Quantifying the contribution of Tibetan Plateau (TP) uplift and CO_2 decrease for late Eocene and present day climate with emphasis on Meridional Ocean Circulation

Intensified Atlantic vs. weakened Pacific meridional overturning circulations in response to Tibetan Plateau uplift

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Many forcing factors have changed from Eocene to present day with major impact on global/regional climate changes:

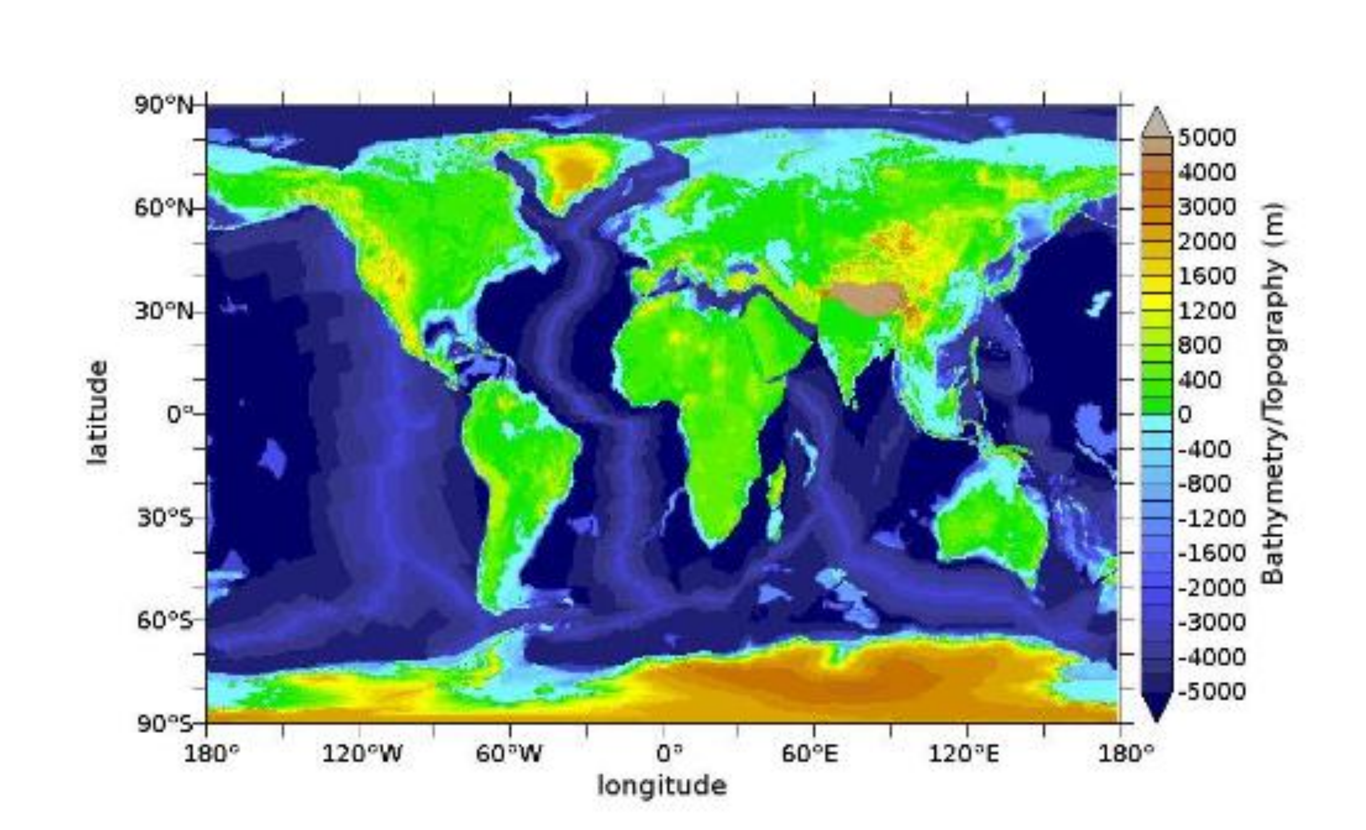
- ✓A large decrease of atmospheric CO2 (from 4 to 1 PAL)
- ✓Paleogeographical changes
  - Continent/ocean distribution
  - Orogenesis
  - Seaways opening/closure
  - Paratethys shrinkage

Focus on the impact of Tibetan Plateau and Himalaya uplift

- ✓Height of the mountain range (Botsyun CP 2015)
- ✓Northward shift of the mountain range (Zhang et al. EPSL 2017)

Impact on atmospheric simulation, but also on ocean dynamics (Su et al. CP 2018)

Direct paleogeographic impact: East Tethys seaway closure



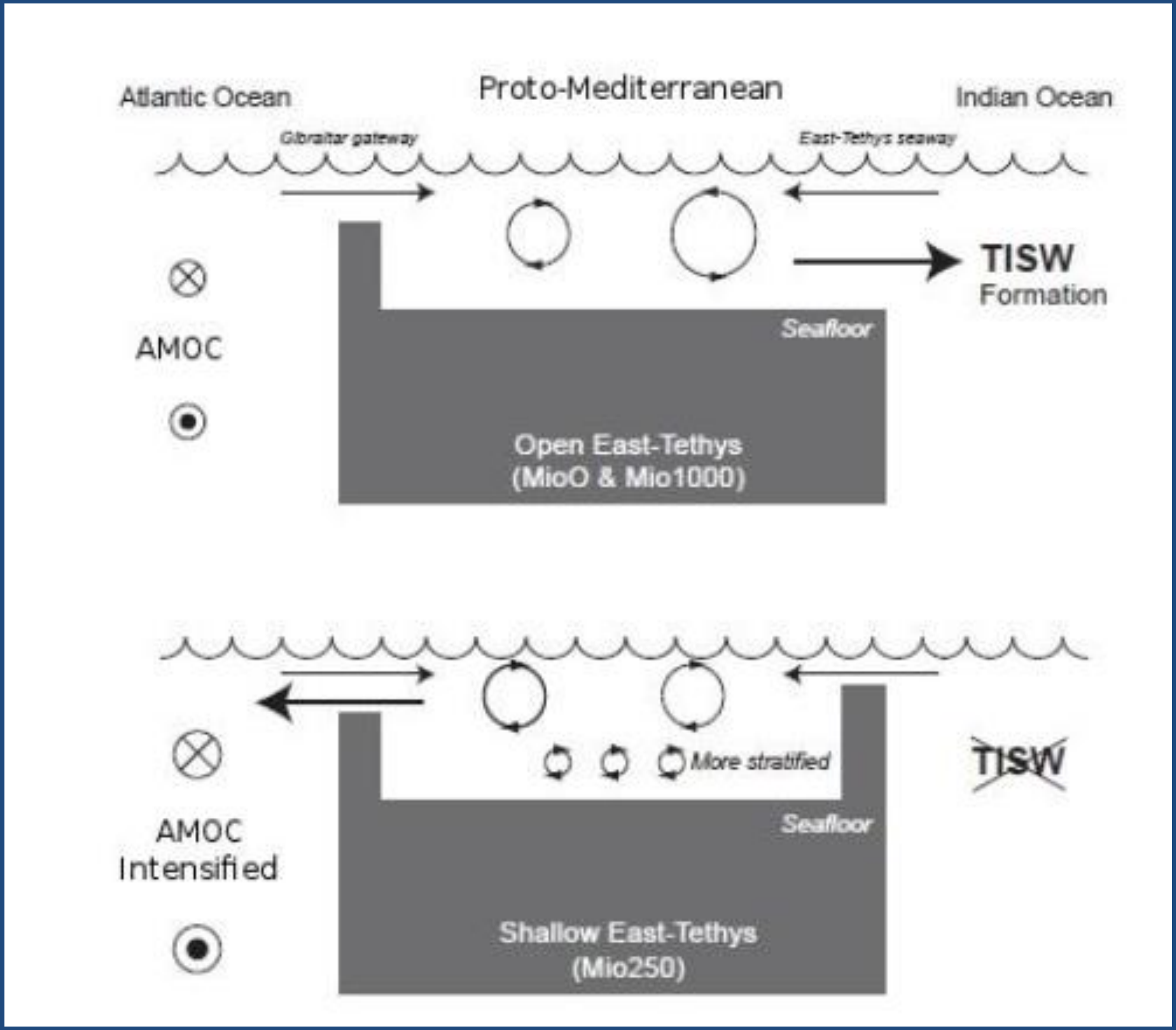
Middle Miocene geography used in the Mio4000 experiment
(Tethys seaway depth =4000 m)

Hamon et al., Clim Past, 2013

Climatic impact of the East Tethys seaway closure

Open East-Tethys

Shallow East-Tethys



Hamon et al., Clim Past, 2013

An **indirect** impact of TP uplift on ocean dynamics

Target:

The impact of TP on ocean dynamics has for long been pointed out, especially for the meridian ocean circulation changes.

Background:

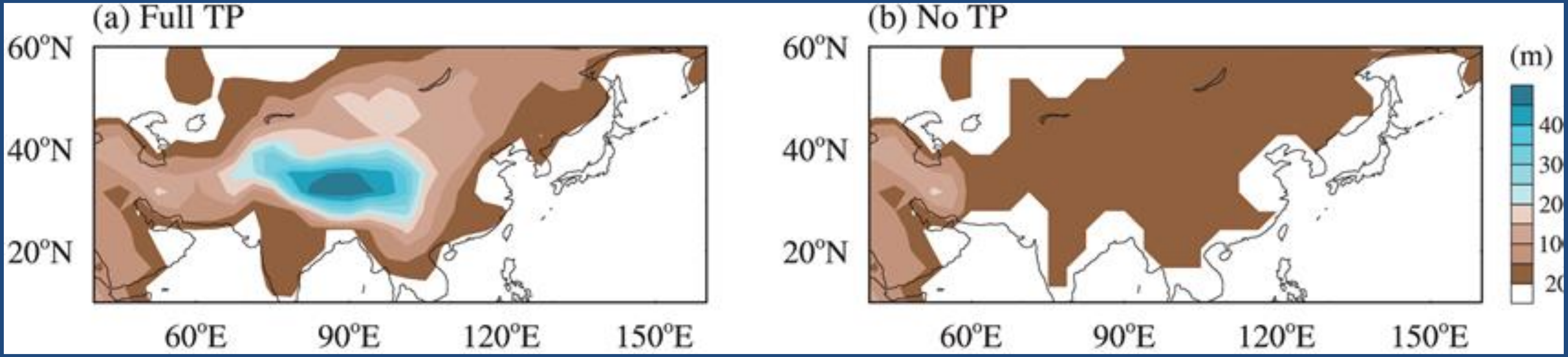
- Very first concept Bolin 1950
- First numerical experiment Rudiman and Kutzbach 1989
- First coupled experiments D. Rind 1997, A. Kitoh 2004.

New results:

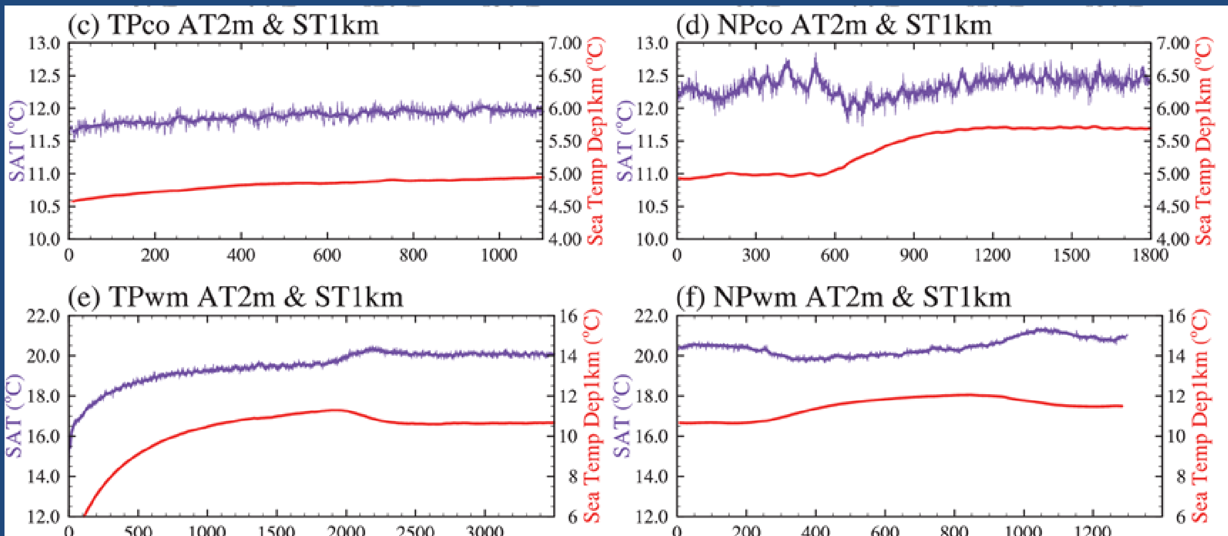
Through a very simple scenario (modern-NoTP) but very long simulations (>1000 yr) with CESM 1.05 (T31) AOGCM, we show that TP and Himalaya impact on ocean dynamics led to a large AMOC increase and a drawdown of the PMOC.

These features capture large changes in ocean dynamics since Eocene.

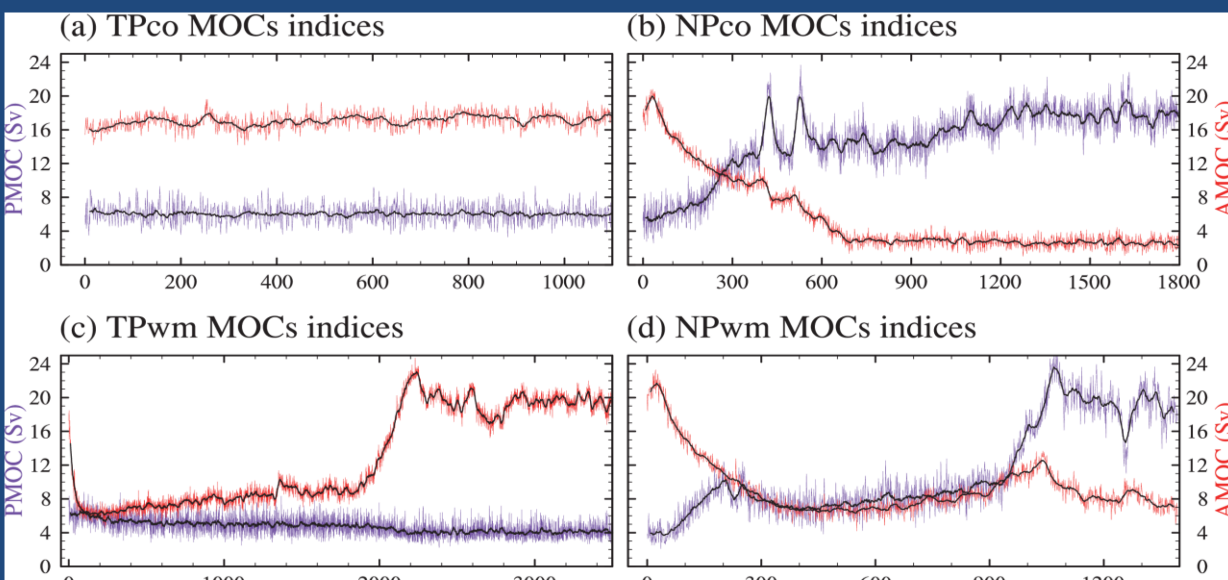
The TP topography used in all the experiments



(a) Full TP (b) No TP



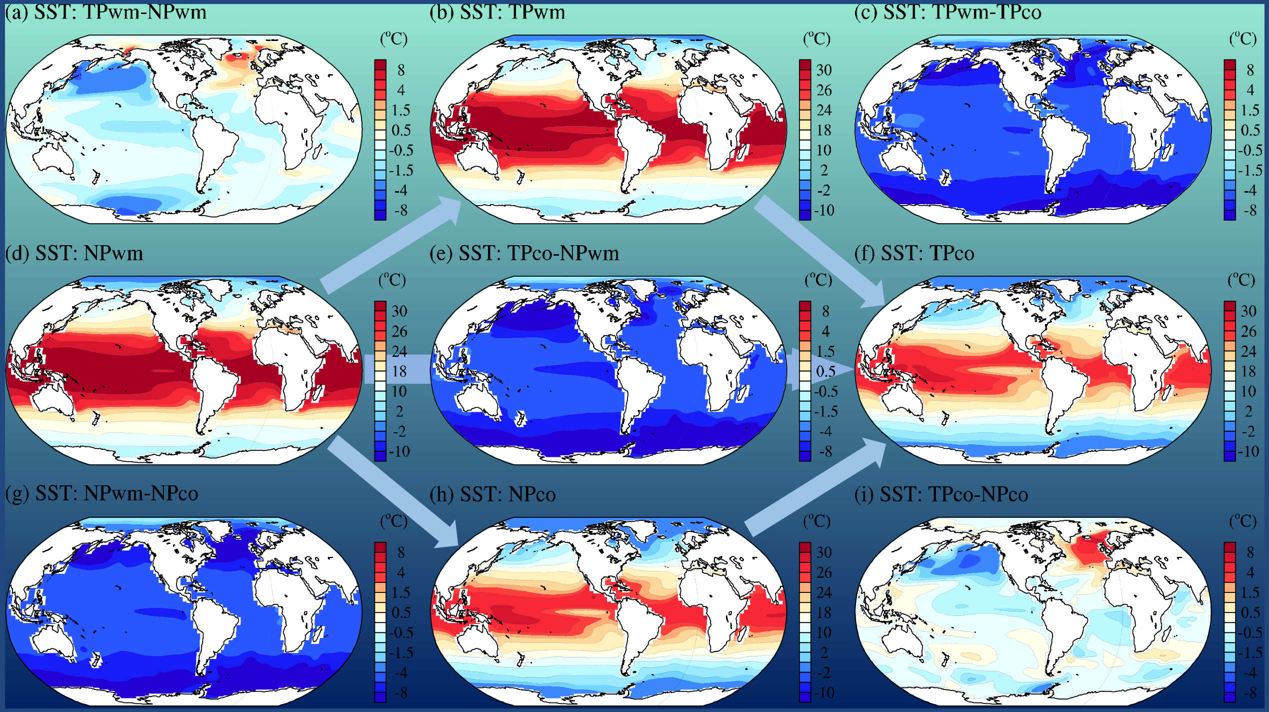
Time series of annual mean globally averaged 1000 m depth ocean temperature and air temperature (SAT) change in (c) TPco, (d) NPco, (e) TPwm, and (f) NPwm



Evolution of PMOC and AMOC for the 4 experiments

The indices are derived from the annual maximum of the meridional stream function value North of 28°N and below a depth of 500 m, respectively

SST of the 4 major experiments (b, d, f, h) and their differences



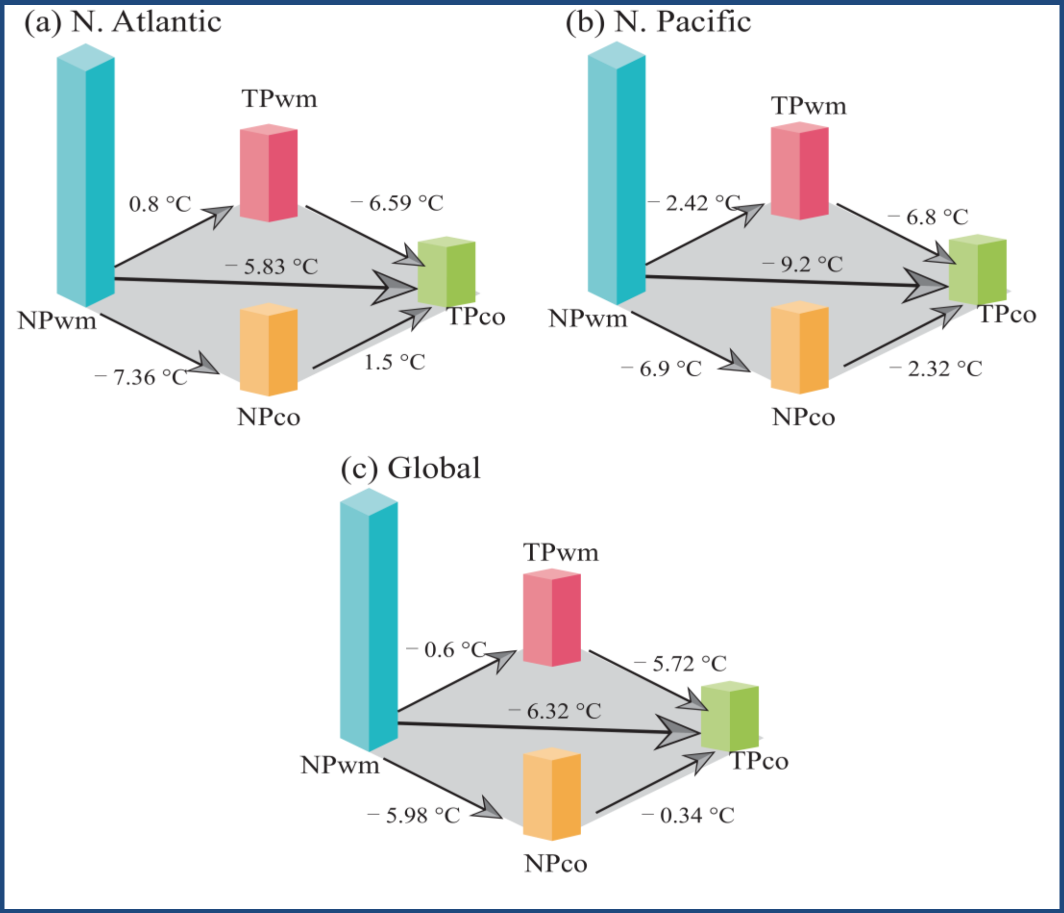
Simulated climatology annual sea surface temperature (SST) for (d) NPwm, (h) NPco, (b) TPwm, (f) TPco.

The SST differences between the (a) TPwm and NPwm and (i) TPco and NPco , are applied to test the individual role of TP uplift on North Atlantic and North Pacific SSTs.

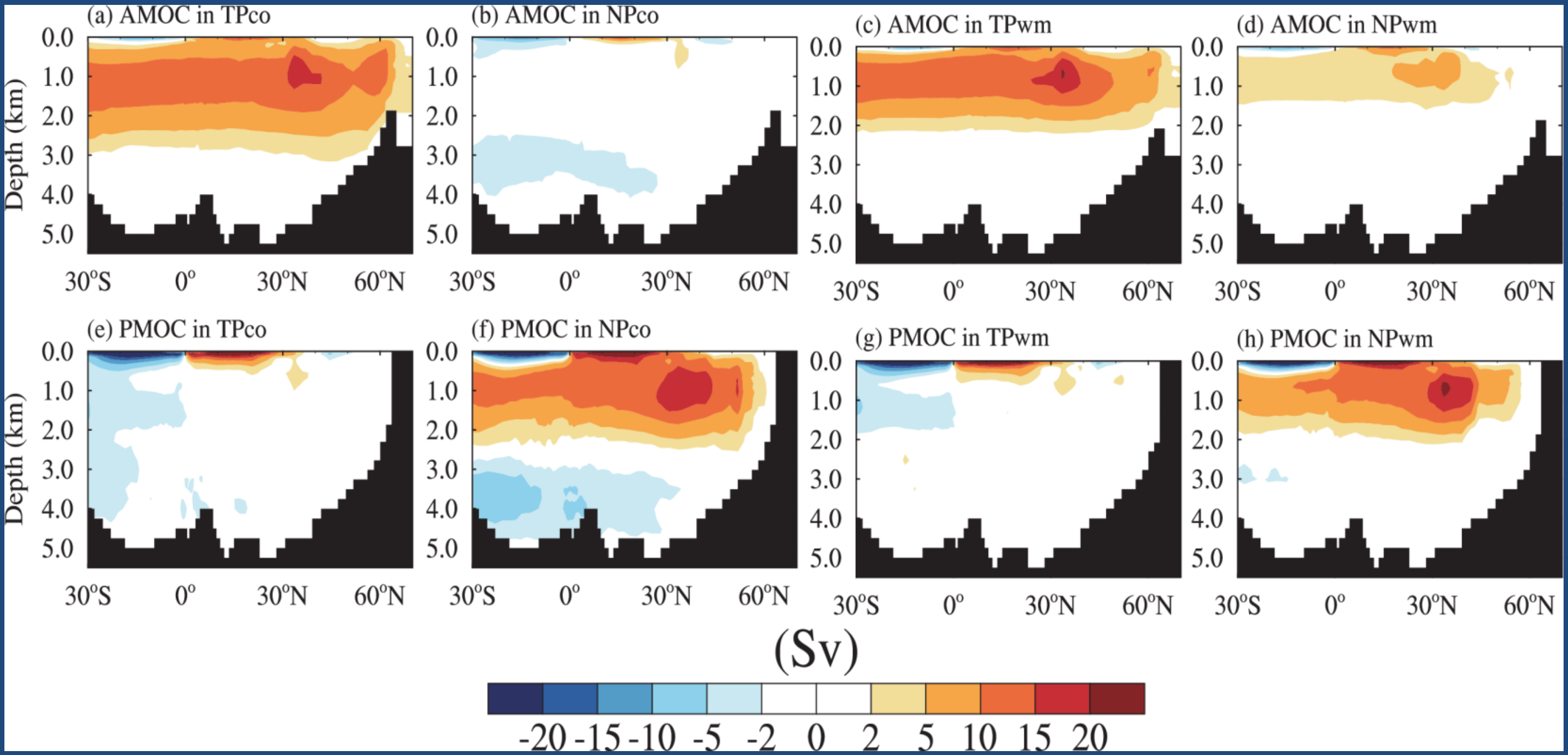
(c) TPwm and TPco and (g) NPwm and NPco are applied to test the impact of CO2 for a sixth geologic configuration NP or TP.

Last but no least: (e) TPco and NPwm is the most realistic difference between a cold world with TP and a warm world without TP.

Schematic diagrams of regional basins and global averaged SST changes from warm to cold conditions experiments: (a) North Atlantic (b) North Pacific (c) Global ocean



Climatological annual mean overturning stream function



Profiles of meridional overturning stream function over Atlantic (AMOC, upper panel) and Pacific (PMOC, bottom panel) in (a) and (e) for TPco, (b) and (f) for NPco, (c) and (g) for TPwm, (d) and (h) for NPwm

Positive shading : clockwise circulations
Negative shading : counterclockwise circulations

Conclusion

- The decrease of pCO_2 from 4 PAL to 1 PAL has a global impact, especially the enhancement of the thermal gradient from Equator to Pole during Cenozoic

- The uplift of TP has only a regional impact over mid to high latitudes of the Northern hemisphere

- Interestingly its impact is different in North Atlantic and North Pacific basins:

  * In a warm or in a cold world for North Pacific basin, it is a cooling with a similar amplitude (-2,42°C and -2,32°C)

  * Whereas in a warm or in a cold world for North Atlantic, it is a warming with a strong modulation (+ 0,8°C and + 0,5°C)

<u>Limits and caveat of the study:</u>

1) This study only focuses on pCO_2 and PT uplift but there are many other forcing factors

2) These long simulations are conducted with a low resolution model (T31)