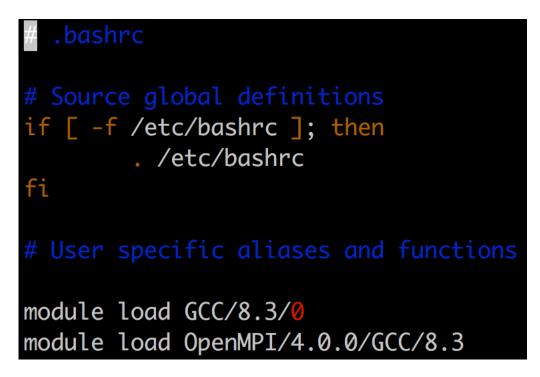
Tutorial for Running WRFV4 on Optimum

Updated: January 2023

Preliminaries

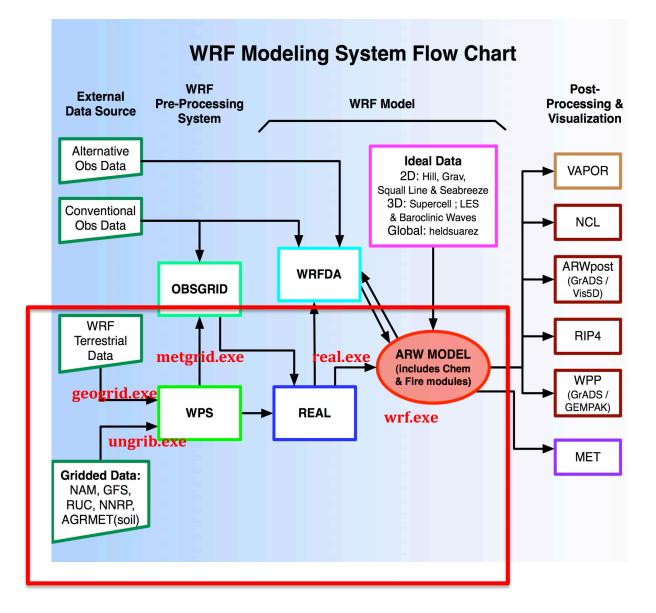
- Ensure that WRF has been installed in ~/WRF/WRF
- Ensure that WPS has been installed in ~/WRF/WPS
- Ensure that the proper modules have been loaded
 - o module load GCC/8.3/0
 - o module load OpenMPI/4.0.0/GCC/8.3
 - $\circ~$ Can add these to your ~/.bashrc as follows for automatic startup:



- Relevant data directories have been placed in /data/rstull/shared/ATSC507
 - DO NOT WRITE INTO THIS DIRECTORY; YOU SHOULD ONLY BE COPYING STUFF FROM THIS DIRECTORY
 - o GEOG
 - Terrestrial data needed for running geogrid.exe
 - o IBCS

- U.S. Global Forecast System (GFS) Initial-boundary conditions needed for running ungrib.exe
- Valid from 2018-12-18 0000 UTC to 2018-12-23 0000 UTC
 - Wind storm case study (highest number of BC Hydro outages in provincial history)
- o metgrid
 - Sample metgrid files produced from metgrid.exe
- ungrib (will not be used)
 - Sample ungrib files produced from ungrib.exe
- o WRF
 - Sample wrfout files produced from real.exe and wrf.exe; baseline case

Workflow



- geogrid.exe (~/WRF/WPS/geogrid)
 - Interpolates terrestrial data to user-defined model domain
 - Includes terrain heights, land-use data (e.g. vegetation types), land/sea flags, etc.
 - Interpolation options controlled by GEOGRID.TBL
 - Terrestrial data already downloaded in /data/rstull/shared/ATSC507/GEOG
 - You generally need to do this yourself, but there's no point in everyone each having a copy of the same 30+ GB directory, and because it takes time to download and unpack

- Creates geo_em*.nc files containing terrestrial data for the domains
 - Used as input into metgrid.exe
- Controlled by namelist.wps (copy found in ~/WRF/WPS)
 - Only domain information matters (i.e. projection, domain bounds, nest starting points)
 - Ignores timing information
- Will only need to run once for a new domain; because domains don't change day-to-day, we don't run geogrid.exe daily

• ungrib.exe (~/WRF/WPS/ungrib)

- Translates raw national centre Grib/Grib2 meteorological data files into an intermediate format (FILE*) for metgrid.exe
- Controlled by namelist.wps
 - Only timing information matters (i.e. start date, end date, frequency of file output)
 - Ignores domain information
- Variables in Grib/Grib2 files have an encoding that matches World Meteorological Organization (WMO) standard
 - Different national centres have different names for the same variables, e.g. Meteo-France may have a different name for 2-m Temperature than Environment Canada, but 2-m Temperature is 2-m Temperature...so the WMO Grib code is the same for both
- O Grib codes are translated by ungrib.exe based on information given in variable tables (Vtables → found in ~/WRF/WPS/ungrib/Variable_Tables)
- Needs to be run each time a new forecast initialization time is used, i.e. run once for 2019-12-18 0000 UTC; run once for 2019-12-18 0600 UTC; run once for 2019-12-18 1200 UTC; run once for 2019-12-18 1800 UTC, etc.

• metgrid.exe (~/WRF/WPS/metgrid)

- Combines the output from geogrid.exe (geo_em*.nc) and ungrib.exe (FILE*)
 - Horizontally interpolates intermediate meteorological data files onto the domain created by geogrid.exe
 - Interpolation options controlled by METGRID.TBL
- Controlled by namelist.wps
 - All domain and timing information needed
- Outputs met_em*.nc files, for use in real.exe
- Needs to be run after each new run of ungrib.exe

• real.exe (~/WRF/WRF/main/real.exe)

- Takes the output from metgrid.exe and performs the required initializations prior to wrf.exe
- Vertical interpolation of fields given by metgrid.exe onto userdefined model vertical levels
- Pre-allocation of needed arrays (including scalar arrays in microphysics schemes)
- Creation of initial condition (wrfinput*) and boundary condition (wrfbdy*) files
- Controlled by namelist.input
 - All information needed
- Needs to be run after each new run of metgrid.exe
- If namelist.input is changed after real.exe is run, real.exe must be run again prior to running wrf.exe

• wrf.exe (~/WRF/WRF/main/wrf.exe)

- Runs WRF, and outputs wrfout* files containing model-produced fields
- Controlled by namelist.input
 - Must match namelist.input for real.exe

Tutorial

- GOAL: Make a single-domain simulation of the December 20, 2018 wind storm
 - 5-day forecast initialized on December 18, 2018 at 0000 UTC, centred over British Columbia
 - Experiment with different planetary boundary-layer schemes to see how they affect the forecast
 - Gain expertise in initializing and running a real-data WRF simulation
 - Gain expertise in simple WRF output visualization
- Log onto optimum
 - ssh username@optimum.eos.ubc.ca
- Ensure modules are loaded (they should be in ~/.bashrc)
 - module load GCC/8.3/0
 - o module load OpenMPI/4.0.0/GCC/8.3
- Go into your user-allocated scratch directory; this is the directory we'll be writing into for our WRF runs
 - o cd \$SCRATCHDIR
 - o pwd
 - You should see that you're in /scratch/rstull/username
 - DO NOT MAKE WRF RUNS IN ~/ (see warning message when you first log onto optimum)
- Make a tutorial directory and cd into it
 - \circ mkdir tutorial
 - \circ cd tutorial
 - We should never make runs in the source WRF or WPS directories; those directories are meant to be originals. Instead, always make runs by copying or linking required files into your own directories.
- Make a WPS directory and cd into it
 - o mkdir WPS
 - o cd WPS
- Copy over a blank namelist.wps
 - o cp ~/WRF/WPS/namelist.wps .

• Edit your namelist.wps with the following geographic information:

```
&share
 wrf_core = 'ARW',
 max_dom = 1,
 start_date = '2018-12-18_00:00:00',
 end_date = '2018-12-23_00:00:00',
 interval_seconds = 10800
 io_form_geogrid = 2,
&geogrid
 parent_id
 parent_grid_ratio = 1, Grid-spacing ratio of parent
i_parent_start = 1, x-coordinate starting location relative to p
i parent_start = 1. y-coordinate starting location relative to p
 j_parent_start = 1,
            = 121, Number of west-east (x-direction) points
= 121, Number of south-north (y-direction) points
 e_we
 e_sn
 ! The default datasets used to produce the MAXSNOALB and ALBEDO12M
 ! fields have changed in WPS v4.0. These fields are now interpolated
 ! from MODIS-based datasets.
 ! To match the output given by the default namelist.wps in WPS v3.9.1,
 ! the following setting for geog_data_res may be used:
 ! geog_data_res = 'maxsnowalb_ncep+albedo_ncep+default', 'maxsnowalb_ncep+albedo_ncep+default',
 :
geog_data_res = 'default', Interpolation resolution (defaults set in GEOGRID.TBL)
dx = 36000, x-direction grid spacing (m)
dy = 36000, y-direction grid spacing (m)
map_proj = 'polar', Map projection (polar stereographic for high latitudes)
ref_lat = 47.83, Latitude of center of coarsest domain
 ref_{lon} = -127.3,
 truelat1 = 60.0,
 truelat2 = 90.0,
 stand_lon = -90.0,
 geog_data_path = '/data/rstull/shared/ATSC507/GEOG' Location of terrestrial data
 opt_geogrid_tbl_path = '.' Loc
&ungrib
 out_format = 'WPS',
 prefix = 'FILE',
&metarid
 fg_name = 'FILE'
 io_form_metgrid = 2,
 opt_metgrid_tbl_path = '.'
```

- Link over geogrid.exe and GEOGRID.TBL into tutorial/WPS
 - o ln -s ~/WRF/WPS/geogrid.exe .
 - o ln -s ~/WRF/WPS/geogrid/GEOGRID.TBL
- Run geogrid.exe by invoking an interactive session
 - o Iqsub
 - Interactive job submission, so that we can log onto a compute node for runs
 - We cannot make large compute/memory-heavy runs on the login node (i.e. sigma, delta)
 - Iqsub 0.5 1 1
 - Request an interactive session for half an hour, with 1 node and 1 processor on the node
 - o ./geogrid.exe
 - 0 **ls**
 - Should see that geo_em.d01.nc has been produced
 - o exit
 - Log off the compute node to return it back to the queue; we don't want to waste unused resources

• Edit your namelist.wps with the following timing information:

```
&share
wrf_core = 'ARW',
max_dom = 1,
start_date = '2018-12-18_00:00:00',
end_date = '2018-12-18_12:00:00',
interval_seconds = 10800
Start date corresponding to Grib files; we o
Time period between Grib files (3 hours)
io_form_geogrid = 2,
&geogrid
parent_id
                 = 1,
parent_grid_ratio = 1,
i_parent_start = 1,
j_parent_start = 1,
        = 121,
= 121,
e_we
e_sn
! The default datasets used to produce the MAXSNOALB and ALBED012M
! fields have changed in WPS v4.0. These fields are now interpolated
! from MODIS-based datasets.
! To match the output given by the default namelist.wps in WPS v3.9.1,
! the following setting for geog_data_res may be used:
! geog_data_res = 'maxsnowalb_ncep+albedo_ncep+default', 'maxsnowalb_ncep+albedo_ncep+default',
geog_data_res = 'default',
dx = 36000.
dy = 36000,
map_proj = 'polar',
ref_lat = 47.83,
ref_lon = -127.3,
truelat1 = 60.0,
truelat2 = 90.0,
stand_lon = -90.0,
geog_data_path = '/data/rstull/shared/ATSC507/GEOG'
opt_geogrid_tbl_path = '.'
&unarib
out_format = 'WPS',
prefix = 'FILE',
&metgrid
fg_name = 'FILE'
io_form_metgrid = 2,
opt_metgrid_tbl_path = '.'
```

- Link in ungrib-related files
 - o ln -s ~/WRF/WPS/ungrib.exe .
 - ln -s ~/WRF/WPS/ungrib/Variable_Tables/Vtable.GFS
 ./Vtable
 - The line above should be on one line
 - Vtable.GFS must be named Vtable in the current directory for ungrib.exe
 - o ln -s ~/WRF/WPS/link_grib.csh .
 - This is a shell script used to link the Grib files in an alphabetical format recognized by ungrib.exe
- Link in the Grib files using link_grib.csh
 - ./link_grib.csh /data/rstull/shared/ATSC507/IBCS/gfs*
 - o ls
 - Should see a how bunch of linked files like GRIBFILE.AAA, GRIBFILE.AAB, etc.
 - You can check that they're linked to the original GFS Grib files by running ls -lh
- Run ungrib.exe (we are only doing a 12-hour run; the full 5-day run would take too long in WPS)
 - Iqsub 0.5 1 1
 - o ./ungrib.exe
 - o ls
 - Should see FILE:2018-12-18_00, FILE:2018-12-18_03, etc.
 - o exit
- Link in metgrid-related files
 - o ln -s ~/WRF/WPS/metgrid.exe .
 - o ln -s ~/WRF/WPS/metgrid/METGRID.TBL .
- Run metgrid.exe (we are only doing a 12-hour run; the full 5-day run would take too long in WPS)
 - Iqsub 0.5 1 1
 - o ./metgrid.exe
 - o ls
 - Should see met_em.d01.2018-12-18_00:00:00.nc, etc.
 - \circ exit
- WPS is done! For WRF, we'll be using the full 5-day metgrid files that have been pre-made

- Return to the tutorial directory
 - $\circ~$ cd \ldots
- Make a WRF directory, and cd into it
 - o mkdir WRF
 - \circ cd WRF
- Link in all required files, including look-up tables for physics schemes

 ln -s ~/WRF/WRF/test/em_real/* .
- However, we don't want a link of namelist.input, because we don't want to change the original; hence, we should remove the link, and replace it with a copy instead
 - o rm namelist.input
 - o cp ~/WRF/WRF/test/em_real/namelist.input .
- Make the following changes to namelist.input:

run_days= 0,run_hours= 120,Number of hours for runrun_minutes= 0,run_seconds= 0,start_year= 2018,start_month= 12,start_month= 12,start_day= 18,start_day= 23,End_year= 2018,end_optar= 00,Start_hour= 00,start_hour= 00,end_day= 23,End day= 23,End day= 23,End day= 60,Input_from_file= true.,interval_seconds= 108800Frames_per_outfile= 1,Hox namy output times per vriout filerestart= 1,io_form_restart= 2io_form_nestart= 2io_form_prestart= 2io_form_prestart= 2io_form_prestart= 2io_form_boundary= 2/&domains= 1,time_step_fract_den= 1,max_dom= 1,e_we= 121,Must match namelistyps (is met_ent)e_vet= 32,p_top_requested= 5000,num_metgrid_levels= 32,num_metgrid_id= 1,grid_id= 1,grid_id= 1,grid_id= 1,grid_id= 1,grid_id= 1,grid_id= 1,grid_id= 1,grid_id= 1,grid_id= 1,grid_id<	<pre>&time_control</pre>	
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parent_grid_ratio= 1,parent_time_step_ratio= 1,feedback= 1,smooth_option= 0use_adaptive_time_step= .true.step_to_output_time= .true. weird output time somax_step_increase_pct= 5,target_cfl= 1,	i_parent_start	= 1,
parent_time_step_ratio= 1,parent_time_step_ratio= 1,feedback= 1,smooth_option= 0use_adaptive_time_step= .true.step_to_output_time= .true.max_step_increase_pct= 5,target_cfl= 1,		
feedback= 1,smooth_option= 0use_adaptive_time_step= .true.step_to_output_time= .true.max_step_increase_pct= 5,target_cfl= 1,		
smooth_option= 0use_adaptive_time_step= .true.step_to_output_time= .true.max_step_increase_pct= 5,target_cfl= 1,CFL condition for adaptive time step to meet		= 1,
use_adaptive_time_step= .true.Use adaptive time stepstep_to_output_time= .true.Align time step to output time somax_step_increase_pct= 5,Maximum time step increasetarget_cfl= 1,CFL condition for adaptive time step to meet		
use_dadptive_time_step= .true.step_to_output_time= .true.max_step_increase_pct= 5,target_cfl= 1,CFL condition for adaptive time step to meet		= 0
step_to_output_time= .true. weird output times don't show upmax_step_increase_pct= 5,target_cfl= 1,CFL condition for adaptive time step to meet		= .true. Align time step to output time so
target_cfl = 1, CFL condition for adaptive time step to meet		= .true. weird output times don't show up
, j,		
		= 1, CFL condition for adaptive time step to meet

&physics	
physics_suite	= 'CONUS' CONUS physics suite
mp_physics	= -1,
cu_physics	= -1,
ra_lw_physics	= -1,
ra_sw_physics	= -1,
<pre>bl_pbl_physics</pre>	= -1, PBL scheme; -1 = use CONUS PBL scheme (MYJ)
sf_sfclay_physics	$= -1, \qquad 1 \qquad = YSU (sf_sfclay_physics = 1)$
sf_surface_physics	$= -1, \qquad 5 \qquad = MYNN2 (sf_sfclay_physics = 5) - 30, \qquad 7 \qquad = ACM2 (sf_sfclay_physics = 1)$
radt	$= 30', \qquad 7 = ACM2 (sf_sfclay_physics = 1)$ = 0, $11 = Shin-Hong (sf_sfclay_physics = 1)$ = 0, $12 = GRM (sf_sfclay_physics = 1)$
bldt	
cudt	= 0,
icloud	= 1, Lond use seterarias (see smid default uses MODIS = 21 alass)
num_land_cat	 = 21, Land-use categories (geogrid default uses MODIS = 21 class)
sf_urban_physics	= 0,
/	
&fdda	
/	
8 dunami co	
&dynamics	= 2, Use hybrid-eta vertical coordinates (hybrid_opt = eta)
hybrid_opt	
w_damping diff_opt	= 0, = 1,
km_opt	= 1, = 4,
diff_6th_opt	= -+, = 0,
diff_6th_factor	= 0, = 0.12,
base_temp	= 290.
damp_opt	= 3,
zdamp	= 5000.,
dampcoef	= 0.2,
khdif	= 0,
kvdif	= 0,
non_hydrostatic	= .true.,
moist_adv_opt	= 1,
scalar_adv_opt	= 1,
gwd_opt	= 1,
/	
&bdy_control	
spec_bdy_width	= 5,
specified	= .true.
&grib2	
/	
&namelist_quilt	
nio tasks per aroup = 0.	
nio_tasks_per_group = 0, nio_groups = 1,	

- Link in finished met_em* files
 - o ln -s /data/rstull/shared/ATSC507/metgrid/* .
- Run real.exe; make sure you've chosen your desired boundary-layer scheme (bl_pbl_physics) and accompanying surface-layer scheme (sf_sfclay_physics)
 - Iqsub 1 1 10
 - We're going to request 1 hour, and 10 cores, so that we can run wrf.exe in parallel immediately after
 - o mpirun -np 1 ./real.exe
 - o cat rsl.error.0000
 - Log written here; should see SUCCESS COMPLETE REAL_EM INIT at bottom
- Run wrf.exe with 10 processors (ranks; -np 10)
 - o nohup mpirun -np 10 ./wrf.exe &
 - Note the & at the ver end
 - nohup <blah> & sends <blah> to the background and disowns the process, allowing you to use the command line and log out without fear of losing the process
 - o cat nohup.out
 - Allows you to see the immediate stdout and stderr output (i.e. what would have been printed to the screen if you hadn't used nohup)
 - You should see
 - starting wrf task 5 of 10
 - starting wrf task 7 of 10
 - etc. (order doesn't matter)
 - ls -lh rsl*
 - Should see one rsl.error* and rsl.out* file for each process
 - rsl.error.0000 (log file of master process) has everything printed to it, and is the master log file
 - Other files may contain error information not printed to rsl.error.0000, including CFL-related errors
 - If a run fails unexpectedly and rsl.error.0000 does not give the required information, you can do the following searches:
 - grep cfl rsl*
 - Searches all rsl files for the string "cfl"
 - grep error rsl*
 - grep ERROR rsl*
 - tail -n5 rsl*
 - Prints out the last 5 lines in each rsl file
 - tail -f rsl.error.0000
 - You can watch the model run as the log is printed in real-time to screen (should see SUCCESS COMPLETE WRF once done)
 - Ctrl + C to escape

- While we're waiting, we can experiment with IDV using already created grids in /data/rstull/shared/ATSC507/WRF/
- Open up a new terminal window on your laptop, and find a location for you to hold some wrfout files
 - o mkdir wrfouts_original
 - cd wrfouts_original
 - scp username@optimum.eos.ubc.ca:/data/rstull/shared/ATSC50 7/WRF/wrfout_d01_2018-12-20* .
 All on one line
 - scp username@optimum.eos.ubc.ca:/data/rstull/shared/ATSC50 7/WRF/wrfout_d01_2018-12-21* .
 - All on one line
 - o Total: 2.8 GB
- Download IDV and install onto your computer
 - o <u>https://www.unidata.ucar.edu/downloads/idv/current/index.jsp</u>