RCE and Processes in Deep Convective Organization

Workshop on Spatial Organization of Convection, Clouds and Precipitation

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Allison Wing
Department of Earth, Ocean and Atmospheric Science
Florida State University

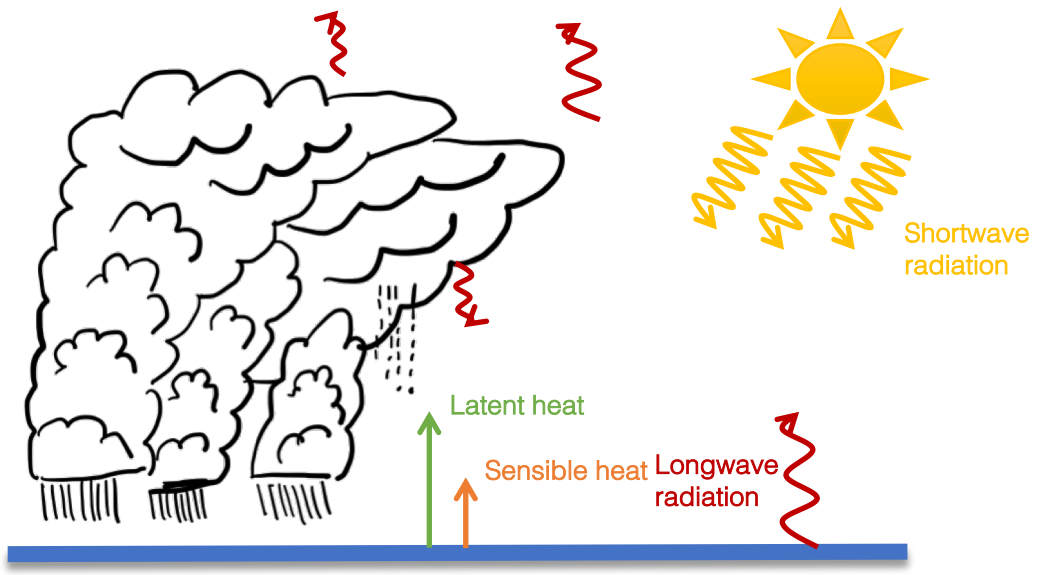
Some synthesis and open questions…

Some questions

- How does self-aggregation impact the mean state?
  - → *hydrological cycle*
- How does self-aggregation change with warming?
- Does self-aggregation impact climate sensitivity?
- How are the mechanisms of organization modified when elements of realism are added to RCE?
  - → *Adrian & Caroline discuss*
- How do different mechanisms of organization interact with each other?
  - → *Adrian & Caroline discuss*

Radiative-Convective Equilibrium: A tool for studying convective organization and its impacts

A statistical equilibrium: balance between net radiative cooling and convective heating

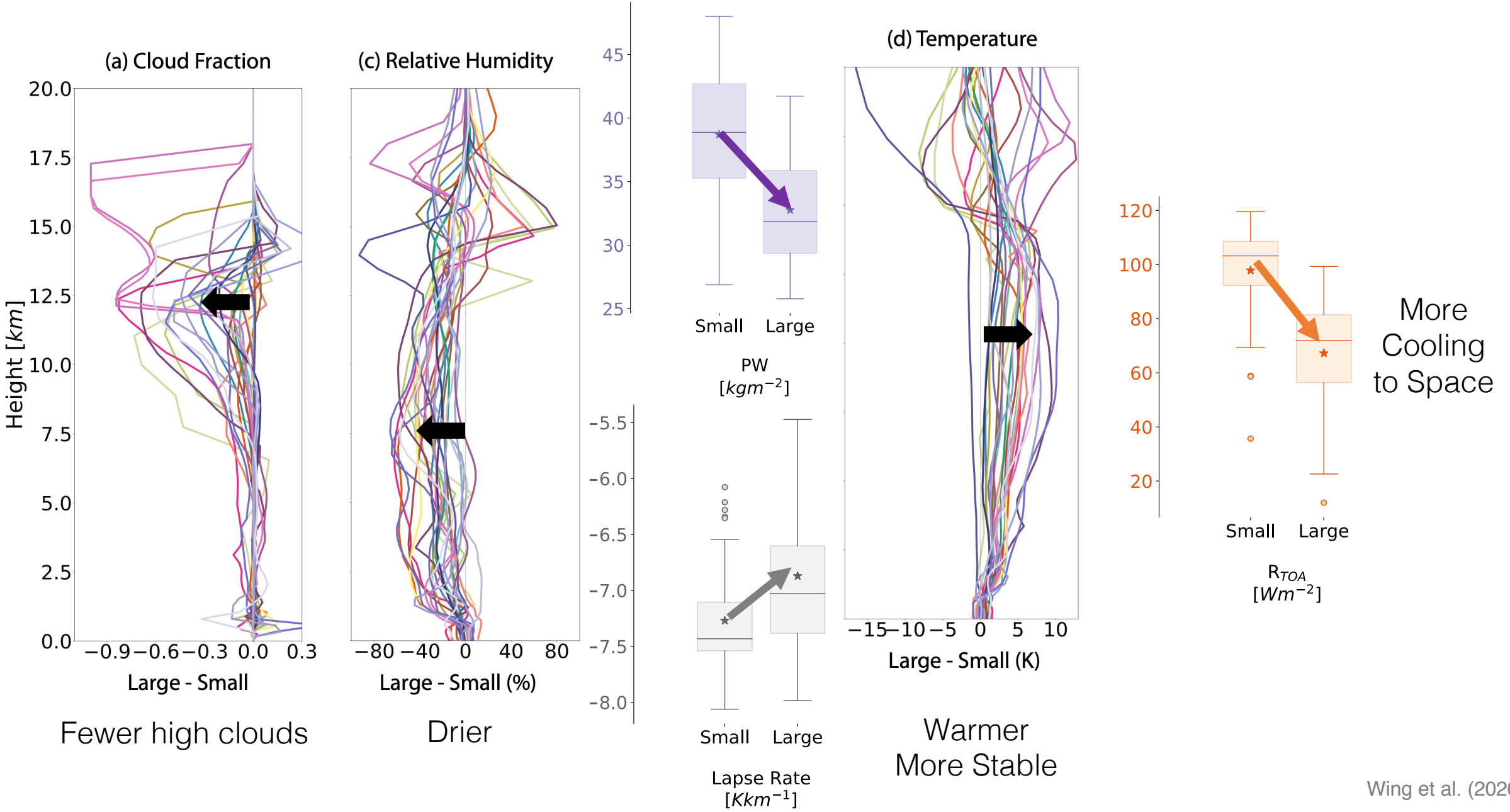


"Time-honored idealization for understanding the tropical atmosphere and its sensitivity to relevant forcings"

Bretherton et al. (2005)

- Simplest possible way to phrase questions about climate
- Accessible by many model types
- Common baseline provided by RCEMIP
  - 30 different models
  - Configured in a consistent manner
  - Small domains without aggregation
  - Large domains with aggregation

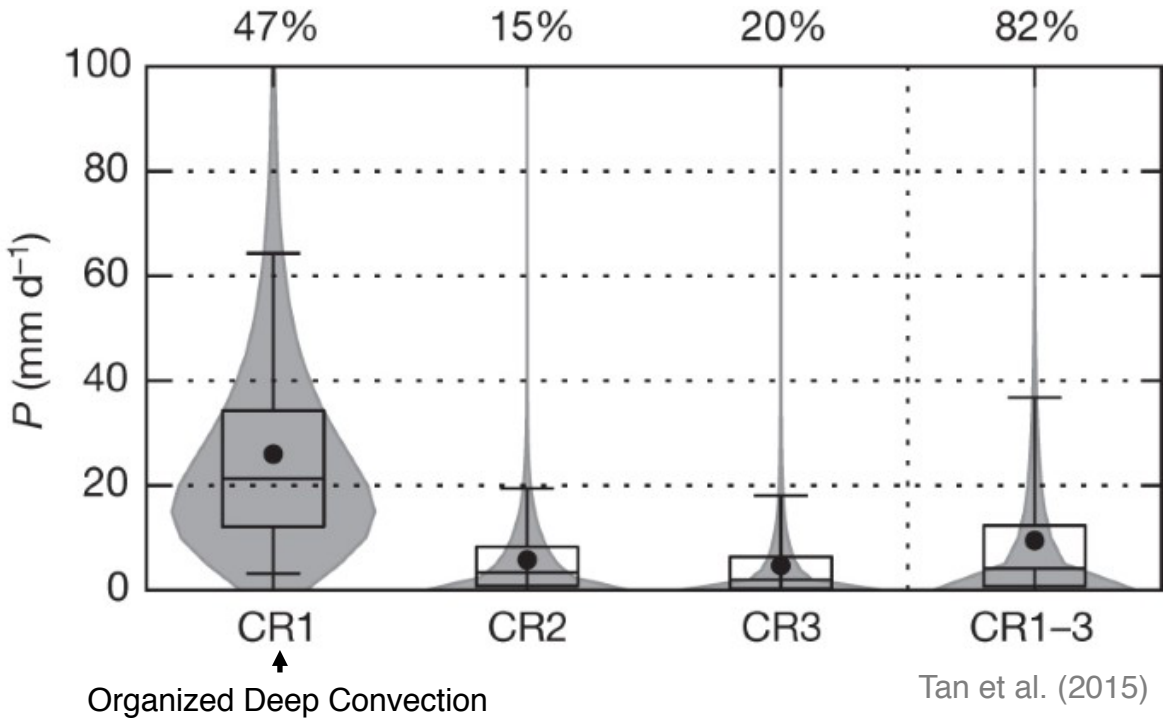
How does self-aggregation impact the mean state?



Wing et al. (2020)

How does aggregation impact mean precipitation?

Mean Precipitation



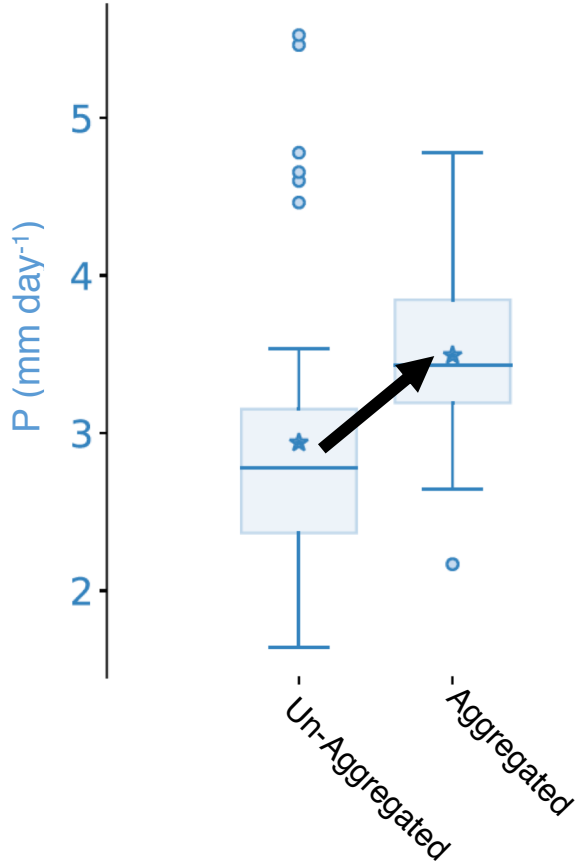
Organized Deep Convection

Tan et al. (2015)

Observed mesoscale organized convection contributes ~half of total tropical rainfall

Conflicting results on relationship between degree of organization and local precipitation

From today's posters:

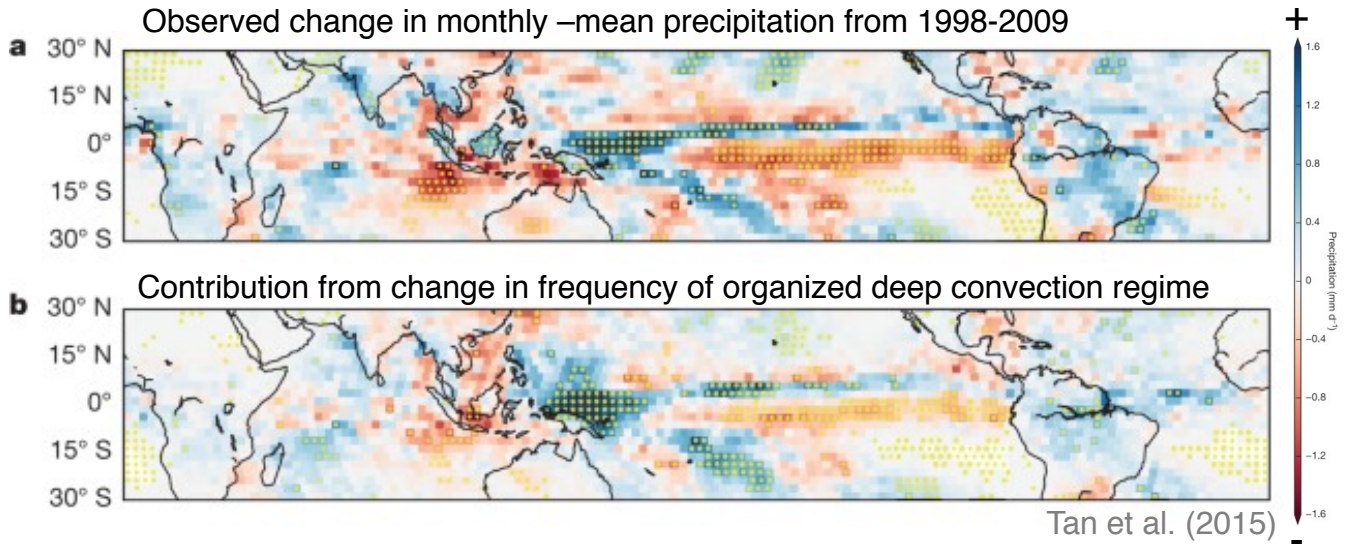


Wing et al. (2020)

Simulations of aggregated convection have ~20-25% more precip than un-aggregated, across large ensemble of RCE simulations

How does aggregation impact changes in mean precipitation?

Changes in Mean Precipitation



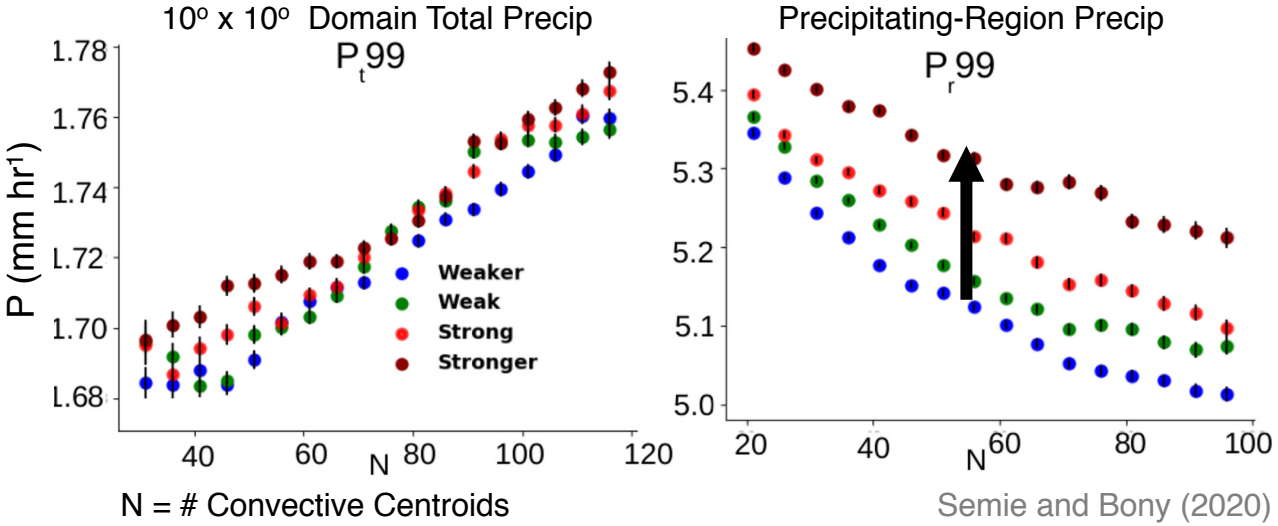
Tan et al. (2015)

Observational evidence that most of the regional increases in tropical precipitation are associated with an increase in the frequency of organized convection

In some RCE modeling studies, changes in mean precipitation with warming are similar between unaggregated and aggregated simulations

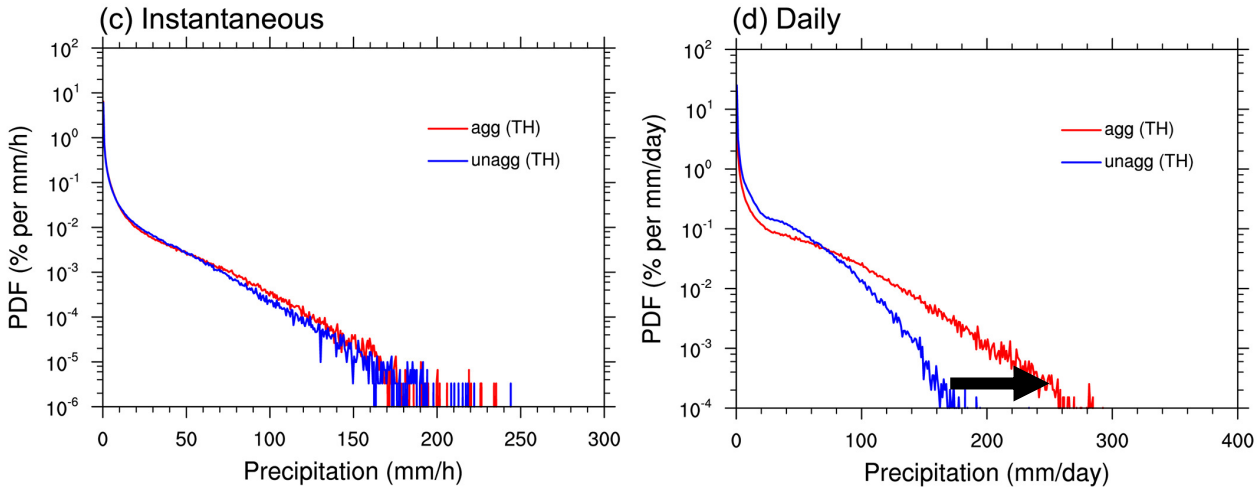
How does aggregation impact extreme precipitation?

Extreme Precipitation



N = # Convective Centroids

Semie and Bony (2020)



Bao and Sherwood (2018)

Some observations show that local extremes depend on organization, but domain-average extremes don't

Other observations indicate the reverse: fine spatio-temporal scale extremes similar but coarser scale extremes depend on degree of organization

Instantaneous precip extremes are similar in aggregated & un-aggregated RCE simulations, but longer accumulation extremes greater in aggregated simulations

How does aggregation impact extreme precipitation?

From today's posters:

Jiawei Bao: Vary terminal velocity of raindrops in realistic GCRM

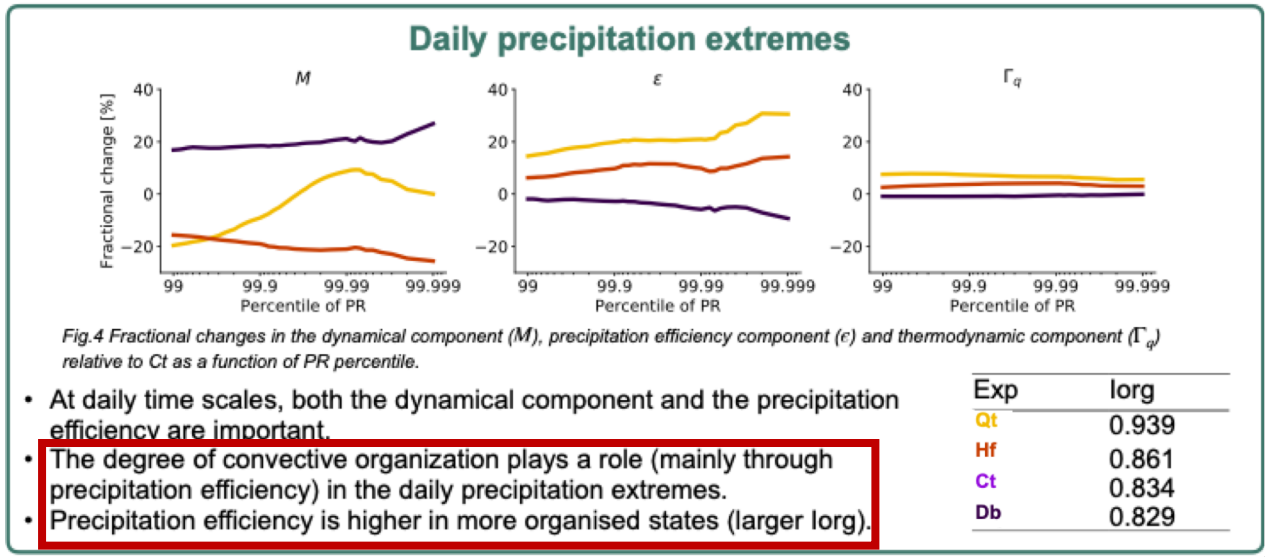


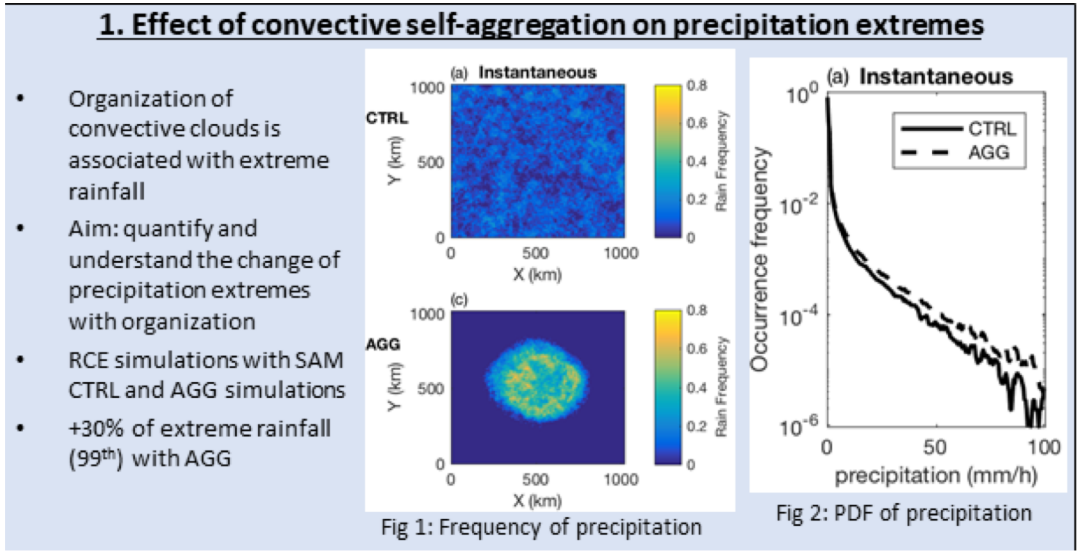
Fig.4 Fractional changes in the dynamical component (M), precipitation efficiency component (ϵ) and thermodynamic component (Γ_q) relative to Ct as a function of PR percentile.

- At daily time scales, both the dynamical component and the precipitation efficiency are important.
- The degree of convective organization plays a role (mainly through precipitation efficiency) in the daily precipitation extremes.
- Precipitation efficiency is higher in more organised states (larger lorg).

Exp	lorg
Qt	0.939
Hf	0.861
Ct	0.834
Db	0.829

- Hourly precip extremes influenced by microphysics via dynamics (change in updraft strength)
- Daily precip extremes more sensitive to microphysical modulation on convective organization via precipitation efficiency

Nicolas Da Silva: Amplification of instantaneous extreme precipitation with self-aggregation



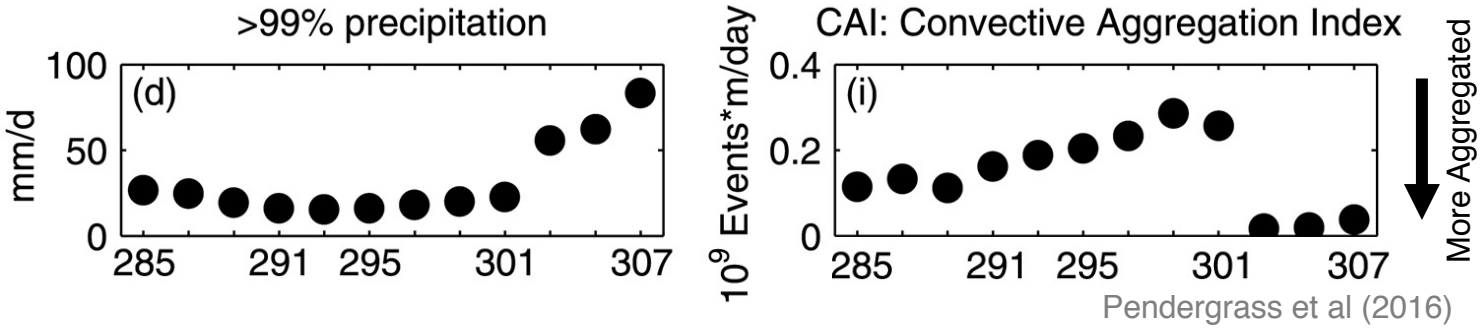
- Aggregation also increases 3-hourly precip extremes
- Mostly through precipitation efficiency
  - Contributions from both less rain re-evaporation & increased accretion efficiency

How to reconcile these and other conflicting results?

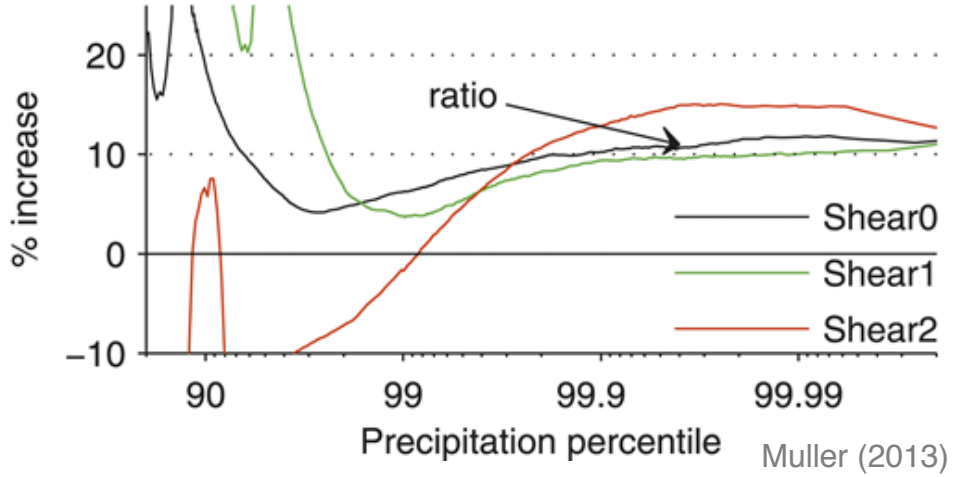
Conflicting dependencies on number of events, size of events, intensity of events, spatial scale, temporal duration

How does aggregation impact changes in extreme precipitation?

Changes in Extreme Precipitation



Pendergrass et al (2016)



Muller (2013)

In some RCE simulations with parameterized convection, the rate of increase in extreme precipitation with warming increases with increasing aggregation

In other RCE simulations with explicit convection, changes in extreme precipitation with warming are similar between unaggregated and aggregated simulations

In simulations of squall-line organized convection, increase in extreme precipitation with warming is similar with no shear (disorganized) & critical shear, greater with supercritical shear

How does aggregation impact changes in extreme precipitation?

From today's posters:

Kai Lochbihler: Cold pool dynamics shape the response of extreme rainfall events to climate change

- Warmer conditions lead to larger and more intense rainfall events
- Consequently, enhanced cold pool dynamics and more moisture accumulation in confined regions
- Enhanced local rainfall extremes with warming

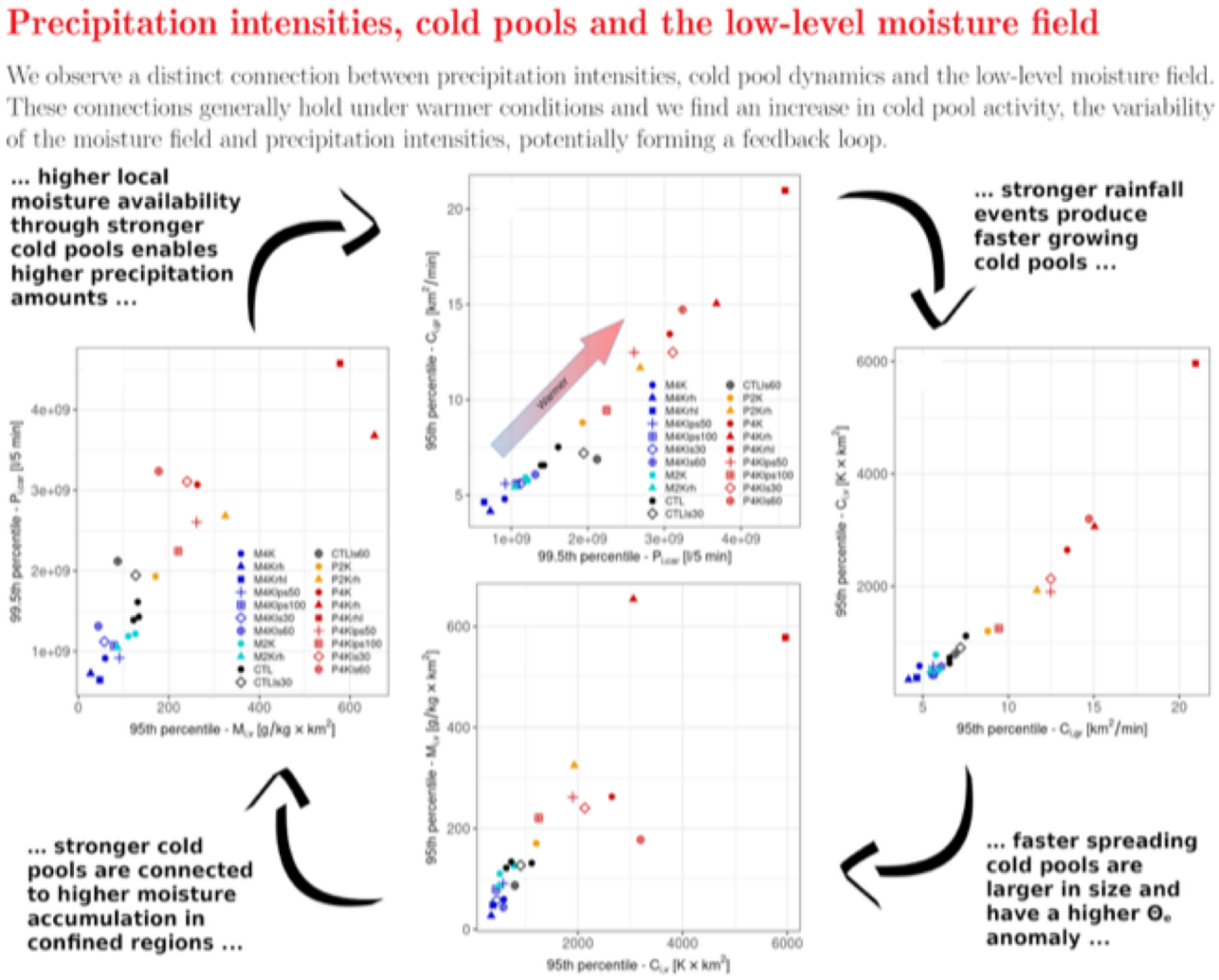


Figure 2: *High percentiles of rain cell aggregated intensities ($P_{i,car}$), cold pool growth rate ($C_{i,gr}$) and volume ($C_{i,v}$), and moist patch volume ($M_{i,v}$).*

Convective organization seems to influence mean & extreme precipitation and their changes with warming…

…but seemingly conflicting results across studies.

Is this is technical/definition issue?

- Time and space scale considered?
- Mode of organization?
- How organization defined?

Or an issue of model/dataset dependence?

Or a physical difference?

Maybe RCEMIP can help rule out model dependence of results?

Impact of organization on mean humidity, clouds, energy budget seems more robust (across observations and a large ensemble of RCE simulations) → implications for climate!