Ocean Model Spin-Up Practices in Diverse Contexts

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- Tim Graham (UK Met Office)
- Andy Moore (UCSC)
- Gokhan Danabasoglu (NCAR)
- Samar Khatiwala (Oxford)
- Dan Amrhein (NCAR)
- Andrew Gettlemann (PNNL)

- Plus others (modeling centers from survey replies)

Ocean Model Spin-Up Practices in Diverse Contexts

The group has had meetings with a variety of different types of modeling centers over the past few years.

The goal is to collect information about practices for ocean model spin-up in coupled configurations, including especially:

CMIP-class projections

Mesoscale and km-scale sims.

S2S forecasts

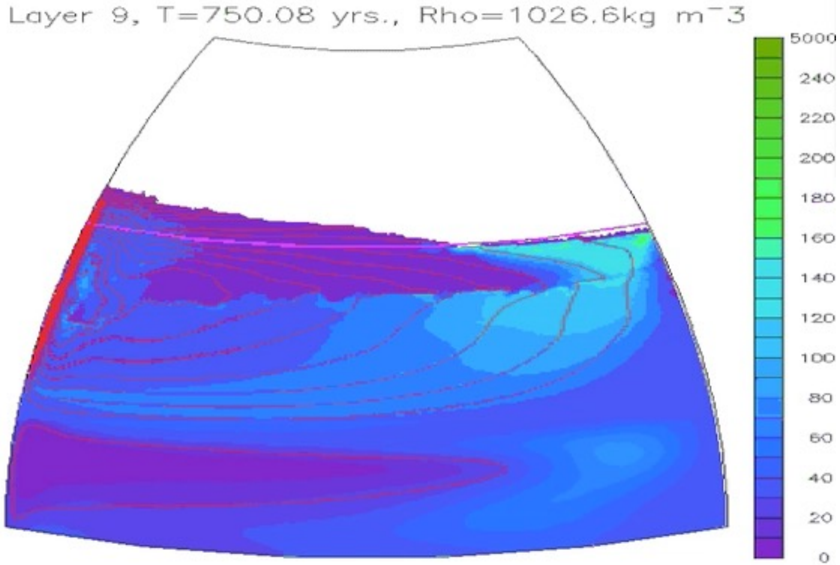
Coupled NWP

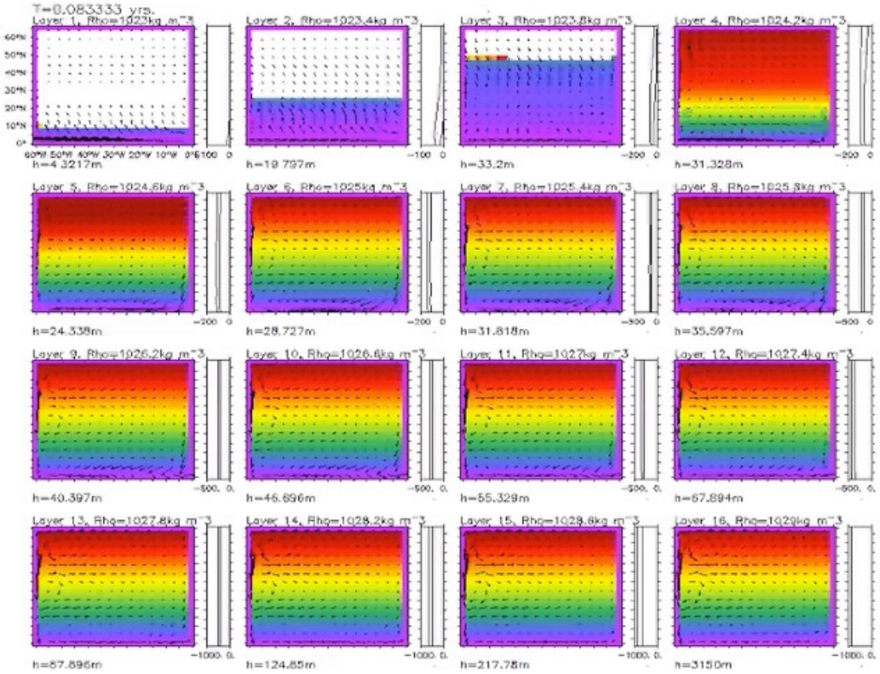
It has become clear that a diverse set of approaches are used, and that these depend on application.

There is the potential for learning across disciplines, and new mathematical acceleration approaches that may be useful.

A community paper is being created to draw together and share these insights.

Ocean Spin-Up Theory

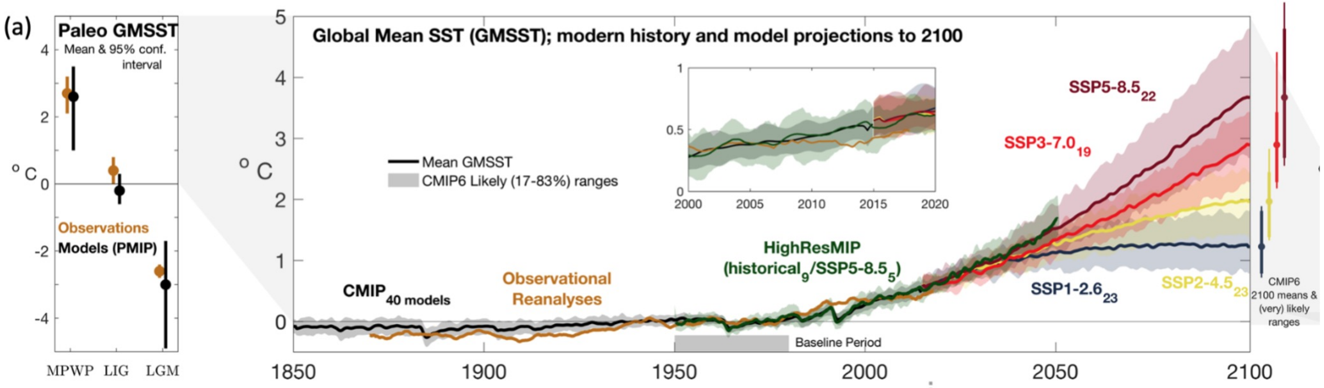




It is the propagation of waves or advection along isopycnals that spins up a non-diffusive model… Timescales set by advection/wave crossing times (Pedlosky et al. 1984). Diffusion takes longer (Boccaletti et al. 2004).

Sea Surface Temperature (SST) Anomalies and Maps

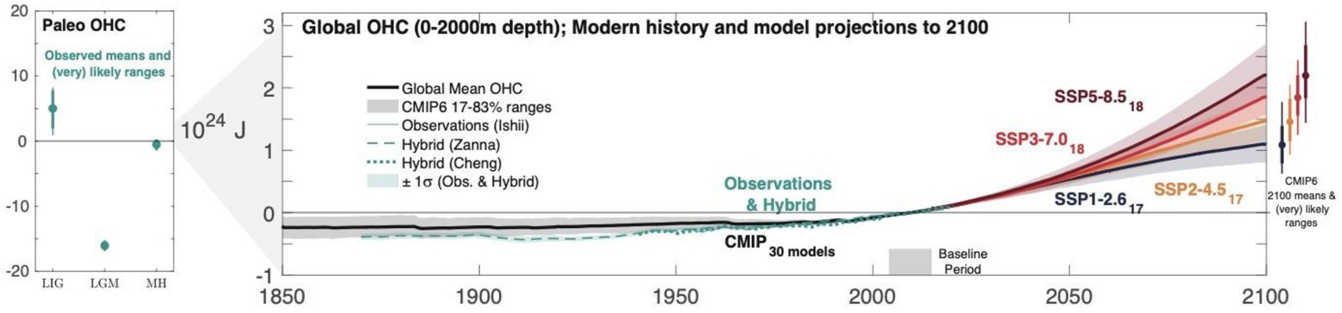
Observation-based estimates and CMIP6 multi-model means, biases and projected cha



Shallow ocean response

Ocean Heat Content (OHC) Anomalies and Maps

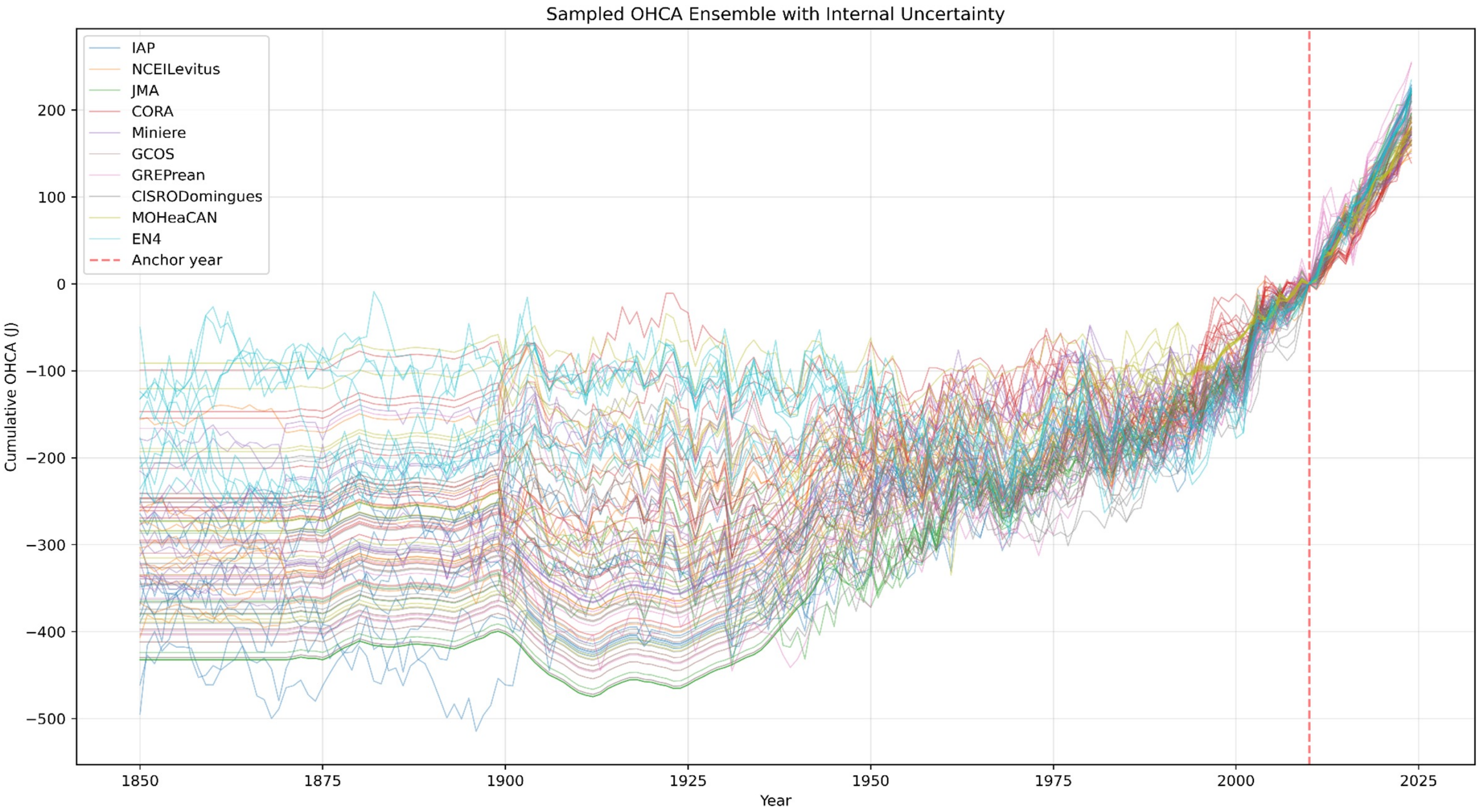
Observation-based estimates and CMIP6 multi-model means, biases and projected changes



Deep ocean response

BFK, H. T. Hewitt, C. Xiao, G. Adalgeirsdottir, S. S. Drijfhout, T. L. Edwards, N. R. Golledge, M. Hemer, R. E. Kopp, G. Krinner, A. Mix, D. Notz, S. Nowicki, I. S. Nurhati, L. Ruiz, J.-B. Sallee, A. B. A. Slangen, and Y. Yu. *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, chapter Ocean, Cryosphere and Sea Level Change, pages 1211--1362. Cambridge University Press, 2021. http://dx.doi.org/10.1017/9781009157896.011

Whole-Depth Ocean Heat Content Anomaly Ensemble from Observations and Reanalyses



ESMO Earth System Modelling and Observations

Thorne, Nicklas et al. (in prep). Figure: John Nicklas.

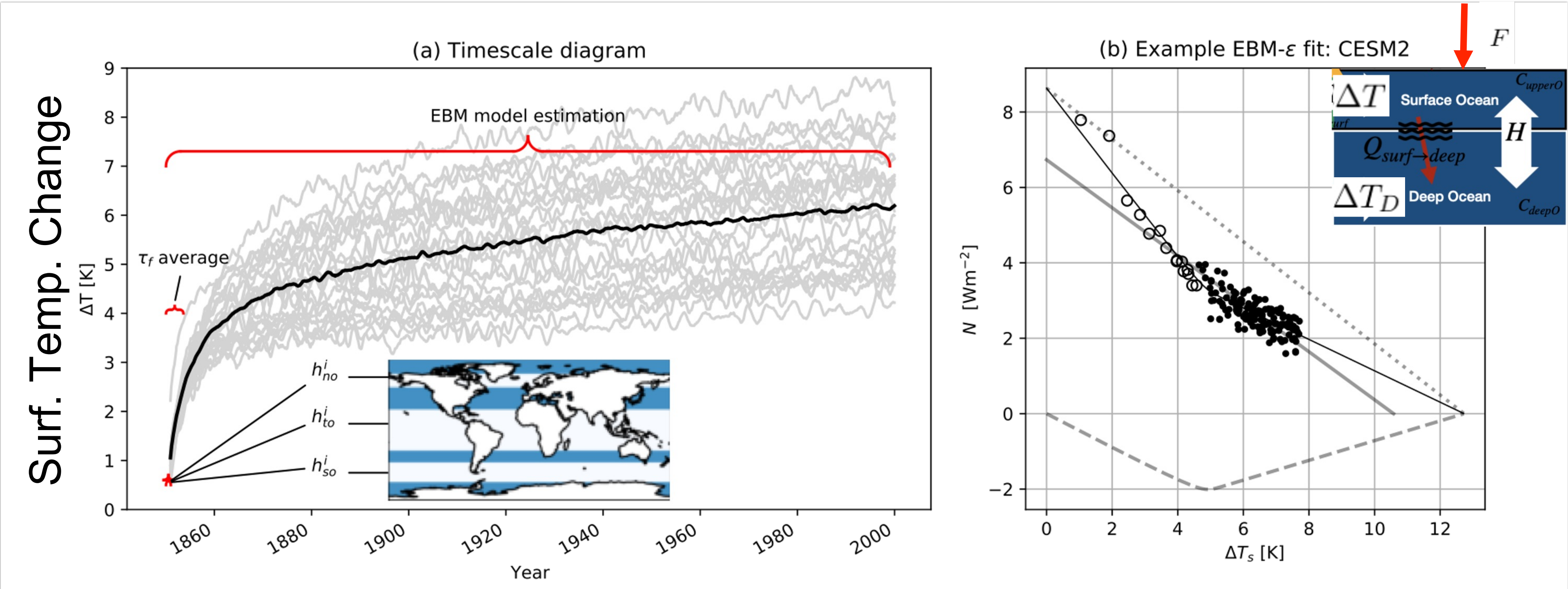
WCRP World Climate Research Programme

Simple Emulator: 2-Layer Homogeneous Energy Balance Model (Hasselmann 1976; Gnanadesikan, 1999; Gregory, 2000; Winton et al. 2010; Geoffroy et al. 2013; Palmer et al. 2018)

G. Hall and BFK. Regional mixed layer depth as a climate diagnostic and emergent constraint. In revision.

This emulator has parameters that are not observable, but...
can be estimated by DECK simulations

$$C_S \frac{d\Delta T}{dt} = F - \lambda \Delta T - \varepsilon\gamma(\Delta T - \Delta T_D),$$
$$C_D \frac{d\Delta T_D}{dt} = \gamma(\Delta T - \Delta T_D);$$



CMIP5 Ocean Model Timescales (Geoffroy et al. 2013)

From this analysis, one could shorten spin-up to:

O(4.2 yr) for global mean SST spin-up

O(290 yr) for global mean OHCA spin-up

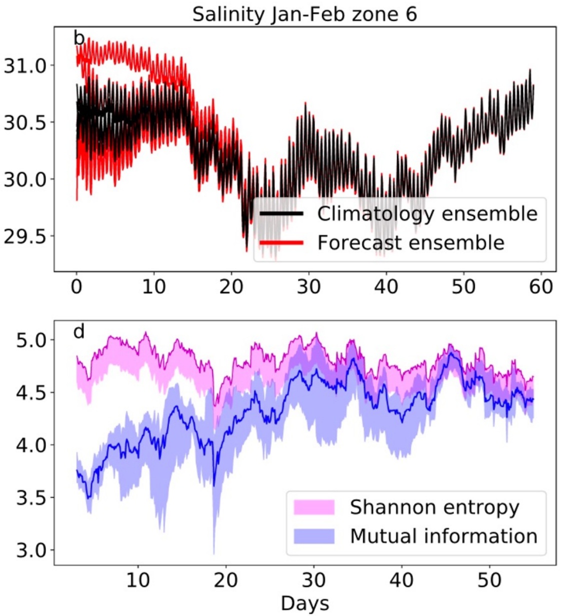
Observations say oldest water is O(1500 yr)--Gebbie & Huybers (2011, 2012)

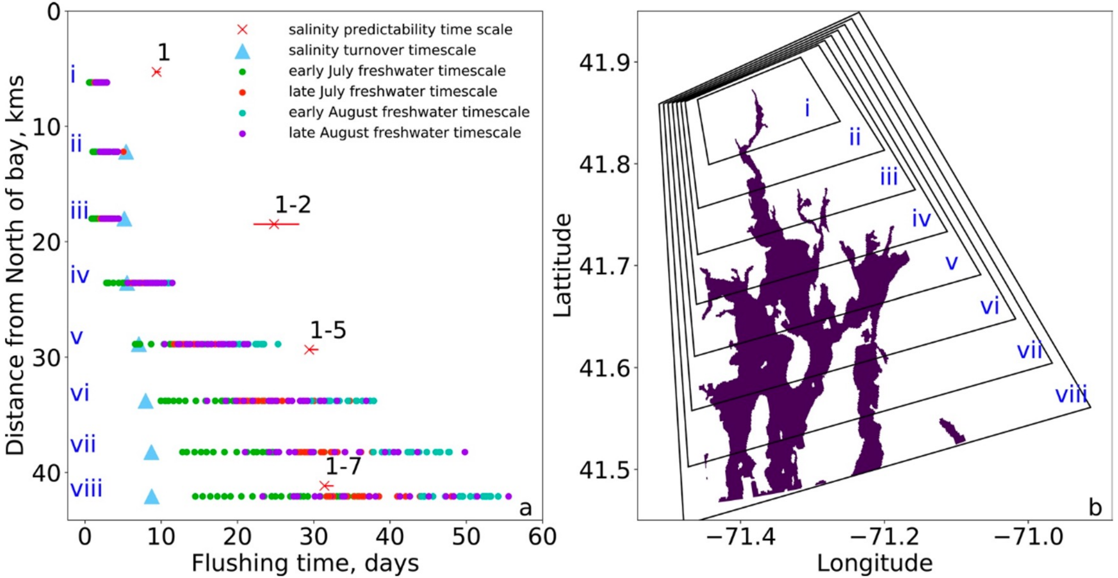
Hence the CMIP approach, where a piControl run of many hundreds of years, after a previous (?? yr) spin-up

TABLE 2. The atmosphere/land/upper-ocean heat capacity C, deep-ocean heat capacity C_0, heat-exchange coefficient γ, and fast and slow relaxation times estimates in the framework of the EBM-ε of the 16 CMIP5 models used in this paper, and their multimodel mean and standard deviation.

Model	C (W yr m^{-2} K^{-1})	C_0 (W yr m^{-2} K^{-1})	γ (W m^{-2} K^{-1})	τ_f (yr)	τ_s (yr)
BCC-CSM1–1	8.4	56	0.59	4.1	152
BNU-ESM	7.3	89	0.54	5.0	262
CanESM2	8.0	77	0.54	4.5	239
CCSM4	7.6	72	0.81	3.0	160
CNRM-CM5.1	8.3	95	0.51	5.2	266
CSIRO-Mk3.6.0	8.5	76	0.71	4.2	316
FGOALS-s2	7.5	138	0.72	4.3	387
GFDL-ESM2M	8.8	112	0.84	3.6	233
GISS-E2-R	6.1	134	1.06	1.7	224
HadGEM2-ES	7.5	98	0.49	5.4	457
INM-CM4	8.5	271	0.67	4.0	546
IPSL-CM5A-LR	8.1	100	0.57	5.5	327
MIROC5	8.7	158	0.73	3.6	338
MPI-ESM-LR	8.5	78	0.62	4.0	220
MRI-CGCM3	9.3	68	0.59	4.4	181
NorESM1-M	9.7	121	0.76	4.1	328
Multimodel mean	8.2	109	0.67	4.2	290
Standard deviation	0.9	52	0.15	0.9	107

Estuary Ocean Models: Predictability Timescales

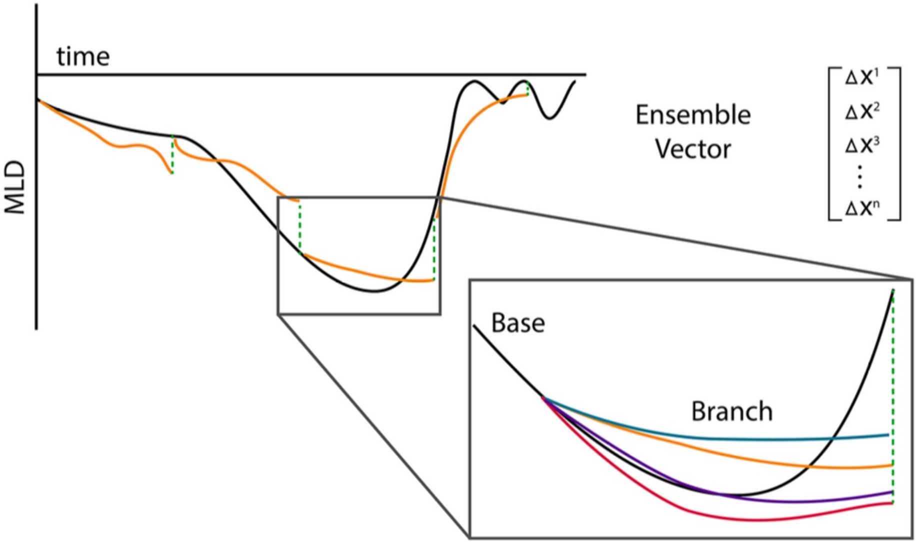




Consistent Predictability of the Ocean State Ocean Model Using Information Theory and Flushing Timescales

Aakash Sane[1], Baylor Fox-Kemper[2], David S. Ullman[3], Christopher Kincaid[3], and Lewis Rothstein[3]

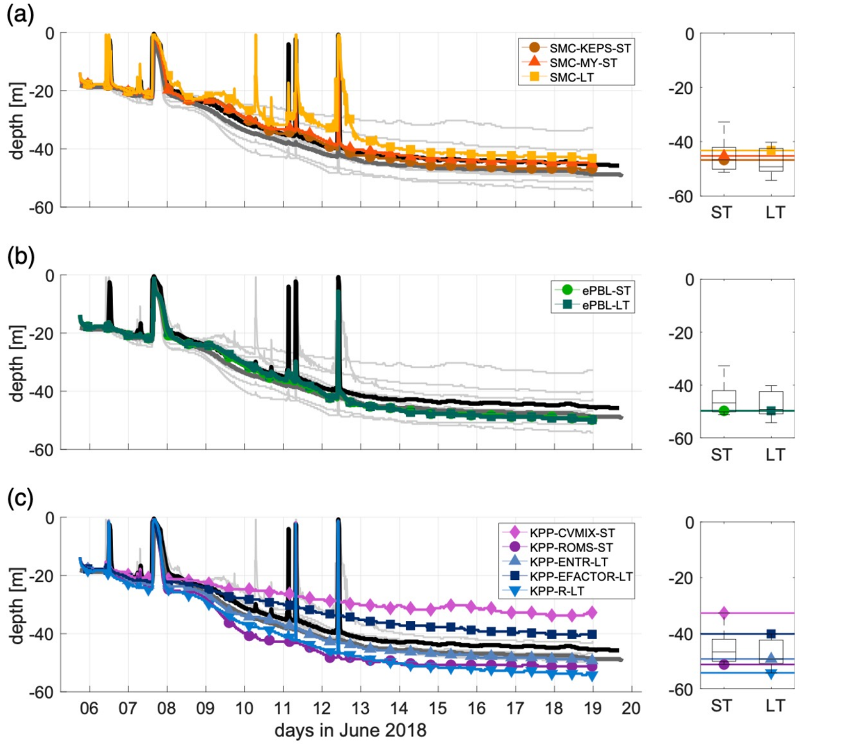
Mixed Layer Models: Predictability Timescales



A Finite-Time Ensemble Method for Mixed Layer Model Comparison

LEAH JOHNSON,[a] BAYLOR FOX-KEMPER,[a] QING LI,[b] HIEU T. PHAM,[c] AND SUTANU SARKAR[c]

JOURNAL OF PHYSICAL OCEANOGRAPHY VOLUME 53



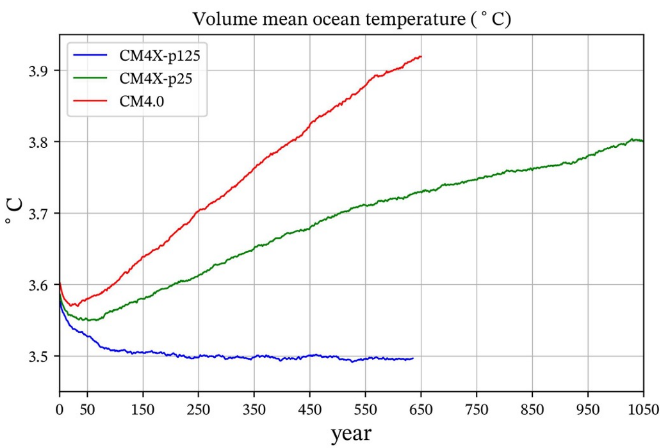
ESMO Earth System Modelling and Observations

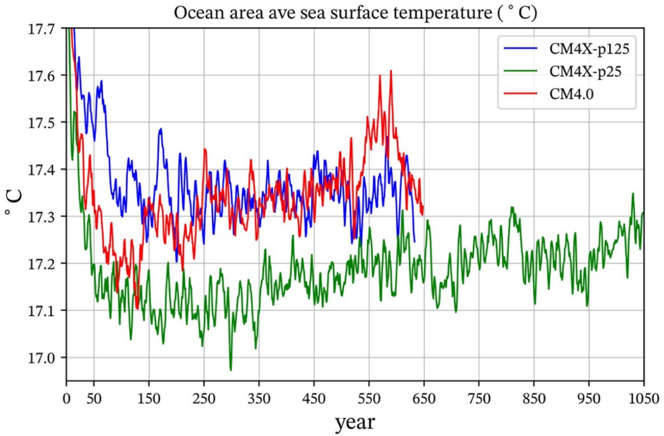
WCRP World Climate Research Programme

The GFDL CM4X-p125 Exception:

6.4.3 Summarizing the Mesoscale Dominance Hypothesis

We hypothesize that there are three ocean model properties necessary to support a centennial rather than the millennial time scale for piControl thermal equilibration into an ocean that is cooler (with roughly 400 ZJ less heat content than early 21st century) in its 1850 piControl state: (a) enhanced fidelity of mesoscale features, including transient eddies and boundary currents; (b) accurate strength and geography of parameterized numerical mixing processes; and (c) negligible levels of spurious mixing from numerical discretization. We refer to ocean models that possess these three properties as *mesoscale dominant models*. Mesoscale dominant models contrast to those where deep ocean diabatic processes (either parameterized or spurious numerically induced) play a prominent (and sometimes dominant) role in piControl thermal equilibration. We infer that models that are not mesoscale dominant engage their deep ocean circulation during the 1850 piControl, thus rendering far longer thermal equilibration time scales. These long thermal spin-ups also affect long spin-up times for biogeochemical cycles, though biogeochemical spin-ups are also impacted by other processes (Khatiwala, 2023, 2024; Orr et al., 2017).





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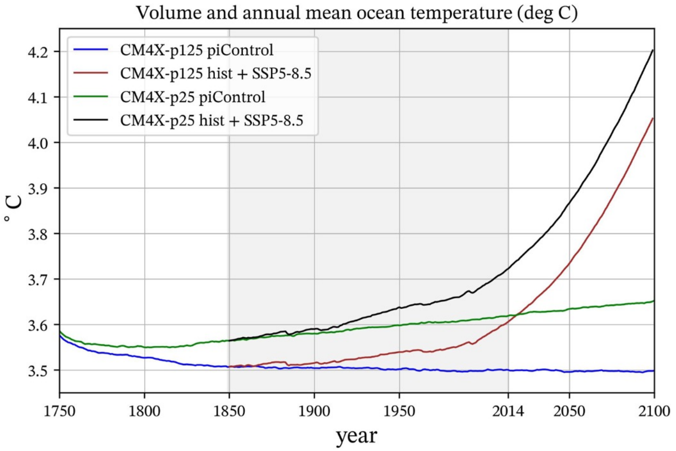
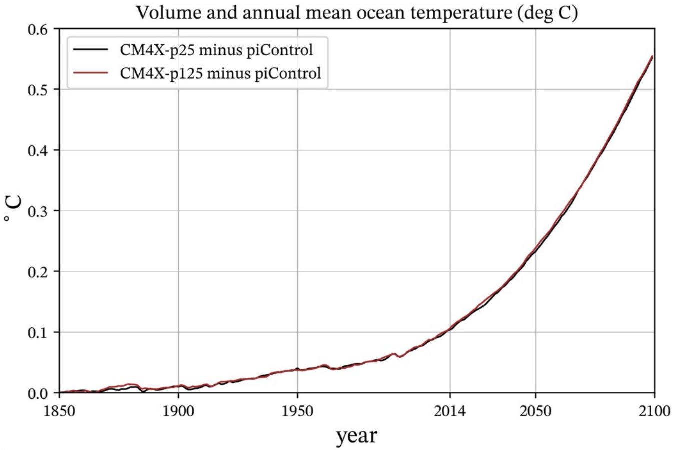
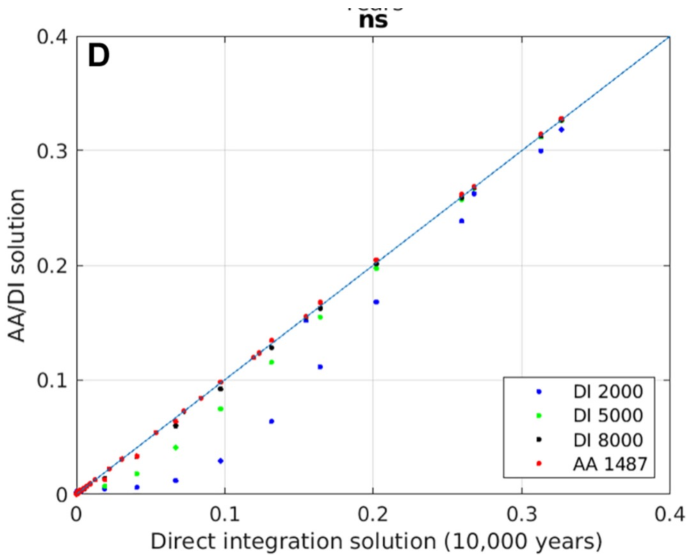




Acceleration Techniques, e.g., Anderson Accel.



Comparison of AA and DI solutions for JULES configured for 63°N, 149°W. JULES is vertically discretized into 20 soil layers, for each of which there are four carbon and nitrogen pools representing decomposable and resistant plant material, microbial biomass, and a long-lived humified pool

Efficient spin-up of Earth System Models using sequence acceleration

SAMAR KHATIWALA Authors Info & Affiliations

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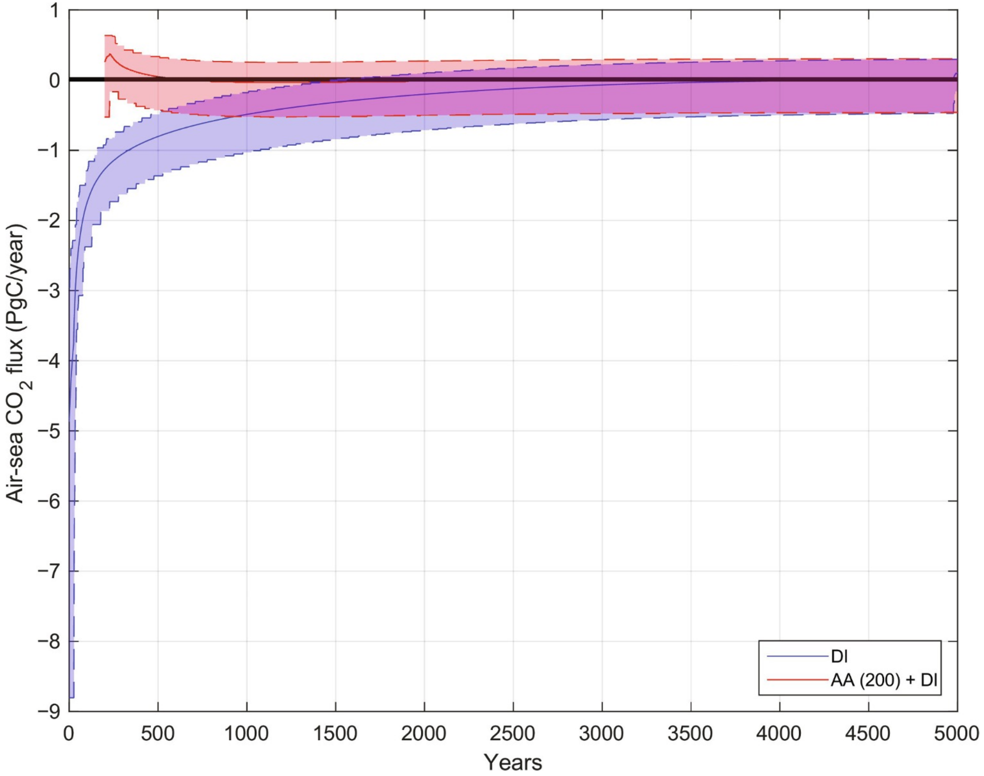

Net annual air-sea flux of CO_2 in MITgcm-BLING driven by interannually varying circulation and forcing.

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