Introduction to HWRF

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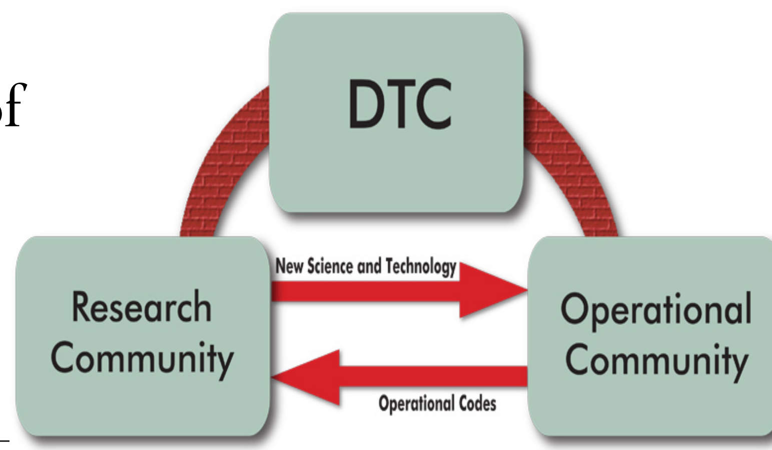
Developmental Testbed Center

www.dtcenter.org

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



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Outline for Introduction to HWRF

- What is Hurricane WRF
- Grid configuration
- 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
- Possible 2013 upgrades and future development

What is HWRF?

- A NOAA 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
- New implementations of HWRF occur every year in the beginning of the hurricane season – the model is always evolving and improving
- This talk focuses on 2012 HWRF (some info on plans for 2013 provided)

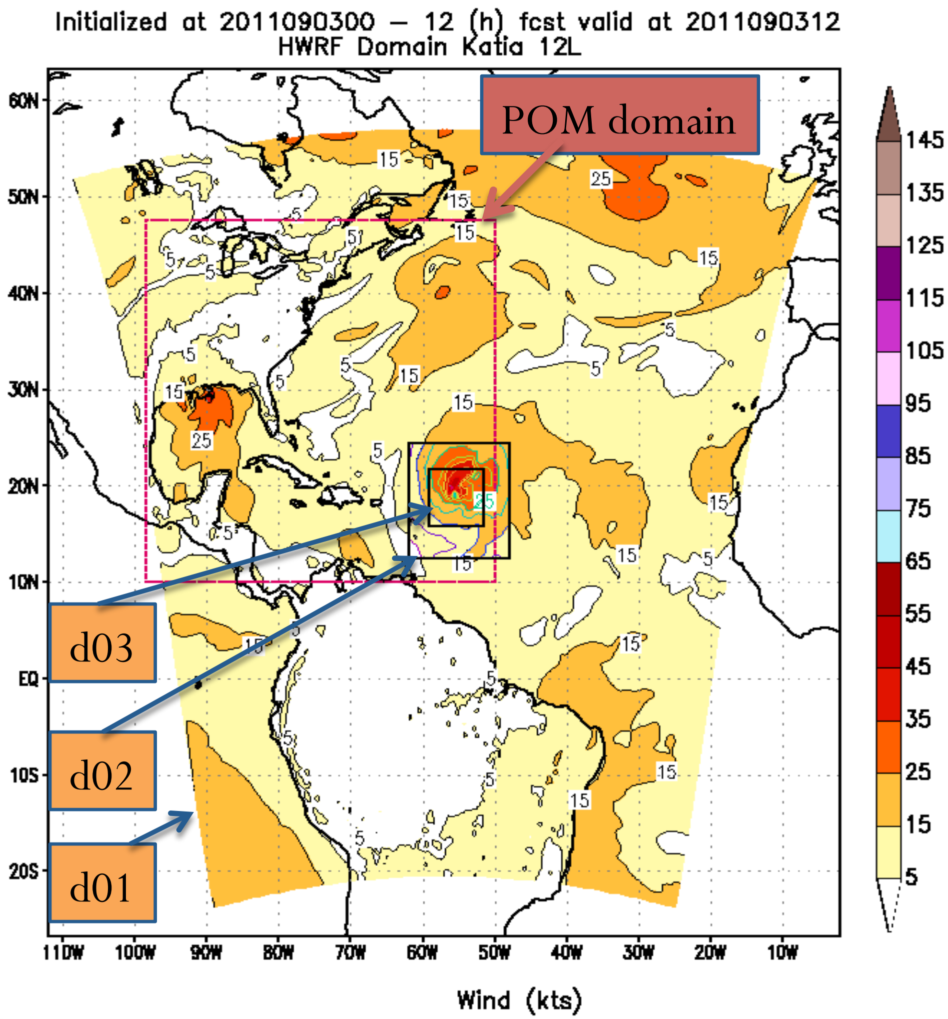
Operational forecasts
http://www.emc.ncep.noaa.gov/gc_wmb/vxt/

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

HWRF 2012 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
- Model top 50 hPa

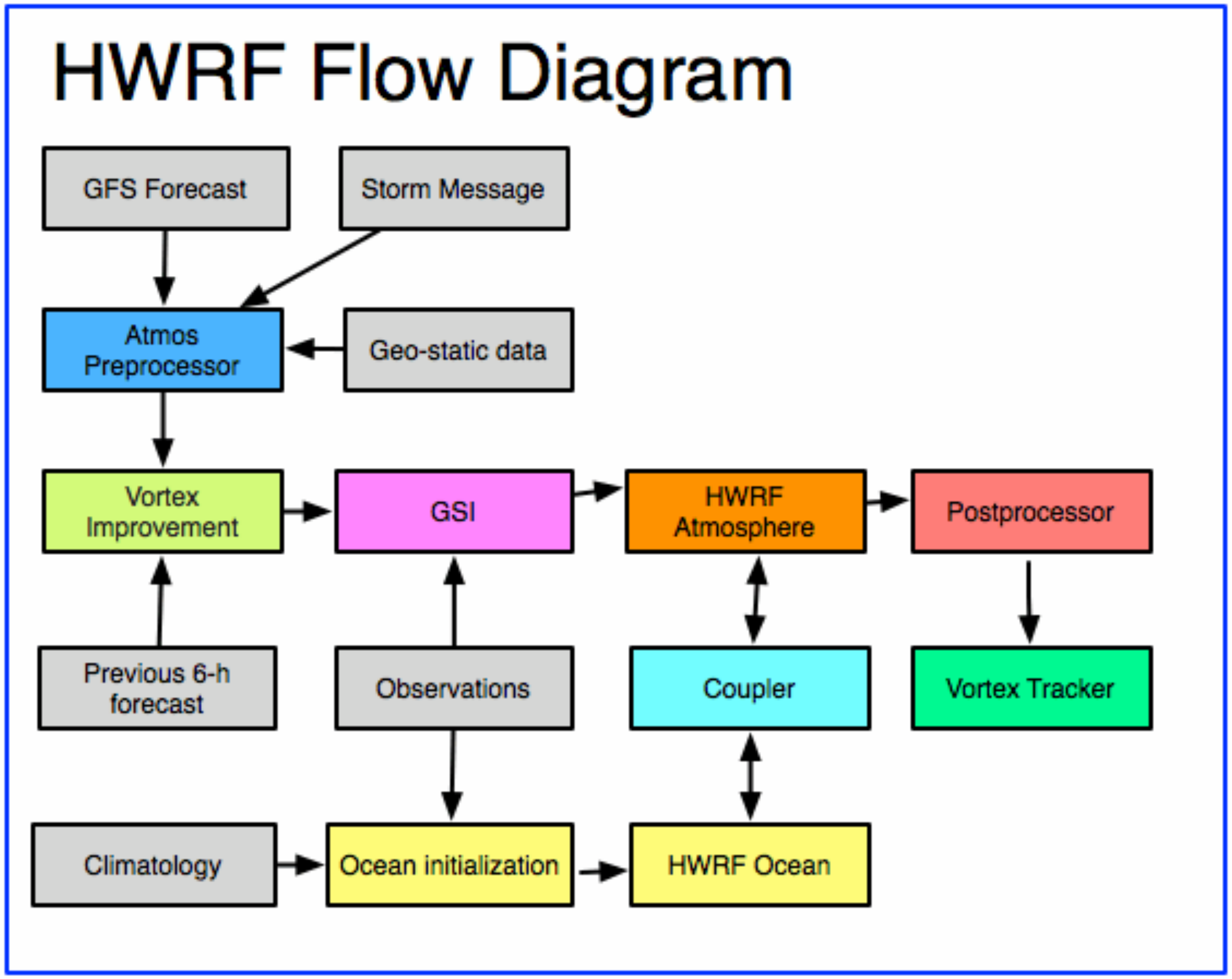
Oceanic configuration

- 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
- In this tutorial, 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 Components

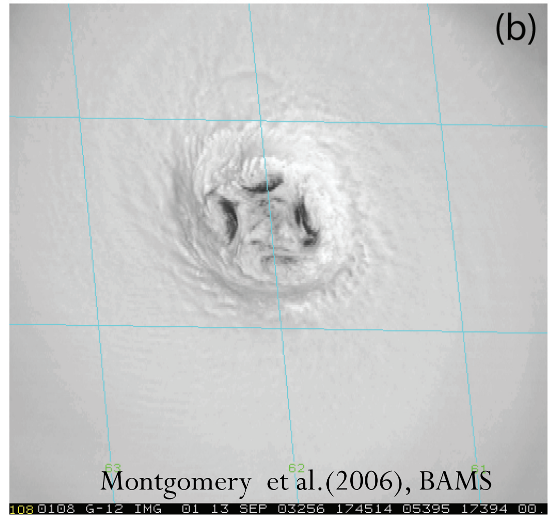
WRF model
Pre-Processor (WPS)
Vortex initialization
Data assimilation (GSI)
Coupler (NCEP)
Ocean (POM-TC)
Post-Processor (UPP)
Vortex Tracker (GFDL)

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
- HWRF uses the NMM dynamic core

Moving Nest

- 9-km domain follows the 3-km domain, which follows storm
- The storm center is determined based on the centroid of a function of the mass (MSLP)
- Algorithm reduces the chances of the nest getting caught on an island or the nest jumping to the wrong storm

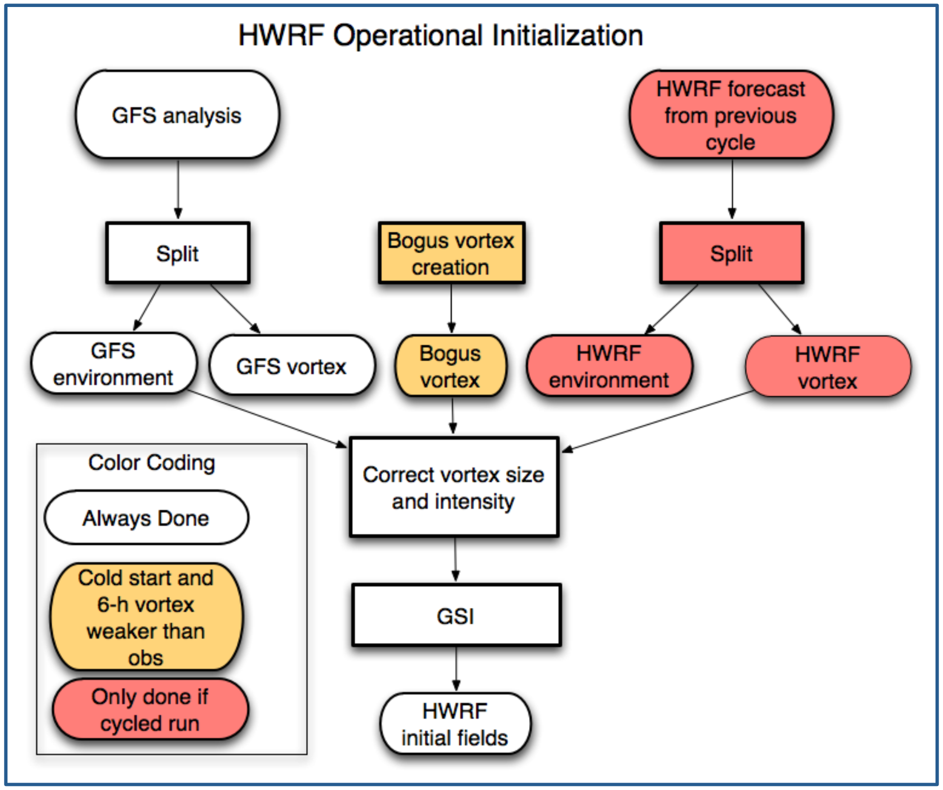


Montgomery et al.(2006), BAMS

Presence of mesovortices makes storm tracking a challenge

HWRF 2012 Initialization

It is challenging to initialize a high-resolution hurricane model from the analysis of a global model because the storm in the global model is weak



HWRF initialization

- Use GFS for initial and boundary conditions
- If a previous HWRF forecast is available
  - Remove GFS vortex
  - Add previous HWRF vortex
  - Correct location, intensity, and structure based on observations
- If a previous HWRF forecast is not available or if HWRF vortex is too weak
  - Enhance with bogus vortex
- Perform data assimilation with GSI

HWRF Data Assimilation

- GSI is a 3D-Variational data assimilation system
- Data is assimilated in the storm environment and not near the storm
- For HWRF, the following data are used
  - 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 GSI: http://www.dtcenter.org/com-GSI/users/.

HWRF 2012 operational physics

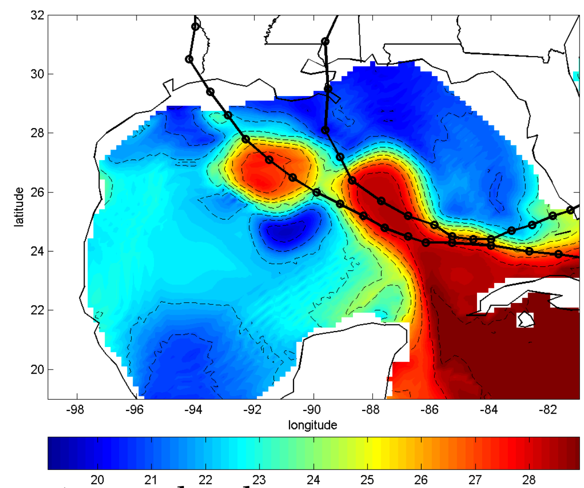
Physics	Parameterization	Option
Cumulus (only d01 & d02)	SAS with deep and shallow convection	84
Microphysics	Ferrier for the tropics	85
Planetary Boundary Layer	GFS (Hong and Pan 1996, modified)	3
Surface Layer	GFDL (modified)	88
Land Surface Model	GFDL slab model	88
Radiation	GFDL	98

Note that the cumulus parameterization is only run on d01 (27 km) and d02 (9 km). In d03 (3 km), the microphysical parameterization explicitly resolves the clouds.

HWRF Ocean Component

Rita Katrina, 2005

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



75-m depth temperature

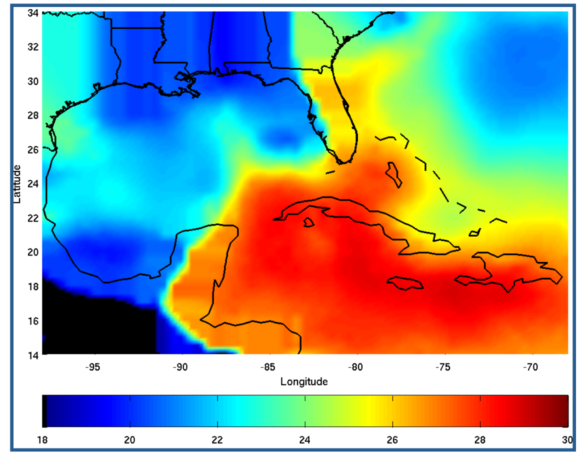
Courtesy R. Yablonsky (URI)

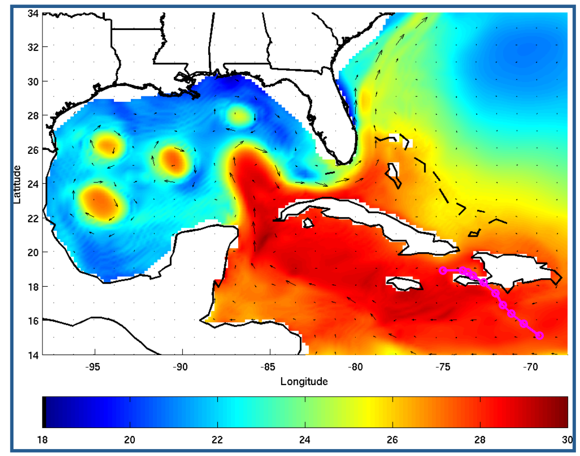
- When a storm is over cold ocean, it tends to weaken
- A storm can cause the SST to change due to turbulent mixing with deeper, cold water and due to upwelling
- Models that do not include SST evolution may have SSTs too warm and make storms too strong

When storms goes over warm ocean, they can intensify

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





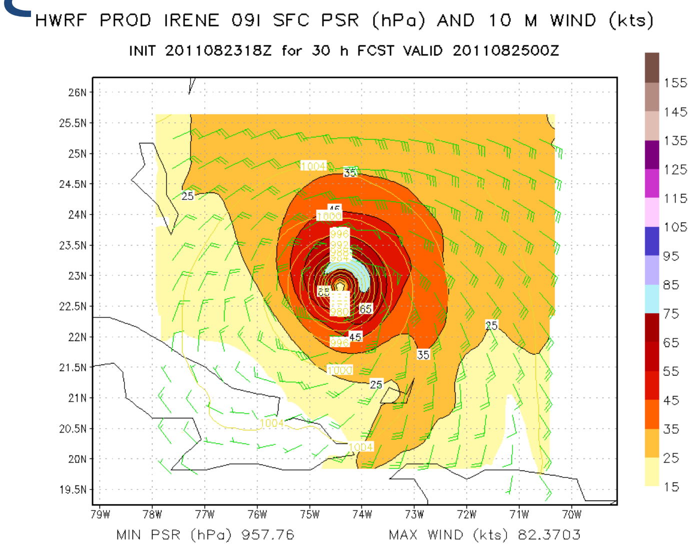
Gustav (2008): 75-m deep temperature from climatology (top) and after initialization procedure

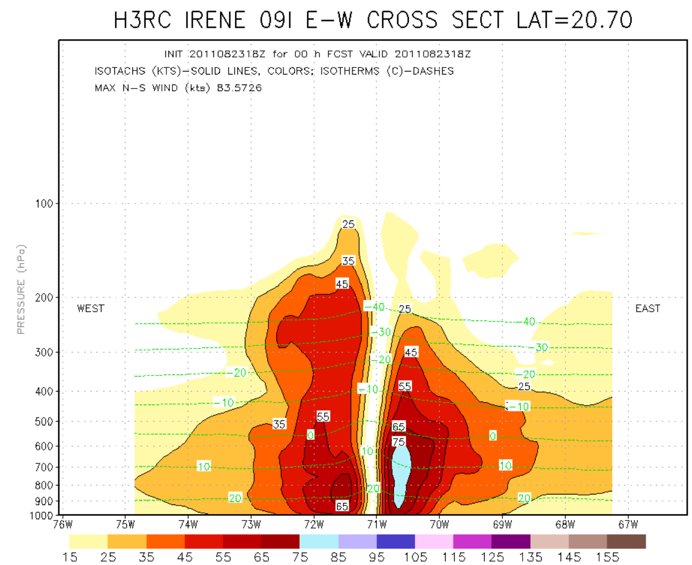
HWRF Coupler

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

HWRF Post-Processing

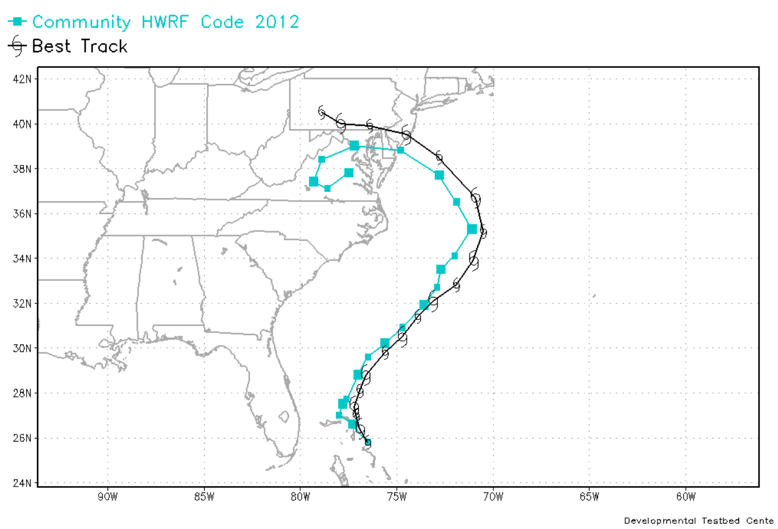
- Uses the Unified post-processor (UPP)
  - Computes derived variables
  - Interpolates the forecast
    - Horizontally from the WRF native grid to a lat-lon grid
    - Vertically from WRF native levels to isobaric levels
  - Generates output in GRIB format
- Domains are postprocessed separately and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

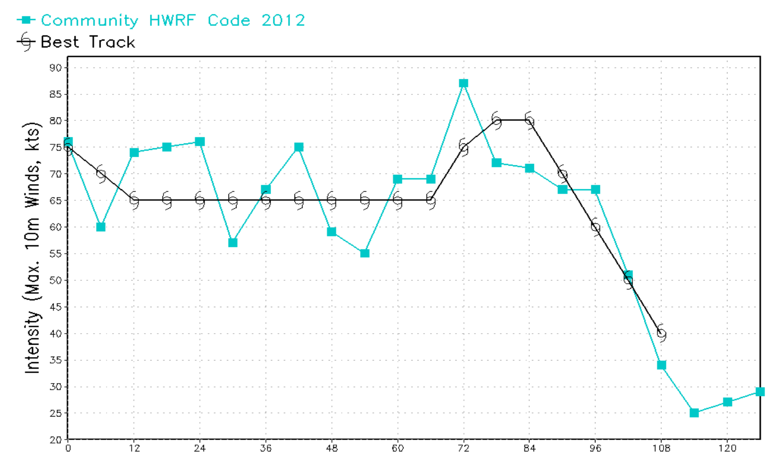




GFDL External Vortex Tracker

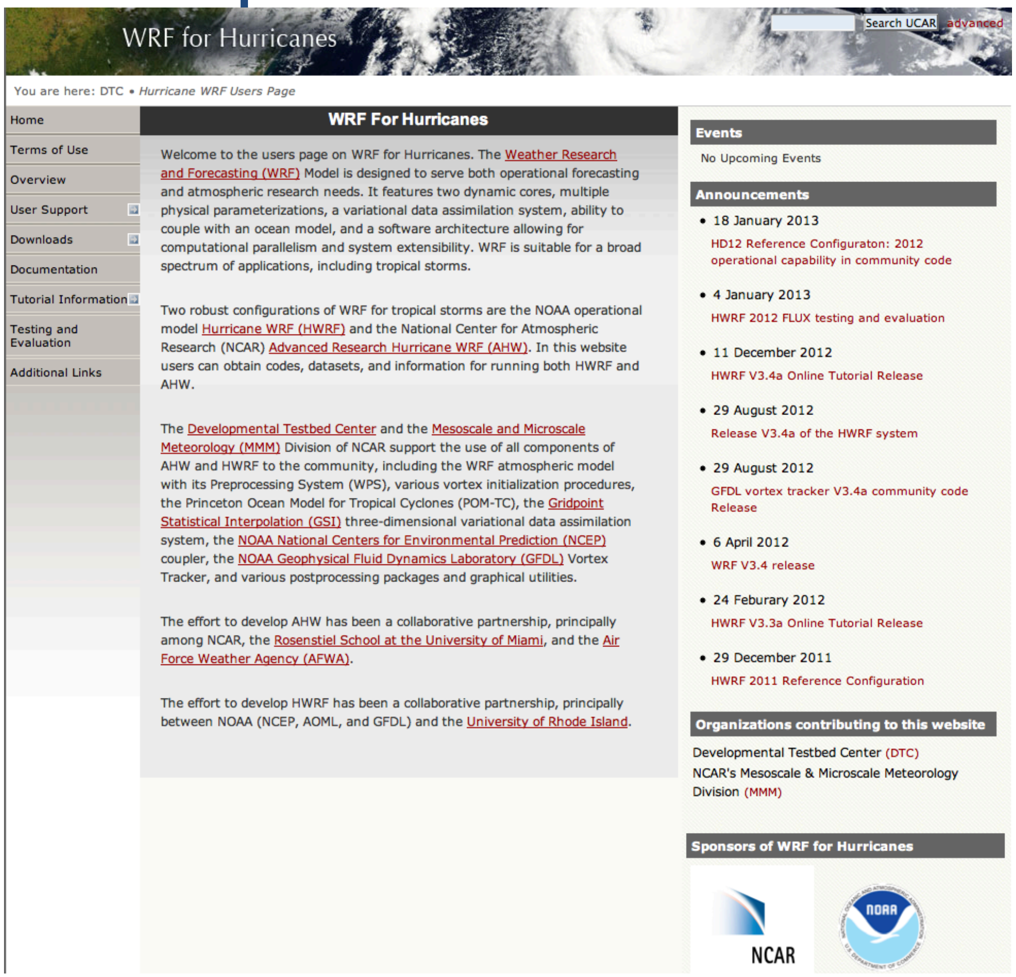
- Extracts storm properties from the 3D forecast fields
  - Location, intensity, structure
- Outputs text file which can be used for plotting
- Can be used for HWRF or any other model, as long as proper files are provided in GRIB format





Sandy 2012: Sample of Community HWRF 2012 Reference Configuration runs by DTC www.dtcenter.org/HurrWRF/users

Developmental Testbed Center support



Code downloads, datasets, documentation, online tutorial, helpdesk

500 registered users

Yearly releases corresponding to operational model of the year

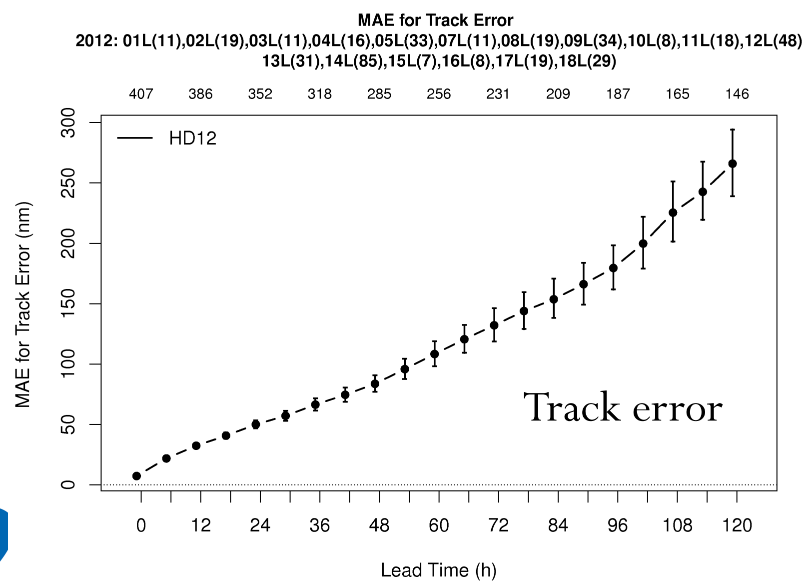
Stable, tested code

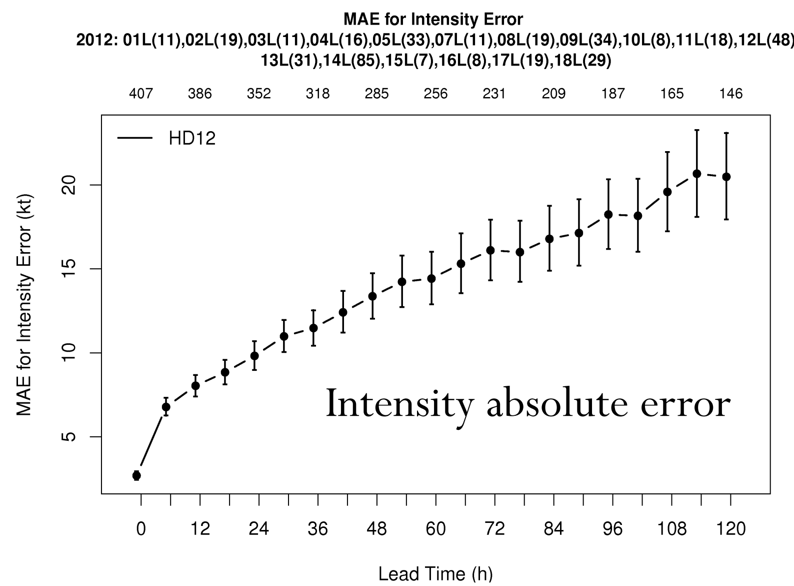
Benchmarks available

Current release: HWRF v3.4a (2012 operational)
Next release: HWRF v3.5a (2013 operational) – June 2013

DTC Reference Configuration

- Robust statistical evaluation of the HWRF performance
- User can compare against his own results
- Sample of HWRF v3.4a Reference Configuration
- Track and intensity errors for all 2012 season
- Sample for Atlantic





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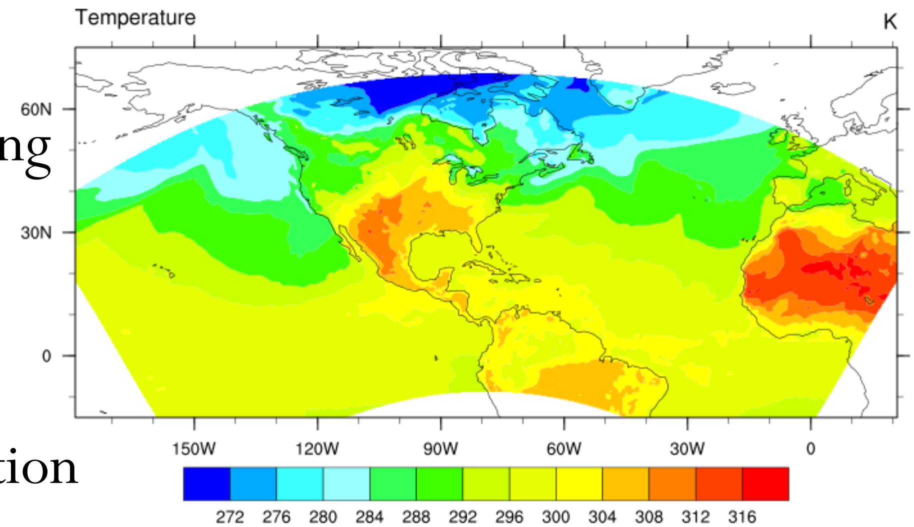
Currently in test for possible implementation in 2013 HWRF

- More sophisticated data assimilation with use of tail-Doppler radar observations when available from aircraft reconnaissance
- New nest-parent interpolation routines: more efficient, faster, allow HWRF to run with alternate microphysical configurations
- Revised internal tracking more moving nest
- Updates in planetary boundary layer
- New convective parameterization scheme: meso-SAS
- RRTM-G radiation scheme
- Modification in momentum flux for atmosphere to ocean
- Non-operational
  - Extension to Central and West Pacific, Indian basins (non-oper)
  - Idealized capability

Planned new capabilities for HWRF v3.5a

- Pending testing…
  - Complete support for HWRF 2013 implementation
  - Idealized tropical cyclone with prescribed vortex
  - Ability to run with additional microphysics packages
  - Support for all basins (central and west Pacific, Indian etc)

Challenges and ongoing work



- **Configuration:** larger parent with multiple moving nests, vert levels
- **Ocean:** HYCOM, initialization with more sophisticated data assimilation
- **Data Assimilation and Ensembles**
  - Hybrid (EnKF) variational data assimilation
  - Use of all available datasets, including storm-scale observations
  - Ensemble systems for uncertainty estimation
- **Physics:** radiation, PBL, LSM, MP, convection, MP, sea spray
- **Coupling**: wave model

Thank you!

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