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Towards Understanding and Parameterizing Cold Pools over tropical Oceans

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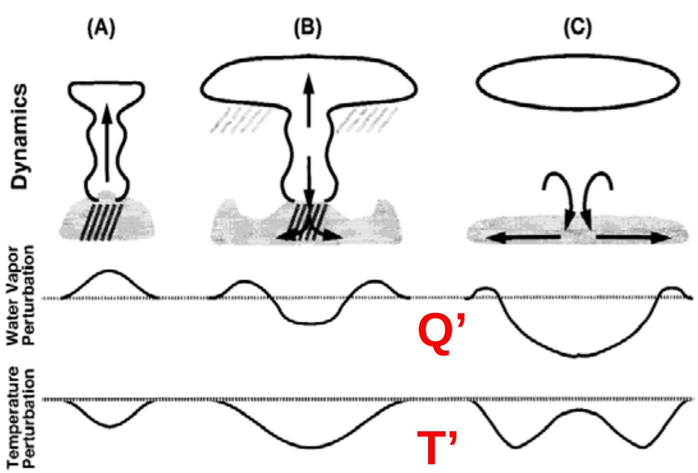
2014 ASR Science Team Meeting

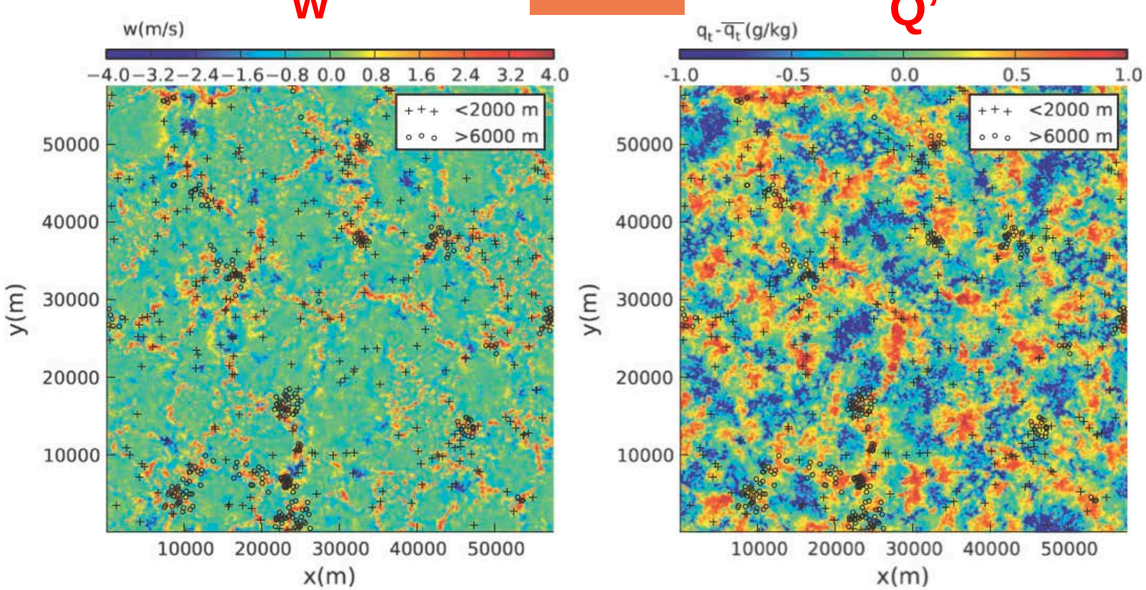
Why are cold pools important?

- **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**

Oceanic



Land



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**

AMIE/DYNAMO Experiment

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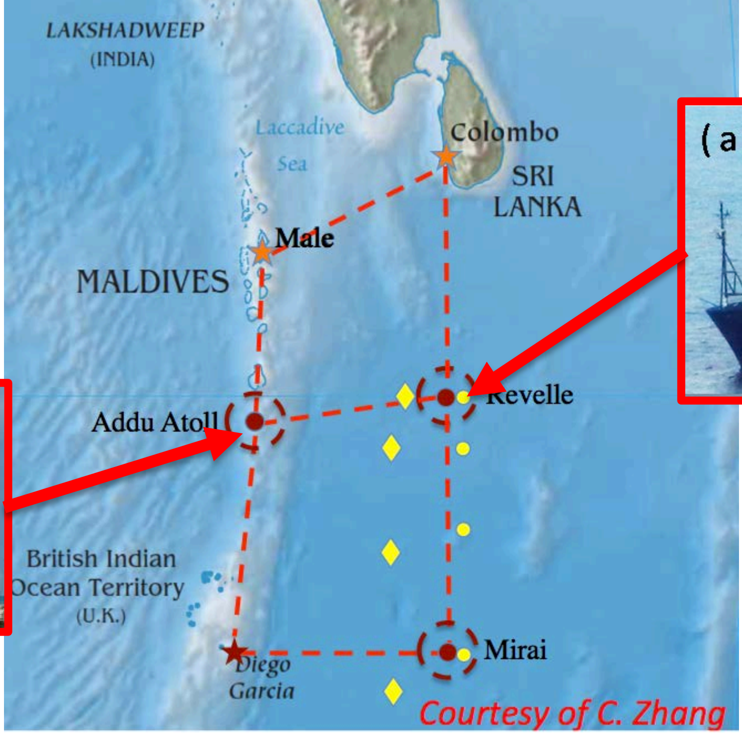
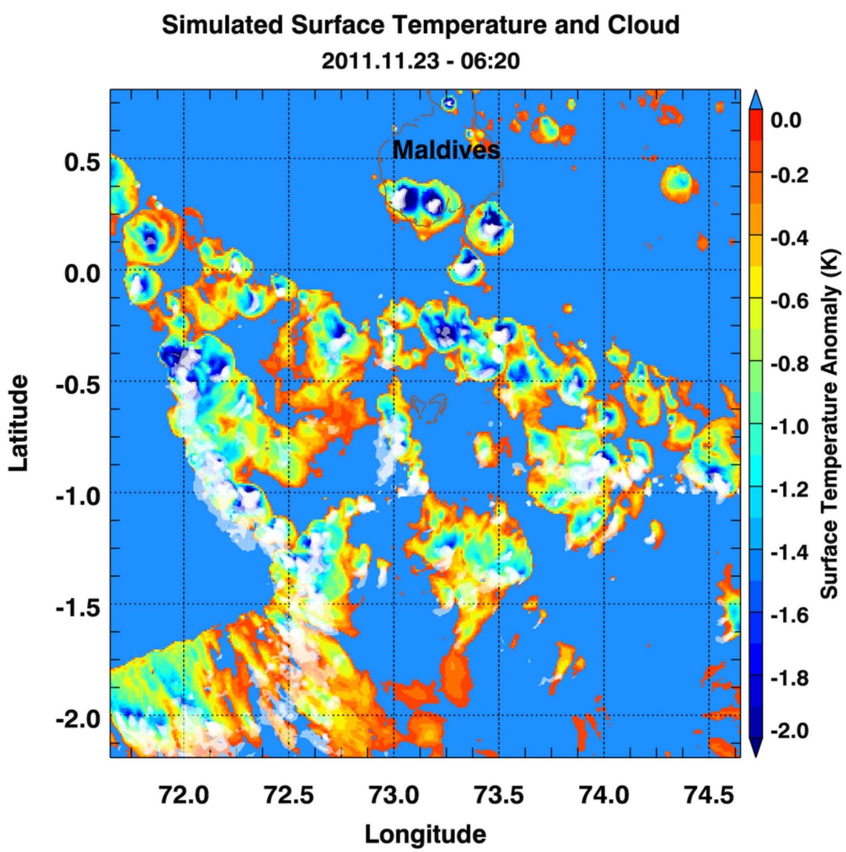
- **Observations used:**
- **S-Pol radar convective cloud statistics and precipitation**
- **Revelle surface meteorology observations**



Yoneyama et al. (2013)

High-res WRF Simulation

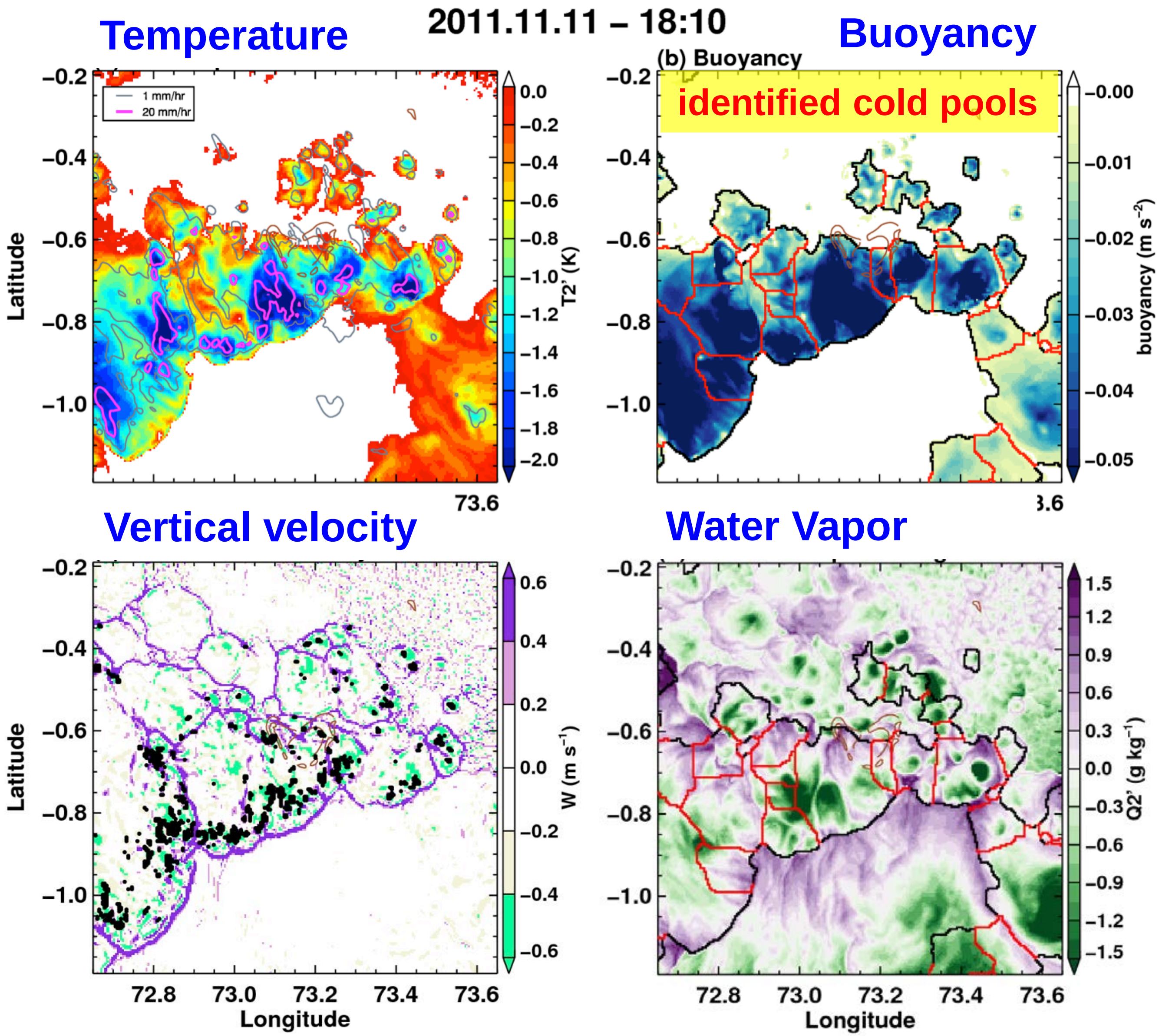
- **Real-world simulation in large domain to obtain cold pool statistics**



	Model Setup
Period	**Nov 1 – 20, 2011**
Domain	**1000 x 500 km**
Horizontal res.	**500 m**
Vertical res.	**50 m (lowest 1 km)** 40 levels
Microphysics	**Thompson**
Forcing	ERA-I 6-hourly analysis
PBL	UW
Surface	MO

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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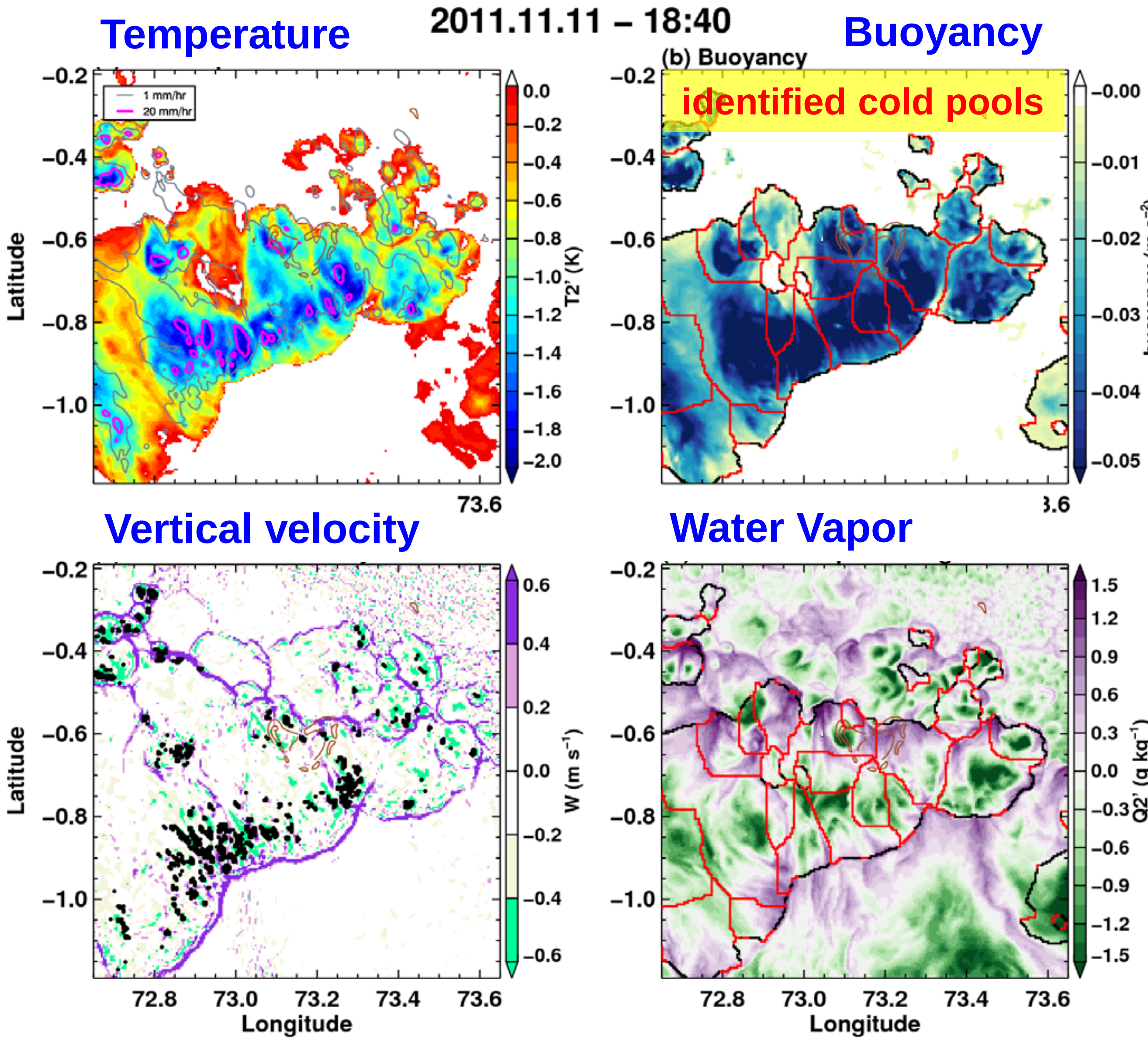
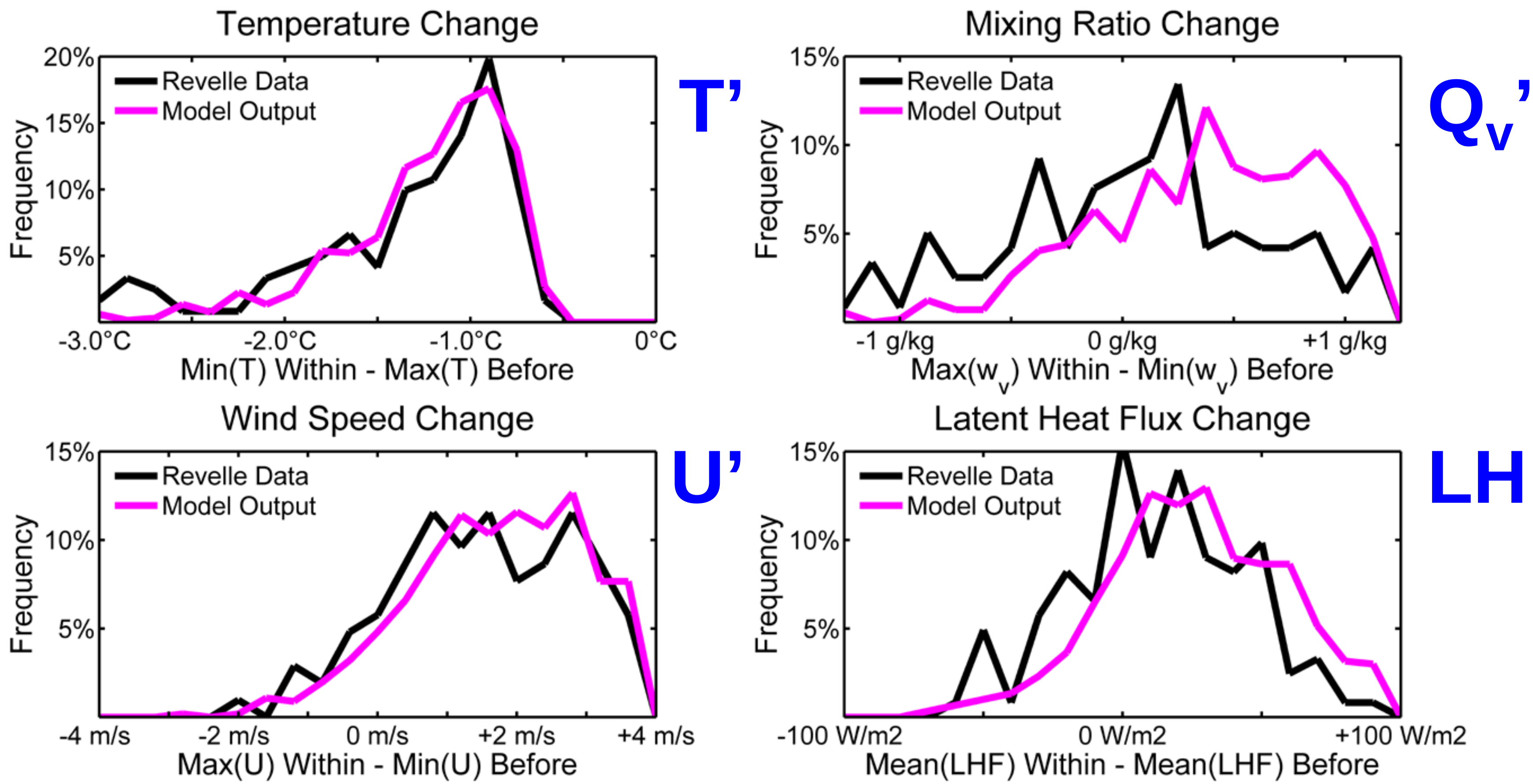


Comparison with Revelle Surface Meteorology



- **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**

Parameterize Cold Pool Effects on Wind Gustiness

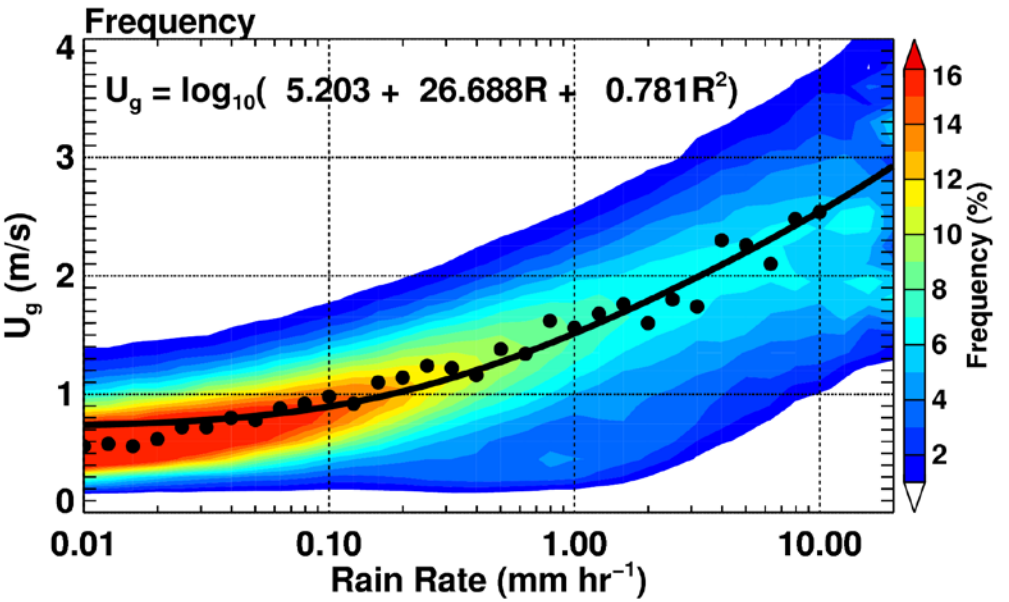
- Surface wind gustiness (Zeng et al. 2002) is a result of precipitation driven cold pool, it enhances surface fluxes
- Wind gustiness (U_g):

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

$$\begin{cases} \textbf{vector wind}: & U_v = \left(\overline{u}^2 + \overline{v}^2\right)^{1/2} \\ \textbf{scalar wind}: & U = \overline{\left(u^2 + v^2\right)^{1/2}} \end{cases}$$

- Parameterize U_g based on CRM simulation

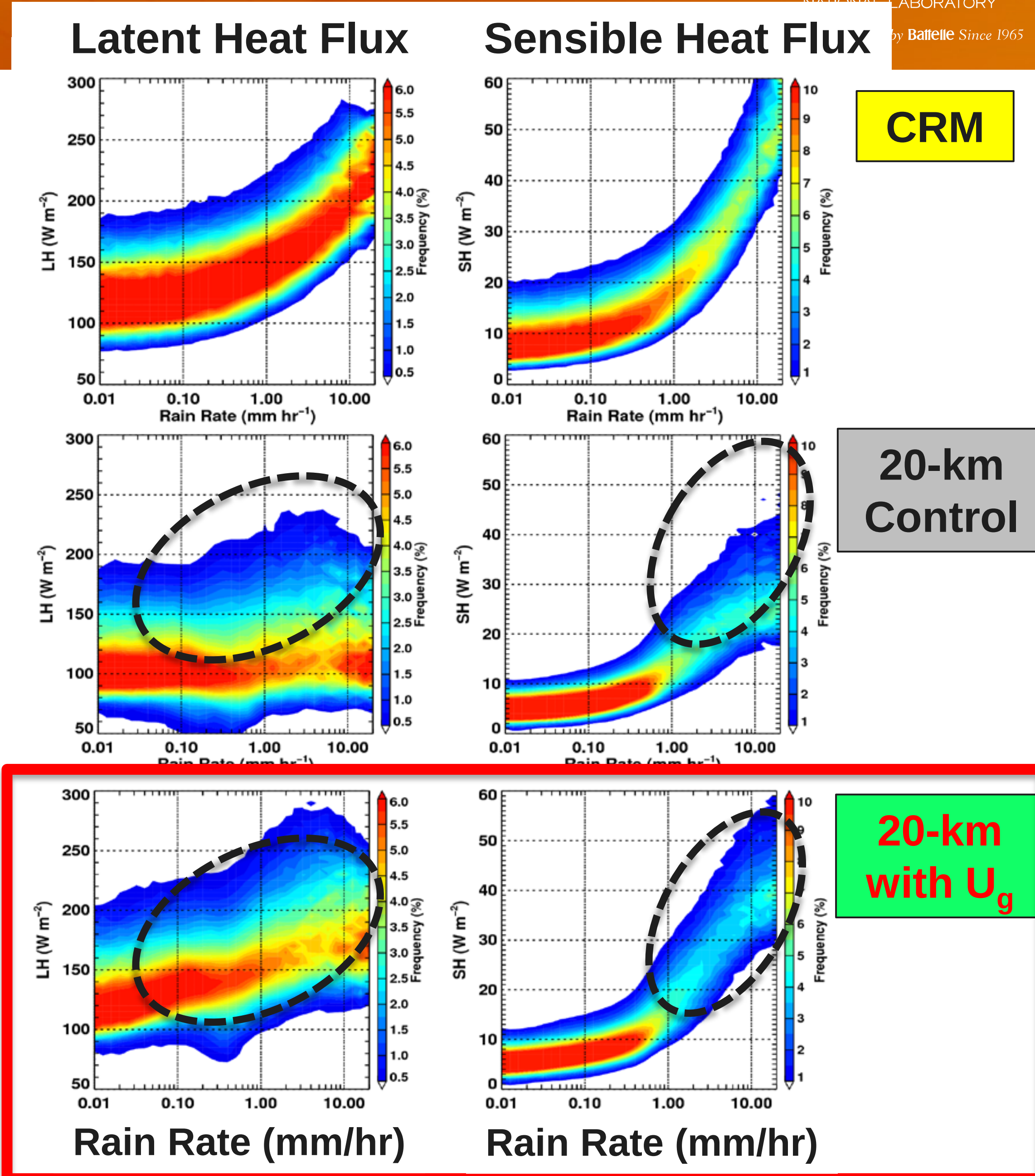
Wind Gustiness vs. Precipitation (CRM)



$$\boxed{U_g = f\left(Rain\right)}$$

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

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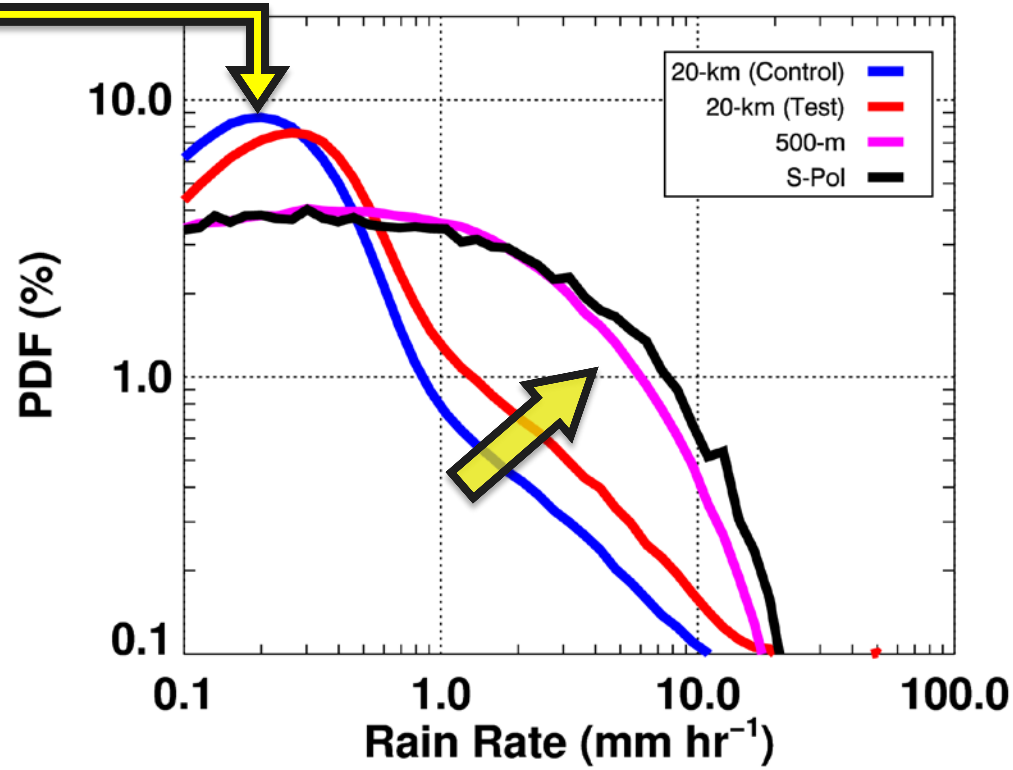
- Too much drizzle is a common problem in GCMs (Dai 2006)
- Enhances surface fluxes increases light to moderate rain rate
- But rain rates are still underestimated compared to both CRM and S-Pol
- Next-step: cold pool dynamic effect

Distribution of Rain Rate



S-Pol: derived rain rate
Model: direct rain rate

Cold Pool Effects on Secondary Updraft

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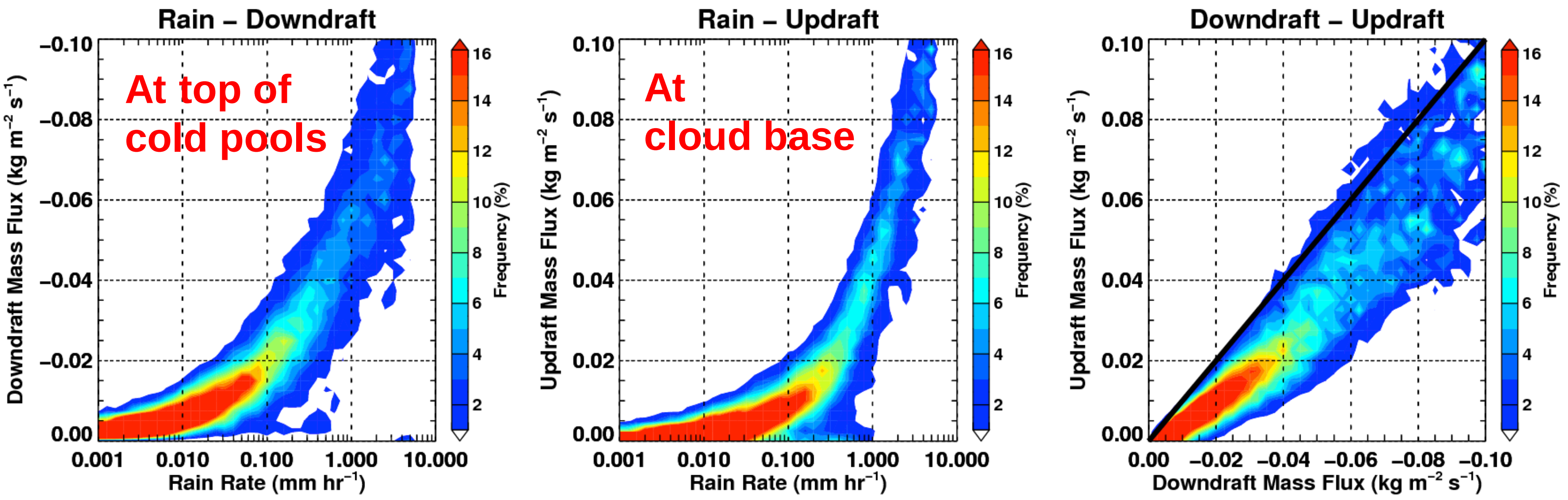

- Identify downdraft and secondary updraft associated with cold pools, average in 100 km box (GCM resolution)
- Strong relationship between precipitation, downdraft mass flux at cold pool top, secondary updraft mass flux
- Will work on parameterizing this dynamic effect

Summary

- 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