Impacts on ecosystem processes

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Key processes in Wadden Sea ecosystem functioning

- Primary production: food production

$$CO_2 + H_2O + \text{Nutrients} \xrightarrow{\text{photosynthesis}} \text{Algal biomass (= food)} + O_2$$

- Remineralization: nutrient recycling

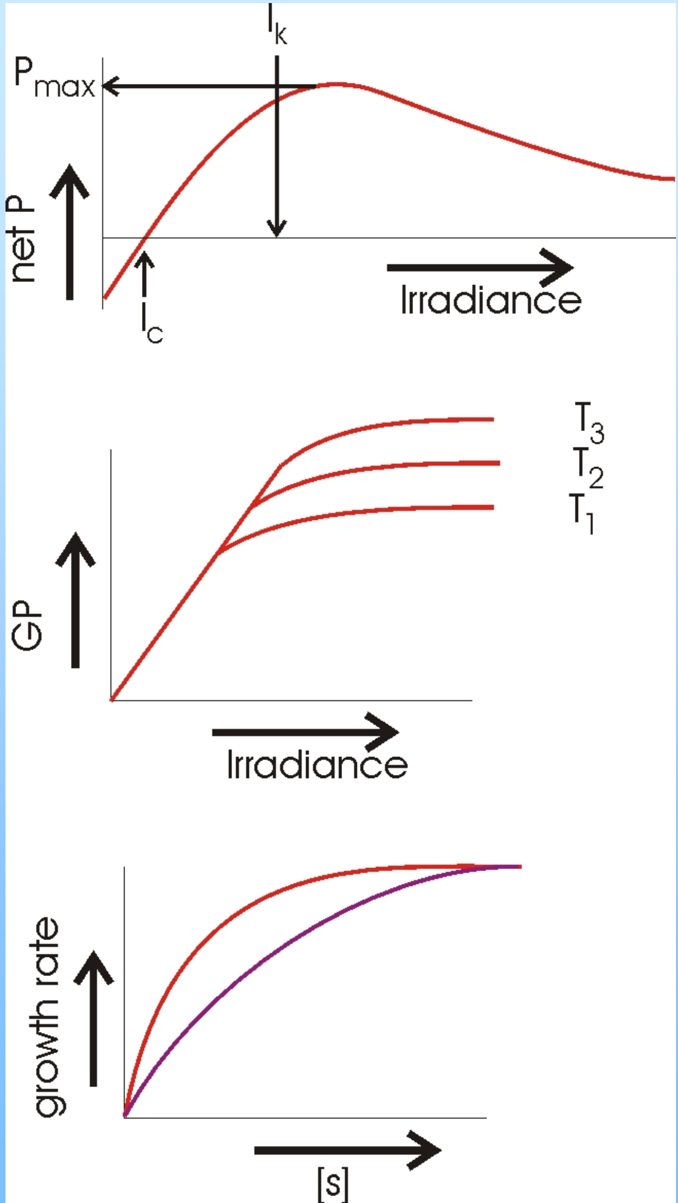
$$CO2 + H2O + \text{Nutrients} \longleftarrow \text{Organic Matter} + \text{oxidant}$$

- Engine of the food web: Sets the limits to mass and energy flow and carrying capacity of the system
- Controls the biogeochemical cycling of elements

- Annual rates of estuarine primary production in g C m^{-2} y^{-1}:

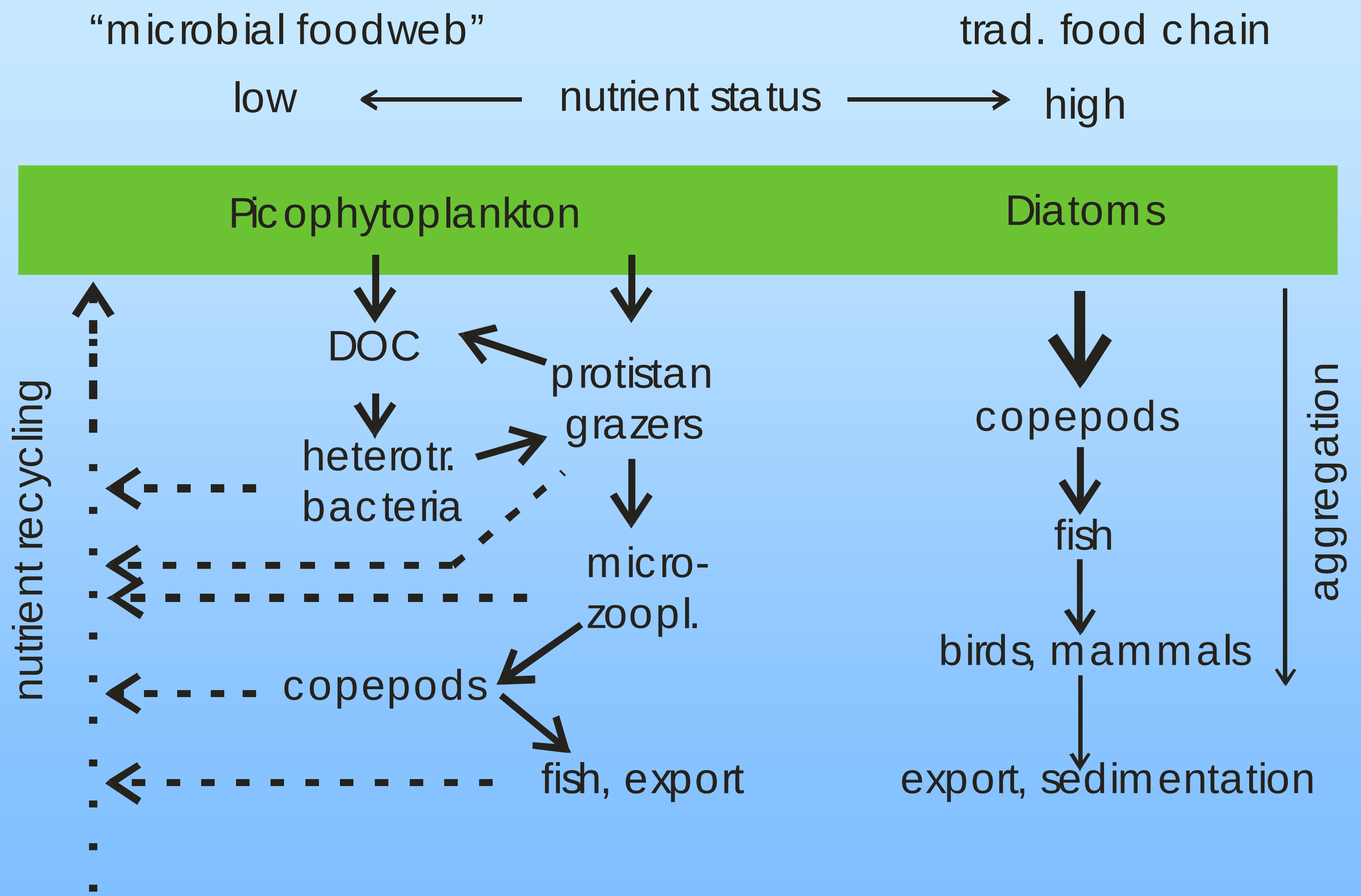
	range	typical	W.Wadden Sea	
pelagic	7 – 875	190	150-200	
benthic	29 – 234	120	60 - 140	

- System-wide estimates hard to obtain:
  - Methodology used (gross, net, gross-net?)
  - Spatio-temporal heterogeneity of biota and controlling factors hampering upscaling small scale measurements



- Light
  - Incident irradiance
  - Transparency
  - (deci-)Meters versus millimeter
- Temperature
  - Seasonal conditions
  - emersed or submerged
- Nutrients
  - River input
  - Water column and sediment regeneration

- Phytoplankton
  - Export
  - Respiration
  - Natural mortality (nutrient limitation)
  - Virus induced lysis
  - Grazing by zooplankton and filterfeeders
- Microphytobenthos
  - Respiration
  - Resuspension and export
  - Mixing and burial in sediment
  - Respiration by heterotrophs
  - Grazing


"microbial foodweb"
trad. food chain
low
nutrient status
high
Picophytoplankton
Diatoms
DOC
protistan grazers
heterotr. bacteria
micro-zoopl.
copepods
fish, export
nutrient recycling
copepods
fish
birds, mammals
export, sedimentation
aggregation

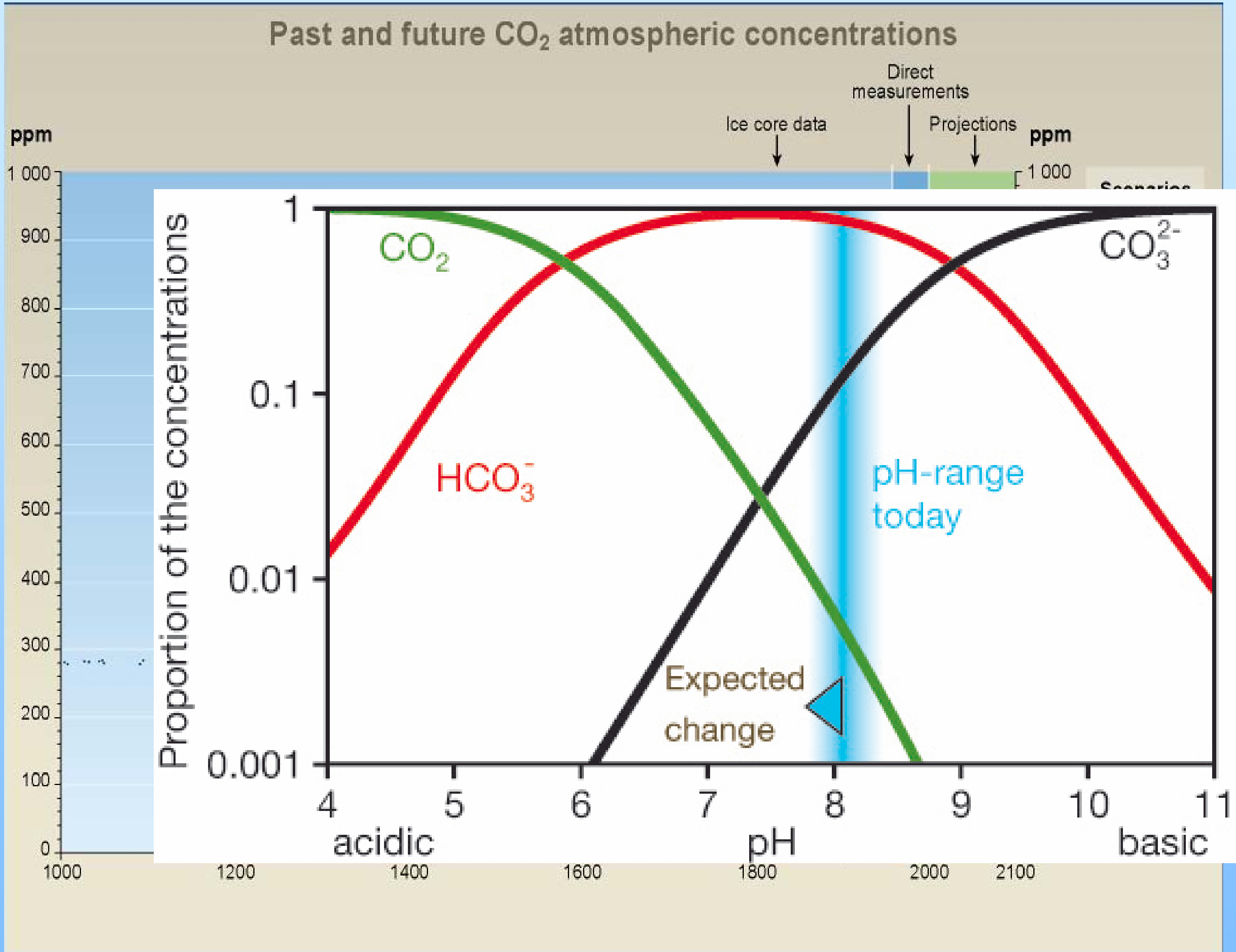
Central question:

How does climate change affect primary production and community composition, and remineralization?

variable	physiology	Ecosyst. Char.
pCO_2	+	?
Temperature	+	+
Precipitation	-	+
Wind	-	+

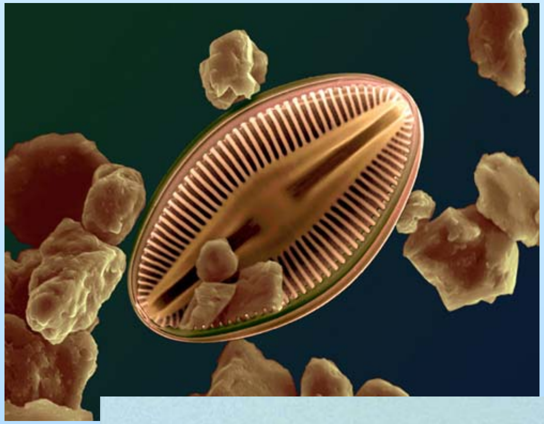
- What is the nature of change?
  - Long term mean
  - Daily & seasonal amplitude
  - Frequency of extreme

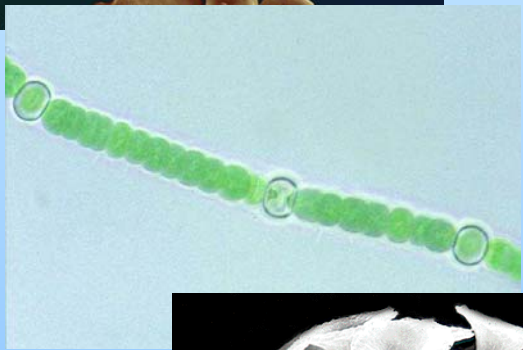
Time scales – acclimation or adaptation
Synergistic effects between variables?


Past and future CO2 atmospheric concentrations
Direct measurements
Ice core data
Projections
ppm
1 000
900
800
700
600
500
400
300
200
100
0
1000
1200
1400
1600
1800
2000
2100
Proportion of the concentrations
1
0.1
0.01
0.001
CO2
HCO3-
CO3 2-
pH-range today
Expected change
4
5
6
7
8
9
10
11
acidic
pH
basic

Source: IPCC

- Higher concentration CO_2 and lower concentration of $CO_3^{=}$
- Reduces carbonate saturation state (calcite, aragonite)
  - promotes dissolution
  - reduced calcification
- increases protonation of P, Si, NH3
  - affects uptake kinetics and potentially metabolic rates (e.g. nitrification)
- lowers sorption capacity of ligands and clays for trace metals (micronutrients)





Diatoms and Phaeocystis

photosynthesis saturated at present atmospheric levels (Rost et al. 2003)

doubling pCO2 increases P up to 10% and stimulates extracellular release (Raven et al. 2005, Riebesel),

N2 fixing cyanobacteria (Trichodesmium)

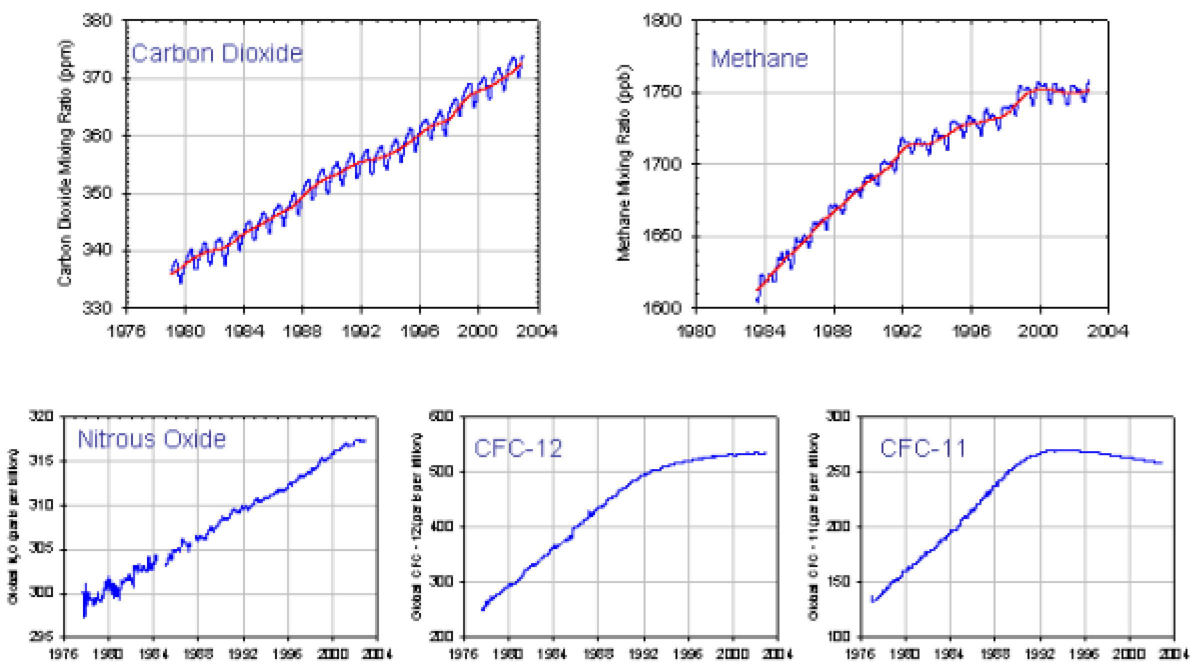
100% increase in growth

Size reduction and clear change in elemental composition (Barcelos e Ramos et al. 2007)

Cocclithophorids

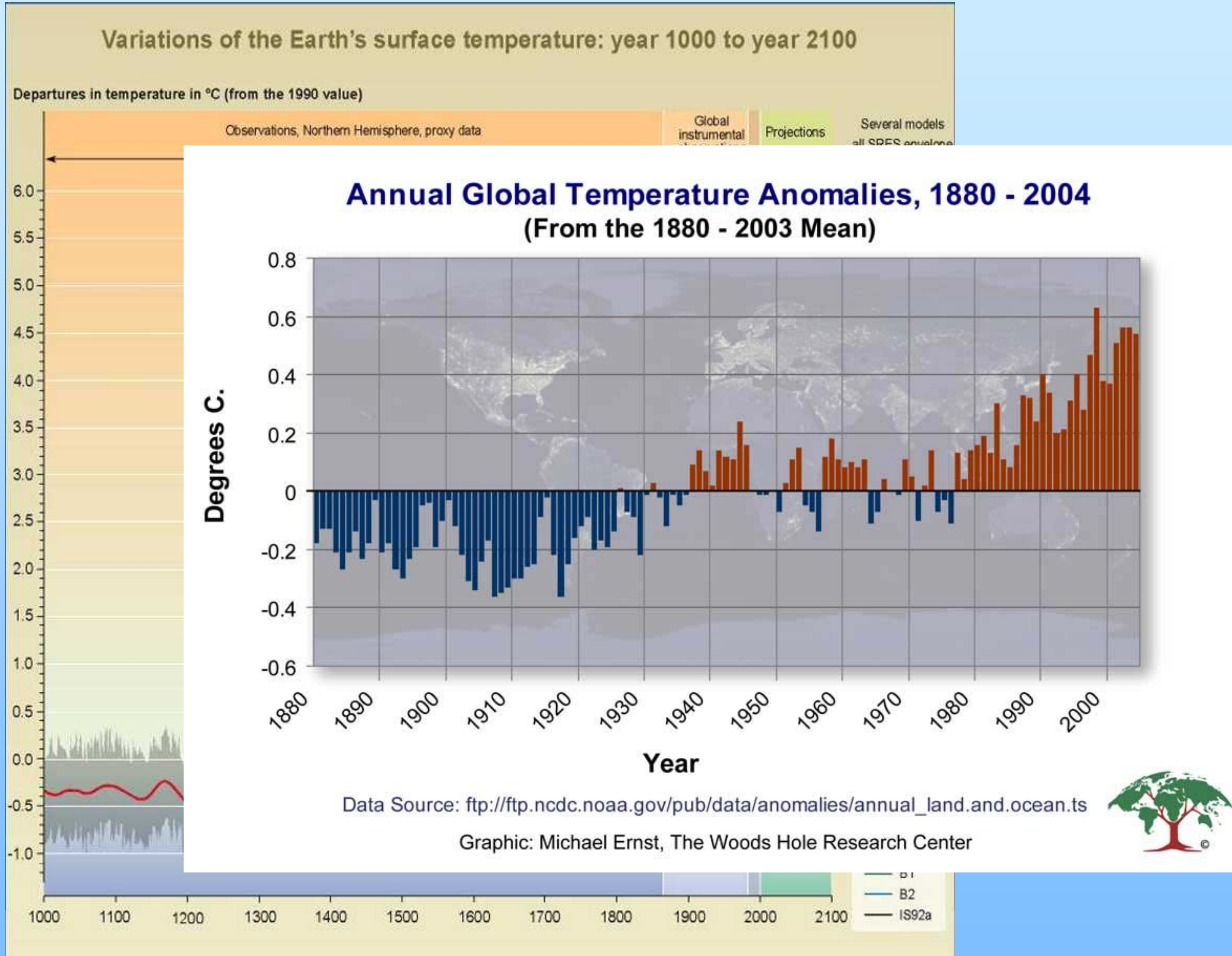
doubling pCO2 reduces calcification by 10 - 30% (Riebesel et al. 2000, 2004)

Global Trends in Major Greenhouse Gases to 1/2003



Global trends in major long-lived greenhouse gases through the year 2002. These five gases account for about 97% of the direct climate forcing by long-lived greenhouse gas increases since 1750. The remaining 3% is contributed by an assortment of 10 minor halogen gases, mainly HCFC-22, CFC-113 and CCl_4.

Annual global temperature anomalies



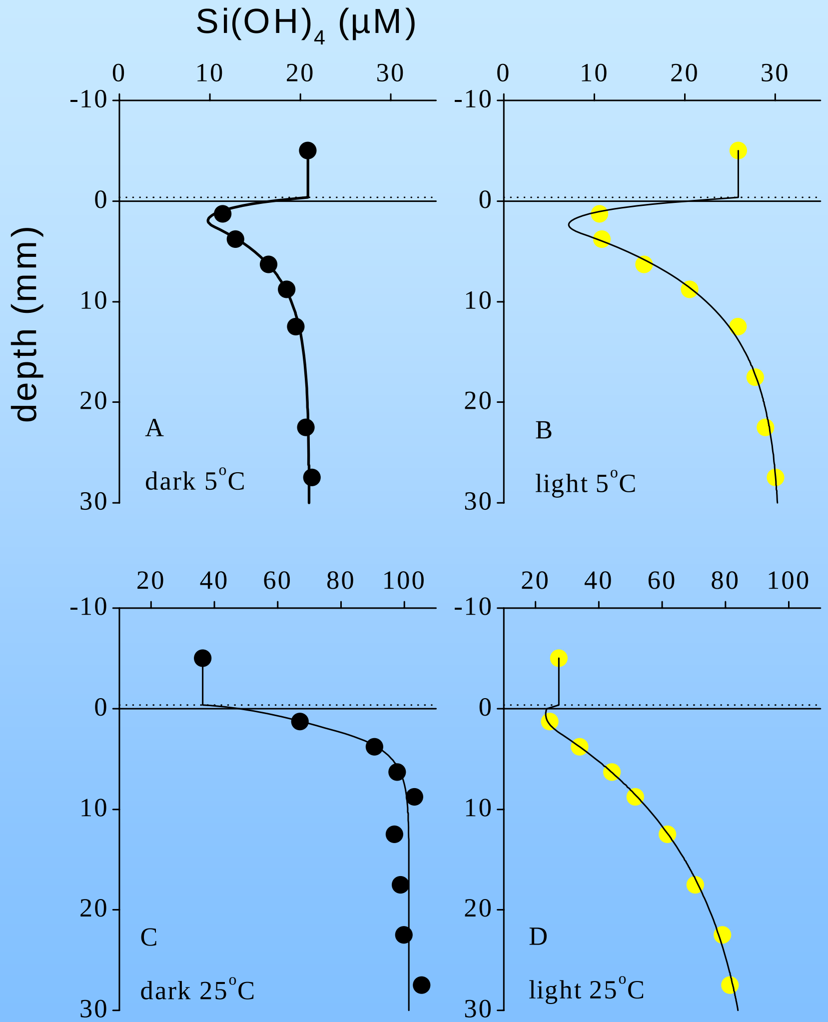
source: IPCC

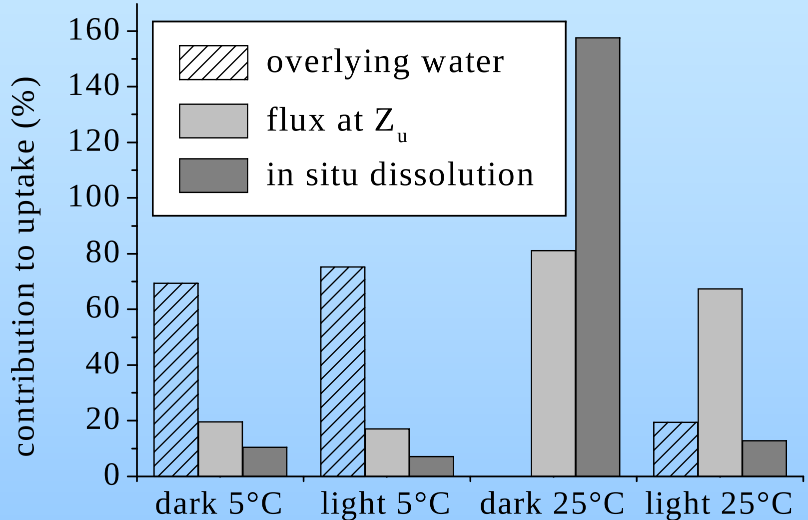
Reported Q10 values

	Gross photosynthesis (light saturated!)	Remineralization
pelagic	2.0 – 5.4	1.5 - 6
benthic	1.0 – 2.6	1.6 – 5.2

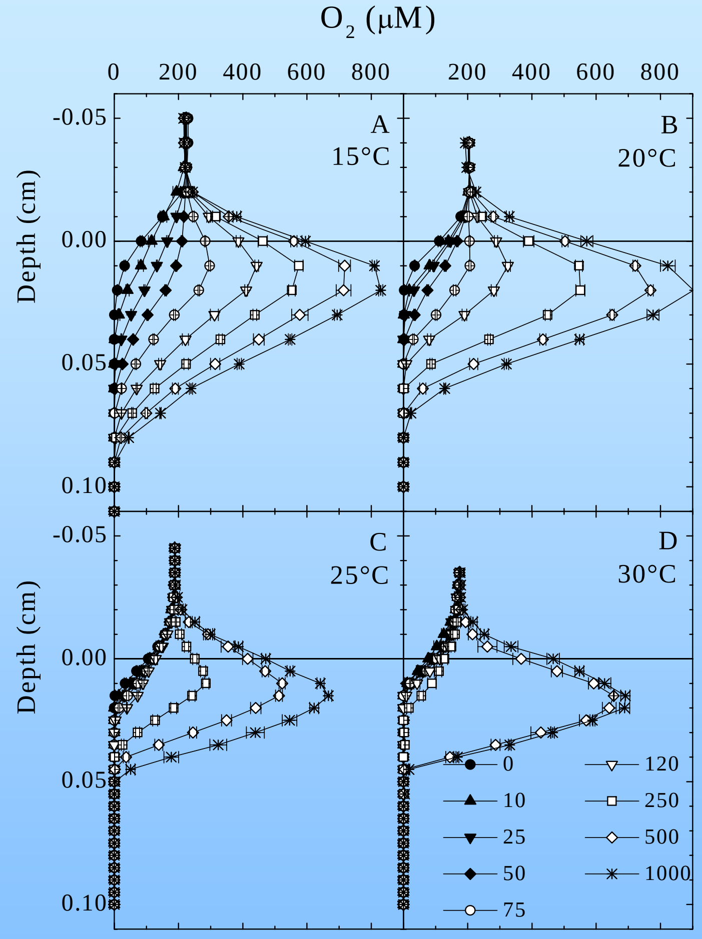
Conclusion:

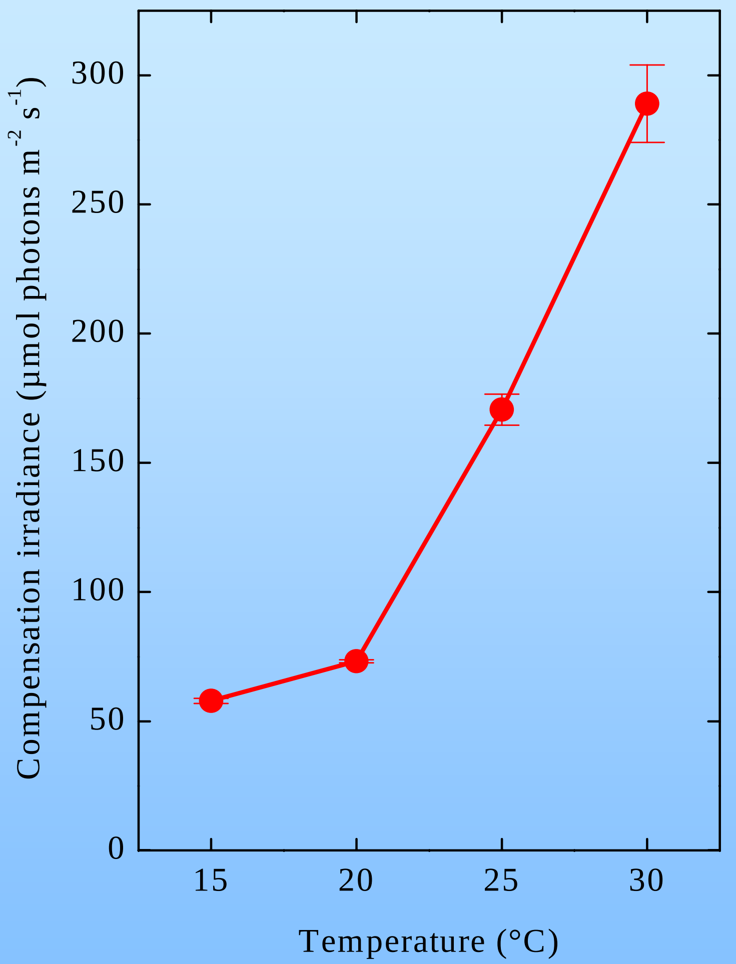
Remineralization responds stronger to changes in temperature than gross photosynthesis


Si(OH)4 (µM)
depth (mm)
A
dark 5°C
B
light 5°C
C
dark 25°C
D
light 25°C


contribution to uptake (%)
overlying water
flux at Zu
in situ dissolution
dark 5°C
light 5°C
dark 25°C
light 25°C

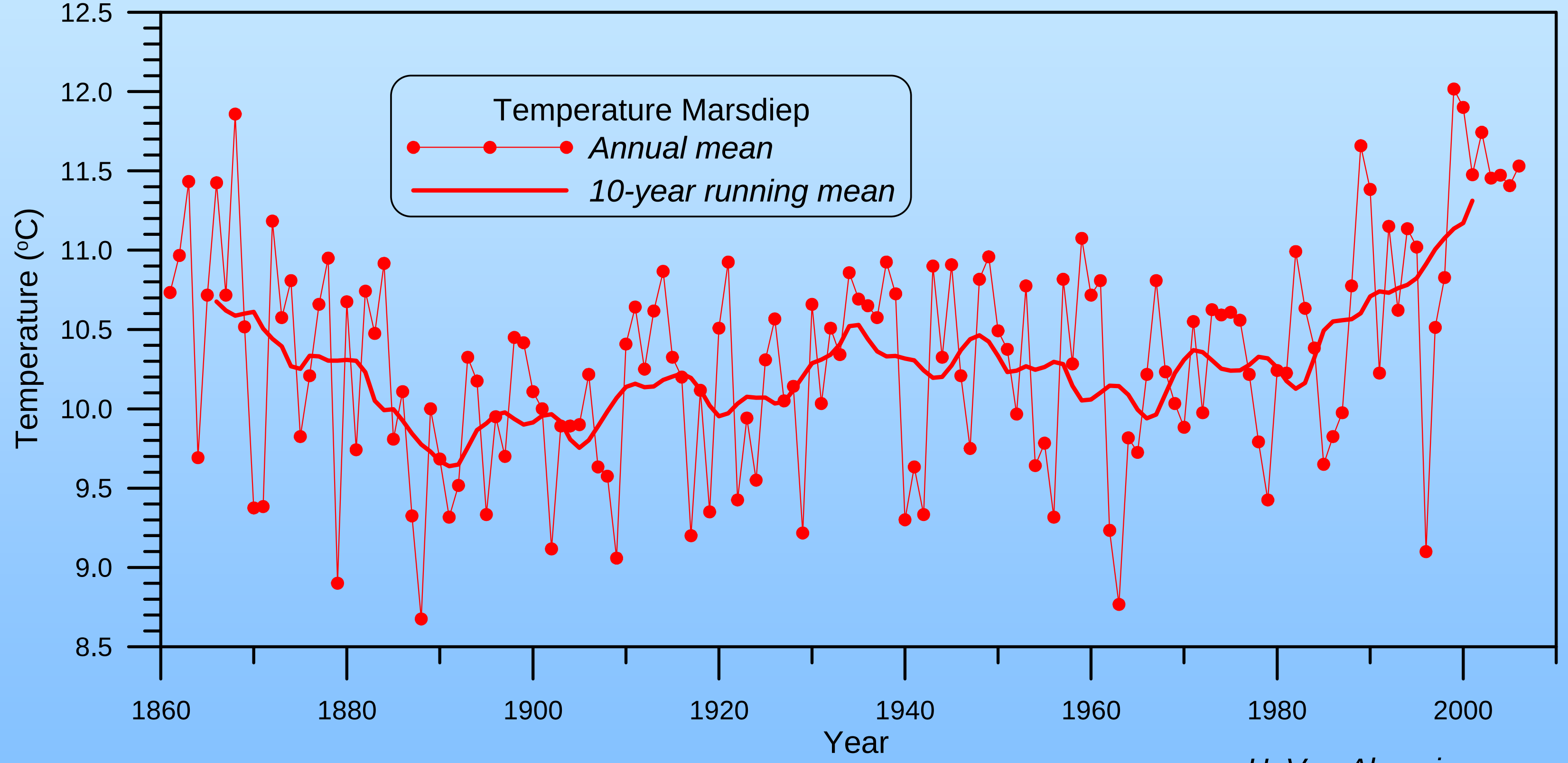
Temperature and benthic community oxygen metabolism



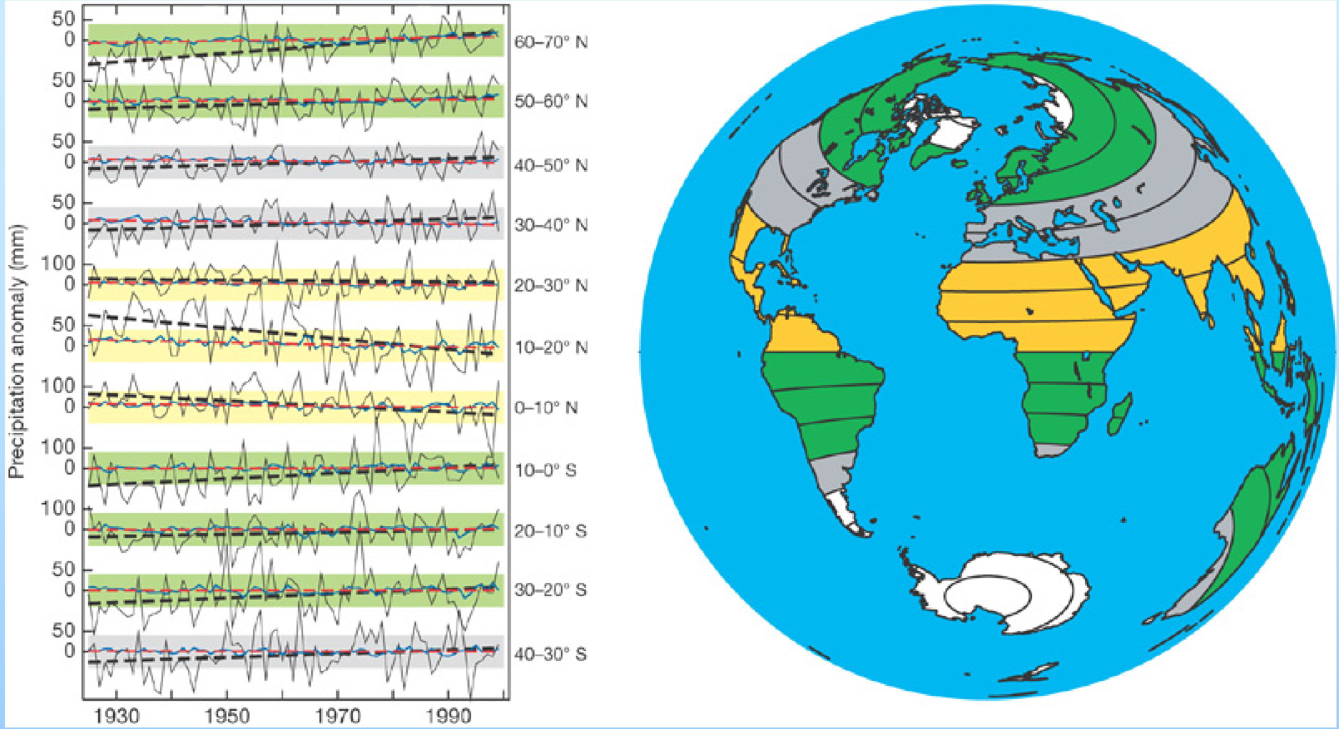


Risk of hypoxia?

Temperature Time series W. Wadden Sea



H. Van Aken, in prep



Zhang et al. 2007

- Predicted
  - Slight increase in annual precipitation
  - Increased frequency in catastrophic events
- Consequences
  - Enhanced spatiotemporal variability in salinity
  - Pulsed supply of nutrients and suspended matter
- Management
  - Discharge policies - loadings - nutrient ratios – primary production - phytoplankton diversity.

- Enhanced resuspension
  - increased light attenuation
  - erosion of microphytobenthos
  - Sorting of sediments by winnowing and focusing?
  - Stronger lateral gradients in sediment geochemistry?
  - Release of benthic nutrients
  - de-/ad-sorption of nutrients (P, N, metals)

- Increased wave action
  - Enhanced mineralization in permeable sands and
  - Efficient exchange of nutrients between sediment and water column

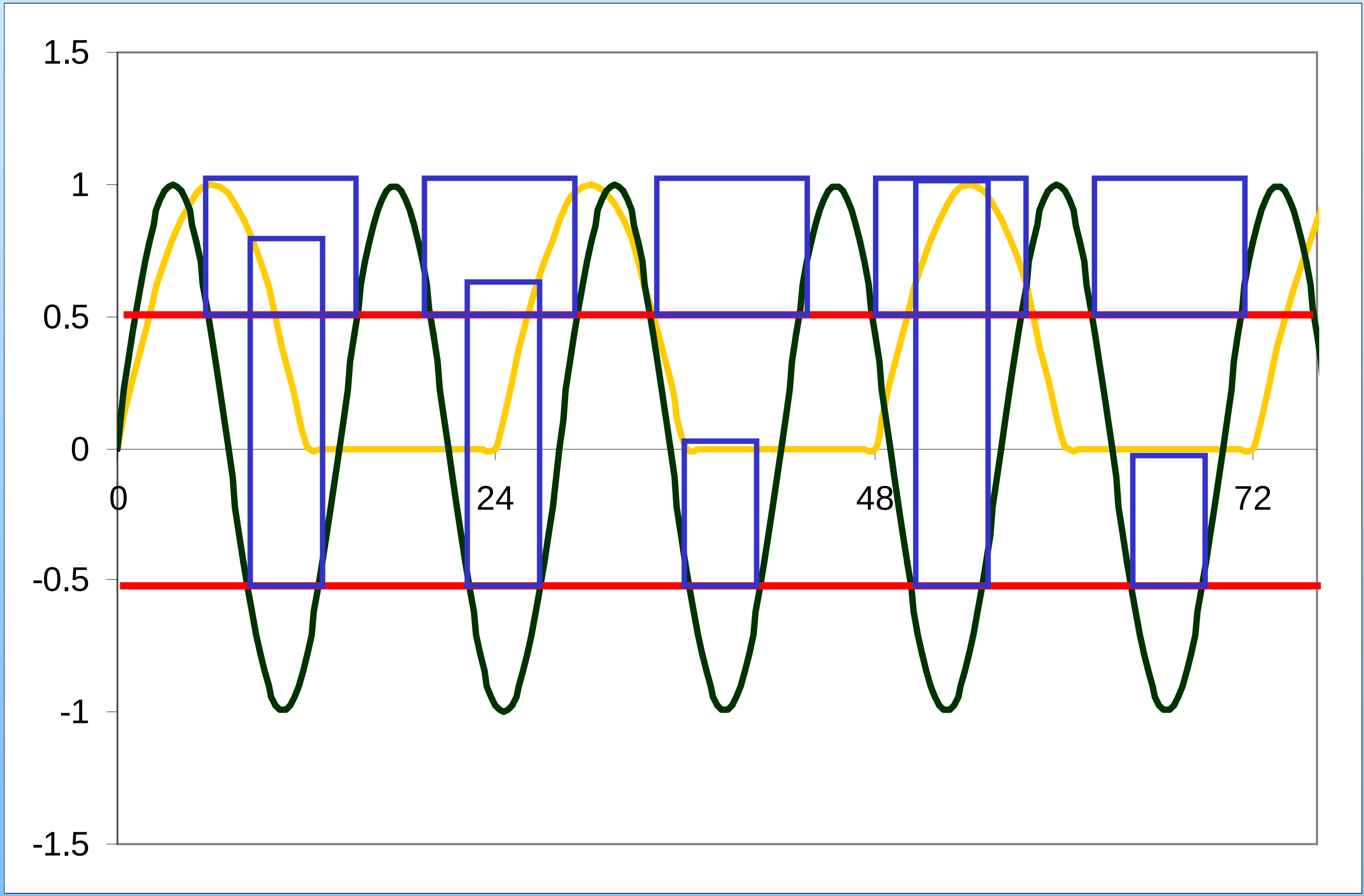
Can we predict the effect of climate change on primary production,
i.e. the base of the food web?

We know effects of variables on some individual algal species or strains but:

- Synergistic or antagonistic effects of climate variables on physiology of primary producers?
- What is the effect of climate change on the intermediate trophic levels? Grazers, zooplankton?
- What is the effect on complex biotic systems? direction of change?

What are potential feedback mechanisms?

Most difficult to predict is the change in the physicochemical environment


1.5
1
0.5
0
-0.5
-1
-1.5
0
24
48
72