Physics in Hurricane models

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Outline

- Goals of physics for hurricane models
- HWRF physics vs FV3GFS physics
- Physics schemes have been tested and investigated
- Summary

Our primary goal is to improve forecast performance through improvement in physics algorithms

- **We understand that there is no final recipe for physics developments because of numerous limitations and associated problems. As such, better track and intensity skill for storms remains our first priority.**

- **Improvements in basic storm structure are also important including the merits of accurate physical representation of dynamics.**

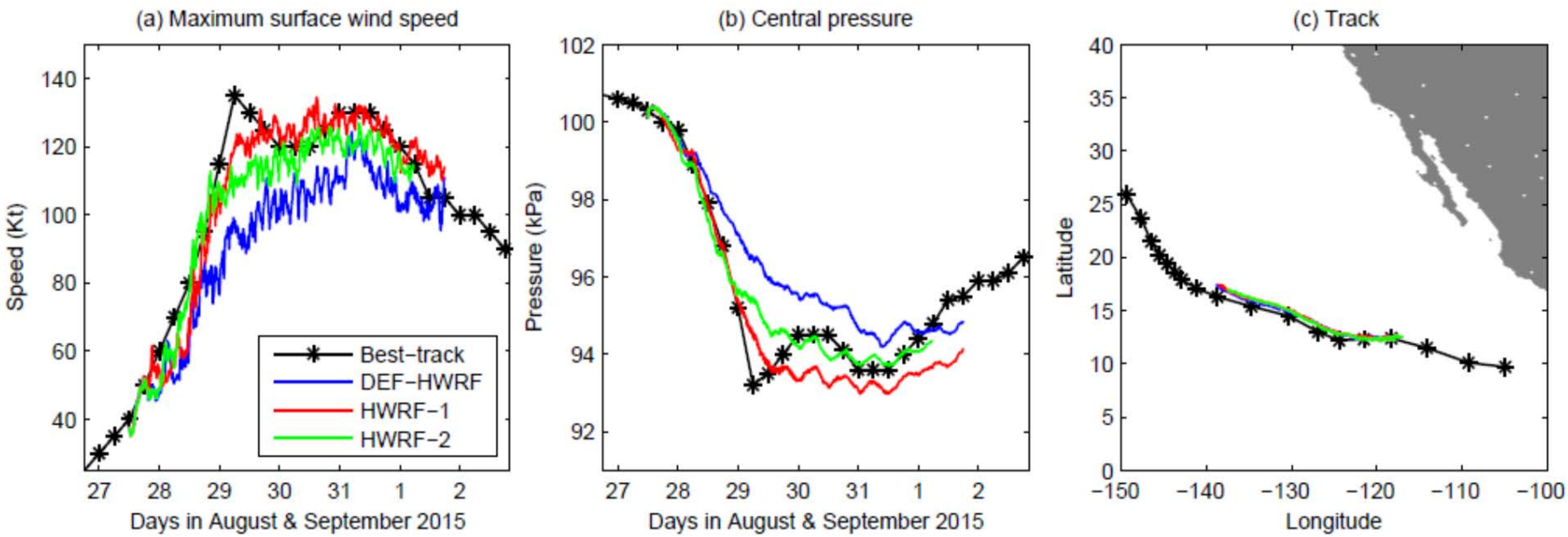
- **Since hurricane models are "driven" by global (FV3GFS) model, maintaining consistency and/or diversity with FV3GFS physics is another consideration.**

H218 and FV3GFS physics schemes

Physics \ Models	H218	FV3GFS
Microphysics scheme	Ferrier-Aligo	GFDL Microphysics
PBL scheme	GFS K profile-EDMF	K-profile EDMF
Convection scheme	Scale-aware SAS	Deep: Scale-aware SAS Shallow: Scale-aware MF
Radiation scheme	RRTMG	RRTMG
Land scheme	Noah	Noah

Items in red are differences between H218 and FV3GFS.

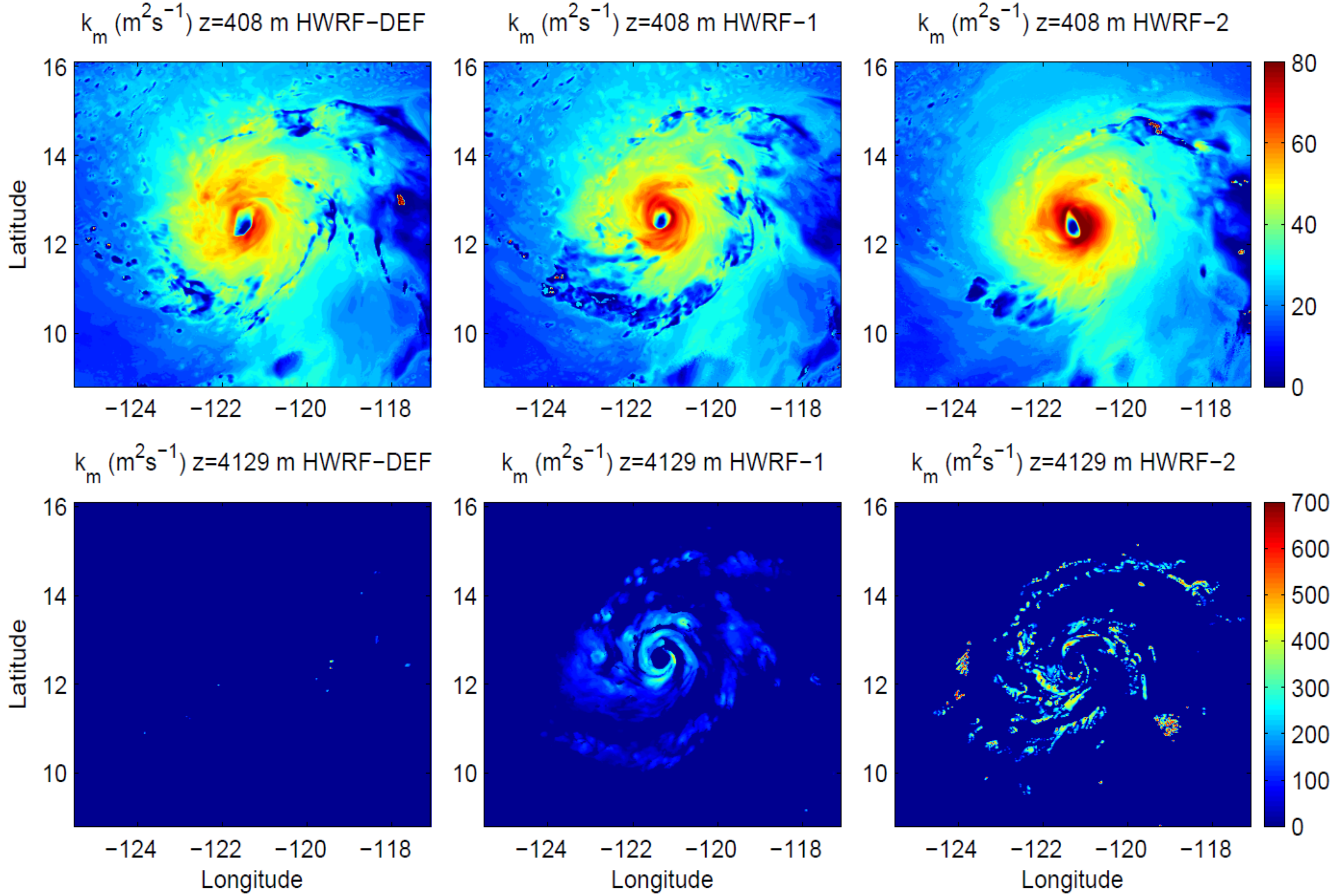
GFS-EDMF Improved in-cloud turbulent mixing parameterization



HWRF-1: parameterization of in-cloud turbulent mixing based on the TL concept
HWRF-2: parameterization of in-cloud turbulent mixing by recalculating N^2 in clouds

by Ping Zhu

GFS-EDMF Improved in-cloud turbulent mixing parameterization



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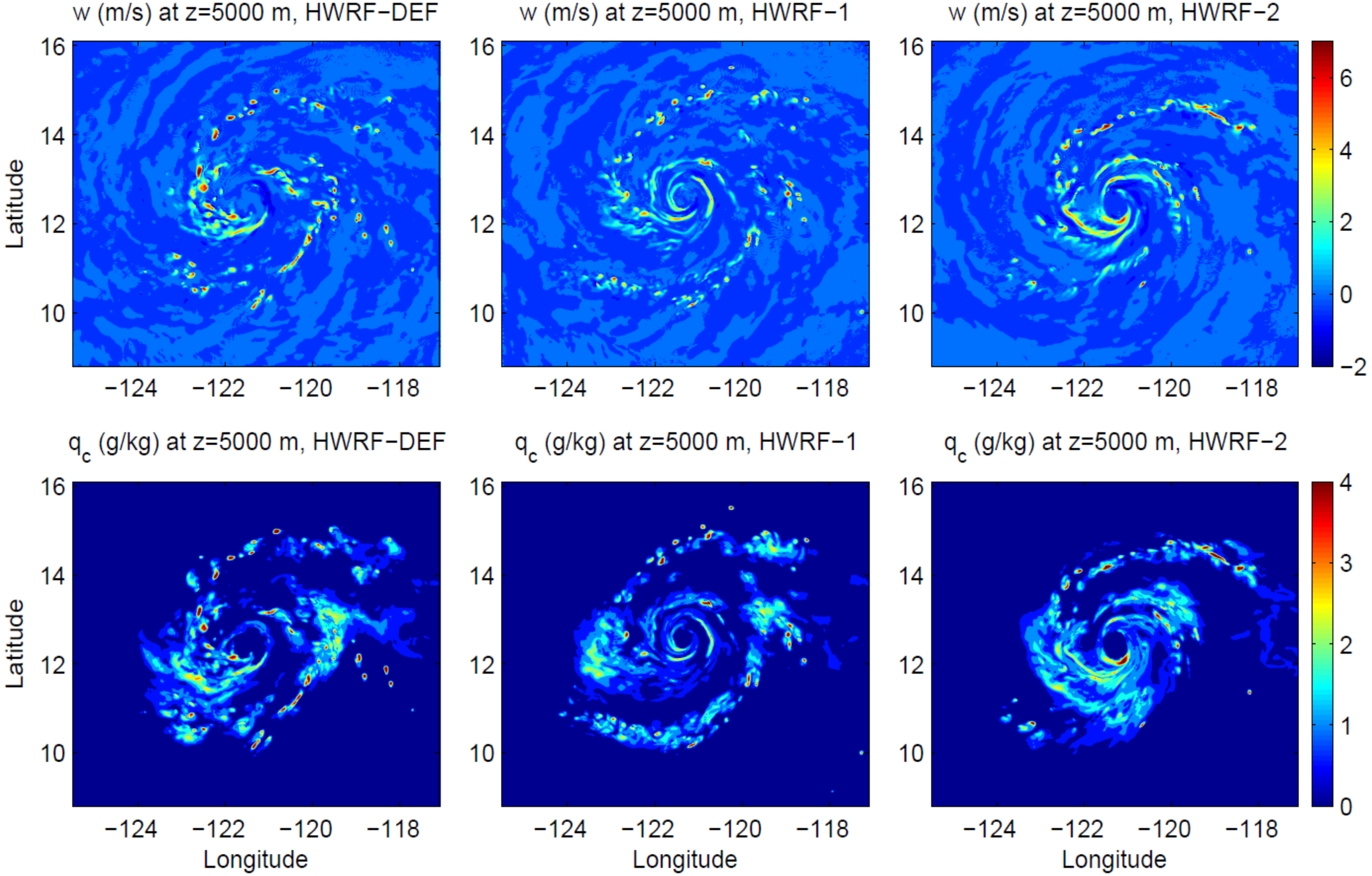
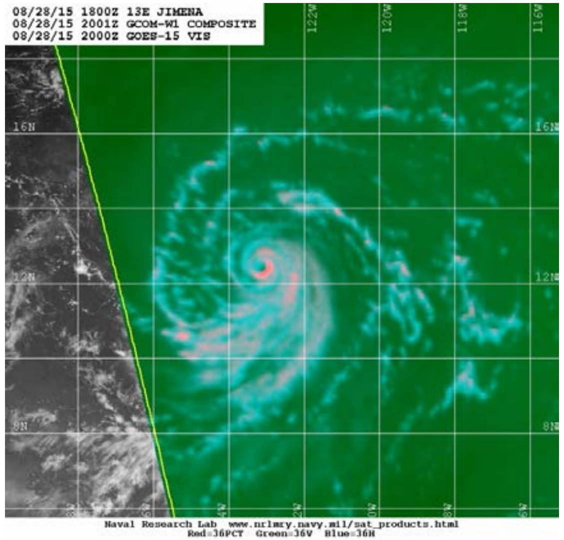
Eddy exchange coefficients of Hurricane Jimena at 12:00 UTC, 28 August, 2015

GFS-EDMF Improved in-cloud turbulent mixing parameterization

20:00 UTC August 28, 2015



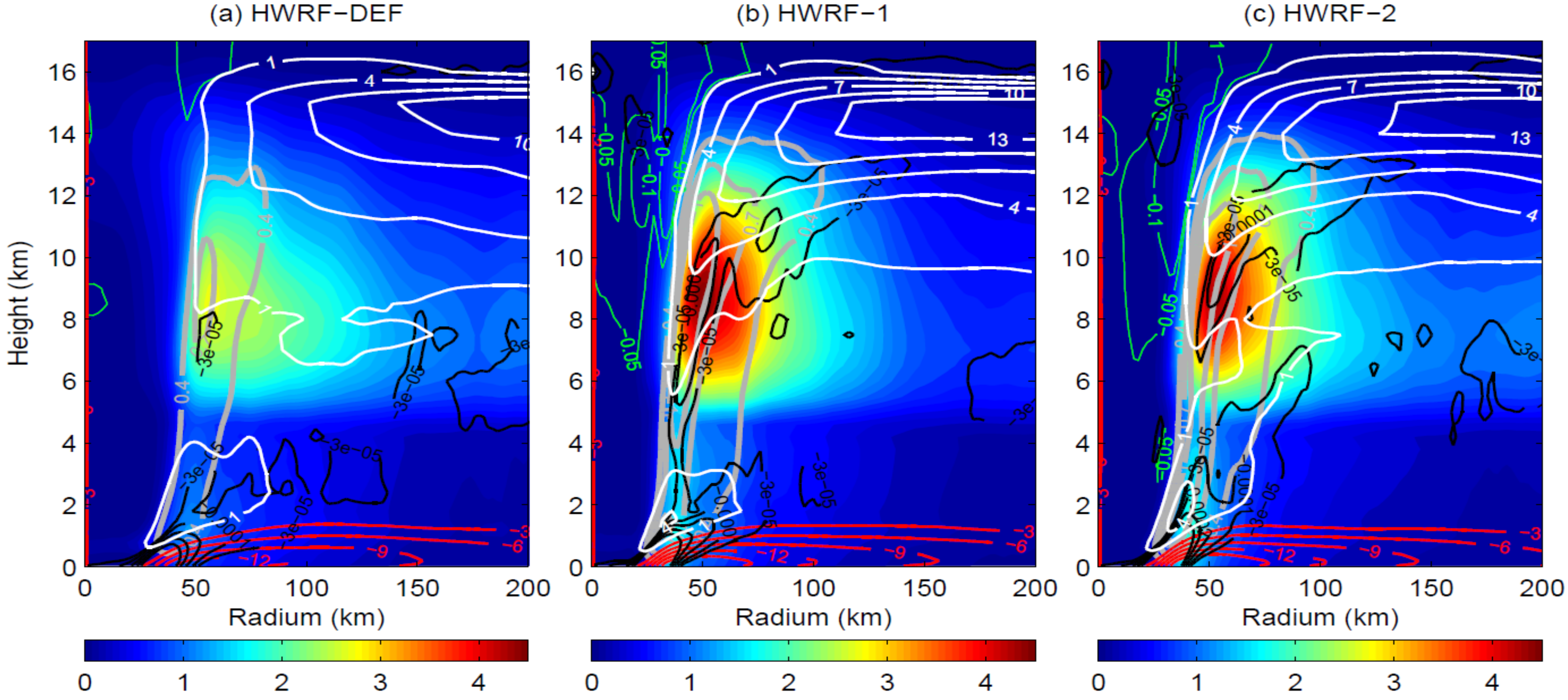


by Ping Zhu

Comparison of TC inner-core structure of Jimena (2015) between satellite observations and three HWRF simulations right before Jimena's RI.

GFS-EDMF Improved in-cloud turbulent mixing parameterization

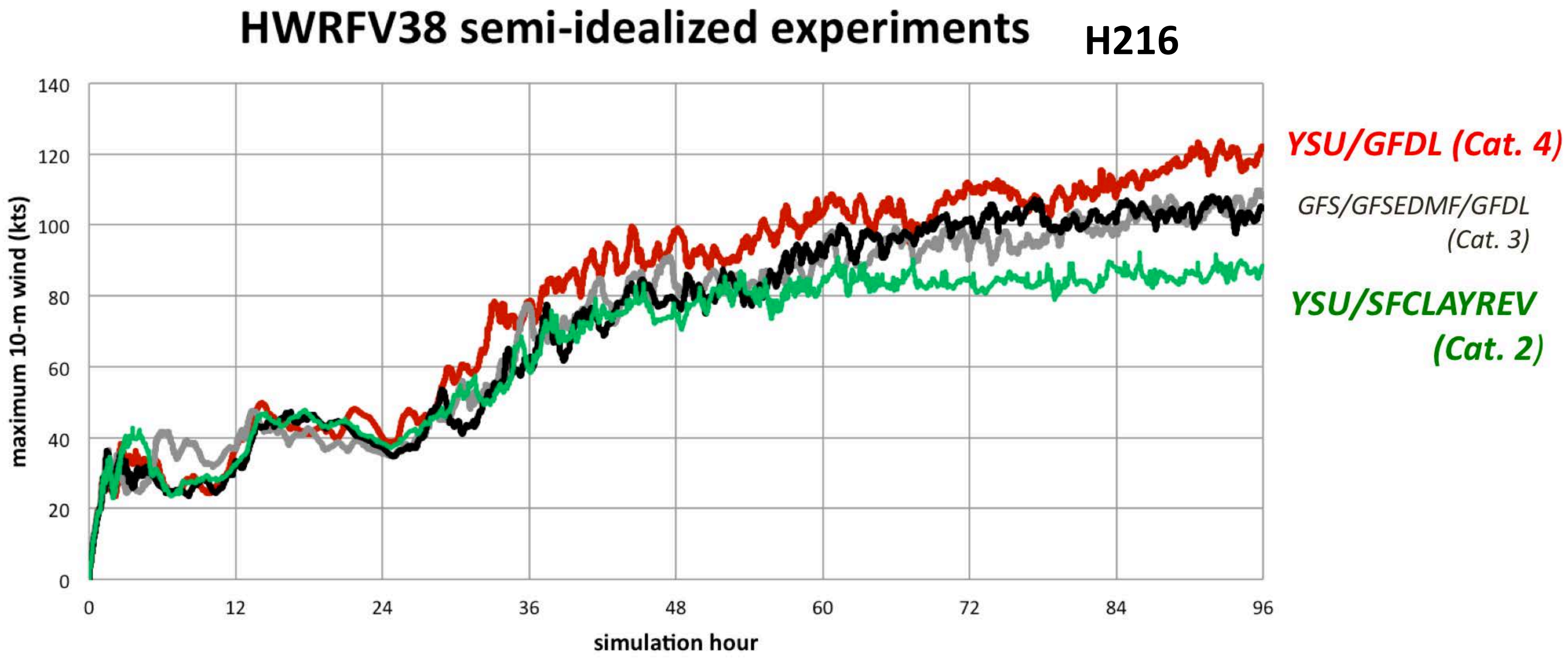
Azimuthal-mean radius-height structure of Jimena (2015) simulated by HWRFs averaged over the RI period from 12:00 UTC 08/28 to 06 UTC 08/29, 2015.



Hydrometeor mixing ratio (color shades), updrafts (gray contours), downdraft (green contours), radial inflow (red contours), radial outflow (white contours), and convergence of radial flow (black contours)

by Ping Zhu

YSU



GFS-non-local scheme

Too much mixing

Too deep and weak inflow layer

Fixed with

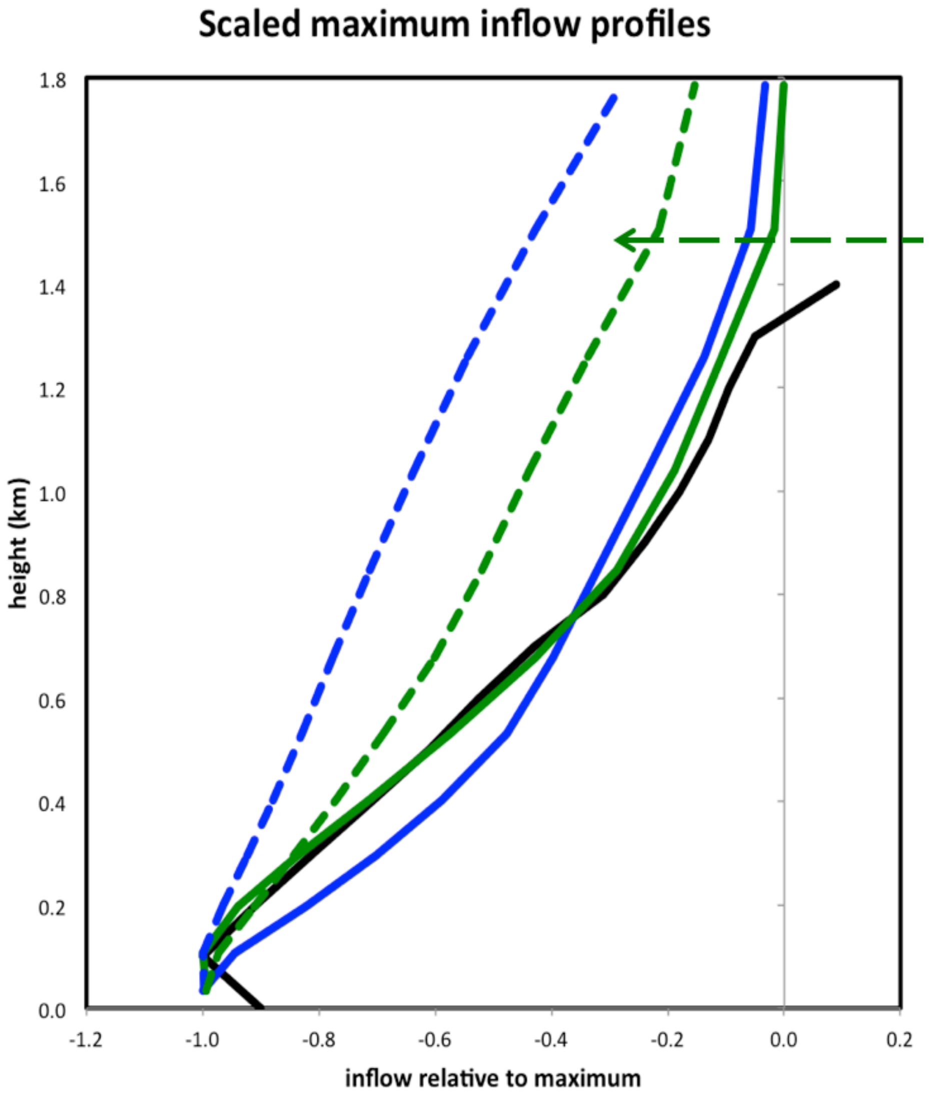
PBL height as a function of Rossby number (derived for stable PBL)

$\alpha < 1$ parameter (*ad hoc* modification)

YSU, includes cloud-top entrainment

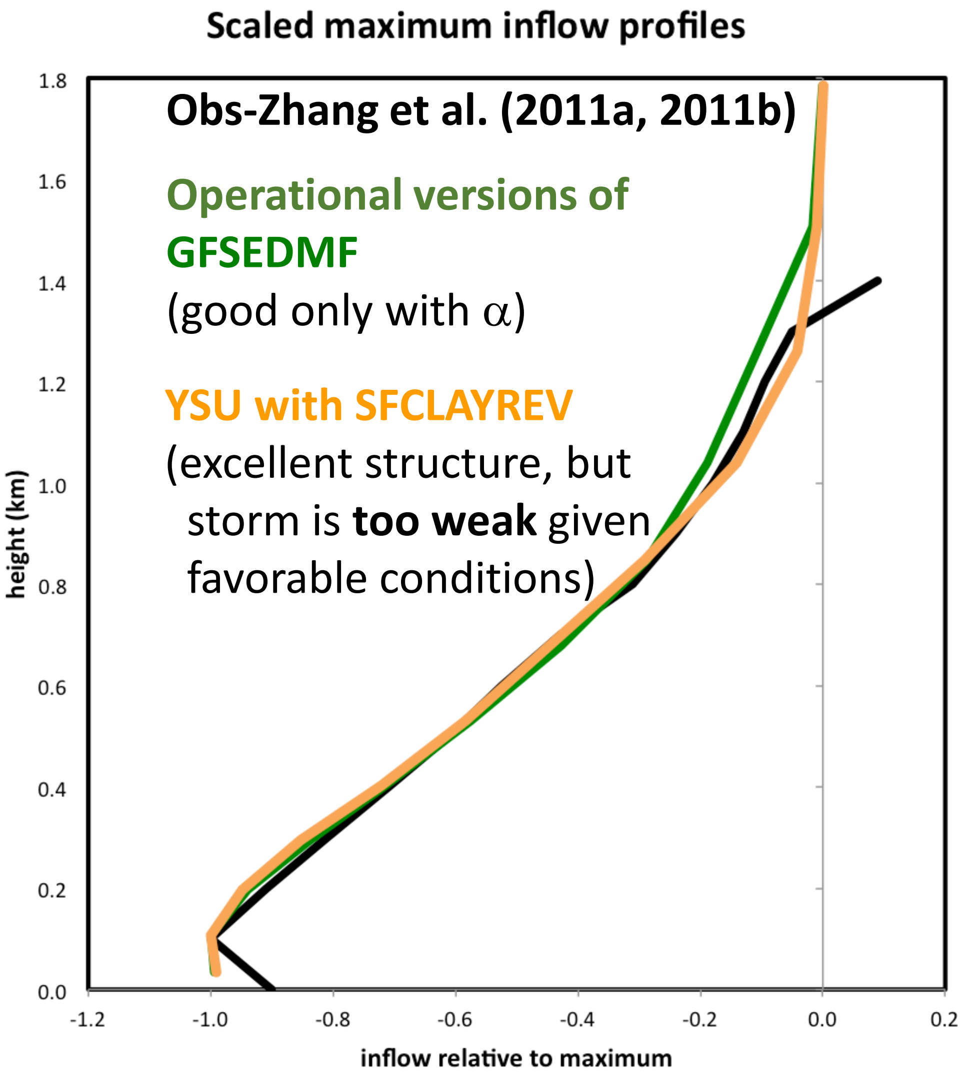
by Robert Fovell

YSU

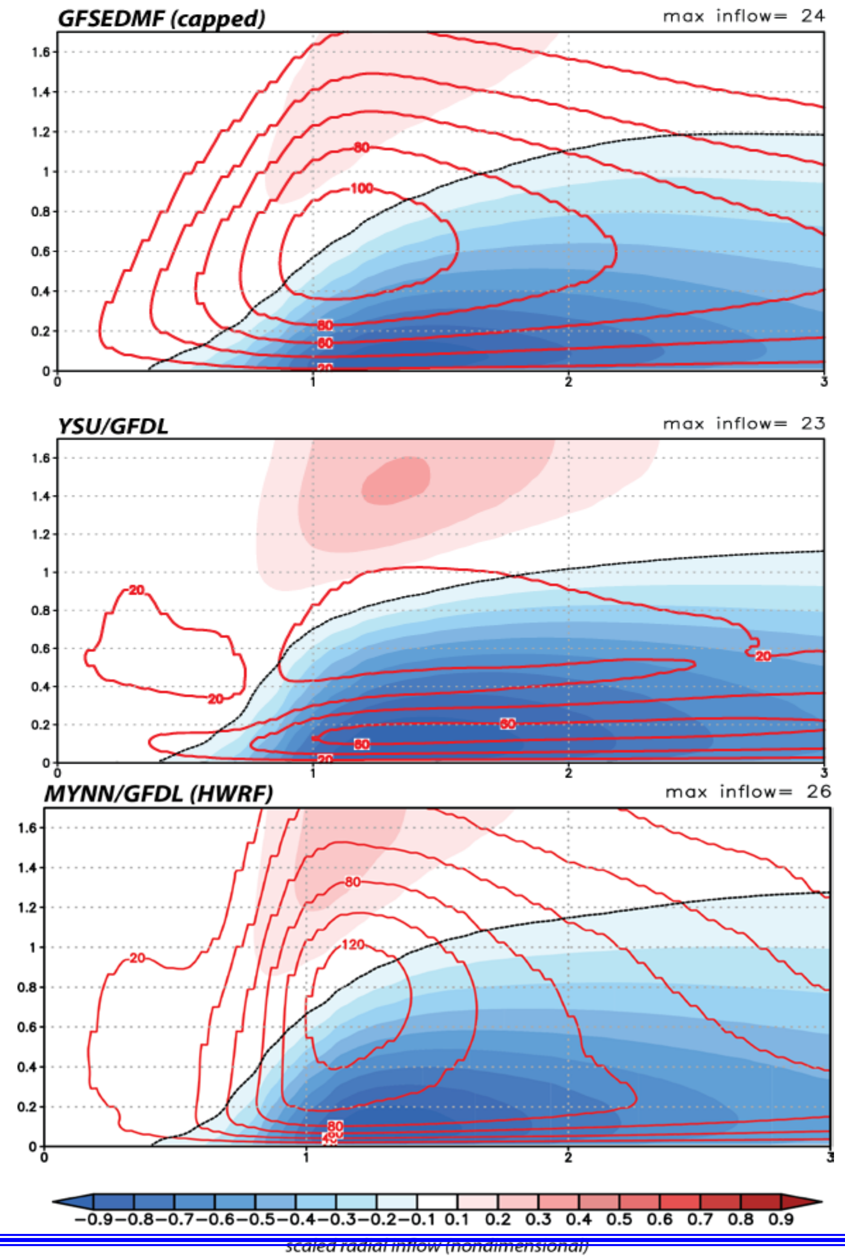


GFS/GFSEDMF *without*
α adjustment

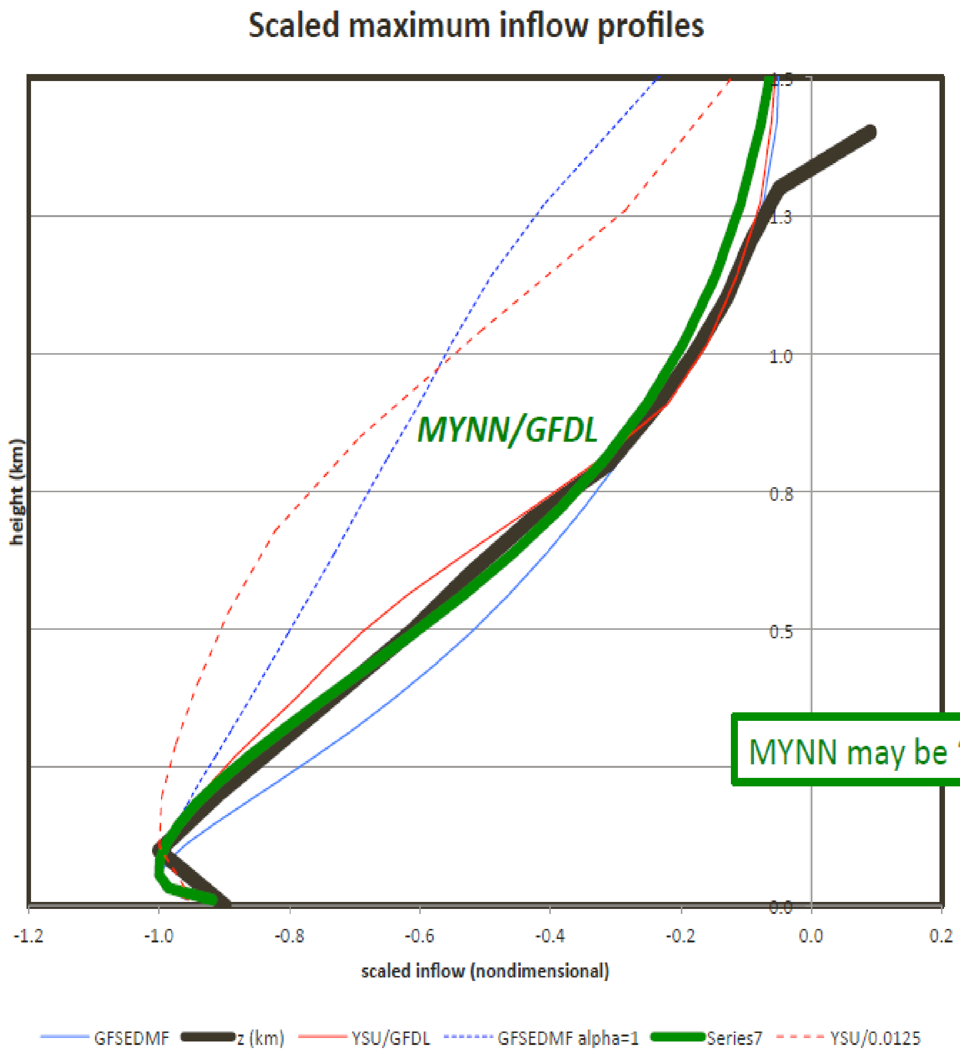
- too diffusive, far too deep, too little shear



MYNN (TKE based parameterization)



- Scaled inflow (shaded)
- Eddy mixing (contoured)

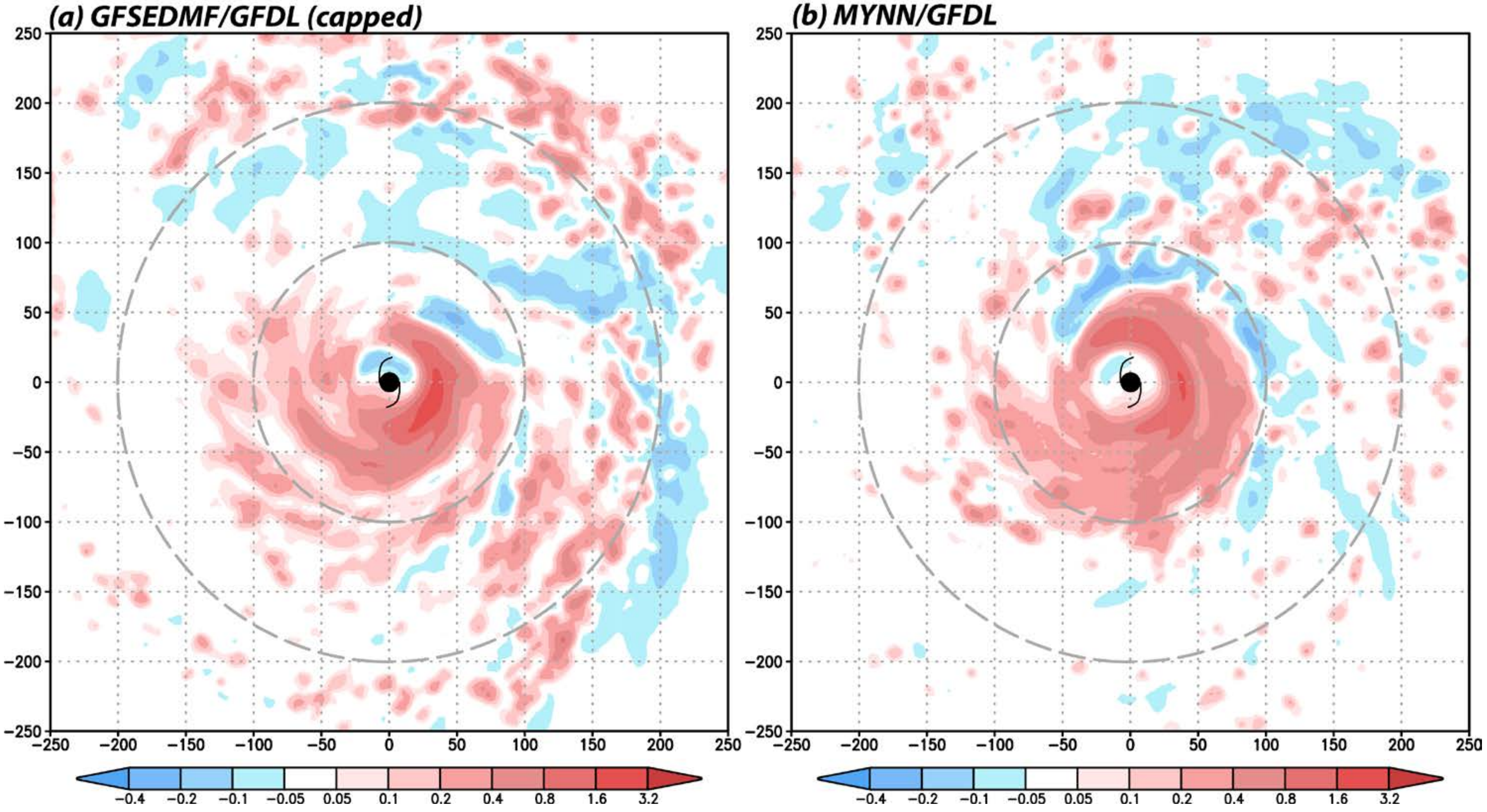


MYNN may be "less wrong"

By Robert Fovell

MYNN (TKE based parameterization)

vertical velocity at 500 mb



- GFSEDMF shows more peripheral convective activity

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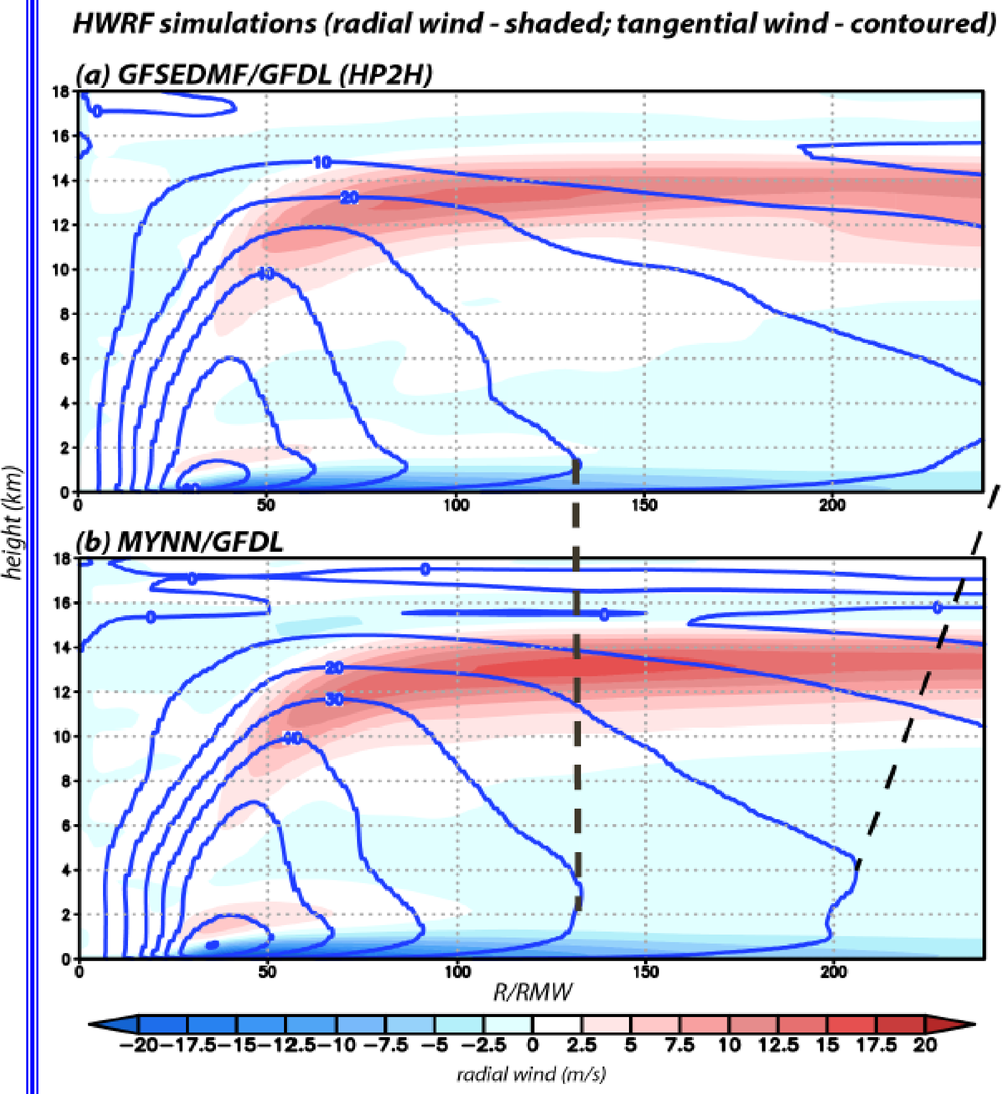
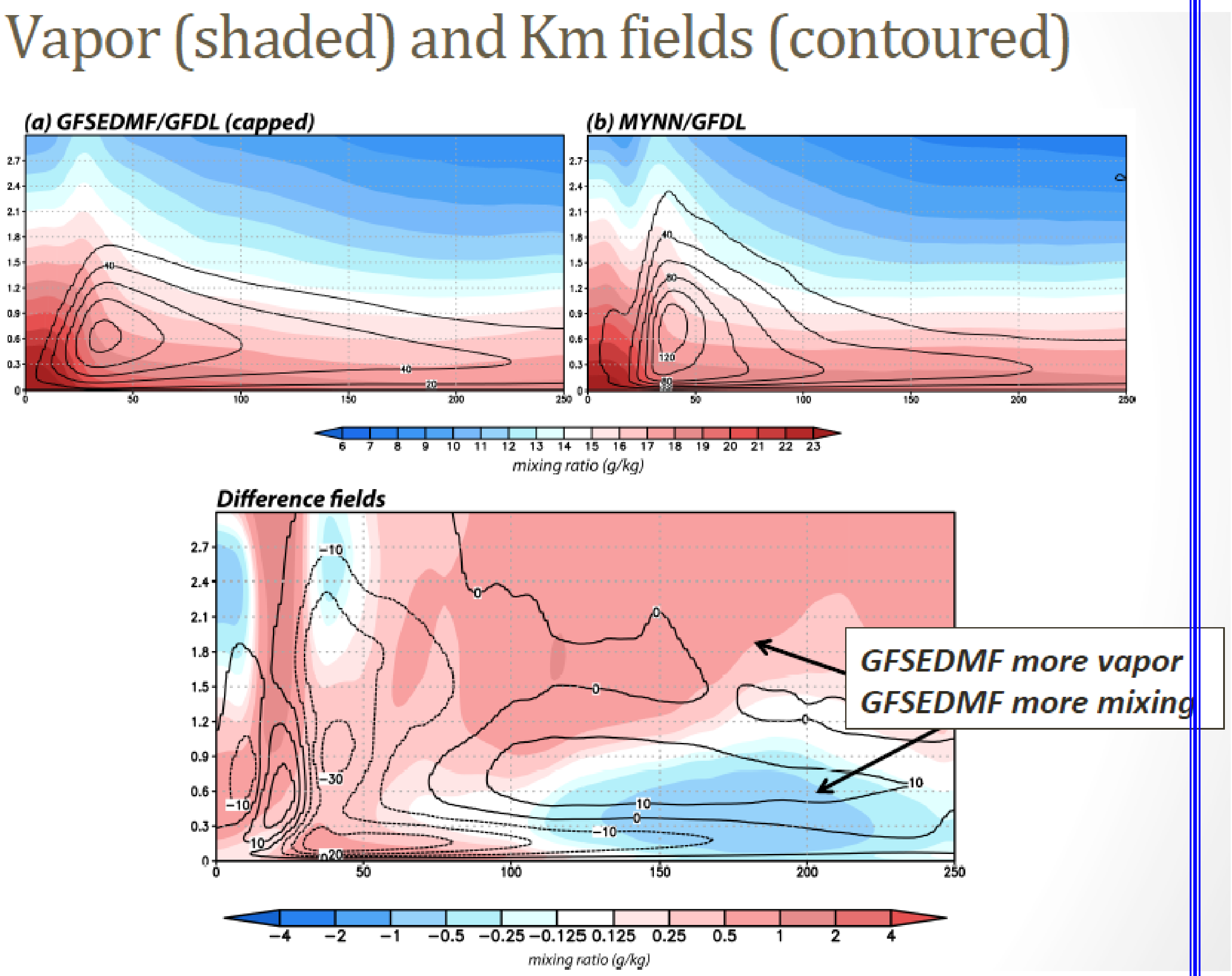
MYNN (TKE based parameterization)





- MYNN not as wide above surface at outer radii

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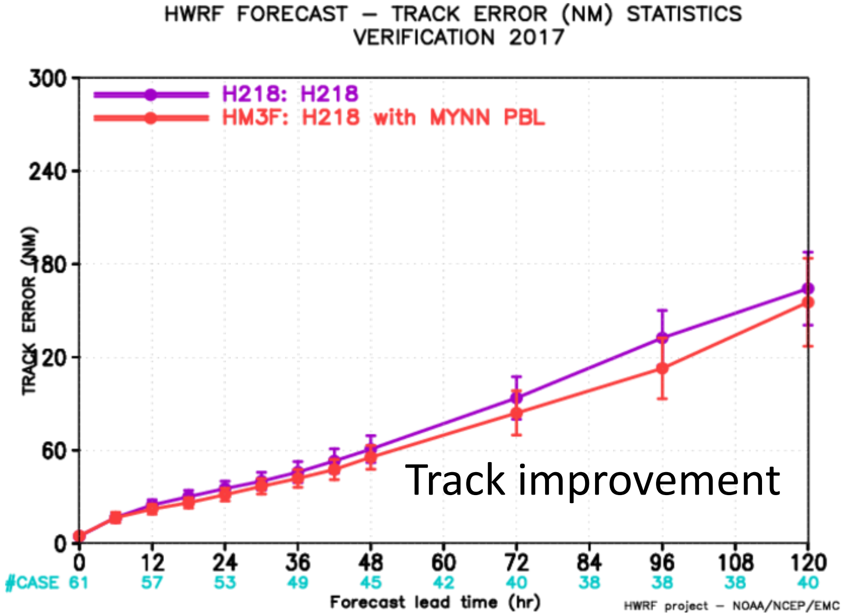
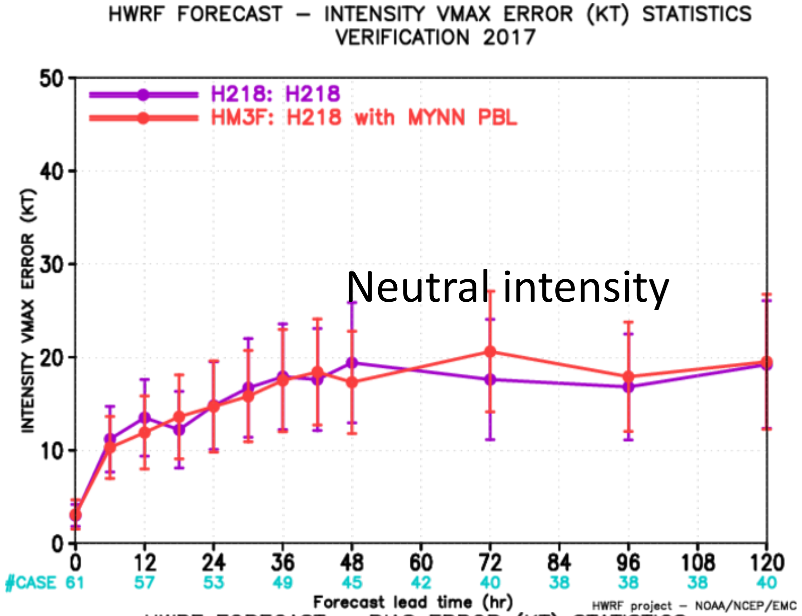
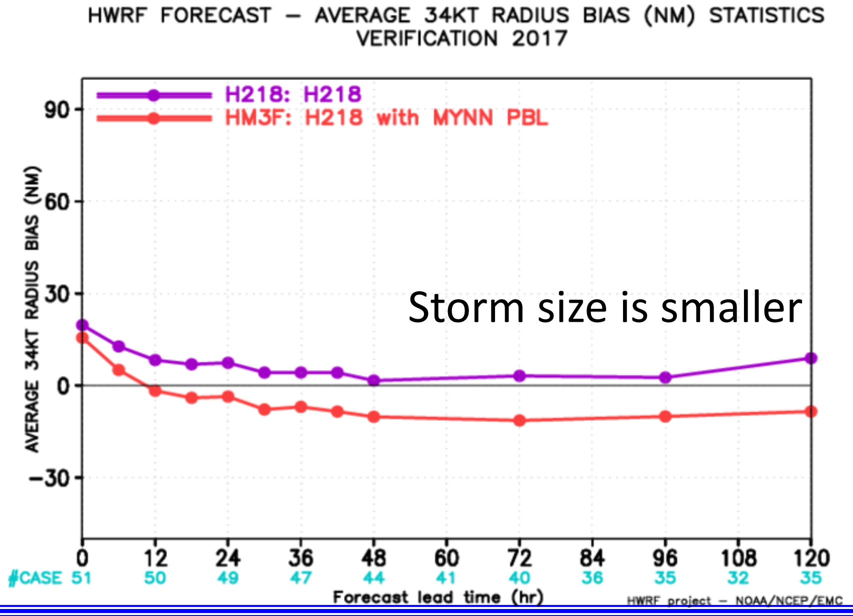
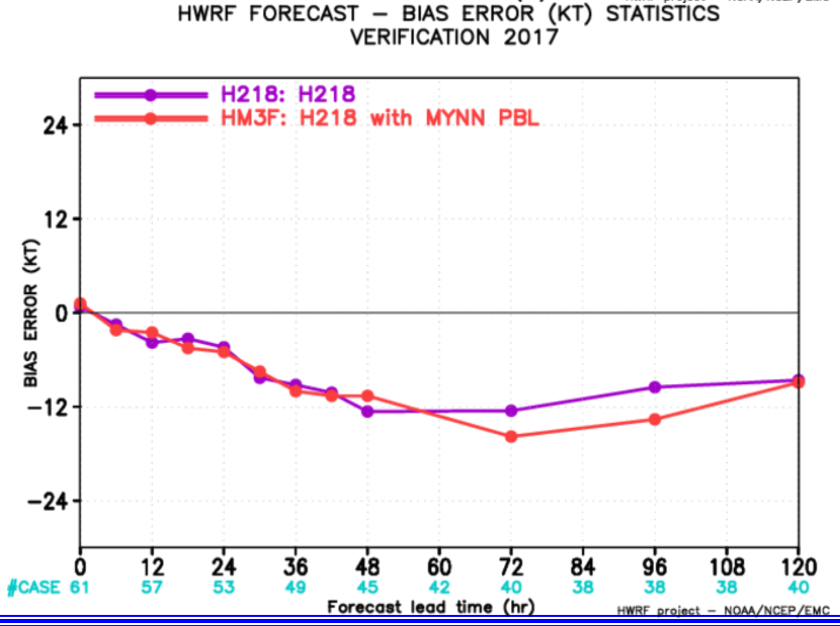
MYNN (TKE based parameterization)

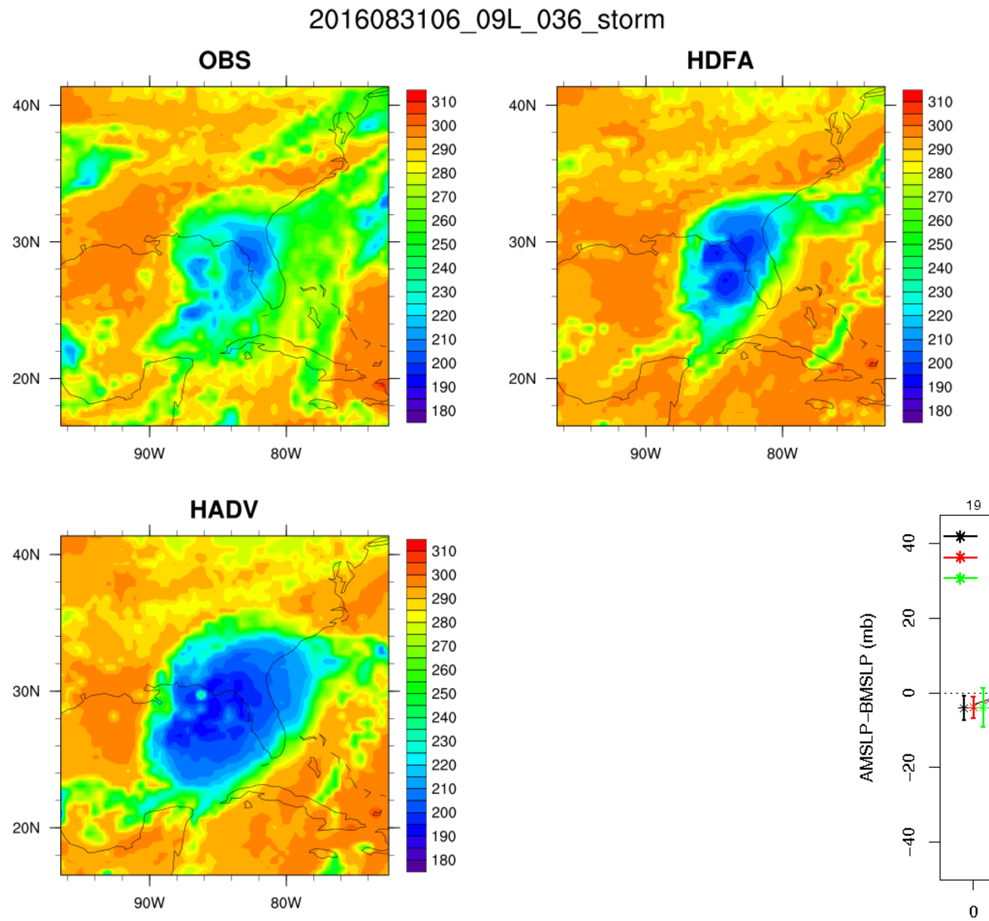






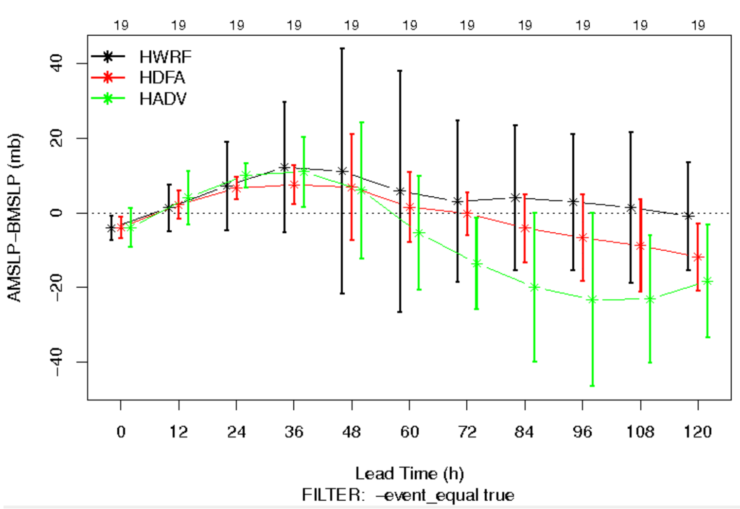


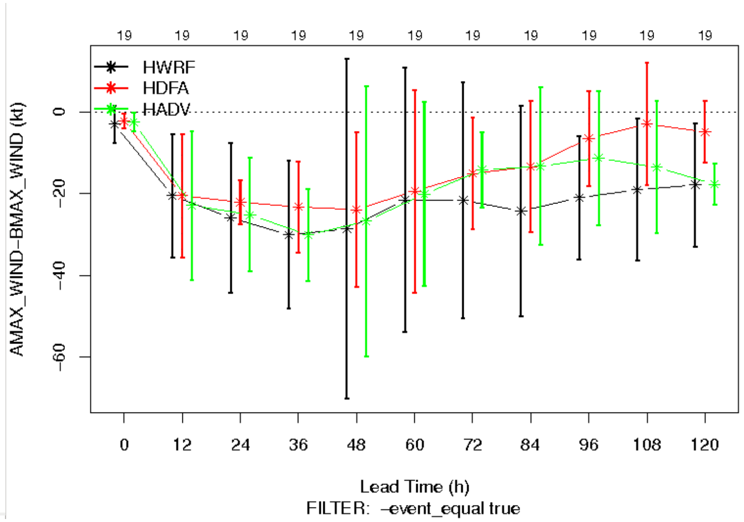
F-A Microphysics, include advection of species?



By including advection of species "FA-ADV" generates:

- **Lower P_{min} and larger low MSLP coverage**
- **Larger 34kt 10m wind contour area**
- **Weaker Vmax**
- **Heavier rainfall**
- **Unfavorable wind/pressure relationship**





Even though this is a more physical approach, it did not show enough promise to be considered for H218, where we needed to prioritize computationally cheaper advances

by Shaowu Bao

RRTMG Radiation could overlap

RRTMG Sub-Grid Cloud Options: Cloud Overlap

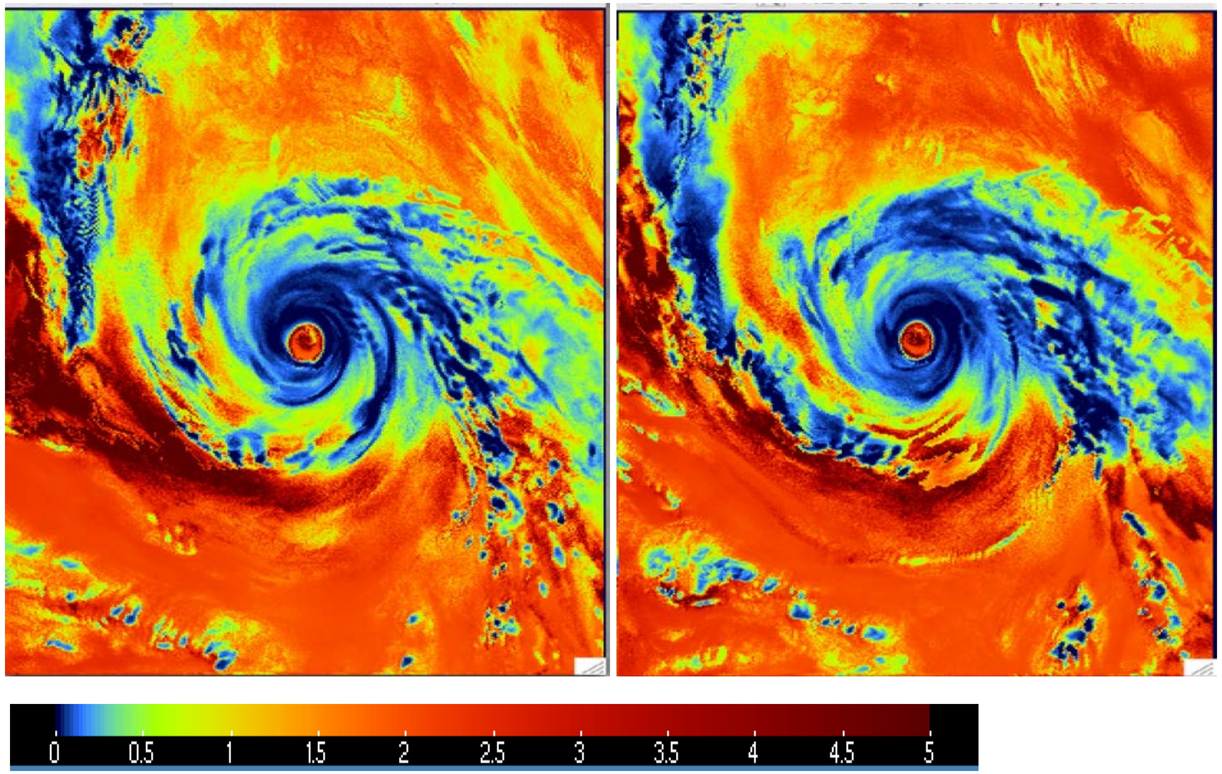
- Cloud overlap: Vertical correlation of fraction clouds
- Default method: **Maximum-random**
  - Continuous cloud layers overlap as much as possible; blocks of cloud layers with clear between are oriented randomly
- Alternate method 1: **Exponential-random**
  - Continuous cloud layers use overlap that transitions exponentially from maximum to random with distance through cloud, blocks of cloud layers with clear between oriented randomly
  - Constant decorrelation length (Z_0= ~1-2 km) controls rate of exponential transition.
- Alternate method 2: **Exponential-random, with variable Z_0**
  - Same as method 1, but Z_0 varies with latitude and day of year
  - Allows greater tendency for maximum overlap at low latitudes and random overlap at high latitude

By Mike Lacono/DTC

RRTMG Radiation could overlap

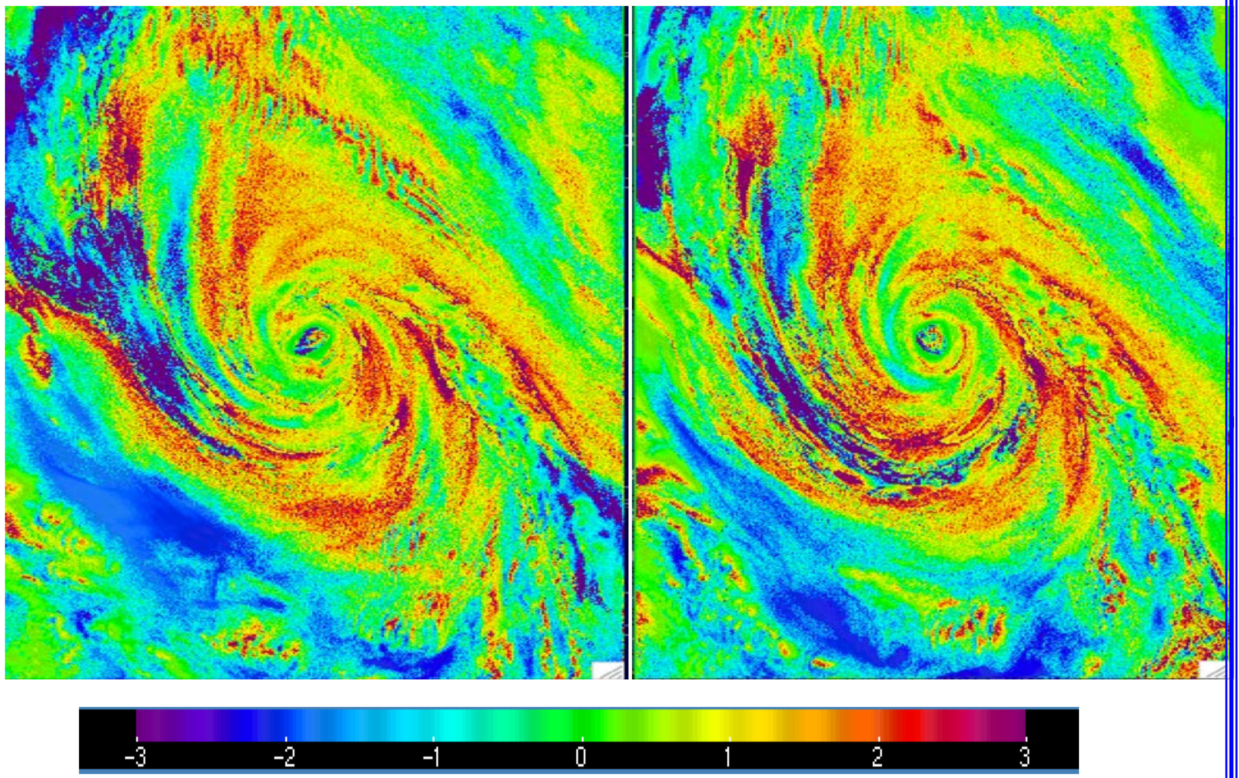
Radiative Heating Rate - Short Wave

Maximum-Random Exponential-Random



Radiative Heating Rate - long Wave

Maximum-Random Exponential-Random



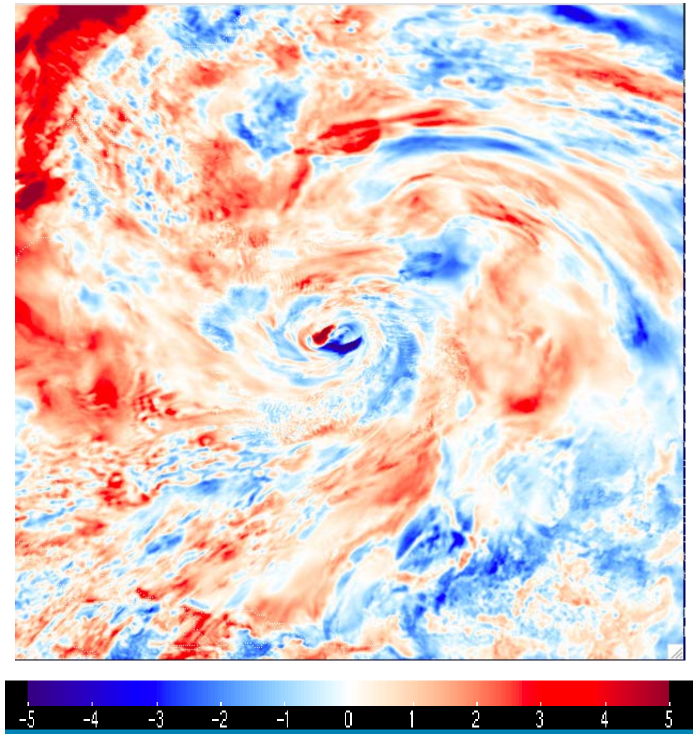
- Long wave and short wave radiative heating rates are significantly different

By Mike Lacono/DTC

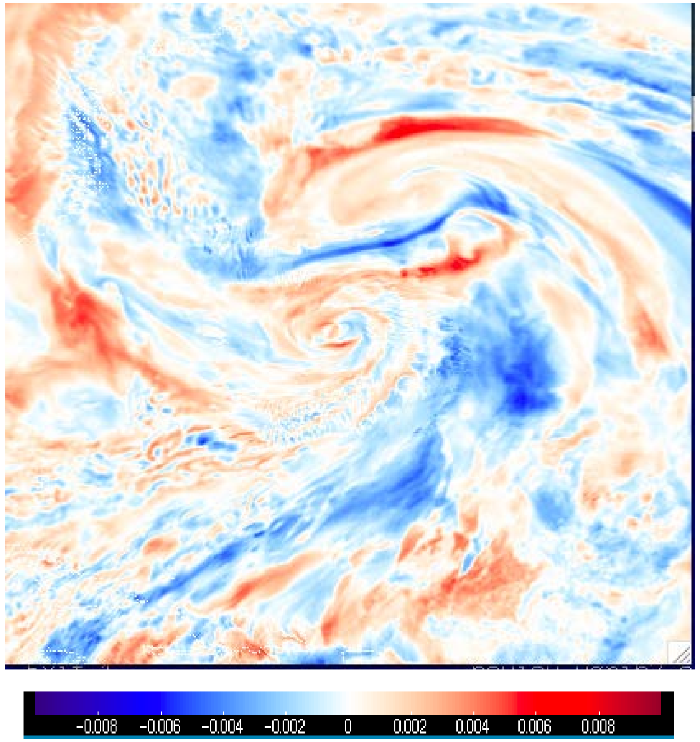
RRTMG Radiation could overlap

Impact of cloud overlap method (Maximum-random – Exponential-random)

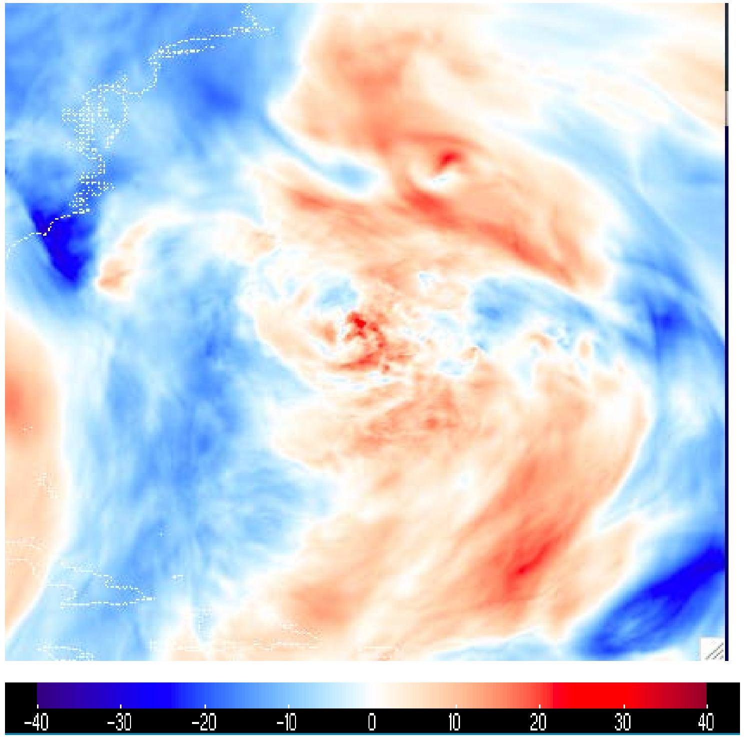
Temperature at 850 hPa



Specific Humidity at 850 hPa



Wind Speed at 200 hPa



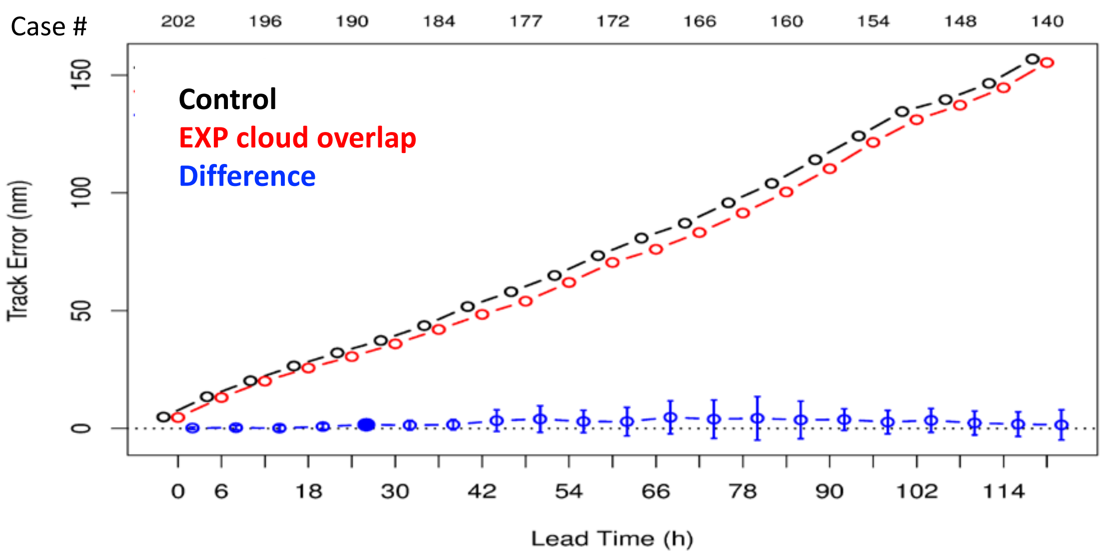
- Temperature, moisture and wind speed are all sensitive to cloud overlap near storms and in the surrounding environment

By Mike Lacono/DTC

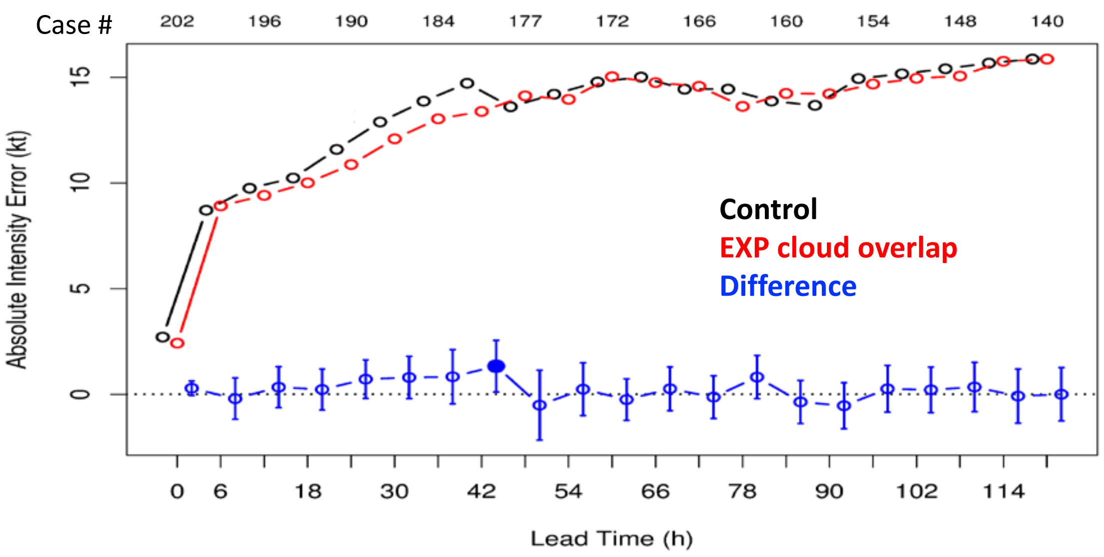
Alternate Cloud Overlap Methodology

M. Iacono, J. Henderson (AER)

Mean Track Error



Mean Absolute Intensity Error



- Examined the effect of replacing the default maximum-random (MR) cloud overlap assumption with an exponential cloud overlap (EXP) method within the RRTMG
  - Improved hurricane track and intensity forecast
  - EXP cloud overlap accepted for 2018 operational HWRF

Developmental Testbed Center

Summary

Main physics schemes have been discussed:

- PBL (GFS-EDMF, YSU, MYNN)
- Microphysics (Advected F-A)
- Radiation (RRTMG cloud overlap)

More schemes that we could consider:

- Convection (Grell-Freitas)
- Microphysics (Thompson)
- Cd/Ch
- Scale awareness (eg. scale-aware PBL)

Thank you !

Strategic plan for model physics (FV3GFS): 3 Stages

1. FV3-GFSv1 (Q2FY19 implementation; GFSv15):
   - Mostly GSM physics, but with GFDL MP

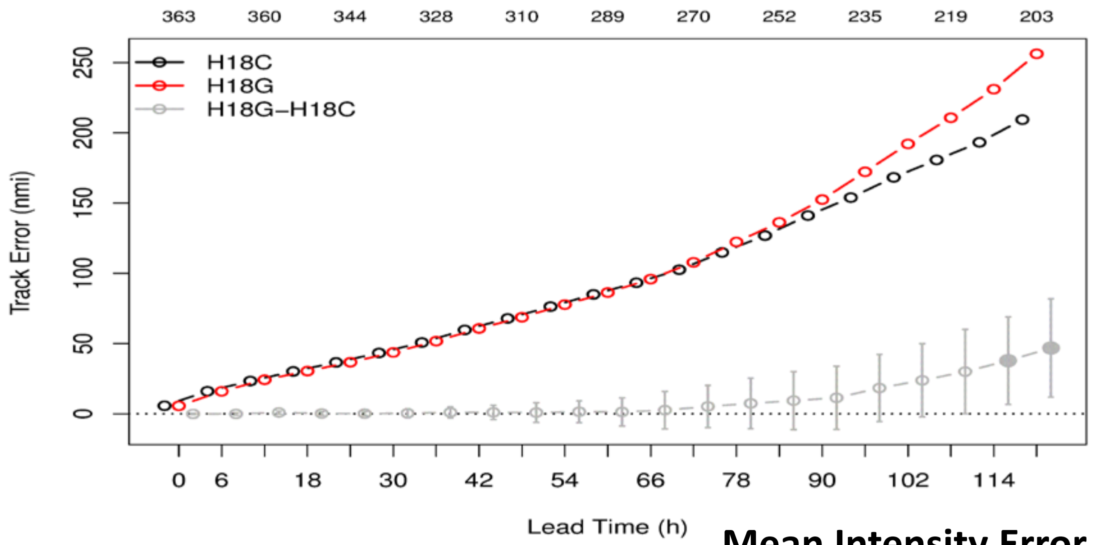
2. FV3-GFSv2 (Q2FY21 implementation; GFSv16):
   - Model Physics implemented via Common Community Physics Package (CCPP)
   - Potential full-suite replacement

3. GFSv17+ (FY22 and beyond):
   - Physics upgrades driven by community-supported Hierarchical Testing Framework connected to CCPP

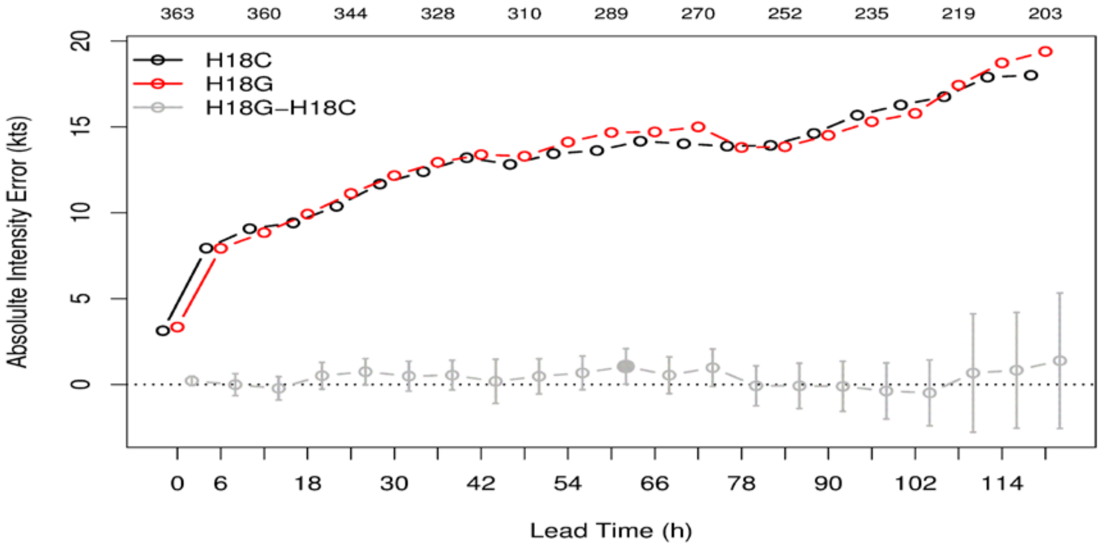
GF SASAS Difference

Grell-Freitas cumulus

Mean Track Error

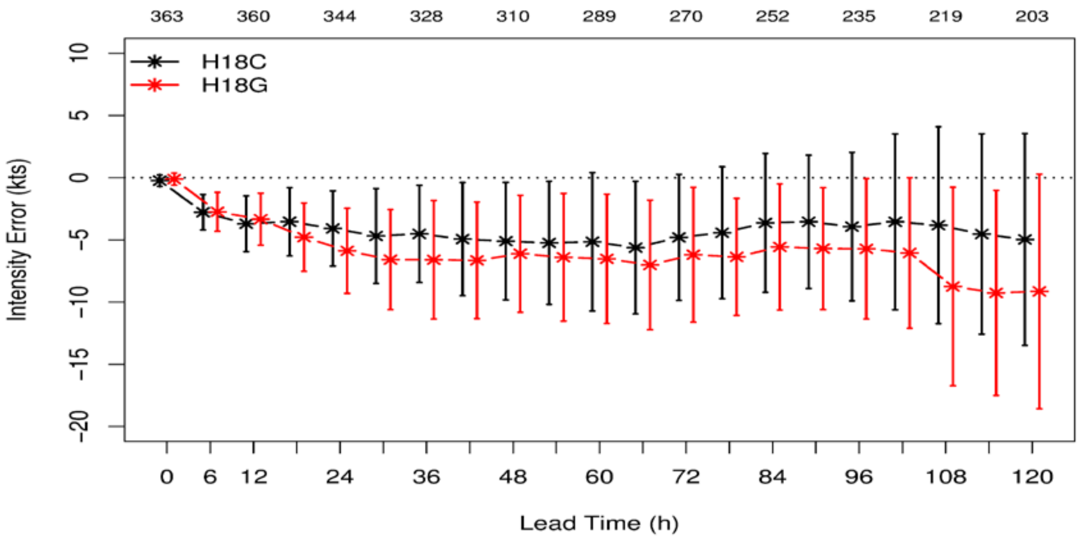


Mean Absolute Intensity Error



Storms:
Fred, Fiona, Hermine, Harvey, Irma, Kate, Jose, Nicole, Maria, Nate, Ophelia

Mean Intensity Error

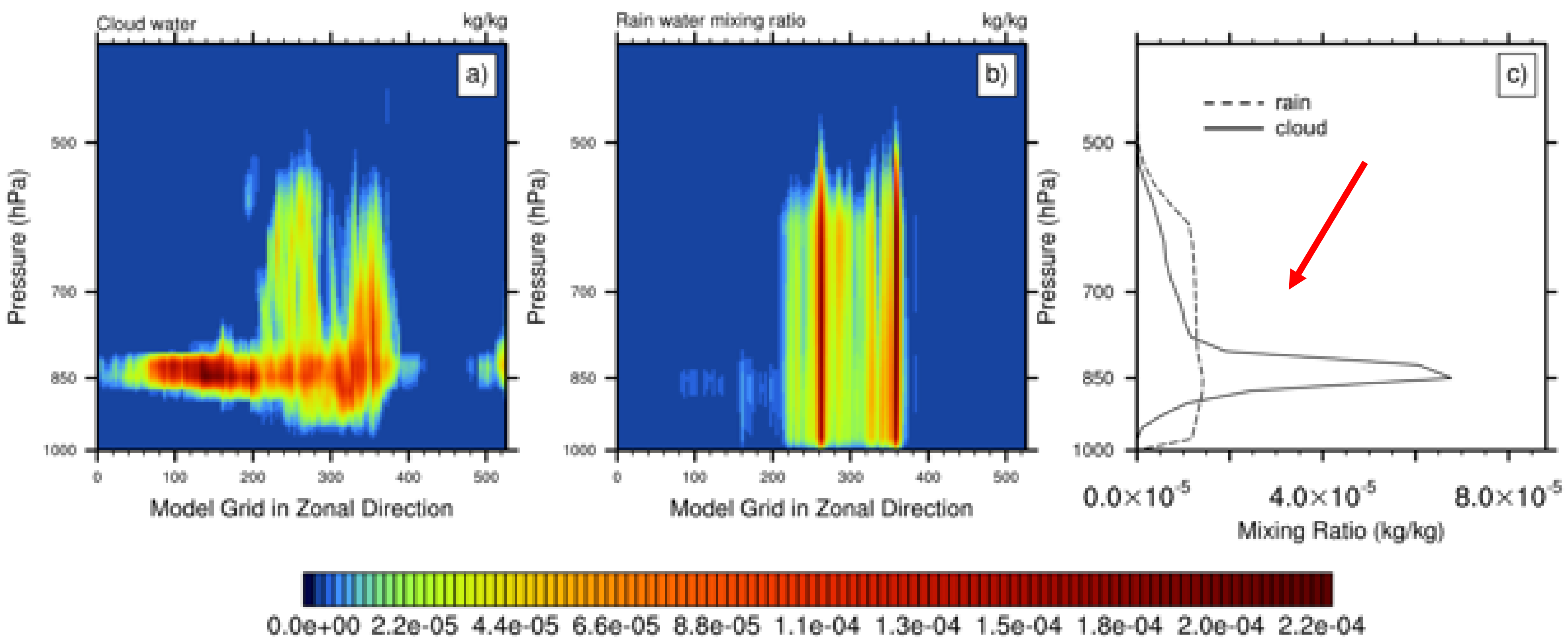


Degradation in track forecasts for GF configuration at longest lead times
Neutral intensity errors differences between the GF and SASAS
Negative intensity bias present in both configurations

Developmental Testbed Center

F-A

Diagnosing the excess cloud ice in advected FA



- A maximum in cloud water content near cloud base that gets advected upward and freezes into cloud ice may be the reason for the excess ice.
- Would be masked in the non-advected FA scheme by the advection of total condensate only.

by Shaowu Bao