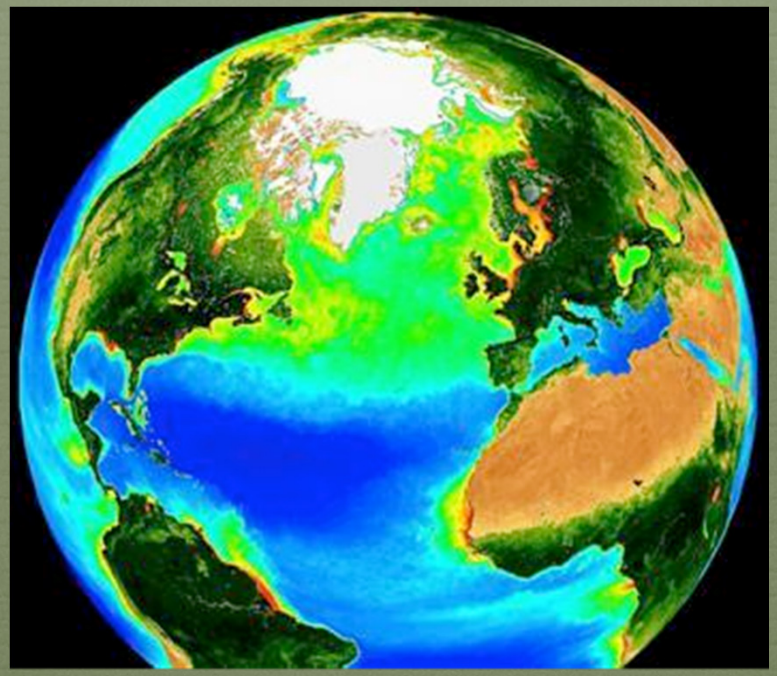
Phytoplankton blooms in the Nordic Seas

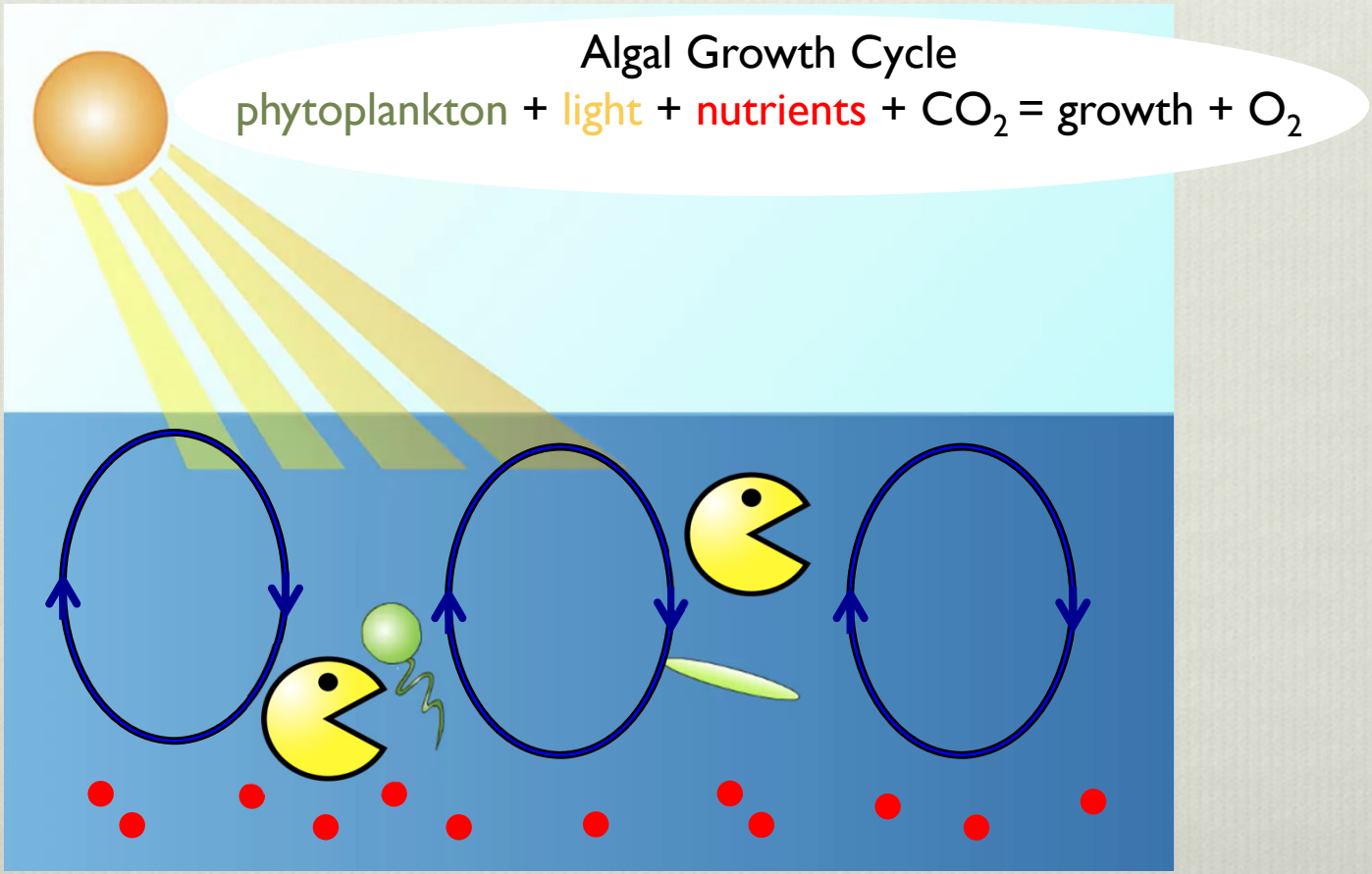


Raffaele Ferrari
Alex Mignot, Glenn Flierl, Stephanie Dutkiewicz
Massachusetts Institute of Technology

Introduction

Phytoplankton blooms

- Controls on division rates: light, nutrients, turbulence
- Controls on losses: grazing and viral lysis



NPZ model of blooms

$$\frac{dP}{dt} = \mu(t)NP - m_P P - gPZ$$

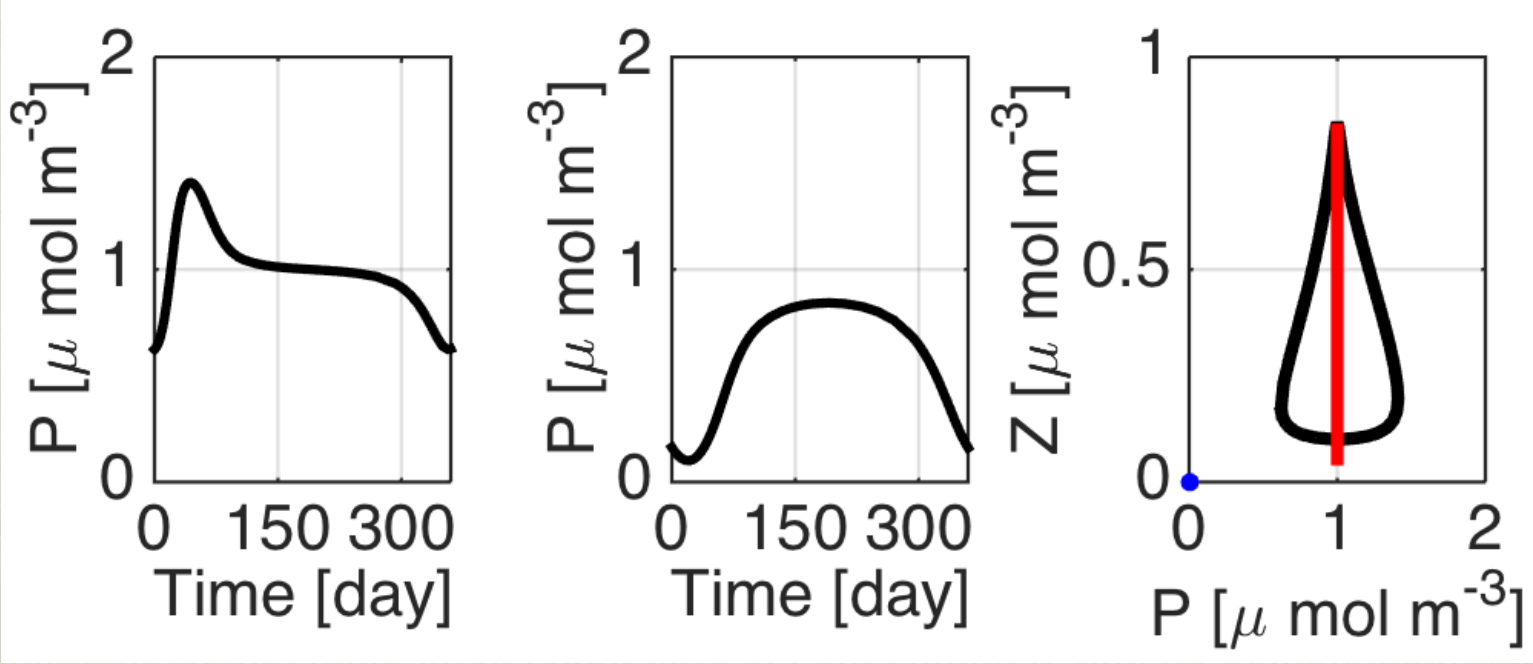
P is phytoplankton

$$\frac{dZ}{dt} = agPZ - m_Z Z$$

Z is zooplankton

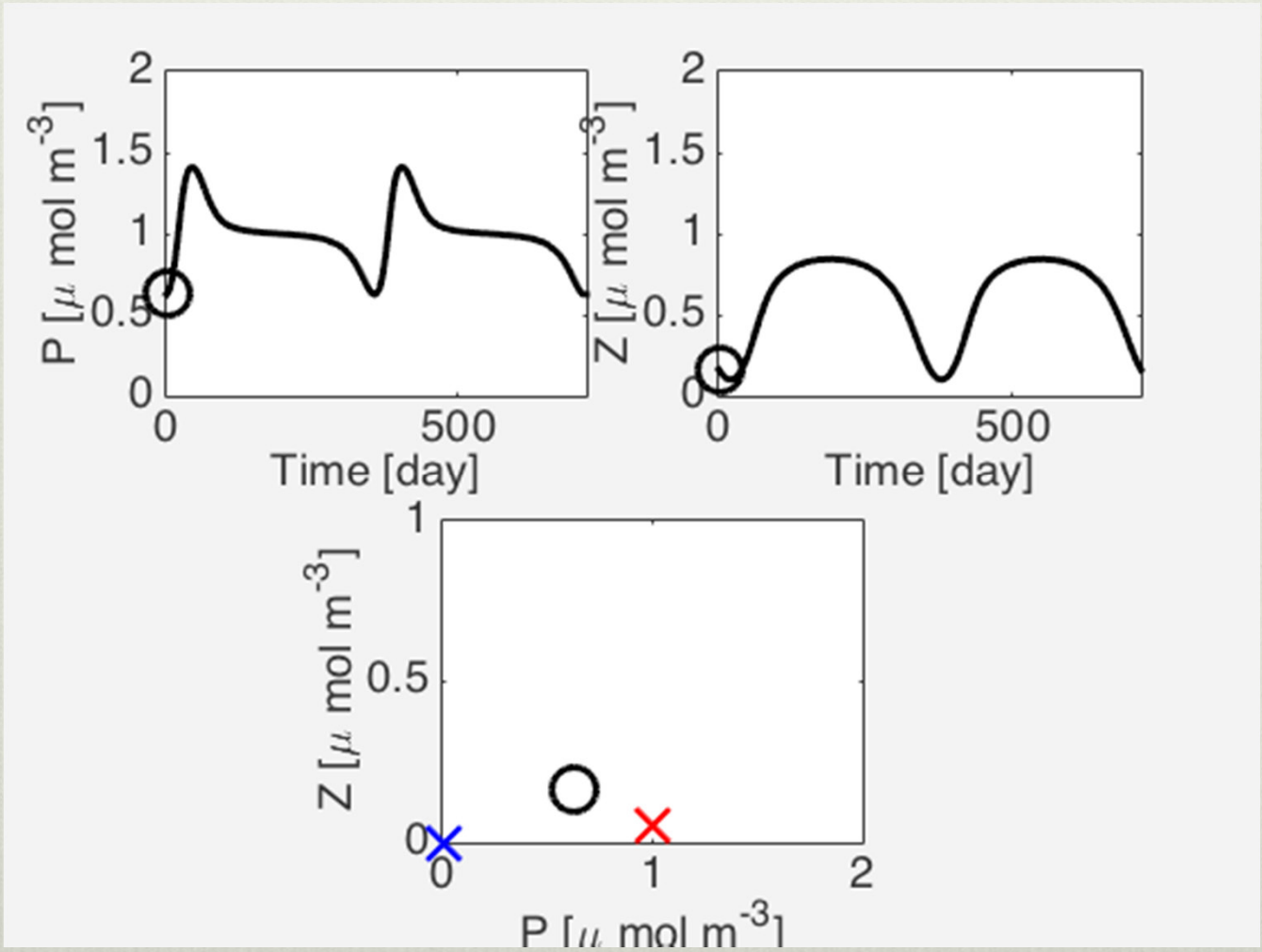
$$N + P + Z = N_T$$

N is nutrient



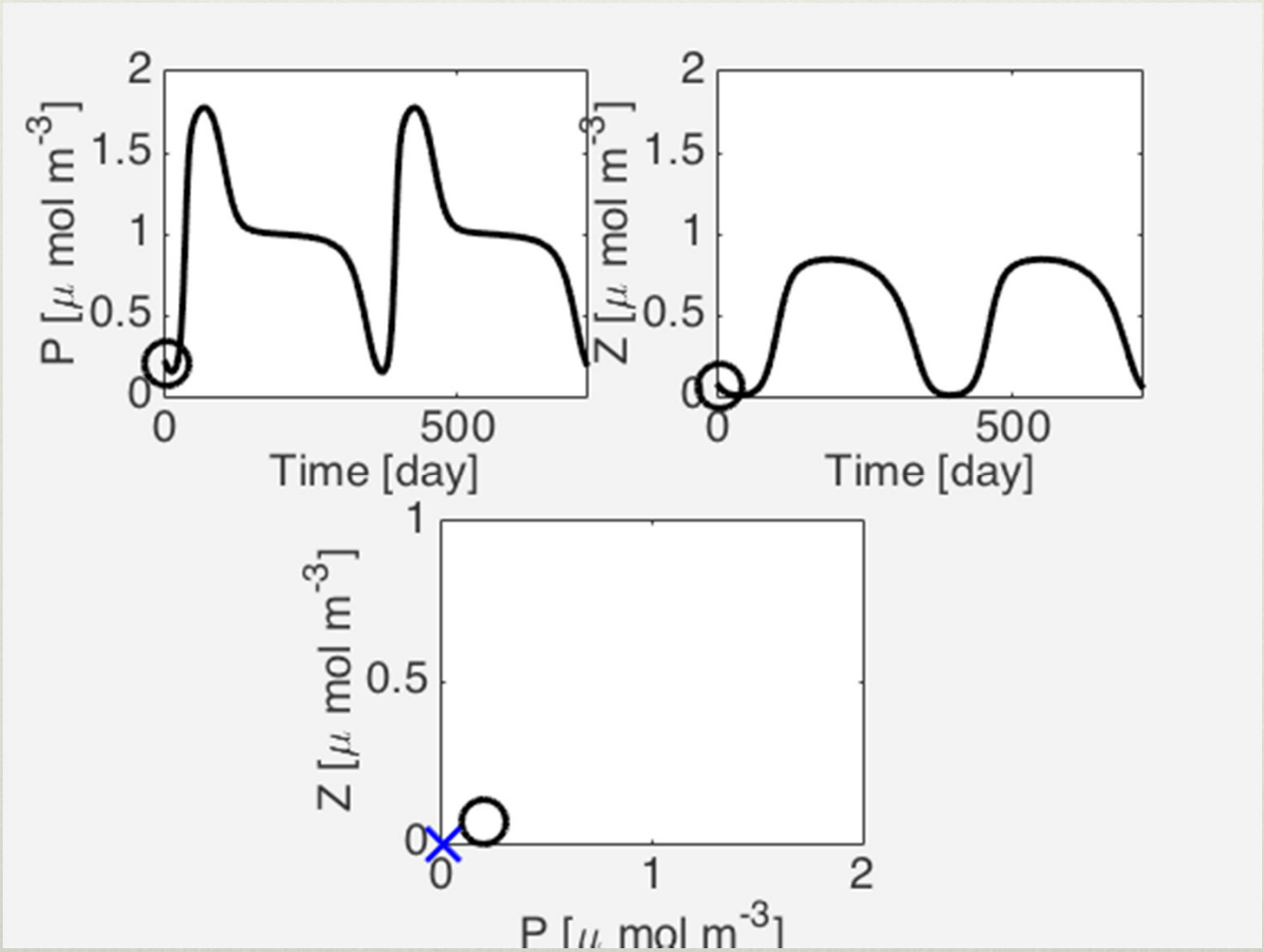
NPZ model of blooms

Small environmental perturbations ➔ strong PZ coupling



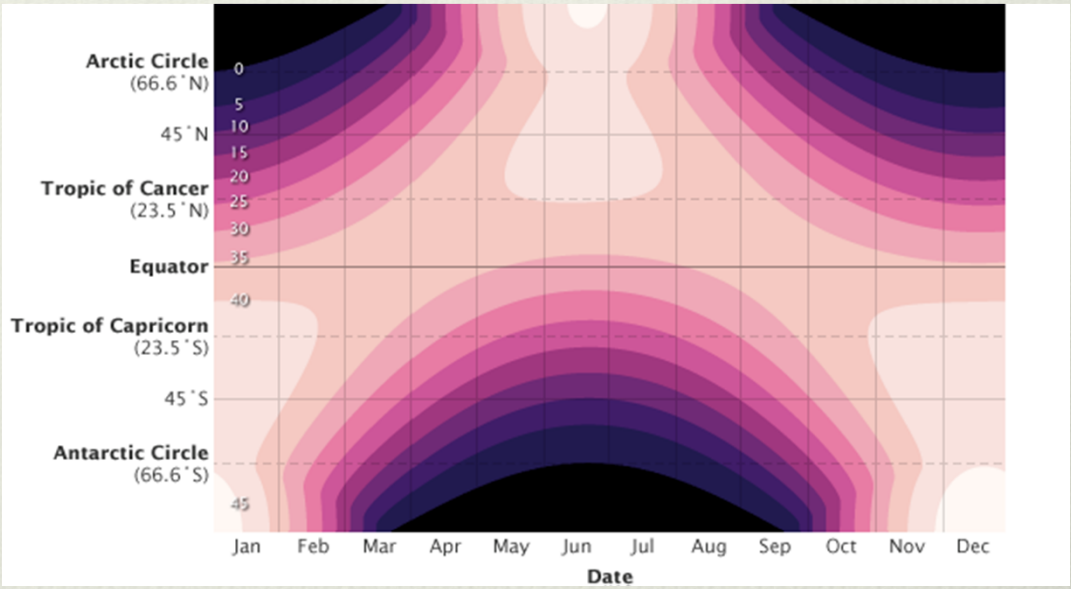
NPZ model of blooms

Large environmental perturbations ➔ weaker PZ coupling



Environmental perturbations

Surface insulation



Vertical mixing

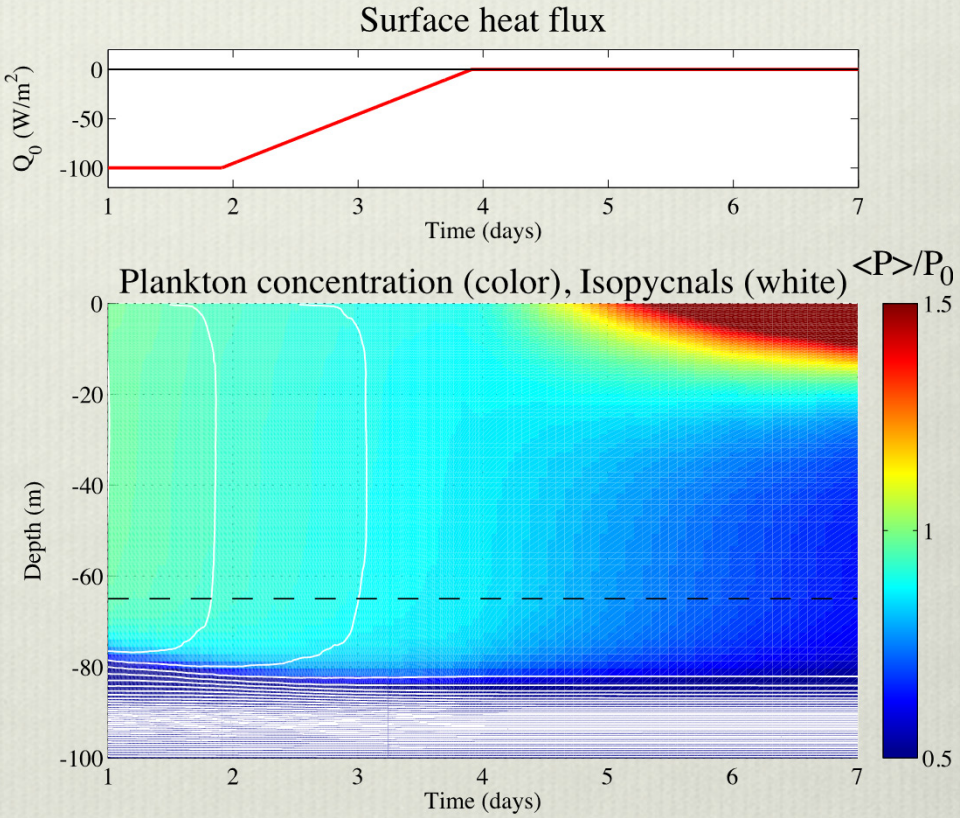
Lateral density fronts

Environmental perturbations

Surface insulation

Vertical mixing

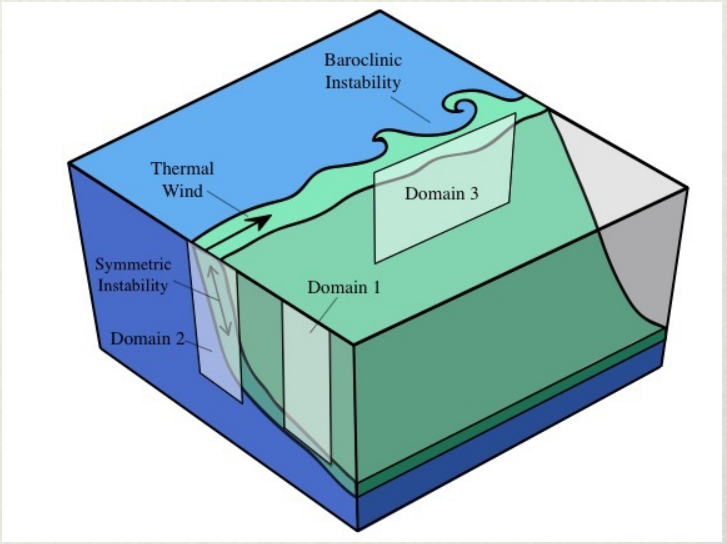
Lateral density fronts



Taylor and Ferrari (L&O, 2010)

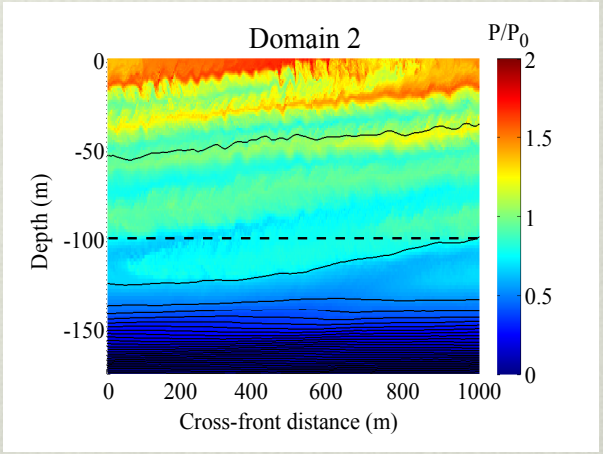
Environmental perturbations

Surface insulation



Vertical mixing

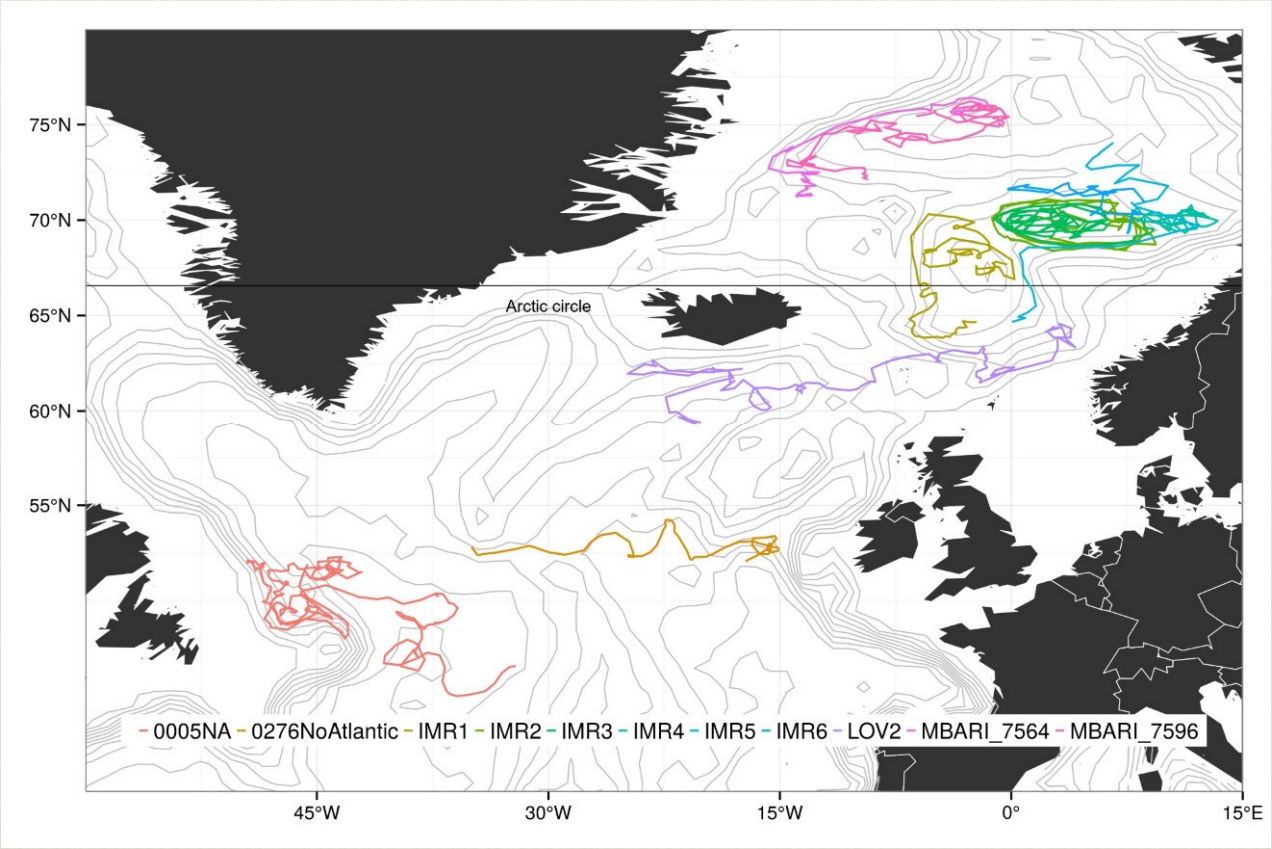
Lateral density fronts



Taylor and Ferrari (L&O, 2011)

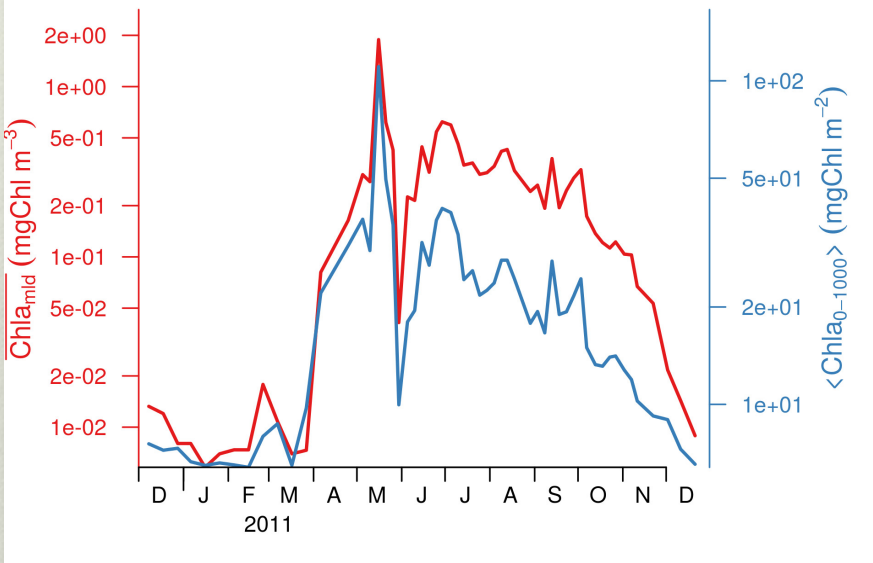
Real blooms

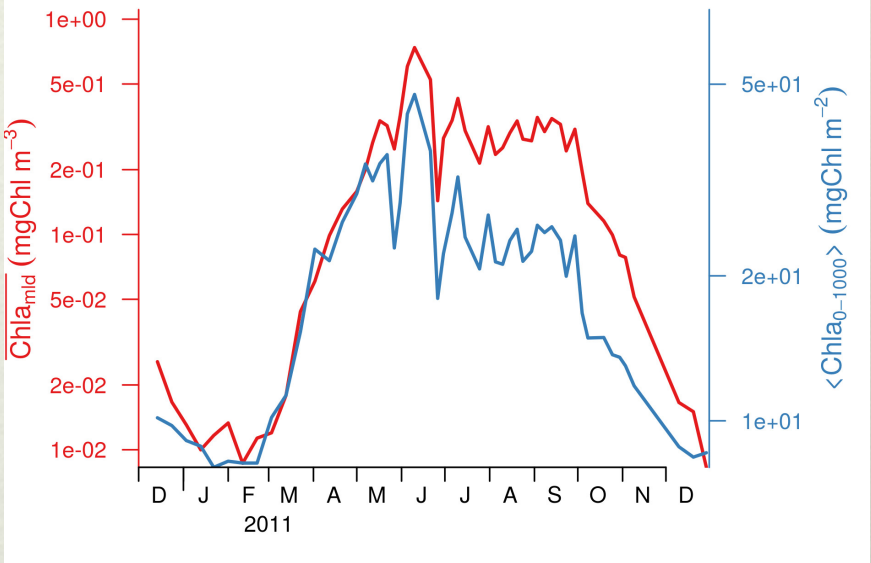
Nordic Seas Bio-Argo floats



Bio-Argo floats with optical sensors: chlorophyll-a fluorescence, CDOM fluorescence, backscattering of light by particles

Bio-Argo float blooms

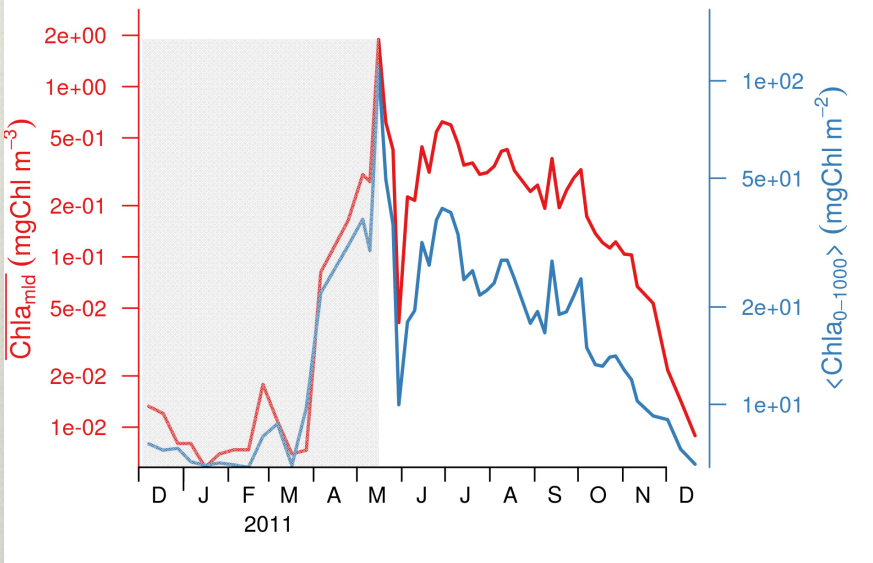


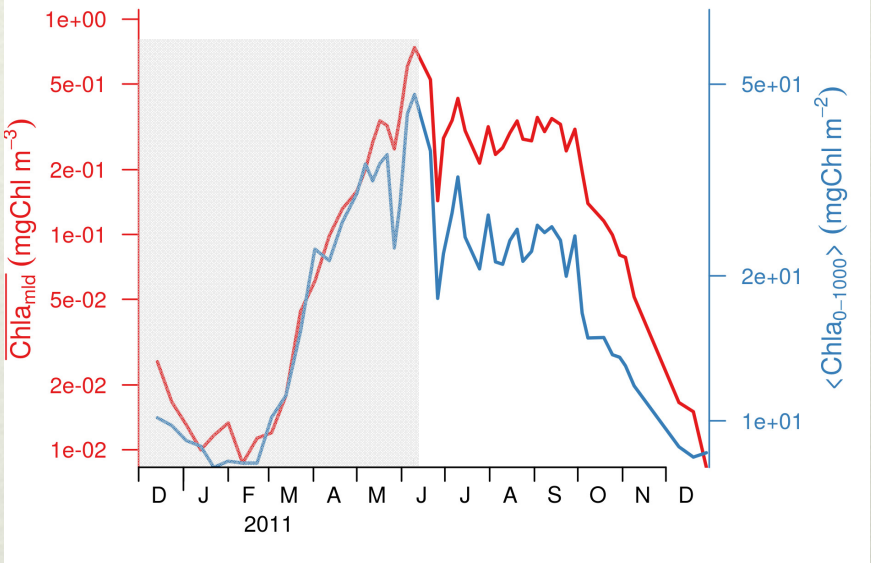


Bloom are characterized by three distinct phases

- onset with rapid growth rates
- settling to a stable phytoplankton concentration
- termination

Bio-Argo float blooms





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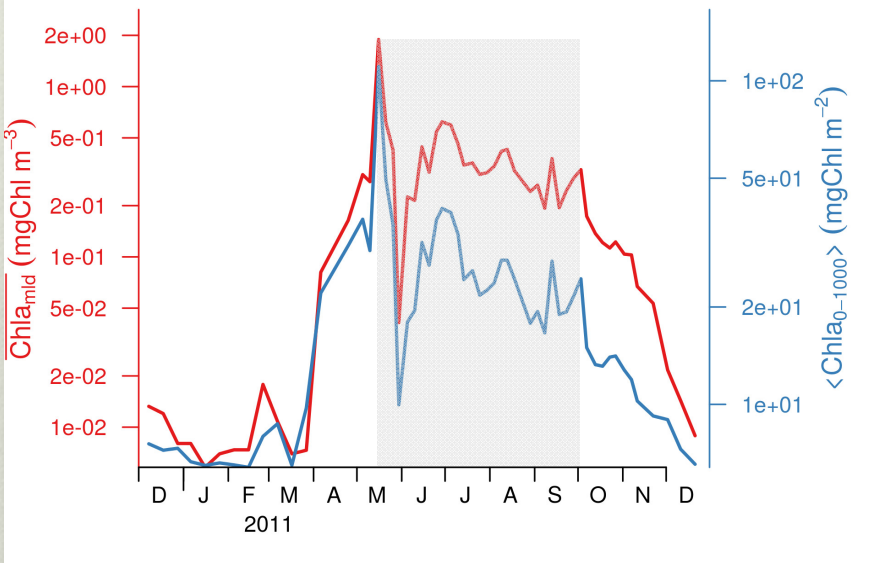

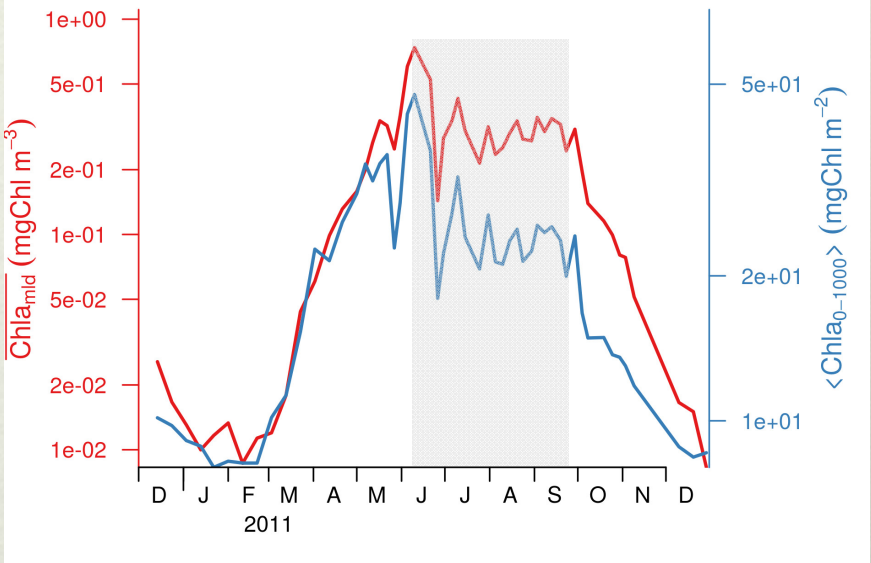

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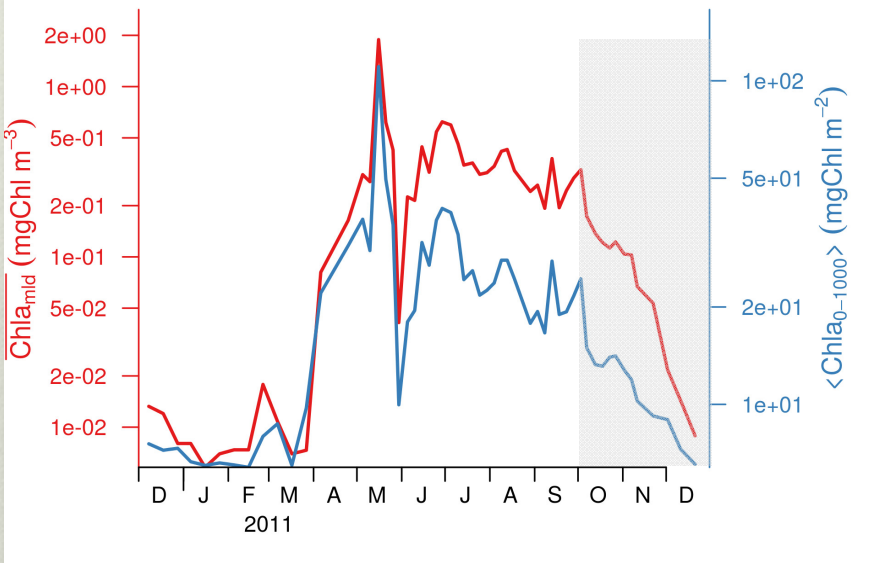

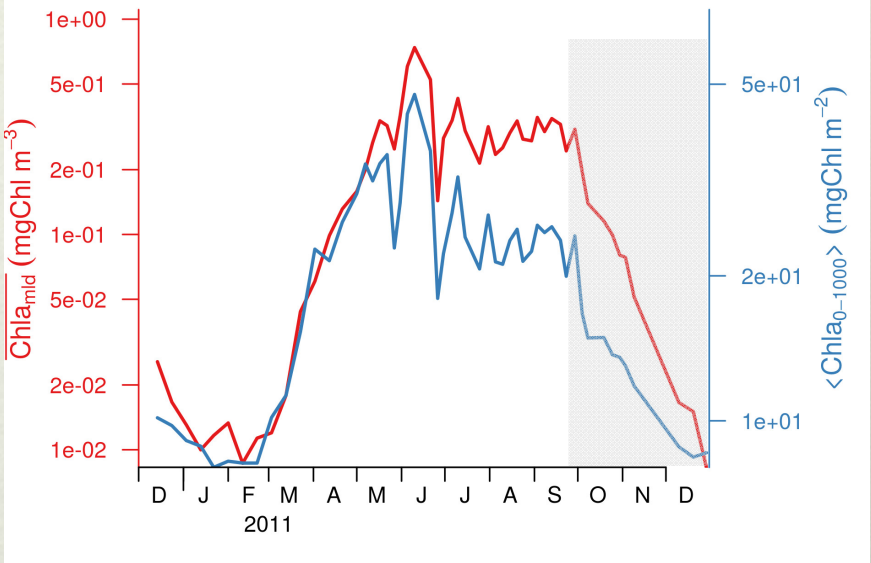

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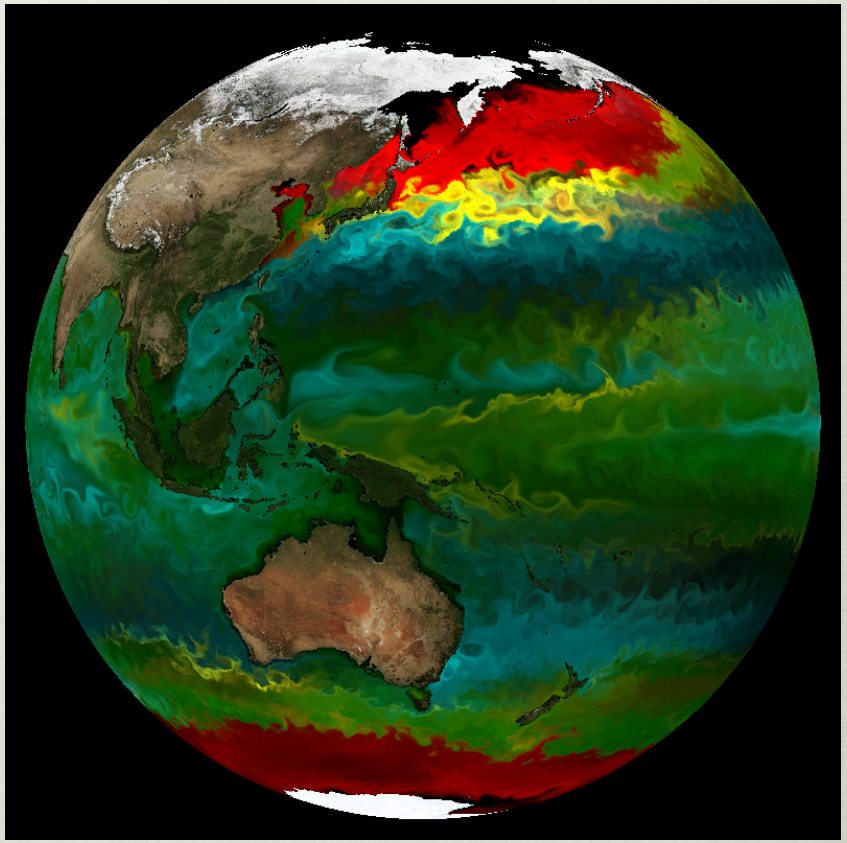
Darwin Model

MIT general circulation model

- 1° × 1° resolution

Darwin biogeochemistry model

- **N**: DIN, Fe, PO_4, Si,O_2, DIC
- **P**: 9 phytoplankton types: Diatom, SmEuk, LgEuk, Syn, LL/HL Proc, Cocco, Tricho, Uni Diaz
- **Z**: 2 types of zooplankton large and small
- **D**: POC, DOC, CDOM, PIC



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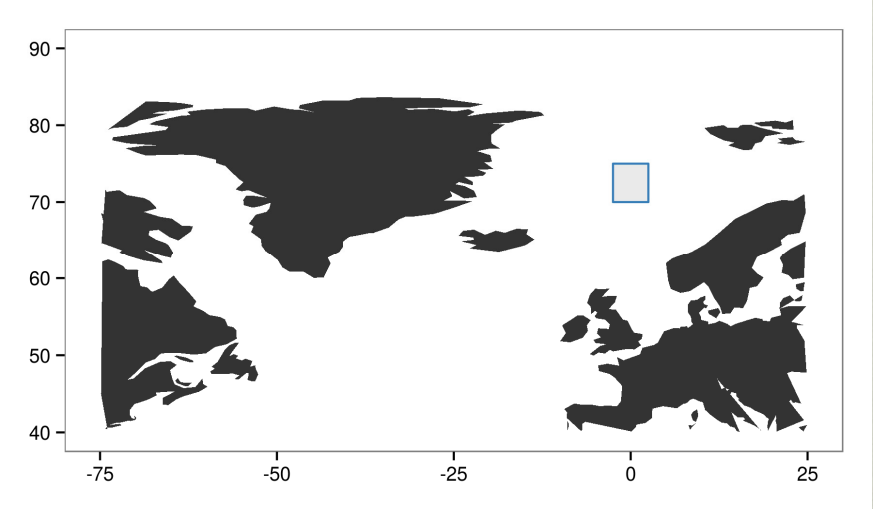
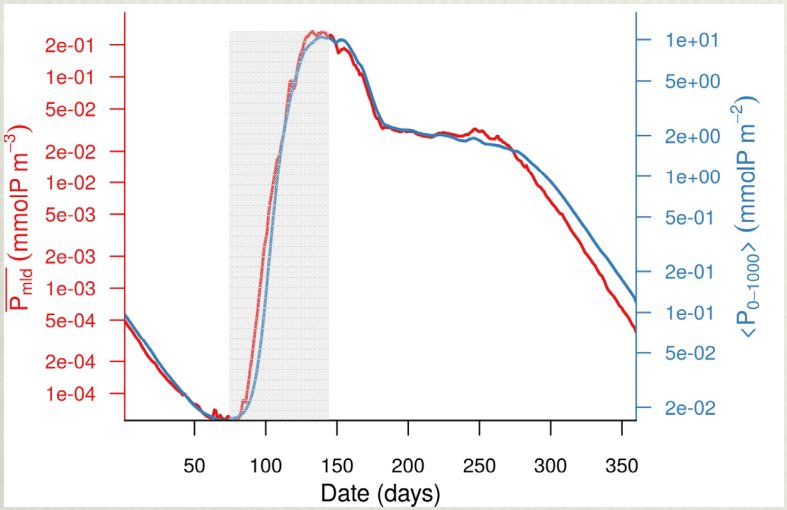


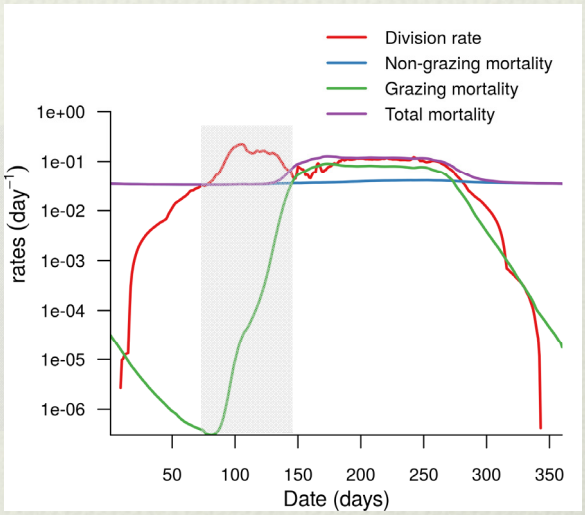
Dutkiewicz et al. (Biogeosciences, 2015)

Bloom onset

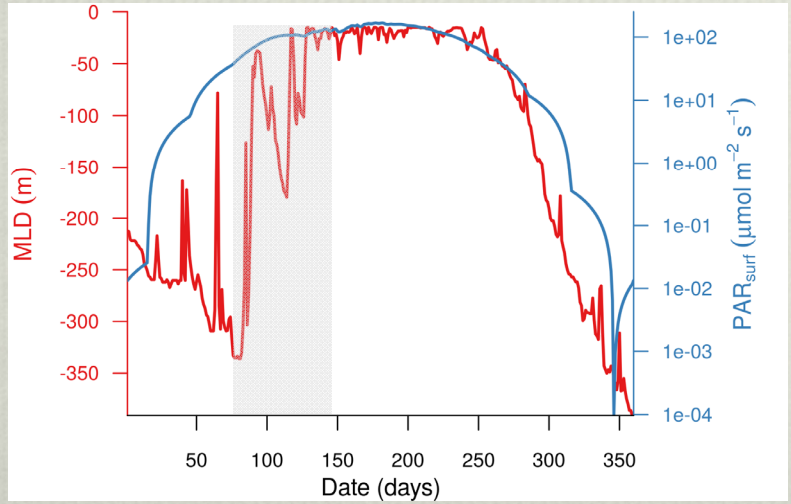
Phytoplankton



Division rates, respiration & grazing



Surface PAR & mixed layer depth

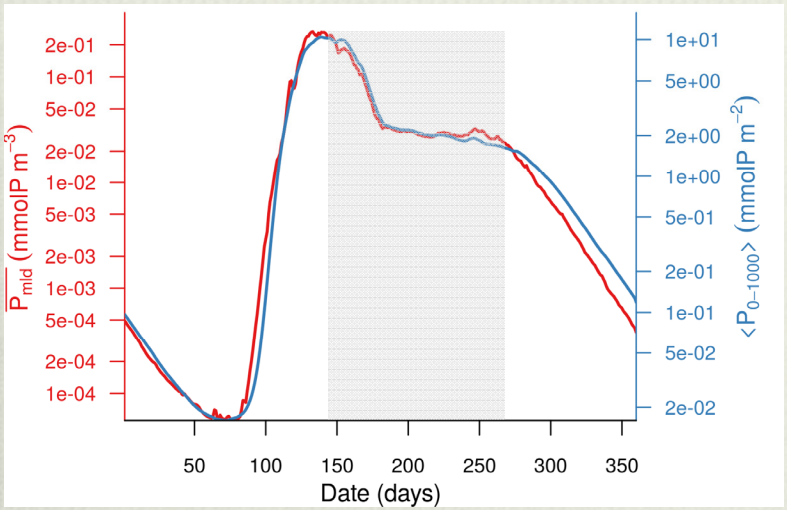


Bloom starts

- when surface PAR increases
- while mixed layer deepens
- when grazing is weak
- P & Z are decoupled

Bloom maturation

Phytoplankton



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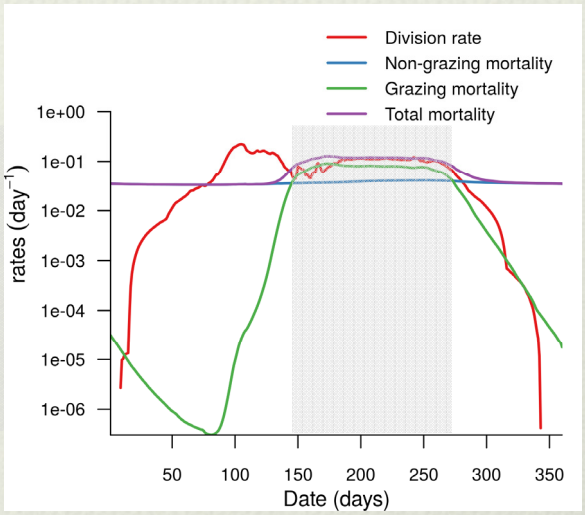
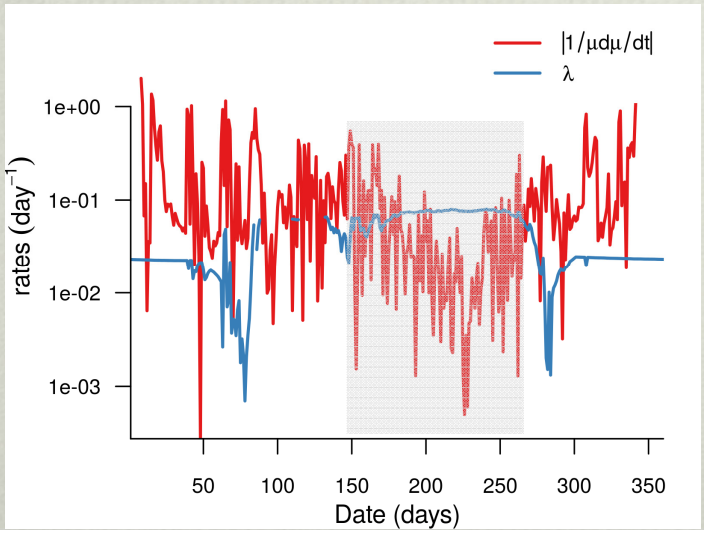


Stable environment

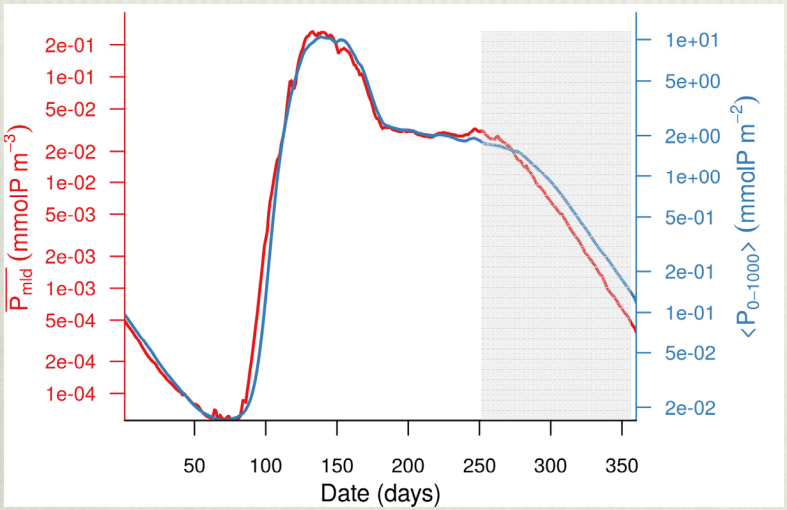


Bloom matures when

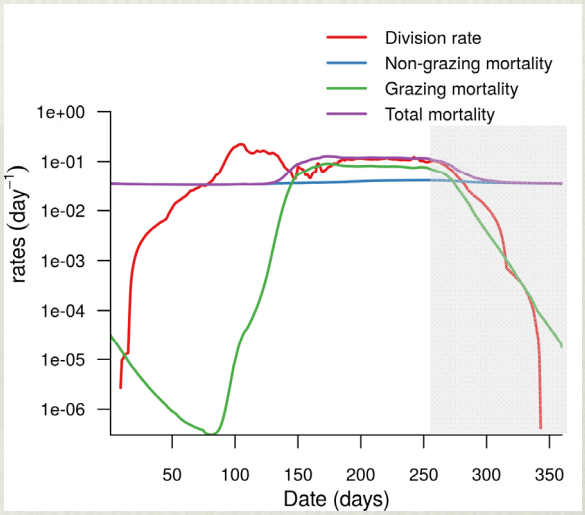
- grazing catches up with growth
- environment is stable
- P & Z are coupled

Bloom termination

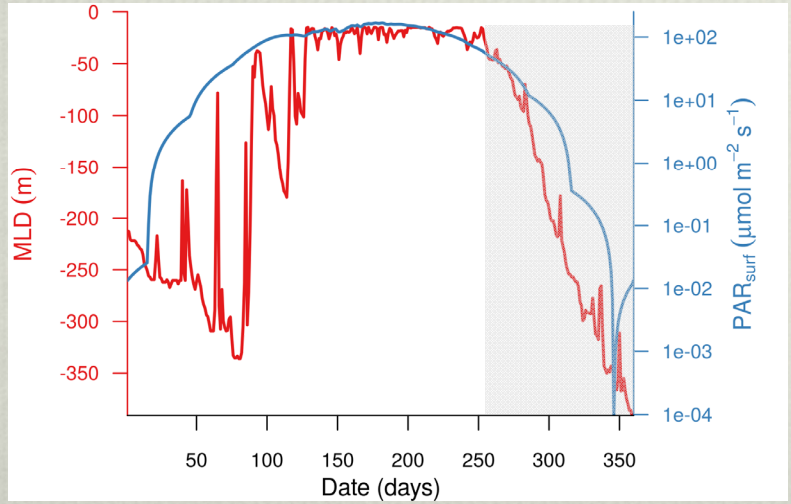
Phytoplankton



Division rates, respiration & grazing



Surface PAR & mixed layer depth

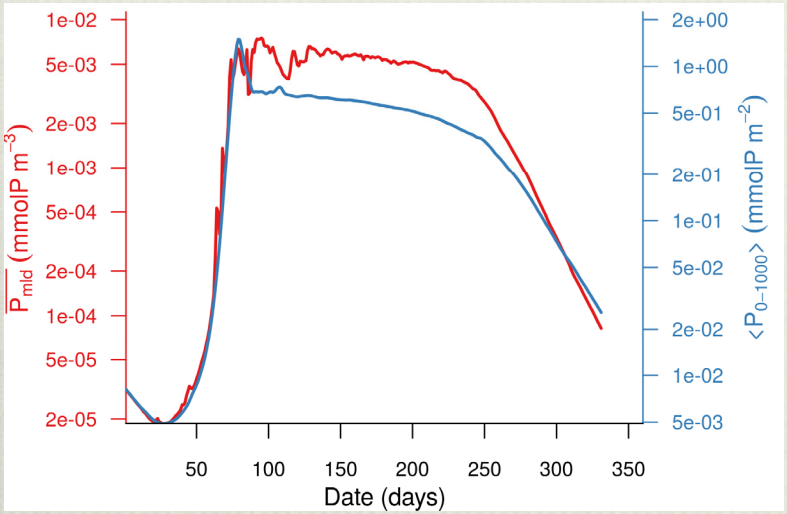


Bloom starts

- when surface PAR increases
- while mixed layer deepens
- when grazing is weak
- P & Z are decoupled

Bloom with strong grazing

Phytoplankton



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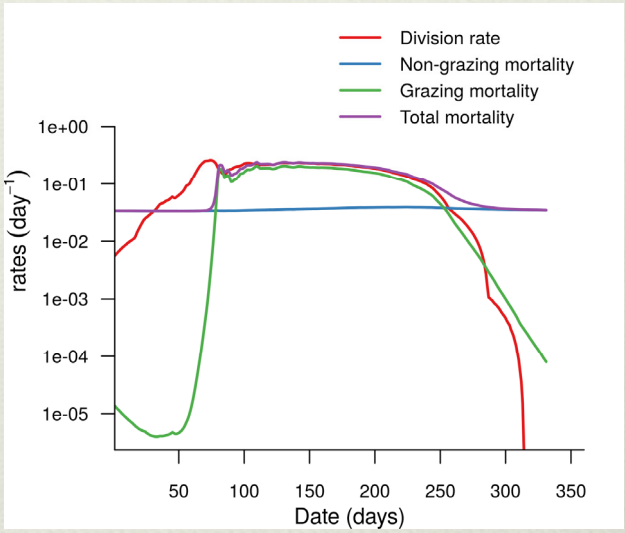

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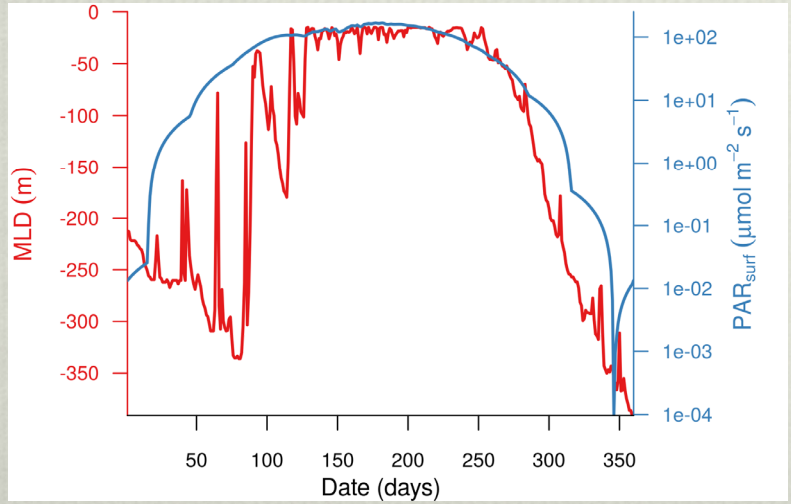
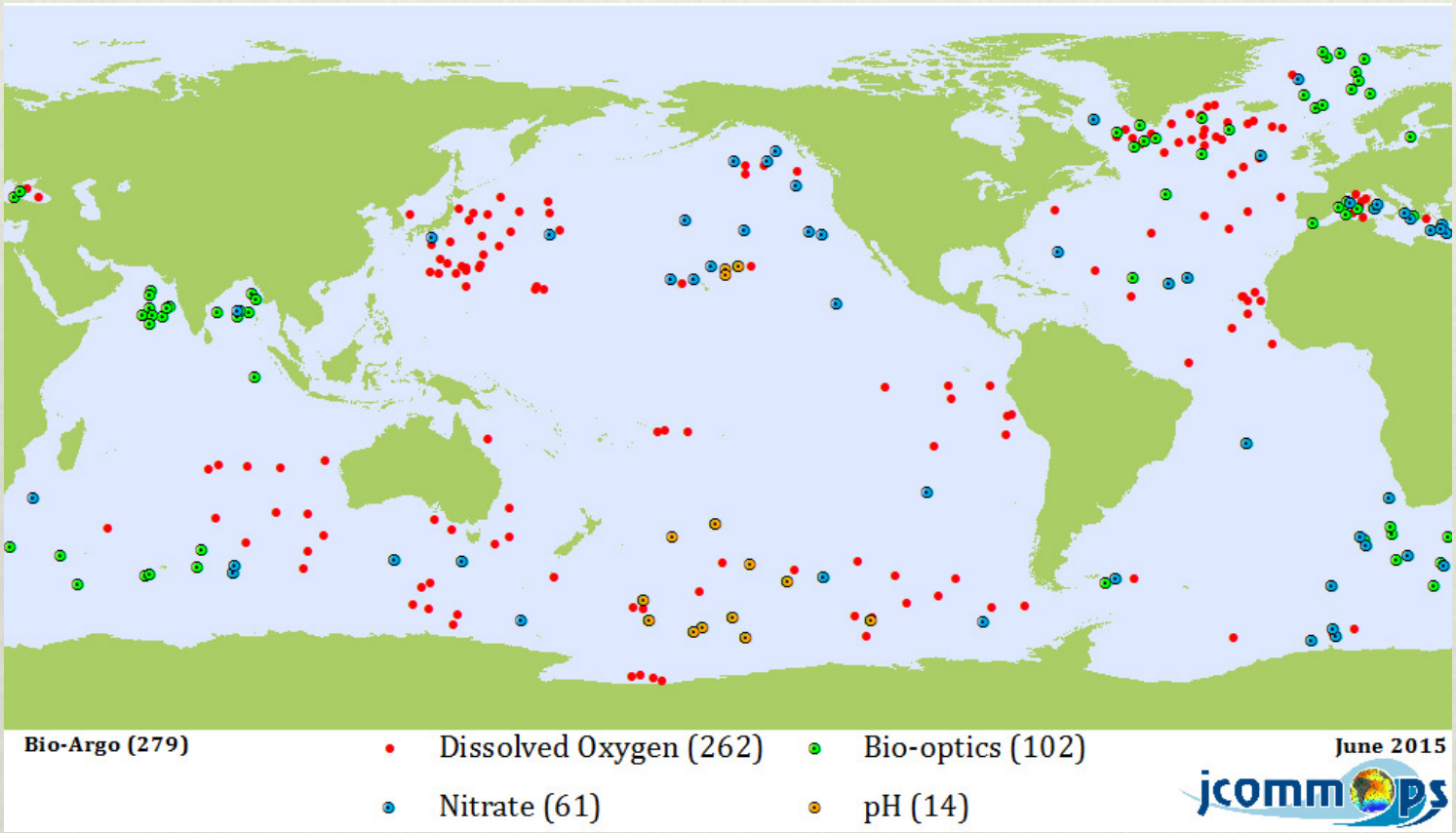


Conclusions

- Eight phytoplankton blooms were sampled north of the Arctic Circle by Bio-Argo floats
- The major characteristics of the blooms are captured by the Darwin model
- Phytoplankton blooms north of the Arctic Circle are characterized by three phases
  - Rapid onset without much grazing (decoupled PZ system)
  - Stable maturation with strong grazing (coupled PZ system)
  - Termination (decoupled PZ system)

Bio-Argo float fleet



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