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

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**Thermodynamic equation**

\[
\frac{\partial T}{\partial t} = -u \frac{\partial T}{\partial x} - v \frac{\partial T}{\partial y} + \frac{P}{R} \sigma + \frac{\tilde{Q}}{C_p} + FT + \text{adiabatic heating}
\]

- **Dynamics**
  - Time tendency
  - Horizontal advection
- **Physics**
  - Vertical advection
  - H diffusion

Explicitly Resolved grid scale

Not Resolved subgrid/Parameterized
Subgrid Processes

- Radiation
- Microphysics
- Convection
- Turbulence
- Land/Ocean surface
<table>
<thead>
<tr>
<th>Process</th>
<th>What to do</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Land/ocean Surface</td>
<td>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</td>
</tr>
<tr>
<td>(2) Surface Layer</td>
<td>Atmospheric exchange coefficients, stability functions (Surface fluxes) needed by surface models and PBL</td>
</tr>
<tr>
<td>(3) Boundary Layer</td>
<td>Turbulent scale mixing, vertical fluxes</td>
</tr>
<tr>
<td>(4) Microphysics</td>
<td>Grid-resolved clouds, effects of vapor-liquid-ice phase changes</td>
</tr>
<tr>
<td>(5) Radiation</td>
<td>Heating and cooling due to short and long wave radiation</td>
</tr>
<tr>
<td>(6) Cumulus convection (deep &amp; shallow)</td>
<td>temperature, water, momentum changes due to convection too small to be resolved explicitly by grid spacing. reducing the thermodynamic instability</td>
</tr>
<tr>
<td>(7) Gravity wave drag</td>
<td>Impact of sub-grid scale perturbations excited by orography and convection</td>
</tr>
</tbody>
</table>
### HAFS physics schemes

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

• HAFS specifies roughness lengths for momentum ($z_0$) and scalar ($z_f$) as a function of wind to match observed drag coefficients ($C_d$, $C_h$)

• $C_d$ 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.
Comparison with Observations

Wind near RMW
Test results

Two experiments
(1) Max mixing length $L = 300$ vs 200
(2) Physics Suites 1 vs 2

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
$L_{\text{max}} = 300 \text{ vs } 200$

- **Track error**
- **Intensity bias**
- **Pressure bias**

**Graphs:**
- **Track error**
- **Intensity error**
- **Intensity bias**
- **Pressure bias**
Phys suites 1 and 2

Track error

Intensity error

Intensity bias

Pressure bias

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
   ….