The impact of bathymetry on the simulated carbon at the LGM

fanny.lhardy@lsce.ipsl.fr

F. Lhardy, N. Bouttes, D. M. Roche, A. Abe-Ouchi, Z. Chase, K. Crichton, R. Ivanovic, M. Jochum, M. Kageyama, H. Kobayashi, L. Menviel, J. Muglia, R. Nuterman, A. Oka, G. Vettoretti, and A. Yamamoto

Ocean volume of PMIP models

PMIP-carbon: 1st multimodel comparison of coupled climate-carbon simulations at the LGM

Model name	Ocean resolution lat × lon (levels)	Atmospheric CO_2	Ice sheet reconstruction	Ocean boundary conditions	Adjustment of DIC, alkalinity, nutrients
MIROC4m	$\sim 1^\circ \times 1^\circ \times$ (43)	freely evolving	ICE-5G	unchanged	no
CLIMBER-2	$2.5^\circ \times 3$ basins (21)	freely evolving	ICE-5G	unchanged	yes (3.3%)
CESM	$\sim 400 - 40$ km (60)	freely evolving	ICE-6G-C	changed	yes (5.7%)
iLOVECLIM	$3^\circ \times 3^\circ$ (20)	freely evolving	GLAC-1D, ICE-6G-C	changed	yes (3.9%)
IPSL-CM5A2	$2^\circ - 0.5^\circ$ (31)	prescribed	PMIP3	changed	yes? (3%?)
MIROC-ES2L	$1^\circ \times 1^\circ$ (63)	prescribed	ICE-6G-C	changed	yes (3%)
LOVECLIM	$3^\circ \times 3^\circ$ (20)	prescribed	ICE-6G-C	unchanged	yes (3.3%)
UVic	$3.6^\circ \times 1.8^\circ$ (19)	prescribed	GLAC-1D, ICE-6G-C, PMIP3	unchanged	no

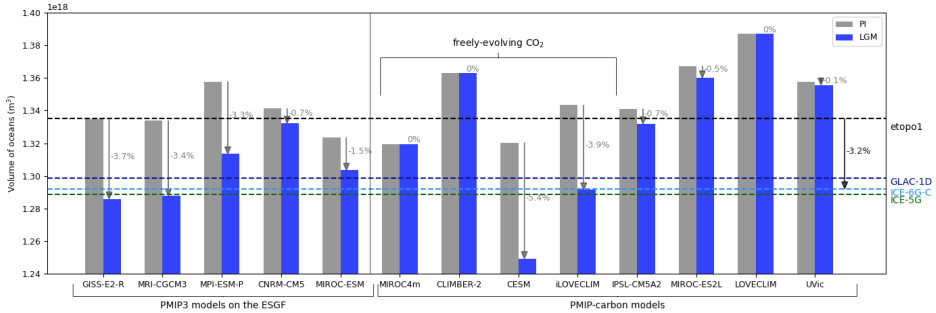


Fig.: Ocean volume in PMIP models. Dashed lines: ocean volume computed from high resolution topographic files.

We see that the changes associated with a **low sea level** are accounted differently in models:

- Ocean volume is **rarely accurate** in PMIP simulations of the LGM.
- Ocean volume change **conditions the adjustments** recommended in Kageyama et al., 2017.

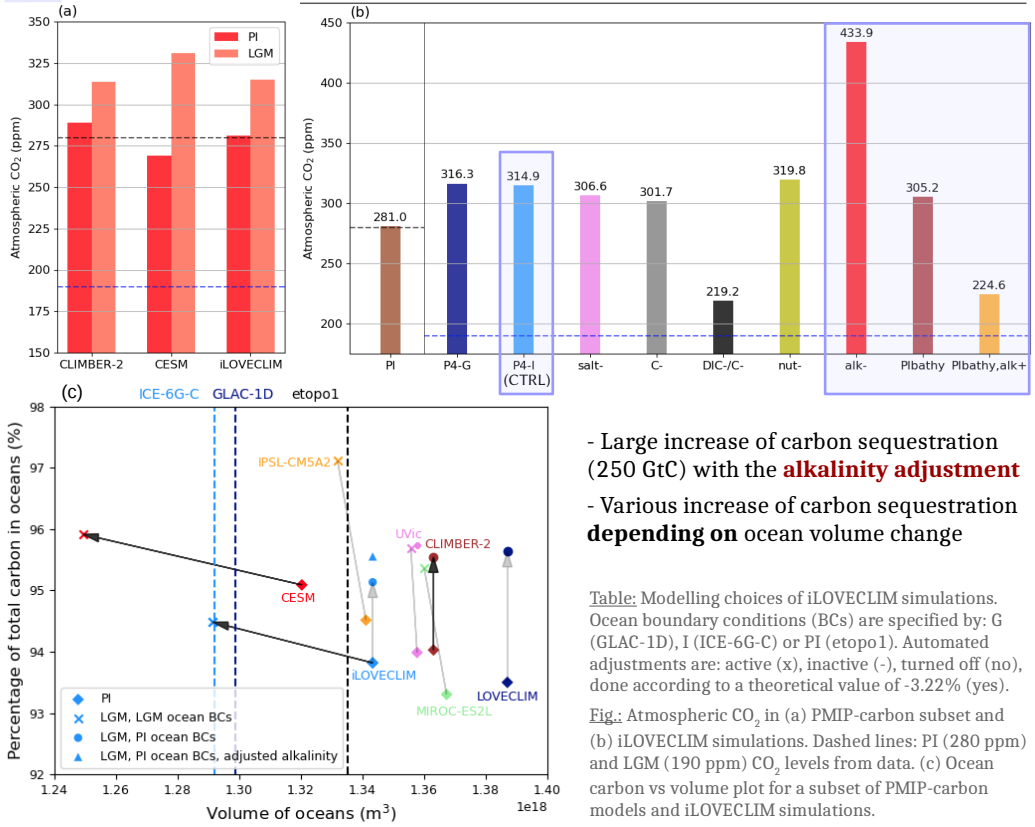
Take-home messages

- **Consistency** between models is needed when dealing with large changes of bathymetry to enable multimodel comparisons of coupled carbon-climate simulations at the LGM .
In particular, the **ocean volume and related alkalinity adjustment** should be carefully considered as there is a risk of simulating a low CO_2 for the wrong reasons.
- PMIP-carbon models are **far from simulating the CO_2 drawdown**, especially if they have a low ocean volume at the LGM.

Simulated carbon at the LGM

iLOVECLIM sensitivity tests

Simulation name	P4-G	P4-I	salt-	C-	DIC-/C-	nut-	alk-	PIbathy	PIbathy,alk+
Ocean BCs	G	I	I	I	I	I	I	PI	PI
Salt conservation	×	×	no	×	×	×	×	–	–
Carbon conservation	×	×	×	no	no	×	×	–	–
DIC adjustment	×	×	×	×	no	×	×	–	–
Nutrients adjustment	×	×	×	×	×	no	×	–	–
Alkalinity adjustment	×	×	×	×	×	×	no	–	yes



- Large increase of carbon sequestration (250 GtC) with the **alkalinity adjustment**
- Various increase of carbon sequestration **depending on** ocean volume change

Table: Modelling choices of iLOVECLIM simulations. Ocean boundary conditions (BCs) are specified by: G (GLAC-1D), I (ICE-6G-C) or PI (etopo1). Automated adjustments are: active (x), inactive (-), turned off (no), done according to a theoretical value of -3.22% (yes).

Fig.: Atmospheric CO_2 in (a) PMIP-carbon subset and (b) iLOVECLIM simulations. Dashed lines: PI (280 ppm) and LGM (190 ppm) CO_2 levels from data. (c) Ocean carbon vs volume plot for a subset of PMIP-carbon models and iLOVECLIM simulations.

Kageyama et al. (2017). The PMIP4 contribution to CMIP6 Part 4: Scientific objectives and experimental design of the PMIP4-CMIP6 Last Glacial Maximum experiments and PMIP4 sensitivity experiments. *GMD*.