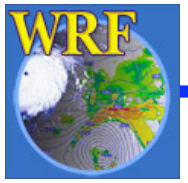
Post-processing Tools: NCL

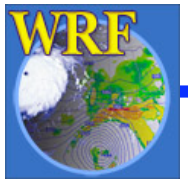
(WRF-ARW Only)

Cindy Bruyère

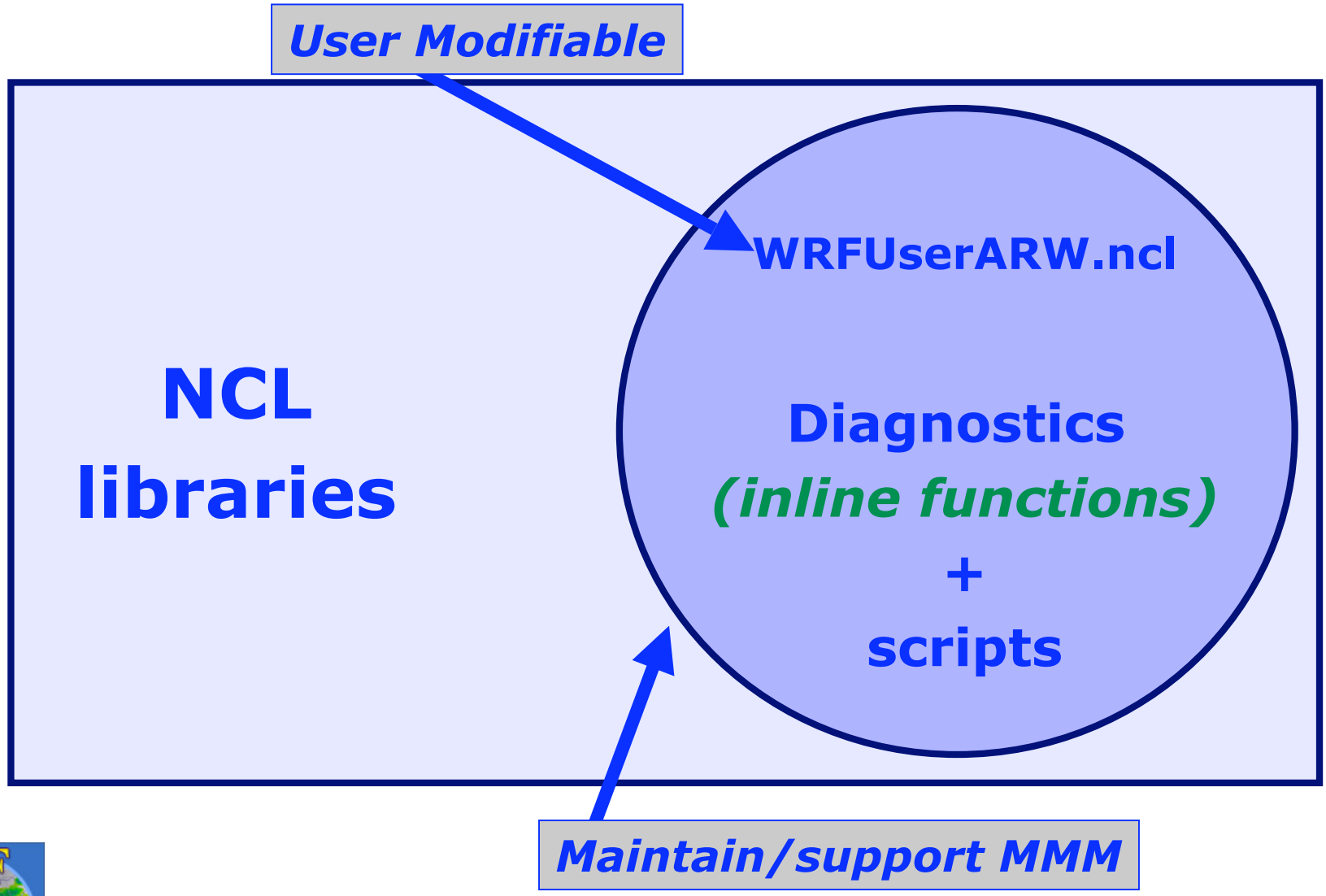


NCL

- **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 5.1.1 or later *(current v5.2)*
- **NCARG_ROOT environment variable**
  - setenv NCARG_ROOT /usr/local/ncl



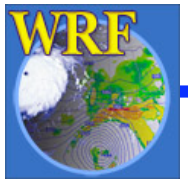
NCL & WRF


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

Home Directory → ~/.hluresfile ← Very Important

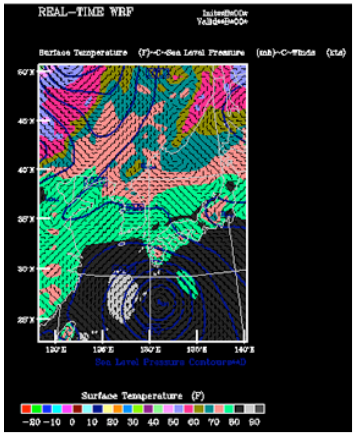
- **Required by NCL libraries**
- **Must be in your "~/" directory *(home directory)***
- **Control**
  - color table ; font
  - white/black background
  - size of plot
  - control characters

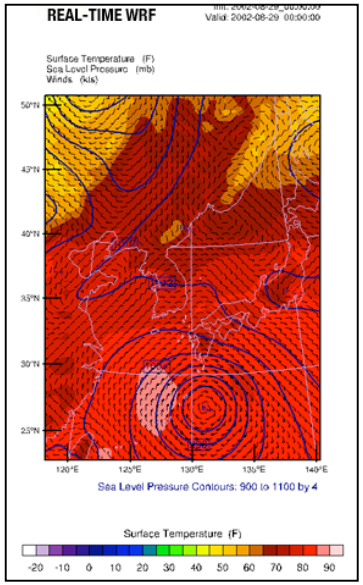
- **http://www.ncl.ucar.edu/Document/Graphics/hlures.shtml**



~/.hluresfile

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

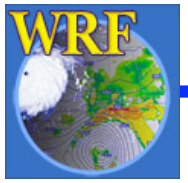




http://www.mmm.ucar.edu/wrf/OnLineTutorial/Graphics/NCL/.hluresfile

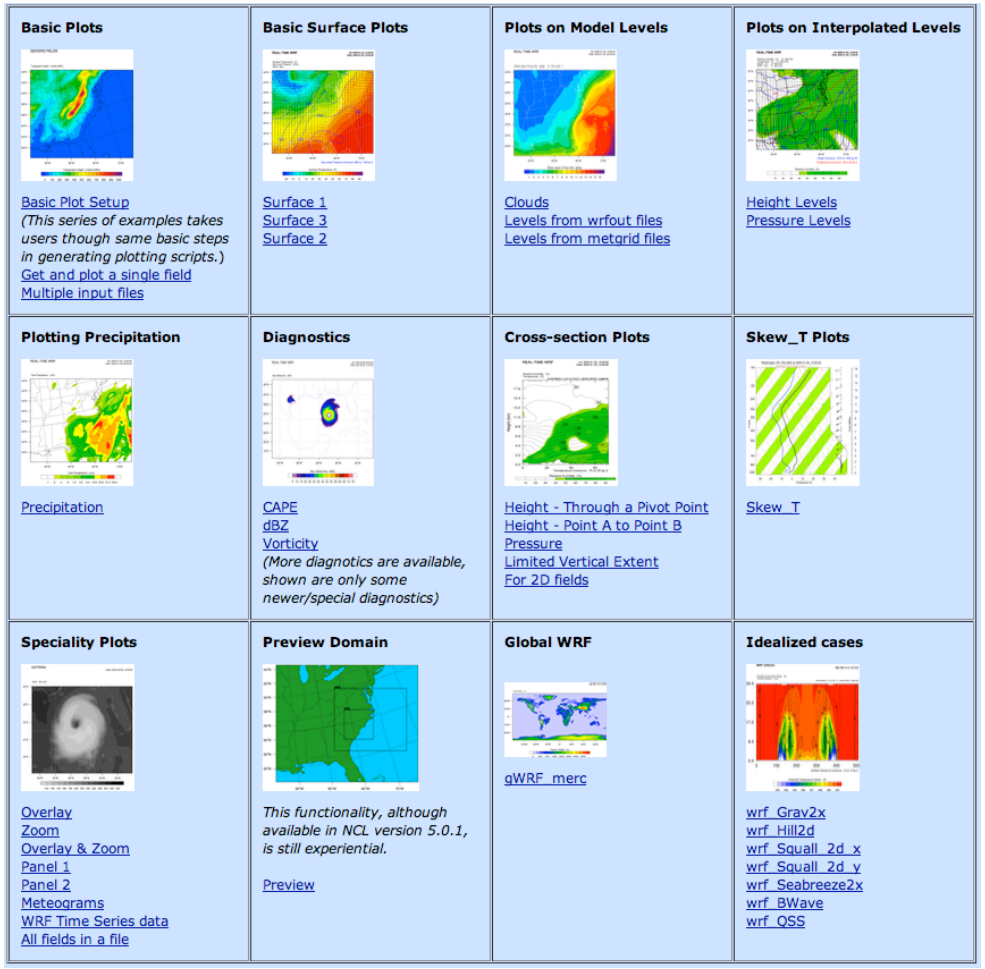
Generate Plots with NCL

- **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)
- **Run NCL script**
  - *ncl wrf_real.ncl*



Generate Plots: *A good start - OnLine Tutorial*

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



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

Basic Surface Plots

Surface 1
Surface 3
Surface 2

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
Vorticity
(More diagnotics 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

Skew_T Plots

Skew_T

Speciality Plots

Overlay
Zoom
Overlay & Zoom
Panel 1
Panel 2
Meteograms
WRF Time Series data
All fields in a file

Preview Domain

This functionality, although available in NCL version 5.0.1, is still experiential.

Preview

Global WRF

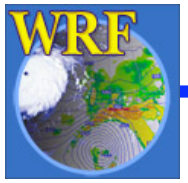
gWRF_merc

Idealized cases

wrf_Grav2x
wrf_Hill2d
wrf_Squall_2d_x
wrf_Squall_2d_y
wrf_Seabreeze2x
wrf_BWave
wrf_QSS

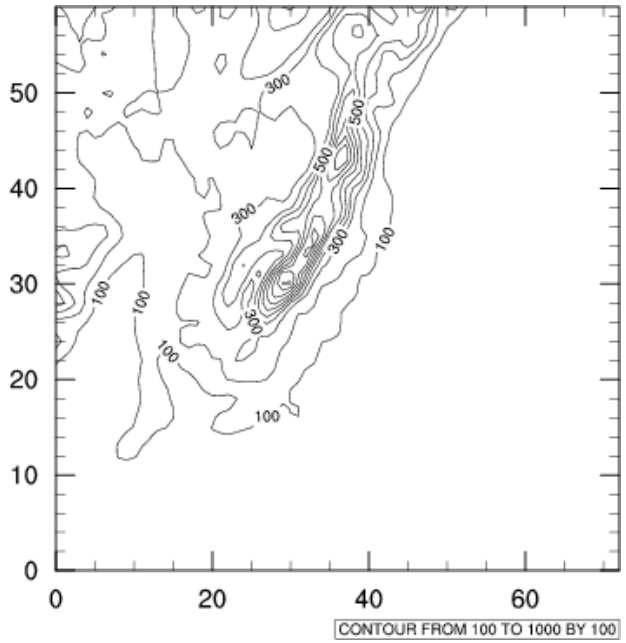
Creating a Plot : NCL script

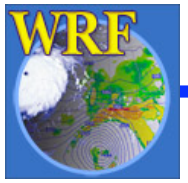
```
load ncl library scripts

begin

  ; Open graphical output
  ; Open input file(s)

  ; Read variables

  ; Set up plot resources & Create plots
  ; Output graphics

end
```



Generate Plots

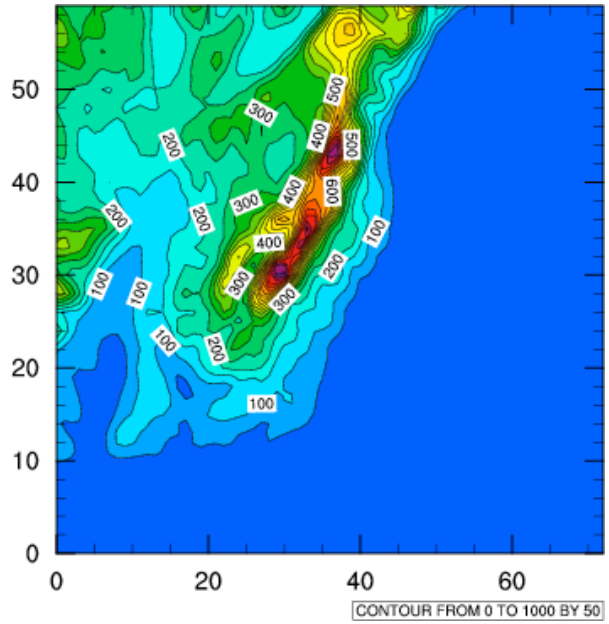
```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"

begin
  a = addfile("./geo_em.d01.nc","r")
  wks = gsn_open_wks("pdf","plt_ter1")
  ter = a->HGT_M(0,:,:)
  plot = gsn_contour(wks,ter,True)
end
```





Generate Plots

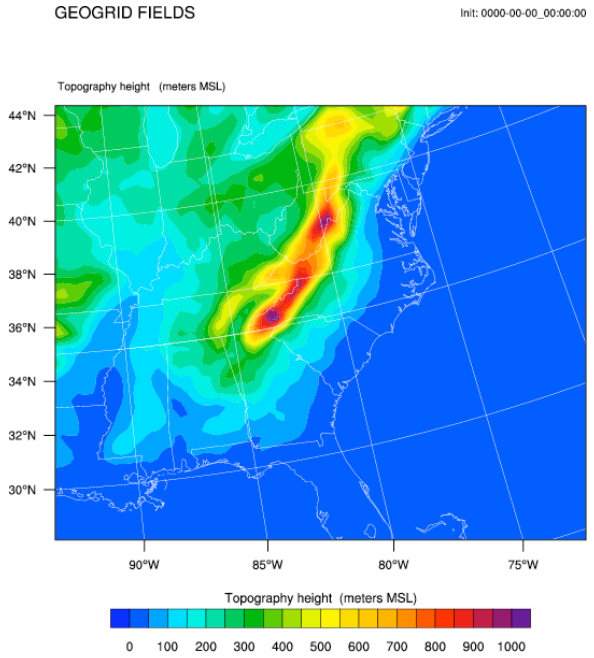
```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"

begin
  a = addfile("./geo_em.d01.nc","r")
  wks = gsn_open_wks("pdf","plt_ter1")
  ter = a->HGT_M(0,:,:)
  res = True
  res@cnFillOn = True
  res@gsnSpreadColors = True
  res@cnLevelSelectionMode = \
     "ManualLevels"
  res@cnMinLevelValF = 0.
  res@cnMaxLevelValF = 1000.
  res@cnLevelSpacingF = 50.
  plot = gsn_contour(wks,ter,res)
end
```



Basic NCL resources - *there are over 1400 controlling contours, labelbars, legends, maps, etc.*

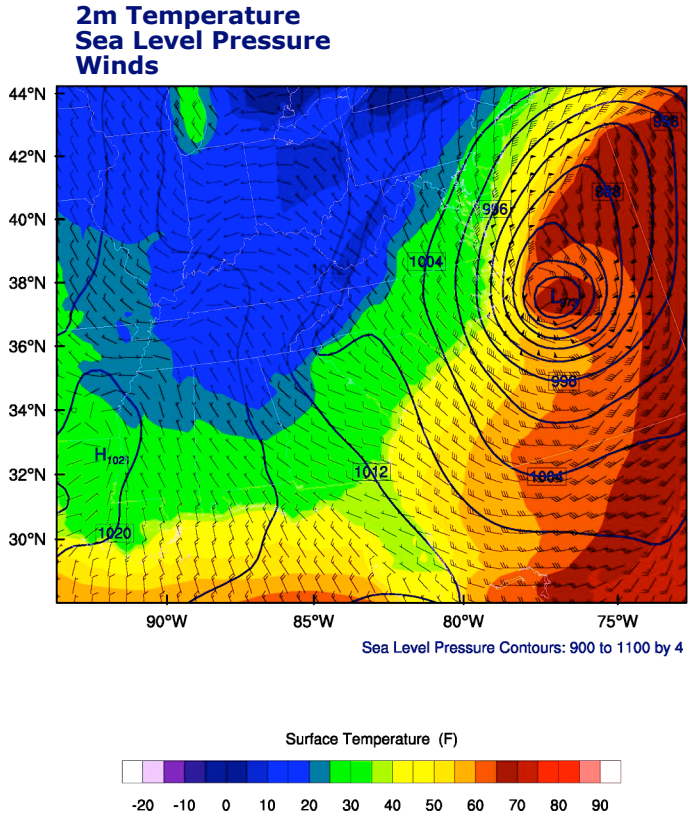
Generate Plots

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

begin
  a = addfile("./geo_em.d01.nc","r")
  wks = gsn_open_wks("pdf","plt_ter5")
  res = True
  res@MainTitle = "GEOGRID FIELDS"
  pltres = True
  mpres = True

  ter = wrf_user_getvar(a,"HGT_M",0)
  res@cnFillOn = True
  res@ContourParameters = (/0.,1000.,50./)
  contour = wrf_contour(a,wks,ter,res)
  plot = wrf_map_overlays(a,wks,(/contour/),\
    pltres,mpres)
end
```



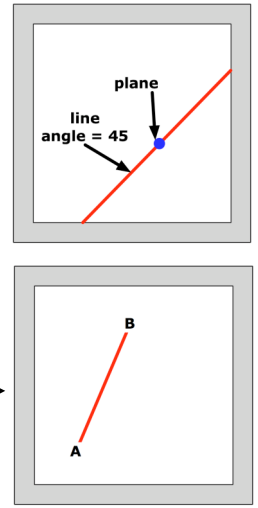
Generate Plots

```
slp = wrf_user_getvar(a,"slp",5)
t2  = wrf_user_getvar(a,"T2",5)
u10 = wrf_user_getvar(a,"U10",5)
v10 = wrf_user_getvar(a,"V10",5)

os@cnLineColor = "NavyBlue"
c_slp = wrf_contour(a,wks,slp,os)
ot@cnFillOn = True
c_tc = wrf_contour(a,wks,t2,ot)
ov@NumVectors = 47
vec = wrf_vector(a,wks,u10,v10,ov)

plot = wrf_map_overlays(a, wks, \
       (/c_tc,c_slp,vec/), 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_list_times**
  Get list if times available in input file
- **wrf_user_unstagger**
  Unstaggers an array

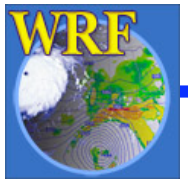


Special WRF NCL Functions

- **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)

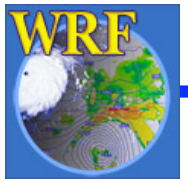
  avo/pvo: Absolute/Potential Vorticity,
  cape_2d: 2D mcape/mcin/lcl/lfc, **cape_3d**: 3D cape/cin,
  dbz/mdbz: Reflectivity (3D and max),
  geopt/geopotential: Geopotential,
  p/pres/pressure: Pressure, **rh/rh2**: Relative Humidity (3D and 2m),
  slp: Sea Level Pressure, **td/td2**: Dew Point Temperature (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)



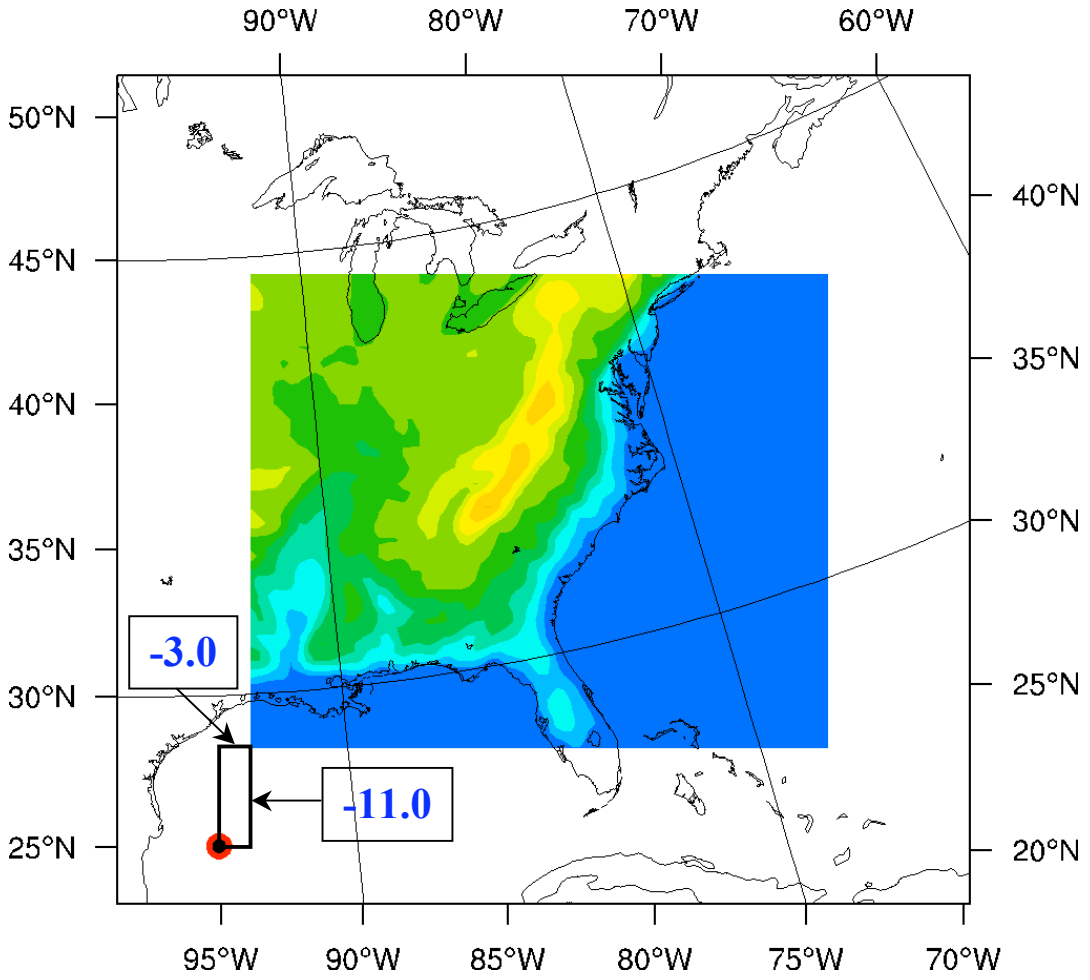
Diagnostics

```
PH      = nc_file->PH(5,:,:,:)
PHB     = nc_file->PHB(5,:,:,:)
   PH     = ( PH + PHB ) / 9.81
   z = wrf_user_unstagger(PH,PH@stagger)

P       = nc_file->P(5,:,:,:)
PB      = nc_file->PB(5,:,:,:)
   P = P + PB

T       = nc_file->T(5,:,:,:)
   T = T + 300.
   tk = wrf_tk( P , T )

QVAPOR = nc_file->QVAPOR(5,:,:,:)
   QVAPOR = QVAPOR > 0.000


slp = wrf_slp( z, tk, P, QVAPOR )
```

```
slp = wrf_user_getvar(nc_file,"slp",5)
```

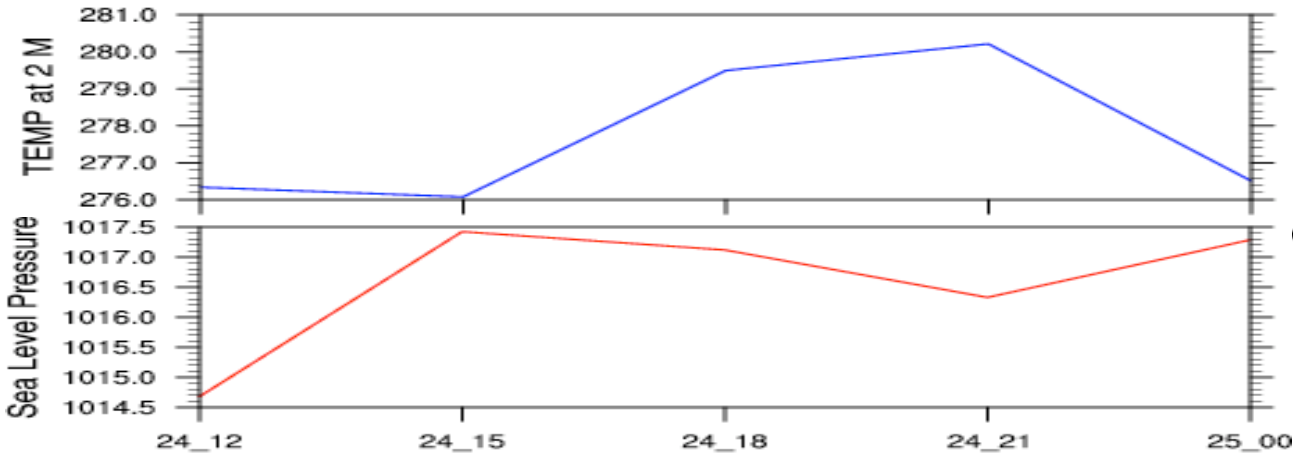


wrf_user_ll_to_ij



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)
```



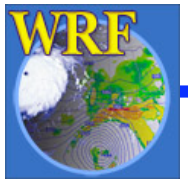
NCL and WRF_NCL

- **Combine strength of WRF_NCL specific and NCL general capabilities**

```
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)
```

```
res@cnLevelSelectionMode = \
     "ManualLevels"
res@cnMinLevelValF = 0.
res@cnMaxLevelValF = 1000.
res@cnLevelSpacingF = 50.
contour=wrf_contour(a,wks,ter,res)


res@ContourParameters = \
     (/0.,1000.,50./)
contour=wrf_contour(a,wks,ter,res)
```

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


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

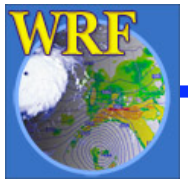


Resources

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

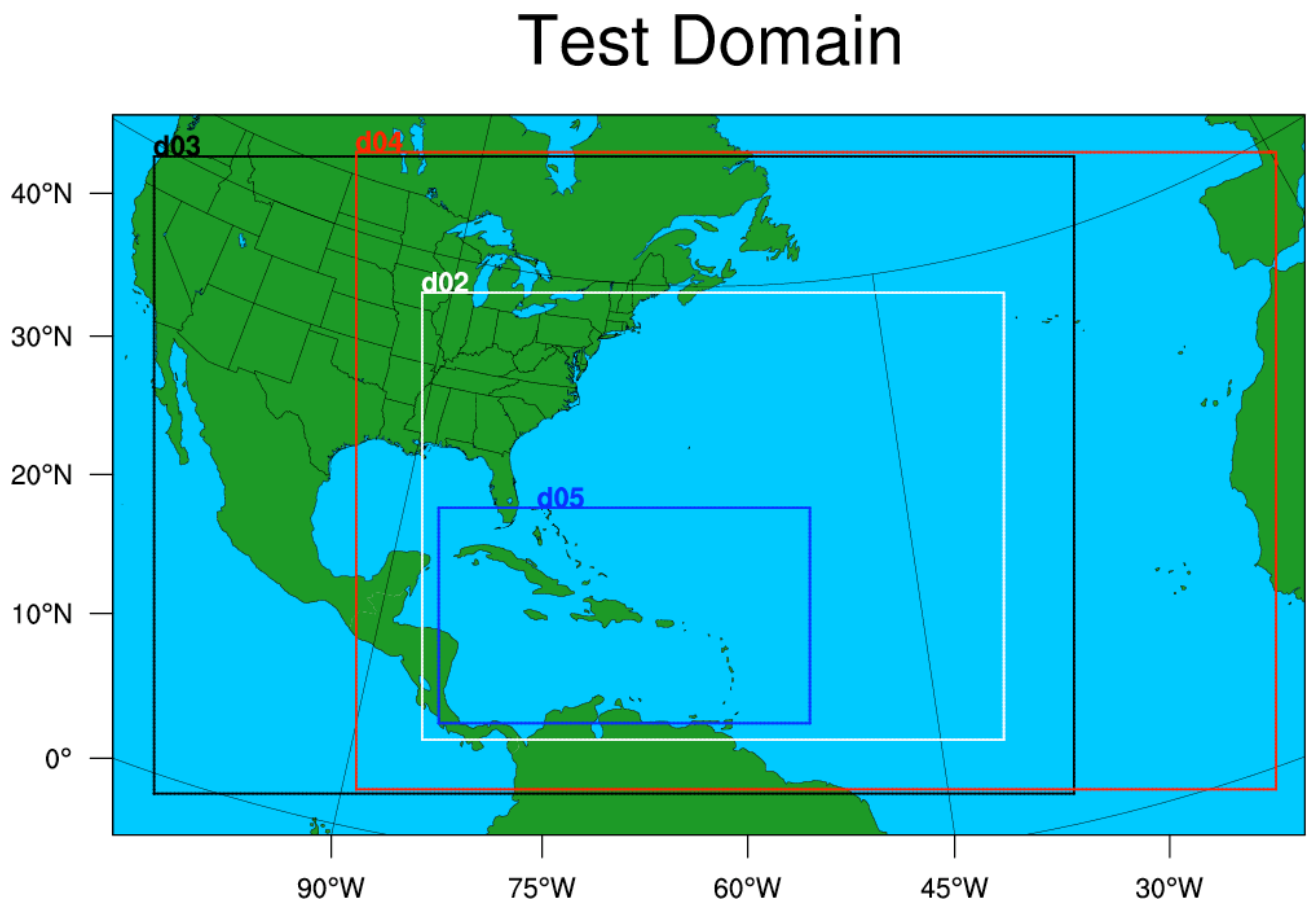
- **All general NCL resources can also be used to control the plot:**
  http://www.ncl.ucar.edu/Document/Graphics/Resources

  - 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)

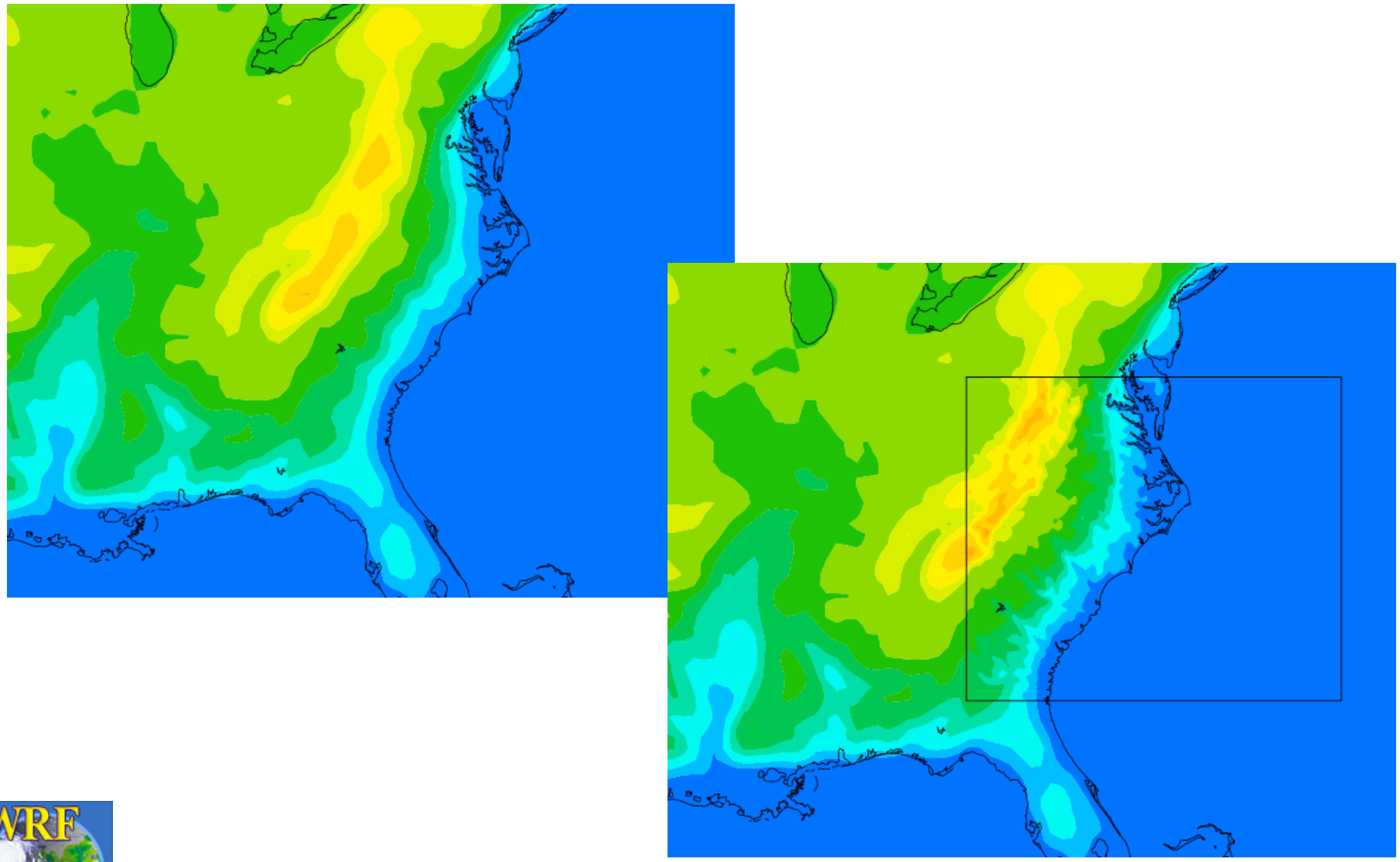


Domain Design

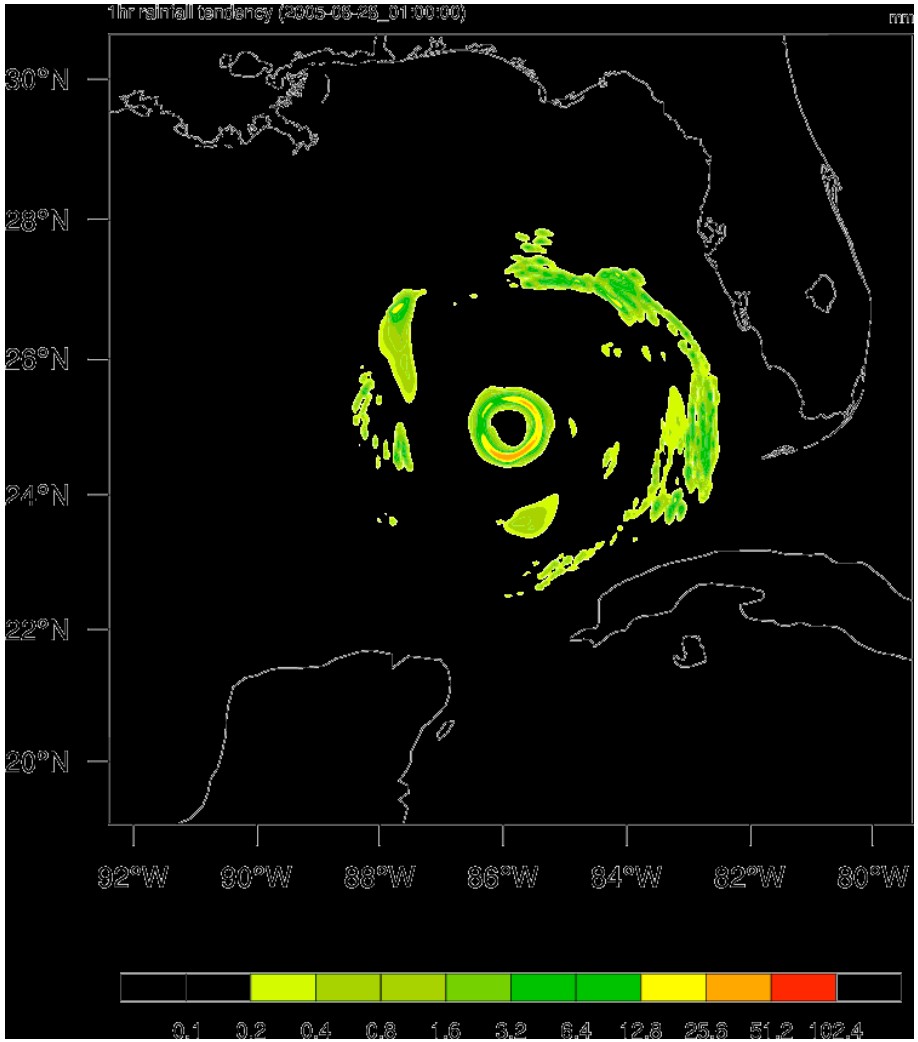
mp = wrf_wps_dom (wks, mpres, lnres, txres)



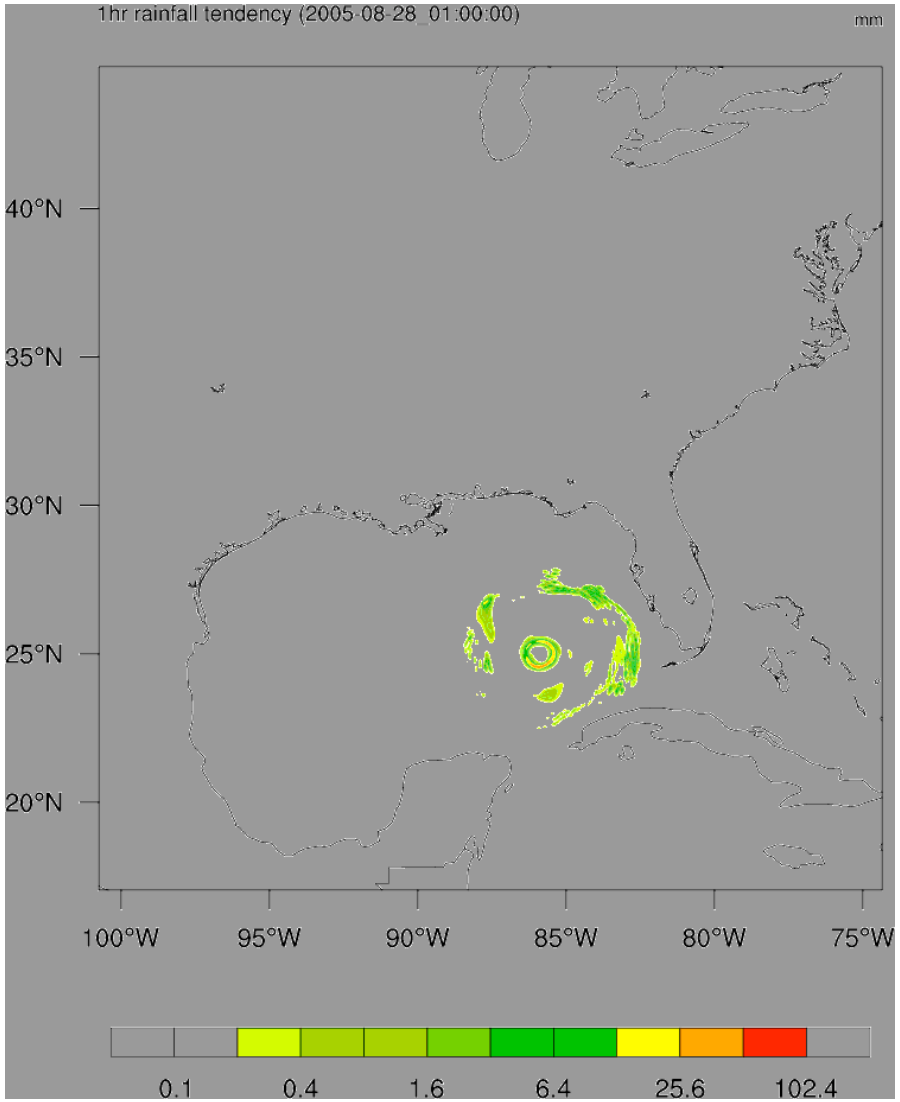
Over Domains



Moving Nests



Moving Nests



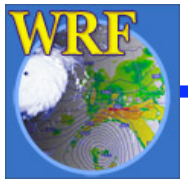
Calling FORTRAN code from NCL

- **Easier to use F77 code, but works with F90 code**

- **Need to isolate definition of input variables and wrap it with special comment statements:**

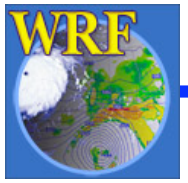
```
C NCLFORTSTART
C NCLEND
```

- **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
```

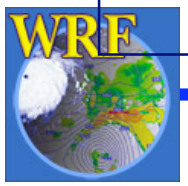


myTK.so - *Create & use in NCL script*

```
% WRAPIT myTK.f
```

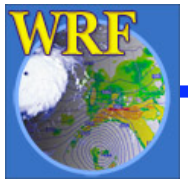
This will create a "myTK.so" file

```
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

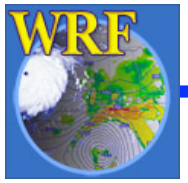
- **Can use simple FORTRAN 90 code**
- **Your FORTRAN 90 program may not contain any of the following features:**
  - pointers or structures as arguments,
  - missing/optional arguments,
  - keyword arguments, or
  - recursive procedure.



FORTRAN 90 code

myTK.f90

```
subroutine compute_tk (tk, pres, theta, nx, ny, nz)
  implicit none
  integer :: nx,ny,nz, i,j,k
  real (nx,ny,nz) :: tk, pres, theta
  real ::    pi


  pi(:,:,:)=(pres(:,:,:)/1000.)**(287./1004.)
  tk(i,j,k) = pi(:,:,:)*theta(i,j,k)

end subroutine compute_tk
```



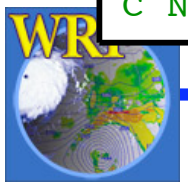
FORTRAN 90 code

myTK.f90

```
subroutine compute_tk (tk, pres, theta, nx, ny, nz)
  implicit none
  integer :: nx,ny,nz, i,j,k
  real (nx,ny,nz) :: tk, pres, theta
  real ::    pi


  pi(:,:,:)=(pres(:,:,:)/1000.)**(287./1004.)
  tk(i,j,k) = pi(:,:,:)*theta(i,j,k)

end subroutine compute_tk
```

myTK90.stub

```
C NCLFORTSTART
  subroutine compute_tk (tk, pres, theta, nx, ny, nz)
  implicit none
  integer nx,ny,nz
  real    tk(nx,ny,nz)
  real    pres(nx,ny,nz), theta(nx,ny,nz)
C NCLEND
```



myTK90.so - *Create & use in NCL script*

```
% WRAPIT myTK90.stub  myTK.f90
```

This will create a "myTK90.so" file

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/wrf/WRFUserARW.ncl"
external myTK90 "./myTK90.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
        myTK90 :: compute_tk (tk,p,t,dim(2),dim(1),dim(0))
end
```