
- Choose a rectangular domain on earth, with a fixed center point and projection type.
- Edit the domain specifications for the number of grid points, the grid spacing, the standard latitude and standard longitude, and to ensure that the resulting map covers the desired area with this set of parameters.
- Determine the vertical grid and the distribution of vertical levels.
- Set the directory paths to access geography datasets including: terrain, land-use, greenness fraction, albedo, top and bottom layer soil types, deep soil mean temperature, maximum snow albedo, and terrain slope index.
- Run the localization scripts.
- Generate latitude and longitude pairs for all grid points and process the geography data onto the domain grid.
- Verify that the localization is correct.

The ***Domain Selection*** editing tool interface has the following six panels: *Domain, Horizontal Grid, Vertical Grid, Localization Parameters, Localize Domain,* and *Domain Graphics* (Figs. 2-11). The order in which the panels appear reflect the order in which the steps of localization need to be performed, starting from the left and proceeding to right. Below the panels are two control buttons: **<Back** and **Next>** for the user to navigate step-by-step through an otherwise complicated process with instructions and choices specified as needed.

3.2.1 *Domain Panel*

The *Domain* panel (Figs. 2-4) initiates the first part of the domain localization process. Users must choose from four options on the pull-down menu under the instruction '***Choose what you want to do***'. These options allow users to create, load, copy, or delete a domain. After a domain is created, only then can it be edited, copied, or deleted.

To serve as a learning tool for a new user, the SI installation automatically creates a demonstration domain, called *default*. By loading the *default* domain into the GUI, a user can learn about the steps of domain localization by advancing through the *Domain Selection* interface. Note that the *default* domain cannot be modified or deleted; however, it can be copied to a new domain that can be edited.

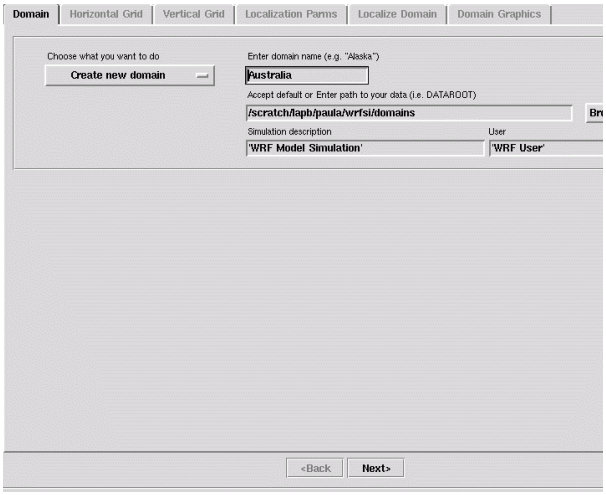

Figure 2. Display of Domain Selection Interface showing the Domain panel.

Within the *Domain* panel are four entry box fields for entering: 1) the domain name, 2) the path to your data, called DATAROOT, (with a file Browser widget), 3) a simulation description, and 4) a user description. The primary purpose of the *Domain* panel when creating or editing a domain, is to set key WRF SI environment variables, specifically the MOAD_DATAROOT, a domain identifier that is used in many of the SI scripts. This variable is actually a directory that is created by appending the DATAROOT with the *domain name*. Fig. 5, for example, shows an area encompassing Australia with *Australia* entered as its domain name. In this case, since the DATAROOT is */home/wrf/wrfsi/domains,* then the MOAD_DATAROOT would become */home/wrf/wrfsi/domains/Australia*.

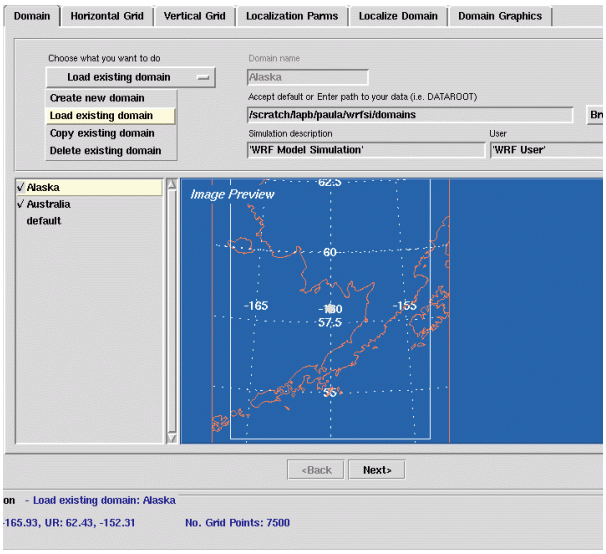

Figure 3. Display of Domain panel showing "Load existing domain" mode. Notice that there is a preview image of the domain.

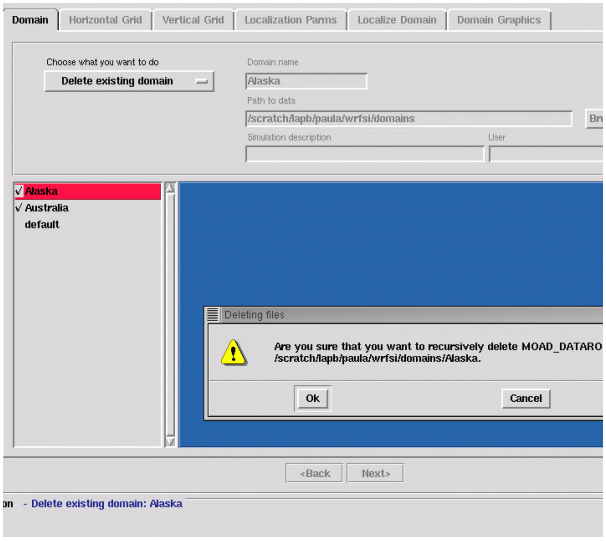

Figure 4. Display of Domain panel showing "Delete existing domain" mode.

To edit an existing domain, choose the *'Load'* option from the pull-down menu shown on the *Domain* panel under the instruction '***Choose what you want to do'***. Then, choose a domain of interest from the list of available domains. This loads an existing domain into the GUI. Everything about an existing domain can be modified except for its name.

To create a new domain from an existing domain, choose *'Copy'* from the list of pull-down menu options, then choose a domain of interest. A name for the copied domain is created from the original name by appending a case number. For example, if *Australia* were selected by the user to be copied, its automatic domain name would be *Australia_001*, with a limit of 999 cases. The user is free to edit any parameter for this domain including its name.

To delete a domain, choose '*Delete'* from the list of pull-down menu options. Subsequently, choosing a domain of interest will highlight the domain selection in red, then ask the user to confirm this action before 'remove' is performed.

3.2.2 *Horizontal Grid Panel*

The Horizontal Grid panel interface (Fig. 5) allows the user to define a model domain by drawing a bounding box on a map (left side) and editing map projection variables (right side). The map initially shows a Cylindrical Equidistant projection of the world centered at Latitude 0 and Longitude 0. The entire global map is not displayed, but the panel has a sliding scroll bar on the bottom and right sides to reposition it in the panel. The map can be increased or decreased in size by pressing the appropriate zoom-in or zoom-out buttons. The map projection's interface (the right side of Figs. 5-7) is used to set the political background map, projection type, and center point values.

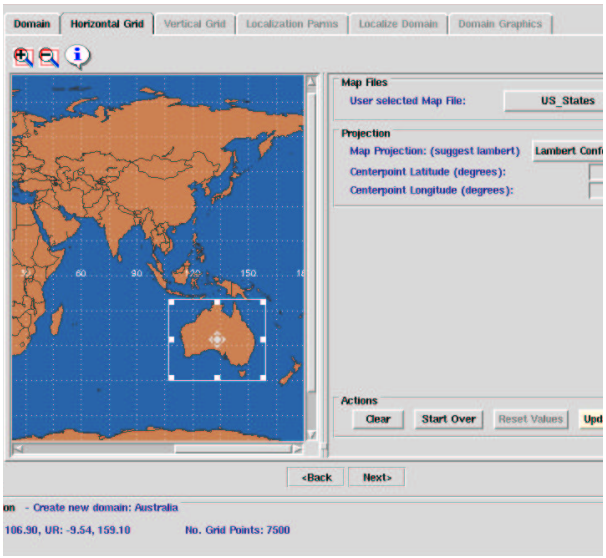

Figure 5. Display of Horizontal Grid panel.

As the user presses mouse button 1, on the global map, and drags the mouse to a new location, a white domain bounding box will be drawn that specifies the domain. Status information will be displayed in the **Hints & Information** panel, specifical-

ly, the lower left (LL) and upper right (UR) corner latitudes and longitudes and the total number of X, Y grid points in the selected domain.

As the domain bounding box is moved or resized, the map projection values will update. Likewise, the user can type in the map projection center point values or grid size and the domain bounding box display will update.

The SI satisfies global domain localizations for three commonly used map projections: Lambert Conformal (both tangent and secant), Mercator, and Polar Stereographic. Basic understanding of map projections is valuable but not mandatory because the GUI has built-in criteria to suggest to the user a projection type based on the domain's center point latitude value. For example, the **Map Projection** label (Fig. 6) suggests using Lambert Conformal based on center latitude of 63 degrees, but Polar Stereographic could be chosen instead, if desired.

Validation checks of user entered values are integral to the GUI. If errors are detected, a warning dialog box will appear suggesting steps for the user to take. A button that is highlighted in the color yellow (Fig. 5) indicates that this button needs to be pressed before continuing.

At the bottom of the map projection's interface are four action buttons: *Clear, Start Over, Reset Values,* and *Update Map.* The **Update Map** button will draw a new map from a domain bounding box and grid values. The **Start Over** button will undo all commands that updated the originally drawn domain bounding box into a domain map. The **Clear** button erases the domain bounding box, returns to the global map and resets all widget values. The user can fine-tune the domain bounding box and, again, press **Update Map** to commit these changes or press **Reset Values** to cancel the pending changes.

When the user presses **Update Map,** both the map and map editing interface of the Horizontal Grid editor update. The map (as seen in the change from Fig. 5 to Fig. 6). is now displayed in projection space based on user-selected information. The lower left, LL, and upper right, UR, corner point values change slightly due to the transformation from a map projection in the global Cylindrical Equidistant to the gridded map projection in, this case, Lambert Conformal.

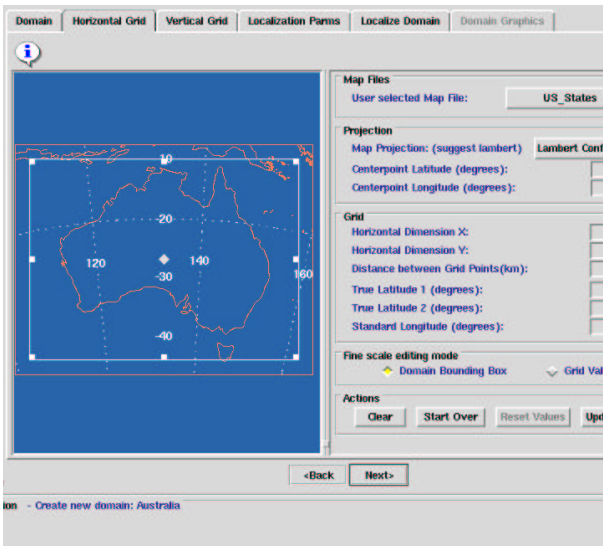

Figure 6. Display of Horizontal Grid panel following the user action of pressing 'Update Map'.

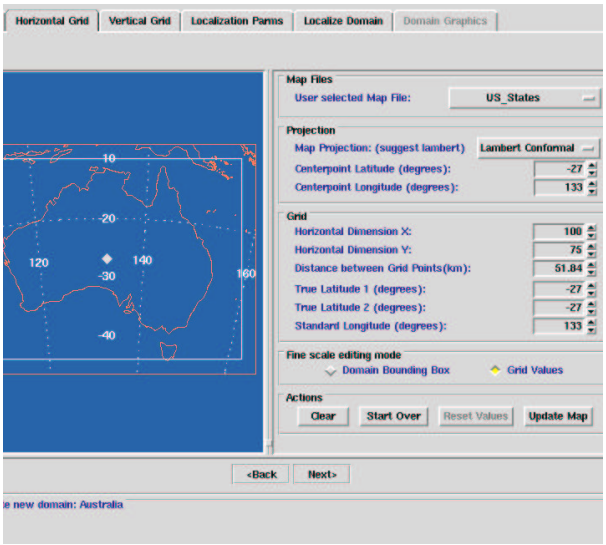

Figure 7. Display of Horizontal Grid panel with 'Grid Values' selected as the method to fine-tune the domain.

It is common for users to refine the domain bounding box until they are satisfied with the area it covers and its grid description values. There are two choices to do fine scale editing: to move the domain bounding box or to change the grid values. Selecting the ***Domain Bounding Box*** button allows the user to interactively resize the domain bounding box using the cursor to manipulate the white bounding box in the left map panel (Fig. 6) while keeping the center point and grid spacing values fixed. Selecting the ***Grid Values*** button allows the user to enter values to adjust the domain bounding box (Fig. 7).

When the ***Grid Values*** is selected, the white domain bounding box loses its movable 'tags' to reenforce that the box is not currently interactive. When users are satisfied with the domain's map, they proceed to the *Vertical Grid* panel by pressing **Next>**. This step both advances to the next panel as well as creates a directory and writes the wrfsi.nl, dataroot.txt and domain.gif files there.

3.2.3 *Vertical Grid Panel*

The *Vertical Grid* panel (Fig. 8) allows a user to view sigma levels (left side) and edit these levels (right side). Included are several options to edit the sigma levels. One option allows the user to enter the number of levels, then choose one of three sigma level schemes to automatically generate levels. The options for schemes are to calculate linear levels in sigma, to calculate square root levels in sigma, or to calculate the top 1/3 of the requested levels in linear and the lower 2/3 of the requested levels in square root in sigma.

A second option is to load an existing file. A third option allows the user to add or remove sigma levels via a text editing window. Status information sent to the **Hints & Information** panel contains the minimum and maximum sigma height distance values. Vertical sigma levels can be displayed in log pressure, or not, with the press of a button.

3.2.4 *Localization Parameters Panel*

From the beginning of the editing session, the user's selections modify the variables in the domain's wrfsi.nl namelist, including the paths to surface geography files (Fig. 9). When the user is satisfied with the values thus far, they advance to the *Localize Domain* panel.

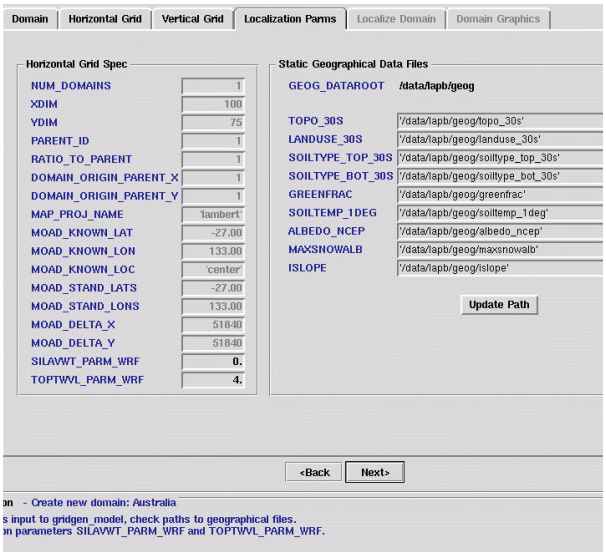

Figure 9. Display of Localization Parameters panel.

3.2.5 *Localize Domain Panel*

At this point the user is ready to run the Perl scripts and Fortran programs to localize the domain. The window_domain_rt.pl command with command line arguments is shown in a (non-editable) text window (Fig. 10). To run this process, the user presses **Localize**. Depending on the grid size and grid spacing of the configured domain, this process can take seconds to several minutes to run to

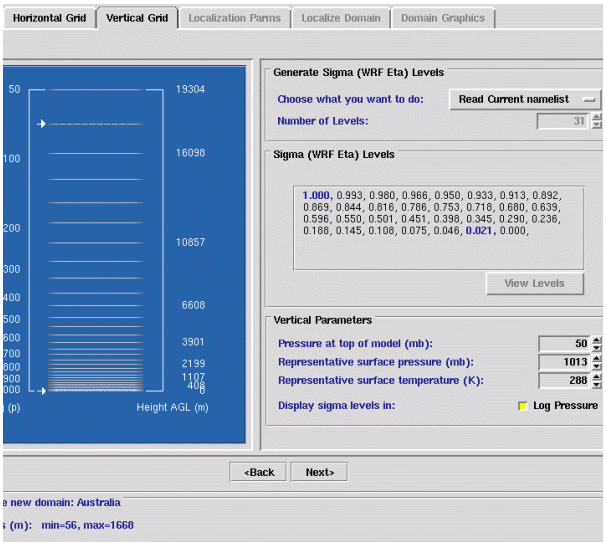

Figure 8. Display of Vertical Grid panel.

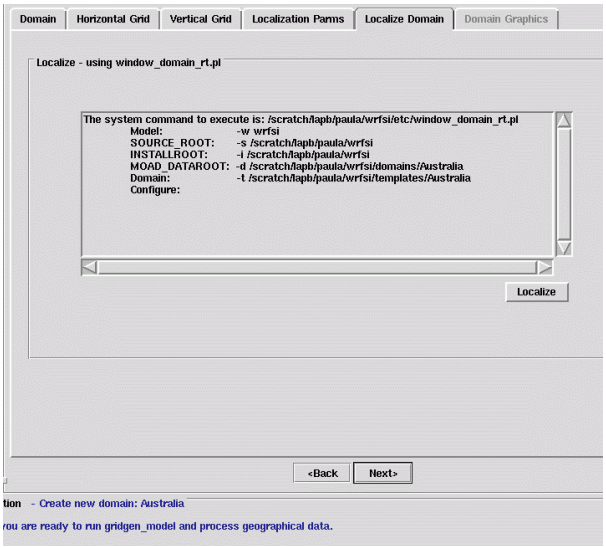

Figure 10. Display of Localize Domain panel.

completion. Status output from the process is sent to the same window.

The end product of domain localization is a defined and localized three-dimensional grid. Of specific interest is a netCDF (network Common Data Format) file called MOAD_DATAROOT/static/static.wrfsi. This *static* file contains all non-varying information required for the WRF model, including terrain, land-use, latitudes and longitudes, map factor, and several other quantities.

Figure 11. Display of Domain Graphics panel. This user has NCAR Graphics NCL available and is able to create and view output from domain localization.

3.2.6 *Domain Graphics [Optional]*

The user can view the results of localization if NCAR Graphics 4.2.0 (or higher) is installed. Images of graphics output from the *Australia* localization are seen in Figs. 12-14. These images are generated and viewable by an NCAR Graphics tools launched from within the GUI.

3.3 *Initial Data Interface*

In addition to domain localizations, the SI prepares large-scale model data for WRF model initialization and lateral boundary condition requirements. The ***Initial Data*** interface (Figs. 16-17) performs the first of a two-part task to provide the initial and lateral boundary condition data files. This section of the user interface runs the script, grib_prep.pl, which acquires background data, then uses specified directories to decode and store this data.

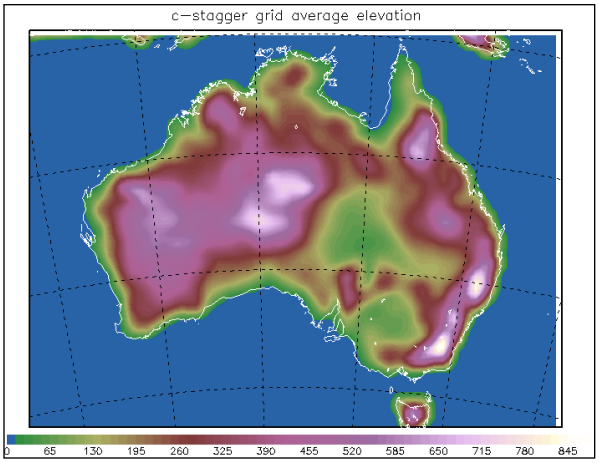

Figure 12. Image of terrain for the Australian domain localized in the example.

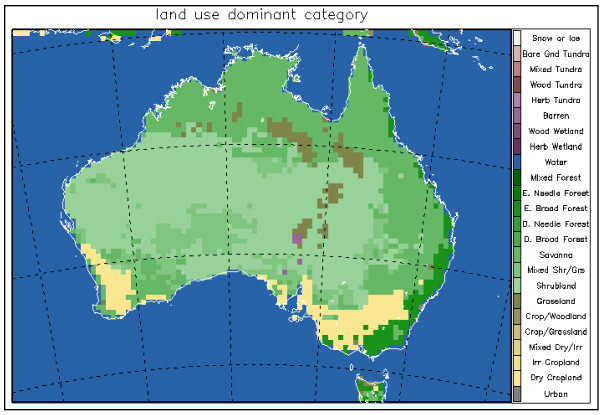

Figure 13. Image of land use for the Australia domain localized in the example.

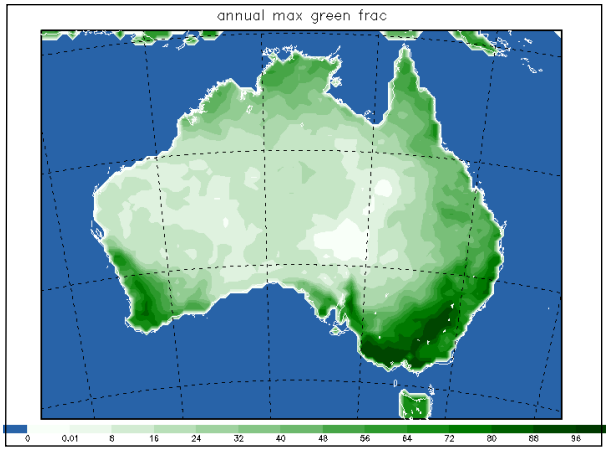

Figure 14. Image of max greenness for the Australia domain localized in the example.

To continue with an illustrative example, once the *Australia* domain has been localized, you would press the ***Initial Data*** button from the *tool selector* (Fig. 15) and the *Initial Data* editing tool interface would display.

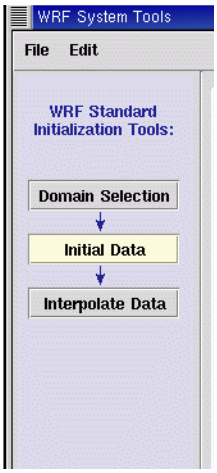

Figure 15. Process buttons from the tool selector.

3.3.1 *Sources Panel*

The grib_prep Fortran executable is responsible for decoding GRIB files. The grib_prep.nl namelist is a file that controls the execution of the grib_prep executable. This *Source* panel interface (Fig. 16) allows a user to add (GRIB formatted) models that are available to their computer system, and to be able to create WRF background datasets. An entry line, for each model, is separated into five columns of important information that needs to be configured. Pressing the **Save** button both writes the grib_prep.nl namelist file and will update the pull-down menu list of model **Data Sources** located on the *Script* panel (Fig. 17).

3.3.2 *Script Panel*

The *Scripts* panel interface assists a user in configuring their Perl grib_prep.pl script, which runs the Fortran executable grib_prep (which in turn reads the file grib_prep.nl, discussed in the previous section).

First, the *Script* panel assists the user in composing command line arguments for grib_prep.pl. By choosing a **Data Source** from a pull-down menu, for example AVN, the grib_prep.pl command is created in a text window. A list of command line

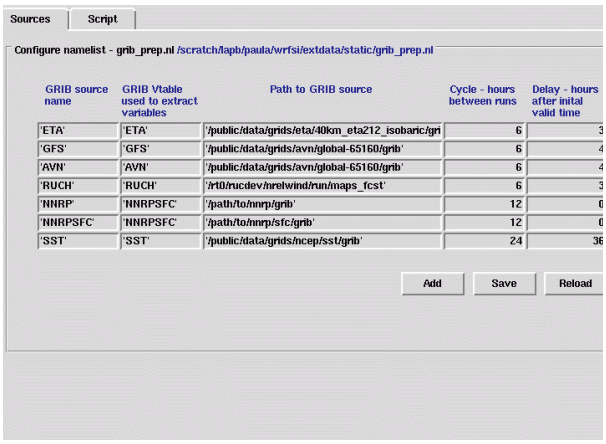

Figure 16. Initial Data interface - Sources panel.

options is also shown. Second, the user can run this command by pressing **Run**, or save the command to a script file with **Save**.

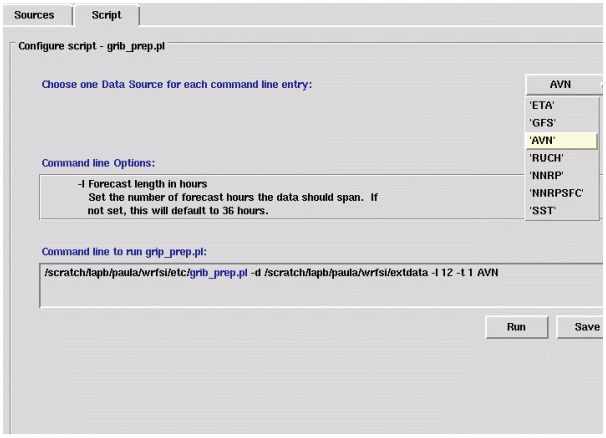

Figure 17. Initial Data interface - Scripts panel.

In the illustrative example of setting up WRF for a model run over *Australia*, you would press **Run** to acquire background data, after filling in the model data sources that are available on your system.

3.4 *Interpolate Data Interface*

The ***Interpolate Data*** editing tool interface (Fig. 18-19) performs the second of a two-part task in providing the initial and lateral boundary condition data files. This section of the user interface runs the script wrfprep.pl, which *interpolates background data to a specific domain*. Note that this interface is disabled unless the selected domain has been localized.

3.4.1 *Controls Panel*

The *Controls* panel (Fig. 18) contains parameters to interpolate initial and lateral boundary condition files to the domain. These values are written to the namelist, wrfsi.nl, and are used by Perl scripts to interpolate the initial and lateral boundary files discussed in section 3.3 ***Initial Data*** interface.

3.4.2 *Script Panel*

The Interpolate Data's *Scripts* panel interface (Fig. 19) assists a user to configure their wrfprep.pl command with a list of command line options shown. A text window labeled 'Data files' lists the data files found on the system created by running grib_prep.pl in the first part of this two-part task. The list of data files can help a user correctly set command line options such as setting the forecast time interval (-t) equal to 3 hours and likewise setting the forecast length (-l) equal to 36 hours.

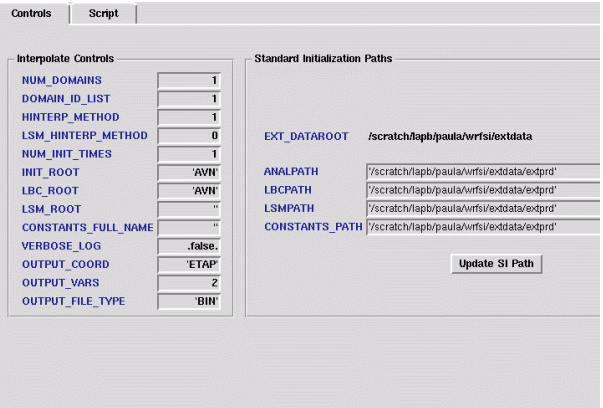

Figure 18. Interpolate Data interface - Controls panel.

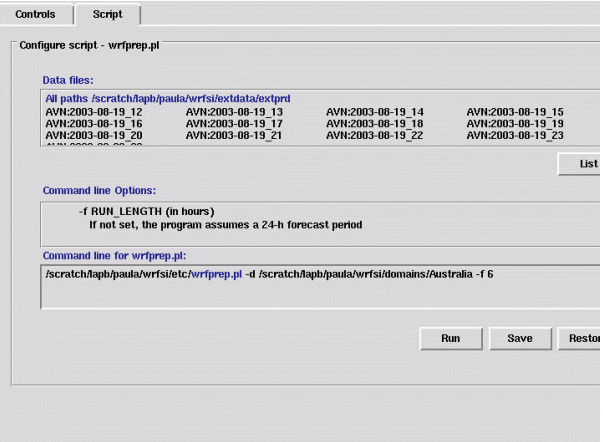

Figure 19. Interpolate Data interface - Script panel.

The user is able to immediately run this command by pressing **Run**, or to save the script to a file with **Save**. In the example case, you would press **Run** to interpolate background data to the *Australia* domain, completing the final step in the illustrative example.

3.5 *Path Preferences*

The ***Path Preferences*** menu button to display the *Path Preferences* interface is found under the toolbar's **Edit** pull-down menu (Fig. 20).

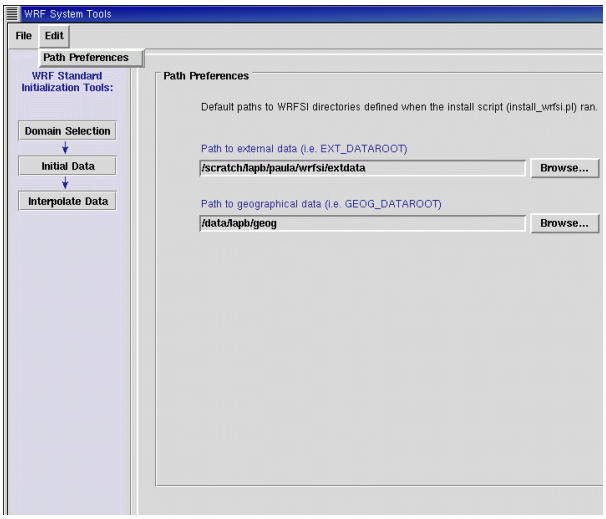

Figure 20. Display of Path Preferences panel.

The ability to edit path preferences allows users to enter new paths specifically to external and geographical data from the values that were defined when the install script (install_wrfsi.pl) ran. A user may want to change these if, say, a group of modelers are using the same software and prefered to locate their datasets in a different directory locations.

4. FUTURE WORK

The WRF GUI is not a finished product, and there are plans for upgrades and additional capabilities. We envision the GUI capable of assisting the user with many other tasks associated with WRF system setup, running, and evaluation.

Because of a failure of the Perl system call to 'sysread' in the release of Perl version 5.8, if you are using Perl 5.8 then the GUI version 1.3.2 (and older) will crash during a localization. We are addressing this problem and currently recommend use of Perl 5.6.1 (or earlier).

4.1 *Model Setup and Nesting*

The GUI does not yet allow the user to interact with the WRF model namelist file, wrf.nl, though this has been discussed. Plans to incorporate the nesting functionality are in progress and should be available by Spring 2004. The variables *num_domains, ratio_to_parent and parent_id* will be the basis for configuring nesting in the SI.

4.2 *Graphics Displaying SI Meteorology*

Because the SI generates the initial and lateral boundary condition files for WRF, it is important that users evaluate this data. Currently there is no method for displaying the meteorology in these interpolated data files. We expect to use existing graphics packages similar to those already used in the GUI to generate such graphics.

5. SUMMARY

The Forecast System Laboratory has created a graphical user interface capable of accommodating researcher needs when using the SI. Since the SI is a necessary first step when using the WRF model, the GUI provides an easy method to prepare an otherwise quite complicated system. Currently more than 100 users have downloaded the latest SI version 1.3.2 containing the GUI. Some valuable feedback has been obtained from the users. We plan to update the version frequently to keep up with users' needs and the latest software.

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