Introduction to Hurricane WRF

Ligia Bernardet

NOAA - Earth System Research Laboratory

CIRES - University of Colorado

Developmental Testbed Center (DTC)

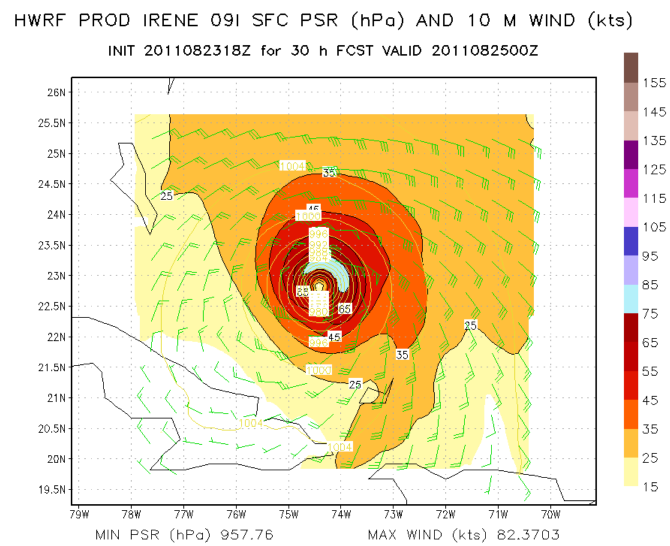
Boulder

Developmental Testbed Center

January 2014

Outline for Introduction to HWRF

- What is the Hurricane WRF
- HWRF domains
- HWRF as a configuration
- Overview of components
- Dynamic core
- Moving nest
- Initialization and data assimilation
- Physics
- Ocean and coupler
- Post-processor and tracker
- User support
- New in 2014 and future development
  - HWRF for additional basins
  - Idealized capability

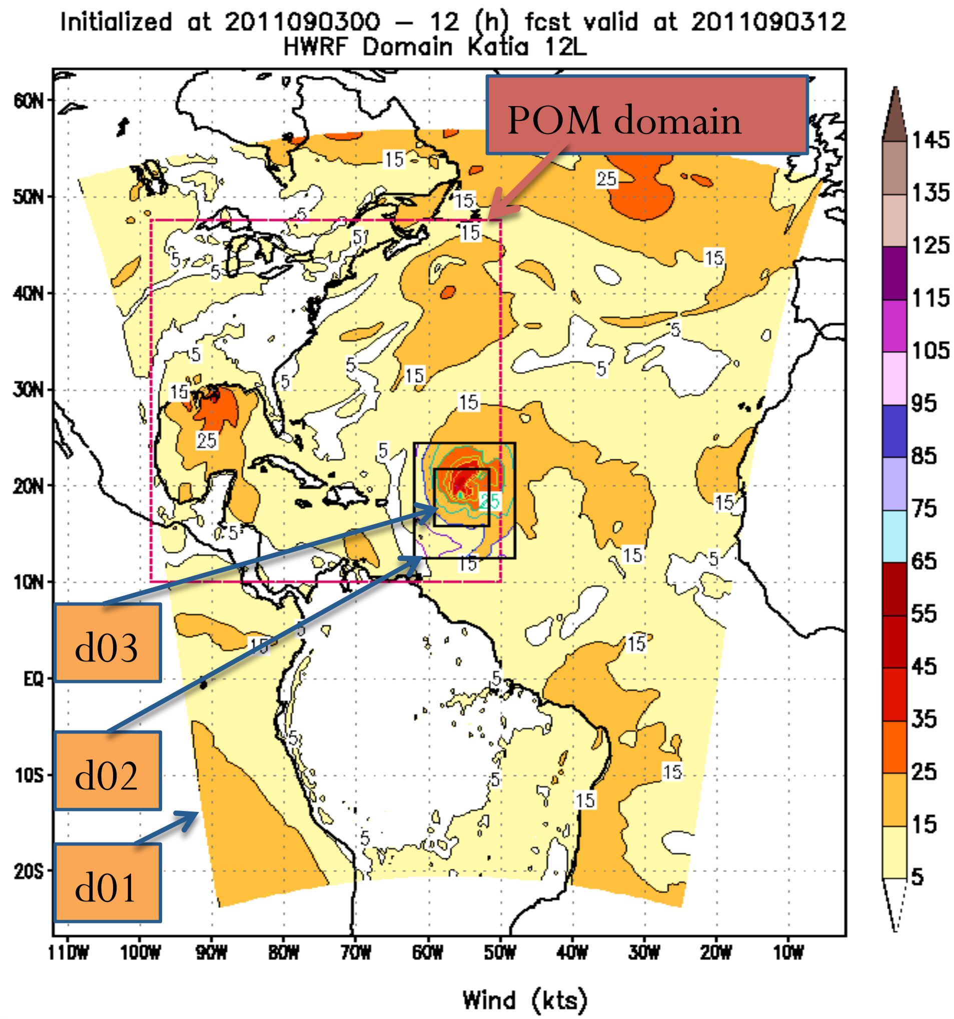


What is the Hurricane WRF?

- A US NWS operational model used to provide numerical forecast guidance of track, intensity, and structure to the National Hurricane Center (NHC) for the North Atlantic and Eastern North Pacific basins
- A model that can be run for all Northern Hemisphere basins (coupled only in AL and EP) and that contains an idealized tropical cyclone capability
- A community supported code
- A model that is always evolving and improving: new operational implementations of HWRF occur every year in the beginning of the hurricane season
- This talk focuses on 2013 HWRF (some info on plans for future provided)

Operational forecasts
http://www.emc.ncep.noaa.gov/gc_wmb/vxt/

HWRF 2013 grid configuration



Atmospheric configuration

- Horizontal grid spacing: 27, 9, 3 km
- Inner nests move to follow storm
- Domain location vary from run to run depending on storm location
- 42 vertical levels; top at 50 hPa

Oceanic configuration

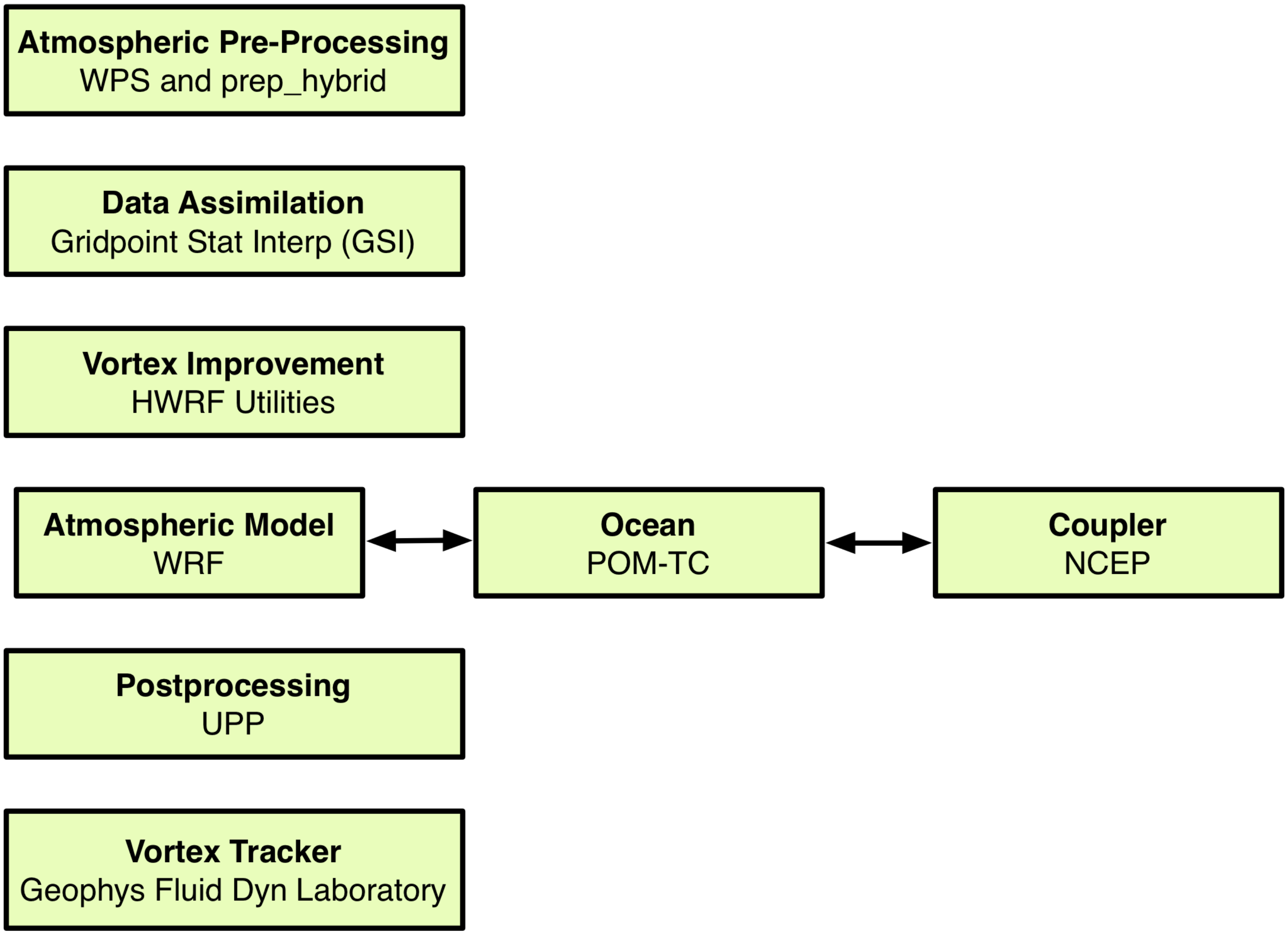
- Horizontal grid spacing: 18 km
- Size, location of grid depends of location of storm
- Pacific
  - 1-D (column) model
  - 16 vertical levels
- Atlantic
  - 3-D model
  - 23 vertical levels

Developmental Testbed Center

HWRF as a configuration

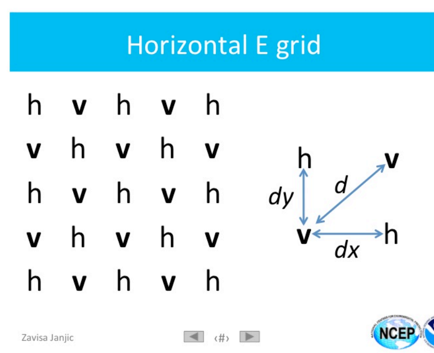
- The atmospheric component of HWRF uses the WRF model
- You have learned that WRF can be configured in many different ways
- HWRF uses a specific configuration of WRF
  - 3-domains with fixed sizes, method for placement, and grid spacing
  - Specific physics options
  - Specific timestep
  - Specific way of being initialized and postprocessed
  - Choices made to make best forecast under various constraints, mainly the operational time window
- There are other, non-operational, configurations of WRF that can be used for hurricane forecasting (not covered in this presentation)

HWRF has many components

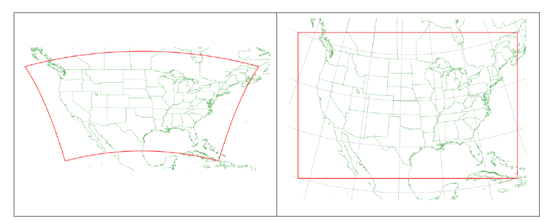


HWRF dynamical core

- WRF has two dynamic cores: ARW and NMM (Non-Hydrostatic Mesoscale Model)
- The dynamic core encompasses the grid projection, grid staggering, system of equations for solving the equations of motion and thermodynamics, the numerical methods, and the nesting mechanisms
- This Tutorial only covered the ARW core. For NMM core, refer to
  - WRF-NMM website: http://www.dtcenter.org/wrf-nmm/users/
  - Presentation about WRF-NMM in 2012 WRF tutorial http://www.mmm.ucar.edu/wrf/users/tutorial/201201/NMM_Dynamics_jan2012_tut_cnvsym.pptx.pdf
  - Scientific Documentation for the NMM Solver http://nldr.library.ucar.edu/collections/technotes/asset-000-000-000-845.pdf



Sample rotated lat-lon domain

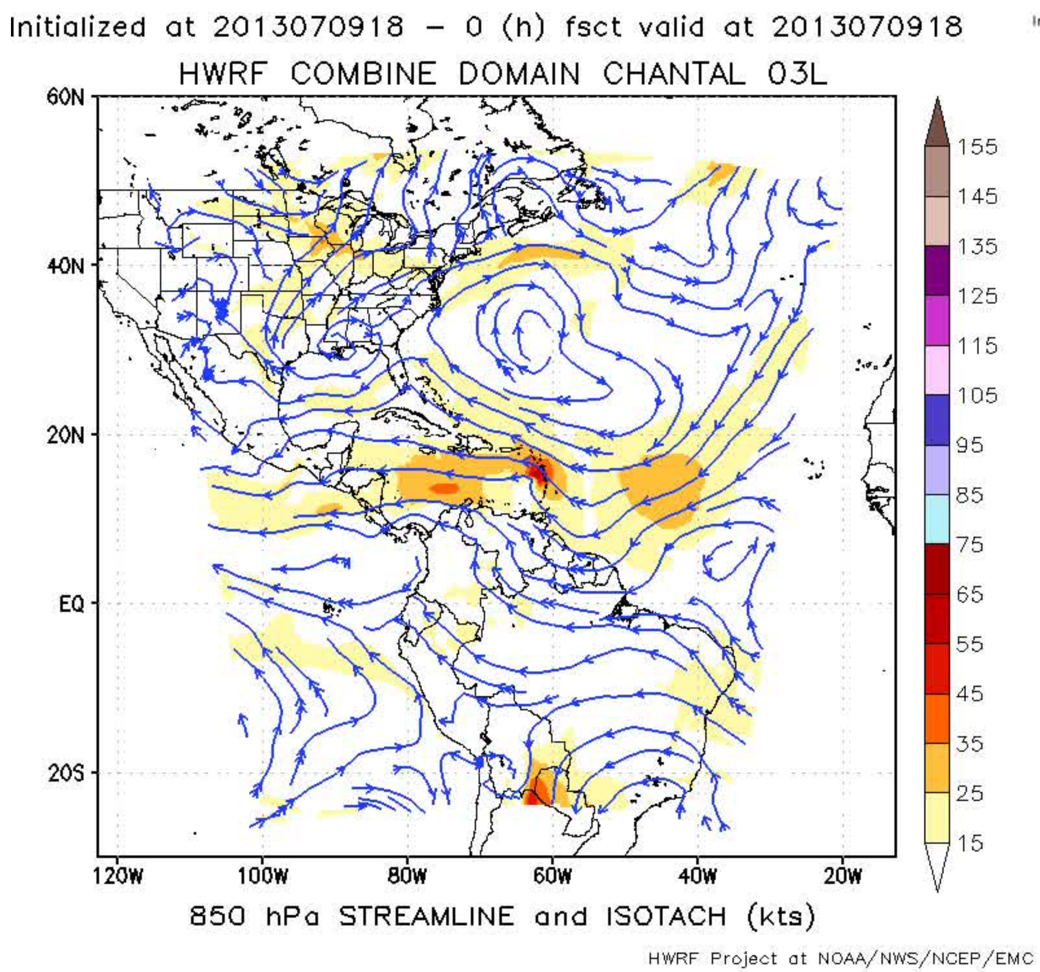


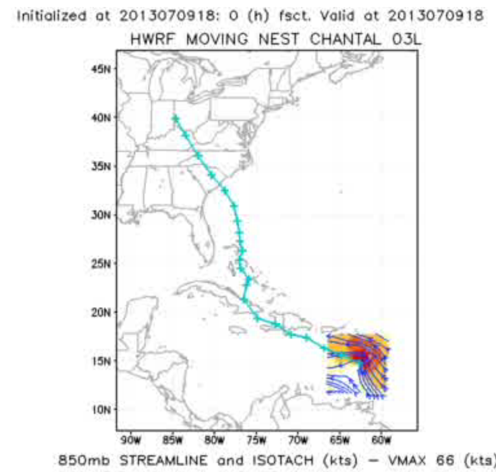
On a regular lat-lon map background

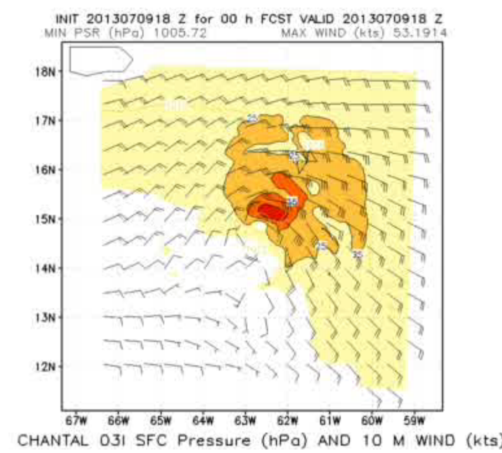
On a rotated lat-lon map background (same rotation as model grid).

Courtesy: Z. Janjic NOAA/NCEP/EMC

HWRF Moving Nests

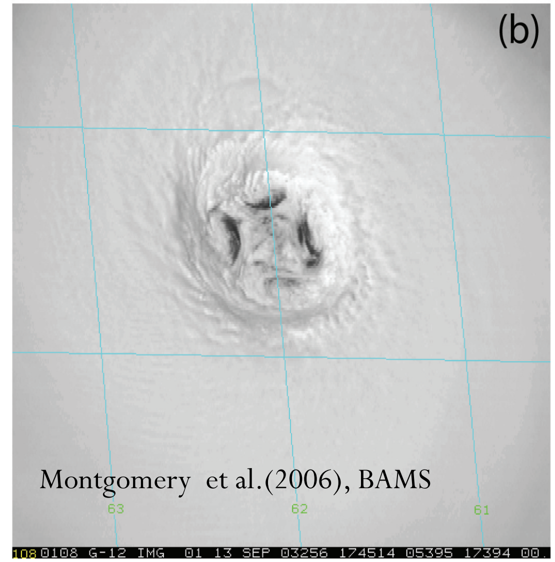






Inner nest follows the vortex

- Why nests: need high-resolution to resolve convection in hurricane but cannot afford it everywhere in domain
- 27-km parent domain does not move in a run
- 9-km domain moves following the 3-km domain, which follows storm center
- A vortex tracking algorithm is used to track the center of the storm and automatically move the nest
- The storm center is determined based on surface p, winds and 850/700 hPa geopotential/winds
- Straight forward for well-defined vortices
- Challenge: following disorganized TS and mesovortices, so tracking algorithm is sophisticated
- When nest moves, fields on leading edge must be interpolated down from parent and high-res terrain interpolated from high-res static file



Montgomery et al.(2006), BAMS

Chantal, 7/8/2013

HWRF 2013 Initialization

Challenges

- Initializing a 3-km grid from a lower-resolution global model
  - Storm has wrong place, size and/or structure
  - Weak storm may dissipate in hurricane model

Solutions

- Use a vortex relocation and correction algorithm

HWRF Initialization

- Use global model (GDAS) for first guess
- Perform data assimilation on d01 (27-km) with GSI
- Remove vortex
- Insert a corrected vortex
    - Usually 6-h forecast from HWRF previous cycle
    - Vortex location, intensity, and structure corrected using observations

HWRF Data Assimilation (GSI 3DVar)

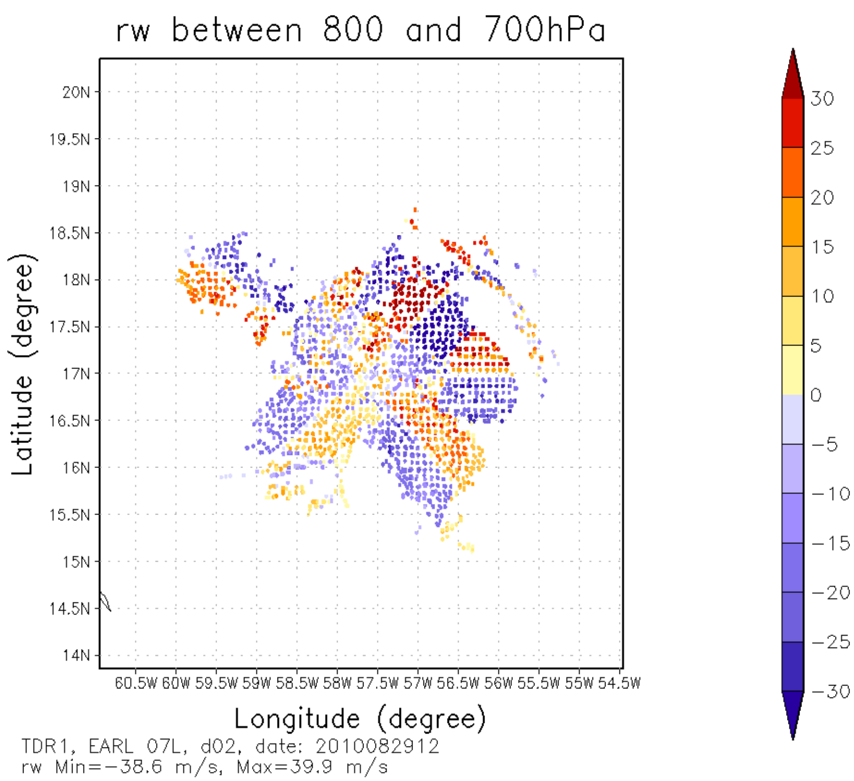
- 27-km: data assimilated in environment, not near storm
  - Radiosondes
  - Aircraft reports (AIREP/PIREP, RECCO, MDCRS-ACARS, TAMDAR, AMDAR)
  - Surface ship and buoy observations
  - Surface observations over land
  - Pibal winds
  - Wind profilers
  - VAD wind
  - Dropsondes

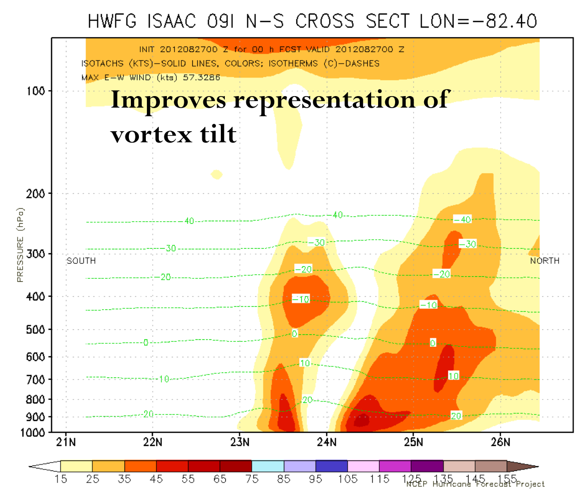
More information on Gridpoint Statistical Interpolator

- http://www.dtcenter.org/com-GSI/users/

HWRF Data Assimilation (GSI 3DVar)

- 3-km: perform DA to assimilate tail Doppler radar in storm core (if available)





HWRF 2013 operational physics

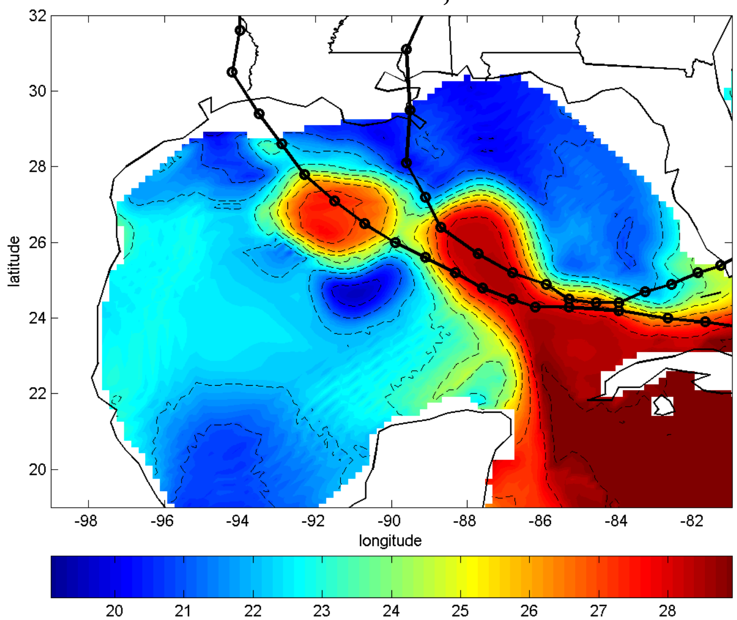
Physics	Parameterization	Option
Cumulus (only d01 & d02)	SAS deep and shallow convection	84
Microphysics	Ferrier for the tropics	85
Planetary Boundary Layer	GFS (modified Hong & Pan 1996)	3
Surface Layer	GFDL (modified)	88
Land Surface Model	GFDL slab model	88
Radiation	GFDL	98

Cumulus parameterization: only on d01 (27 km) and d02 (9 km).
In d03 (3 km), microphysical parameterization explicitly resolves clouds.

HWRF Ocean Component

- Princeton Ocean Model for Tropical Cyclones (POM-TC)
- POM creates an accurate sea-surface-temperature (SST) field that **evolves** during the model run
- Moisture/heat fluxes from the ocean provide energy for hurricanes

Rita Katrina, 2005



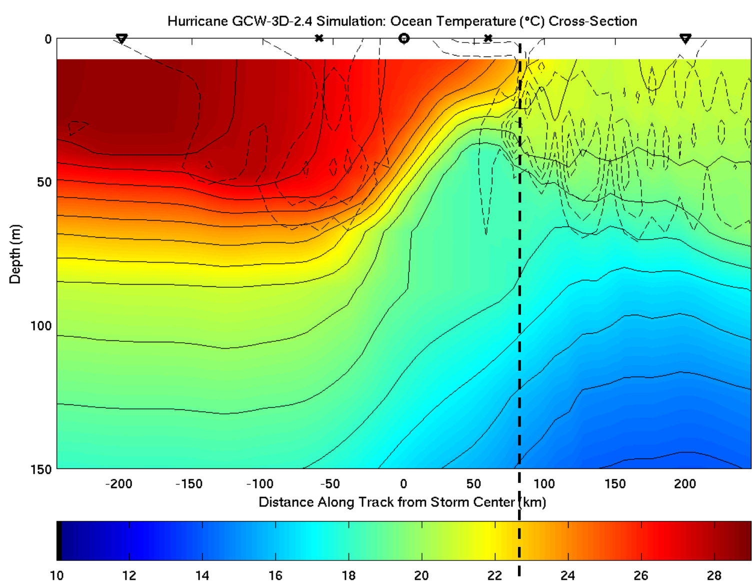
75-m depth temperature
Courtesy R. Yablonsky (URI)

Warmer ocean leads to more intense storms

Developmental Testbed Center

HWRF Ocean Component

- When a storm is over cold ocean, it tends to weaken
- A storm can cause the SST to change due to turbulent mixing with deeper, cold water and due to upwelling
- Models that do not include SST evolution may have SSTs too warm and make storms too strong



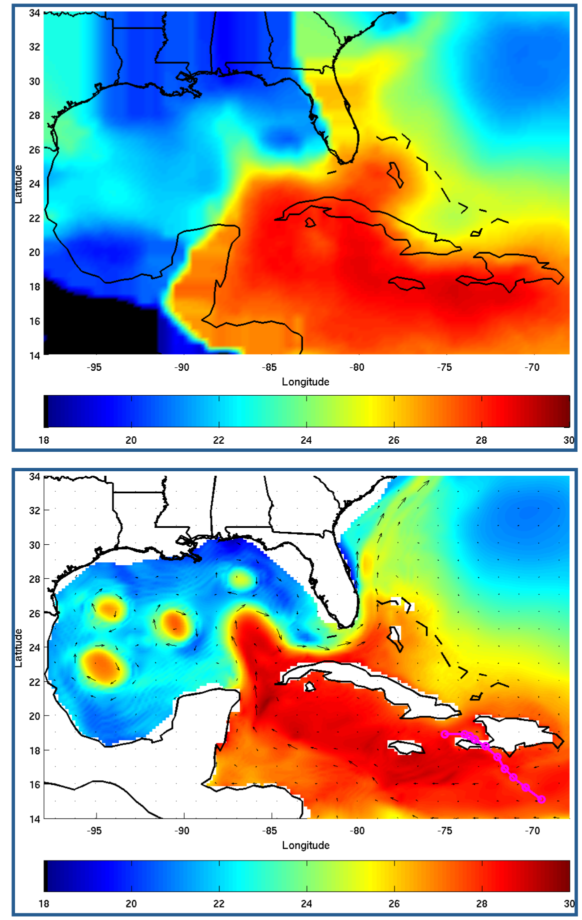
Colder ocean leads to weaker storms

POM-TC idealized simulation of storm moving to left at 2.4 ms^{-1}: SST cools 6°C.

Ocean temperature
Courtesy R. Yablonsky (URI)

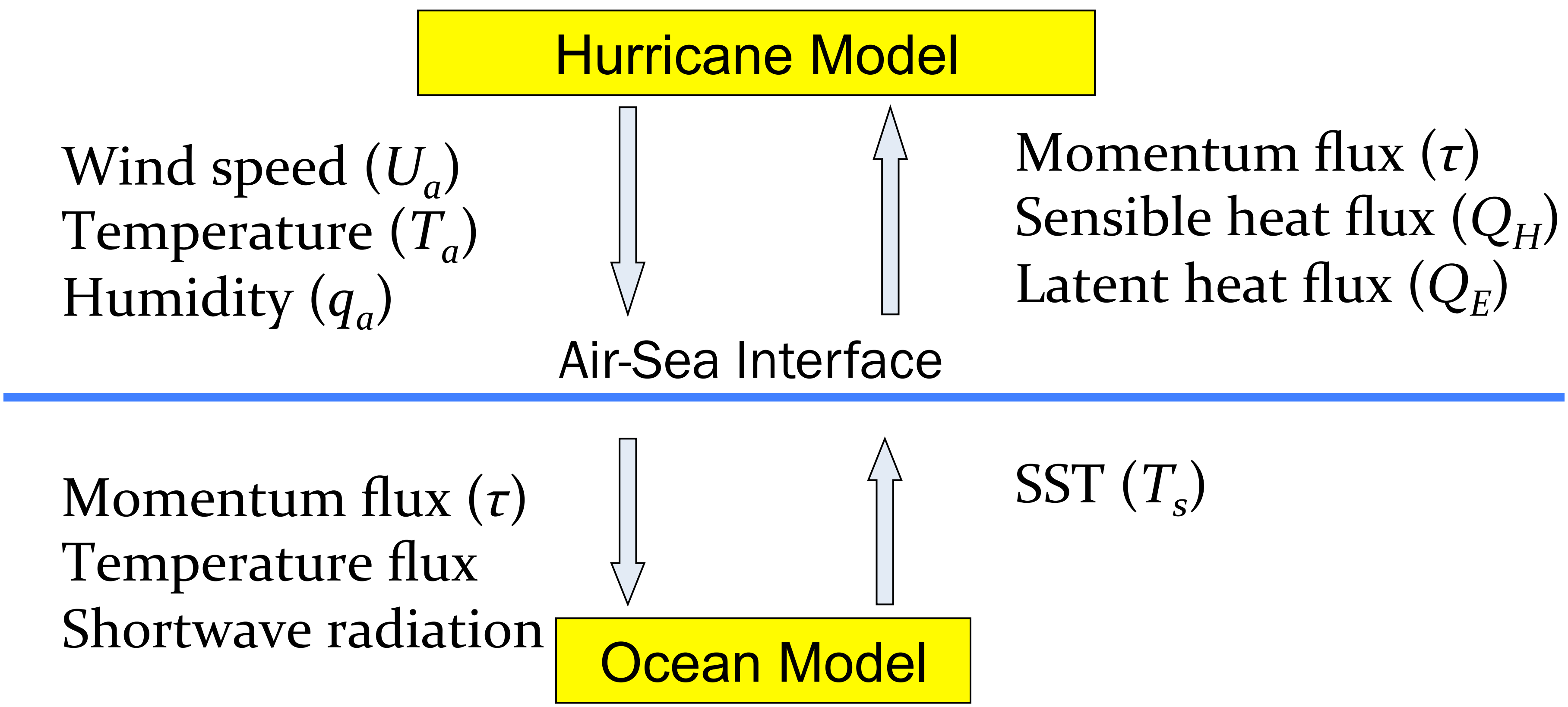
POM-TC Initialization

- Aims at creating an accurate meso-scale representation of SST distribution
- Employs
  - Salinity and SST climatology
  - SST from global model (GFS)
  - Altimetry information to locate warm and cold core rings and loop current
  - TC location and intensity



Gustav (2008): 75-m deep temperature from climatology (top) and after initialization procedure

NCEP coupler handles communication between WRF and POM-TC

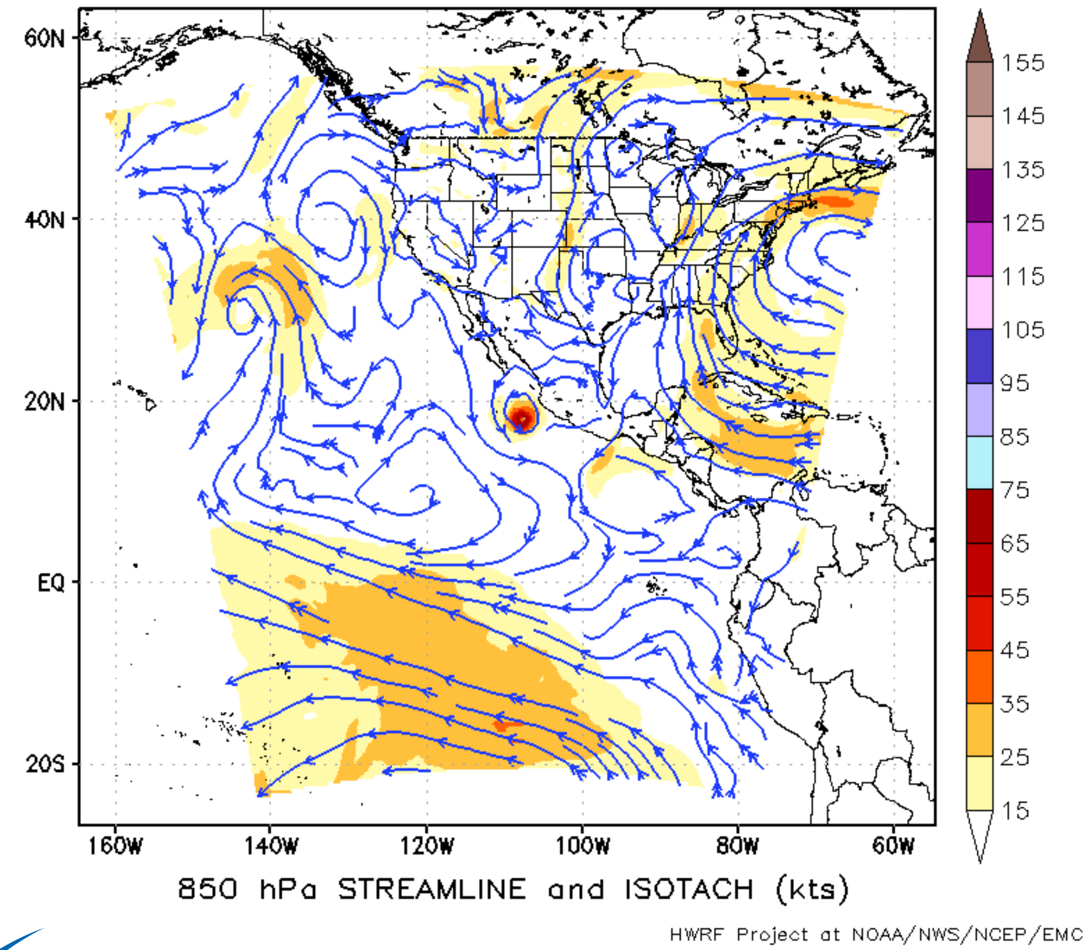


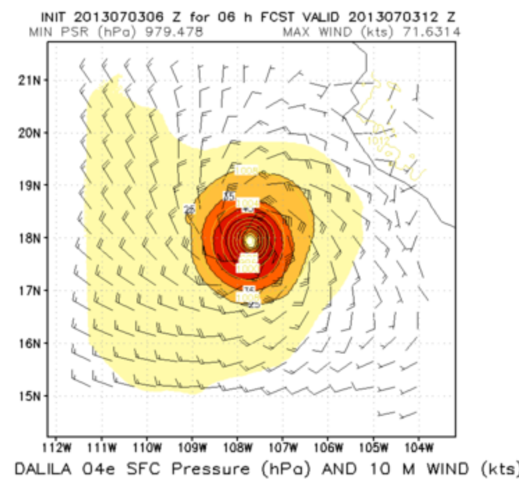
$$\tau = \rho_a C_D U_a U_a \qquad Q_H = C_H U_a (T_a - T_s) \qquad Q_E = \frac{L_V}{C_P} C_E U_a (q_a - q_s)$$

HWRF Post-Processing

- Uses the Unified post-processor (UPP)
  - Computes derived variables
  - Interpolates the forecast
    - Horizontally from the WRF native grid to a lat-lon grid
    - Vertically from WRF native levels to isobaric levels
  - Generates output in GRIB format
- Domains processed separately, then combined
- Output is used for
  - Graphics
  - Running the external vortex tracker

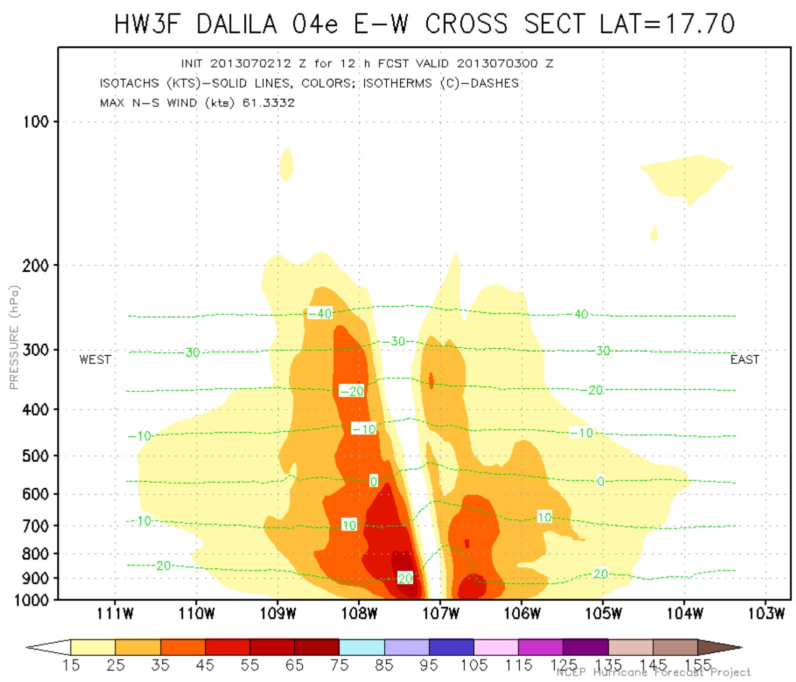
Surface or isobaric fields

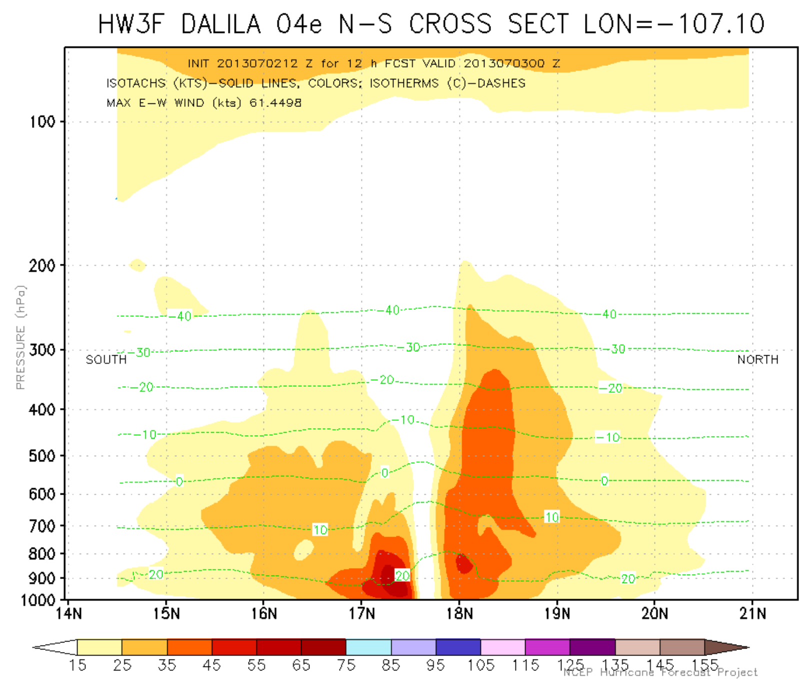




12-h forecast TS Dalila (2013)

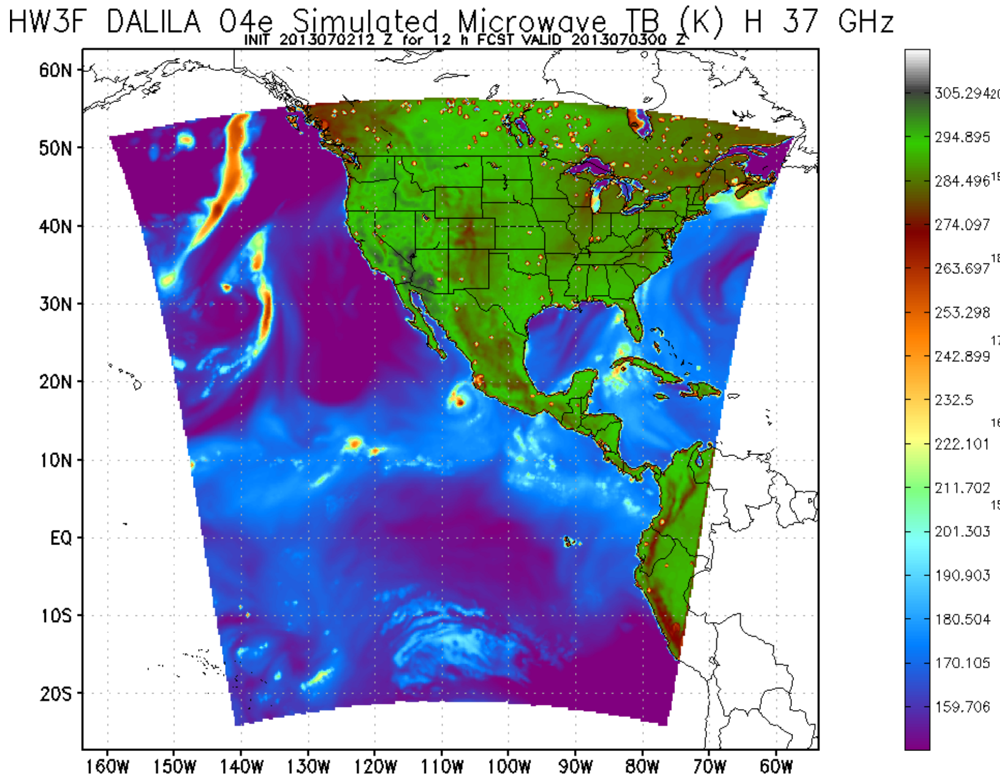
Vertical cross sections

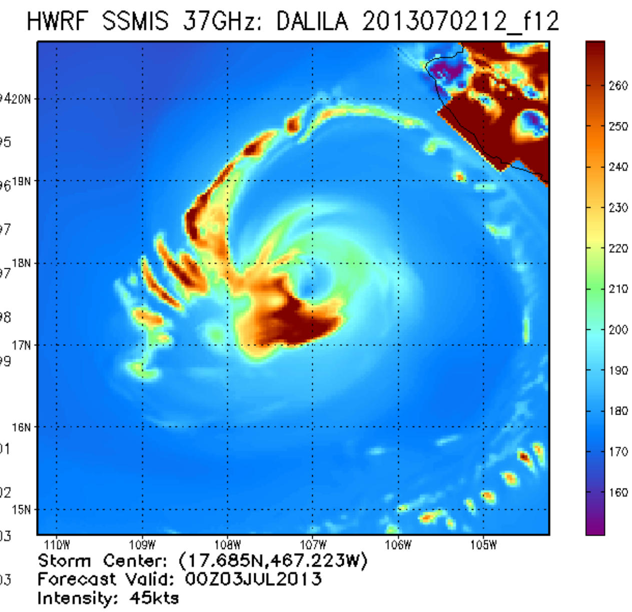




12-h forecast TS Dalila (2013)

Simulated 37 GHz (TS Dalila)

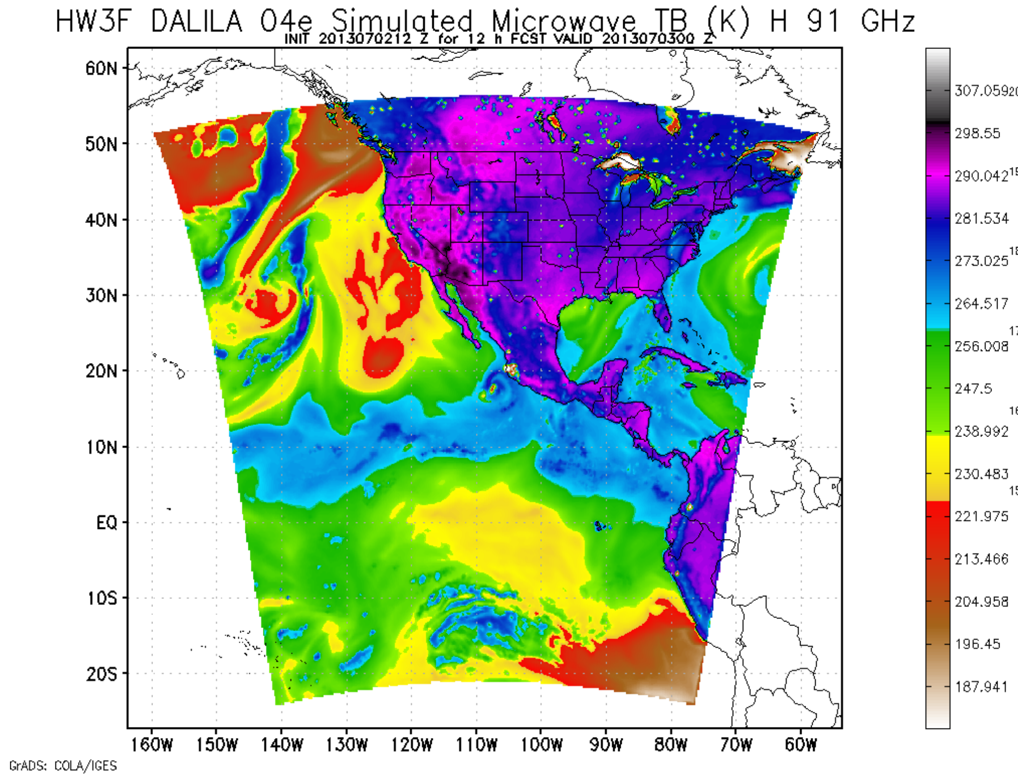


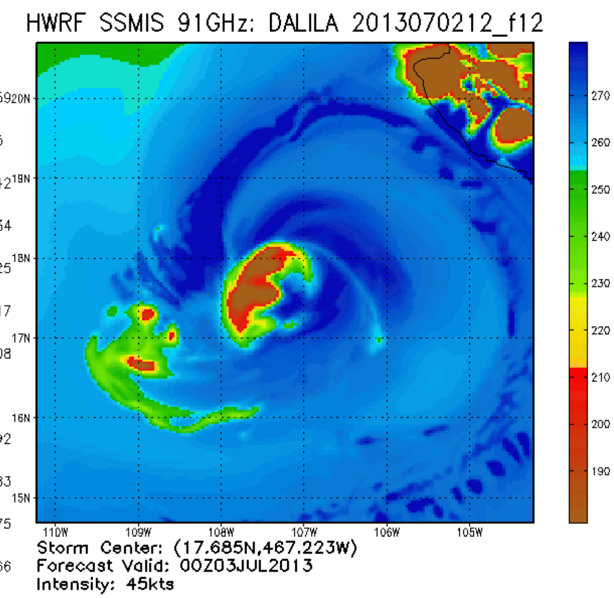


12-h forecast TS Dalila (2013)

Developmental Testbed Center

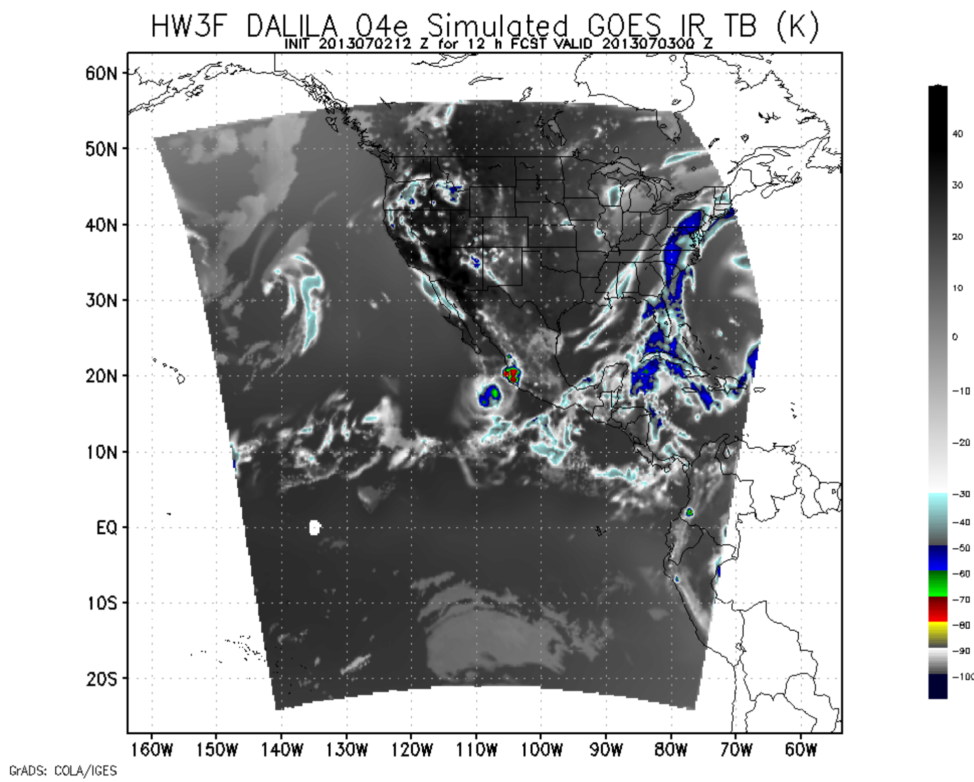
Simulated 89 GHz (TS Dalila)

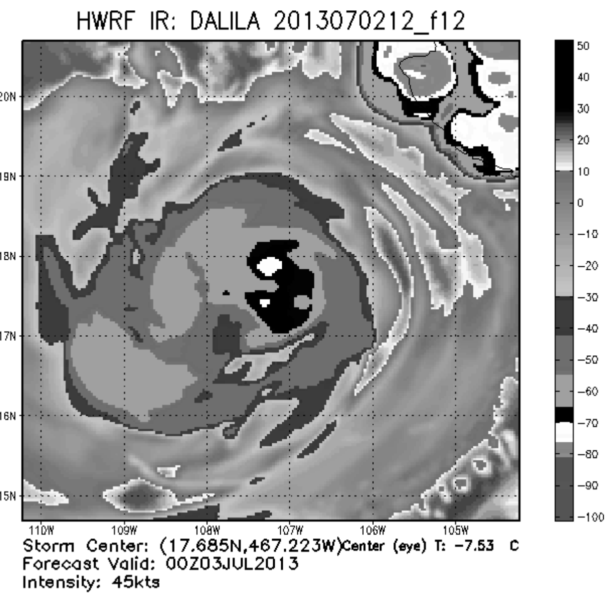




12-h forecast TS Dalila (2013)

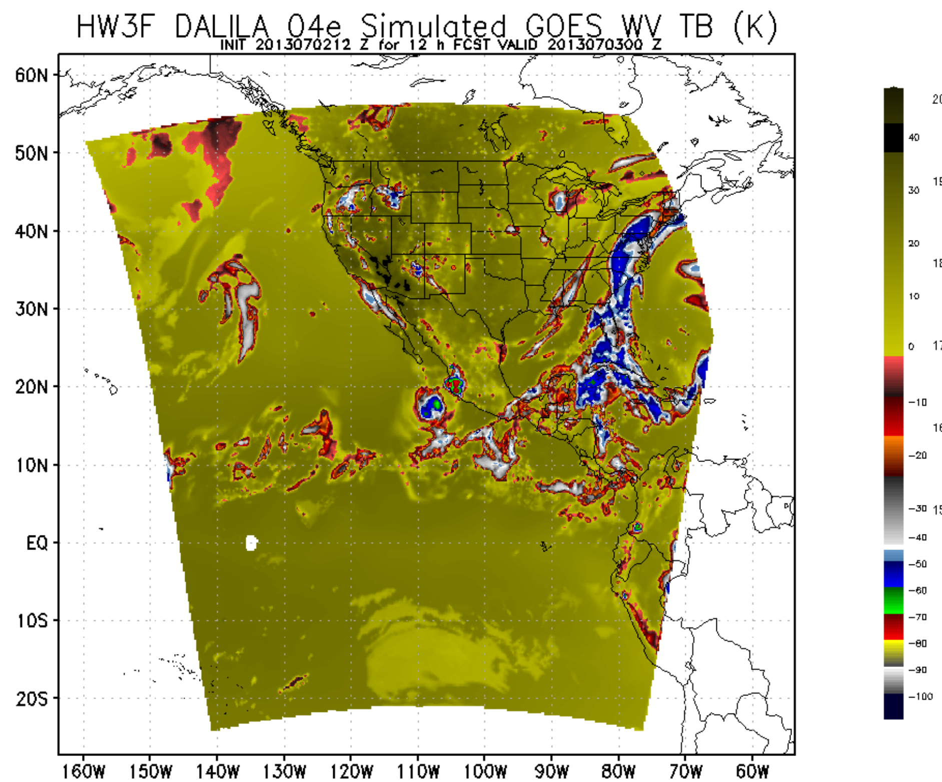
Simulated IR

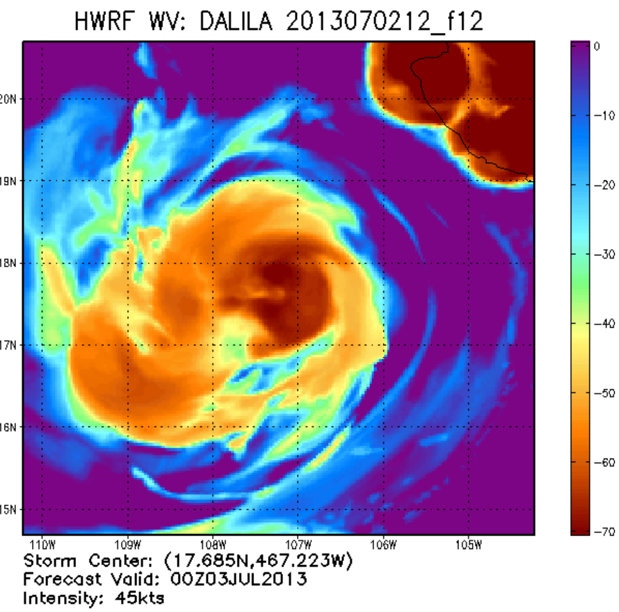




12-h forecast TS Dalila (2013)

Simulated Water Vapor

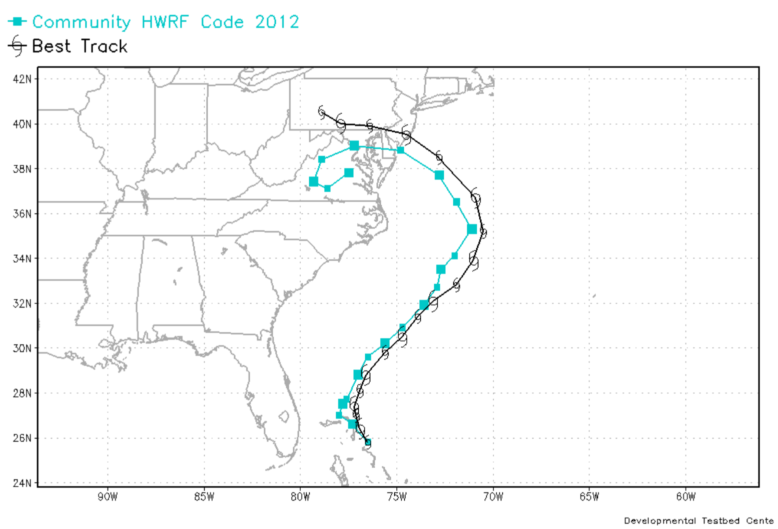


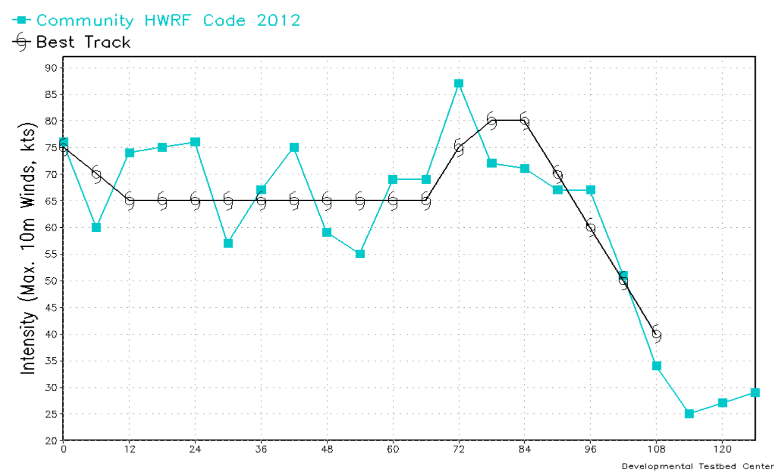


12-h forecast TS Dalila (2013)

GFDL External Vortex Tracker

- Extracts storm properties from the 3D forecast fields
  - Location, intensity, structure
- Outputs text file which can be used for plotting
- Can be used for HWRF or any other model, as long as proper files are provided in GRIB1 format



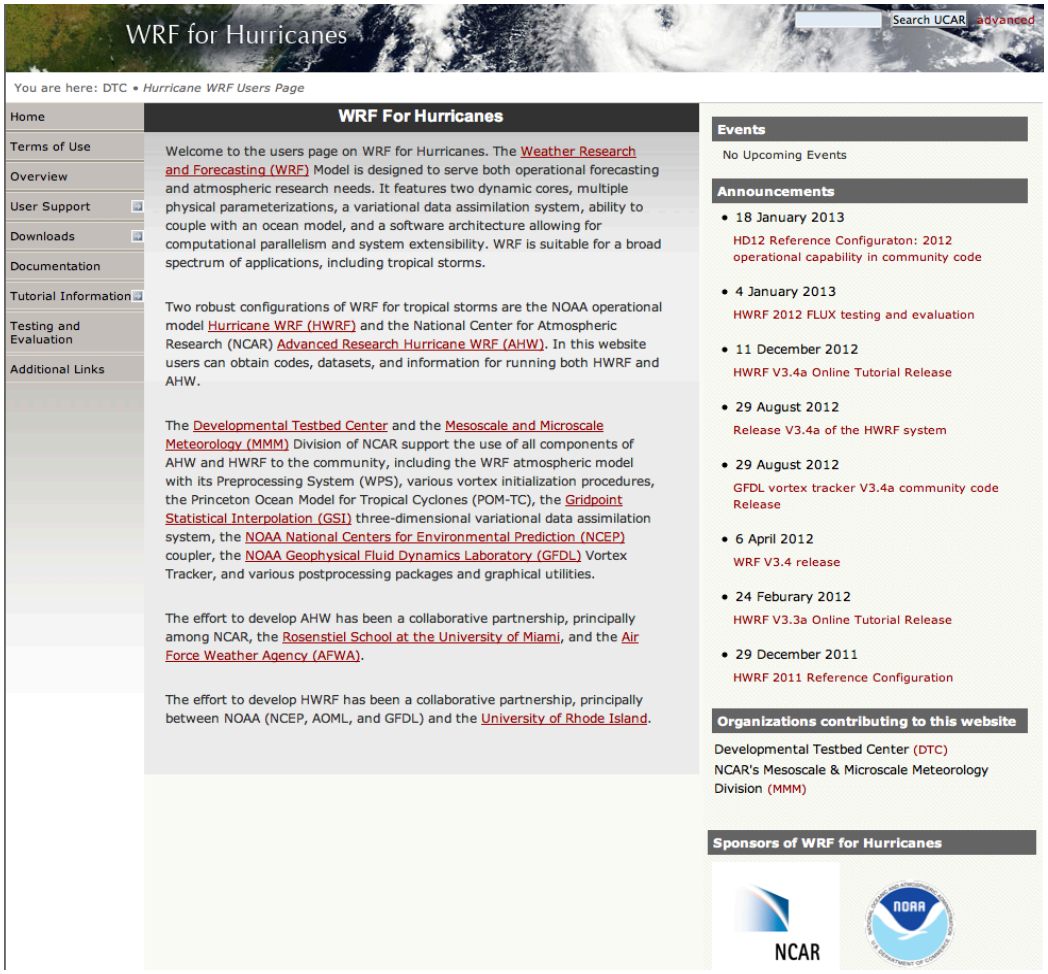


Sandy 2012: Sample of Community HWRF runs by DTC

DTC Developmental Testbed Center

www.dtcenter.org/HurrWRF/users

Community support


WRF for Hurricanes

Search UCAR advanced

You are here: DTC • *Hurricane WRF Users Page*

- Home
- Terms of Use
- Overview
- User Support
- Downloads
- Documentation
- Tutorial Information
- Testing and Evaluation
- Additional Links

WRF For Hurricanes

Welcome to the users page on WRF for Hurricanes. The Weather Research and Forecasting (WRF) Model is designed to serve both operational forecasting and atmospheric research needs. It features two dynamic cores, multiple physical parameterizations, a variational data assimilation system, ability to couple with an ocean model, and a software architecture allowing for computational parallelism and system extensibility. WRF is suitable for a broad spectrum of applications, including tropical storms.

Two robust configurations of WRF for tropical storms are the NOAA operational model Hurricane WRF (HWRF) and the National Center for Atmospheric Research (NCAR) Advanced Research Hurricane WRF (AHW). In this website users can obtain codes, datasets, and information for running both HWRF and AHW.

The Developmental Testbed Center and the Mesoscale and Microscale Meteorology (MMM) Division of NCAR support the use of all components of AHW and HWRF to the community, including the WRF atmospheric model with its Preprocessing System (WPS), various vortex initialization procedures, the Princeton Ocean Model for Tropical Cyclones (POM-TC), the Gridpoint Statistical Interpolation (GSI) three-dimensional variational data assimilation system, the NOAA National Centers for Environmental Prediction (NCEP) coupler, the NOAA Geophysical Fluid Dynamics Laboratory (GFDL) Vortex Tracker, and various postprocessing packages and graphical utilities.

The effort to develop AHW has been a collaborative partnership, principally among NCAR, the Rosenstiel School at the University of Miami, and the Air Force Weather Agency (AFWA).

The effort to develop HWRF has been a collaborative partnership, principally between NOAA (NCEP, AOML, and GFDL) and the University of Rhode Island.

Events

No Upcoming Events

Announcements

- 18 January 2013
  HD12 Reference Configuraton: 2012 operational capability in community code
- 4 January 2013
  HWRF 2012 FLUX testing and evaluation
- 11 December 2012
  HWRF V3.4a Online Tutorial Release
- 29 August 2012
  Release V3.4a of the HWRF system
- 29 August 2012
  GFDL vortex tracker V3.4a community code Release
- 6 April 2012
  WRF V3.4 release
- 24 Feburary 2012
  HWRF V3.3a Online Tutorial Release
- 29 December 2011
  HWRF 2011 Reference Configuration

Organizations contributing to this website

Developmental Testbed Center (DTC)

NCAR's Mesoscale & Microscale Meteorology Division (MMM)

Sponsors of WRF for Hurricanes

NCAR

NOAA

Code downloads, datasets, documentation, online tutorial, helpdesk

500 registered users

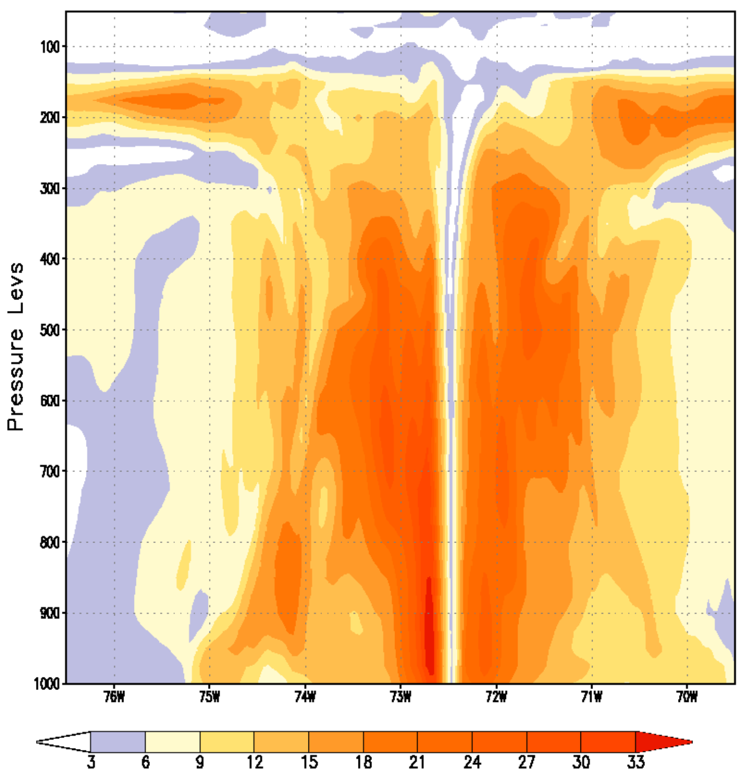
Yearly releases corresponding to operational model of the year

Stable, tested code

Current release: HWRF v3.5a (2013 operational)

Idealized HWRF

Vertical x-section



Specifications

- Quiescent environment
- Prescribed T, Td sounding
- Specified vortex
  - intensity
  - size
- No ocean coupling

Useful research tool for testing physics and concepts

Challenges and ongoing work for 2014 and beyond

- **Configuration:** larger grids with multiple moving nests, more vertical levels
- **Ocean**
  - Transition to MPIPOM-TC, later to HYCOM
- **Data Assimilation and initialization**
  - Use of all available datasets, including storm-scale observations and satellite
- **Ensemble**: for uncertainty estimation
- **Physics:** radiation, PBL, LSM, MP, convection, sea spray
- **Coupling**: wave model, storm surge, inundation

HWRF: A collaborative effort

- HWRF is developed under the coordination of NOAA/NWS/NCEP/EMC
- Besides EMC, many groups participate in HWRF development
- Many receive funding from NOAA Hurricane Forecast Improvement Project

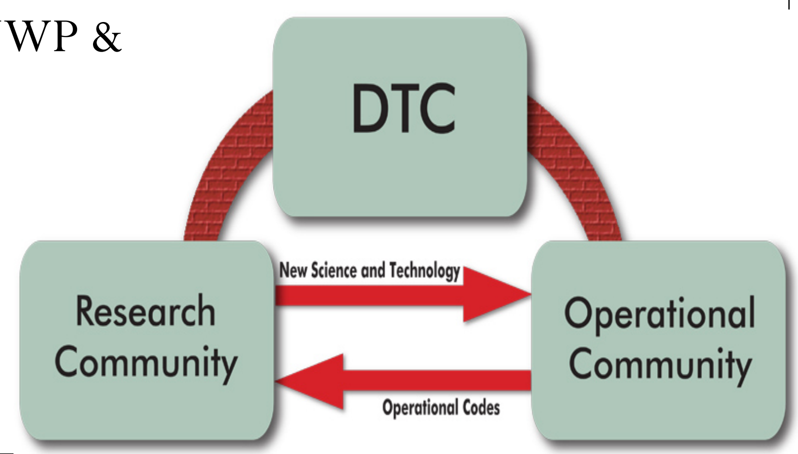
Institution	Role
NOAA NWS Natl Hurricane Center	Main customer, evaluation, diagnostics
NOAA NWS/NCEP/EMC	Coordination and overall development
NOAA Research AOML/ESRL/GFDL	Nesting, physics, initialization, vortex tracking, diagnostics
NCAR	WRF model infrastructure
University of Rhode Island	Ocean component (POM-TC)
Developmental Testbed Center	Code management, community support, testing
Your institution!	**You could be the next HWRF user and developer**

DTC (NOAA, Air Force, NSF, & NCAR)

The purpose of the DTC is to facilitate the interaction & transition of NWP technology between research & operations. DTC facilitates:

- R2O transition by performing testing & evaluation of new NWP innovations over an extended period
- O2R transition by making the operational NWP systems available to the research community & providing user support (WRF, HWRF etc.)

- Interaction between research & operations through the organization of community workshops on NWP & hosting DTC Visitor Program



Thank you!

- Questions?
  - http://www.dtcenter.org/HurrWRF/users
  - ligia.bernardet@noaa.gov
  - wrfhelp@ucar.edu

Dennis, 7/10/2005