Cold Pool Analysis from the Cold Pool Model Intercomparison Project (CP-MIP)

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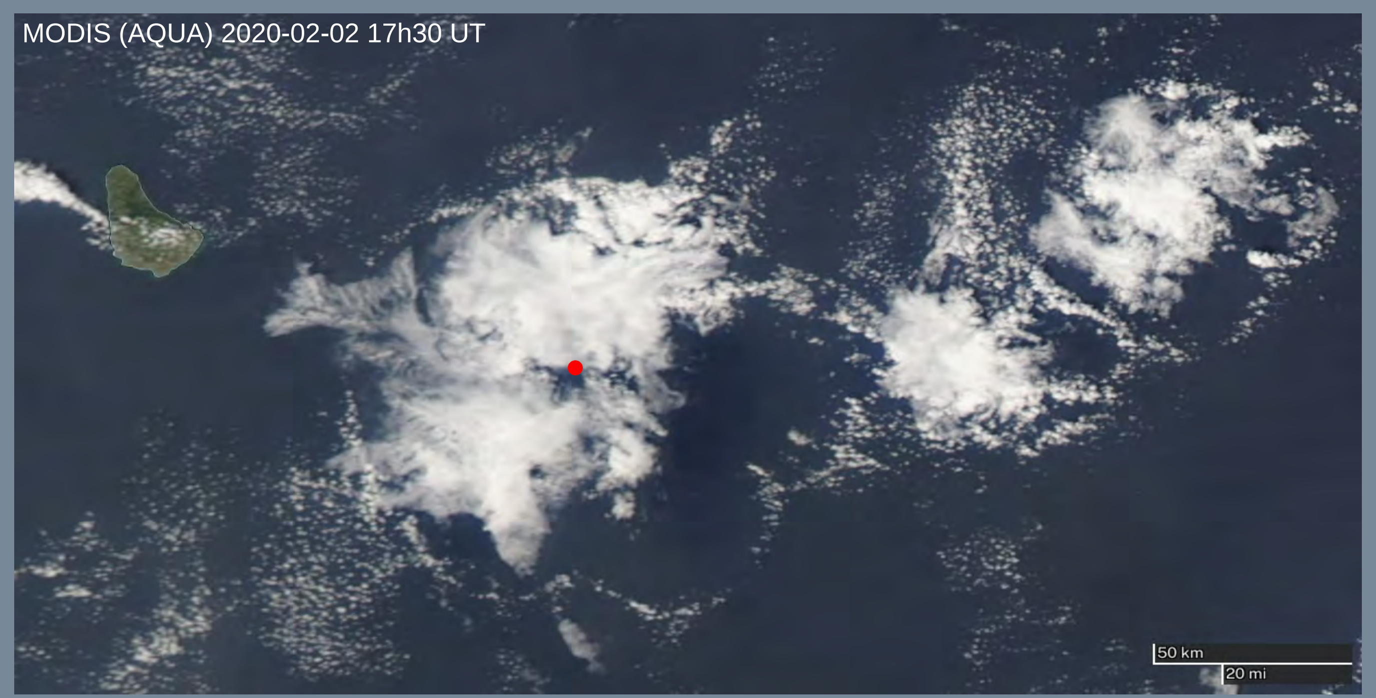
The Project

- CP-MIP identifies, characterizes, and quantifies:
  - Differences between models in the representation of cold pools
  - Biases relative to observations
- This poster shows simulations of a cold pool that forms underneath a "Flower" type shallow cumulus cloud
- The Flower cloud and its cold pool formed on February 2 2020, near Barbados, in the region sampled by the EUREC^{4}A and ATOMIC field campaigns

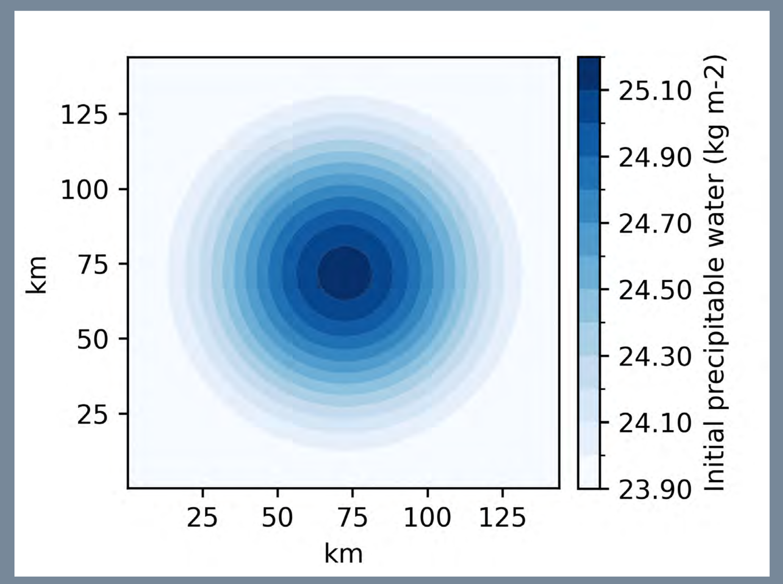


Simulations

- Domain moves along an ERA5 500 m ASL wind speed trajectory
- The trajectory runs through ● 12.75 °N, -58.5 °E on 2020-02-02, 17h00 UT
- Domain: 144 × 144 × 7 km^3
- Duration: 2020-02-01, 16h00m00s - 2020-02-02, 18h00m00s UT
- dt = 2 s, dx = dy = 150 m, dz = 40 m 0–5 km, 19 geometric levels 5–7 km
- Periodic boundary conditions
- Forcing:
  - ERA5 geostrophic wind and subsidence
  - ERA5 horizontal advective tendencies of temperature and moisture
  - ERA5 sea surface temperature
  - Interactive surface fluxes of sensible heat, latent heat, and momentum

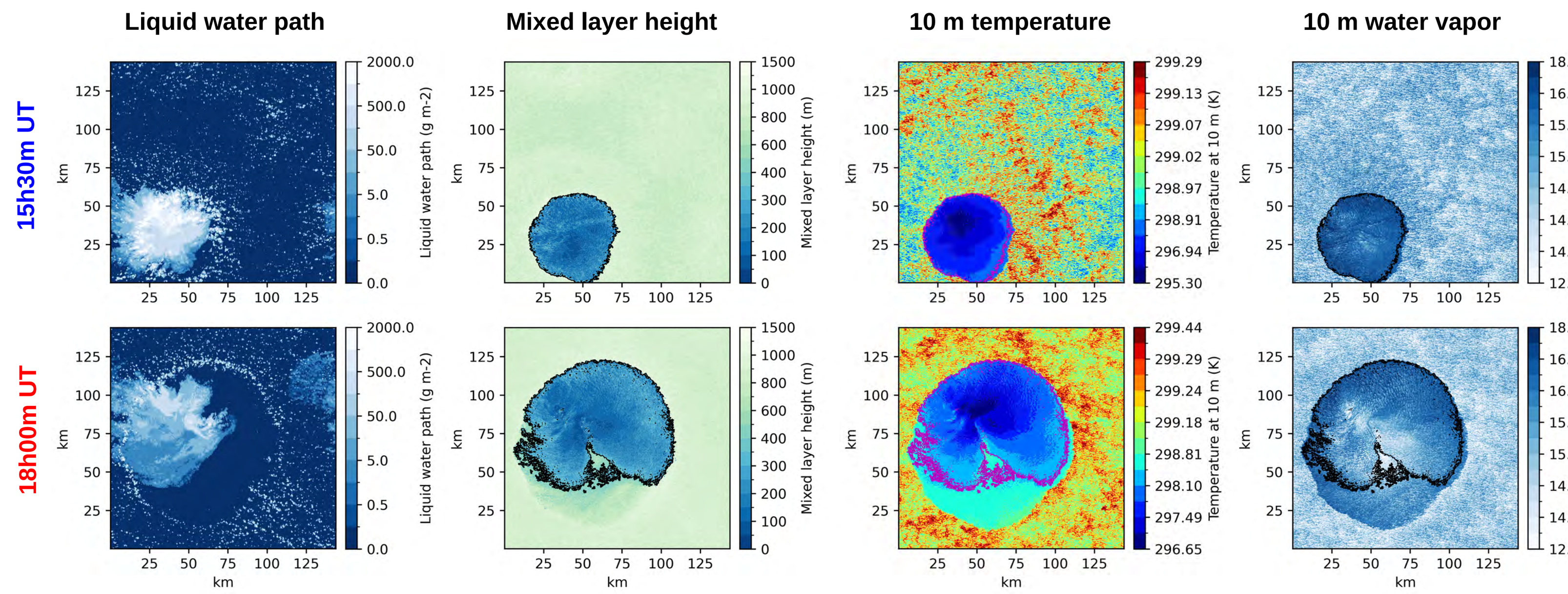
Initialization

- Aerosol number: 400 mg^{-1} in the boundary layer
- Cylindrical water vapor anomaly in the boundary layer, amplitude = 1 g kg^{-1}.
  - Mimics mesoscale moisture accumulation that would occur had the simulations been initialized 1–2 days earlier.
  - Mesoscale moisture anomalies give rise to the formation of Flower-type trade cumulus clouds and thus to cold pools
  - Advantages:
    - The simulations need not to be initialized 1–2 days earlier,
    - All simulations start out with the same mesoscale moisture anomaly



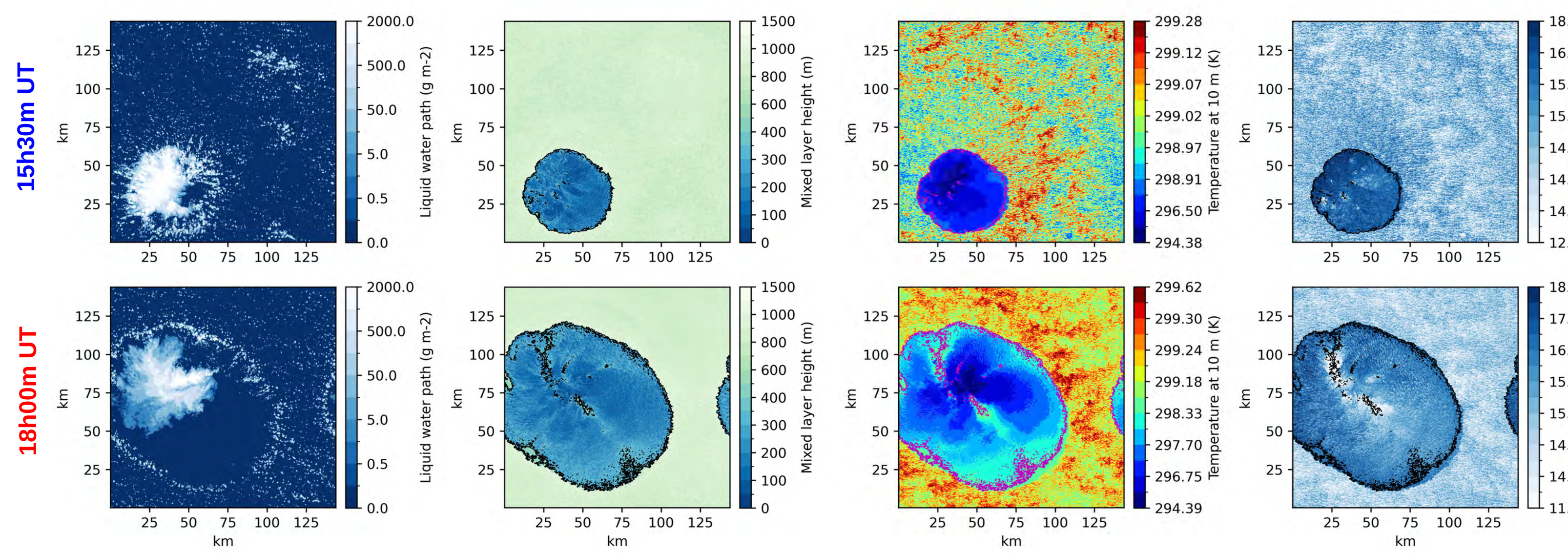
SAM (bin)

- System for Atmospheric Modeling (Khairoutdinov and Randall, 2003)
- 2-moment bin microphysics (Feingold et al., 1996, Tzivion et al., 1987)
- Prognostic aerosol/cloud/rain drop numbers



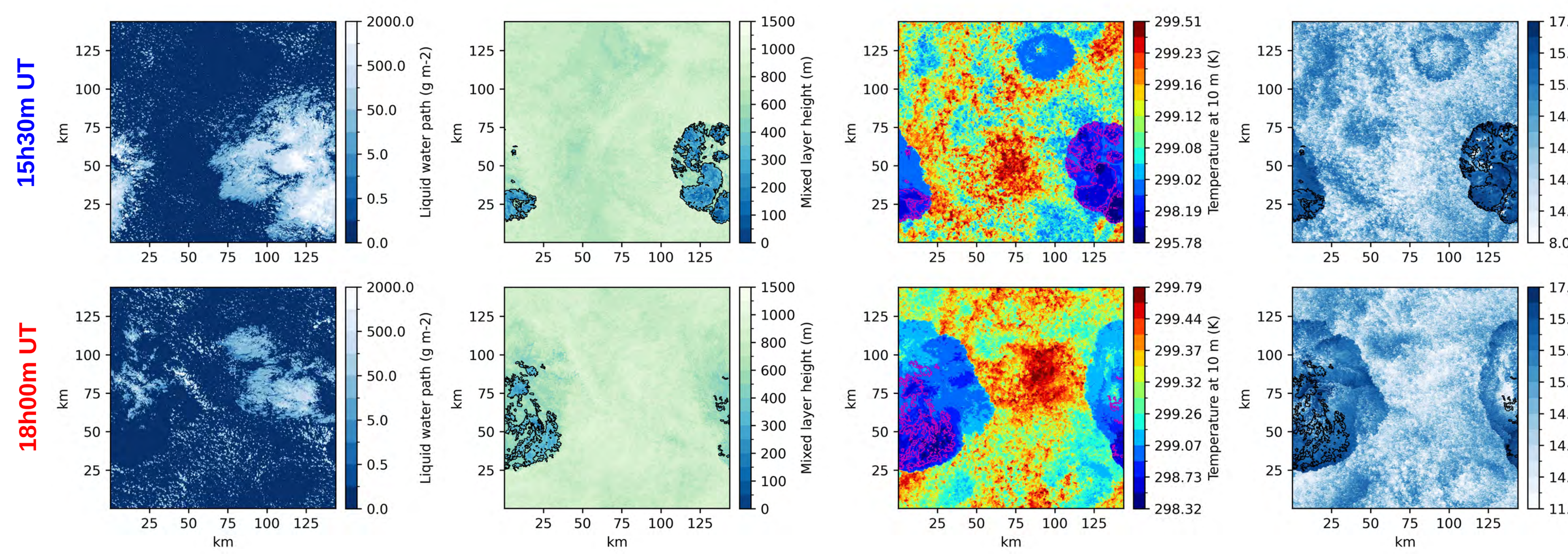
SAM (bulk)

- System for Atmospheric Modeling (Khairoutdinov and Randall, 2003)
- 2-moment bin-emulating bulk microphysics (Feingold et al., 1998; Wang and Feingold, 2009a, 2009b; Yamaguchi et al., 2017)
- Prognostic aerosol/cloud/rain drop numbers



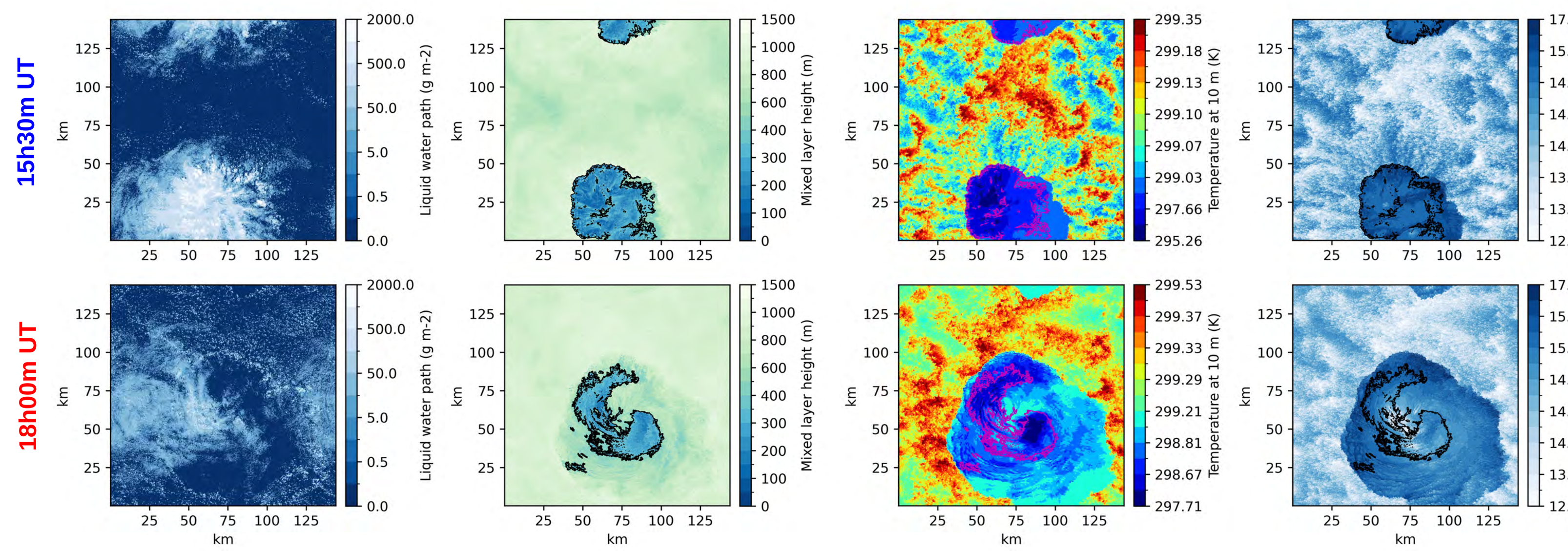
MicroHH

- GPU-enabled LES model (Van Heerwaarden et al., 2017)
- 2-moment bulk microphysics (Seifert and Beheng, 2006)
- Fixed cloud drop number



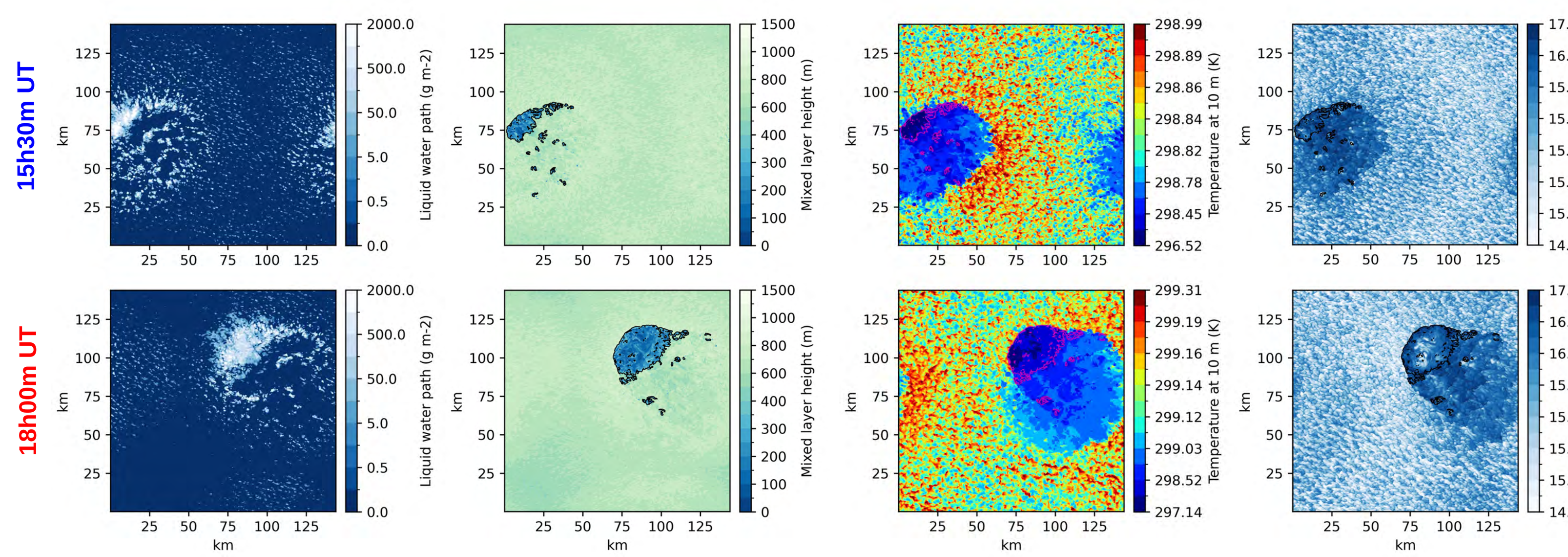
DALES

- Dutch Atmosphere Large Eddy Simulation (Heus et al., 2010)
- 2-moment bulk microphysics (Seifert and Beheng, 2006)
- Fixed cloud drop number



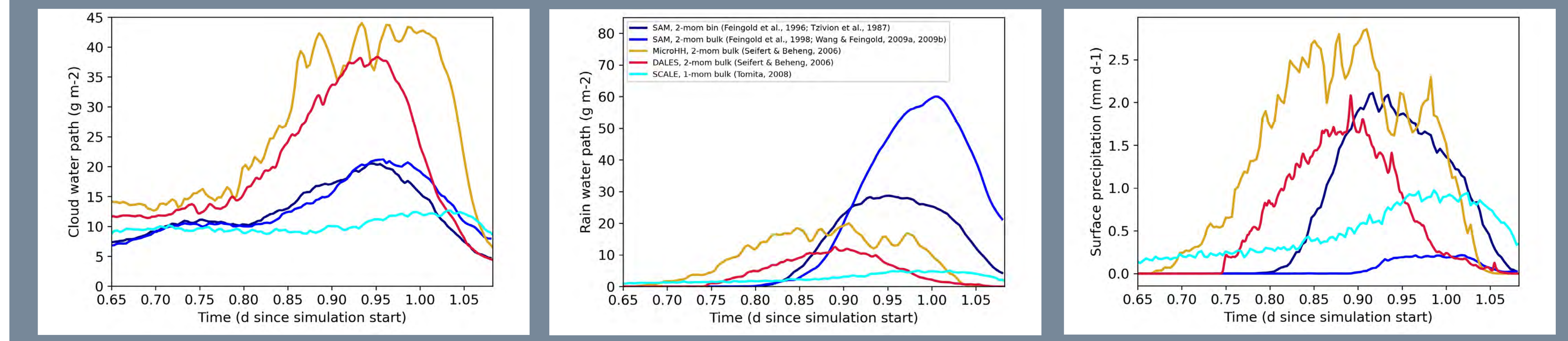
SCALE

- Scalable Computing for Advanced Library and Environment (SCALE) library LES (Sato et al., 2015)
- 1-moment bulk scheme (Tomita, 2008)
- Fixed cloud drop number

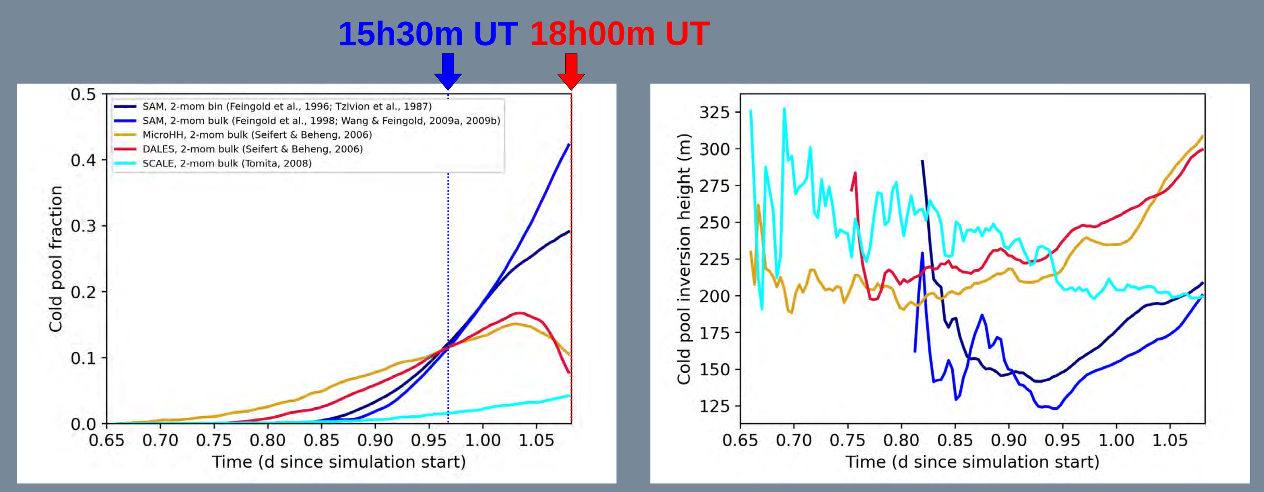


Evolution of Cold Pool Properties

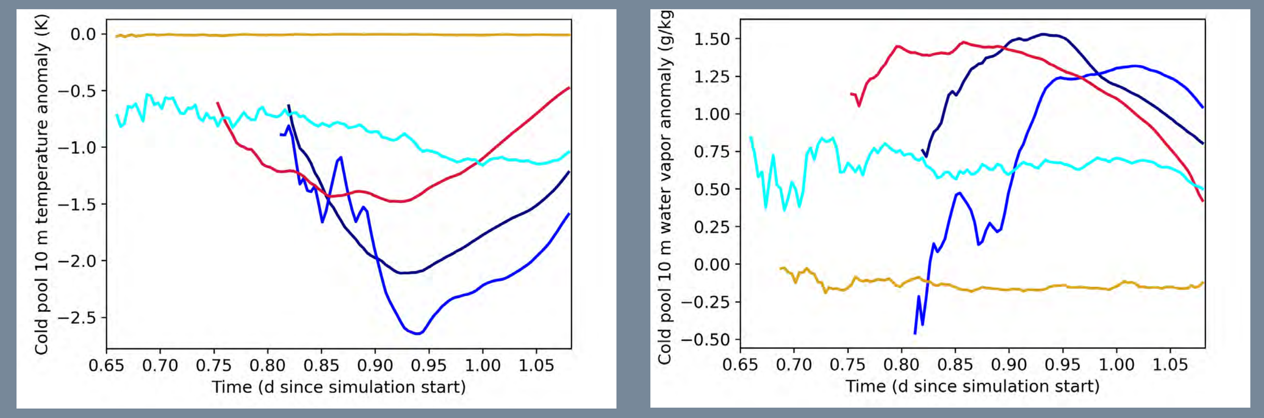
- MicroHH and DALES, with the same cloud microphysics scheme, produce similar cloud water path, rain water path, and surface precipitation, as well as similar timing in these quantities.
- SAM produces a nearly identical cloud water path with the bin and bulk microphysics. Yet, the bulk microphysics gives a high rain water path with low surface precipitation. This is the result of rapid sub-cloud evaporation of rain in the bulk scheme.
- SCALE's single-moment microphysics produces the lowest values of cloud water path, rain water path, but with still appreciable surface precipitation.



- The results separate into three groups based on the model cloud microphysics when considering the cold pool fraction and cold pool inversion height:
  - SAM (bin and bulk 2-moment microphysics) – with the caveat that the bulk microphysics produces the largest cold pool fraction towards the end of the simulation, as a result of its strong sub-cloud rain evaporation and associated surface layer cooling
  - MicroHH and DALES (2-moment bulk microphysics, Seifert and Beheng, 2006)
  - SCALE (1-moment bulk microphysics, Tomita, 2008)



- No obvious grouping appears when considering the surface layer temperature and water vapor anomalies. This is in part caused by a disagreement between the temperature and water vapor anomaly extent and cold pool extent defined based on the mixed layer height. Cold pools are defined based on a mixed layer height ≤ 400 m following Touzé-Peiffer et al. (2022), denoted by black or magenta contours in the spatial plots (poster center panel).



Next Steps

- Compare
  - probability density functions of 10 m temperature and water vapor anomalies, mixed layer height
- Evaluate
  - Cold pool definition based on mixed layer height and on 10 m temperature anomaly
  - Dynamical quantities, such as horizontal wind speed and divergence inside cold pools, and vertical velocity along the cold pool periphery
  - Cold pool dissipation, in terms of surface layer temperature and water vapor recovery
- Include results from the ICON model (Giorgetta et al., 2018)