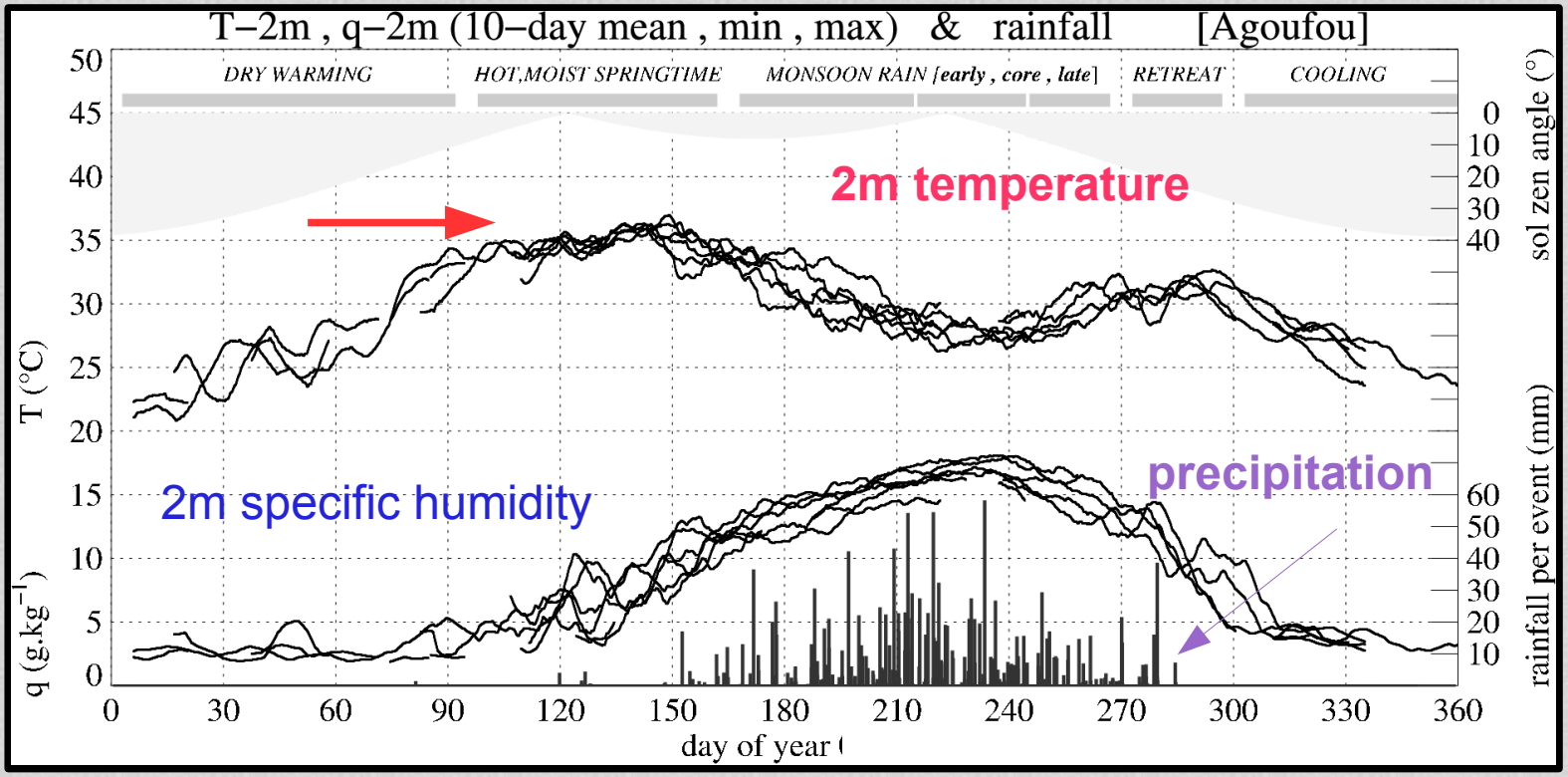
Warming patterns over West Africa and repercussion on the annual cycle of temperature

Françoise GUICHARD [1], Laurent KERGOAT [2], Eric MOUGIN [2], Frédéric HOURDIN [3], Birama DIARRA [4]

1: CNRM 2: GET 3: LMD/ IPSL 4: DNM Mali

May monthly mean T2m ***35°C***



Automatic weather Station

Agoufou Mali (1.5°W,15.3°N)

In the Sahel, temperatures are very high in Spring (climatic)

=> a long lasting ('flat') maximum : why? *diurnal cycle considerations*

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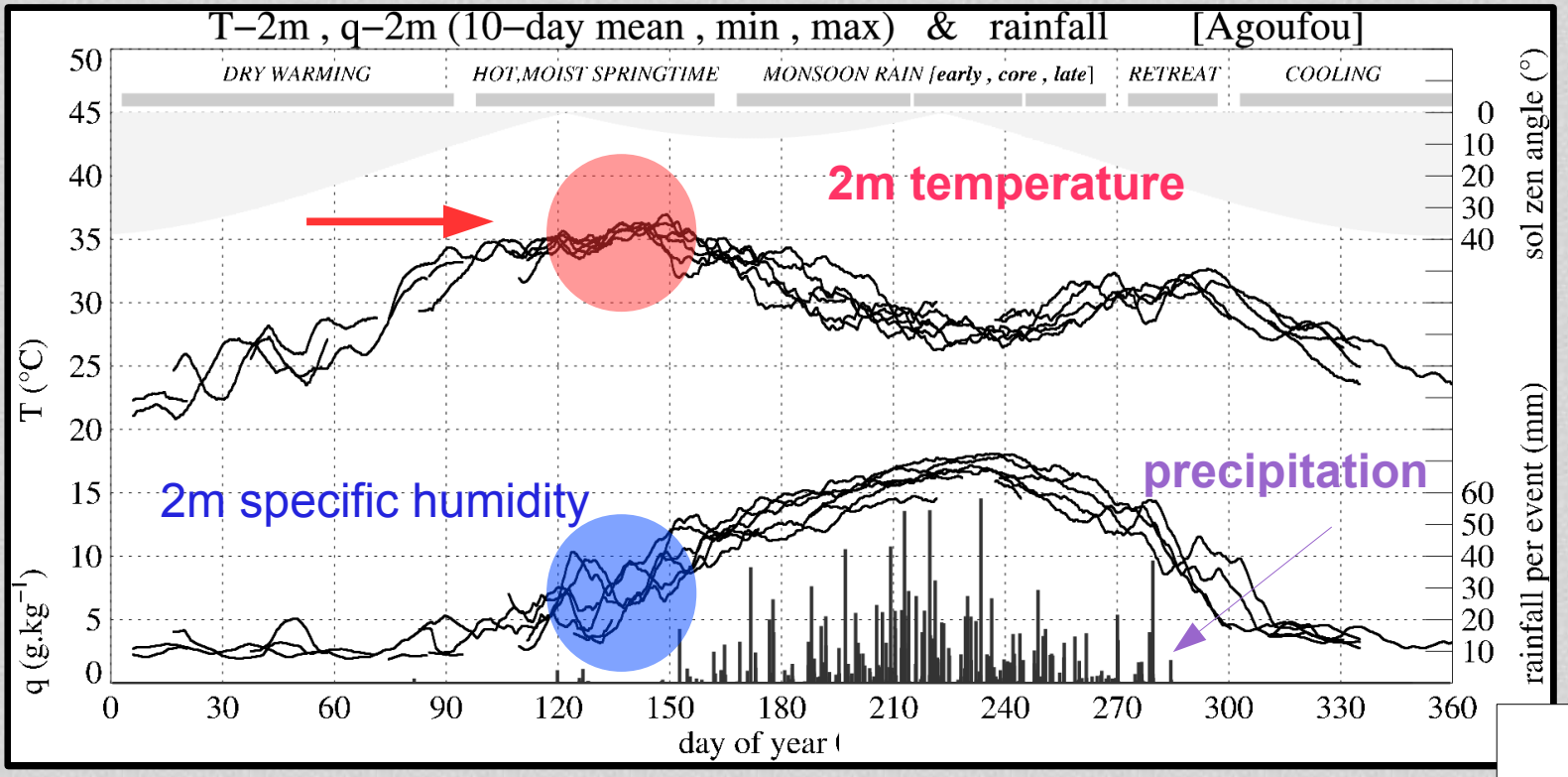

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ANR escape

In the Sahel, temperatures are very high in Spring (climatic)

=> a long lasting ('flat') maximum : why? *diurnal cycle considerations*

=> weak interannual variability ? *From a few years to multidecennal...*

=> modelling issues: CMIP5 climate simulations

Data, products, models

SYNOP data

m*eteorological stations: daily data*
either daily average, min and max, or 0, 6, 12, 18h UTC

=> 1900/1950 à 1980 et 1995 à 2011 [AMMA database]
=> 1980-2011 *[thanks to SEDOO/OMP & F. Favot]*
=> Hombori SYNOP station in Mali (1.5°W, 15.3°N), Mougin et al.
long series, controlled, very few holes
no data since February 2012

Gridded products

=> CRU 2.1 1952-2003, CRU 3.1: 1901-2009 (monthly, 0.5 deg resolution)
=> BEST (monthly many more stations, monthly)

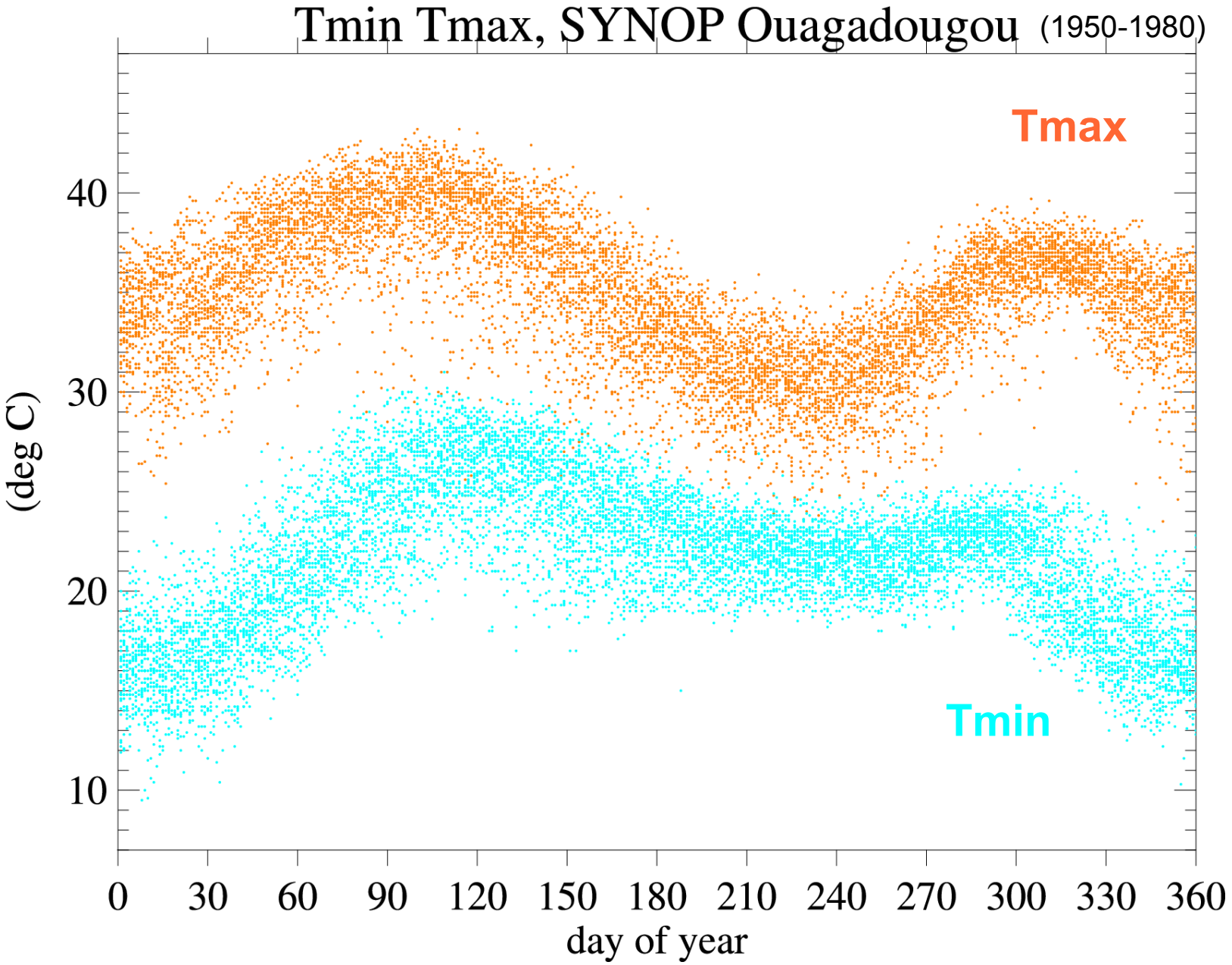
Models

=> meteorological reanalyses
ERA 40: 1958-2002
ERA-Interim, MERRA, NCEP-CSFR, all ~ 1979-2010
=> Climate models CMIP5 (runs amip, historical, historicalNat, piControl- cfSites)

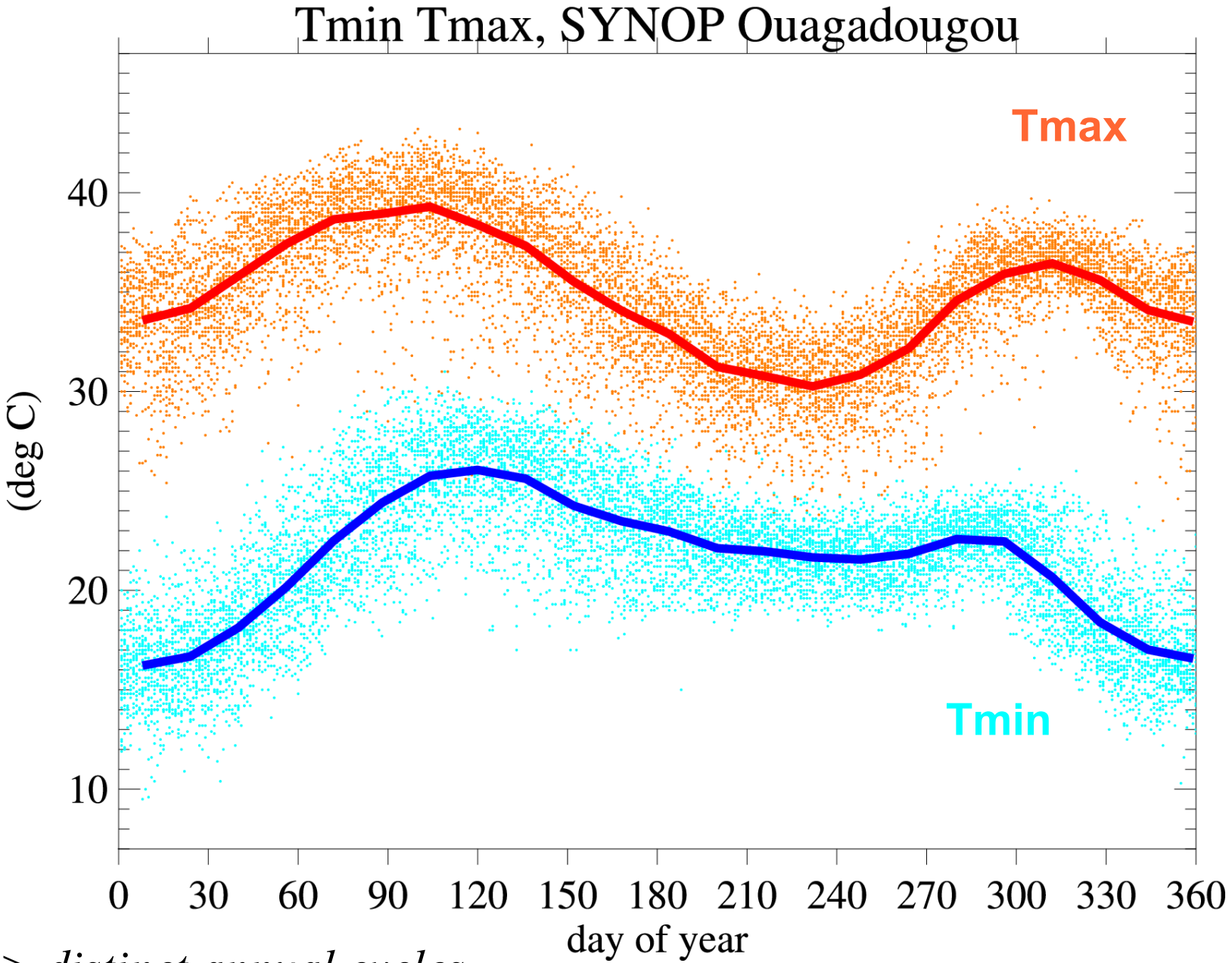
Automatic weather stations AMMA Catch

(thermo)dynamic-radiative couplings, interpretation of SYNOP data

Analyses over box averages or selected points (cfSites),same conclusions for observations



Representative of the annual cycle in the Sahel, East of 10°W [fct (latitude)]

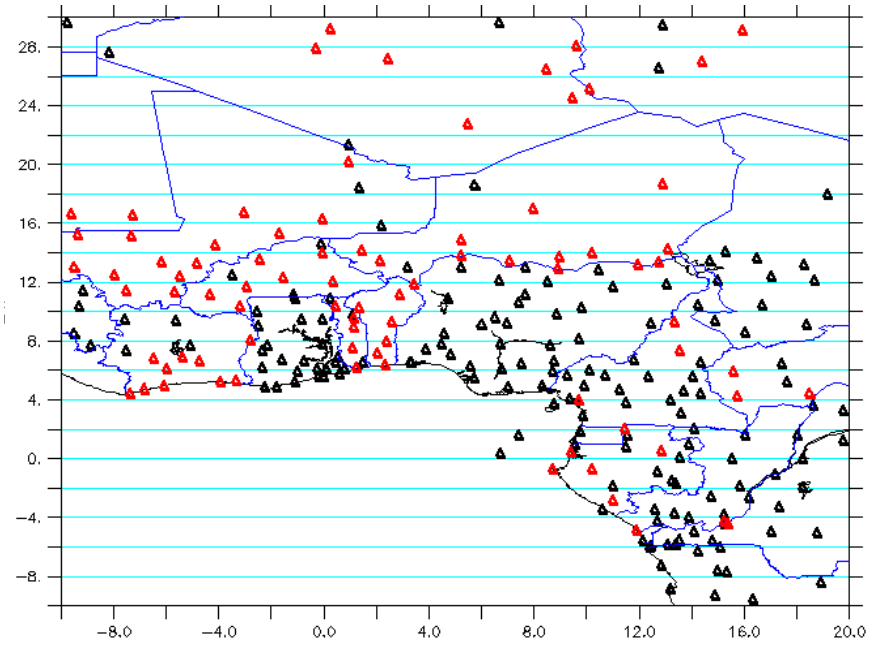


=> *distinct annual cycles*

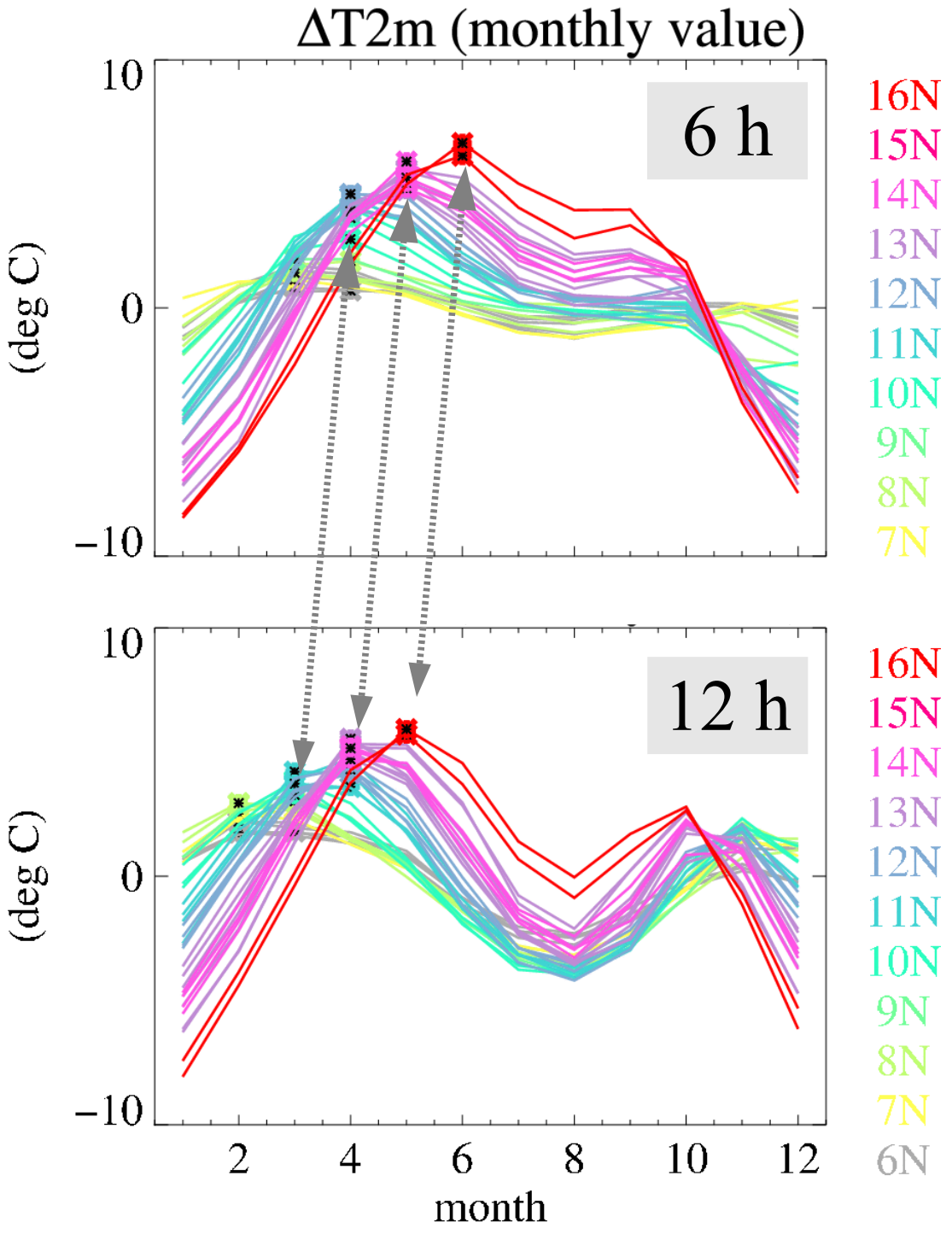
=> *lags between Tmin et Tmax extrema*

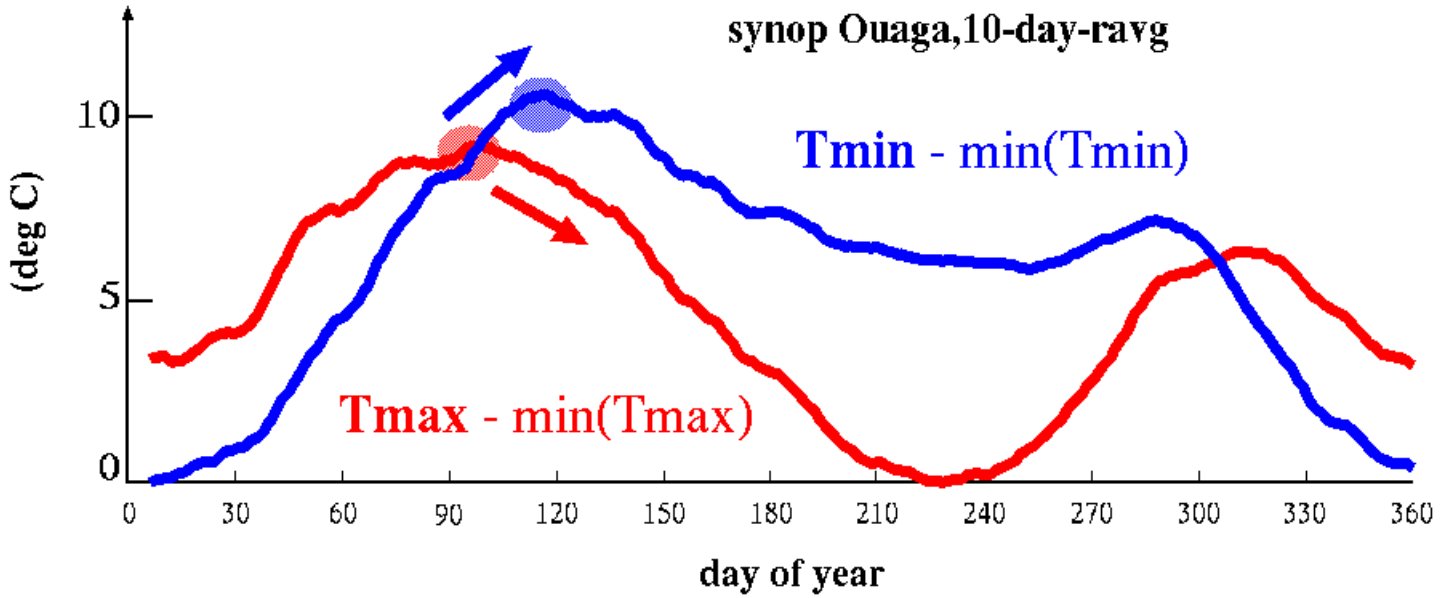
Only a limited decrease of interannual Tmin & Tmax variability in Spring

SYNOP data



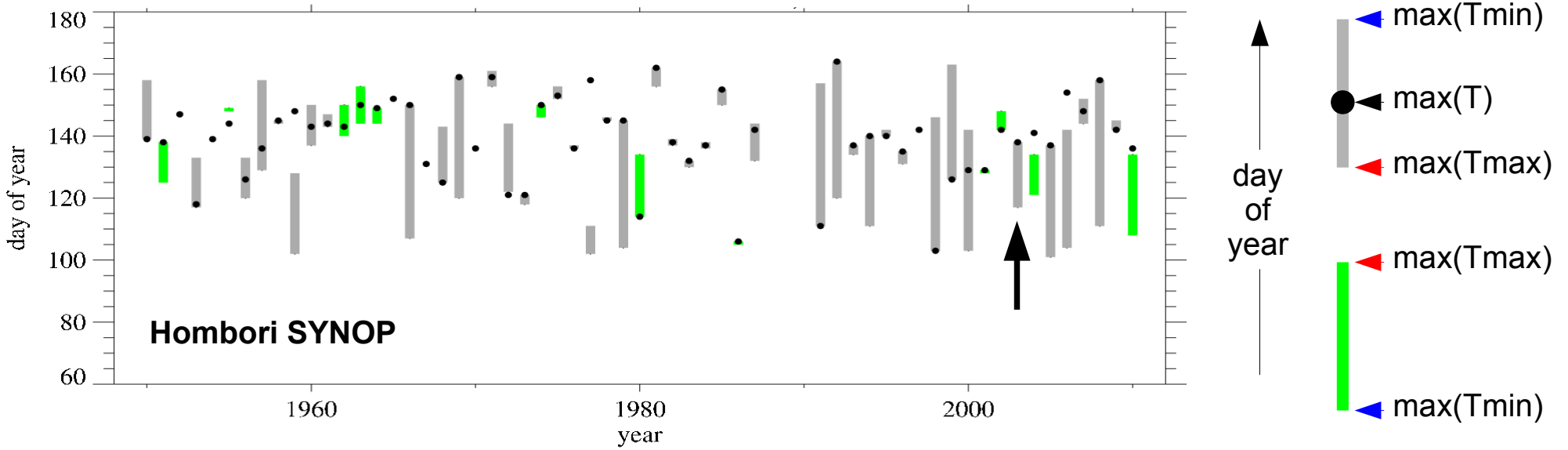
Δ : more than 25 years of data [1980,2010]

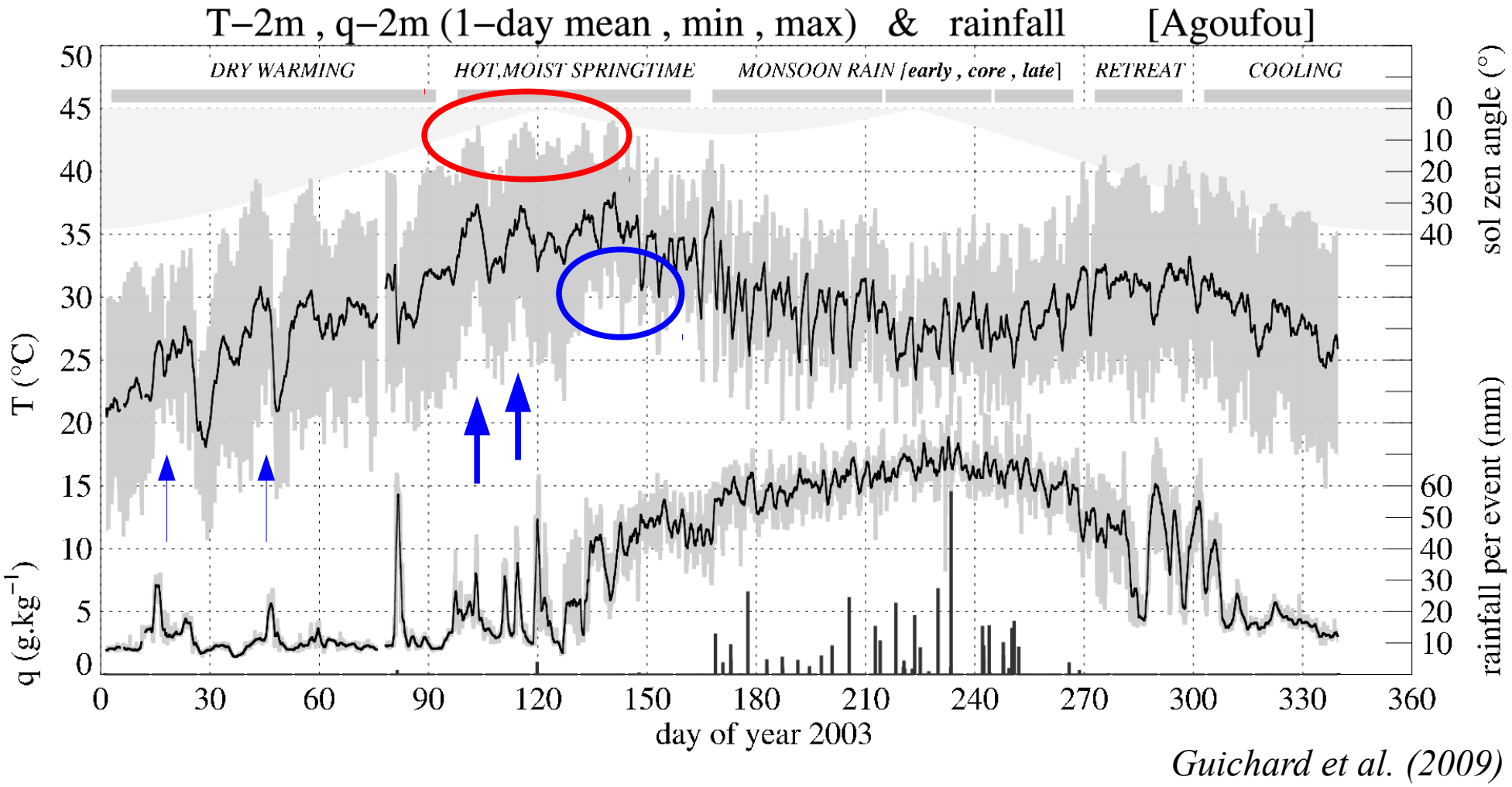




=> distinct cycles of Tmin & Tmax: leads to extend the duration of the spring maximum of daily T

interannual variability of the dates of Tmin and Tmax





Guichard et al. (2009)

=> Spring Tmin increases with the moonsoon moist flow

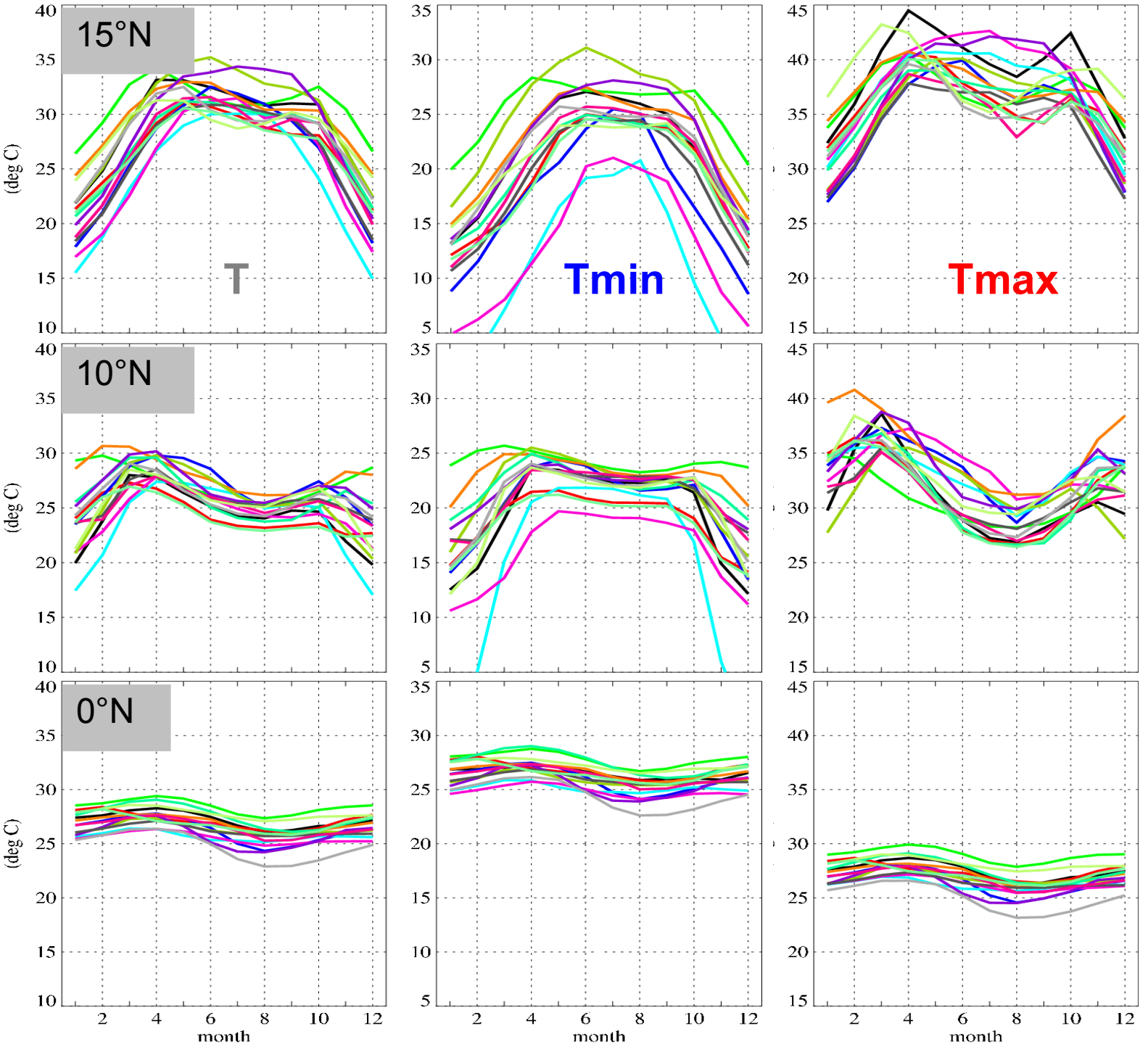
Annual cycle of 2m temperature in CMIP5 simulations

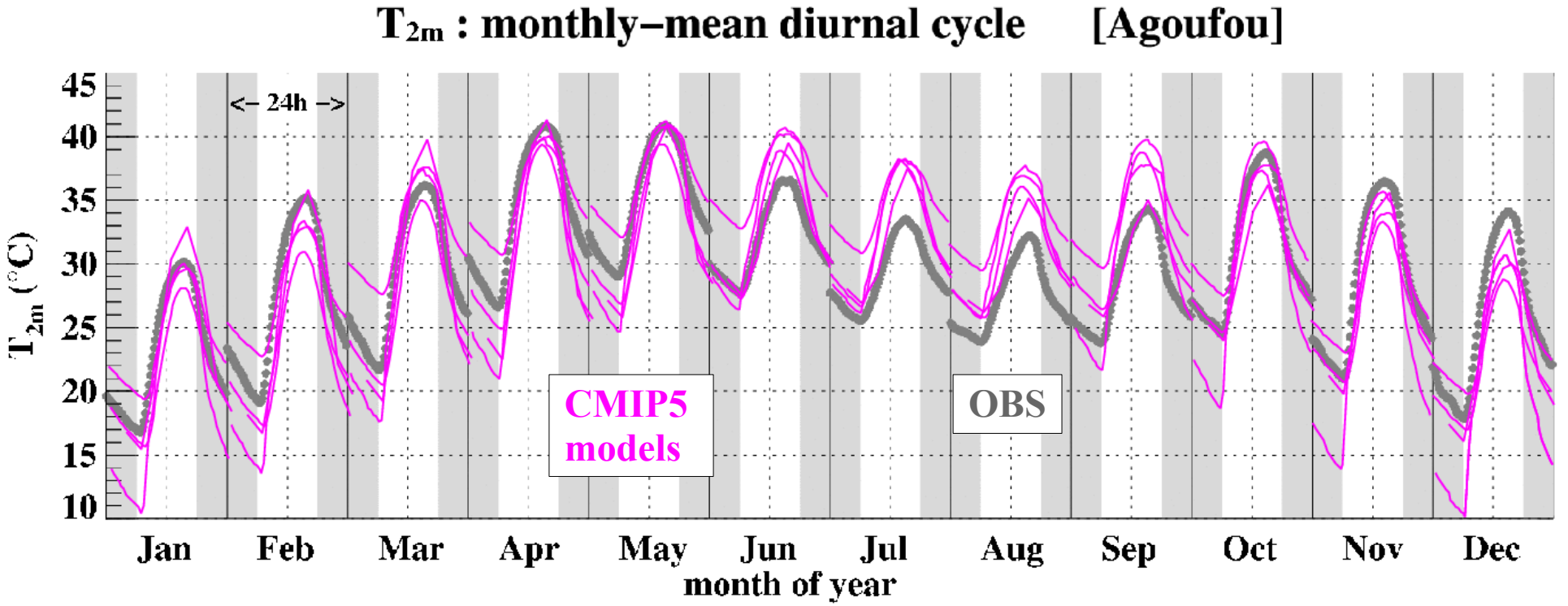
each model has its own annual cycle regardless of run types (amip, historical, picontrol)

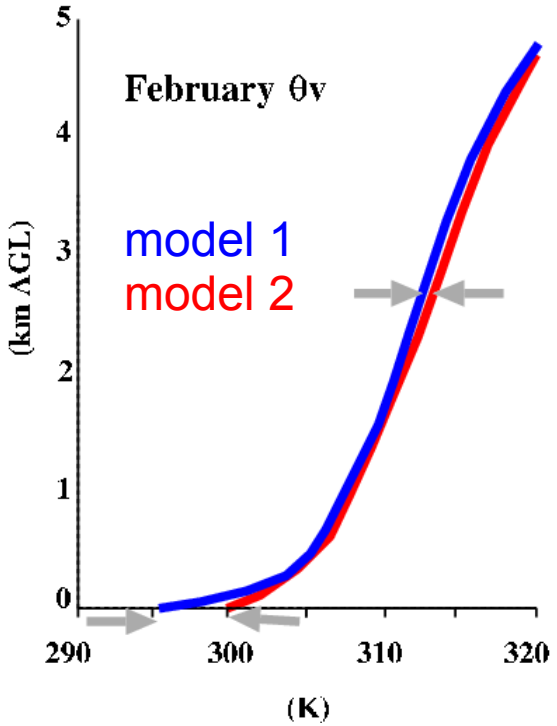
more spread among models in semi-arid areas than in the wet tropics

more spread outside of the monsoon season, especially for Tmin

results consistent with Traoré (2011) AMMA-MIP (Hourdin et al. 2010)







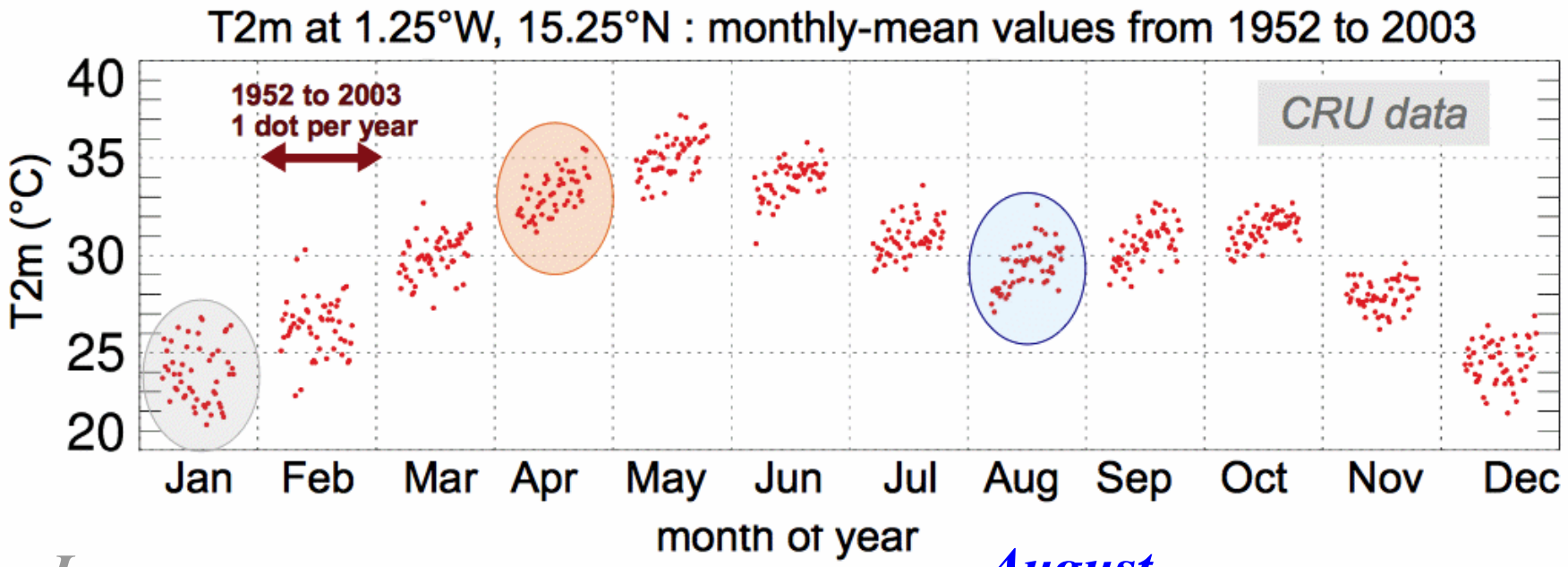
JFMA: cold bias at night
JJAS: warm bias during the day

Outside of the moister months, issues with the simulation of the nocturnal boundary layer

- *surface-turbulence-radiation + couplings with advection in the lowest levels*
- *not simply an issue with water vapour bias*

Complexity of the annual cycle of 2m temperature
Delicate processes in the very low atmosphere

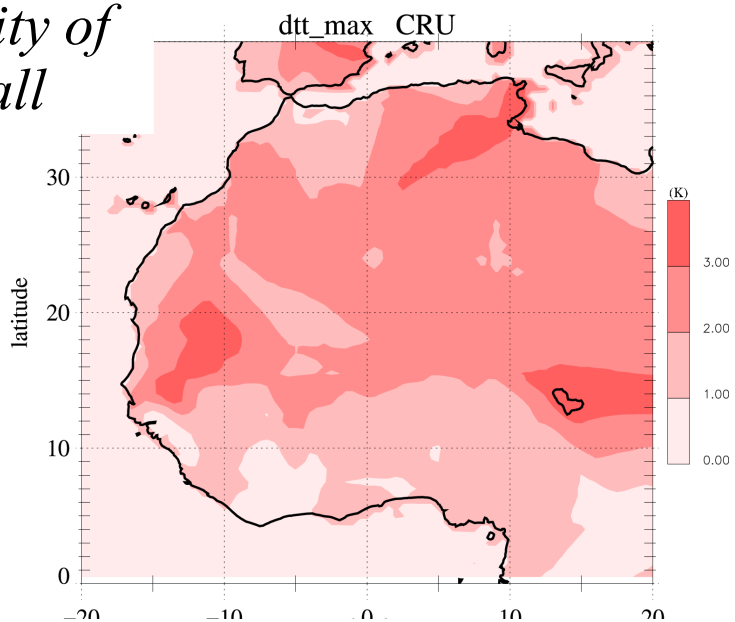
Decadal variations: CRU, central Sahel



January
dominated by short interannual variability

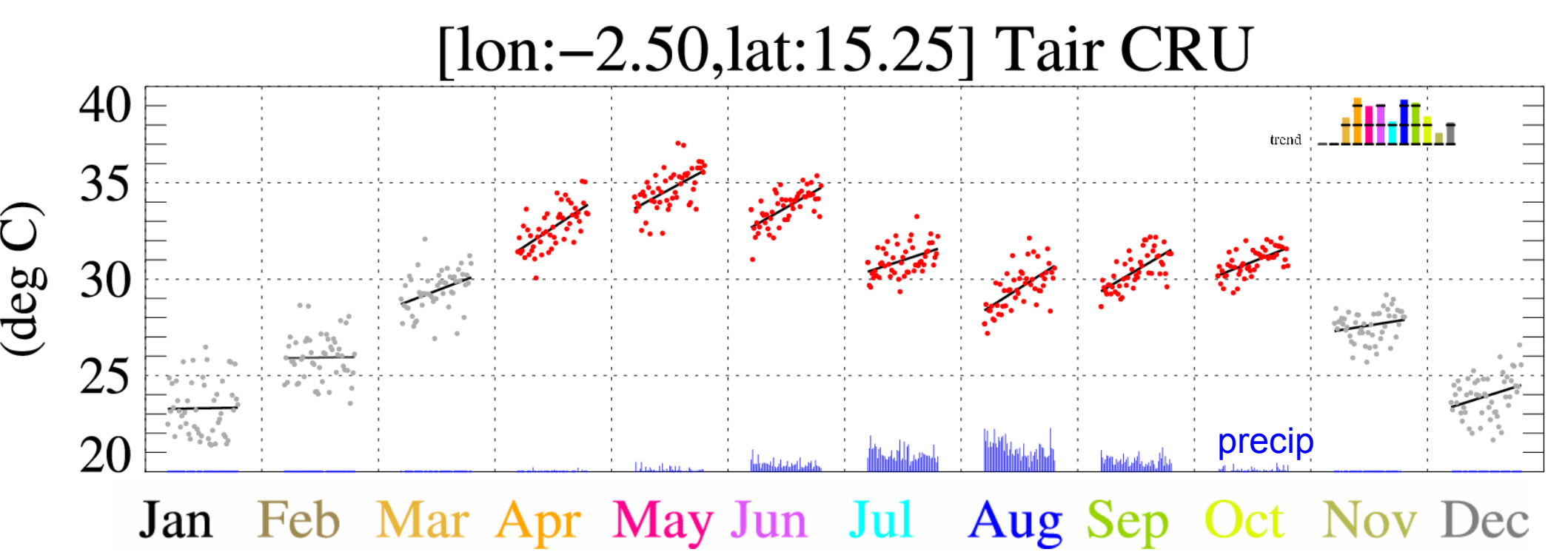
April
multidecadal trend dominates, strong!

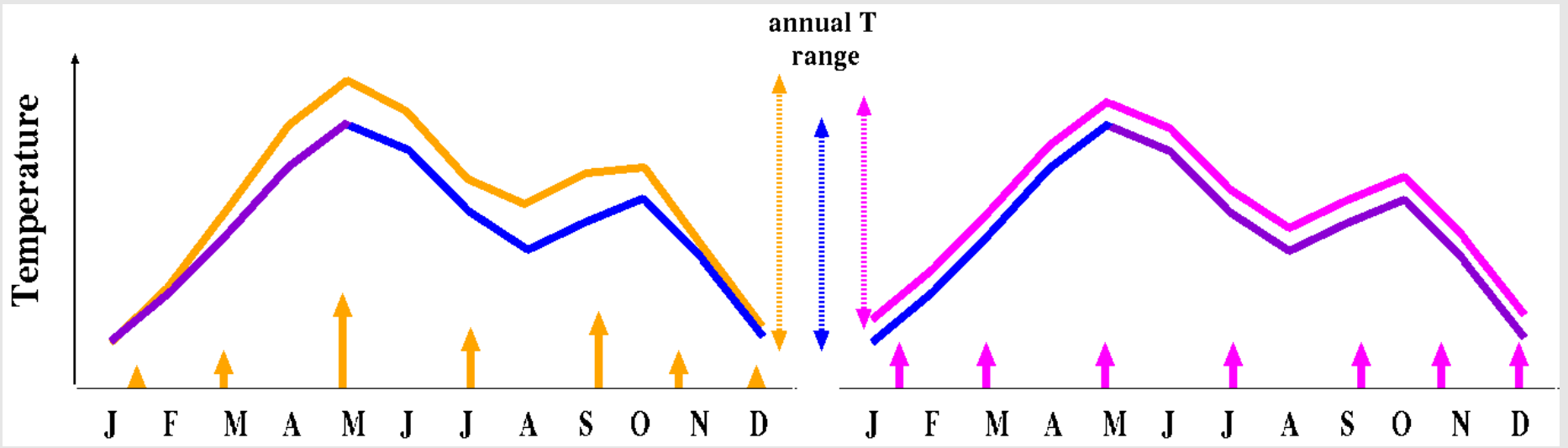
August
coupling with variability of rainfall



=> spatial coherency spatiale of this warming

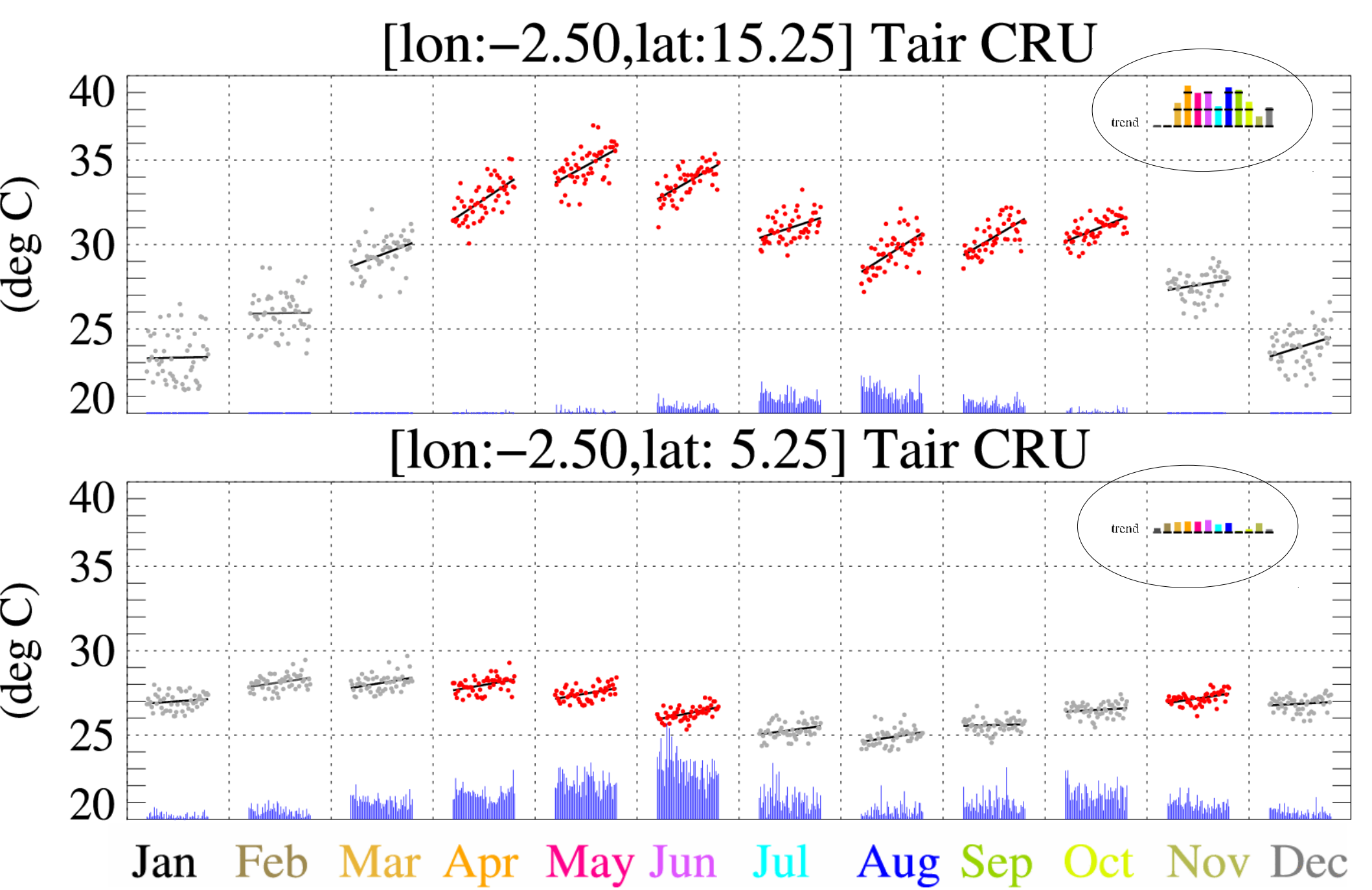
=> strong warming in other datasets too
including those starting in 1980





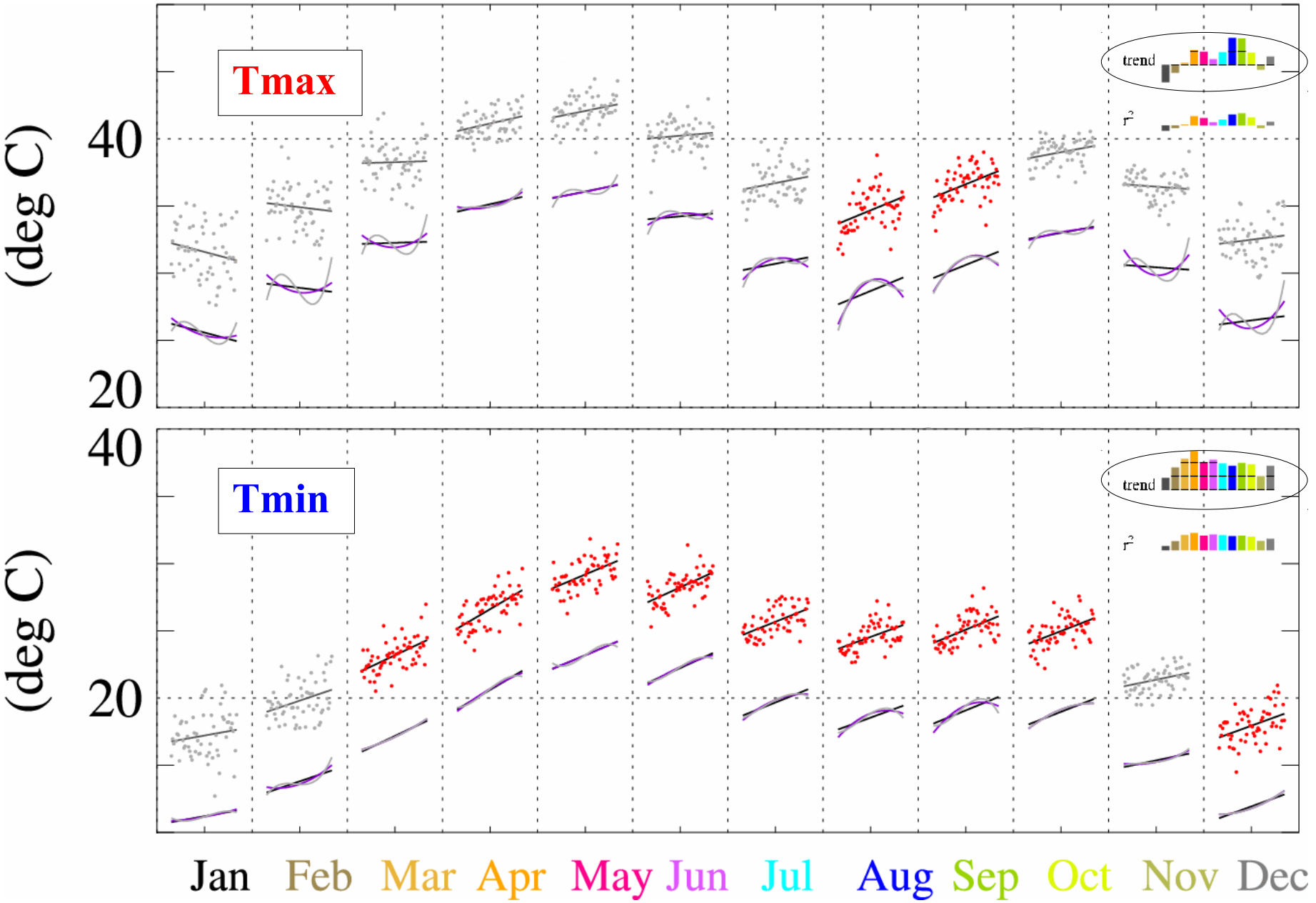
modification of the structure of the annual cycle

As opposed to a uniform increase which is not observed



Much stronger warming in the Sahel compared to southern locations

Hombori SYNOP data, 1950-2010



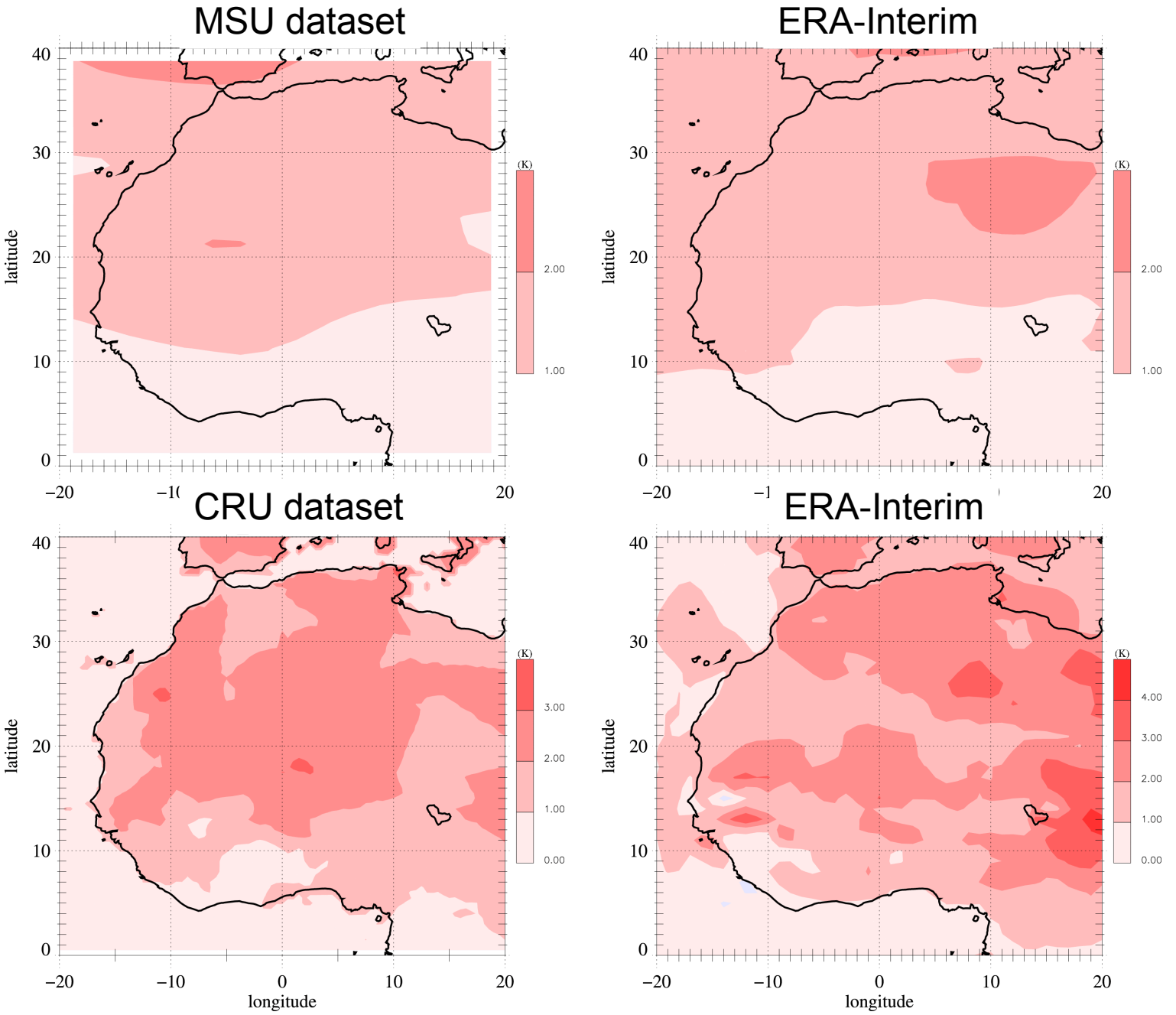
Temperature increase dominated by increase of Tmin

Maps of temperature trends 1980-2010 (monthly maximum)

Temperature In the lower troposphere

MSU: 0-8 km
ERA-I: 700 hPa

Temperature 2m above the surface

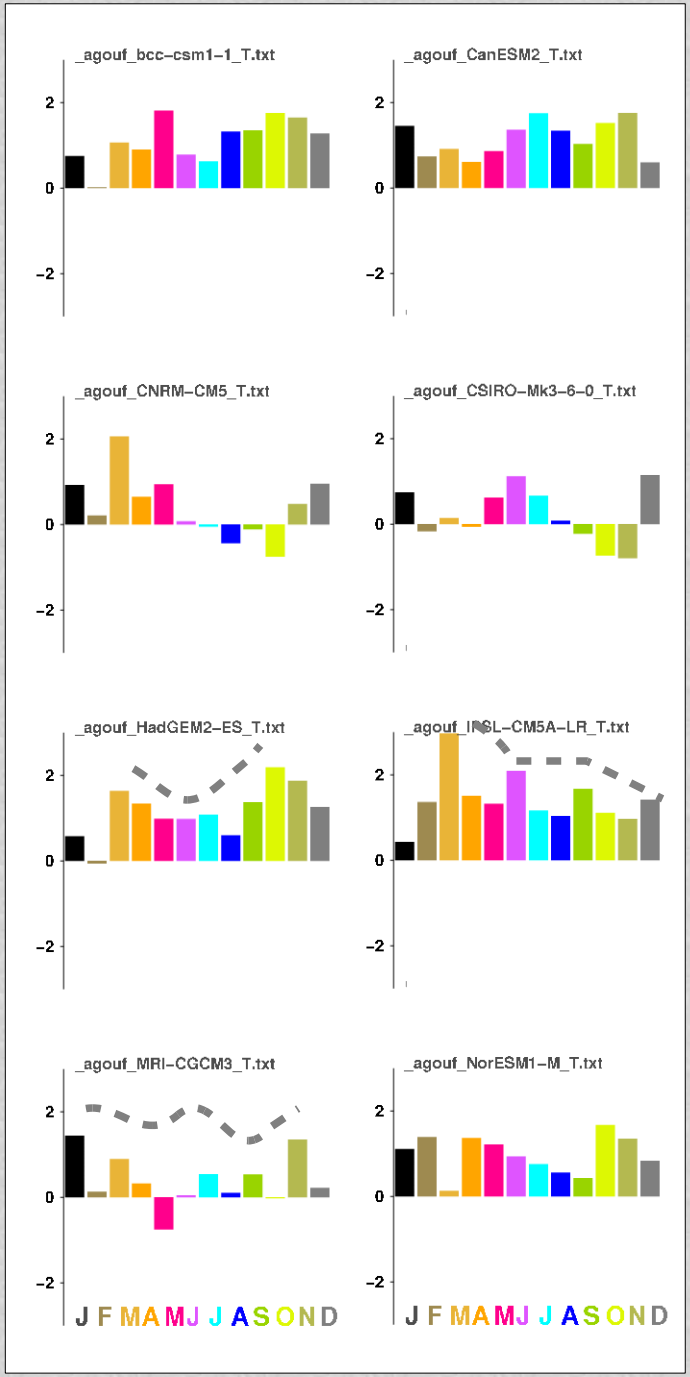


MSU: consistent with Collins et al. (2011)

CMIP5 historical runs, 1950-2010 trends, Sahel (Agoufou cfSite point)

Temperature (T)

- *T increase with diverse seasonalities, magnitudes*



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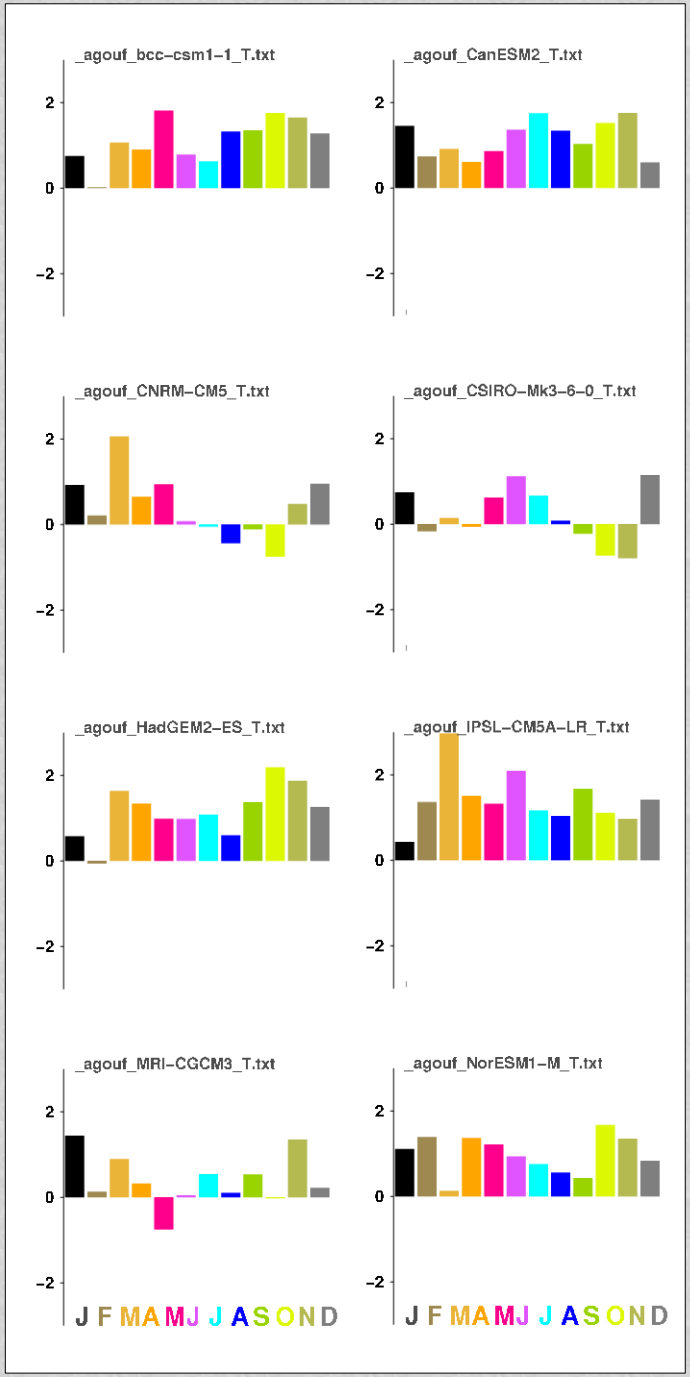
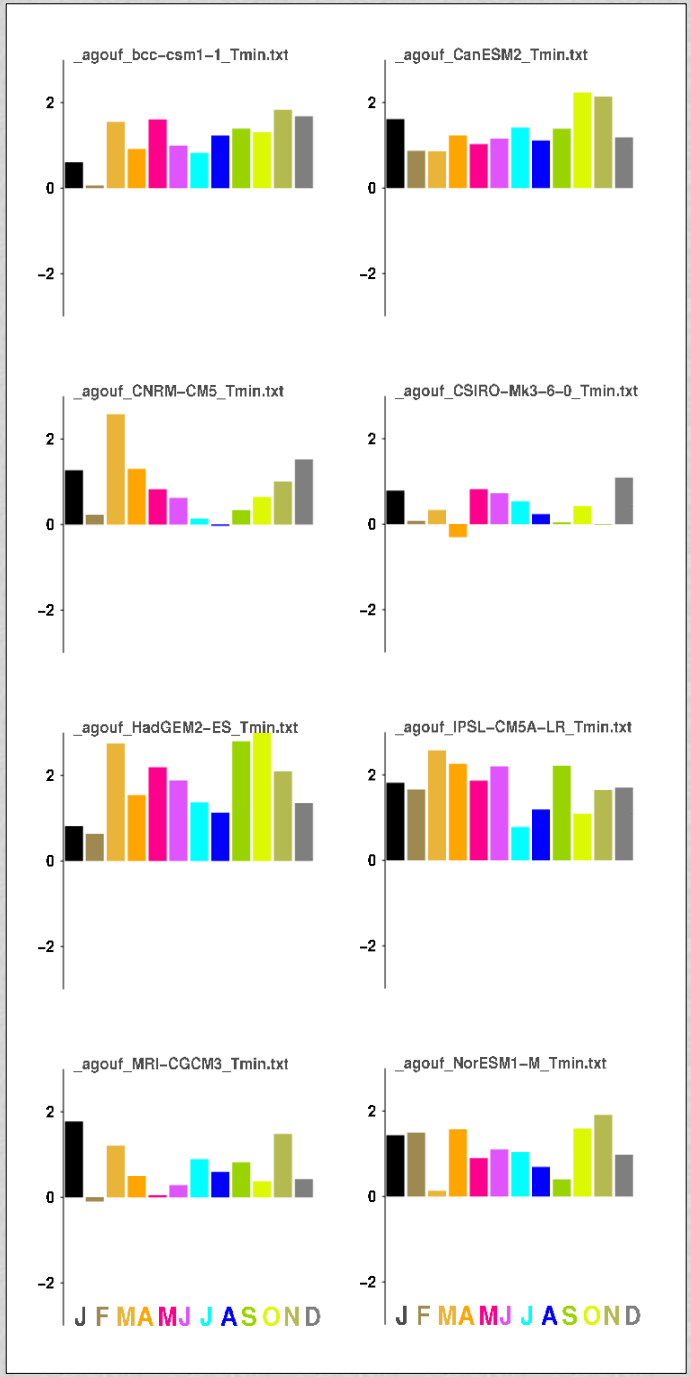


Minimum temperature (Tmin)



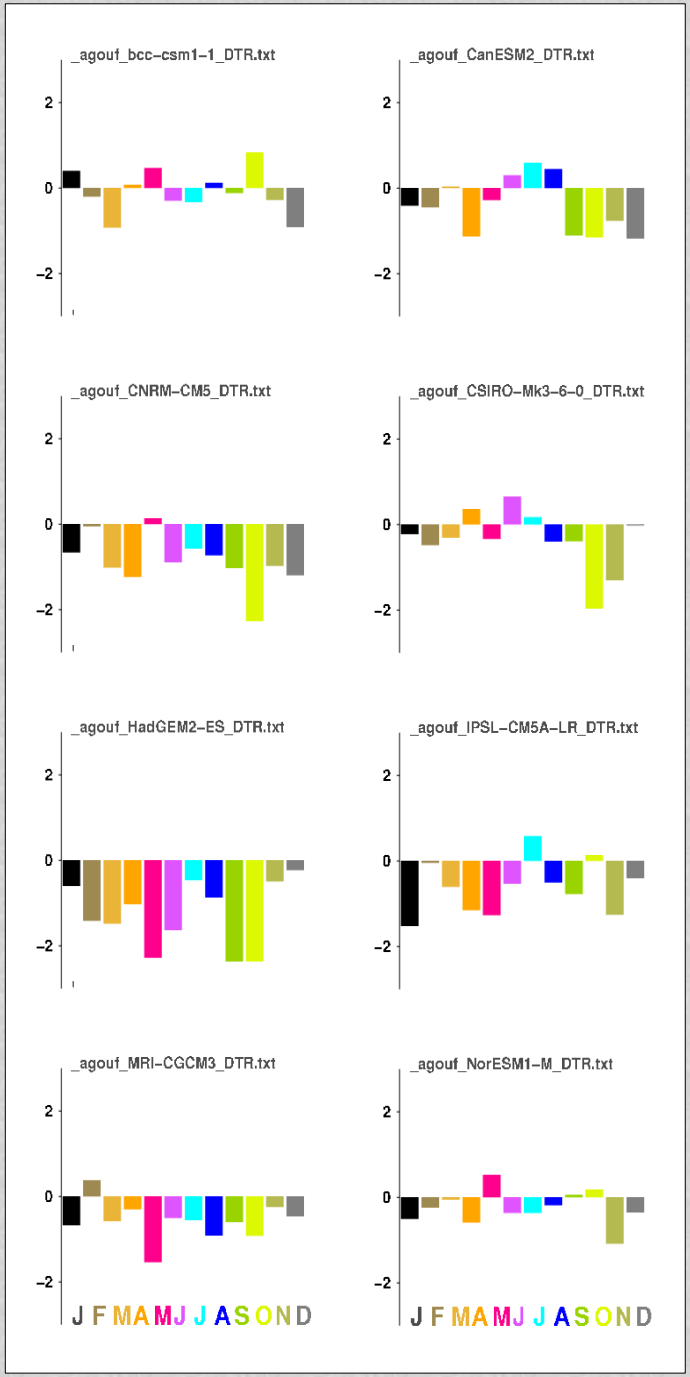
CMIP5 historical runs, 1950-2010 trends, Sahel (Agoufou cfSite point)

- *T increase with diverse seasonalities, magnitudes*

- *Tmin increase often more pronounced*

- *DTR decreases*

DTR (diurnal T range)



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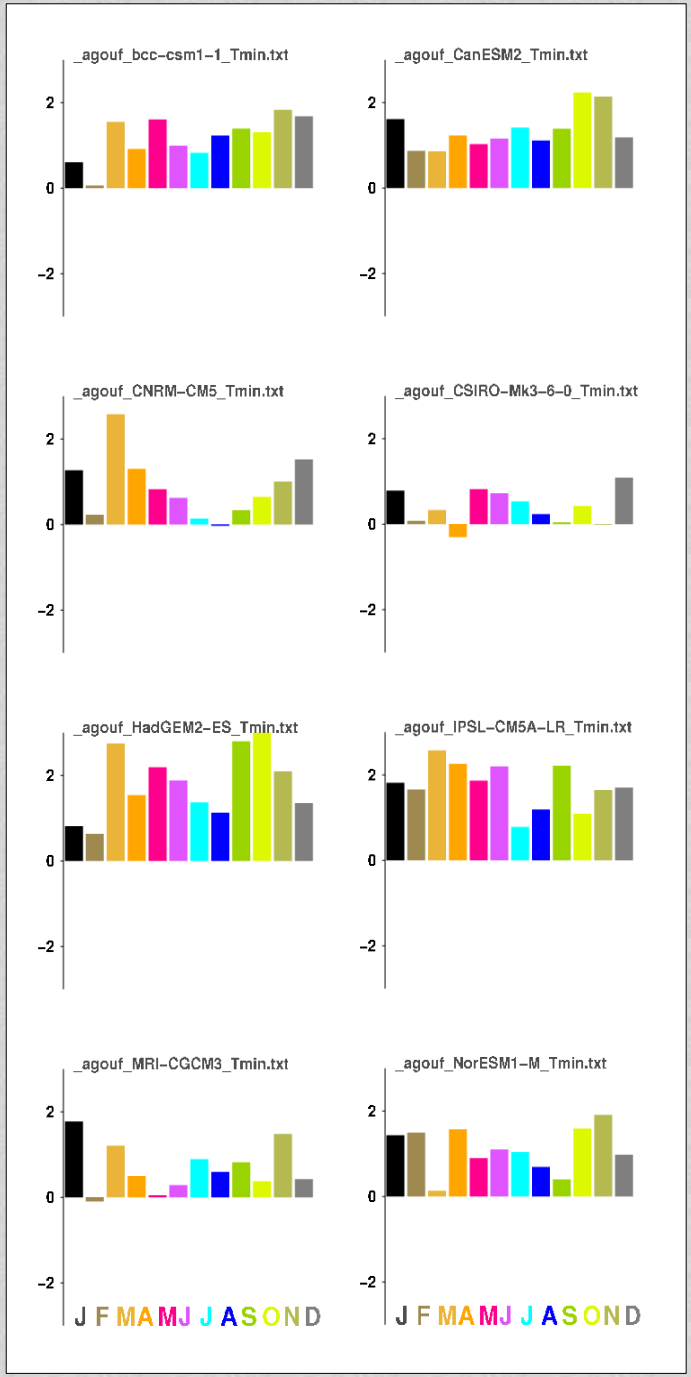

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- *various qv trends in spring too*

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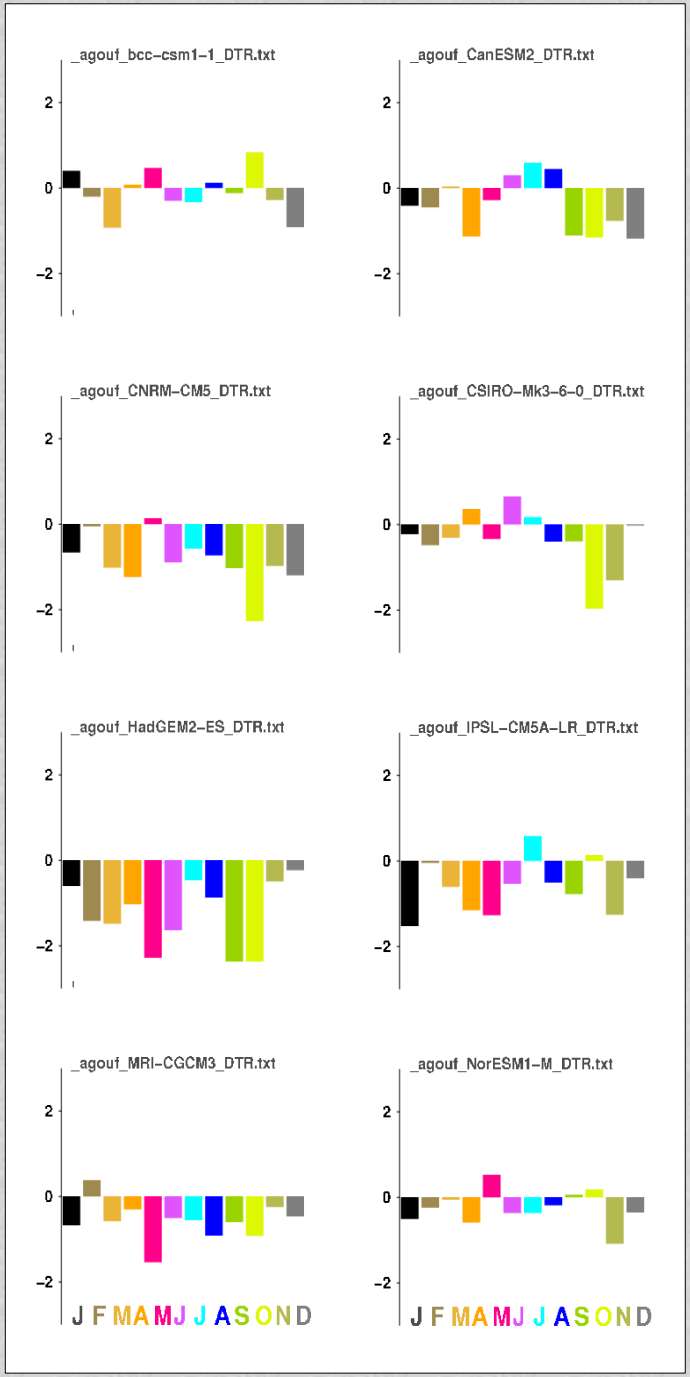
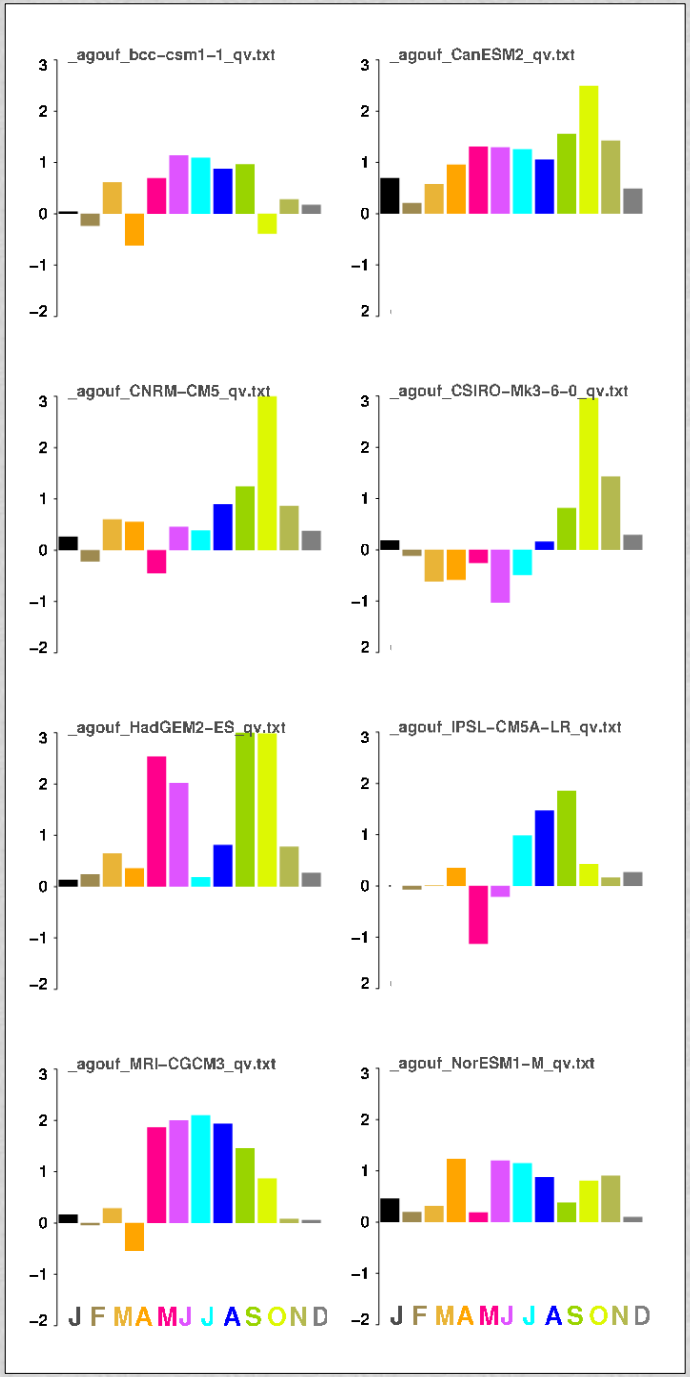


Specific humidity (qv)



CMIP5 historical runs, 1950-2010 trends, Sahel (Agoufou cfSite point)

- *T increase with diverse seasonalities, magnitudes*

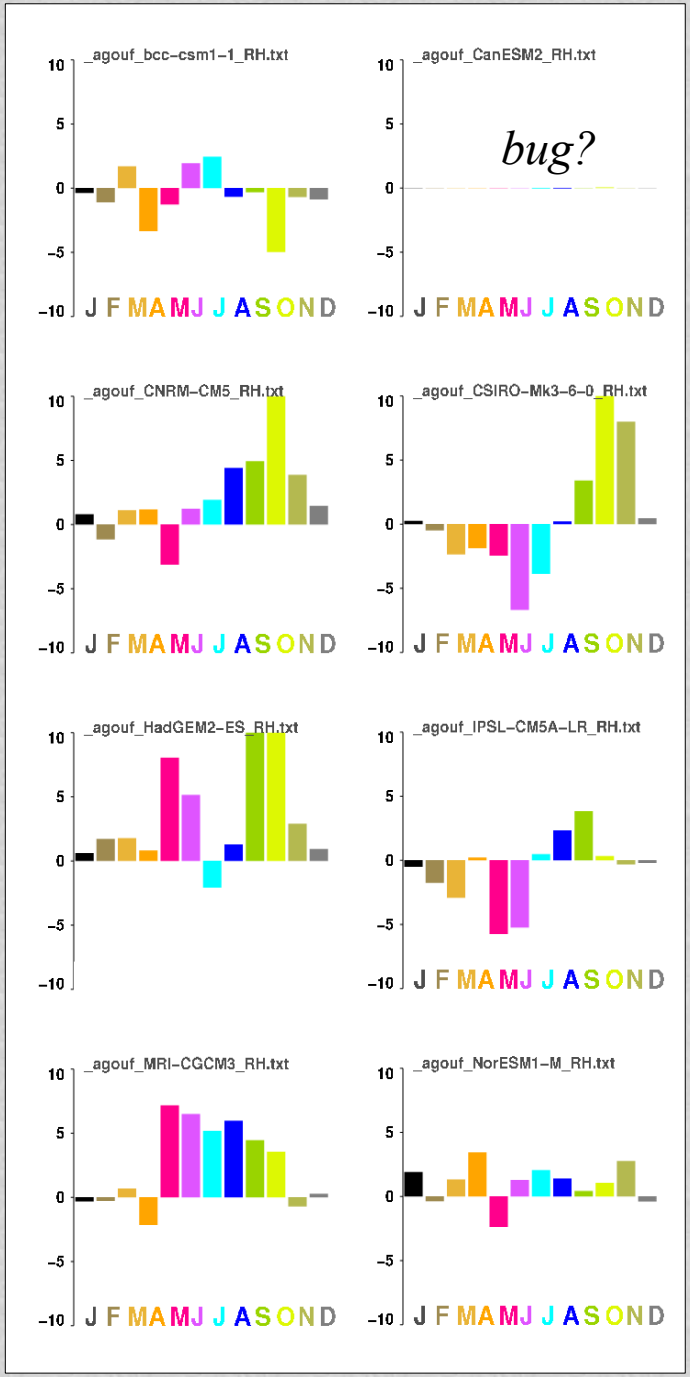
- *Tmin increase often more pronounced*

- *DTR decreases*

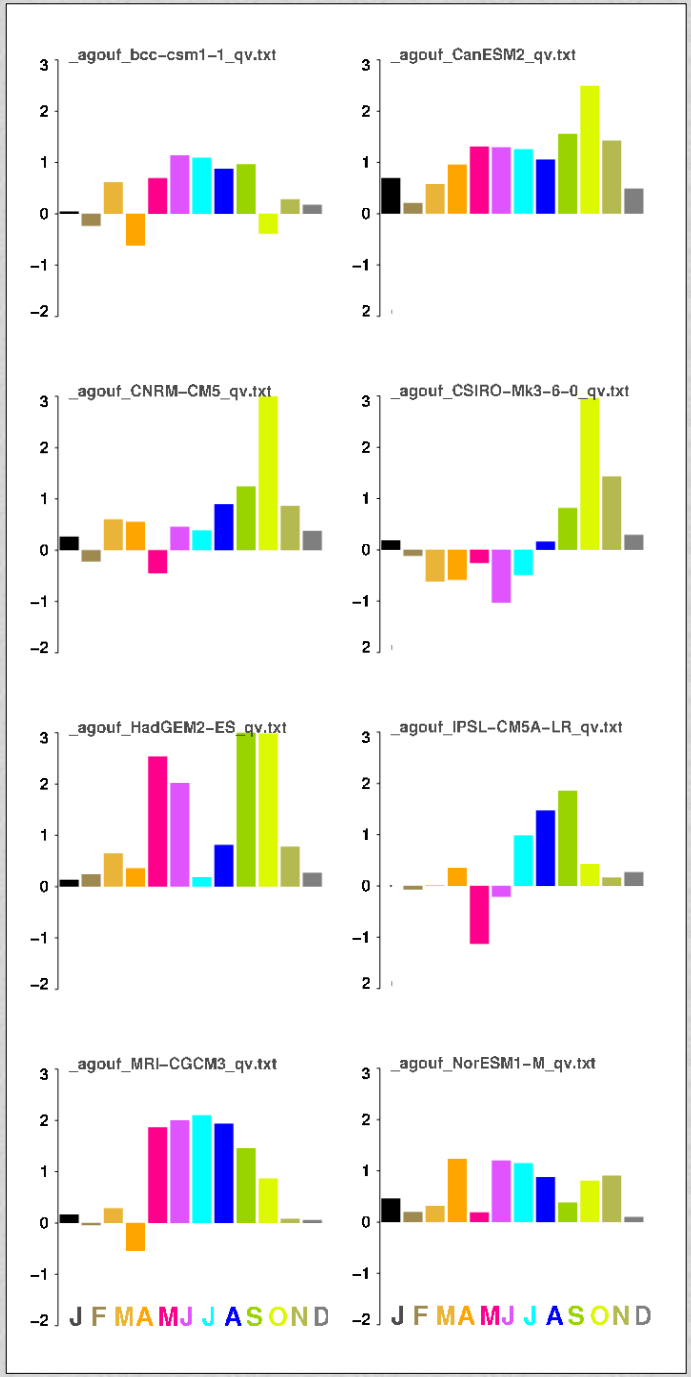
- *various qv and RH trends in spring too*

Error in rainfall cannot alone account for the wide spread among models

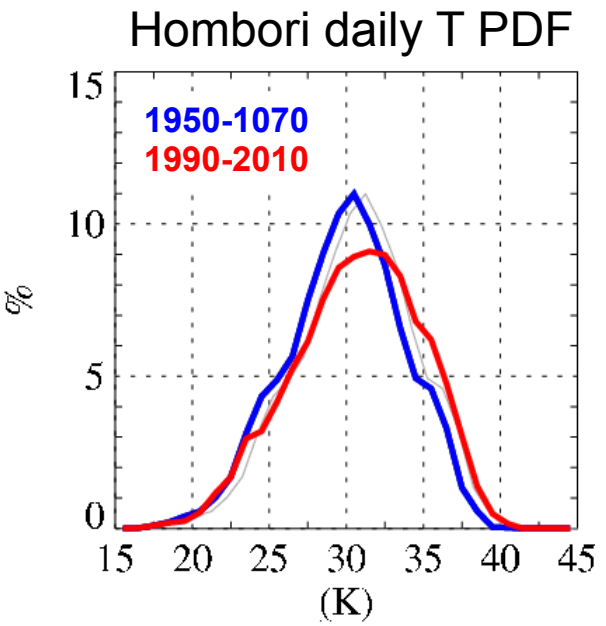
Relative humidity (RH)



Specific humidity (qv)



Conclusion, perspectives



Observations show a non-uniform warming in the Sahel during the past 60 years

increase of the amplitude of the annual cycle of temperature

- no clear warming during the dry cool season ~ JFM, ND
  "dry" meaning "very low moisture", not "no rain"
- strong warming during warmer moist months ~ AMJ
- weaker warming during the monsoon rain ~ JAS

Some data suggest a possible joint moistening at the surface in some areas (CRU, HadCRUH, SYNOP) *more work needed*

<u>interpretation/speculation</u>

A large radiative impact of water vapour in Spring (role of the monsoon flow?)
In summer, this impact is weakened by precipitations (cooling of the surface)
Need for more analyses of emerging couplings between temperature, humidity, DTR, radiative fluxes, precipitations, clouds and aerosols (obs & models)

<u>Several questions...</u>

impact of this spring warming on the monsoon onset? length versus intensity?
local and larger scale considerations (e.g. meridional gradient)
impact on convection intensity?
And beyond: vegetation perhaps, but also social, human issues...