**Quick Start Guide for Setting Up and Running SnowPALM**

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**Step 1, download some forcing data**

The first step for setting up a model run is to download the forcing data. First, go to the’ Forcing Data’ directory - modify domains.m to add additional forcing domains to download forcing data for. These domains need to be larger than the SnowPALM model domains (by ~0.25 degrees) because of the use of adjacent pixels to compute lapse rates / interpolation. One domain (called 'Valles' is already set up). Another thing that you will need to do before downloading data is to register to download NASA EarthData data following the instructions at: <https://disc.gsfc.nasa.gov/earthdata-login> (if you don’t already have an account). You will then need to enter your EarthData username / password into the get\_prism\_corrected\_nldas.m script (in the ‘Forcing Data’ directory) for it to be able to access the files (lines 15+16).

To download the forcing data onto your machine, at the Matlab command line, type get\_prism\_corrected\_nldas(Domain,StartMonth,StartYear,EndMonth,EndYear), where Domain is the name of a domain defined in domains.m. For example, get\_prism\_corrected\_nldas('Valles',10,2005,10,2005), would download and correct (using PRISM) NLDAS data during October 2005 for the 'Valles' domain. get\_prism\_corrected\_nldas('Valles',10,2005,11,2005), would download and correct NLDAS data during October-November 2005 for the 'Valles' domain. Downloading data will take a while (maybe an hour per month even with a fast internet connection - unfortunately data for the entire US needs to be downloaded before the files are subset).

This will script create netcdf files with data subsetted for the domain. These will be saved in a subfolder called 'prism\_corrected\_nldas\_Valles' (the last part of the name will change for different domains).

**Step 2: Prepare the Spatial Data**

SnowPALM needs, as input, three raster data files (bare earth DEM, canopy height model, and canopy closure map). The format and projection of these files is flexible as SnowPALM will automatically convert and subset the spatial data. Generally if the files open in GIS software (e.g. QGIS), they are readable by SnowPALM. It is up to the user to ensure that the files are appropriate (e.g. of a sufficient resolution). Paths to these files will be specified in 'program\_pars.m'

**Step 3: Set Up Model Options**

The most important options to get SnowPALM to run are in ‘program\_pars.m’. Here is where you set paths for various model directories, to input spatial data files, setup model domains, and specify the forcing data source and how it will be handled. The important model files and directories are specified by:

* Info.ProgramFilesDir: the program files directory, where the model codes are located
* Info.ModelStatesDir: the directory that contains model state files that are generated during model execution including restart files, compressed model outputs, and interpolated forcing files
* Info.SpatialDataDir: the directory that contains processed spatial data that is pre-generated before model execution – including cut out spatial data, and derived spatial indices
* Info.DisplayDir: the directory that contains model outputs – both output GIS files and csv files
* Info.POIDir: the directory that contains shapefiles that specify places of interest (POIs) for which to save model timeseries data.
* Info.ForcingDirs: specifies directory where forcing data is located (note that multiple forcing datasets can be specified for different variables – see below).
* Info.DTMFile: the bare earth DTM file
* Info.VegHeightFile: the Vegetation height file
* Info.VegCoverFile: the Vegetation coverage file
* Info.Proj4String: the PROJ4 string which specifies the desired model projection

‘program\_pars.m’ also contains information to setup the model subdomains. These subdomains will share model parameters and setup information but will run the model for different areas (e.g. an area immediately surrounding a snow pillow or a large area encompassing multiple measurements). Parameters are:

* Info.NewResolution: model resolution for the model subdomain
* Info.NSWE: the bounding box specifying the model boundaries
* Info.ExtentFile: a shapefile specifying the model boundaries. Note that if this is specified then Info.NSWE is unnecessary; the shapefile can have a complex shape, like a watershed).
* Info.SxSource: the name of the domain for which the Sx wind index is to be computed (if using the wind model, it is generally necessary to generate it for a domain that is larger than the modeled domain so that the Sb index can be computed near the model boundaries)
* Info.MaxSquarePixels the maximum number of pixels that can make up a single model tile. SnowPALM works over large areas and speeds up computation for smaller areas by tiling the model domain and working on each tile in parallel. The model will run for smaller tiles much faster than larger ones, and if the model is running on many small tiles at the same time, overall computation time can be reduced dramatically.

Finally, ‘program\_pars.m’ also contains information about how to handle model forcing data. Each forcing variable can be interpolated differently, be from different forcing data sources, or can be adjusted by elevation or not. Parameters in this section include.

* Info.Forcing.var: the name of the forcing variable
* Info.Forcing.source: its source (see the Info.ForcingDirs parameter)
* Info.Forcing.interpMethod: the method by which it will be interpolated (linear, nearest, next, previous, pchip, cubic, spline) – see matlab documentation for ‘griddedinterpolant’
* Info.Forcing.useLapseRate: adjust for elevation effects

For now, leaving these parameters as their default values is recommended.

The user must also specify the bounding box of forcing data to consider (given by the parameter ‘Info.Forcing\_ULLR’). If forcing data is only downloaded for a small area, this bounding box can be the same as the extent of the downloaded forcing data, but if forcing data is downloaded for larger regions, it is recommended to set this bounding box relatively small as it will improve model performance. This bounding box needs to be larger than the SnowPALM model domains (by ~0.25 degrees) because of the use of adjacent pixels to compute lapse rates / interpolation.

**Step 4: Process spatial data, precompute model indices**

Before model execution, you must process spatial data and precompute model indices (e.g. horizon angles, wind indices) that will be used during model execution. Although these will be computed automatically, it is highly recommended that the user does this in a stepwise fashion, checking the outputs, as errors are bound to arise. For this, use the program ‘model\_output.m’ to make maps of specific variables. First, it is recommended to make maps of the basic terrain parameters as these are quickly computed from the input spatial data. Turn on the options Info.DEM, Info.Slope, Info.Northness, Info.VegHT, and Info.Cover. Run the program by typing model\_output(StartDate,EndDate,SubDomain) at the Matlab prompt. For example, typing model\_output(‘10/1/2005’, ‘10/1/2005’,’Test’) will start execution for the ‘Test’ domain. Right now, the Start and End Dates don’t matter because we are outputting spatial data, but later on, these dates will become important. This will begin processing of the spatial data for each model tile (tile discretization is determined automatically based on the value of ‘Info.MaxSquarePixels’). At the end, Maps (geotiffs, or .mat files) will be produced by merging the model tiles and saved in the directory specified by ‘Info.DisplayDir’ (and in the GIS/<Model Subdomain Name> directory. GeoTiffs can be inspected using a GIS application, and .mat files load quickly into the matlab workspace. If there is an error, double check that all parameter options in ‘model\_pars.m’ are correct. This is also a good time to double check whether all maps look correct. If they are not, this could indicate a problem with the original data. If you need to redo this step (if the spatial data is successfully processed but incorrect), remove the folder < Info.SpatialDataDir>/<SubDomain>. It is much easier to do this now because later processing steps take much longer, and would be more time consuming to redo. Note that at the top of ‘model\_output.m’ the user can specify whether to run the model in parallel and the maximum number of workers to assign to the parallel job. At this point, it is easier to debug if parallel processing is off.

Next, turn on the options for ‘Info.SkyView’, ‘Info.SFI\_BareEarth’, and ‘Info.SFI\_Veg’ and turn off the remaining options (no need to regenerate these maps) and run ‘model\_output.m’. This will create maps for skyview, bare-earth solar forcing index, and solar forcing index at the ground level, considering the effects of canopy. Note that the start and end dates are important here as a solar forcing index map will be generated for each day. All of these maps require the computation of horizon angles. This is a time consuming process which could take several hours. It is highly recommended that for this step that parallel processing is turned on.

Only do the following if you are interested in using the model with the wind indices:

Next, turn on the option for ‘Info.Sx’. This will create a map for the Sx wind index. Computation of Sx is fast and the Sx map must be mosaicked (cannot be done as tiles) because Sb, depends on upstream values of Sx. The other thing to consider is that Sx could should be computed for a larger domain than the model domain of interest (for the same reason) and potentially at a different resolution (e.g. 10 meters, for the example program, the Sx index is simply computed for the ‘test’ domain for demonstration purposes). This is controlled by Info.SxSource. Sx will only be successfully computed if Info.SxSource is the same as the current model subdomain. Otherwise, SnowPALM will try to load the already generated Sx map from the subdomain specified by Info.SxSource. If it does not yet exist, this will result in an error. Parameter values for Sx can be controlled in ‘model\_pars.m’. Note that each time these parameters are changed, new Sx maps will (and must) be generated reflecting the new parameter values. Finally, turn on the option for ‘Info.Sb’. This will create a map for the Sb wind index. Again, this is a time consuming process because for each pixel, the program is doing a search involving nearby pixels. Like Sx, parameters for Sb are found in ‘model\_pars.m’. One tip is to compute both Sx and Sb for the larger domains at lower resolution (e.g. 10 m) – as this is the scale that they were designed to work at, and their computation is much faster. Get them to where you like them, and then run all of the computations on the smaller (higher resolution) domain.

As a last step, check to make sure that the forcing data is being read correctly. Turn on the option for the air temperature map (FVars(3).map = 1, just to the right of ‘AirT’ – ‘AirT’ is the name given to the output map) and run ‘model\_output.m’. This will create air temperature maps for the date specified. Note that these maps (all forcing data maps, and all model data maps) can be outputted either daily or hourly (depending on whether ‘Info.outputType’ is ‘day’ or ‘ts’ – model timestep)

At this point, all spatial data has been processed and spatial indexes computed for SnowPALM to run

**Step 5: Run the model and visualize results**

To run the model, use ‘run\_model’. For example, type from the matlab command line ‘model\_output(‘10/1/2005’, ‘10/1/2005’,’Test’)’ to start execution for the ‘Test’ domain for 10/1/2005. There are a couple of model options here:

* Info.UseWindModel: flag to use or not to use the wind model
* Info.RunParallel: flag to run the model using parallel processing
* Info.MaxNumWorkers: maximum number of parallel workers
* Info.MapType: output interval to make output data available (‘day’ or ‘ts’)
* Info.SaveDailyRestartFiles: flag to specify whether to save model restart files every day. These are saved by default at the end of the run. These are needed for SnowPALM to continue where it left off, and will be picked up automatically where it left off (e.g. to have it pick up from where it left off on a run beginning 10/2/2005, there must be a restart file that saves the model state at the end of 10/1/2005).
* Info.SaveForcingInterpFiles: flag to saves forcing interpolation files. This will take up space, but results in much faster performance if a simulation is rerun multiple times for days on which the forcing data is already processed. Recommended especially for very small domains that are run to get multiyear timeseries’.

The user also needs to specify which variables to put on the model output tape, and whether to make these available as spatial maps. SnowPALM will output all variables that are specified in the ‘MVars’ struct in timeseries for Places of Interest (POI’s), though spatial maps will only be saved if the MVars(i).map flag is set to 1. The user can put any variable he/she desires on the output tape. It just needs to be given a name (MVars(i).Name), and it must be specified which variable it corresponds to (MVars(i).modelvar; look through the code of ‘SnowPALM\_run.m’ for a variable to output). Most likely, all relevant variables are already in the commented code in ‘run\_model.m’.

To set up POIs, put a shapefile containing a feature within the model domain into <Info. POIDir>. These are automatically read during model execution and data is outputted for these points or areas (as area averages). Both hourly and daily data will be outputted to CSV files in the directory specified by ‘Info.DisplayDir’ (and in the Tabular/<Model Subdomain Name> subdirectory). Data will only be outputted for a POI if it is in the model subdomain. To create GIS data of the spatial model outputs, we again need to use the ‘model\_output.m’ program because all of the model data are tiled and need to be combined to produce GIS maps. Turn on these variables in ‘model\_output.m’ by setting the MVars(i).map flag to 1 (and probably turn the others off at this point), and run ‘model\_output.m’ for a specified date range and subdomain that has model data.

At first, do a short run to make sure that the tabular data at the POIs and the GIS data output correctly. Then, expand on these runs.