HAFS PHYSICS PARAMETRIZATIONS

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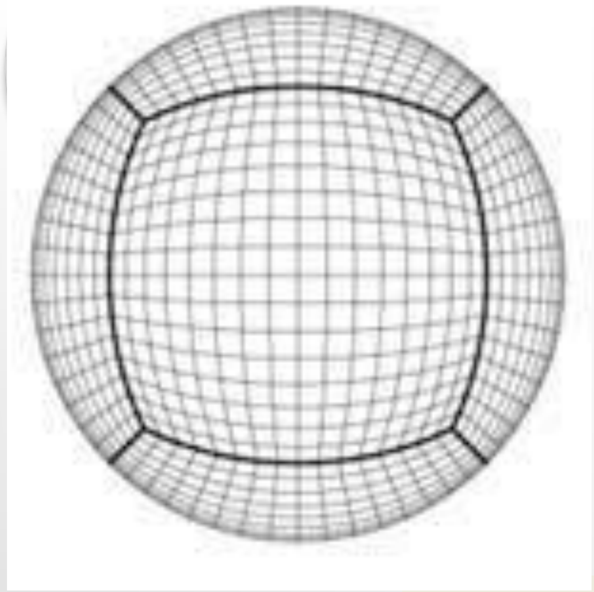
OUTLINE

- PARAMETERIZATIONS/PROCESSES
- HAFS PHYSICS SCHEMES
- TROPICAL-CYCLONE-RELATED MODIFICATIONS
- TEST RESULTS
- CHALLENGES AND FUTURE WORK



Parameterization:

… approximate processes that are too small-scale or complex to be physically represented (resolved) in the model…..

-Wikipedia

Thermodynamic equation

Dynamics | Physics

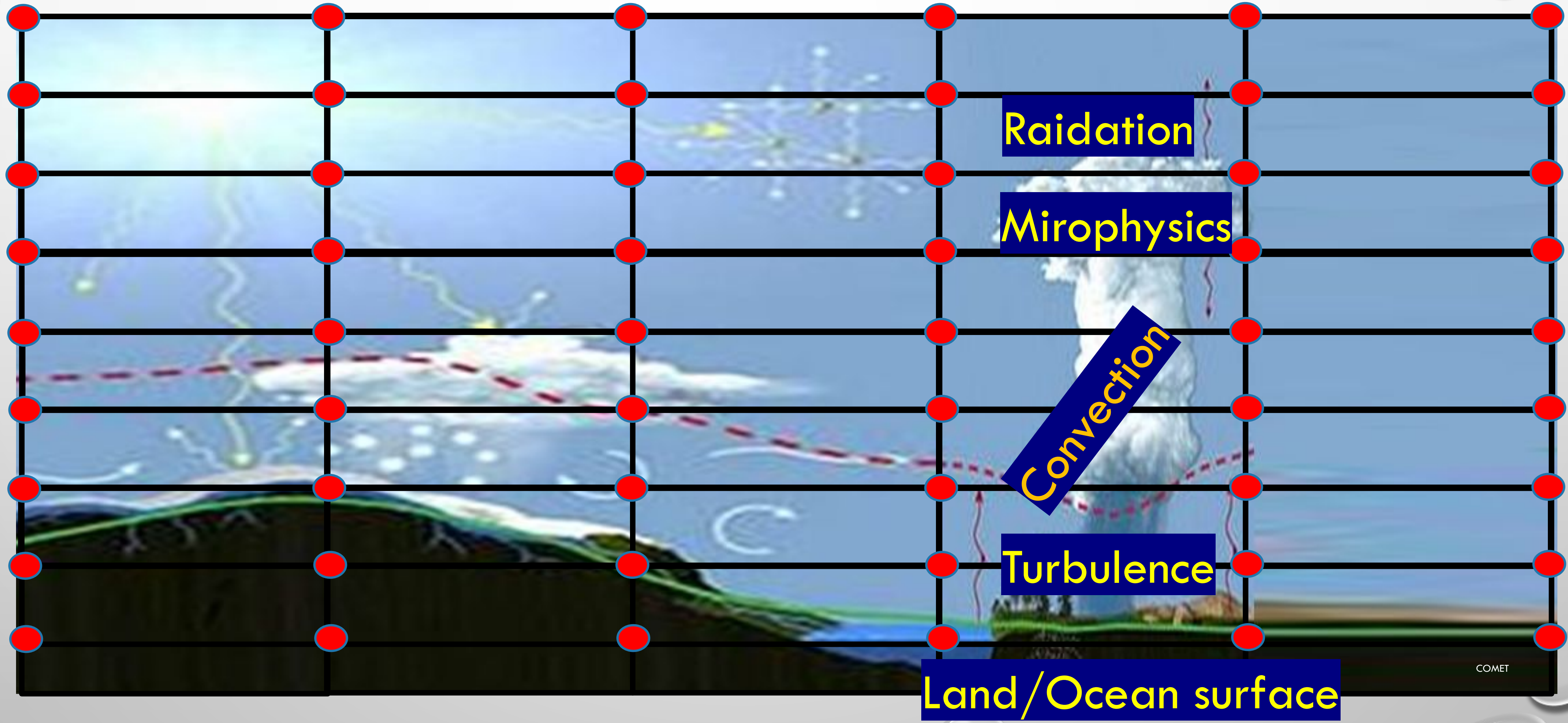
$$\frac{\partial T}{\partial t} = -u\frac{\partial T}{\partial x} - v\frac{\partial T}{\partial y} + \frac{P}{R}\omega\sigma + FT + \frac{\check{Q}}{C_P}$$

Time tendency — horizontal advection — vertical advec. + adiabatic heating — H. diffusion — diabatic heating

Explicitly Resolved grid scale

Not Resolved subgrid/Parameterized

Subgrid Processes



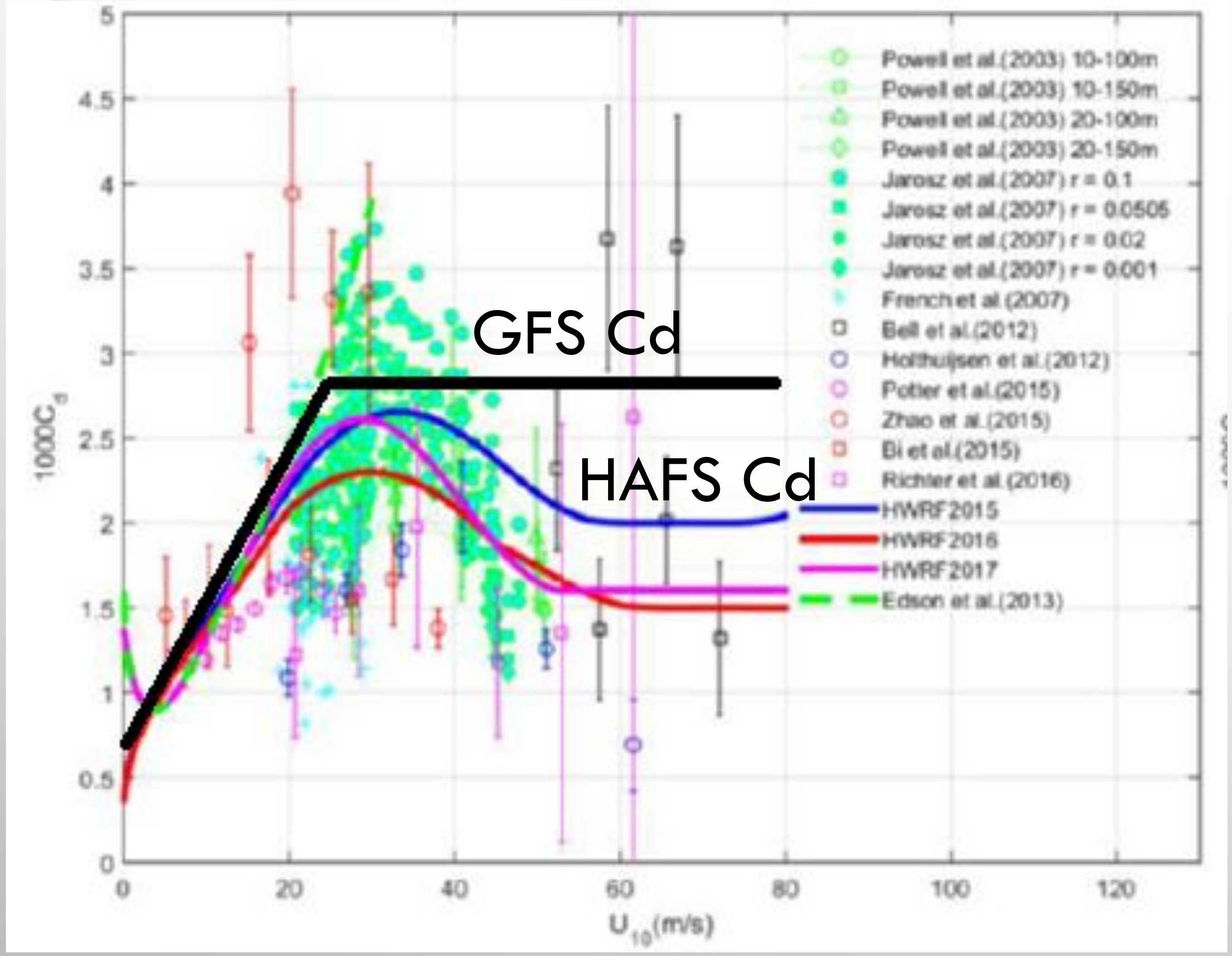
Subgrid Processes

Process	What to do
(1) Land/ocean Surface	provide surface temperature, heat and moisture fluxes over land, sea-ice, and ocean points. These serve as a lower boundary condition for the vertical transport in the PBL schemes
(2) Surface Layer	Atmospheric exchange coefficients, stability functions (Surface fluxes) needed by surface models and PBL
(3) Boundary Layer	Turbulent scale mixing, vertical fluxes
(4) Microphysics	Grid-resolved clouds, effects of vapor-liquid-ice phase changes
(5) Radiation	Heating and cooling due to short and long wave radiation
(6) Cumulus convection (deep & shallow)	temperature, water, momentum changes due to convection too small to be resolved explicitly by grid spacing. reducing the thermodynamic instability
(7) Gravity wave drag	Impact of sub-grid scale perturbations excited by orography and convection

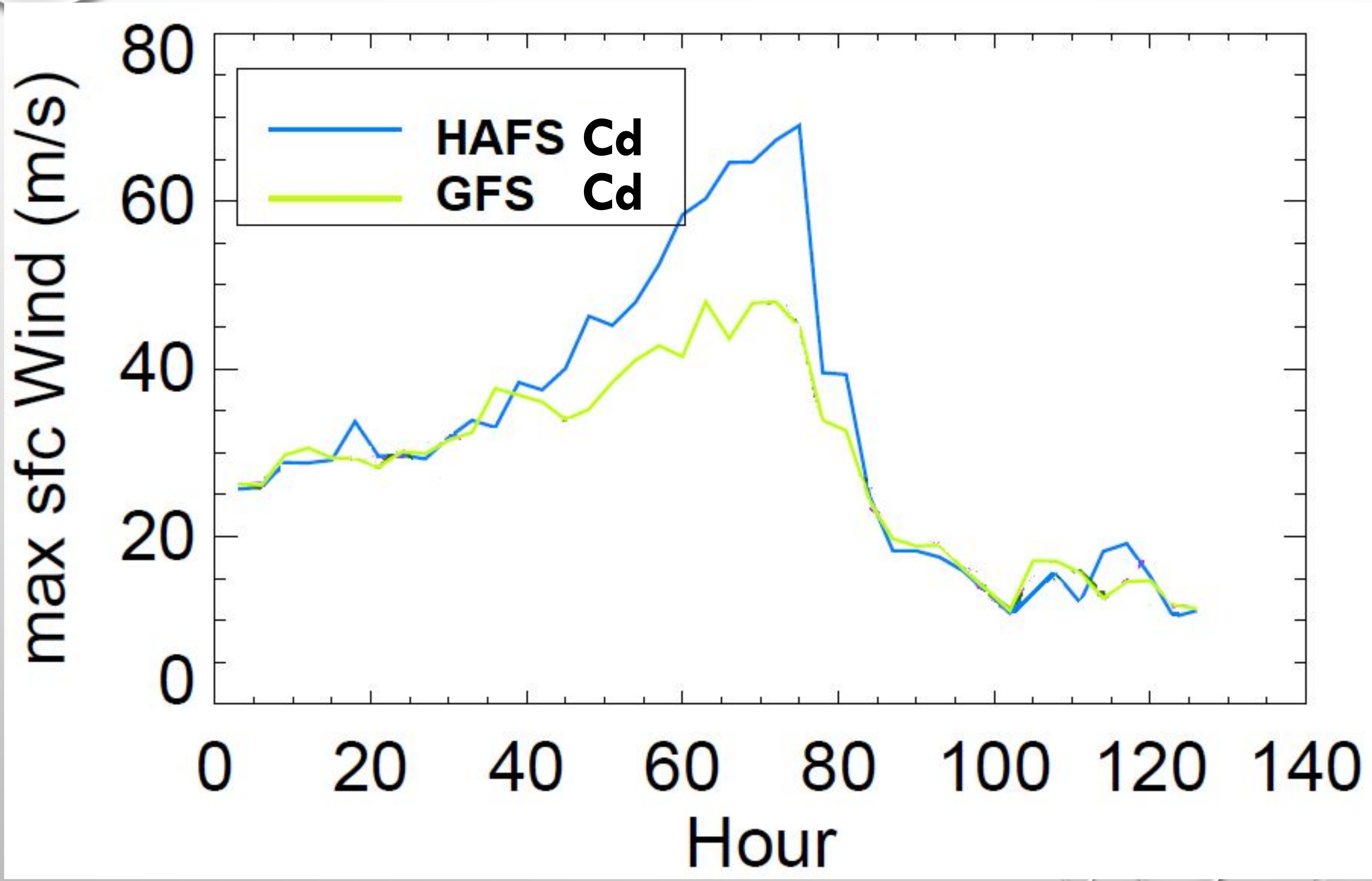
HAFS physics schemes

Process	Suite 1	Suite 2	Reference
Land/ocean Surface	NOAH, HYCOM	NOAH MP, HYCOM	Ek et al. (2003) …
Surface Layer	GFS , TC-related Z0	GFS, TC-related Z0	Miyakoda and Sirutis (1986); Long (1984, 1986)
Boundary Layer	Sa-TKE-EDMF, TC-related tuning (L)	Sa-TKE-EDMF, TC-related tuning (L, mass flux..)	Han et al. (2019)
Microphysics	GFDL single-moment	Thompson double-moment	Lin et al. (1983) Chen and Lin (2013)
Radiation	RRTMG	RRTMG	Iacono et al. (2008)
Cumulus convection (deep & shallow)	Scale-aware-SAS	Scale-aware-SAS, TC-related tuning (flux, trigger)	Han et al. (2017)
Gravity wave drag	GWD (orographic on/convective off)	GWD (orographic on/convective off)	Alpert et al. (1988)

TC-RELATED MODIFICATIONS-1

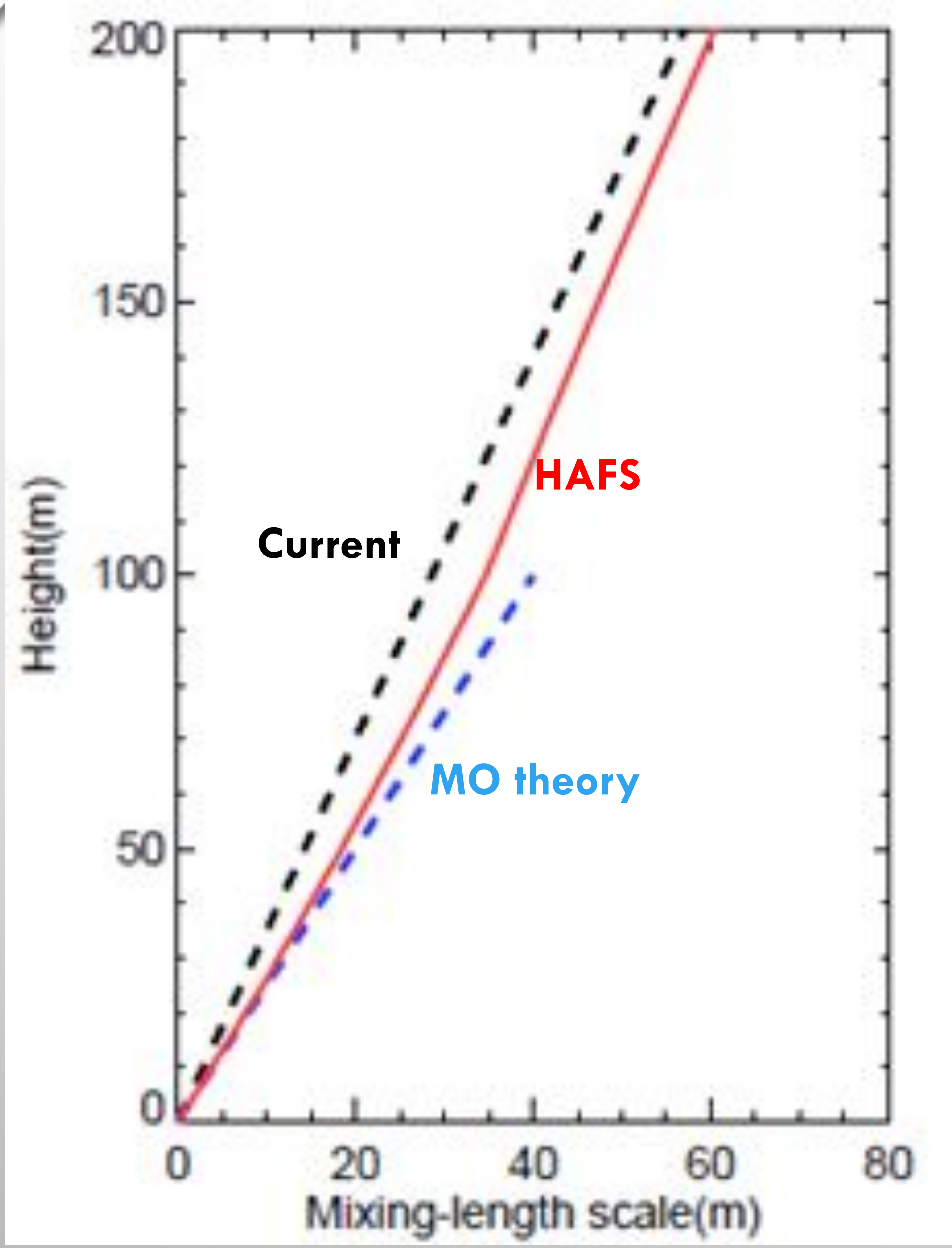


- HAFS specifies roughness lengths for momentum(z0) and scalar (*zt*) as a function of wind to match observed drag coefficients (Cd, Ch)
- *Cd decreases with wind speed when wind > 35 m/s*



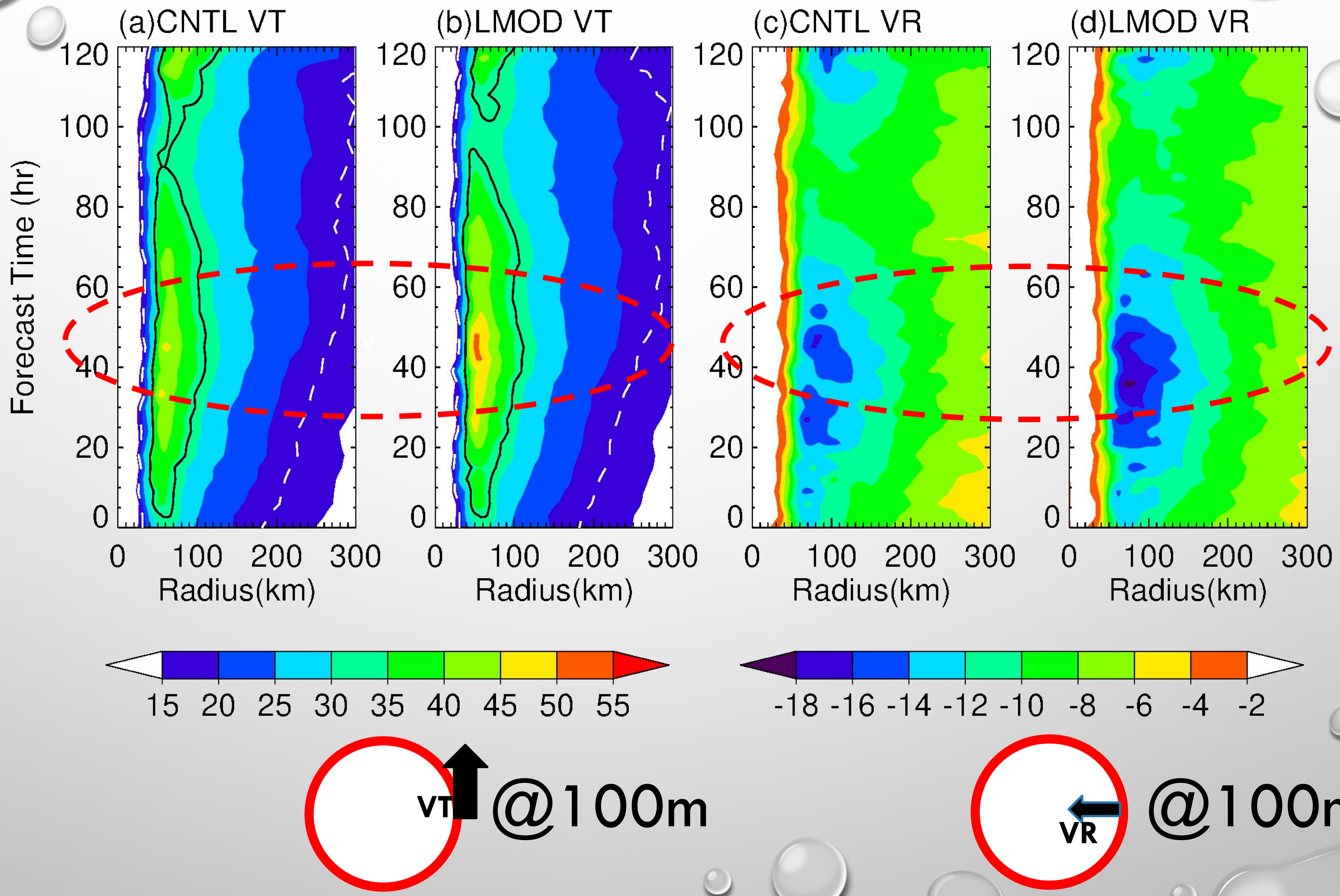
Hurricane Michael (14L)

Init: 2018100712



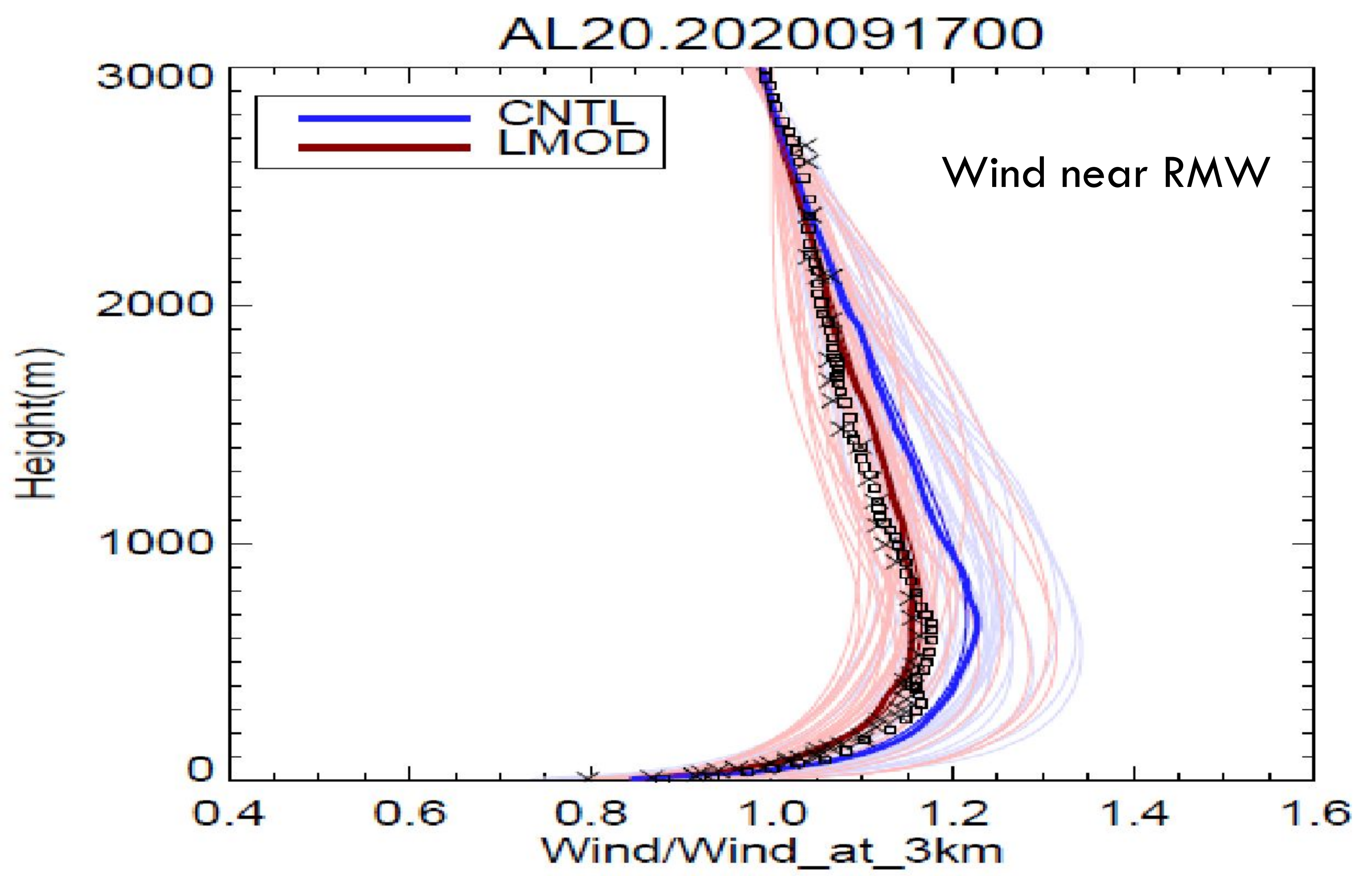
TC-RELATED MODIFICATIONS-2

- HAFS uses a modified mixing length scale (Red) near the surface, closer to MO theory (blue).
- Default one may be up to ~ 20-30% smaller than MO in some scenarios.

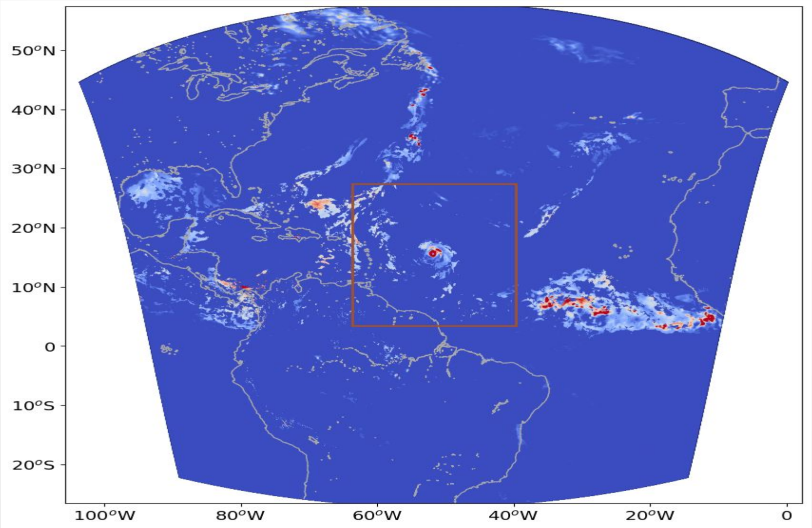


(a)CNTL VT
(b)LMOD VT
(c)CNTL VR
(d)LMOD VR
Forecast Time (hr)
0 20 40 60 80 100 120
Radius(km)
0 100 200 300
15 20 25 30 35 40 45 50 55
-18 -16 -14 -12 -10 -8 -6 -4 -2
VT
@100m
VR
@100m

Comparison with Observations



Test results



Setup

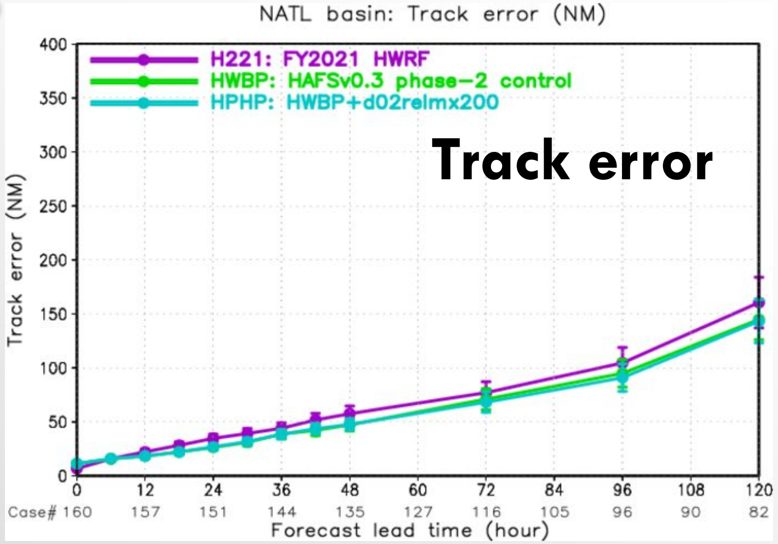
- Storm-centric 6-km parent with a 2-km storm-following moving nest
- L81 vertical levels, 2-hPa top
- Model physics time step of 90s
- Vortex initialization + DA
- Ocean: hycom

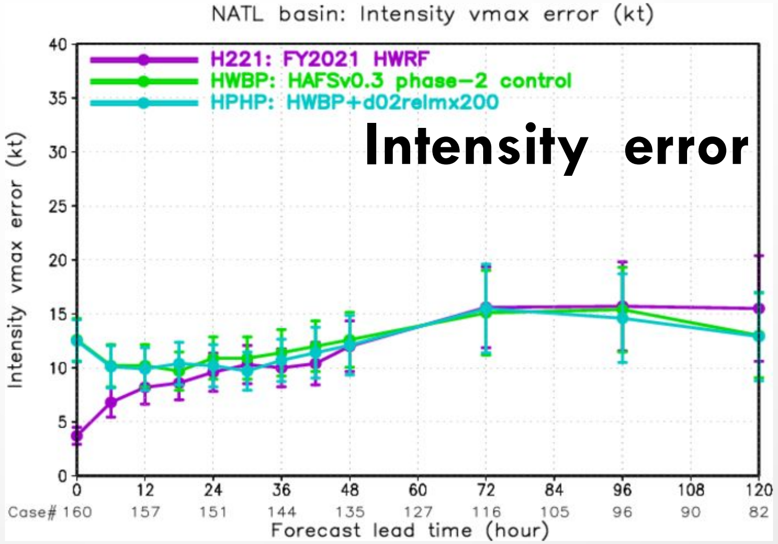
Two experiments

(1) Max mixing length L =300 vs 200

(2) Physics Suites 1 vs 2

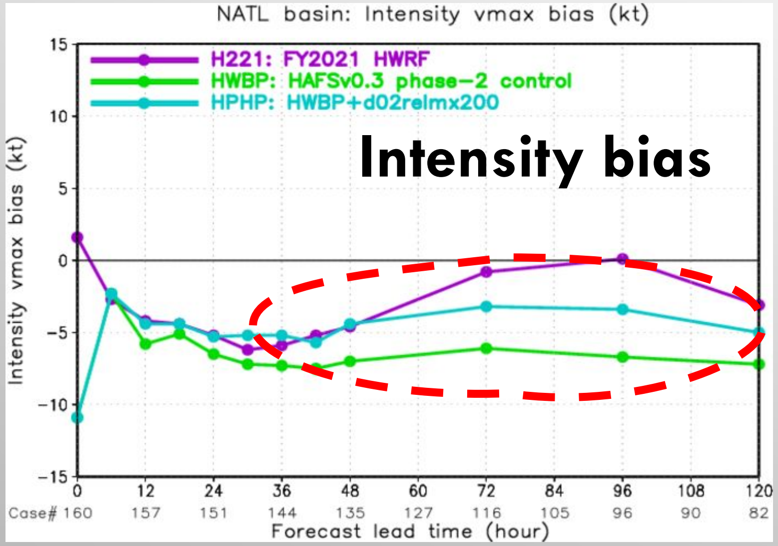
L_max = 300 vs 200

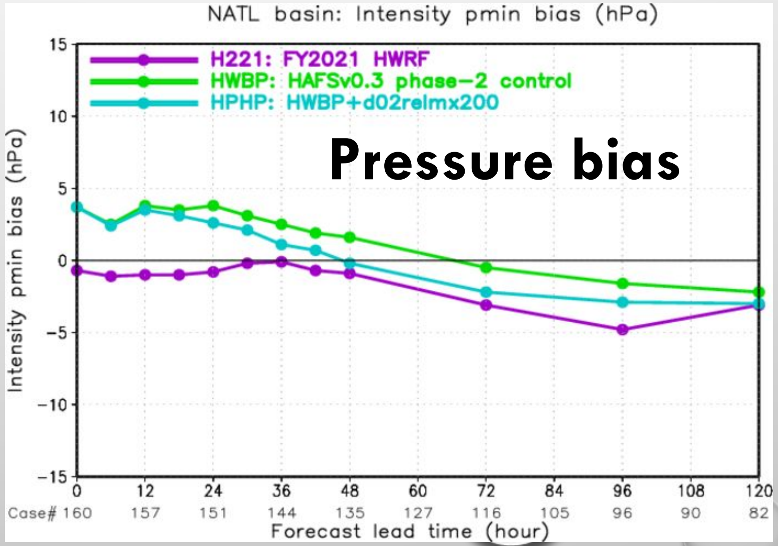




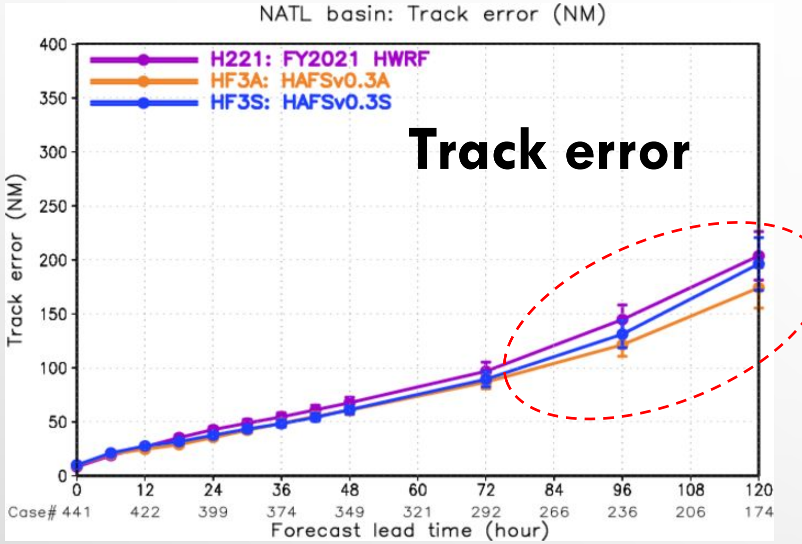
300m

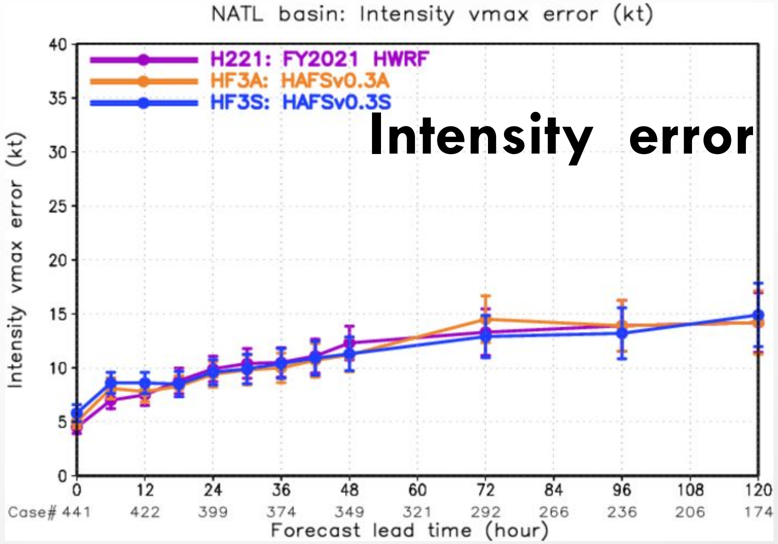
200m

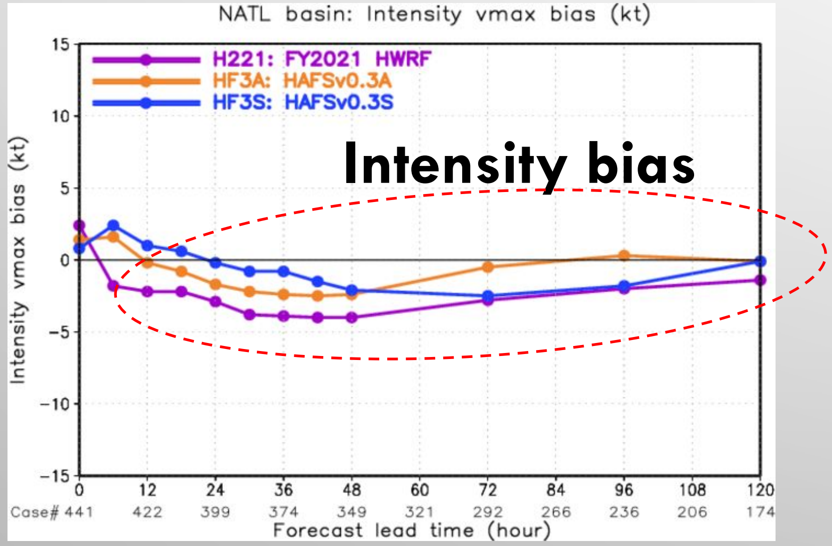


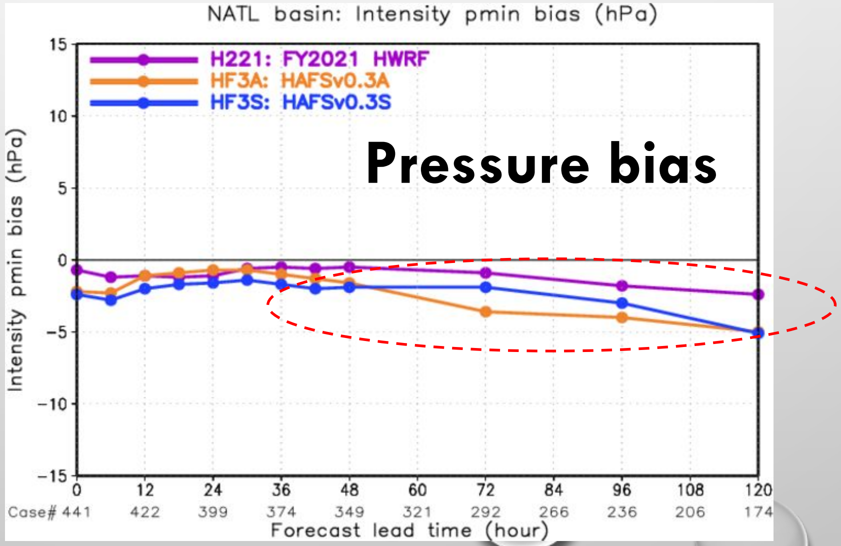


Phys suites 1 and 2









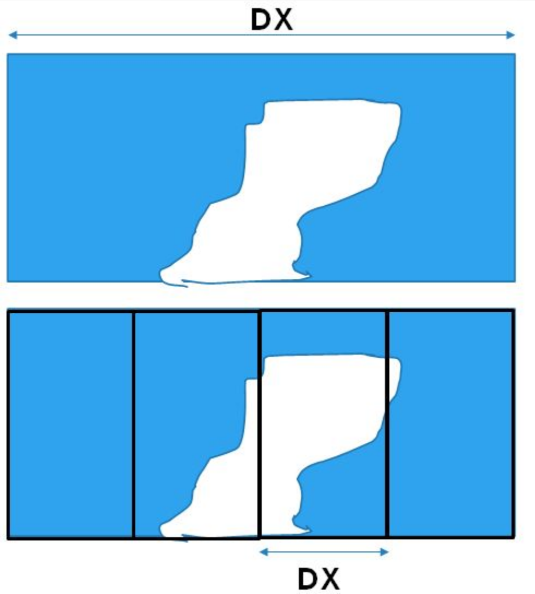
S1 GFDLMP

S2 THOMPSON MOD BL,CU

Challenges and future work

(1) Grid-related

+ Multi-scale (scale-aware) physics schemes
  horizontal grid >> system scale.
  horizontal grid ~ or < system scale.
+ One-column physics?
  Dynamics and physics are separate
  Some systems extend > one grid



(2) TC-related developments

TC conditions (strong wind, shear..), e.g.
+ PBL mixing, PBLH, convection…
+ Cloud drop distributions
+ surface layer with strong pressure gradient
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