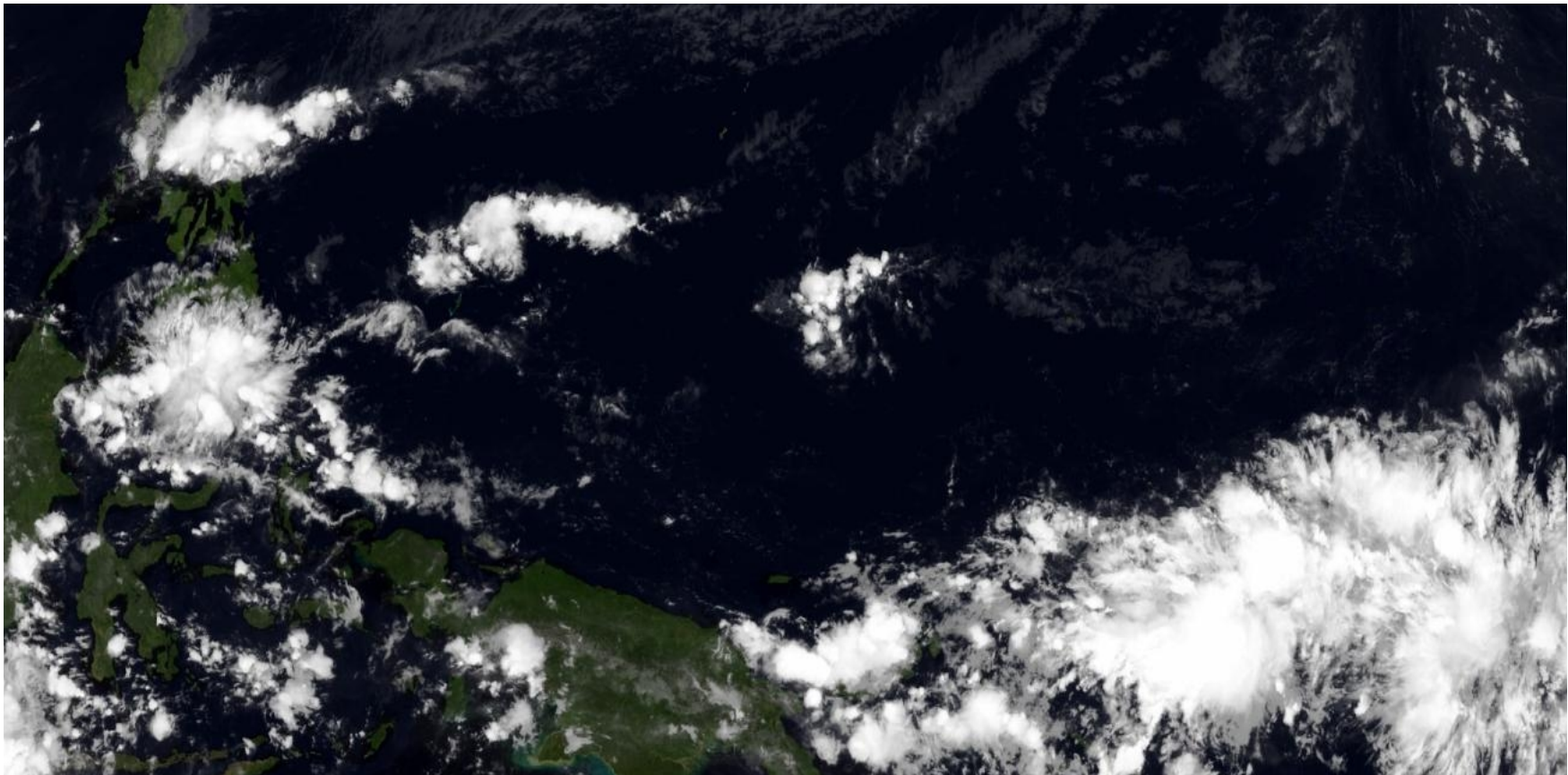


Aggregation of Tropical Convection : Observations and Implications for Climate Modelling

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with

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CFMIP/EUCLIPSE meeting, Hamburg, 10-14 June 2013

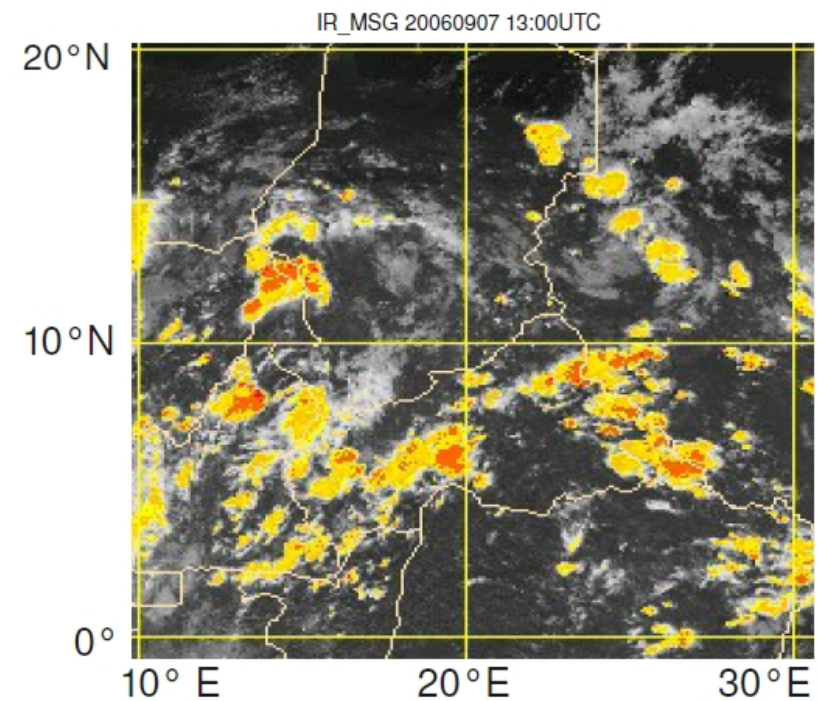
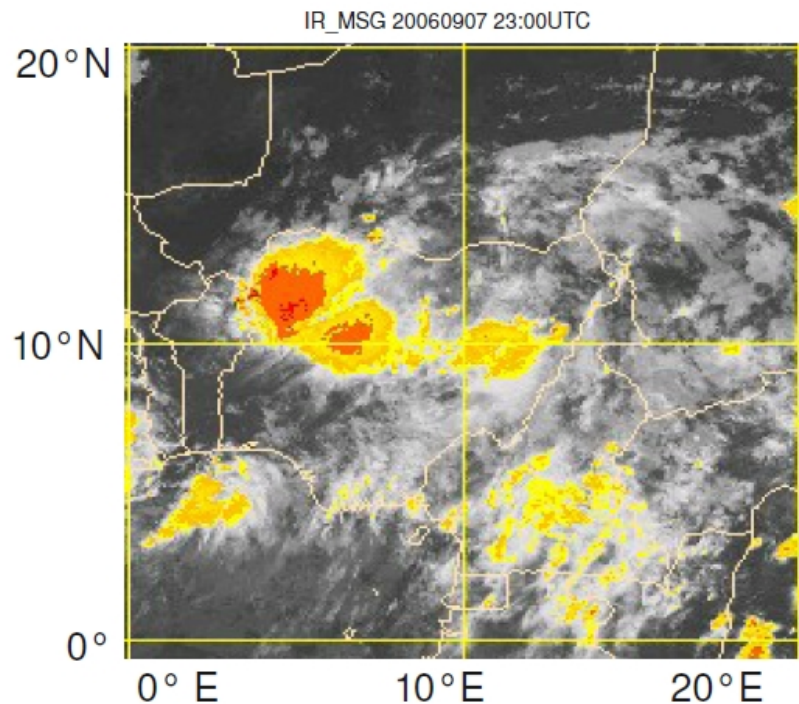
Tropical convection

Tropical convection exhibits a large diversity of organizations

What role does convective organization play in climate ?

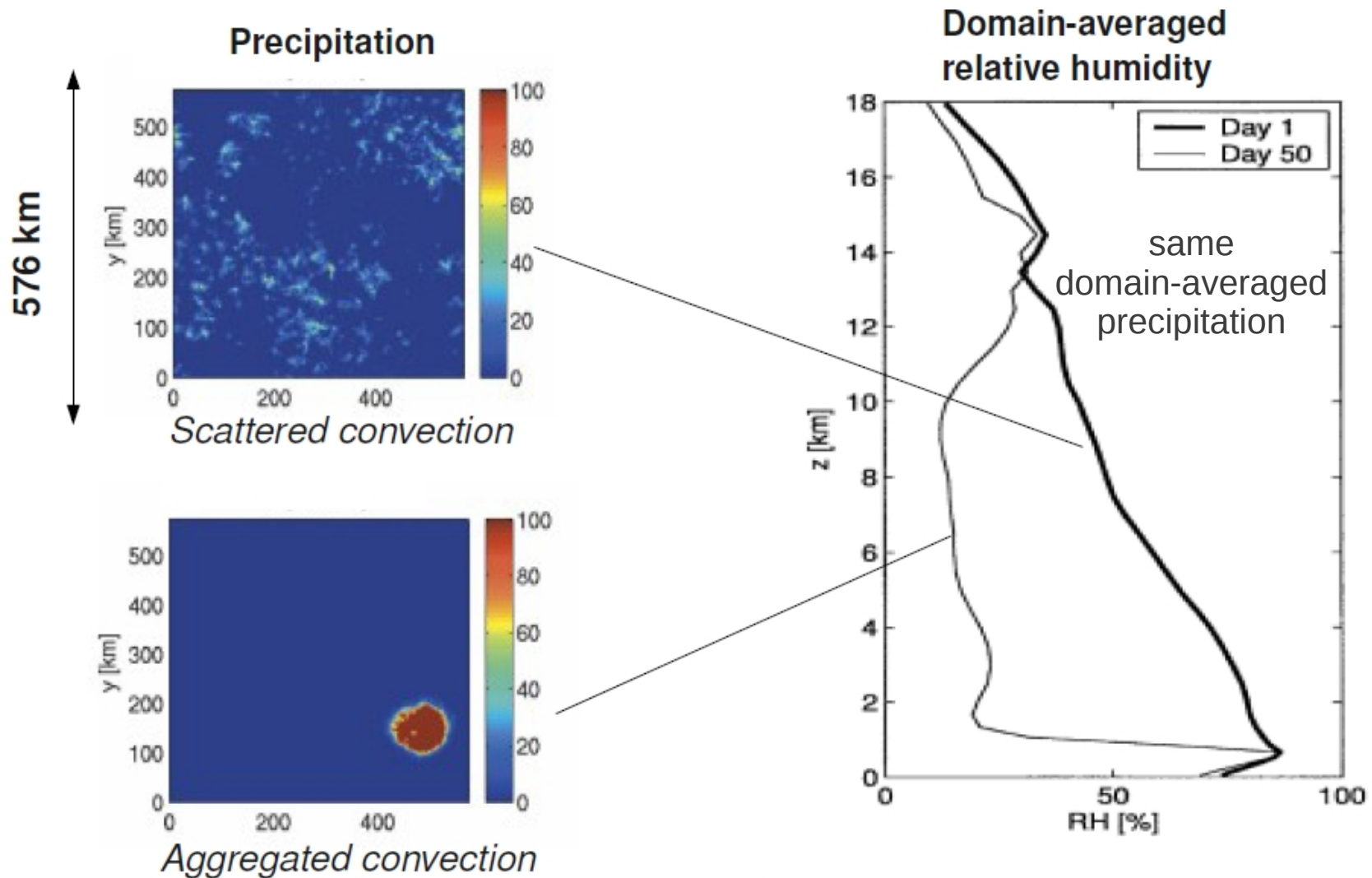
Convective organization poorly represented by global models

What implications for the simulation of current and future climates ?



Cloud Resolving Models suggest that convective aggregation matters 1) for the large-scale atmospheric state

Idealized simulations of radiative-convective equilibrium

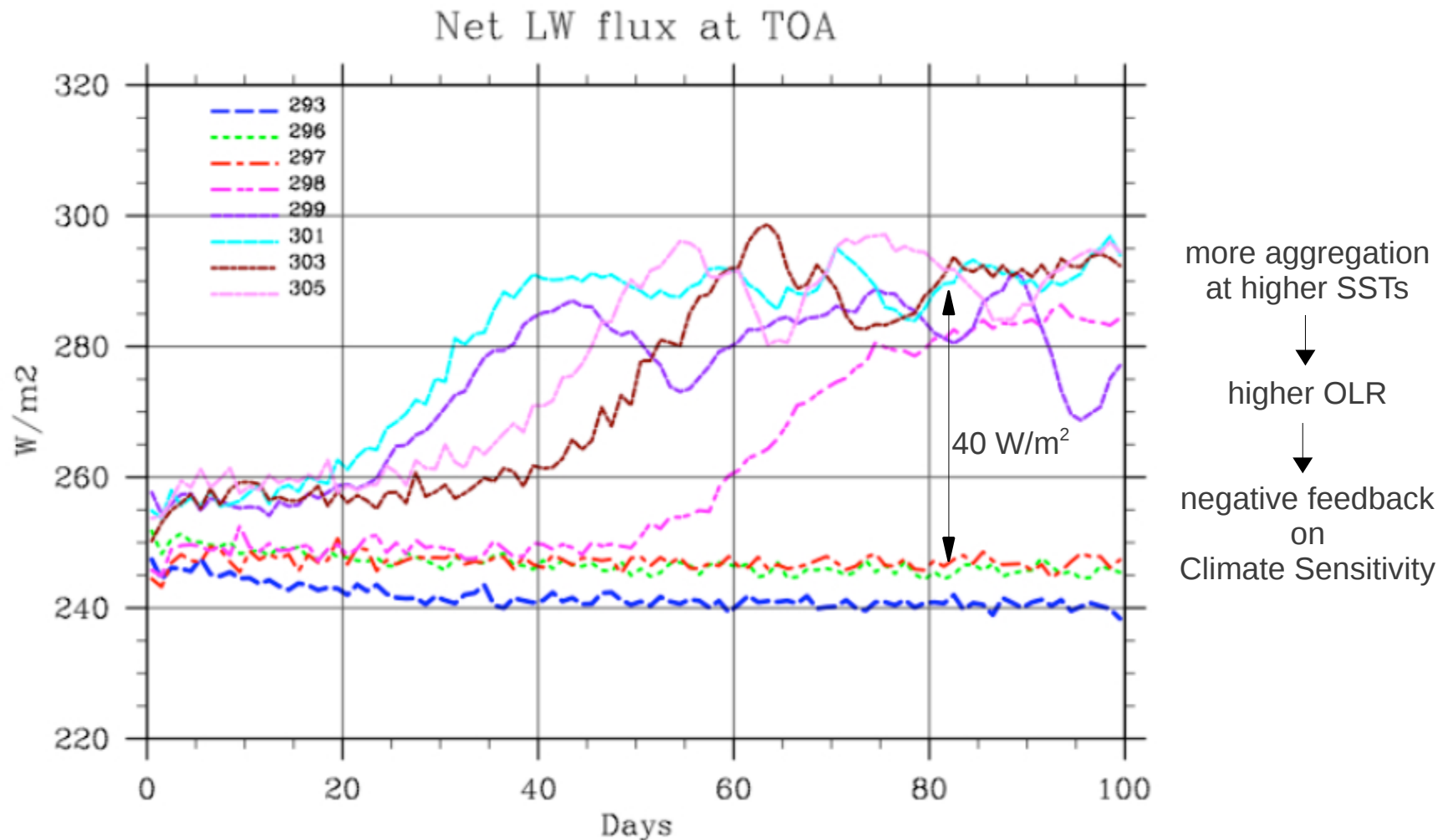


(Bretherton, Blossey and Khairoutdinov, JAS, 2005)

Cloud Resolving Models suggest that convective aggregation matters

2) for climate sensitivity

Idealized simulations of radiative-convective equilibrium



(Khairoutdinov & Emanuel, AMS, 2010)

However, CRM results might be sensitive to
experimental design, resolution, size of the domain, model physics, etc

What do Observations Suggest ?

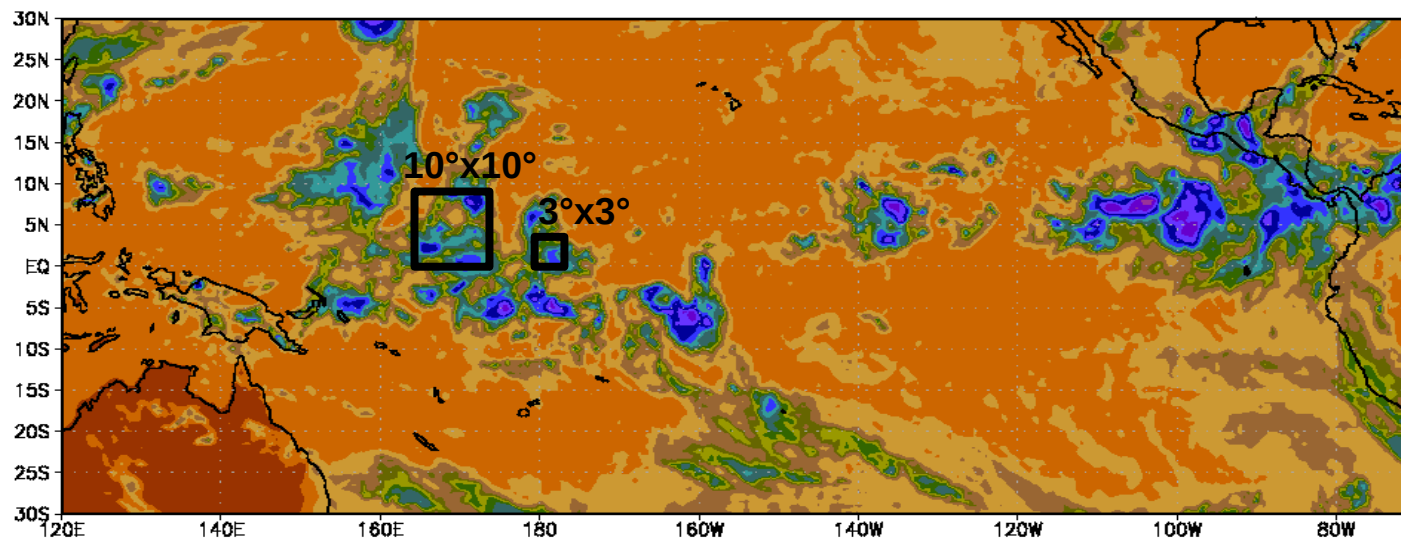
However, CRM results might be sensitive to experimental design, resolution, size of the domain, model physics, etc

What do Observations Suggest ?

1. Characterize convective aggregation using geostationnary data

2. For given domain-averaged precipitation and large-scale forcings :

How does the atmospheric state depend on the degree of aggregation of deep convection ?

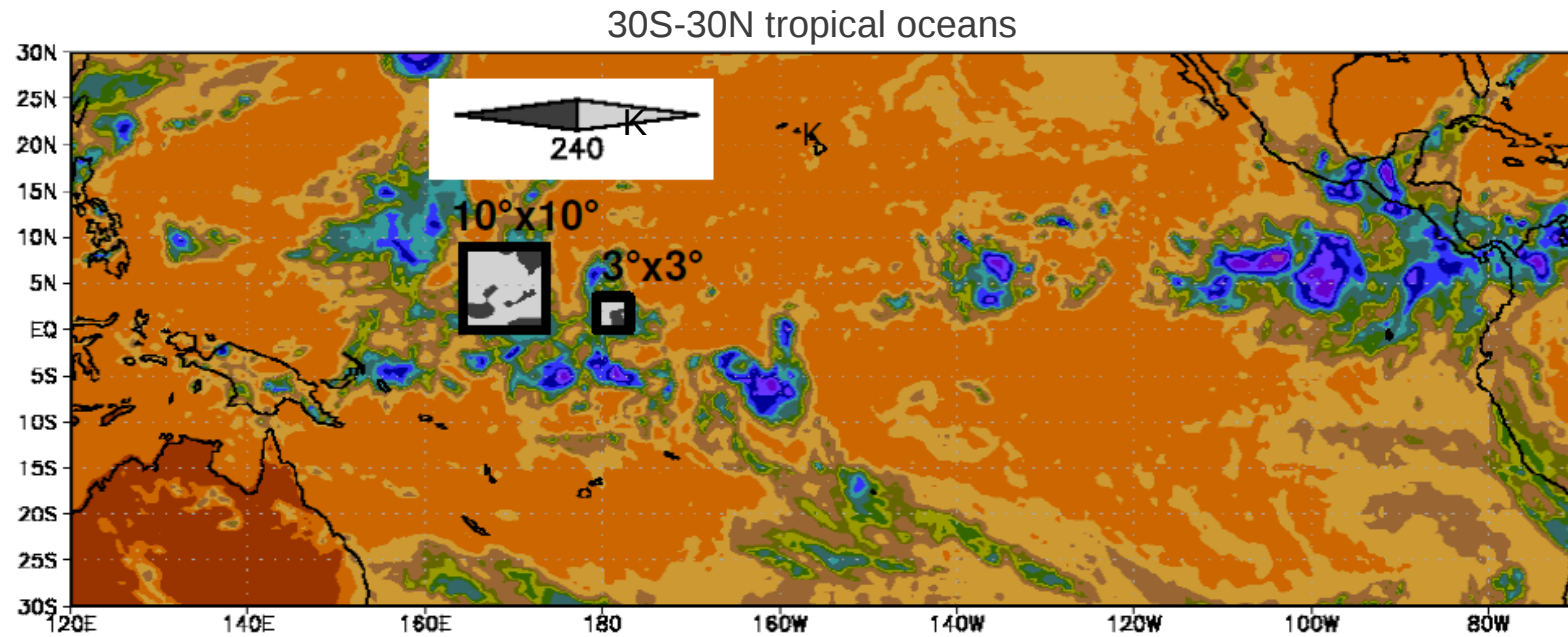


(Tobin, Bony & Roca, *J. Climate*, 2012 ; Tobin et al., *JAMES*, submitted)

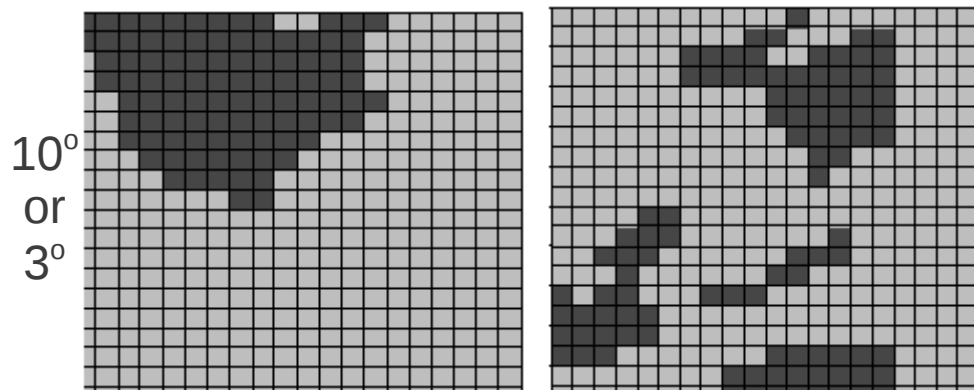
Datasets

Name	Variable	Spatial resolution	Temporal sampling	Period	Reference
CLAUS	IR brightness temperature	0.5°	3 hourly	1983–2005	Hodges et al. (2000)
HOAPS	Surface rain	1°	Twice daily	1988–2005	Andersson et al. (2010)
	Precipitable water				
	Surface sensible heat flux				
	Surface latent heat flux				
	Sea surface temperature				
	10-m wind speed				
	Air–sea difference in humidity				
ERA-Interim	RH	0.75° 37 levels	6 hourly	1989–present	Simmons et al. 2007
	Vertical velocity	0.75° 37 levels	6 hourly	1989–present	
AIRS	RH	1°	Twice daily	2002–present	Aumann et al. 2003
OLR-NOAA	OLR	2.5°	Daily	1976–present	Liebmann and Smith 1996
CERES	OLR	5°	Daily	2000–04	http://ceres.larc.nasa.gov/
	Reflected shortwave				
METEOSAT	IR & WV Tb	5 km	30 min	1991-2006	
ISCCP-FD	Radiative fluxes	2.5°	3 hourly	1998-2005	Zhang et al. 2004
ISCCP-DX	Cloud top pressure, optical thickness	30 km	3 hourly	1998-2005	Rossow and Schiffer 1999

Characterization of Convective Aggregation

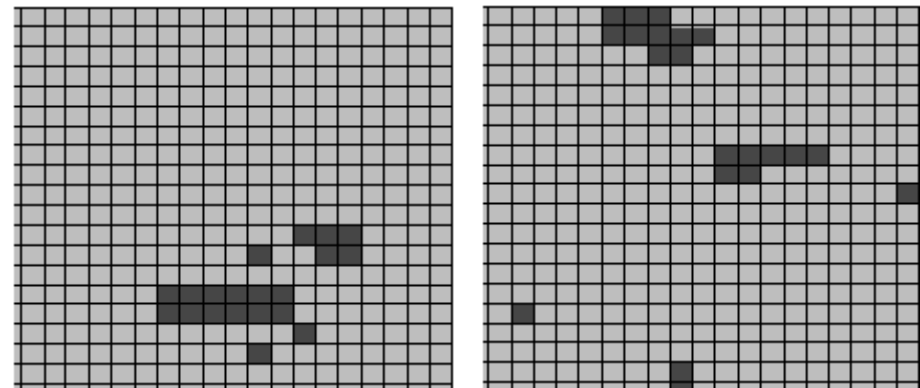


Number of convective clusters



Tb threshold : 240 K

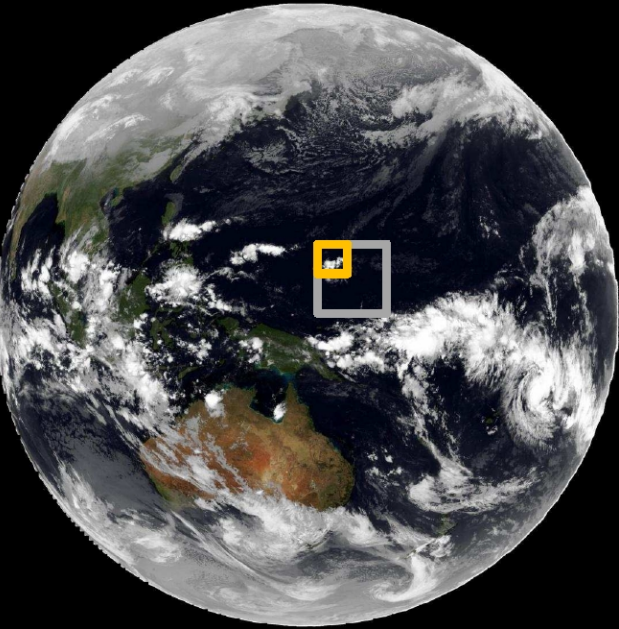
Clumping of convective clusters



$$D_0 = (d_0 \dots x d_i \dots d_n)^{1/n}$$

Gauvrit et Delahaye, 2006

(Tobin, Bony & Roca, *J. Climate*, 2012)

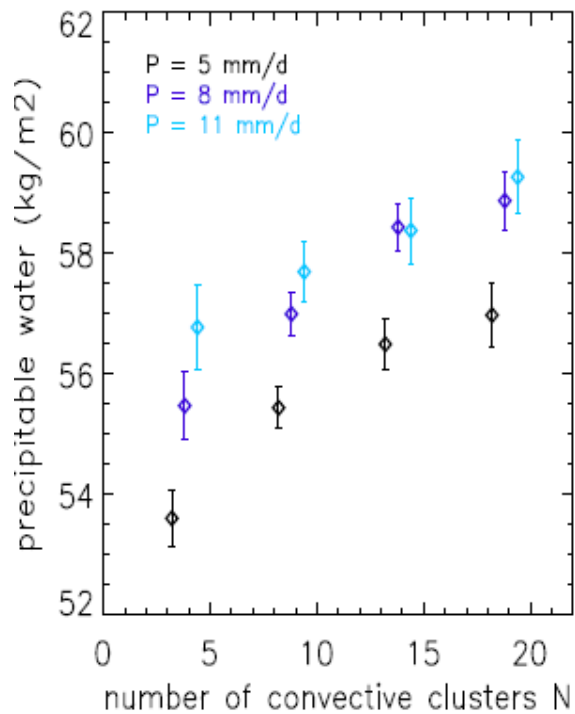


Water Vapor

For given domain-averaged precipitation and LS forcings :
 more convective aggregation \longleftrightarrow drier free troposphere

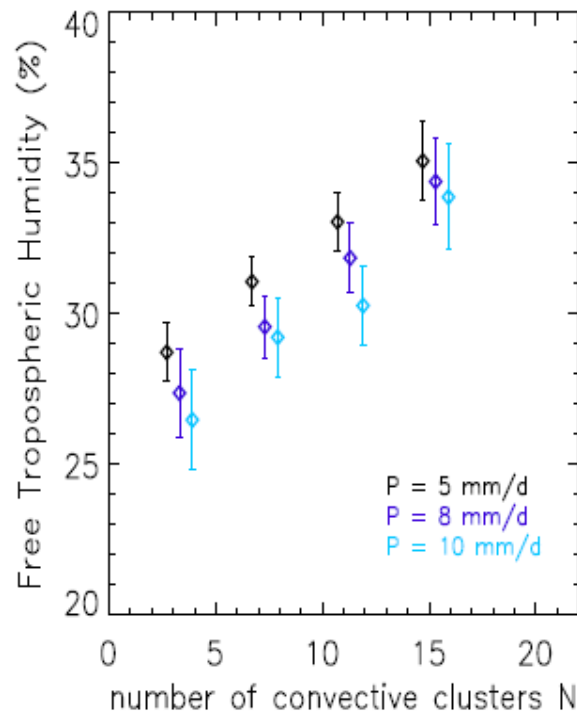
Both at the synoptic scale ($10^\circ \times 10^\circ$) and **at mesoscale ($3^\circ \times 3^\circ$)**

SSM/I precipitable water

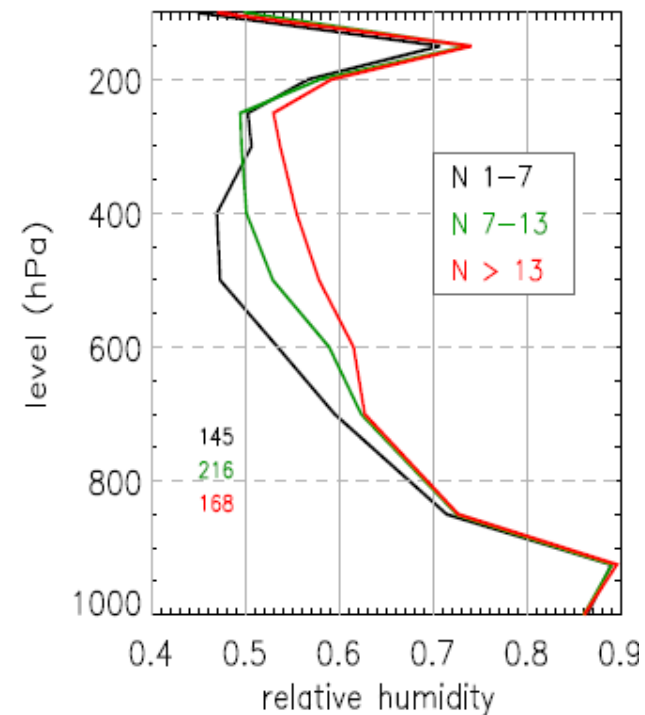


more aggregation
 \longleftarrow

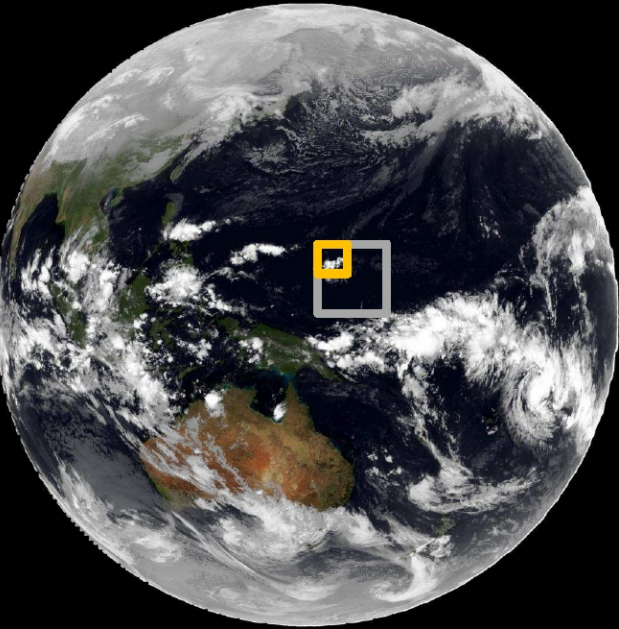
METEOSAT FTH



AIRS relative humidity



(Tobin et al., JAMES, submitted)

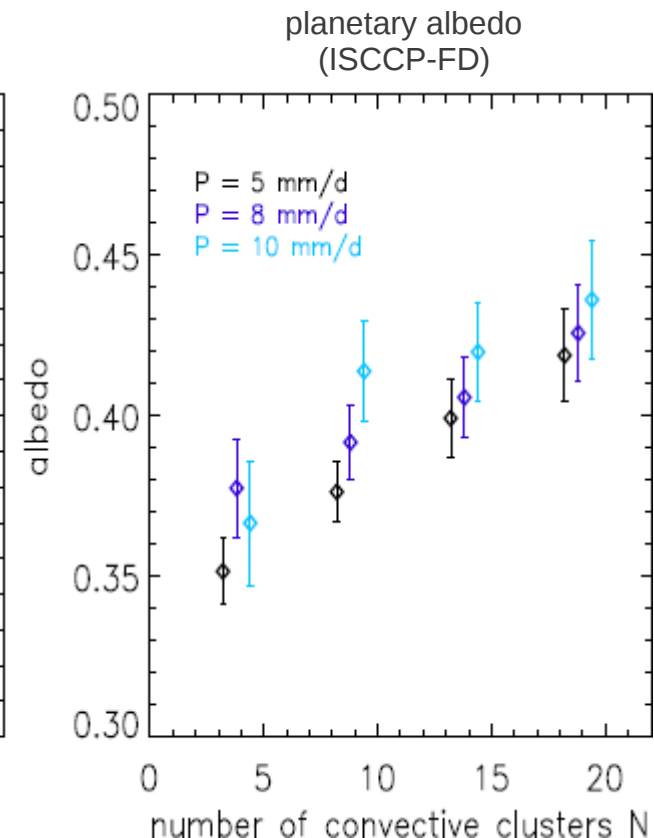
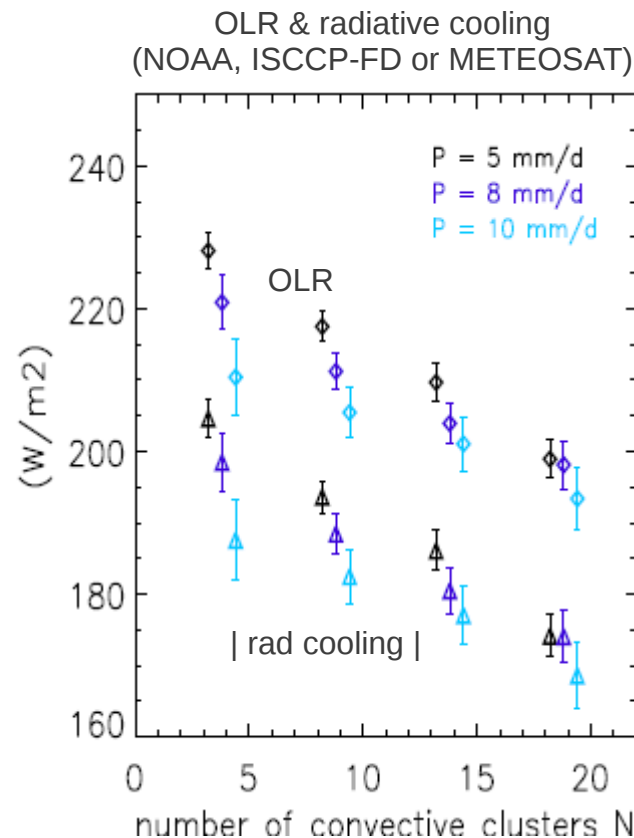
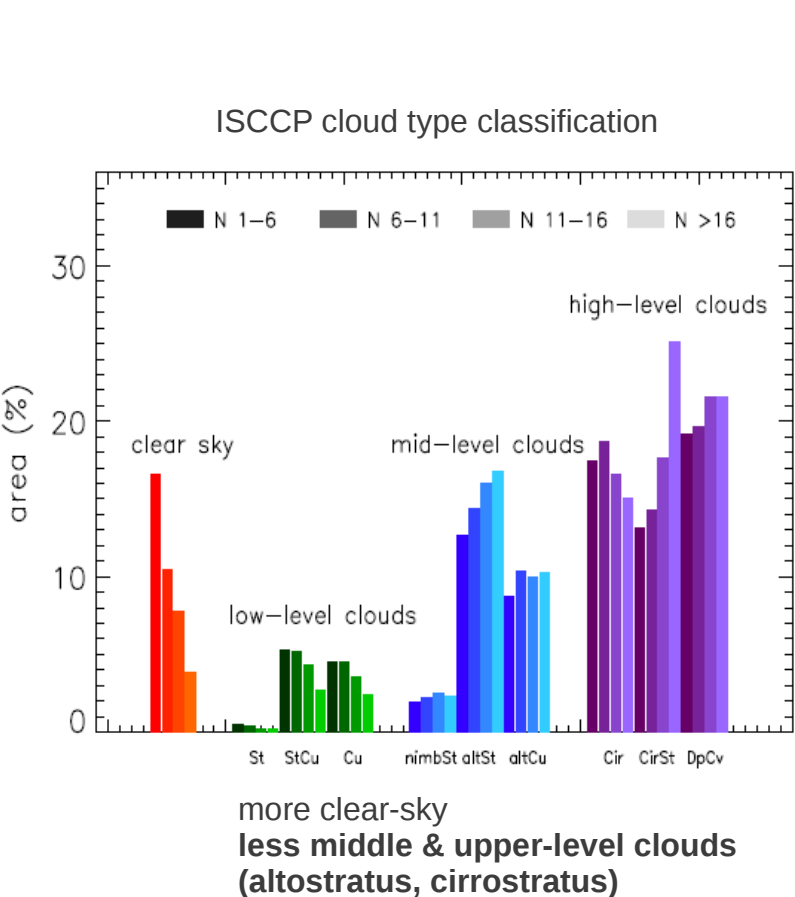


Radiation

For given domain-averaged precipitation and LS forcings :

more convective aggregation \longleftrightarrow more radiative cooling,
more OLR, less albedo

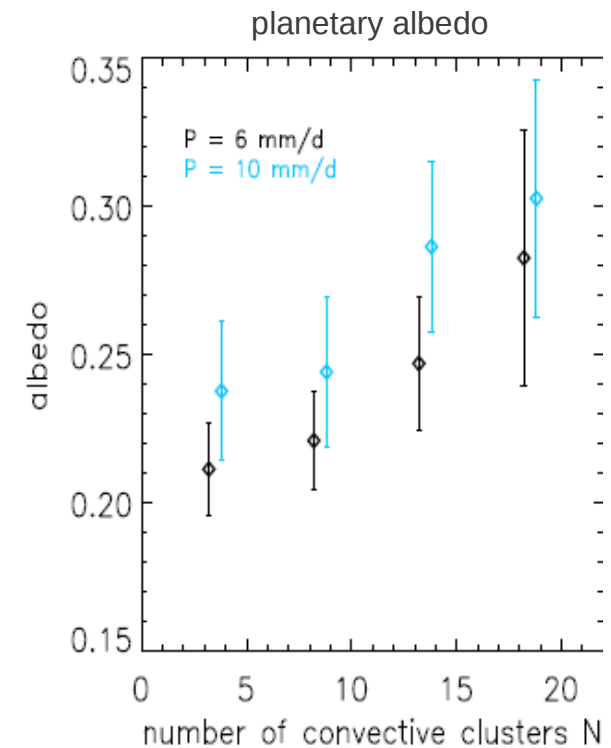
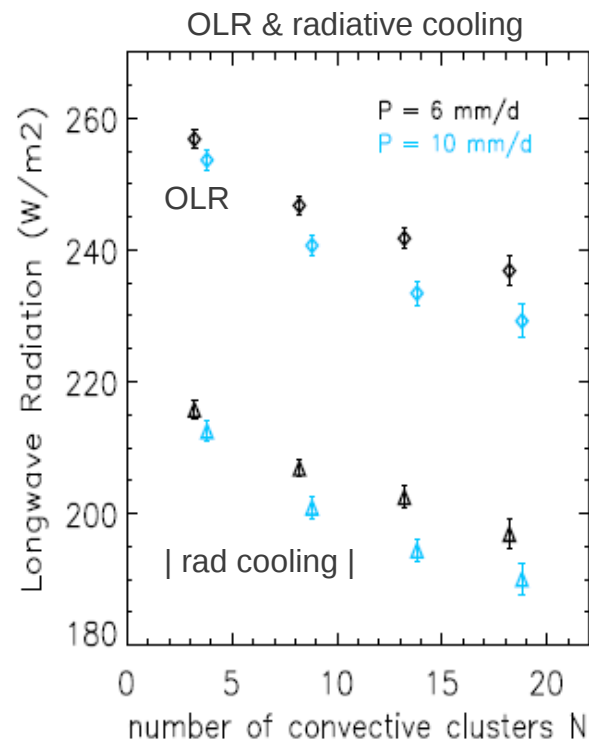
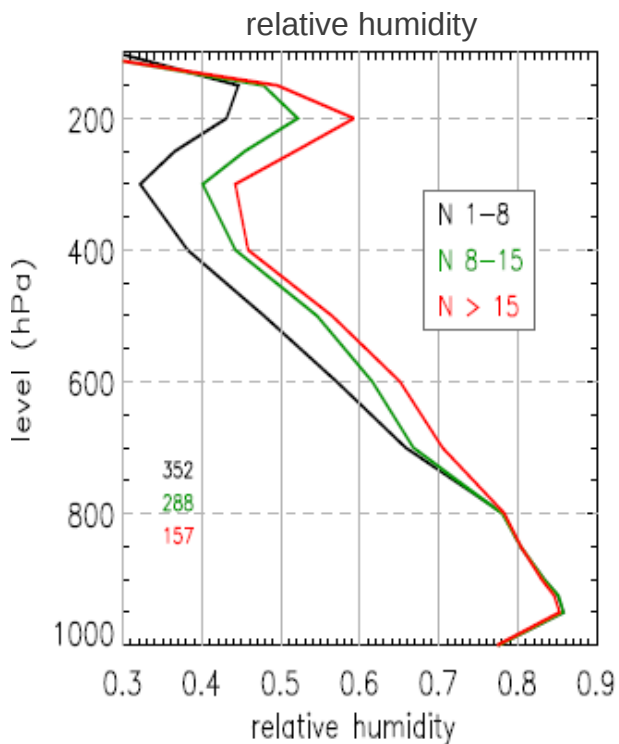
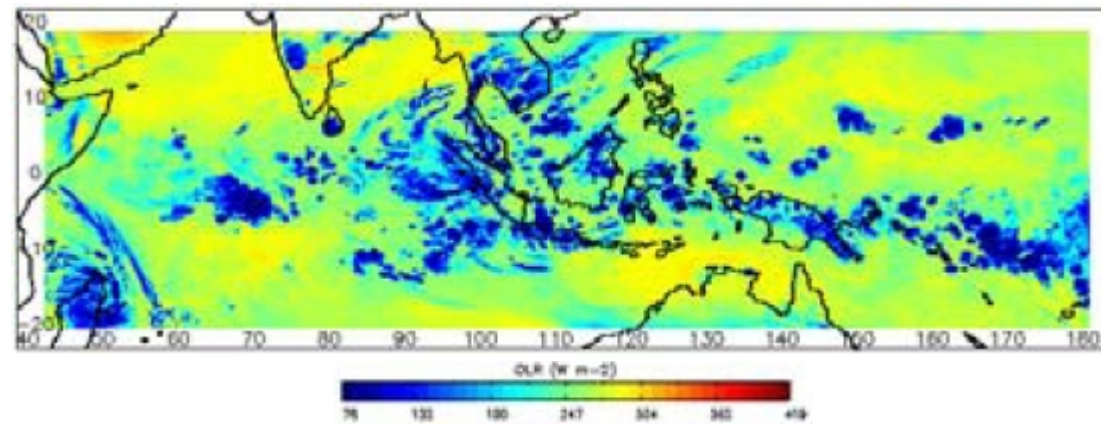
Both at the synoptic scale ($10^\circ \times 10^\circ$) and **at mesoscale ($3^\circ \times 3^\circ$)**



(Tobin et al., JAMES, submitted)

Observed Behaviour Reproduced by (at least) one Cloud Resolving Model

CASCADE CRM simulation (4km 3D Smag)



(Tobin et al., JAMES, submitted)

Conclusion

Observations show that for given domain-averaged convective activity and large-scale forcings :

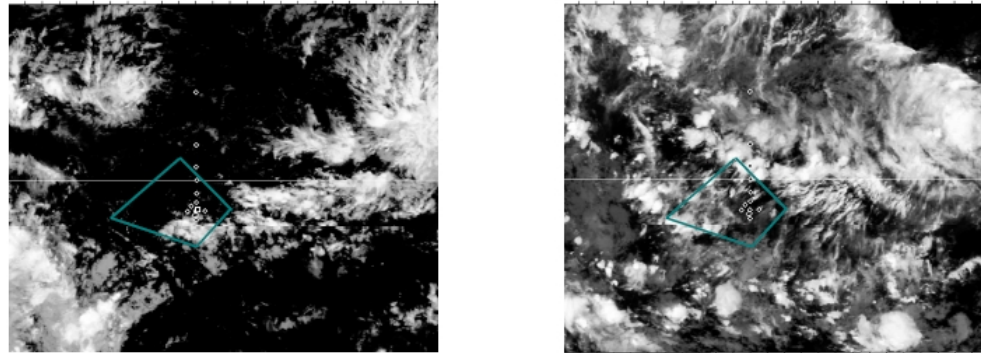
- **the large-scale atmospheric state and energetics (e.g. humidity, radiation, sfc fluxes) depend on the state of aggregation of deep convection**
- the modulation is significant (several tens of W/m^2 , several kg/m^2)
- consistent with CRM results
- observed both at the synoptic scale and **at the mesoscale**



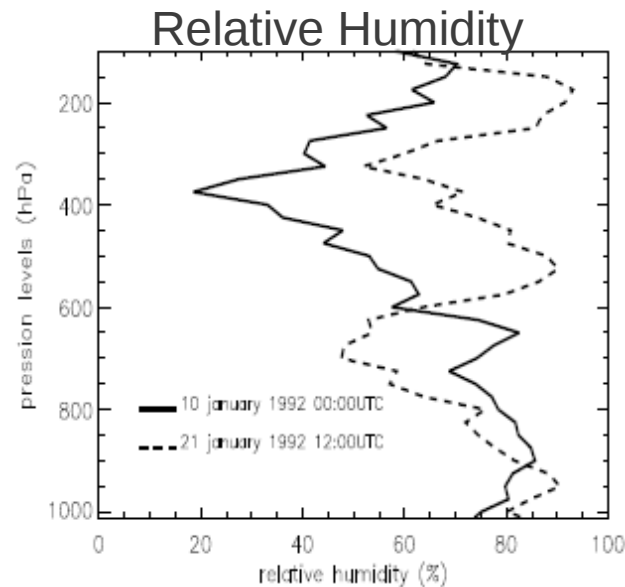
Implications for climate and large-scale modelling ?

Large-scale modelling

- Mesoscale organization = missing degree of freedom in current convective parameterizations ?



Two days of
TOGA-COARE

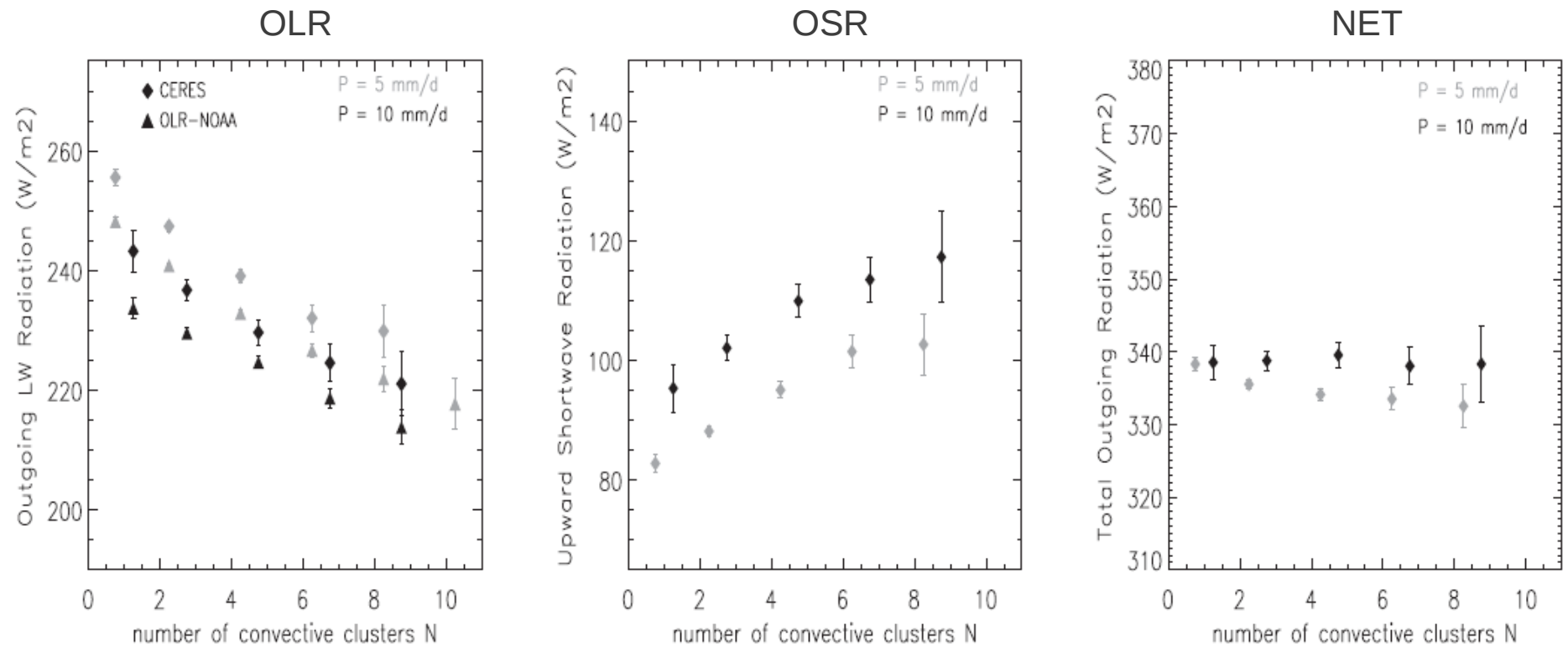


same omega
same precip
same SST

- Further observational and process studies needed to guide parameterizations developments.**
- In the meantime : what possible consequences ?

Climate Sensitivity

No evidence for a significant modulation of the TOA NET radiation budget by convective aggregation

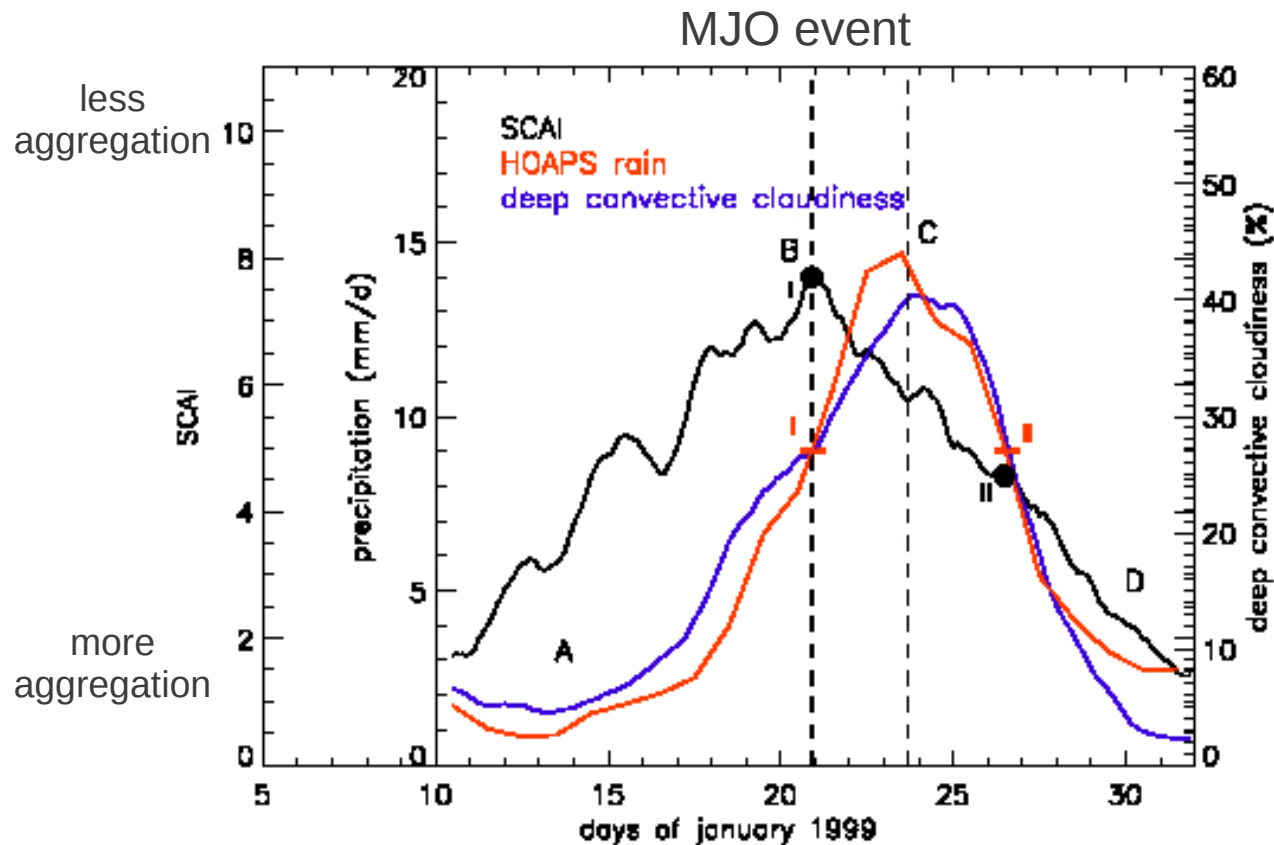


(Tobin, Bony, Roca, *J. Climate*, 2012)

Large-Scale Atmospheric Circulation

- Convection-humidity interactions depend on convective aggregation (e.g. higher ε_p in aggregated states)
- Evidence for a modulation of the moist static energy input into the atmosphere (LH + SH + RadCooling):
scattered convection : moist conditions, build up of MSE \rightarrow strengthening LS ascent
aggregated convection : drier conditions, decrease of MSE input into the column \rightarrow weakening LS ascent
- **Suggests a positive feedback between convective aggregation and large-scale vertical motions.**

By how much ?...



A satellite image of Earth from space, showing a large portion of the globe. The image is dominated by dark blue oceans and white, swirling cloud patterns. In the lower-left corner, a landmass with brown and tan terrain is visible, likely Australia. To its north, a large green landmass, possibly South America, is partially obscured by clouds. The text "Thank You" is overlaid in the upper right quadrant.

Thank You