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solid living changing
EARTH OCEAN
The School of Earth and Ocean Sciences

Ocean Alkalinity Modification

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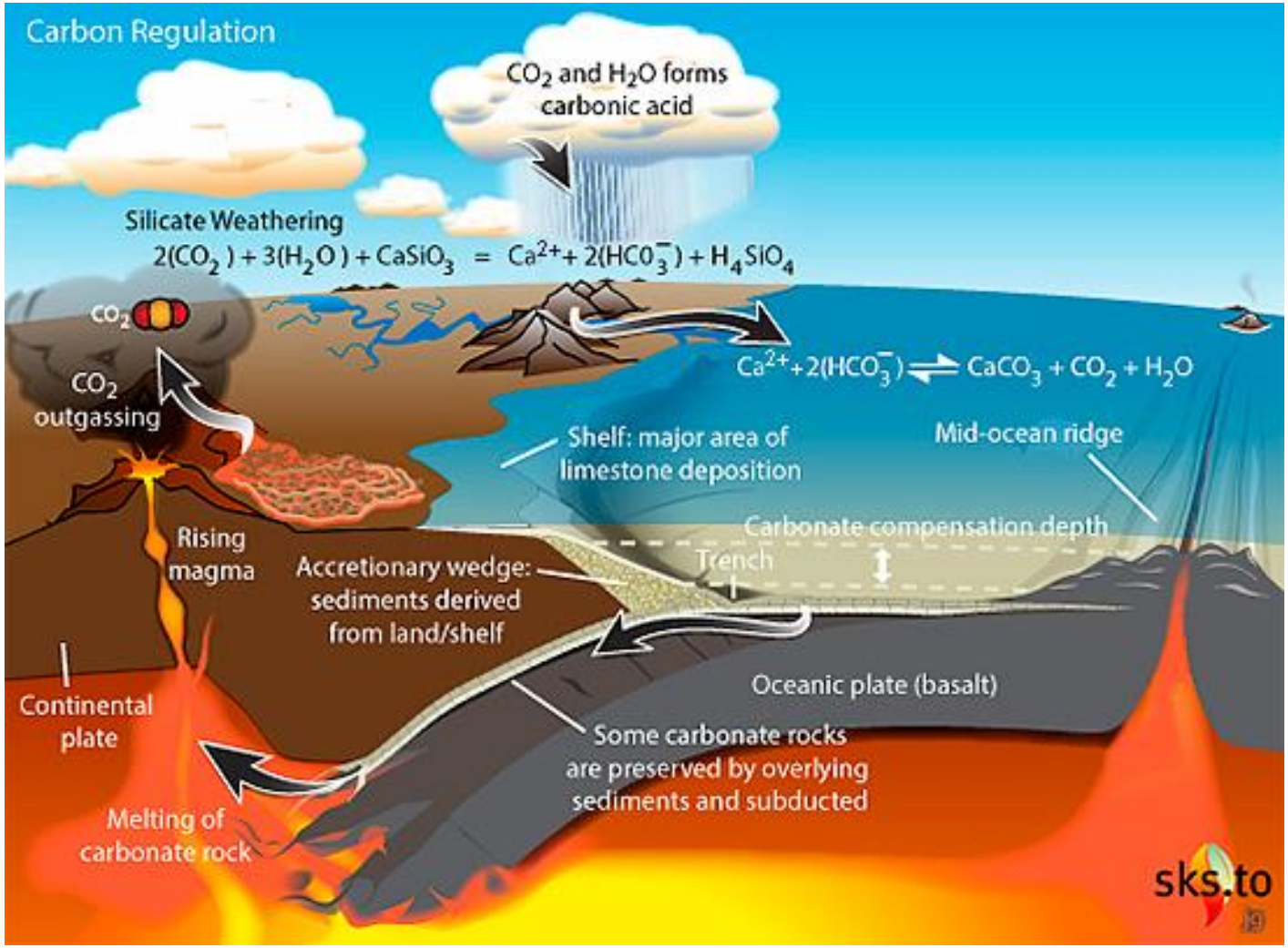
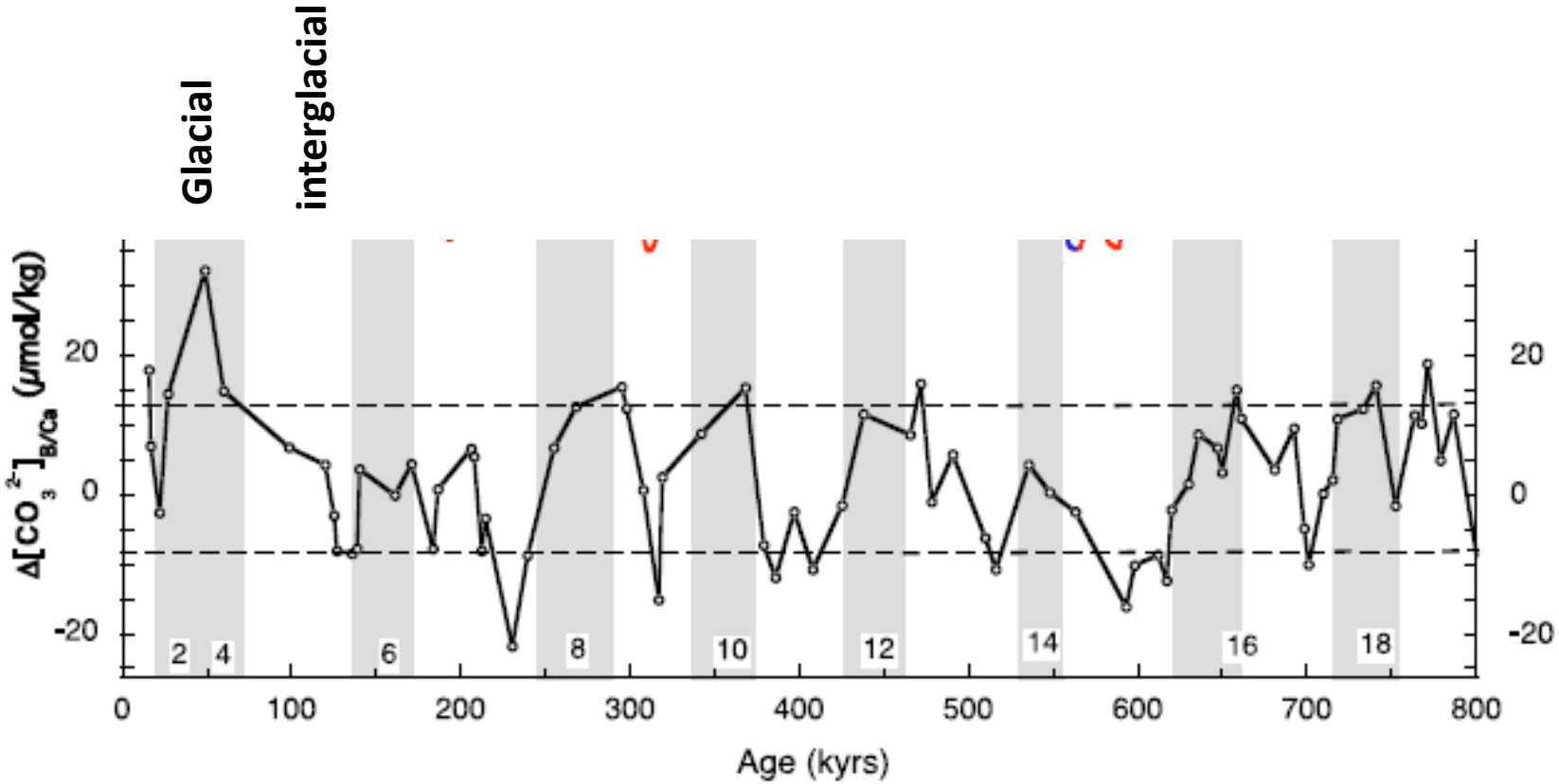
London Convention and Protocol Scientific Groups

$$CaCO_3 + CO_2 + H_2O \rightarrow Ca^{2+} + 2HCO_3^-$$

$$Mg_2SiO_4 + 4CO_2 + 4H_2O \rightarrow 2Mg^{2+} + 4HCO_3^- + H_4SiO_4$$





Rickaby et al., 2010 Paleoceanography

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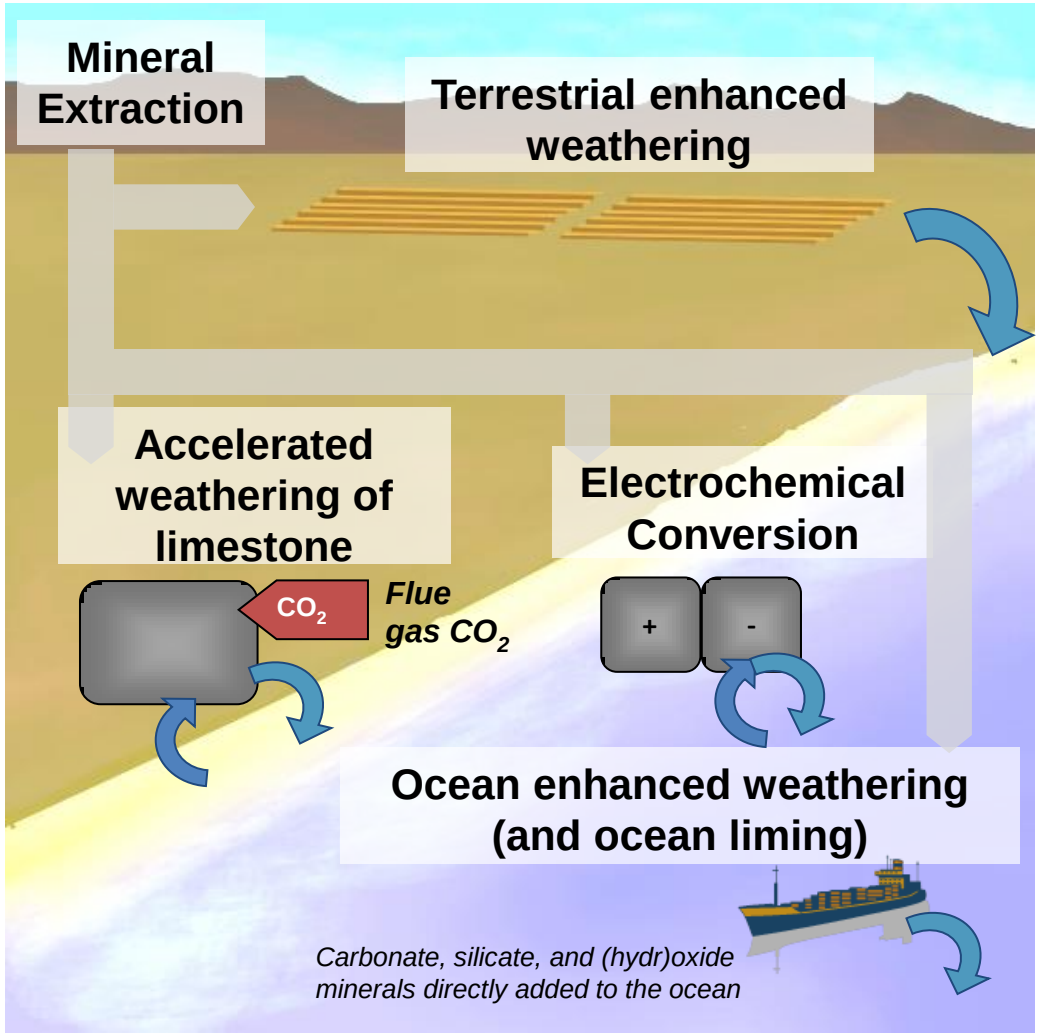
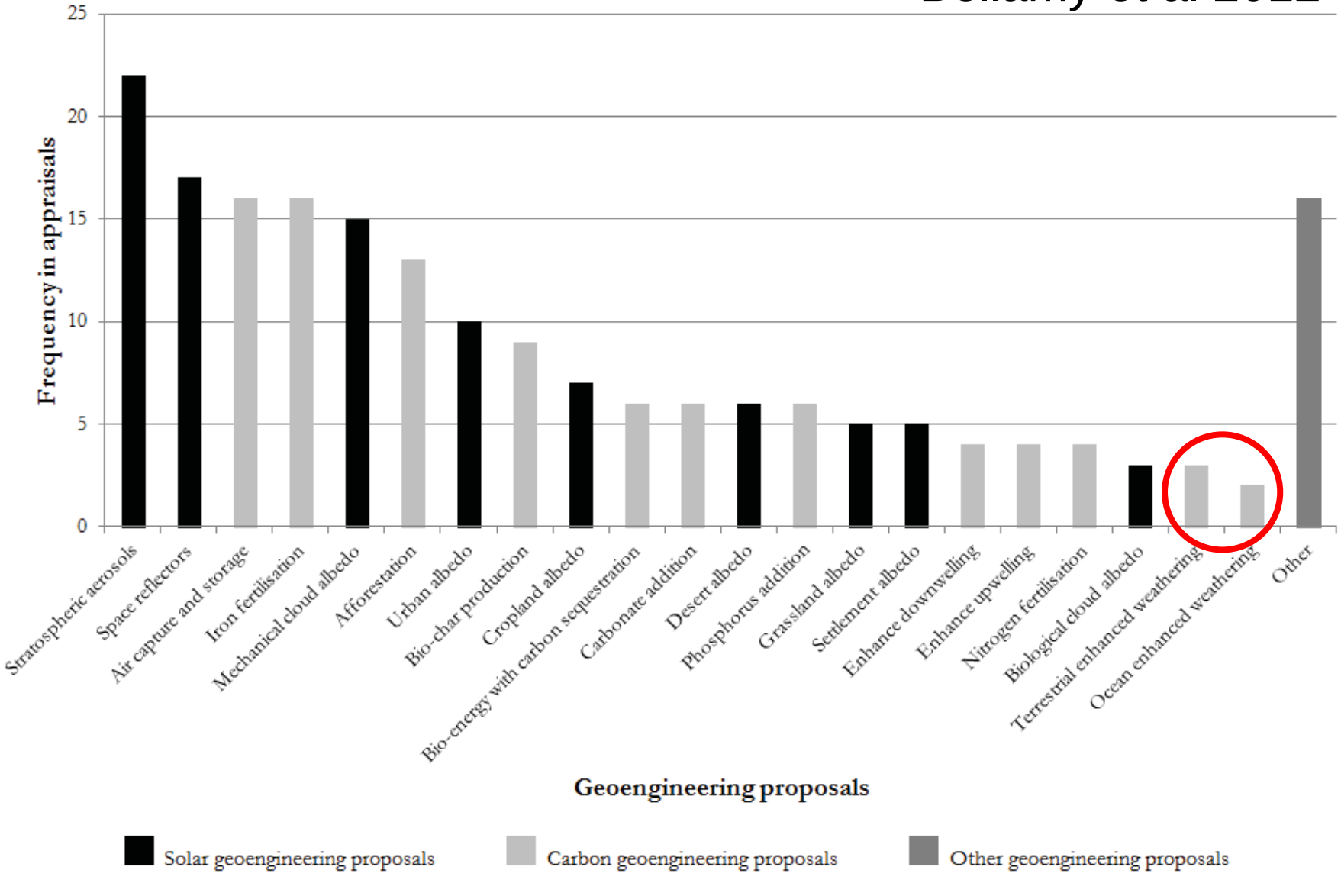
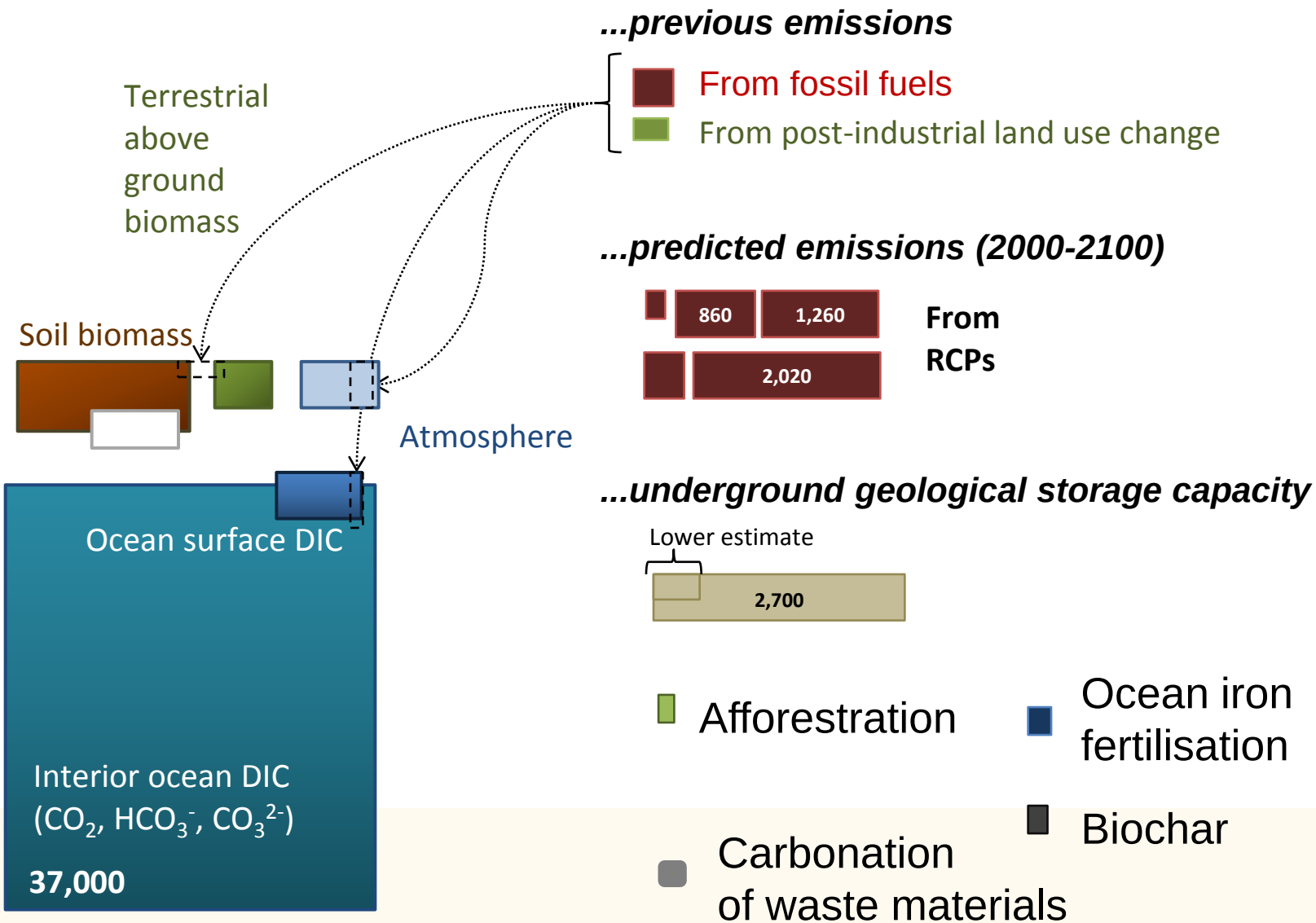
Enhanced Weathering



Bellamy et al 2012



The potential of ocean alkalinity as a carbon sink



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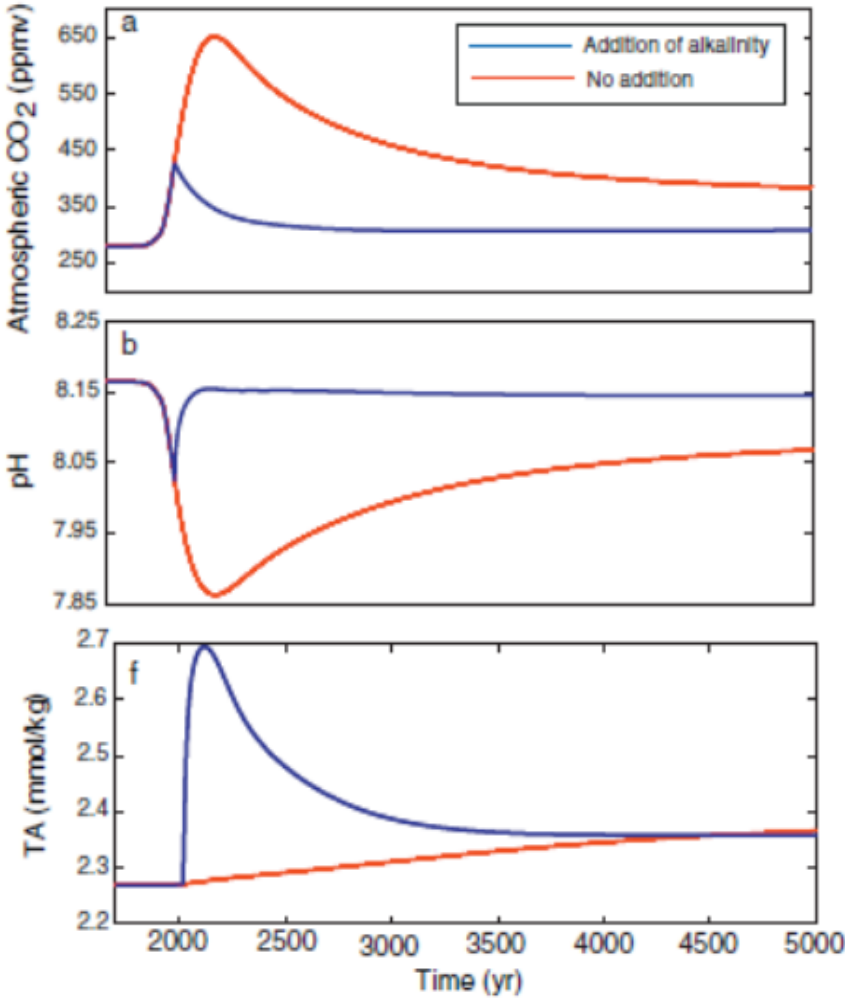

Paquay and Zeebe, 2013

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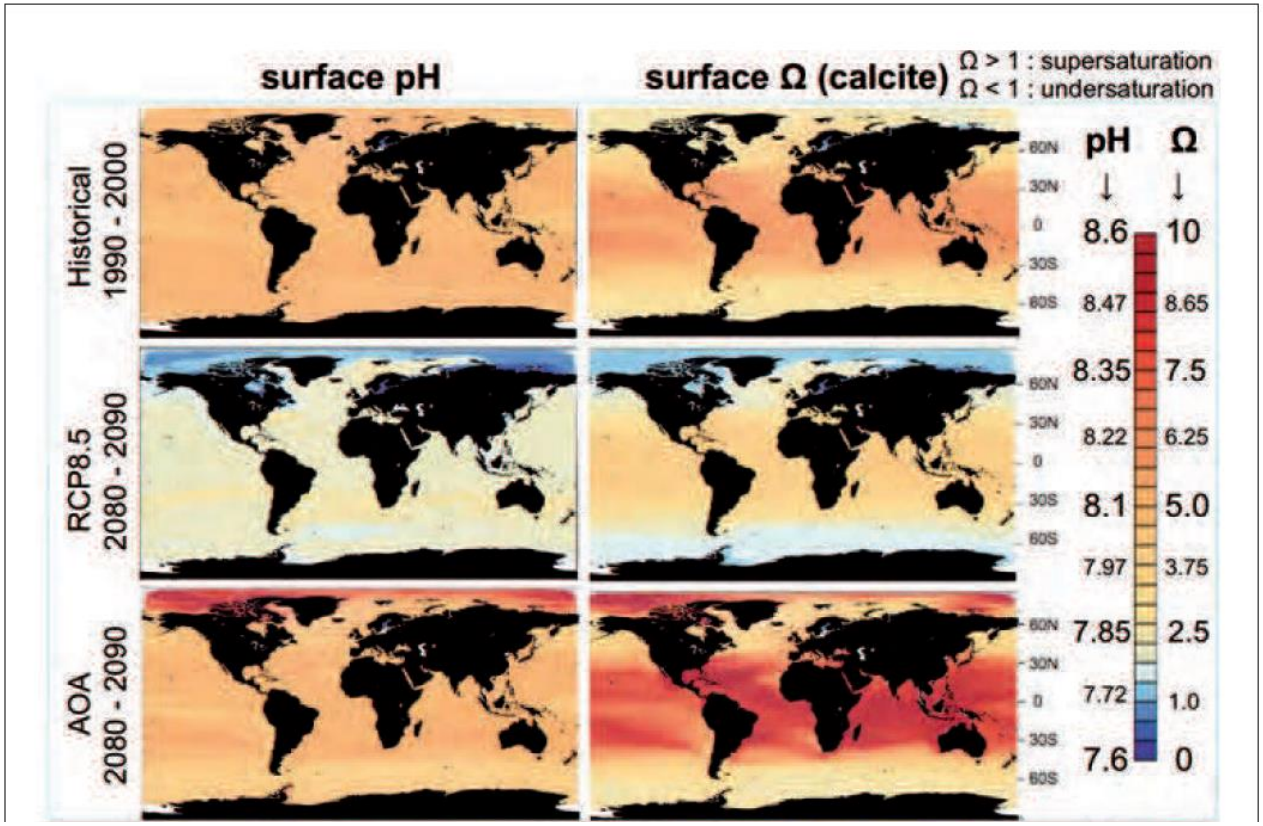

Ferrer-Gonzalez and Ilyina 2015

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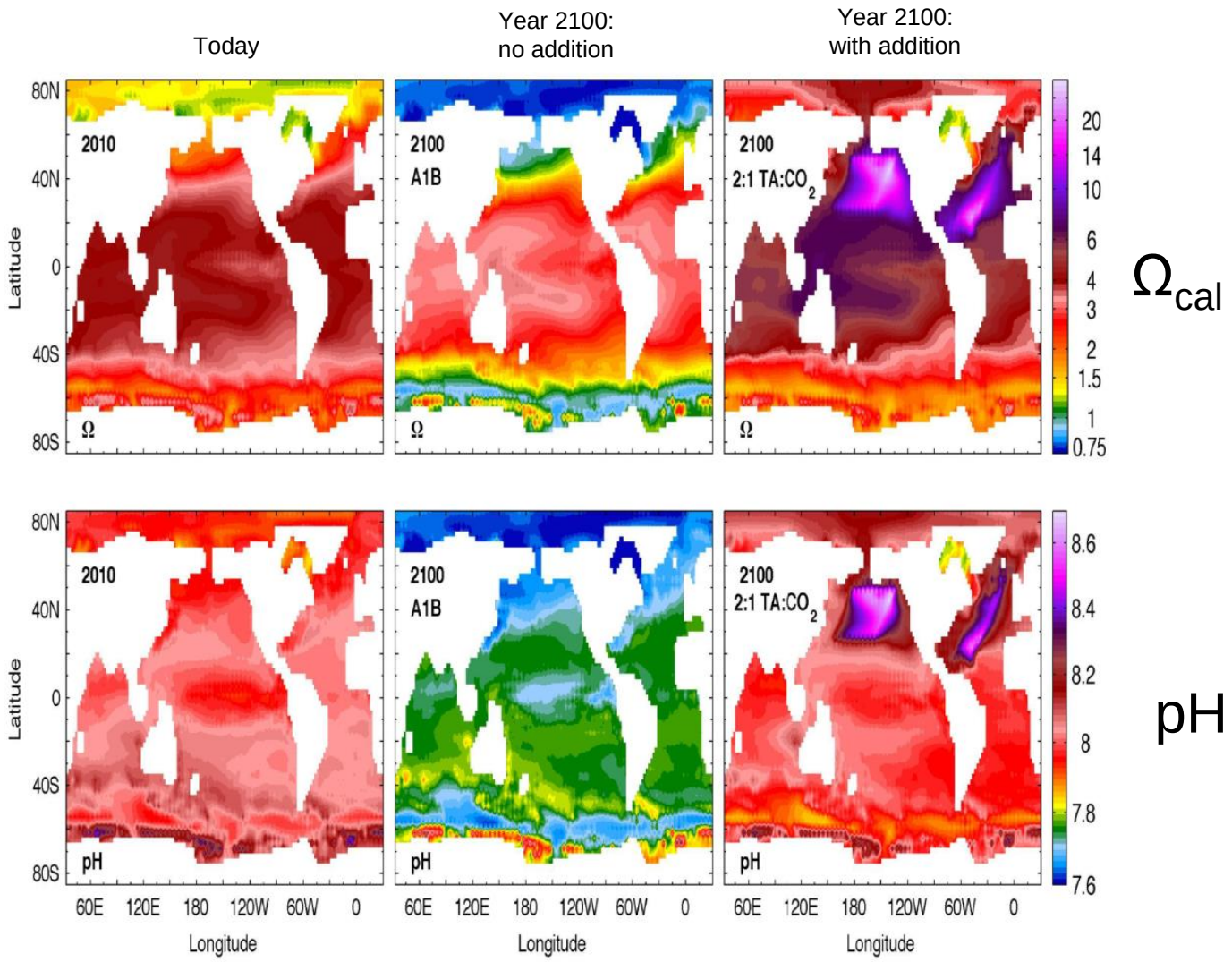
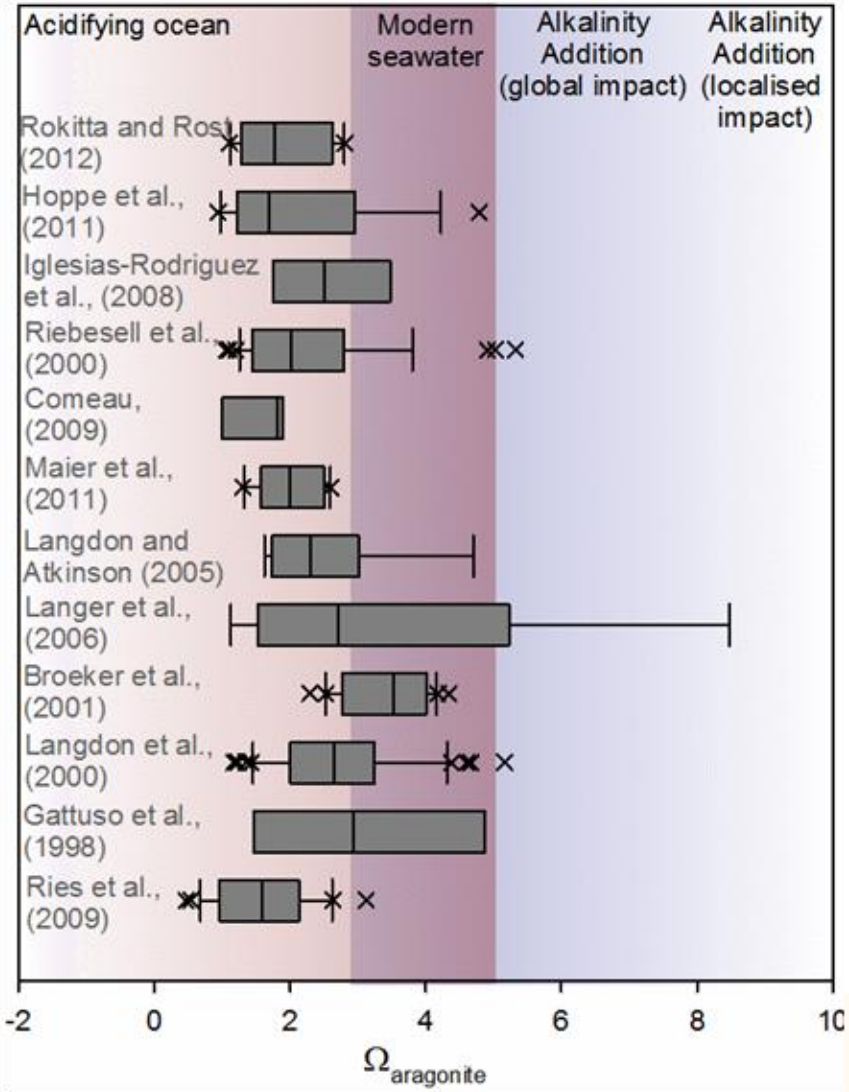


Ilyina et al., 2013

Longevity and biological response



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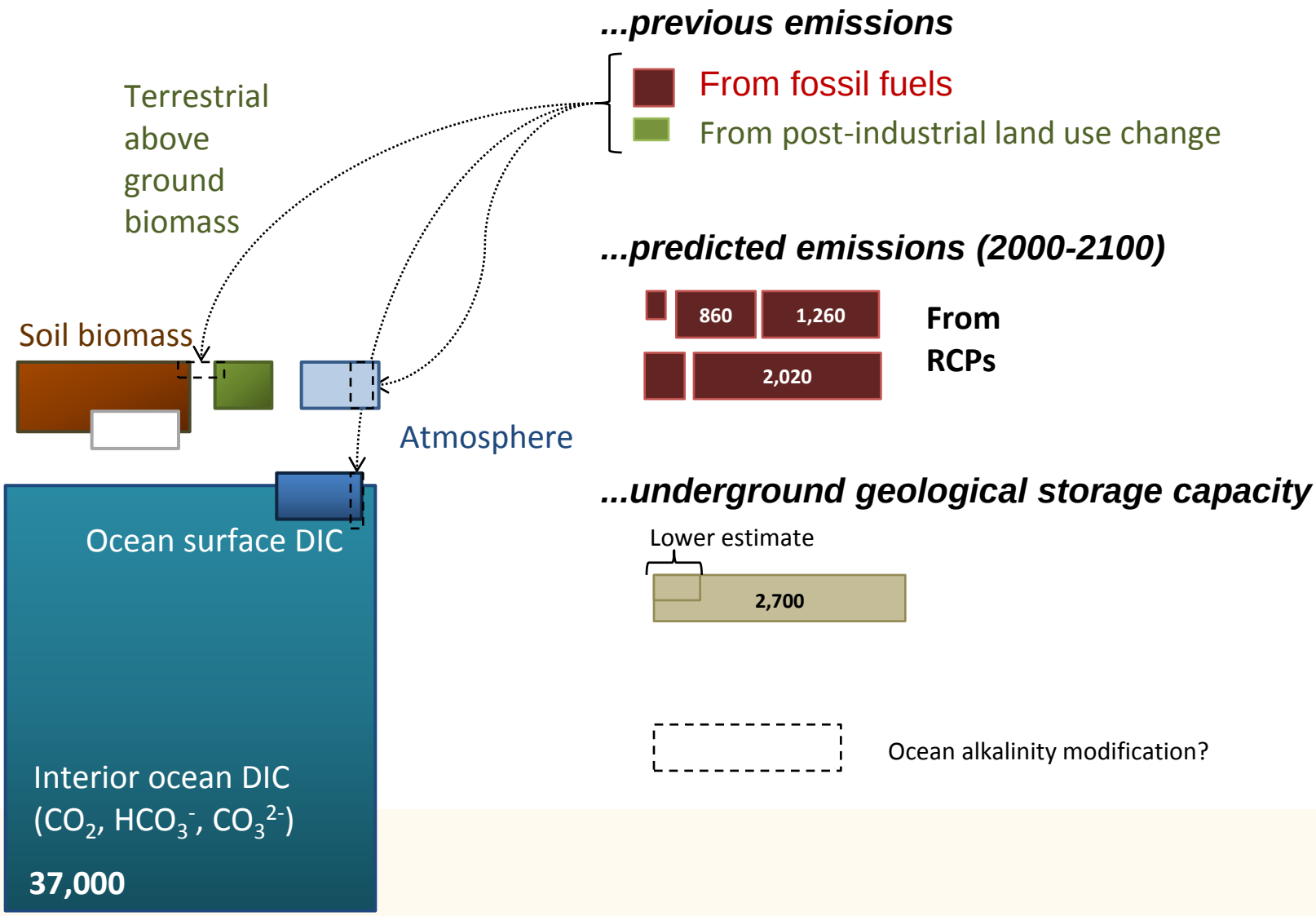
The potential of ocean alkalinity as a carbon sink



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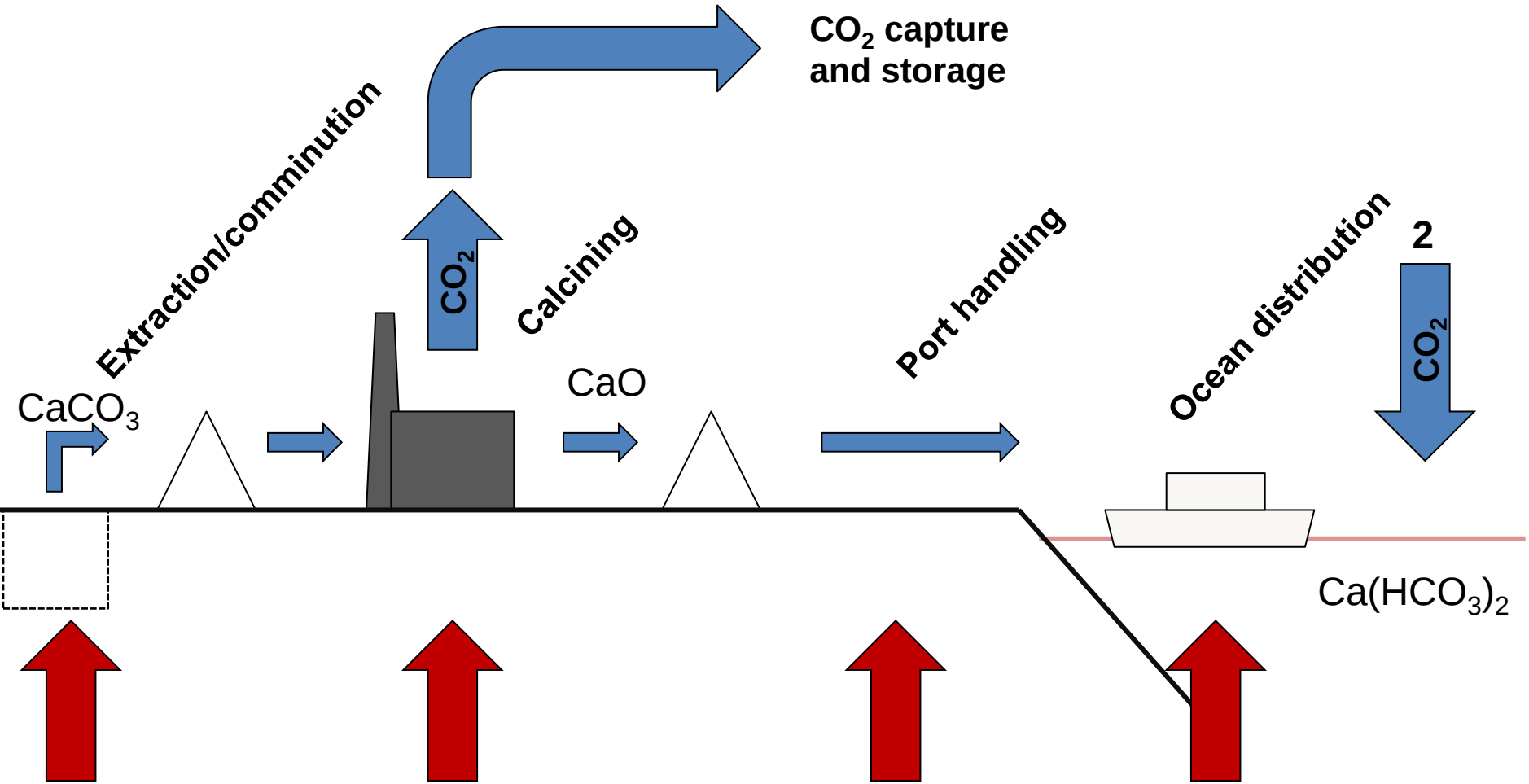
Ocean Liming – Ocean Enhanced Weathering

Mineral	Reference
Lime (CaO) +hyd	Keshgi (1995) Renforth et al (2013)
Dolime (MgO.CaO) +hyd	Renforth et al (2013)
Periclase (MgO) +hyd	Renforth and Kruger (2013)
Olivine (Mg_2SiO_4)	Köhler et al (2013)
Calcium carbonate ($CaCO_3$)	Harvey (2003)

Ocean liming



Energy/resource input

$Ca(HCO_3)_2 \rightarrow CaCO_3 + CO_2 + H_2O$

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Renforth et al (2013) Energy

- Cost: US$72 tCO_2^{-1} and US$126 tCO_2^{-1}
- To capture 1 $GtCO_2$ per year, a global industry would consume about 5.3 exajoules (approximately 1% of global energy)
- Process and calcine 1.5 Gt of limestone
- Produce 0.9 $GtCO_2$ for sequestration

Environmental impact of ocean liming

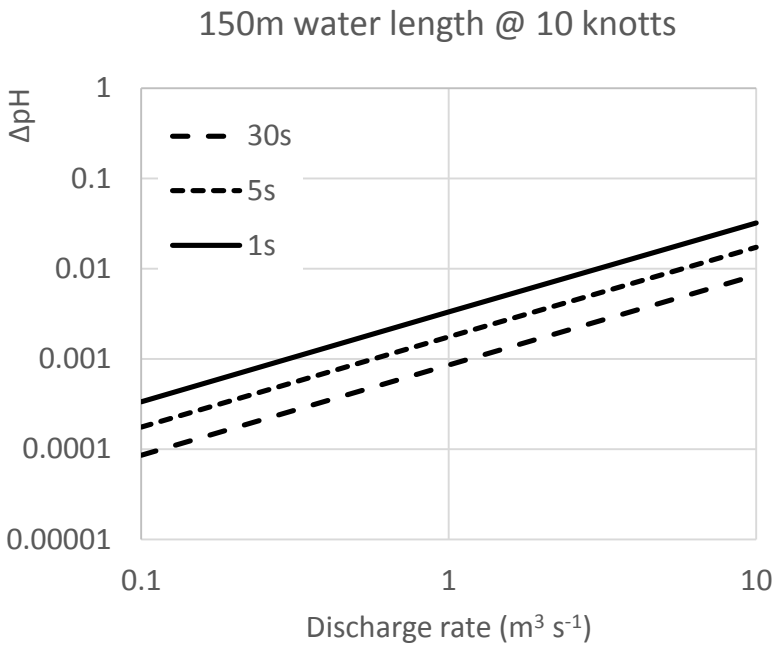
pH ≈ 8 ⟷ pH > 12

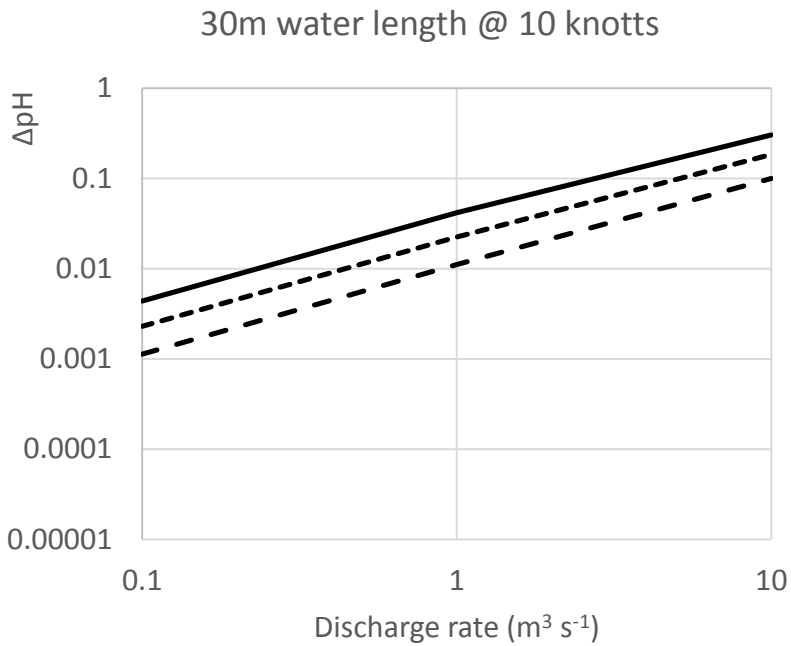
$CaCO_3$

CaO

$Ca(OH)_2$

- Rate of particle addition and dissolution
- Plume attenuation/mixing
- CO_2 in-gassing

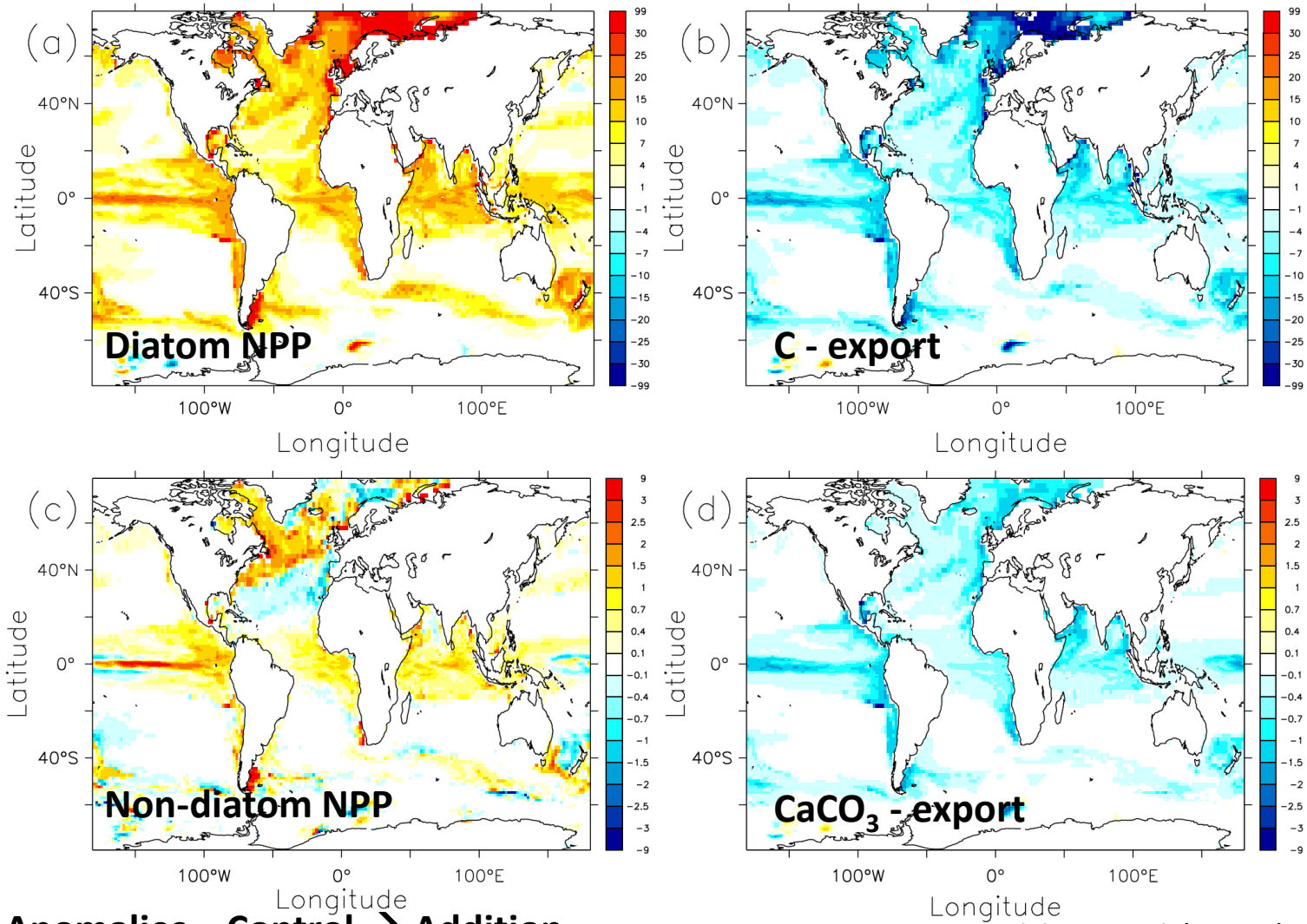




Using the 'IMCO formula'

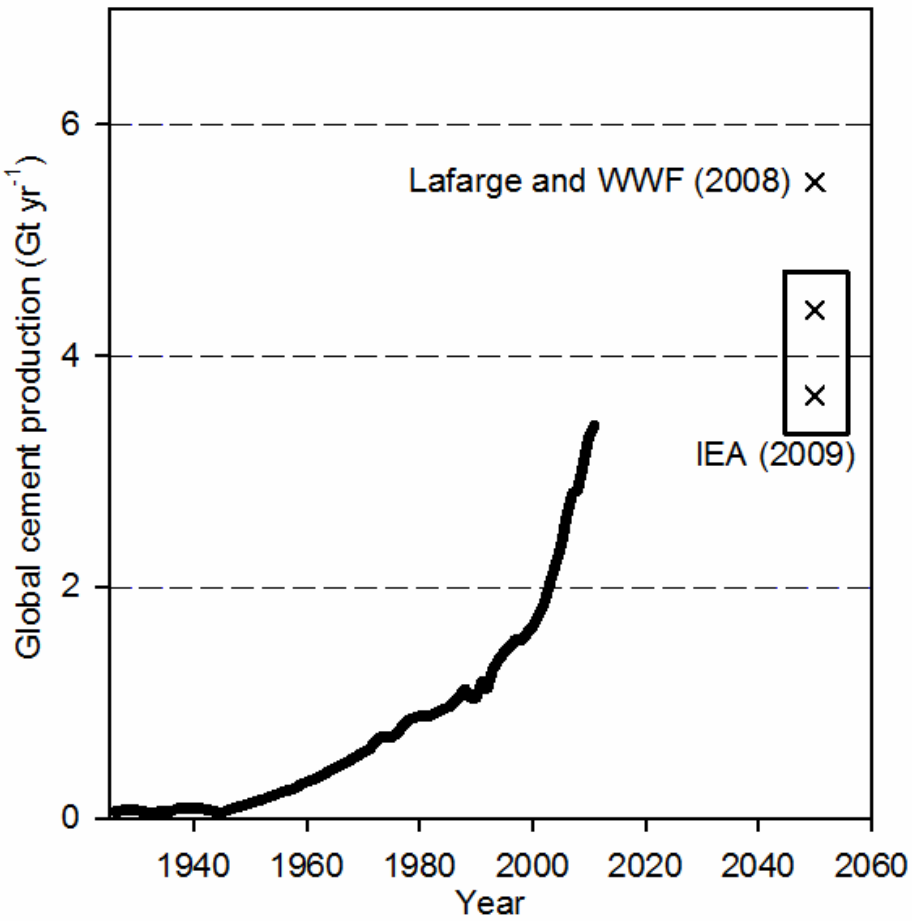
Olivine addition

$$Mg_2SiO_4 + 4CO_2 + 4H_2O \rightarrow 2Mg^{2+} + 4HCO_3^- + H_4SiO_4$$



Anomalies – Control → Addition

Köhler et al (2013)



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Renforth and Kruger 2013; Renforth et al 2013		
	Energy GJ tCO_2^{-1}	Cost US$ tCO_2^{-1}
	Total primary (@40% conv.)	
Mineral carbonation-Ocean Liming	**10.3**	111-130
Ocean liming	**2.8 – 8.6**	71-110
Carbonate addition to the ocean	**3.9**	25*
Electrochemical weathering	**15**	<100
Direct air capture	**3.5 – 56**	150-1000
T. Enhanced weathering	**1.1 – 25.2**	24-578

Energy from coal emissions = 10 GJ tCO_2^{-1}

Carbon capture and storage at a CF power station = 5 GJ tCO_2^{-1}

Summary

- Is it technically possible to increase ocean alkalinity? – Yes
- Is it possible at scale with a meaningful CO_2 impact? – Maybe

- Can it be used to ameliorate ocean acidification? – Maybe
- Will there be side effects? – Probably

Thank you

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