LONG-TERM CLIMATE SCENARIOS

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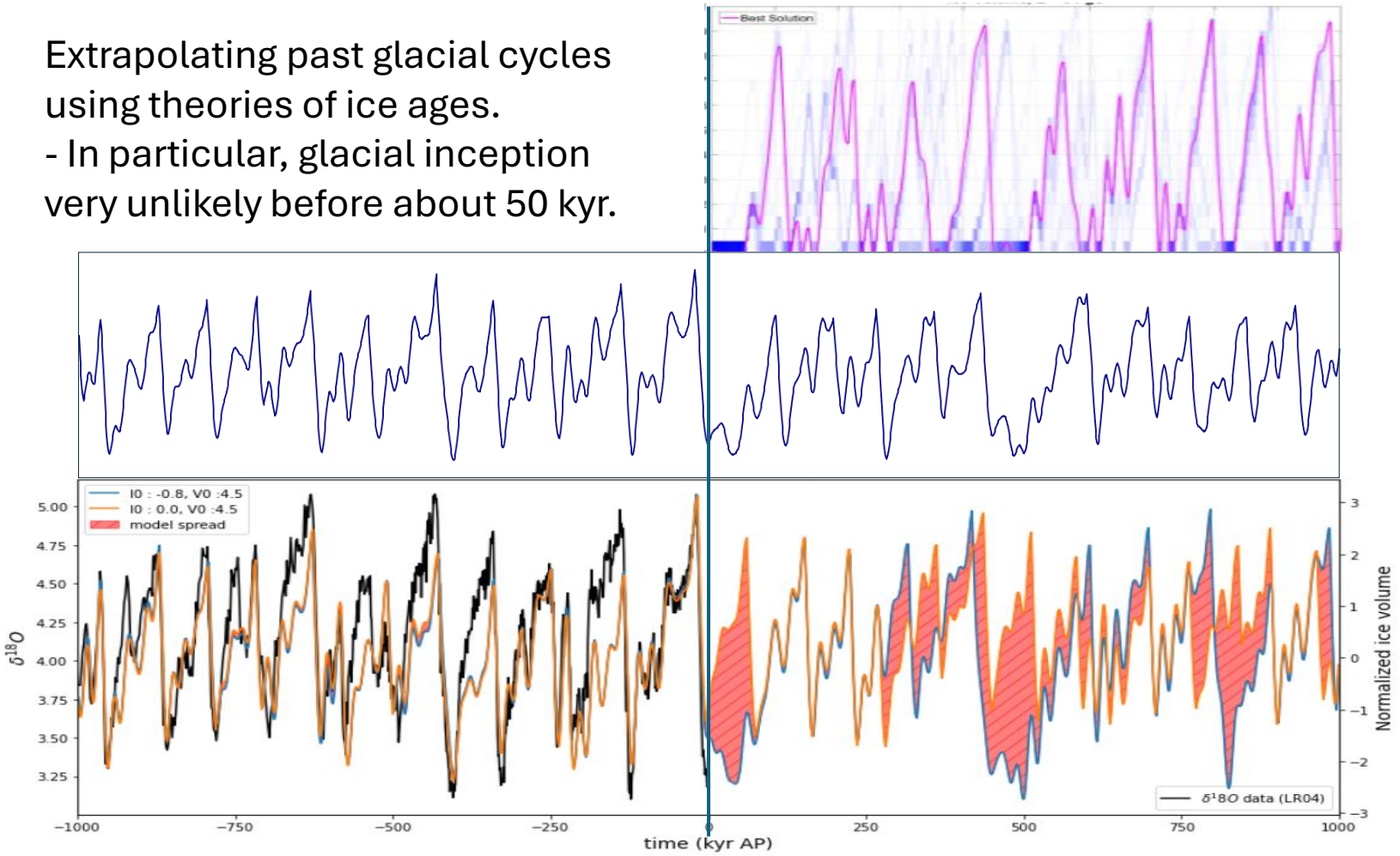
Outline

- Before the BIOCLIM european project : climate follows its natural path.
- BIOCLIM : taking into account anthropogenic GHG emissions.
- What about « tipping points » ? Leaving the Quaternary ?
- What about additional human actions ? Geo-engineering ?

CLIMATE FOLLOWS ITS NATURAL PATH

Extrapolating past glacial cycles using theories of ice ages.
- In particular, glacial inception very unlikely before about 50 kyr.



Talento et al. (ESD, 2021)

Paillard (BIOCLIM, 2001)

Leloup (PhD thesis, 2023)

CLIMATE FOLLOWS ITS NATURAL PATH

- The simplest possible hypothesis (used before BIOCLIM)

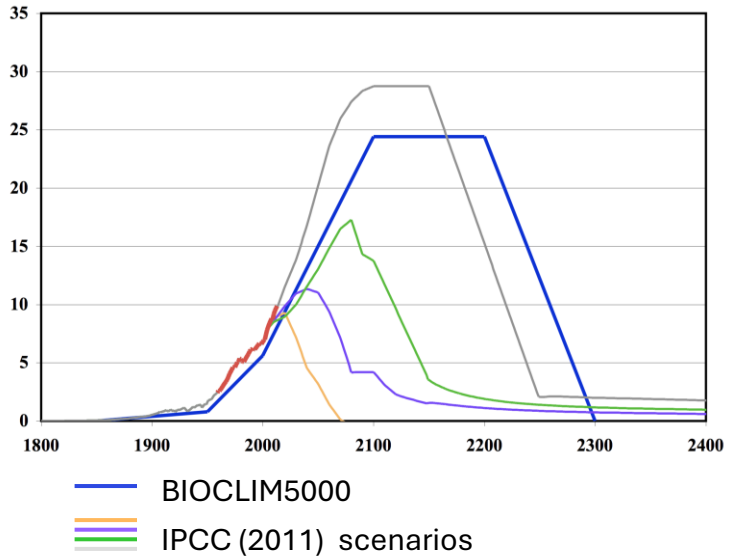
- It is then possible to use analog situations during the recent geological past (Quaternary) to get localized information on the environment

- This is **fully unrealistic**, in particular concerning the 100 to 10,000 year timescales.

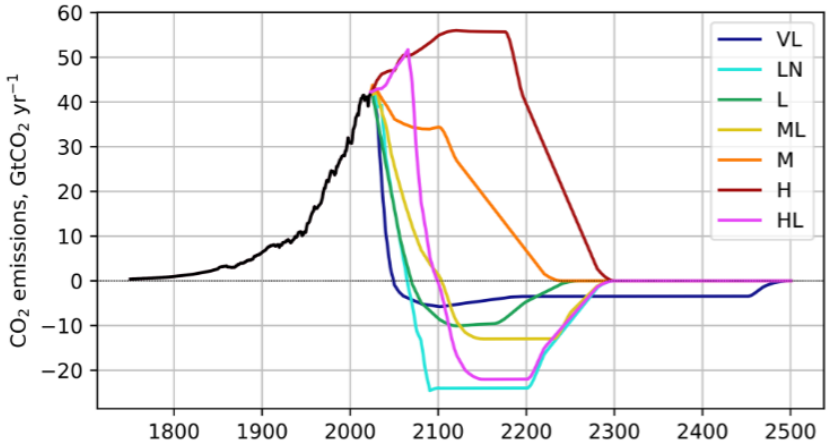
TAKING INTO ACCOUNT ANTHROPOGENIC GHG EMISSIONS

But still assuming a « Quaternary-like » situation : ie. accounting only for northern ice-sheet changes

1 - What will be the future GHG emissions ?



Cumulative emissions = 5360 GtC



CMIP7 (next IPCC) scenarios (van Vuuren et al 2026)

Cumulative emissions ~ 3800 GtC ~ 4700 GtCeq

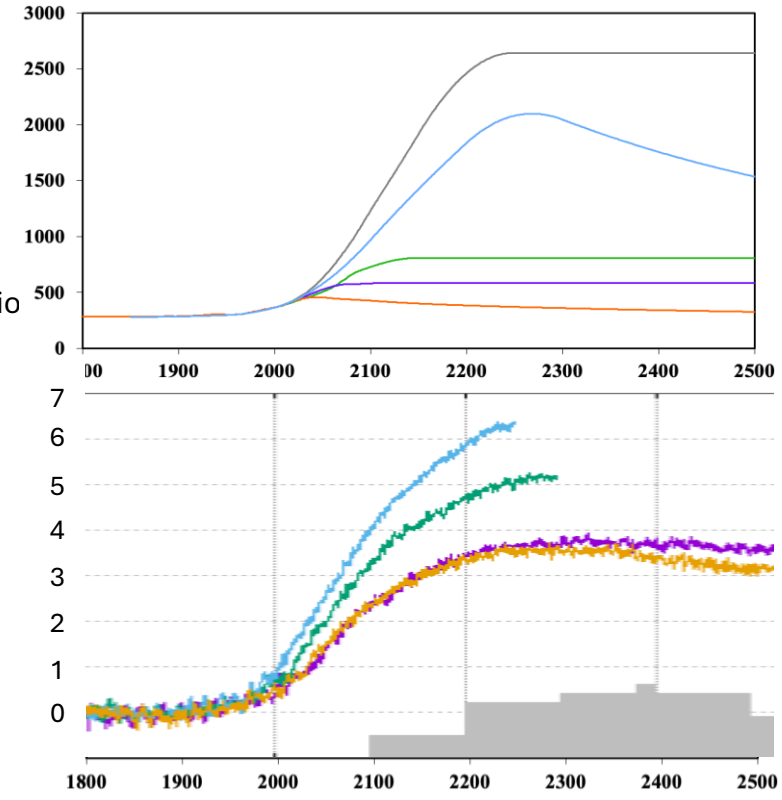
TAKING INTO ACCOUNT ANTHROPOGENIC GHG EMISSIONS

But still assuming a « Quaternary-like » situation : ie. accounting only for northern ice-sheet changes

2 - What will be the atmospheric concentration in GHG and the Earth's global temperature ?

BIOCLIM5000 assuming a crude linear carbon cycle model (exponential decay in the atmosphere)

IPCC (2011) scenario

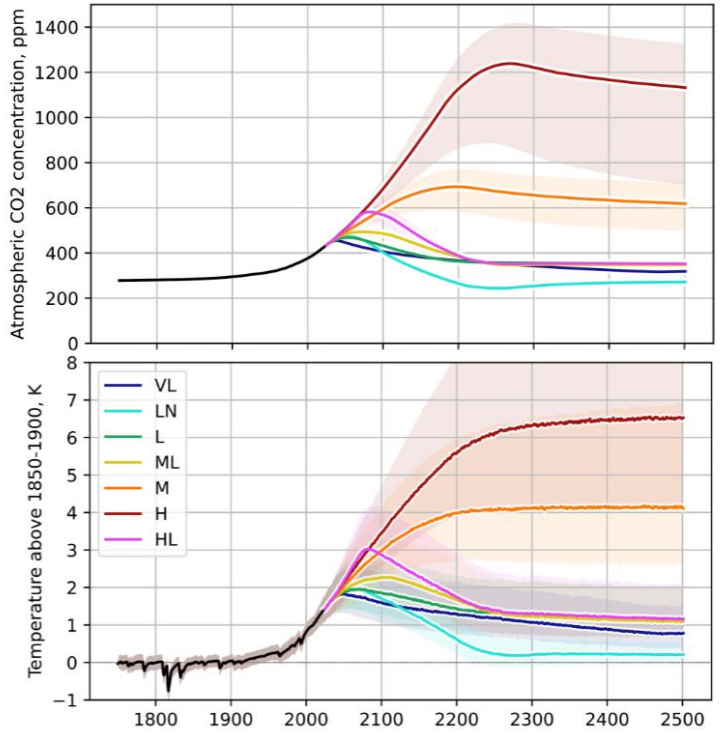


Results from the iLOVECLIM climate model

Enhanced sensitivity

Standard

With FWF



CMIP7 (next IPCC) scenarios (van Vuuren et al 2026)

TAKING INTO ACCOUNT ANTHROPOGENIC GHG EMISSIONS

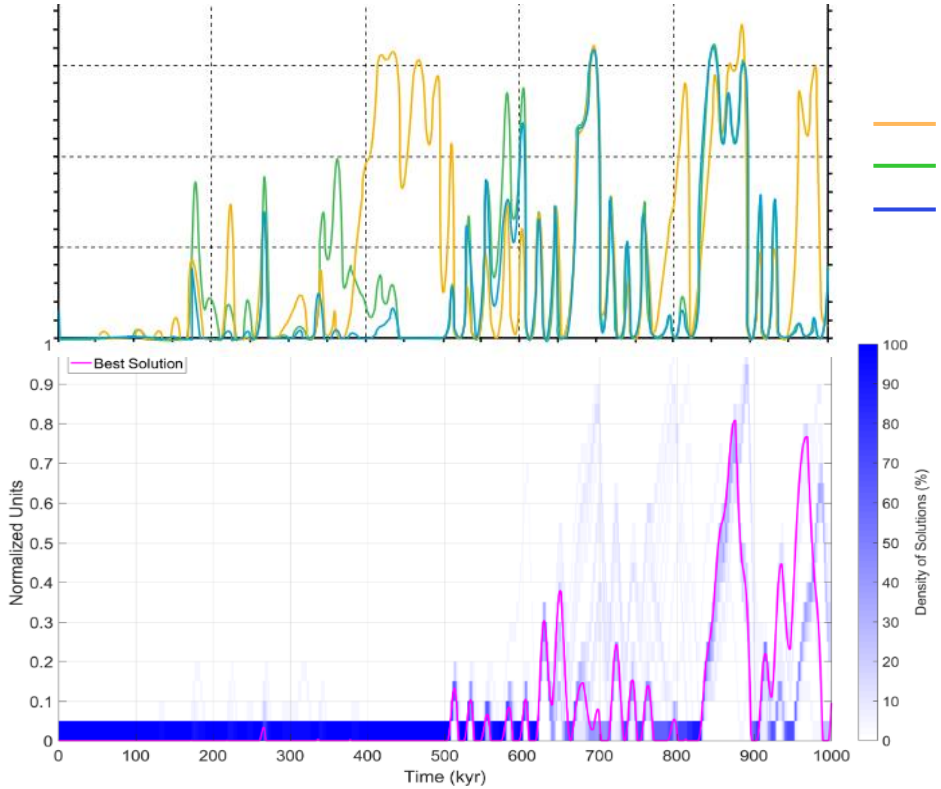
But still assuming a « Quaternary-like » situation : ie. accounting only for northern ice-sheet changes

3 - What will be the ice-sheet long-term future evolution ?

- The standard scenarios are assuming GHG emissions up to about 2300, then a <u>slow natural decrease.</u>

- The natural timescale of carbon being very long (between 200,000 and 400,000 years), the recovery of large glaciations does not happen before the 2nd half of the end of the next million year.

- A much more realistic scenario than the « natural » scenarios, at least for ice-sheets (but not for climate !).



(BIOCLIM, 2001)

BIOCLIM B1 (3000 GtC + regression)
BIOCLIM B3 (3000 GtC + C cycle)
BIOCLIM B4 (5000 GtC + C cycle)

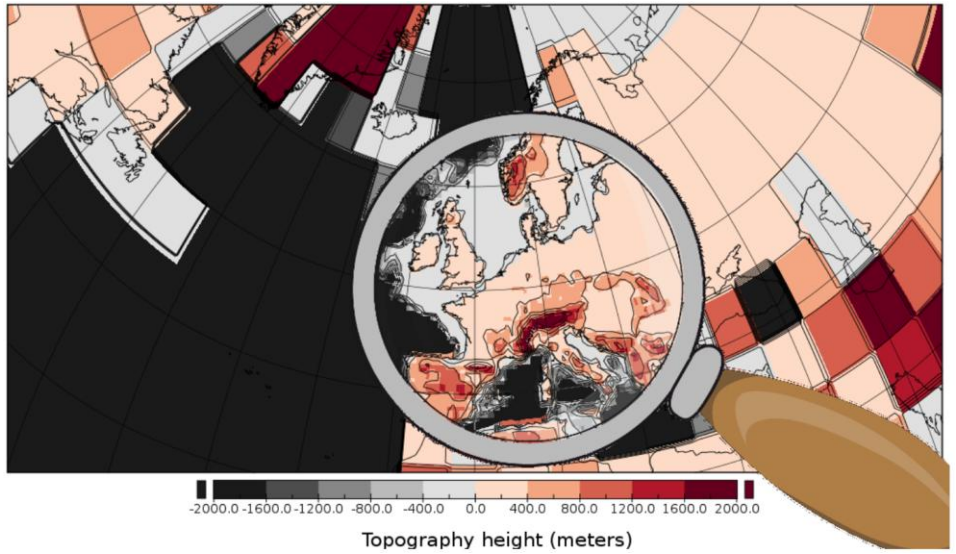
Talento et al. (ESD, 2021)

(3000 GtC + C cycle)

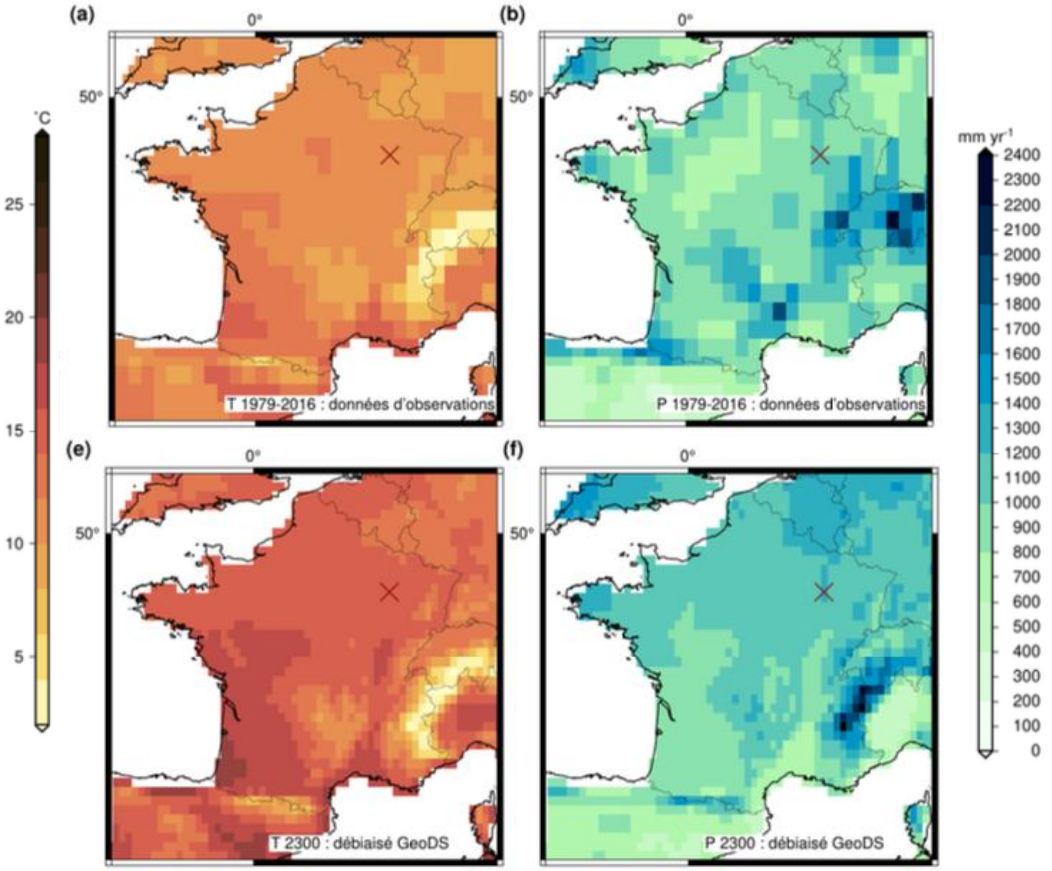
HOW ABOUT THE LOCAL CLIMATE ?

Downscaling

From about 500 km resolution to about 50 km resolution



Brenner et al. (GMD, 2021)



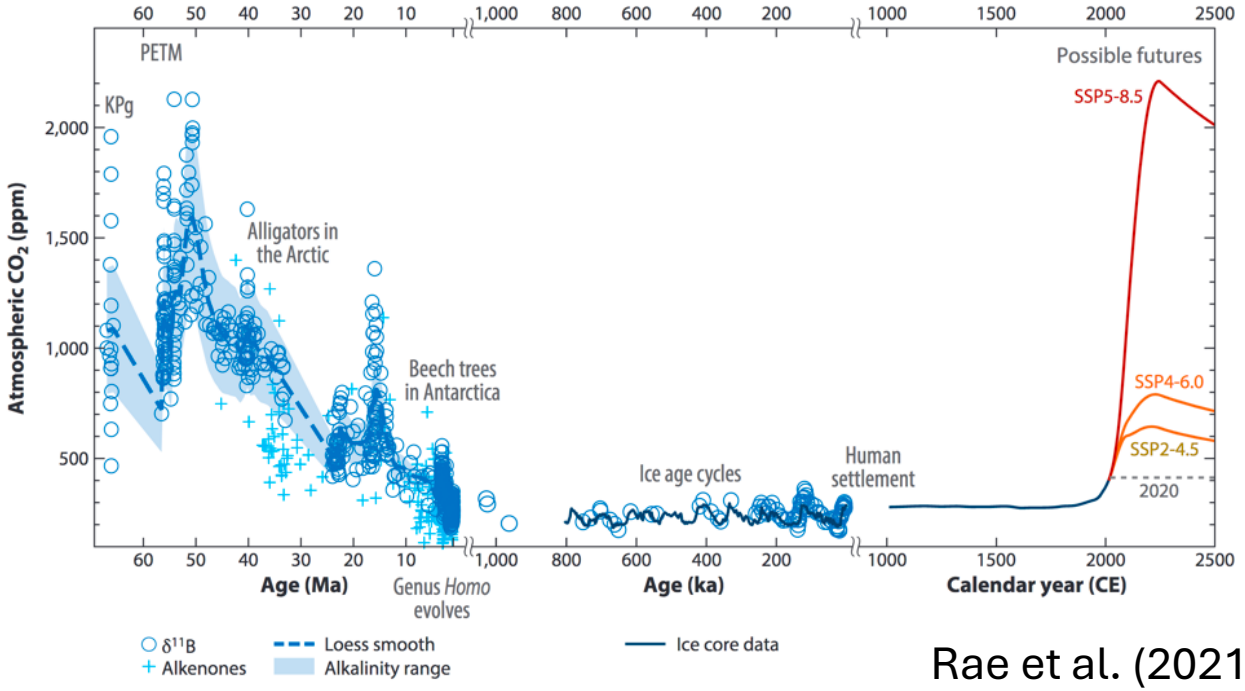
2000
T, P
annual

2300
T, P
annual

WHAT ABOUT « TIPPING POINTS » ?

We are leaving the Quaternary : northern ice-sheets should not be the only phenomena of interest !

- Melting partly or completely Antarctica ?
- Stopping temporarily or permanently the AMOC ?
- Releasing vast amounts of carbon in soils, permafrosts, marine clathrates, … ?
- Changing ecosystems up to the point of affecting Earth's climate ?
- …

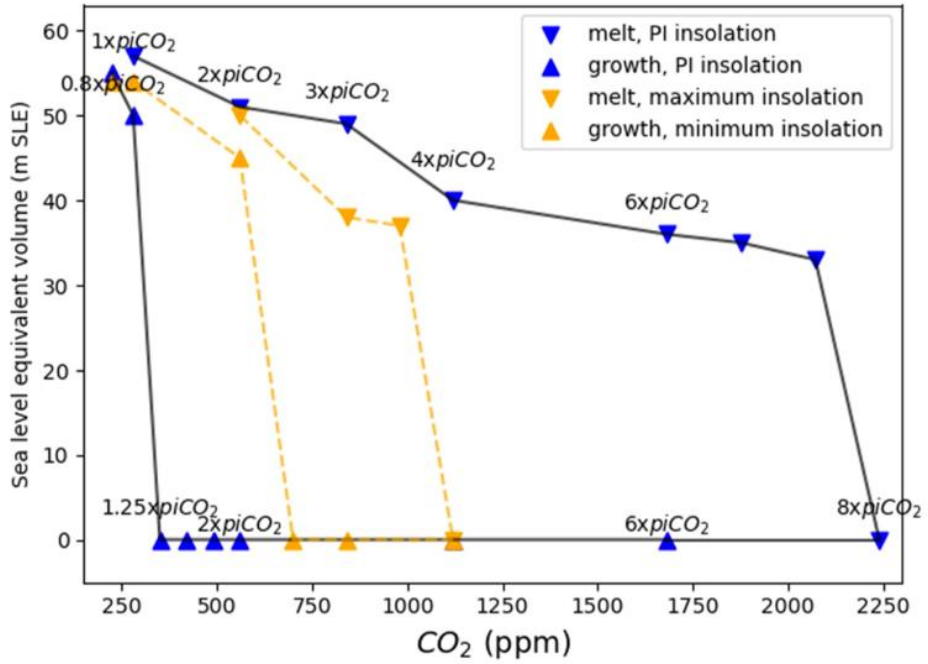


Rae et al. (2021)

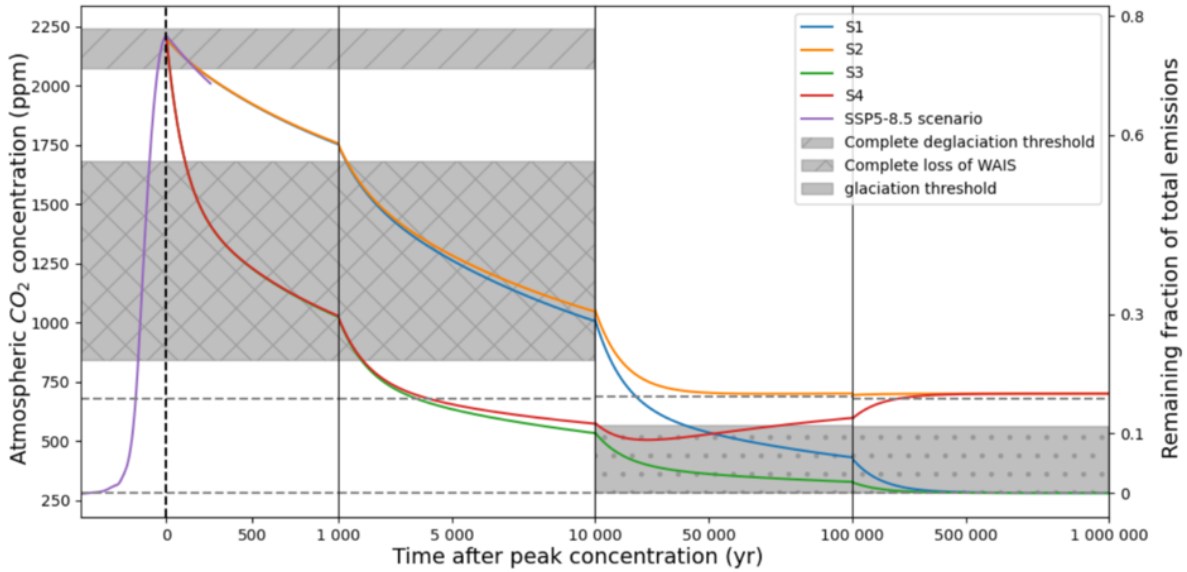
WHAT ABOUT « TIPPING POINTS » ?

Melting partly or completely Antarctica ?

Leloup (PhD thesis, 2023)



Antarctica may melt entirely *for CO_2 levels between 1000 and 2000 ppm and irreversibly as long as CO_2 remains above 600-700 ppm.*

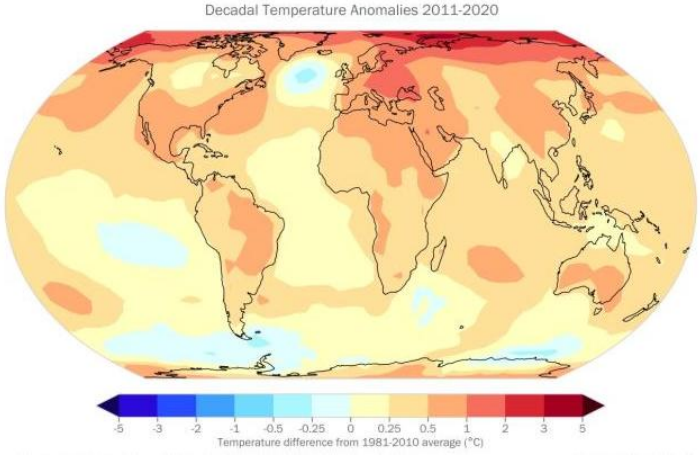


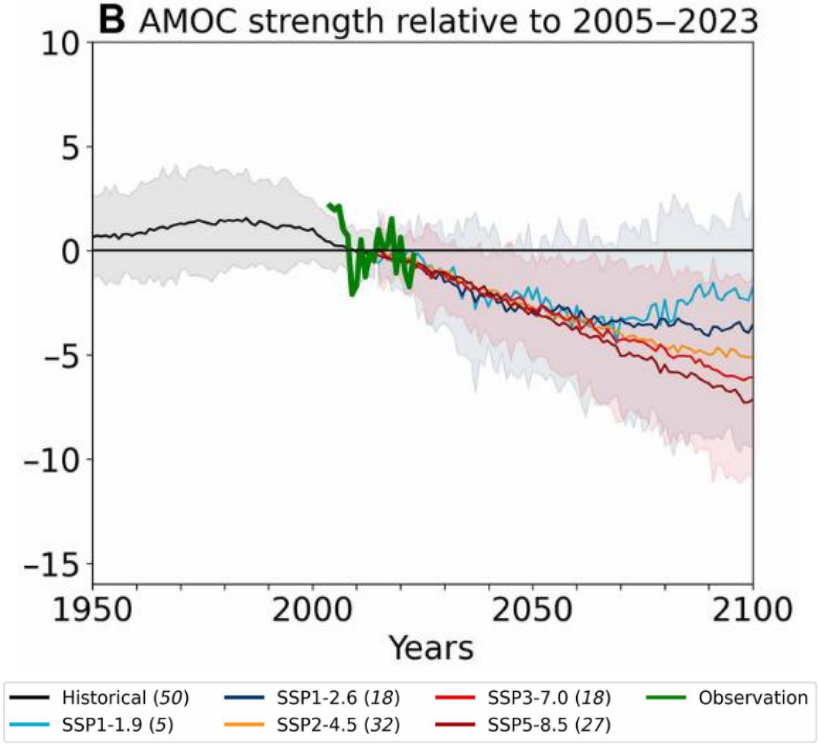
Depending on assumptions, a partial or complete loss of Antarctica may well happen in the future

WHAT ABOUT « TIPPING POINTS » ?

Stopping temporarily or permanently the AMOC ?

- AMOC is already currently slowing down





- Collapse is **likely to happen** in the 22nd century (possibly earlier, or later). It is unlikely to be « permanent ».

- It would affect significantly european climate (in particular in terms of « meteorological events » : extremes of wind, droughts, flooding ...)

WHAT ABOUT ADDITIONAL HUMAN ACTIONS ?

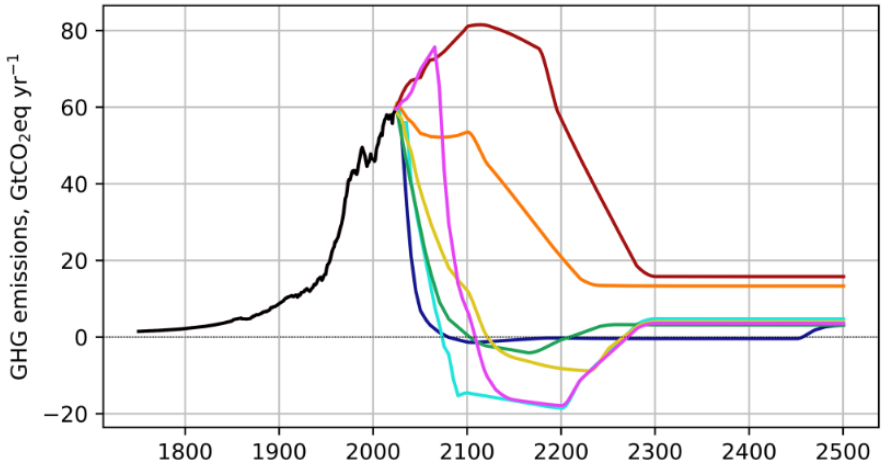
Carbon capture, geo-engineering, …

- Many of the new scenarios of the IPCC rely on « negative emissions » (even though the technology is not there)

- Compensating for long-term (natural) climate evolution would be much more easier (~ 100 smaller carbon fluxes)

- Climate « stabilization » is very unlikely for the 21st century, but **extremely likely** for long-term future (if human society still exist)

- The key difficulty would then become to decide what is the « optimal » climate for human society



CMIP7 (next IPCC) scenarios (van Vuuren et al 2026)

CONCLUDING REMARKS

- Currently, the largest geological force modifying the Earth's future climate is human society : we are leaving the Quaternary period.

- « Natural scenarios » are equivalent to state « humans do not exist »

- « GHG-spike scenarios » are equivalent to state « humans disappear after 2300 » or « technological progress stops right now »

- The IPCC scenarios are based more and more on what human society would like to happen, even if the technology is not there today. Long-term climate scenarios should also consider some « optimal » scenarios that could be chosen in the future.