# WRF SI V2.0: Nesting and Details of Terrain Processing

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## 1. Introduction

The NOAA Forecast Systems Laboratory's (FSL) Local Analysis and Prediction Branch (LAPB) has acquired existing software and written new software to create the Weather Research and Forecasting (WRF) Model Standard Initialization (SI) system (1999 to present). Following the initial development and release of WRFSI, upgrades are based upon input from the user community through The National Center for Atmospheric Research (NCAR) and new WRFSI requirements are determined at meetings, workshops, and teleconferences, and specifically from the WRF WG-14: Land Surface Modeling (LSM) group. Primary members of WG-14 are represented by staff from the U.S. Air Force Weather Agency (AFWA), NOAA, and NCAR. This document presents updates in the recently released WRFSI version 2.0 (V2.0), successor to version 1.3.2. We also describe in detail the parameters used when processing terrain data.

## 2. WRFSI Version 2.0

In V2.0, the basic SI system is very similar to previous releases with the same infrastructure of directories and executable programs with similar scripts and techniques to localize domains and process model backgrounds. However, V2.0 includes the following major upgrades:

- multiple, one-way nesting
- localization of NCEP's non-hydrostatic Meteorological Model (NMM) rotated latitude-longitude grid (hereafter, NMM-rotlat)
- default WRF API output in netCDF (Network Common Data Format)
- efficiency enhancements allowing faster runtime for background model processing and preparations for parallelization (note: NCAR's "real.exe" program has been parallelized with this SI enhancement)
- graphical user interface (GUI) features that include setup and localization of nests.

These changes required modification of the Fortran namelist, "wrfsi.nl", that controls the SI executables which made the code backward compatible. To achieve smooth transition from previous releases to the current one, it is recommended to follow the notes for localizing domains found in the WRFSI README file available in V2.0. Additional documentation for the new namelist variables can be found in file README.wrfsi.

The static grid information files (found in directory "dataroot"/static) now have ".d##" appended to the filenames, where ## = 01 ... 09. The top parent domain, MOAD, is called d01. In support of the NMM-rotlat domain, a fourth projection type was added, called "rotlat". Users can read the file "README.nmm" for details on using WRFSI to generate an NMM grid.

A number of minor improvements to WRFSI have been made in V2.0 including portability to DEC Alpha machines and a more robust global localization capability. Processing of deep soil annual mean temperature data is improved and users **must download a new dataset available at** ftp://aftp.fsl.noaa.gov/divisions/frd-laps/WRFSI/Geog_Data/soiltemp_1deg.tar.gz . Internal consistency checks are made for both Noah LSM variable input and between land-state information and the land-water mask. We have expanded and tuned the capability to ingest time-varying land state information from the various background models. Finally, we improved the NCL (NCAR Graphics Command

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Language) graphics that display many of the land-state fields. In addition to this document, release notes and other updated documentation come with V2.0. The software is available at http://www.wrf-model.org/si/release.

## 3. Nest Domains in SI

Version 2.0 allows generation of multiple nests within a parent domain, whether it is the MOAD or a nest within a nest. Nests are defined by selecting: 1) a parent ID, 2) the ratio of the num of grid points in nest to the num of grid points in parent, 3) the nest's SW and NE corner "i,,j" points within its parent coordinate system. Derived from these three values are the nest's center point, grid spacing, and num of grid points. The derived values are used internally and do not appear in the namelist, but the MOAD values used in the calculations are required namelist values.

All 2-D static land-state fields for nests are calculated independent of the parent; therefore, nests have one-way interactions with the parent (that is, a nest only obtains information from its parent).

There are namelist variables in wrfsi.nl that specify the number of domains, one for the horizontal grid specification (NUM_DOMAINS used by module gridgen_model.exe) and those for the model background processing (NUM_ACTIVE_SUBNESTS and ACTIVE_SUBNESTS). Because localization can be time consuming for large, high-resolution domains, internal checks are made to prevent unnecessary relocalization. That is, changing a nest's configuration causes localization only for that domain and its subnests. Users can set environment variable FORCE_LOCALIZATION (= ##: domain number) to override the relocalization strategy (the GUI can also set this variable).

A new program was added to the SI (called staticpost.exe) that produces reformatted static files (dataroot/static/staticpost.d##) that interface the SI output to real.exe. These files contain information similar to that in the static.wrfsi.d## netCDF file.

### 3.1 Graphical User Interface

The WRFSI GUI is upgraded in V2.0 to allow the user to graphically create nests within the parent domain. The GUI is recommended to create and localize domains. The horizontal grid panel has been expanded with a new panel (NEST DOMAIN) to show controls for creating and editing nest domains (Figure 1). As mentioned in the previous section, the GUI can control nest domains that are localized. Graphical display capability has also been improved for generating displays of land-state information for nests.

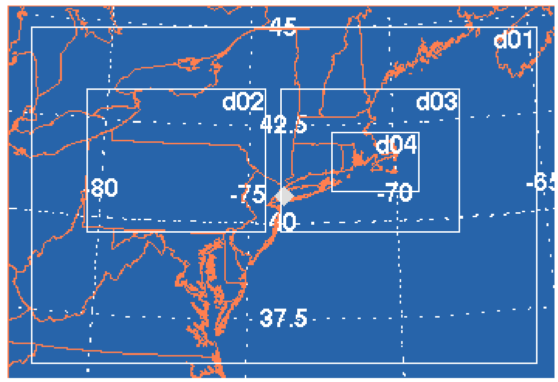


*Figure 1: Graphic from WRFSI GUI showing four domains (3 nests: d02, d03, and d04) within the MOAD (d01). The parent of d04 is d03 and the parent of d02 and d03 is d01.*

## 4. Details of Terrain Processing

The terrain processing software originated with the Regional Atmospheric Modeling System (RAMS). FSL used this software in WRFSI because it has the desired projections, global localization flexibility, was well tested and was the most efficient for meeting the initial 1999 release. The method allows usage of the full resolution (30 arc second, ~1km) raw USGS topography data reformatted into 10 by 10 degree tiles. The robust software allowed FSL to also process the raw land use data, soil texture categories, (both also 30 arc second and in 10x10 tiles), and other categorical data. The technique is nicely described by documentation that comes with the RAMS software (Walko and Tremback 2004). The terrain processing relies on the settings of namelist variables: silavwt_parm_wrf and toptwvl_parm_wrf (hereafter silavwt and toptwvl).

SILAVWT: this namelist variable controls the type of processing of topographic data from input files that are specified by the path to raw terrain data "TOPO_30S" to final values defined on a WRF grid. This is a 3-step process, which involves topography information being defined successively on 4 different grids, called the "O", "P", "Q", and "R" grids. First, a horizontal interpolation is carried out in order to transfer data from the "observed" or "O" grid of the input file, to a projection (Lambert, Mercator, or polar stereographic) grid of comparable resolution, which is the P-grid. The P-grid uses the same projection as the WRF grid (the R-grid) where the data will reside in its final state, but is usually of much higher resolution. Second, data are averaged from this P-grid to a lower-resolution Q-grid, (also a grid in projection coordinates) and have a horizontal grid spacing that is an integer multiple of that on the P-grid. This step automatically filters out small-scale variations, which are not desired on the model grid. In this second averaging step, a choice of averaging algorithms exists and SILAVWT_PARM_WRF is the flag that selects the choice to be used. If SILAVWT_PARM_WRF is set to 1, a conventional mean is used where terrain heights for all P grid cells in a single Q grid cell are summed and divided by that number of P values, to obtain the value for that Q cell. For SILAVWT_PARM_WRF equal to 1, both the conventional mean and a silhouette average are computed, and the value assigned to the Q grid cell is a weighted average of these, with the weights controlled by SILAVWT_PARM_WRF. That is, an envelope orography results when SILAVWT_PARM_WRF equals 2 or 3. The silhouette average finds the mean height of the silhouette, as viewed from the east or west, of the set of P grid terrain heights contained within a single Q grid cell, and a separate silhouette height as viewed from the north or south and averages the two silhouette heights together. This becomes the computed silhouette height for that coarse-grid cell. While the conventional average preserves total terrain volume above sea level, the silhouette average adds mass by filling in valleys. It is used to maintain the effective mean barrier height that air must rise to when crossing a topographic barrier such as a ridge. The conventional average lowers this barrier height, particularly when the barrier height is poorly resolved. When SILAVWT_PARM_WRF equals 2, an envelope topography scheme is used to obtain Q Grid values from P grid values, and this scheme is an alternative method of attempting to preserve barrier heights. When SILAVWT_PARM_WRF equals 3, a reflected envelope topography scheme is used which aims to preserve both barrier heights and valley depths. Naturally, this method leads to the steepest topography in WRF, while still filtering the shortest wavelengths. In the third and final step, topography is interpolated from the Q grid to the R grid, where the R grid is usually of moderately higher resolution than the Q grid.

TOPTWVL: this is a grid dependent namelist variable specifying the wavelength, in grid-cell size units, of the smallest horizontal modes of terrain height data which are to be present on a given model grid. It is applicable only for namelist variable SILAVWT_PARM_WRF set to 1. Referring to the description of namelist variable SILAVWT_PARM_WRF above, the value of TOPTWVL_PARM_WRF controls the ratio of resolution between the Q and R grids. The shortest mode that any grid can resolve is that with a wavelength of twice the grid cell size. In general, the Q grid will contain all wavelengths of topographic data from its own 2 delta-X scale and larger. Hence, if the WRF "R" grid, to which data are interpolated from the Q grid, has, for example, half the cell size of the model grid, the smallest mode that it will receive from the Q grid will be 4 delta-X on the R grid. This smallest mode, in delta-X units of the R grid, is the number specified for TOPTWVL_PARM_WRF. In other words, while the R grid spacing is set by the user, the Q grid spacing will be TOPTWVL_PARM_WRF/2 times the R grid spacing. This is how smoothing of the topographic data is achieved in WRFSI while allowing the variety of enhancing schemes described for SILAVWT_PARM_WRF. Because the numerical model does not properly handle the smallest modes resolvable on a grid, it is generally important not to force these modes into the meteorogological fields through overly fine terrain height modes.

### 4.1 Examples of WRFSI Terrain Processing

The two namelist parameters described in the previous section are applied to all domains (nests) when localizing a dataroot. Though this is limiting, it does force consistency between all domains of the same dataroot.

To better understand how these parameters influence the resulting terrain, we have computed terrain statistics for the domain d01 shown in Figure 1 (delta-x=14540m). The statistics only consider land values in these calculations. We examined graphics corresponding to the different settings, but these are difficult interpretations so we do not show them here. Space limitations only allow figures for d01. Figure 2 shows the maximum terrain height (m) as a function of varying both silavwt (0, 1, and 2) and toptwvl (2, 4, and 6) and Figure 3 shows the average terrain height for the same parameter variations. These figures show that when setting silavwt to 1 (include silhouette average) or 2 (including terrain envelope), the terrain increases in the domain. However, terrain is only substantially added by increasing toptwvl when silavwt is turned on (= 1 or 2).

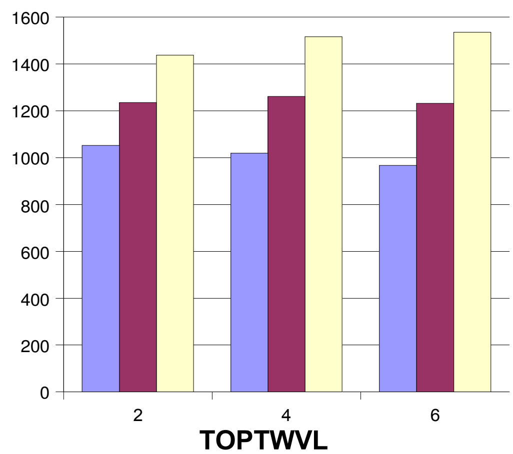


*Figure 2: Maximum terrain height (meters) as a function of various settings for parameters toptwvl and silavwt (where silavwt=0=blue; 1=red; 2=tan) for domain d01.*

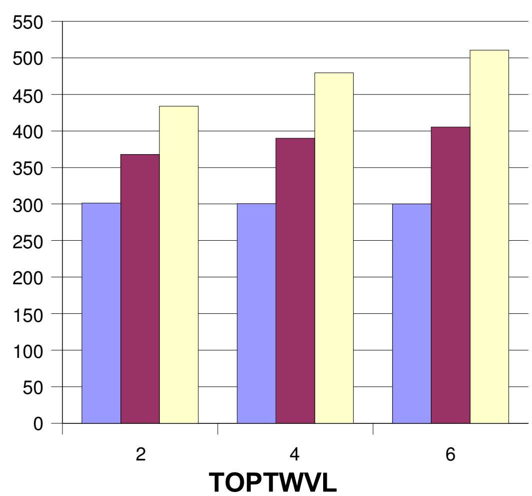


*Figure 3: Same as Figure 2 but average terrain height (m) as a function of parameters toptwvl and silavwt.*

## 5. Summary and Future Work

WRFSI version 2.0 was released in May 2004, replacing version 1.3.2. Numerous upgrades were made in V2.0, most notably the addition of multiple one-way nesting. V2.0 also includes the capability to localize NCEP's Eta rotated latitude-longitude (NMM) grid. We updated the GUI to include generation of nests. Even though V2.0 has been tested by a variety of users, there still is potential for a configuration that has not been thoroughly evaluated. The V2.0 release Web site has several links for documentation including a frequently asked questions (FAQ) section. Additionally, FSL is preparing other on-line documentation.

Included in this document are detailed descriptions of the two terrain processing namelist parameters silavwt and toptwvl. We also show simple statistics for varying these parameters for a sample domain, and the results give a simple view of resulting terrain maximum and average values for a sample domain. We plan to show additional graphics at the workshop that further illustrate how terrain gradients can be modified by adjusting these parameters.

## 6. References


Walko, R. L. and C. J. Tremback, 2004: RAMS, Regional Atmospheric Modeling System, Version 4.3/4.4; Model Input Namelist Parameters.


## 7. Acknowledgements


Software to generate graphics in WRFSI was written by Brian Jamison and Thomas Helman (FSL) using NCAR graphics Command Language. Matthew Pyle (NCEP; Matthew.Pyle@noaa.gov) developed and integrated the NMM rotated lat-lon grid software capability in WRFSI.