Global ocean biogeochemical modelling with FESOM2-REcoM

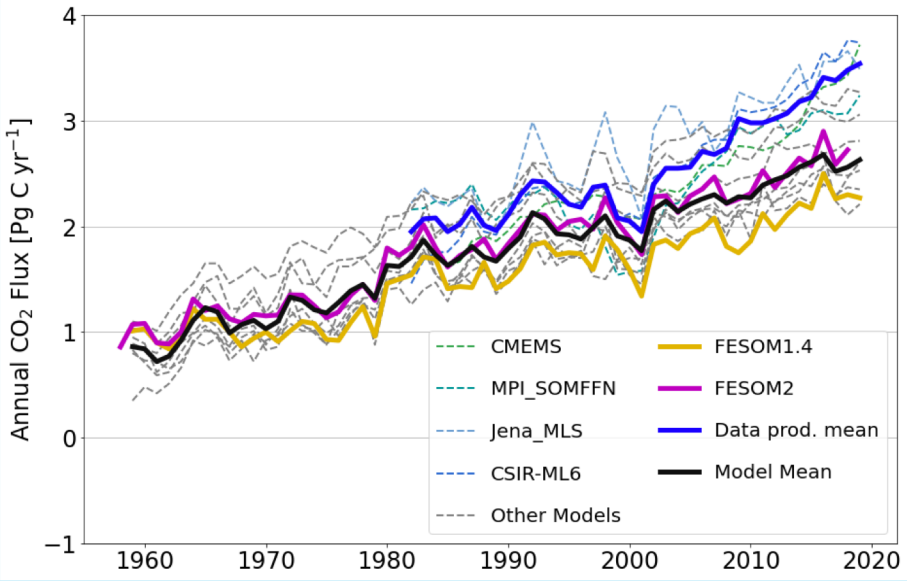
Özgür Gürses, Judith Hauck, Moritz Zeising and Laurent Oziel

Our aim

- Reduction of model uncertainty and biases
- Increase efficiency in coupled ocean biogeochemical models to allow climate simulations
- z star/partial cell implementation

OS3.1

FESOM2-REcoM is 3-5 times faster than FESOM1.4-REcoM



Data: Global Carbon Burget 2020v1.0. (Friedlingstein et al. 2020 [5])

CO2flux

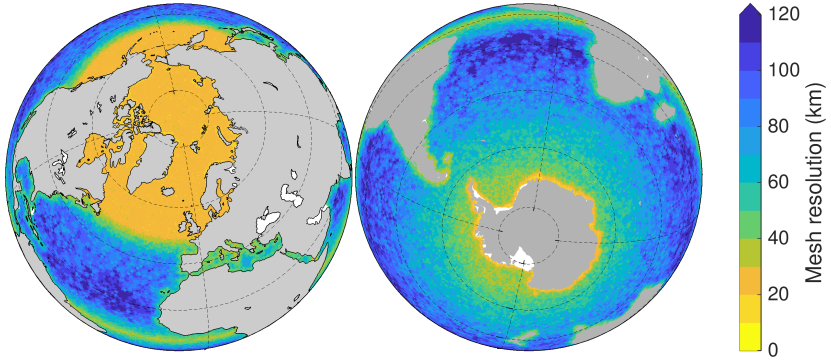
Net Primary Production

Nutrients

MODELS

- FESOM1.4 [1] - finite element discretization
- FESOM2 [2] - finite volume discretization
- REcoM [3] - REgulated Ecosytem Modeling

- global coupled sea ice-ocean model
- unstructured triangular mesh with local refinement
- updated carbonate chemistry with mocsy [4]



Model Setup	
Surface nodes	~125K
vertical res.	47 levels
Time step [min]	45 (FESOM2) 15 (FESOM1.4)
Atm. forcing	JRA55-do-1.4.1
Analysis period	2008-2018

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CO2flux

Experiments	CO2 (ppm)	Atm. Forcing	Period
A spin-up	Variable	Year 1961	1850-1957
A	Variable	JRA55	1958-2019
B spin-up	Constant (278)	Year 1961	1850-1957
B	Constant (278)	Year 1961	1958-2019

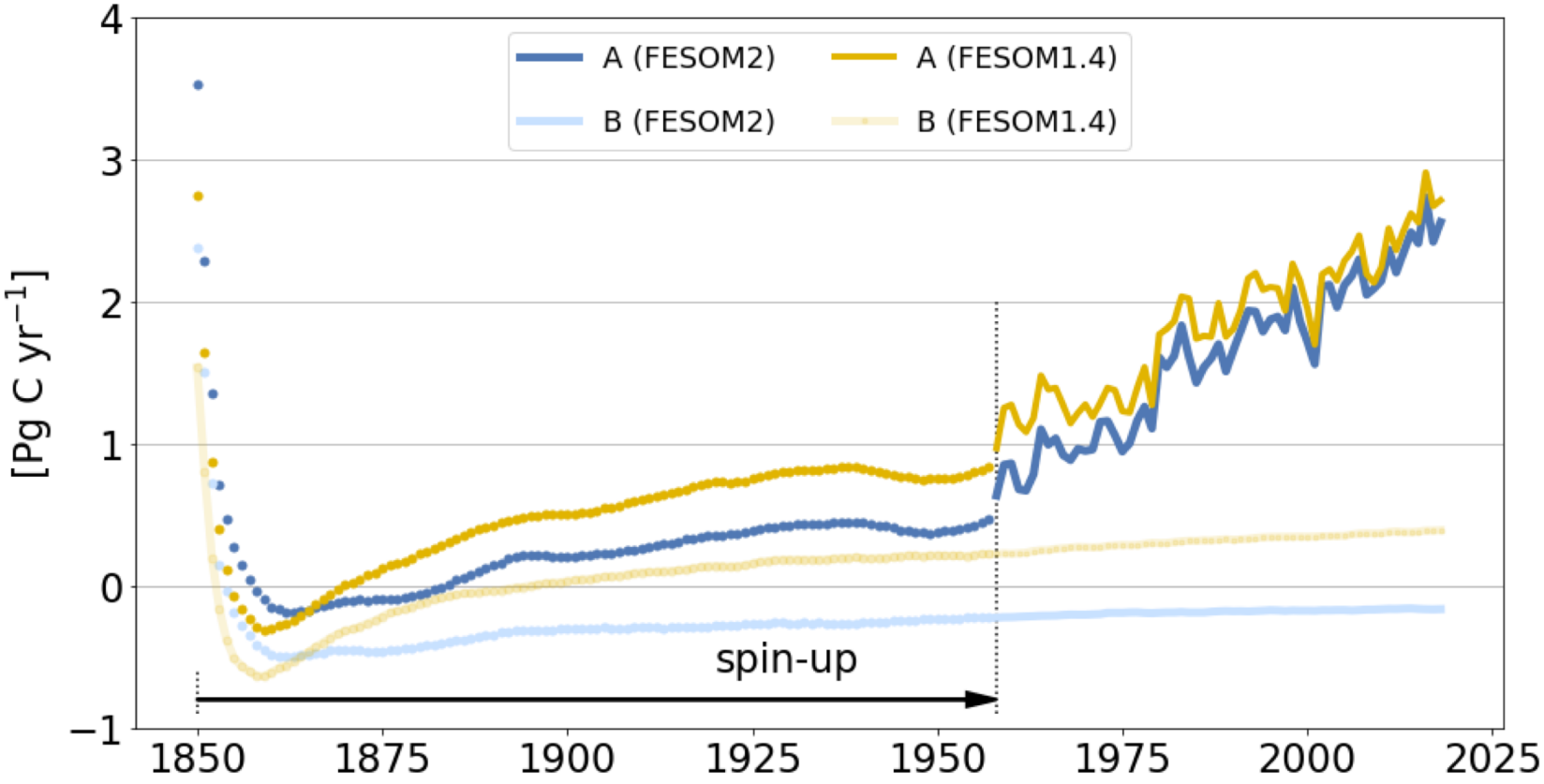
Outcome

Bias-corrected 1990s CO_2 flux in FESOM-2.0 (2.04 PgC/yr) in better agreement with best estimate (2.2 +/- 0.4 PgC/yr, IPCC, 2001, 2007) than in FESOM-1.4.

Similar CO_2 flux in simulation A, despite different CO_2 flux in ctrl simulation B.

[START]

Simulated annual atmosphere-ocean CO2 flux



Positive values indicate fluxes into the ocean

CO2 flux 1990s (PgC/yr)	A	B (control, bias)	A-B (bias-corrected)
FESOM-1.4	2.07	0.34	1.74
FESOM-2.0	1.86	-0.18	**2.04**

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- Global and Southern Ocean fluxes within observational range
- Net Primary Production (NPP) and Export Production (EP) at the lower end

Work in progress:

- Opal export in Southern Ocean relatively low
- Subject to tuning, sensitive to forcing and parameter choice

→ A higher diatom-NPP and opal flux is needed for reasonable DSi distribution

[START]

Global and Southern Ocean biogeochemical fluxes

	Units	FESOM-1.4 (Schourup-Kristensen et al 2014)	FESOM-2.0	Range literature
NPP global	PgC/yr	32.5	31.5	23-70
EP global	PgC/yr	6.1	5.2	5.8-13
Opal export global	Tmol Si /yr	74.5	89.4	69-185
NPP Southern Ocean	PgC/yr	3.1	2.8	1.1-4.9
EP Southern Ocean	PgC/yr	1.1	1.0	1
Opal Southern Ocean	Tmol Si/yr	21.5	17.7	21-54

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Net Primary Production/ Chlorophyll-a

DATA

- OCCCI
- Johnson et al. (2013) Optimized for Southern Ocean

Outcome

- Reasonable simulated latitudinal variation of NPP and Chl-a
- Simulated Chl-a concentration at northern high latitudes and coastal Southern Ocean at the low end of satellite data
- Subject to tuning: diatoms vs small phytoplankton

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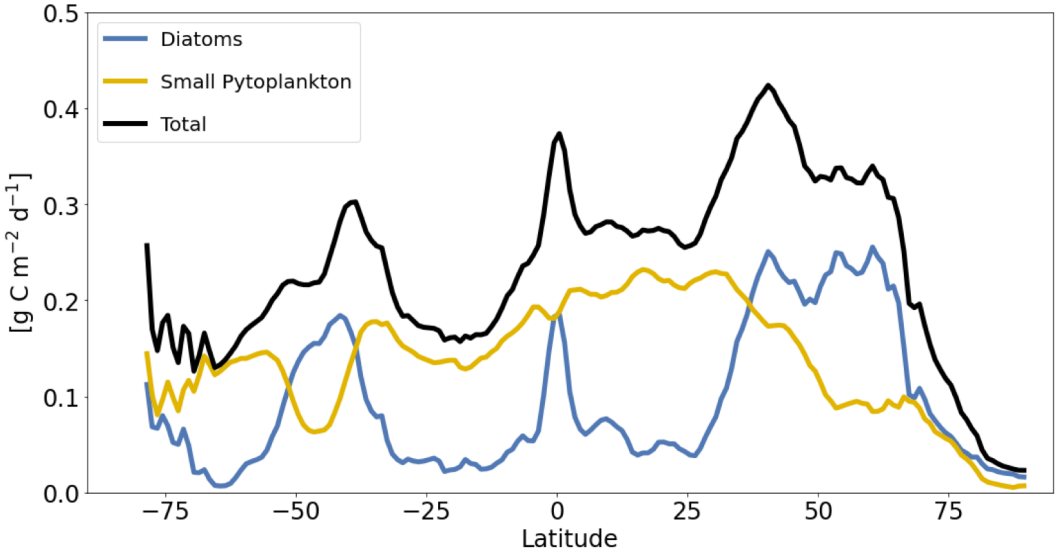
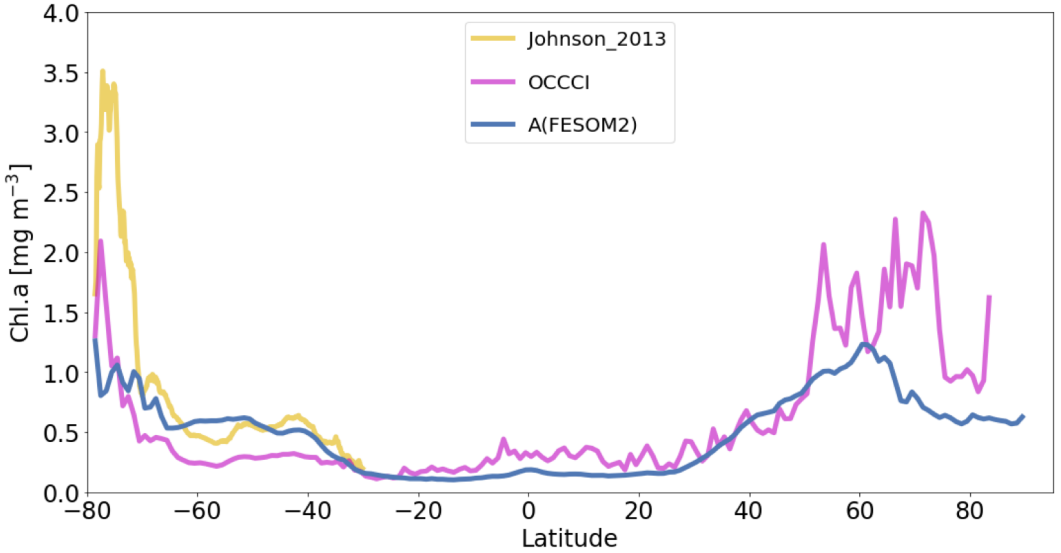
Simulated Net Primary Production per latitude integrated over depth



Simulated Chl-a concentration per latitude integrated over depth



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Sensitivity experiments for NPP/Chl

Exp.	$P_{cm,dia}$	$P_{cm,phy}$	deg_{dia}	deg_{phy}
B01	3.5	3.0	0.2	0.2
B02	3.5	3.0	0.15	0.25
B03	3.5	3.0	0.3	0.3
B04	3.5	3.0	0.5	0.5
B05	3.0	3.0	0.15	0.25
B06	3.0	3.0	0.3	0.3

Pcm= max. rate of C-specific photosynthesis [1/day]
deg= chl degradation rate [1/day]

Outcome

- High sensitivity to parameter choice in Southern Ocean

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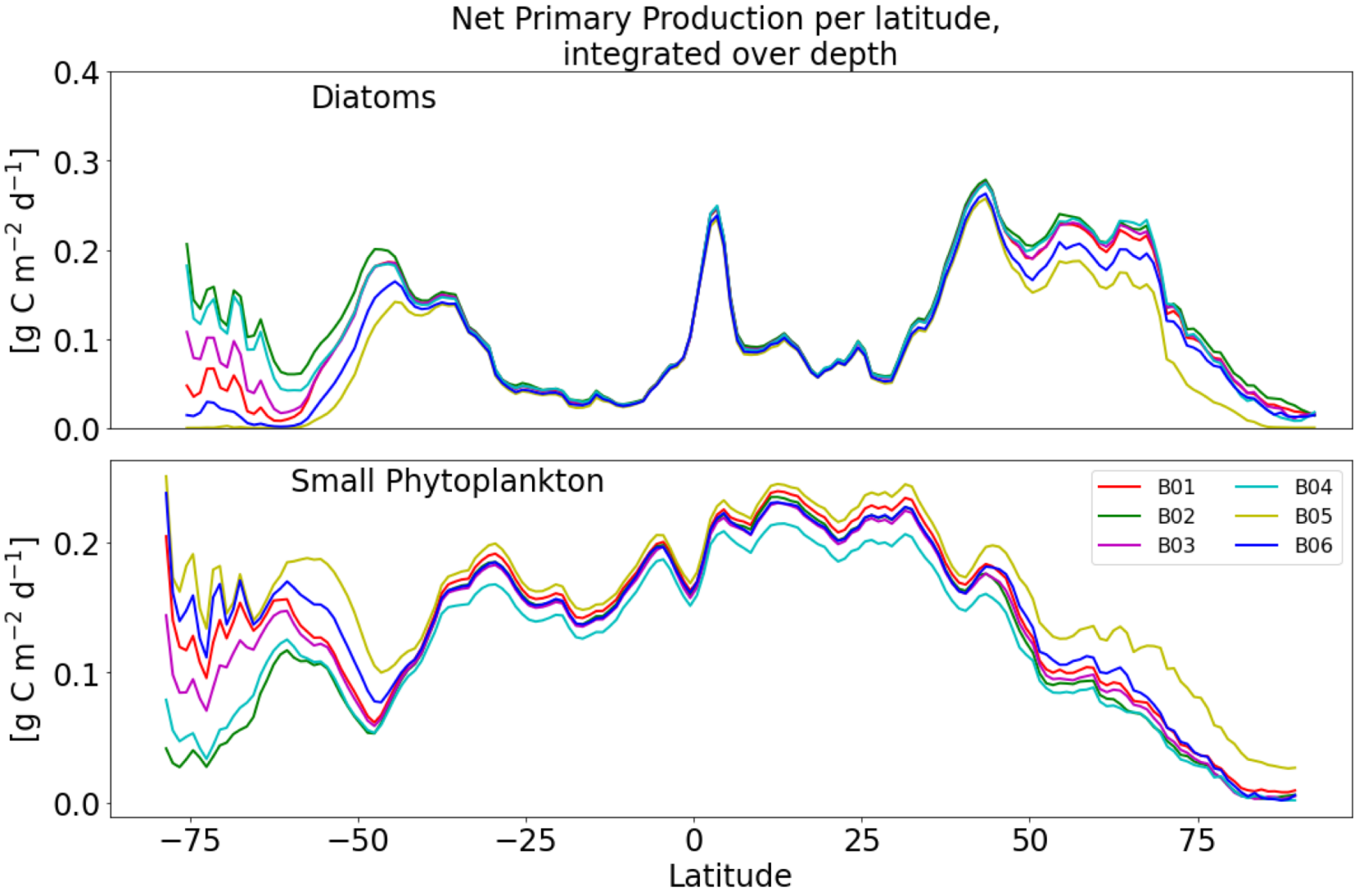

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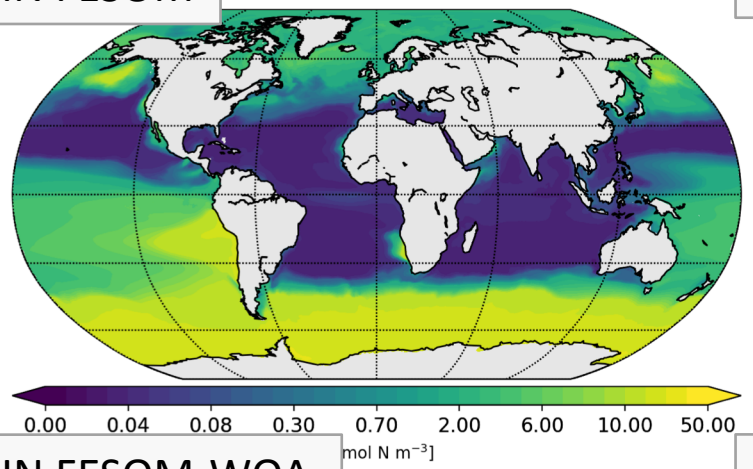
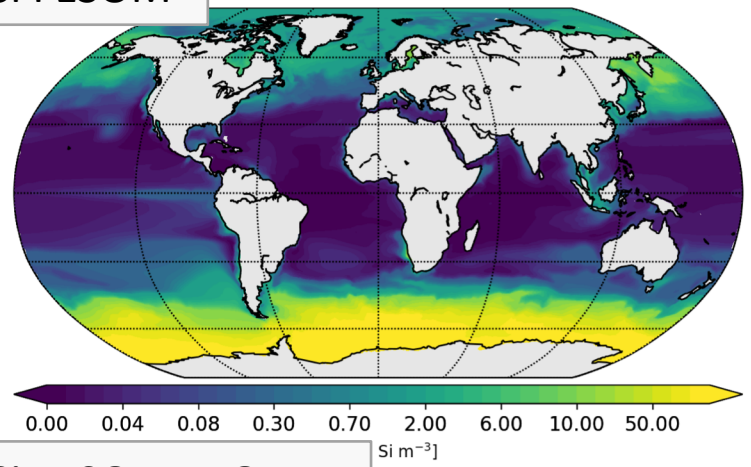
Nutrients

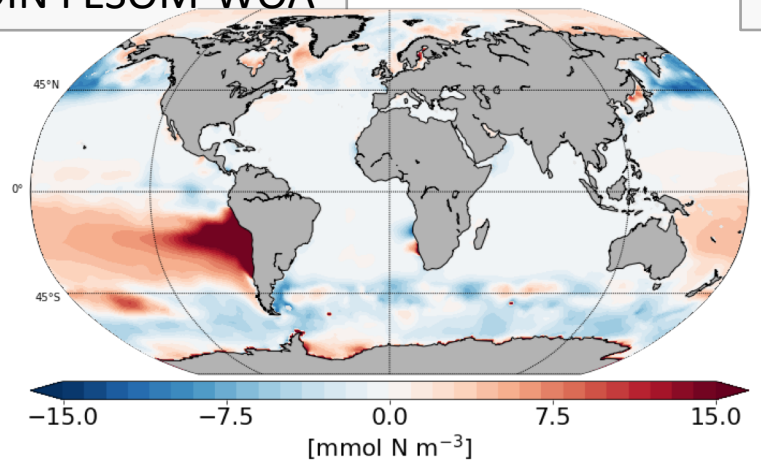
DIN FESOM



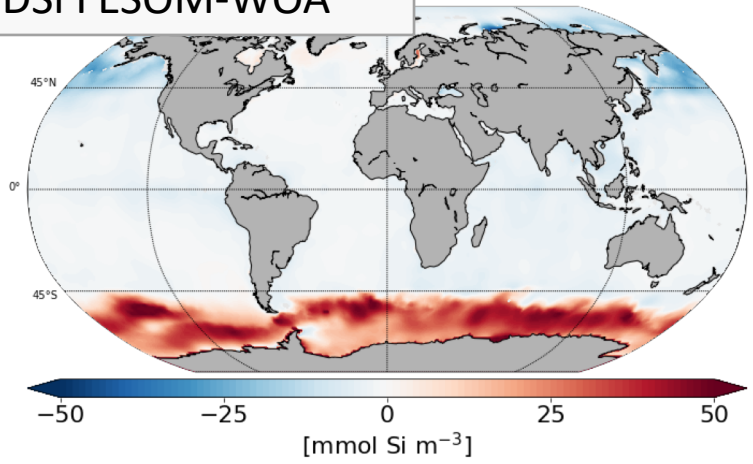
DSi FESOM



DIN FESOM-WOA



DSi FESOM-WOA



DATA

- World Ocean Atlas 18 (WOA)

- High DIN bias in southern Pacific
- High DSi bias in Southern Ocean associated with low diatom production there (slide 4)
  → Tuning is in progress

DIN and DSi shown for simulation A

[START]

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[START]

References

[1] Wang et al., (2014): The Finite Element Sea Ice- Ocean Model (FESOM) v.1.4: formulation of an ocean general circulation model. Geosci. Model Dev., 7(2), 663- 693

[2] Danilov, S., Sidorenko, D., Wang, Q., and Jung, T.: The Finite-volumE Sea ice–Ocean Model (FESOM2), Geosci. Model Dev., 10, 765–789, https://doi.org/10.5194/gmd-10-765-2017, 2017.

[3] Hauck, J., Völker, C., Wang, T., Hoppema, M., Losch, M. and Wolf-Gladrow, D.A. (2013). Seasonally different carbon flux changes in the Southern Ocean in response to the southern annular mode, Global Biogeochemical Cycles, 27 (4), 1236-1245. doi:10.1002/2013GB004600

[4] Orr, J. C., and Epitalon, J.-M. (2015). Improved routines to model the ocean carbonate system: mocsy 2.0. *Geosci. Model Dev.* 8, 485–499.
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[5] Friedlingstein, P., O'Sullivan, M., Jones, M. W., Andrew, R. M., Hauck, J., Olsen, A., Peters, G. P., Peters,..., ..., and Zaehle, S.: Global Carbon Budget 2020, Earth Syst. Sci. Data, 12, 3269–3340, https://doi.org/10.5194/essd-12-3269-2020, 2020.