The Abdus Salam International Centre for Theoretical Physics

1934-32

Fourth ICTP Workshop on the Theory and Use of Regional Climate Models: Applying RCMs to Developing Nations in Support of Climate Change Assessment and Extended-Range Prediction

3 - 14 March 2008

Convection over tropical land regions

REDELSPERGER Jean-Luc

Meteo-France Centre National de Recherches Meteorologiques
Cnrm/Gmgec/Udc
42 Avenue Coriolis
31057 CEDEX 1 Toulouse
FRANCE

Convection over tropical land regions

JL Redelsperger

CNRM (CNRS & Météo-France)

Convection over tropical land regions

Or

Global scale down to Convective Cell scale

Or

Why climate modellers need to take care of convection scale ?

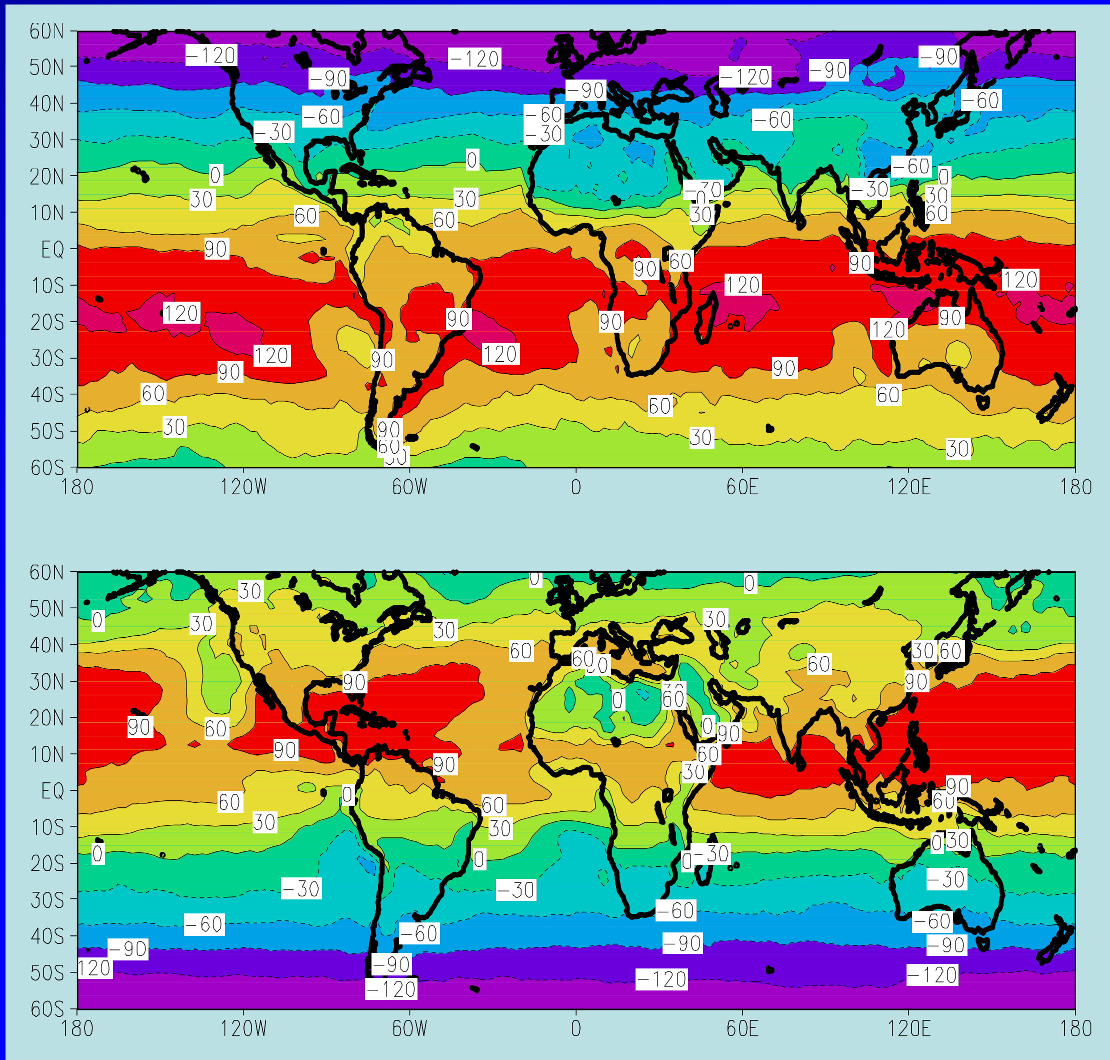
Global scale

Net radiative budget of the earth system

(Average 1985-1989)

February

August



- **Deficit in Polar regions and winter hemisphere**
- **Exceed in tropical regions**

➔ transfert necessary to equilibrate

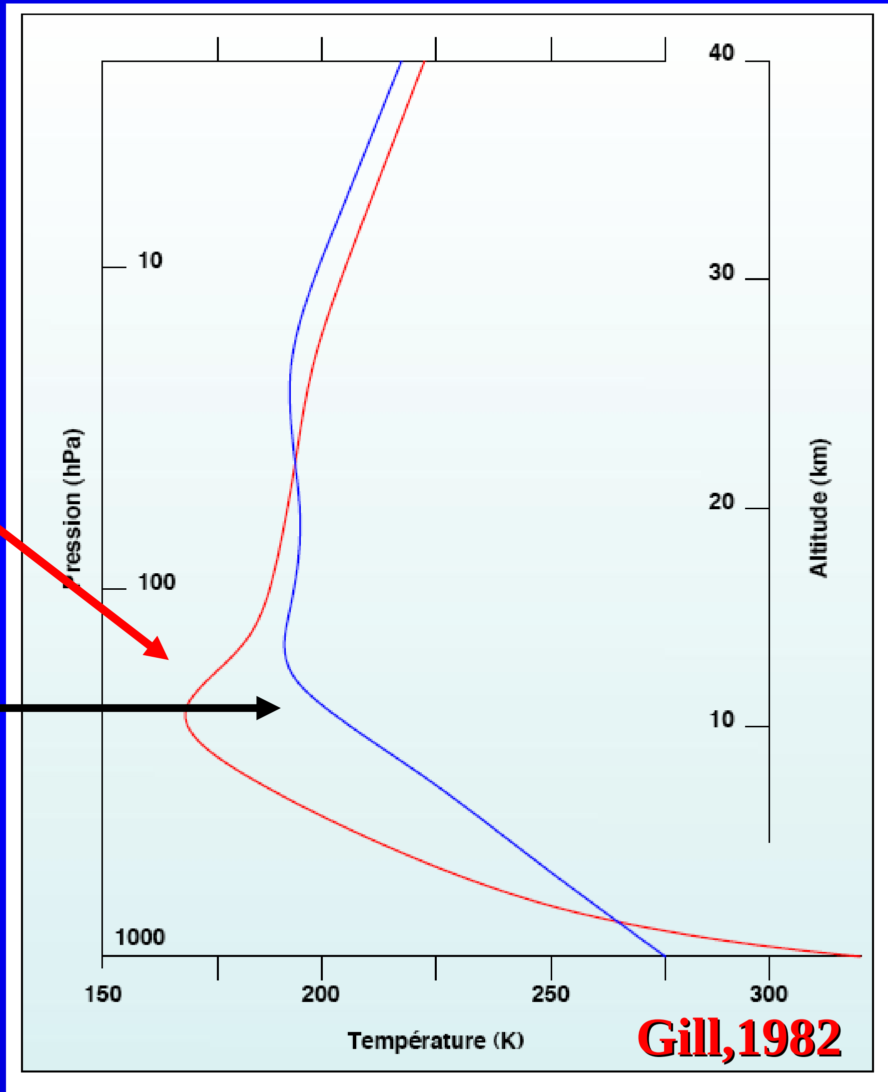
Energetic effect of convection

Vertical profil of temperature

Taking mean global radiation (35°N), solution from radiative budget (uncloudy atmosphere in rest)

Observed (-6,5 °C/km)

A major part of this difference is coming from convective activity



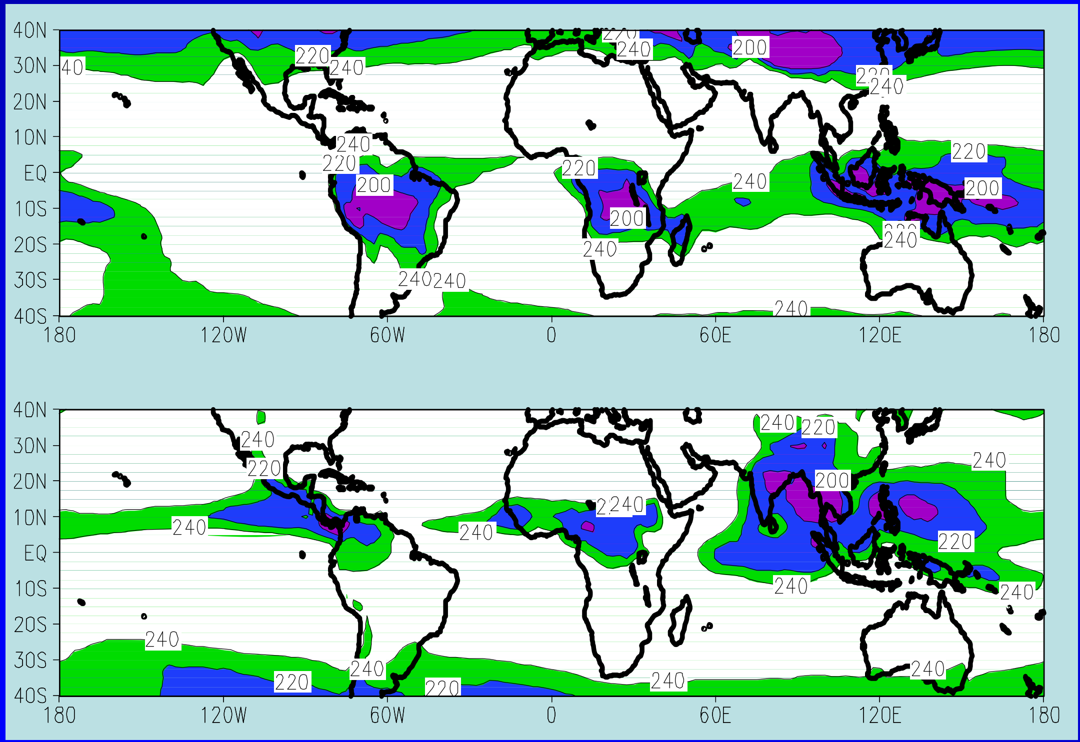
Global scale

Convective region as viewed by OLR (Inter-Tropical Convergence Zone, ITCZ)

(Average 1985-1989)

February

August



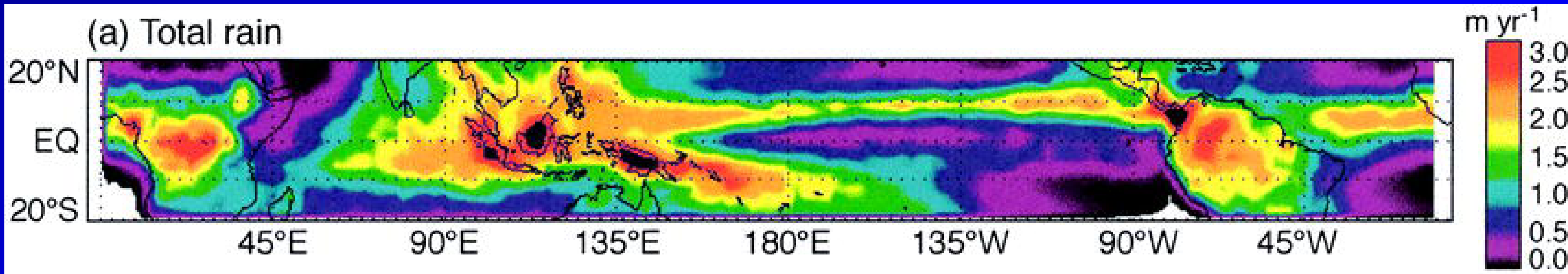
Minimum OLR correspond to convective region (high cloud top)

- ✓ **Minima well marked over tropical continental region**
- ✓ **Seasonal cycle (~ 6 week delay with solar radiation)**

Global scale

Precipitation region as viewed by TRMM

(Average 1998-2000)



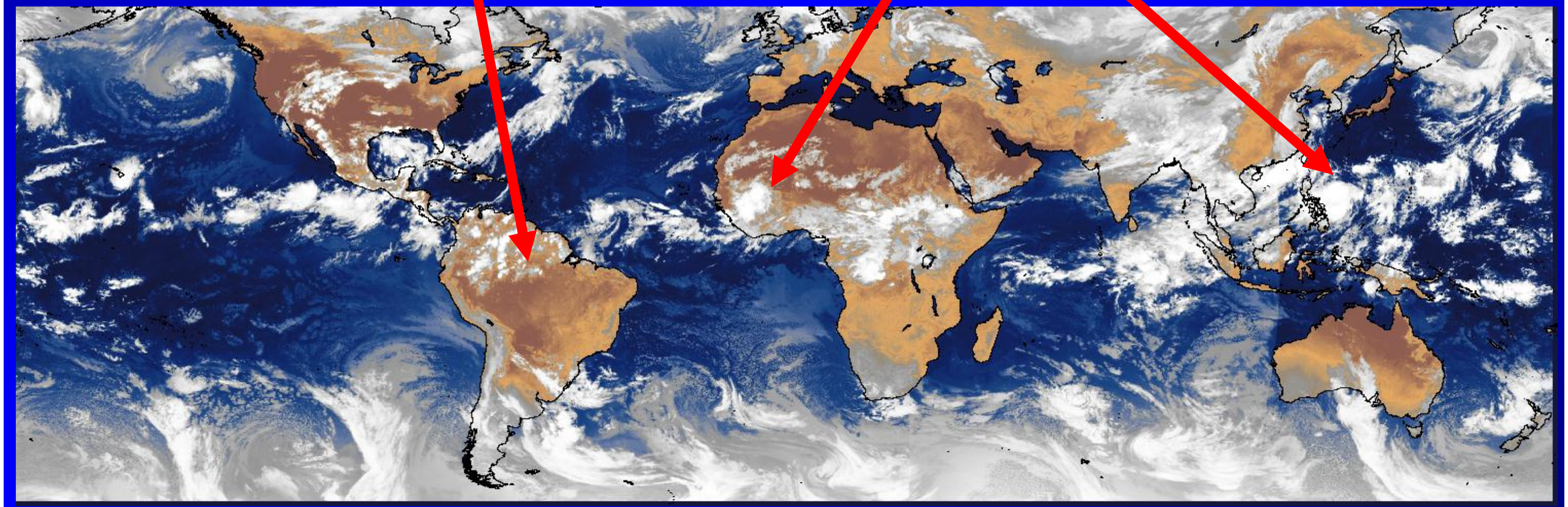
Schumacher and Houze (2003)

Global scale

Convective region as viewed by geostationary satellites at a particular time

Shallow convection

Deep convection



Tropical Moist Convection

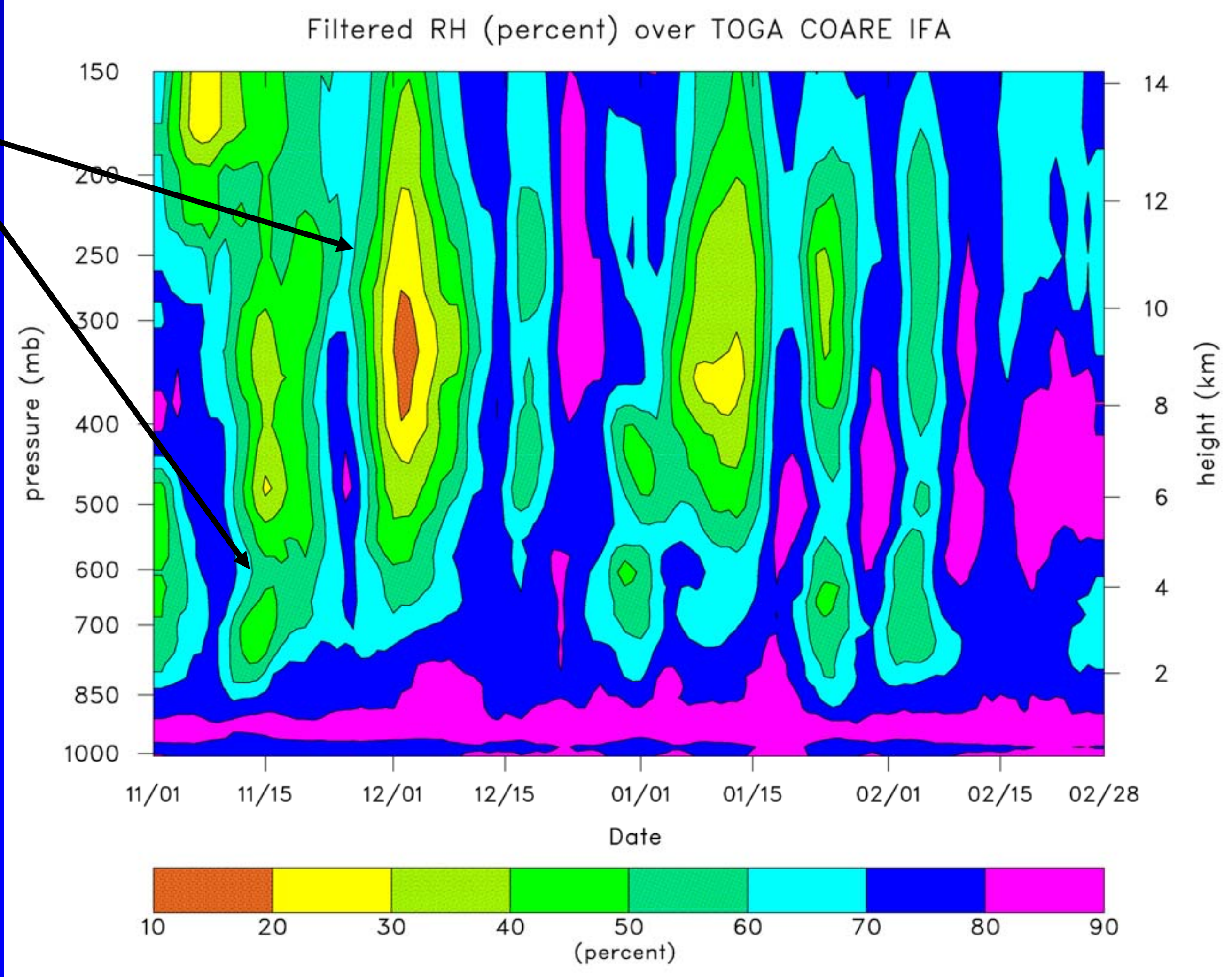
Shallow convection

- Abundant cumulus in trade wind region, capped by a strong inversion
- Vertical transport of water vapor (out of PBL), balancing the drying effects of large-scale subsidence
- Shallow convection also very important in other regions
  - Part of diurnal cycle of land convection: transition stage from shallow to deep
  - Abundant precipitating shallow convection (e.g.TOGA-COARE: around half of precip over the warm pool)

Precipitating shallow convection

- Tropical mid- to upper troposphere is frequently dry (at times from "dry intrusions")...

TOGA-COARE Parsons et al. 2000

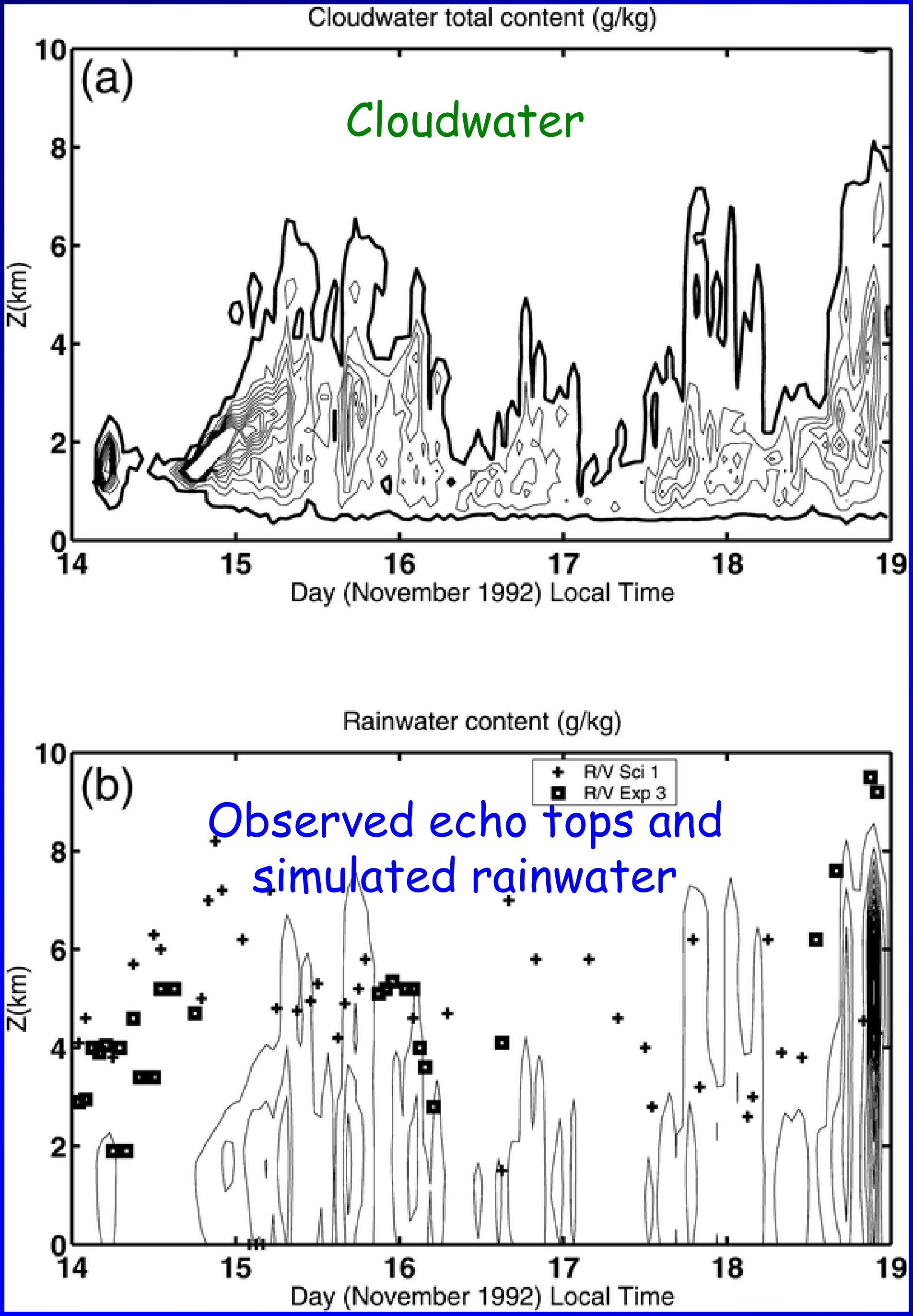


- Entrainment limits the growth of convection, (water loading is a secondary effect)

- Reduction of buoyancy through entrainment makes stable layers more effective in stunting cloud growth

(Redelsperger et al. 2002)

(From Johnson et al, CSU)



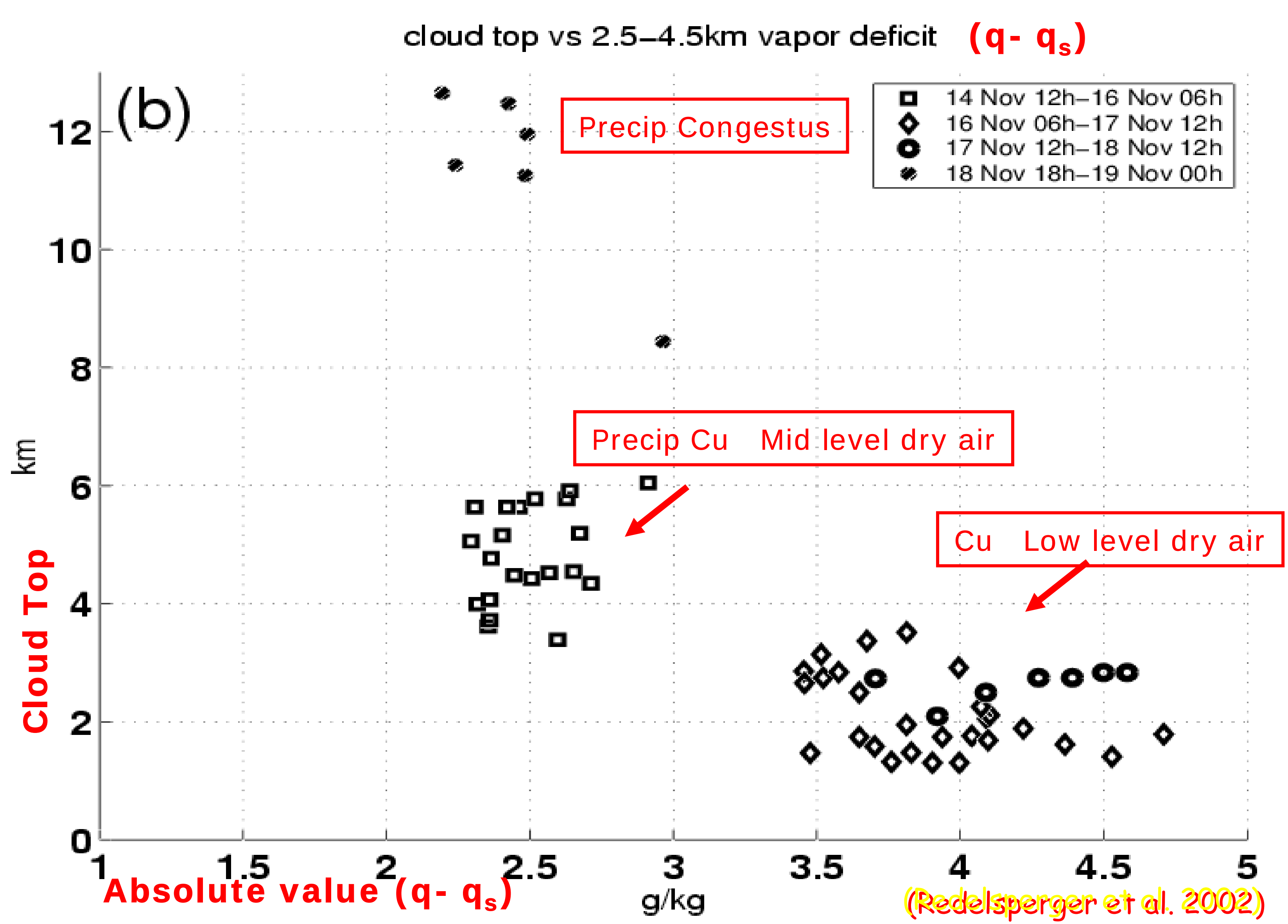
14-19 November 1992

(Redelsperger et al. 2002)

- CRM results indicate that inversions (near the melting level) **and** entrainment limit the growth of convection, water loading being a secondary effect
- Reduction of buoyancy through entrainment makes stable layers more effective in stunting cloud growth

Precipitating shallow convection

Relationship between dry air & cloud top (TOGA-COARE)



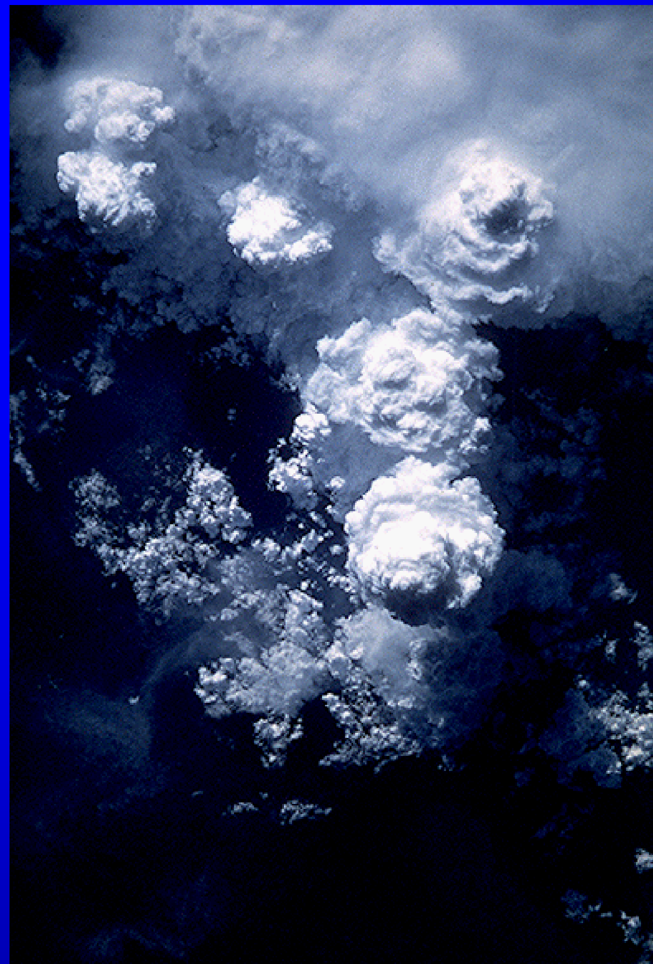
Tropical Moist Convection

Deep convection

- Vertical transport Heat, Moisture and Momentum

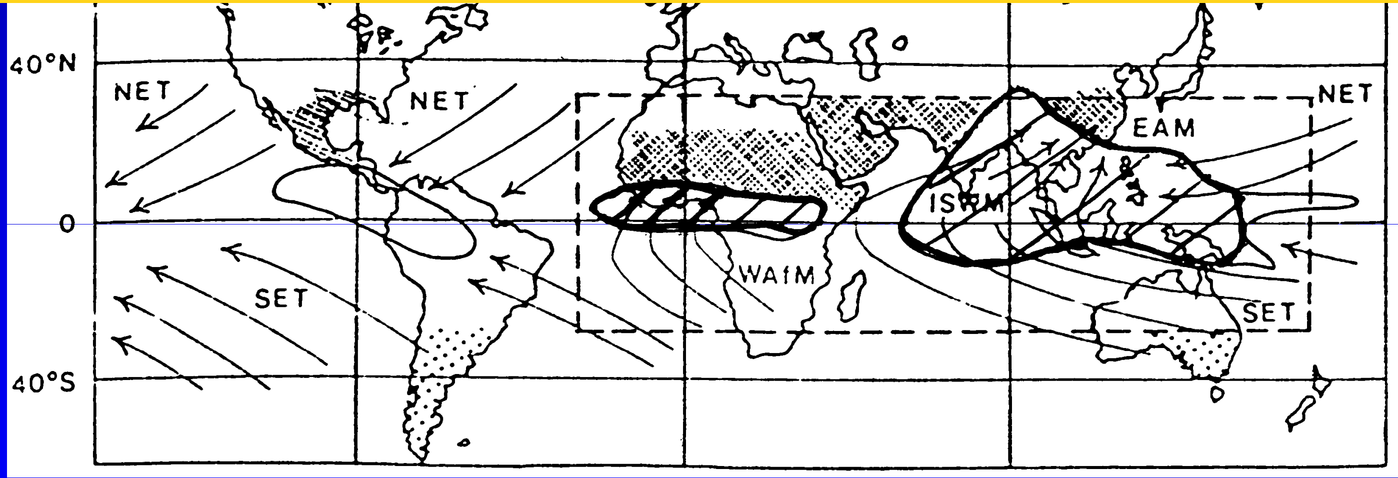
also aerosol & trace gaz

- Production of precipitation
- Radiative effects (including anvils)

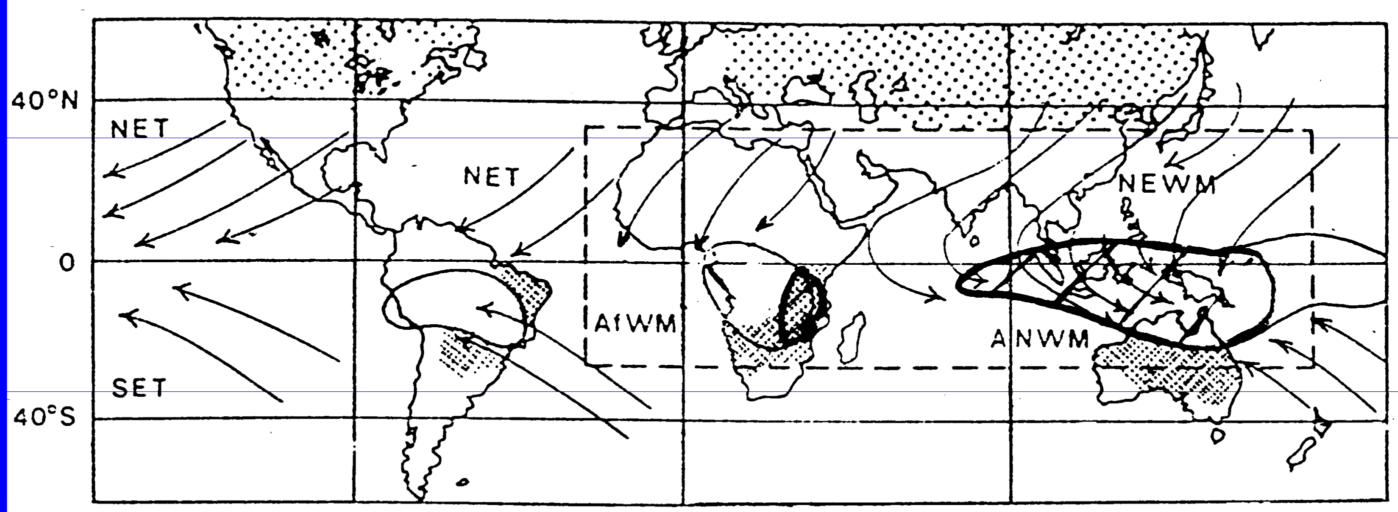


Convection at Regional scale: Monsoon Systems

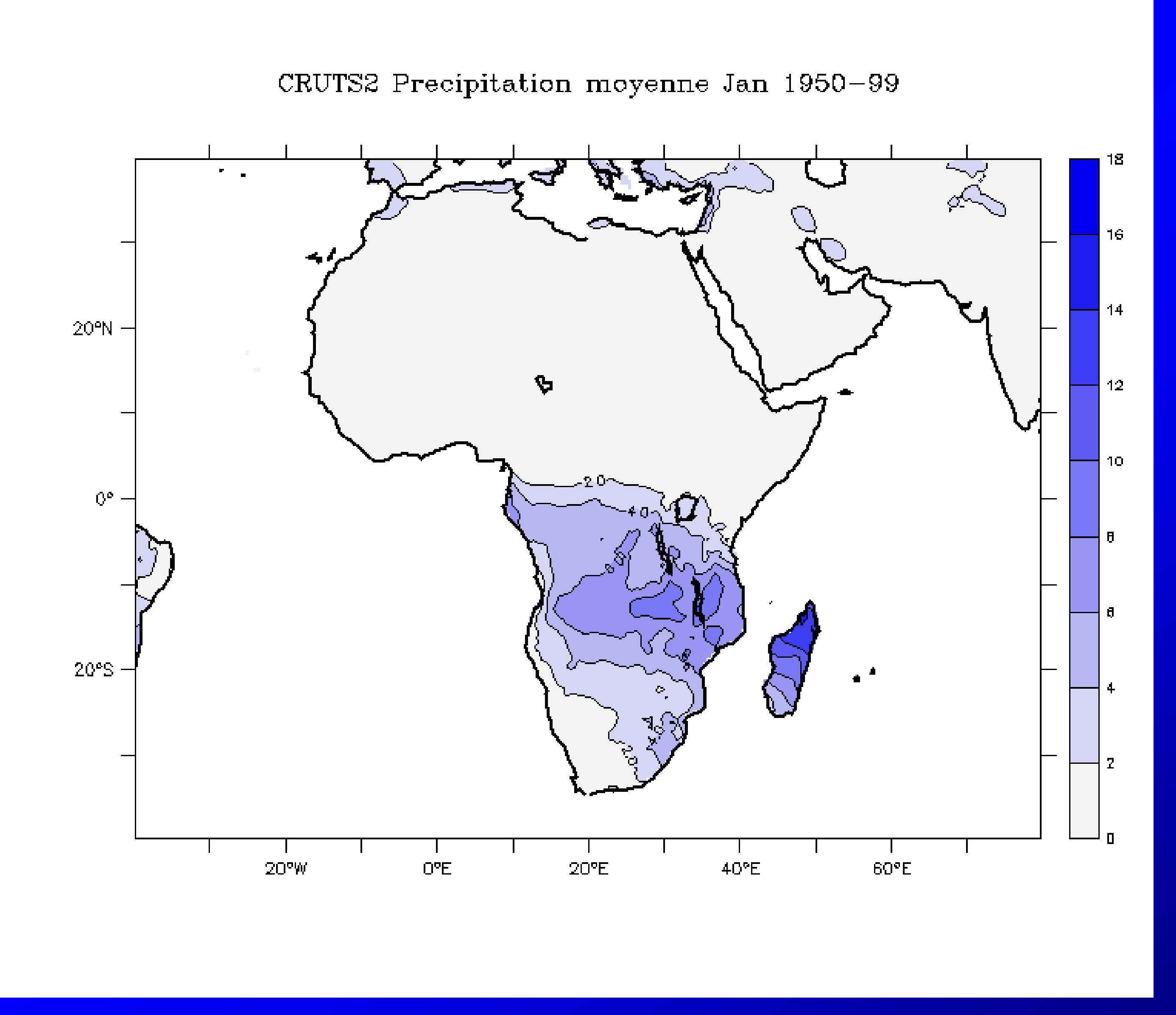
Boreal Summer: Monsoons in West Africa, Asia (India, China), Central-America,

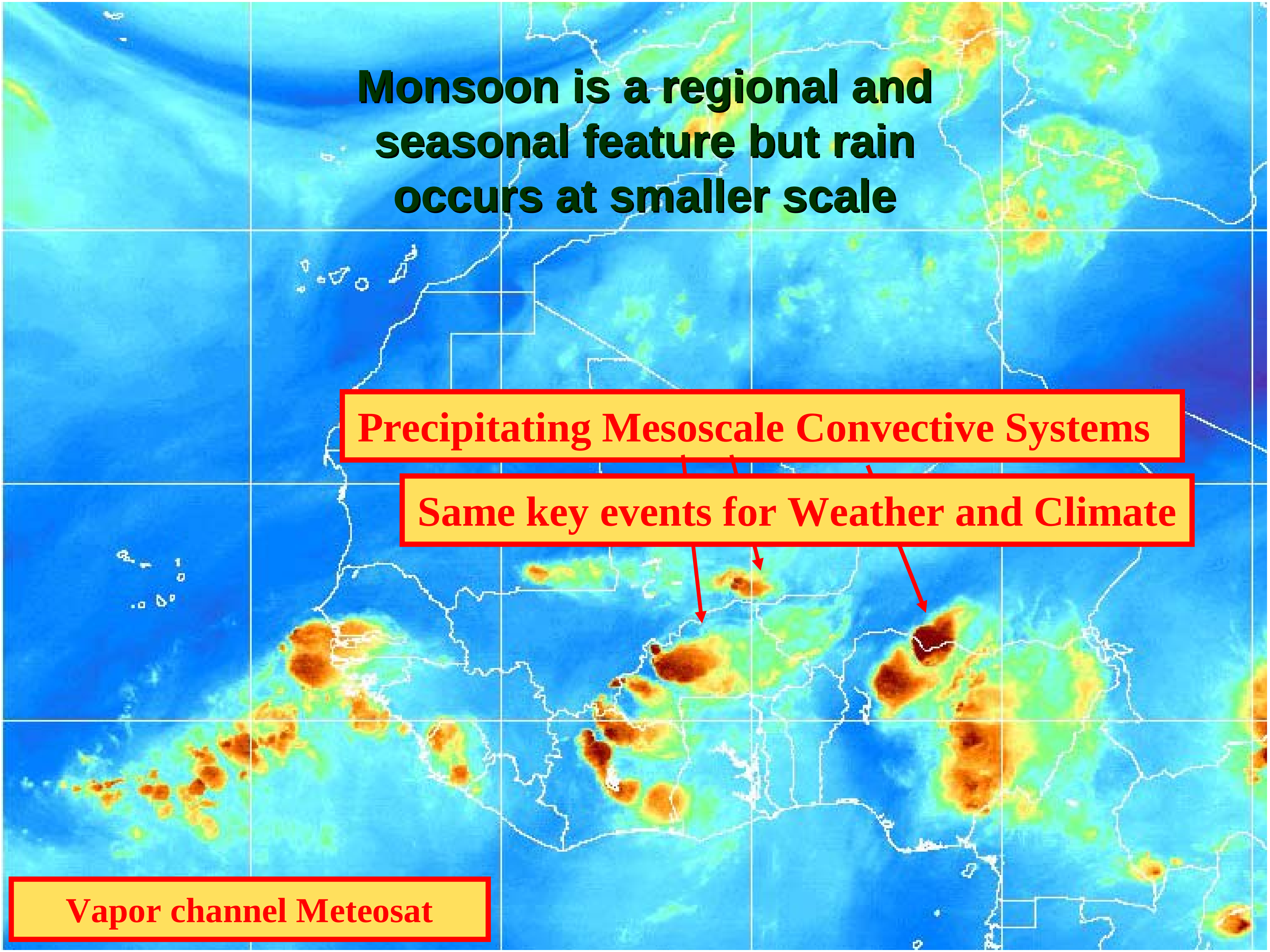


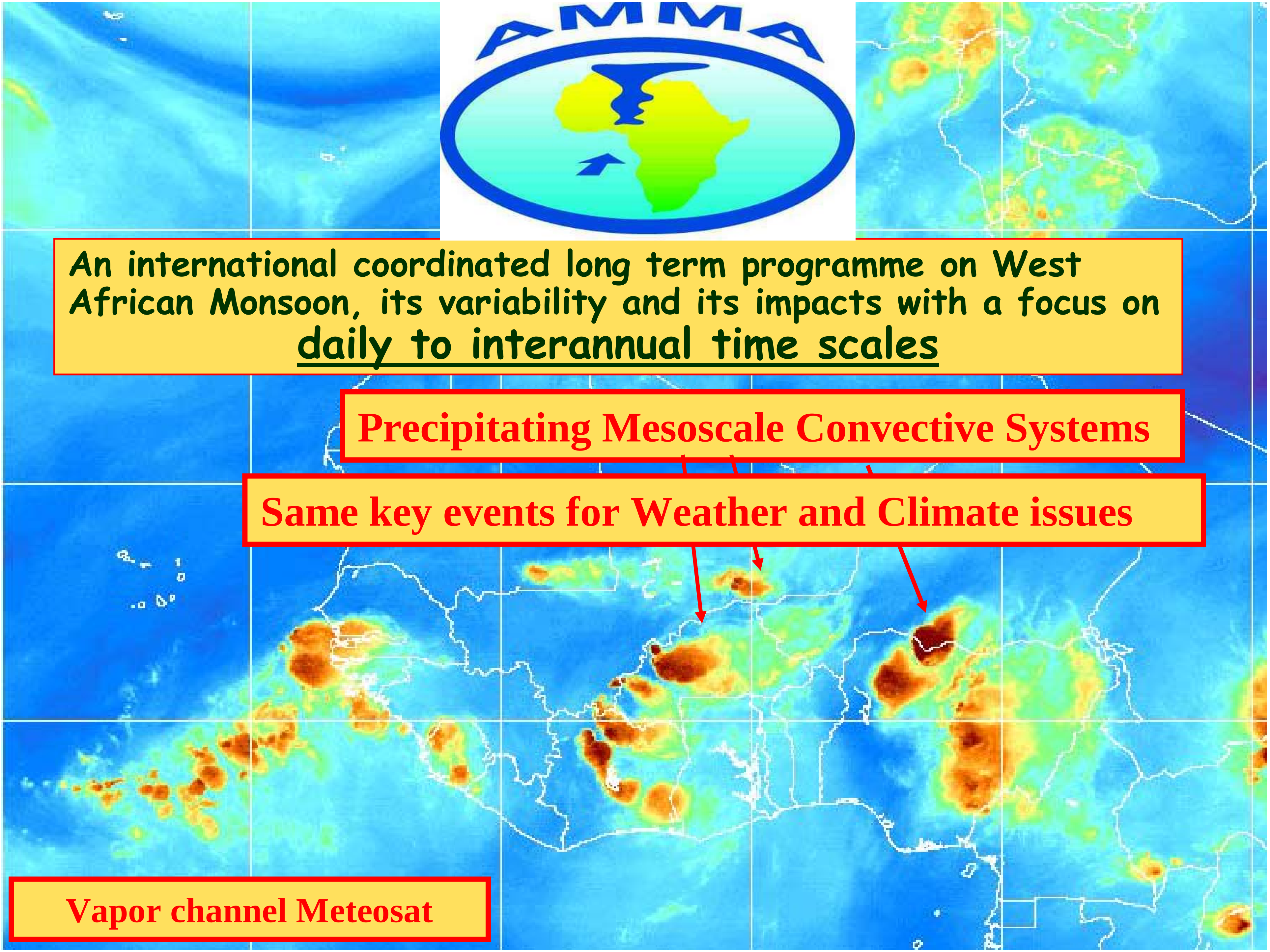
Austral Summer: Monsoons Indonesia, North-Australia, Est Africa, South America,



Regional scale
Seasonal cycle



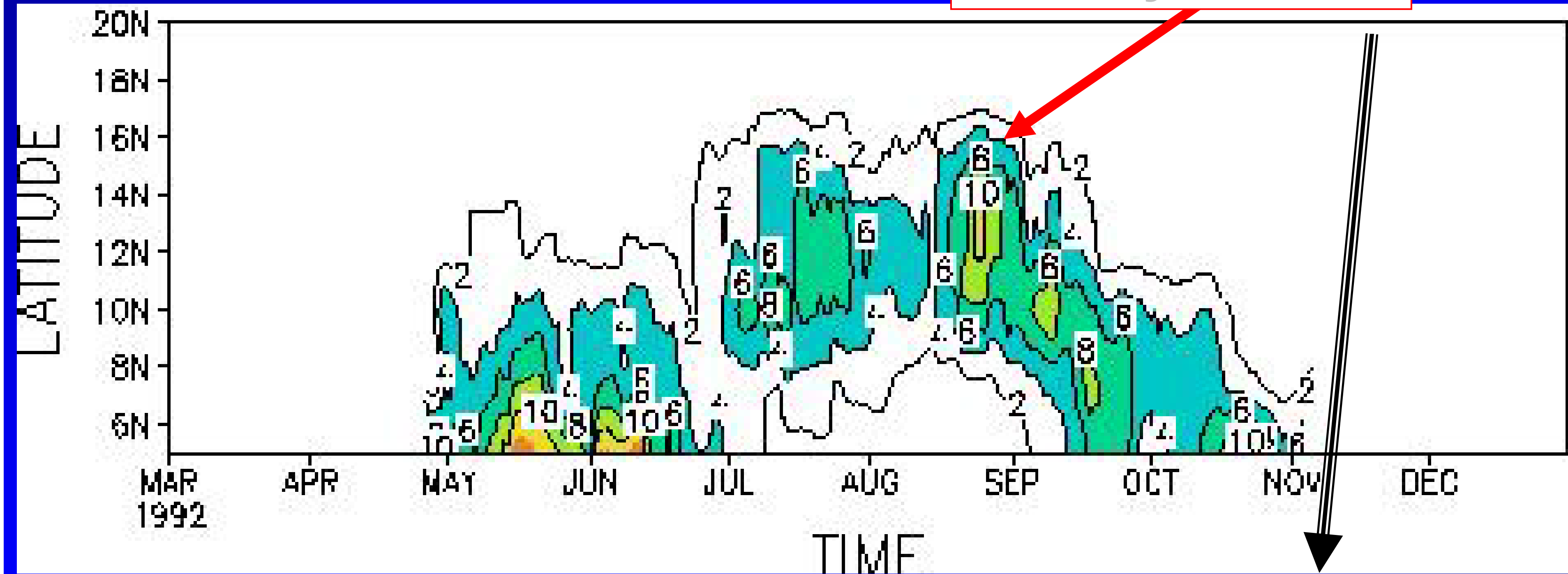

Monsoon is a regional and seasonal feature but rain occurs at smaller scale
Precipitating Mesoscale Convective Systems
Same key events for Weather and Climate
Vapor channel Meteosat


AMMA
An international coordinated long term programme on West African Monsoon, its variability and its impacts with a focus on
daily to interannual time scales
Precipitating Mesoscale Convective Systems
Same key events for Weather and Climate issues
Vapor channel Meteosat

Mesoscale Convective Systems

1992 Seasonal cycle as shown by daily precipitation over West Africa (Average 10°W-10°E)

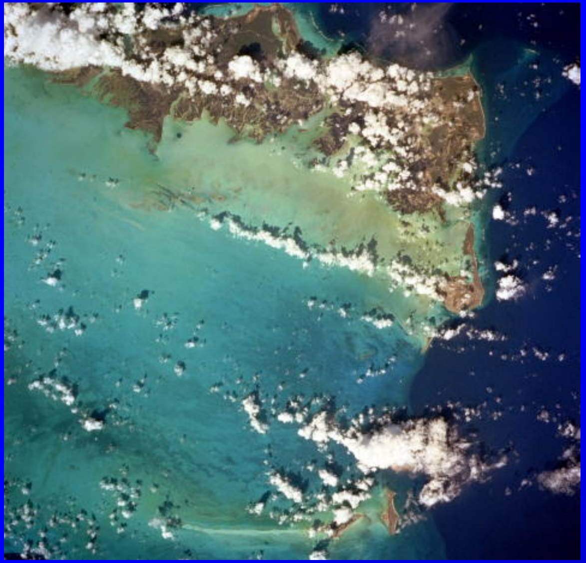
One major MCS



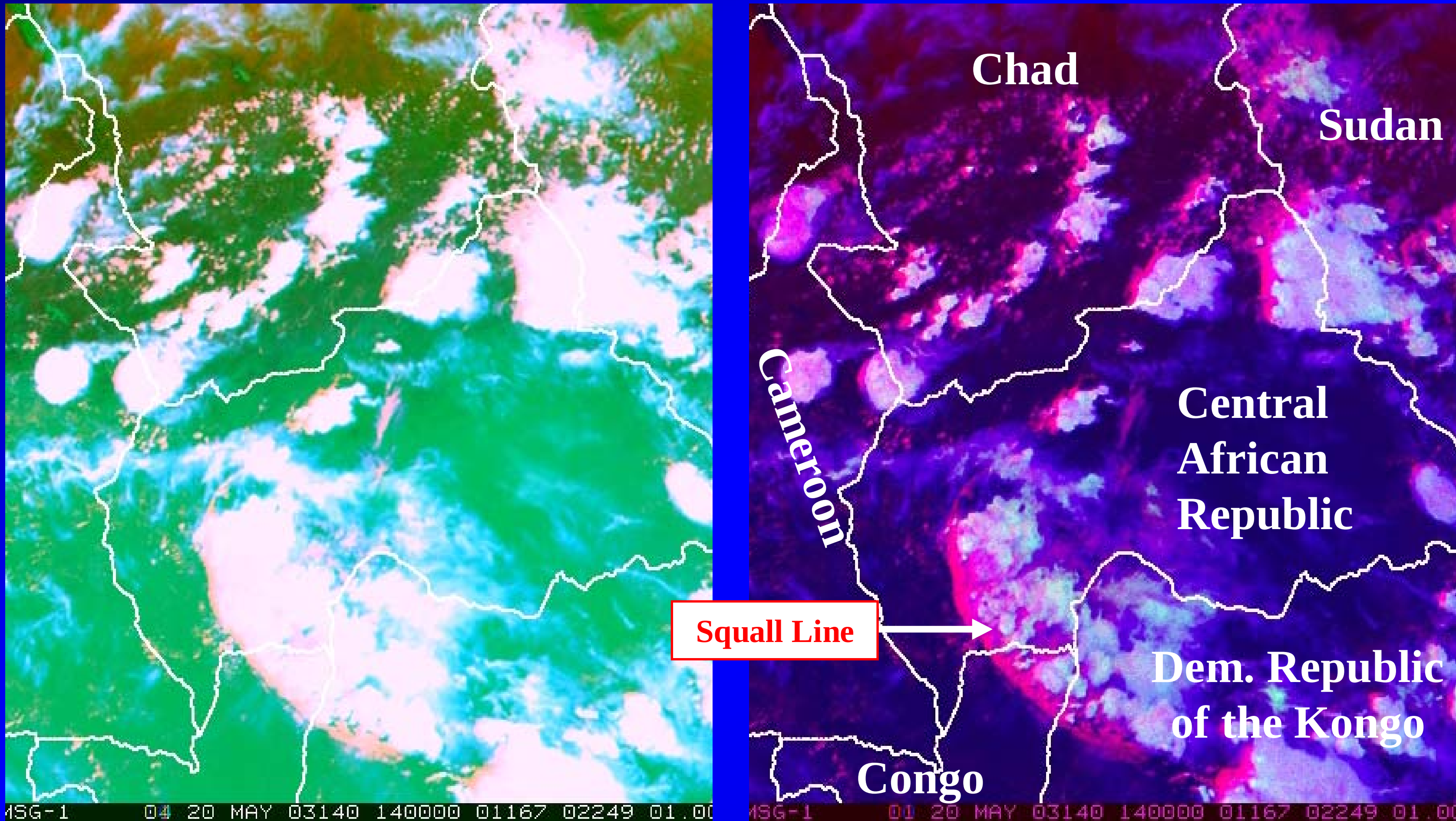
Around 80% of rainfall over Sahel produced by MCS

Mesoscale convective systems

- When wind shear is sufficiently strong, convection typically organizes into cloud bands (Kuettner 1959, 1971)

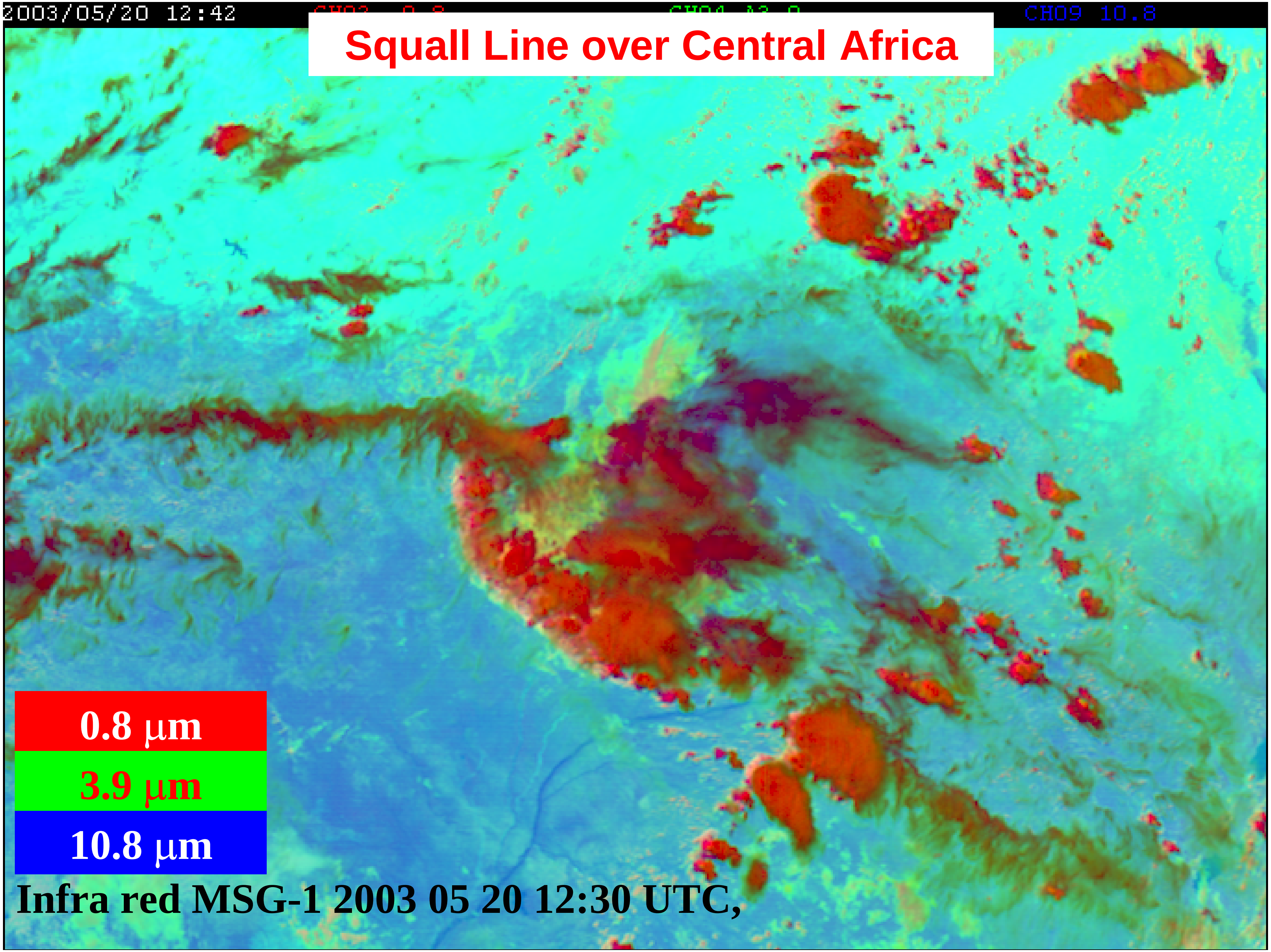


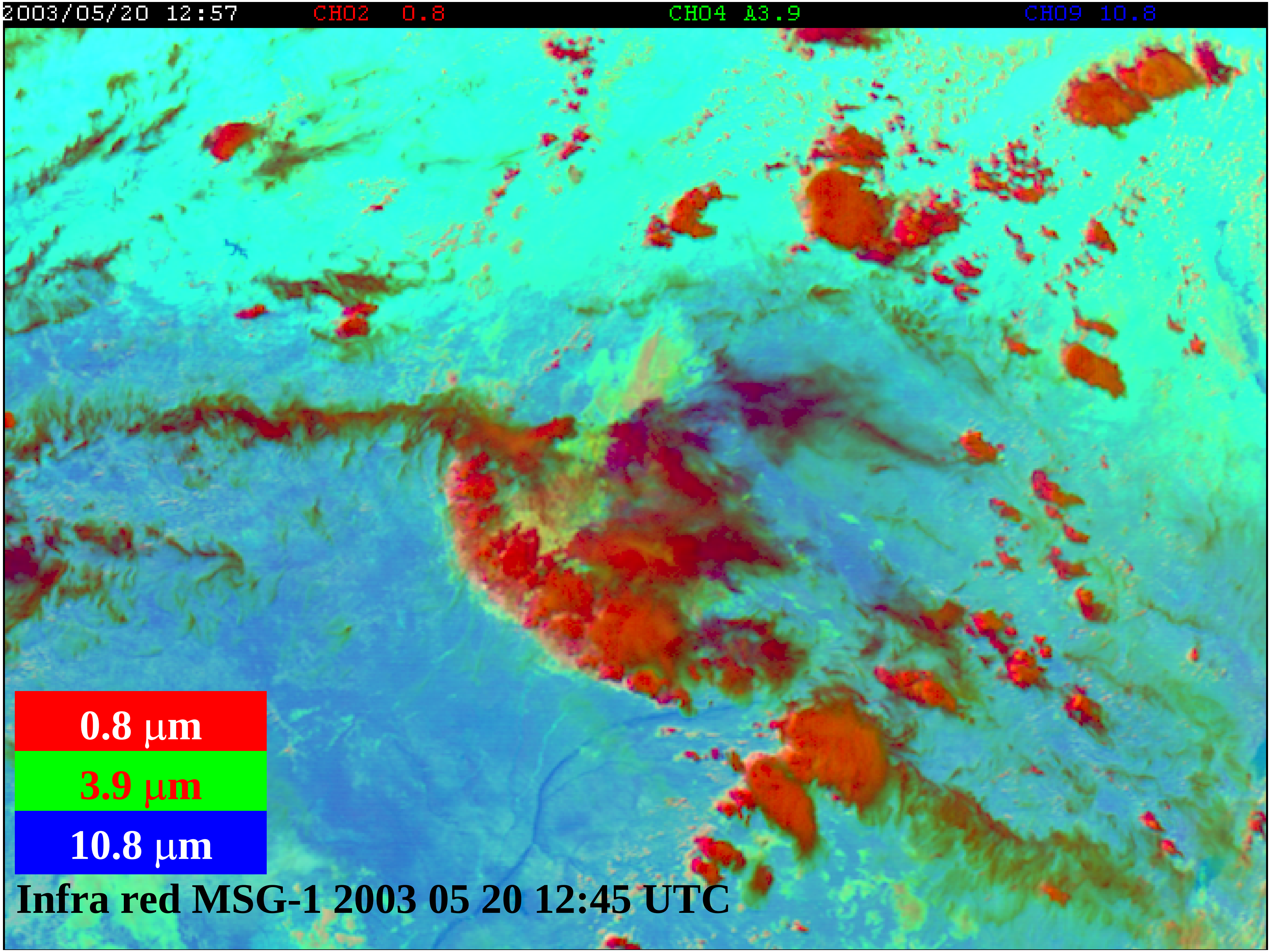
- The organization of deep convective systems is predominantly influenced by wind shear and CAPE (e.g. Moncrieff and Green 1972, Ludlam 1980) and mid-level dry air

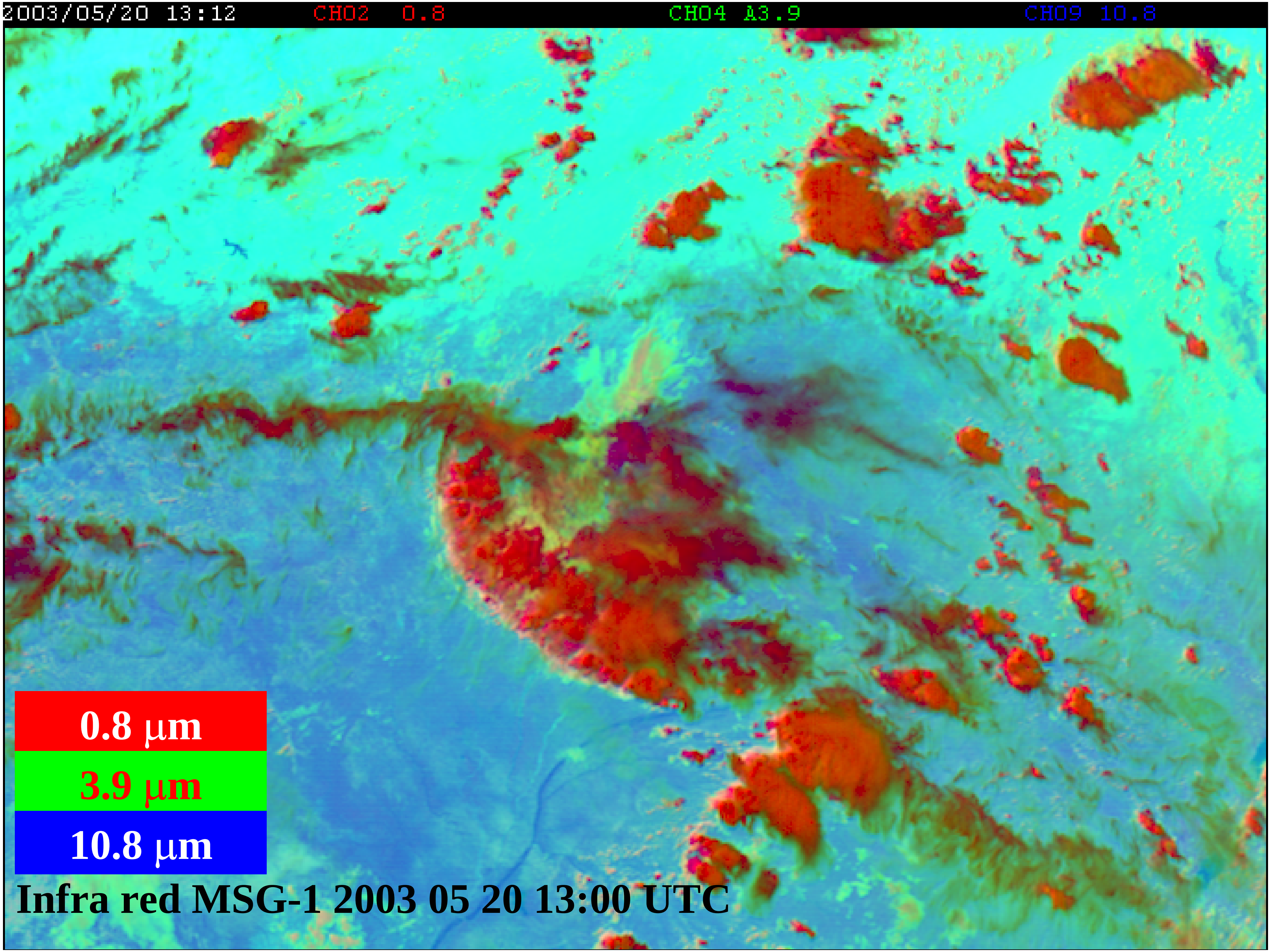


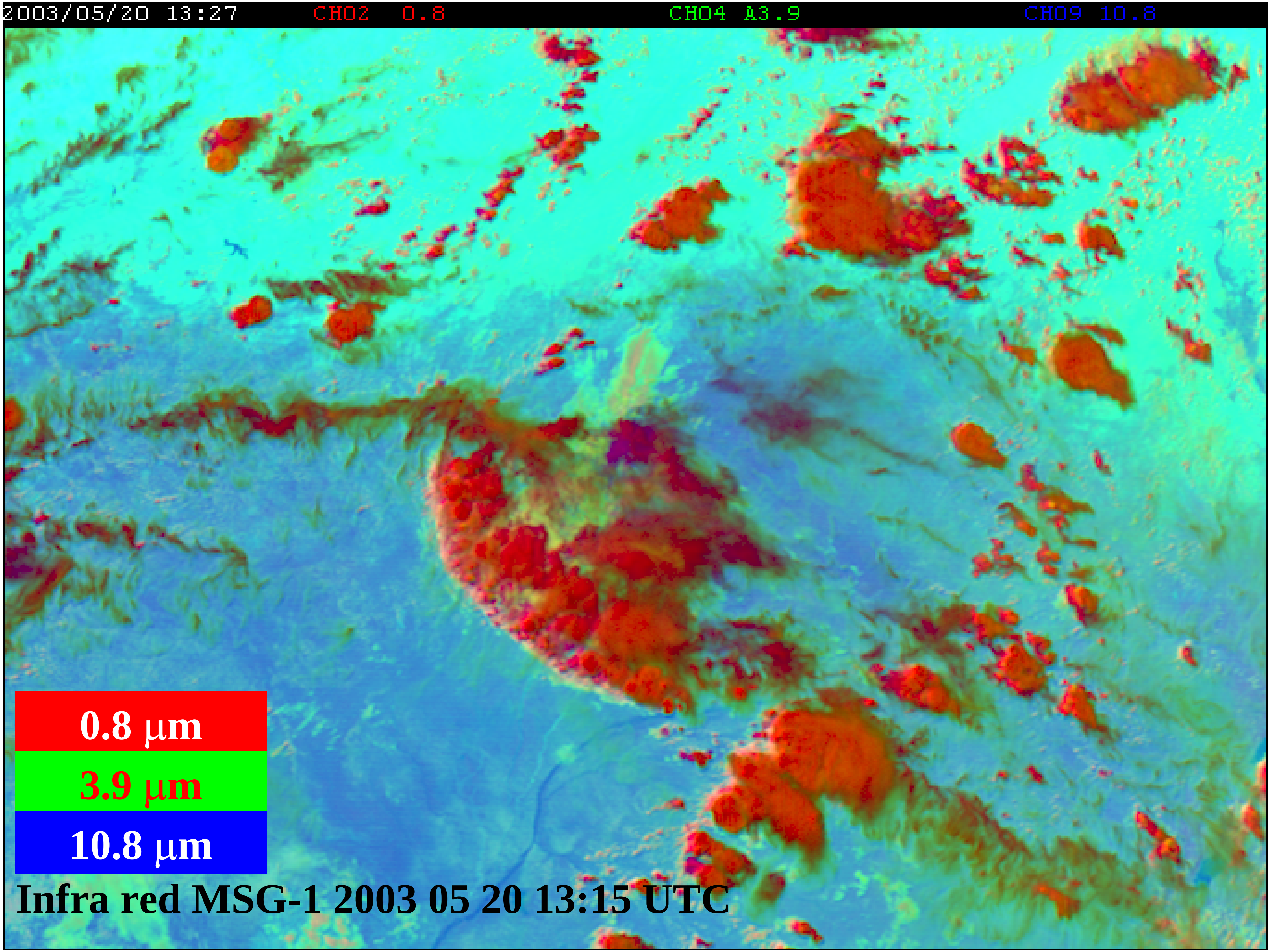
MSG-1, 20 May 2003, 14:00 UTC, RGB VIS0.6 / IR3.9i / IR12.0i
Effect of different enhancements

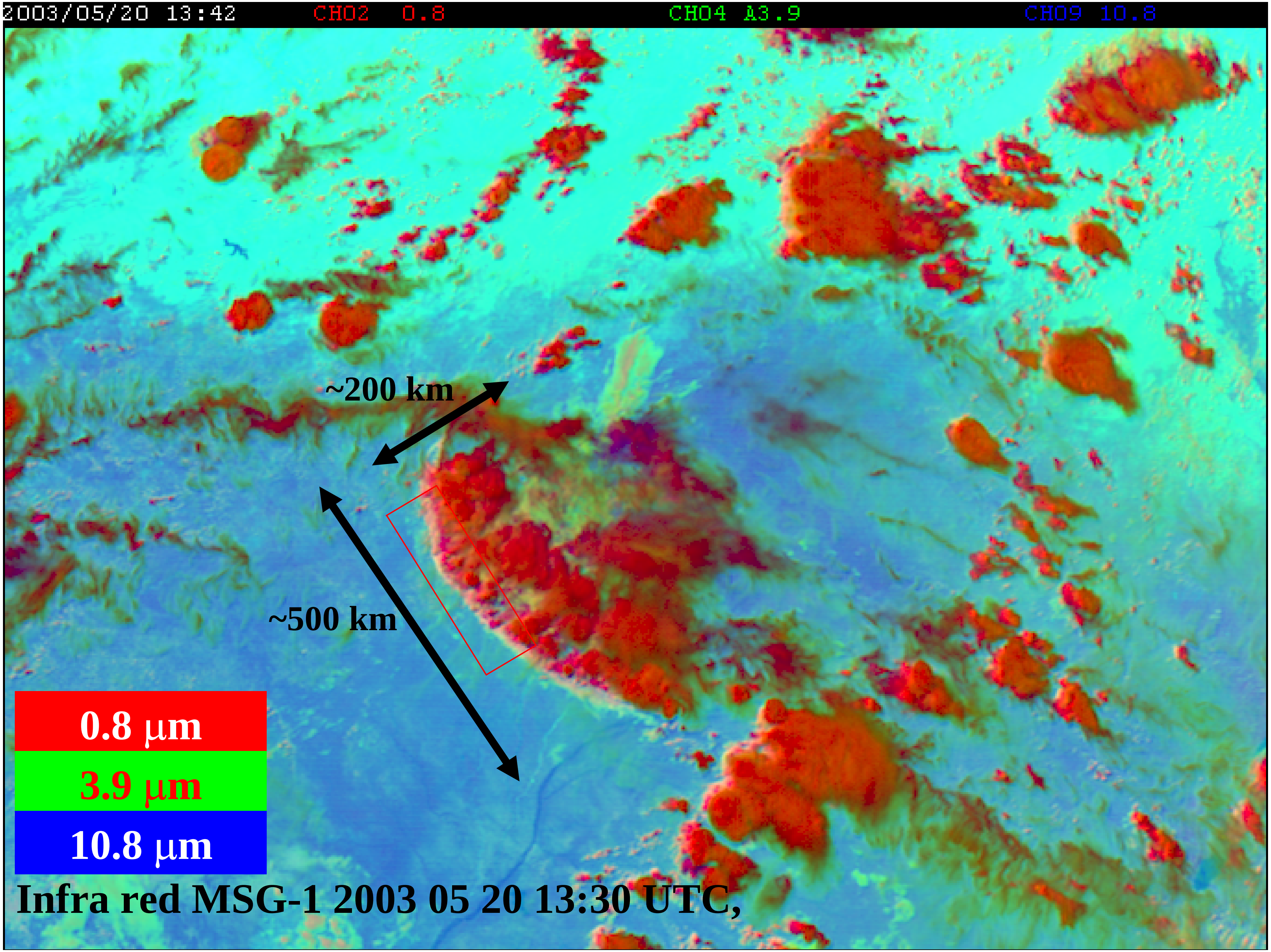
Squall Line over Central Africa




2003/05/20 12:57
CH02 0.8
CH04 A3.9
CH09 10.8
0.8 µm
3.9 µm
10.8 µm
Infra red MSG-1 2003 05 20 12:45 UTC


2003/05/20 13:12
CH02 0.8
CH04 A3.9
CH09 10.8
0.8 μm
3.9 μm
10.8 μm
Infra red MSG-1 2003 05 20 13:00 UTC

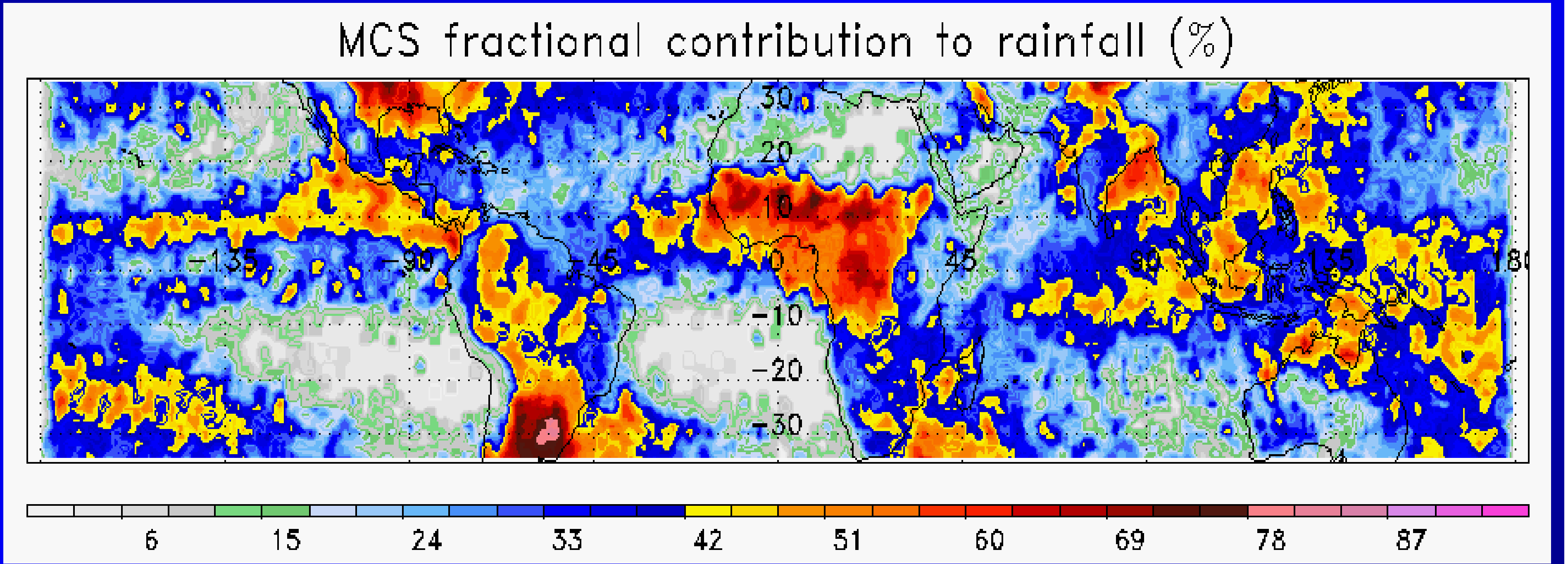

2003/05/20 13:27
CH02 0.8
CH04 A3.9
CH09 10.8
0.8 µm
3.9 µm
10.8 µm
Infra red MSG-1 2003 05 20 13:15 UTC



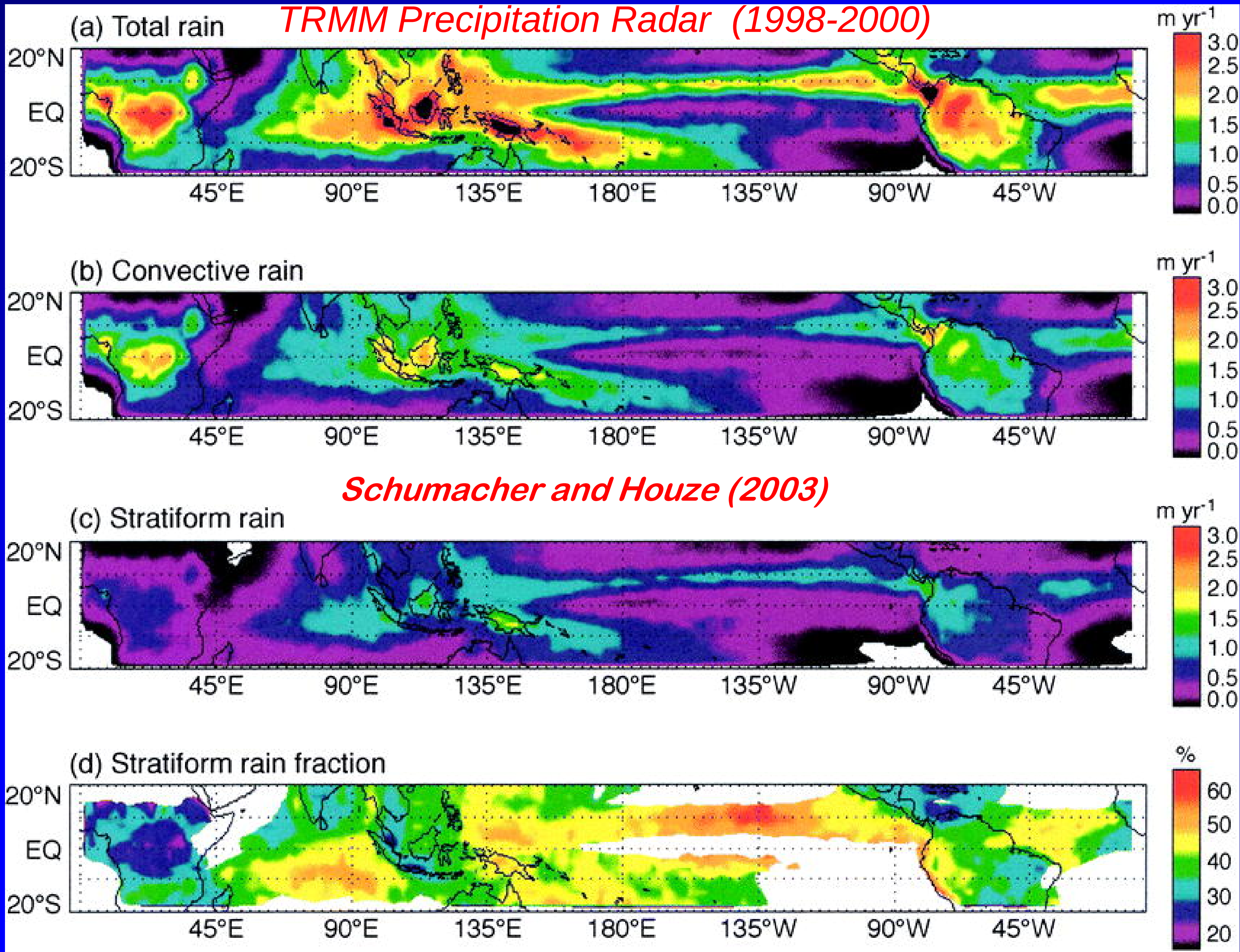
2003/05/20 13:42
CH02 0.8
CH04 A3.9
CH09 10.8
~200 km
~500 km
0.8 µm
3.9 µm
10.8 µm
Infra red MSG-1 2003 05 20 13:30 UTC,

Mesoscale Convective Systems

Global view of MCS contribution to rainfall
from TRMM observations



Zipser et al. (2005)



- Tropical-average stratiform rain fraction ~40%

Mesoscale Convective Systems

MCS tracking from Meteosat IR

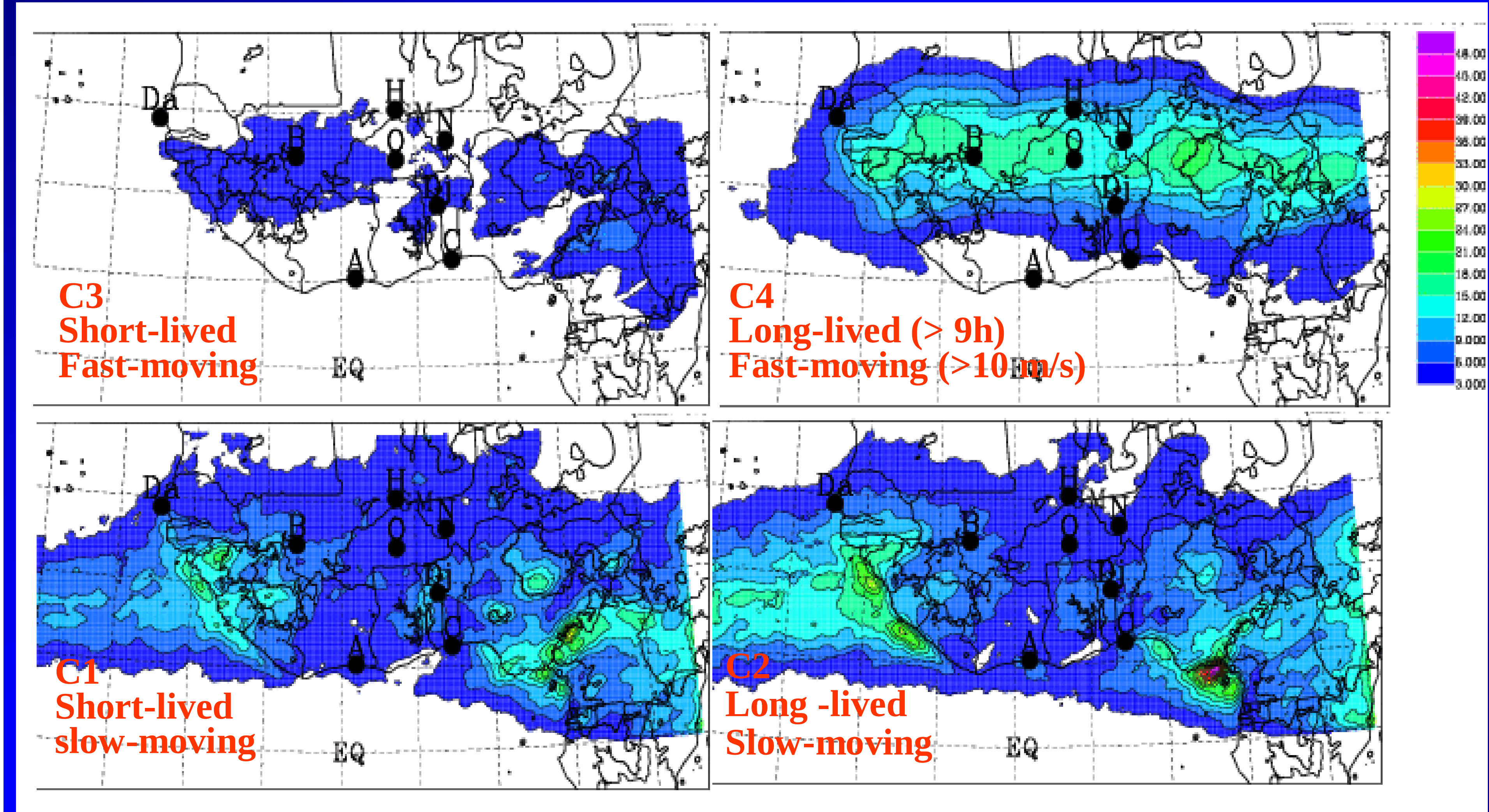
- Method operational for Europe at Meteo-France adapted for AMMA to Africa (operational in ACMAD) (Surface (T<-40°C) > 5000 km)

- Climatology application to 23 years observations from Meteosat first generation

Fiolleau, Tomasini, Laurent, Roca, Lafore, Ramage, …

Convective mesoscale systems

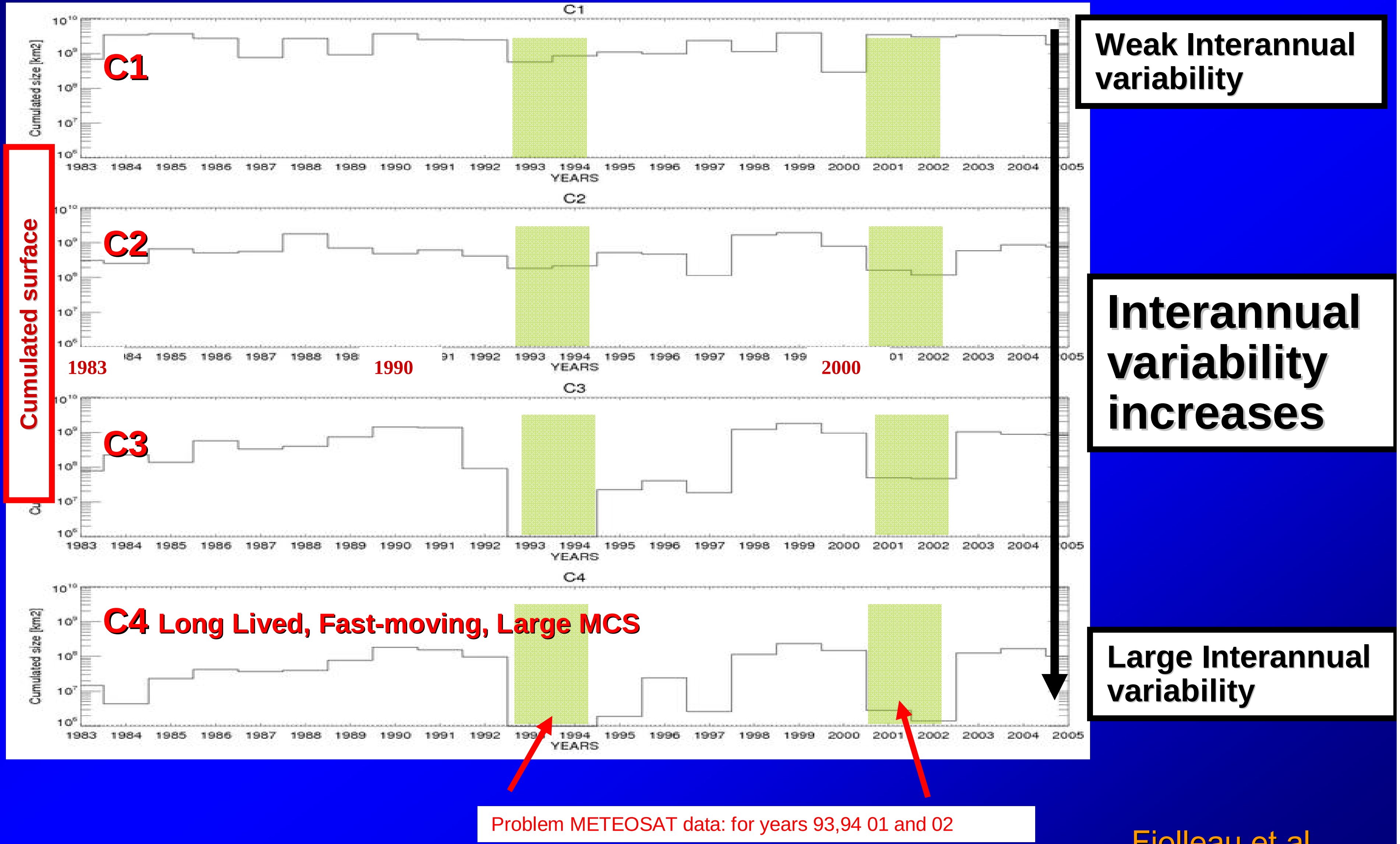
Classification in 4 classes as function of life time & propagation speed



Exemple for mean nebulosity (1996 to 2003)

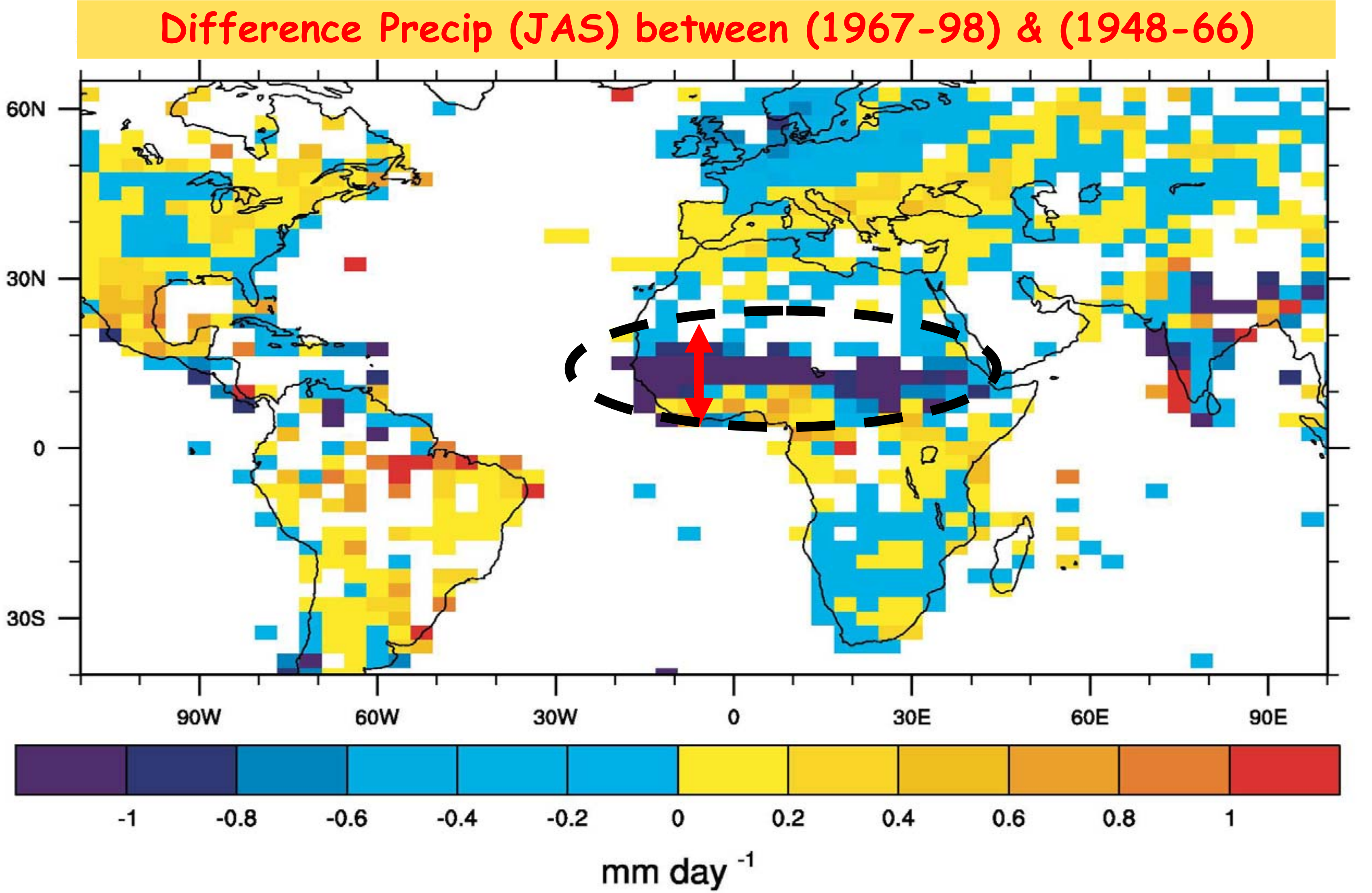
Tomasini et al

Interannual variability of MCS over West Africa 1983 to 2005



Fiolleau et al, AMMA 07 conf

Interannual variability and MCS ?

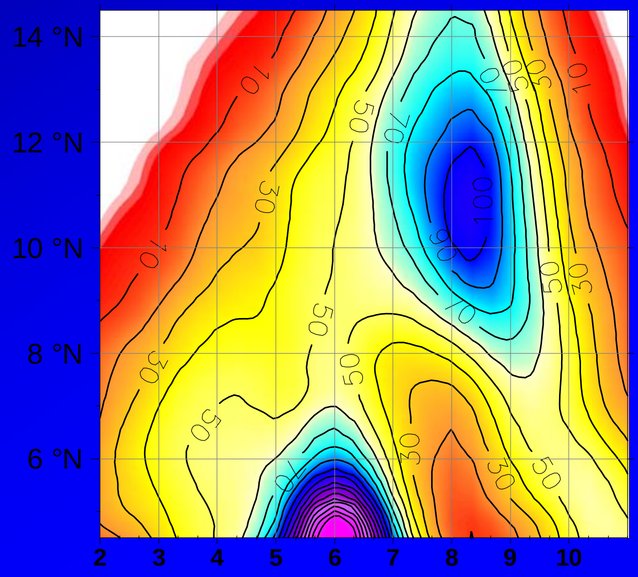


Interannual variability and MCS ?

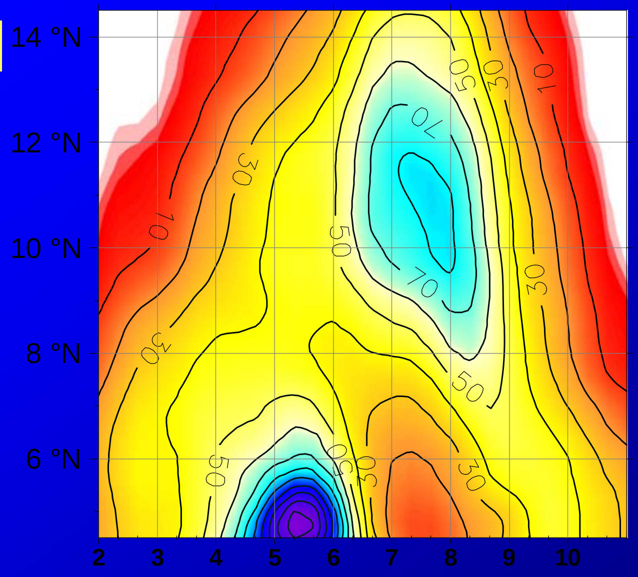
Seasonal cycle of observed rainfall at 5° W

Wet period
(1950-1969)

Dry period
(1970-1989)



Isoligne 1/10 mm/Day



<- Month ->

Le Barbé et al., 2002

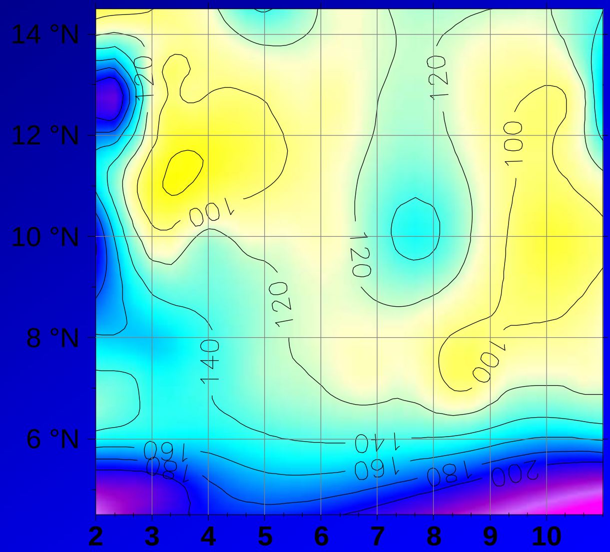
Interannual variability and MCS ?

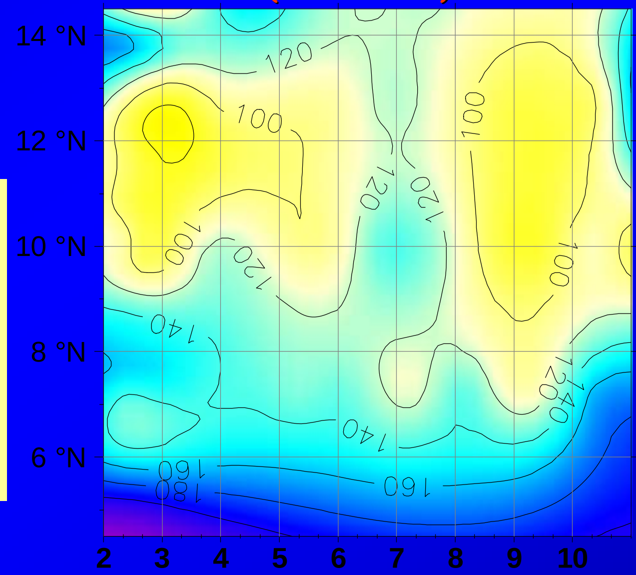
5° W

Wet period
(1950-1969)

Dry period
(1970-1989)

Mean rainfall per event
(1/10 mm/event)



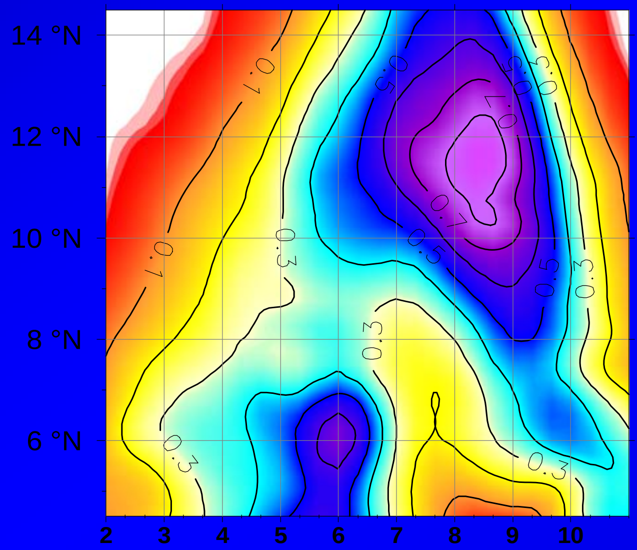


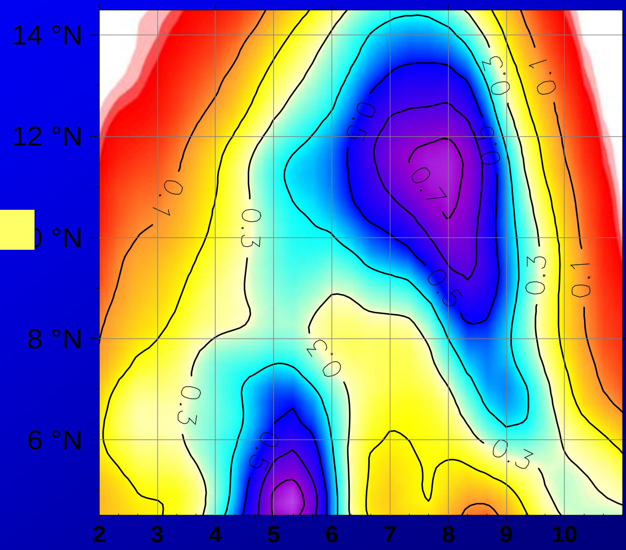
Drought

=

Smaller number of events of unchanged intensity

Mean number of events/Day



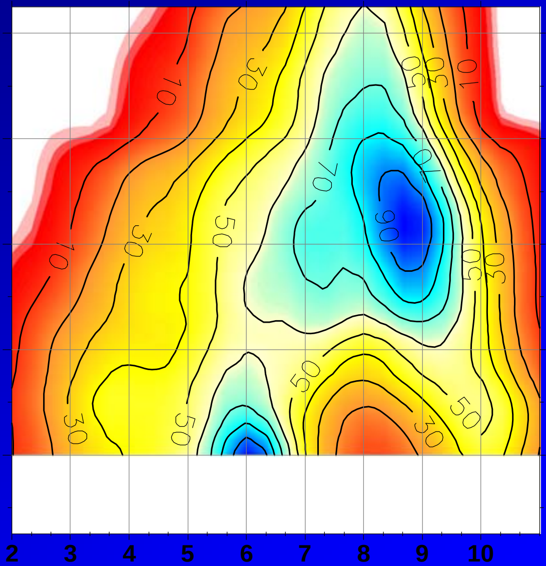


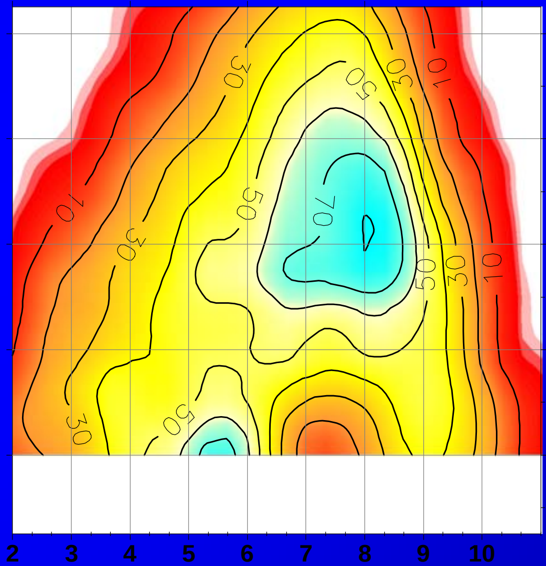
Le Barbé et al., 2002

Interannual variability and MCS ?

Wet period
(1950-1969)

Dry period
(1970-1989)

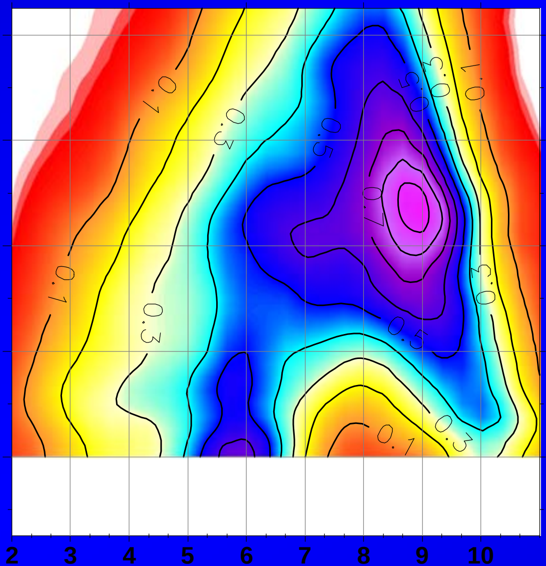


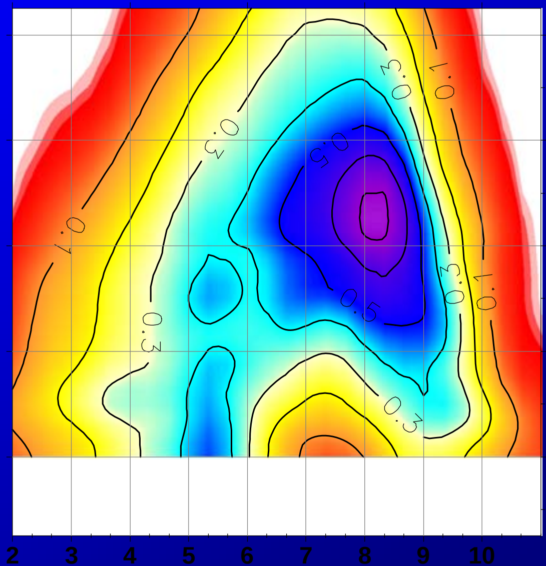


(1/10 mm/Day)

5° E

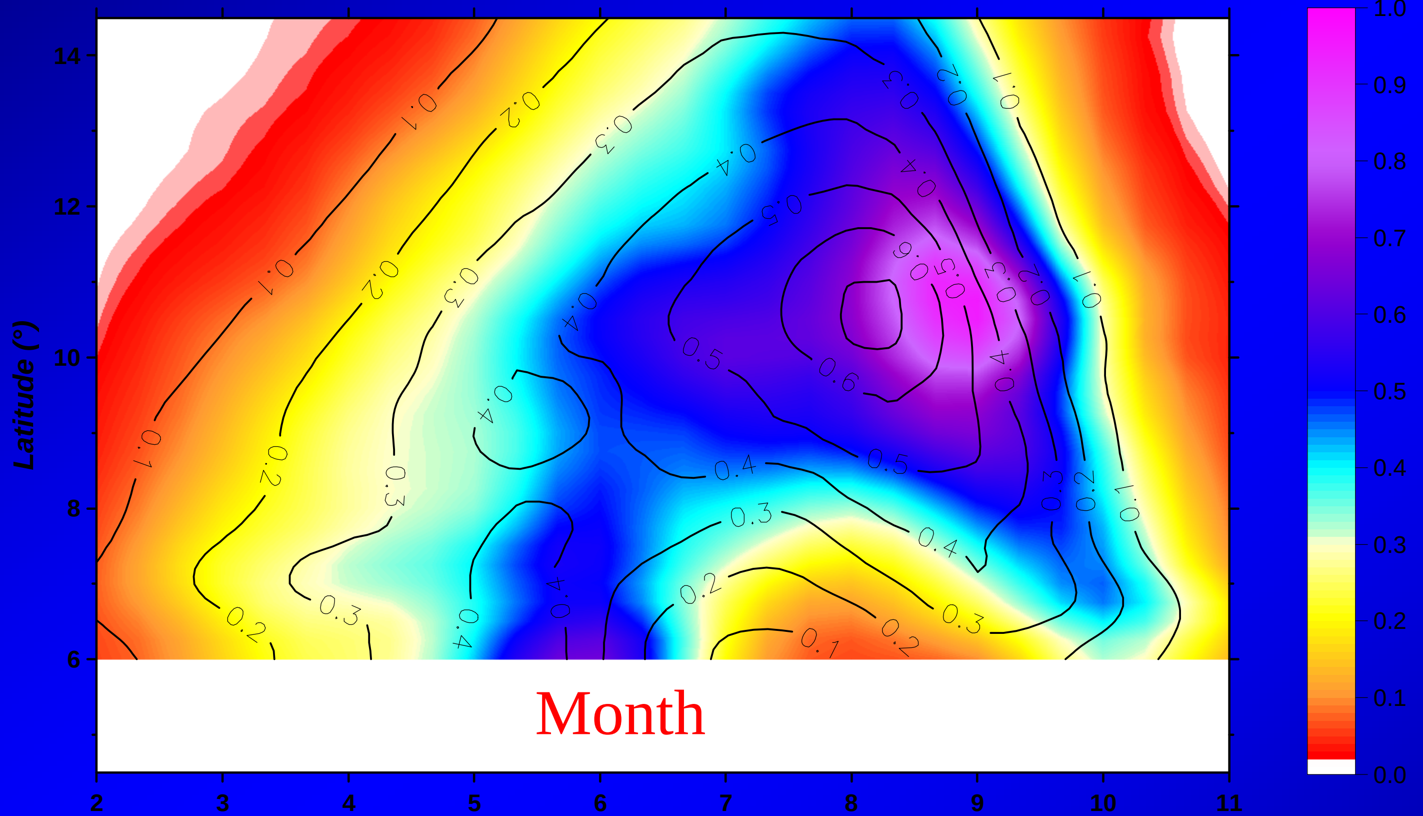
Same story





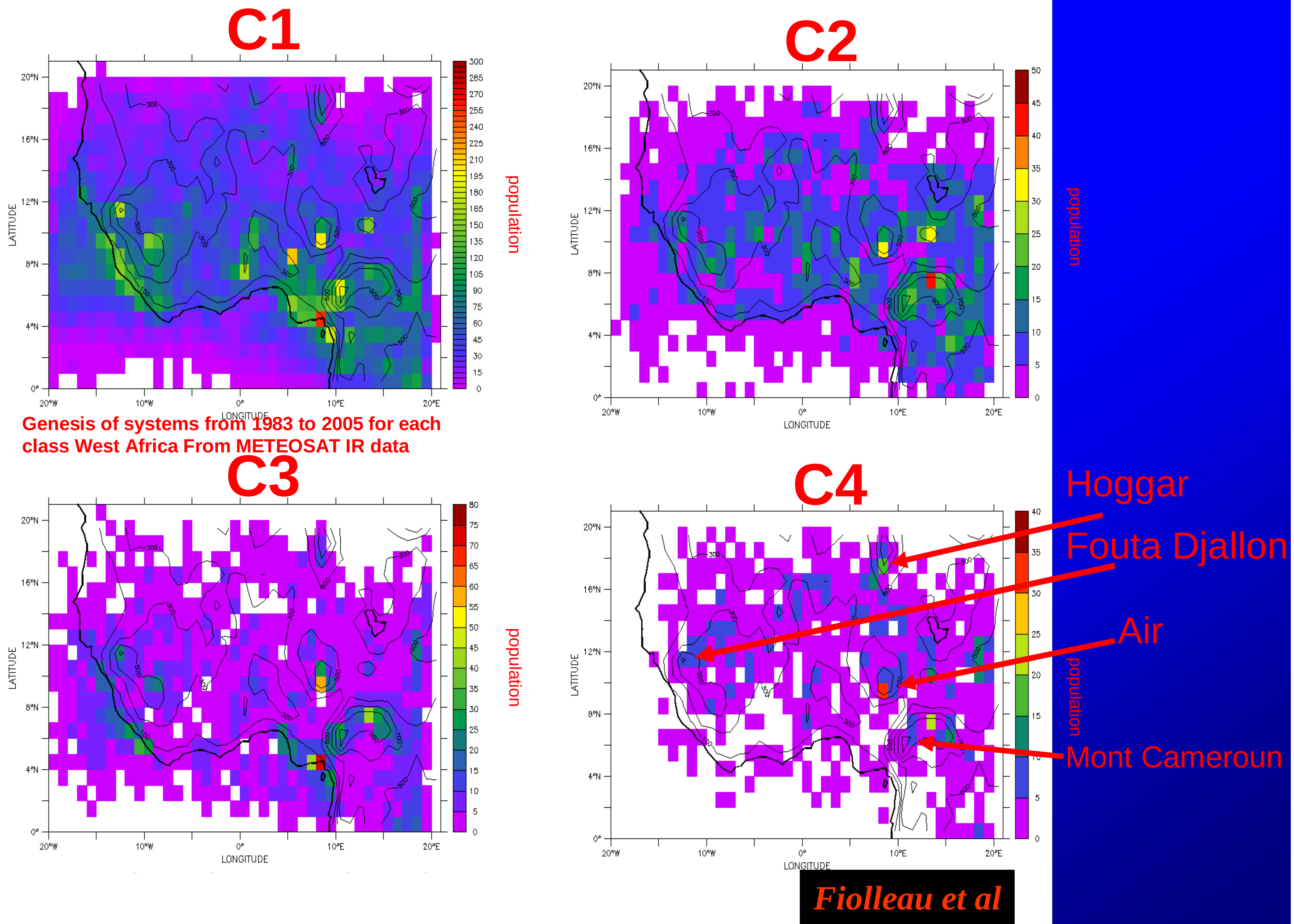
Mean Number of events/Day

Décalage des saisons des pluies



Couleurs : Période Humide; Isolignes : Période sèche

Affaiblissement du cœur de la saison des pluies au Sahel
Baisse et décalage de la seconde saison des pluies au Sud

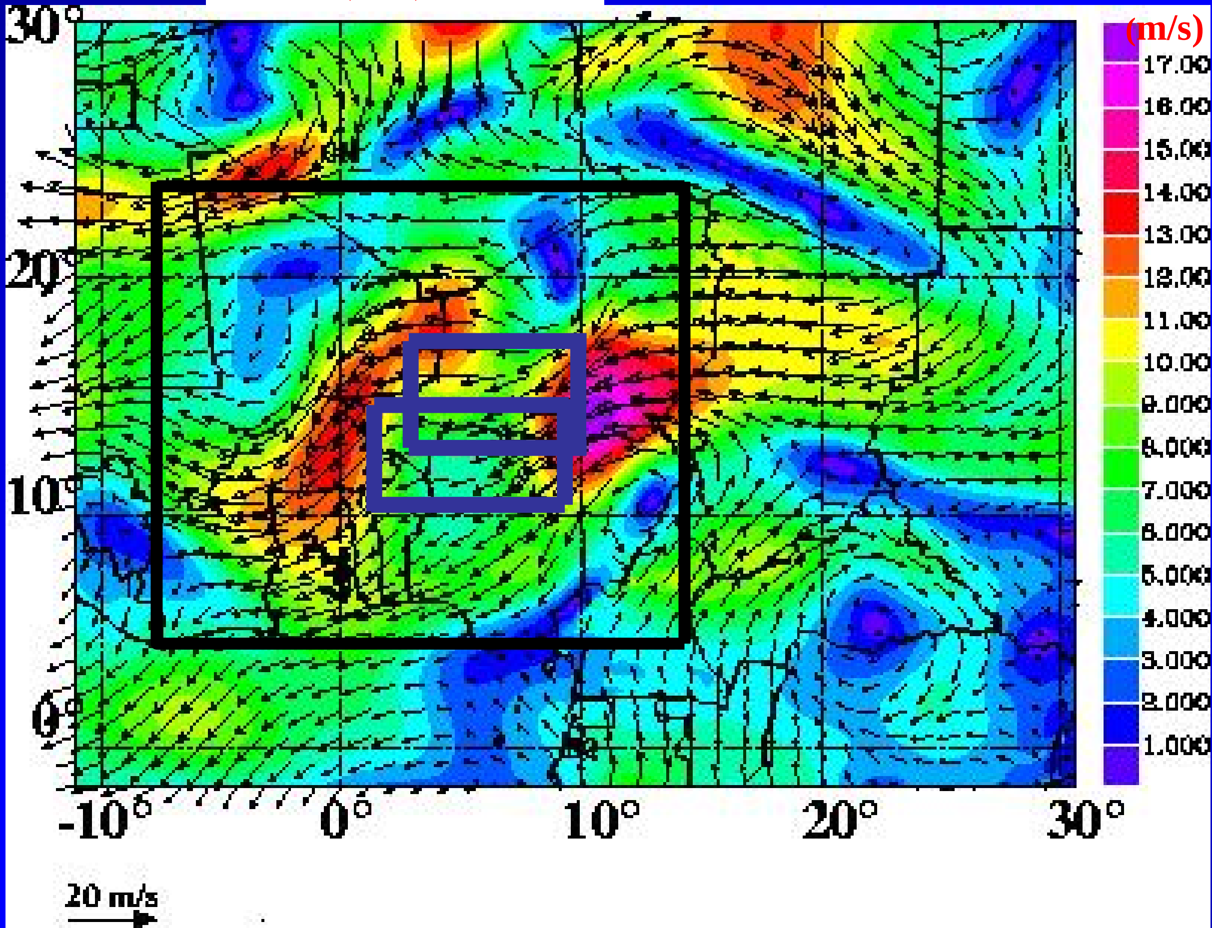


Genesis of systems from 1983 to 2005 for each class West Africa From METEOSAT IR data

Exemple of squall line simulation (HAPEX case)

Meso-NH model with 2-way interactive grid-nesting
ECMWF fields: Initialisation & 1-way coupling of outer model

Wind (m/s) **650 hPa**



ECMWF analysis
Each 6h

Outer Model
Domain : 2400*2400 km²
Dx=30 km DT=40s
Parameterized Convection
Bechtold *et al.* (2001)

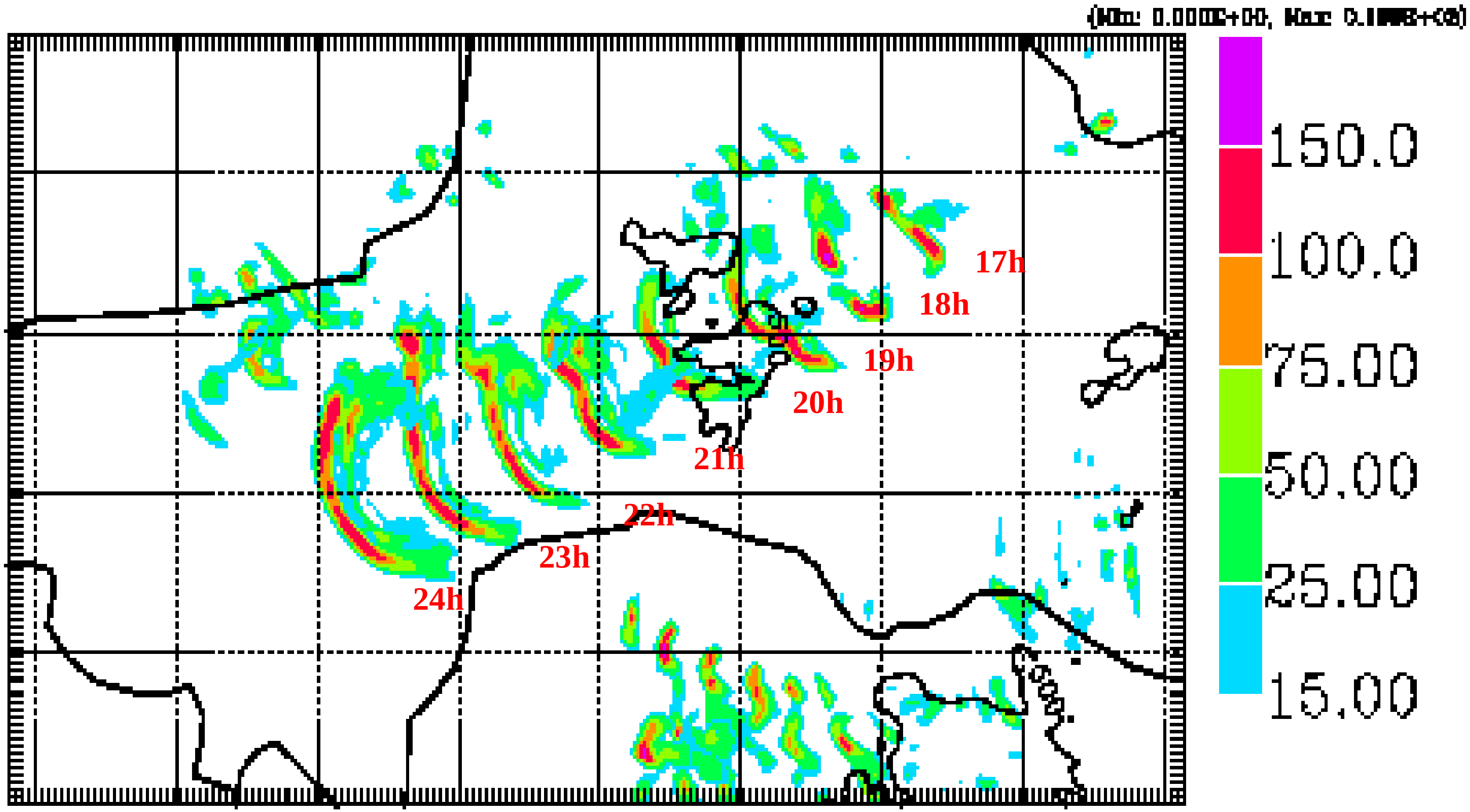
2 Inner Models
Domains : 750 x 590 km²
900 x 590 km²
Dx=5 km, DT=10s
« Resolved » Convection

Integration : 24 h

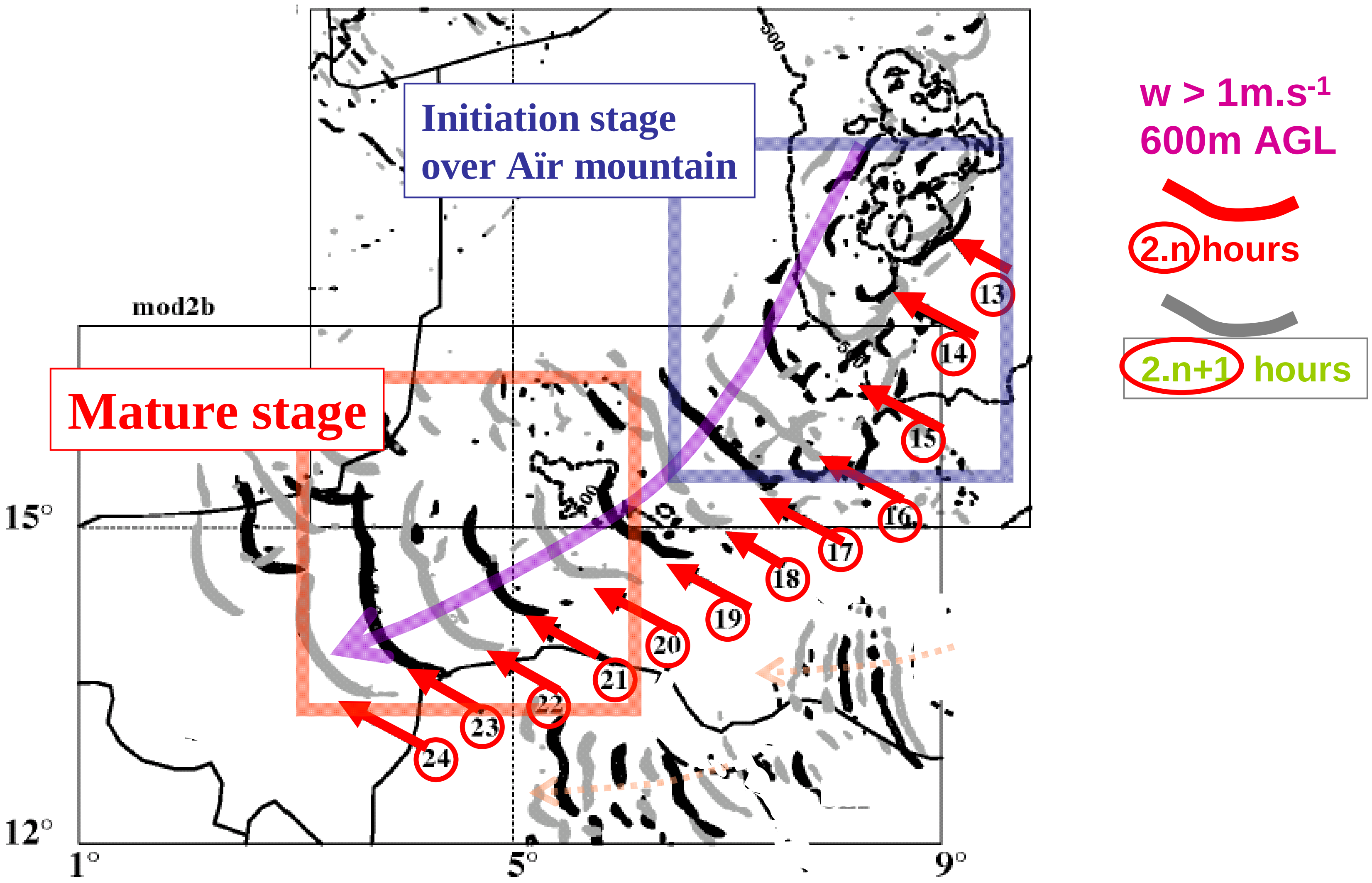
Diongue et al QJRMS 2002

Multiscale simulation Squall Line observed during HAPEX-92

Propagation from 17:00 to 22:00



Diongue et al QJRMS 2002

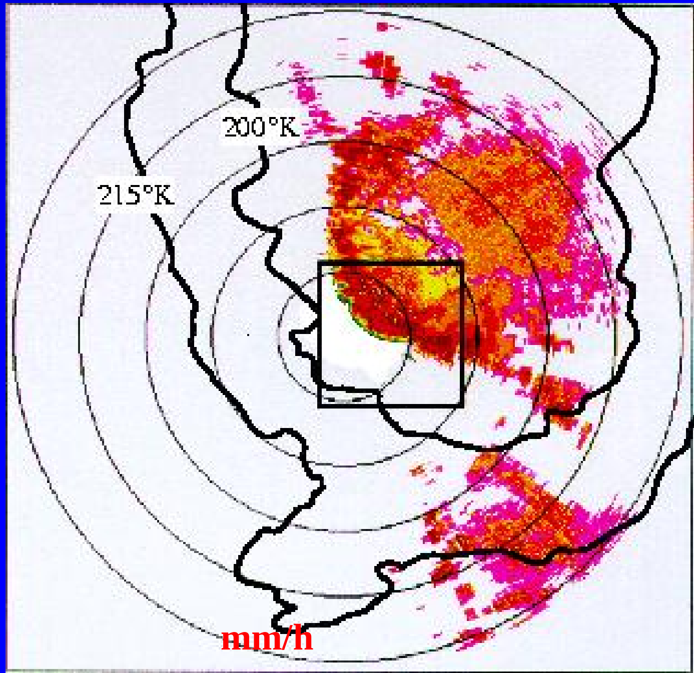


« Quasi-stationary » behaviour during several hours

covers 1000 km in 15 hours, propagation speed of 17 $m.s^{-1}$

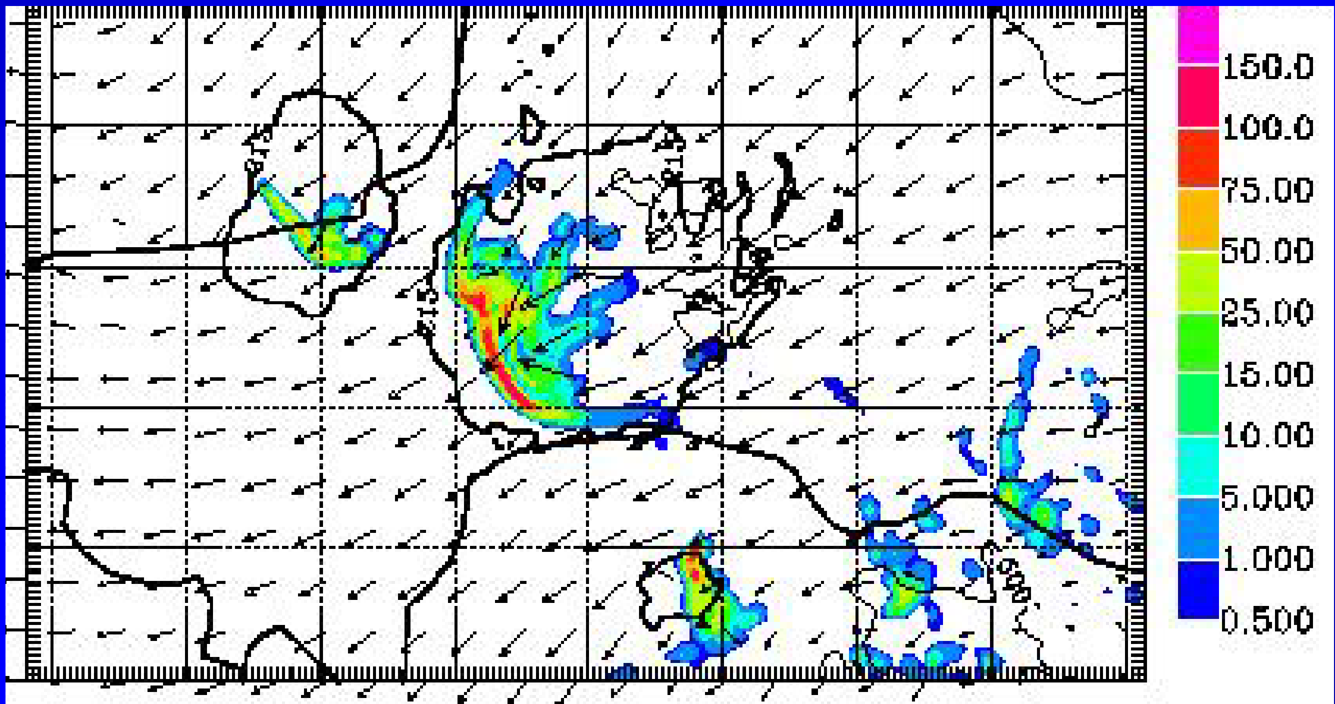
Mature phase of Squall Line Comparison with radar observation at 22UTC

Niamey Radar (dbZ)



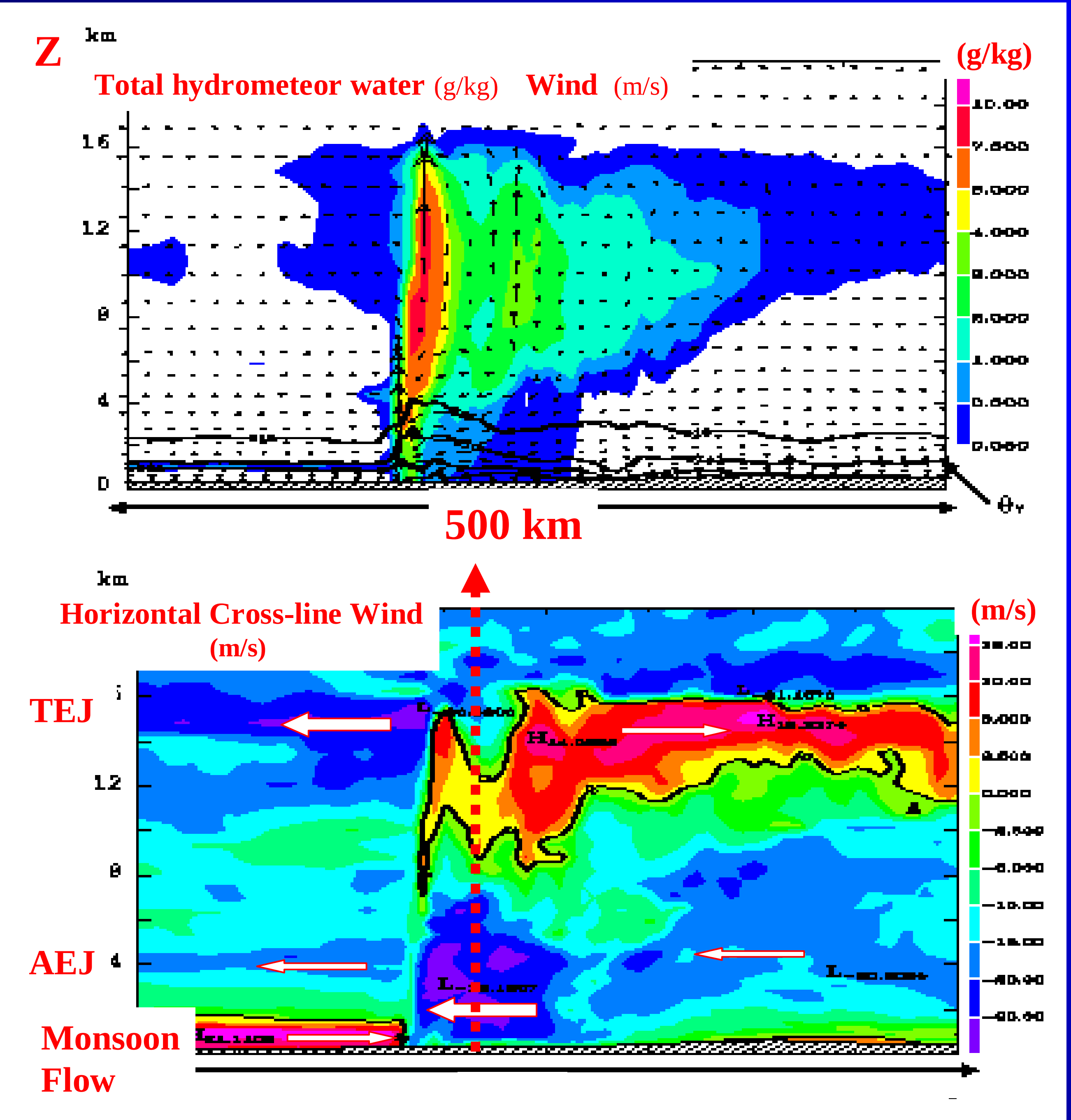
Rainfall (mm/h)

30m/s Wind (m/s) 650 hPa (AEJ)



Diongue et al QJRMS 2002

Vertical cross-section



- •Convective part
- •Stratiform part
- •Density current
  Height~ 2-3 km

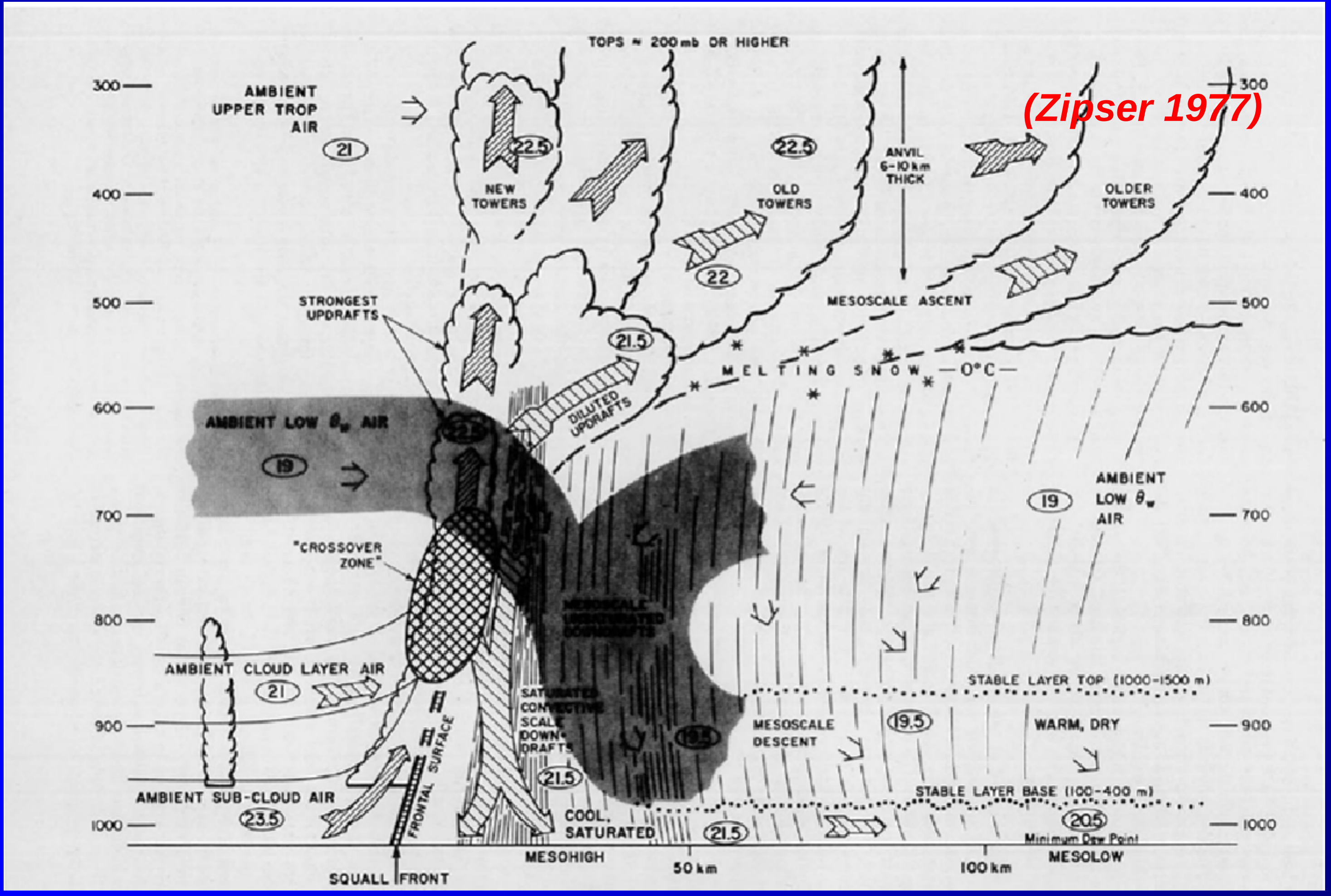
- •Upper level divergence
- •Mid level Rear Inflow
- .LL Convergence

Diongue et al QJRMS 2002

Mesoscale Organization

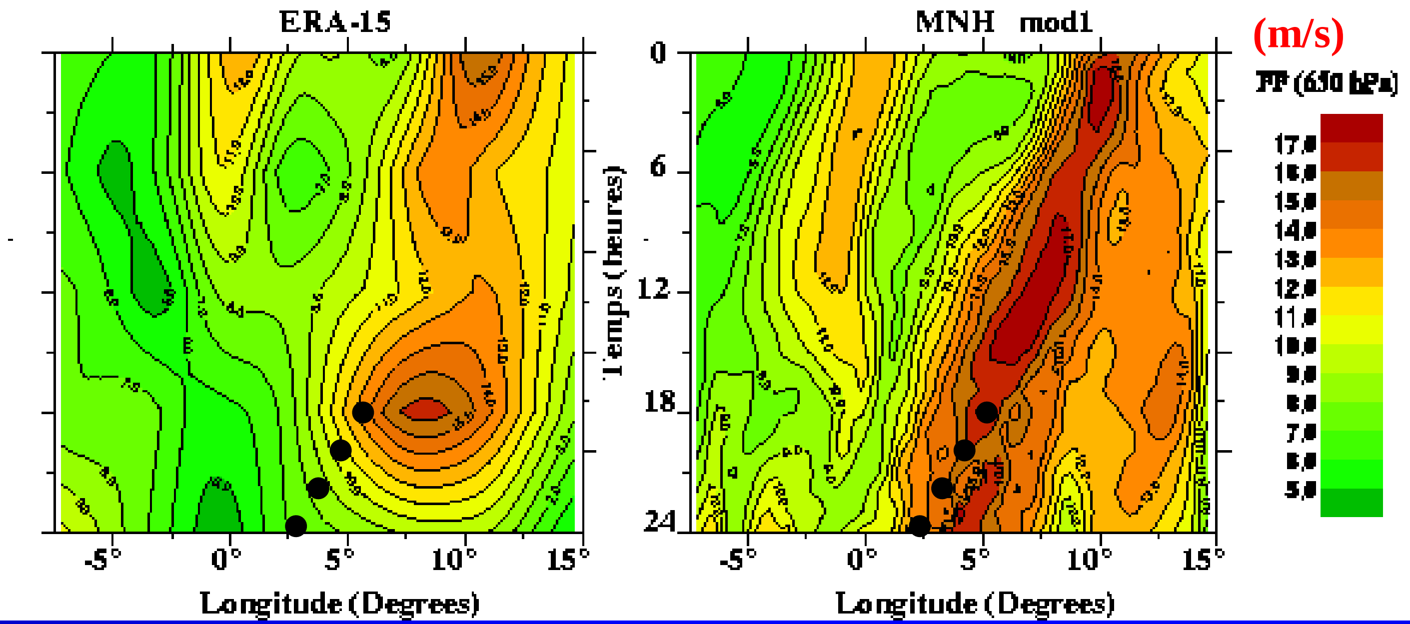
Mesoscale circulation exists and contributes to maintain the ascent region in front of system and the density current strength

Convective and Mesoscale downdrafts



(Zipser 1977)

Squall Line Impact on African Easterly Jet

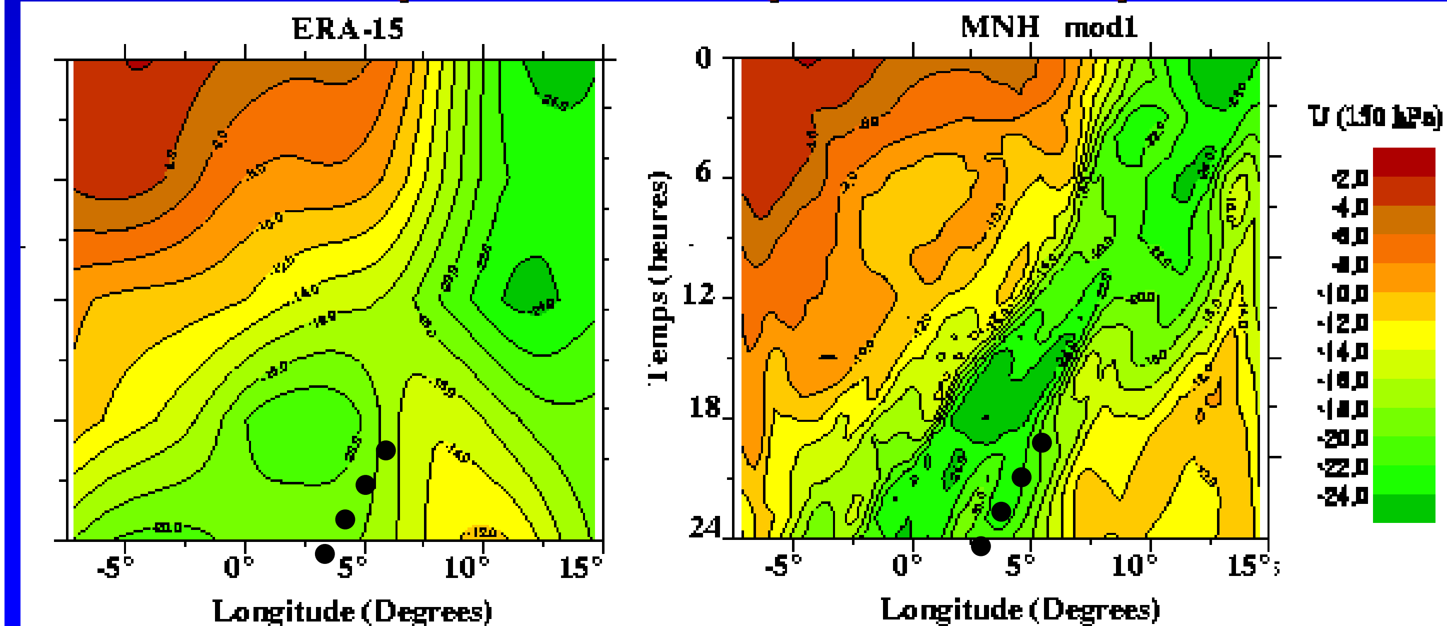


(m/s)

AEJ weaker in front of convection

AEJ stronger behind convection

Squall Line Impact on Tropical Easterly Jet

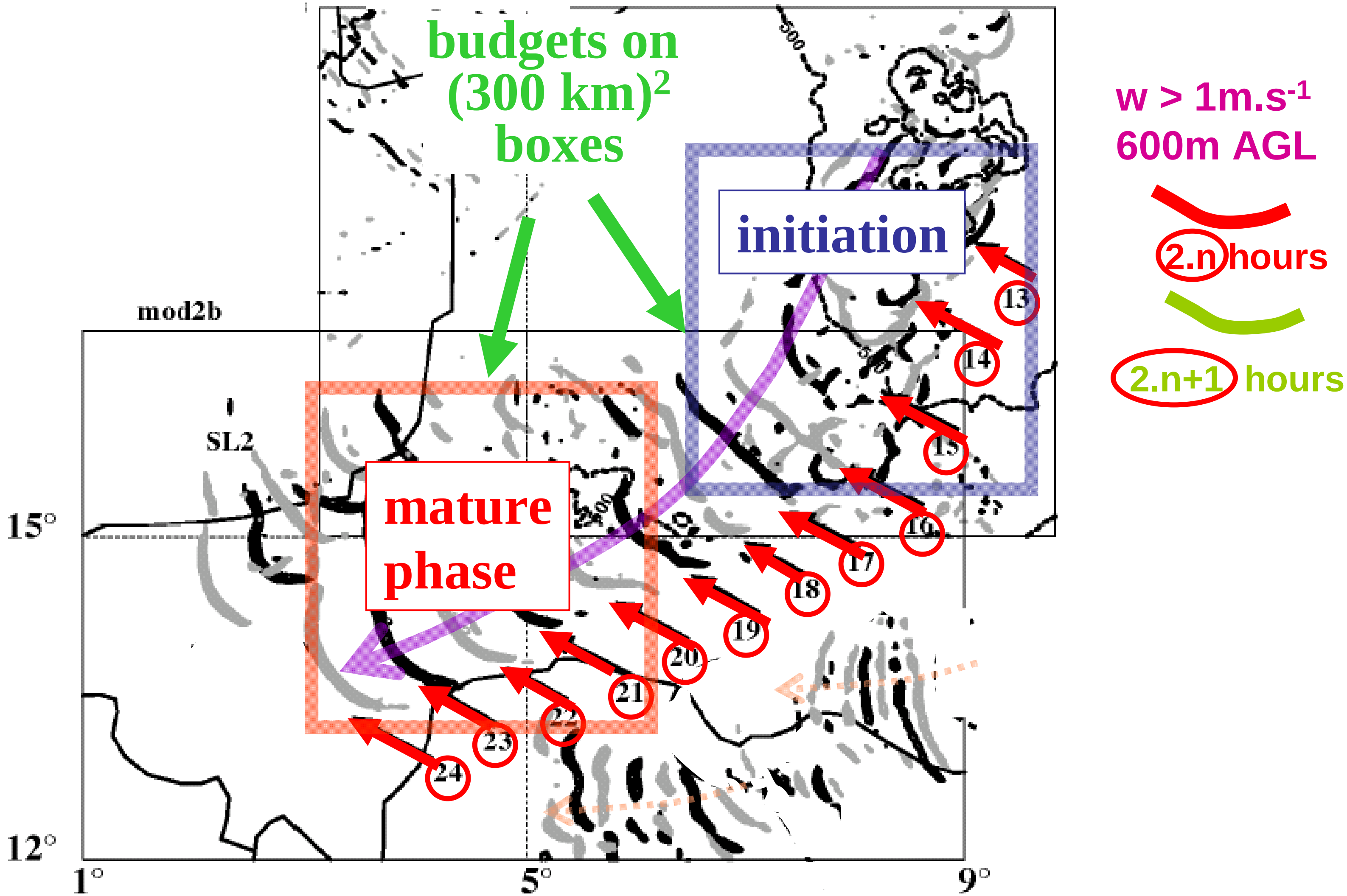


-Explains the double structure of TEJ

-TEJ stronger in front of convection

-TEJ weaker behind convection

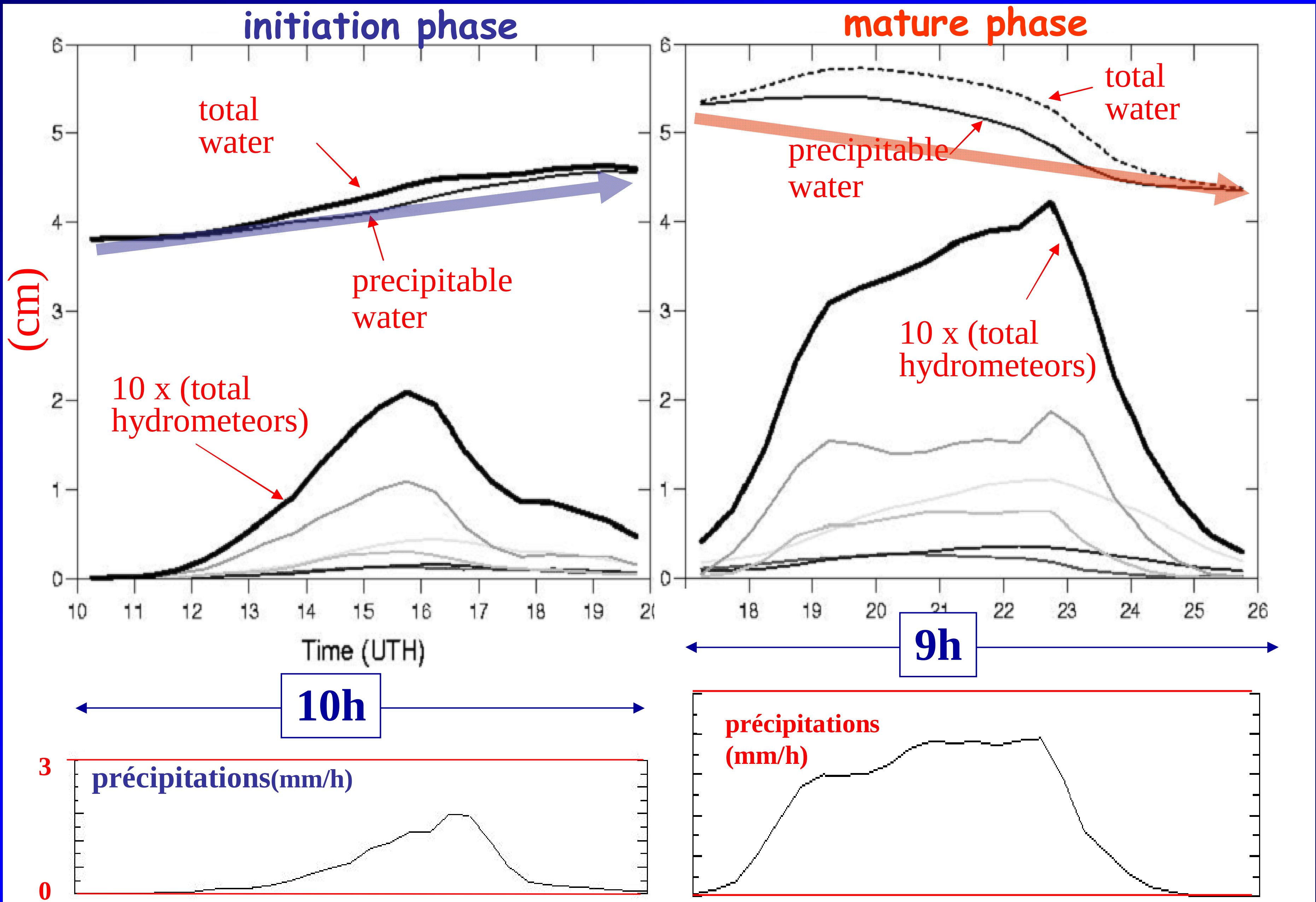
Diongue et al QJRMS 2002



« quasi-stationary » behaviour during several hours

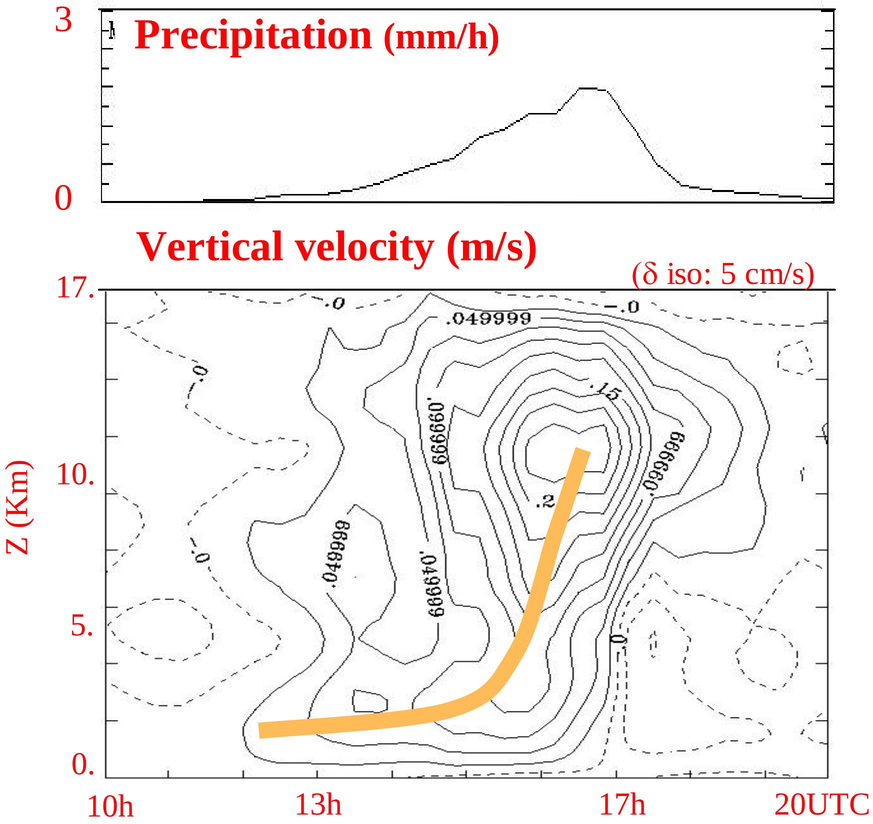
cover 1000 km in 15 hours, propagation speed of 17 $m.s^{-1}$

CRM simulation: average budgets on (300 km)^2 boxes

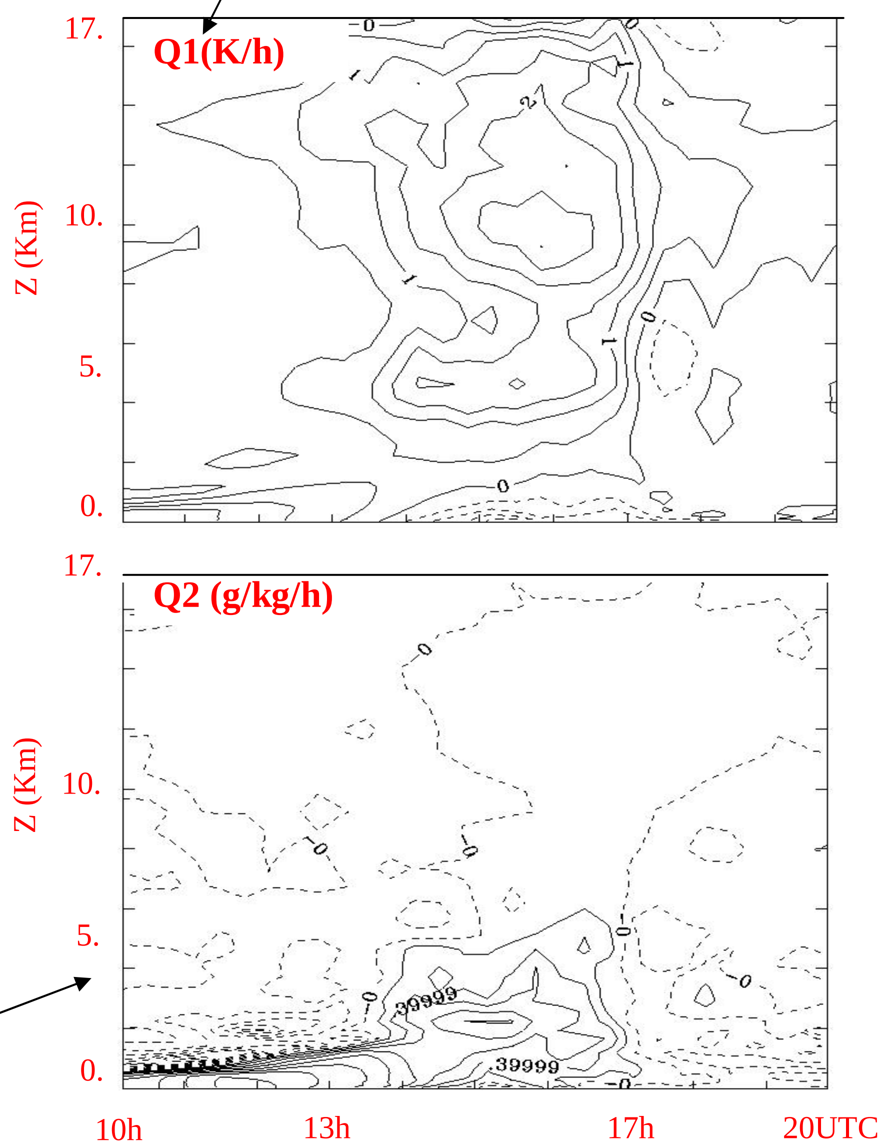


Initiation phase

zone B1 (~ 300 km x 300 km)

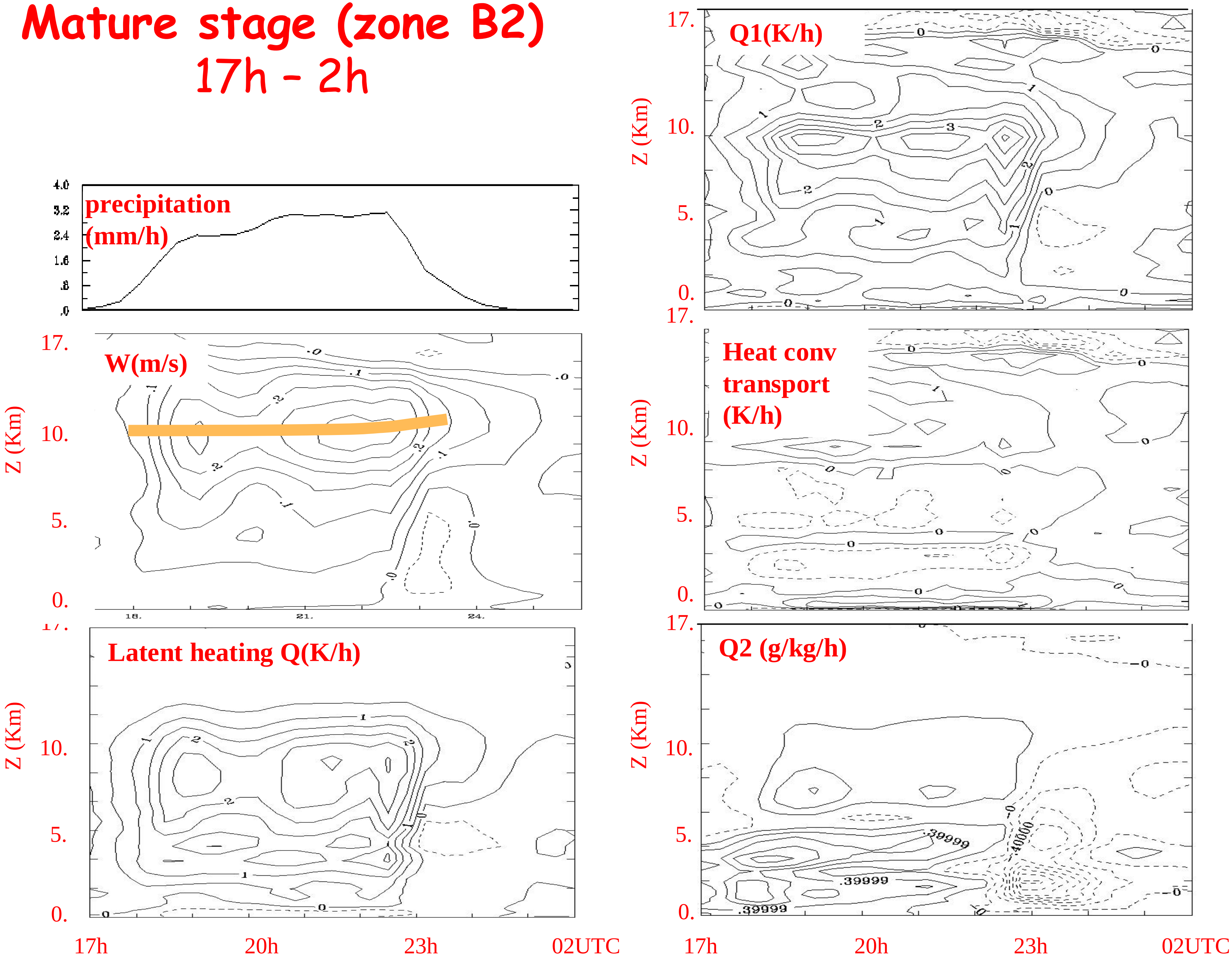


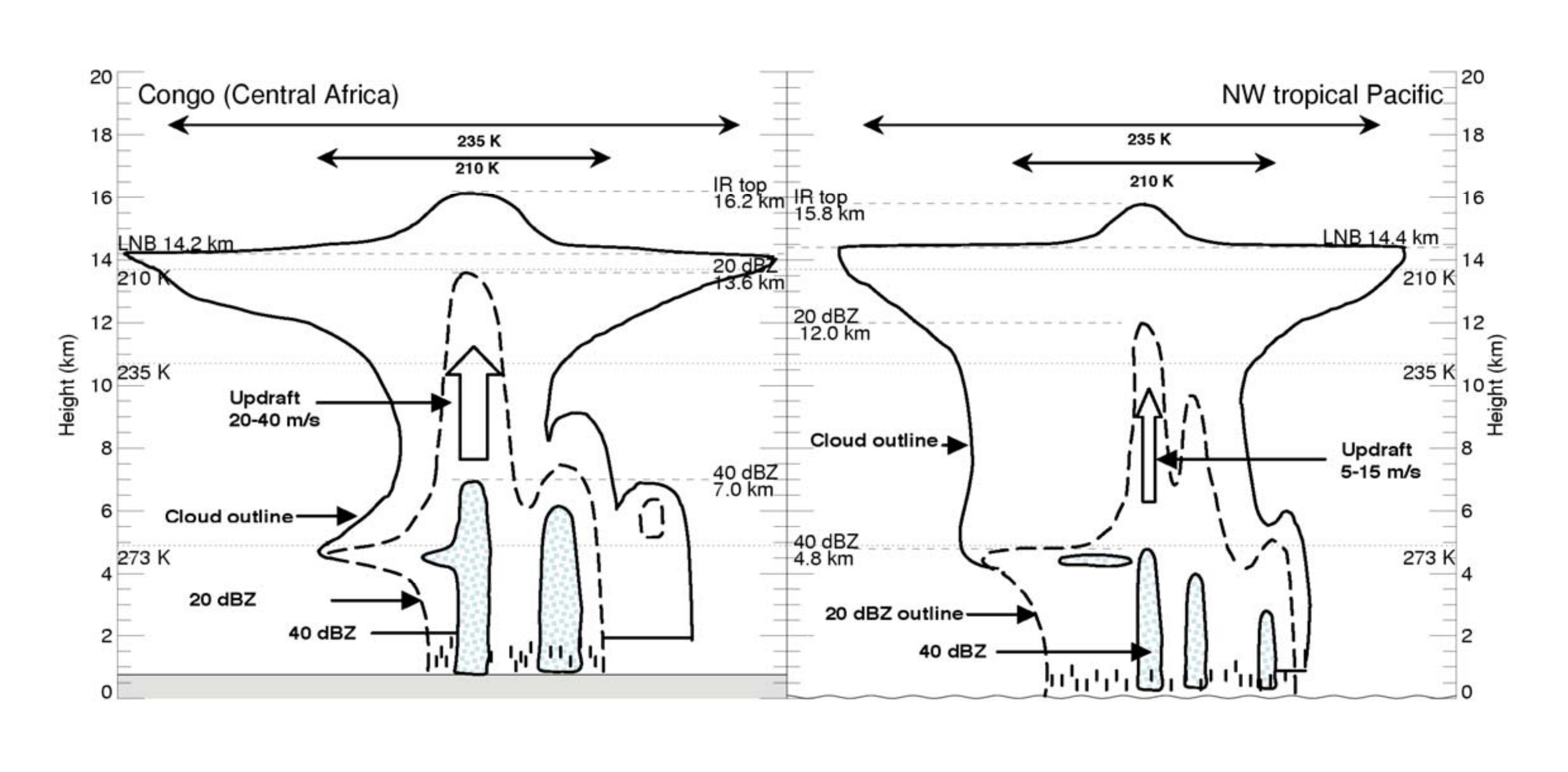
Apparent source of heat Q1
= Convective transport + latent heating



Apparent source of moisture Q2
= -convective transport-latent heating
drying: Q2 > 0, moistening: Q2 < 0

Mature stage (zone B2)
17h - 2h





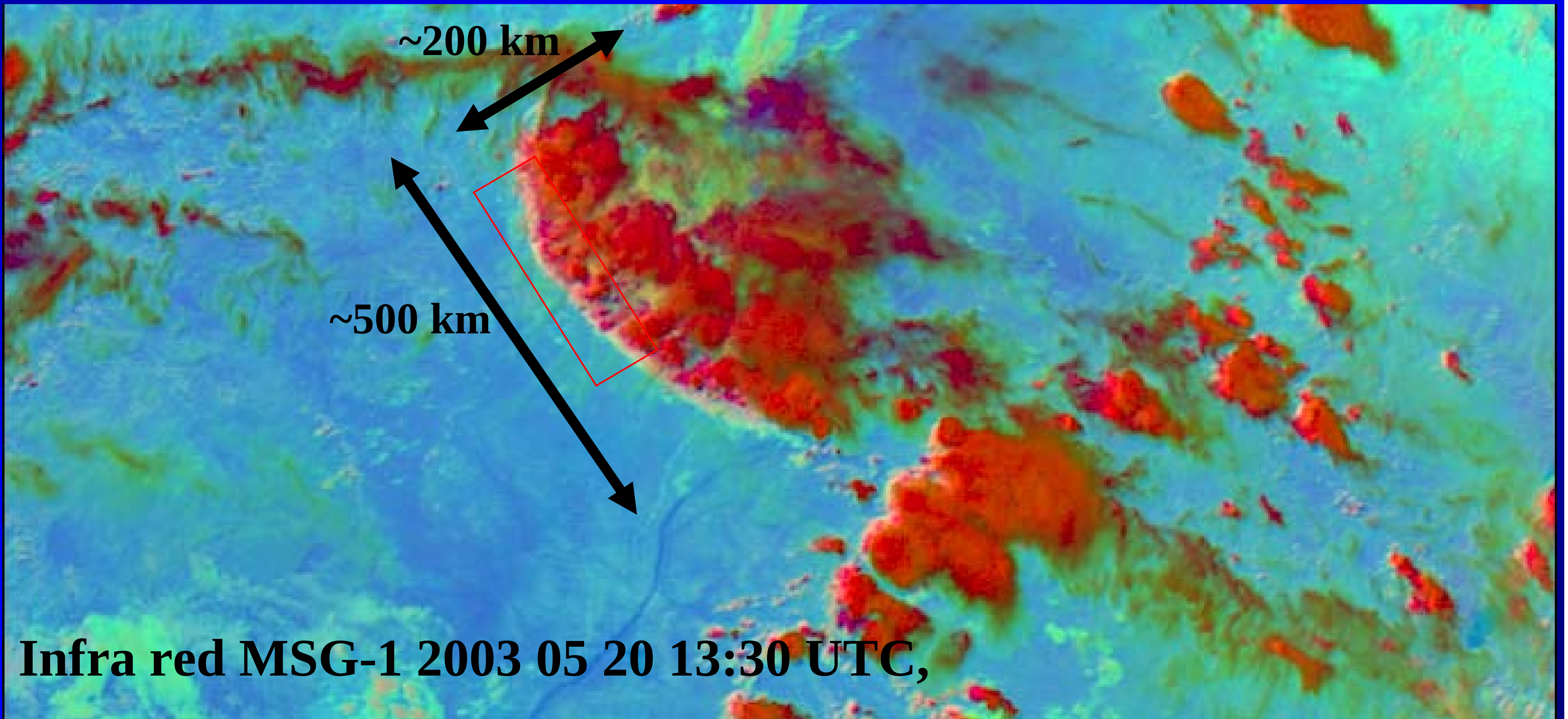
Convection over tropical continents

- Updrafts 20-40 m/s
- Radar echoes much higher
- Anvils thinner but large optical depth
- Larger fraction of convective rain; smaller stratiform area

Convection over tropical oceans

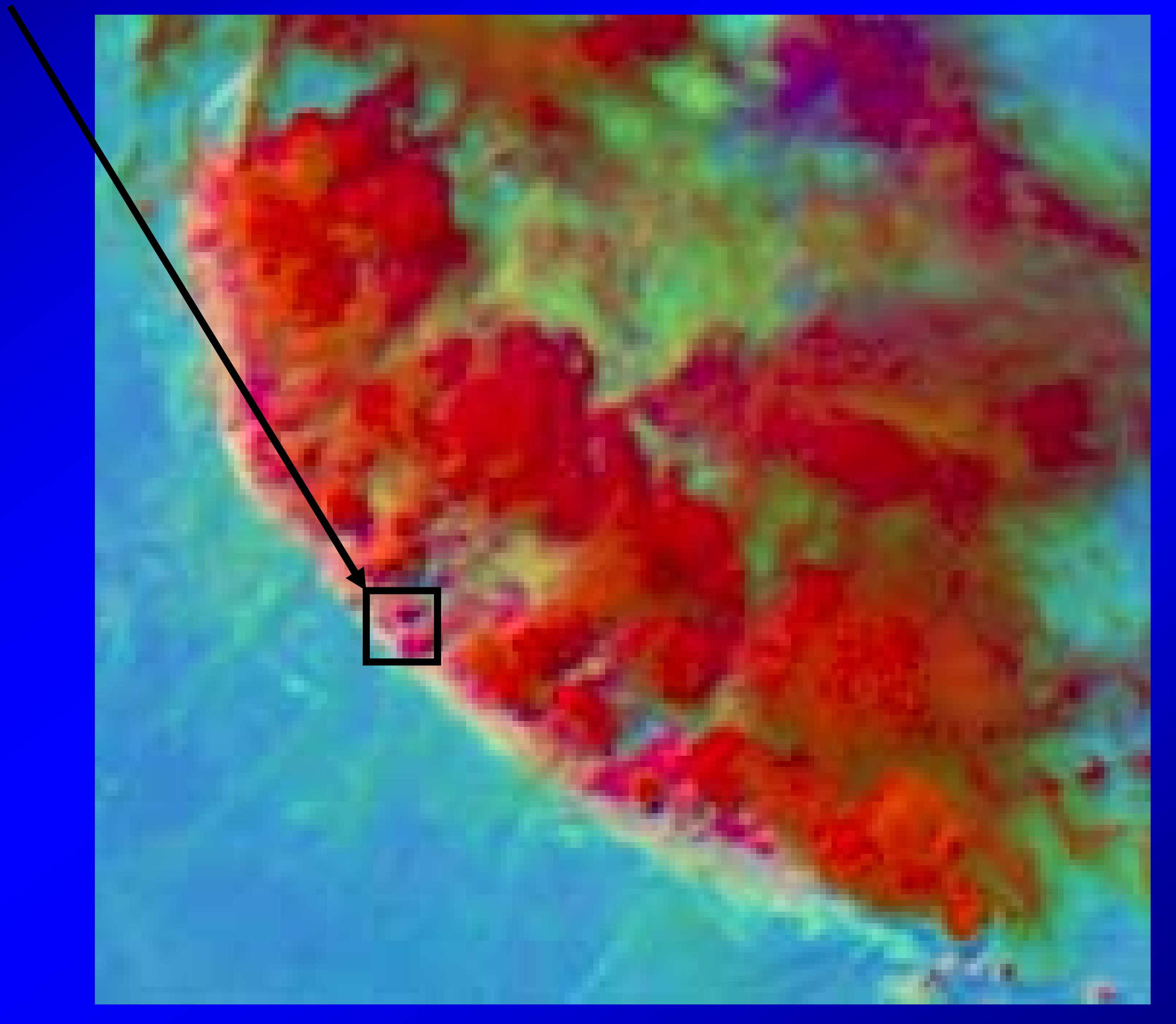
- Updrafts 5-15 m/s
- Radar echoes limited in height
- Anvils thicker with smaller optical depth
- Smaller fraction of convective rain; larger stratiform precip area

Convective cell scale



Convective cell scale

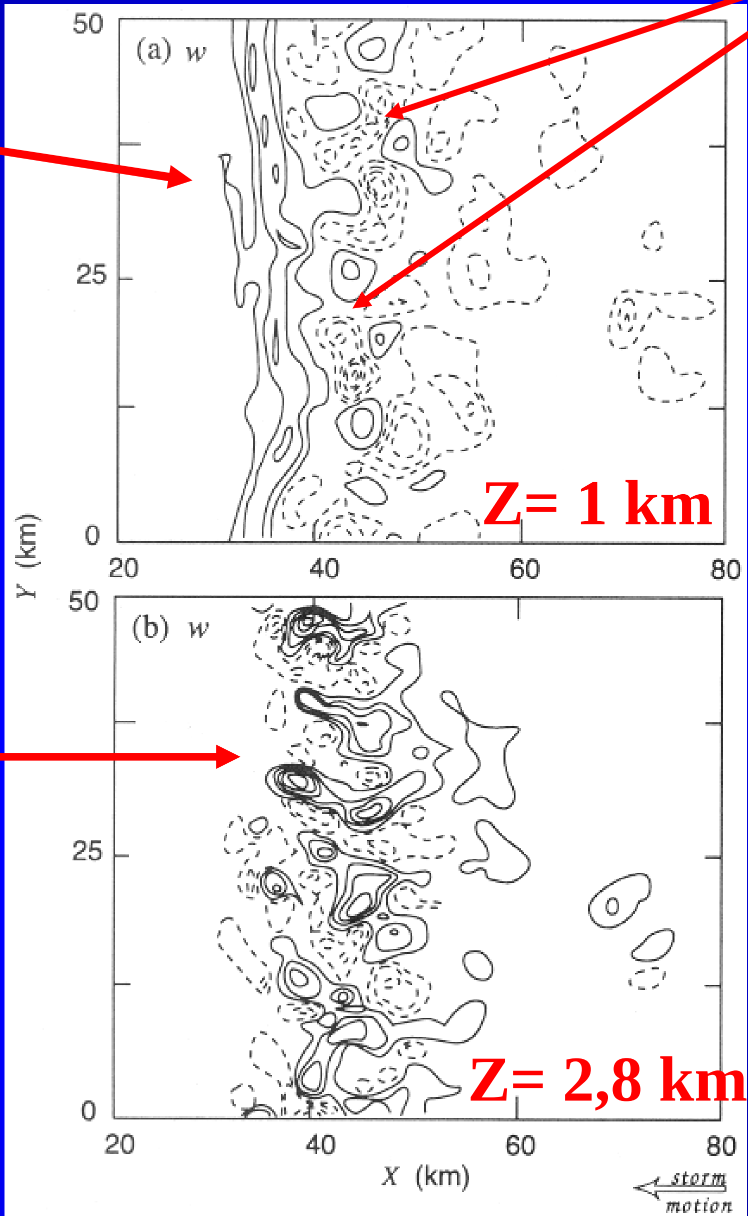
Convective part of MCS = Cells ~5-10km horiz extent



Convective cell scale

3D convective structure (simulation)

Continous ascent at low levels along the gust front



Convective cell structure above

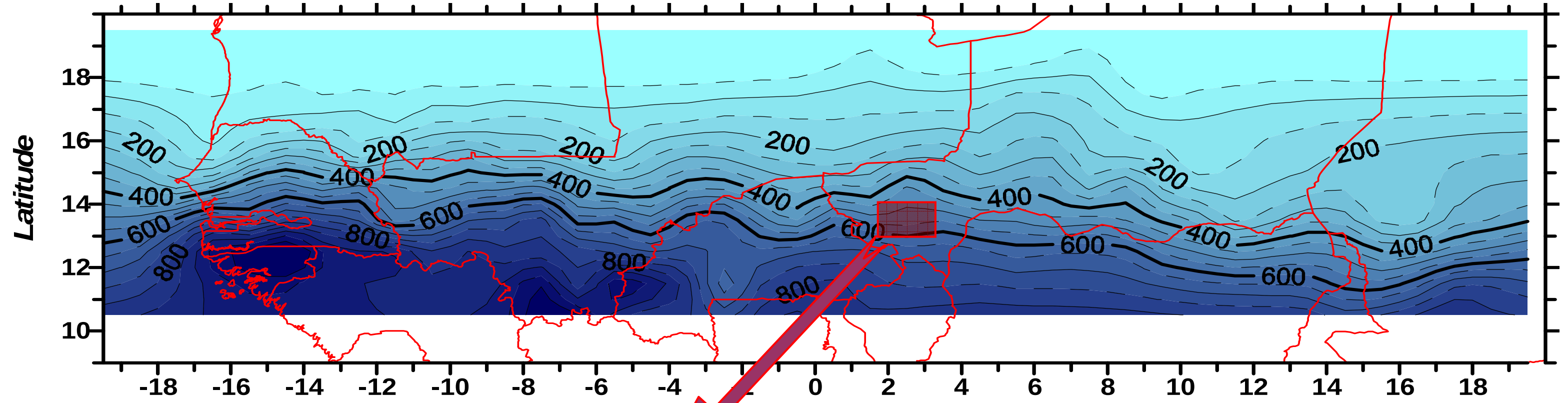
Cell structure of convective downdraft

⇒Significant rain inhomogeneity at this scale (5-10km)

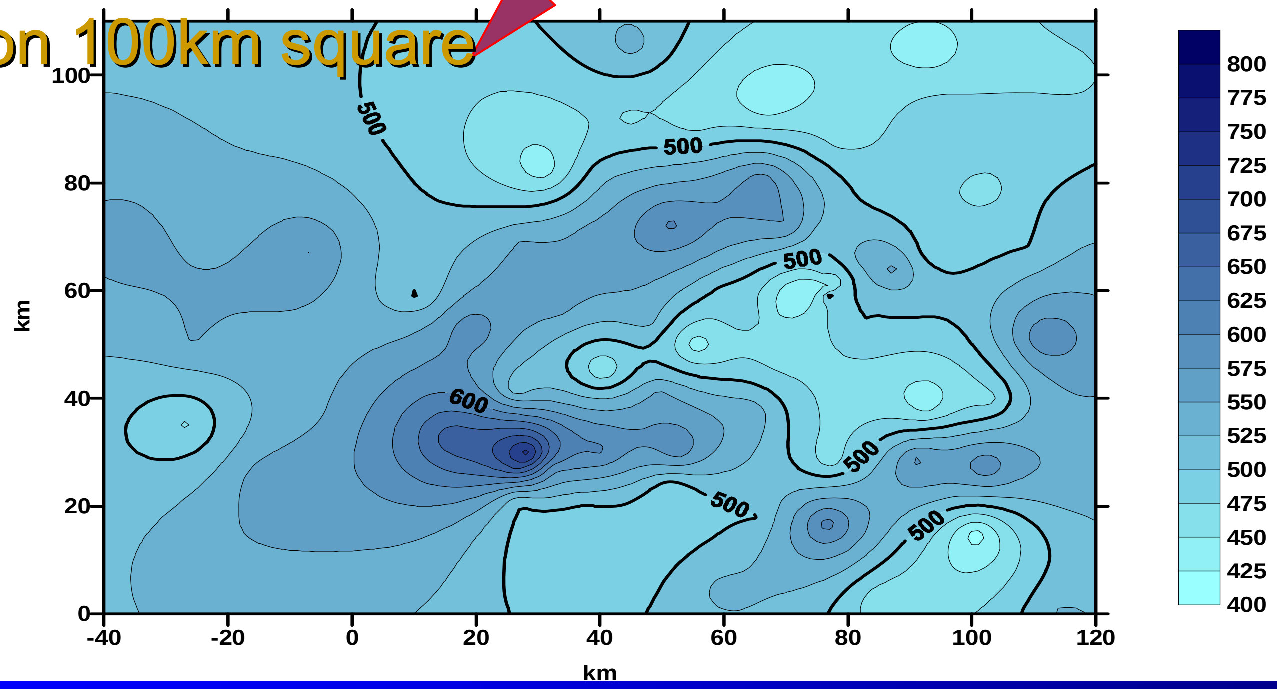
Propagation direction

Spatial variability of observed annual precipitation

Sahel region

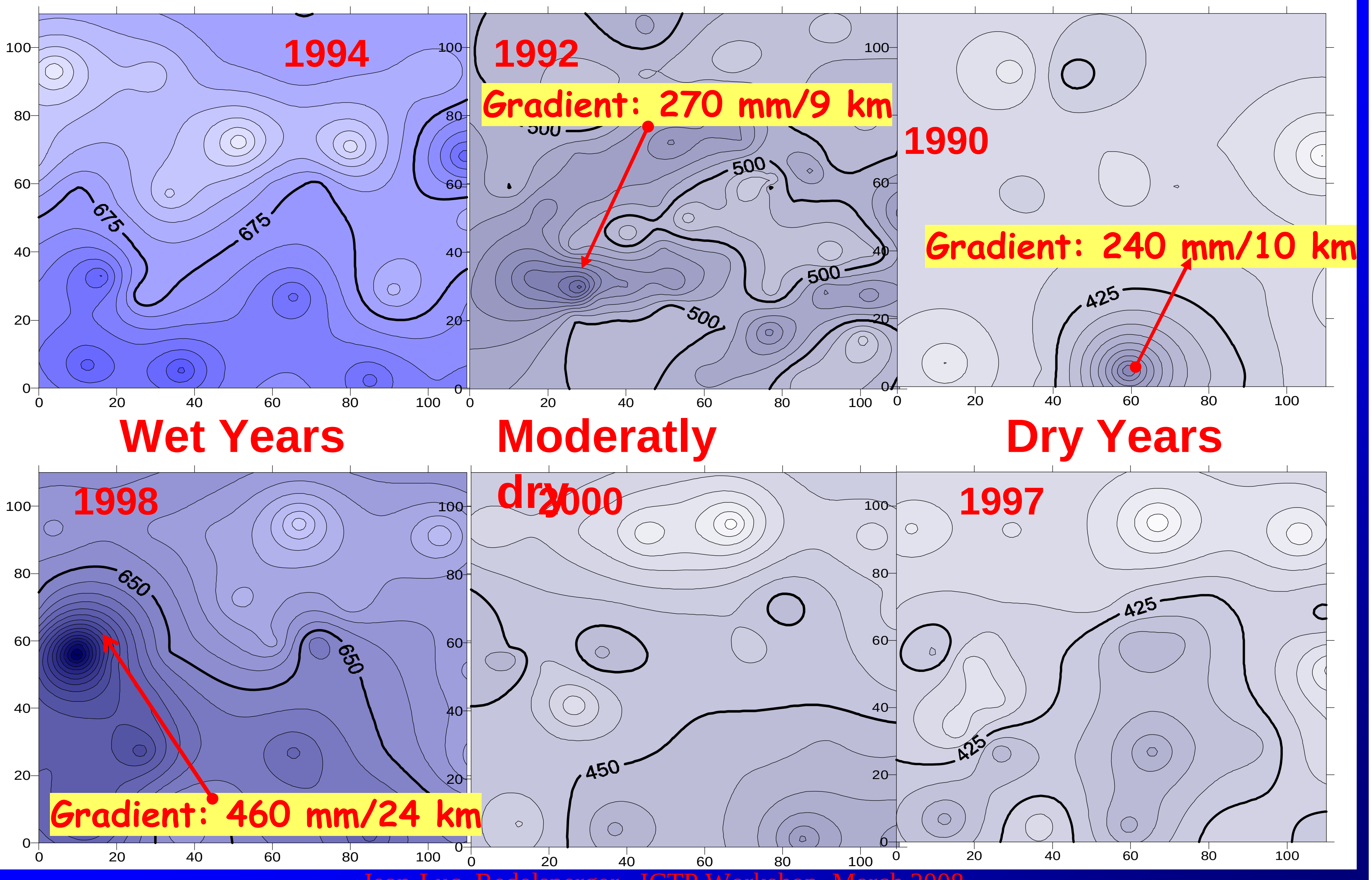


Zoom on 100km square

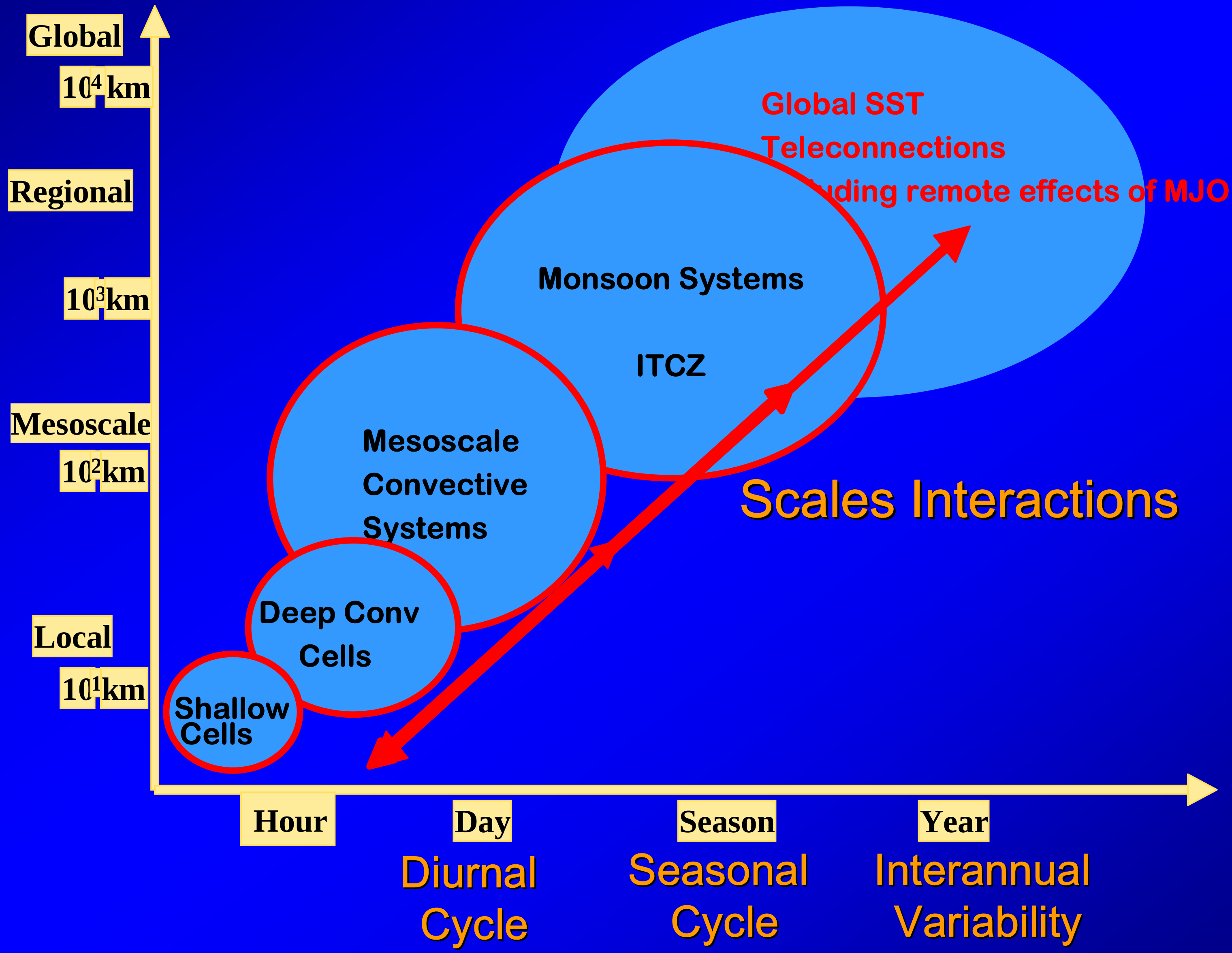


Spatial variability of observed annual precipitation

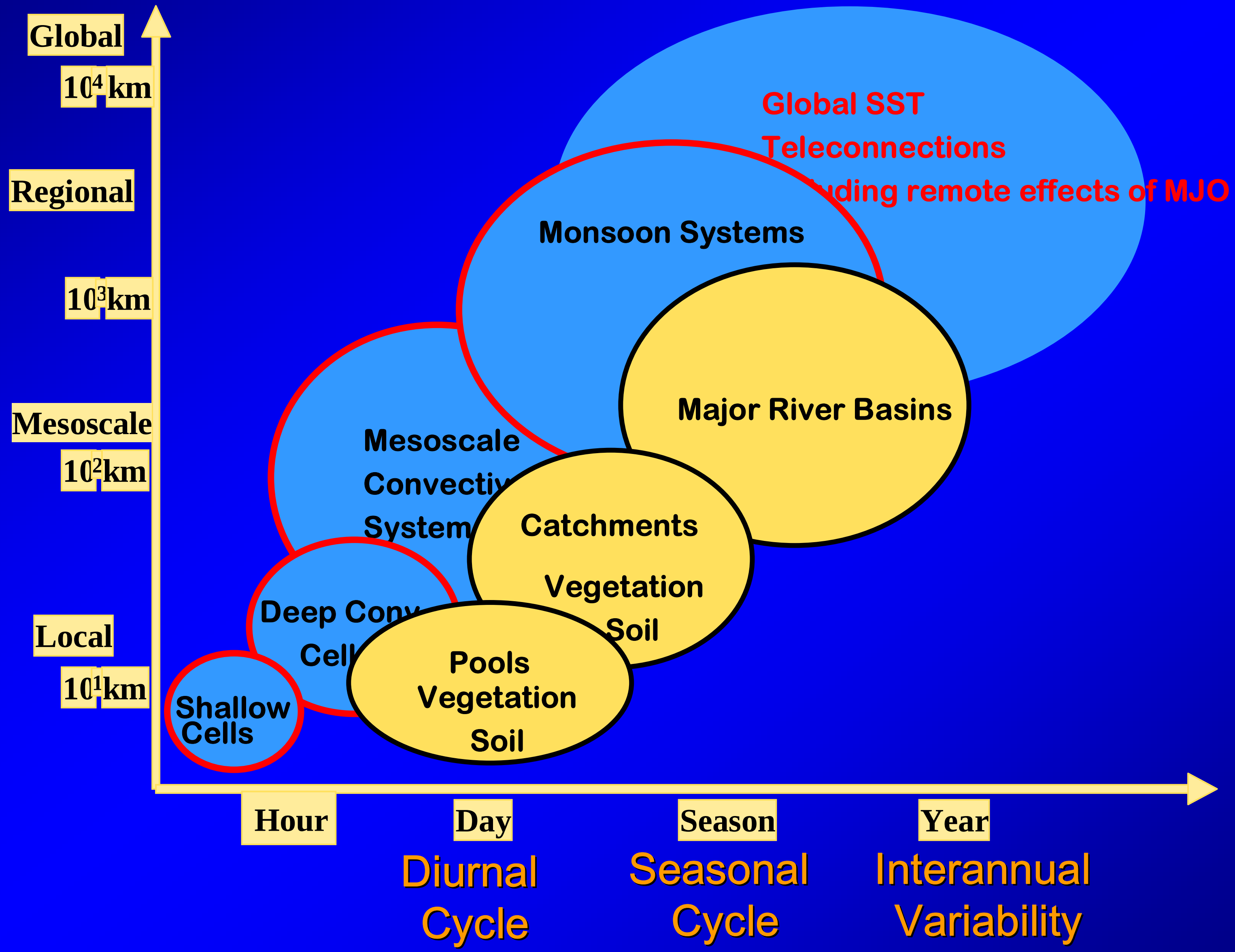
Scales similar to rainy convective downdrafts
⇒ Result from feedbacks between convection-surface processes ?



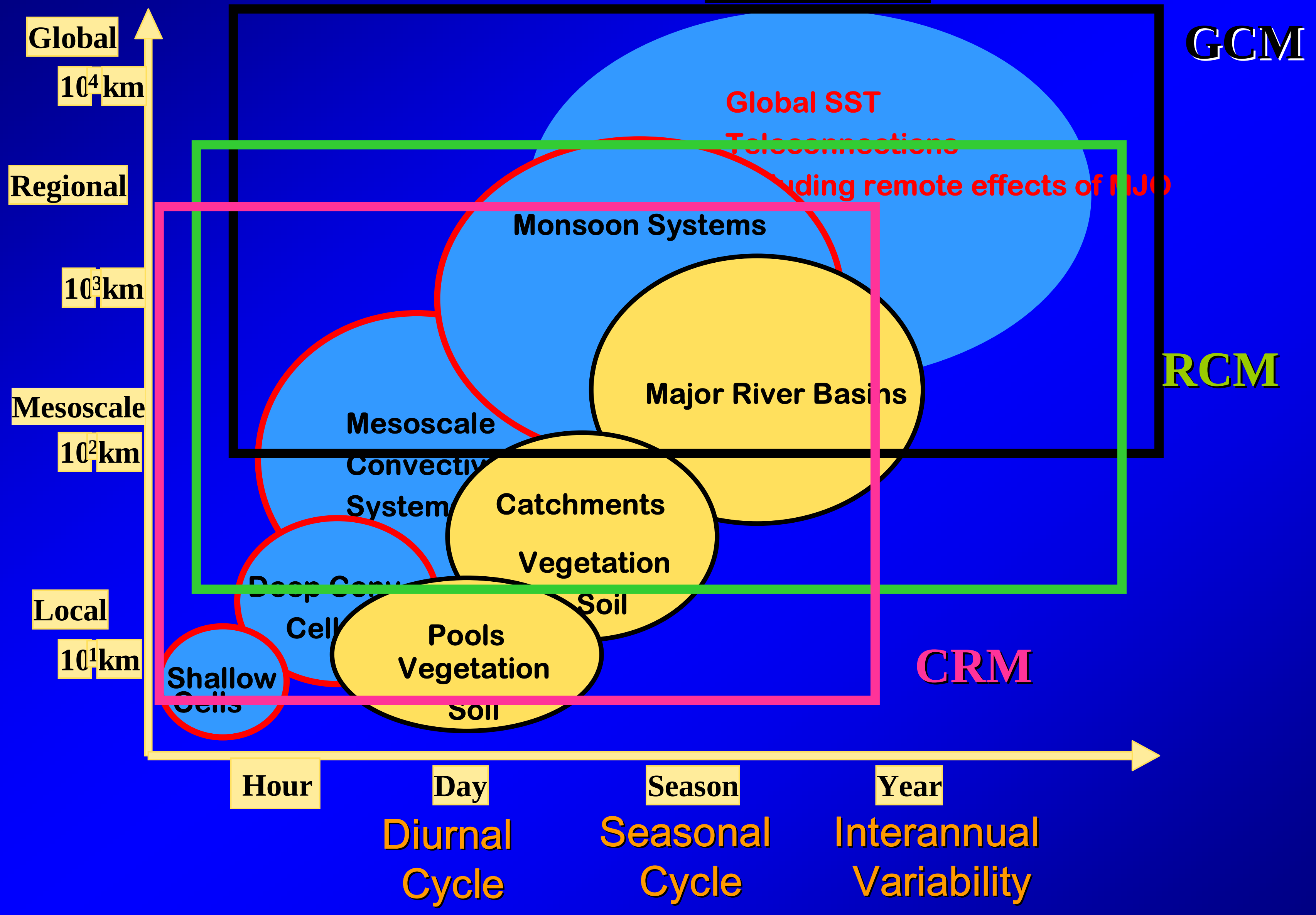
Convection and Scale interactions (or a Summary)



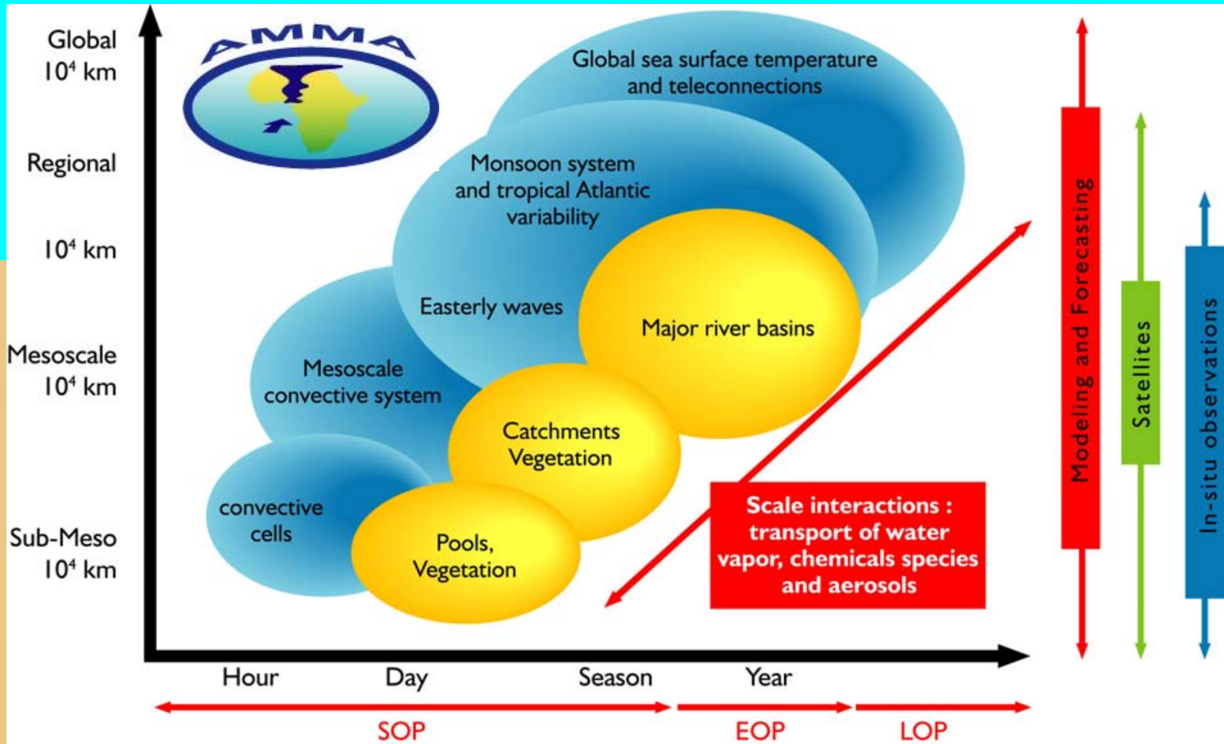
Convection: Scale interactions and Surface



Convection, Scale interactions, Surface & Models



Jean-Luc Redelsperger, ICTP Workshop March 2008



More details in Redelsperger et al, BAMS 2006