Modelling the mid-Pliocene Warm Period with the IPSL-GCM: contribution to PlioMIP and feedback mechanisms from the presence of Mega-Lake Chad

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Pliocene Model Intercomparison Project (PlioMIP)

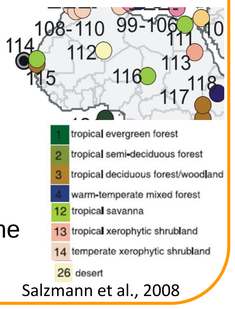
❖ The mid-Pliocene Warm Period spans the 3.3 to 3 Ma interval. It is a good target for paleoclimate modellers since it is the last period of sustained global warming (+2°C), before the onset of the Greenland glaciation (~2.7 Ma). pCO_2 is close to the present-day one (~400 ppm), and continents position are the same. The PlioMIP project aims to compare climatic outputs from different models, forced with the same boundary conditions.

- 2 experiments carried out with mid-Pliocene Boundary Conditions, one using an Atmospheric model with fixed Sea Surface Temperatures (AGCM), the other one with a coupled Atmosphere-Ocean model (AOGCM).

Investigating the Mega-Lake Chad during the Pliocene

❖ Evidence of tropical savanna in the Chad basin region, wetter subtropics
❖ Presence of a Mega-Lake Chad (MLC) during the mid-Pliocene

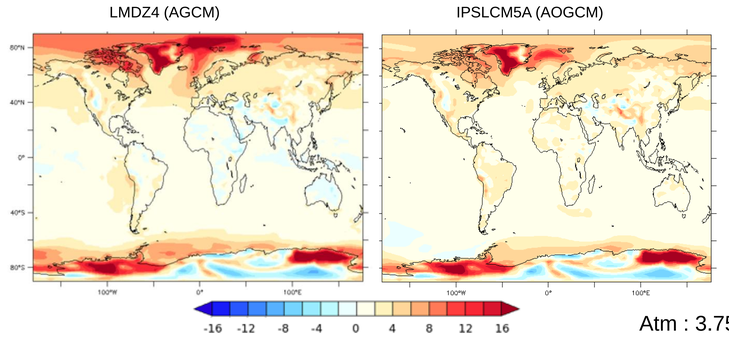
- 2 experiments carried out with an AGCM including a lake surface scheme, LMDZ4_LAKE (Krinner et al., 2003). One without lake, one with an imposed MLC of 20 meters depth and an area of ~ 350 000 km²



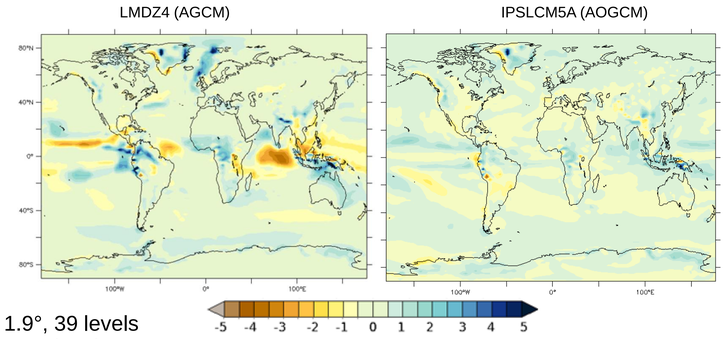
Salzmann et al., 2008

Results of the PlioMIP simulations with IPSLCM5A and LMDZ4 (Contoux et al., 2012)

Mean annual surface temperature anomalies in °C



Mean annual precipitation anomalies in mm/day

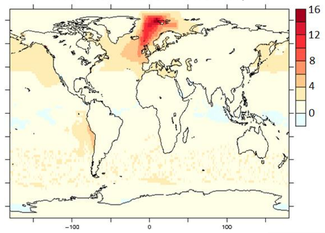


Atm : 3.75° x 1.9°, 39 levels
Ocean : ~ 2/3°, 31 levels

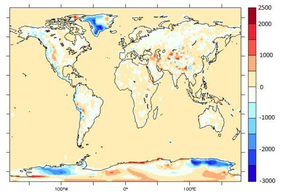
→ The coupled model does not reproduce the reconstructed ocean warming patterns, and subtropics are wetter in the AGCM simulation.

PlioMIP boundary conditions in the IPSL-GCM (Haywood et al, 2010, 2011)

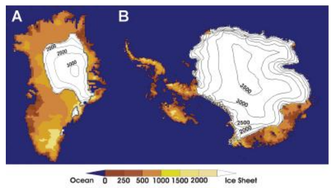
Mean annual SST anomaly



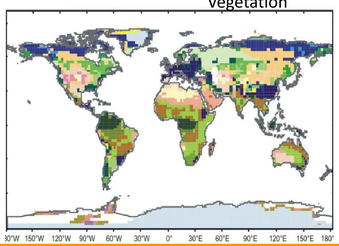
Topography anomaly



Ice sheet extent

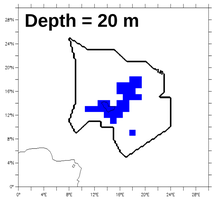


Vegetation

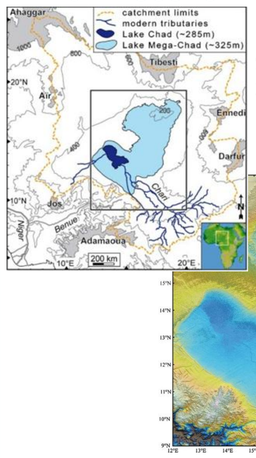


CO2 = 405 ppm
Orbital parameters = modern

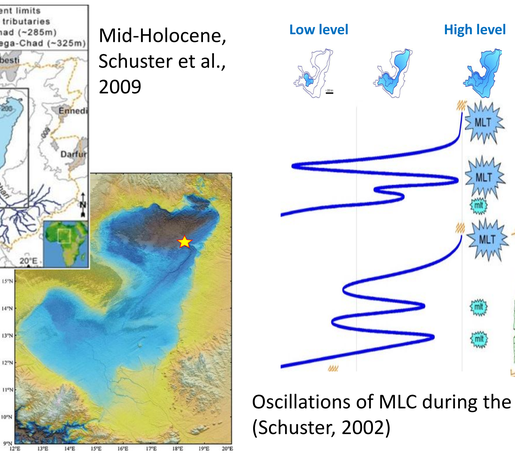
Imposed lake surface in the LMDZ4_LAKE



Evidence of a Mega-Lake Chad (MLC) during the mid-Pliocene



Mid-Holocene, Schuster et al., 2009



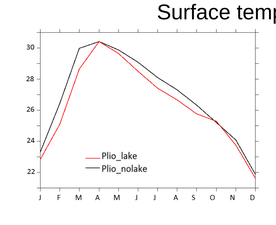
Oscillations of MLC during the Pliocene (Schuster, 2002)

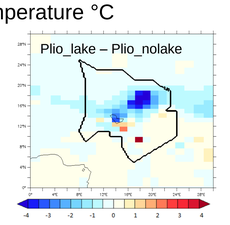
★ Koro-Toro site, age 3.58 ± 0.27 Ma (Lebatard et al., 2008):

❖ Abel (*A. bahrelghazali)* Northern Chad, mosaic landscape bordering a lake or river (Brunet et al., 1997)
❖ Presence of ichtyofauna (11 fish taxa) (Otero et al., 2010)

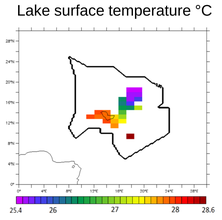
Results of LMDZ4_LAKE model including lake surfaces: feedbacks of Mega-Lake Chad on climate

Surface temperature °C

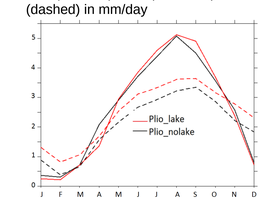




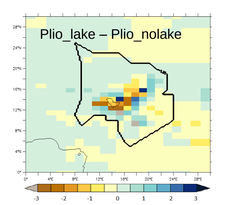
Lake surface temperature °C



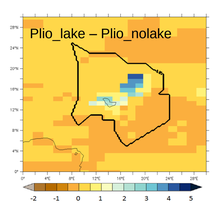
Precipitation (full line) and evaporation (dashed) in mm/day



Precip in mm/day



Evap in mm/day



Atm : 3.75° x 2.5°,19 levels. Zoom x3 on the Lake Chad region

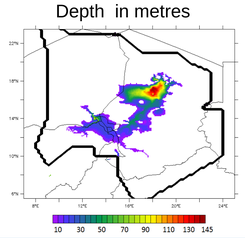
→ The presence of an open water surface impacts the local surface temperature and hydrological cycle.

Ongoing work : simulating the Mega-Lake Chad extent during the Pliocene with HYDRA/THMB (Coe, 2000).

- Climate : LMDZ4 outputs (precip., evap., runoff, drainage)
- Geomorphology : modern (Digital Elevation Model, basin limits, drainage direction)

→ The model produces a MLC which is coherent with data, this validates our simulated climate with LMDZ4 in this region.

Depth in metres



Conclusions and perspectives

The presence of a Mega-Lake Chad clearly impacts the local climate. This study shows that open water surfaces should be taken into account for a better representation of the climate. Using BIOME4 forced with LMDZ4_LAKE outputs will allow to better capture the vegetation patterns in the Chad basin region. We are currently using the river routing model HYDRA/THMB to investigate the extent of MLC under the mid-Pliocene climate simulated with LMDZ4. Comparisons with the mid-Holocene climate and sensitivity tests to orbital parameters are planned, in order to better characterise the mechanisms leading to the arid/humid variations in the Chad basin during the Cenozoic.

Brunet et al. (1997). A new Pliocene hominids site. *C. R. Acad. Sci .Paris.* **Coe (2000)** Modeling terrestrial hydrological systems at the continental scale : testing the accuracy of an AGCM. *J. Clim.* **Contoux et al. (2012)**. Modelling the mid-Pliocene climate with the IPSL model. *Geosci. Model Dev. Discuss.* **Haywood et al. (2010)**. PlioMIP experiment 1.Geosci. *Model Dev*. **Haywood et al. (2011)** PlioMIP experiment 2. *Geosci. Model Dev*. **Krinner et al. (2003)** Impact of lakes and wetlands on boreal climate. *J. Geophys. Res.* **Lebatard et al. (2008)** Cosmogenic nuclide dating of Mio-Pliocene hominids from Chad. *PNAS.* **Otero et al. (2010)** The early/late Pliocene ichthyofauna from Koro-Toro, Eastern Djurab, Chad. *Geobios.* **Salzmann et al. (2008)** A new global biome reconstruction for the Middle Pliocene. *Global Eco. Biogeogr.* **Schuster (2002)** Sédimentologie et paléoécologie des séries à vertébrés du paléolac Tchad depuis le Miocène supérieur. PhD thesis. Unpublished. **Schuster et al. (2009)** Chad Basin: paleoenvironments of the Sahara since the late Miocene *C. R. Geosci.*