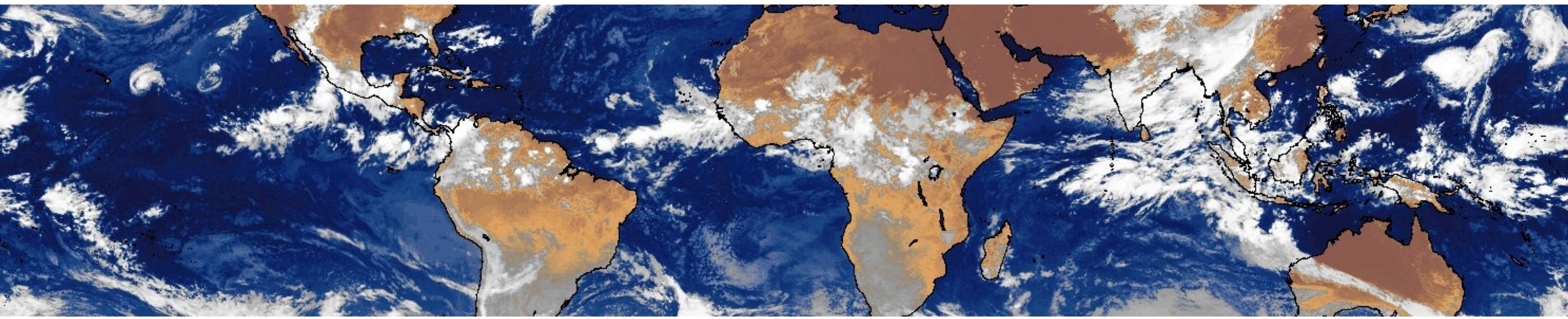
Contribution of Mesoscale Convective Systems to the water and energy budget of the tropics



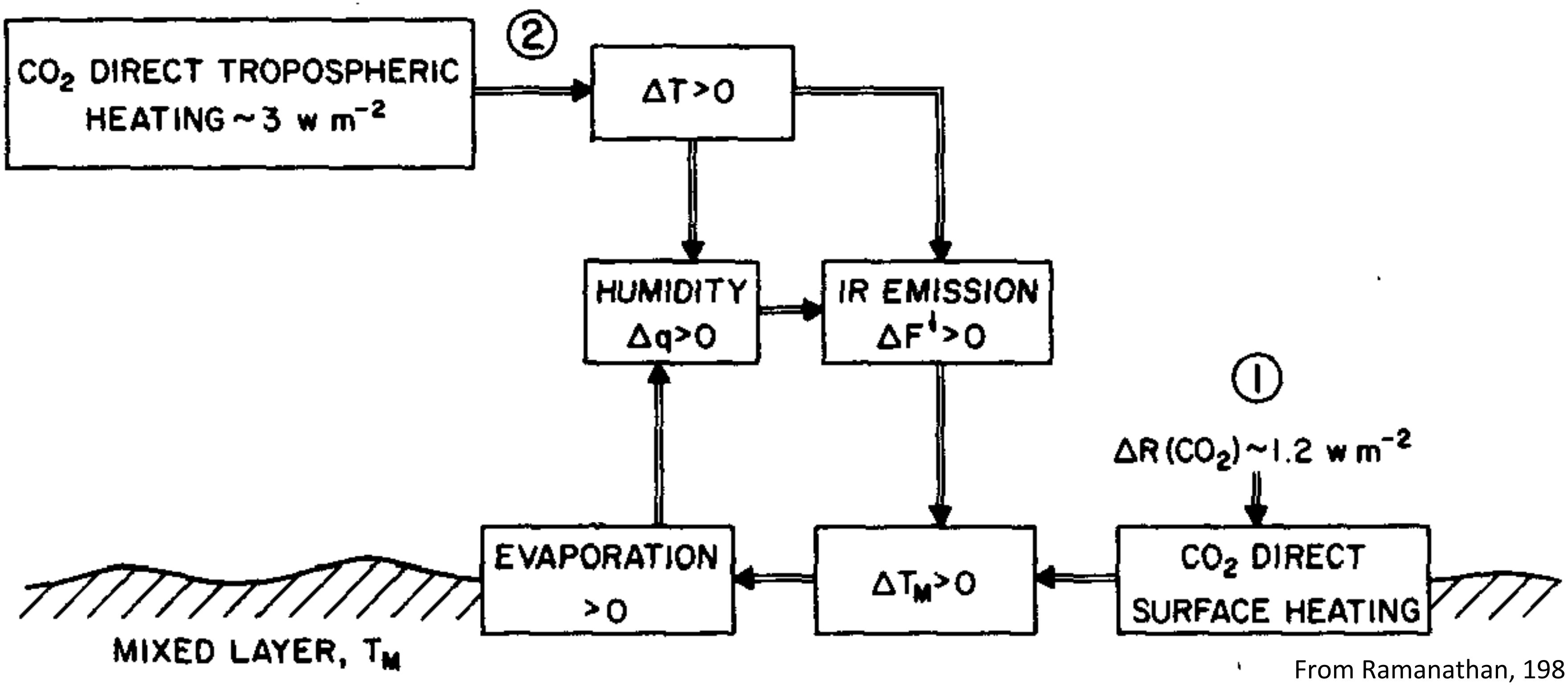
IR mozaic 22 July 2016 06Z Courtesy of www.satmos.meteo.fr

Rémy Roca (CNRS)
OMP/LEGOS, Toulouse, France

Acknowledgments to Thomas Fiolleau and Dominique Bouniol CRNM, Météo-France

The changing water cycle under radiative-convective equilibrium

Theoretical expectation for global climate to an increased CO2 concentration

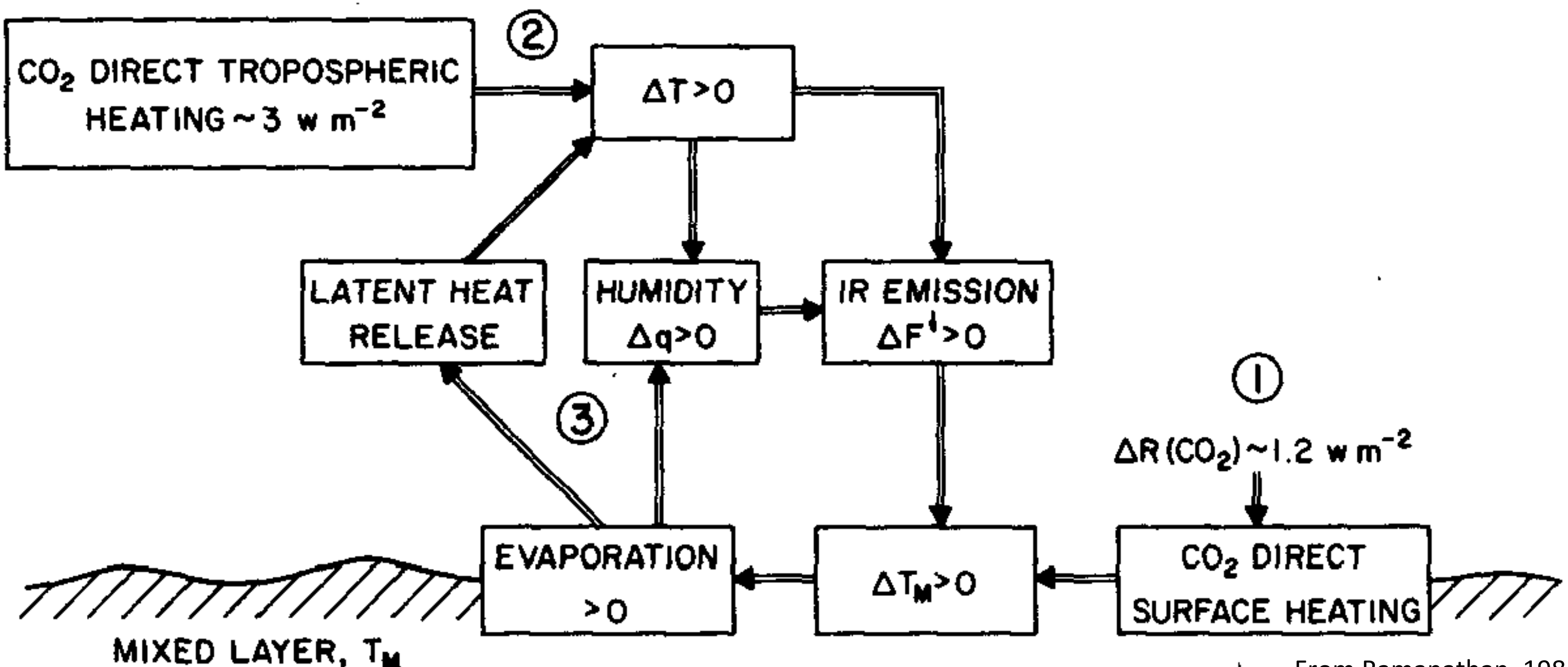


From Ramanathan, 1981

Global « warming » = verified
Global « moistening » = ~ verified

The changing water cycle under radiative-convective equilibrium

Global energy controls of precipitation



From Ramanathan, 1981

Global « warming » = verified
Global « moistening » = ~ verified
Global « raining » = verified?

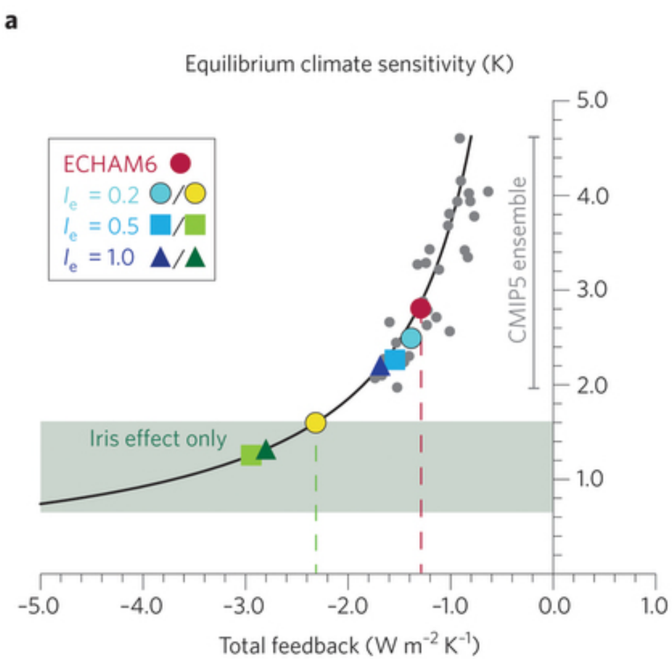
Global energy budget dictates P increase following atmospheric radiative cooling
The rate is estimated at ~2-3%K^{-1} (Stephens and Ellis, 2008)

Strong sensitivity to the details of the convection parameterization

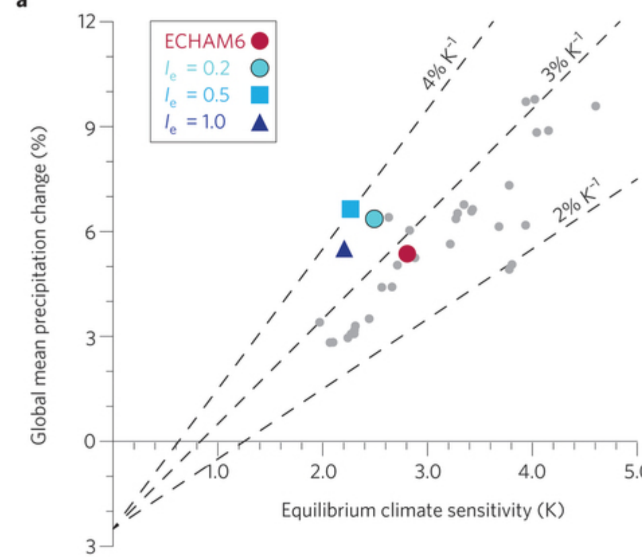
Global water cycle in climate models

$$C_p(T_s) = C_o\,(1 + I_e)^{T_s - T_o}$$

Rate of converion of water vapor in rain
~ Detrainement decreseases with temperature for various scenarios mor or less strong



Mauristen and Stevens, 2015



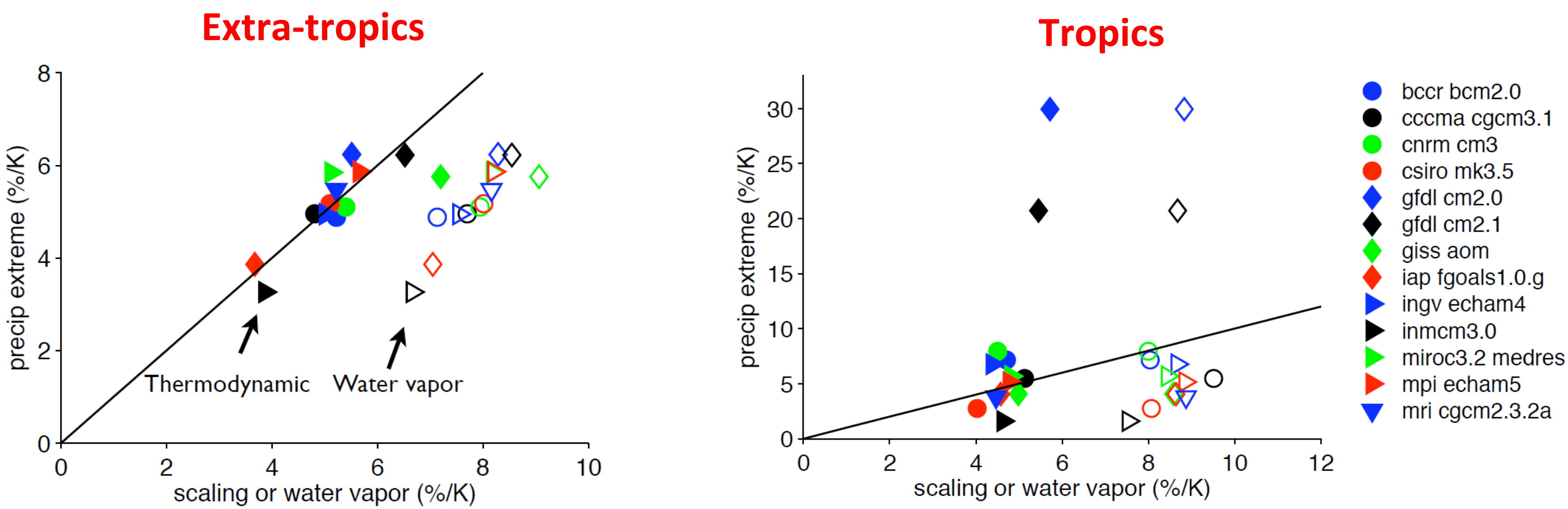
The water cycle and climate sensitivity are strongly modified when slight modifications of « organisation » of convection are accounted for.

Limited constraints on regional scale changes

What about the response of the DISTRIBUTION of precipitation ?

A look at the 99.9th percentile of daily precipitation

O'Gorman and Schneider, PNAS, 2009



3 to 6%/K

1.3 to 30%/K

More scattered tropical extremes responses in models compared to extra-tropics

Tropical Mesoscale Convective systems !

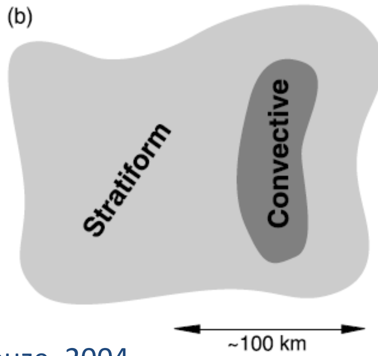
Outline of the presentation

- Introduction
- **What is a tropical Mesoscale Convective system ?**
- Quantifying the contribution of systems to the tropical rainfall and radiation
  - Rainfall
  - TOA radiation
- Conclusion and on going work : revisiting the conceptual model of the life cycle of the MCS
  - TOA Radiation, Links to microphysics, Rainfall

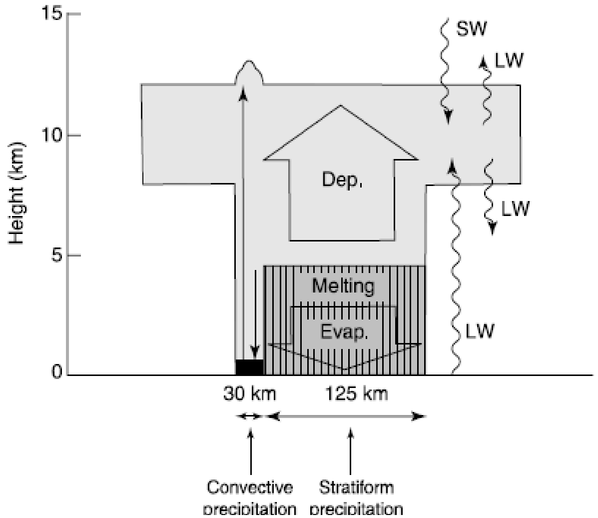
What is a mesoscale convective system (MCS) ?

A large corpus of knowledge from radar meteorology, campaigns etc… (1/2)

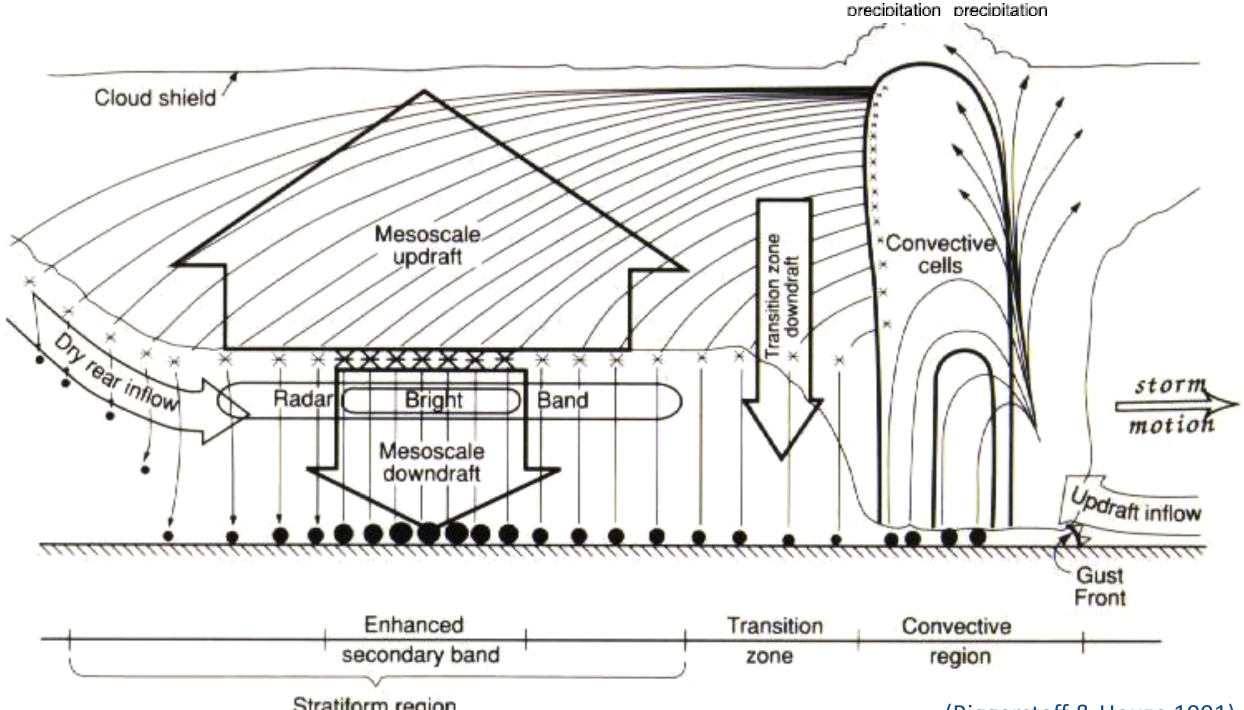
Picture from US Airforce rocket 1948



Houze, 2004



Continuous cold cloud shield

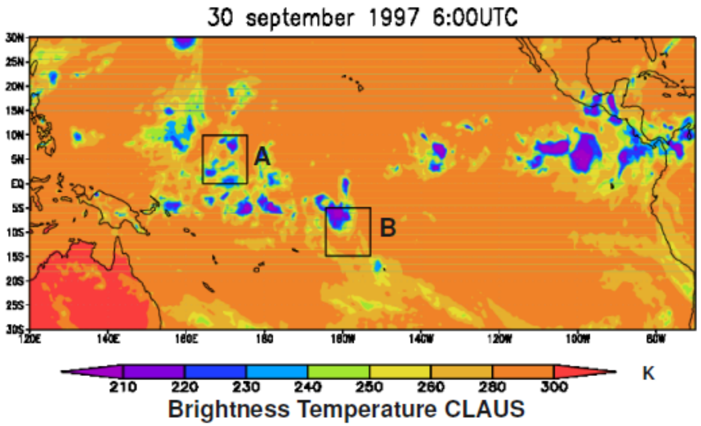


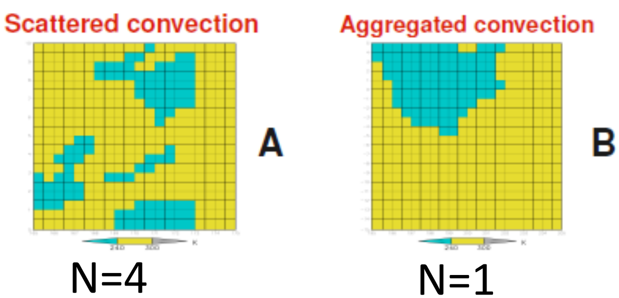
(Biggerstaff & Houze 1991)

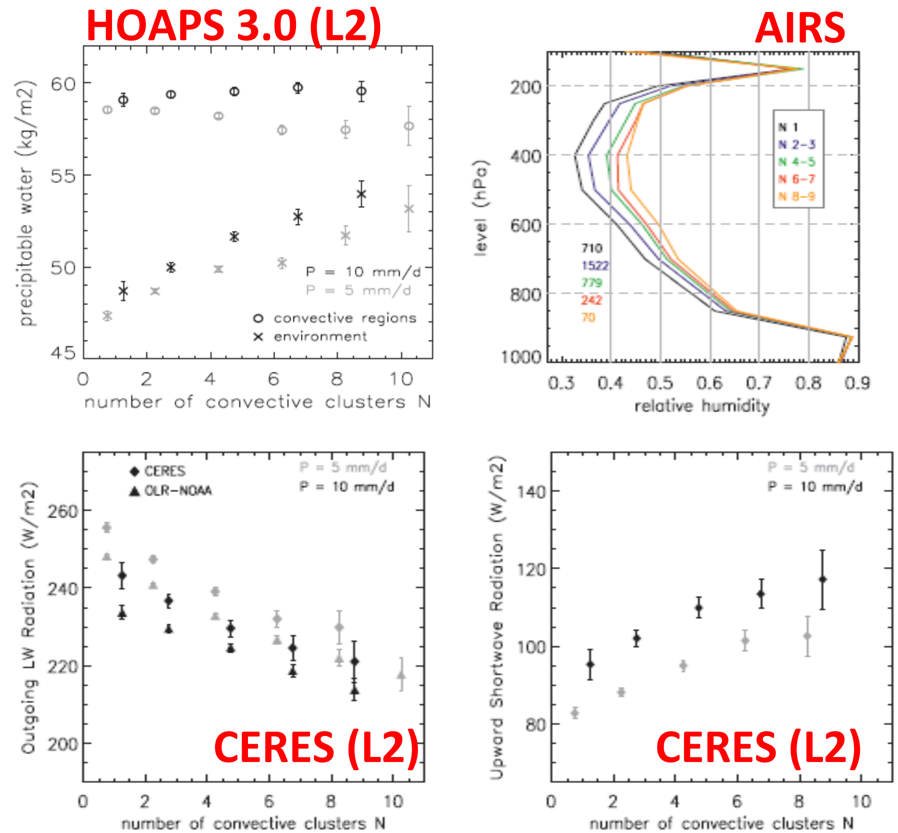
The contribution of MCS to the tropical radiation

Importance of agregation and organisation

From Tobin, Bony and Roca, J Clim, 2012





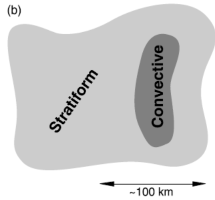


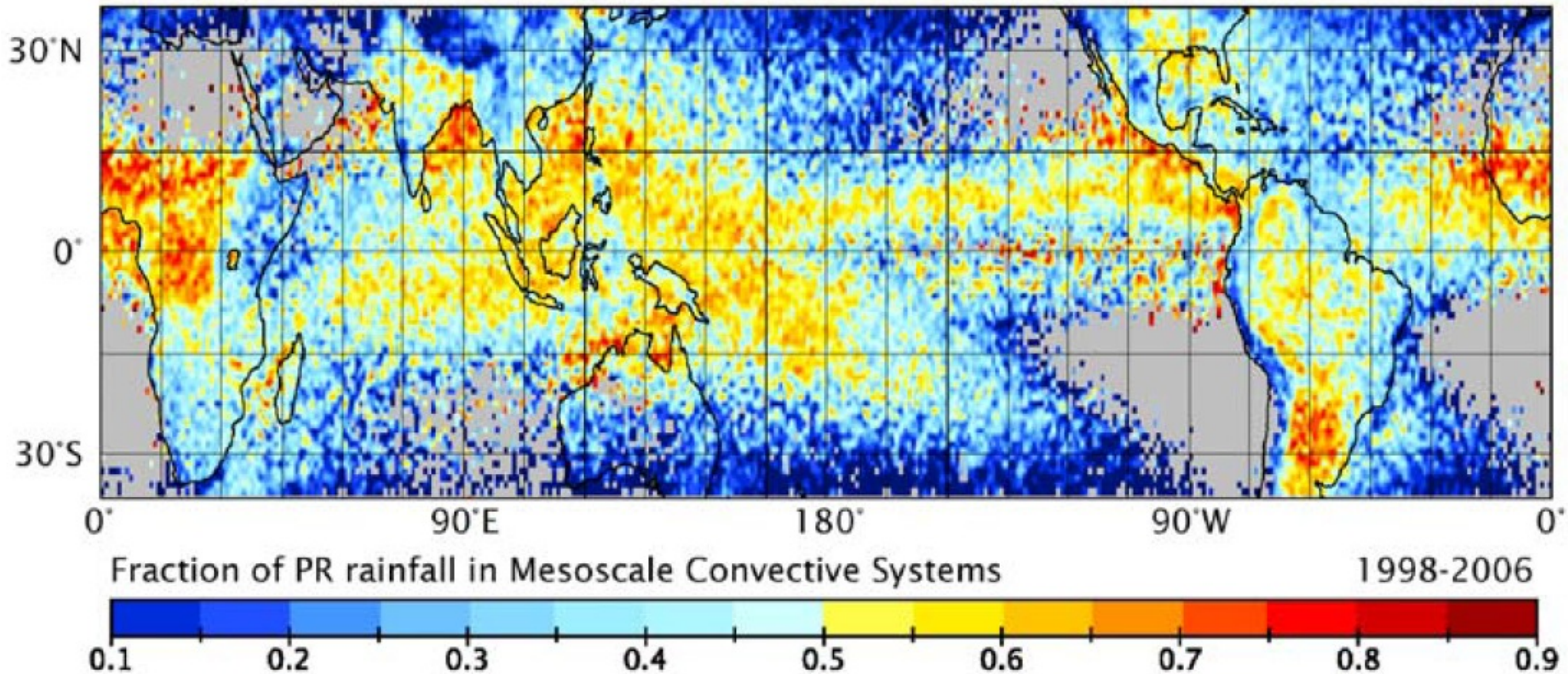
- 10°x10°
- SST=28°C, P=cte

At given large scale conditions (SST & P), the agrégation of convection discriminates the TOA flux, PW and RH distribution.

The contribution of MCS to the tropical precipitation

An achievement of the TRMM mission

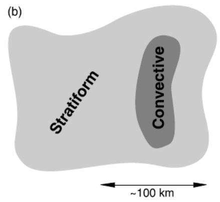




From Tao and Moncrieff, 2009; Nessbitt et al., 2006

The contribution of MCS to the tropical rainfall extremes

Importance of organisation



Muller, 2013

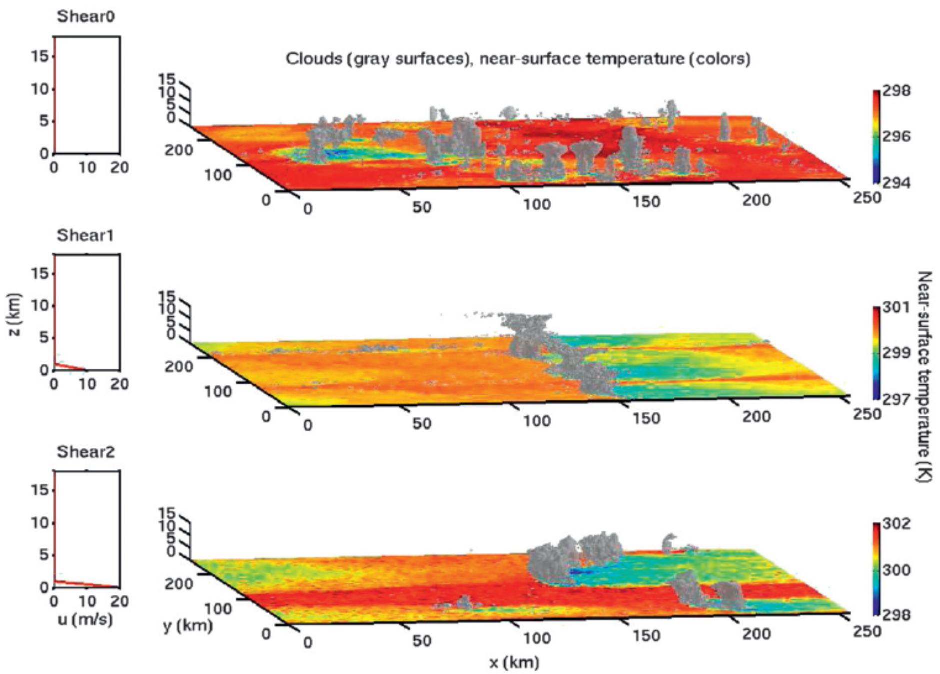


FIG. 2. Snapshots of clouds (gray surfaces) and near-surface temperatures (first model level $z = 37.5$ m) in the CTRL runs with SST = 300 K (i.e., cold runs; the warm runs have similar organization) for (left) three shear profiles: (top) without shear, convection is not organized and resembles "popcorn" convection; (middle) with critical shear (decreasing linearly from 10 m s^{-1} at the surface to 0 at 1 km), the convection organizes into a squall line perpendicular to the shear (the shear is in the x direction); and (bottom) with supercritical shear (twice the critical shear), the arcs are oriented at an angle of about 45° so that the projected shear is critical.

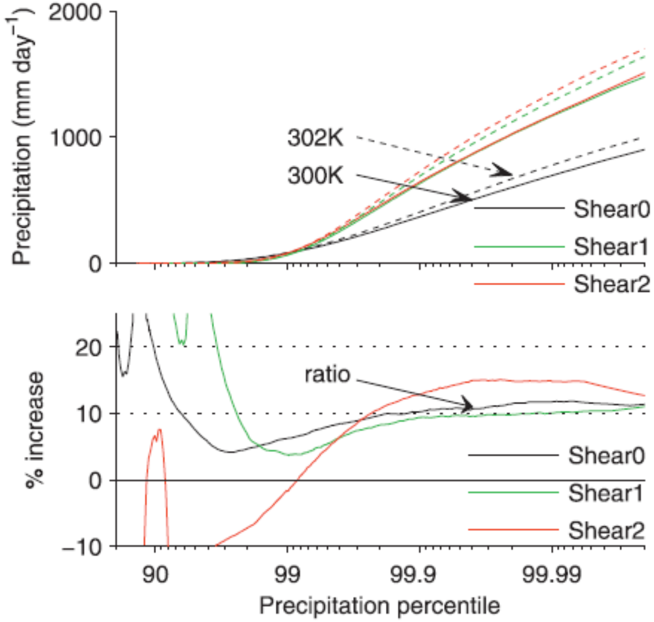


FIG. 8. Changes in the distribution of hourly mean pointwise precipitation extremes accompanying a 2-K SST increase in the CTRL case (see Table 1 for details) for the three shears. (top) The values of precipitation (mm day^{-1}) vs percentiles in the cold and warm simulations and (bottom) the fractional (%) increase in rainfall rates between those two runs.

Idealized configuration of CRM

Trends in the recent decades in the tropical organizec convection

Based on the ISSCP satellite dataset

C1 mesoscale organized convection

1998-2009

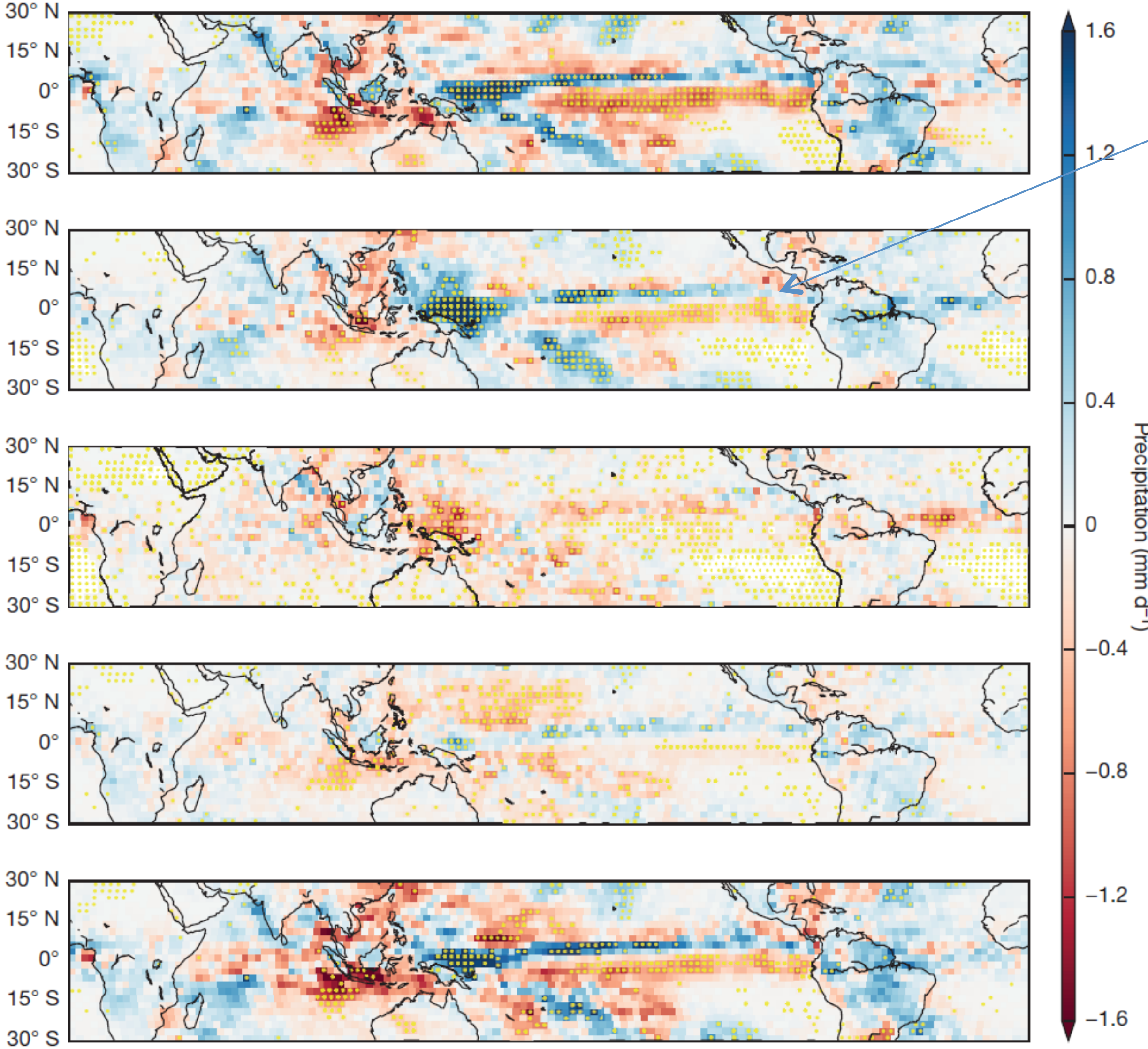
ΔP

Δf1C1

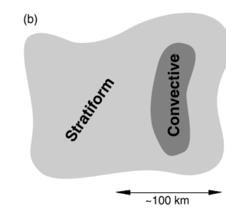
Δf1**C1**

2 & 3

ΣΔfiCi+fi**ΔCi**



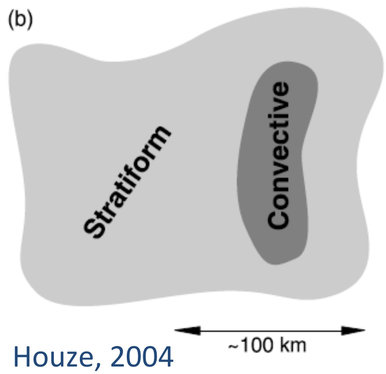
Change in occurrence of C1 ~ dynamical response



Tan et al., 2015

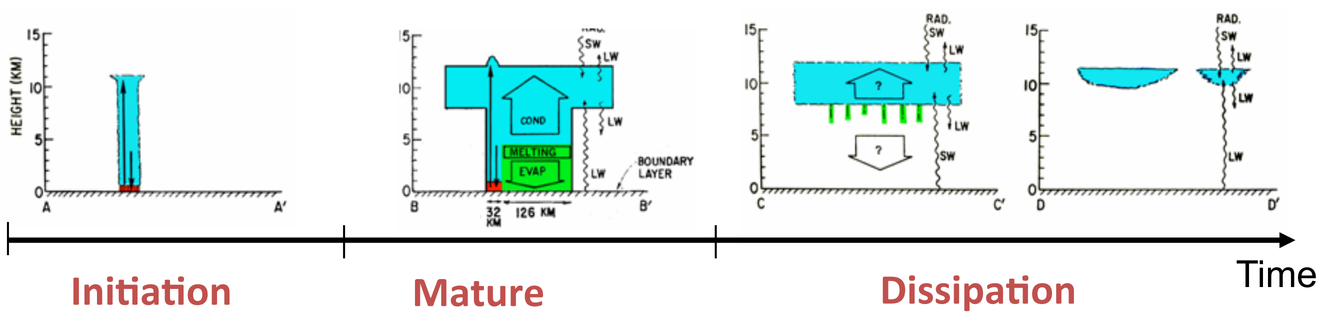
What is a mesoscale convective system (MCS) ?

A large corpus of knowledge from radar meteorology, campaigns etc… (2/2)



Houze, 2004

Houze, 1982



Continuous cold cloud shield that evolves during its life cycle from genesis to lysis

The organization of deep convection can be characterized by the MCS dynamical morphology:

- **its duration in hours**
- **its propagation distance in km**
- **etc….**

READILY

obtained from geostationnary infrared imagery and a pattern recognition and tracking algorithm

Fiolleau T. and R. Roca, (2013), An Algorithm For The Detection And Tracking Of Tropical Mesoscale Convective Systems Using Infrared Images From Geostationary Satellite, Transactions on Geoscience and Remote Sensing, doi: 10.1109/TGRS.2012.2227762.

What is a mesoscale convective system (MCS) ?

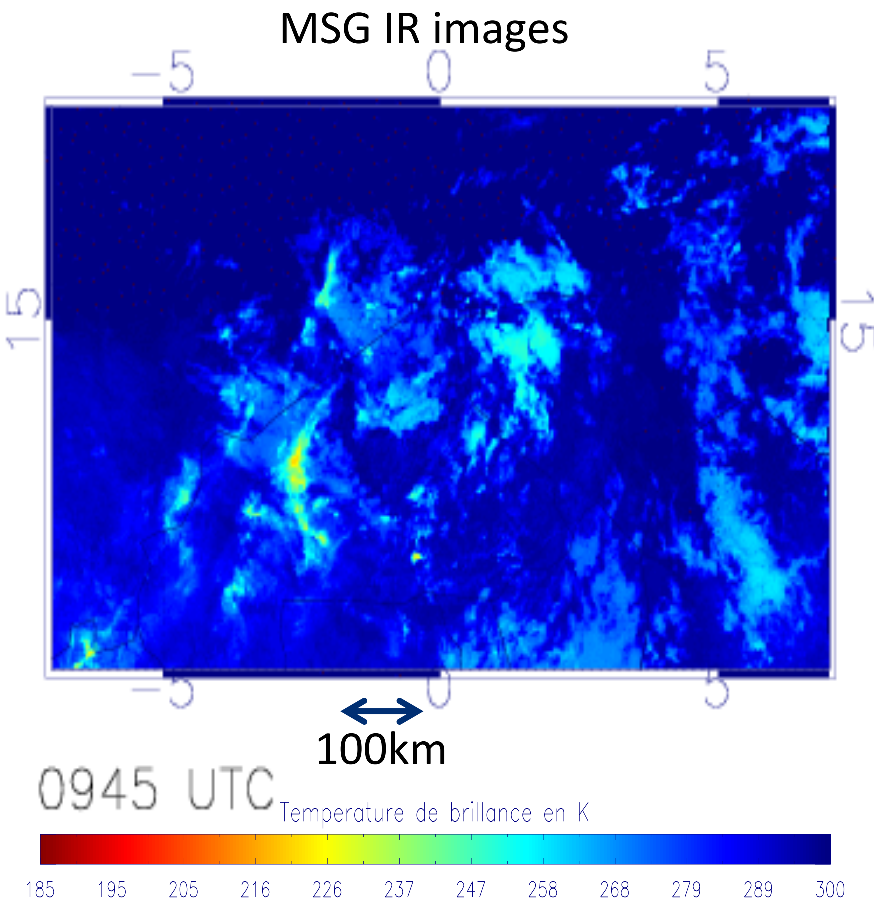
A long long time existing observing capability

Canal visible de ATS-1 lancé en 1966

What is a mesoscale convective system (MCS) ?

An example from METEOSAT observations

Sahel : Niger and Mali during the AMMA campaign (11/09/2006)

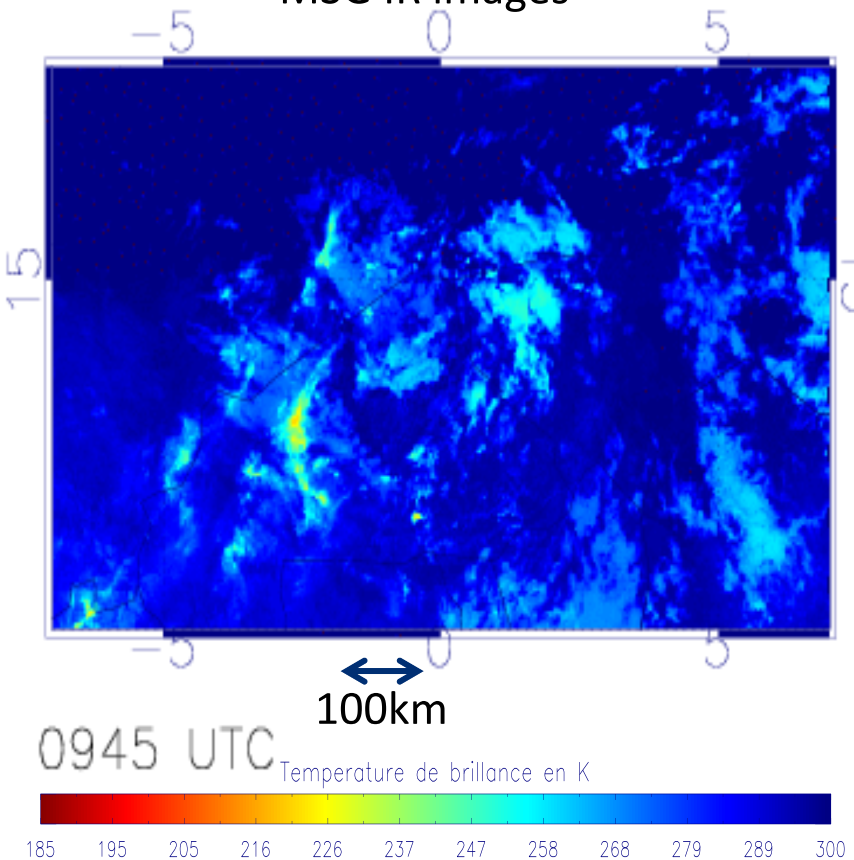


What is a mesoscale convective system (MCS) ?

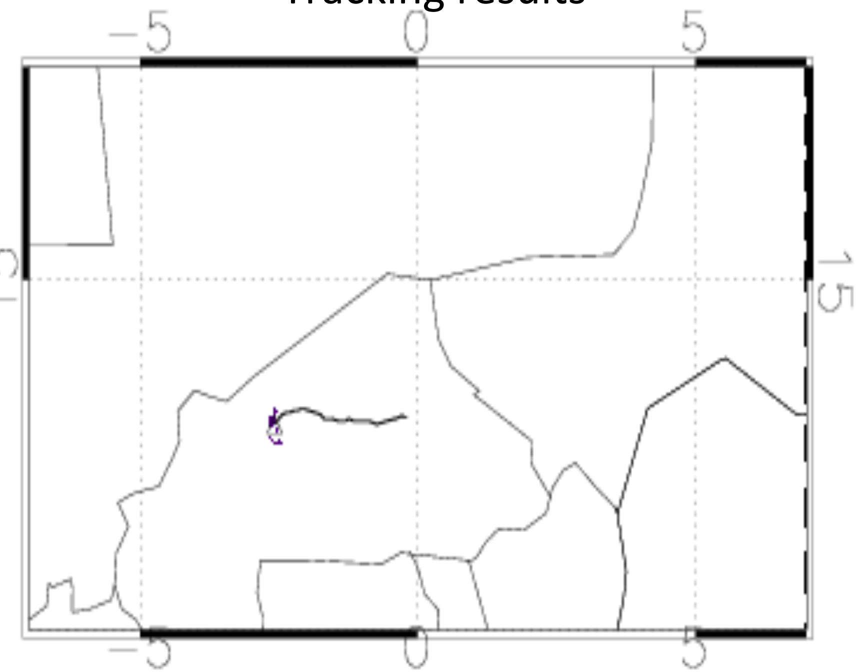
An example from METEOSAT observations

Sahel : Niger and Mali during the AMMA campaign (11/09/2006)

MSG IR images



Tracking results



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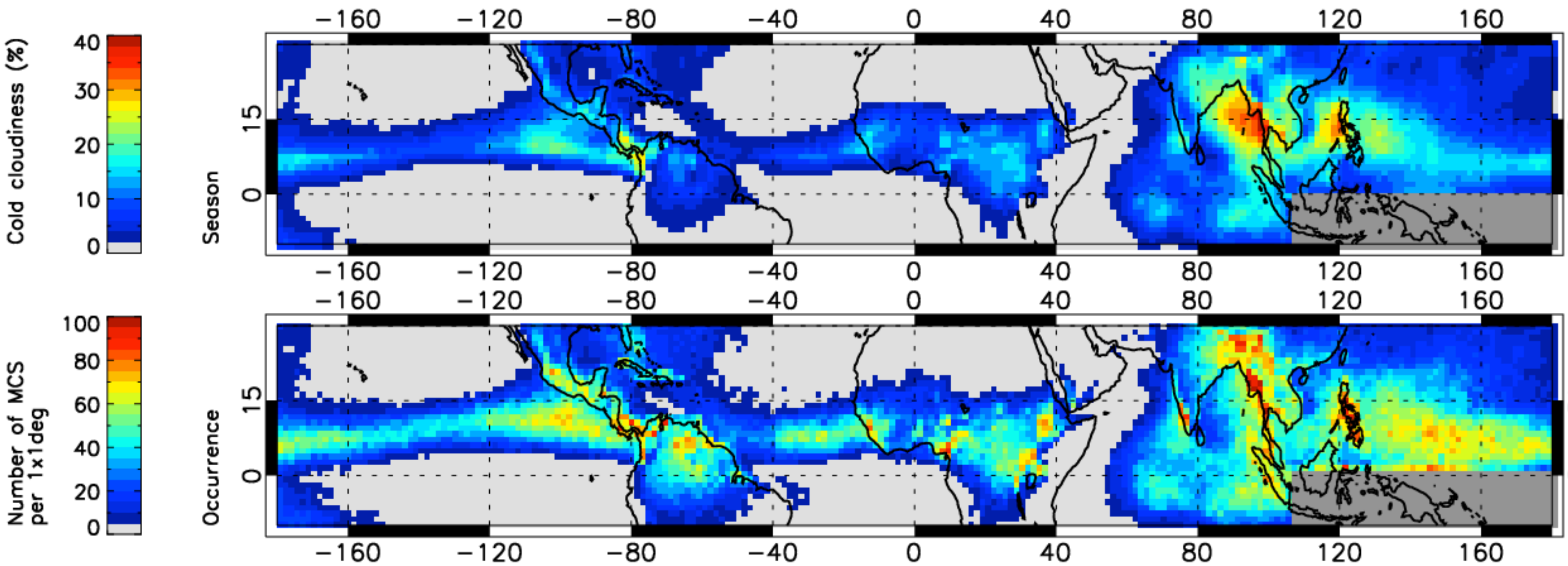
The contribution of MCS to the tropical precipitation
Summer 2012 4 months of data 1°/1 day

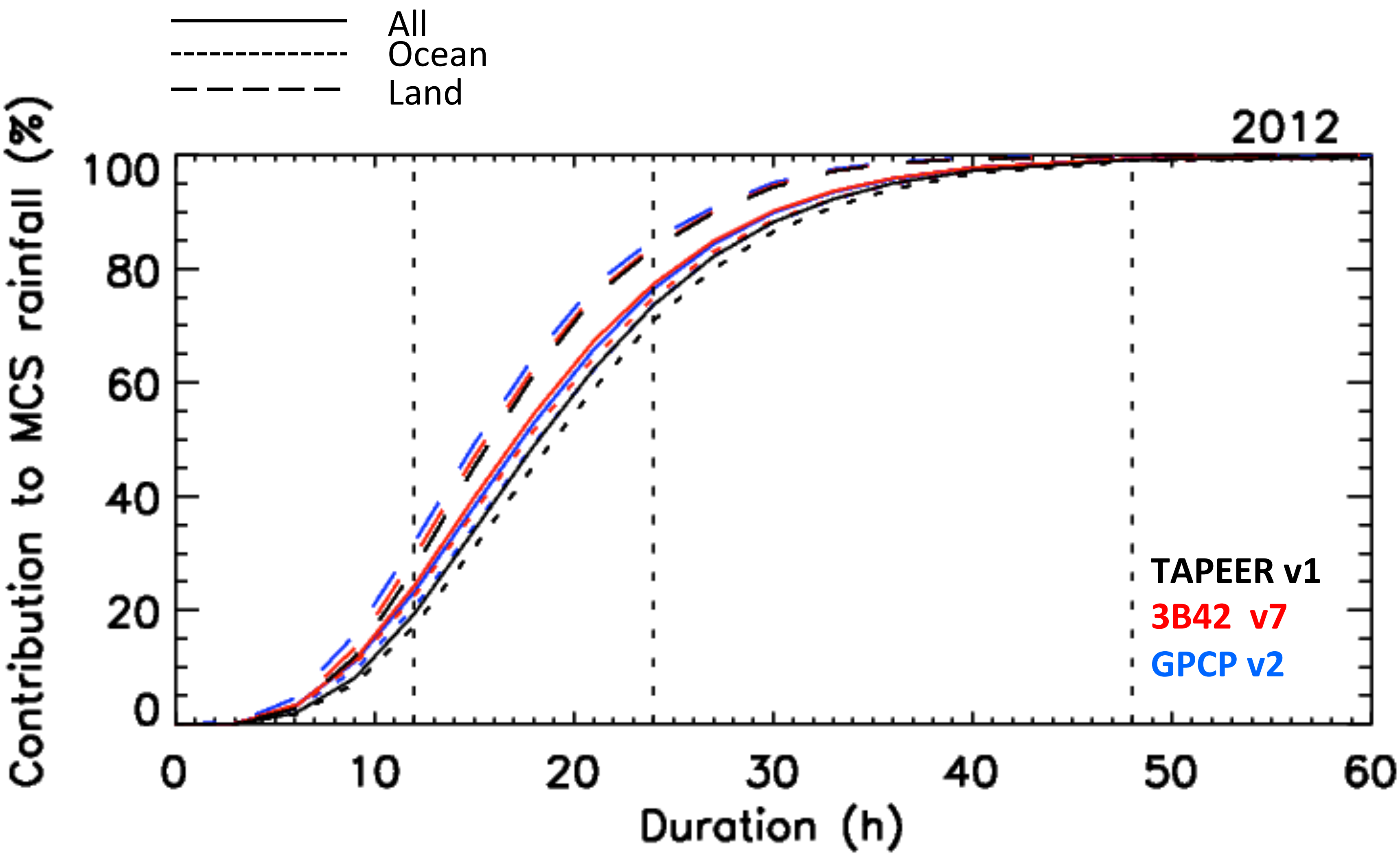
- **MCS**

Cloud tracking algorithm run using the full resolution GEO infrared imagery
GOES-15,GOES-13 , GOES-14,MSG-2, MET-7 and MTSAT-2.
only where 30 minutes, ~5km
missing southern hemisphere over Australia and West Pacific
gridded on a regular grid to match the precipitation data (Roca et al., 2014)



The contribution of MCS to the tropical precipitation

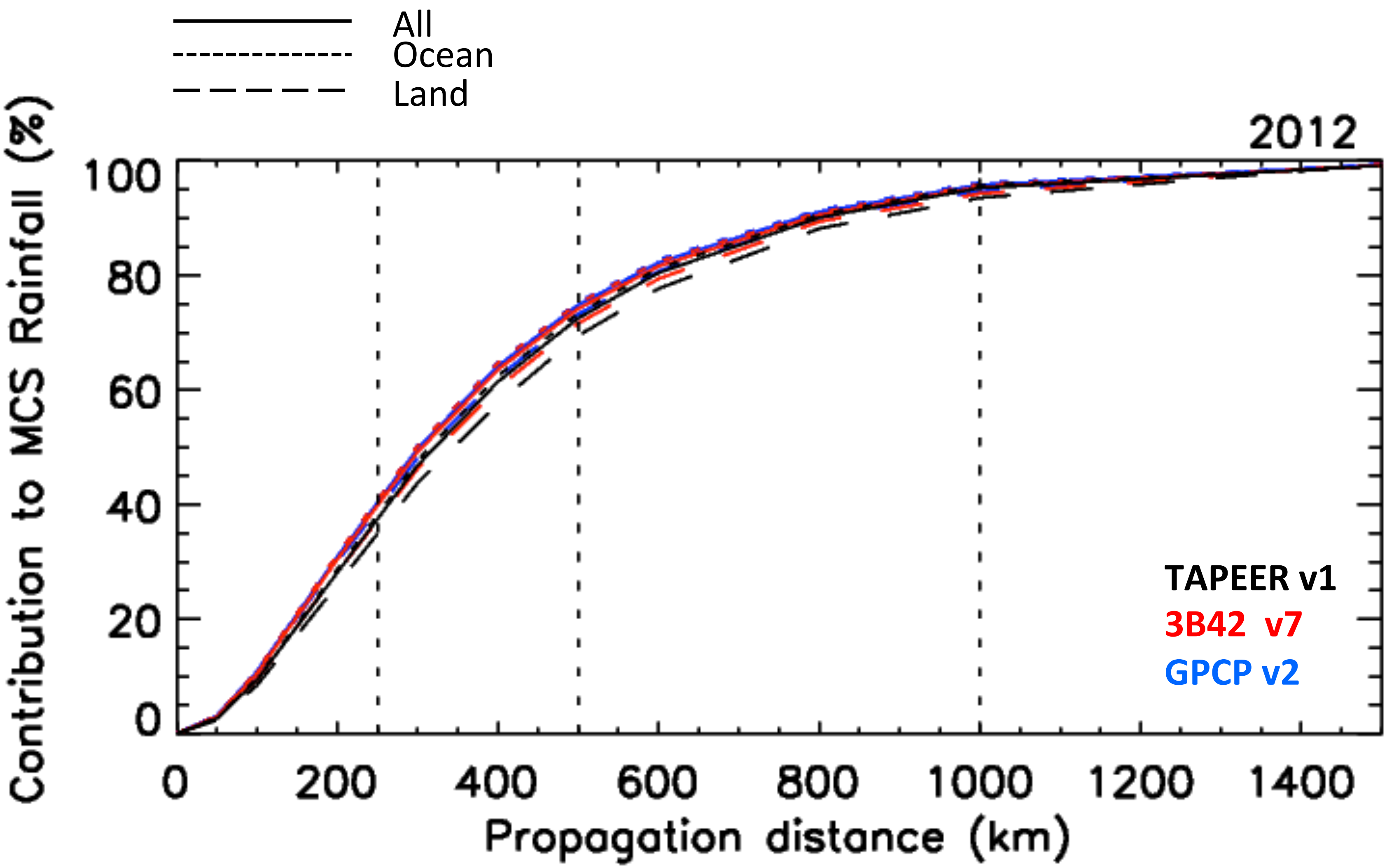
Quantifying the importance of organized convection



Update from Roca et al., J Clim, 2014

The contribution of MCS to the tropical precipitation

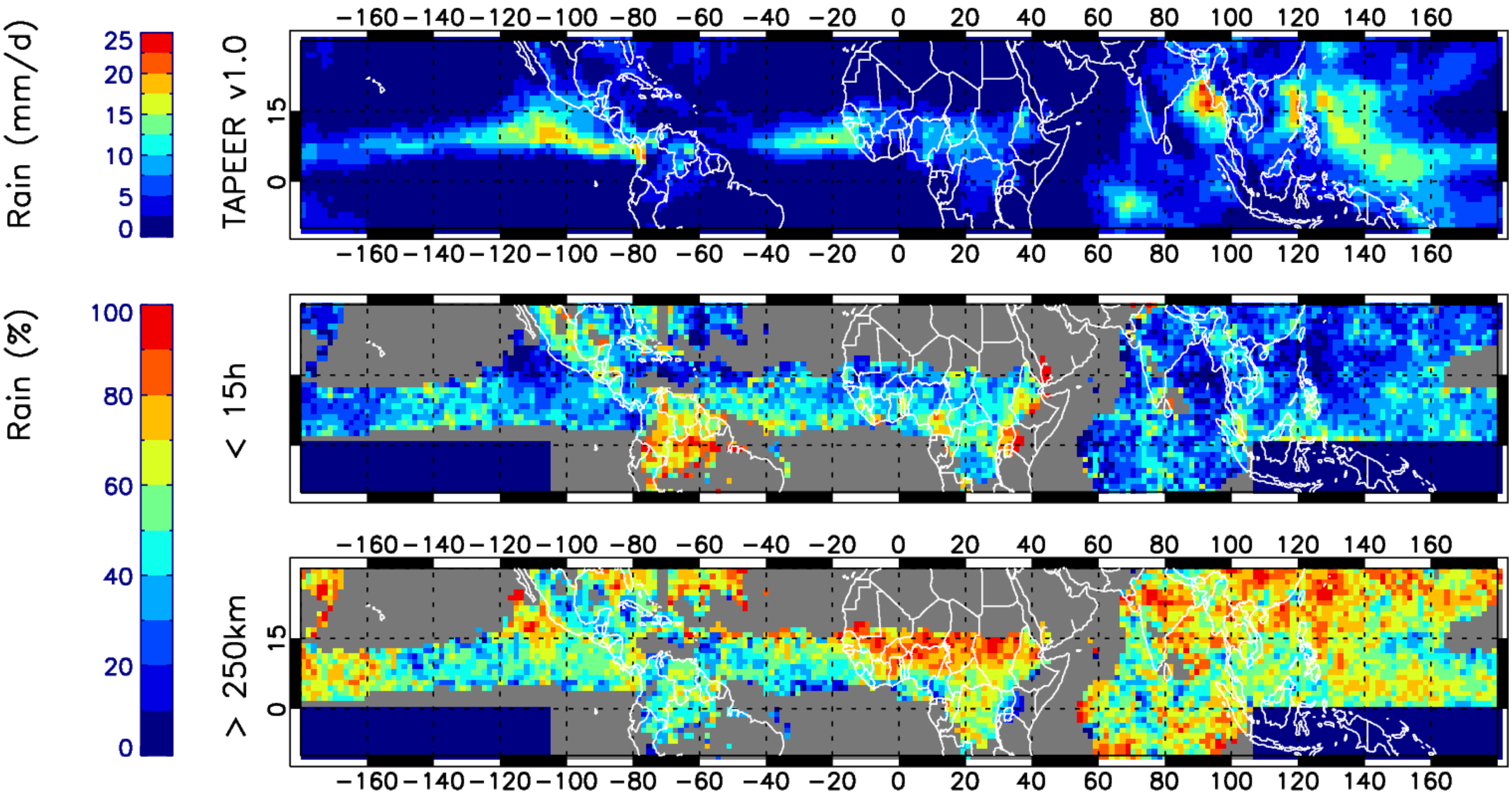
Quantifying the importance of organized convection



The contribution of MCS to the tropical precipitation

Tracking organized convection on the GEOring

Mean daily rain for JJAS 2012

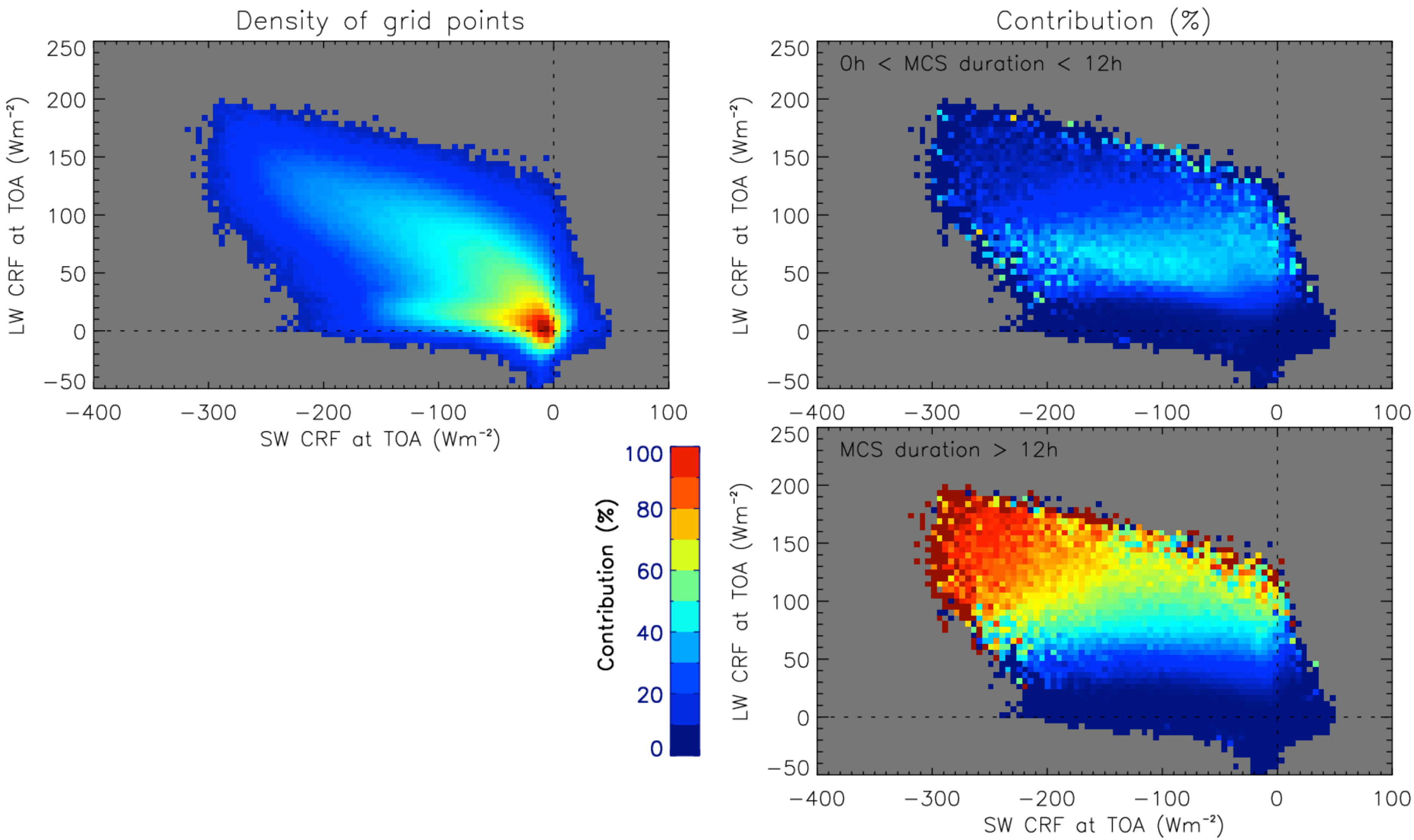


Update from Roca et al., J Clim, 2014

The contribution of MCS to tropical radiation budget

Importance of long lasting systems to the distribution of CRF

JJAS 2009 / 30°s-30°n / 1°-1day/ CERES SYN products + « Most representative MCS of the day » product



The role of MCSs to the water and energy budget

Importance of long lasting systems to the water and energy budget

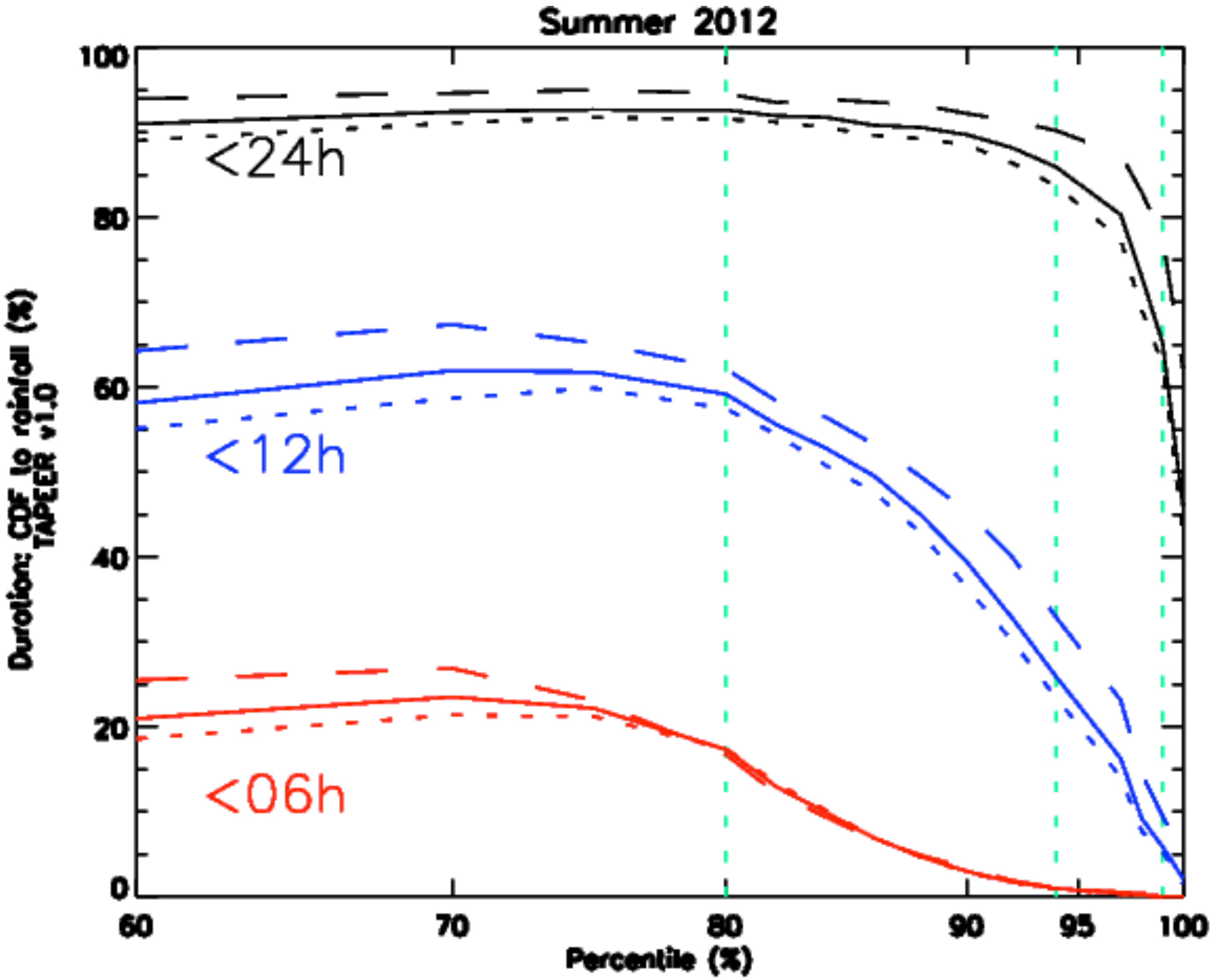
JJAS 2009 / 30°s-30°n / 1°-1day/ SYN products + « Most representative MCS of the day » product + TAPEER

			Weighted contribution in %			
		Occurrence	**Rainfall**	**SWCRF**	**LWCRF**	**NETCRF**
ALL MCS	Land	39	92	65	71	51
	Ocean	32	93	55	67	39
	All	**34**	**93**	**58**	**68**	**42**
Duration <12h	Land	25	36	35	37	29
	Ocean	15	21	19	25	15
	All	17	25	23	28	18
Duration >12h	Land	15	56	30	34	23
	Ocean	17	72	36	42	24
	All	**16**	**68**	**35**	**40**	**24**

Roca et al., J Climate, 2014

Extreme rainfall events and MCS

Importance of organized (long lasting & propagating storms)



(Unpublished yet)

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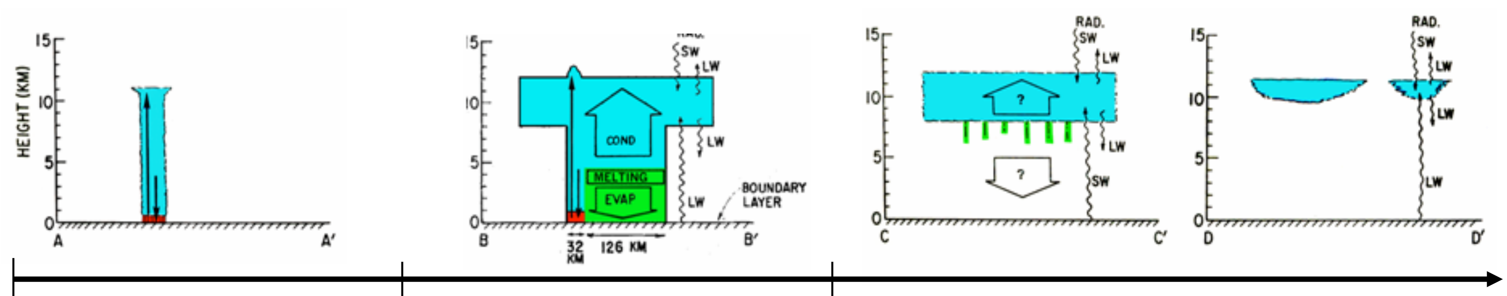
Documenting and understanding the life cycle of the tropical MCS

Approche Composite



Initiation | Mature | Dissipation

Houze, 1982

? Wm^{-2}
? mm/day
? duration
? Microphysical Process

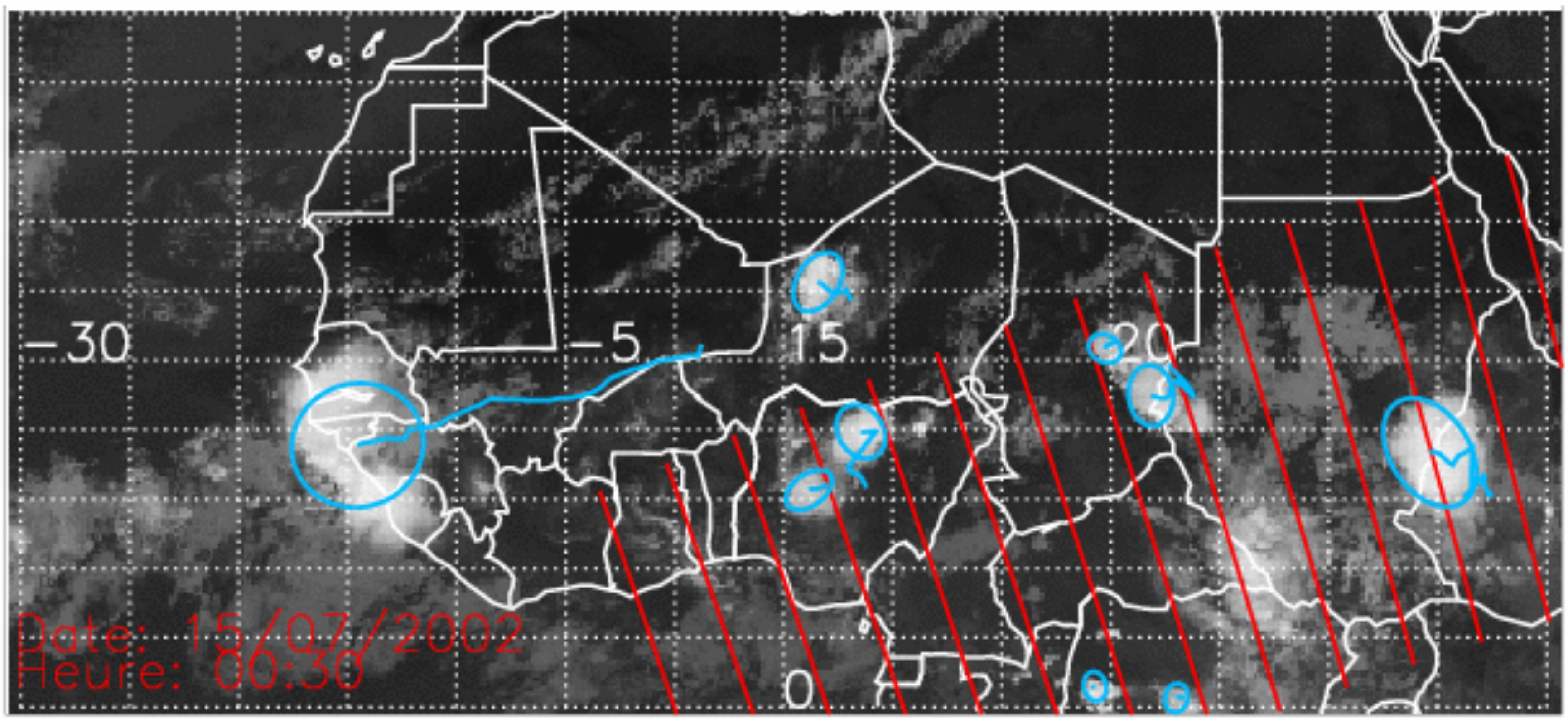
? Wm^{-2}
? mm/day
? duration
? Microphysical Process

? Wm^{-2}
? mm/day
? duration
? Microphysical Process

? Wm^{-2}
? mm/day
? duration
? Microphysical Process

Details of the compositing method using SCARAB-3/ MT TOA flux

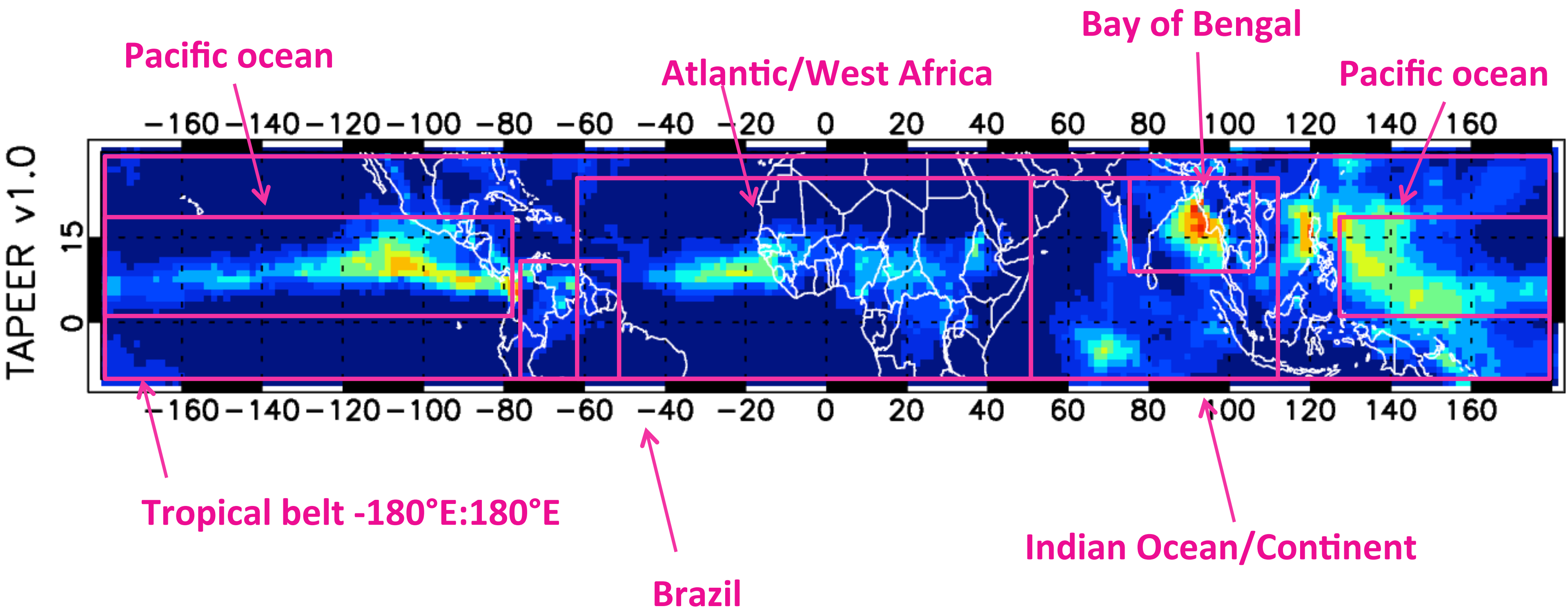
Making use of the high repetitivity of MT



Source: Thomas Fiolleau

Results using SCARAB-3/MT TOA flux

All the regions under investigations

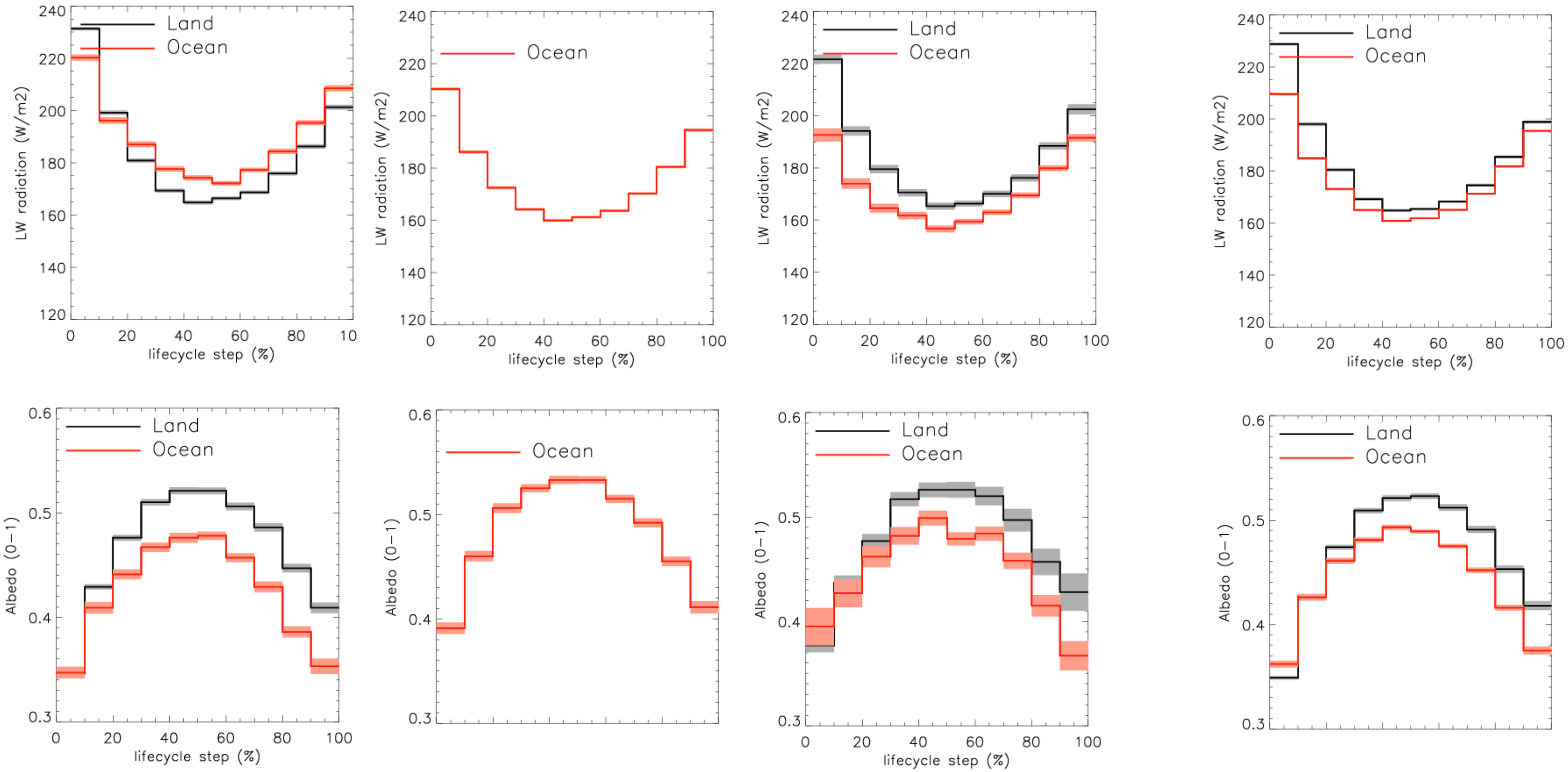


Results using SCARAB-3/MT TOA flux

Regional commonalities and differences

JJAS 2012/Class 2a/Day light

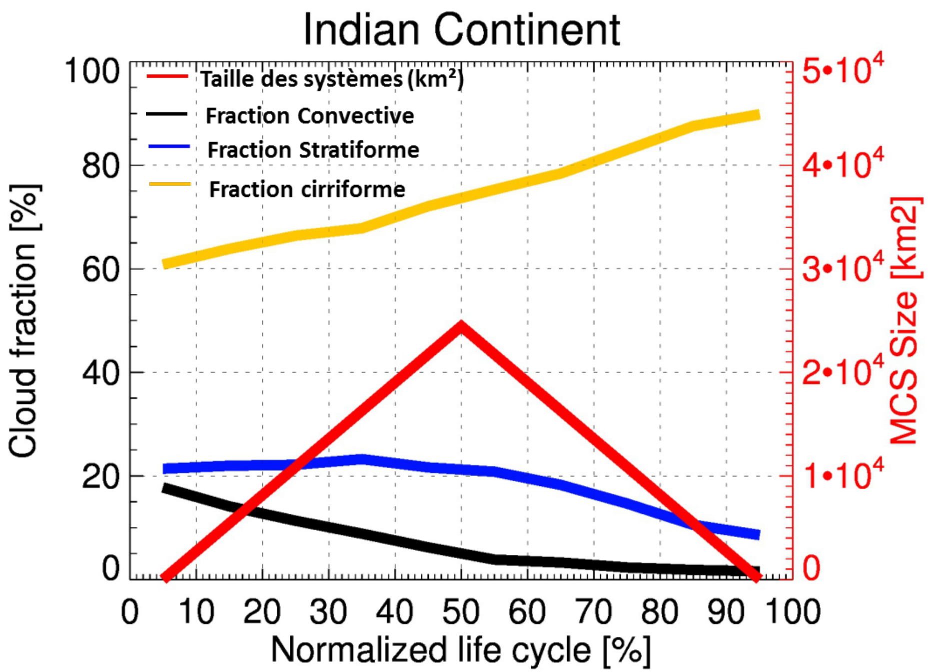
West Africa /Atlantique | Pacific ocean | Bay of Bengal | Tropical belt



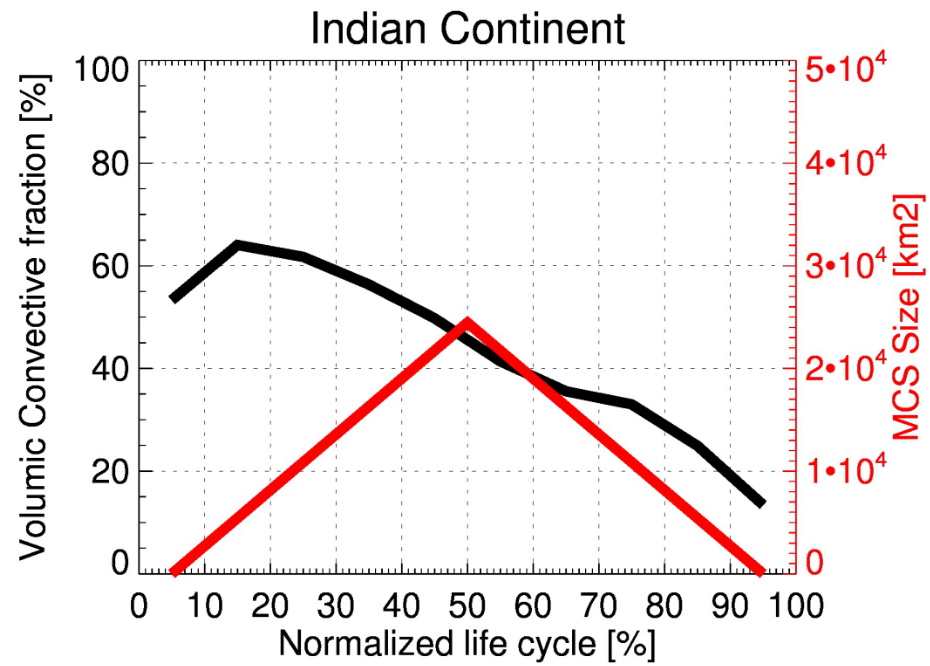
Results using Cloudsat and TRMM/PR

An exemple for the indian continent

Fractions Convectives/Stratiformes/Cirriformes (%)



Fraction Volumique de pluie convective



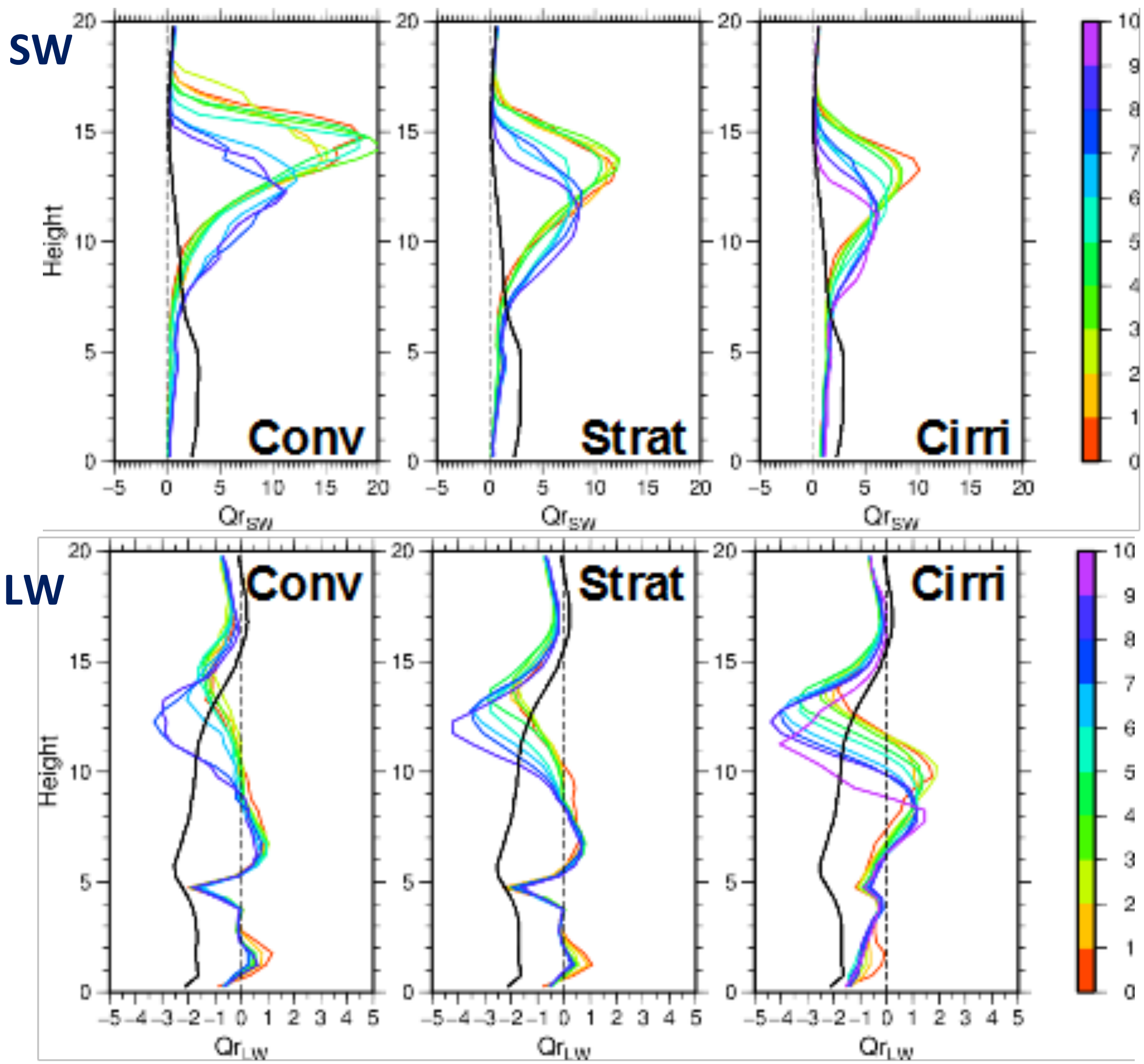
1 - Croissance de la fraction de pluie convective jusqu'à la phase [10%-30%] du cycle de vie normalisé

2 - Décroissance de la fraction de pluie convective

Results using A-TRAIN data

CERES/CALIPSO/Cloudsat data

Bouniol et al., 2016



- SW++ in the beginning of the life cycle
- LW++ at the end of the life cycle
    - cooling top
    - heating lower part
    - Maintenance of the anvil in the time

Fusion CloudSAT+Géo

Summary

Importance of organized, long lasting & propagating storms to the tropical water and energy budget

The systems lasting more than 12h contribute to 70% of the total rain, a little less over land but only 24% of the net TOA radiation

- Large geographical variability due to the various MCS regimes
- Robust results over the precipitation products

Compositing along the life cycle as a framework to go from « snapshots » to the dynamics of deep convection

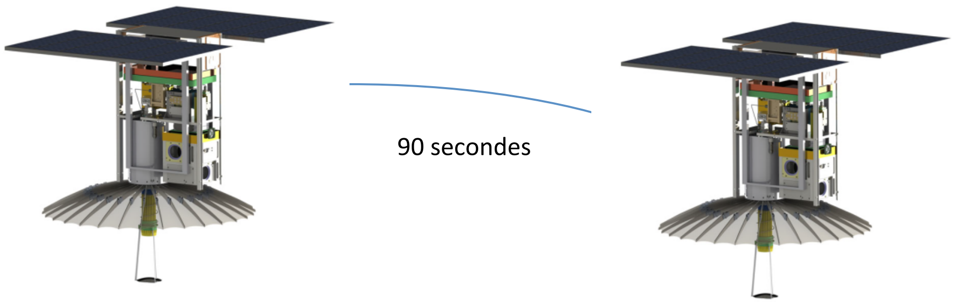
Coherent time evolution of the morphology of the system

- growing and decaying cloud shield
- albedo and TOA budget with regional variability
  - cirriform fraction increases with life
  - stratiform decreases after 50% of life
  - convection fraction decrease up to 50% of life
  - contribution to rainfall increase up to 30% of life

On a farther horizon

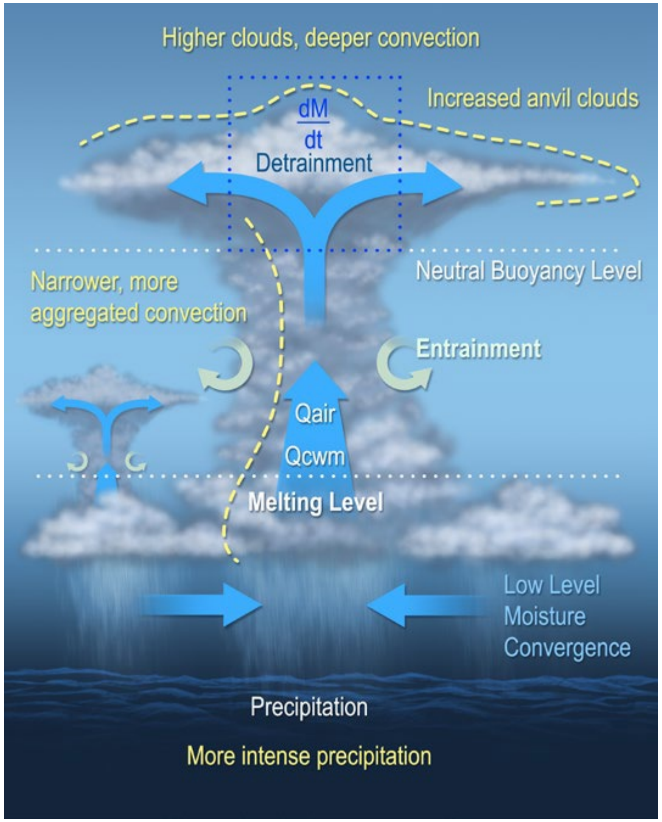
- **New Mission « D-Train »**

tropical radars train for convective transport measurement lead G. Stephens & Z. Haddad, **JPL**, **Submitted to NASA Decadal Survey**



Sy et al., 2015

$$d_t Z_{[\mathrm{dBZ}]}(\boldsymbol{r},t) \approx \frac{10\beta(\boldsymbol{r},t)}{\ln(10)} \frac{d_t M(\boldsymbol{r},t)}{M(\boldsymbol{r},t)},$$



Stephens et al., 2015

- **Vertical transport along the the life cycle** (Approche Bouniol et al., 2016)

- **Why not having other instruments on the D-Train ? (183GHz, …)**

Thank you for your attention