HFIP Physics in AHW

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Atlantic Hurricanes (2011)

- 36 km outer domain with 12km and 4 km moving nests for tropical systems
- Moving nest automatically tracks vortex
- 00Z, 06Z, 12Z and 18Z 5-day runs of all active TCs
- Initial conditions from continuous Ensemble KF 6-hr data assimilation cycle
- Ocean mixed-layer depth analysis and sea-surface temperature from HYCOM ocean analysis
- Lateral boundary conditions from GFS

Atlantic Hurricanes (2011)

- Tiedtke cumulus parameterization on 36/12 km, no cumulus on 4 km domain
- WSM6 microphysics (includes graupel)
- YSU PBL scheme for vertical mixing
- One-layer ocean-mixed layer model for feedback (cooling effect under high winds)
- Wind-dependent formulations for drag (Donelan) and enthalpy (Garratt) surface fluxes plus dissipative heating effect

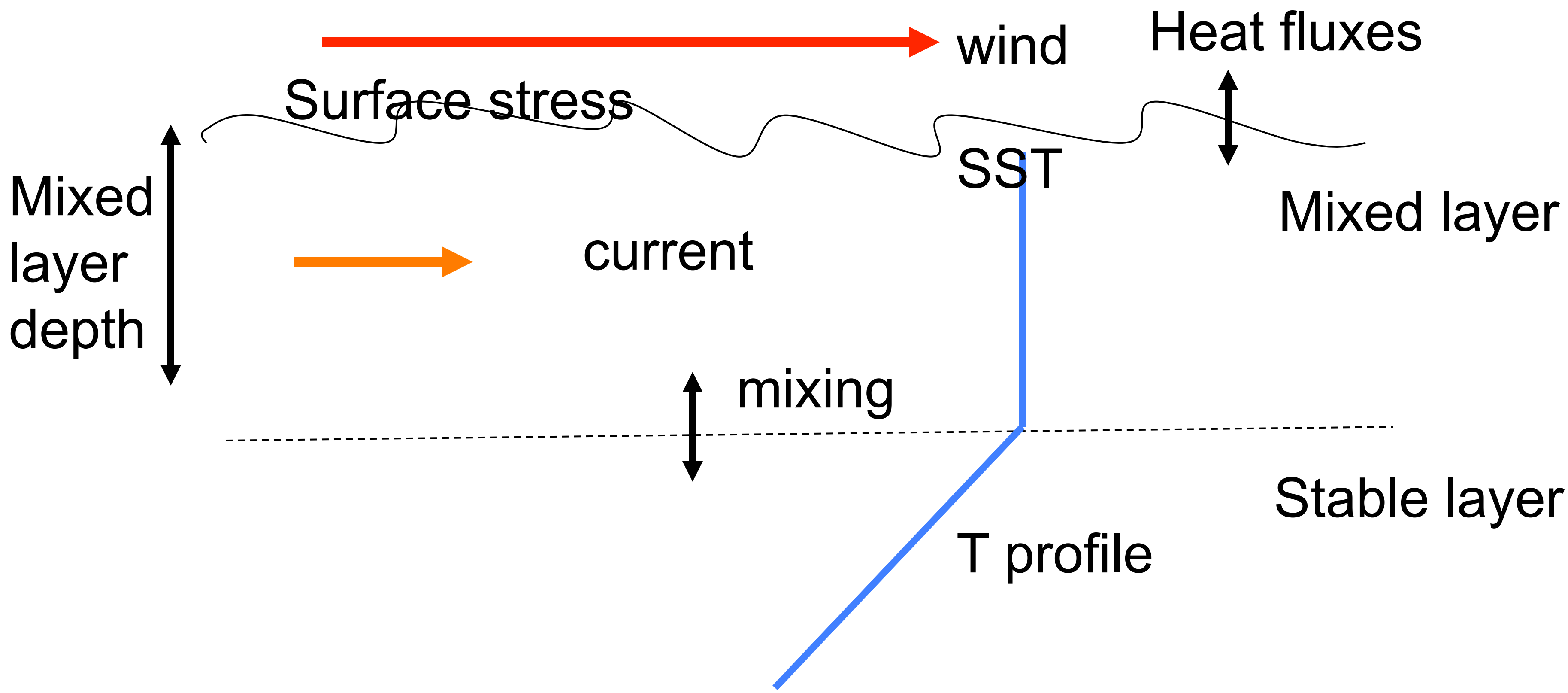
Hurricane-specific physics

- 1-dimensional Ocean mixed-layer
- Surface flux formulations

1D Ocean Mixed-Layer Model

- Model
  - Slab mixed layer
    - Predicts depth, vector current components, temperature
  - Initial depth specified from HYCOM analysis
  - Initial temperature is from 1/12 degree NCEP daily SST
    - Min temperature mixing limit for shallow regions
  - Initial current is zero
    - hurricane induced currents are assumed to dominate over pre-existing currents
  - Lapse rate below mixed layer is specified from climatology
  - Inertial turning effects from Coriolis are included
  - Thermal energy balance in mixed layer due to surface fluxes and radiation is included (small)
  - Atmospheric stress reduced by 50% for ocean stress

1D Ocean Mixed-Layer Model



Surface Fluxes

- Heat, moisture and momentum

$$H = \rho c_p u_* \theta_* \qquad E = \rho u_* q_* \qquad \tau = \rho u_* u_*$$

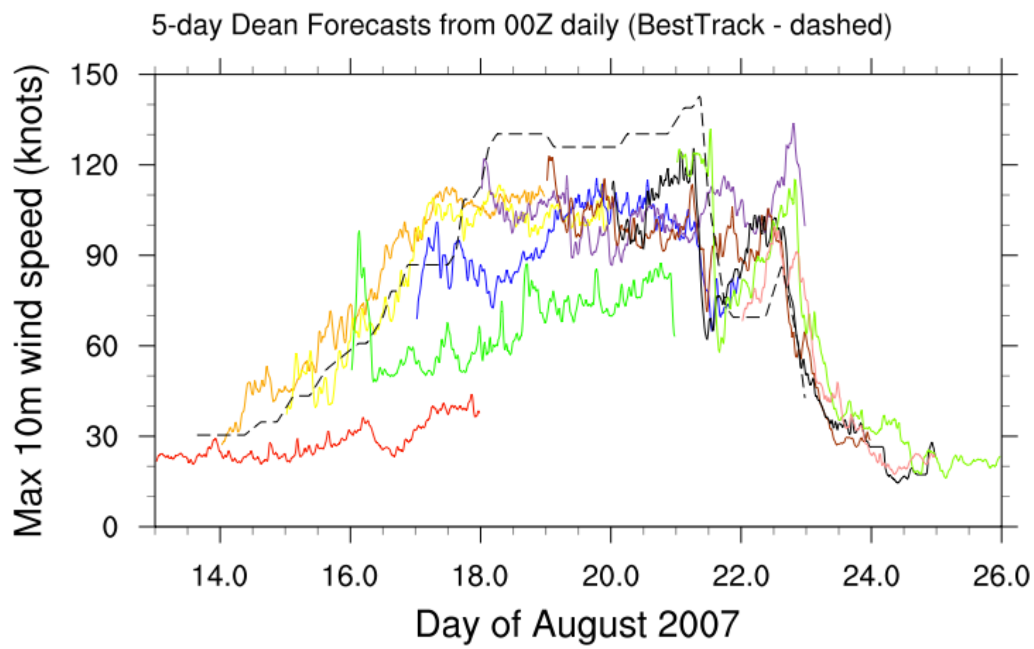
$$u_* = \frac{kV_r}{\ln(z_r / z_0) - \psi_m} \qquad \theta_* = \frac{k\Delta\theta}{\ln(z_r / z_{0h}) - \psi_h} \qquad q_* = \frac{k\Delta q}{\ln(z_r / z_{0q}) - \psi_h}$$

Subscript *r* is reference level (lowest model level, or 2 m or 10 m)
z_0 are the roughness lengths

Ck Sensitivity (Dean 2007)

- Previous experience shows sensitivity to Ck
- Tried a ramp z_{0q} function to enhance fluxes at higher wind

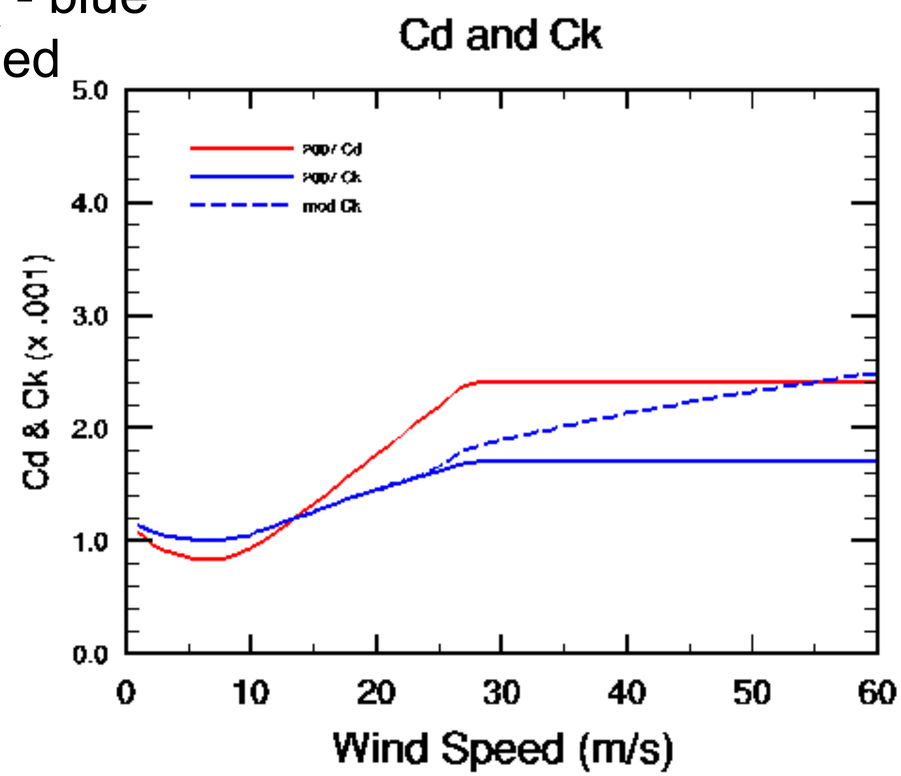
Hurricane Dean (2007)

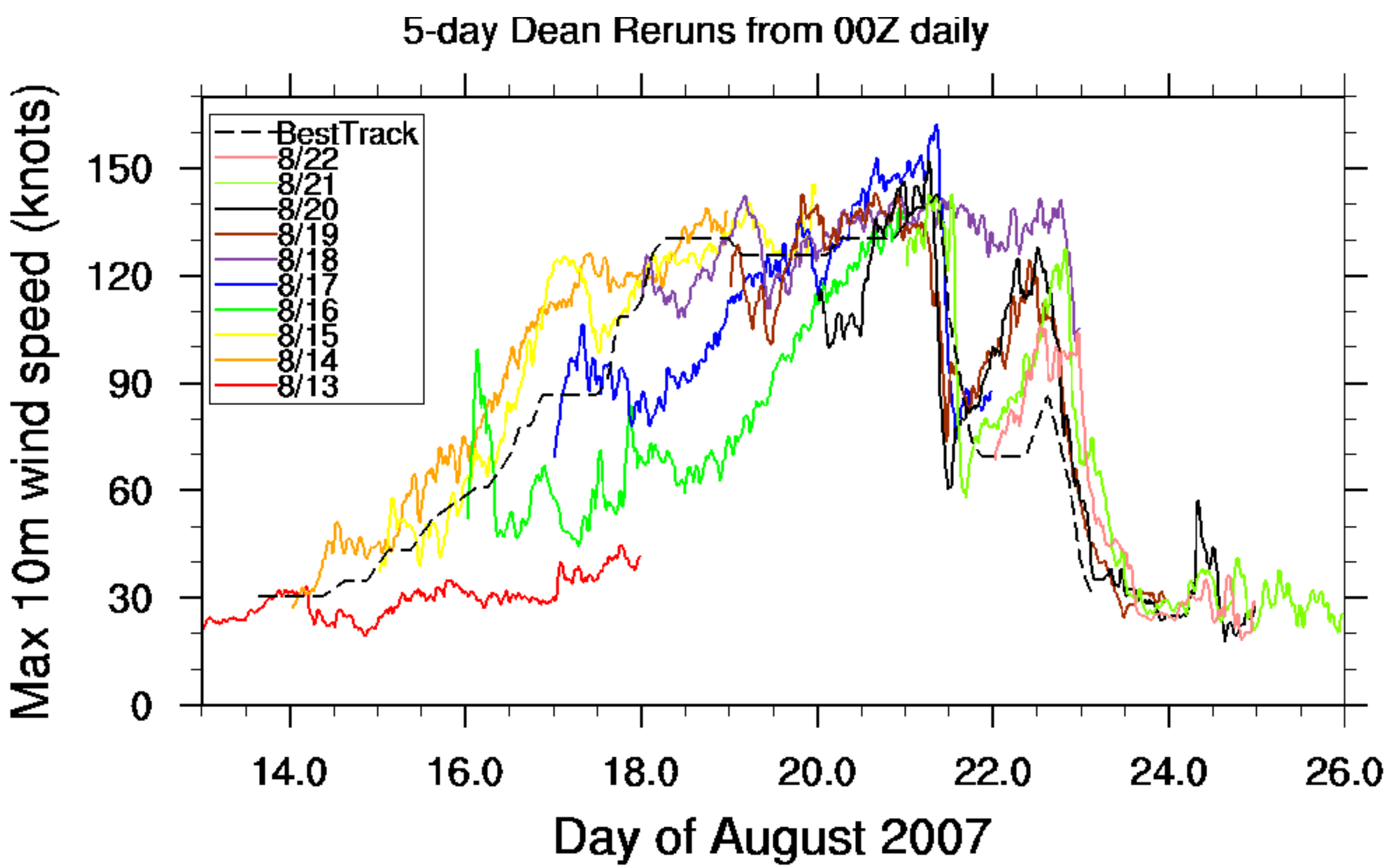


Note that forecasts underestimate maximum windspeed

Modification to C_k in AHW

C_d - red, C_k - blue
New - dashed
Old - solid




5-day Dean Reruns from 00Z daily
Max 10m wind speed (knots)
0
30
60
90
120
150
BestTrack
8/22
8/21
8/20
8/19
8/18
8/17
8/16
8/15
8/14
8/13
14.0
16.0
18.0
20.0
22.0
24.0
26.0
Day of August 2007

Current Cd and Ck

- Donelan still used (small change in gradient)
- In 2010 implemented Garratt Ck because more recent studies support a lower more flat Ck
- Added dissipative heating

Surface TC Fluxes

$$H = \rho c_p u_* \theta_* \quad + \rho u_*^2 V_r$$ Dissipative heating

$$E = \rho u_* q_*$$

$$\tau = \rho u_* u_*$$

Donelan (z$_0$ function below gives linear C_D with V in neutral case)

$$u_* = \frac{kV_r}{\ln(z_r / z_0) - \psi_m}$$

$$z_0 = 10\exp(-9.5u_*^{-1/3}) + 0.165 \times 10^{-5} / u_*$$

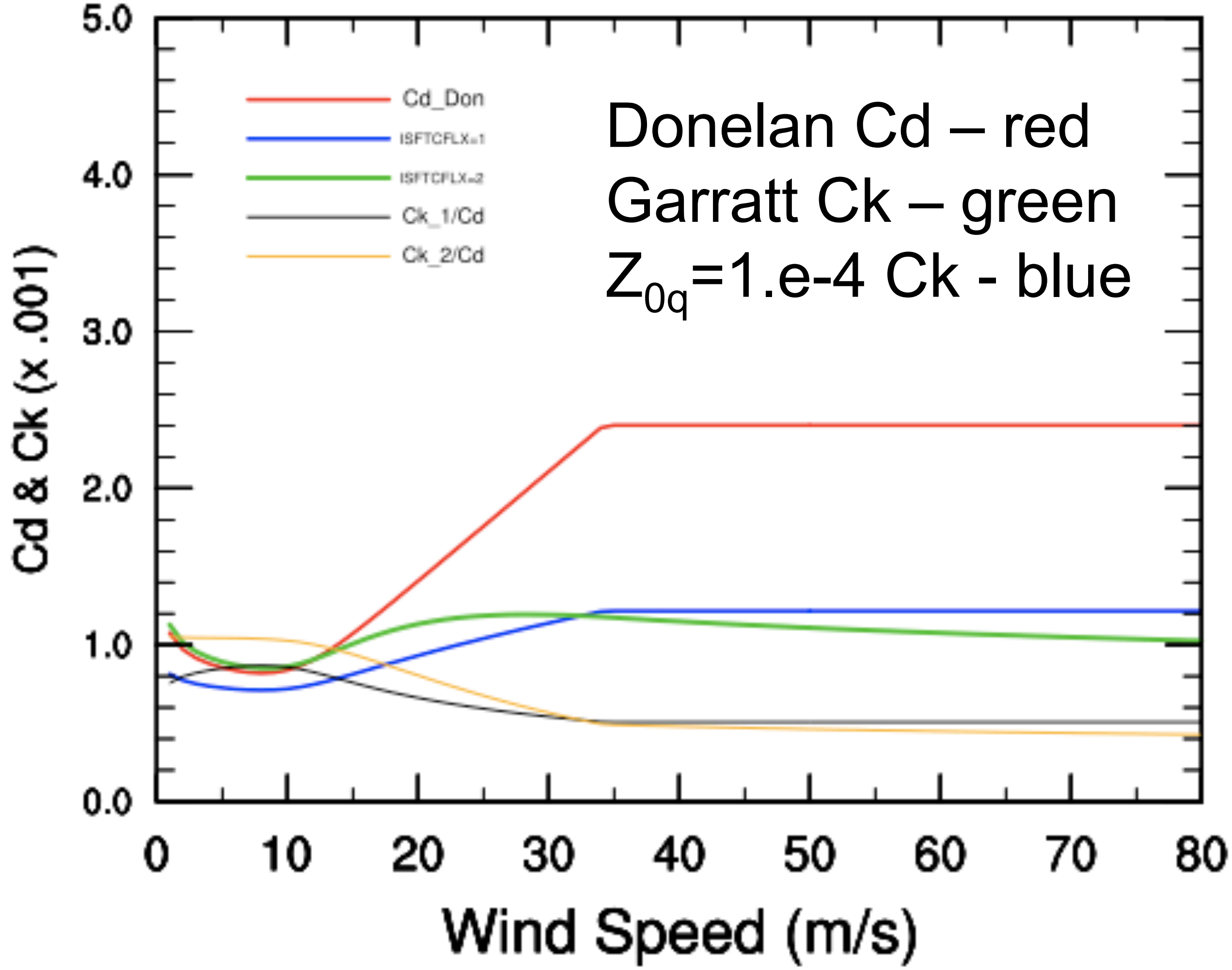
$$[1.27 \times 10^{-7} < z_0 < 2.85 \times 10^{-3}]$$

Garratt

$$\theta_* = \frac{k\Delta\theta}{\ln(z_r/z_0) - \psi_h + 2.48\mathrm{Re}^{1/4} - 2}$$

$$q_* = \frac{k\Delta q}{\ln(z_r/z_0) - \psi_h + 2.28\mathrm{Re}^{1/4} - 2}$$

Surface TC Options

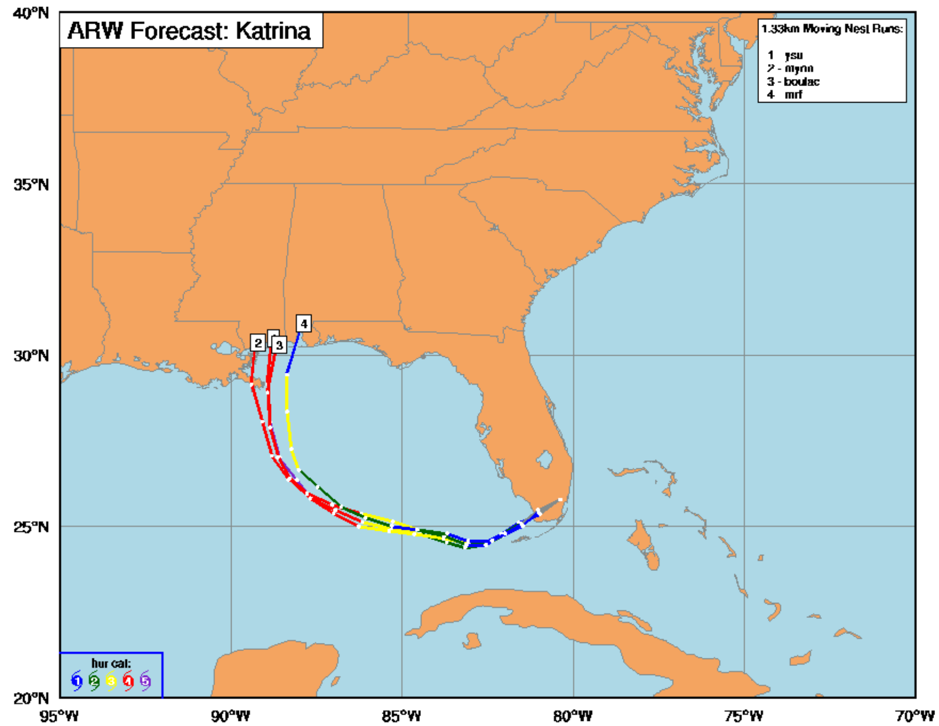


2010 Physics Changes

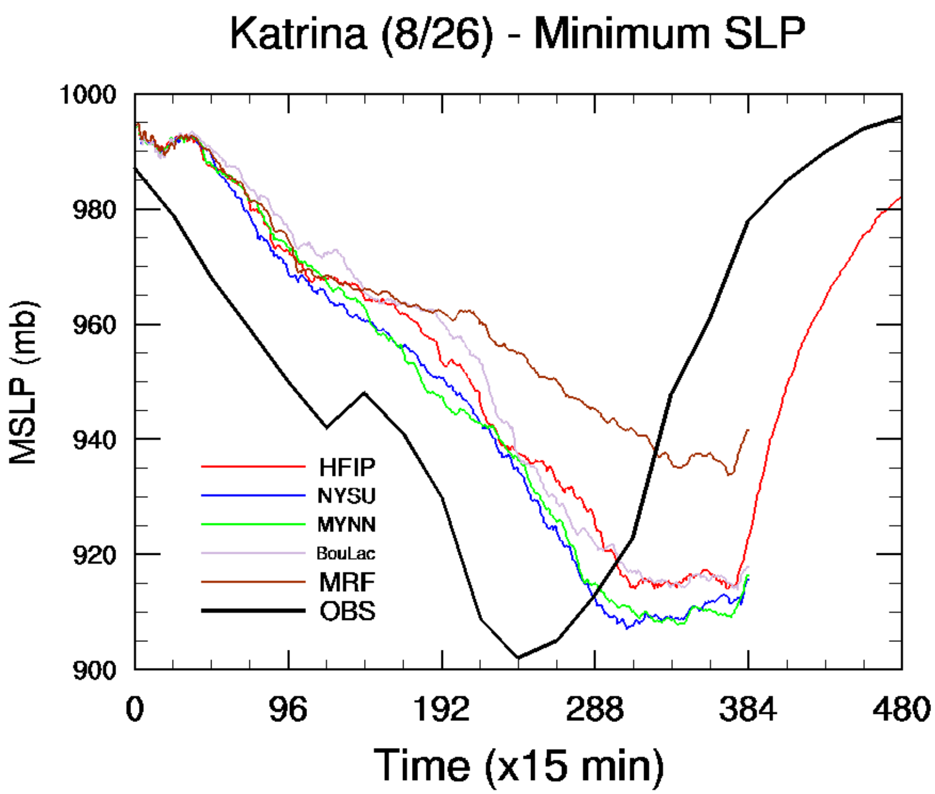
- Garratt flux would tend to reduce hurricane strength
- Move from WSM5 to Thompson would tend to increase hurricane strength because Thompson adds graupel category
- These were offsetting changes in terms of intensity (we wanted to preserve 2009 intensity)

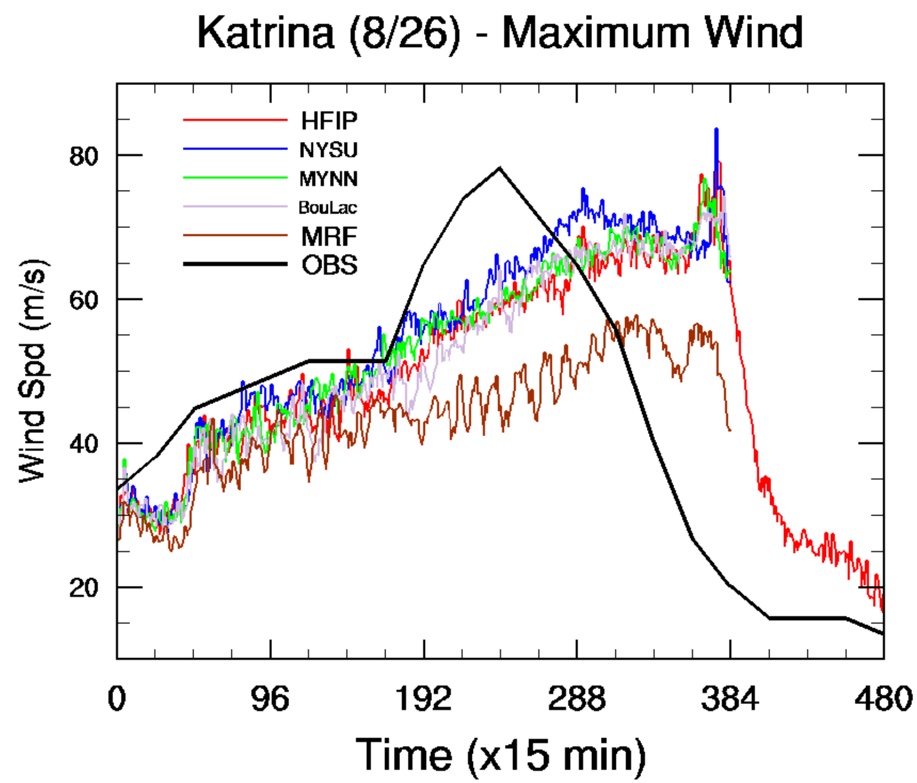
Katrina (2005) PBL Comparison

- Initialized August 26th (EnKF)
- GFS forecast boundaries
- 12/4/1.33 km moving nests
- 96 hours
- YSU default versus MYNN, BouLac and MRF



PBL Comparison





PBL Comparison

- MRF scheme with deeper mixing than others is the outlier (Braun and Tao result)
- PBL schemes otherwise behave similarly

Summary

- Hurricanes are sensitive to surface physics
  - Ocean mixed layer
  - Surface exchange coefficients
  - PBL scheme