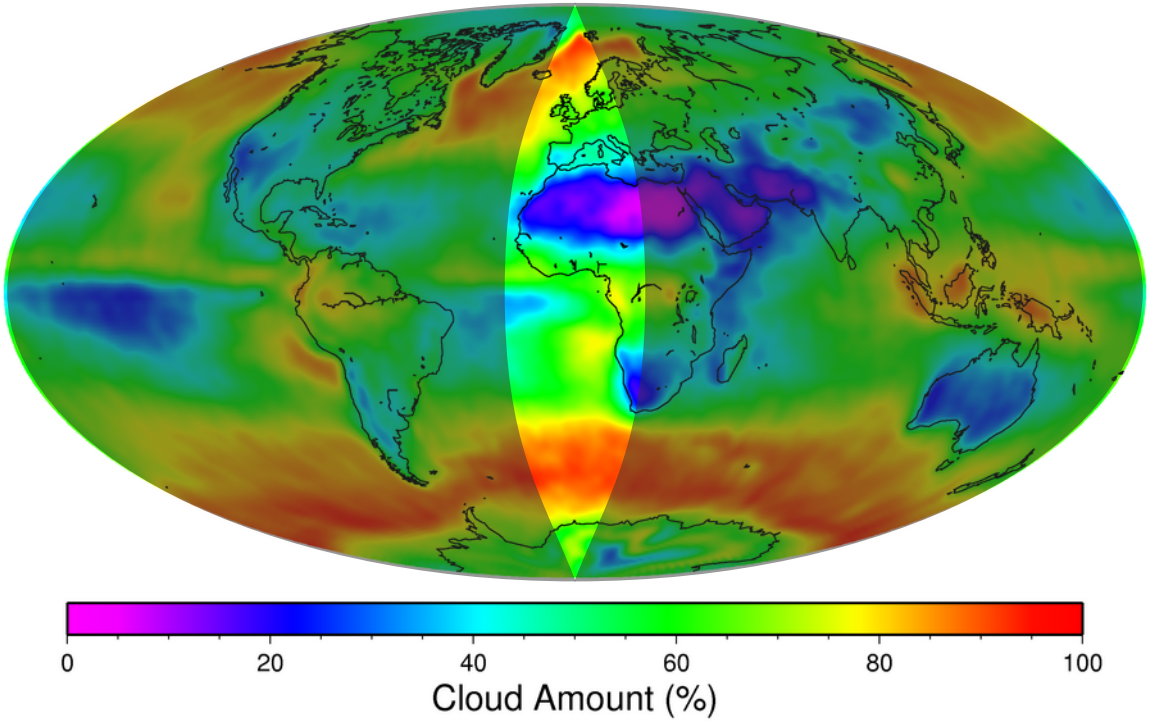
Simulation of clouds and cloud radiative forcing over West Africa with a focus on ARPEGE model

Françoise Guichard, Dominique Bouniol, Fleur Couvreux, Amanda Gounou, Sophie Tyteca, Boutheina Oueslati, Gilles Bellon and Hervé Douville

data acquisition, analyses
model evaluation/intercomparison
AMMA-MIP, Hourdin et al. (2010)
WAMME, Xue et al. (2010)

more direct focus on clouds
cfSites CFMIP model outputs

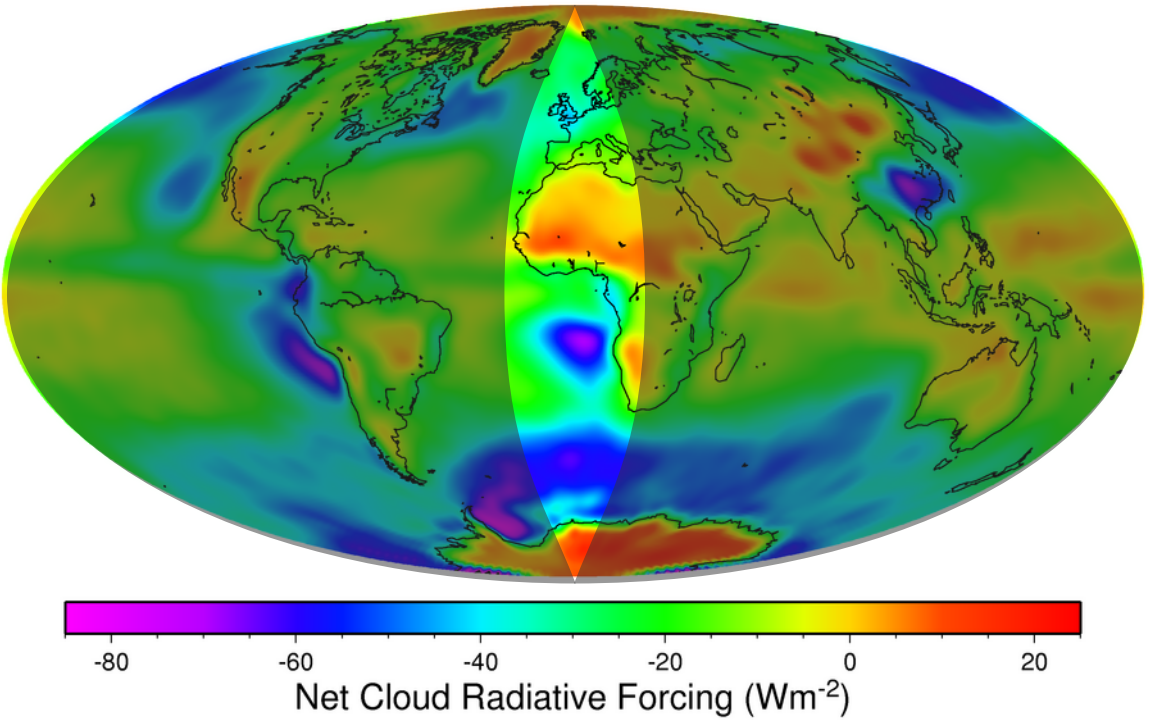


Source : LARC-NASA, T. Wong

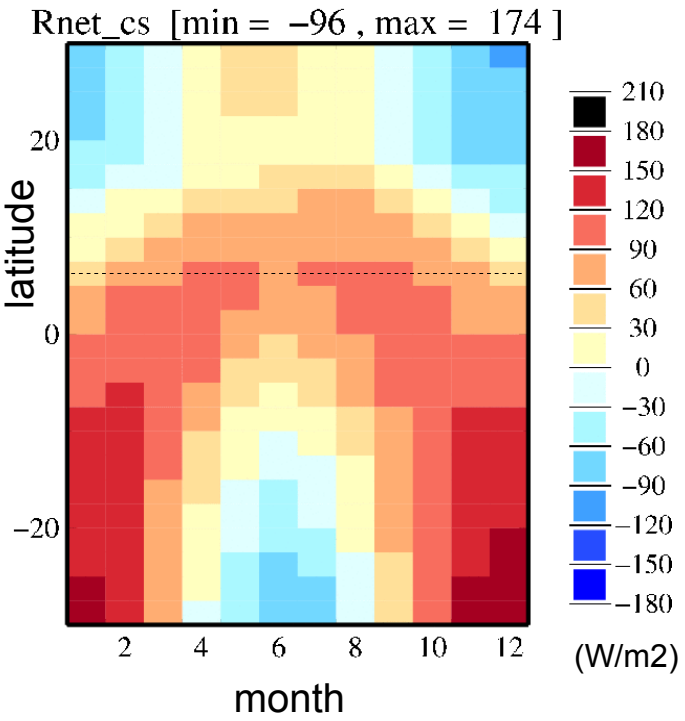
meriodional transect

Gulf of Guinea to the Sahara

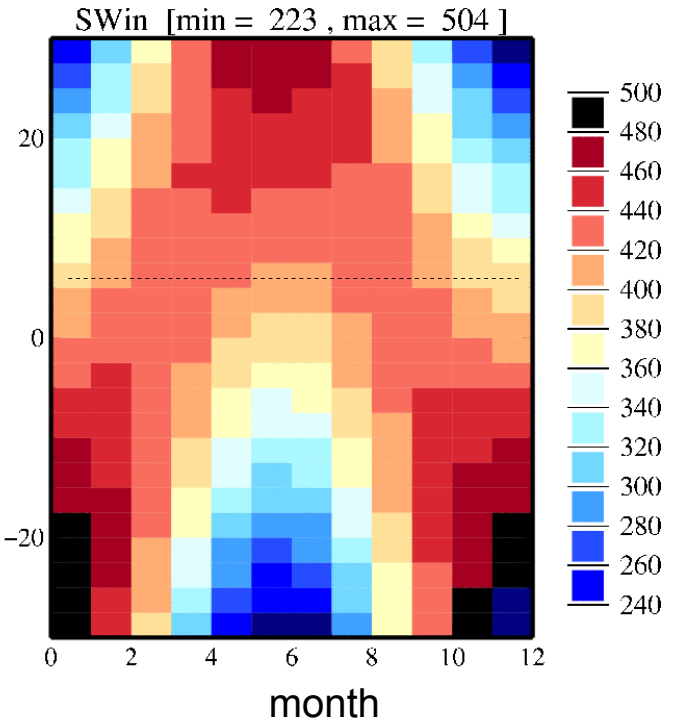
[10°W, 10°E]



Rnet TOA clear sky



SWin TOA



land

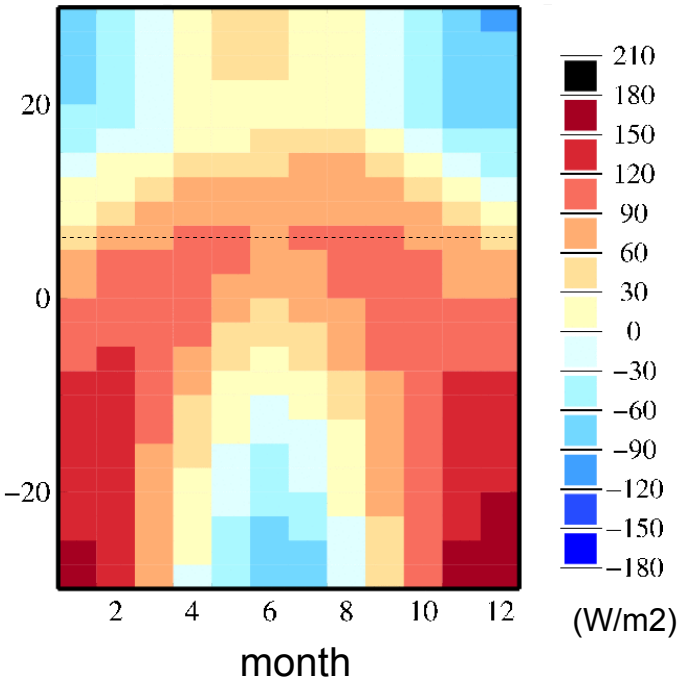
ocean

annual cycle, monthly mean value, [10°W,10°E], 2.5° x 2.5°CERES data

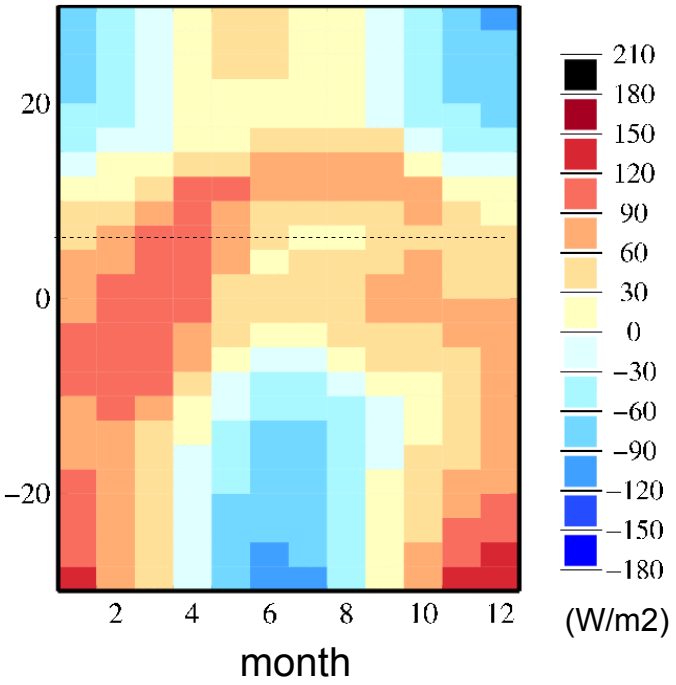
over land, Rnet TOA ~ Fnet, net energy input to the atmospheric column
radiative fluxes, sensible and latent heat flux
(surface energy balance)

thermodynamic factor , Fnet + favours convection (cf. Chou and Neelin 2002)

Rnet TOA clear sky



Rnet TOA



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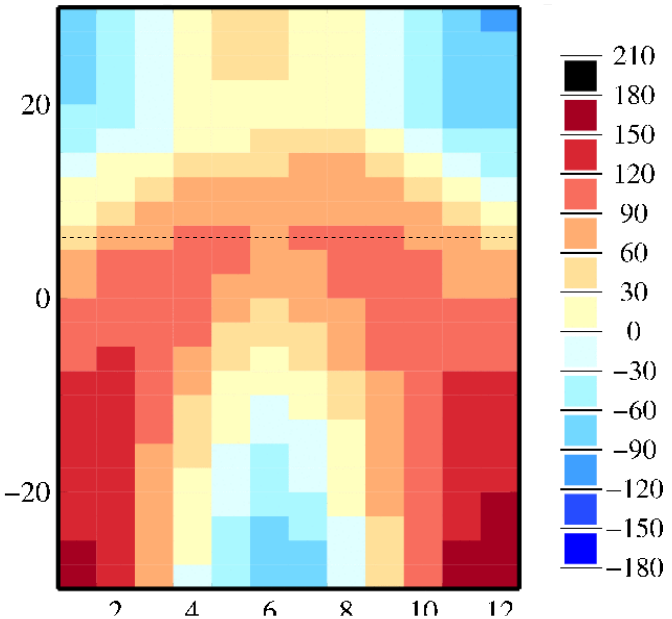
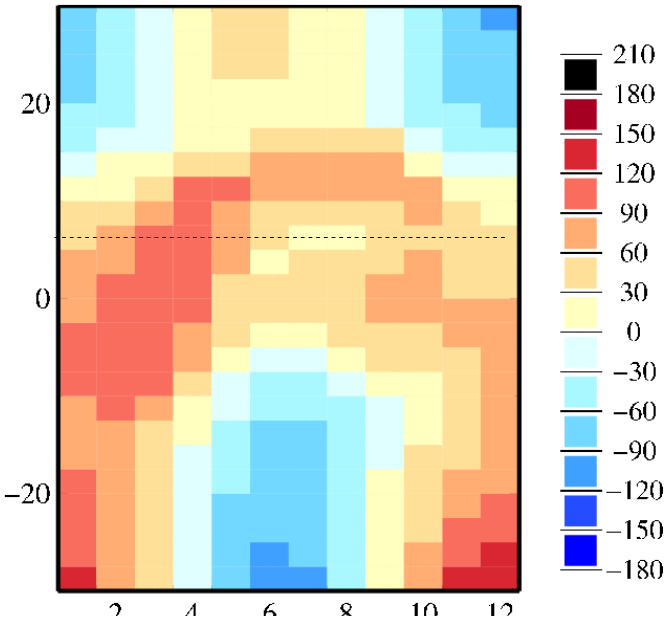
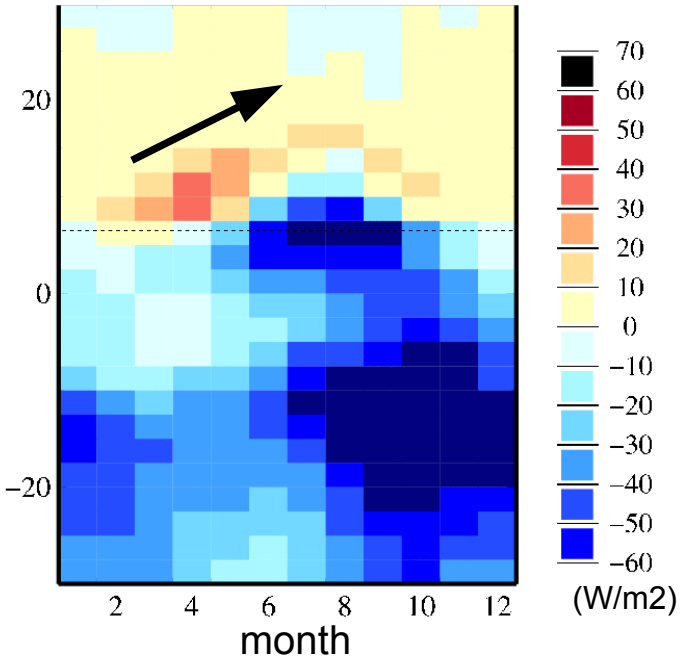


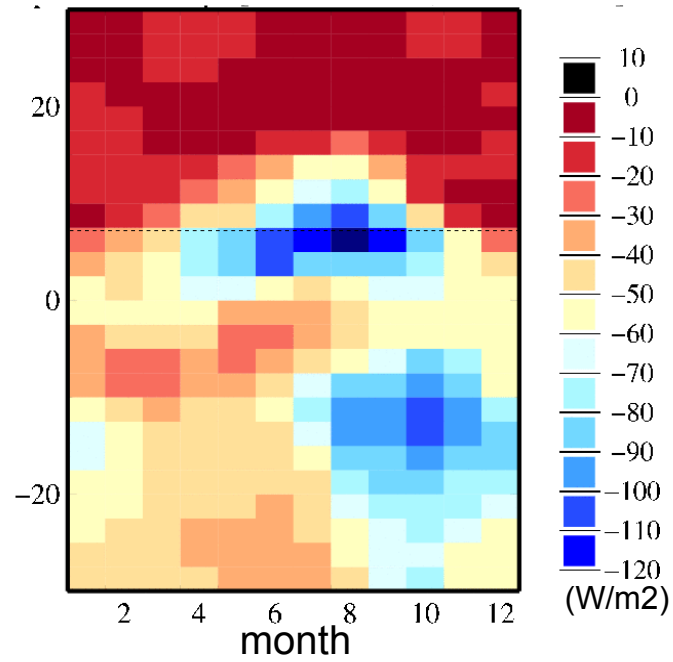
Rnet TOA



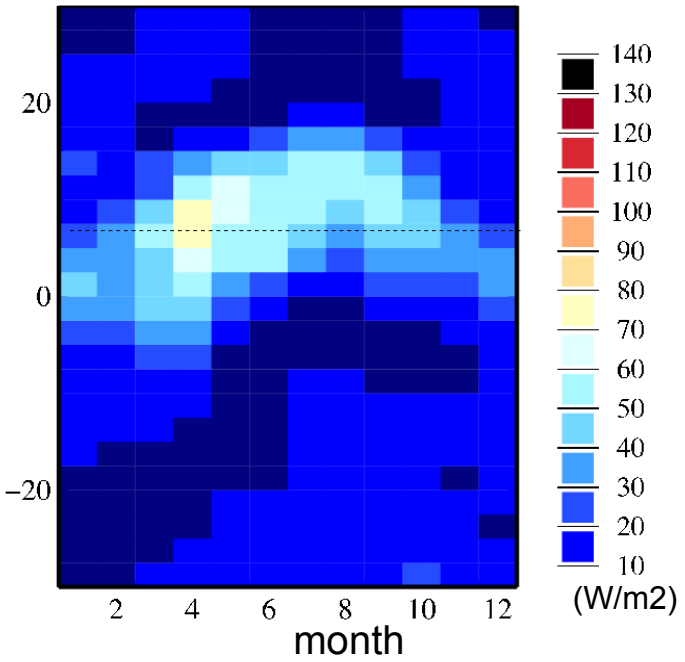
Rnet -Rnet clear sky

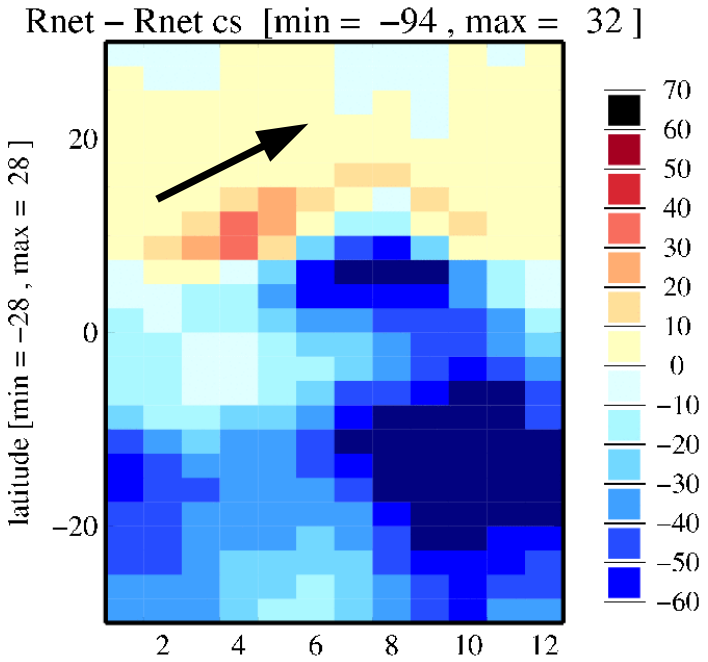


SWup clear sky -SWup



OLR clear sky - OLR





A cloud-related energetic signature of the monsoon northward migration of a tongue of high Rnet TOA

is this feature playing an active role ?
is it reproduced in simulations ?
at least qualitatively by some (not all)
but probably not always for good reasons

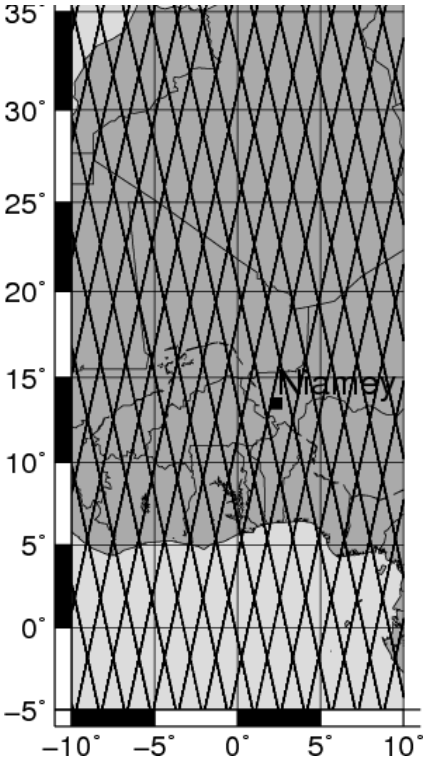
amount and vertical structure of clouds

inference from CloudSat/CALIPSO

~ 3 km (x,y) x 200 m (z)
2 samplings per day
2006, 2008 (aggregating data)

► frequency of occurrence of clouds

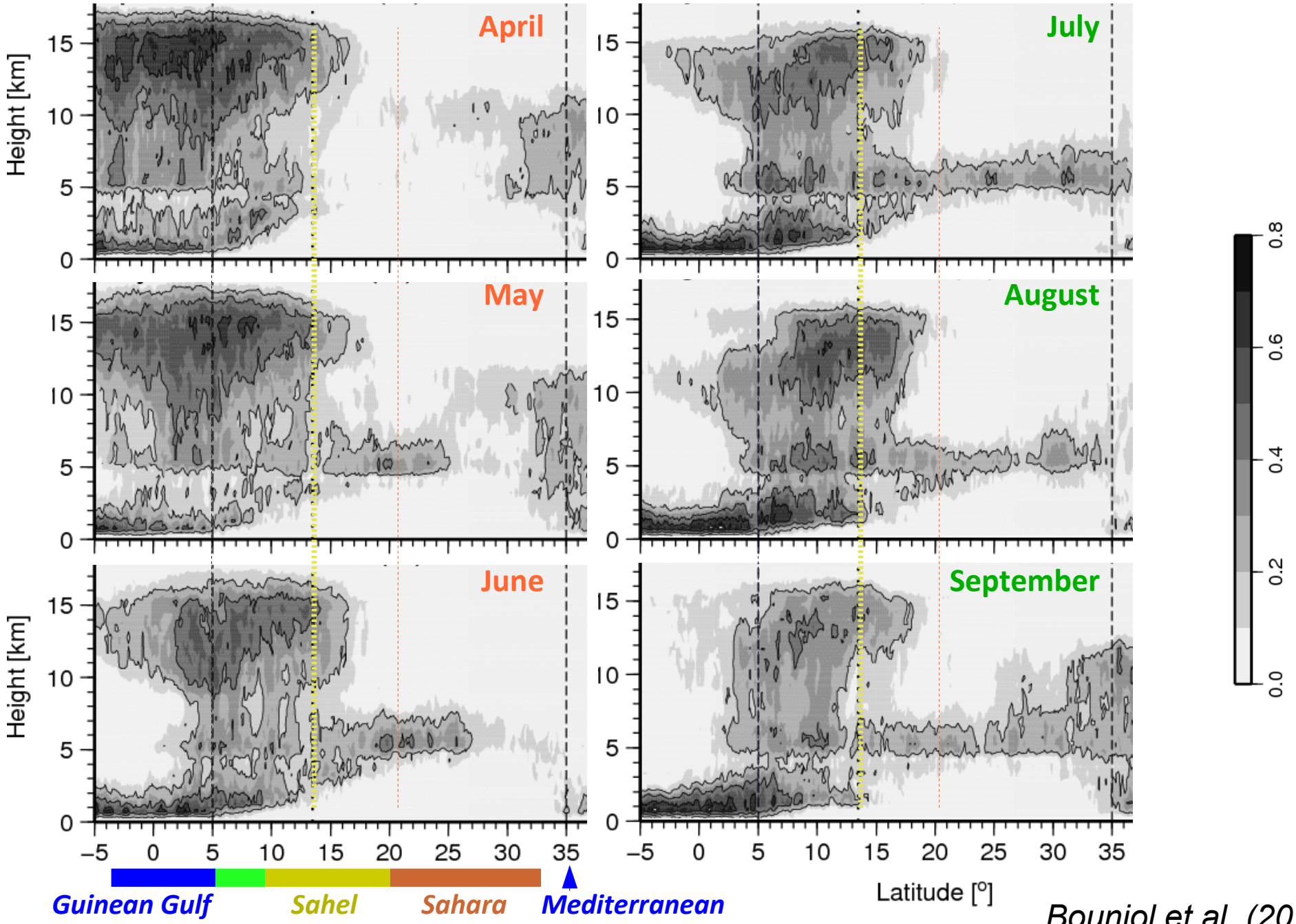
16-day ground track



Bouniol et al. (2010)

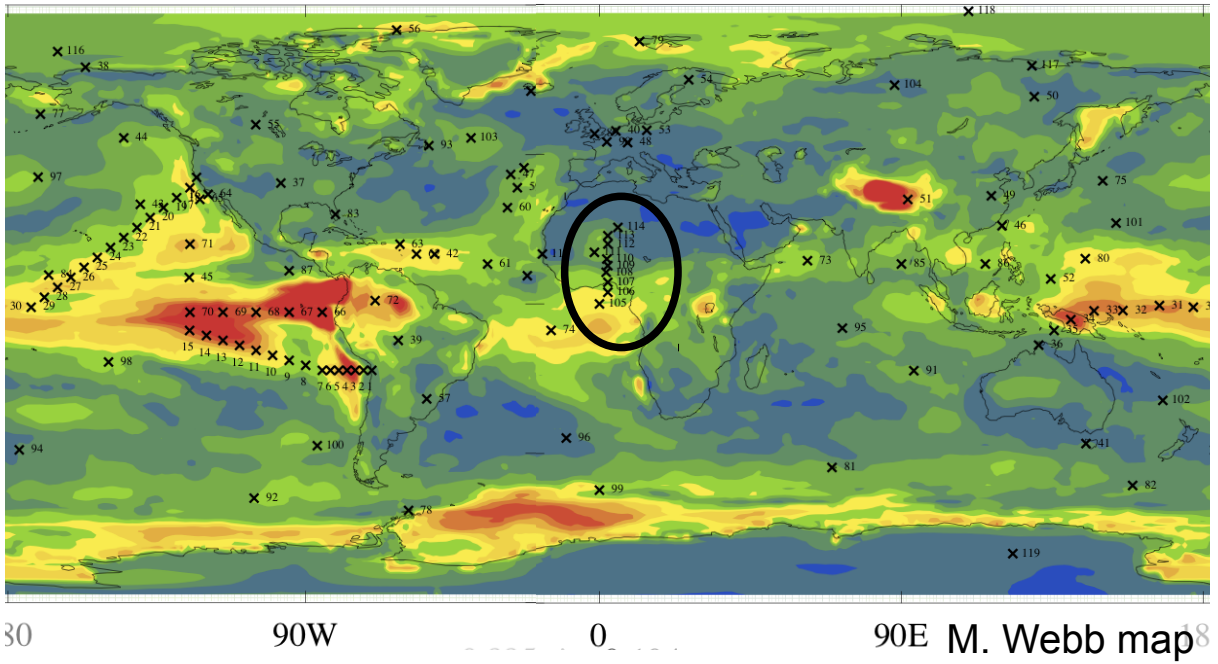
Monthly latitude-altitude cross-sections of cloud frequency of occurrence

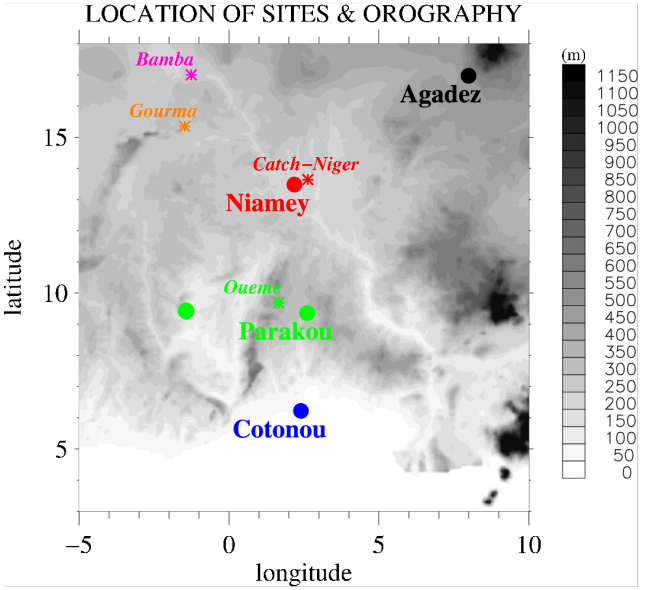
CloudSat radar and CALIPSO lidar [10°E,10°W] for 2008

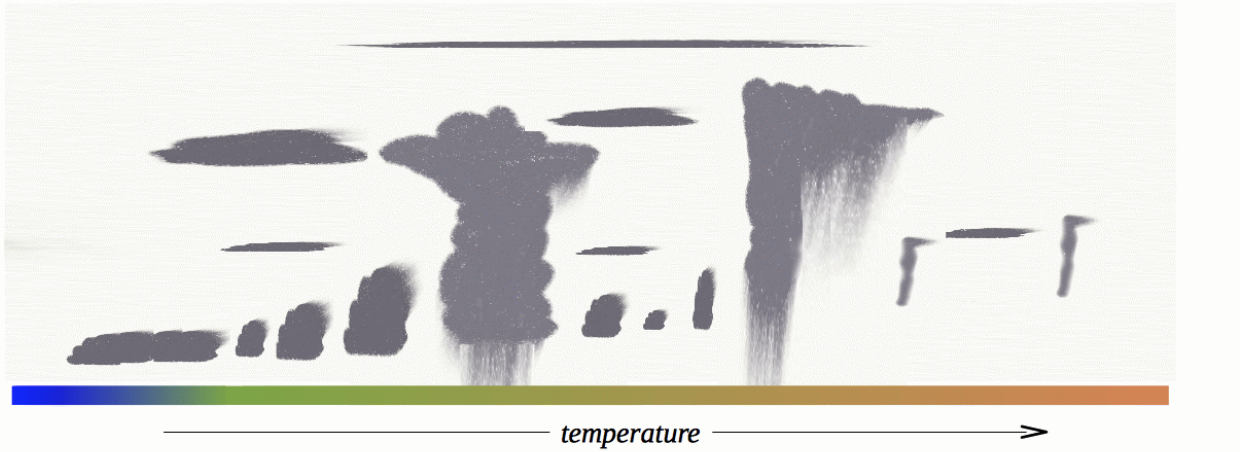


Bouniol et al. (2011)

CFMIP cfSites







automatic weather stations (rad)
flux stations
precipitable water from GPS
high time frequency, several years

soundings (high-frequency)

AMF Niamey (for 2006)

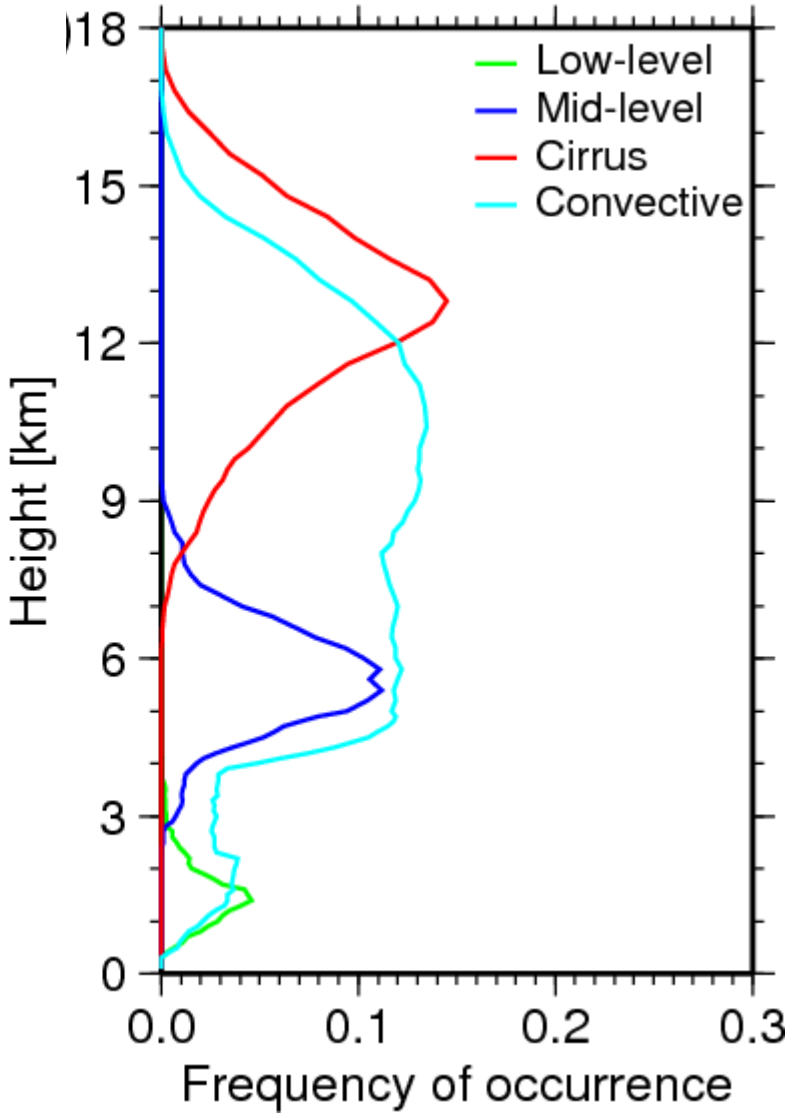
other cloud infos from ceilometers
also extractions on these points of satellite products, analyses

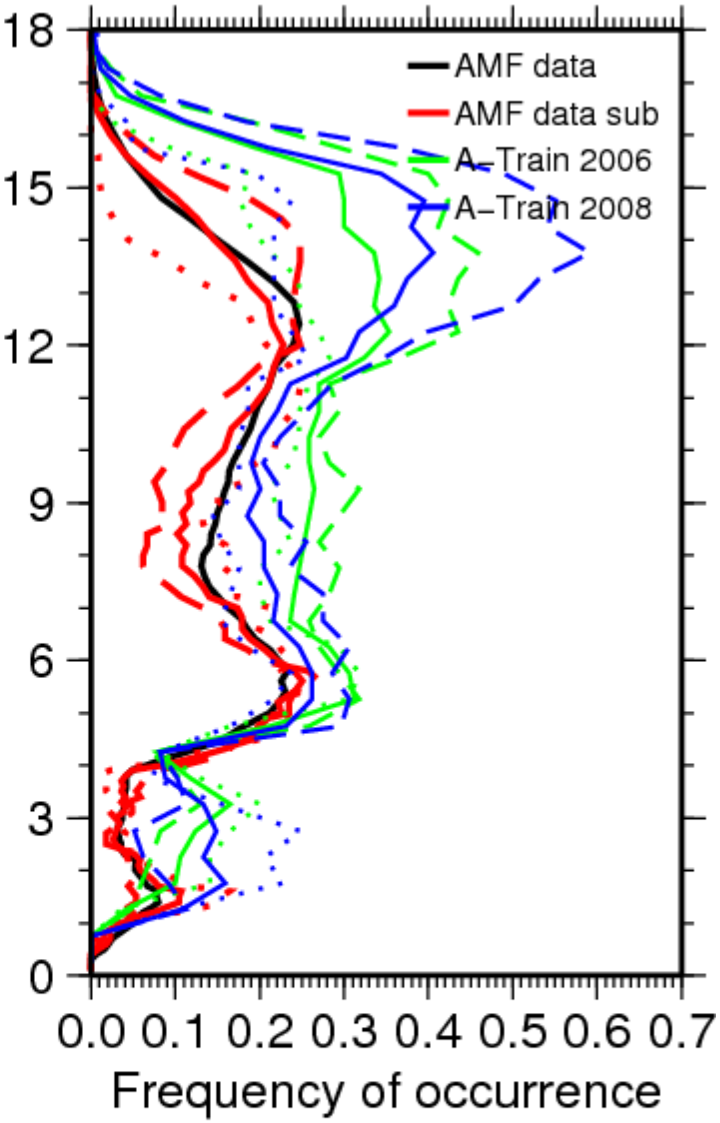
annual, diurnal cycles
synoptic, intraseasonal, interannual

cfSites : started to analyse ARPEGE CMIP5, ARPEGE NWP & ≠ ECMWF model versions

expected changes of the thermodynamic balances along the gradient :
from more radiative-convective (wet Tropics) to more advective-radiative-convective equilibrium (semi-arid Sahel), daytime low clouds during the monsoon...

CLOUD FREQUENCY OF OCCURRENCE 2006 MONSOON (JJAS) AT NIAMEY

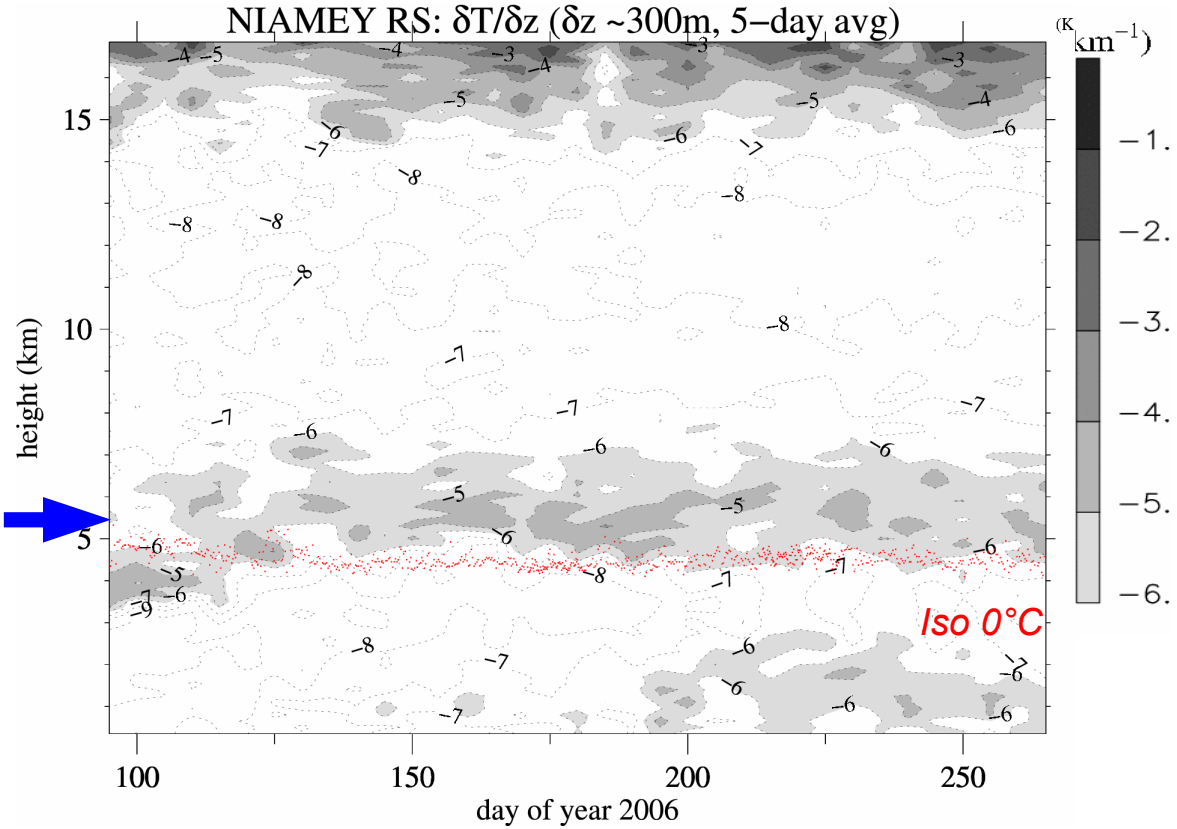


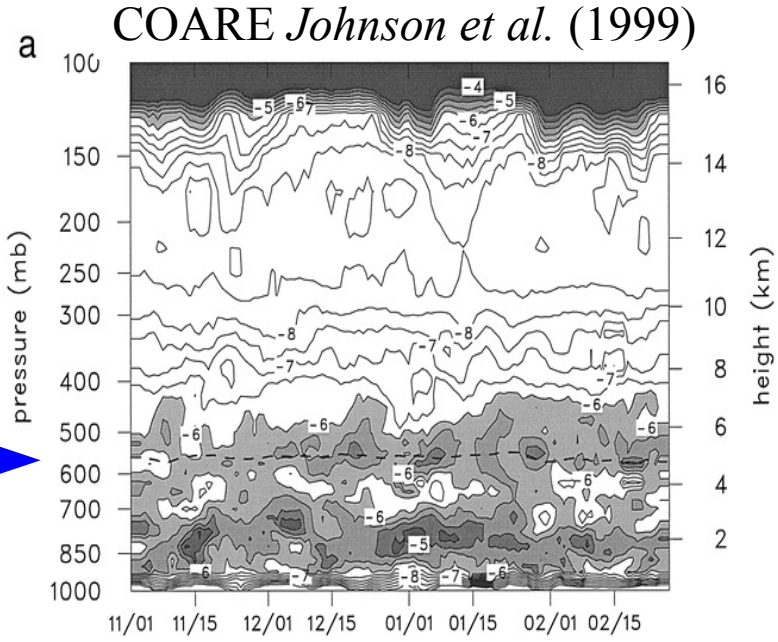


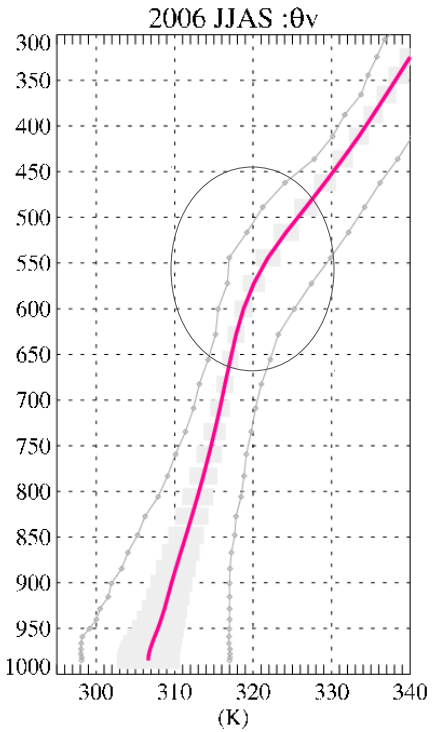
Bouniol et al. (2011)

low-level : (cloud base – Plcl) < 500 m and cloud top < 3 km
mid-level : 3 km < cloud base < 7 km
high-level : 8 km < cloud base
convective : cloud thickness above iso 0° > 5 km or cirrus part of MCS (using MCS tracking info)

PROMINENT FEATURES OF THE ENVIRONMENT OF MID-LEVEL CLOUDS







5-7 km: layer of steeper lapse-rate coincides with a max of relative humidity

causes of this maximum of mid-level clouds?

detrainment from « shallow » clouds below ?

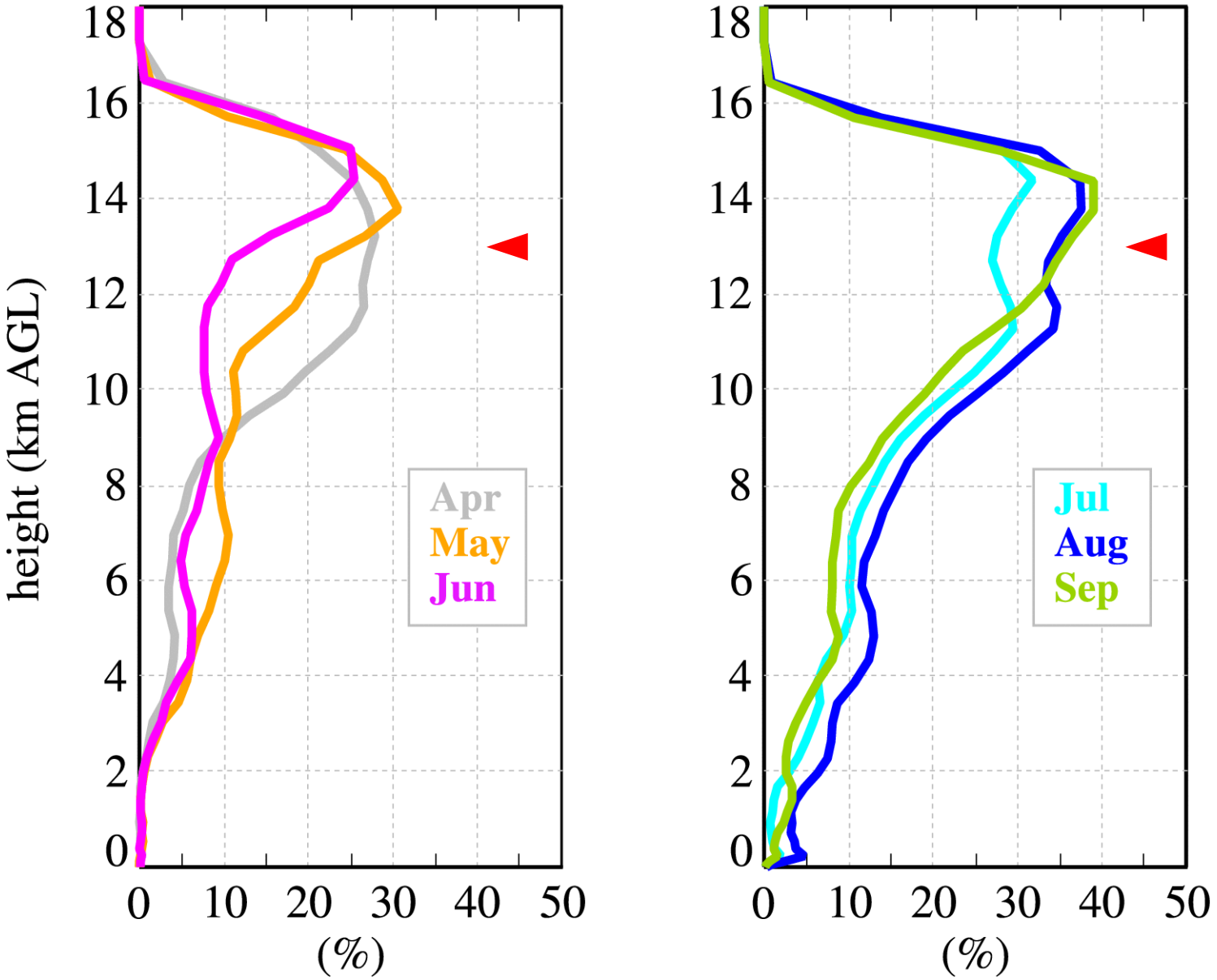
mid-level outflows from MCSs?

(present in Spring, prior to MCSs, in Sahara)

role of the African easterly jet?

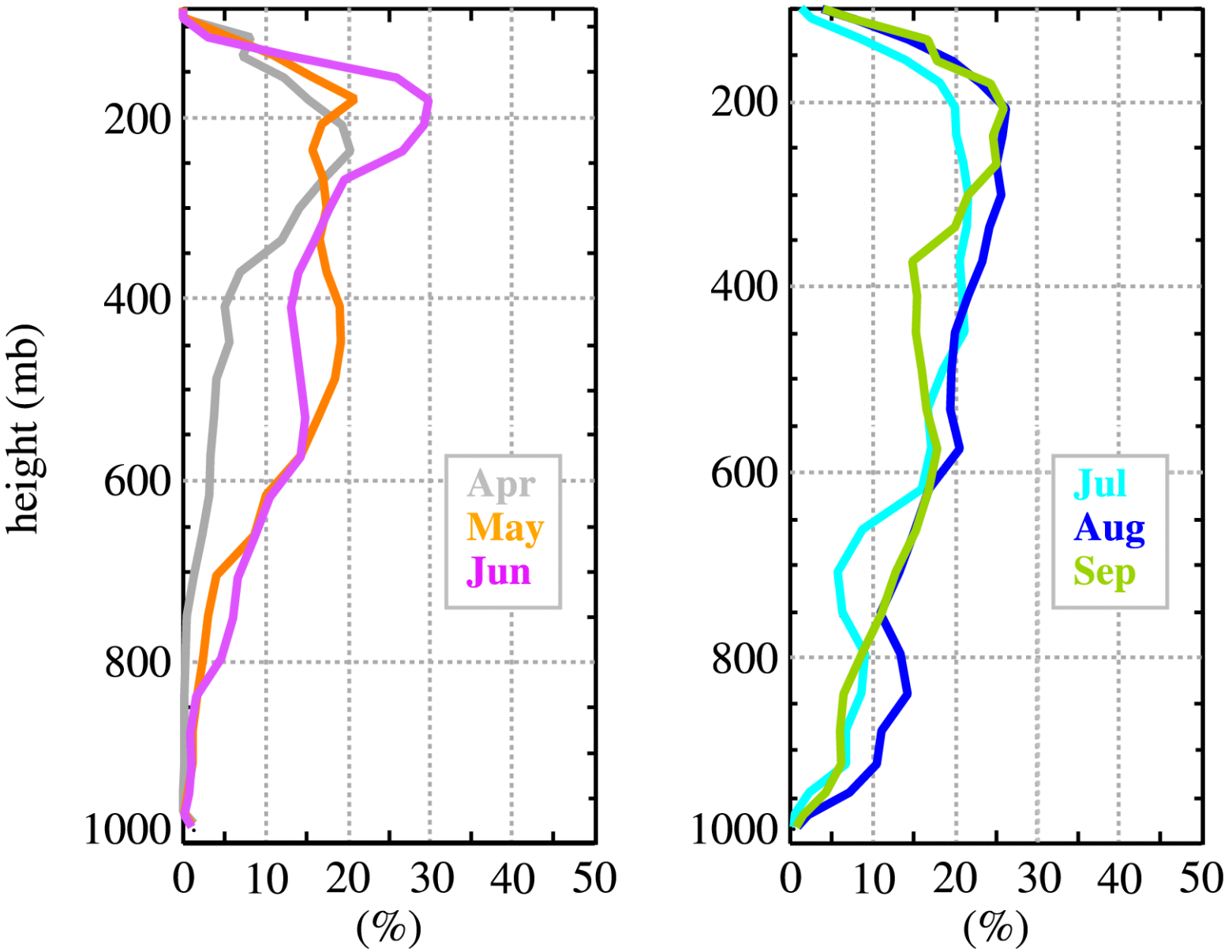
does it involves cloud feedbacks on the environment?

Cloud fraction ARPEGE NWP



dominated by high clouds, no real peaks at low and mid levels

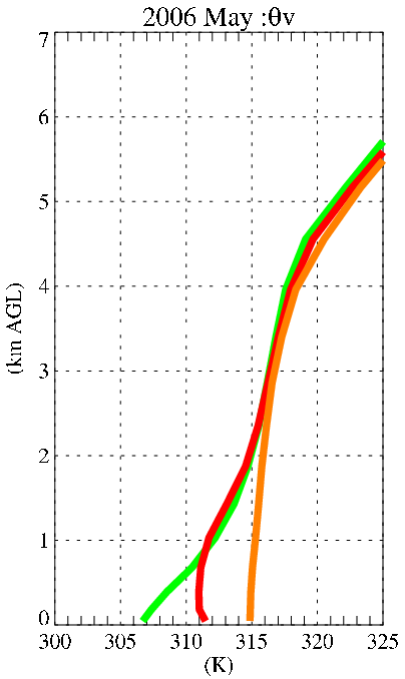
Cloud fraction ARPEGE AMIP run



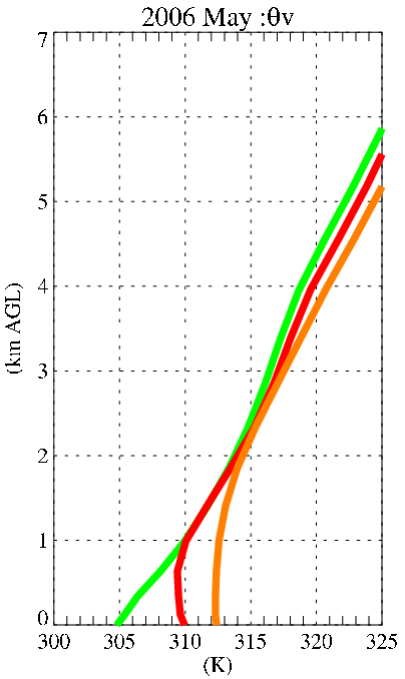
dominated by high clouds, no peaks at mid levels, a local maximum in low levels in JA

monthly-mean profiles in May (moist, not wet)

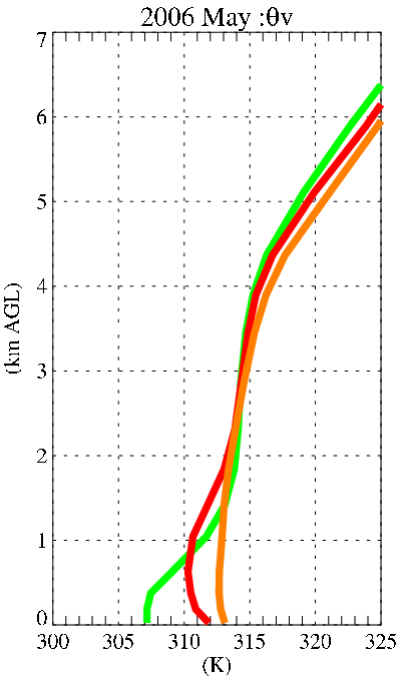
SOUNDINGS



ARPEGE CMIP5

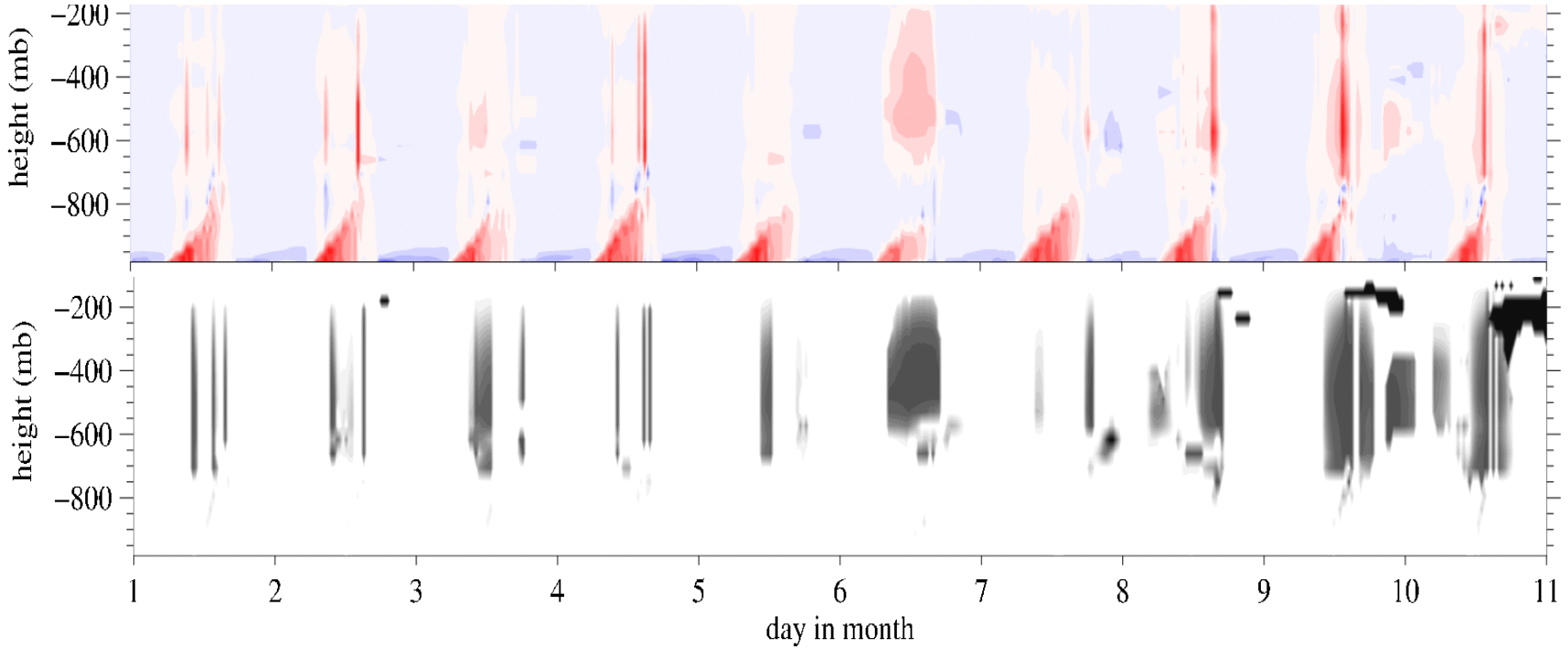


ARPEGE NWP



diabatic processes

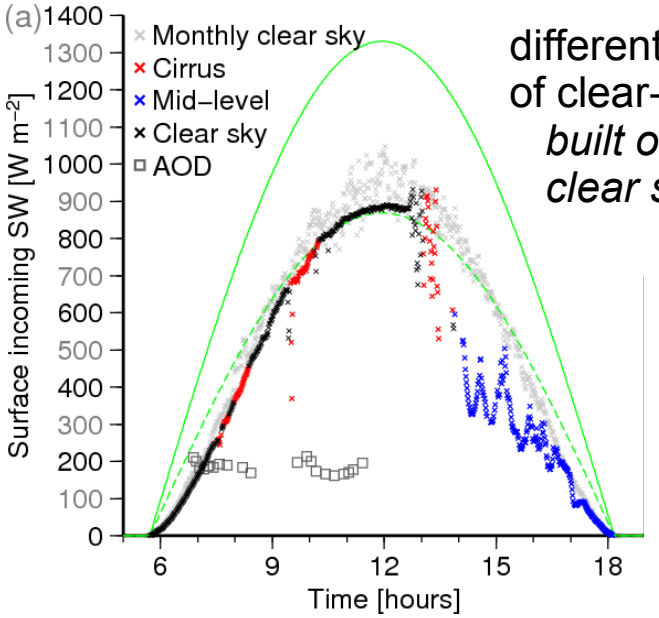
cloud fraction



Cloud radiative impact at the surface

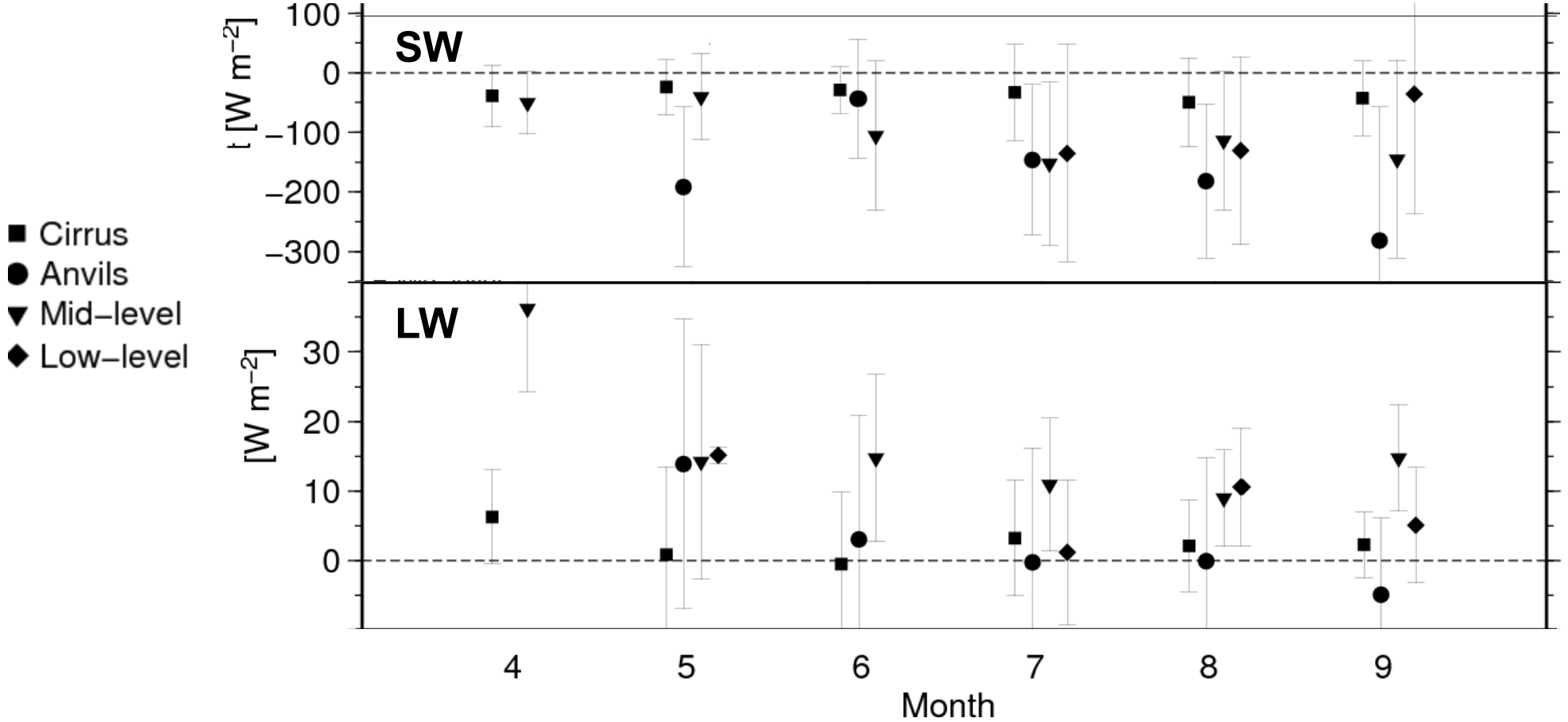
► monthly mean values up to
~ 25% (~ 70 W/m2) at 15°N
~ 50% (~150W/m2) at 10°N
not negligible !

► by cloud type :

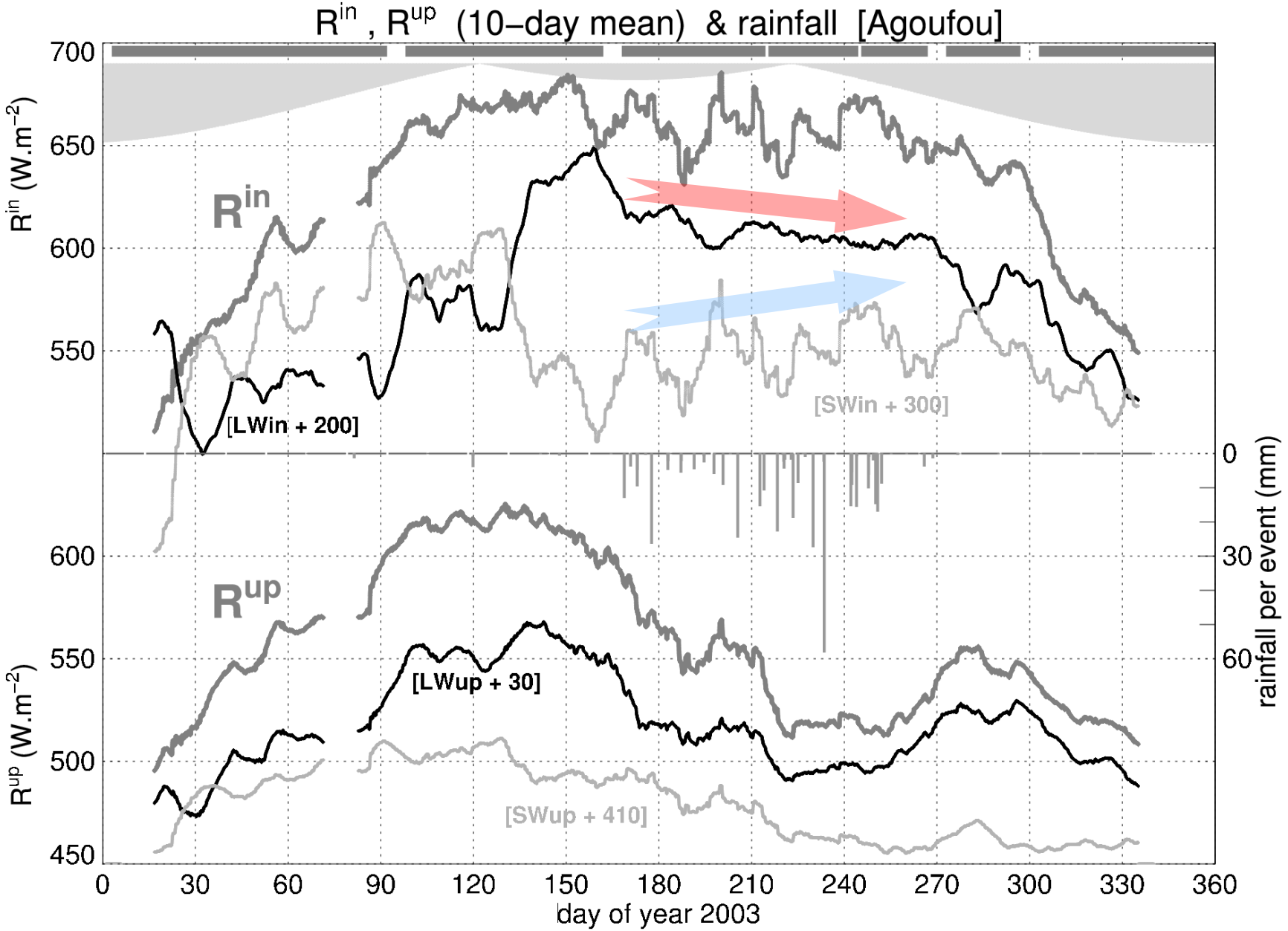


different estimates
of clear-sky SWin
built of a monthly mean clear sky values fitted to TOA

Bouniol et al. (2011)



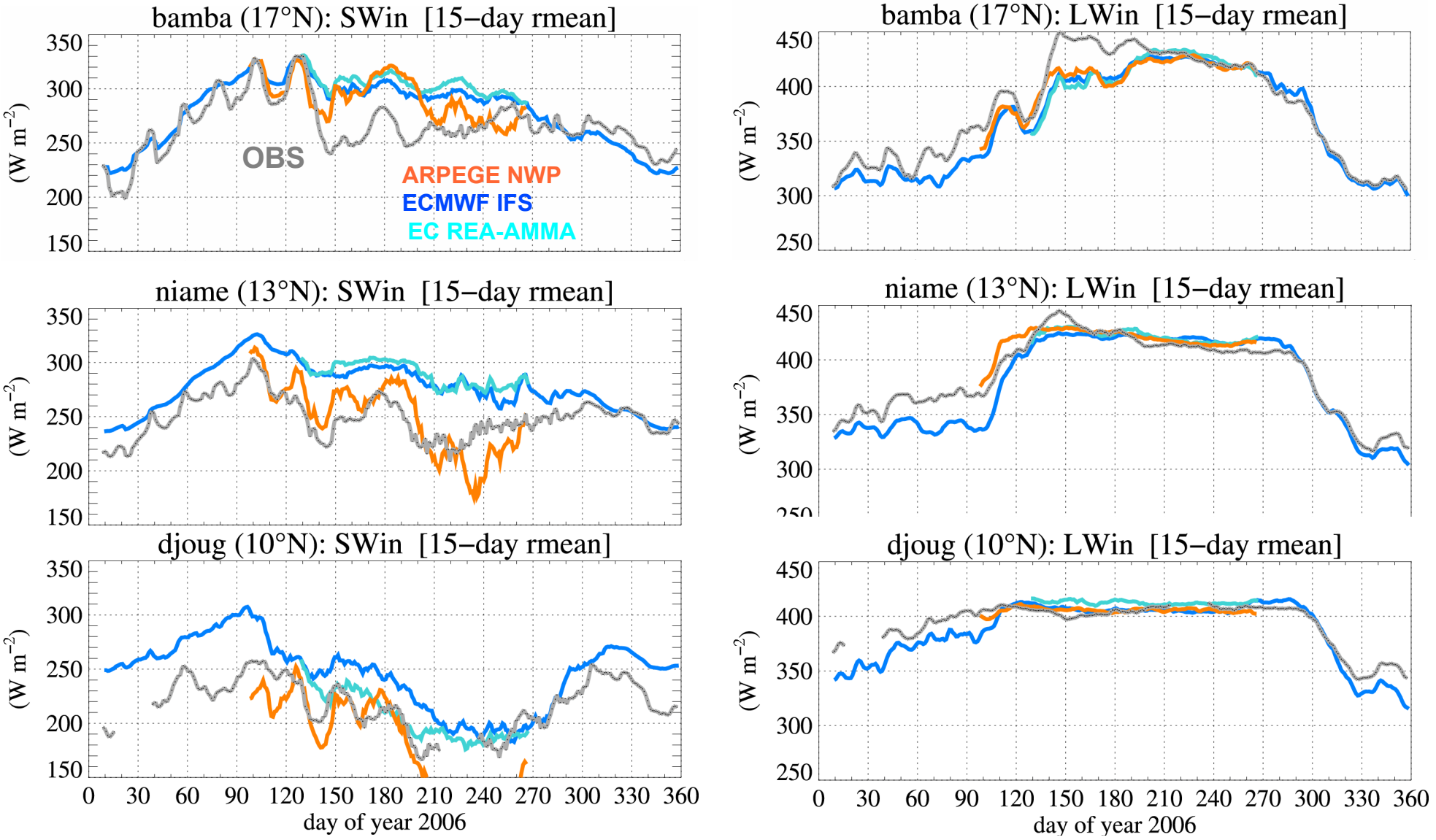
Annual cycle of the surface radiative balance at the surface



satellite products not yet able to properly reproduce this
importance of ground-based datasets

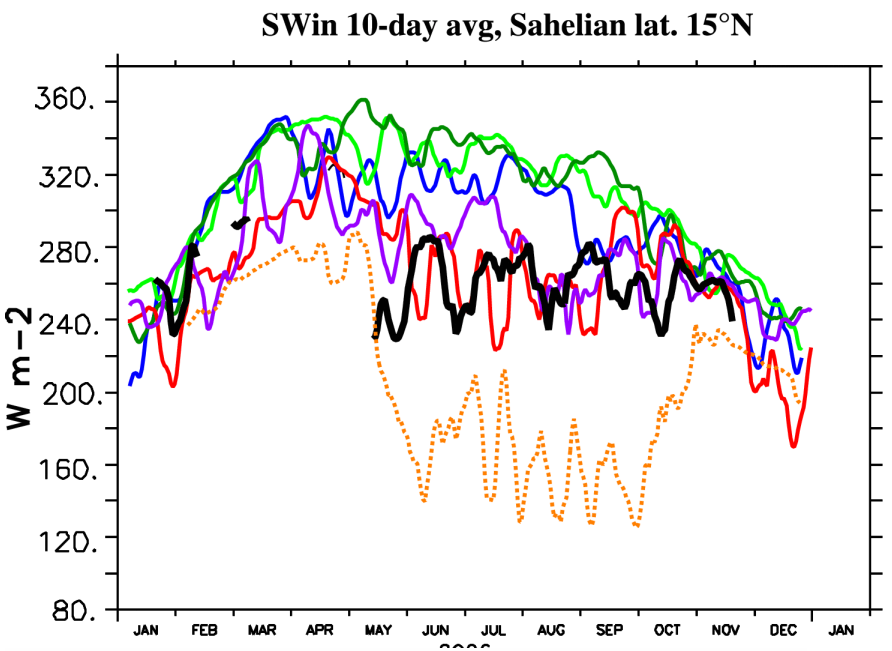
Guichard et al. (2009)
see also Slingo et al. (2009)

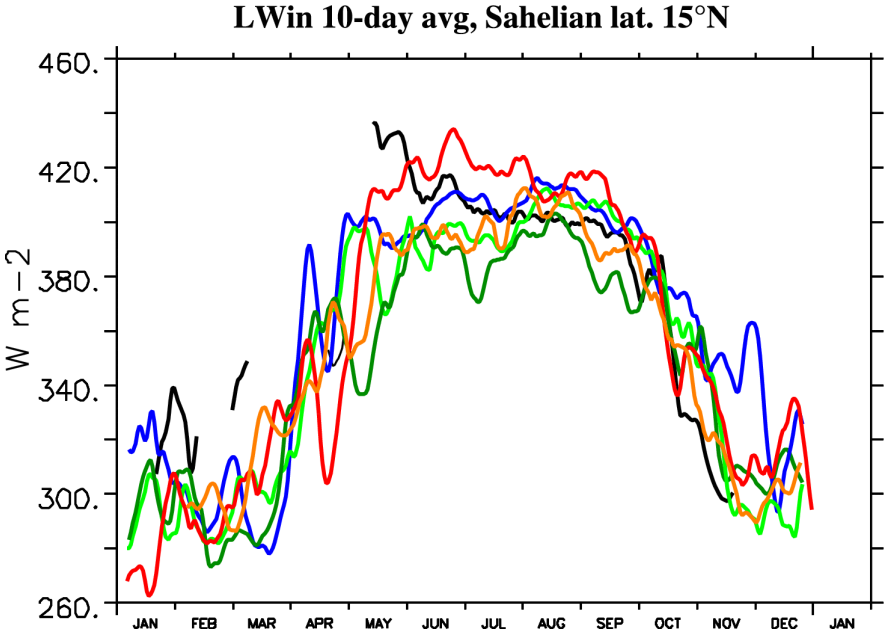
surface incoming radiation in NWP models

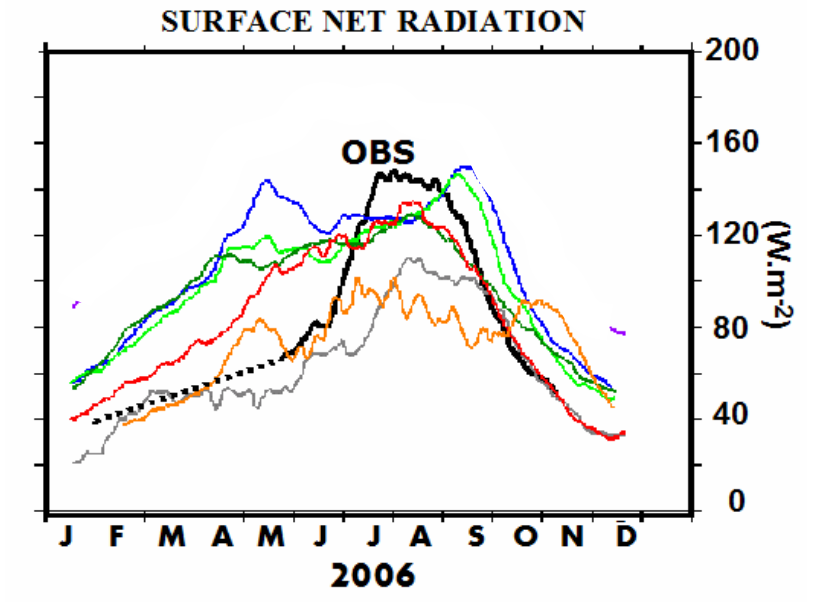


Large and distinct departures from observations in the SW
LW bias reduced during the monsoon, not much sensitivity to differences in clouds
significance of aerosols in Spring, early Summer, but still, cloud equally important

surface incoming radiation in climate models (global and regional)

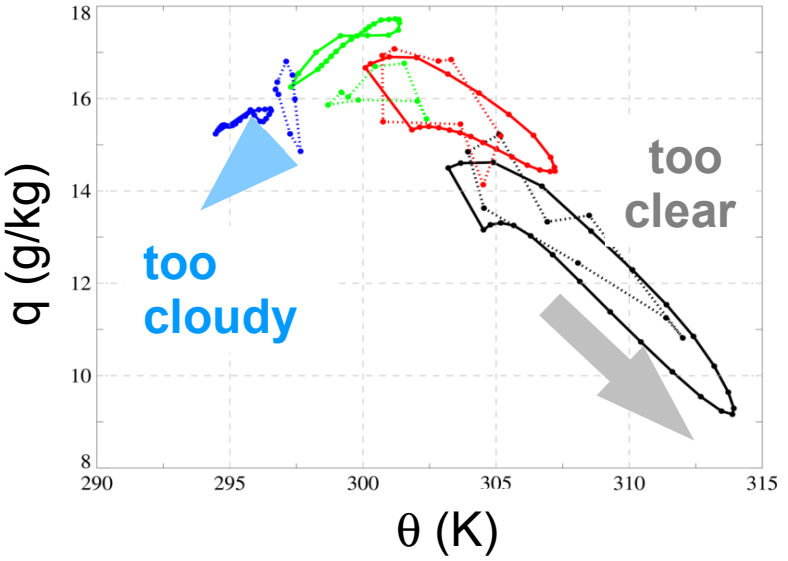






Hourdin et al. (2010)
A.K. Traore (2011)

SCM runs, quick shifts



A. Gounou (2011)

SUMMARY

Datasets, diagnostics, to assess convective and cloud-related processes in models over land in West Africa along contrasted land-atmosphere environments

Next : refine estimates of cloud radiative impact at the surface
EUCLIPSE, radiation model

Still a lot to do with existing ongoing AMMA datasets
preparation (consistency, quality...) and data analysis
composites analyses (MCSs..), interannual variability,....

A lack of mid-level clouds in ARPEGE, not simply environmentally controlled

An underestimation of cloud SW forcing in a large number of models
impact on short time scales via the surface energy balance
which impact on the timing of daytime convective triggering?

What about the other CMIP5 simulations ?

Which sensitivity of these simulations? distinct feedbacks operating?
budgets, compare balances of processes
stratification: analyses by Ts, rainfall...

Role of clouds in the couplings observed between surface LWnet & Plcl (RH) (+DTR)?


Thank you

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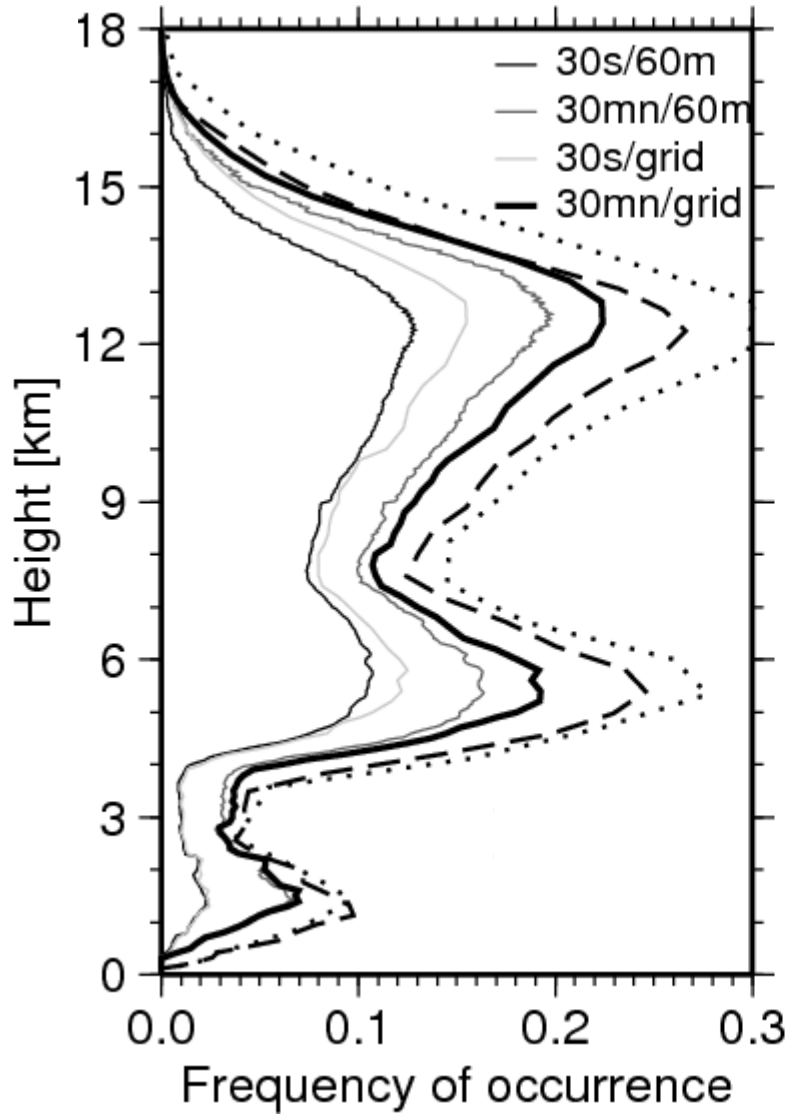

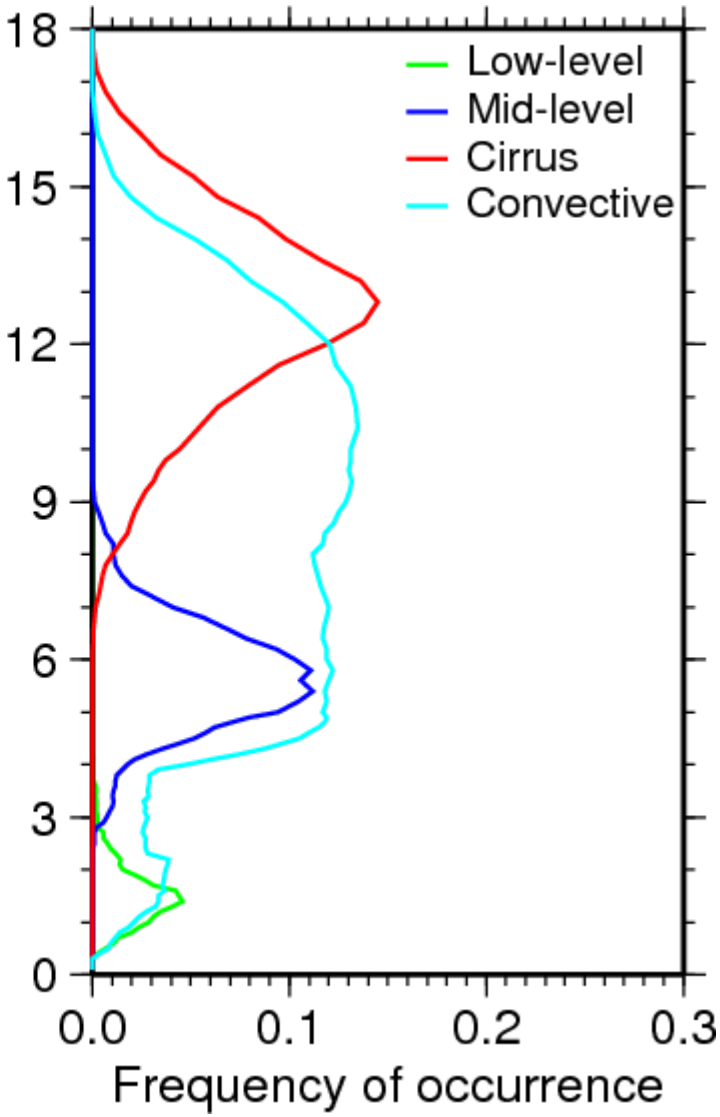

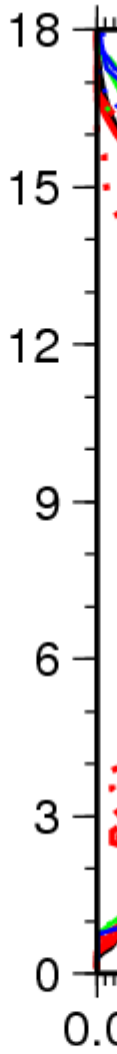

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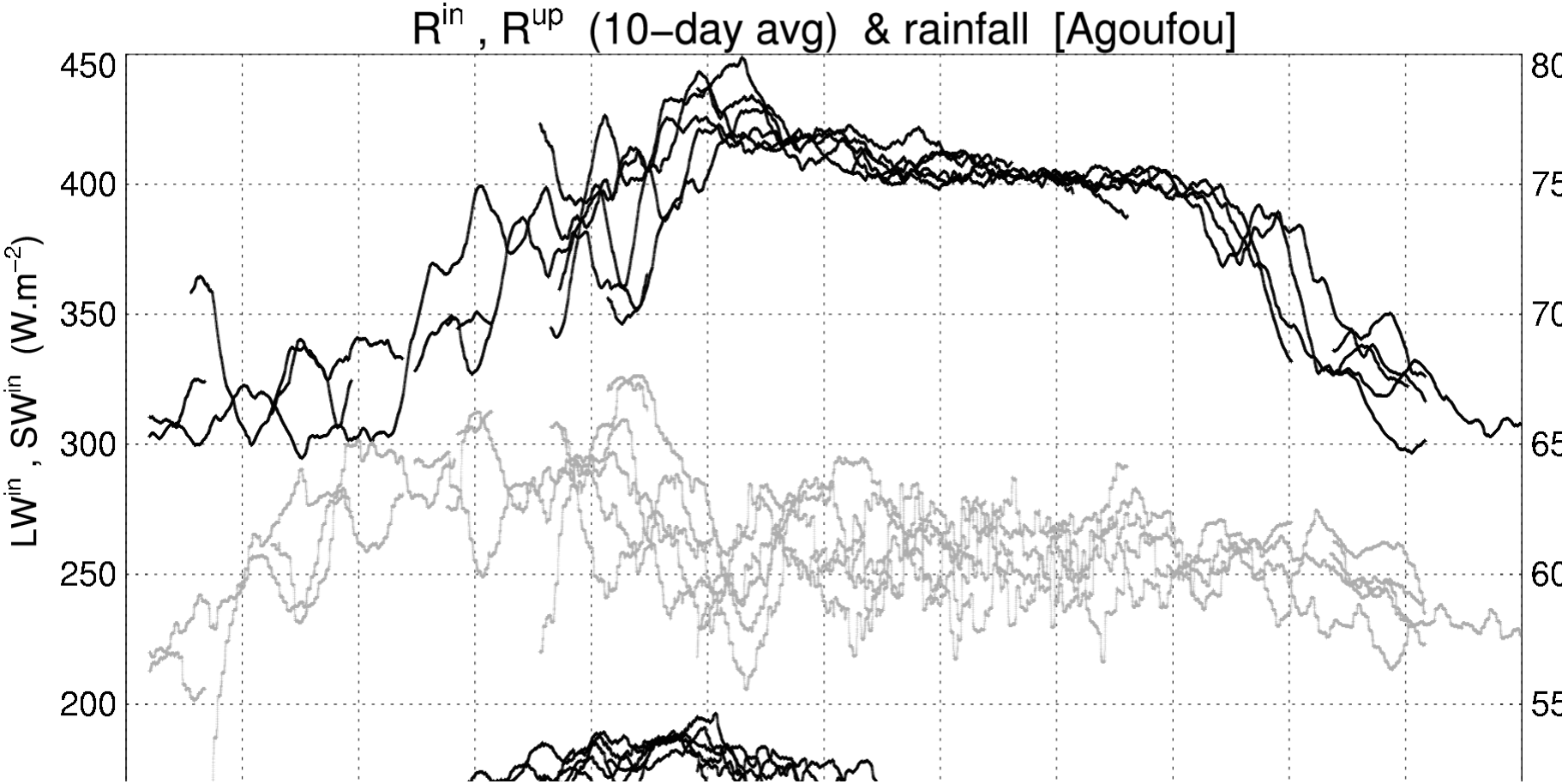
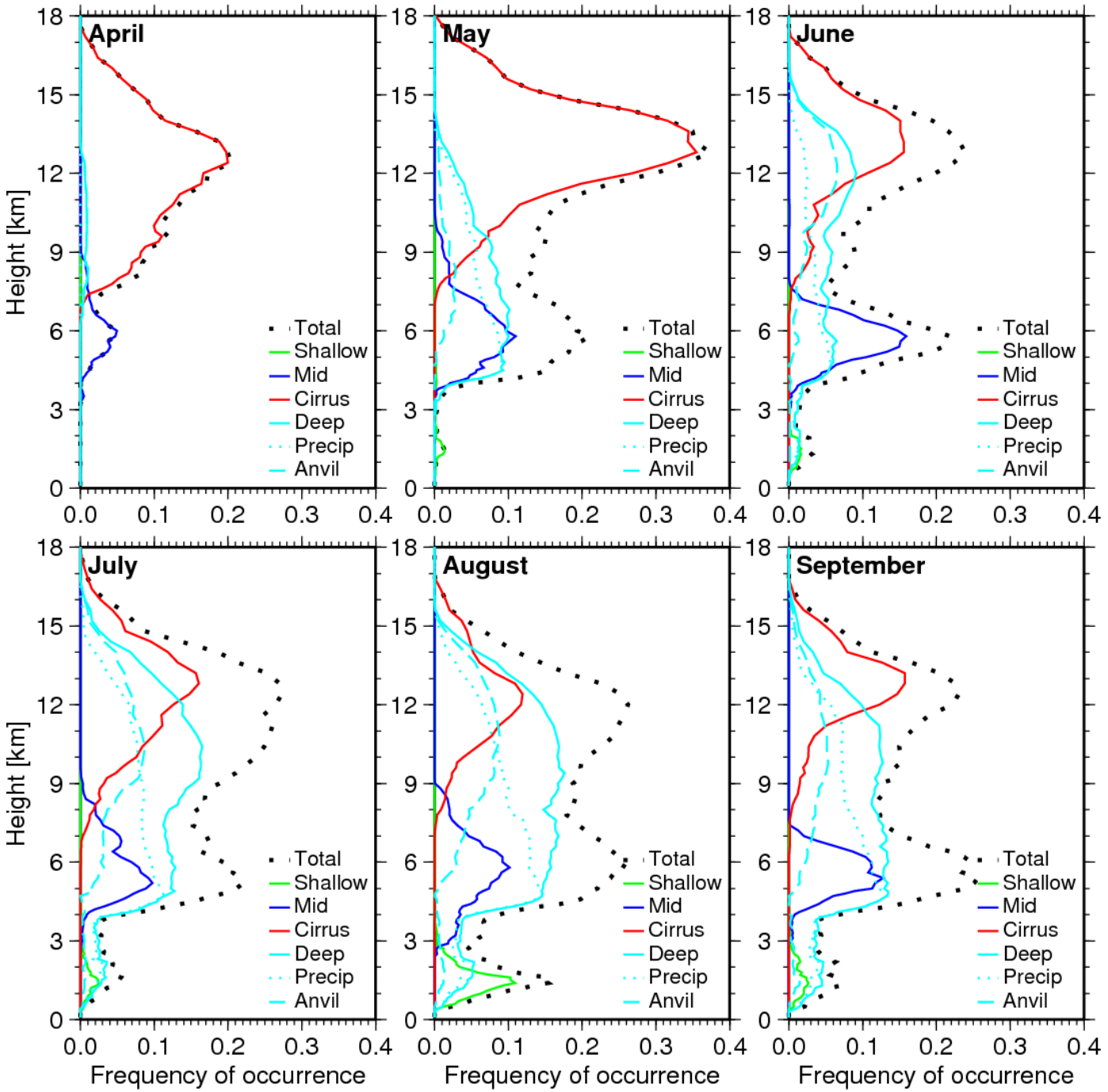

R^in , R^up (10–day avg) & rainfall [Agoufou]
LW^in , SW^in (W.m^-2)
450
400
350
300
250
200
80
75
70
65
60
55



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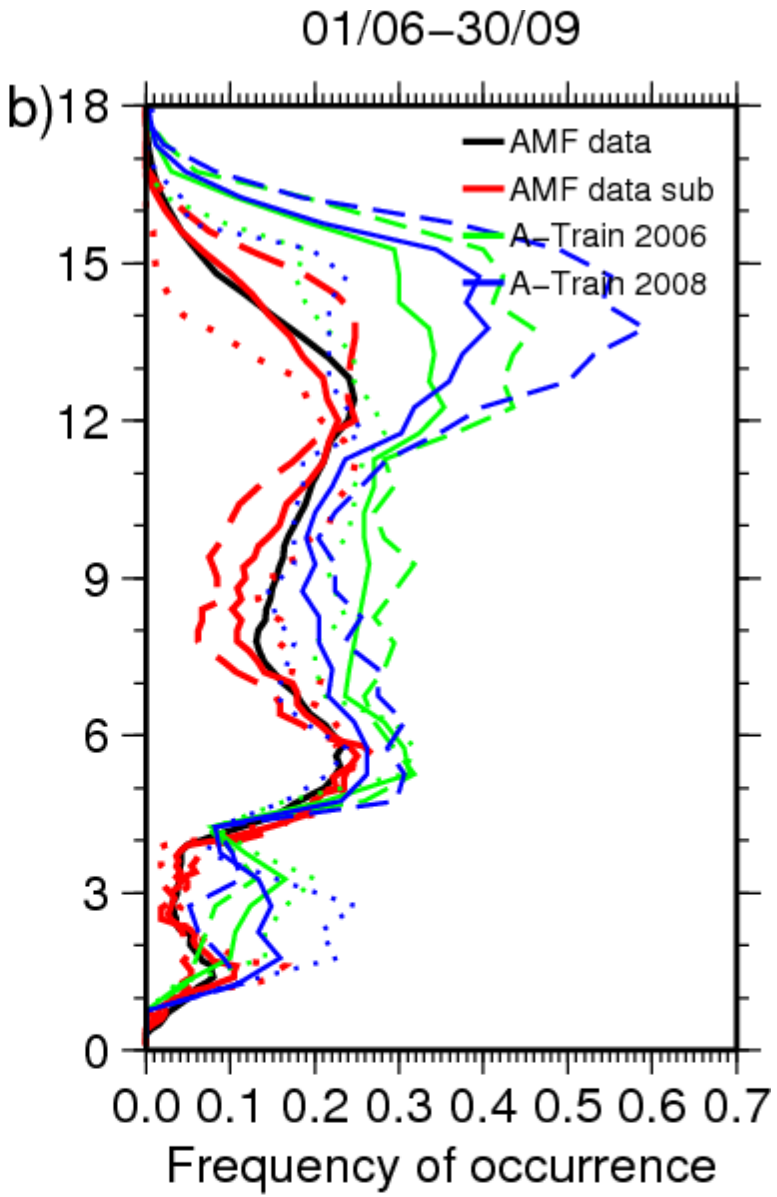
01/06–30/09
b)
18
15
12
9
6
3
0
AMF data
AMF data sub
A–Train 2006
A–Train 2008
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7
Frequency of occurrence