The Impact of Sea Spray on the Structure of Tropical Storms: Preliminary Results

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Outline

- Sea-spray physics
- HWRF example
- ARW example
- Preliminary Conclusions

The NOAA/ESRL Parameterization Scheme of Sea Spray in the HWRF Model

- A physical model of sea-spray generation function consistent with wave breaking dynamics

- An extension of the Monin-Obukhov similarity framework to take into account the feedback effects

$$u_* = \frac{\kappa(U - U_0)}{\ln(z/z_0) + \Psi_m(z/L)}, \qquad \frac{-\left(\langle \theta w \rangle + \langle \theta_{sp} w \rangle\right)}{u_*} = \frac{\kappa(\Theta - \Theta_0)}{\ln(z/z_0) + \Psi_h(z/L)}$$

$$L^{-1} = -\frac{kg\overline{\vartheta_v' w'}}{\vartheta_v u_*} + \frac{\sigma \overline{S' w'}}{u_*^3} = L_{MO}^{-1} + L_{SP}^{-1}$$

$$\Psi_m(z/L) = \Psi_{m1}(z/L_{MO}) + \Psi_{m2}(z/L_{SP})$$

$$\Psi_h(z/L) = \Psi_{h1}(z/L_{MO}) + \Psi_{h2}(z/L_{SP})$$

Summary of the Sea Spray Physics

- The suspension of sea-spray droplets reduces the buoyancy and makes the surface layer more stable, reducing the friction velocity and the downward turbulent mixing of momentum.

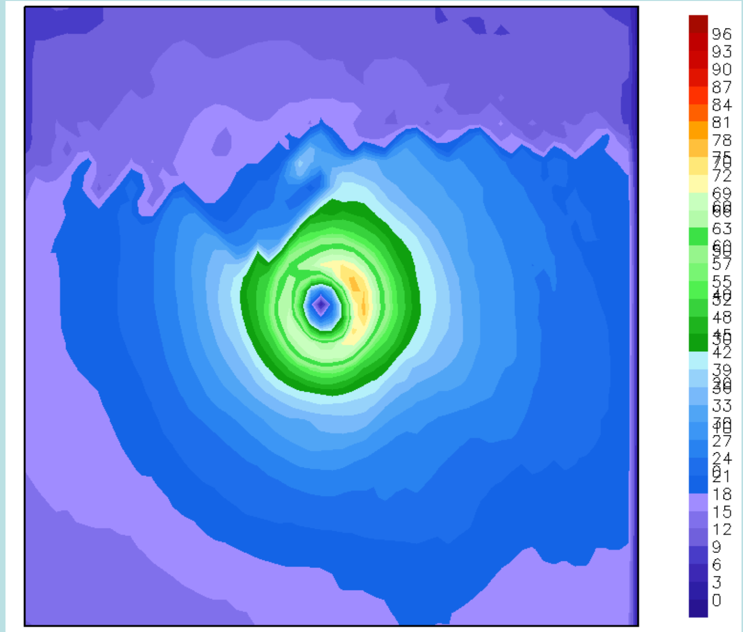
- Sea-spray droplets tend to cool and moisten the surface boundary layer at winds below 35 ms^{-1} , but they tend to warm and moisten the surface boundary layer at winds above 50 ms^{-1}.

- The sign of the flux Richardson number is opposite to the droplet Richardson number at hurricane-strength winds.

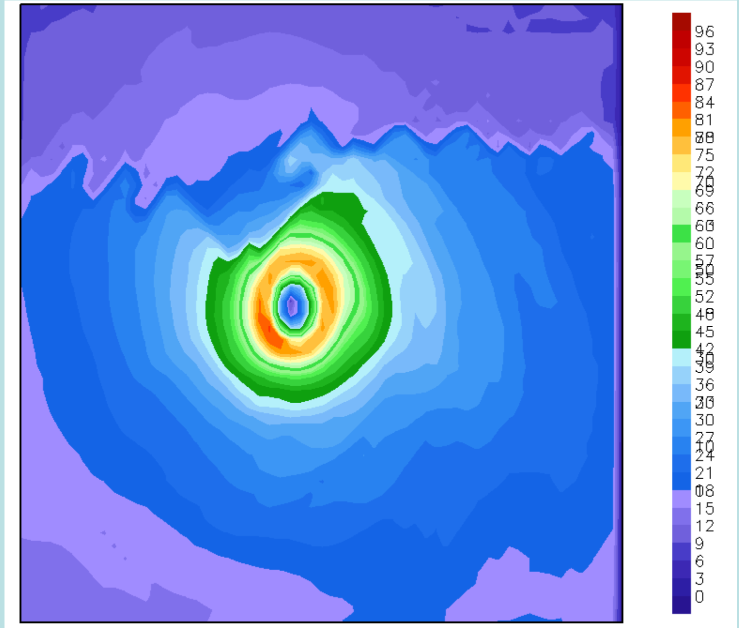
- The effect of the flux Richardson number is smaller than that of the droplet Richardson number at hurricane-strength winds, rendering the overall effect of sea-spray to be that the vertical mixing of both momentum and heat are enhanced.

Wind Speed of Hurricane Katrina (2005) from HWRF

control



thermal + momentum

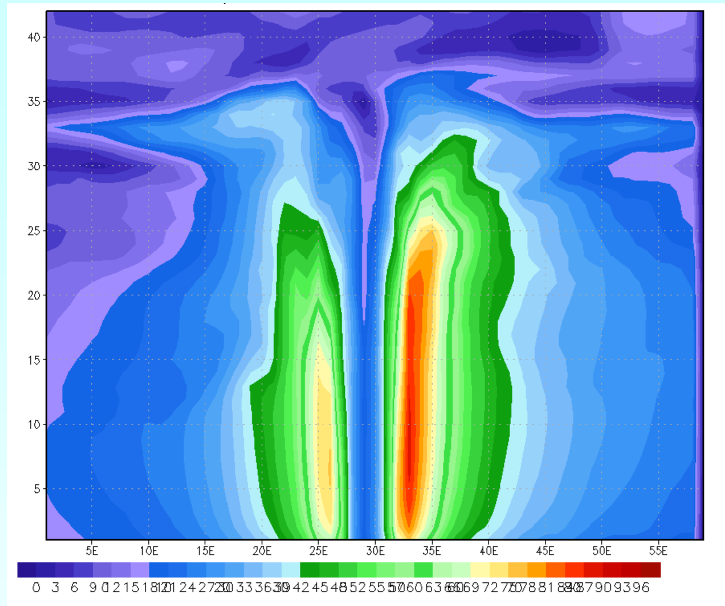


Initial time: 0000 UTC 27 August 2005

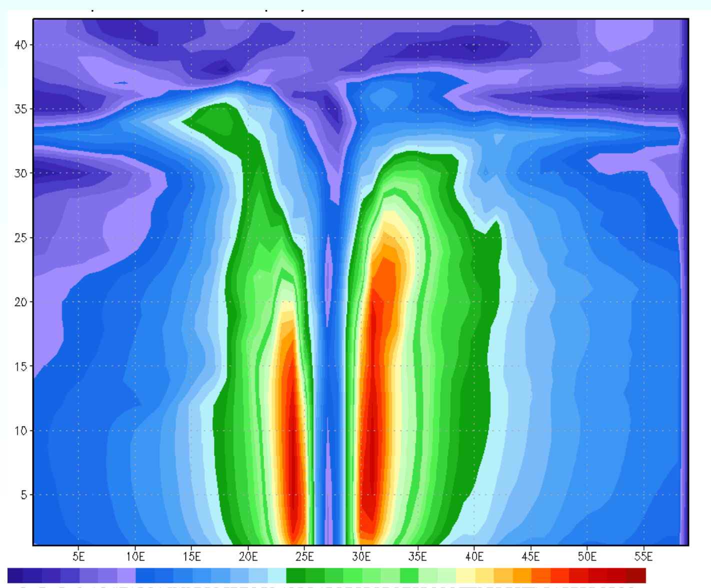
Valid at 0060 UTC 29 Aug 2005

Wind Speed of Hurricane Katrina (2005) from HWRF

control



thermal + momentum

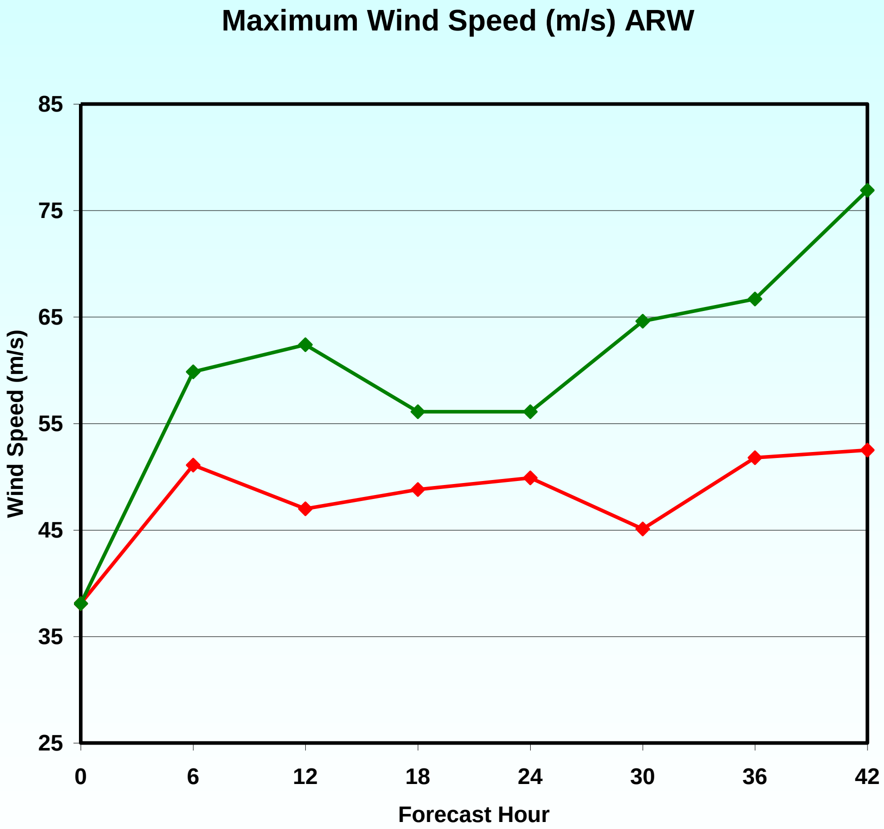


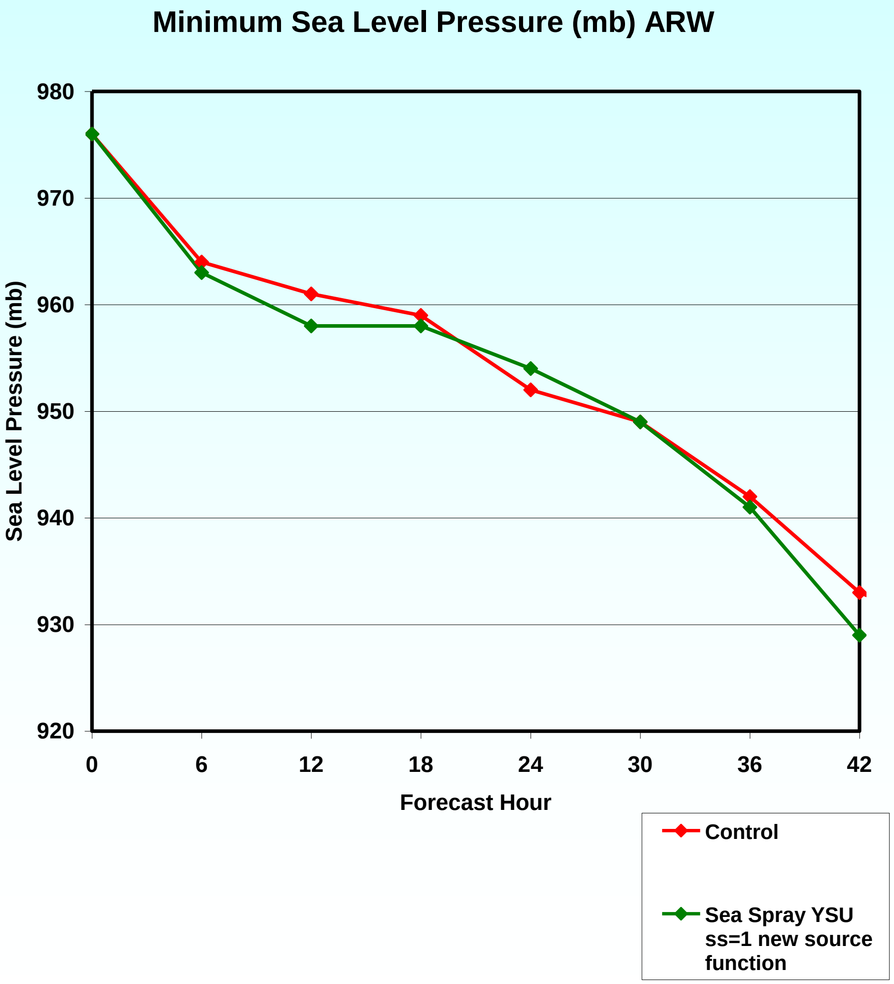
E-W cross section
Valid at 0060 UTC
29 Aug 2005

WRF ARW SETUP

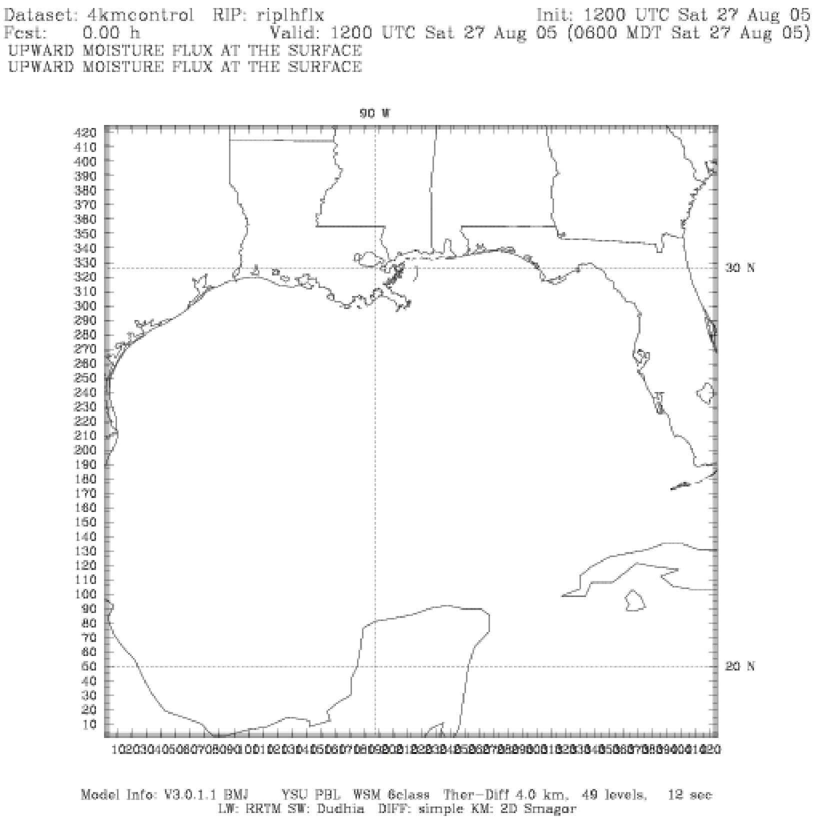
- WRF V 3.0.1
- 4-km grid: 425 x 425 grid points in the horizontal with 50 vertical levels
- WSM 6-class graupel scheme
- RRTM longwave scheme, Dudhia shortwave scheme
- Monin-Obukhov surface layer scheme, thermal diffusion land surface scheme
- YSU boundary layer scheme
- Initialized at 1200 UTC 27 Aug 2005 using the GFS analysis

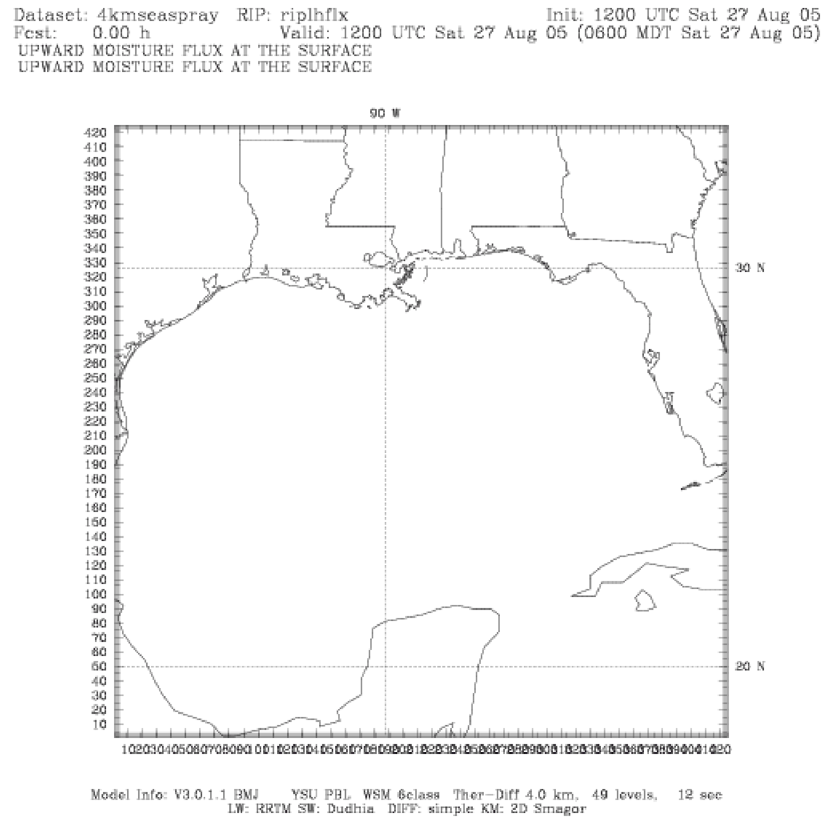
Intensity Comparison



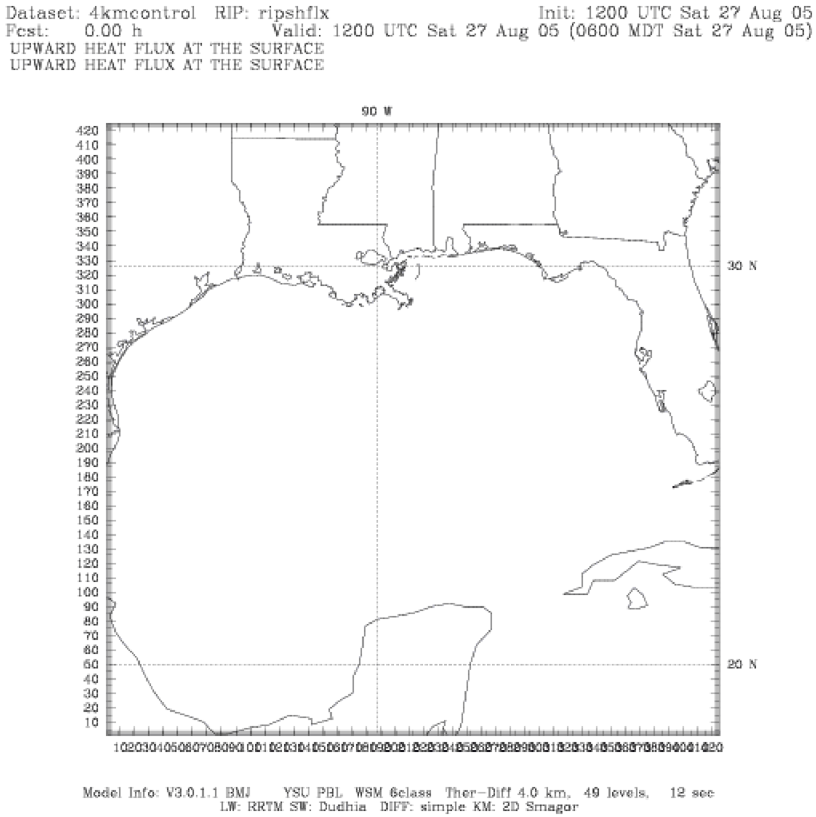


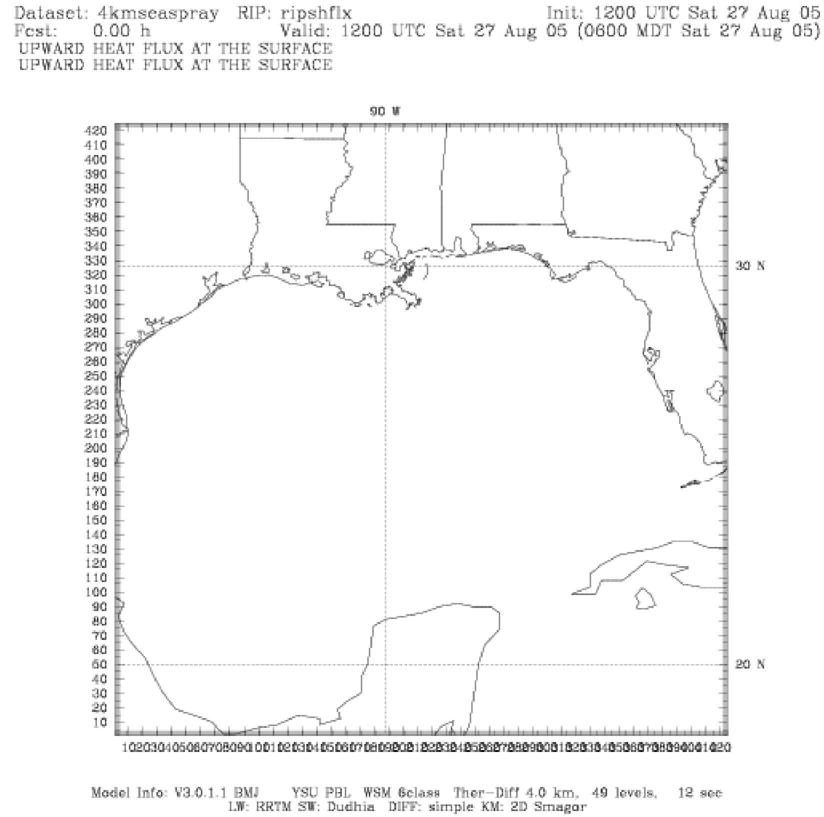
Moisture Flux



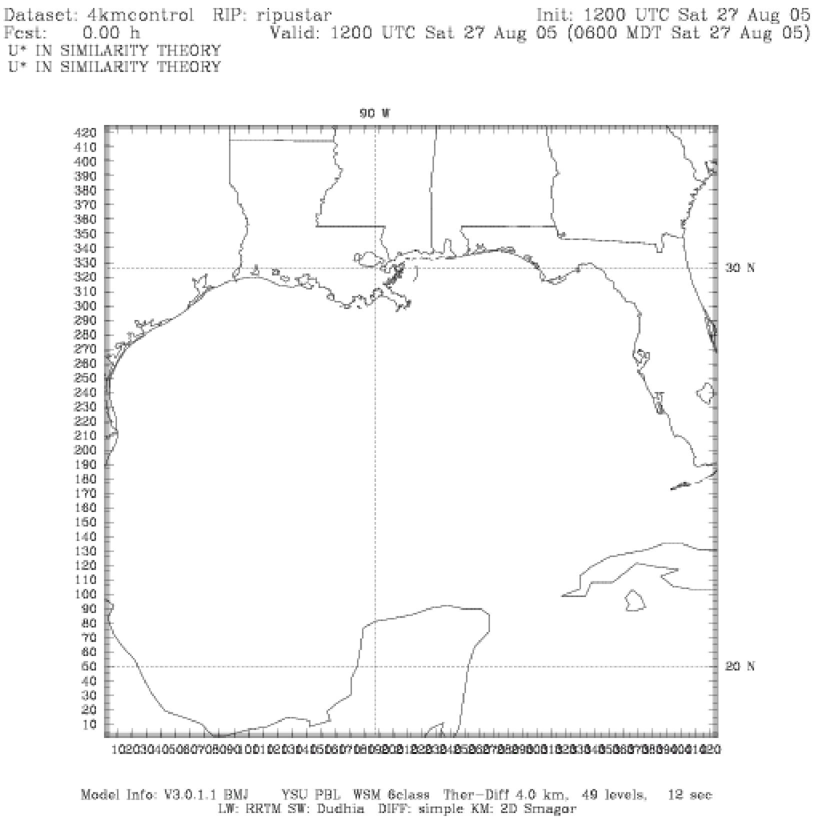


Sensible Heat Flux

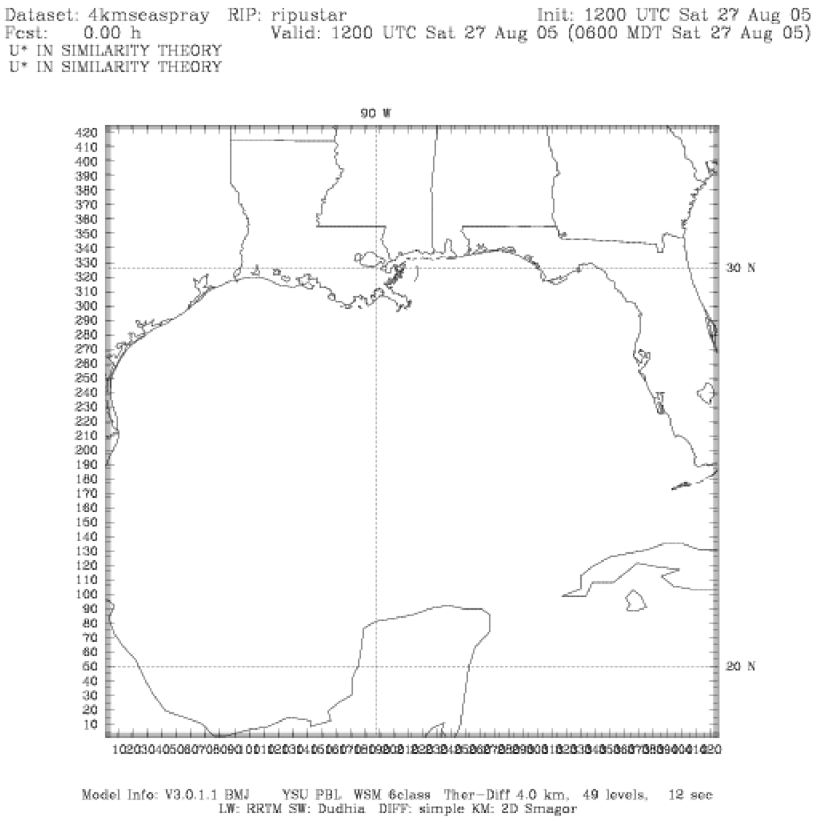




U*



Dataset: 4kmcontrol RIP: ripustar
Init: 1200 UTC Sat 27 Aug 05
Fcst: 0.00 h
Valid: 1200 UTC Sat 27 Aug 05 (0600 MDT Sat 27 Aug 05)
U* IN SIMILARITY THEORY
U* IN SIMILARITY THEORY
90 W
30 N
20 N
Model Info: V3.0.1.1 BMJ YSU PBL WSM 6class Ther-Diff 4.0 km, 49 levels, 12 sec
LW: RRTM SW: Dudhia DIFF: simple KM: 2D Smagor



Dataset: 4kmseaspray RIP: ripustar
Init: 1200 UTC Sat 27 Aug 05
Fcst: 0.00 h
Valid: 1200 UTC Sat 27 Aug 05 (0600 MDT Sat 27 Aug 05)
U* IN SIMILARITY THEORY
U* IN SIMILARITY THEORY
90 W
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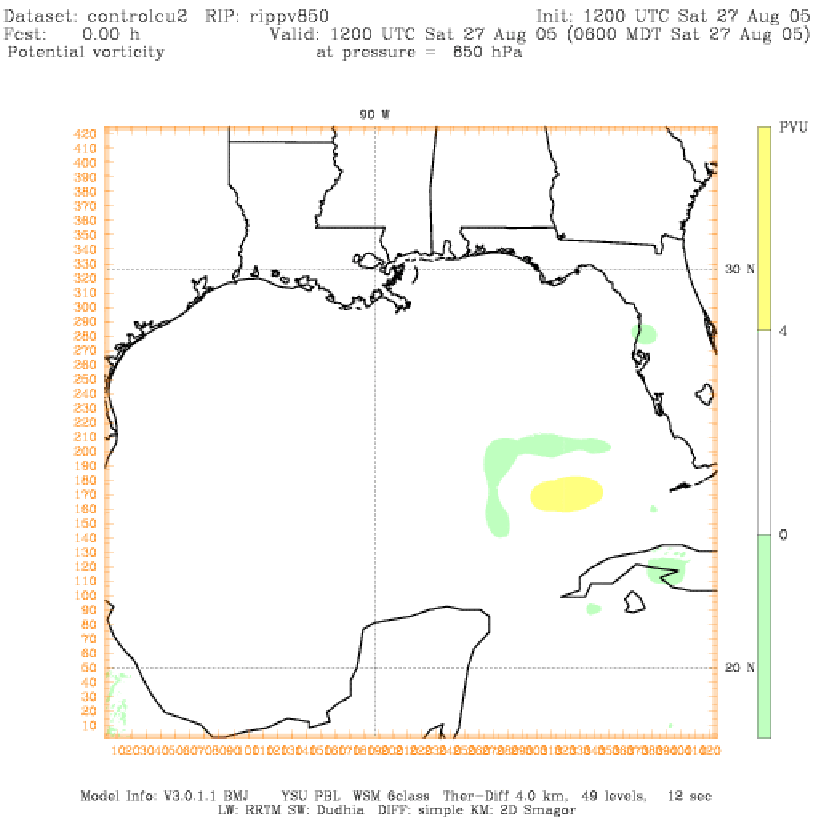
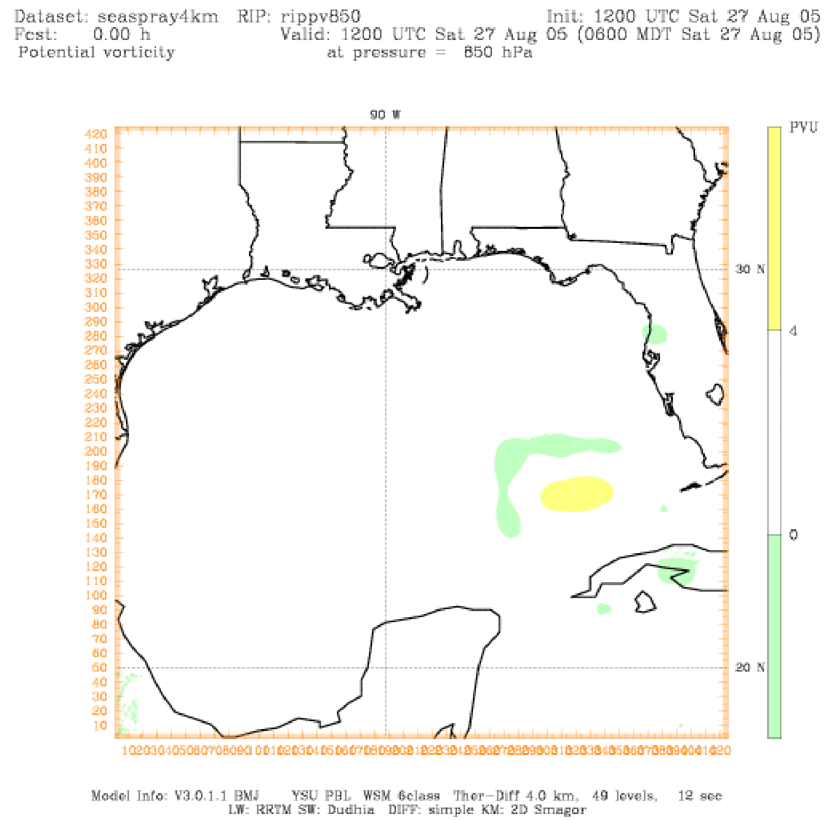
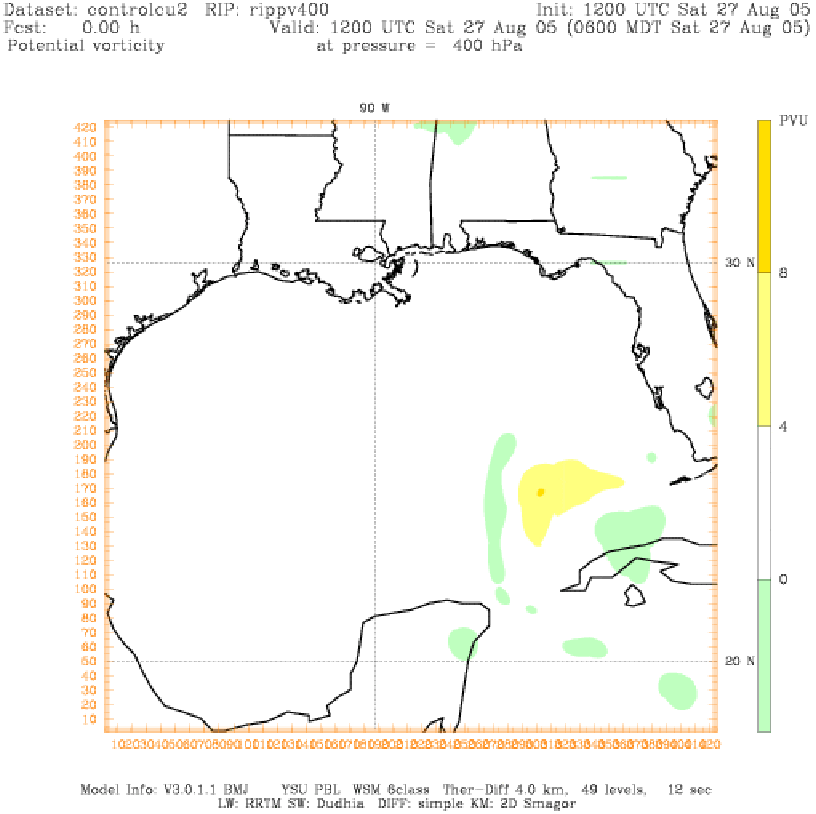
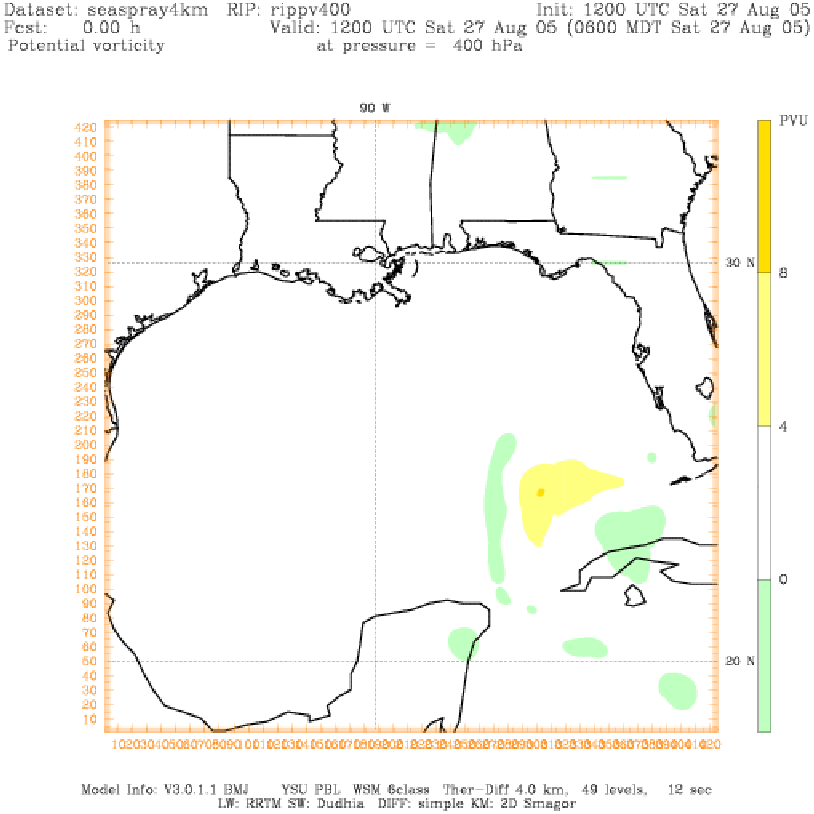
Potential Vorticity at 850 mb



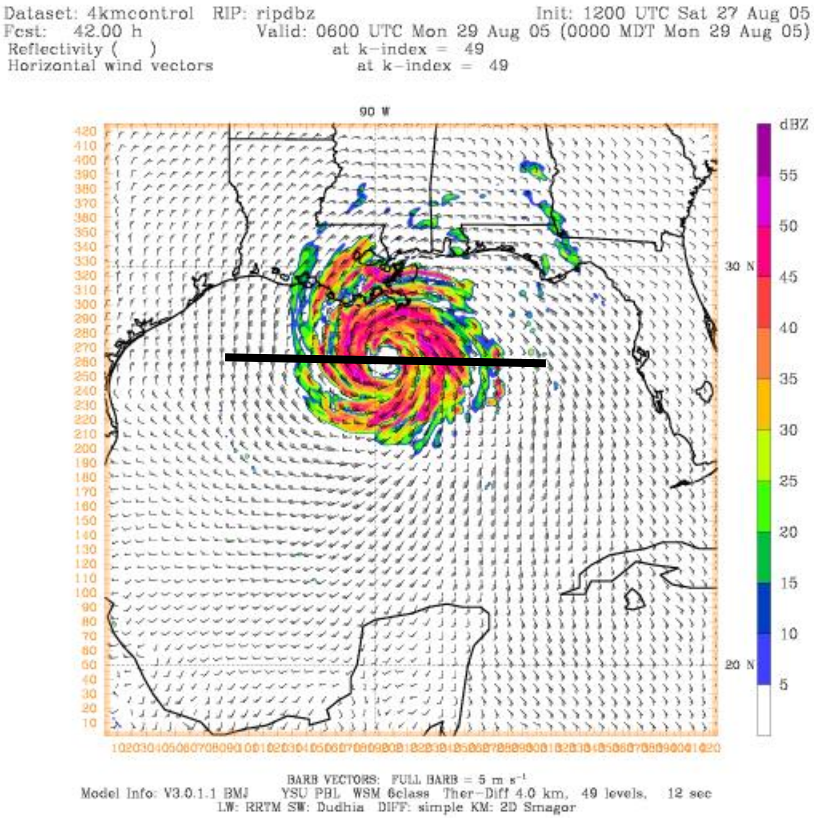


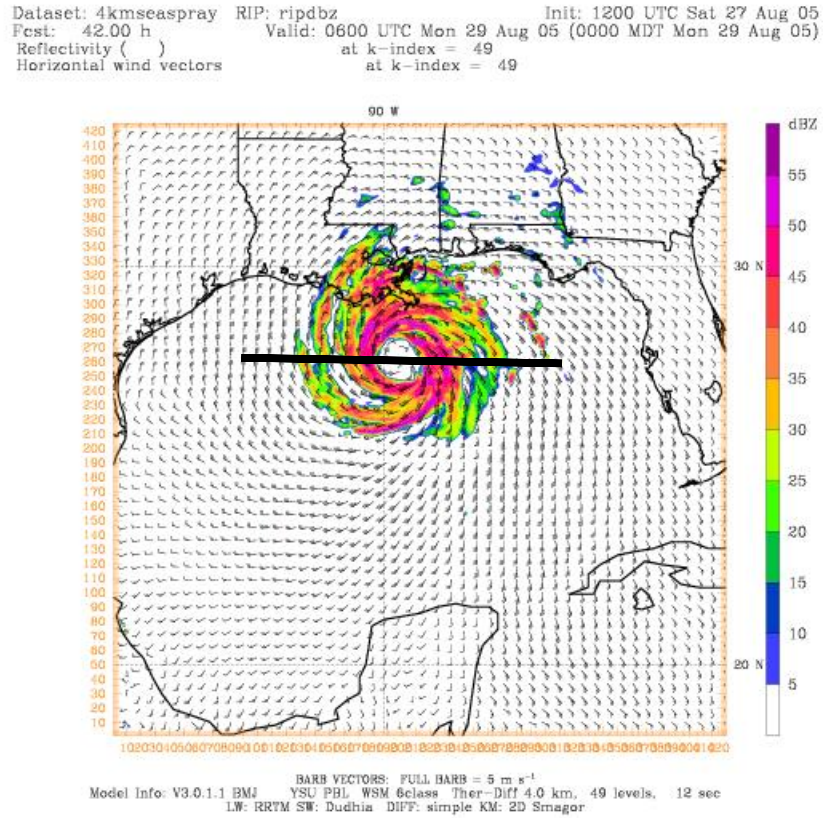
Potential Vorticity at 400mb



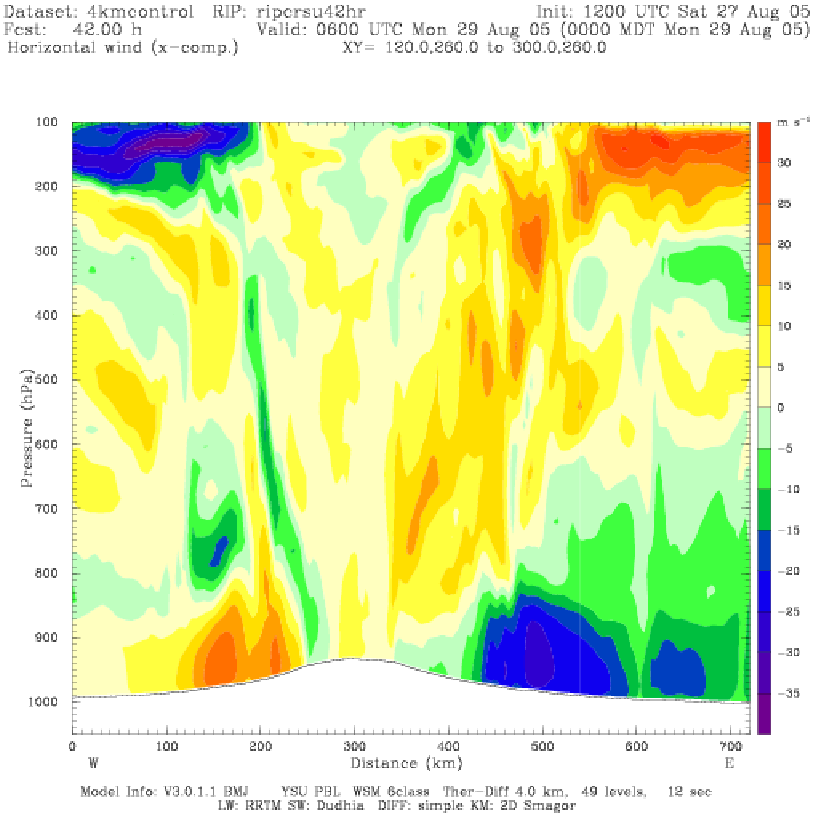


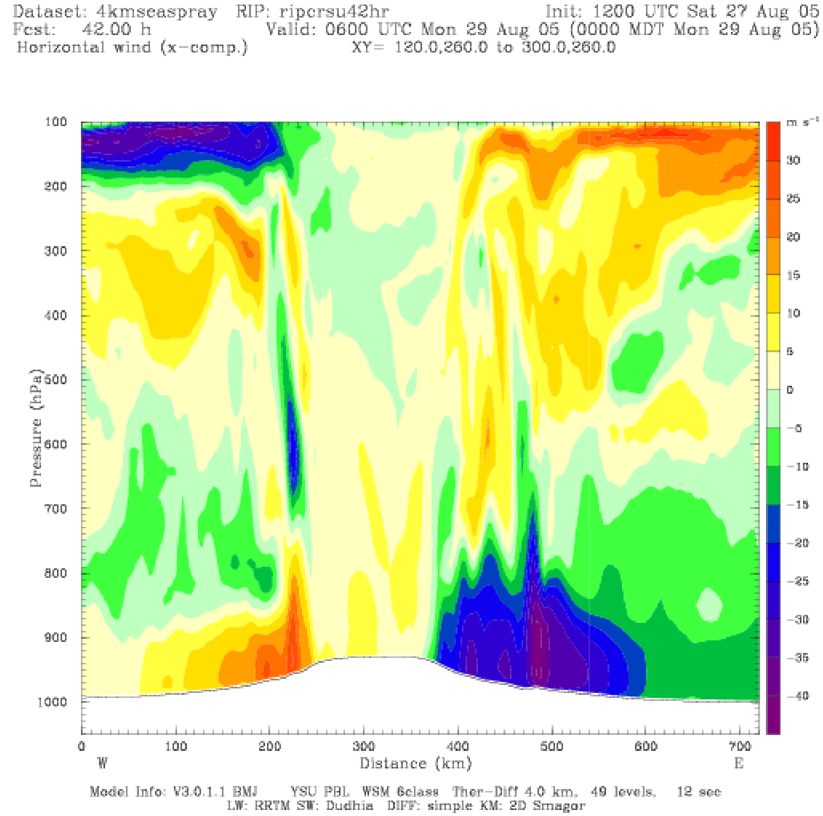
Reflectivity and Surface Winds at Hour 42



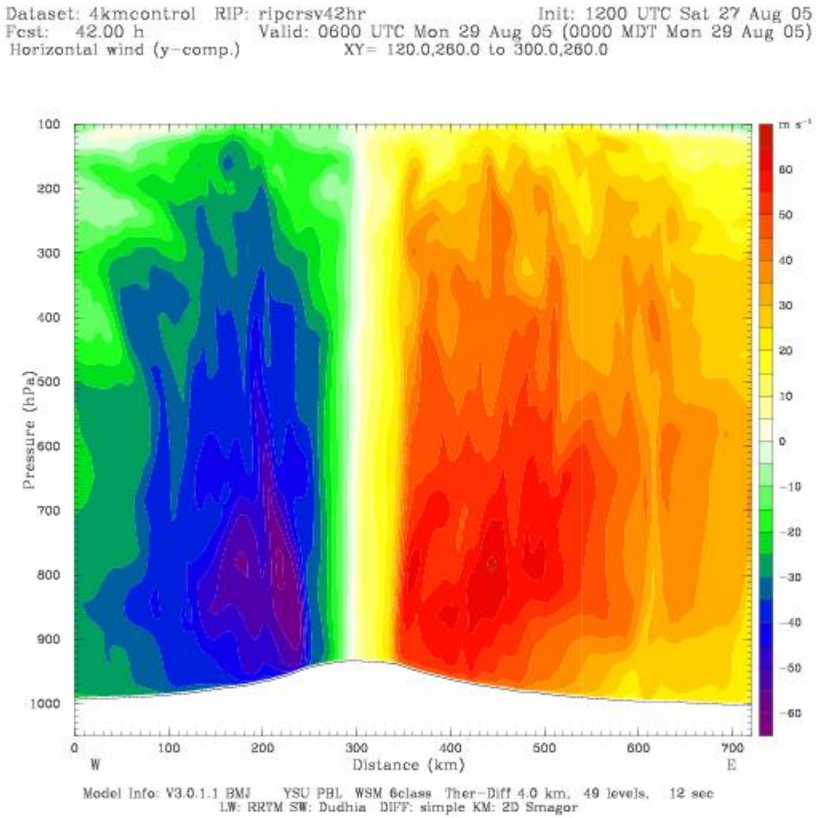


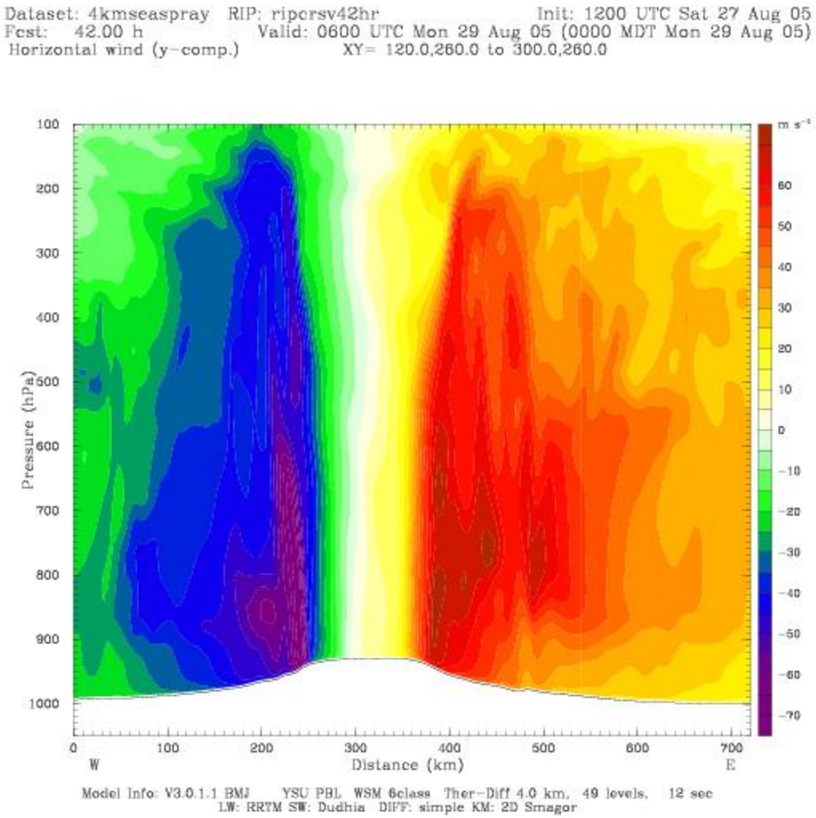
Radial-Component of the Wind at Hour 42



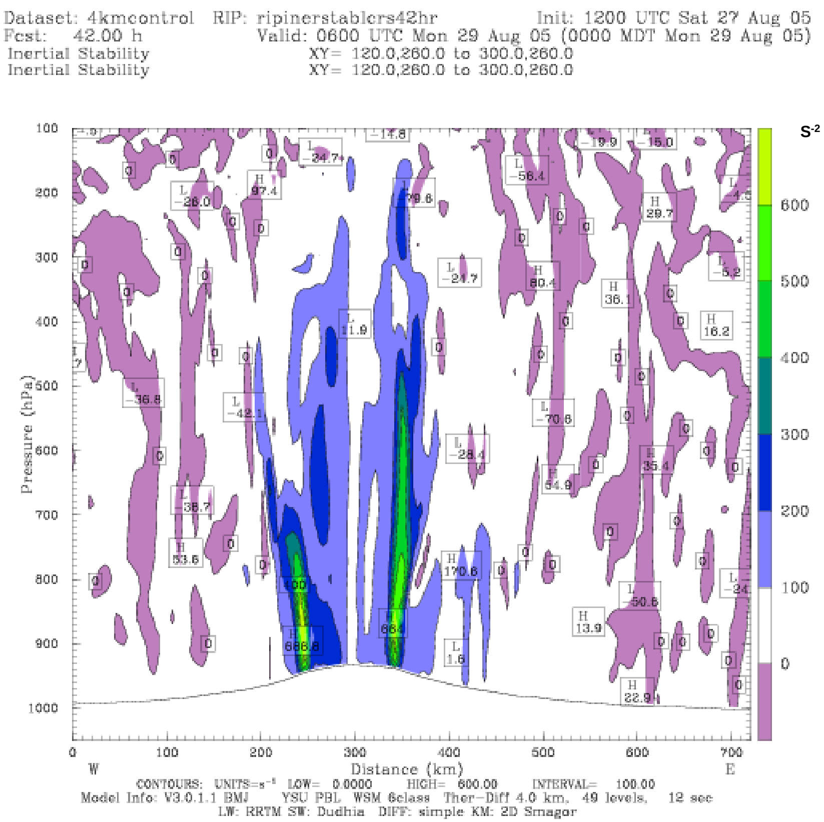


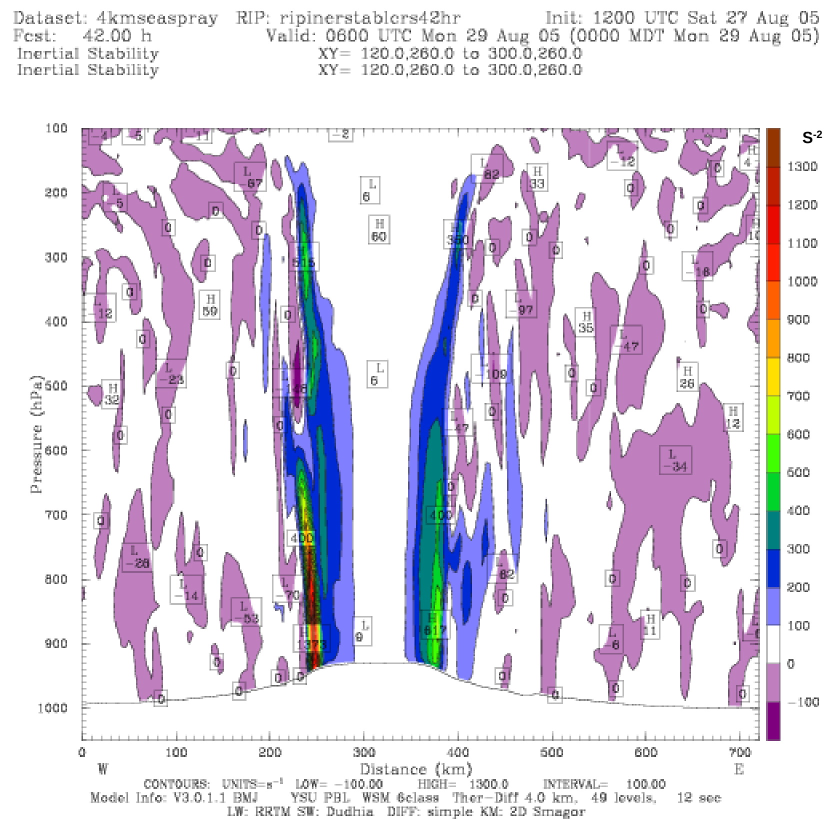
Tangential-Component of the Wind at Hour 42



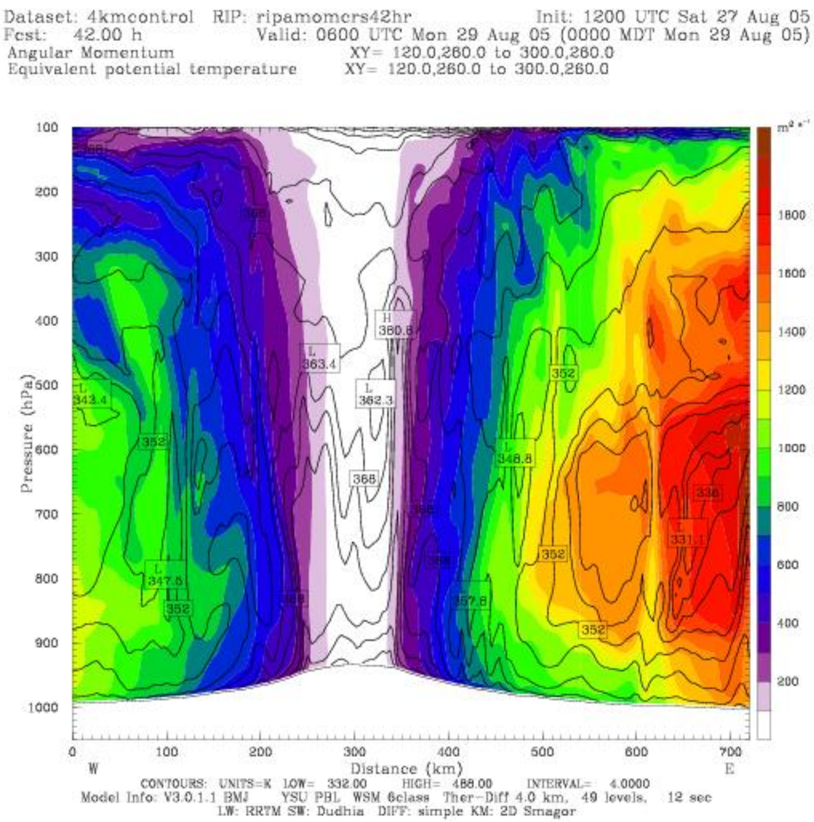


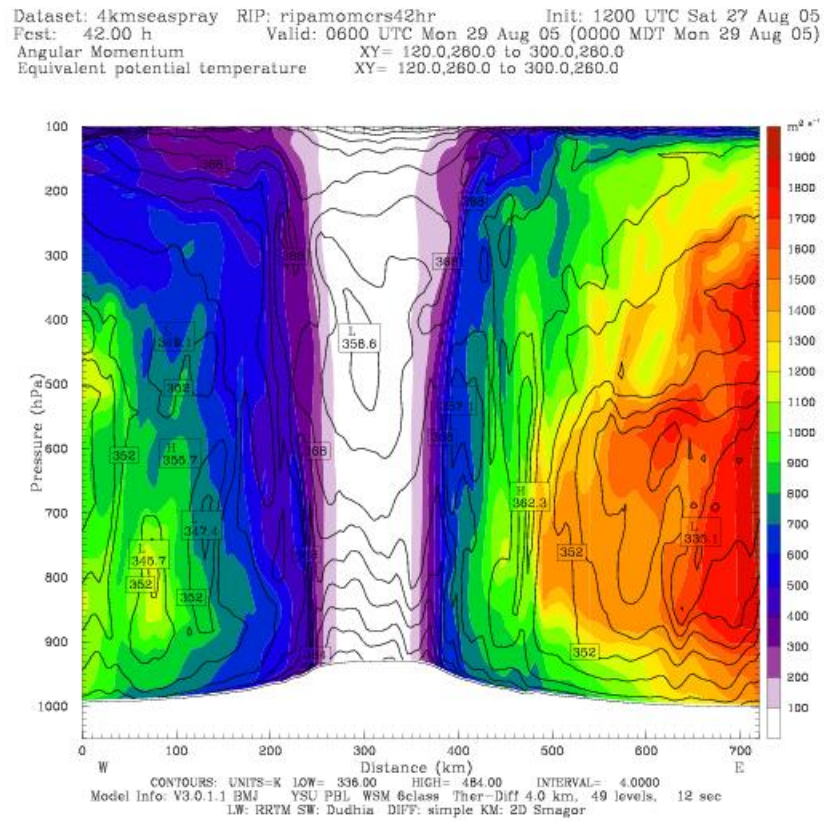
Inertial Stability at Hour 42 (Scaled by 10^8)





Angular Momentum and θ_e at Hour 42 (Scaled by 10^{-5})





Preliminary Conclusions

- Sea spray increases enthalpy flux, but reduces momentum flux.
- Sea spray tends to enlarge the size of storm eyewall in ARW, but not in HWRF.
- Sea spray leads to a stronger PV ring due to the enhanced heating as the storm intensifies.
- Sea spray results in smaller (greater) inertial stability inside (outside) the eye of the storm.
- Sea spray effects can also be seen in the angular momentum and equivalent potential temperature fields above the atmospheric boundary layer.