Biological CO_2 Fixation in Polar Oceans

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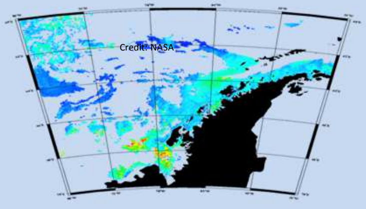


Southern ocean

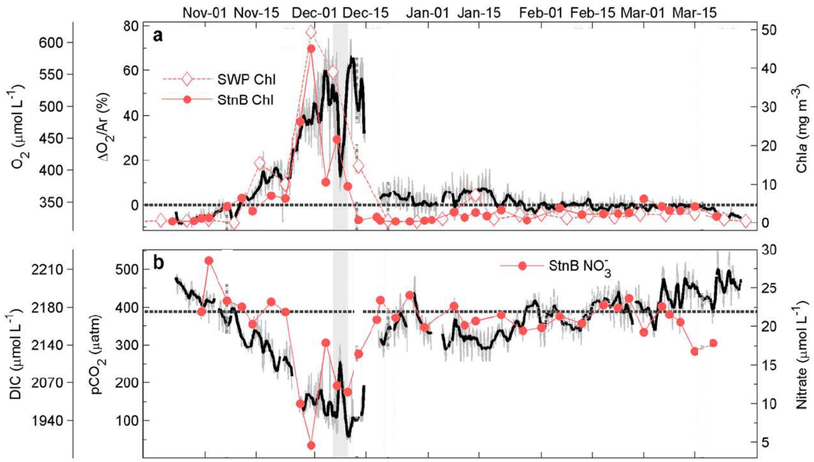
- Disproportionally productive area of the global ocean
- Particularly sensitive to climate change
- An important sink for anthropogenic CO_2 driven by **intense** spring phytoplankton blooms, characterized by:
  - High rates of Gross Carbon fixation despite cold temperatures
  - Low respiration

- What are the adaptations that enable high photosynthesis and low respiration at low temperatures ?
- How do the organisms adapt to the variation of diel cycle?
- How will the increase of temperature impact future bloom productivity?

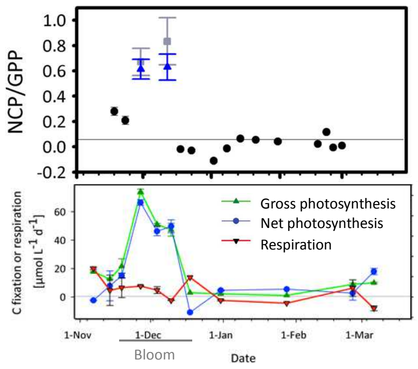
The biological CO_2 sink in the polar oceans is poorly understood due to low resolution sampling and a lack of knowledge of the mechanisms that control primary production.

The spring phytoplankton bloom in the Western Antarctic Peninsula

- We visited the highly productive Western Antarctic Peninsula (WAP) in the spring-summer of 2012/2013 and witnessed one of the largest phytoplankton blooms over the 25 year record.
- The phytoplankton bloom reduced the surface ocean concentration of CO_2 from 480 ppm to 80 ppm.
- Those massive blooms support an abundant and diverse ecosystem

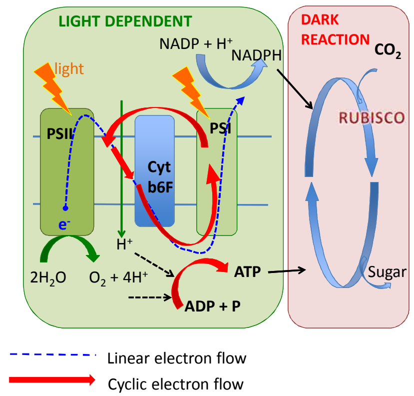


High net primary production is due to high ratios of Photosynthesis/Respiration

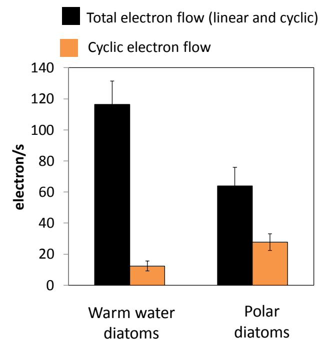


- The blooms in the WAP are characterized by very high ratio of photosynthesis to respiration
- In particular, we observed very low respiration at the maximum daylight during the bloom
- Since respiration gives cells energy through production of ATP how do the cells compensate?

Photosynthesis



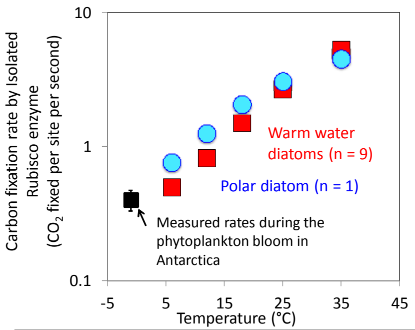
Cyclic Electron Flow is high in polar phytoplankton and might generate some of the energy needed

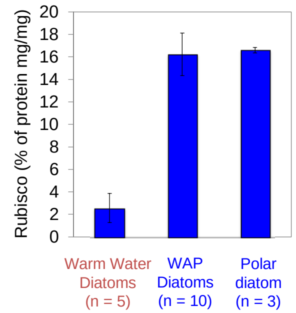


- Photosynthesis produces O_2 in the light dependent reaction and fixes CO_2 in the dark reaction
- Electrons produced during water splitting go through a linear electron transport chain, generating ATP and reductant that power CO_2 fixation in the dark reaction.
- Another process can also occur in the light reaction: Cyclic Electron Flow that also generates ATP

Phytoplankton are fixing carbon as fast as they can at cold temperatures

- CO_2 is fixed in the dark reaction of photosynthesis by the enzyme RUBISCO
- RUBISCO is very slow, even at warm temperatures, and is often the rate-limiting step of photosynthesis
- The rate of CO_2 fixation slows exponentially with temperature. The rate is 8 times slower at 0 °C compared to 20 °C.
- To compensate, polar phytoplankton dramatically increase their RUBISCO content within their cells.
- There is a limit to how much energy and nitrogen phytoplankton can invest in making RUBISCO. It is likely they are producing their maximum amount of RUBISCO





Given that all their Rubisco is active, it appears that WAP on during a bloom are fixing carbon at their theoretical maximum rate.

References
Goldman J.G. et al. (2015) *New Phytologist* 205(1): 182-191 DOI: 10.1111/nph.13125, **Young**, J.N. et al. (2015) *New Phytologist*, 205(1): 172-181. DOI: 10.1111/nph.13021, **Tortell**, P.D. et al. (2014) *Geophysical Research Letters*, DOI:10.1002/2014/gbc.20045