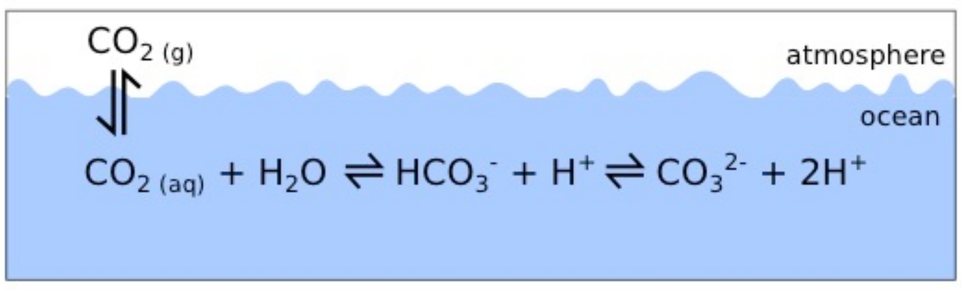
Rising atmospheric CO_2 leads to **large impact of biology on Southern Ocean CO_2 uptake** via changes of the Revelle factor

Judith Hauck and Christoph Völker
Alfred-Wegener-Institut, Helmholtz-Zentrum für Polar- und Meeresforschung, Bremerhaven, Germany
judith.hauck@awi.de

The Revelle factor



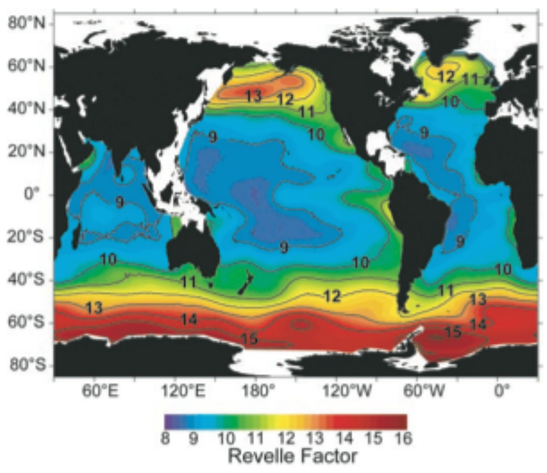
Revelle and Suess, 1957:

" Because of the peculiar buffer mechanism of sea water, however, the increase in the partial CO_2 pressure is about 10 times higher than the increase in the total CO_2 concentration of sea water when CO_2 is added and the alkalinity remains constant."

$$R = \frac{\Delta pCO_2}{pCO_2} / \frac{\Delta DIC}{DIC}$$

Revelle factor: ratio of the relative change of seawater pCO_2 (or, alternatively, $CO_{2\,(aq)}$) to the relative change of DIC

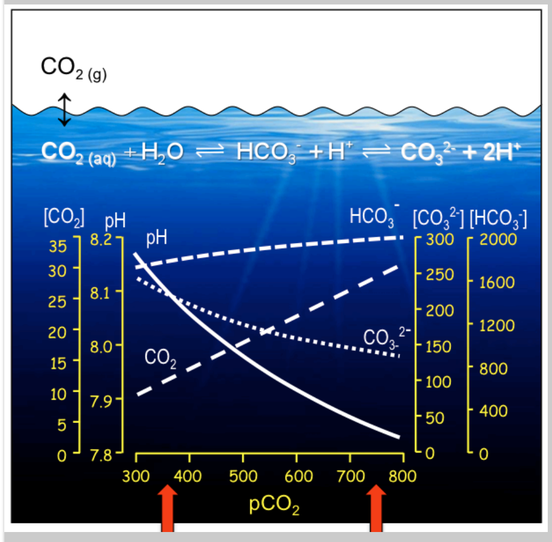
The Revelle factor is a measure of the ocean's resistance to atmospheric CO_2



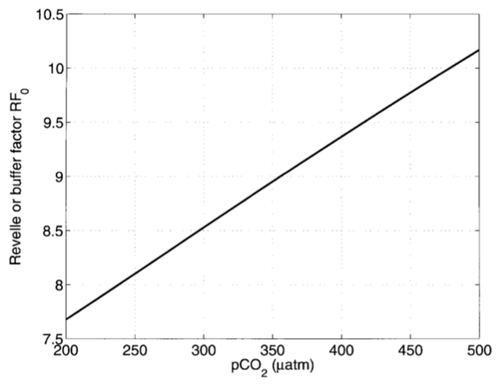
R = 9: CO_2 increase by 9% → DIC increase by 1%
R = 15: CO_2 increase by 15% → DIC increase by 1%

The lower the Revelle factor, the more efficient is the anthropogenic CO_2 uptake

Figure: Revelle factor from Sabine et al (2004)



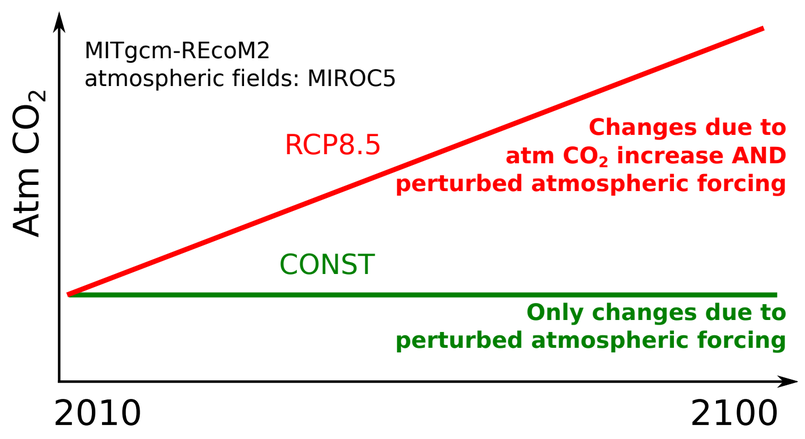
As the ocean continues to take up CO_2, the carbonate system is pushed towards higher $CO_{2\,(aq)}$ concentrations...



...and the Revelle factor increases
→ decrease of buffering capacity: less CO_2 uptake in future relative to atm CO_2 increase (positive feedback)

T = 25°C,
Zeebe and Wolf-Gladrow, 2001

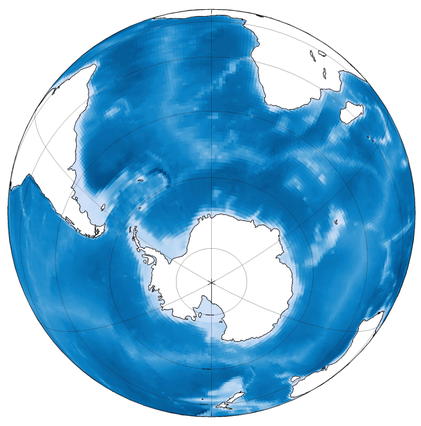
Model simulation



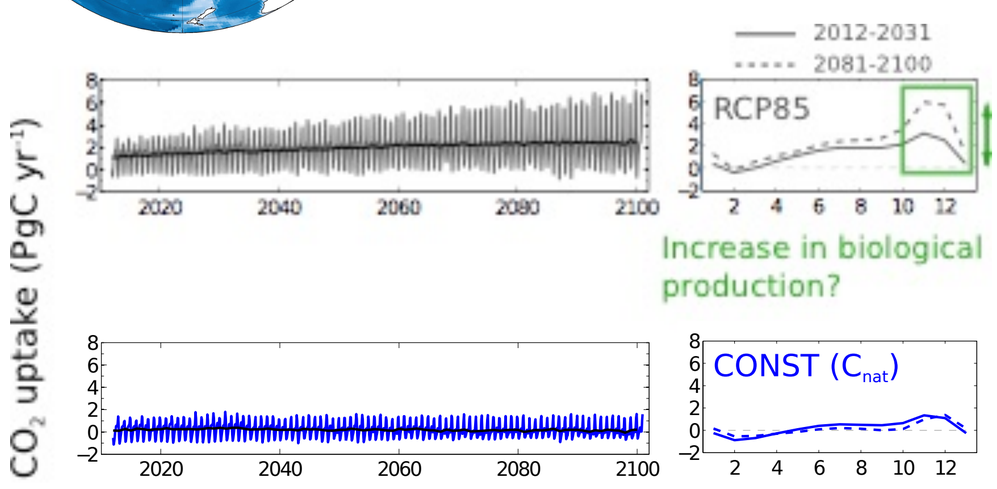
CO_2 increase + climate change

climate change

Impact on Southern Ocean CO_2 flux



Strong increase in summer CO_2 uptake (south of 30°S) between 2012 and 2100:

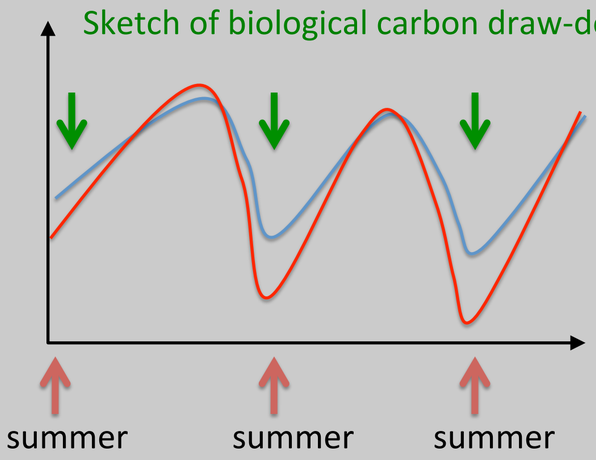


Increase in biological production?

But not apparent in CONST simulation which only considers climate change. Hence: Not caused by increased biological production

What then?

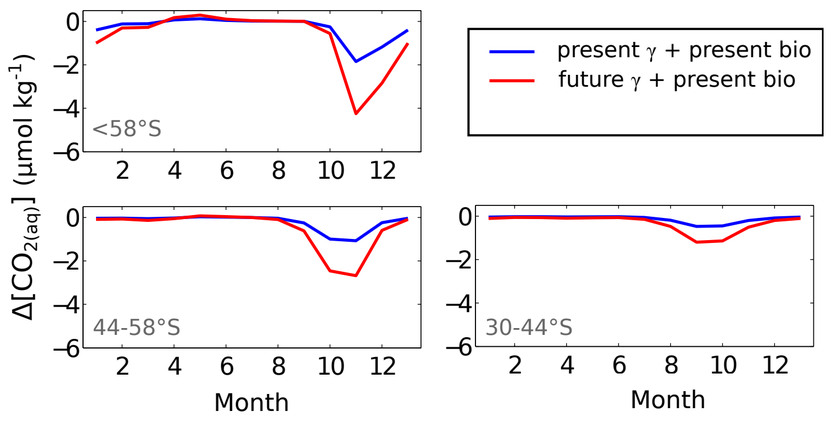
Sketch of biological carbon draw-down by biology



stronger gradient between pCO2 atmosphere and ocean → more CO_2 uptake

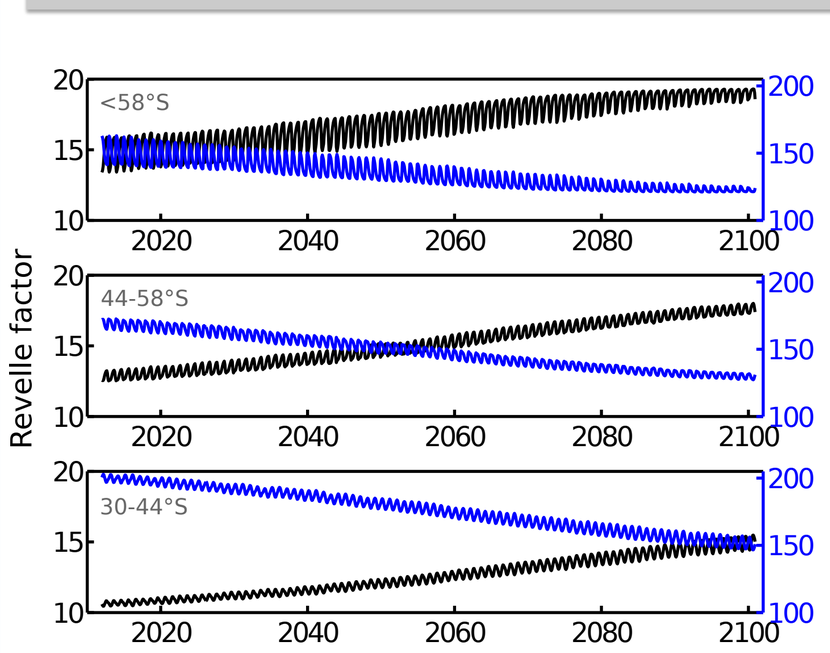
→ R = 10: DIC draw-down by biology of 1% → pCO2 draw-down of 10%
→ R = 15: DIC draw-down by biology of 1% → pCO2 draw-down of 15%

Modelled biological carbon draw-down by biology



Summer $CO_{2(aq)}$ draw-down increases at constant biological DIC draw-down

Dissolved CO_2 ($CO_{2(aq)}$) is responsible for gas-exchange, therefore the larger $CO_{2(aq)}$ draw-down at higher Revelle factor leads to more CO_2 uptake (negative feedback!) These two opposing effects are intrinsic emergent properties of the CO_2 system.



Revelle factor increases = buffer factor (Egleston et al., 2010) decreases