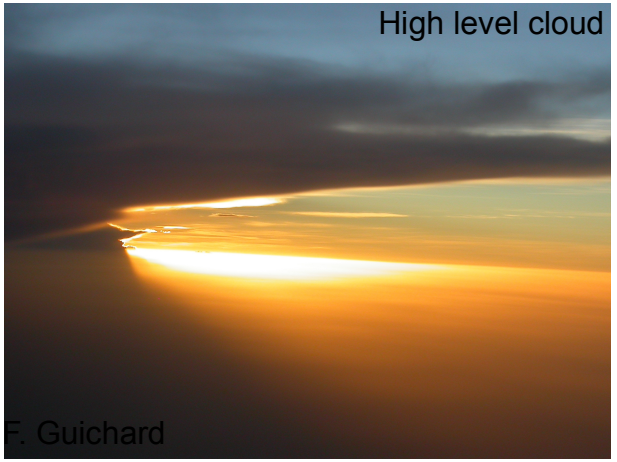
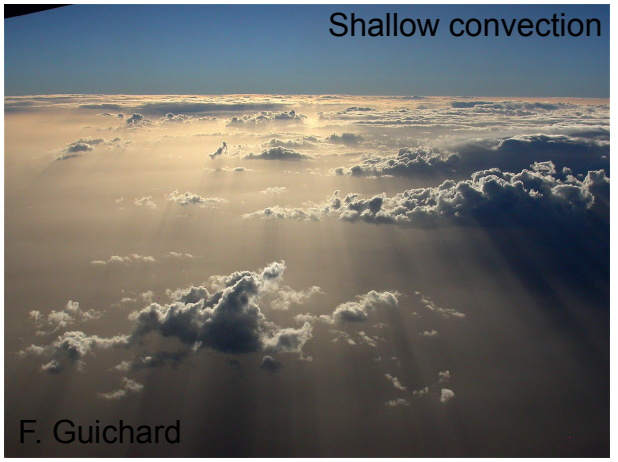
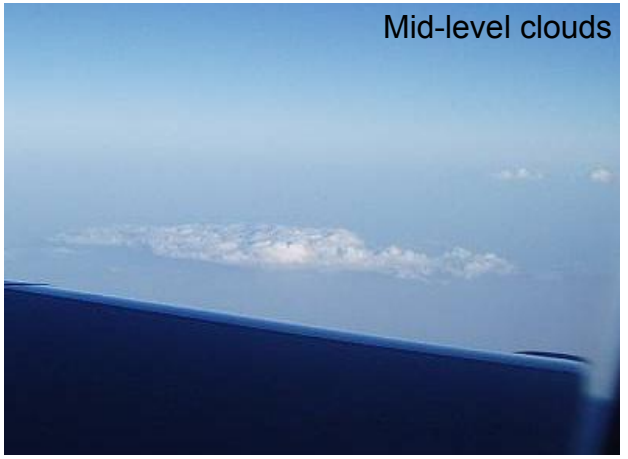






Evaluation of CMIP5 models over West-Africa : focus on cloud representation and radiative feedbacks

D. Bouniol[1], F. Favot[1], F. Guichard[1], F. Couvreux[1], I. Beau[1], H. Douville[1], F. Hourdin[2], A. Voldoire[1], S. Tyteca[1]

[1]CNRM/GAME Météo-France/CNRS, Toulouse, France
[2]LMD, IPSL, Paris, France

Motivations

Before AMMA studies of clouds in the Tropics were mainly devoted to oceanic regions
- clouds can alter temperature gradients and vertical stability => affect circulation patterns
- continental regions are expected to be sensitive to cloud feedbacks on radiative processes that are themselves affecting surface processes and energy balance

New data sets are now to fully/accurately document the cloudiness over WA (ground-based or satellites)
- full description of the vertical cloud profile + associated radiation

Strong effort from the climate community to provide cloud parameters at various time scales (CFMIP/EUCLIPSE)
- understand the processes between cloud/radiation/dynamics

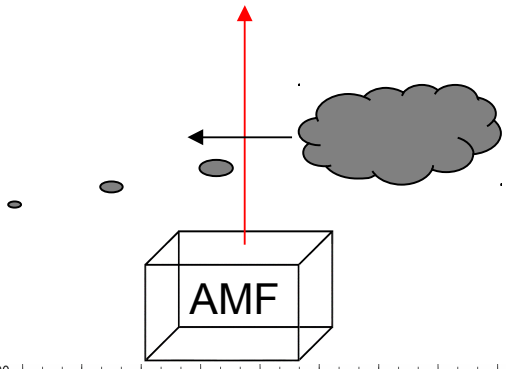
Objectives / outlines

To document the cloud cover before and during the WAF at the continental scale
- related cloud types and processus
- radiative impact of clouds at BOA and TOA

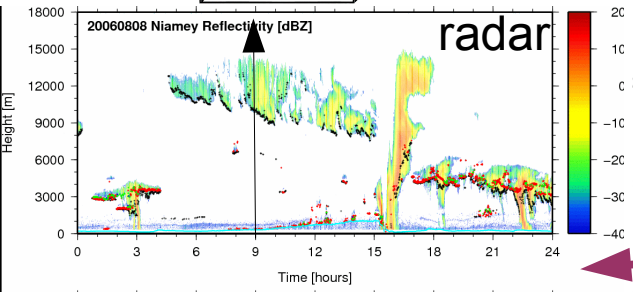
To evaluate the ability of CMIP5 climate models
- in representing the WAF and associated dynamical, rainfall, cloud and radiative patterns
- in representing the various interactions between this components
- in comparison with AMMA-MIP models

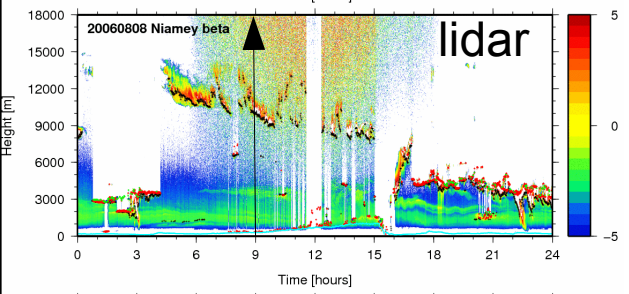
Data sets

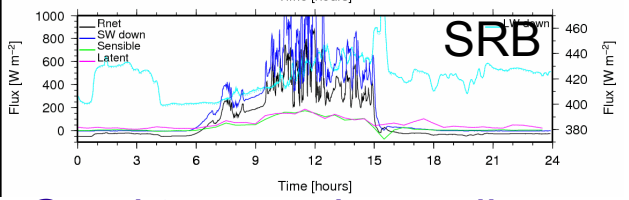
Niamey : 1 year of continous measurements of cloud properties



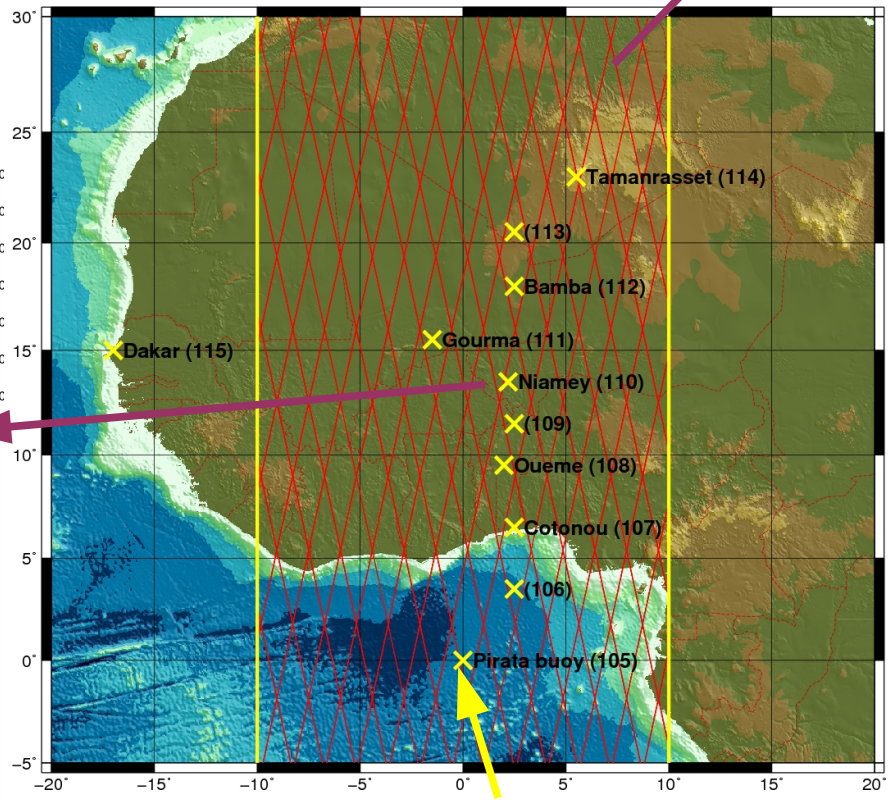
A-Train (CloudSat+CALIPSO)



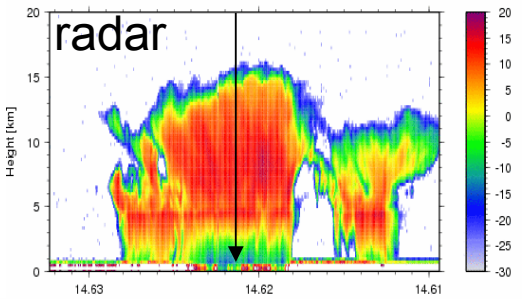


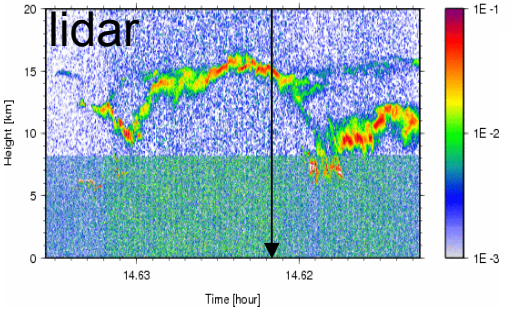


Good temporal sampling



Ground based measurements along the meridional transect





Good spatial coverage

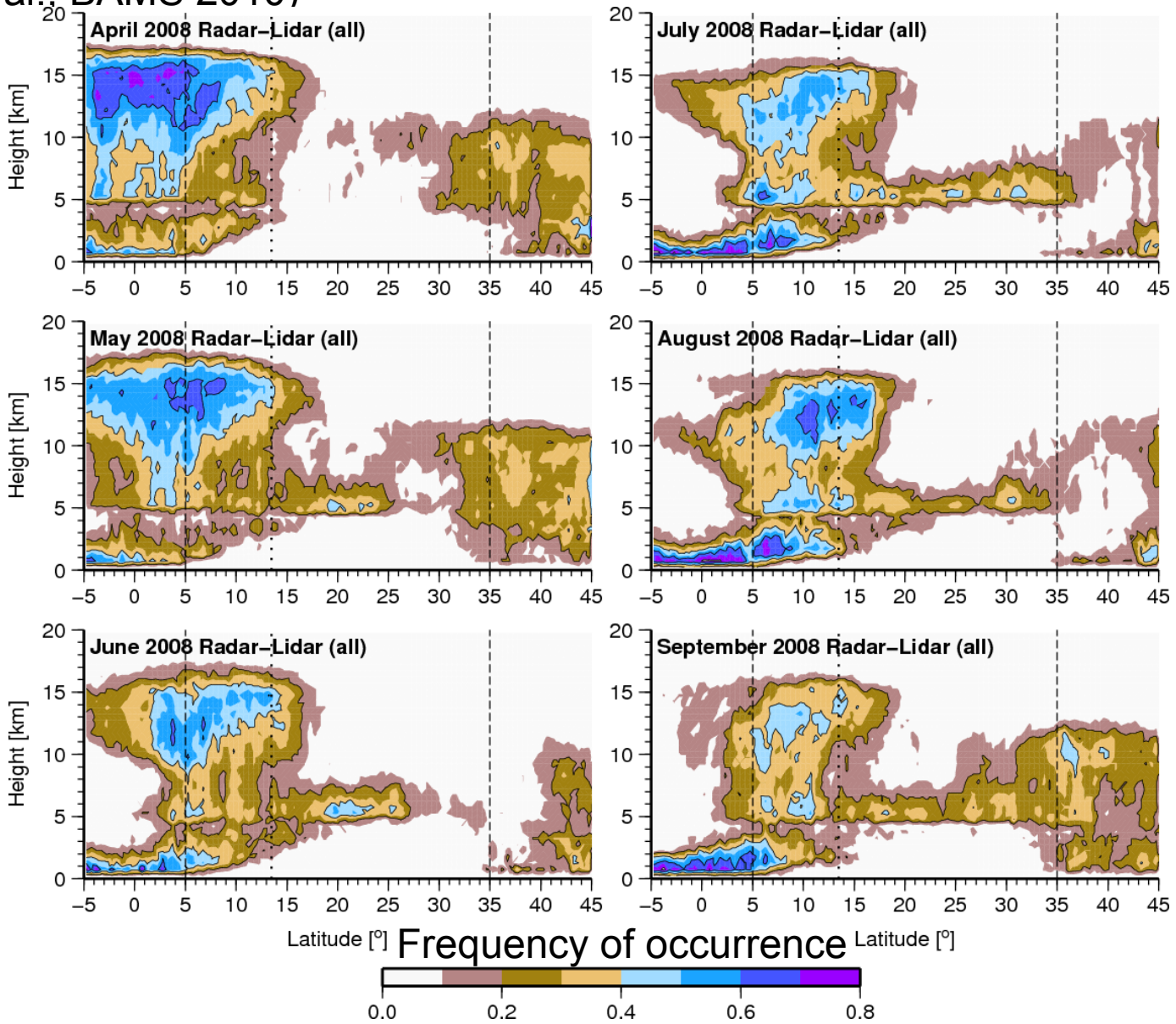
+ other satellites from the A-Train (Aqua), TRMM,...
+ geostationnary satellites
=> ISCCP, GERB...

CFMIP data base :

Model output including cloud parameters in 3D at different temporal resolutions
119 selected stations with high frequency outputs (30 mn), in WA collocated with the measurements sites

Seasonal cycle at the scale of West Africa

A-Train twice a day within [10W ; 10E] transect => each track representative of 0E (cf Hourdin et al., BAMS 2010)



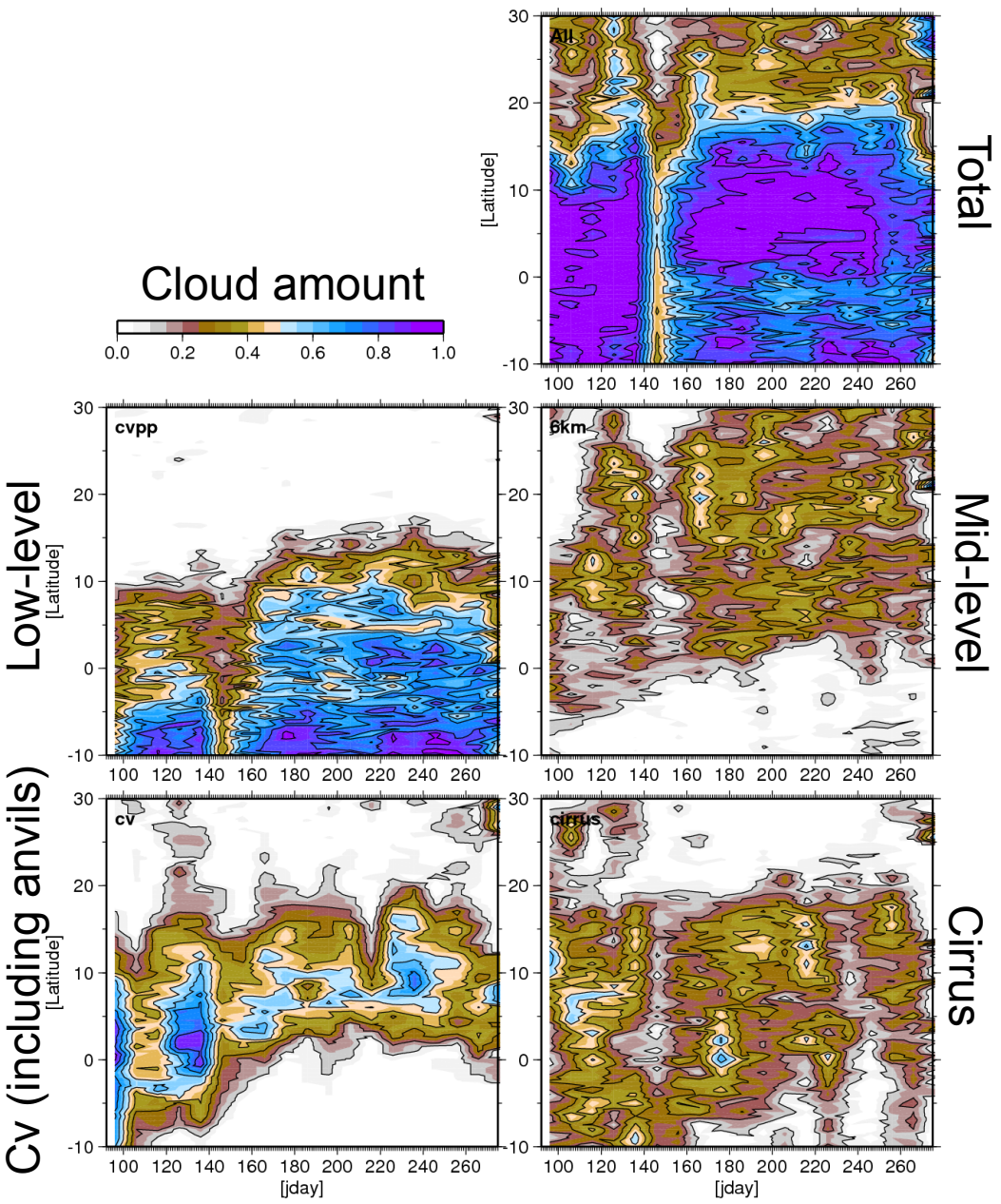
4 main cloud types over the continent

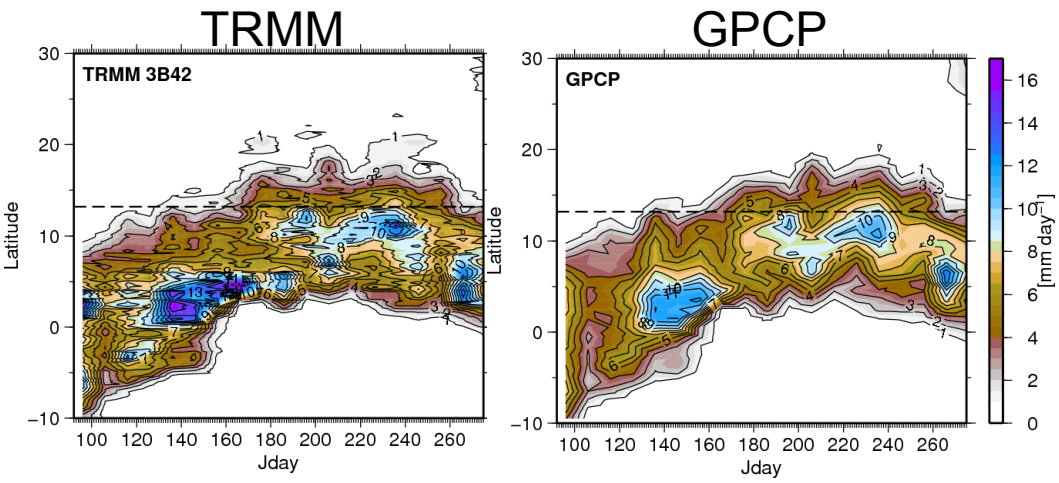
Simple morphological criteria:
Low-level : base < 2km, no deeper than 3,5 km
Mid-level : 2.5 < base < 7 km, top < 8 km
Cirrus : base > 7km
Cv : base < 8 km, top > 5 km, deeper than 5 km + continuity

+Sc over the ocean

J. Slingo (QJRMS 1980) results from GATE : « *to begin to describe a cloud field adequaly, it was necessary to divide clouds into four groups : low-level, middle level, high level and convective* ».

Seasonal cycle at the scale of West Africa

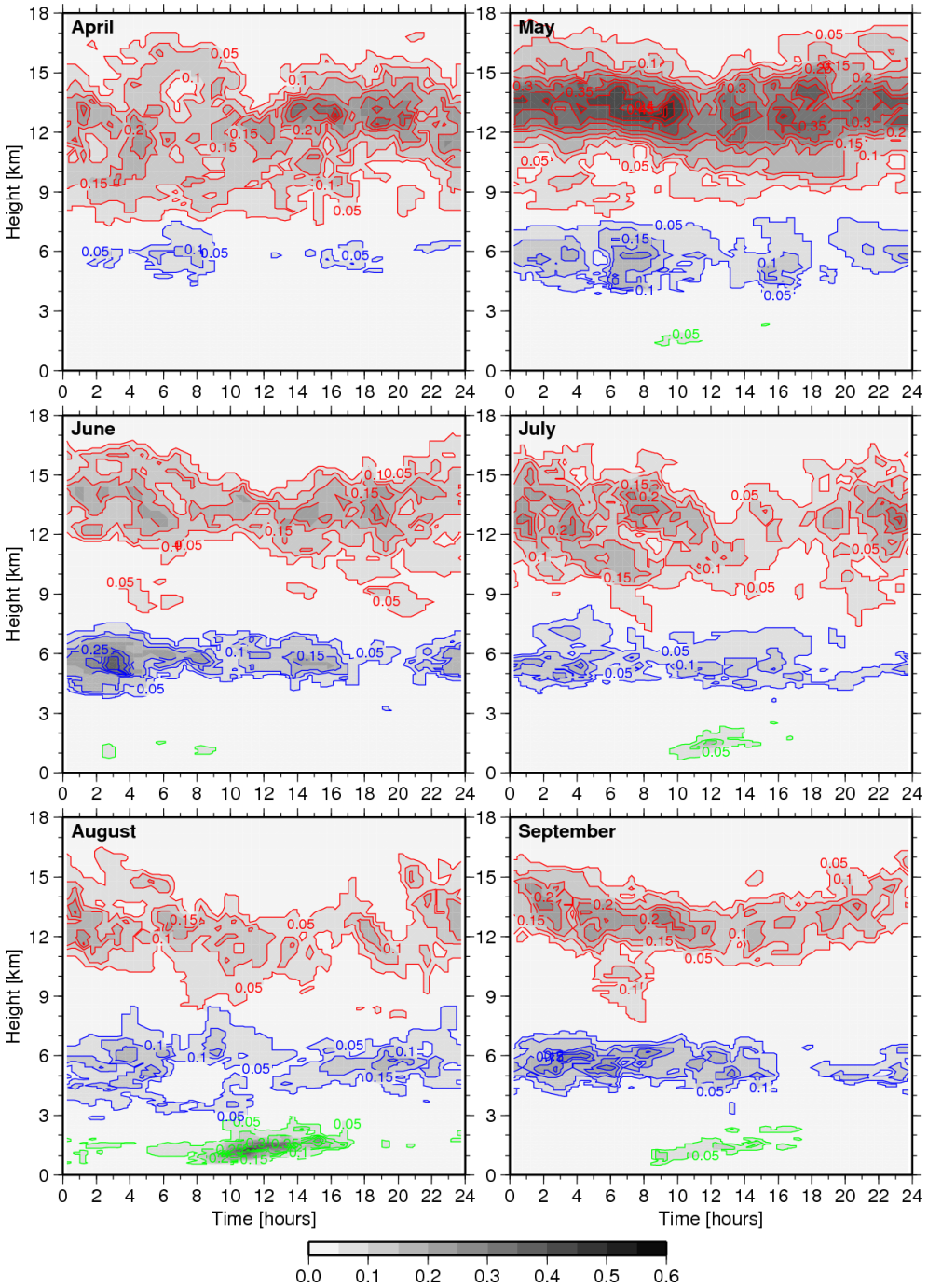




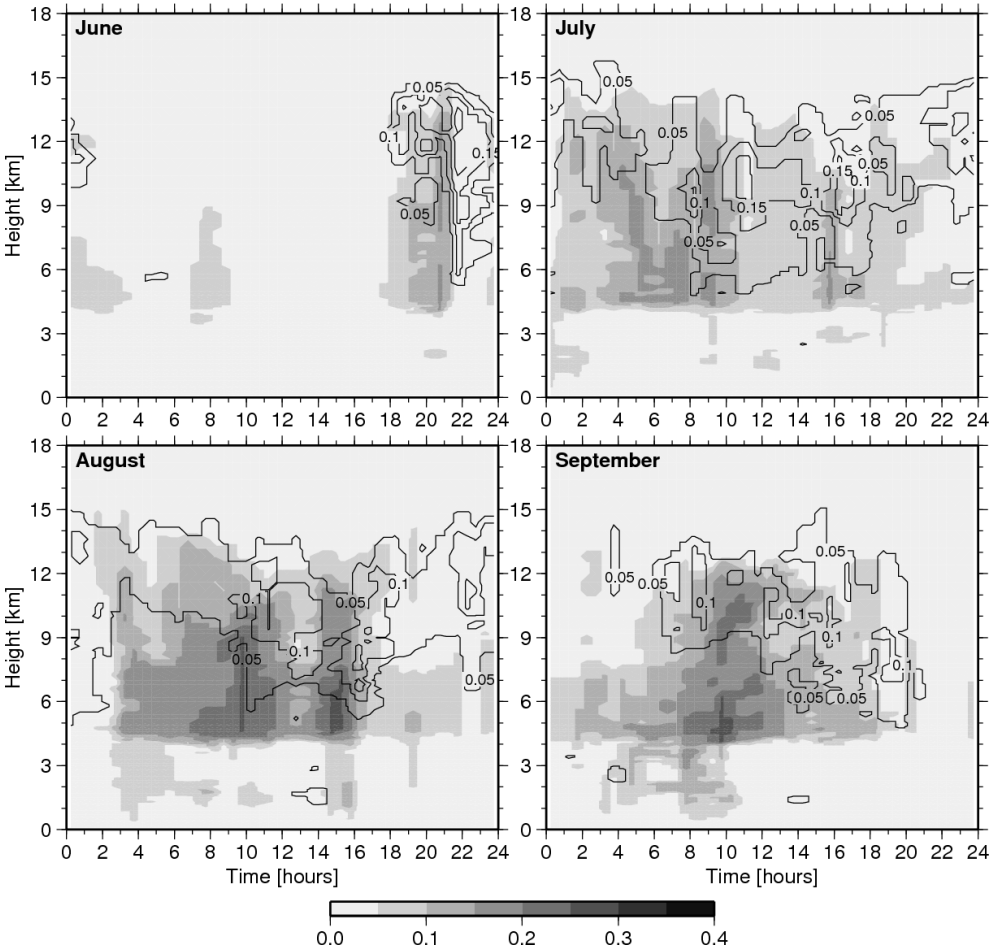
- As expected the rain is strongly correlated with Cv (cf Mathon et al. 2002)
- Low level clouds exist over the Sahel when the monsoon is present
- Cirrus & Mid-level are present all the year long (substancial amount)

Diurnal cycle of the various cloud types at the Niamey station

Cirrus, mid-level, low level



Cv : precipitating (shading) + anvil (contours)

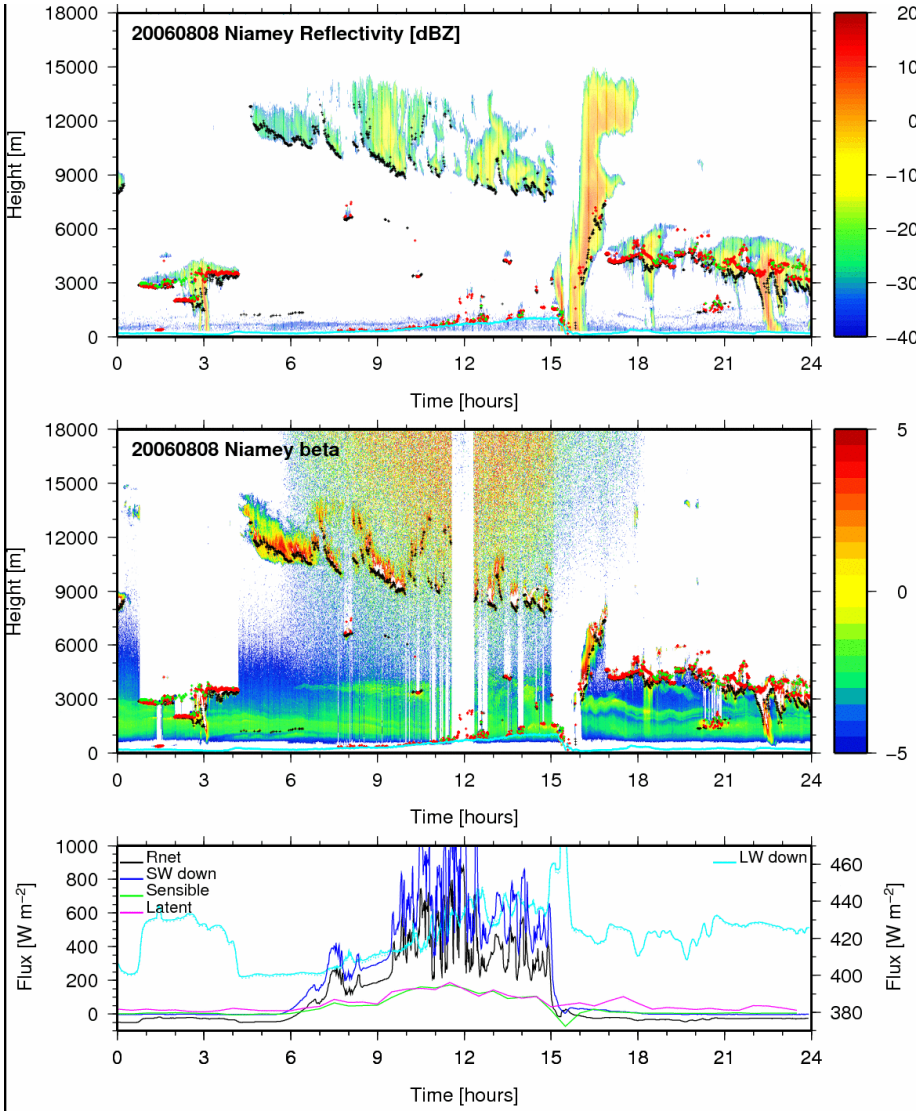


Strong diurnal cycle of all cloud types :

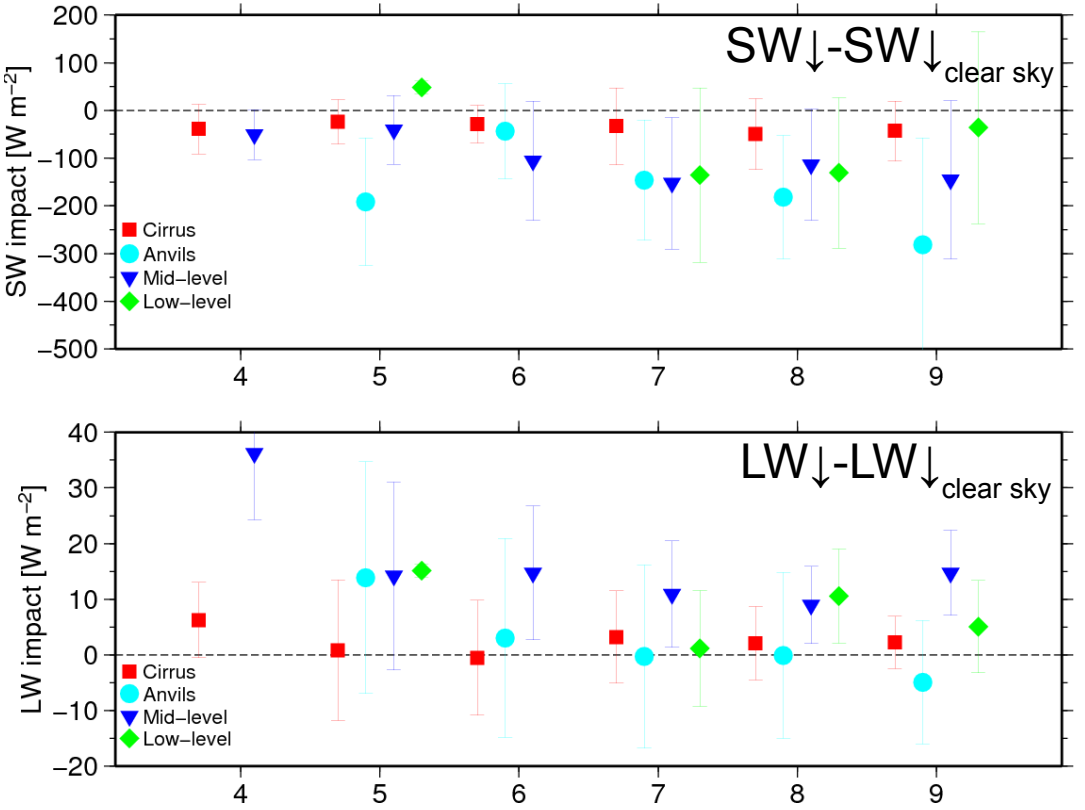
- low-level follow the PBL deepening
- max in mid-level between 3 and 6 UTC
- max in cirrus during night time
- 2 max in precipitations (july & august) followed by extended anvils

Results consistent with Duvel (1989) using IR data

Cloud radiative effect at the surface

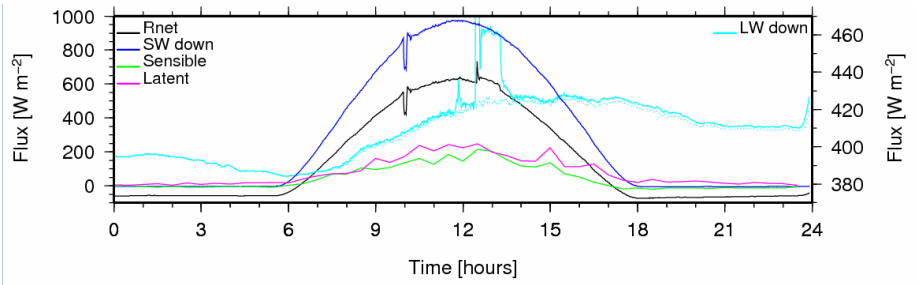


Emperical estimation using only data



Mid-level clouds have a strong effect in SW and LW
Strong effect for anvils & low-level in the SW

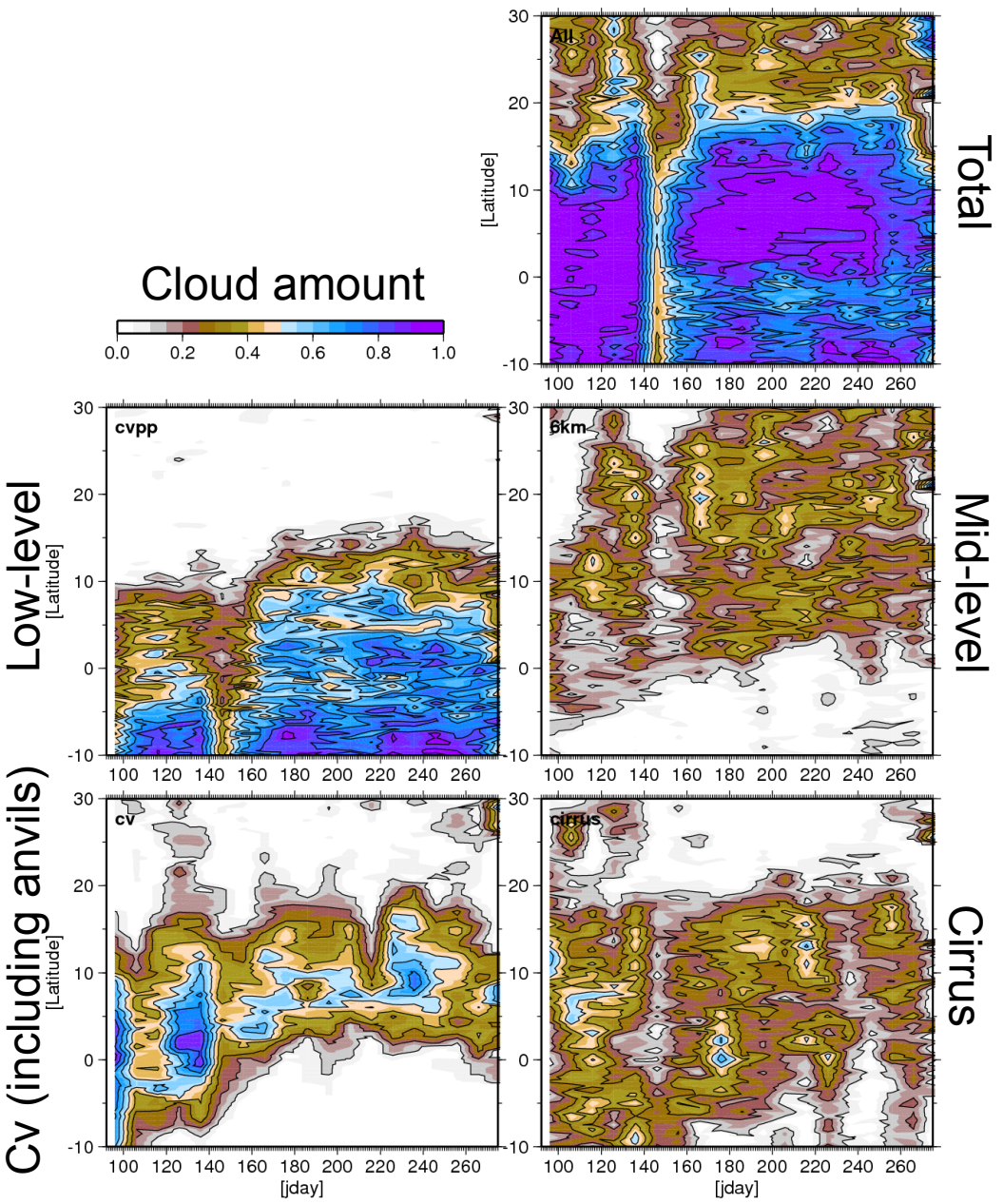
Surface radiative measurements on a clear day



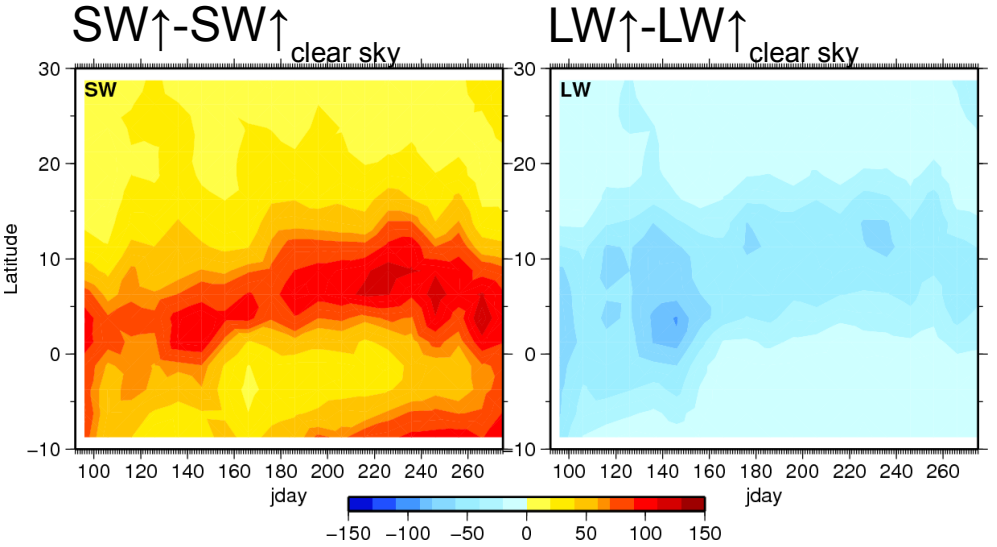
These estimates need to be refined :

- LW estimation (need to better take into account thermodynamical profiles)
- Need to better take into account aerosol loading

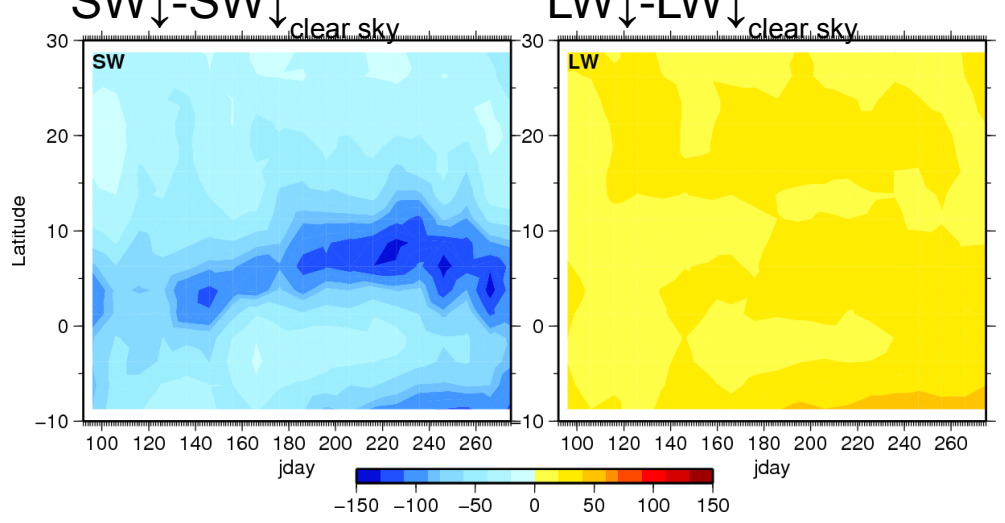
At the continental scale



TOA CRE from ISCCP



BOA CRE from ISCCP



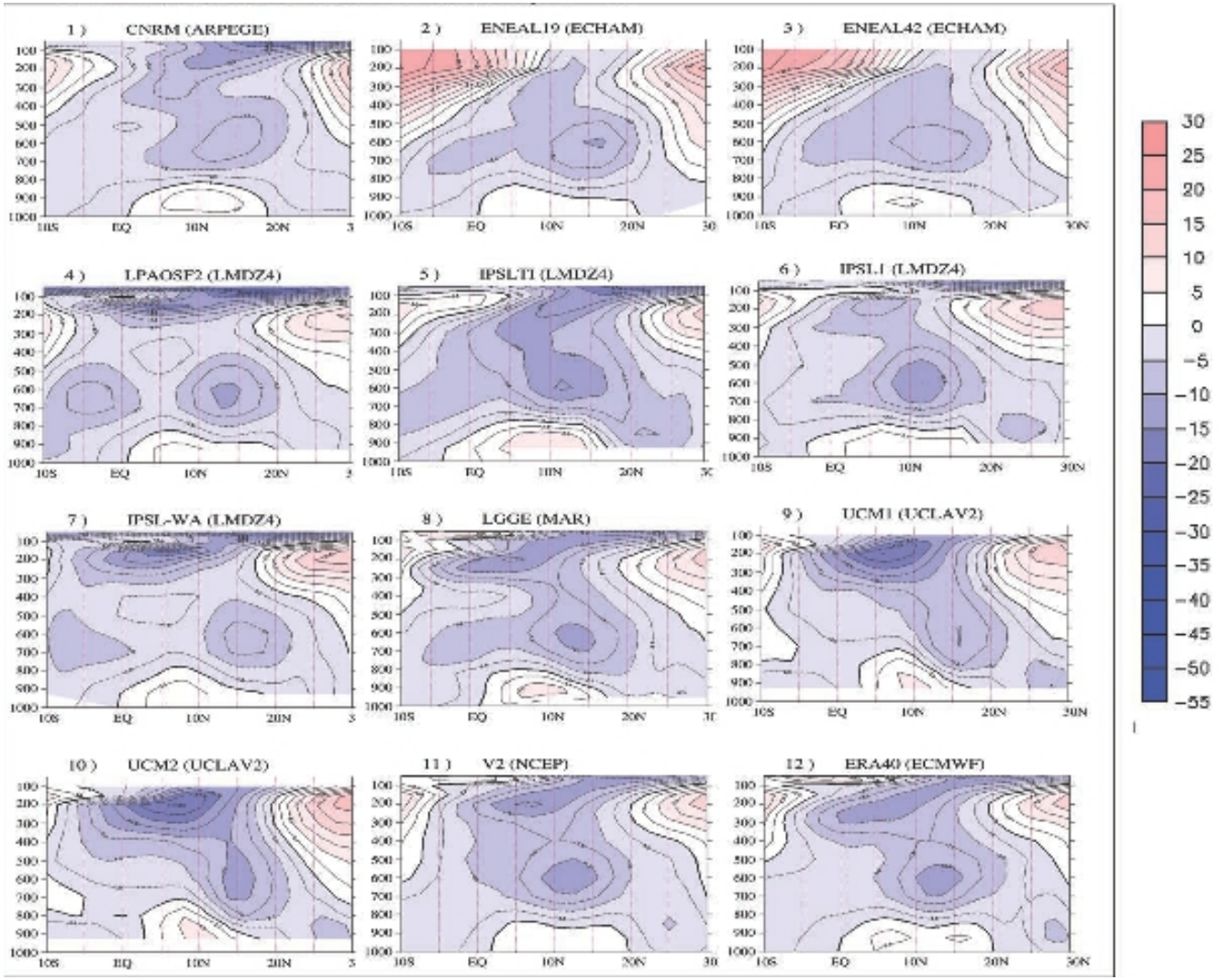
Strongest values are correlated with cv, but non negligible contribution of other cloud types (6km over Sahara)

WAF in AR5 simulations : zonal wind JJAS

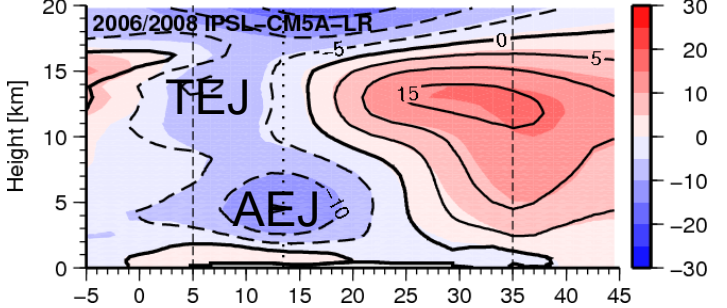
AMIP experiment = prescribed SST

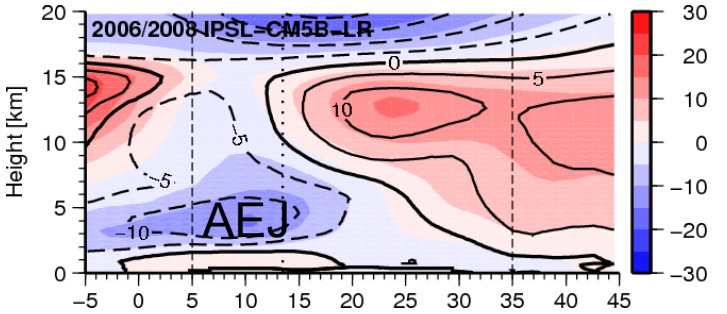
2006/2008

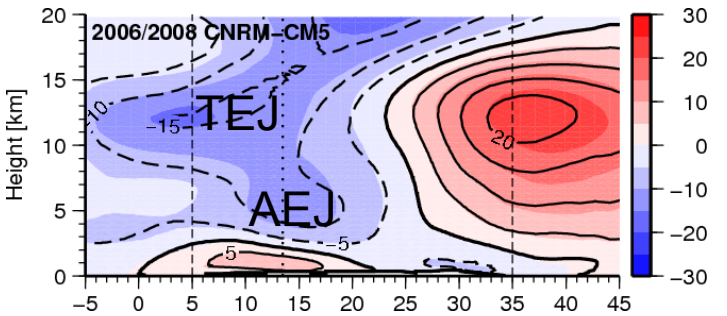
AMMA-MIP : 2000

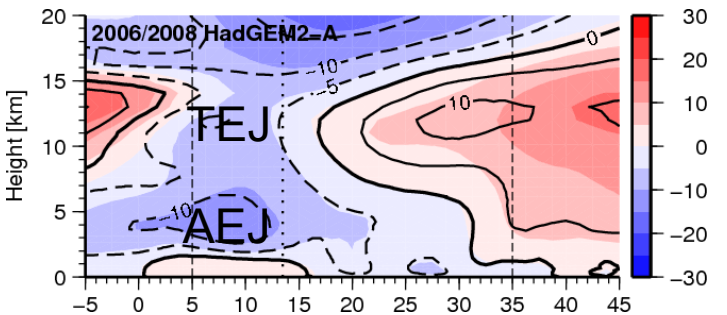


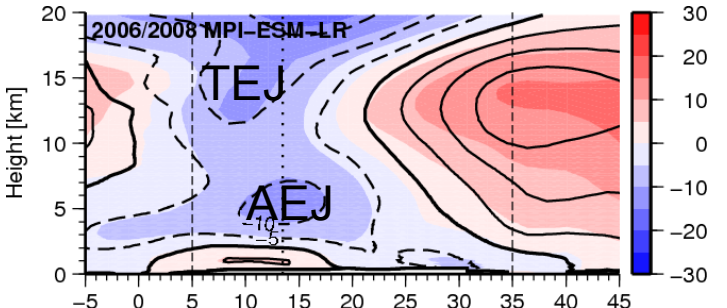
Hourdin et al. (2010)



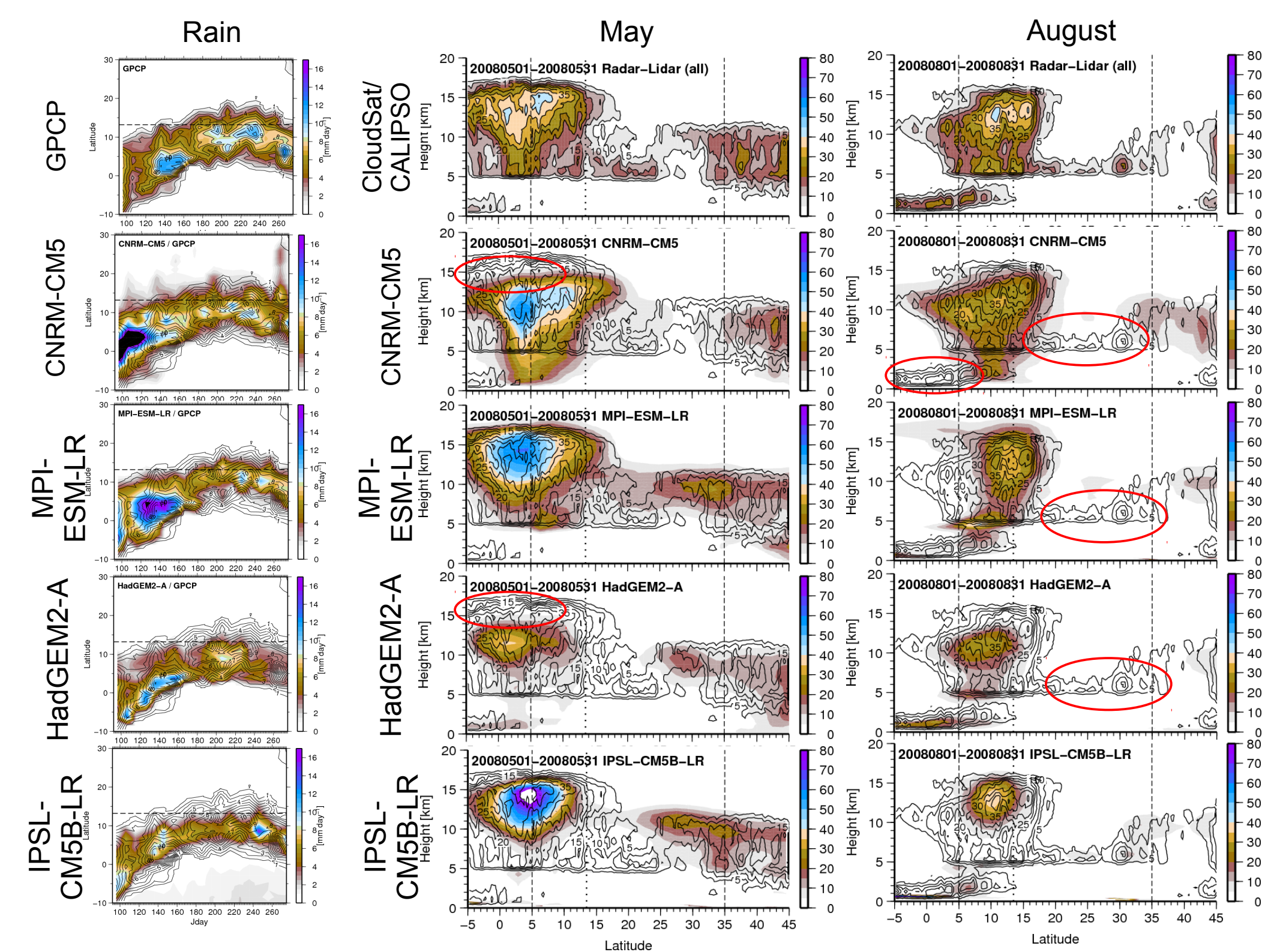






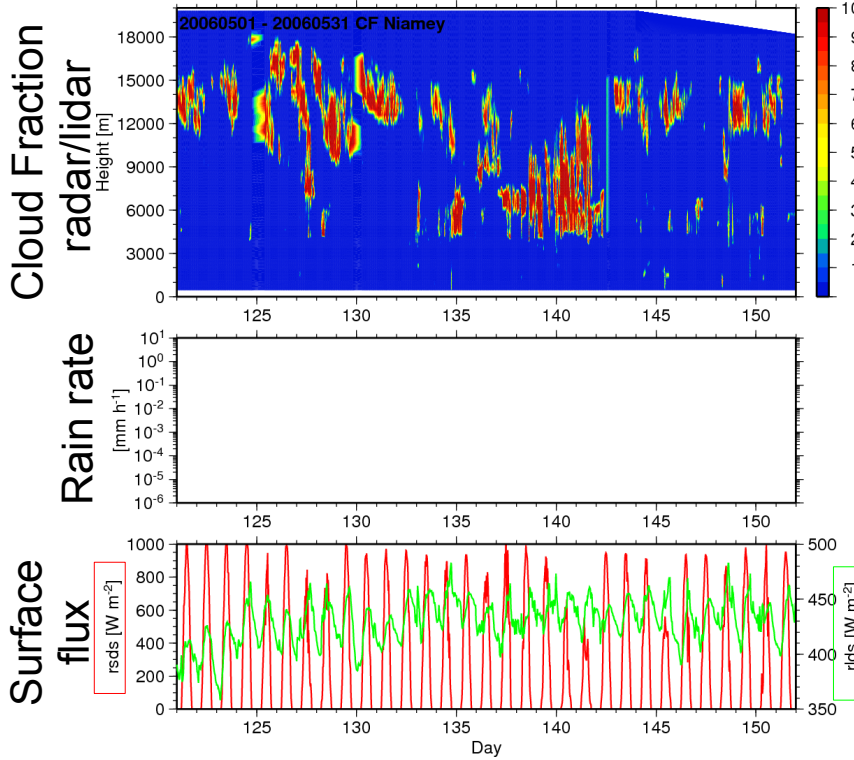


Monsoon flow & AEJ simulated but with spread in intensity & position


Rain
May
August
GPCP
CNRM-CM5
MPI-ESM-LR
HadGEM2-A
IPSL-CM5B-LR
CloudSat/ CALIPSO
GPCP
CNRM–CM5 / GPCP
MPI–ESM–LR / GPCP
HadGEM2–A / GPCP
20080501–20080531 Radar–Lidar (all)
20080501–20080531 CNRM–CM5
20080501–20080531 MPI–ESM–LR
20080501–20080531 HadGEM2–A
20080501–20080531 IPSL–CM5B–LR
20080801–20080831 Radar–Lidar (all)
20080801–20080831 CNRM–CM5
20080801–20080831 MPI–ESM–LR
20080801–20080831 HadGEM2–A
20080801–20080831 IPSL–CM5B–LR
Latitude
Height [km]
Jday
[mm day⁻¹]

At smaller temporal scale : Niamey
May = pre-monsoon

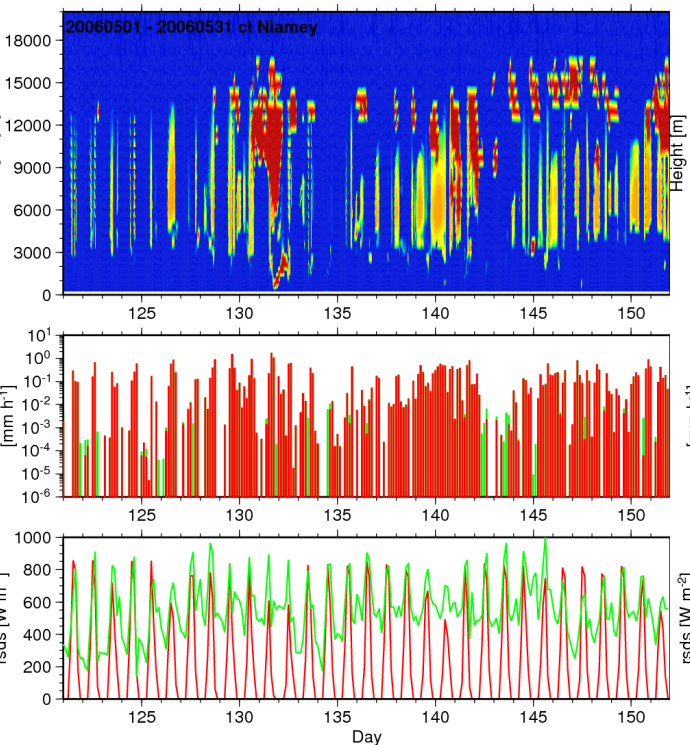
AMF measurements
30 mn averaged



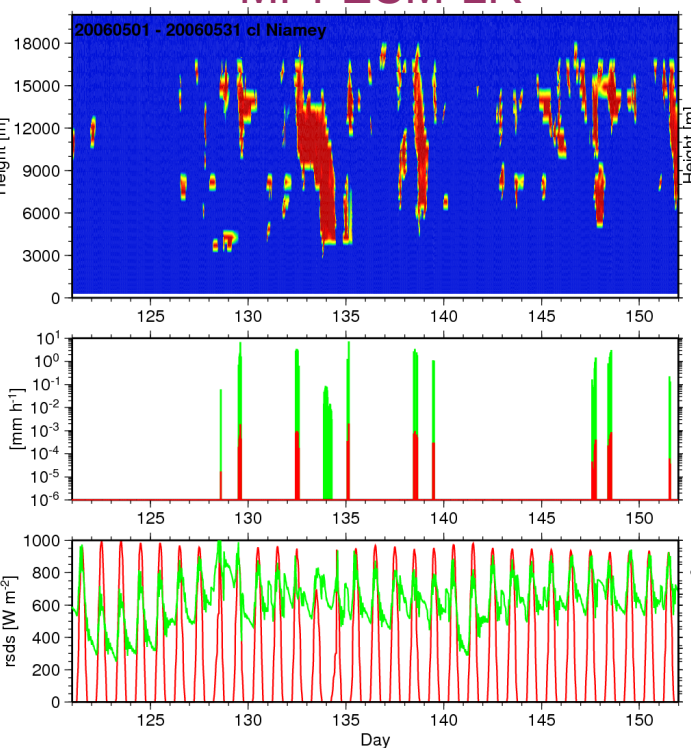
Isolated cv system,
few rain event
Mid-level + Cirrus

The monthly mean results from very different time series

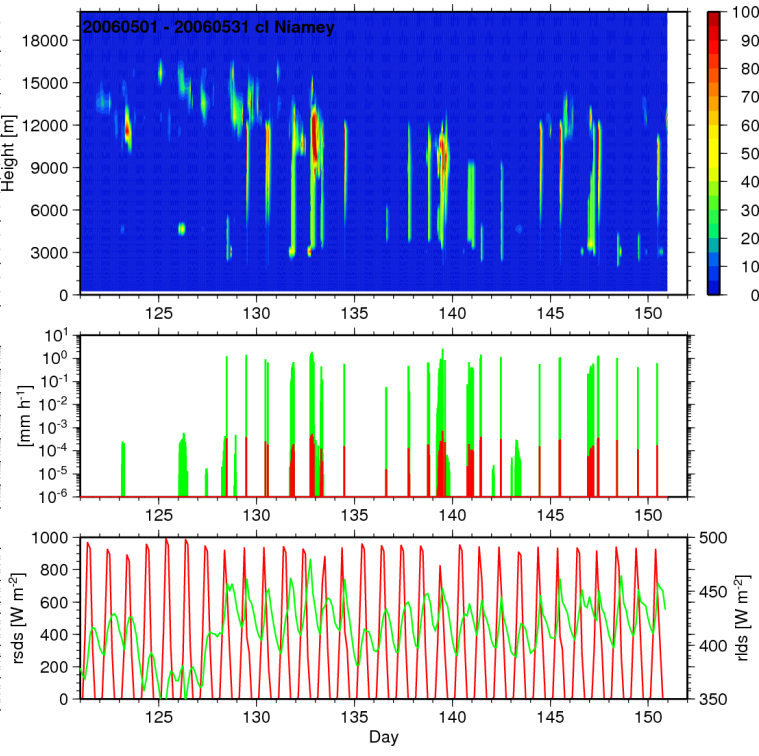
CNRM-CM5



MPI-ESM-LR



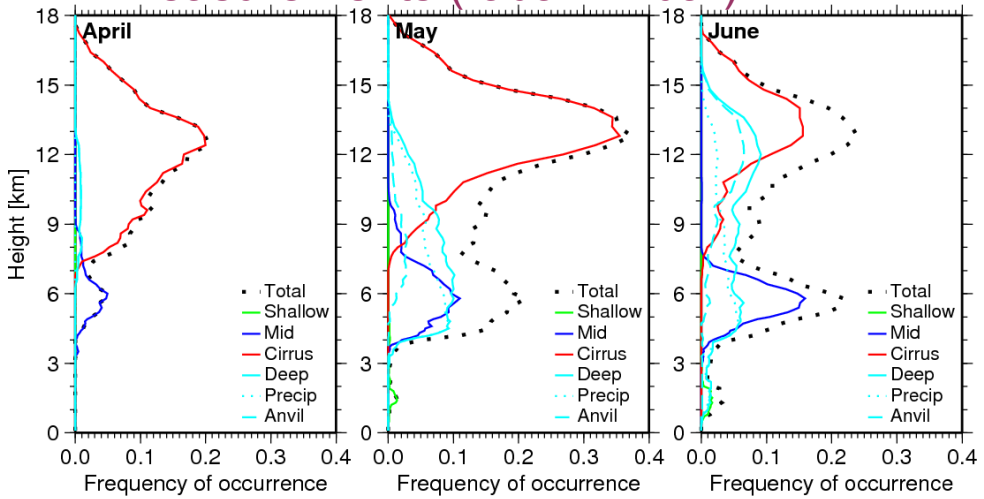
HadGEM2-A



Separation by cloud types : pre-monsoon / Niamey

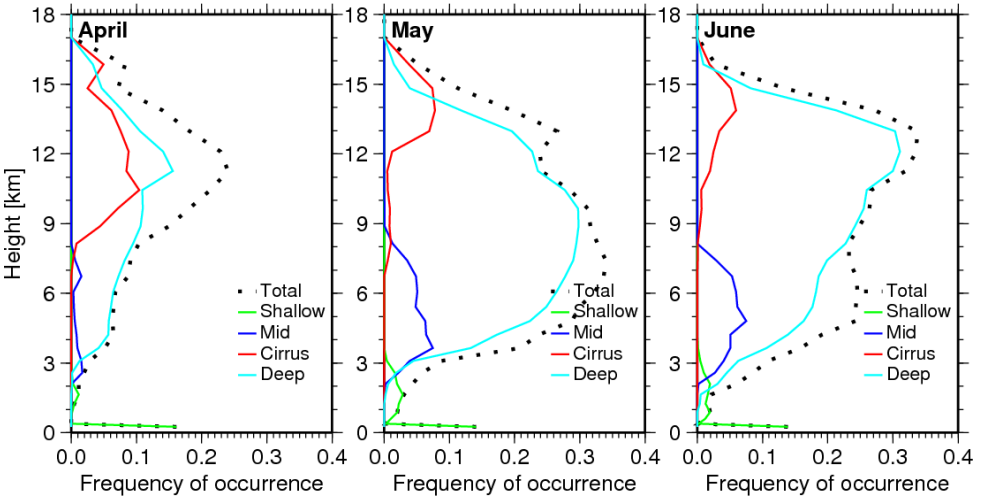
4 categories :
Low-level : base < 2km + no deeper than 3.5 km
Mid-level : 2.5 < base < 7 km + top < 8km
Cirrus : base > 7 km
Cv : base < 8 km, top > 5 km, deeper than 5 km + continuity

AMF measurements (radar + lidar)

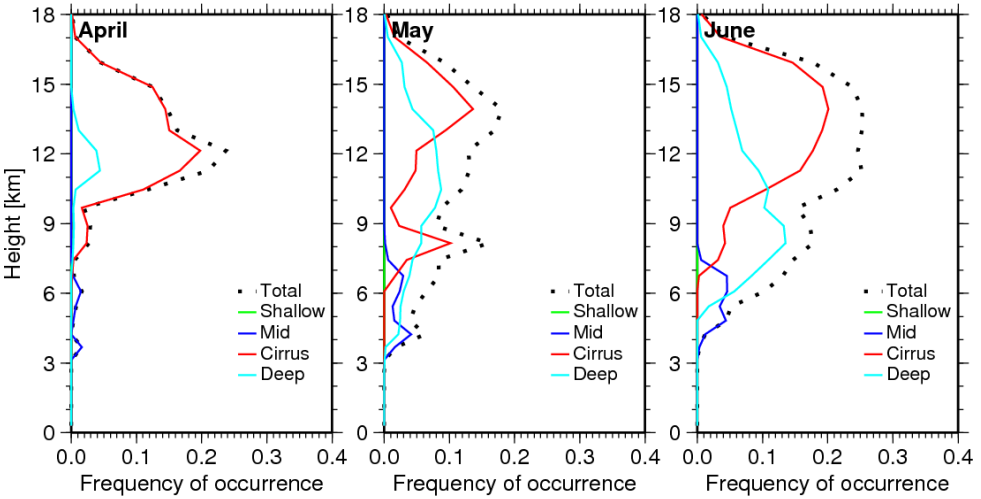


All models have mid-level clouds + cirrus (not numerous enough)
HadGEM2-A & CNRM-CM5 have deep cv clouds all the year long

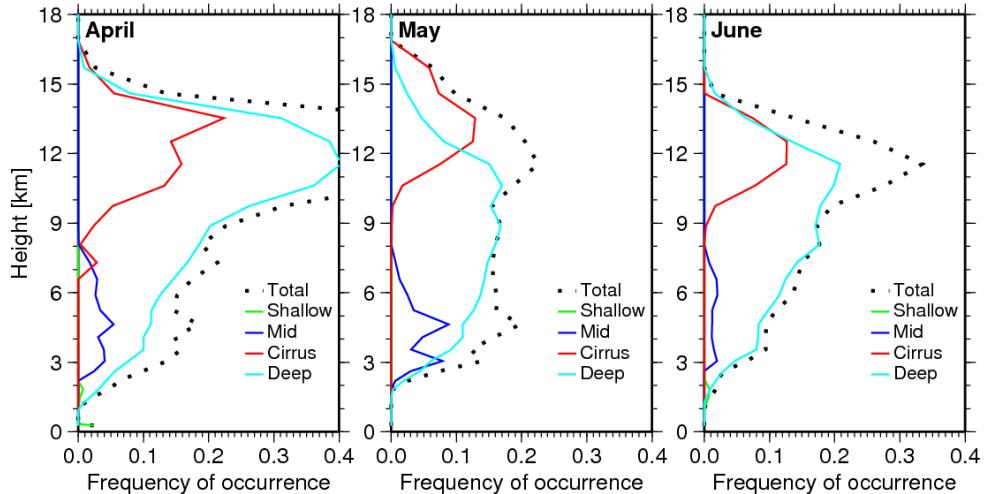
CNRM-CM5



MPI-ESM-LR

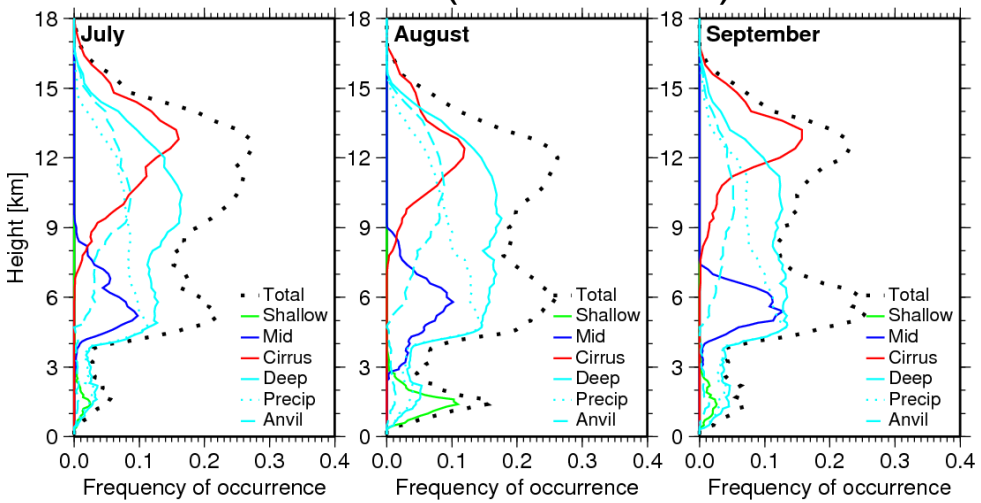


HadGEM2-A



Separation by cloud types : monsoon / Niamey

AMF measurements (radar + lidar)

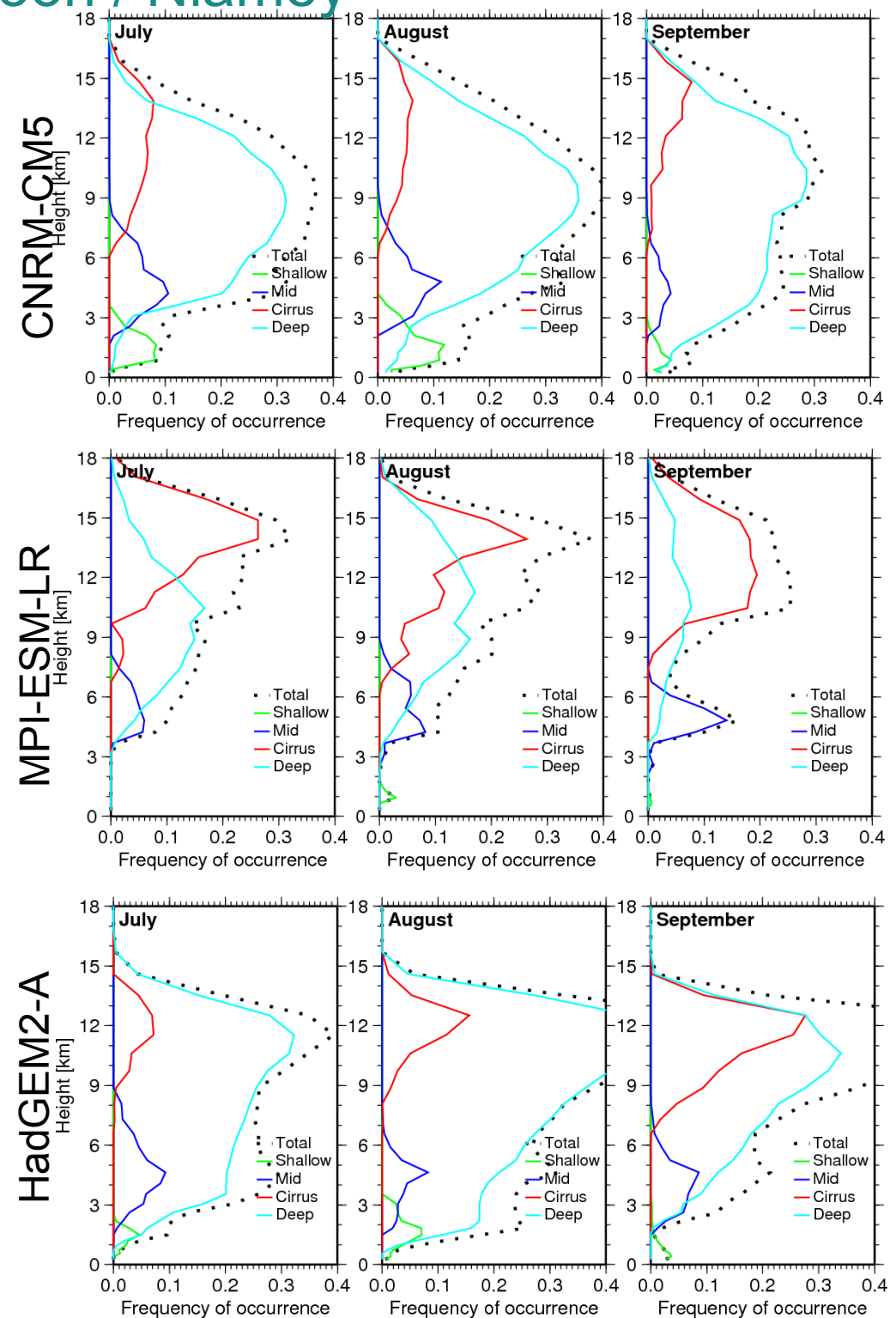


Relatively good occurrence of cirrus & mid-level clouds for all models

HadGEM2-A & CNRM-CM5 :

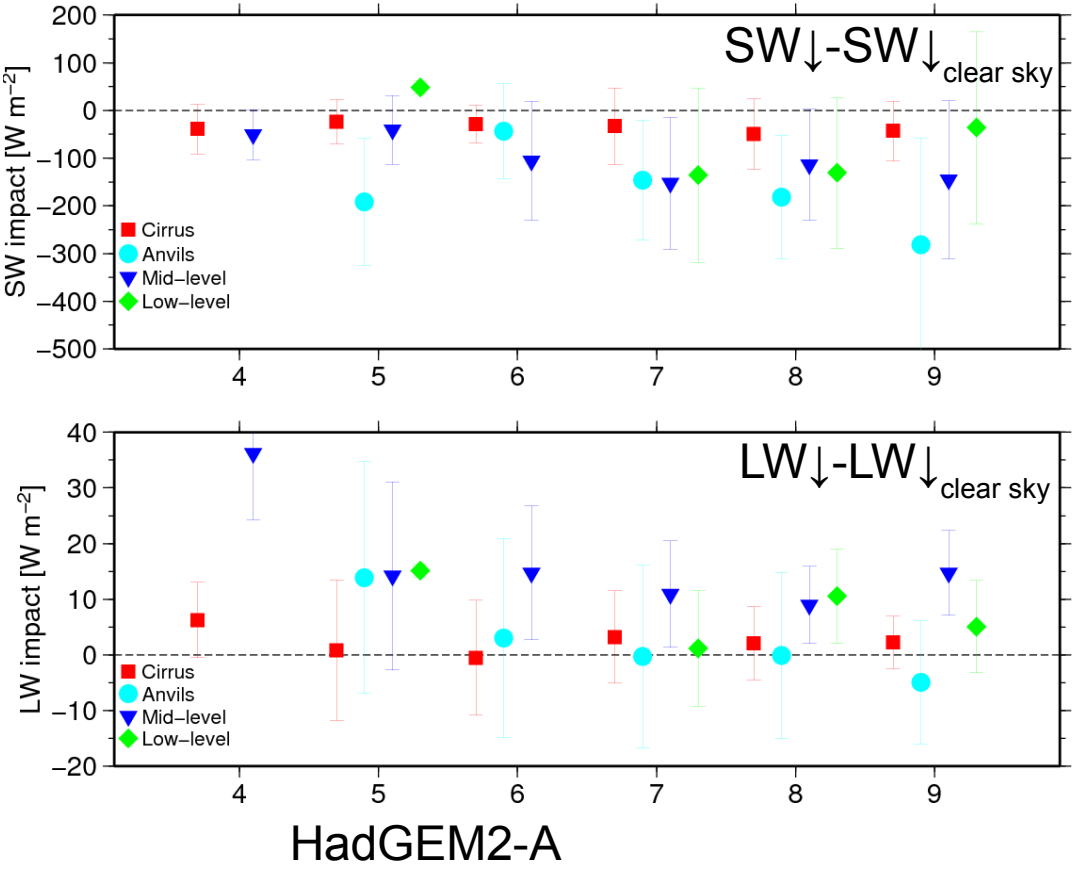
- too strong cv occurrence (too low CF)
- relatively good occurrence for low-level clouds

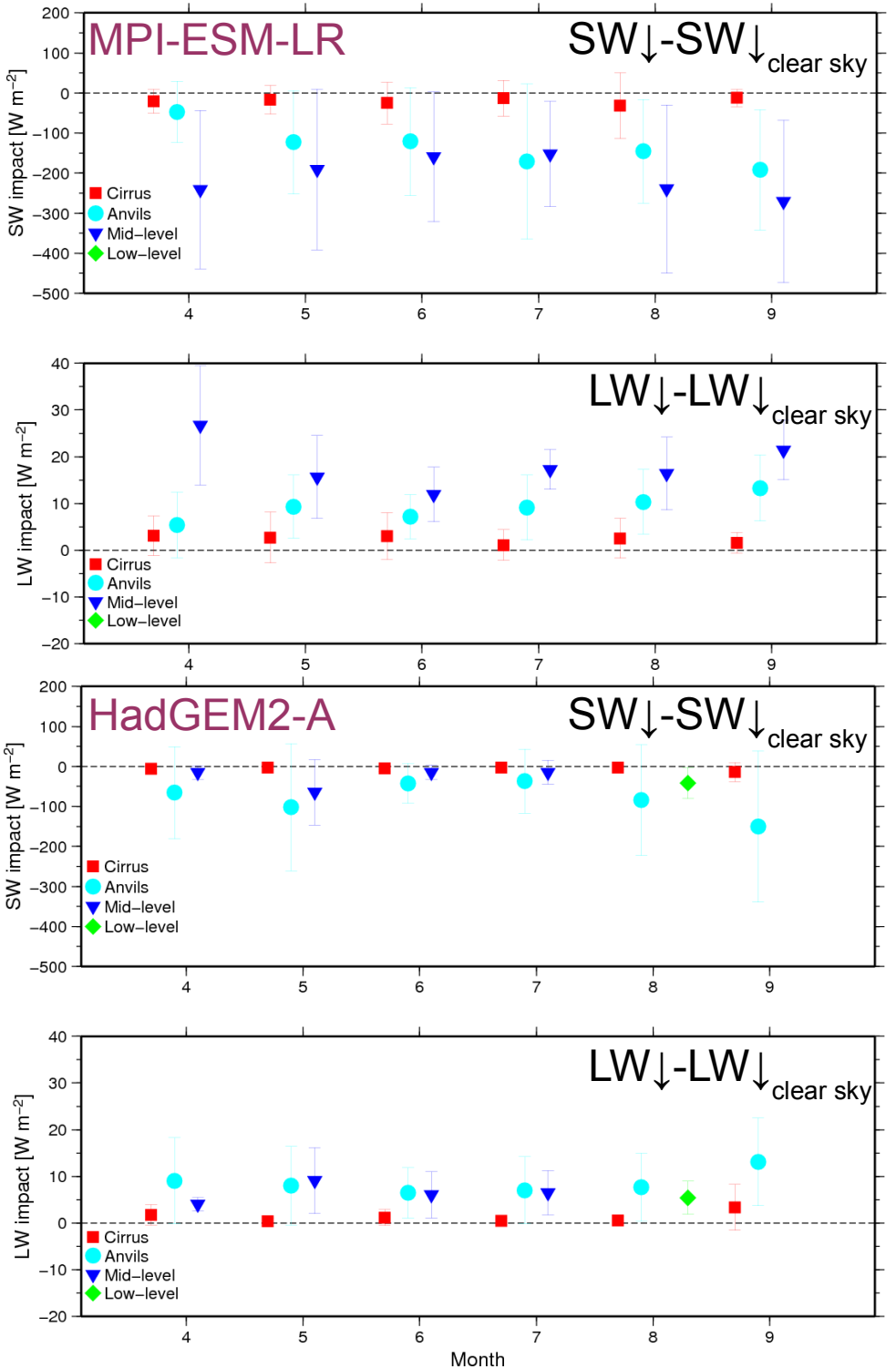
MPI-ESM-LR misses a lot of low-level clouds



Cloud radiative effect by cloud types at the surface

Emperical estimation using only data



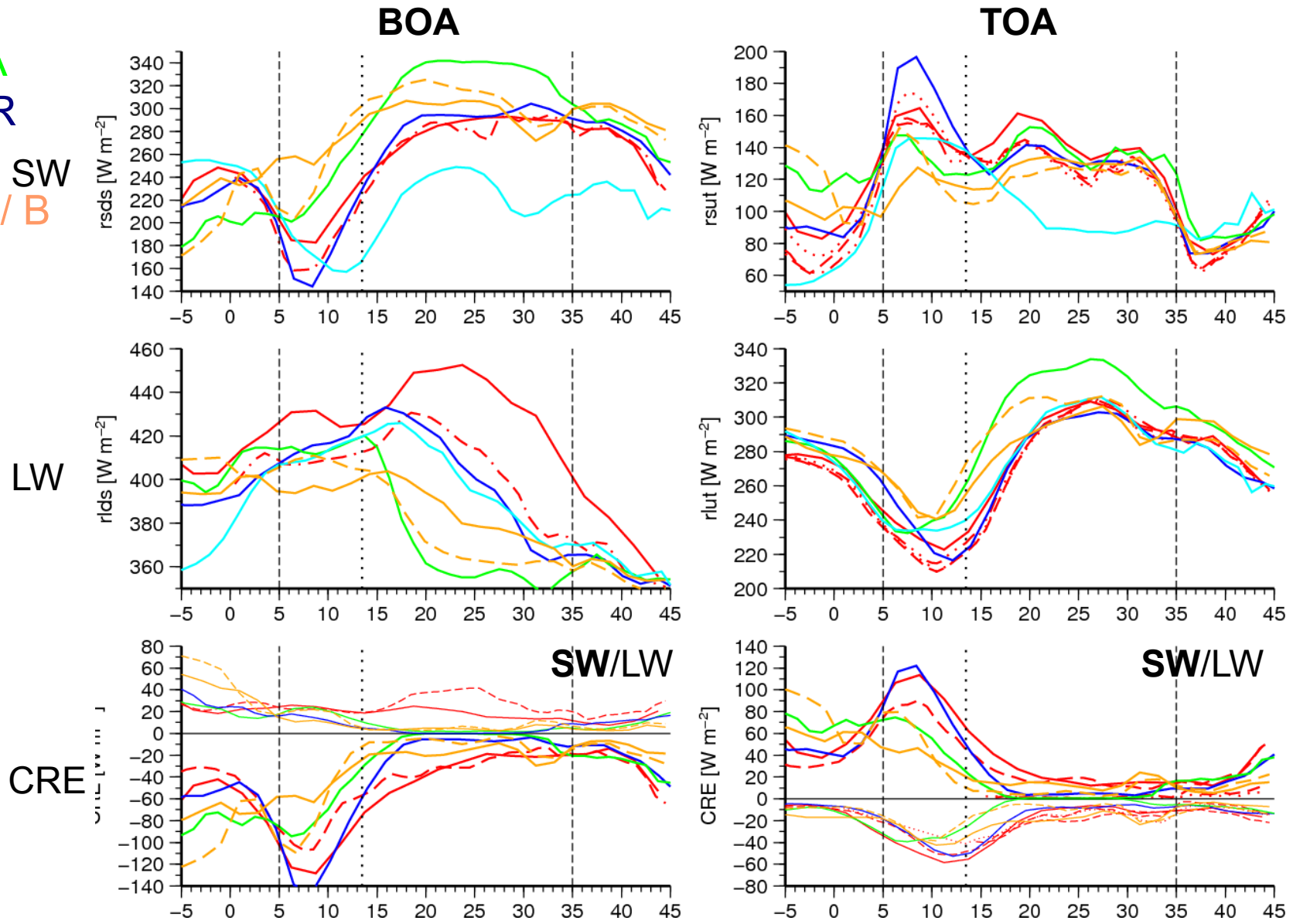


MPI-ESM : Good order of magnitude for CRE, but too large for mid-level (too low in the model => water/ice partition ?)

HadGEM2 : Too large SW↓ : too low CF ?

Cloud radiative effect at WA scale (august)

Data
HadGEM2-A
MPI-ESM-LR
CNRM-CM5
IPSL-CM5A / B



At TOA radiation is directly responding to occurrence of deep cv clouds
At BOA large spread in incoming radiation
CRE generally underestimated over the continent / overestimated over the ocean

Summary / perspectives

Analysis of the new data sets Niamey and satellites :
- 4 main cloud types (low & mid levels, cirrus, cv), with mid-level and cirrus present most of the year
- all present a diurnal cycle that evolves during the monsoon
- radiative impact has been quantified : as expected high CRE for anvils and low-level but also for mid-level (in SW and in LW)
→ see Bouniol et al. (JAMC 2012) for more details

Very good data set for the evaluation of the NWP/Climate model cloud representation at different temporal and spatial scale

Evaluation of the CMIP5 model over WA :
- results similar AMMA-MIP : all the models have a relatively realistic monsoon
- some cloud types are systematically missed or here all the time : ie mid-level clouds over the Sahara + cirrus / cv with precipitation
- identify compensating error in radiation

Better analyse the CRE at BOA in the measurements at the various point along the transect
Better analyse the diurnal cycle in the models at the measurement points