HWRF v3.9a Tutorial
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HWRF Idealized Capability

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Overview of idealized capability

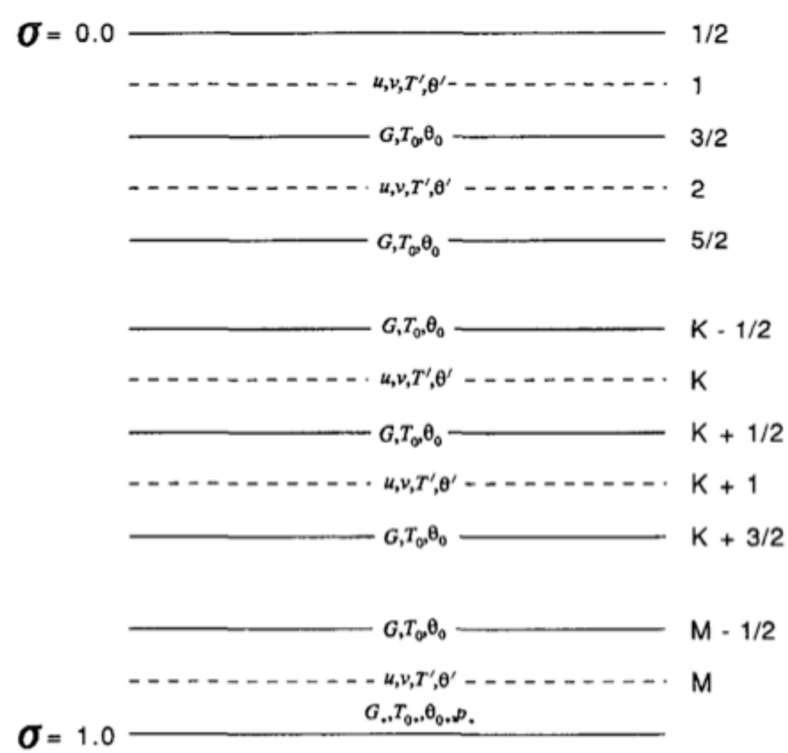
- Initialization uses a prescribed vortex superposed onto a quiescent environment. Default
  - Max intensity of 20 ms^{-1}
  - Radius of maximum winds (RMW) - 90 km
- The model configuration is same as the real run
  - Three domains with telescopic nests
- f- or β-plane
- Lower boundary is water (no land masses) (Default)
  - Landfall option available only with GFDL Slab land surface
- Sea surface temperature
  - time-invariant (no ocean coupling)
  - horizontally homogeneous
  - default =302 K
- Uses: research and development

Wang, Y., 1995: An inverse balance equation in sigma coordinates for model initialization *Mon. Wea. Rev.*, **123**, 482–488.

Creation of the idealized vortex - I

The vortex is based on the balance equation relating prescribed wind fields to mass fields

- The atmosphere is divided into M layers in the sigma coordinate system.
- The initial background state temperature (T_o) along with a prescribed forcing term (G) in the balance equation are defined at the interfaces of the model layers.
- The initial vortex winds along with the temperature perturbation (T'), derived from the background state are defined at mid-levels levels between the interfaces.



Creation of the idealized vortex - II

- The wind field of the initial vortex is prescribed in cylindrical polar coordinates by:

$$V(r,\sigma) = V_m\left(\frac{r}{r_m}\right)\sin\left(\frac{\pi\sigma}{2}\right)e^{\frac{[1-(r/r_m)]^b}{b}}$$

where V_m is the maximum wind at the surface, r_m is the radius of maximum wind, r is the radius from the vortex center, and $b = 1$.

- The forcing term in the balance equation is given by:

$$G(u,v) = 2J(u,v) + f\zeta - u\beta$$

where J is the Jacobian, f is the Coriolis parameter, ζ is the vorticity and β is the meridional gradient of the Coriolis parameter.

Creation of the idealized vortex - III

- The pressure at $\sigma = 1$ is obtained by solving the Poisson equation:

$$\nabla^2 \ln(p_*) = \frac{G_d}{RT_d^0}$$

where subscript d denotes the variable evaluated at $\sigma = 1$.

- The temperature perturbations at the rest of the sigma levels are determined by solving Poisson equation:

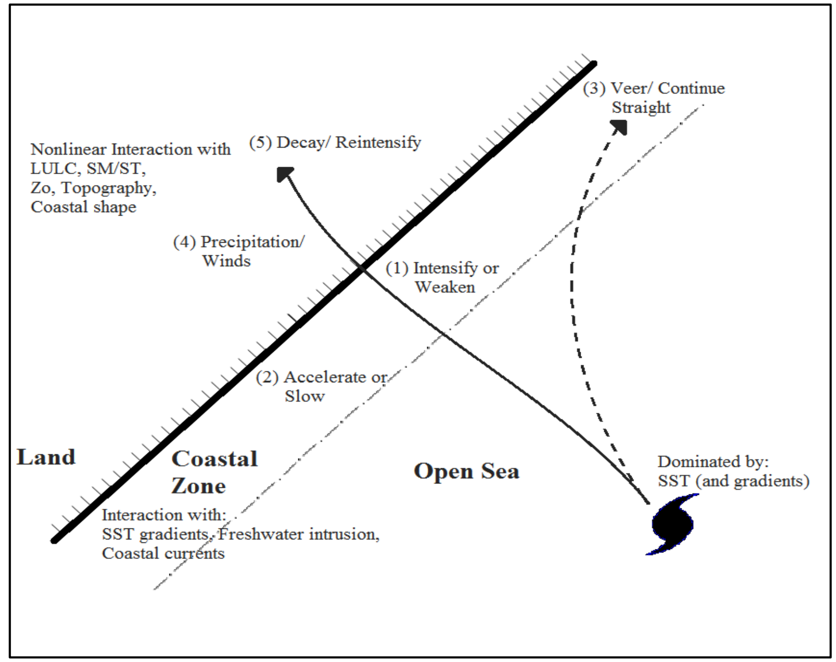
$$\nabla^2 T_k' = \nabla \cdot \left[\left(\frac{\partial T'}{\partial \ln(\sigma)} \right) \nabla \ln(p_*) \right] + \left[\left(\frac{\partial T_0}{\partial \ln(\sigma)} \right) \nabla^2 \ln(p_*) \right]_k - \left[\frac{\partial G}{R \partial \ln(\sigma)} \right]_k$$

- Finally, using the non-hydrostatic approximation, the geopotential heights are obtained from the total temperature and moisture fields.

Land falling capability

Land surface in TC dynamics

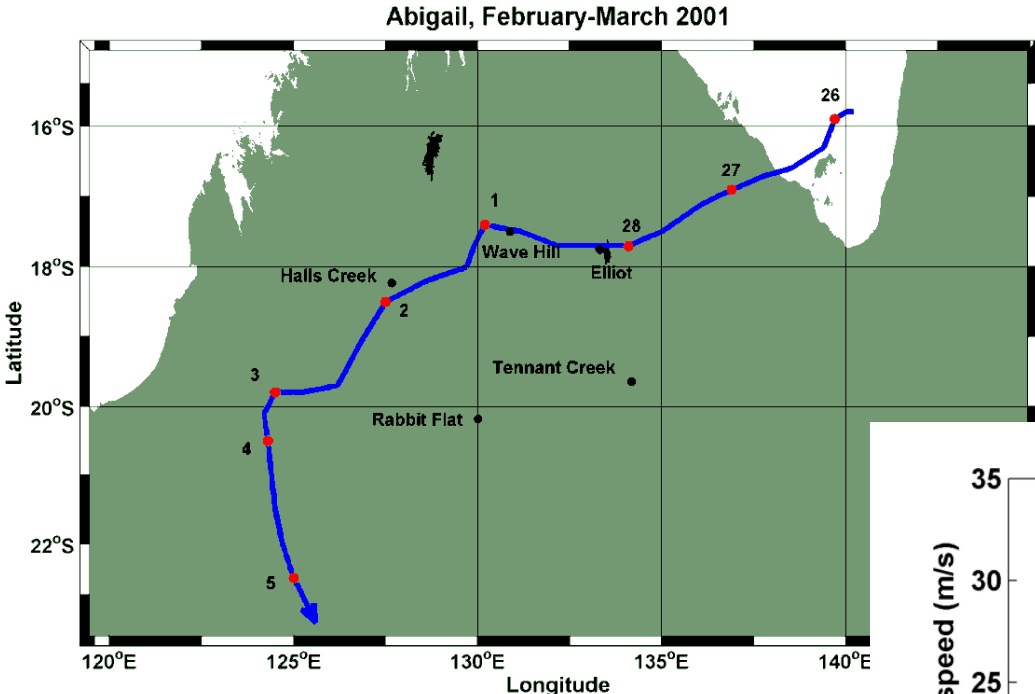
- Decay due to loss of energy source, increased friction
- Transition into an extra tropical storm – cold core
- Not very often – sustain, re-intensify after landfall

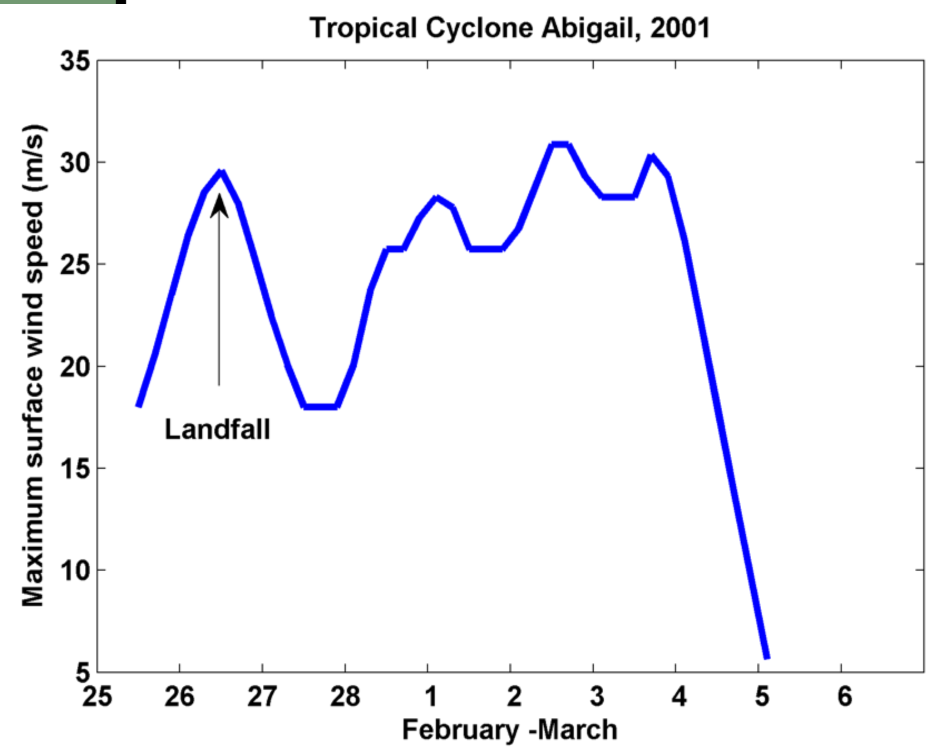


Terrain, land use, soil temperature, moisture availability etc. can affect convective systems including tropical cyclones

(Tuleya 1994; Pielke, 2001; Emanuel et al.,2008; Chang et al., 2009; Kellner et al., 2012; Bozeman et al., 2012; Kishtawal et al., 2012)

TC ABIGAIL 2001 (Australia)





Source: Emanuel et al 2008.

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Land surface in Ideal HWRF

land.nml

```
&init_land
mvland = .true.
imin = 260
imax = 288
jmin = 0
jmax = 576
logic_temp = .false.
s_temp = 308.0
VEG_ID = 19
SOIL_ID = 1
/

&param_land
DIRN = 1
VEG_ID = 19
SOIL_ID = 1
land_emiss = 0.90
land_albedo = 0.25
land_vgfrac = 0.20
land_z0 = 0.01
land_smc = 0.02
/
```

urface

```
  IF(DIRN == 1) THEN
  DO J = MAX(JTS,2), MIN(JTE,JDE-1)
   DO I = MIN(ITE,IDE),MAX(ITS,2),-1
       SM(I,J)=SM(I-1,J)          ! West to East
   ENDDO
  ENDDO
 ELSE
  DO J = MAX(JTS,2), MIN(JTE,JDE-1)
   DO I = ITS, MIN(ITE,IDE-1)
       SM(I,J)=SM(I+1,J)          ! East to west
   ENDDO
  ENDDO
  ENDIF
```

```
move_land_time=nint(1200./30)
```

Code and scripts

- **WPS**
  - *geogrid.exe, ungrib.exe, mod_levs.exe, metgrid.exe*
- **No vortex initialization, data assimilation, or ocean coupling**
- **WRF**
  - <u>Must</u> compile HWRF with IDEAL_NMM_TC=1
    - Specifying `./compile nmm_tropical_cyclone` on the command line
  - *wrf.exe, ideal.exe* (cannot use wrf.exe from real compilation)
- **UPP and graphics**
- **Scripts**
  - Do not use the wrappers in hwrf-utilities to run
  - Just run executables (all in command line; except *ideal.exe and wrf.exe* in batch)
  - Use a script to run UPP and generate GrADS graphics

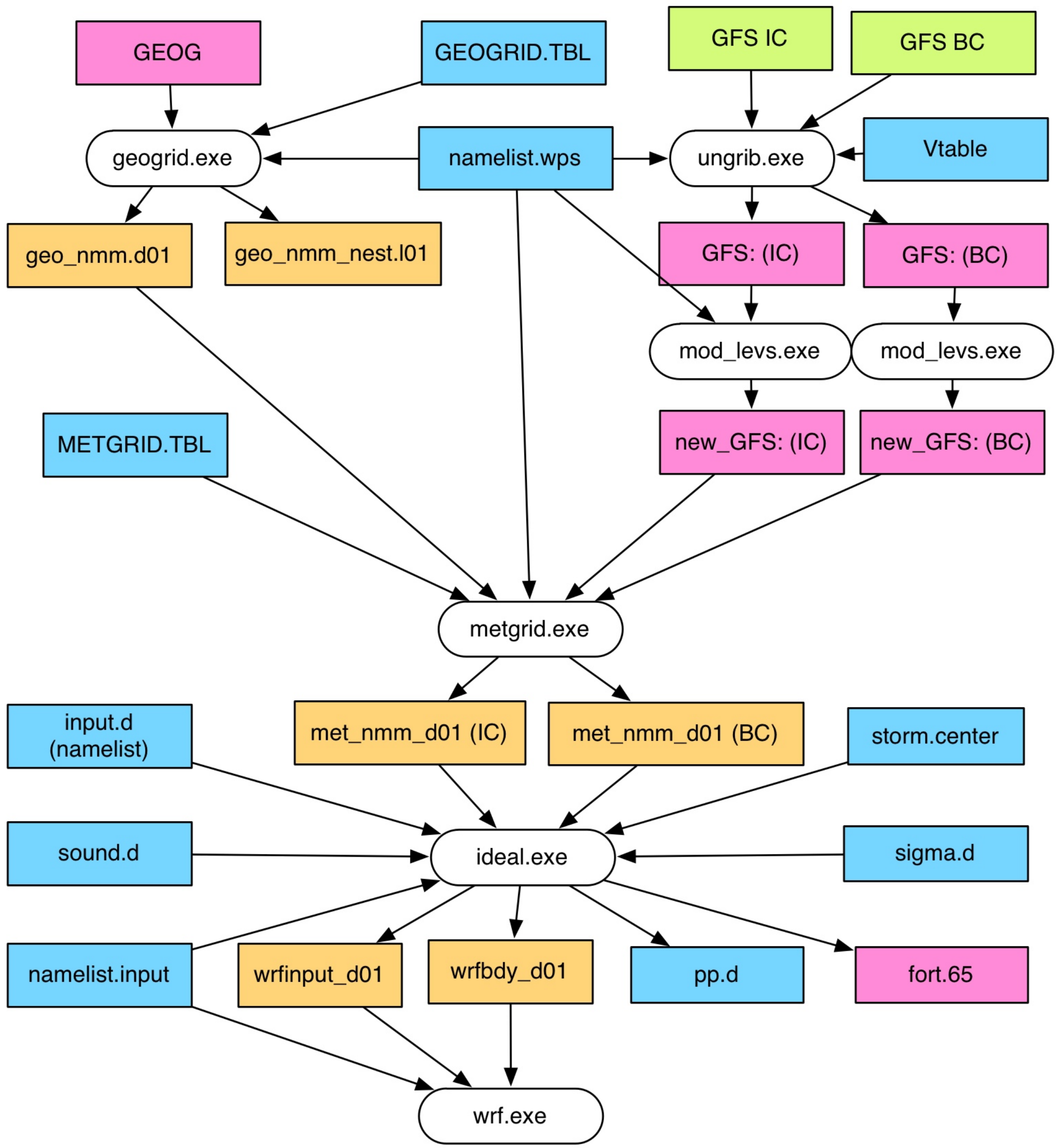
Input files

- Two GFS GRIB files to provide a template for IC and LBC
  - Files ***gfs.t12z.pgrb2.0p25.f000*** and ***gfs.t12z.pgrb2.0p25.f126***
- Files in *WRFV3_idealized/test/nmm_tropical_cyclone*
  - Namelist file for WPS: ***namelist.wps***
  - Namelist file for WRF*:* ***namelist.input***
  - Vortex description file: ***input.d***
    - Intensity, RMW, f or β plane
  - Sounding data: ***sound.d***
    - 30 levels (or change number of levels in code)
  - Vortex center file: ***storm.center***
  - Sigma file: ***sigma.d***
    - Do not change this file
  - Land description: ***land.nml (Default: No land)***
    - Soil characteristics and direction of landfall
- Lookup tables for running WRF in *hwrf-utilities/parm*

Idealized model initialization

- Use WPS (*geogrid)* to setup domain
- Use WPS *(ungrib, mod_levs, and metgrid*) to process GFS for IC/LBC
  - *mod_levs* is used to reduce data in GFS file to expedite processing
  - Outputs are just a template to add the environment and vortex
- Use *ideal.exe* to create the actual IC and LBC (*wrfiput* and *wrfbdy*)
  - LBC are quiescent. This inevitably leads to some reflection when waves emanating from the vortex reach the outer domain boundaries

Flow Diagram for NMM Tropical Cyclone



Color convention for file formats: Binary | Ascii | NetCDF | GRIB

Working directories

- Will need a working directory
  - workdir = ***/glade/scratch/${USER}/Idealized***
  - Subdirectories
    - WRFV3
    - WPSV3
    - *wpsprd* (for running WPS: geogrid, ungrib, mod_levs, metgrid)
    - *wrfprd* (for running ideal and wrf)

Submitting to batch system

- *geogrid.exe, ungrib.exe, mod_levs.exe, metgrid.exe, ideal.exe*
  - Executables can be run on command line
- *wrf.exe*
  - *Will be submitted to the batch system*

Running geogrid

Enter the working directory

```
cd $workdir/wpsprd
```

Copy the WPS namelist

```
cp ${WORKDIR}/ WRFV3/test/nmm_tropical_cyclone/namelist.wps .
```

Edit *namelist.wps* and set path

`geog_data_path =` location of file

Run executable *geogrid.exe* on a compute node or batch system

```
${WORKDIR}/WPSV3/geogrid.exe
```

Verify that the output files were created

```
ls -l geo_nmm.d01.nc geo_nmm_nest.l01.nc \
                     geo_nmm_nest.l02.nc
```

Running ungrib

Link the ungrib table

```
ln –fs ${WORKDIR}/WPSV3/ungrib/Variable_Tables/Vtable.GFS Vtable
```

Link the two input GFS files

```
ln -fs ${DATA}/gfs.t12z.pgrb2.0p25.f* .
```

Link the GFS files to the names expected by ungrib

```
${WORKDIR}WPSV3/link_grib.csh gfs.t12z.pgrb2.0p25.f000 \
                              gfs.t12z.pgrb2.0p25.f120
ls -l GRIBFILE.AAA GRIBFILE.AAB
```

Run *ungrib*

```
${WORKDIR}/WPSV3/ungrib.exe
```

Verify that the output files were created

```
ls -l GFS:2012-10-26_12 GFS:2012-10-31_12
```

Running mod_levls

Run mod_levs. Not MPI job, so does not require batch system

```
${WORKDIR}/WPSV3/util/mod_levs.exe GFS:2012-10-26_12 new_GFS:2012-10-26_12
${WORKDIR}/WPSV3/util/mod_levs.exe GFS:2012-10-31_12 new_GFS:2012-10-31_12
```

Verify that the output files were created

```
ls -l new_GFS:2012-10-26_12 new_GFS:2012-10-31_12
```

- Note: only the levels listed in variable *press_pa* in *namelist.wps* will be retained.

Running metgrid

Link the metgrid table

```
ln –fs ${WORKDIR}/WPSV3/metgrid/METGRID.TBL.NMM ./METGRID.TBL
```

Edit *namelist.wps* set paths

```
opt_metgrid_tbl_path = = '.'
```

Run *metgrid*

```
${WORKDIR}/WPSV3/metgrid.exe
```

Verify that the output files were created

```
ls -l met_nmm.d01.2012-10-26_12_00_00.nc \
      met_nmm.d01.2012-10-31_12_00_00.nc
```

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Running ideal - I

Enter the working directory

```
cd $workdir/wrfprd
```

Link WRF input files

```
ln -fs ${WORKDIR}/WRFV3/run/ETAMPNEW_DATA ./
ln -fs ${WORKDIR}/WRFV3/run/ETAMPNEW_DATA.expanded_rain ./
ln -fs ${WORKDIR}/WRFV3/run/GENPARM.TBL ./
ln -fs ${WORKDIR}/WRFV3/run/LANDUSE.TBL ./
ln -fs ${WORKDIR}/WRFV3/run/SOILPARM.TBL ./
ln -fs ${WORKDIR}/WRFV3/run/VEGPARM.TBL ./
ln -fs ${WORKDIR}/WRFV3/run/tr49t67 ./
ln -fs ${WORKDIR}/WRFV3/run/tr49t85 ./
ln -fs ${WORKDIR}/WRFV3/run/tr67t85 ./
ln -fs ${WORKDIR}/WRFV3/run/ozone.formatted ./
ln -fs ${WORKDIR}/WRFV3/run/ozone_lat.formatted ./
ln -fs ${WORKDIR}/WRFV3/run/ozone_plev.formatted ./
ln -fs ${WORKDIR}/WRFV3/run/RRTM_DATA ./
ln -fs ${WORKDIR}/WRFV3/run/RRTMG_LW_DATA ./
ln -fs ${WORKDIR}/WRFV3/run/RRTMG_SW_DATA ./
```

Running ideal - II

Link the WPS files

```
ln -fs ${WORKDIR}/wpsprd/met_nmm* .
ln -fs ${WORKDIR}/wpsprd/geo_nmm* .
```

Copy namelist input

```
cp ${WORKDIR}/WRFV3/test/nmm_tropical_cyclone/namelist.input .

*If using landfall option set sf_surface_physics=88,88,88
```

Running ideal - III

Copy the idealized simulation input files

```
cp ${WORKDIR}/WRFV3/test/nmm_tropical_cyclone/input.d .
cp ${WORKDIR}/WRFV3/test/nmm_tropical_cyclone/sigma.d .
cp ${WORKDIR}/WRFV3/test/nmm_tropical_cyclone/sound.d .
cp ${WORKDIR}/WRFV3/test/nmm_tropical_cyclone/storm.center .
*If using landfall option
cp ${WORKDIR}/WRFV3/test/nmm_tropical_cyclone/land.nml .
```

Edit and modify files ***input.d***, ***sound.d***, ***land.nml**** if desired

File ***storm.center*** should not be altered (storm in center of inner nest)

File ***sigma.d*** should not be altered (vertical levels to create the initial vortex)

Run ***ideal.exe*** using script to submit it to batch queue

Verify that the output files were created

```
ls –l wrfinput_d01 wrfbdy_d01 fort.65
```

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Running WRF

Run ***wrf.exe*** using script to submit it to batch queue

```
bsub < run.wrf.ideal.csh
```

Verify that the output files were created

```
ls –l wrfout_d01* wrfout_d02* wrfout_d03*
```