The Cold Pool Model Intercomparison Project (CP-MIP)

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Objectives

- Characterize differences in simulated cold pools across models,
- Identify the underlying causes,
- Evaluate simulated cold pools with observations from the EUREC⁴A field campaign and the Barbados Cloud Observatory,
- Improve the representation of cold pools in simulations.

First set of models

SAM: System for Atmospheric Modeling (Khairoutdinov and Randall, 2003), two-moment cloud microphysics (Feingold et al., 1998). We nudge the total particle number to maintain a cloud drop number of 400 cm^{-3}.

MONC: Met Office/NERC Cloud Model (Brown et al., 2015), two-moment cloud microphysics (CASIM, Field et al., 2023). We fix the cloud drop number at 490 cm^{-3}.

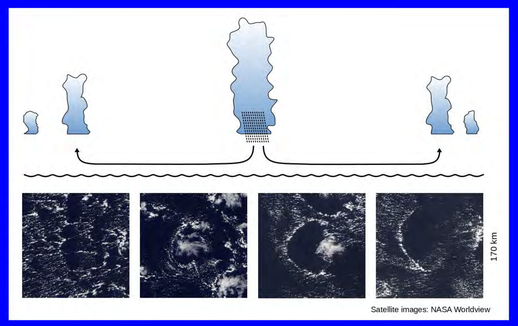
MicroHH: van Heerwaarden et al. (2017), two-moment cloud microphysics (Seifert and Beheng, 2001). We fix the cloud drop number at 400 cm^{-3}.

Simulations

We give a first survey of trade cumulus cold pools simulated by select models in the EUREC⁴A Lagrangian Model Intercomparison (Raghunathan et al., poster A33P-2762). The simulations are forced with ERA5 reanalysis meteorology and sea surface temperature. They run along trajectories that follow the boundary layer wind towards Barbados.

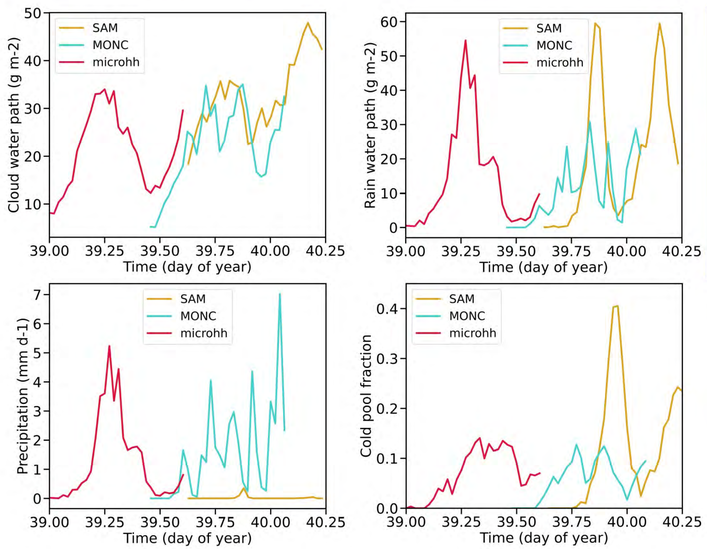
Cold pools

Atmospheric cold pools are created by precipitating downdrafts. Over the oceans, cold pools appear as cloud-free regions of tens to hundreds of kilometers in size, which last for hours. The occurrence, Fractional coverage, and the evolution of cold pools across the diurnal cycle modulate surface shortwave radiative heating.



Cold pool evolution

Timing and amount of surface precipitation and the cold pool fraction differ between models. SAM produces larger cold pools and less surface precipitation than MONC and MicroHH. This suggests that different rates of rain evaporation in the models cause different strengths of precipitating downdrafts, and hence smaller or larger cold pools.

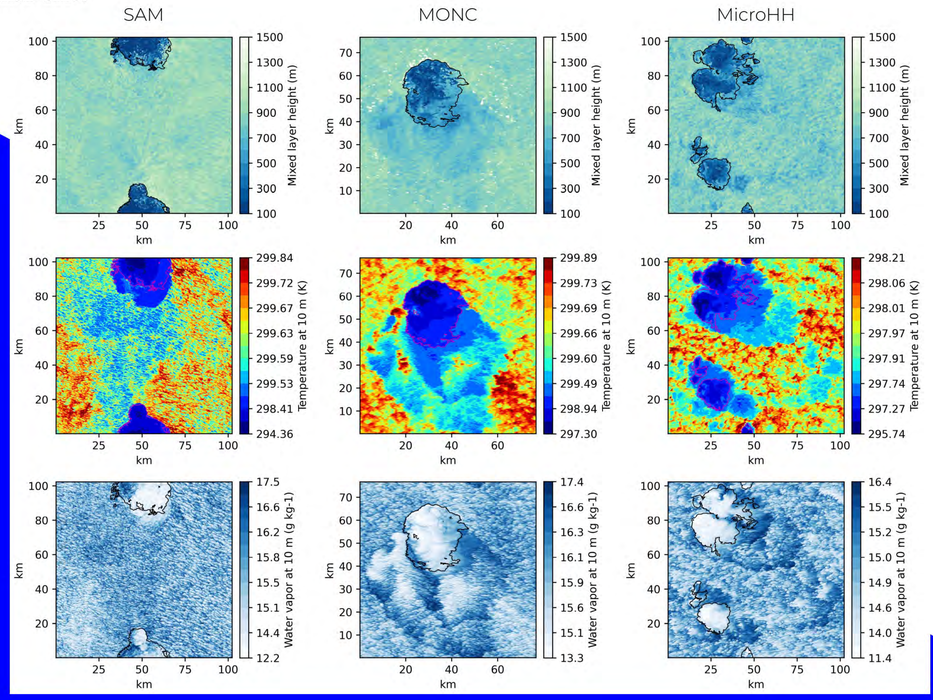


Cold pool detection

We define cold pools as

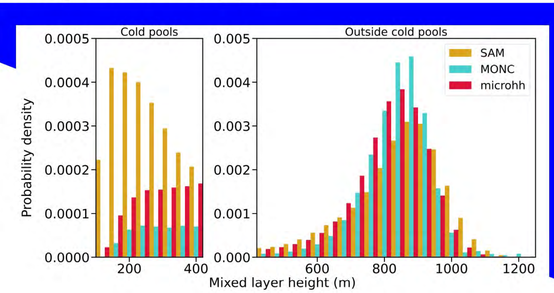
- connected regions with a mixed layer height ≤ 400 m,
- with an area larger than 1 km^2,
- which are extended with locations where the virtual potential temperature $\theta_v \leq \mathrm{mean}(\theta_v) - \mathrm{std}(\theta_v)$.

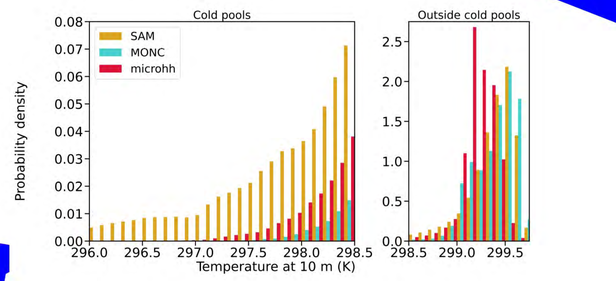
The mixed layer height is calculated with the method of Touzé-Peiffer et al. (2022). Contours indicate cold pools in the following snapshots that were taken when the simulated cold pools have similar size:

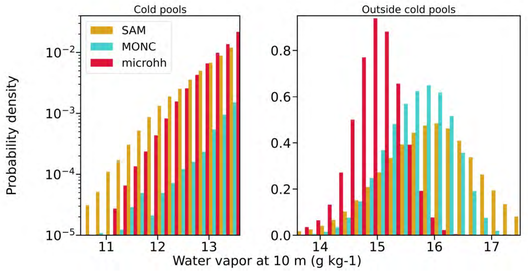


Cold pool properties

Probability distributions of cold pool properties were constructed from 15 hours of the simulations, starting at the formation of cold pools in each simulation. SAM produces the coldest, driest, and the flattest cold pools. The models produce a similar mixed layer height outside cold pools.







What's next?

- Include more models and more cold pools
- Further develop cold pool diagnostics: quantify the growth and decay rate of cold pools, and study their life cycle across models
- Compare the horizontal structure of cold pools across models, in particular the spatial distribution of water vapor
- Evaluate simulated cold pools with observations from the EUREC⁴A field campaign and the Barbados Cloud Observatory

Open questions

- How can we tie differences in cold pool properties between models to specifics of the model formulation?