Challenges raised by global ocean configurations in the context of climate modelling

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NEMO R&D team's *chef*

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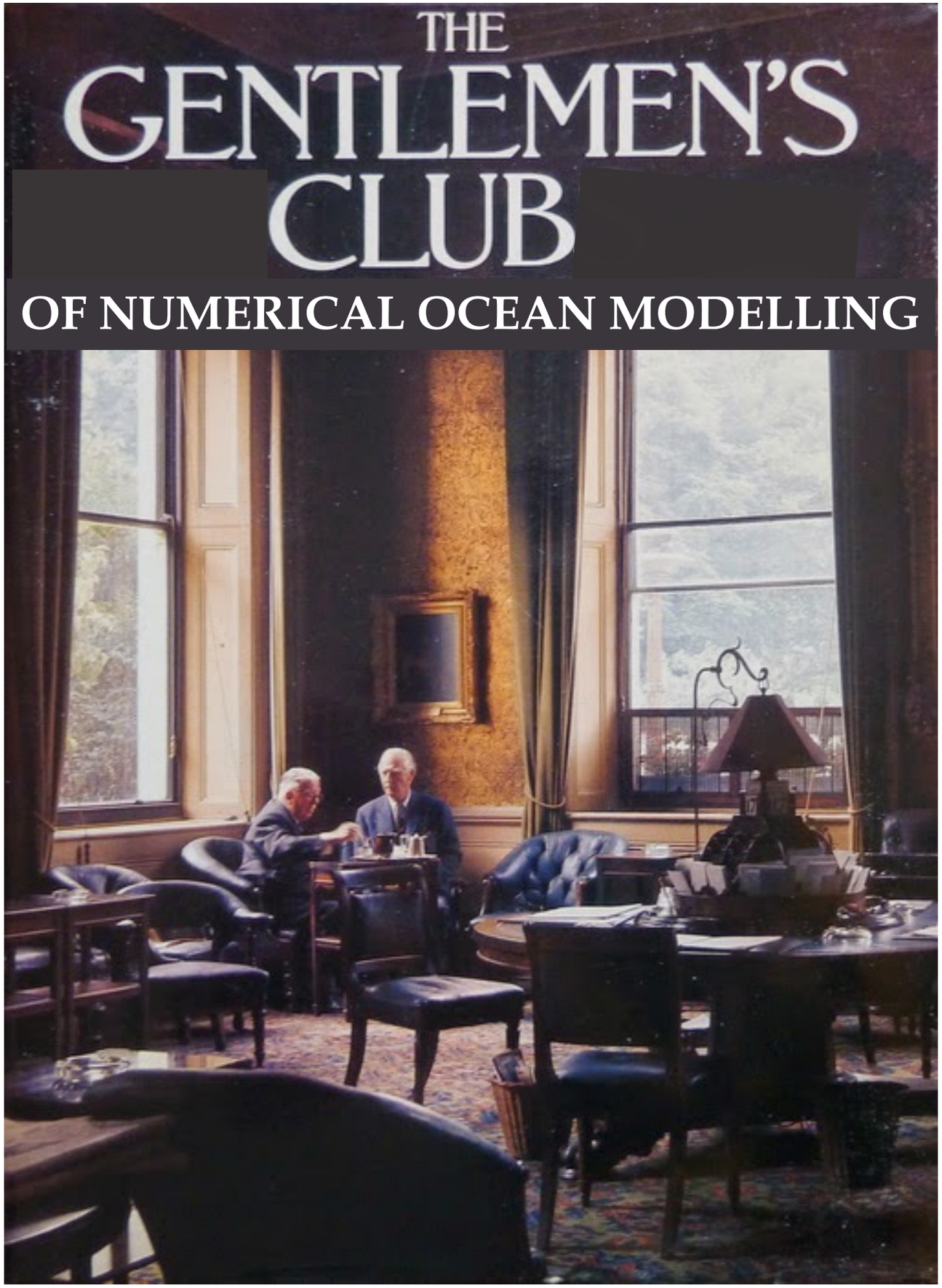
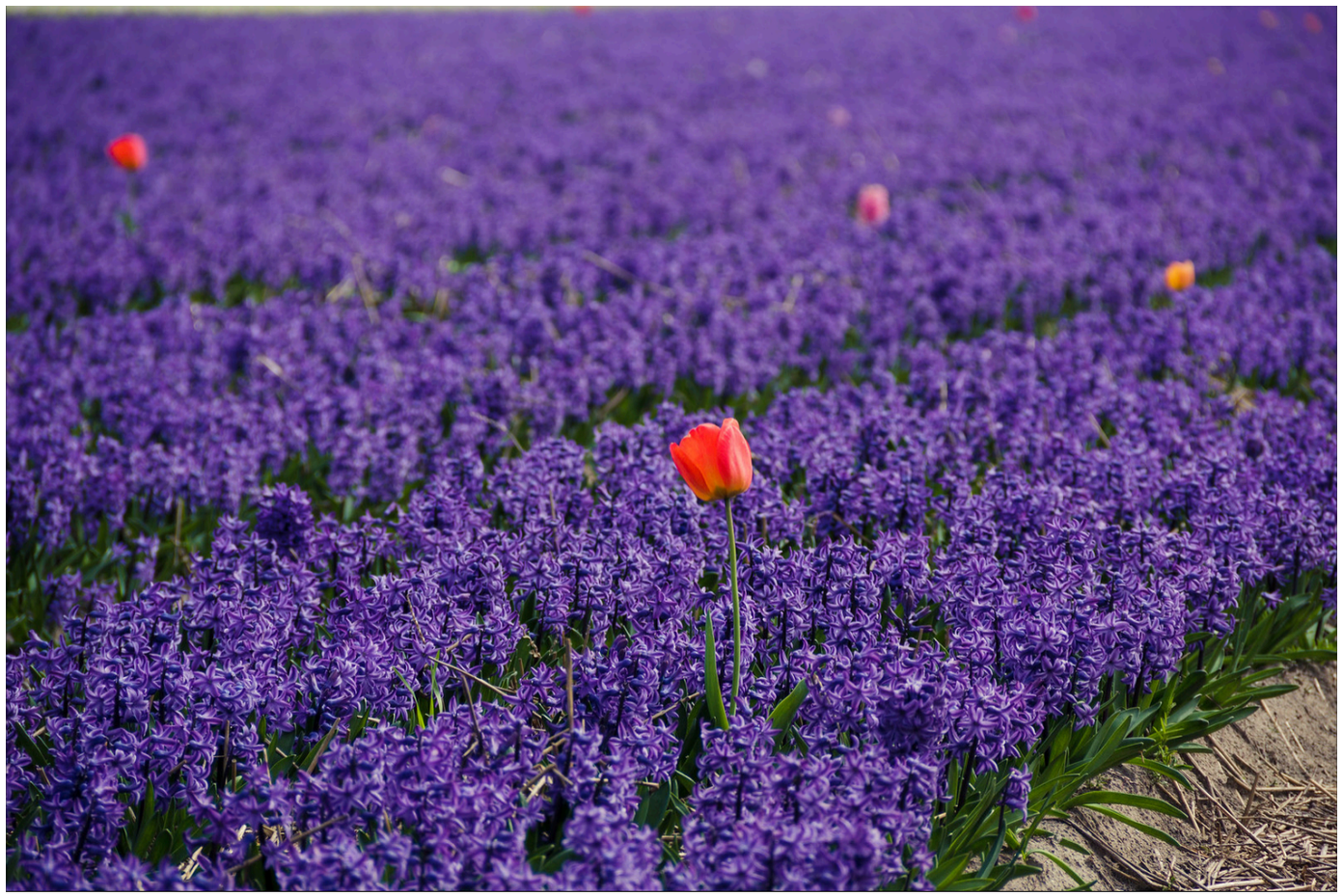

THE
GENTLEMEN'S
CLUB
OF NUMERICAL OCEAN MODELLING



[1] In IPSL-CM6A-LR, after more than 2,000 yr of integration (using pre-industrial external forcings), the deep ocean has not reached an equilibrium, yet….

IPSL-CM6A-LR = NEMO (362x332x75) + LMDz (144x143x79) + ORCHIDEE (land) + OASIS (coupled) + XIOS (I/O)

Environmental cost of CMIP6 exercice at IPSL ?

100 x10^6 CPU hours for CMIP6 production required 2.4 x10^9 Wh

1.2 PB data (accessible via ESGF) requires 300 x10^6 Wh for storage each year

in France, electricity produces 40 g CO_2 / kWh

Hence IPSL-CM6A-LR **production** of CMIP6 simulations emitted **~100 tons of CO2**

+ 200 x10^6 CPU hours for model development, tuning, adjustment (in coupled mode)

+ construction/destruction of supercomputer

+ environmental footprint of collaborators

still in development:

IPSL-CM6A-ESM

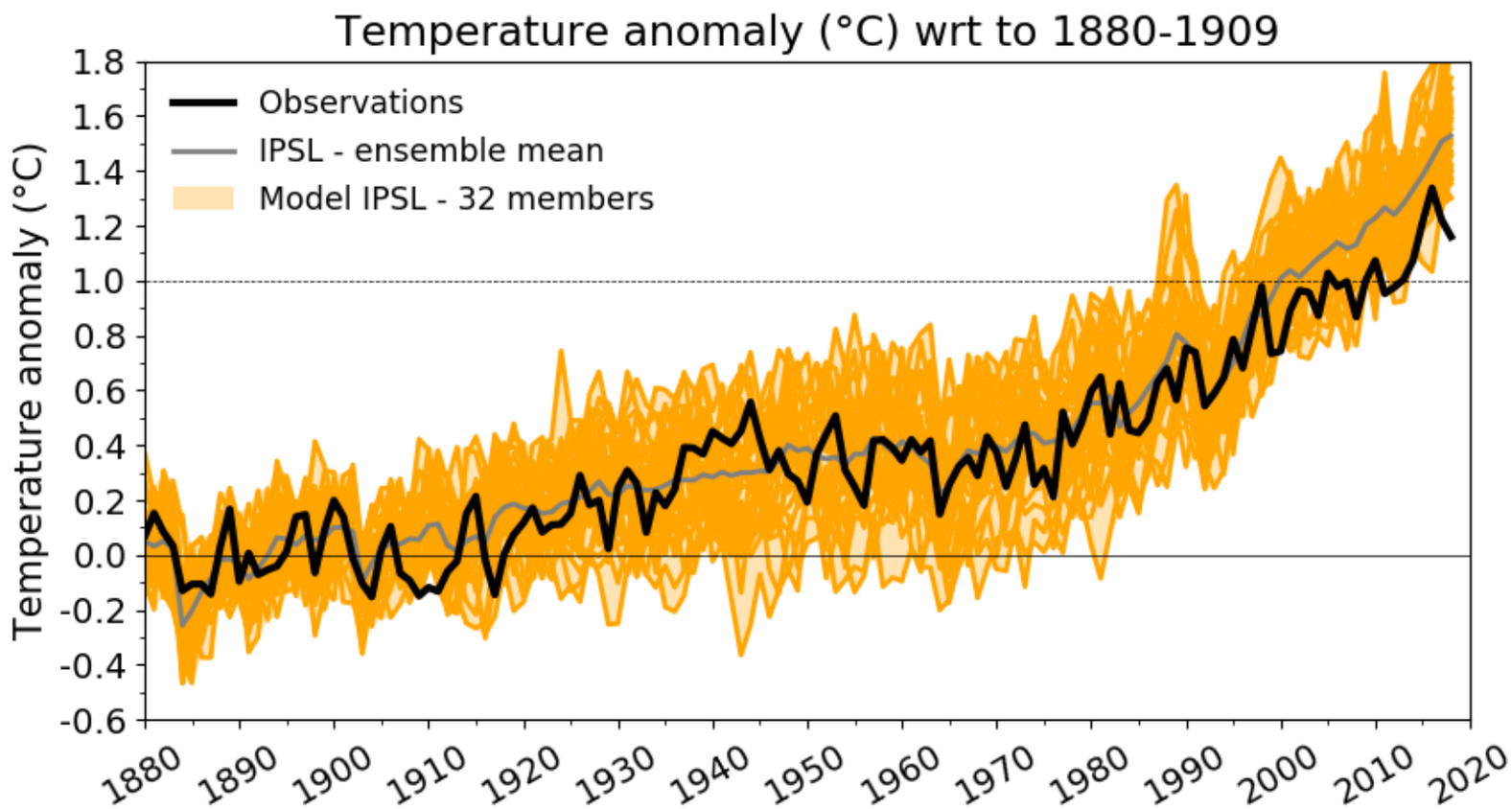
IPSL-CM6-MR1

IPSL-CM6-MR025

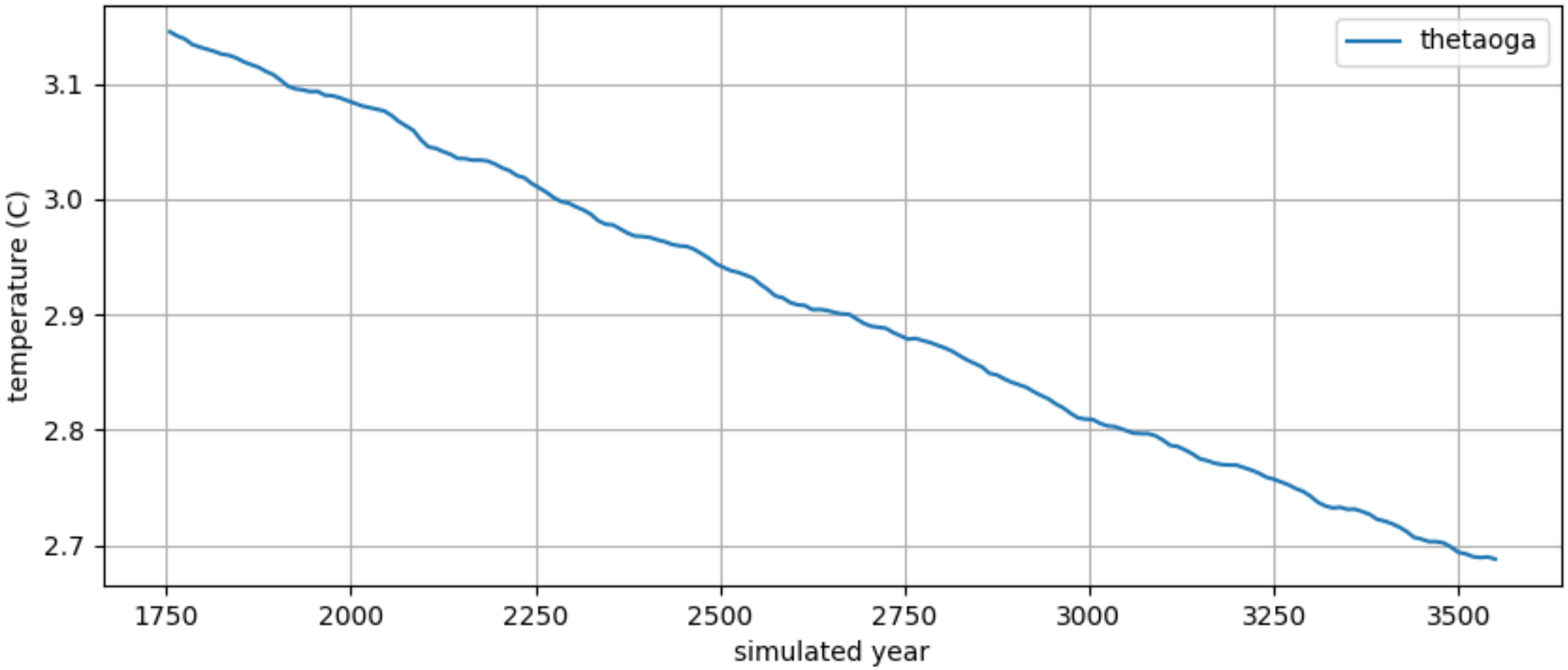
Boucher O. et al, submitted to JAMES

Institut Pierre Simon Laplace

CMC Climate Modelling Center

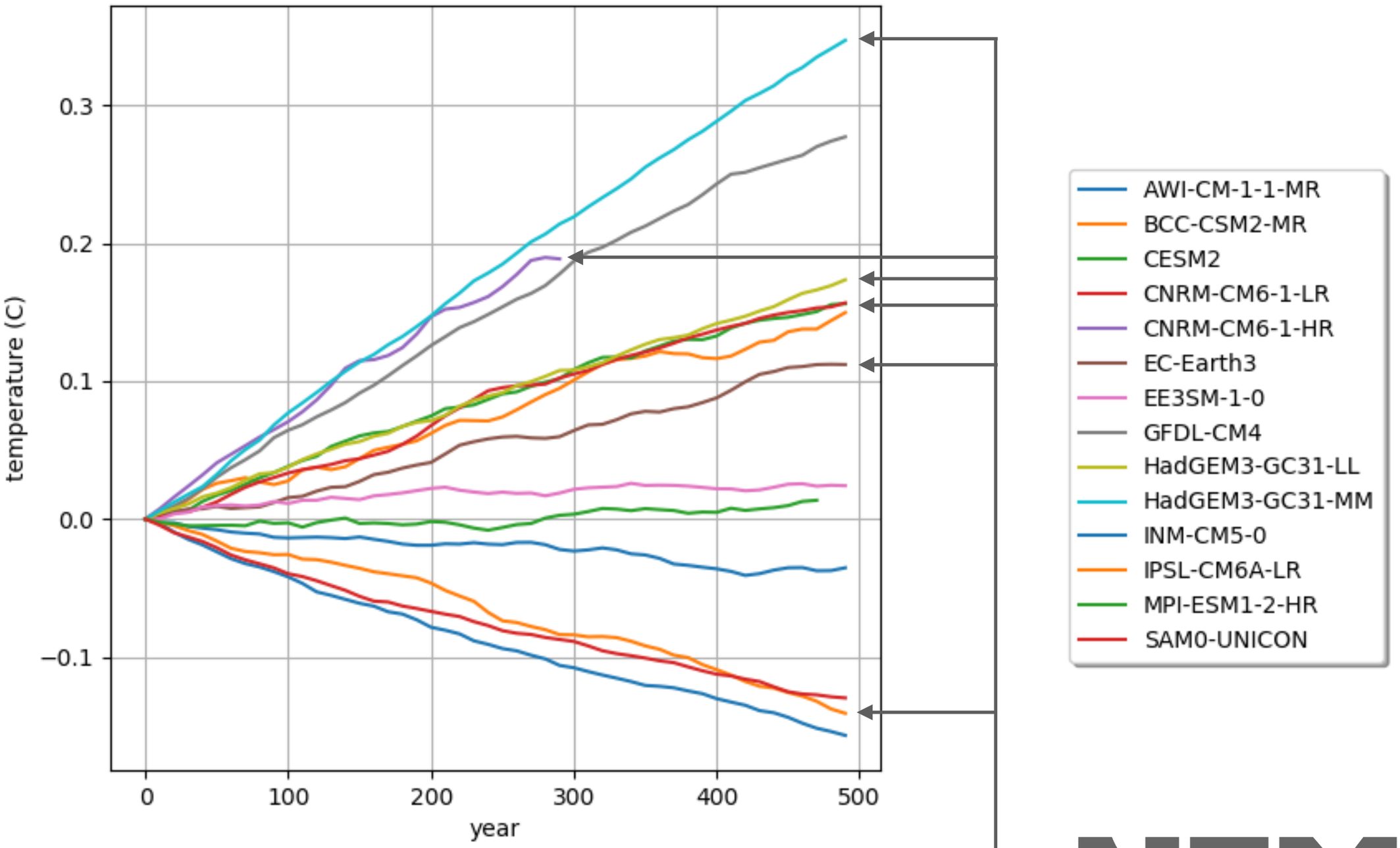


Long-term evolution of globally averaged temperature,
under fixed pre-industrial conditions (piControl experiment of CMIP6)

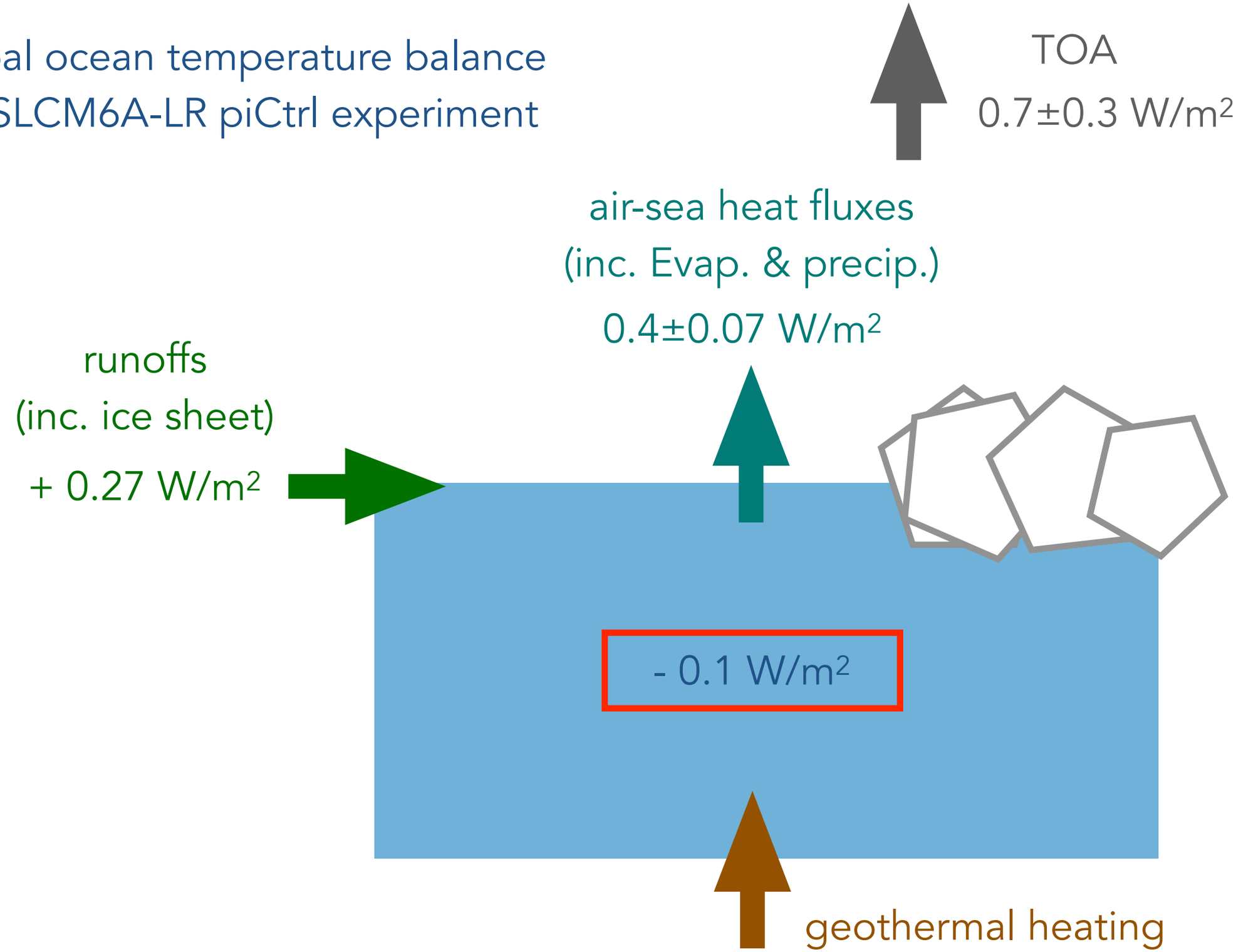


cooling trend of - 0.02 °C/100 yr
equivalent to - 0.1 W/m^2

Globally averaged temperature in various CMIP6 models (anomalies from first year of analysis)

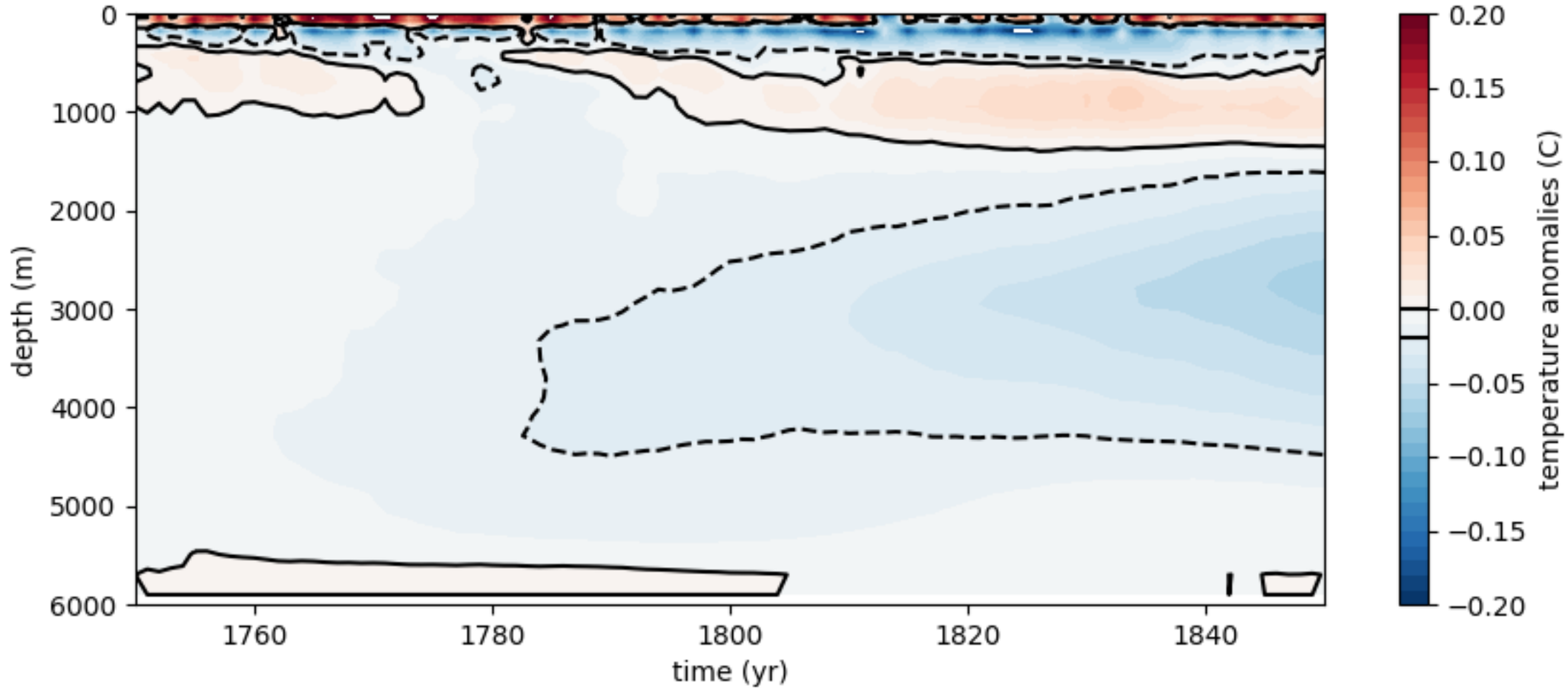


Global ocean temperature balance
in IPSLCM6A-LR piCtrl experiment



Reminder: 2 * anth. CO_2 ≈ +4 W/m²

Globally averaged temperature in IPSLCM6A-LR as a function of depth (anomalies from first year of analysis)



[1] In IPSL-CM6A-LR, after more than 2,000 yr of integration (using pre-industrial external forcings), the deep ocean has not reached an equilibrium, yet….

[physics] because of structural imbalance in air-sea heat fluxes ?
reflecting (excessive ?) deep ventilation in the Southern Ocean…

[numerics] because of numerics ? T and S advected separately, conservation of volume rather than ρ, spurious numerical diffusion …
how does long-term drift compare with accuracy of individual components (in particular the atmosphere) ?

[2] Sensitivity experiments exploring structural and parametric uncertainties indicate that some intrinsic climatic features of IPSL-CM6A-LR model are quite robust…

Within IPSL-CM6A-LR, we have identified 3 types of uncertainty in climate model simulations :

the **structural uncertainty**, related to each component (resolution, physics, numerics…),

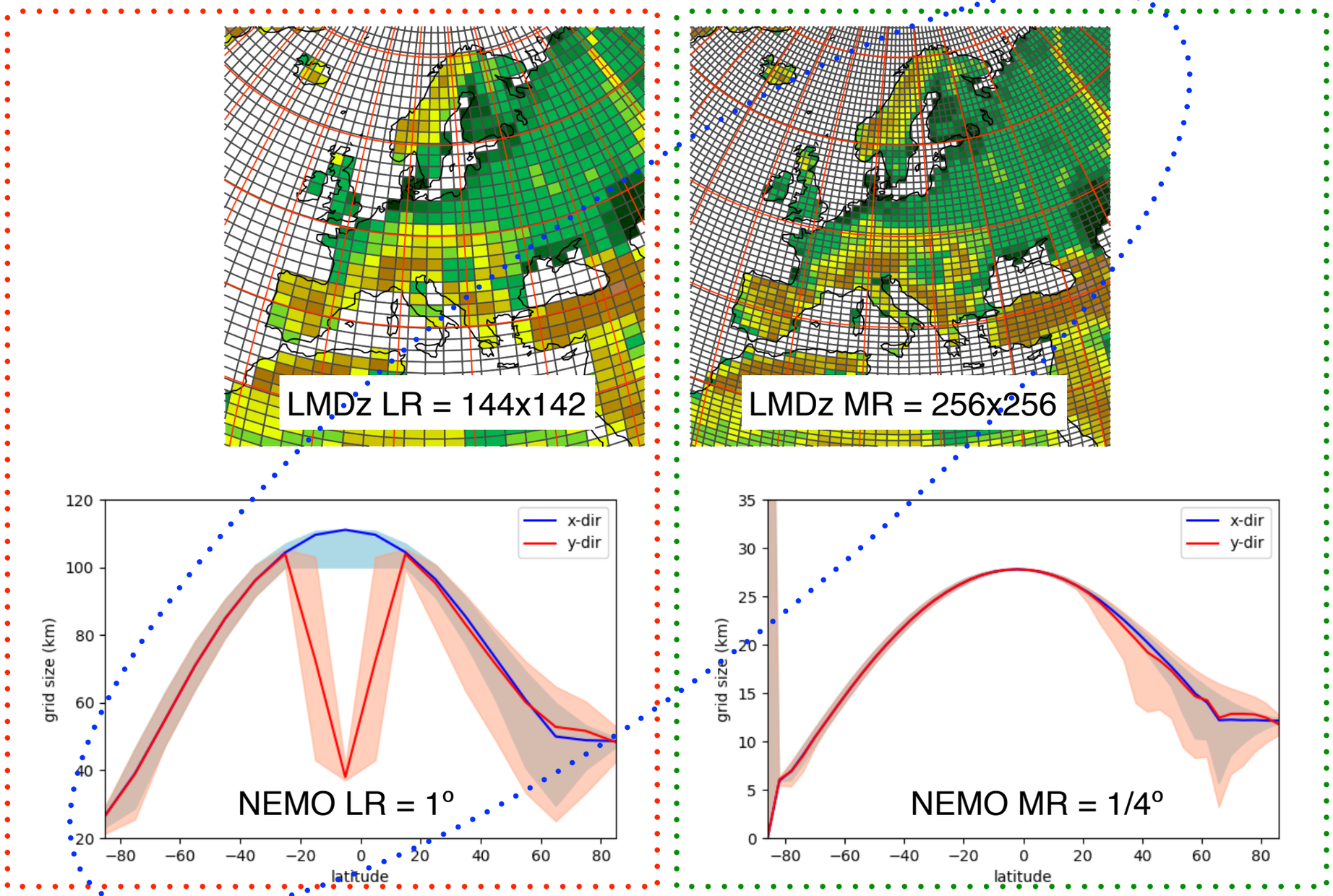
the **parametric uncertainty**, related to sub-grid-scale processes within each component and processes of interaction between components,

the **intrinsic uncertainty** due to the chaotic nature of climate.

→ 32 members in CMIP6 historical ensemble
5-11 members per ScenarioMIP
10 members per DAMIP
10 members per GMMIP
4 members per RFMIP

→ PRACE QUEST project, with Juliette Mignot and Frederic Hourdin

We are currently exploring **structural uncertainty** in IPSL-CM6A-LR through new configurations with increased resolution in ocean and/or atmosphere components :

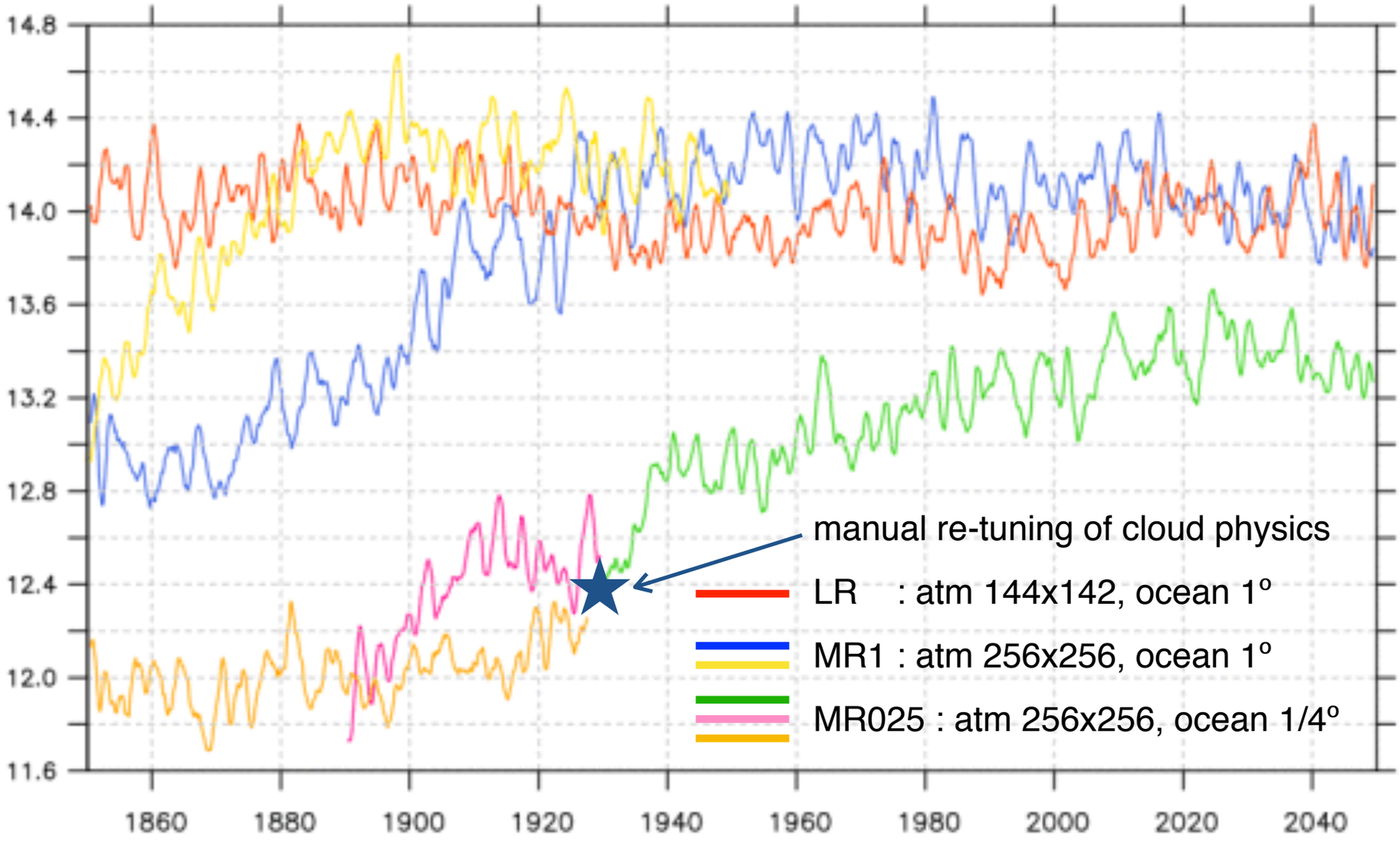


environmental cost of simulations presented here, of CMIP6 prod.

Atm LR, Ocean LR	960 cores	18,000 CPUh / 10 yr	348 kg CO2	**100 tons of CO2**
Atm MR, Ocean LR	1 800 cores	32,000 CPUh / 10 yr	920 kg CO2	***>170 tons of CO2***
Atm MR, Ocean MR	4 720 cores	100,300 CPUh / 10 yr	2 320 kg CO2	***>500 tons of CO2***

In present-day conditions (with artificially enhanced ocean surface albedo to compensate for the transient oceanic heat uptake):

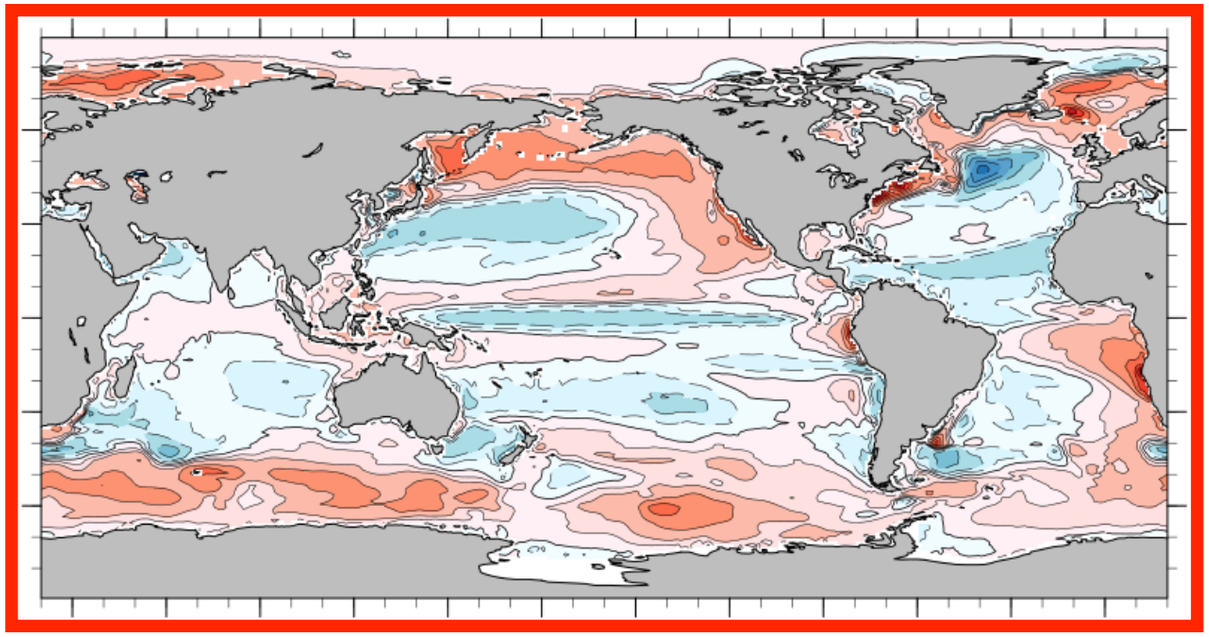
Globally averaged T2m (°C)

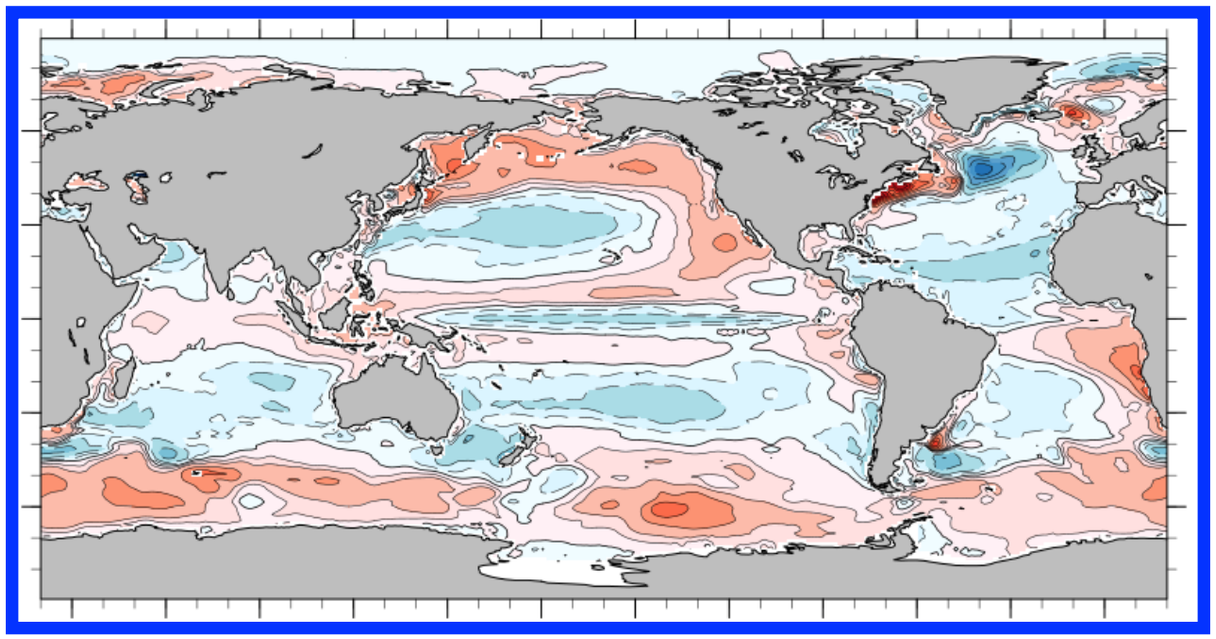


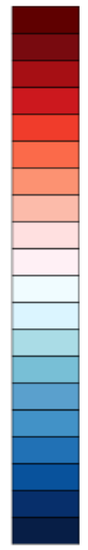
We are also exploring **parametric uncertainty** in ocean and atmosphere components :

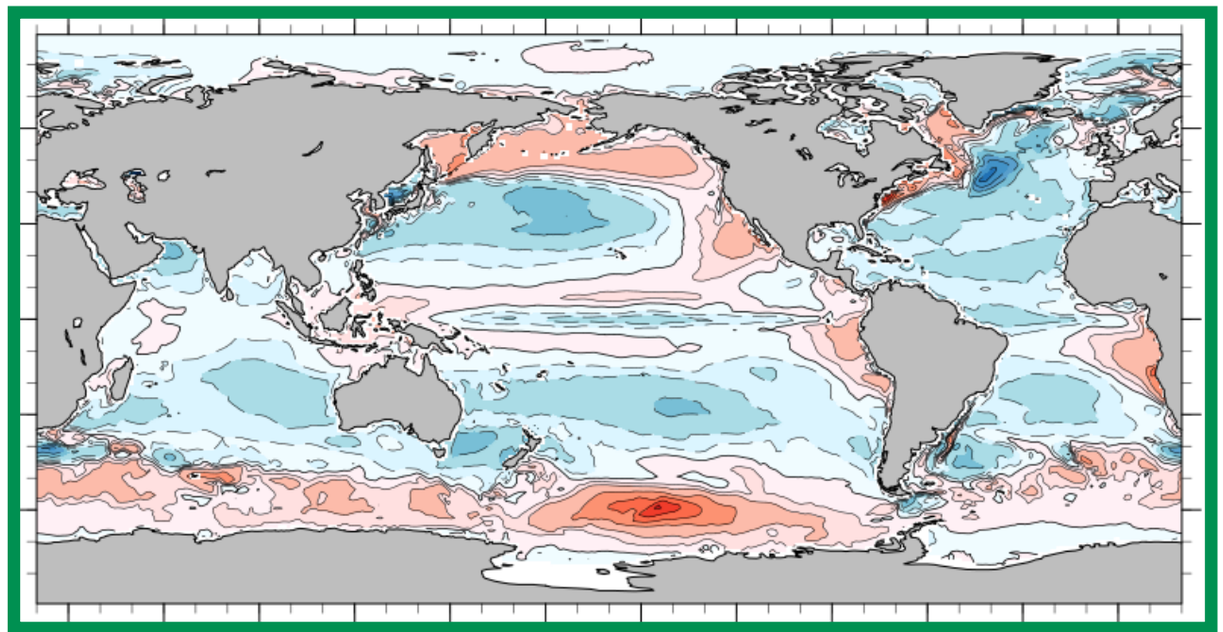
- ocean 1/4° with meso-scale parameterization
- ocean 1/4° without meso-scale parameterization
- atm 256x256 with ad-hoc tuning
- atm 256x256 with automatic tuning

SST anomalies from WOA13



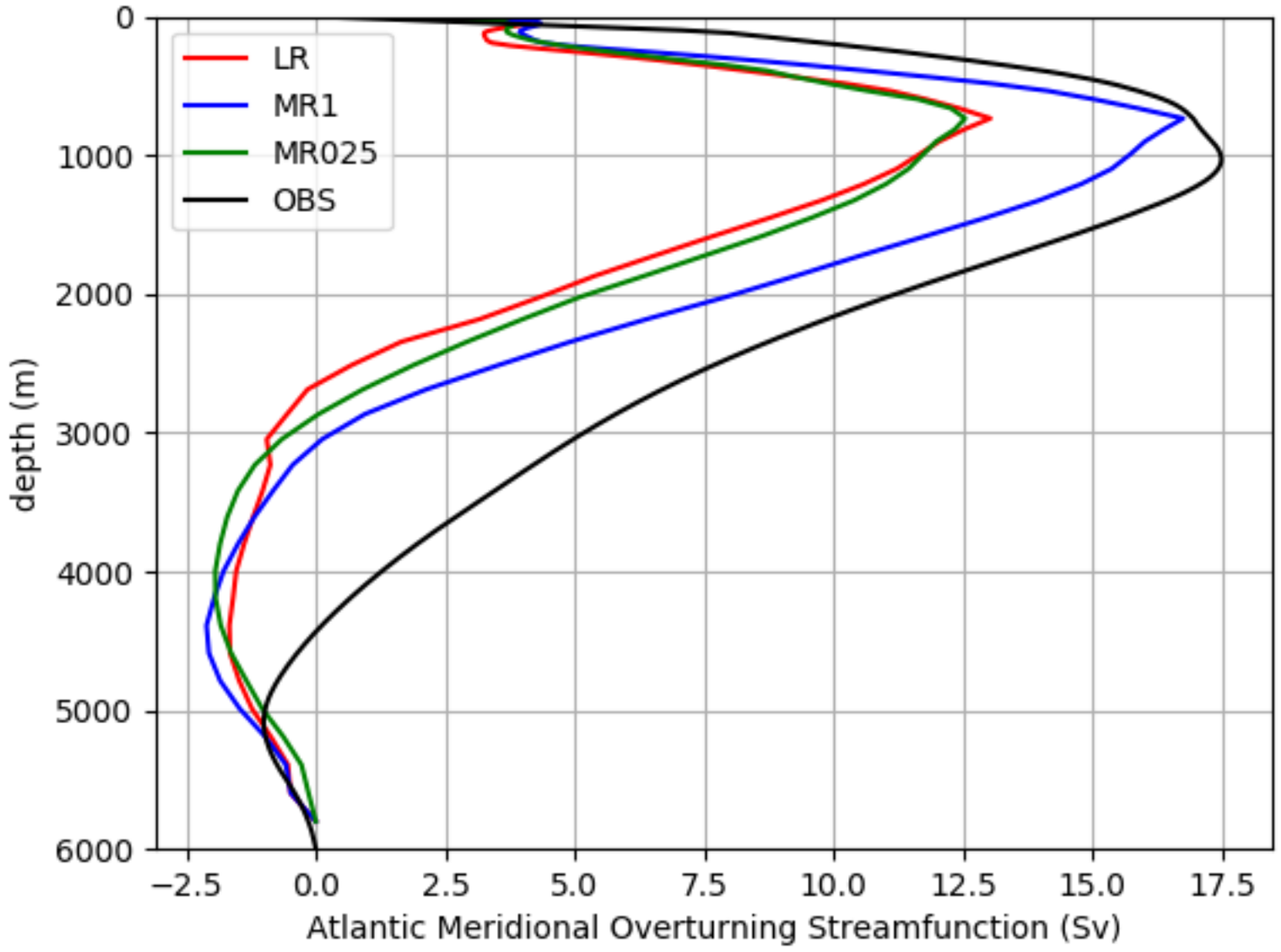






LR : atm 144x142, ocean 1°
MR1 : atm 256x256, ocean 1°
MR025 : atm 256x256, ocean 1/4°

Maximum of Atlantic Meridional Overturning Streamfunction at 26N



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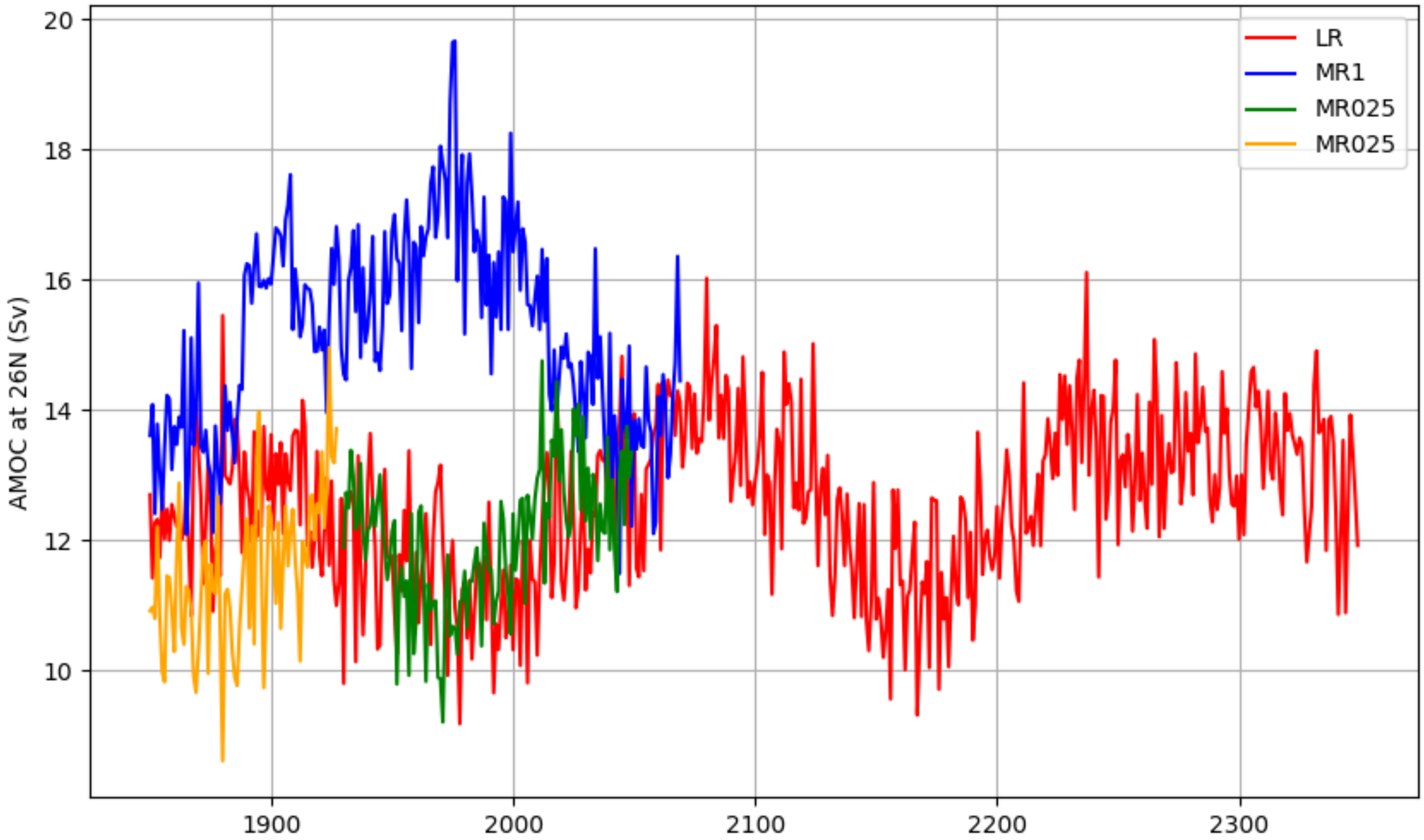

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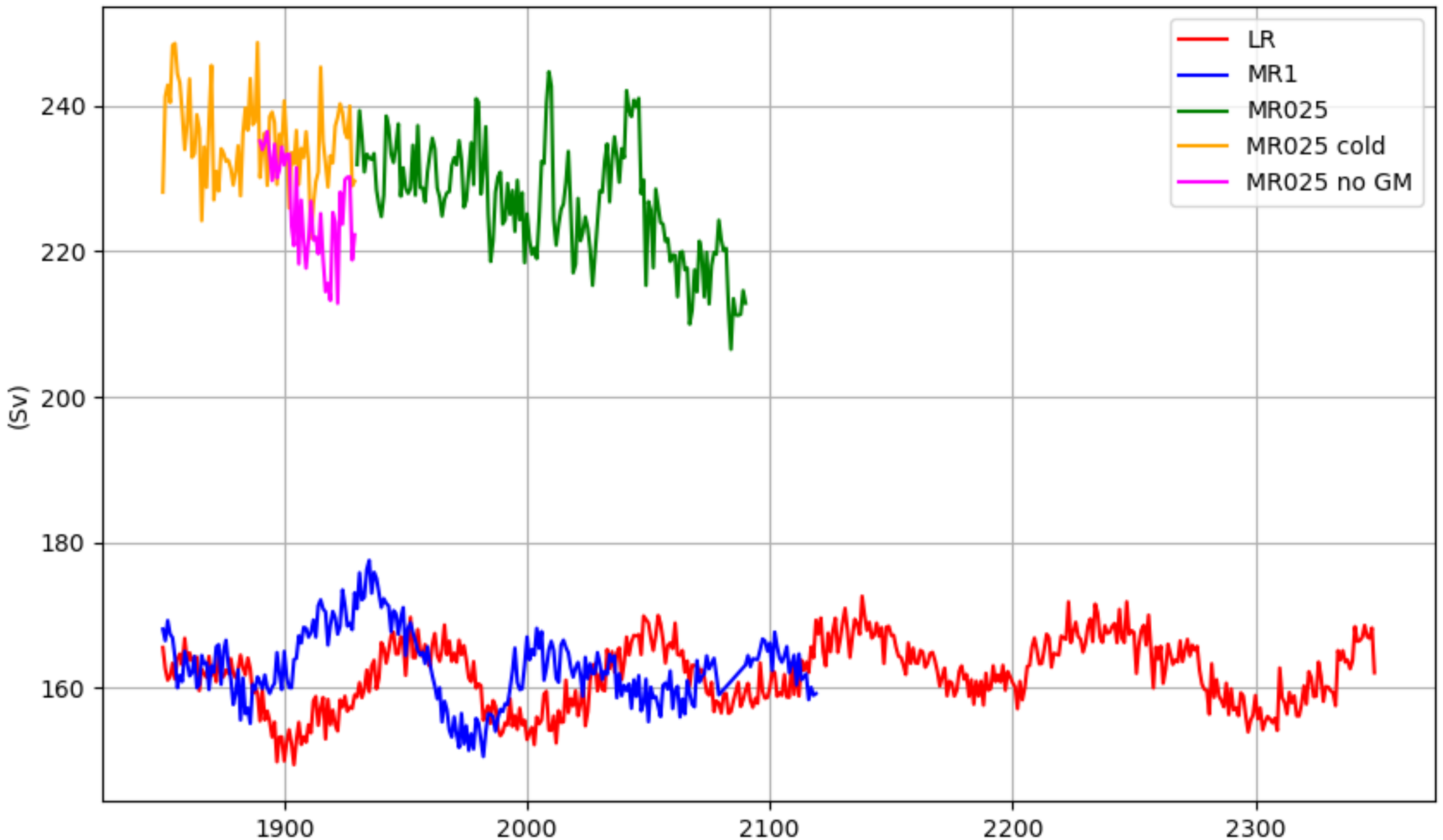
Antarctic Circumpolar Current at Drake Passage (total volume transport)



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[physics] in particular the centennial variability in AMOC,
hence is it *relevant* to increase spatial resolution ?

[numerics] because our exploration is too *conservative* ?

My conclusions

Beyond running CMIP6 experiments, more work is needed to
quantify uncertainty in climate model simulations hence future projections.

Running future climate projections at high resolution (ocean grid ≦1/4°) is currently inappropriate because
[i] testing sensitivity to (non-scale aware) model parameters is too expensive,
[ii] running long-term experiments is too expensive.

My questions

Could numerical choices be responsible for long-term drift in IPSL-CM6A-LR ?
Should I worry for it ?
Considering that my MR is far from convergence, is it worth exploring more the parametric and structural uncertainties ?

interested in model code, configuration settings, simulation outputs ?

keen to visit NEMO R&D for short or longer term ?

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