Surface, boundary layer and cloud couplings over land in climate models: inferences from evaluation of SCM and CMIP5 simulations over West Africa

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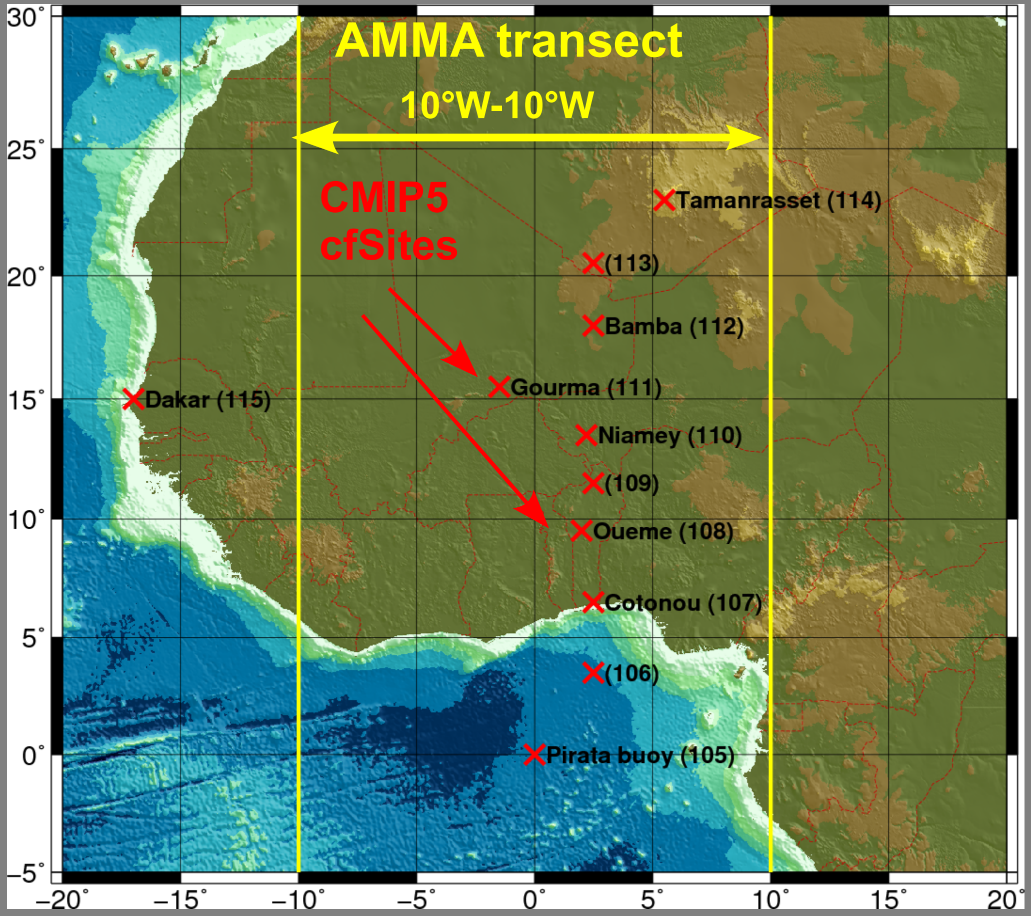


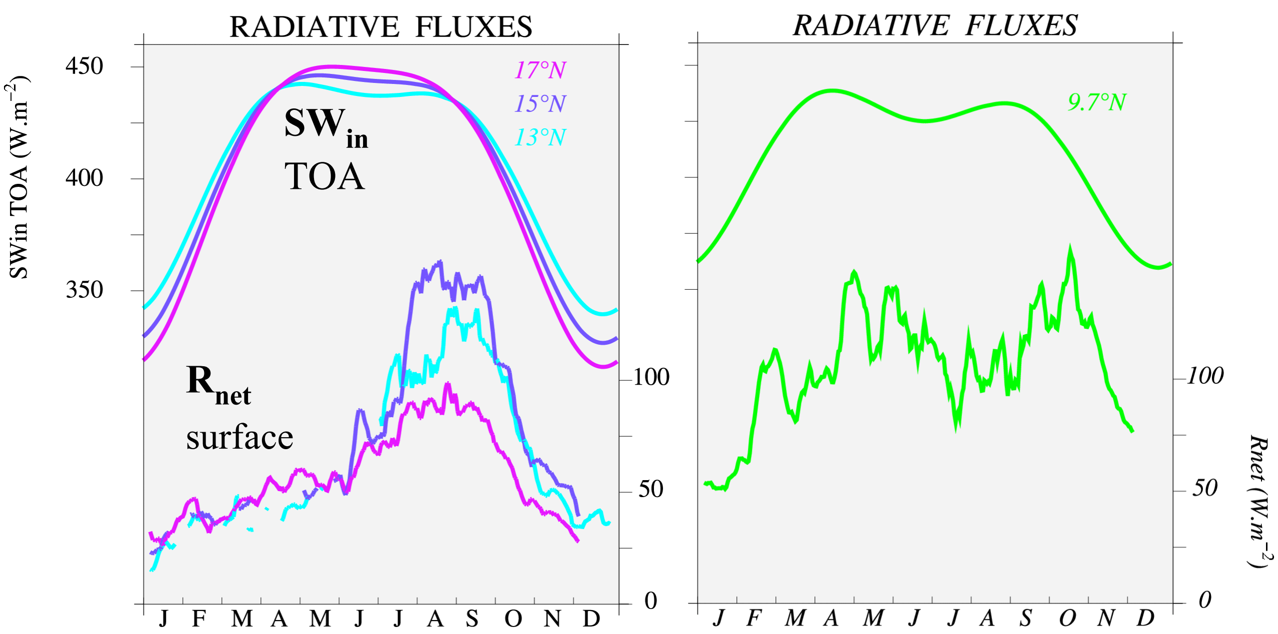
Contrasts in surfaces, boundary layers (BL) and clouds (with couplings)

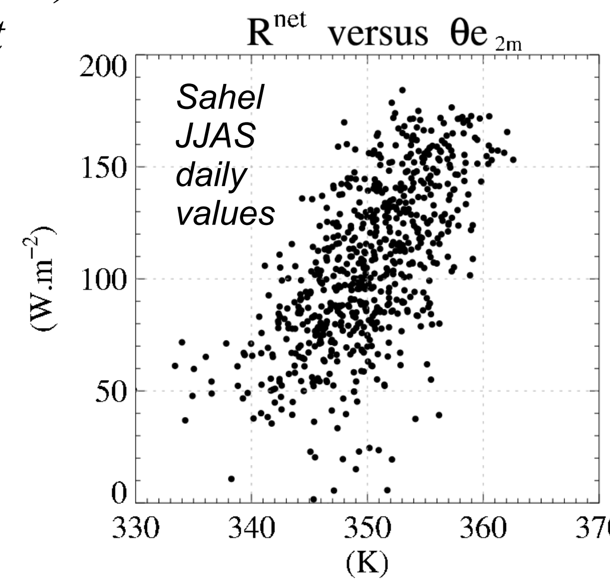
Surface energy budget is a critical issue (local & large scale)

involves processes which are not all well, nor simple to represent

- incoming SW TOA, water vapour, aerosols and clouds, rainfall
- land surface temperature, soil moisture, albedo, vegetation

Especially true in the Sahel (all are important)

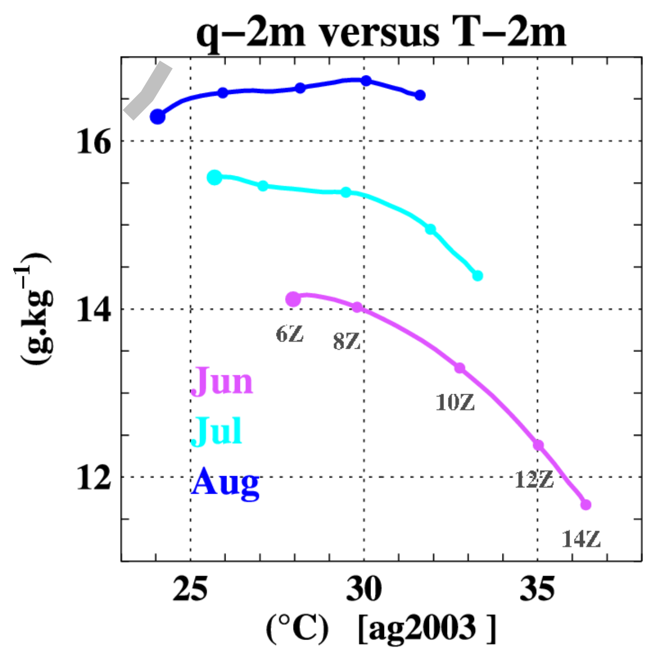




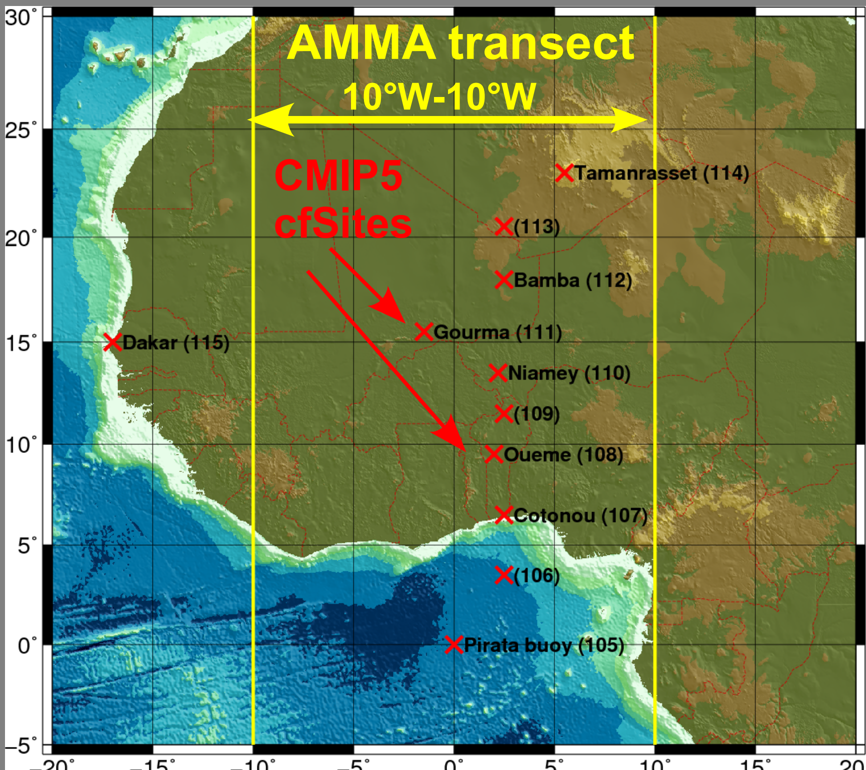
$$R_{net} = H + LE \sim \Phi_s(\theta_e)$$

Monsoon establishement: from drier & higher to cooler, moister & cloudier convective boundary layers, change in the diurnal dynamics

daytime BL dynamics



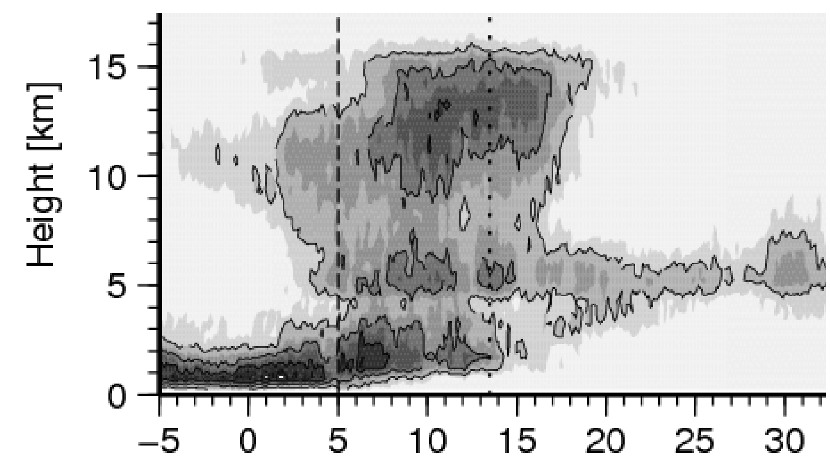
Model evaluation: AMMA TRANSECT and CMIP5 cfSites



AMMA TRANSECT: large-scale climatological gradient

AMMA-MIP: Hourdin et al. (2010)

***cloud frequency of occurrence**, Aug, CloudSat-Calipso*

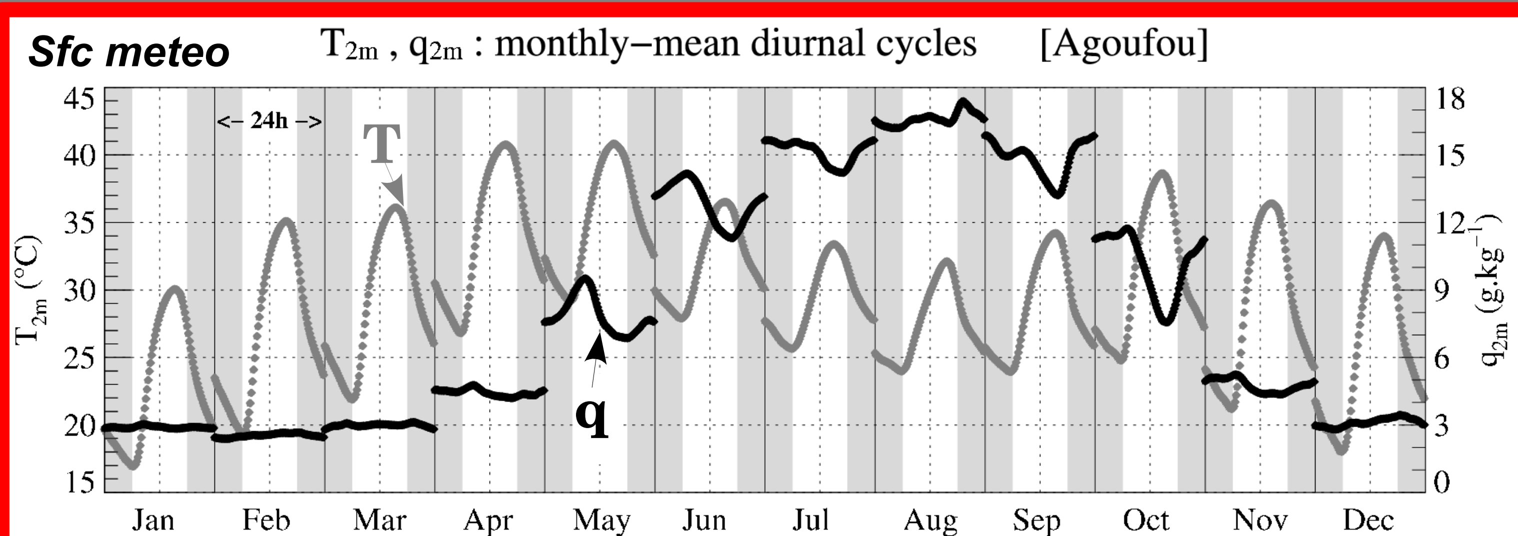


Bouniol et al. (2012)

CMIP5 cfSites

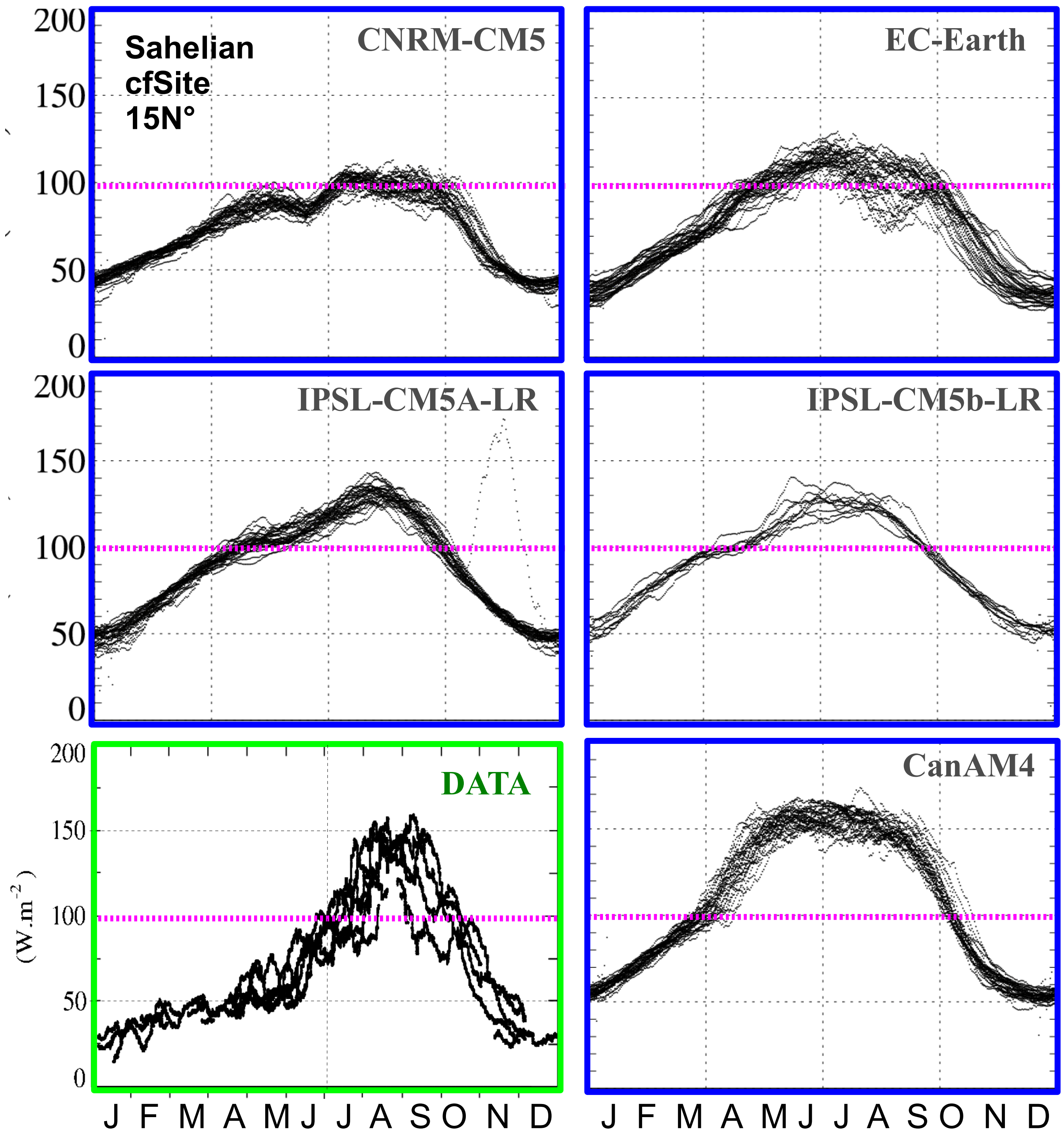
locations where ground data available (AMMA, ARM MF Niamey, others)

MORE became available recently



Guichard et al. (2009)

Net radiation at the surface R_{net} ($R_{net}=SW_{in} - SW_{up} + LW_{in} - LW_{up}$)

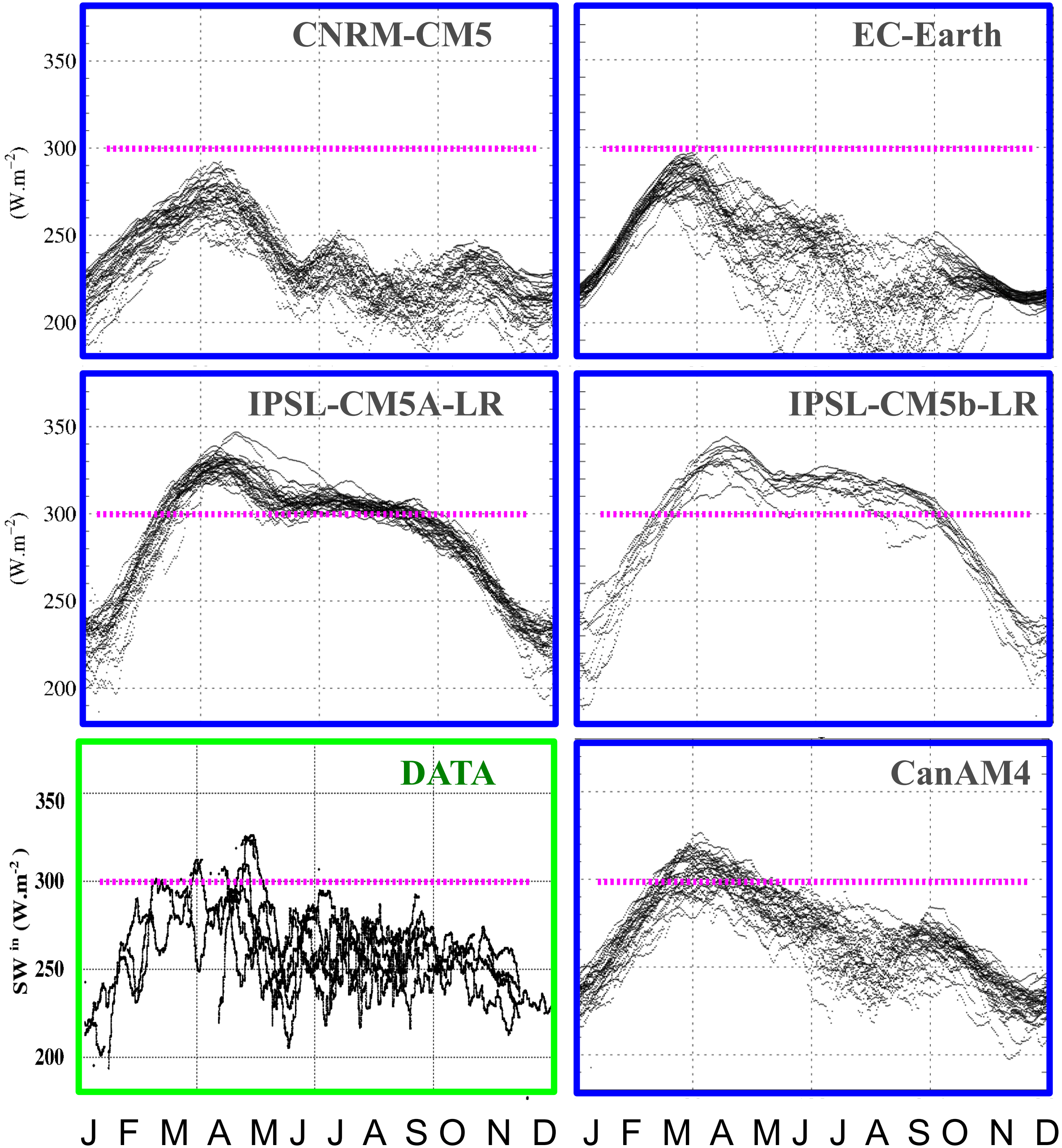


A common tendency to overestimate Rnet in Spring

Stronger Rnet for models with lower rainfall, the opposite in observations (interannual)

Means errors in H and LE

Surface incoming shortwave flux SW_{in}

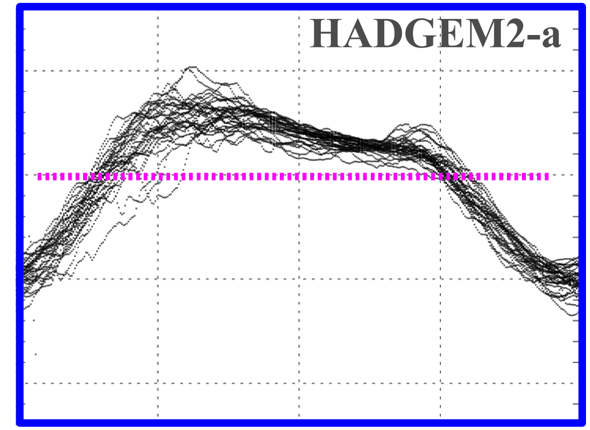


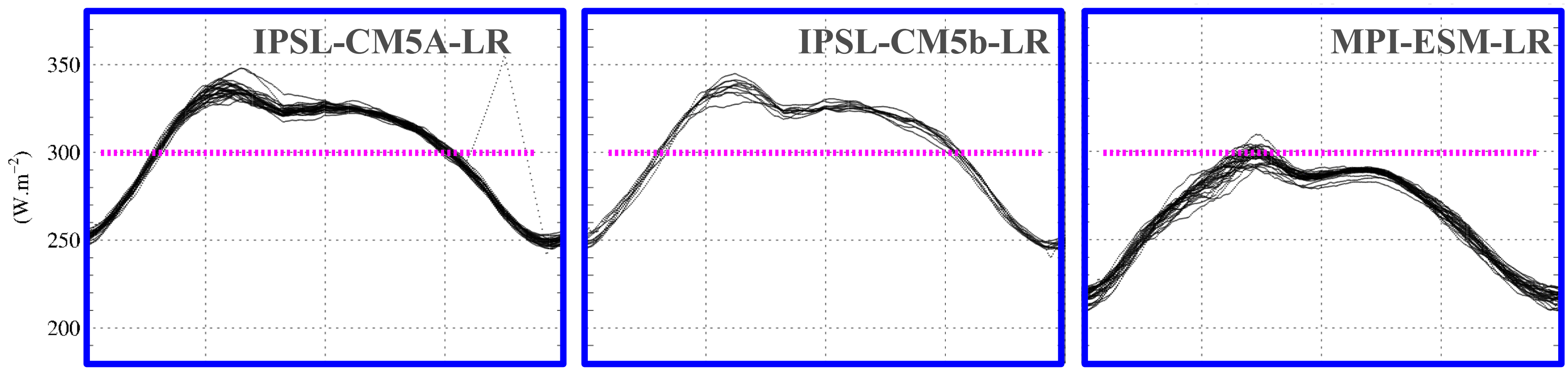
Larger spread in SWin than in Rnet

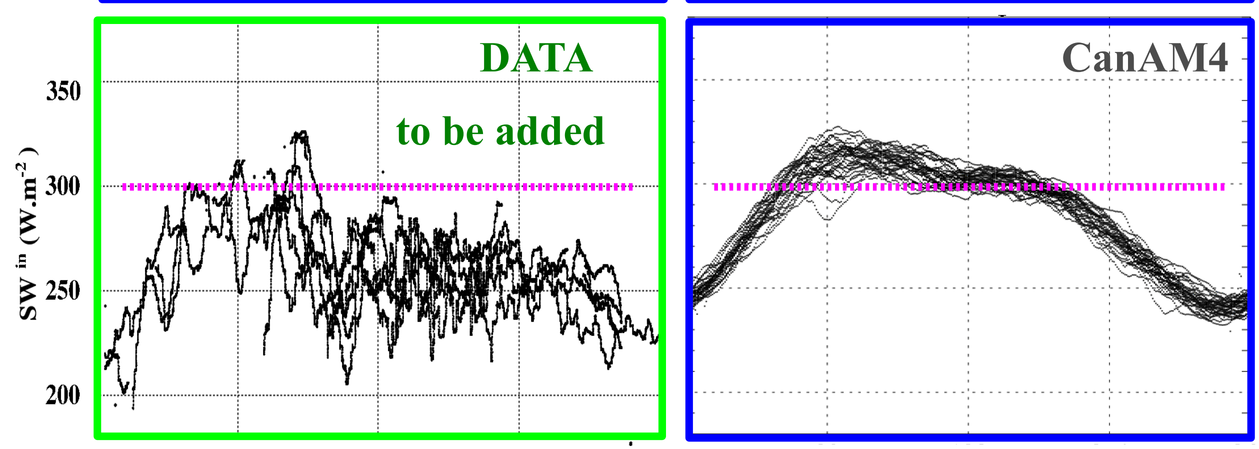
indicative of distinct balance of processes in each model (compensations of errors)

raises model sensitivity issues

Surface incoming shortwave flux SW_{in} clear sky







Not at all the same clear sky !! why ?

clean v clear sky

Some clarifications to arise from Olivier's work

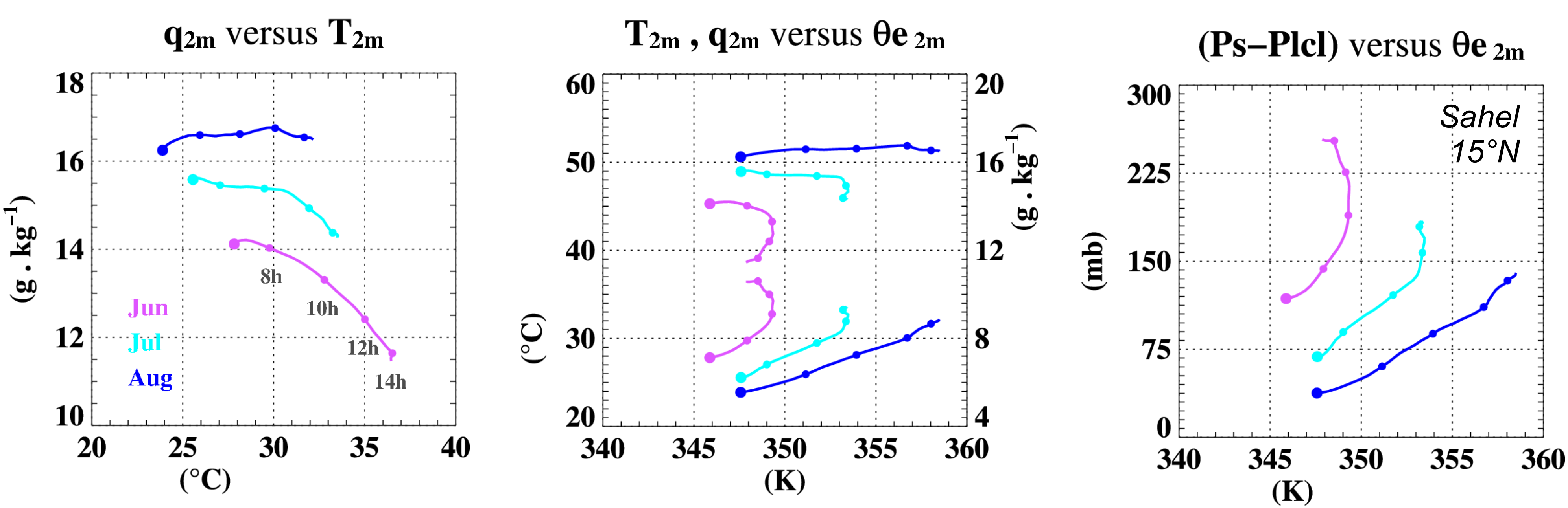
cfSite Budgets

Several reasonable features

Diurnal cycle : nighttime advection of cooler & moister air during the early monsoon
Seasonal transformation of the surface, boundary layer and clouds
Some consistency of the sensitivity of the convective BL to surface evaporative fraction

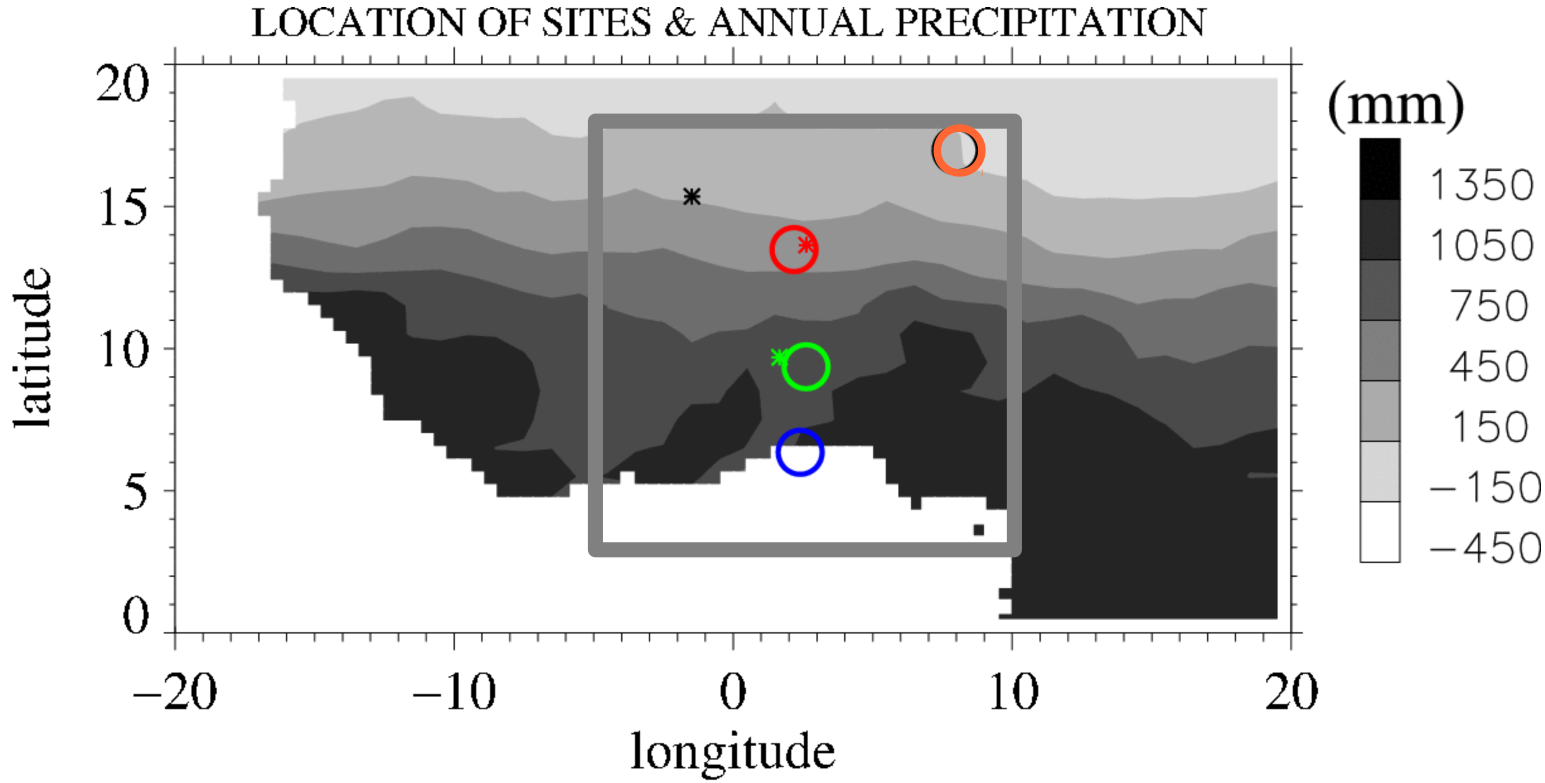
But notable difficulties, during the months of establishement of the monsson (May to August)
with large quantitative differences

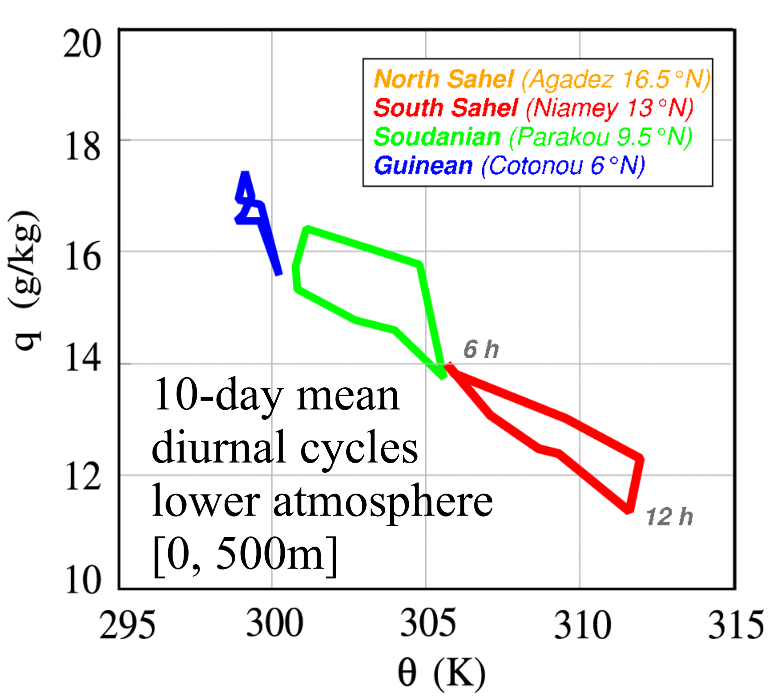
Importance of daytime processes for SEB ***(more in Roehrig et al. J. Climate 2013)***

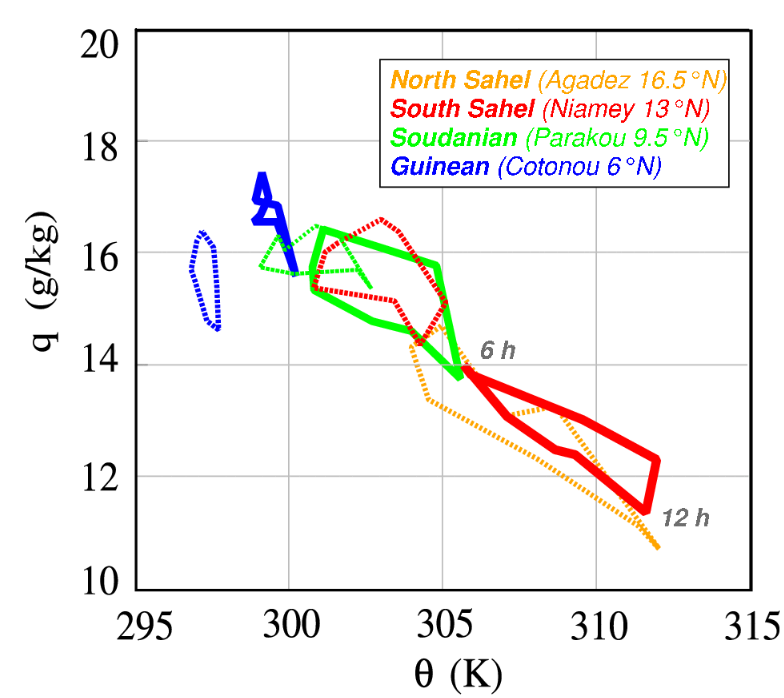


1) Dynamics of the diurnal cycle of the atmospheric low levels in ≠ environments sensitivity to rainfall range, cloud radiative impact...

2) Design a few selected cases & design 1D simulations using data and observationnally-based datasets as guides, further simplify the setup whenever relevant







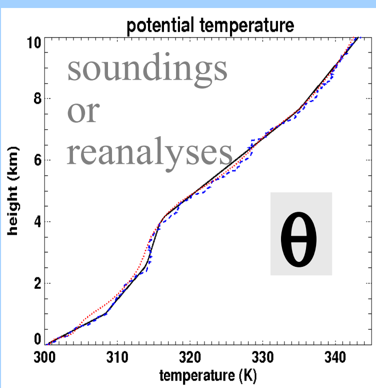
Adapted from Gounou et al. (2012)

SCM SET-UP

4 cases, 10-day run each : guinean (heavily cloudy), soudanian (convective, wet), sahelian monsoon (deep convection), Sahel in late spring (moist but not wet, no rain, semi-arid)

Simulations performed with MesoNH
10x 1 day or 1 x 10 days

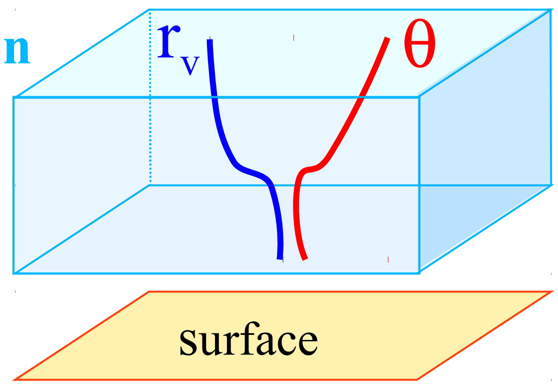
Early morning profiles



r_v U

atmos. initialisation

atmos. boundary conditions
larger-scale advection



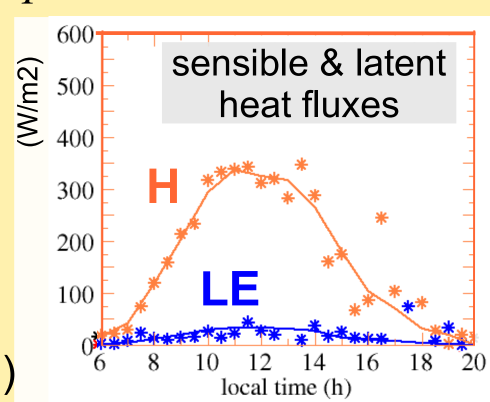
Surface initial & boundaryconditions

Surface properties & state

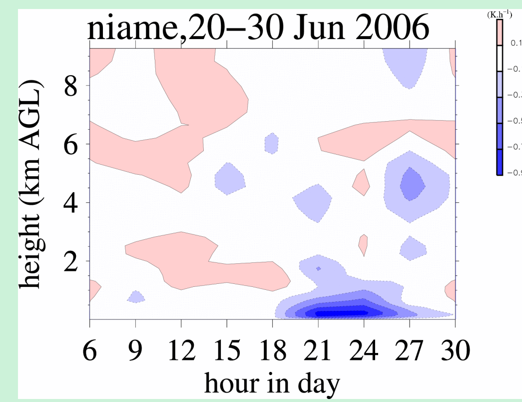
albedo, emissivity...

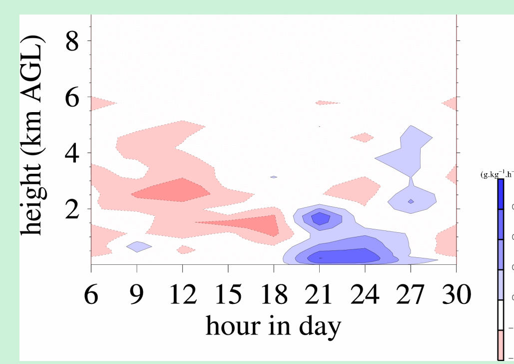
soil moisture, soil temperature

Local data & ALMIP, Boone et al BAMS 2009)



ECMWF AMMA reanalysis (3h) used a broad guide (sensitivities & corrections)





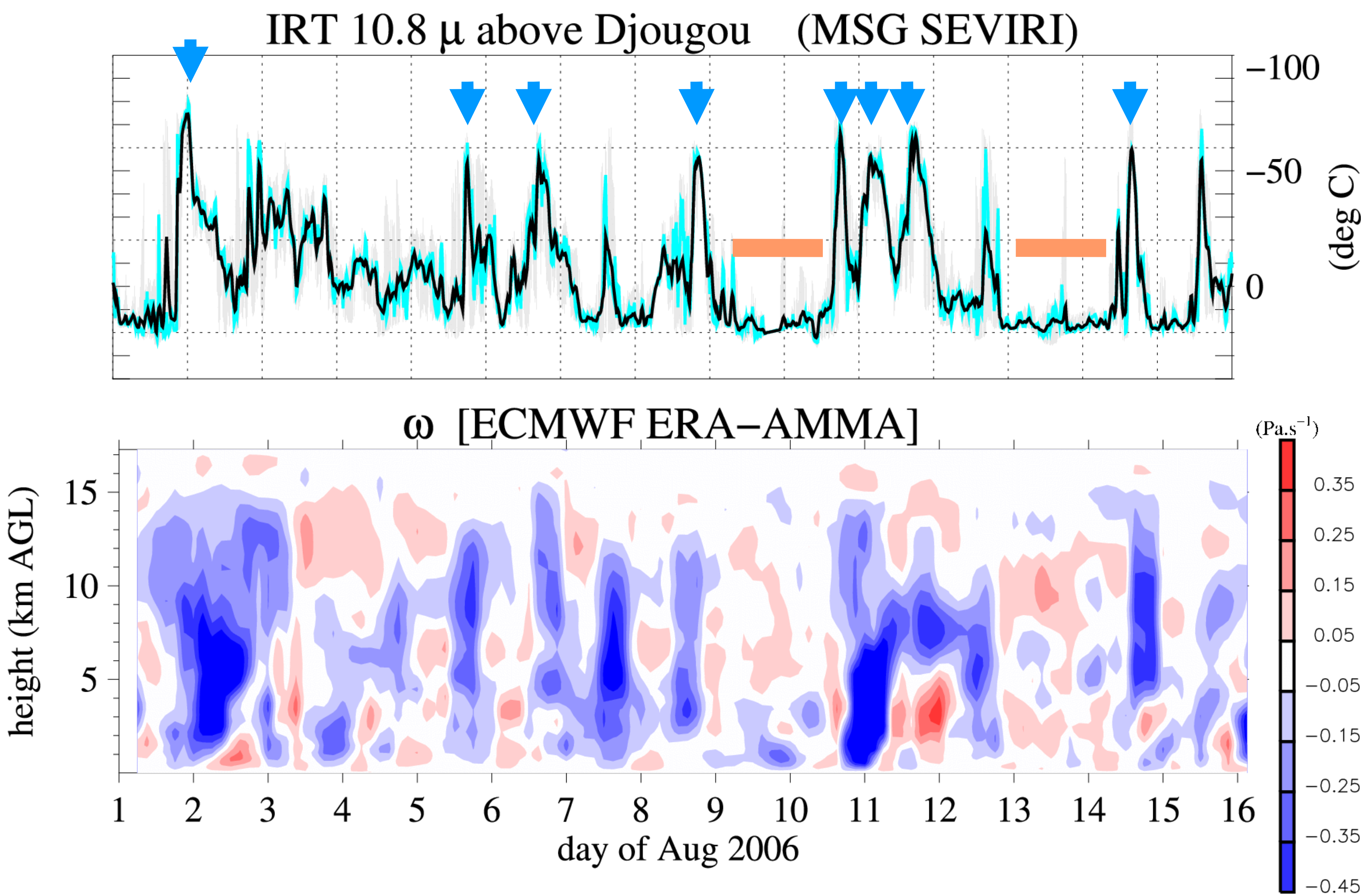
larger-scale advection

diagnosed from the ECMWF AMMA reanalysis

limitations: deep convection, low-level monsoon bursts (too weak)... drifts
but still usually able to capture synoptic variability in convective activity

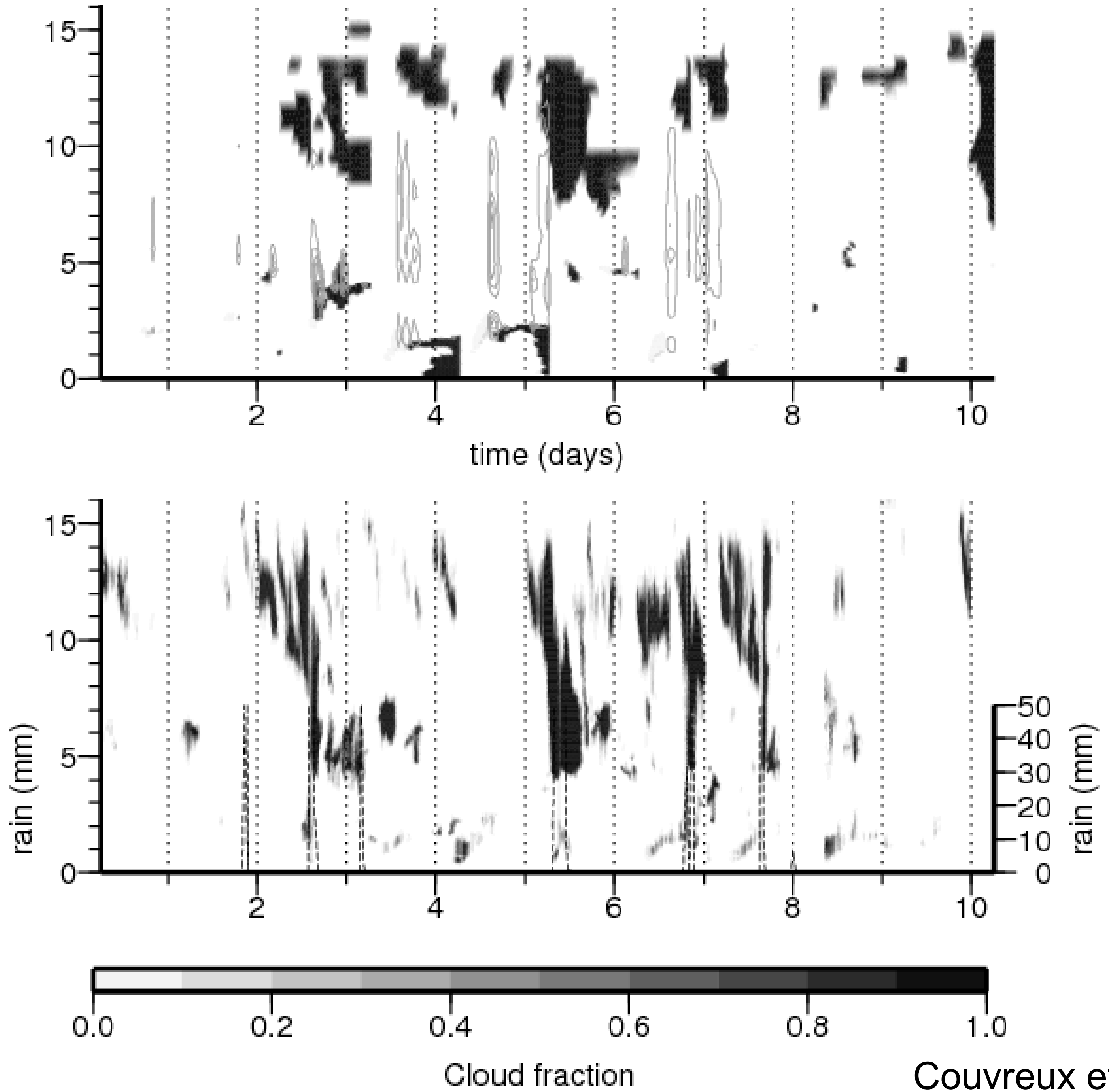
high cloud top
often coincides with
local strong max of omega in ERA-AMMA (omega<0 equiv. to positive vertical velocity)

no high cloud top
corresponds to periods with enhanced subsidence in ERA-AMMA (red)

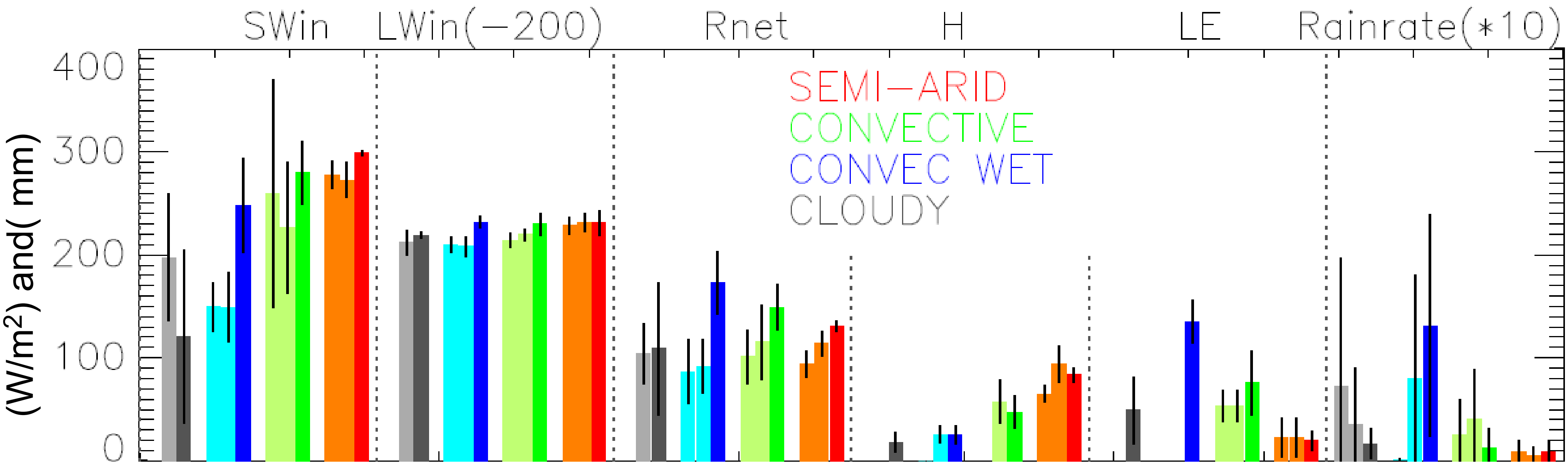


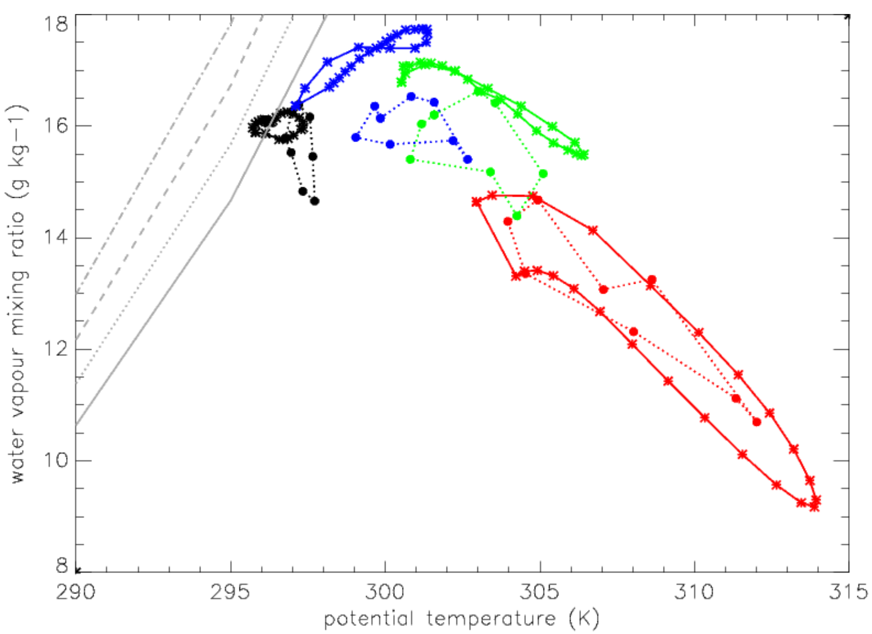
Simulation

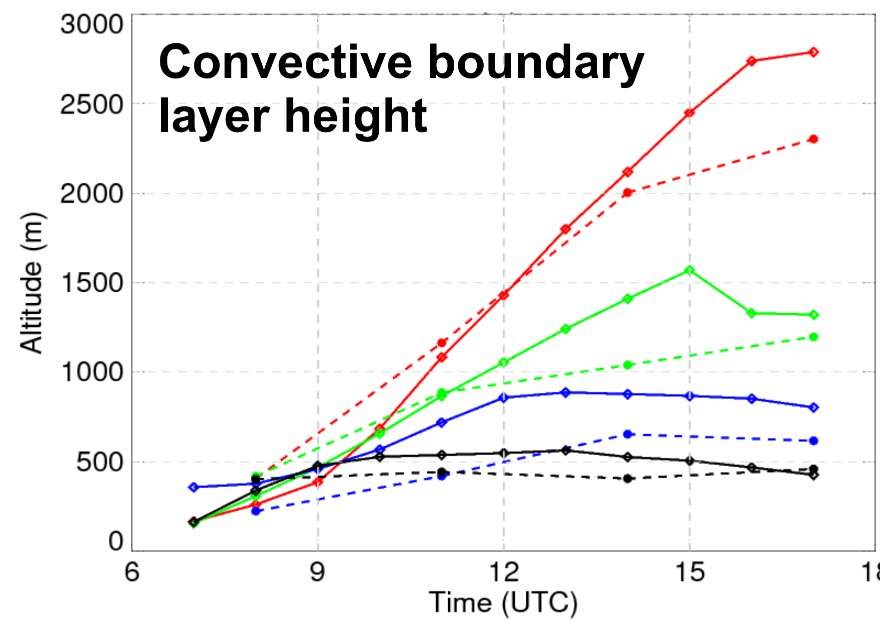
Observations
Niamey
ARM



Couvreux et al. (2013)







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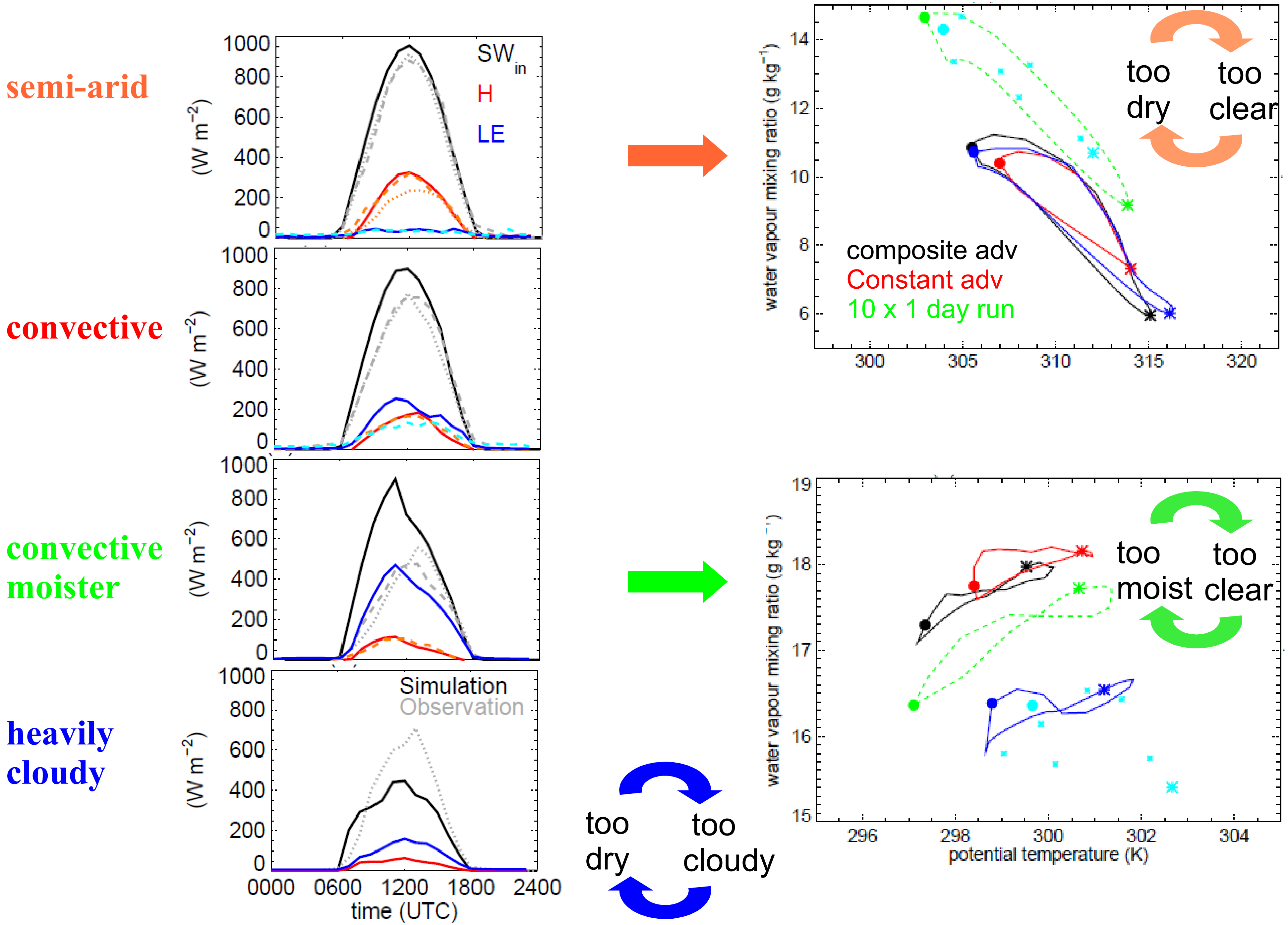
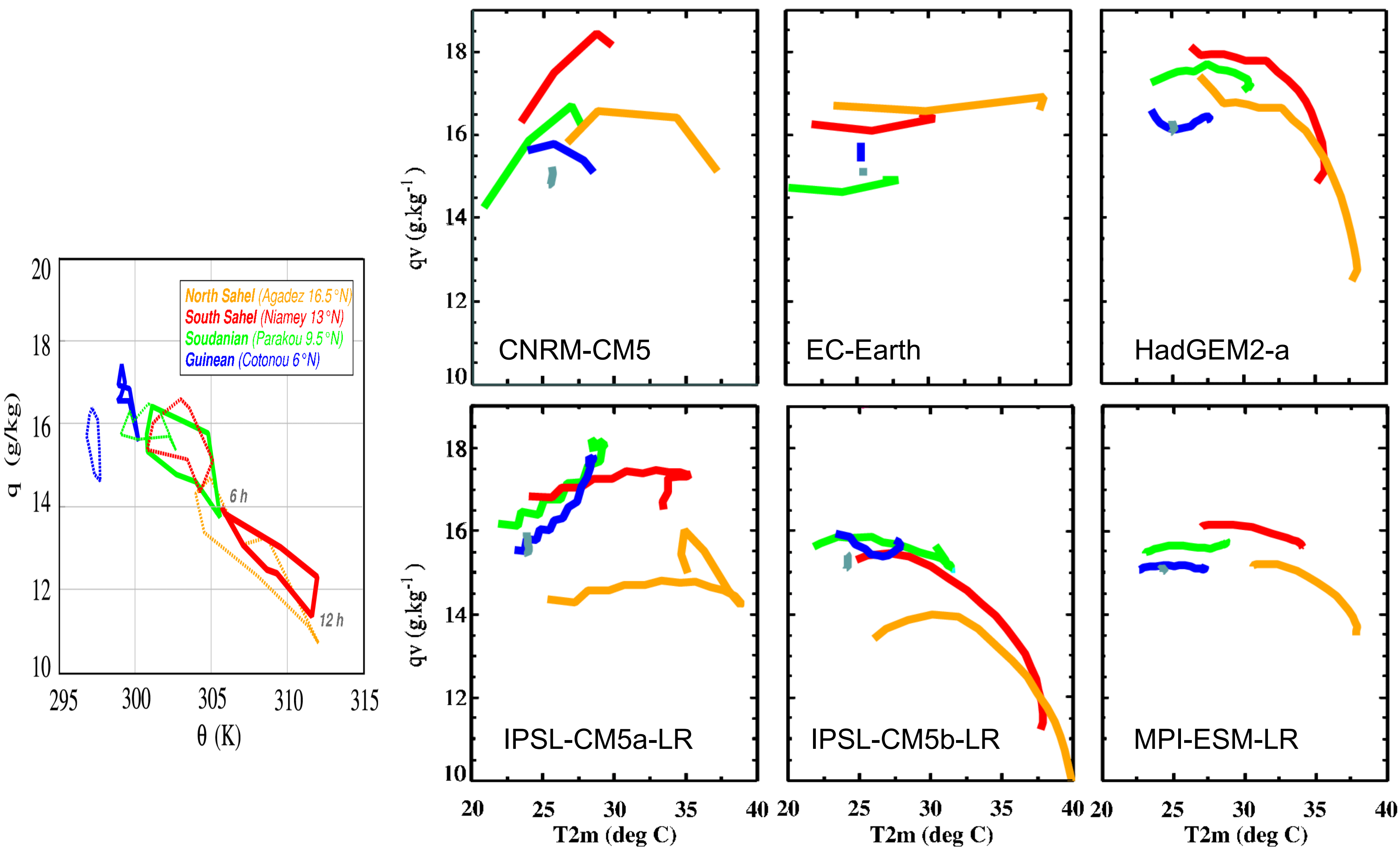


Simple setup from which studying coupled processes in model

Couvreux et al. (2013)



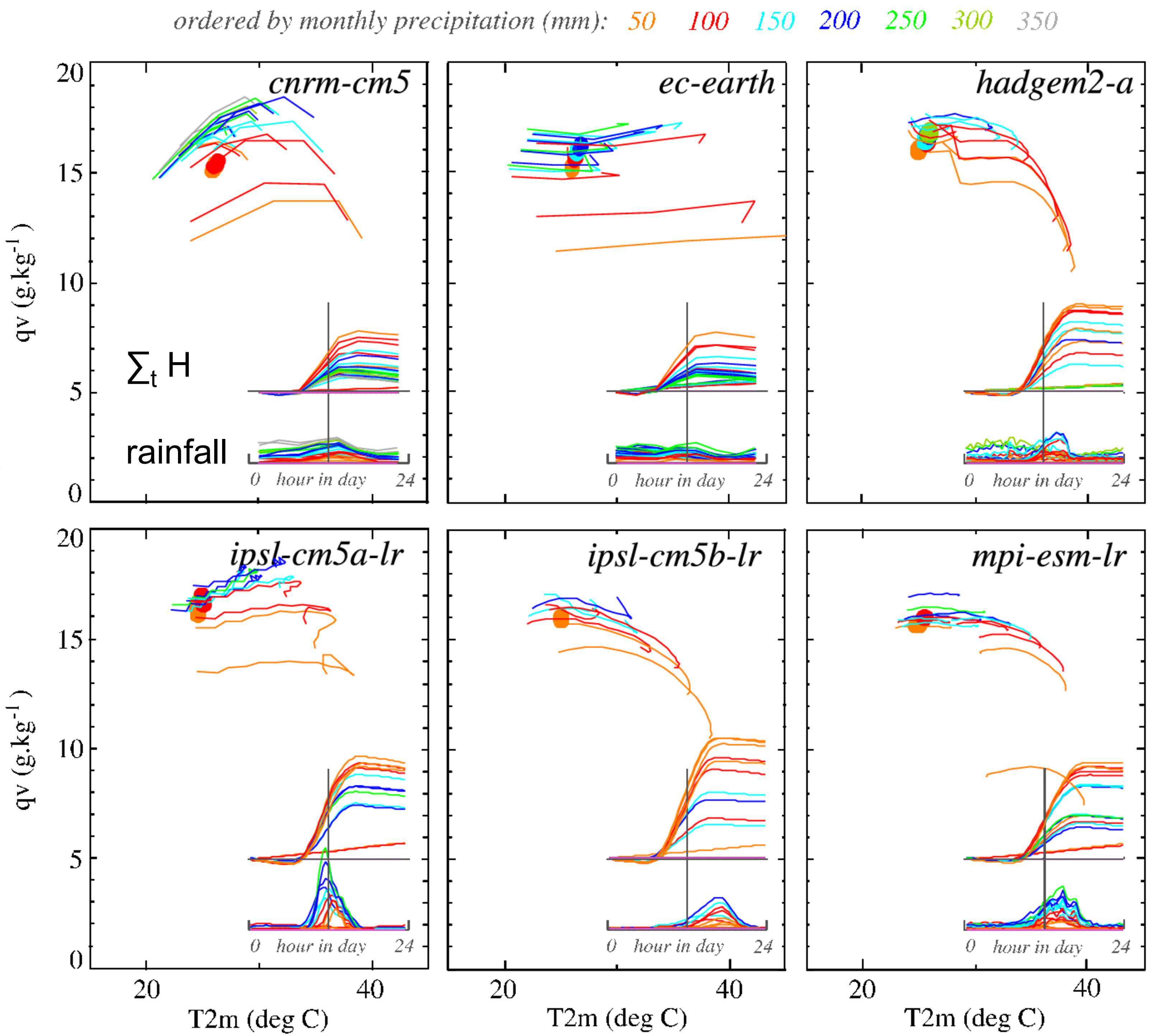
difficult to conclude from such a literal comparison
many 'climatic' diffferences at a given location among models

All (6) sites from The Guinean Gulf to the Sahara (3.5°N to 20.5°N)

30 years

Monthly mean Diurnal cycles sorted by monthly mean precipitation rate

Some consistency but surprisingly distinct behaviour of each model



Summary

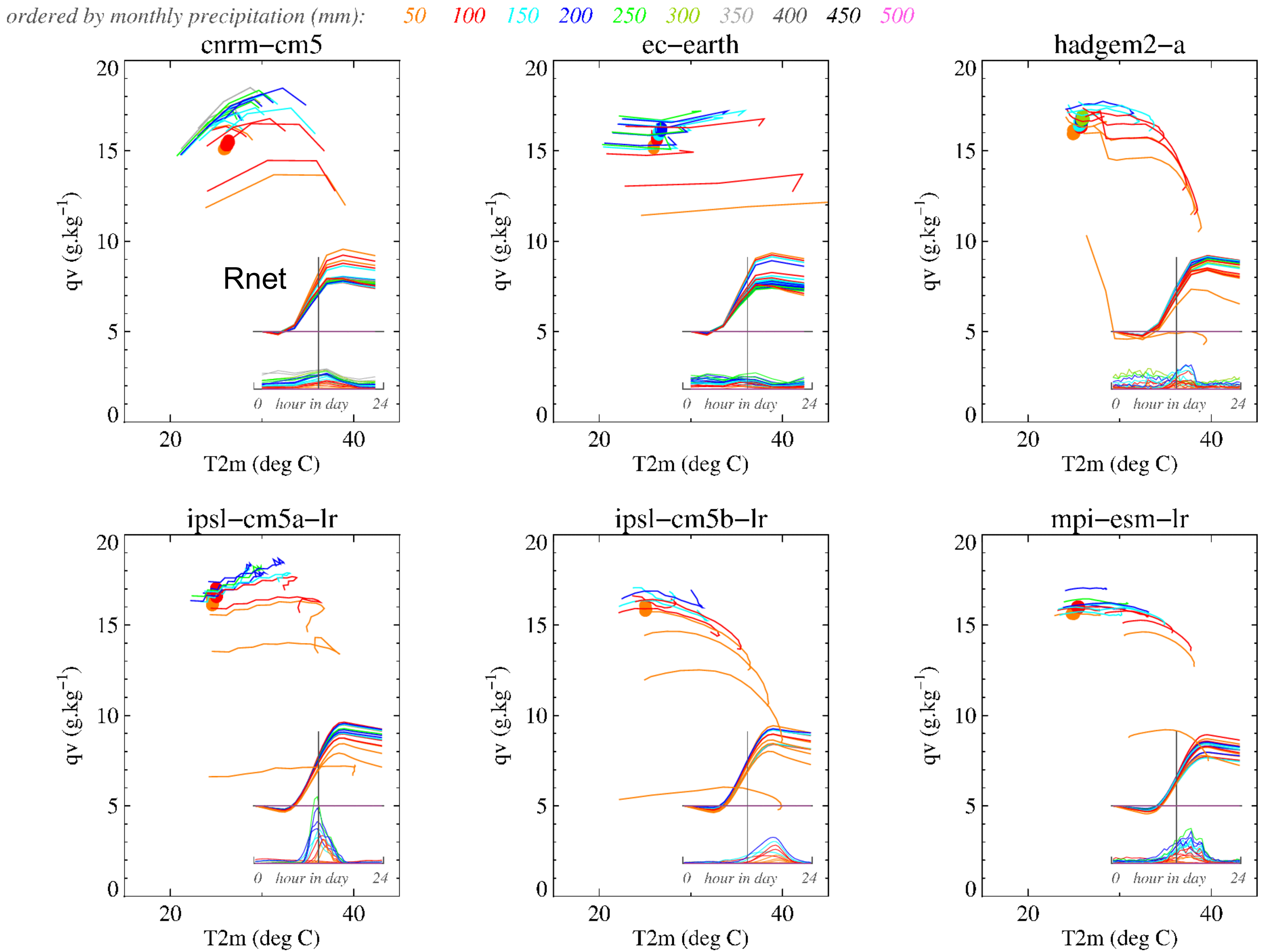
Much more CMIP5 cfSites outputs than one year ago, IPSL-CM5s (3), EC-Earth, + 3 others

- *broadly speaking, AMIP runs: numerous features of the West African monsoon, even regarding fine-scale phenomena such as the diurnal cycle of the monsoon flow dynamics*
- *basic issues with the simulation of the annual cycle (location in both space and time), differences among models dominate over interannual variability of each (possibly too weak)*
- *large differences in clear sky SWin and LWin at the surface (a few tens of $W.m^{-2}$)*
- *data indicate large biases in SEB with more spread in SWin than in Rnet (not intuitive)*

Daytime dynamics of the surface and lower atmosphere (SEB, thermodynamics, clouds)

- *characterized from observations, focused on ≠ land regimes, documented SEB, BL & clouds*
- *set-up of a simple framework to jointly simulate these cases with a model (SCM, LES)*
  - biases involve distinct feedbacks between surface, BL & clouds depending on the mean state
  - biases do not appear to be so strongly driven by the large-scale dynamics, emphasizes the importance of local physical processes, and of their couplings

- *CMIP5 cfSites* :
  differences in the mean thermodynamics of the low levels strongly linked to mean rainfall
  but daytime evolution still displays important model-specificities
  Next step : use cfSites profiles and budgets to analyse these differences (surface, BL & clouds),
  analyse of feedback loops, similarities with finding from SCM?



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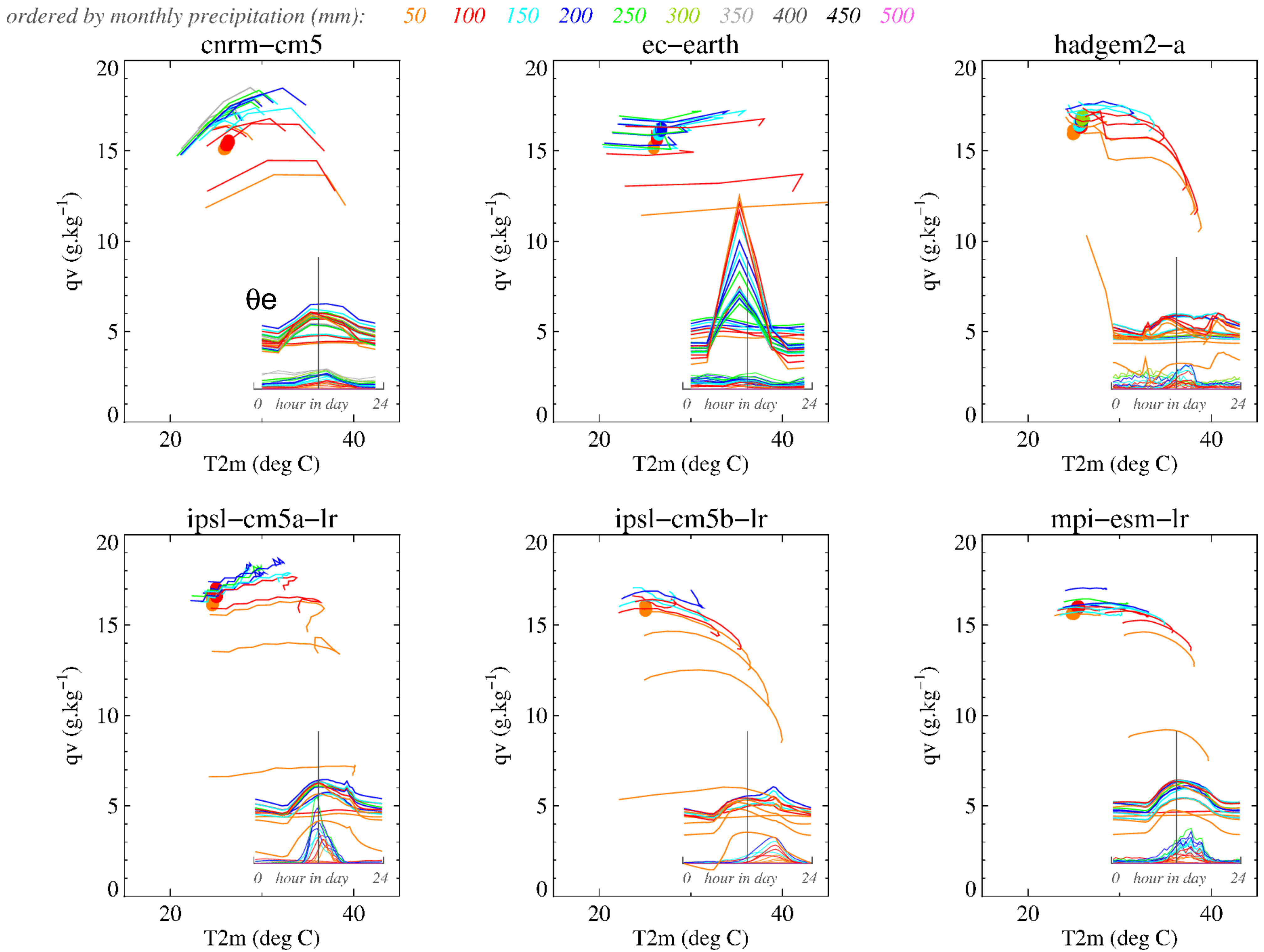
T2m (deg C)
0 hour in day 24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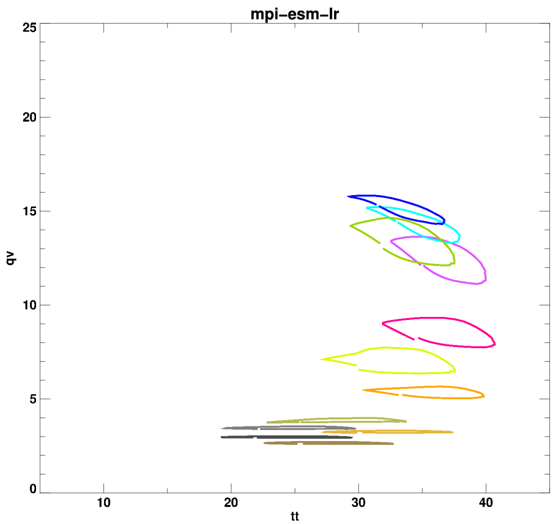
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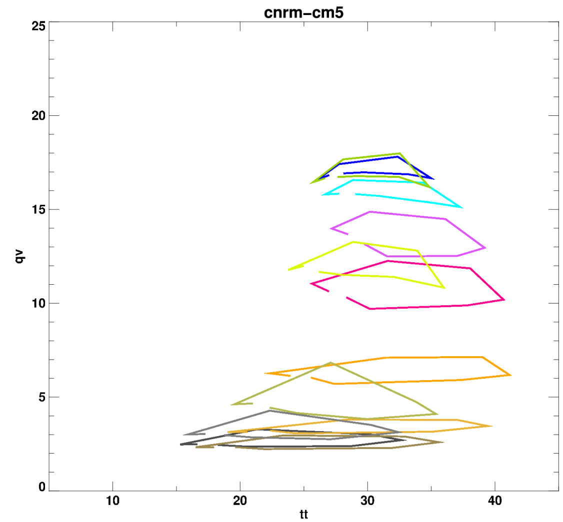
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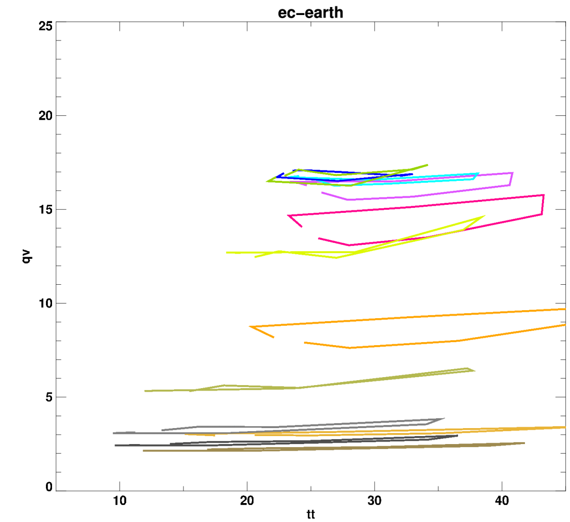
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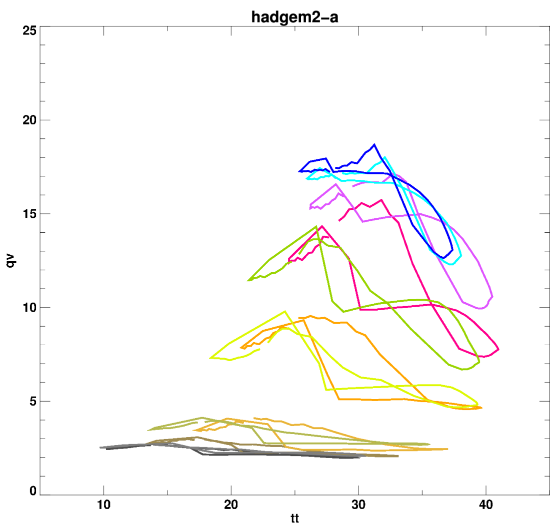
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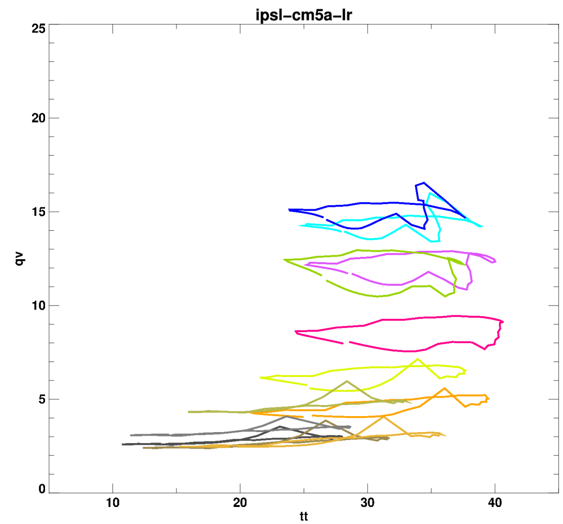
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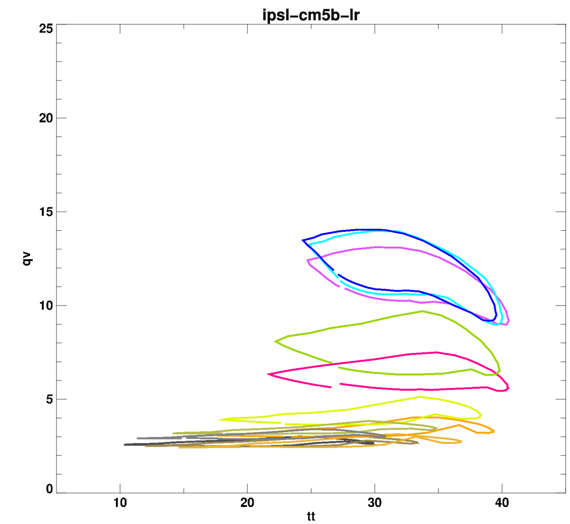
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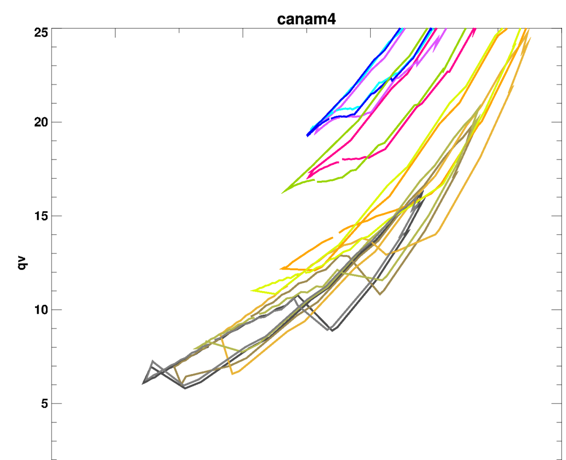
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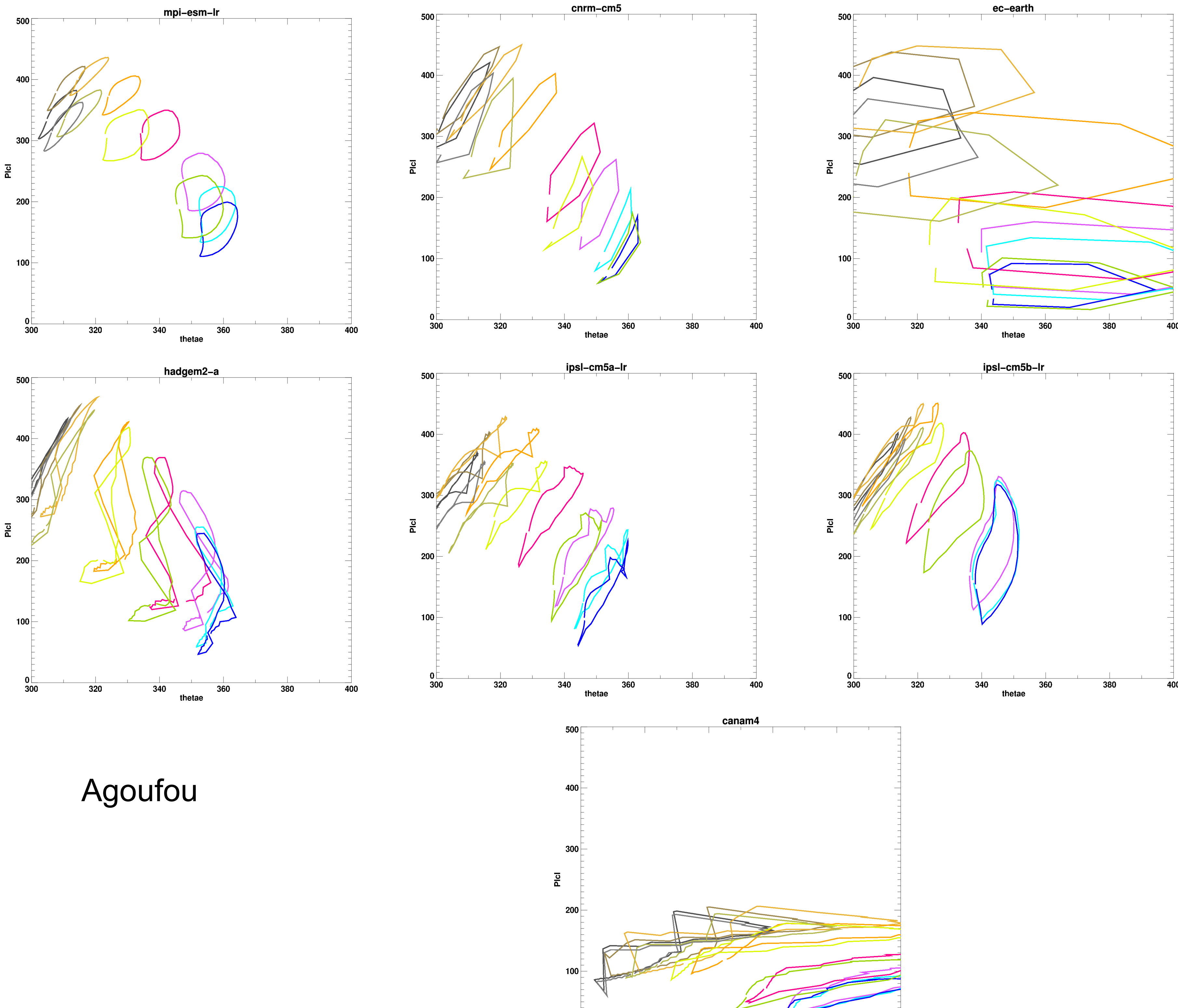
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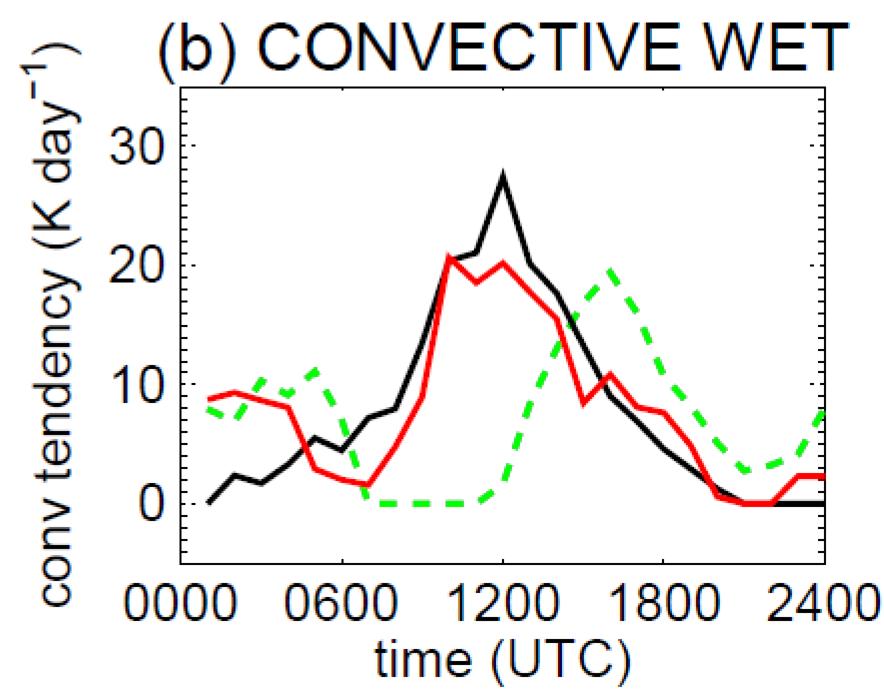
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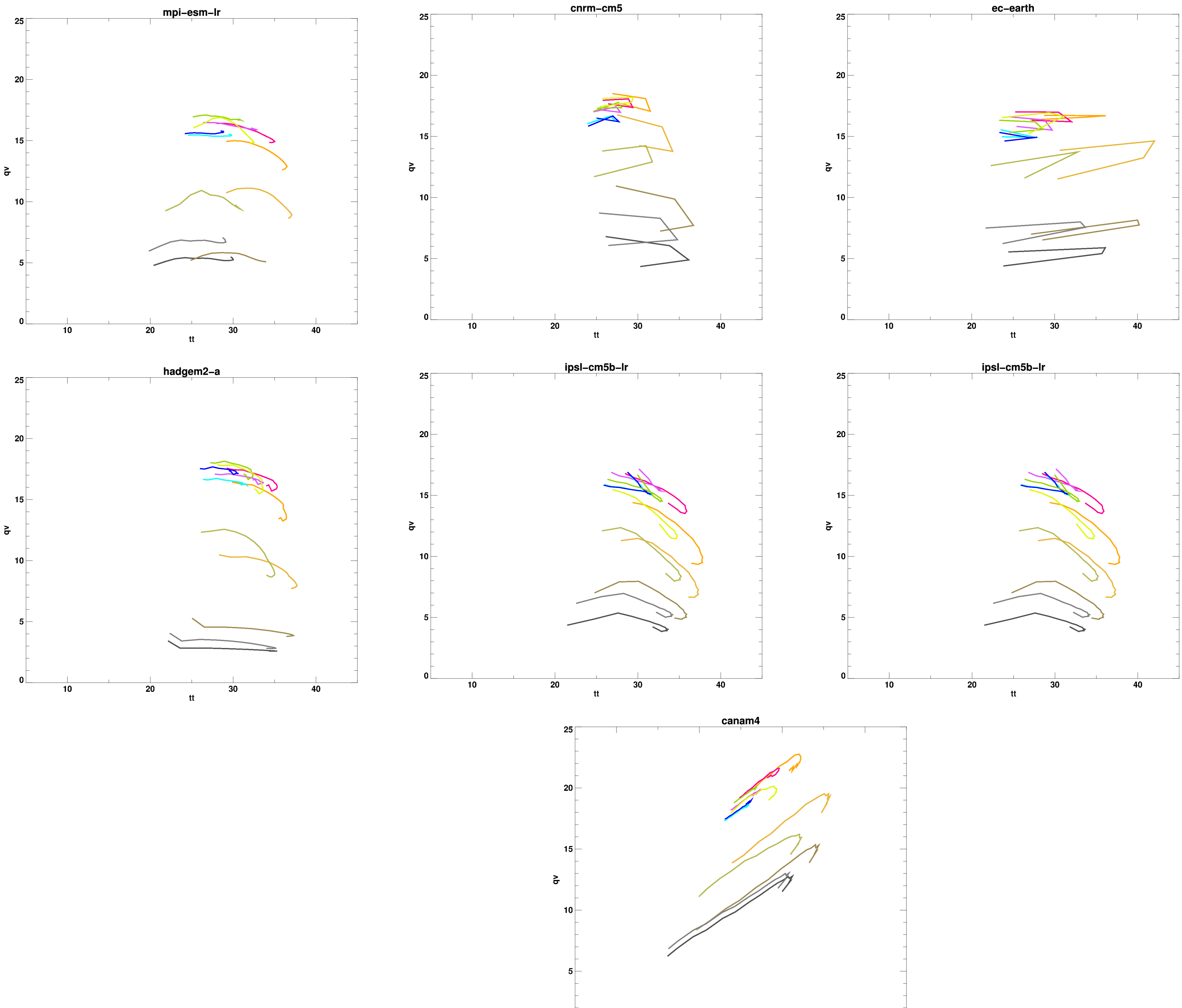
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