Program REAL

Description of General Functions

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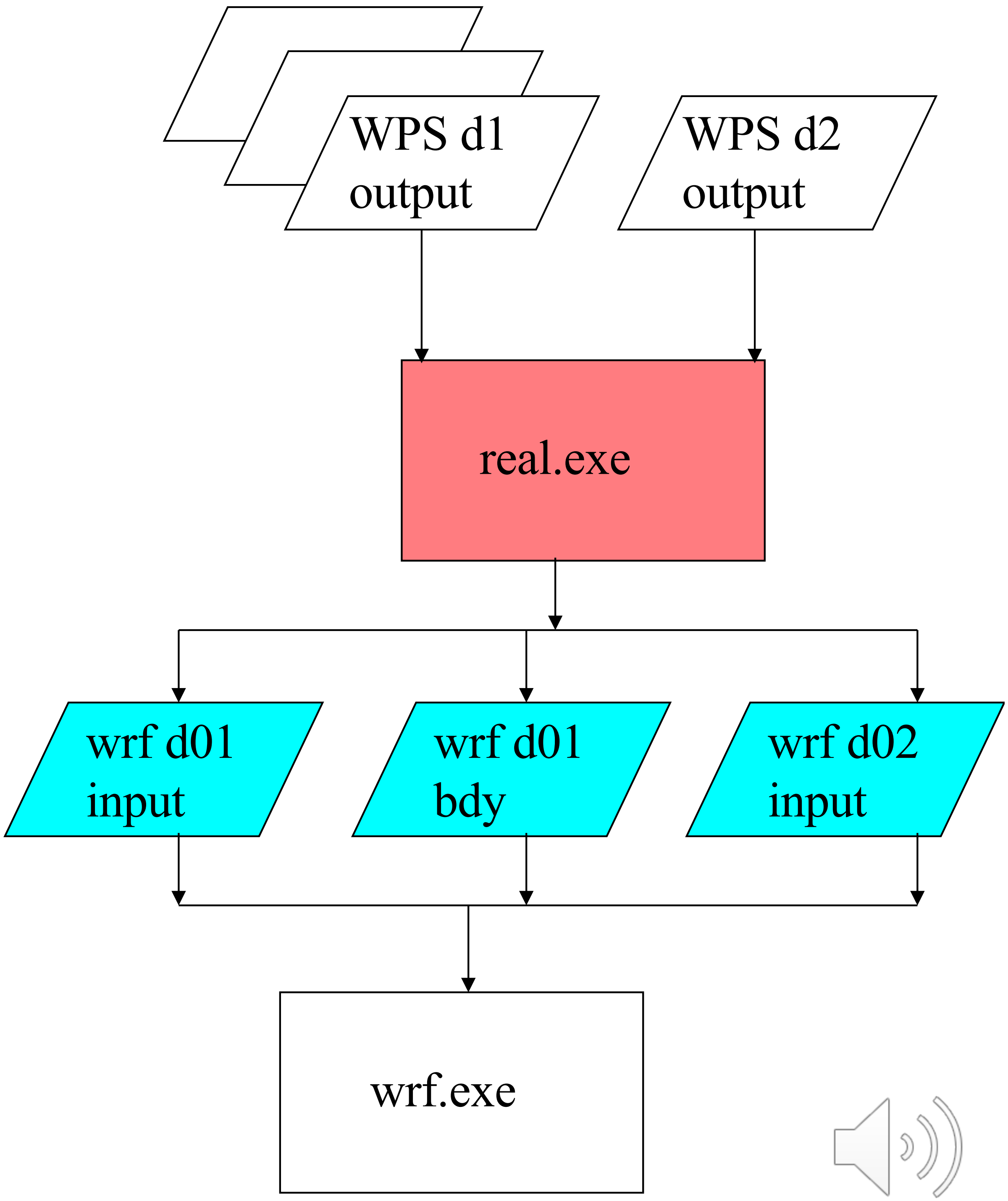

- Introduction to WRF
- WPS: Fundamental Capabilities
- Real – Description of General Functions
- Running the WPS
- WRF – Set-up and Run
- Fundamentals in Atmospheric Modeling
- Overview of Physical Parameterizations
- WRF Best Practices
- Idealized Cases
- WRF-ARW Dynamics Solver
- Nesting in WRF
- NCL Post-processing Tool
- How to Use the WRF Registry
- Additional WRF Run-time Options
- WRF Physics (Part 1)
- WRF Physics (Part 2)
- WRF 4DDA
- Compiling WRF and WPS
- Advanced Usage of the WPS
- Verification of WRF Simulations
- WRF Computation
- WRF Data, Utilities, & Post-Processing

WRF Online Tutorial Suggestion:
New WRF users should initially view the presentations that are highlighted in yellow. The remainder of the presentations may be viewed in any order. Associated presentations are highlighted similarly, and may be viewed together as a whole.

Real program in a nutshell

- Function
- Standard input variables
- Base State
- Standard generated output
- Vertical interpolation
- Soil level interpolation

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- Function

Loads of definitions …

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What are the required, optional variables?

From whence do they come?

What are the restrictions on metgrid vertical coordinates?

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What is the vertical coord?

Not exactly potential temperature

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What are the mandatory files for success?

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How does the user change the vertical coordinate?

Are there recommendations?

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Why is the surface layer scheme a good example of changing physics options?

Function

- The WRF model pre-processor is ***real.exe***
- The real.exe program is 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 program takes data ***from WPS*** and transform the data ***for WRF***
- Similar to the ARW idealized data pre-processor, real.exe is tightly coupled to the WRF model through the ***Registry***

Function

- ***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 (maybe usage of nudging capabilities)

Function

- A non-Cartesian ***projected domain***
  - Lambert conformal, Mercator, polar stereographic, rotated latitude/longitude (global or regional)
- 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

Function

- 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 for each of the requested domains
- Creation of a ***lateral boundary file*** for the most coarse domain
- ***Vertical interpolation*** for 3d meteorological fields and for sub-surface soil data

Function

- **Run-time options**
  - specified in the Fortran namelist file (namelist.input for real and WRF)
- **Compile-time options**
  - Changes inside of the source code
  - Compiler flags
  - CPP ifdefs
  - Modifications to the Registry file

Standard Input Variables

- The metgrid program typically provides meteorological data to the real program.
- Coordinate:
  - The real program is able to input and correctly process any ***strictly monotonic in pressure*** vertical coordinate
    - Isobaric: OK
    - Sigma: OK
    - Hybrid: OK

Standard Input Variables

- The metgrid program typically provides meteorological data to the real program.
- Mandatory:
  - 3d and surface: horizontal winds, temperature, relative humidity, geopotential height
  - 3d soil: soil temperature
  - 2d fields: surface pressure, sea-level pressure, land mask
- Optional (but desirable):
  - 3d soil: soil moisture
  - 2d fields: topography elevation of input data, SST, sea-ice, skin temperature

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Base State

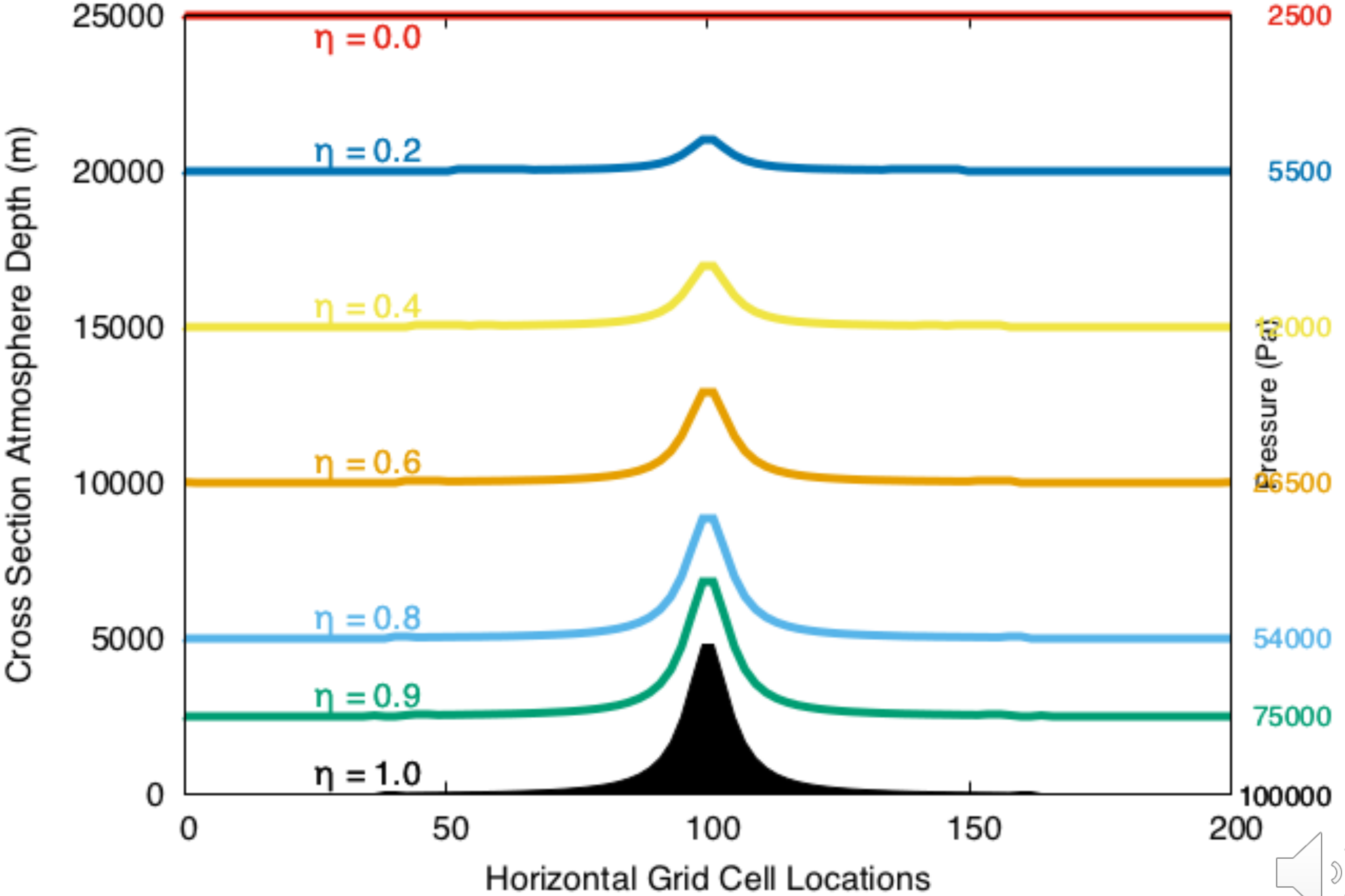
- Several of the mass-point fields are ***separated*** into a time-independent ***base state*** (also called a reference state) and a ***perturbation*** from the base state
- The base state fields are only functions of the ***topography*** and a few user-selectable constants
- If the ***topography changes***, such as with a moving nest, the base state fields are modified
- ***Feedback*** for 2-way nesting also impacts base state fields through topographic averaging – ***inside of the WRF model***
- No base state computations are required ***prior to the real program***

Hybrid Vertical Coordinate

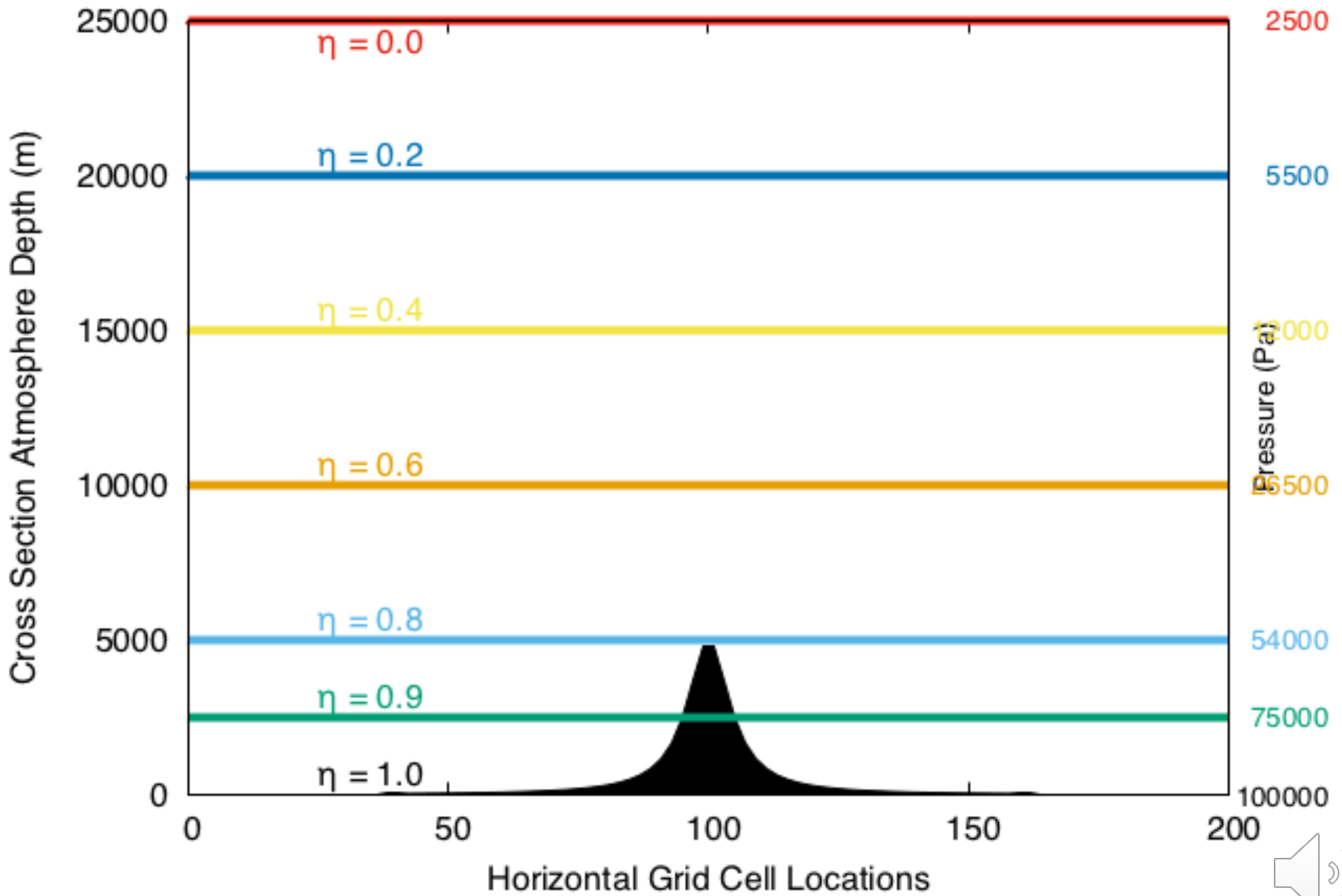
- WRF has the capability to have a ***HVC*** hybrid vertical coordinate
  - a ***terrain following*** coordinate near the surface
  - relaxing to ***isobaric surfaces aloft***

- This is the ***default*** starting with version 4.0

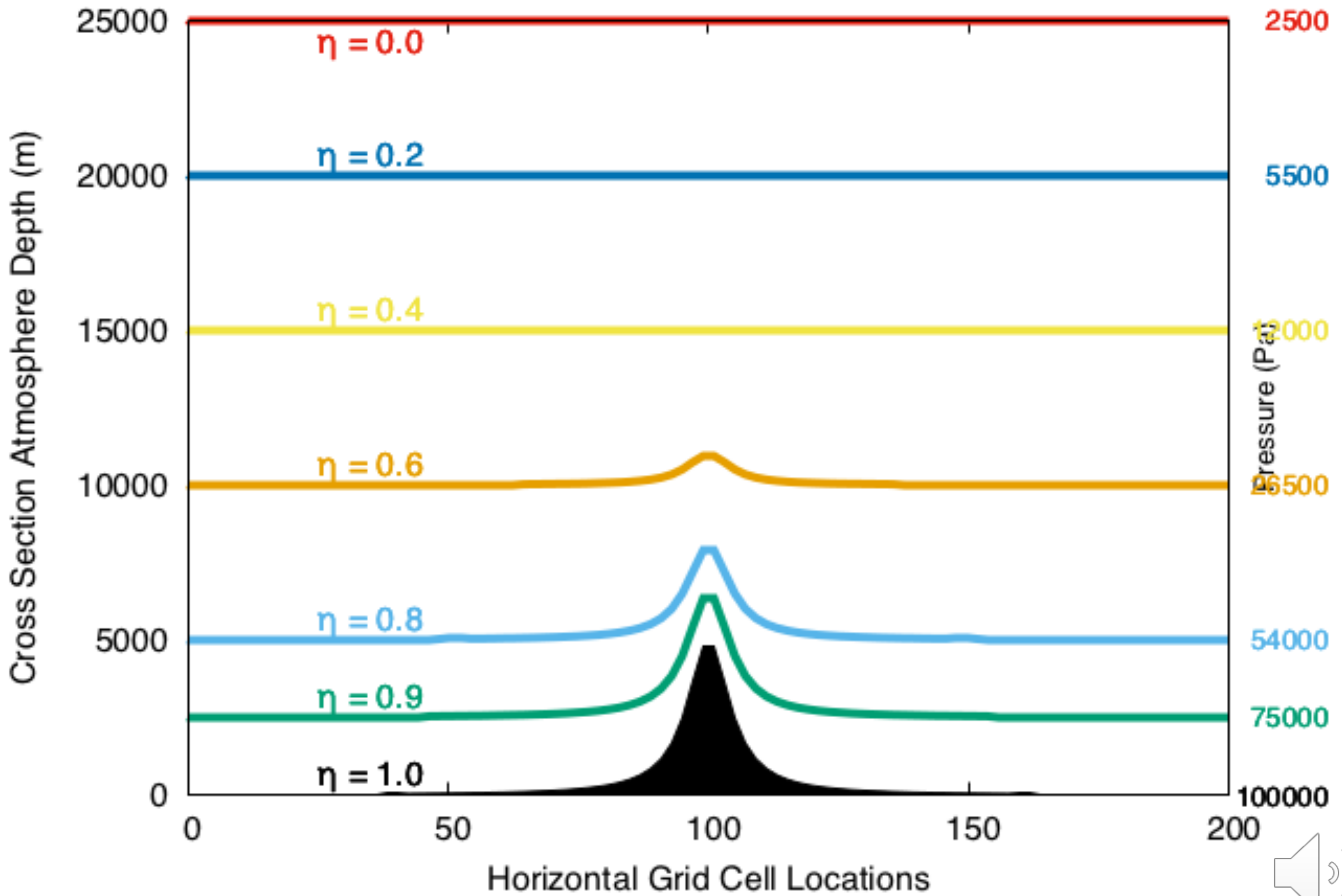
TERRAIN FOLLOWING Vertical Coordinate System



ISOBARIC Vertical Coordinate System



HYBRID Vertical Coordinate System



Moist Potential Temperature

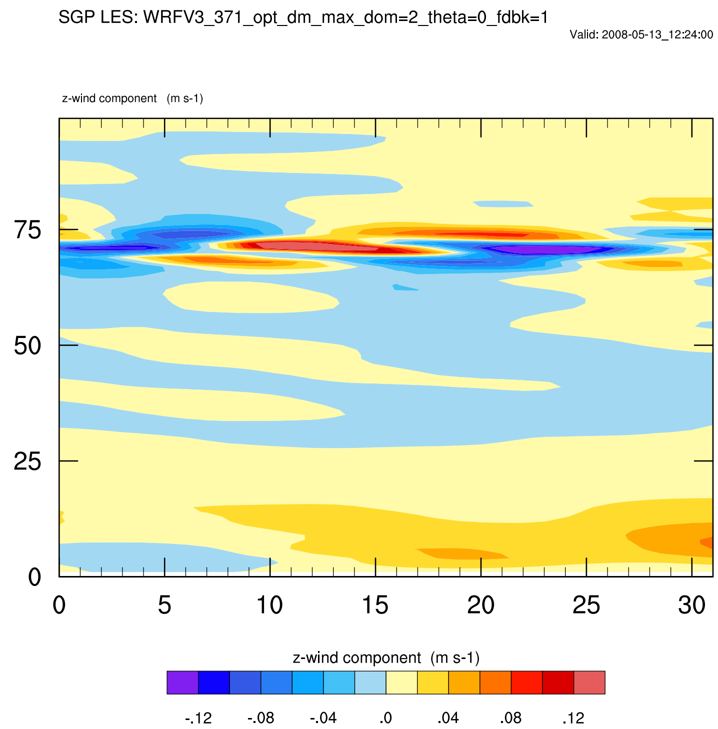
- The potential temperature outside of physics used in the WRF model equations may optionally be a "moist" potential temperature perturbation

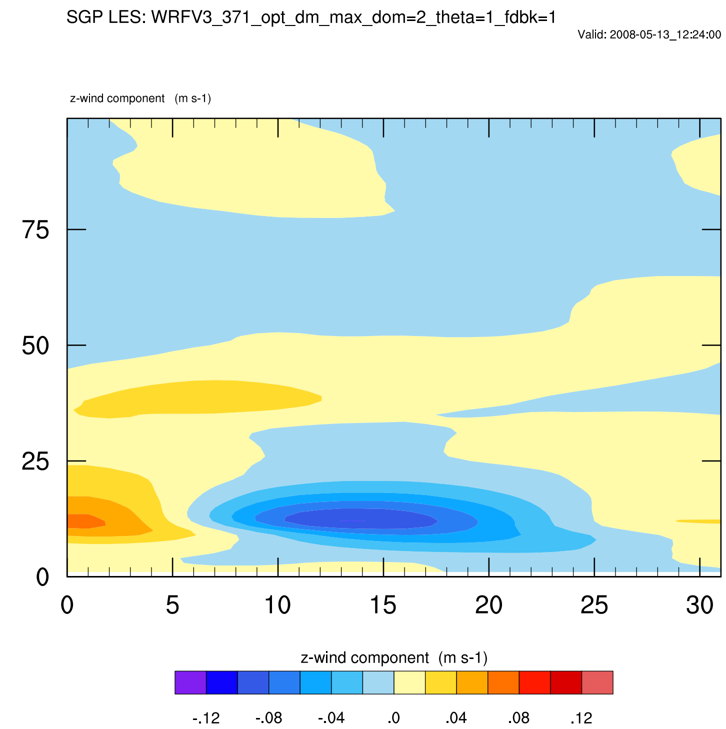
- WRF theta ***(dry)*** = T (p0 / p)^ (Cp / Rd) - 300
- WRF theta ***(moist)*** = T (p0 / p)^ (Cp / Rd) ***(1+Rv/Rd) Qv*** – 300

- The moist option is the ***default*** since v4.0

Moist Potential Temperature

- This has been found to give better and more stable solutions in some LES cases with vertical moisture gradients with vertical shear

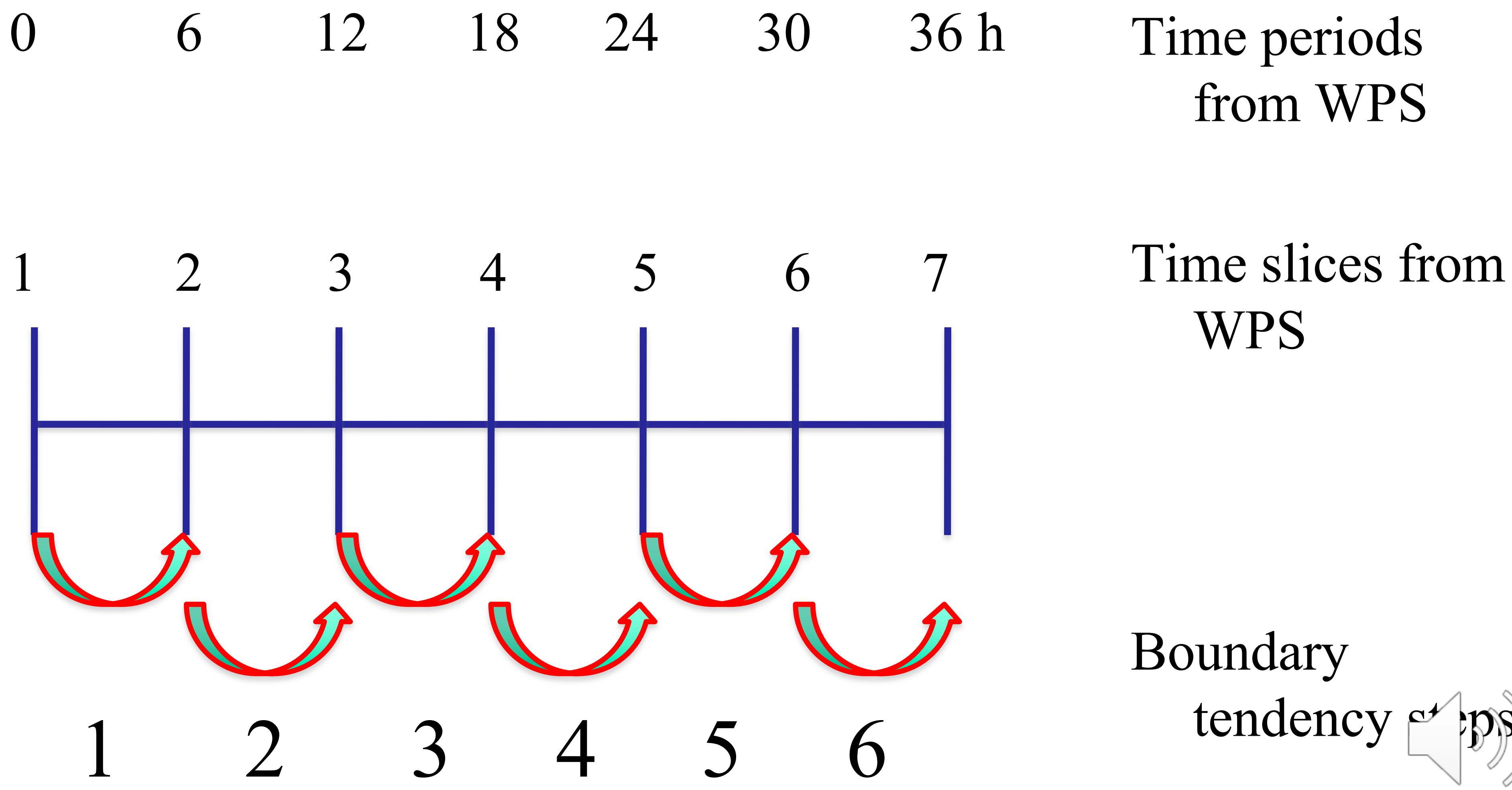




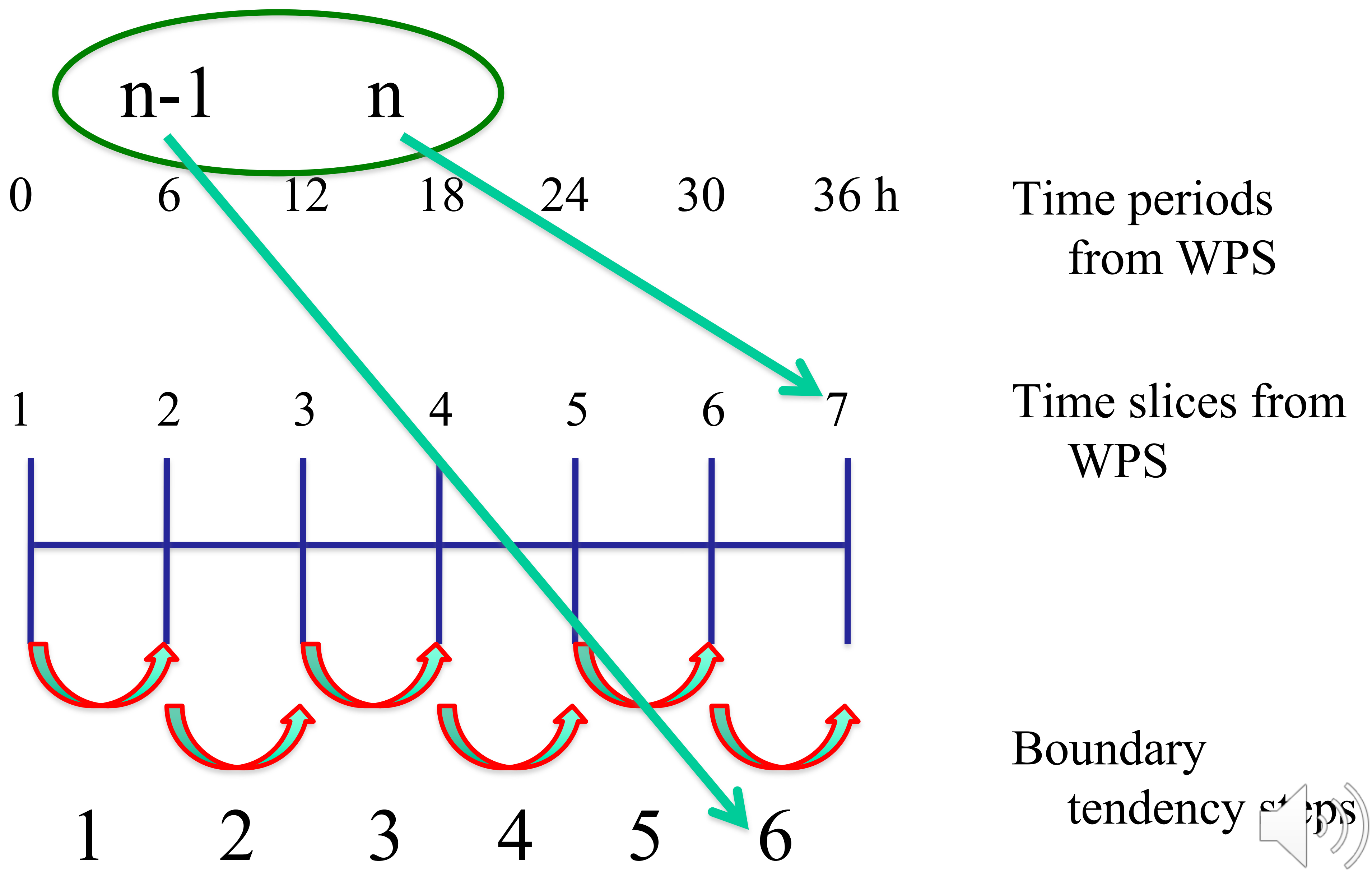
Standard Generated Output

- For regional forecasts, the real program generates both an both an initial (***wrfinput_d01***) and a lateral boundary (***wrfbdy_d01***)
- The boundary file is not required for ***global forecasts*** with ARW (look at MPAS for global simulations)
- The ***initial condition*** file contains a ***single time period*** of data
- These files contain data used directly by the WRF model
- The initial condition file may be ingested by the ***WRFDA*** code (referred to as a *cold-start*)
- If ***n*** times were processed with WPS and real, the lateral boundary file contains ***n-1*** time slices

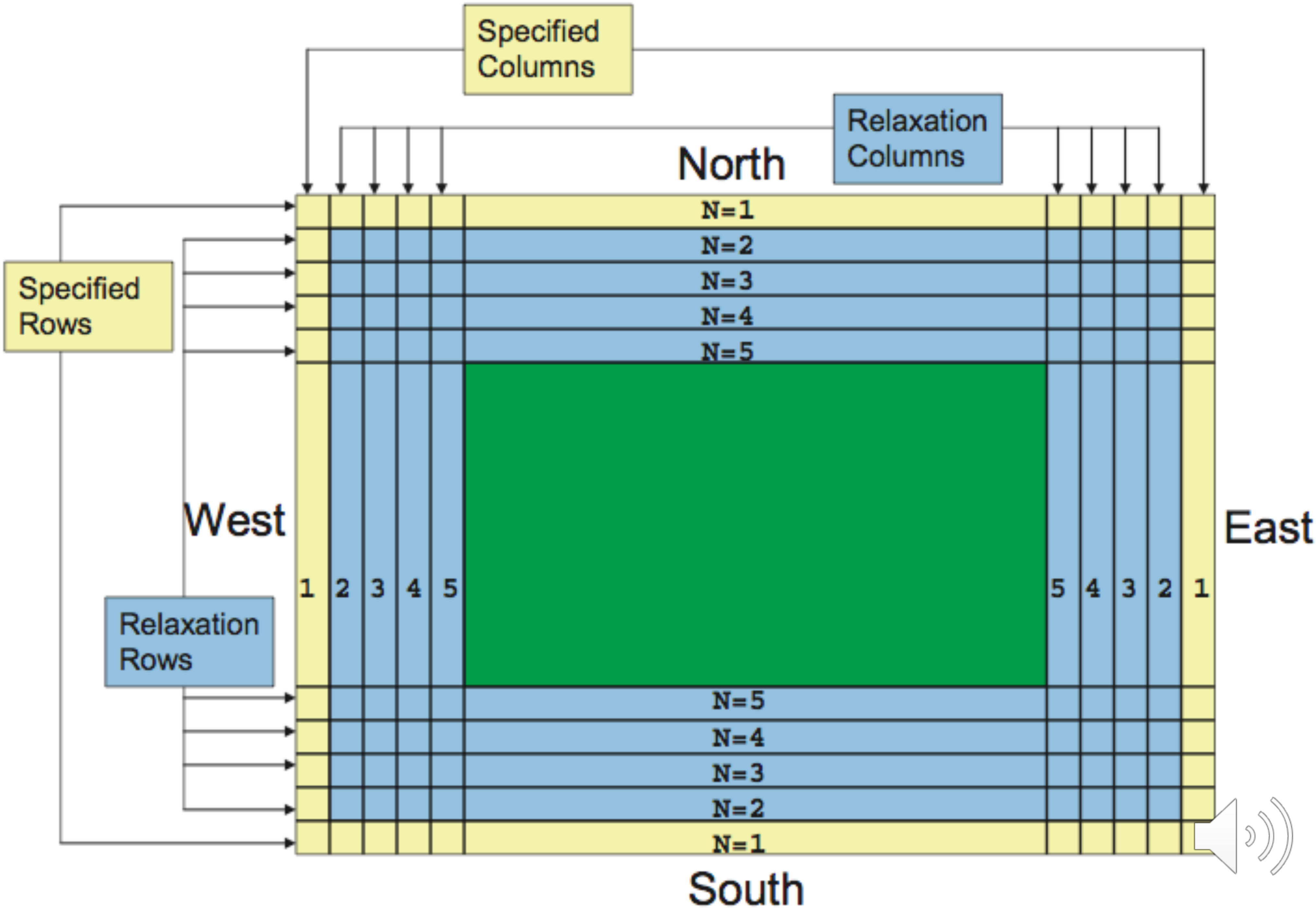
Lateral Boundary Condition Times



Lateral Boundary Condition Times



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



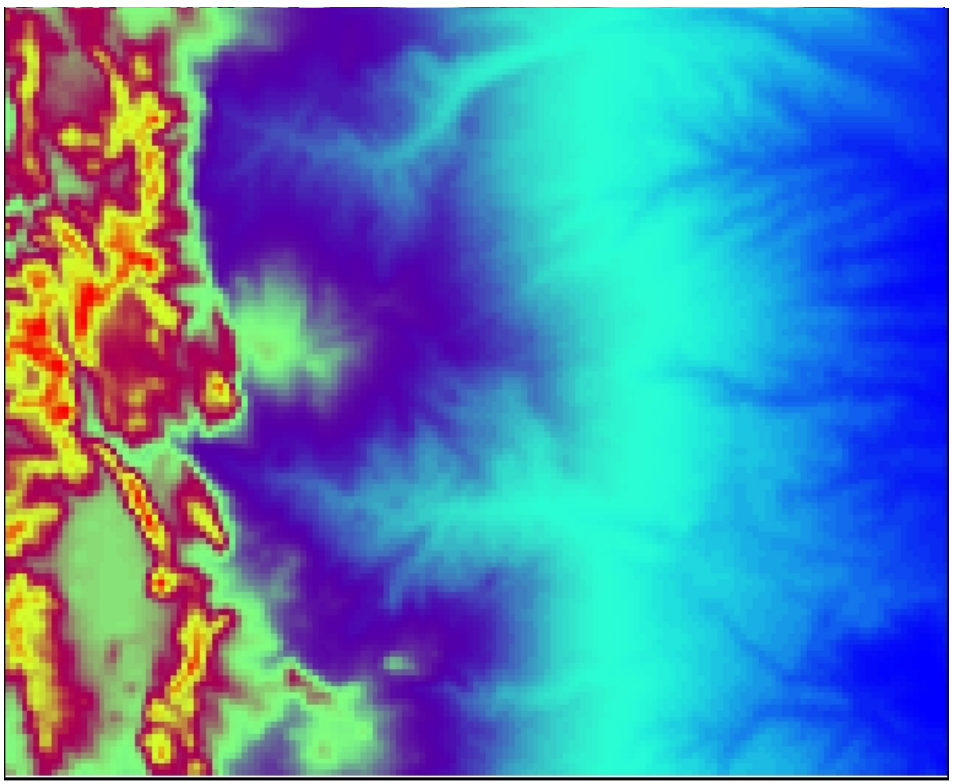
Vertical Interpolation

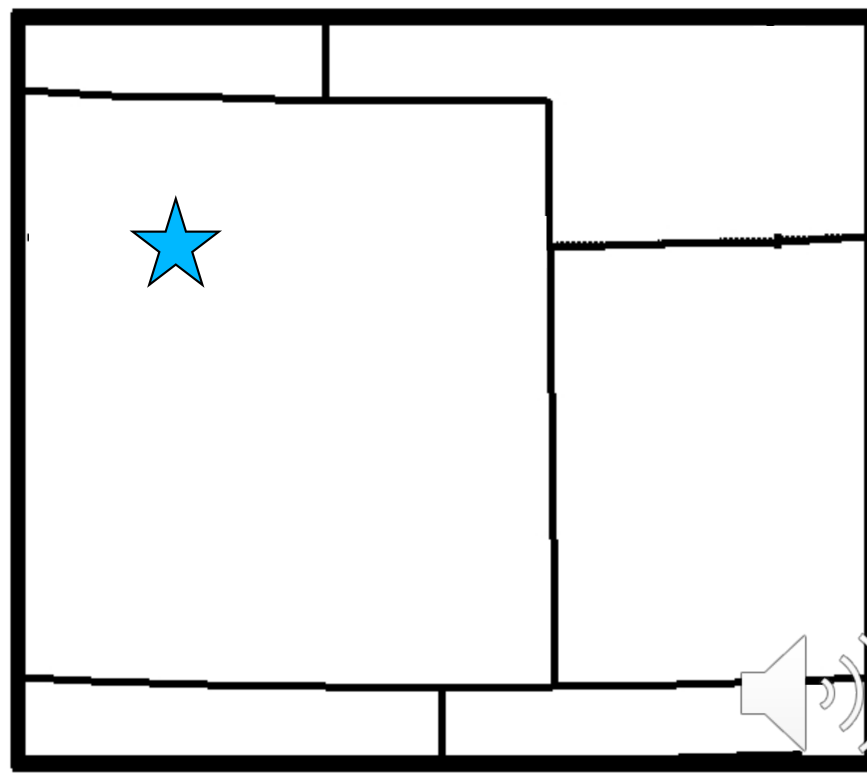
- A number of vertical ***interpolation options*** are available to users
- The options can have a significant impact on the initial conditions passed to the model
- More information is contained in the info file ***README.namelist*** in the ***run*** directory
- Options are located in the ***&domains***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

Vertical Interpolation

- 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

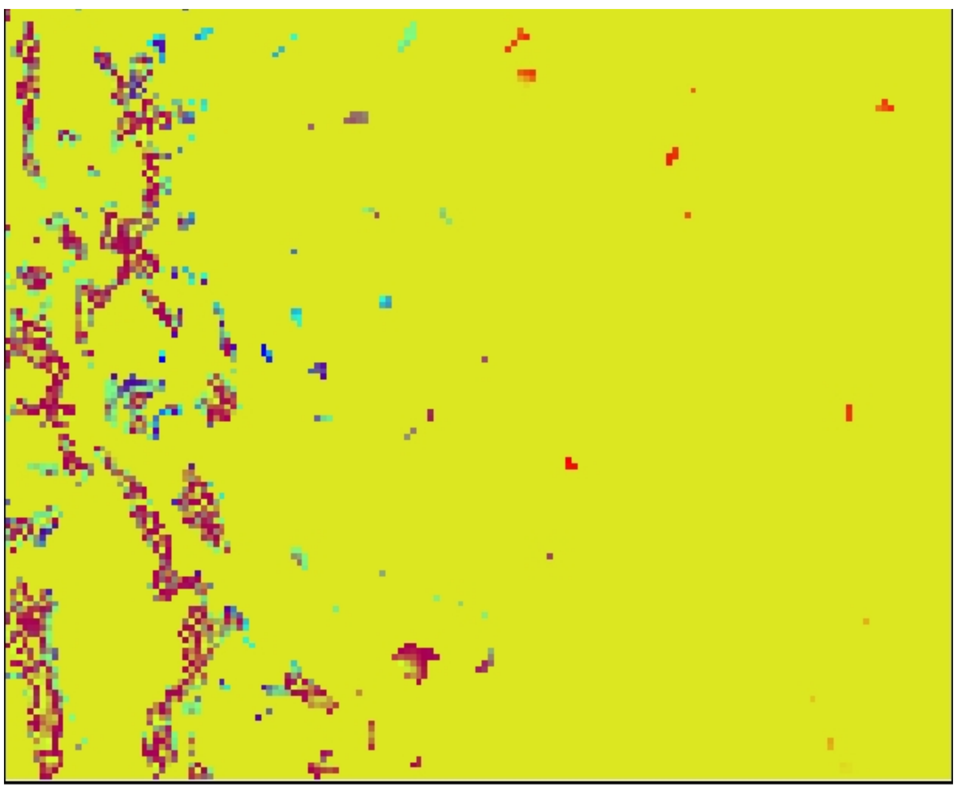




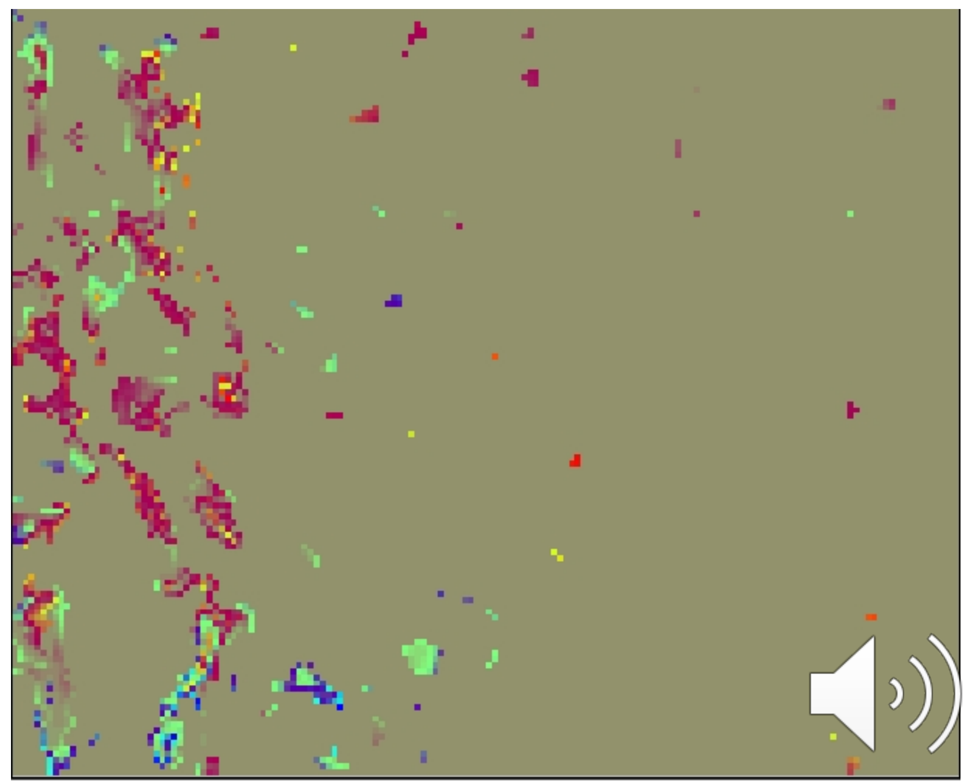
Vertical Interpolation

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

- Theta (–8 K blue, 0 K yellow)



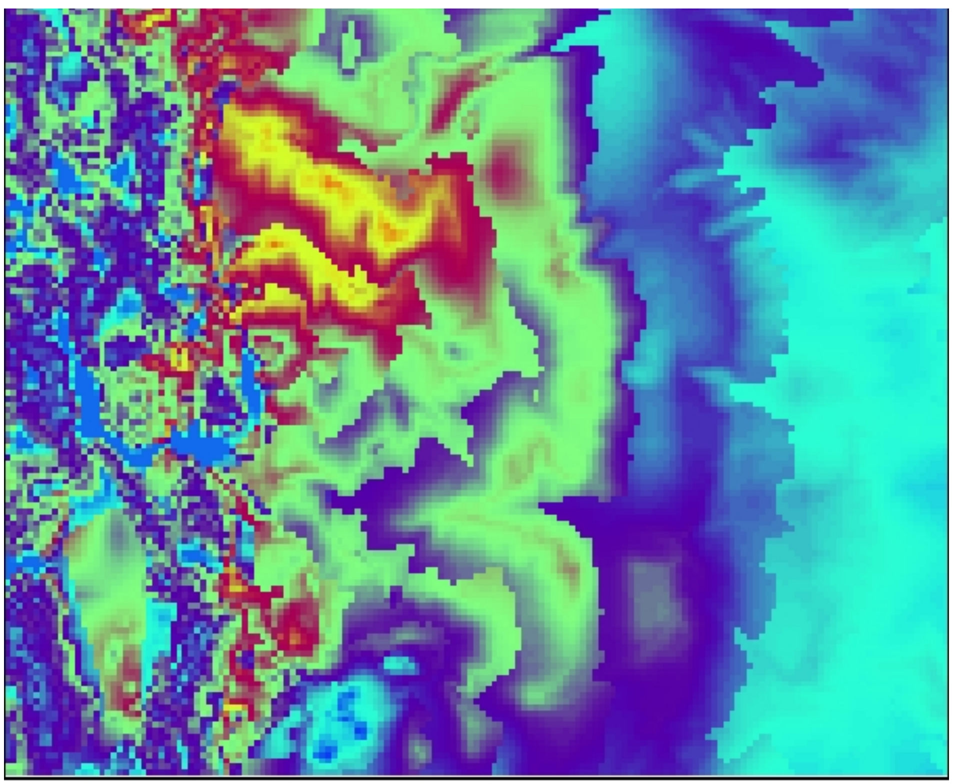
- U (–3 m/s blue, 2 m/s red)



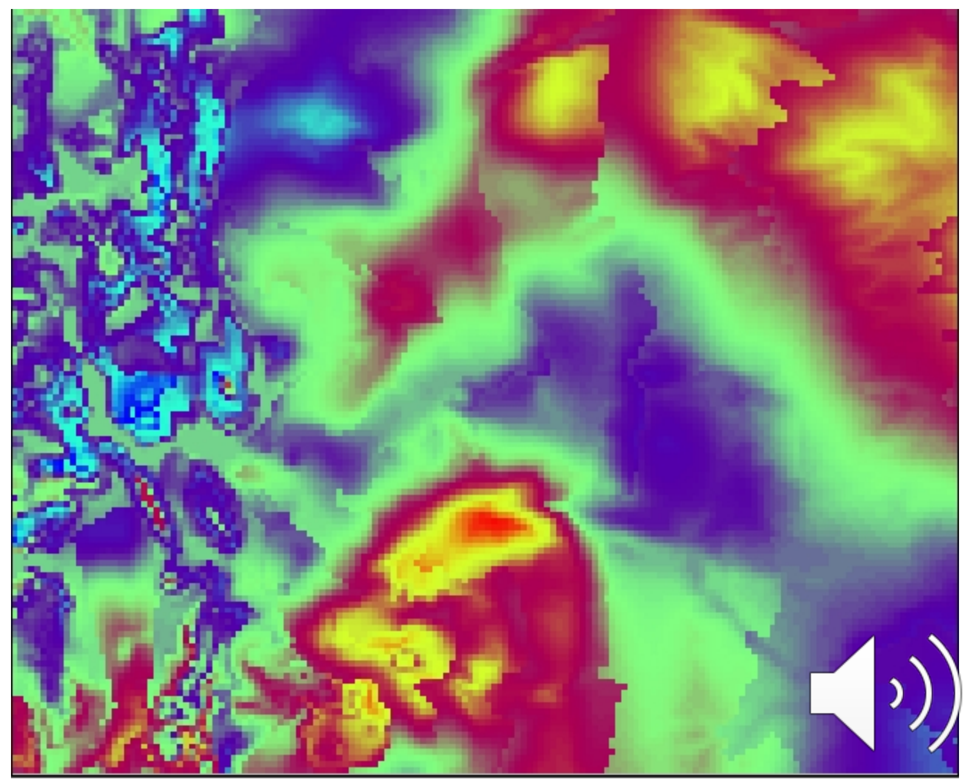
Vertical Interpolation

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

- Theta (0 K blue, 10 K red)



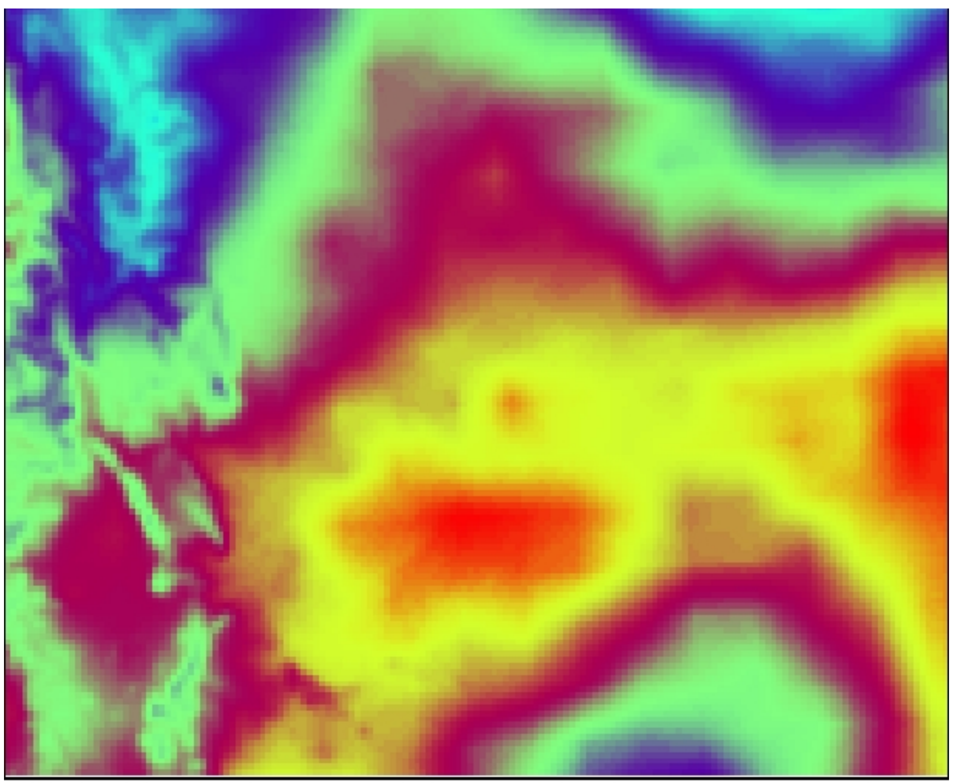
- U (−5 m/s blue, 6 m/s red)



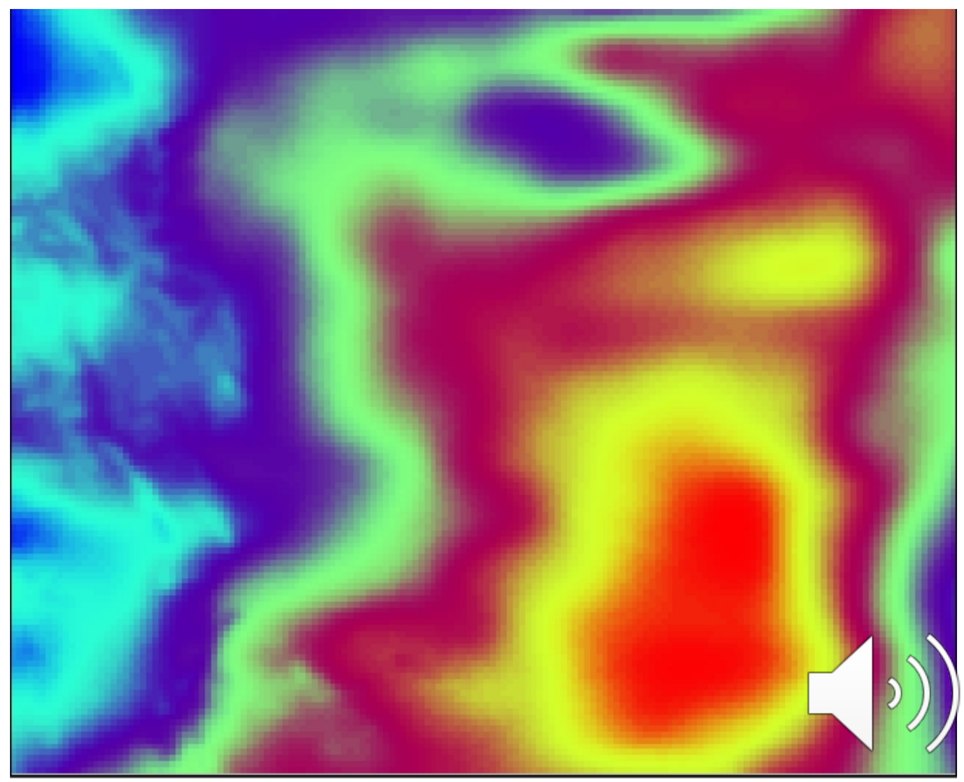
Vertical Interpolation

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

- Theta (0.7 K blue, 1.6 K red)



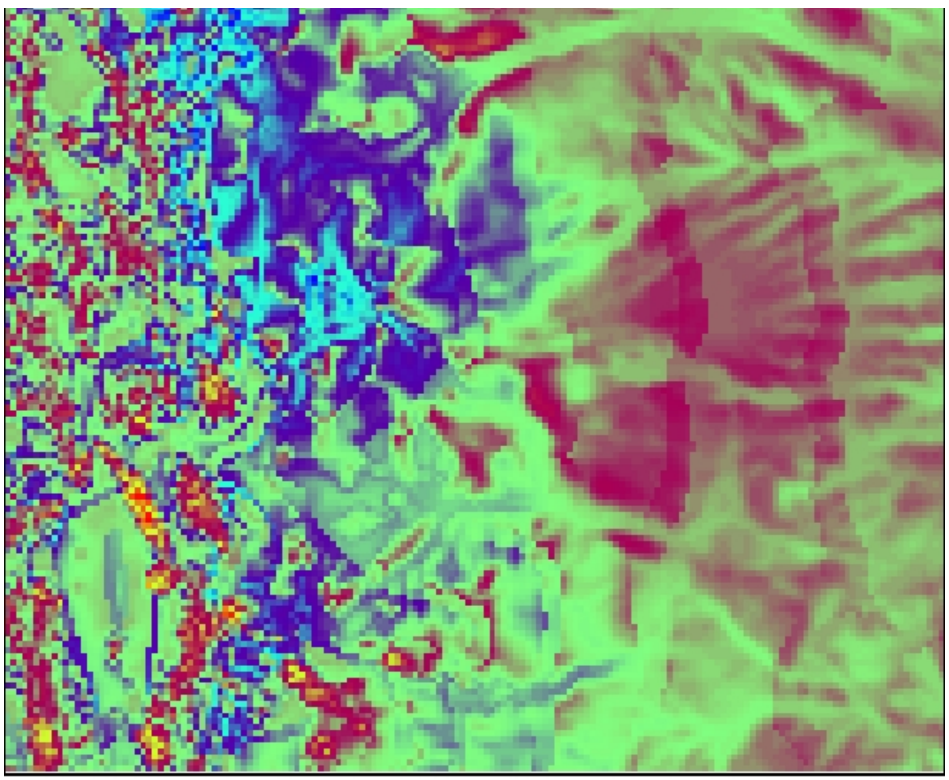
- U (0.4 m/s blue, 1.4 m/s red)



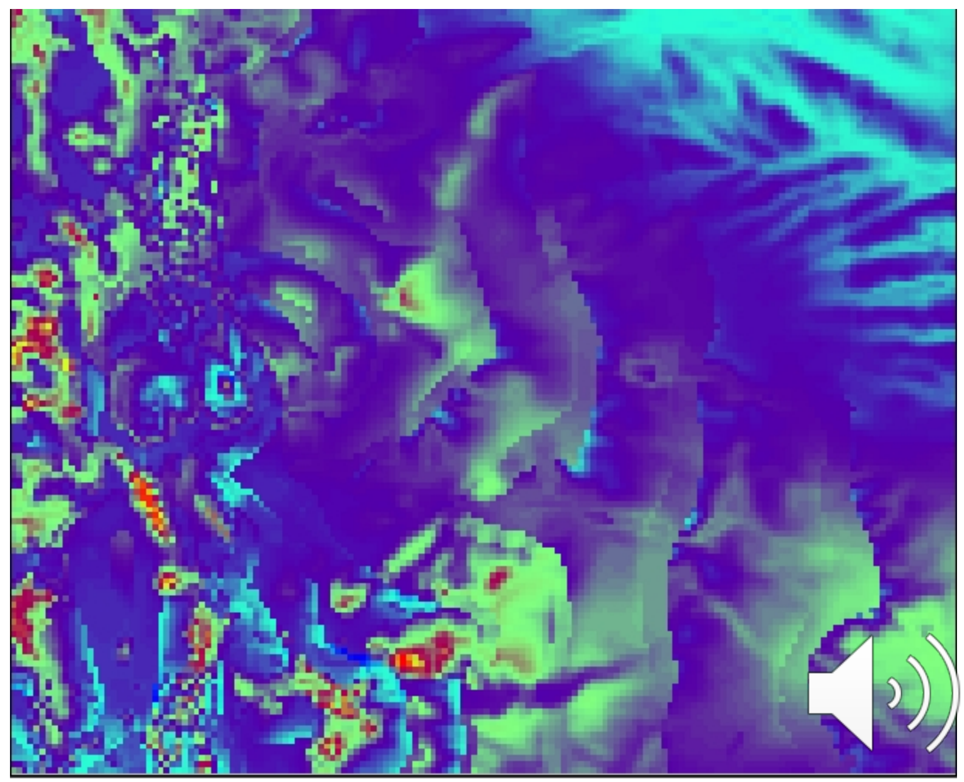
Vertical Interpolation

- 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)



Vertical Interpolation

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

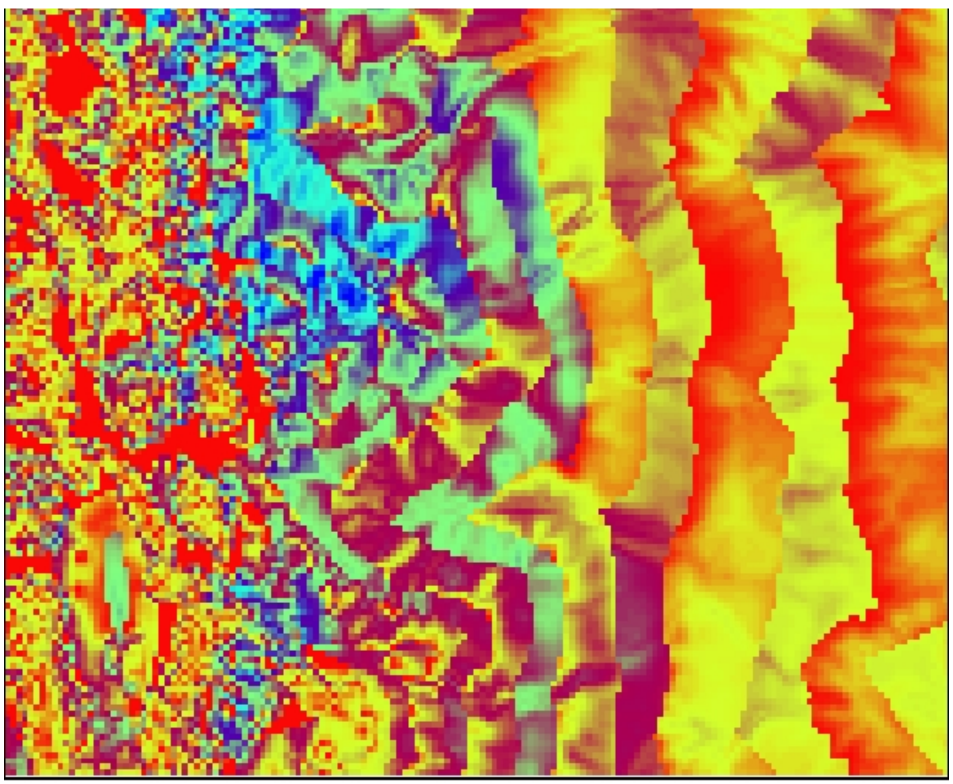
- Theta (-10 K blue, 9 K red)

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

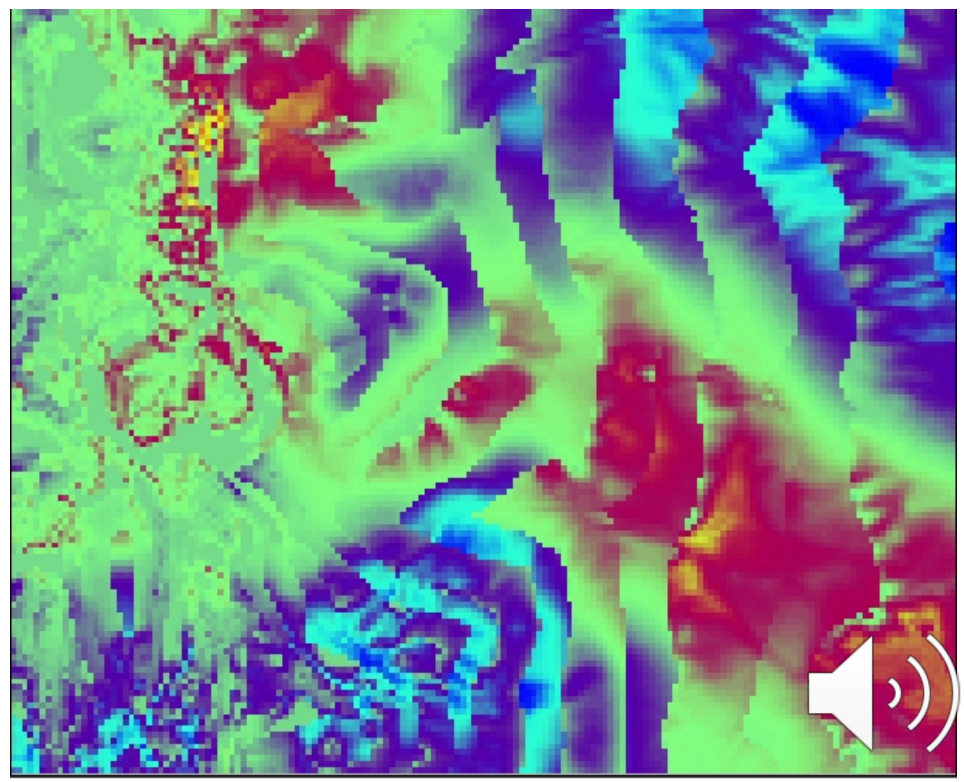
Vertical Interpolation

- 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)



Vertical Interpolation

Make sure input data is vertically ***ordered*** as expected

Input 3-D pressure and T, topo, Z, moisture used to compute total ***surface pressure***

Compute target ***vertical coordinate*** using normalized dry column pressure pressure

The $\boldsymbol{\eta}$ ***surfaces*** may be computed or selected

Vertically interpolate input fields in pressure to the $\boldsymbol{\eta}$ ***surfaces*** in dry pressure: default all variables linear in log(pressure)

Vertical Interpolation

- Select reasonable η levels, or let the real program do it for you
- Verify that the ***"thicknesses" are acceptable***, generally about the same value in the free-atmosphere and less than 1000 m
- It is ***SAFEST to NOT initially choose η values***
  - Initially, ***select the number*** of *η* levels
  - ***Plot profiles*** of the resultant heights
  - ***Adjust the η levels*** accordingly

- A few namelist options, the terrain elevation, and eta levels completely define the model coordinate for the WRF code

Vertical Interpolation

- The ***η surfaces*** are computed with a few NML parameters:

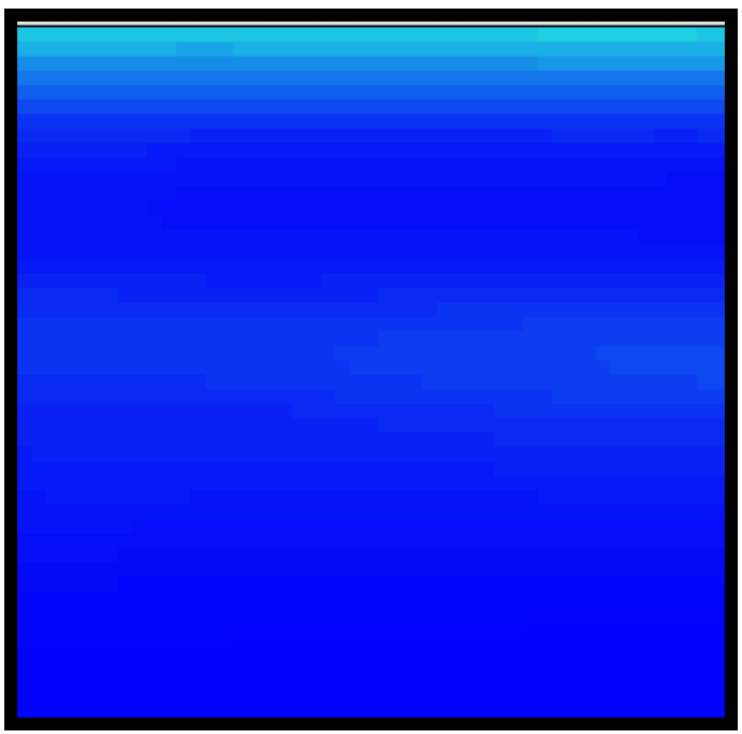
```
&domains
e_vert              = 50,    50,   50
p_top_requested     = 1000,

&dynamics
base_temp           = 290,
iso_temp            = 200,
base_pres_strat     = 5500,
```

Vertical Interpolation

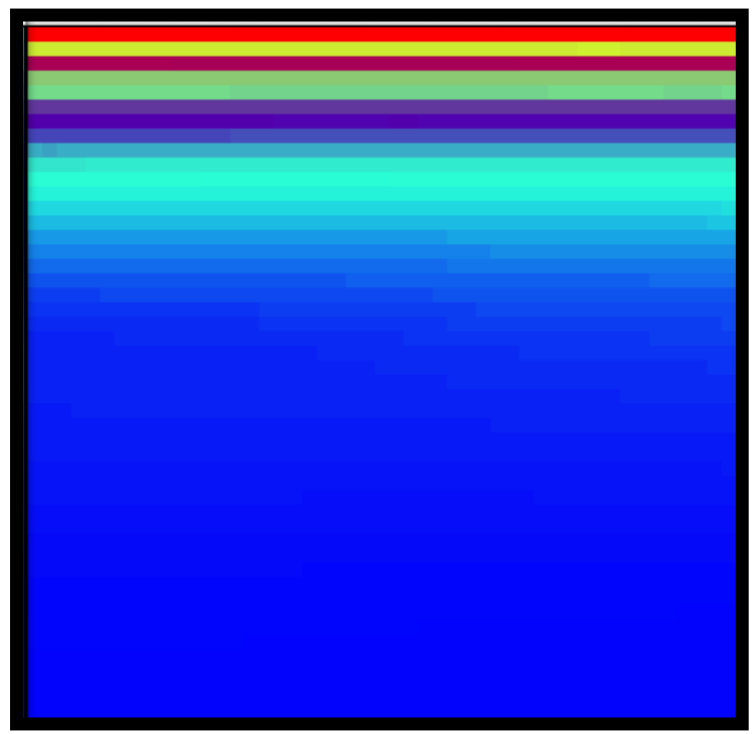
Vertical cross sections of THICKNESS of each model layer, with 50 vertical levels above the PBL, ptop = 10 hPa.

Uniform layers

720-820 m



Exaggerated Stretching



Physical Parameterization Settings

- The real program and the WRF model are ***tightly coupled***
- Many ***physical parameterization*** settings and other options used by the WRF model are ***initialized by the real*** program
- If you ***change physics options***, it is safest to ***re-run*** the real program

Soil Level Interpolation

- The WRF model supports several Land Surface schemes:
  - sf_surface_physics = 1, Slab scheme
  - 5 layers
  - Defined with thicknesses: 1, 2, 4, 8, 16 cm

Noah

Layers	Mid point
000 – 010 cm	-- 005 cm
010 – 040 cm	-- 025 cm
040 – 100 cm	-- 070 cm
100 – 200 cm	– 150 cm

RUC

Levels
000 cm
005 cm
020 cm
040 cm
160 cm
300 cm

Soil Level Interpolation

- The WRF model supports several Land Surface schemes:
  - sf_surface_physics = 2, Unified Noah scheme
  - 4 layers
  - Defined with layers: 0-10, 10-40, 40-100, 100-200 cm

Noah

Layers Mid point

000 – 010 cm -- 005 cm

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100 – 200 cm – 150 cm

RUC

Levels

000 cm

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300 cm

Soil Level Interpolation

- The WRF model supports several Land Surface schemes:
  - sf_surface_physics = 3, RUC scheme
  - 6 levels
  - Defined at levels: 0, 5, 20, 40, 160, 300 cm

Noah

Layers	Mid point
000 – 010 cm --	005 cm
010 – 040 cm --	025 cm
040 – 100 cm --	070 cm
100 – 200 cm –	150 cm

RUC

Levels
000 cm
005 cm
020 cm
040 cm
160 cm
300 cm

Soil Level Interpolation

- The WRF model supports several Land Surface schemes:
  - sf_surface_physics = 7, PX scheme
  - 2 layers
  - Defined with layers: 0-1, 1-100 cm

Noah

Layers	Mid point
000 – 010 cm	-- 005 cm
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040 – 100 cm	-- 070 cm
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Questions?

- WRF User Support Statement: https://www2.mmm.ucar.edu/wrf/users/wrf_support_statement.html
- Questions about the WRF modeling system should be directed to the WRF Forum: forum.mmm.ucar.edu

Resources

- Users may take advantage of the WRF homepage: www2.mmm.ucar.edu/wrf/users
- The WRF and WPS source codes are maintained with github at github.com/wrf-model/WRF and github.com/wrf-model/WPS

(as close as possible, Klingon for *finis*)