The impact of eddy mixing on the sensitivity of ocean biogeochemical cycling to doubled CO^2 within an earth system model

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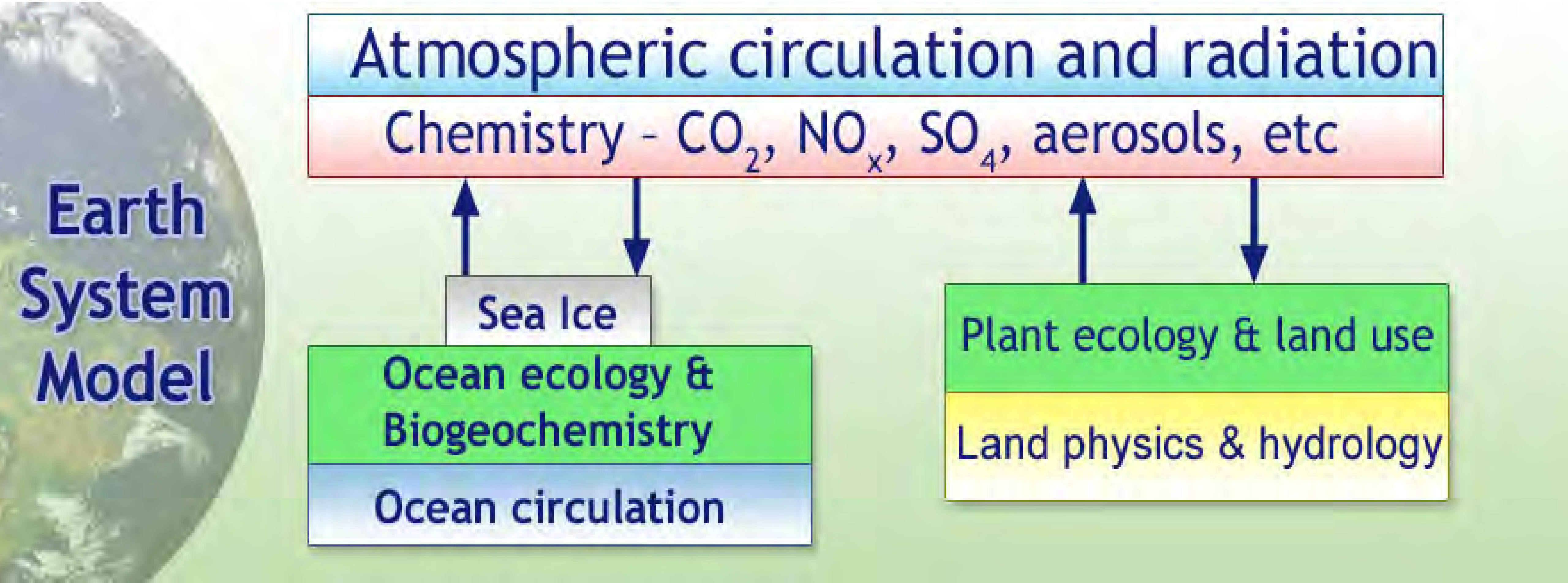
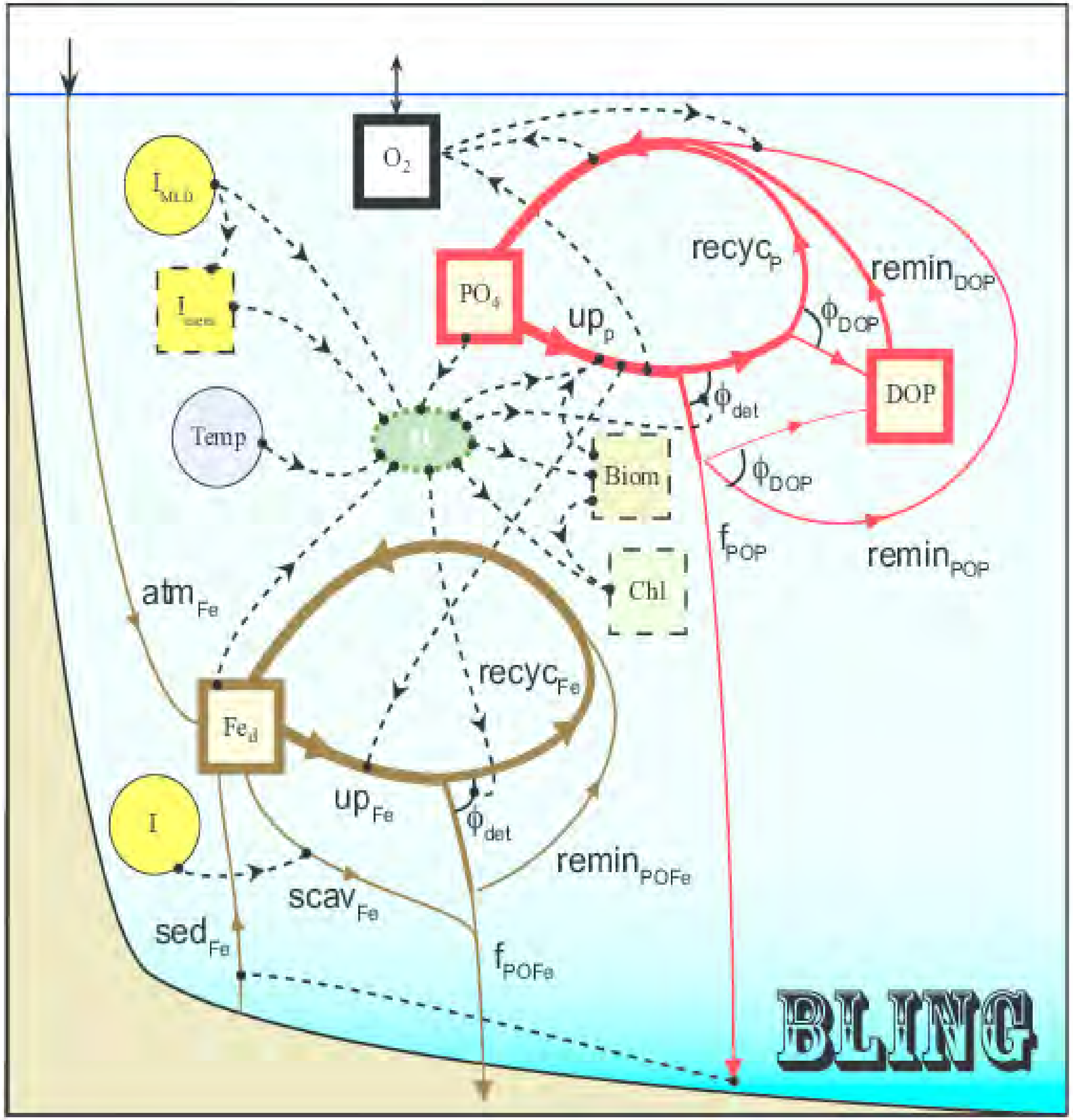
- How do we properly parameterize eddy mixing within an earth system model to simulate realistic results?
- What is driving changes in deoxygenation under climate change?

ESM2Mc Galbraith et al. (2011)





BLING: Biochemistry, Light, Iron, Nutrients and Gases.

- *Prognostic tracers:*
  - Dissolved organic material
  - PO_4 and NO_3 (Macronutrient)
  - Dissolved inorganic carbon
  - Alkalinity
  - Fe_d (Micronutrient)
  - Oxygen

- *Diagnostic tracers:*
  - Chlorophyll
  - Biomass

- *More information on model: Galbraith et al. (2011)*

A_{REDI}

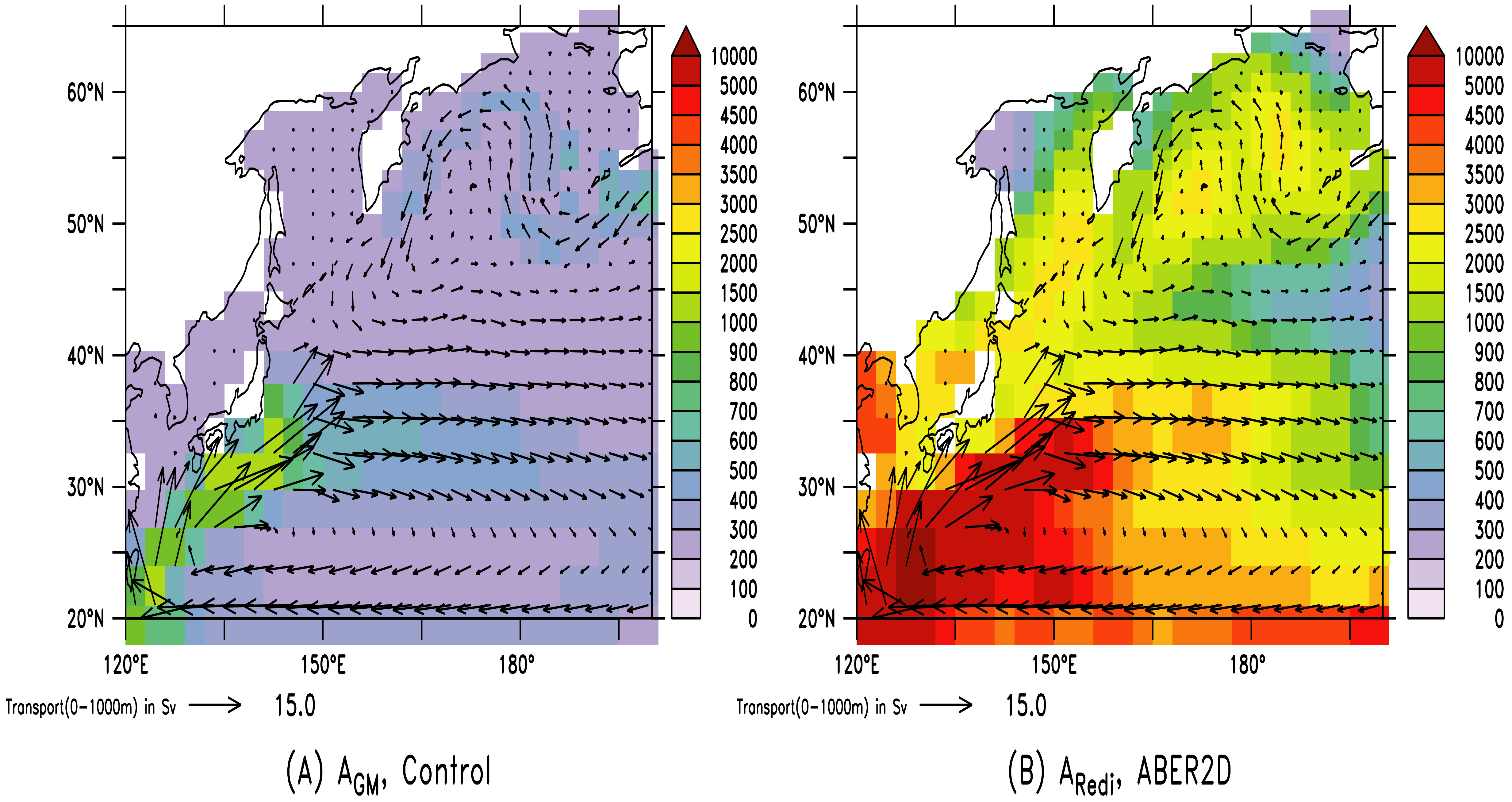
- determines the turbulent flux of different tracer properties along isopycnals using a Fickian diffusion approximation such that the flux of tracer C in direction x is given by (Redi, 1982):

$$F_x^C = -A_{REDI}\frac{\partial C}{\partial x}$$

A_{GM}

- Rearranges tracers through an advective flux which parametrizes the eddy form drag associated with mesoscale eddies using a shear-dependent coefficient scheme (Gent and McWilliams, 1990):

$$F_x^C = -C \times A_{GM} \frac{\partial S_x}{\partial z}$$


60°N
50°N
40°N
30°N
20°N
120°E
150°E
180°
10000
5000
4500
4000
3500
3000
2500
2000
1500
1000
900
800
700
600
500
400
300
200
100
0
Transport(0–1000m) in Sv
15.0
(A) A_{GM}, Control
(B) A_{Redi}, ABER2D

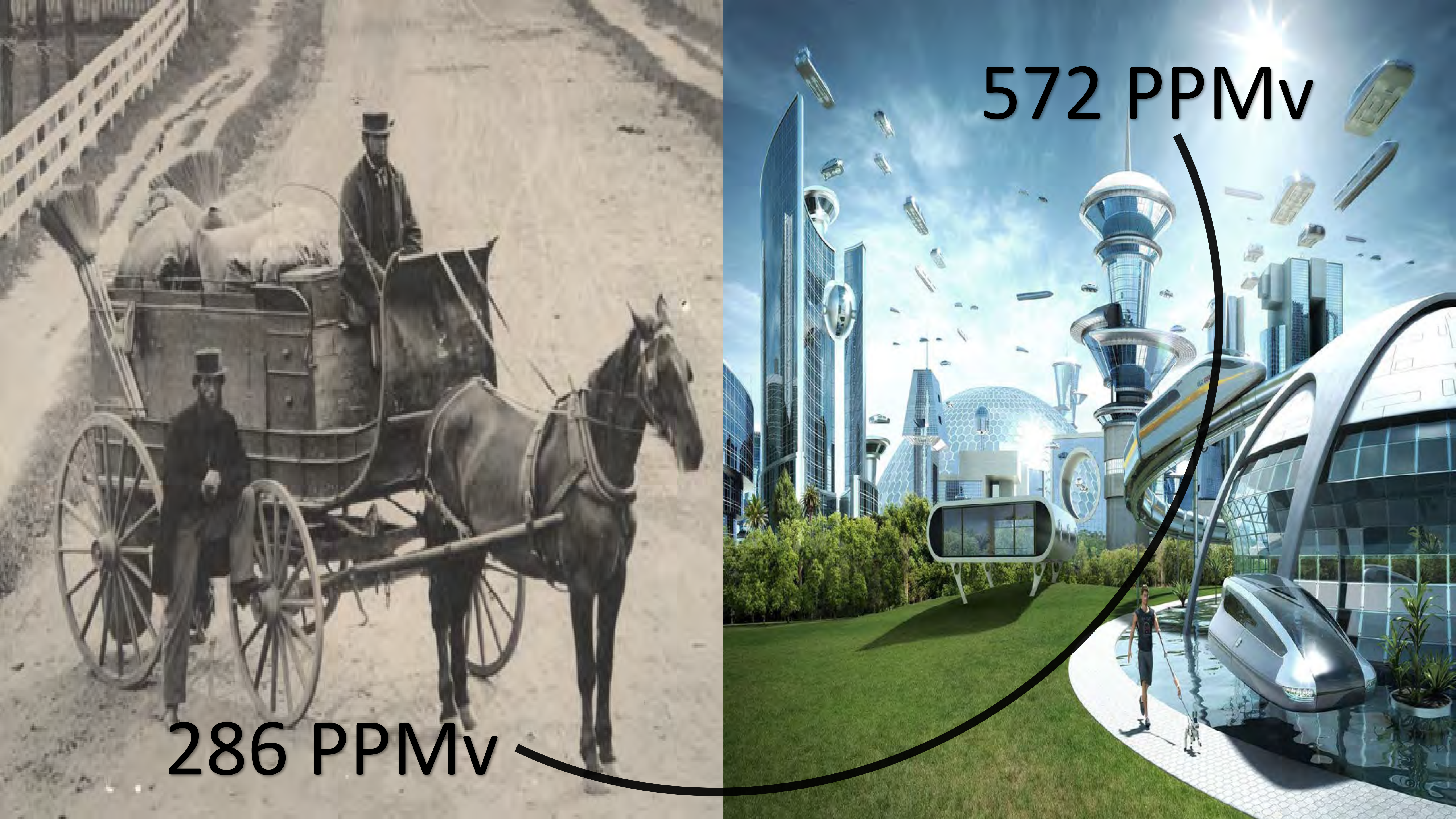
AREDI400
AREDI800
AREDI1200
AREDI2400

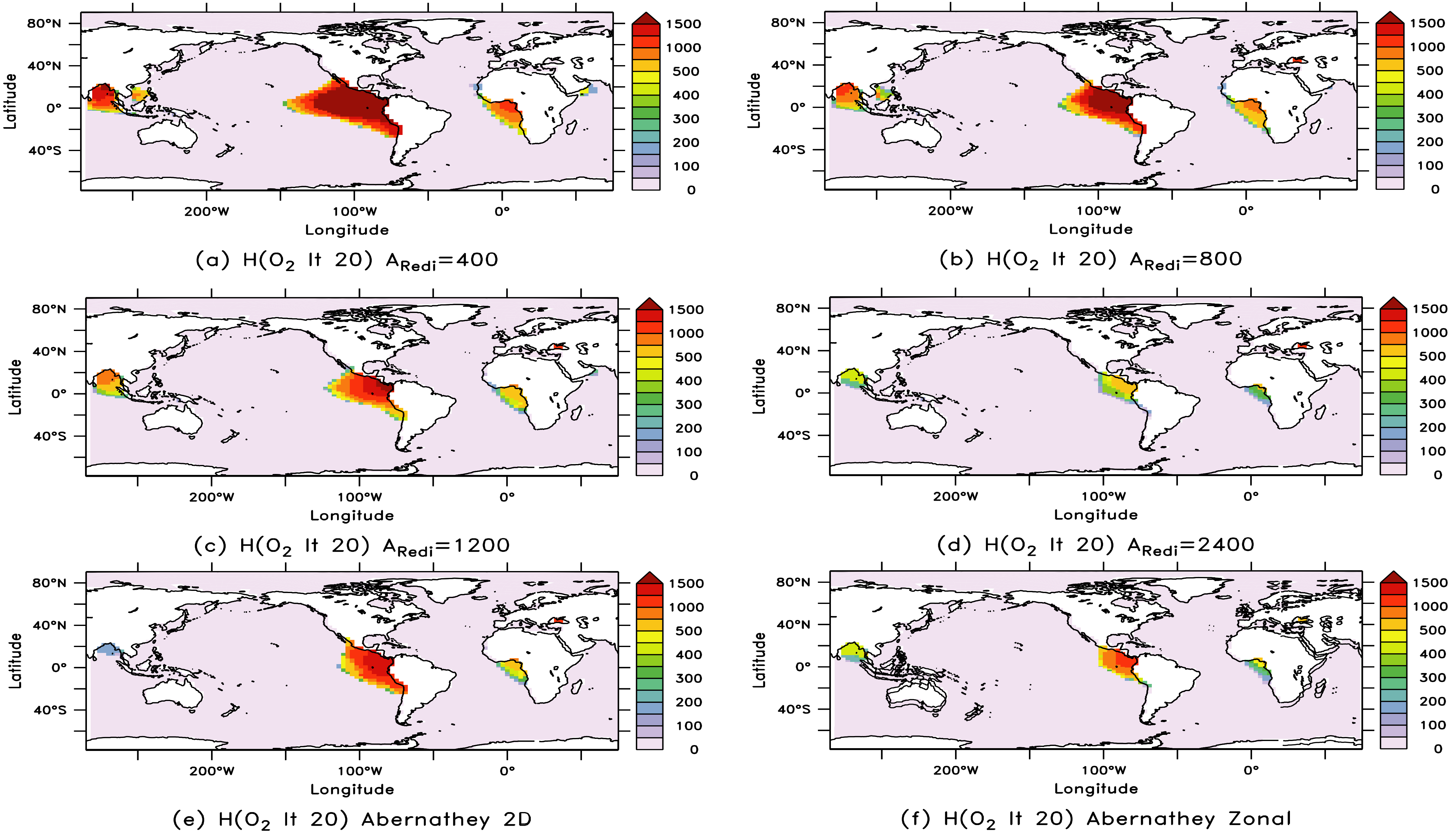
Constant in space and time

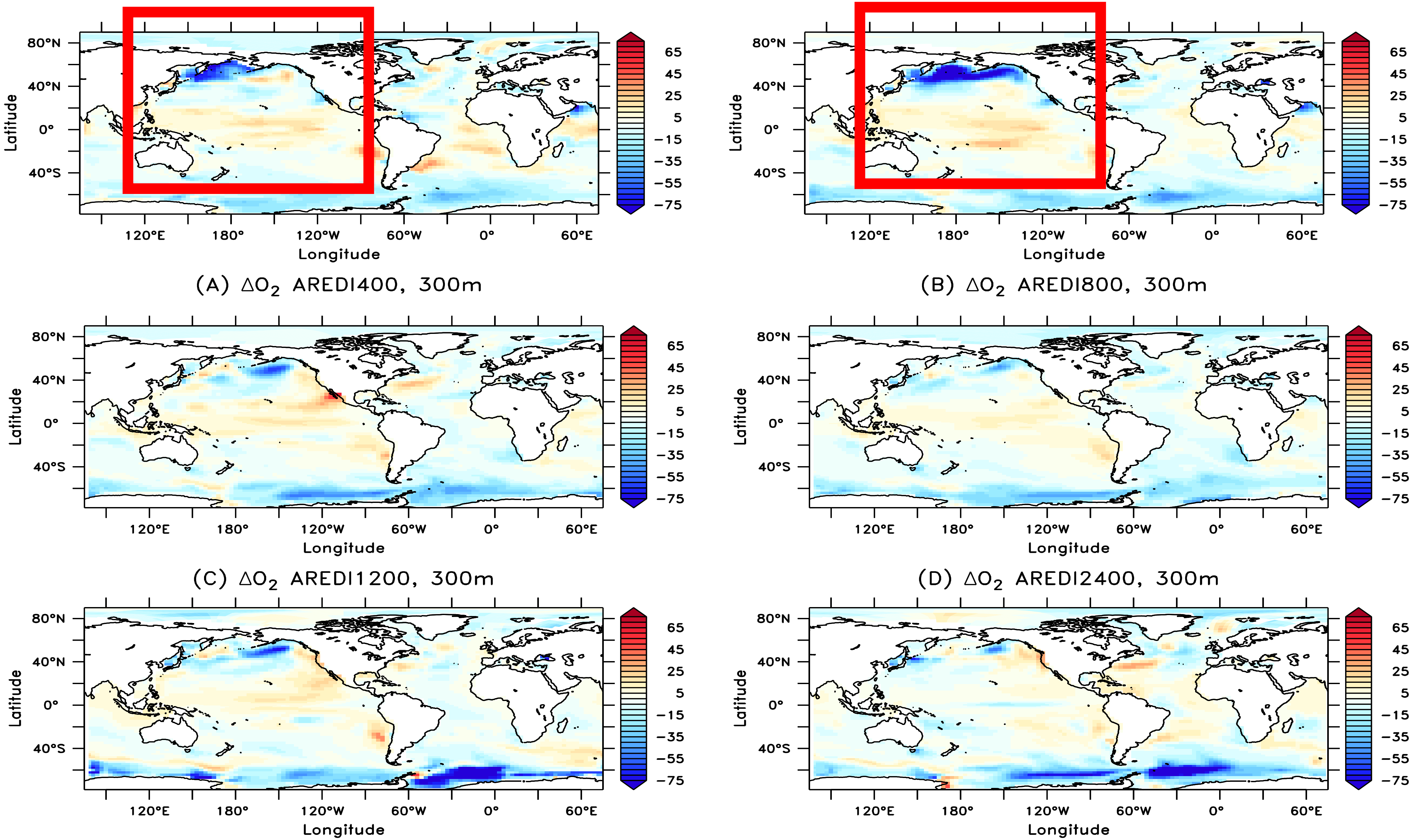
ABER2D
ABERZONAL

Vary in space, but not in time

Abernathey and Marshall (2013)


572 PPMv
286 PPMv


80°N
40°N
0°
40°S
Latitude
200°W
100°W
0°
Longitude
1500
1000
500
400
300
200
100
0
(a) H(O2 lt 20) ARedi=400
(b) H(O2 lt 20) ARedi=800
(c) H(O2 lt 20) ARedi=1200
(d) H(O2 lt 20) ARedi=2400
(e) H(O2 lt 20) Abernathey 2D
(f) H(O2 lt 20) Abernathey Zonal



(A) ΔO_2 AREDI400, 300m

(B) ΔO_2 AREDI800, 300m

(C) ΔO_2 AREDI1200, 300m

(D) ΔO_2 AREDI2400, 300m

(E) ΔO_2 ABER2D, 300m

(F) ΔO_2 ABERZONAL, 300m

A_{REDI} (m^2/s)	Global average TEMP (and its change) °C	O_2 concentration (and its change) µM/kg	Volume of O_2<88 µM (and its change) Mkm^3	Volume of O_2<20 µM (and its change) Mkm^3	PO4-PO4_pre (and its change) mol/kg
Obs.	3.660	177.1	150.1	17.70	N/A
400	4.846 (0.319)	154.7 (-4.127)	182. 6 (3.908)	51.28 (-1.939)	0.905 (0.021)
800	4.604 (0.326)	161.4 (-5.625)	141.8 (2.139)	31.39 (-1.910)	0.844 (0.034)
1200	4.379 (0.324)	173.5 (-6.984)	102.1 (-0.677)	20.10 (-0.999)	0.755 (0.042)
2400	4.244 (0.318)	185.5 (-7.023)	42.71 (-0.899)	5.450 (-0.597)	0.661 (0.042)
2D	4.604 (0.324)	168.3 (-6.721)	87.0 (0.224)	13.3 (-1.190)	0.775 (0.045)
Zonal	4.448 (0.323)	176.7 (-5.998)	53.9 (1.255)	4.84 (-0.812)	0.752 (0.037)

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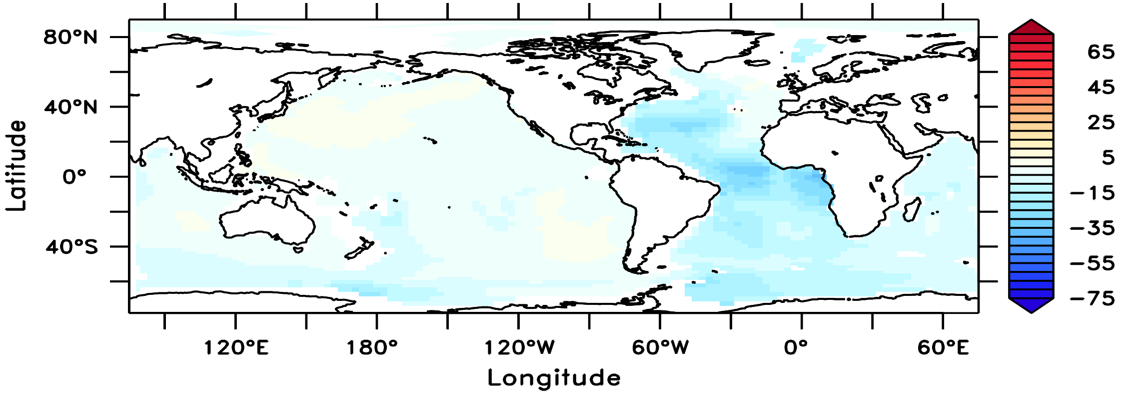
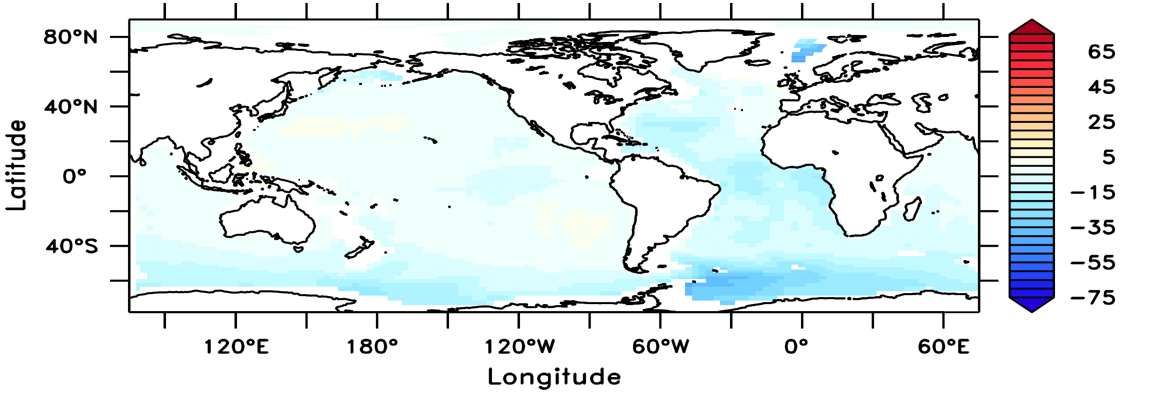
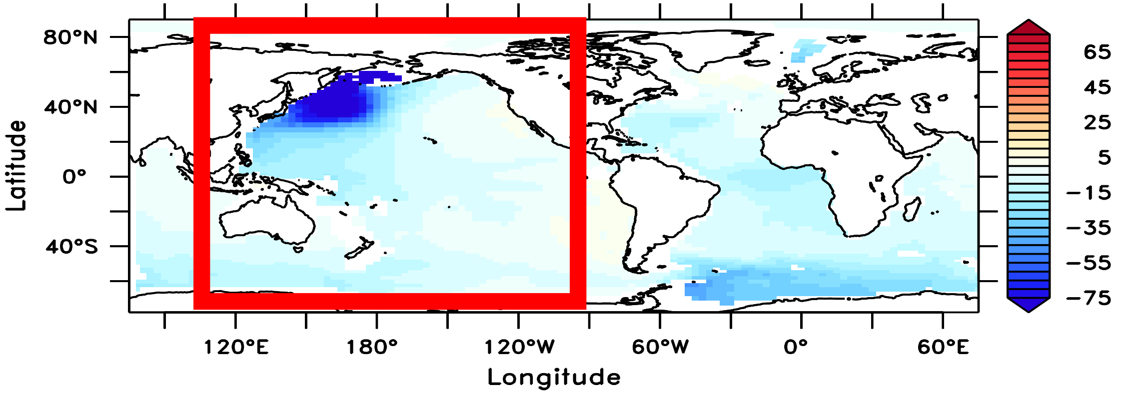


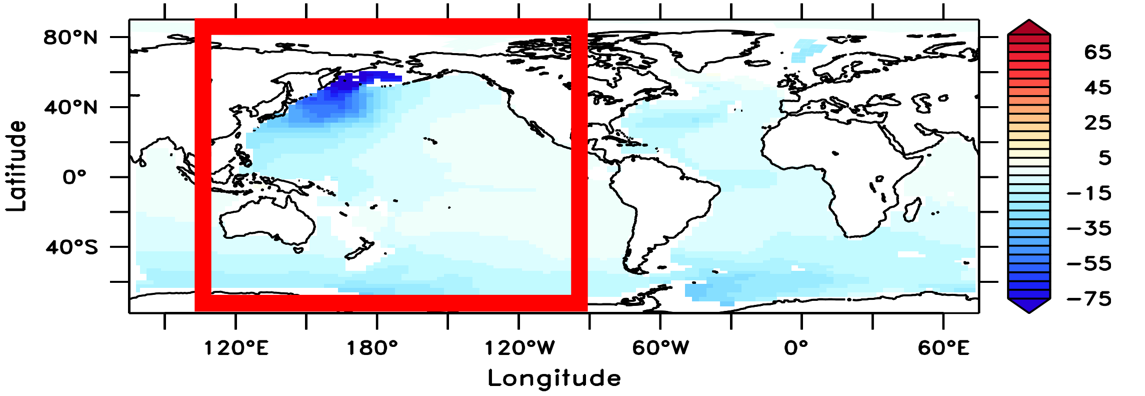
(A) ΔO_2 AREDI400, 3000m



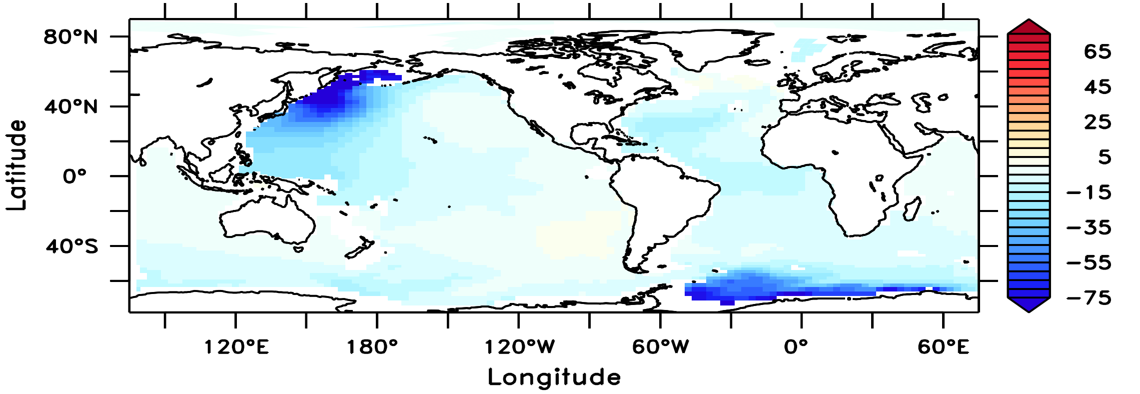
(B) ΔO_2 AREDI800, 3000m



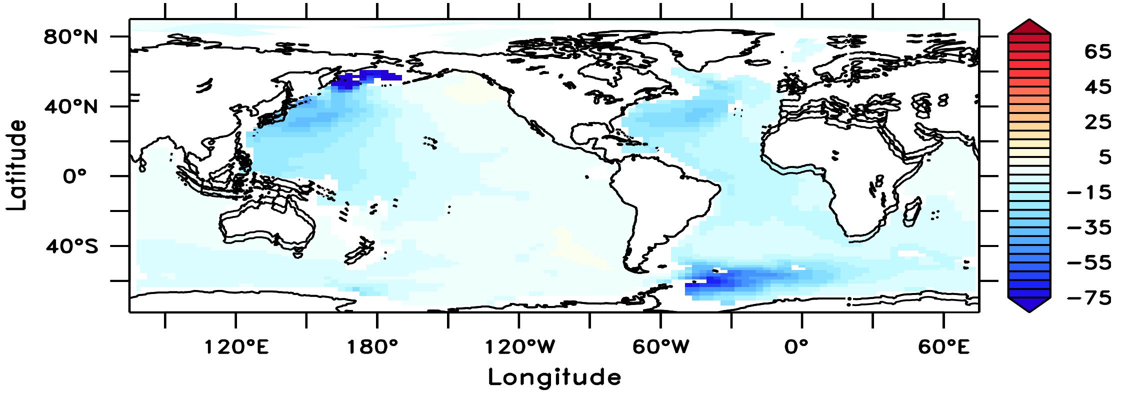
(C) ΔO_2 AREDI1200, 3000m



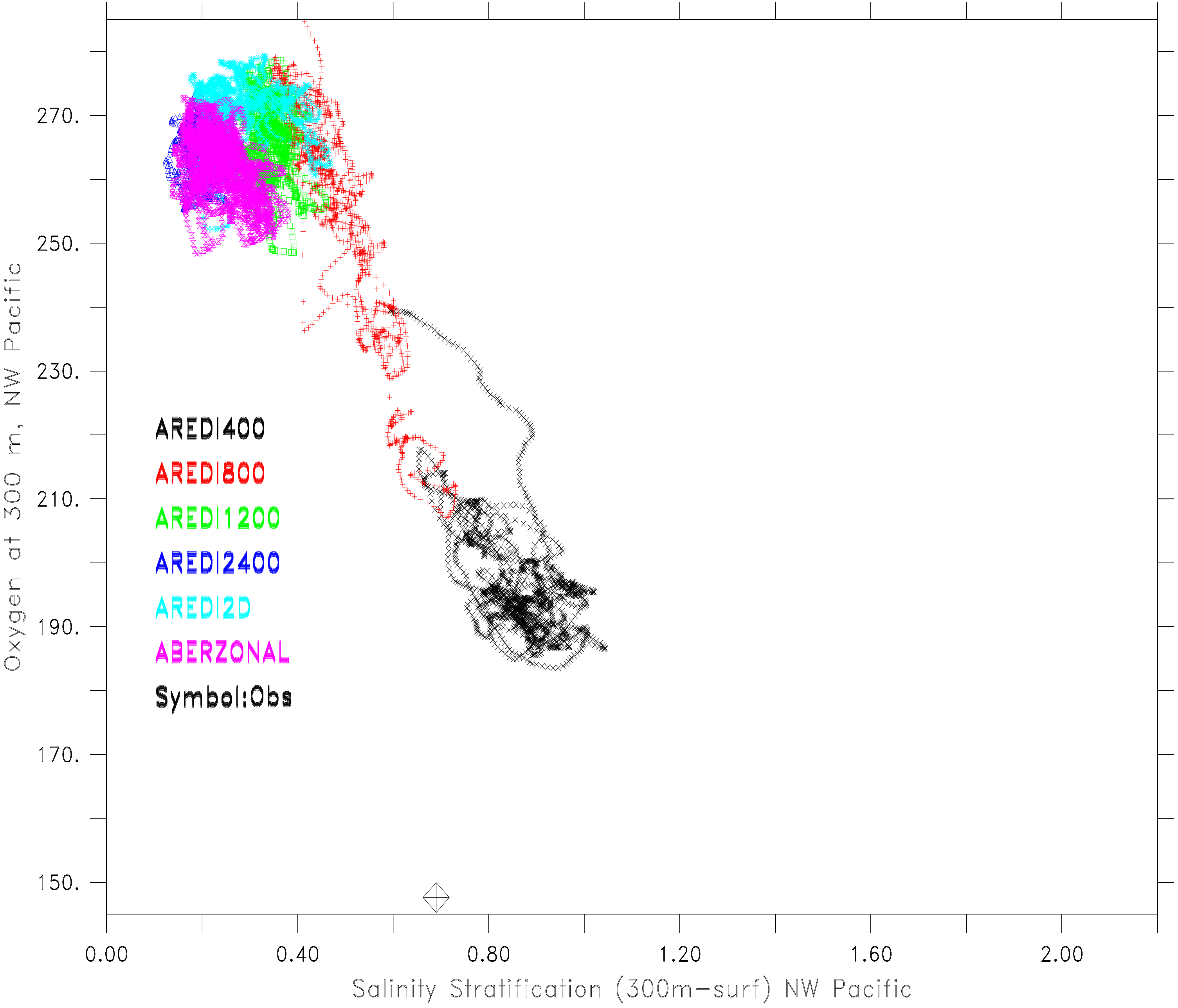
(D) ΔO_2 AREDI2400, 3000m



(E) ΔO_2 ABER2D, 3000m



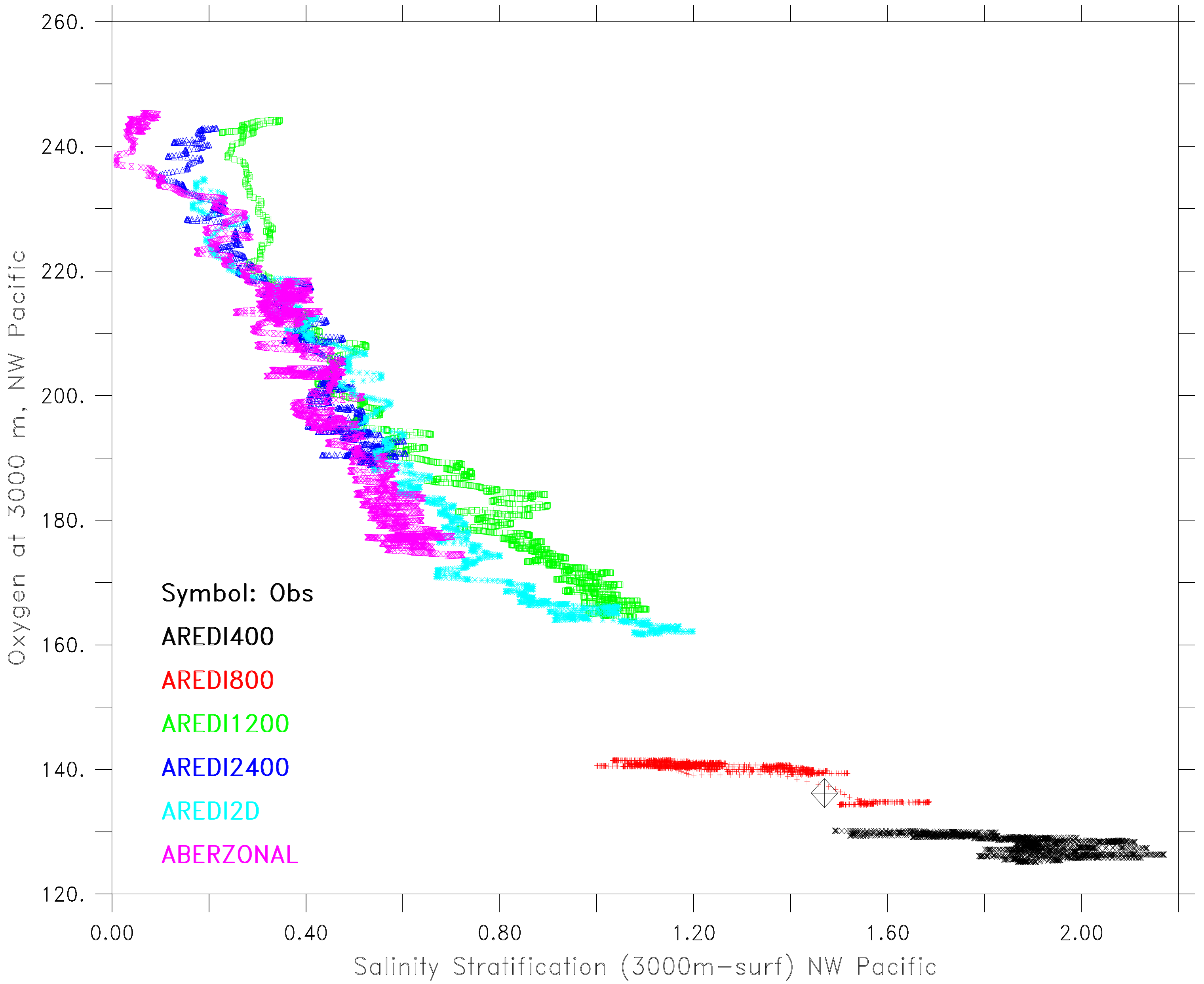
(F) ΔO_2 ABERZONAL, 3000m



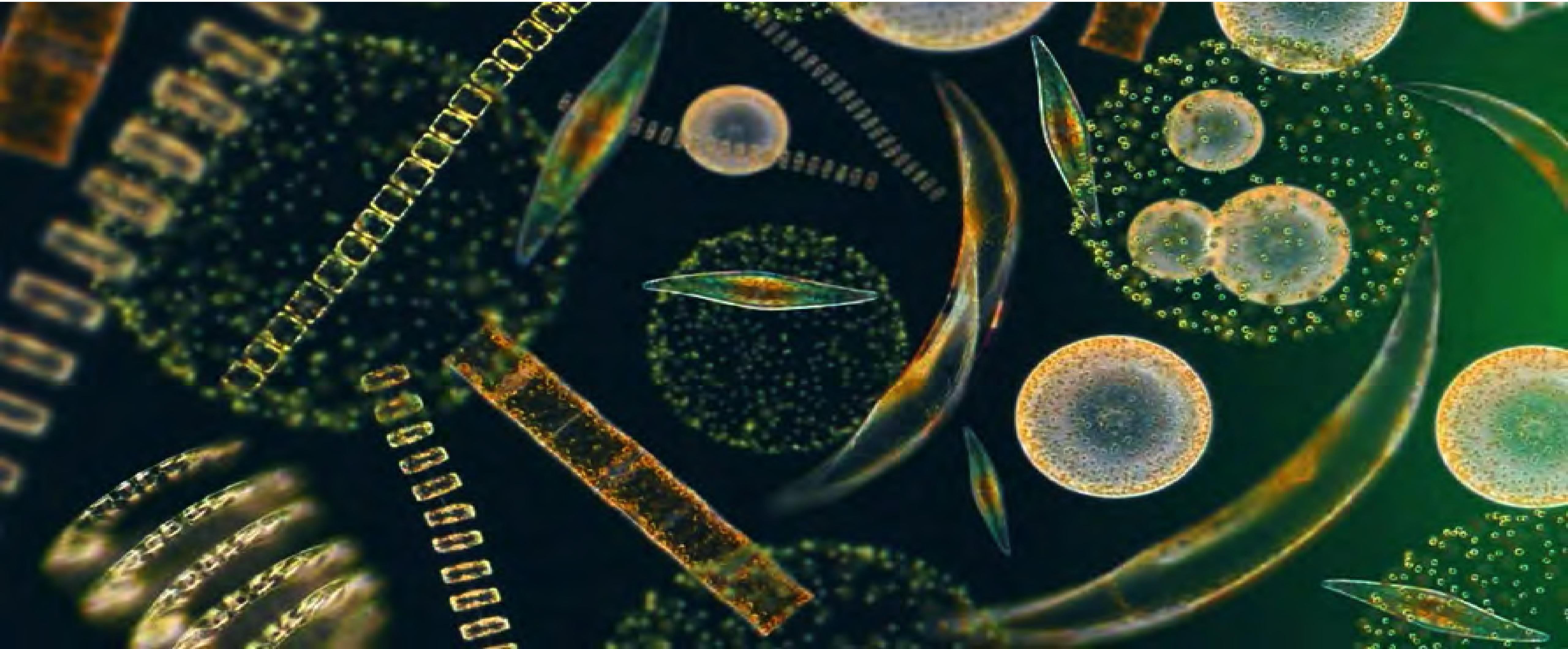
Scatter plot results from six model runs (AREDI400, AREDI800, AREDI1200, AREDI2400, ABER2D and ABERZONAL) with doubled CO_2, compared to observations (symbol), in the NW Pacific

- At 300m there is less salinity stratification amongst the models resulting in higher oxygen concentration.

At 3000m there is greater salinity stratification amongst the low mixing models and a lower salinity stratification amongst the high mixing models and ABER2D and ABERZONAL, thus resulting in higher oxygen concentrations.



What about our marine phytoplankton friends?



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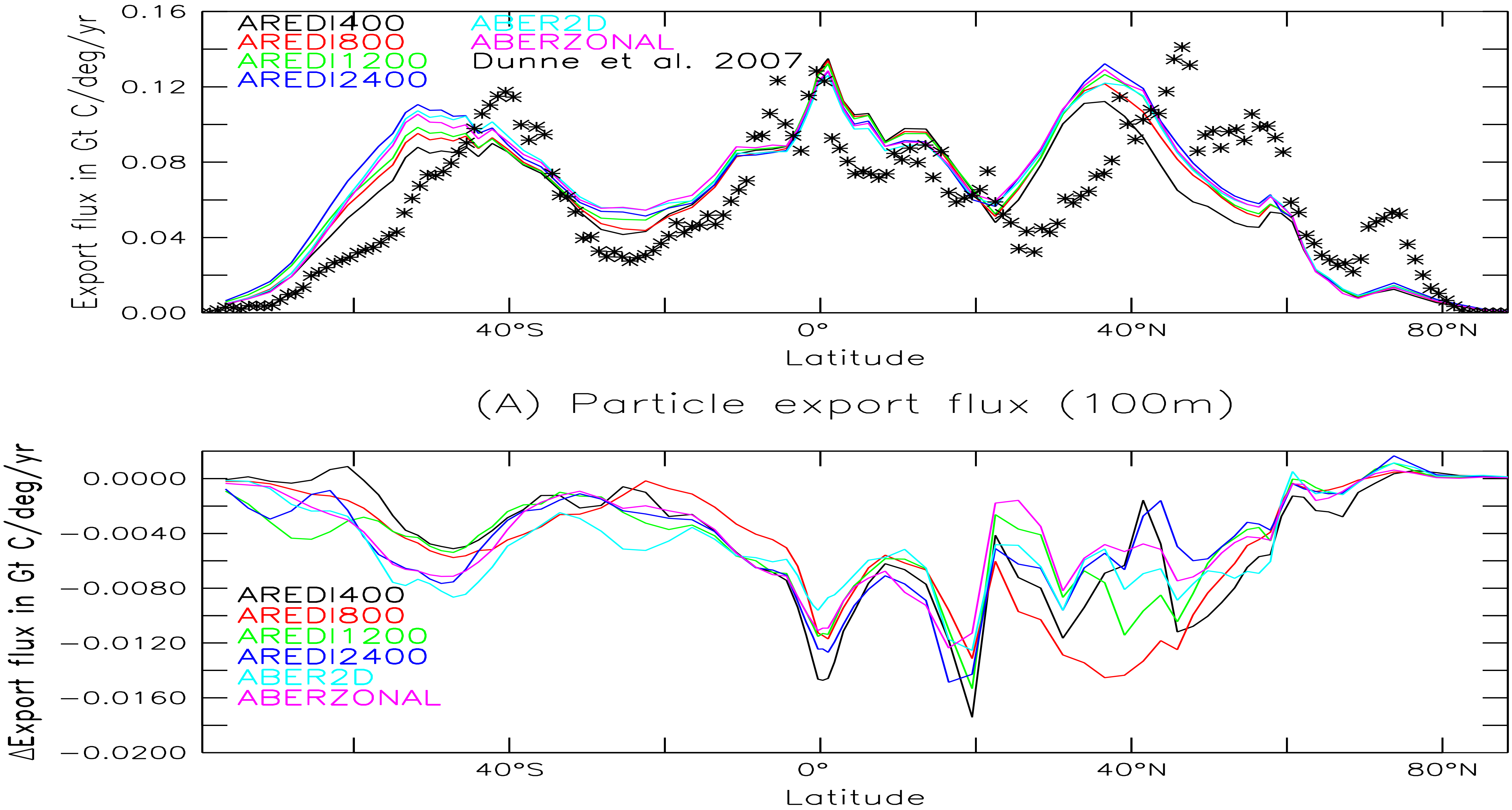


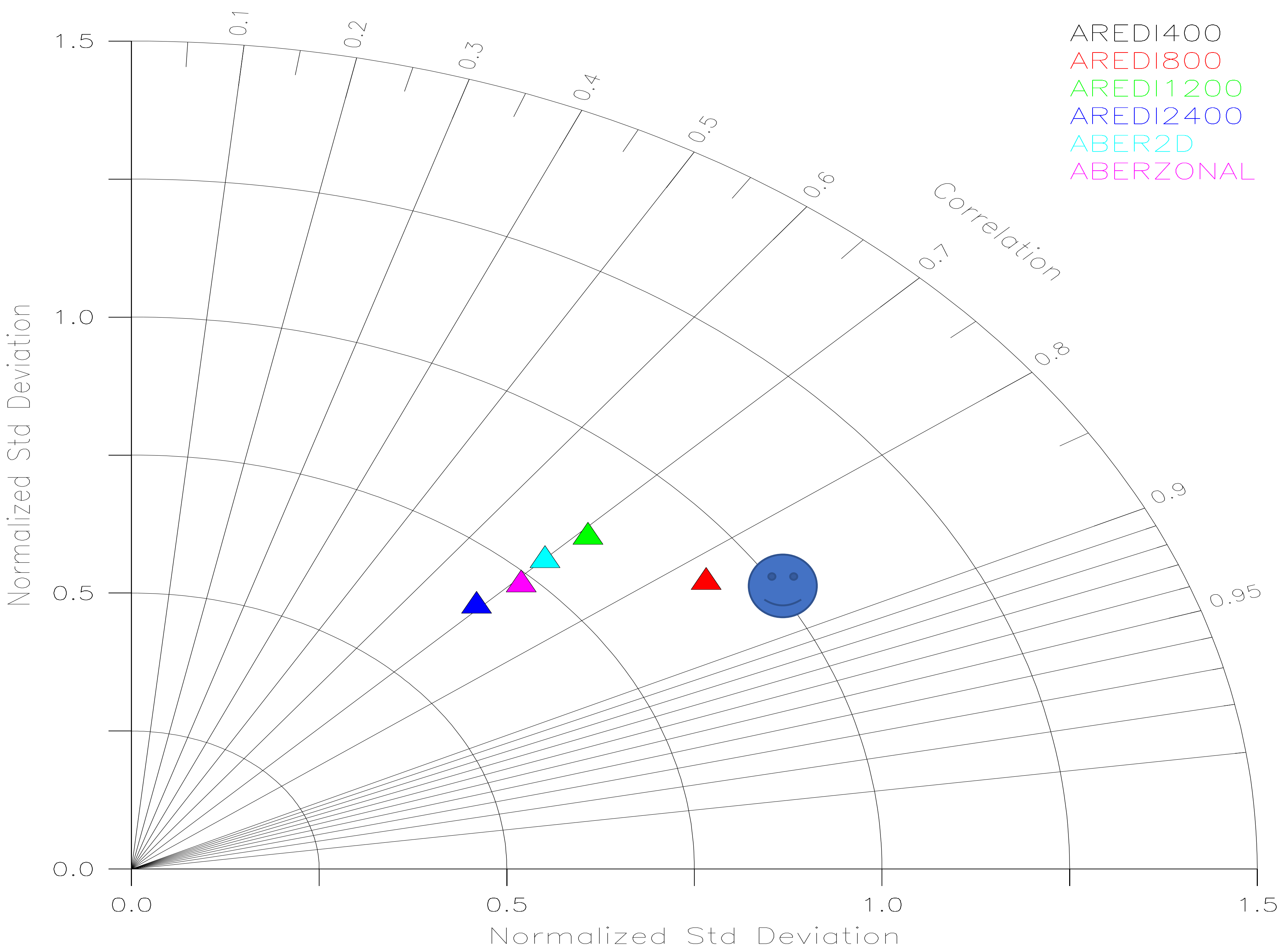
(A) Particle export flux (100m)

(B) Change in Export Production 40−140 yrs after CO_2 doubling

Export production with a 100-year average climatology and a depth of 100m, and the change in consumption in parentheses with doubled CO_2, across the model suite. Changes are seen 40-140 years after doubling.

	Global	Atlantic 30N-65N	Pacific 30N-65N	Southern Ocean <30S	Tropics 30S-30N
Satellite	9.8 +/- 20%	1.1	1.5	2.4	3.9
AREDI400	9.95 (-0.73)	1.31 (-0.14)	1.14 (-0.12)	2.69 (-0.09)	5.01 (-0.45)
AREDI800	10.4 (-0.78)	1.31 (-0.09)	1.43 (-0.22)	2.86 (-0.14)	5.02 (-0.39)
AEDI1200	10.7 (-0.73)	1.26 (-0.04)	1.56 (-0.20)	2.96 (-0.15)	5.12 (-0.39)
AREDI2400	11.1 (-0.73)	1.28 (-0.08)	1.65 (-0.09)	3.25 (-0.17)	5.08 (-0.44)
ABER2D	10.9 (-0.78)	1.25 (-0.06)	1.62 (-0.18)	3.14 (-0.20)	5.13 (-0.41)
ABERZONAL	10.9 (-0.67)	1.26 (-0.13)	1.60 (-0.05)	3.04 (-0.16)	5.21 (-0.37)

Taylor Diagram




not when I shift into
maximum oversdrive

Future work

- Tripling CO_2 from pre-industrial values
  - Change in volume
  - Change in dynamical pump and/or biological pump
  - Change regionally

- Climate Change effects on biological pump and therefore, future ocean sequestration
  - Implications on Nationally Determined Contributions (NDCs) from Parties that ratified the Paris Agreement
  - Change in phytoplankton biomass
  - Biological pump change and its effects on the global carbon cycle


Thank you!
Contact:
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Sources:

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