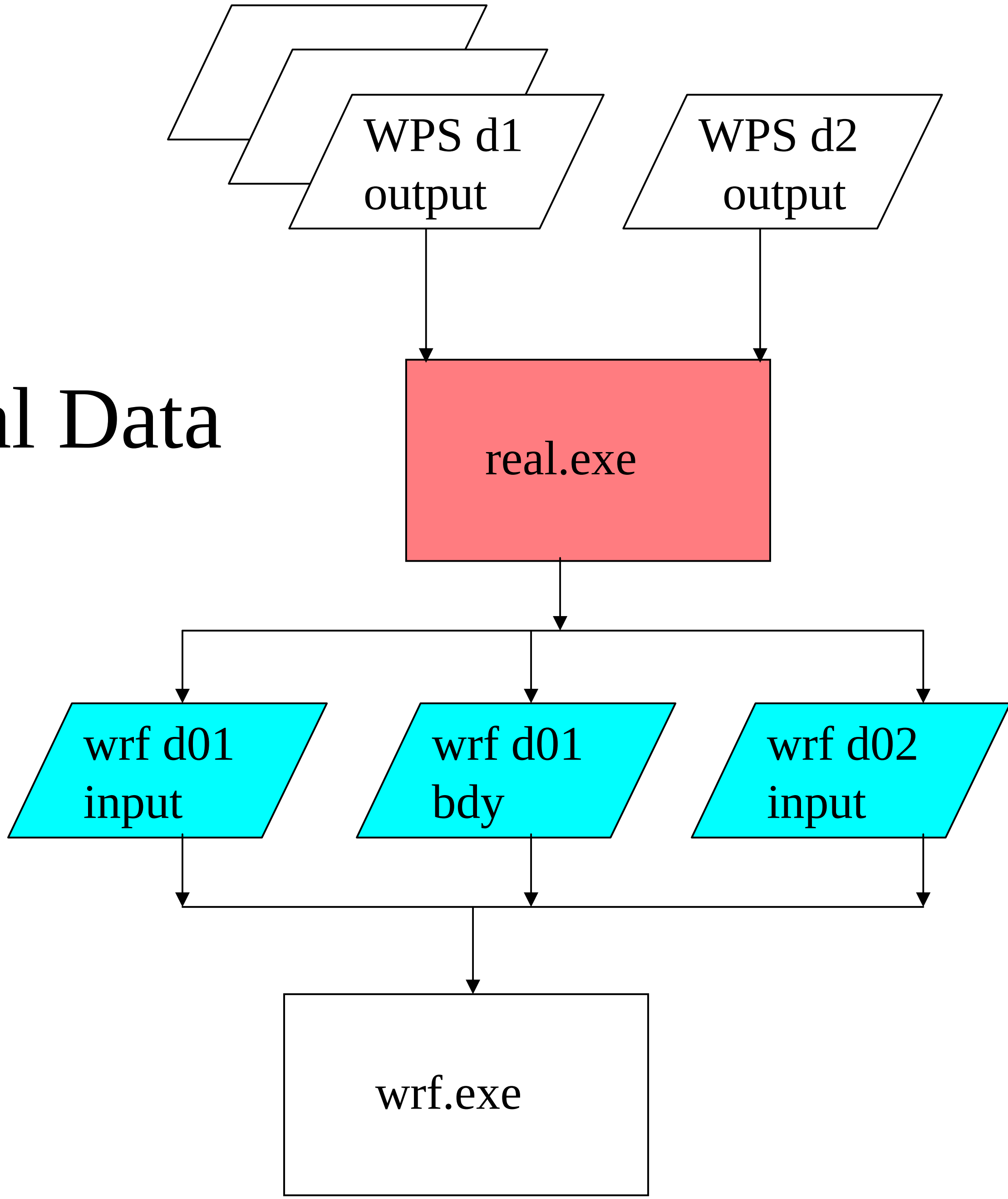
WRF ARW

Initialization for Real Data
real.exe

Dave Gill
gill@ucar.edu



Real-Data Initialization - ARW

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

Definition of Terms: real.exe

- The ARW 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 takes data ***from WPS*** and transforms the data ***for WRF***
- Similar to the idealized data pre-processor, real.exe is 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 (or the SI, but we'll use WPS wolog) package
- Anticipated ***utilization of physics*** packages for microphysics, surface conditions, radiation, convection, and boundary layer (maybe usage of nudging capabilities)

Definition of Terms: Real Data Case

- A ***projected domain***: Lambert conformal, Mercator, polar stereographic
- Selection of ***realistic static fields*** of topography, land use, vegetation, and soil category data
- Requirement of ***time dependent*** lateral boundary conditions (periodic in east-west with a channel domain that extends around the globe)

Definition of Terms: Initialization

- Not referring to the ***Variational*** 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.)
- Computation of ***reference*** and ***perturbation*** fields
- Generation of ***initial*** state for model for each of the requested domains, and a ***lateral boundary file*** for the most coarse domain
- ***Vertical interpolation*** for 3d meteorological fields (WPS) and for sub-surface soil data

Purpose of the Initialization Program
Input Files for the WRF Model

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

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

- 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
Input Data for real.exe

- Ingest ***time dependent*** upper-air (horizontal winds, potential temperature, mixing ratio), surface (dry surface pressure, sea ice, sea-surface temperature, skin temperature), and subsurface (soil temperature, soil moisture)
- Ingest ***static fields*** for terrestrial (elevation, land use, vegetation category, soil texture category) and projection (map factors, latitude and longitude, projection rotation angles)
- ***Multiple time periods*** of data are processed for the outer-most grid (for the lateral boundary conditions), while only the ***initial time of the fine grid*** domains are processed

Tasks of the Initialization Program

Consistency Checks

- 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

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

- If the first guess 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 bypassed 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

- 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: 0 – 10 cm soil temperature, sea-surface temperature, annual mean temperature
- Verify that necessary fields for each grid point are available (***bounds check***, stop code prior to model running)

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 the wilting 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.

Tasks of the Initialization Program

Consistency Checks

- Both the static and the first-guess fields provide categories for ***land use*** and for ***soil texture***.
- Static: 30 sec resolution, fractional values (24 USGS land use / vegetation type, 16 soil texture categories)
- First-Guess: the resolution of the data file, typically from NAM, or 1 degree resolution from GFS
- ***User selects*** which to provide to the WRF model

Tasks of the Initialization Program
Soil Fields

- Fields: soil temperature, soil moisture, soil liquid (for the Noah scheme, if no liquid soil field is found, this field is defined in the model based on the soil temperature)
- ***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)
- 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 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
- Options for linear in pressure or linear in log(pressure), (also, 2^{nd} order available)

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

- Horizontal momentum (rotated to the domain's projection) potential temperature, and mixing ratio are provided on the WRF model's computational surfaces
- U, V, Qv, Θ are on the correct horizontal stagger
- U, V, Qv pass through without any modification, other than vertical interpolation
- Potential temperature has constant factor removed (300 K) for numerical round-off purposes

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

- All variables are on the correct horizontal staggering: U, V, Qv, T, etc
- U, V, Qv pass through without any modification (other than vertical interpolation for WPS input)
- Other species (cloud water, snow, rain, graupel, cloud ice) are available as input, but require uncommenting out code (an easy way to reduce memory)
- Potential temperature has constant factor removed (300 K) for numerical round-off purposes

Tasks of the 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 Initialization Program
Base State

```
p_surf = p00 * EXP (-t00/a + ((t00/a)**2
  - 2.*g*ht(i,j)/a/r_d ) **0.5 )
```

User defined constants:

p00 – ref sea level pressure (10^5 Pa, fixed)

a – lapse rate (50 K, fixed)

t00 – ref sea level temperature (290 K, variable)

ht – terrain elevation (m)

Tasks of the Initialization Program
Base State

```
pb(i,k,j) = znu(k)*(p_surf - p_top) +
  p_top

t_init(i,k,j) = (t00 +
  A*LOG(pb(i,k,j)/p00))
  *(p00/pb(i,k,j))**(r_d/cp) - t0

alb(i,k,j) =
  (r_d/p1000mb)*(t_init(i,k,j)+t0)
  *(pb(i,k,j)/p1000mb)**cvpm
```

Reference 3d pressure, potential temperature, inverse density (defined at mass points, half levels)

Tasks of the Initialization Program
Base State

```
mub(i,j) = p_surf - p_top

phb(i,k,j) = phb(i,k-1,j) - dnw(k-
  1) *mub(i,j)*alb(i,k-1,j)
```

Reference geopotential (full levels, k=1 defined as terrain*g)

Tasks of the Initialization Program
Perturbation Fields

```
p(i,k,j) = p(i,k+1,j) - (mu_2(i,j)
  + qvf1*mub(i,j))/qvf2/rdn(k+1)
alt(i,k,j) = (r_d/p1000mb)*
  (t_2(i,k,j)+t0)*qvf*
 (((p(i,k,j)+pb(i,k,j))/p1000mb)
  **cvpm)
al(i,k,j) = alt(i,k,j) - alb(i,k,j)
```

- Integrate perturbation pressure downward (assumed = 0 at the model lid), diagnose perturbation inverse density

Tasks of the Initialization Program
Perturbation Fields

```
ph_2(i,k,j) = ph_2(i,k-1,j) -
   dnw(k-1) * (
   (mub(i,j)+mu_2(i,j))*al(i,k-1,j) +
   mu_2(i,j)*alb(i,k-1,j) )
```

- Integrate perturbation geopotential upward
- Assume that the surface geopotential is defined as gravity * terrain elevation
- The geopotential field is on full vertical levels, with k=1 defined at the ground surface, and the top level is defined at the model lid

Tasks of the Initialization Program
Output Fields to WRF

- Output fields for WRF model ***initial condition*** file for starting time of the model only (analysis FDDA option allows multiple times)
- Loop over all domains for data processing and output

Tasks of the Initialization Program *Output Fields* to WRF

- ***Couple*** momentum with total dry surface pressure and map factors for use in ***lateral boundary*** values and tendencies
- Geopotential, potential temperature, and moisture (Qv only) are coupled with total dry surface pressure for boundary conditions
- Boundary tendencies are linear one-sided ***forward 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), and several rows/columns (user defined)
- ***One less boundary time*** period is created than time periods of WPS data processed

Tasks of the Initialization Program
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 Initialization Program

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 (except during grid nudging)
- ***User specifies*** which domains to process and that an additional input file is being supplied

Required Input Files

- The input files required by real.exe are output from the WPS (optionally from the SI is still OK)

```
cd ./WRFV2/test/em_real
ls ../../../WPS/met_em*
```

- The WPS output files are usually ***linked*** into the real-data directory

```
ln -s ../../../WPS/met_em* .
```

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

Generated Output Files
IC and *BC*

- Two standard types of output files are generated by the real.exe program: wrfinput_d01 and wrfbdy_d01
  - Multiple domain runs will create wrfinput_d***xx*** files for each domain id **# *xx***
- The time in wrfinput is the initial time of the WRF forecast (from the namelist)

```
ncdump –v Times wrfinput_d01 | tail
```

- Time periods from wrfbdy_d01 file cover forecast period (reported time is at the beginning of the lateral boundary interval)

Generated Output Files
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

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