HWRF v3.9a Tutorial
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HWRF Initialization Overview

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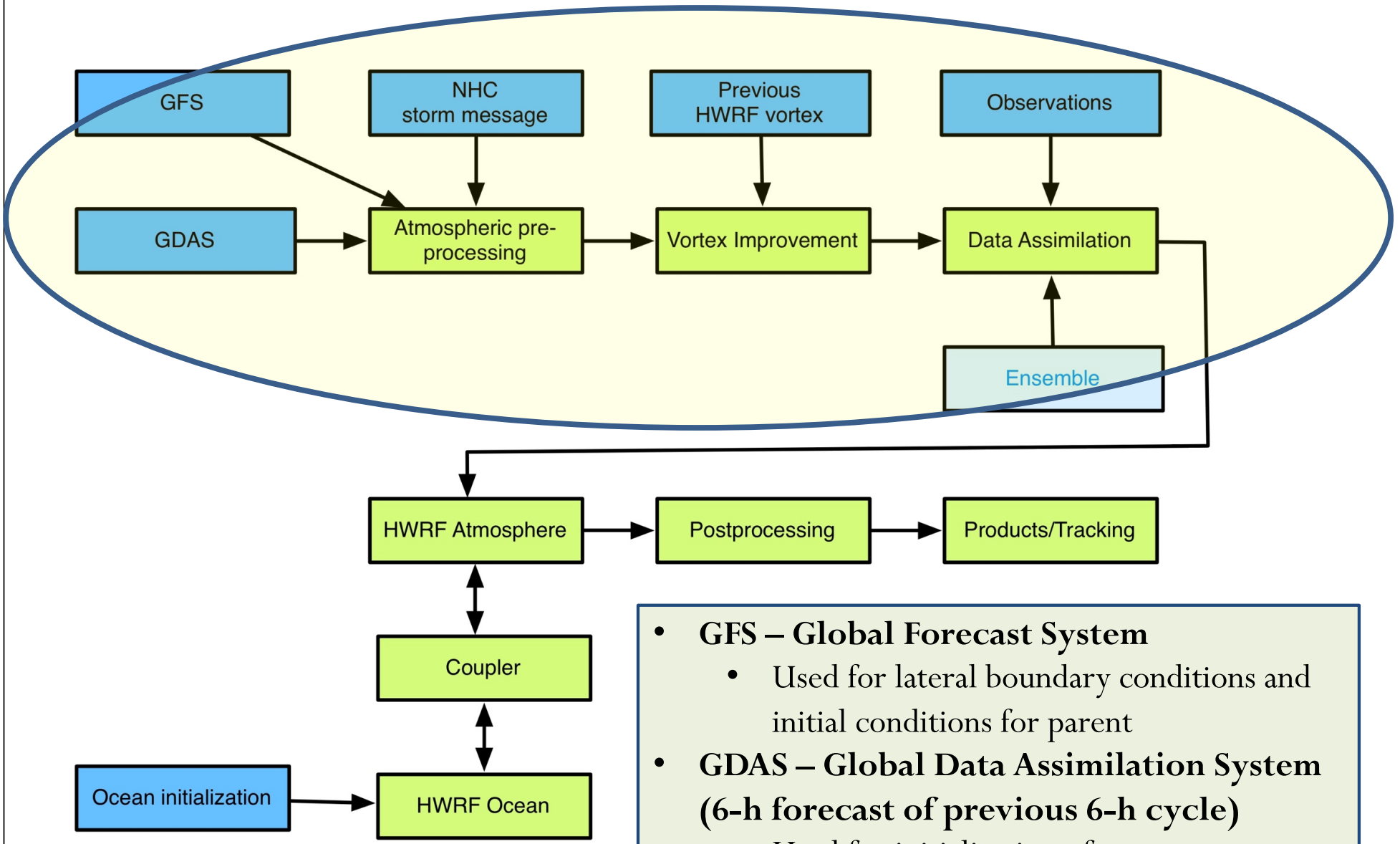
HWRF v3.9a overview (AL configuration)



- **GFS – Global Forecast System**
  - Used for lateral boundary conditions and initial conditions for parent
- **GDAS – Global Data Assimilation System (6-h forecast of previous 6-h cycle)**
  - Used for initialization of nests
- **GFS ensemble**
  - Used for hybrid DA

Parent domain location

Storm location (10*lat , 10*lon)

HWRF is only launched when a storm message is issued

Parent domain location depends on the basin, storm location, and 72-h official projection

- e.g., JTWC 07W SOULIK 20130709 1200 203N 1381E 285 057 …
- Domain center latitude (CENLA)
  - ILAT is an average of the current and 72-h forecast latitude

    if ILAT < 15.0 then CENLA = 15.0

    if 15.0 ≤ ILAT < 25.0 then CENLA = ILAT + 5.0

    if 25.0 ≤ ILAT < 35.0 then CENLA = 30.0, etc.
    - This algorithm differs slightly in the WPAC/Indian oceans
- Domain center longitude (CENLO)
  - The domain center longitude is an average of the current and 72-h forecast longitude
- If 72-h forecast absent, it is assumed to be 10 N, 20 W from current storm position
- To ensure that the domain center is separated from the storm center by at most 5 degrees:

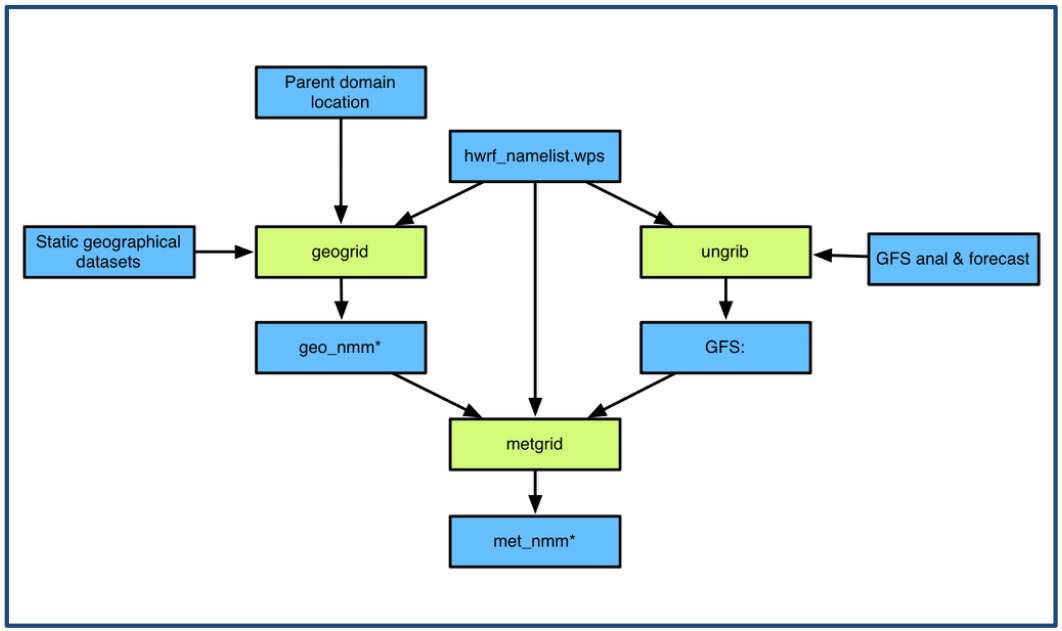
  if CENLO > STORM_LON + 5 then CENLO = STORM_LON + 5
  if CENLO < STORM_LON – 5 then CENLO = STORM_LON – 5

Direction(°); speed (dm/s)

The outer nest (d02) and inner nest (d03) are centered on the storm

More details: ush/hwrf/storminfo.py

WRF Preprocessing System (WPS)



Script determines domain location

Geogrid reads geographical static data (topography etc.) and interpolates them to WRF grids

Ungrib reads selected variables from global model analysis and forecast in GRIB format

Metgrid horizontally interpolates global model data to WRF grid

WRF Preprocessing System Users' Guide (see Chapter 2):
https://dtcenter.org/HurrWRF/users/docs/scientific_documents/WRF-NMM_2017.pdf

Example of WPS namelist

```
&share
 wrf_core = 'NMM',
 max_dom = 3,
 start_date = '2016-08-19_18:00:00',
 end_date = '2016-08-25_00:00:00',
 interval_seconds = 21600,
 io_form_geogrid = 2, /

&geogrid
 parent_id         = 1,1,2,
 parent_grid_ratio = 1,3,3,
 i_parent_start    = 1,10,10,
 j_parent_start    = 1,10,10,
 e_we              = 288, 265, 235,
 e_sn              = 576, 532, 472,
 geog_data_res = '2m','2m','2m',
 dx = 0.135,
 dy = 0.135,
 map_proj =  'rotated_ll',
 ref_lat   = 26.0,
 ref_lon   = -48.9,
 geog_data_path = path_to_datasets/wps_geog,
 opt_geogrid_tbl_path = path_to_geogrid_table,

&ungrib
 out_format = 'WPS',
 prefix = 'FILE',/

&metgrid
 fg_name = 'FILE',
 io_form_metgrid = 2,
 opt_metgrid_tbl_path = path_to_metgrid_table
```

Center of parent domain

WPS geographical dataset

(i,j) of SW corner of parent domain

All namelists are automatically generated by the python scripts – set options in parm/*.conf files.

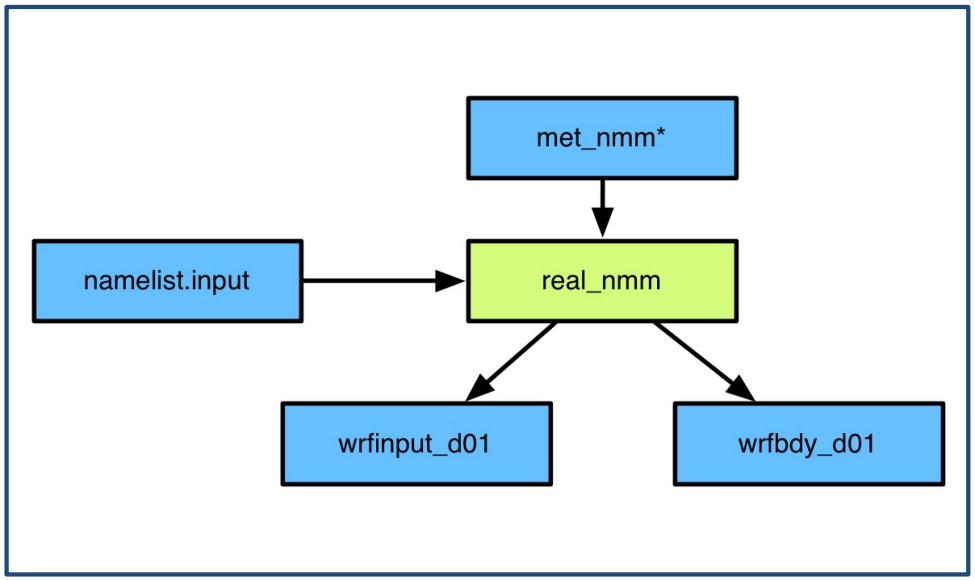
Grid spacing of d01

Number of grid points in each domain

Additional files used in WPS

- **Geogrid table**
  - Specifies source and interpolation method for geographical datasets
- **Ungrib table: Vtable**
  - Specifies which fields to extract from GRIB file
- **Metgrid table**
  - Specifies methods for interpolating parent model data to WRF grid

The *real* program



The *real_nmm.exe* program is used to vertically interpolate the global model data to the WRF levels

HWRF uses 75 levels in AL, EP, CP; 61 in WP, NIO; & 43 in SIO, SP by default. (These configurations can be used in any basin)

Real_nmm.exe is also used to compute derived variables that are not present in the global data but are needed by WRF

Real_nmm.exe outputs initial and boundary conditions that can be used to start WRF

For idealized simulations, program *ideal.exe* is used instead of *real_nmm.exe*

Real Users' Guide (see Chapter 3):
https://dtcenter.org/HurrWRF/users/docs/scientific_documents/WRF-NMM_2017.pdf

The real/WRF namelist

&time_control

Begin, end time

Freq of boundary files

Freq of output

&domains

Timestep

Number of domains and dimensions

Grid spacing

Location of nests

Vertical levels

&physics

Cumulus, microphysics, radiation, PBL

Physics timesteps

Vortex tracker options

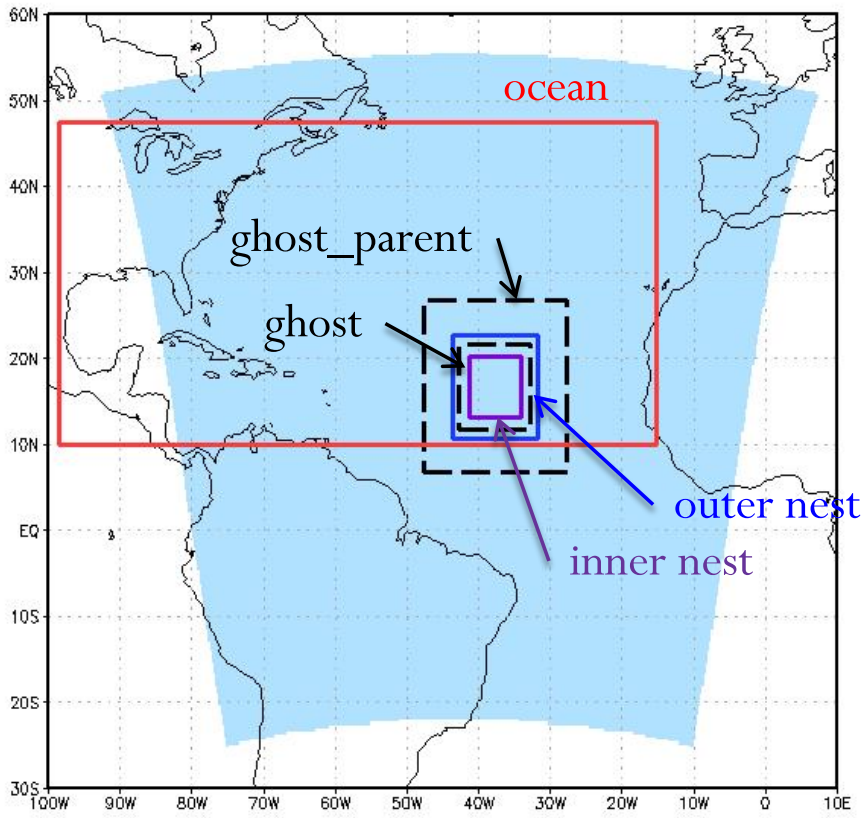
WRF also uses several lookup tables to expedite computations in the physical parameterizations

WRF Users' Guide (see Chapter 4):
https://dtcenter.org/HurrWRF/users/docs/scientific_documents/WRF-NMM_2017.pdf

Review

- **Step 1**: define location of parent domain
- **Geogrid**: puts geographical static data in WRF grid
- **Ungrib & Metgrid**: horizontally interpolate GFS data (in GRIB format) to WRF parent grid for initialization
- **Real**: interpolate metgrid output to WRF vertical levels
- Once steps above are completed, a full set of ICs in the 3D parent WRF grid are available for starting the main forecast
- All of the steps above are performed automatically by the HWRF Python scripts using information from configuration files and the storm message
- The next steps are used to improve the vortex in these ICs

Preparing vortex initialization: *Analysis*

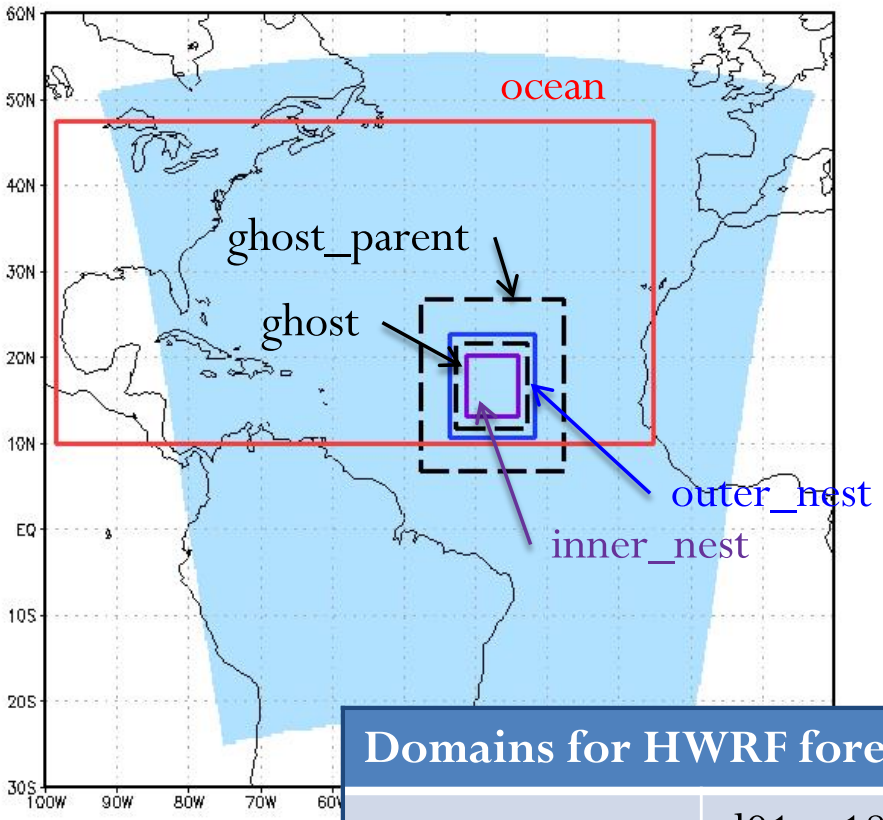


Step 1: *WRF Analysis* run (60 s WRF run)

- Is used as a tool to downscale global data from *real*'s wrfinput_d01 file to HWRF outer nest (d02) and inner nest (d03)
- Outputs "analysis" files for d02 and d03, which are t=0 wrfout files, containing variables needed by vortex relocation

Domains for *WRF Analysis* and HWRF forecast are identical		
d01 – 18 km	d02 – 6 km	d03 – 2 km
80°x80°	24°x24°	7°x7°

Preparing vortex initialization: *Ghost*



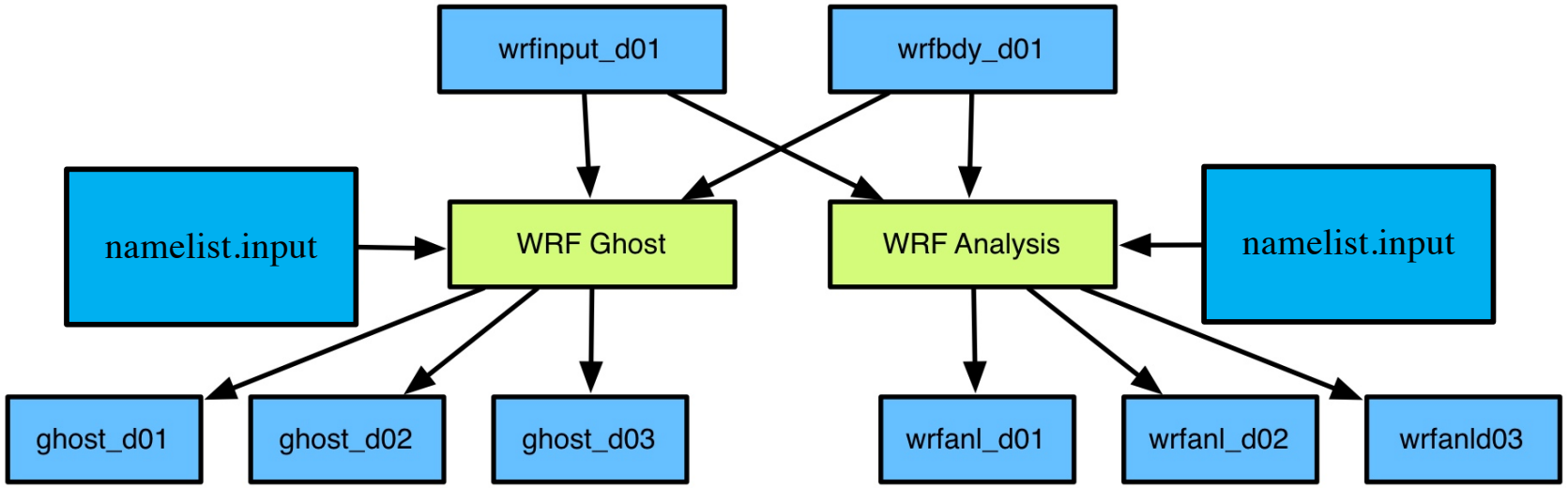
Step 2: *WRF Ghost* run (60 s WRF run)

- Downscales global data from *real*'s wrfinput_d01 file to a large high-resolution domain for storm-scale data assimilation
- Outputs ghost-sized "analysis" files for ghost d02 and ghost d03, containing variables needed by DA package

Domains for HWRF forecast, *WRF Analysis, WRF Ghost*

	d01 – 18 km	d02 – 6 km	d03 – 2 km
HWRF Forecast	80°x80°	24°x24°	7°x7°
WRF Analysis	80°x80°	24°x24°	7°x7°
WRF Ghost	80°x80°	28°x28°	15°x15°

Summary of last Analysis & Ghost runs



***WRF Ghost* 60-s run**

- Downscales info from global model
- Provides first guess for storm-scale DA

***WRF Analysis* 60-s run**

- Downscales info from global model
- d01,d02,d03 used as main input to vortex initialization procedure
- d01 output used for identifying location of vortex in global model for removal

Vortex Initialization: Brief Overview

- **Vortex initialization can be considered as a mini data analysis for storm vortex using TcVital information, and includes three parts:**
  - storm **relocation** (data used: storm center position)
  - storm **size** correction (data used: radius of maximum surface wind speed, radius of 34-kt winds, radius of the outermost closed isobar)
  - storm **intensity** correction (data used: maximum surface wind speed, and minimum sea level pressure)

  Note: Do storm size correction before storm intensity correction to avoid broad eyewall structure, or worse, two distinct eyewalls.

- **If the background vortex is close to the observation, all corrections are small.**
  - If the storm location, storm size and storm intensity in the background fields match the observations, there will be no changes to any of the background fields

Model-consistency

Generally speaking, the differences are large between the model and the observation in hurricane area. We have two choices:

a) Small correction

pro: model-consistent

small adjustment during model forecast

con: vortex structure may be bad

➔ HWRF vortex initialization can be considered as small correction (correction is large in some cases):

Storm size correction is limited to 15%

wind speed correction is not limited, but hopefully < 15%

As model physics improve, the vortex structure will become better, and the final analysis eventually will converge to observation.

Model-consistency (continued)

b) Large correction

pro: better vortex structure

con: most likely not model-consistent

Large adjustment during model forecast

Once model forecast starts, the good vortex structure can be lost in several hours forecast time.

Example: 2005 Wilma has an 8-km eyewall size at 140 knots wind. Model forecast gives ~ 20km eyewall size in the background fields. If we force the initial vortex to be 8-km eyewall size in HWRF initial fields, the eyewall will collapse, and significant spin-down will occur in model forecast. The current HWRF model does not have the capability to maintain this kind of hurricane structure.

Vortex initialization: Stage 1

Cold Start

OR

Cycled Start

IF

Intensity < 14 m s^{-1}

OR

Previous 6-h forecast NOT available

THEN

Exit Stage 1

IF

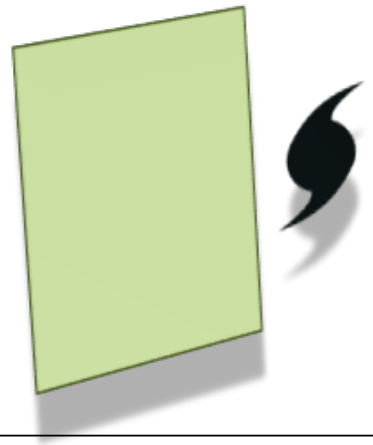
Intensity ≥ 14 m s^{-1}

AND

Previous 6-h forecast IS available

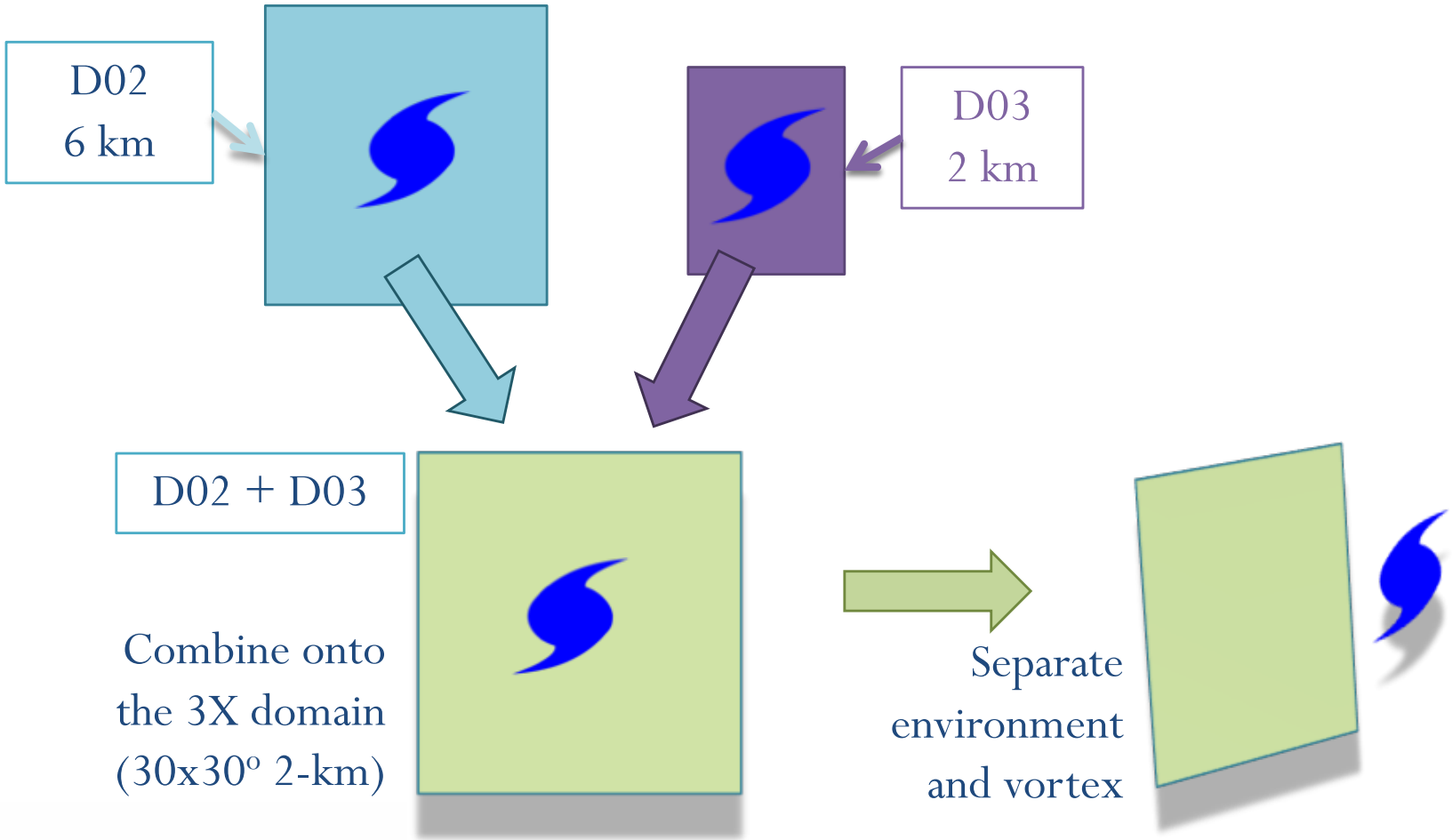
THEN

Start vortex adjustment process by extracting HWRF vortex from previous forecast



Vortex initialization: Stage 2

Separate the GDAS first guess vortex from environmental flow



Vortex initialization: Stage 3

Determine which vortex will be used for initializing HWRF and update it using TC Vitals

Cold Start

OR

Cycled Start

Int < 20 m/s

OR

Int >= 20 m/s

Update and use vortex from downscaled GDAS fields (Stage 2)

Use an axisymmetric bogus vortex

Update and use vortex from previous HWRF forecast (Stage 1)

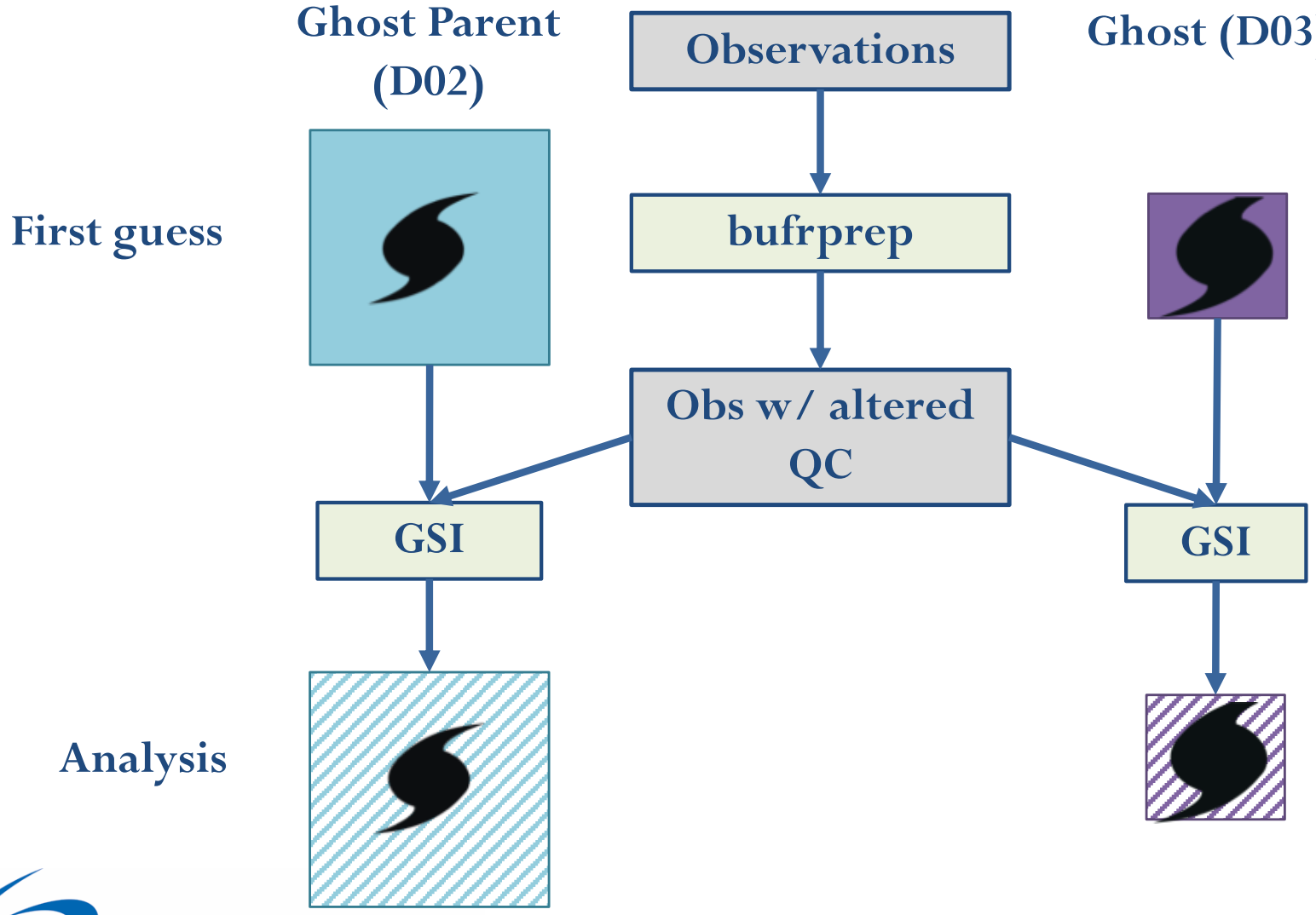
Vortex initialization: Stage 3

Put selected vortex in GDAS environmental flow for both analysis and ghost domains

Final result is updated fields for

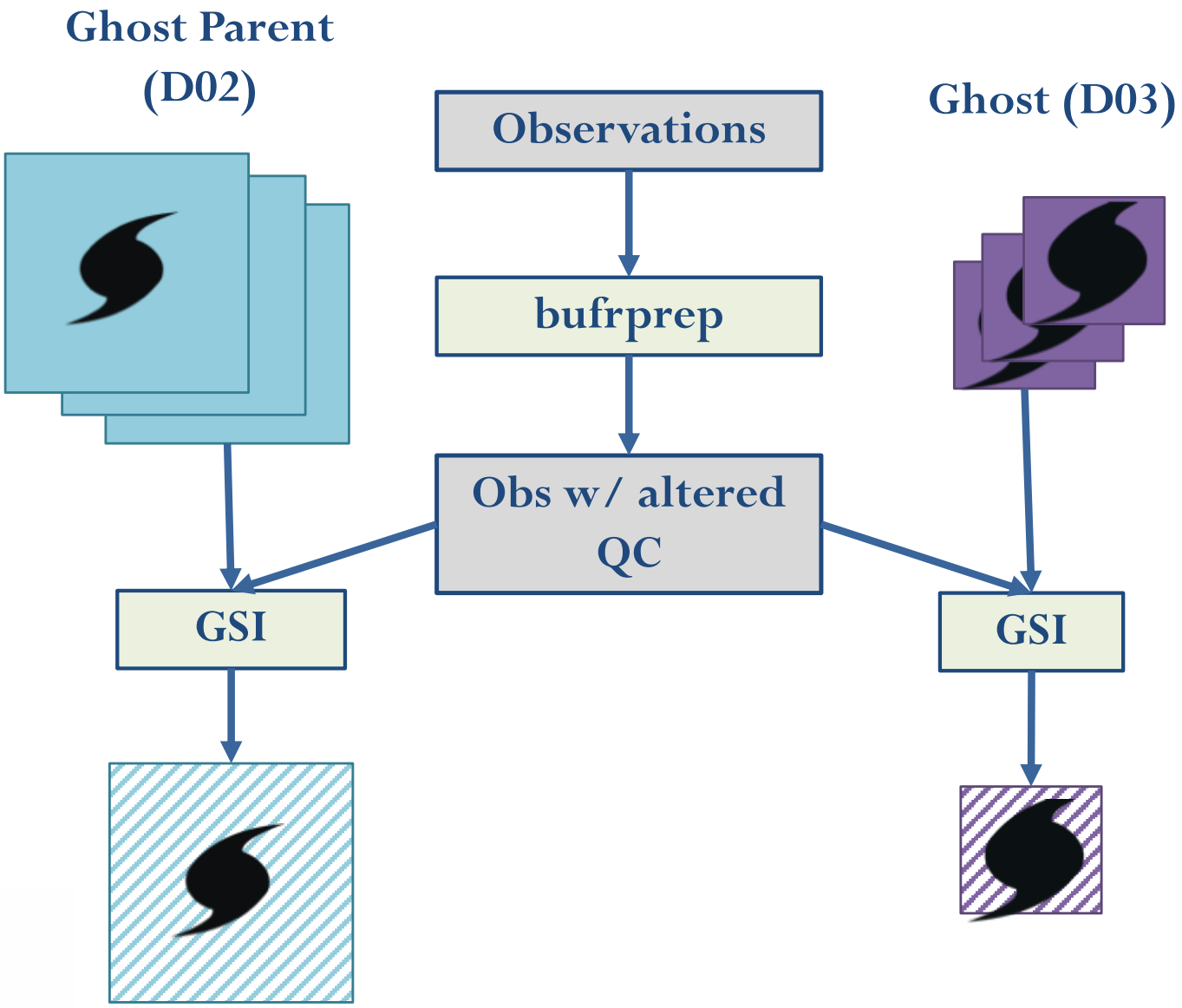
- *HWRF Forecast domains*
  - *d02 (outer nest)*
  - *d03 (inner nest)*
- *HWRF DA domains*
  - *ghost (d03)*
  - *ghost parent (d02)*

GSI data assimilation (simplified)

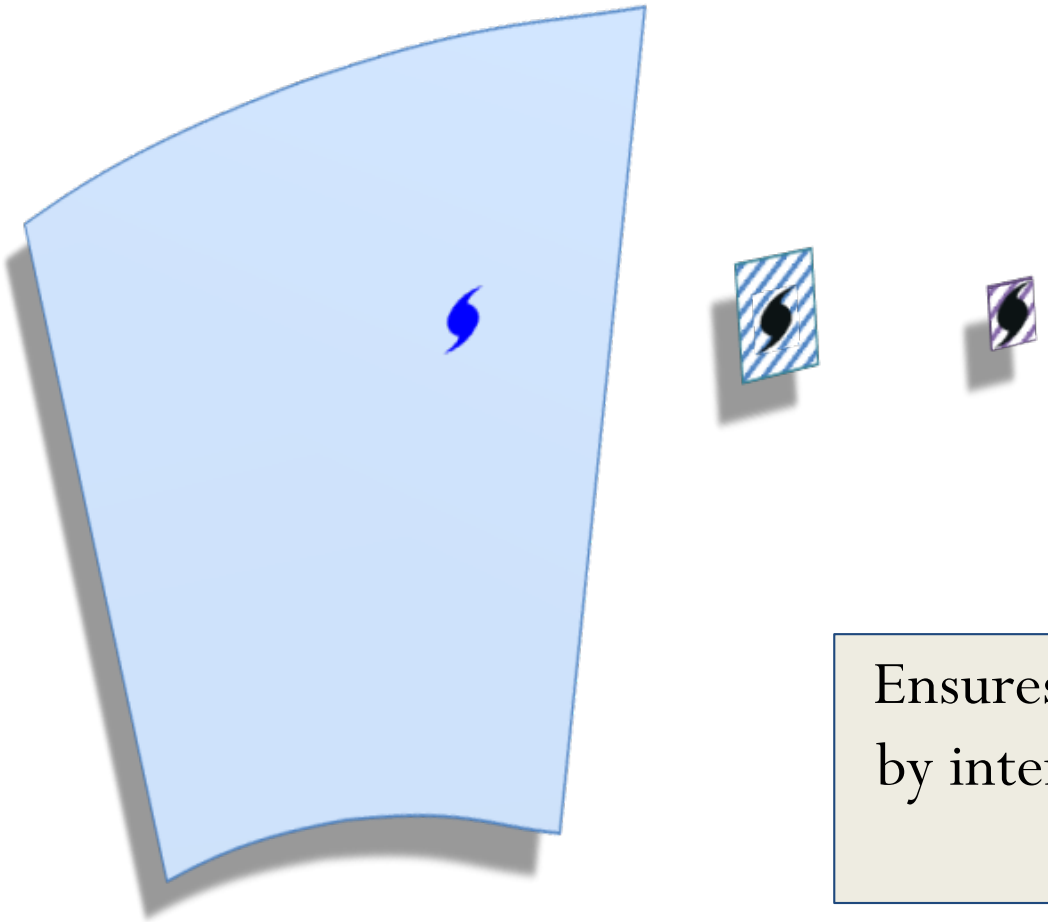


GSI data assimilation (FGAT detail)

First guesses at -3h, 0h, +3h (WPS, Ghost, Analysis, real, and relocate are done for 3 time levels in order to use First Guess at Appropriate Time – FGAT)

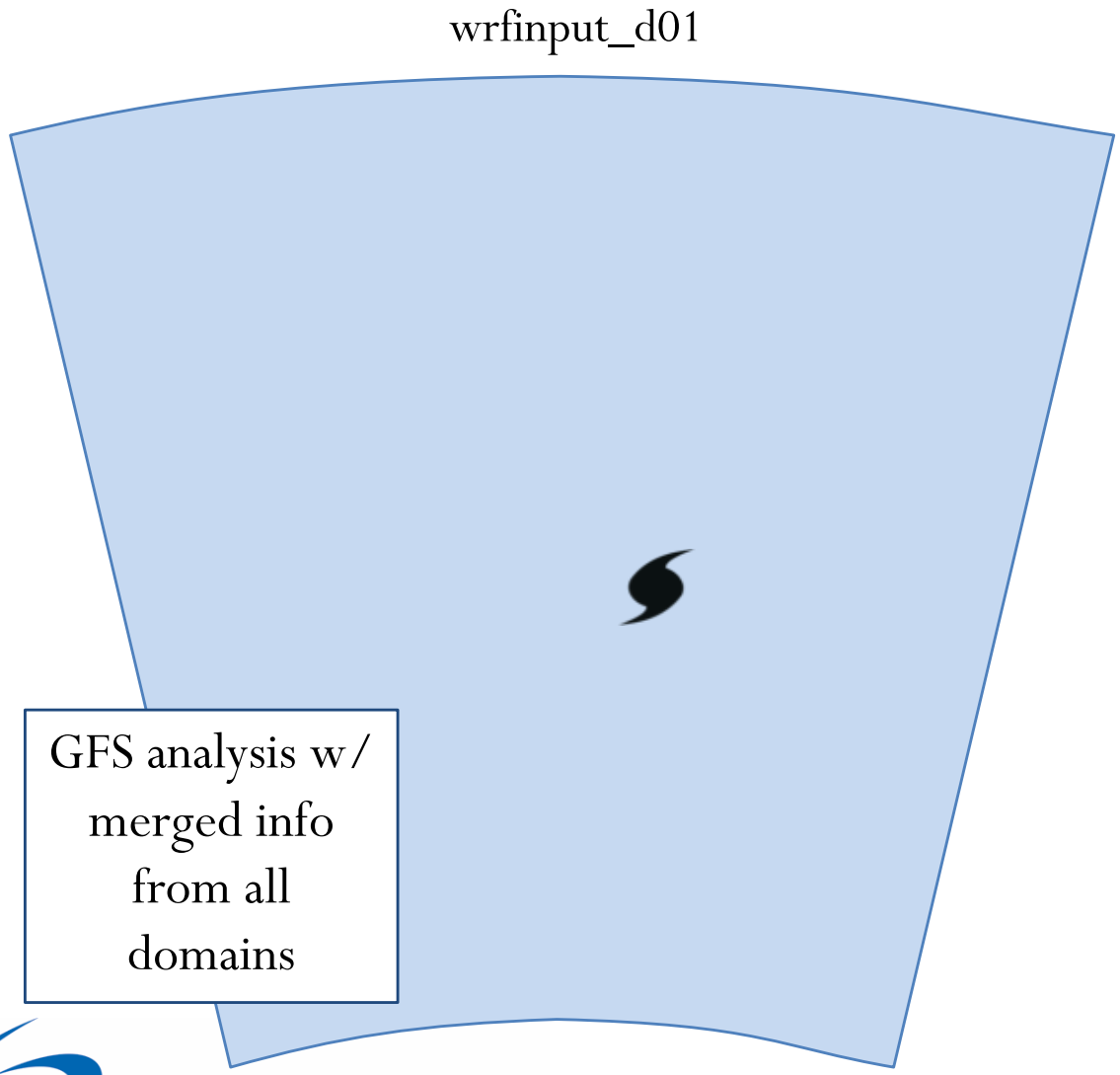


Merge



Ensures consistency between domains by interpolating data from inner nests to their parent

Initial conditions for HWRF forecast



GFS analysis w/ merged info from all domains

wrfinput_d02

wrfinput_d03

GDAS background w/ vortex improvement, GSI data assimilation, and merged info from all domains

Thank you for your interest!

You can…

- Ask questions during the tutorial
- Visit our website: http://www.dtcenter.org/HurrWRF/users
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