Improving HWRF's Ability to Predict Rapid Change in Tropical Cyclone Intensity Governed by Internal Physical Processes

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Milestones last year

- Importance of radial transport and distribution of solid-phase hydrometeors to TC intensification and inner-core structure change including secondary eyewall formation (SEF) and eyewall replacement cycle (ERC).

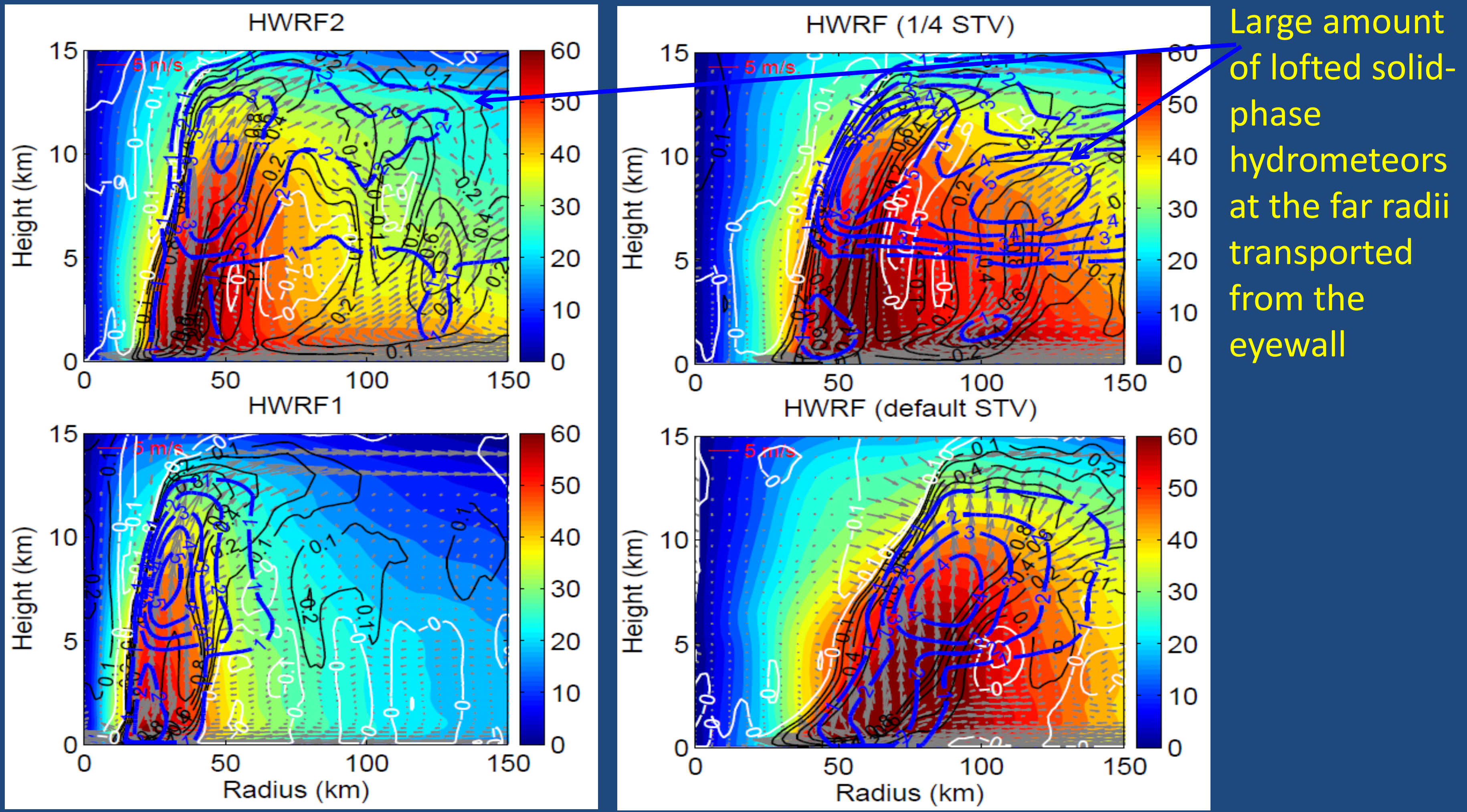
- Importance of in-cloud turbulent mixing to rapid intensification (RI) of TCs.

Key Result 1: A ‘top-down’ pathway to SEF

HWRF idealized simulations

HWRF1: operational physics.
HWRF2: RRTM/Dudhia, Thompson, KF

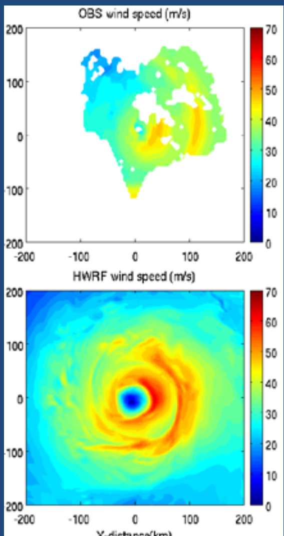
Sensitivity experiments on snow terminal velocity (STV)



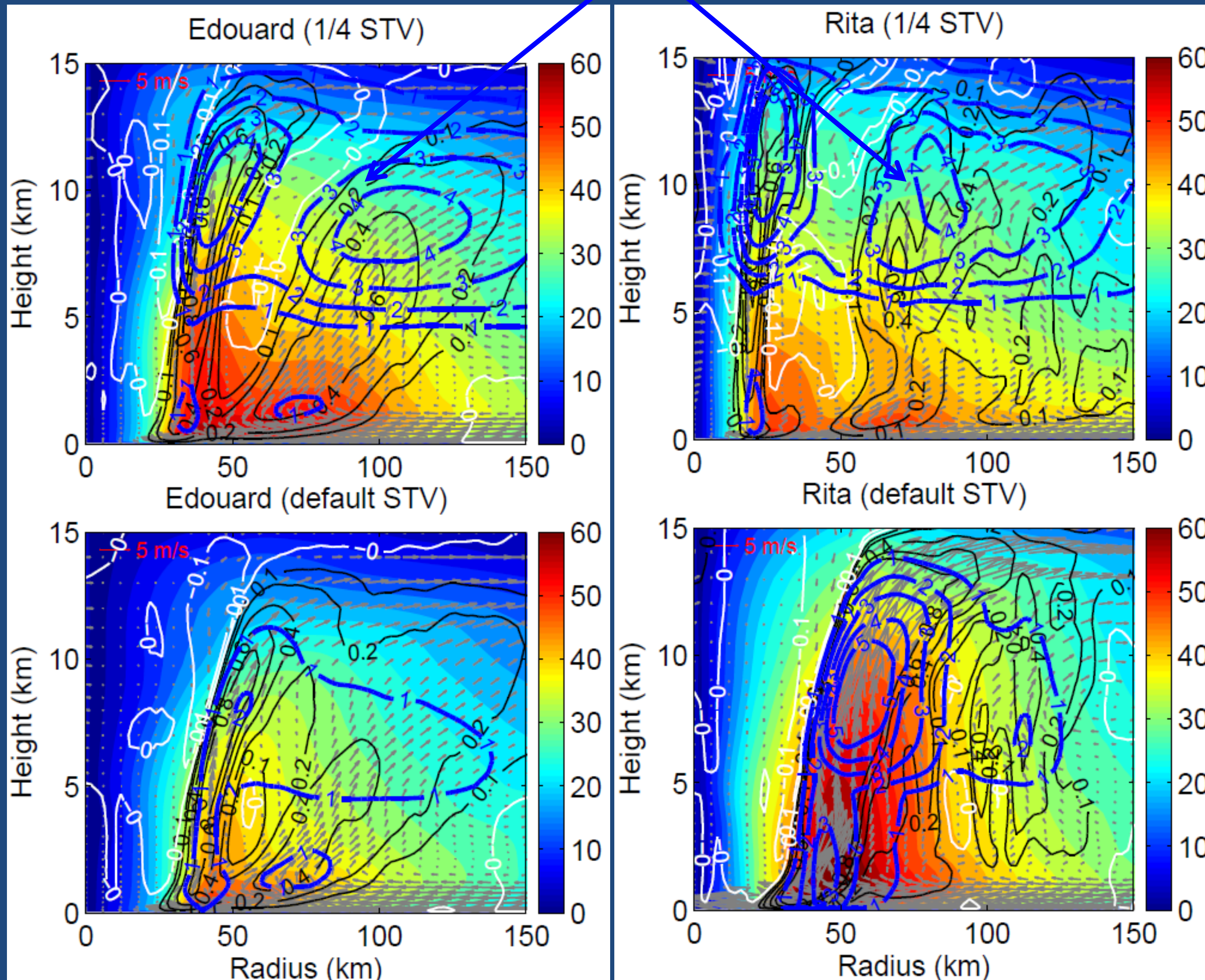
Azimuthal-mean tangential wind speed (color shades, ms^{-1}), hydrometeor (g/kg, blue contours), updrafts (black, ms^{-1}), downdrafts (white, ms^{-1})

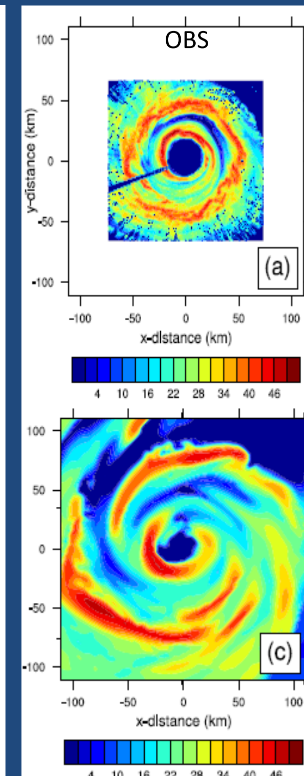
HWRF real case simulations

Large amount of lofted solid-phase hydrometeors at the far radii transported from the eyewall



Observed and Simulated 3-km wind speed at 17:20 UTC 16 Sept., 2014

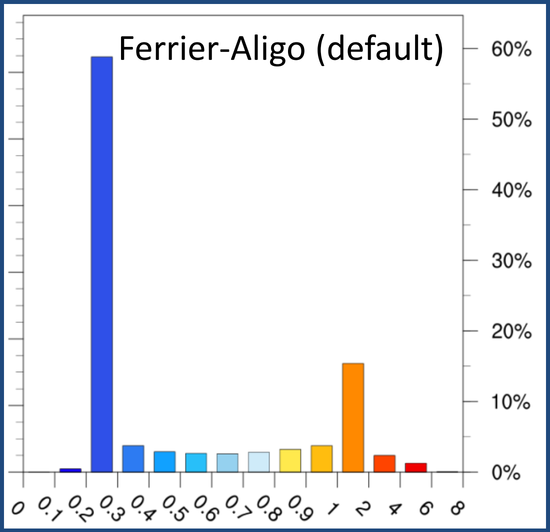


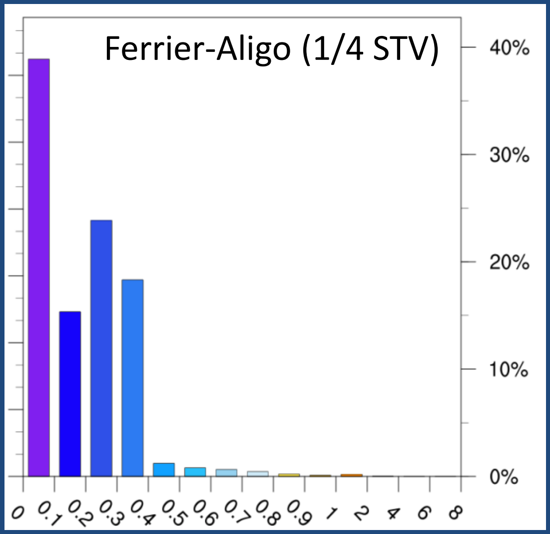


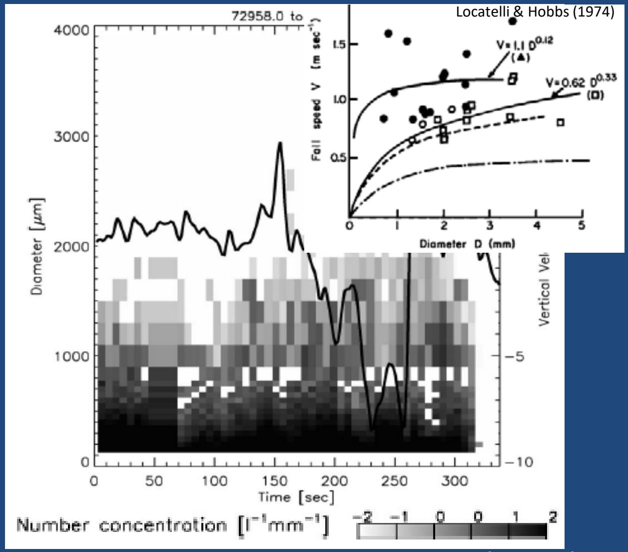
Observed and Simulated 4-km reflectivity (dBz) at 18:00 UTC 22 Sept., 2005

Azimuthal-mean tangential wind speed (color shades, ms^{-1}), hydrometeor (g/kg, blue contours), updrafts (black, ms^{-1}), downdrafts (white, ms^{-1})

Fall velocity from Rita simulations







McFarquhar & Black (2004)

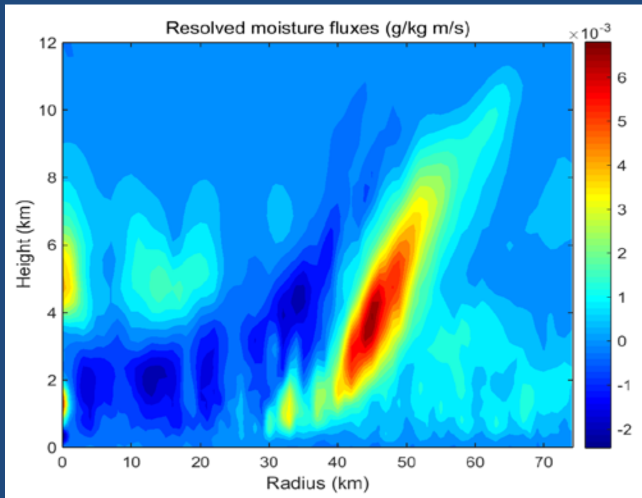
Ferrier-Aligo scheme does not produce the small, light solid-phase hydrometeors that are capable of being lofted and transported from the eyewall to outer radii.

Conclusion 1

There exists a “**top-down**” pathway to SEF triggered by the penetrative downdraft resulting from the fall-out of lofted solid-phase hydrometeors at the far radii from the primary eyewall.

Radial transport and distribution of solid-phase hydrometeors are shown to be one of the keys that can substantially affect the TC inner-core structure in HWRF simulations. Although the causing reason may vary from case to case, the incorrect radial transport of solid-phase hydrometeors and the resultant distribution are one of the culprits for HWRF not to simulate the observed SEF/ERC.

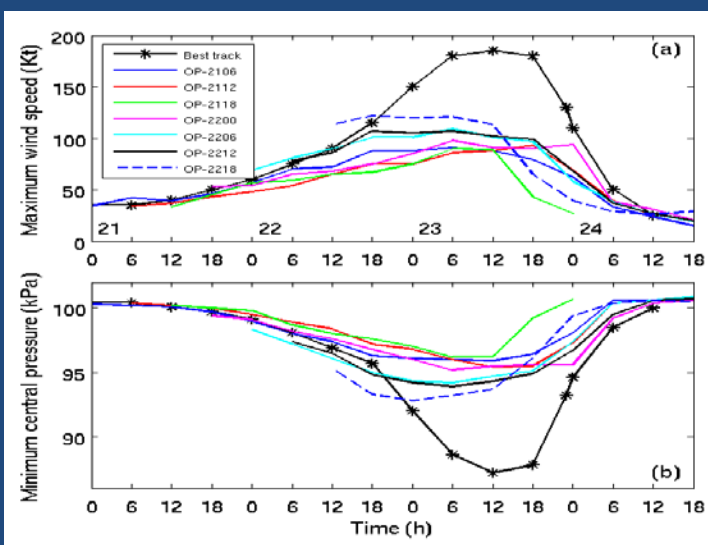
Key Result 2: Importance of in-cloud turbulent mixing to RI



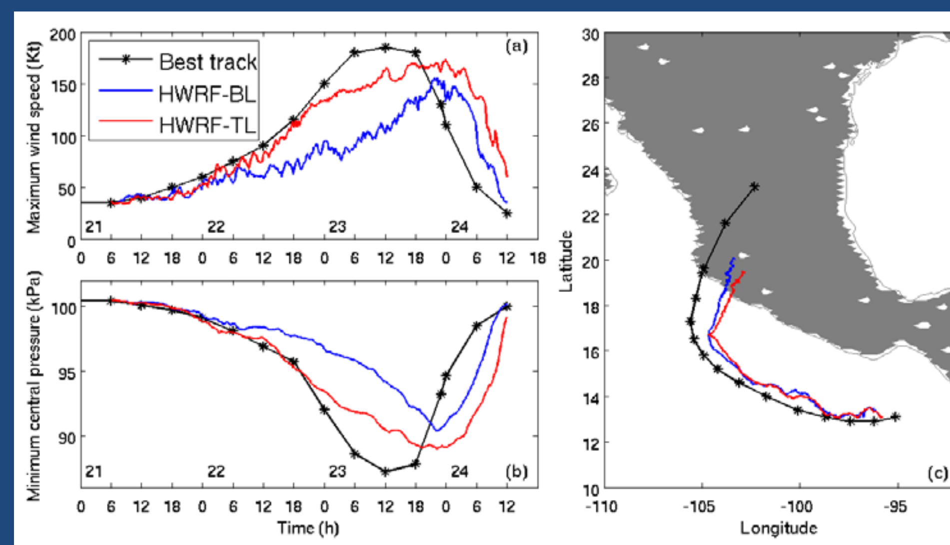
Azimuthal-mean resolved moisture fluxes from a Giga-LES of Isabel (2003)

1. In the eyewall and rainbands, there is no physical interface that separates the turbulence generated by the surface processes and cloud processes.

2. In HWRF, the turbulent mixing is parameterized separately by the diagnosed PBL height. Above the PBL, the eddy exchange coefficient is calculated by $K_m = l^2 f_m(Ri_g)\left|\frac{\partial U}{\partial z}\right|$, which was originally developed to represent the clear-sky free atmosphere diffusion.

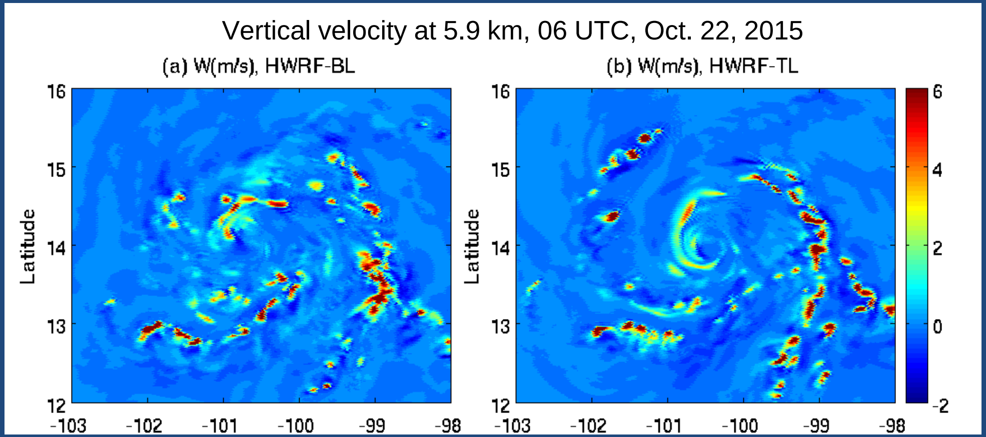


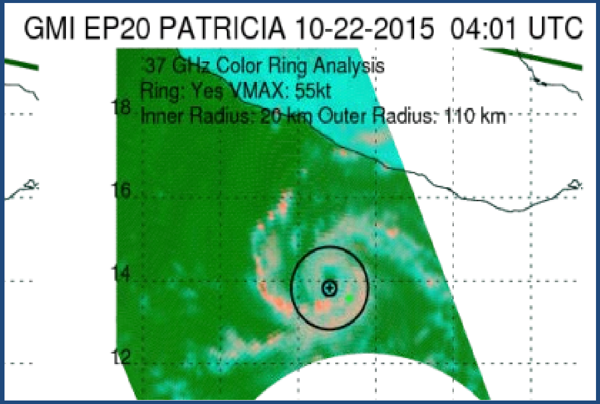
HWRF operational forecasts of Hurricane Patricia (2015)



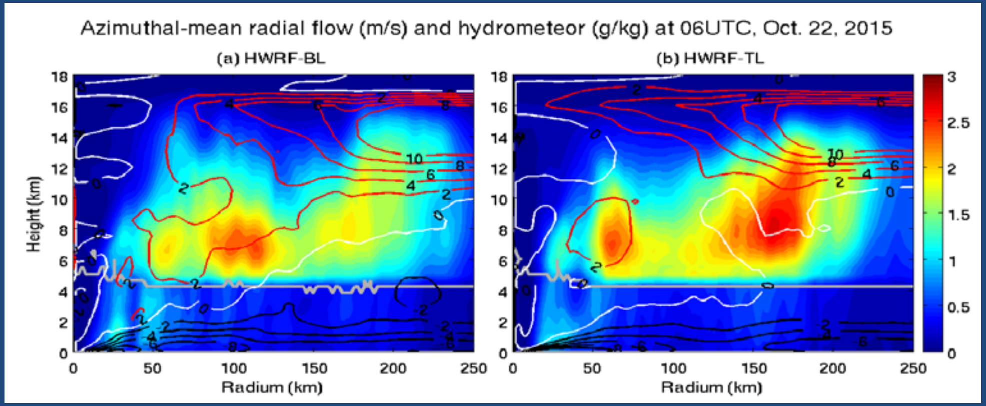
HWRF simulations using the integrated turbulent mixing scheme (red) and the default PBL scheme (blue)

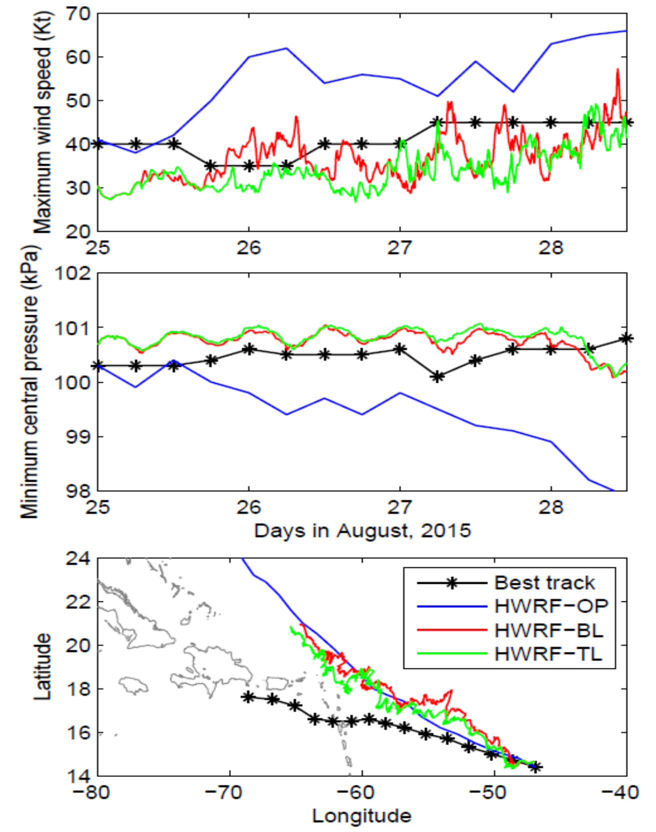
Importance of TC inner-core structure to RI

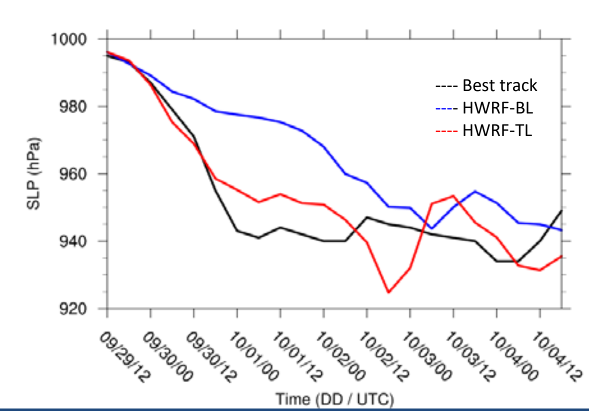


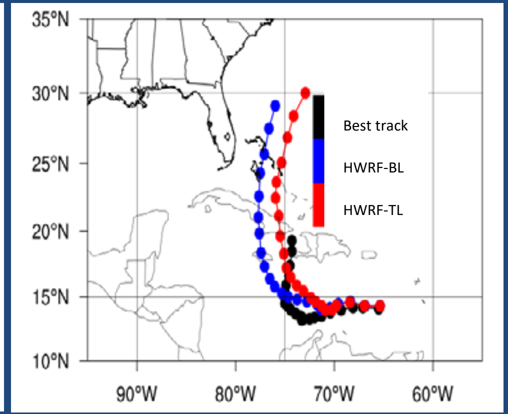


Courtesy of Dr. Haiyan Jiang





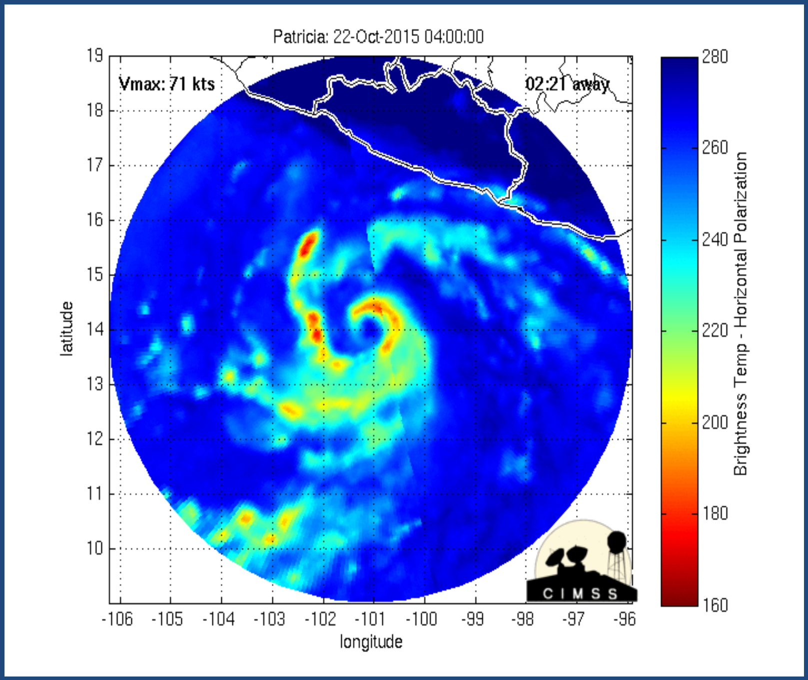


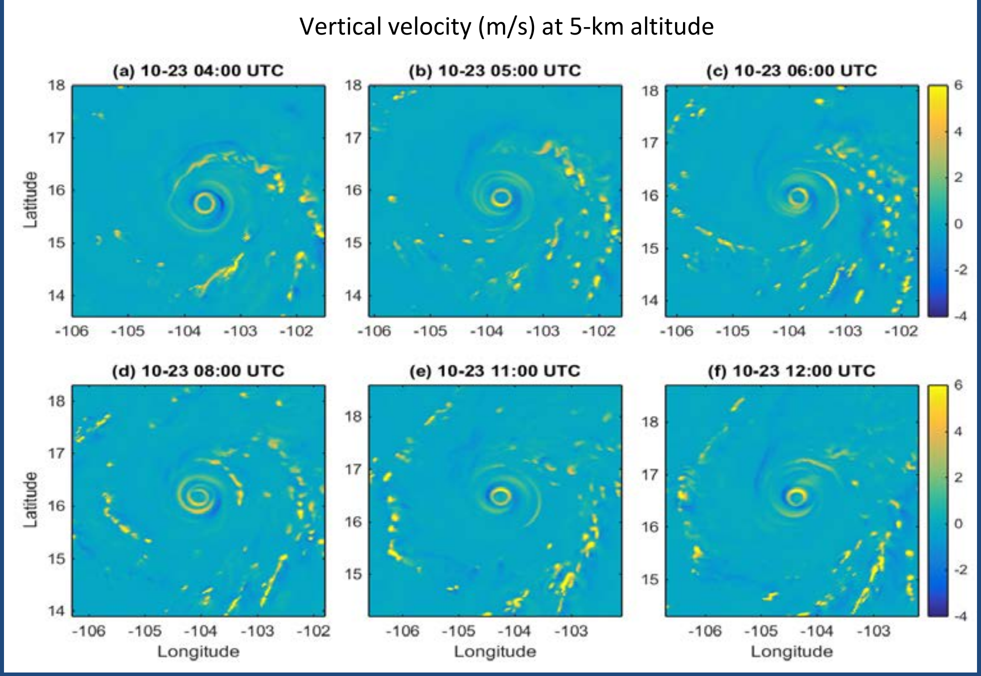


HWRF simulations of Hurricane Matthew (2016)

HWRF simulations of TS Erika (2015)

Importance of interaction between in-cloud turbulence and microphysics to TC inner-core structure





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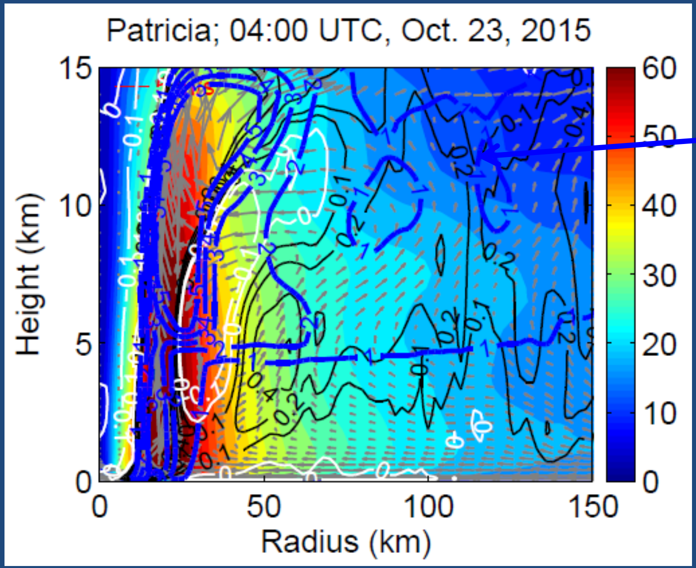

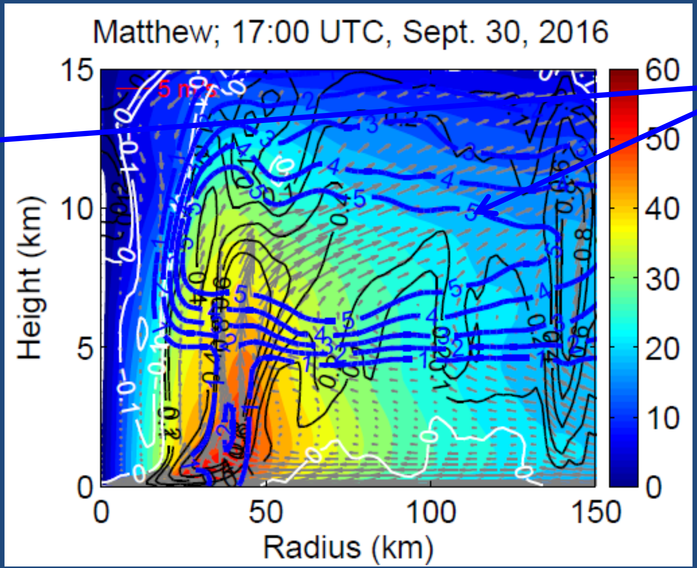

Large amount of lofted solid-phase hydrometeors at the far radii transported from the eyewall

Conclusion 2

Inappropriate parameterization of in-cloud turbulence generated by latent heating, radiative cooling, and evaporative cooling in the eyewall and rainbands appears to be one of the major problems of HWRF. Since in-cloud turbulent mixing is directly linked to microphysics, it can substantially affect the performance of microphysics and the radial transport/distribution of solid-phase hydrometeors, which is shown to be critical to TC inner-core structure change and intensification including RI.

Path forward/suggested priorities and milestones in 2017

- Refining the proposed integrated turbulent mixing scheme.
- Searching for better methods to parameterize in-cloud turbulence within the existing HWRF PBL parameterization framework.
- Improving HWRF simulation of radial transport and distribution of solid-phase hydrometeors.