Towards Understanding and Parameterizing Cold Pools over tropical Oceans

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An important mechanism for organized convection
- Accelerates transition from shallow-to-deep convection [Khairoutdinov and Randall 2006]
- Deep convection preferentially develops at the edge of cold pool (moist & unstable; forced ascend at gust front) [Tompkins 2001; Lima and Wilson 2008; Boing et al. 2012]

Their effects are not treated in most GCMs

**Why are cold pools important?**

- Tompkins (2001)
- Boing et al. (2012)
Objectives

- Use AMIE/DYNAMO observations to validate high-resolution WRF simulation in correctly representing cold pool statistics.

- Parameterize effects of cold pool by using data from high-resolution simulation.
Observations used:

- S-Pol radar convective cloud statistics and precipitation
- Revelle surface meteorology observations

DYNAMO Field Experiment (October 2011 – March 2012)

Yoneyama et al. (2013)
Real-world simulation in large domain to obtain cold pool statistics

Model Setup

<table>
<thead>
<tr>
<th>Period</th>
<th>Nov 1 – 20, 2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domain</td>
<td>1000 x 500 km</td>
</tr>
<tr>
<td>Horizontal res.</td>
<td>500 m</td>
</tr>
<tr>
<td>Vertical res.</td>
<td>50 m (lowest 1 km)</td>
</tr>
<tr>
<td>Microphysics</td>
<td>Thompson</td>
</tr>
<tr>
<td>Forcing</td>
<td>ERA-I 6-hourly analysis</td>
</tr>
<tr>
<td>PBL</td>
<td>UW</td>
</tr>
<tr>
<td>Surface</td>
<td>MO</td>
</tr>
</tbody>
</table>
Examples of Simulated Cold Pool

- Identify and track individual cold pools using buoyancy
- 2m water vapor: moist anomaly at the edge, dry anomaly in the center
- Enhanced boundary layer vertical velocity at gust front
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Comparison with Revelle Surface Meteorology

- Identify cold pools using the same method
- Model produces comparable changes in temperature, wind speed and LH flux statistics with observations, but have a moist bias
Surface wind gustiness (Zeng et al. 2002) is a result of precipitation driven cold pool, it enhances surface fluxes.

Wind gustiness ($U_g$):

$$U_g = \left( U^2 - U_v^2 \right)^{1/2}$$

\[
\begin{align*}
\text{vector wind}: \\ U_v &= \left( \bar{u}^2 + \bar{v}^2 \right)^{1/2} \\
\text{scalar wind}: \\ U &= \left( u^2 + v^2 \right)^{1/2}
\end{align*}
\]

Parameterize $U_g$ based on CRM simulation.

Wind Gustiness vs. Precipitation (CRM)

$$U_g = \log_{10}(5.203 + 26.688R + 0.781R^2)$$
Impacts of Parameterization on Surface Fluxes

- CRM results show clear relationship of LH & SH flux with precipitation

- Control simulation: (20-km resolution)
  - LH has no sensitivity to precipitation
  - SH sensitivity is lower

- Simulation with parameterized $U_g$ improves SH & LH flux and compares better with CRM
Feedback on Precipitation

- Too much drizzle is a common problem in GCMs (Dai 2006)
- Enhances surface fluxes increases light to moderate rain rate
- But rain rates are still underestimated compared to both CRM and S-Pol
- Next-step: cold pool dynamic effect

Distribution of Rain Rate

S-Pol: derived rain rate
Model: direct rain rate
Identify downdraft and secondary updraft associated with cold pools, average in 100 km box (GCM resolution)

Strong relationship between precipitation, downdraft mass flux at cold pool top, secondary updraft mass flux

Will work on parameterizing this dynamic effect
High-resolution WRF simulation are performed over tropical Indian Ocean during AMIE/DYNAMO, model produced comparable observed precipitation and cold pool statistics.

Cold pool effects on enhancing surface fluxes through wind gustiness are parameterized.

Future work will also parameterize updraft enhancement.

Test parameterizations on climate models.