Phytoplankton in a high-CO_2 world: biological responses and their biogeochemical implications

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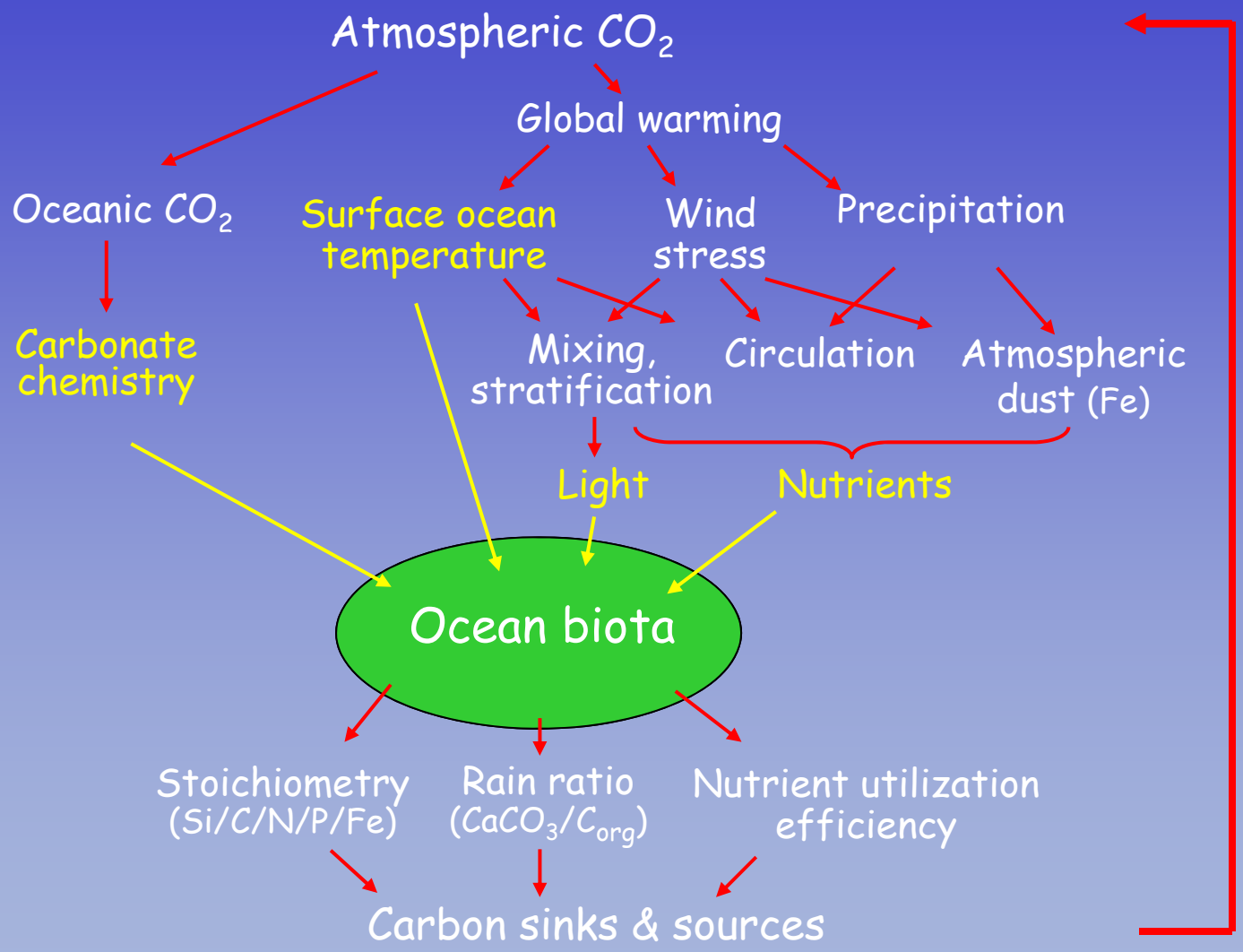
Potential drivers in a high-CO_2 world



Criteria for evaluating the biogeochemical relevance of feedbacks

Sign of change

positive feedback ⟶ amplifies initial perturbation
negative feedback ⟶ dampens initial perturbation

Sensitivity

level of perturbation needed to trigger a feedback

Capacity

strength of feedback compared to initial perturbation

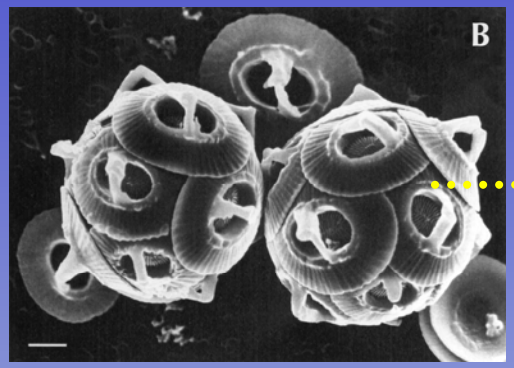
Longevity

relevant time-scales: permanent vs. transient

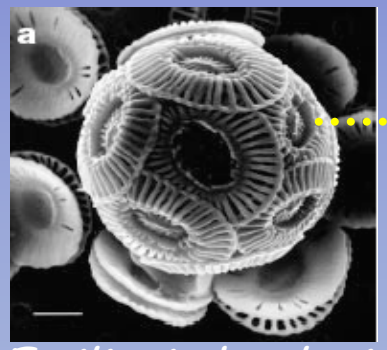
CO_2-Calcification feedback

Today's world

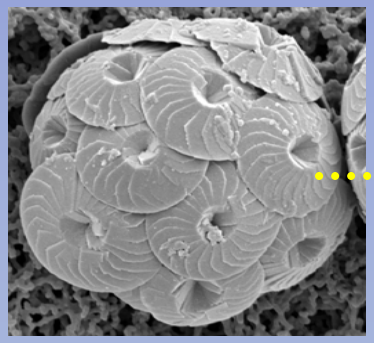
pCO_2: 280-380 ppmV



Gephyrocapsa oceanica



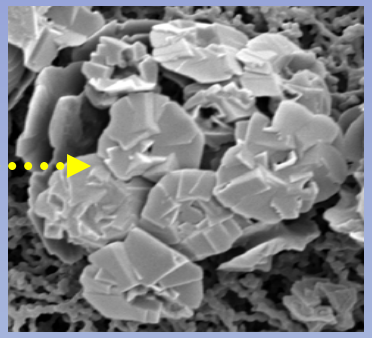
Emiliania huxleyi

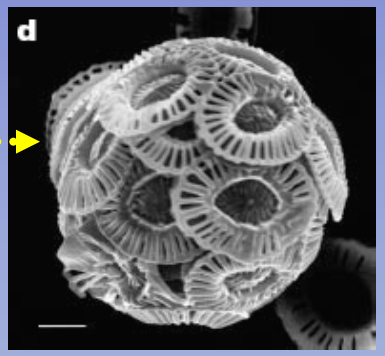


Calcidiscus leptoporus

High-CO_2 world

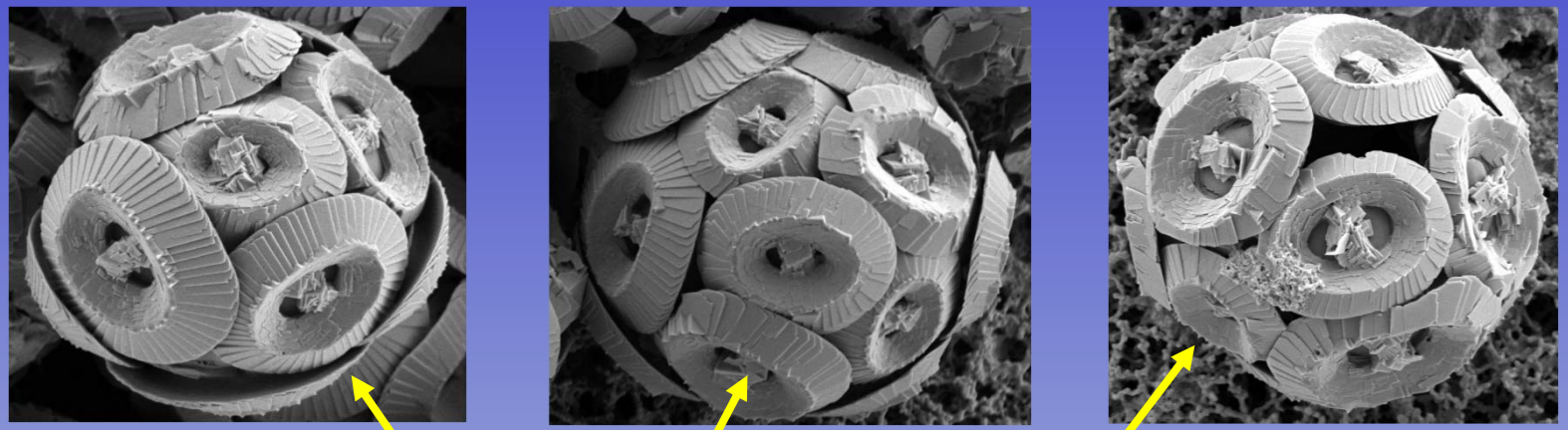
pCO_2: 580-720 ppmV

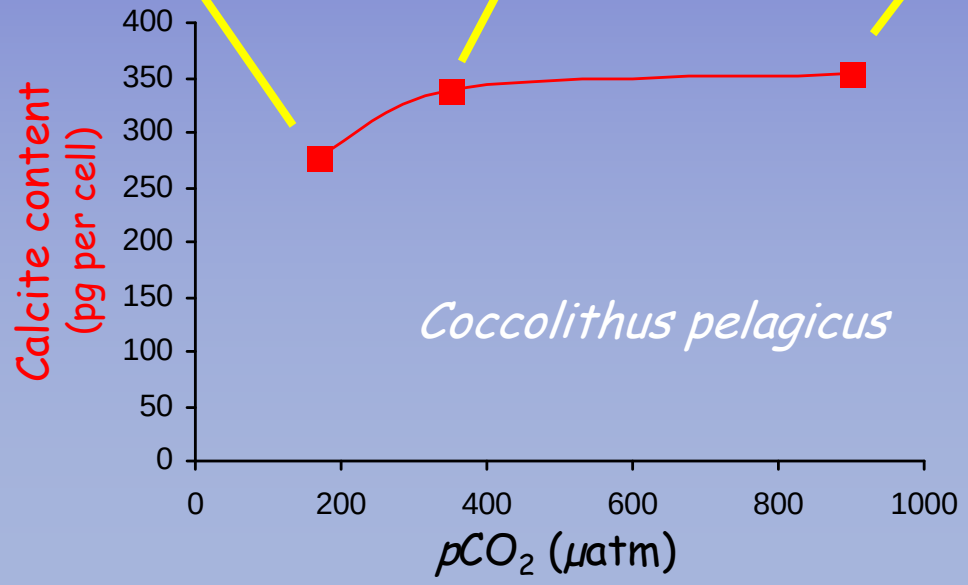




CO_2-Calcification feedback

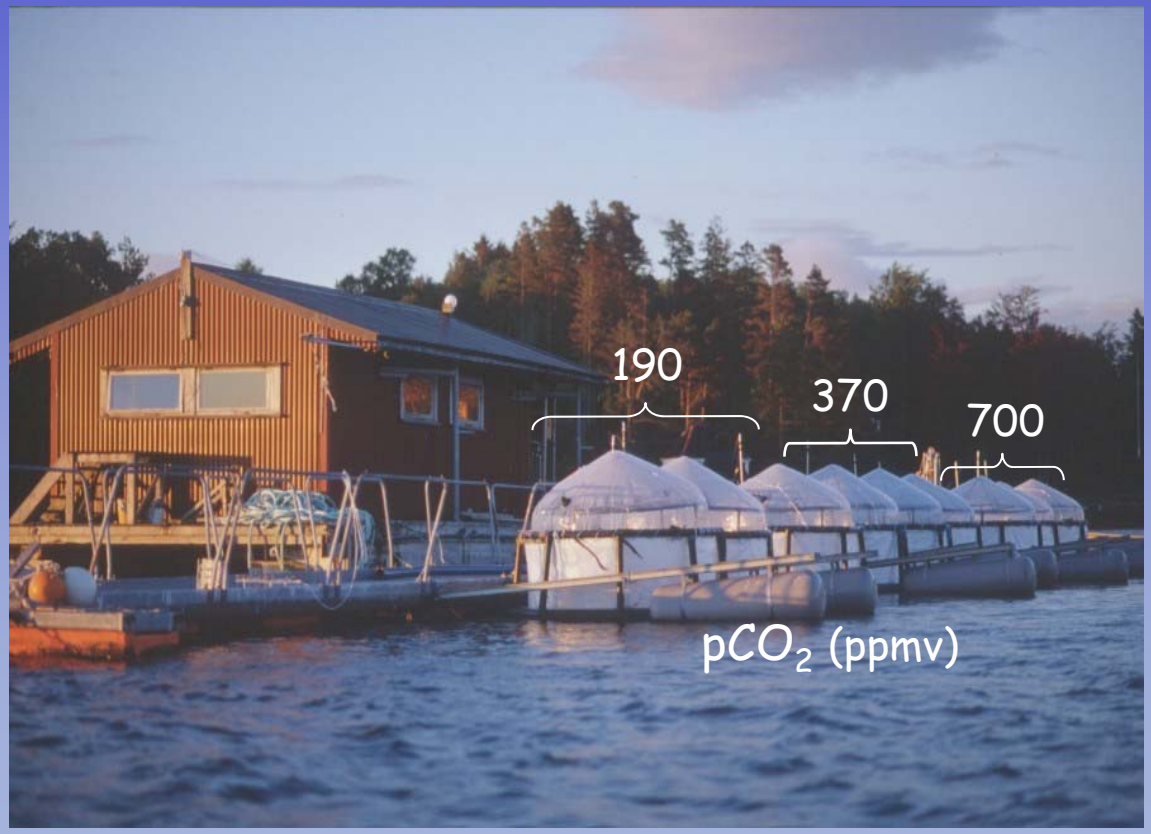
BUT !



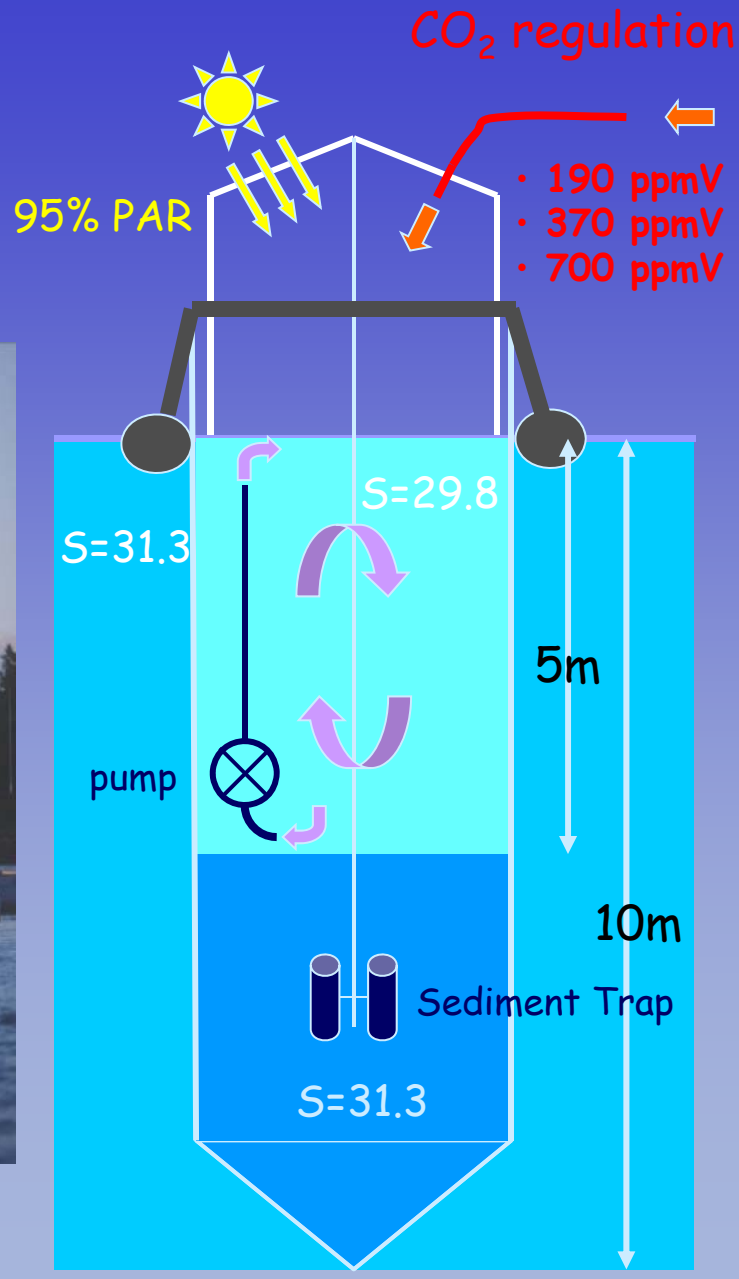


Plankton development under past, present and future CO_2

(Mesocosm experiments in 2000 and 2003)



Large Scale Facilities, Bergen, Norway

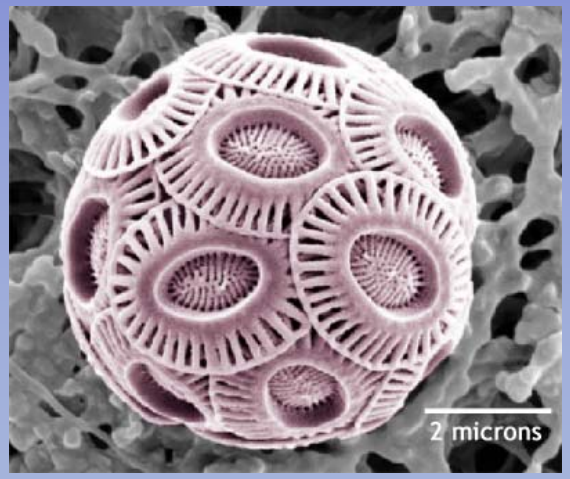


Mesocosm experiment Bergen 2000

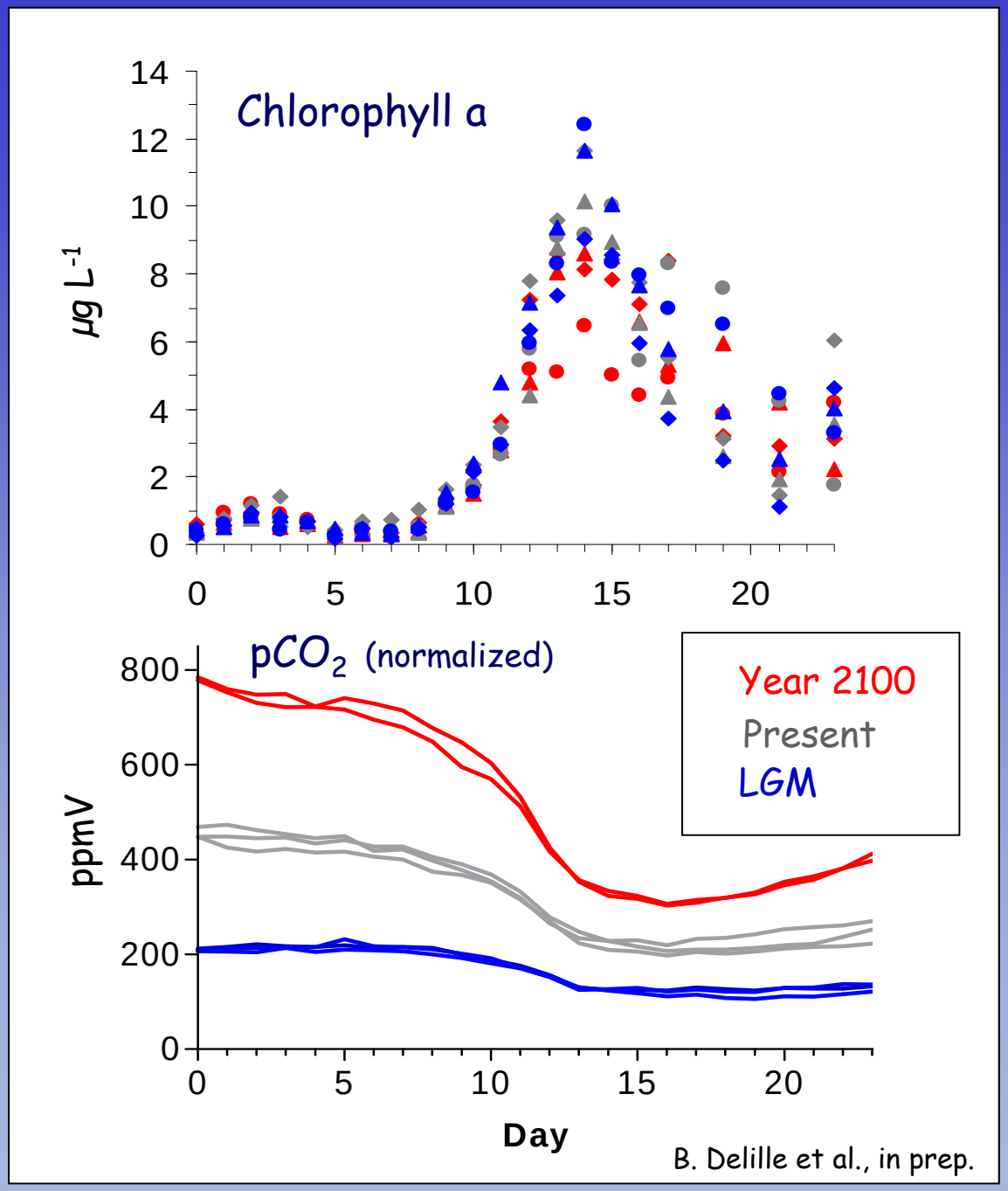
Initial nutrient concentrations:

NO_3^-	15.5 mmol m^{-3}
PO_4^{3-}	0.51 mmol m^{-3}
$Si(OH)_4$	~0

NO_3^- and PO_4^{3-} exhausted on day 13

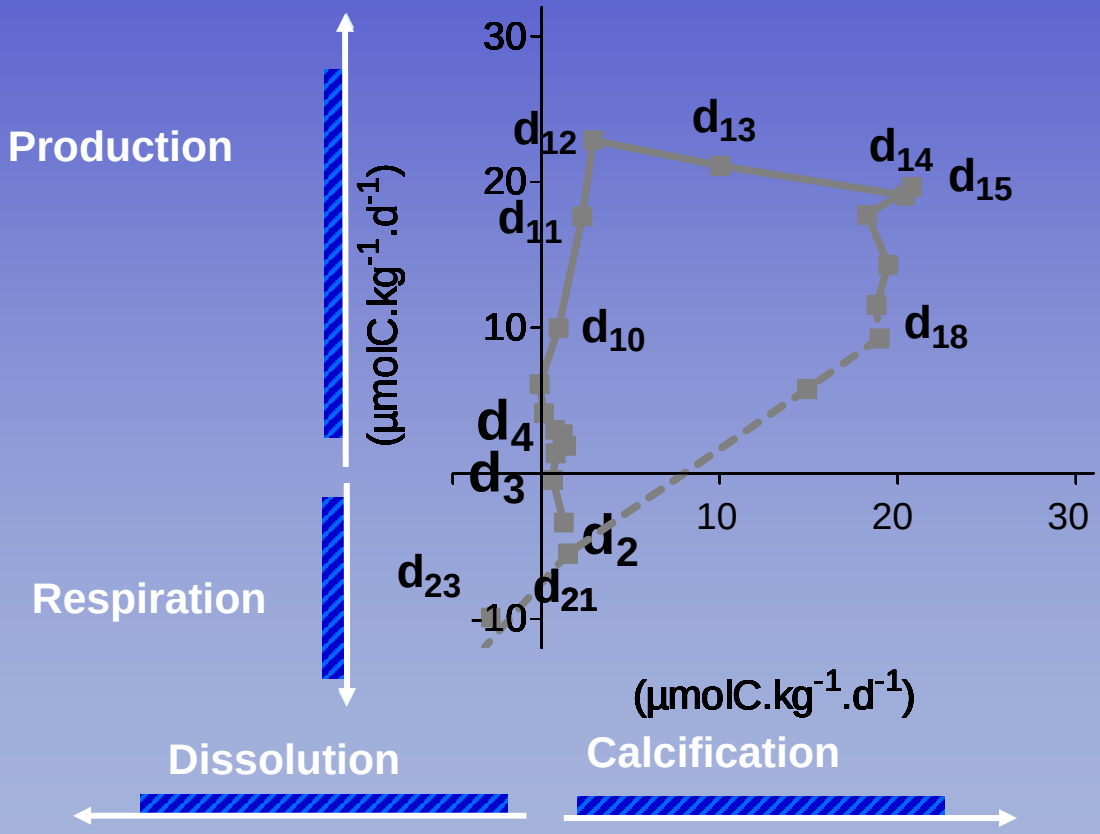


Emiliania huxleyi

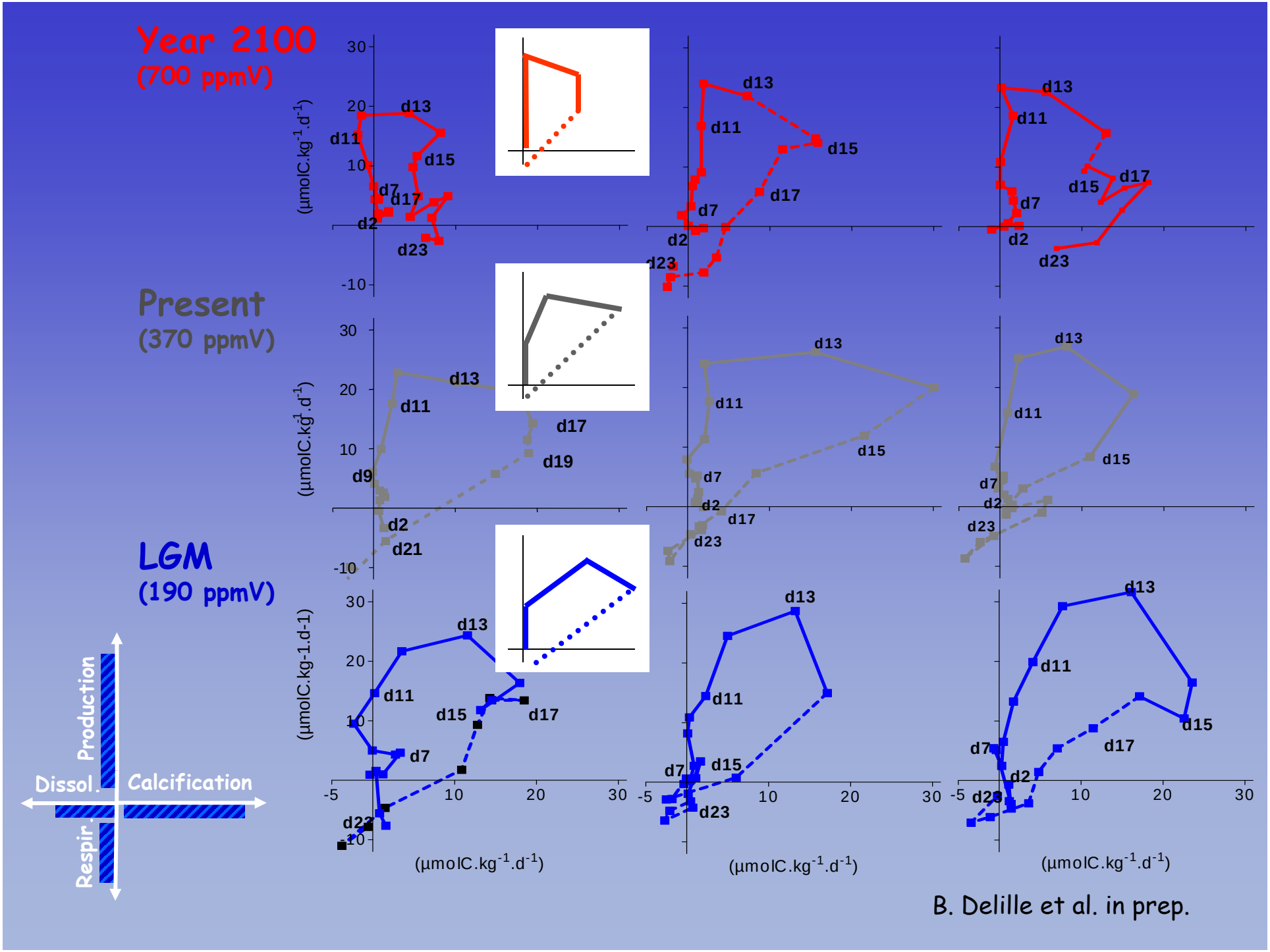


CO_2-Calcification feedback

Primary production and calcification during a bloom of *Emiliania huxleyi*



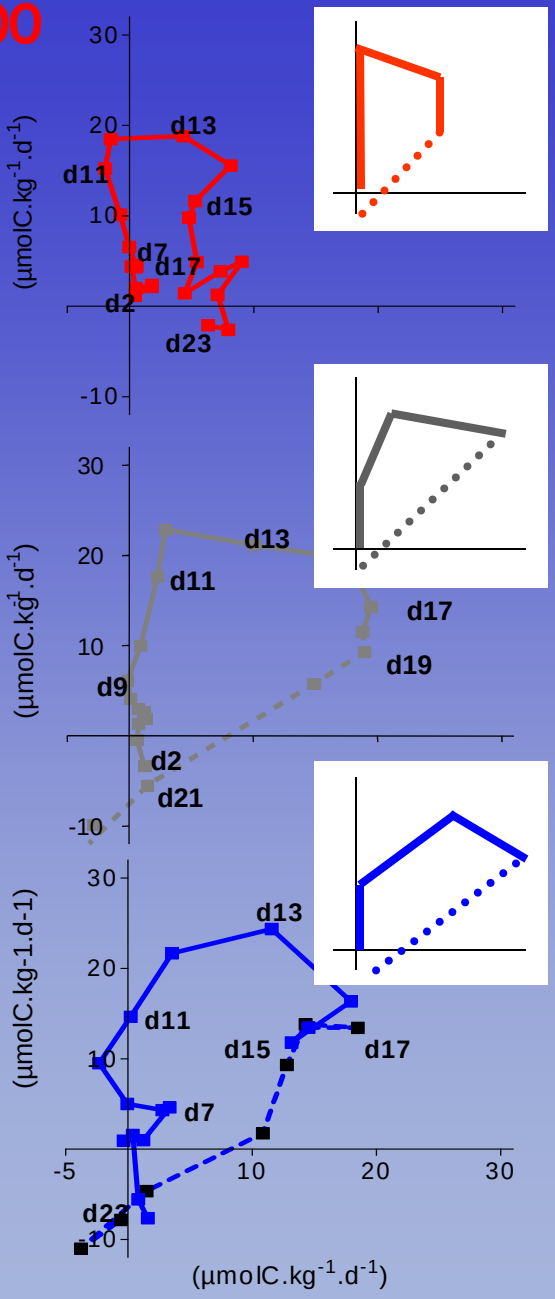
B. Delille et al. in prep.

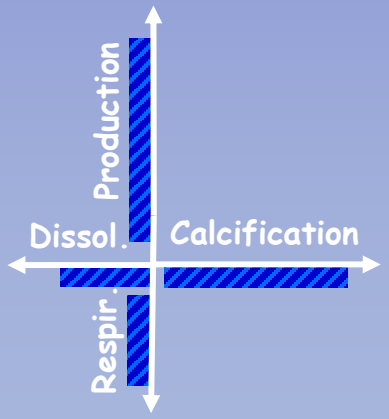

Year 2100
(700 ppmV)
Present
(370 ppmV)
LGM
(190 ppmV)
Production
Dissol.
Calcification
Respir.
(µmolC.kg-1.d-1)
(µmolC.kg-1.d-1)
(µmolC.kg-1.d-1)
(µmolC.kg-1.d-1)
(µmolC.kg-1.d-1)
(µmolC.kg-1.d-1)
B. Delille et al. in prep.

Year 2100
(700 ppmV)

Present
(370 ppmV)

LGM
(190 ppmV)





Increasing pCO_2 from 190 ppmV to 700 ppmV caused

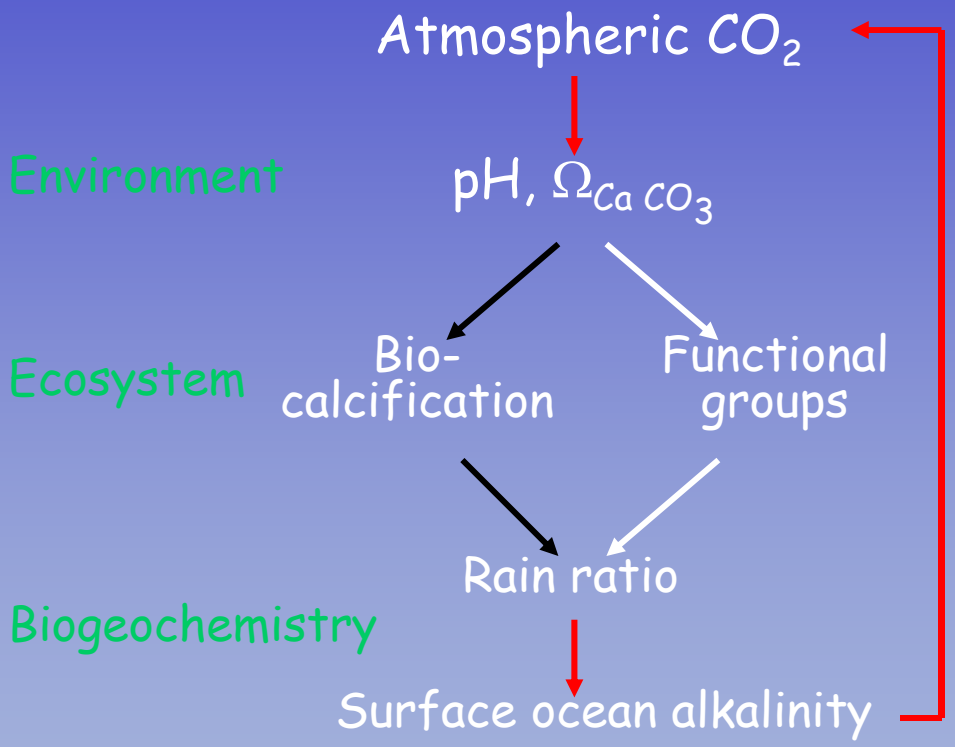
→ 24-48 h delay in the onset of calcification

→ 40% decrease in $CaCO_3$ production

B. Delille et al. in prep.

CO_2-Calcification feedback

positive influence
negative influence



Sign of change
negative feedback
(dampens initial perturbation)

Sensitivity
high

Capacity
low (6-30 Gt C until 2100 for 20-40% decrease)

Longevity
permanent vs. transient ?

Loop with even number of negative influences: positive feedback
odd number of negative influences: negative feedback

Mesocosm experiment Bergen 2003

Initial nutrient concentrations:

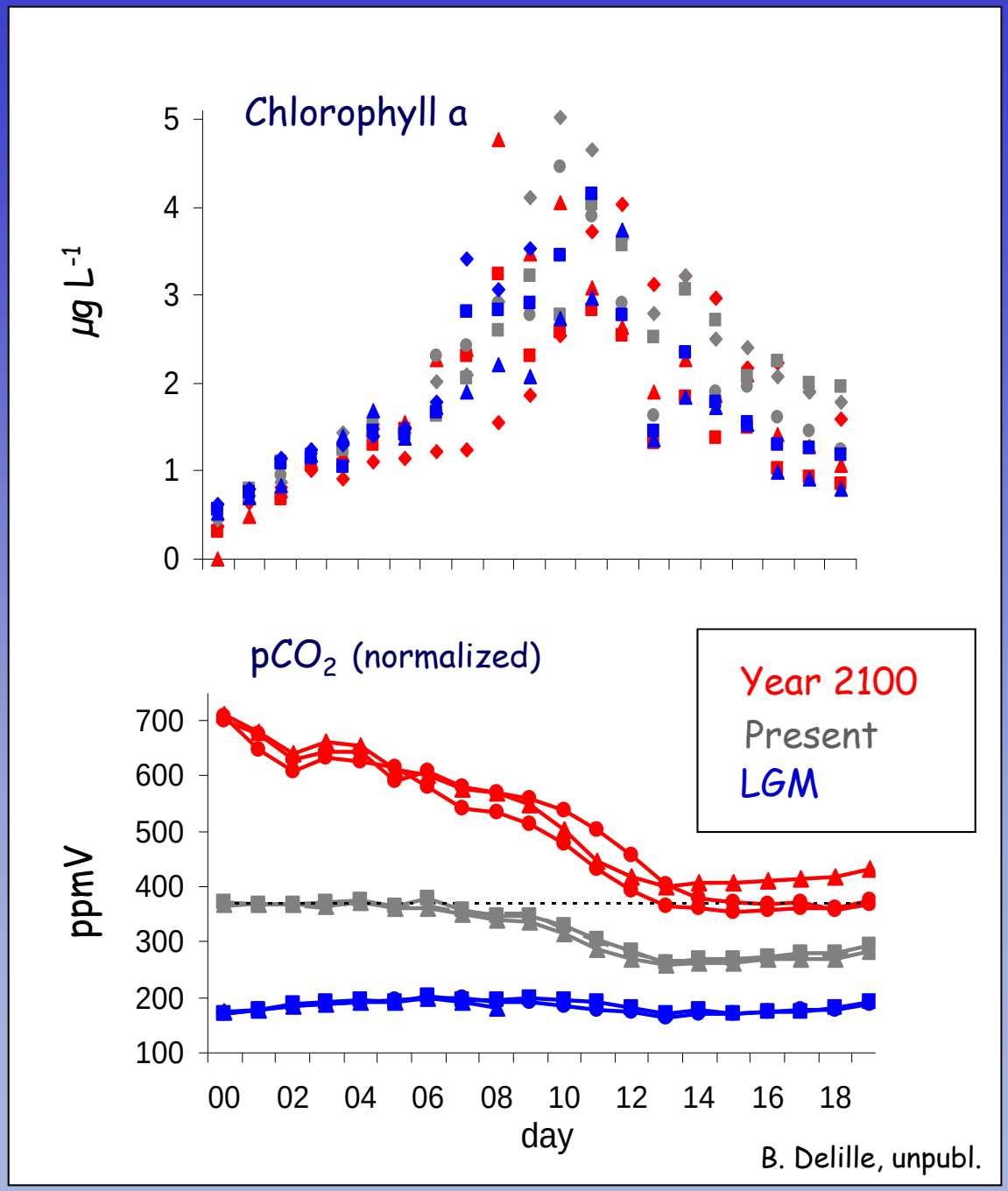
NO_3^-	8.0	mmol m^{-3}
PO_4^{3-}	0.5	mmol m^{-3}
$Si(OH)_4$	12.0	mmol m^{-3}

NO_3^- exhausted on day 12

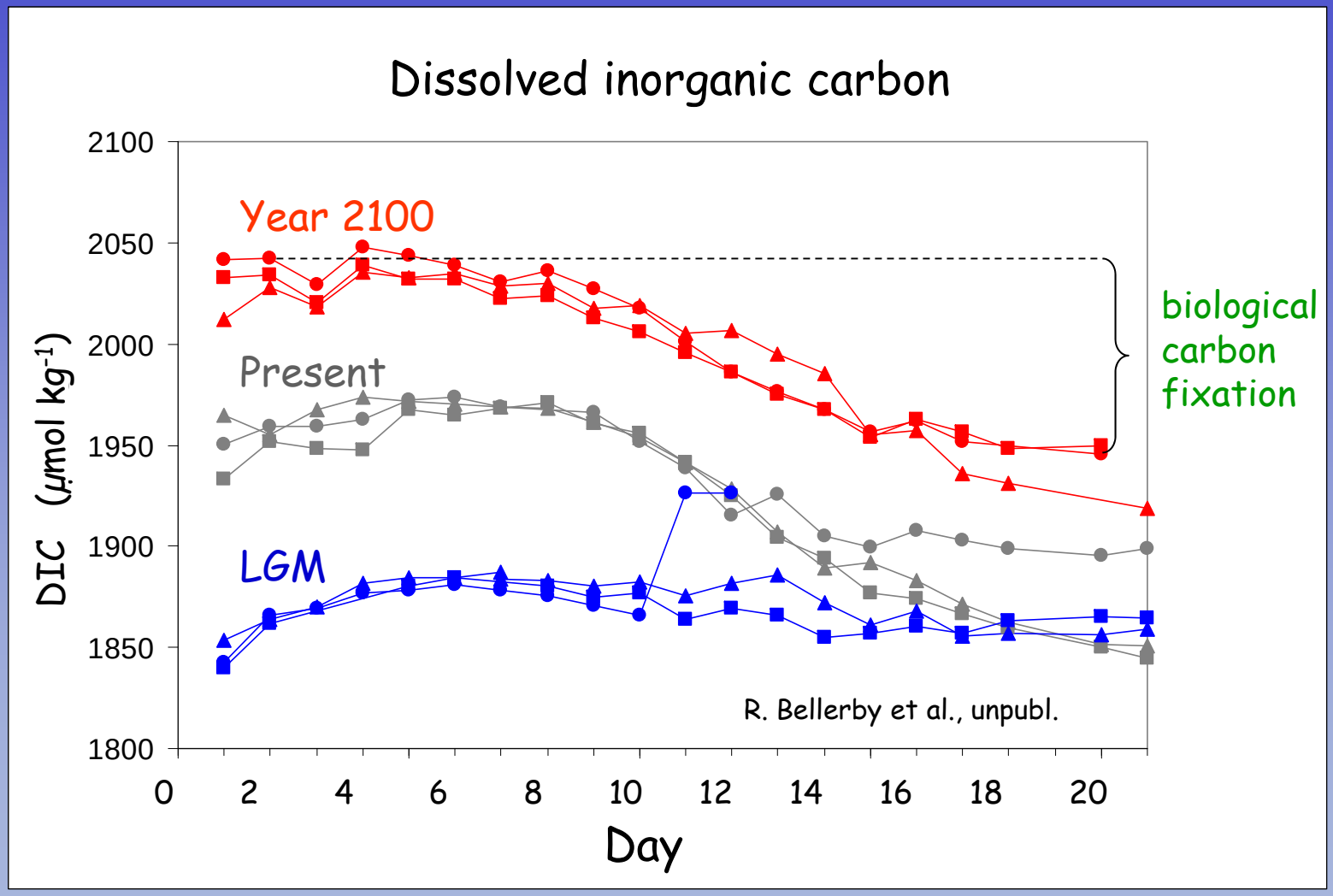
Year 2100:
Diatoms > Dinophyceae
(> Coccolithophores)

Present:
Coccolithophores > Diatoms
(> Dinophyceae > Chlorophyceae)

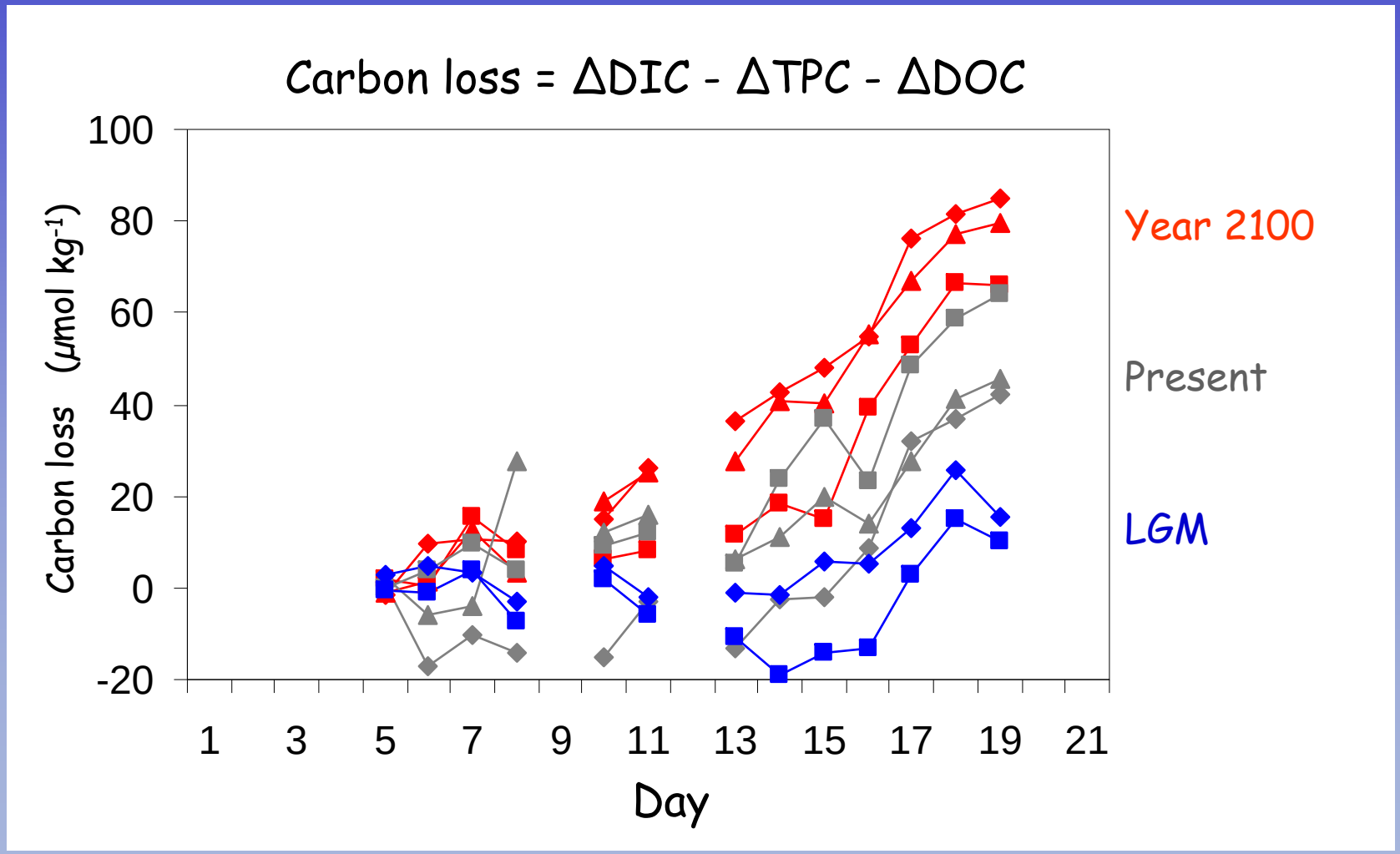
LGM:
Diatoms
(> Dinophyceae > Coccolithophores)



Carbon over-production feedback



Carbon over-production feedback



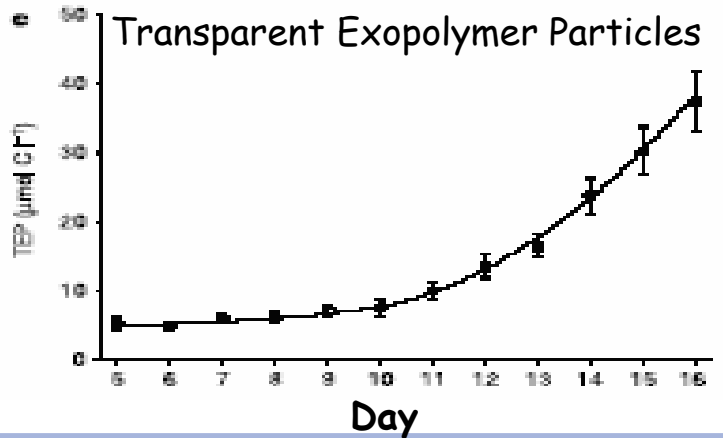
Carbon over-production feedback

Sign of change
negative feedback

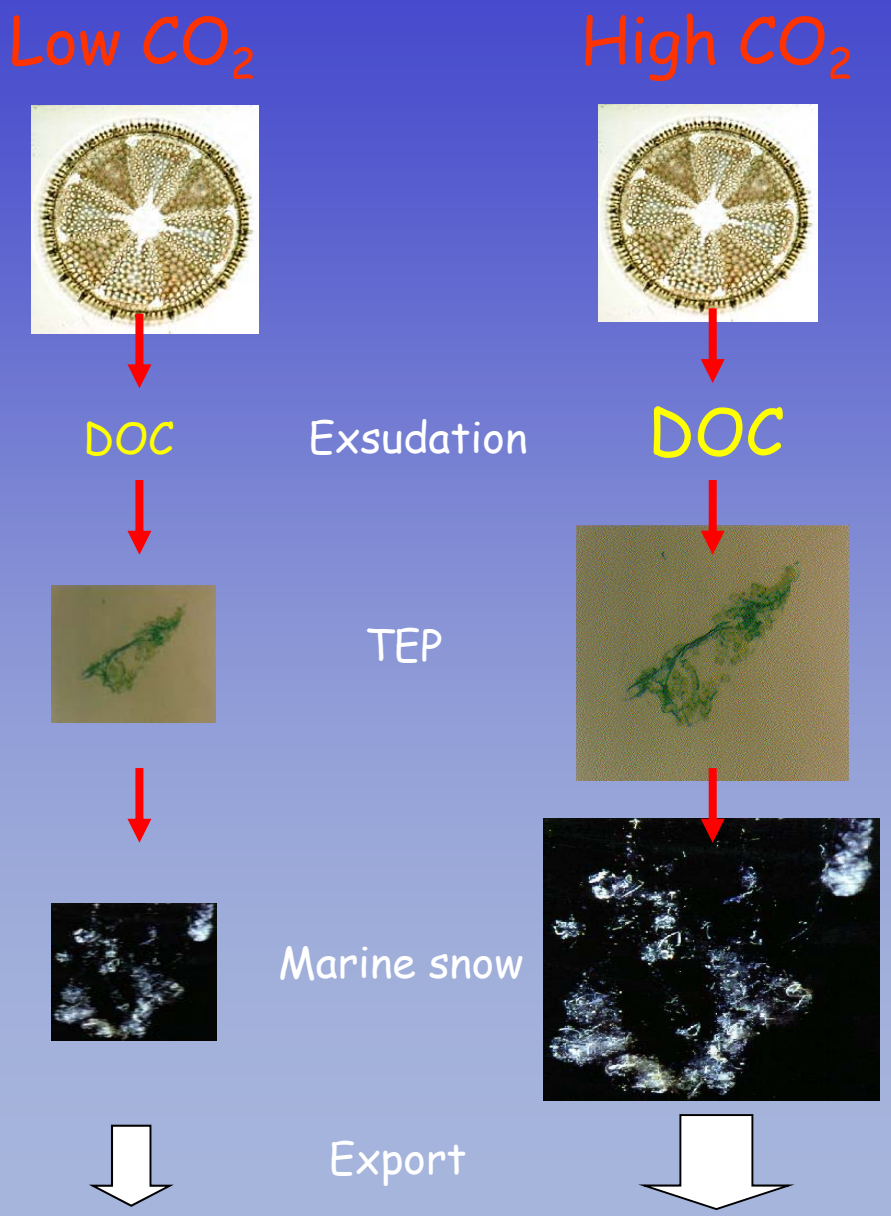
Sensitivity
?

Capacity
high

Longevity
permanent vs. transient ?

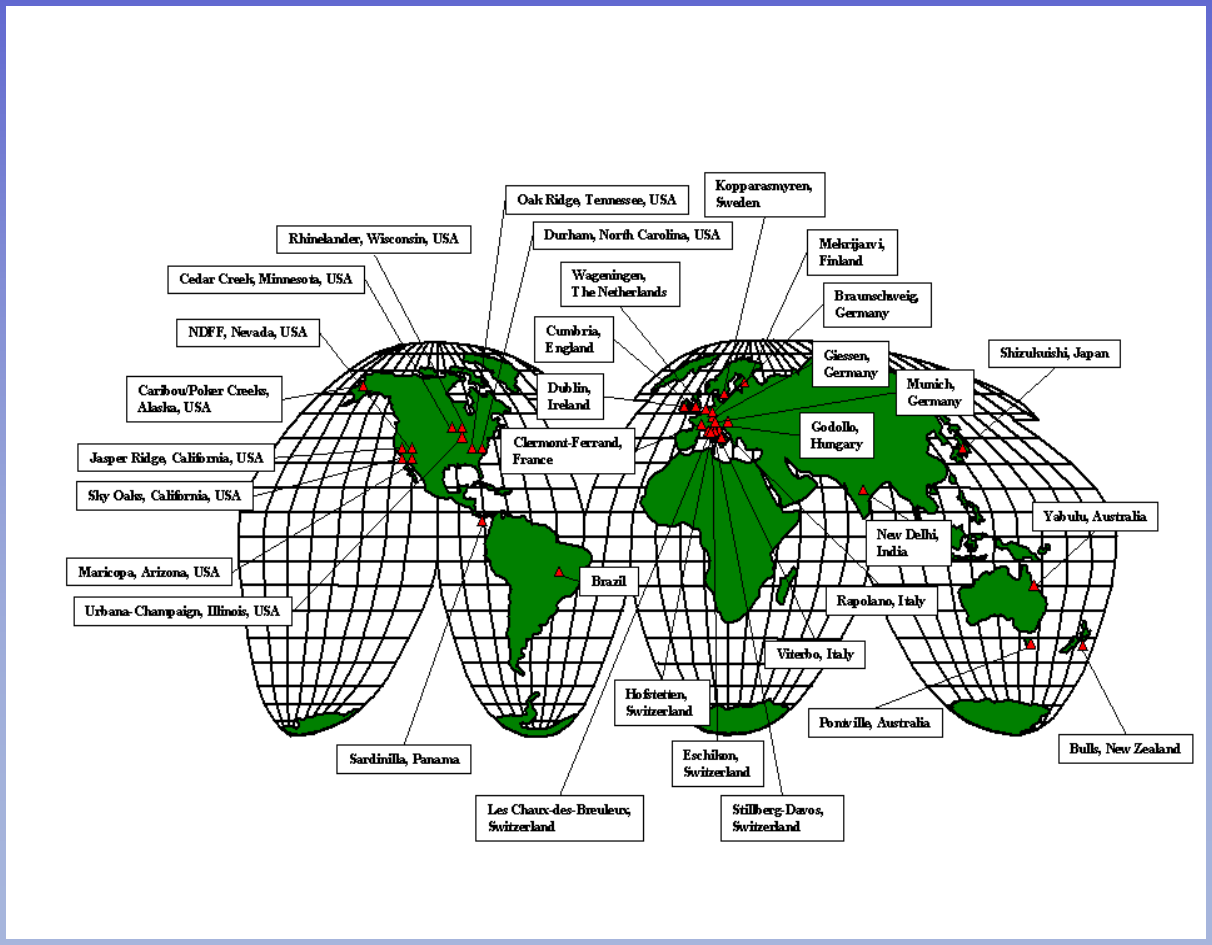


Engel et al. 2004 Nature 428, 929



FACE (Free Air CO_2 Enrichment) Program

- with worldwide 33 experimental sites
- 16 sites in Europe



Research needs:

Observational studies on combined CO_2 and T-effects
- assess biological responses
- unravel biogeochemical processes and potential feedbacks

through a suite of perturbation studies
- laboratory experiments
- mesocosm studies
- open ocean CO_2 fertilization experiment