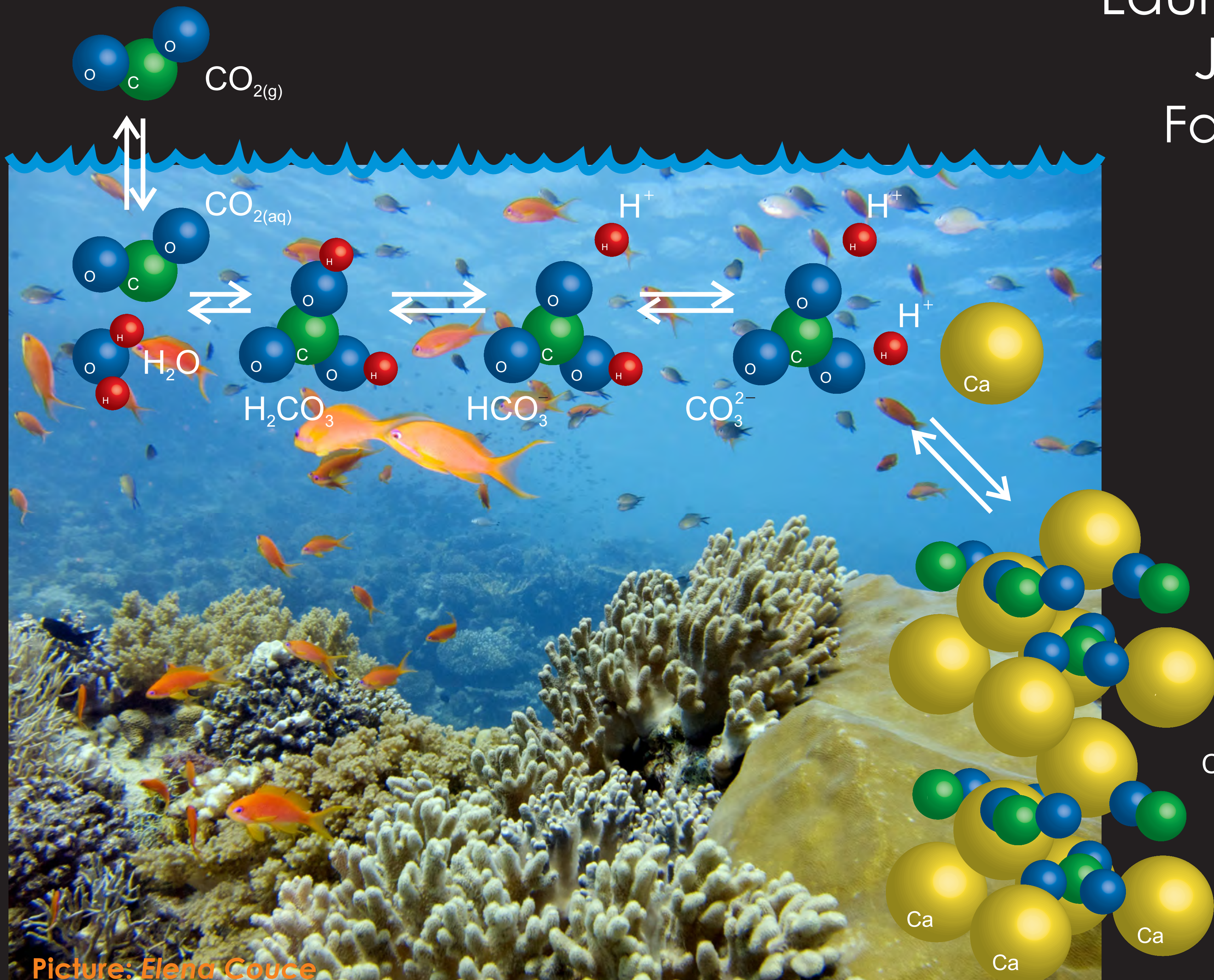
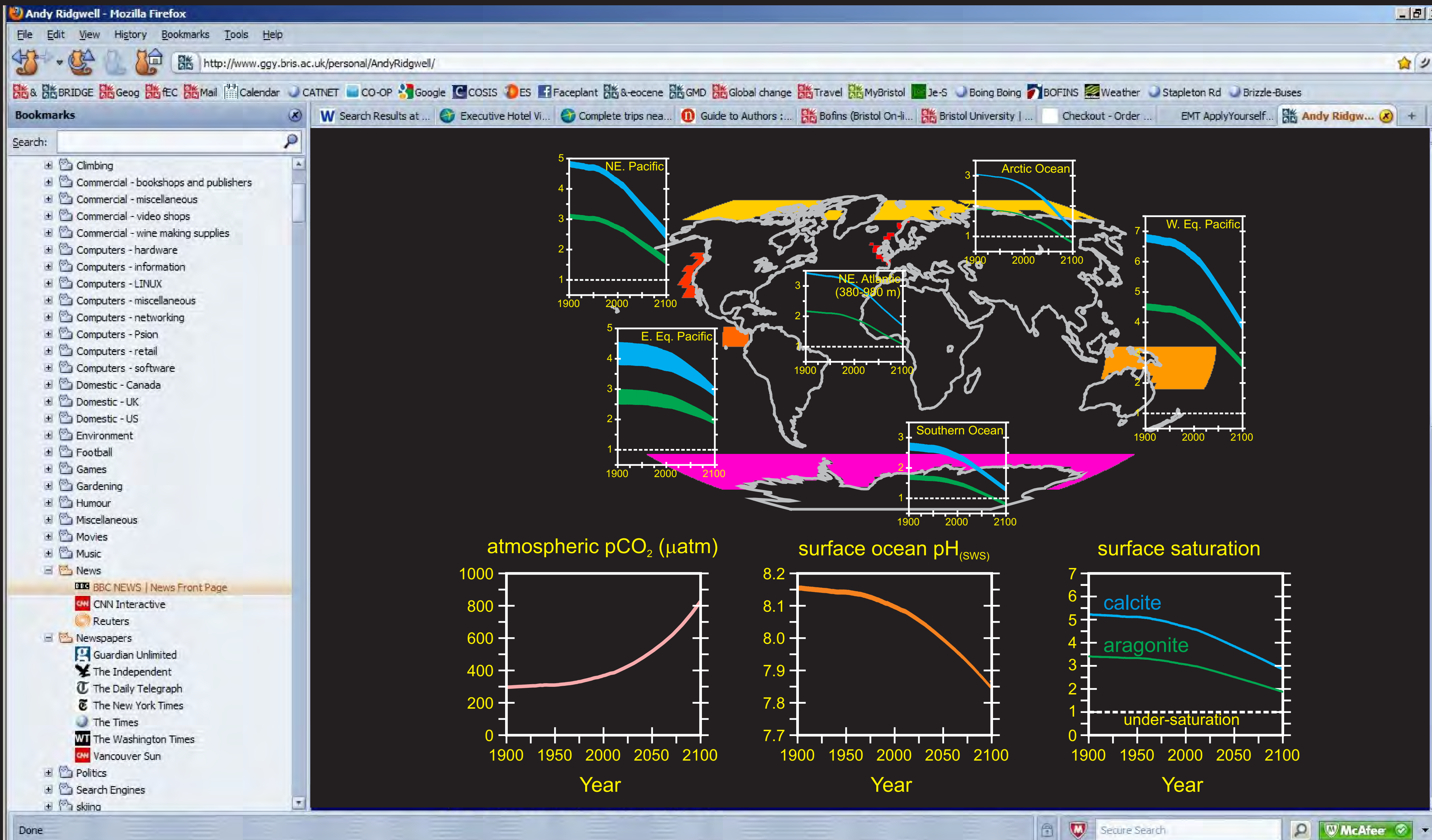
CO_2-CarbonCycle-Climate-Interactions C^4I

Lauren Gregoire
Jamie Wilson
Fanny Monteiro
Steve Barker
Andy Ridgwell

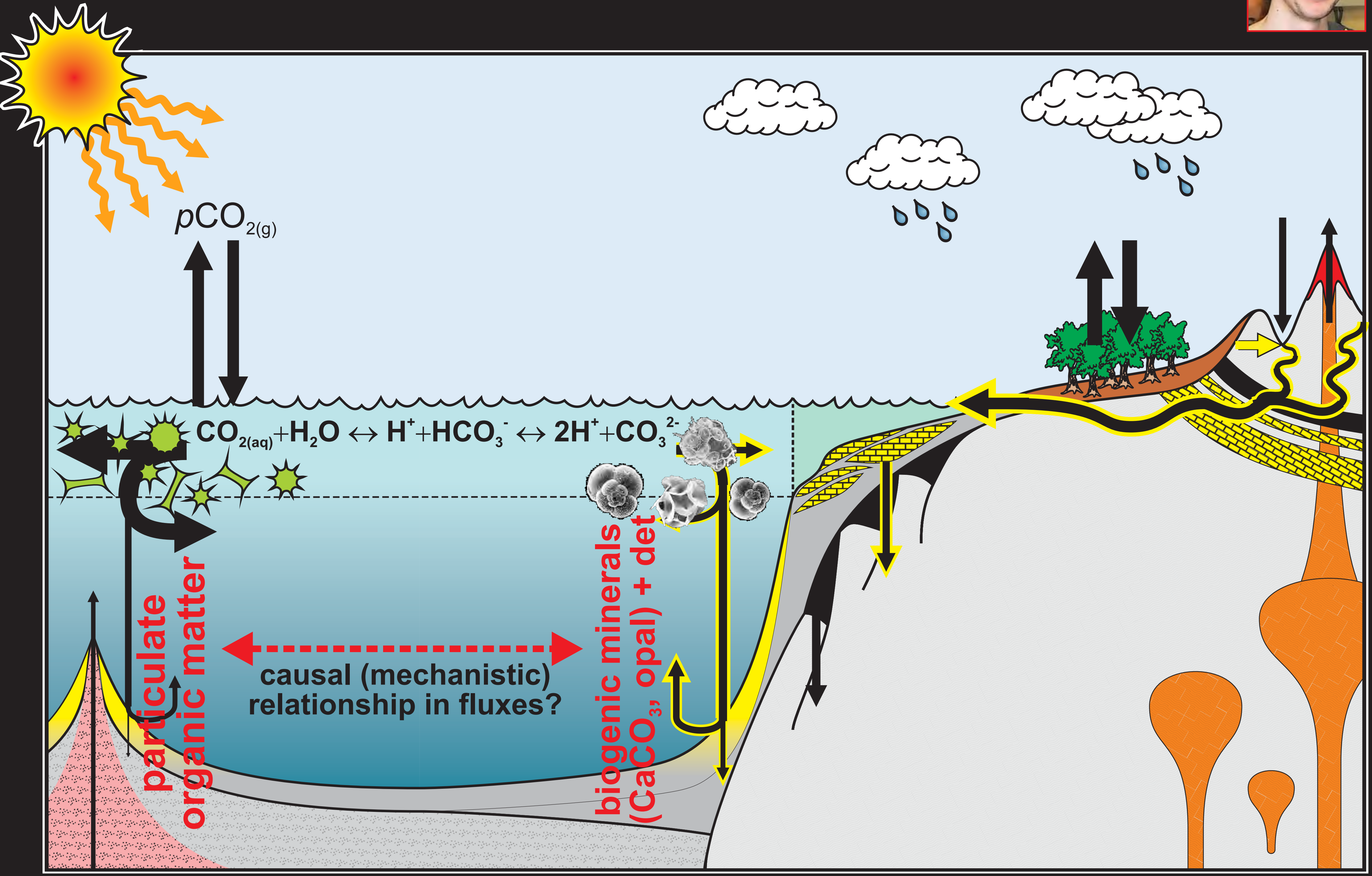


projecting global (bio)geochemical impacts

(and the 'ocean acidification viewer')



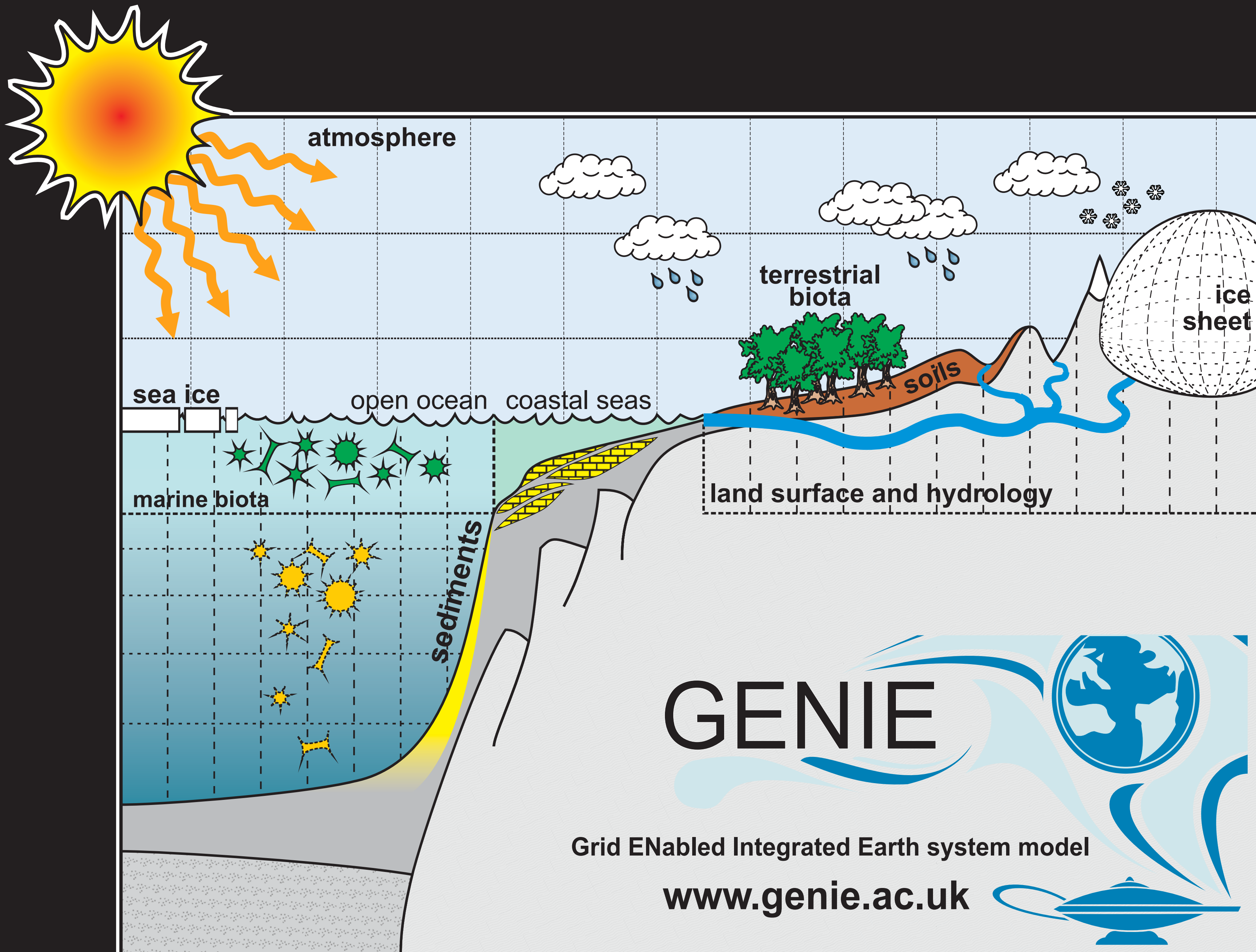
The biological pump and mineral 'ballasting'



‘Hands on’ OA (Earth system) modelling workshop(s)

mid/late summer 2012/13? ... TELL ME!

(also: carbonate chemistry calculation tutorials?)

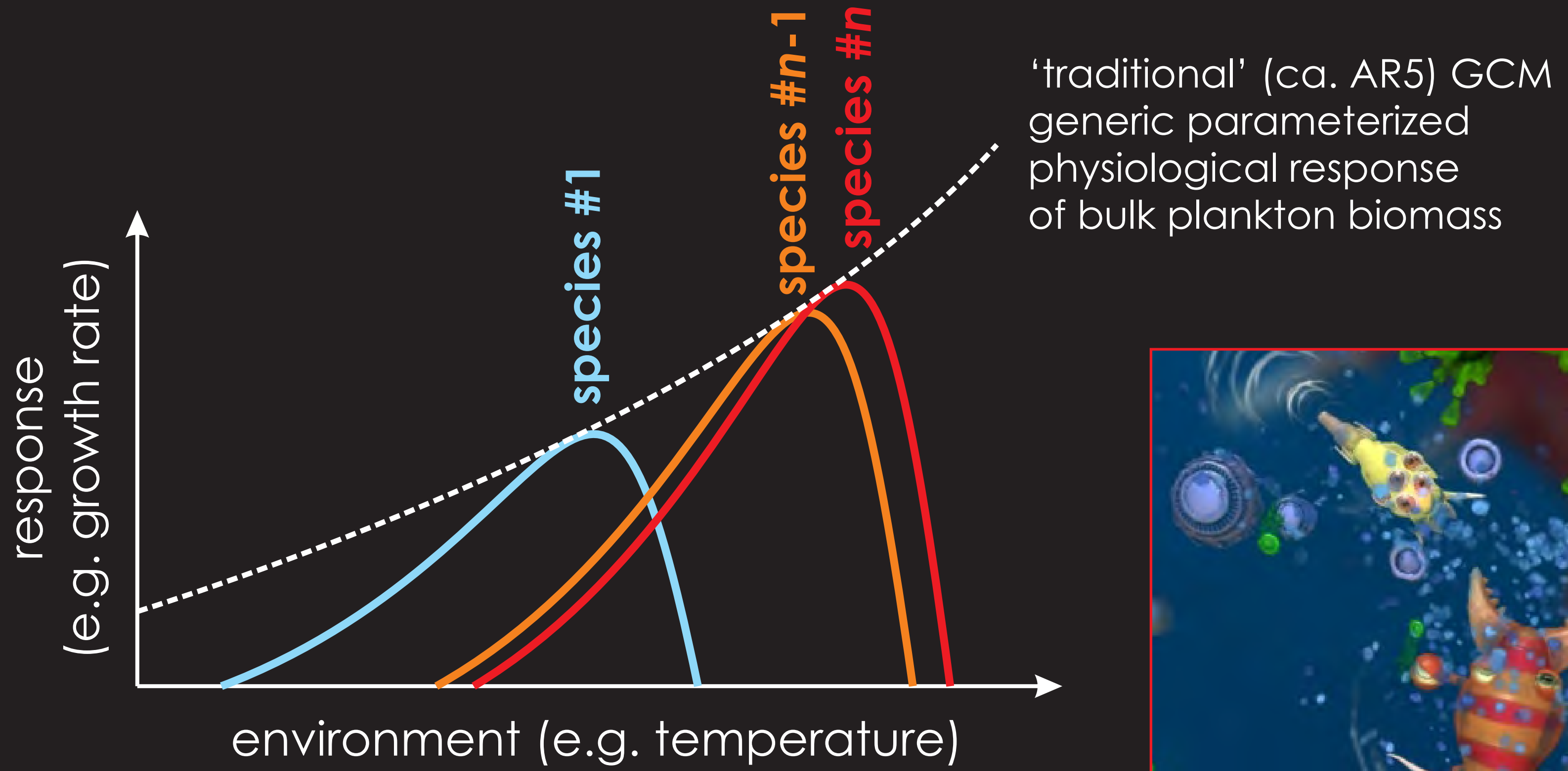


UKOA-AVA activity:

'Modelling the ecology of coccolithophores in the ocean'

2-day workshop to bring together:
observationalists+experimentalists+geneticists+evolutionary 'historians' (geologists?) and ... computer modellers, in conjunction with explicit hypothesis-testing in an advanted global ecosystem model 'framework'

13+14th September 2012
(organiser: Dr. Fanny Monteiro)



University of BRISTOL

‘Climatology’ of ocean acidification for a range of CO_2 emission scenarios

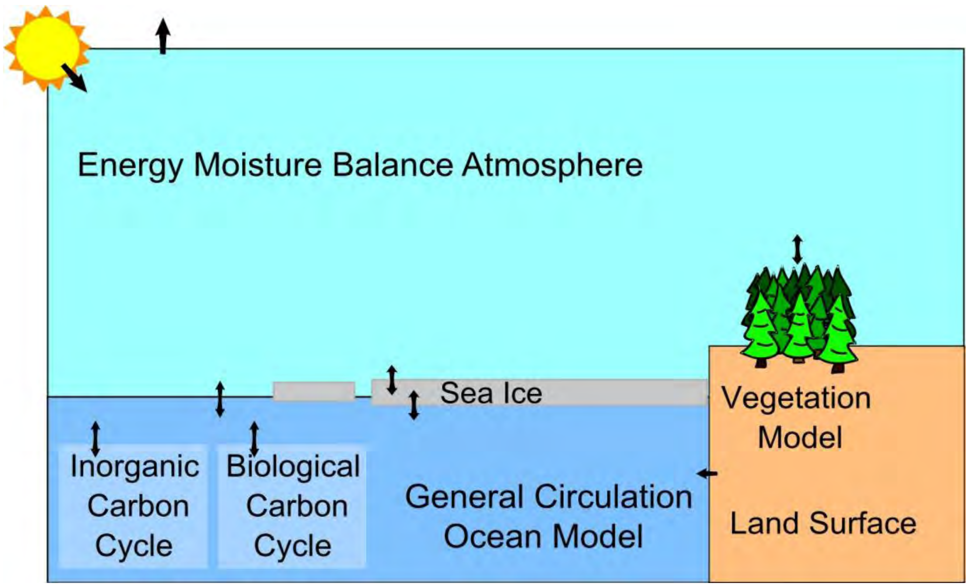
Lauren J Gregoire, Andy Ridgwell, Chris Vernon, Michael Eby

UK Ocean Acidification Research Programme

University of Victoria

BRIDGE

Uvic-ESCM



Global model of the Earth system
Resolution: 3.6° longitude x 1.8° latitude
19 levels in the ocean
Can solve seasonal cycle but not interannual varibility

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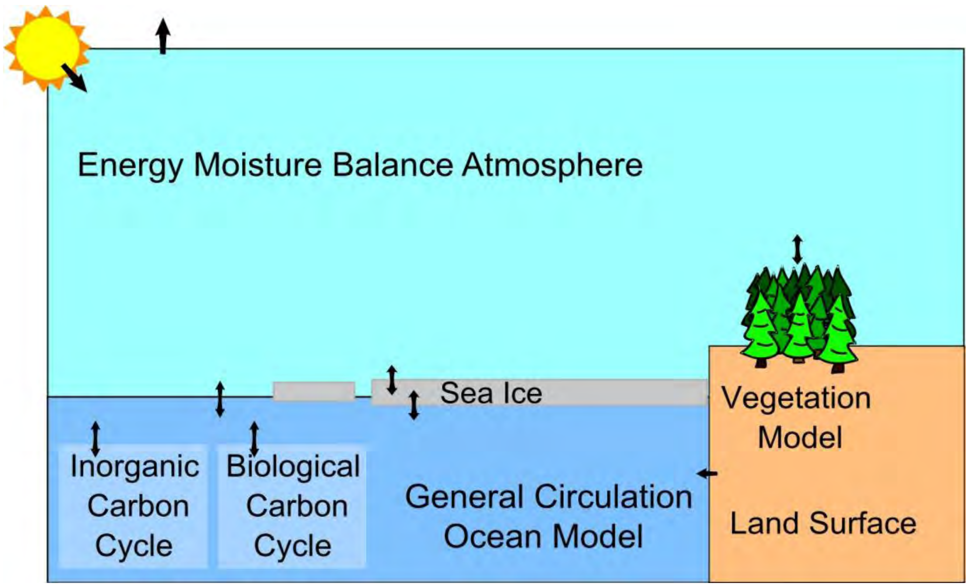
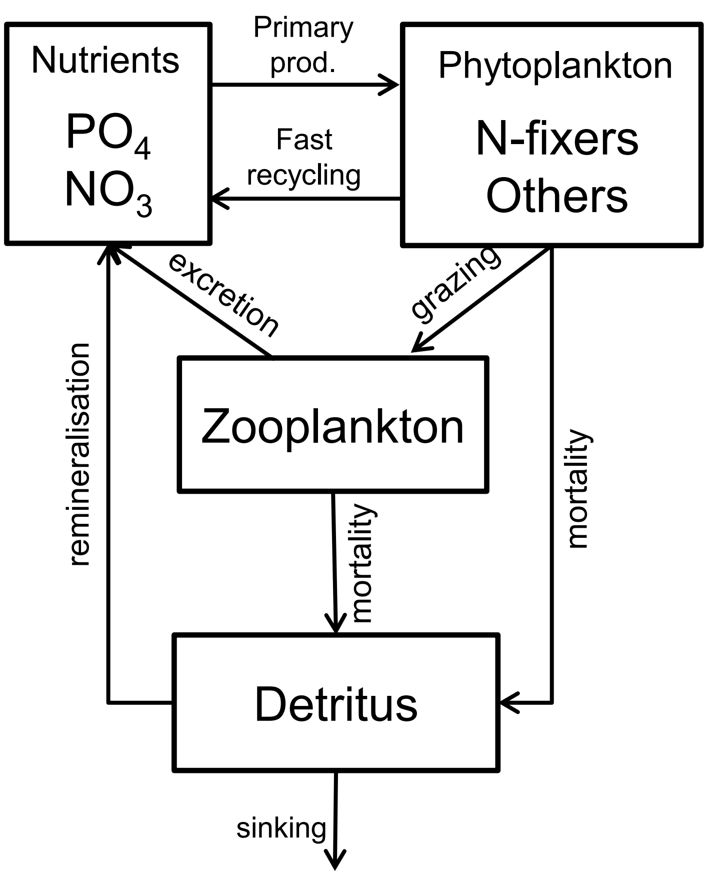
Uvic-ESCM



NPZD model



Global model of the Earth system
Resolution: 3.6° longitude x 1.8° latitude
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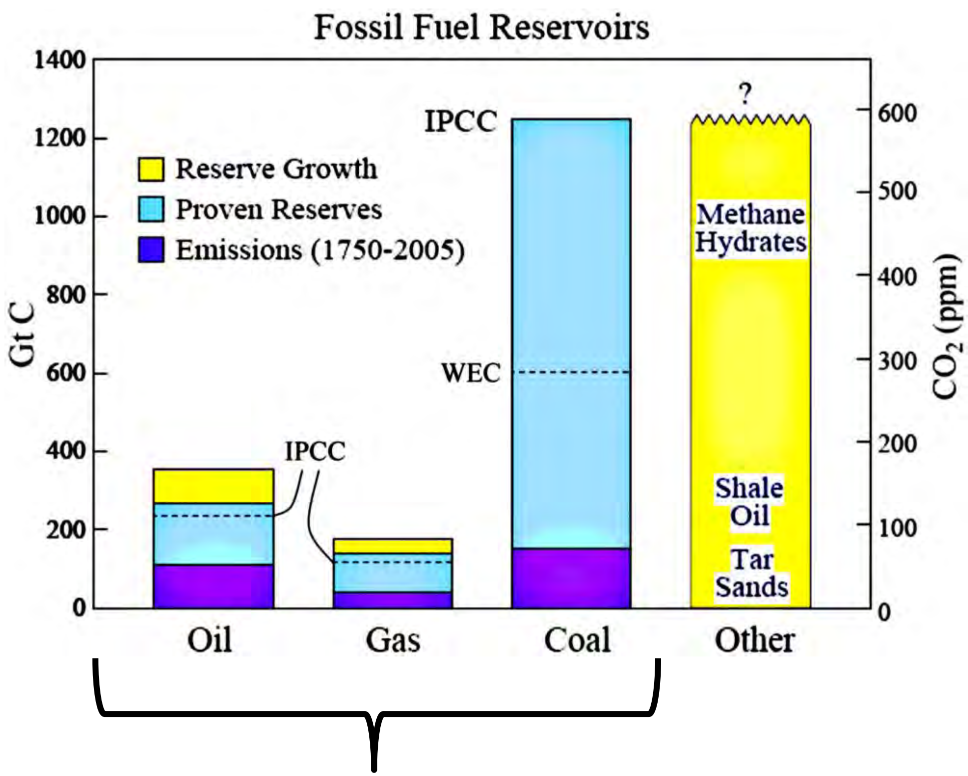
CO_2 emission scenarios



Max =1800 Gt C

Scenarios		Cummulative emissions / Gt C
Demand-driven	Caldeira	5000
	A1B	5000
	A2	5000
	B1	5000
Supply-limited	Tans High	1225
	Tans low	725
	Rutledge	550

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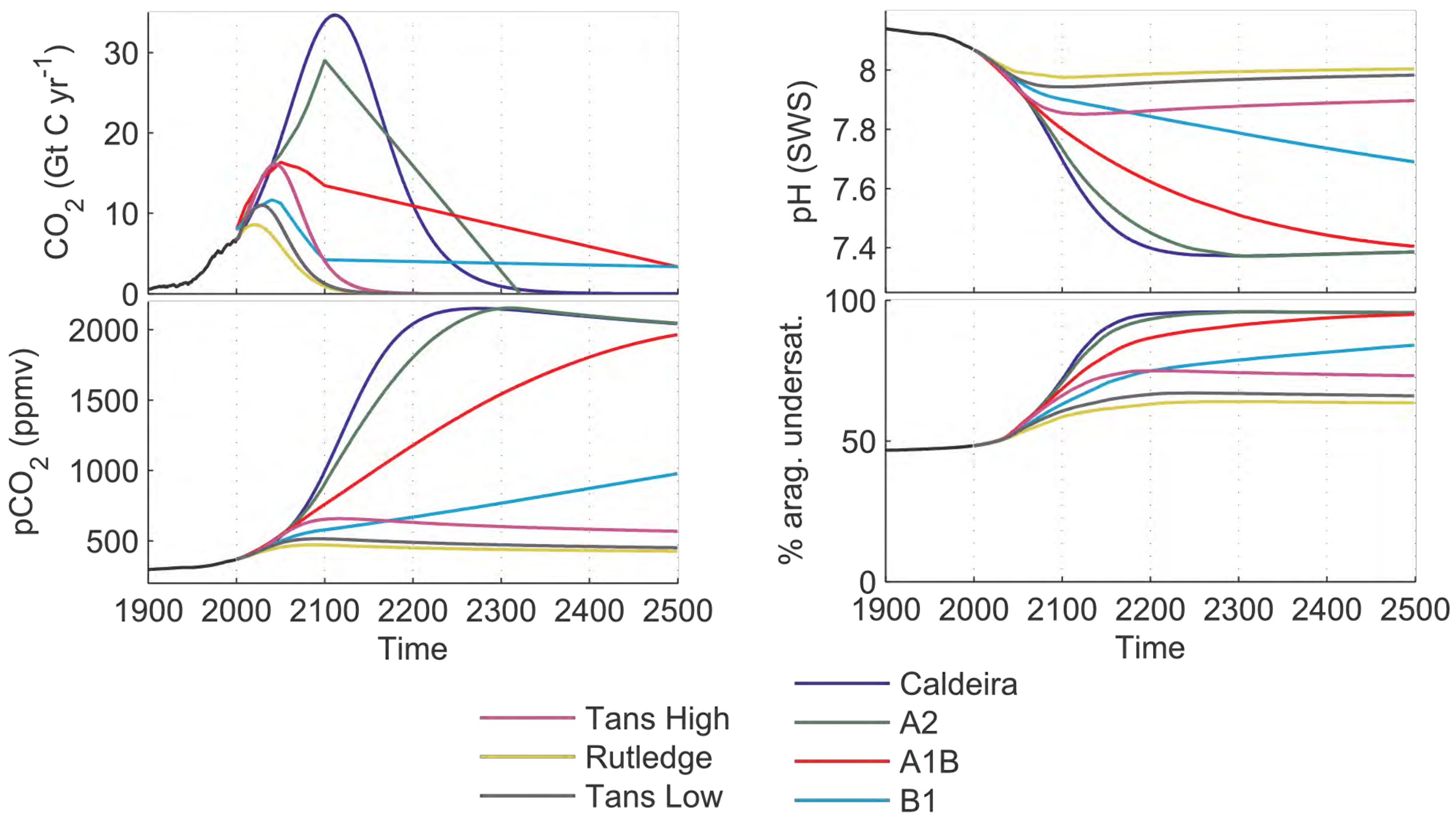
Projections of ocean acidification



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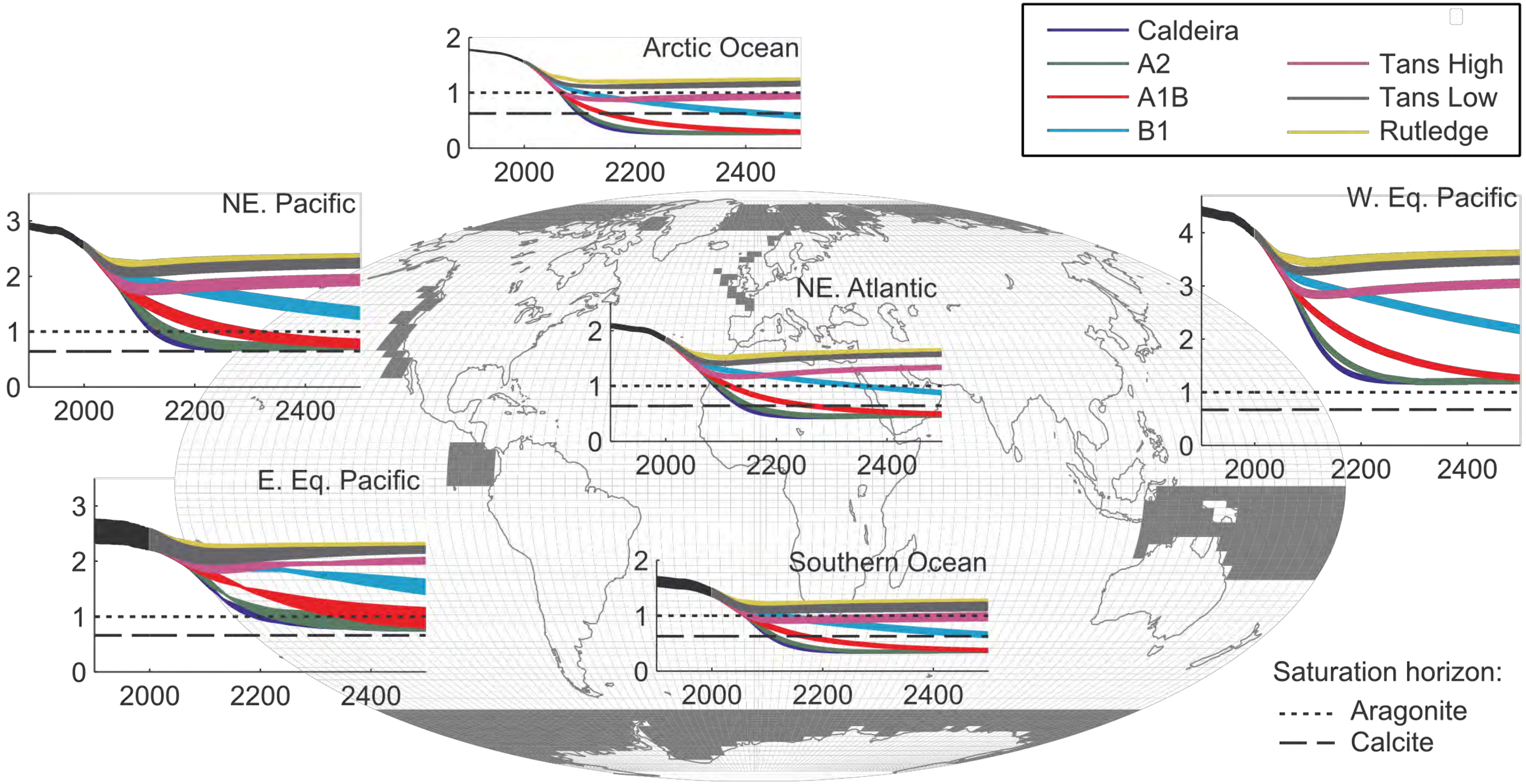
Aragonite saturation by region



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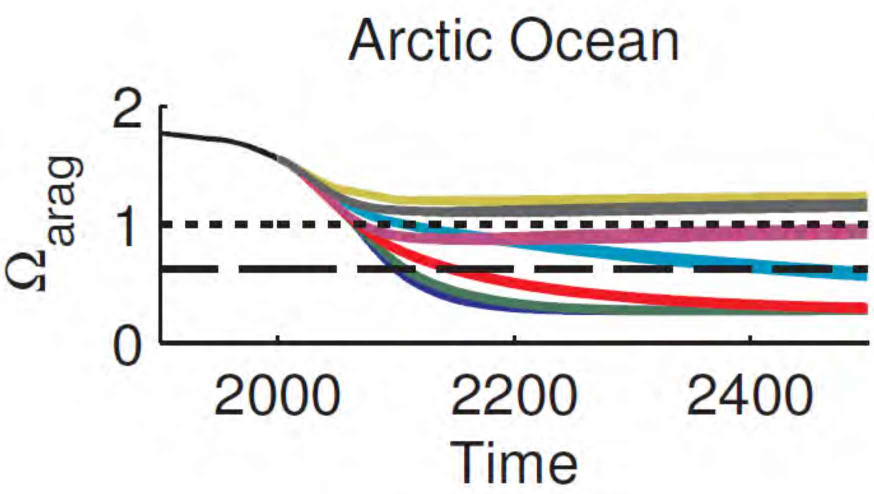
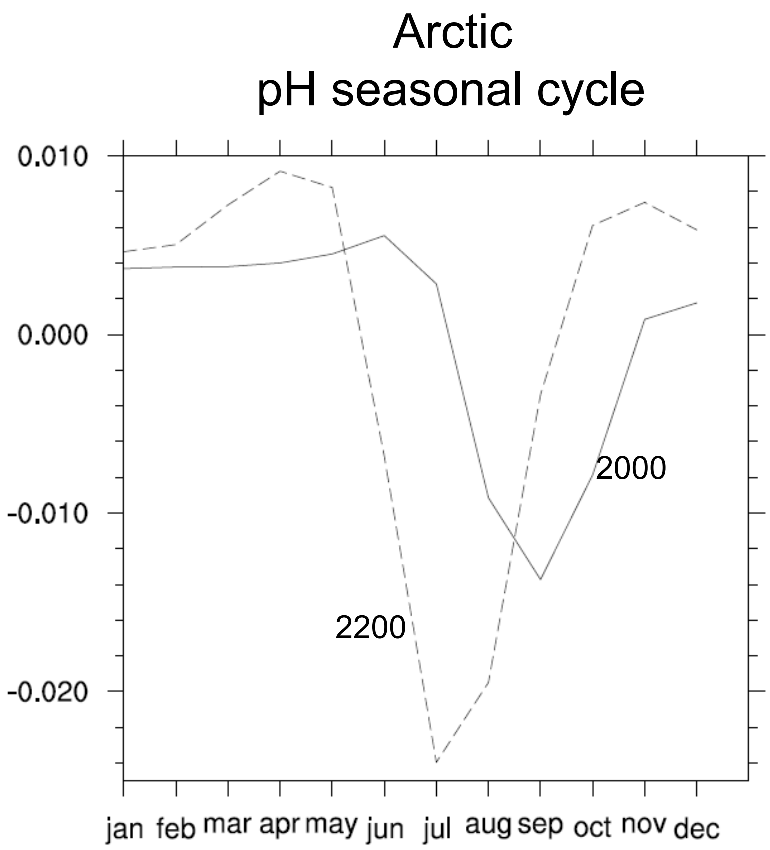
High latitudes





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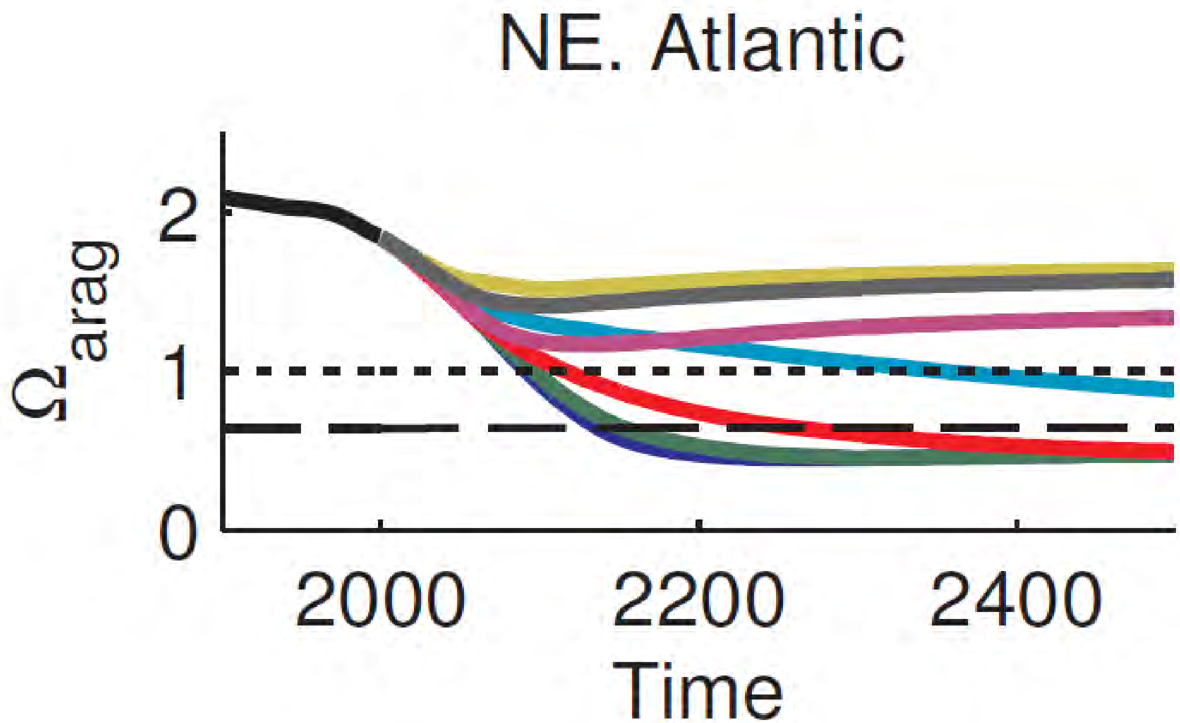
NE Atlantic ocean floor



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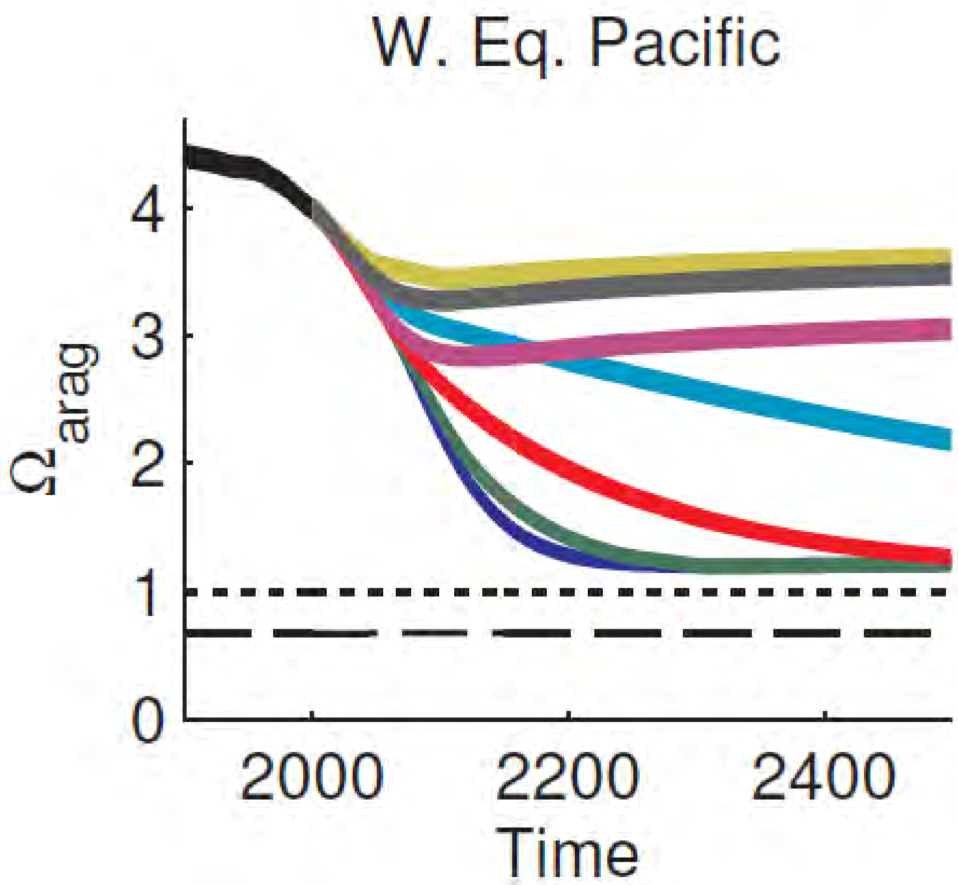

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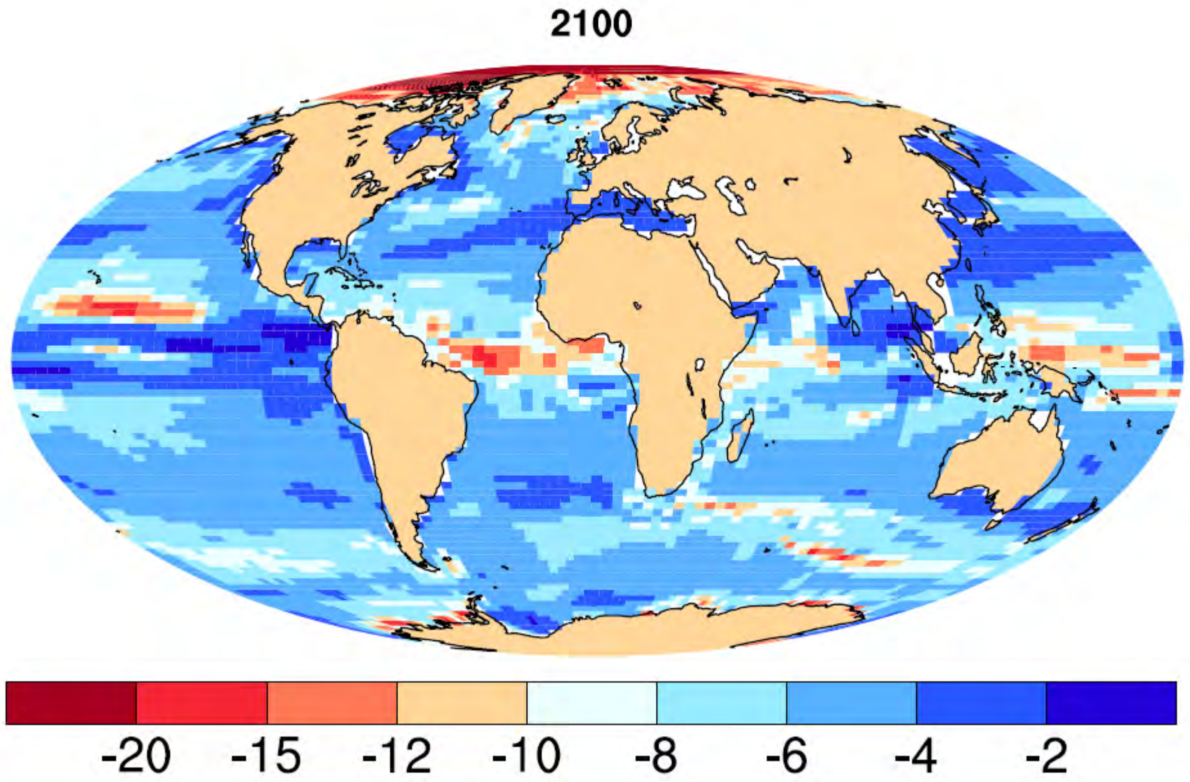
pH change / pH variability

Scenario A1B



$$\frac{pH(2100)-pH(2000)}{varpH\ (2000)}$$

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Ocean acidification viewer

- Functionalities:
  - Plot :
    - Time series: global mean or local
    - Maps of annual mean or specific month
    - Depth profiles at specific location
  - Download 4-D data (lat, lon, depth, time) in netcdf format
  - Download subset of data in text format
- Feedback wanted

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Summary

- Future projections of ocean acidification simulated by UVic model, with a range of future scenarios
- Arctic and Southern ocean reach calcite undersaturation in all but two scenarios.
- East equatorial pacific subject to large changes in carbonate chemistry compared to the current variability
- Shifts in seasonality of carbonate chemistry
- Ocean acidification viewer

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Assessing the spatial variability in ballasting statistics

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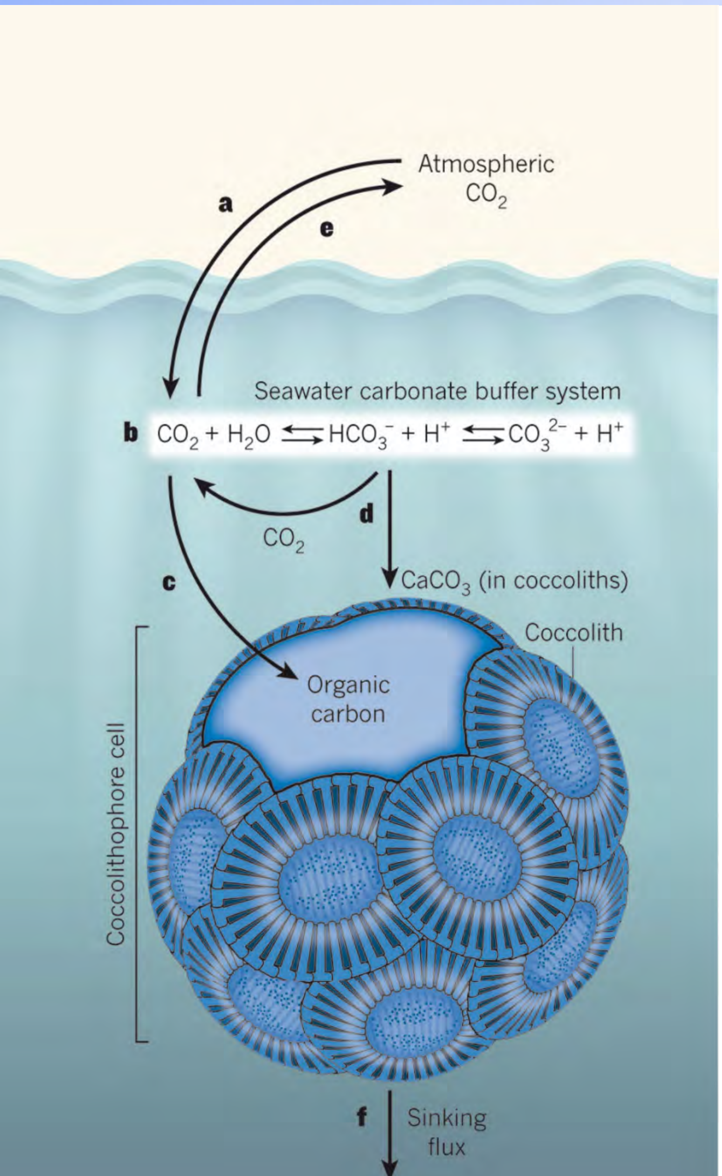
Stephen Barker & Andy Ridgwell

Outline

- Introduction: Ballasting
- Assessing Spatial Variability: Geographically weighted regression
- Implications for the ballast hypothesis
- Questions/Comments
- Poster

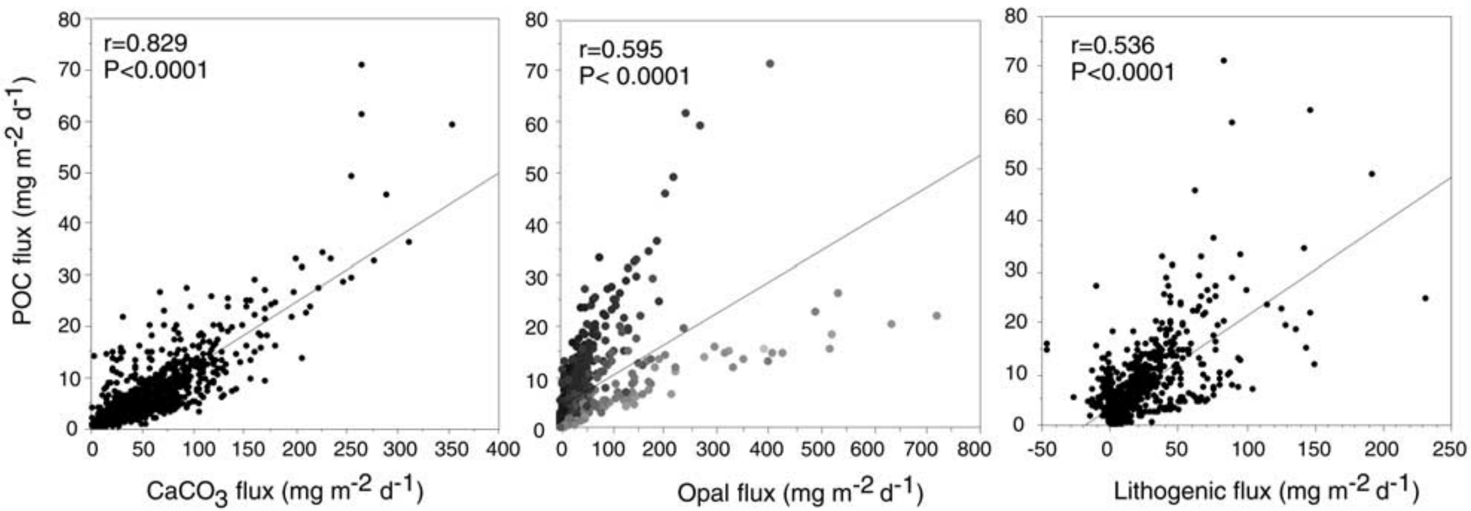
Introduction



Hutchins (2011)

- Biological Pump – transfers carbon from the surface ocean to the deep ocean and sediments
- Efficiency of the Bio. Pump is an important factor in the ocean carbon cycle
- Ballasting is suggested to be a major control on this efficiency
- The ballast hypothesis states that the sinking of POC is aided by the presence of minerals, particularly $CaCO_3$, through excess density
- Could potentially act as a positive feedback to atmospheric CO_2

Defining Ballasting



Klaas and Archer (2002)

$$F_{POC} = \beta_1 \cdot F_{CaCO_3} + \beta_2 \cdot F_{opal} + \beta_3 \cdot F_{litho}$$

β_1 ($CaCO_3$) 0.075 ± 0.011

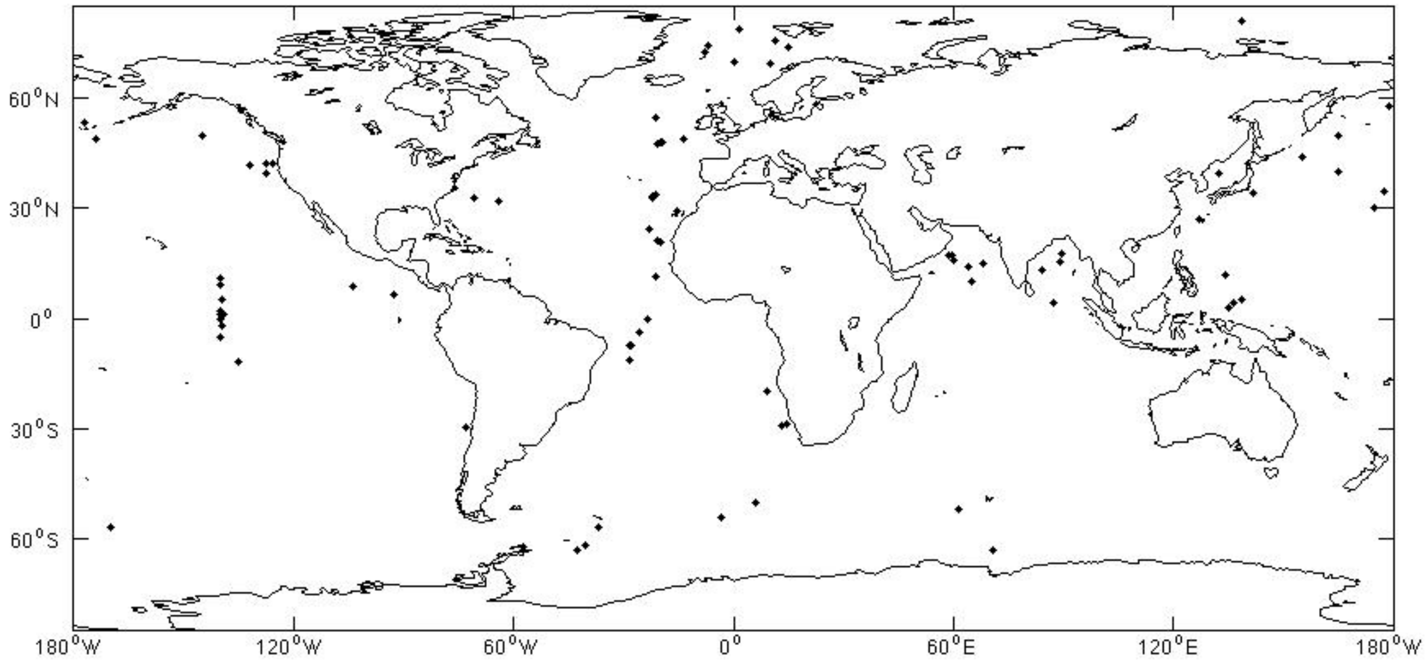
β_2 (Opal) 0.029 ± 0.008

β_3 (Litho.) 0.052 ± 0.018

'Carrying Coefficients'

$R^2 = 0.94$

Reassessing Ballasting



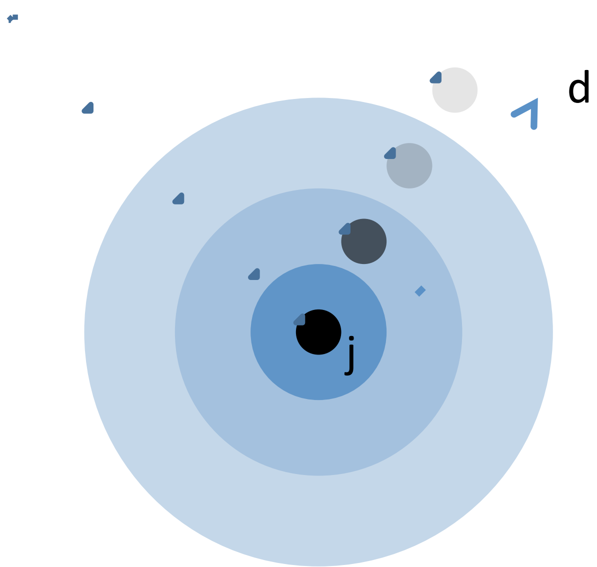
160 data points (≥1500m) *c.f.* 62-78
Increased spatial coverage
Increased temporal coverage

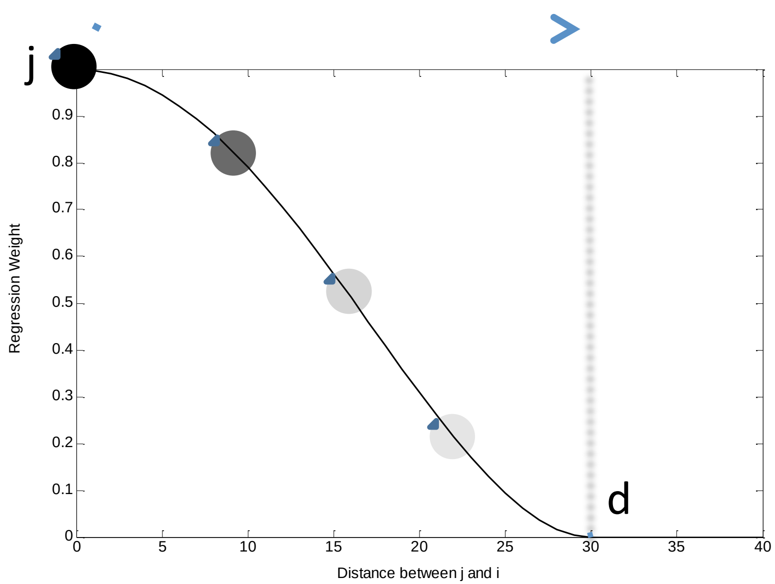
β_1	($CaCO_3$) 0.090 ± 0.012	
β_2	(Opal) 0.023 ± 0.011	R^2 = 0.66
β_3	(Litho.) 0.036 ± 0.019	

Geographically Weighted Regression

- a technique that allows regression coefficients to vary in space

- defines a subset of data centred at each data point by a calibrated parameter ('bandwidth')
- weights the data points by distance to the central point
- performs ordinary least squares regression with weighted dataset
- objective approach

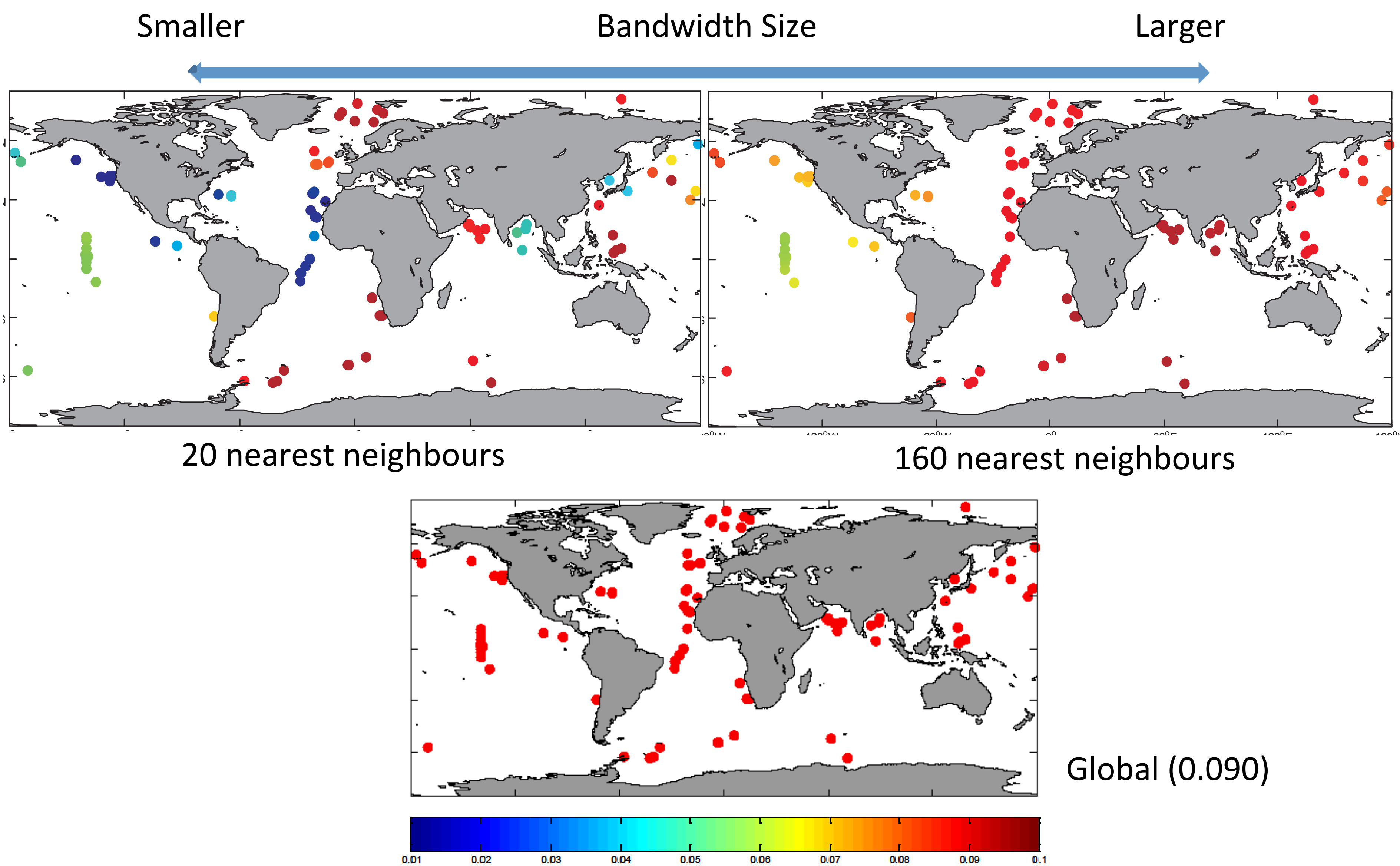




Weighting function

Fotheringham *et al.* (2002)

Choosing the Bandwidth



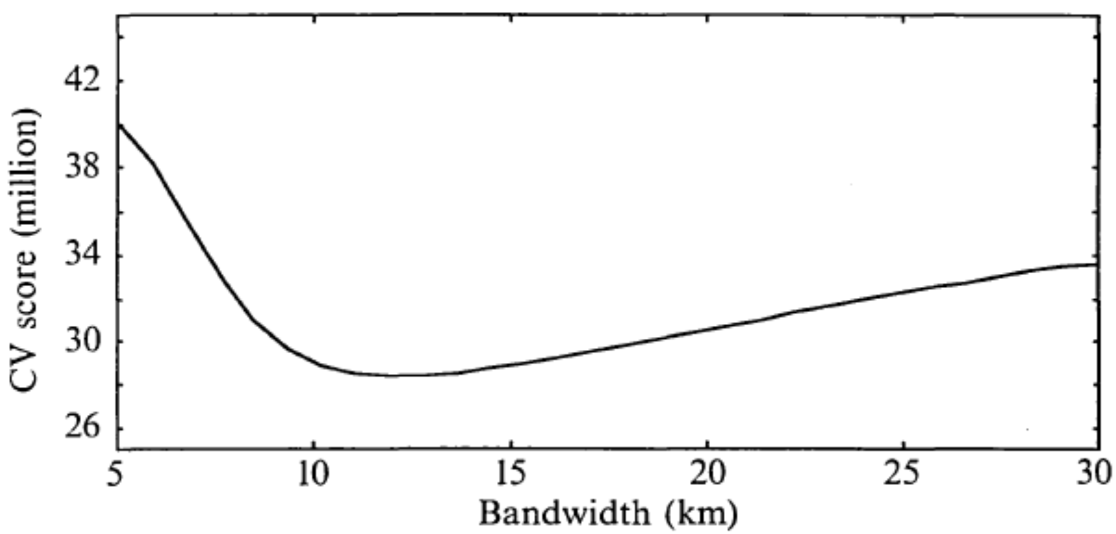
Choosing the Bandwidth

- calibrated using a metric of regression model performance
- requires consideration of bias and variance:

Smaller — Bandwidth Size — Larger

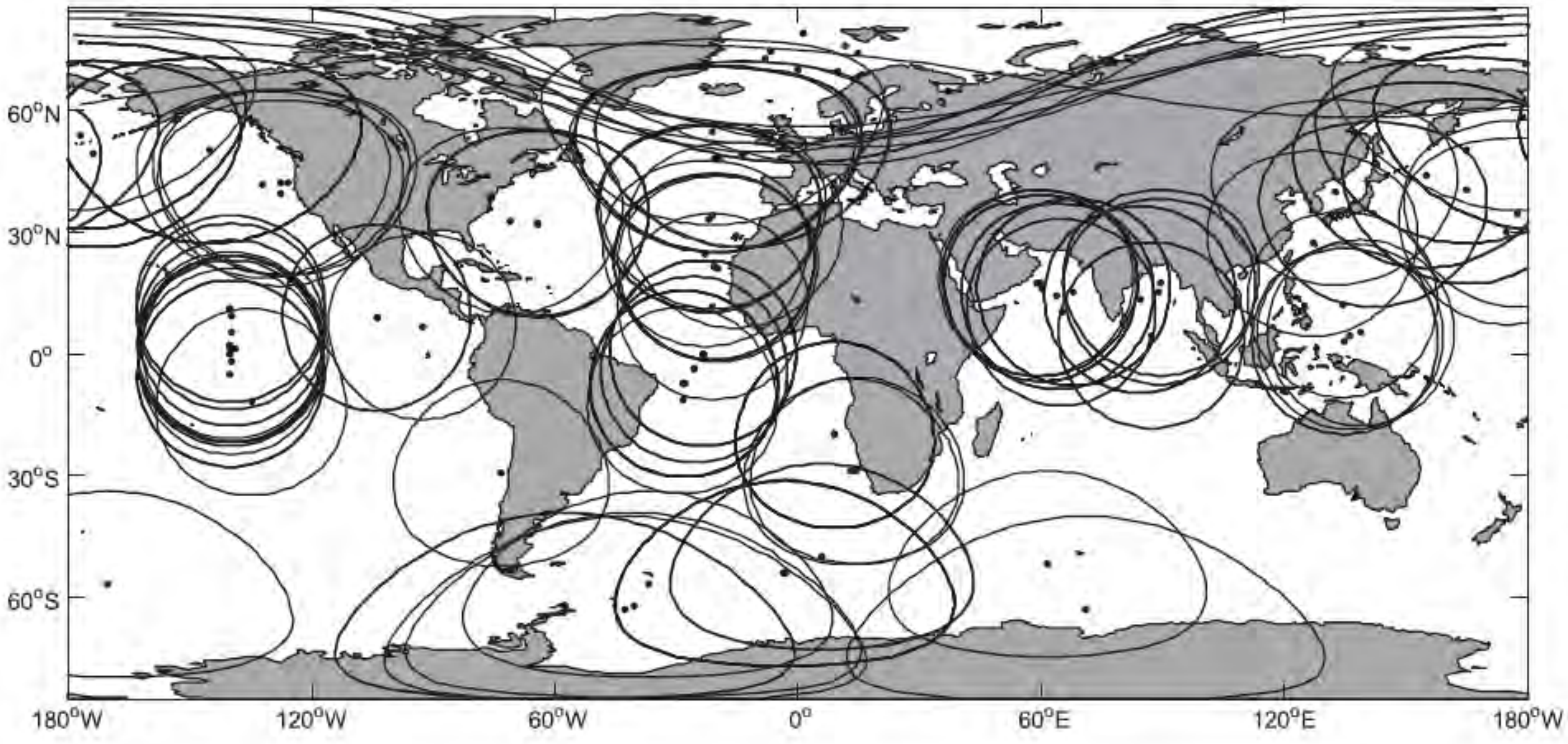
Large variance and errors

Bias towards global coefficients



Fotheringham *et al.* (1998)

Choosing the Bandwidth



- illustration of the bandwidth and weighting function
- bandwidth = 50 nearest neighbours
- weighting function shown ≥0.75

Results: General

- Bandwidth of 50 nearest neighbours is calibrated

- Increase in R^2 (goodness of fit) from 0.66 to 0.84

- Significant improvement in model skill scores

- ANOVA results rejects null hypothesis that the regional model is no better improvement on the global model.

- Monte Carlo results reject null hypothesis that there is no spatial variability in coefficients

Median carrying coefficients:

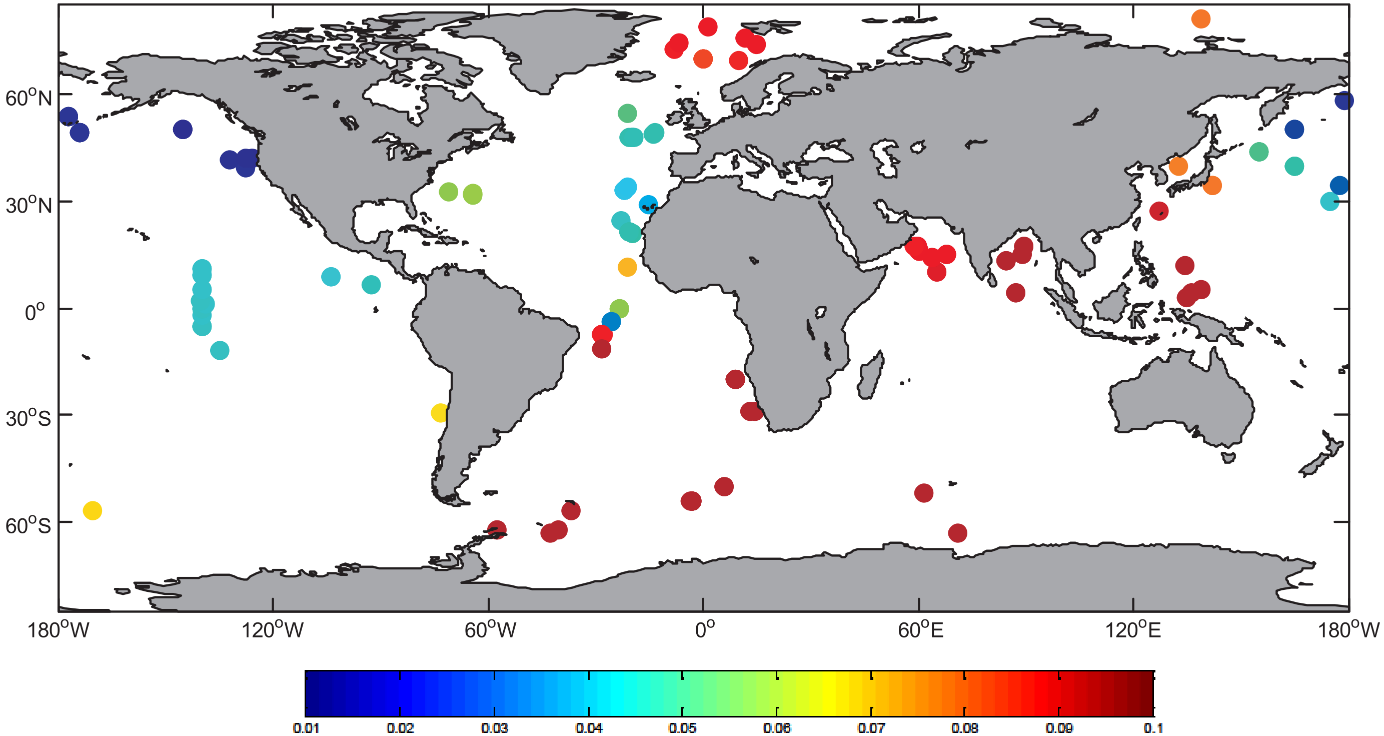
- $CaCO_3$ 0.056
- Opal 0.038
- Litho. 0.022

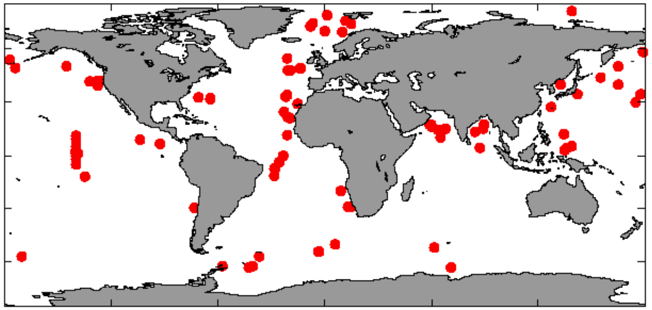
c.f.

Global carrying coefficients:

- $CaCO_3$ 0.090
- Opal 0.023
- Litho. 0.036

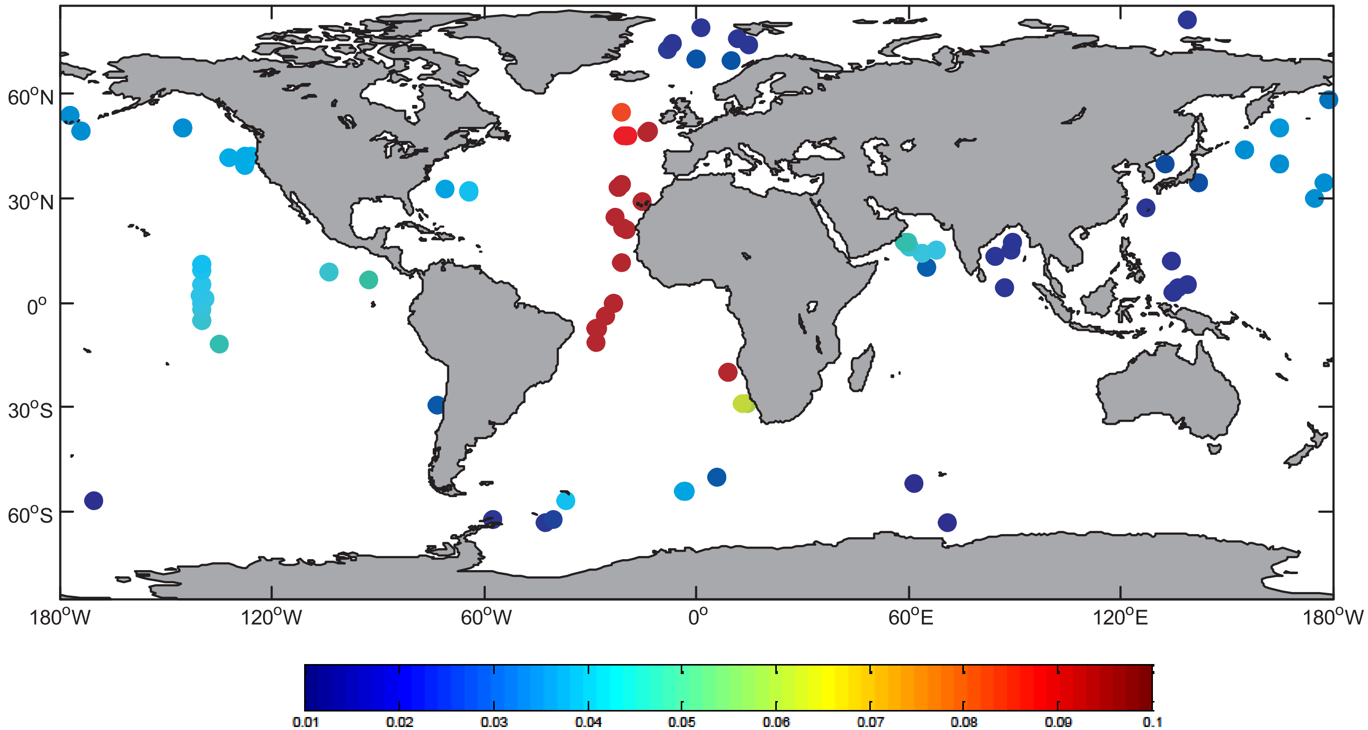
Results: $CaCO_3$

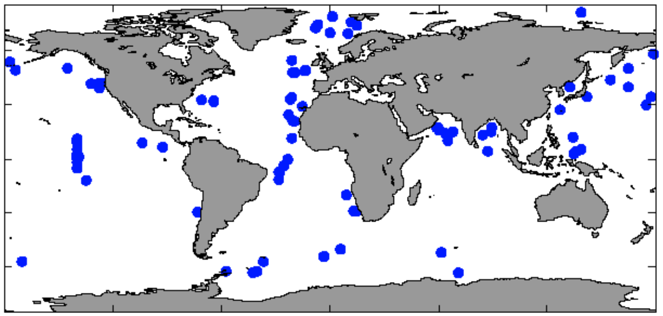




Global: 0.090

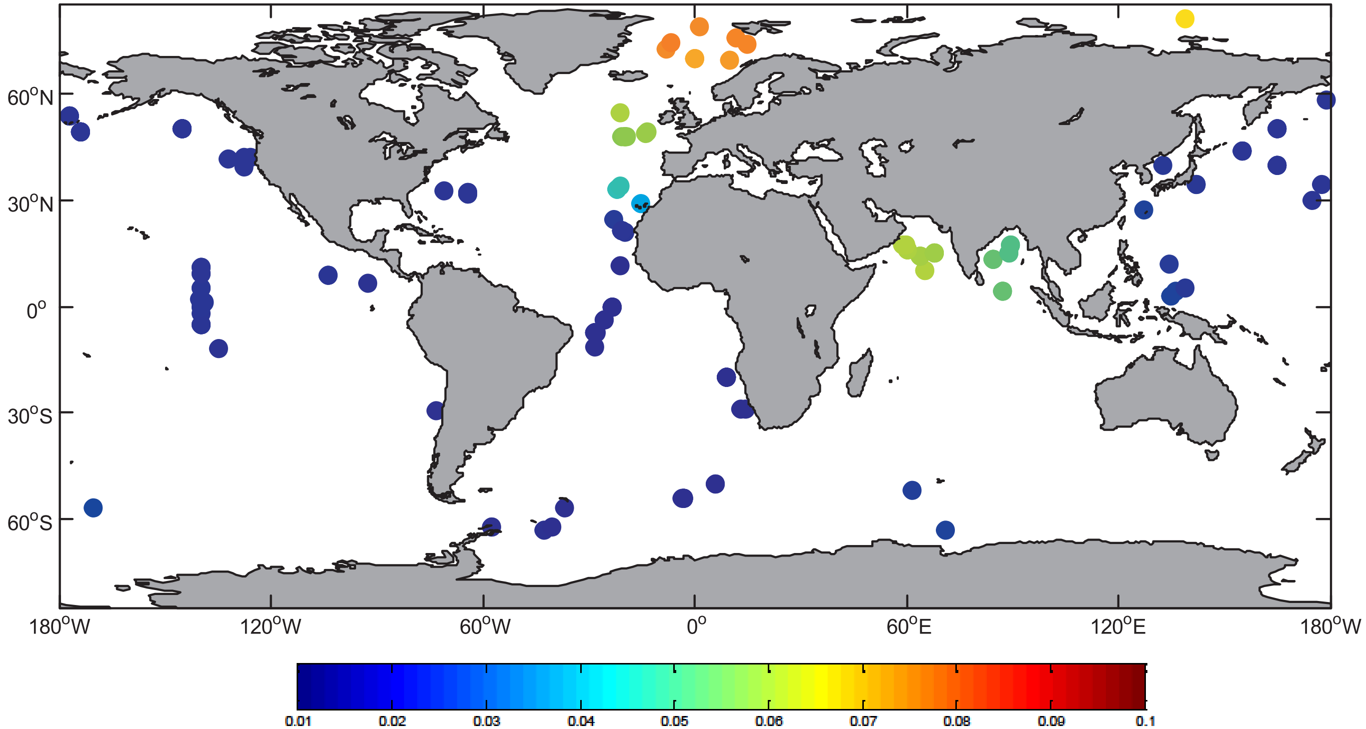
Results: Opal

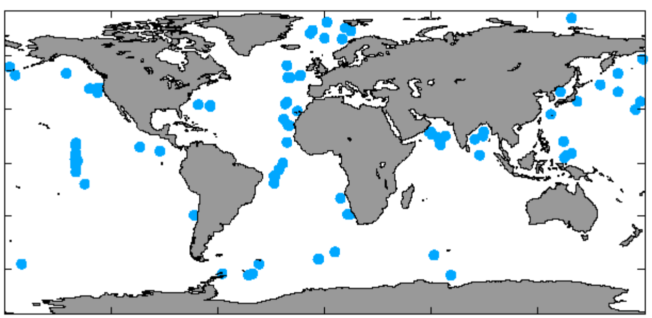




Global: 0.023

Results: Lithogenic

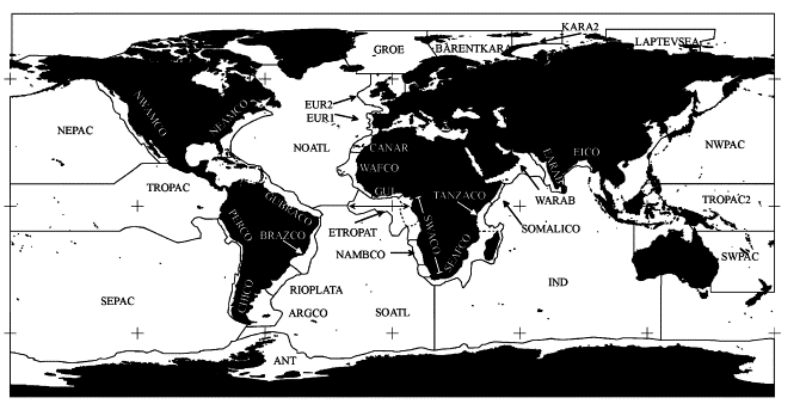




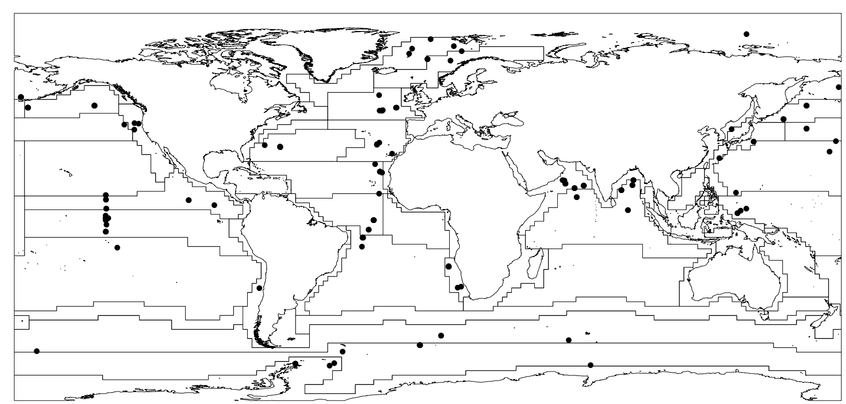
Global: 0.036

Implications for Ballasting

- The strong global relationship between POC and $CaCO_3$ hides significant spatial variability
- There are no consistent relationships between minerals and POC
- Unclear on the mechanism(s) resulting in the spatial patterns
  - May reflect biogeochemical provinces and ecosystem characteristics
- Implications for use of ballasting as a parameterisation in modelling
  - May suggest different feedback mechanisms



Degradability of POC (Seiter *et al.* 2004)



Biogeochemical Provinces (Vichi *et al.* 2011)

Questions…

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Does the ballast hypothesis still pull its own weight?: Understanding marine particulate fluxes and their effect on atmospheric CO_2

References:

Fotheringham, A.S.., Charlton, M.E., and Brunsdon, C., (1998) Geographically weighted regression: a natural evolution of the expansion method for spatial data analysis. *Environment and Planning A.* 30 (11), 1905 – 1927

Fotheringham, A.S., Brunsdon, C., and Charlton, M.E., (2002) *Geographically Weighted Regression: the analysis of spatially varying relationships.* Wiley: Chichester

Hutchins D.A., (2011) Oceanography: Forecasting the rain ratio. *Nature.* 476, 41 - 42

Klaas, C., and Archer, D.E., (2002) Association of sinking organic matter with various types of minreal ballast in the deep sea: Implications for the rain ratio. *Global Biogeochemical Cycles.* 3 (4)

Seiter, K., Hensen, C., Schroter, J., and Zabel, M., (2004) Organic carbon content in surface sediments – defining regional provinces. *Deep Sea Research Part I: Oceanographic Research Papers.* 51 (12), 2001 - 2026

Vichi, M., Allen, J.I., Masina, S., and Hardman-Montford, N.J., (2011) The emergence of ocean biogeochemical provinces: a quantitative assessment and a diagnostic for model evaluation. *Global Biogeochemical Cycles.* 25