Evaluation and modification of a TKE-based PBL scheme in HMON

-- Application of a SGS scheme

Weiguo Wang[1], Lin Zhu[1], Avichal Mehra[2],
Vijay Tallapragada[2]

[1] IMSG @EMC/NCEP
[2] EMC/NCEP, College Park, MD

Outline

1. Motivation
2. Equation and parameterization
3. NCEP HMON Model setup
4. Results
5. Summary and future work

Motivation

- Studies have shown that the widely-used eddy-diffusivity approach might fail to represent sub-grid scale (SGS) fluxes in some situations, particularly in convective conditions.
- Parameterization in PBL has bee extensively studied to represent turbulent fluxes in convective condition. Examples: counter-gradient approach, EDMF approach, ……
- Above PBL, a simple *K* approach is usually used to represent SGS fluxes. This may have issues for convective areas, e.g., in convective clouds, hurricane eyewall areas, …
- Some studies have proposed and tested new approaches to represent SGS fluxes in convective cloudy areas (e.g., Moeng, 2012,2014, Verrelle et al, 2017, ……)
- Our work is to test how new SGS approach may affect hurricane forecast in NCEP operational hurricane models.

Equation and parameterization

$$\overline{w's'} = -K\frac{\partial s}{\partial z}$$

For scalars, S,
Usually, K-closure is used to parameterize flux terms (above PBL)

$$\overline{w's'} = \mathrm{C}\,\Delta^2\left(\frac{\partial \bar{w}}{\partial x}\frac{\partial \bar{s}}{\partial x} + \frac{\partial \bar{w}}{\partial y}\frac{\partial \bar{s}}{\partial y}\right)$$

Relate SGS flux to horizontal gradients of mean vertical velocity and mixing ratio
Propsed by Moeng (2012,2014) , Verrelle et al. (2017) tested. Give better counter-gradient structure,....

$$\frac{\partial \bar{e}}{\partial t} = -\bar{u}_j \overline{\frac{\partial e}{\partial x_j}} - \overline{u_i' u_j'} \overline{\frac{\partial u_i}{\partial x_j}} + \frac{g}{\bar{\theta}} \left(\overline{w' \theta_v'} \right) - \overline{\frac{\partial u_j' e}{\partial x_j}} - \frac{1}{\bar{\rho}} \frac{\partial \overline{u_i' p'}}{\partial x_i} - \varepsilon,$$

TKE simulation is sensitive to production terms, particularly, thermal term in relatively coarse grid.

$$\overline{w'\theta_v{}'} = A\, \overline{w'\theta_l{}'} + B\, \overline{w' q_{np}{}'}$$

Where θ_l *for liquid potential temperature.*
q_{np} *for non-precipitating water mixing ratio*
A, B coefficients.

Note, in our preliminary tests, new approach is applied only to heat flux in TKE/heat equation in convective areas (above PBL) .

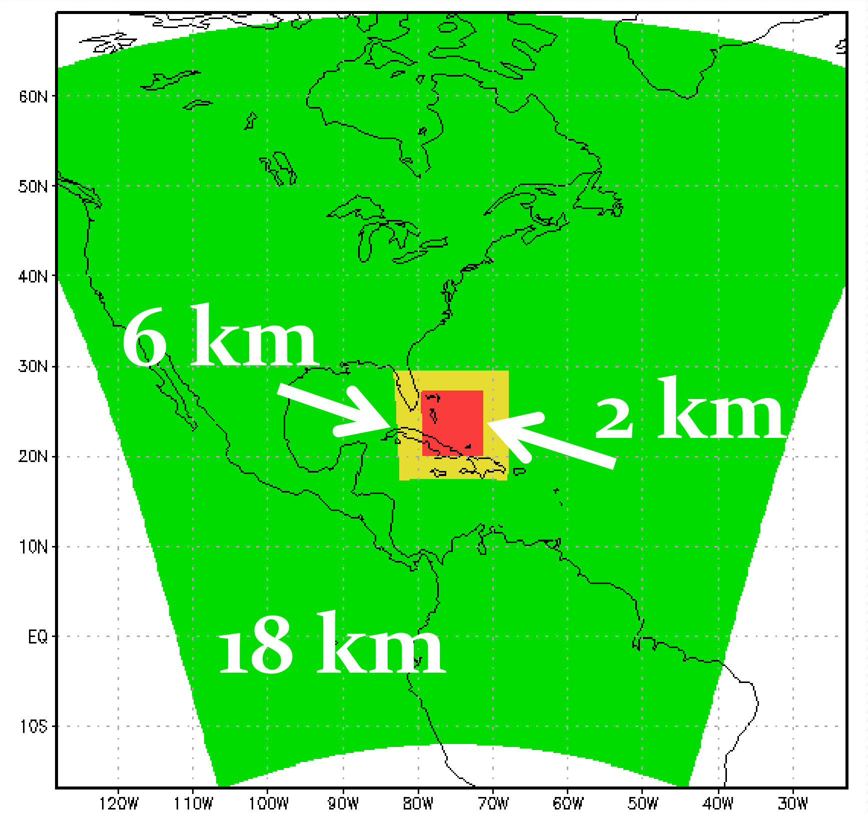
HMON

Hurricanes in a **M**ulti-scale **O**cean coupled **N**on-hydrostatic model

One of NCEP operational hurricane forecast systems

- **Dynamic core: NMMB**
- **Vortex initialization**
- **Moving nests**
- **Well-tuned Physics package**
- **Coupled to Ocean models (HYCOM)**

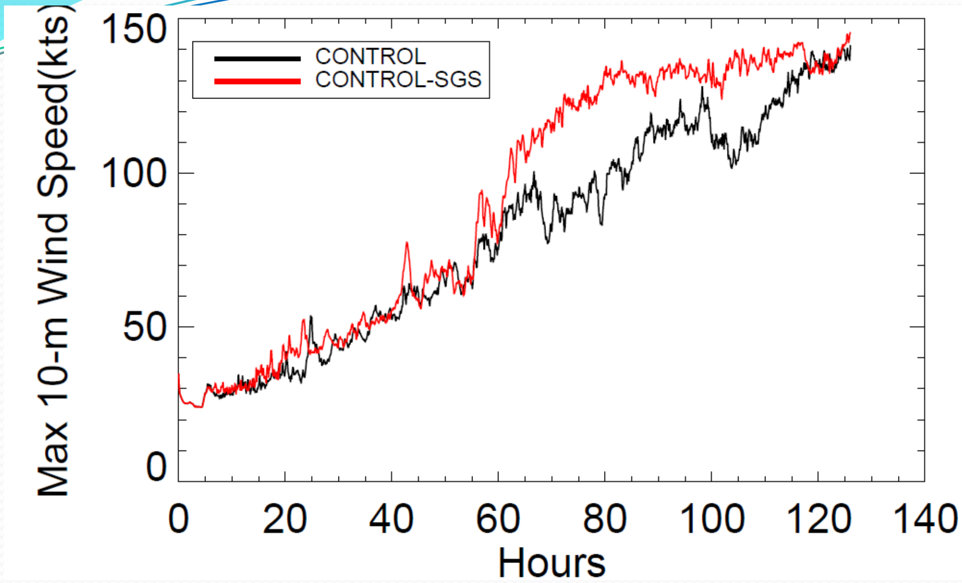
Idealized HMON configuration

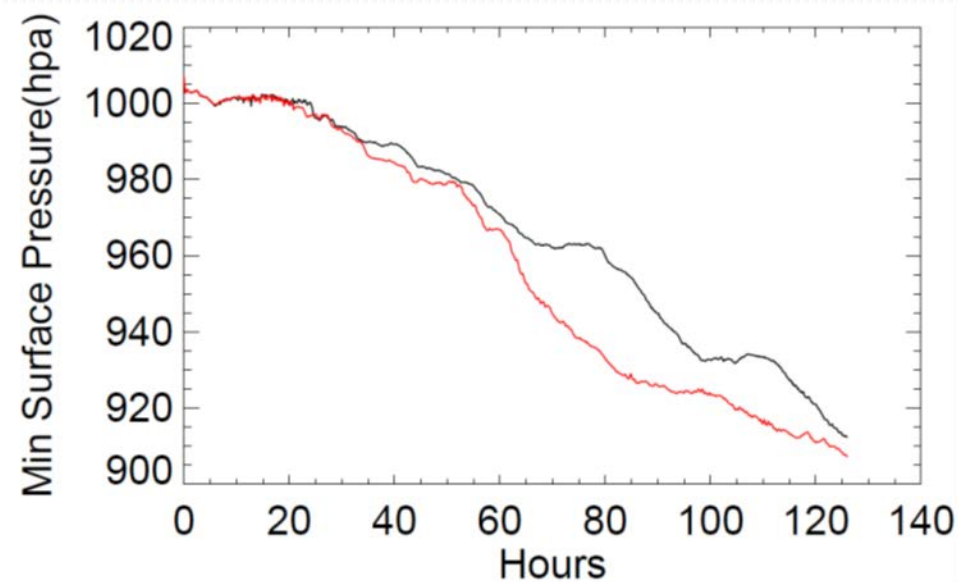


- No ocean, const SST
- Zero background wind
- 42 levels
- Three domains, two nests
- D1: ~65° x 65°
  D2: ~ 12° x 12°
  D3: ~ 7° x 7°

Physics schemes

Scheme	Description
Land model	Noah land surface model
Surface layer	MYJ surface layer, with cd, ch matching obs.
PBL	MYJ PBL
Convection	D1 and D2: Simplified Arakawa-Schubert (SAS) scheme with modifications. D3 none
Microphysics	Ferrier-Aligo scheme for high resolution model
Radiation	RRTM, partial cloudiness



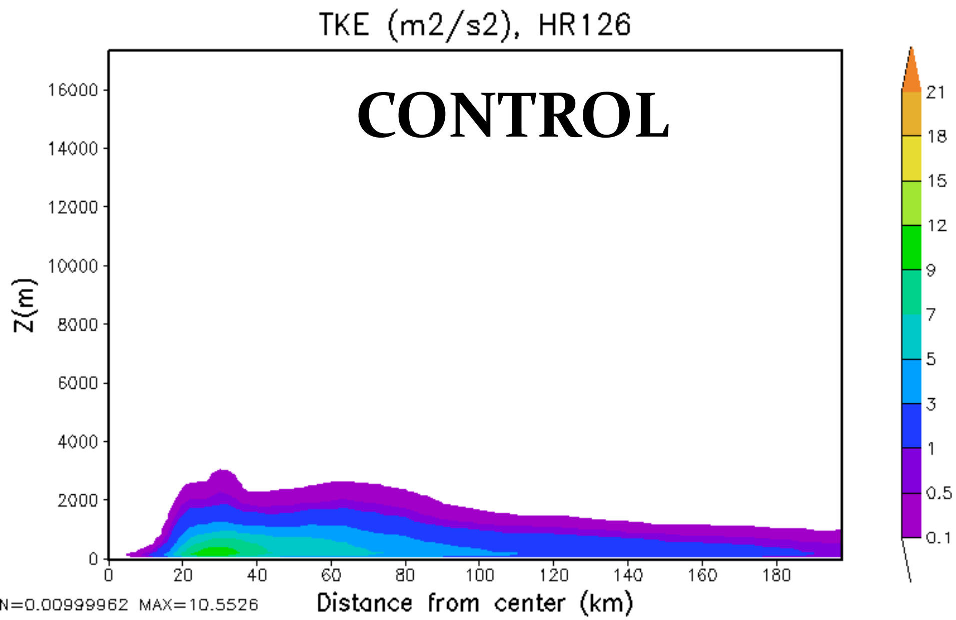


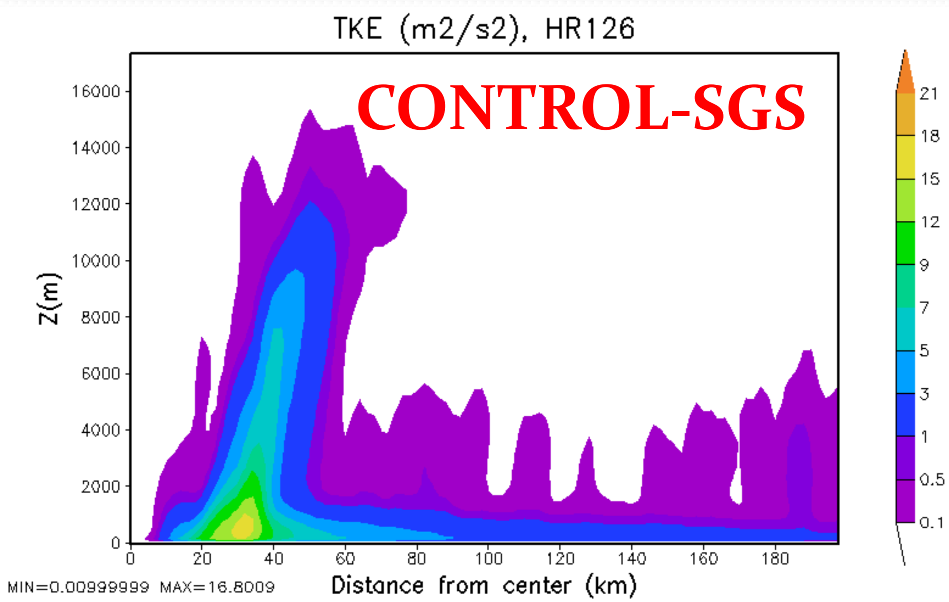
Two simulations

CONTROL:
default MYJ PBL

CONTROL-SGS :
default MYJPBL
+ SGS scheme for heat

- Max winds are close
- New run is more rapidly intensified.





TKE

+ Using new SGS produces results much closer to OBS
+ Control run using *K*-closure underestimates TKE in eyewall area. Failed to simulate TKE buoyance production term in convective area

Radar-derived, Lorsolo et al. 2010

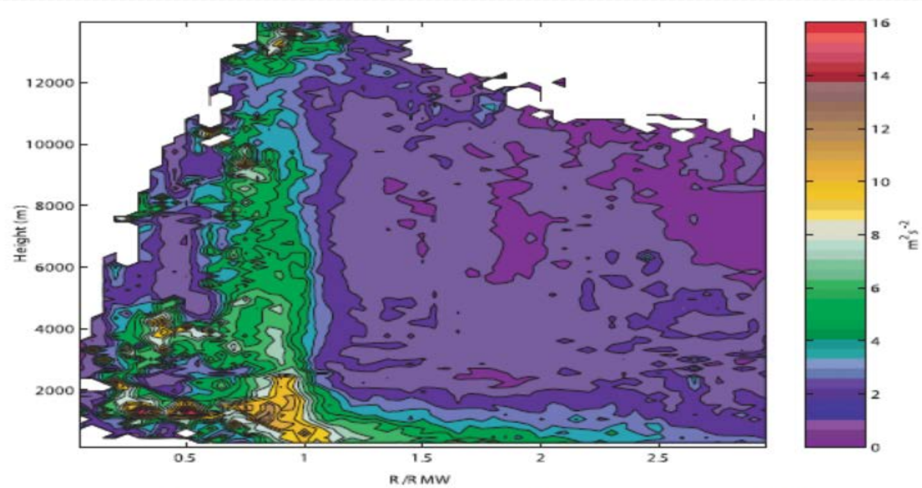
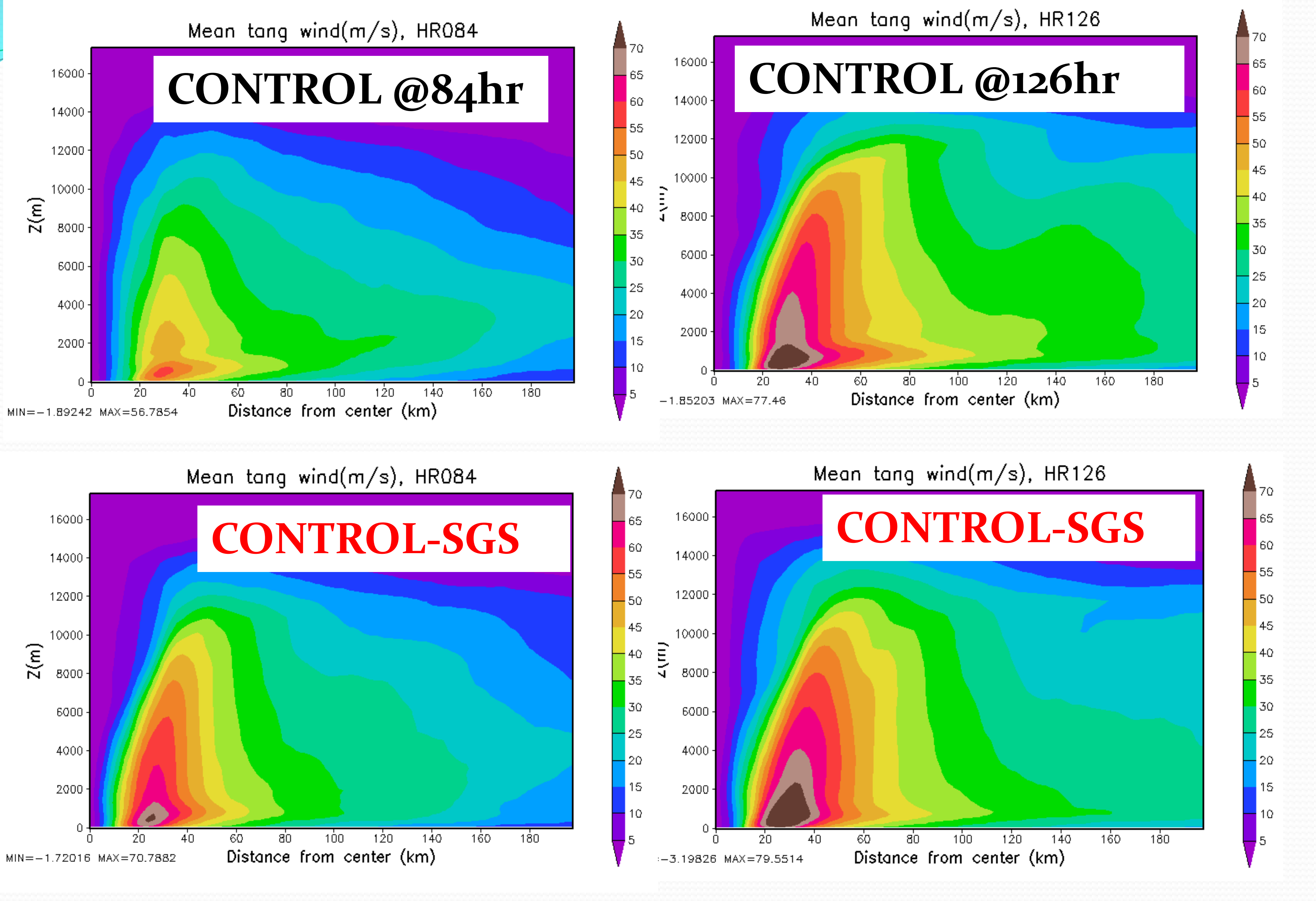


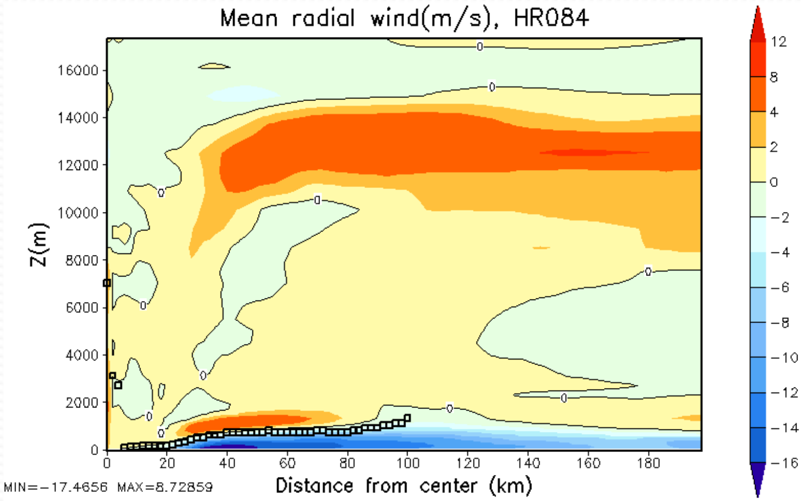
FIG. 7. The *R*–*Z* mean cross section of TKE for all cases, scaled on RMW.

Tangential wind

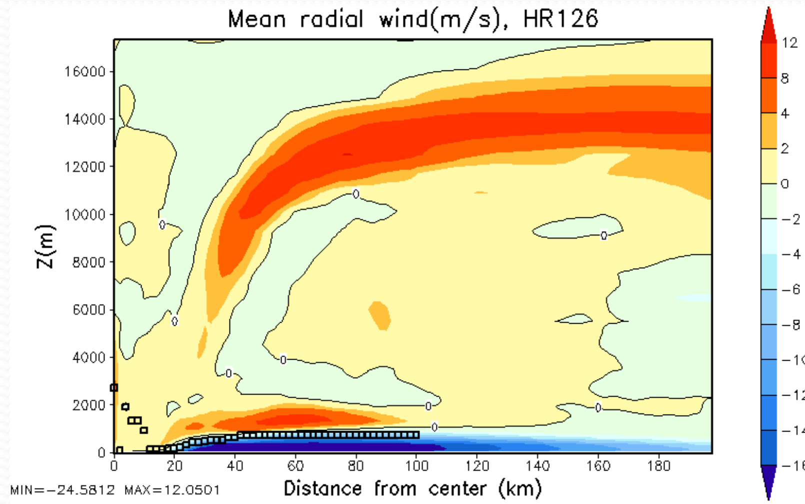


Radial wind

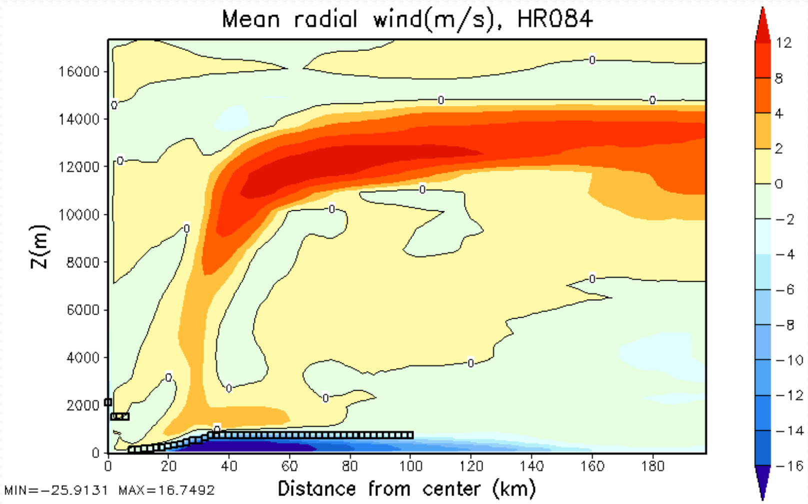
CONTROL @84hr



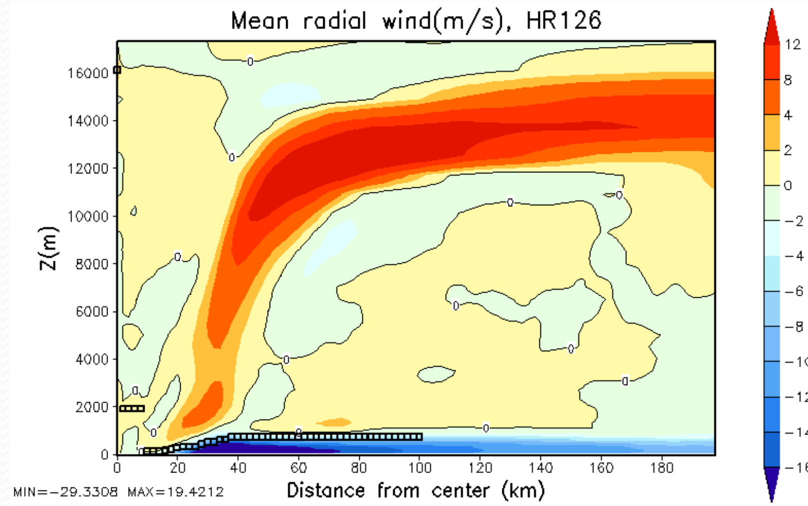
CONTROL @126hr



CONTROL-SGS



CONTROL-SGS



Summary

1. A SGS scheme was applied to MYJ TKE PBL scheme

2. With the scheme,
    The model can realistically simulate TKE
        distribution in convective eyewall area.
    TC is more rapidly developed.

3. Future Plan:
    + Make real-case simulations and further evaluate results
    + Introduce the scheme to NCEP hurricane models (HWRF/HMON)