Real

Description of General Functions

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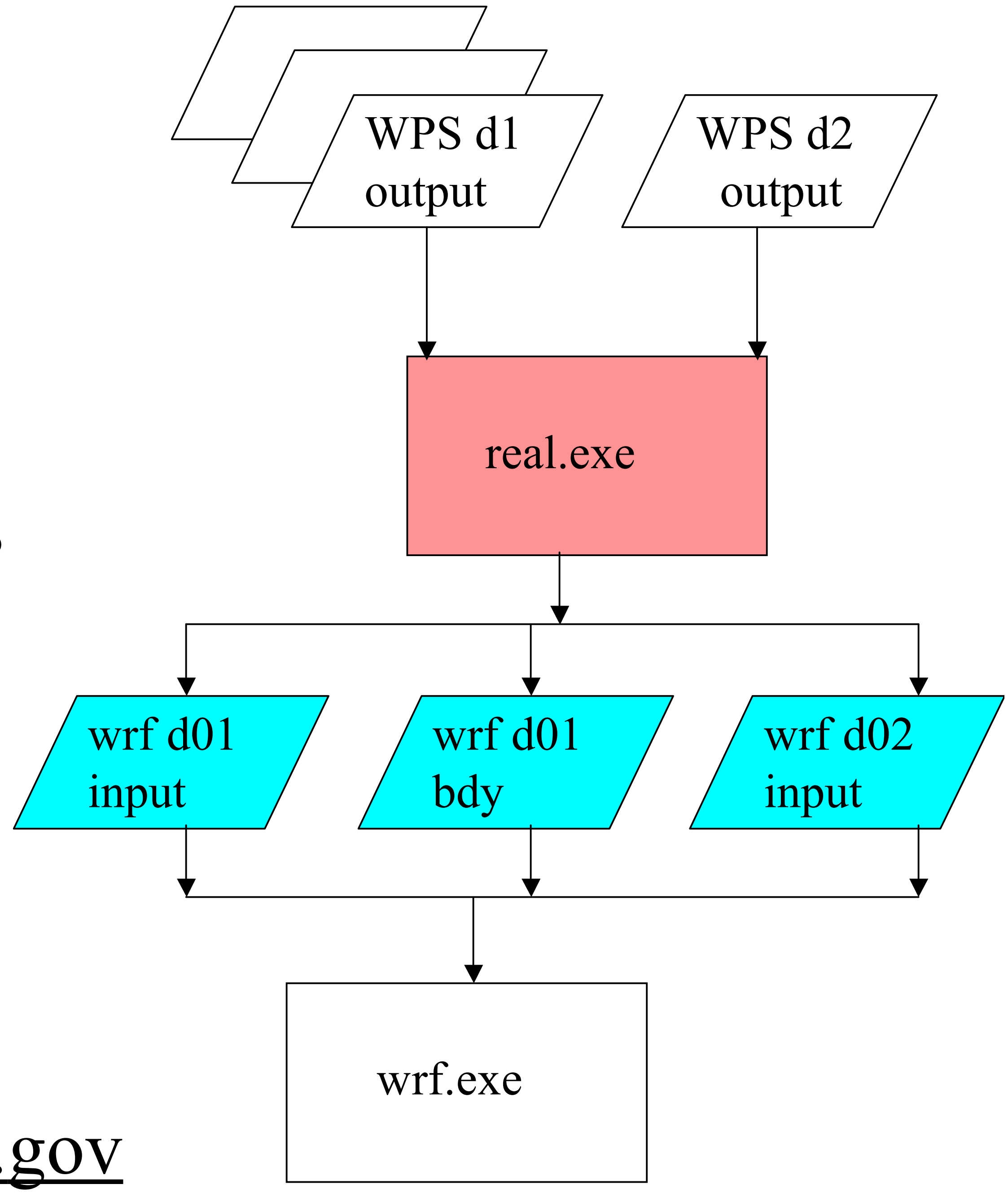

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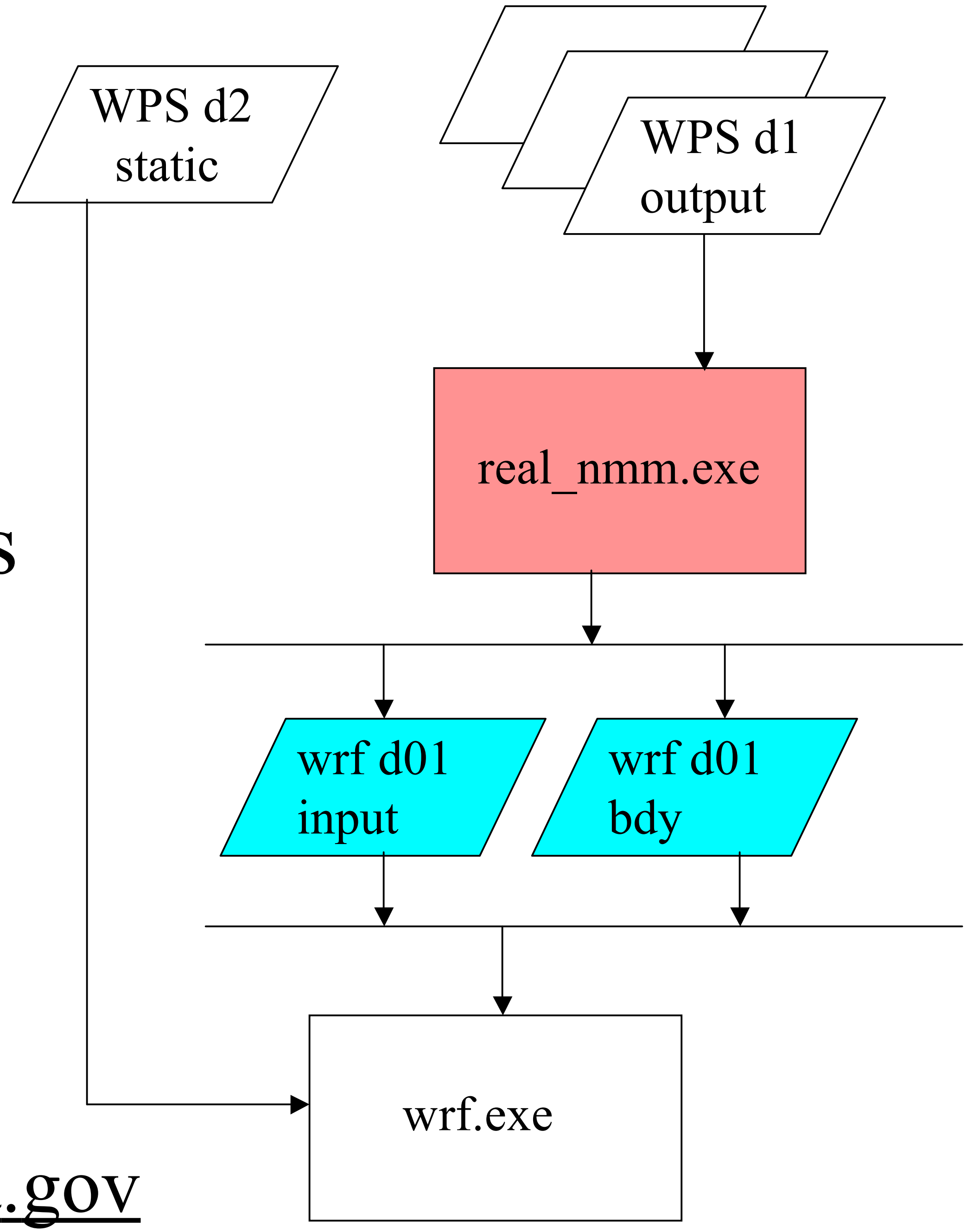

Real-Data Initialization – ARW & NMM

- Definition of Terms
- Purpose and Tasks of Initialization Program
- Files before and after

Definition of Terms: real.exe & real_nmm.exe

- The ARW WRF model pre-processor is ***real.exe***
- The NMM WRF model pre-processor is ***real_nmm.exe***
- The real.exe and real_nmm.exe programs are available ***serial*** or ***DM parallel*** (primarily for aggregate memory purposes, as opposed to timing performance)
- This program is automatically generated when the model is built and the requested use is for a real data case
- The real.exe and real_nmm.exe programs take data ***from WPS*** and transform the data ***for WRF***
- Similar to the ARW idealized data pre-processor, both real.exe and real_nmm.exe are tightly coupled to the WRF model through the ***Registry***

Definition of Terms: Real Data Case

- ***3D forecast*** or simulation
- ***Meteorological input*** data that primarily originated from a previous forecast or analysis, probably via the WPS package
- Anticipated ***utilization of physics*** packages for microphysics, surface conditions, radiation, convection, and boundary layer (ARW: maybe usage of nudging capabilities)

Definition of Terms: Real Data Case

- A non-Cartesian ***projected domain***
  - ARW: Lambert conformal, Mercator, polar stereographic, rotated latitude/longitude (global or regional)
  - NMM: rotated latitude/longitude
- Selection of ***realistic static fields*** of topography, land use, vegetation, and soil category data
- Requirement of ***time dependent*** lateral boundary conditions for a regional forecast

Definition of Terms: Initialization

- Not referring to the ***Variational*** or the ***Digital Filtering*** usage of Initialization

- Generation of ***diagnostics*** necessary for assumed WRF model input
- Input field ***adjustment*** for consistency of static and time dependent fields (land mask with soil temperature, etc.)
- ARW: computation of ***reference*** and ***perturbation*** fields
- Generation of ***initial*** state
  - ARW: for each of the requested domains
  - NMM: for the coarse grid only
- Creation of a ***lateral boundary file*** for the most coarse domain
- ***Vertical interpolation*** for 3d meteorological fields and for sub-surface soil data

Real-Data Initialization – ARW & NMM

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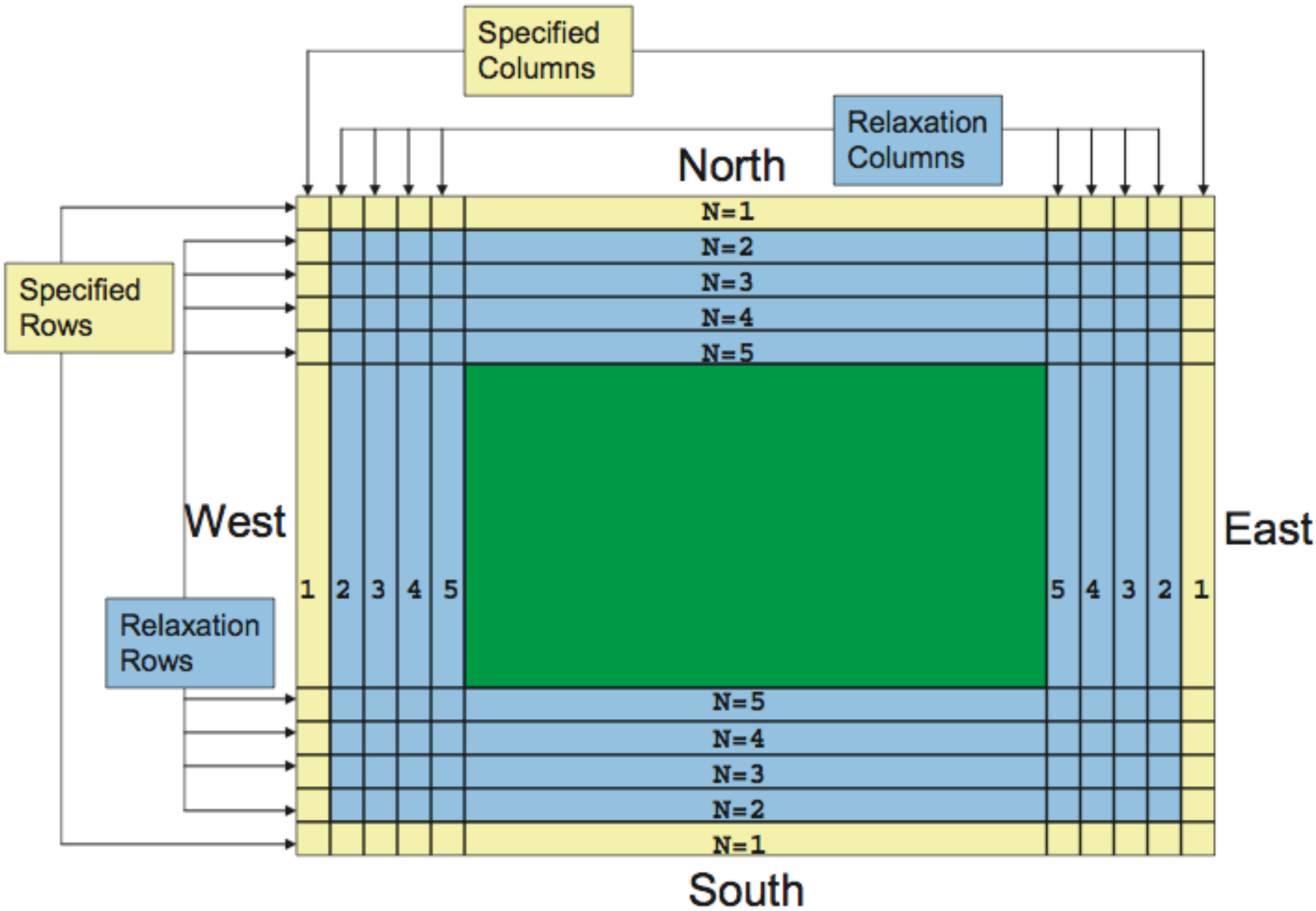
Tasks of the Initialization Program

- The primary purpose for the Real program (either ***real.exe*** and ***real_nmm.exe***) is to ***input*** data from WPS and create data for the WRF model, for a specific dynamical core. For the basic configuration, both an initial (***wrfinput_d01***) and a lateral boundary (***wrfbdy_d01***) file are generated.

Tasks of the Initialization Program
Input Data for real.exe

- Ingest ***time dependent*** upper-air (horizontal winds, height, temperature, relative humidity), surface (SLP, surface pressure, elevation, sea ice, sea-surface temperature, skin temperature), and sub-surface (soil temperature, soil moisture)
- Ingest ***static fields*** of terrestrial (elevation, land use, vegetation category, soil texture category, monthly climo for greenness and albedo) and projection (map factors, latitude and longitude, projection rotation angles) information
- ***Multiple time periods*** of data are processed for the outer-most grid (for the lateral boundary conditions)
  - ARW: the ***initial time of the fine grid*** is processed
  - NMM: ***fine grid*** static information is provided by ***WPS*** directly to the model

Real-Data Lateral Boundary Condition: Location of Specified and Relaxation Zones



Tasks of the Initialization Program

Consistency Checks

- ARW: defining ***sea ice*** based on user criteria: a water point and the skin temperature or sea-surface temperature is cold enough (user defined setting, default about 271 K)
  - Switching to a sea ice point requires changing approximately a dozen associated fields: turn the location into a land point, fix the soil category and land use category
  - Compute a sub-surface temperature, linearly interpolated from the sea-surface temperature and the skin temperature (for example, 4 levels evenly spaced through a depth of 3 m for the Noah LSM scheme)

Tasks of the Initialization Program
Consistency Checks

- NMM: defining ***sea ice*** based on nearby fields:
  - If a land point or a water point is surrounded by sea ice, turn the middle value into a sea ice point, reset the land mask to a water point
  - After adjustment, make sure that the SST, skin temperature, land mask, and sea ice all agree

Tasks of the Initialization Program
Consistency Checks

- Figure out what ***optional data*** is available (soil data, sea-surface temperature, surface pressure, elevation of first guess data)

- ARW: consistency check for ***land mask*** and time dependent fields
  - Land grid points require fields such as soil category, skin temperature, soil temperature (optionally soil moisture, depending on the surface physics selection)
  - If not all of these fields are available, the grid point is turned into a water point

Tasks of the Initialization Program
Consistency Checks

- ARW: If the first-guess (GFS, NAM, etc.) elevation is available:
  - -6.5 K/km lapse rate is applied for the ***soil temperature*** and ***skin temperature*** fields
  - Large elevation adjustments (> 3 km) are bypassed as probably reflecting flag values in the first guess elevation
  - Water points for skin temperature are skipped for the elevation-based lapse rate adjustment.
- Assignment of ***sea-surface temperature*** to the skin temperature array when the location is a water point as defined by the land mask field

Tasks of the Initialization Program
Consistency Checks

- NMM: Modify the model topography when it differs significantly from the input hybrid surface height:
  - If the incoming topo is ***more than 150 m less*** than RUC, set the topo to RUC surface height minus 150
  - If the incoming topo is ***more than 150 m greater*** than RUC, set the topo to RUC surface height plus 150

- NMM: ***Smooth*** the lateral boundary ***topography*** (6 mass points in from the left and right, 12 rows in from the top and bottom) if not a water point

Tasks of the Initialization Program
Consistency Checks

- Assignment of reasonable fields to ***skin temperature*** if the field is undefined at the location due to internal consistency checks or if the WPS provided a flag value:
  - ARW: 0 – 10 cm soil temperature, sea-surface temperature, annual mean temperature, surface air temperature
  - NMM: surface air temperature

Tasks of the Initialization Program
Consistency Checks

- Verify that necessary fields for each grid point are available (***bounds check***)
- Stop code prior to model running is obvious errors occur in soil temperature, soil moisture, skin temperature, deep soil/annual mean temperature, surface pressure, sea-level pressure

Tasks of the Initialization Program

Consistency Checks

- The soil moisture field for the ***Noah LSM*** scheme assumes a total volumetric content.
- The soil moisture from the ***RUC LSM*** provides the amount of moisture in excess of a specified point for that soil category.
- ***Mixing*** Noah input and the RUC selection in the model (or vice versa), requires that adjustments are made to the soil moisture arrays to account for total and residual amounts.

Tasks of the Initialization Program
Consistency Checks

- Both the static and the first-guess fields can provide information for ***land use*** and for ***soil texture***.
- Static: 30 sec resolution, fractional values (24 USGS land use / vegetation type, 16 soil texture categories), not consistent with soil moisture field
- First-Guess: the resolution of the data file, dominant category, but consistent with the soil moisture field
- ***User selects*** which to provide to the WRF model at run-time

Tasks of the Initialization Program
Soil Fields

- Fields: soil temperature, soil moisture, soil liquid (ARW: for the Noah scheme, set to zero, then reinitialized in model based on soil moisture and soil temp)
- ***Vertically interpolated*** to the levels required by the specified surface physics option from the namelist file
- At least two vertical levels must be provided from the WPS that surround the output levels requested (for manufactured sea ice, a skin temperature and the SST threshold are linearly interpolated)
- ***Schemes***: simple diffusion (5 layers, temperature only), Noah (4 layers), RUC (6 levels), Pleim-Xiu (2 levels)
- The ***different number of levels*** is why the real program is re-run when the surface layer is changed in the model

Tasks of the ARW Initialization Program
3D Time Dependent Data ***from WPS***

- The 3d fields are vertically interpolated to the η surfaces
- SLP, topo, T, Qv, Z used to compute total surface p
- Remove moisture in column of input fields for dry pressure
- User specifies the selected η surfaces in the namelist
- Dry surface pressure to compute target WRF coordinates
- Vertically interpolate input fields in dry pressure

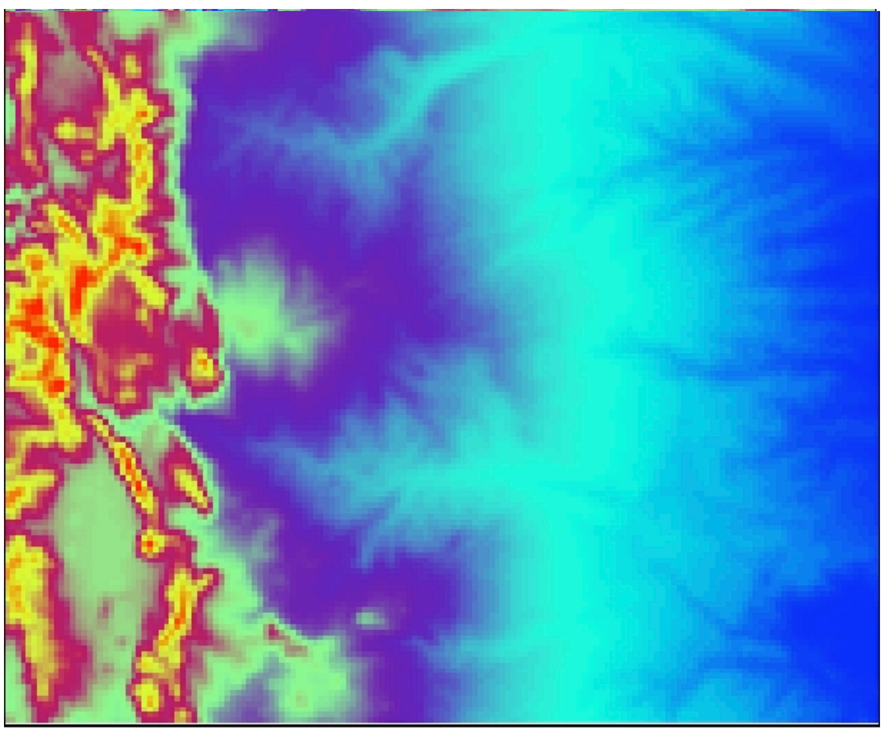
Tasks of the ARW Initialization Program
3D Time Dependent Data ***from WPS***

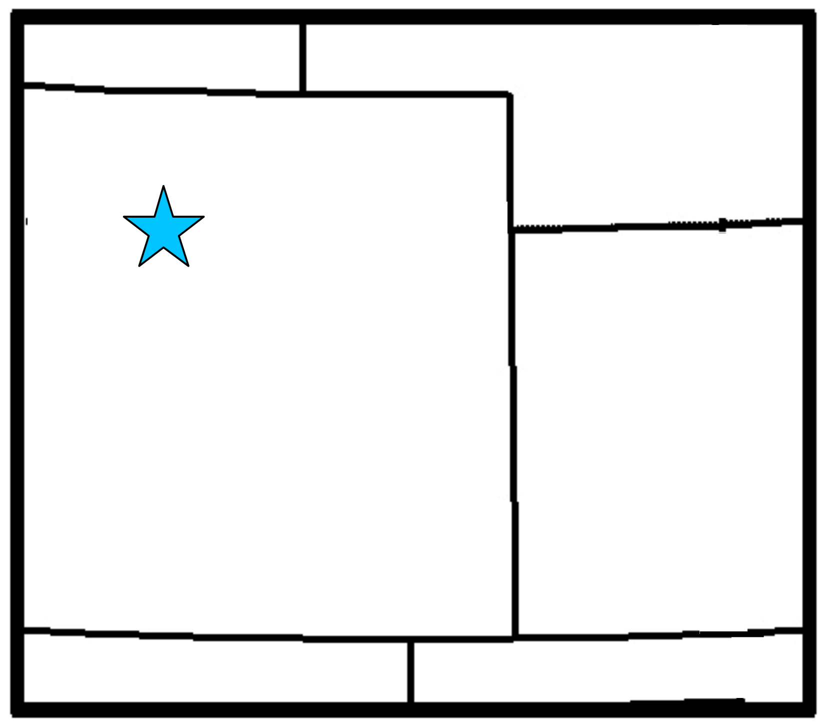
- A number of vertical interpolation options are available to users
- The options can have a significant impact on the initial conditions passed to the model
- More information is contained in the info file ***README.namelist*** in the ***run*** directory
- Options are located in the ***&domains*** namelist record of ***namelist.input***

Tasks of the ARW Initialization Program
3D Time Dependent Data *from WPS*

- Impact: *Expected region of changes*
- *Non-standard setting*
- Which level is being viewed

- Topography and domain for difference plots, 160x140, 4 km, input = 40 km NAM

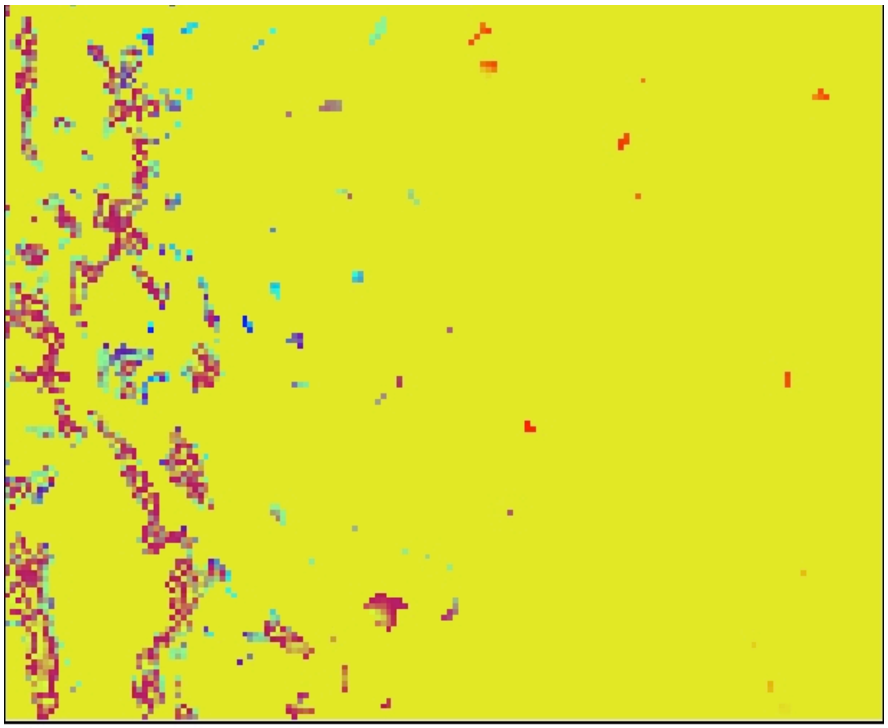




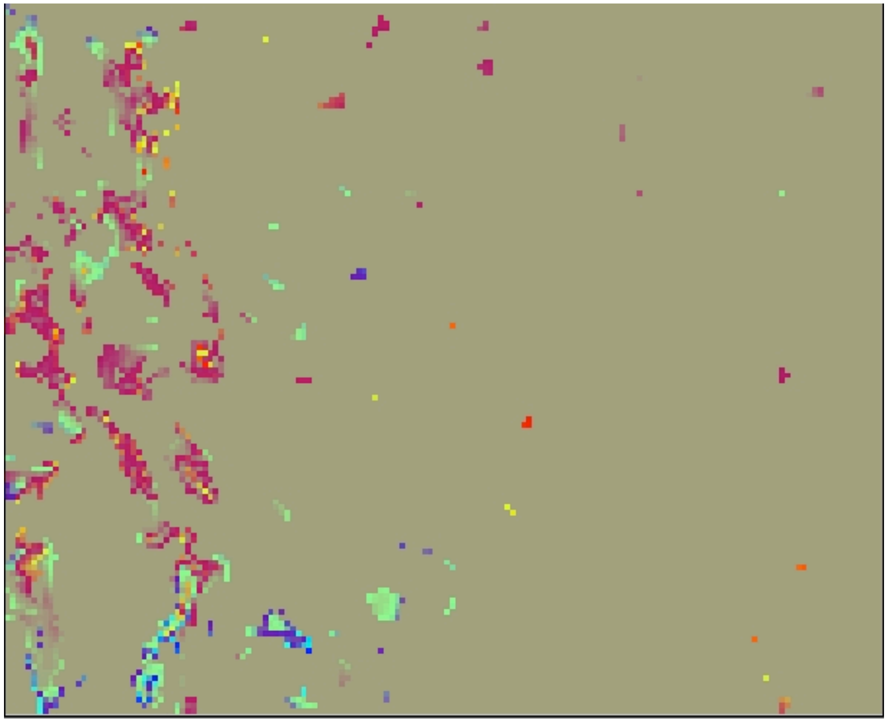
Tasks of the ARW Initialization Program
3D Time Dependent Data *from WPS*

- Impact: few lowest levels only
- force_sfc_in_vinterp = 0
- η level 1

- Theta (-8 K blue, 0 K yellow)



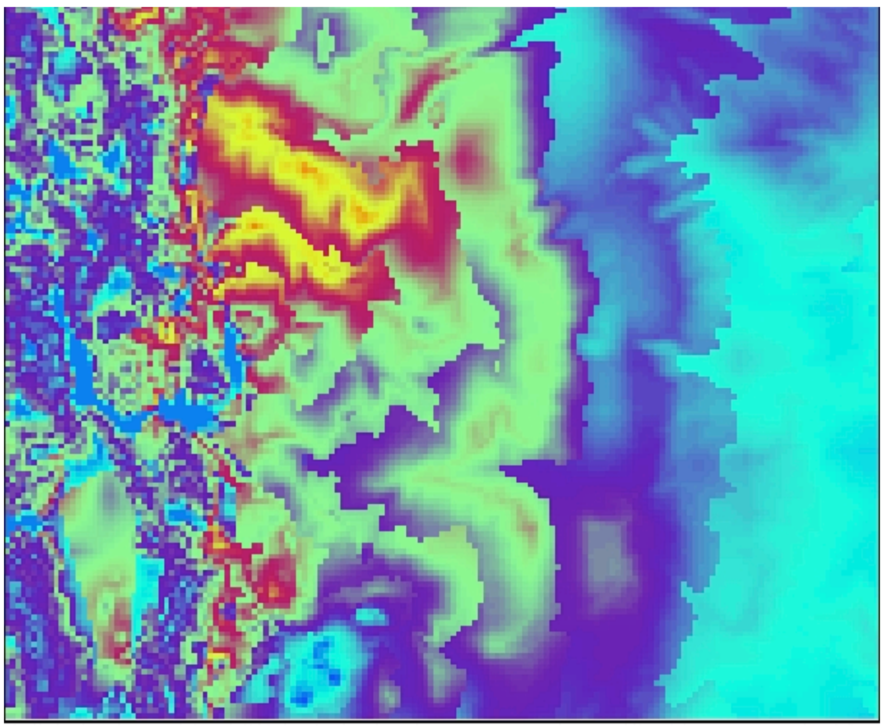
- U (-3 m/s blue, 2 m/s red)



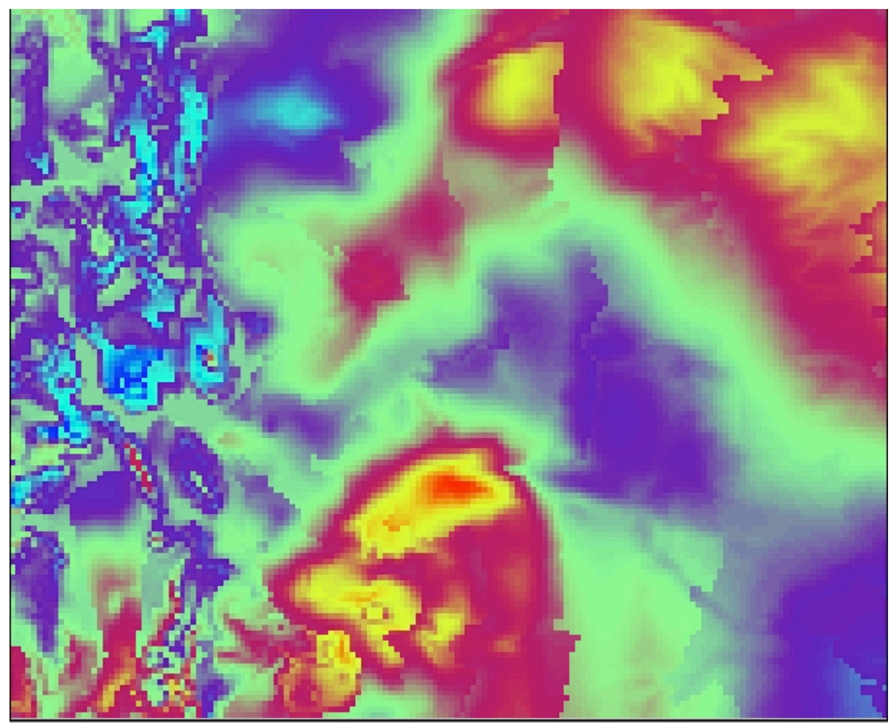
Tasks of the ARW Initialization Program
3D Time Dependent Data *from WPS*

- Impact: few lowest levels only
- force_sfc_in_vinterp = 6
- η level 4

- Theta (0 K blue, 10 K red)



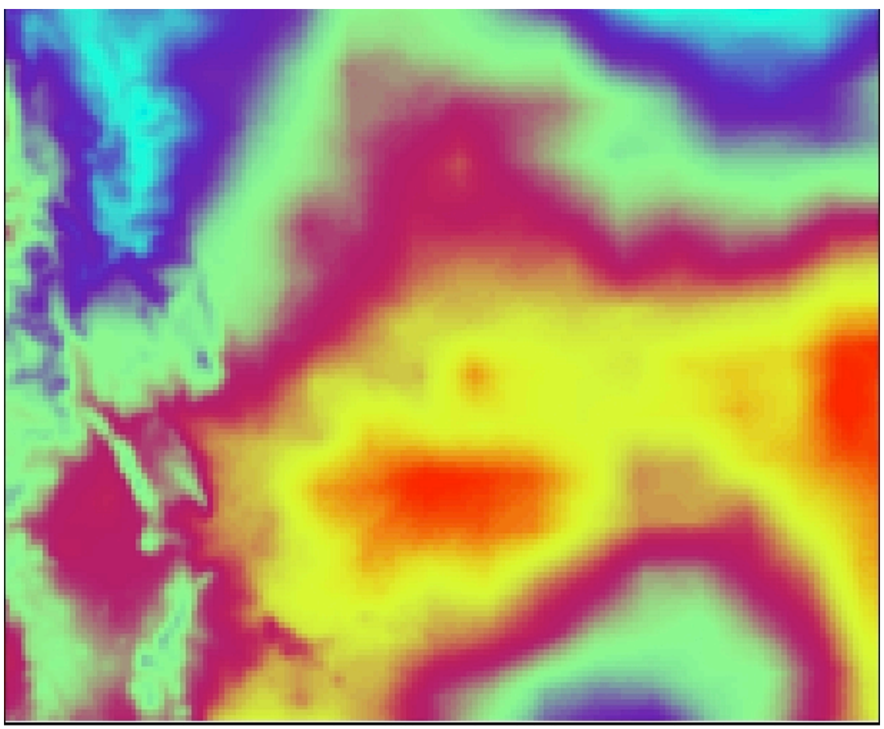
- U (-5 m/s blue, 6 m/s red)



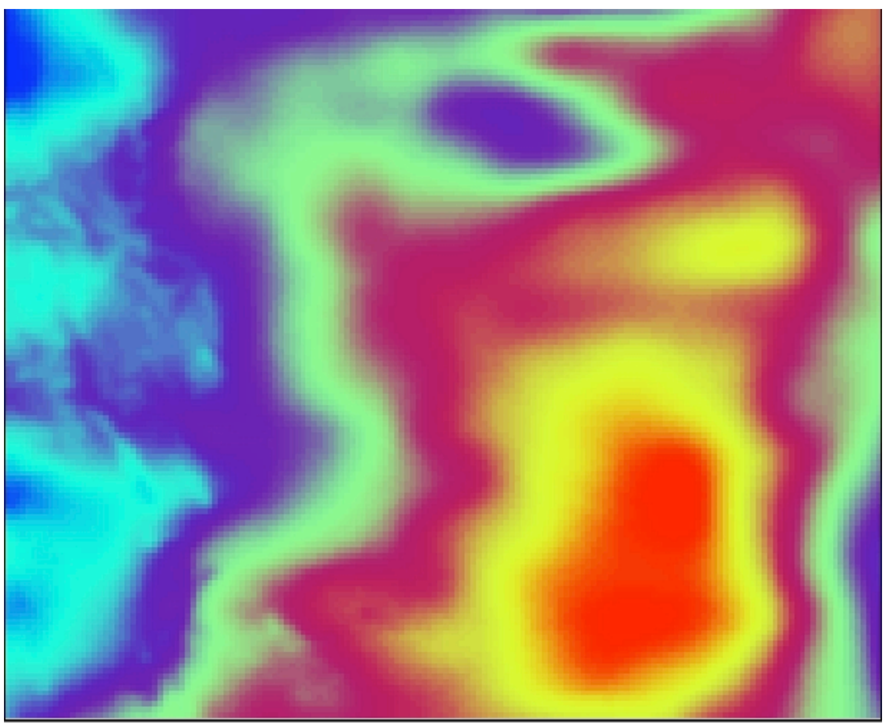
Tasks of the ARW Initialization Program
3D Time Dependent Data *from WPS*

- Impact: above first 4 levels, most near tropopause
- lagrange_order = 2
- η level TOP

- Theta (0.7 K blue, 1.6 K red)



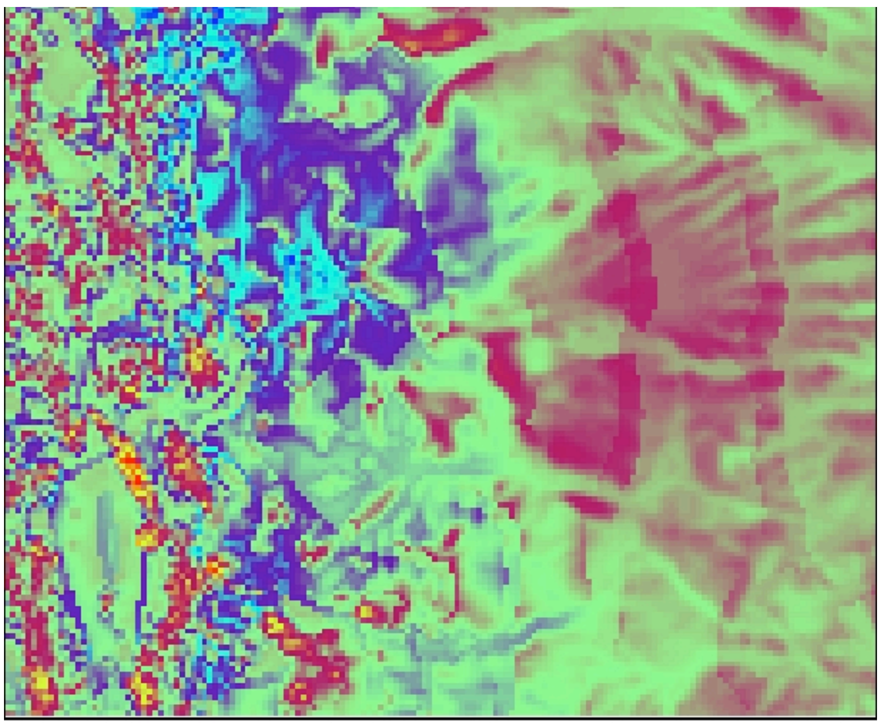
- U (0.4 m/s blue, 1.4 m/s red)



Tasks of the ARW Initialization Program
3D Time Dependent Data *from WPS*

- Impact: lowest level only
- lowest_lev_from_sfc = T
- η level 1

- Theta (-10 K blue, 8 K red)



- U (-3 m/s blue, 7 m/s red)

Tasks of the ARW Initialization Program
3D Time Dependent Data *from WPS*

- Impact: outer few rows and column, amplitude damps upward
- smooth_cg_topo = T
- η level 1

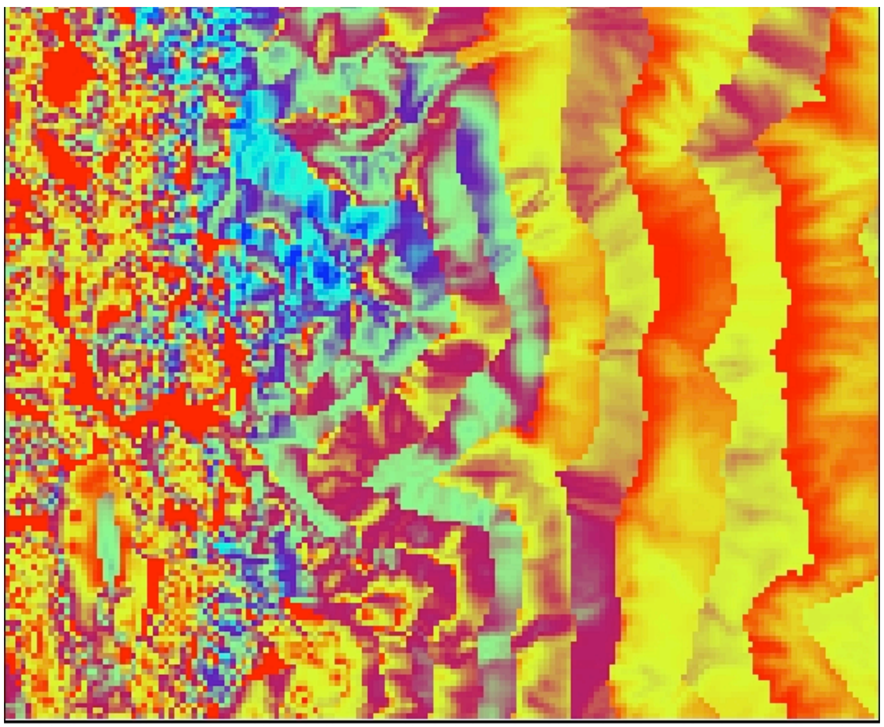
- Theta (-10 K blue, 9 K red)

- U (-6 m/s blue, 6 m/s red)

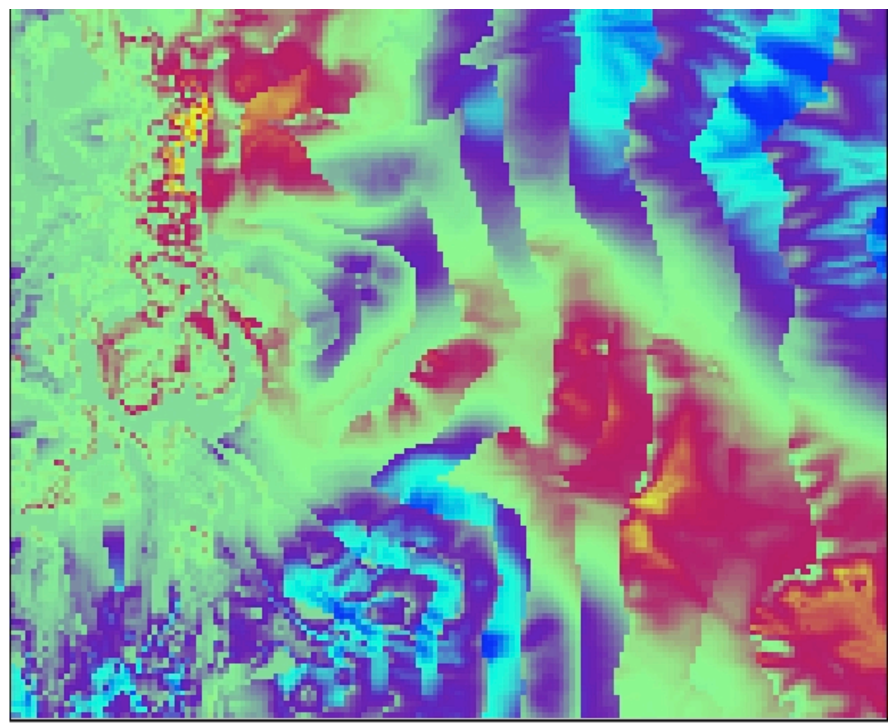
Tasks of the ARW Initialization Program
3D Time Dependent Data *from WPS*

- Impact: lowest few levels
- use_surface = F
- η level 1

- Theta (-11 K blue, 0 K red)



- U (-3 m/s blue, 4 m/s red)



Tasks of the ARW Initialization Program 3D Time Dependent Data ***from WPS***

- All variables are on the correct horizontal staggering: U, V, relative humidity, temperature, height
- U, V, Qv (diagnosed) pass through without any modification (other than vertical interpolation for WPS input)
- Other moisture species (cloud water, snow, rain, graupel, cloud ice) are available as input, but require the compile-time use of a ***-DRUC_CLOUD*** cpp directive; initialized, not used in lateral boundary file)
- Potential temperature has constant factor removed (300 K) for numerical round-off purposes (***looks like Celsius*** near surface, be careful)

Tasks of the NMM Initialization Program 3D Time Dependent Data ***from WPS***

- Make sure input data is vertically ordered as expected, limit hybrid topography deviation
- Input 3-D pressure and T, topo, Z used to compute total surface pressure
- Compute target vertical coordinate, total surface pressure through dp/dz, 3d pressure
- User specifies the selected σ surfaces in the namelist (or can be computed)
- Vertically interpolate input fields in pressure to the σ surfaces: T linearly in pressure; mixing ratio linearly in log(pressure); u and v linear (then an adjustment if using a hybrid input source)

Tasks of the NMM Initialization Program 3D Time Dependent Data ***from WPS***

- All input variables are on the correct horizontal staggering: u, v, RH, temperature, *etc.*
- u, v pass through without any modification (other than vertical interpolation for WPS input)
- Specific humidity diagnosed from relative humidity
- Monthly values greenness fraction and albedo interpolated to a specific date
- Adjust albedo for sea-ice and soil moisture fields over water, and snow cover and snow depth over land

Tasks of the ARW Initialization Program
Base State

- Mass coordinate (ARW WRF model's computational surface) is reference pressure based, surfaces move up and down in pressure space
- Base state surface pressure is a function of terrain elevation plus several user supplied constants
  - Base surface pressure => base 3D pressure
  - Base 3D pressure => base 3D potential temperature
  - Base 3D pressure and potential temperature => base inverse density
  - Base inverse density integrated up => geopotential
- Base state computations follow the model's definition of the equation of state and the hydrostatic relation

Tasks of the NMM Initialization Program Surface Level, Projection, Boundaries

- Compute and analytically define ground temperature
- Sort SST to be only over water and skin temperature to be only over land points
- Set “soil” temperature for sea ice and water points to fixed constants
- Compute roughness height based on land mask and elevation
- Compute projection constants: Coriolis, grid distance
- Increase diffusion along lateral boundaries

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Purpose of the Initialization Program *Input Files* for the WRF Model

- Provide ***initial condition*** data from the WPS to the WRF model (if ARW, then possibly for multiple domains)
- Compute ***lateral boundary*** conditions for outer-most grid

- ARW optional file: ***lower boundary file*** with time dependent sea-surface temperature and sea ice
- ARW optional file: ***grid nudging*** requires multiple time periods of data in the initial condition format

- ARW: output from the real.exe program is suitable to be used as input to the WRF Var package for a “cold start”

Tasks of the Initialization Program ***Boundary Output Fields*** to WRF

- ARW: ***couple*** momentum with total dry column pressure and map factors for use in ***lateral boundary*** values and tendencies
- ARW: geopotential, potential temperature, and moisture (Qv only) are coupled with total dry column pressure for boundary conditions

- NMM: pressure, u, v, T, specific humidity, cloud water, TKE are the boundary output fields

Tasks of the Initialization Program
Output Fields to WRF

- Boundary tendencies are linear ***differences*** valid between the bounding times provided from the WPS data's temporal availability
- The lateral boundaries are arrays for each of the four domain sides; defined for the entire length of the side, the entire height (for 3D arrays)

- ARW: several rows/columns (user defined)
- NMM: one row and column

- ***One less boundary time*** period is created than time periods of WPS data processed

Tasks of the Initialization Program
ARW Nest Domains

Loop over model ***domains***

Loop over time ***periods***

Input Data from WPS

Process Data (consistency, base state, perturbation calculations)

If time loop = 1 => output IC

If time loop = 1 & domain loop > 1 => exit time loop

If time loop >1 => couple data, output BC

End time period loop

End model domain loop

Tasks of the ARW Initialization Program

ARW Nest Domains

- Must have ***WPS input*** data for each nested domain to be initialized by real.exe (the model can horizontally interpolate domains)
- No inter-domain consistency checks, handled by the model during feedback steps
- No horizontal interpolation from the parent domain to the child domain
- Fine domains are only processed at the ***first time*** provided from the WPS by default (except during grid nudging, or run-time namelist request)
- ***User specifies*** 1) which domains to process and 2) that an additional input file is being supplied

Required Input Files

- Simple data checks: times, dims, grid distance, model top
- Physics options are infrequently impacted by WPS output EXCEPT – the real program must be re-run when ***changing the surface physics option*** in the WRF model

Generated Output Files
ARW optional: ***Lower Boundary File***

- An optional file that is available for output is the lower boundary condition file
- Contains time dependent ***sea-surface temperature*** and ***sea ice***
- Values are provided, ***no tendencies***
- The ***temporal resolution*** is the same as for the lateral boundary file
- Useful typically for ***long model runs***, such as where a static sea-surface temperature is an invalid assumption