Introduction to Hurricane WRF

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Boulder

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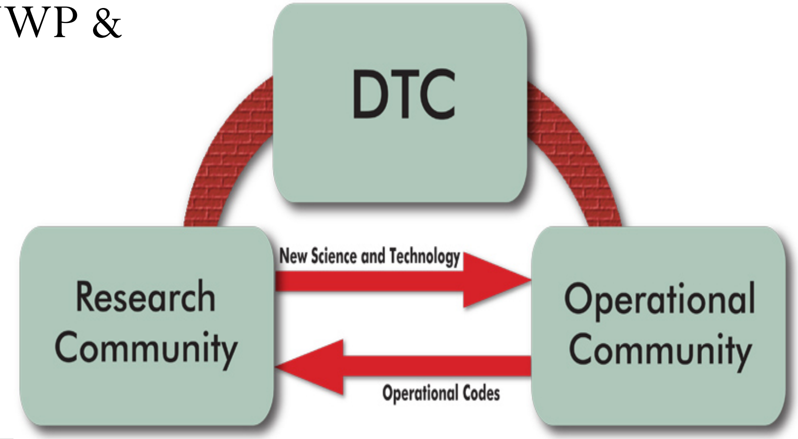
DTC (NOAA, Air Force, NSF, & NCAR)

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

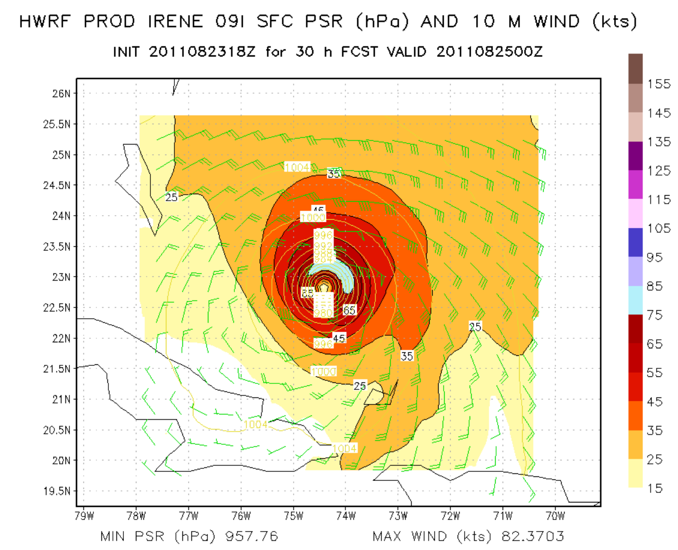
- R2O transition by performing testing & evaluation of new NWP innovations over an extended period
- O2R transition by making the operational NWP systems available to the research community & providing user support (WRF, HWRF etc.)

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



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 2013 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 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)

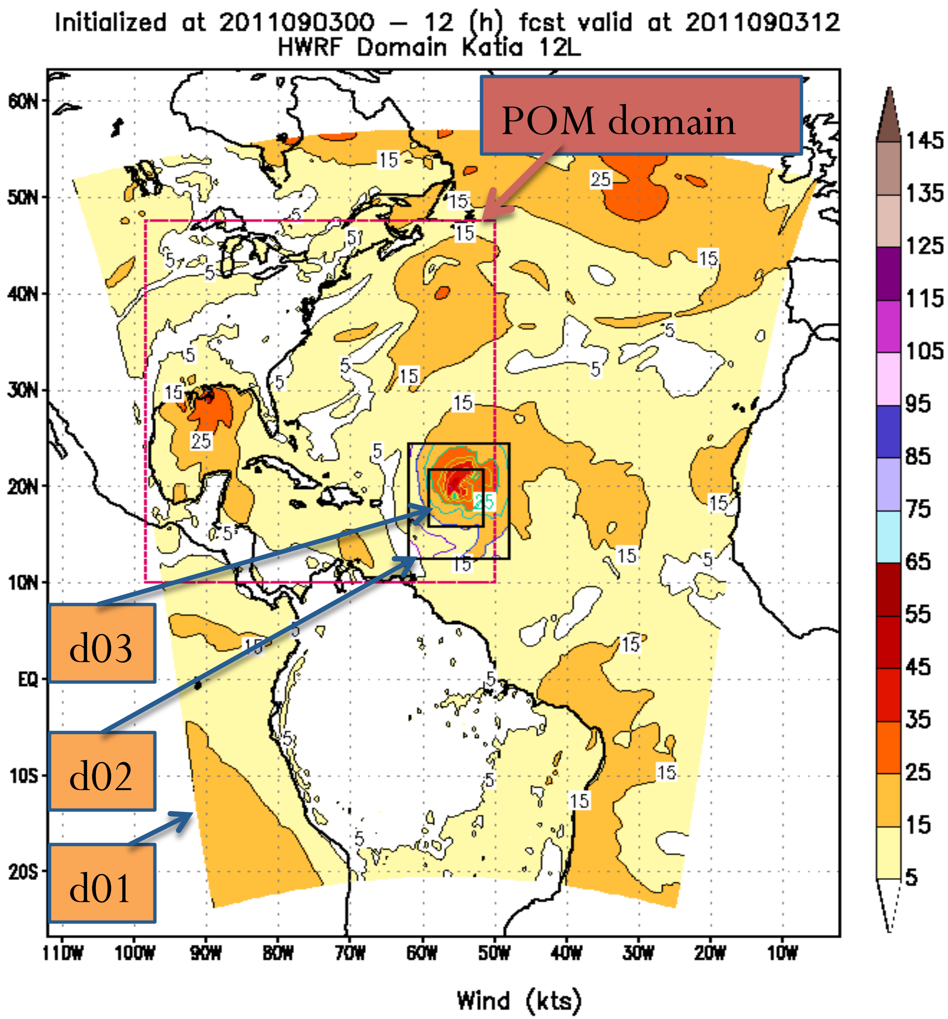
Operational forecasts
http://www.emc.ncep.noaa.gov/gc_wmb/vxt/

HWRF: A collaborative effort

- HWRF is developed under the coordination of Dr. Vijay Tallapragada at NOAA/NWS/NCEP/EMC
- Besides EMC, many groups participate in HWRF development

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**

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

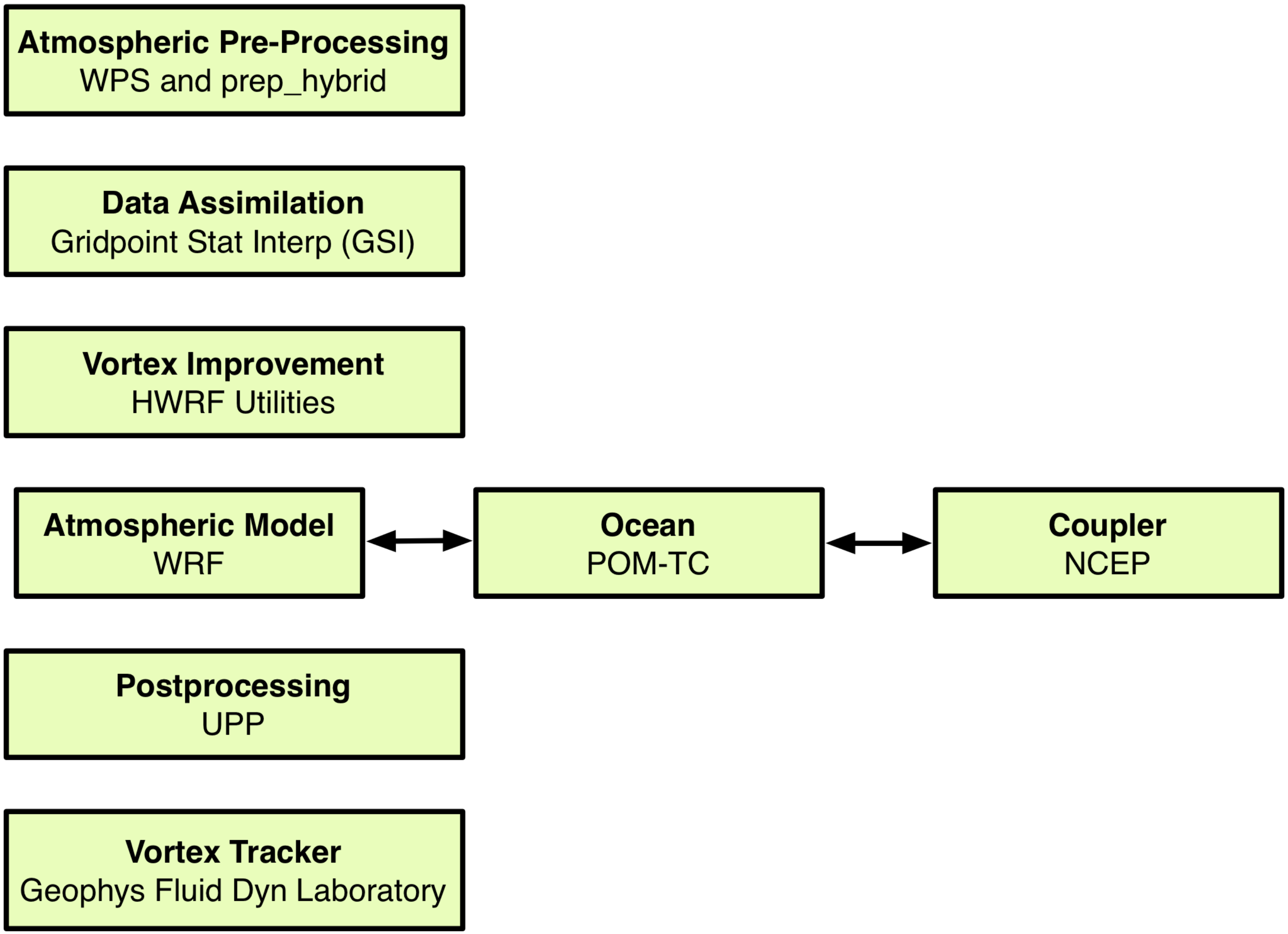
Oceanic configuration

- 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

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)

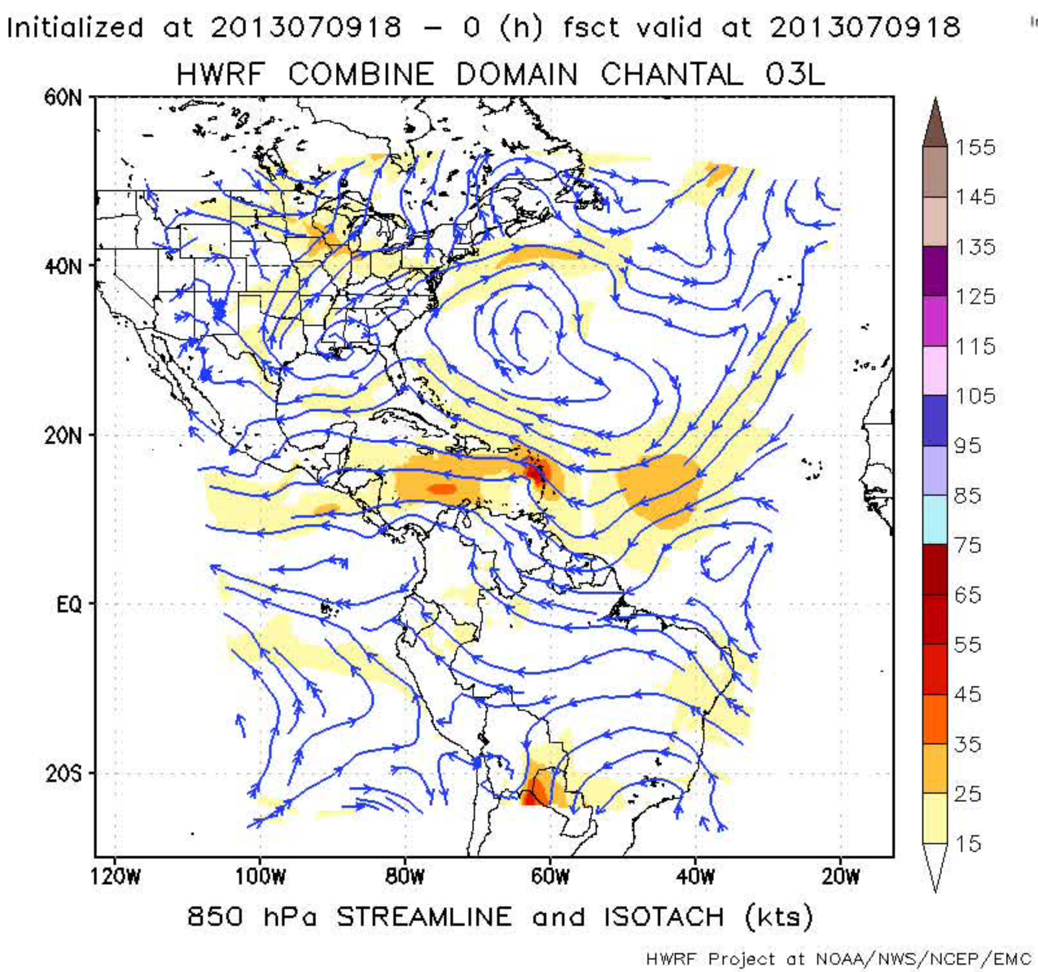
HWRF has many components

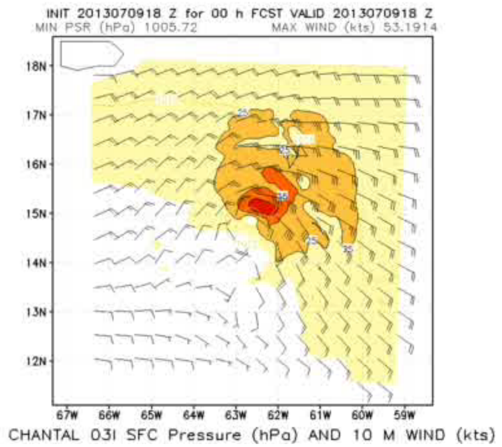


HWRF dynamical core

- 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
- More information about the inner works of the NMM core
  - 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

HWRF Moving Nest

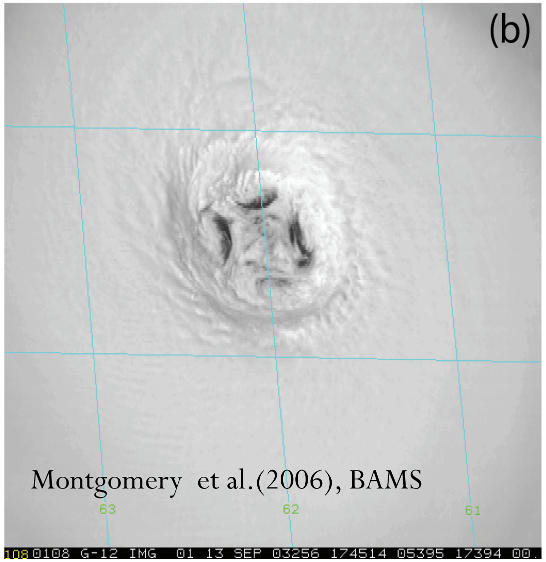




Developmental Testbed Center

Inner nest follows the vortex

- 9-km domain follows the 3-km domain, which follows storm center
- 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
- When nest moves fields on leading edge must be interpolated down from parent and high-res terrain interpolated from high-res static file



Chantal, 7/8/2013

HWRF 2013 Initialization

Challenges

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

Solutions

- Use a vortex relocation and correction algorithm

HWRF Vortex Relocation/Correction

- 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
  - If observed storm is very weak, use GDAS vortex
  - Vortex location, intensity, and structure corrected using observations

HWRF Data Assimilation (GSI 3DVar)

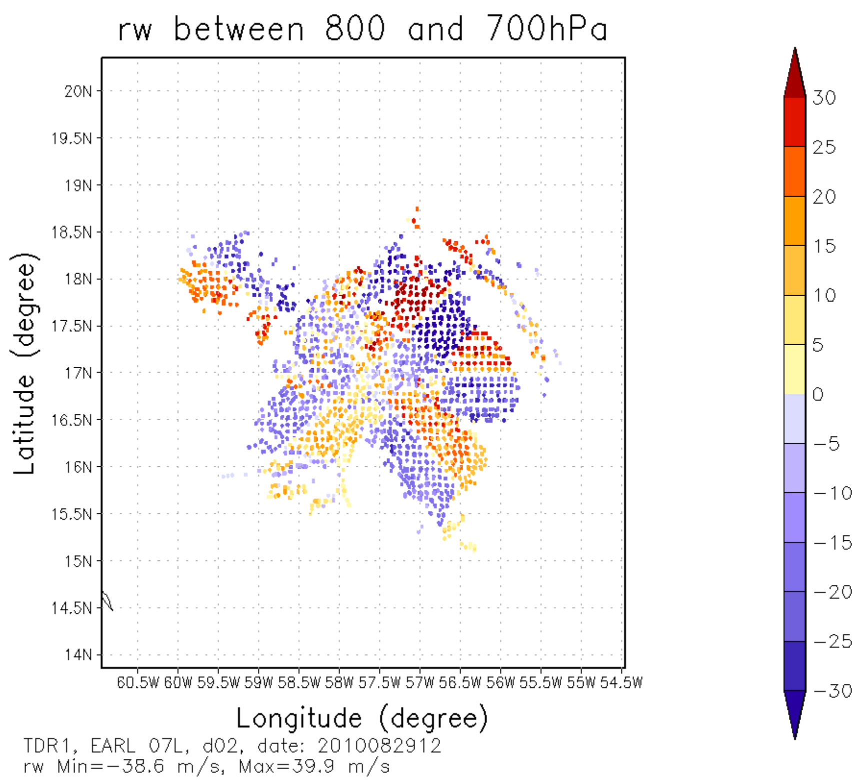
- 27-km: data assimilated in environment, not near storm
  - Radiosondes
  - Aircraft reports (AIREP/PIREP, RECCO, MDCRS-ACARS, TAMDAR, AMDAR)
  - Surface ship and buoy observations
  - Surface observations over land
  - Pibal winds
  - Wind profilers
  - VAD wind
  - Dropsondes

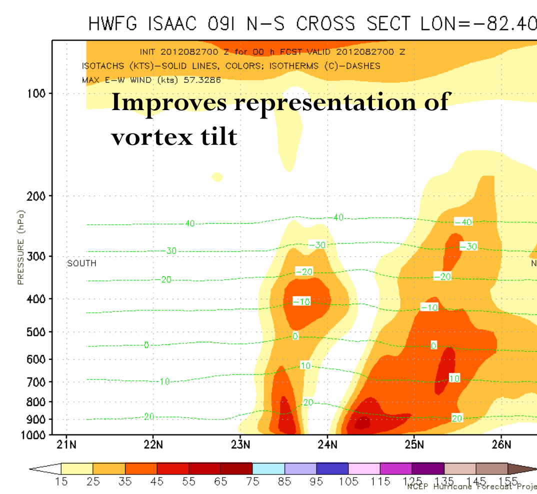
More information on Gridpoint Statistical Interpolator

- http://www.dtcenter.org/com-GSI/users/
- Tutorial in August 2013

HWRF Data Assimilation (GSI 3DVar)

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





HWRF 2013 operational physics

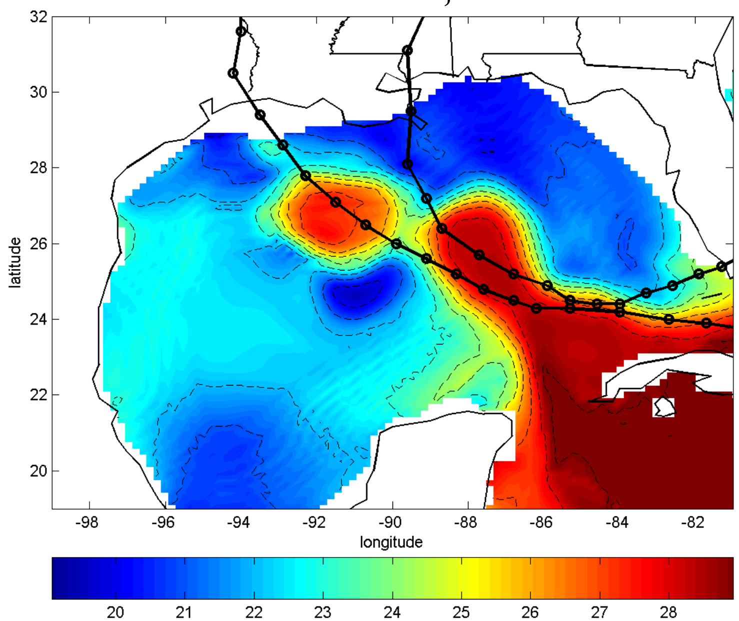
Physics	Parameterization	Option
Cumulus (only d01 & d02)	SAS deep and shallow convection	84
Microphysics	Ferrier for the tropics	85
Planetary Boundary Layer	GFS (modified Hong & Pan 1996)	3
Surface Layer	GFDL (modified)	88
Land Surface Model	GFDL slab model	88
Radiation	GFDL	98

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

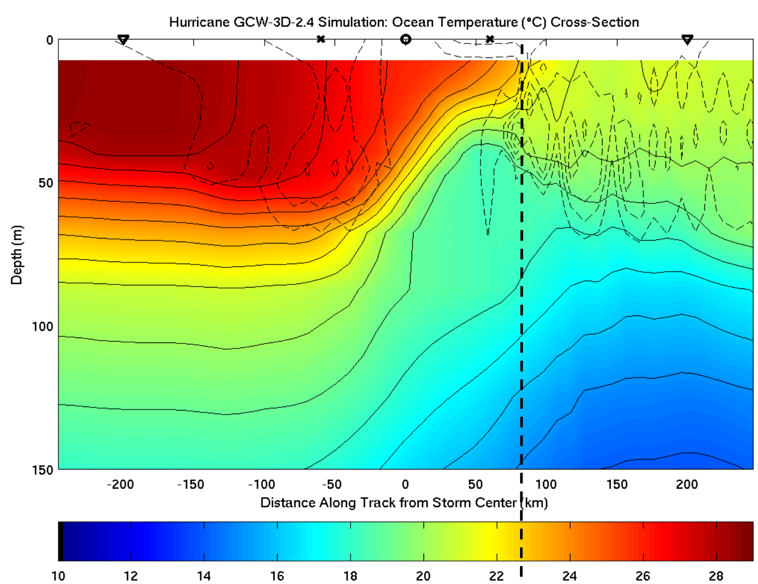


75-m depth temperature
Courtesy R. Yablonsky (URI)

Warmer ocean leads to more intense storms

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



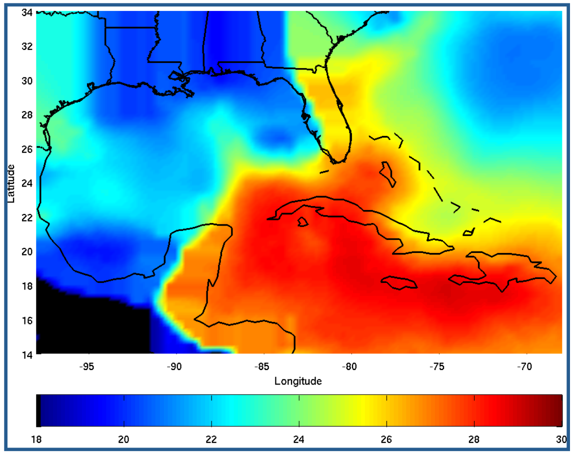
Colder ocean leads to weaker storms

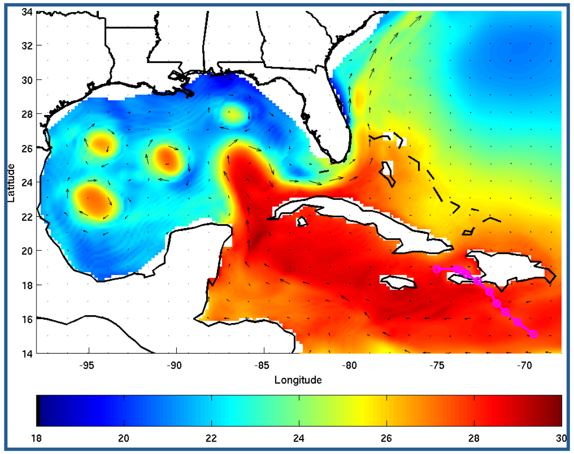
POM-TC idealized simulation of storm moving to left at 2.4 ms^{-1}: SST cools 6^{o}C.

Ocean temperature
Courtesy R. Yablonsky (URI)

POM-TC Initialization

- Start with GDEM (Atlantic) or Levitus (Pacific) monthly temperature and salinity climatology
- Horizontally-interpolate temperature and salinity onto POM grid
- Assimilate bathymetry and land/sea mask
- Use feature-based model to adjust Gulf Stream, Loop Current, and warm and cold core rings to near real-time positions (Atlantic only)
- Assimilate SST from GFS
- Integrate POM-TC to spin up ocean currents from background density field (Atlantic only)
- Integrate POM-TC with observed hurricane wind forcing to create cold wake





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

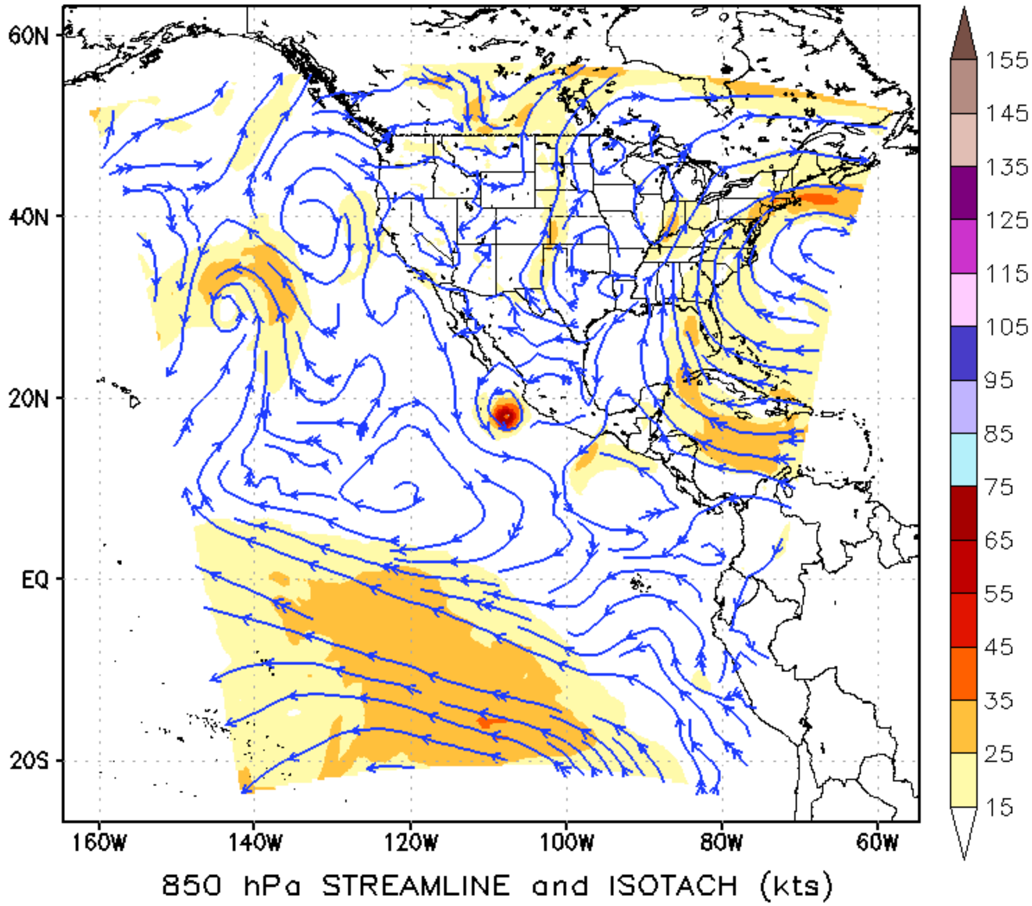
HWRF Coupler

- Developed at NOAA NCEP
- Acts as an independent interface between atmospheric (WRF) and oceanic (POM-TC) components
- Handles all grid interpolations and facilitates passing information between HWRF and POM-TC

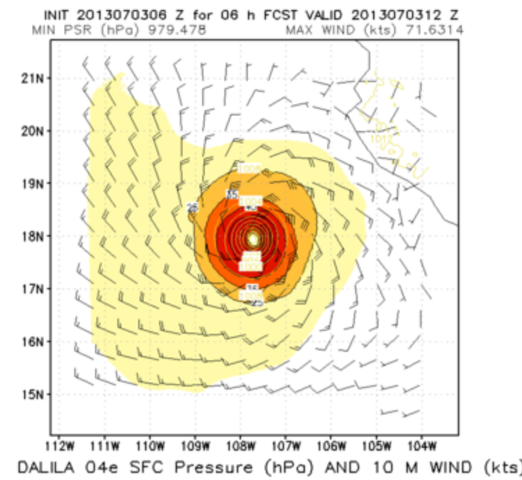
HWRF Post-Processing

- 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

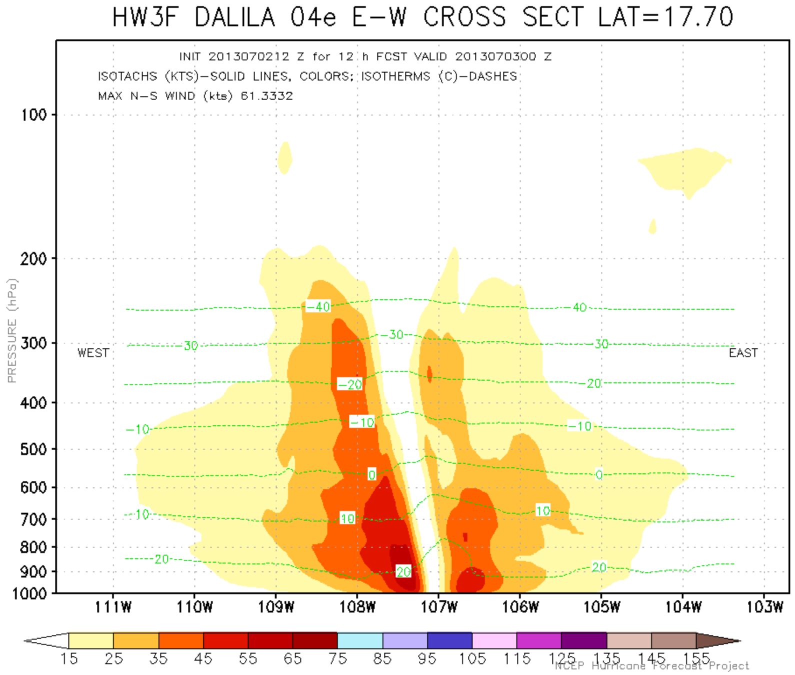


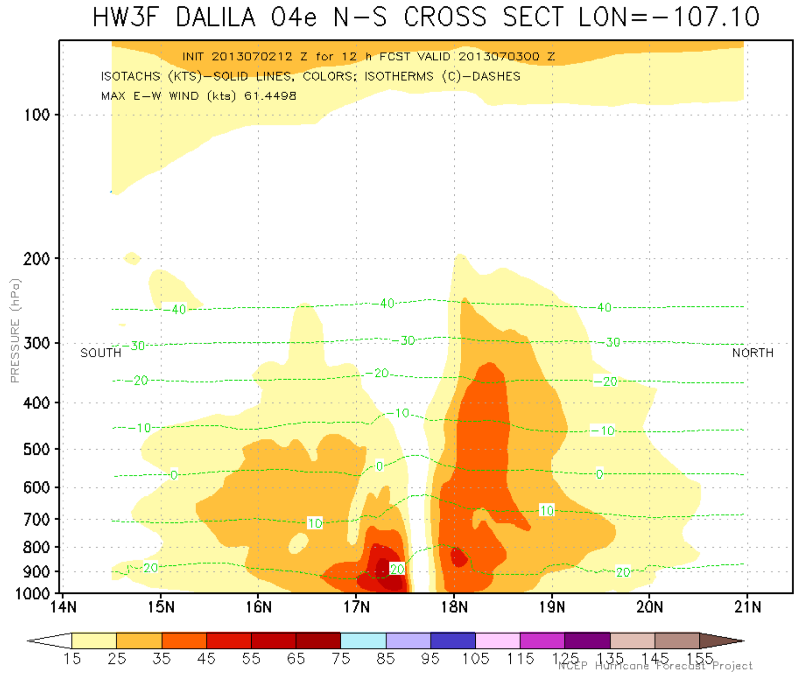
HWRF Project at NOAA/NWS/NCEP/EMC



12-h forecast TS Dalila (2013)

Vertical cross sections

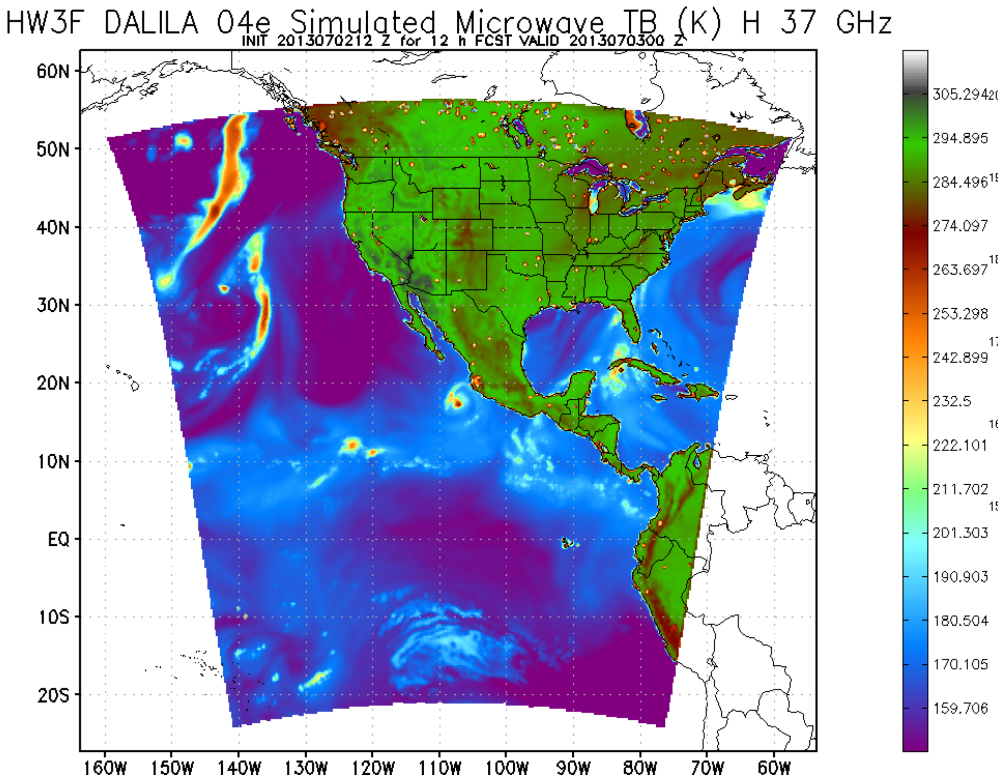


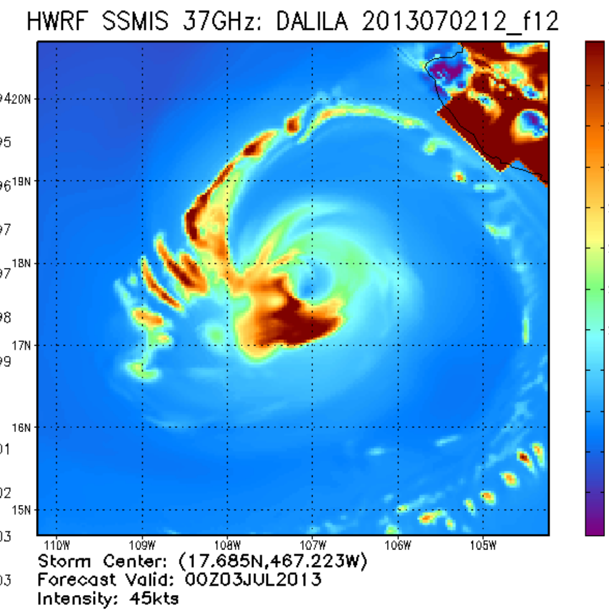


12-h forecast TS Dalila (2013)

Developmental Testbed Center

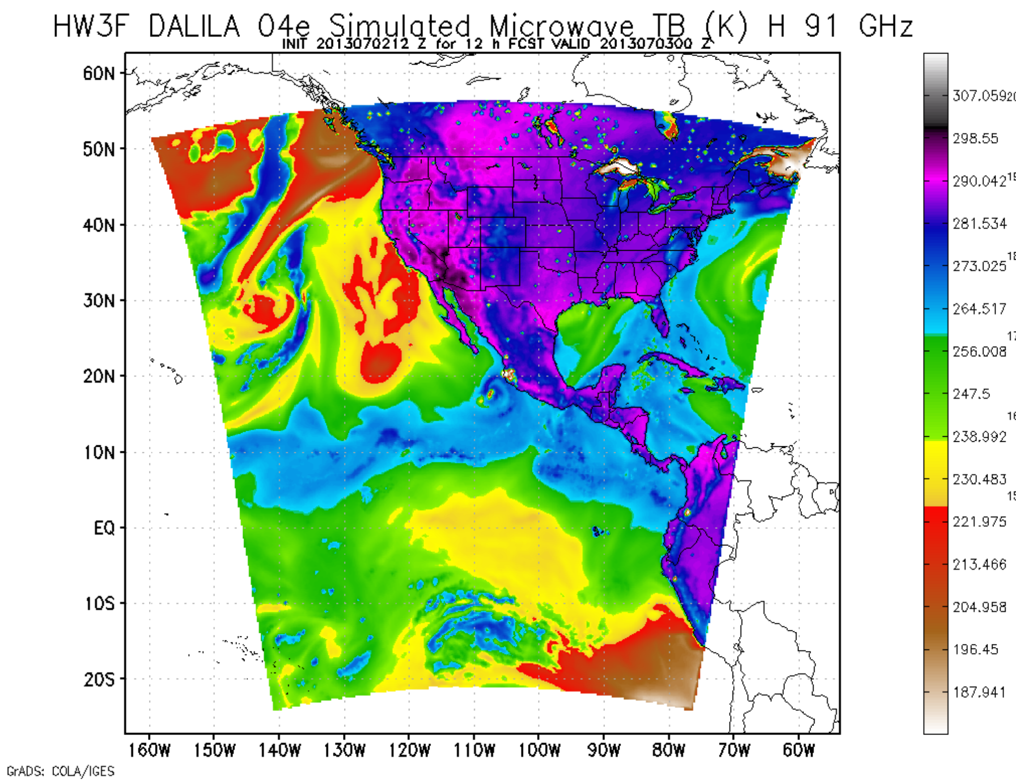
Simulated 37 GHz (TS Dalila)

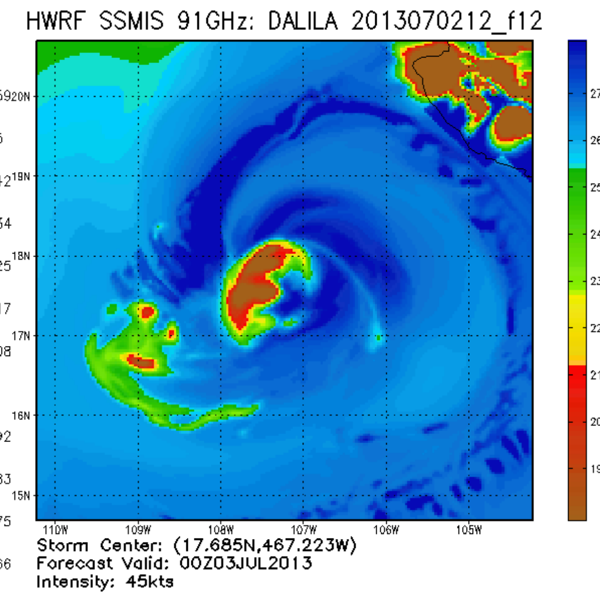




12-h forecast TS Dalila (2013)

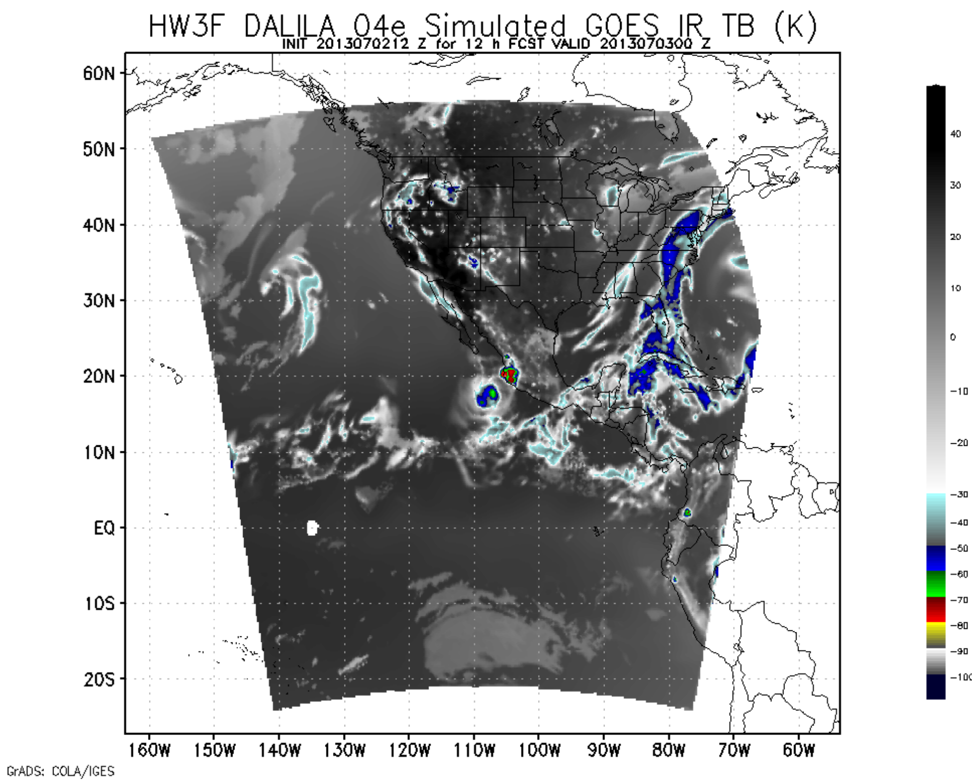
Simulated 89 GHz (TS Dalila)

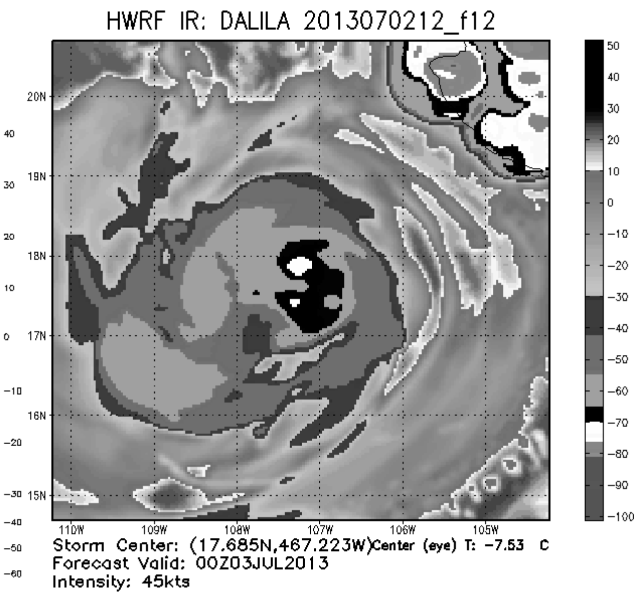




12-h forecast TS Dalila (2013)

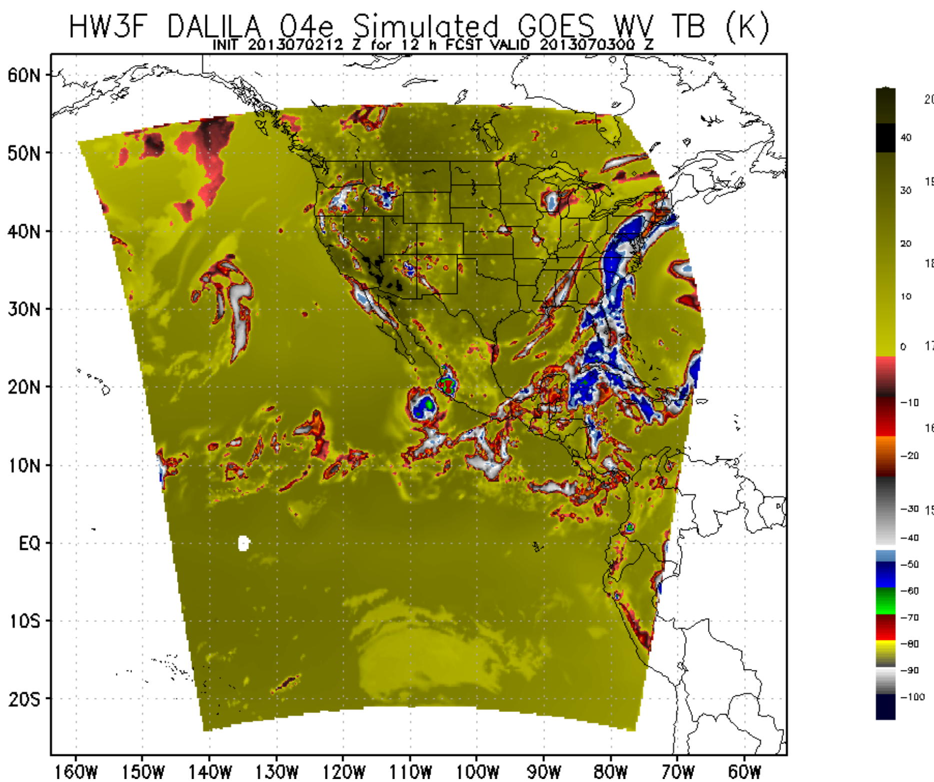
Simulated IR

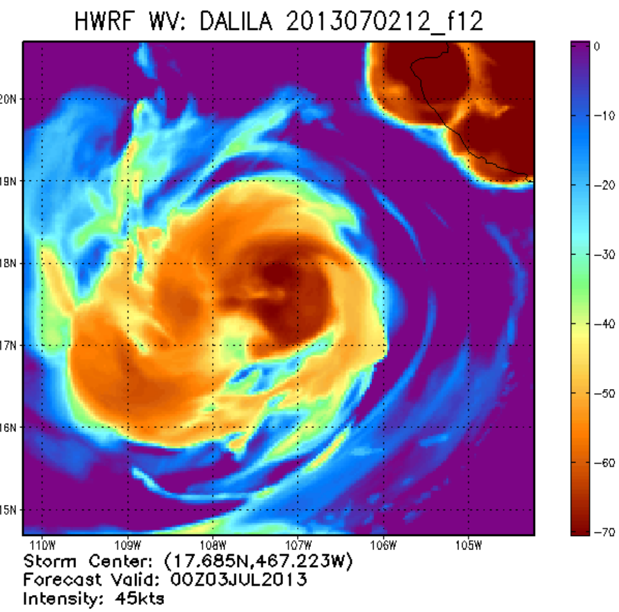




12-h forecast TS Dalila (2013)

Simulated Water Vapor

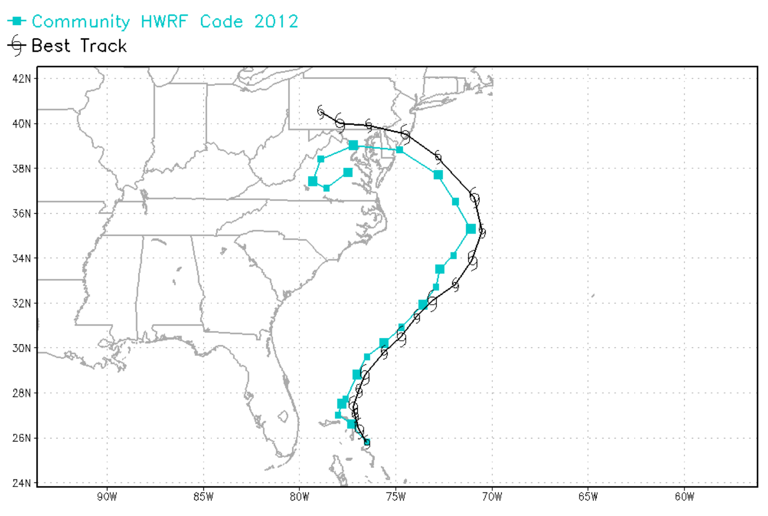




12-h forecast TS Dalila (2013)

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

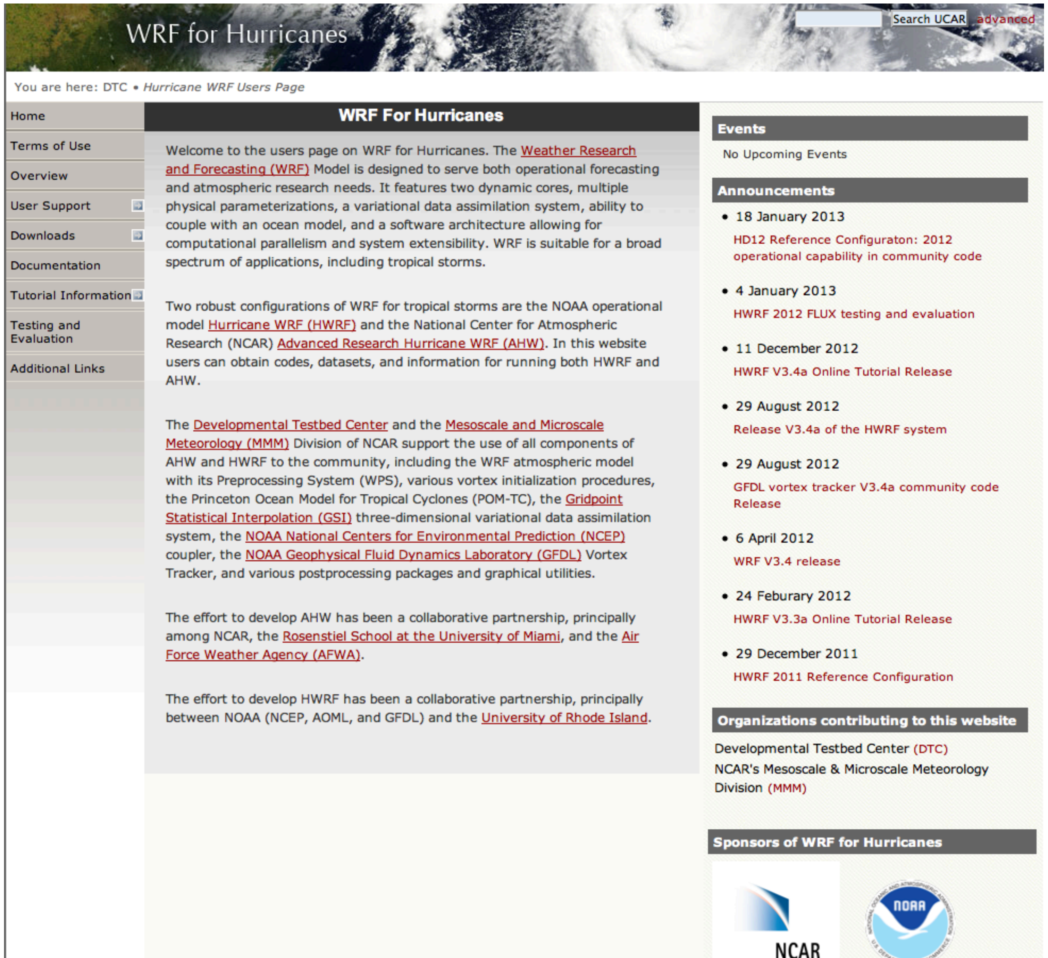


Sandy 2012: Sample of Community HWRF runs by DTC

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
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- 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

Benchmarks available

Current release: HWRF v3.4a (2012 operational)

Next release: HWRF v3.5a (2013 operational) – this month!

New in 2013 operational HWRF

- Data assimilation
  - Use of tail-Doppler radar observations
- WRF
  - More efficient, faster nest-parent interpolation
  - Revised internal tracking for moving nest
  - Updates in planetary boundary layer physics
- POM-TC
  - Changes in atmos-ocean momentum flux

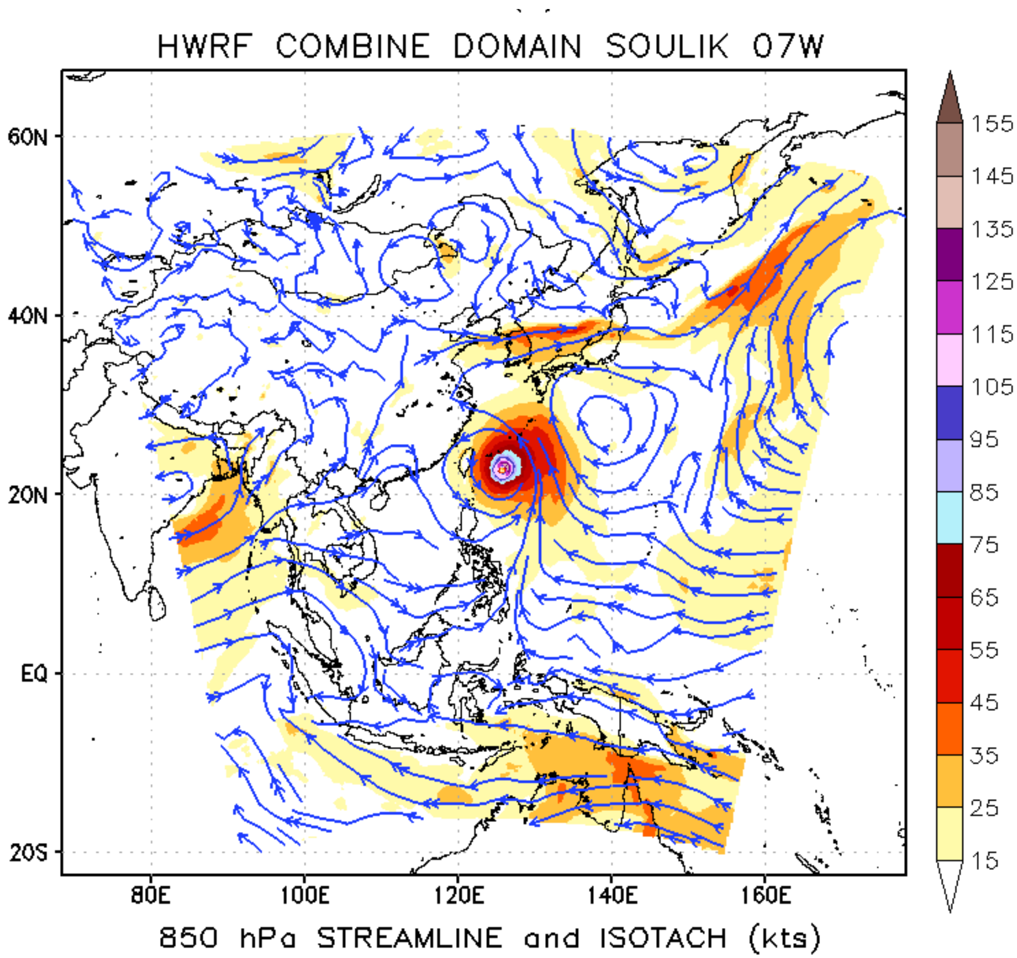
New in Community HWRF v3.5a

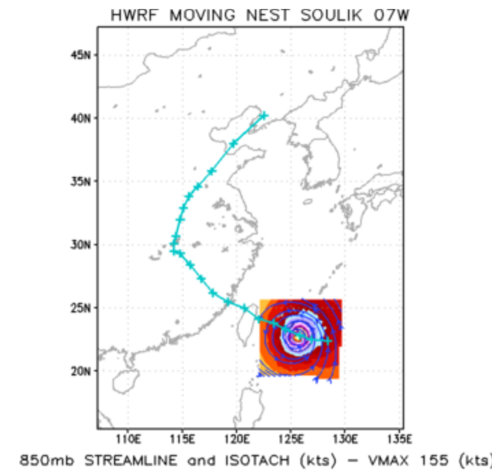
- Support for HWRF 2013 implementation
- Idealized tropical cyclone with prescribed vortex
- More interoperability: ability to run with multiple convective and microphysics parameterizations
- Support for all Northern Hemisphere basins (central and west Pacific, Indian etc)

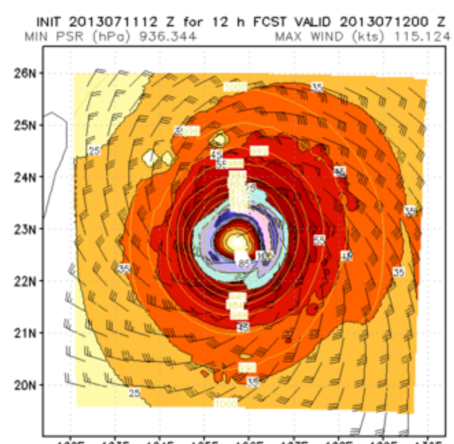
Release planned for July 2013

HWRF in West Pacific (Soulik 2013)

HWRF now available for all N Hemisphere basins (uncoupled)



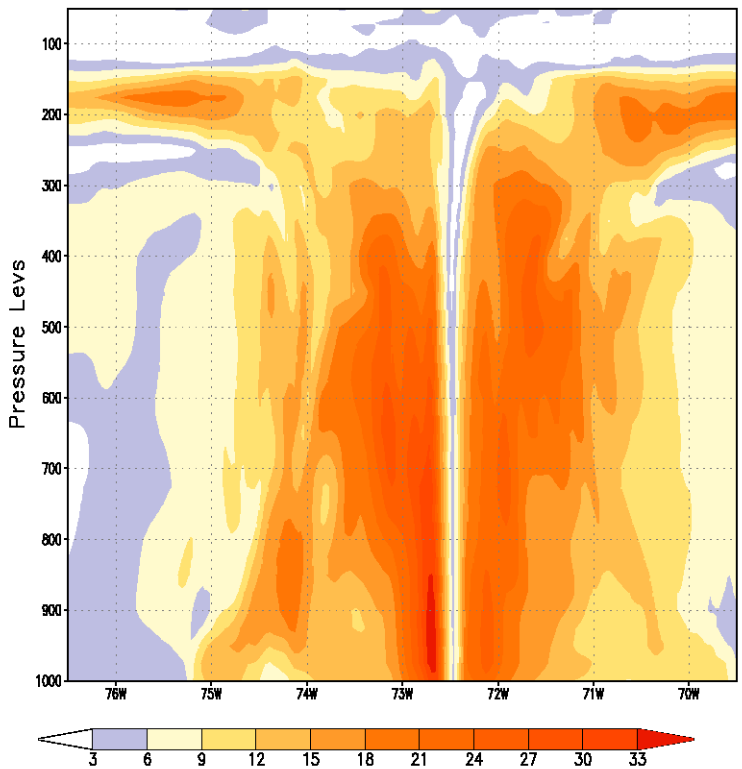




Courtesy: Environmental Modeling Center

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

- **Configuration:** larger parent with multiple moving nests, more vertical levels
- **Ocean:** MPIPOM-TC or HYCOM, initialization with more sophisticated data assimilation
- **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, MP, sea spray
- **Coupling**: wave model, storm surge, inundation

Thank you!

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

Dennis, 7/10/2005