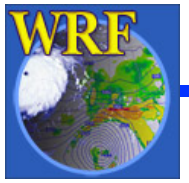
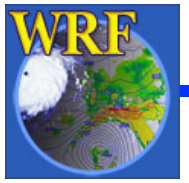
Post-processing Tools: NCL

Cindy Bruyère

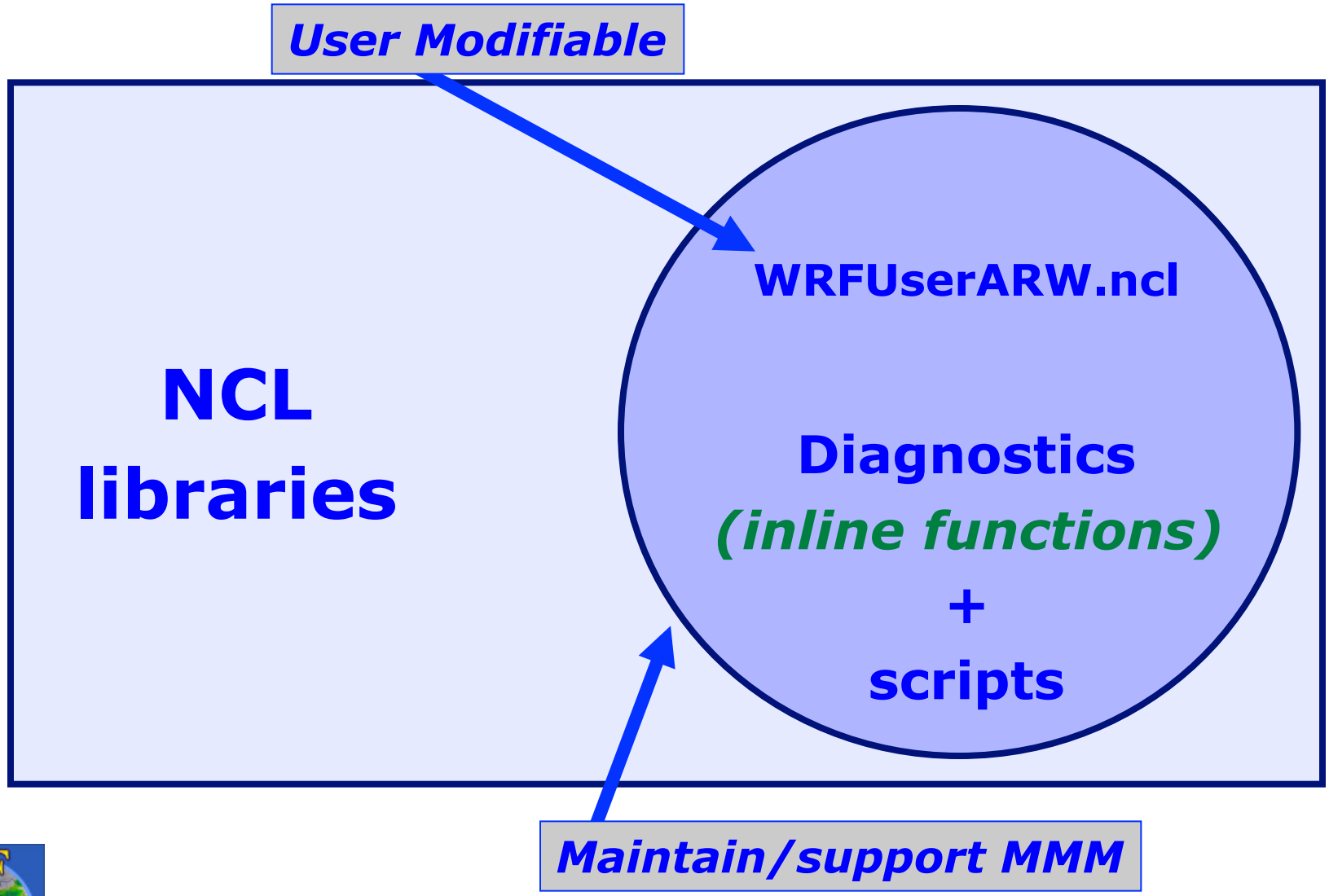


NCL

- NCAR Command Language
- http://www.ncl.ucar.edu
- Read WRF-ARW data directly
- Generate a number of graphical plots
  - Horizontal, cross-section, skewT, meteogram, panel
- Download
  - http://www.ncl.ucar.edu/Download
  - Fill out short registration form *(there is a short waiting period)*
  - Read and agree to OSI-based license
  - Get version 6 or *later (current v6.1.2 – highly recommended)*
- NCARG_ROOT environment variable
  - setenv NCARG_ROOT /usr/local/ncl



NCL & WRF

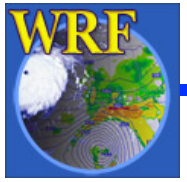

User Modifiable
WRFUserARW.ncl
NCL
libraries
Diagnostics
(inline functions)
+
scripts
Maintain/support MMM

Home Directory → ~/.hluresfile ← Very Important

- Required by NCL libraries
- Must be in your "~/" directory *(home directory)*
- Control
  - color table ; font
  - white/black background
  - size of plot
  - control characters

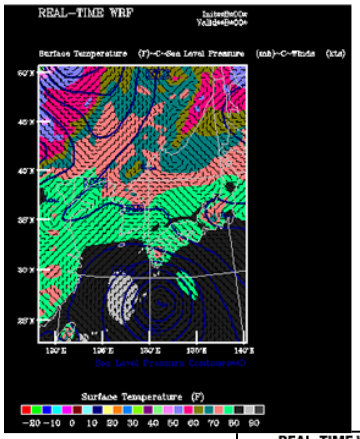
- http://www.ncl.ucar.edu/Document/Graphics/hlures.shtml

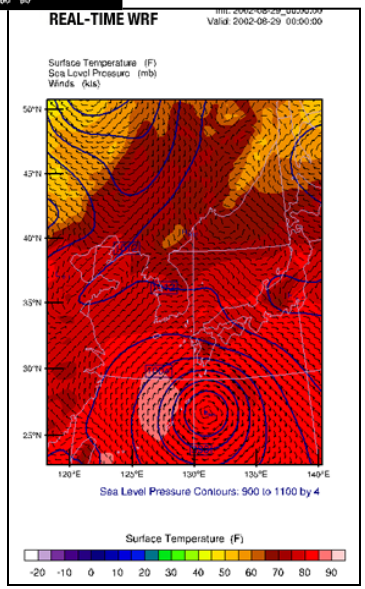
- Less important in NCL version 6 and higher



~/.hluresfile

```
*wkColorMap              : BlAqGrYeOrReVi200
*wkBackgroundColor       : white
*wkForegroundColor       : black
*FuncCode                : ~
*TextFuncCode            : ~
*Font                    : helvetica
*wkWidth                 : 900
*wkHeight                : 900
```



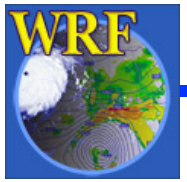



```
PLCHHQ - CHARACTER NUMBER 26 (.) IS NOT A LEGAL FUNCTION CODE
PLCHHQ - CHARACTER NUMBER 29 (t) IS NOT A LEGAL FUNCTION CODE
PLCHHQ - CHARACTER NUMBER 30 (o) IS NOT A LEGAL FUNCTION CODE
PLCHHQ - CHARACTER NUMBER 32 (.) IS NOT A LEGAL FUNCTION CODE
PLCHHQ - CHARACTER NUMBER 35 (b) IS NOT A LEGAL FUNCTION CODE
PLCHHQ - CHARACTER NUMBER 36 (y) IS NOT A LEGAL FUNCTION CODE
```

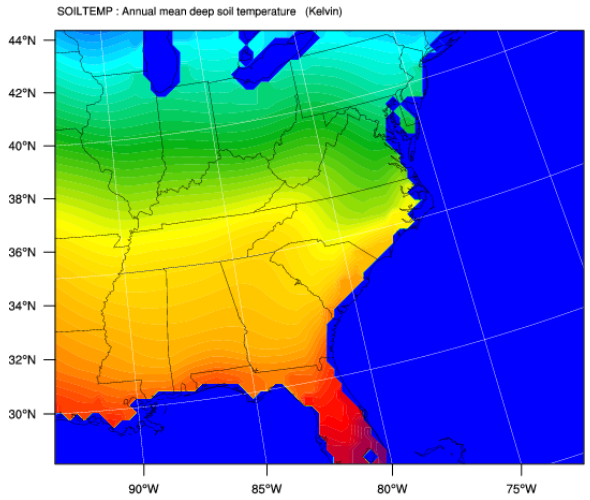
http://www.mmm.ucar.edu/wrf/OnLineTutorial/Graphics/NCL/.hluresfile

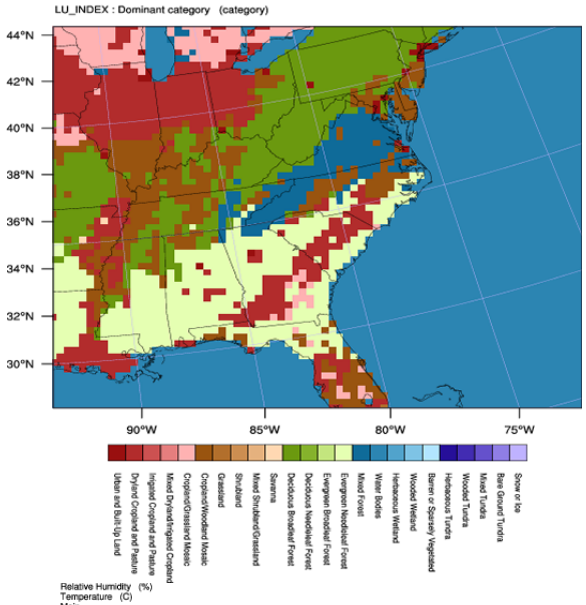
Generate Plots with NCL

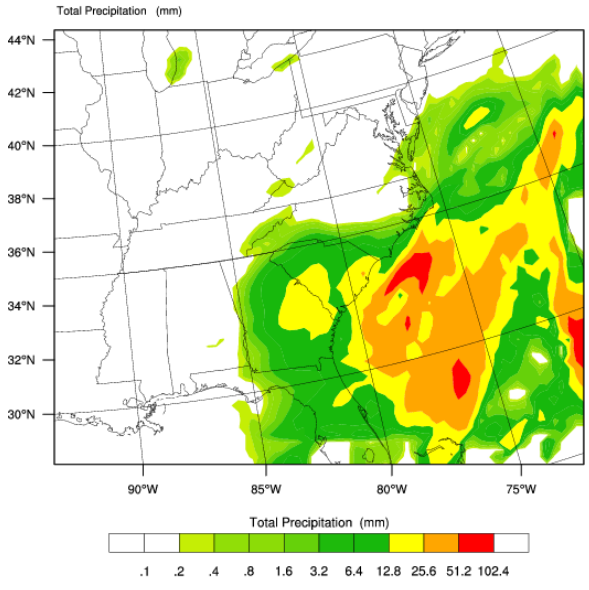
- **Set NCARG_ROOT environment variable:**
  - *setenv NCARG_ROOT /usr/local/ncl*
- **Ensure you have an ~/.hluresfile file**
- **Create a script**
  - *wrf_real.ncl*
    (start with a sample script)
    Most of the WRF script routines are called from
    "$NCARG_ROOT/lib/ncarg/nclscripts/wrf/WRFUserARW.ncl"
    Feel free to add or change this script
- **Run NCL script**
  - *ncl wrf_real.ncl*

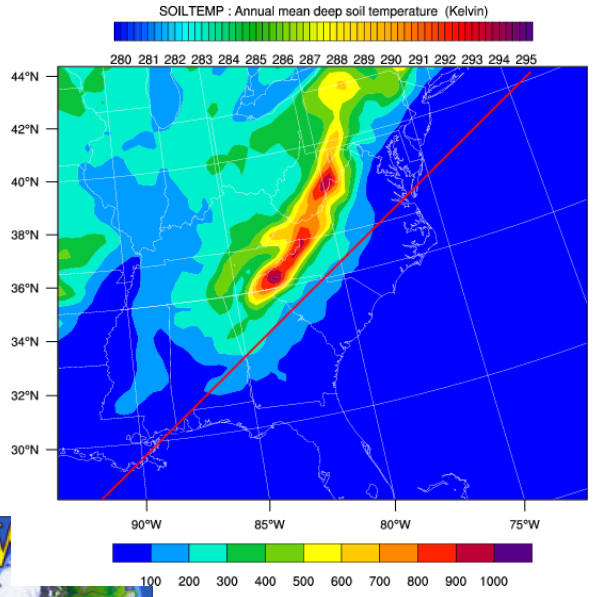


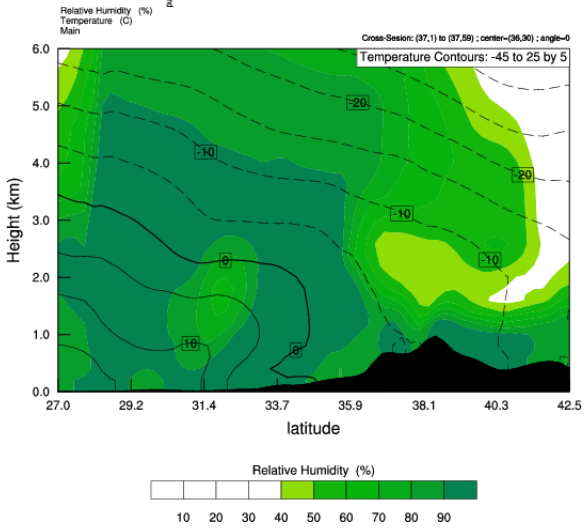
Examples

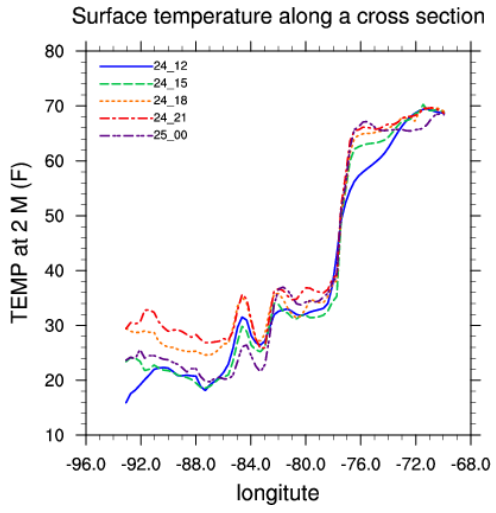

SOILTEMP : Annual mean deep soil temperature (Kelvin)
44°N
42°N
40°N
38°N
36°N
34°N
32°N
30°N
90°W
85°W
80°W
75°W


LU_INDEX : Dominant category (category)
44°N
42°N
40°N
38°N
36°N
34°N
32°N
30°N
90°W
85°W
80°W
75°W
Urban and Built-Up Land
Dryland Cropland and Pasture
Irrigated Cropland and Pasture
Mixed Dryland/Irrigated Cropland
Cropland/Grassland Mosaic
Cropland/Woodland Mosaic
Grassland
Shrubland
Mixed Shrubland/Grassland
Savanna
Deciduous Broadleaf Forest
Deciduous Needleleaf Forest
Evergreen Broadleaf Forest
Evergreen Needleleaf Forest
Mixed Forest
Water Bodies
Herbaceous Wetland
Wooded Wetland
Barren or Sparsely Vegetated
Herbaceous Tundra
Wooded Tundra
Mixed Tundra
Bare Ground Tundra
Snow or Ice

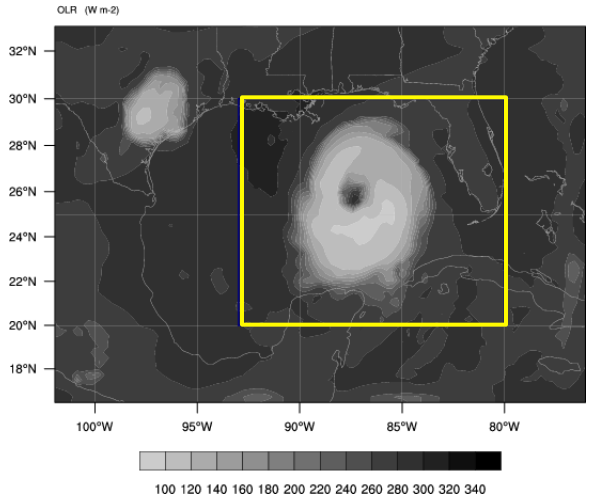

Total Precipitation (mm)
44°N
42°N
40°N
38°N
36°N
34°N
32°N
30°N
90°W
85°W
80°W
75°W
Total Precipitation (mm)
.1
.2
.4
.8
1.6
3.2
6.4
12.8
25.6
51.2
102.4

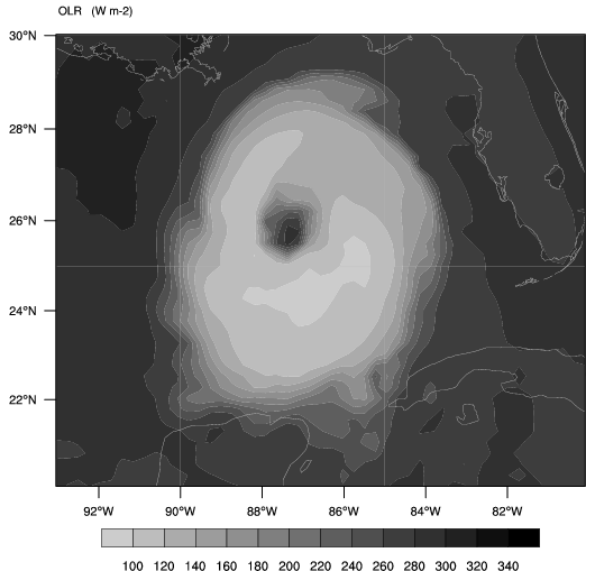

SOILTEMP : Annual mean deep soil temperature (Kelvin)
280 281 282 283 284 285 286 287 288 289 290 291 292 293 294 295
44°N
42°N
40°N
38°N
36°N
34°N
32°N
30°N
90°W
85°W
80°W
75°W
100 200 300 400 500 600 700 800 900 1000

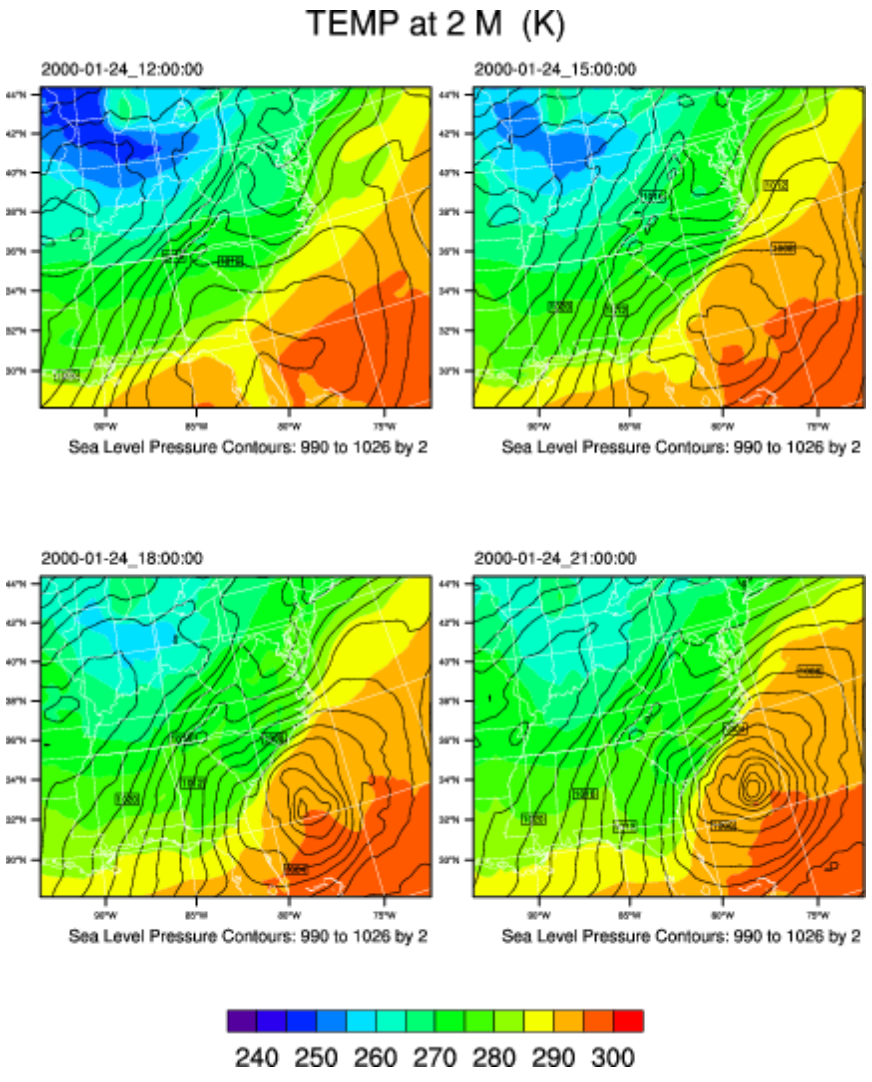

Relative Humidity (%)
Temperature (C)
Main
Cross-Sesion: (37,1) to (37,59) ; center=(36,30) ; angle=0
Temperature Contours: -45 to 25 by 5
Height (km)
6.0
5.0
4.0
3.0
2.0
1.0
0.0
27.0
29.2
31.4
33.7
35.9
38.1
40.3
42.5
latitude
-20
-10
0
Relative Humidity (%)
10 20 30 40 50 60 70 80 90


Surface temperature along a cross section
24_12
24_15
24_18
24_21
25_00
TEMP at 2 M (F)
80
70
60
50
40
30
20
10
-96.0
-92.0
-88.0
-84.0
-80.0
-76.0
-72.0
-68.0
longitute

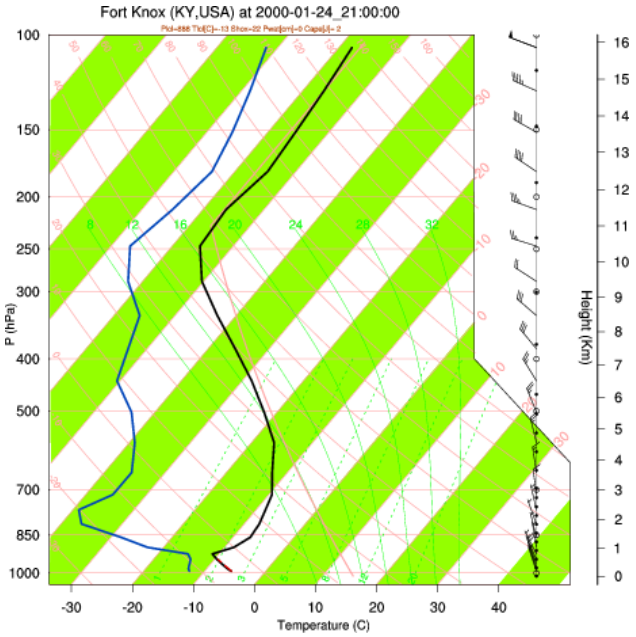
Examples

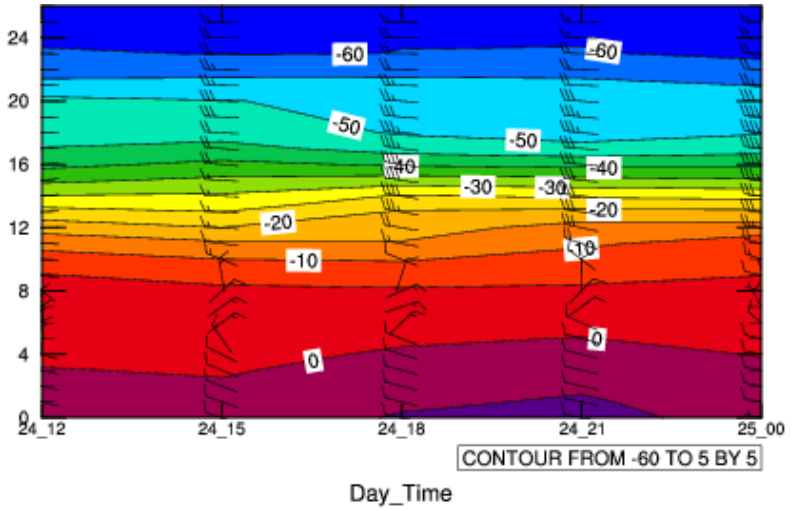

OLR (W m-2)
32°N
30°N
28°N
26°N
24°N
22°N
20°N
18°N
100°W
95°W
90°W
85°W
80°W
100 120 140 160 180 200 220 240 260 280 300 320 340

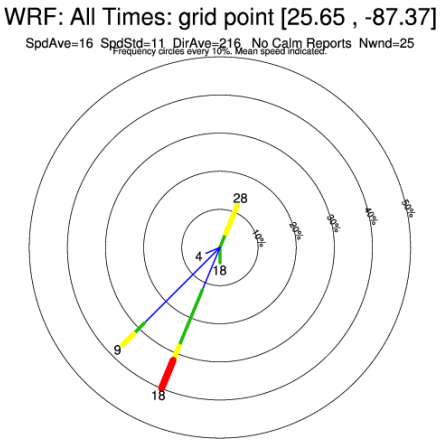

OLR (W m-2)
30°N
28°N
26°N
24°N
22°N
92°W
90°W
88°W
86°W
84°W
82°W
100 120 140 160 180 200 220 240 260 280 300 320 340

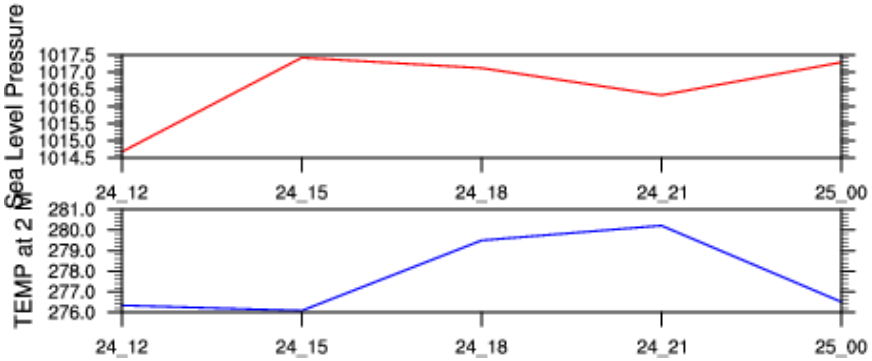

TEMP at 2 M (K)
2000-01-24_12:00:00
2000-01-24_15:00:00
2000-01-24_18:00:00
2000-01-24_21:00:00
Sea Level Pressure Contours: 990 to 1026 by 2
240 250 260 270 280 290 300

Examples

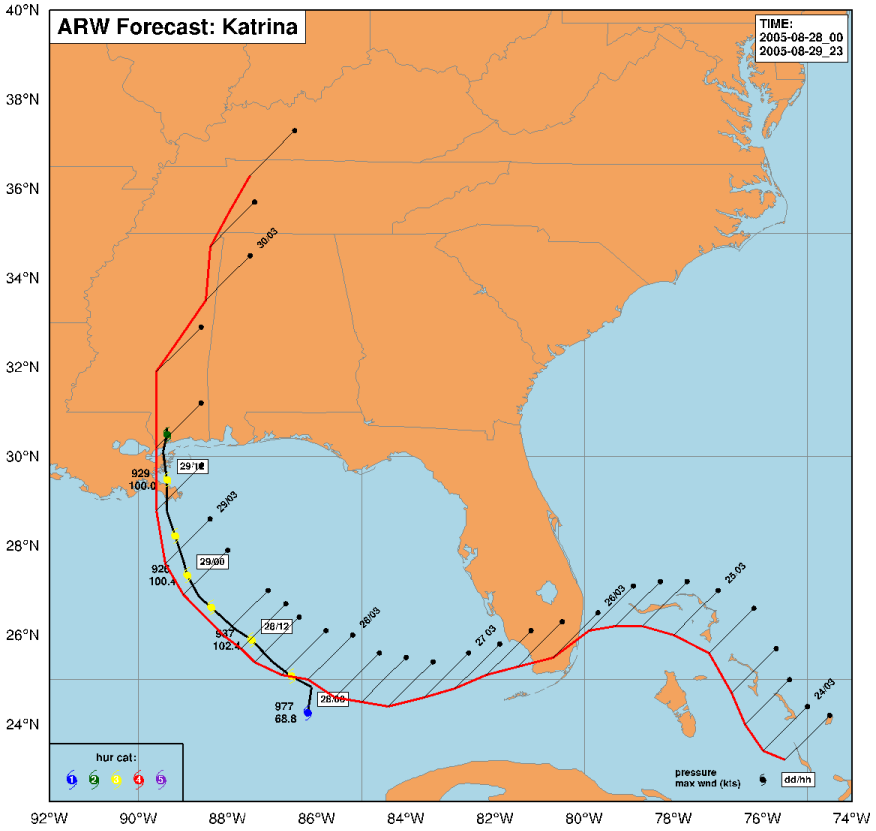

Fort Knox (KY,USA) at 2000-01-24_21:00:00
P (hPa)
Height (Km)
Temperature (C)

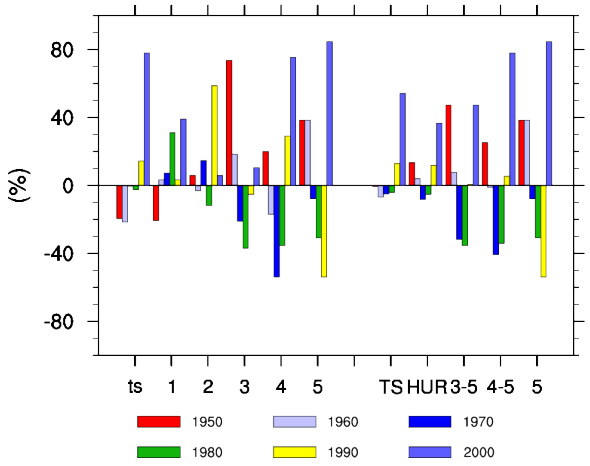

CONTOUR FROM -60 TO 5 BY 5
Day_Time

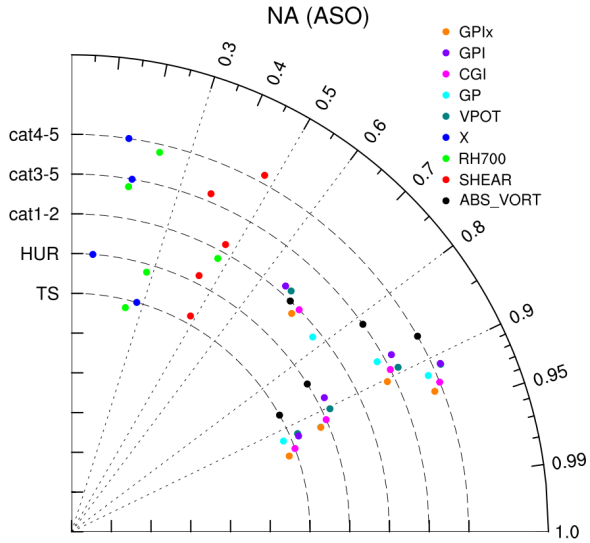

WRF: All Times: grid point [25.65 , -87.37]
SpdAve=16 SpdStd=11 DirAve=216 No Calm Reports Nwnd=25


Sea Level Pressure
TEMP at 2 M

Examples

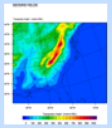

ARW Forecast: Katrina
TIME:
2005-08-28_00
2005-08-29_23
40°N
38°N
36°N
34°N
32°N
30°N
28°N
26°N
24°N
92°W
90°W
88°W
86°W
84°W
82°W
80°W
78°W
76°W
74°W
hur cat:
pressure
max wnd (kts)
dd/hh


80
40
0
-40
-80
(%)
ts
1
2
3
4
5
TS
HUR
3-5
4-5
5
1950
1960
1970
1980
1990
2000


NA (ASO)
GPIx
GPI
CGI
GP
VPOT
X
RH700
SHEAR
ABS_VORT
cat4-5
cat3-5
cat1-2
HUR
TS
0.3
0.4
0.5
0.6
0.7
0.8
0.9
0.95
0.99
1.0

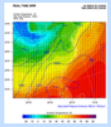
Generate Plots: *A good start - OnLine Tutorial*

Basic Plots



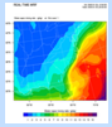
Basic Plot Setup
(This series of examples takes users though same basic steps in generating plotting scripts.)
Get and plot a single field
Multiple input files
Plot all fields in a file

Basic Surface Plots



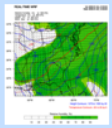
Surface 1
Surface 3
Surface 2
Surface with multiple input files

Plots on Model Levels



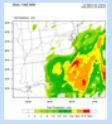
Clouds
Levels from wrfout files
Levels from metgrid files

Plots on Interpolated Levels



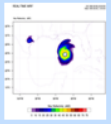
Height Levels
Pressure Levels

Plotting Precipitation



Precipitation

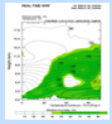
Diagnostics



CAPE
dBZ
PW
Vorticity
helicity
updraft_helicity

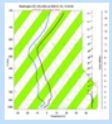
(More diagnostics are available, shown are only some newer/special diagnostics)

Cross-section Plots



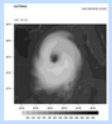
Height - Through a Pivot Point
Height - Point A to Point B
Pressure
Limited Vertical Extent
For 2D fields
Smooth terrain

Skew_T Plots



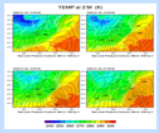
Skew_T

Overlay and Zoom



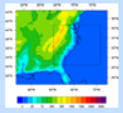
Overlay
Zoom
Overlay & Zoom

Panel Plots



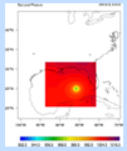
Panel 1
Panel 2

Overlay Domains



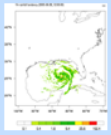
Overlay 2 domains

Moving Nest



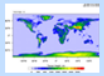
Moving Nest
Keeping a fixed background for moving nest domain

Moving Nest



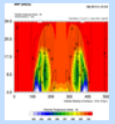
Precip Tendencies for a Moving Nest
Keeping a fixed background for moving nest domain, and plotting rainfall tendencies in the overlapping regions
Domain 1 and 2 Precip Tendencies on a single plot (domain 2 is a moving nest)

Global WRF



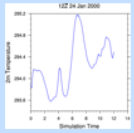
gWRF_merc

Idealized cases



wrf_Grav2x
wrf_Hill2d
wrf_Squall_2d_x
wrf_Squall_2d_y
wrf_Seabreeze2x
wrf_BWave
wrf_QSS

Time Slice Plots

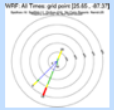


Meteograms
WRF Time Series data

Track Cyclone

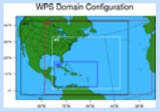
Plot Cyclone Vortex

Wind Roses



Create a wind rose

Preview Domain

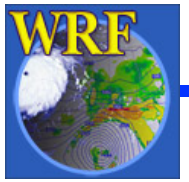


Preview
Note: This example script makes use to the WPS namelist directly

http://www.mmm.ucar.edu/wrf/OnLineTutorial/Graphics/NCL/index.html

Creating a Plot : NCL script

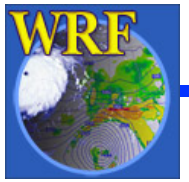
```
load ncl library scripts


begin

  ; Open input file(s)
  ; Open graphical output

  ; Read variables

  ; Set up plot resources & Create plots
  ; Output graphics

end
```



Creating a Plot : NCL script

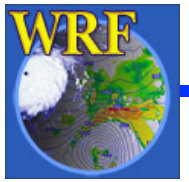
```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/wrf/WRFUserARW.ncl"

begin

  ; Open input file(s)
  ; Open graphical output

  ; Read variables

  ; Set up plot resources & Create plots
  ; Output graphics

end
```

```
load "/mydir/myWRFUserARW.ncl"
```



Creating a Plot : NCL script

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/wrf/WRFUserARW.ncl"

begin

  ; Open input file(s)
  ; Open graphical output

  ; Read variables

  ; Set up plot resources & Create plots
  ; Output graphics

end
```

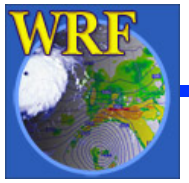


Creating a Plot : NCL script

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/wrf/WRFUserARW.ncl"

begin

 a = addfile("./wrfout_d01_2012-09-28_00:00:00.nc","r")
 ; Open graphical output

 ; Read variables

 ; Set up plot resources & Create plots
 ; Output graphics

end
```

```
a = addfile("./
wrfout_d01_2005-10-08_00:00:00.nc","r")
Can be "r", "w", "c"
```

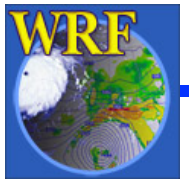
```
> ls wrfout*
  wrfout_d01_2005-10-08_00:00:00

a = addfile("./
wrfout_d01_2005-10-08_00:00:00.nc","r")
```



Creating a Plot : NCL script

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/wrf/WRFUserARW.ncl"

begin

 a = addfile("./wrfout_d01_2012-09-28_00:00:00.nc","r")
 wks = gsn_open_wks("X11","plt_Surface")

 ; Read variables

 ; Set up plot resources & Create plots
 ; Output graphics

end
```

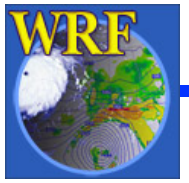
Can output either on the screen (X11), or as pdf, ps, cgm



Creating a Plot : NCL script

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/wrf/WRFUserARW.ncl"

begin

 a = addfile("./wrfout_d01_2012-09-28_00:00:00.nc","r")
 wks = gsn_open_wks("X11","plt_Surface")

 T2 = wrf_user_getvar(a,"T2",0)

 ; Set up plot resources & Create plots
 ; Output graphics

end
```

```
T2 = wrf_user_getvar(a,"T2",0)
T2 = a->T2(0,:,:)

T2 = wrf_user_getvar(a,"T2",-1)
T2 = a->T2
```

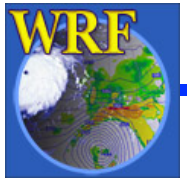


Special WRF NCL Functions

wrf_user_getvar
Get fields from input file

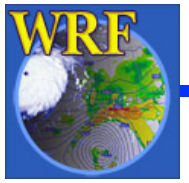
```
ter = wrf_user_getvar(a,"HGT",0)      {ter=a->HGT(0,:,:)}
t2  = wrf_user_getvar(a,"T2",-1)      {t2=a->T2}
slp = wrf_user_getvar(a,"slp",1)
```

avo/pvo: Absolute/Potential Vorticity, eth: Equivalent Potential Temperature,
cape_2d: 2D mcape/mcin/lcl/lfc, cape_3d: 3D cape/cin,
dbz/mdbz: Reflectivity (3D and max),
geopt/geopotential: Geopotential,
helicity/updraft_helicity: Storm Relative Helicity/Updraft helicity,
p/pres/pressure: Pressure, pw: Precipitable Water,
rh/rh2: Relative Humidity (3D and 2m),
slp: Sea Level Pressure, times: Time as a string [*(TIMES: Time as characters)*],
td/td2: Dew Point Temperature (3D and 2m),
tc/tk: Temperature (C and F), th/theta: Potential Temperature,
z/height: Height, ua/va/wa: wind on mass points,
uvmet/uvmet10: wind rotated to earth coordinates (3D and 10m)



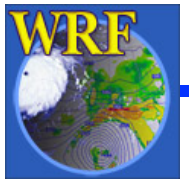
Creating a Plot : NCL script

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/wrf/WRFUserARW.ncl"

begin

 a = addfile("./wrfout_d01_2012-09-28_00:00:00.nc","r")
 wks = gsn_open_wks("X11","plt_Surface")

 T2 = wrf_user_getvar(a,"T2",0)

 ; Set up plot resources & Create plots
 ; Output graphics

end
```



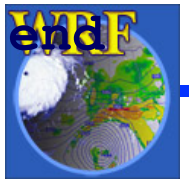
Creating a Plot : NCL script

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/wrf/WRFUserARW.ncl"

begin

 a = addfile("./wrfout_d01_2012-09-28_00:00:00.nc","r")
 wks = gsn_open_wks("X11","plt_Surface")

 T2 = wrf_user_getvar(a,"T2",0)

 pltres = True
 mpres = True
 opts = True
 opts@cnFillOn = True
 ; Output graphics

end
```



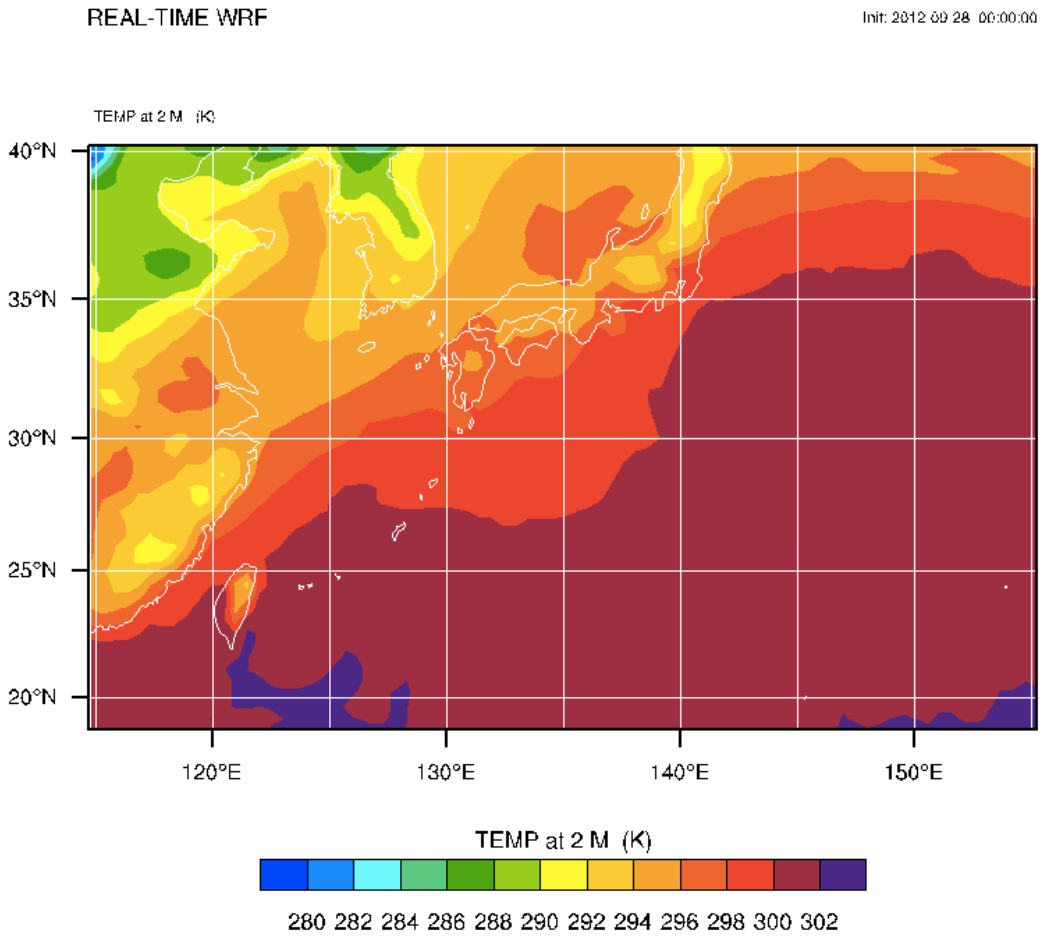
Creating a Plot : NCL script

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/wrf/WRFUserARW.ncl"

begin

 a = addfile("./wrfout_d01_2012-09-28_00:00:00.nc","r")
 wks = gsn_open_wks("X11","plt_Surface")

 T2 = wrf_user_getvar(a,"T2",0)

 pltres = True
 mpres = True
 opts = True
 opts@cnFillOn = True
 contour_t2 = wrf_contour(a,wks,T2,opts)
plot = wrf_map_overlays(a,wks,(/contour_t2/),pltres,mpres)
```



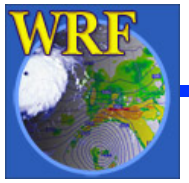
Creating

```
load "$NCARG_ROOT/lib/                                    "
load "$NCARG_ROOT/lib/                                    cl"

begin

  a = addfile("./wrfout
  wks = gsn_open_wks("X

  T2 = wrf_user_getvar(

  pltres = True
  mpres = True
  opts = True
  opts@cnFillOn = True
  contour_t2 = wrf_contour(a,wks,T2,opts)
plot = wrf_map_overlays(a,wks,(/contour_t2/),pltres,mpres)
```



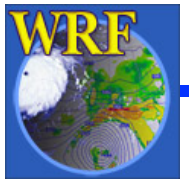
Creating a Plot : NCL script

```
  T2 = wrf_user_getvar(a,"T2",-1)
  times = wrf_user_getvar(a,"times",-1)
  ntimes = dimsizes(times)

 do it=0,ntimes-1

  pltres = True
  mpres = True
  opts = True
  opts@cnFillOn = True

 contour_t2 = wrf_contour(a,wks,T2(it,:,:),opts)
plot = wrf_map_overlays(a,wks,(/contour_t2/),pltres,mpres)

 end do
```



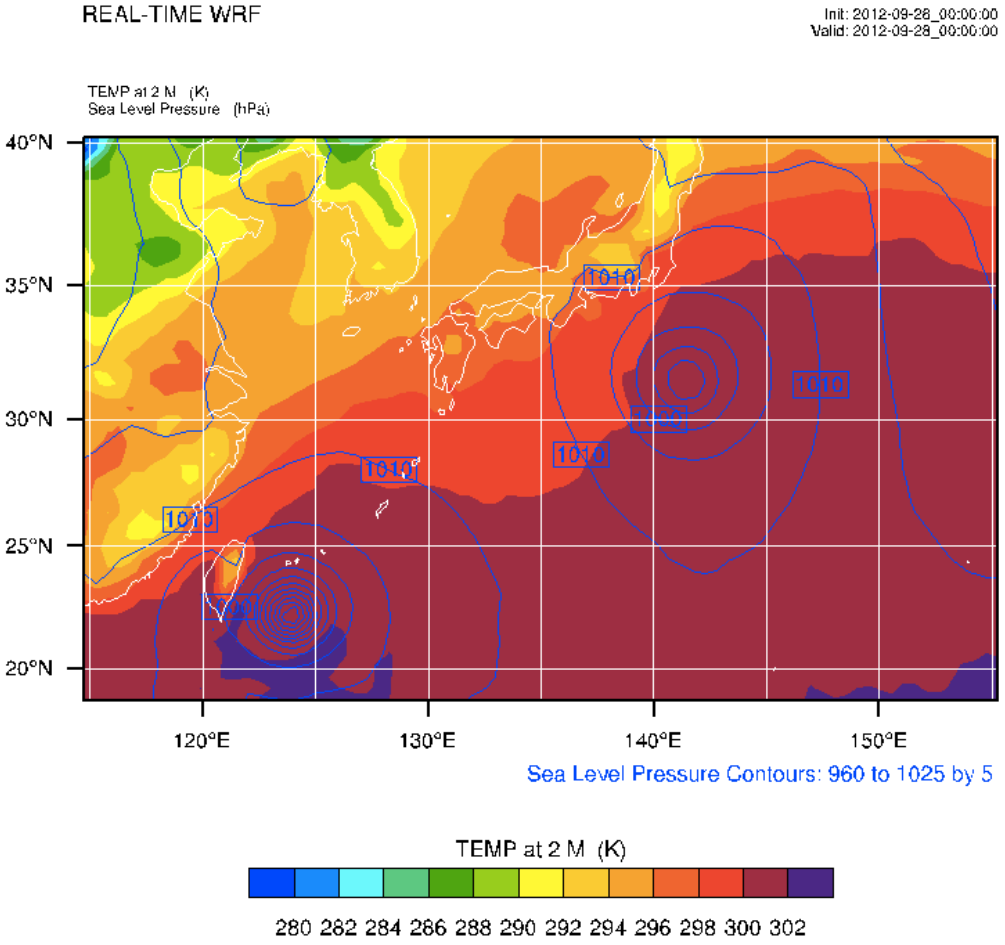
Creating a Plot : NCL script

```
  T2 = wrf_user_getvar(a,"T2",0)
  slp = wrf_user_getvar(a,"slp",0)
  pltres = True
  mpres = True

  opts = True
  opts@cnFillOn = True
  contour_t2 = wrf_contour(a,wks,T2,opts)
  delete(opts)
  opts = True
  opts@cnLineColor = "Blue"
  contour_slp = wrf_contour(a,wks,slp,opts)
  delete(opts)

plot = wrf_map_overlays(a,wks,(/contour_t2,contour_slp/),
pltres,mpres)
```



Creating a

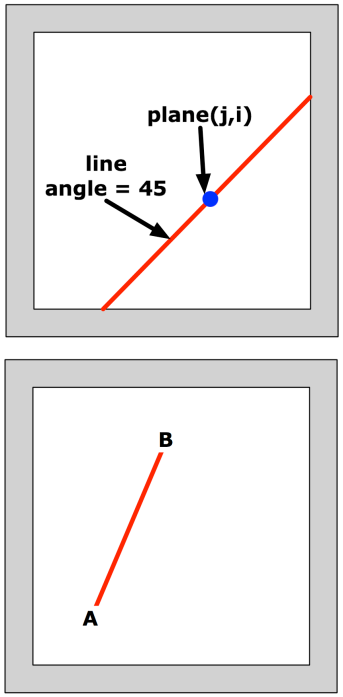
```
T2 = wrf_user_getvar(a,"
slp = wrf_user_getvar(a,
pltres = True
mpres = True

opts = True
opts@cnFillOn = True
contour_t2 = wrf_contour
delete(opts)
opts = True
opts@cnLineColor = "Blue
contour_slp = wrf_contou
delete(opts)
```



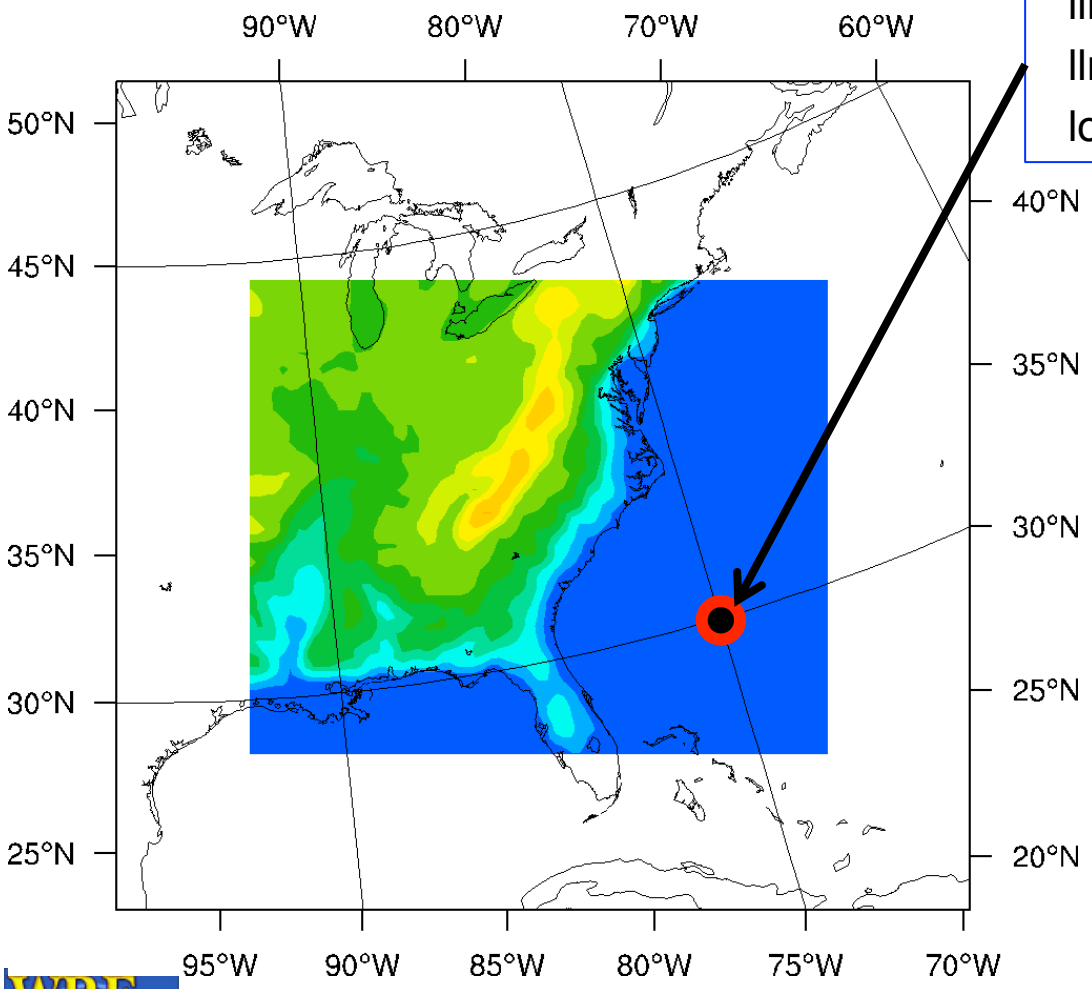

```
plot = wrf_map_overlays(a,wks,(/contour_t2,contour_slp/),
pltres,mpres)
```

Special WRF NCL Functions

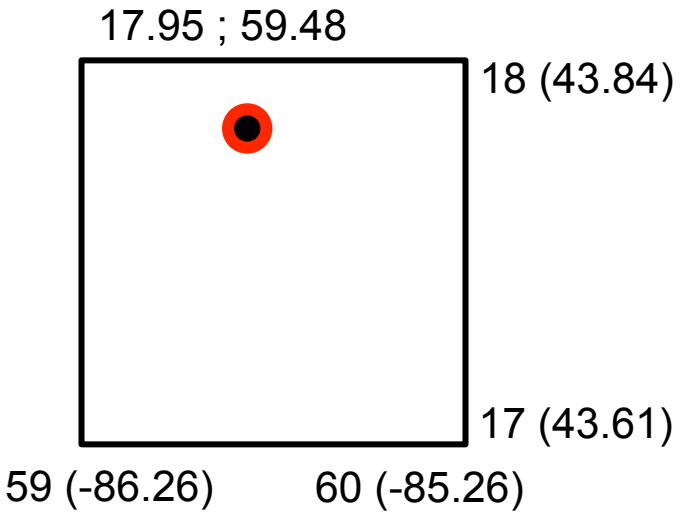
- **wrf_user_getvar**
  Get native and diagnostic variables
- **wrf_contour / wrf_vector**
  Create line/shaded & vector plots
- **wrf_map_overlays / wrf_overlays**
  Overlay plots created with wrf_contour and wrf_vector
- **wrf_user_intrp3d / wrf_user_intrp2d**
  Interpolate horizontally to a given pressure/height (3d data only)
  Interpolate vertically along a given line
- **wrf_user_ll_to_ij / wrf_user_ij_to_ll**
  Convert: lat/lon ⟺ ij
- **wrf_user_unstagger**
  Unstaggers an array



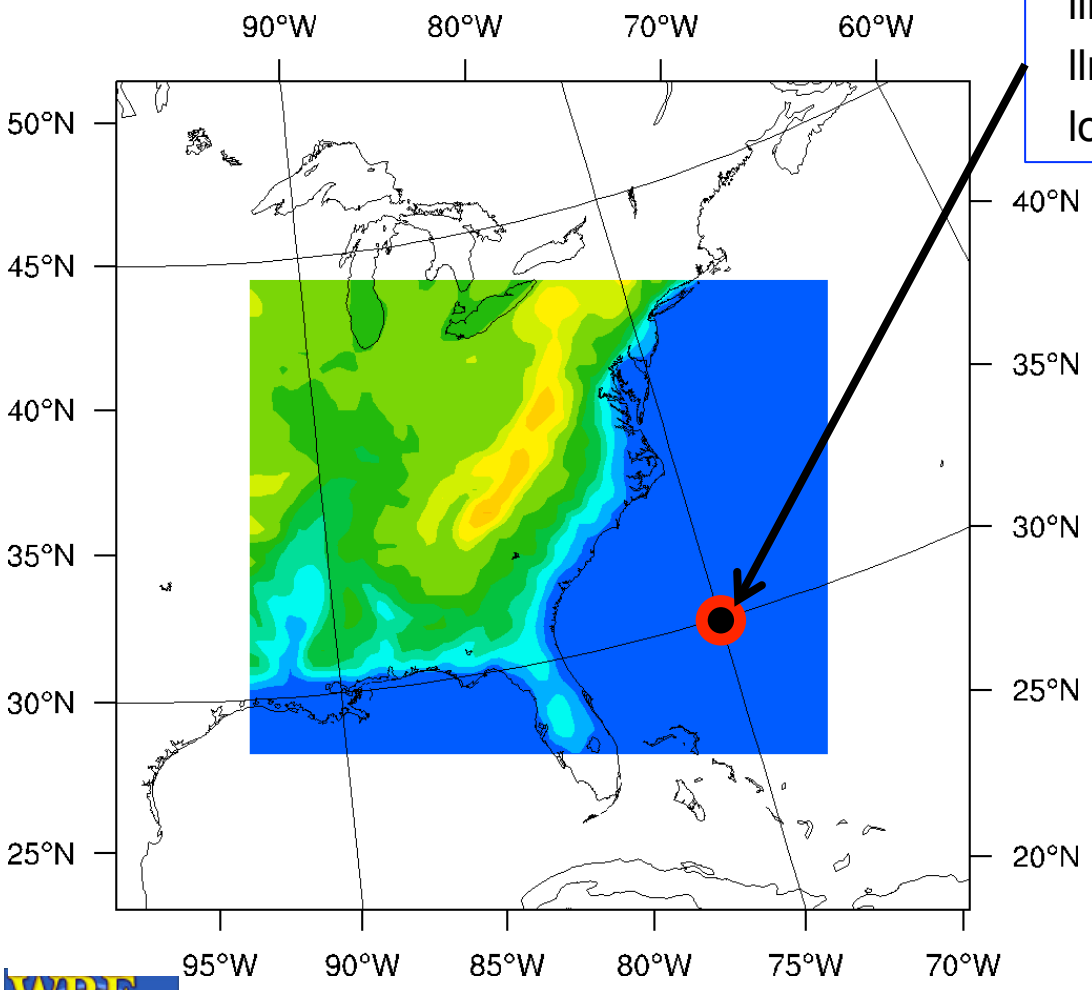
wrf_user_ll_to_ij



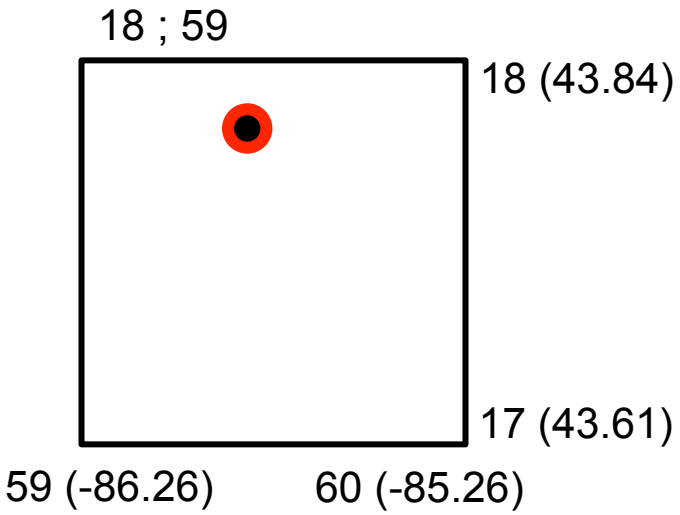

```
llres = True
llres@returnInt = False
locij = wrf_user_ll_to_ij(a, 30.0, -75.0, llres)
```



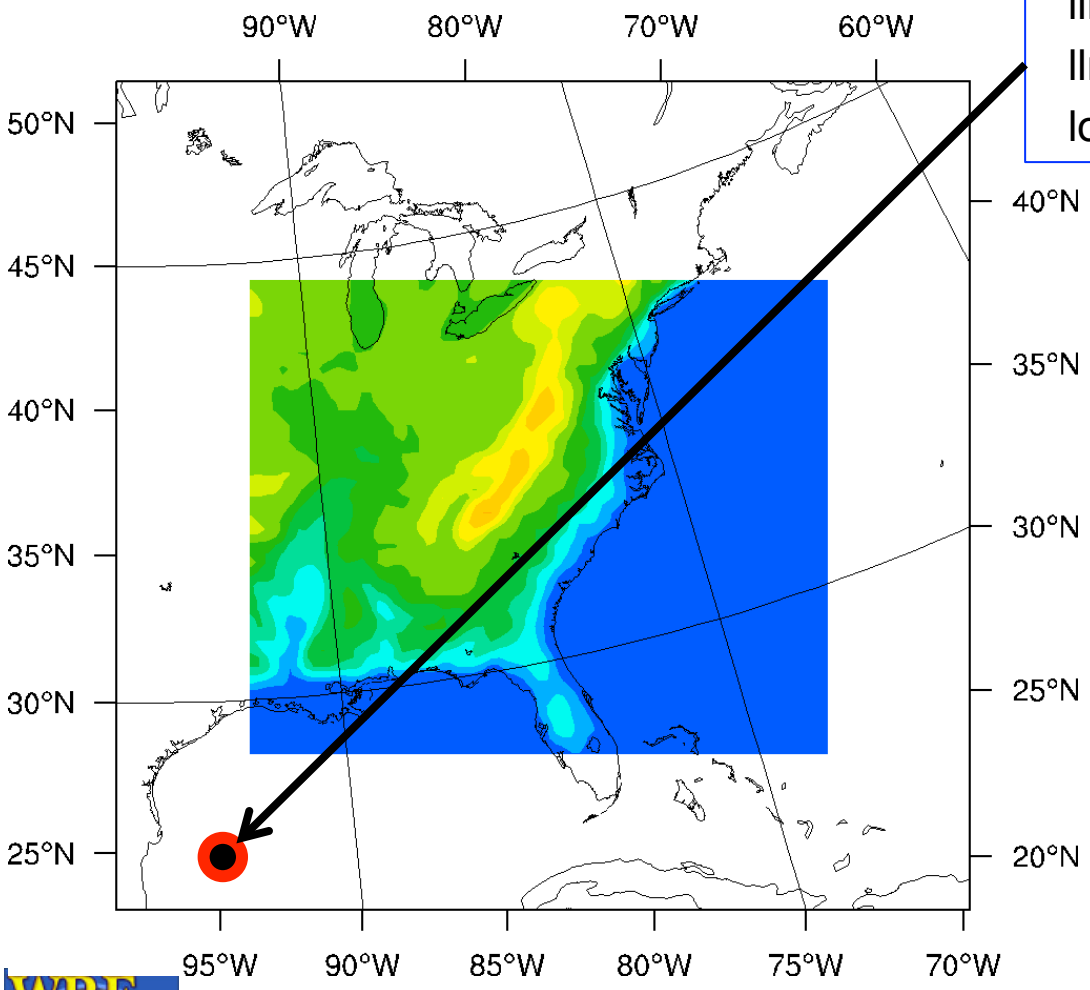
wrf_user_ll_to_ij




```
llres = True
llres@returnInt = True
locij = wrf_user_ll_to_ij(a, 30.0, -75.0, llres)
```



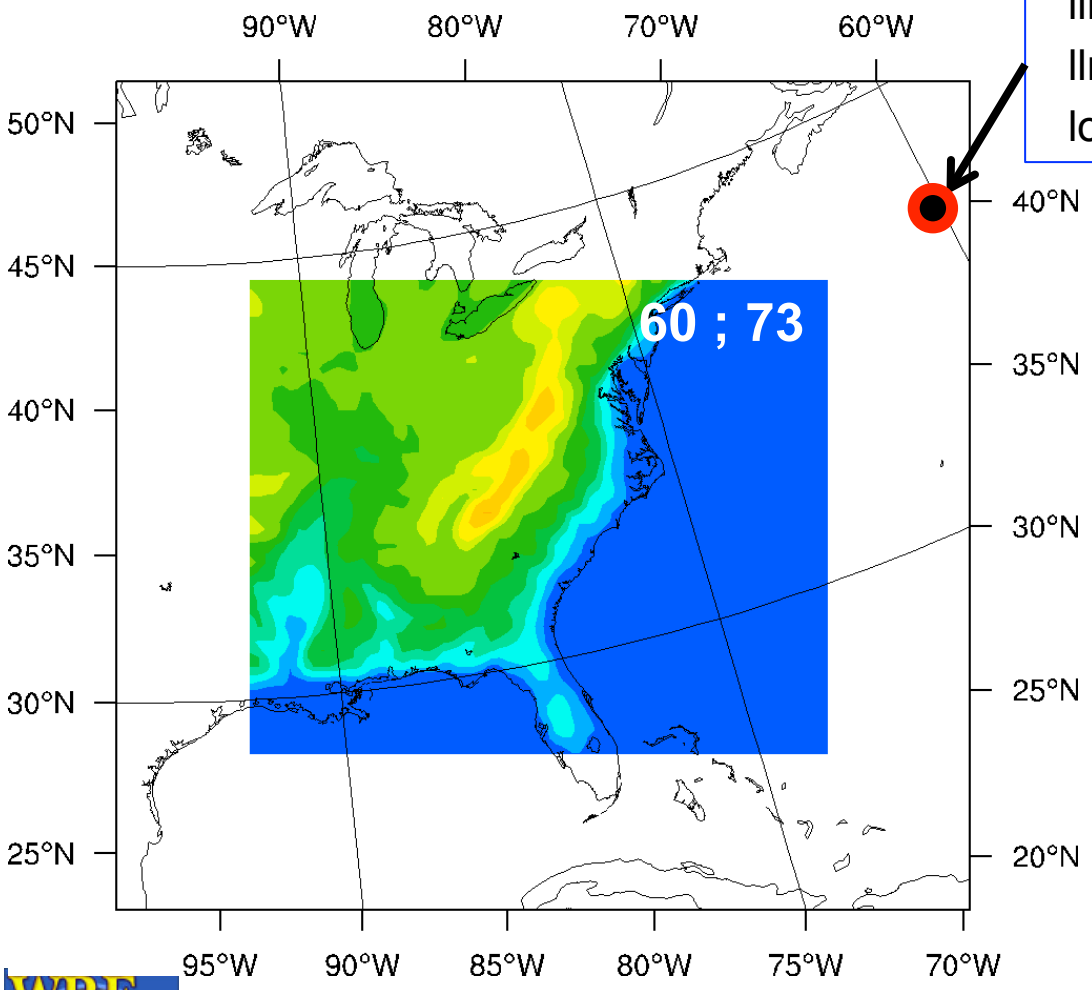
wrf_user_ll_to_ij




```
llres = True
llres@returnInt = True
locij = wrf_user_ll_to_ij(a, 25.0, -95.0, llres)
```

-10 ; -2

wrf_user_ll_to_ij

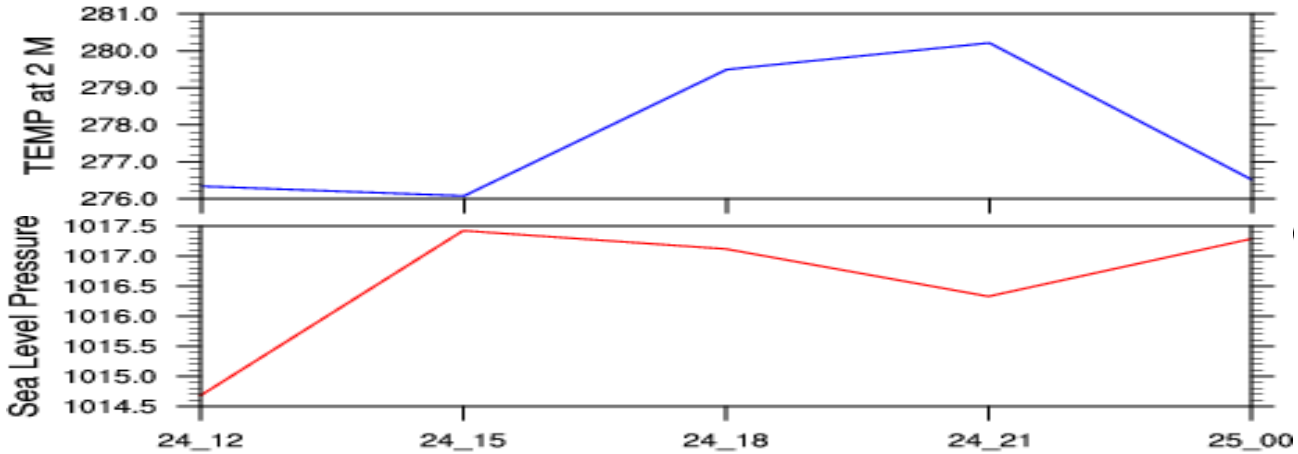



```
llres = True
llres@returnInt = True
locij = wrf_user_ll_to_ij(a, 25.0, -95.0, llres)
```

68; 87

Time Series

```
locij = wrf_user_ll_to_ij(a, -87., 32.5, llres)
locij = locij - 1
locX = locij(0)
locY = locij(1)

t2_point  = a->T2(:,locY,locX)
t2_plot   = gsn_csm_xy(wks,taus,t2_point,t2_res)

slp   = wrf_user_getvar(a,"slp",-1)
slp_point  = slp(:,locY,locX)
slp_plot  = gsn_csm_xy(wks,taus,slp_point,t2_res)
```

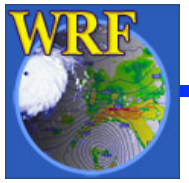


NCL and WRF_NCL

- Combine strength of WRF_NCL specific and NCL general capabilities

```
plot = wrf_map_overlays \
  (a,wks,(/contour/),pltres,mpres)

mpres@mpGridSpacingF = 45
 plot = wrf_map_overlays \
  (a,wks,(/contour/),pltres,mpres)

 mpres@mpGeophysicalLineColor
 mpres@mpGridLineColor
 mpres@mpNationalLineColor
 mpres@mpUSStateLineColor

 mpres@mpOutlineBoundarySets
    "NoBoundaries"   ; "Geophysical"
    "National"       ; "USStates"
    "GeophysicalAndUSStates"
    "AllBoundaries"
```

```
a = addfile("./wrfout.d01.nc","r")

t2 = a->T2(5,:,:)

t2 = wrf_user_getvar(a,"T2",5)

qv = a->QVAPOR(5,:,:,:)

qv = wrf_user_getvar(a,"QVAPOR",5)

t2 = a->T2

t2 = wrf_user_getvar(a,"T2",-1)

t2 = wrf_user_getvar(a,"T2",
(/0,10,2/))
t2 = wrf_user_getvar(a,"T2",
(/1,2,3,4,5/))
```

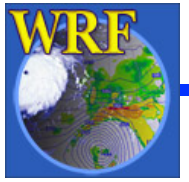


Resources

- **The special WRF functions have unique resources:**
  http://www.mmm.ucar.edu/wrf/OnLineTutorial/Graphics/NCL/NCL_functions.htm

- **All general NCL resources can also be used to control the plot:**
  http://www.ncl.ucar.edu/Document/Graphics/Resources

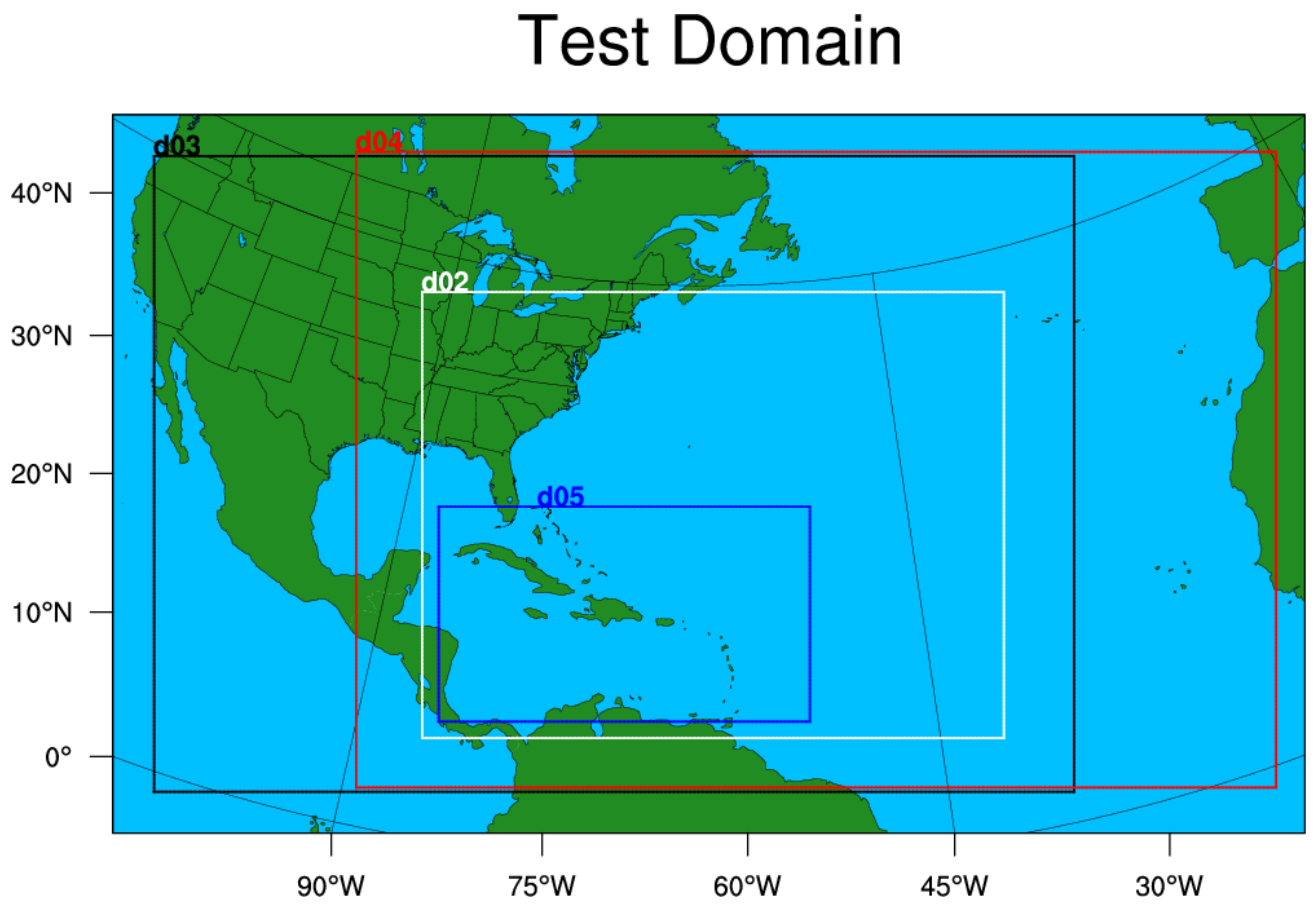
  - am (annotation manager)
  - app (app)
  - ca (coordinate array)
  - cn (contour)
  - ct (coordinate array table)
  - dc (data comm)
  - err (error)
  - gs (graphic style)
  - gsn (gsn high-level interfaces)
  - lb (label bar)
  - lg (legends)
  - mp (maps)
  - pm (plot manager)
  - pr (primitives)
  - sf (scalar field)
  - st (streamline)
  - tf (transformation)
  - ti (title)
  - tm (tickmark)
  - tr (irregular transformation)
  - tx (text)
  - vc (vectors)
  - vf (vector field)
  - vp (view port)
  - wk (workstation)
  - ws (workspace)
  - xy (xy plots)



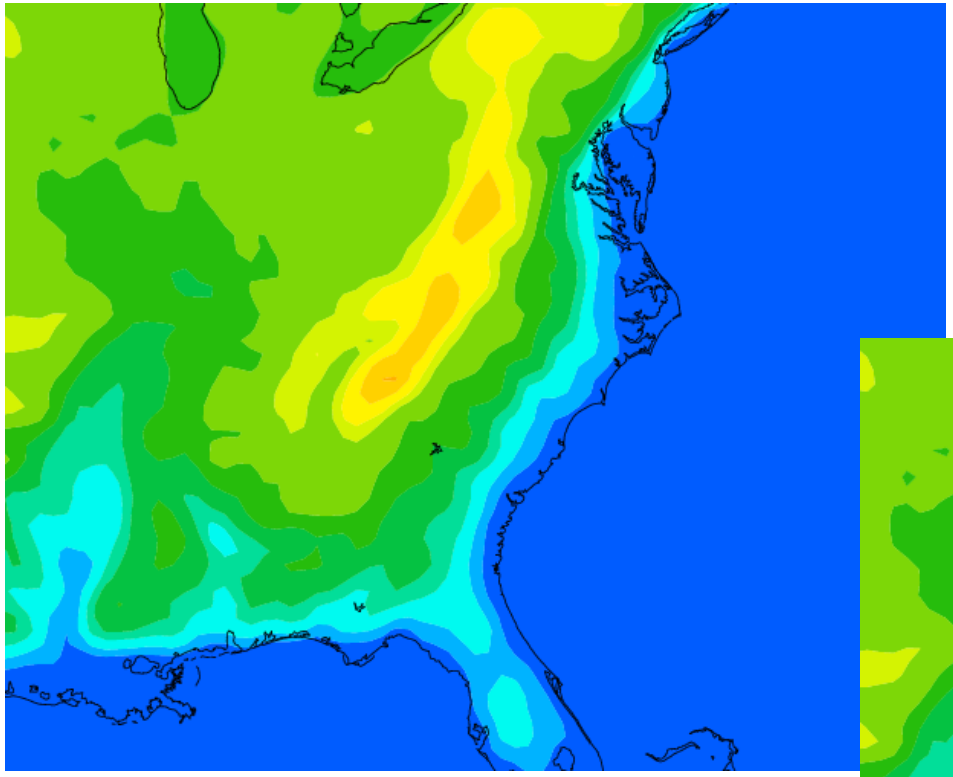
Domain Design

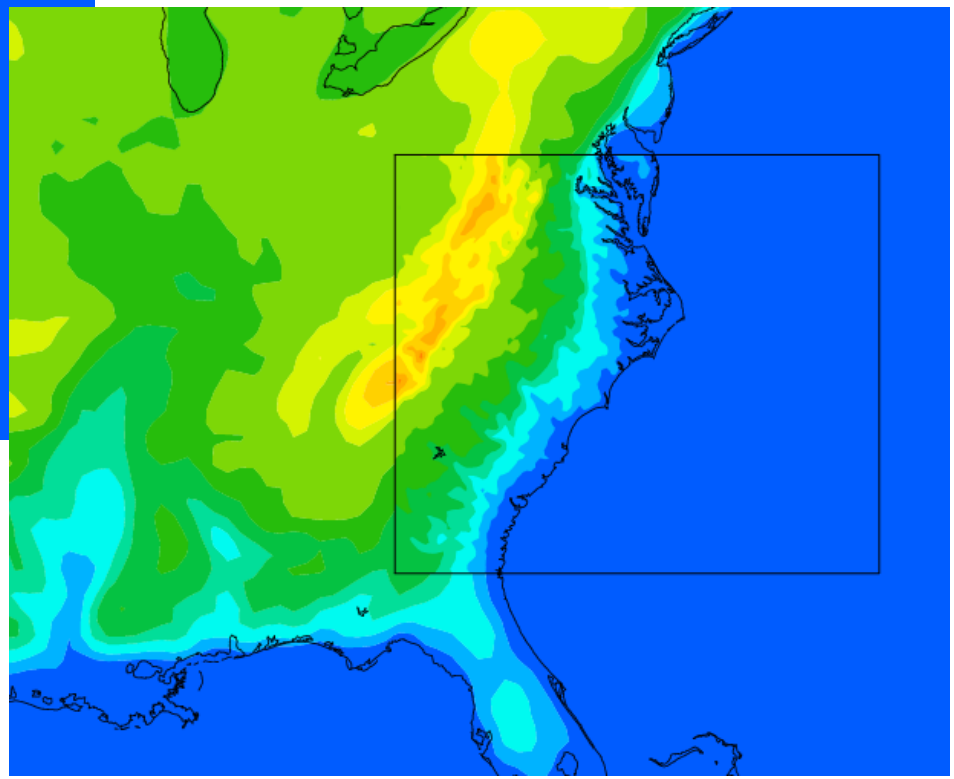
mp = wrf_wps_dom (wks, mpres, lnres, txres)

WPS/util/plotgrids.ncl

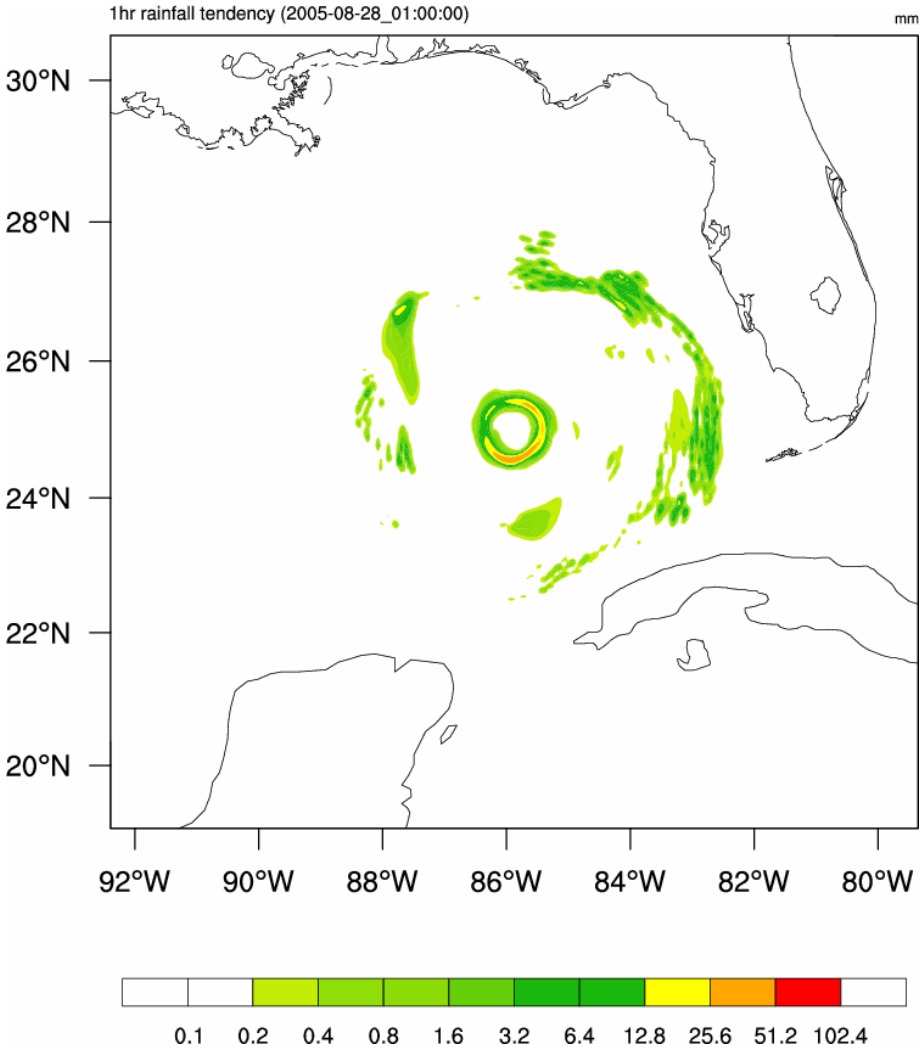


Over Domains

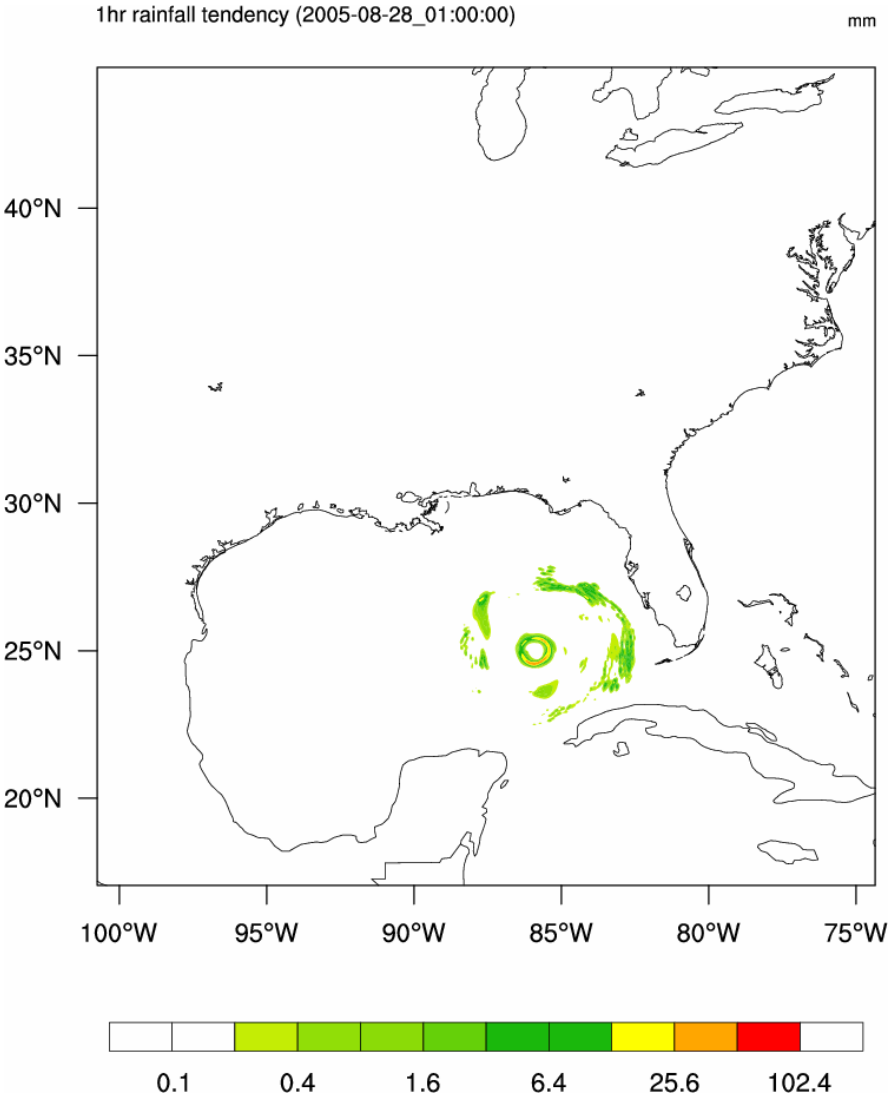




Moving Nests

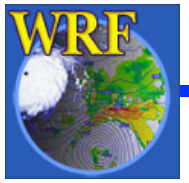


Moving Nests

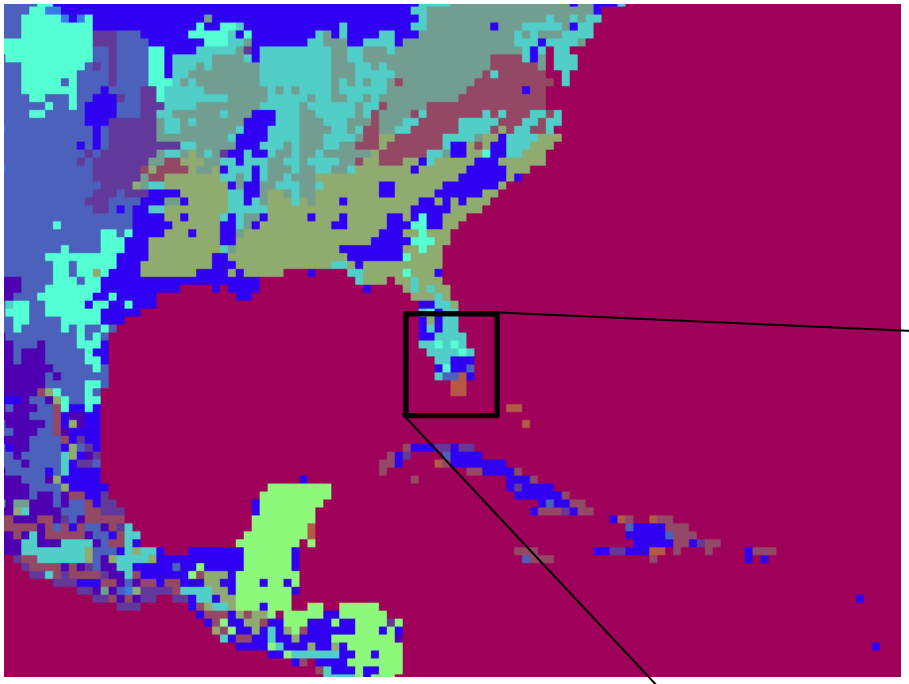


Change fields in netCDF file

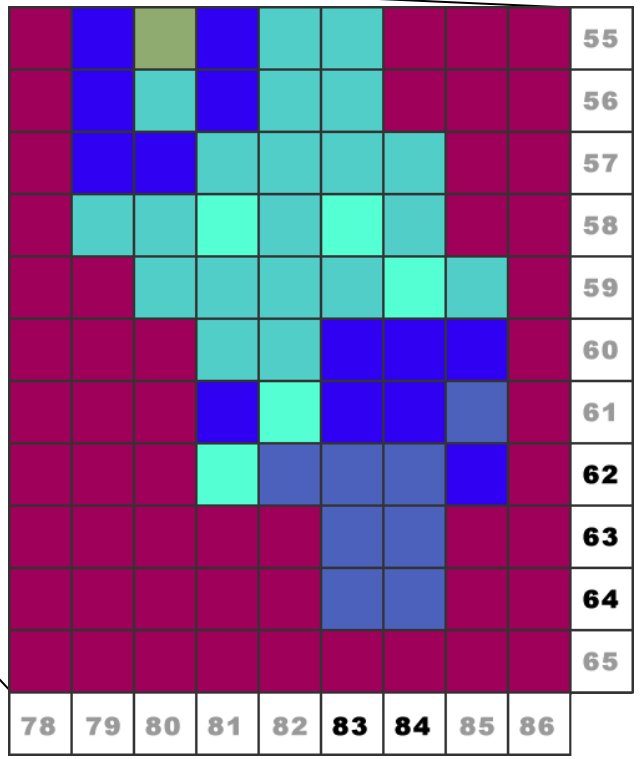
```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"


Begin


  a = addfile("./met_em.d01.2000-01-24_12:00:00.nc",”w")


  sst = a->SST       ; read a field
  sst = sst + 10; change the field
  a->SST = sst       ; write the field


end
```



Change fields in netCDF file



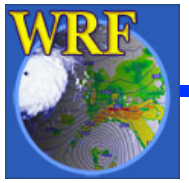
```
a = addfile("./geo_em.d01.nc","w")
var= a->LANDUSE

var(:,63:64,83:84) = 7
var(:,62,84) = 7

a->LANDUSE = var
```



NCL and Fortran/C Code

- **Link Fortran/C Code to NCL scripts**
  - Create a library from your Fortran/C code
  - Link to NCL script

- **Link Low Level NCL (NCAR Graphics) to Fortran Code**
  - Add calls to code inside Fortran code
  - Compile Fortran Code with NCL libraries
  - Example: WPS/utils/plotfmt.exe
  - *Older way or creating plots – not recommended*

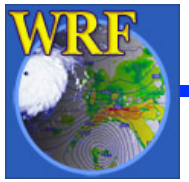


Calling FORTRAN code from NCL

- Easier to use F77 code, but works with F90 code
- Need to isolate definition of input variables and wrap it with special comment statements:

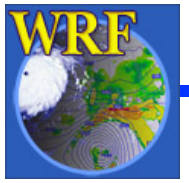
```
C NCLFORTSTART
C NCLEND
```

- Use a tool called `WRAPIT` to create a `*.so` file
- Load `*.so` file in NCL script with "`external`" statement
- Call Fortran function with special "`::`" syntax
- Must pre-allocate arrays!



myTK.f

```
C NCLFORTSTART
      subroutine compute_tk (tk,pressure,theta, nx, ny, nz)
        implicit none
        integer nx,ny,nz
        real    pi, tk(nx,ny,nz)
        real    pressure(nx,ny,nz), theta(nx,ny,nz)
C NCLEND
       integer i,j,k

        do k=1,nz
          do j=1,ny
          do i=1,nx
             pi=(pressure(i,j,k) / 1000.)**(287./1004.)
             tk(i,j,k) = pi*theta(i,j,k)
          enddo
          enddo
        enddo

        end
```

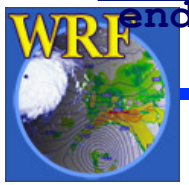


myTK.so - *Create & use in NCL script*

```
% WRAPIT myTK.f
```

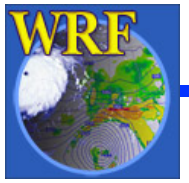
This will create a "myTK.so" file

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/wrf/WRFUserARW.ncl"
external myTK "./myTK.so"

begin
    t = wrf_user_getvar(a,"T",5)

    t = t + 300
    p = wrf_user_getvar(a,"pressure",5)

    ; Must preallocate space for output arrays
    dim = dimsizes(t)
    tk = new( dimsizes(t), typeof(t) )

    ; Remember, Fortran/NCL arrays are ordered differently
        myTK :: compute_tk (tk,p,t,dim(2),dim(1),dim(0))
end
```



FORTRAN 90 code

- Can use simple FORTRAN 90 code
- Your FORTRAN 90 program may not contain any of the following features:
  - pointers or structures as arguments,
  - missing/optional arguments,
  - keyword arguments, or
  - recursive procedure.



Compiling with ncl

```
In function `write_png':
  undefined reference to `png_create_write_struct'
  undefined reference to `png_create_info_struct'
  undefined reference to `png_destroy_write_struct'
  undefined reference to `png_destroy_write_struct'
```

-L<path_to_png_lib> -lpng -L<path_to_z_lib> -lz

```
/usr/local/ncl/lib/libncarg.a(agcurv.o): In function `agcurv_':
agcurv.f:(.text+0x69): undefined reference to `_gfortran_copy_string'
/usr/local/ncl/lib/libncarg.a(aggtch.o): In function `aggtch_':
aggtch.f:(.text+0x3e): undefined reference to `_gfortran_copy_string'
aggtch.f:(.text+0x7b): undefined reference to `_gfortran_copy_string'
```

-L<path_to_gfortran_lib> -lgfortran