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

-- Application of a SGS scheme

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Outline

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3. NCEP HMON Model setup
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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 been 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

\[ w's' = -K \frac{\partial S}{\partial z} \]

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

\[ w's' = C \Delta^2 \left( \frac{\partial \bar{w}}{\partial x} \frac{\partial \bar{s}}{\partial x} + \frac{\partial \bar{w}}{\partial y} \frac{\partial \bar{s}}{\partial y} \right) \]

Relate SGS flux to horizontal gradients of mean vertical velocity and mixing ratio
TKE simulation is sensitive to production terms, particularly, thermal term in relatively coarse grid.

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

\[w' \theta'_v = A w' \theta'_l + B w' q_{np}' \]

Where \( \theta_l \) 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 Multi-scale Ocean coupled Non-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

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<td>Surface layer</td>
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<td>PBL</td>
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<td>Convection</td>
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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
Tangential wind

Mean tang wind (m/s), HR084

CONTROL @84hr

Mean tang wind (m/s), HR126

CONTROL @126hr

Mean tang wind (m/s), HR084

CONTROL-SGS

Mean tang wind (m/s), HR126

CONTROL-SGS
Radial wind

CONTROL @84hr

CONTROL-SGS

CONTROL @126hr

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)