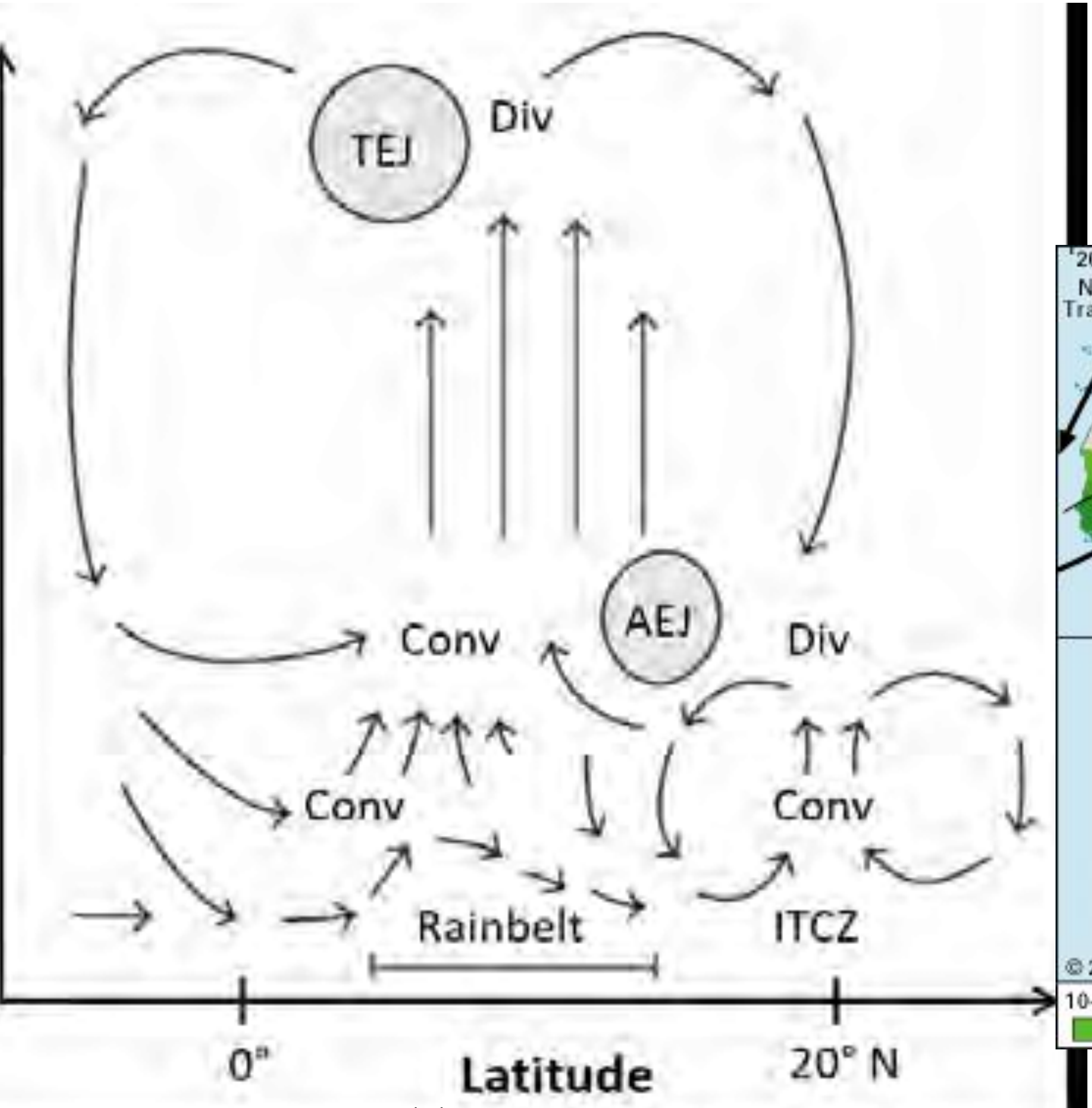
  

La fin de la période humide africaine comme exemple de changement radical du climat et de la végétation

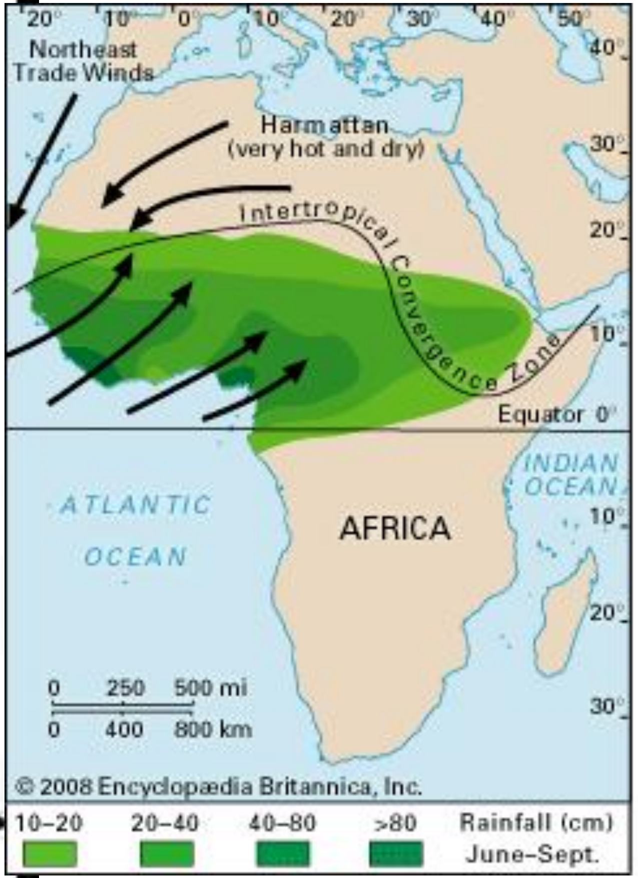
Pascale Braconnot

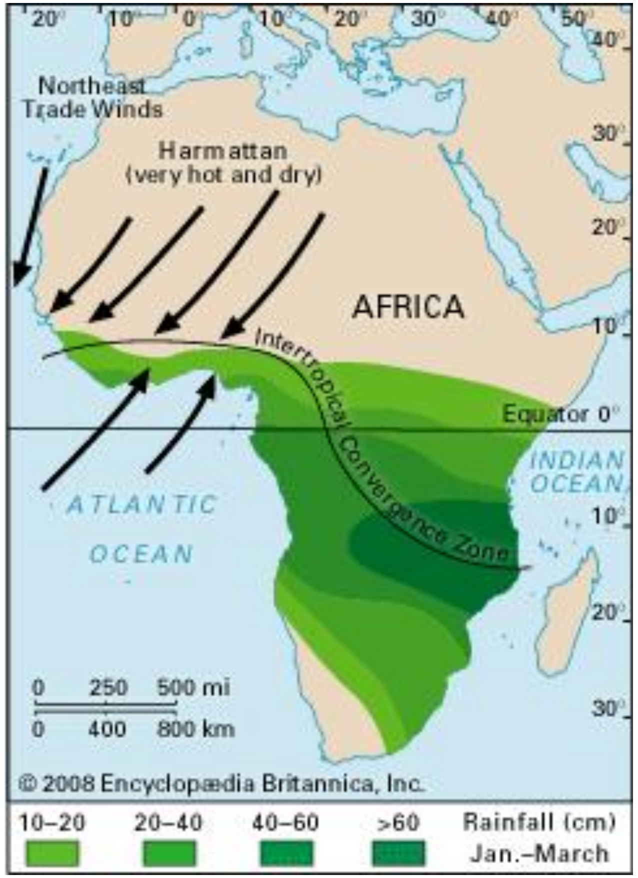
Laboratoire des Sciences du Climat et de l’Environnement – Institut Pierre Simon Laplace, France

African monsoon : a winter/summer reversal

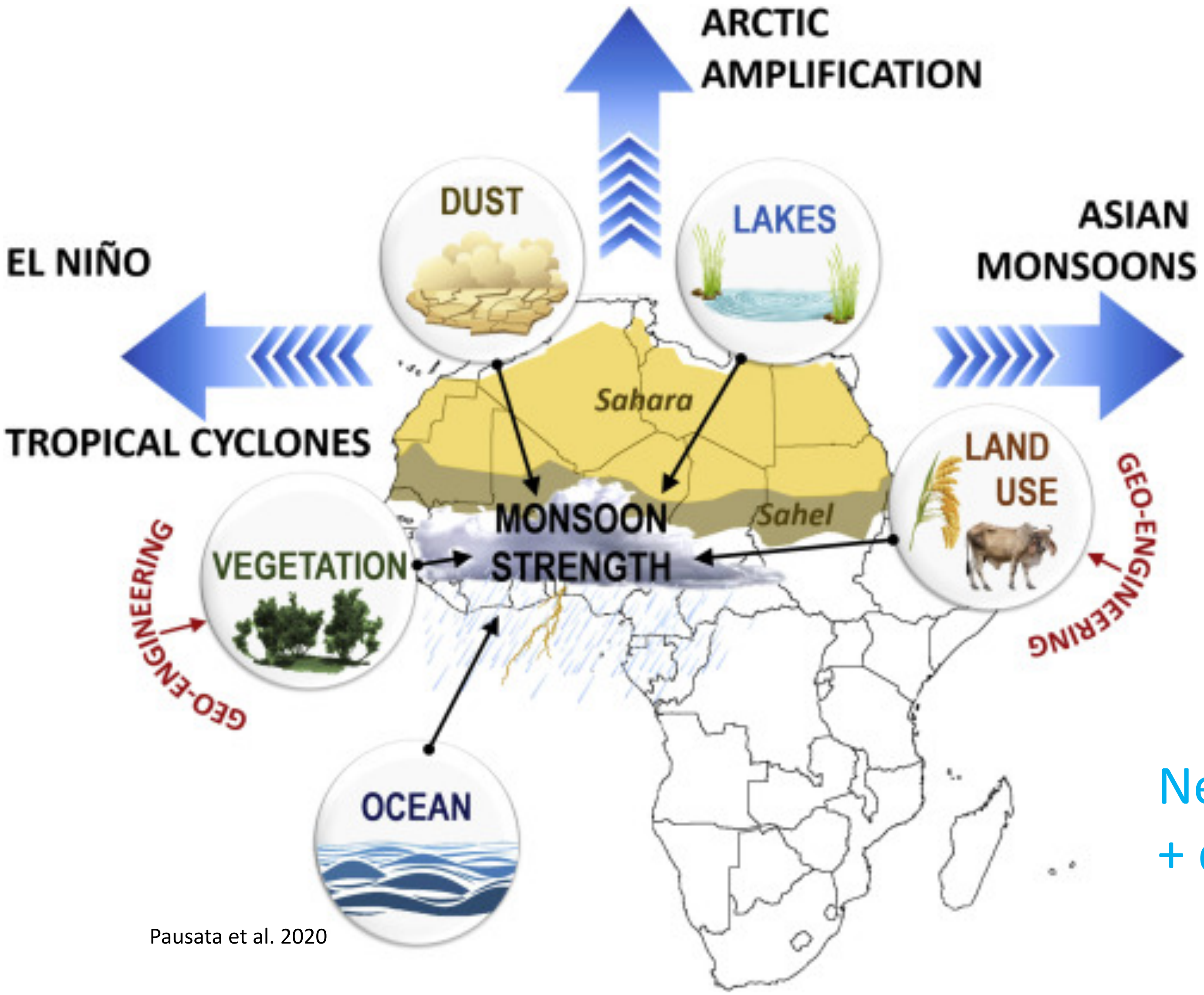


Nicholson, 2009





At the heart of lots of interactions and teleconnections



Pausata et al. 2020

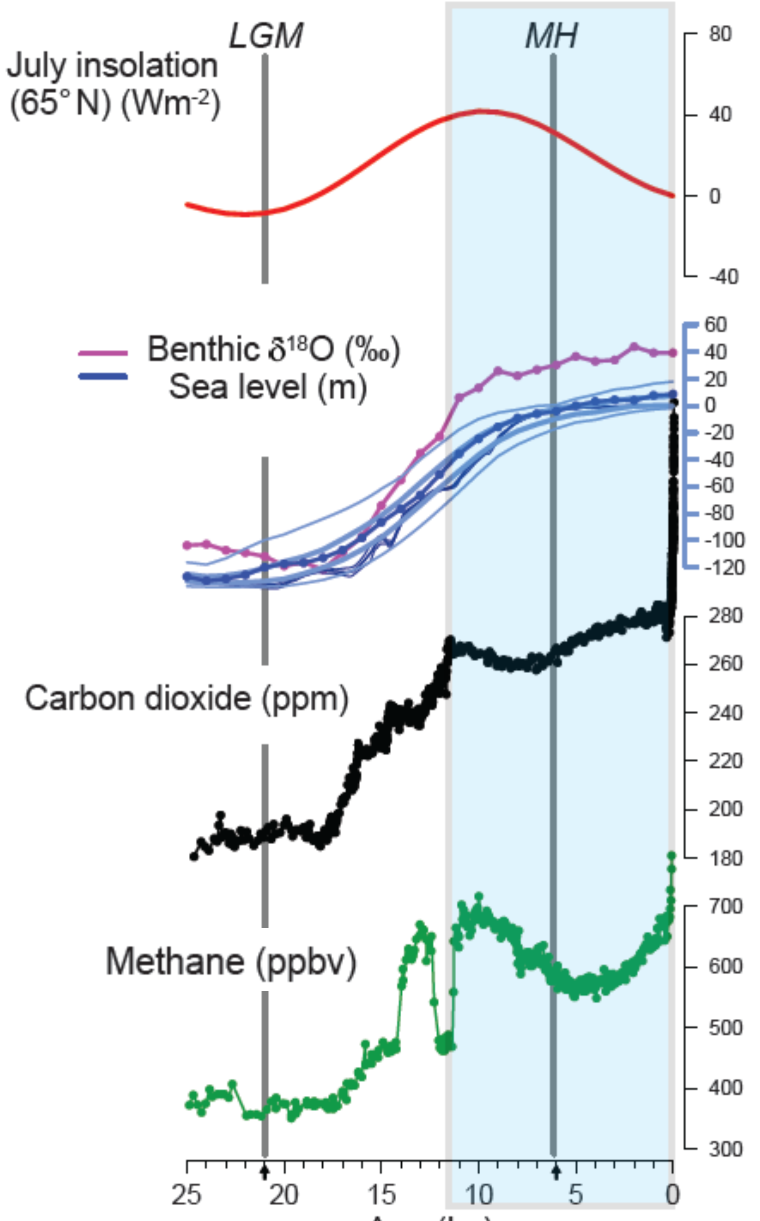
Lots of progress in the last 30 years

BUT relative impact or importance of the different factors not understood and still under debate

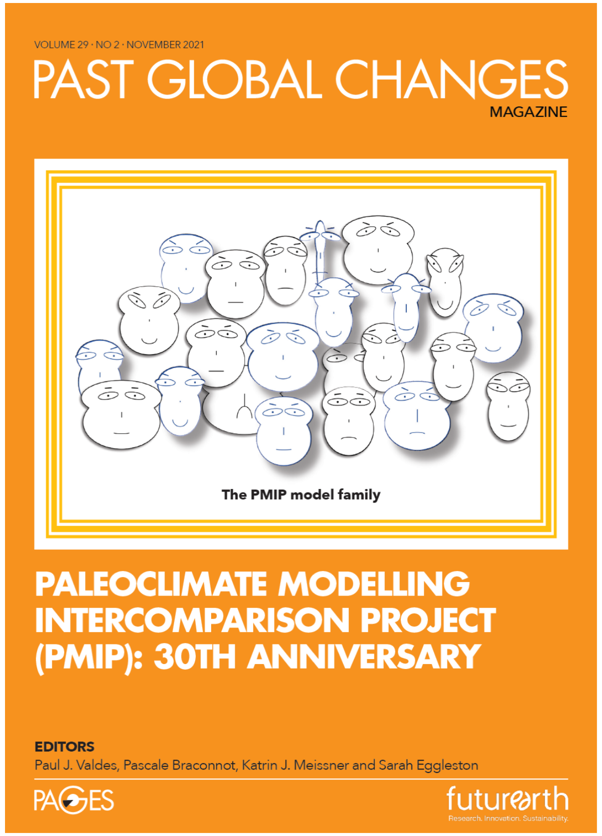
Need to deal with : lack of observations + difficult for climate model

The Holocene

- Period during which agriculture, farming, writing, cities, ….. developed



Kageyama et al. 2018



VOLUME 29 · NO 2 · NOVEMBER 2021

PAST GLOBAL CHANGES
MAGAZINE

The PMIP model family

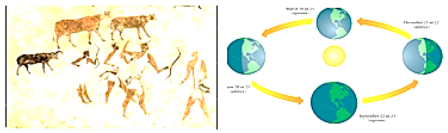
PALEOCLIMATE MODELLING INTERCOMPARISON PROJECT (PMIP): 30TH ANNIVERSARY

EDITORS
Paul J. Valdes, Pascale Braconnot, Katrin J. Meissner and Sarah Eggleston

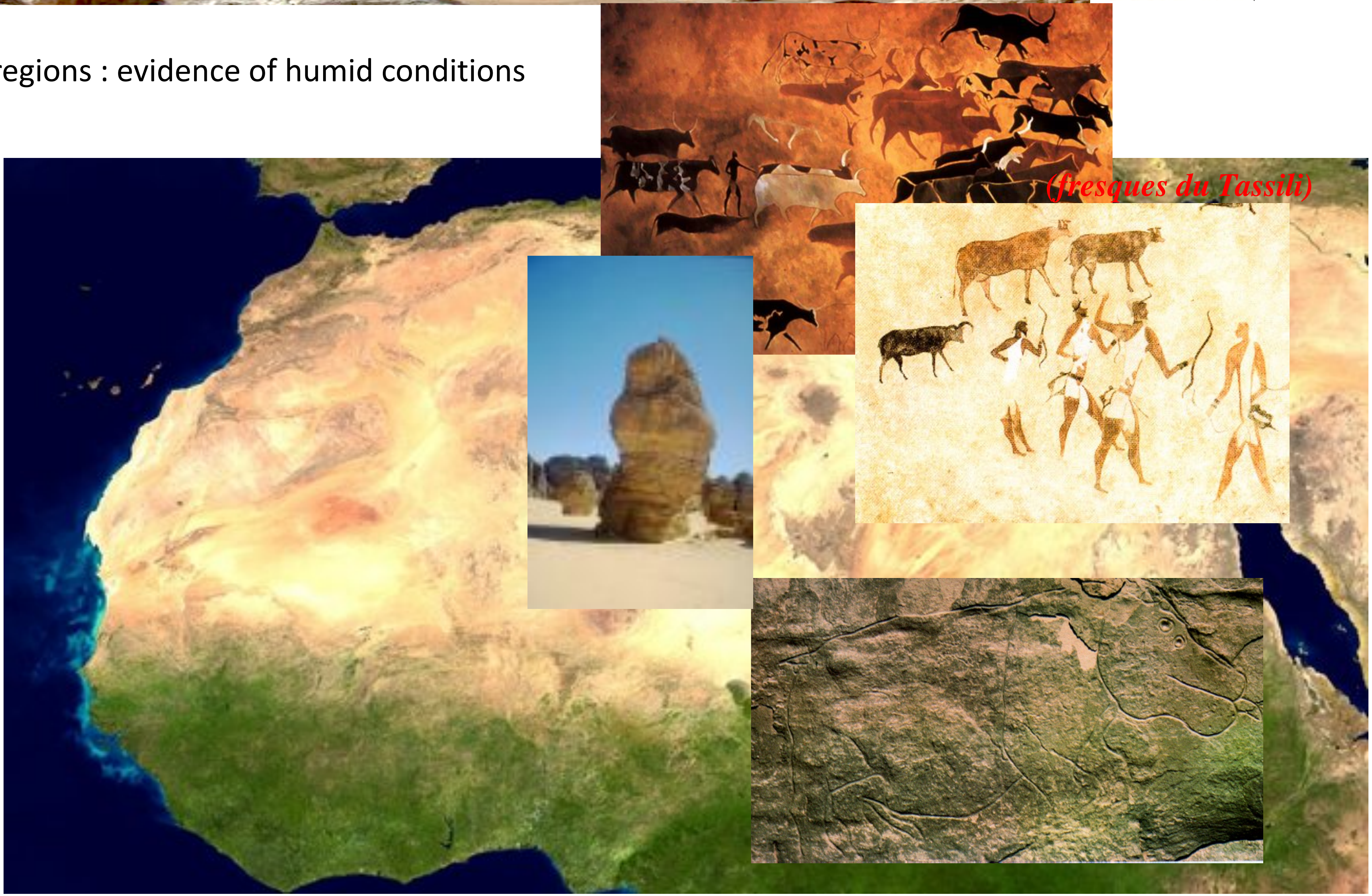
PAGES
futurearth
Research. Innovation. Sustainability.

Models are not good or bad, they are like us, they are all different and have they own skill …

Monsoon at the time of the green Sahara



In now dry regions : evidence of humid conditions



@ CNRS)

A schematic for the last 6000 years

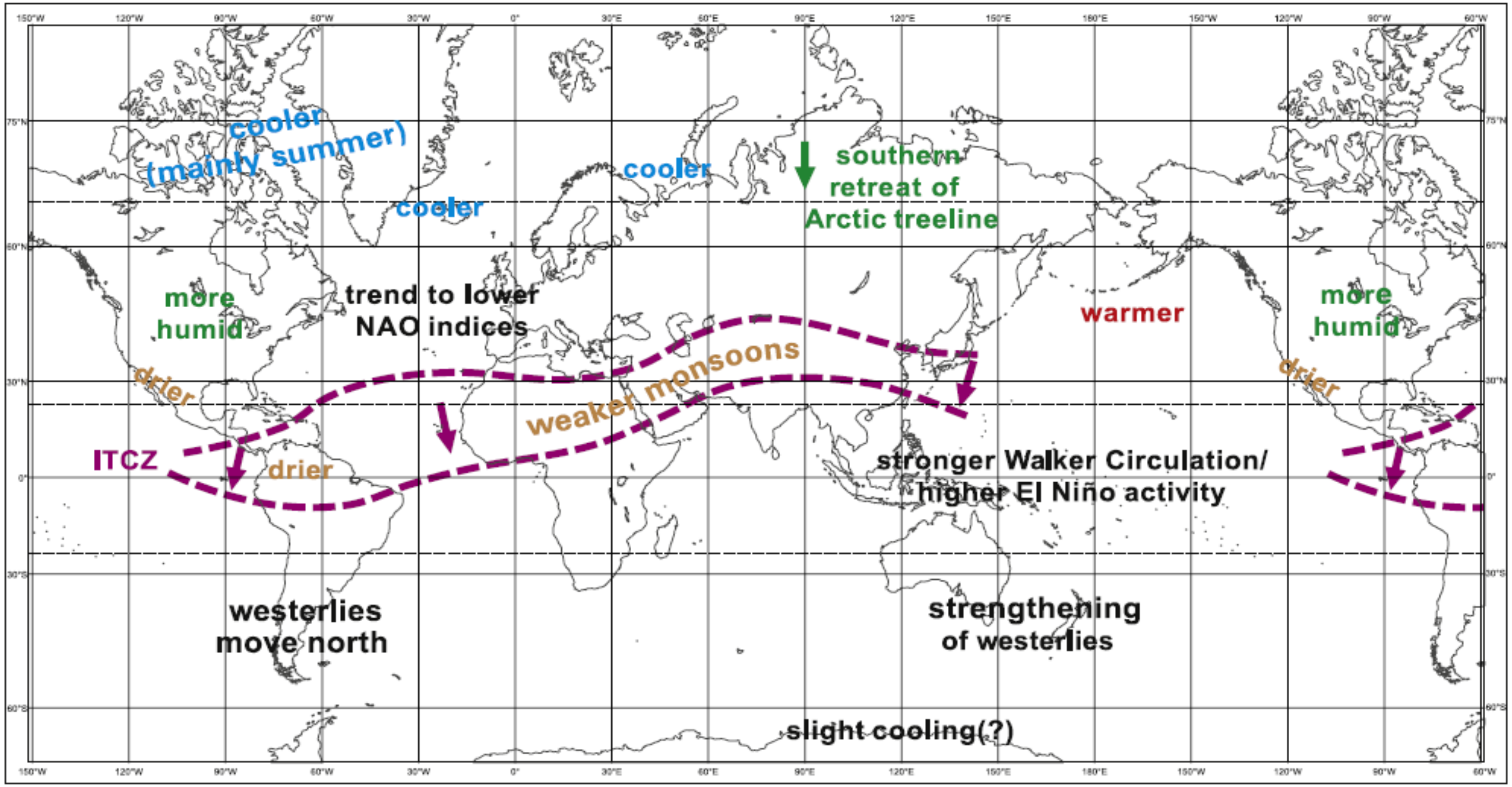


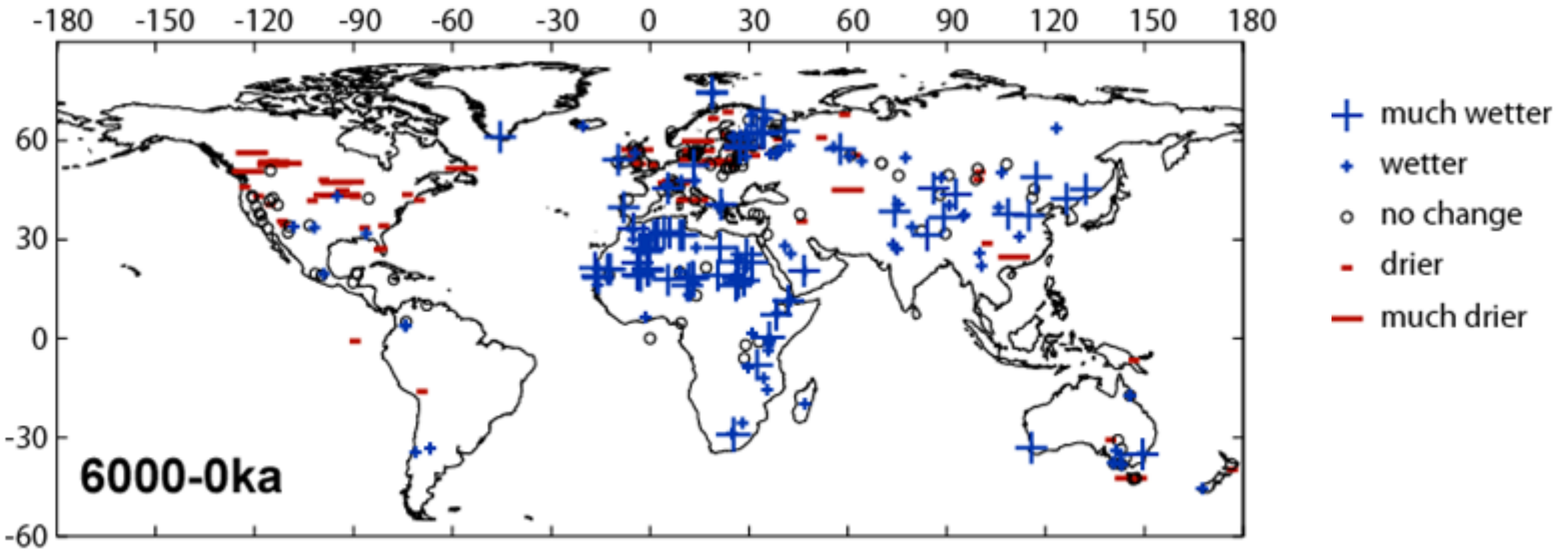
Fig. 18. Spatial synthesis: global climate change for the preindustrial period (AD ~1700) compared to the MH (~6000 cal years BP).

- Long term trends those detailed characteristics/timing still need refinements
- Response to insolation forcing? Annual, seasonal Internal variability? Role of ocean, ice, vegetation, dust…. Feedbacks?

Wanner et al. 2008

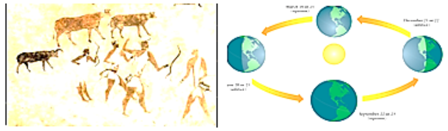
Un Holocène moyen plus humide : prédiode de référence (PMIP)

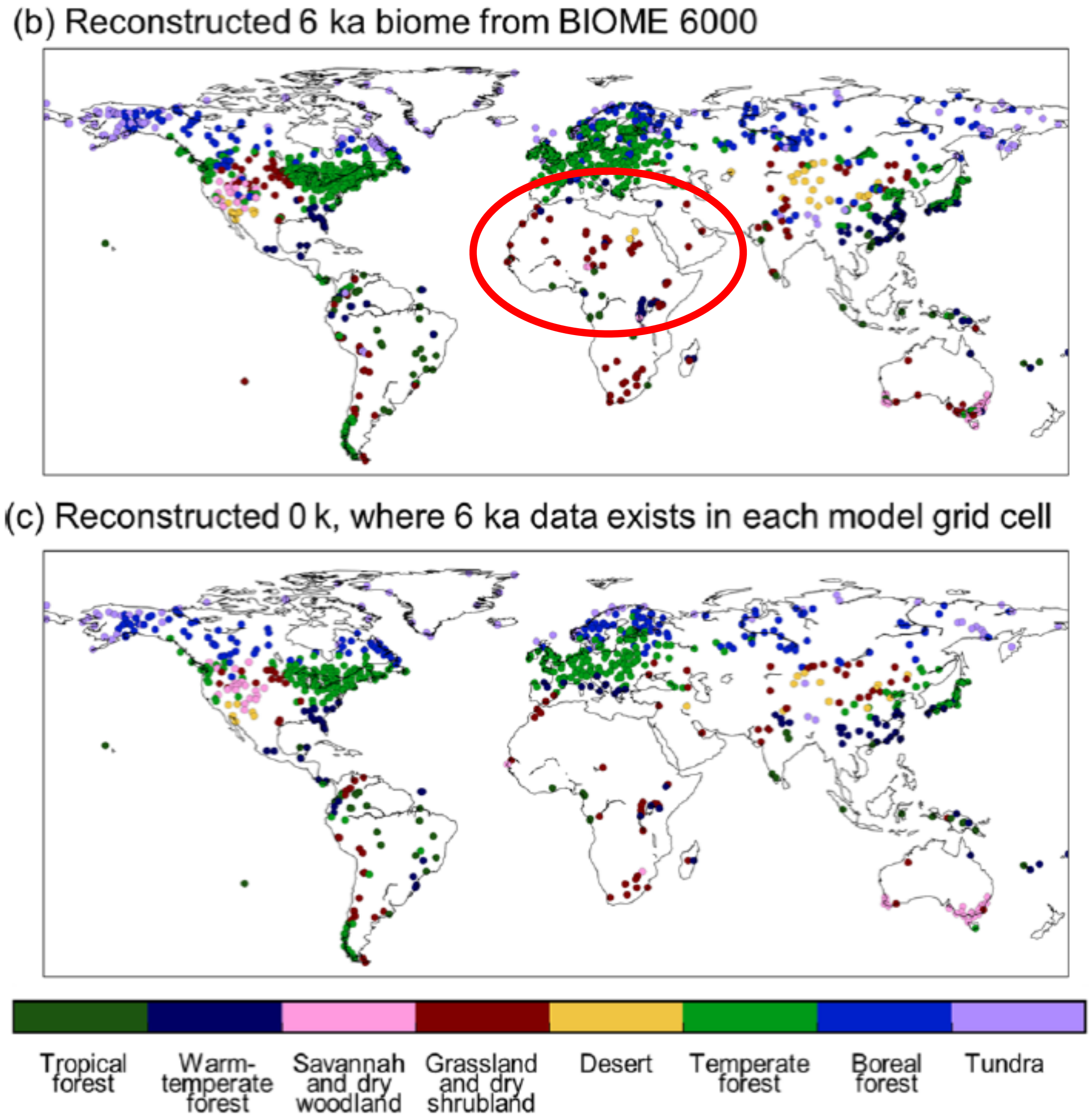
Lake status



Kohfeld and Harrison, 2000
@PMIP2 https://pmip2.lsce.ipsl.fr/synth/lakestatus.shtml

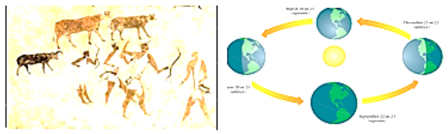
BIOME6000: from pollen data



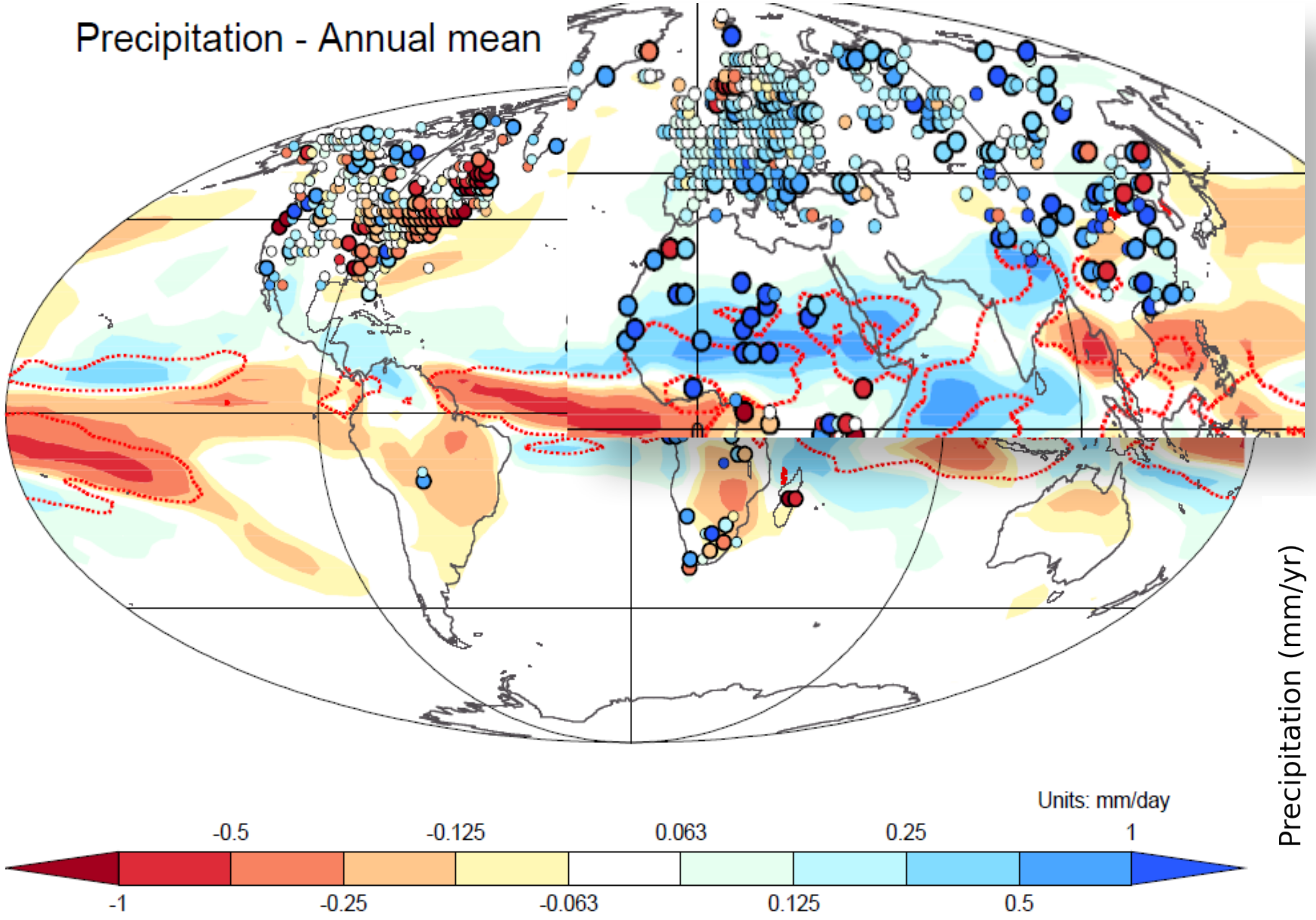


Prentice et al. 1996 (data set see [Harrison, Sandy](#) (2017): BIOME 6000 DB classified plotfile version 1. University of Reading. Dataset. https://doi.org/10.17864/1947.99

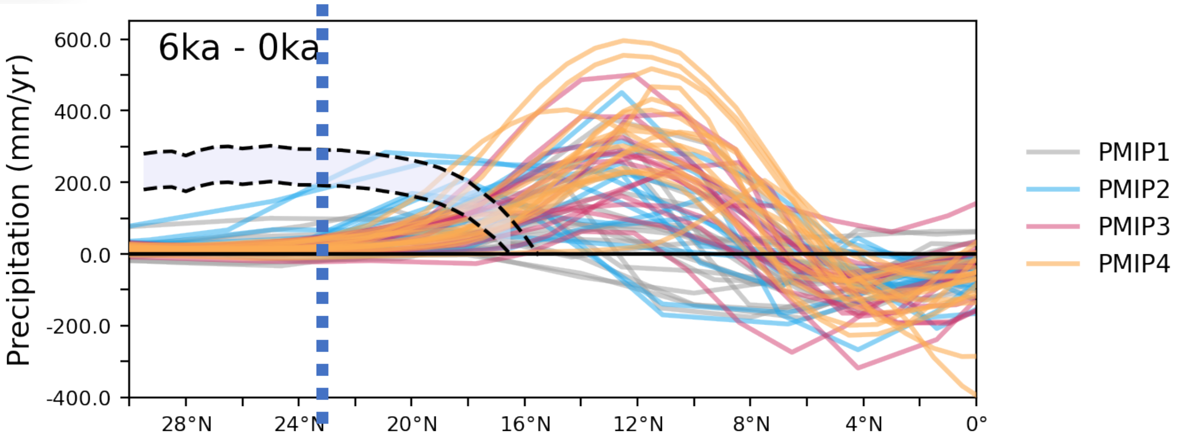
Precipitation reconstruction and simulations



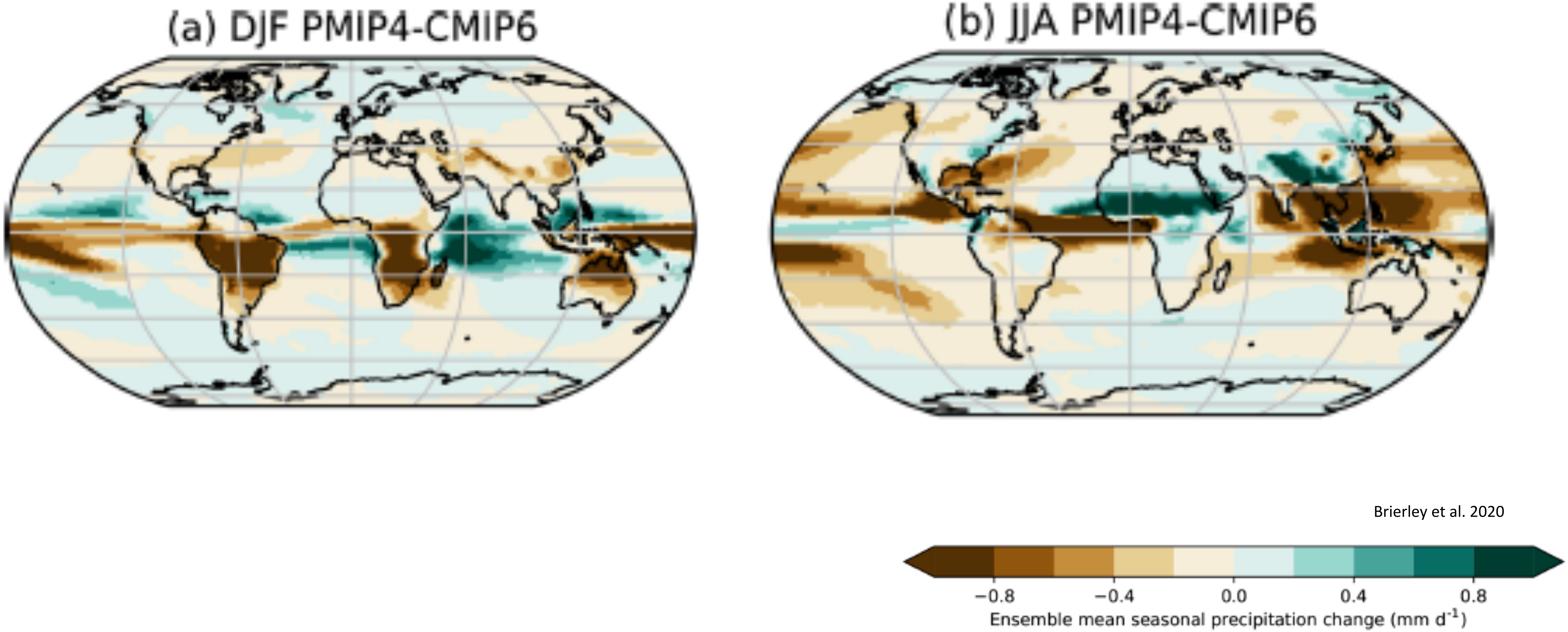
Reconstruction precipitation and temperature
see Bartlein et al. 2011
PMIP3 simulations
See AR4 chap. 9



Precipitation in Africa (W monsoon 20°W-30°E)

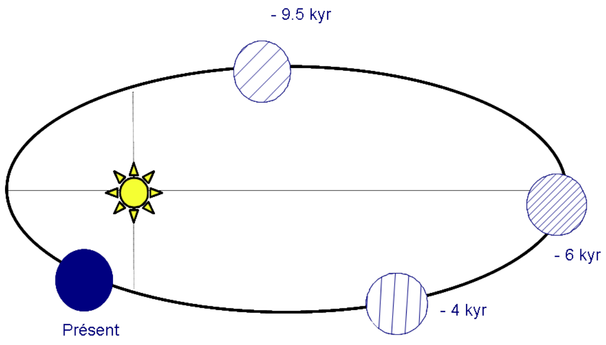


Do not forget : annual mean is the result of changes in seasonality

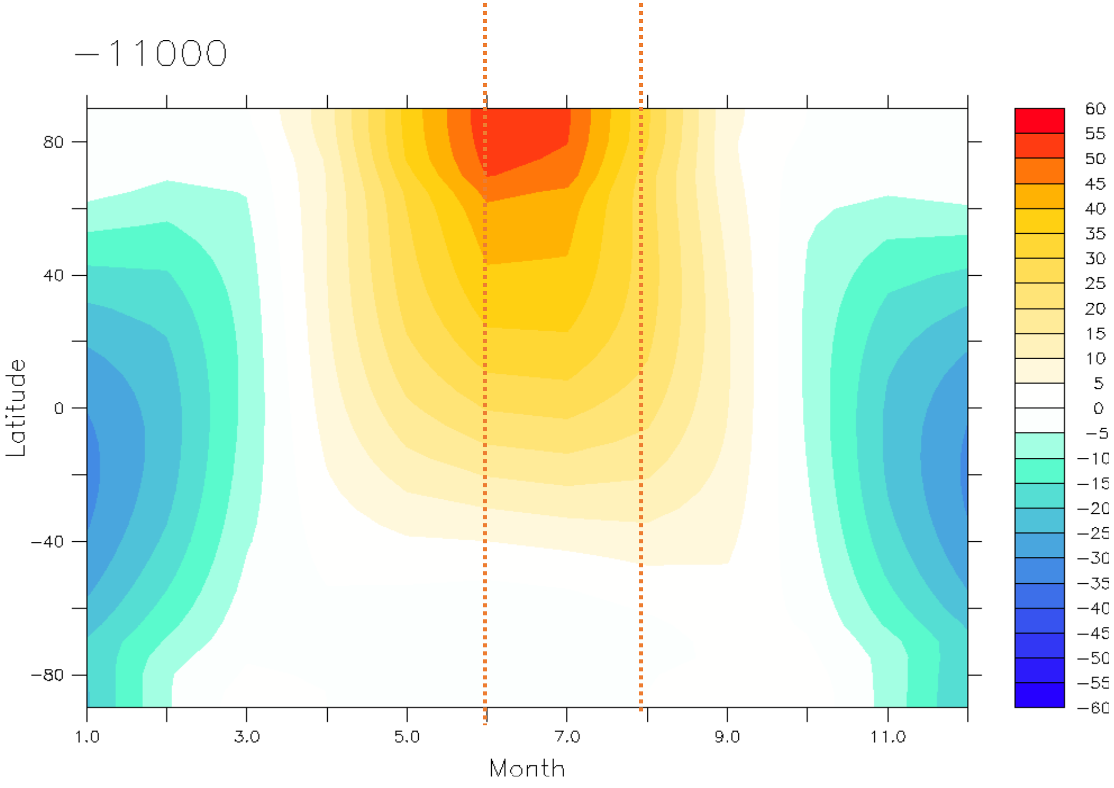


Brierley et al. 2020

Earth’s orbital parameters and changes in seasonality : Holocene

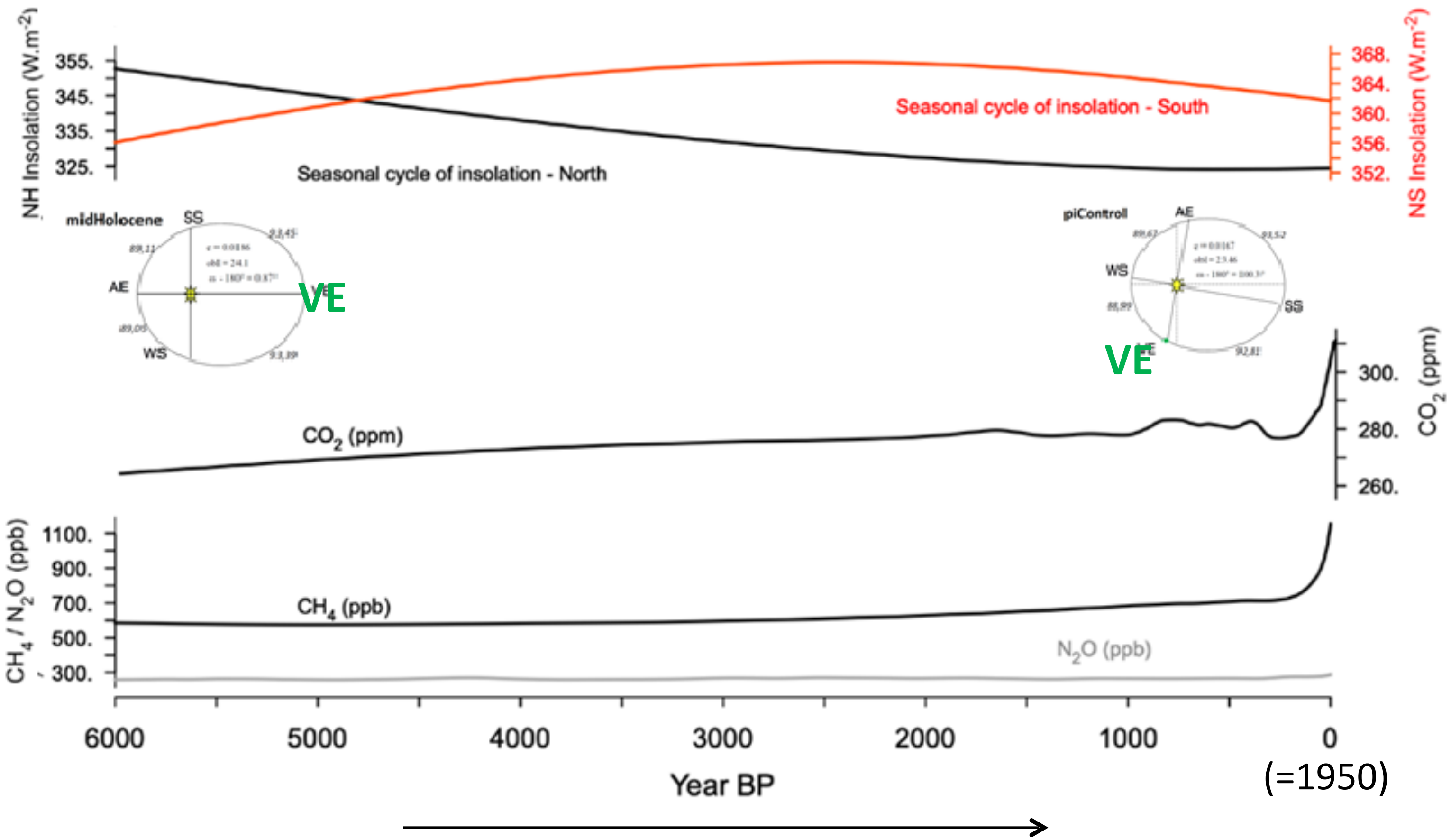


Position de l’équinoxe de printemps



Transient Holocene simulations

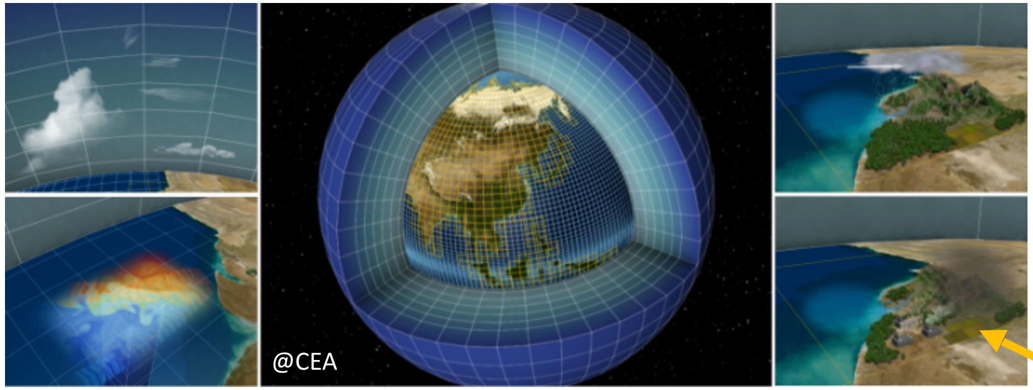
- Test climate response to insolation (Earth’s orbit) and trace gases



Computing time : PRACE TRHOL Project + GENCI allocation on curie at TGCC (~20Mh)

Un terrain de jeu pour la modélisation

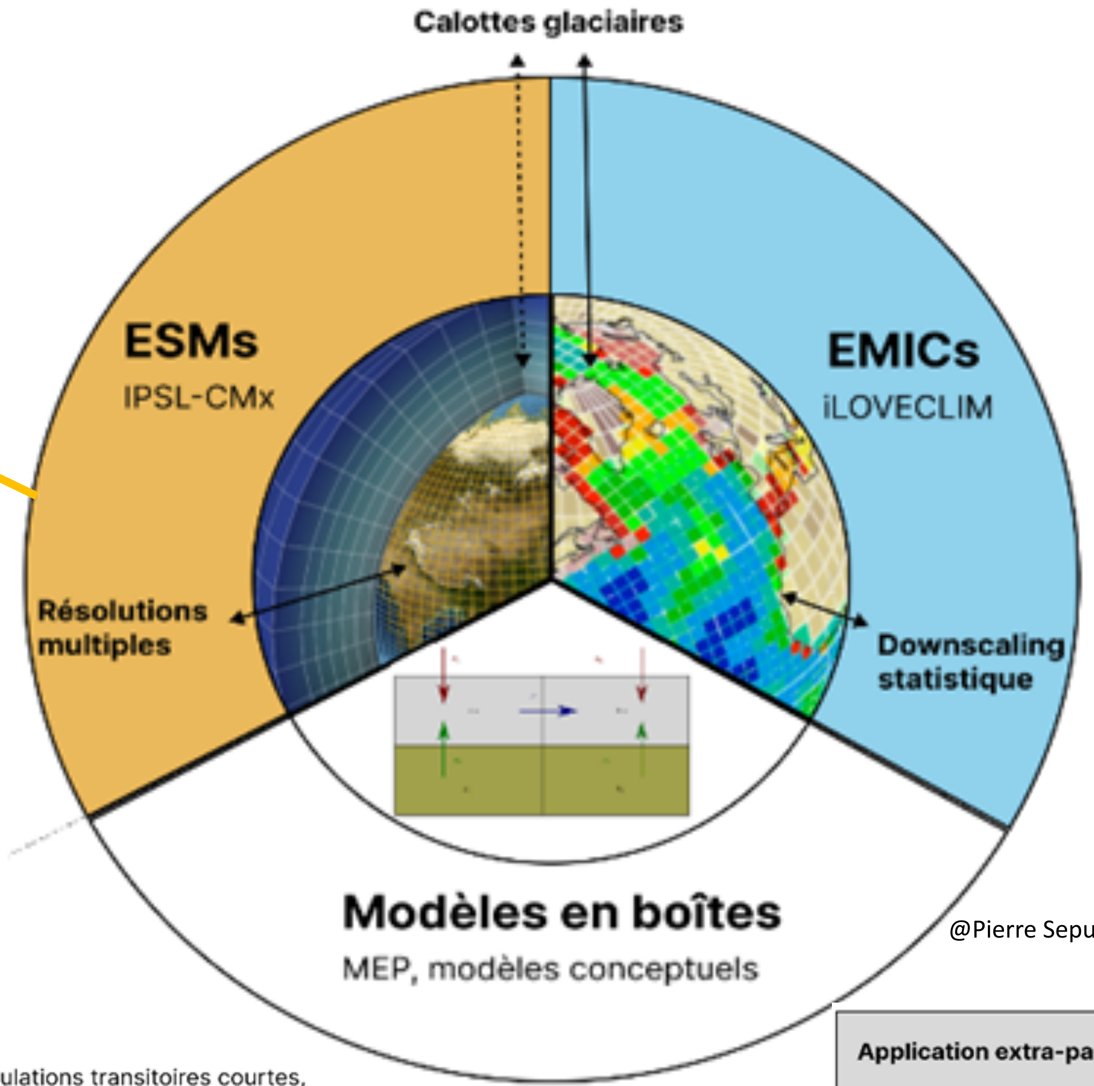
Proxies simulés: d18O, d13C, pCO2, eps-Nd



Earth System model : ex IPSL

➢Atmosphere (LMDZ)-2°ocean (NEMO)-sea-ice (LIM) et land surface (ORCHIDEE)

➢Ocean and land carbone cycle, (dynamical vegetation)



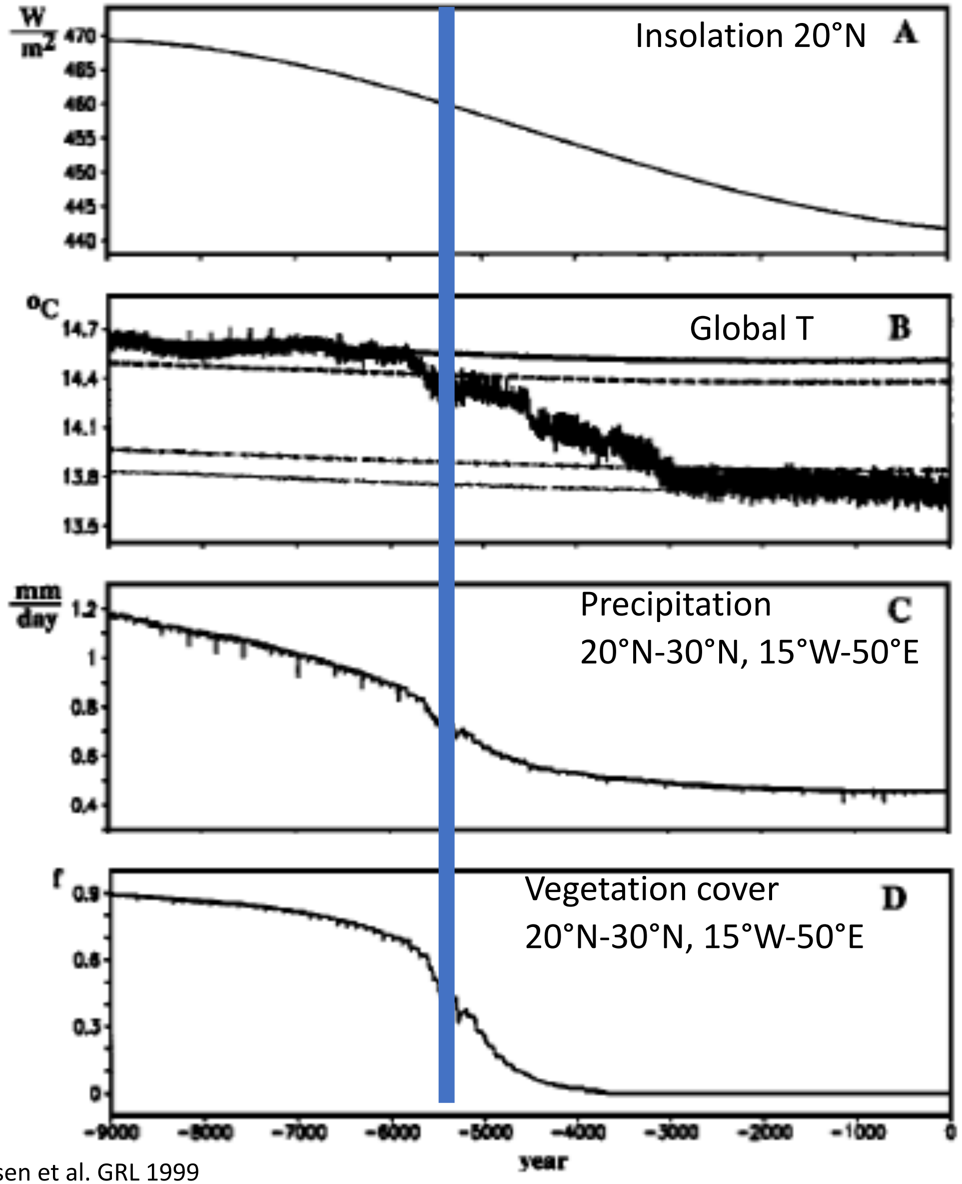
@Pierre Sepulchre

- Paléoclimats anciens et récents, Simulations transitoires courtes, Coût calcul élevé (moyens nationaux)
- Paléoclimats Quaternaire, Simulations transitoires longues, Coût calcul faible (clusters locaux)
- Tous les paléoclimats, Etude de processus oscillatoires, Coût calcul négligeable (poste de travail)

Application extra-paléoclimatiques :

- Cycles biogéochimiques à long-terme
- Distribution d'espèces (e.g. Maxent)
- Biodiversité (e.g. RPANDA, GEN3SIS)

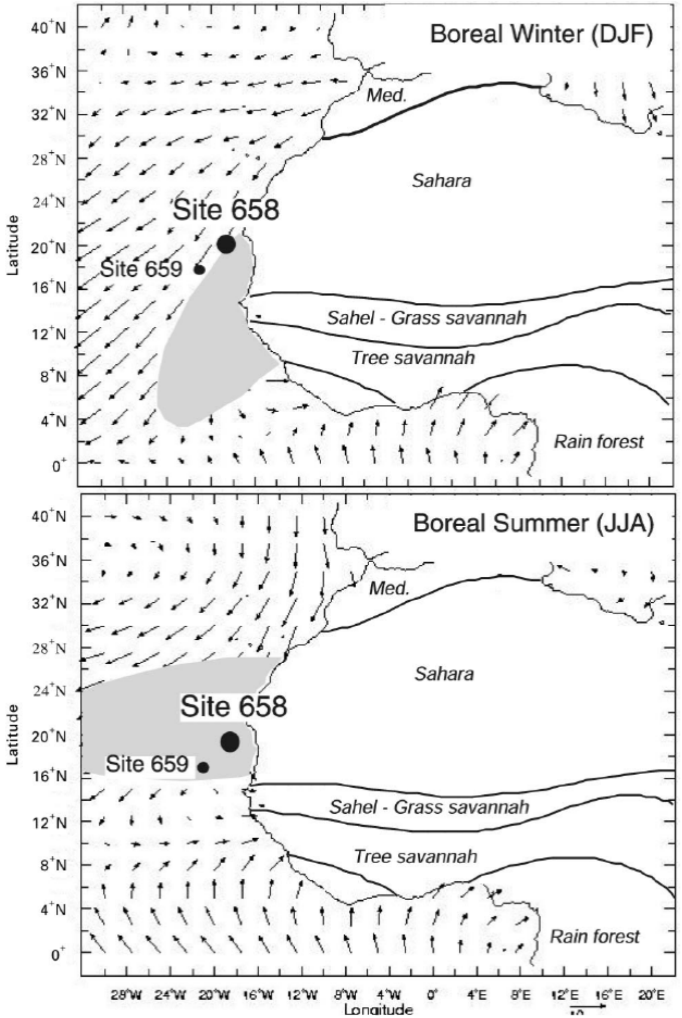
Abrupt change and vegetation

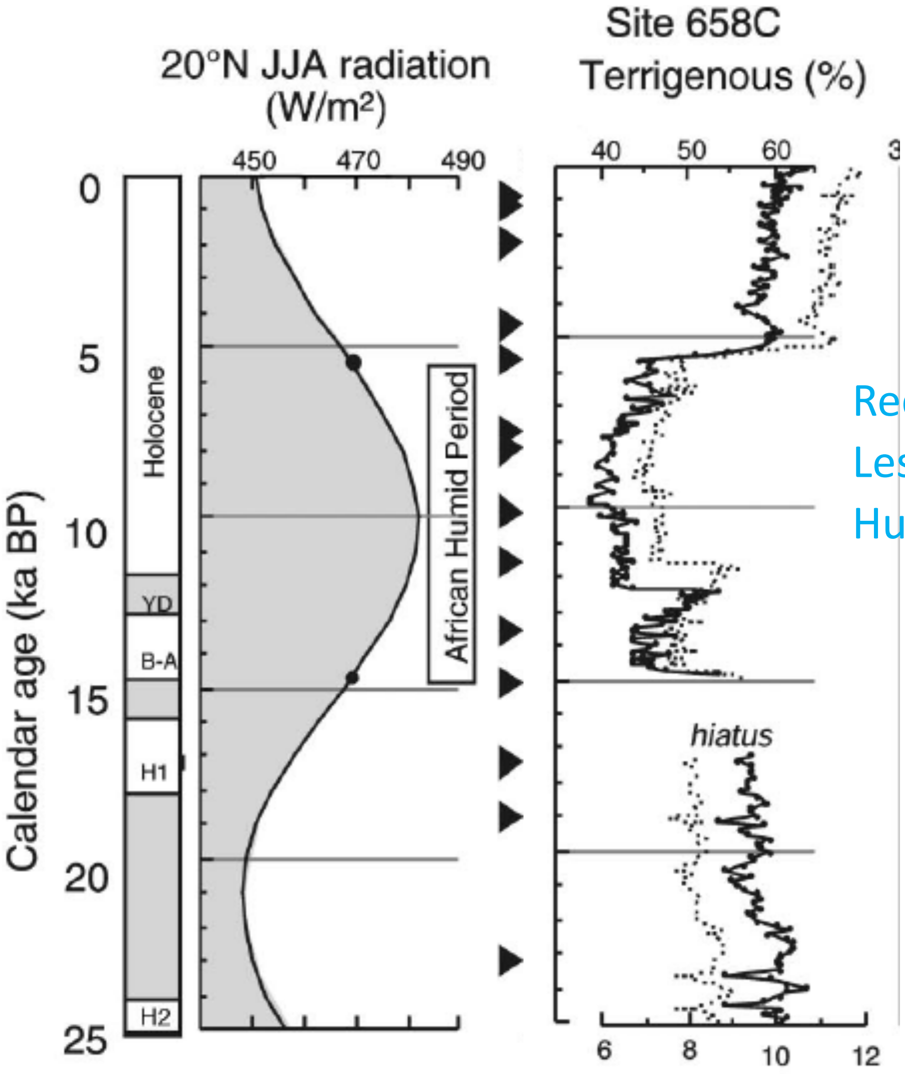


Claussen et al. GRL 1999

Climber : Intermediate complexity model
Forcing : insolation
Interactive (dynamical) vegetation

Abrubt change ?





Reduction during AHP

Less dust

Humidity + vegetation over land

De Menocal et al QSR 2000

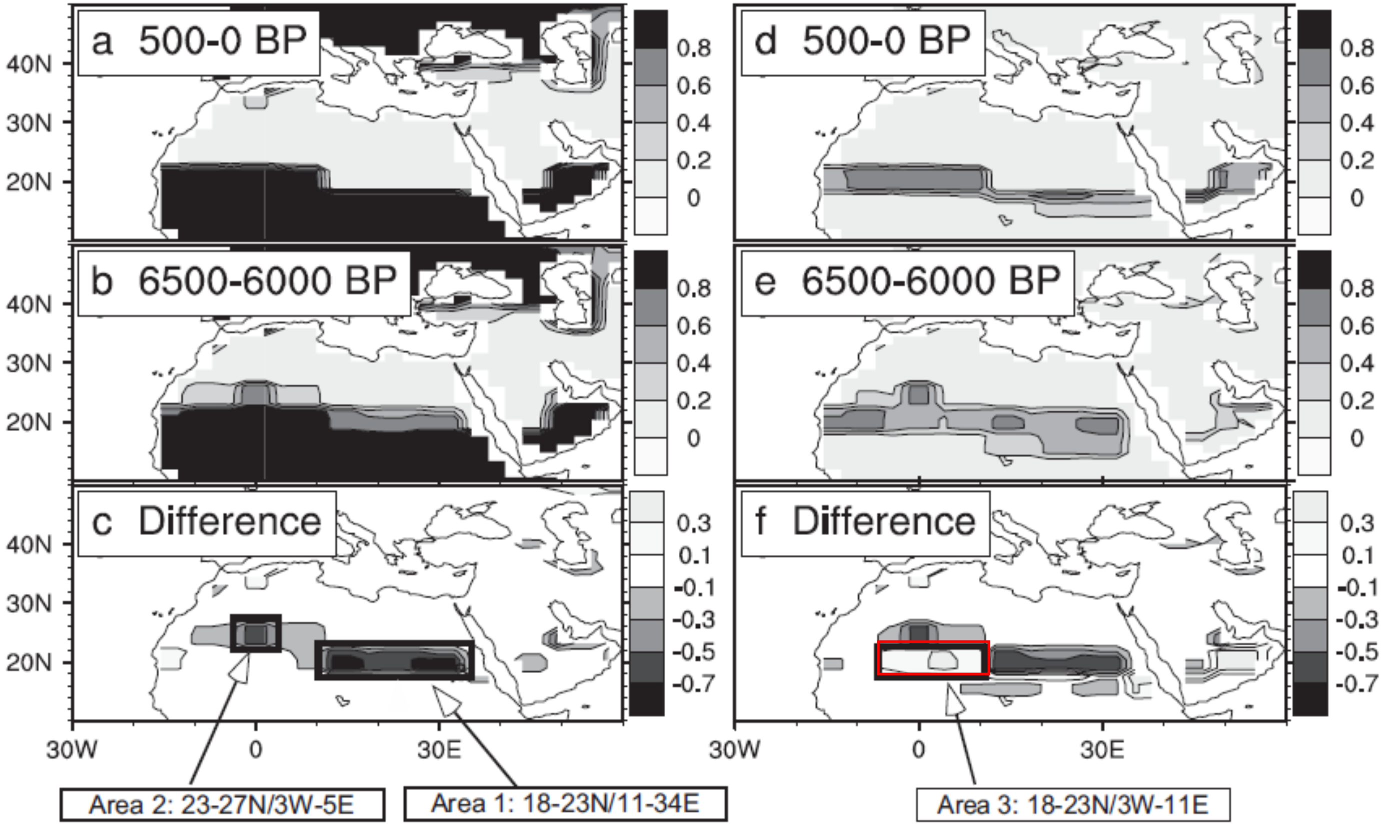
Abupt change in vegetation also simulated by Liu et al. 2007

Using Foam model: Atmosphere resolution 7°x4.8°x18L
+ LPJ for dynamical vegetation
Ocean 1.4°x2.8°x32L

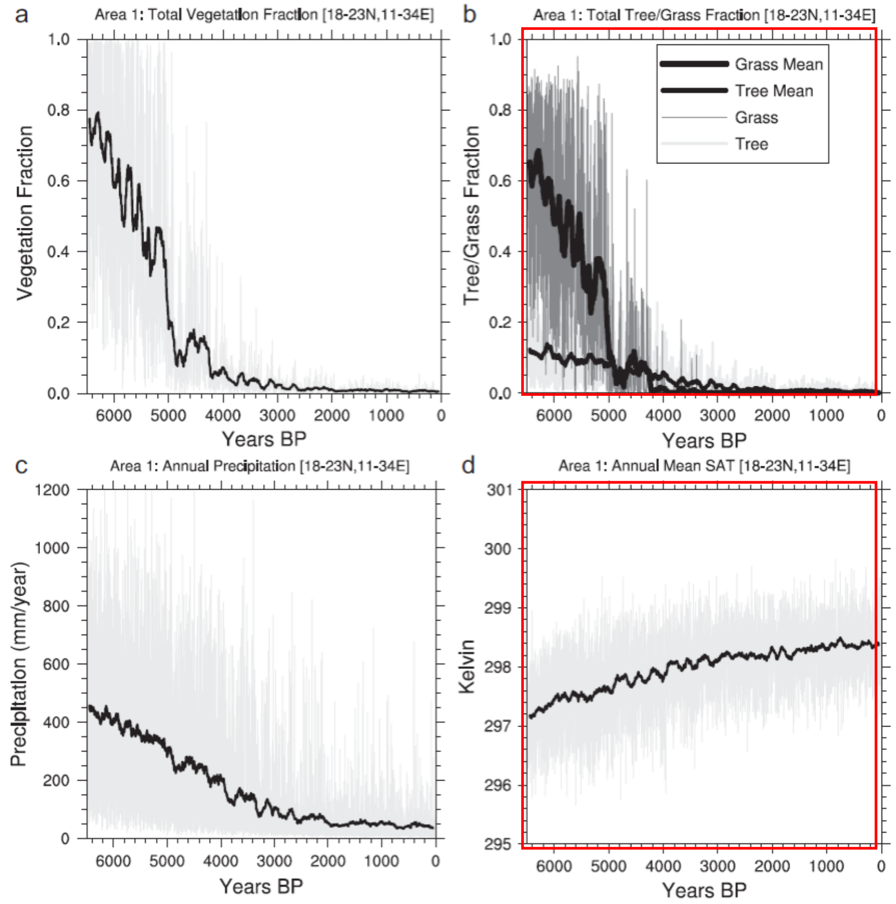
Small area where vegetation collapses
3°W-5°E; 23°N-27°N

Total vegetation

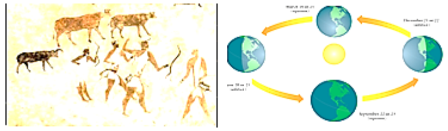
Grass



Liu et al. QSR, 2006



Approche conceptuelle: Liu et al. 2006



Start from Brovkin et al. 1998

$$P_E(V) = P_d(t) + D_B V$$

Add noise to account for variability

$$P(V,t) = \max\{P_E(V) + P_N(t), 0\}$$

P_E equilibrium precipitaiton

P_d : background precipitation

V vegetation

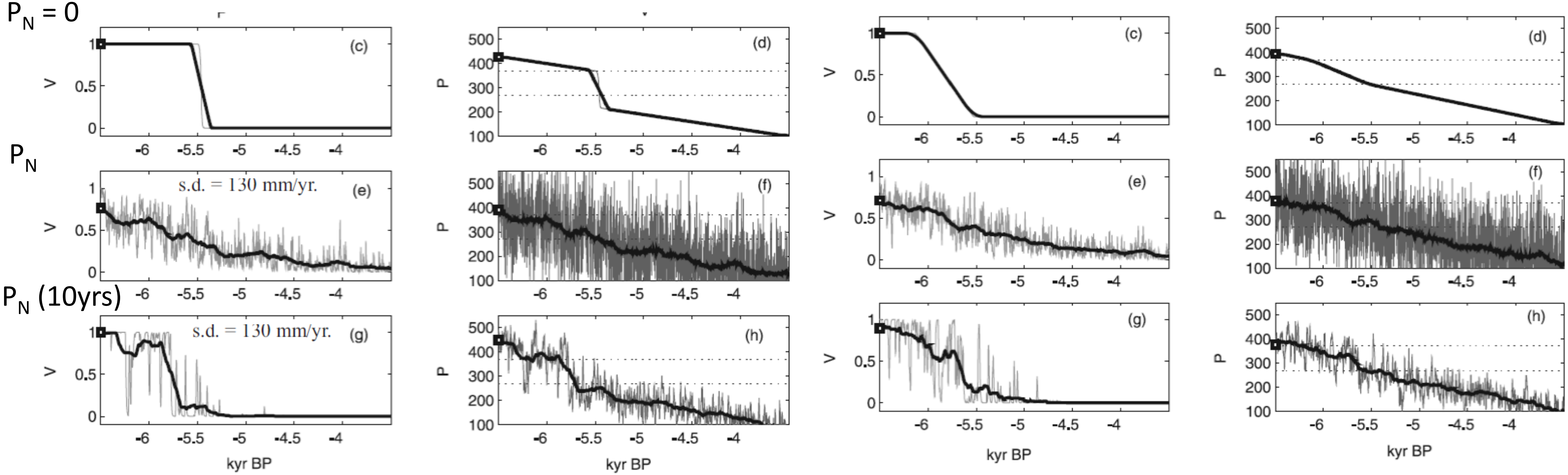
D_B : vegetation feedback

P_N: variability represented as a stochastic forcing

Simulations : vary Pd and V to mimic insolation

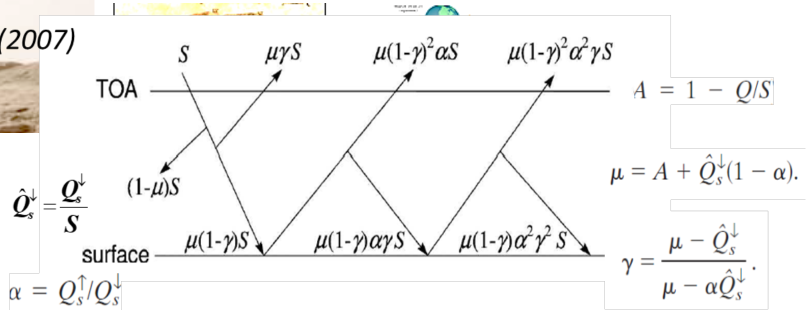
Strong coupling D_B = 150 mm/yr

weak coupling D_B = 150 mm/yr

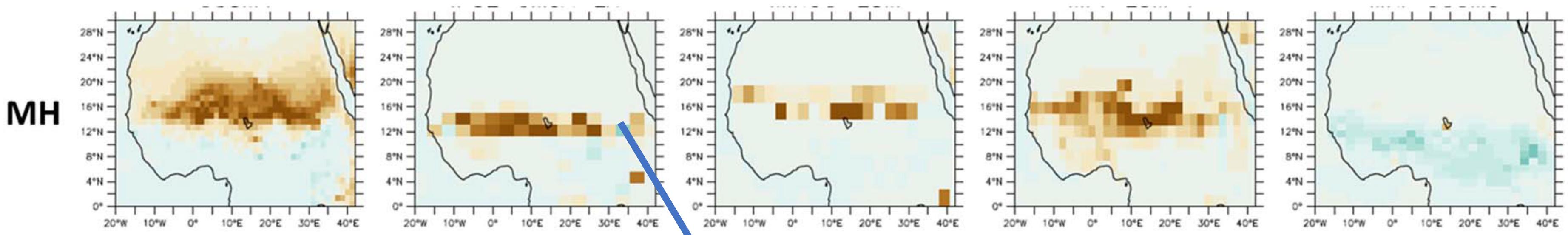


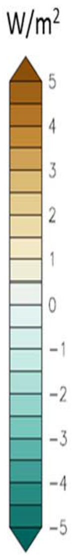
Radiative impact of vegetation cover (August)

Taylor et al.(2007)

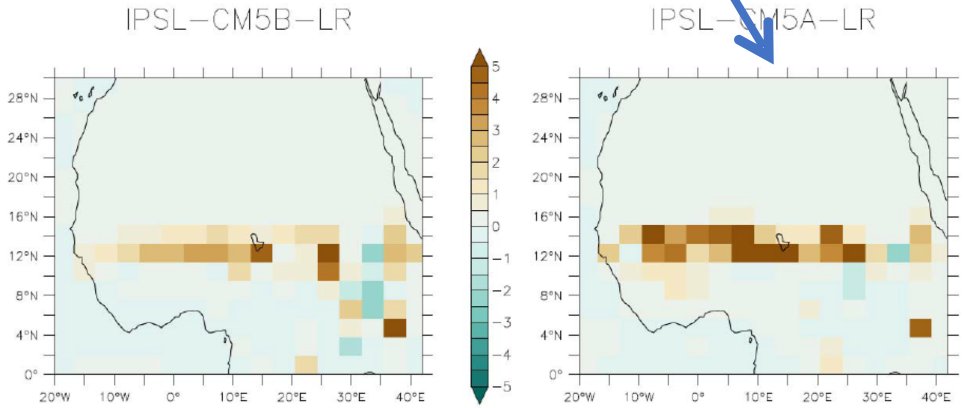


PMIP3 simulations (5 models): mid-Holocene (6ka)





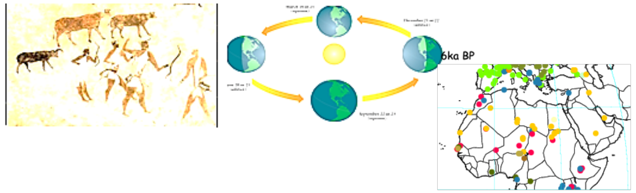
Two versions of the IPSL model : differences only in atm physics.



Role or control simulation : not only vegetation or surface modeling but also Location of ITCZ, precipitation /convective regimes, soil moisture in semi-arid area, description of surface vegetation in model gridbox, model tuning….

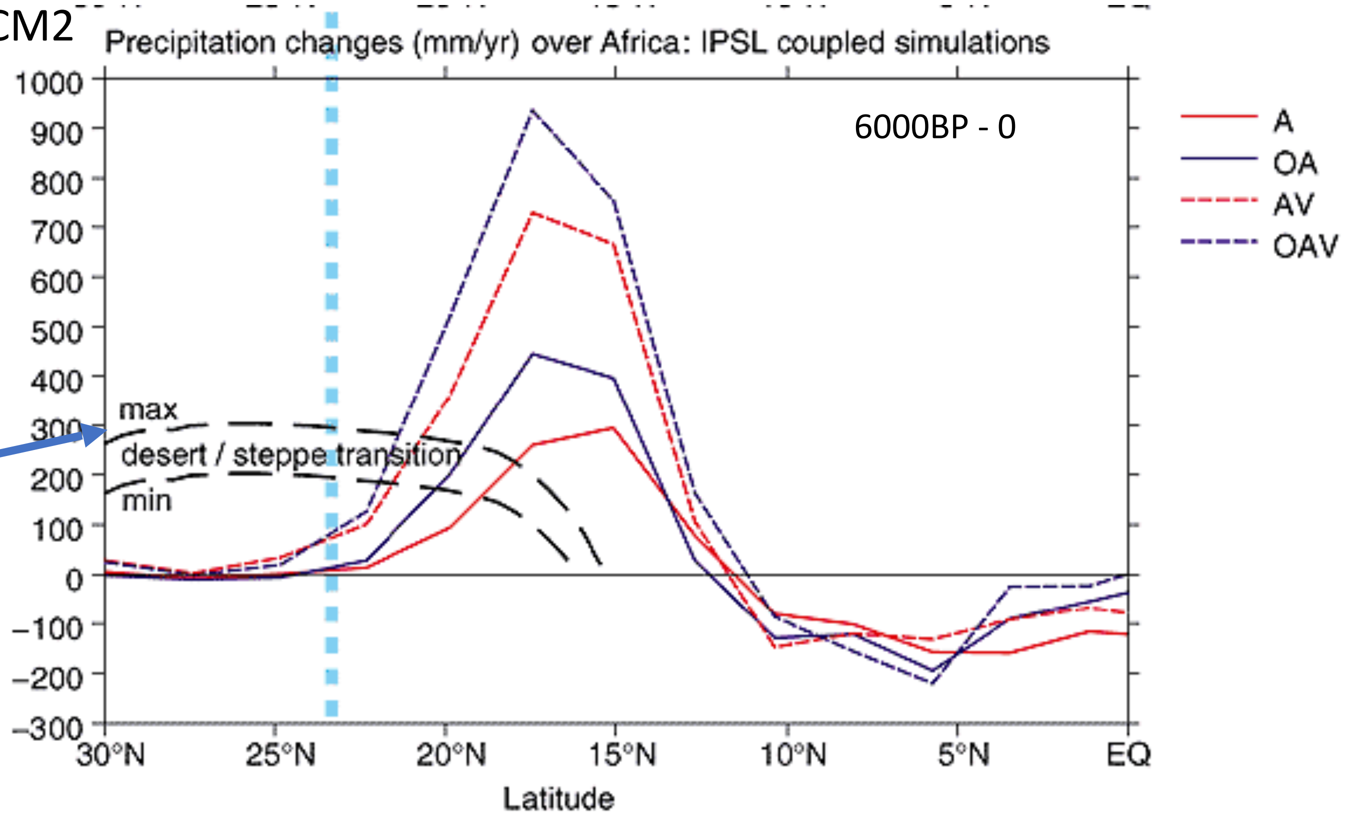
Braconnot and Kageyama, 2015

Ocean feedback a key factor

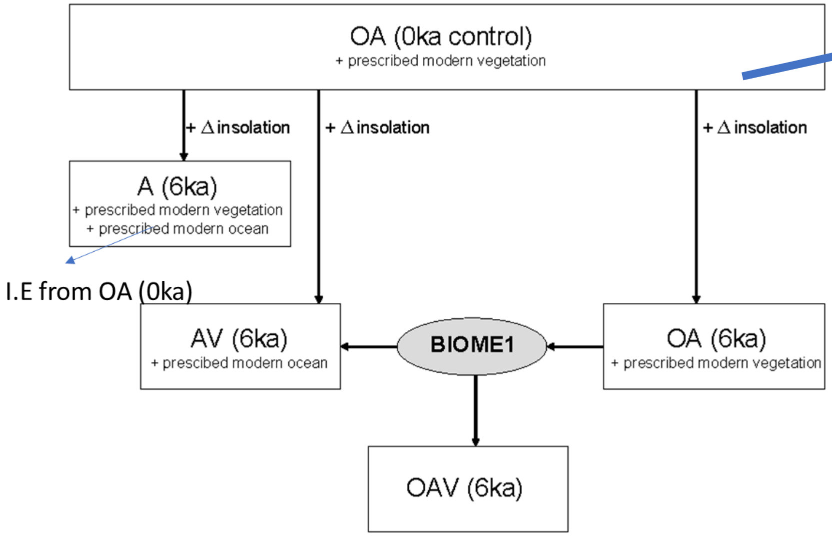


- Model underestimate northward shift
- Ocean and vegetation feedback needed
- But also other factor to consider : soil moisture, lakes, dust, soil composition, resolution

IPSL-CM2



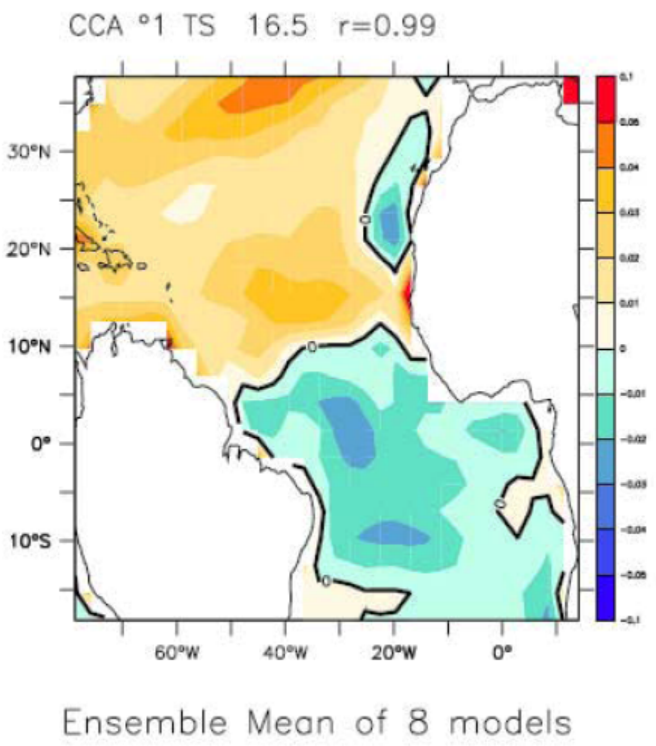
Adapted from Joussaume et al 1999 and Braconnot et al. 1999

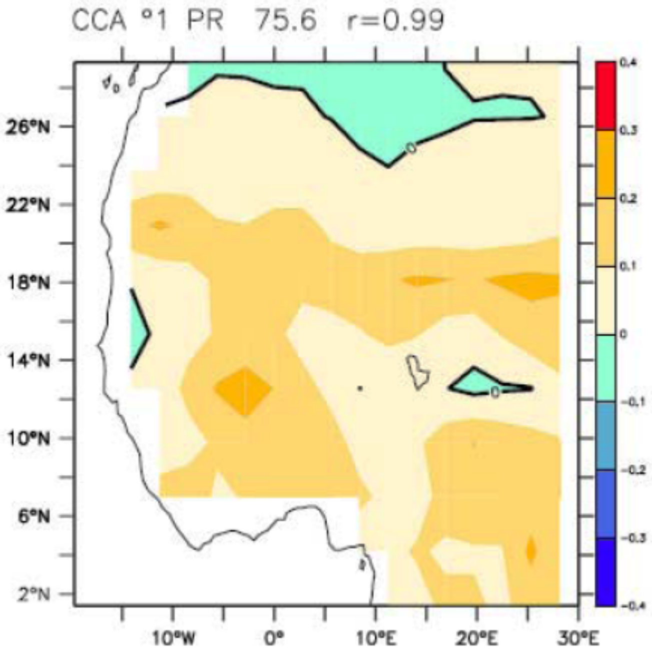


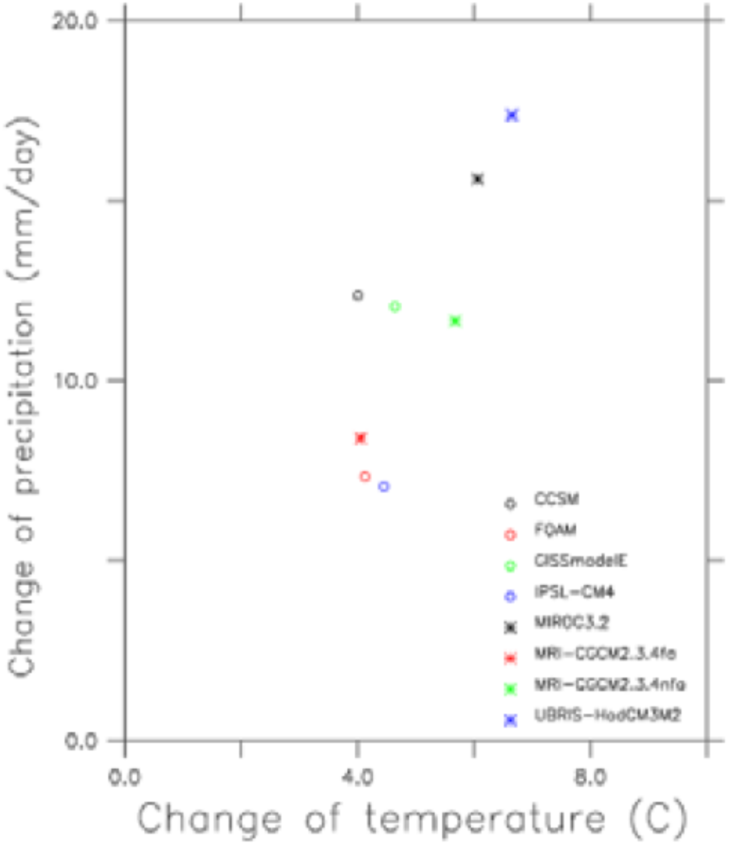
Method adapted from Texier et al. 1997

Ocean feedback : a key factor

- Tropical ocean colder in spring : impact on tropics/extra tropics and land/sea gradients (T, slp, moist static energy)
- Ocean SST dipole favouring humidity transport into African monsoon region + warmer NH in Autumn maintain "summer anomalies" and delay monsoon withdrawal



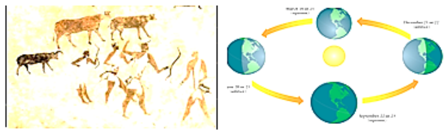


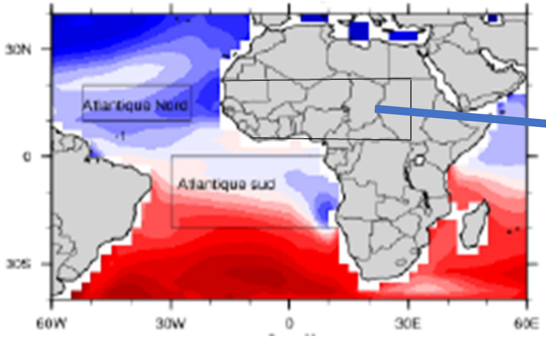


Zhao et al. 2007,

→ Still a need to develop mode-data comparisons to fully assess model results

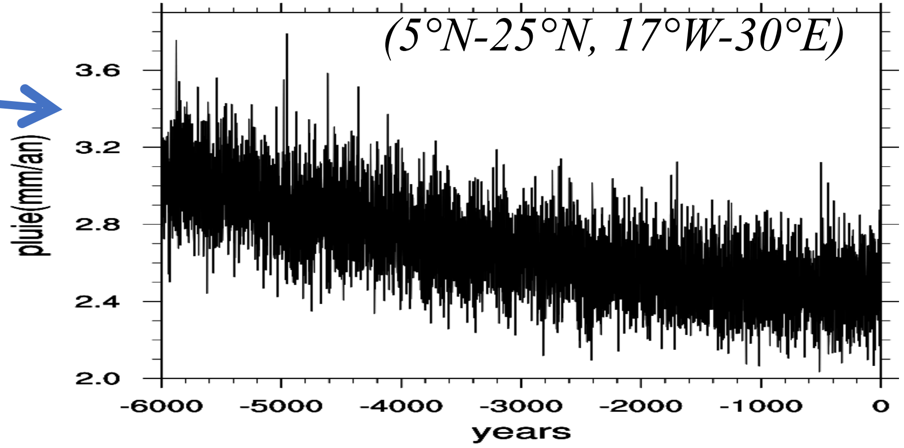
African monsoon: last 6000 years



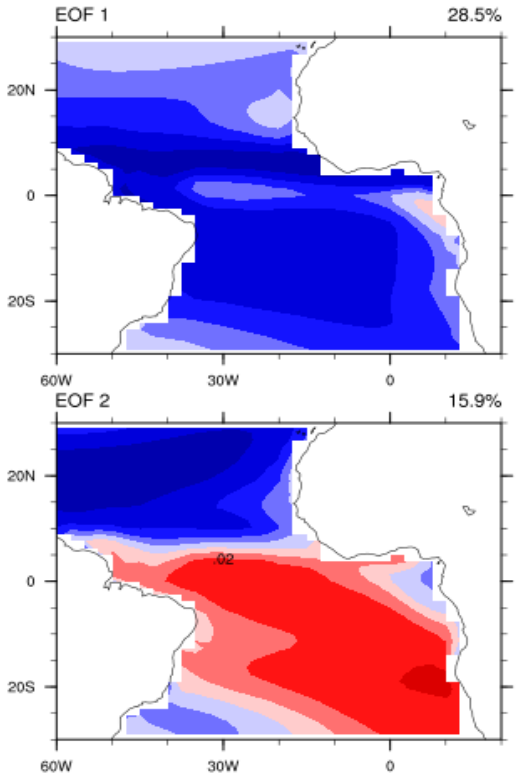


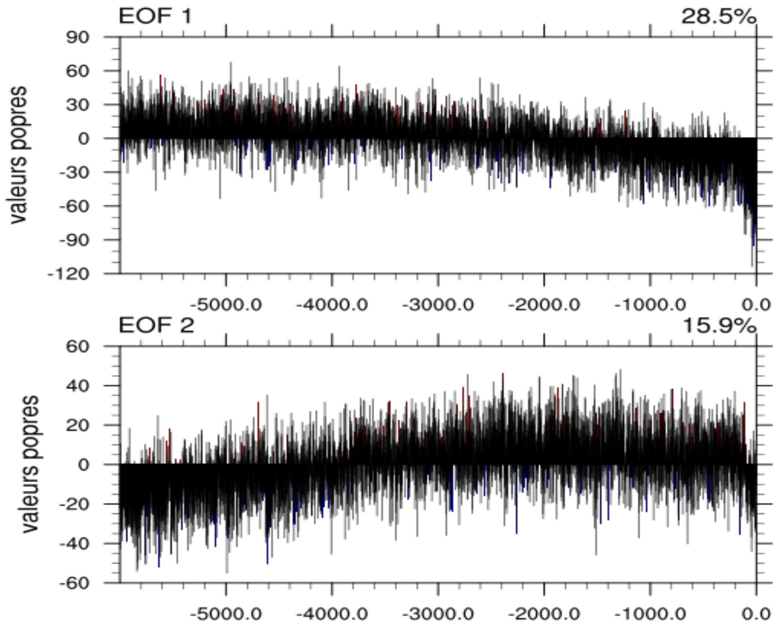
Modes of variability of the Atlantic *SST*

Evolution of JJA monsoon precipitation



IPSLCM5A model



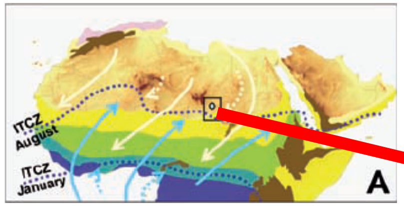


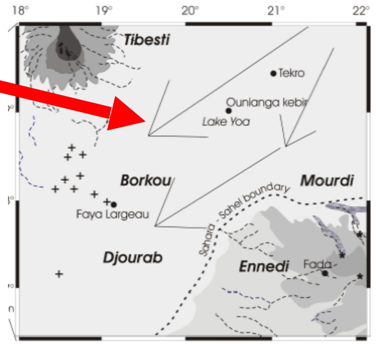
- Drying from 6k to 2k. Different time scales for variability, including large events.

- SST : combination of SST warming, mainly from 2k to 0k, and reduction of the Atlantic dipole from 6k to 2k.
  → combination of impact of insolation in the first part and trace gazes in the second part

Sanogo, master 2 report

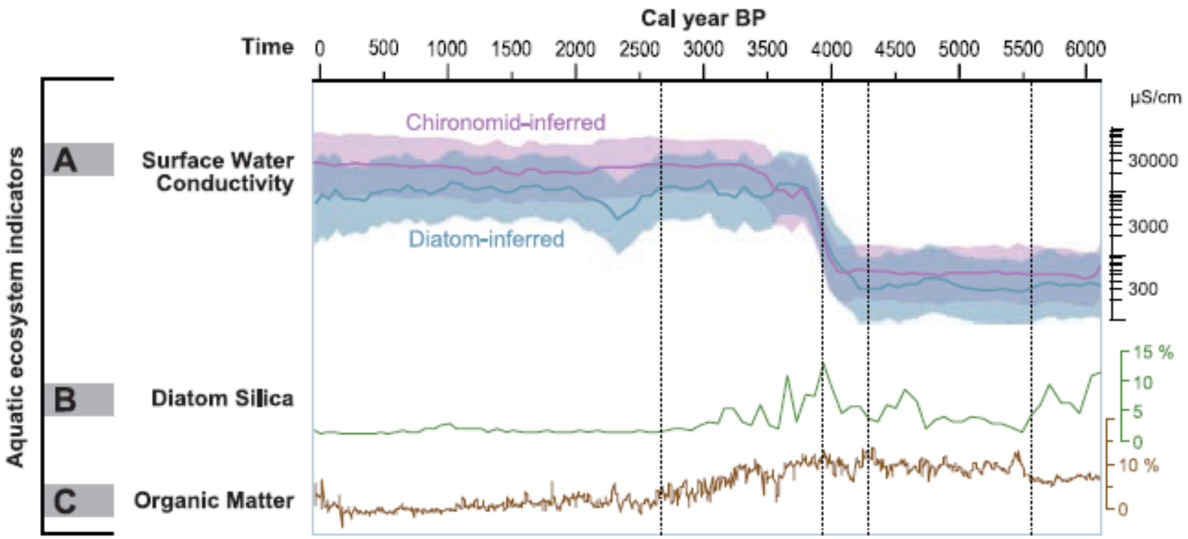
Lake Yoa : 19.03° N, 20.31° E, 380 m



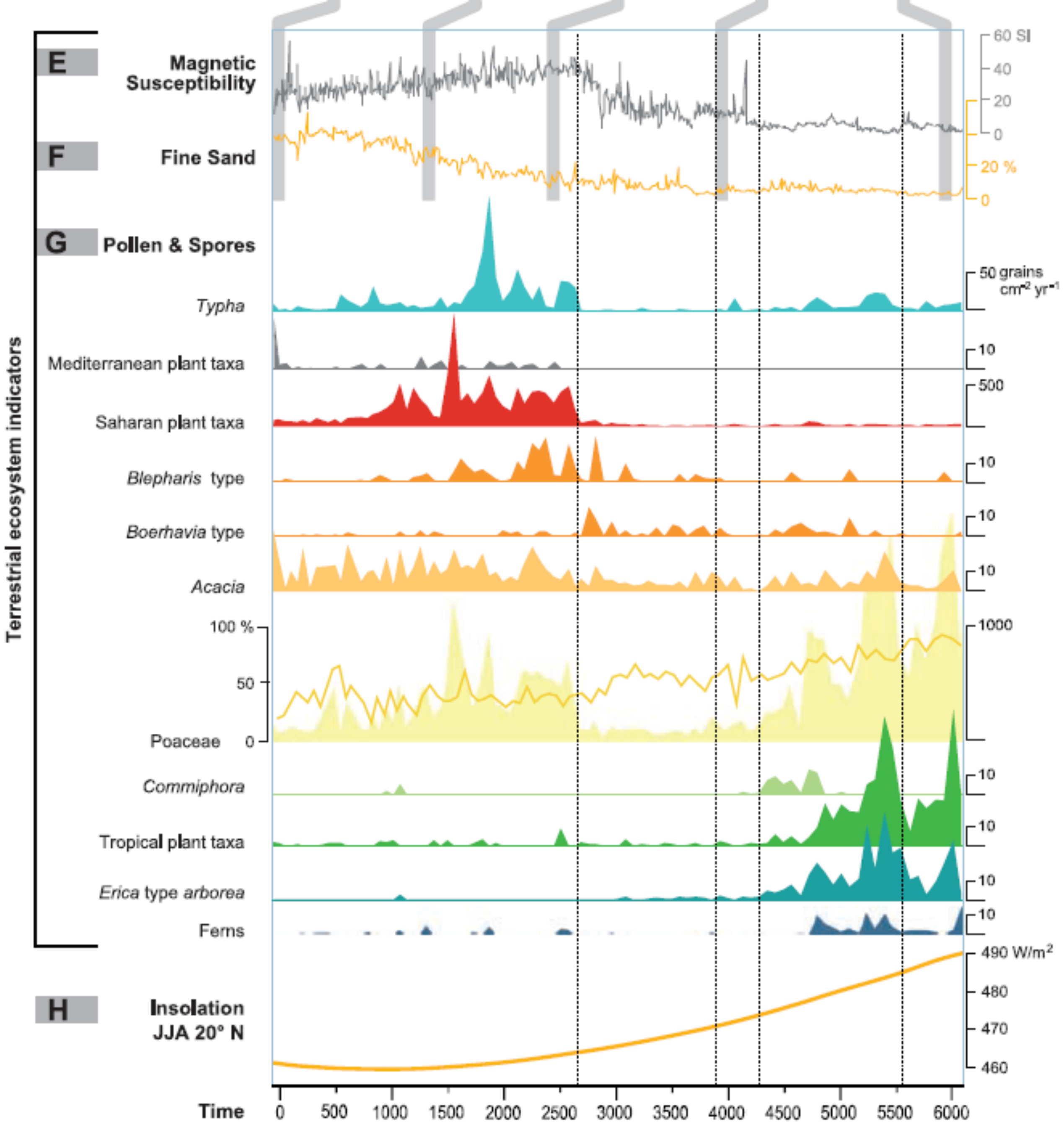


Environnemental changes

- ✓ Hydrology
- ✓ vegetation



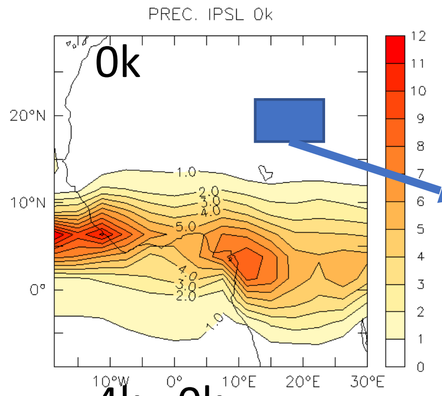
Kroepling et al. Science, 2008

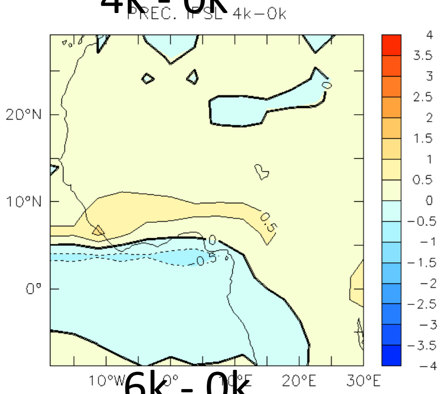


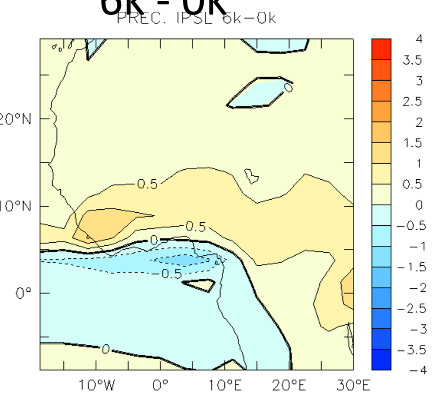
Snap shot experiments 6k, 4k, 0k

Convective regimes

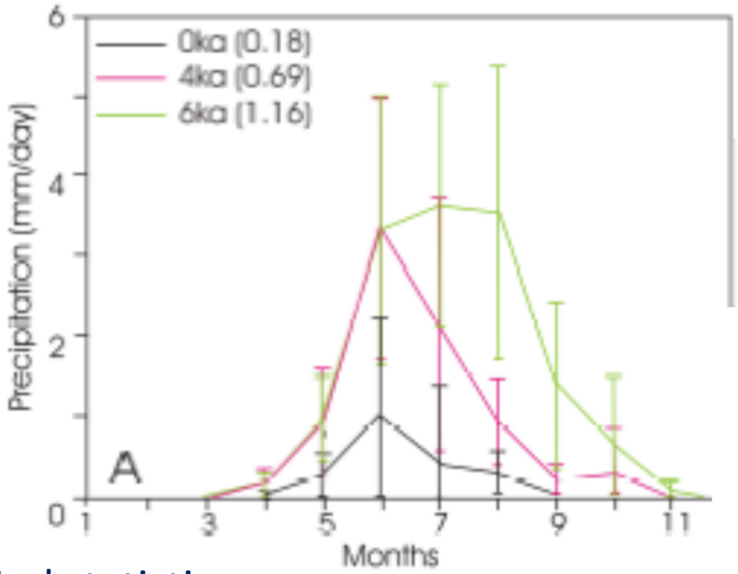
Changes in JJAS precipitation

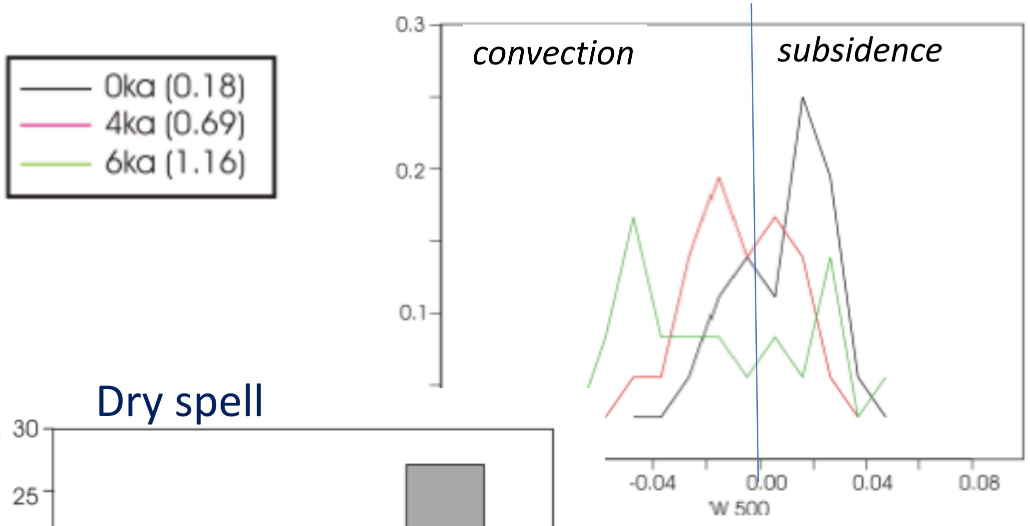




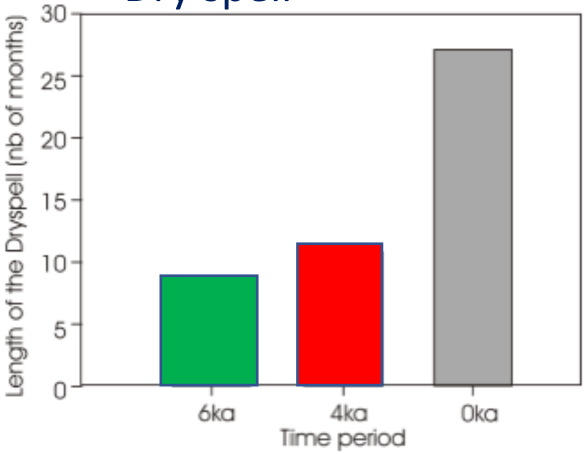


Length of rainy season



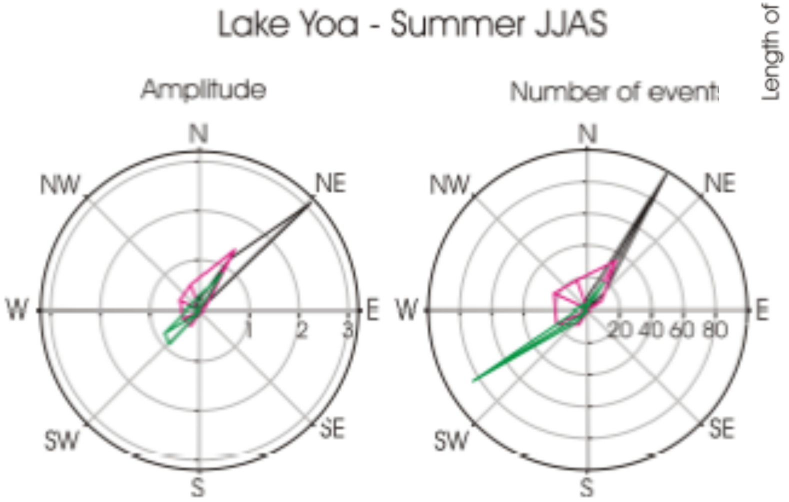


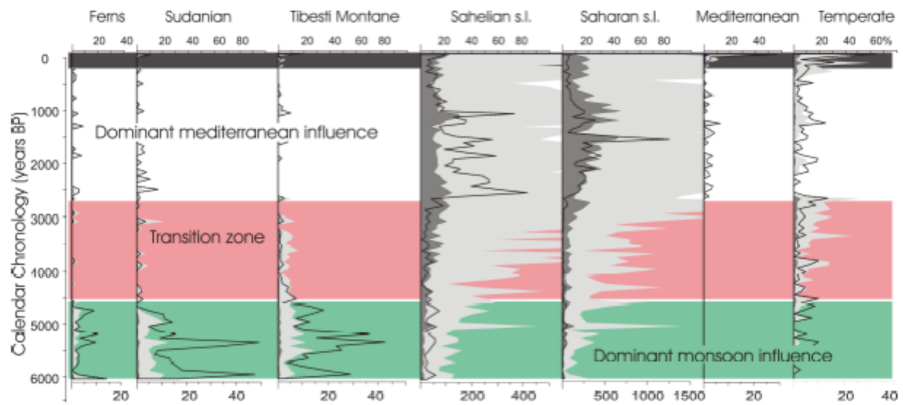
Dry spell



Larger diversity in precipitation regimes and wind at 4k than at 6k or 0k

Wind statistics

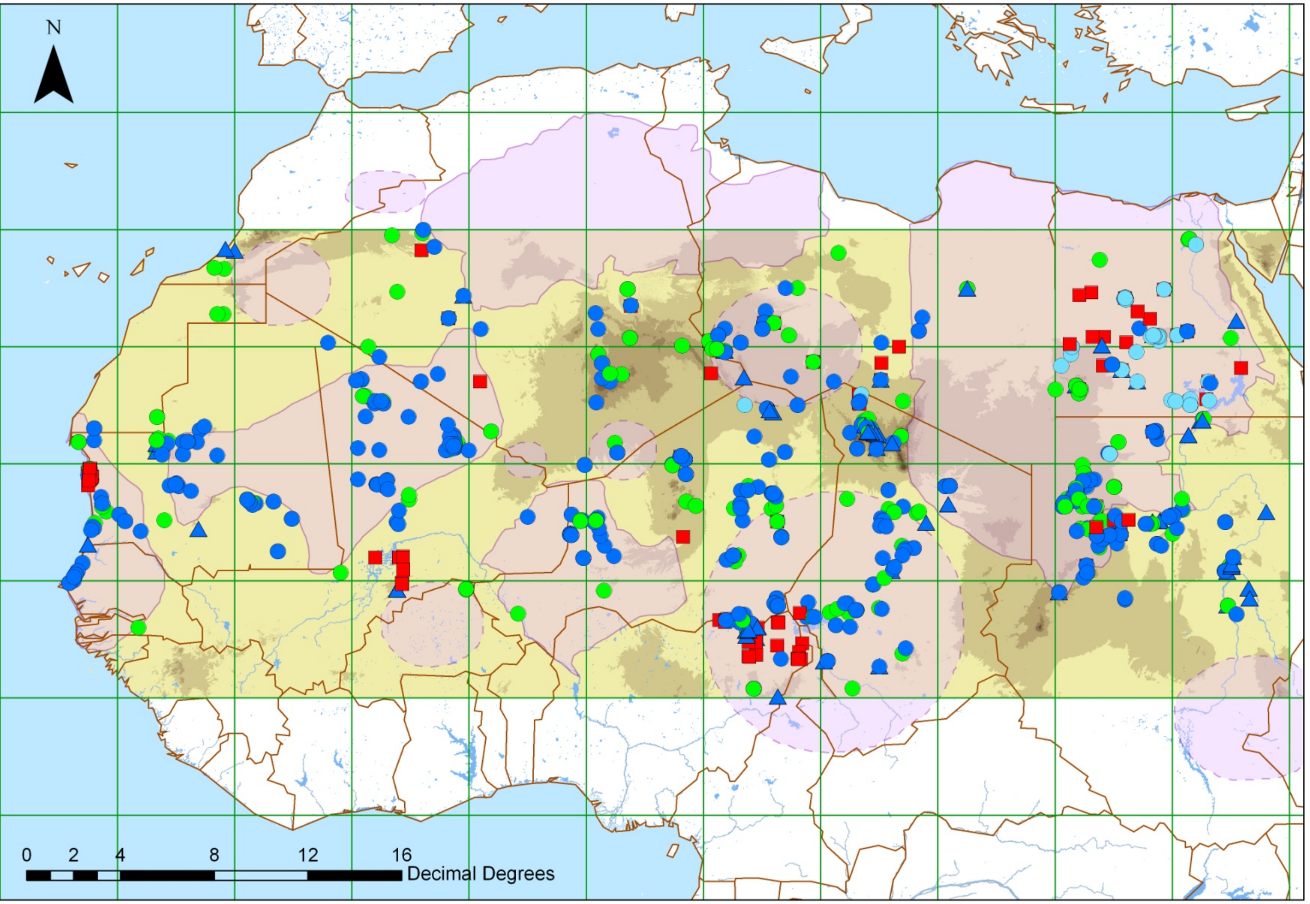


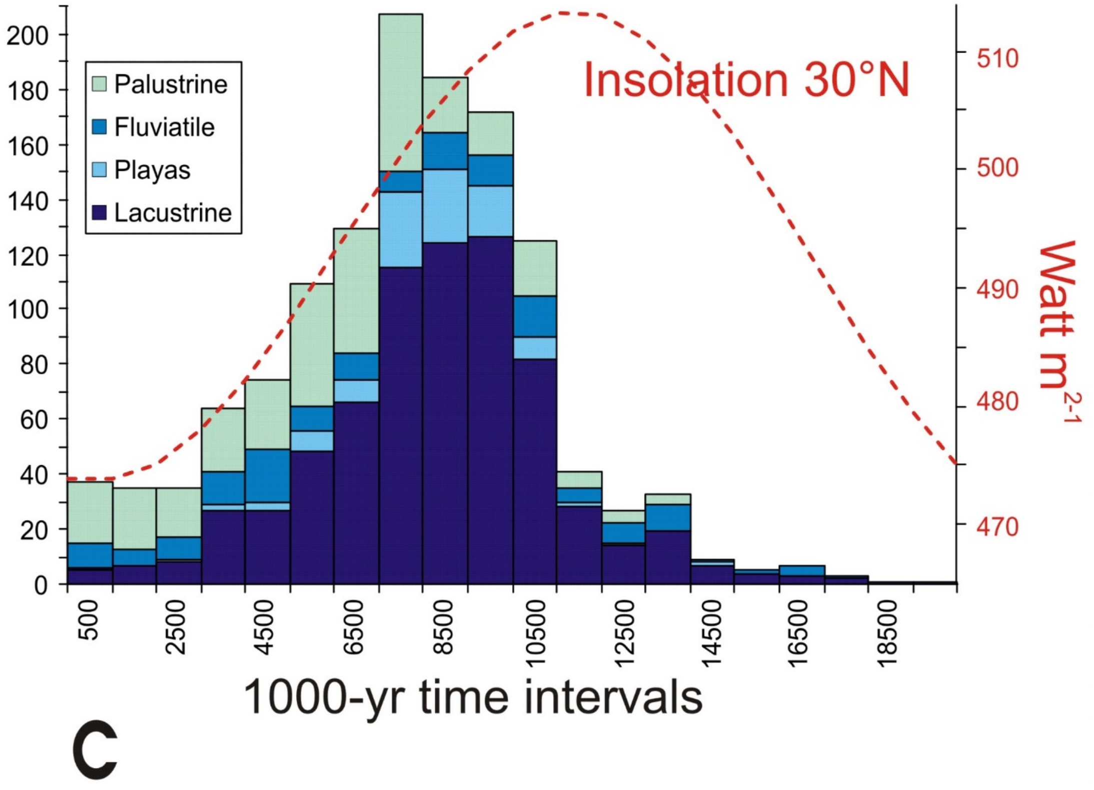


Lezine et al. 2011

al.

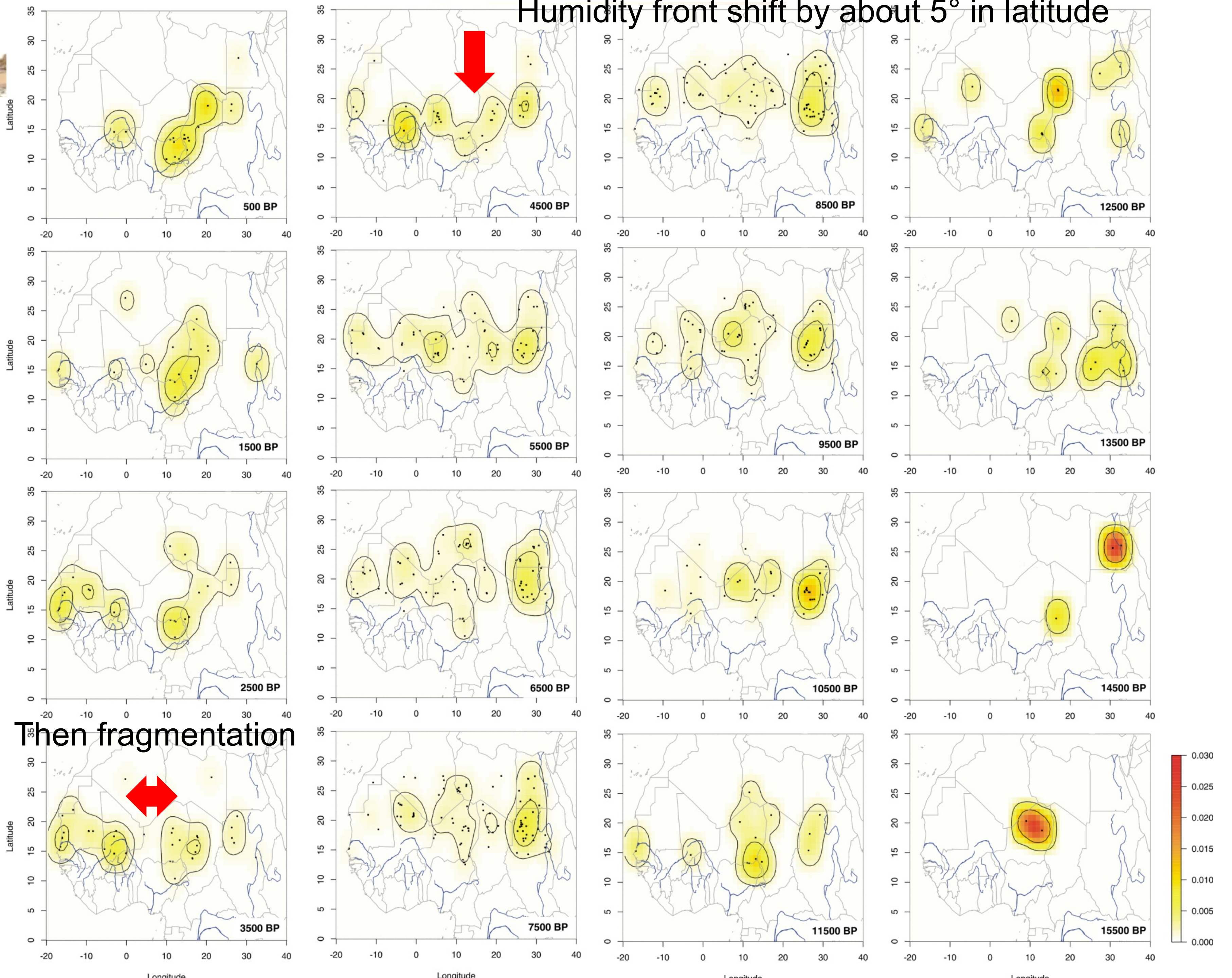
Hydrological reconstruction





Projet ANR SAHELP –AM Lézine coord, Lezine et al. 2011.

Hydrological evolution infered from numer of dated sites within 1000 year windows

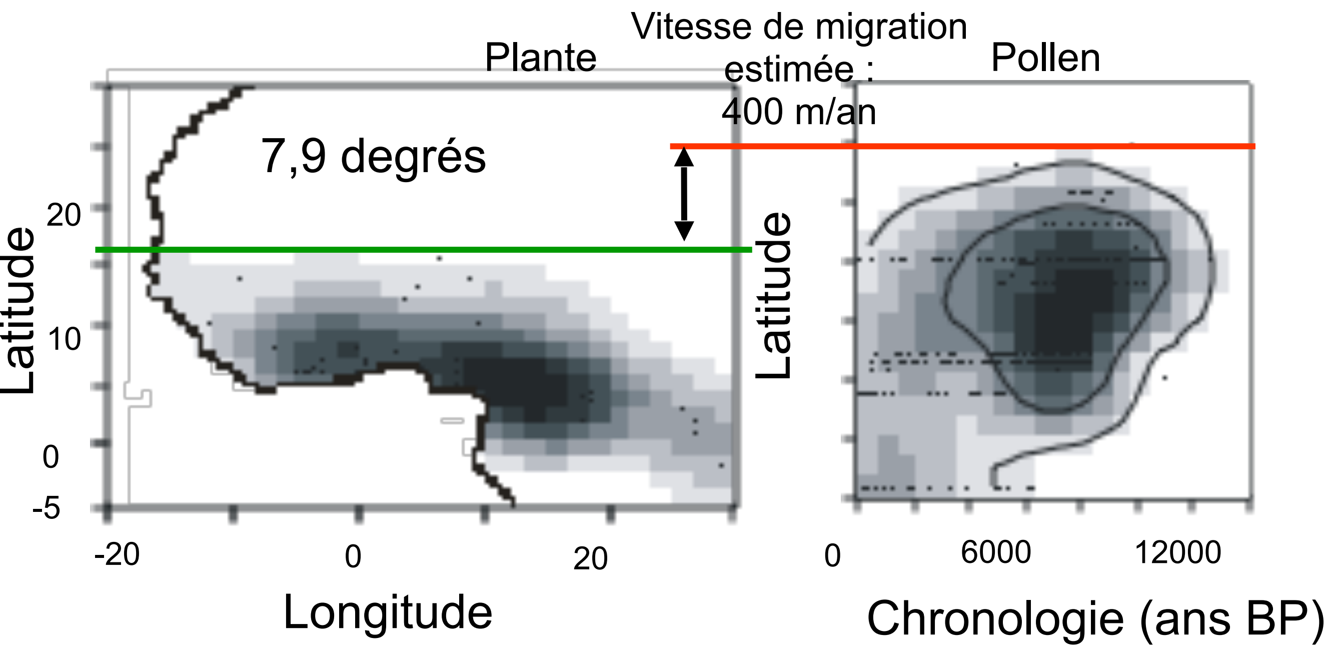


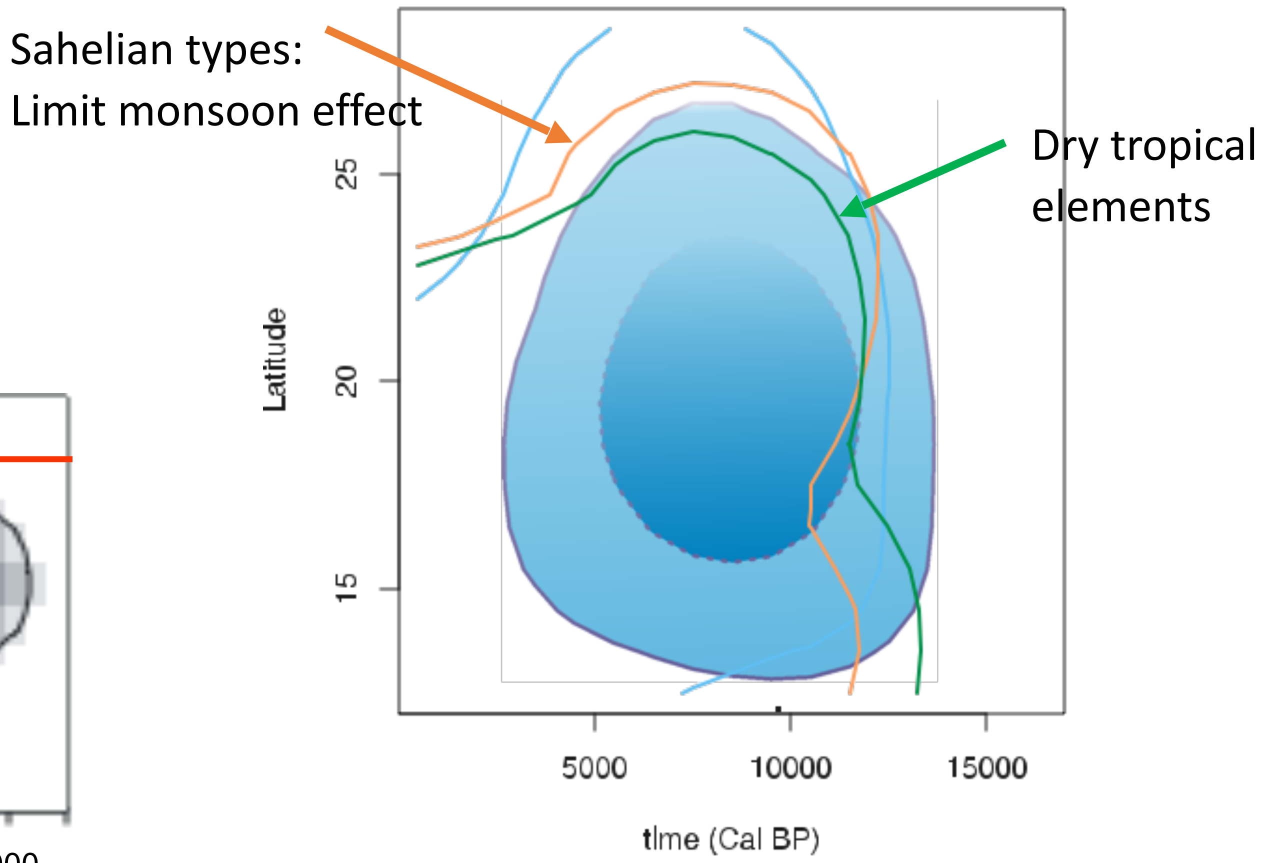
Lezine et al; QSR, 2011

Northard penetration of tropical taxa during the green Saharap period

Celtis-type

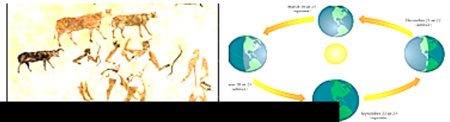
Synthesis when considering the different taxa





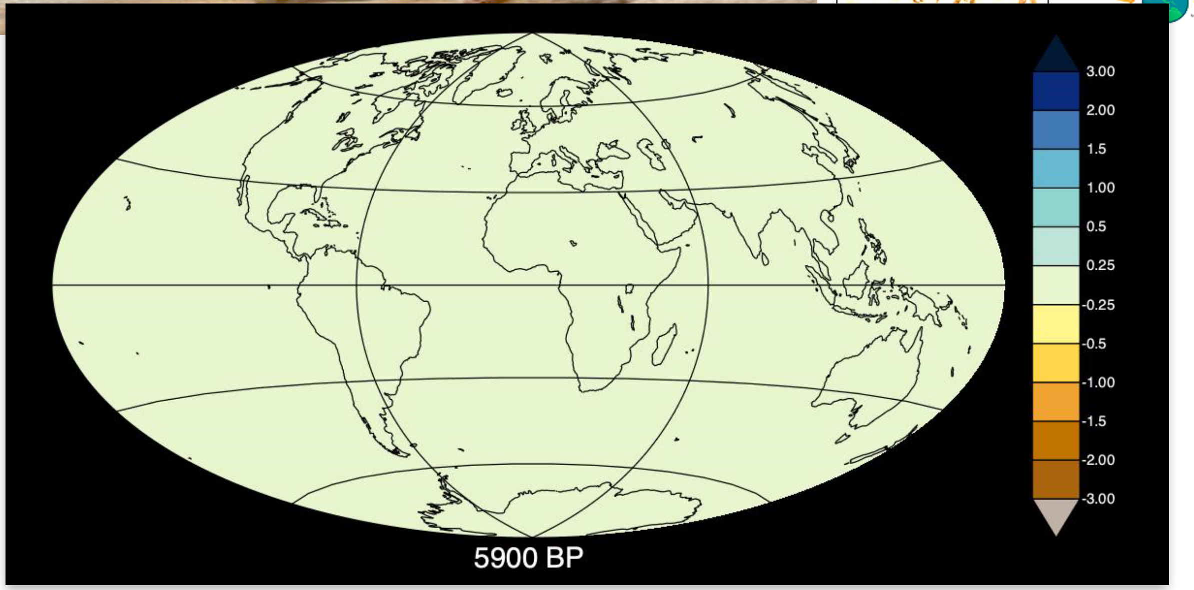
Watrin et al 2009

Evolution of precipitation : IPSLCM5A model



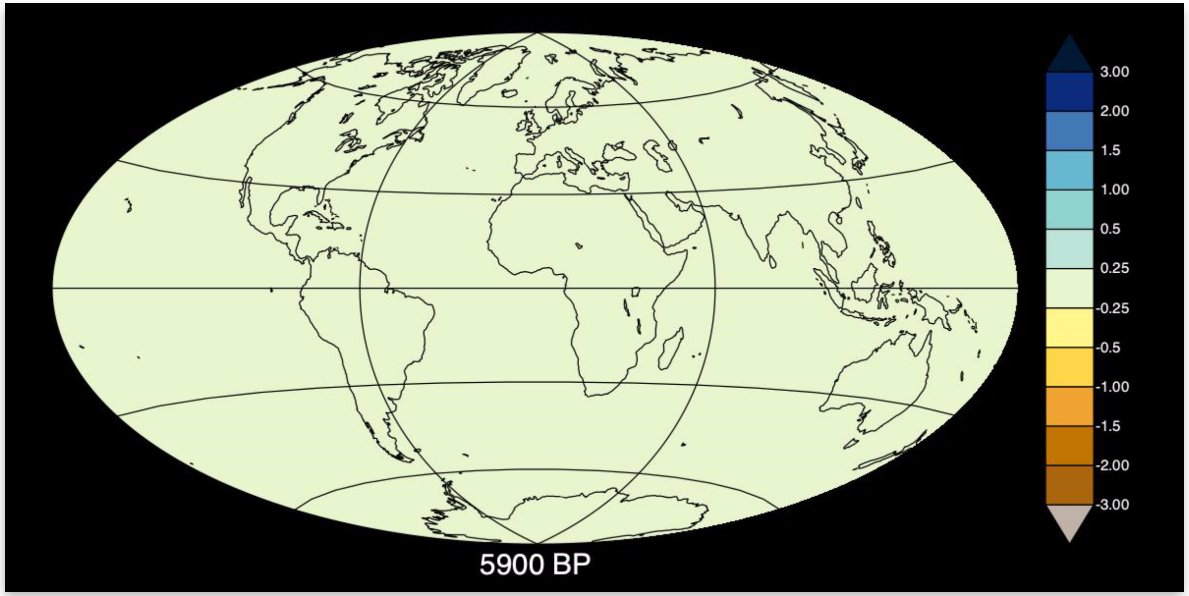
JJA precipitation 6ka to 0k : differences with 6ka initial state (10 year averages)

TR5AS-Vlr01



Stadard model version

TR6AV-Sr02

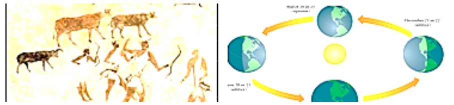


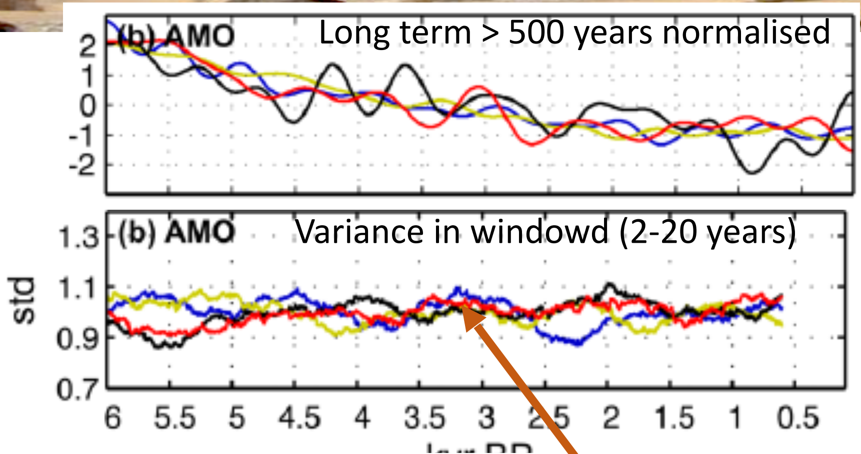
IPSLCM6 soil hydrology and snow model

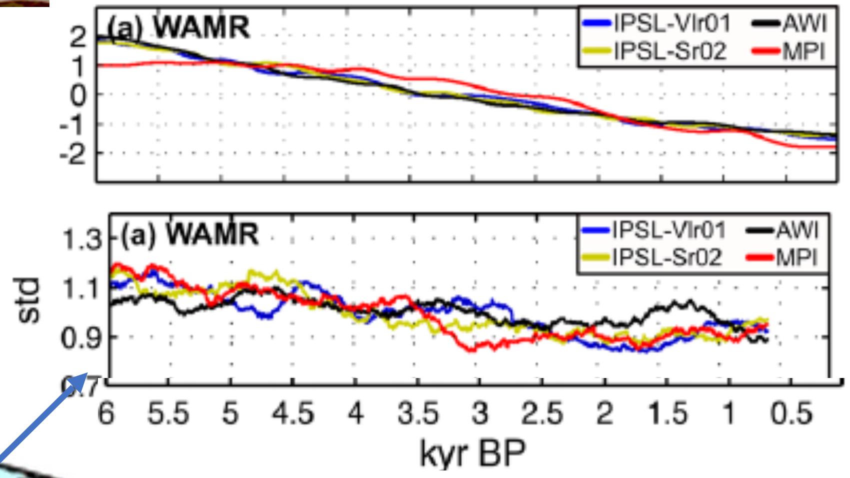
Dynamical vegetation

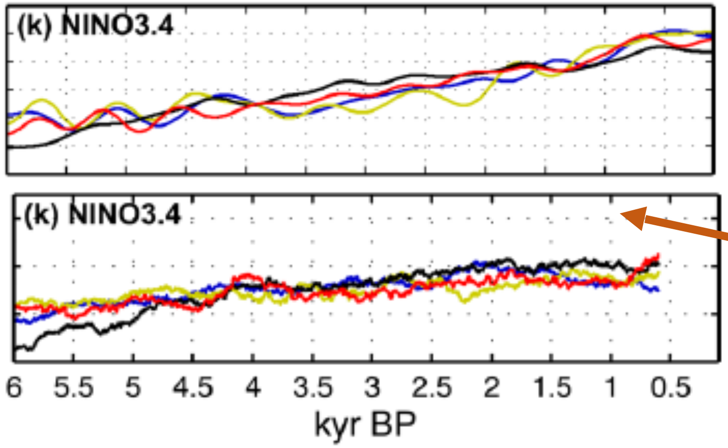
Braconnot et al. GRL, 2019

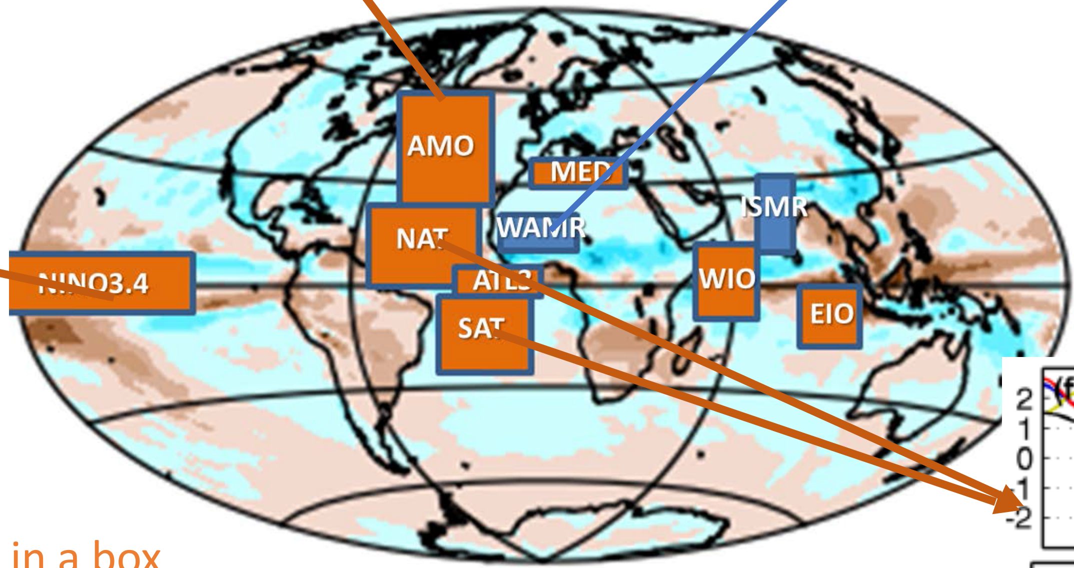
Method : EOFs analyses of climate indices



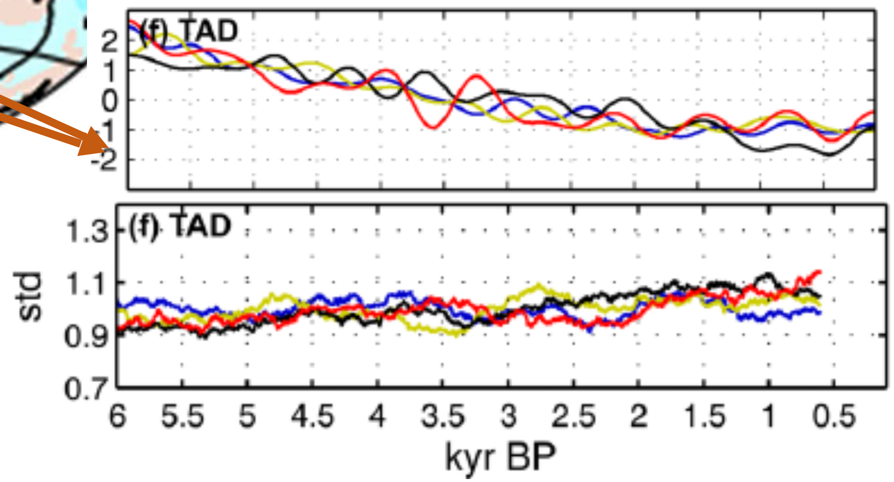








TAD = tropical Atlantic Diapol



Index sea surface temperature in a box

Index precipitation in a box

12 indices, 6000 time steps (JJAS values for each simulated year)

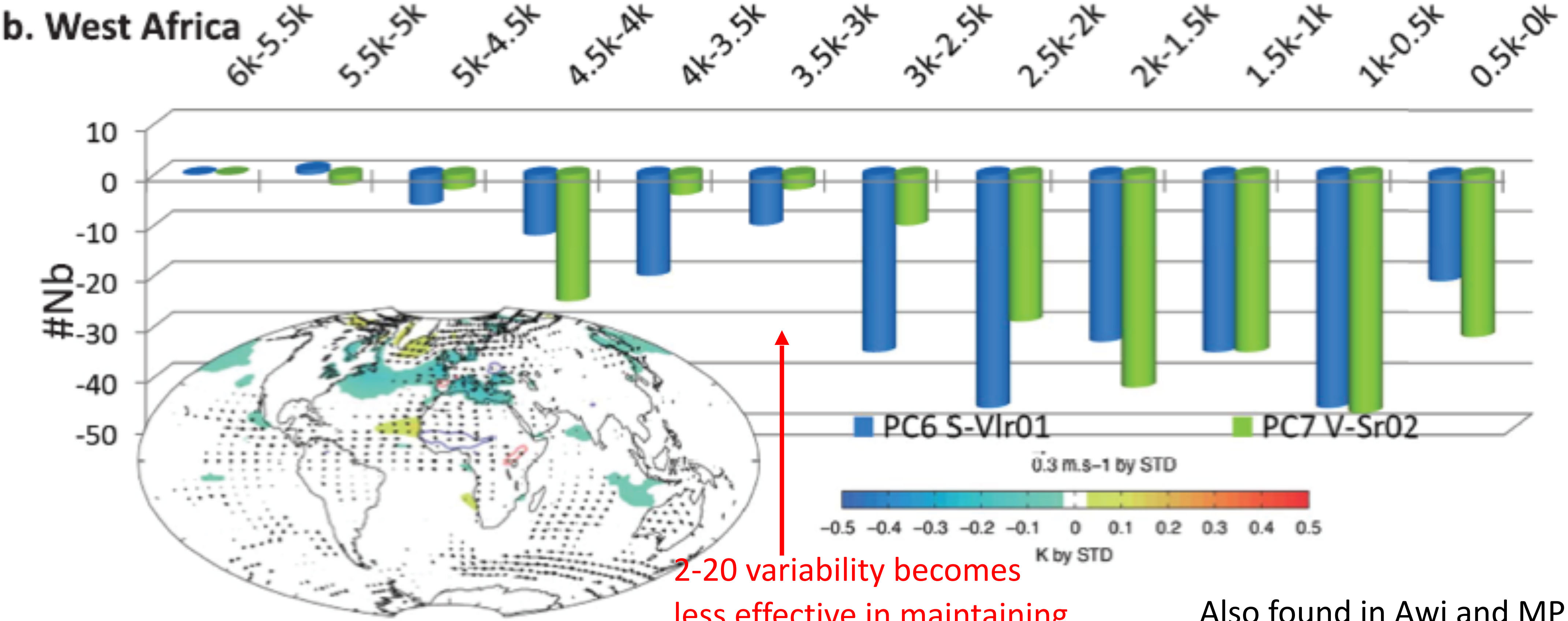
Different variability band (2-20 years; 50-500 years; > 500 years

Braconnot et al. GRL 2019.

Origin of rainfall 2-20 year variability trends

- Trends in variability only in 2-20 year band !
- Possible to isolate variability pattern associated to the trend
  part of the pattern common to the 2 simulations

→ Teleconnection Atlantic/Mediterranean (Africa)



2-20 variability becomes less effective in maintaining precipitation

Also found in Awi and MPI simulations
Cretat et al. submitted

Braconnot et al, GRL 2019

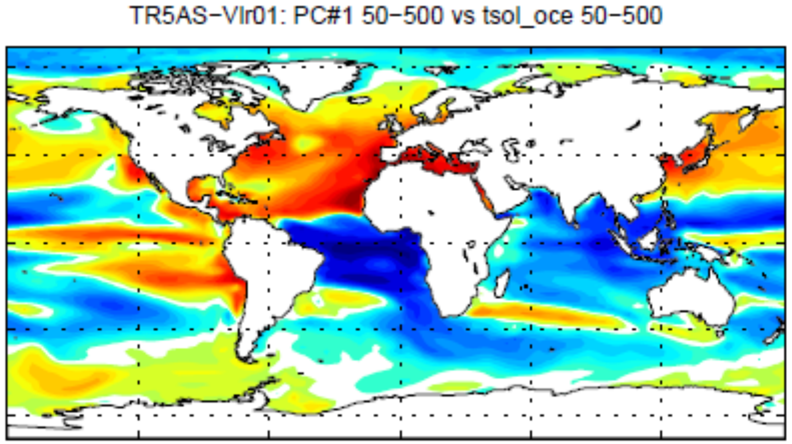
50-500 year variability

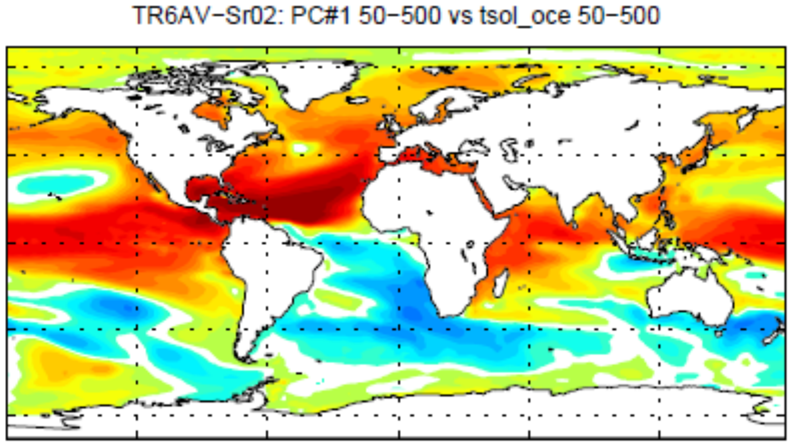
➢Modes are different between the two simulations

➢No obvious linkage with the long term trend in mean state

Ex Mode 1 Atlantic dipole pattern →increase African rainfall

but the other ocean basin are in different states → different impact on the Indian rainfall





Future research direction : Role of centennial to millennium variability??

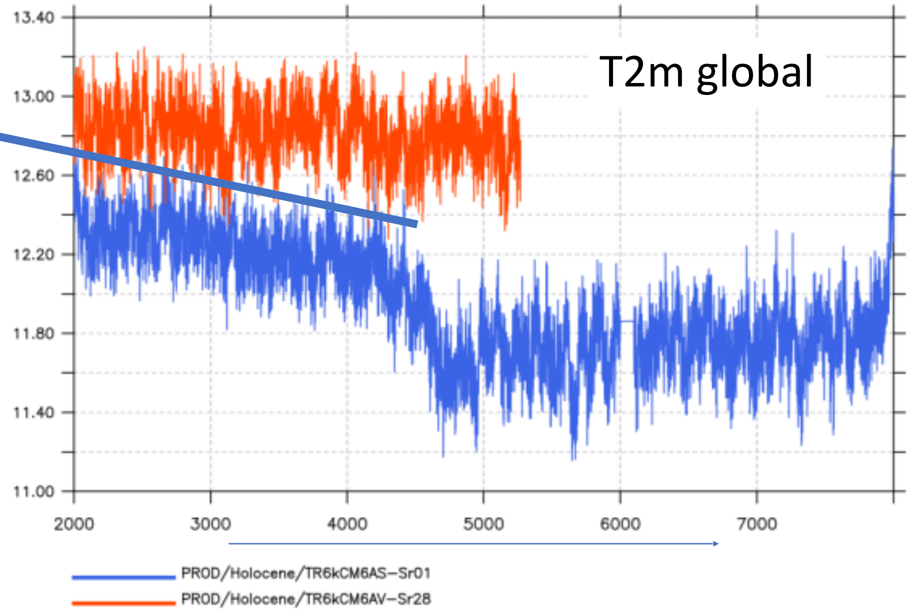
Braconnot et al. GRL2019

Opportunities

- ✓ New simulations transient simulations with dynamical vegetation in better agreement with observations in different modeling groups : – ex Dallmeyer et al, 2020, 2021, Hoptcroft and Valdes 2022, Thomson 2022 …..

- ✓ New simulations with and without dynamical vegetation with the IPSLCM6 model (ongoing)

Décrochement de la circulation thermohaline



Version standard

Version avec vegetation dynamique

New transient simulations with interactive vegetation

Evolution total vegetation, forest limit and Sahelian type region

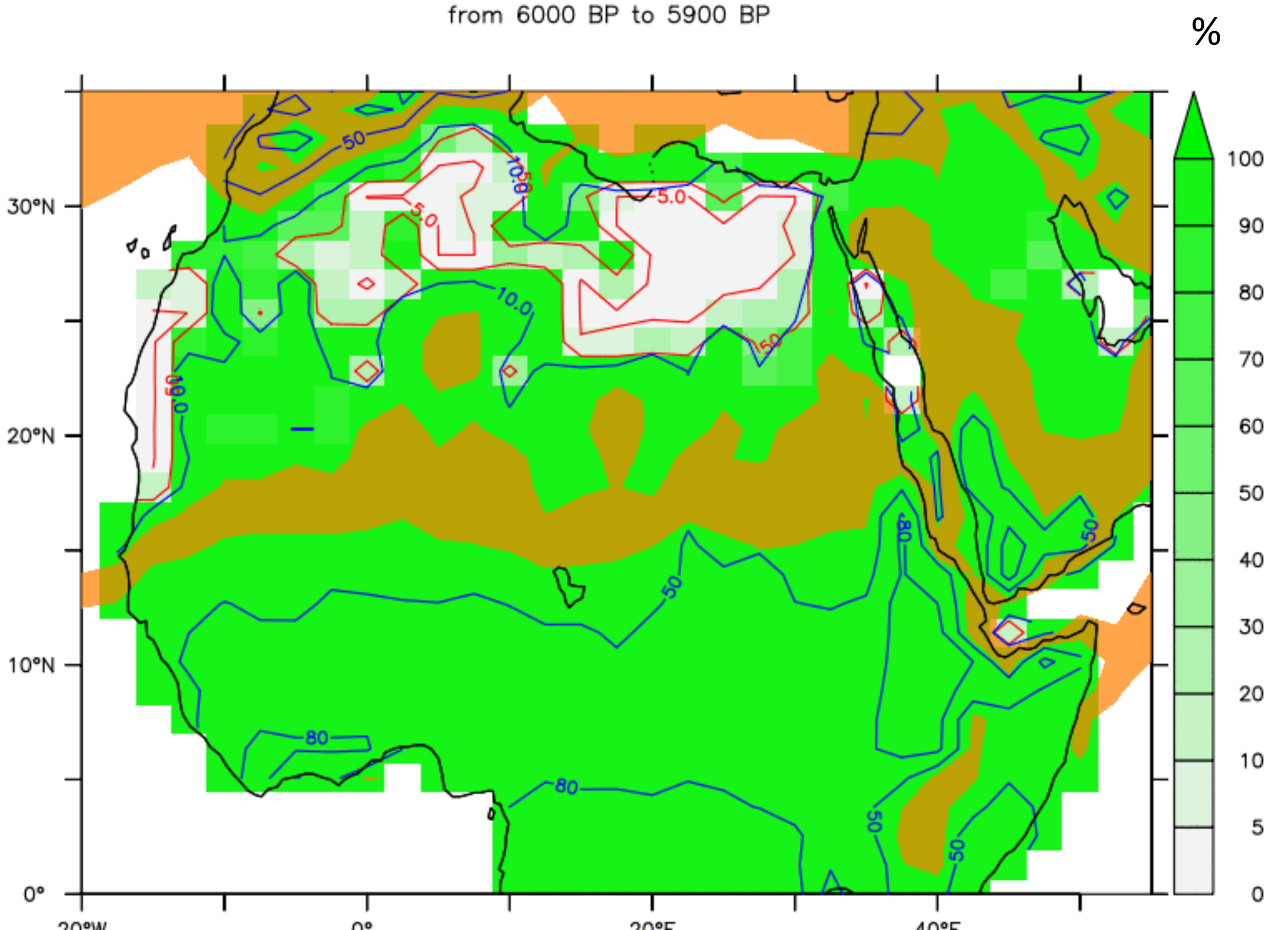
Sahelian region
Precipitation = 200 to 400 mm/yr

Total vegetation
5% and 10% limits

Total forest
10%, 50% and 80% limits

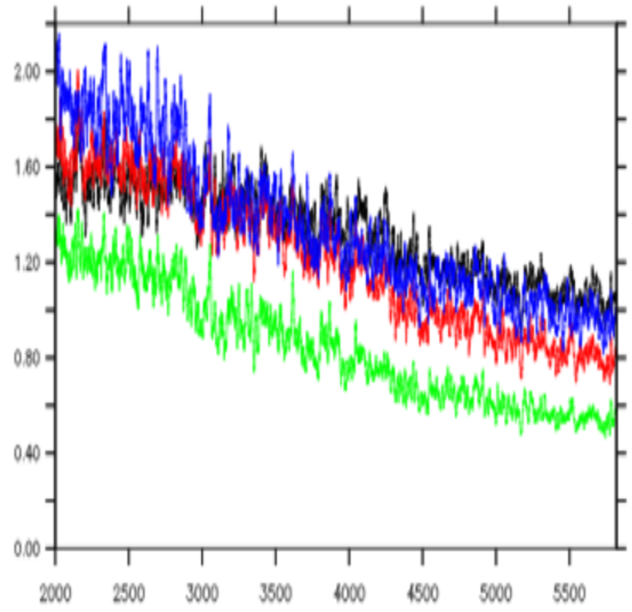
IPSLCM6 with dynamical vegetation : ongoing work

Total vegetation cover

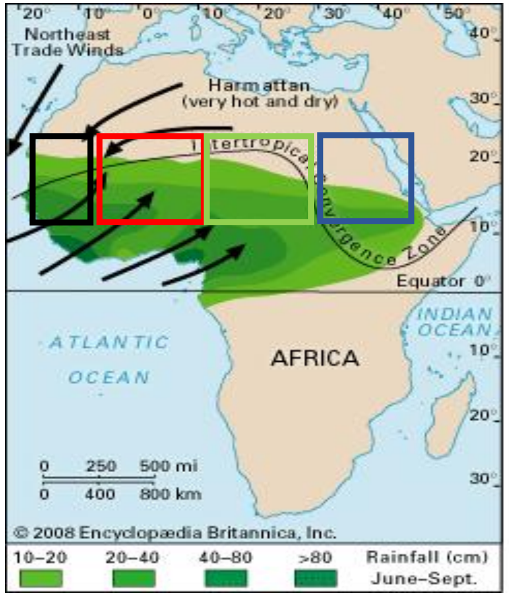


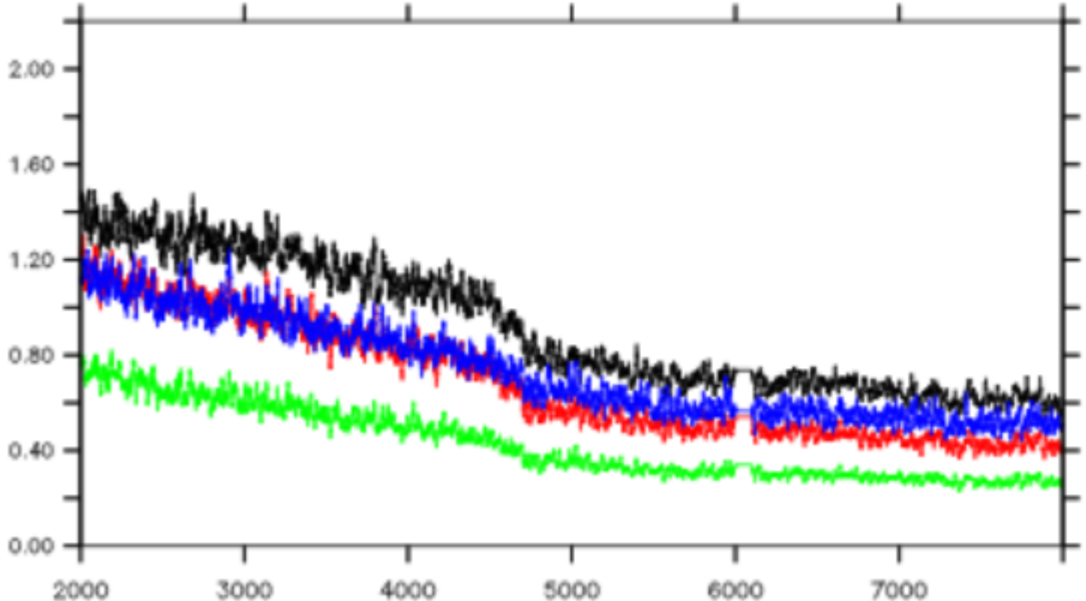
Precipitation in the new IPSL transient simulations

Version with dynamical vegetation Vdyn28



- ✓ Abrupt reduction depending on region with interactive vegetation and larger variability





- ✓ Precipitation less intense in stadard version
- ✓ Effect of abrupt thermohaline change seen in some of the regions,

Conclusion

- Revival of the questions of the AHP around the transient simulations
- EU-TIPESM project (starting January 2024) : analyses of abrupt changes in vegetation, E/W asymmetry in Africa; linkage with ocean and variability
- ANR Nilafar (The NILe and AFAR regions: hydrologic changes and impact on human adaptation in the last 20,000 years**)**
- Need to develop new types of diagnostics for model-data so as to answer more targeted questions (resilience, threshold, climate/ environmental events, society)
- Open question on the role of multi-decadal to millennium variability on key events
- Implications for today's climate and future changes