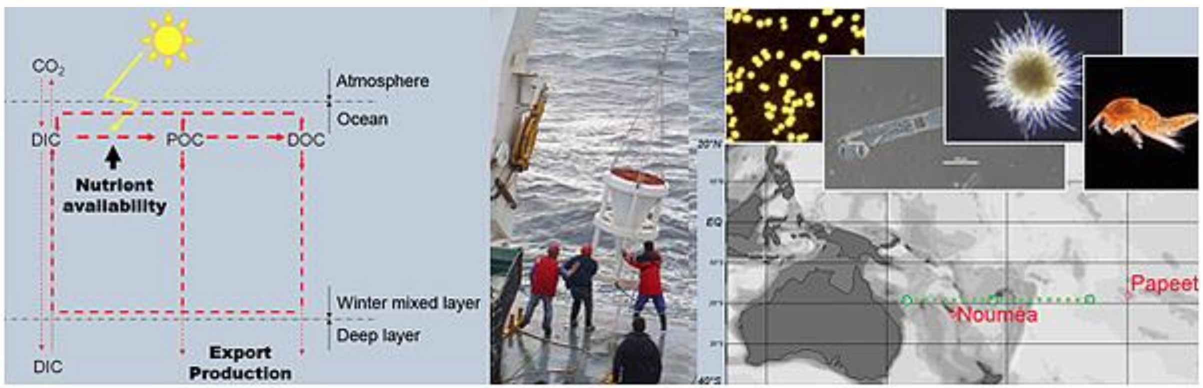
“Studying Phytoplankton Adaptations to Different Marine Environments” with Solange Duhamel & Andy Juhl



Earth2Class Workshop
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- BA and MS University of Paris
- Ph.D. University of Aix-Marseille
- Post-docs at Lamont, Woods Hole, and C-MORE

Andrew Juhl

- Lamont Associate Research Scientist and Adjunct Associate Professor in DEES
- BA University of Wisconsin-Madison
- MS Oregon State University
- Ph.D. Scripps Institute of Oceanography

Research focuses on:

- Abundance, diversity, and activity of aquatic microbes in the open ocean, coastal marine, lake, river, and wetland ecosystems
- Investigate role of microorganisms as agents of biogeochemical transformations
- Special focus on role of nutrients, especially P, in distribution, growth, and productivity of microplankton

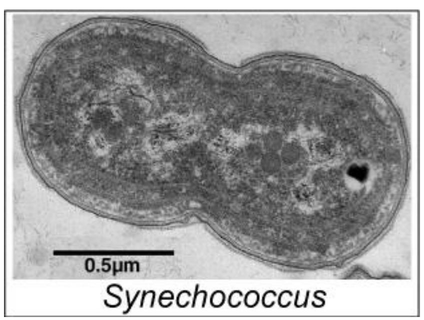
How Can Plankton Adapt to Vastly Different Environments in the Ocean?

- Temperature variations
  Over 40^o C to below 0^o C
- Light variations
  Day/night
  Surface euphotic gradually dims to complete darkness by selective absorption
- Nutrient variations
  Low-nutrient (oligotrophic) to high-nutrient

Cyanobacteria (aka blue-green algae)

Important in primary production and carbon cycles in the open ocean and elsewhere

- Focus on role of light in uptake of organic substrates (esp. carbon, nitrogen, and key nutrients)



http://www.whoi.edu/science/B/people/ewebb/Syne.html

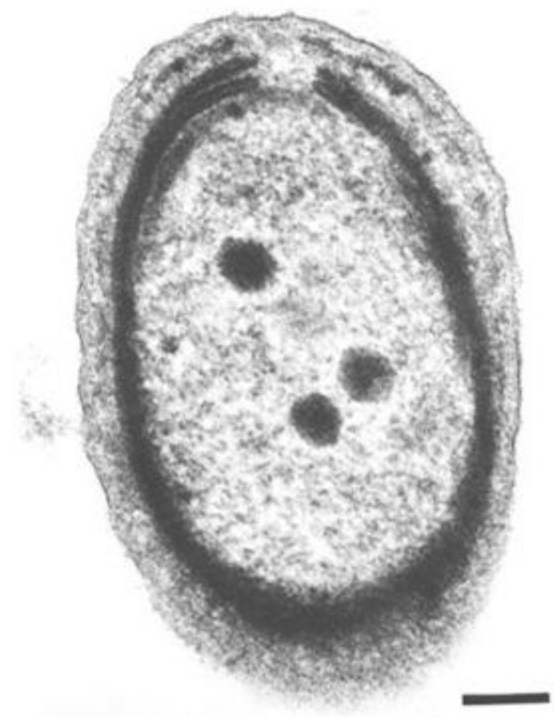
http://genome.jgi.doe.gov/prom9/prom9.home.html

General Characteristics and Importance

- Extremely small—some can have 100 in a row and be the width of a human hair
- May trace back to 3.5 billion years – mutation gene able to split H_2O and release O_2
- Generally exist from surface to 200 m
- Many strains identified showing significant differences in ability to utilize levels and wavelengths of light, handle trace elements, etc.

Prochlorococcus

- 0.5 to 0.7 µm – smallest known photosynthesizer
- Possibly account for 5 – 10% of global photosynthesis
- Only discovered within past few decades (1980s)
- Ubiquitous within 40° N – 40° S



Additional points of interest

- First discovered with flow cytometers onboard research vessels
- Now possible to analyze in labs, but extremely delicate and sensitive
- Often studied by DNA and chlorophyll
- Important in **oligotrophic** (low nutrient) zones in Pacific and Atlantic – surface/volume ratio
- Only divides once a day

Importance in the C and N Cycles

Trichodesmium

http://www.whoi.edu/oceanus/feature/a-most-ingenious-paradoxical-plankton

- "Fix" (chemically bond) CO_2 into organic molecules
- Also fixes N into proteins and DNA
  - N_2 has triple-bond that requires a lot of energy to break
  - Special enzymes
- Releases nitrogen compounds for other organisms

Importance of photoheterotrophy

- We are most familiar with “photoautotrophs”
- Organisms of interest here use light to produce energy-rich molecules (ATP) not solely from CO_2—can utilize carbohydrates, fatty acids, and alcohols
- Recent technologies and discoveries have opened many ‘research doors’

Mixotrophs

- Organisms that can use combinations of energy and carbon sources, rather than one

Possible combinations:

- Photo- and chemotrophy
- Auto- and heterotrophy
- Litho- and organotrophy

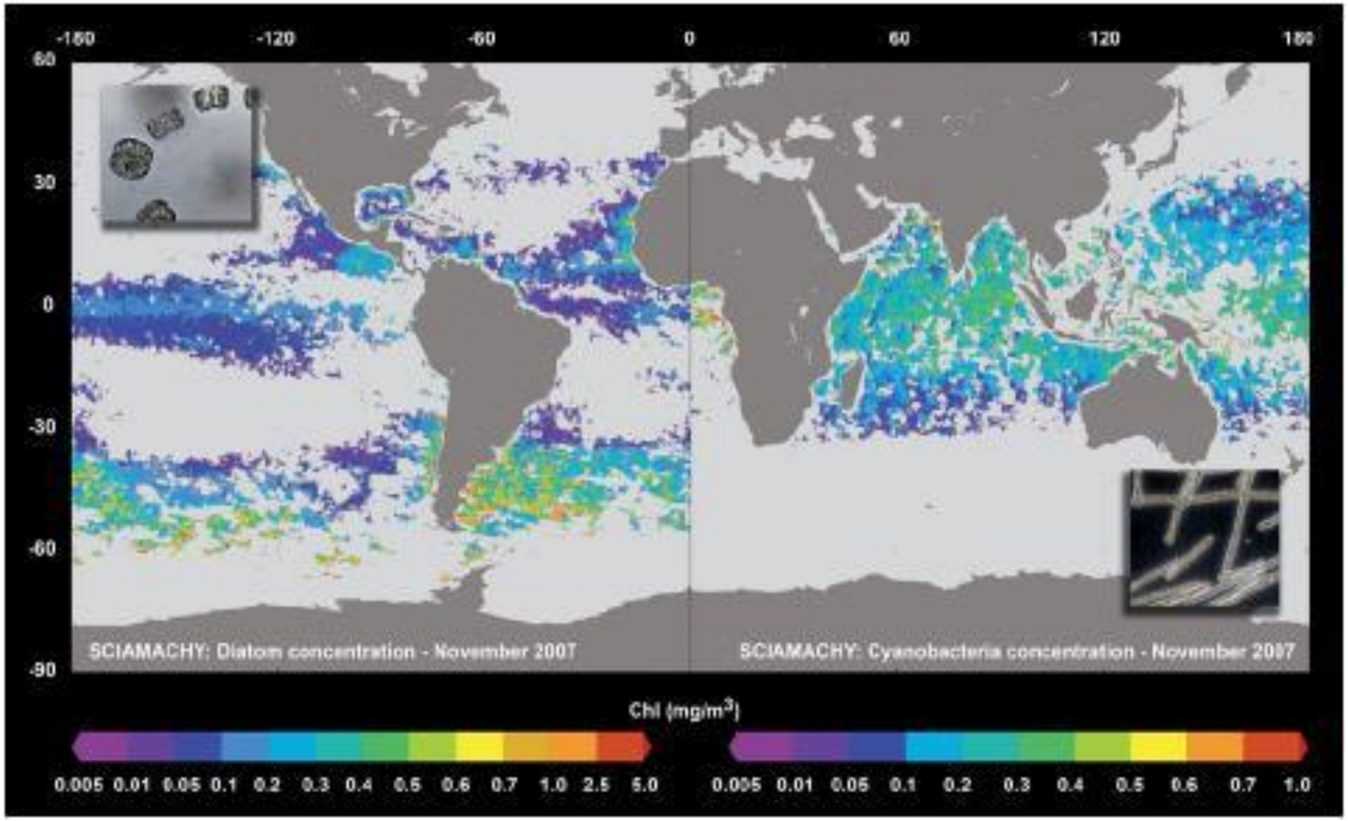
May be eukaryotic or prokaryotic

Lab Experiments

- Laboratory experiments in controlled cultures of ecologically relevant cyanobacteria
- Employs innovative methods, including single cell assays and molecular tools that target individual cyanobacteria and evaluate response to light for assimilation of organic substrates
- Flux measurements:
  - Carbon (C) (primary production and bacterial production)
  - P incorporation rates using radioactive tracers
  - ATP turnover (energy fluxes)
  - C and P release using radioactive tracers
  - enzymatic activities using fluorogenic substrates

Types of Lab Research

- **Flow cytometry** (e.g. cell counts and cell sorting).
- **Epifluorescence microscopy** (e.g. cell counts and identification)
- **Fluorometry** (e.g. enzymatic activities, polyphosphate and chlorophyll concentrations)
- **Bioluminescence assay** (e.g. ATP concentrations)
- **Radioisotope lab** (3H, 14C, 35S, 32P and 33P) equipped with an ultra low level liquid scintillation counter
- **High-performance liquid chromatography** (HPLC) (e.g. phospholipids)

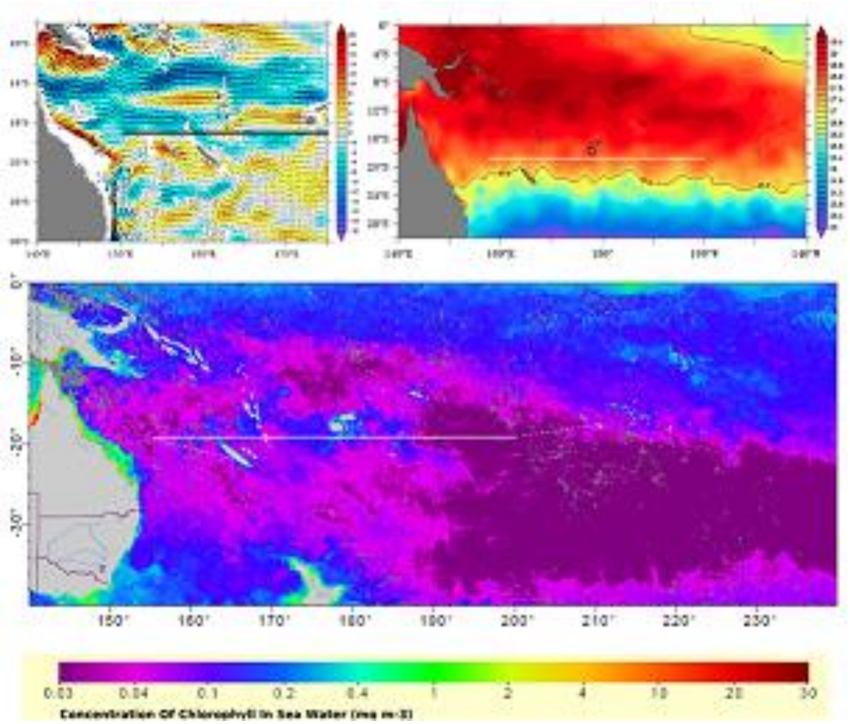


Global biomass distributions of diatoms (left hemisphere) and cyanobacteria (right hemisphere) in November 2007 as derived from SCIAMACHY data using the PhytoDOAS method. The insets show members of the two algae groups. (Graphics: A. Bracher IUP-IFE, University of Bremen and Alfred Wegener Institute for Polar and Marine Research, adapted from Bracher et al. 2009; photo diatoms: E. Allhusen, cyanobacteria: S. Kranz; both Alfred Wegener Institutefor Polar and Marine Research)

https://earth.esa.int/web/guest/missions/esa-operational-eo-missions/envisat/instruments/sciamachy-handbook/wiki/-/wiki/SCIAMACHY%20Handbook/Oligotrophic+Oceanic+Regions

OUTPACE

- **<u>O</u>**ligotrophy to **<u>U</u>**l**<u>t</u>**ra-Oligotrophy **<u>Pac</u>**ific **<u>E</u>**xperiment https://outpace.mio.univ-amu.fr/
- 18 Feb – 3 Apr 2015

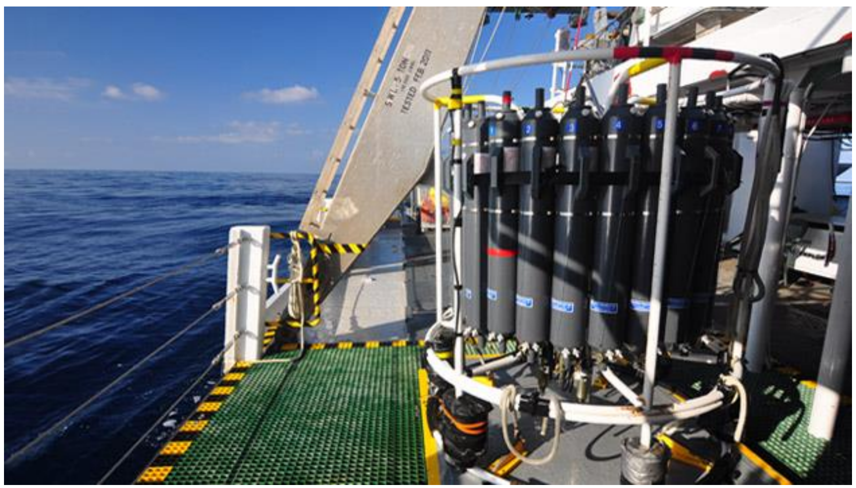


Video
http://solangeduhamel.wix.com/duhamellab

- Zonal description of biological diversity and biogeochemical functioning in Southwest Pacific

https://outpace.mio.univ-amu.fr/

Bermuda Institute of Oceanic Studies
Bermuda Atlantic Time-Series Study (BATS)



- Collect data over a long period of time to understand how the ocean responds to global climate change
- Sample throughout water column at multiple sites in Sargasso Sea
- CTD, tows, other sampling techniques

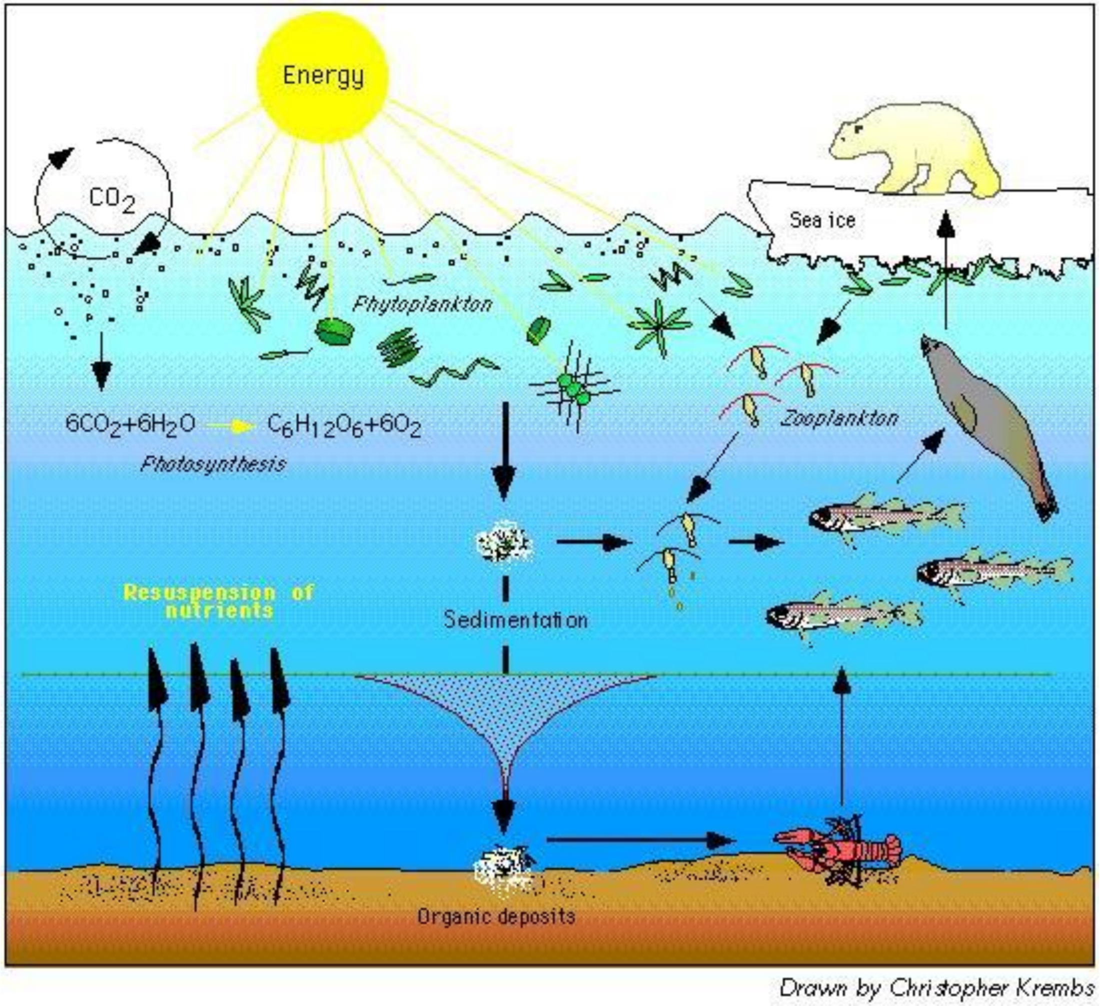
Andy Juhl

- Aquatic ecologist and oceanographer

- Coastal marine systems, estuaries, rivers, lakes
- Planktonic algae, protists, invertebrate zooplankton, bacteria
- Water quality – HABS, pollutants, hypoxia, etc.
- Arctic Sea-Ice Ecology

Important questions about sea-ice ecology

- What factors control the growth of algae inside of sea ice?
- How is the community of organisms inside sea ice connected with other arctic marine organisms?
- What is the fate of organic matter that builds up inside sea ice?



http://www.earthgauge.net/kids-archives/january2011_archives

Brine Channels Provide Habitats for Diatoms

- **Diatoms** have adapted to the conditions in brine channels

- Red, yellow, and green pigments often produce a brown “stain” on the underside of sea ice

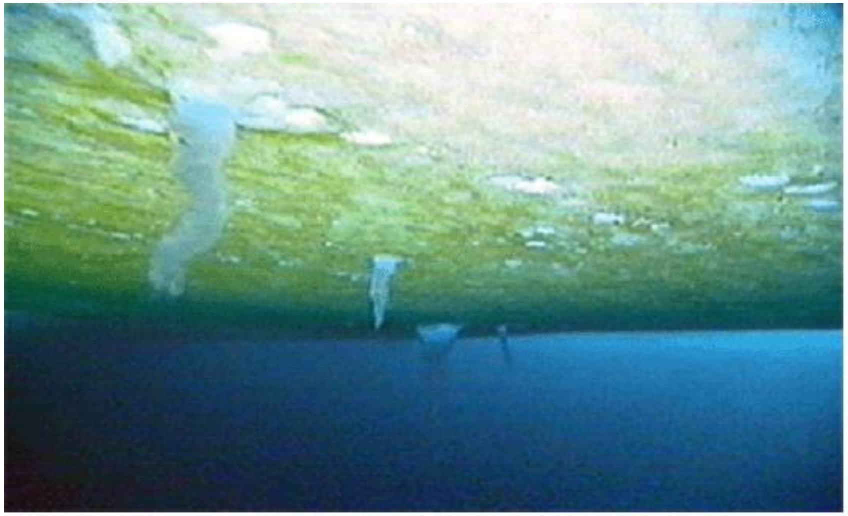


Photo courtesy Doug Allen, Change in Arctic Marine Production (CAMP) Project.

http://research.iarc.uaf.edu/amg/icephec3.gif

Sea Ice Microstructure

Depends on ice formation processes

- Wind and wave turbulence create **granular ice**
- Calm conditions produce **columnar ice**
- Usually, both form and can be seen in layers under a microscope

- **Ice crystals** consist of pure water, because the **dissolved salts are excluded during freezing**
- **Salinity** of liquid water increases, lowering the freezing point and increasing the density
- Some remains between crystals as **brine channels**

Phytoplankton “blooms”

- As polar night ends around the equinox, return of sunlight and melting of ice fosters “bloom” of algae that utilize the nutrients in surface waters

http://earthobservatory.nasa.gov/Features/Phytoplankton/

Andy's Videos

- "The Arctic's Secret Garden"
  https://vimeo.com/77549279
  https://vimeo.com/album/2578899

- Sampling NYC's Waterways after Hurricane Sandy
  http://www.ldeo.columbia.edu/~andyjuhl/Research_Movies.html