



Supplement of

One size fits all? Calibrating an ocean biogeochemistry model for different circulations

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Table S1. General setup and properties of different offline circulations. See section 2.1 for more information on the setup of the offline circulations.

	MIT28*	UHigh*	U20*	U17.5*	ECCO*	Obs (ECCO)
Ocean model:	MIT28	UVic	UVic	UVic	ECCO	
Horizontal resolution:	$2.8^\circ \times 2.8^\circ$	$3.6^\circ \times 1.8^\circ$	$3.6^\circ \times 1.8^\circ$	$3.6^\circ \times 1.8^\circ$	$1.0^\circ \times 1.0^\circ$	$1.0^\circ \times 1.0^\circ$
Vertical resolution:	15	19	19	19	23	23
<i>Outcrop area ($\text{m}^2 \times 10^{13}$)</i>						
North: $26.5 \leq \sigma < 27$	0.347	0.556	0.590	0.596	0.461	0.446
North: $27 \leq \sigma < 27.5$	0.380	0.501	0.430	0.430	0.444	0.436
North: $27.5 \leq \sigma$	0.521	0.124	0.088	0.088	0.204	0.191
South: $26.5 \leq \sigma < 27$	1.595	2.101	1.847	1.846	2.093	2.451
South: $27 \leq \sigma < 27.5$	2.477	3.301	2.593	2.566	2.850	2.909
South: $27.5 \leq \sigma$	1.955	0.369	0.948	0.970	0.482	0.407
<i>Deep MLD area ($\text{m}^2 \times 10^{12}$)</i>						
North: Area MLD ≥ 200 m	7.279	5.492	5.476	5.476	4.255	3.680
North: Area MLD ≥ 400 m	3.373	2.875	2.888	2.942	1.685	1.130
South: Area MLD ≥ 200 m	29.269	27.945	28.148	27.964	16.873	14.047
South: Area MLD ≥ 400 m	5.860	9.669	14.672	14.242	0.478	3.193
<i>Ideal age (y)</i>						
NADW	154	131	167	208	209	
CDW	597	370	376	336	461	
NPDW	1399	1269	1398	1348	1229	
ETP	300	227	220	208	314	
Global	652	583	628	606	643	

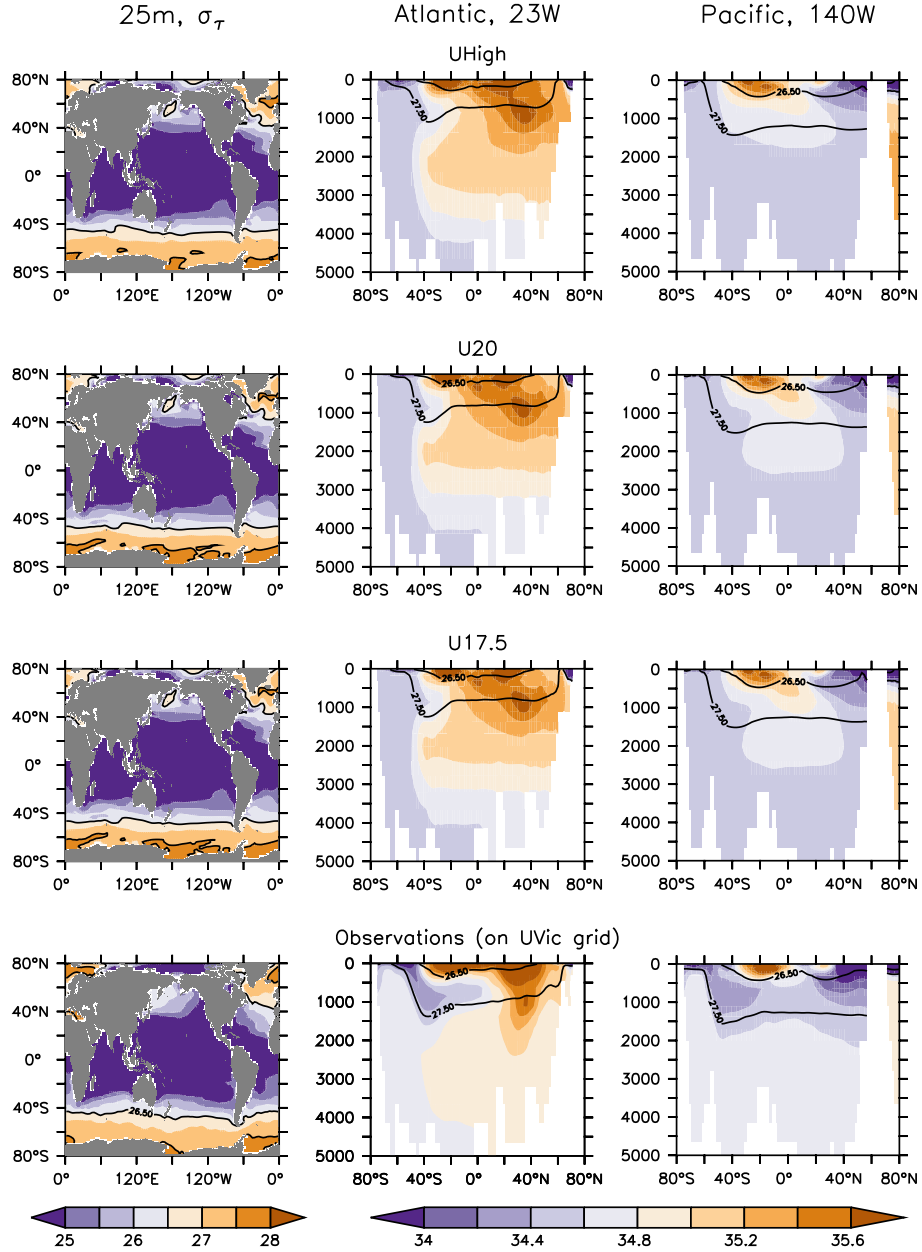


Figure S1. Density at 25 m (left panels), and salinity along sections at 23°W and 140°W (middle and right panels), of circulations (top to bottom) UHigh, U20 and U17.5 circulation. The lower panel shows observations mapped onto UVic geometry. Density has been derived from annual mean potential temperature and salinity. Contour lines in left panels highlight isopycnal of $\sigma_\theta = 26.5$ and $\sigma_\theta = 27.5$.

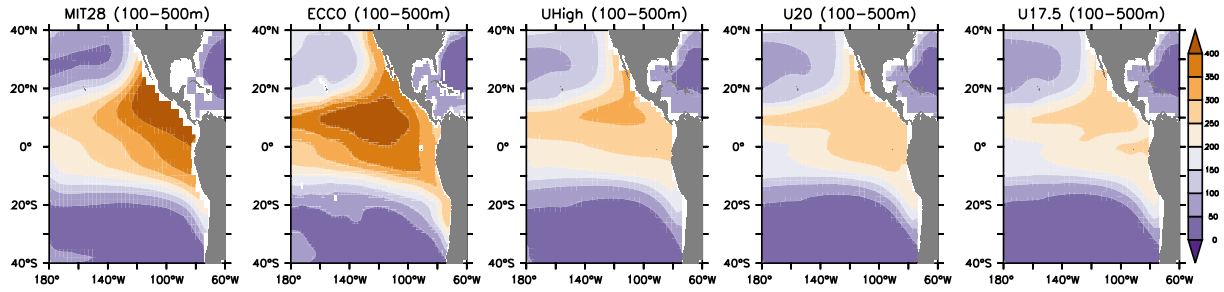


Figure S2. Ideal age averaged over 150 to 500 m in the eastern tropical and subtropical Pacific of (left to right) MIT28, ECCO, UHigh, U20 and U17.5. Units are in years.

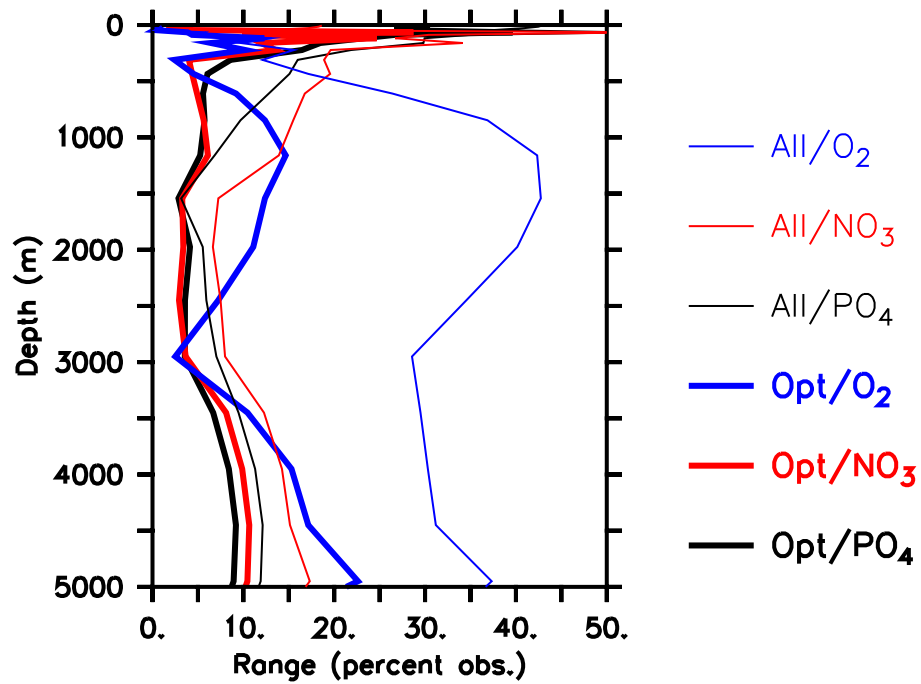


Figure S3. Range of variation in global mean vertical profiles (as percent of observations) across optimal models (thick lines) and across all model experiments (thin lines). Black lines: phosphate; red lines: nitrate; blue lines: oxygen. Prior to averaging, all model have been regridded onto the ECCO grid, using nearest neighbour filling in the vertical, and linear interpolation horizontally.

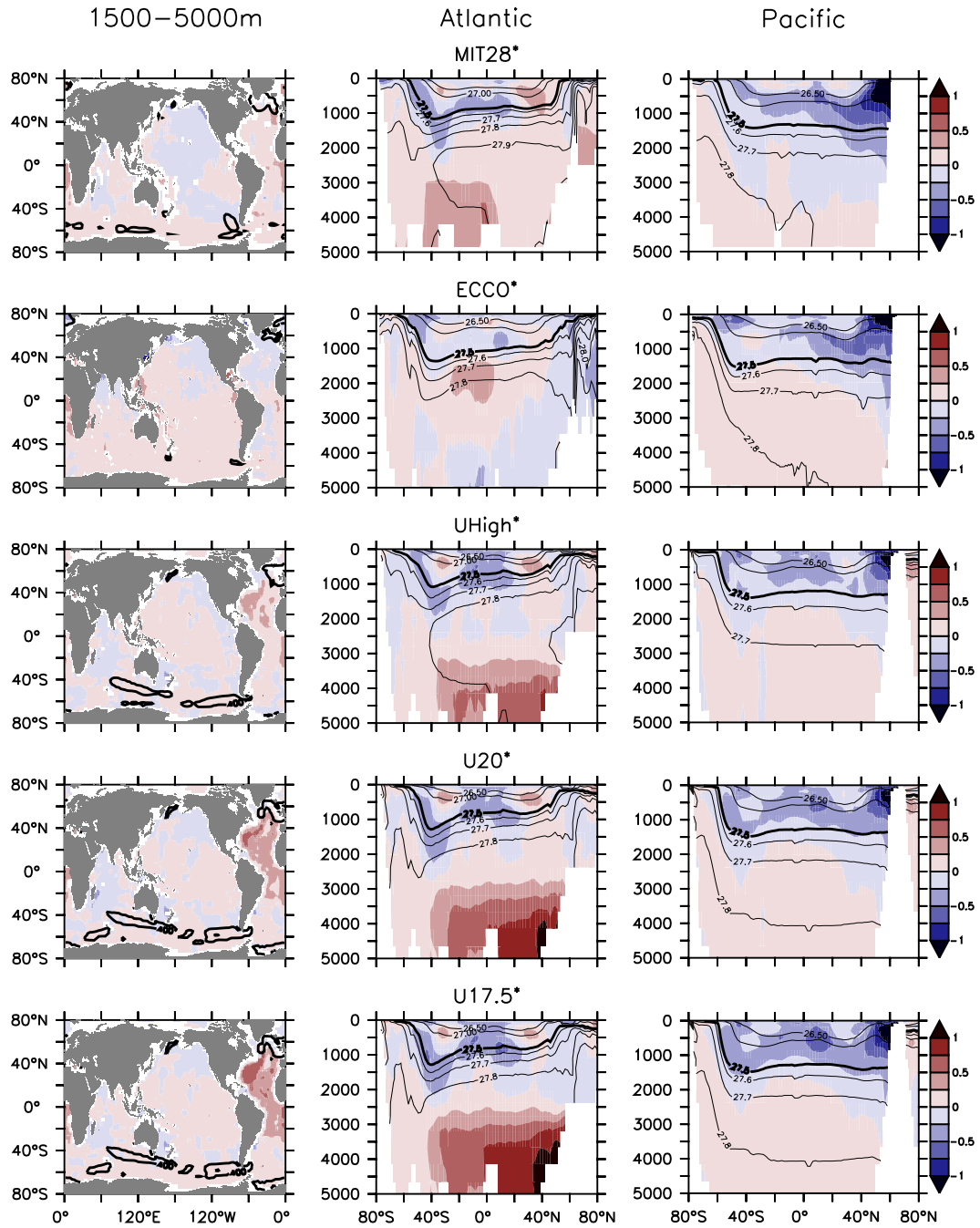


Figure S4. Deviation between simulated and observed phosphate of optimised models. Left panels: deviation of nitrate averaged over 1500-5000 m. Middle panels: deviation between zonal mean nitrate in the Atlantic. Right panels: deviation between zonal mean nitrate in the Pacific. Lines in the left panels indicate regions where maximum mixed-layer depth (calculated as in Fig. 2) is equal or larger than 400 m. Lines in the middle and right panels indicate potential density, averaged zonally. Units are in mmol m^{-3} .

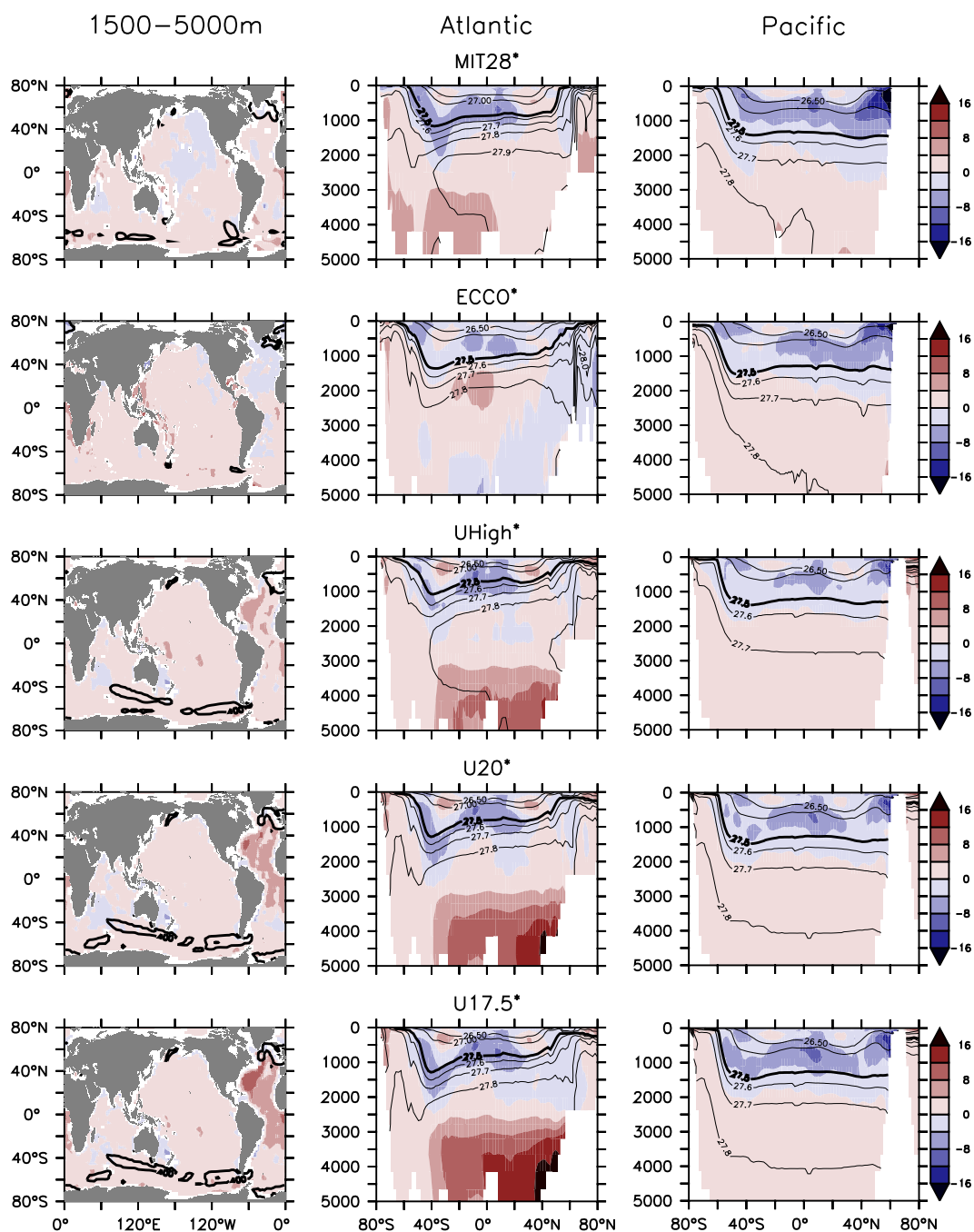


Figure S5. As Figure S4, but for nitrate.

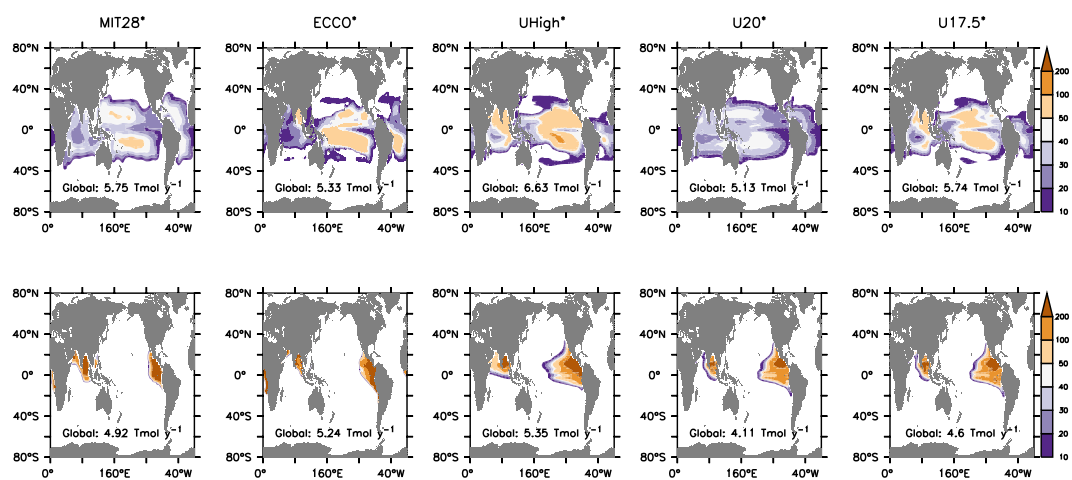


Figure S6. Vertically integrated nitrogen fixation (top) and denitrification (bottom) in the optimal model runs. Fluxes (colourbar) are in mmol N m⁻² y⁻¹. Numbers in panels give globally integrated flux.

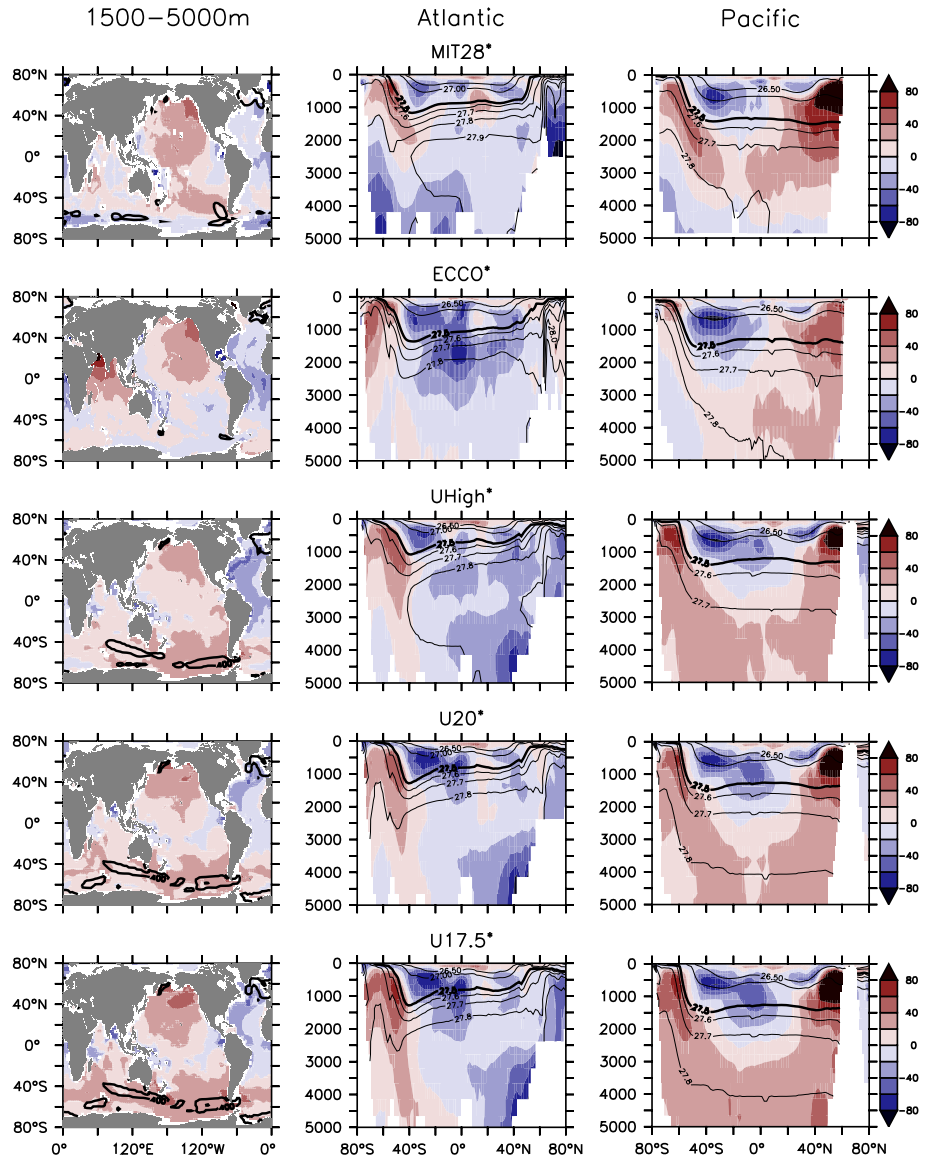
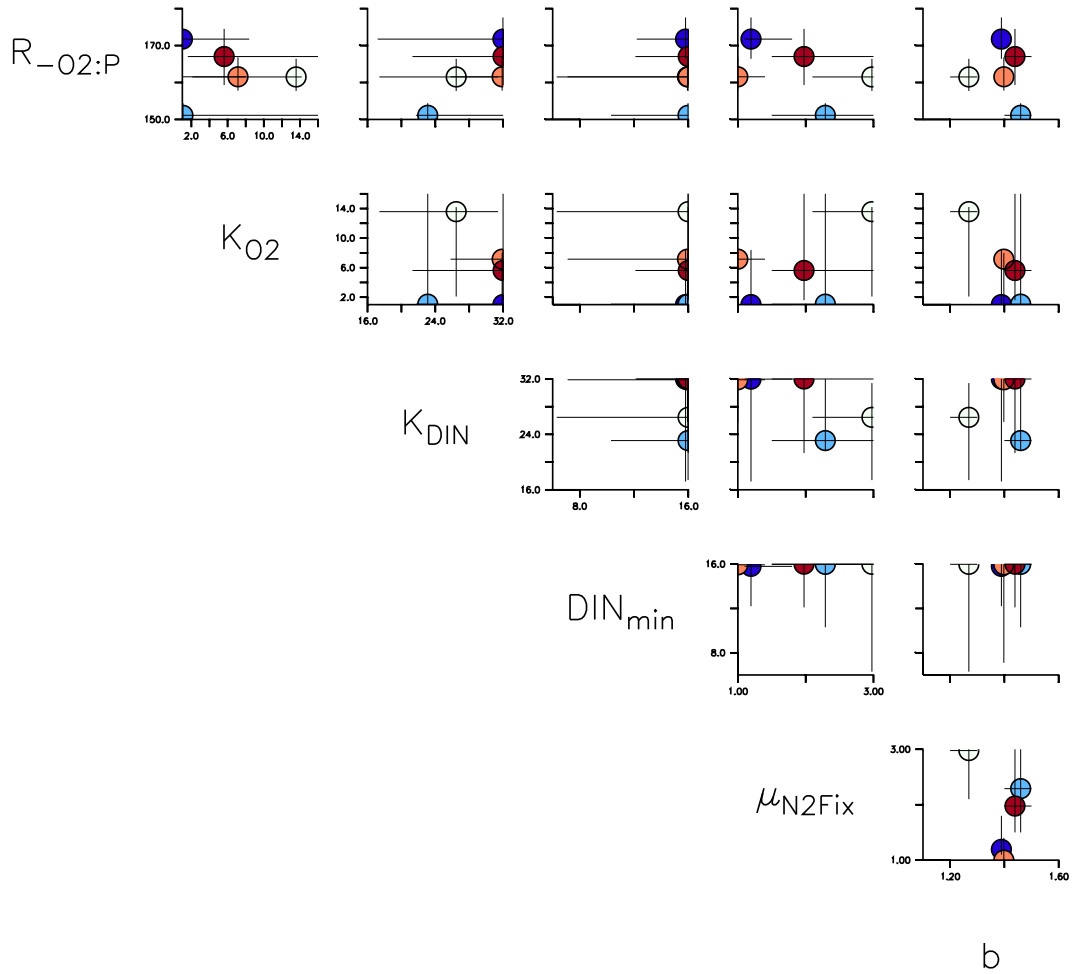


Figure S7. As Figure S4, but for oxygen.



b

Figure S8. Pairs of optimal parameters for the five model optimisations. Colour indicates model type. Dark blue: MIT28*. Light blue: ECCO*. White: UHigh*. Orange: U20*. Dark red: U17.5*. Horizontal and vertical bars indicate the uncertainty range (parameters for which misfit J_i deviates less than 1% from the optimal misfit J^* ($J_i/J^* - 1 \leq \Delta_J$, with $\Delta_J = 0.01$)).

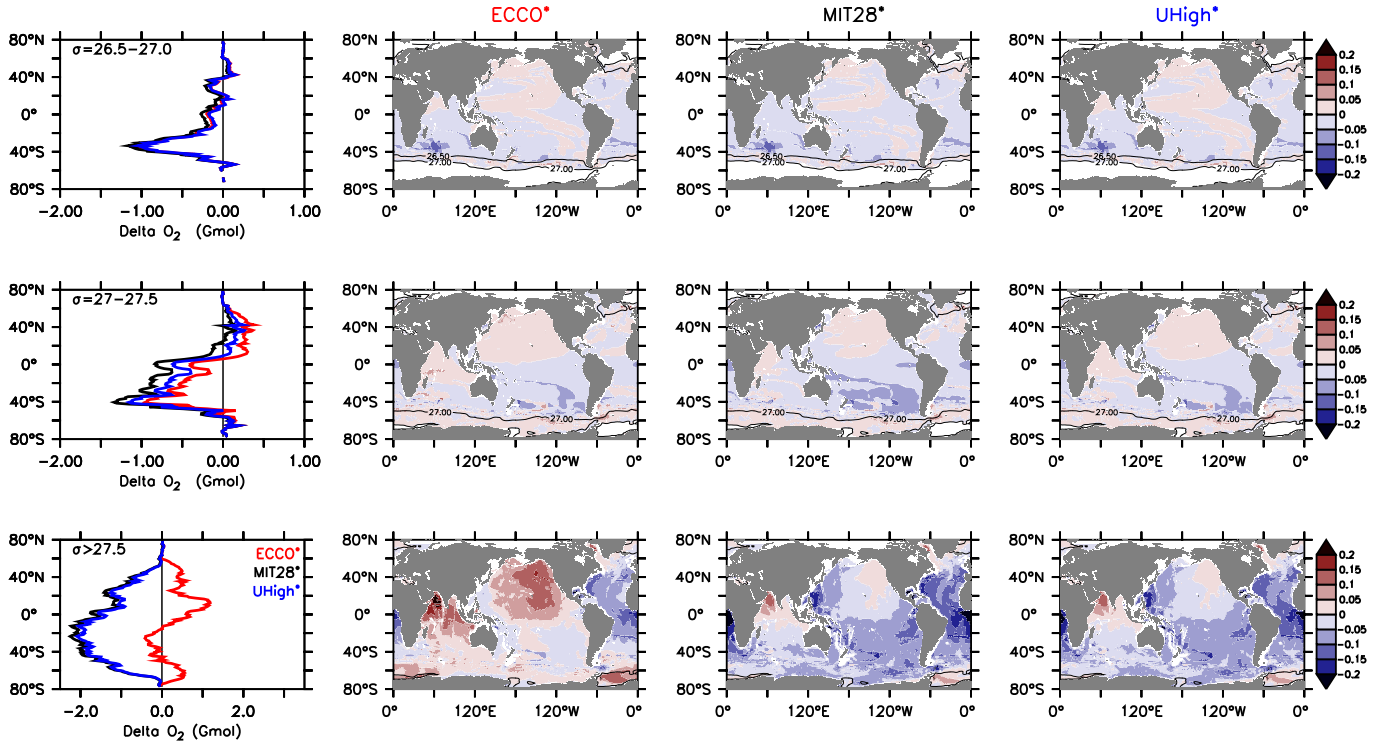


Figure S9. Vertically integrated deviation (kmol m^{-2}) of simulated to observed oxygen in three different domains, for simulations with ECCO circulation and the three different parameter sets of ECCO*, MIT28* and UHigh*). Upper panels: for domain between $\sigma = 26.5$ and $\sigma = 27.0$. Middle panels: for domain between $\sigma = 27.0$ and $\sigma = 27.5$. Lower panels: for domain of $\sigma > 27.5$. Thin lines denote the outcrop areas of the water masses. The left panels show the bias of zonal integrals (in Pmol O_2) for simulations with parameters of ECCO* (red), UHigh* (blue) and MIT28* (black).