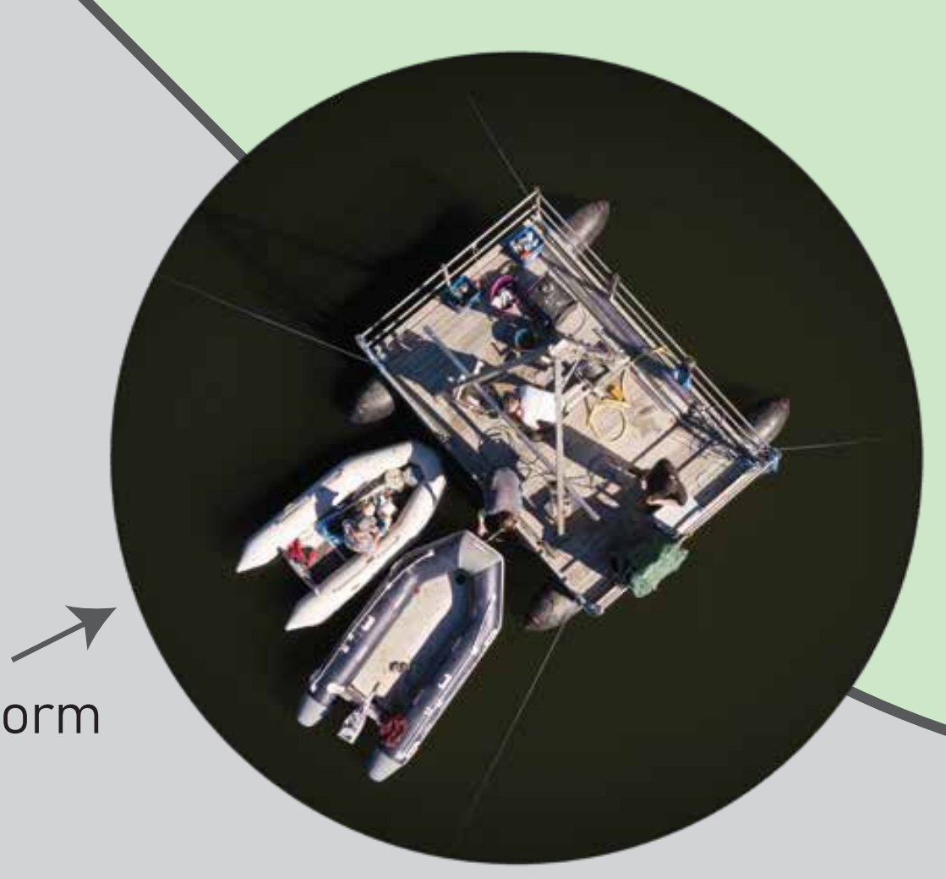
This presentation participates in OSPP
EGU
Outstanding Student & PhD candidate Presentation contest

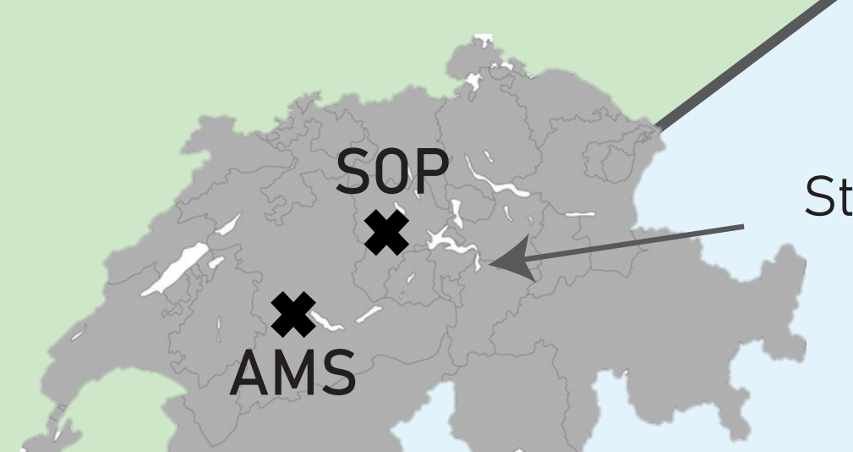
Vote here!


Coring platform

Did climate warming cause eutrophication and anoxia?

Lessons learned from Late-Glacial sediments of lakes Amsoldingen and Soppen, Switzerland.

Stan J. Schouten[1,2], Petra Zahajská[1,2], Noé R.M.M. Schmidhauser[1,2], Andrea Lami[3], Paul D. Zander[4], Rik Tjallingii[5], Petra Boltshauser-Kaltenrieder[1,6],
Jacqueline van Leeuwen[1,6], Luyao Tu[7], Hendrik Vogel[1,8], and Martin Grosjean[1,2]



UNIVERSITÄT BERN
OESCHGER CENTRE
CLIMATE CHANGE RESEARCH

Introduction

Why? Eutrophication and associated hypoxia are globally deteriorating lake water quality, threatening aquatic ecosystems and water resources [1,2]. The link between rapid climate warming and eutrophic phases in natural environments needs to be better understood.

Research Questions:

I. What drove **algal community shifts** during large-scale climatic re-arrangements?
II. Did higher aquatic primary **productivity lead to anoxia** or vice versa?
III. How did the **aquatic ecosystems and primary producer communities evolve** during the Late-Glacial on the Swiss plateau?

What? We investigated temperature-driven phytoplankton successions and chemical feedbacks (P, Fe, Mn) occuring during rapid warmings throughout the Late-Glacial (e.g., Bølling-Allerød; 16-11 ka BP) in Amsoldingersee and Soppensee.

Methods

- **High-resolution productivity** from hyperspectral imaging [4].
  I. Bacteriopheophytin-a (Bphe-a) – purple sulfur bacteria (PSB; purple; Figure 1 & 2).
  II. Bacteriopheophytin-e (Bphe-e) – green sulfur bacteria (GSB; blue; Figure 1 & 2).
  → Hypolimnetic anoxia with chemocline in the photic zone.
  III. Chlorophylls and chlorins – productivity (green; Figure 1 & 2).
  IV. Phycocyanin – cyanobacteria (pink; Figure 1 & 2)
- **Algal community:** Low resolution pigments using HPLC-DAD [3].
- **Redox sensitive elements:** Sequential phosphorous, iron, and manganese extraction using ICP-MS
- **Dust & runoff:** X-ray fluorescence
- **Age:** ^{14}C-dating & tephro- and palynostratigraphy
- **Nutrients:** CNS-analysis

Soppensee: anoxia during WARM phases ↔ Amsoldingensee: anoxia during COLD phases

Results

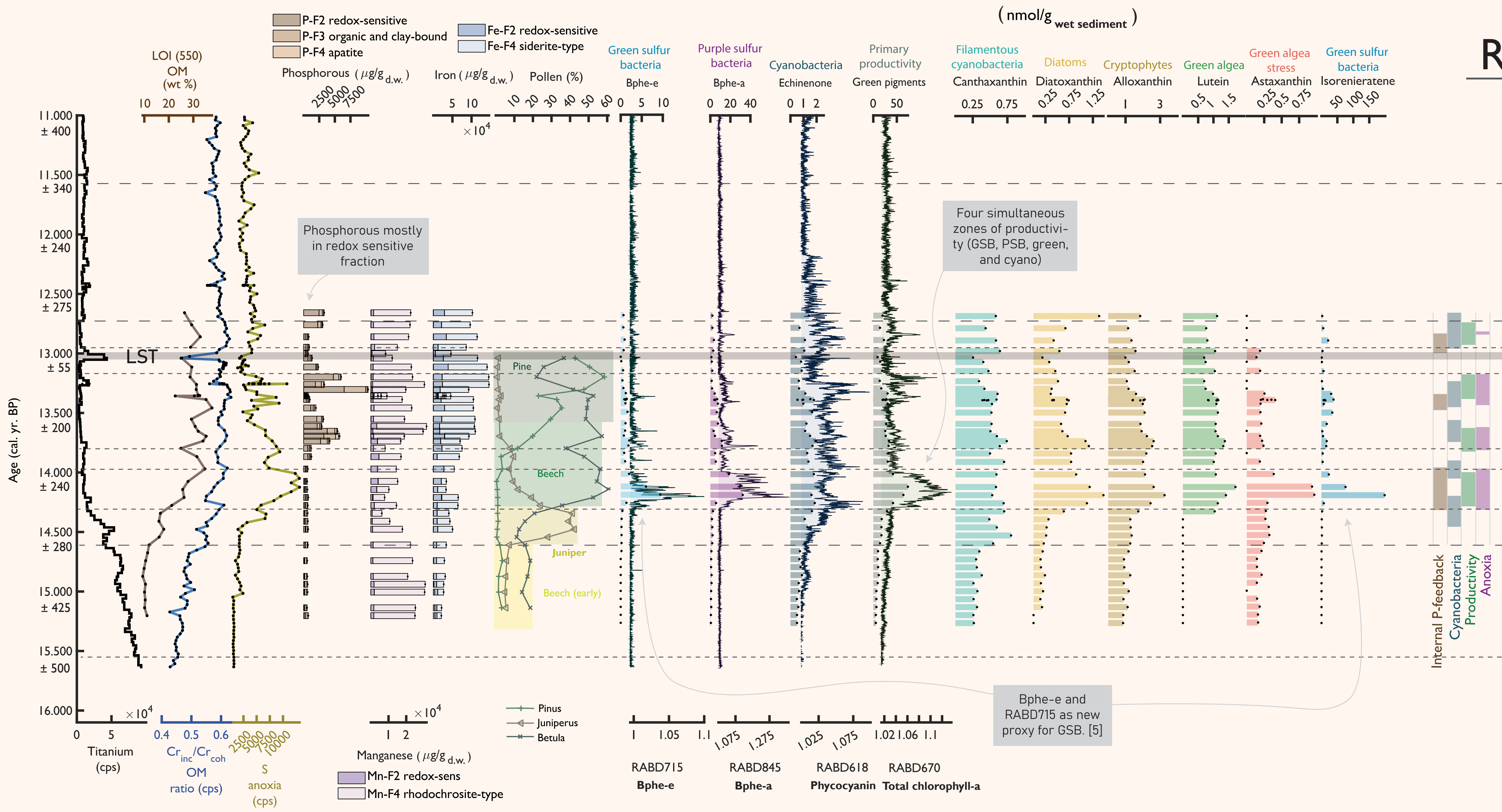


Figure 1: Soppensee record of XRF data, sequentially extracted phosphorous, manganese, and iron, pollen counts, pigment data from hyperspectral scanning and HPLC. On the left side chronozones: AO (GI-1d) Aegelsee oscillation; GO (GI-1b) Gerzensee oscillation. Laacher See tephra (LST) indicated in grey.

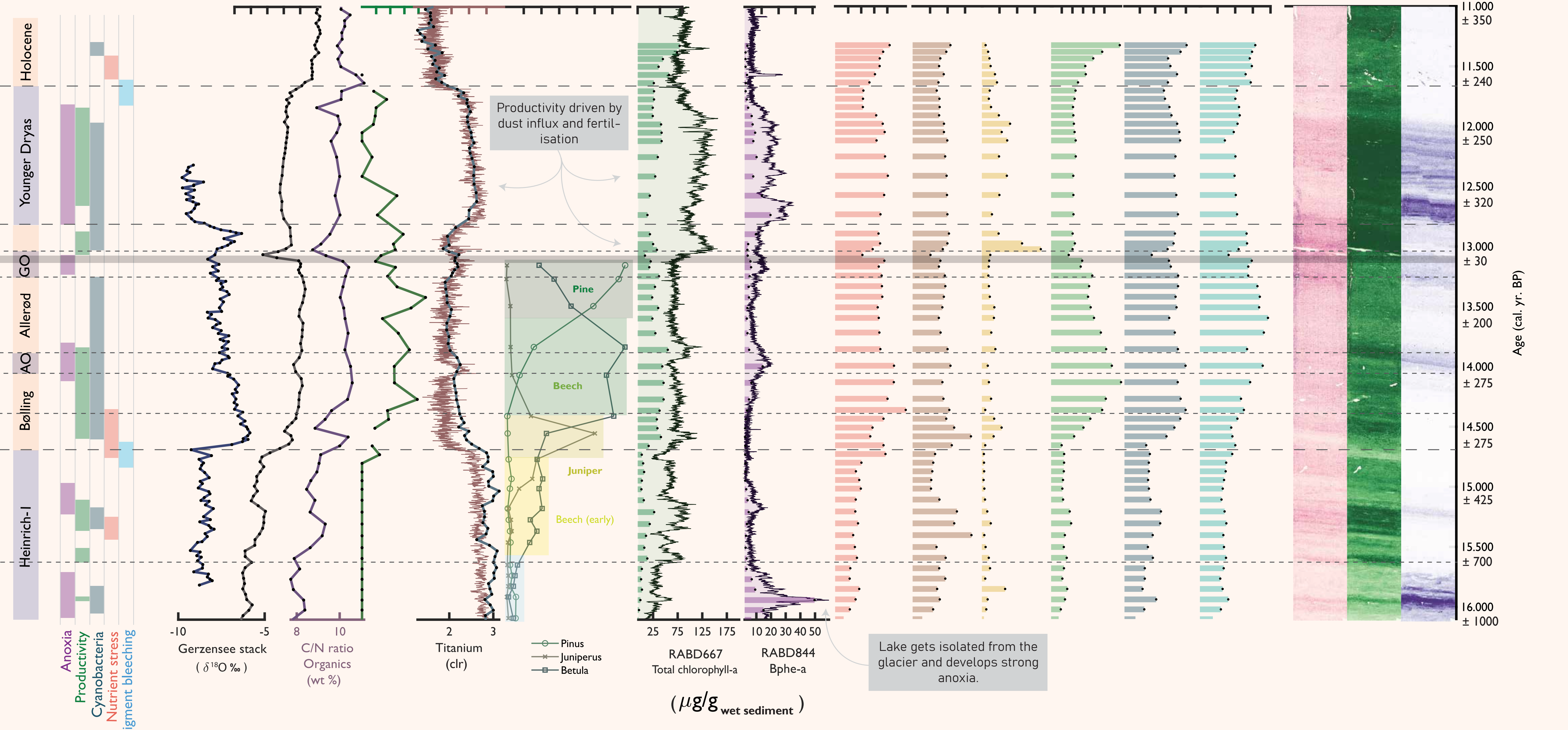


Figure 2: Gerzensee oxygen isotopes [6], Amsoldingensee record of XRF data, NGRIP dust record [7], sequentially extracted phosphorous, pollen counts, pigment data from hyperspectral scanning and HPLC; On the right side hyperspectral maps: RABD618 (phycocyanin); RABD667 (chlorophylls-a); RABD844 (bacteriopheophytin-a)

Conclusions

- **Natural rapid warming,** like the Bølling-Allerød, increased productivity. However, nutrients are more important in regulating the productivity records in detail (Figure 1, ~14.2 ka & Figure 2, ~14.4 ka).
- **Dust and tephra inputs can fertilise** phytoplankton communities by supplying phosphorous, silica and iron in nutrient limited lakes (Figure 2, ~ Younger dryas & LST).
- **Internal redox feedback did occur** in Soppensee, a deep lake with a catchment that has sufficient input of inorganic phosphorous to the lake (Figure 1, ~14.2 ka).
- **Several phases of extensive anoxia exist.** The lakes stratified due to wind shielding by surrounding tall vegetation or ice-cover. (Figure 1, ~Bølling & Figure 2 ~Younger Dryas)[8].
- **Anoxia did not cause irreversible shifts** in pigment composition, hence phytoplankton communities were not hysteric to anoxia (Figure 3, right).
- **Eutrophication in Soppensee occured** at the onset of beech afforestation during the Bølling, it receded at the timing of cold snaps, likely because the lake was mixed more often by wind and seasonal overturning (Figure 1, ~14 ka).
- **A productive phase occurred before the onset of the Bølling** (Figure 2 ~ 15.8 ka), showcasing that insolation is also an important driver of productivity and Heinrich-1 was not a homogenously cold phase.

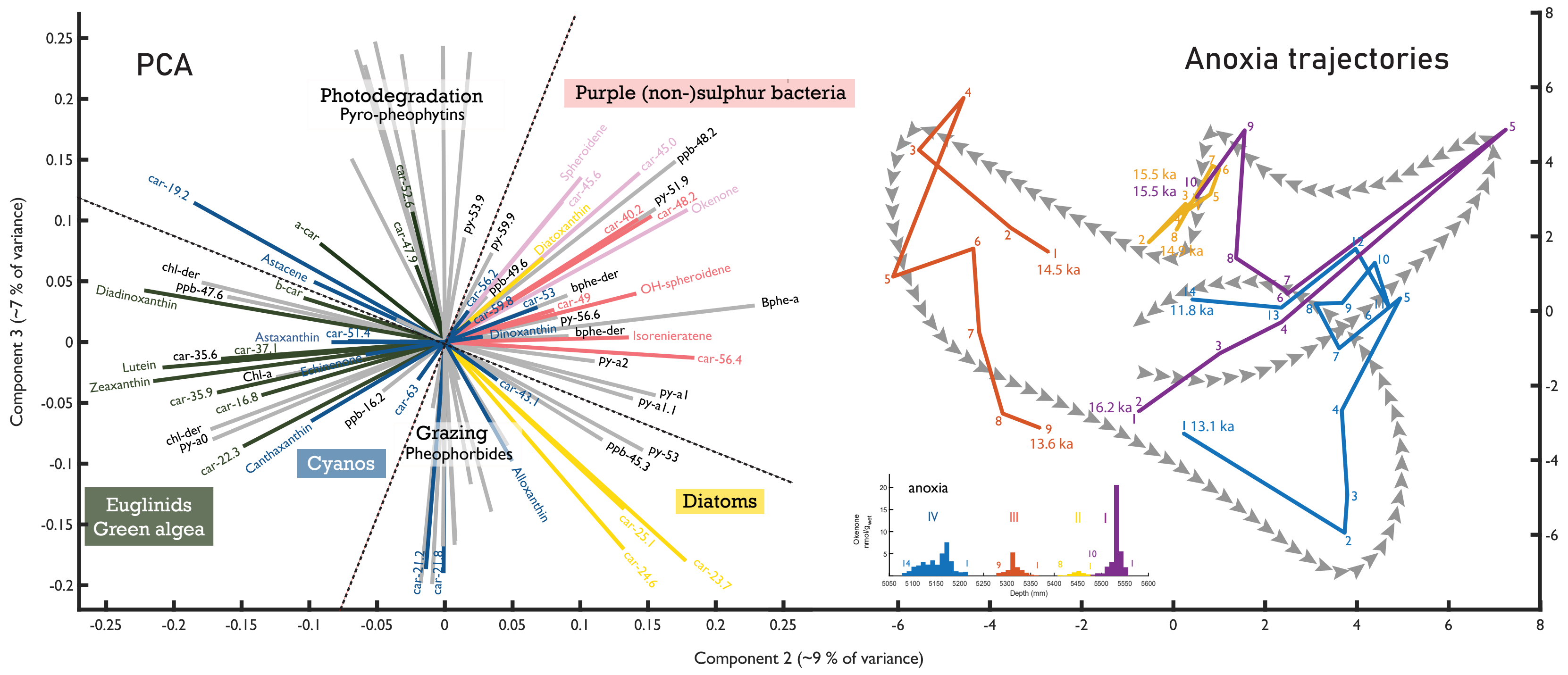
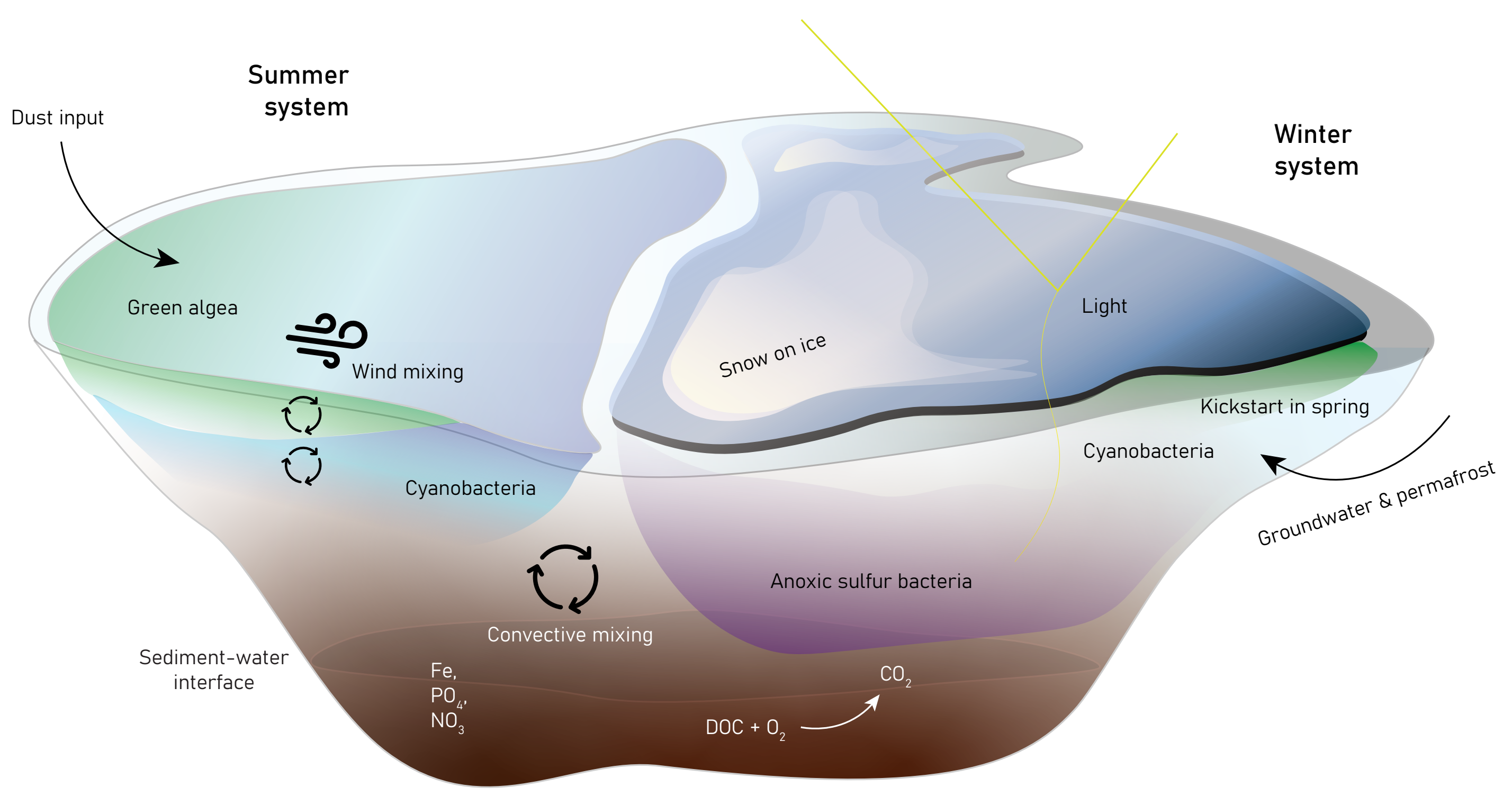


Figure 3: (left) Principal component analysis of pigments in Amsoldingersee, (right) trajectories of the pigment compositing during anoxia in Amsoldingersee. The second and third principal components are used because they reflect composition shifts.

Figure 4: Schematic sketch of the Amsoldingersee system during colder phases of the record. The lake develops a seasonal ice cover, depleting oxygen, and allowing photosythetic bacteria to grow under the ice.



Find us

Swiss National Science Foundation

*** Institute of Geography, Hallerstrasse 12, 3012 Bern, Switzerland,**
mail: stan.schouten@unibe.ch

Project funded by the Swiss National Science Foundation (SNSF) grant nr: 200020_204220

[1] Oeschger Center for Climate Change Research, Universität Bern, Switzerland.
[2] Institute of Geography, Universität Bern, Bern, Switzerland.
[3] Water Research Institute (CRN-IRSA), Unit Verbania, Verbania, Italy.
[4] Climate Geochemistry Department, Max Planck Institute for Chemistry, Mainz, Germany
[5] Section Climate Dynamics and Landscape Evolution, GFZ Research Centre for Geosciences, Potsdam, Germany
[6] Institute of Plant Sciences, Universität Bern, Bern, Switzerland
[7] College of Marine Science and Engineering, Nanjing Normal University, Nanjing, China
[8] Institute of Geology, Universität Bern, Bern, Switzerland

REFERENCES

[1] Steffen, W. et al. Planetary boundaries: Guiding human development on a changing planet. Science, 347(6223), 1259855. (2015).
[2] Jane, S. F. et al. Widespread deoxygenation of temperate lakes. Nature, 594(7861), 66-70. (2021).
[3] Lami, A. et al. . High resolution analysis of fossil pigments, carbon, nitrogen and sulphur in the sediment of eight European Alpine lakes: the MOLAR project. Journal of Limnology, 59(1s), 15-28. (2000)
[4] Butz, C. et al. Hyperspectral imaging spectroscopy: a promising method for the biogeochemical analysis of lake sediments. Journal of Applied Remote Sensing, 9(1), 096031-096031. (2015)
[5] Zander, P. D. et al. Hyperspectral imaging sediment core scanning tracks high-resolution Holocene variations in (an) oxygenic phototrophic communities at Lake Cadagno, Swiss Alps. Biogeosciences, 20(12), 2221-2235. (2023)
[6] Van Raden, U. J. et al. High-resolution late-glacial chronology for the Gerzensee lake record (Switzerland): δ18O correlation between a Gerzensee-stack and NGRIP. Palaeogeography, Palaeoclimatology, Palaeoecology, 391, 13-24. (2013)
[7] North Greenland Ice Core Project members. High-resolution record of Northern Hemisphere climate extending into the last interglacial period. Nature 431, 147–151 (2004).
[8] Klanten, Y. et al. Oxygen depletion in Arctic lakes: circumpolar trends, biogeochemical processes, and implications of climate change. Global Biogeochemical Cycles, 37(5). (2023)