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HIGH PERFORMANCE COMPUTING
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WRF Model Webinar

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What is WRF?

- WRF: Weather Research and Forecasting Model
- It is a supported “community model”, i.e. a free and shared resource with distributed development and support
- Its early development was led by NCAR, NOAA/GSL and NOAA/NCEP/EMC in early years with partnerships at AFWA, FAA, DOE/PNNL and collaborations with universities and other government agencies in the US and overseas.



WRF Community Model

- Version 1.0 WRF was released December 2000
- Version 2.0: May 2004 (added nesting)
- Version 3.0: April 2008 (added global ARW version)
- Version 3.9: April 2017
- Version 4.0 (June 2018) (
- Version 4.1 (April 2019)
- Version 4.2 (April 2020)
- Version 4.3 (May 2021)
- Version 4.4 (April 2022)
- Version 4.5 (April 2023)
- Version 4.6 (April 2024)
 - Version 4.6.1
- Version 4.7 (April 2025) – last major release
 - Version 4.7.1 (June 2, 2025) – bug-fix release

WRF Version v4.7.0

The WRF model has been update to Version v4.7.0 on April 25, 2025

Acknowledgements: We would like to thank

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- Benjamin Kirk & Negin Sobhani (NSF NCAR / CISL)
- Cenlin He [@cenlinhe](#) and Tzu-Shun Lin (NCAR)
- Charlie Li, software developer from lakes environmental, Canada
- Jakub Lewandowski (University of Leeds)
- James Ruppert (University of Oklahoma)

<https://github.com/wrf-model/WRF.git>

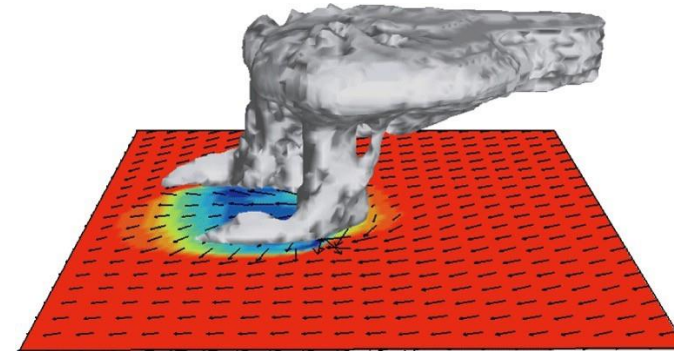
What is WRF-ARW?

- WRF-ARW: **The Advanced Research WRF (ARW)**
 - WRF and WRF-ARW are synonymous.
 - Referring to its dynamical core: includes mostly advection, pressure-gradients, Coriolis, buoyancy, filters, diffusion, and time-stepping.
 - Since WRF v4.3.1, this is the only dynamical core.
- WRF-ARW or WRF: its development, maintenance and support are centered at NCAR/MMM

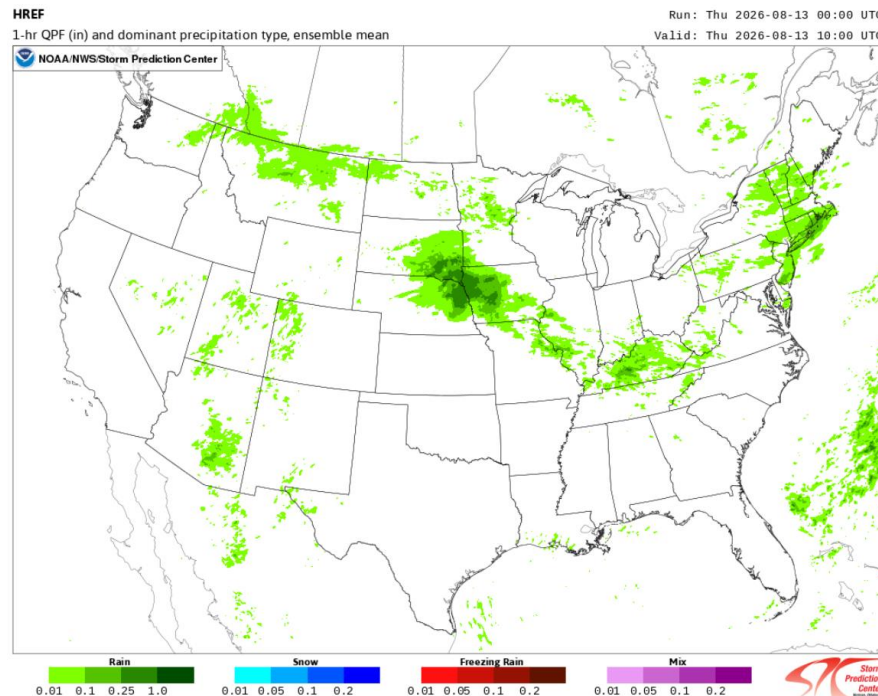
What is WRF?

- A research and forecasting tool:

Idealized simulations

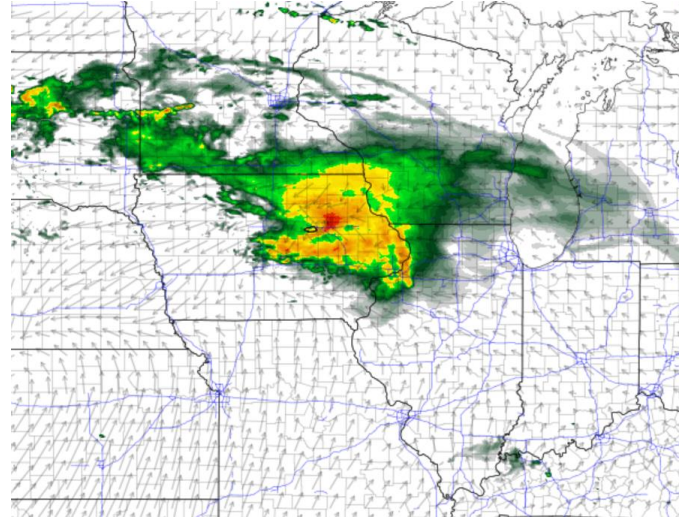


← Experimental real-time forecast



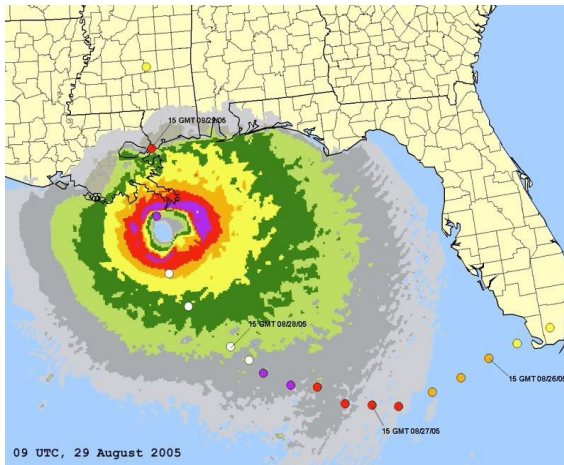
What is WRF?

- A research and forecasting tool:

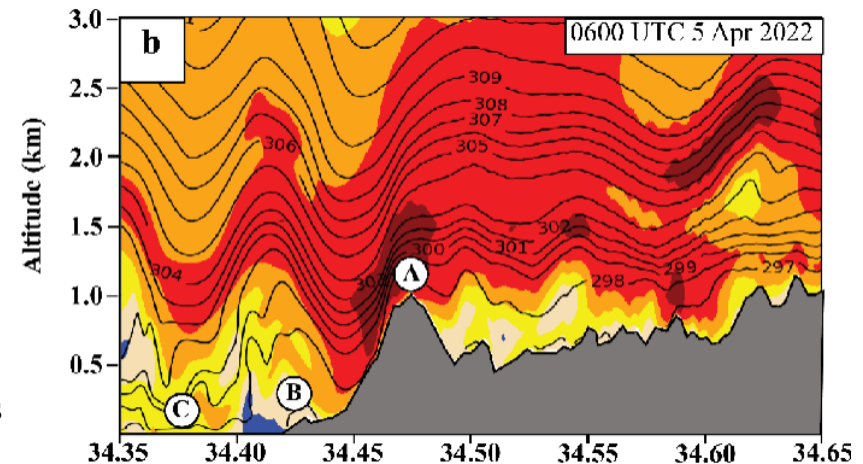


Forecast of thunderstorms/convection

Simulations of hurricanes



Downslope winds over mountain slopes



What can WRF be used for?

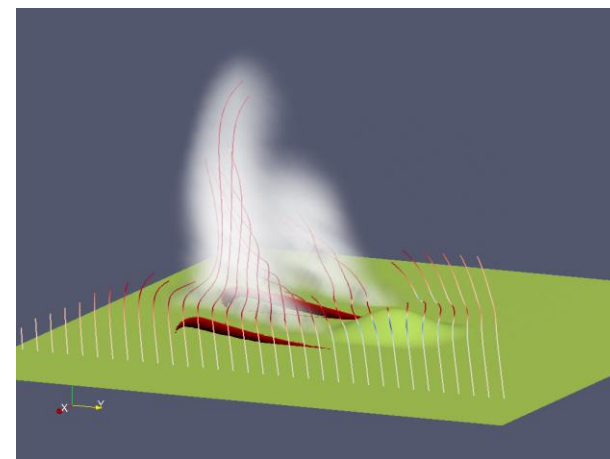
- A tool for research
 - Develop and test physical parameterizations
 - Case-study research for specific weather events
 - Regional climate studies
 - Coupled-chemistry, fire, and hydrological applications
 - Data assimilation research
 - Teaching modeling and NWP
- A tool for numerical weather prediction
 - Hind-casting
 - Real-time (operational) forecasting
 - Forecasting for wind, solar and air quality (online and offline)



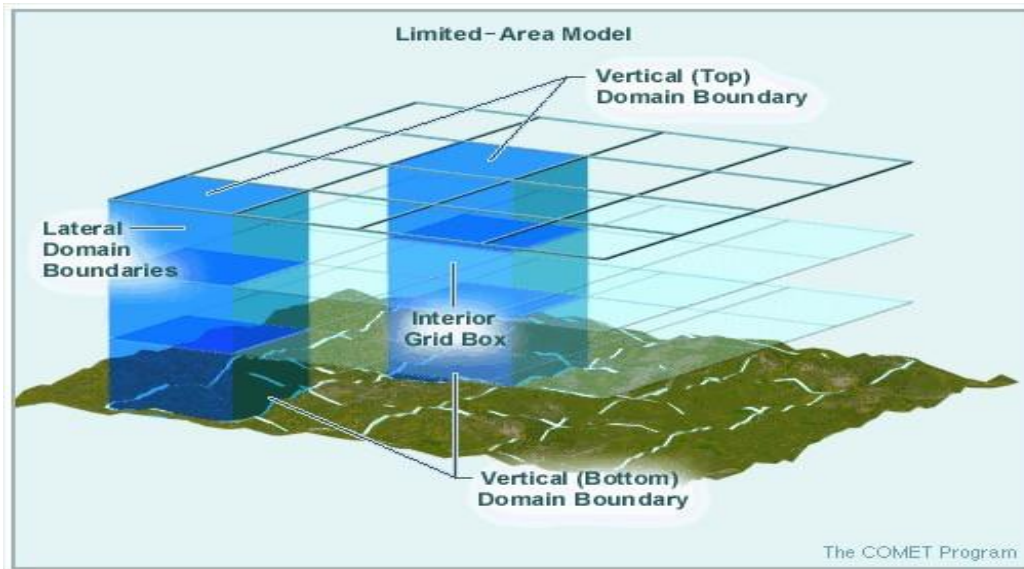
WRF-Fire



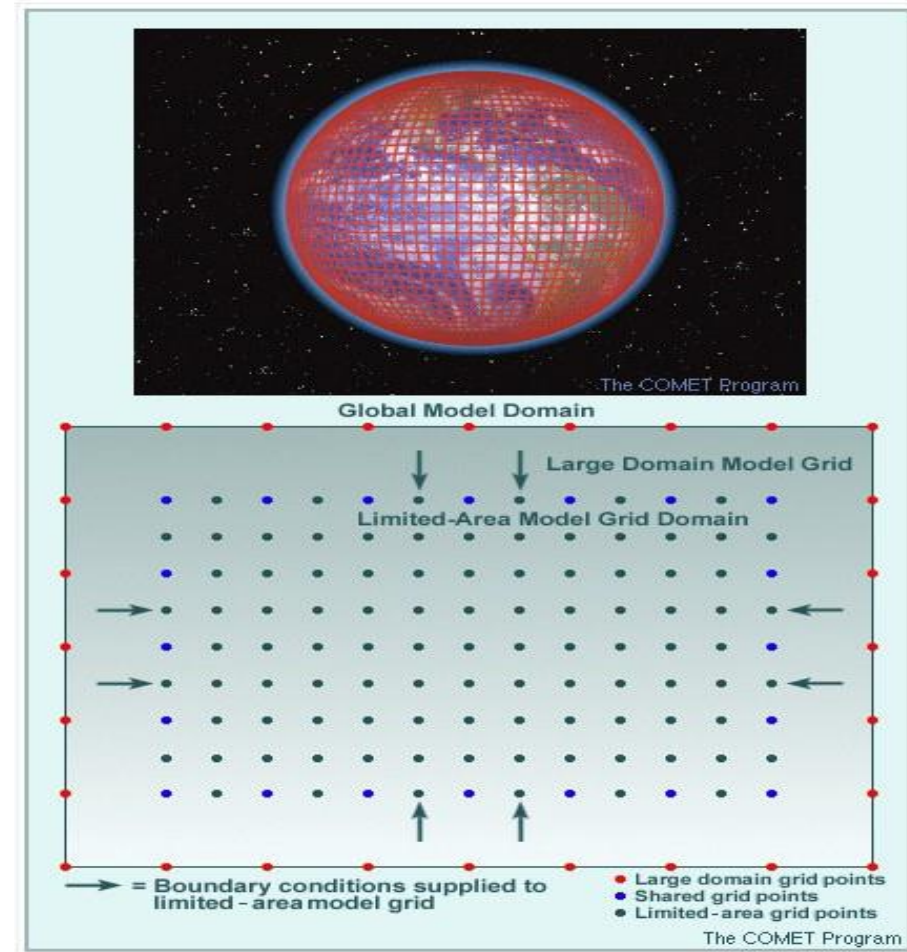
WRF-Hydro®



Basic Model concepts: Lateral Boundary Conditions

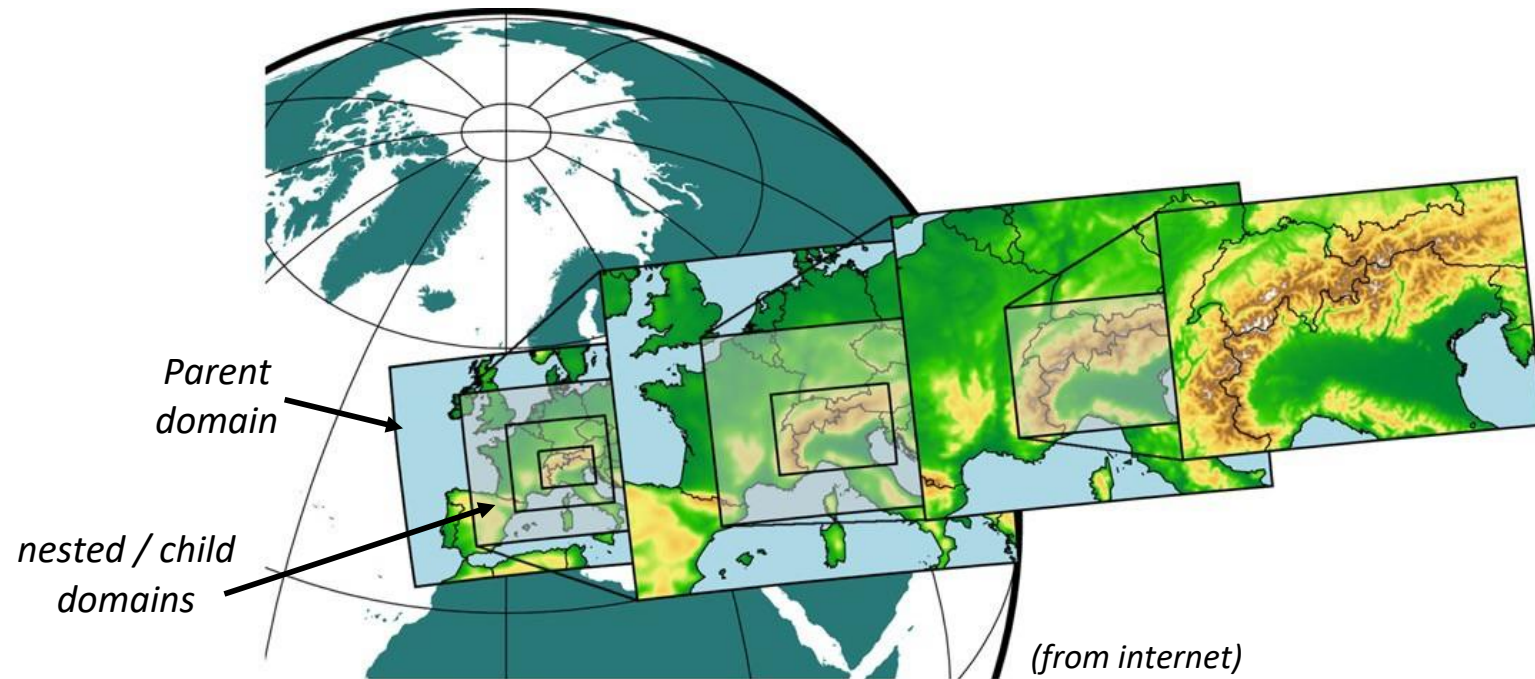


(from COMET)



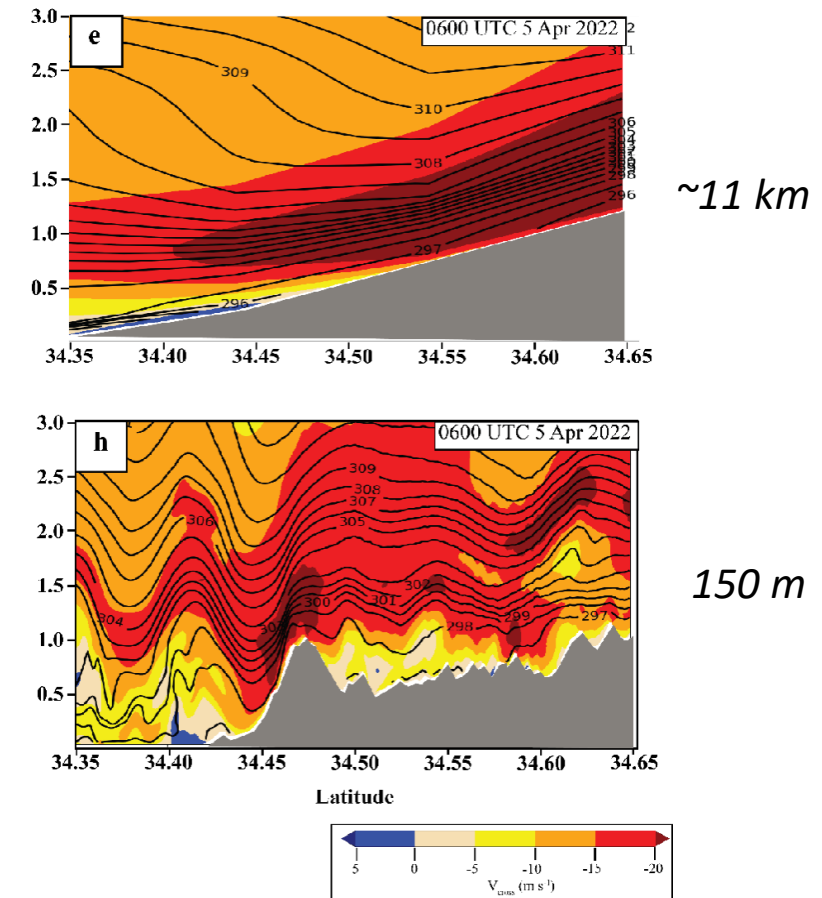
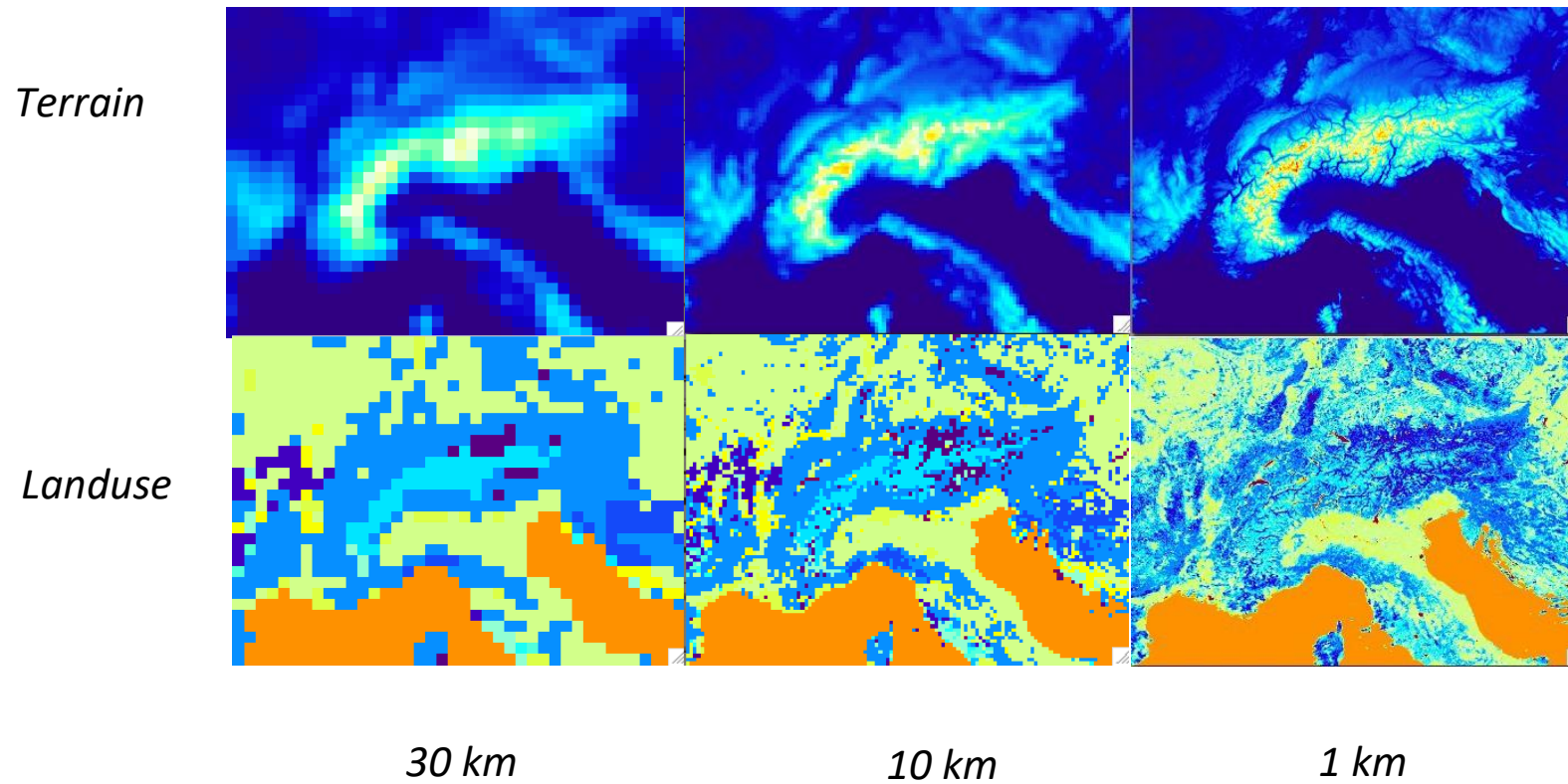
Basic Model Concepts: Model Nesting

- Model nesting example



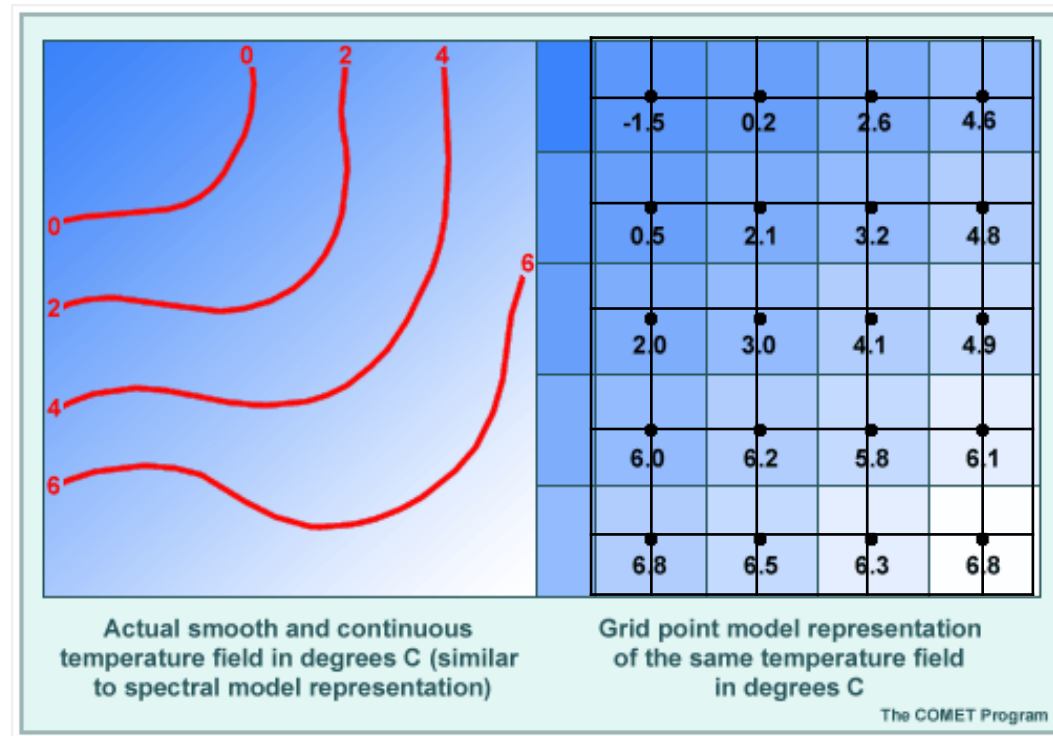
Model Nesting (one way)

- Why nesting? An efficient way to obtain high resolution model solutions.



Some basic concepts: Model grid

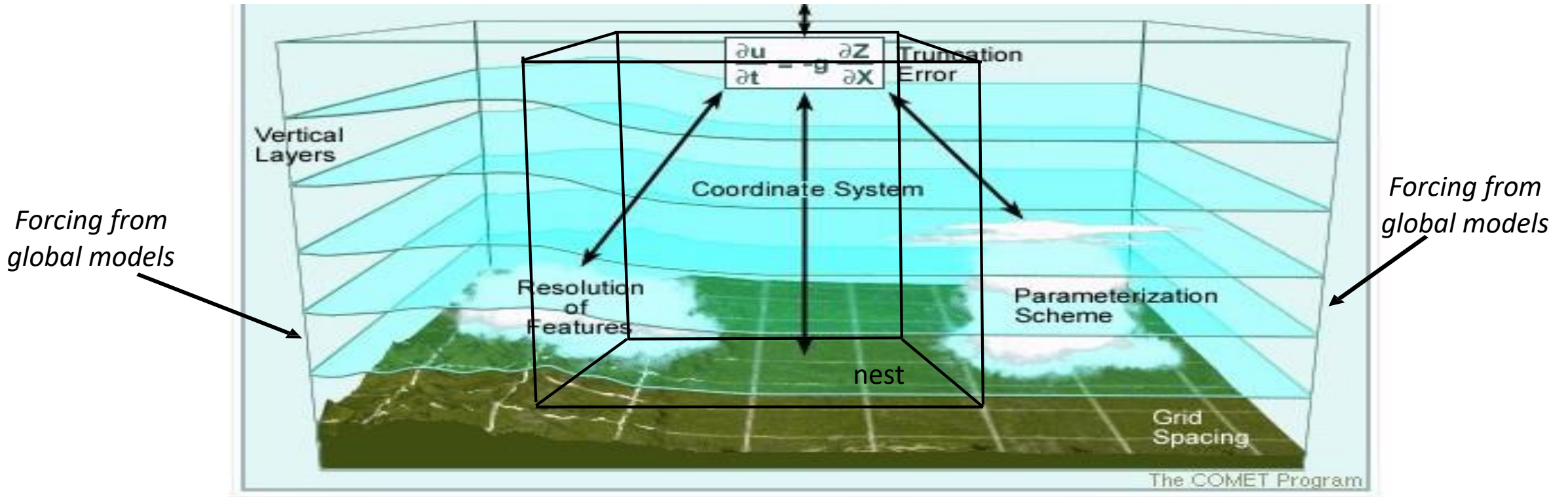
- How are data represented, and equations solved on a model grid?



(from COMET)

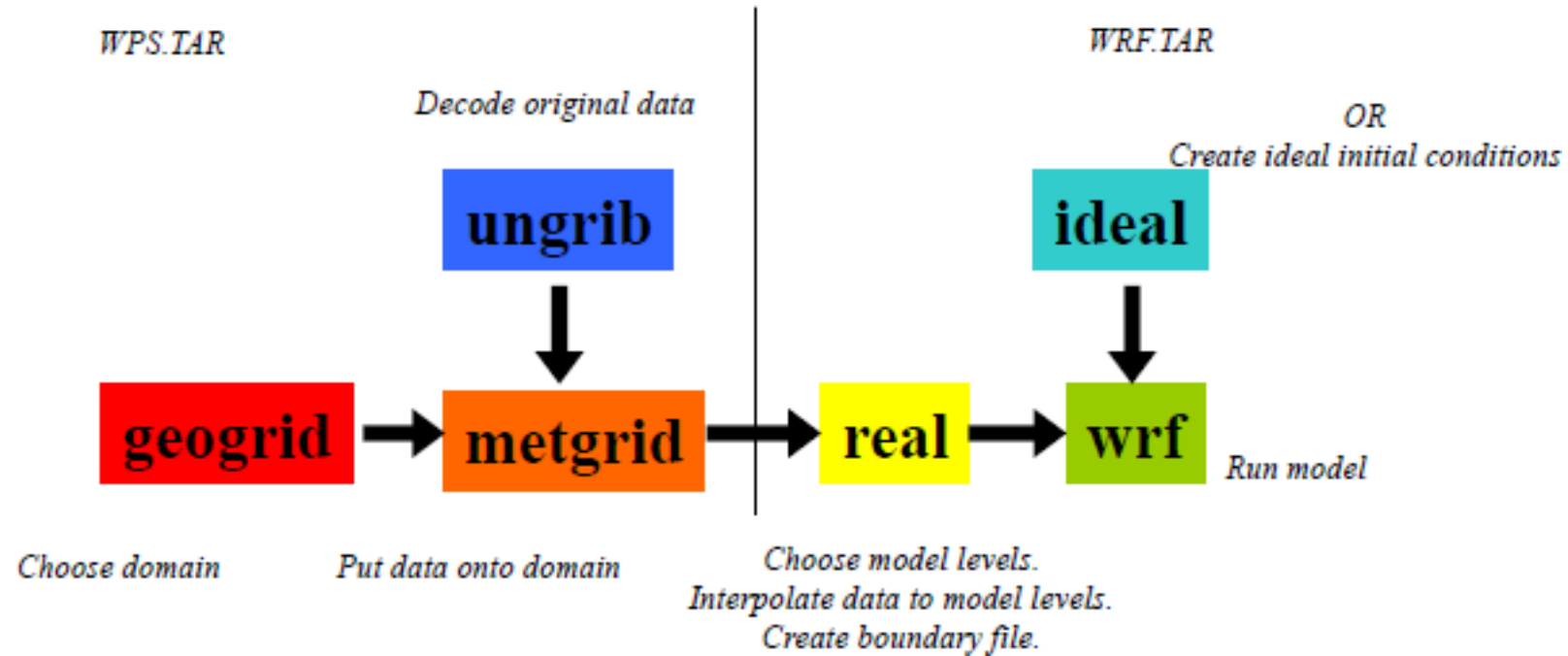
Some basic concepts: Model Grid

- A 3D view of Domain

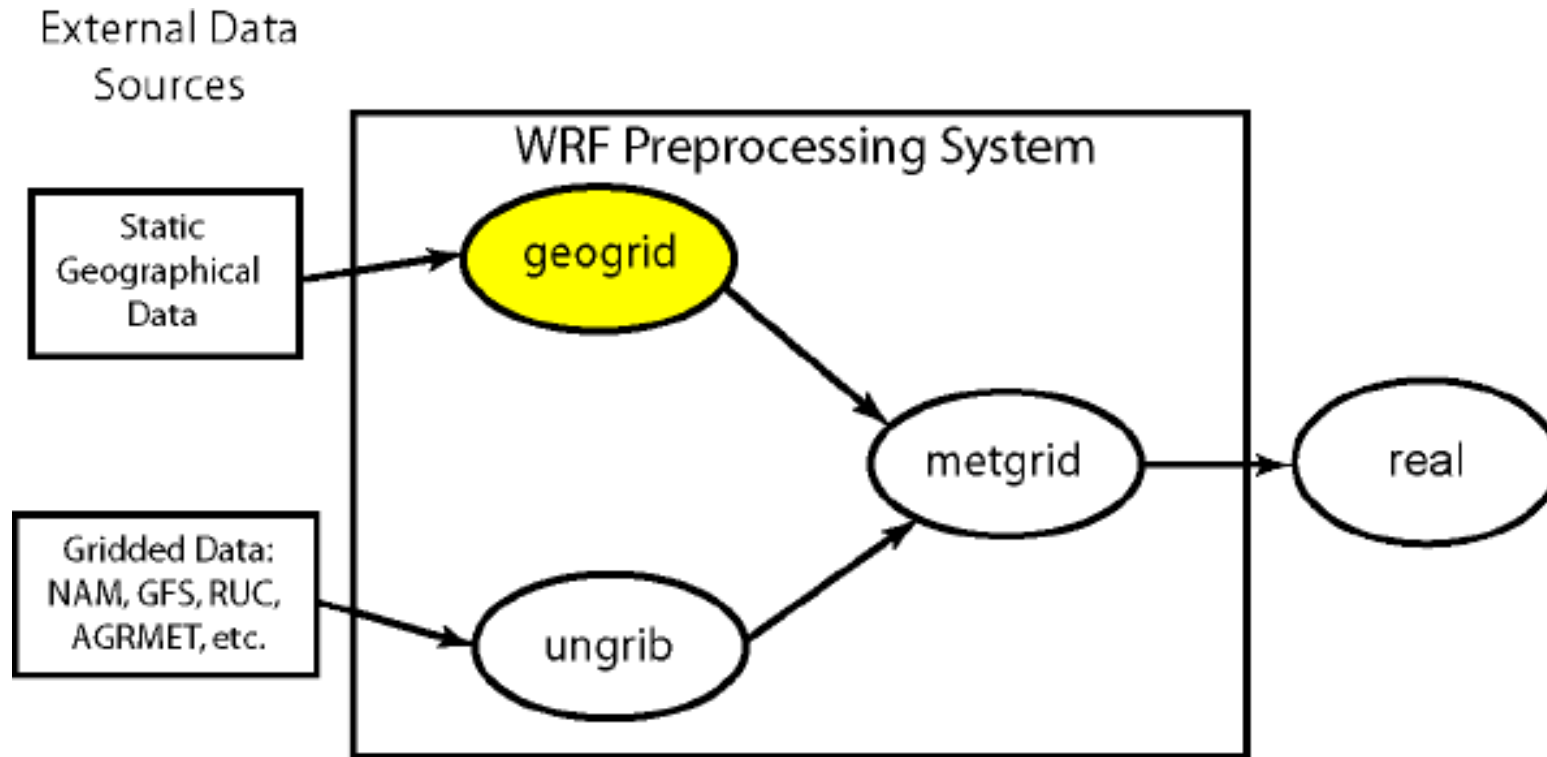


General WRF Model workflow: WPS and WRF programs

WPS and WRF Program Flow



The *geogrid* program



geogrid: think geographical

The Geogrid Program

- We use the geogrid program to define:
 - Map projection (all domains must use the same projection)
 - Geographic location of domains
 - Dimensions of domains
 - Horizontal resolution of domains
- Geogrid provides values for **static** (time-invariant) fields at each model grid point
 - Compute latitude, longitude, map scale factor, and Coriolis parameters at each grid point
 - Horizontally interpolate static terrestrial data (e.g., topography height, land use category, soil type, vegetation fraction, monthly surface albedo) from global datasets

What is a 'namelist?'

1. *Change directories ('cd') to make sure you are in the appropriate running directory.*

2. *Edit the namelist.wps file*

```
e_we      = 150,  
e_sn      220  
dx dy     ,  
          = 130,  
          214  
          ,  
          = 15000,
```

Modifying Namelists

- A Fortran namelist is a list of user-specified runtime options the code will read in during execution.
- A namelist file may contain multiple namelist records

```
&namelist  : record start  
/          : record end
```

The format is very specific so as a general rule:

- Settings for multiple columns: domain dependent
- Only a single column setting: value valid for all domains

Edit the namelist.wps file

number of domains

&share

```
wrf_core = 'ARW',  
max_dom = 2,  
/
```

domain grid spacing
map projection
geography data

&geogrid

```
parent_id           = 1, 1,  
parent_grid_ratio   = 1, 3,  
i_parent_start      = 1, 53,  
j_parent_start      = 1, 25,  
e_we               = 150, 220,  
e_sn               = 130, 214,  
geog_data_res       = 'default', 'default',  
  
dx                 = 15000,  
dy                 = 15000,  
map_proj           = 'lambert',  
ref_lat            = 33.00,  
ref_lon            = -79.00,  
truelat1           = 30.0,  
truelat2           = 60.0,  
stand_lon          = -79.0,  
geog_data_path     = '/data/static/WPS_GEOG/'  
/
```

Geogrid: Interpolating Static Fields

Given definitions of all computational grids, geogrid interpolates terrestrial, time-invariant fields:

- Topography height
- Land use categories
- Soil type (top layer & bottom layer)
- Annual mean soil temperature
- Monthly vegetation fraction
- Monthly surface albedo

https://www2.mmm.ucar.edu/wrf/users/download/get_sources_wps_geog.html

Example of Geography data

Example of Geogrid.TBL data

=====

```
name=SOILCTOP
  priority=1
  dest_type=categorical
  z_dim_name=soil_cat
  dominant=SCT_DOM
  interp_option =
bnu_soil_30s:nearest_neighbor
  interp_option = 30s:nearest_neighbor
  interp_option = 2m:four_pt
  interp_option = 5m:four_pt
  interp_option = 10m:four_pt
  interp_option = default:nearest_neighbor
  rel_path= bnu_soil_30s:bnu_soiltype_top/
  rel_path= 30s:soiltype_top_30s/
  rel_path= 2m:soiltype_top_2m/
  rel_path= 5m:soiltype_top_5m/
  rel_path= 10m:soiltype_top_10m/
  rel_path= default:soiltype_top_30s/
```

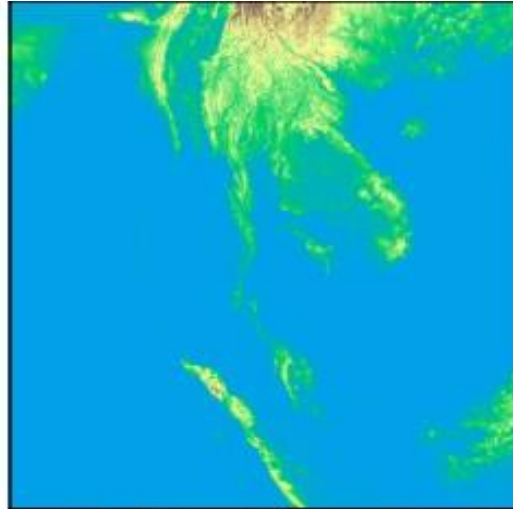
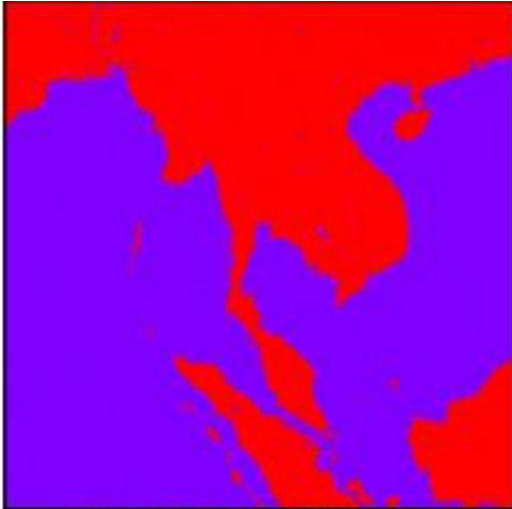
=====

```
name=LANDUSEF
  priority=1
  dest_type=categorical
  z_dim_name=land_cat
  dominant = LU_INDEX
  landmask_water = nlcd2006_9s:17      # Calculate a landmask from this field
  landmask_water = nlcd2006_30s:17     # Calculate a landmask from this field
  landmask_water = nlcd2011_9s:17      # Calculate a landmask from this field
  landmask_water = nlcd2006:17         # Calculate a landmask from this field
  landmask_water = ssib_10m:16         # Calculate a landmask from this field
  landmask_water = ssib_5m:16          # Calculate a landmask from this field
  landmask_water = modis_15s:17        # Calculate a landmask from this field
  landmask_water = modis_15s_lake:17,21 # Calculate a landmask from this field
  landmask_water = modis_30s:17        # Calculate a landmask from this field
  landmask_water = modis_30s_lake:17,21 # Calculate a landmask from this field
  landmask_water = usgs_30s:16         # Calculate a landmask from this field
  landmask_water = usgs_lakes:16,28    # Calculate a landmask from this field
  landmask_water = modis_lakes:17,21   # Calculate a landmask from this field
```

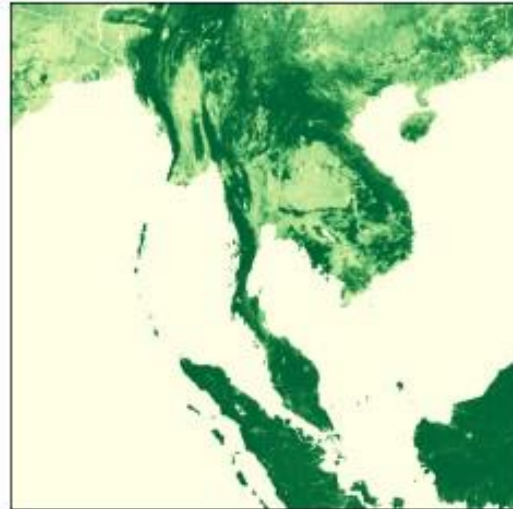
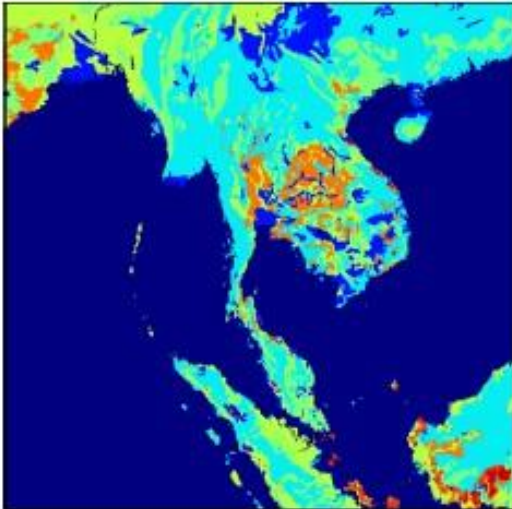
Geogrid: Example Output Fields

Run geogrid:

> **./geogrid.exe**

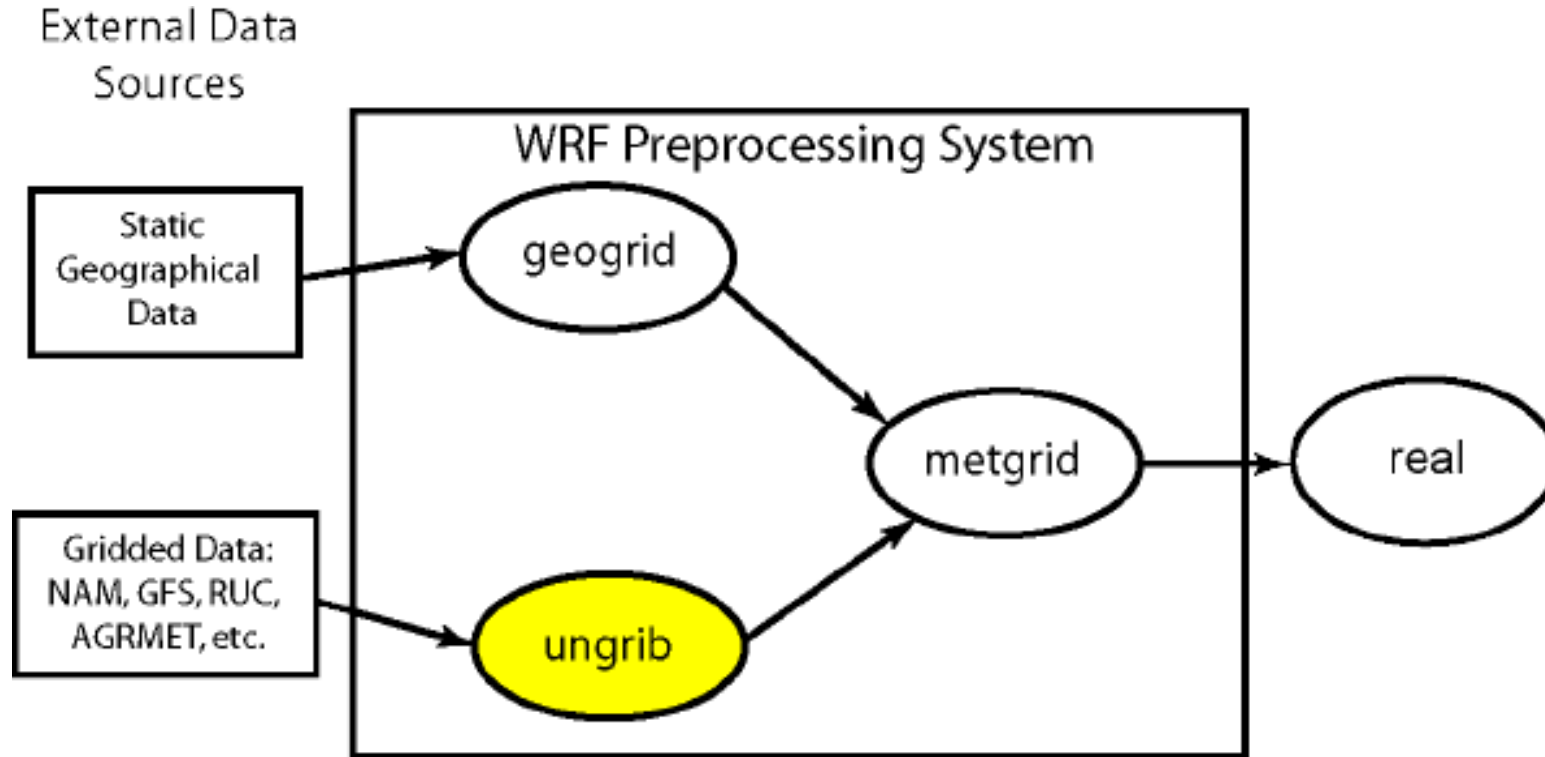


Topography
height



Climatological
vegetation
fraction
(January)

The *ungrib* program



ungrib: think un+grib

What is a GRIB file?

- GRIB is a WMO standard file format for storing regularly-distributed (e.g., gridded) fields
 - “General Regularly-distributed Information in Binary”
- Fields within a GRIB file are compressed with a lossy compression
 - Think of truncating numbers to a fixed number of digits
- A record-based format
- Fields in a file are identified only by code numbers
 - These numbers must be referenced against an external table to determine the corresponding field (see Vtable on next slide)

Use the ‘link_grib.csh’ script provided in the WPS directory

```
> ./link_grib.csh path-to-your-grib-files/gribfile-prefix  
> ls GRIBFILE*
```

```
GRIBFILE.AAA -> ../data/gfs.0p25.2019090412.f000.grib2  
GRIBFILE.AAB -> ../data/gfs.0p25.2019090412.f003.grib2  
GRIBFILE.AAC -> ../data/gfs.0p25.2019090412.f006.grib2  
GRIBFILE.AAD -> ../data/gfs.0p25.2019090412.f009.grib2  
GRIBFILE.AAE -> ../data/gfs.0p25.2019090412.f012.grib2
```

Ungrib: GRIB2 Vtable Entries

```
>ln -sf ungrib/Variable_Tables/Vtable.GFS Vtable
```

```
>ls Vtable
```

metgrid	GRIB2	GRIB2	GRIB2	GRIB2
Description	Discp	Catgy	Param	Level
Temperature	0	0	0	100
U	0	2	2	100
V	0	2	3	100
Relative Humidity	0	1	1	100
Height	0	3	5	100
Temperature at 2 m	0	0	0	103
Relative Humidity at 2 m	0	1	1	103
U at 10 m	0	2	2	103
V at 10 m	0	2	3	103
Surface Pressure	0	3	0	1
Sea-level Pressure	0	3	1	101
Soil Moist 0-10 cm below grn layer (Up)	2	0	192	106
Soil Moist 10-40 cm below grn layer	2	0	192	106
Soil Moist 40-100 cm below grn layer	2	0	192	106
Soil Moist 100-200 cm below gr layer	2	0	192	106
Soil Moist 10-200 cm below gr layer	2	0	192	106
T 0-10 cm below ground layer (Upper)	0	0	0	106
T 10-40 cm below ground layer (Upper)	0	0	0	106
T 40-100 cm below ground layer (Upper)	0	0	0	106
T 100-200 cm below ground layer (Bottom)	0	0	0	106
T 10-200 cm below ground layer (Bottom)	0	0	0	106
Ice flag	0	2	0	1
Land/Sea flag (1=land, 0 or 2=sea)	2	0	0	1
Terrain field of source analysis	2	0	7	1
Skin temperature (can use for SST also)	0	0	0	1
Water equivalent snow depth	0	1	13	1
Dominant soil type cat. (not in GFS file)	2	3	0	1
Dominant land use cat. (not in GFS file)	2	0	198	1

Ungrib: Intermediate File Format

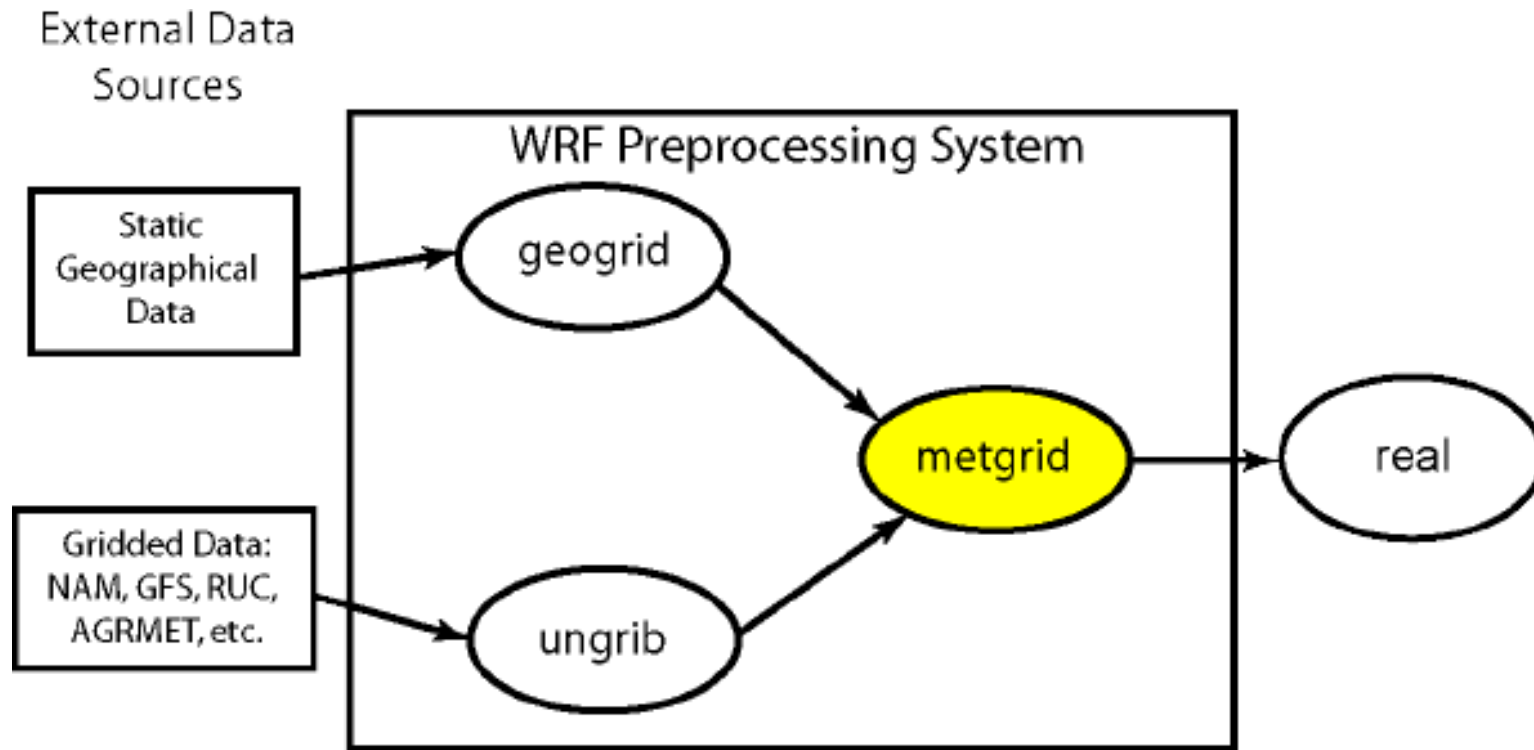
- After extracting fields listed in Vtable, ungrib writes those fields to intermediate format
- For meteorological data sets not in GRIB format, the user may write to intermediate format directly
 - Allows WPS to ingest new data sources; basic programming required of user
 - Simple intermediate file format is easily read/written using routines from WPS (read_met_module.F and write_met_module.F)

Run ungrib:

> **./ungrib.exe**

```
FILE:2022-05-07_12  
FILE:2022-05-07_13  
FILE:2022-05-07_14  
FILE:2022-05-07_15  
FILE:2022-05-07_16
```

The *metgrid* program



metgrid: think meteorological

The *metgrid* program

- Horizontally interpolate meteorological data (extracted by ungrib) to simulation domains (defined by geogrid)
 - Masked interpolation for masked fields
 - Can process both isobaric and native vertical coordinate data sets
- Rotate winds to WRF grid
 - i.e., rotate so that U-component is parallel to x-axis, V-component is parallel to y-axis

Editing namelist.wps for metgrid

&share

```
wrf_core = 'ARW',  
max_dom = 1,
```

```
start_date      = '2019-09-04_12:00:00', '2019-09-04_12:00:00',  
end_date        = '2019-09-05_00:00:00', '2019-09-  
05_00:00:00',
```

```
interval_seconds = 10800  
io_form_geogrid = 2,
```

Data Time Range

Intermediate File Prefixes

Time range to process for each domain.

&metgrid

```
fg_name = 'FILE',  
/
```

Prefix(es) of intermediate files

* This should match the prefix
given in ungrib

Run metgrid:

> ./metgrid.exe

Processing messages are written

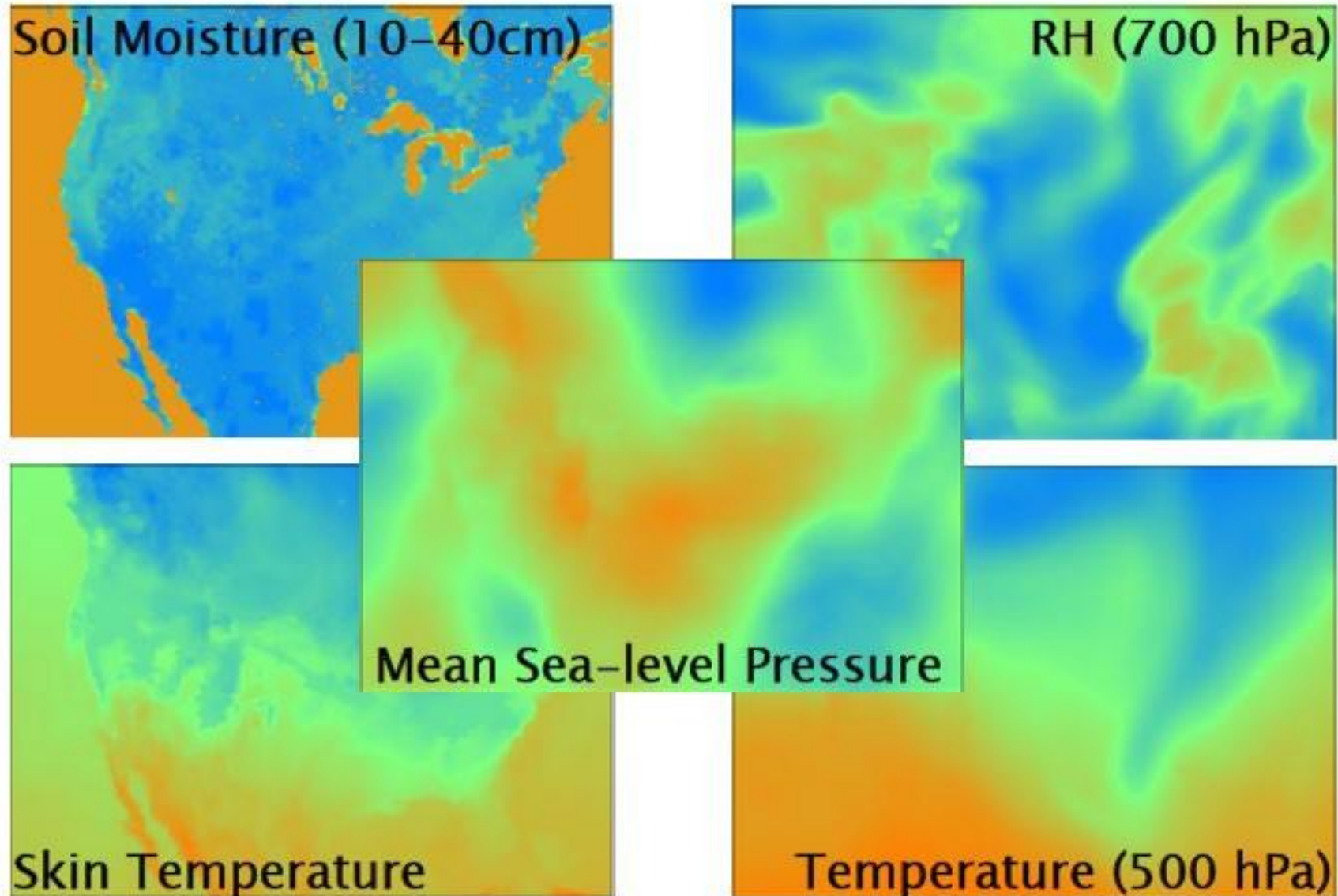
- To the metgrid.log file
- To the screen

Output

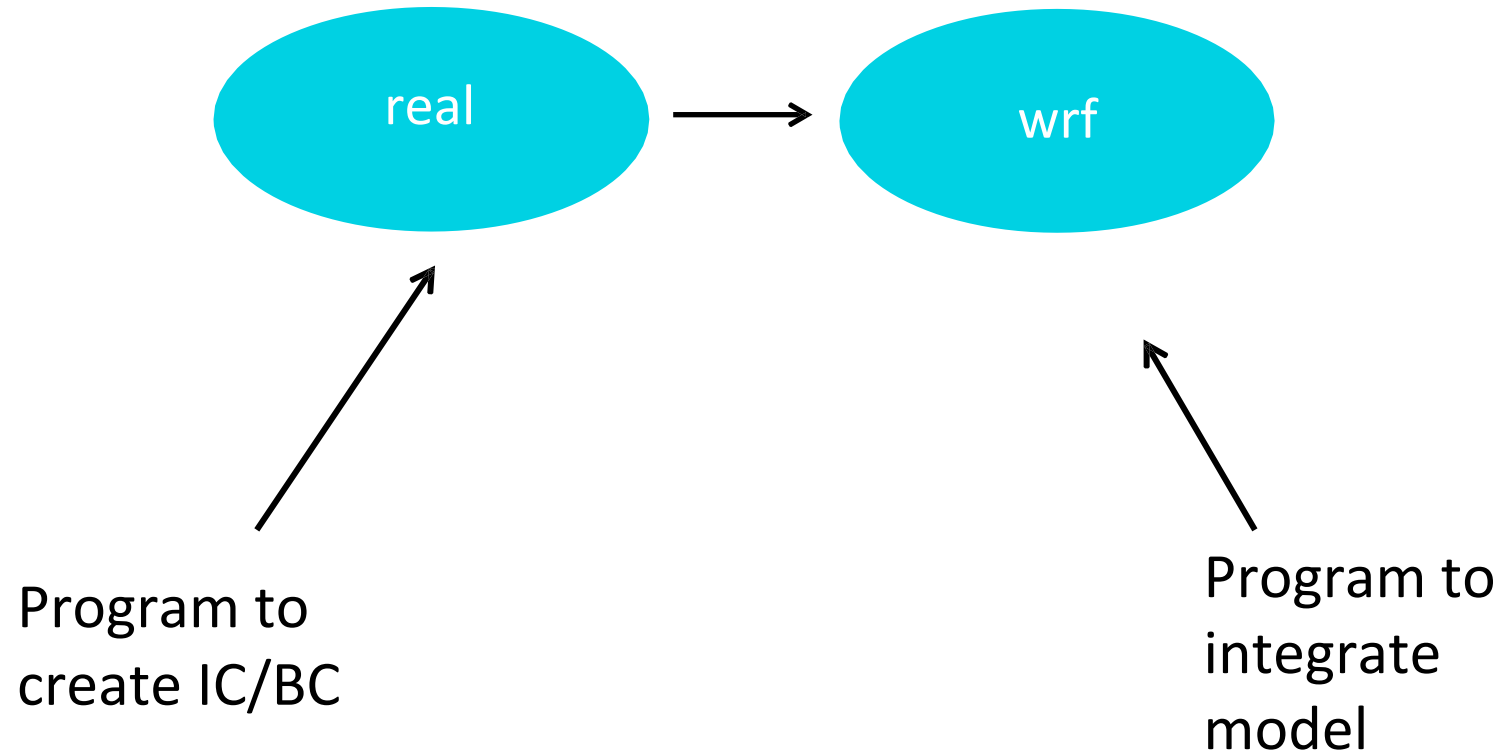
met_em.d01.2019-09-04_12:00:00.nc
met_em.d01.2019-09-04_15:00:00.nc
met_em.d01.2019-09-04_18:00:00.nc
met_em.d01.2019-09-04_21:00:00.nc
met_em.d01.2019-09-05_00:00:00.nc

```
Processing domain 1 of 1
Processing 2012-01-27_00
    FILE
Processing 2012-01-27_06
    FILE
Processing 2012-01-27_12
    FILE
Processing 2012-01-27_18
    FILE
Processing 2012-01-28_00
    FILE
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!           Successful completion of metgrid.
!
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
```

Metgrid: Example Output



WRF Model



Other Model Physics Files

Other model physics data files needed

Some of these files are editable.

```
LANDUSE.TBL -> ../../run/LANDUSE.TBL
GENPARM.TBL -> ../../run/GENPARM.TBL
SOILPARM.TBL -> ../../run/SOILPARM.TBL
VEGPARM.TBL -> ../../run/VEGPARM.TBL
URBPARM.TBL -> ../../run/URBPARM.TBL
RRTM_DATA -> ../../run/RRTM_DATA
RRTMG_SW_DATA -> ../../run/RRTMG_SW_DATA
RRTMG_LW_DATA -> ../../run/RRTMG_LW_DATA
ozone.formatted -> ../../run/ozone.formatted
ozone_lat.formatted -> ../../run/ozone_lat.formatted
ozone_plev.formatted -> ../../run/ozone_plev.formatted
...
namelist.input - editing required
```

VEGPARM.TBL example

Vegetation Parameters

USGS

27,1,'SHDFAC NROOT RS RGL HS SNUP MAXALB LAIMIN LAIMAX EMISSMIN EMISSMAX ALBEDOMIN ALBEDOMAX Z0MIN
Z0MAX

ZTOPV ZBOTV'

1,	.10,	1,	200.,	999.,	999.0,	0.04,	46.,	1.00,	1.00,	.880,	.880,	.15,	.15,	.50,	.50,
	0.00,	0.00,	'Urban and Built-Up Land'												
2,	.80,	3,	40.,	100.,	36.25,	0.04,	66.,	1.56,	5.68,	.920,	.985,	.17,	.23,	.05,	.15,
	0.50,	0.01,	'Dryland Cropland and Pasture'												
3,	.80,	3,	40.,	100.,	36.25,	0.04,	66.,	1.56,	5.68,	.930,	.985,	.20,	.25,	.02,	.10,
	0.50,	0.01,	'Irrigated Cropland and Pasture'												
4,	.80,	3,	40.,	100.,	36.25,	0.04,	66.,	1.00,	4.50,	.920,	.985,	.18,	.23,	.05,	.15,
	0.50,	0.01,	'Mixed Dryland/Irrigated Cropland and Pasture'												
5,	.80,	3,	40.,	100.,	36.25,	0.04,	68.,	2.29,	4.29,	.920,	.980,	.18,	.23,	.05,	.14,
	0.50,	0.01,													

&time_control

run_days = 0,
run_hours = 36,
run_minutes = 0,
run_seconds = 0,

run_* variables

Model simulation length

- Not domain-dependent. Only set a single value
- Only wrf.exe reads these

start_year = 2019, 2019,
start_month = 09, 09,
start_day = 04, 04,
start_hour = 12, 12,
end_year = 2019, 2019,
end_month = 09, 09,
end_day = 06, 06,
end_hour = 00, 00,

start_* and end_* variables

- Program real uses WPS output (met_em*) between these times to produce lateral and boundary conditions

interval_seconds = 10800
input_from_file = .true., .true.,
history_interval = 60, 60,
frames_per_outfile = 1, 1,
restart = .false.,
restart_interval = 7200,

Lateral boundary conditions

- Interval in seconds of lateral boundary conditions update on edge of outer domain

Editing namelist.input file

Editing namelist.input file

&domains

```
time_step      = 90,  
time_step_fract_num = 0,  
time_step_fract_den = 1,
```

time_step* variables

Time step for model integration (seconds)
Generally should not be $> 6 \times dx$

```
max_dom        = 1,  
e_we           = 150, 220,  
e_sn           = 130, 214,  
e_vert         = 45, 45,  
dzstretch_s    = 1.1  
p_top_requested = 5000,  
num_metgrid_levels = 34,  
num_metgrid_soil_levels = 4,  
dx             = 15000,  
dy             = 15000,  
grid_id        = 1, 2,  
parent_id      = 0, 1,  
i_parent_start = 1, 53,  
j_parent_start = 1, 25,  
parent_grid_ratio = 1, 3,  
parent_time_step_ratio = 1, 3,  
feedback       = 1,  
smooth_option  = 0
```

e_we and e_sn

The full west-east and south-north dimensions of the domain

e_vert

Number of vertical model levels

num_metgrid_levels

Number of metgrid (input) data levels

num_metgrid_soil_levels

Number of metgrid (input) soil data levels

dx and dy

Grid distance
(resolution) in meters

&physics

- Model physics options
- A summary of physics options can be found here:

https://www2.mmm.ucar.edu/wrf/users/wrf_users_guide/build/html/index.html

- More details on different parameterizations can be found in the WRF user guide and specific literature papers.

&dynamics

- Damping, diffusion options
- Advection options

PBL Scheme Options

Scheme	Option	Works With sfclay Option	Prognostic Variables	Diagnostic Variables	Cloud Mixing
YSU	1	1 91	none	exch_h	QC QI
MYJ	2	2	4	EL_PBL exch_h	QC QI
QNSE-EDMF	4	4	TKE_PBL	EL_PBL exch_h exch_m	QC QI
MYNN2	5	1 2 5 91	QKE	Tsq Qsq Cov exch_h exch_m	QC
MYNN3	6	1 2 5 91	QKE Tsq Qsq Cov	exch_h exch_m	QC
ACM2	7	1 7 91			QC QI
BouLac	8	1 2 91	TKE_PBL	EL_PBL exch_h exch_m	QC
UW	9	1 2 91	TKE_PBL	exch_h exch_m	QC
TEMF	10	10	TE_TEMF	*_temf	QC QI
Shin-Hong	11	1 91		exch_h	QC QI

Running a Real-data Case

- Successfully running **real.exe** will create model initial and boundary files (type **ls -l** to see the files):

wrfinput_d01
wrfbdy_d01

*Single time level
data at model's
start time*

*N-1 time-level data for
lateral boundaries, and
only for domain 1*

N: the number of time periods processed

ncdump -v Times wrfbdy_d01

Serial or smpar compile

Running WRF model

```
> ./wrf.exe >& wrf.log
```

Parallel (dmpar) compile

```
> mpiexec -np N ./wrf.exe
```

Where N is the number of processors requested
- outputs rsl.out.* and rsl.error.* for each processor

Look at the end of the log file or
rsl.out.0000 file for:

SUCCESS COMPLETE WRF

Output Files

wrfout_d01_YYYY-MM-DD_hh:mm:ss

Model output at time interval specified by
history_interval, and dependent on
frames_per_outfile

Analyzing WRF output



Inspecting WRF output files with Panoply

	wrfout_d01_2005-08-27_00/00/00.nc	netCDF Dataset
	wrfout_d01_2005-08-27_00/00/00.nc	netCDF Dataset
	wrfout_d01_2005-08-28_00/00/00.nc	netCDF Dataset
	wrfout_d01_2005-08-28_00/00/00.nc	netCDF Dataset
	wrfout_d01_2005-08-29_00/00/00.nc	netCDF Dataset
	wrfout_d01_2005-08-29_00/00/00.nc	netCDF Dataset
	wrfout_d05_2017-05-19_00/00/00.nc	netCDF Dataset

The screenshot shows the Panoply application window. The 'Sources' tab is active, displaying a list of variables. The variable 'U10' is selected and highlighted in blue. To the right, the details for 'U10' are shown, including its file path and a snippet of its NetCDF structure.

Name	Long Name	Type
TLP_STRAT	TLP STRAT	1D
TMN	TMN	Geo2D
TSK	TSK	Geo2D
TSK_FORCE	TSK FORCE	1D
TSK_FORCE_TEND	TSK FORCE TEND	1D
TSLB	TSLB	Geo2D
U	U	Geo2D
U10	U10	Geo2D
UDROFF	UDROFF	Geo2D
UST	UST	Geo2D
V	V	Geo2D

Variable "U10"
In file "wrfout_d05_2017-05-19_00:00:00.nc"

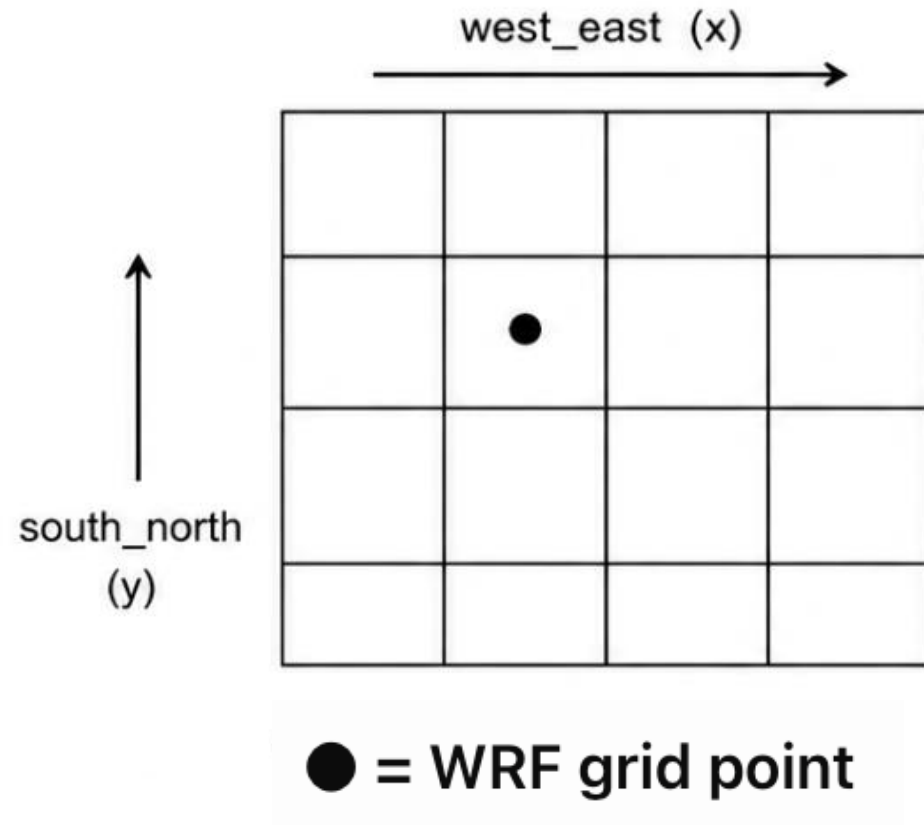
```
float U10(Time=73, south_north=195, west_east=195);
:FieldType = 104; // int
:MemoryOrder = "XY ";
:description = "U at 10 M";
:units = "m s-1";
:stagger = "";
:coordinates = "XLONG XLAT XTIME";
:_ChunkSizes = 1U, 98U, 98U; // uint
```

WRF output files contain the model variables needed to explore the atmosphere across space, time, and height.

WRF Model Grid

Understanding the model grid and variable dimensions is essential for analyzing WRF output

WRF Horizontal Grid (one model level)



- Surface variables have dimensions **(time, y, x)**
- 3-D atmospheric variables also include a **vertical dimension**
- Latitude and longitude identify the geographic location of each grid cell

Common WRF Output Variables and Dimensions

Variable	Description	Dimensions
U	x-direction wind component	(time, z, y, x)
T2	2-m air temperature	(time, y, x)
U10	10-m U wind component	(time, y, x)
HGT	Terrain elevation (MSL)	(y, x)
XLAT	Latitude	(y, x)
XLONG	Longitude	(y, x)

Reading WRF output with Python

Useful Python packages for WRF analysis

- **WRF-Python**: WRF diagnostics and interpolation
- **xarray**: Supports Multidimensional data analysis
- **matplotlib**: Great for making plots quickly
- **cartopy**: Mapping and geographic projections
- **netCDF4**: Reading NetCDF files

READING WRF OUTPUT WITH PYTHON

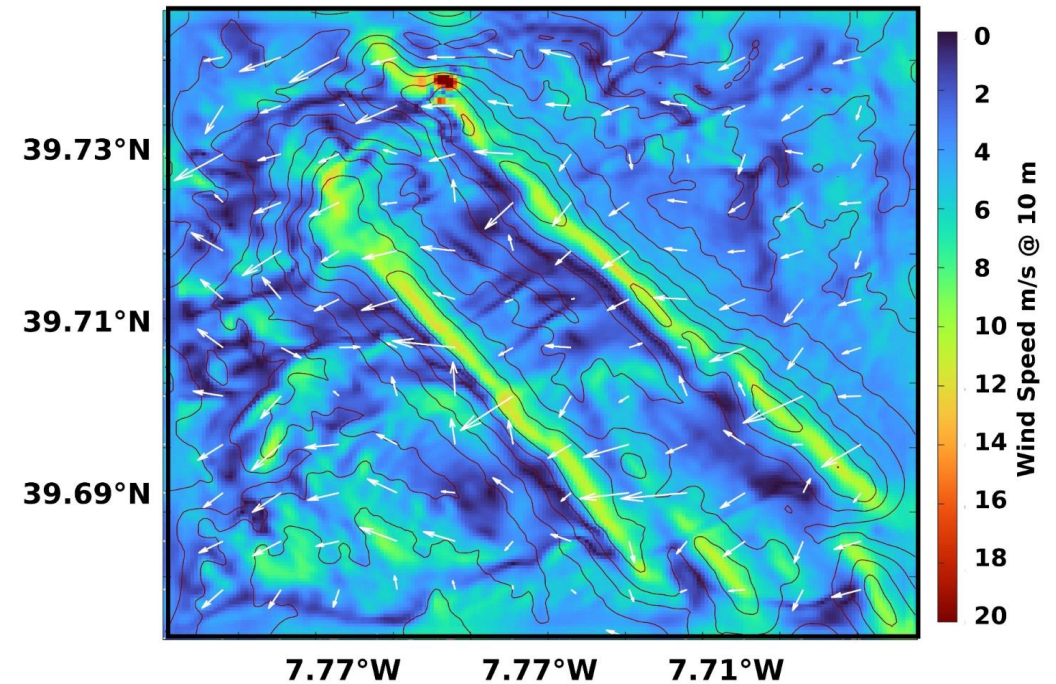
```
from netCDF4 import Dataset
from wrf import getvar, get_cartopy
import numpy as np
import matplotlib.pyplot as plt
import cartopy.crs as ccrs

# -----
# 1. Open the WRF output file
# -----
ncfile = Dataset("wrfout_d05_2017-05-19_00:00:00")

# -----
# 2. Extract variables
# -----
t2 = getvar(ncfile, "T2")      # 2-m temperature [K]
u10 = getvar(ncfile, "U10")    # 10-m U wind component [m s-1]
v10 = getvar(ncfile, "V10")    # 10-m V wind component [m s-1]

# -----
# 3. Calculate 10-m wind speed
# -----
wspd10 = np.sqrt(u10**2 + v10**2)
```

Example: Spatial field of Wind speed at 10 m



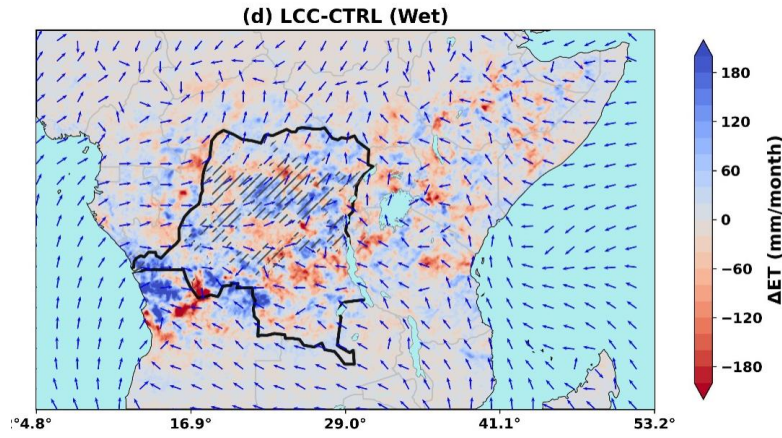
Analyzing WRF output

Many ways to explore model output depending on your scientific question

The same WRF output can support many different types of analyses

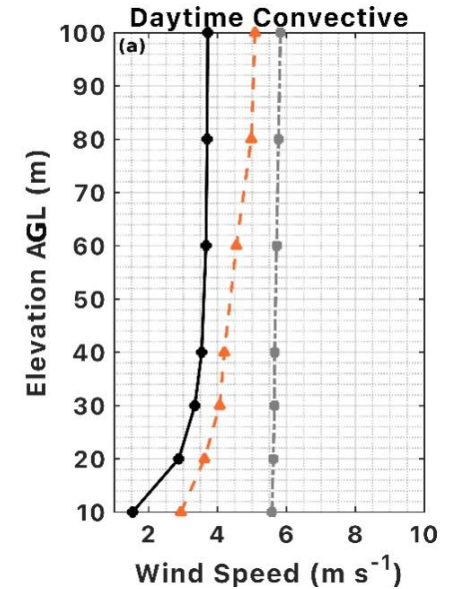
1. Spatial Maps

What does the field look like in space?



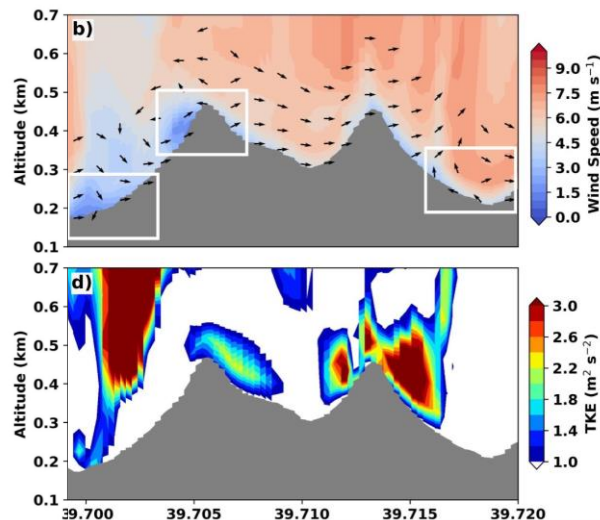
2. Vertical Profiles

How does the field vary with height?



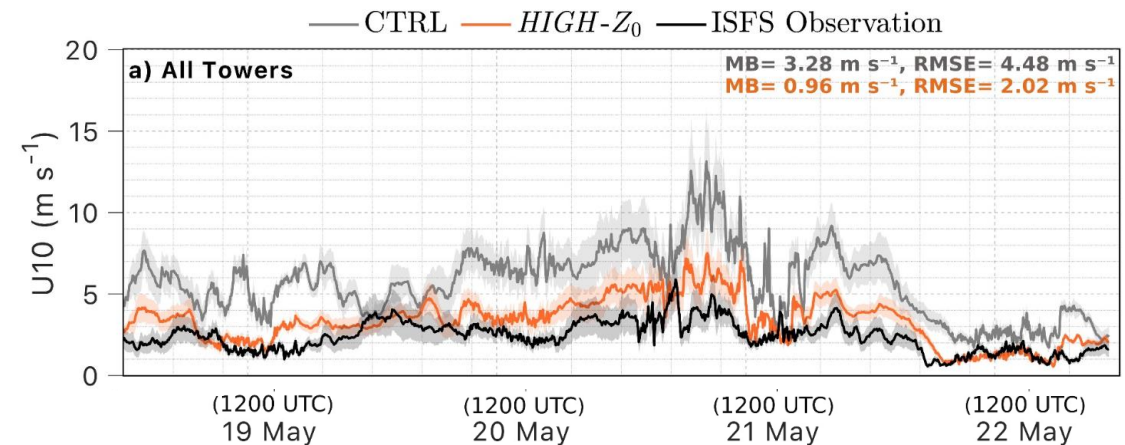
3. Cross Sections

How does the field vary across the terrain?



4. Time Series

How does the field change over time?



WRF Workflow and Commands



Step	Before running: link / check	Run	Expected output
geogrid	Link <code>namelist.wps</code> , <code>GEOGRID.TBL</code> , and <code>geogrid.exe</code> ; Check <code>geog_data_path</code>	<code>qsub batchgeogrid.sh</code>	<code>geo_em_d01.nc</code>
ungrib	Link <code>Vtable</code> , <code>ungrib.exe</code> , and <code>link_grib.csh</code> ; Link pressure-level and surface GRIB files; Check the appropriate <code>prefix</code> settings (<code>FILE</code> and <code>SFC</code>)	<code>qsub batchungrib.sh</code>	<code>FILE:XXX, SFC:XXX</code>
metgrid	Link <code>metgrid.exe</code> and <code>METGRID.TBL</code> ; Check <code>fg_name='FILE', 'SFC'</code> and <code>OPT_METGRID_TBL_PATH</code>	<code>qsub batchmet.sh</code>	<code>met_em.d01.*.nc</code>
real.exe	Link the WRF run files and <code>met_em*</code> ; Link and edit <code>namelist.input</code>	<code>qsub batchreal.sh</code>	<code>wrfinput_d01,</code> <code>wrfbdy_d01</code>
wrf.exe	Check <code>namelist.input</code> ; Confirm that <code>wrfinput_d01</code> and <code>wrfbdy_d01</code> exist	<code>qsub batchwrf.sh</code>	<code>wrfout_d01_*</code>

WRF Workflow and Commands



- Batch Script module

batchgeogrid.sh

```
#!/bin/csh
#$ -M user
#$ -m abe
#$ -pe smp 8
#$ -q queue_name
#$ -N geogrid

module load geos
module load proj
module load netcdf/4.9.2/intel/24.2
module load wrf/4.7/intel/24.2
geogrid.exe >& geogrid.log
```

batchreal.sh

```
#!/bin/bash
#$ -M user
#$ -m abe
#$ -pe mpi-64 64
#$ -q queue_name
#$ -N realjob

module load netcdf/4.9.2/intel/24.2
module load wrf/4.7/intel/24.2
module load mpich/4.1.2/intel/24.2

ulimit -s unlimited
mpiexec -np 64 /path_to_real.exe/real.exe >& real.log
```

WRF Resources

- WRF Model Users' Page:
<https://www2.mmm.ucar.edu/wrf/users/>
- WRF-ARW Online Tutorial:
<https://www2.mmm.ucar.edu/wrf/OnLineTutorial/>
- WRF User's Guide:
https://www2.mmm.ucar.edu/wrf/users/wrf_users_guide/build/html/index.html

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Thank you!