Tropical Pacific *Atmospheric* Observing Needs

Kathleen Schiro

University of Virginia

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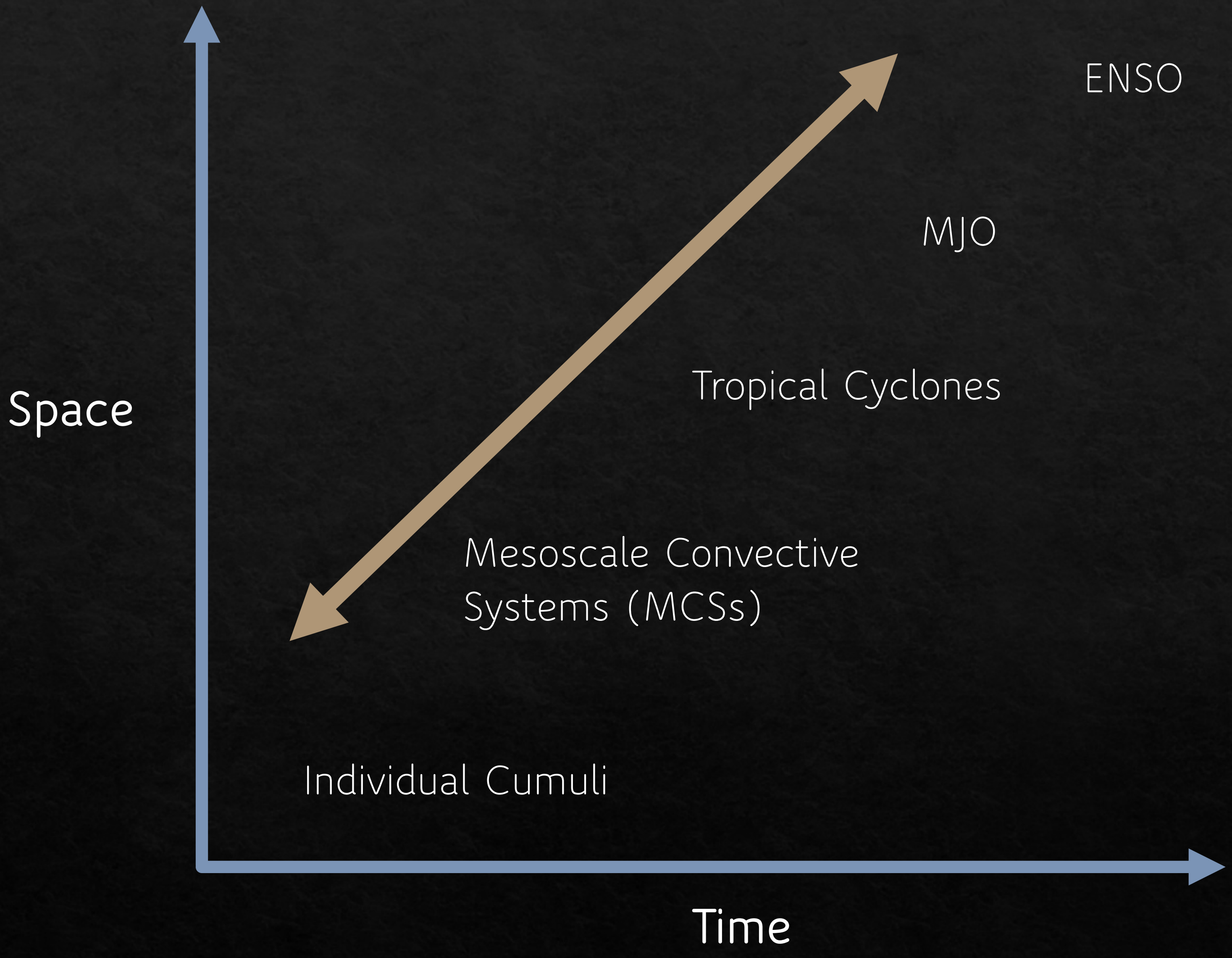
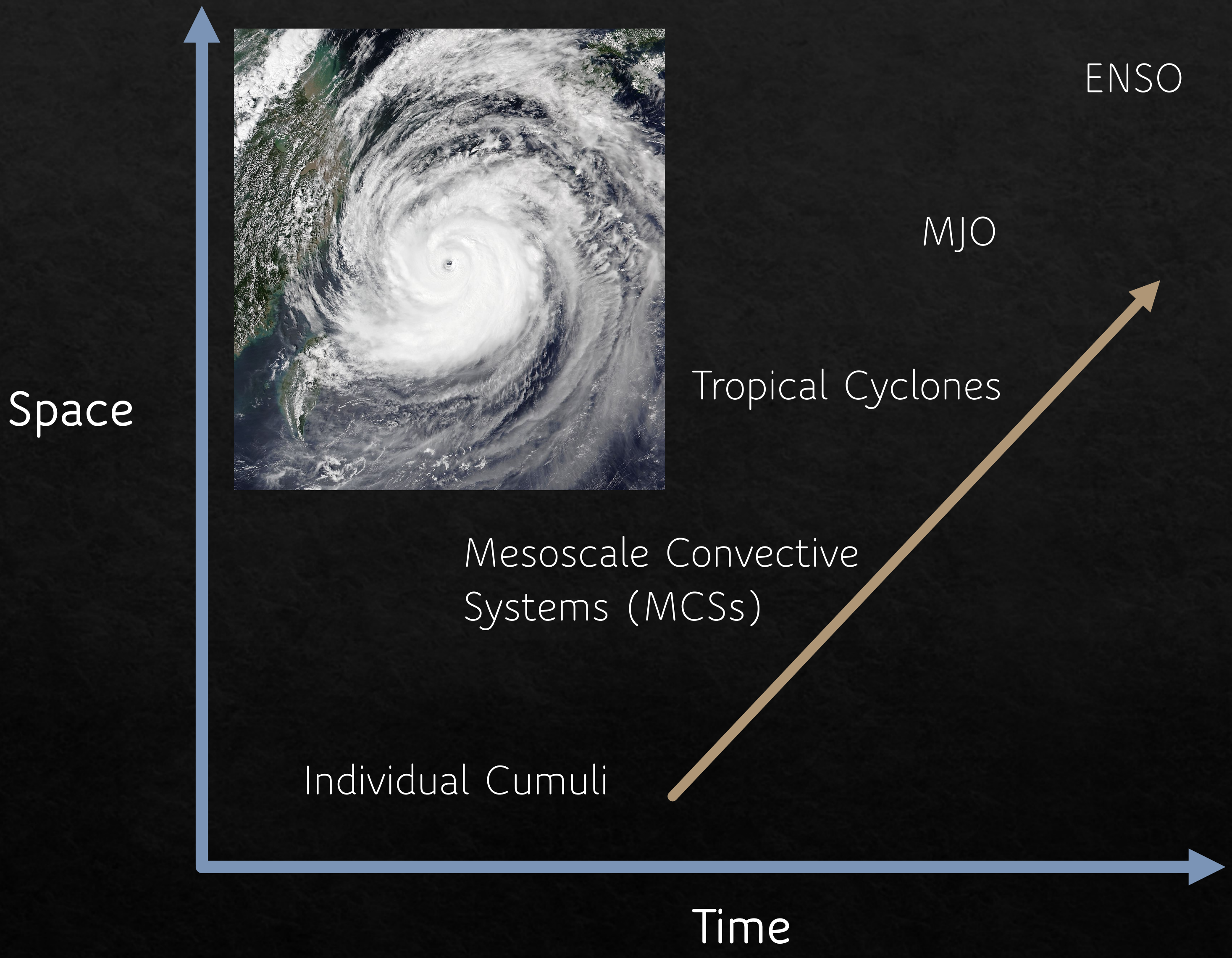


Major Knowledge Gaps

- Multi-scale interactions between clouds/convection/precipitation and atmospheric/oceanic variability



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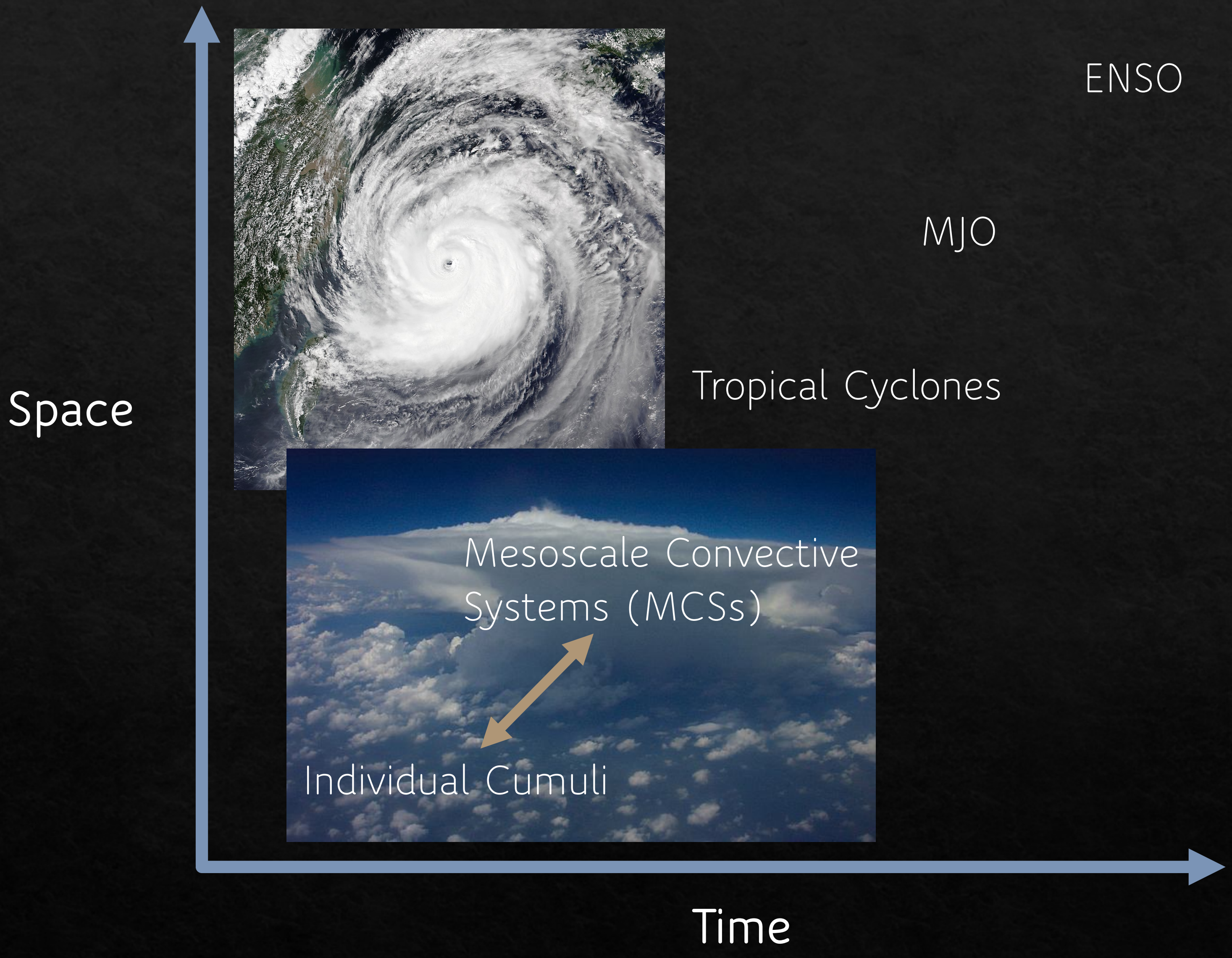
- Upscale growth of deep convection



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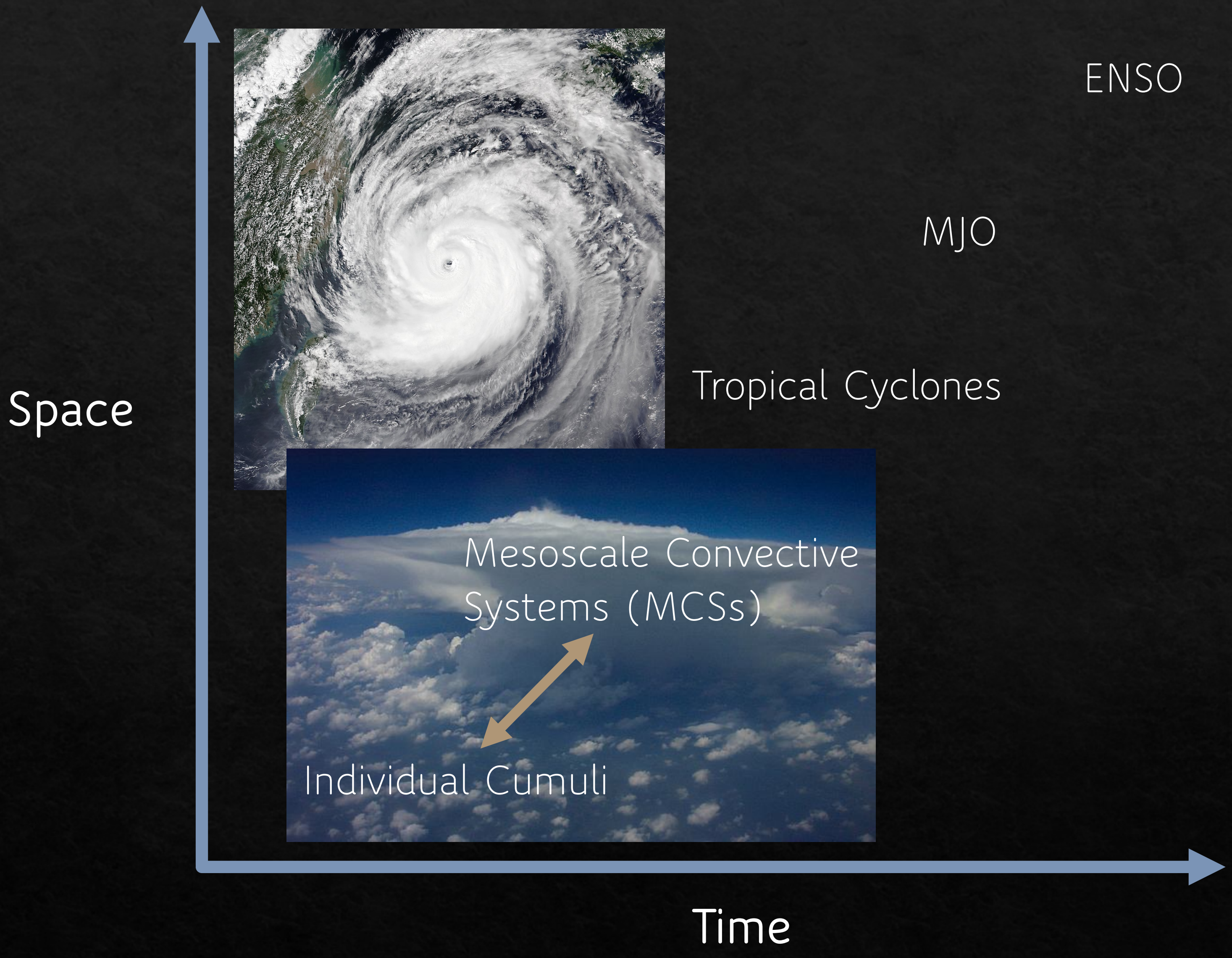
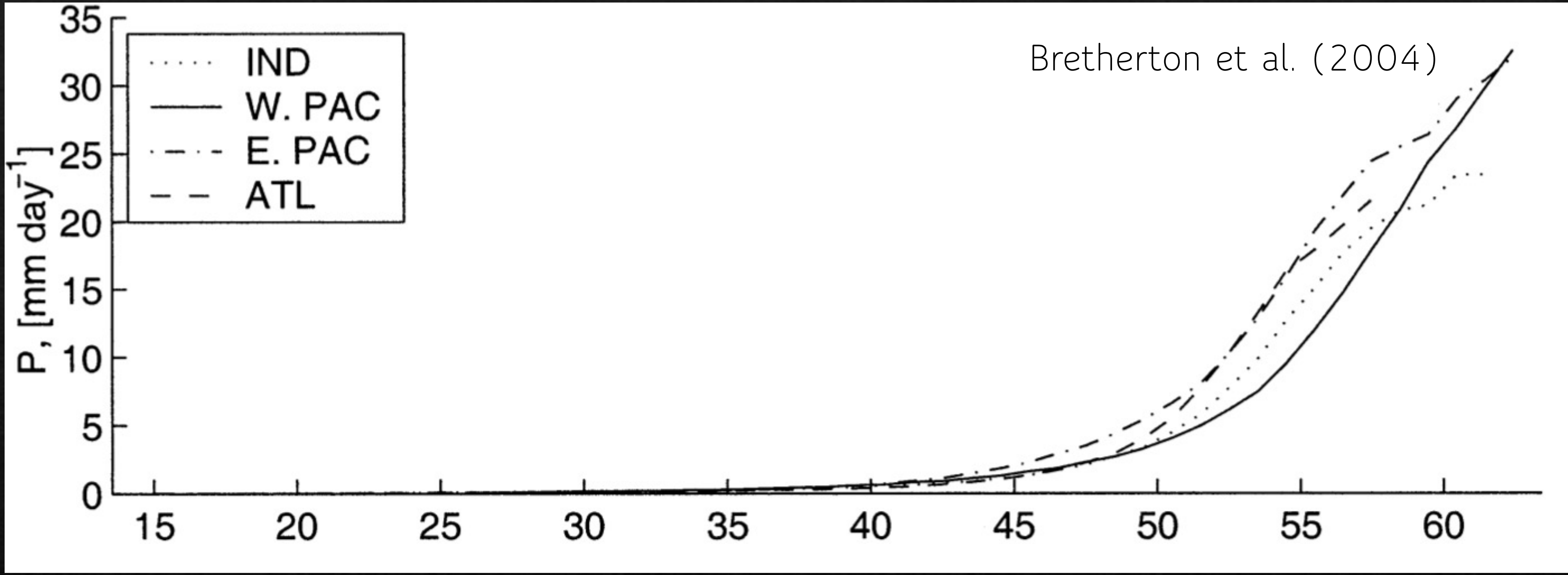
- Interaction between deep convection and its environment at sub-daily scales



Major Knowledge Gaps

- Multi-scale interactions between clouds/convection/precipitation and atmospheric/oceanic variability
- Upscale growth of deep convection
- Interaction between deep convection and its environment at sub-daily scales
- Modeling deep convection in global models, impact on model biases

A key relationship underpinning these multi-scale interactions:



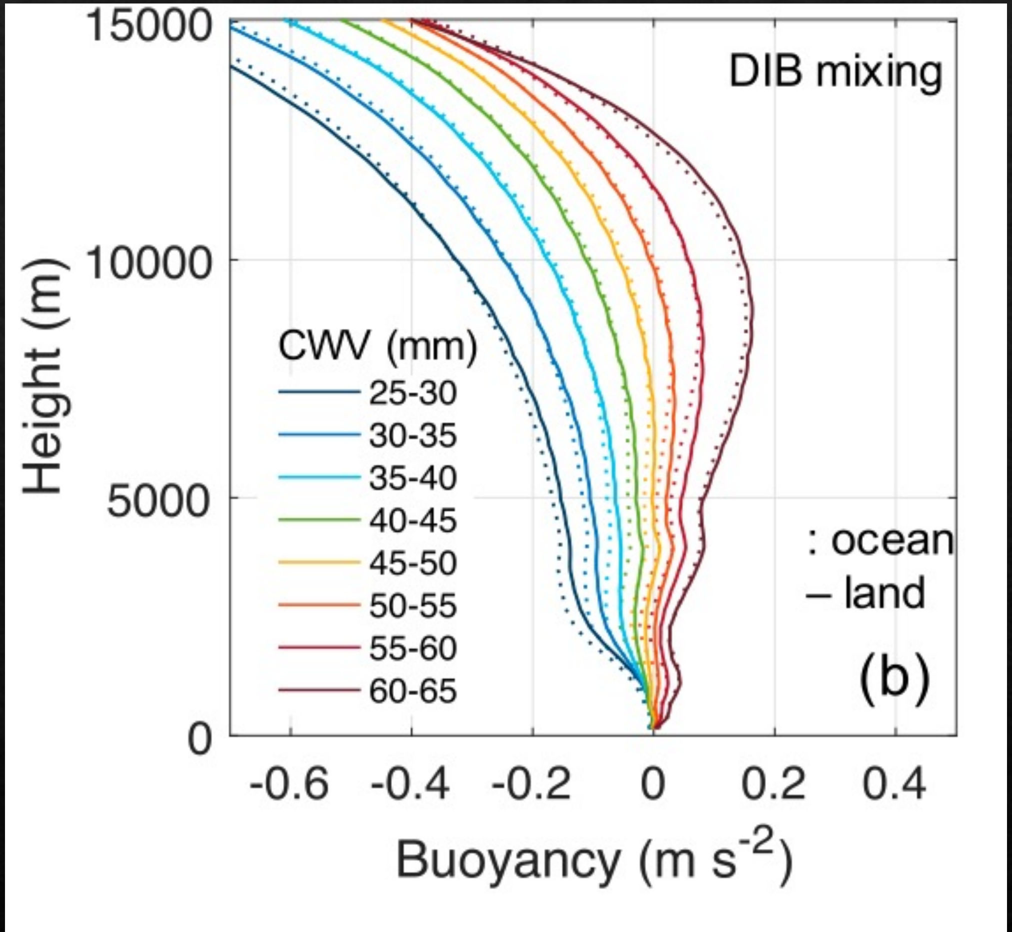
Total column-integrated water vapor (daily)

We can retrieve column-integrated moisture from radiosondes, space-borne and ground-based microwave radiometer (space-borne: over oceanic regions only), and GPS radio occultation (e.g. COSMIC).

A mechanistic explanation:

Greater moisture in lower troposphere (boundary layer and lower free troposphere) results in increased buoyancy available to entraining convective updrafts

Shout-out to many other studies that have been instrumental to the recent advancement of our understanding of the CWV-Pr relationship at sub-daily scales, including but not limited to Neelin et al. 2009; Holloway and Neelin 2009; Sahany et al. 2012; Ahmed and Schumacher 2015; Kuo et al. 2017; Ahmed and Neelin 2018; Igel et al. 2017; Powell 2019; Wolding et al. 2020; Adames et al. 2020.

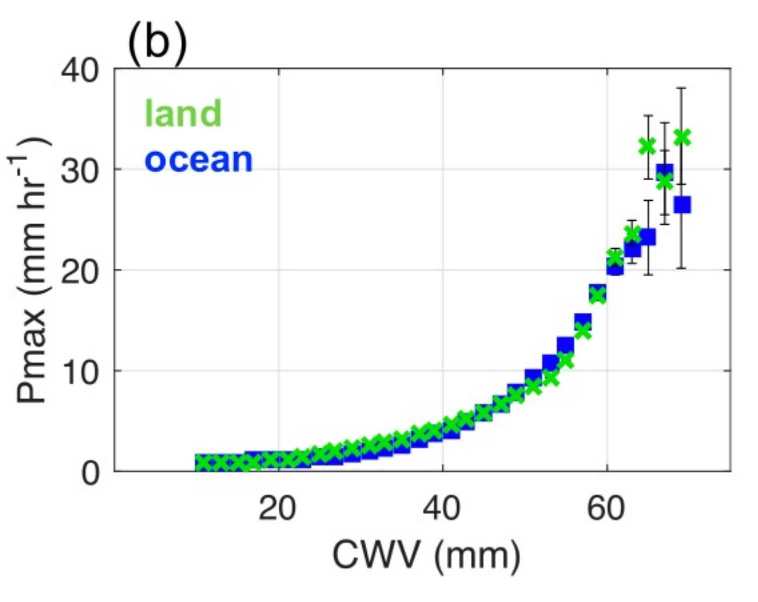


Schiro et al. (2020)

Rather universal relationship (land vs. ocean, MCS vs. non-MCS, nighttime vs. daytime), despite known differences in convective characteristics.

Example (right): MCS precipitation maxima remarkably similar for same CWV over land and ocean

Schiro et al. (2020)



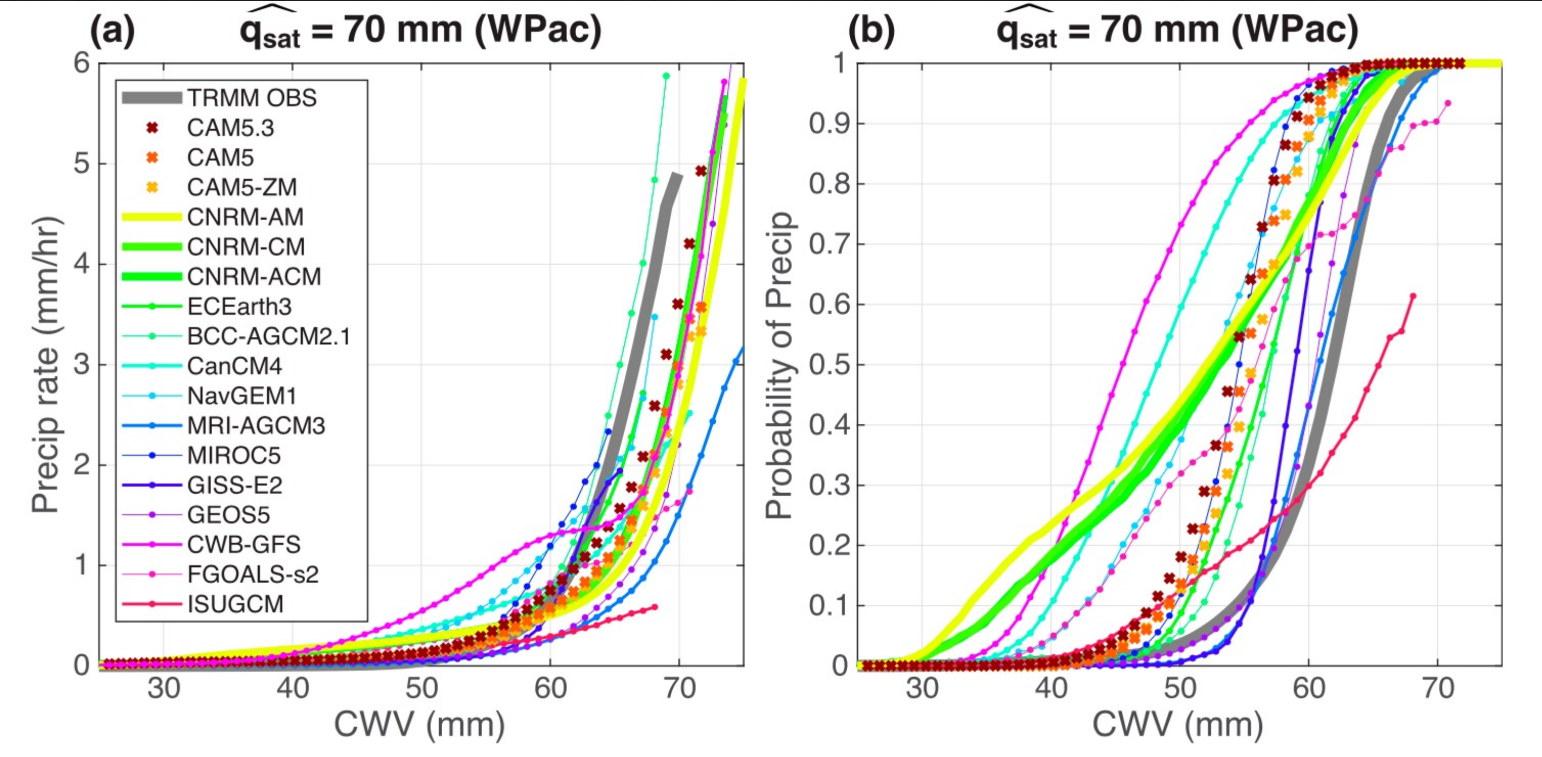
Data: ISCCP Convective Tracking database of Mesoscale Convective Systems, ERA-I moisture, TRMM 3B42 precip

See also Schiro et al. (2016), Schiro et al. (2018), Ahmed and Schumacher (2017), Schiro and Neelin (2019)

Overall, great for precipitation predictability, but not the whole story.

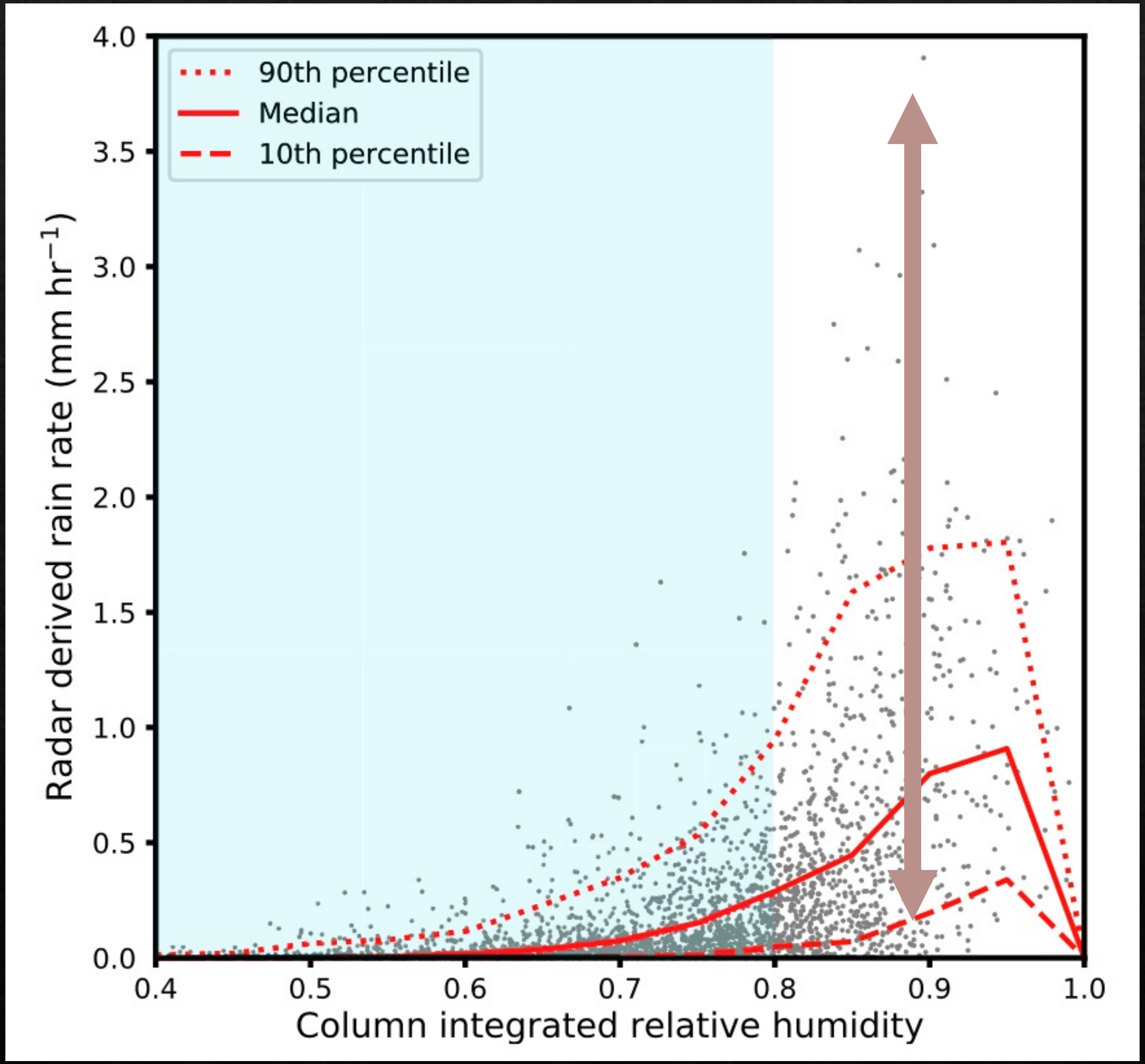
- Some climate models still struggle to simulate realistic sensitivity of deep convection and precipitation to column moisture. However, many are consistent with observed CWV-precip relationship, <u>a promising result</u>
- Those that are more sensitive to lower tropospheric moisture and have more realistic mean-state moisture gradients better simulate MJO propagation (e.g. Gonzalez and Jiang 2017)

Kuo et al. (2020)



Models from MJOTF/GASS task force. Model data are 6 hourly (average for precipitation) regridded to 2.5° resolution prior to our analysis.

Diagnosing differences in precipitation among models at high CWV requires understanding of complex feedbacks and processes.



Powell (2019)

Very large spread in rain rates at high column relative humidity.

High column moisture is a ***necessary but insufficient*** condition to trigger or sustain intense precipitation.

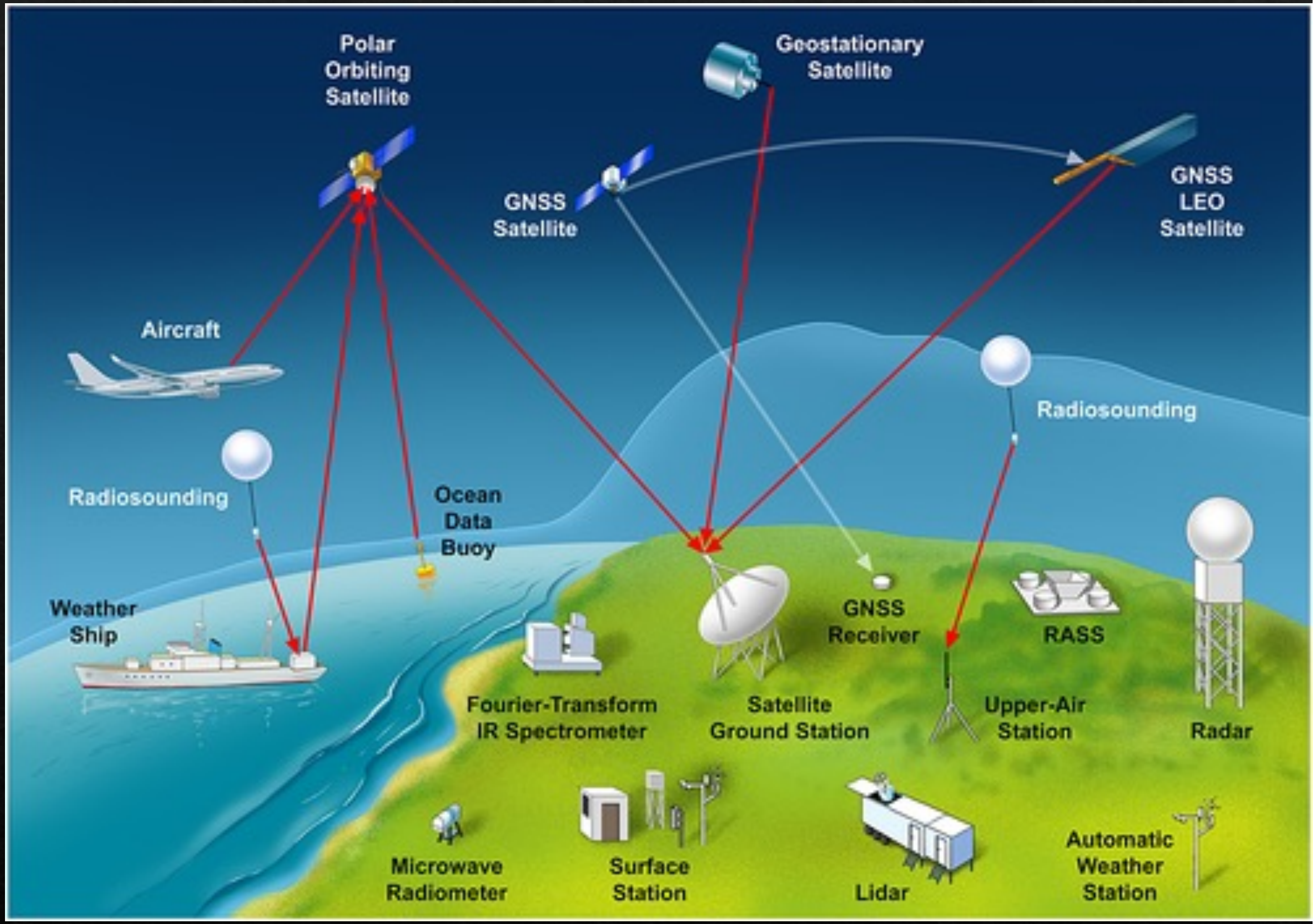
Missing information about the convective lifecycle, boundary layer vs. lower free tropospheric influence on convection, critical feedbacks, and how convection is modifying the environment *(**two-way interaction**)*

Wulfmeyer et al. (2015)

Key observational challenge:

#1: The thermodynamic environment is difficult to sample at sufficiently high resolution*, limiting our understanding of critical processes and feedbacks governing convective lifecycles and upscale growth.

*Particularly in the boundary layer



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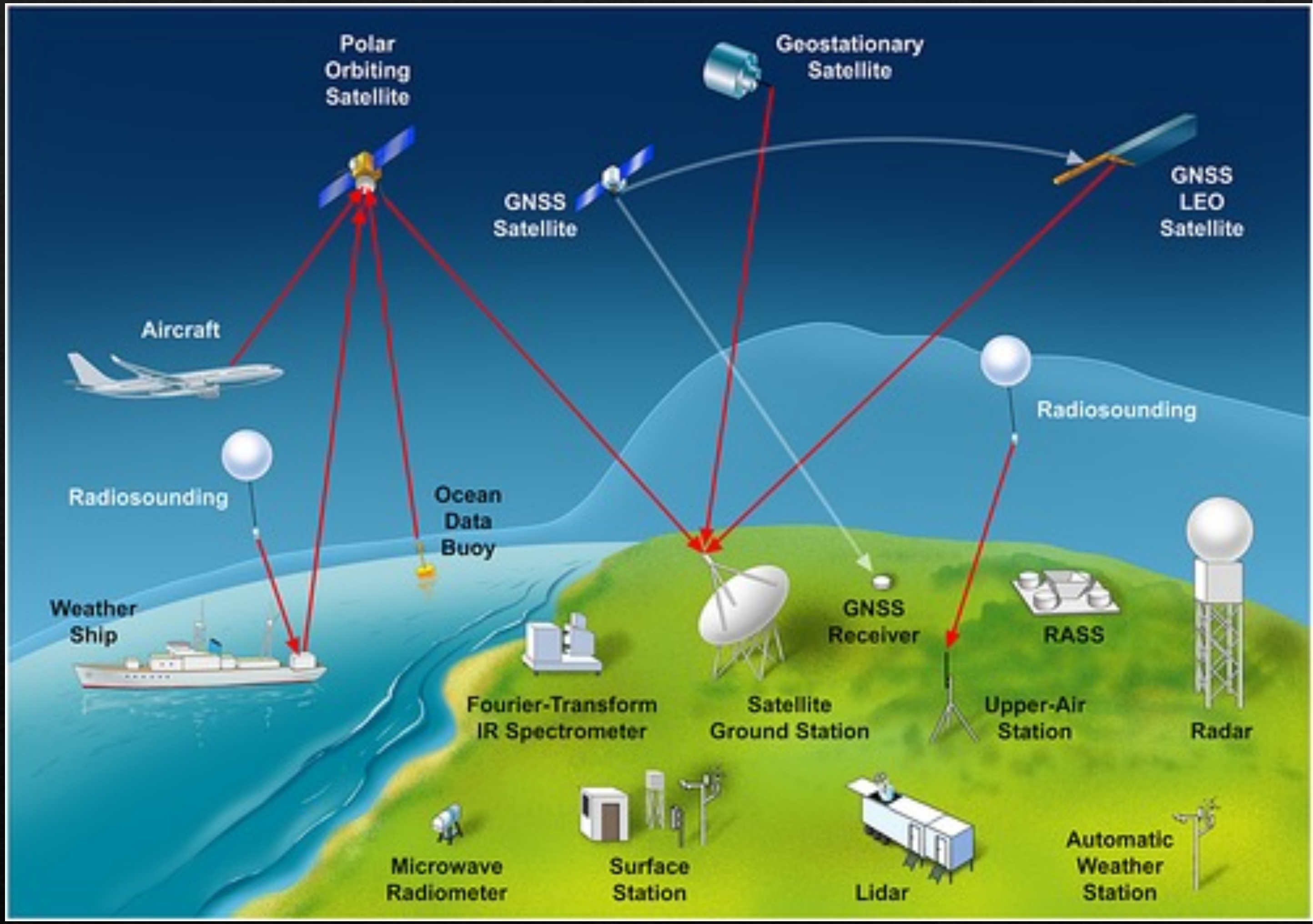
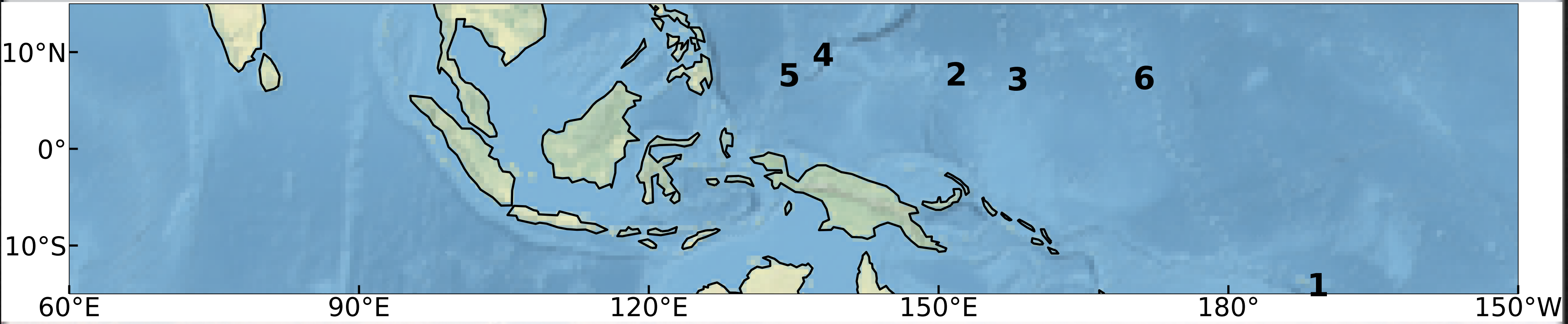


Thermodynamic convection coupling in Observations vs. Reanalysis

NOAA IGRA Soundings vs ERA5 Thermodynamic Profiles



115,000 NOAA Integrated Global Radiosonde Archive (IGRA) soundings from six small islands

twice daily, spanning 1970 – 2018

co-located with "nearest" 0.25° x 1 hr ERA5 profiles

composited with respect to observed TRMM precipitation convective lifecycle

shallow → convective → stratiform

similar results if purely oceanic COSMIC GPS radio occultations are used

Courtesy of Brandon Wolding

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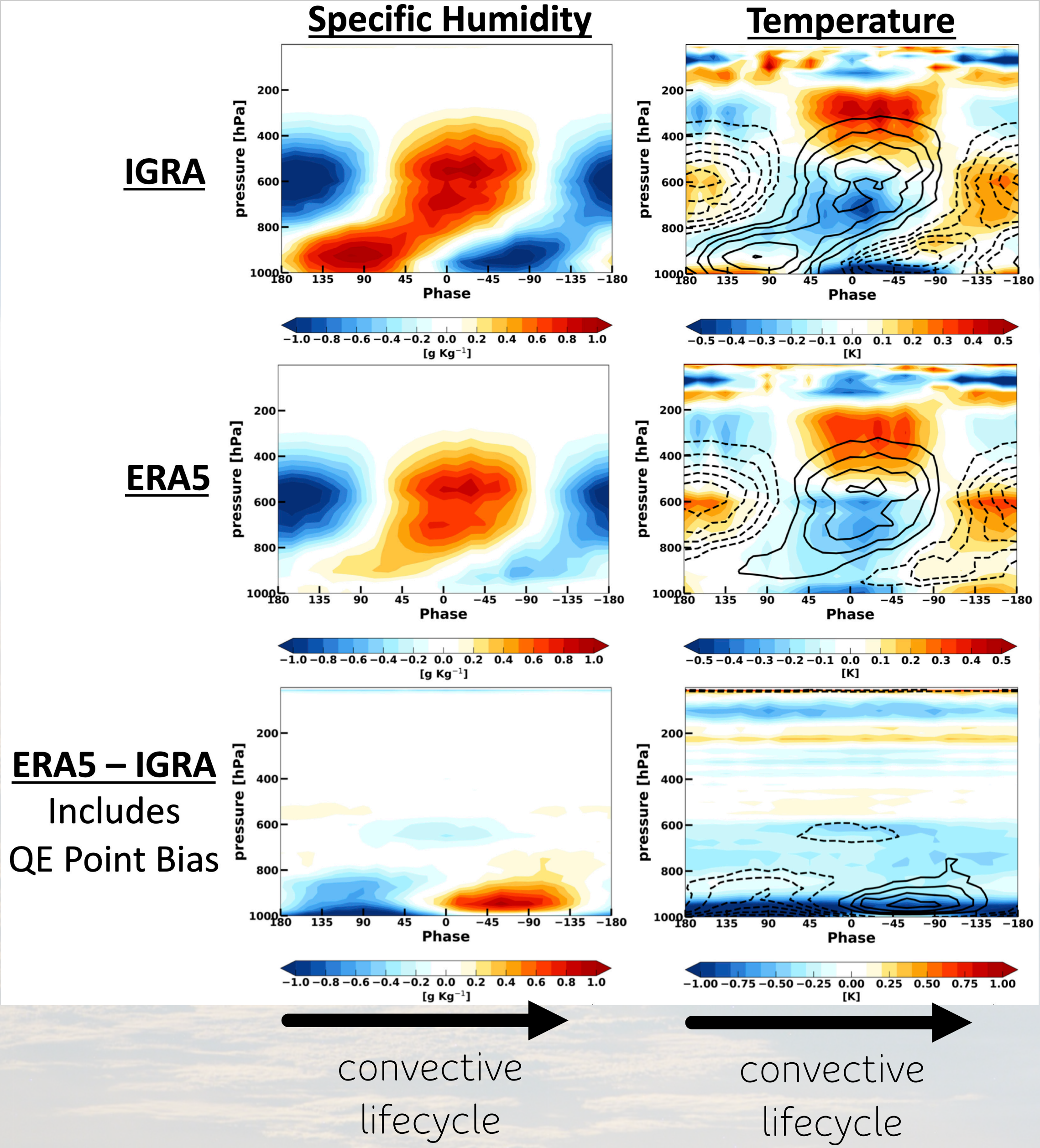


Preliminary Results of Comparison

agree reasonably well in free troposphere

disagree on magnitude and timing of moisture and temperature variations in the boundary layer

lack of thermodynamic observations in the boundary layer creates large dependence on assimilating model

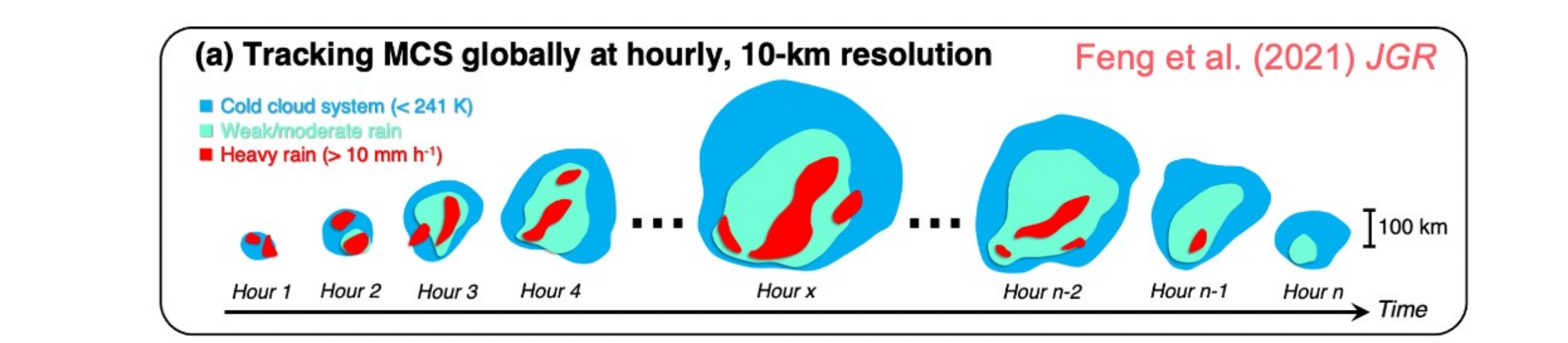
changes how we perceive relationship between convection and its thermodynamic environment

Wolding et al. (in prep)

Courtesy of Brandon Wolding

MCSs account for 50% or more of tropical precipitation (regionally-dependent; Nesbitt et al. 2006)

New MCS tracking algorithm and high-res global MCS datasets have been recently developed from Geostationary IR imagery and GPM Precipitation Radar (e.g. Feng et al. 2021 *JGR*) to advance our understanding of upscale growth and convective lifecycles.



Still missing: reliable, high-resolution, all-weather sampling of the thermodynamic environment

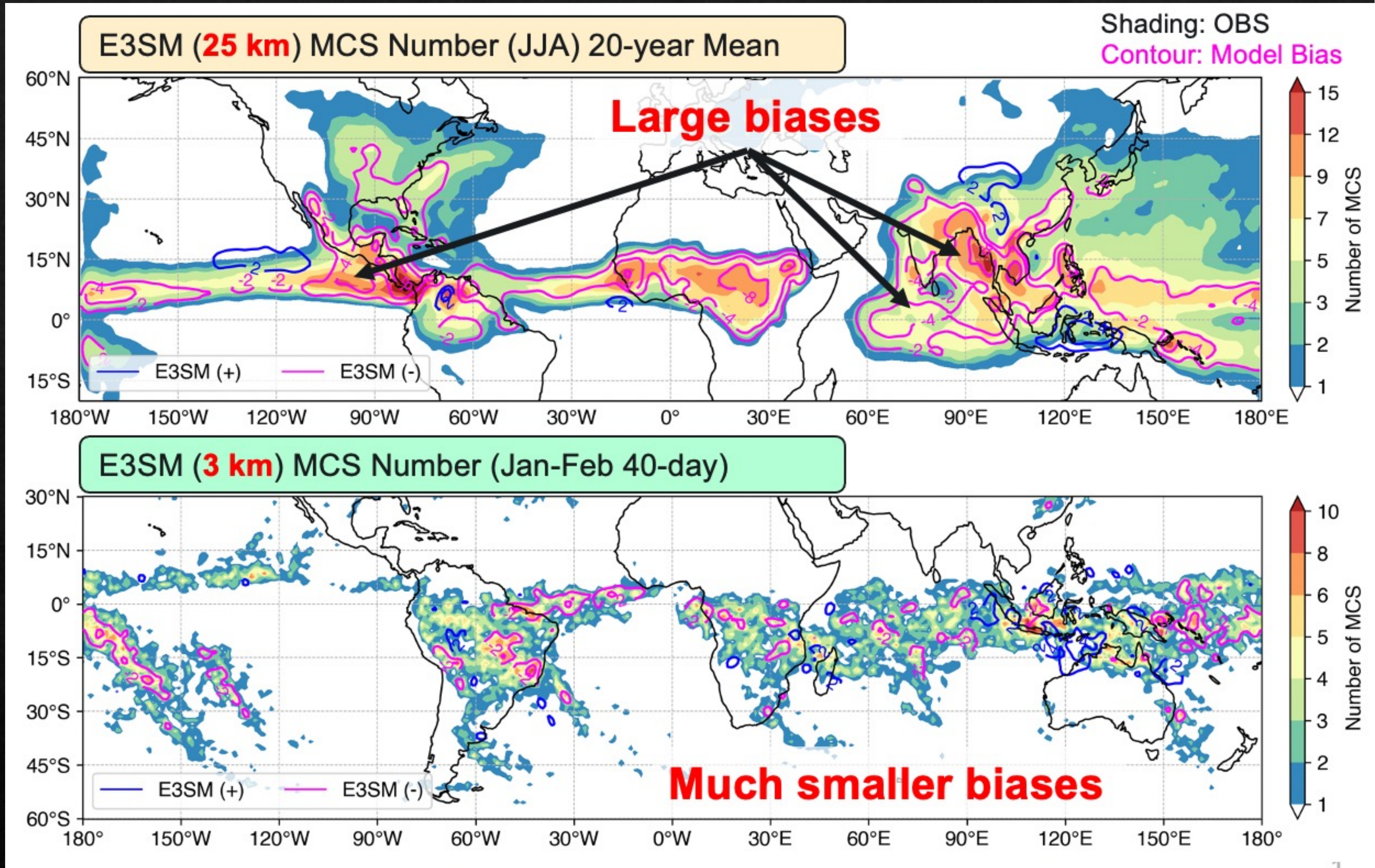
In the meantime, collocate with AIRS, COSMIC, available radiosondes, reanalysis.

Representing MCSs in global models: the key to reducing long-standing precipitation biases?

Resolution matters: global models (e.g. E3SM) show significant improvements in better simulating MCS when grid-spacing decreases from 25 km to 3 km, despite in experimental mode

How are critical processes represented (e.g. cold pools, cloud-radiation interactions, entrainment)? Are MCSs represented for the right reasons? *We need multi-scale, multi-platform observations to validate.*

Courtesy of Zhe Feng

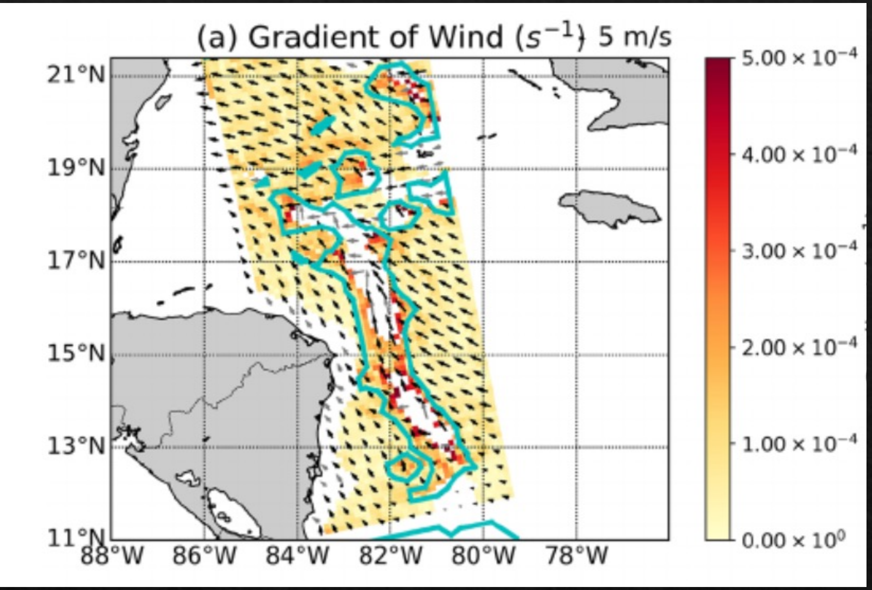


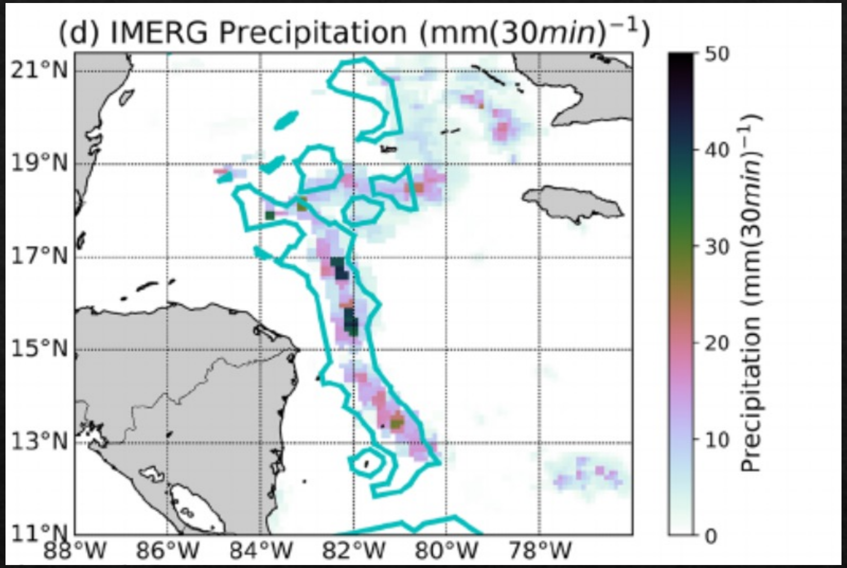
Global 3 km simulation provided by the E3SM project – Caldwell et al. in review

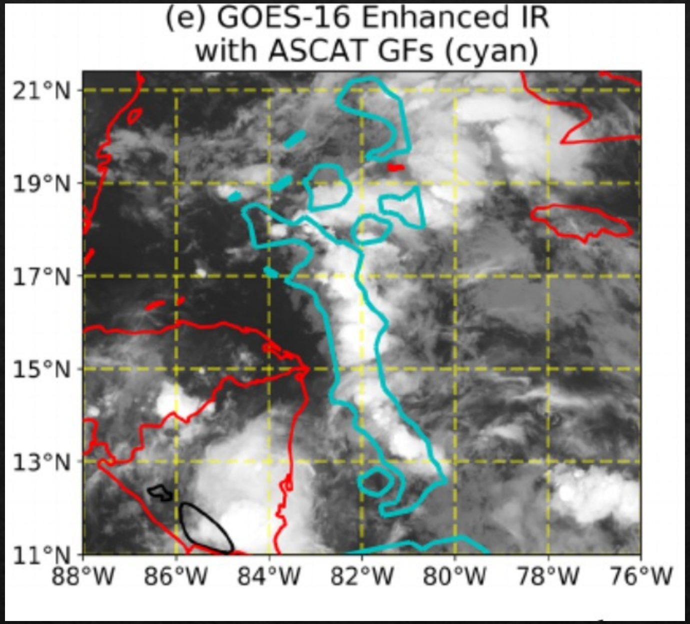
Critical Process: Cold Pools

A new, novel approach: detect cold pools from spaceborne scatterometry

Garg et al. (2020)

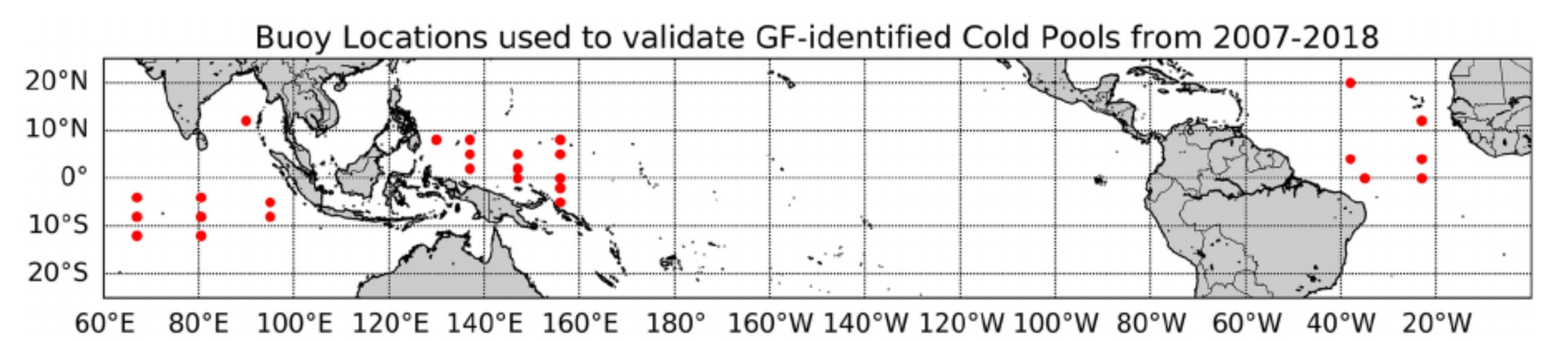






Turbulent flux measurements extremely difficult to estimate from current space-borne platforms.

Buoy data invaluable for measuring temperature/humidity and fluxes at air-sea interface.

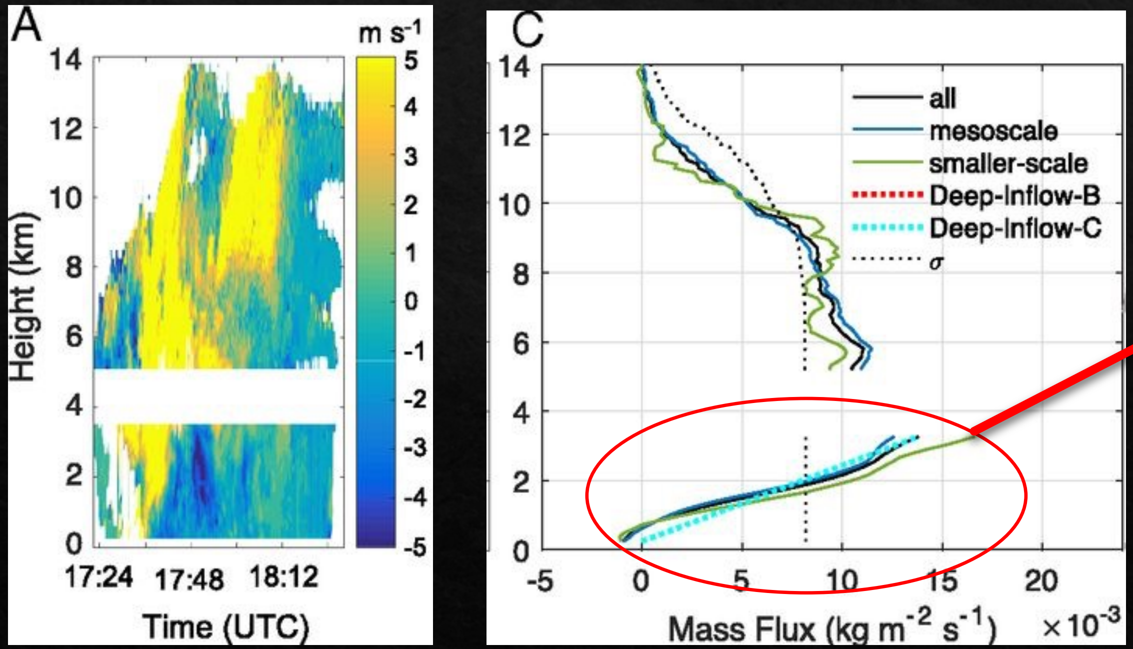


Critical Process: Vertical Velocity/Entrainment

Radar wind profiler observations of vertical velocity can be combined with other data and/or assumptions to derive mass flux and infer properties of entrainment

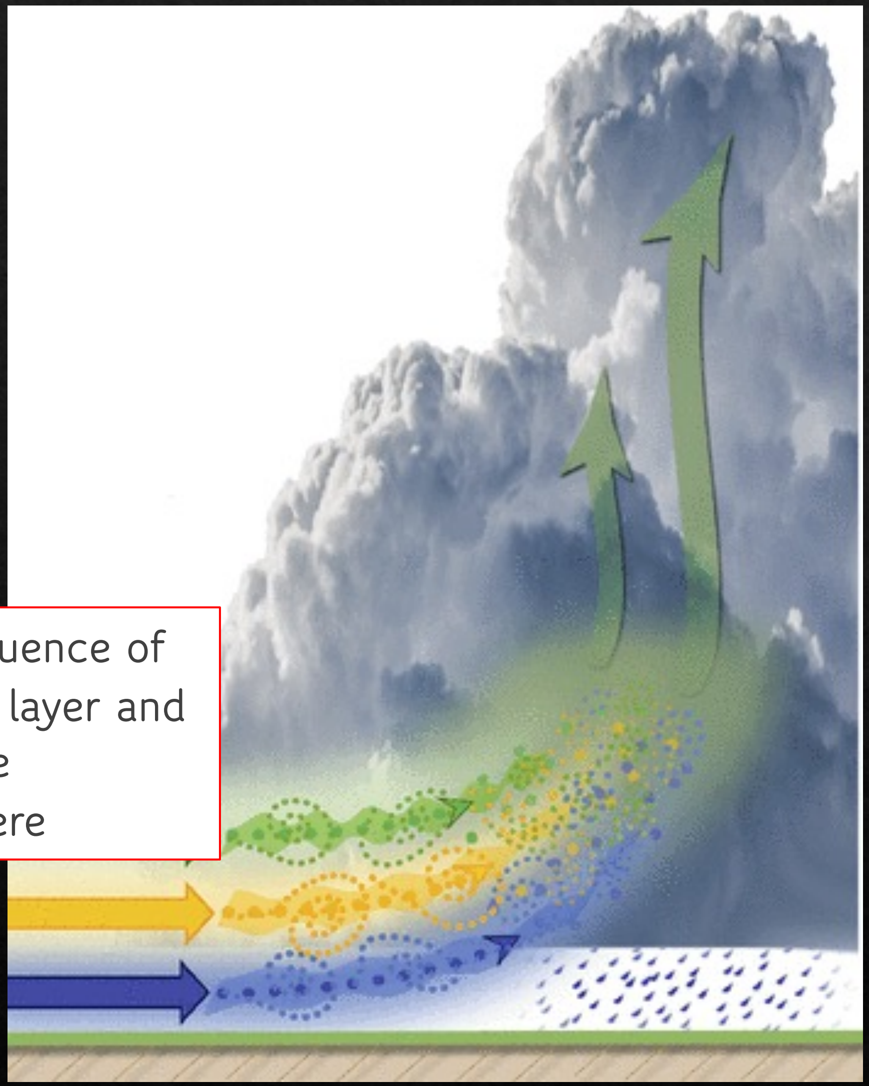
S-Band radar to infer size/organizational characteristics

Example: GoAmazon2014/5



Schiro et al. (2018)

Equal influence of boundary layer and lower free troposphere



See also Giangrande et al. (2016), Kumar et al. (2015), Wang et al. (2019) for analysis of convective vertical motions using RWP data

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Cloud microphysics

Existing technologies that have been particularly helpful in advancing our understanding of convective processes from past field deployments:

- Radiosondes, Microwave Radiometers (thermodynamic profiling)
- X/W-Band Cloud Radars (transition from shallow to deep convection, cloud-radiation interactions)
- S-band/Ka-band Dual Polarization, Dual Wavelength Doppler Radar (updraft/inflow characteristics, spatial characteristics of convection, convective lifecycle, upscale growth, degree of organization)
- Radar Wind Profilers (vertical velocity)

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Field campaigns

Satellite Observations

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No single platform will be sufficient, so a significant challenge is how do we integrate different types of measurements (in situ, field campaign, satellite) to support convection process studies.