HFIP Nonhydrostatic Model Physics Team Update for FY09

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Milestones and Deliverables
FY2009

1. Determine the best combination of Cd and Ch values to produce accurate intensity and hurricane size forecasts, while retaining skillful track forecasts. (Streams 1 & 2)

2. Implement a proto-type version of sea-spray parameterization into the operational HWRF system if current testing shows improvement in forecast skill. Companion tests in COAMPS-TC system. (Streams 1 & 2)

3. Improvements to moist physics and boundary layer parameterizations. (Stream 2)

4. Exchange new surface physics routines among HFIP groups, based on the performance for the operational and HFIP Demo models.

EMC Summary

1. Modify the surface physics code of HWRF by adding various options for air-sea exchange coefficient formulation [Cd (Powell 2003, 2007) & Ch (CBLAST) options]
2. Perform impact tests of air-sea flux formulations on the HWRF track and intensity forecast skill
3. Include prototype sea spray parameterization scheme in HWRF (in progress) for testing

EMC Summary

Results

- Forecast tracks relatively insensitive (compare to other physics changes)
- Forecast intensity depends importantly on exchange coefficients
- Results agree with NRL COAMPS-TC testing

Tests executed for:

Hurricanes Bertha, Ike, Gustav and Hanna (2008)

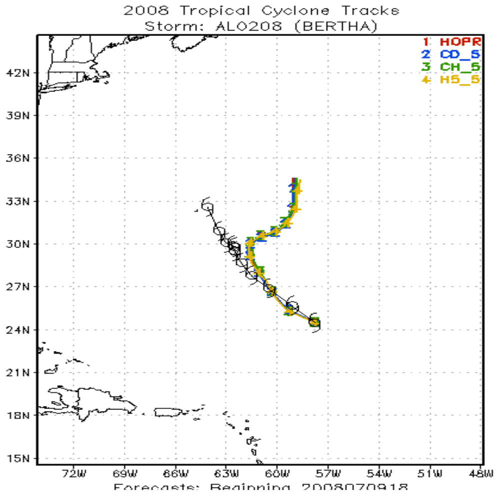
Track Forecasts for HWRF

Sensitivity Tests

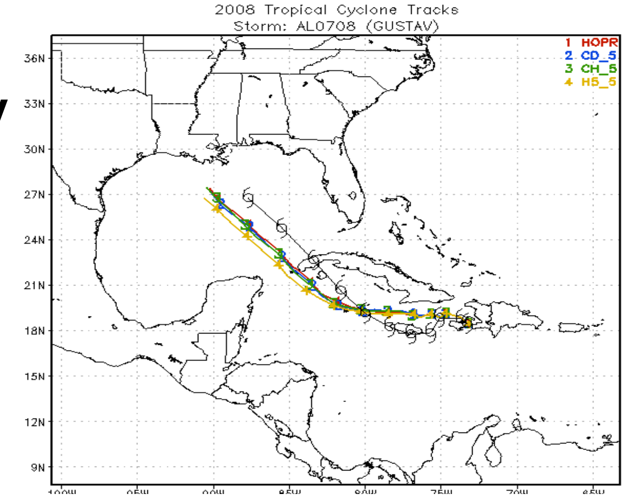
Operational HWRF (red), Sensitivity tests (various colors)

Best track (black)

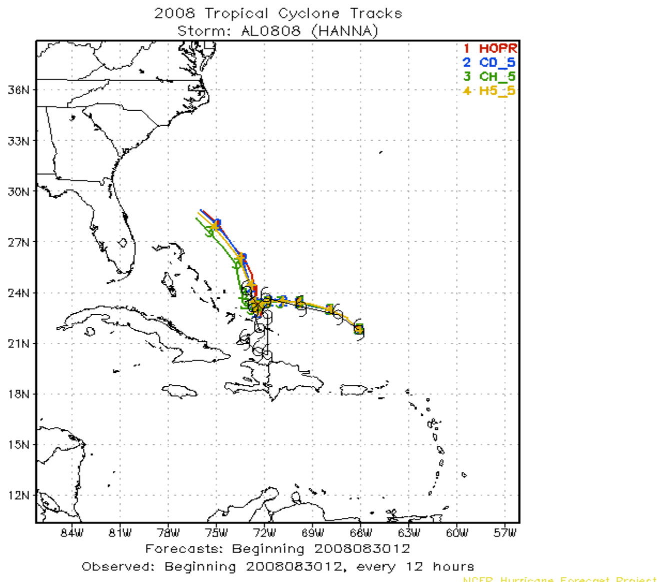
Bertha



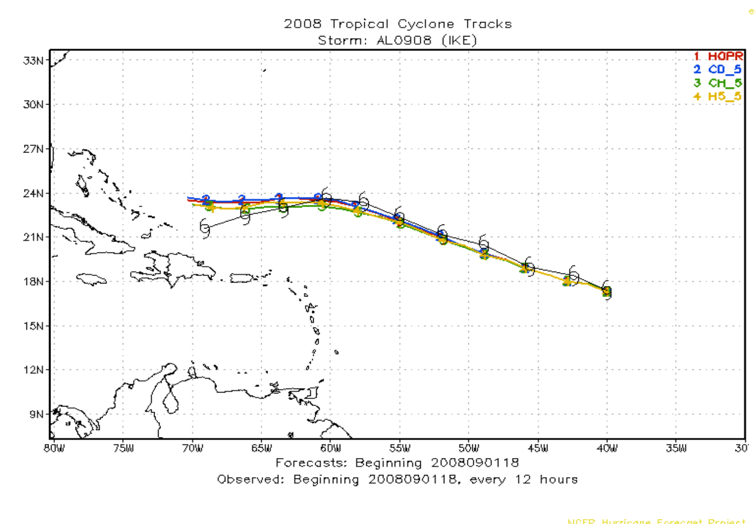
Gustav



Hanna



Ike



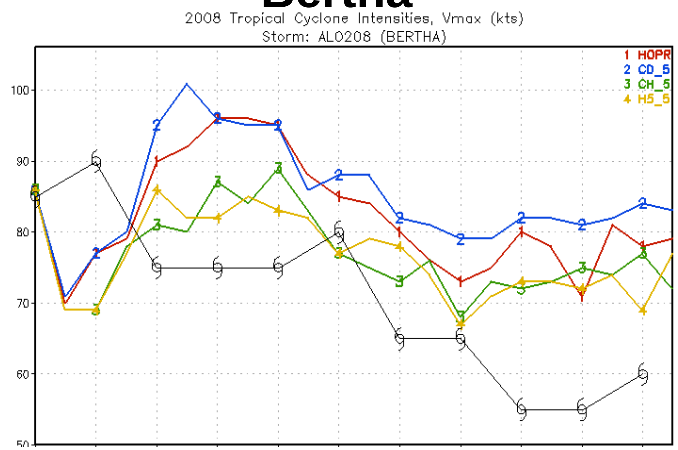
Intensity Forecasts for HWRF

Sensitivity Tests

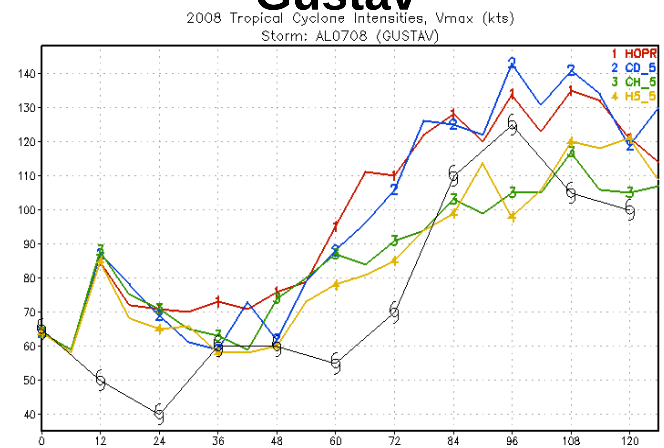
Operational HWRF (red), Sensitivity tests (various colors)

Best track (black)

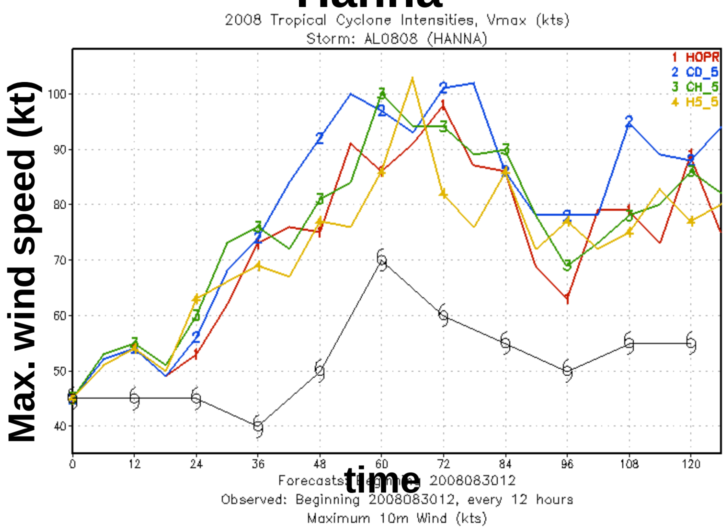
Bertha



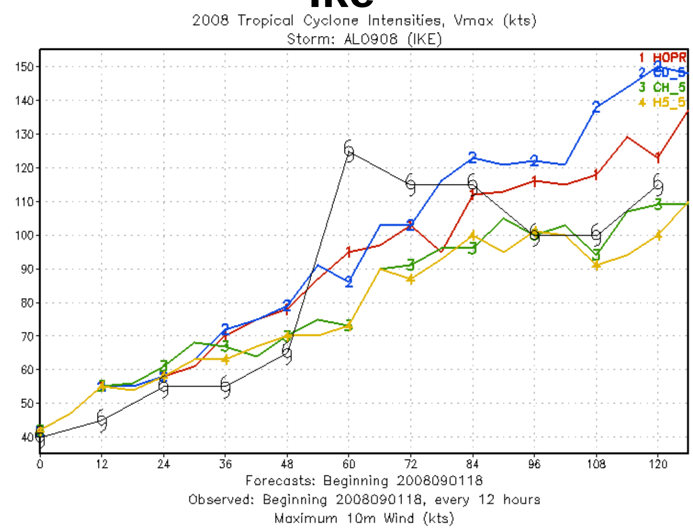
Gustav



Hanna

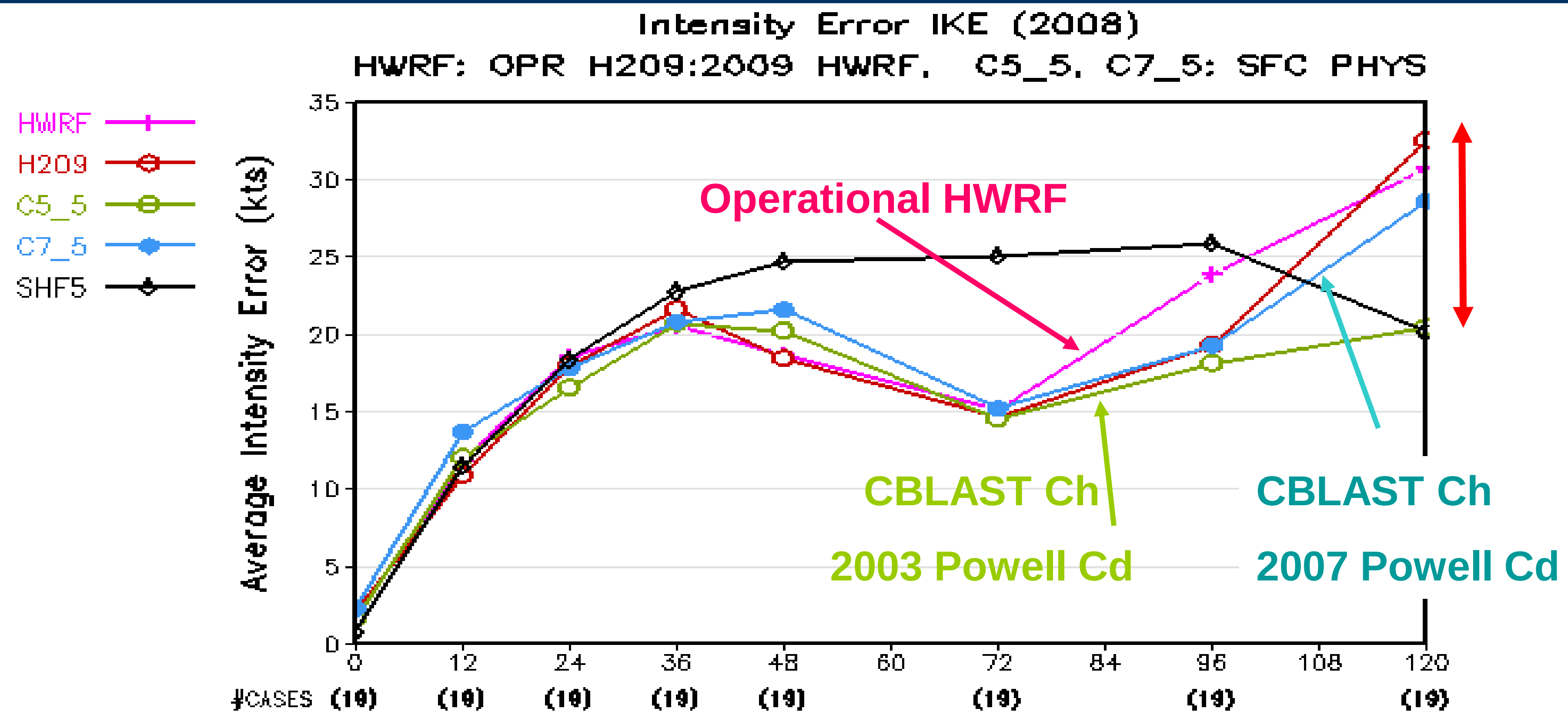


Ike



Intensity Forecasts for HWRF

Cd/Ch Results

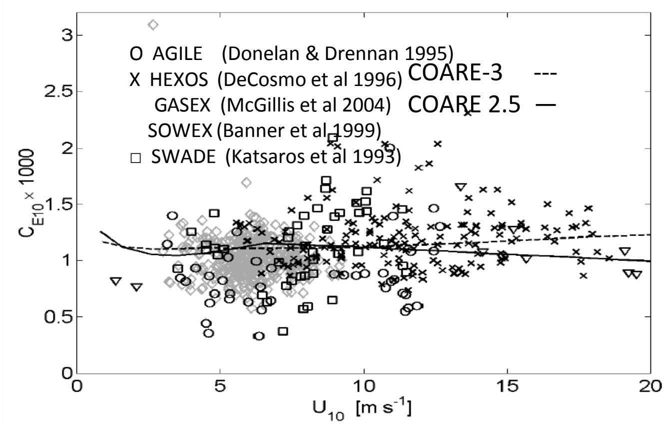


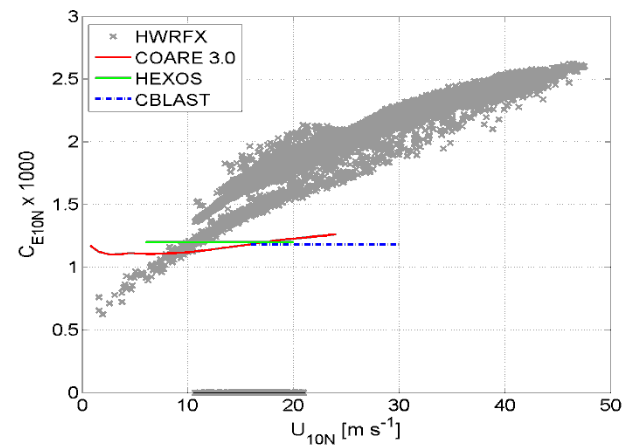
- The new observation based Cd/Ch test results improve the intensity forecast skill of HWRF by reducing the positive bias of current operational HWRF.
- Track skill is similar or slightly improved (~40nm at 5day).
- Note that exchange coefficients beyond ~30 $m\ s^{-1}$ are extrapolated.

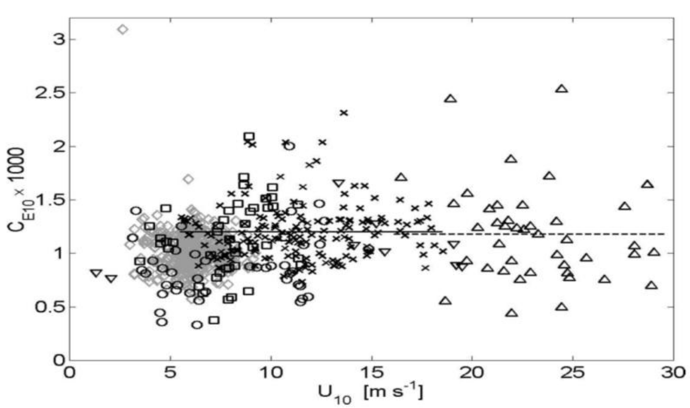
HRD Results

Air-Sea Interaction in HWRFx

Exchange coefficients for latent heat transfer used in HWRFx



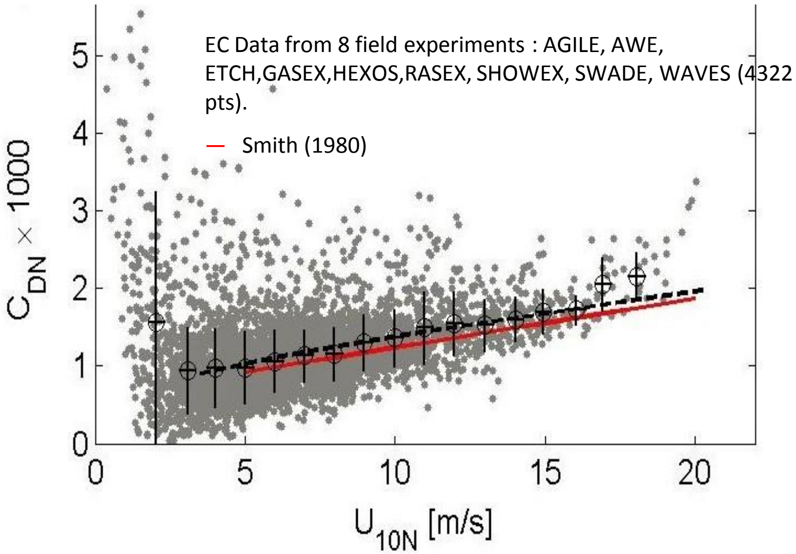


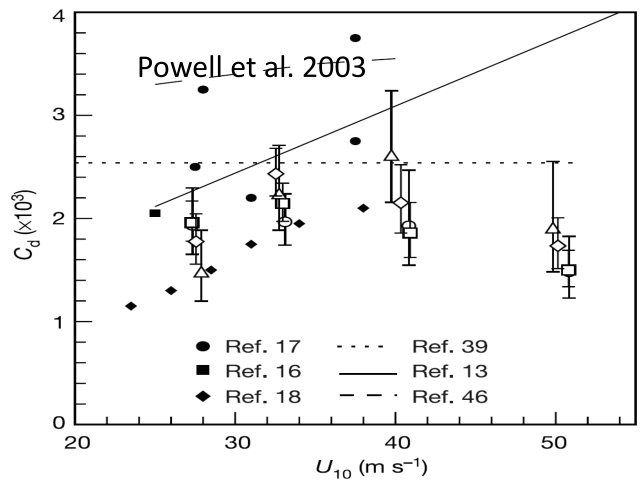


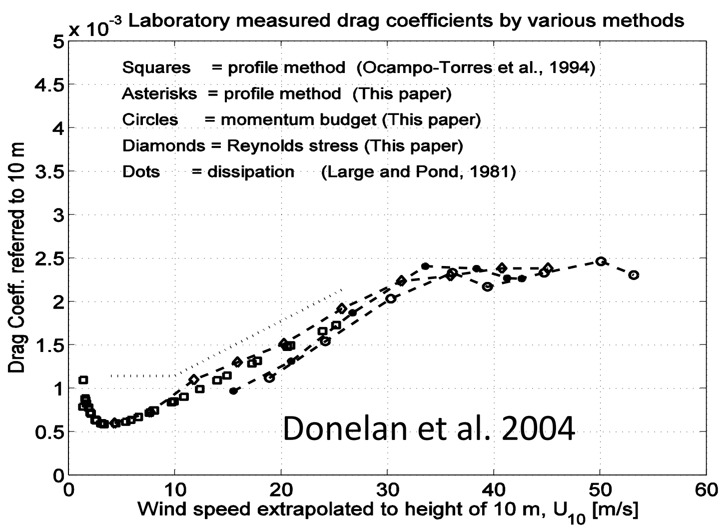
The exchange coefficient for latent heat transfer (Ce) used in HWRFx is significantly larger than that from observational studies for wind speed lower than 30 m s^{-1}, which may cause high bias in the intensity forecast for tropical storms.

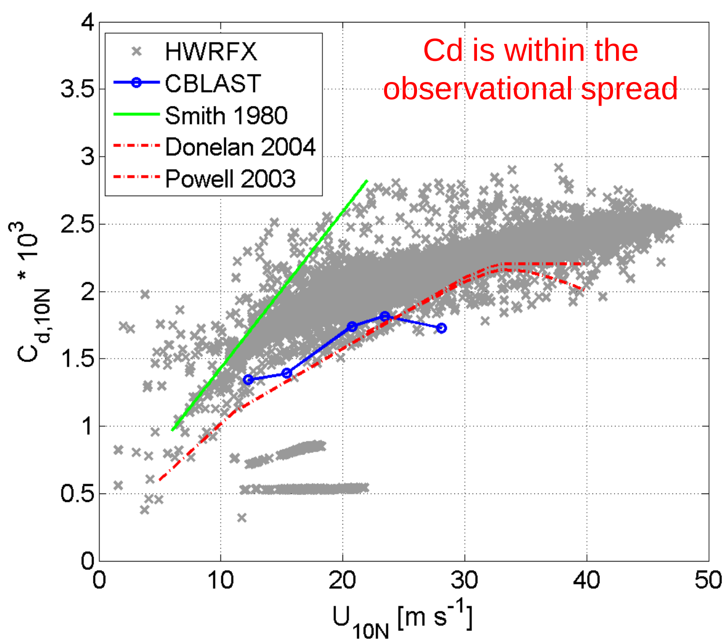
HRD Results

Drag coefficients used in HWRFx compared to observations









NRL COAMPS-TC Physics

Summary

- **Improvements to physics in preparation for real-time COAMPS-TC Demo forecasts:**
  - Bougeault type of mixing (PBL & above)
  - New sfc moisture transfer coefficient
  - New dissipative heating formulation
  - New sea spray parameterization
  - New shallow convection
  - New ice nucleation
- **Establish COAMPS-TC skill for 2008 season:**
  - Verified and diagnosed results for 2008 season in the Atlantic basin
- **Real-time COAMPS-TC forecasts for 2009 ATL:**
- **Diagnosis of HFIP Demo project results:**
  - Identify systematic problems with the physics (in progress)
  - Formulated next steps for FY10

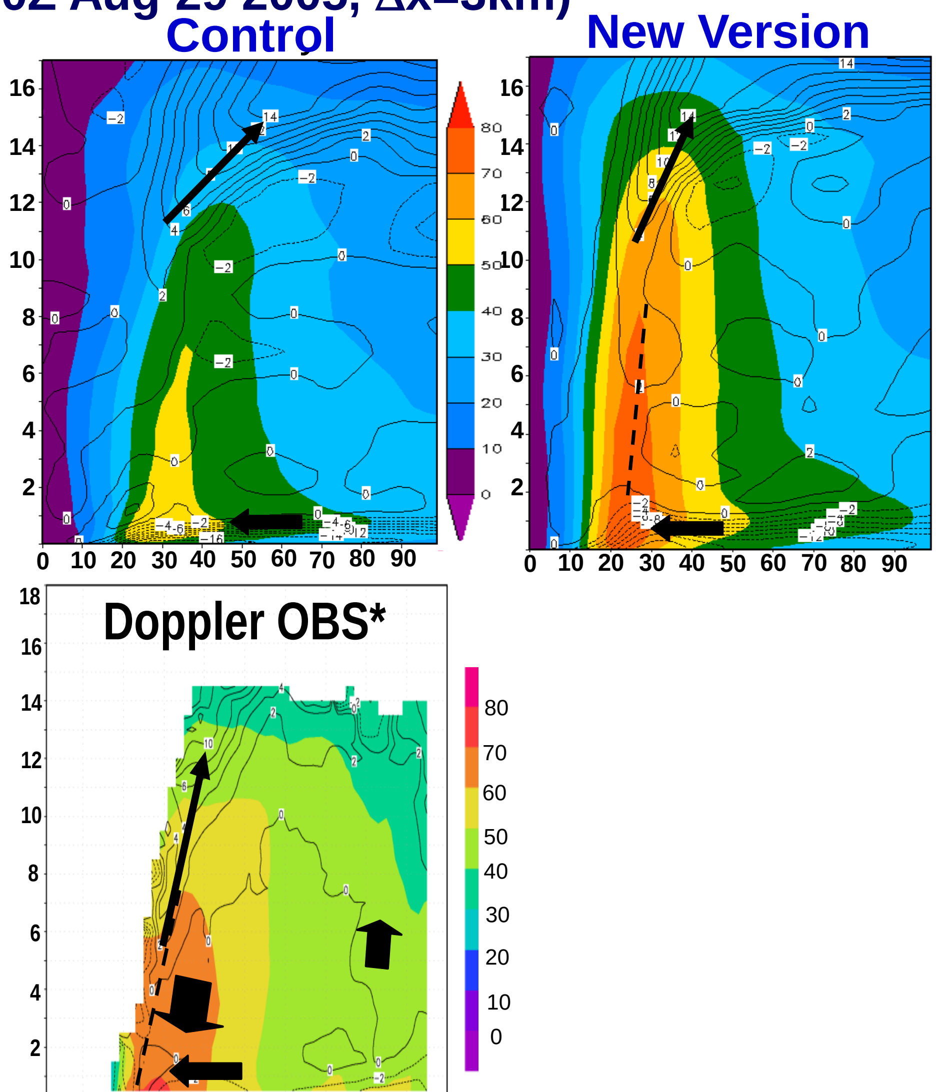
COAMPS-TC Physics Summary

Physics Development Prior to HFIP Demo

Azimuthally average tangential (shaded) and radial (contour) winds
Hurricane Katrina (72 h valid 00Z Aug 29 2005, Δx=3km)

New Version of COAMPS-TC

- *Physics: Control Version*
  - *Baseline TC surface parameterization*
  - *No sea spray*
- *Physics: New Version*
  - *Bougeault type of mixing (PBL & above)*
  - *New sfc moisture transfer coefficient*
  - *New dissipative heating formulation*
  - *New ice nucleation*
  - *New sea spray parameterization*
  - *New shallow convection*



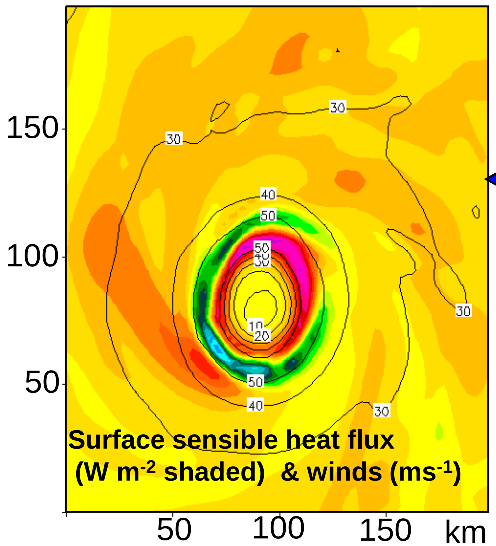
*R. Rogers (HRD)

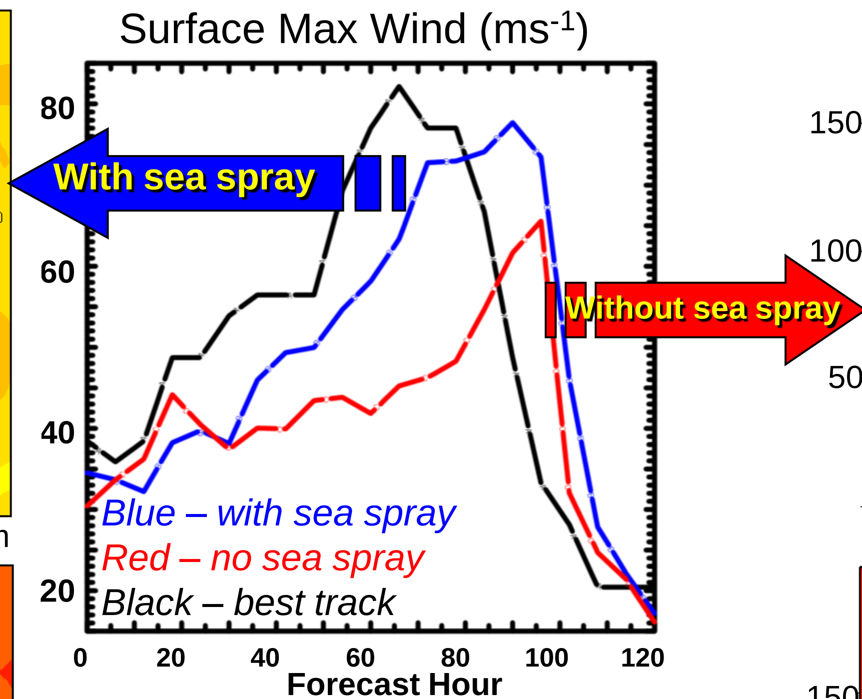
- **New COAMPS-TC**
  - -Improves initial & forecast intensity
  - -Improves the convective structure
  - -Good agreement with Doppler obs.

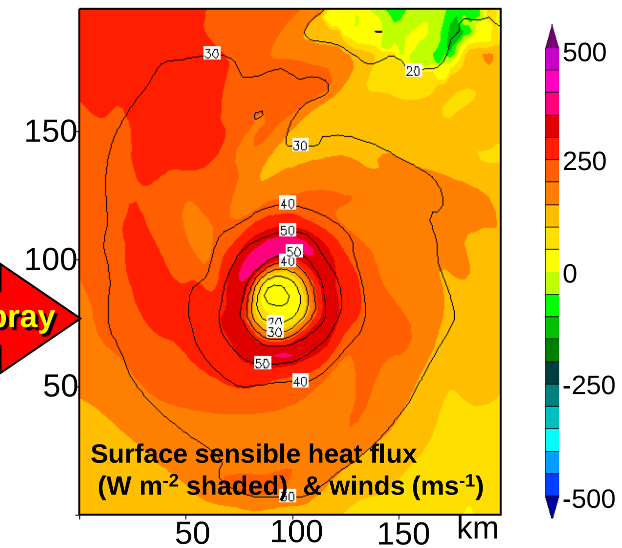
COAMPS-TC Results

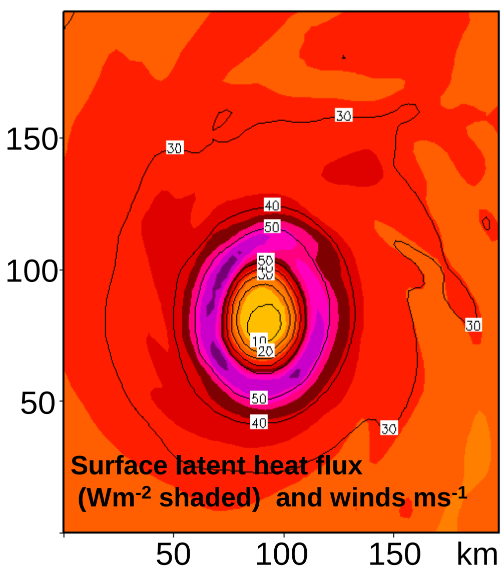
Sea Spray Parameterization

Hurricane Katrina (26-31 Aug 2005, 3-km)

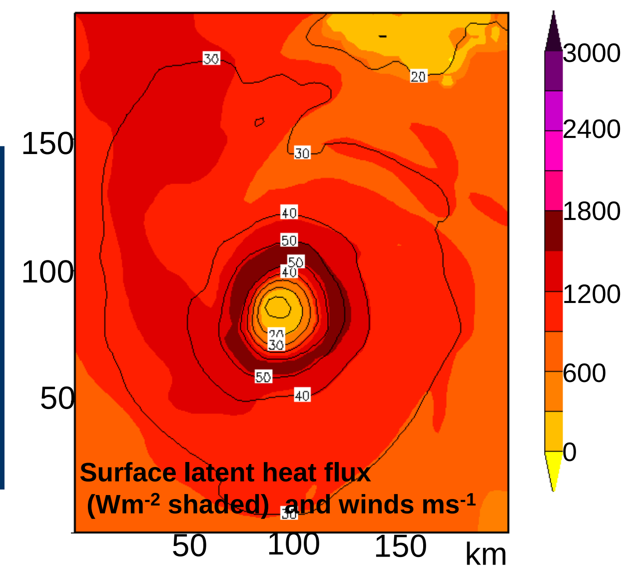








- Contributions from sea spray become important during RI.
- Significant amounts of negative surface sensible heat flux occurs in the eyewall due to evaporative cooling of droplets

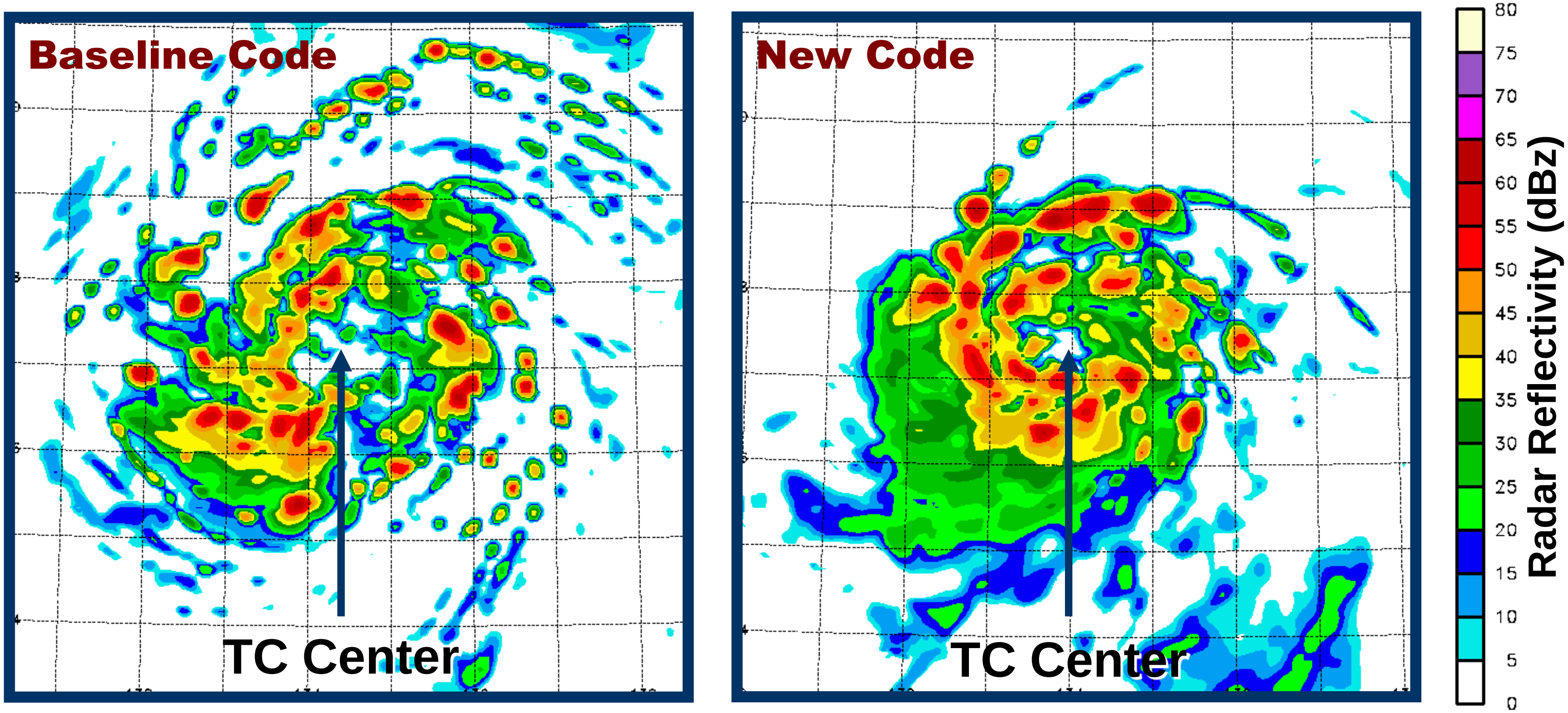


COAMPS-TC Physics Results

Shallow Convection Parameterization

Effect of Shallow Cumulus Parameterization and Improved Vertical Mixing on Initial Convection

12h Forecasts of Radar Reflectivity for baseline code (left) and new code (right)



Use of shallow cumulus parameterization & stronger vertical mixing in clouds removes spurious convection & positions the convection around the TC center

ESRL Summary

1. Worked with Vijay Tallapragada and Young Kwon at EMC and Isaac Ginis at URI to test the ESRL sea spray parameterization in HWRF and the GFDL coupled atmosphere-ocean-wave model

2. Collaborated with Gopal at AOML to implement a procedure to initialize WRF-NMM with an idealized axisymmetric vortex and simple background flows for physics sensitivity studies

3. Began studies of the sensitivity of WRF-NMM to atmospheric boundary layer physics, particularly the surface flux parameterizations at high resolutions

4. Participated in coordinated activities of the Non-Hydrostatic Model Physics Team

ESRL Summary

Sensitivity of TC BL Winds to Sea-Spray Modified C_d C_h

Motivation

Improve our understanding of the sensitivity of the model boundary layer wind and temperature to model physics, particularly the surface flux parameterizations at *high resolution*

Model Initialization

A weak axisymmetric vortex disturbance in an idealized tropical environment; use of the nonlinear balance equation to obtain initial mass and wind fields

Sensitivity Experiments

Exp 1: without sea spray

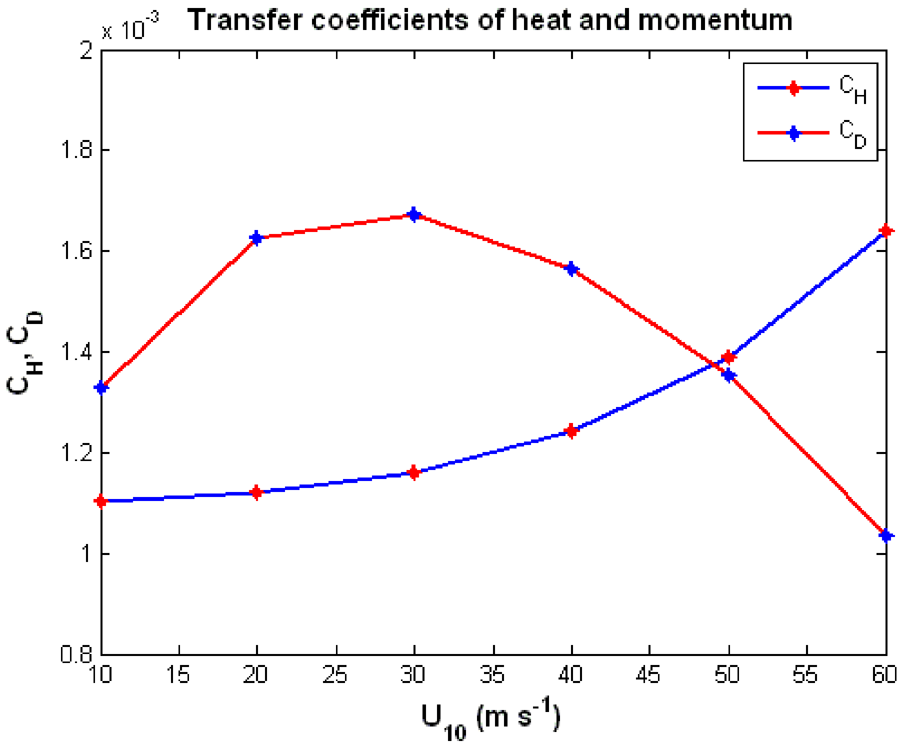
Exp 2: with sea spray impact only on the surface enthalpy fluxes

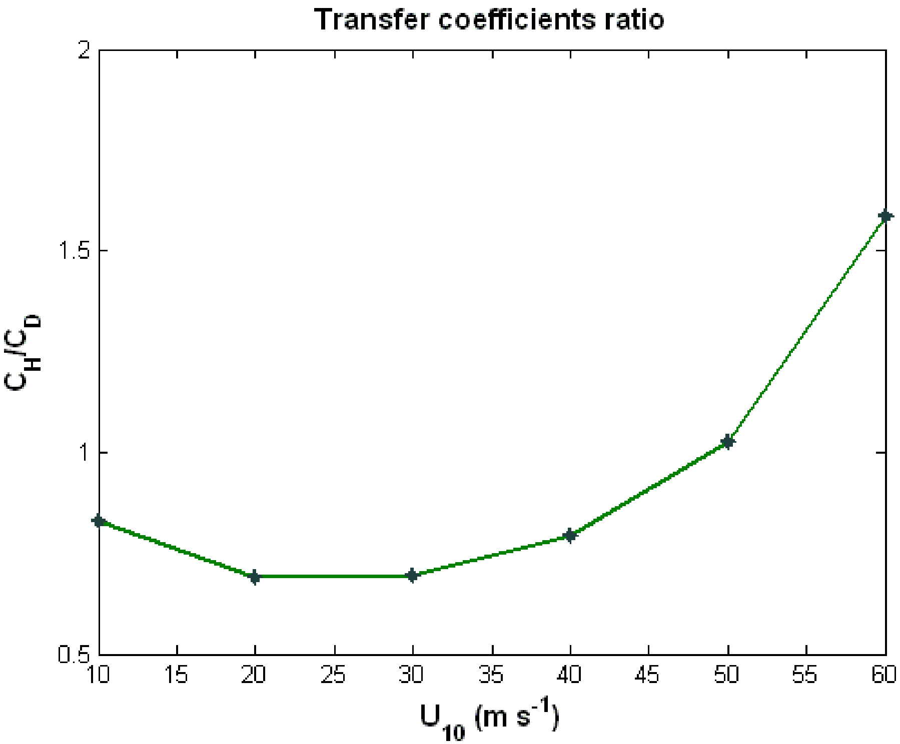
Exp 3: with sea spray impact only on the surface momentum flux

Exp 4: with sea spray impact on surface momentum and enthalpy fluxes

ESRL Results

Impact of Sea Spray on the Exchange Coefficients





- **Overall impact of sea spray is to increase C_h and reduce C_d for wind speeds beyond 30 m s^{-1}.**
- **Transfer coefficient ratio may be overestimated at extreme winds.**

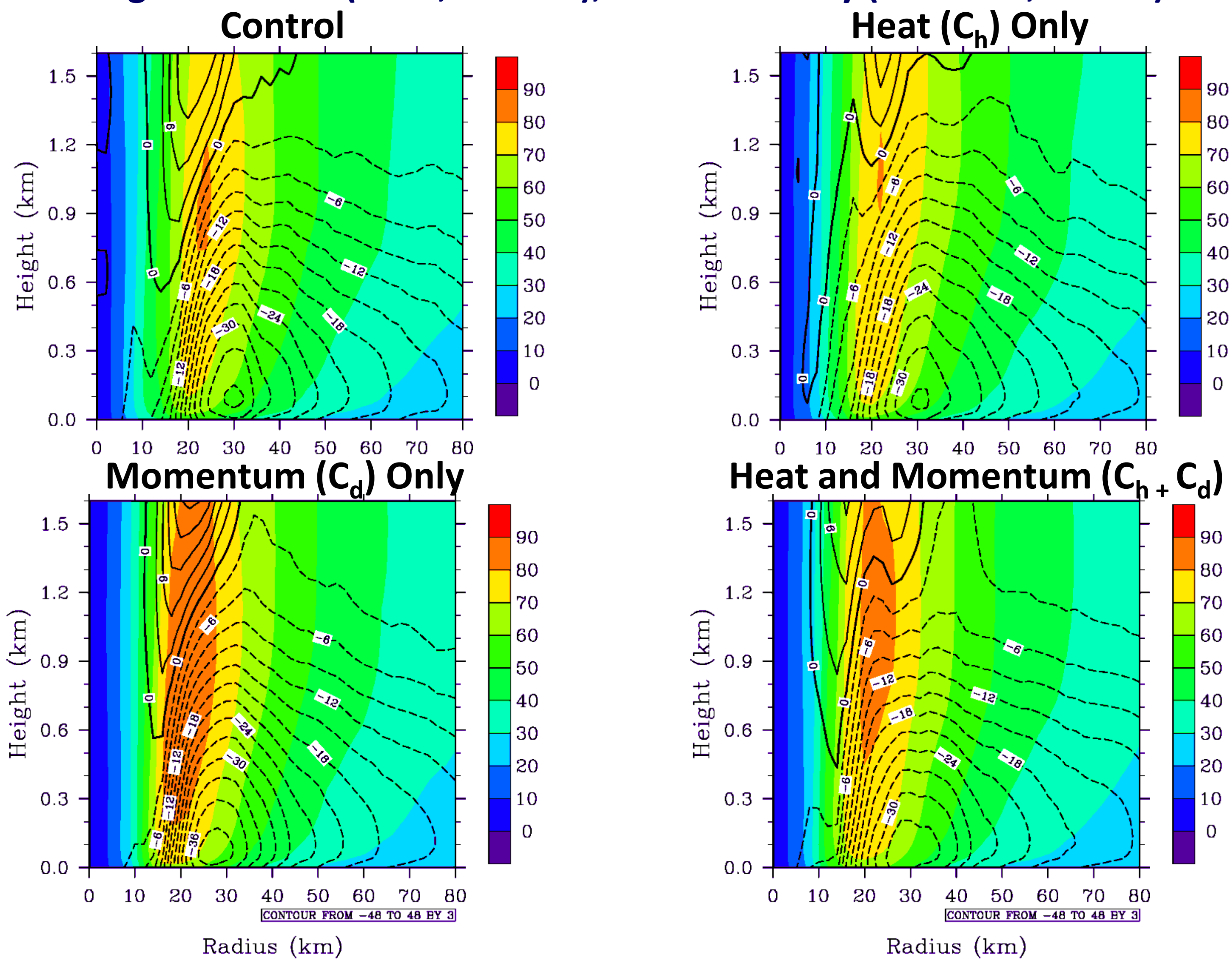
ESRL Results

Impact of Sea Spray on the Exchange Coefficients (HWRFx)

Azimuthal Average Tangential and Radial winds at 9 h after Sea Spray Activation

Tangential wind (color, 10 ms^{-1}), Radial velocity (contours, 3 ms^{-1})

ΔX=2 km



Nonhydrostatic Model Physics Team

Milestones and Deliverables for FY2010

- Physics improvements in operational & HFIP demo models
  - -Full pre-operational testing of NOAH LSM system
  - -Upgrades to surface fluxes, boundary layer for COAMPS-TC
  - -Upgrades of physical parameterizations in HWRFx
- Evaluate new boundary layer and mixing parameterizations, and assess their impact on the boundary layer winds within the hurricane and storm structure.
  - -Evaluate parameterizations in HWRF, HWRFx, COAMPS-TC
- Evaluate improvements to moist physics parameterizations, and assess their impact on the hurricane intensity and storm structure.
  - -Carefully evaluate the linkage between microphysics and mixing
- Test the sensitivity of physics to resolution ranging from an explicit PBL resolving resolution (<100m) to mesoscale (~5km) in order to guide parameterization development in coarse resolution models.
  - -However, resolution alone is not going to solve physics problems
  - -Parameter tuning based on LES & VLES need ground truth
- Test cases (real or idealized) to compare physics in HFIP models

Nonhydrostatic Model Physics Team

Further Points for Discussion

- Some key physical parameterizations have been developed for applications other than hurricanes
  - (e.g., Boundary layer; Cumulus & Microphysics)
  - Do we need more specialized parameterizations for hurricane scale?
- Limited by a lack of observations of key physical processes
- Physics needs be optimized as part of a suite
  - Interactions between processes needs more attention
- Physics in the outer grids have an important impact on inner grids.
  - Moving nests ingest outer mesh points (increase the resolution sensitivity)
  - Need to develop resolution independent or at least consistent physics
- High resolution (e.g., $\Delta x \sim 1$km) physics challenges:
  - Uncertainties remain with microphysical, BL, sfc flux parameterizations.
  - Unresolved portions of convection; Terra Incognita for HBL
  - May need “non-local” physics (communication between neighbors)
- 5-day forecasts stress the physics in news ways (How accurate is the tropical synoptic-scale in these regional models? On par with GCMs?)
- Development of coupled physics is in the early stages
- Stochastic physics for the mesoscale are needed to represent model error for ensembles (hurricane specific? gravity wave radiation?)