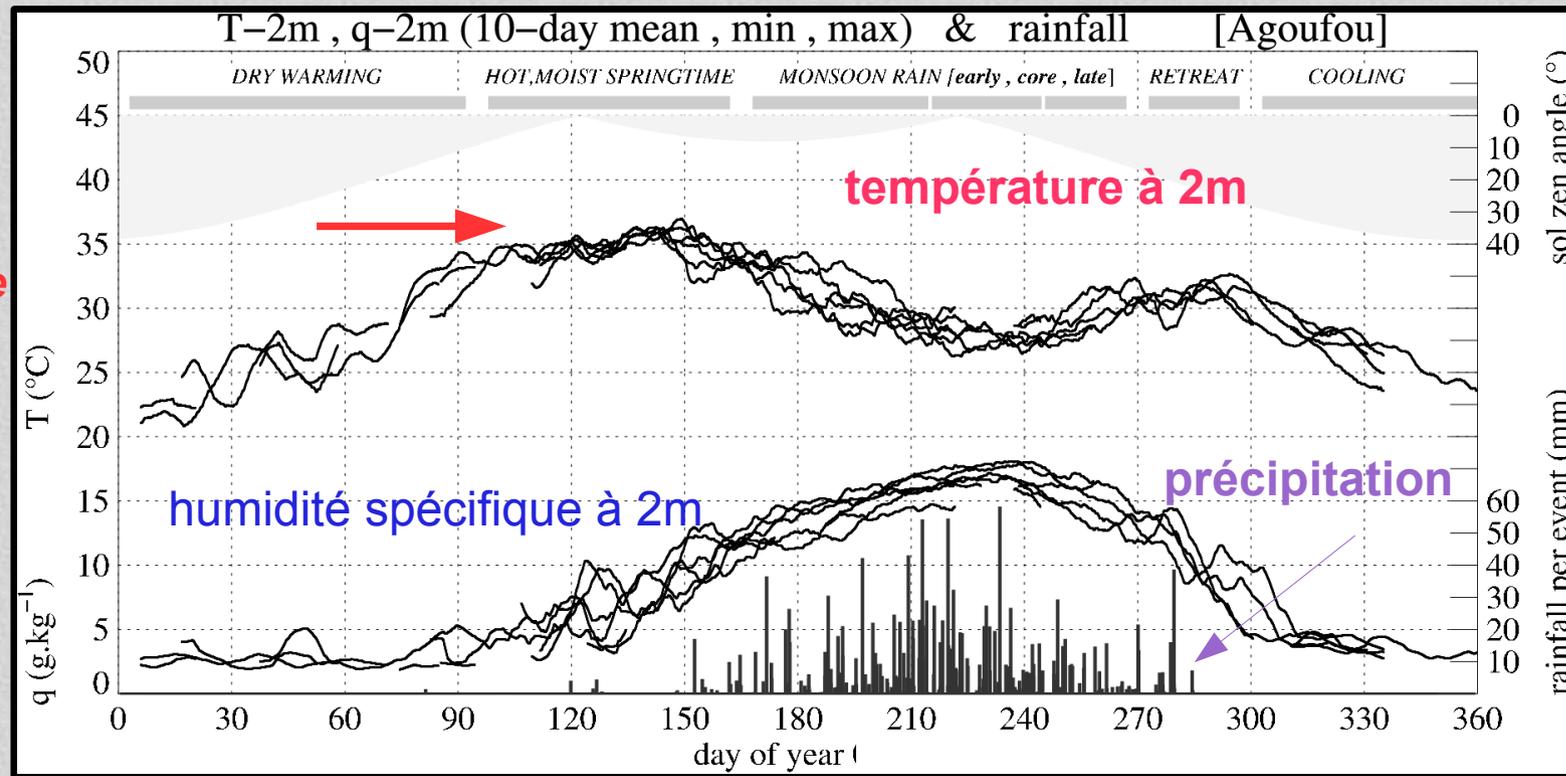


Réchauffement au Sahel

cycle annuel de la température (T)

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



Mai
moyenne mensuelle
T à 2m
35°C

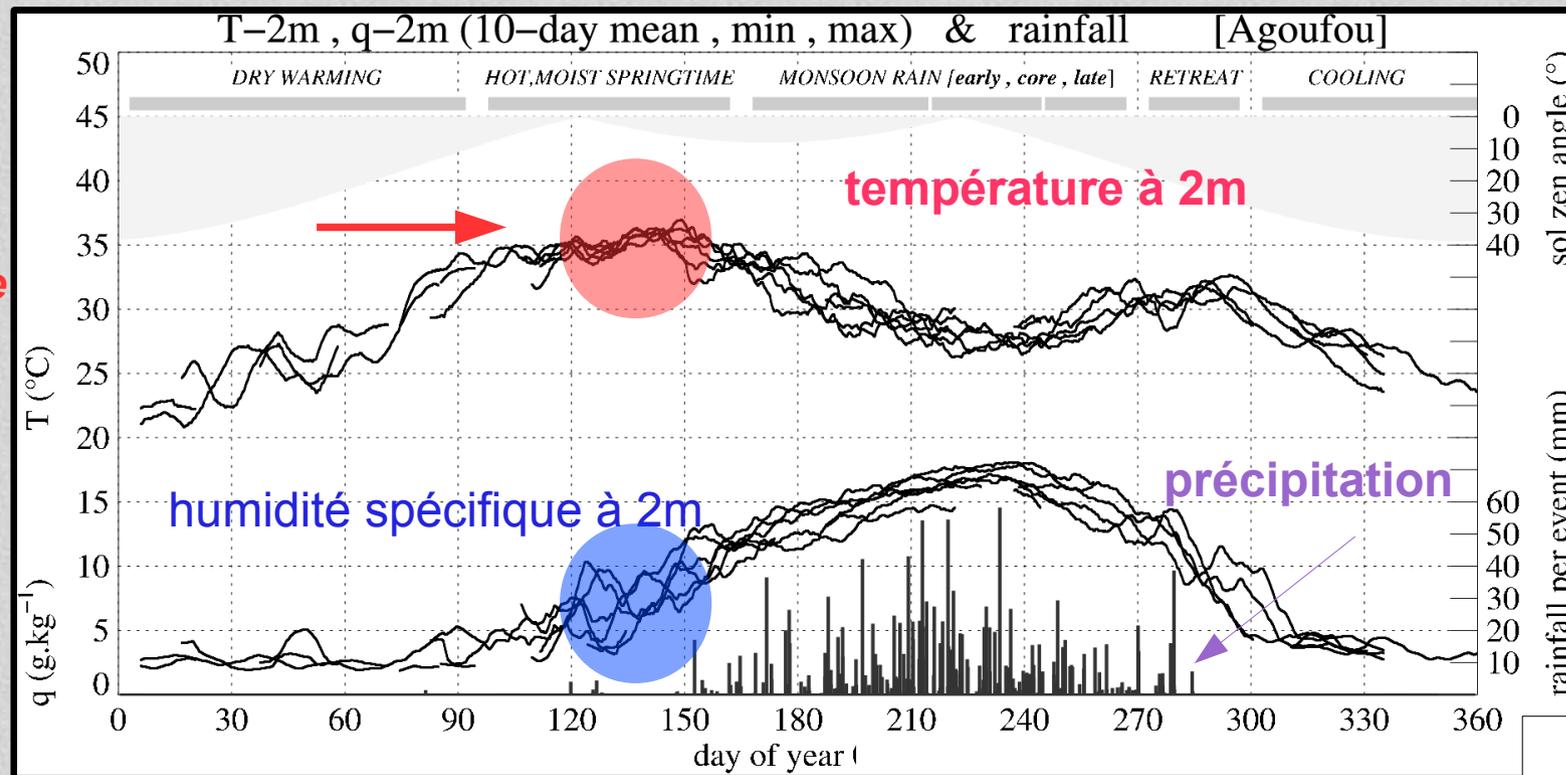
Au Sahel, températures très élevées au printemps (climatique)

=> plusieurs semaines (maximum 'plat') : pourquoi? cycle diurne

Réchauffement au Sahel

cycle annuel de la température (T)

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



Station
météo
automatique

Agoufou
Mali
(1.5°W, 15.3°N)

ANR

escape

Au Sahel, températures très élevées au printemps (climatique)

- ⇒ plusieurs semaines (maximum 'plat') : pourquoi? *cycle diurne*
- ⇒ fluctuations d'une année à l'autre ? *Fde qq à qq dizaines d'années...*
- ⇒ que simulent les modèles climatiques actuels (CMIP5) ?

Mai
moyenne
mensuelle
T à 2m
35°C

Données, produits, modèles

Données SYNOP

Stations météo: données journalières, valeurs min et max, ou 0, 6, 12, 18h UTC

=> 1900/1950 à 1980 et 1995 à 2011 [*min, max: base de données AMMA*]

=> 1980-2011 [*0,6,12,18h*]

=> station SYNOP d'Hombori au Mali (*1.5°W, 15.3°N*), *Mougin et al.*
longue série, vérifiée, peu de trous, arrêtée en février 2012

Stations météo automatiques AMMA Catch (~ 10 ans)

Couplages (thermo)dynamic-radiative, interpretation des données SYNOP

Produits grillés

=> CRU 2.1 1952-2003, CRU 3.1: 1901-2009 (mensuel, 0.5 deg x 0.5 deg)

=> BEST (mensuel, stations très nombreuses)

Modèles

=> reanalyses météorologiques

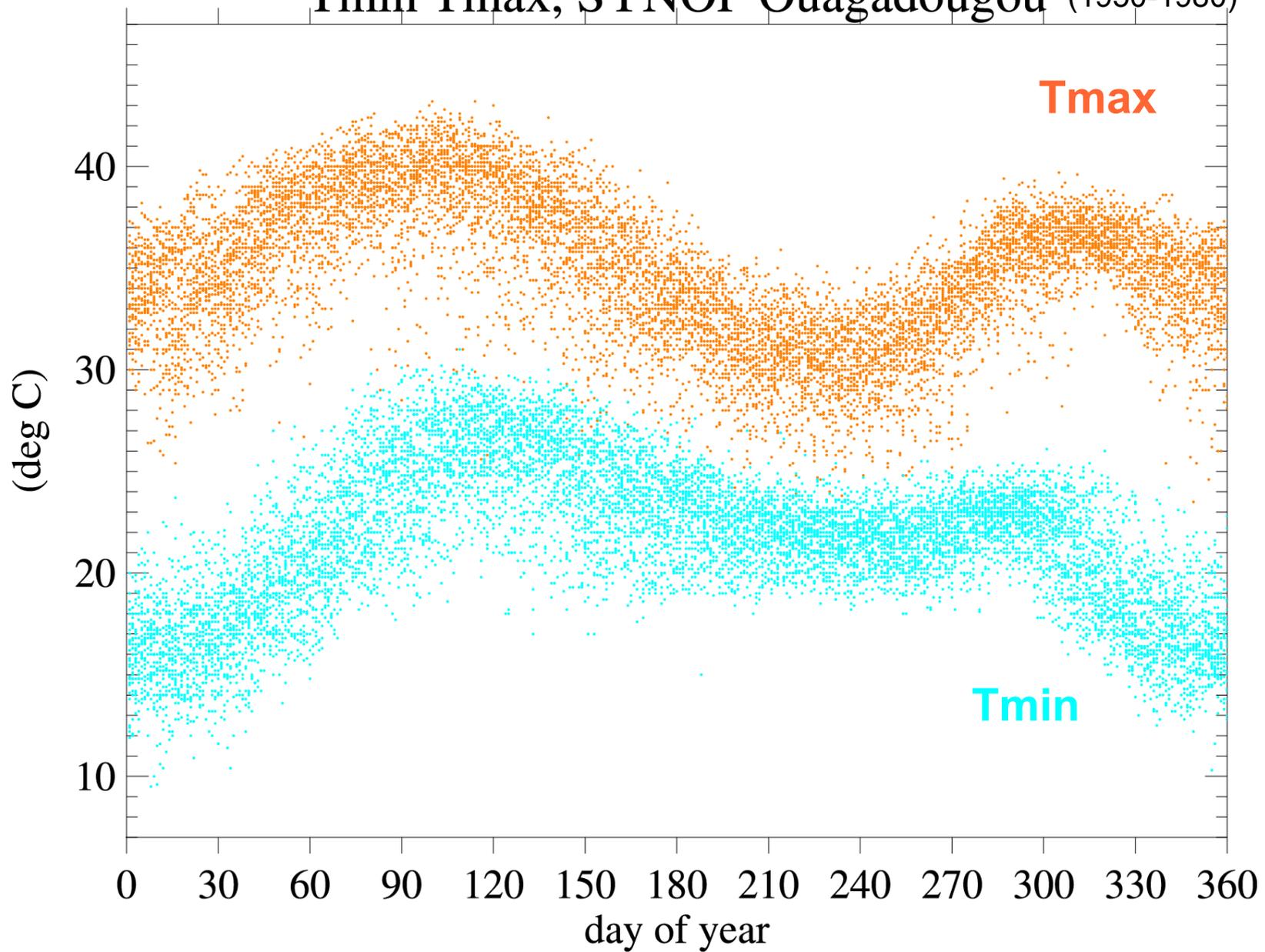
ERA 40: 1958-2002

ERA-Interim, MERRA, NCEP-CSFR, all ~ 1979-2010

=> Modèles climatiques CMIP5 (simulations **amip**, historical, historicalNat, piControl) cfSites

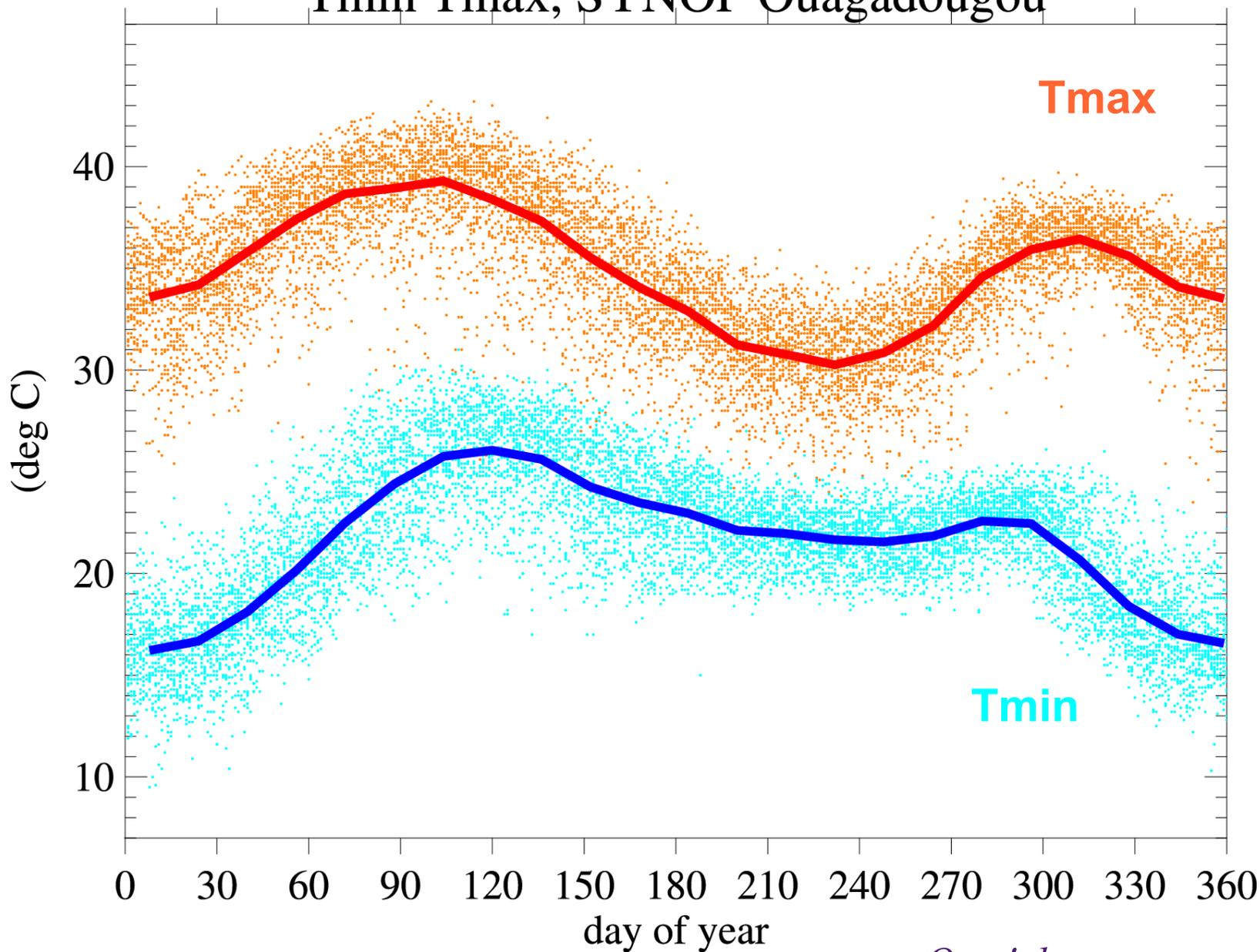
Analyses sur des boîtes ('Sahel'..) ou pour des sites précis (points cfSites), mêmes conclusions

Tmin Tmax, SYNOP Ouagadougou (1950-1980)



Representatif du cycle annuel au Sahel, à l'est de 10°W [fct (latitude)]

Tmin Tmax, SYNOP Ouagadougou

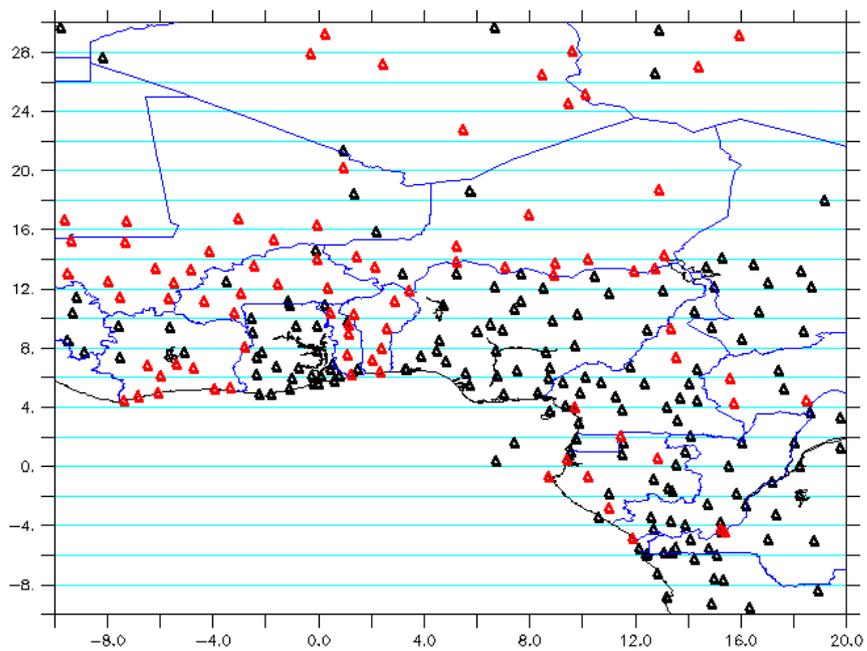


=> cycles annuels de Tmin et Tmax distincts

=> décalage des extrêmes de Tmin et Tmax

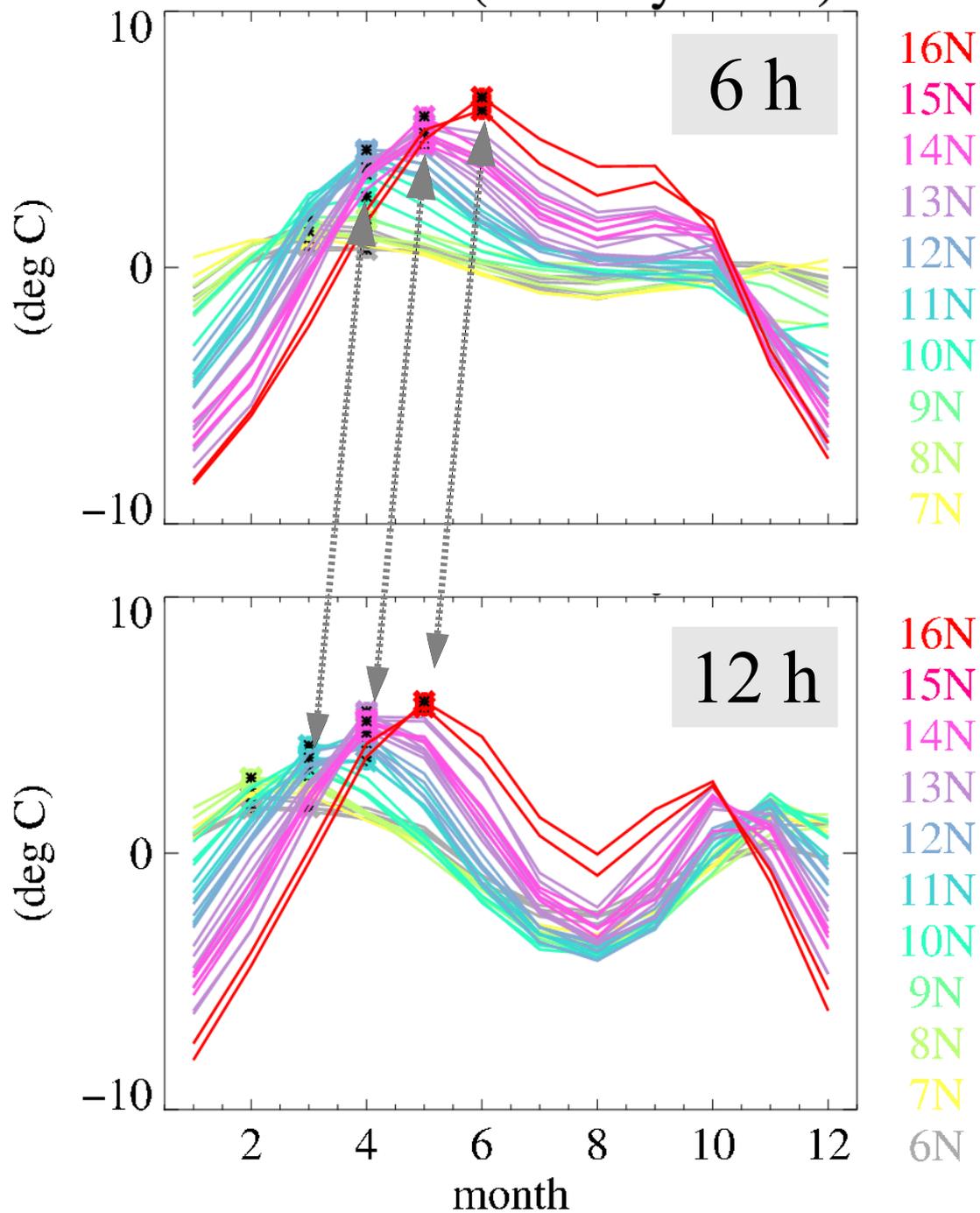
On n'observe pas une variabilité interannuelle de Tmin & Tmax au printemps bcp plus faible relativement au reste de l'année

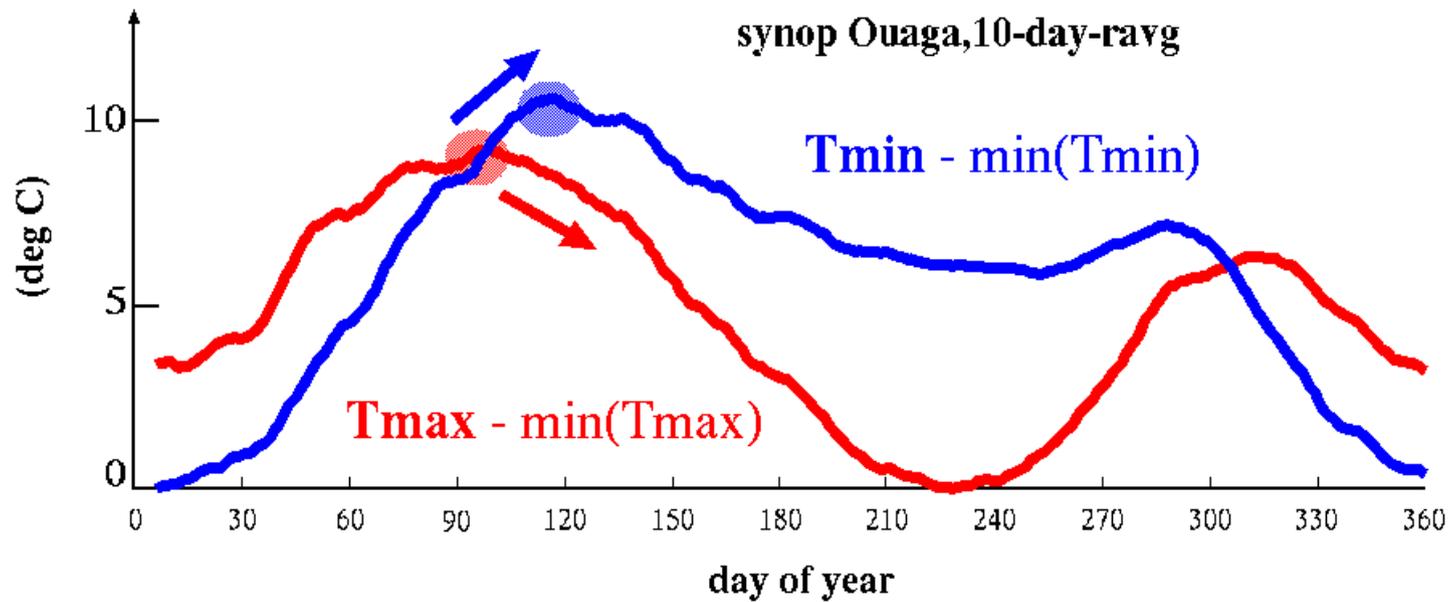
SYNOP data



données sur ~ 25 ans ou plus [1980,2010]

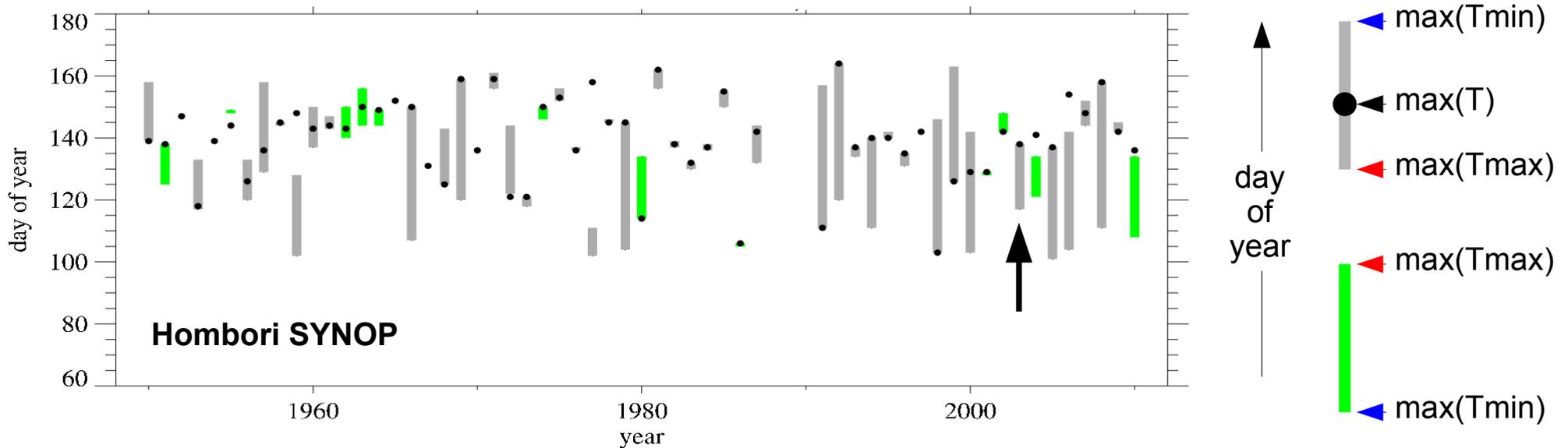
ΔT_{2m} (monthly value)



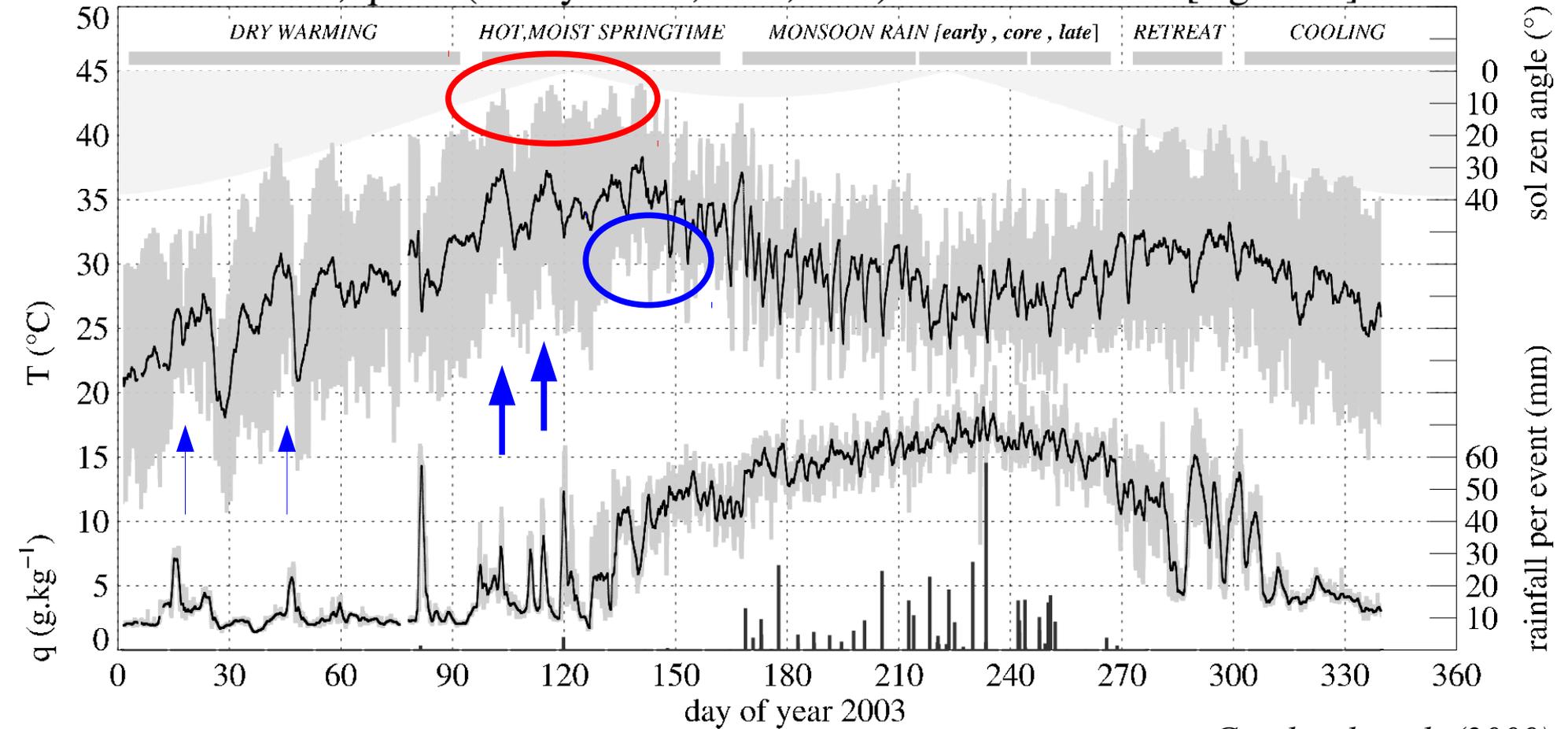


=> cycles annuels de T_{min} & T_{max} distincts conduisent à une longue durée du maximum printanier de la température journalière

Variabilité interannuelle des dates de maximum de T_{min} , T_{max} , $T_{journalier}$



T-2m , q-2m (1-day mean , min , max) & rainfall [Agoufou]



Guichard et al. (2009)

=> fortes augmentations des T_{min} au printemps, lors des incursions du flux de mousson avant les premières pluies

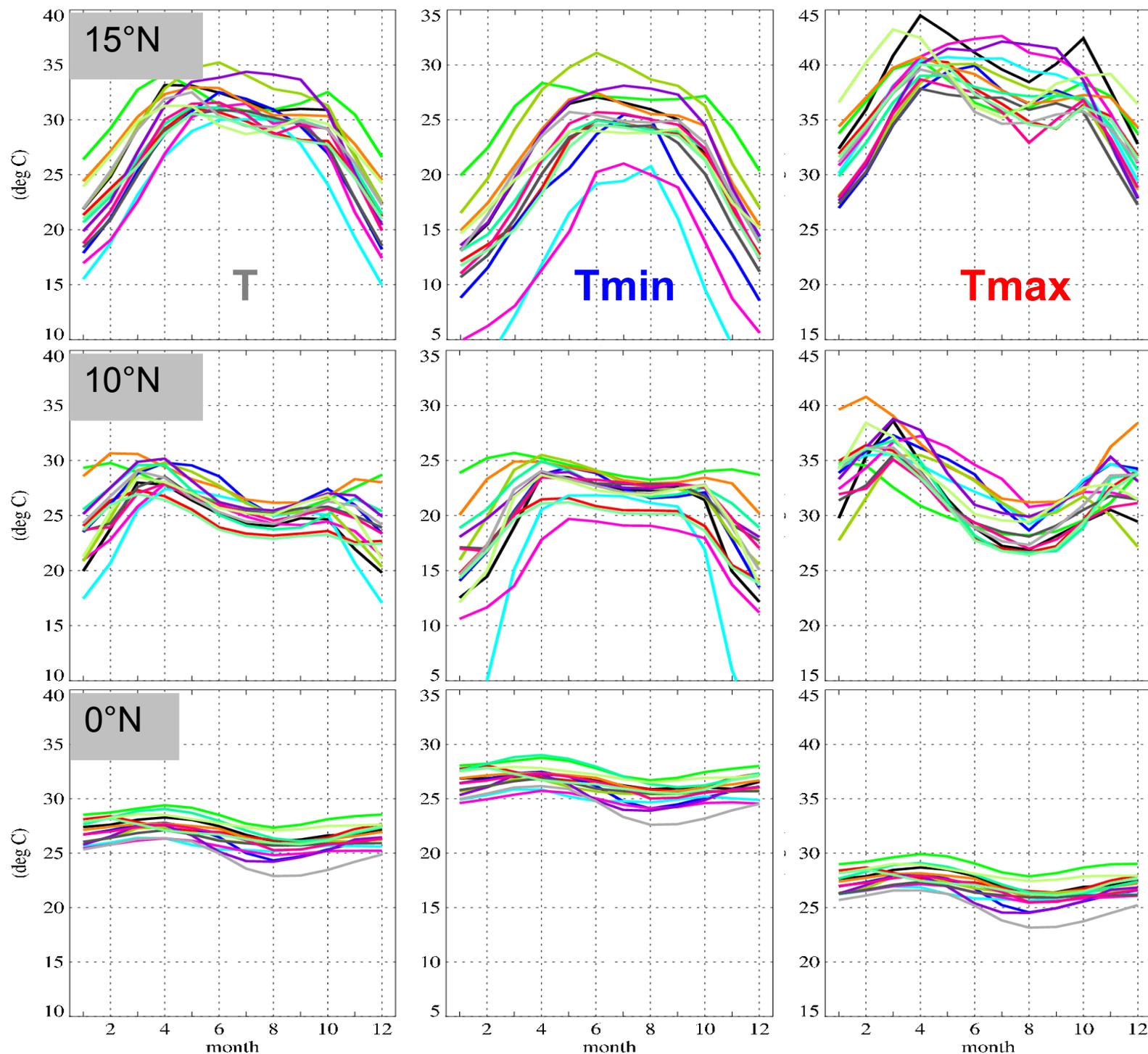
cycle annuel de la température à 2m dans les simulations climatiques CMIP5

Des différences entre modèles plus fortes que la sensibilité au scénario considéré (amip, historical, picontrol...)

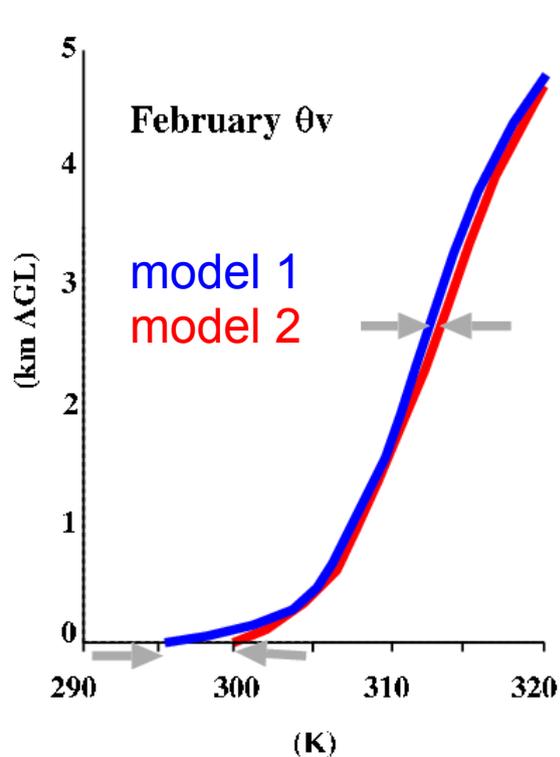
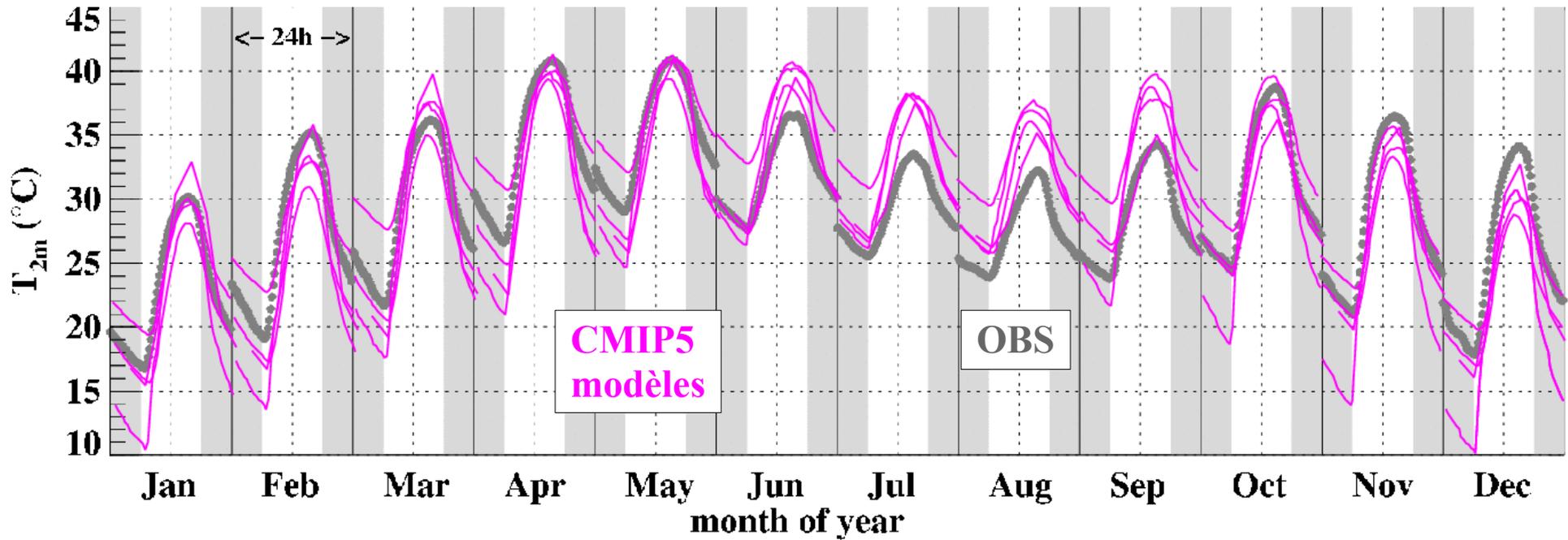
Plus de dispersion en climat semi-aride et aride

Plus de dispersion hors de la saison de mousson, en particulier pour Tmin

Résultats cohérents avec ceux de Traoré (2011) et AMMA-MIP (Hourdin et al. 2010)



T_{2m} : monthly-mean diurnal cycle [Agoufou]



JFMA: biais froid la nuit
JJAS: biais chaud le jour

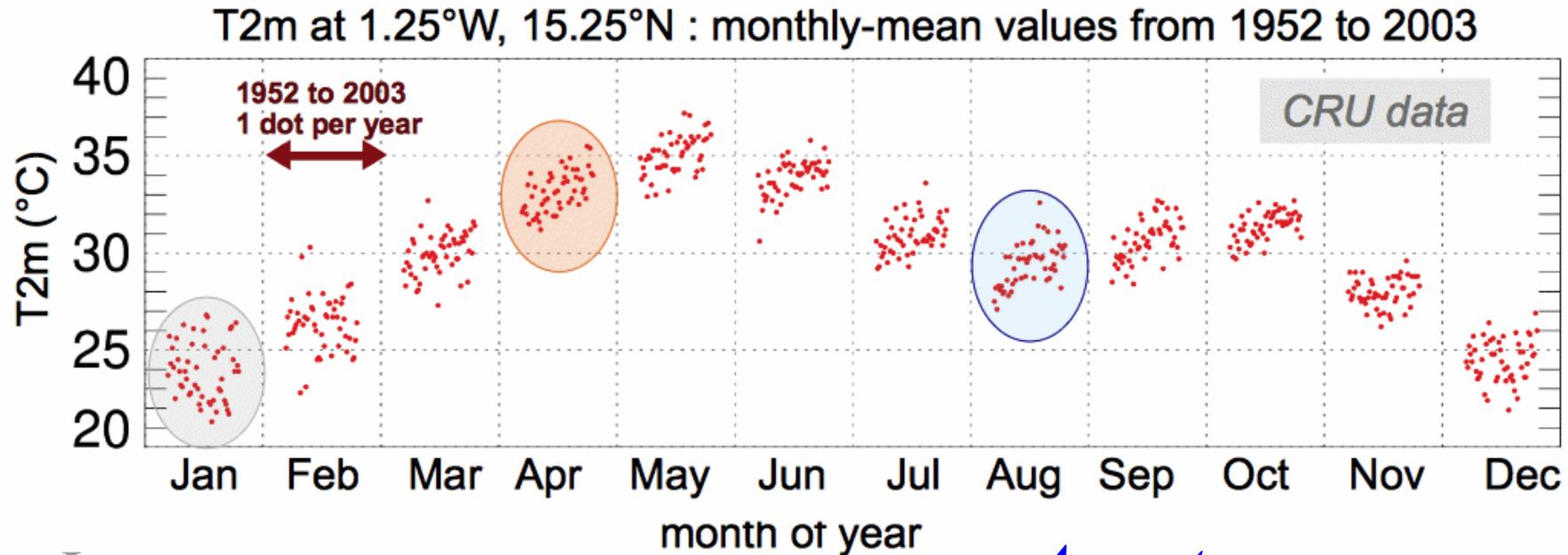
Hors de la saison de mousson, difficulté de simulation de la couche limite nocturne

- surface-turbulence-rayonnement +
- couplages avec les advections de basses couches
- pas un pb simple de biais de vapeur d'eau

Cycle annuel de la température à 2 m complexe

Importance des processus de surface et des basses couches atmosphériques

Variations multidécennales: CRU, Sahel central



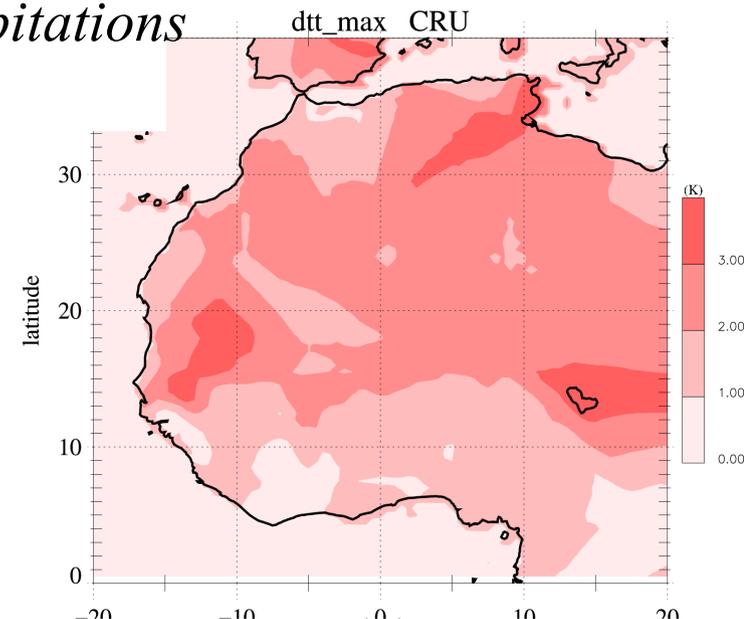
January
dominé par la
variabilité
interannuelle courte

April
Tendance
multidécennale
domine
forte!

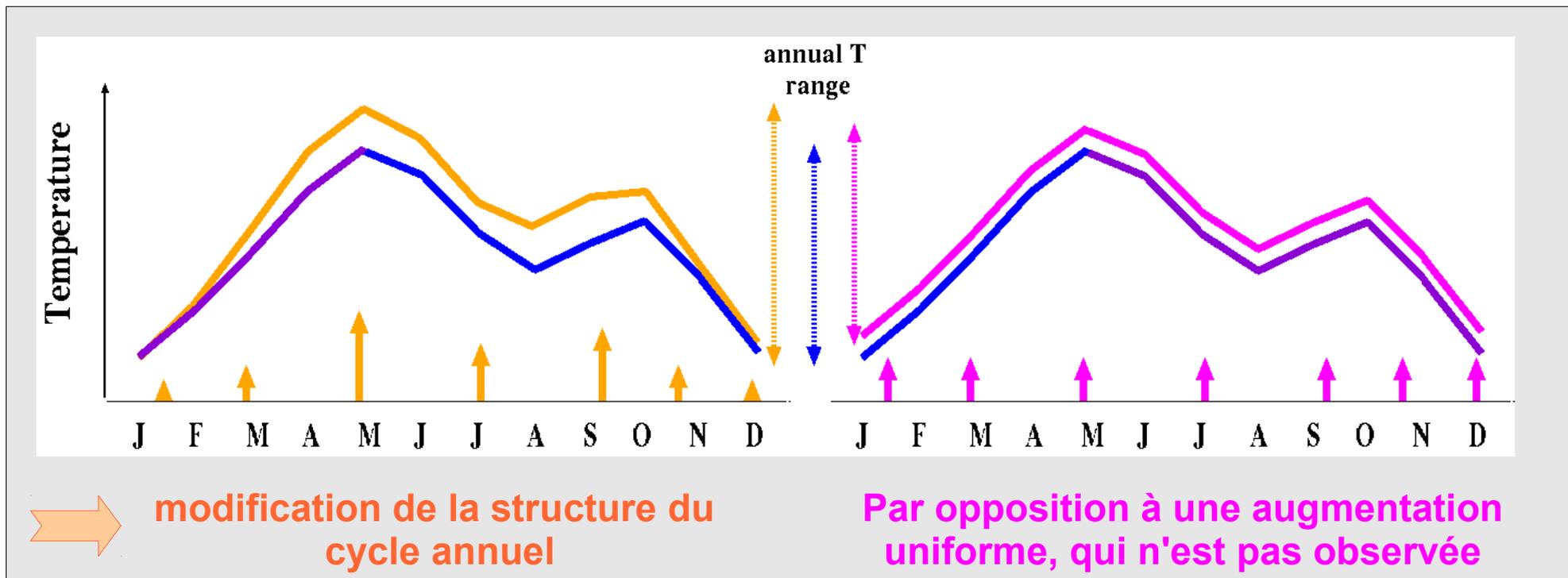
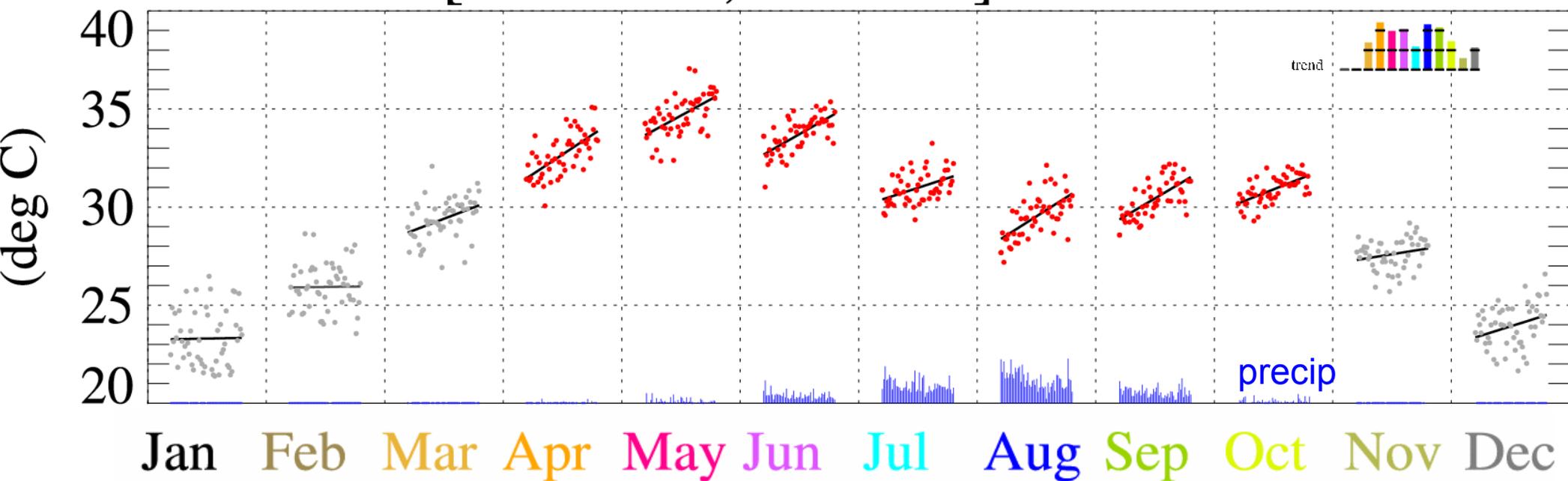
August
Couplage avec les
précipitations

=> cohérence spatiale de ce réchauffement

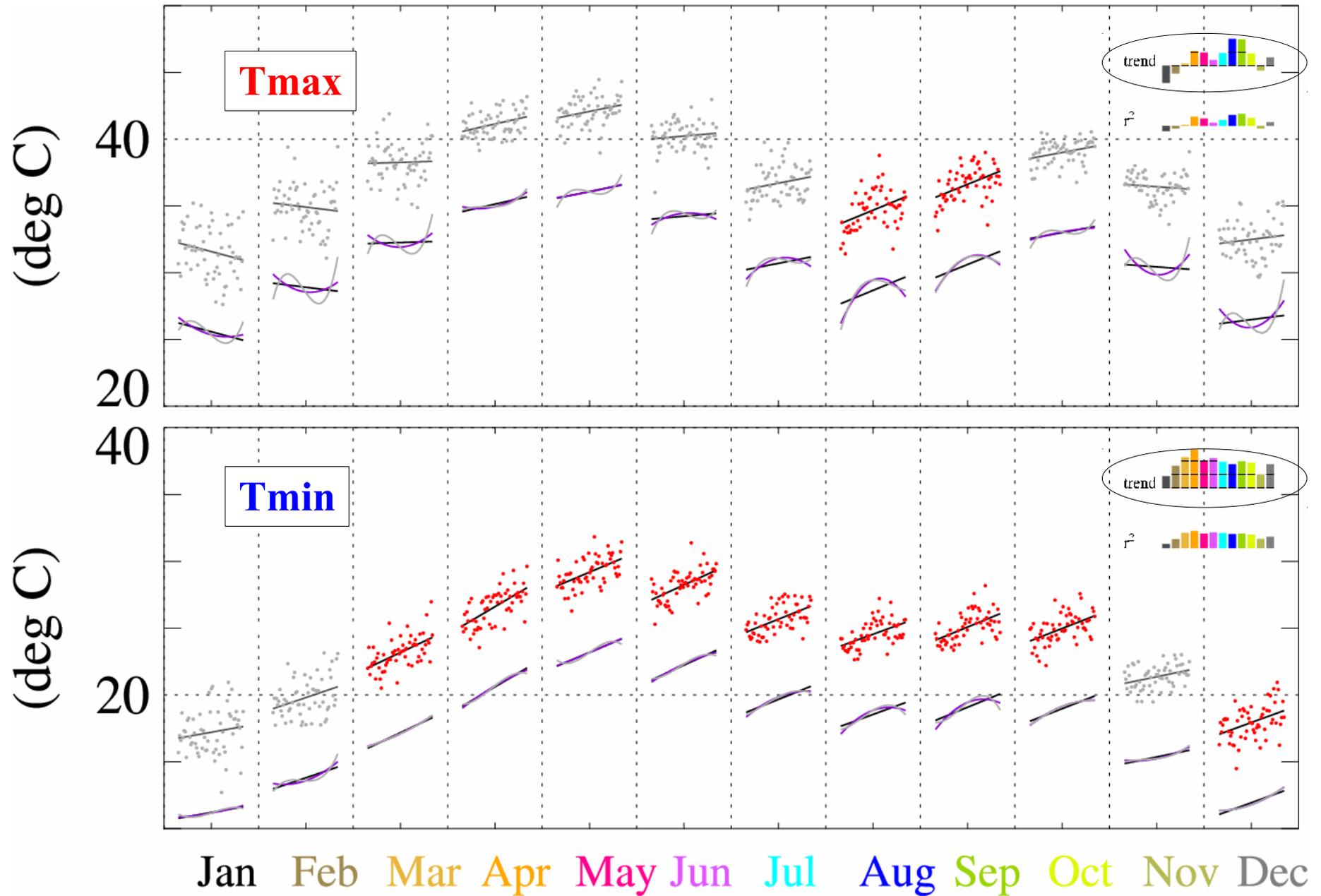
=> réchauffement également important dans les autres jeux de données, inclus ceux démarrant en 1980



[lon:-2.50,lat:15.25] Tair CRU

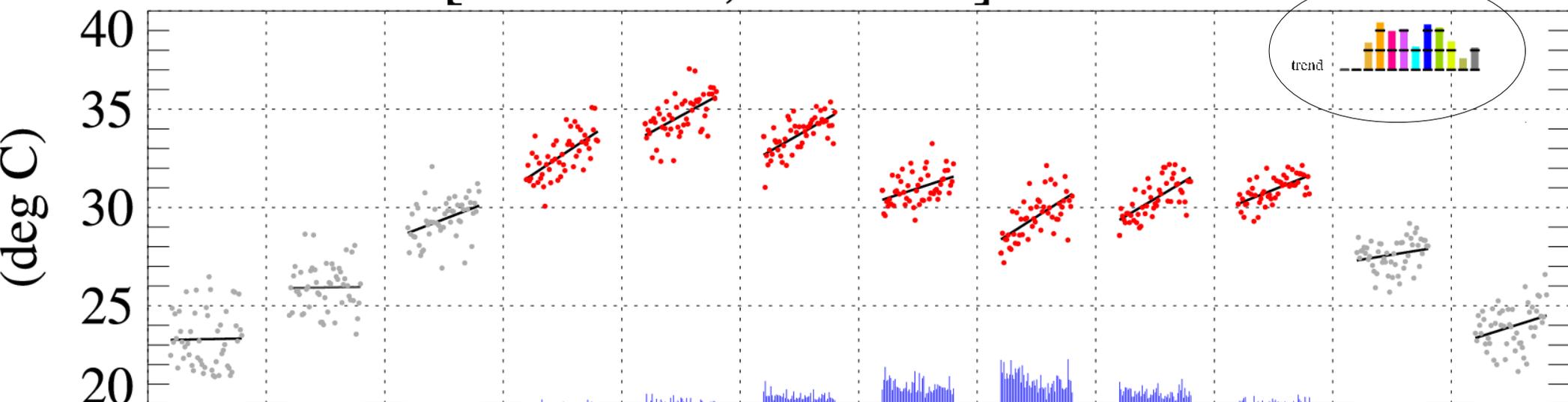


Hombori SYNOP data, 1950-2010

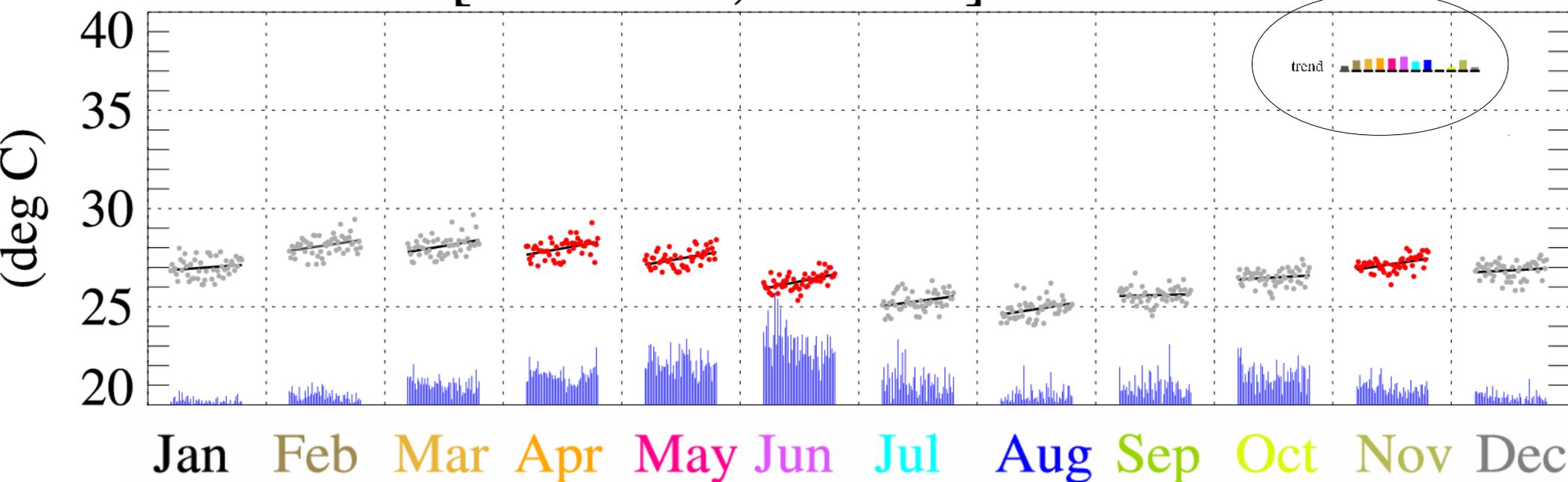


L'augmentation de température est plus importante, nette la nuit

[lon:-2.50,lat:15.25] Tair CRU

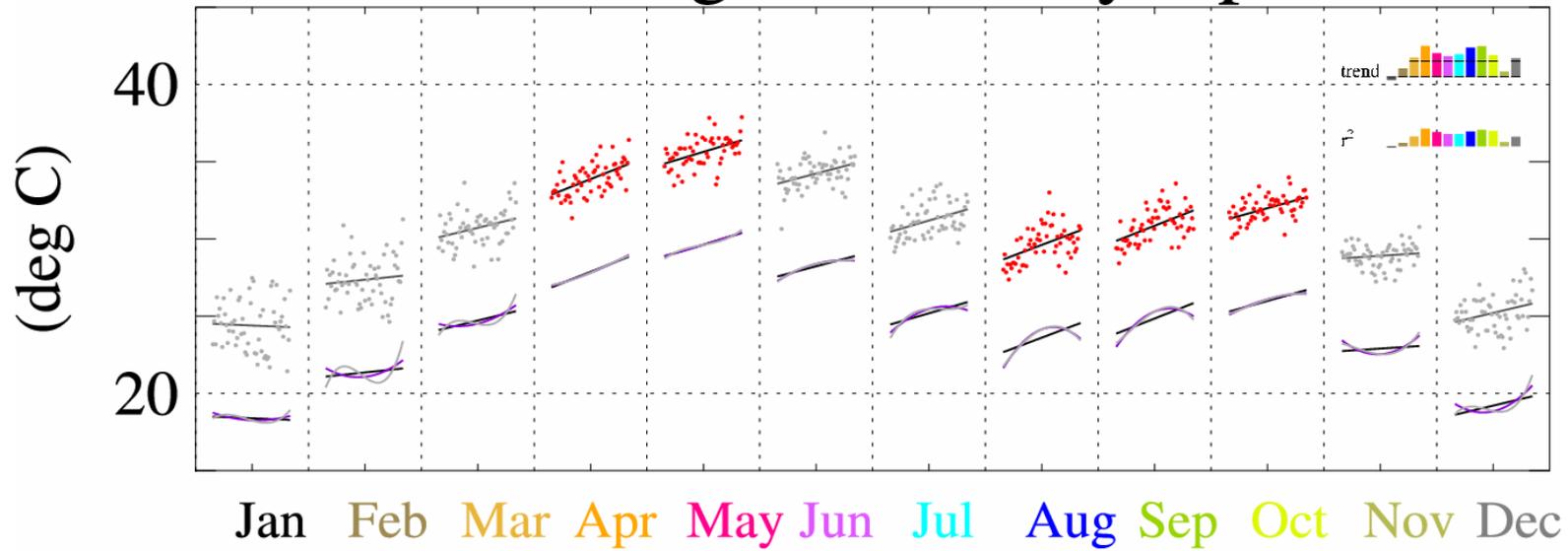


[lon:-2.50,lat: 5.25] Tair CRU

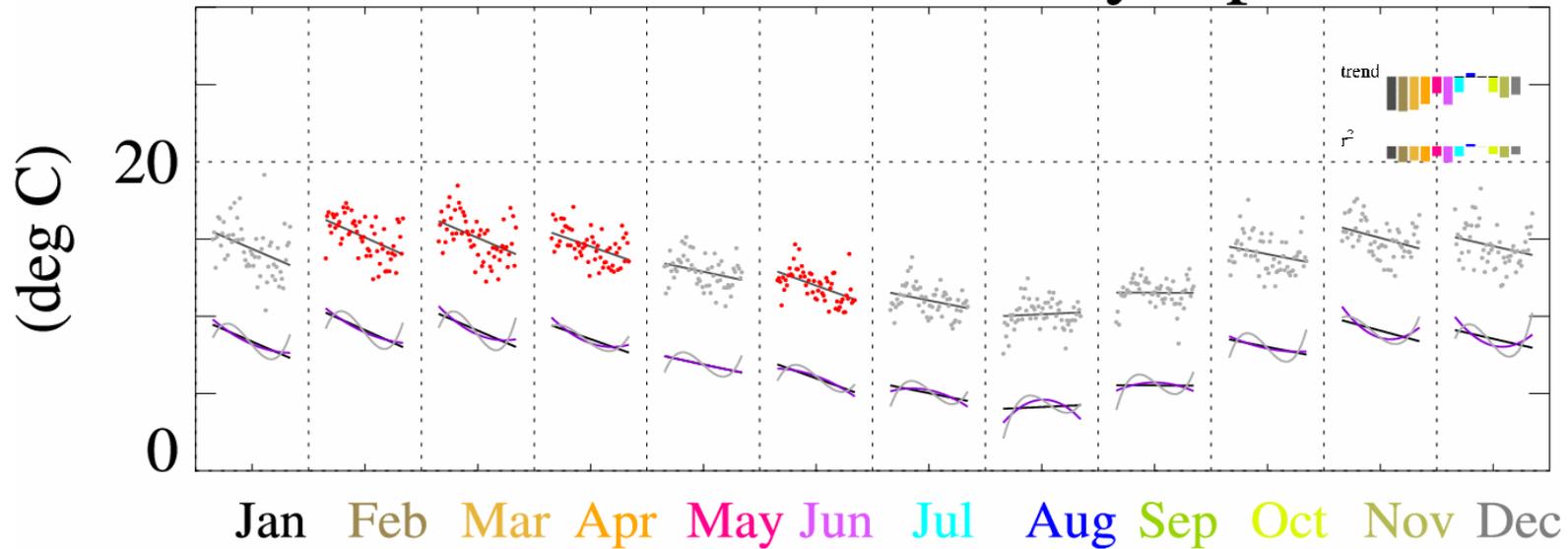


Much stronger warming in the Sahel compared to southern locations

15.3N Tavg Hombori synop EM



15.3N DTR Hombori synop EM

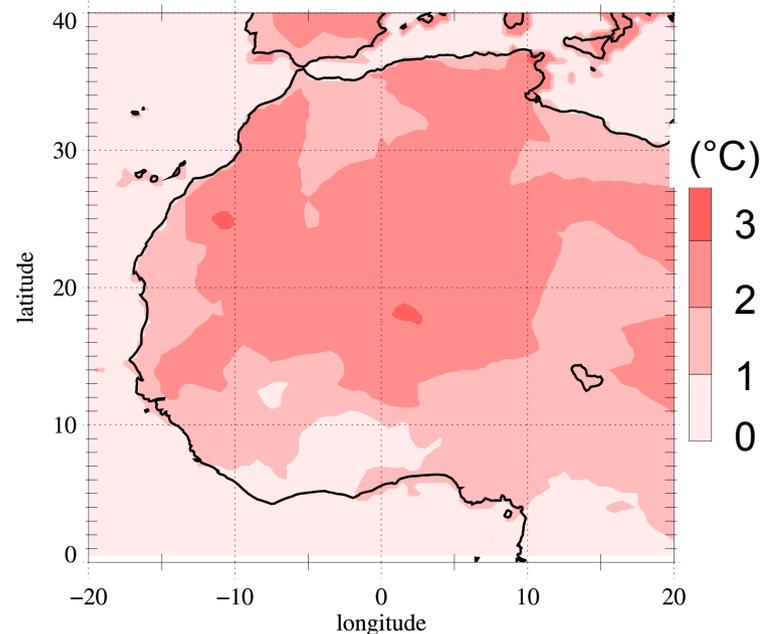
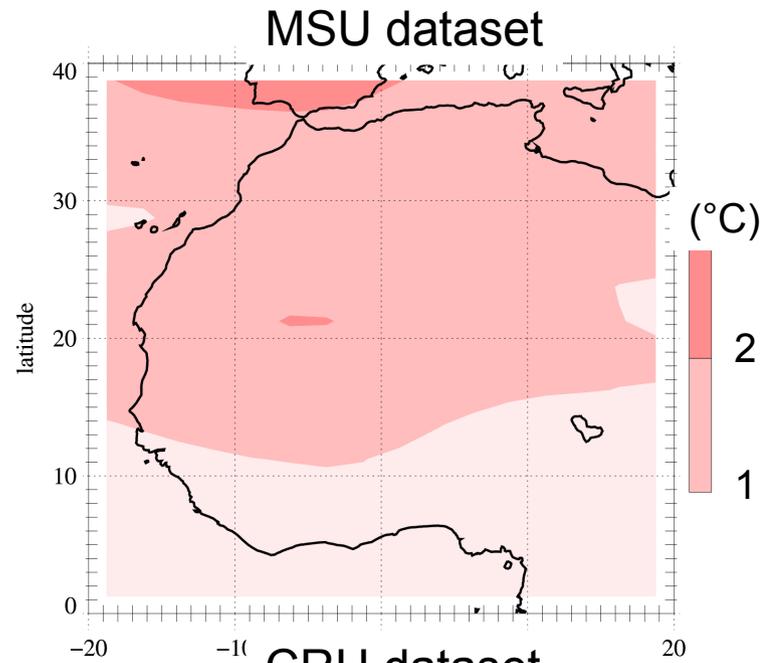


Tendances des température 1980-2010 (pour le mois du maximum)

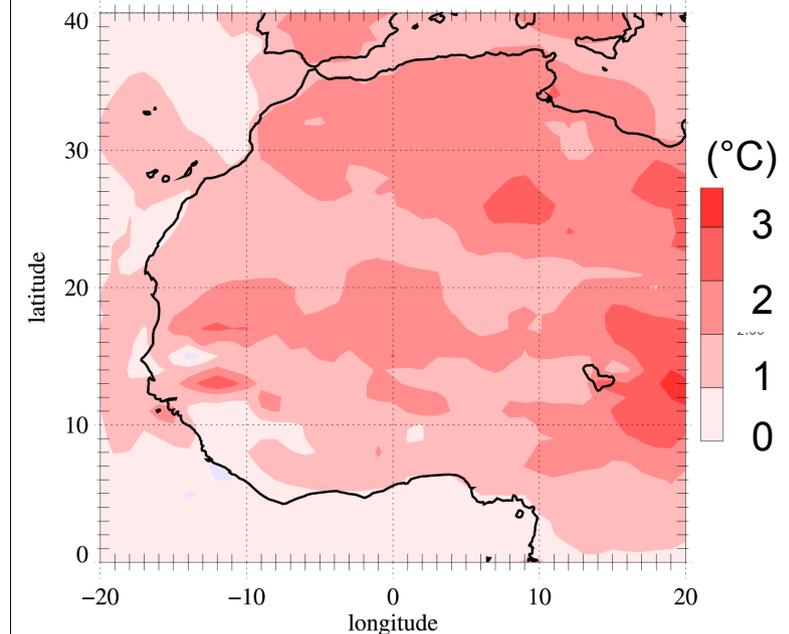
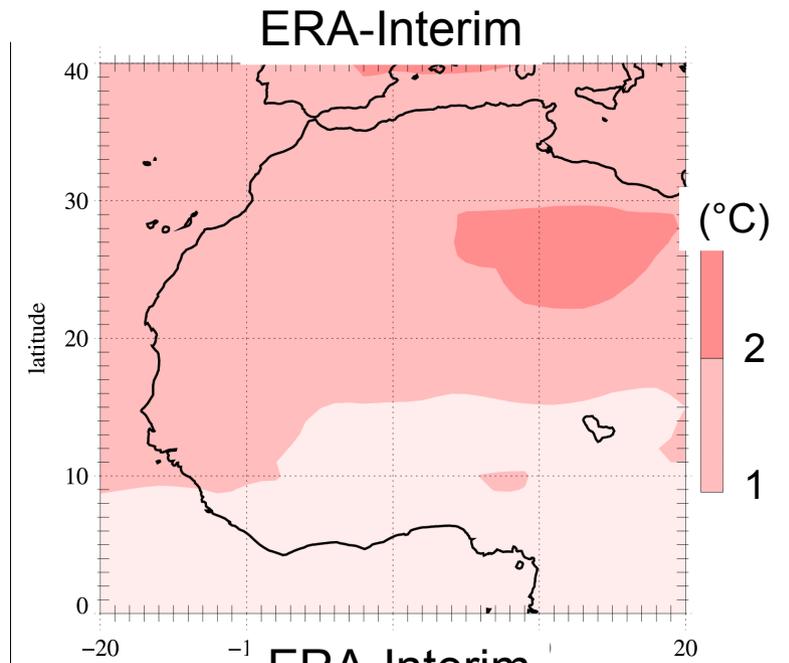
**Température
en basse
troposphère**

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

“obs”



“analyse météo”



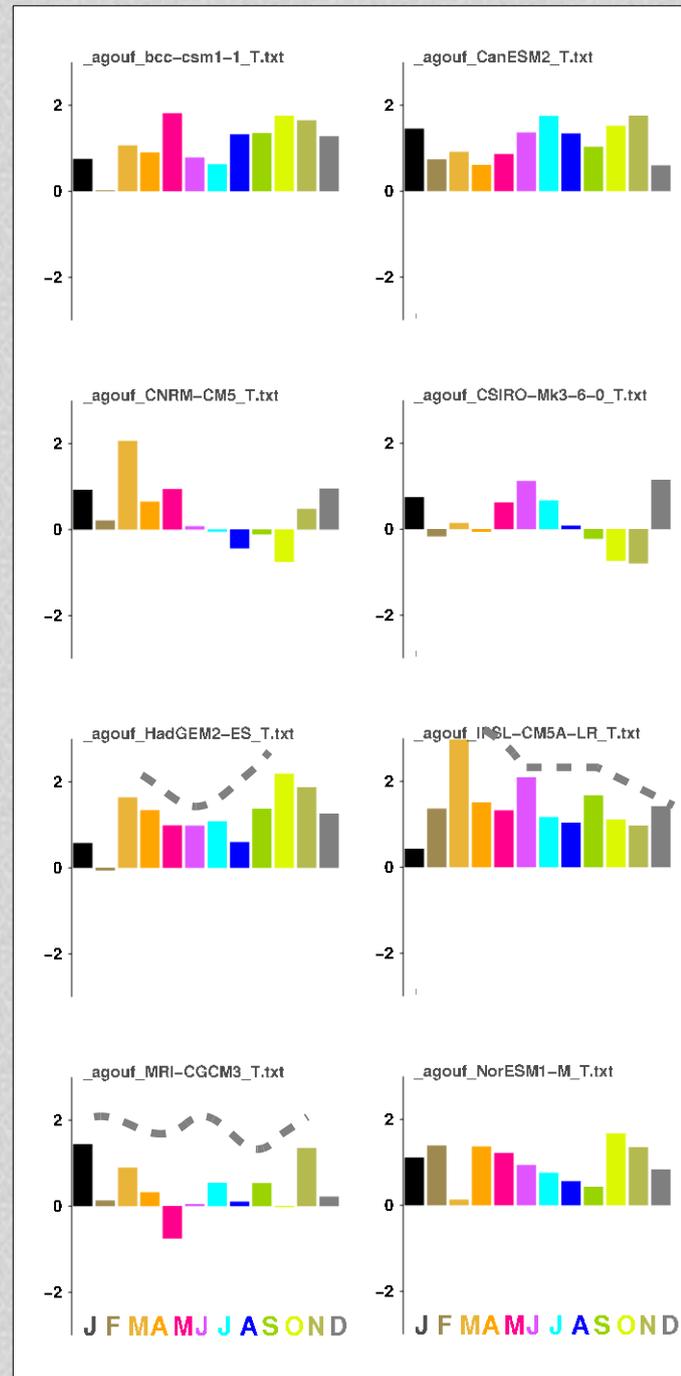
**Température
à 2m au dessus
de la surface**

*MSU: consistent
with Collins et al.
(2011)*

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

Temperature (T)

- *T increase*
with diverse
seasonalities,
magnitudes



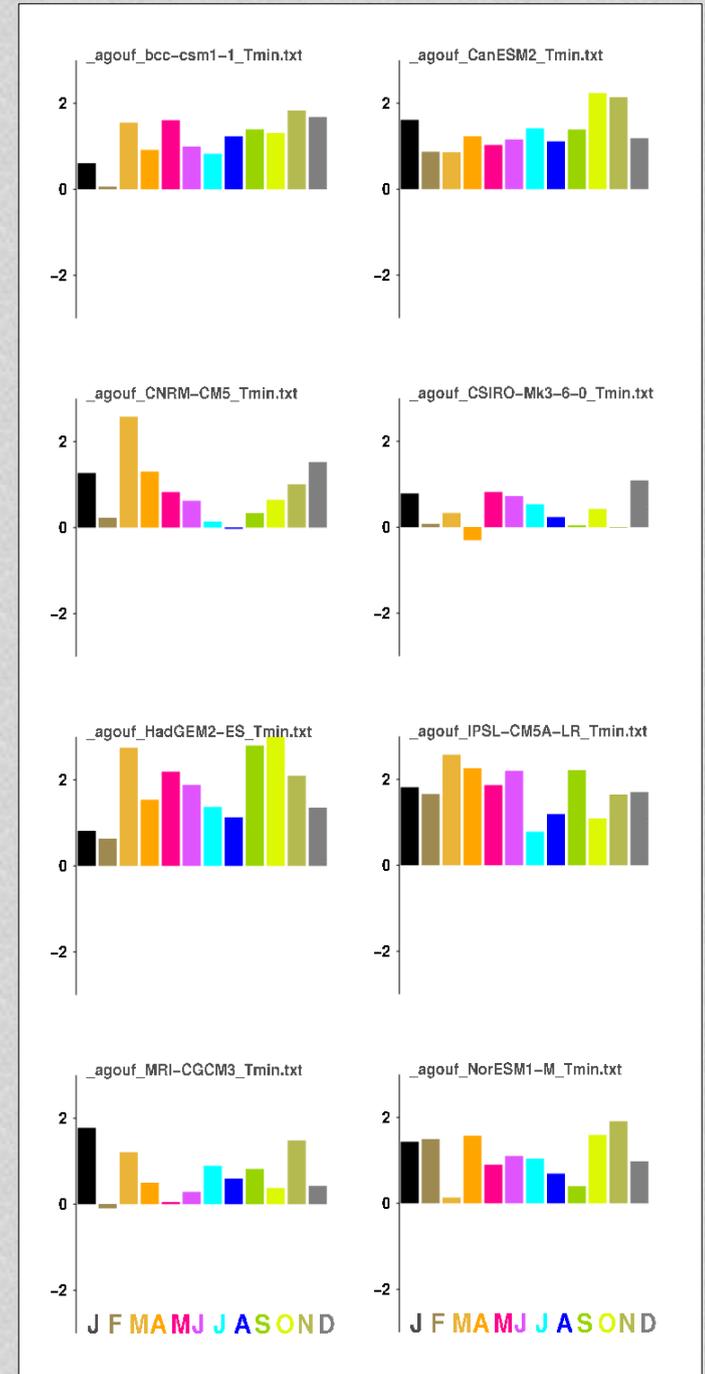
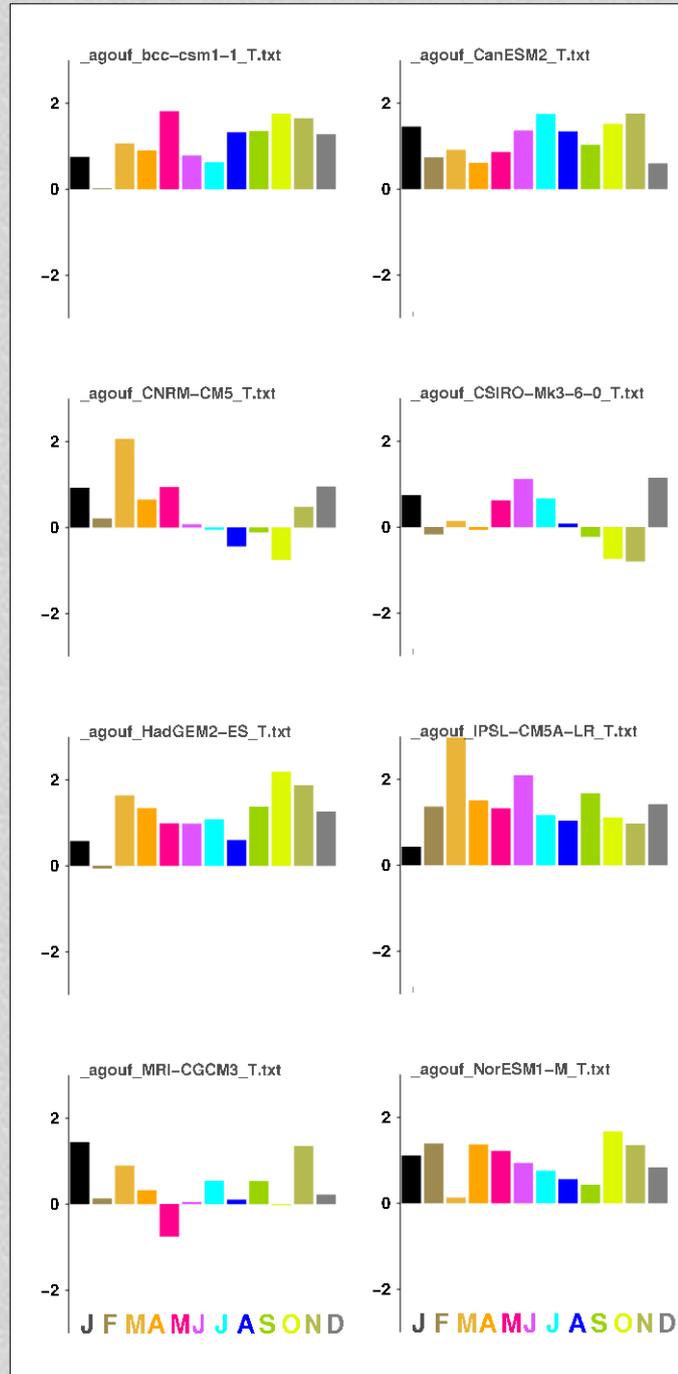
CMIP5 historical runs, 1950-2010 trends, Sahel (Agoufou cfSite point)

Temperature (T)

Minimum temperature (Tmin)

- *T increase with diverse seasonalities, magnitudes*

- *Tmin increase often more pronounced*

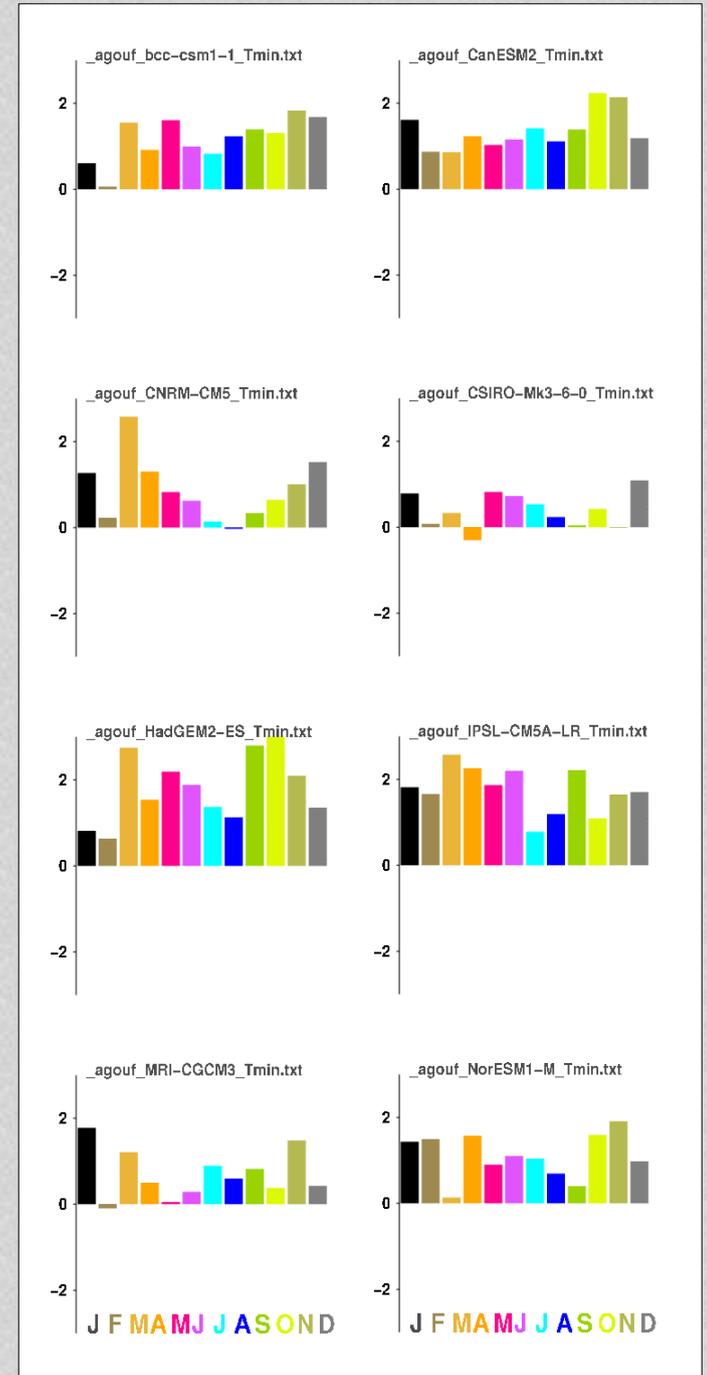
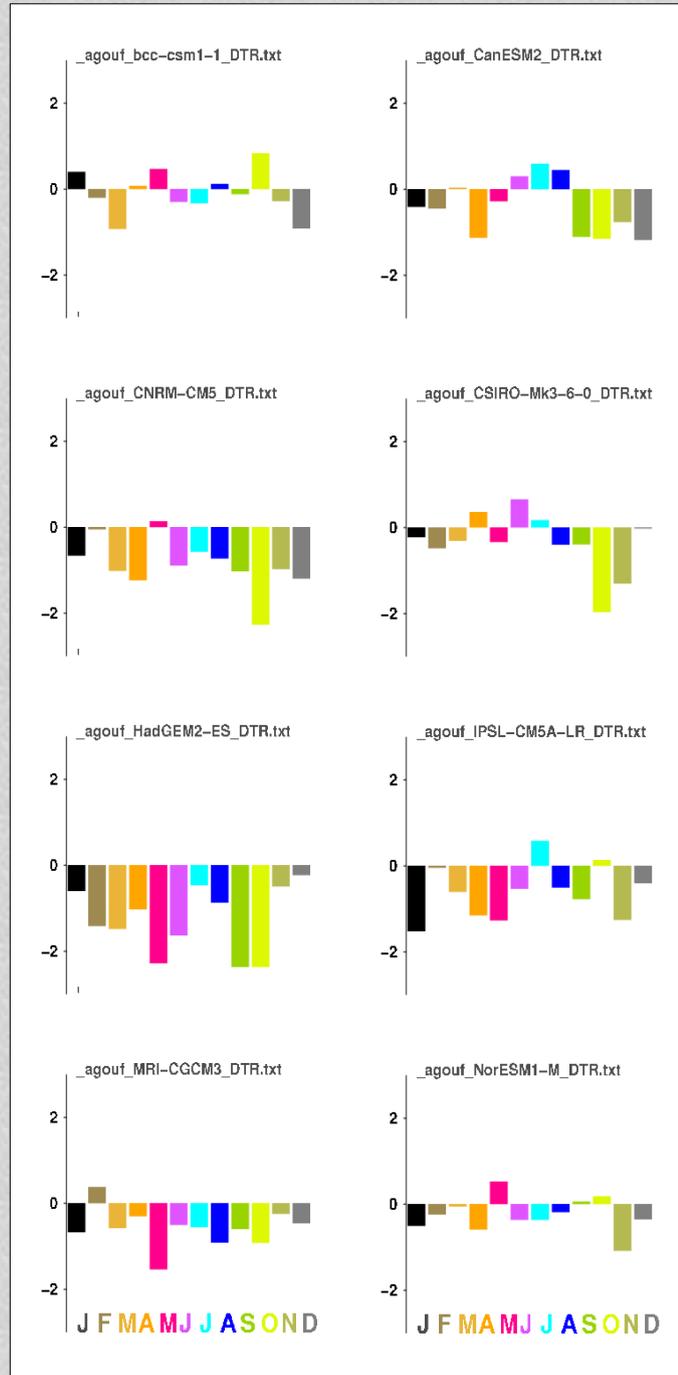


CMIP5 historical runs, 1950-2010 trends, Sahel (Agoufou cfSite point)

DTR (diurnal T range)

Minimum temperature (Tmin)

- *T increase with diverse seasonalities, magnitudes*
- *Tmin increase often more pronounced*
- *DTR decreases*

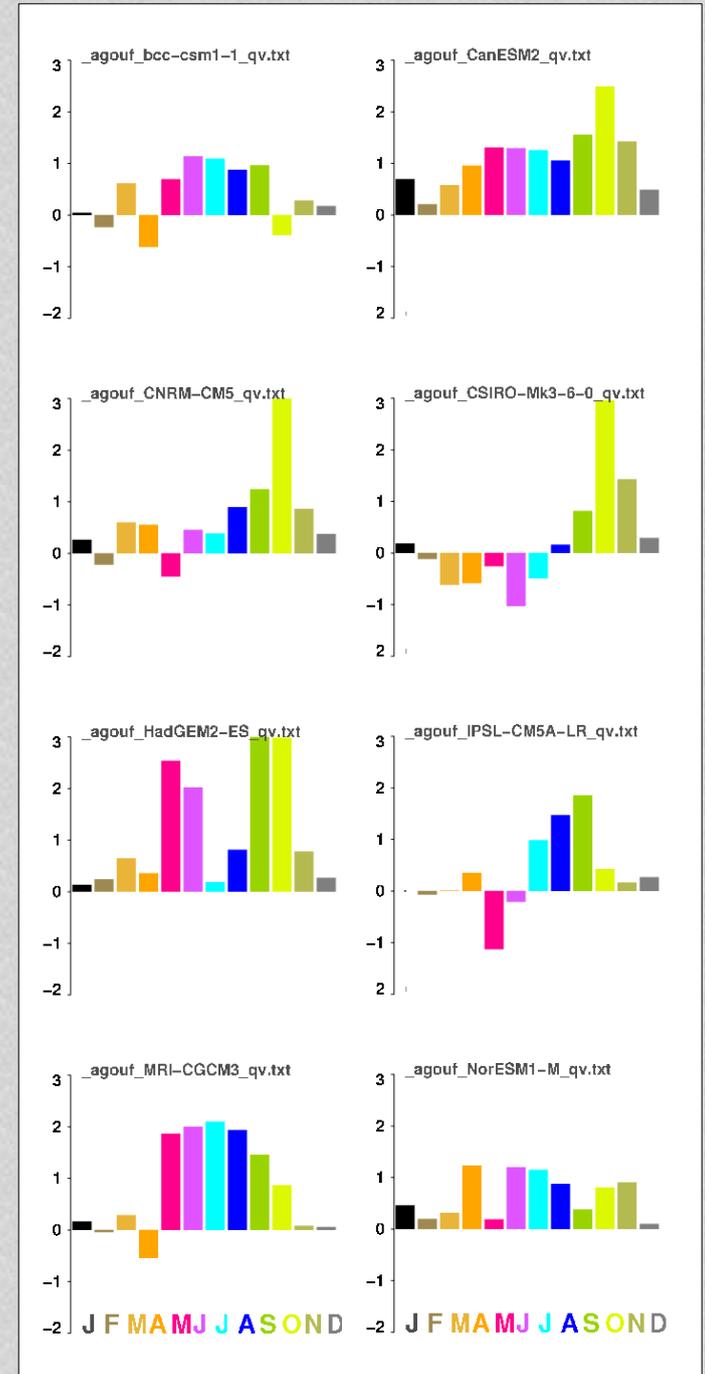
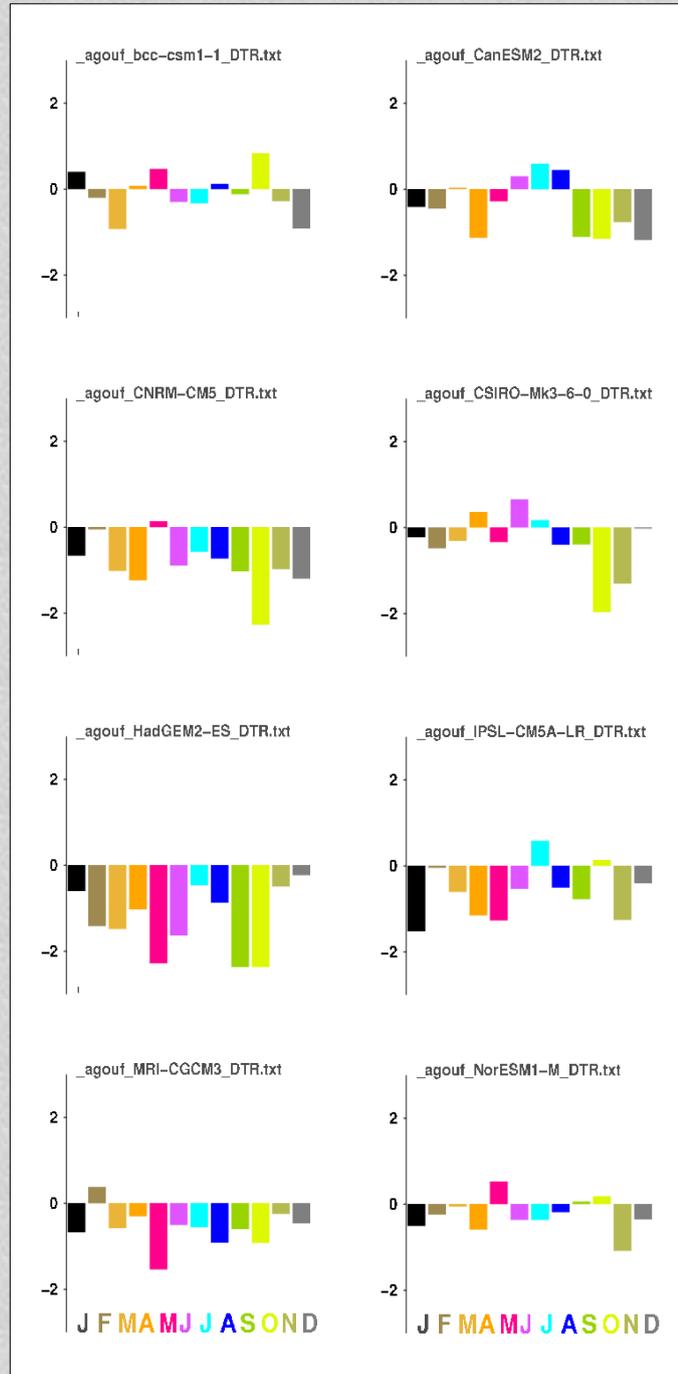


CMIP5 historical runs, 1950-2010 trends, Sahel (Agoufou cfSite point)

DTR (diurnal T range)

Specific humidity (qv)

- *T increase with diverse seasonalities, magnitudes*
- *Tmin increase often more pronounced*
- *DTR decreases*
- *various qv trends in spring too*



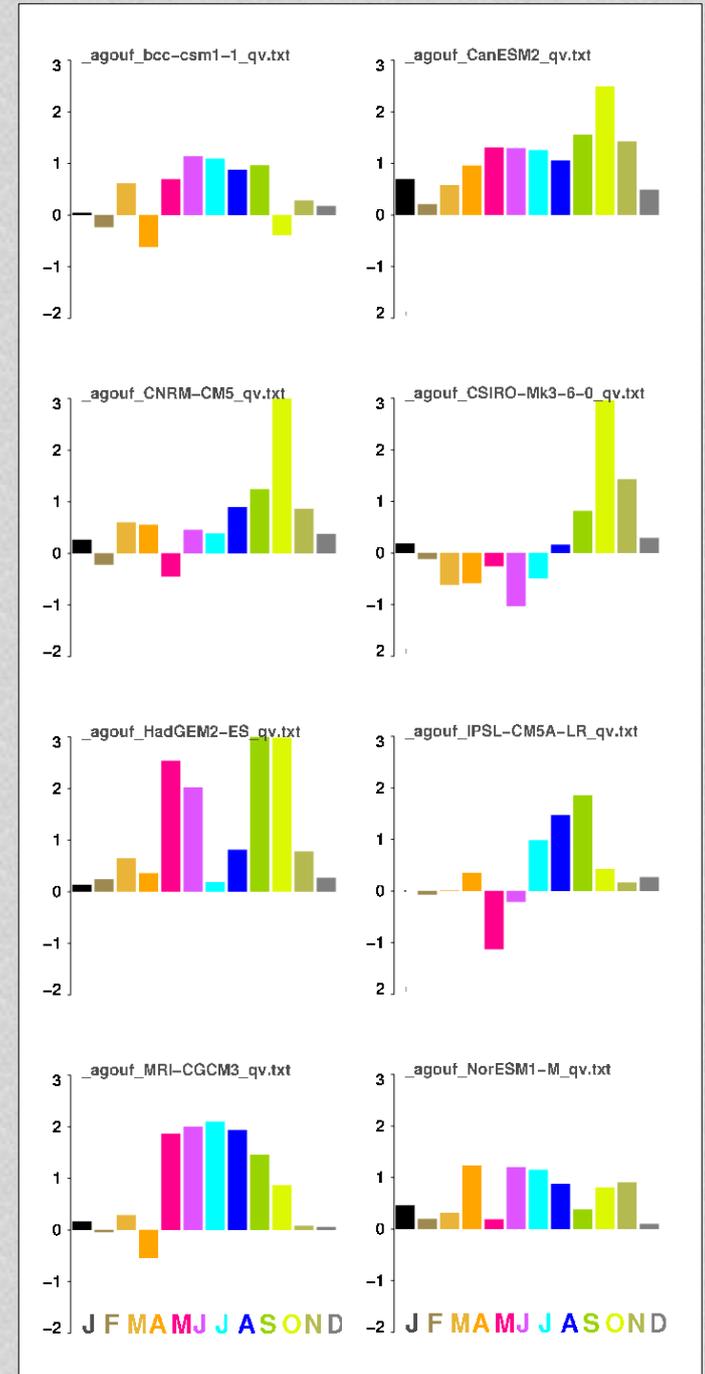
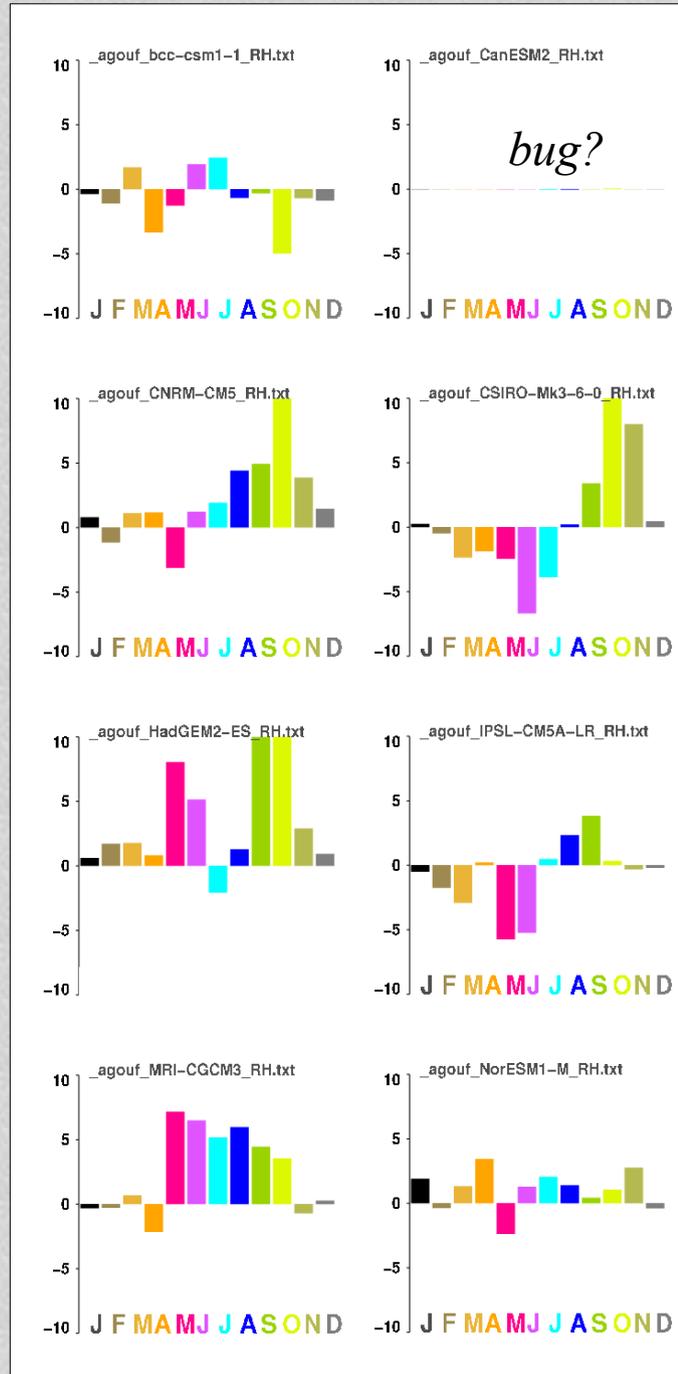
CMIP5 historical runs, 1950-2010 trends, Sahel (Agoufou cfSite point)

Relative humidity (RH)

Specific humidity (qv)

- *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

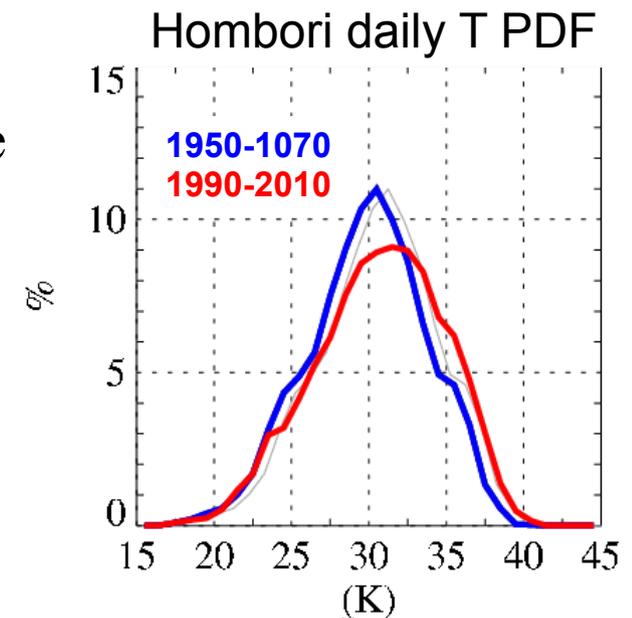


Conclusion, perspectives

Les observations indiquent un réchauffement non-uniforme au Sahel au cours des 60 dernières années

amplitude du cycle annuel plus important

- saison sèche et froide ~ JFM, ND : pas de tendance nette
sec: peu de vapeur d'eau, et non pas peu pluvieux
- Printemps ~ AMJ, mois les plus chauds: fort réchauffement
- Pendant la mousson ~ JAS: réchauffement plus modéré



Humidité: pb de cohérences des différents jeux de données/réanalyses, humidification versus assèchement (CRU, HadCRUH, SYNOP, ERA40): *pas très clair... à creuser*

interprétation/spéculation

impact radiatif de la vapeur d'eau au printemps, rôle du flux de mousson à préciser en été, impact atténué par les précipitations (refroidissement de la surface)

Analyse des couplages émergents entre température, humidité, DTR, flux radiatifs, précipitations, nuages et aérosols (obs & modèles)

Questions...

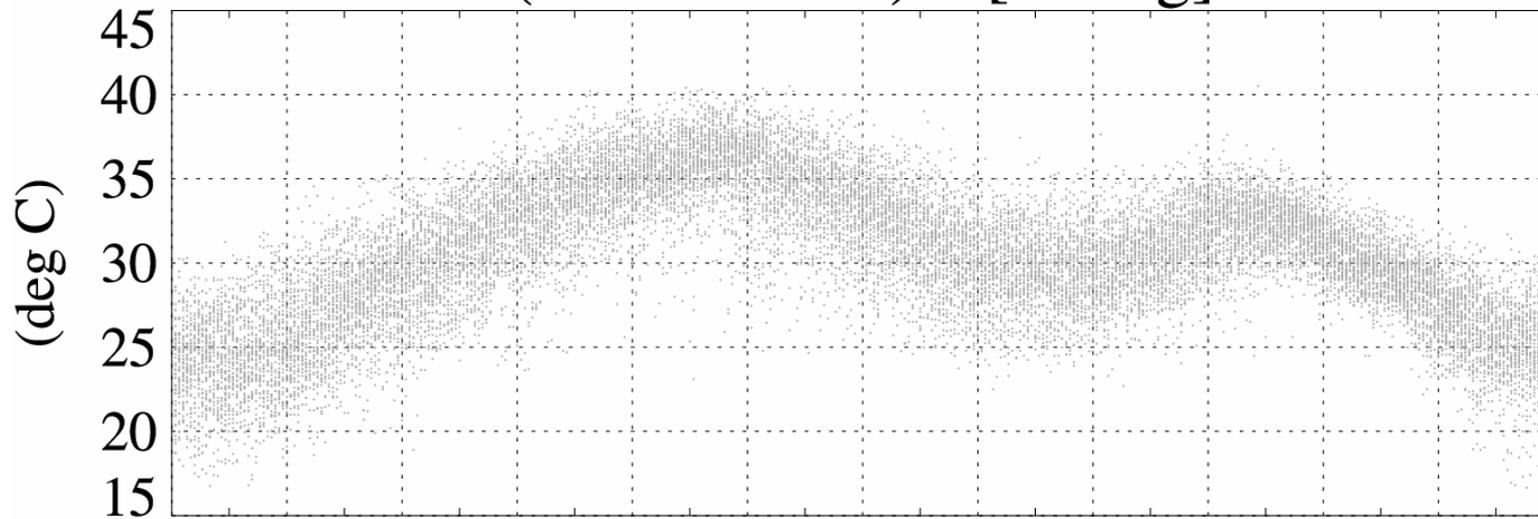
quel impact du réchauffement printanier sur l'arrivée des pluies, le saut de mousson?

considérations locales et à plus grande échelle (e.g. gradient meridional)

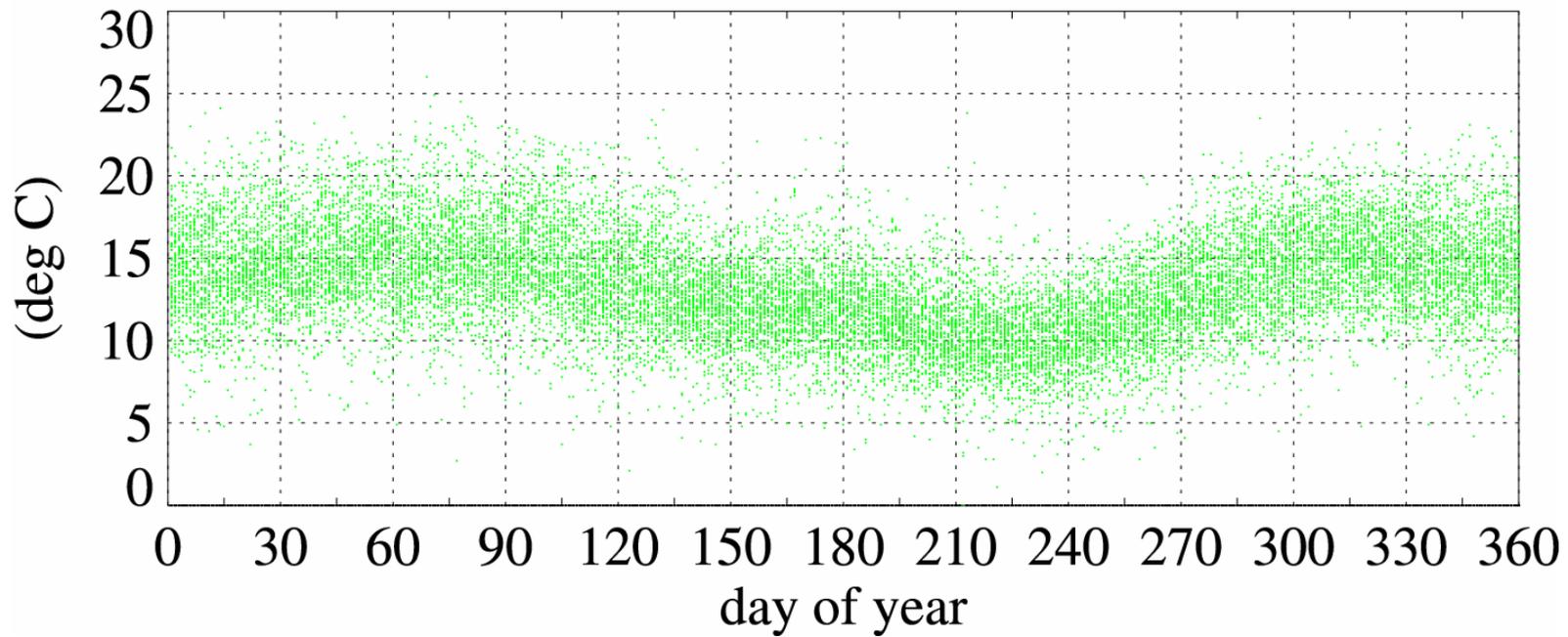
impact sur l'intensité des précipitations? au delà: végétation, impact sociétaux, santé...

Modélisation climatique: Roehrig et al. *Journal of Climate* (2013)

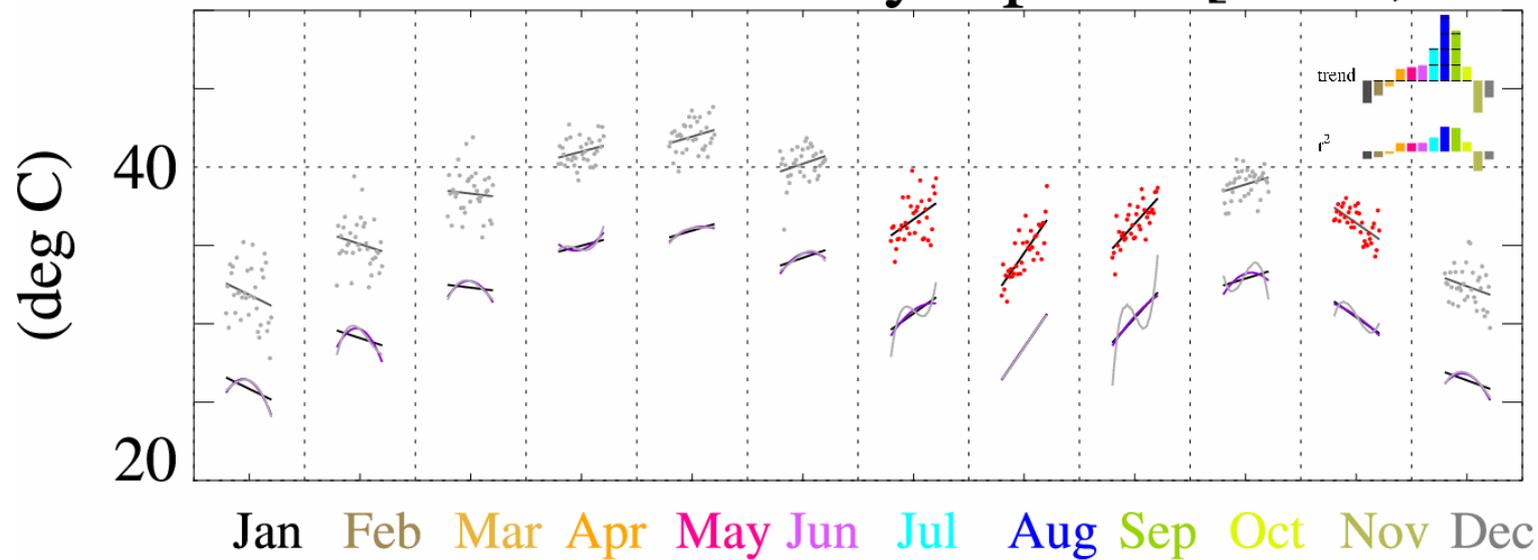
$(T_{\min}+T_{\max})/2$ [$\sim T_{\text{avg}}$]



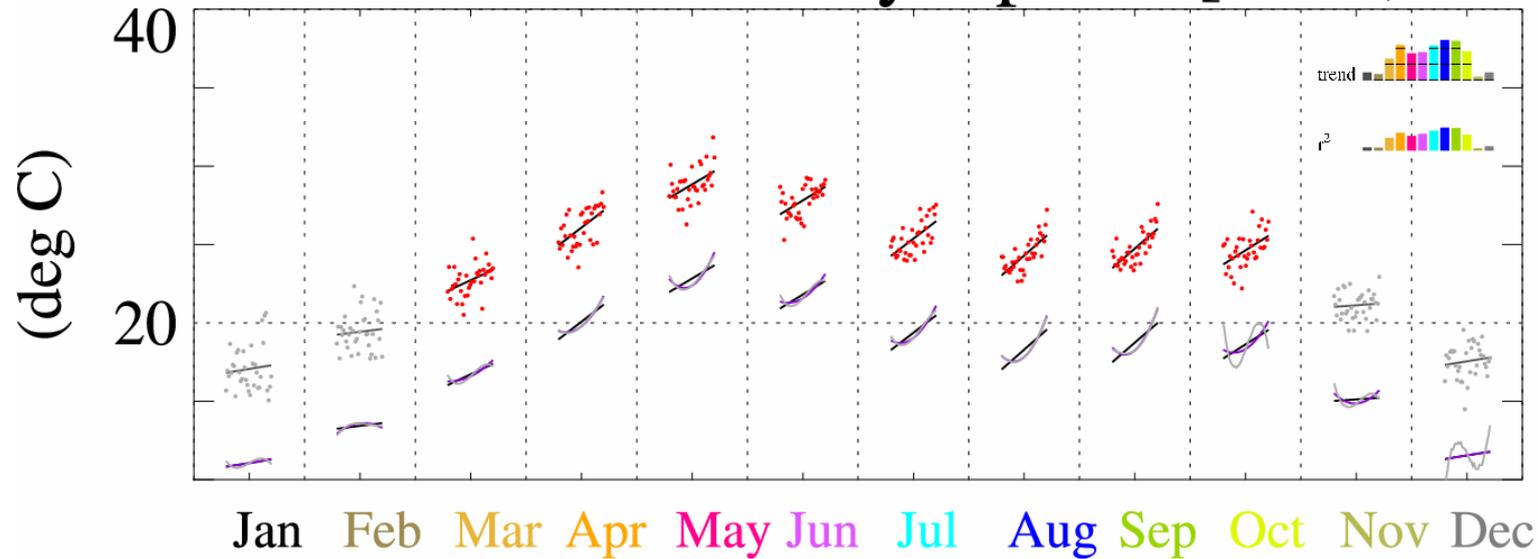
DTR



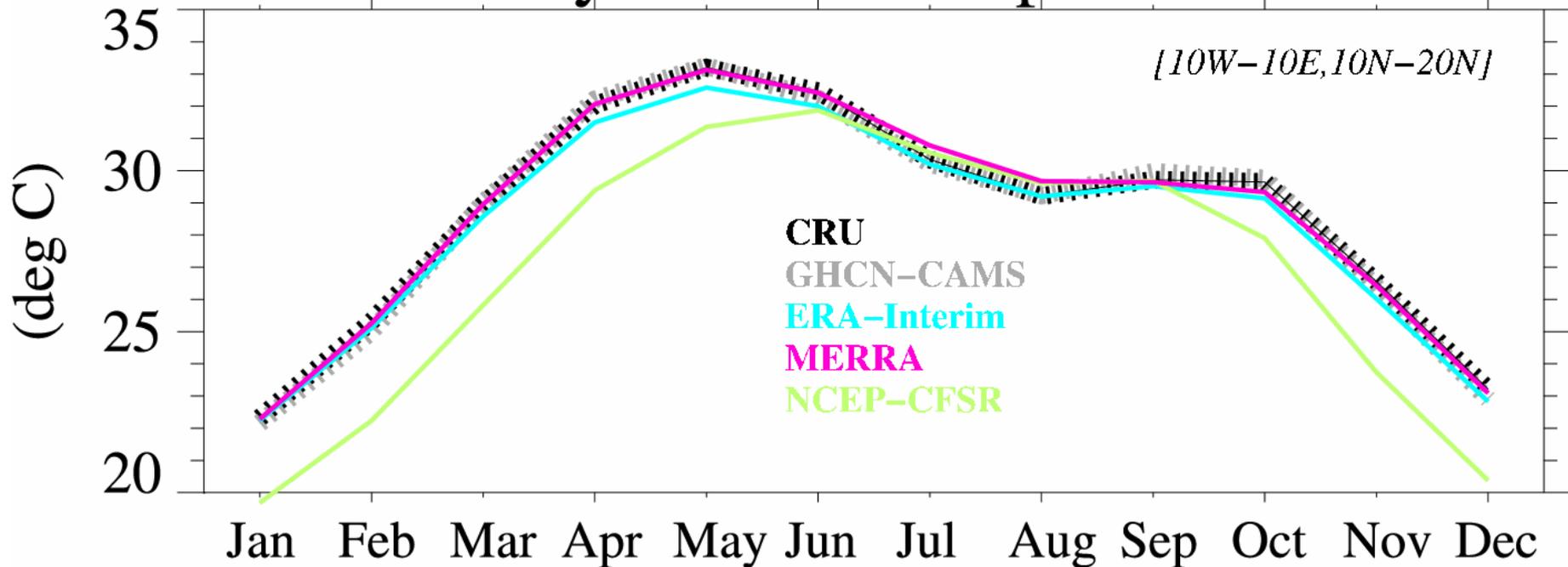
15.3N Tmax Hombori synop EM [1950,1984]



15.3N Tmin Hombori synop EM [1950,1984]

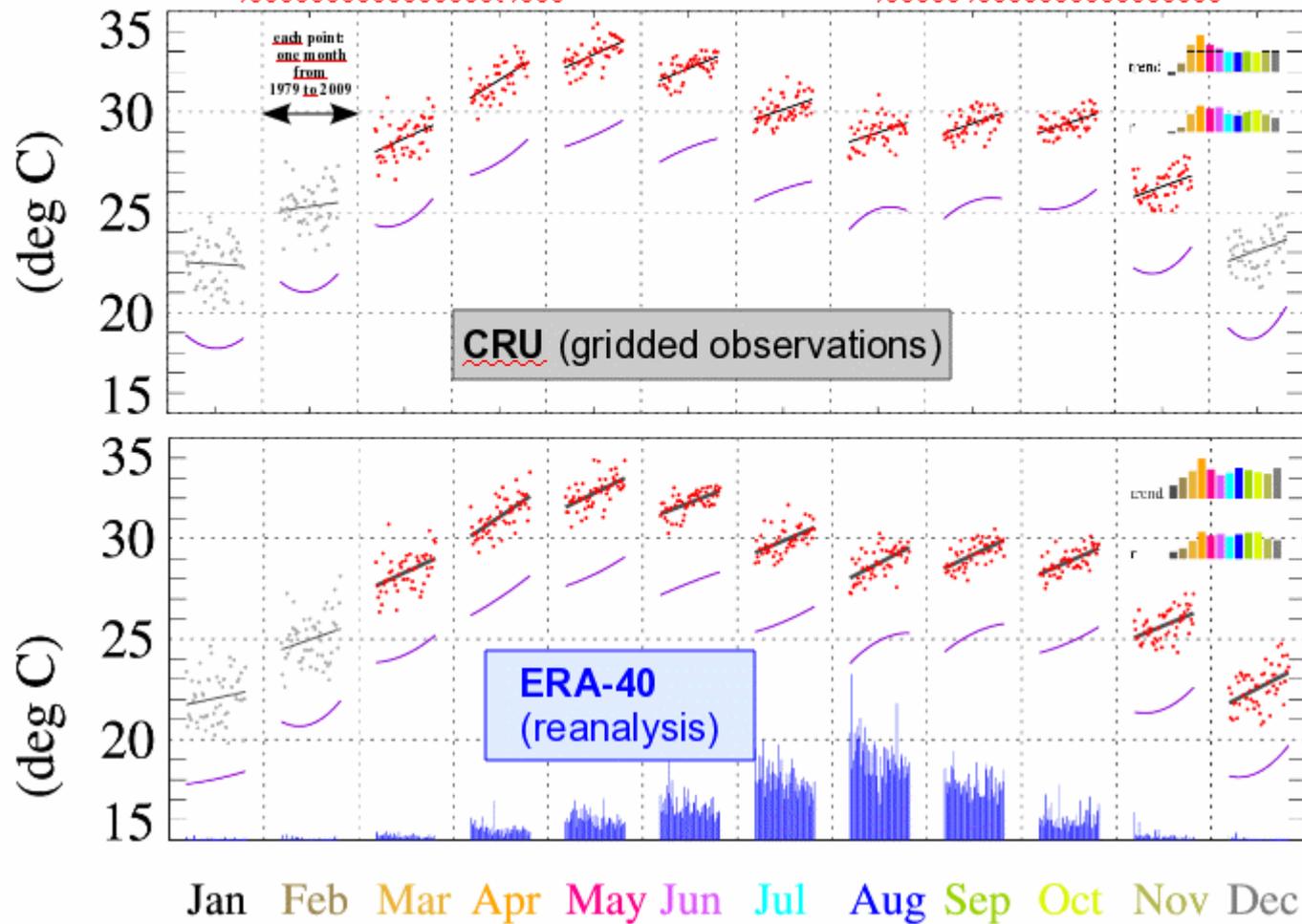


Annual cycle of the temperature at 2m



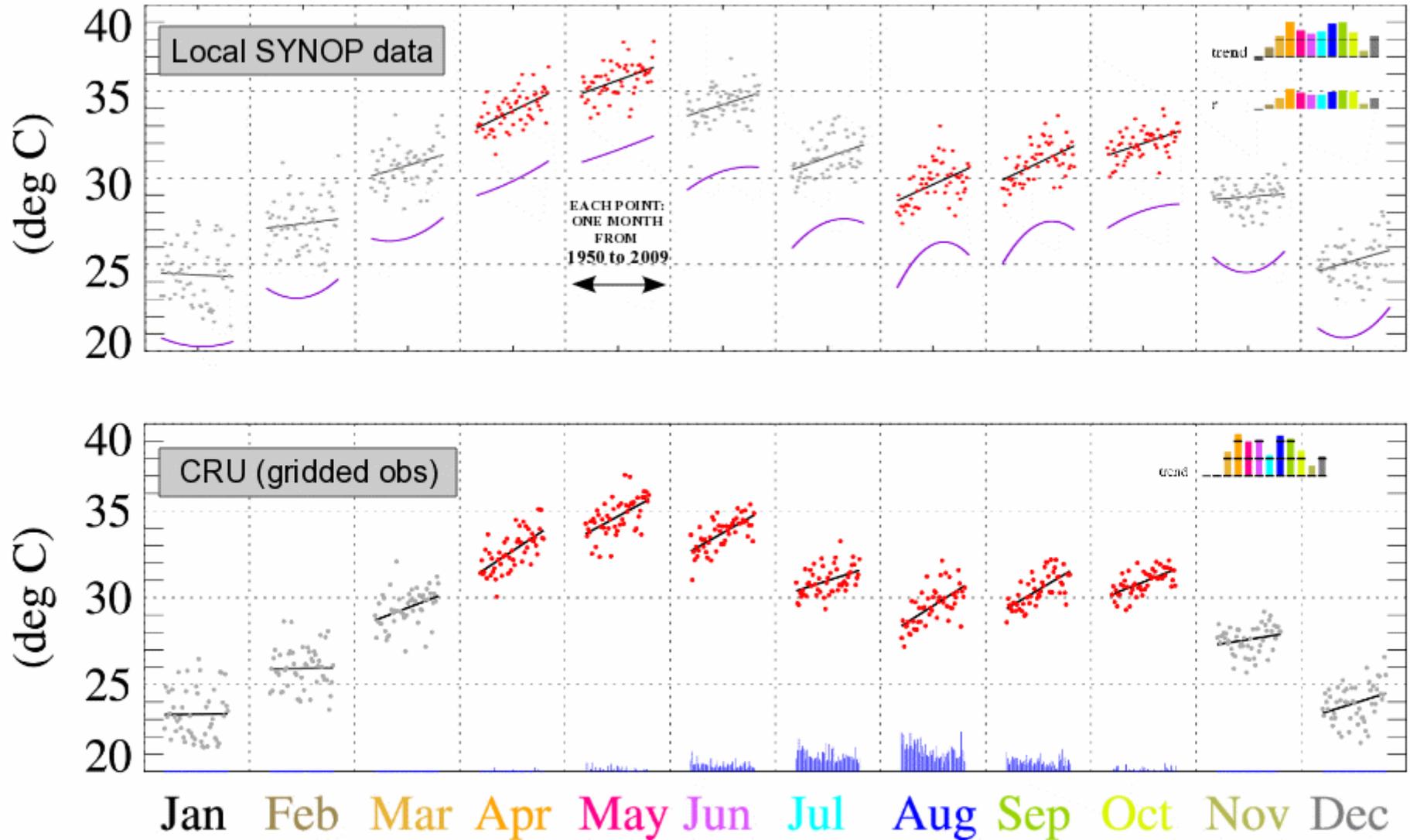
Annual cycle of T2m on average over the Sahelian region [10°W-10°E, 10°N-20°N] estimated by CRU, GHCN-CAMS, ERA-Interim, MERRA and NCEP-CFSR – using monthly-mean values averaged over a common 30-year period (1979-2009).

**EVOLUTION OF THE ANNUAL CYCLE OF TEMPERATURE AT 2M
FROM 1958 TO 2009: [10°W-10°E, 10°N-20°N]
COMPARISON OF OBSERVATIONS AND REANALYSES**



ERA-Interim is used after 2002 when ERA-40 stops, after an adjustment

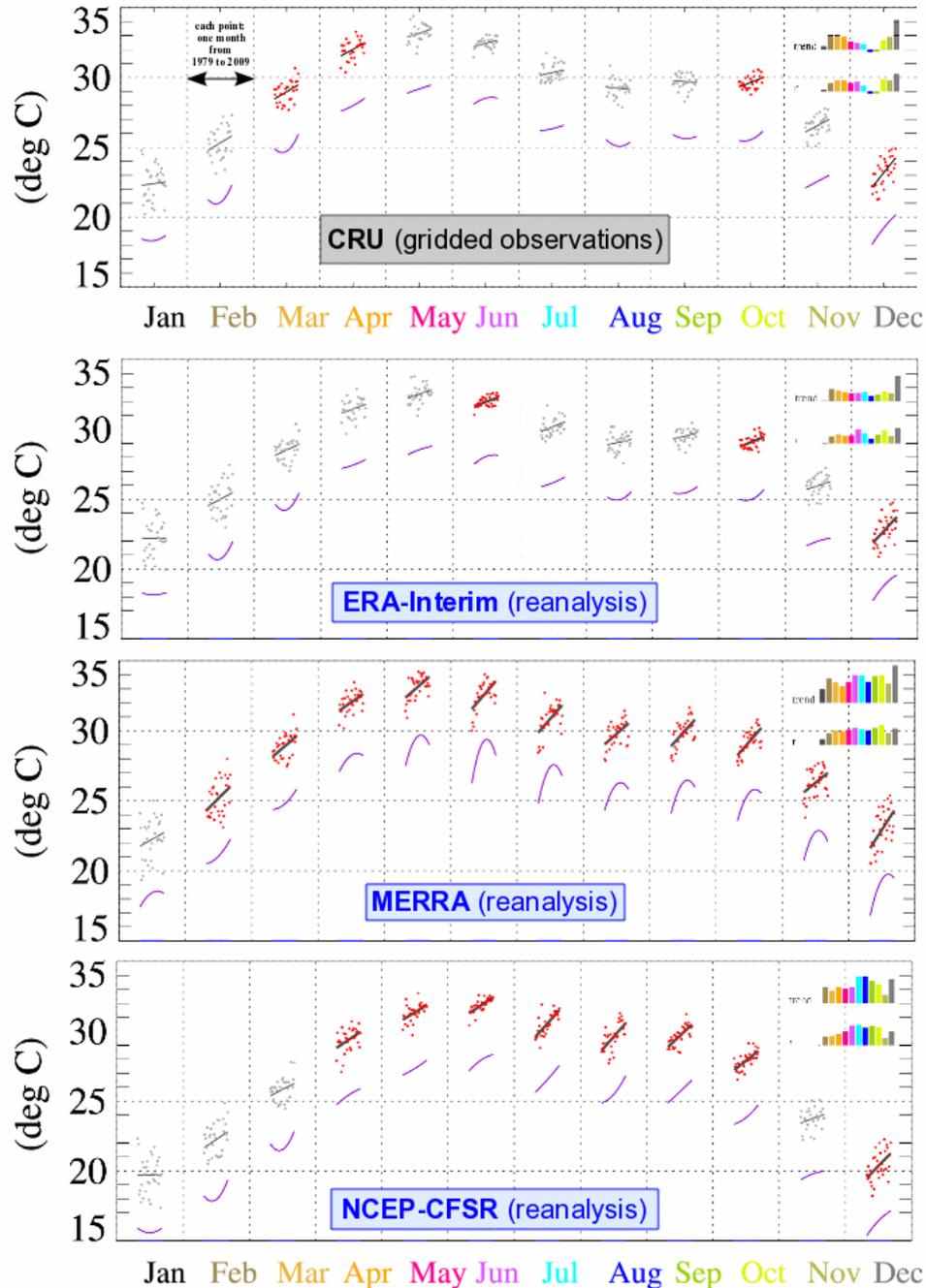
EVOLUTION OF THE ANNUAL CYCLE OF TEMPERATURE FROM 1950 TO 2009 AT HOMBORI : LOCAL SYNOP and GRIDDED OBSERVATIONS

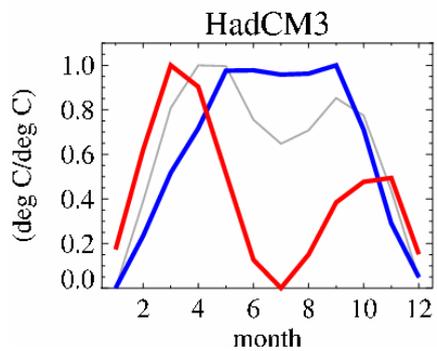
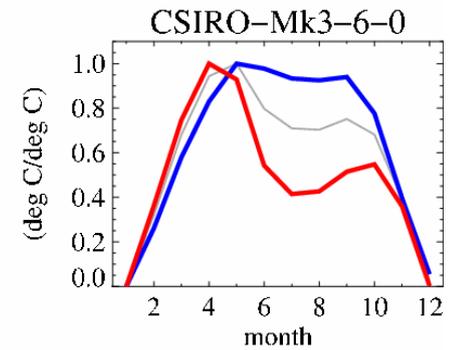
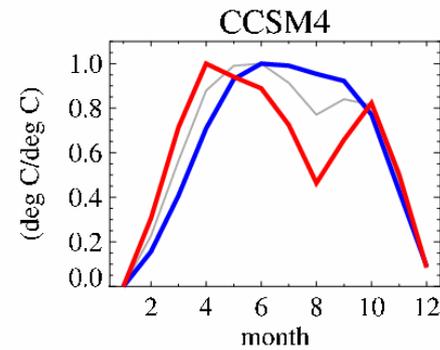
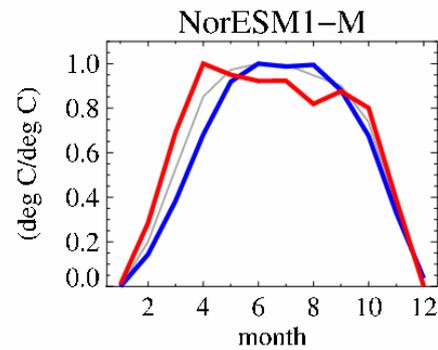
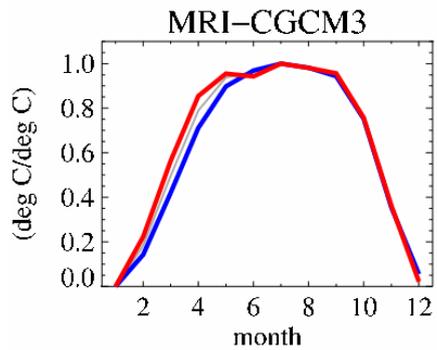
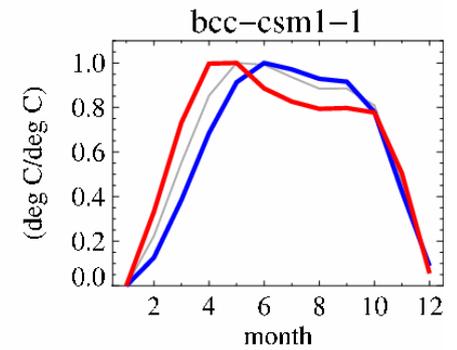
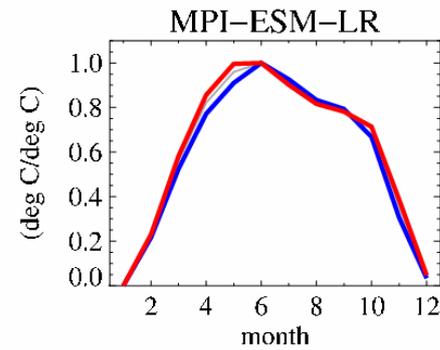
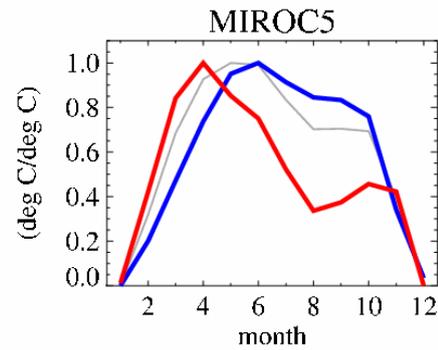
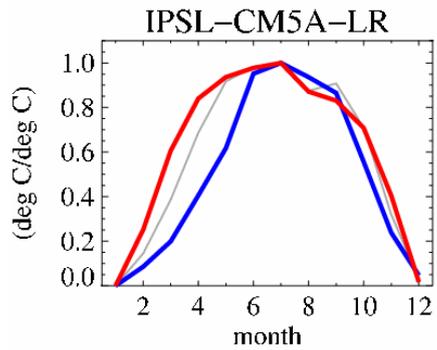
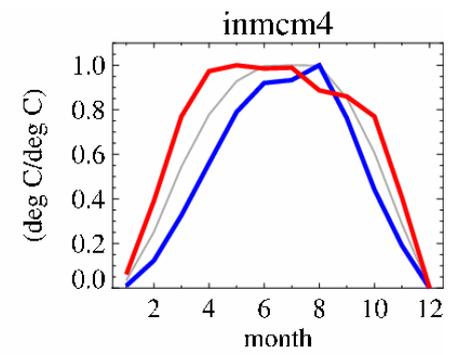
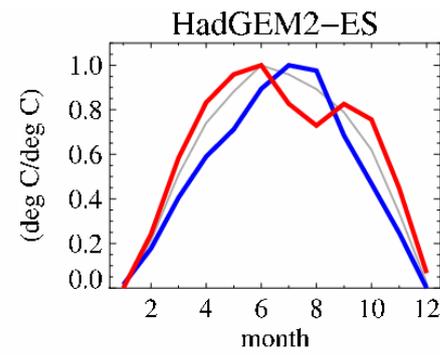
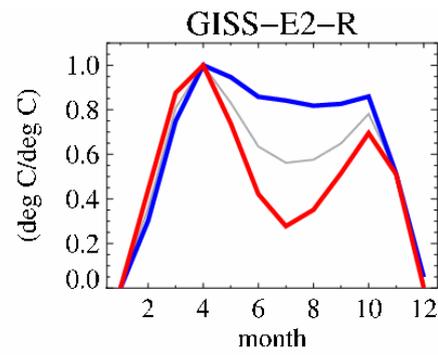
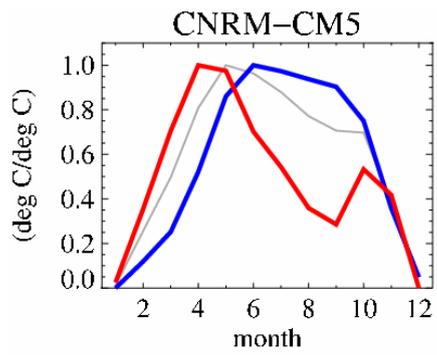


Trends in the annual cycle of temperature (T2m) in the Central Sahel: SYNOP data of Homori (top) and closest CRU point, from 1950 to 2009. For each months, the series of dots correspond to the monthly-mean values obtained from 1950 to 2009. A linear fit is added, and, for comparison, a second order fit is displayed below. The trends over this 60-year period is also indicated for each month on the top-right (coloured bars). Dots are shown in red for correlations greater than 0.4. The blue bars in the bottom plot indicate the months when rainfall occurs.

EVOLUTION OF THE ANNUAL CYCLE OF TEMPERATURE AT 2M FROM 1979 TO 2009:

COMPARISON OF OBSERVATIONS AND REANALYSES

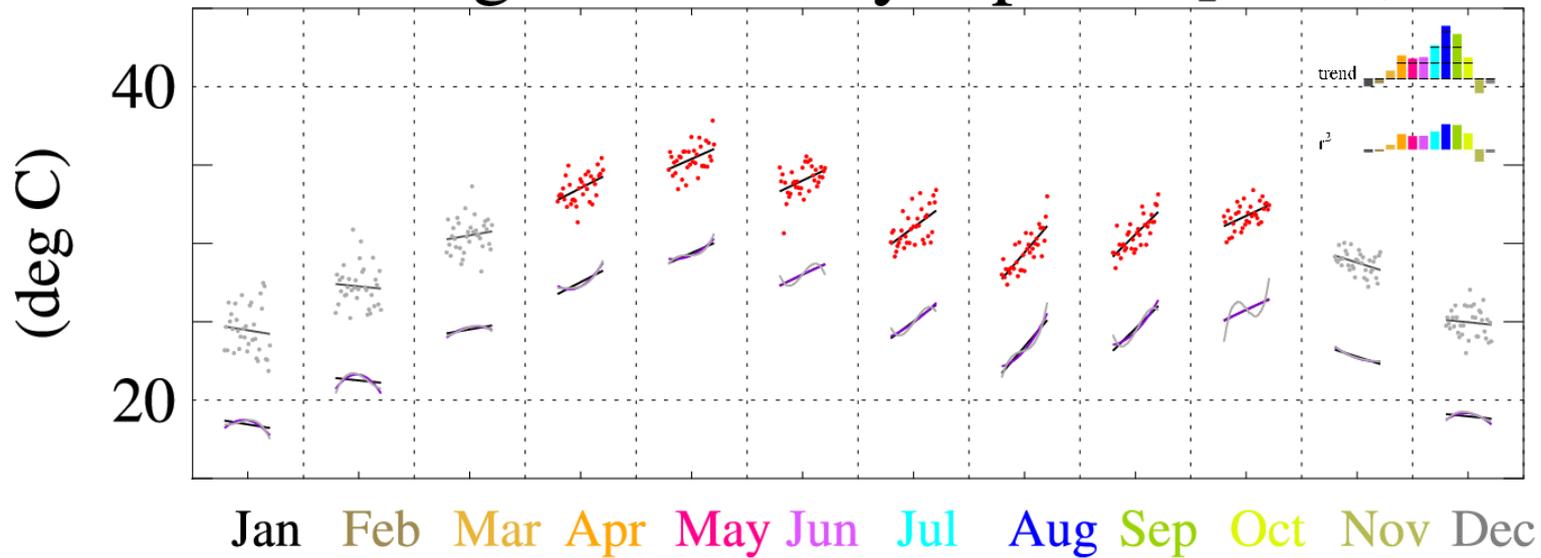




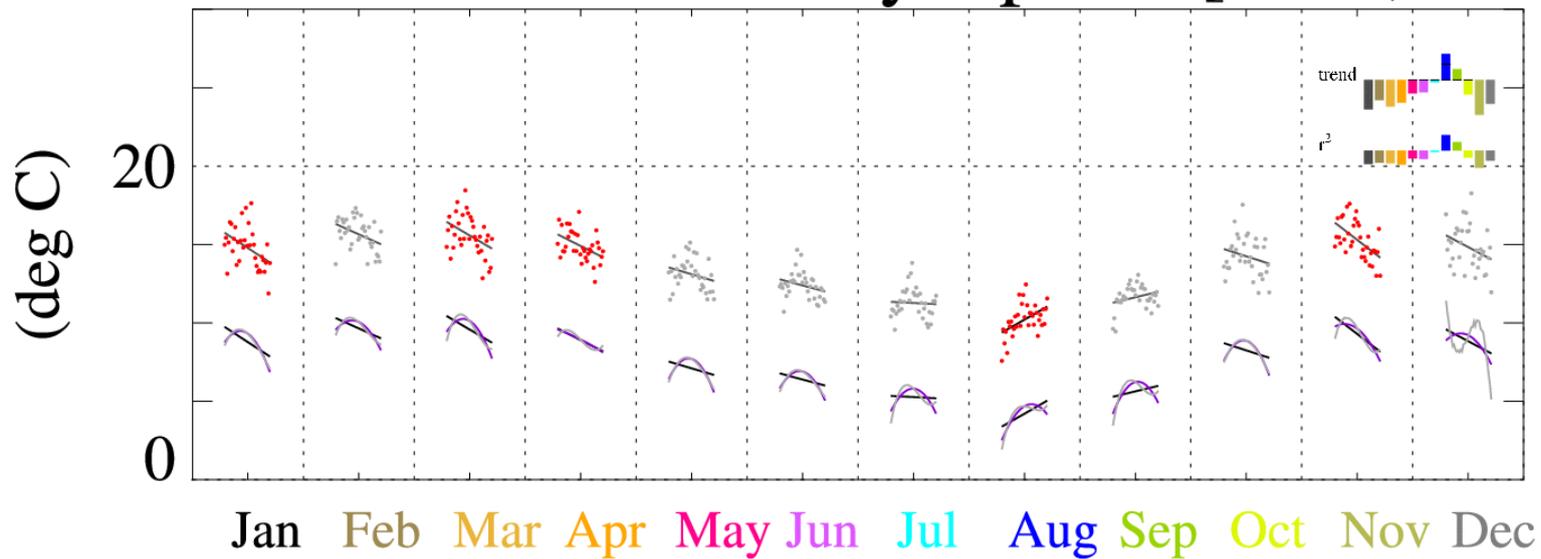
CMIP5, la structure saisonnière

On trouve bien un décalage des max de Tmax et Tmin pour la plupart des modèles (*satisfaisant*)

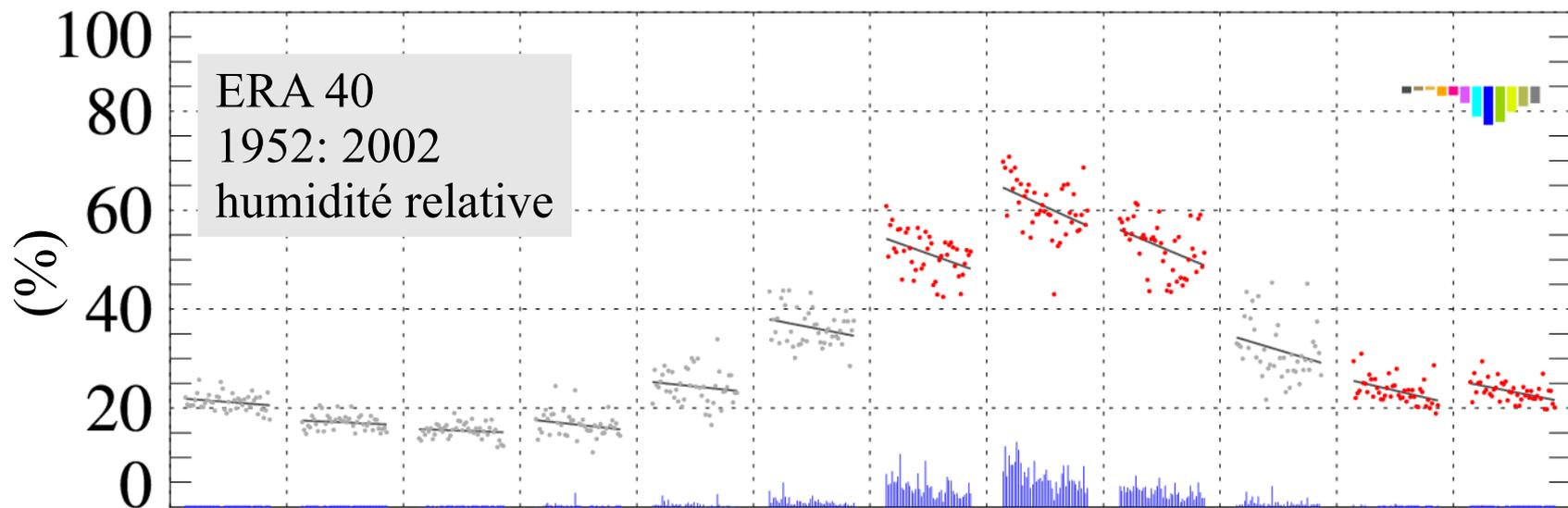
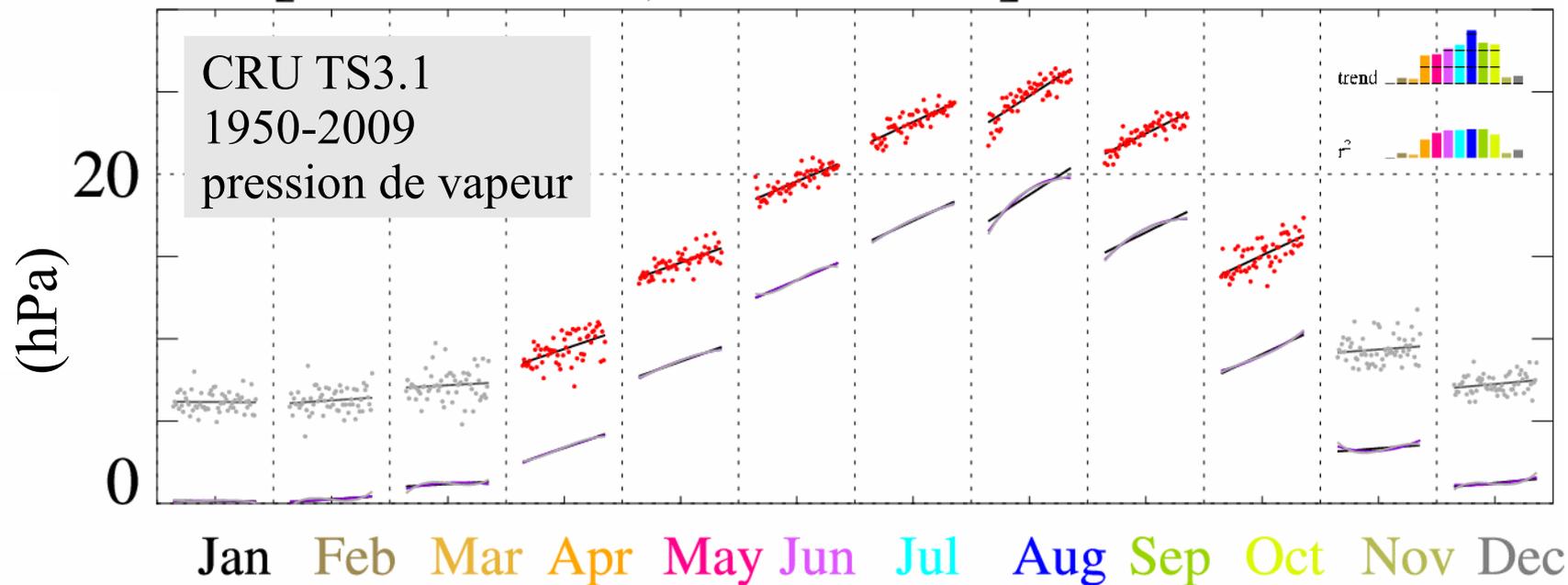
15.3N Tavg Hombori synop EM [1950,1984]



15.3N DTR Hombori synop EM [1950,1984]

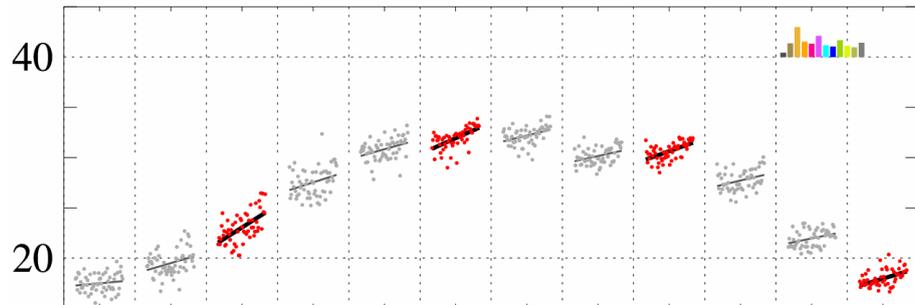


[10W-10E, 14N-17N]

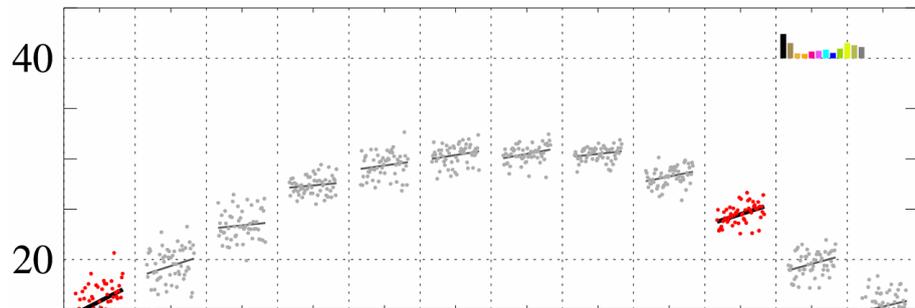


Réanalyses: cohérence des résultats pour la température, mais pas pour l'humidité

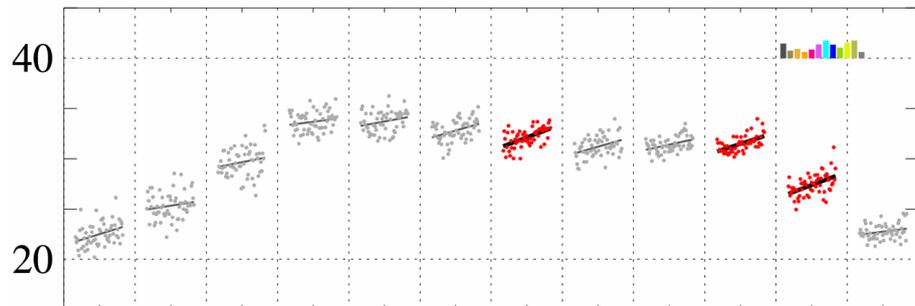
16.11 IPSL-CM5A-LR T



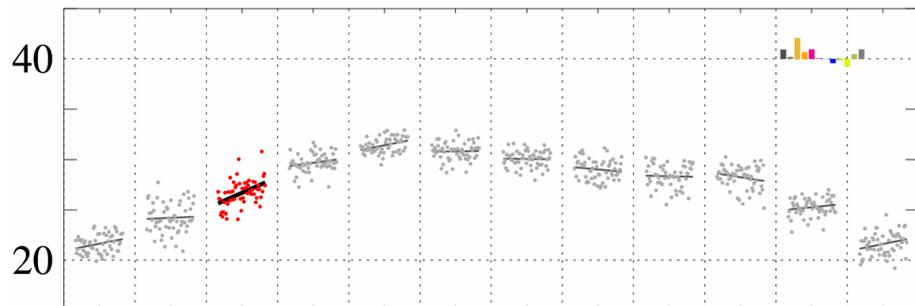
15.75 inmcm4 T



15.35 CanESM2 T

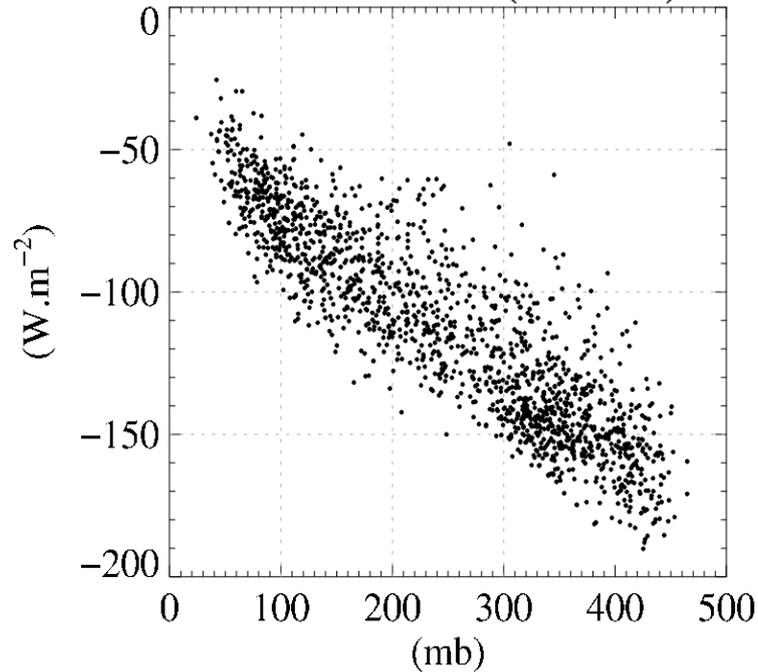


14.71 CNRM-CM5 T

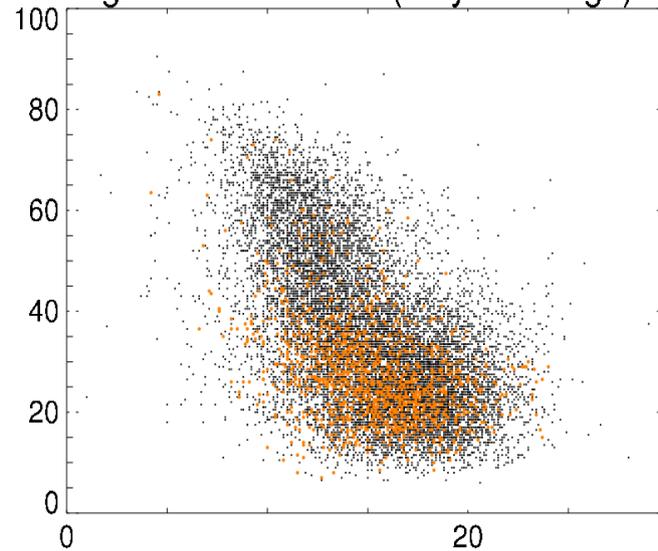


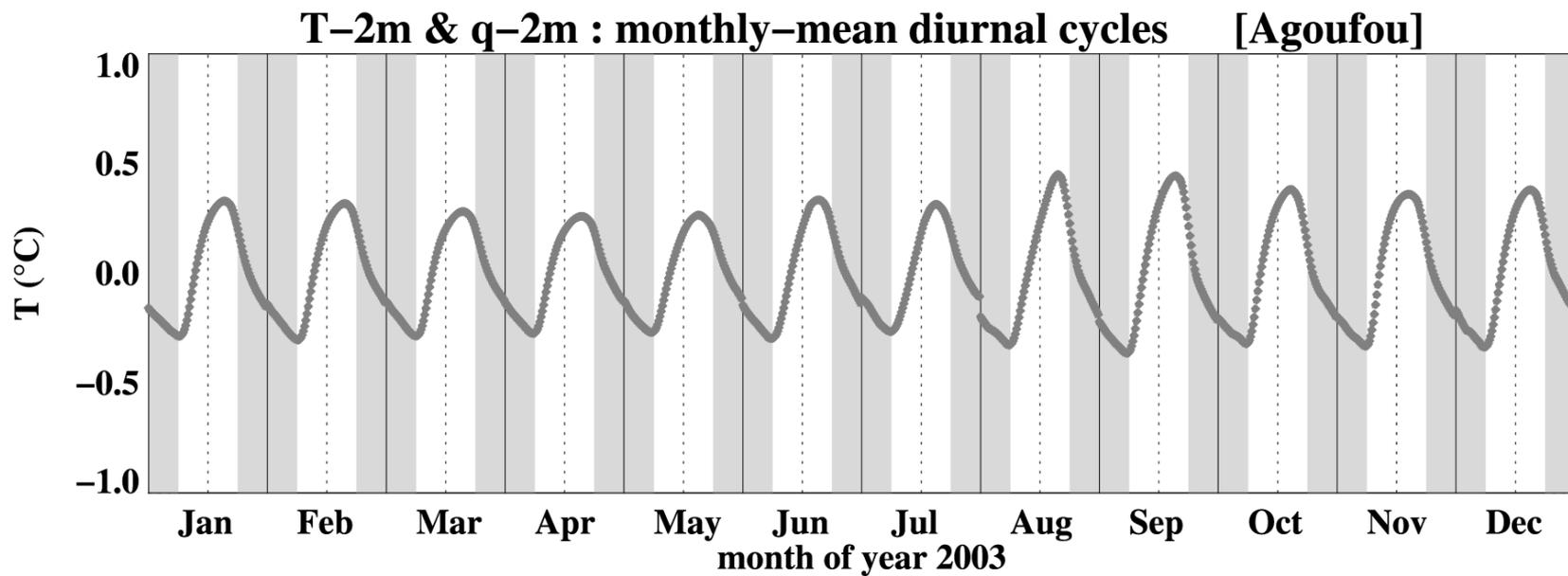
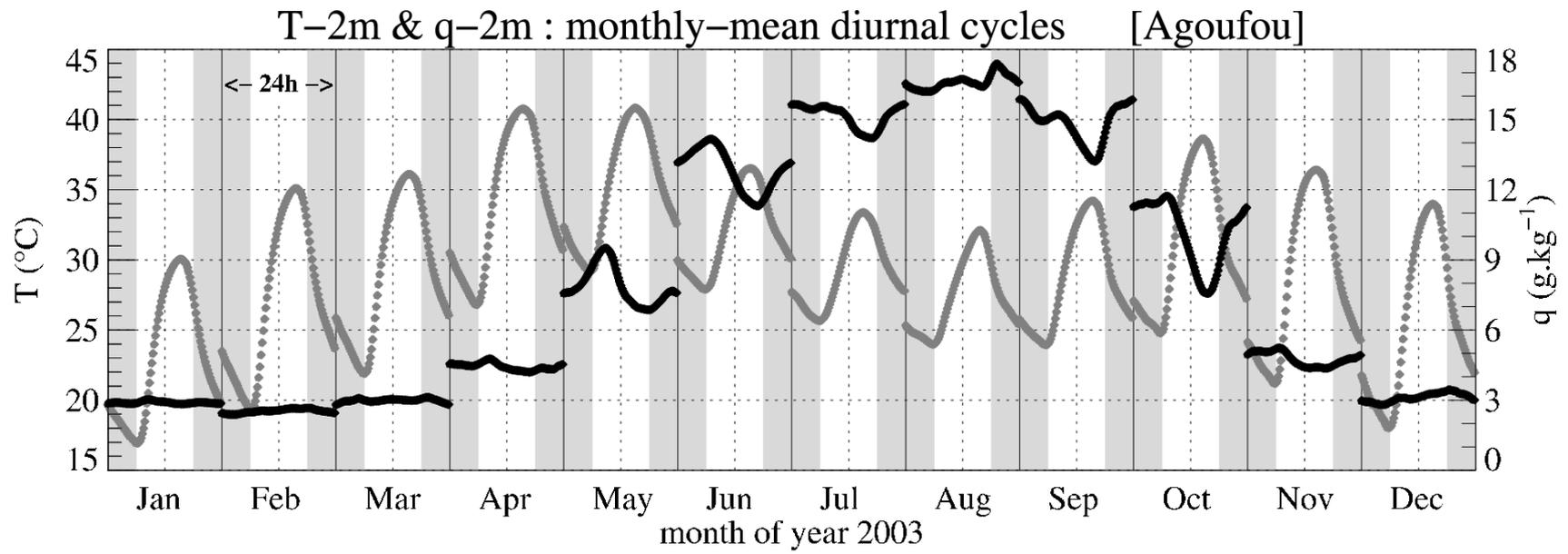
1 2 3 4 5 6 7 8 9 10 11 12 13

LW^{net} versus $(P_s - P_{lcl})$ ~ RH 2m



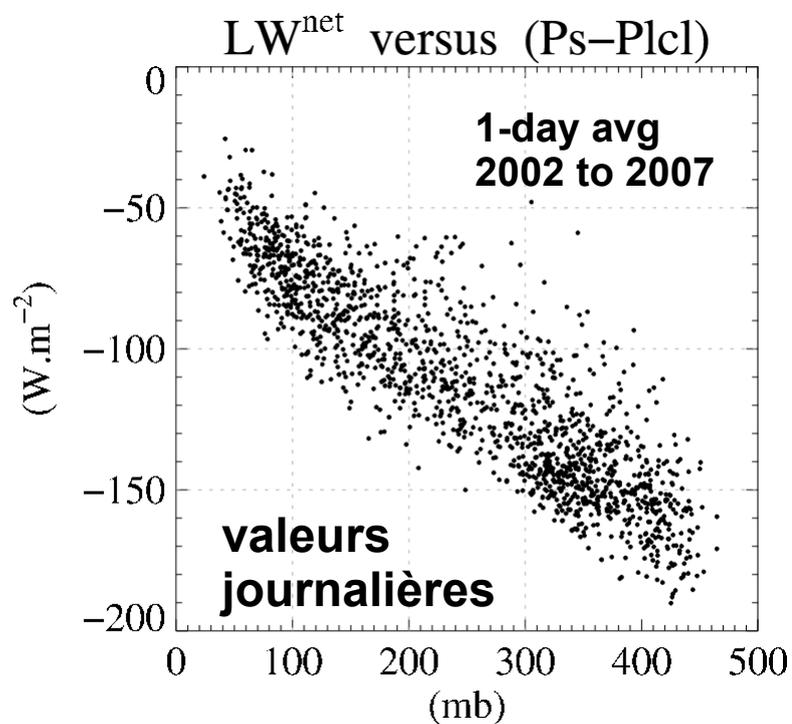
gaoxx:RH fct DTR (May in orange)



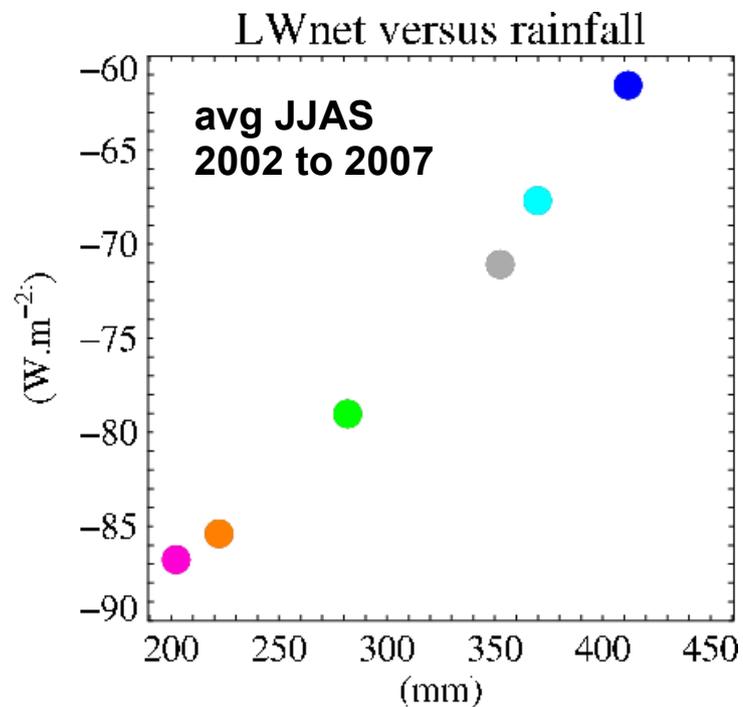


exemples de couplages

humidité-flux radiatif net



Forte variabilité interannuelle
couplées des pluies et des flux



diagnostic
modélisation

→
ECMWF

