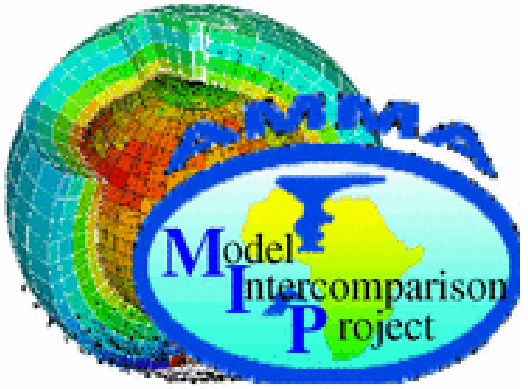
Evaluation of climate models over West-Africa : AMMA-MIP

Françoise Guichard

CNRM-GAME, CNRS & Météo-France, Toulouse

for the AMMA-MIP *coare team :*
F. Hourdin, F. Favot, I. Musat, *P. Ruti* & myself

main page http://amma-mip.lmd.jussieu.fr/



note: I am on strike as a researcher from CNRS but here because I had told Samuel that I would be there some time ago

MIP: model intercomparison project

African Monsoon Multidisciplinary Analyses

Analyses Multidisciplinaires de la Mousson Africaine

Afrikanischer Monsun: Multidisziplinäre Analysen

Analisis Multidiciplinar de los Monzones Africanos

international program with European, African & individual countries components

multi-(time & space) **scales** & multi-disciplinary approach *(Redelsperger et al. BAMS 2006)*

atmospheric *&* ***surface*** *processes,* ***hydrology***, ***vegetation***, ***aerosols***, *chemistry...*

long observation period (LOP), extended (EOP) 2005-2007 & special (SOPs) 2006

reinforcement of the existing sounding network, surface stations (flux, GPS...)

SOP: aircrafts, enhanced frequency of soundings, radars, AMF, lidars, balloons...

e.g. Parker et al. (2008), Lebel et al. (2009)

few routine observations and field campaigns over West Africa

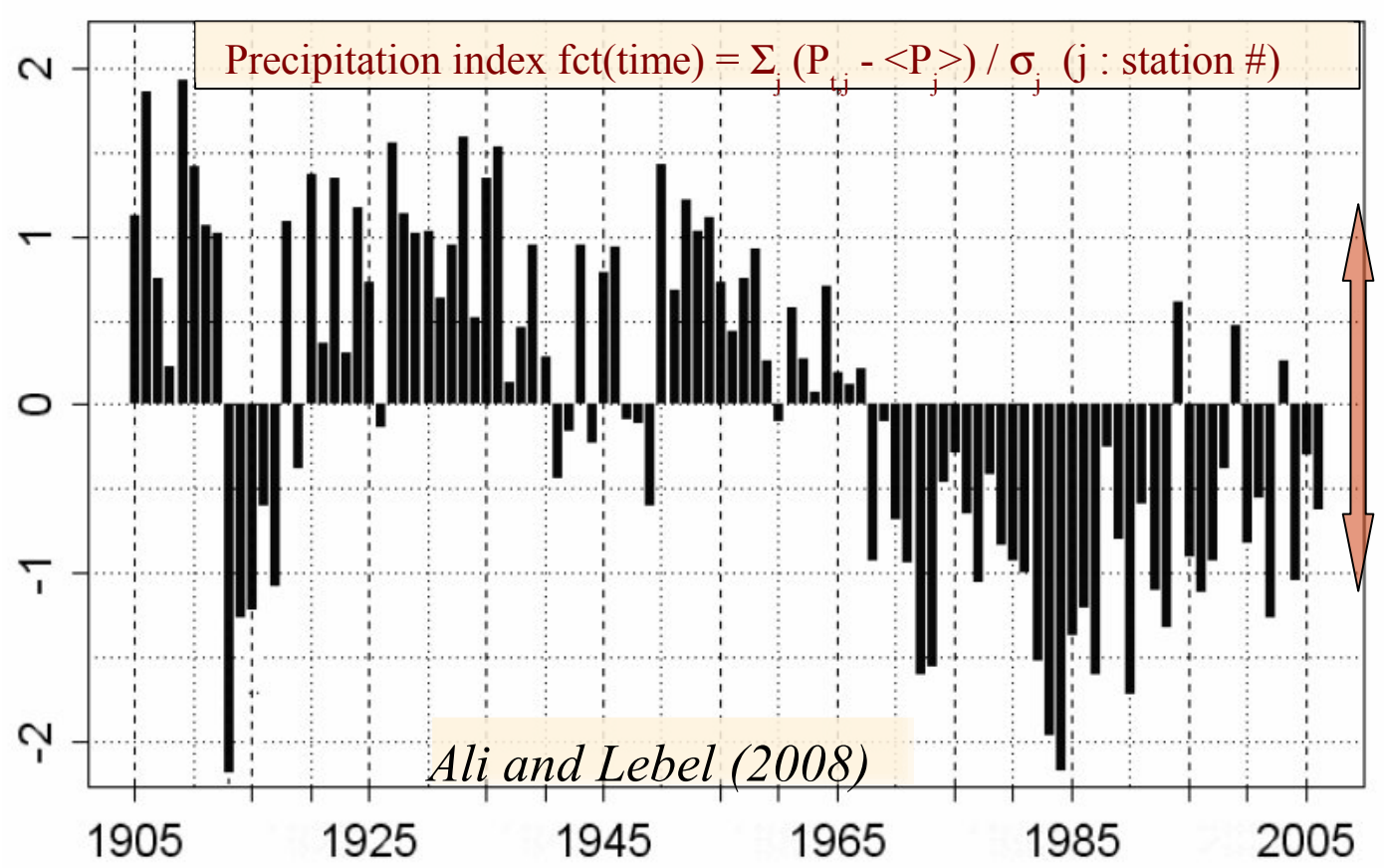
GATE 1974, COPT 1981, HAPEX-Sahel (1992), JET 2000 , all limited in time & space

a widening of the research community involved (obs & model)

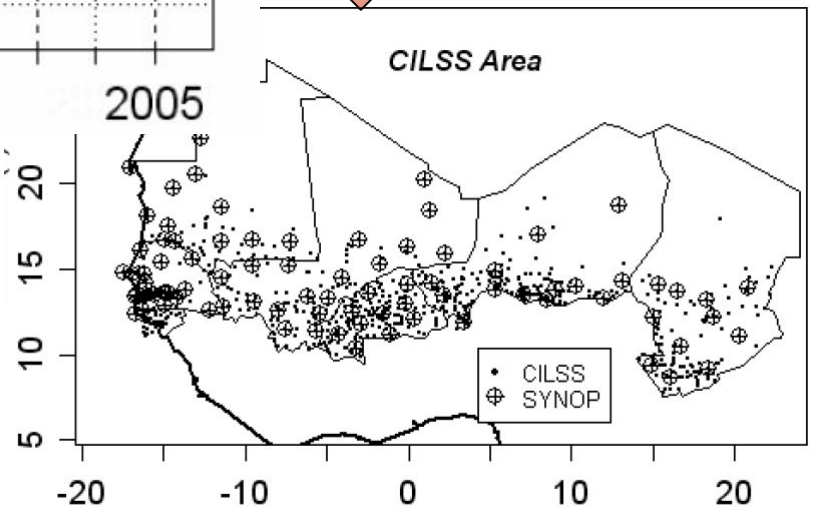
several AMMA special issues (J. Hydrology 2009, QJRMS 2009, JGR, Wea. For., Clim. Dyn,...)

Rainfall variability at different scales : a major motivation of AMMA

« most dramatic example of multidecadal variability » (Hulmes 2001)



20-30 % decrease



causes not yet fully understood / explained

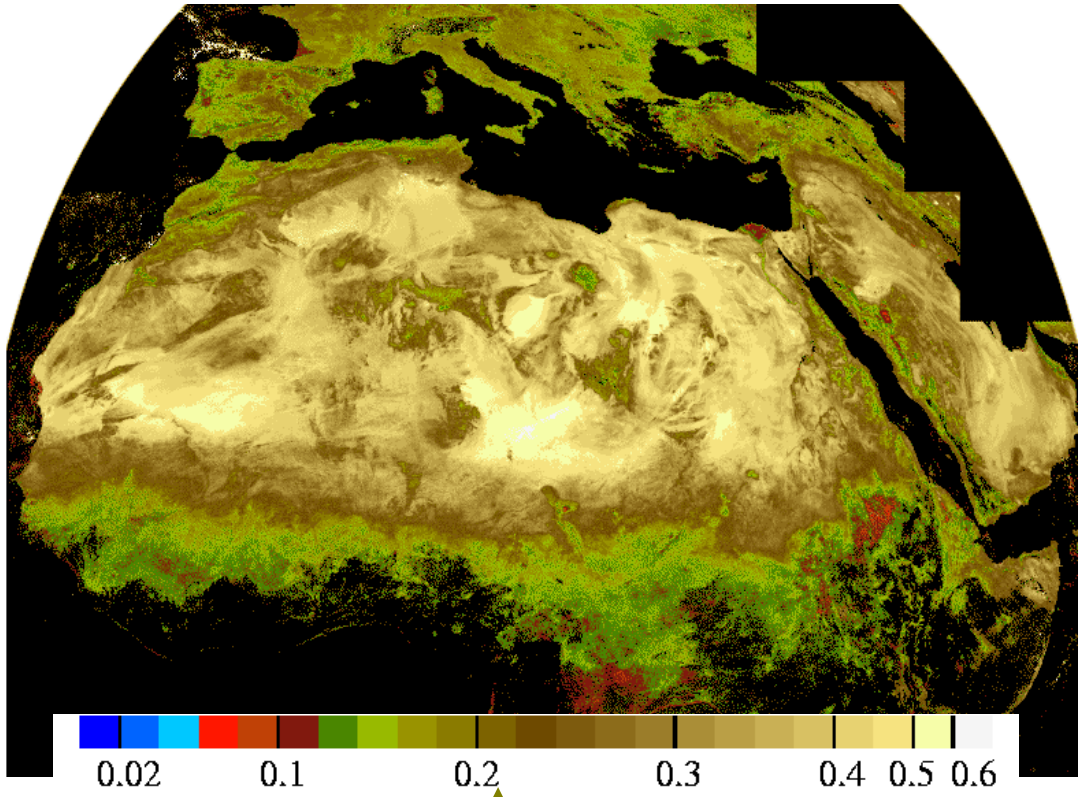
land changes versus ocean influences

climatic projections diverge *(Cook & Vizi 2006)*

context: rainfall critical , Sahel *means* shore (a few degrees of latitude)

Specific features at large scale

albedo June 1996 EUMETSAT/JRC



at the surface

vegetation, albedo, rainfall...

in the atmosphere

e.g. the African easterly jet (AEJ)

present the Summer

well defined strong meridional gradients

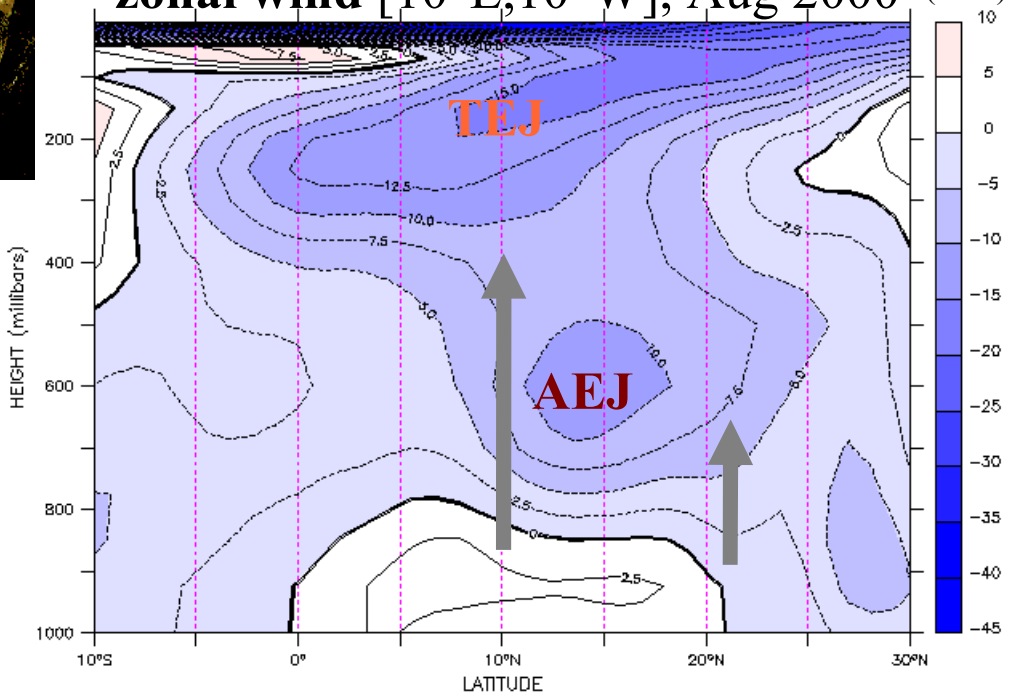
seasonal cycle , jumps

interannual variability

- *inspired several studies based on a 2D modelling approach*
  - Zheng & Eltahir (1998)
  - Peyrille et al. (2007)

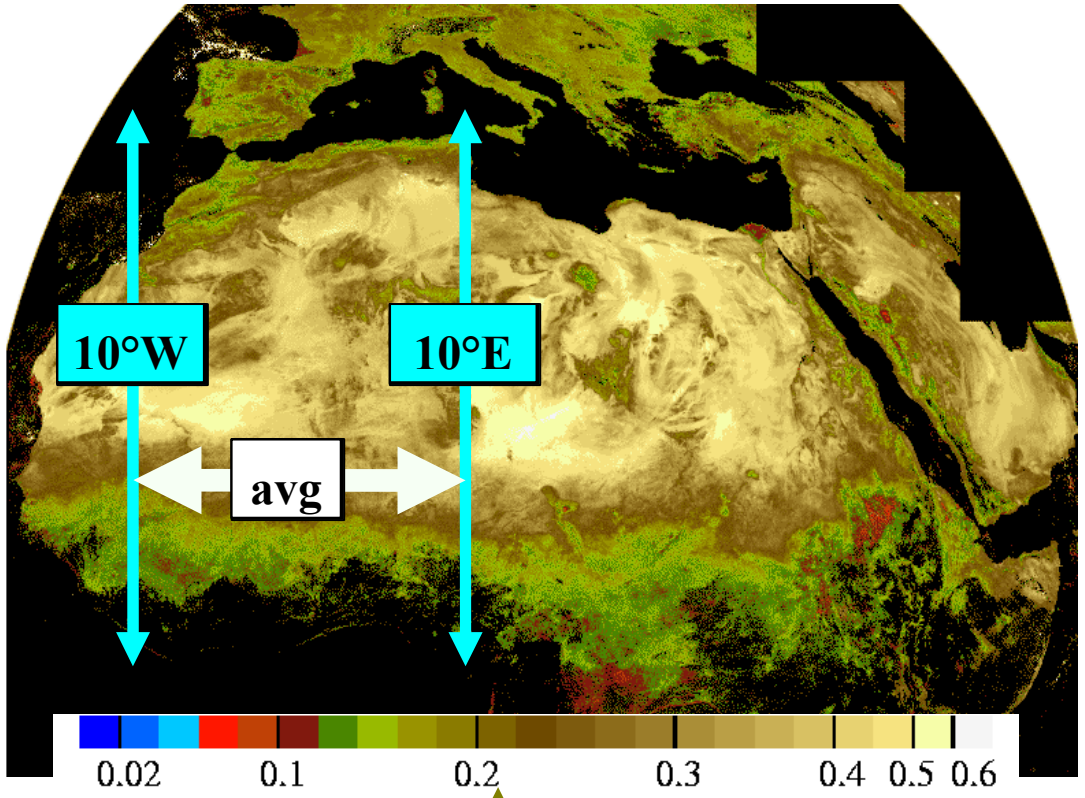
ERA40

zonal wind [10°E,10°W], Aug 2000 (m.s^{-1})



Specific features at large scale

albedo June 1996 EUMETSAT/JRC



at the surface

vegetation, albedo, rainfall...

in the atmosphere

e.g. the African easterly jet (AEJ)

present the Summer

well defined strong meridional gradients

seasonal cycle , jumps

interannual variability

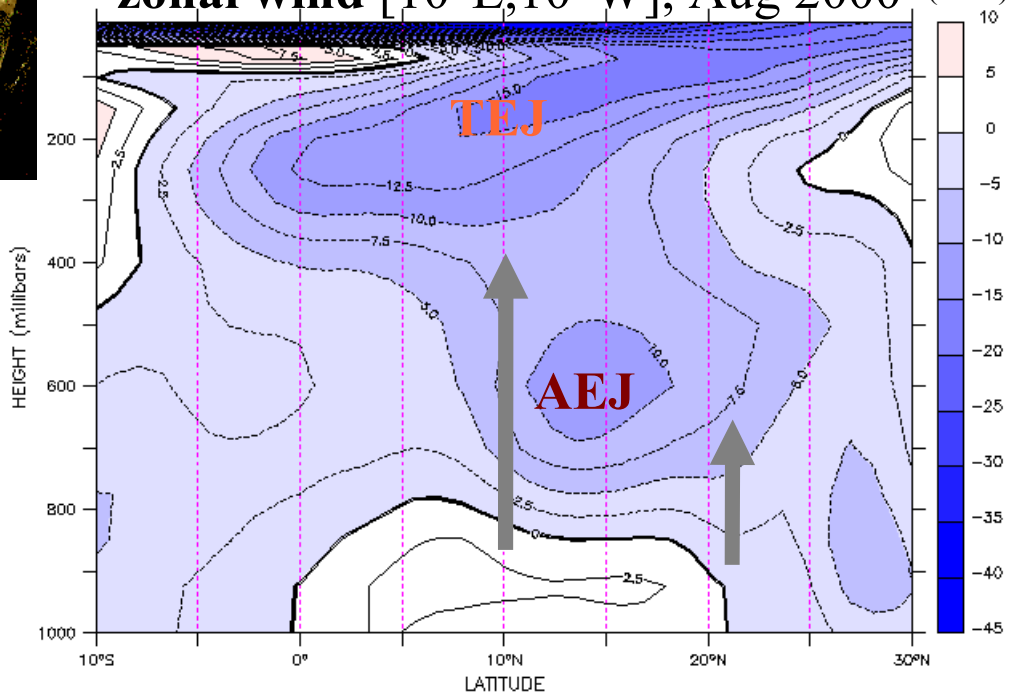
- *inspired several studies based on a 2D modelling approach*
  - Zheng & Eltahir (1998)
  - Peyrille et al. (2007)

- ***motivated AMMA-CROSS***
  - **Hourdin et al. (2008)**

~ EUROCS , GEWEX GCSS PCI

ERA40

zonal wind [10°E,10°W], Aug 2000 (m.s^{-1})



moist convection over West Africa

- very deep convection, intense lightning, transport of dusts/aerosols
- importance of MCSs: explain ~70-80% of the precipitation *(Mathon et al. 2002)*
  - strong couplings between convection & synoptic African easterly waves
  - coupled to patchiness of rainfall, down to 10 km scale at seasonal timescales *(Taylor & Lebel 1998)*

surface & low atmospheric levels

- thought to be key elements of the West African monsoon

  starting from Charney (1975), Gong & Eltahir (1996)
  - ≠ space and time scales (paleo to diurnal, meso scales)
  - ≠ mechanisms of surface-atmosphere interactions
- mechanisms not well known/quantified , not all known

strong diurnal cycles *of physical processes and dynamics (e.g. Parker et al. 2005)*

in brief & partial, about **AMMA, processes and models**

- monsoon system , strong couplings among dynamic & physical processes
- a variety of surface, boundary layer and convective regimes *in space and time*
- processes over *lands* : tropical (Soudanian), semi-arid (Sahel) to desertic (Sahara)

- emergence of new ideas/questions

  African easterly waves, their nature, initiation

  significance of processes at mesoscale: which ones? where? when? for what?

- need to assess more precisely the performances & limitations of models

  interannual, seasonal, intraseasonal, diurnal cycles and water cycle

- need to analyse the large amount of data collected

  guidance, discriminate between mechanisms that are actually operating versus others

modelling at large scale

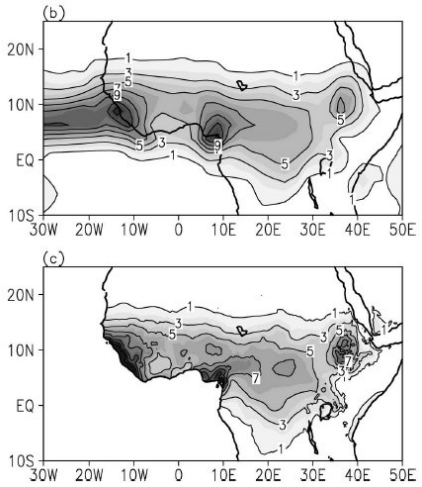
ocean coupled IPCC runs

Cook and Vizi (2006)

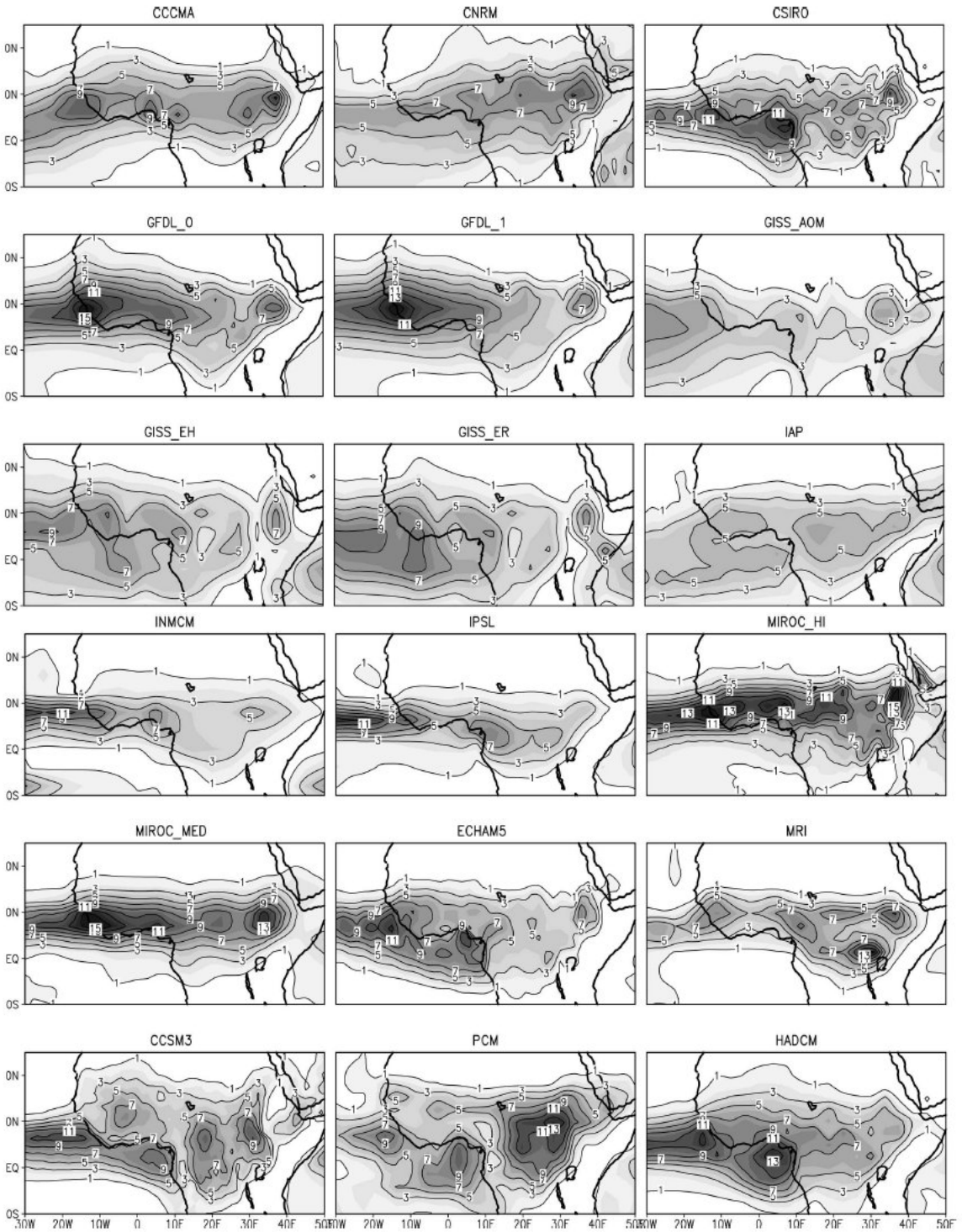
a critical location for models which perform much better elsewhere

JJAS 1979-2005 (CMAP)

JJAS 1961-1990 (CRU)



JJAS 1949-2000

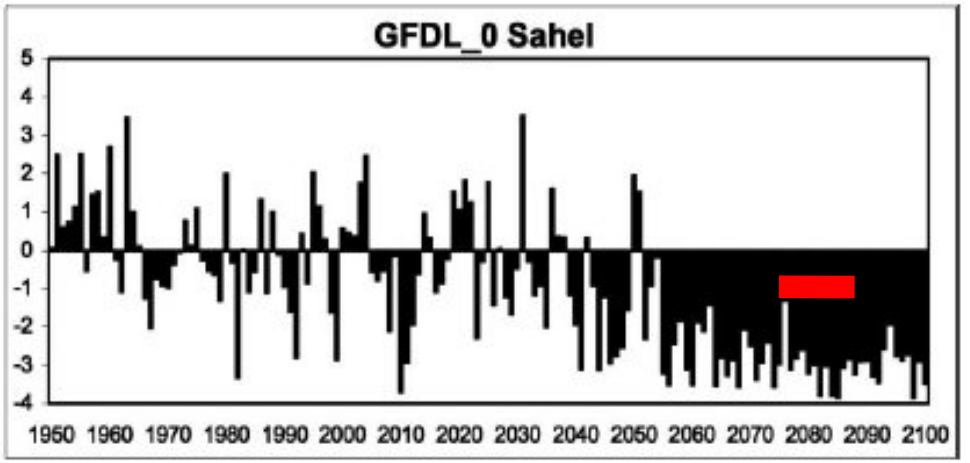


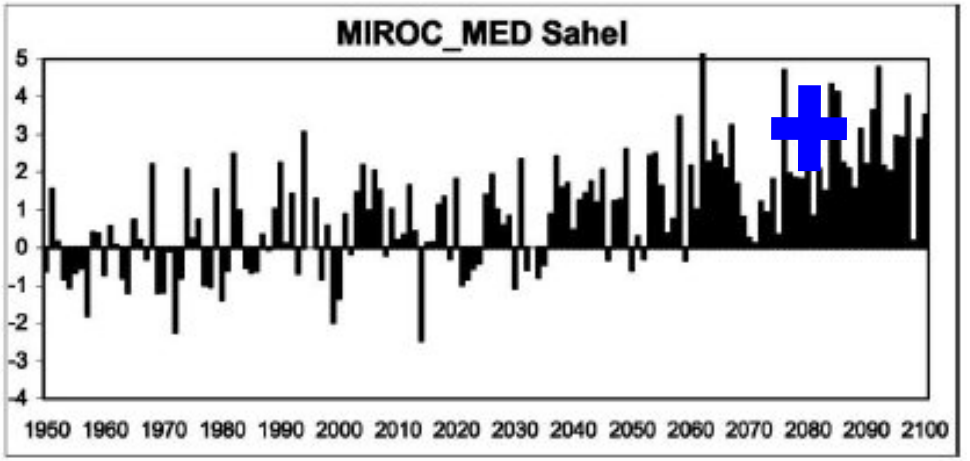
Cook and Vizi (2006)

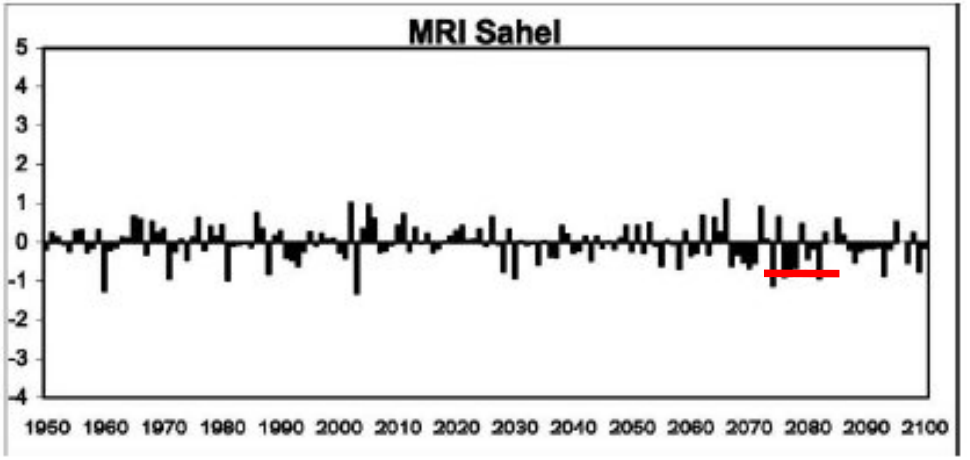
projections for XXI century

with the 3 “more satisfying” GCMs

(i.e. able to reproduce some specific features of the West African monsoon system)







AMMA-MIP

"A cross-section analysis provides light but relevant framework to assess the model skill in terms of seasonal and intra-seasonal variations of West African monsoon" *(Hourdin et al. BAMS 2009)*

AMMA-MIP = AMMA-CROSS + AMMA-MAPS

prescribed SST

1st step

simulations of two contrasted years : 2000 (dry) and 2003 (wet)

preparation of model and observational products outputs *(small netcdf files)*

observational products : satellite prods & (re-) analyses for model evaluation

2nd step

simulations of 2005 and **2006** (SOP AMMA)

more advanced evaluation with AMMA data

diurnal cycle issues , surface-atmosphere feedbacks, ...

GCMs , RCMs and their simulations for AMMA-MIP

Simulation	Model	Horizontal res (km)	number of layers	details
CNRM	ARPEGE-Climat	300	31	1 member
ENEAL19	ECHAM-4	370	19	1 member
ENEAL42	ECHAM-4	370	42	1 member
UCM1-10	UCLA	220	29	10 members
IPSL1-5	LMDZ4	300	19	5 members
IPSLTI	LMDZ4	300	19	Tiedtke convection scheme instead of Emanuel
IPSLWA	LMDZ4	80	19	zoomed over West Africa
LPAOSF	LMDZ4	150	19	zoomed over West Africa
LGGE	MAR	40	40	Limited area model

TABLE 1. AMMA-MIP model configurations.

AMMA-CROSS
Hourdin *et al.*
BAMS (2009)

GCMs/RCMs with prescribed SST

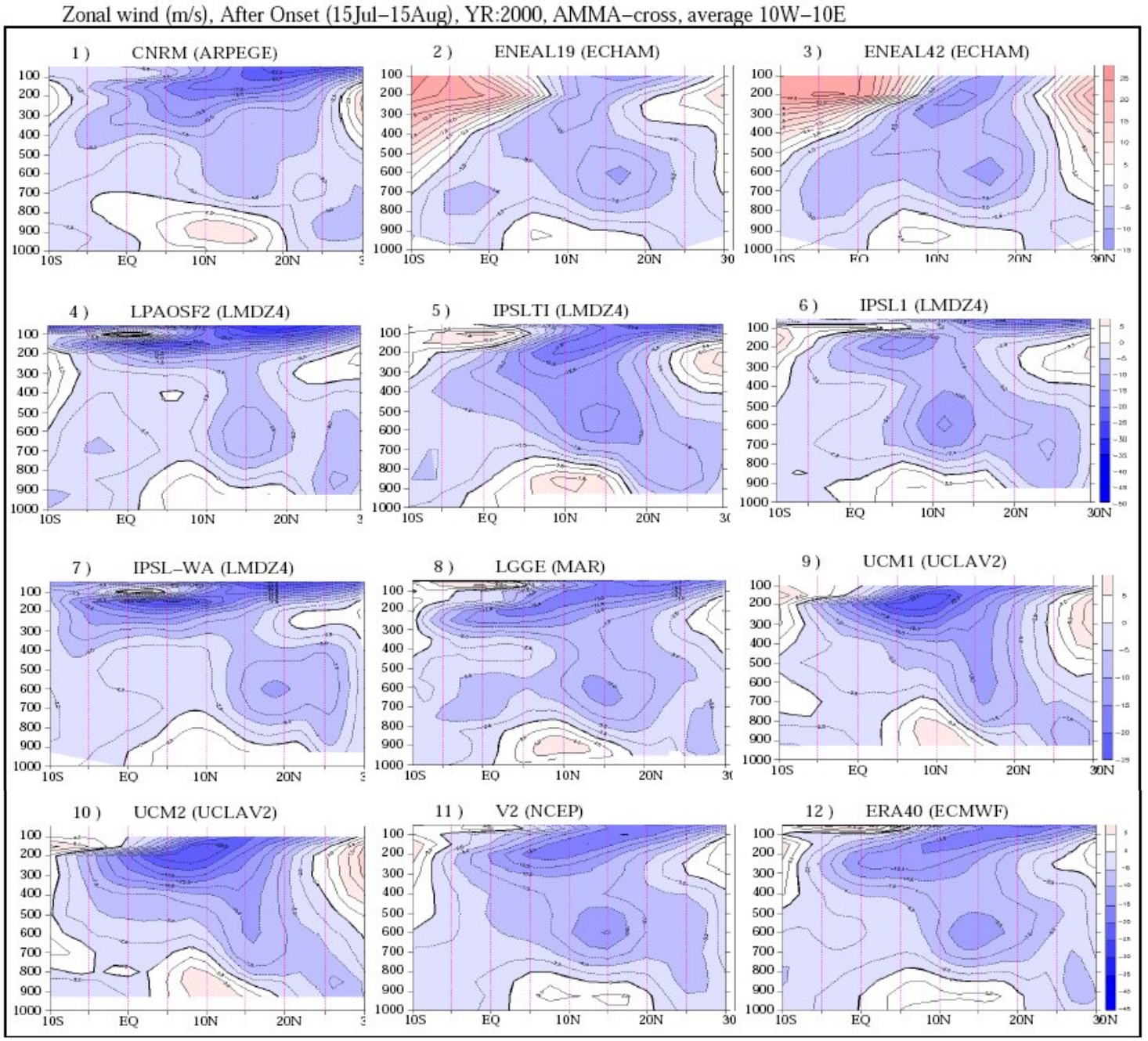
5 models, some with ≠ configs.

monsoon flow & AEJ simulated

but with spread in intensity & position

no generic explanation accounting for differences

zonal wind fct(latitude , height)



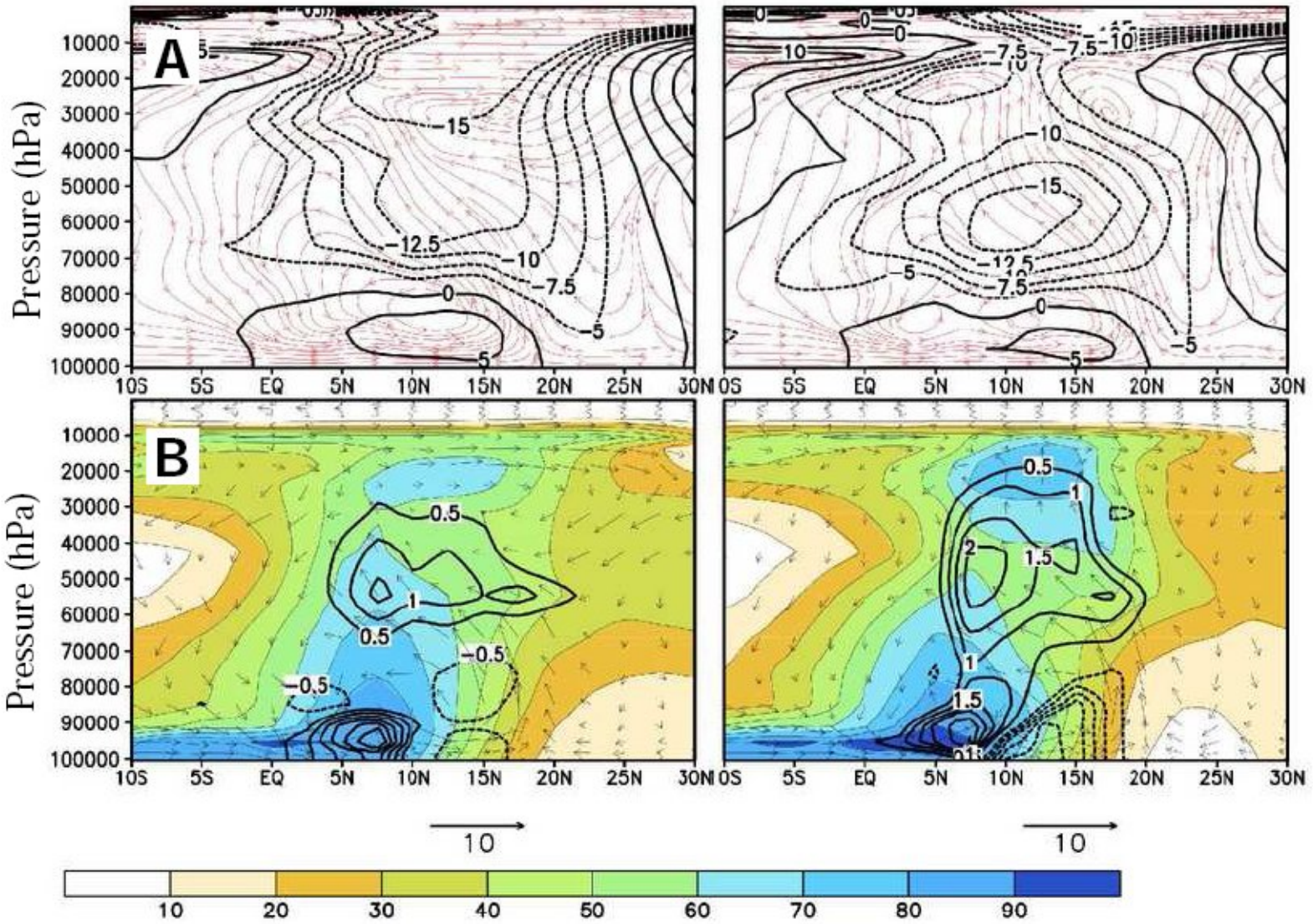
internal variability for 1 GCM << variability among GCMs
<< sensitivity to parametrization/resolution

sensitivity to parametrizations : convection scheme

zonal wind ($m.s^{-1}$)

convective heating rate (isolines, $K.day^{-1}$)

RH (colors)

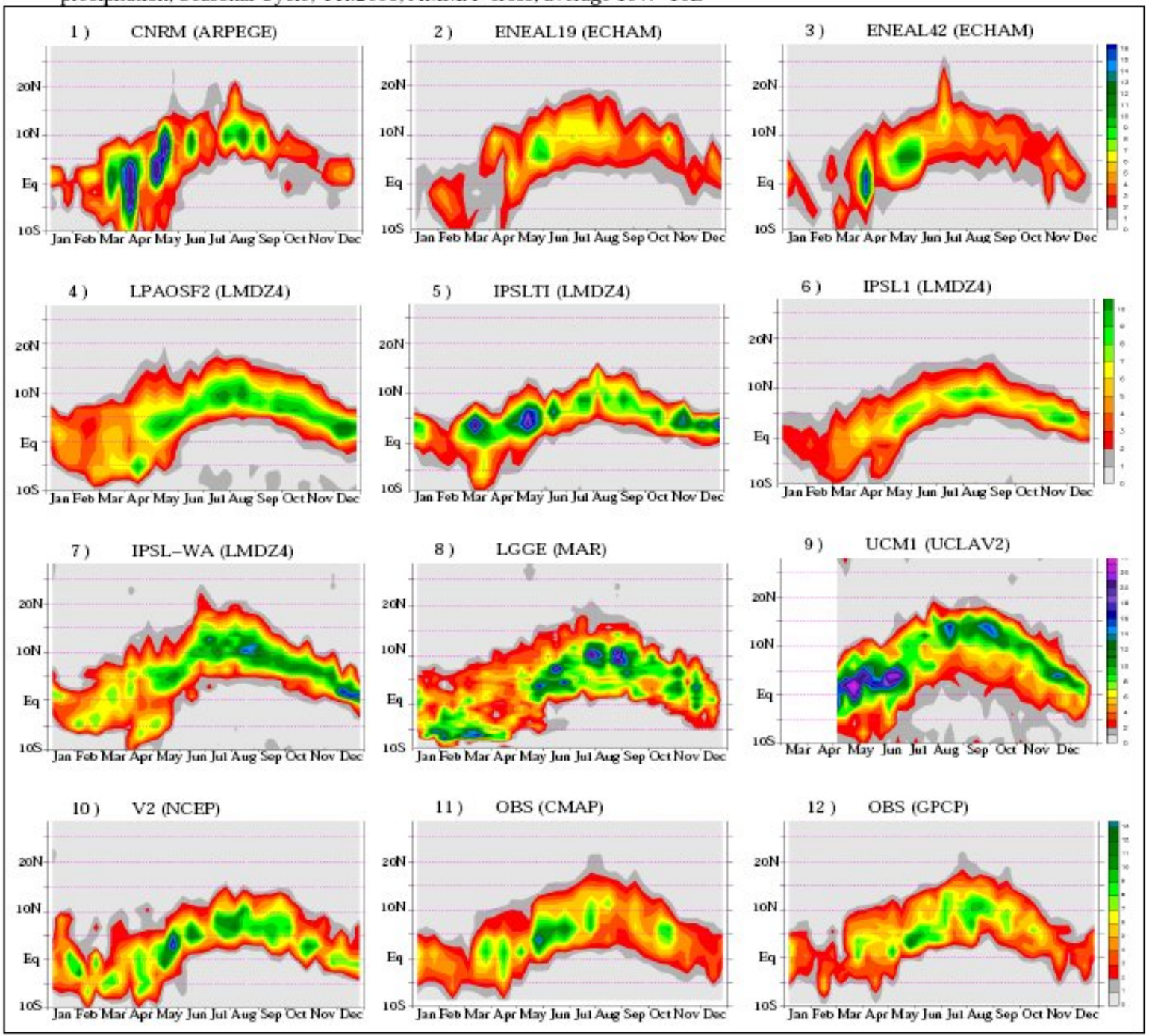


Hourdin et al. (2009)

Precipitation fct(time , latitude)

no simple links
between biases
in AEJ & rainfall

intraseasonal
variability
in GCMs :
why?
good reasons?
to be explored

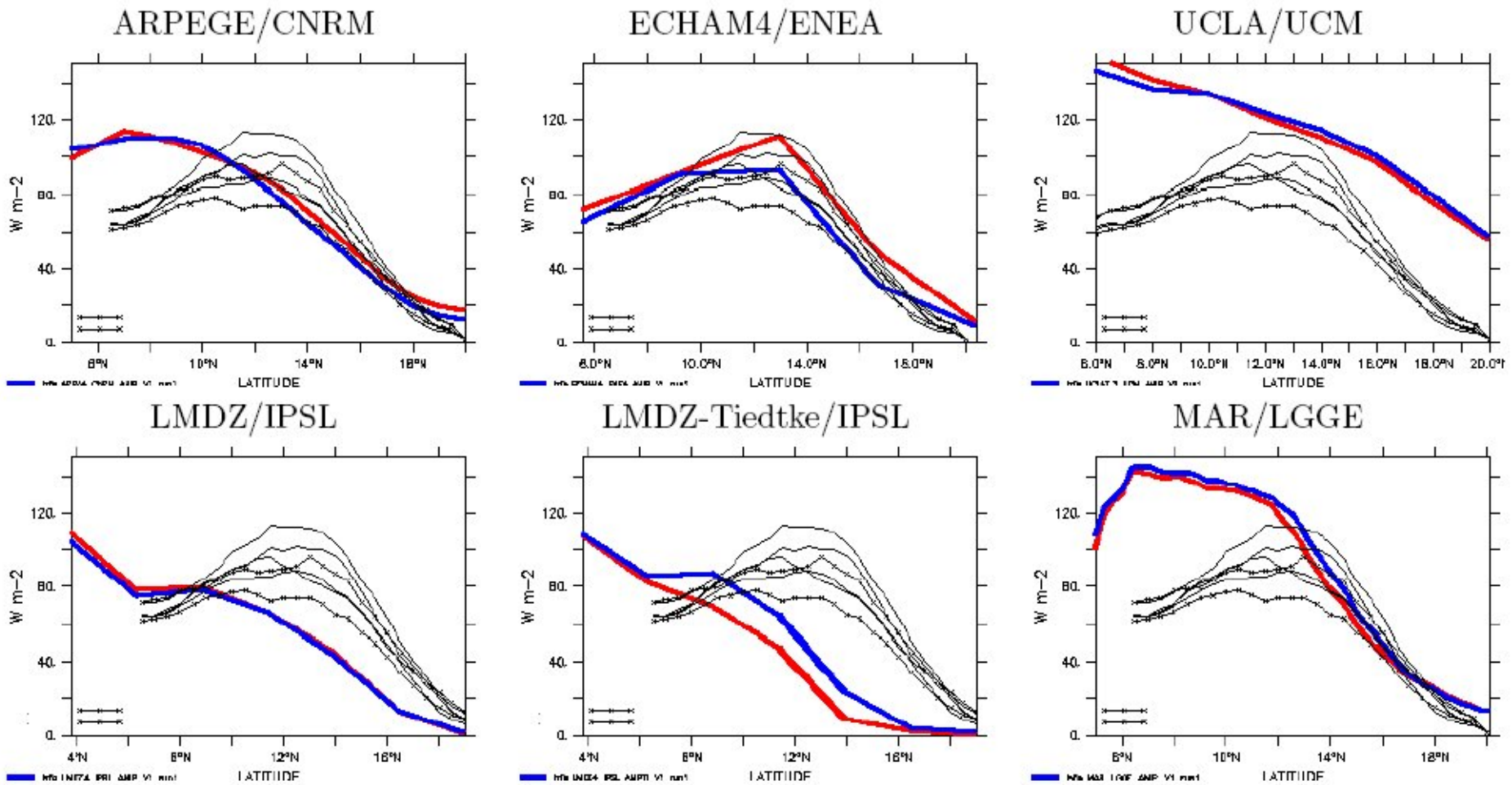


Hourdin et al. (2009)

evapotranspiration :
[10°E,10°W]
during monsoon

GCMs
1 dry & 1 wet year

& **LSMs offline** (ALMIP)
1 line = 1 LSM



all over the place, significant impact of errors in rainfall likely
LSM outputs are valuable

Hourdin et al. (2009)

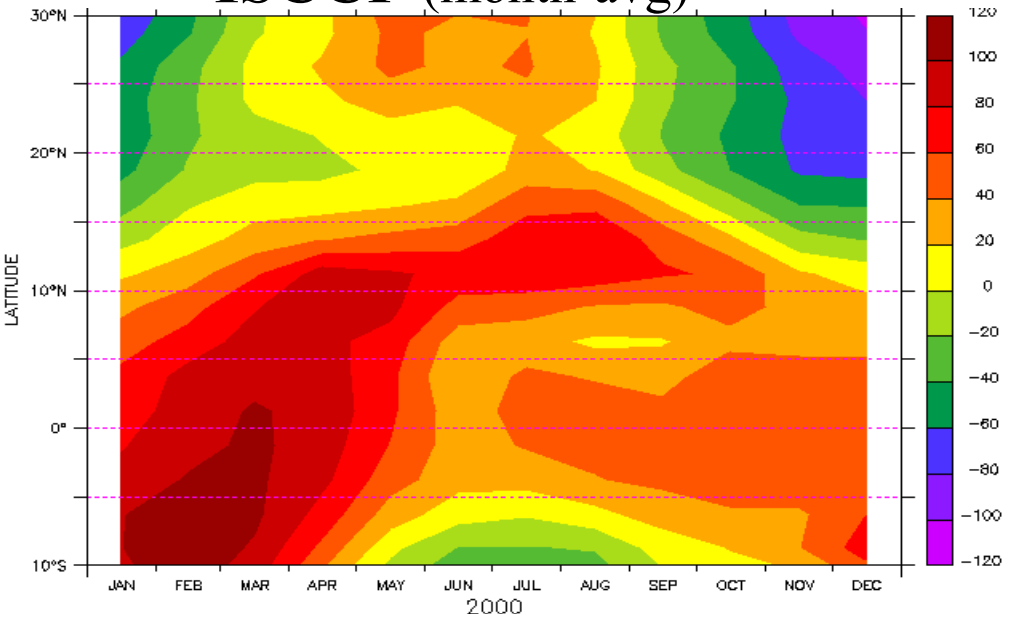
TOA net radiative flux

tongue of max incoming net radiation at TOA located over the Sahel in July-August

involves :

- surface albedo
- LW & SW cloud radiative forcings

ISCCP (month-avg)



TOA net radiative flux

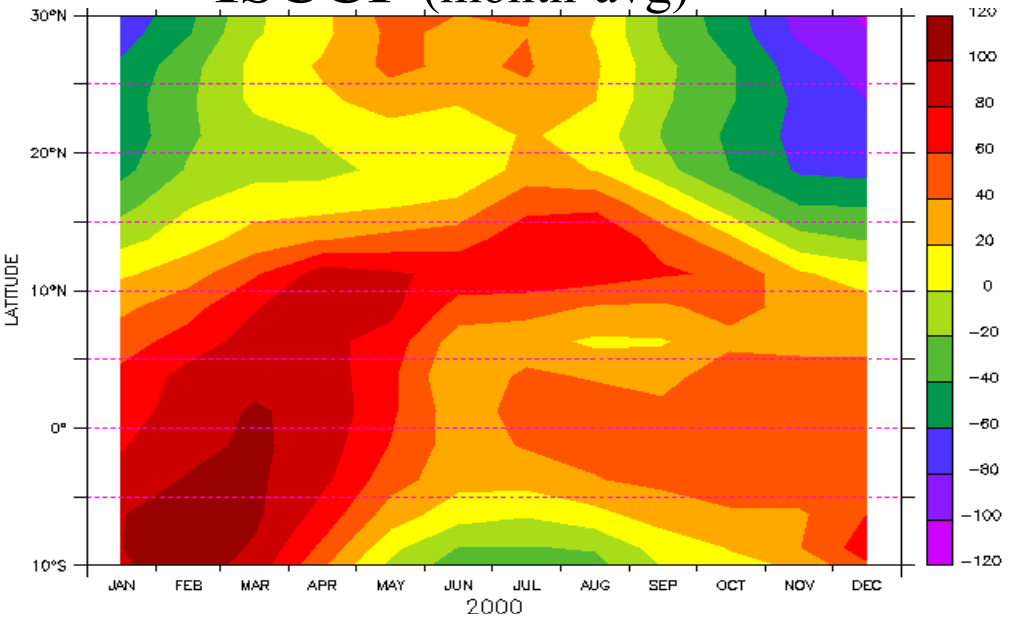
tongue of max incoming net radiation at TOA located over the Sahel in July-August

involves :

- surface albedo
- LW & SW cloud radiative forcings

what about models ? do they care?

ISCCP (month-avg)



TOA net radiative flux

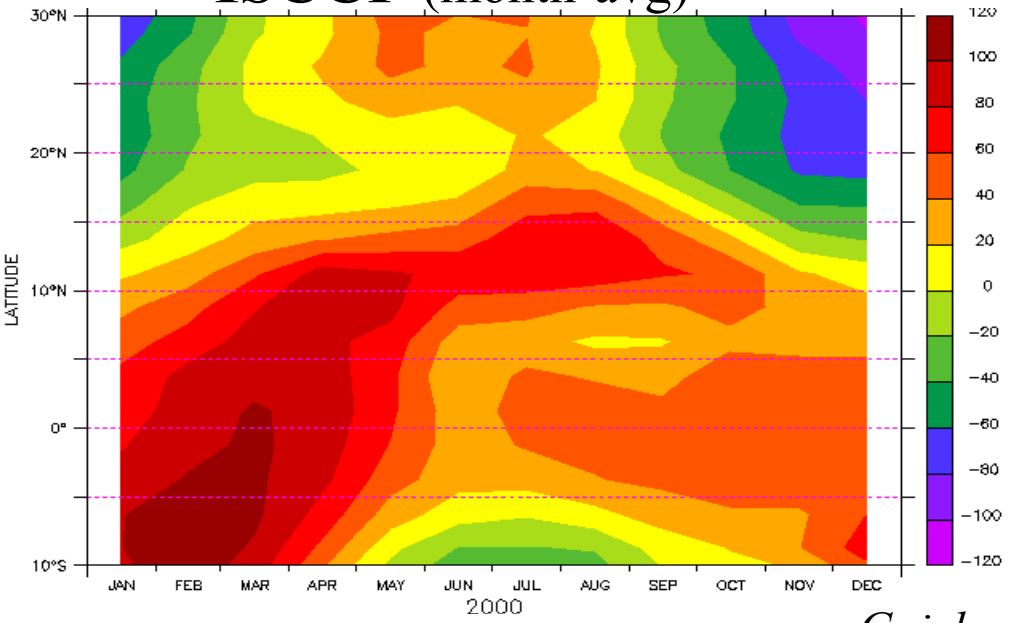
tongue of max incoming net radiation at TOA located over the Sahel in July-August

involves :

- surface albedo
- LW & SW cloud radiative forcings

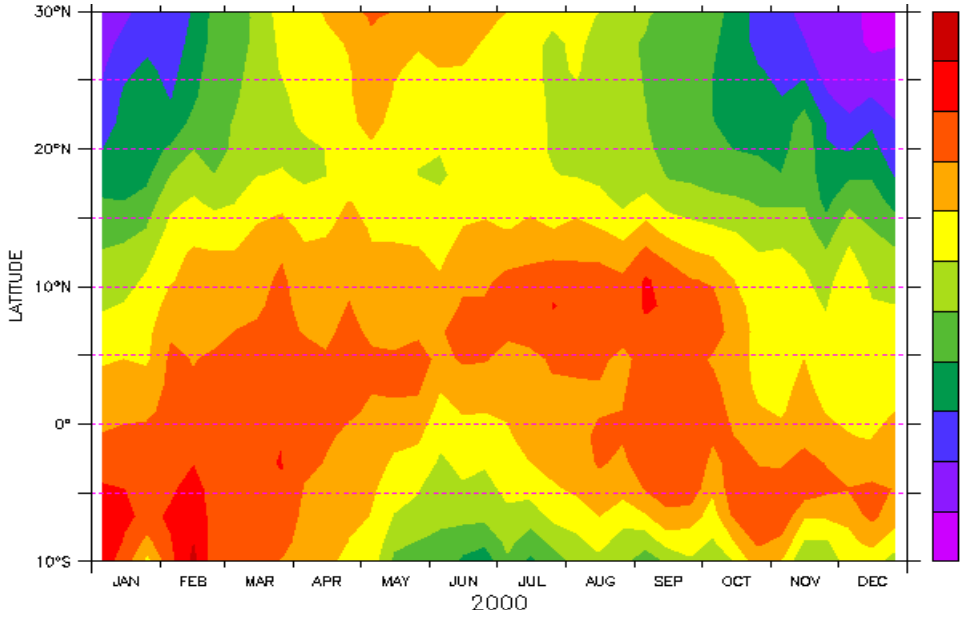
what about models ? do they care?

ISCCP (month-avg)

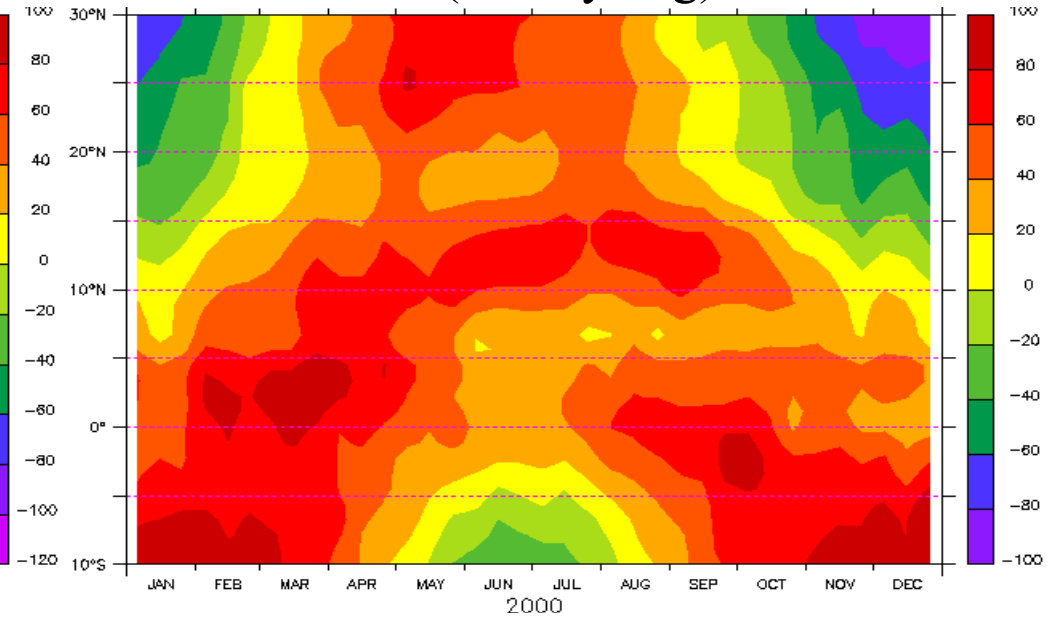


Guichard, ECMWF seminar (2009)

NCEP (10-day avg)



ERA40 (10-day avg)



Observational products

(re-)analyses : weaknesses in rainfall, cloud, surface and TOA fluxes

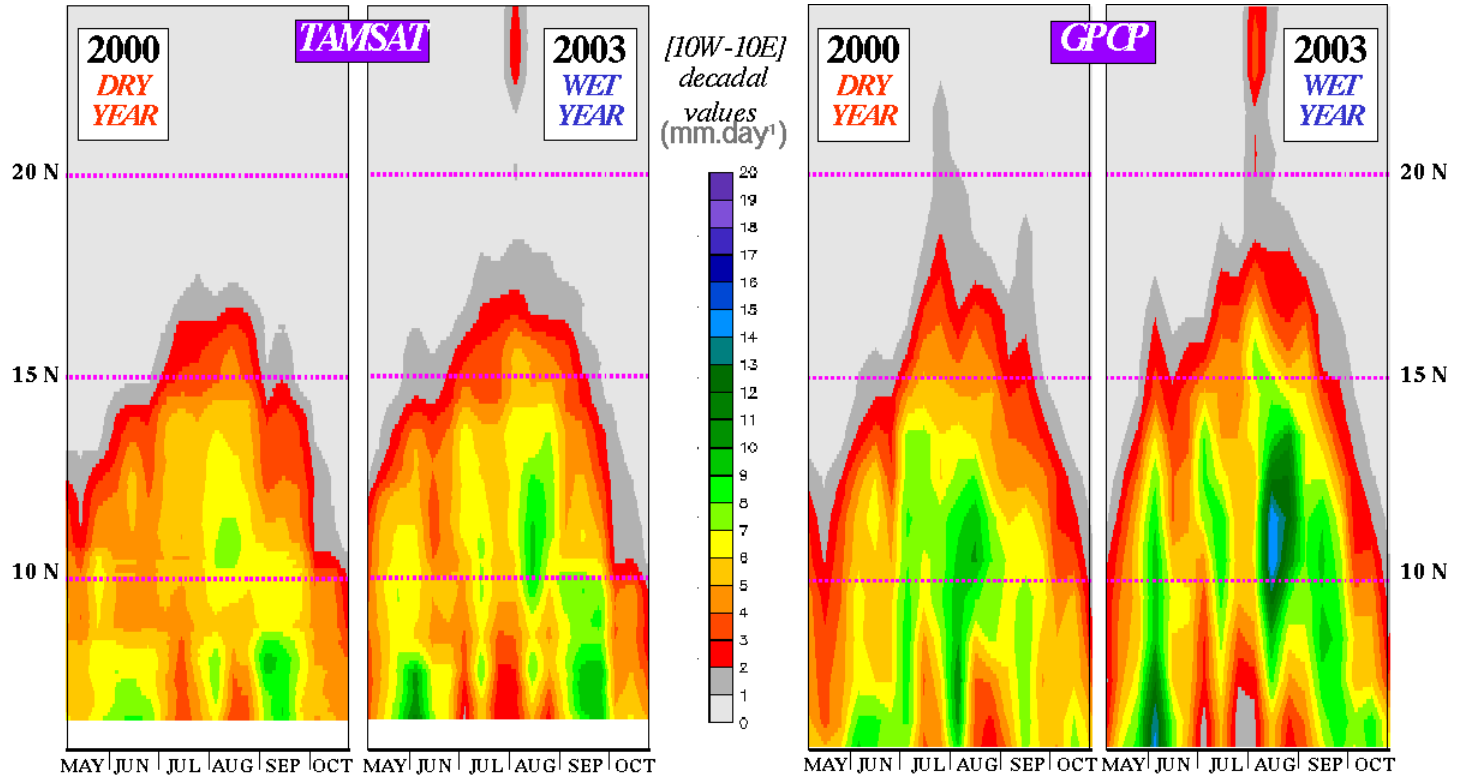
differences in low atmospheric levels (boundary layers)

satellite products :

rainfall : no perfect product (e.g. below)

other issues with radiative products

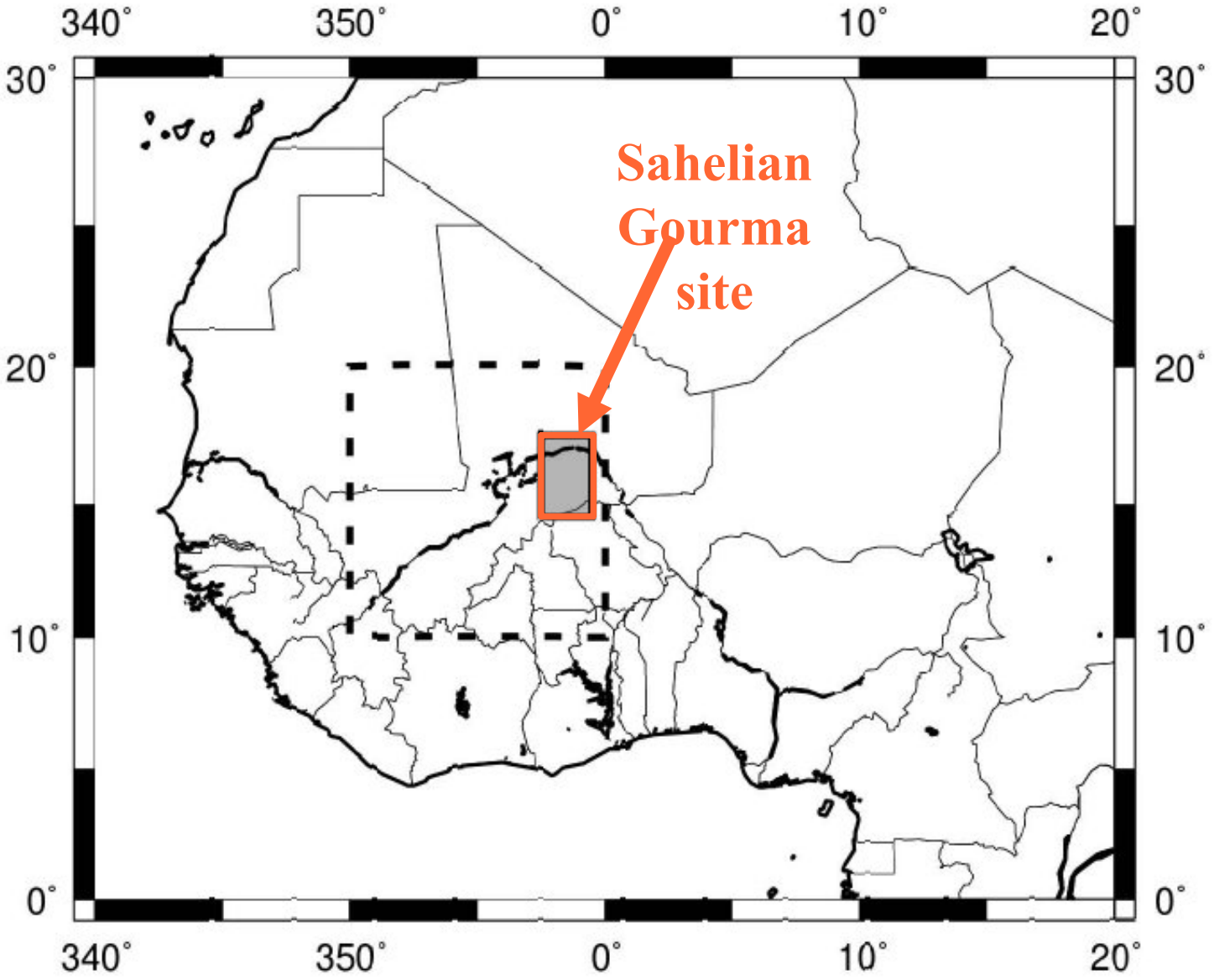
investigated by other people within AMMA + exchanges/comm.



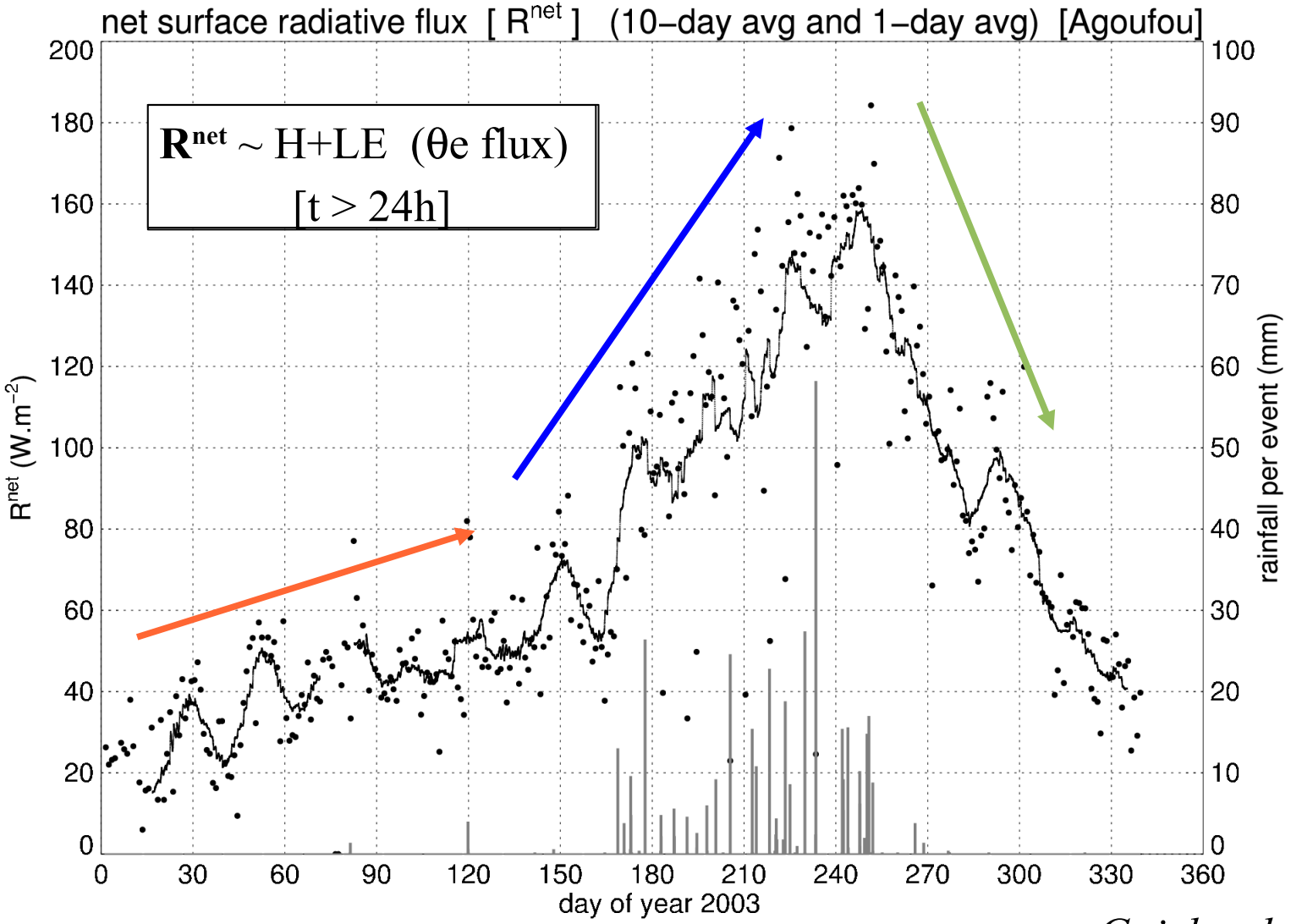
http://www.cnrm.meteo.fr/amma-moana/transect/index.html

diagnostics from observations

an example : surface radiative budget and thermodynamic-radiative couplings



seasonal cycle of surface radiative fluxes

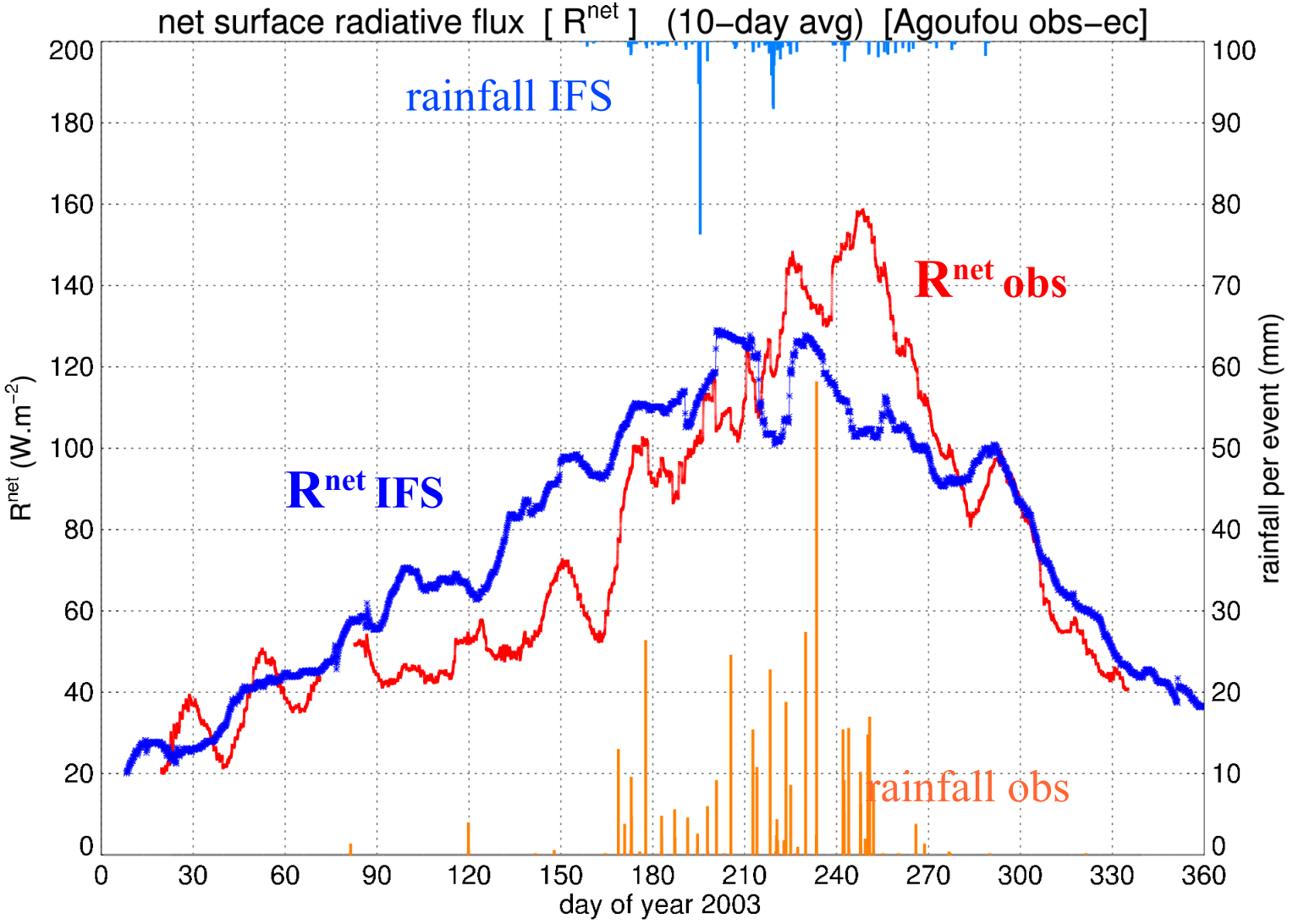


Guichard et al.
J. Hydrology (2009)

strong seasonal fluctuations *(desert / grassland)*
how, why?

$\longrightarrow \quad \mathbf{R^{net}} = LW^{in} - LW^{up} + SW^{in} - SW^{up}$

a glance at the ECMWF-IFS



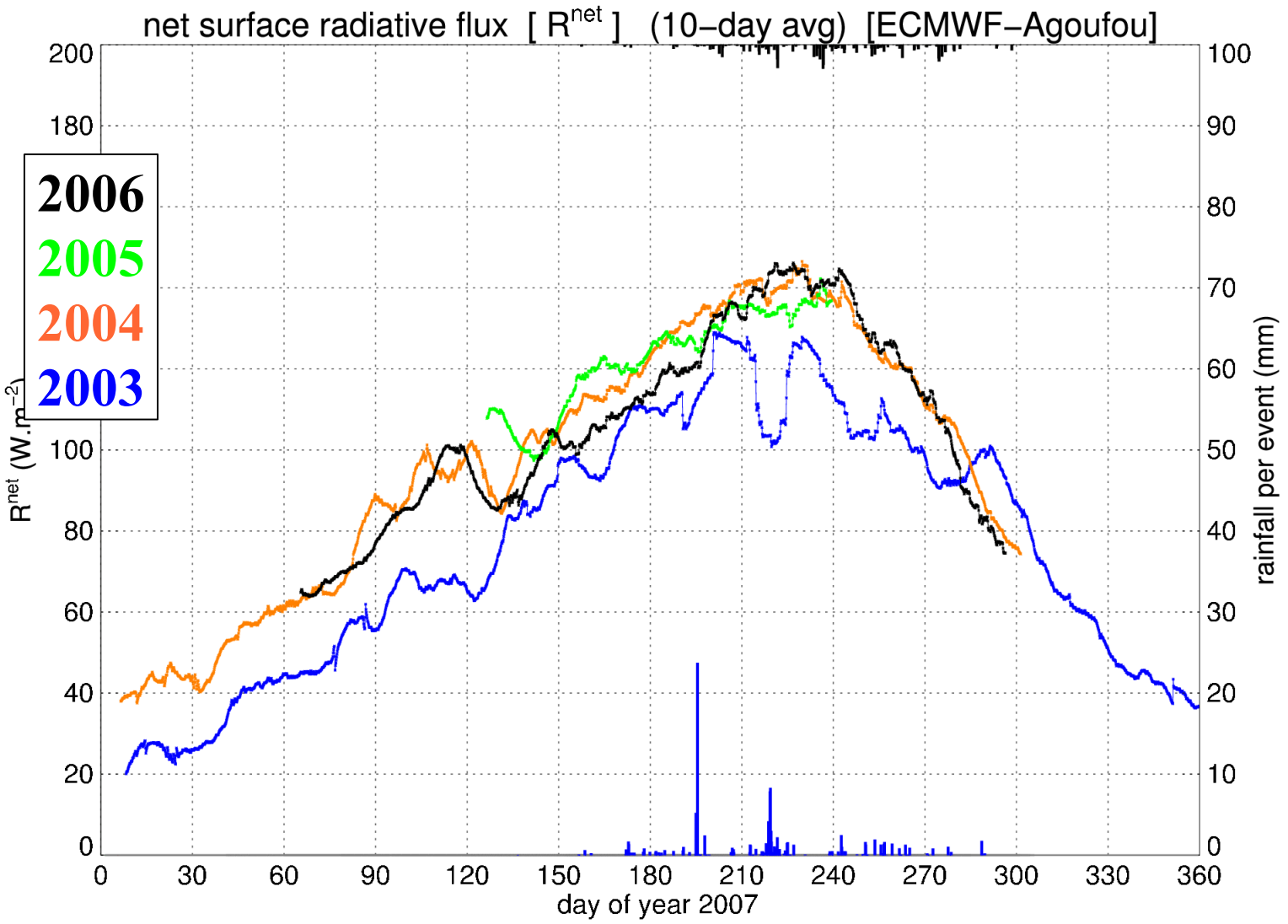
Guichard, ECMWF seminar, proceedings (2009)

more symetric, less dynamic, too strong in spring, early Summer

response to rainfall events too long (& strong)

year 2003: old aerosol climatology, more opaque atmosphere at that time

interannual variability in the ECMWF IFS

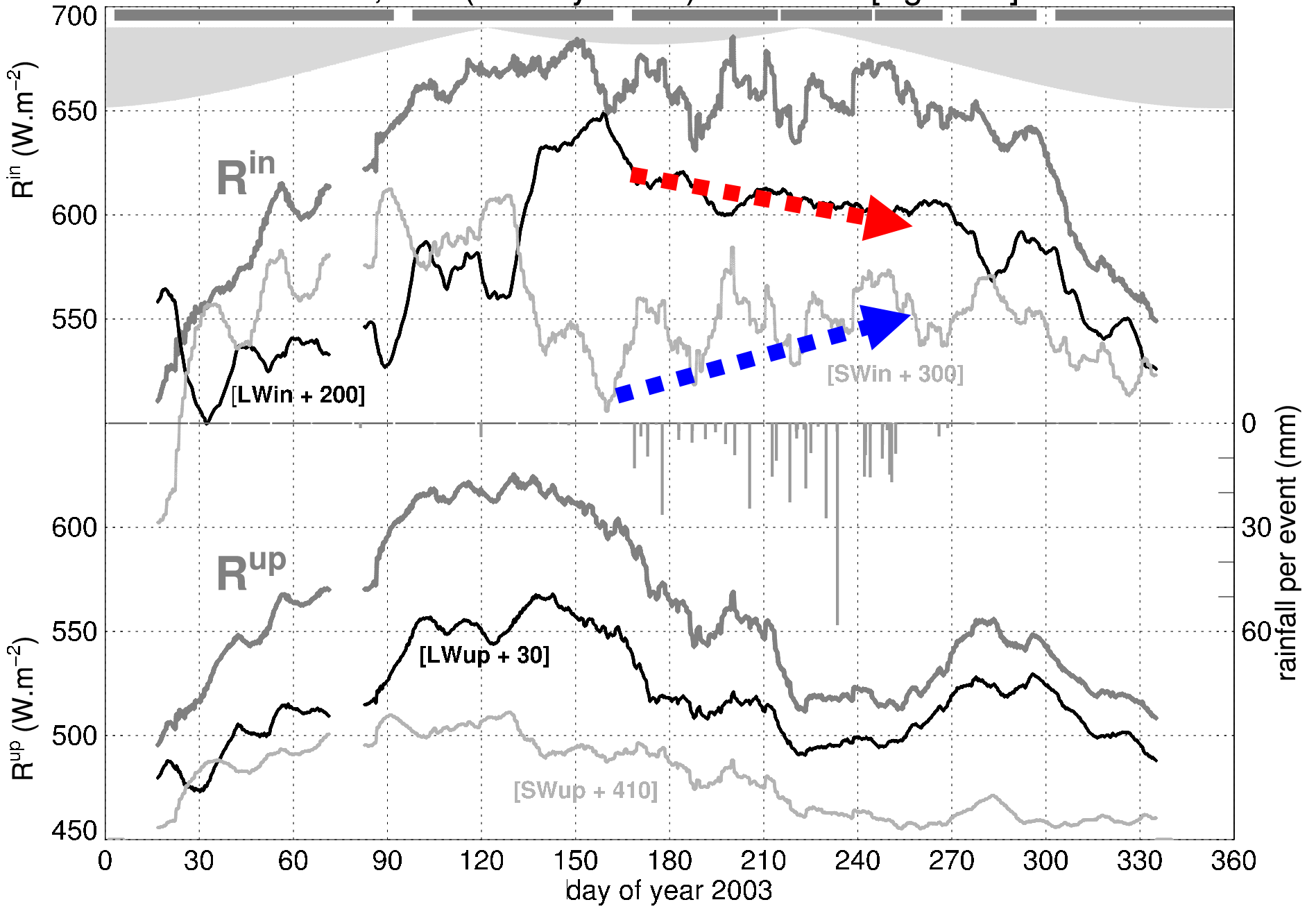


Guichard, ECMWF seminar (2009)

it is dominated by the change in the aerosol climatology (2003 ≠ following years)

$\mathbf{R^{net}} = (LW^{in} + SW^{in}) - (LW^{up} + SW^{up}) = R^{in} - R^{up}$, details

R^{in}, R^{up} (10–day mean) & rainfall [Agoufou]



Guichard et al. J. Hydrology (2009)

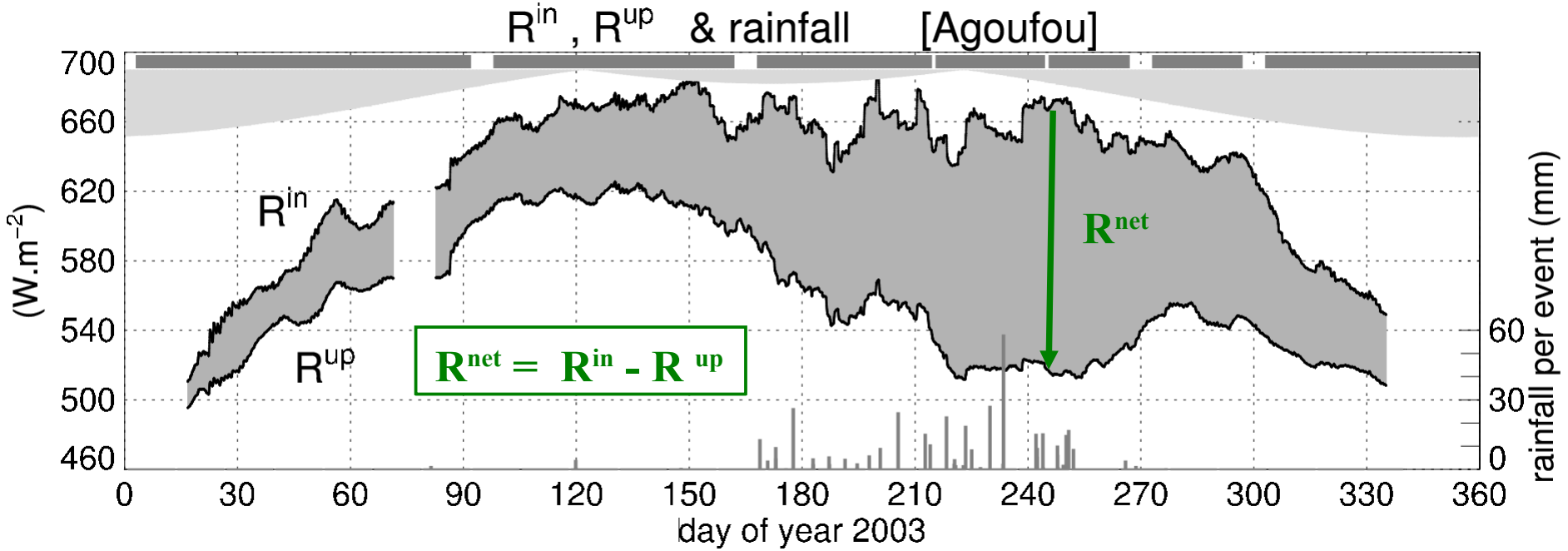
seasonal cycle of surface radiative fluxes

From June to September, variations of R^{net} (↑) driven by R^{up} (which ↓)

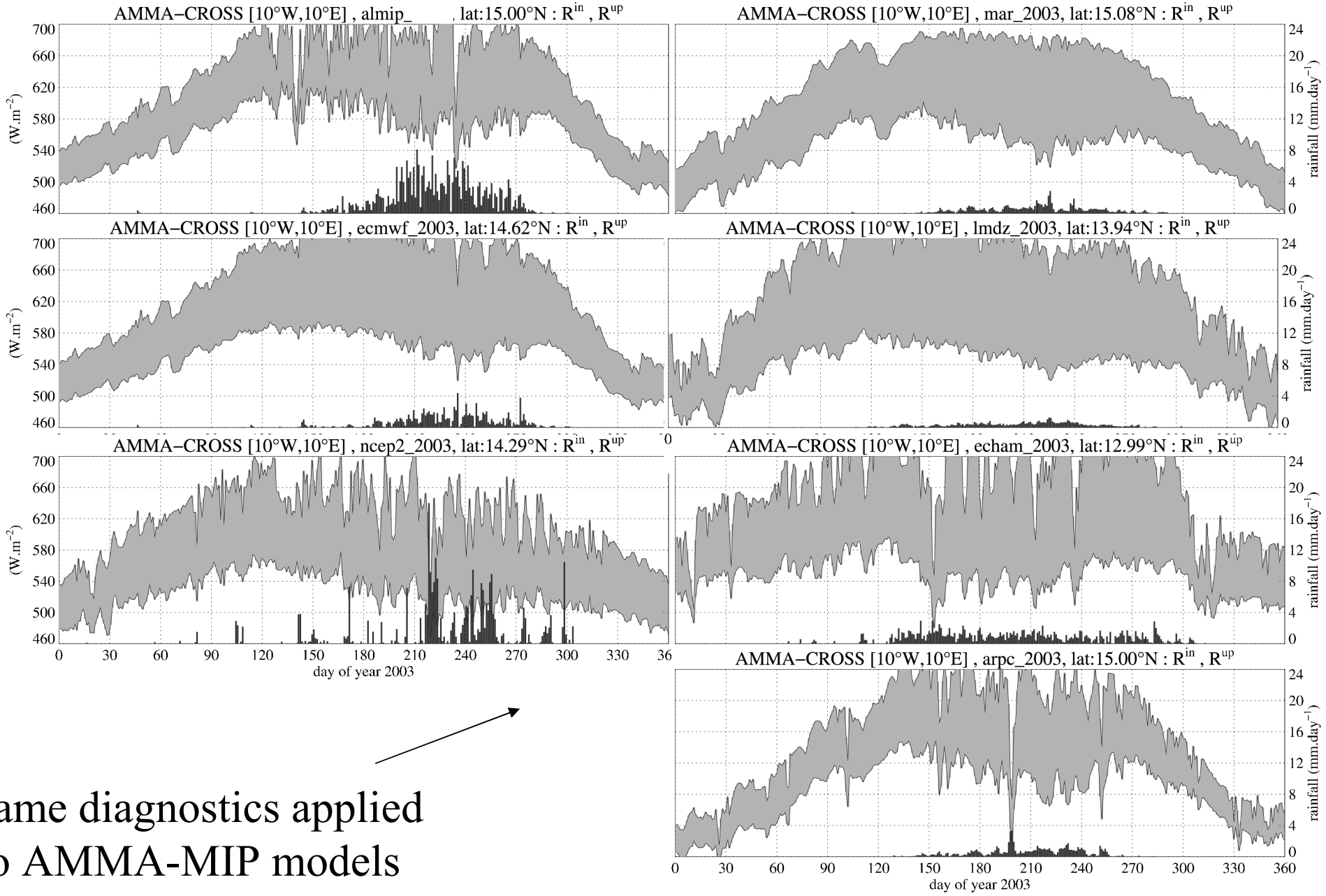
caution : does not mean that radiative impact of clouds & aerosols negligible !

e.g. clouds + aerosols : a reduction of SW^{in} ~ 25% in July-August

but does not mean either that they play an important role in interannual variability



Guichard et al. J. Hydrology (2009)



same diagnostics applied
to AMMA-MIP models
[10°W,10°E]

work in progress

thermodynamic-radiative coupling during the monsoon

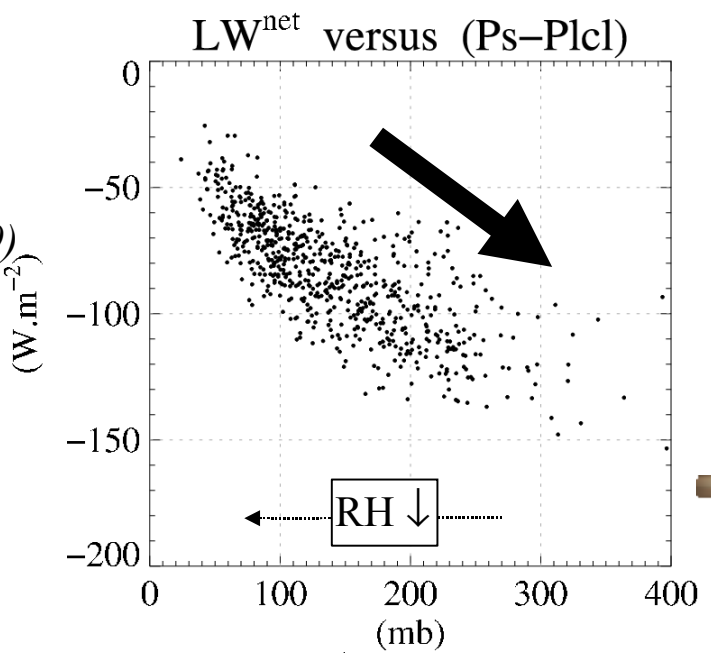
Daily mean values, JJAS 2002 - 2007

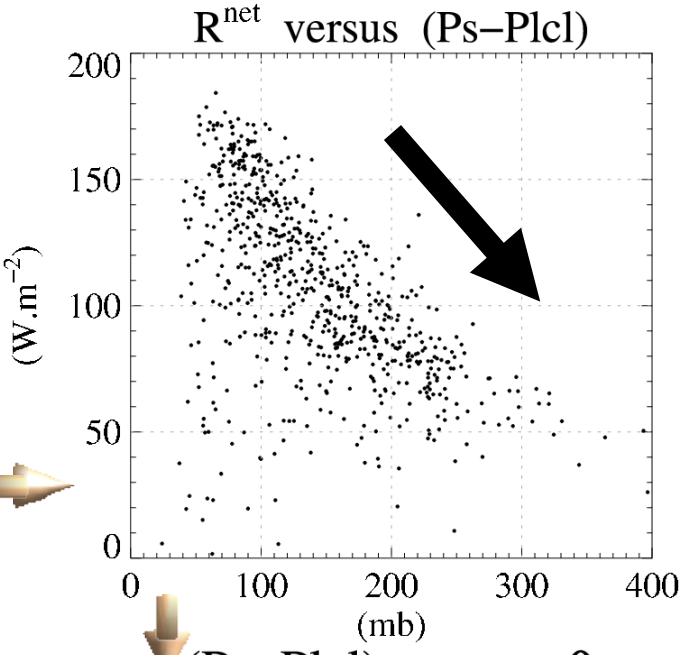
(1)

Consistent with previous studies *(Betts 2004, Schär et al. 1999)*

extended to dryer ranges

valid throughout the year

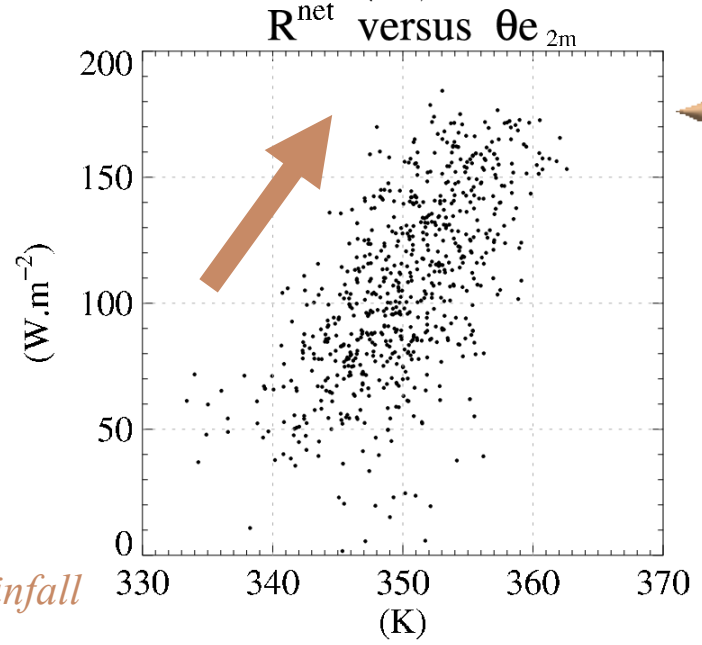


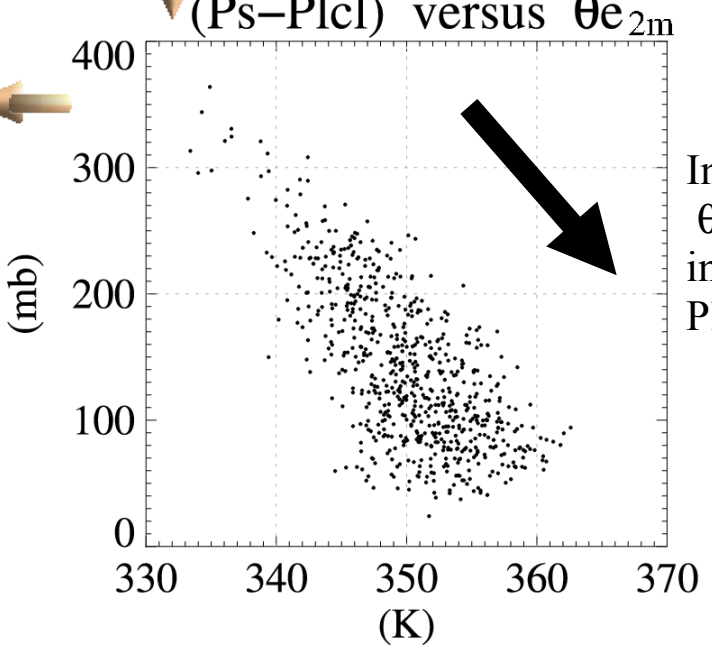


(2)

R^{net} increases even more than LW^{net} with Plcl (& RH) because SW^{net} does not decreases as RH increases

semi-arid region cloud impact does not dominate





(4)

R^{net} and θe correl > 0

involves transformations from Jun to Sept imply > 0 feedback soil moisture / rainfall at this scale

(3)

Increase of θe coupled to increase of Plcl, RH

beyond warmer / dryer (T+,q-)

Guichard et al. J. Hydrology (2009)

Summary

within AMMA-MIP

coordinated evaluation of large-scale models organized within AMMA

light framework (small files and few years of runs)

comprehensive documentation of model performances over West Africa

high sensitivity to parametrization

no simple scheme of explanation

(convection, cloud, surface processes, but also aerosol & vegetation)

data provide valuable diagnostics/guidance regarding processes at play

incorporate new model runs (2006) and observational products , among which

ERA-Interim

AMMA re-analysis from ECMWF

(Panareda *et al* , 2008)– corrected humidity from soundings)

ALMIP, ...

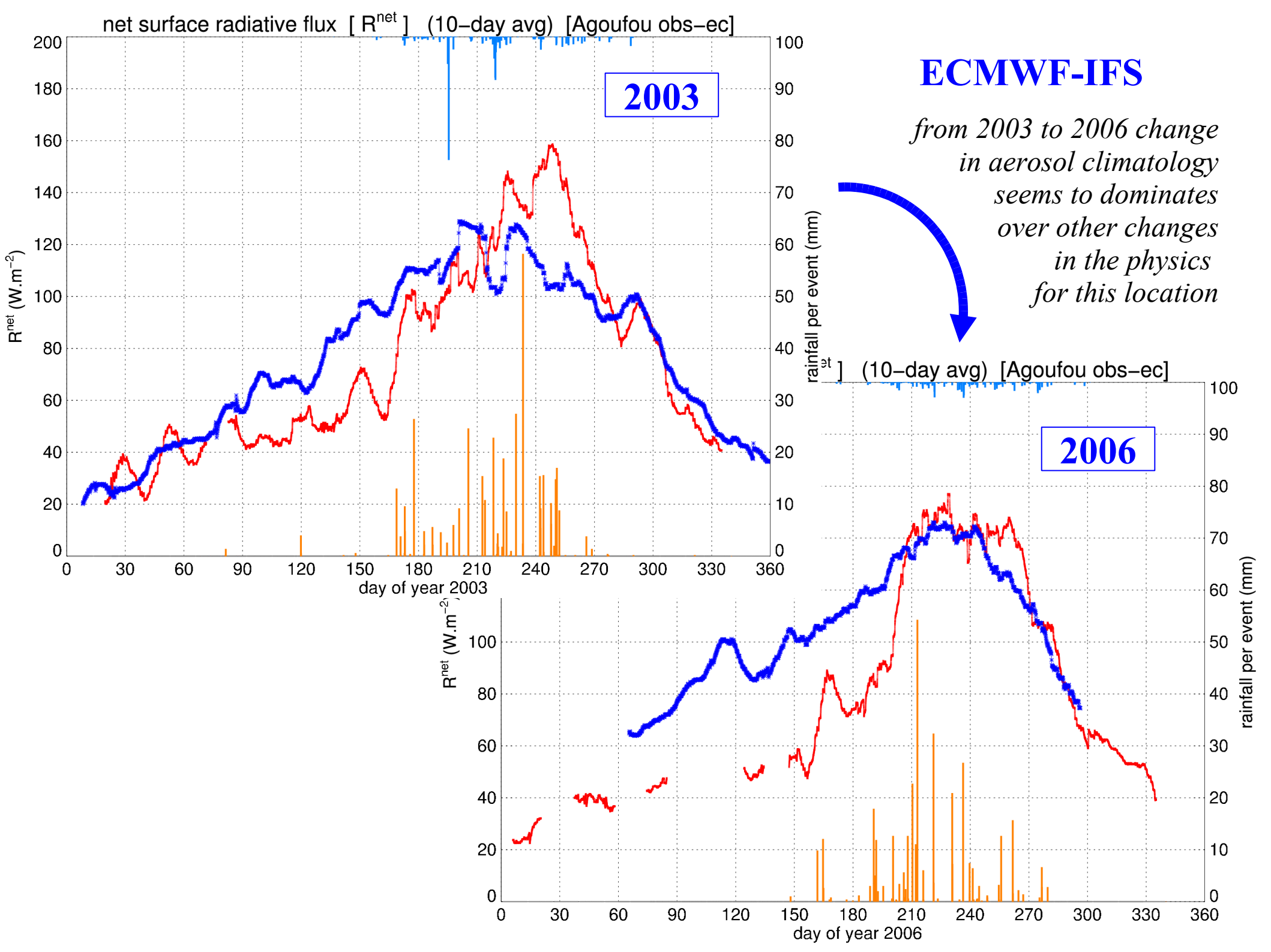
develop new diagnostics for assessing models , focus on process-couplings

more statistical approaches (surface data, fluxes)

cloud issues not to be overlooked

Thank you

Photos Guichard, Kergoat
CNRS copyright
clouds in the Sahel (Mali)


net surface radiative flux [R^net] (10–day avg) [Agoufou obs–ec]
2003
R^net (W.m^-2)
rainfall per event (mm)
day of year 2003
ECMWF-IFS
from 2003 to 2006 change
in aerosol climatology
seems to dominates
over other changes
in the physics
for this location
[R^net] (10–day avg) [Agoufou obs–ec]
2006
R^net (W.m^-2)
rainfall per event (mm)
day of year 2006