Observed and simulated changes in the effects of cloud pools on cloud organization with the Madden-Julian Oscillation

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ARM/ASR Joint User Facility/PI Meeting

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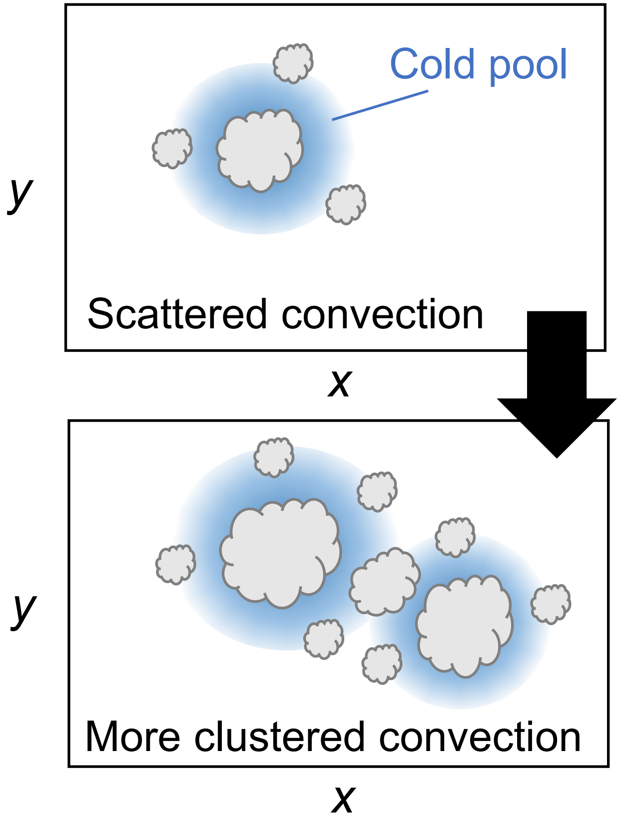
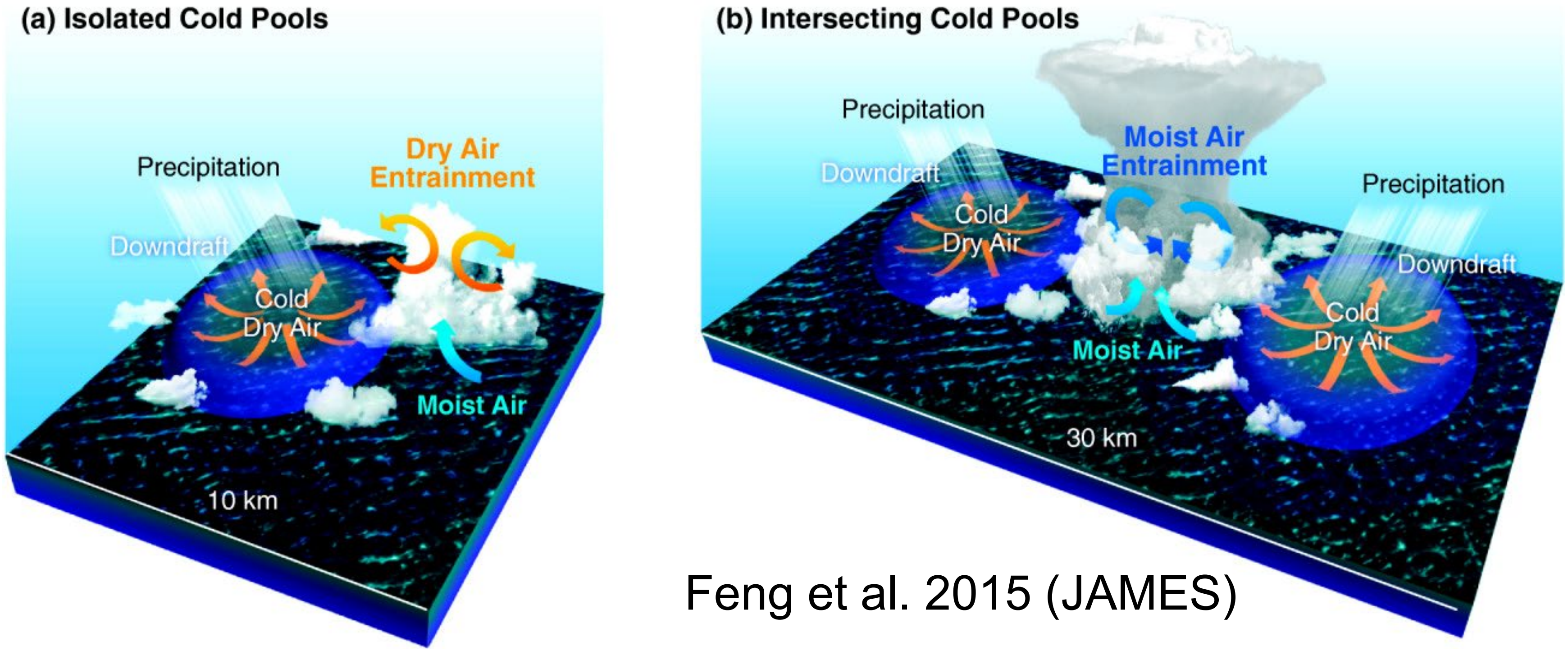
ASR Atmospheric System Research

Suggested Effects of Cold Pools on Cloud Organization



Over Warm Tropical Ocean

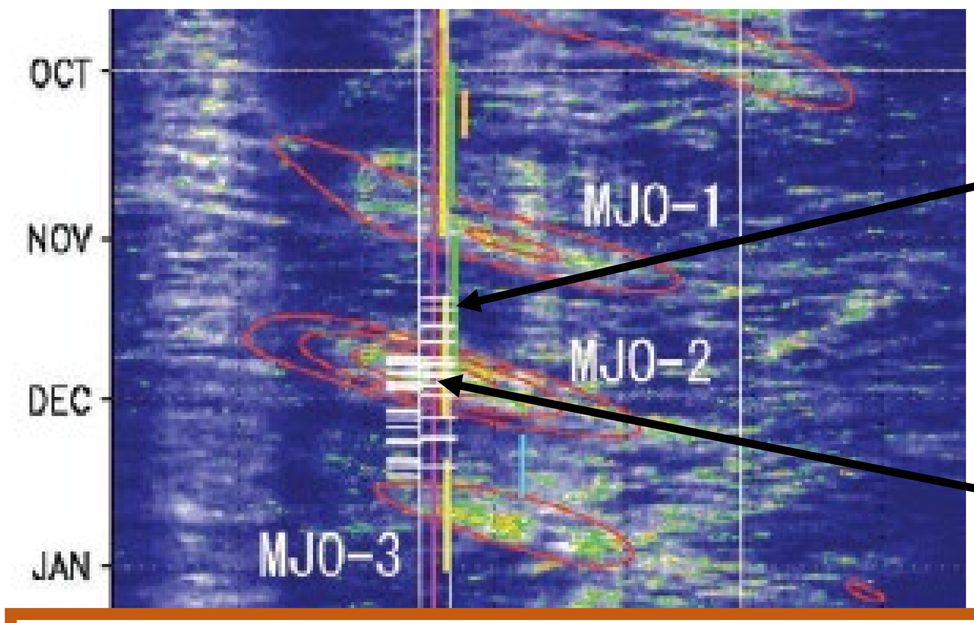


Feng et al. 2015 (JAMES)

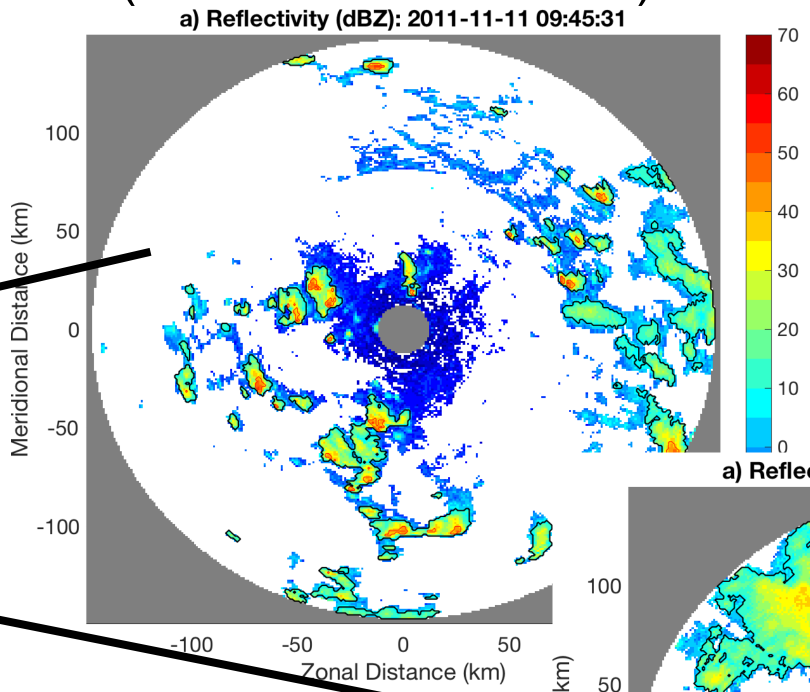
- Cold pools are thought to lead to the clustering (organization) of clouds by triggering new clouds nearby existing clouds (e.g., Feng et al. 2015, Rowe et al. 2015).
- However, some studies suggest that gravity waves are more important to cloud organization over warm tropical ocean (e.g., Grant et al. 2018).

Cloud Organization Changes with the Madden-Julian Oscillation

Time-Longitude 10°N-10°S Precipitation (Yoneyama et al. 2013)

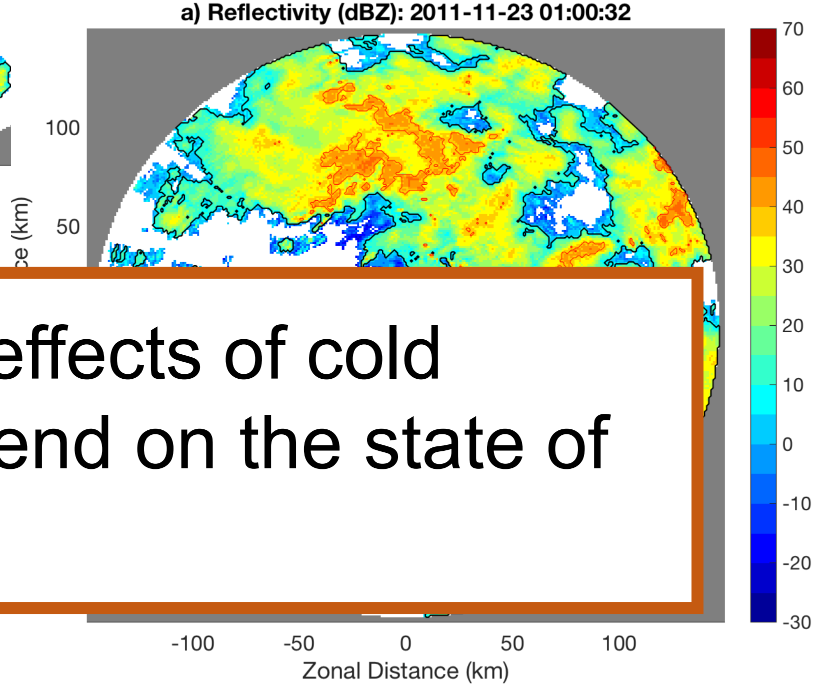


MJO Suppressed Phase (Scattered convection)



During DYNAMO/AMIE field campaign

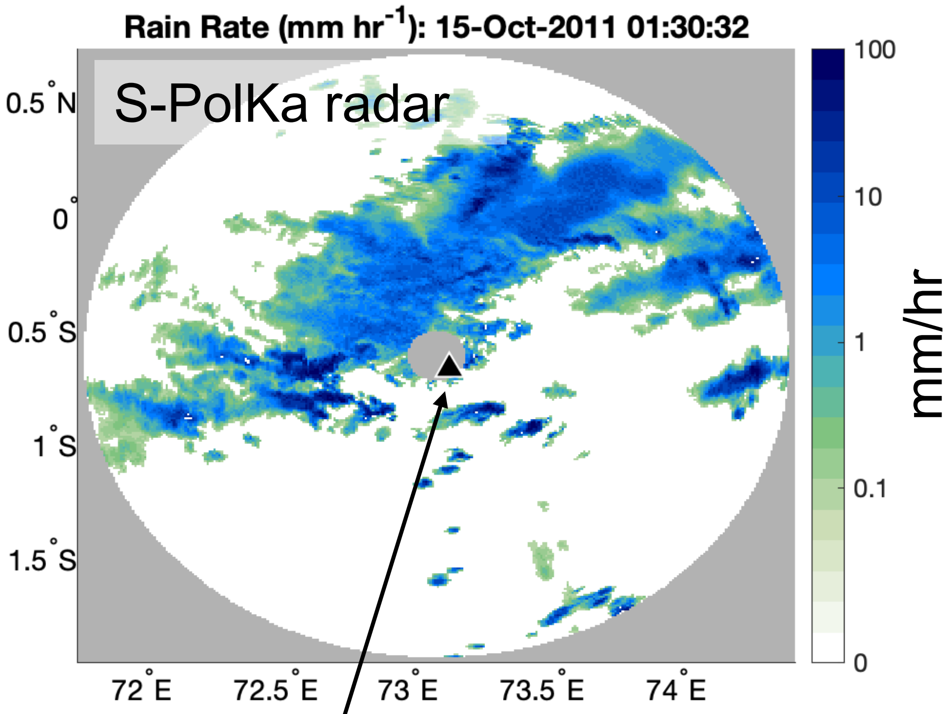
MJO Enhanced Phase (Organized convection)

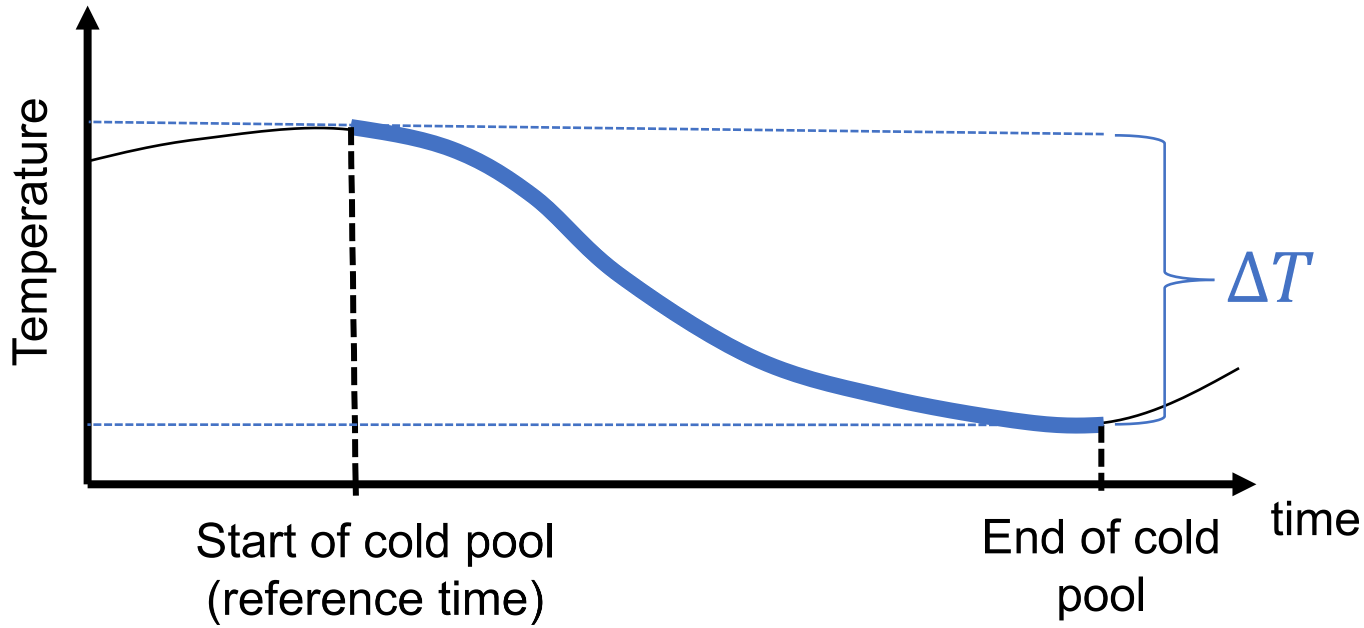


Research Question: What are the observed effects of cold pools on cloud organization? How does it depend on the state of the MJO?

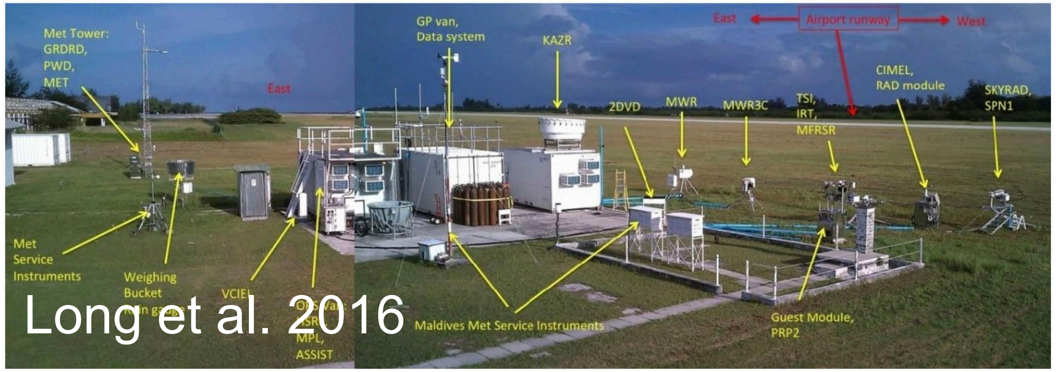
Location of S-PolKa radar

Identification of Observed Cold Pools during DYNAMO/AMIE



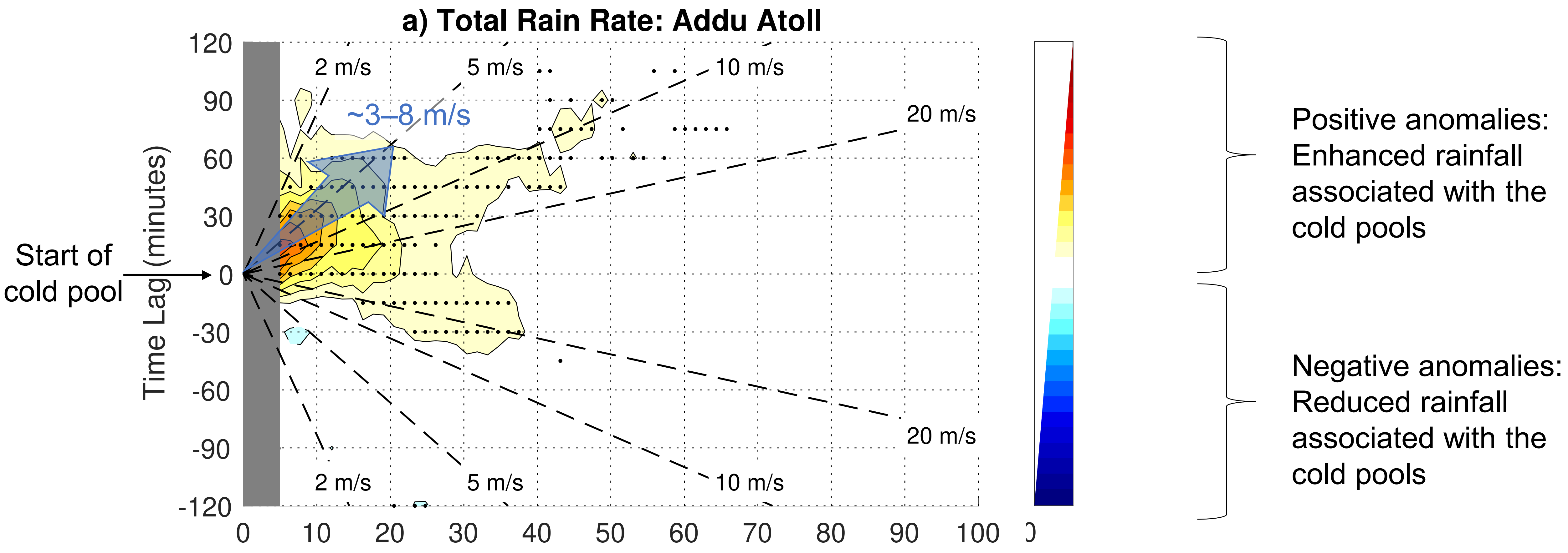


AMF-2 Surface Meteorology Data



- Study period: Oct 2011 – Jan 2012
- We follow the method of de Szoeke et al. 2017 after removing the diurnal cycle of temperature.
- Temperature drops that exceeds a selected threshold were identified as “cold pools” (sample size > 500).

Evidence of Rainfall Triggering by Cold Pools



- Two separate propagation speeds are identified (including the effects of ~5 m/s background winds)
  - 3–8 m/s (slow) propagation: likely cold pools
  - 10–20 m/s (faster) propagation: gravity waves or “gust front” waves (Tulich and Mapes 2008)

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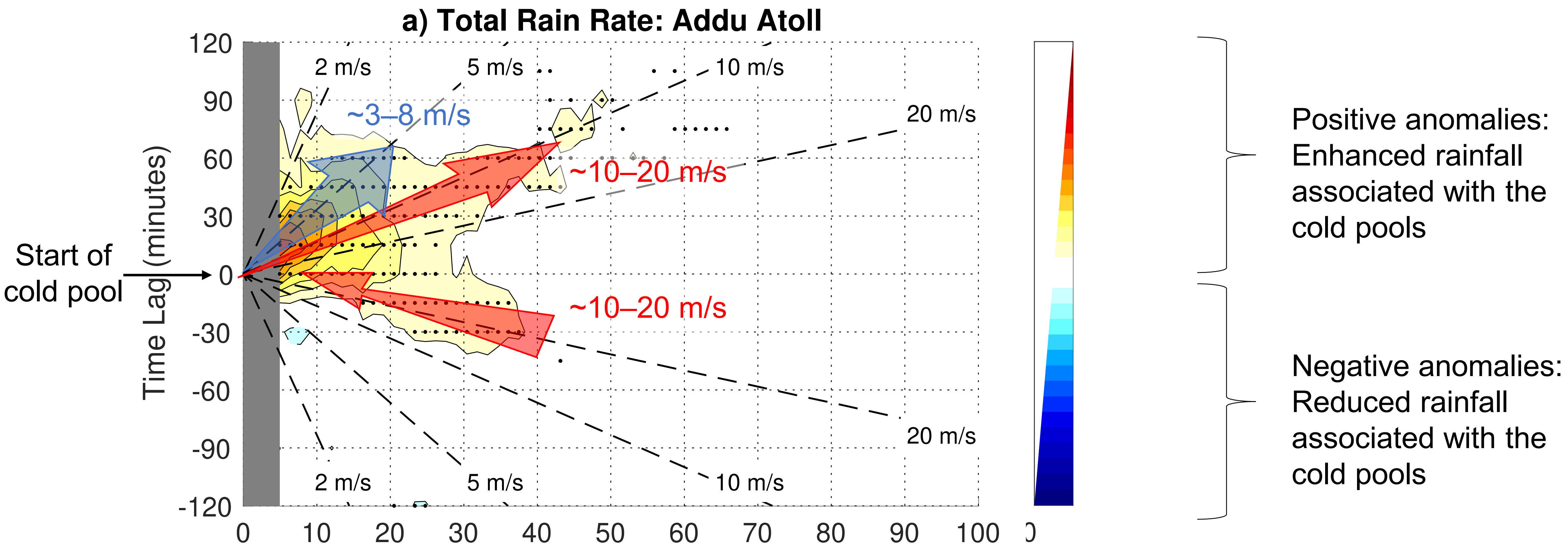

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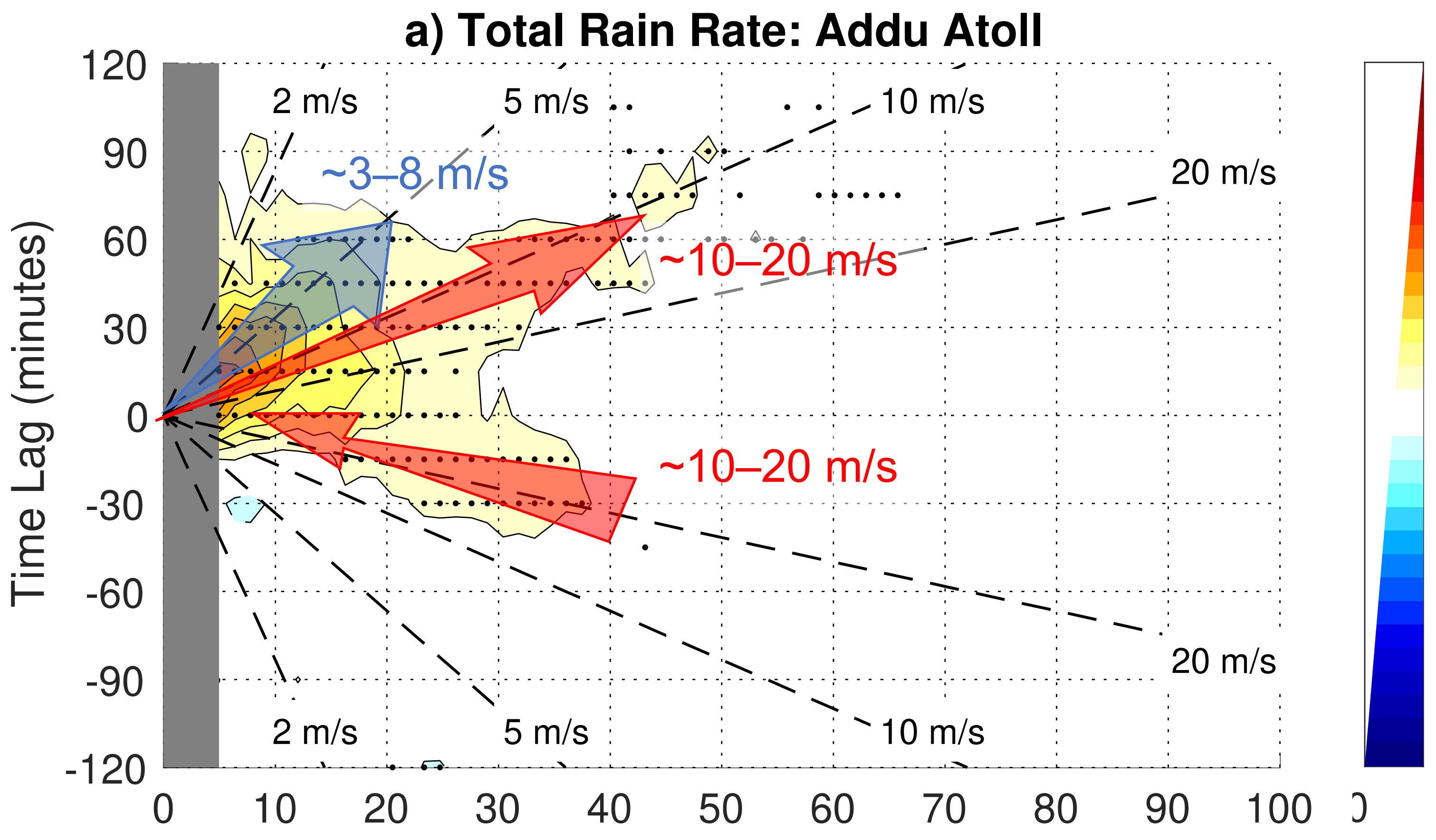

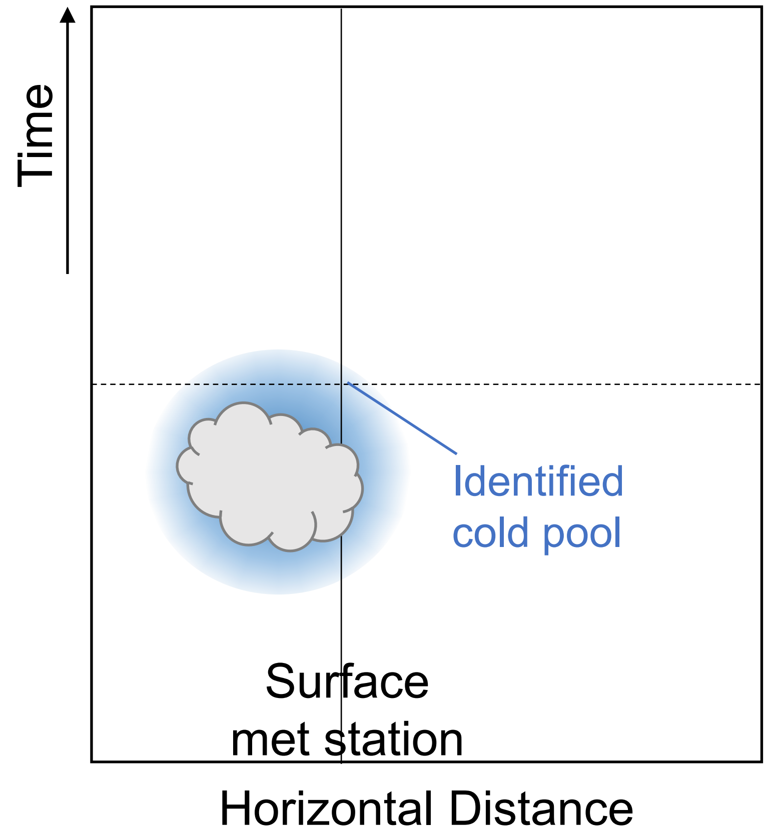

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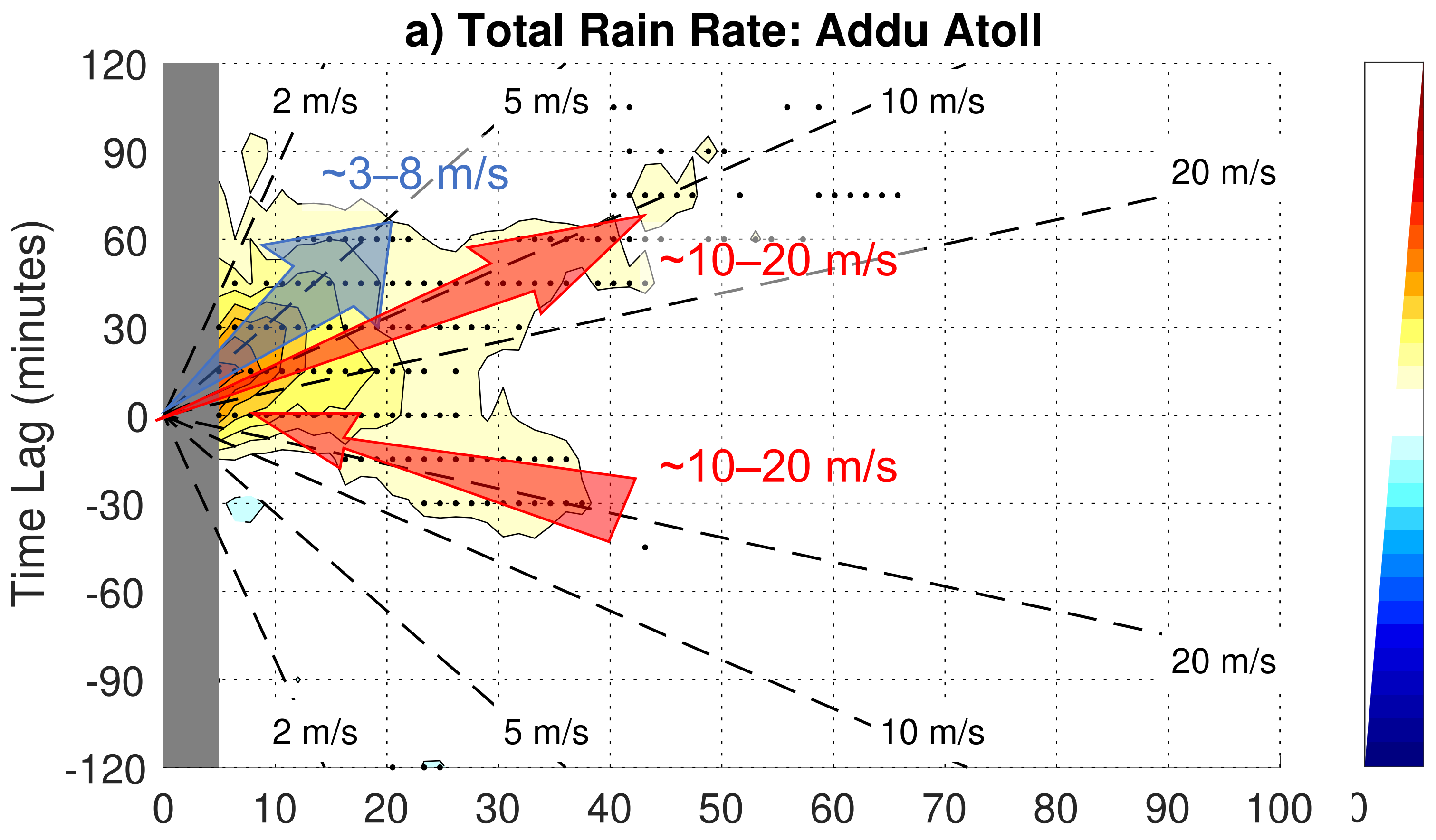
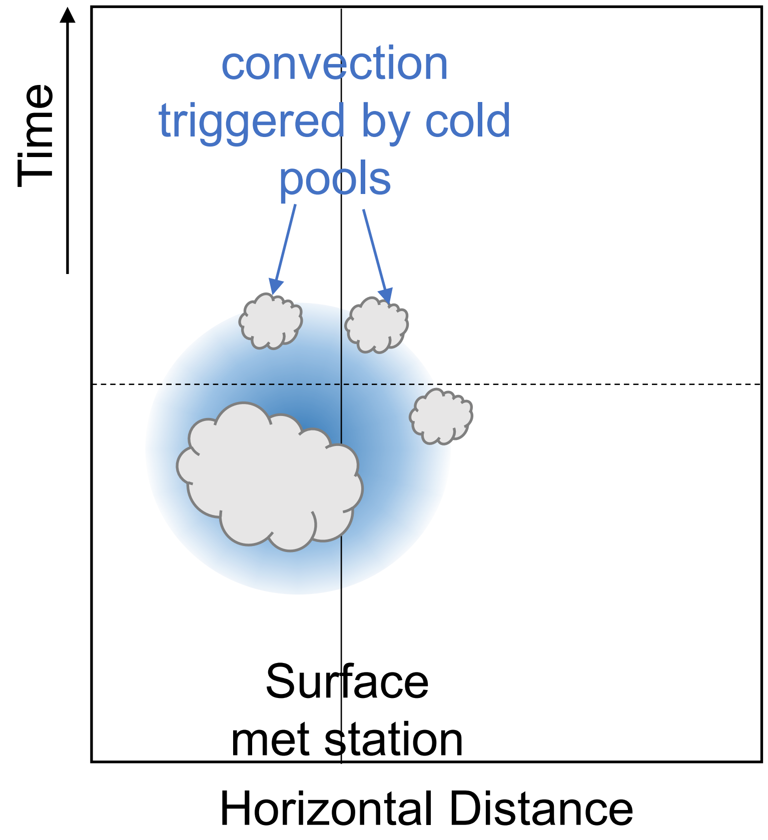
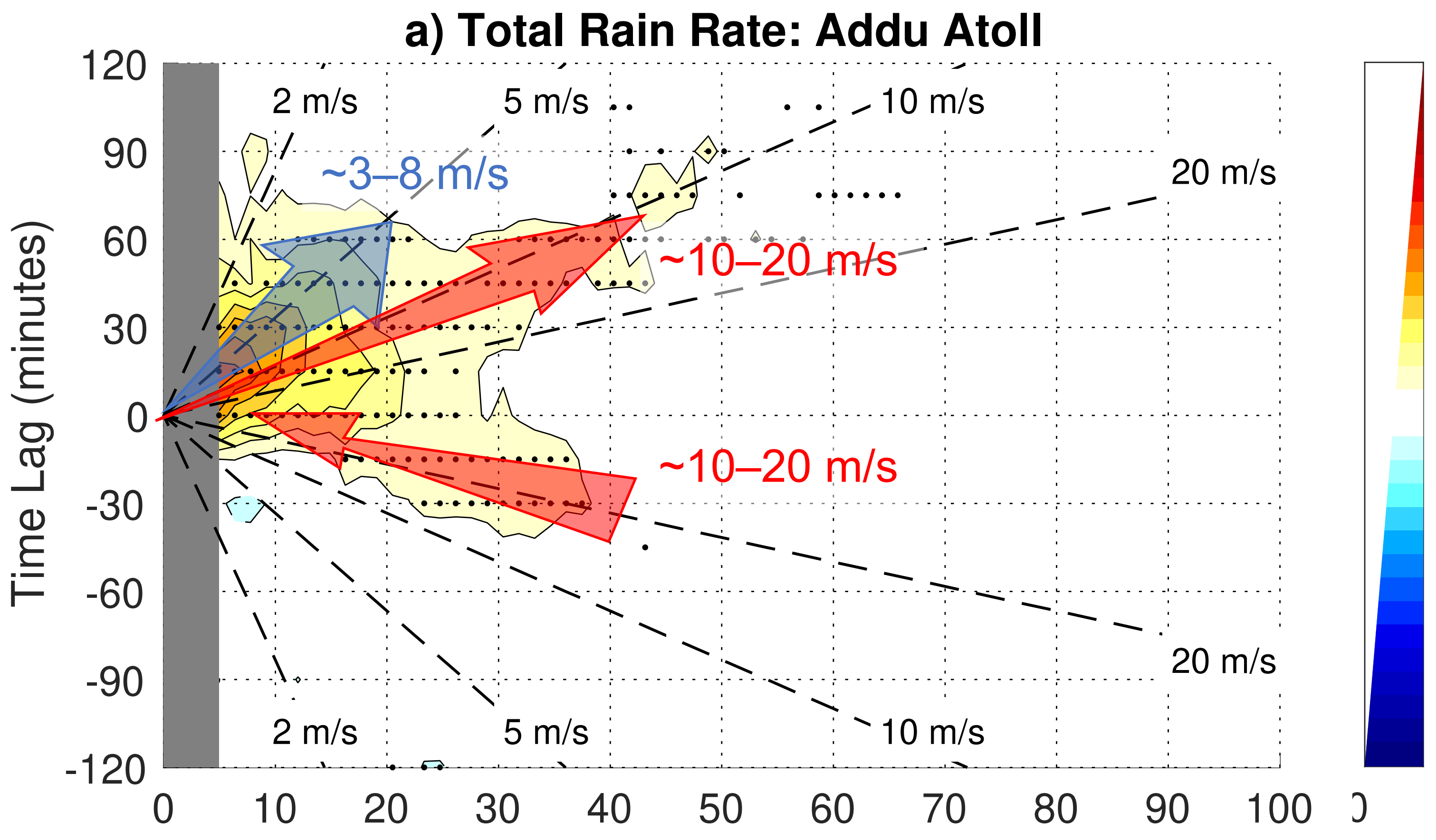
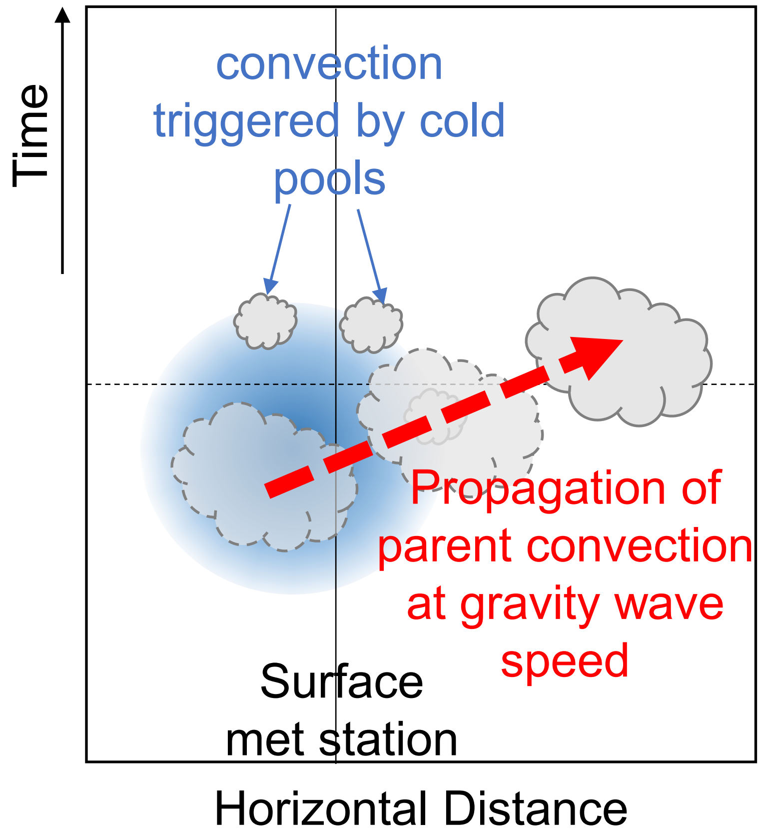




- Cold pools trigger new rainfall within 20 km.

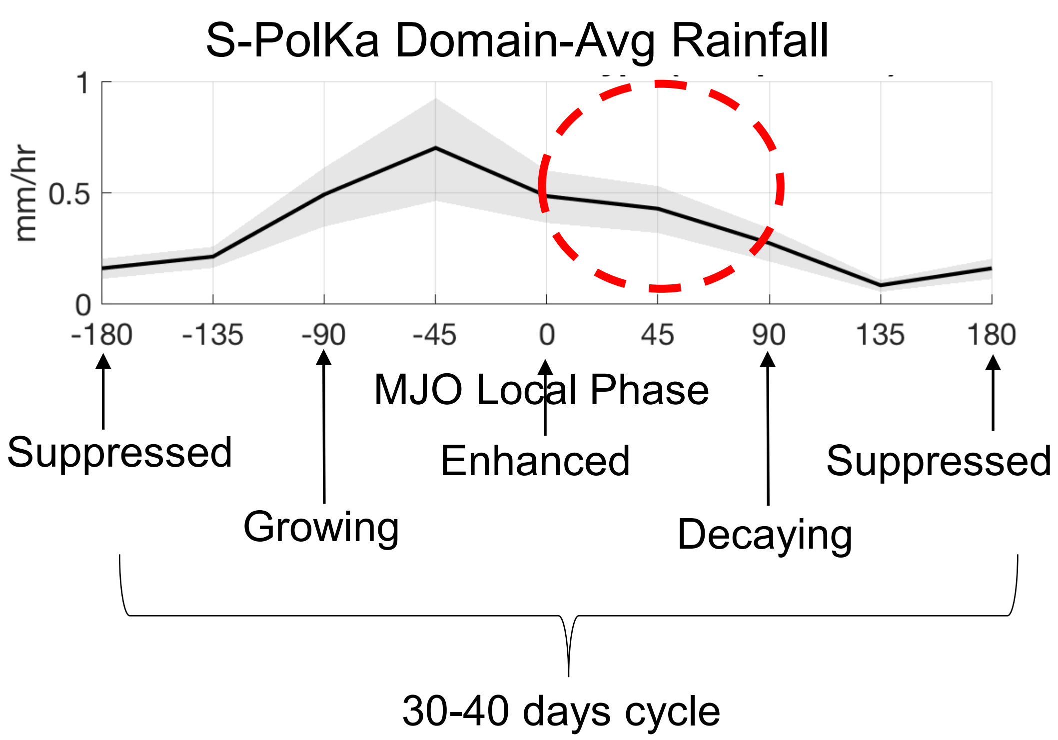
Evidence of Rainfall Triggering by Cold Pools

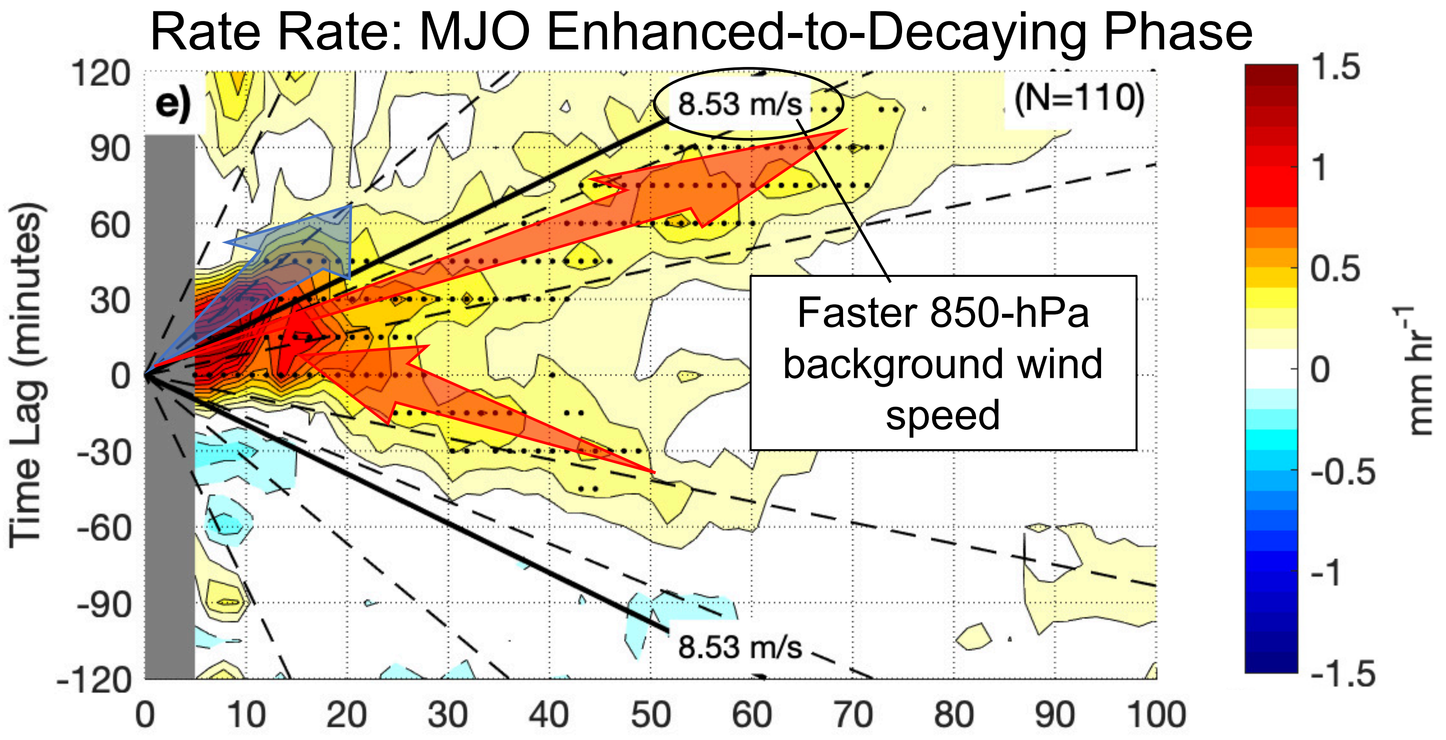




- Cold pools trigger new rainfall within 20 km.
- At the same time, “parent convection” moves at the speed of gravity waves over broader distances.

Strongest Effects of Cold Pool after MJO Enhanced Phase





- MJO enhanced-to-decaying phase (weakening rainfall & decreasing moisture)
  - Strongest rainfall enhancement associated with cold pools and gravity waves over broader distances.

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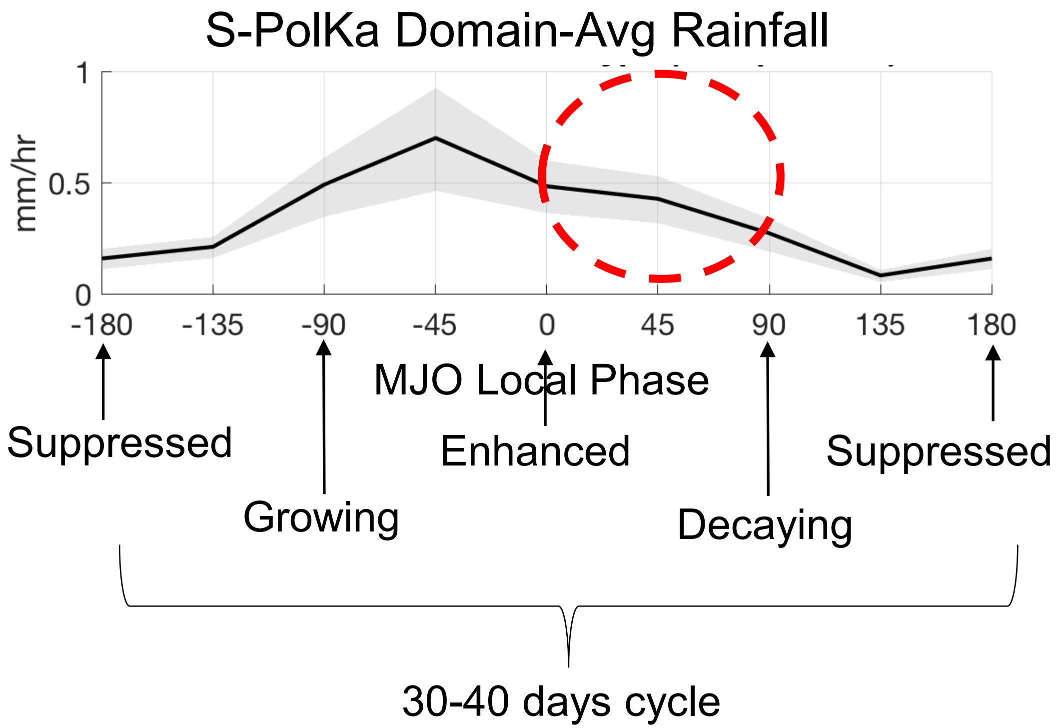
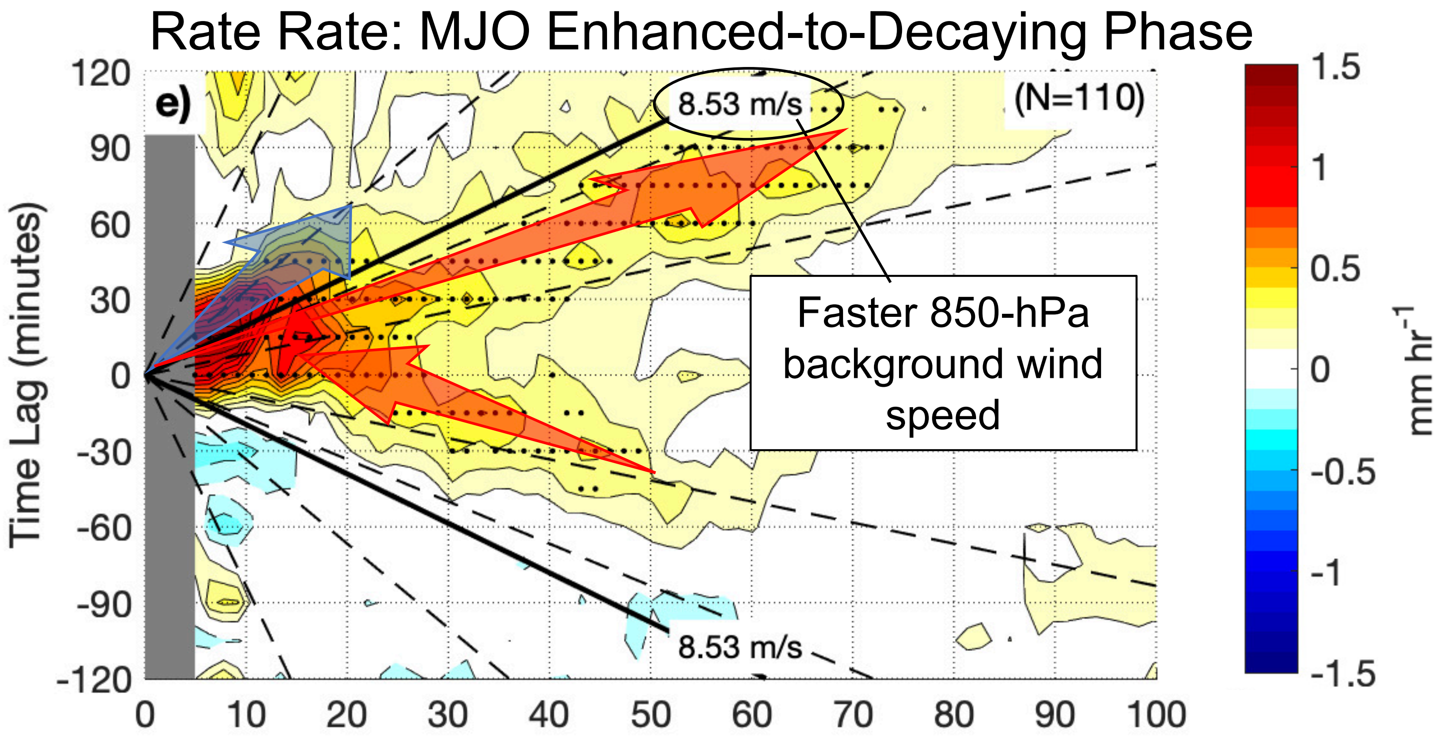
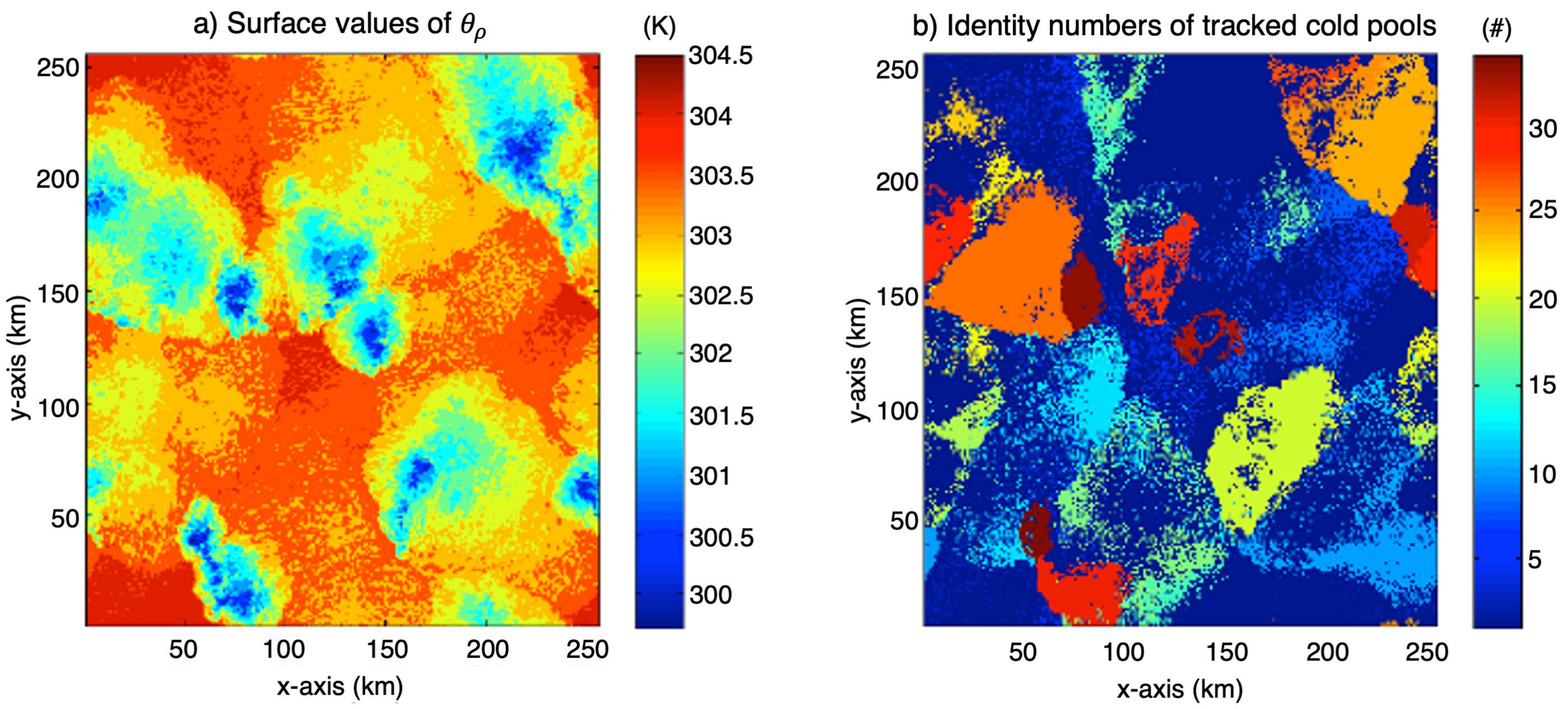




- Possible effects of stronger background wind speed
  - Faster propagation speeds and enhancement of rain over a longer distance
  - Associated with increased vertical wind shear to support rainfall triggering by cold pools
  - Increased surface moisture flux that changes cold pool properties

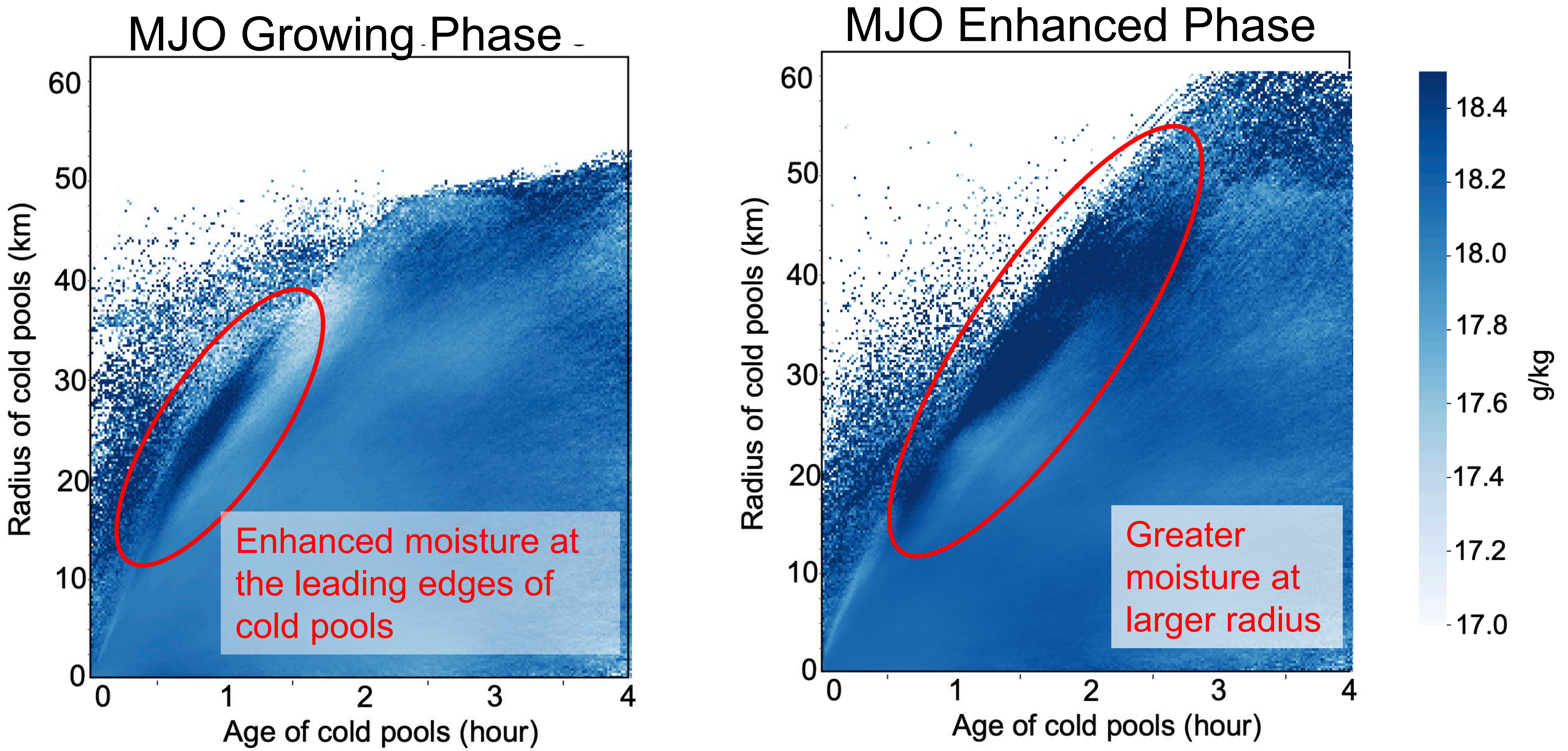
Tracking Cold Pool Properties in Simulations

- Examination of possible mechanisms by initializing simulations with different phases of the MJO.
- Model Setup:
  - System for Atmospheric Modeling (SAM) and Lagrangian Particle Dispersion Model to track cold pools



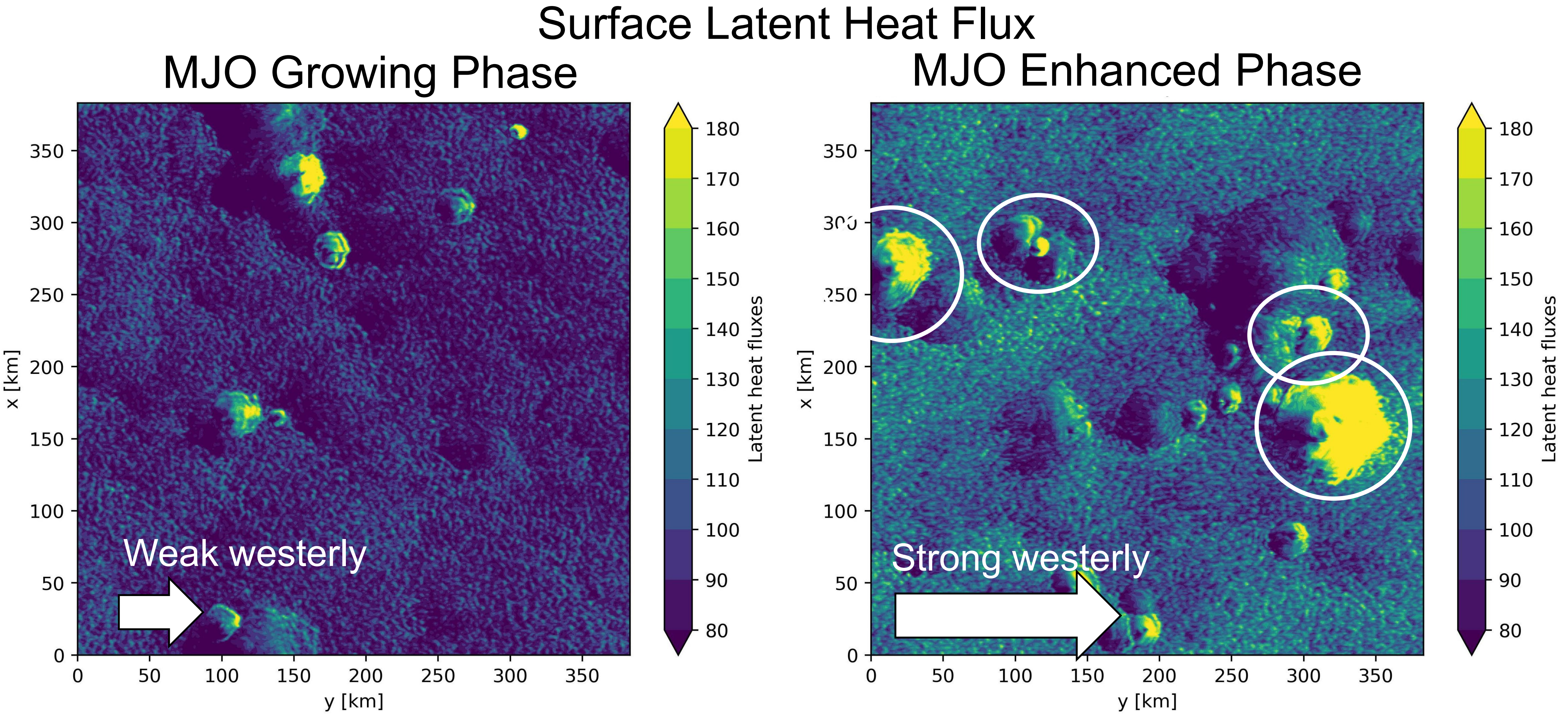
Simulated MJO-Dependent Cold Pool Properties

Water Vapor Mixing Ratio associated with parcels within cold pool



- Greater moisture at the leading edges of cold pools may support convection development

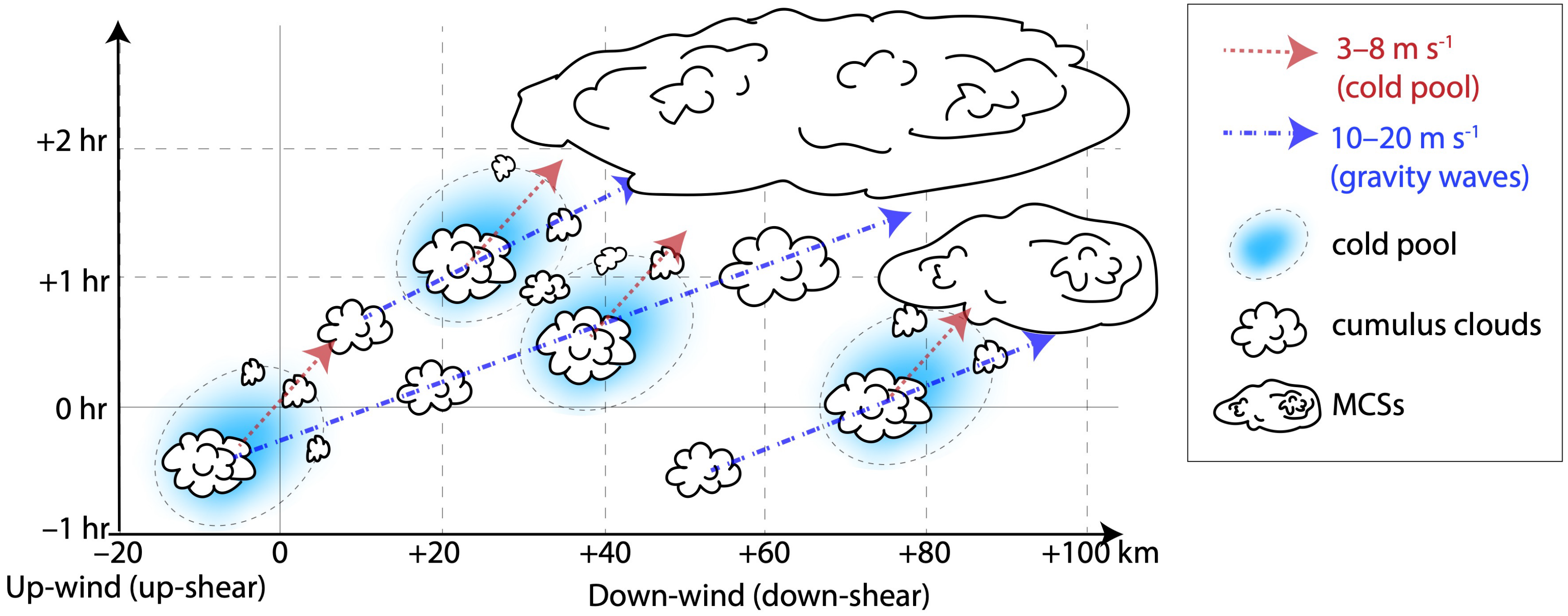
Impacts of Surface Latent Heat Flux on Cold Pools



- Higher surface latent heat fluxes and stronger advection by background wind seem to lead to higher moisture at the down-wind leading edges of cold pools.

Conclusion

- A new observational approach showed that both cold pools and gravity waves trigger rainfall at different ranges of distances, leading to the clustering of convection over tropical ocean.
- The effectiveness of rainfall triggering by cold pools and gravity waves strongly depend on the state of the MJO due to changes in the large-scale environment and cold pool properties.

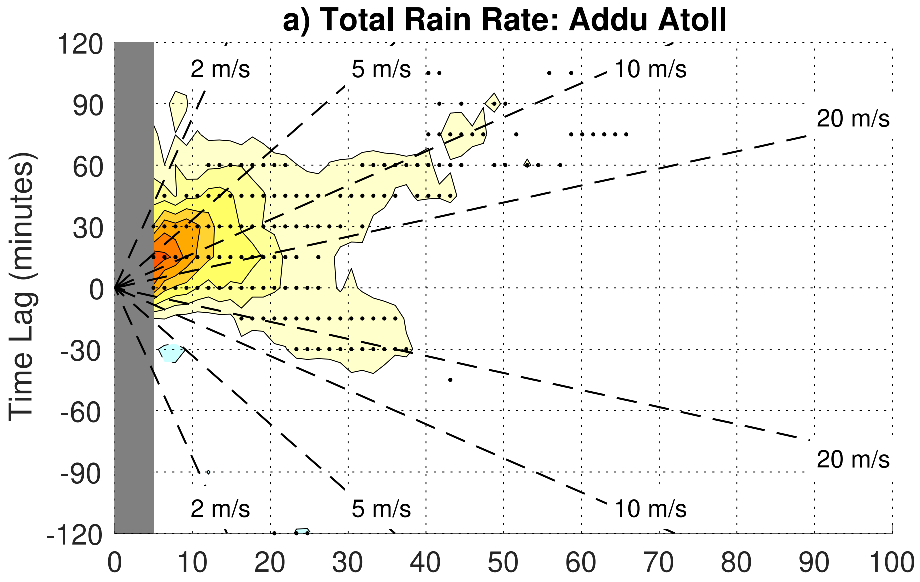


Sakaeda and Torri (2023): Observed effects of cold pools on convection triggering and organization during DYNAMO/AMIE (JGR: Atmosphere, in review)

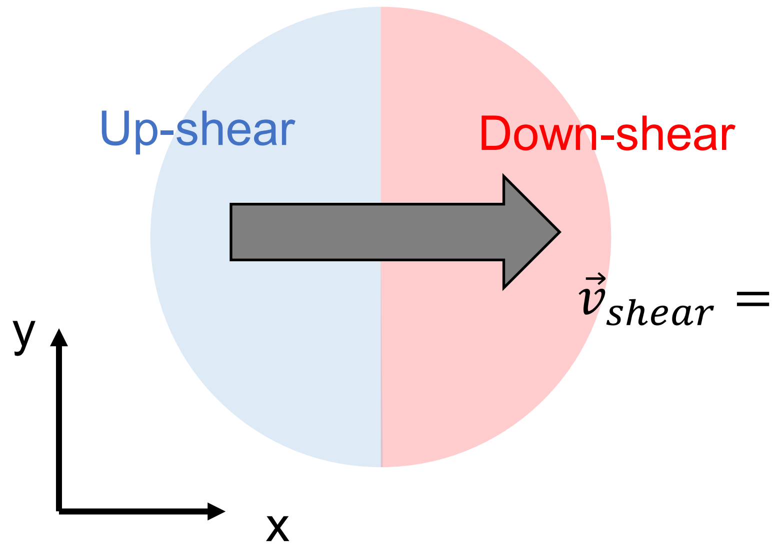
Tang, Torri, and Sakaeda (2023): The simulated organization of deep convection during the MJO (in preparation)

Additional Figures

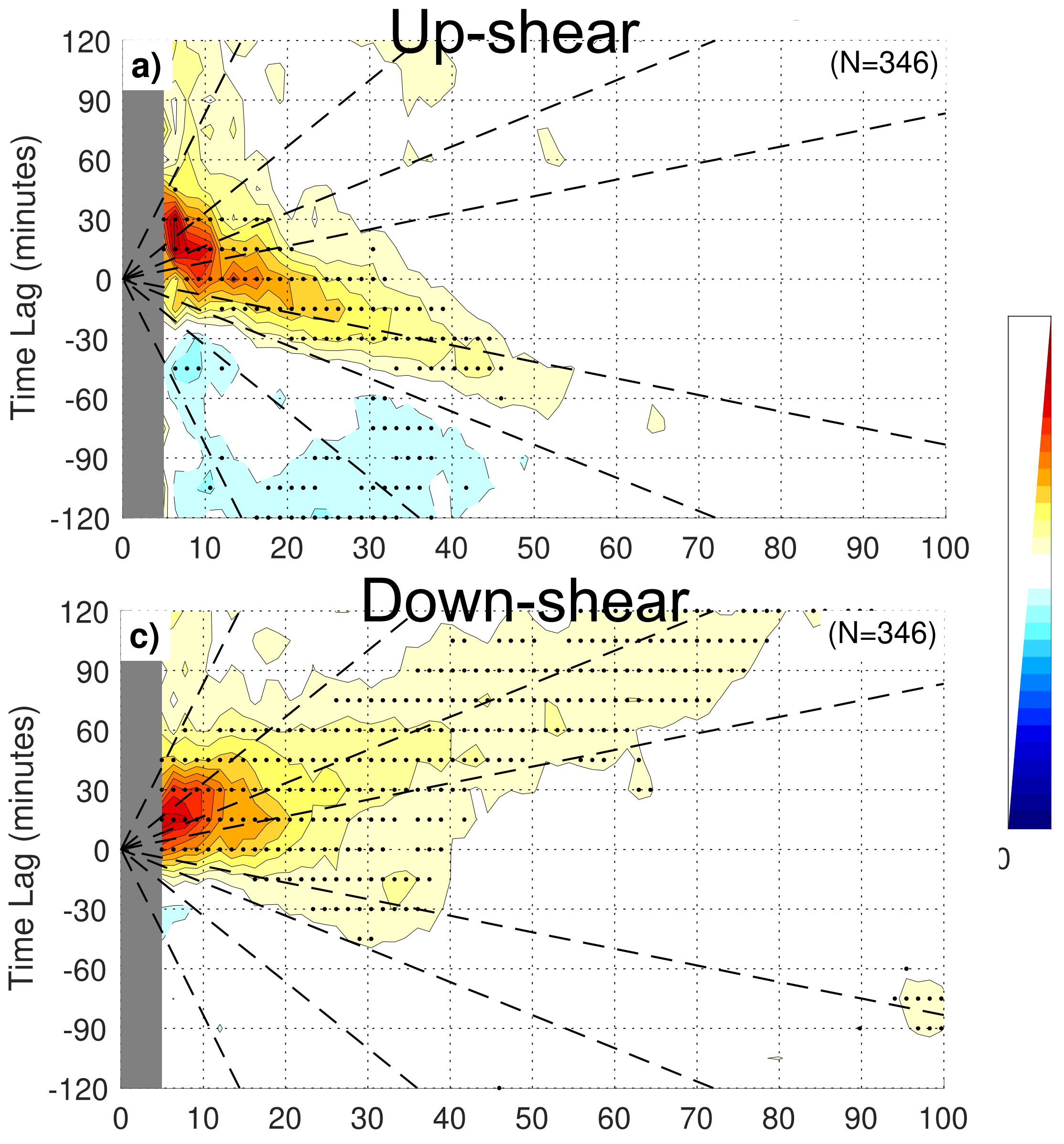
Triggering of Rainfall Types by Cold Pools



Stratification by Boundary Shear Direction



$$\vec{v}_{shear} = \vec{v}_{900mb} - \vec{v}_{1000mb}$$



Large-Scale Environment Changes with the MJO