Third International Symposium
Effects of Climate Change on the World's Oceans
Santos, Brazil 23-27.March 2015

How does horizontal mixing affect the primary production on the Faroe Shelf?

By: Sólvá Káradóttir Eliasen

Co-workers:

Karin Margretha Húsgarð Larsen

Bogi Hansen

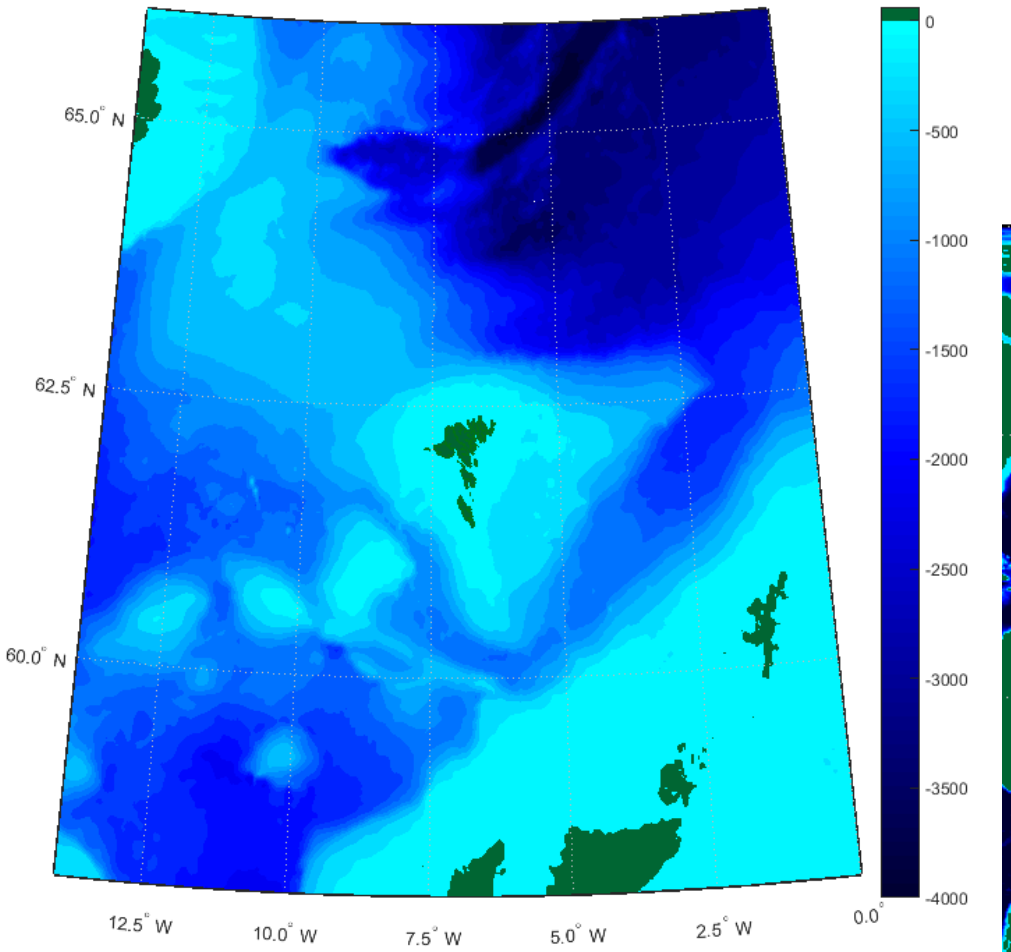
Hjálmar Hátún

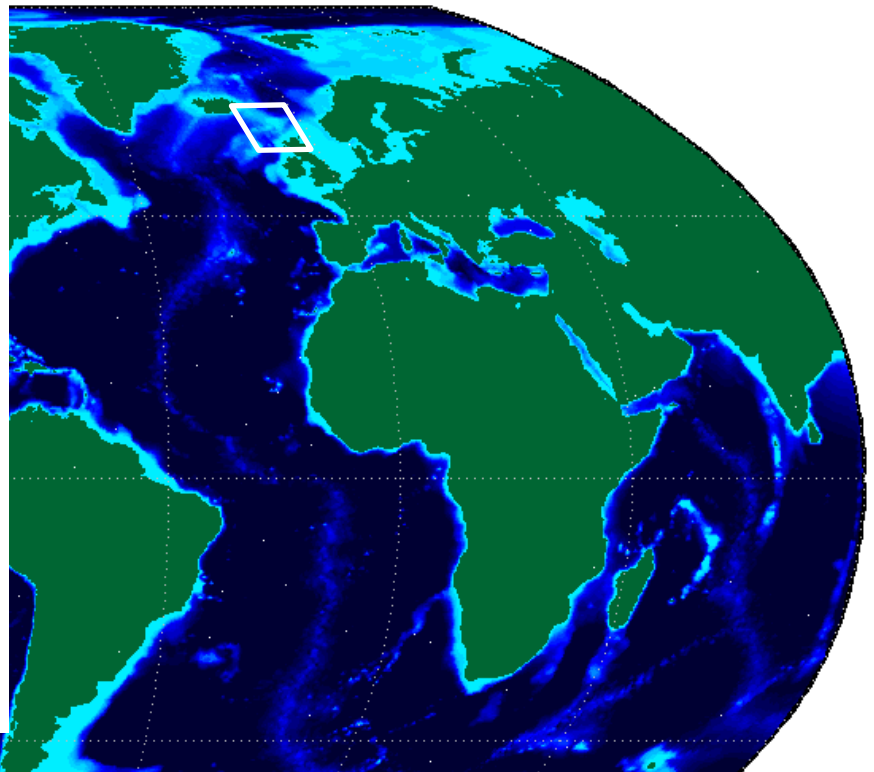
HAVSTOVAN
FAROE MARINE RESEARCH INSTITUTE

Where are we?

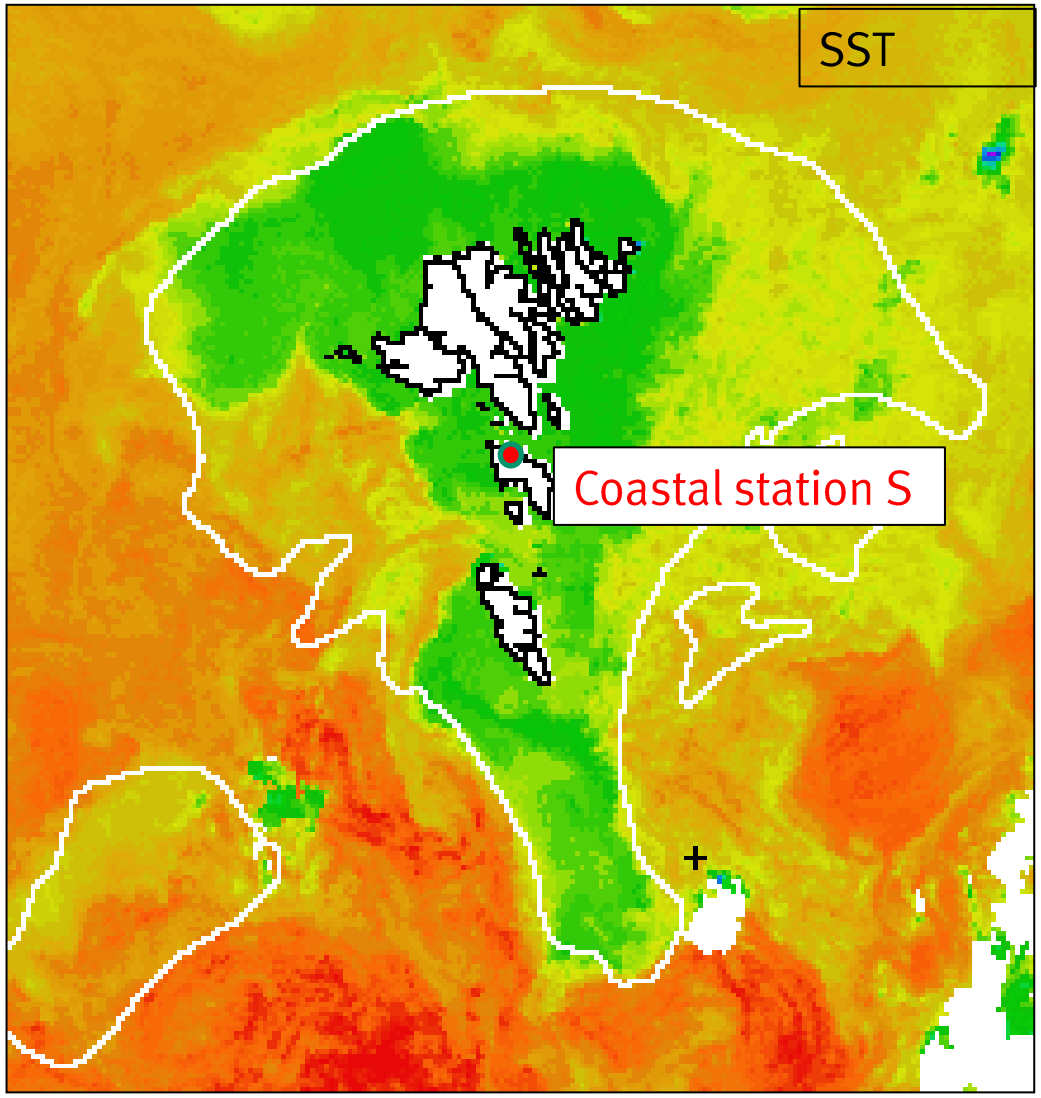
… Here!

- Small archipelago
- Shallow shelf
- Surrounded by deeper oceanic water

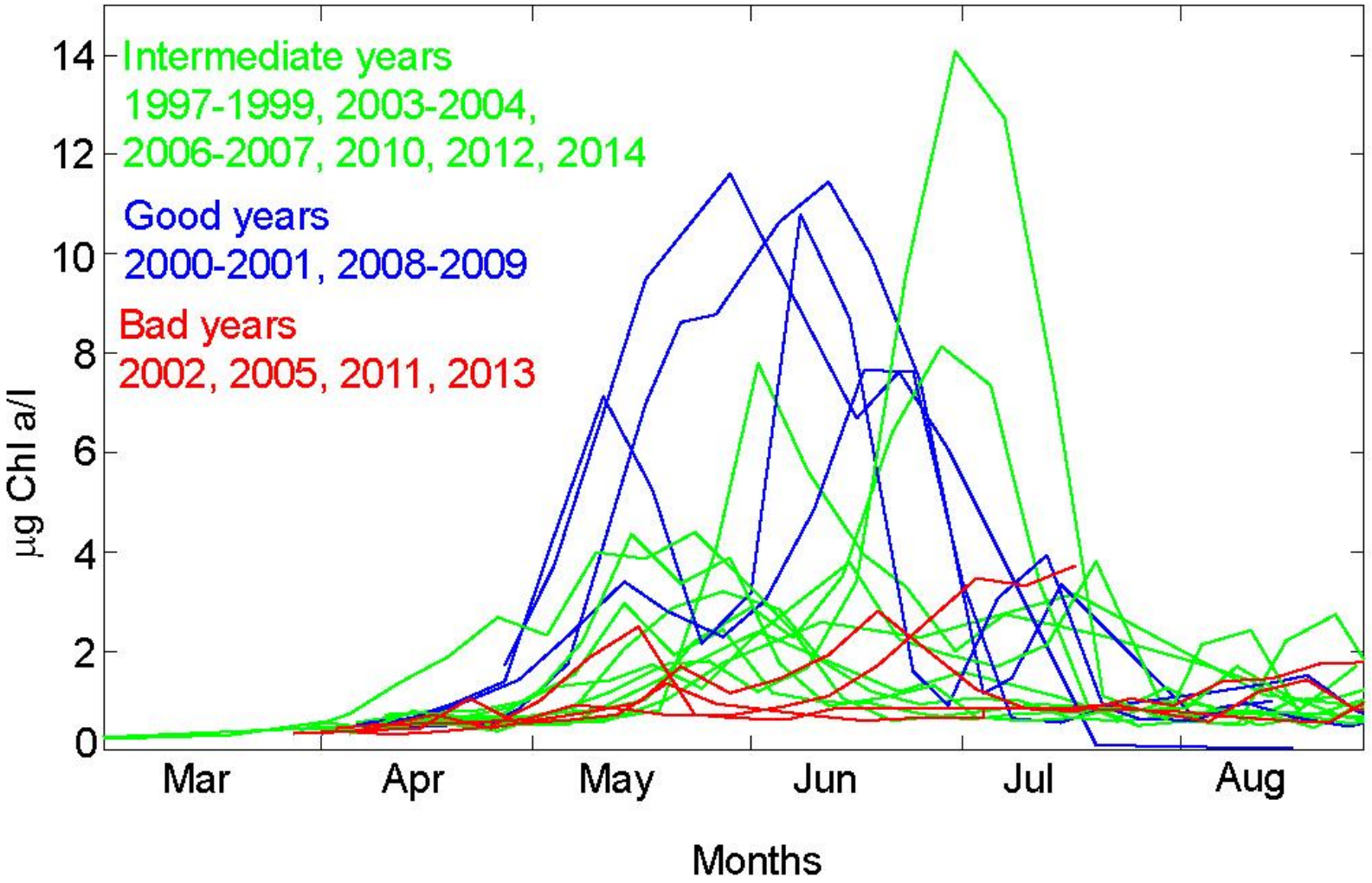




Faroe Shelf

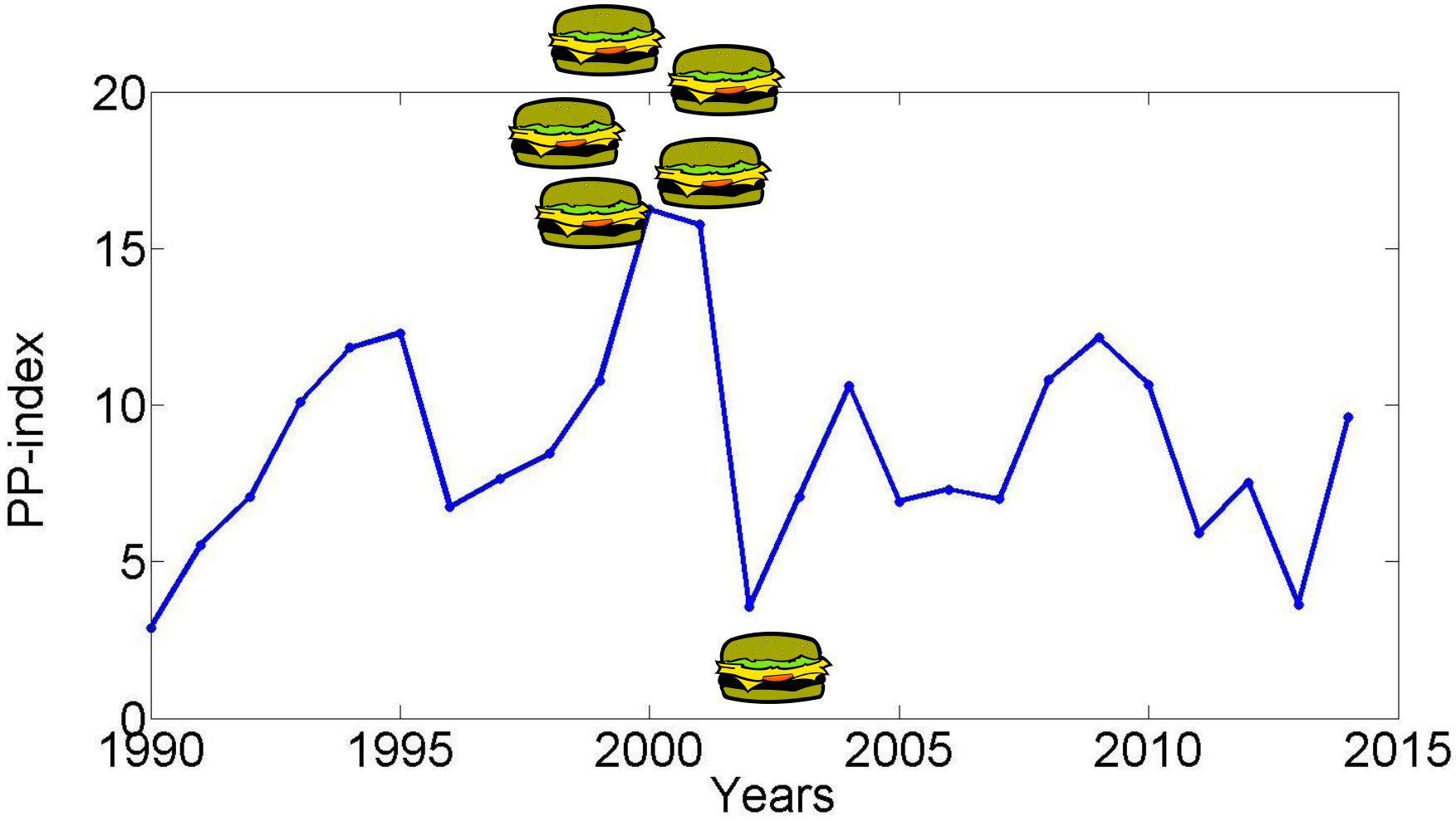


Chlorophyll *a* at coastal station S

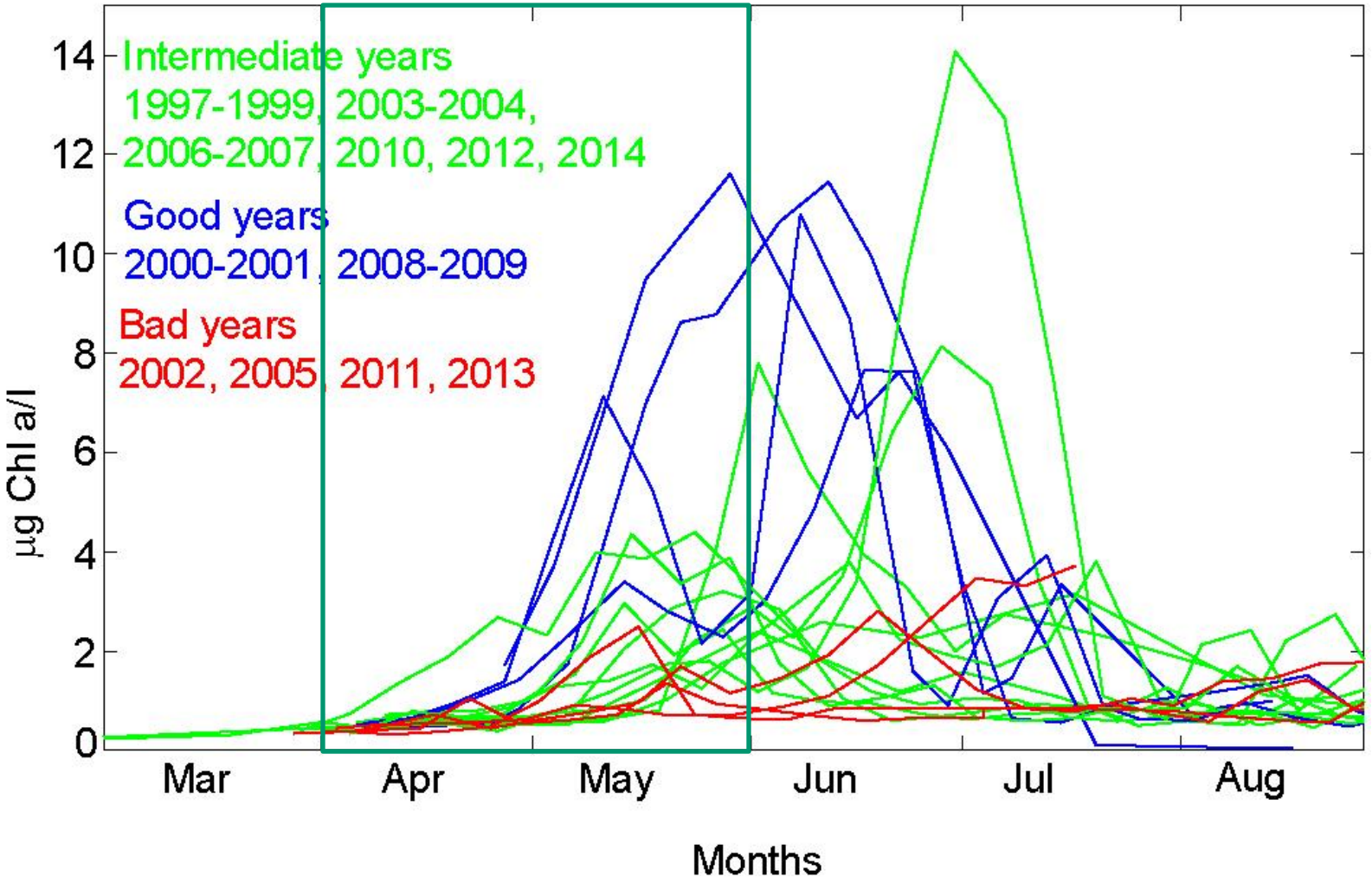


Primary Production Index

The total production is estimated every year by the nitrate draw-down on the shelf



Chlorophyll *a* at coastal station S

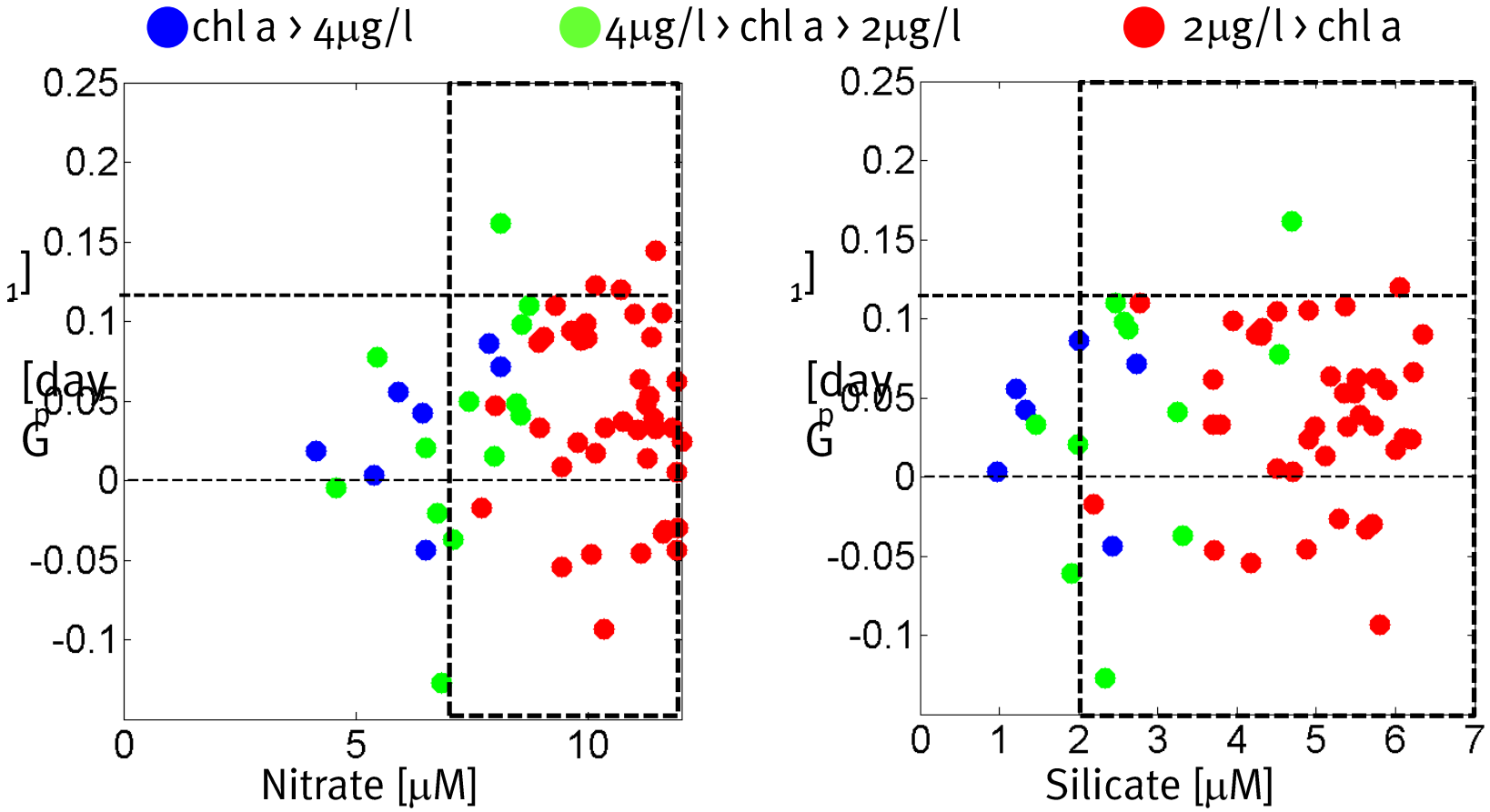


Net observed chl *a* increase in April and May (net growth, G_p)

- Light is not limiting
- Nutrients are not limiting

$$G_p = \frac{1}{P}\frac{dP}{dt}$$

➢ Why isn't the growth rate always 0.1 day^{-1}?



What affects the growth rate?

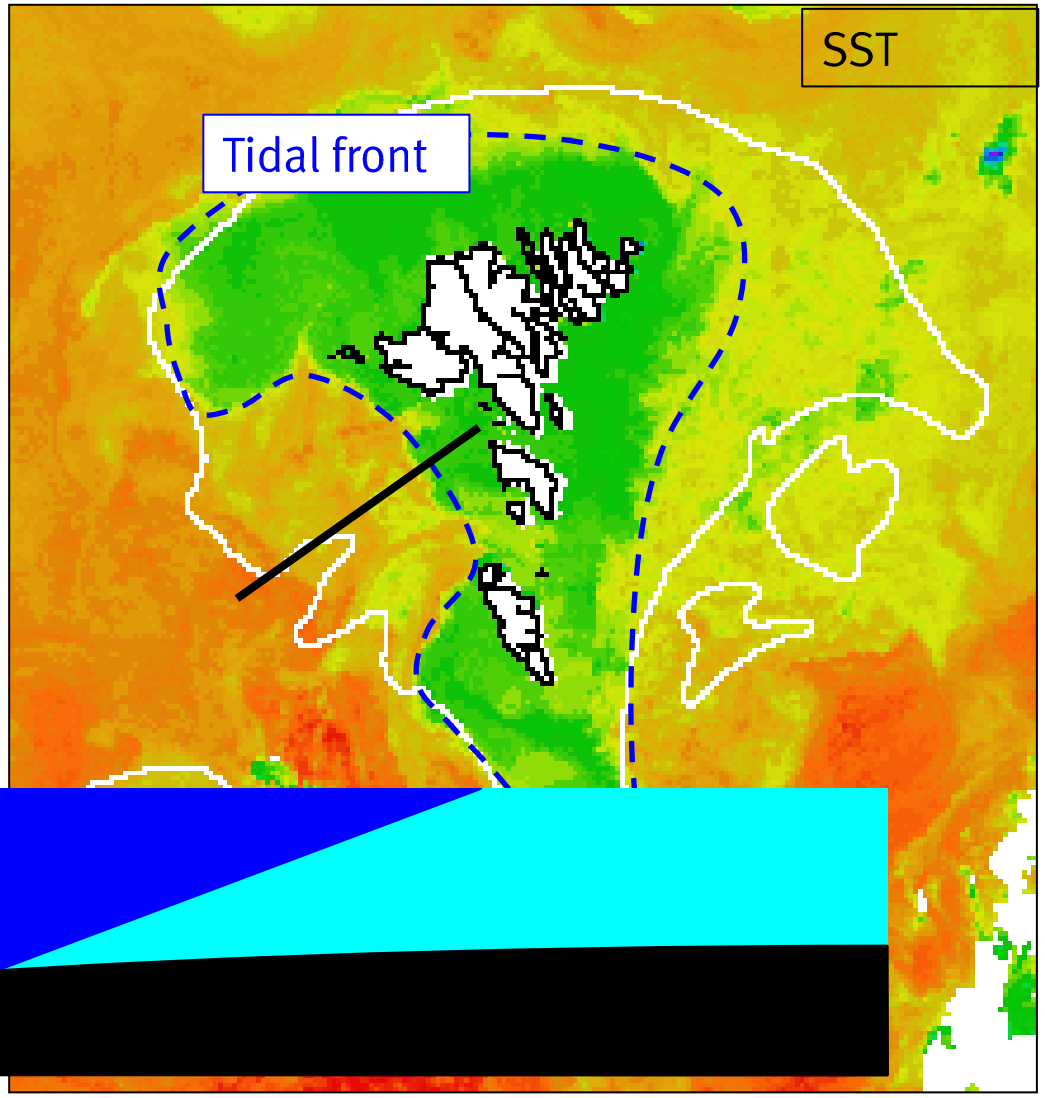
- Growth (g_p)
- Losses
  - Respiration (r_p)
  - Mortality (sinking & grazing) (m_p)
  - Horizontal transport/exchange (L)

$$\underbrace{\frac{dP}{dt}}_{\leq 0.11\ \text{day}^{-1}} = \underbrace{\left(g_p - r_p\right)}_{0.23\ \text{day}^{-1}} \underbrace{- m_p}_{\geq 0.12\ \text{day}^{-1}} \cdot P - L$$

- Debes et al, 2008: g_p-r_p= 0.23 day^{-1}
- If $G_P = \frac{1}{P}\frac{dP}{dt} \leq 0.11\ day^{-1}$ then $m_P - \frac{L}{P} \geq 0.12\ day^{-1}$

Faroe Shelf

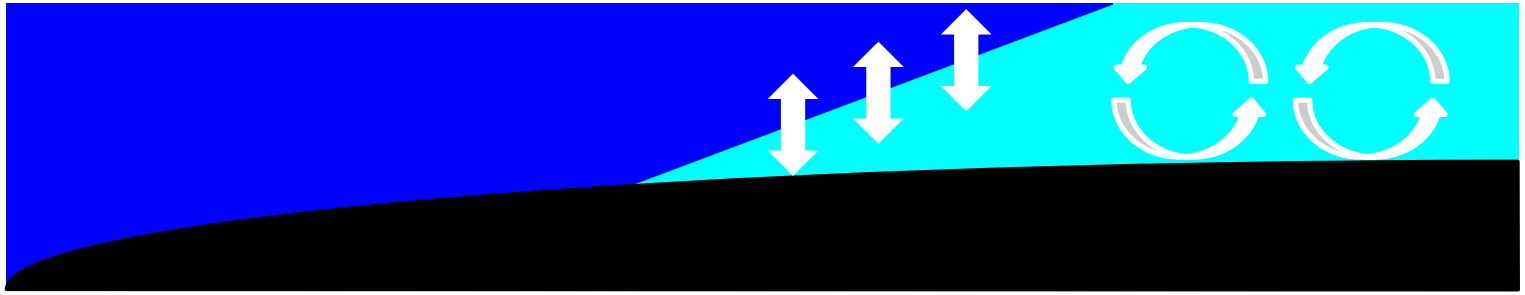
- Well mixed homogeneous water mass
- Transect



Winter/spring

Hypothesis

- Varying horizontal exchange causes variation in early spring bloom
- Vertical turbulent diffusion through the front limits the horizontal exchange



Simple theoretical model

- *Osborne relation* + *law of the wall* have been used to derive volume flux through the Faroe Shelf front

- Flux $$q \approx \frac{62 \cdot U^3}{(T_o - T_i) - 0.3}$$

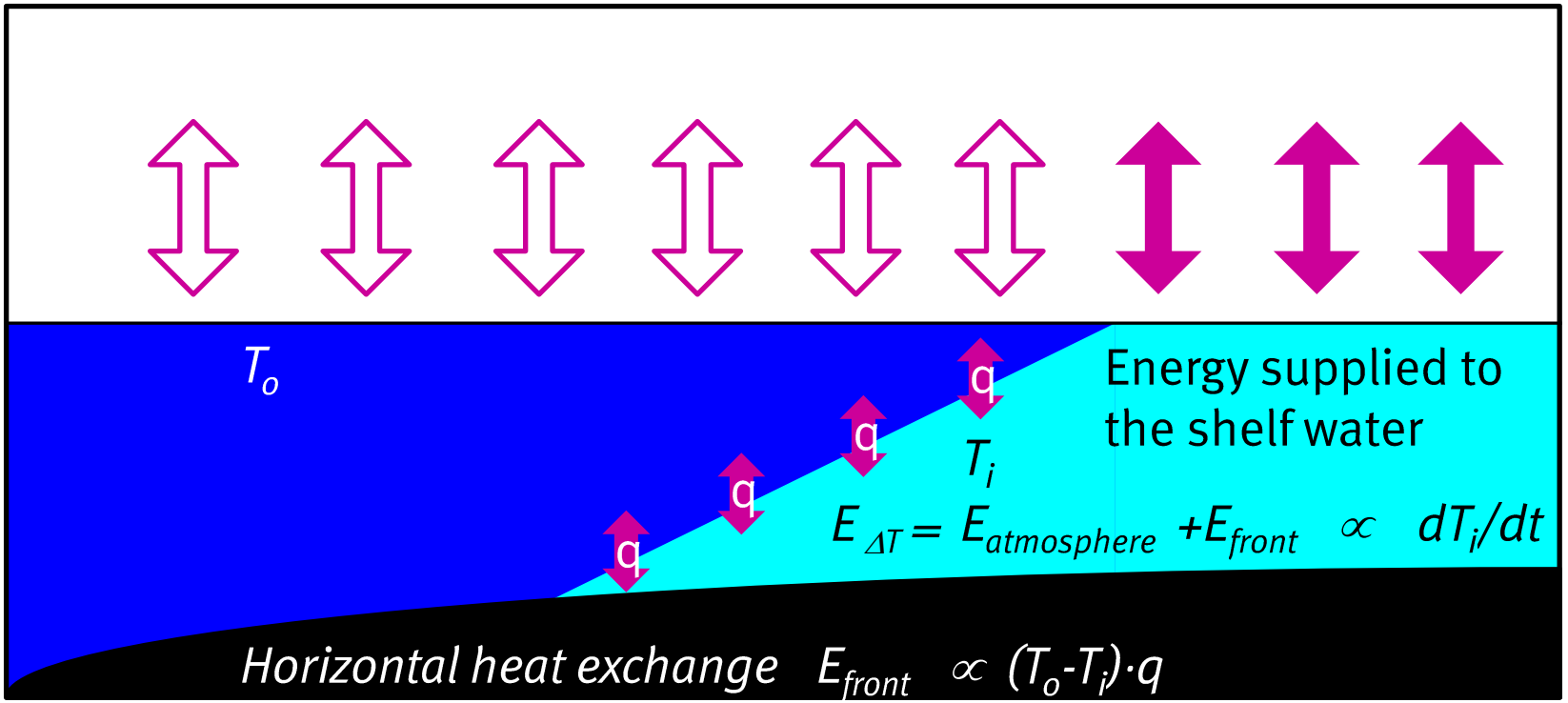
  – Proportional to current speed cubed

  – Inversely proportional to density difference

Horizontal transport/exchange

- Can be derived from energy

➢The flux (q) is what we search for!



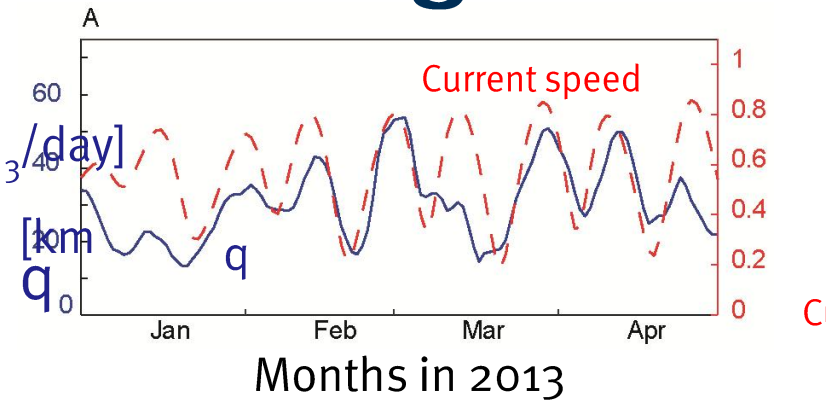
During the winter (January-April) the front is strong and $T_o - T_i \geq 0.4$ °C

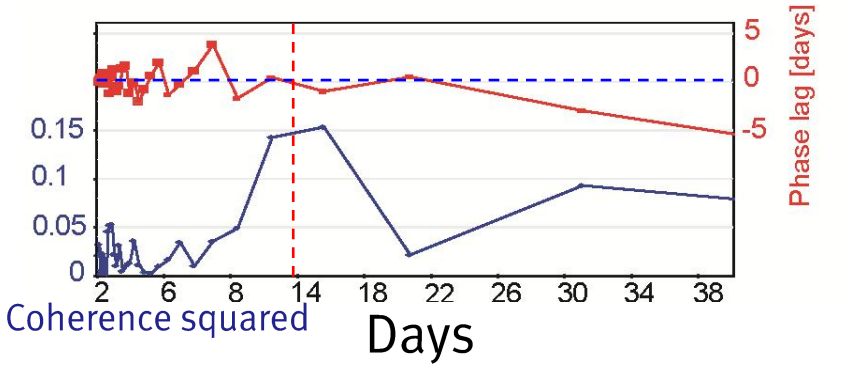
Horizontal flux/exchange

- q is found to depend on tidal current speed
- q depends on the temperature gradient across the front
- Regression analysis

$$q \approx 68 \cdot \frac{U^3}{(T_o - T_i) - 0.1}$$

- Close to theory: $q \approx 62 \cdot \frac{U^3}{(T_o - T_i) - 0.3}$



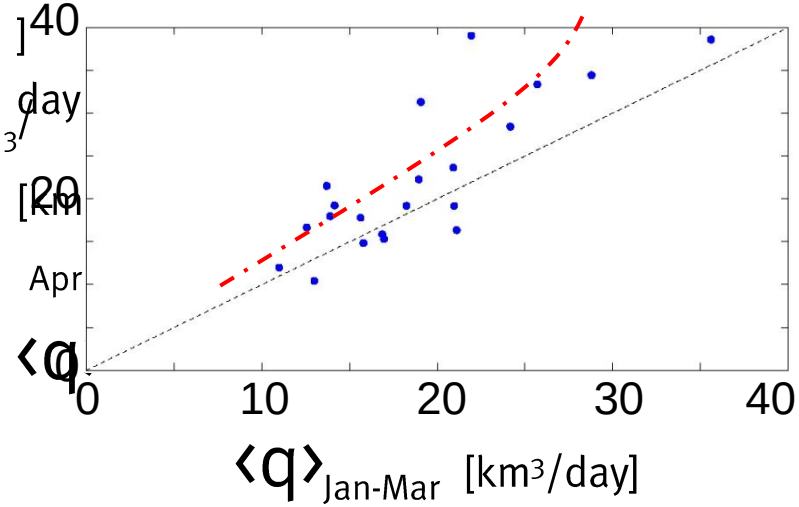


Horizontal flux/exchange

- q is found to depend on tidal current speed
- q depends on the temperature gradient across the front
- Regression analysis

$$q \approx 68 \cdot \frac{U^3}{(T_o - T_i) - 0.1}$$

- Close to theory: $q \approx 62 \cdot \frac{U^3}{(T_o - T_i) - 0.3}$

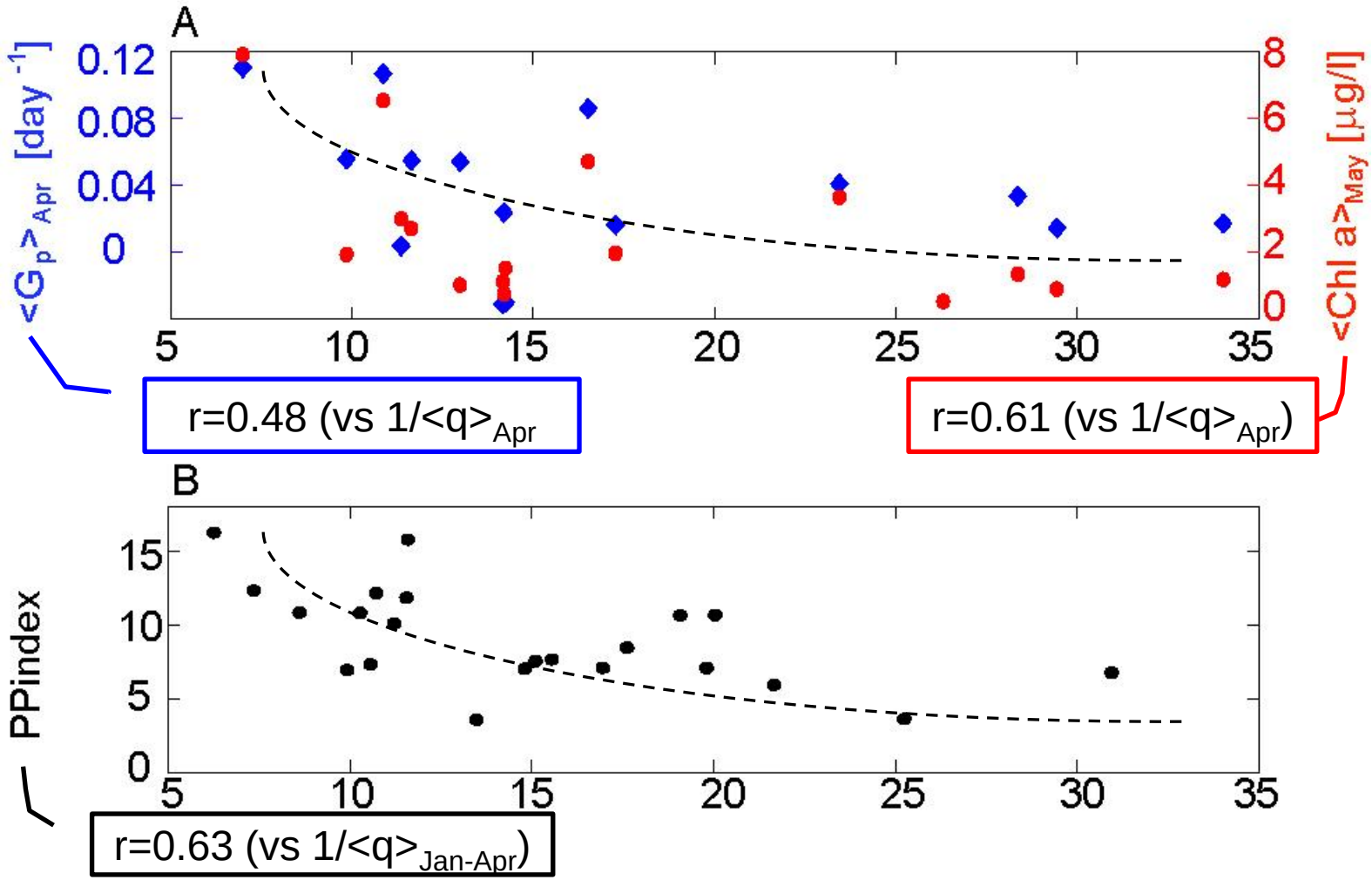


- An initially low flux will tend to stay low and vice versa – 'Memory'

Horizontal flux/exchange

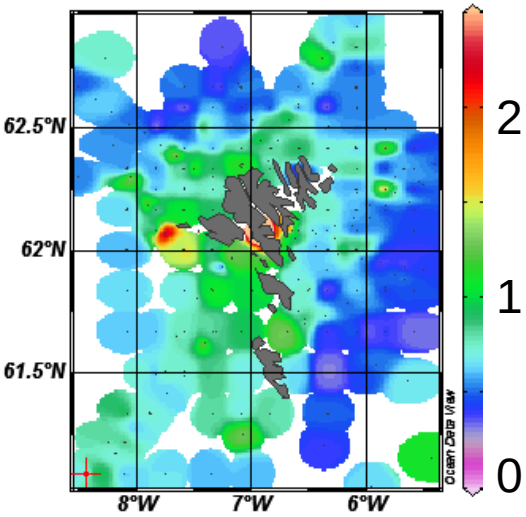
- Annual average winter (Jan-Apr) values vary corresponding to a shelf water exchange time in the range 21-66 days

How does exchange affect the primary production?



How does exchange affect the primary production?

Chl *a* in uppermost 40 m 15/4–10/5, 1994, 1996-2001, 2003-2009



$$\frac{dP}{dt} = \left(g_p - r_p - m_p\right) \cdot P - L$$

$$L = \frac{q}{V_{shelf\ water}} \Delta P$$

q	Volume flux
$V_{shelf\text{-}water}$	Shelf water volume
ΔP	$P_{on\text{-}shelf} - P_{off\text{-}shelf}$

- Assume $P_{off\text{-}shelf} = 0$

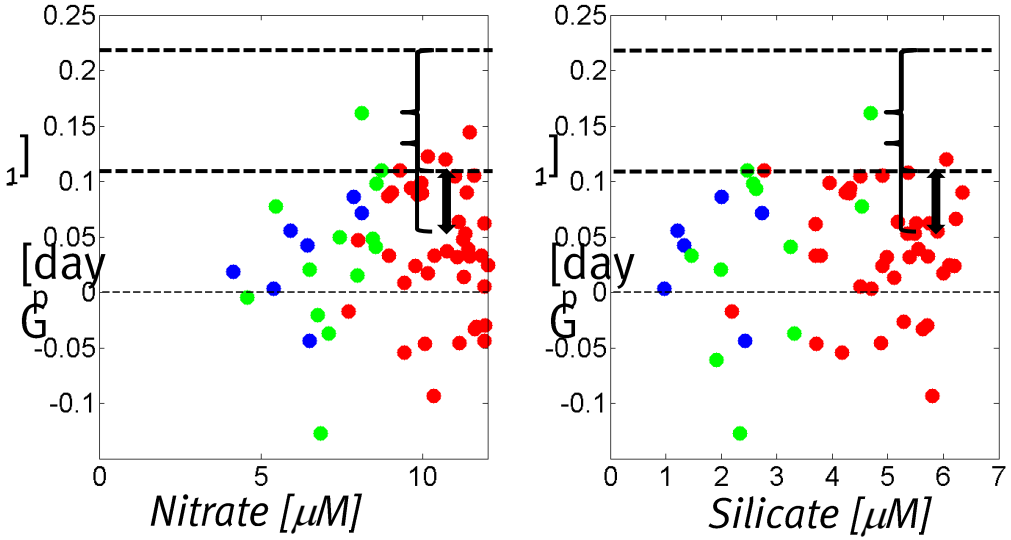
$$\frac{L}{P_{on-shelf}} \approx \frac{q}{V_{shelf\ water}}$$

- With $P_{off\text{-}shelf} = 0$ and the exchange time varying 21-66 days, L/P is in the range $0.02 - 0.05\ day^{-1}$

Loss of phytoplankton

- A variable volume flux can account for a variation of at least 0.05 day^{-1} in the first phases of the spring bloom

$$\frac{dP}{dt} = \underbrace{\left(g_p - r_p\right)}_{0.23\ \text{day}^{-1}} - \underbrace{m_p}_{\geq 0.12\ \text{day}^{-1}} \cdot P - L$$



- NB: These considerations are only valid in early spring when the shelf water is well mixed and when nutrients are abundant

Main Message

Shelf-ocean exchange can impede the early spring bloom

Thank you