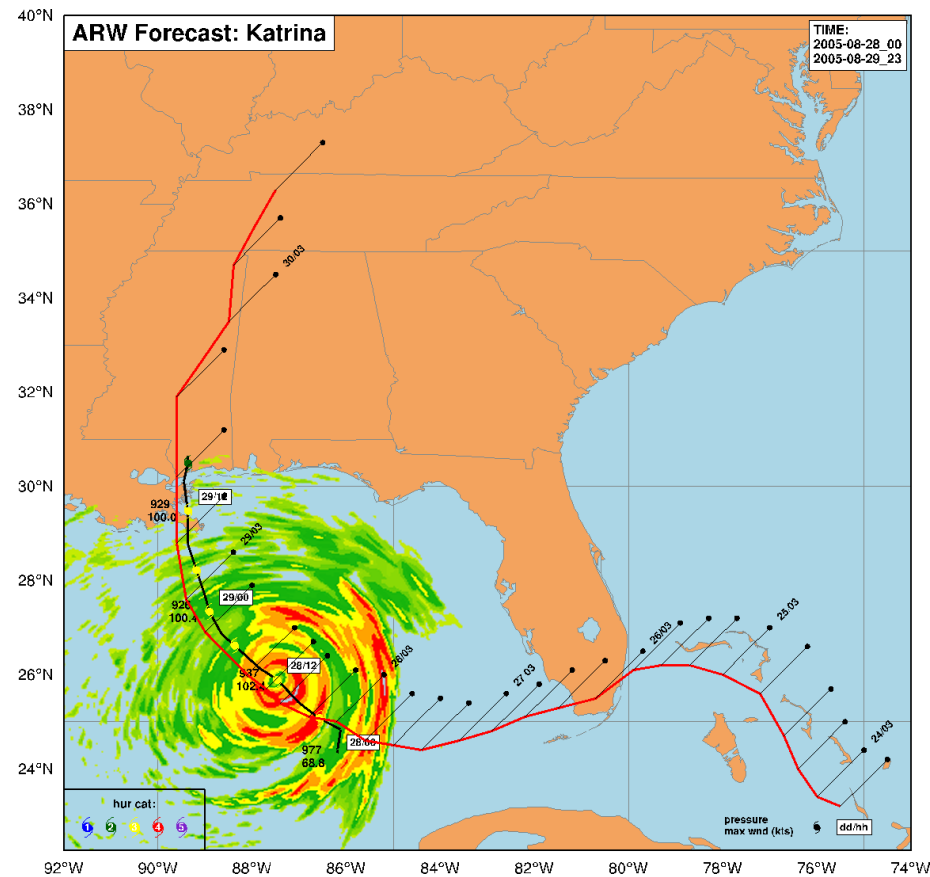


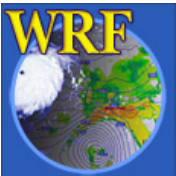
Post-processing Tools

Cindy Bruyère

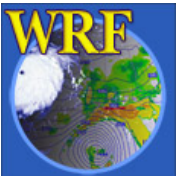
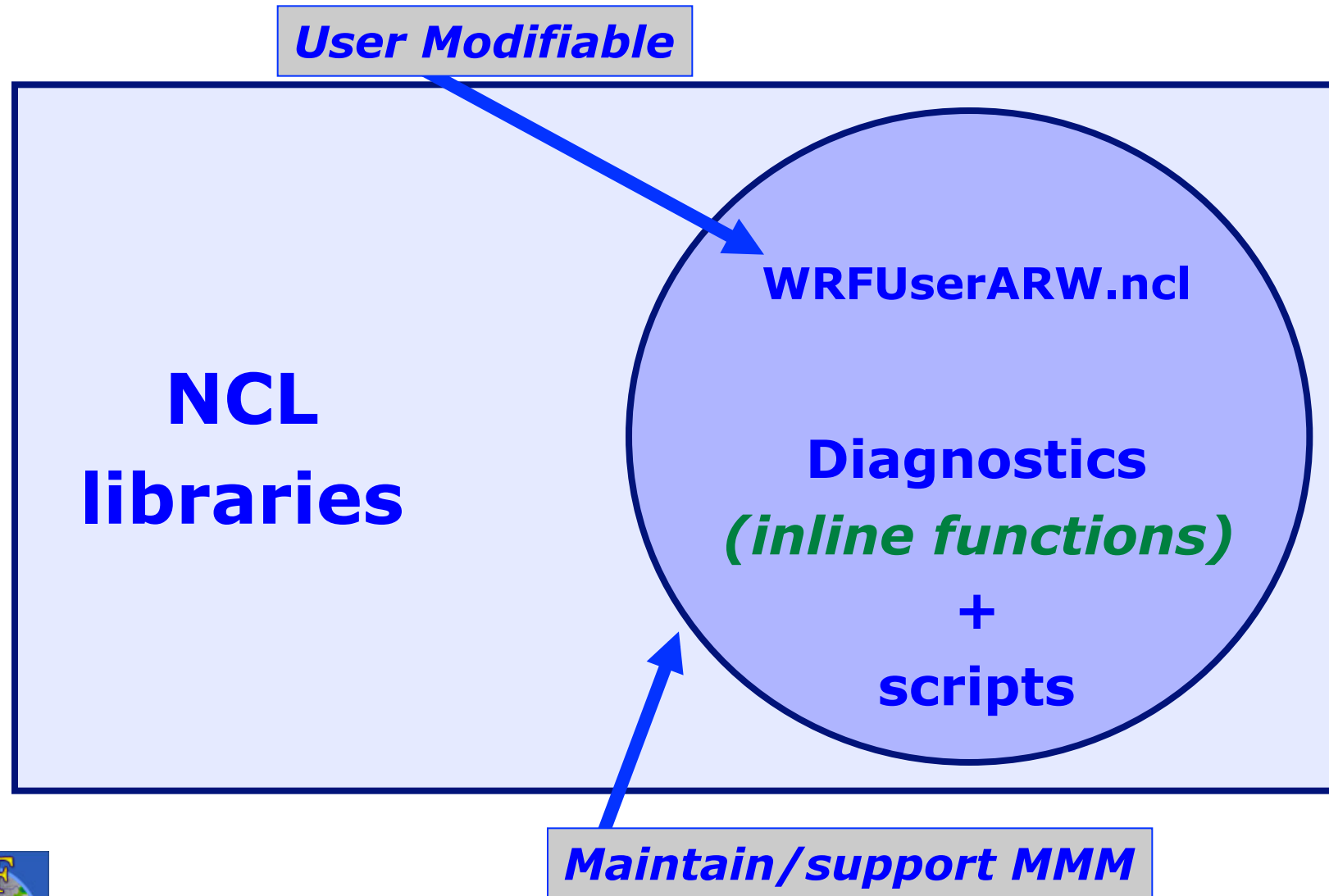


NCL

- 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



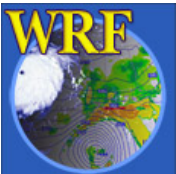
Home Directory



~/.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

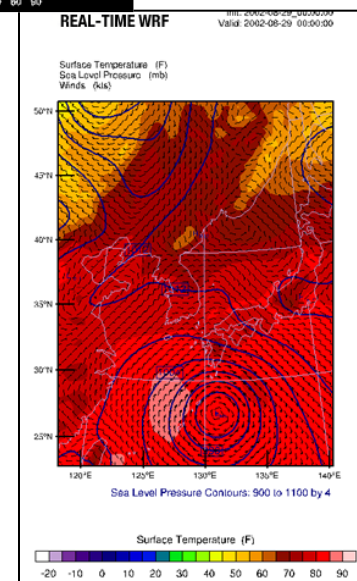
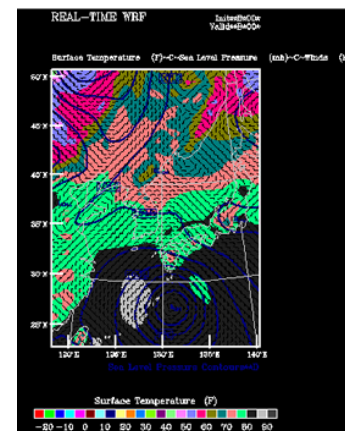
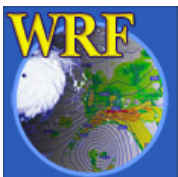


~/.hluresfile

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

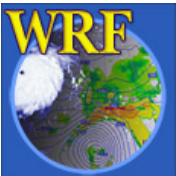
```
PLCHHQ - CHARACTER NUMBER 26 (.) IS NOT A LEGAL FUNCTION CODE
PLCHHQ - CHARACTER NUMBER 29 (t) IS NOT A LEGAL FUNCTION CODE
PLCHHQ - CHARACTER NUMBER 30 (o) IS NOT A LEGAL FUNCTION CODE
PLCHHQ - CHARACTER NUMBER 32 (.) IS NOT A LEGAL FUNCTION CODE
PLCHHQ - CHARACTER NUMBER 35 (b) IS NOT A LEGAL FUNCTION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

[http://www.mmm.ucar.edu/wrf/
OnLineTutorial/Graphics/NCL/.hluresfile](http://www.mmm.ucar.edu/wrf/OnLineTutorial/Graphics/NCL/.hluresfile)

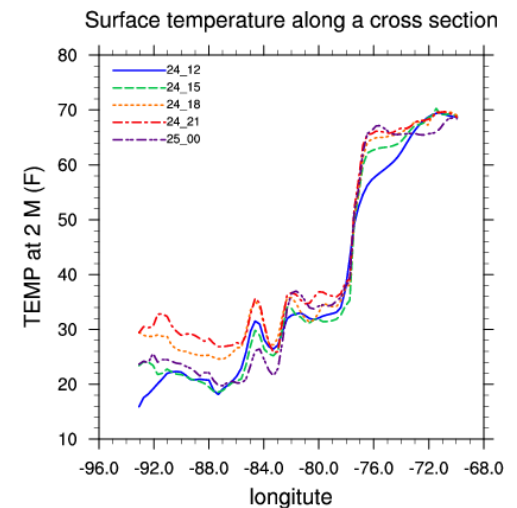
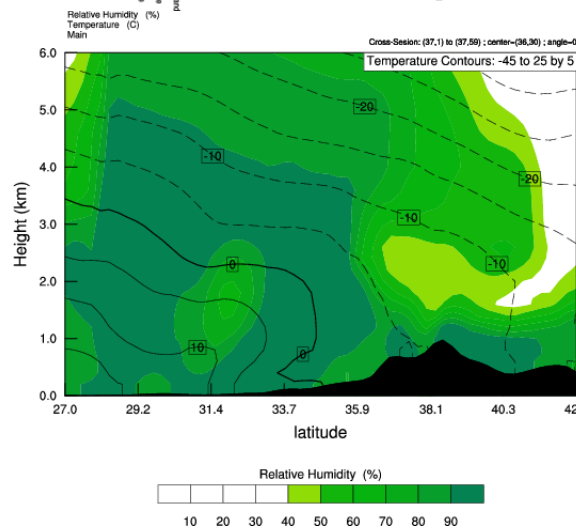
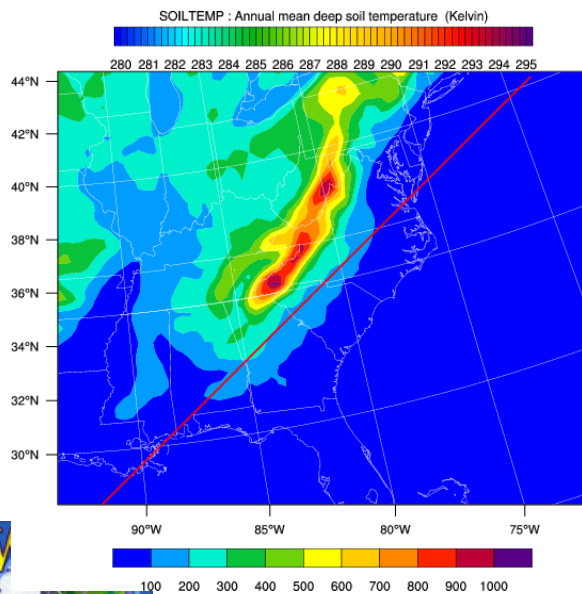


Generate Plots with NCL

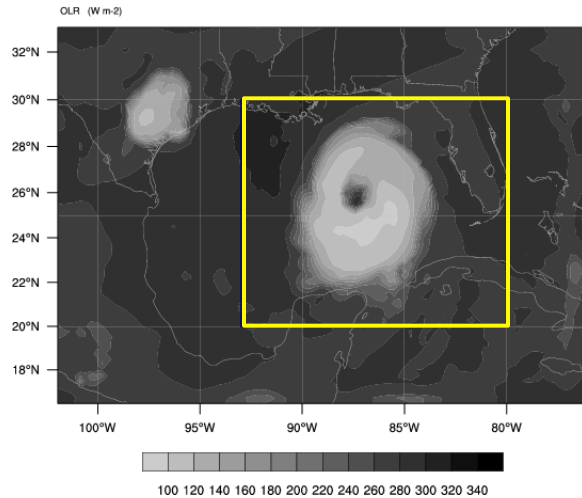
- Set NCARG_ROOT environment variable:
 - `setenv NCARG_ROOT /usr/local/ncl`
- Ensure you have an `~/.hluresfile` file
- Create a script
 - `wrf_real.ncl`
(start with a sample script)
Most of the WRF script routines are called from
`"$NCARG_ROOT/lib/ncarg/nclscripts/wrf/WRFUserARW.ncl"`
Feel free to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



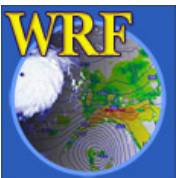
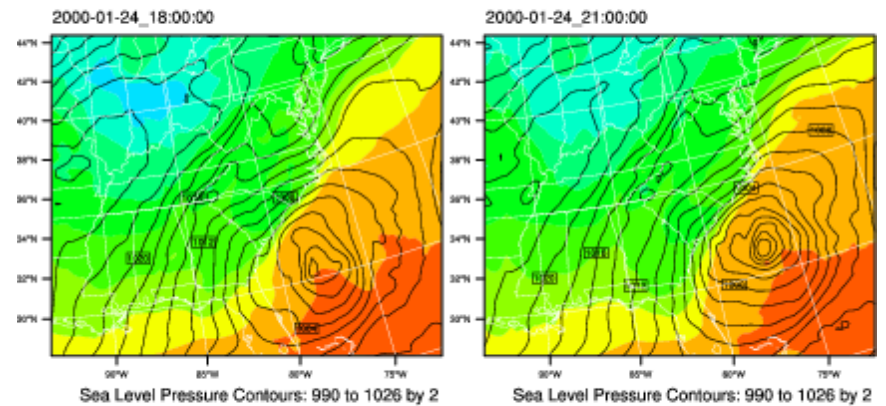
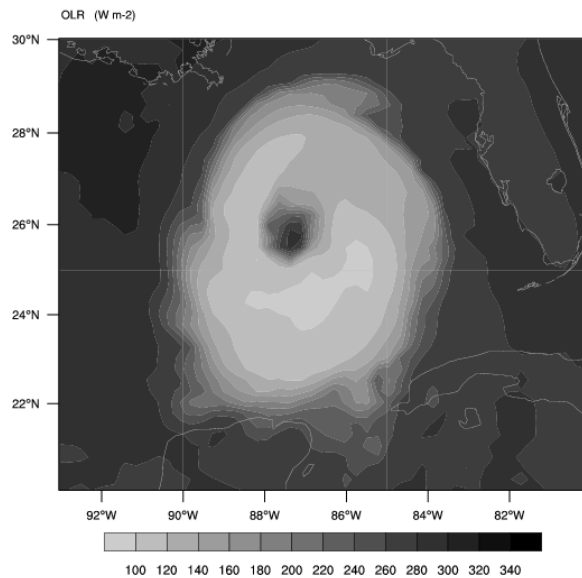
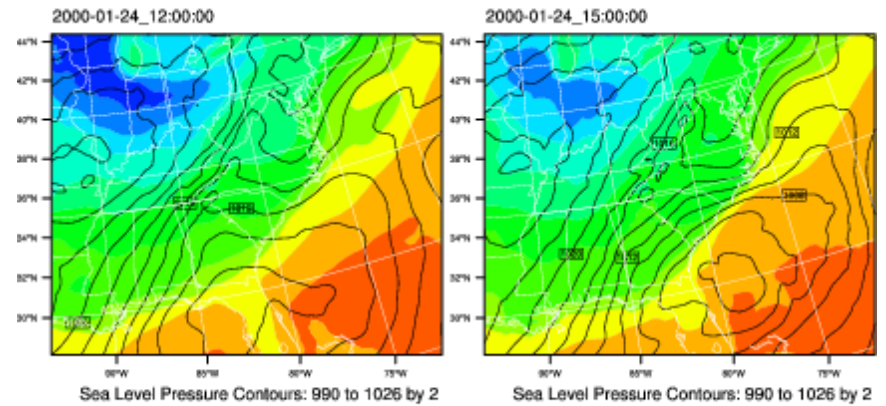
- `ncl wrf_real.ncl`



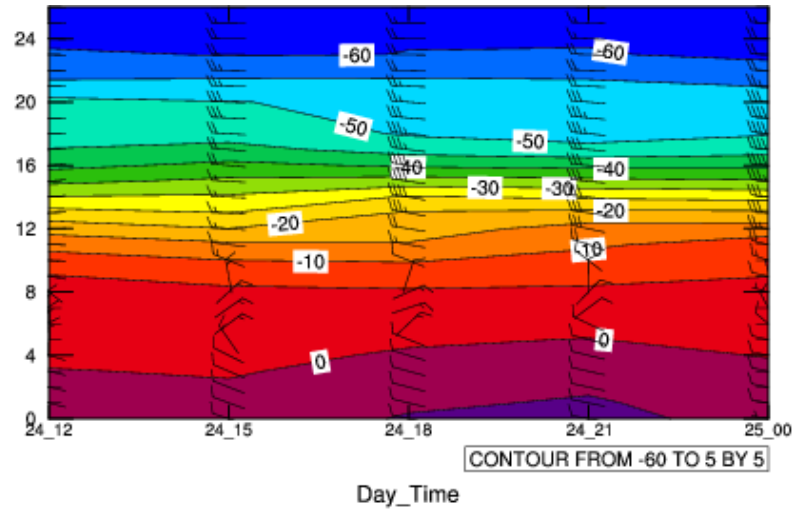
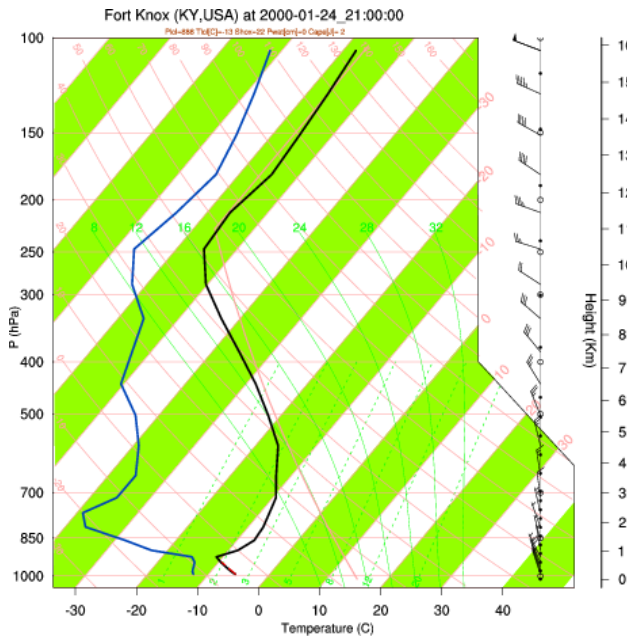
Examples



TEMP at 2 M (K)

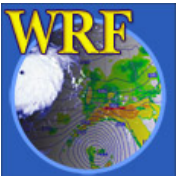
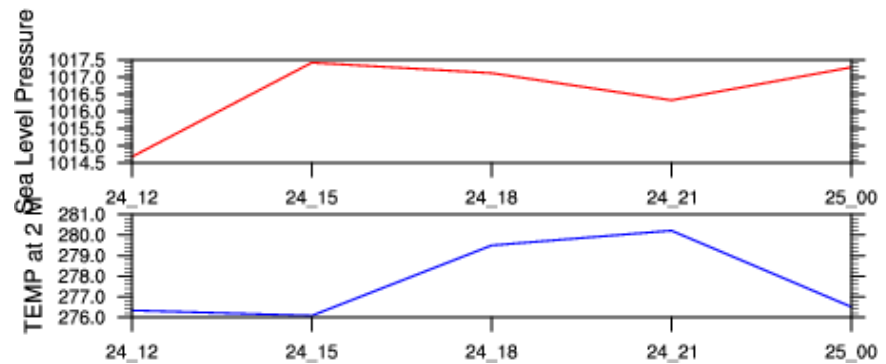
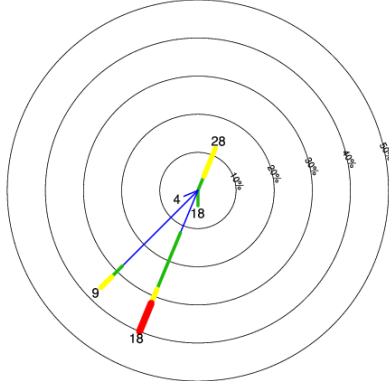


Examples

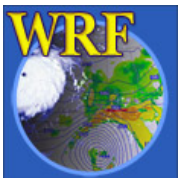
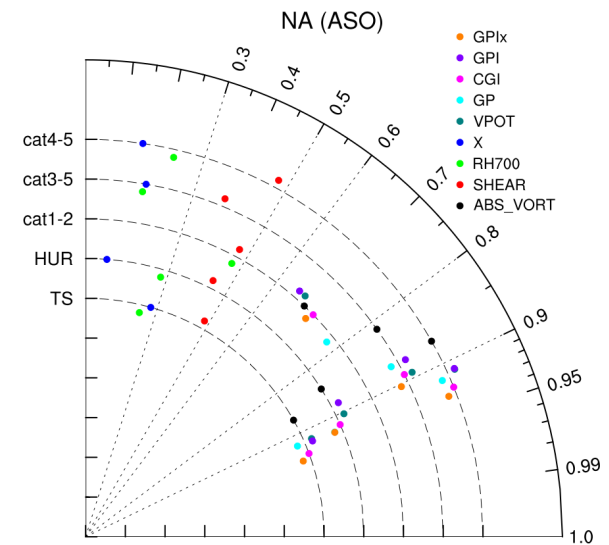
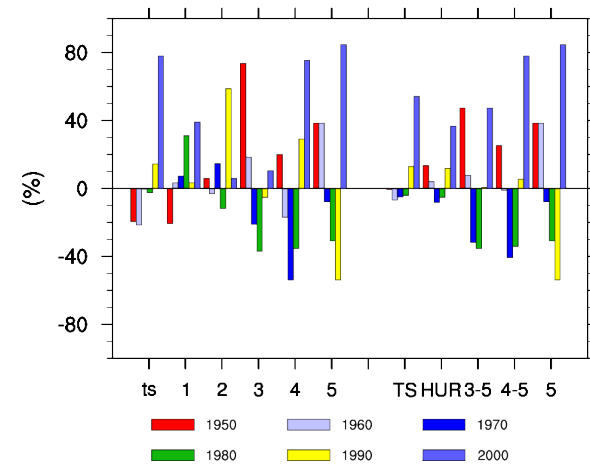
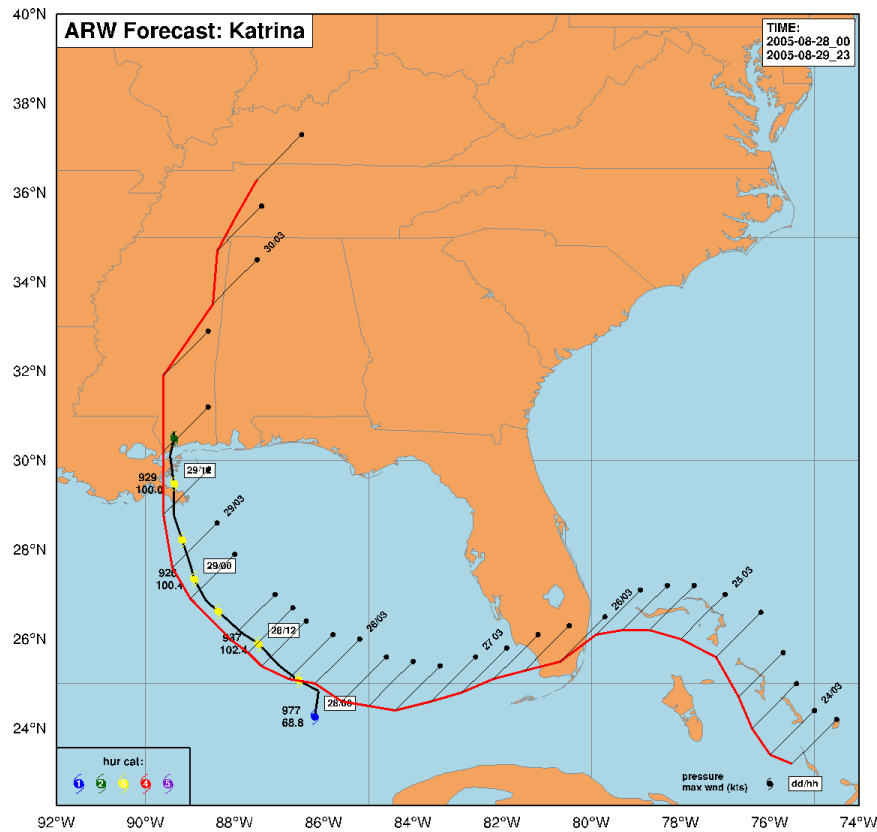


WRF: All Times: grid point [25.65 , -87.37]

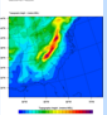
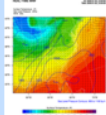
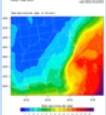
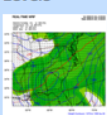
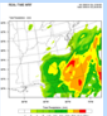
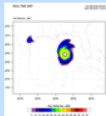
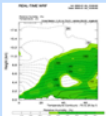
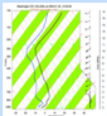
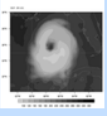
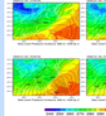
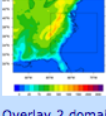
SpdAve=16 SpdStd=11 DirAve=216 No Calm Reports Nwnd=25
Frequency drops every 10%. Mean speed indicated.



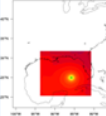
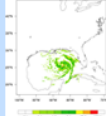
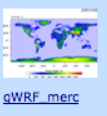
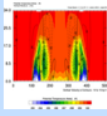
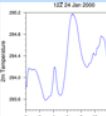
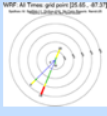
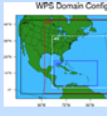
Examples

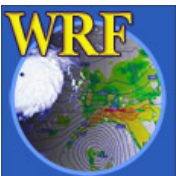


Generate Plots: *A good start - OnLine Tutorial*

Basic Plots  Basic Plot Setup <i>(This series of examples takes users through same basic steps in generating plotting scripts.)</i> 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 <i>(More diagnostics are available, shown are only some newer/special diagnostics)</i>	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	

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

Moving Nest  Moving Nest <i>Keeping a fixed background for moving nest domain</i>	Moving Nest  Precip Tendencies for a Moving Nest <i>Keeping a fixed background for moving nest domain, and plotting rainfall tendencies in the overlapping regions</i> Domain 1 and 2 Precip Tendencies on a single plot <i>(domain 2 is a moving nest)</i>	Global WRF  qWRF_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 <i>Note: This example script makes use to the WPS namelist directly</i>



Creating a Plot : NCL script

```
load ncl library scripts
```

```
begin
```

```
  ; Open input file(s)
```

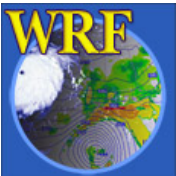
```
  ; Open graphical output
```

```
  ; 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
```

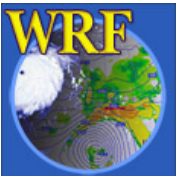
```
load "/mydir/myWRFUserARW.ncl"
```

```
; Open input file(s)  
; Open graphical output
```

```
; Read variables
```

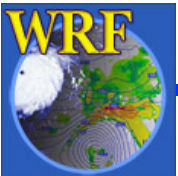
```
; Set up plot resources & Create plots  
; Output graphics
```

```
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
```



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
```

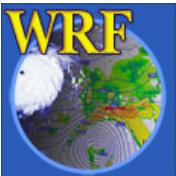
```
  ; Output graphics
```

```
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")
```

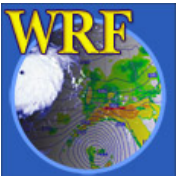
```
end
```



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")  
  
  ; 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
```

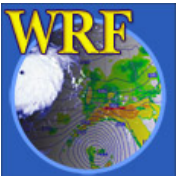
```
end
```

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

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

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

```
T2 = a->T2
```



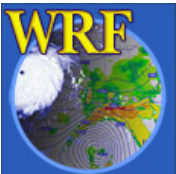
Special WRF NCL Functions

wrf_user_getvar

Get fields from input file

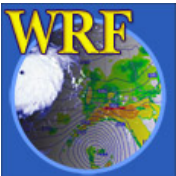
```
ter = wrf_user_getvar(a,"HGT",0)      {ter=a->HGT(0,::,:)}  
t2  = wrf_user_getvar(a,"T2",-1)     {t2=a->T2}  
slp = wrf_user_getvar(a,"slp",1)
```

avo/pvo: Absolute/Potential Vorticity, **eth**: Equivalent Potential Temperature,
cape_2d: 2D mcaps/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"

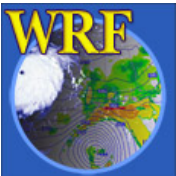
begin

  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"

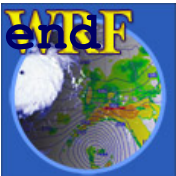
begin

  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)

end
```



Creating

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

```
begin
```

```
  a = addfile("./wrfout  
  wks = gsn_open_wks("\}
```

```
  T2 = wrf_user_getvar(
```

```
  pltres = True
```

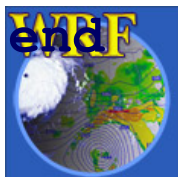
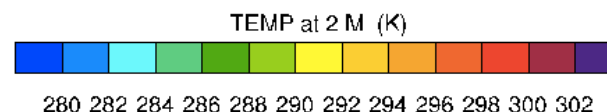
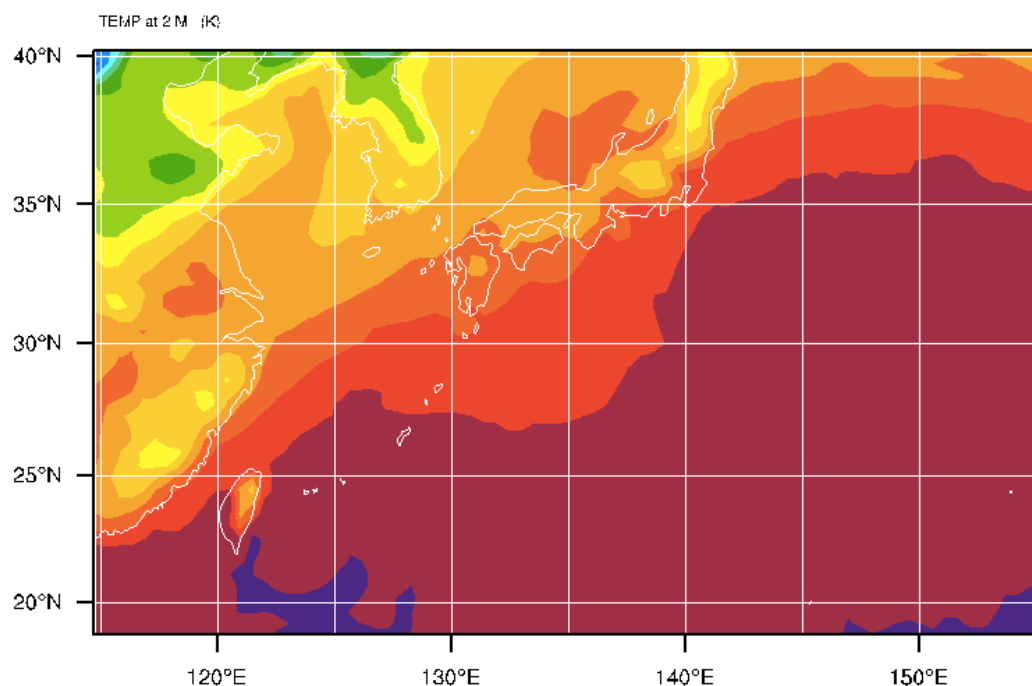
```
  mpres = True
```

```
  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

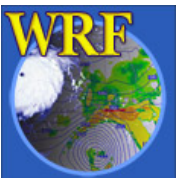
```
T2 = wrf_user_getvar(a,"T2",-1)
times = wrf_user_getvar(a,"times",-1)
ntimes = dimsizes(times)

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
```

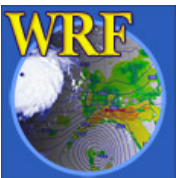


Creating a Plot : NCL script

```
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)
```

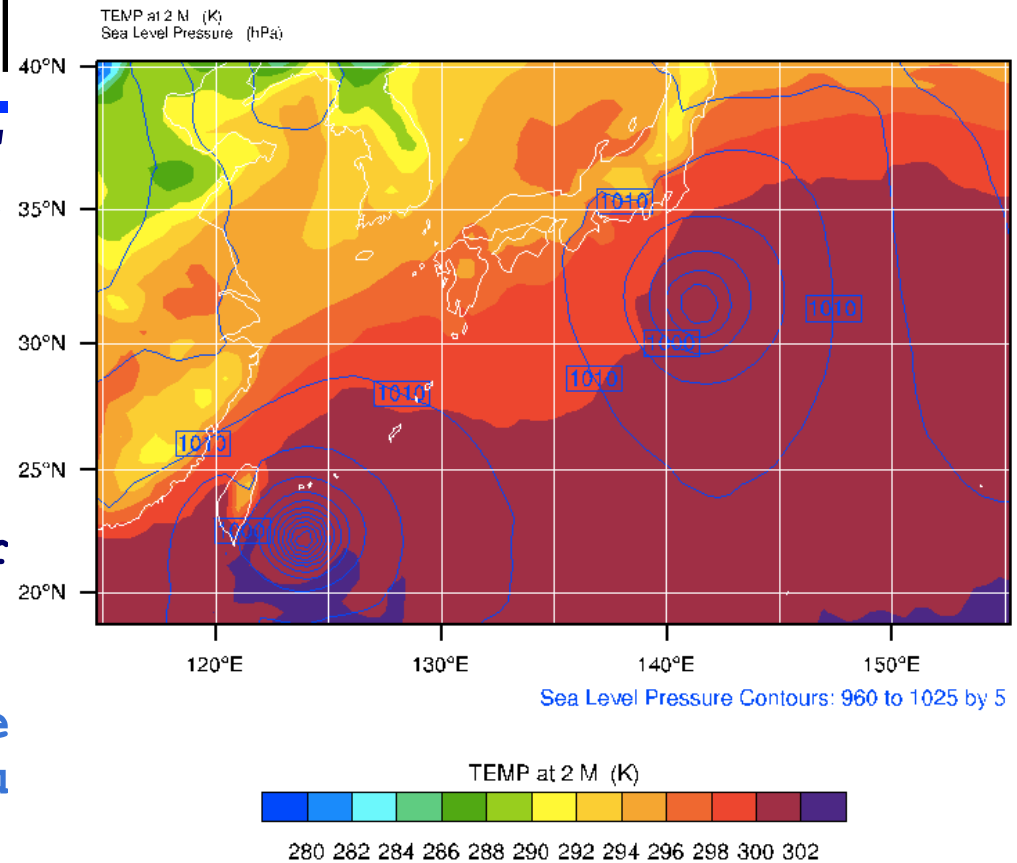
```
plot = wrf_map_overlays(a,wks, (/contour_t2,contour_slp/),
pltres,mpres)
```



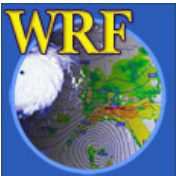
Creating a

```
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)
```

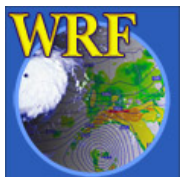
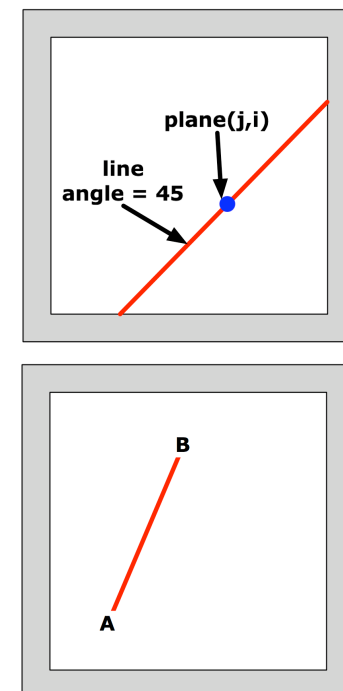


```
plot = wrf_map_overlays(a,wks, (/contour_t2,contour_slp/),
pltres,mpres)
```

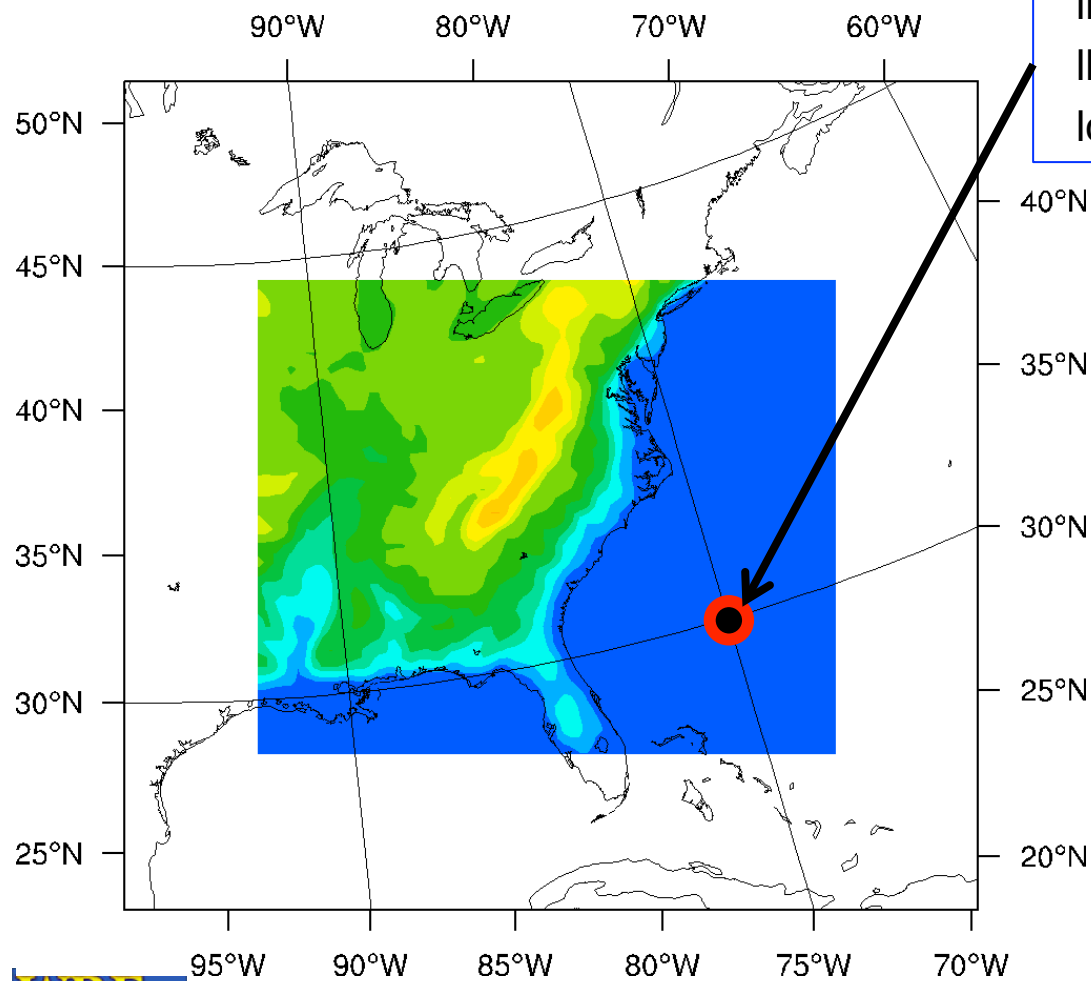


Special WRF NCL Functions

- **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**
Unstagger an array



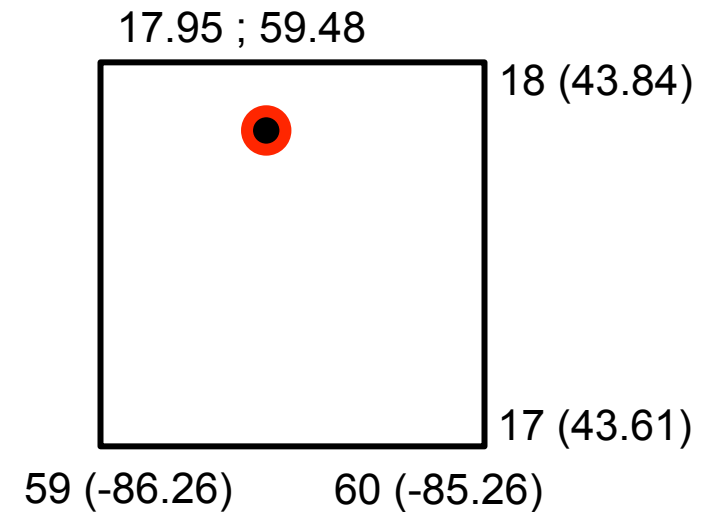
wrf_user_ll_to_ij



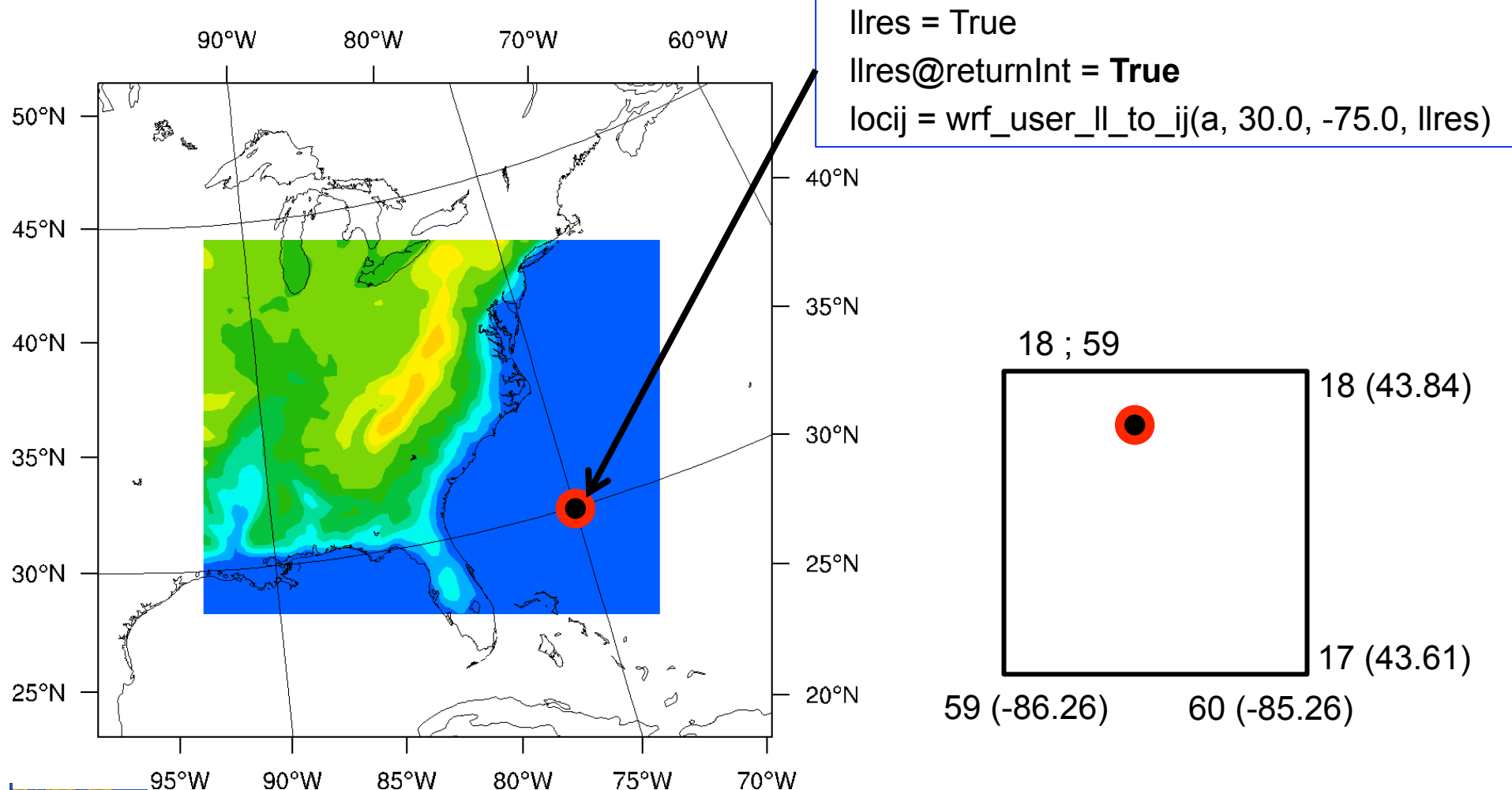
llres = True

llres@returnInt = **False**

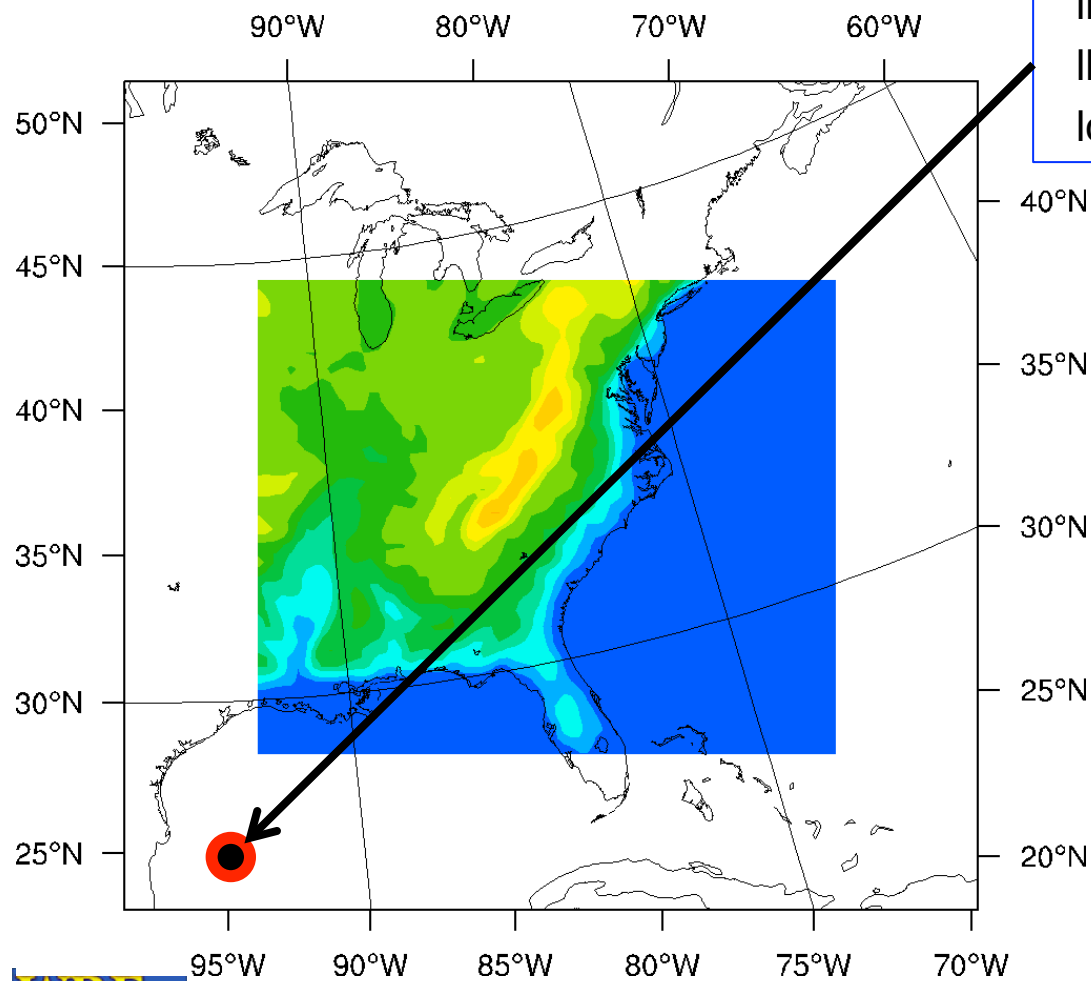
locij = wrf_user_ll_to_ij(a, 30.0, -75.0, llres)



wrf_user_ll_to_ij



wrf_user_ll_to_ij



llres = True

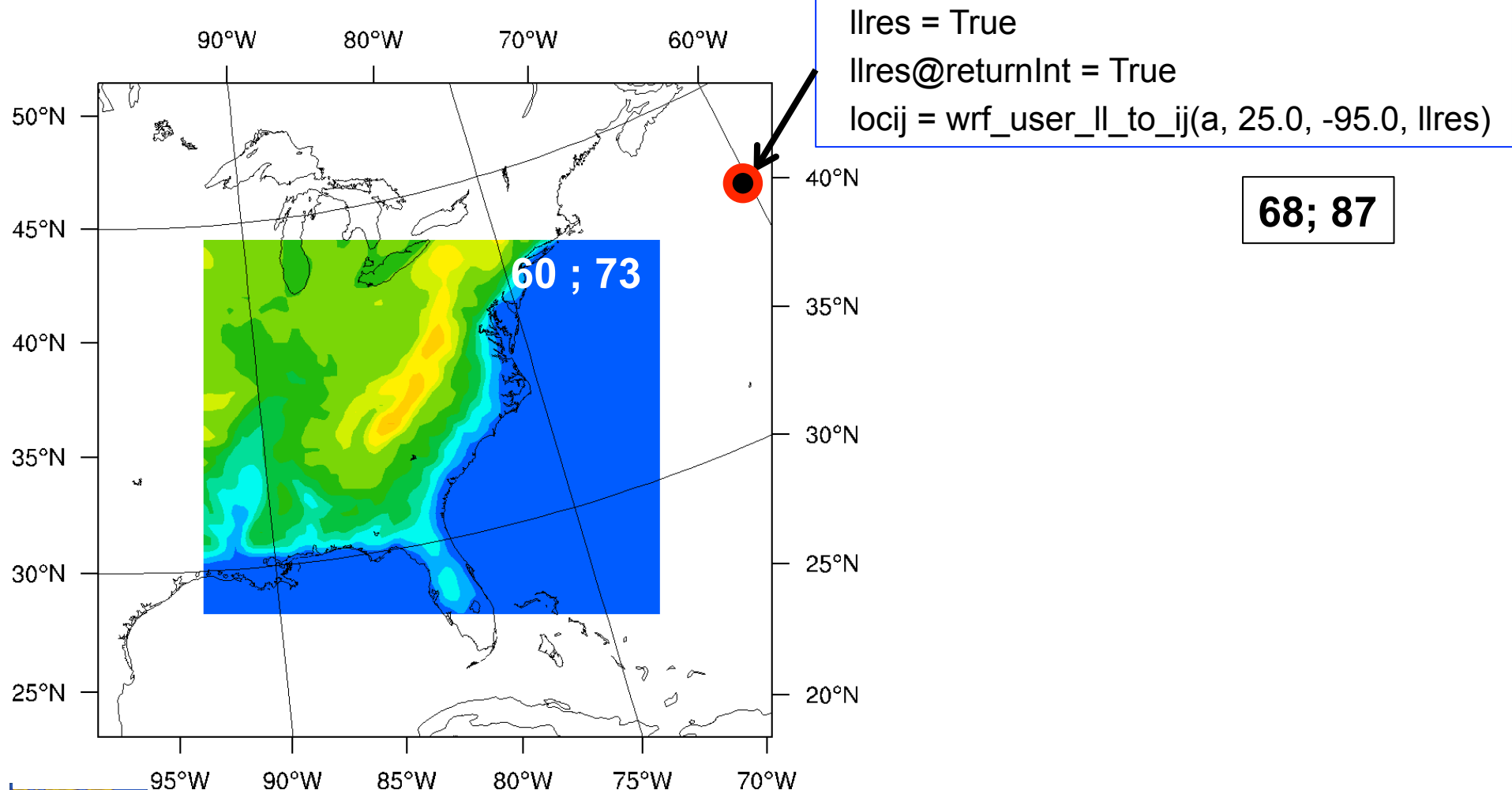
llres@returnInt = True

locij = wrf_user_ll_to_ij(a, 25.0, -95.0, llres)

-10 ; -2



wrf_user_ll_to_ij

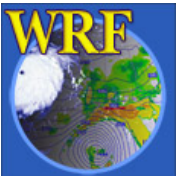
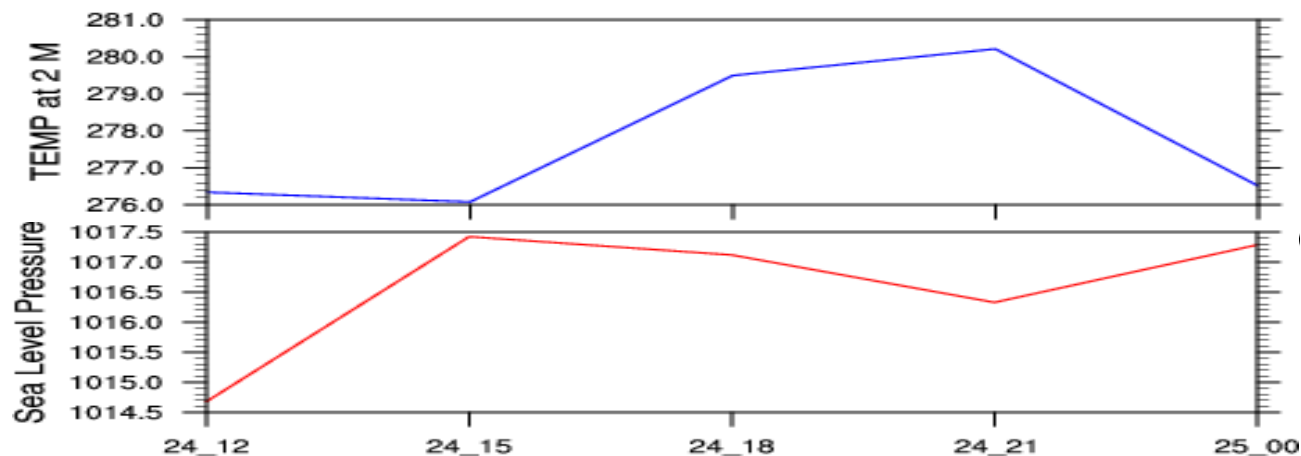


Time Series

```
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

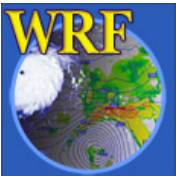
- The special WRF functions have unique resources:

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

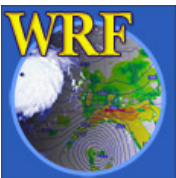
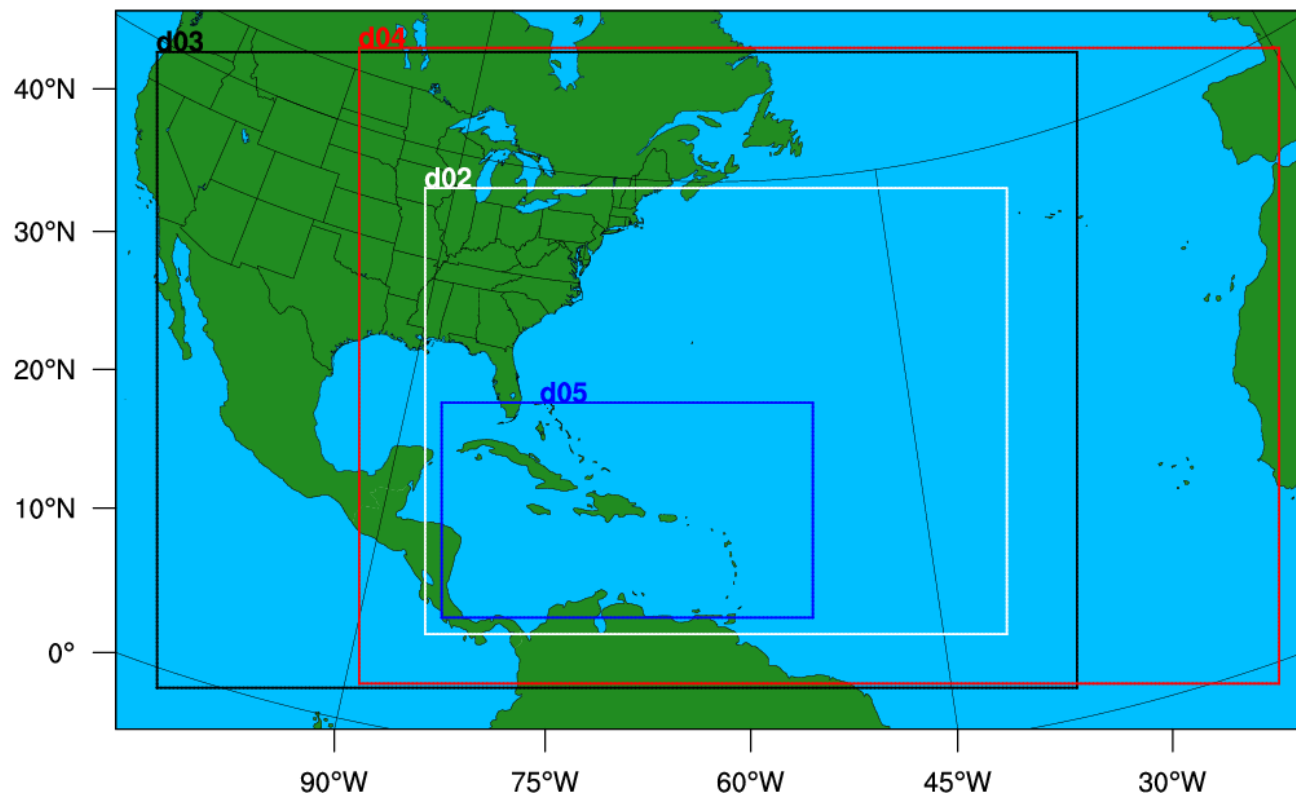


Domain Design

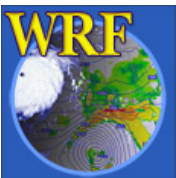
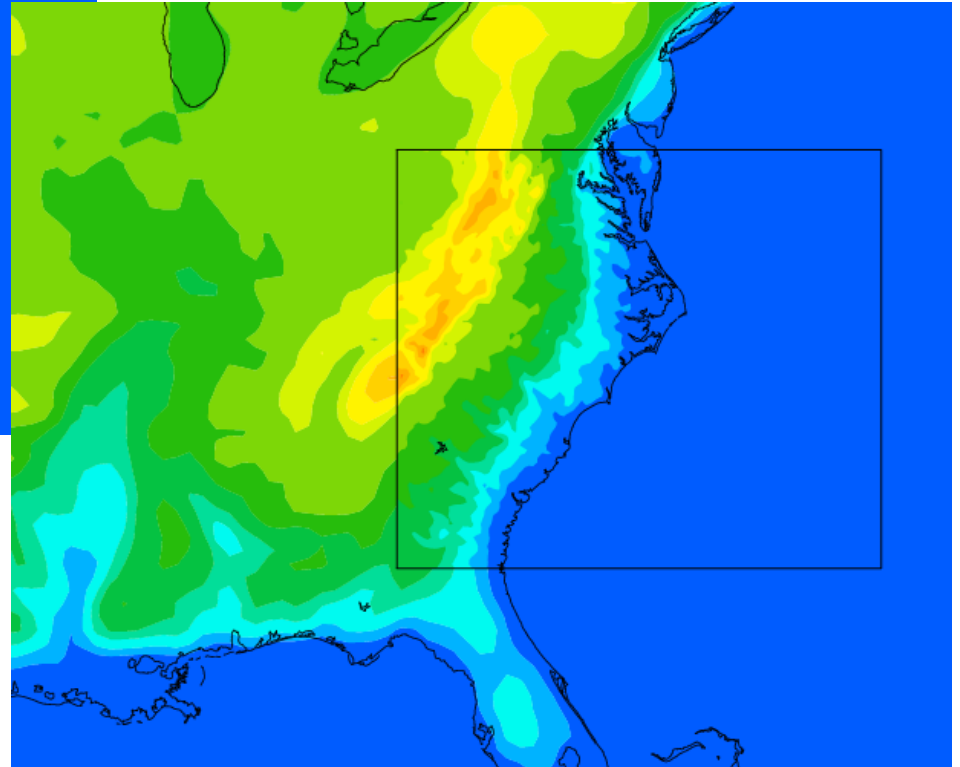
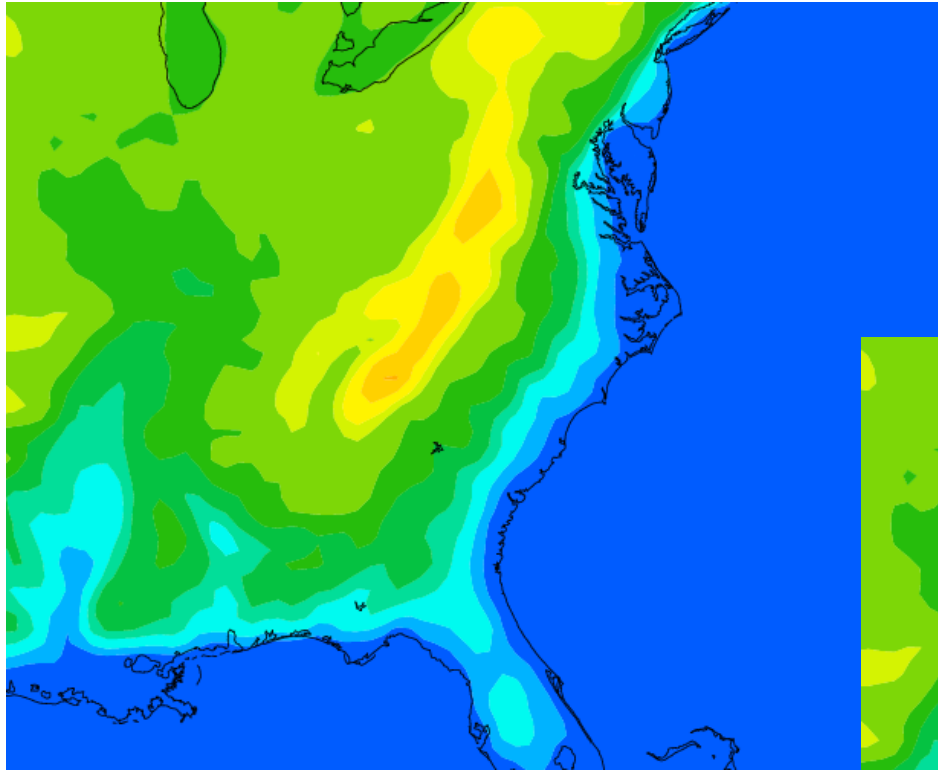
```
mp = wrf_wps_dom (wks, mpres, lnres, txres)
```

WPS/util/plotgrids.ncl

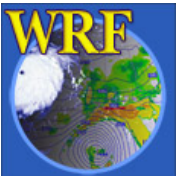
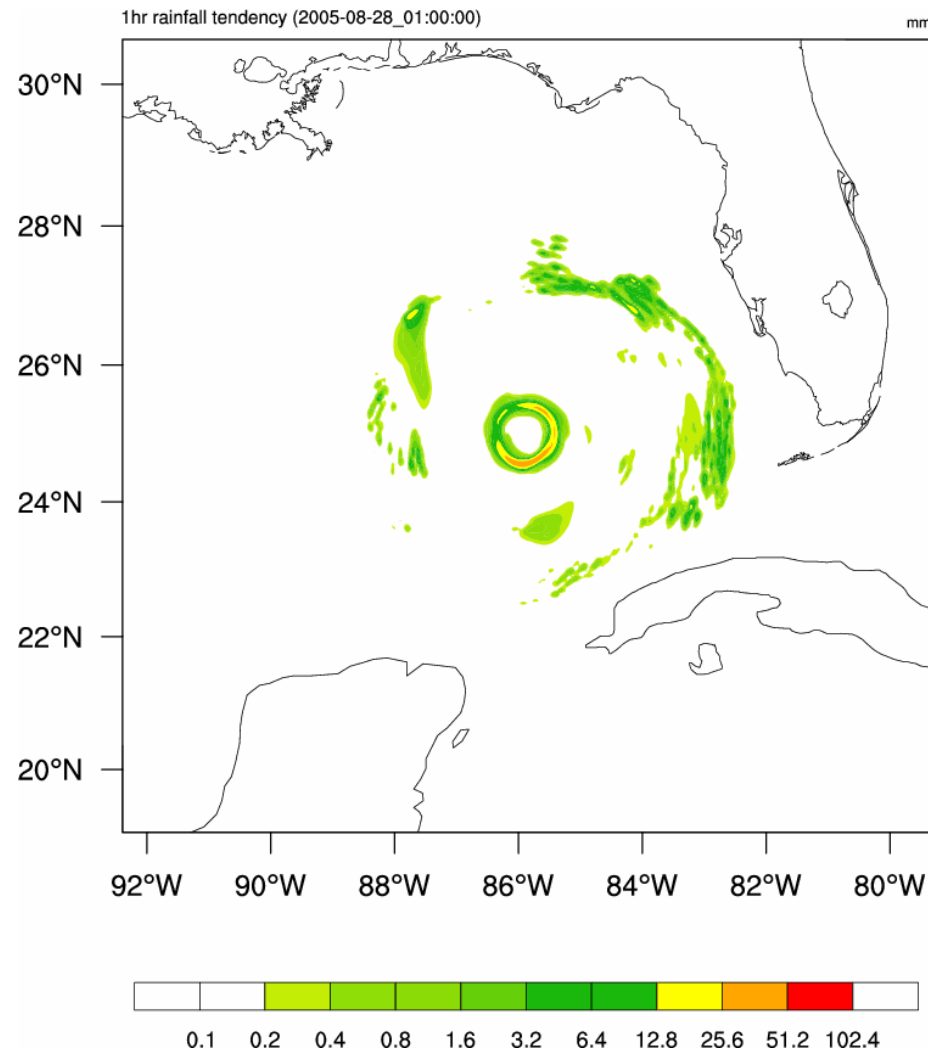
Test Domain



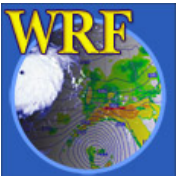
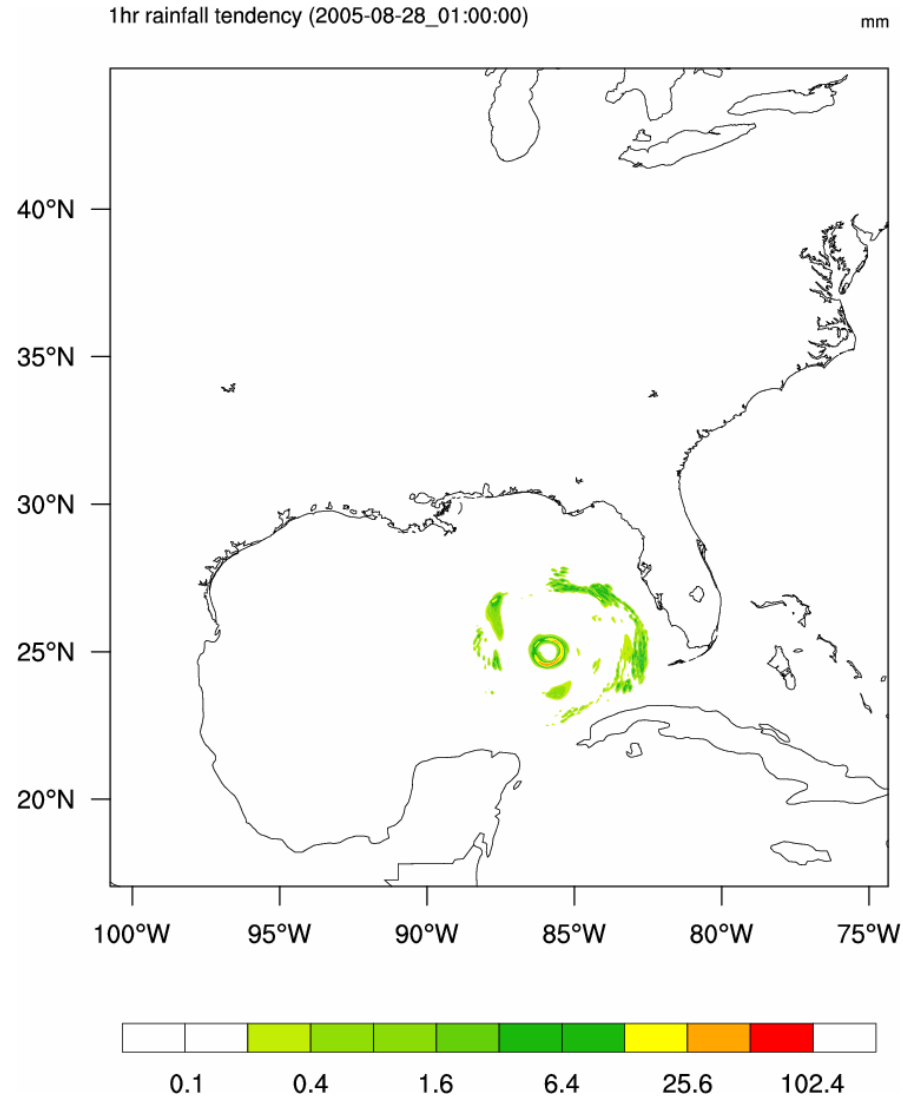
Over Domains



Moving Nests



Moving Nests



Change fields in netCDF file

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

Begin

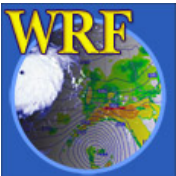
```
a = addfile("./met_em.d01.2000-01-24_12:00:00.nc","w")
```

```
sst = a->SST      ; read a field
```

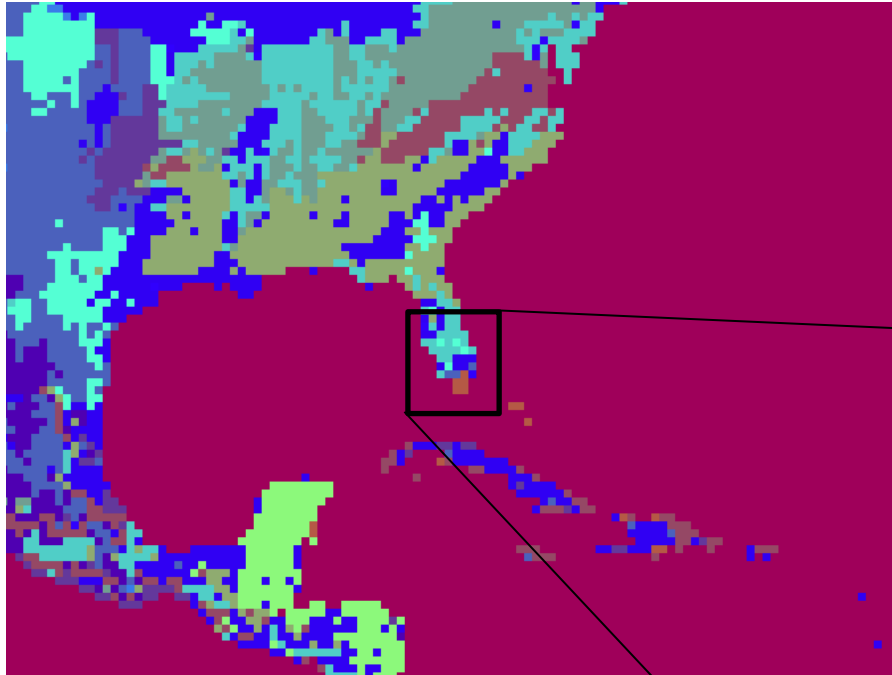
```
sst = sst + 10; change the field
```

```
a->SST = sst      ; write the field
```

end



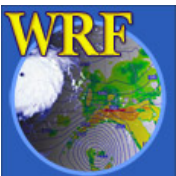
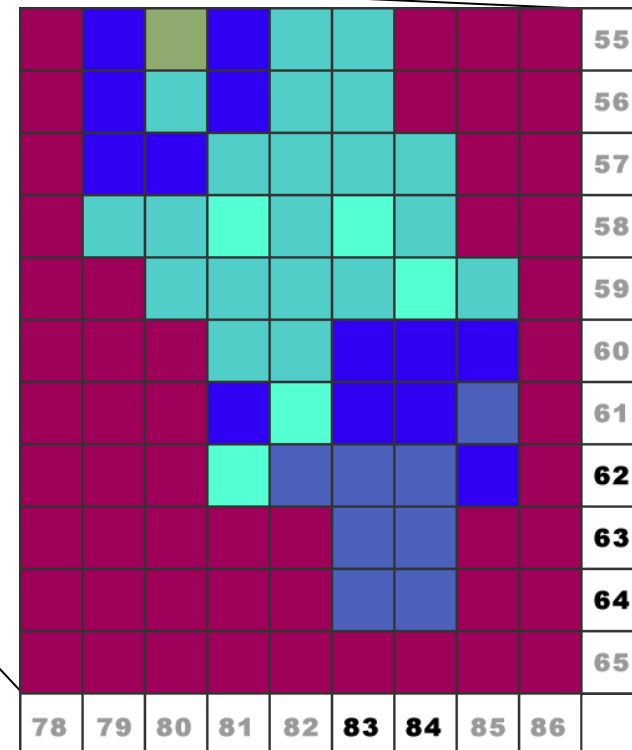
Change fields in netCDF file



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

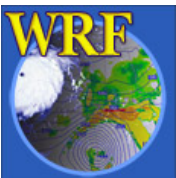
```
var(:, 63:64, 83:84) = 7  
var(:, 62, 84) = 7
```

```
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*

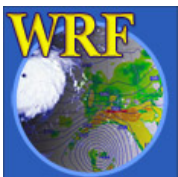


Calling FORTRAN code from NCL

- 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

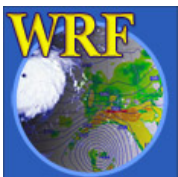
```
subroutine compute_tk (tk,pressure,theta, nx, ny, nz)
  implicit none
  integer nx,ny,nz
  real    pi, tk(nx,ny,nz)
  real    pressure(nx,ny,nz), theta(nx,ny,nz)
```

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
```

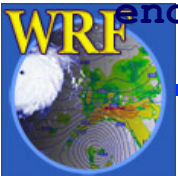
```
    dim = dimsizes(t)
```

```
    tk = new( dimsizes(t), typeof(t) )
```

```
    ; Remember, Fortran/NCL arrays are ordered differently
```

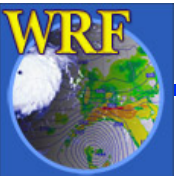
```
    myTK :: compute_tk (tk,p,t,dim(2),dim(1),dim(0))
```

```
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
```

