

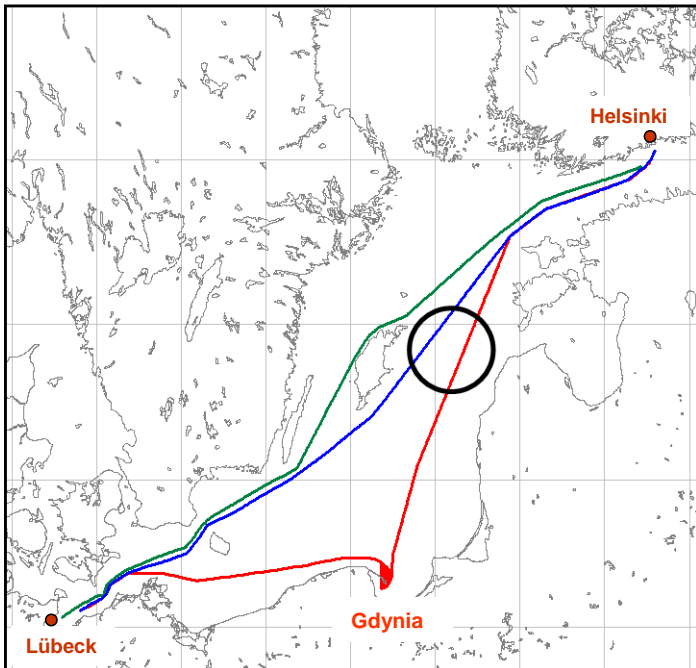
**Ten years of CO<sub>2</sub> measurements on a cargo ship reveal  
new insights and knowledge gaps  
in the Baltic Sea net community production**

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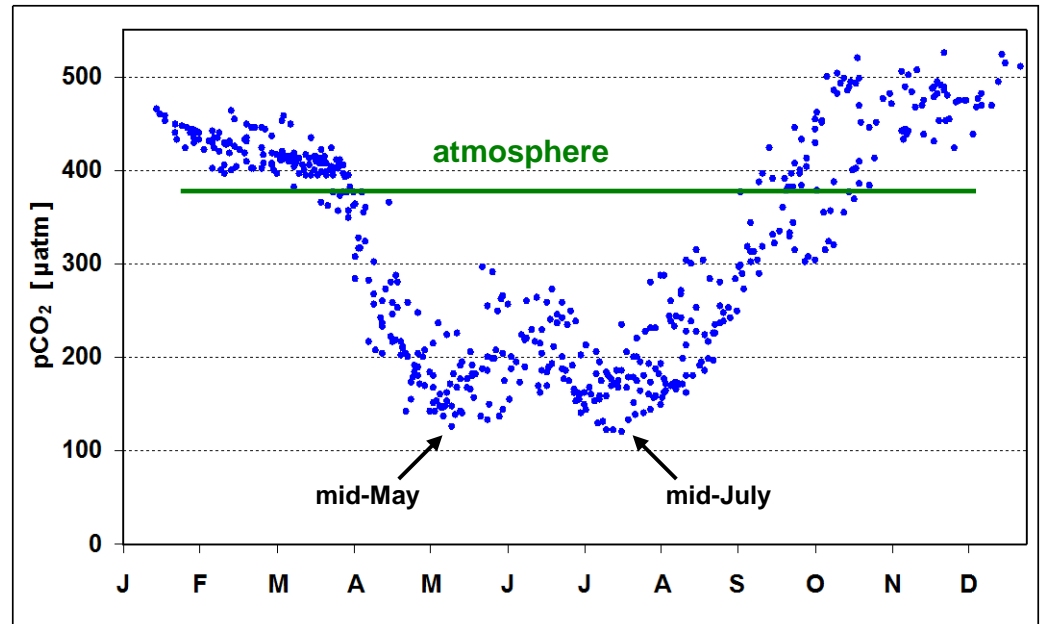
<sup>1</sup> IOW, <sup>2</sup> SYKE, <sup>3</sup>BNI

## Automated pCO<sub>2</sub> measurements on FINNMAID (FINNPARTNER):

- since 2003;
- since 2005 also O<sub>2</sub> measurements
- 4 transects per week;
- about 2 miles spatial resolution;
- sampling for nutrient analysis (Algaline);



Seasonality of the pCO<sub>2</sub> in the eastern Gotland Sea: 2004 - 2011



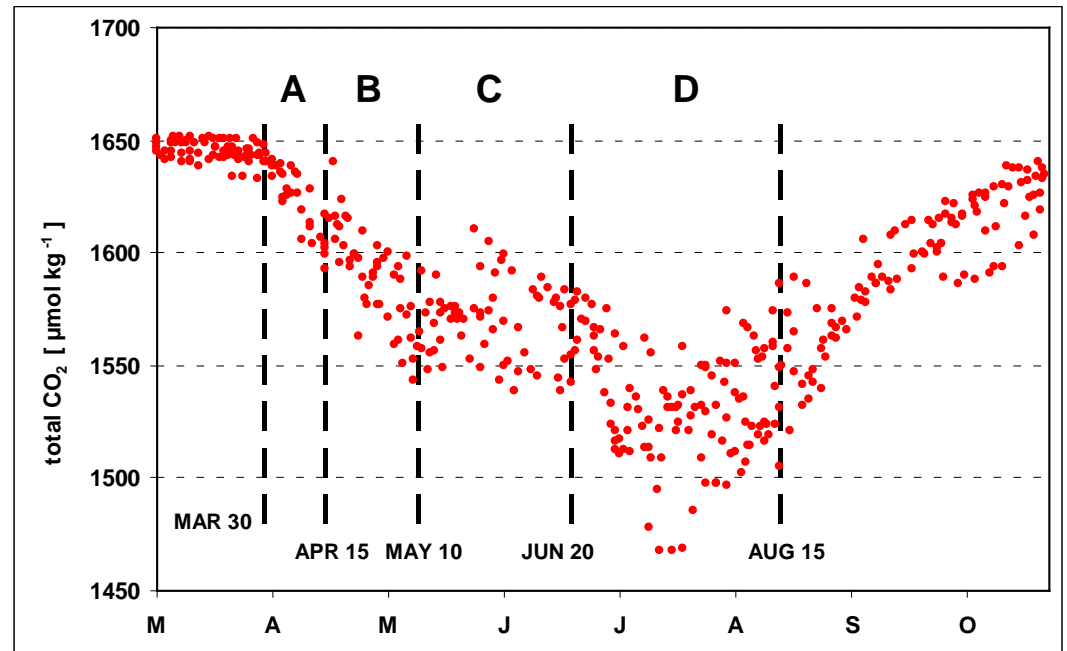
Calculated seasonality of the total CO<sub>2</sub>, definition of 4 production phases:

A: „nitrate bloom“

B: „post-nitrate bloom“

C: regenerated production;

D: mid-summer nitrogen fixation;

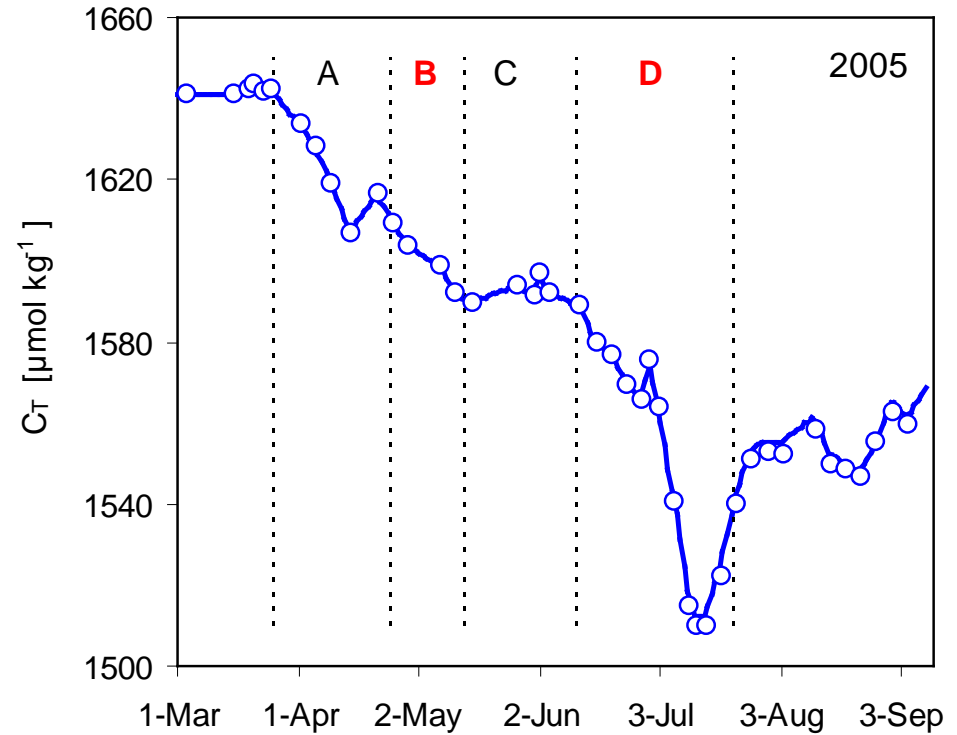


## An example: Seasonality of the total CO<sub>2</sub> in the eastern Gotland Sea in 2005

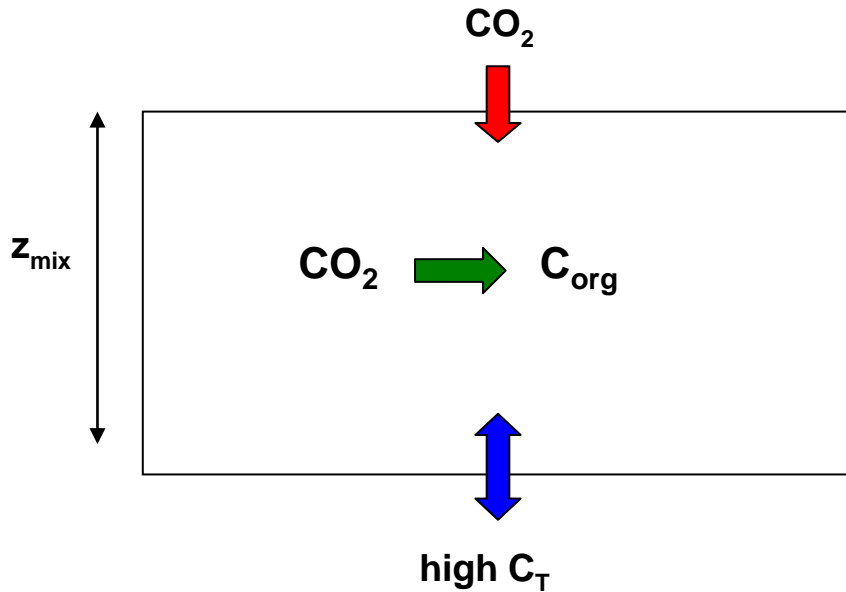
Major questions refer to:

**B – post-nitrate production:**

**D – mid-summer nitrogen fixation:**



Seasonal changes of the total CO<sub>2</sub> allow the calculation of the net community production (particulate organic carbon) by a simple mass balance:

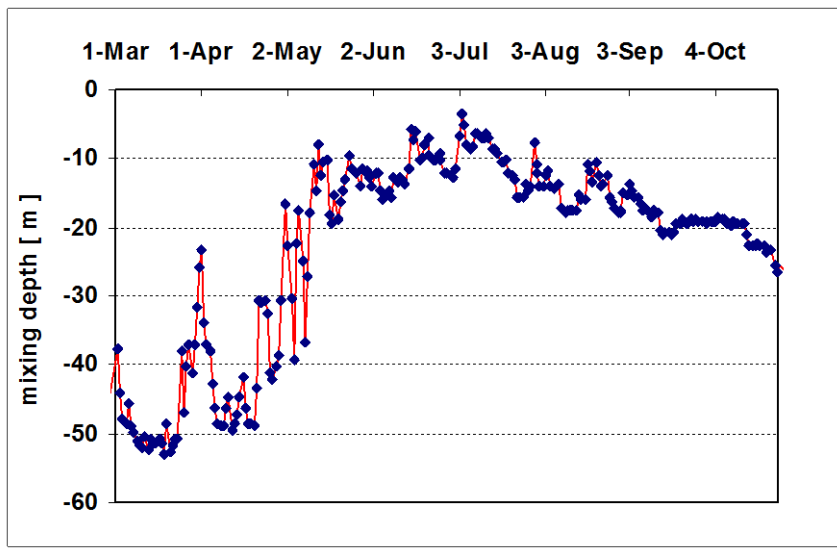


$$\Delta C_T = -\Delta C_{org} + \Delta C_{gasex} + \Delta C_{mix}$$

Taking into account 20 % DOC production, NCP (POC) is given by:

$$NCP = (-\Delta C_T + \Delta C_{gasex} + \Delta C_{mix}) \cdot 0.8$$

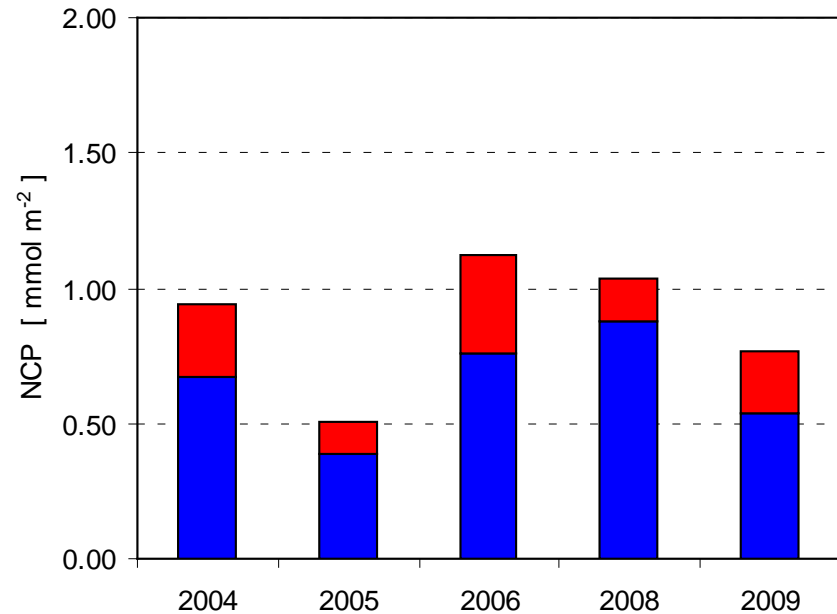
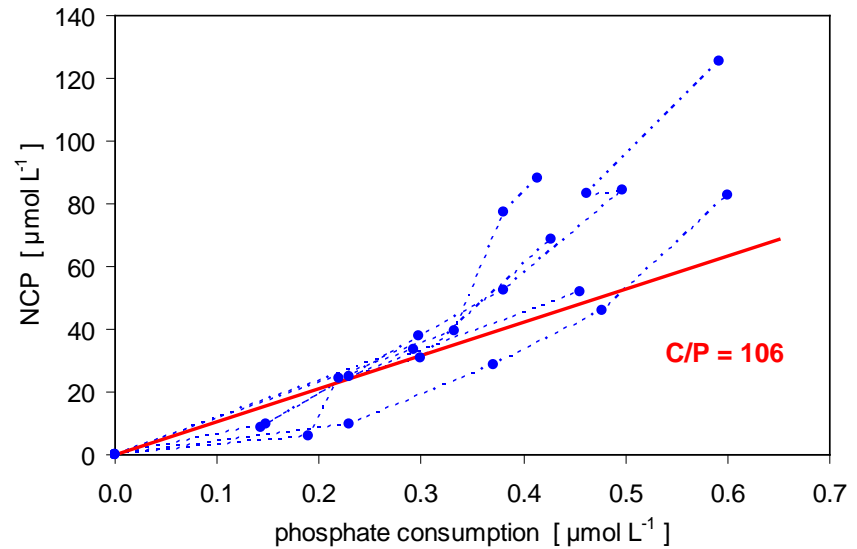
Seasonality of the modeled mixed layer depth:



## B. Post-nitrate bloom

Relationship between accumulated net community production and phosphate consumption;

Net community production [ mol-C m<sup>-2</sup> ]:  
blue - calculated from  $\Delta C_T$  only;  
red – addition from accounting for  
CO<sub>2</sub> gas exchange



Nitrogen demand [ $\text{mmol m}^{-2}$ ] in addition to atmospheric deposition and based on a C/N ratio of 9.7:

2004: 104

2005: 55

2006: 123

2008: 115

2009: 84

mean: 96  $\text{mmol m}^{-2}$

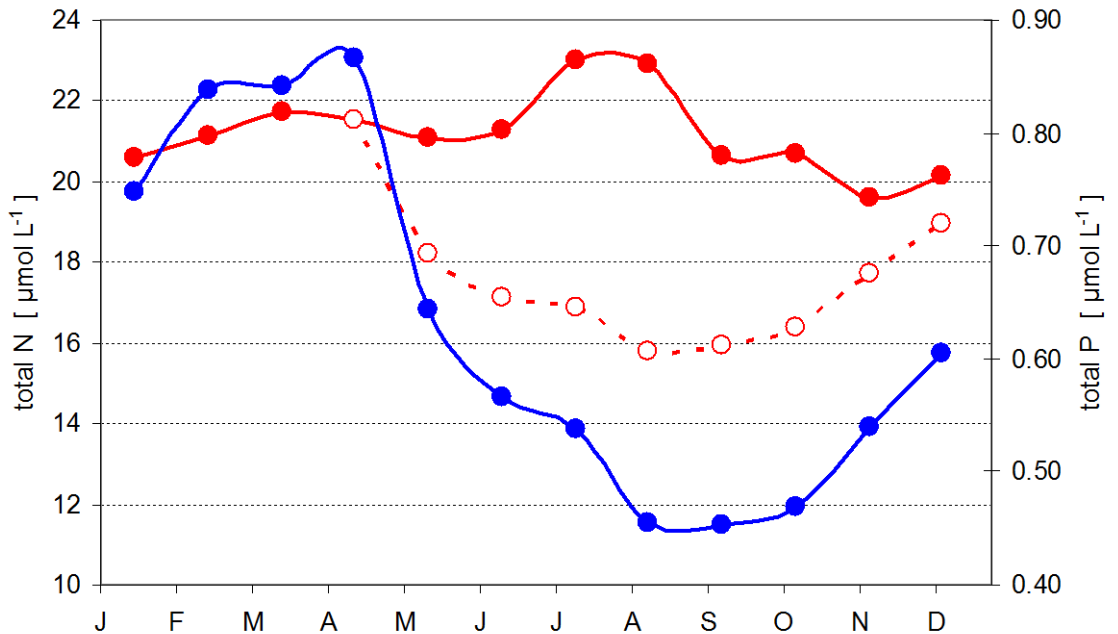
Mean total N and total P, 1994 – 2011 (SMHI Monitoring):

The dashed line gives the hypothetical total N in case that the sedimentation of P occurs together with N according to the Redfield ratio;

 | nitrogen source

Nitrogen source:

- Transfer from the particulate organic matter pool?
- Use of dissolved organic nitrogen?
- Nitrogen fixation?



## C. Mid-summer nitrogen fixation

Net community production during the mid-summer nitrogen fixation period [ mol-C m<sup>-2</sup> ]

Nitrogen fixation [mmol m<sup>-2</sup> ]:

Based on a C/N ratio of 7.5 and taking into account atmospheric deposition:

2004: 90

2005: 110

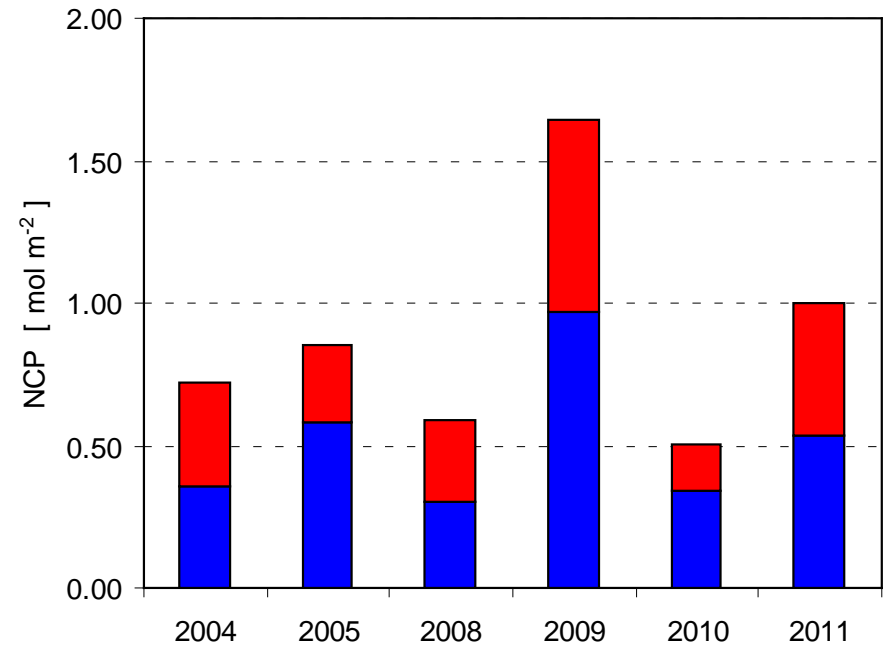
2008: 75

2009: 214

2010: 65

2011: 129

**mean: 114 mmol m<sup>-2</sup>**





**Relationship between production ( $C_T$ ) and temperature:**

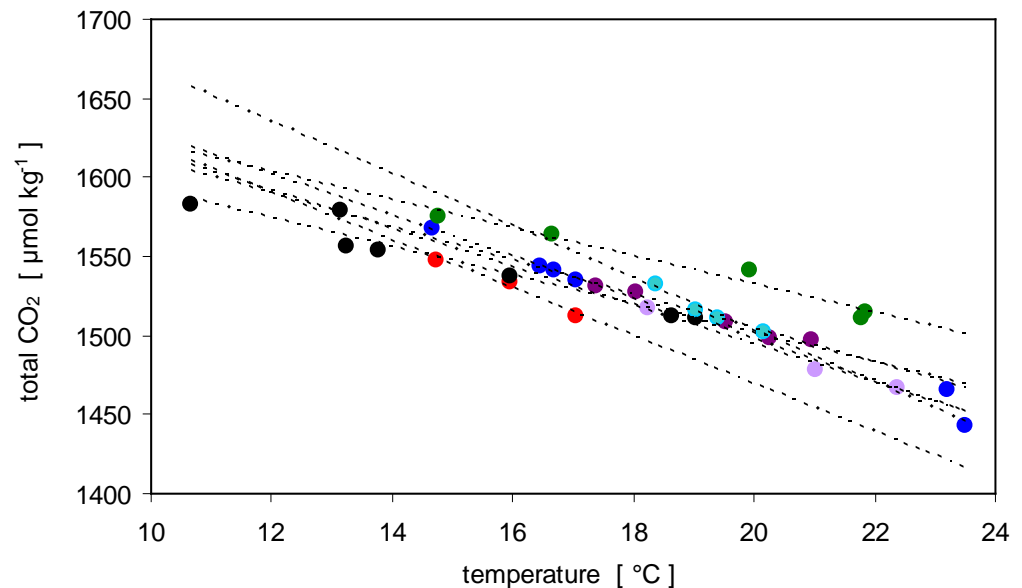
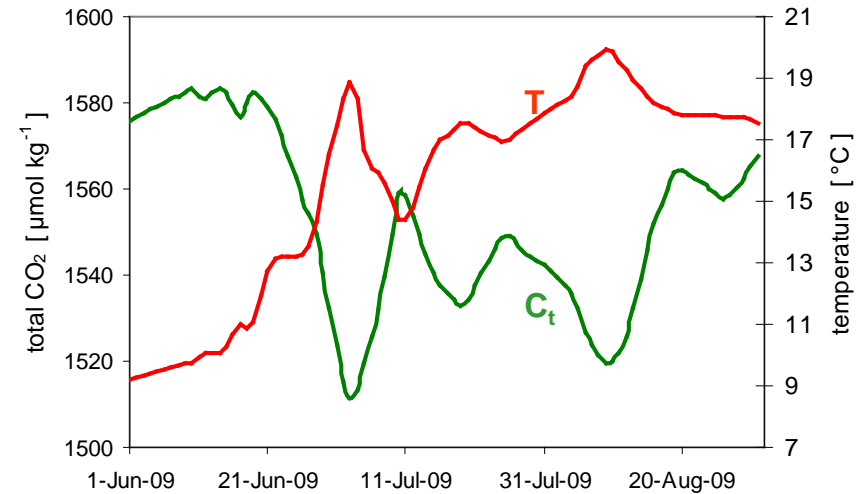
**$C_T$  decrease:**

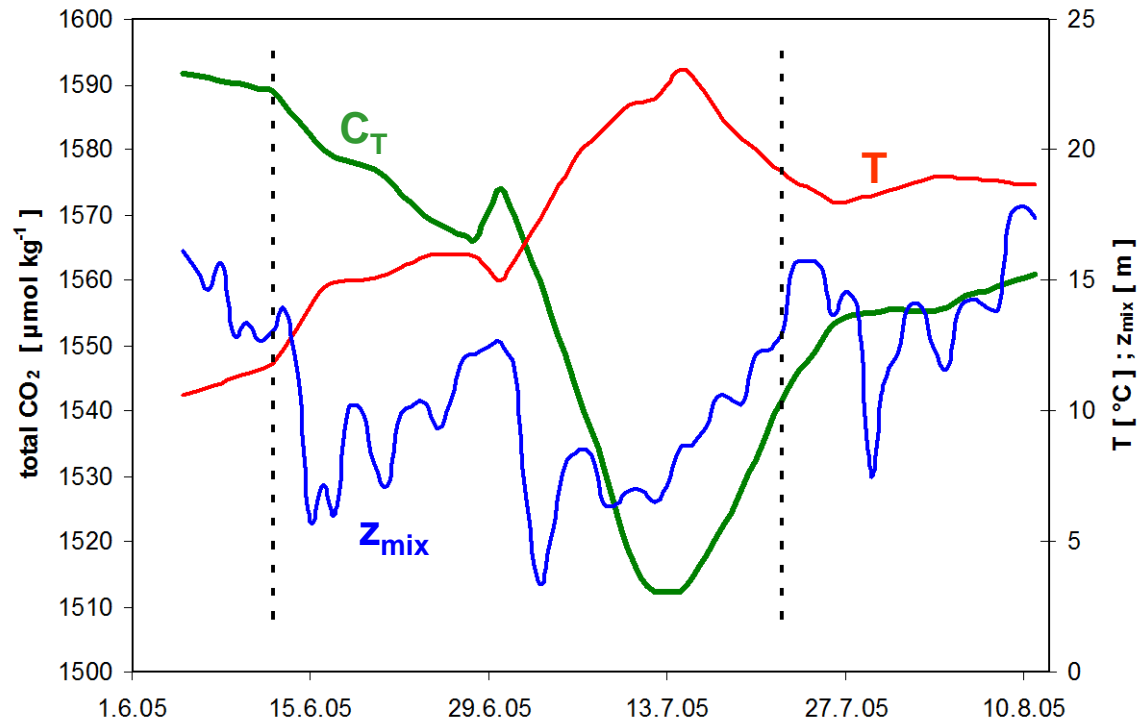
**start: 11.9 °C (June 20)**

**maximum rate: 14.3 °C (June 28)**

**stop: 18.9 °C (July 3)**

**The rate of the  $C_T$  decrease (a measure for N fixation) is linearly correlated with the rate of the temperature decrease, independent on the temperature!**





**Nitrogen fixation and related production is controlled by the mixed layer depth that determines the efficiency of the solar radiation:**

## Conclusions:

It is meaningful to sub-divide the productive period (spring – mid-summer) into four steps:

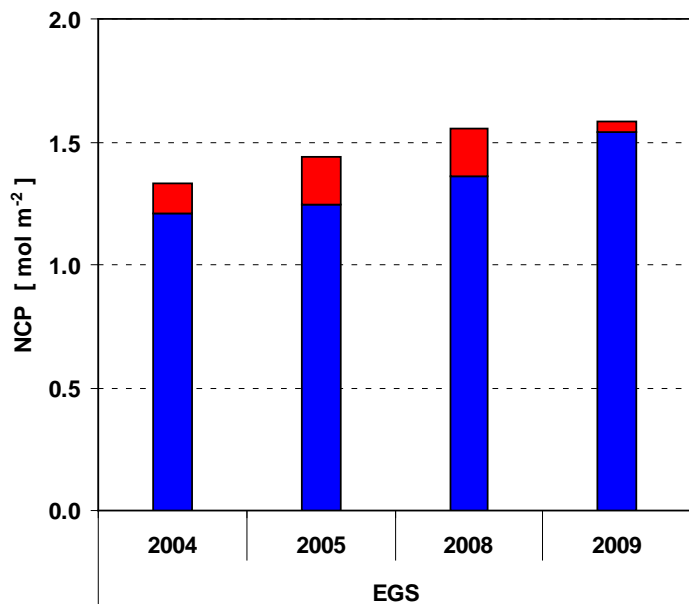
- A. Nitrate driven spring bloom (end of March to mid-April), C/N ratios slightly exceed the Redfield ratio;
- B. Post-nitrate spring bloom (mid-April to mid-May), C/P ratios slightly exceed the Redfield ratio;  
but, more important: a nitrogen source is needed, total nitrogen data indicate early („cold“) nitrogen fixation (mean for 5 years:  $94 \text{ mmol-N m}^{-2}$ );
- C. Regenerated production (mid-May – mid-June), not entirely clear whether also some net production takes place, the calculations are only based on the gas exchange term in the mass balance;
- D. Mid-summer nitrogen fixation can take place already at temperatures of  $12 - 14^\circ\text{C}$ , it is not controlled by temperature but by irradiation that is more efficient at shallow mixing depths; the mean ( 6 years) nitrogen fixation amounted to  $114 \text{ mmol-N m}^{-2}$ ;

# Calculation of the net community production taking into account CO<sub>2</sub> gas exchange and 20% DOC production:

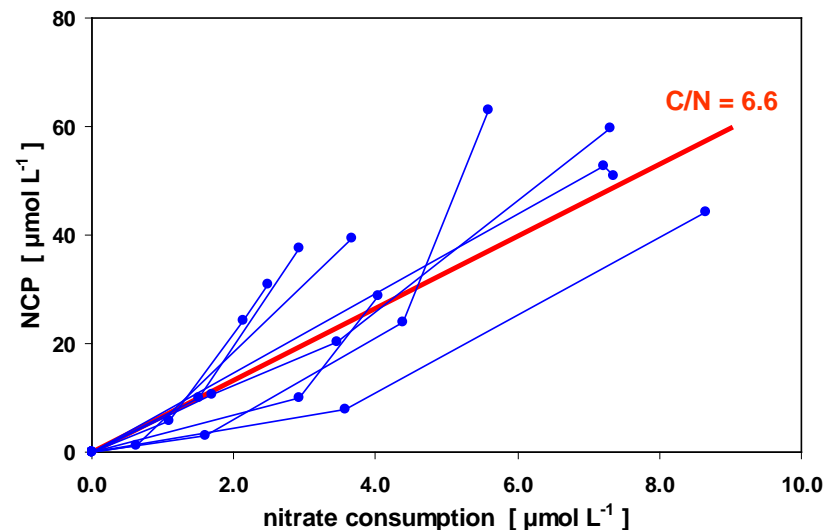
## A. Nitrate bloom

$$NCP = -(\Delta C_T - \Delta C_T^{gasex}) \cdot 0.8$$

blue bars      red bars



net community production [mol m<sup>-2</sup>]



Accumulated net community production vs. silicate consumption:

