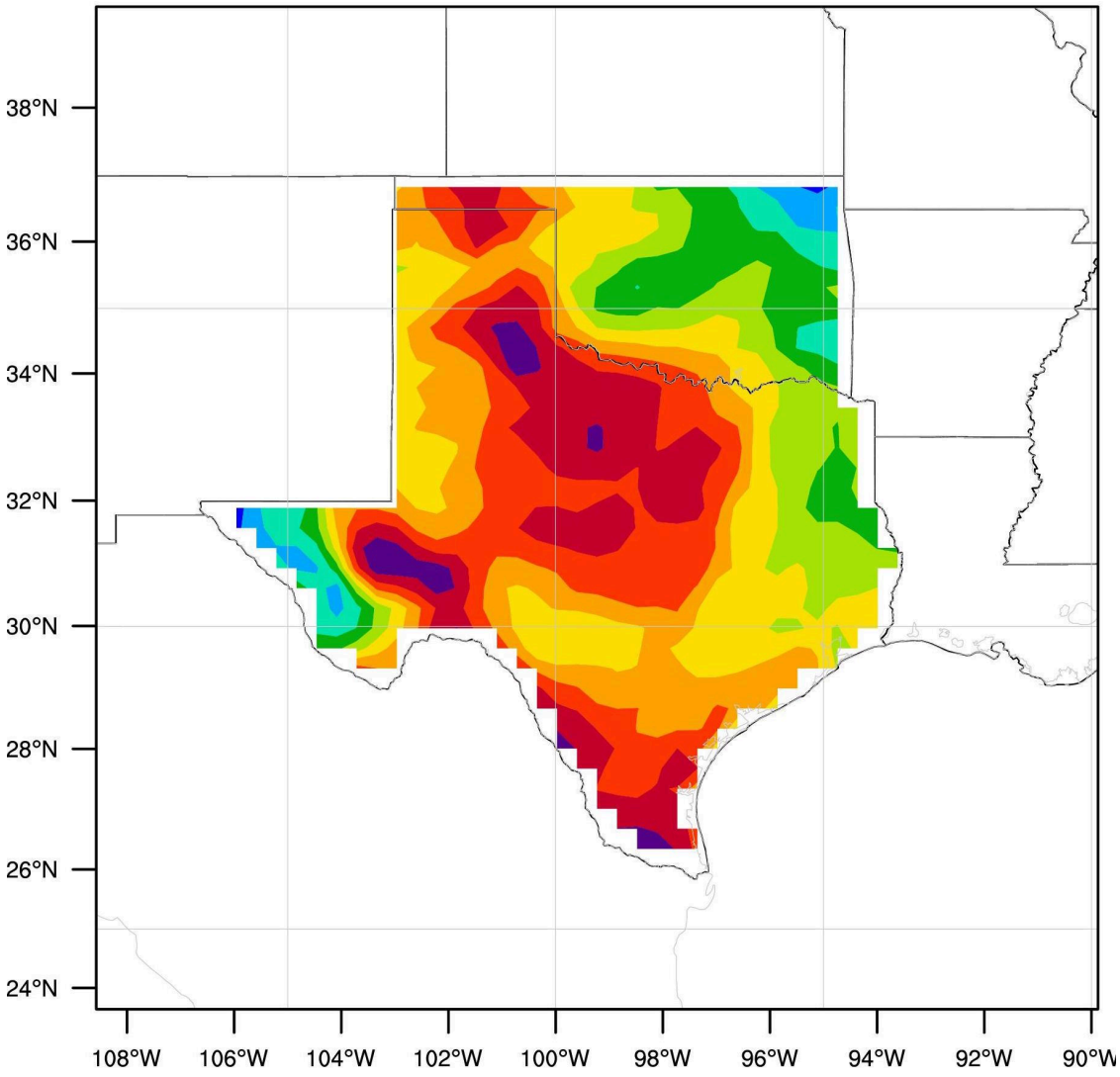
Post-processing Tools: NCL



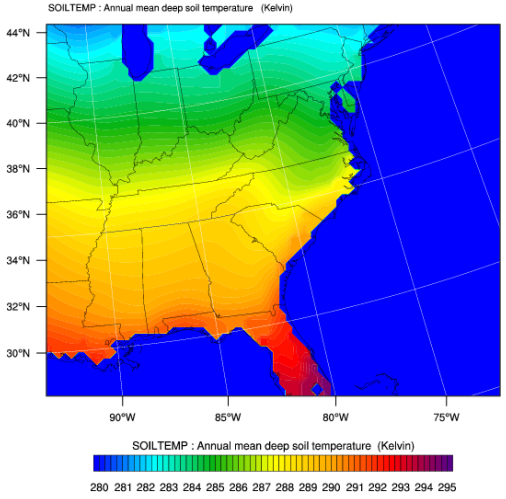
Abby Jaye

NCL

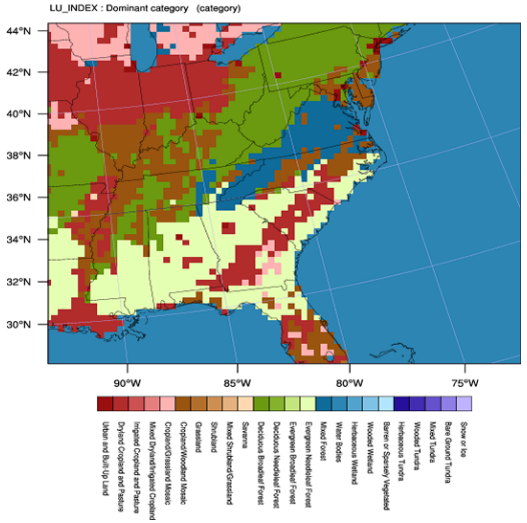
- NCAR Command Language
- Website: http://www.ncl.ucar.edu
- Reads WRF-ARW data directly
- Can generate many types of graphical plots
  - Horizontal
  - Cross-section
  - SkewT
  - Meteogram
  - Panel

Example Plots

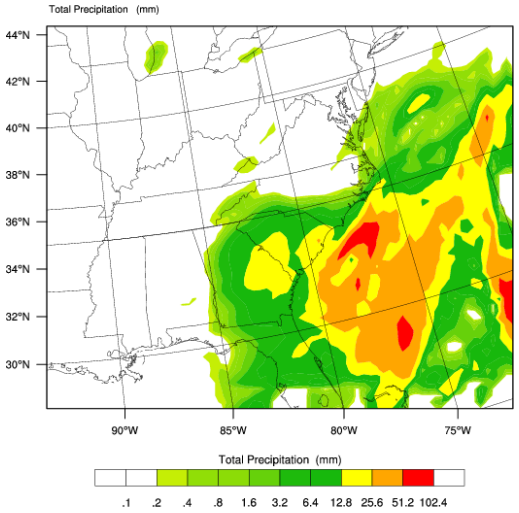
Soil Temperature



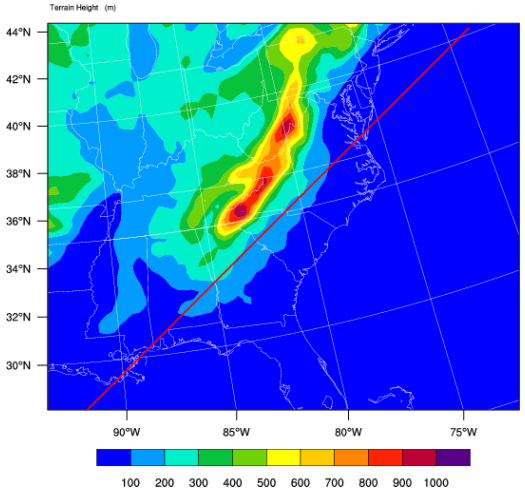
LU-INDEX



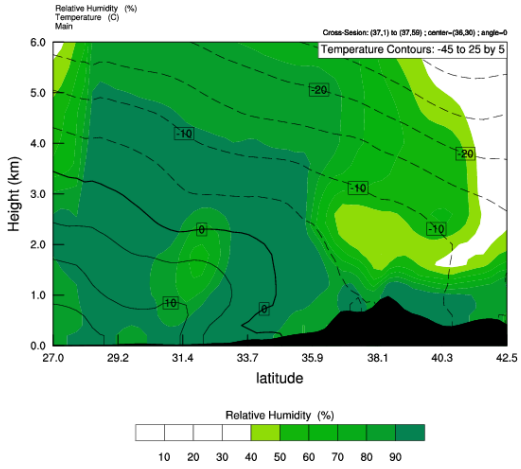
Total Precipitation



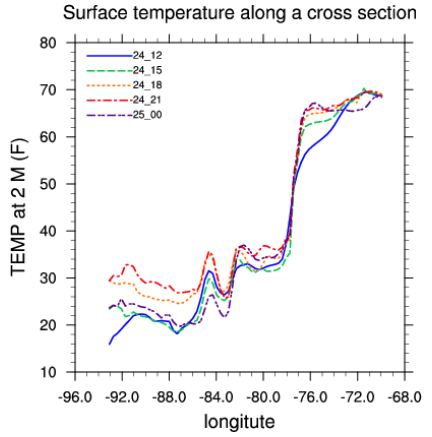
Terrain Height



Relative Humidity Vertical X-section



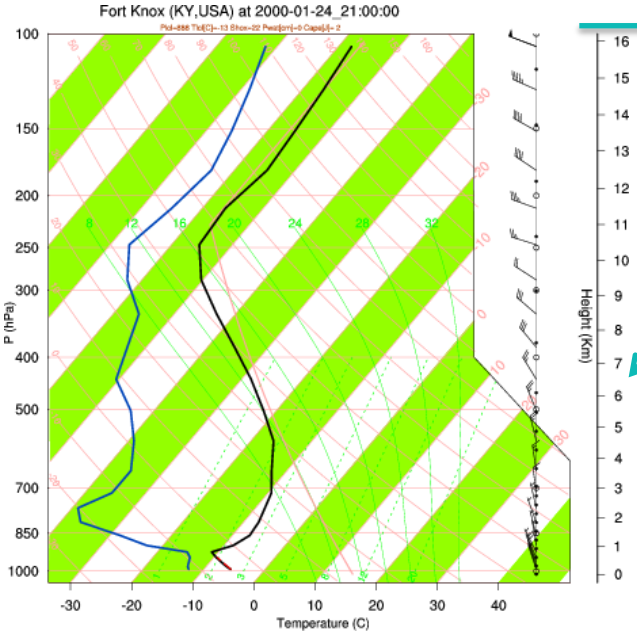
Sfc Temperature Horizontal X-section

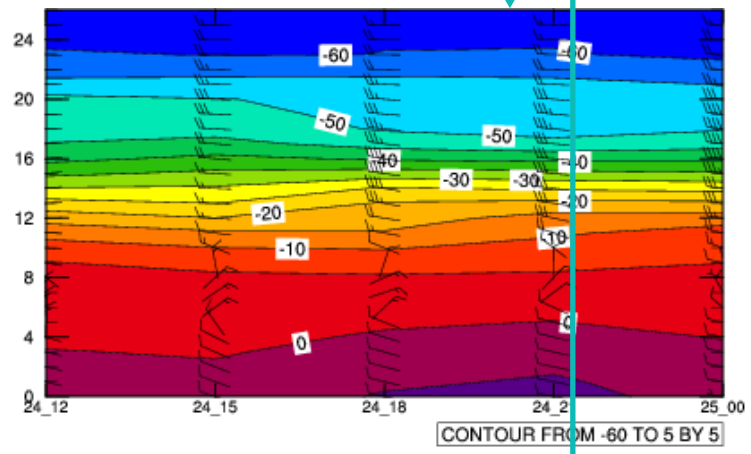


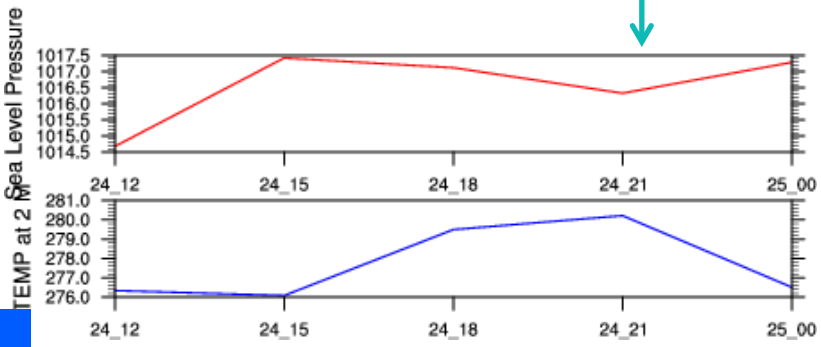
Example Plots

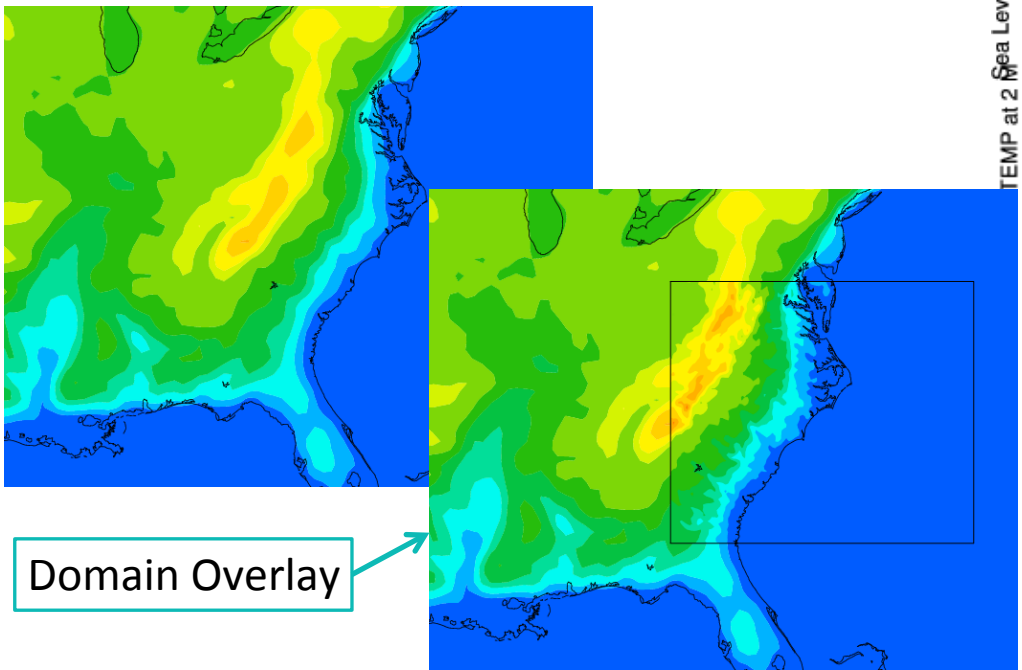
Time Series

Skew-T Diagram



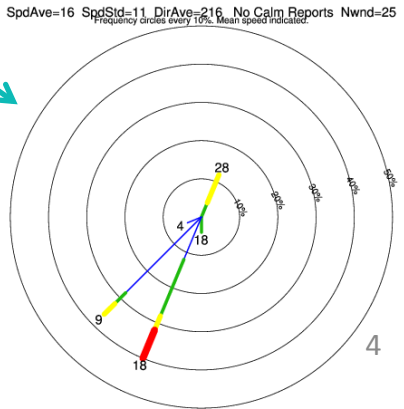






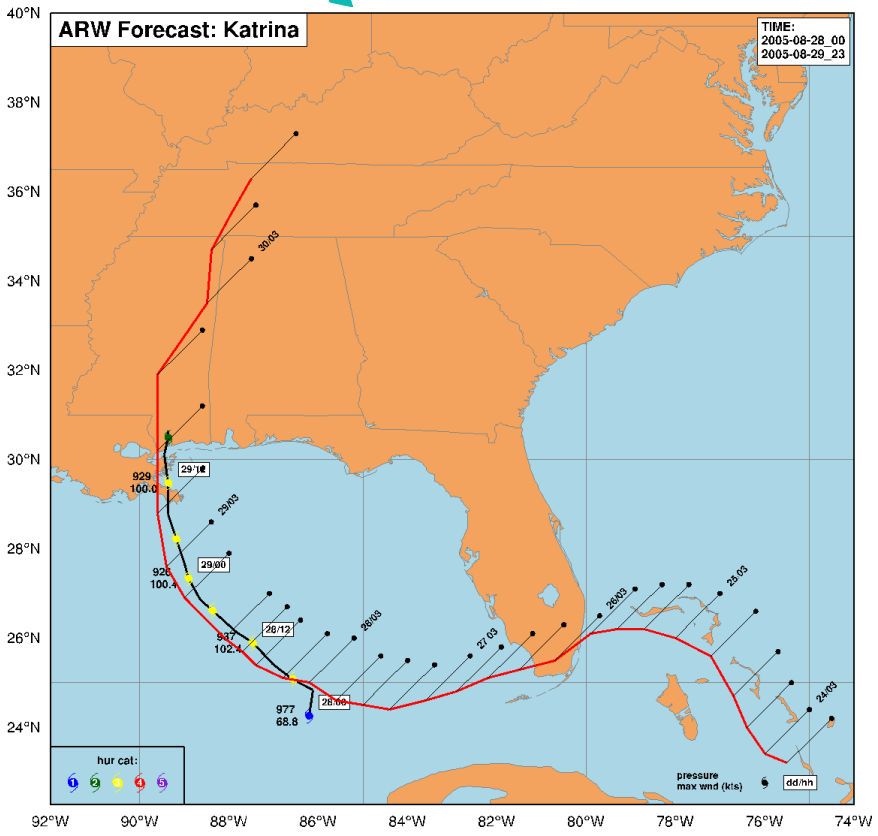
Domain Overlay

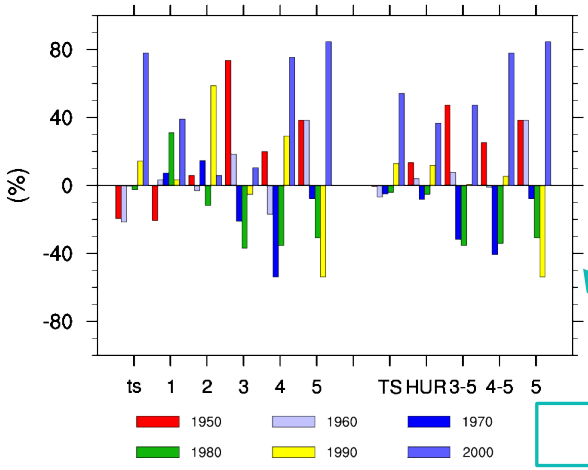
Wind Rose



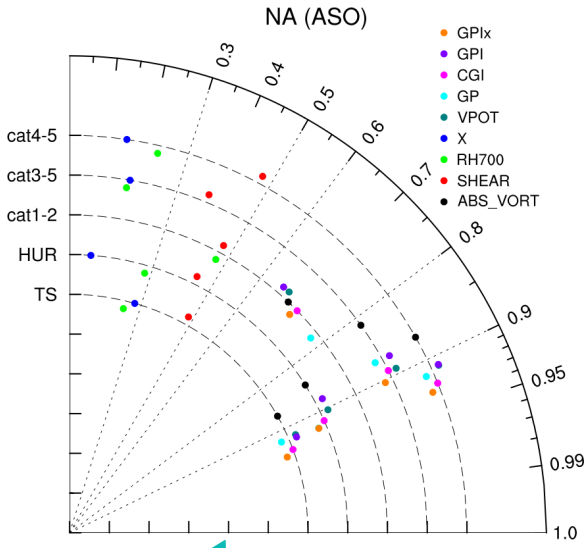
Example Plots

Storm Track





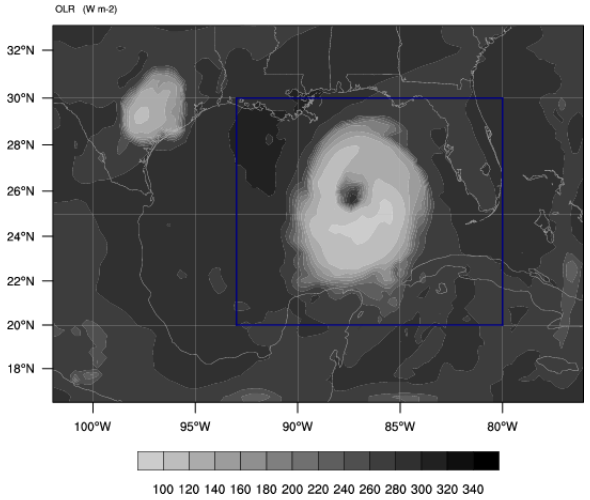
Bar Chart

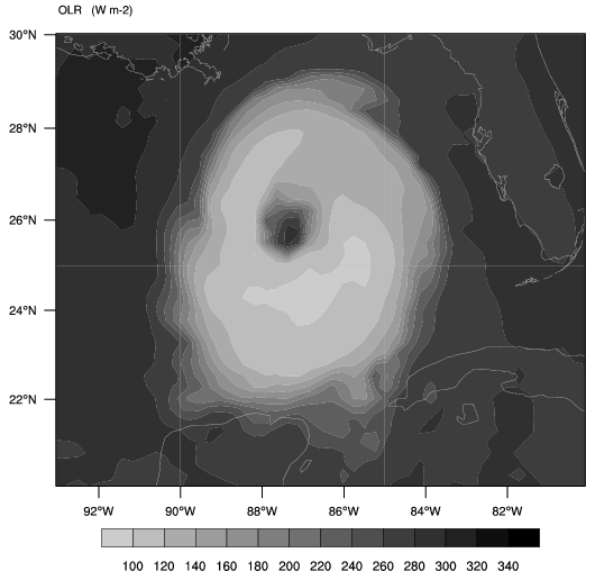


Taylor Diagram

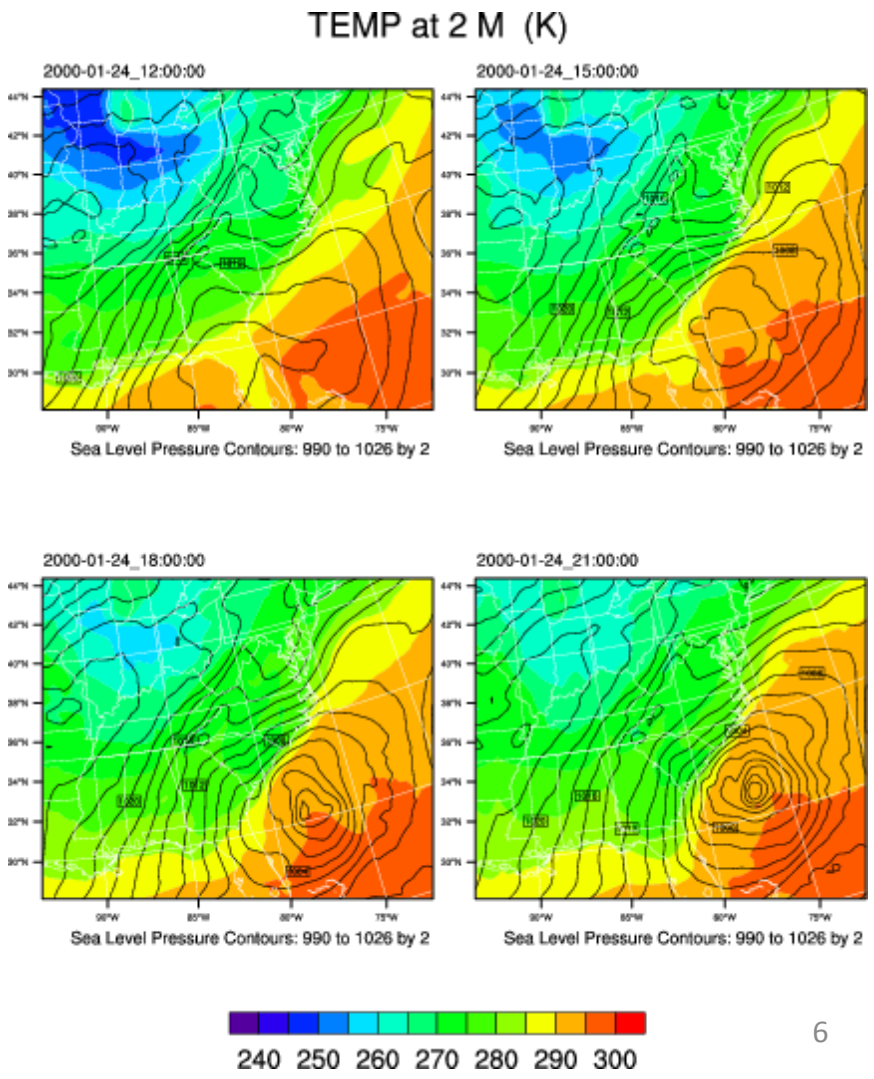
Example Plot Functions

Zooming





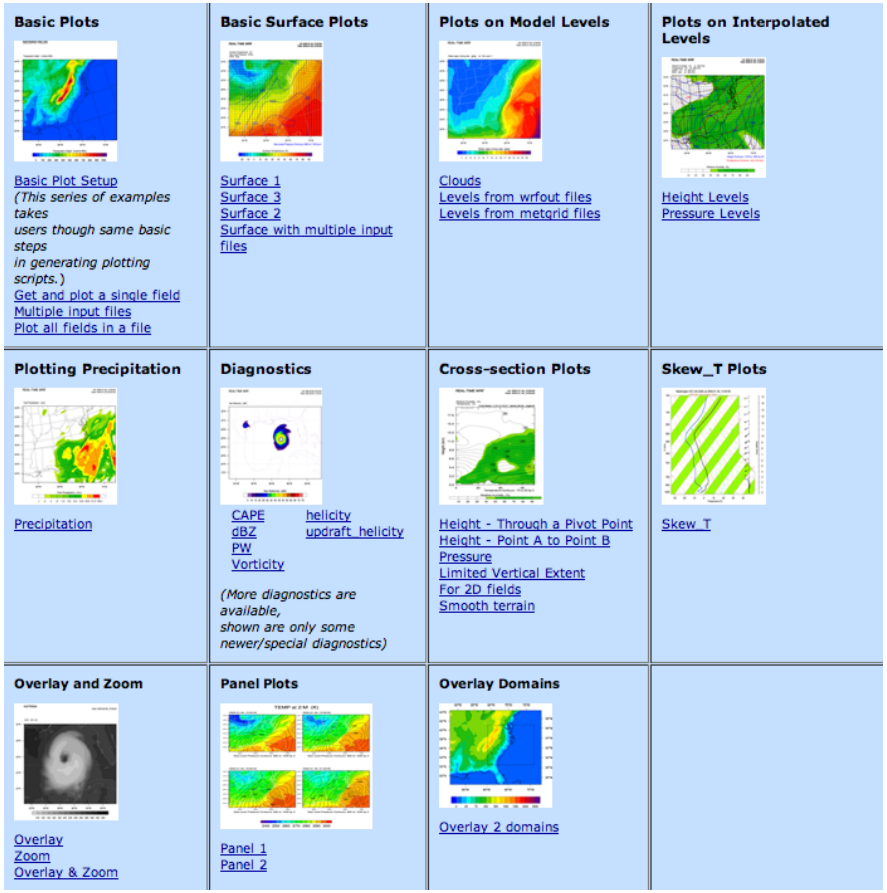
Panel Plots

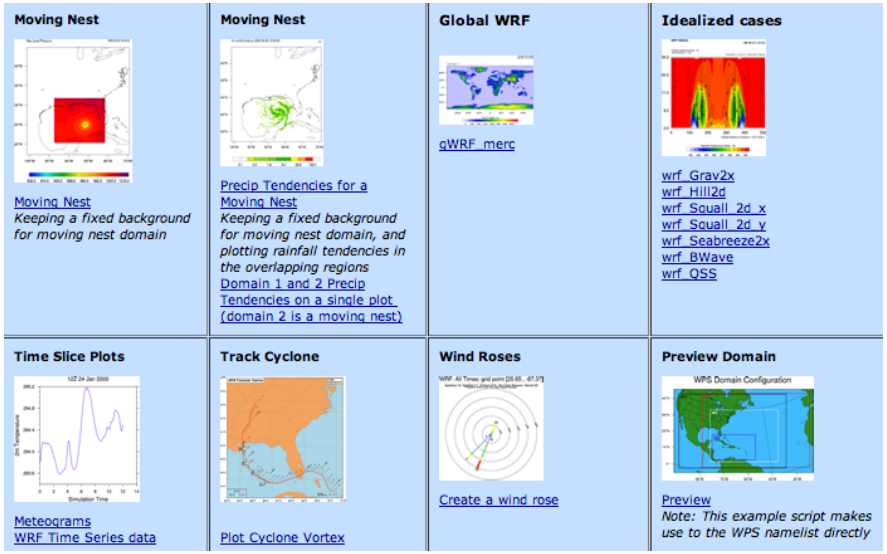


Generating Plots

A good start: WRF Online Tutorial

http://www2.mmm.ucar.edu/wrf/OnLineTutorial/Graphics/NCL/index.html





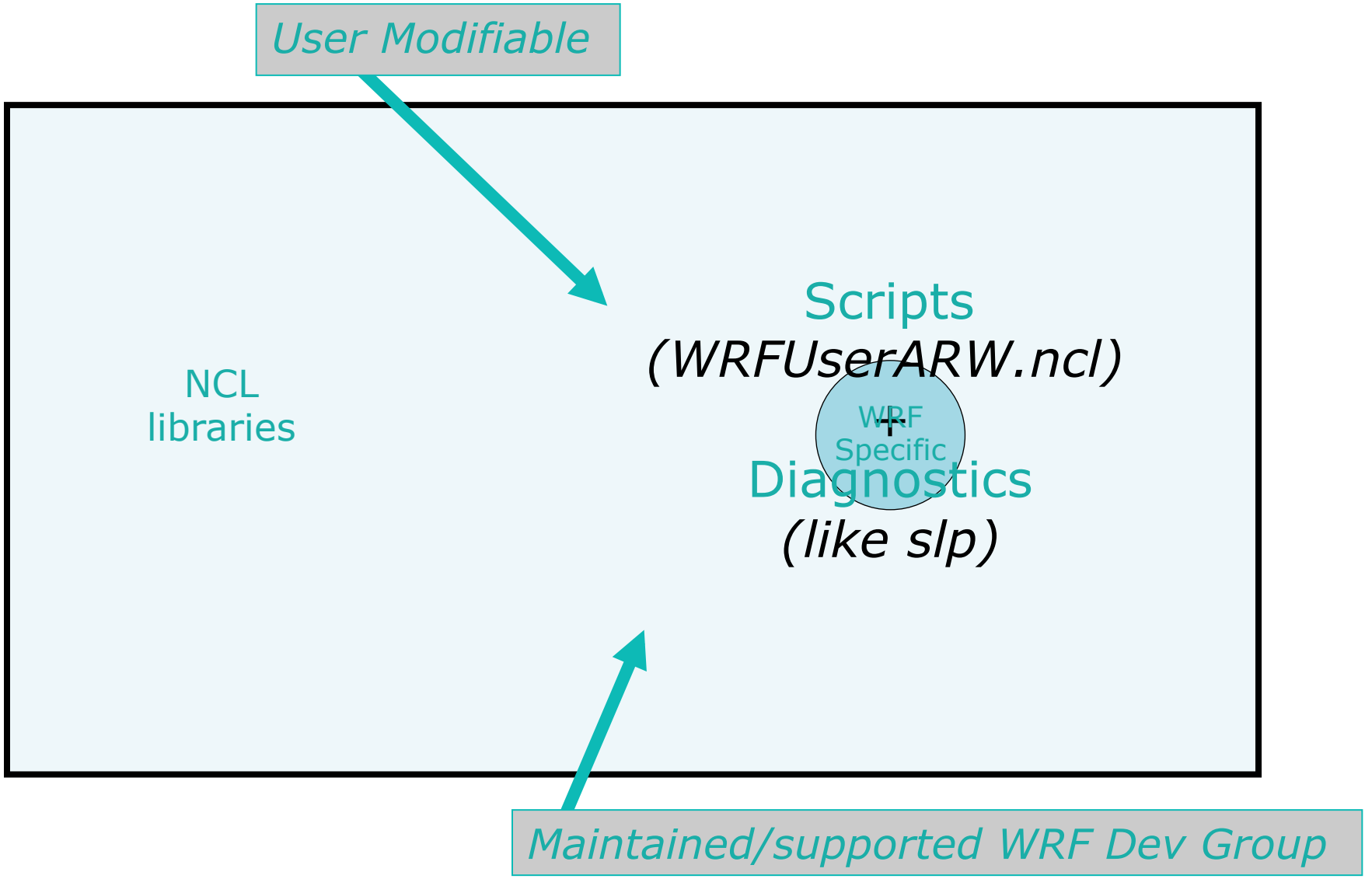
NCL Download

http://www.ncl.ucar.edu/Download

- Fill out short registration form (short waiting period)
- Read and agree to OSI-based license
- Get version 6 or LATER (current: v6.3.0)

****Always download binary code instead of source code****

NCL & WRF


User Modifiable
NCL
libraries
Scripts
(WRFUserARW.ncl)
WRF
Specific
Diagnostics
(like slp)
Maintained/supported WRF Dev Group

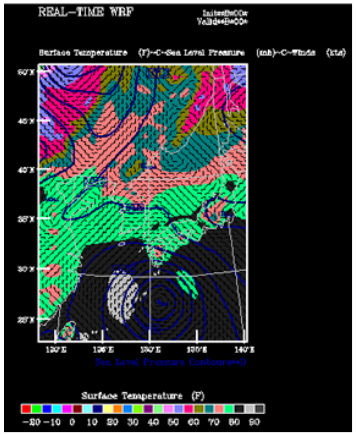
~/.hluresfile

- Very important for NCL versions earlier than v6
  - http://www.ncl.ucar.edu/Document/Graphics/hlures.shtml
- Must be placed in your "~/" directory *(home directory)*
- Will control:
  - Color table; font
  - White/black background
  - Size of plot
  - Characters

~/.hluresfile

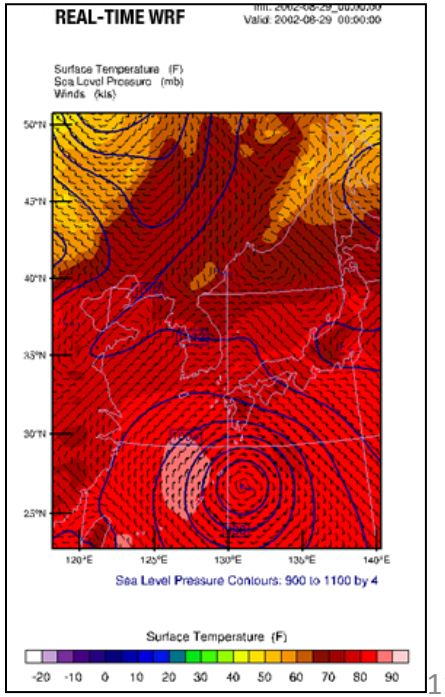
Without it:

```
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
```



With it:

*wkColorMap	: ncl_default
*wkBackgroundColor	: white
*wkForegroundColor	: black
*FuncCode	: ~
*TextFuncCode	: ~
*Font	: helvetica
*wkWidth	: 1000
*wkHeight	: 1000



Generating Plots

- Set NCARG_ROOT environment variable
  setenv NCARG_ROOT /usr/local/ncl ← **for example**

- Ensure you have a ~./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

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 not required for NCL version 6.3
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, eps, ps, png, 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,
ctt: cloud top temperature, dbz/mdbz: Reflectivity (3D and max),
geopt/geopotential: Geopotential, lat/lon: latitude/longitude
helicity/updraft_helicity: Storm Relative Helicity/Updraft helicity,
omg: Omega, 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), ter: terrain,
tc/tk: Temperature (C and F), th/theta: Potential Temperature,
tv: Virtual Temperature, twb: Wetbulb 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
```

pltres: Plotting resources – like overlays
mpres: Map resources – like map resolution and zooming option

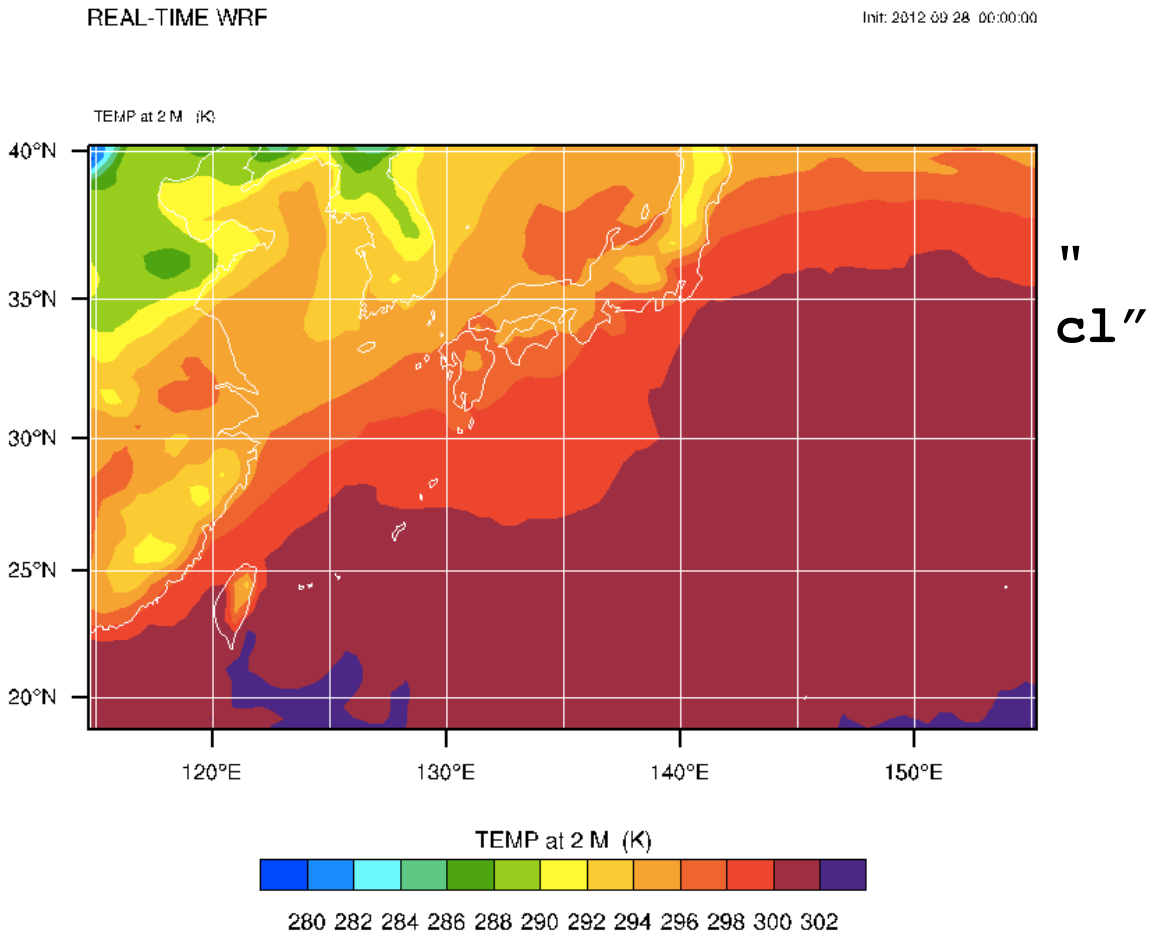
opts: Resources associated with each individual plot

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/                                    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)

end
```

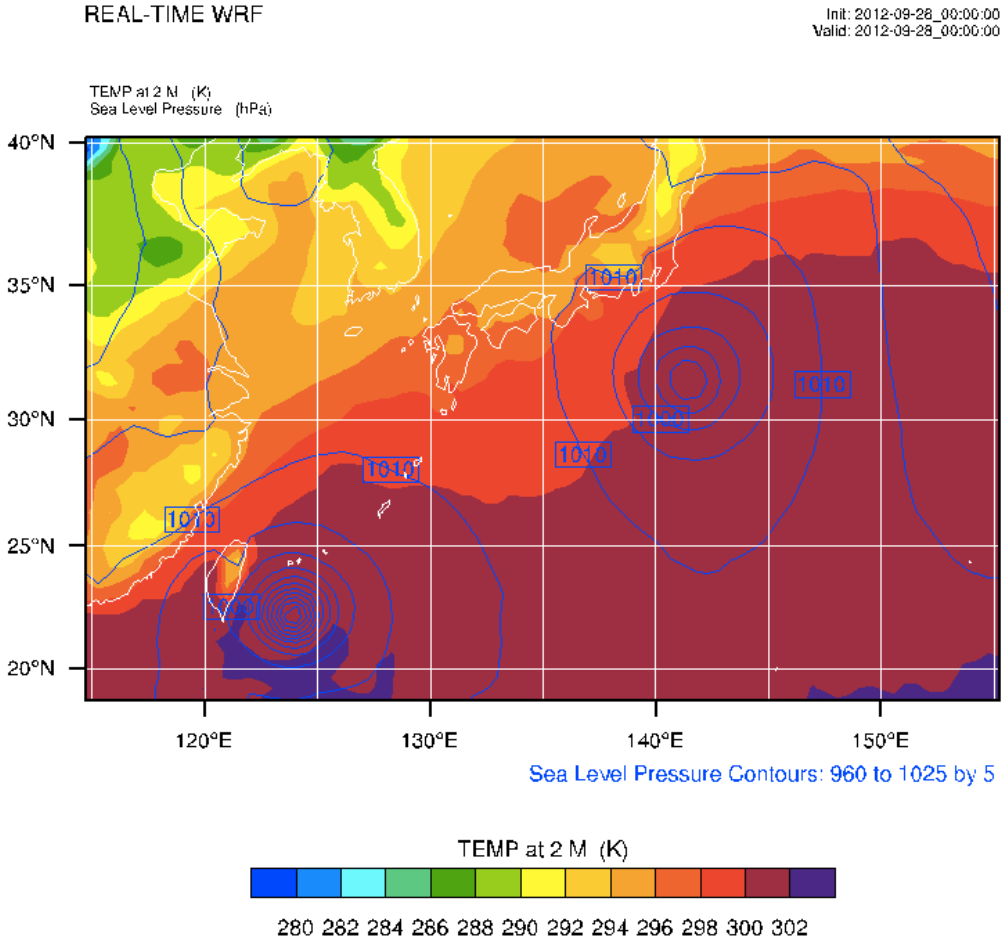


Creating a Plot: NCL script

```
  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)


end
```

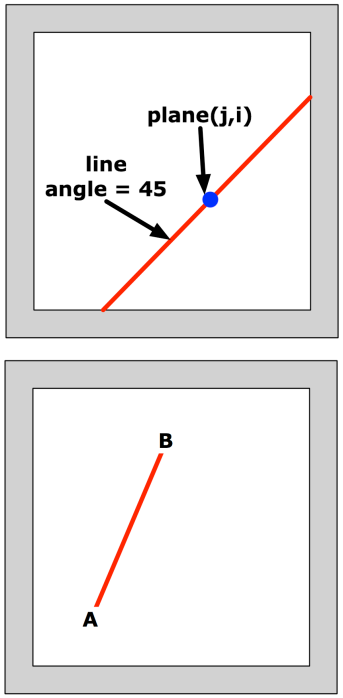
Creating a

```
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)


end
```



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_vert_interp
- wrf_wps_read_int / wrf_wps_write_int



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/))
```

NCL Resources

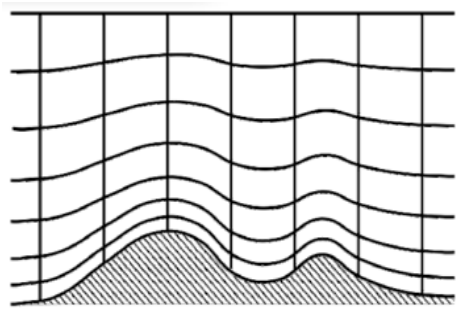
- The special WRF functions have unique resources:
  http://www.ncl.ucar.edu/Document/Functions/wrf.shtml

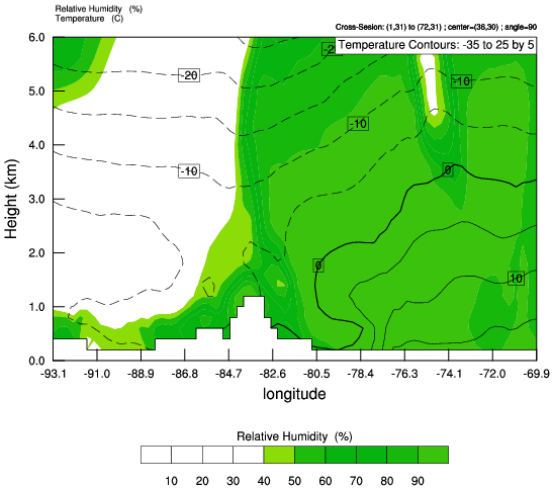
- All general NCL resources can also be used to control the plot:
  http://www.ncl.ucar.edu/Document/Graphics/Resources

am (anotation 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)
tf (irregular transformation)
tx (text)
vc (vectors)
vf (vector fields)
vp (view port)
wk (workstation)
ws (workspace)
xy (xy plots)

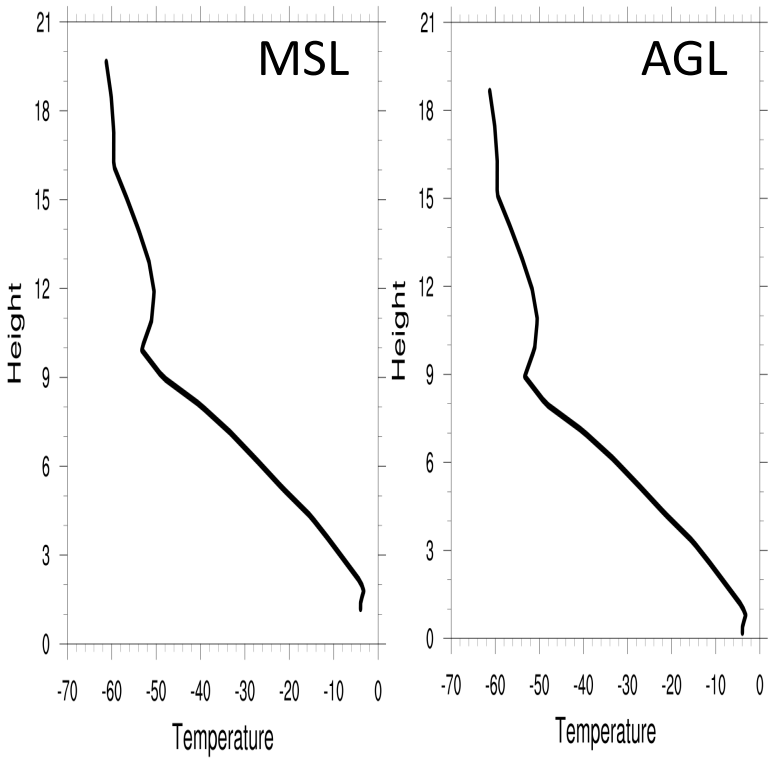
wrf_user_intrp3d

- rh_plane = wrf_user_intrp3d(rh,z,"v",plane,angle,opts)
  - Interpolate “rh” to “z”, which by definition is **Height Above Mean Sea Level**






```
z_AGL = z
dims = dimsizes(z)
do k=0,dims(0)-1
  z_AGL(k,:,:) = z_AGL(k,:,:) - ter(:,:)
end do
```



wrf_user_vert_interp

- Interpolate to:
  - "pressure", "pres" - pressure [hPa]
  - "ght_msl" - grid point height msl [km]
  - "ght_agl" - grid point height agl [km]
  - "theta" - potential temperature [K]
  - "theta-e" - equivalent potential temperature [K]

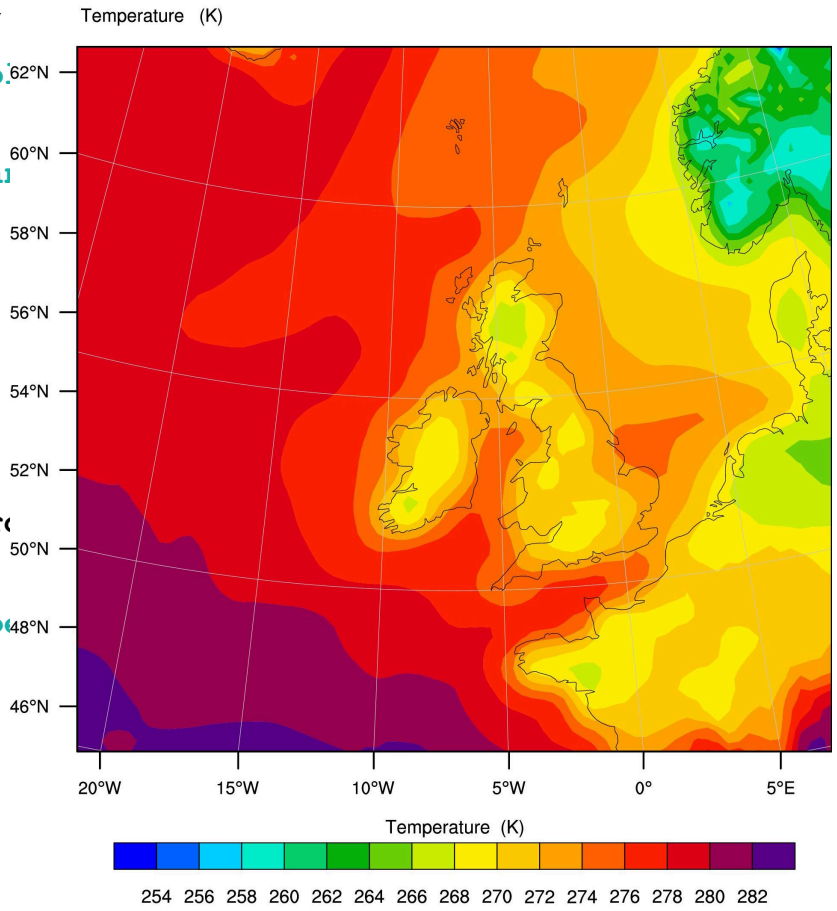
- Extrapolate below the ground
  - **Resource - opts@extrapolate**

wrf_user_vert_interp

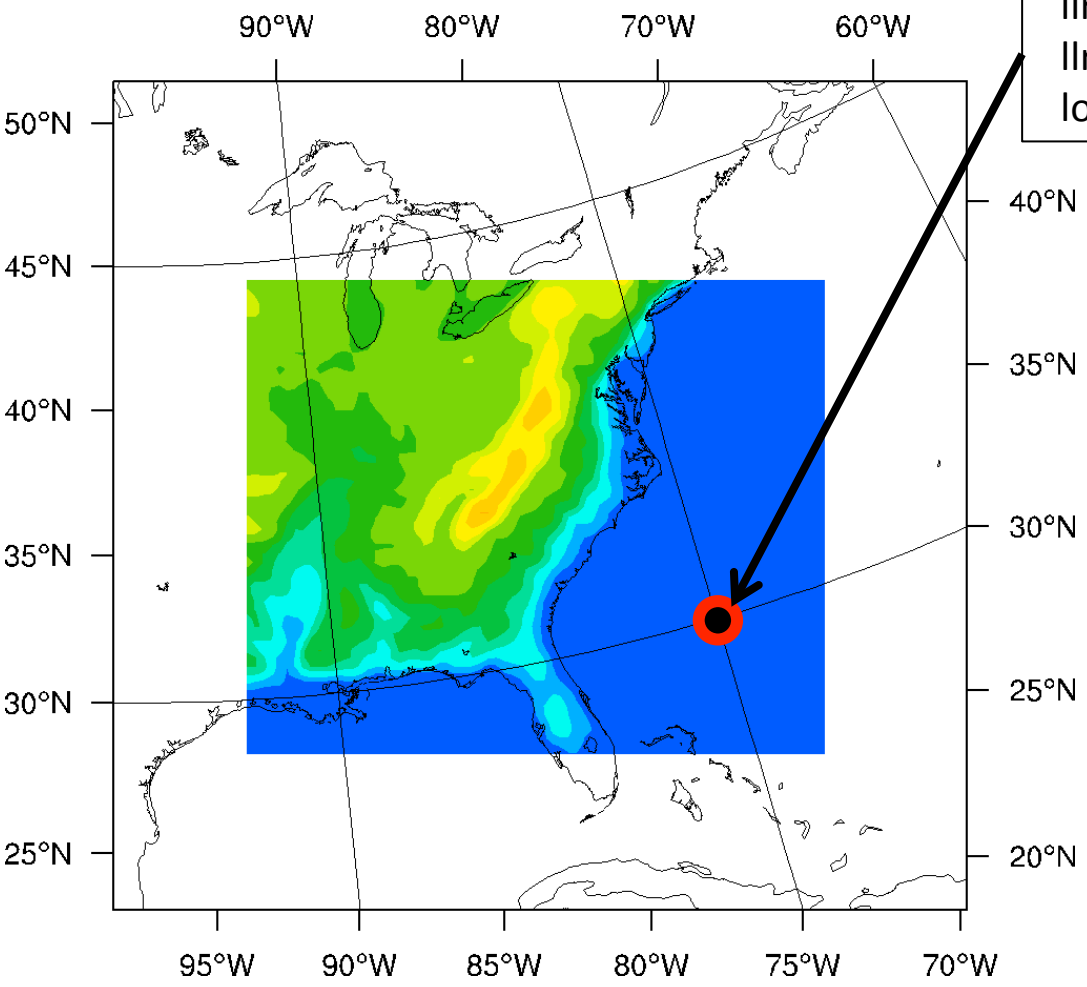
```
begin
  a = addfile("wrfout_d01_1991-01-01_00:00:00.nc","r")
  tk = wrf_user_getvar(a,"tk",0) ; Get our variable

  vert_coord = "pressure" ; Set the surface we want to interpolate to and which levels
  interp_levels = (/200,300,500,1000/)

  opts = True ; Set options for the function
  opts@extrapolate = True
  opts@field_type = "t"
  opts@logP = True
  tk_interp = wrf_user_vert_interp(a,tk,vert_coord,interp_levels,opts)

  wks = gsn_open_wks("X11","plot_tk_1000mb") ; open the workstation
  opts2 = True ; Set options for the plot
  opts2@cnFillOn = True
  pltres = True
  mpres = True
  mpres@mpGeophysicalLineColor = "Black"
  ; Make the contour and plot it over a map
  contour = wrf_contour(a,wks,tk_interp(0,3,:,:),opts2) ; Plot at time 0 and level 3
  plot = wrf_map_overlays(a,wks,(/contour/),pltres,mpres)
end
```

wrf_user_vert_interp

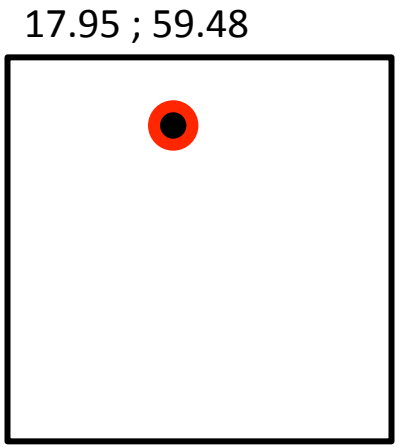
```
begin
  a = addfile("wrfout_d01_1991-01-01_00:00:00.nc"
  tk = wrf_user_getvar(a,"tk",0) ; Get our variab

  vert_coord = "pressure" ; Set the surface we wa
  interp_levels = (/200,300,500,1000/)

  opts = True ; Set options for the function
  opts@extrapolate = True
  opts@field_type = "t"
  opts@logP = True
  tk_interp = wrf_user_vert_interp(a,tk,vert_coor

  wks = gsn_open_wks("X11","plot_tk_1000mb") ; op
  opts2 = True ; Set options for the plot
  opts2@cnFillOn = True
  pltres = True
  mpres = True
  mpres@mpGeophysicalLineColor = "Black"
  ; Make the contour and plot it over a map
  contour = wrf_contour(a,wks,tk_interp(0,3,:,:),opts2) ; Plot at time 0 and level 3
  plot = wrf_map_overlays(a,wks,(/contour/),pltres,mpres)
end
```



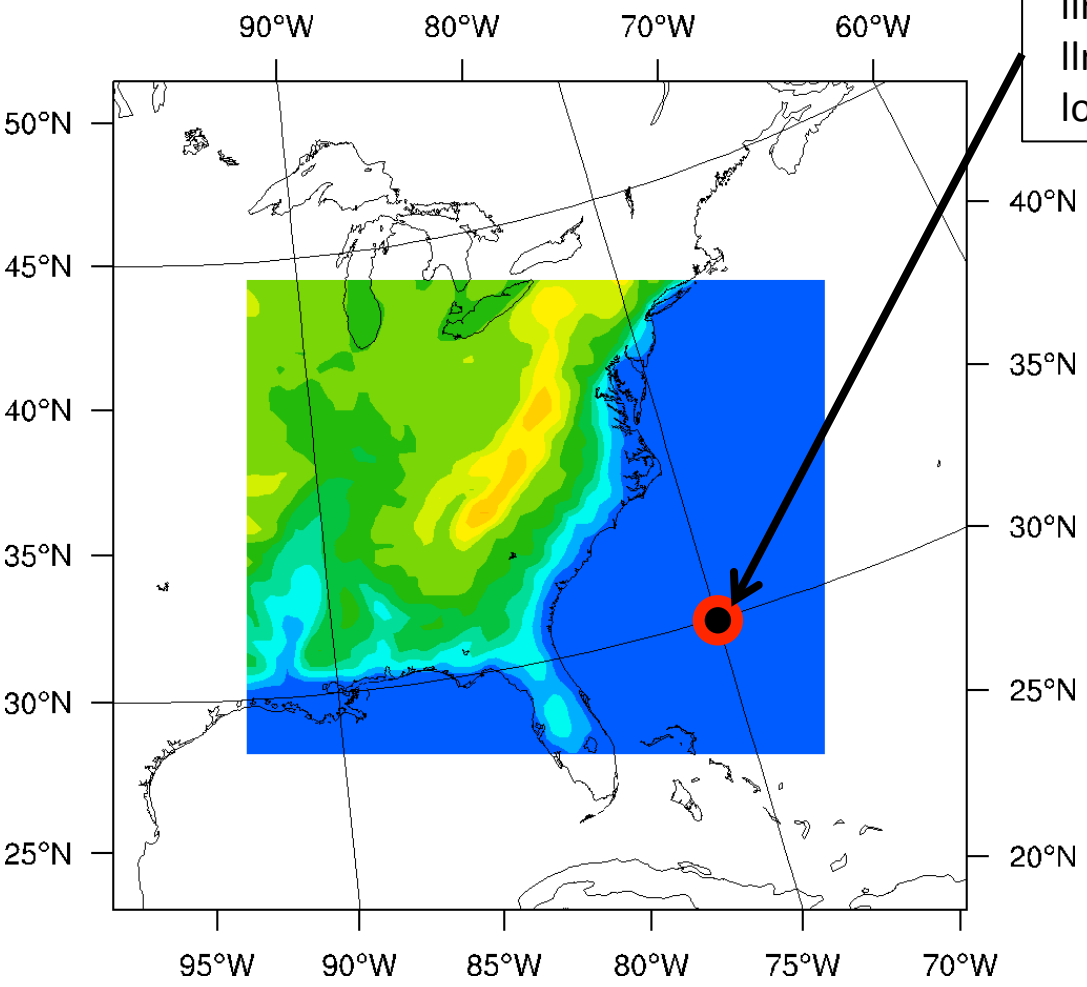
wrf_user_ll_to_ij



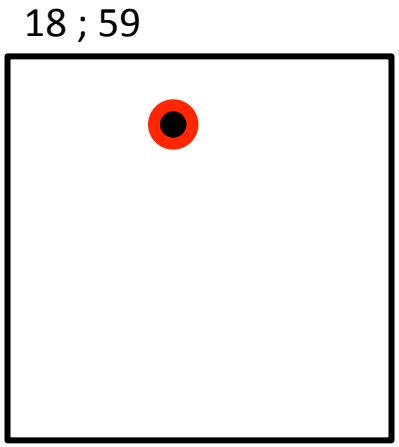
llres = True
llres@returnInt = **False**
locij = wrf_user_ll_to_ij(a, -75.0, 30.0, llres)



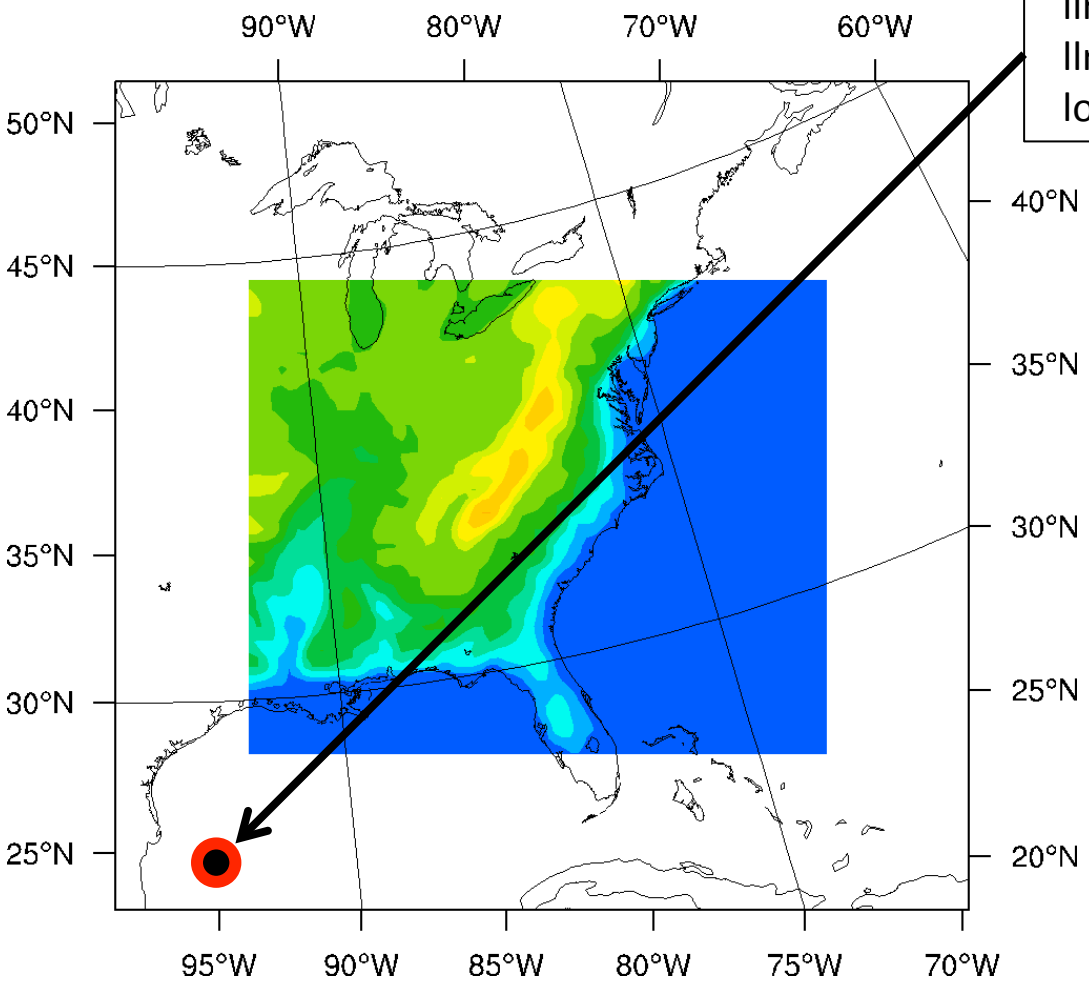
wrf_user_ll_to_ij



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



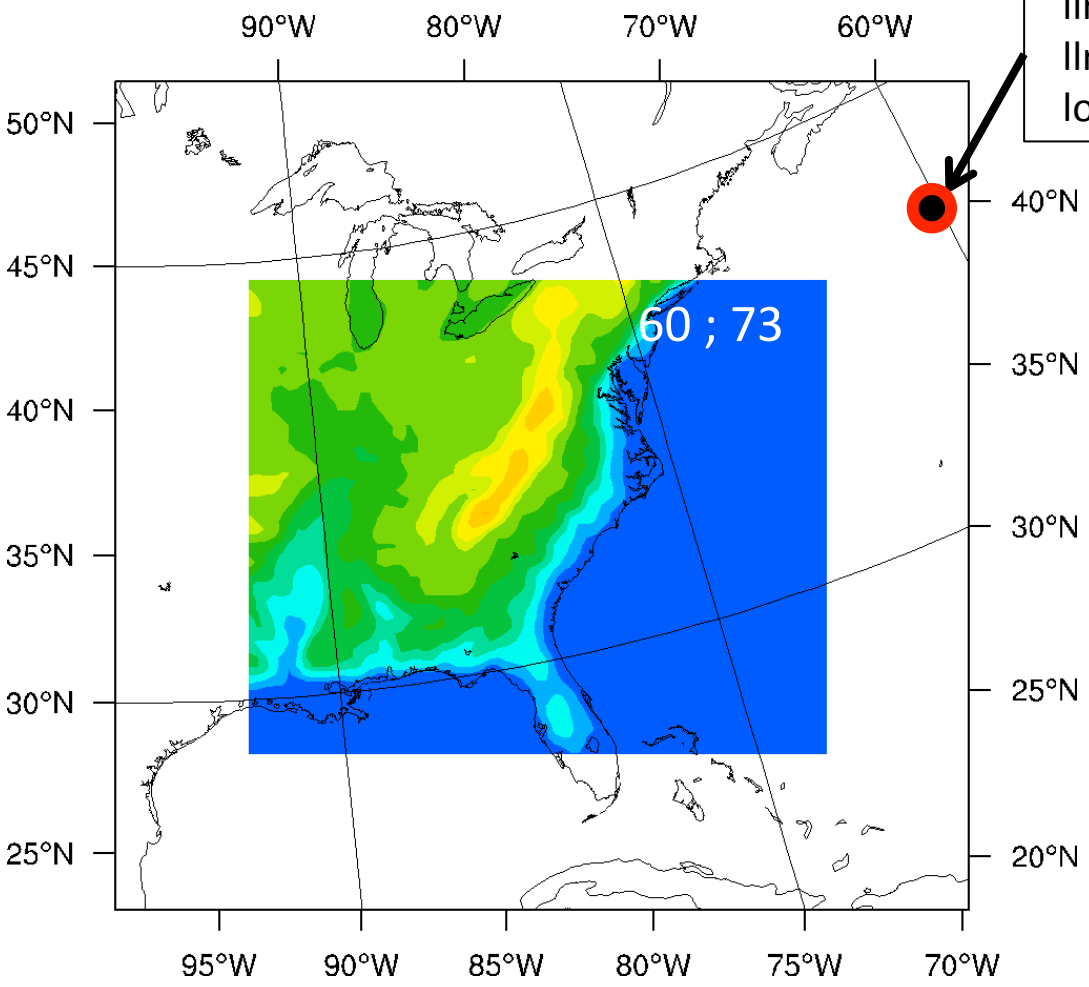
wrf_user_ll_to_ij




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

-10 ; -2

wrf_user_ll_to_ij

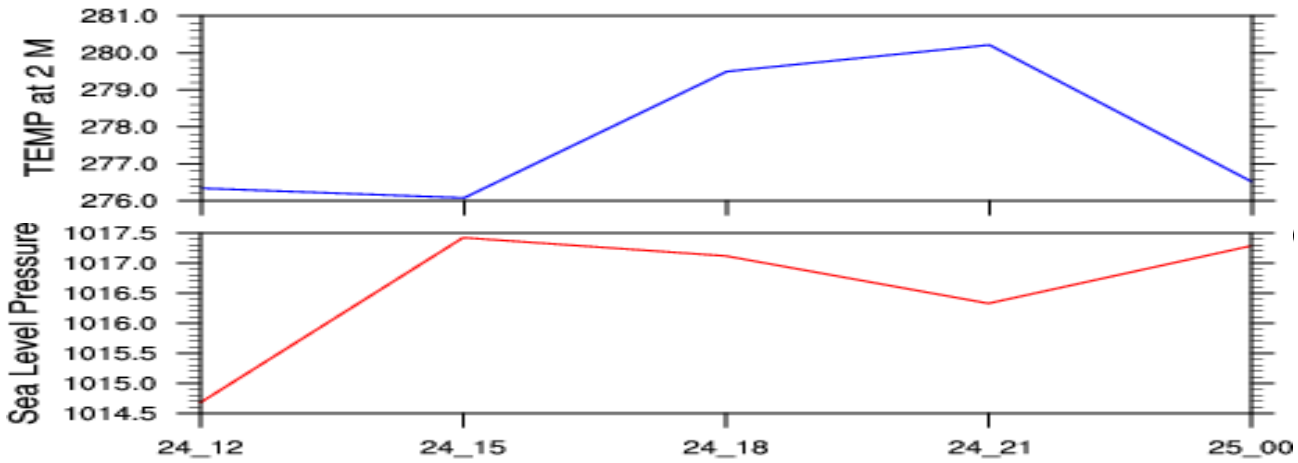



```
llres = True
llres@returnInt = True
locij = wrf_user_ll_to_ij(a, -95.0, 25.0, llres)
```

68; 87

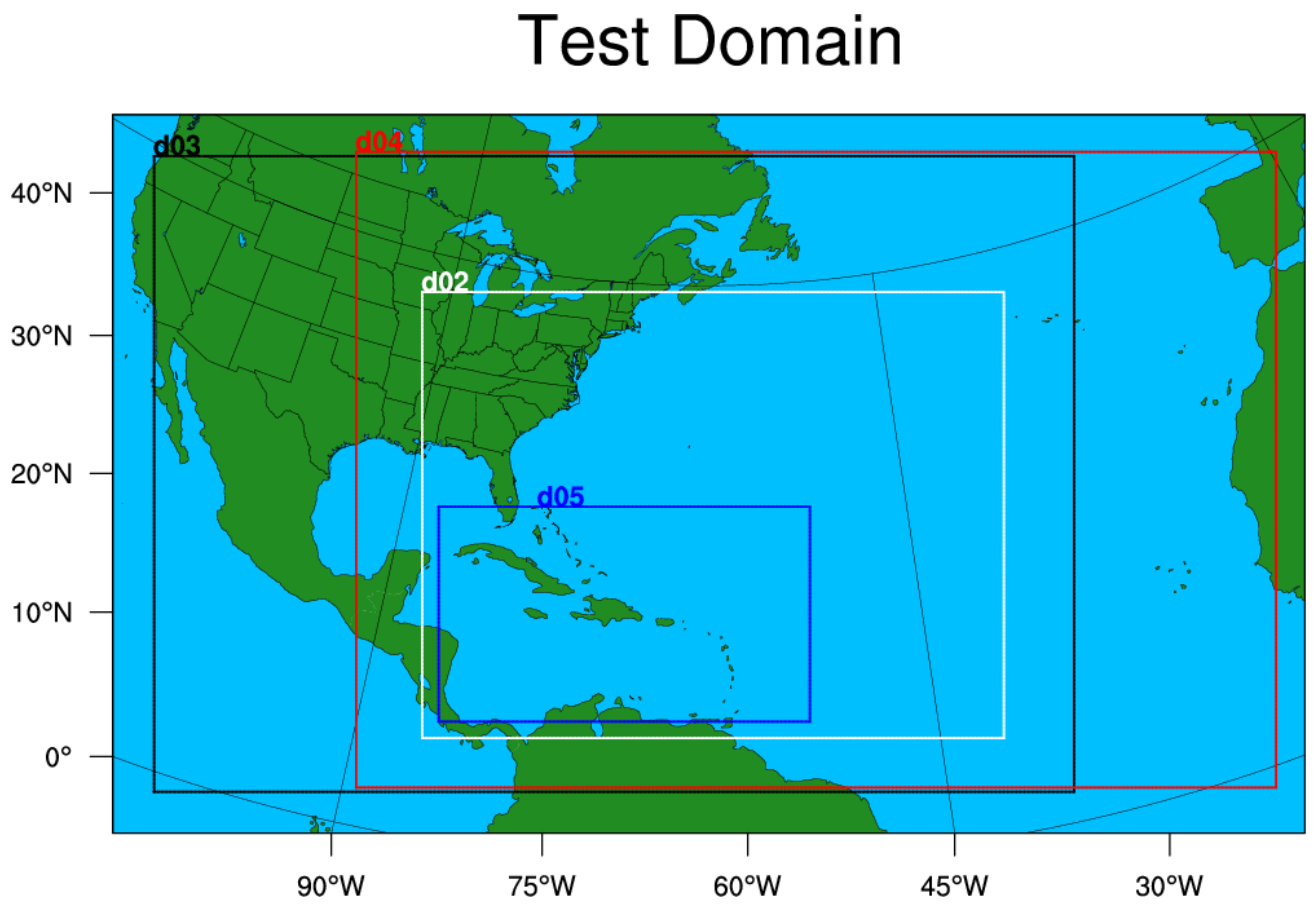
Time Series

```
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)
```

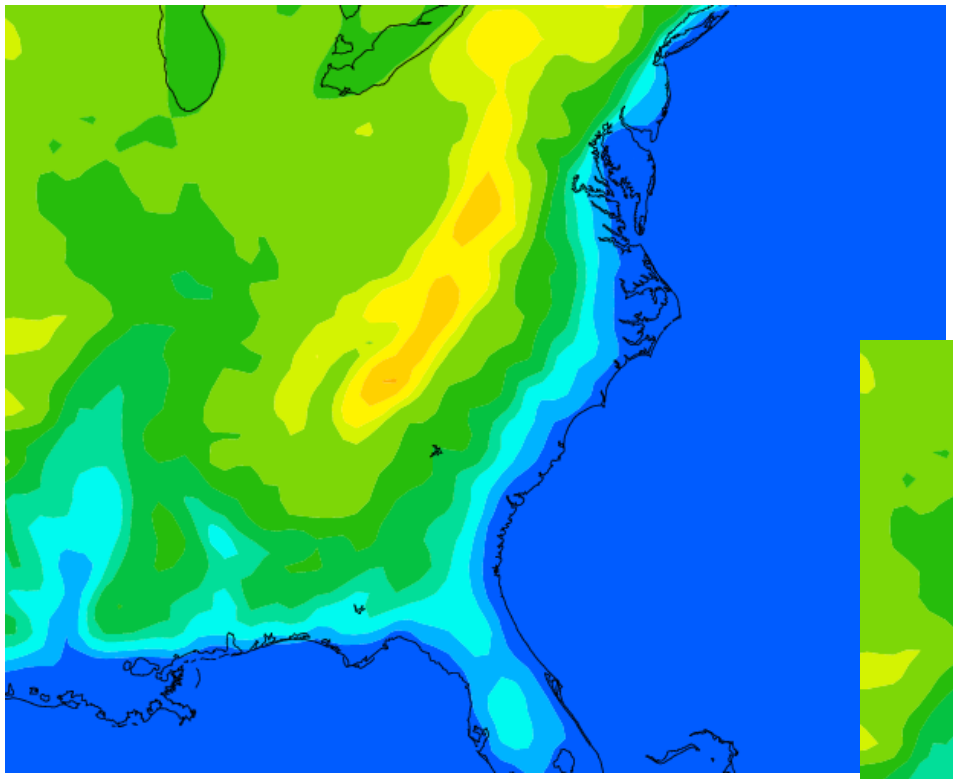


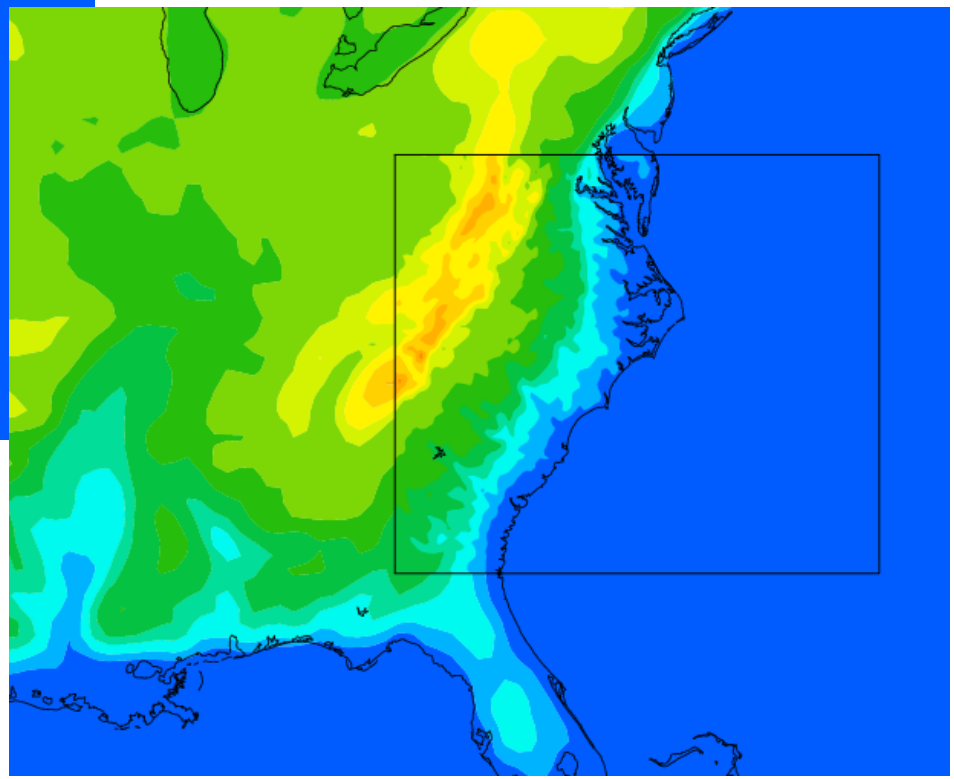
Domain Design

mp = wrf_wps_dom (wks, mpres, lnres, txres)
WPS/util/plotgrids.ncl

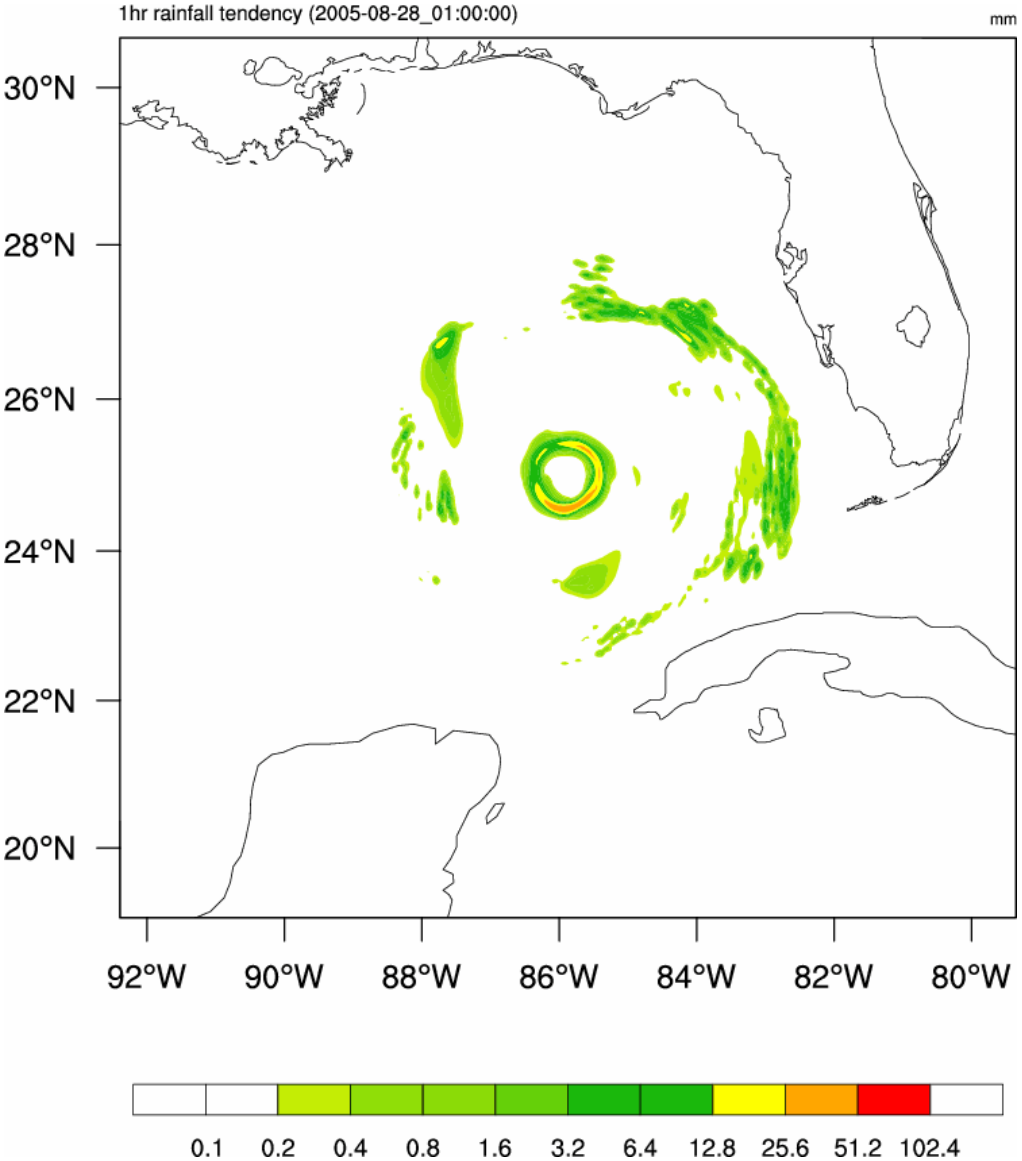


Overlay Domains

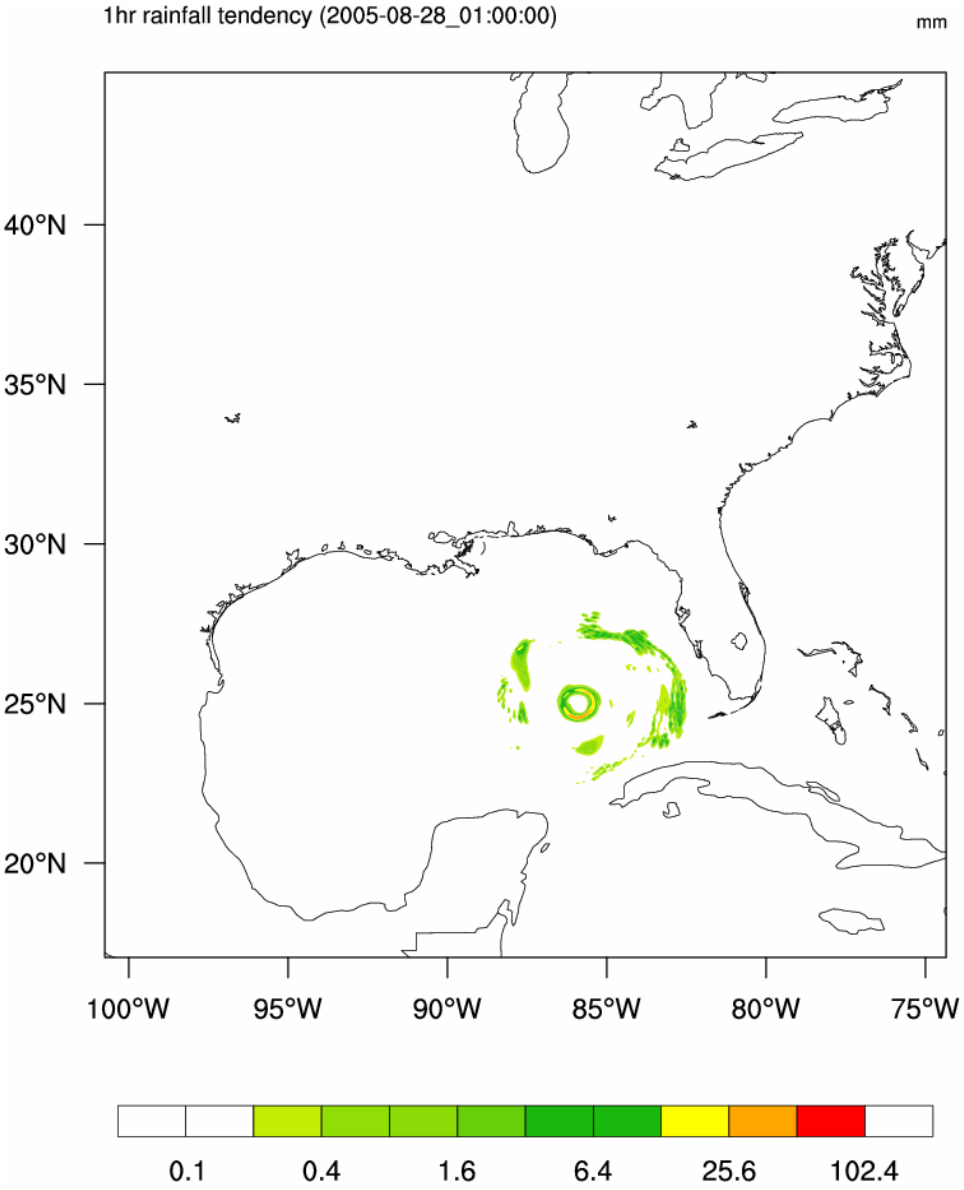




Moving Nests



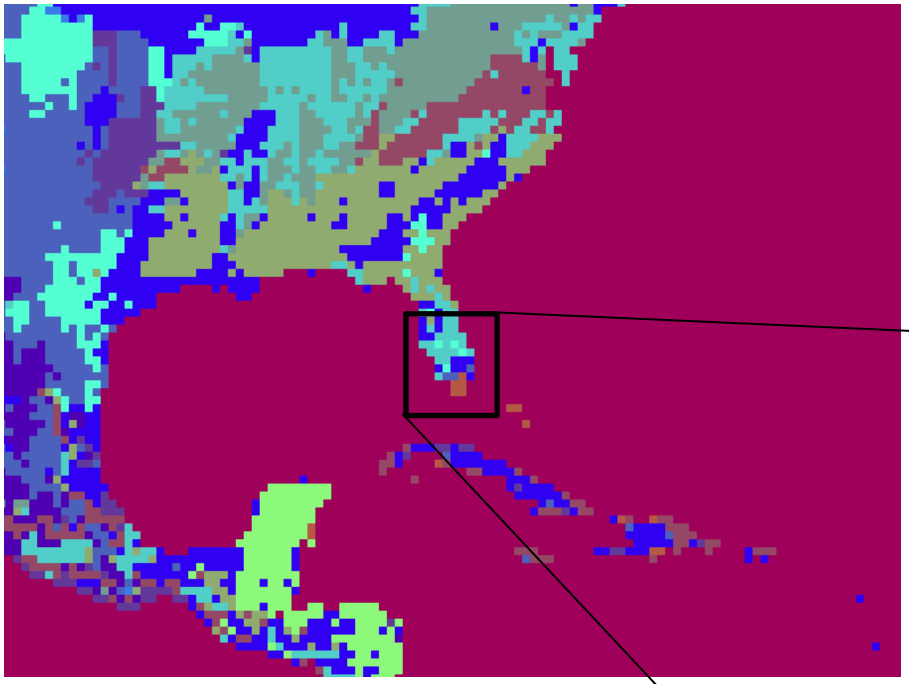
Moving Nests



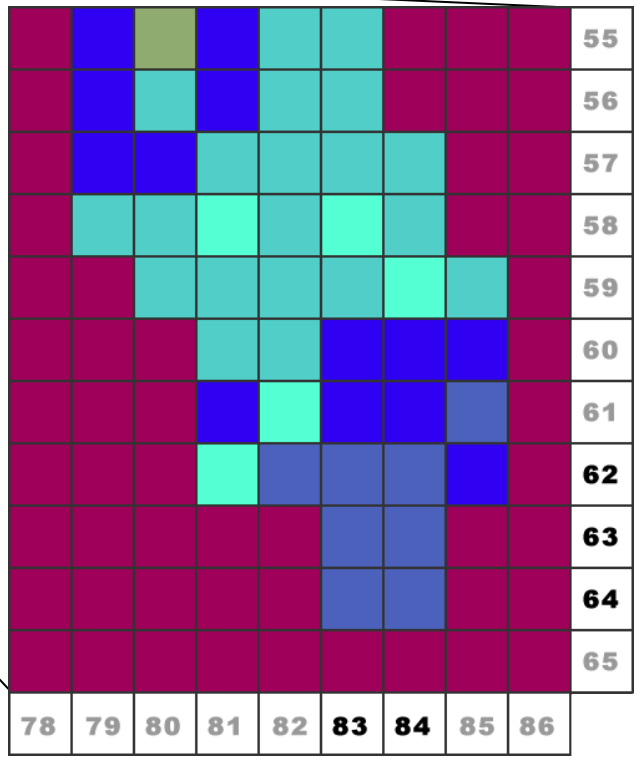
Change Fields in netCDF File

```
begin

  DATADir = "./"
  FILES = systemfunc (" ls -1 " + DATADir + "met_em.d01* ")
  numFILES = dimsizes(FILES)

  do i=0,numFILES-1
    a = addfile(FILES(i),"w")
    sst = a->SST    ; read the field
    sst = sst + 1   ; change the entire field
    a->SST = sst    ; write the field back to the file
  end do

end
```

Change Fields in netCDF File



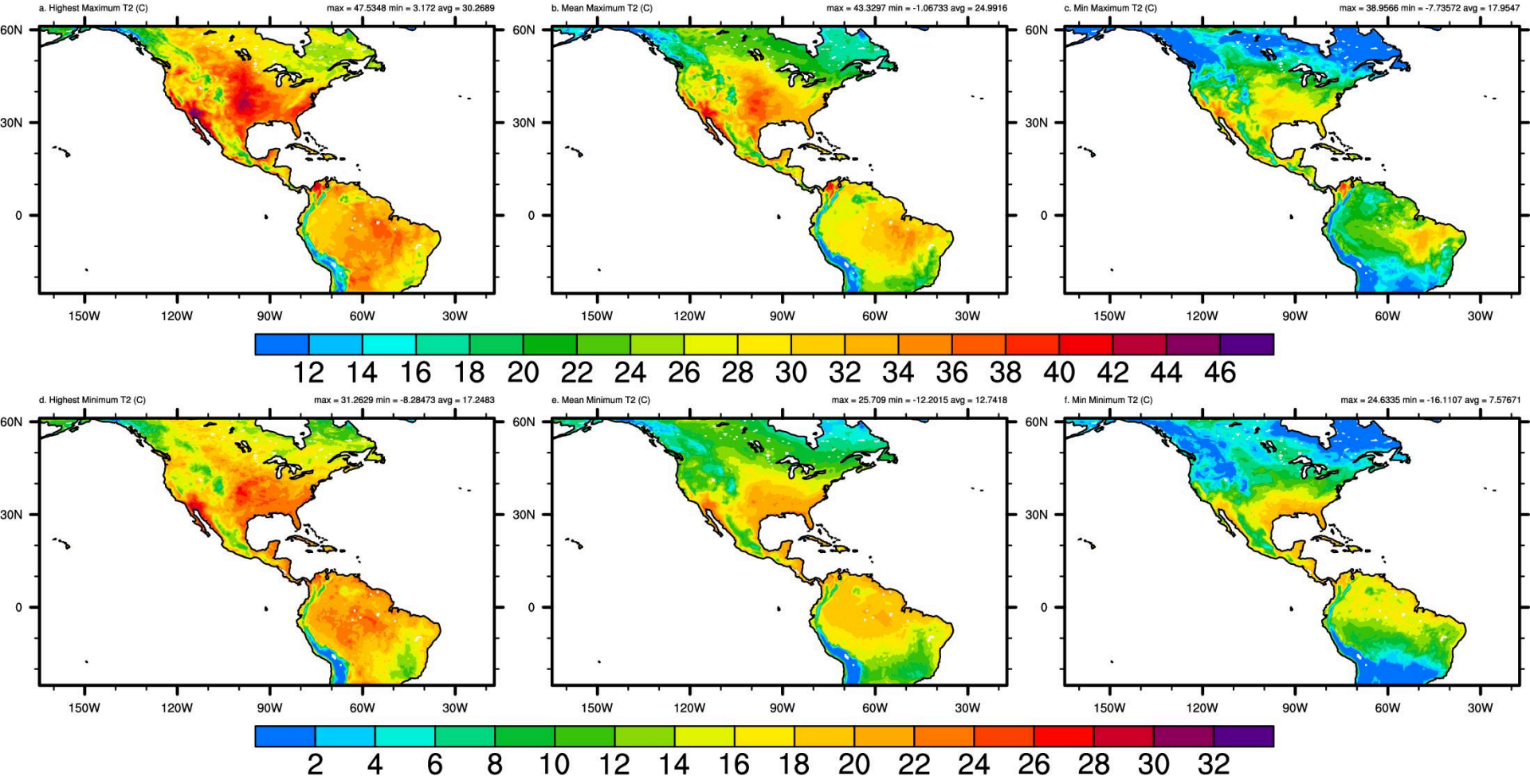
```
a = addfile("./geo_em.d01.nc","w")
var= a->LANDUSE
var(:,63:64,83:84) = 7
var(:,62,84) = 7
a->LANDUSE = var
```



Data Manipulation in NCL

```
begin

    out = addfile("t2_dailymax_1993-08-20.nc","c") ; Create new netCDF file
    filedimdef(out,"Time",-1,True) ; Make Time unlimited

    a = addfile("wrfout_d01_1993-08-20_00:00:00.nc","r") ;File has 24 time steps
    fileattdef(out,a) ; Transfer attributes to new file
    t = a->T2-273.15
    landmask = a->LANDMASK(0,:,:)
    lat = a->XLAT(0,:,:)
    lon = a->XLONG(0,:,:)
    times = a->Times(0,0:9)

    tland = mask(t,landmask,1) ; Mask out the ocean

    tmax = dim_max_n(t,0) ; Daily max
    tlandmax = dim_max_n(tland,0) ; Daily max with ocean masked out

    ; Write attributes for the variable
    tlandmaxday!0 = "Time"
    tlandmaxday!1 = "south_north"
    tlandmaxday!2 = "west_east"
    tlandmaxday@units = "C"
    tlandmaxday@coordinates = "XLONG XLAT"
    tlandmaxday@description = "DAILY MAX TEMP at 2 M (masked)"

    ; Write out data
    out->XLAT = lat
    out->XLONG = lon
    out->LANDMASK = landmask
    out->T2MAX = tlandmaxday

end
```

Data Manipulation in NCL



Reading ASCII Data

```
begin
    fname = "/mydir/ascii.txt"
    foo = asciiread(fname,(/21,6/),"integer")
end
```

```
Variable: foo
Dimensions and sizes:
 [Data|21] x [Columns|6]

(0,0) 1950
(0,1) 13
(0,2) 11
(0,3) 3
(0,4) 8
(0,5) 3
(1,0) 1951
(1,1) 10
```

/mydir/ascii.txt

1950	13	11	3	8	3
1951	10	8	3	5	2
1952	7	6	3	3	1
1953	14	6	2	4	1
1954	11	8	6	2	1
1955	12	9	3	6	2
1956	8	4	2	2	1
1957	8	3	1	2	2
1958	10	7	2	5	3
1959	11	7	5	2	1
1960	7	4	2	2	2
1961	11	8	1	7	4
1962	5	3	2	1	0
1963	9	7	5	2	1
1964	12	6	0	6	4
1965	5	4	3	1	1
1966	11	7	4	3	1
1967	8	6	5	1	1
1968	8	5	5	0	0
1969	18	12	7	5	1
1970	10	5	3	2	0

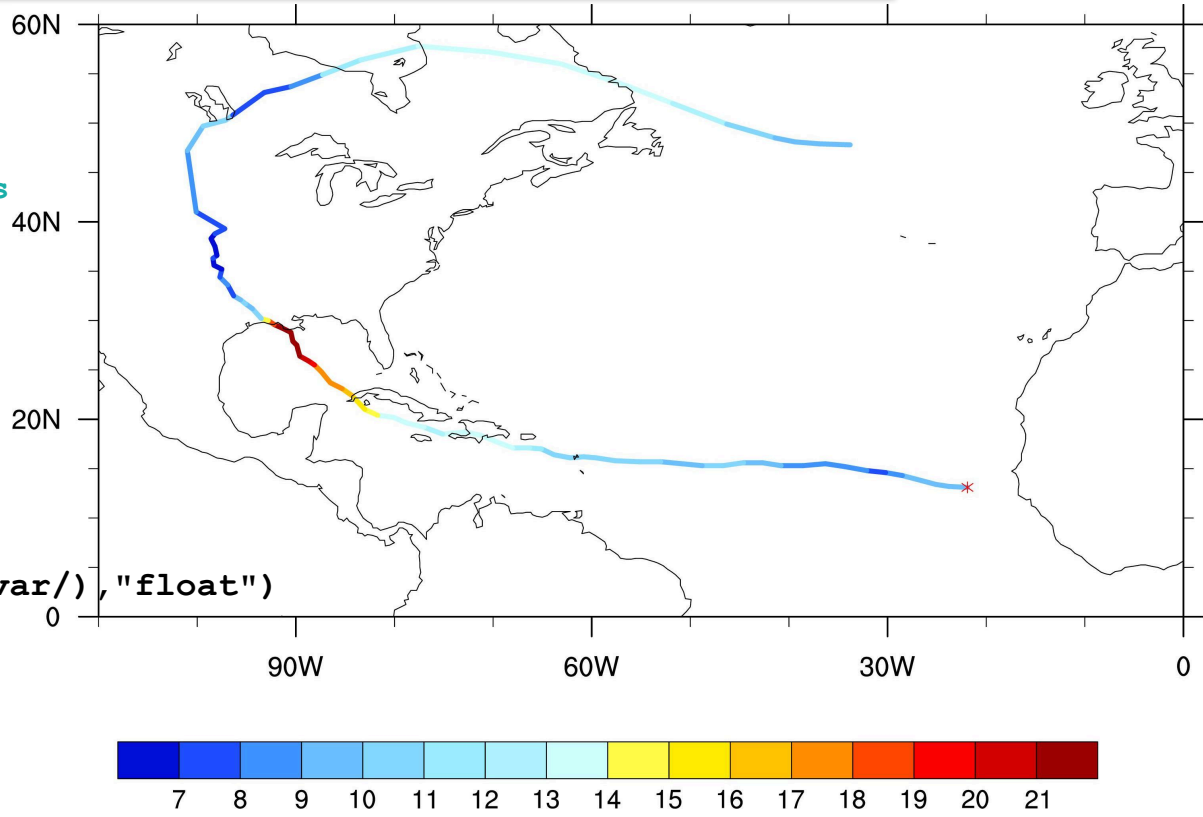
Reading ASCII Data: Trajectory

```
begin

  flnm = "track-1995_0723-0812-380.txt"
  n_col = numAsciiCol(flnm)

  n_var = n_col
  cnLevels = ispan(7, 21, 1)

  wks  = gsn_open_wks("x11", "traj")
  gsn_define_colormap (wks, "GMT_panoply")
  cmap = gsn_retrieve_colormap(wks)

  res = True  ; mapping resources
  res@mpLimitMode = "LatLon"
  res@mpMaxLatF = 60
  res@mpMinLatF = 0
  res@mpMinLonF = -110
  res@mpMaxLonF = 0
  res@mpCenterLonF = -65

  pres = True  ; polyline resources
  pres@gsLineThicknessF = 6.0    ; line thickness

  mres  = True  ; marker resources
  first = True
  first@gsMarkerSizeF = 9.0
  first@gsMarkerColor = "red"
```

```
19950804 12   31.2  265.6 1013.8   16.3   11.2    9.0   32.8    3.9   -4.2    4.6
19950804 18   31.7  264.9 1013.9   17.2   13.6   10.5   27.8    5.7   -2.6    5.5
19950805 00   32.1  264.4 1011.5   19.7   12.5   11.0   37.5    3.9    2.0    4.9
19950805 06   32.5  263.7 1012.7   16.3   10.5    8.9   36.5    4.9   -1.2    3.7
19950805 12   33.6  263.1 1013.7   13.7    7.7    7.0   27.9    5.3   -2.9    3.5
19950805 18   34.1  262.6 1013.3   14.2   10.0    9.1   28.5    5.6   -2.2    5.2
19950806 00   34.4  262.3 1011.6   17.8   10.2    8.8   32.8    4.4    2.6    4.1
19950806 06   35.2  262.5 1013.6   16.1    7.3    6.5   30.5    4.5    1.6    3.1
19950806 12   35.6  261.7 1015.3   11.8    6.6    5.9   21.4    4.9   -6.2    2.9
19950806 18   36.3  261.6 1015.5   11.7    8.4    7.9   31.1    4.9   -6.8    4.7
19950807 00   36.6  262.0 1013.9   13.2   10.3    7.5   34.2    4.7   -5.5    4.2
19950807 06   37.5  261.8 1016.0   13.2    5.4    3.6   23.7    3.3   -0.3    3.9
19950807 12   38.3  261.4 1016.6   10.3    4.4    3.5   28.0    3.9   -1.9    2.8
19950807 18   38.8  261.8 1016.1   10.0    7.8    7.5   24.5    3.4   -4.3    4.2
19950808 00   39.3  262.8 1014.1   11.8    9.4    7.6   21.2    3.4   -3.3    4.4
19950808 06   41.0  259.9 1014.9   21.1    8.8    8.0    1.9    3.0    5.6    2.8
19950808 12   47.2  259.0 1008.7   17.3    9.1    8.4   20.0    6.1  -11.7   -1.6
19950808 18   49.7  260.6 1007.7   19.7   11.5   10.9    4.0    7.3  -14.1   -1.7
19950809 00   50.3  262.9 1007.2   19.3   12.9   11.1    6.4    5.3  -14.4   -1.4
19950809 06   50.8  263.6 1006.9   18.9   10.7    9.8   16.7    5.6  -15.7   -0.8
19950809 12   53.1  266.8 1006.6   17.4    6.5    5.9    5.1    4.7  -17.8   -0.8
19950809 18   53.7  269.5 1003.1   17.9    8.3    8.3    9.5    5.2  -17.7   -0.6
19950810 00   54.9  272.7  999.4   18.3   12.0    9.5   13.3    4.9  -12.0   -0.8
19950810 06   56.4  276.6  997.2   17.8   14.6   13.0   12.4    3.9  -13.2   -1.9
19950810 12   57.8  282.4  997.3   19.0   21.9   11.1   18.7    1.8  -16.0    0.2
19950810 18   57.2  289.7  994.3   25.6   16.8   15.8   34.7    4.1  -20.6    1.7
19950811 00   56.0  296.9  996.1   30.9   14.6   12.1   41.5    3.9  -19.7    2.8
19950811 06   53.8  303.5  997.1   30.8   16.0   14.3   47.2    6.2  -17.0    1.2
```

Reading ASCII Data: Trajectory

```
  mres  = True  ; marker resources
  first = True
  first@gsMarkerSizeF = 9.0
  first@gsMarkerColor = "red"

  map = gsn_csm_map_ce(wks,res)

  n_pt = numAsciiRow(flnm)
  data = asciiread(flnm,(/n_pt,n_var/),"float")
  lat = data (:,2)
  lon = data (:,3)
  var = data (:,7)

  do j = 0, n_pt - 2
    ; assign a color based upon an input scalar variable
    pres@gsLineColor = GetFillColor(cnLevels,cmap,avg((/var(j),var(j+1)/)))
    gsn_polyline(wks,map,(/lon(j),lon(j+1)/),(/lat(j),lat(j+1)/),pres)
  end do
  gsn_polymarker(wks,map,lon(0),lat(0),first) ; draw start of trajectory

  draw(map)
end
```



Writing ASCII Data

```
t2_point  = a->T2(:,locY,locX)
q2_point  = a->Q2(:,locY,locX)

asciiwrite ("t2.txt" , t2_point)
asciiwrite ("q2.txt" , sprintf("%9.3f", q2_point))


npts = dimsizes(t2_point)
data  = new( npts, "string")
  do npt=0,npts-1
    data(npt) = sprintf("%7.1f ", t2_point(npt))
    data(npt) = data(npt) + sprintf("%7.1f ", q2_point(npt))
  end do
asciiwrite ("t2_q2.txt", data)


data2 = new((/npts,2/),"float")
data2(:,0) = t2_point
data2(:,1) = q2_point
write_matrix(data2,"2f7.3",True)
```

write_matrix

Shapefiles and WRF

- A geospatial vector data format for GIS systems software
- We can use it to mask data to specific regional or state borders, rather than drawing a box over an area
- Shapefiles can have three different types of data:
  - Point (locations of cities or places of interest, population data, election data)
  - Polyline (non-closed boundaries like rivers and roads)
  - Polygon (closed geographic boundaries like countries, states, provinces, territories, and lakes)
  - Only one data type per shapefile!

Shapefiles and WRF

```
shp_filename = "cb_2014_us_state_20m.shp"
f = addfile(shp_filename, "r")
print(f)          ; print shapefile metadata

id = f->NAME      ; we know we want the states,
                  ; so read and print the metadata
print(id)
```

```
Variable: f
Type: file
filename:       cb_2014_us_state_20m
path:   /glade/p/p66770001/DNV_Ensembles/T2/ShapeFiles/ShapeFiles_US/cb_2014_us_state_20m.shp
   file global attributes:
      layer_name : cb_2014_us_state_20m
      geometry_type : polygon
      geom_segIndex : 0
      geom_numSegs : 1
      segs_xyzIndex : 0
      segs_numPnts : 1
   dimensions:
      geometry = 2
      segments = 2
      num_features = 52  // unlimited
      num_segments = 132
      num_points = 13785
   variables:
      integer geometry ( num_features, geometry )

      integer segments ( num_segments, segments )

      double x ( num_points )

      double y ( num_points )

      double z ( num_points )

      string STATEFP ( num_features )

      string STATENS ( num_features )

      string AFFGEOID ( num_features )

      string GEOID ( num_features )

      string STUSPS ( num_features )

      string NAME ( num_features )

      string LSAD ( num_features )

      double ALAND ( num_features )

      double AWATER ( num_features )
```

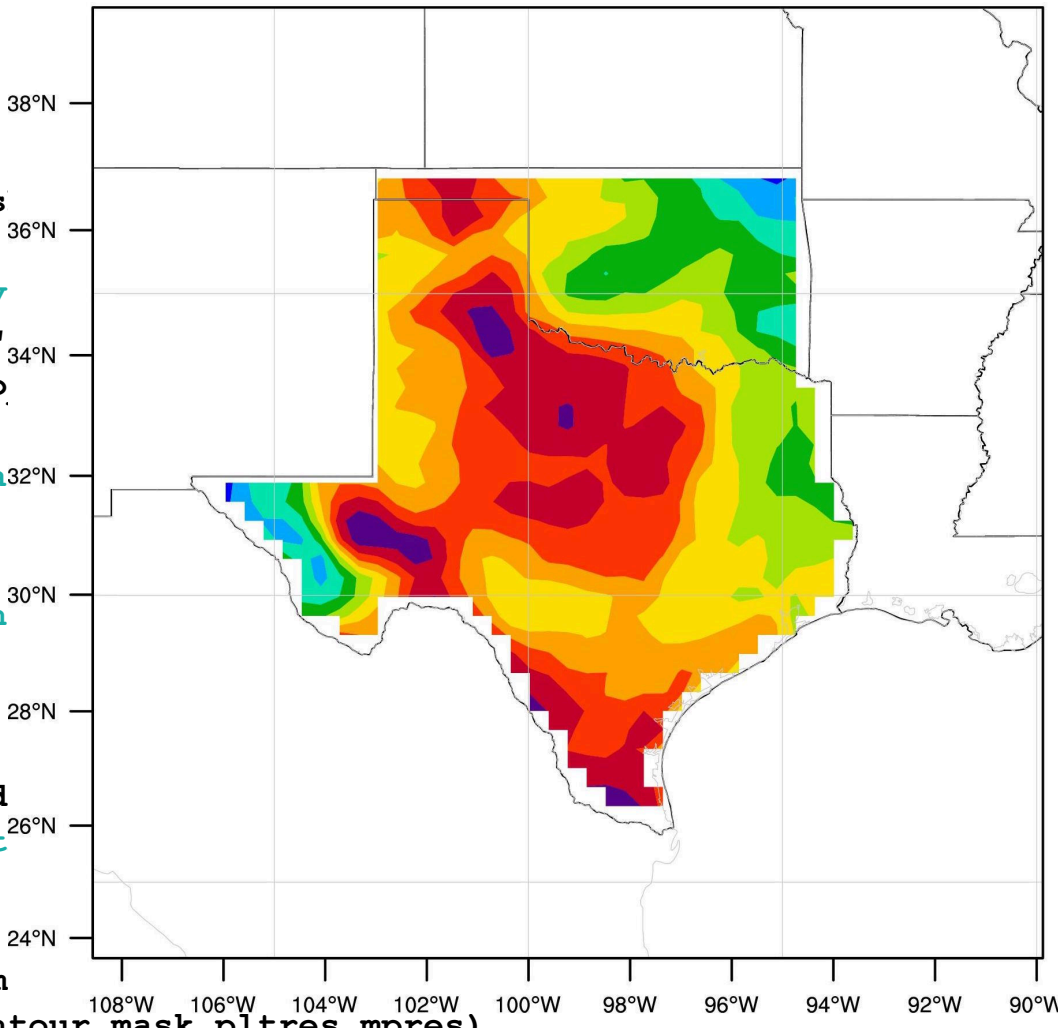
```
Variable: id
Type: string
Total Size: 416 bytes
            52 values
Number of Dimensions: 1
Dimensions and sizes:   [num_features | 52]
Coordinates:
Number Of Attributes: 0
(0)     California
(1)     District of Columbia
(2)     Florida
(3)     Georgia
(4)     Idaho
(5)     Illinois
(6)     Iowa
(7)     Kentucky
(8)     Louisiana
(9)     Maryland
(10)    Michigan
(11)    Minnesota
(12)    Missouri
(13)    New York
(14)    Oregon
(15)    Tennessee
(16)    Texas
(17)    Virginia
(18)    Wisconsin
(19)    Alaska
(20)    Arizona
(21)    Arkansas
(22)    Colorado
(23)    Indiana
(24)    Connecticut
(25)    Hawaii
(26)    Nebraska
(27)    New Mexico
(28)    North Carolina
(29)    Ohio
(30)    Maine
(31)    Massachusetts
(32)    Mississippi
(33)    Montana
(34)    Oklahoma
(35)    South Carolina
(36)    South Dakota
(37)    Utah
(38)    Washington
(39)    West Virginia
(40)    Wyoming
(41)    Delaware
(42)    Rhode Island
(43)    Alabama
(44)    North Dakota
(45)    Pennsylvania
(46)    Vermont
(47)    Puerto Rico
(48)    Kansas
(49)    Nevada
(50)    New Hampshire
(51)    New Jersey
```

Shapefiles and WRF

```
a = addfile("wrfout_d01_2000-07-17_00:00:00.nc","r")
wks = gsn_open_wks("X11","OK_TX")
var = a->T2(0,:,:)
var@lat2d = a->XLAT(0,:,:)
var@lon2d = a->XLONG(0,:,:)
shp_filename = "cb_2014_us_state_20m.shp" ; Shapefile from internet
opt = True
opt@shape_var = "NAME" ; We know the variable name
opt@shape_names = (/"Oklahoma","Texas"/) ; The states we want to mask
var_mask = shapefile_mask_data(var,shp_filename,opt) ; Mask the data
pltres = True
pltres@PanelPlot = True ; We need a panel plot to plot more than one state
mpres = True
mpres@Zoomin = True ; We want to zoom on on our area of interest
mpres@Xstart = 150 ; Grid points of the zoomed in area
mpres@Ystart = 135
mpres@Xend = 200
mpres@Yend = 185
var_mask_zoom = var_mask(y_start:y_end,x_start:x_end) ; Zoomed in variable
; Make contours, draw them on a map, then draw the outline of the polygons
opts = True
opts@cnFillOn = True
contour_mask = wrf_contour(a,wks,var_mask,opts)
plot_mask = wrf_map_overlays(a,wks,contour_mask,pltres,mpres)
id_mask = gsn_add_shapefile_polylines(wks,plot_mask,shp_filename,True)
draw(plot_mask)
frame(wks)
```

Shapefiles and WRF

```
a = addfile("wrfout_d01_2000-07-17_00:00:00.nc","r")
wks = gsn_open_wks("X11","OK_TX")
var = a->T2(0,:,:)
var@lat2d = a->XLAT(0,:,:)
var@lon2d = a->XLONG(0,:,:)
shp_filename = "cb_2014_us_state_20m.s
opt = True
opt@shape_var = "NAME" ; We know the v
opt@shape_names = (/"Oklahoma","Texas"
var_mask = shapefile_mask_data(var,shp
pltres = True
pltres@PanelPlot = True ; We need a pa
mpres = True
mpres@Zoomin = True ; We want to zoom
mpres@Xstart = 150 ; Grid points of th
mpres@Ystart = 135
mpres@Xend = 200
mpres@Yend = 185
var_mask_zoom = var_mask(y_start:y_end
; Make contours, draw them on a map, t
opts = True
opts@cnFillOn = True
contour_mask = wrf_contour(a,wks,var_m
plot_mask = wrf_map_overlays(a,wks,contour_mask,pltres,mpres)
id_mask = gsn_add_shapefile_polylines(wks,plot_mask,shp_filename,True)
draw(plot_mask)
frame(wks)
```



Geo Referenced Graphics

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

 mpres = True
 pltres = True


 do it=0,ntimes-1
  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


 end
```

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/wrf/WRFUserARW.ncl"
load "$VAPOR_HOME/share/examples/NCL/wrf2geotiff.ncl"

begin
 a = addfile("./wrfout_d01_2012-09-28_00:00:00.nc","r")
 wks = gsn_open_wks("ps","plt_Surface")
 wrf2gtiff = wrf2geotiff_open(wks)

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

 mpres = True
 pltres = True
 pltres@gsnFrame = False

 do it=0,ntimes-1
  opts = True
  opts@cnFillOn = True
  contour_t2 = wrf_contour(a,wks,T2(it,:,:),opts)
  plot = wrf_map_overlays(a,wks,(/contour_t2/),pltres,mpres)
  wrf2geotiff_write(wrf2gtiff,a,times(it), wks, plot, False)
  frame(wks)
 end do

 wrf2geotiff_close(wrf2gtiff, wks)
 end
```

Linking NCL to 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 of creating plots – not recommended*

Linking NCL to Fortran/C Code

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

```
C   NCLFORTSTART
C   NCLEND
```

- Use a tool called **WRAPIT** to create a ***.so** file

```
>   WRAPIT myTK.f
```

- Load the ***.so** file into the NCL script with "**external**" statement
- Call Fortran function with special "**::**" syntax
- You must pre-allocate for arrays!

Linking NCL to Fortran/C Code: 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

WRF-Python

- A collection of diagnostic and interpolation routines for use with WRF-ARW
- Functionality is very similar to what is provided by the WRF NCL functions
- When coupled with either matplotlib or PyNGL you can create plots very similar to what you make with NCL

https://github.com/NCAR/wrf-python

Practice Session

- If you want to use an NCL script that needs a wrfout file with multiple time steps:

```
ncrcat wrfout* wrfout_all.nc
```

NCL Support

- wrfhelp@ucar.edu

all questions about WRF and NCL

- ncl-talk@ucar.edu

generic NCL questions