

Modélisation des paléoclimats

Questions, méthodes, enjeux

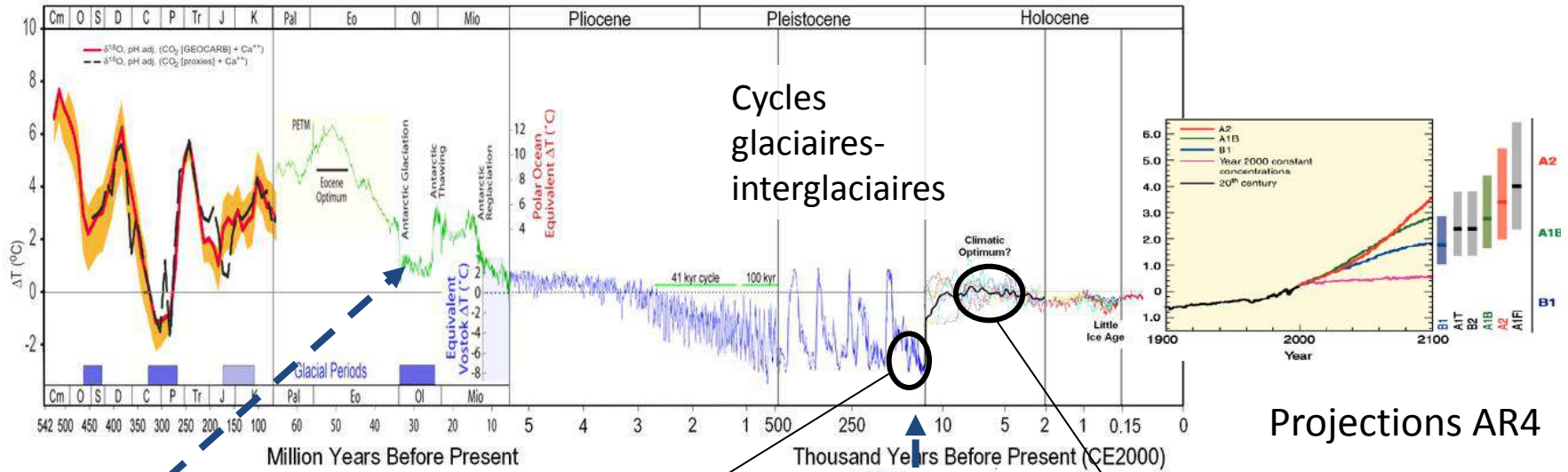
Masa Kageyama, Pierre Sepulchre

Quelles questions sur le changement climatique ?

Pré-Quaternaire

Quaternaire

Anthropocène

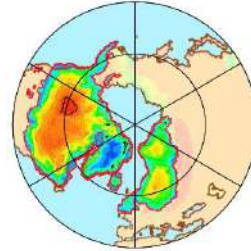
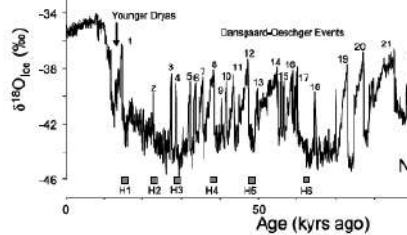


Projections AR4



Transition Eocène-Oligocène

événements abrupts:

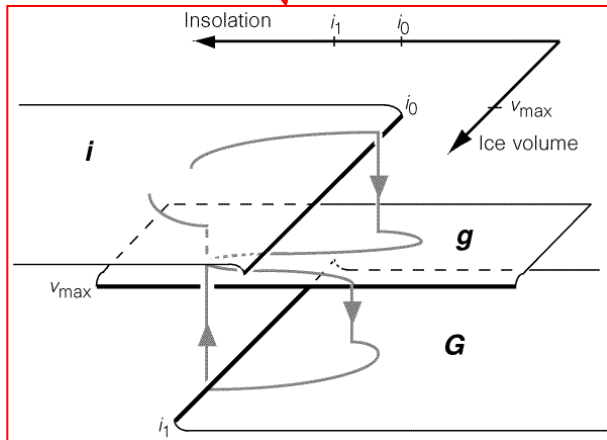
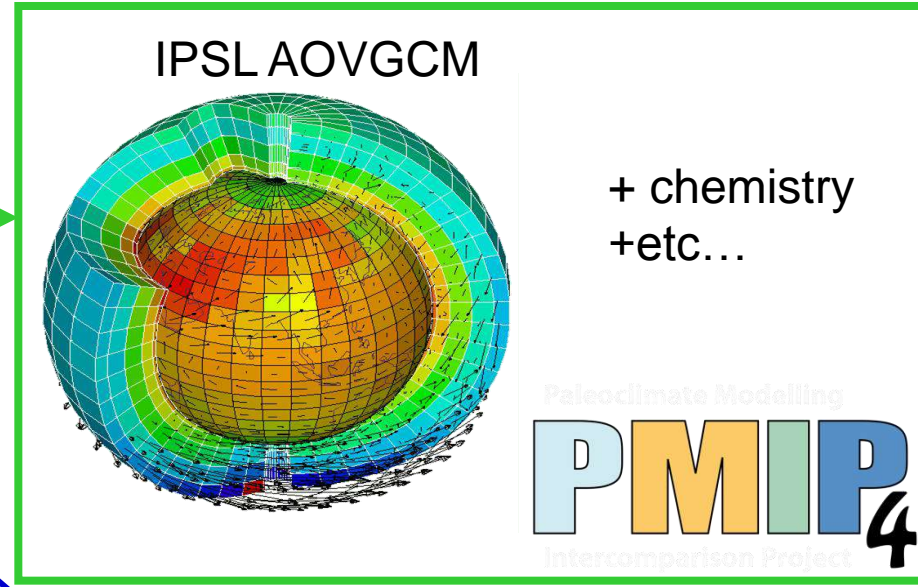
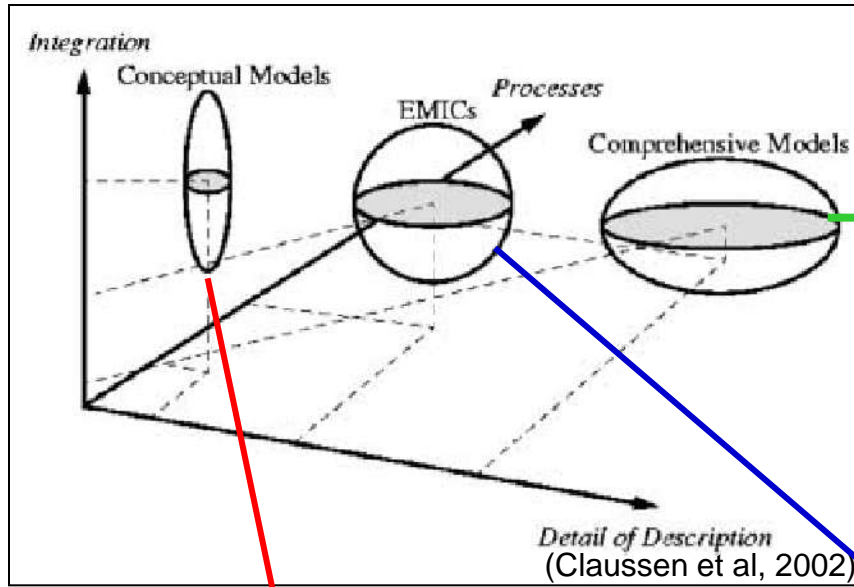


Dernier Maximum Glaciaire

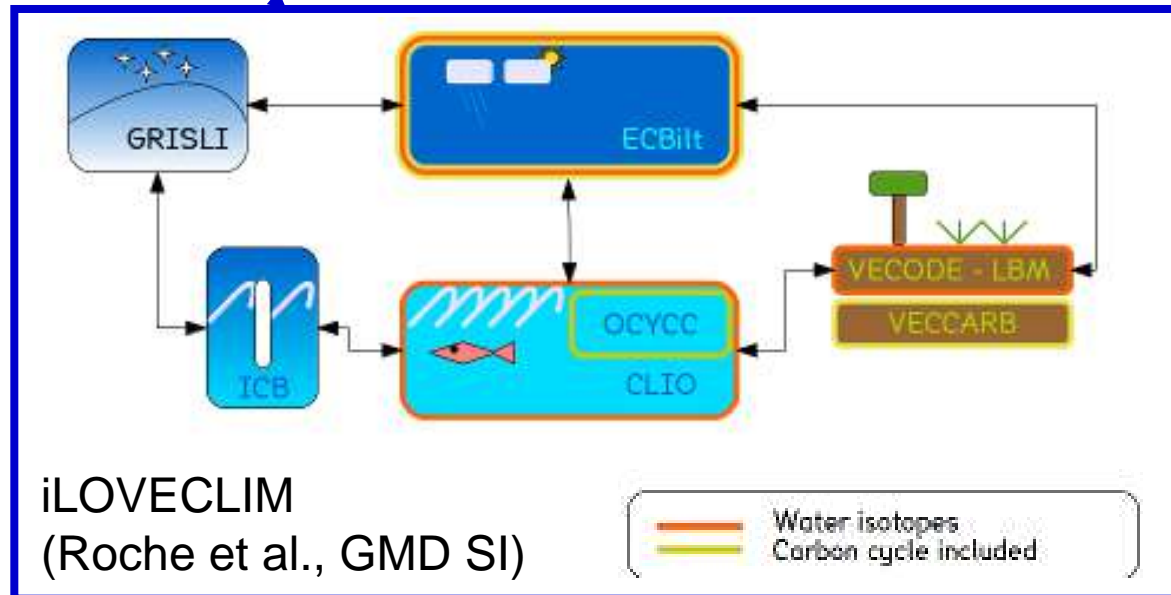
Holocène Moyen
limite plus au nord des forêts boréales, moussons plus intenses, « Sahara vert »

- Amplitudes et échelles de temps très diverses
- Tests de notre compréhension des changements climatiques
- Tests des modèles de climat

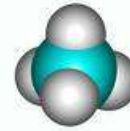
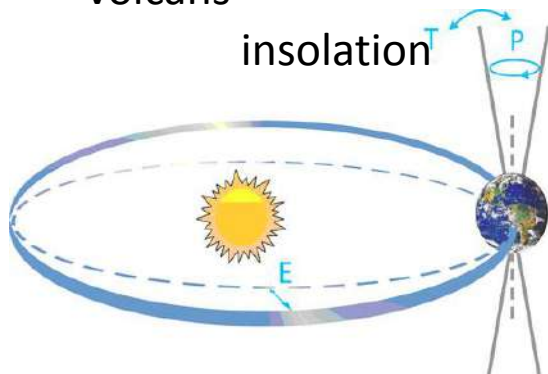
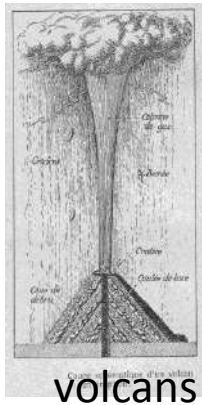
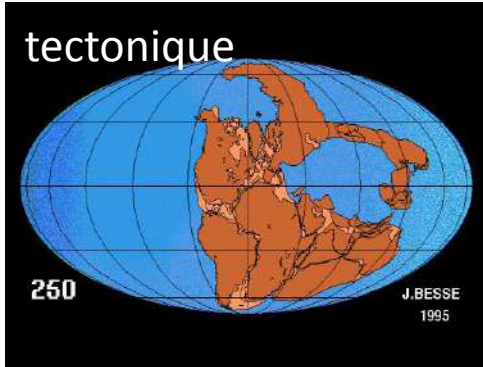
De nombreux modèles pour de nombreuses questions: Exemple de modèles de climat utilisés au LSCE



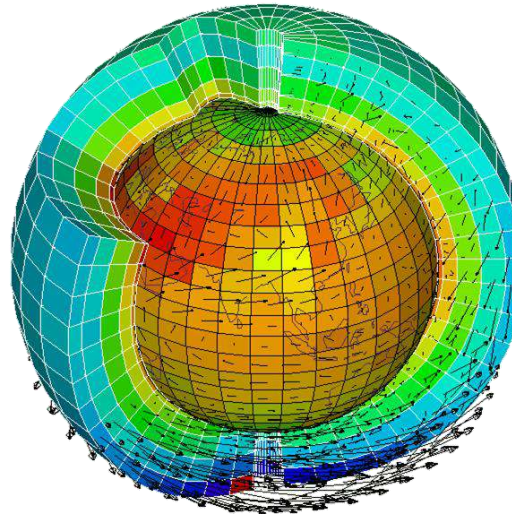
Paillard, 1998



Forçages et rétroactions



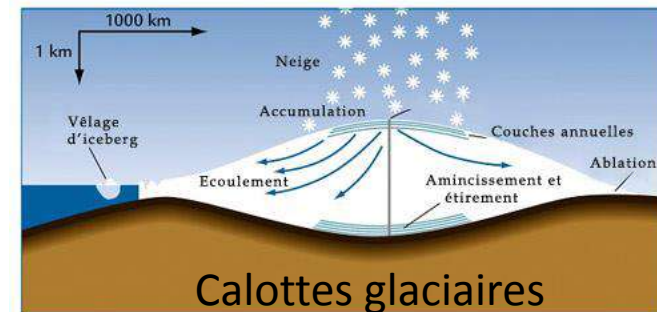
Composition atmosphérique



Végétation

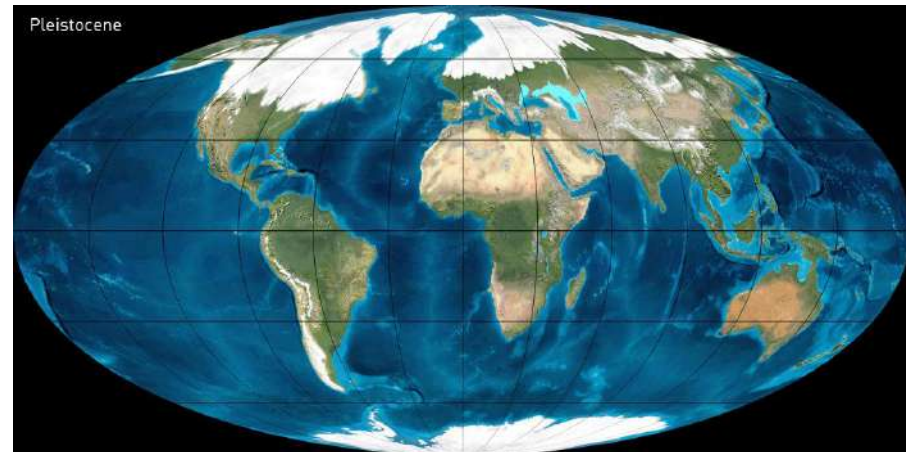
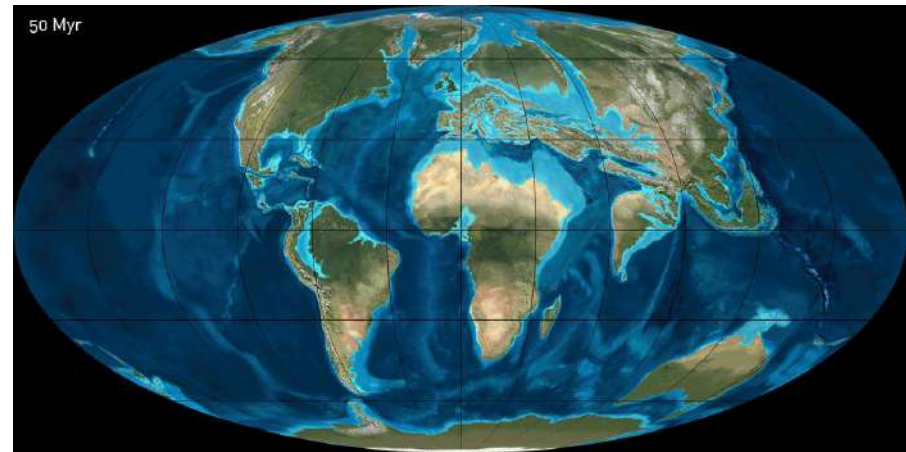
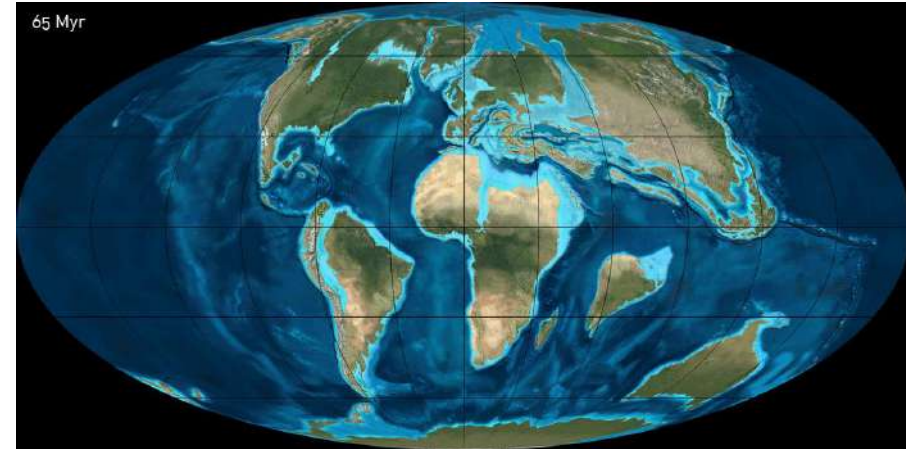


Poussières, aérosols, chimie



Enjeux

- Être capables d'effectuer des simulations longues avec un système couplé océan-atmosphère (et plus):
 - Pour atteindre des équilibres (qq milliers d'années)
 - Pour modéliser les transitions climatiques (~10000 ans)
- Être capables d'étudier l'impact de processus à fine échelle sur la grande échelle:
 - Phénomènes atmosphériques (passages dépressionnaires...)
 - Pour coupler à d'autres composantes
- Être capables de modifier les distributions continents-océans, la topographie, etc.



Impacts of fine-scale processes on climate change?

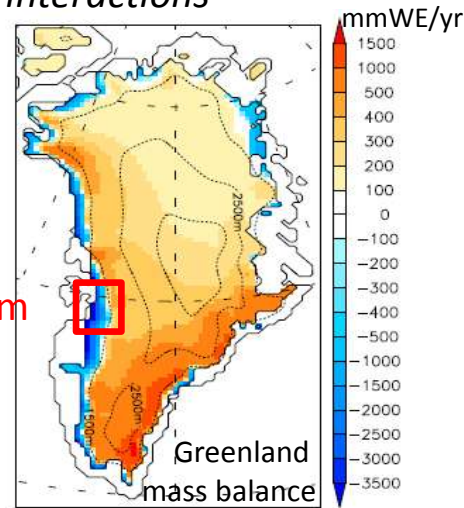
Examples

mountains & rain



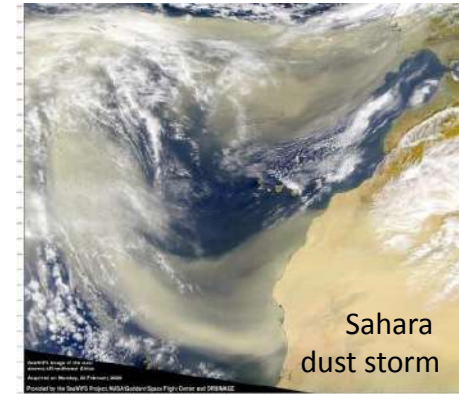
*Site
affected by wind & relief*

*Climate-ice sheet
interactions*



Ice sheet melting

*Dust emissions
f(threshold, wind³)*



*Glacial climates
very dusty*

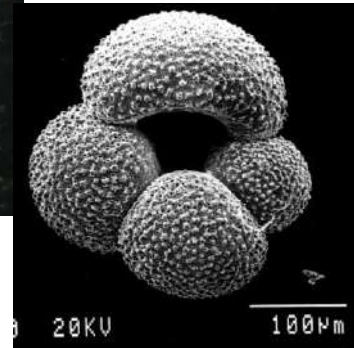
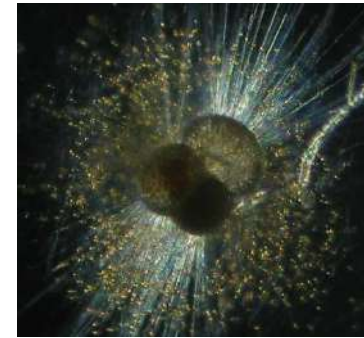
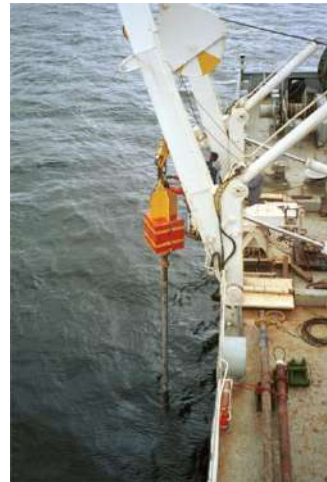
Fine-scale processes → Local climate
→ Large-scale climate (e.g. *via* atm. dynamics, dust)

Un exemple: le climat du Dernier Maximum Glaciaire

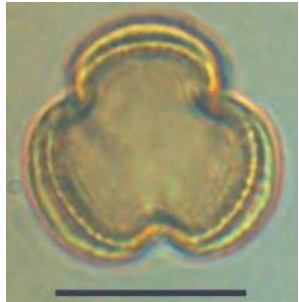
- Indicateurs paléoclimatiques et paléoenvironnementaux.

→ exemples

Plancton, flore et faune marines



Pollens, restes de végétation

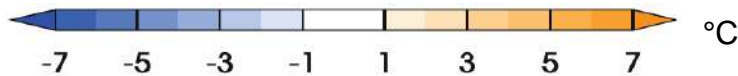
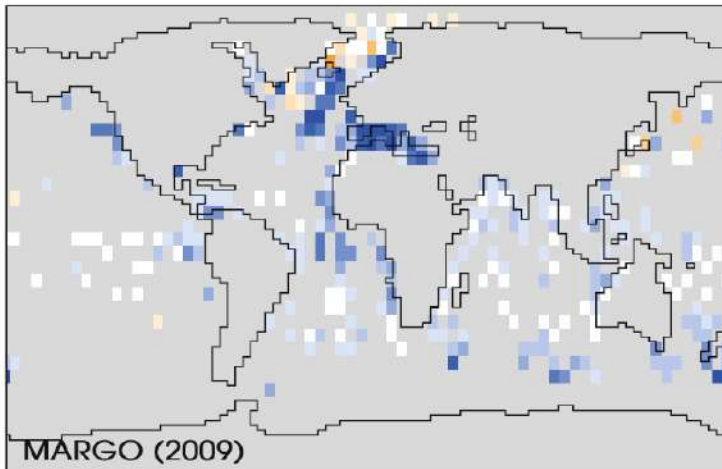


Carottes de glace

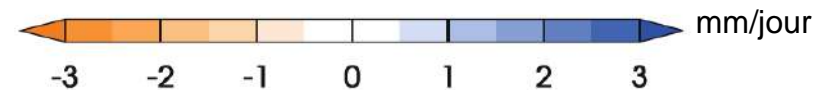
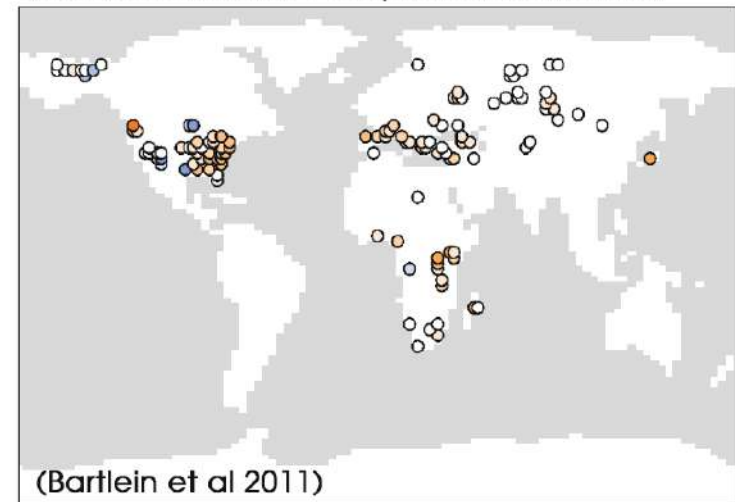


Le climat du Dernier Maximum Glaciaire

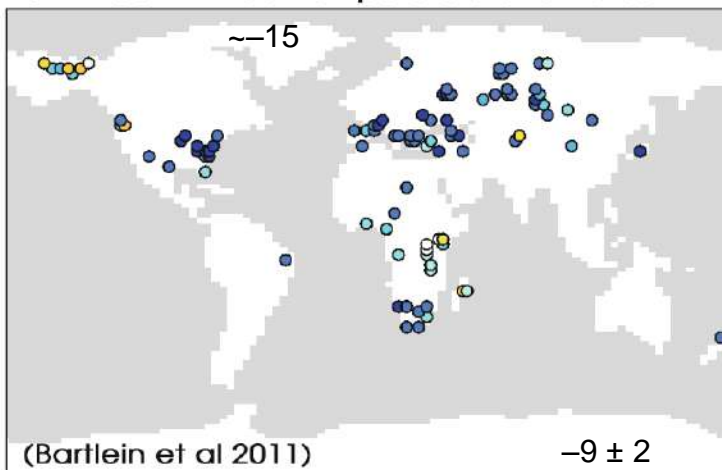
LGM Mean Annual SST anomalies



LGM Mean Annual Precipitation anomalies



LGM Mean Annual Temperature anomalies



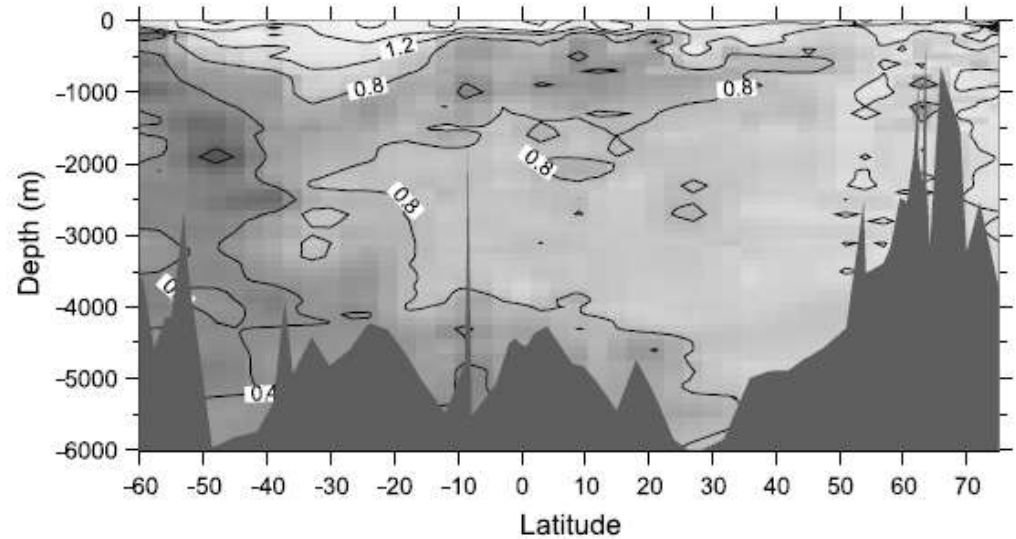
Enjeux:

- expliquer ce climat à partir de ce que l'on connaît du système climatique (forçages, rétroactions)
- évaluer les modèles utilisés pour les prévisions climatiques

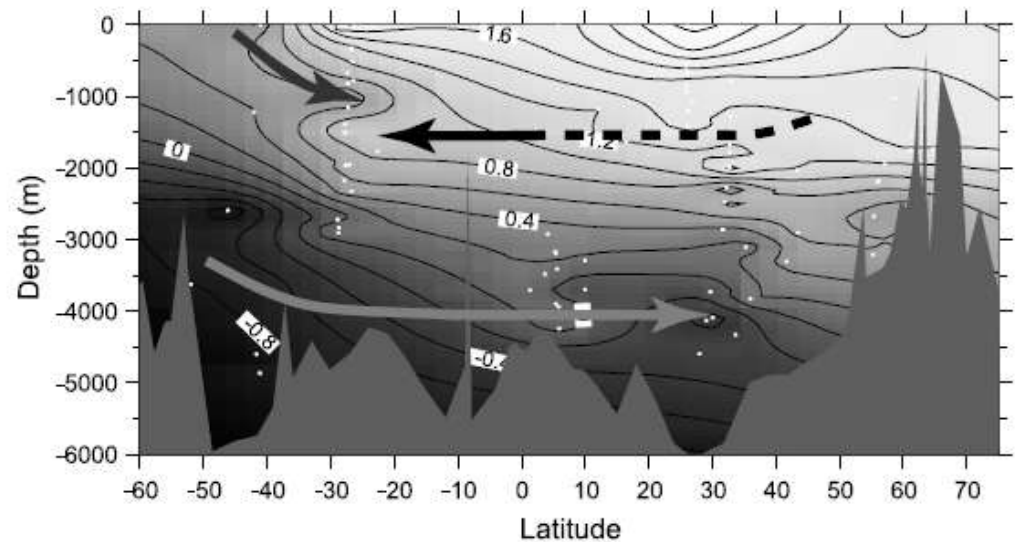
d'autres indicateurs

- Circulation océanique
- exemple: Curry & Oppo, Paleooceanography 2005

Western Atlantic GEOSECS $\delta^{13}\text{C}$ (PDB)



Western Atlantic Glacial $\delta^{13}\text{C}$ (PDB)



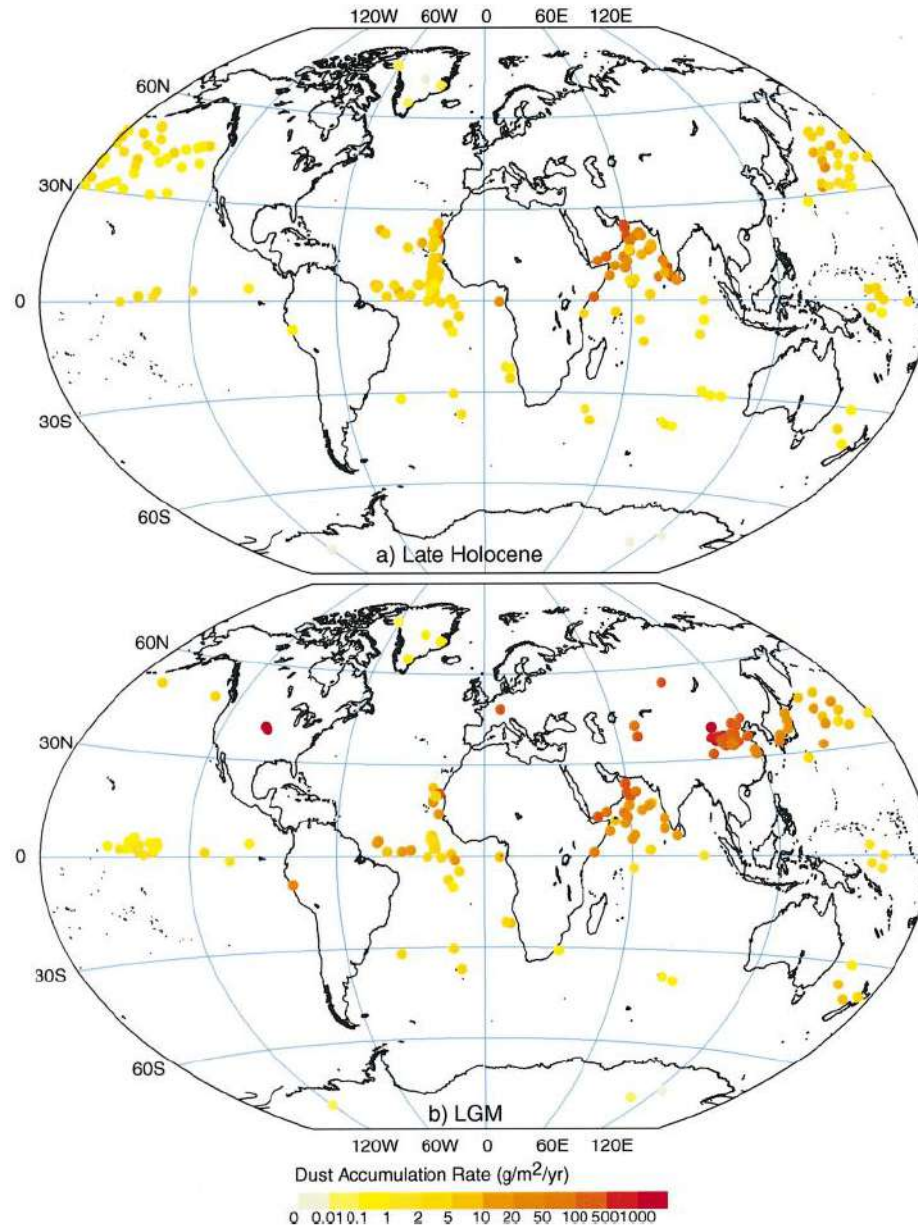
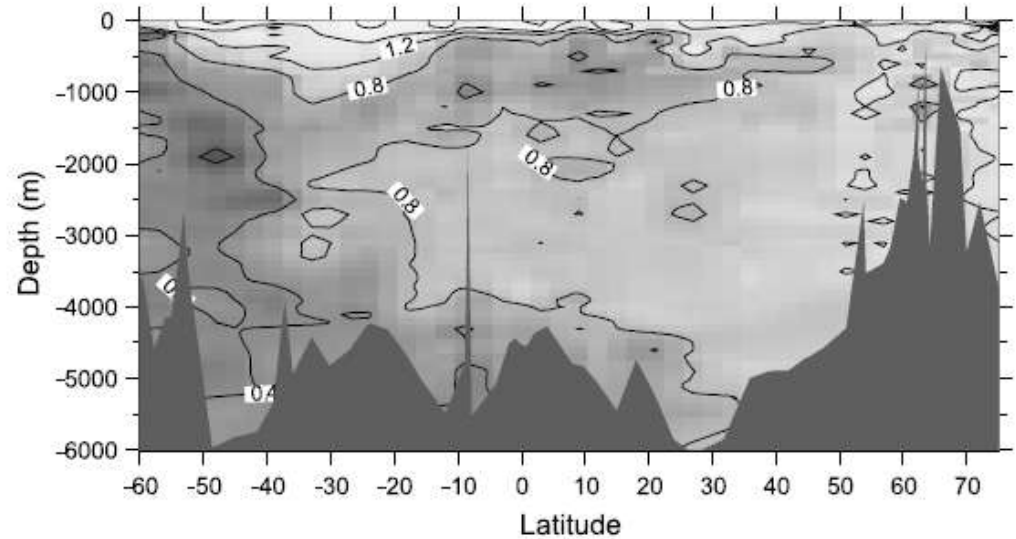
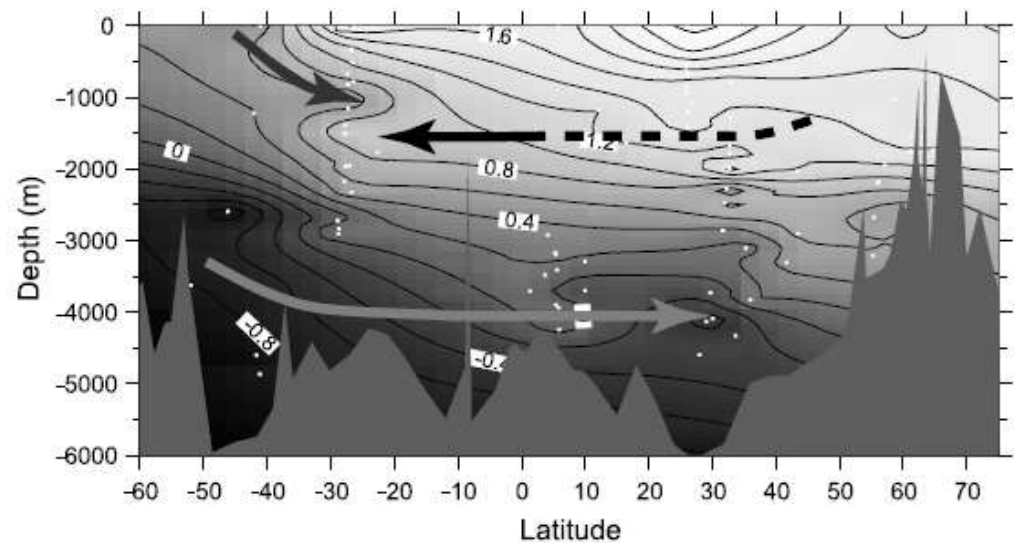


Fig. 3. Dust accumulation rates for (a) the late Holocene and (b) LGM, based on ice core, marine and terrestrial records in the DIRTMAP data base (Mahowald et al., 1999; Kohfeld et al., 1999; Sun et al., 1999).

- Circulation océanique
- exemple: Curry & Oppo, Paleooceanography 2005

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Western Atlantic GEOSECS $\delta^{13}\text{C}$ (PDB)Western Atlantic Glacial $\delta^{13}\text{C}$ (PDB)

Poussières

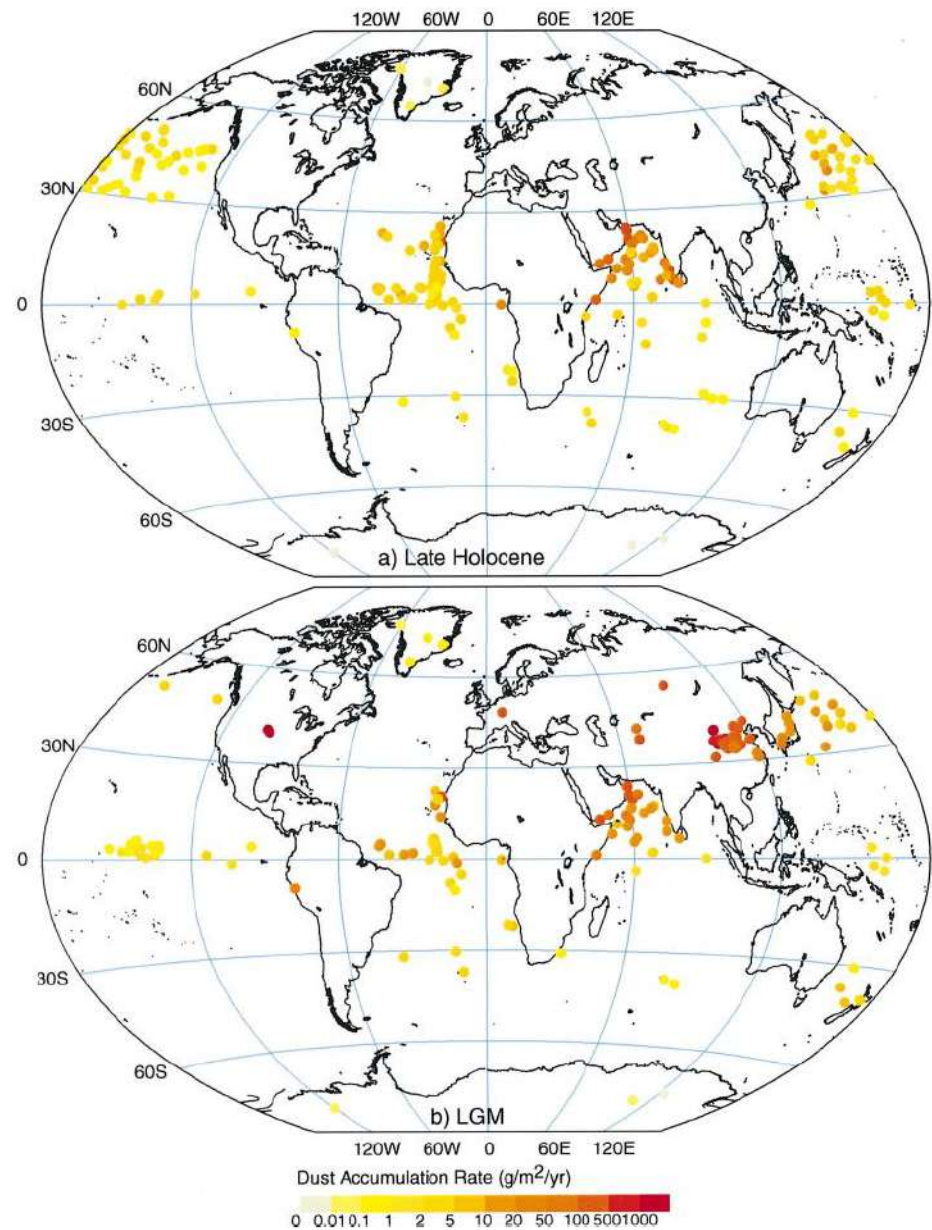
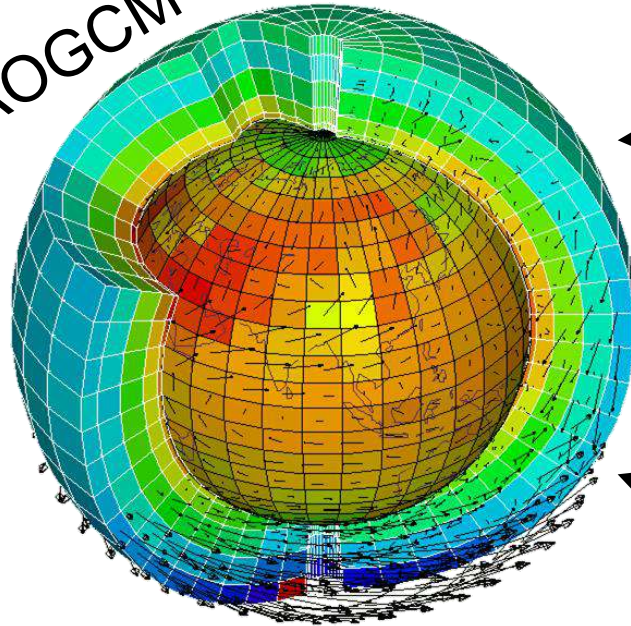


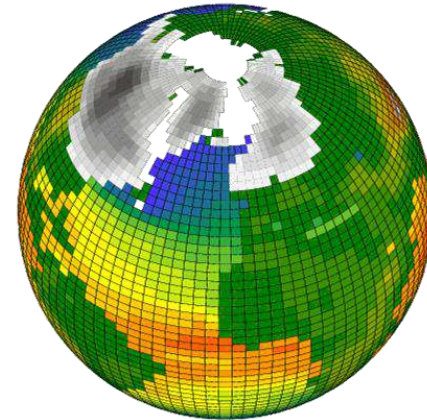
Fig. 3. Dust accumulation rates for (a) the late Holocene and (b) LGM, based on ice core, marine and terrestrial records in the DIRTMAP data base (Mahowald et al., 1999; Kohfeld et al., 1999; Sun et al., 1999).

Forçages/conditions aux limites pour le DMG

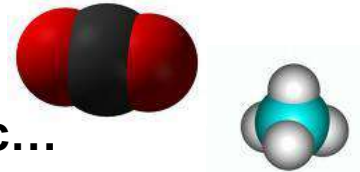
AOGCM



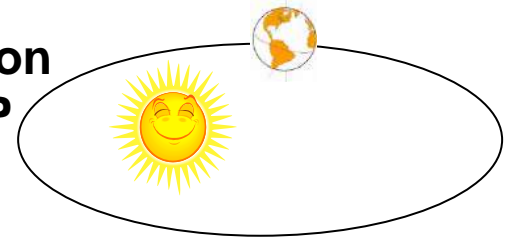
Calottes
glaciaires



Composition
atmosphérique
CO₂: 185 ppm etc...



Insolation
21ky BP

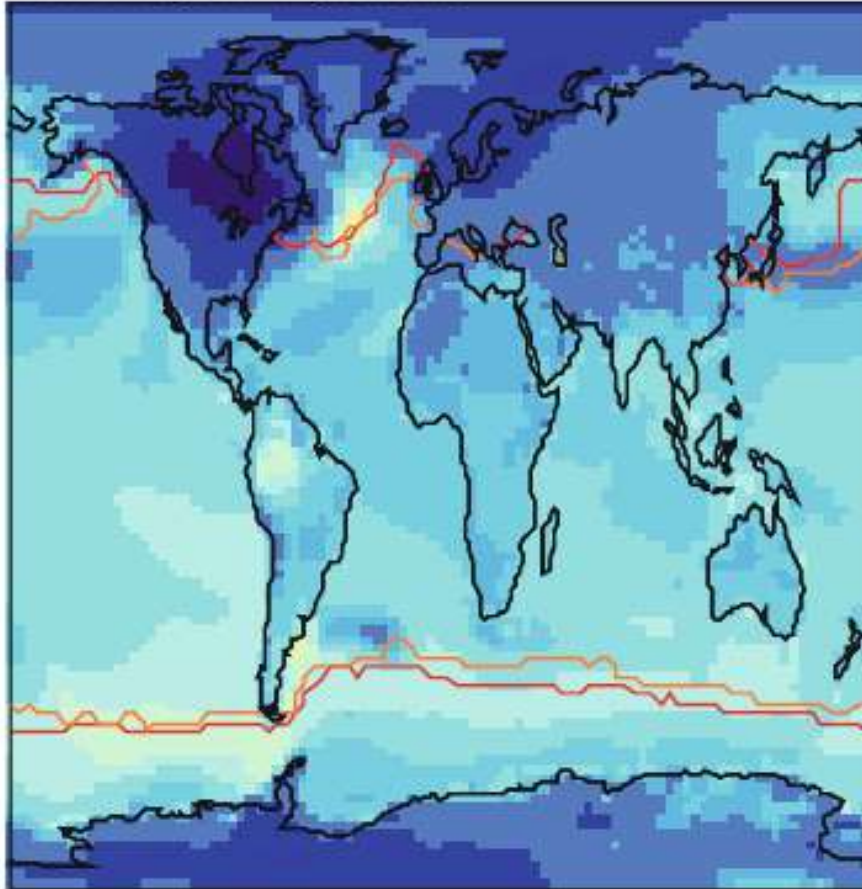


Temps de calcul:
Équilibrage du modèle.....
→ ~6 mois en temps réel !

Quelques résultats

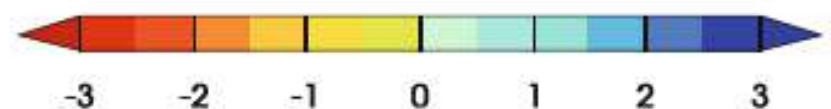
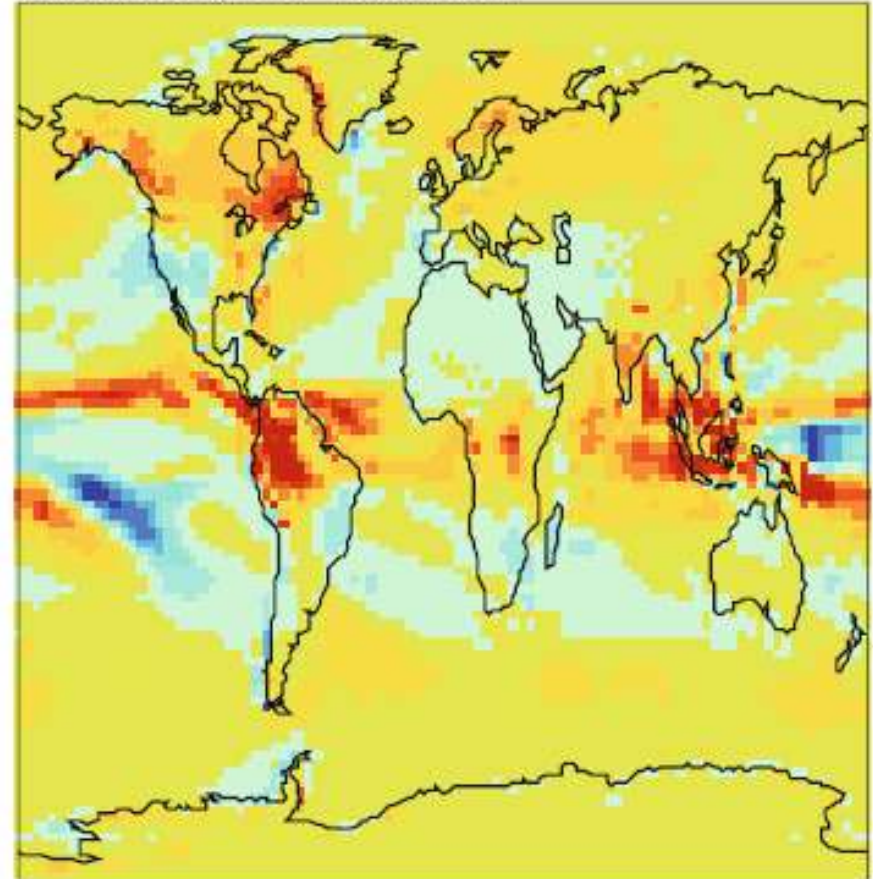
Kageyama et al., 2013

12m ANN (LGM - PI) IPSLCM5



Différences LGM – Pre-ind.
Températures moyennes annuelles (°C)

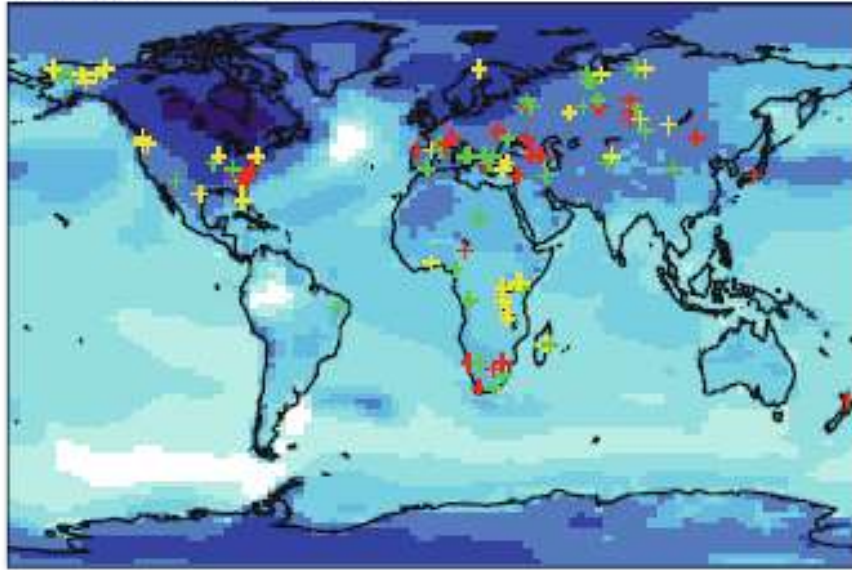
precip ANN (LGM - PI) IPSLCM5



Différences LGM – Pre-ind.
Précipitation moyennes annuelles (mm/j)

Comparaison par rapport aux reconstructions

IPSLCM5 MAT (LGM - PI)

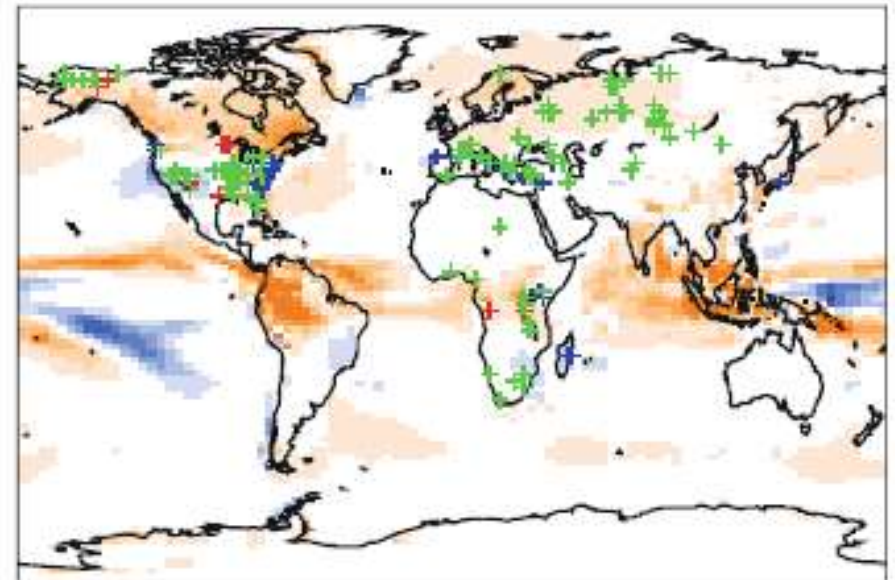


(32 too cold - 37 ok - 29 too warm)

-30 -20 -10 -5 -2 0 2

températures moyennes annuelles
LGM - PI

IPSLCM5 MAP (LGM - PI)



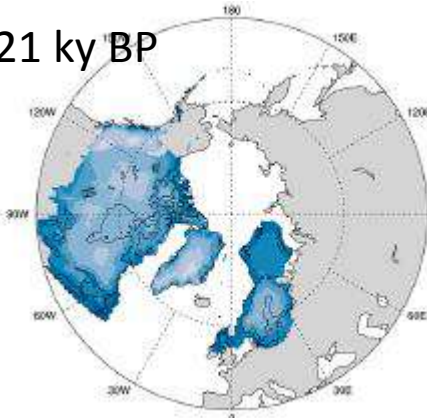
8 too dry - 91 ok - 22 too wet

-3 -2 -1 0 1 2 3

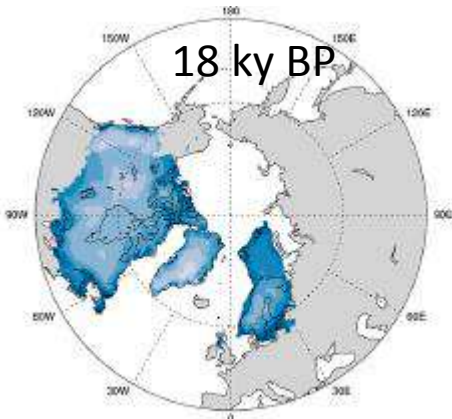
précipitation moyennes annuelles
LGM - PI

Après le Dernier Maximum Glaciaire: la dernière déglaciation

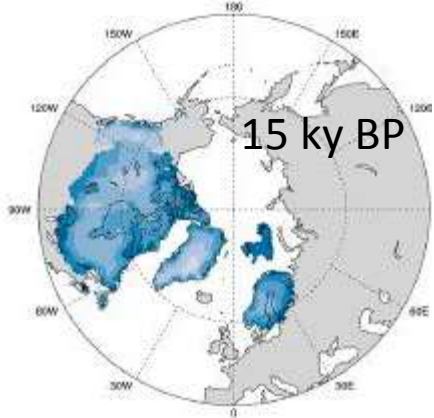
21 ky BP



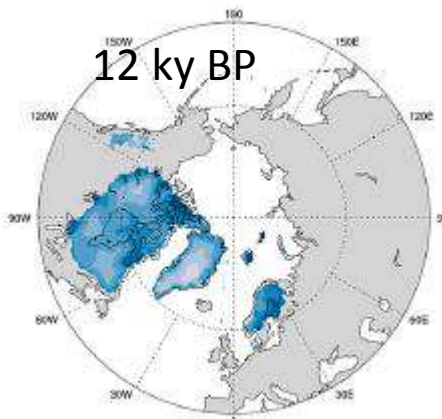
18 ky BP



15 ky BP



12 ky BP



9 ky BP

