Real

Description of General Functions

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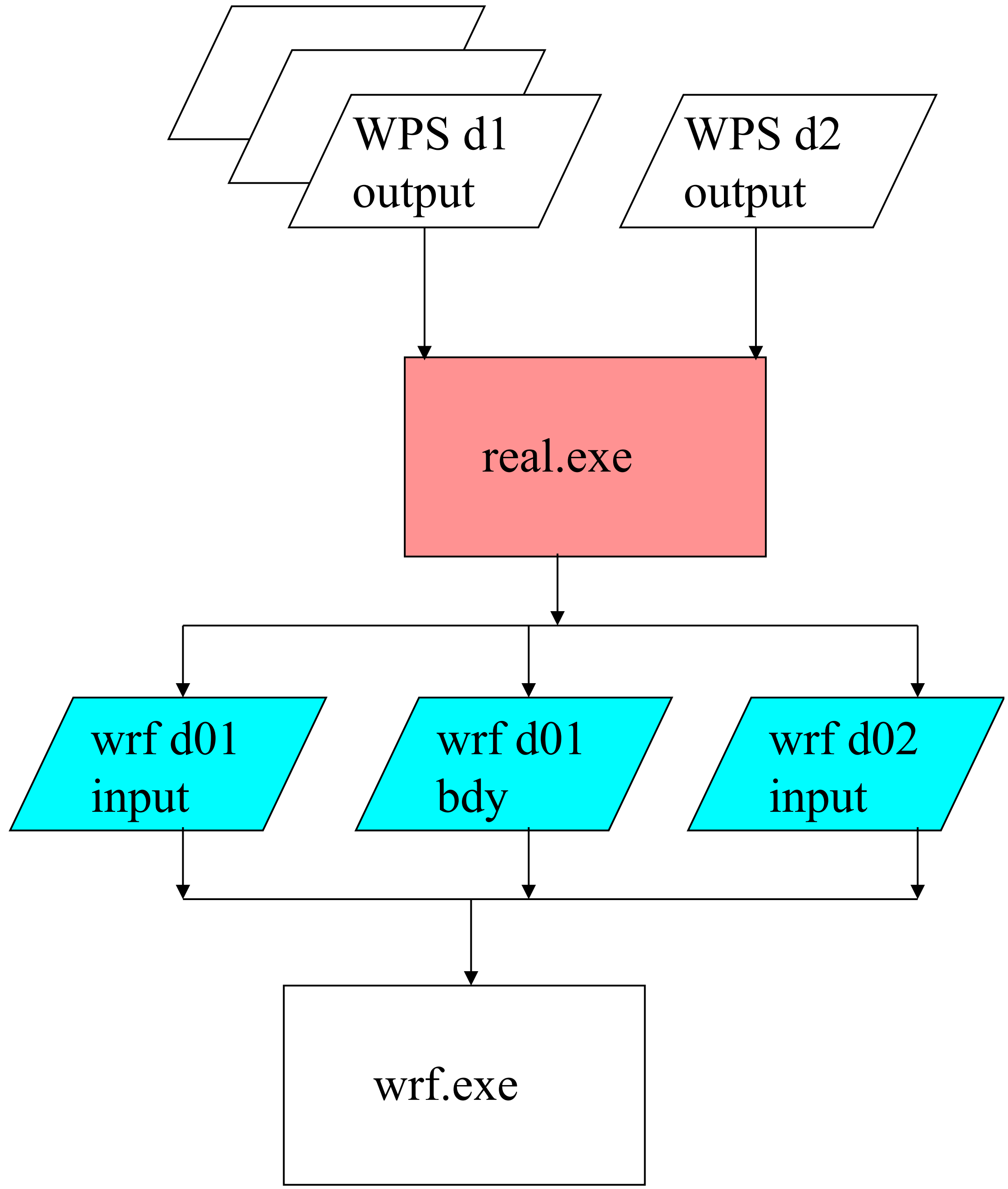


Real program in a nutshell

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

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

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 monotonically oriented*** 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

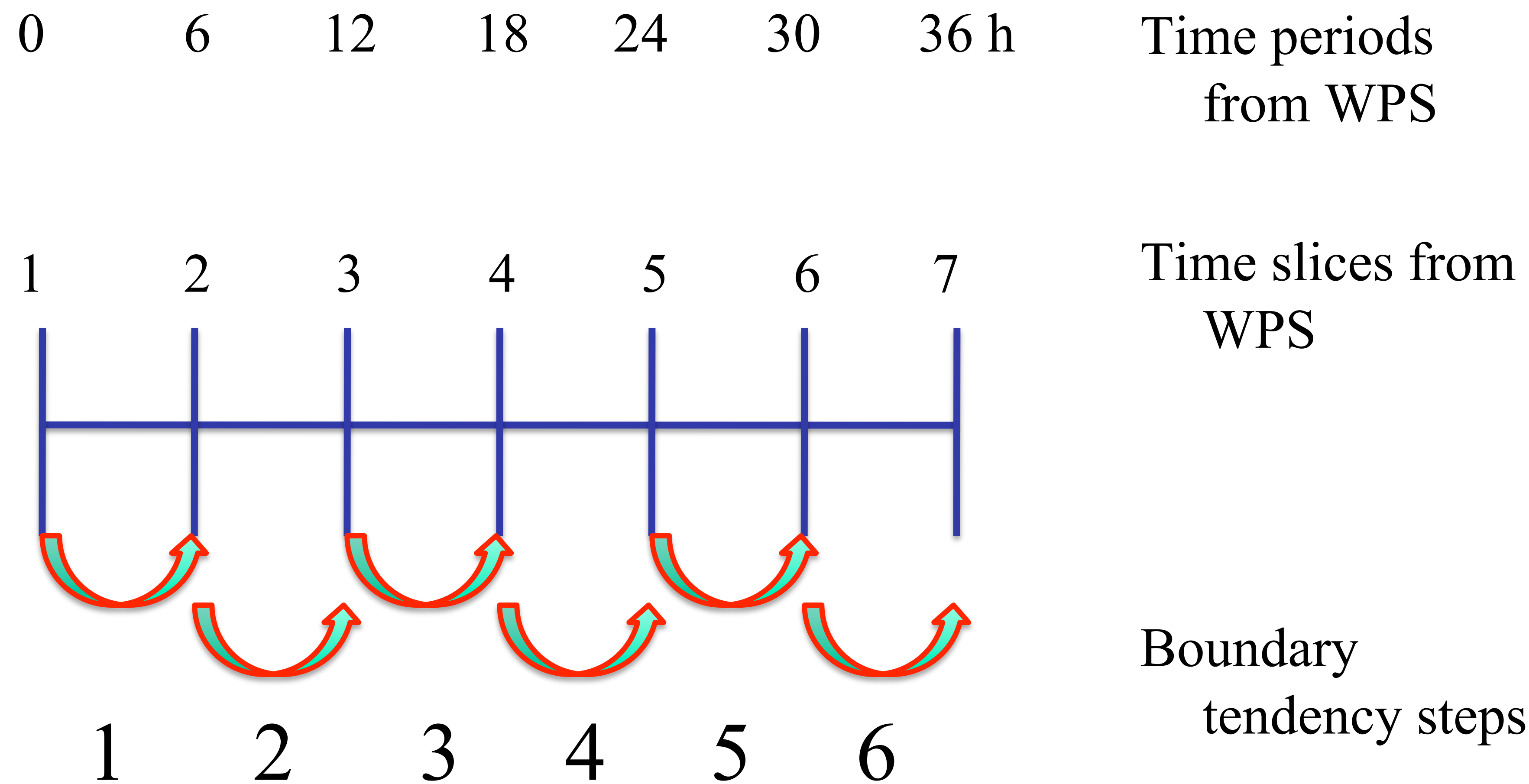
Base State

- 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***

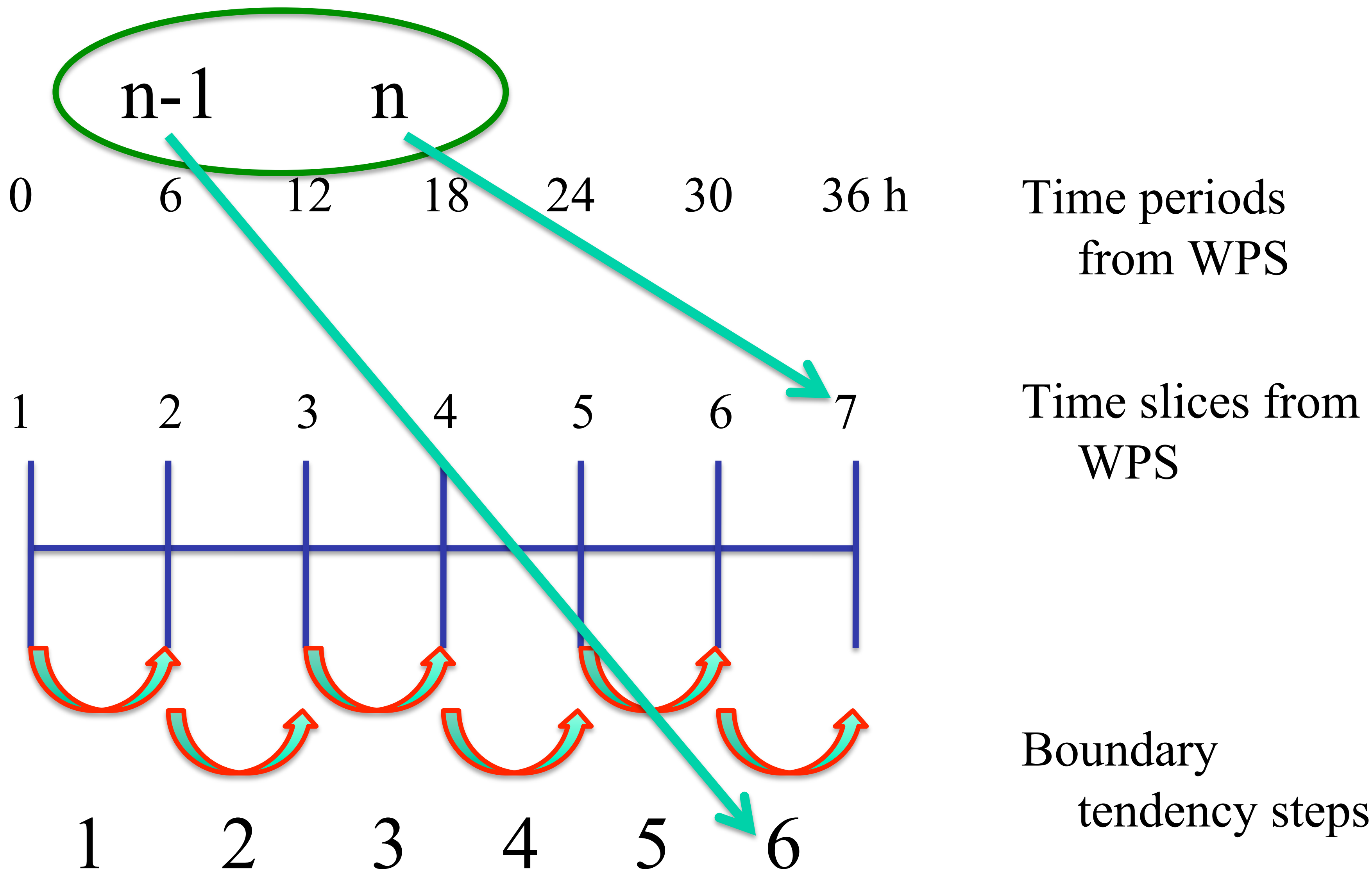
Standard Generated Output

- 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
- 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

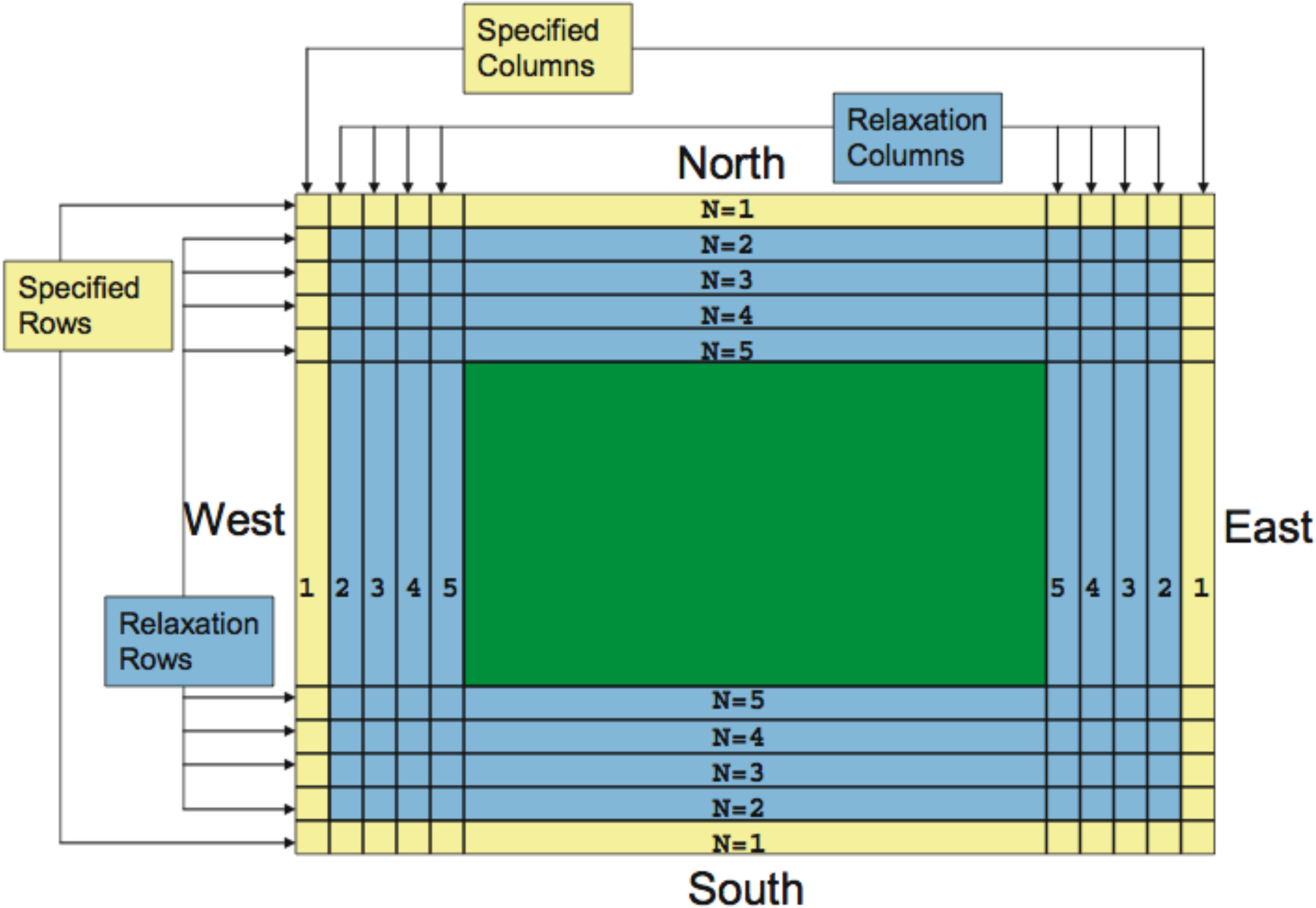
Lateral Boundary Condition Times



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

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 ***h surfaces*** may be computed or selected

Vertically interpolate input fields in pressure to the h surfaces in dry pressure: default all variables linear in log(pressure)

Vertical Interpolation

- Select reasonable h 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 h values***
  - Initially, ***select the number*** of h levels
  - ***Plot profiles*** of the resultant heights
  - ***Adjust the hlevels*** accordingly

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

Vertical Interpolation

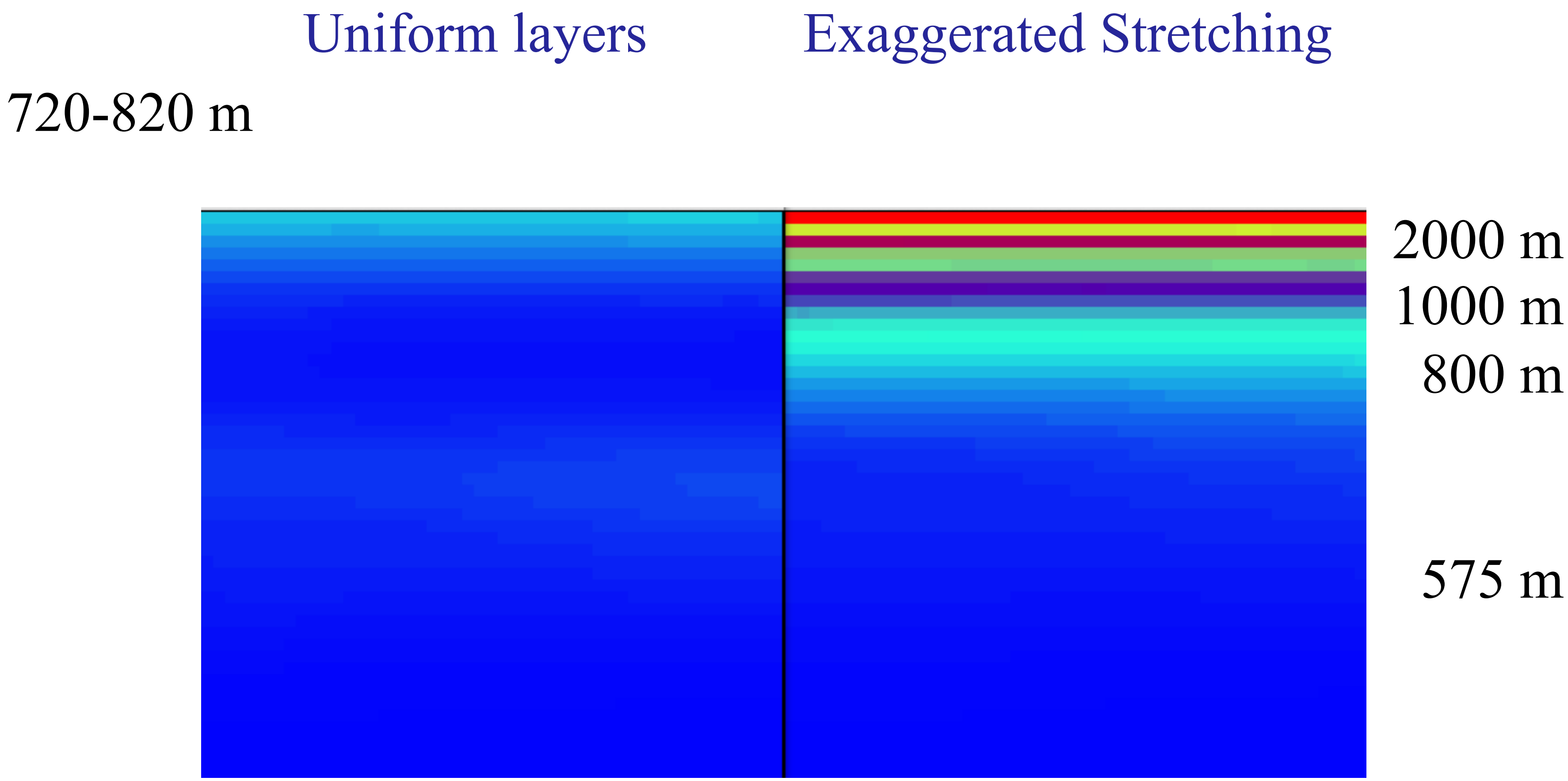
- The ***h surfaces*** are computed with a few NML parameters:

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

&dynamics
base_temp         = 290.
iso_temp          = 200
```

Vertical Interpolation

Vertical cross sections of model height field, with 50 vertical levels and ptop = 10 hPa, above the PBL.



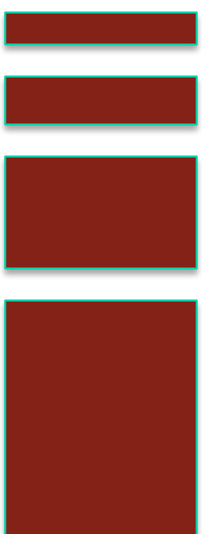
Physical Parameterization Settings

- The real program and the WRF model are tightly coupled
- Most physical parameterization settings in the namlist.input are IGNORED by real
- EXCEPT
  - ***sf_surface_physics***
  - Land surface model (processes soil temperature and soil moisture)
  - Different schemes in WRF use ***differing numbers of layers***
  - The layers are defined in real from the metgrid output

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

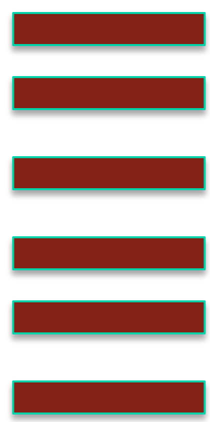
000 – 010 cm -- 005 cm

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

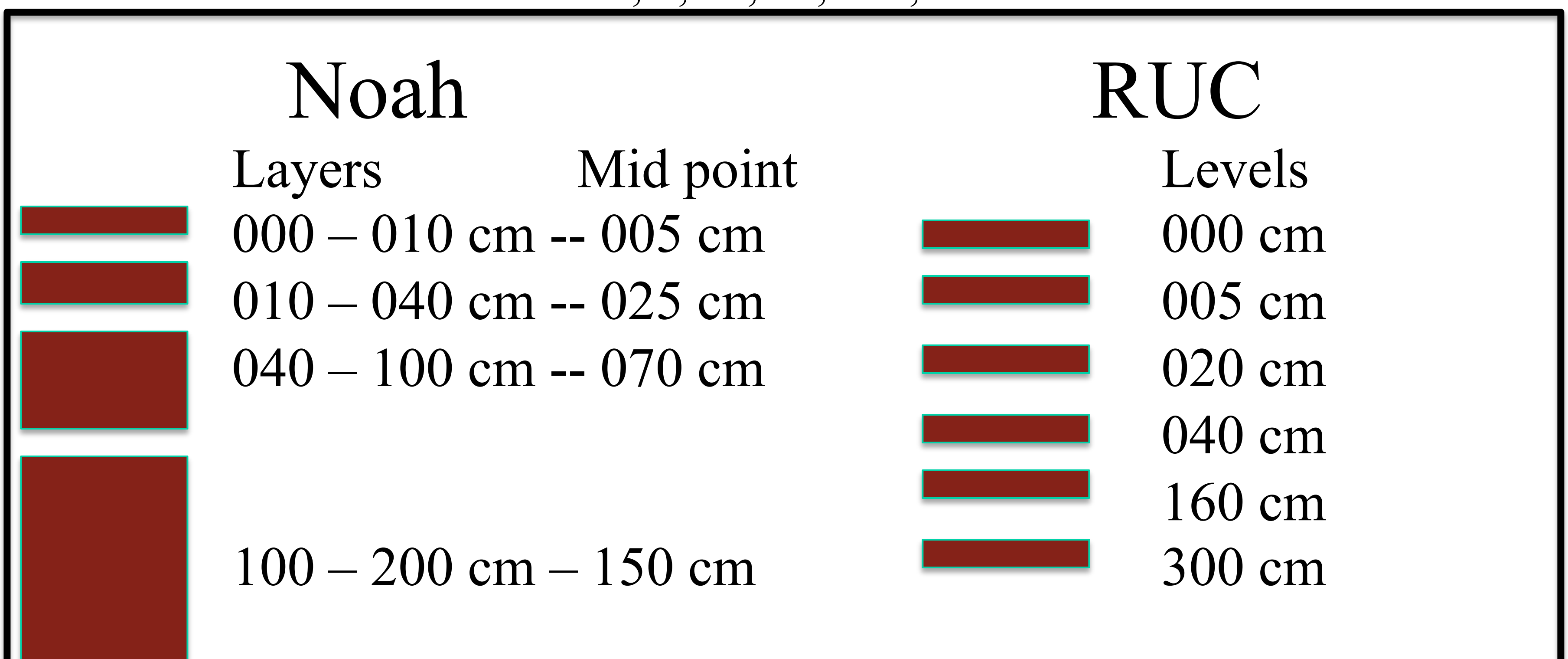
Layers	Mid point
000 – 010 cm --	005 cm
010 – 040 cm --	025 cm
040 – 100 cm --	070 cm
100 – 200 cm –	150 cm

RUC

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

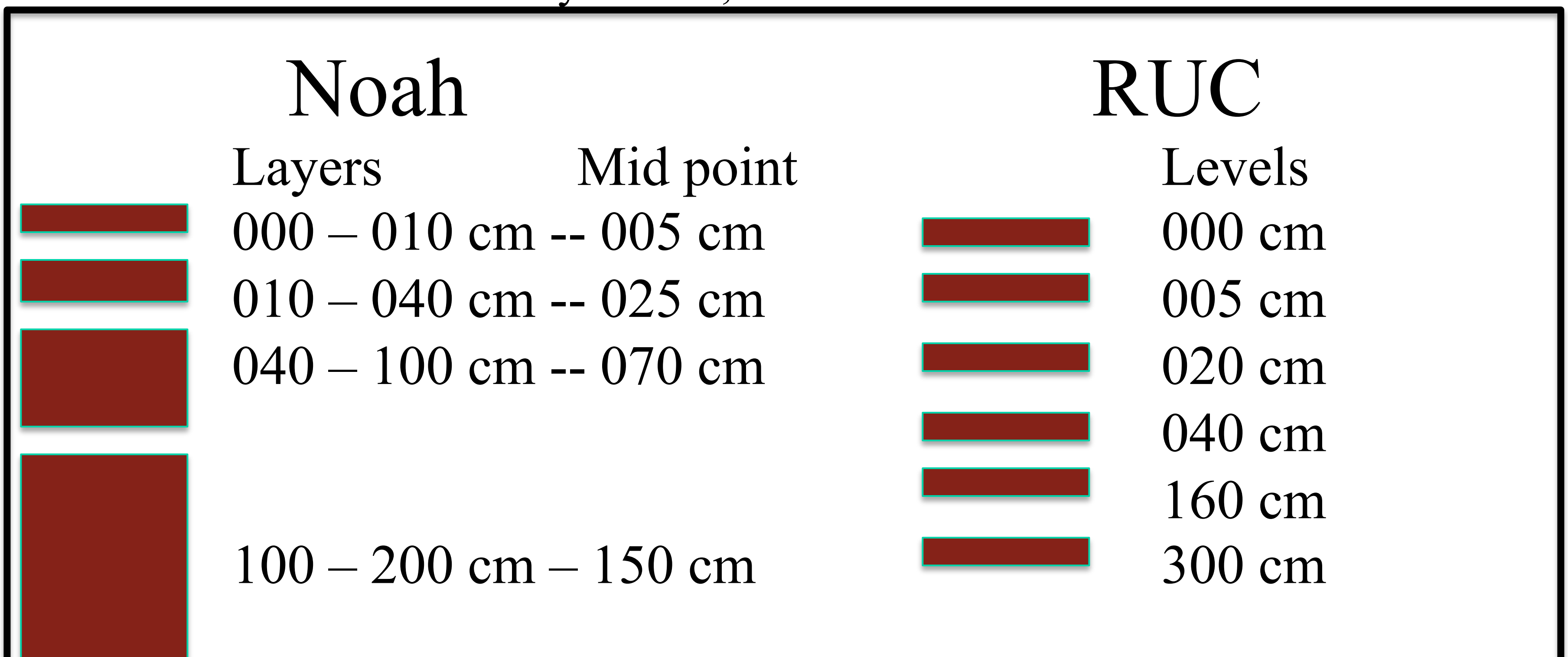
Soil Level Interpolation

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



Nested Processing

- May read ***multiple domain input files*** from metgrid
- Requires only the ***initial time for the fine domains***, unless doing nudging or SST update

- ***No horizontal interpolation from parent to child***

- ***No consistency checks*** between domains (handled in the feedback step for the WRF model)
- A ***wrfinput_d0x*** file is created for each processed input domain
- A ***lateral boundary file*** is created only for the ***most coarse*** domain

Real program in a nutshell

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

Real program in a nutshell: PART 2

- Access to everything
- Eta levels
- Metgrid flags
- Adding a variable for vertical interpolation
- Vertical interpolation
- Tracers
- Trajectories
- Options

Access to Everything

- The primary location to modify the real program is the dyn_em/module_initialize_real.F file
- Contains:
  - Registry information
  - All of the namelist settings selected
  - Variables from the Metgrid program
  - Variables to be sent to the WRF model
- Called for every time period, for every domain

Access to Everything

- The value of every variable input into the WRF model is controlled through module_initialize_real.F
- All variables are accessed through the derived data type "grid"

```
DO j=jts,MIN(jde-1,jte)
   DO i=its,MIN(ide-1,ite)
      grid%sst(i,j) = grid%sst(i,j) + 1
   END DO
END DO
```

Access to Everything

- The dynamics variables have two time levels, indicated by the _1 and _2 suffixes. Only the _2 variables are sent to WRF.
- Some variables sent to WRF are diagnostic only

```
DO j = jts, min(jde-1,jte)
   DO i = its, min(ide,ite)
      grid%u10(i,j)=grid%u_gc(i,1,j)
   END DO
END DO
```

Eta Levels

- The vertical coordinate, eta, used in the WRF model is defined inside of the real program.
- The user may allow the real program to choose the levels (select only the number of levels in the namelist.input file)

```
 &domains
 e_vert     = 30,    30,    30,
 /

&domains
 e_vert     = 30,    40,    50,
 /
```

Eta Levels

- Often the user needs to specify the eta levels (coordinate this with your model top)
- Use the automatic generation to your advantage
- Specify how many levels ABOVE the PBL that you require. Add 8 to this value. For example, you require 50 vertical levels above the PBL.

```
&domains
e_vert    = 58,    58,    58,
/
```

Eta Levels

- Run the real program (single or small domain, one time level), make sure the level thicknesses are OK (< 1000 m)

```
 Converged znw(kte) should be about 0.0 =  -5.2081142E-04
Full level index =    1     Height =     0.0 m
Full level index =    2     Height =    56.6 m      Thickness =   56.6 m
Full level index =    3     Height =   137.9 m      Thickness =   81.4 m
Full level index =    4     Height =   244.7 m      Thickness =  106.8 m
Full level index =    5     Height =   377.6 m      Thickness =  132.9 m
Full level index =    6     Height =   546.3 m      Thickness =  168.7 m
Full level index =    7     Height =   761.1 m      Thickness =  214.8 m
Full level index =    8     Height =  1016.2 m      Thickness =  255.0 m
Full level index =    9     Height =  1207.1 m      Thickness =  190.9 m
Full level index =   10     Height =  1401.8 m      Thickness =  194.6 m
Full level index =   11     Height =  1600.3 m      Thickness =  198.5 m
Full level index =   12     Height =  1802.8 m      Thickness =  202.5 m
Full level index =   13     Height =  2196.1 m      Thickness =  393.3 m
```

Eta Levels

- Get the computed levels from ncdump, after running the real program

```
> ncdump -v ZNW wrfinput_d01
data:

 ZNW =
  1, 0.993, 0.983, 0.97, 0.954, 0.934, 0.909, 0.88, 0.8587637, 0.8375274,
    0.8162911, 0.7950548, 0.7550299, 0.7165666, 0.6796144, 0.6441237,
    0.6100466, 0.5773363, 0.5459476, 0.5158363, 0.4869595, 0.4592754,
    0.4327437, 0.407325, 0.382981, 0.3596745, 0.3373697, 0.3160312,
    0.2956253, 0.2761188, 0.2574798, 0.2396769, 0.2226802, 0.2064602,
    0.1909885, 0.1762376, 0.1621807, 0.1487919, 0.1360459, 0.1239184,
    0.1124378, 0.1017038, 0.09166772, 0.08228429, 0.07351105, 0.06530831,
    0.05763897, 0.05046835, 0.04376402, 0.03749565, 0.0316349, 0.02615526,
    0.02103195, 0.01624179, 0.01176313, 0.007575703, 0.003660574, 0 ;
```

Eta Levels

- Re-run the real program (all domains, all time periods) with the new levels in the nml variable **`eta_levels`**
- Replace the **PBL values** with those of your choosing.
- Augment the number of vertical levels (e_vert)
- Note that both e_vert and eta_levels are full levels

Eta Levels

```
&domains
eta_levels =
    1, 0.993, 0.983, 0.97, 0.954, 0.934, 0.909, 0.88,
    0.8587637, 0.8375274,
    0.8162911, 0.7950548, 0.7550299, 0.7165666, 0.6796144, 0.6441237,
    0.6100466, 0.5773363, 0.5459476, 0.5158363, 0.4869595, 0.4592754,
    0.4327437, 0.407325, 0.382981, 0.3596745, 0.3373697, 0.3160312,
    0.2956253, 0.2761188, 0.2574798, 0.2396769, 0.2226802, 0.2064602,
    0.1909885, 0.1762376, 0.1621807, 0.1487919, 0.1360459, 0.1239184,
    0.1124378, 0.1017038, 0.09166772, 0.08228429, 0.07351105, 0.06530831,
    0.05763897, 0.05046835, 0.04376402, 0.03749565, 0.0316349, 0.02615526,
    0.02103195, 0.01624179, 0.01176313, 0.007575703, 0.003660574, 0
/
```

- Maybe replace with

```
    1, 0.999, 0.998, 0.996, 0.993, 0.990, 0.980. 0.970, 0.960, 0.950,
       0.940, 0.930, 0.920, 0.910, 0.900, 0.890, 0.880, 0.870,
```

Eta Levels

- For vertical nesting, follow the similar procedure for each domain.
- Each domain will need a specification of eta levels
- The assignment of the single eta_levels array is split into pieces for easier understanding

Eta Levels

```
 &domains
 max_dom              = 2,
 e_vert               = 35,     45,
 eta_levels(1:35)     = 1., 0.993, 0.983, 0.97, 0.954, 0.934,
                        0.909, 0.88, 0.840, 0.801, 0.761, 0.722,
                        0.652, 0.587, 0.527, 0.472, 0.421, 0.374,
                        0.331, 0.291, 0.255, 0.222, 0.191, 0.163,
                        0.138, 0.115, 0.095, 0.077, 0.061, 0.047,
                        0.035, 0.024, 0.015, 0.007, 0.
eta_levels(36:81)  =   1.0000, 0.9946, 0.9875, 0.9789, 0.9685,
                        0.9562, 0.9413, 0.9238, 0.9037, 0.8813,
                        0.8514, 0.8210, 0.7906, 0.7602, 0.7298,
                        0.6812, 0.6290, 0.5796, 0.5333, 0.4901,
                        0.4493, 0.4109, 0.3746, 0.3412, 0.3098,
                        0.2802, 0.2524, 0.2267, 0.2028, 0.1803,
                        0.1593, 0.1398, 0.1219, 0.1054, 0.0904,
                        0.0766, 0.0645, 0.0534, 0.0433, 0.0341,
                        0.0259, 0.0185, 0.0118, 0.0056, 0.
 vert_refine_method = 0,     2,
```

Metgrid Flags

- The real program and the WRF model are able to communicate directly through the Registry file
- The real program is only able to talk with the Metgrid program through the input data stream
- Specific information about the incoming data is contained in special flags that the user may set in the Metgrid table file – usually, related to THIS VARIABLE EXISTS

```
========================================
name=PMSL
        interp_option=sixteen_pt+four_pt+average_4pt
        flag_in_output=FLAG_SLP
========================================
```

Metgrid Flags

```
> ncdump -h met_em.d01.2000-01-24_12:00:00.nc | grep FLAG
                 :FLAG_METGRID = 1 ;
                 :FLAG_EXCLUDED_MIDDLE = 0 ;
                 :FLAG_SOIL_LAYERS = 1 ;
                 :FLAG_SNOW = 1 ;
                 :FLAG_PSFC = 1 ;
                 :FLAG_SM000010 = 1 ;
                 :FLAG_SM010040 = 1 ;
                 :FLAG_SM040100 = 1 ;
                 :FLAG_SM100200 = 1 ;
                 :FLAG_ST000010 = 1 ;
                 :FLAG_ST010040 = 1 ;
                 :FLAG_ST040100 = 1 ;
                 :FLAG_ST100200 = 1 ;
                 :FLAG_SLP = 1 ;
                 :FLAG_TAVGSFC = 1 ;
                 :FLAG_QNWFA = 1 ;
                 :FLAG_QNIFA = 1 ;
                 :FLAG_SOILHGT = 1 ;
                 :FLAG_MF_XY = 1 ;
```

Metgrid Flags

- The real program uses this information when deciding how to do many operations:
  - Is the input from Metgrid?
  - Method to compute surface pressure
  - Use RH vs mixing ratio vs specific humidity computations
  - Excluded middle processing
  - Average surface air temperature for lake temperatures
  - Water/Ice friendly vertical interpolation
  - Which levels of soil data are present

- All flags for the Metgrid to real data transfer are contained in share/module_optional_input.F

Metgrid Flags

```
flag_slp      = 0

flag_name(1:8) = 'SLP     '
CALL wrf_get_dom_ti_integer ( fid, 'FLAG_' // &
     flag_name, itmp, 1, icnt, ierr )
IF ( ierr .EQ. 0 ) THEN
   flag_slp      = itmp
END IF
```

Adding a Variable for Vertical Interpolation

- This process is manual
- Every new input 3d variable that needs to be interpolated needs to have an explicit block of code added
- Mass-point variables (such as would be used in all physics schemes) are straight forward, as they may be largely copied using the existing templates already in place
- Most vertical interpolation options are supplied from the namelist.input file
- All interpolation is handled in dry pressure

Adding a Variable for Vertical Interpolation

```
CALL vert_interp ( grid%t_gc , grid%pd_gc , &
     grid%t_2 , grid%pb , &
     grid%tmaxw , grid%ttrop , grid%pmaxw , grid%ptrop , &
     grid%pmaxwnn , grid%ptropnn , &
     flag_tmaxw , flag_ttrop , &
     config_flags%maxw_horiz_pres_diff , &
     config_flags%trop_horiz_pres_diff , &
     config_flags%maxw_above_this_level , &
     num_metgrid_levels , 'T' , &
     interp_type , lagrange_order , t_extrap_type , &
     lowest_lev_from_sfc , use_levels_below_ground , &
     use_surface , zap_close_levels , force_sfc_in_vinterp , &
     ids , ide , jds , jde , kds , kde , &
     ims , ime , jms , jme , kms , kme , &
     its , ite , jts , jte , kts , kte )
```

Tracers

- The WRF model is able to advect arrays of passive scalars (tracer 4d array)
- As with all other variables going into the WRF model, this data is available to be set in the real program
- These variables must be coordinated with the Registry names, as the tracer index is an automatically manufactured name

```
# Tracer Scalars
#
state real tr17_1 ikjftb  tracer 1 -  irhusdf=(bdy_interp:dt) \
      "tr17_1" "tr17_1" "Dimensionless"
```

Tracers

- As with all 4d arrays, no space is allocated unless the packaged variables are requested for processing at run-time

```
package   tracer_test1  tracer_opt==2 -  tracer:tr17_1
```

Tracers

```
!  Template for initializing tracer arrays.
!  A small plane in the middle of the domain at
!  lowest model level is defined.

IF (config_flags%tracer_opt .eq. 2) THEN
  DO j = (jde + jds)/2 - 4, (jde + jds)/2 + 4, 1
    DO i = (ide + ids)/2 - 4, (ide + ids)/2 + 4, 1
      IF ( ( its .LE. i .and. ite .GE. i ) .and. &
           ( jts .LE. j .and. jte .GE. j ) ) THEN
        tracer(i, 1, j, P_tr17_1) = 1.
      END IF
    END DO
  END DO
END IF
```

Trajectories

- The user may specify specific (i,j,k) locations in the model domain to follow parcels: traj_i, traj_j, traj_k (hard coded in the module_initialize_real.F file)

- The current number of trajectory locations is small, 25, and is a run-time option that the user sets in the nml file

```
&domain
 num_traj                   = 25,

&physics
 traj_opt                   = 1,
```

Trajectories

- The trajectory code uses the lat,lon locations, so the initial (i,j) value of the lat,lon is assigned

```
IF (config_flags%num_traj .gt. 0 .and.
    config_flags%traj_opt .gt. 0) THEN
  DO j = (jde + jds)/2 - 2, (jde + jds)/2 + 2, 1
    DO i = (ide + ids)/2 - 2, (ide + ids)/2 + 2, 1
      IF ( its .LE. i    .and. ite .GE. i   .and.  &
           jts .LE. j    .and. jte .GE. j ) THEN
        grid%traj_i   (icount) = i
        grid%traj_j   (icount) = j
        grid%traj_k   (icount) = 10
        grid%traj_lat (icount) = grid%xlat(i,j)
        grid%traj_long(icount) = grid%xlong(i,j)
      END IF
```

Options

- When there are strong normal topo gradients along the outer rows and columns of the most-coarse domain, smoothing the topography to match the incoming first guess data is a good idea.
- This is the same sort processing that is done to make the child and parent domains more consistent in the area of the LBC forcing

```
&domains
 smooth_cg_topo = .true.
/
```

Real program in a nutshell: PART 2

- Access to everything
- Eta levels
- Metgrid flags
- Adding a variable for vertical interpolation
- Vertical interpolation
- Tracers
- Trajectories
- Options