BIOS3300/4300 - Marine Biology

Primary Production (Plankton)
Spatial and temporal scales

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2024-09-04

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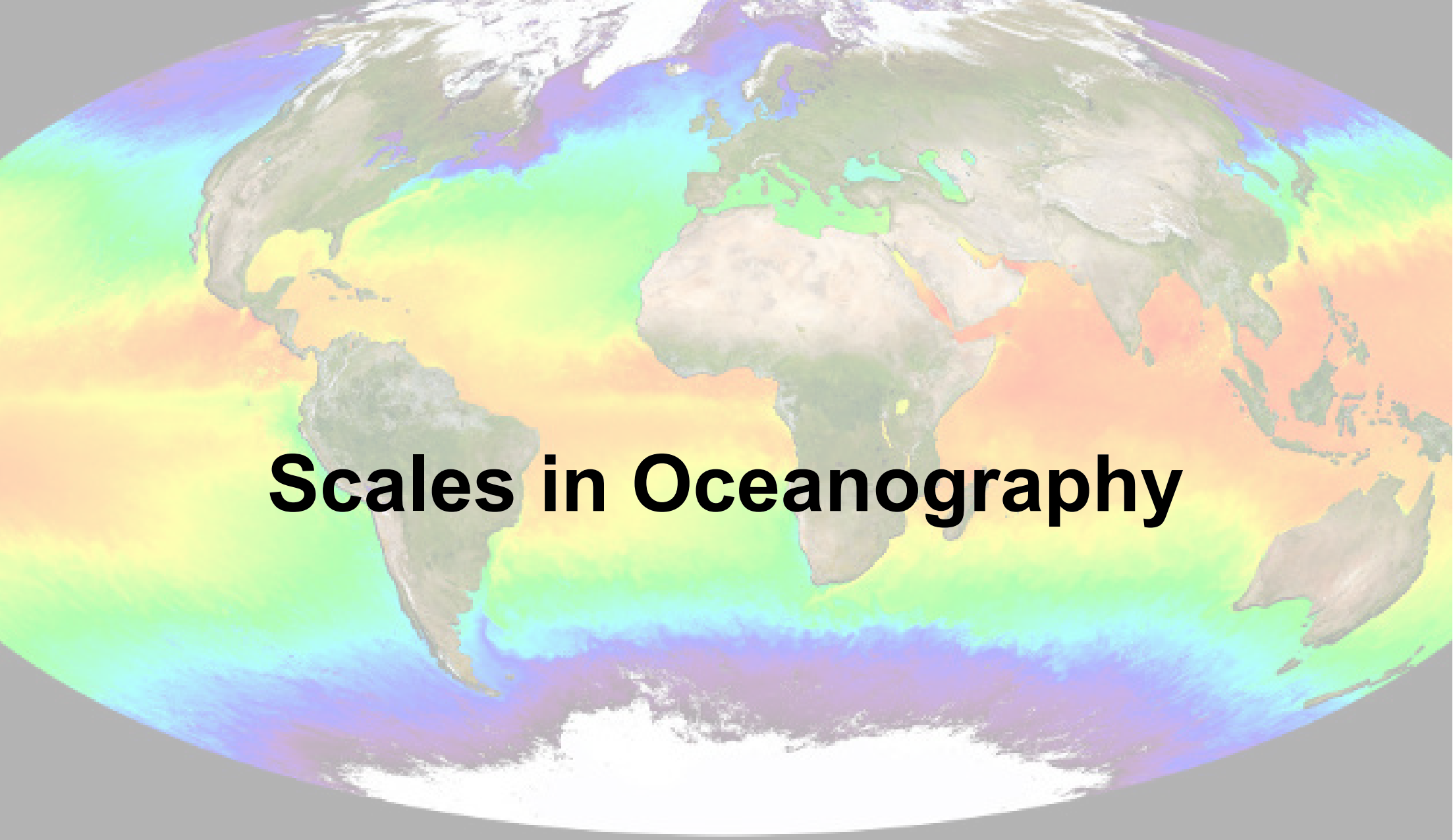
Outline

- Scales in the Ocean
- Ocean physics
- Sampling the Ocean
- Spatial Scales
  - Vertical
  - Horizontal
- Temporal Scales

Reference material

- Kaiser et al. 2020. Marine Ecology. 3rd ed - Chapter 2
- Garrison, T. & Ellis, R. 2016. Oceanography: An Invitation to Marine Science - Chapter 9

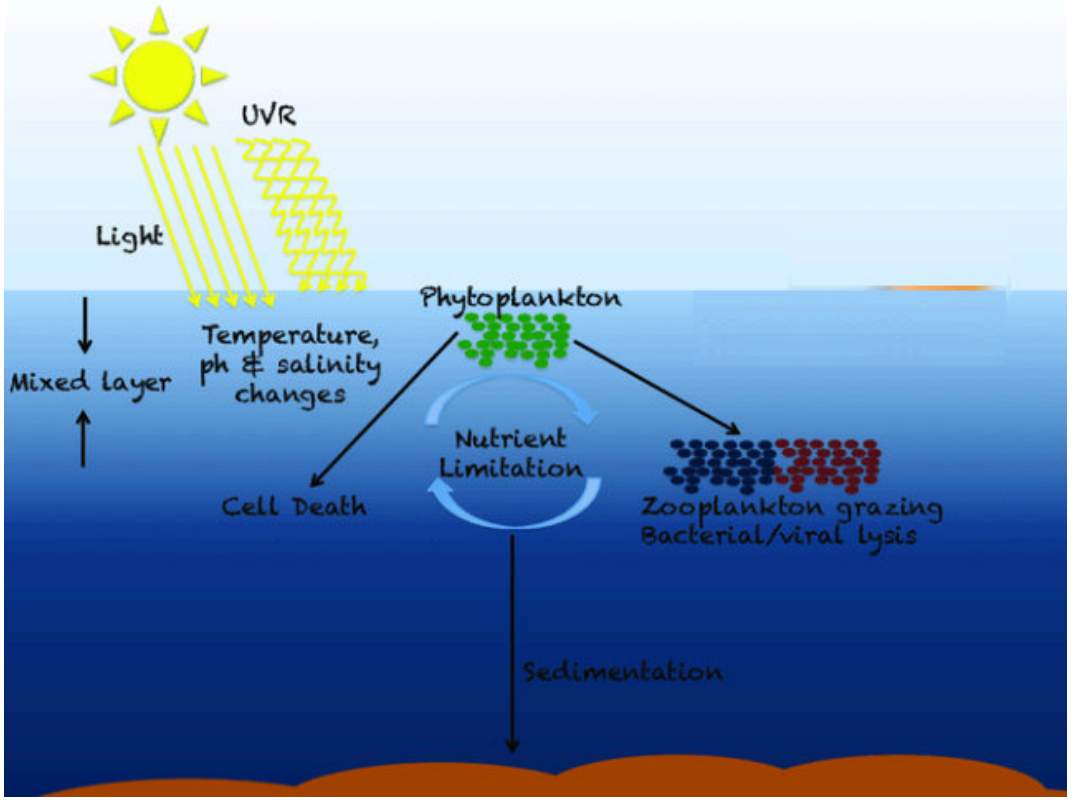
Scales in Oceanography



What controls phytoplankton abundance ?

What factors control phytoplankton abundance and diversity ?

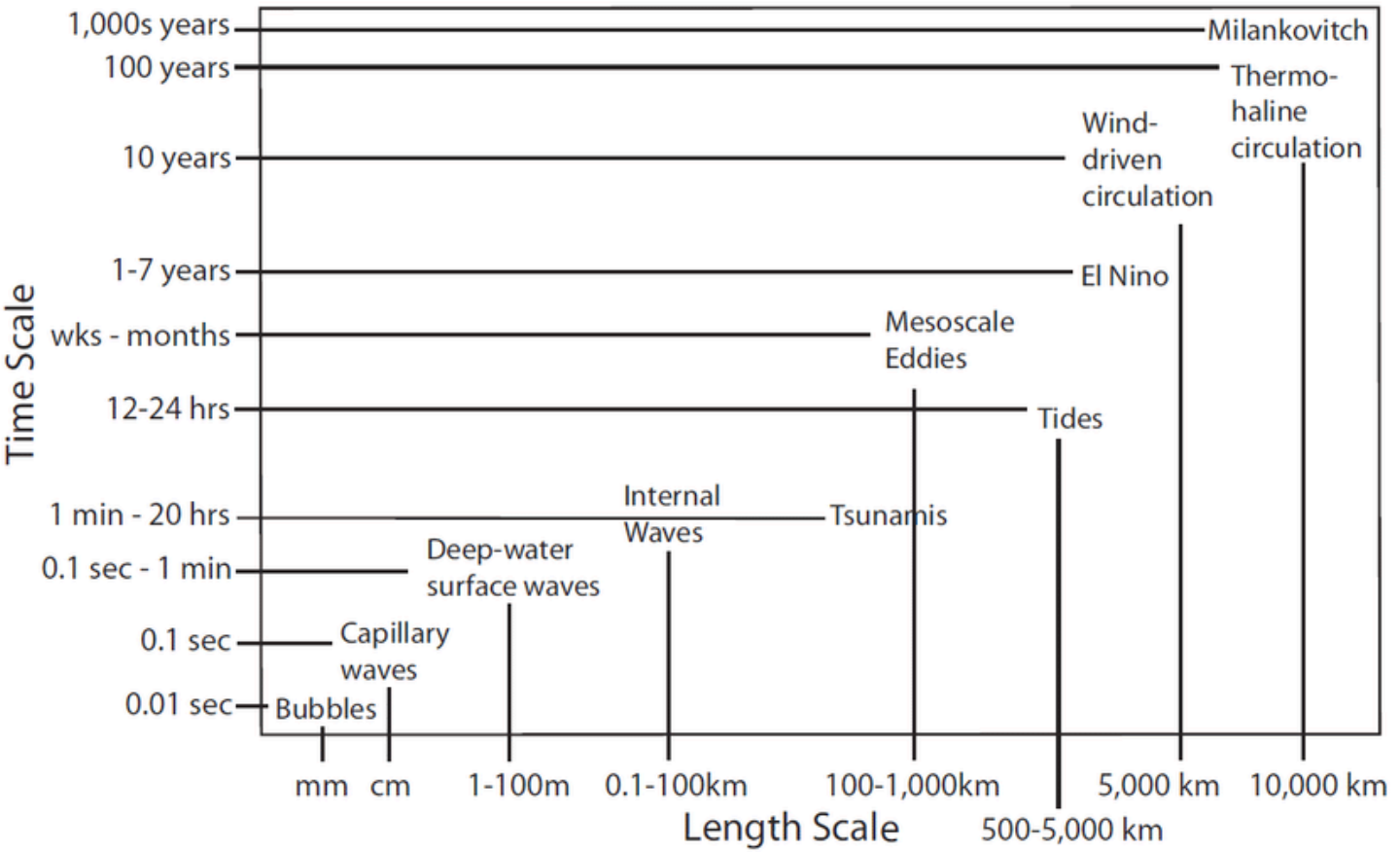
- Resources - Bottom up
  - Light
  - Nutrients (Nitrogen, Phosphorus)
  - Trace elements (Iron)
  - Temperature
  - Salinity
- Top down
  - Predation
  - Parasites (e.g. viruses)
  - Death
- Species selection
- These factors act at different scales

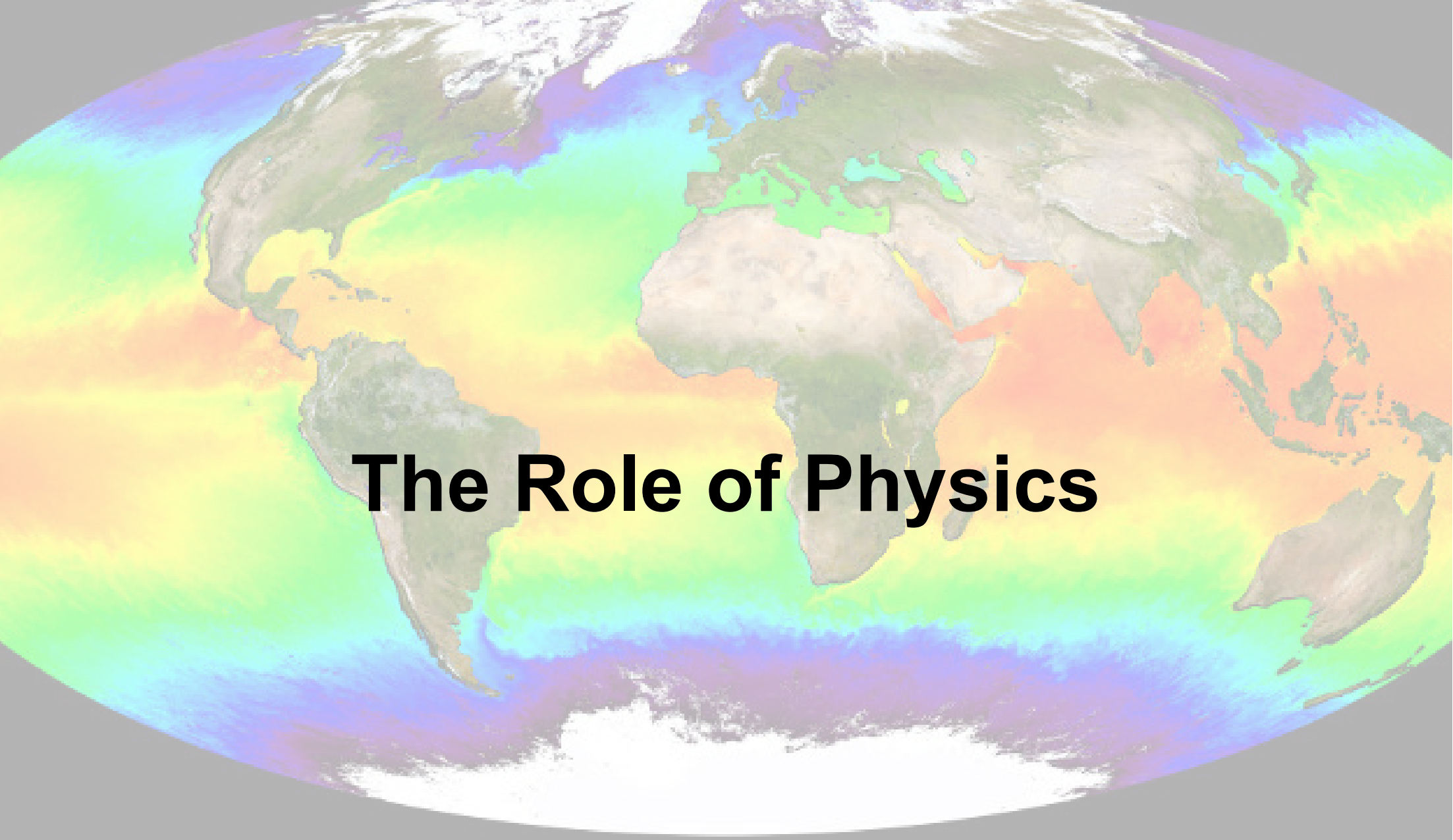


Scales - Space and Time

Can you name some scales in the ocean?

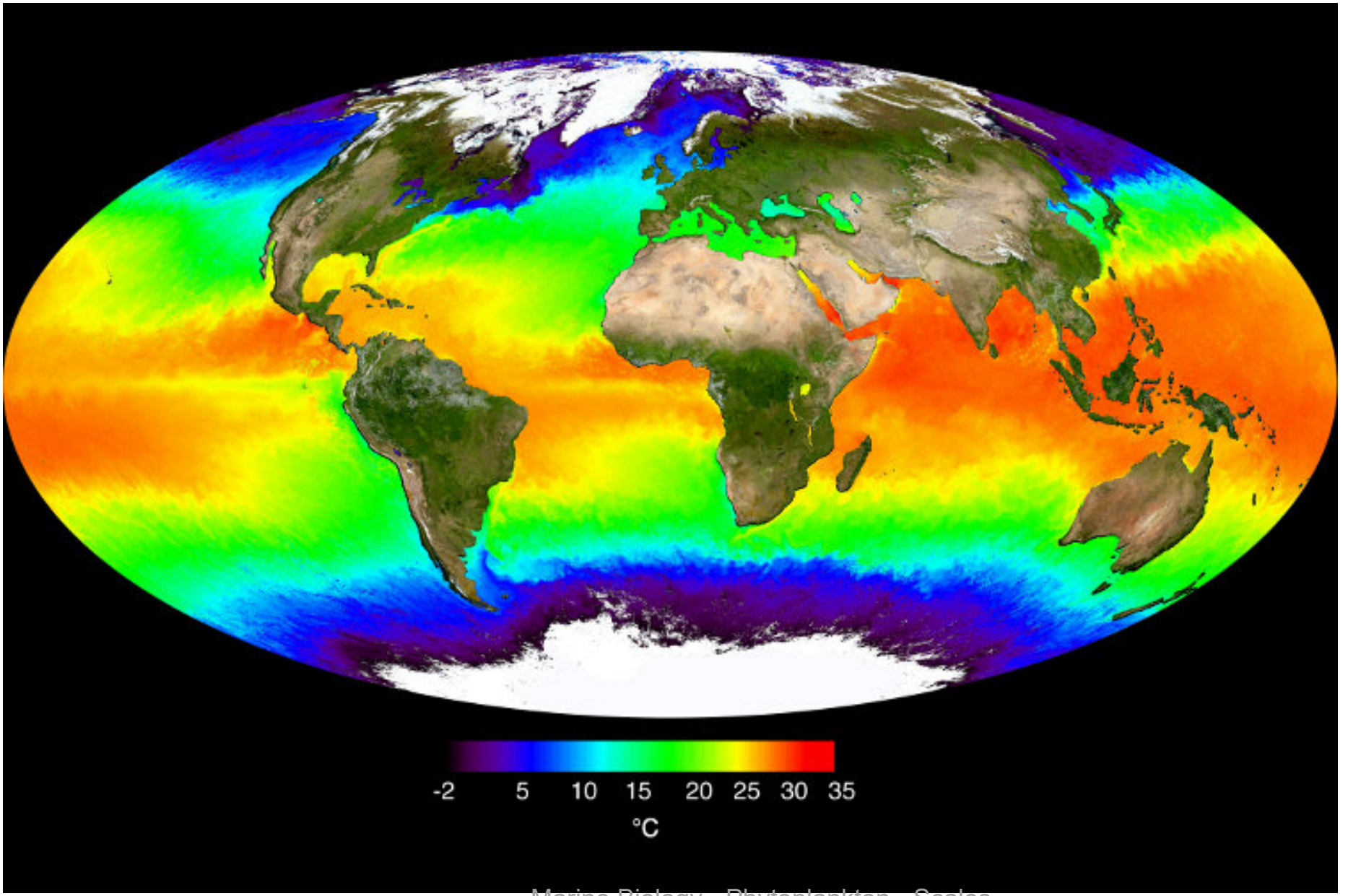
- Spatial
  - Horizontal
    - Basin
    - Region (upwelling)
    - Mesoscale
  - Vertical
    - Water column
    - Euphotic zone
- Temporal
  - Geological
  - Climate change
  - Climate oscillation
  - Eddies
  - Tides
  - Waves





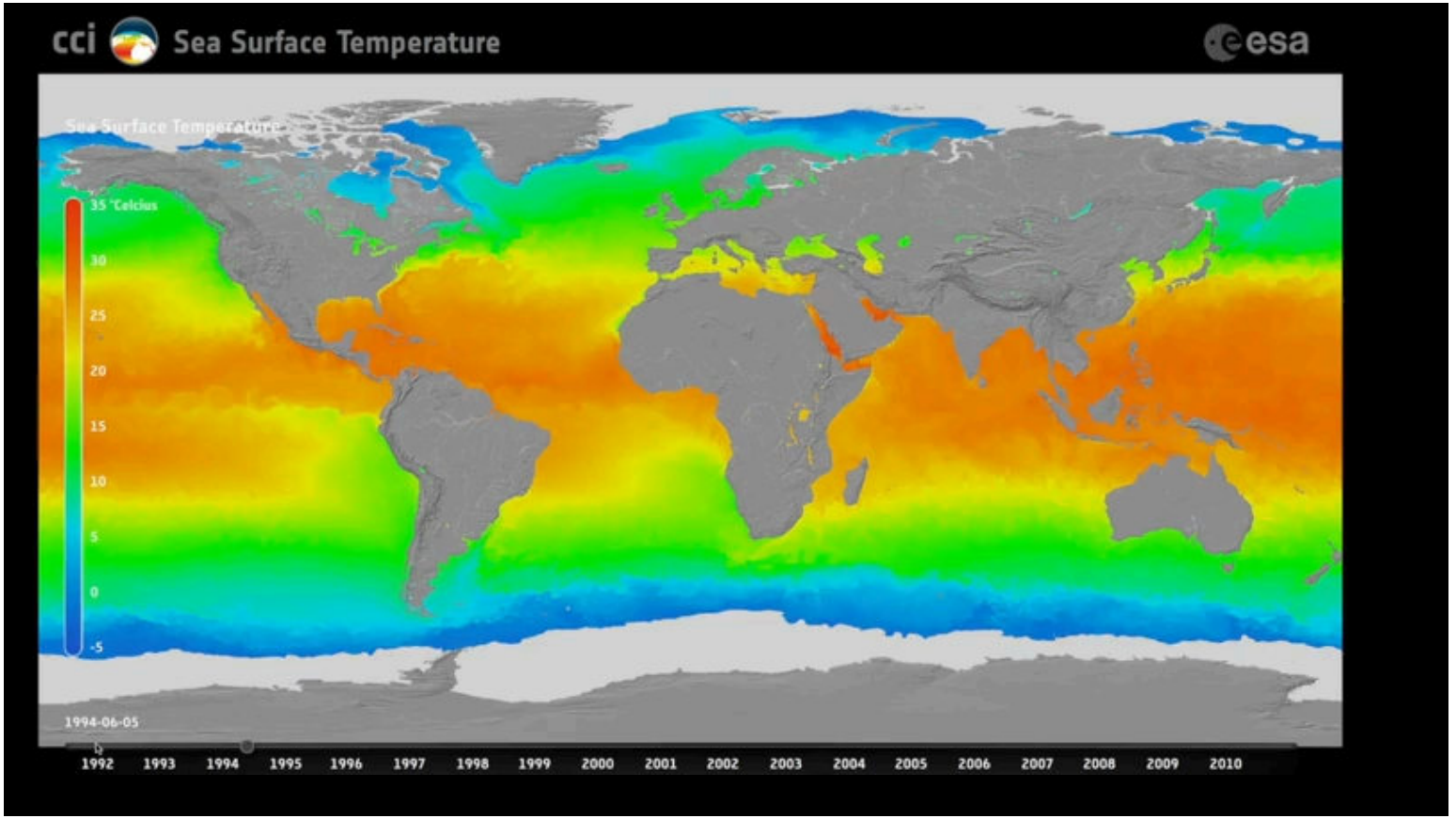
The Role of Physics

Temperature



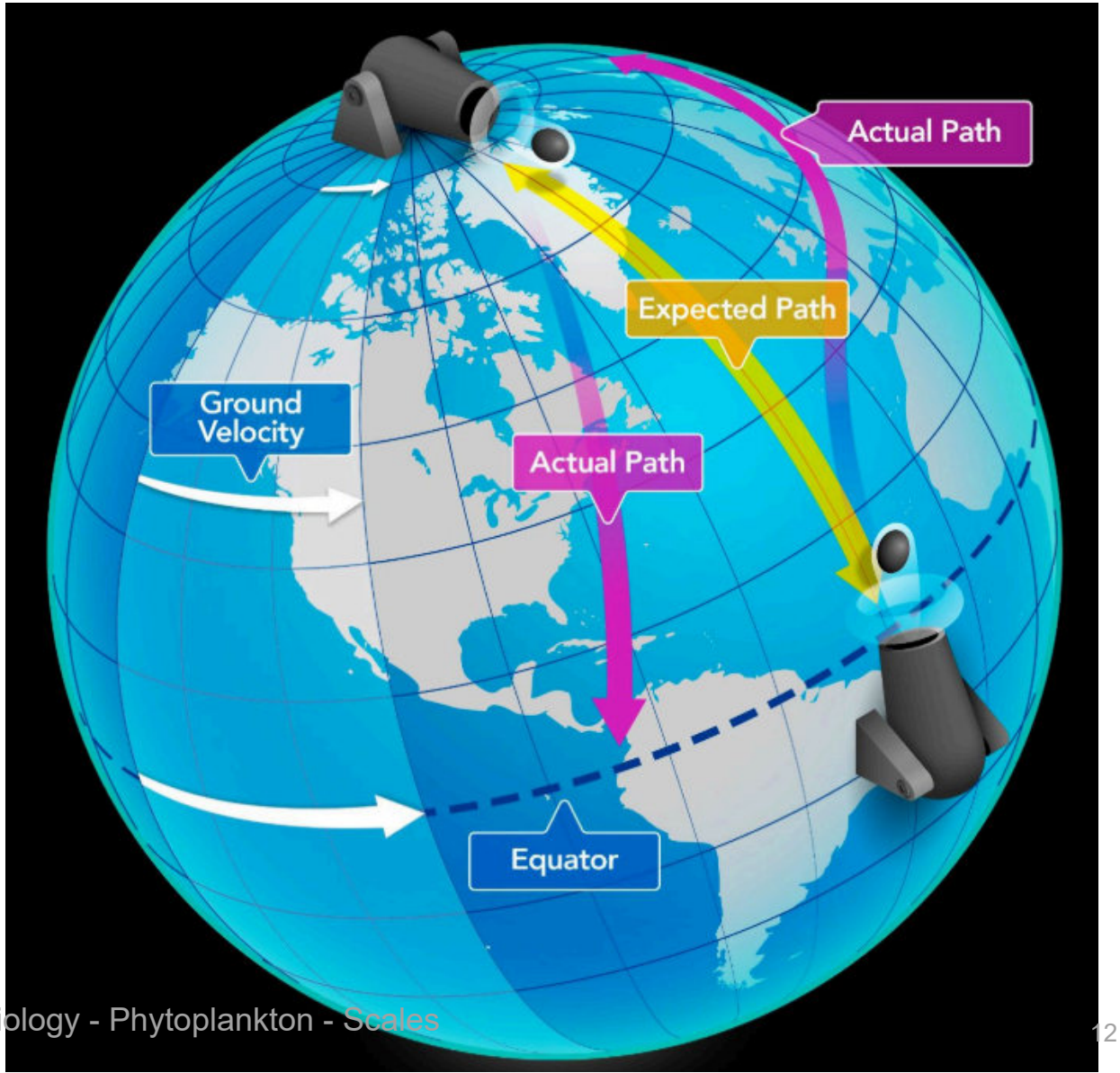
Marine Environment is highly dynamic

Sea temperature over 20 years



Currents

- Wind (Atmospheric Circulation)
- **Earth rotation** (Coriolis effect)
- Water density (Temperature, Salinity)
- Continents
- Turbulence



Currents

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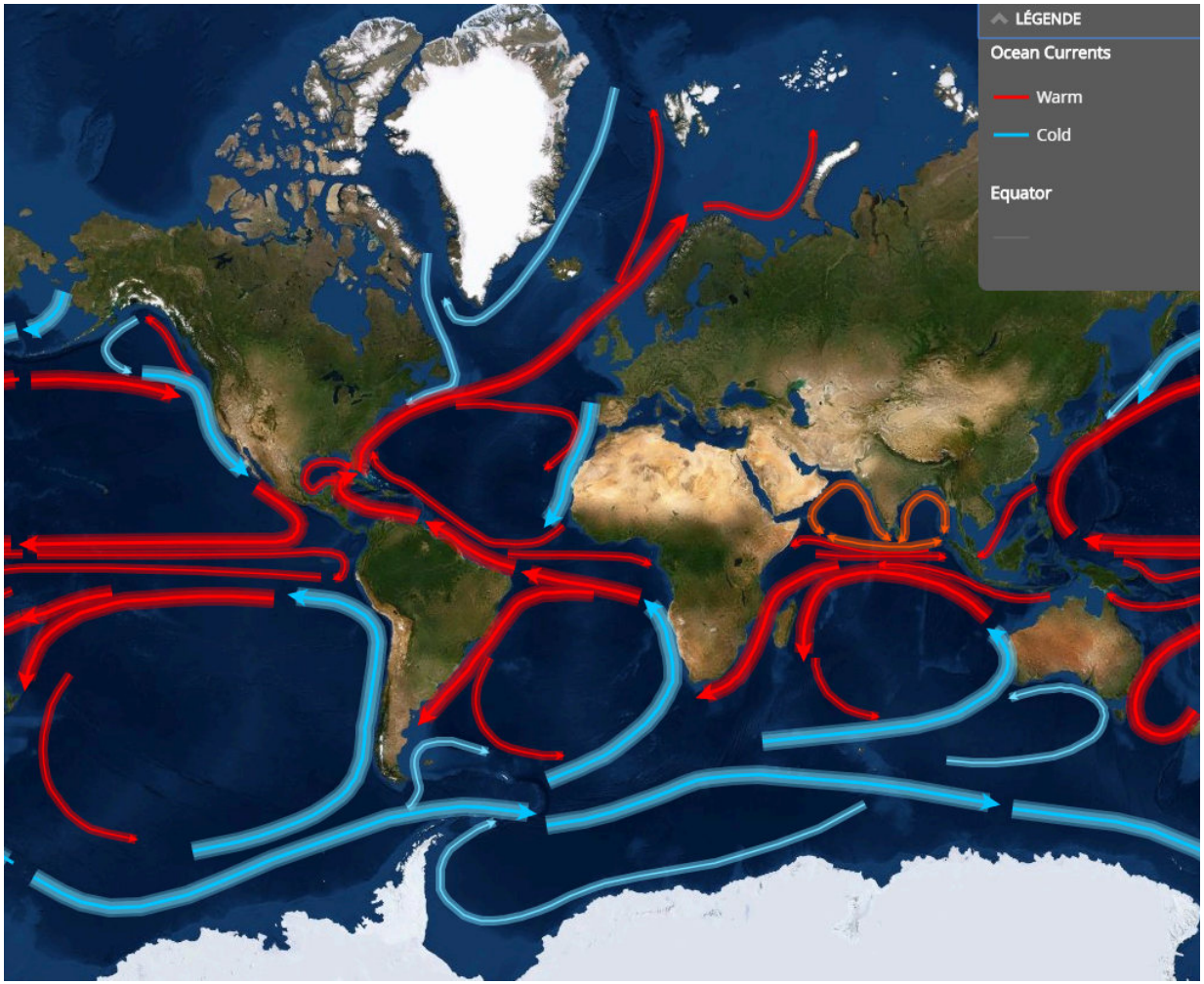
- Turbulence



Currents

- Wind (Atmospheric Circulation)
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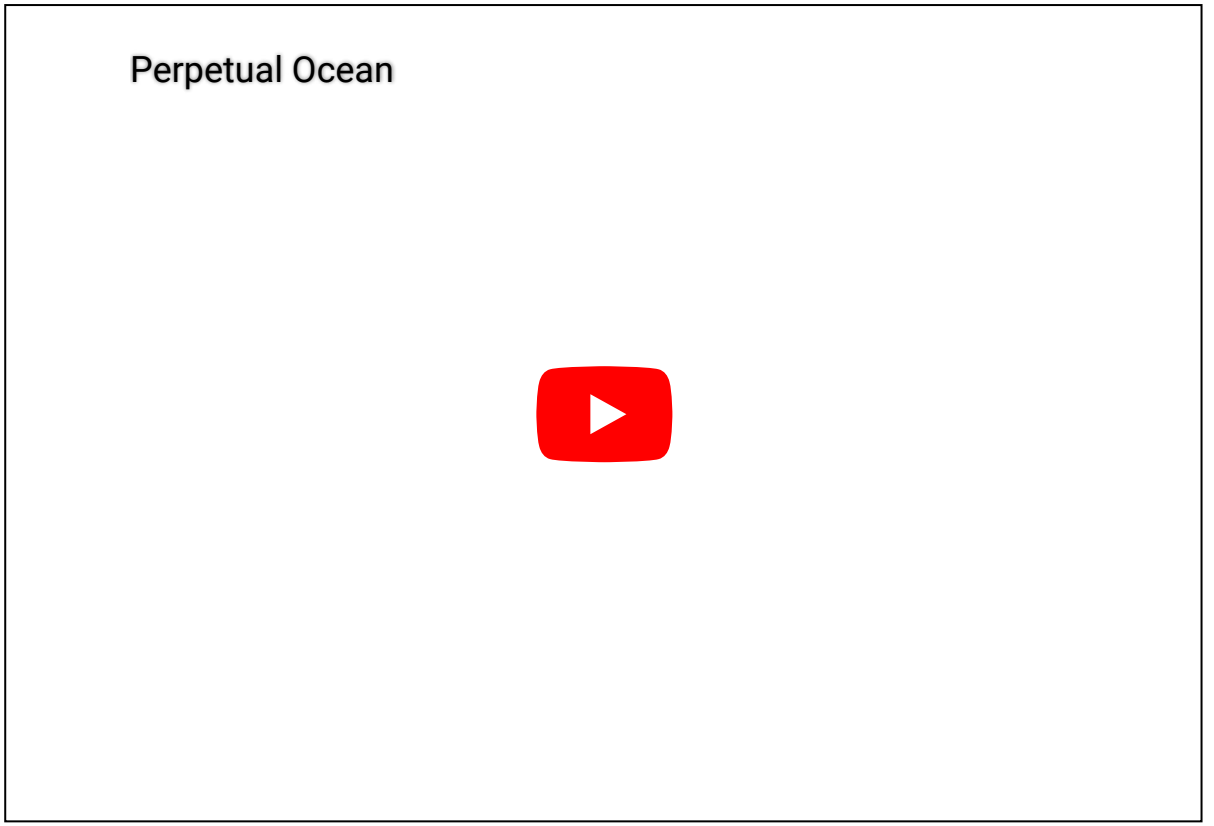
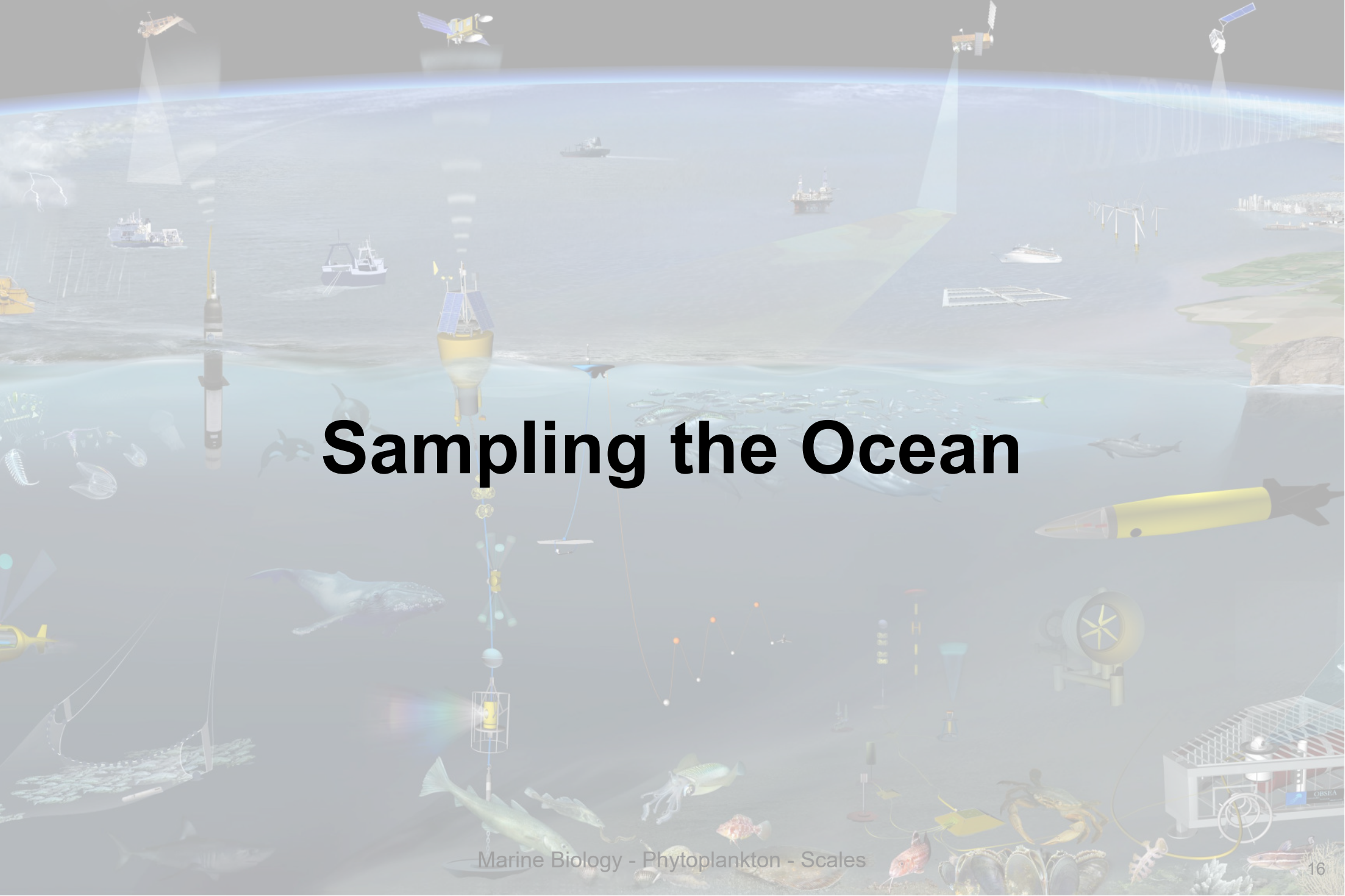
- **Turbulence**

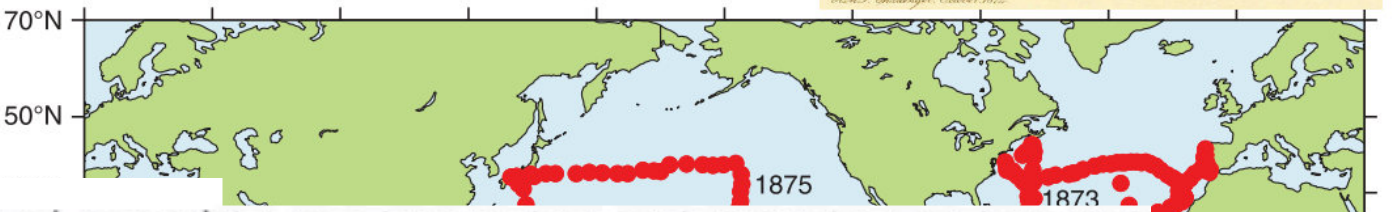


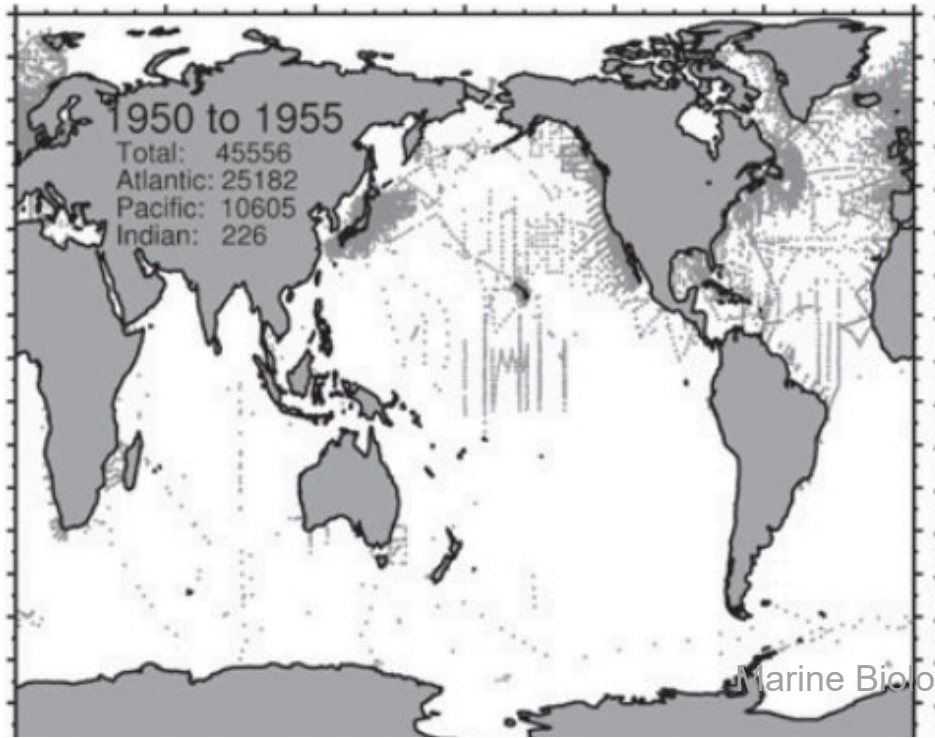


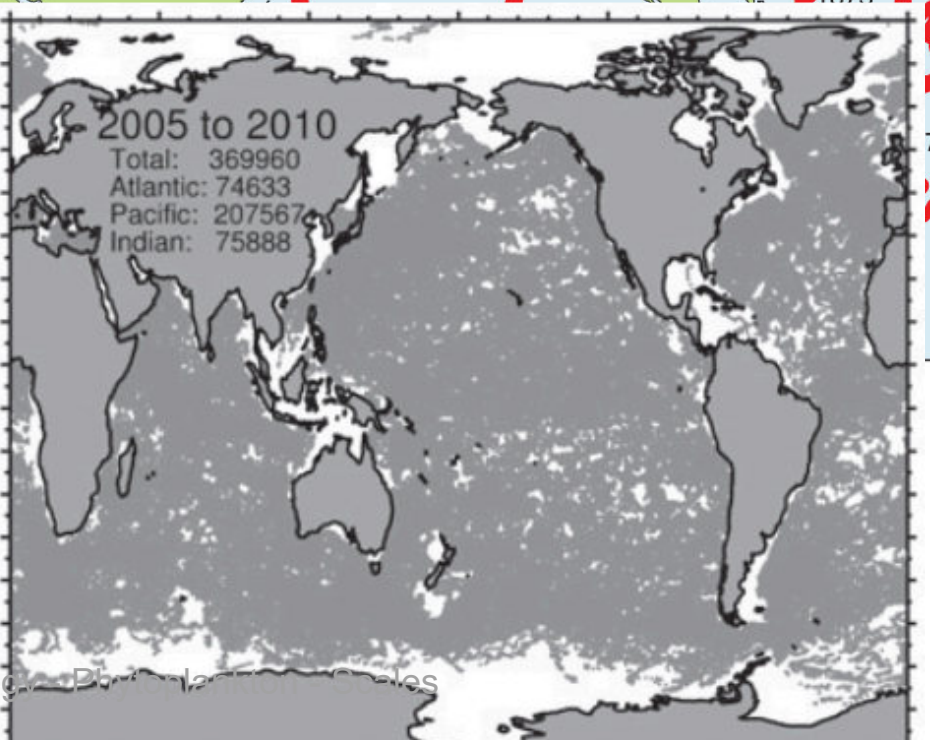
Sampling the Ocean

Sampling the ocean

- Challenger expedition
- Profiles over 5-years periods

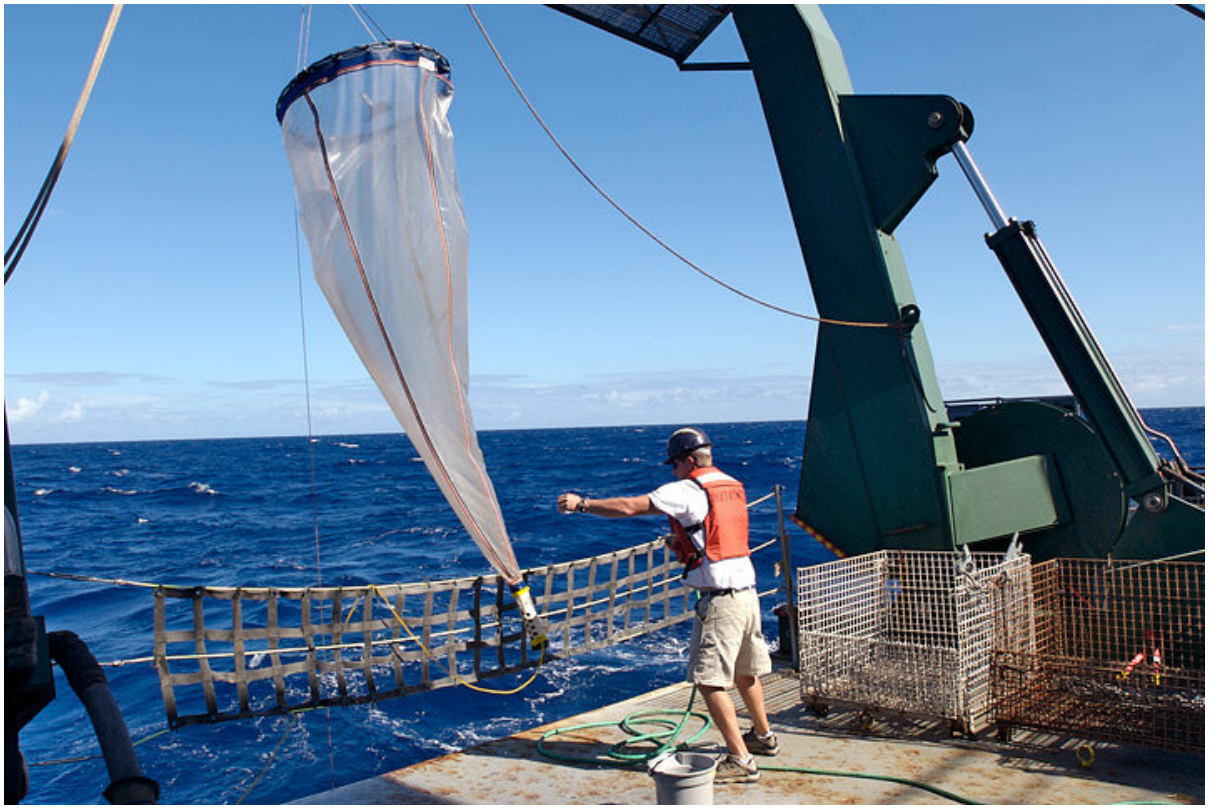






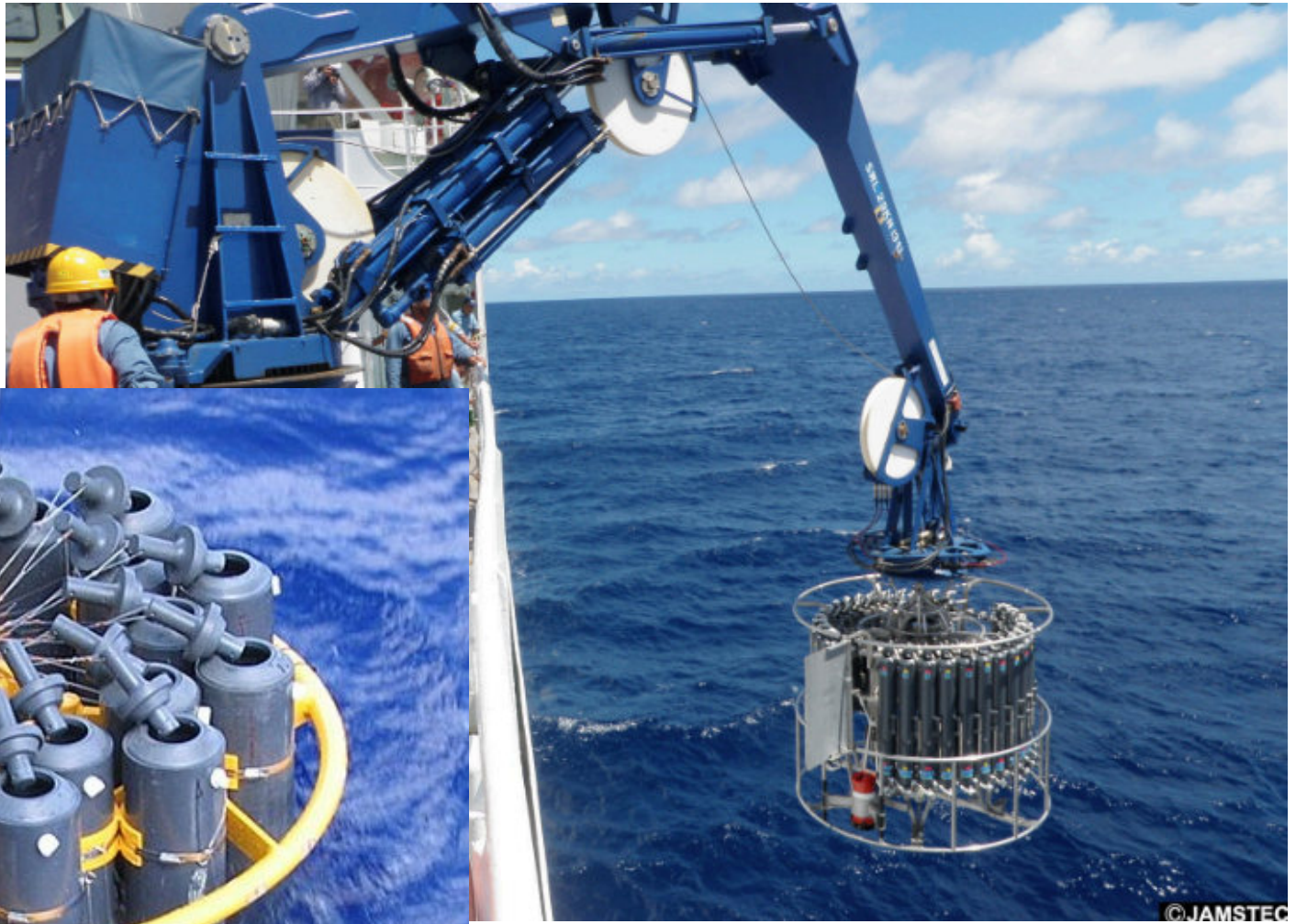
Sampling the ocean: Surface

- Bucket
- Nets



Sampling the ocean: Vertical profile

- Bottles on a Rosette
- CTD
  - Conductivity
  - Temperature
  - Depth

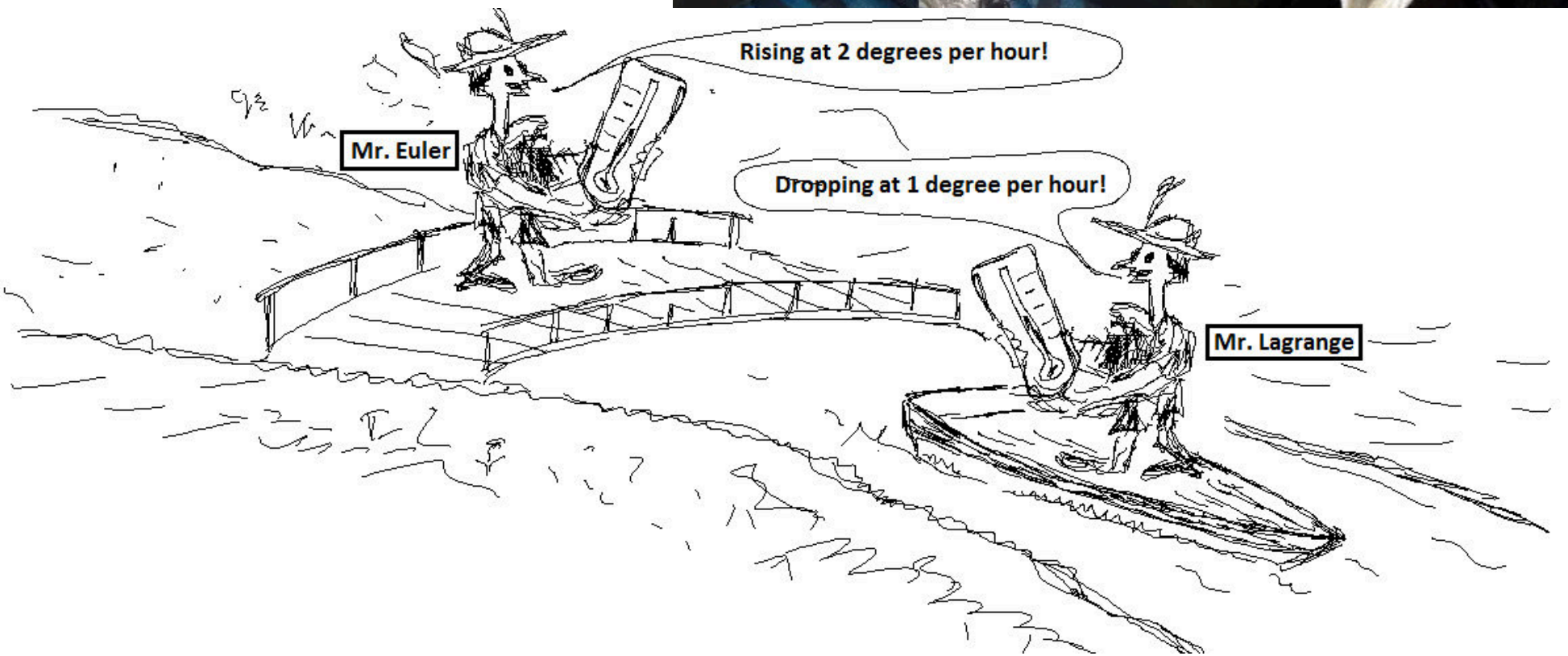


Sampling the ocean

Sampling the ocean

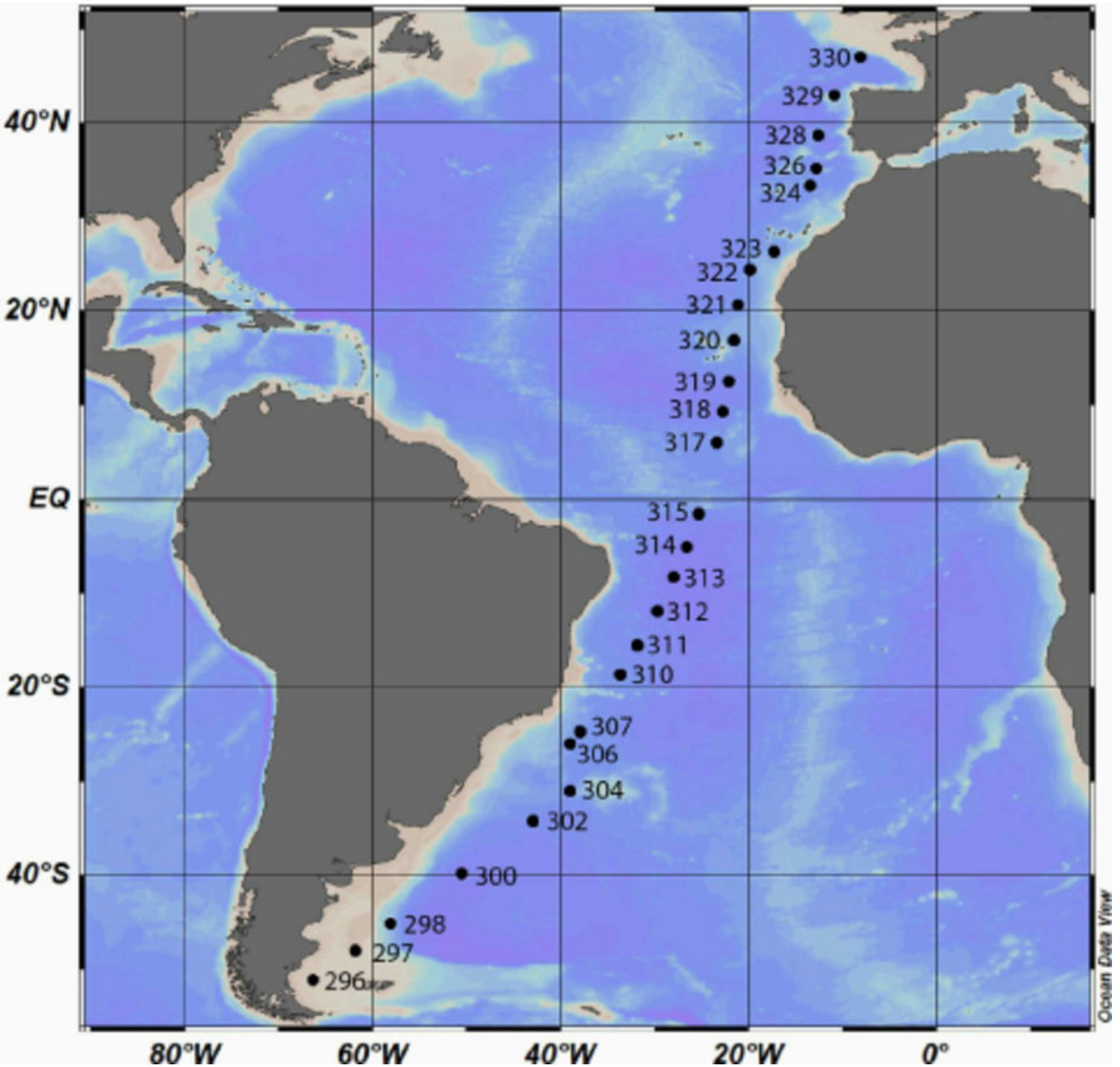
- Eulerian
- Lagrangian

What is the difference ?



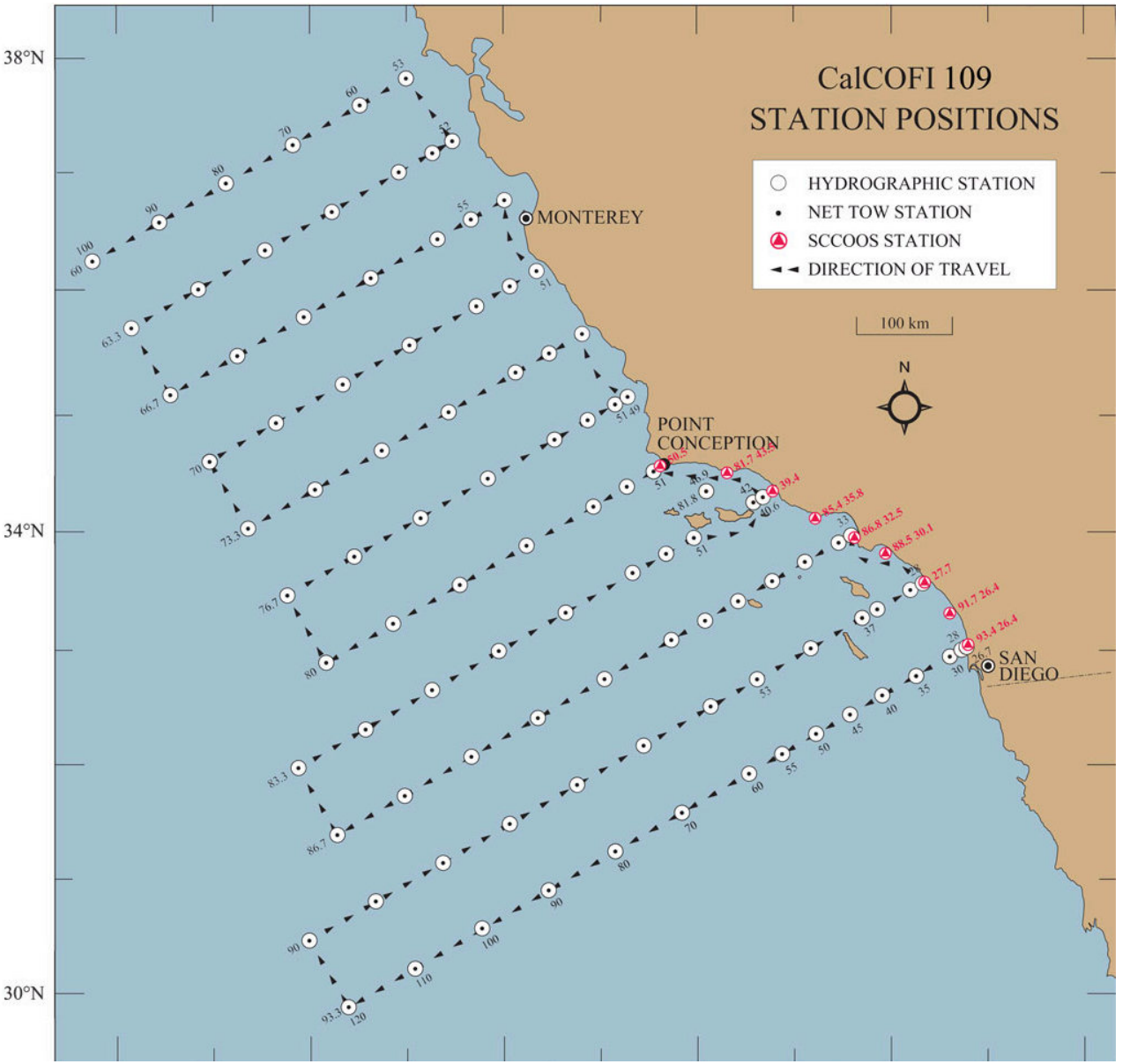
Sampling the ocean

- Transects (Eulerian)



Sampling the ocean

- Grids (Eulerian)



Sampling the ocean

- Drifting buoy (Lagrangian)

What are the advantages of Lagrangian ?

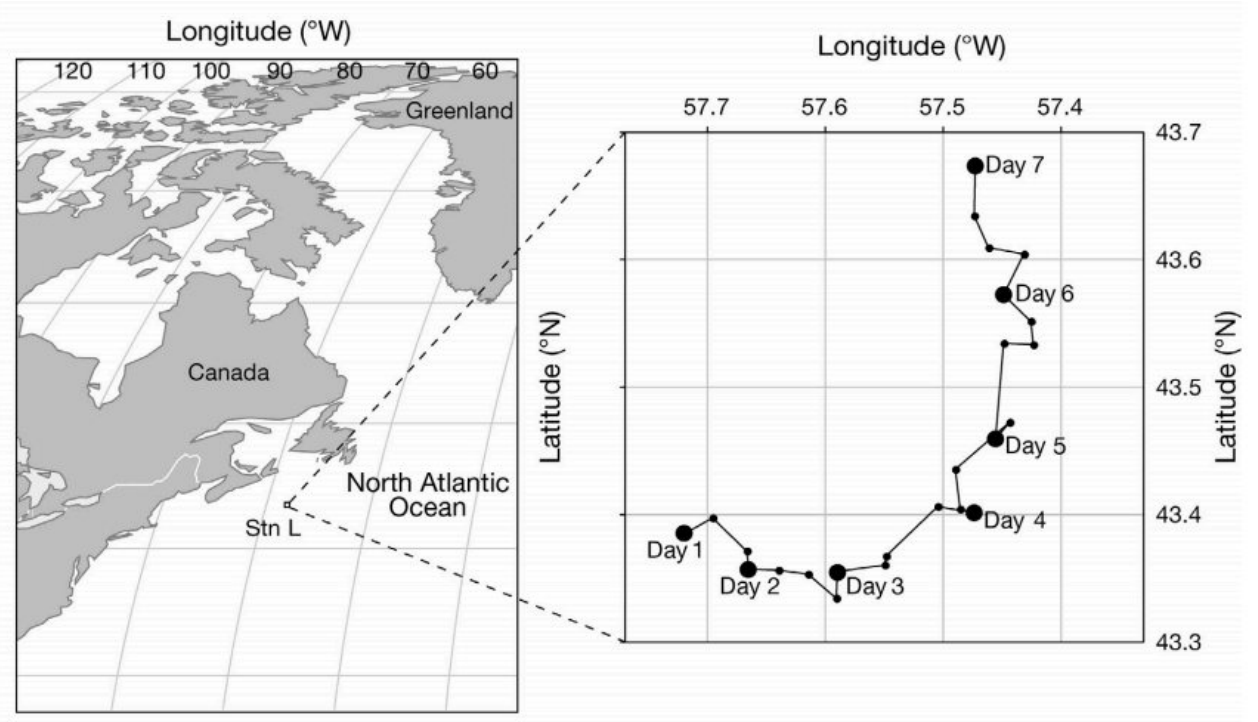


Fig. 1. Location of the Lagrangian station in the northwest Atlantic Ocean over the 7 day period (Day 1 to Day 7). Position of the drifting buoy at every 6 h time point is indicated

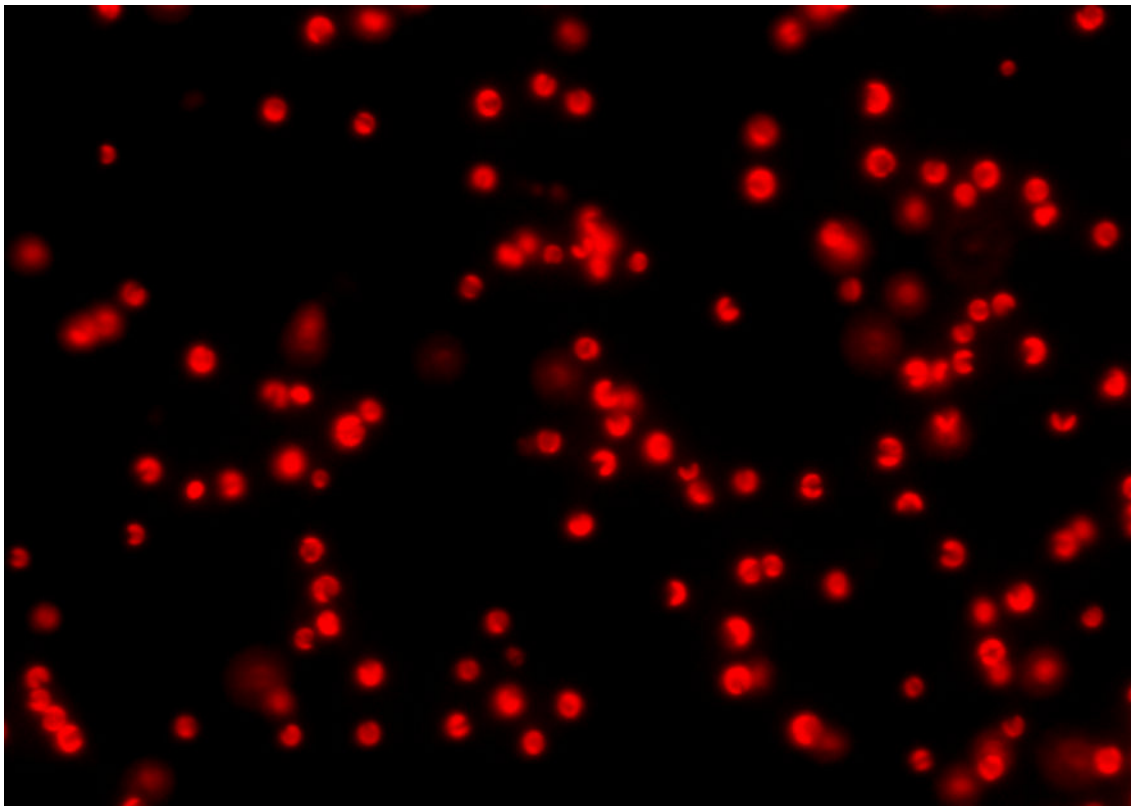
Lizotte et al.(2008) Fate of dimethylsulfoniopropionate (DMSP)... Aquat Microb Ecol 52:159-175

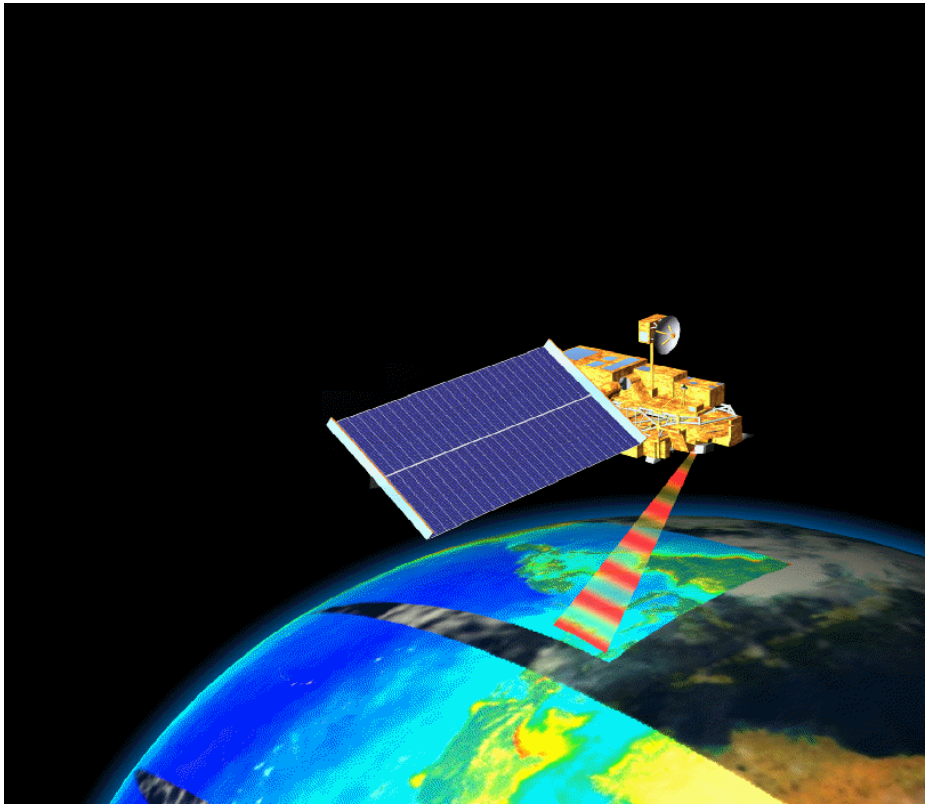
Satellite view

Phytoplankton contains chlorophyll:

- absorbs light
- fluoresces

Satellites measure ocean color

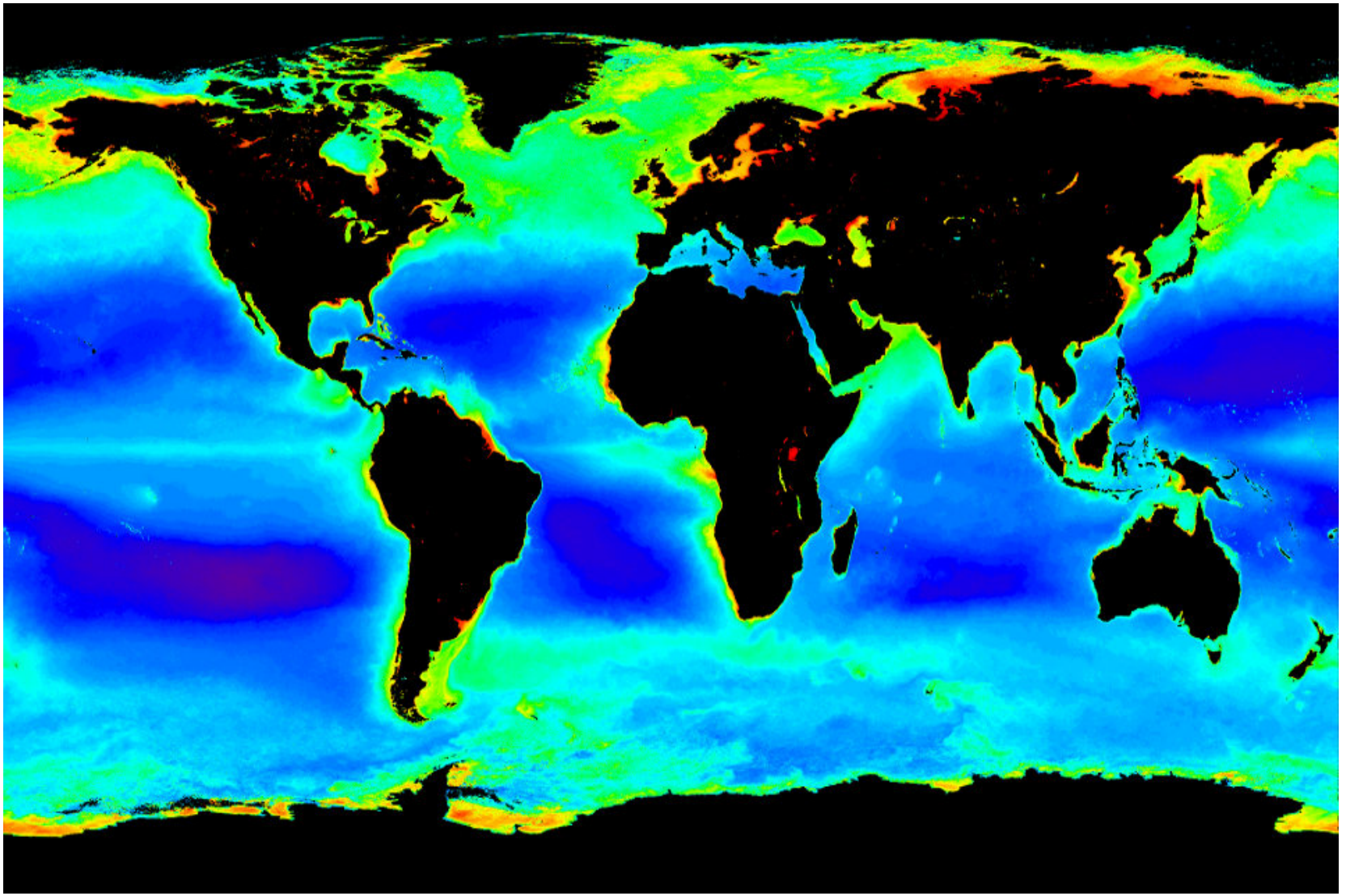




Satellite view

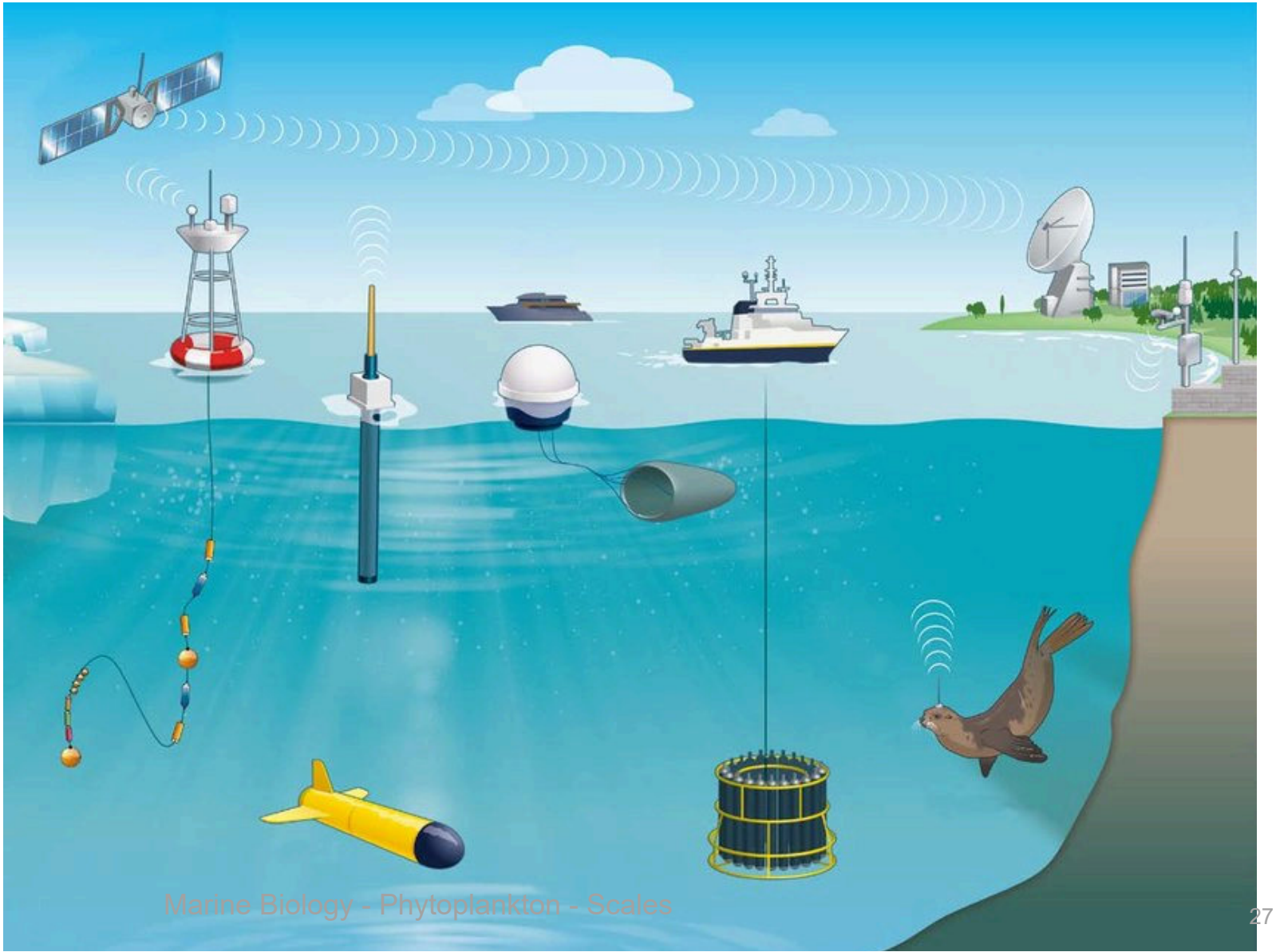
Numerous features can be seen.

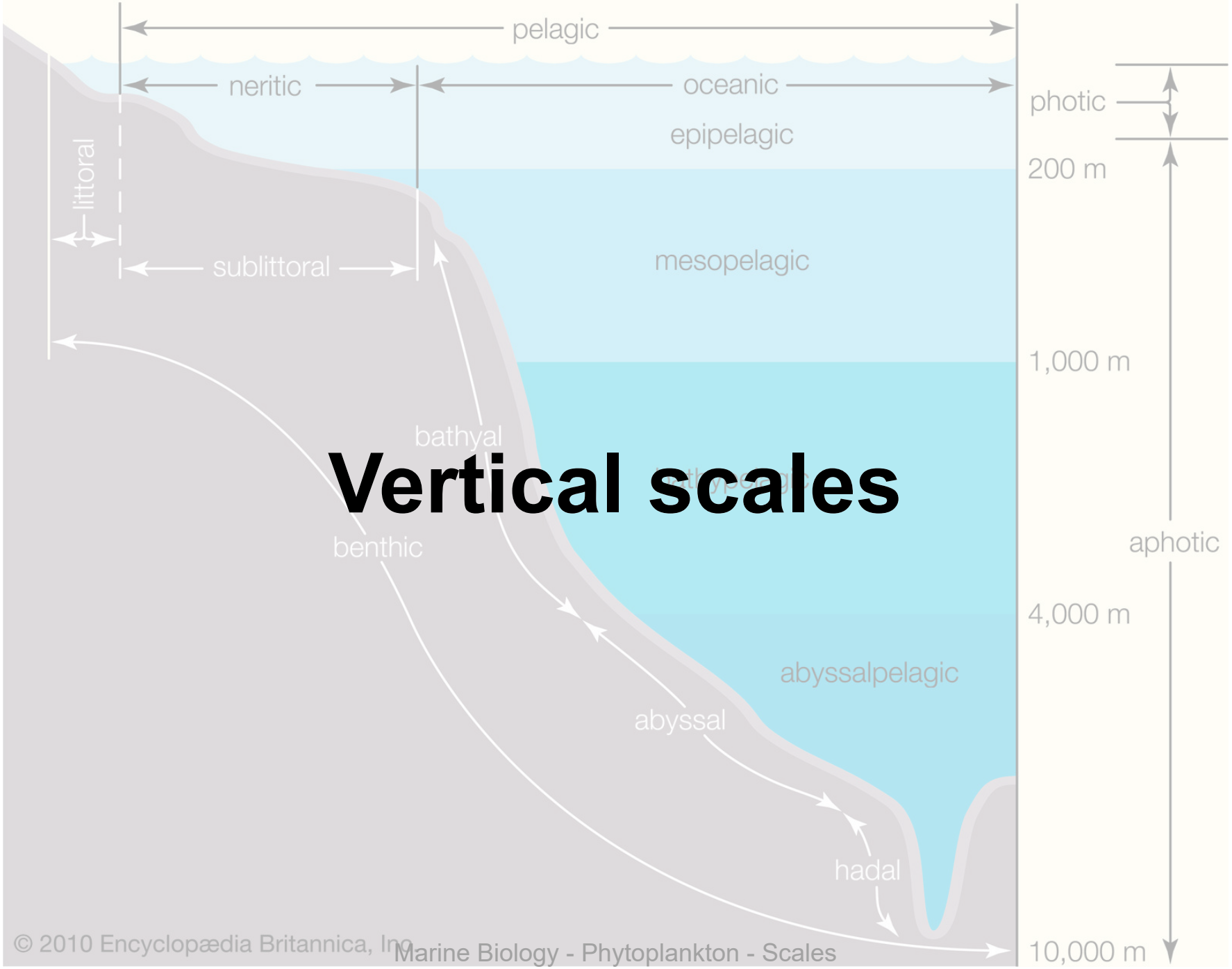
Limitations ?



Multi-instrument strategy

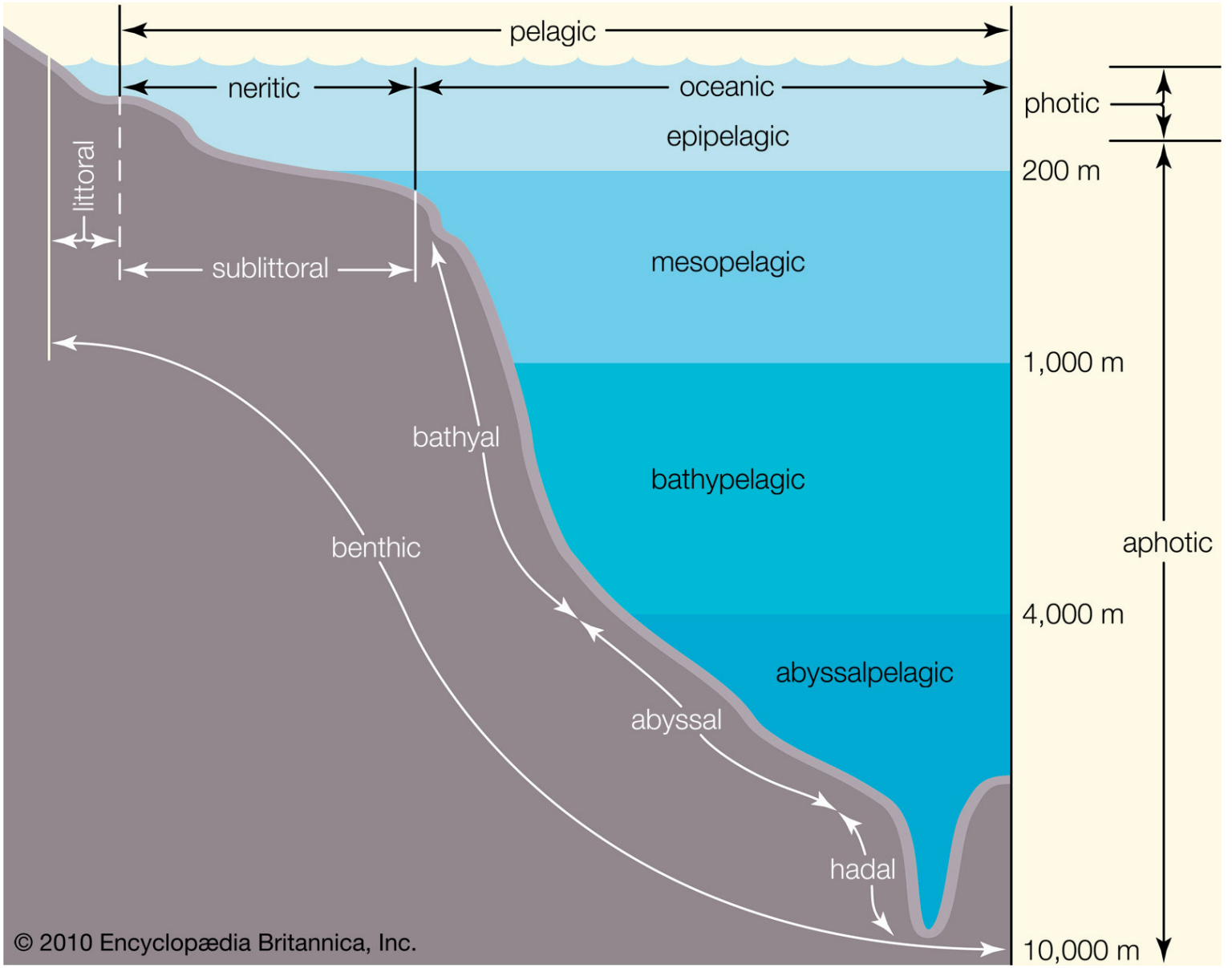
- Ship
- Fixed buoy
- Drifting floats
- Gliders
- Mammals





Vertical scales

Water column



Compensation depth

Photosynthesis vs. Respiration

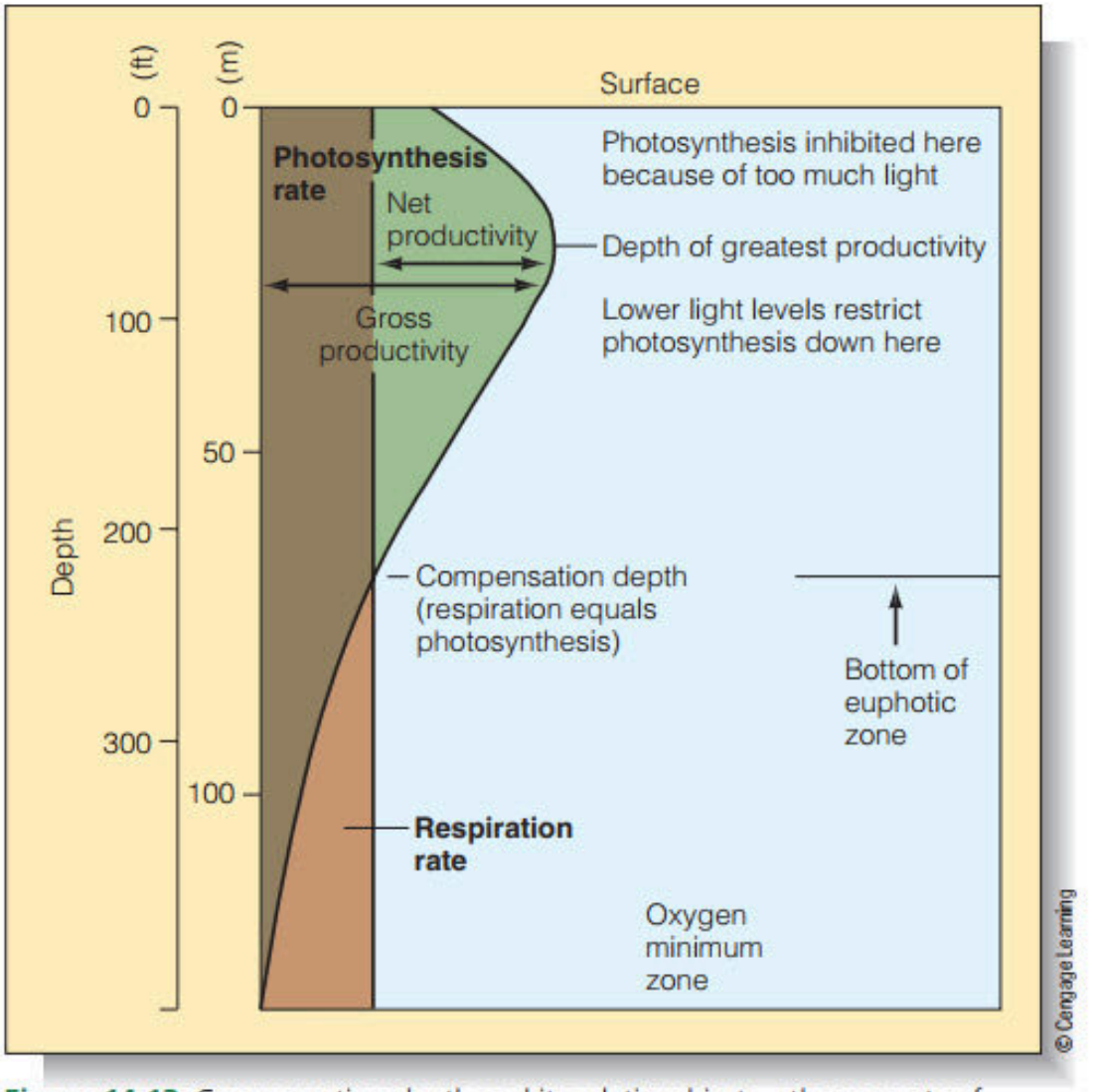
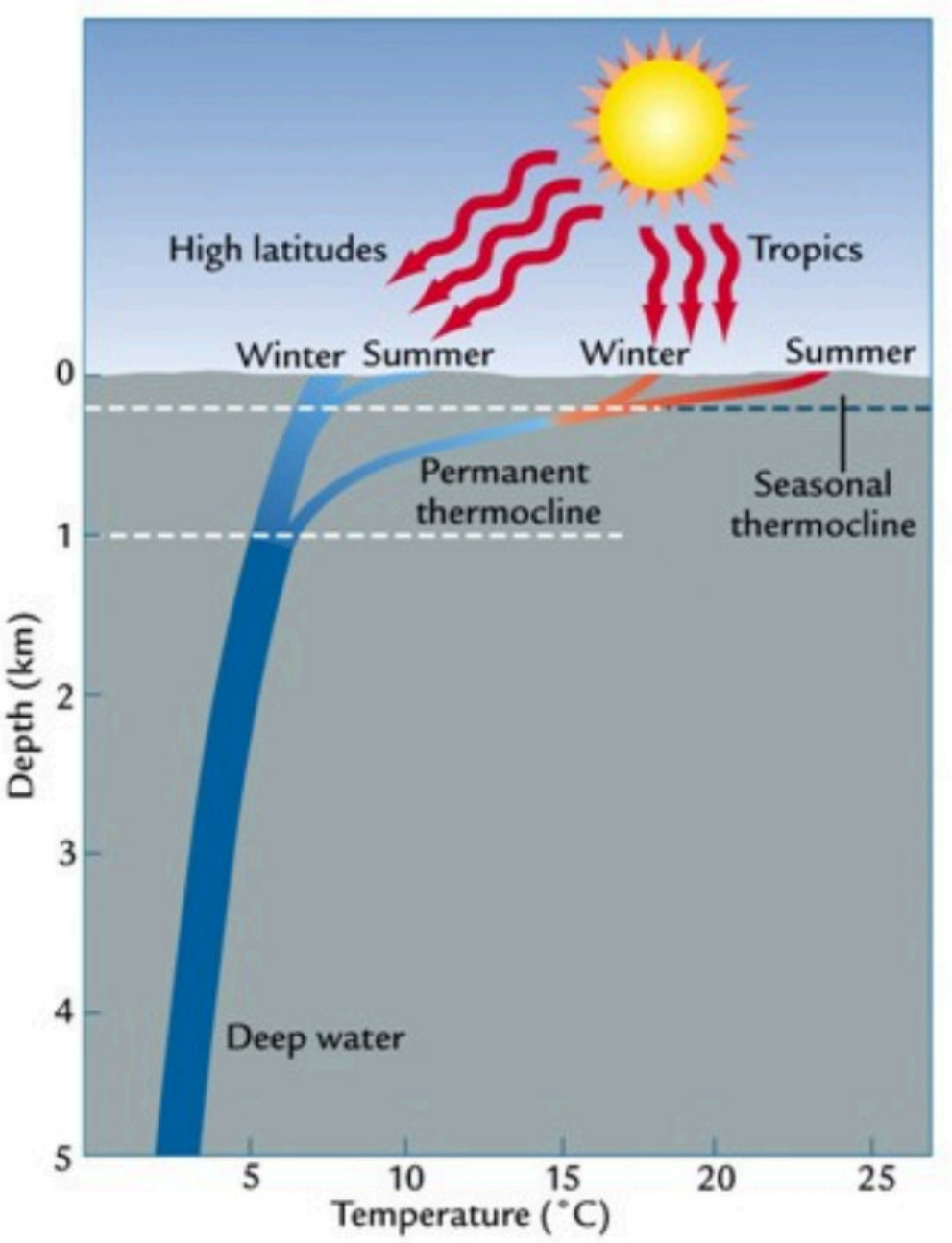


Figure 14.13 Compensation depth and its relationship to other aspects of productivity. Note the position of the bottom of the euphotic zone.

Euphotic layer

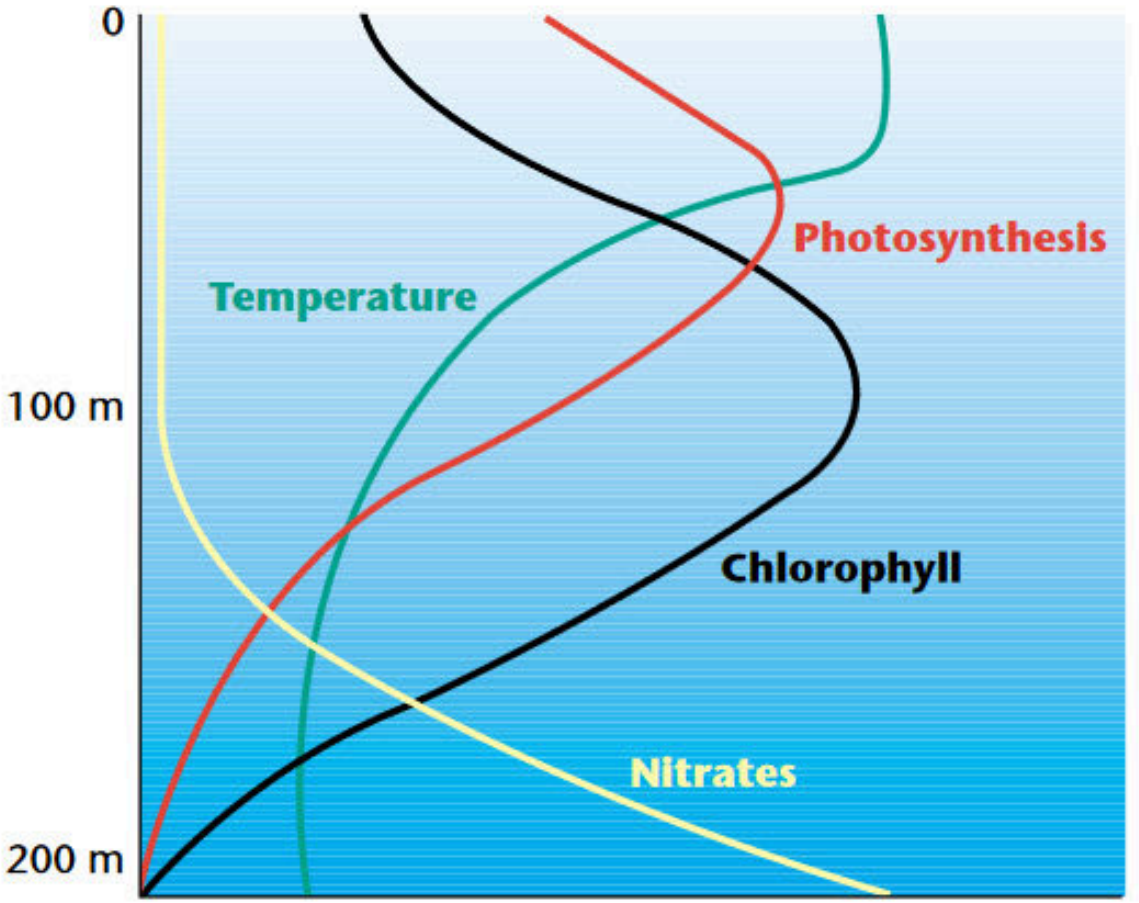
- Temperature structure
- Thermocline



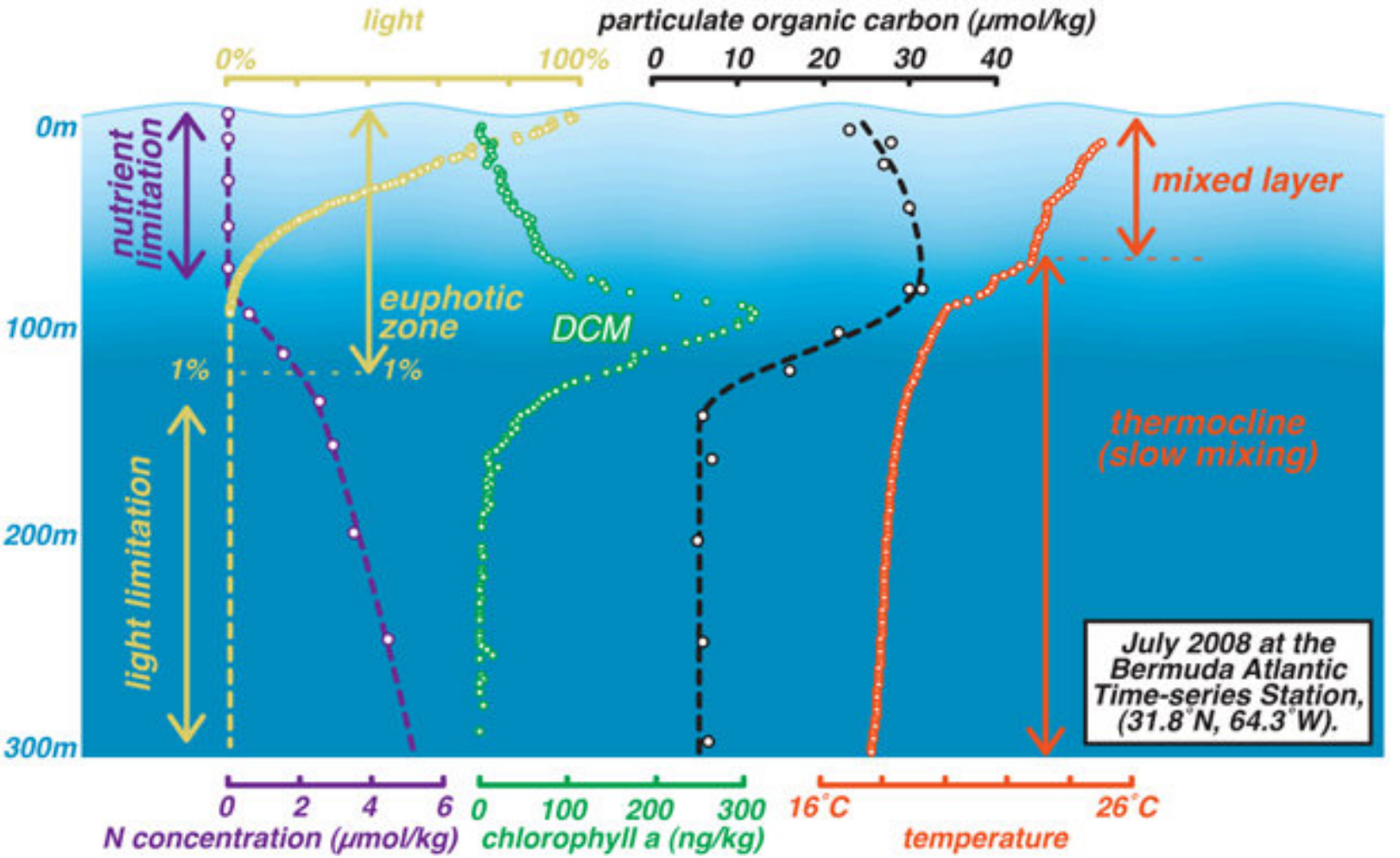
Chlorophyll maximum

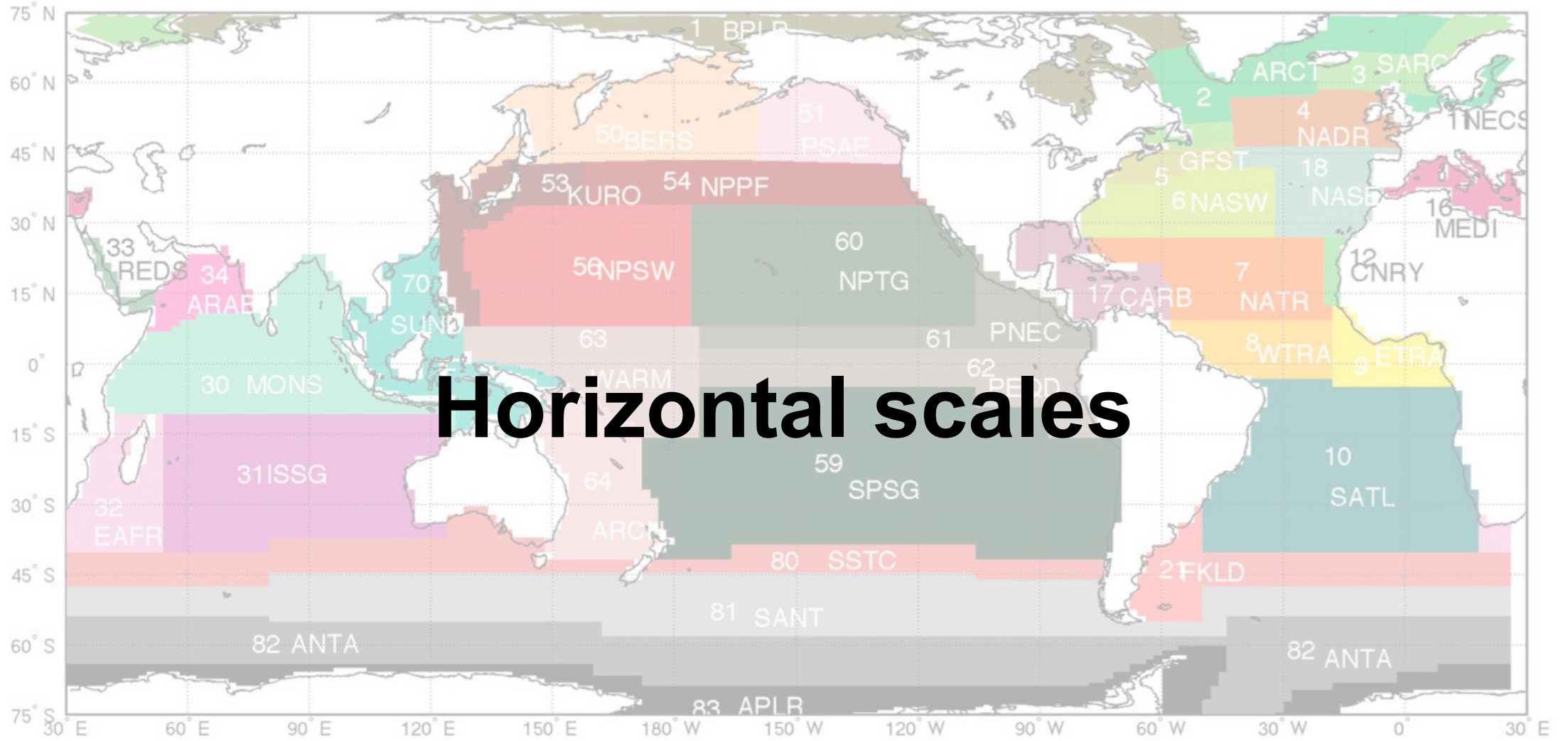
Is phytoplankton abundance maximum at surface ?

Why is production maximum above that of chlorophyll ?



Chlorophyll maximum

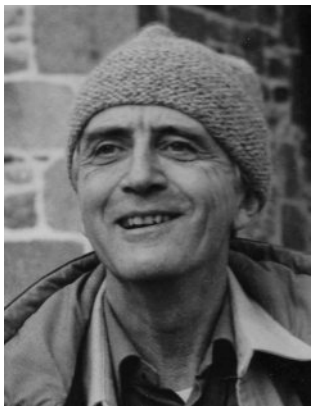




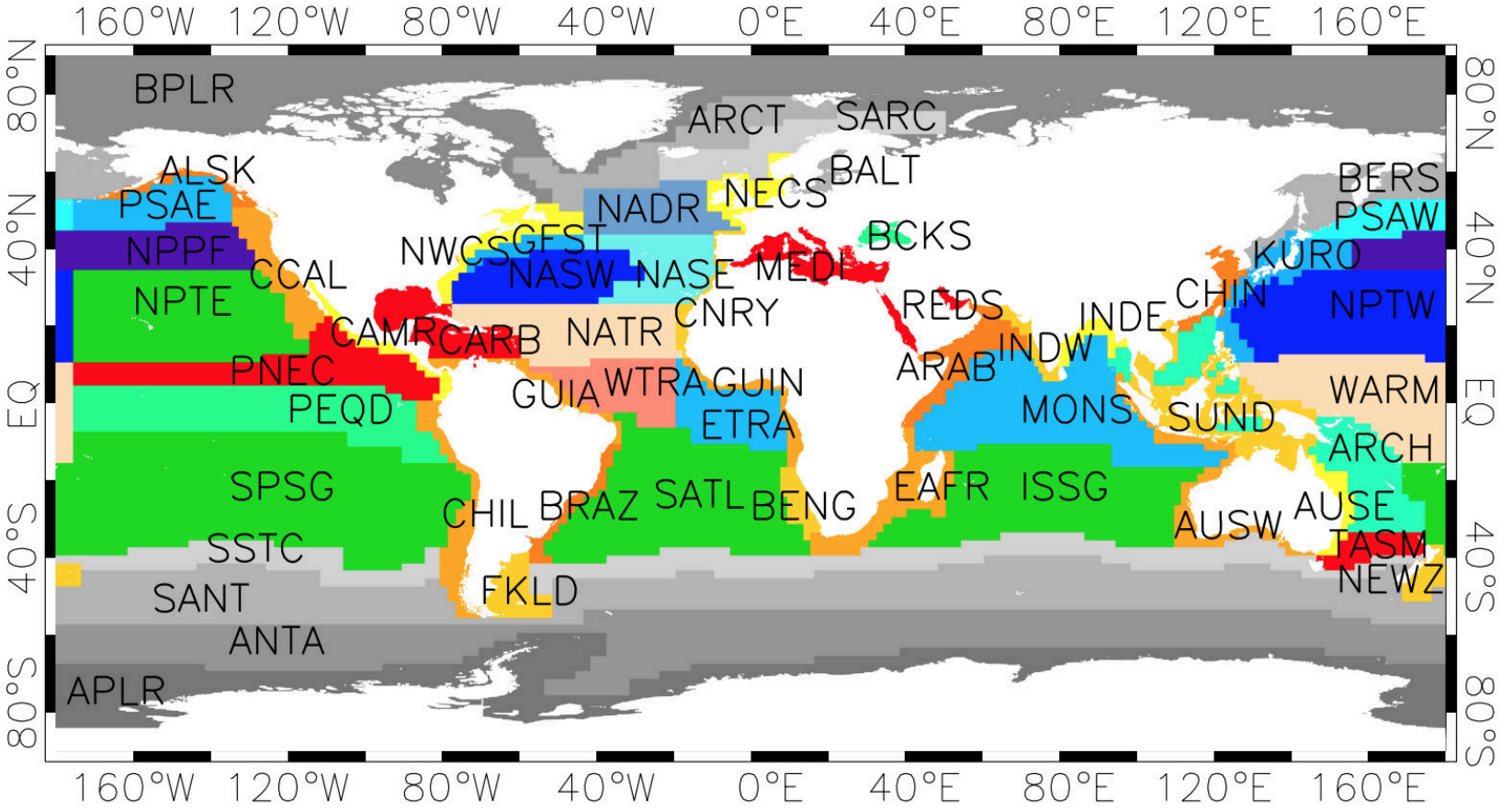
Horizontal scales

Figure 1. Location, names, and numbering of selected *Longhurst*'s [2007] provinces on the model grid.

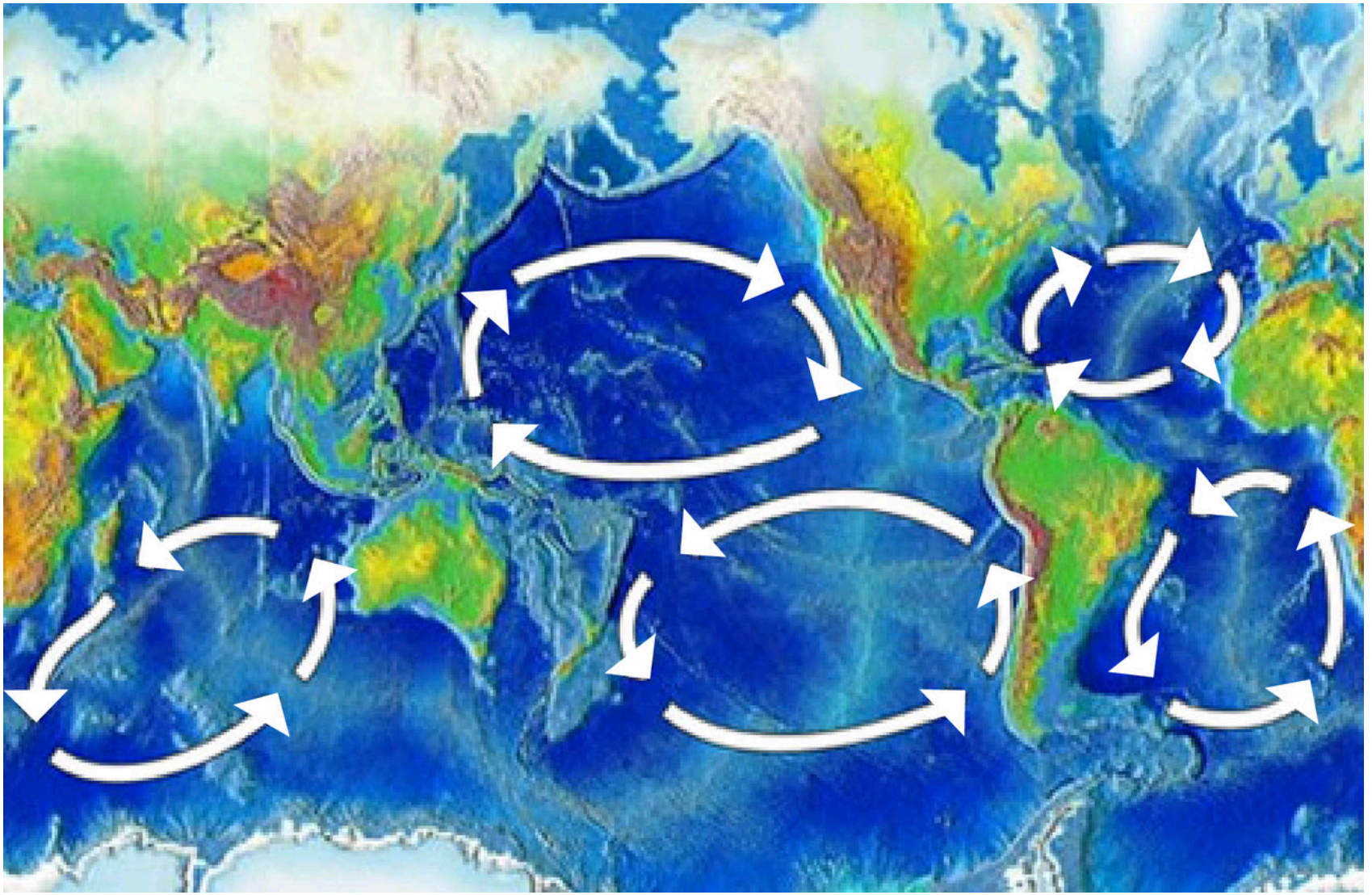
Oceanographic provinces (Loghurst)



- 56 Provinces
-
  - Coastal
  - Trade wind (tropical)
  - Westerly (temperate)
  - Polar



Oceanic gyres



Oceanic gyres

What drives the gyres ?

Figure 9.1 Winds, driven by uneven solar heating and Earth's spin, drive the movement of the ocean's surface currents. The prime movers are the powerful westerlies and the persistent trade winds (easterlies).

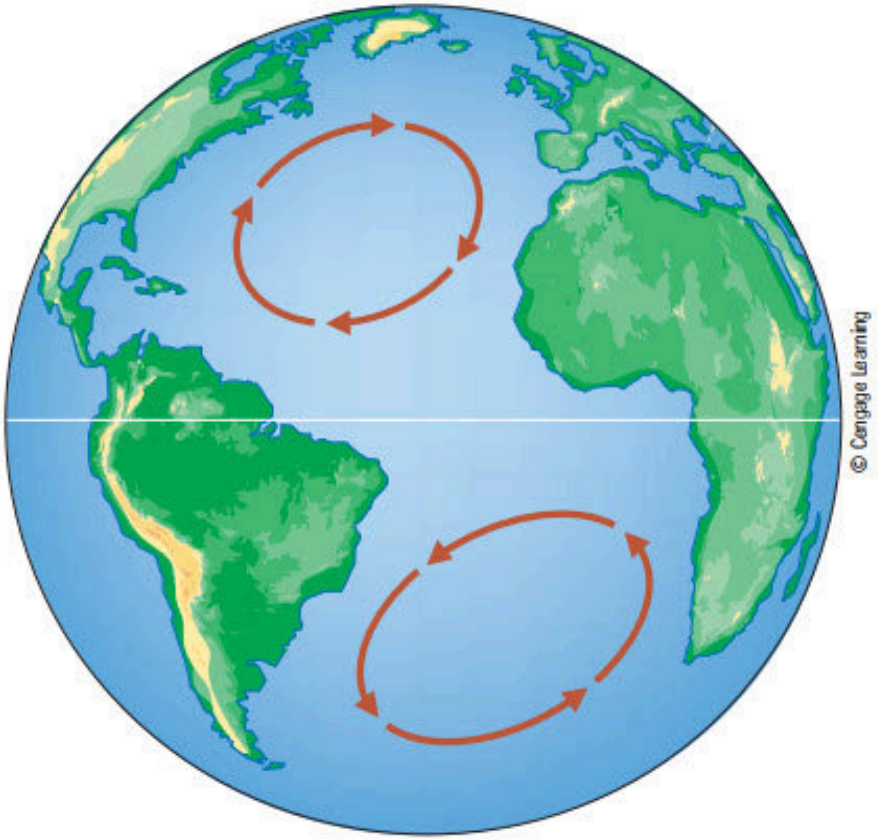
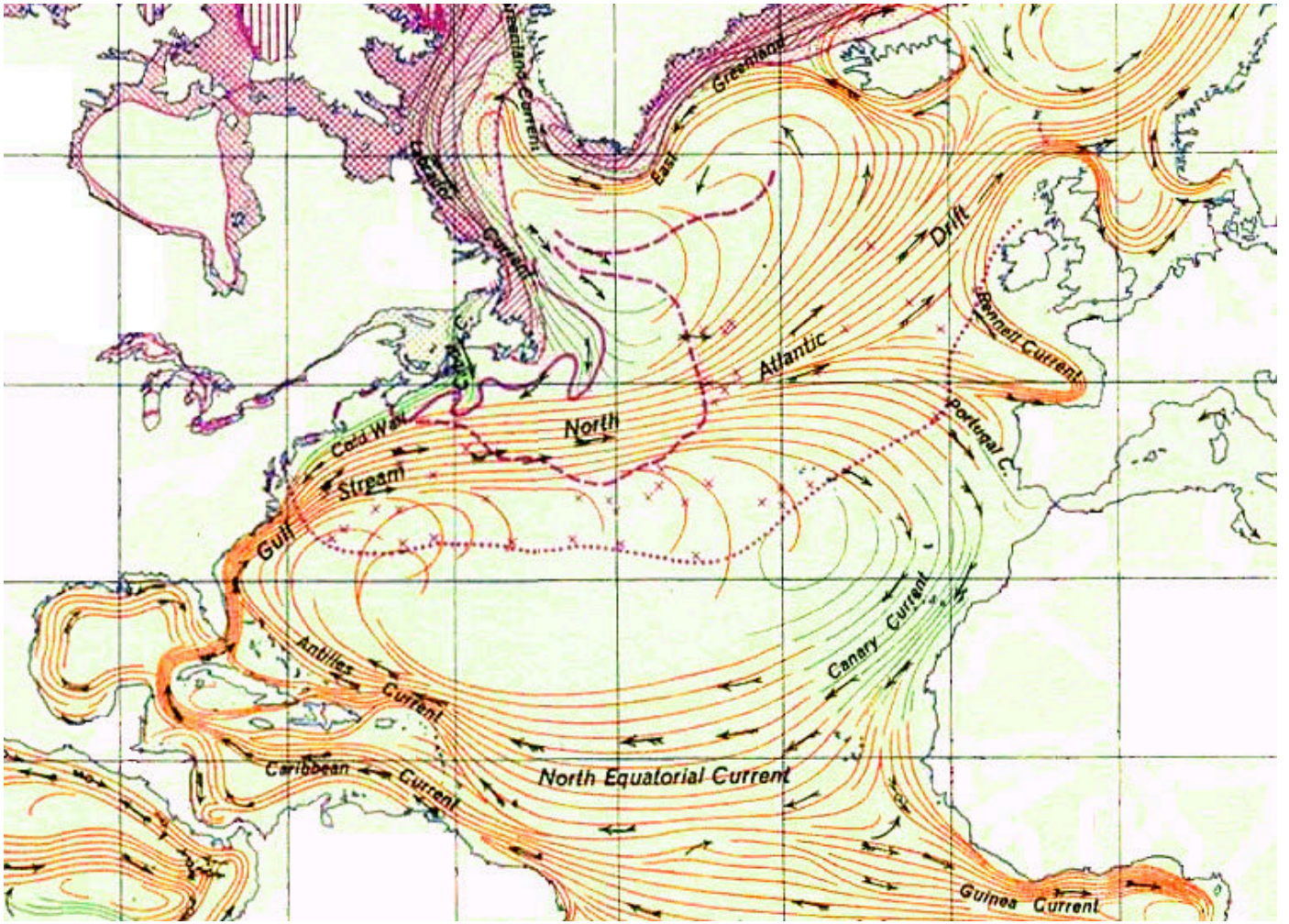


Figure 9.2 A combination of four forces—surface winds, the sun's heat, the Coriolis effect, and gravity—circulates the ocean surface clockwise in the Northern Hemisphere and counterclockwise in the Southern Hemisphere, forming gyres.

Oceanic gyres - North Atlantic

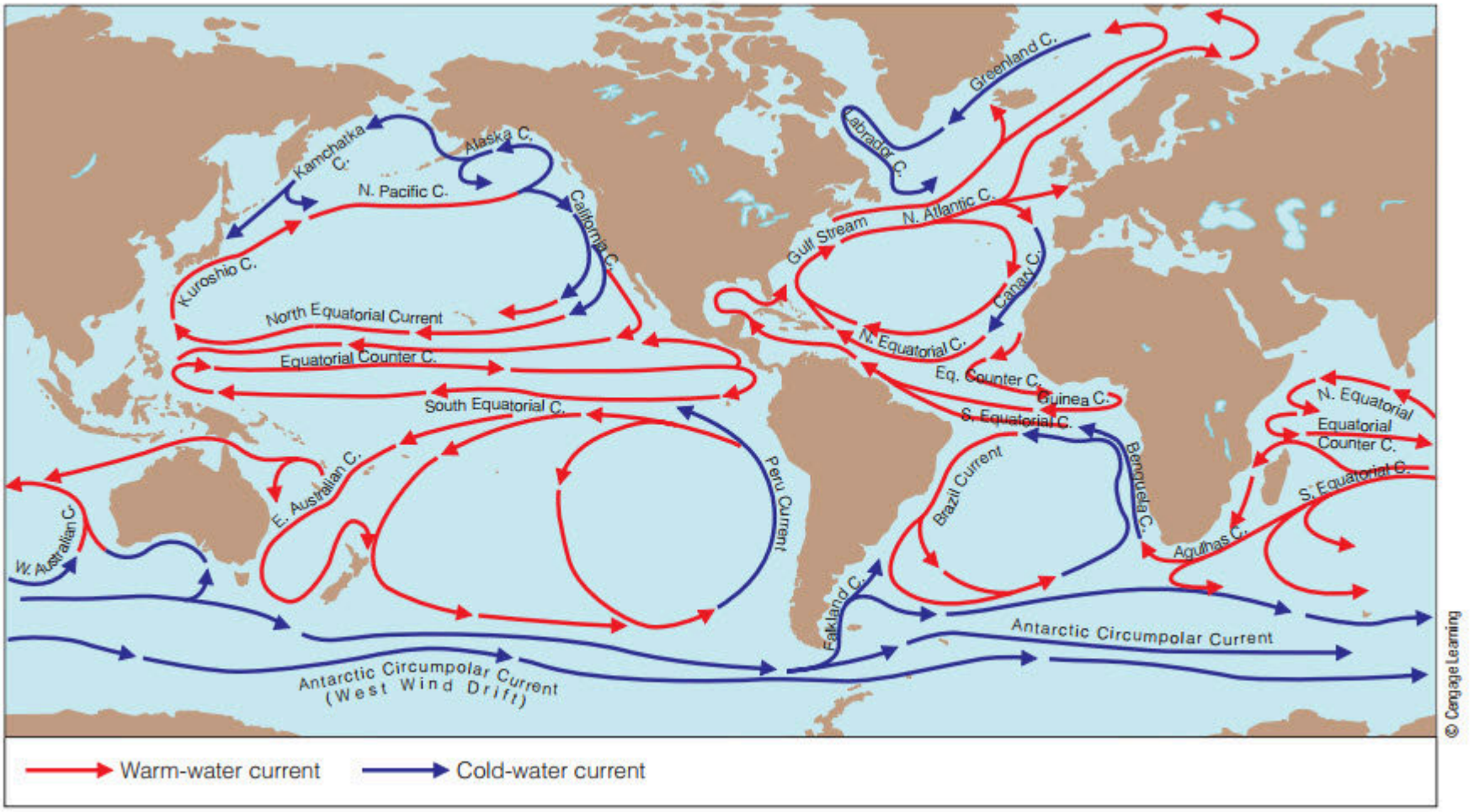
What do you notice ?

- Western boundaries currents
- e.g. Gulf Stream



Oceanic gyres

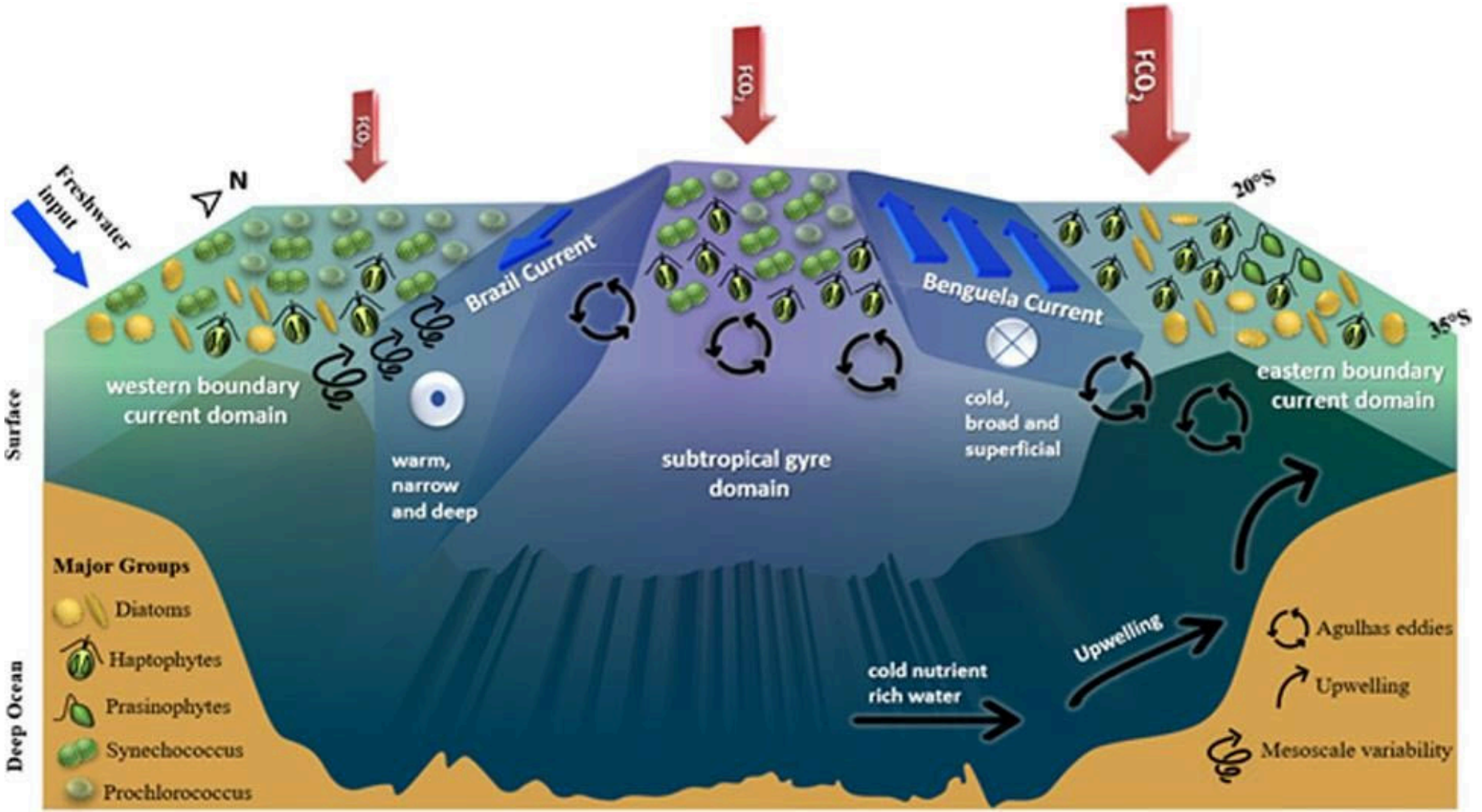
- Major currents



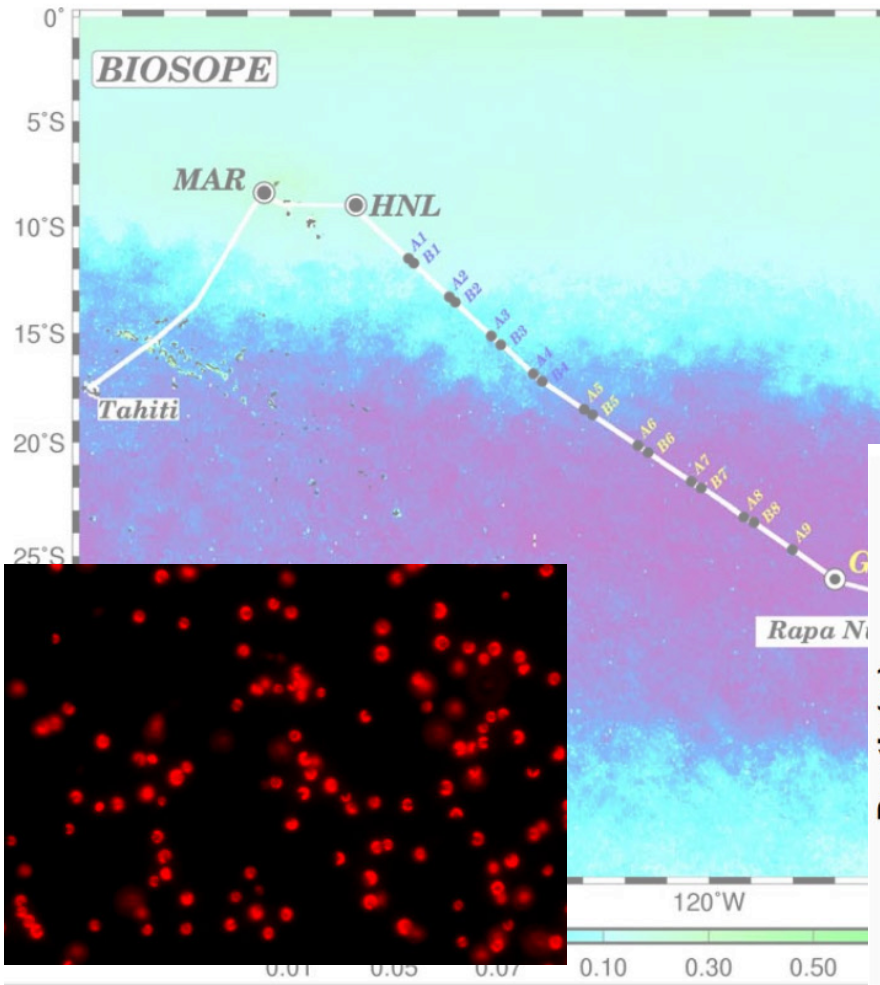
b A chart showing the names and usual direction of the world ocean's major surface currents. The powerful western boundary currents flow along the western boundaries of ocean basins in *both* hemispheres.

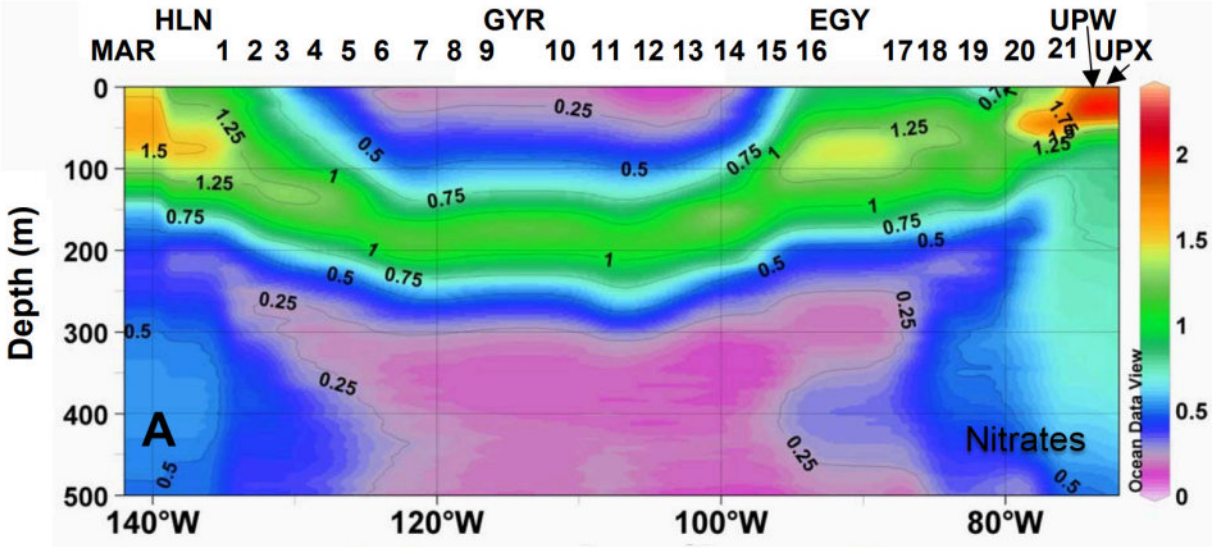
Oceanic gyres - South Atlantic

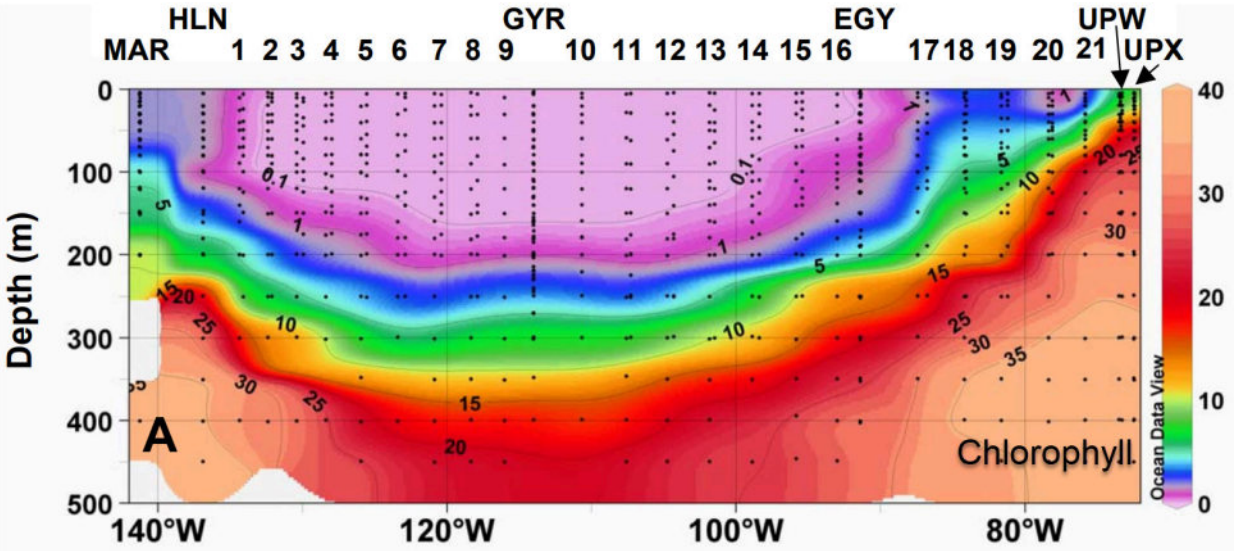
- Upwelling on East side
- Different communities



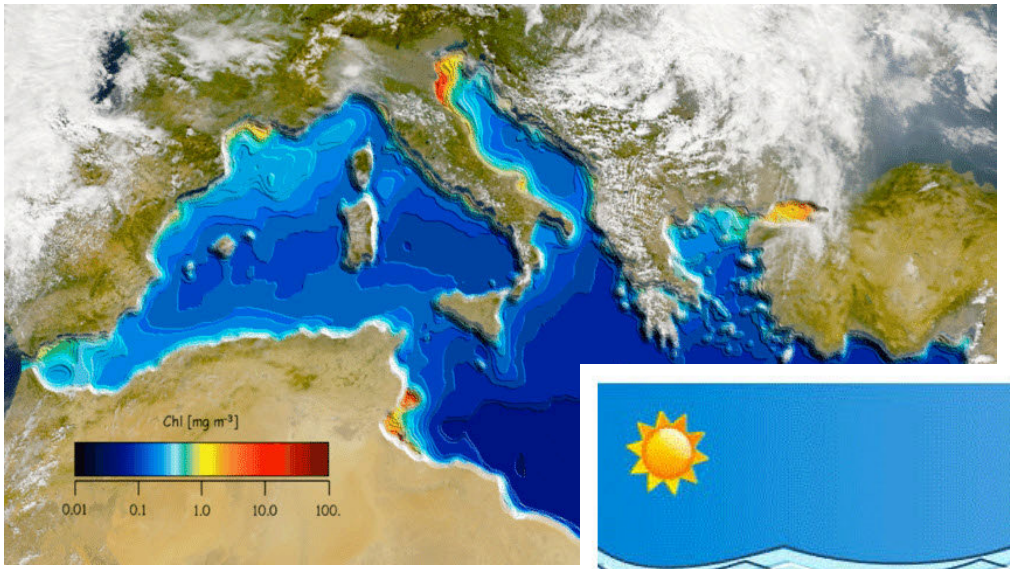
Oceanic gyres - South Pacific

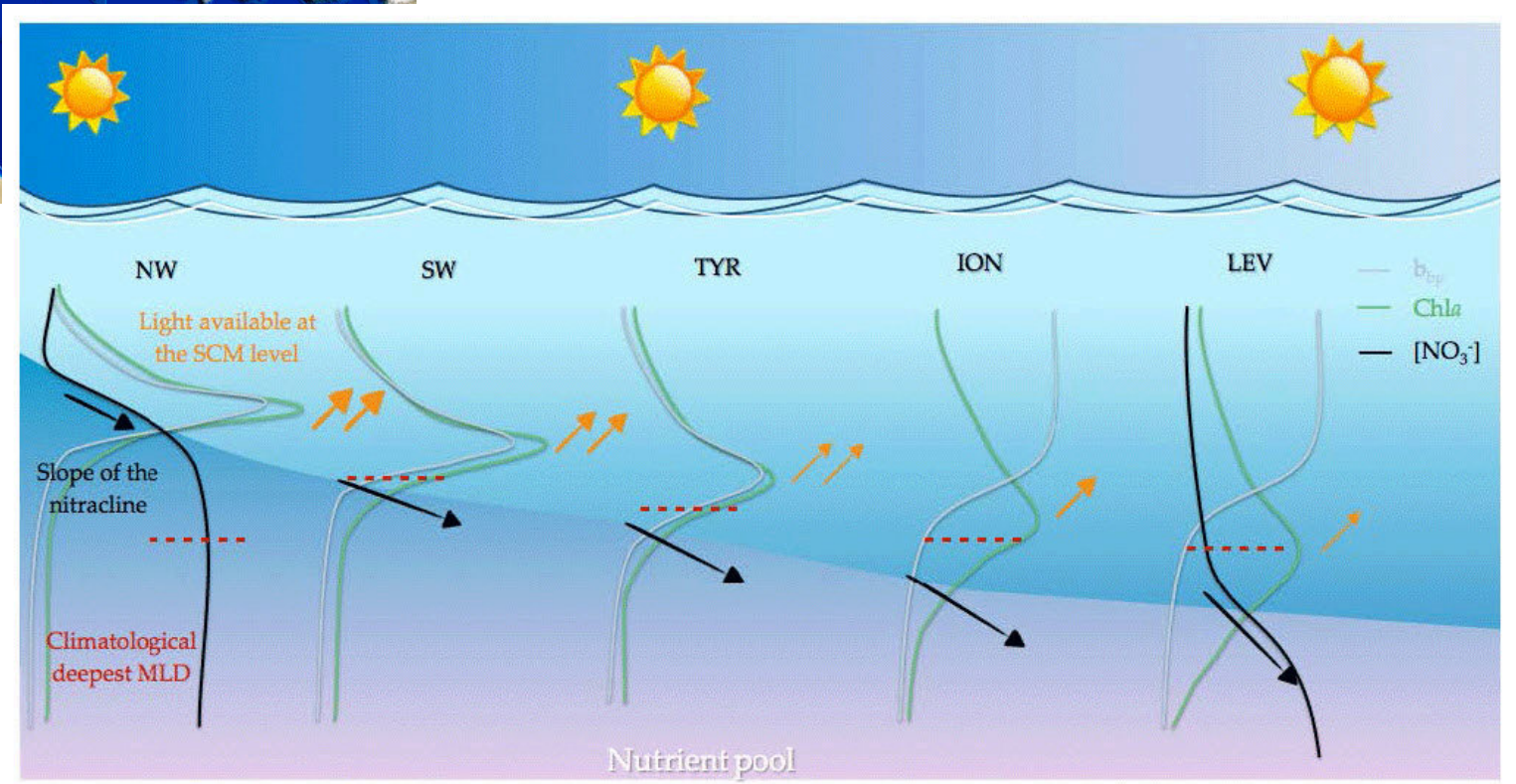






Mediterranean Sea

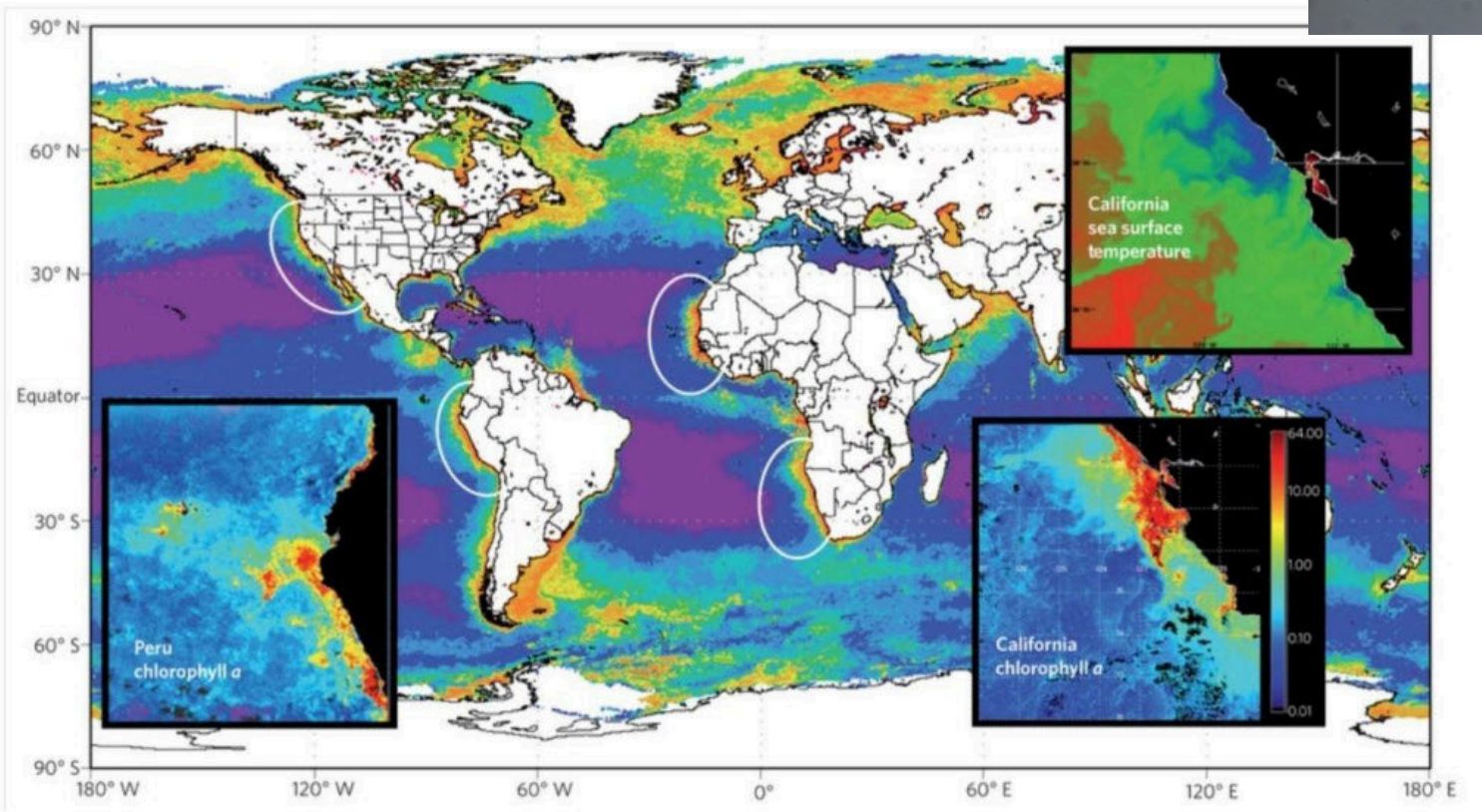




Barbieux et al. 2019. Bio-optical characterization of subsurface chlorophyll maxima in the Mediterranean Sea… Biogeosciences. 16:1321–42.

Upwelling

- West coast of continents
- Often dominated by diatoms

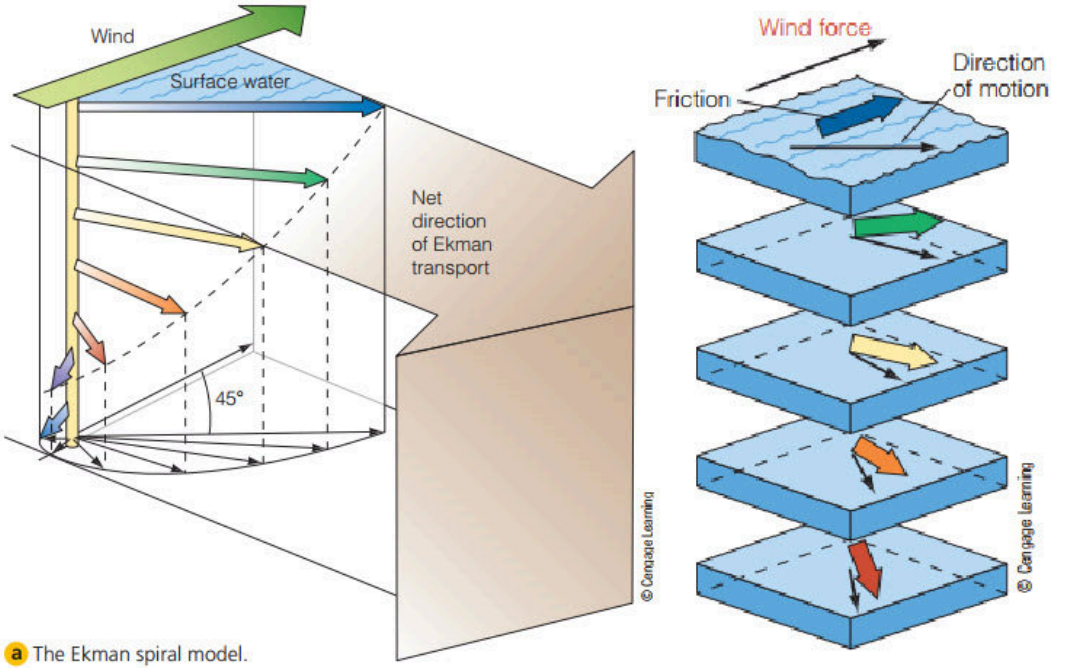


A global false-color compilation of satellite data on ocean chlorophyll from the MODIS Aqua sensor for the year 2011 showing the California, Peru, Canary, and Benguela ecosystems (white ovals). Satellite imagery courtesy of NASA. From Capone and Hutchins, 2013.

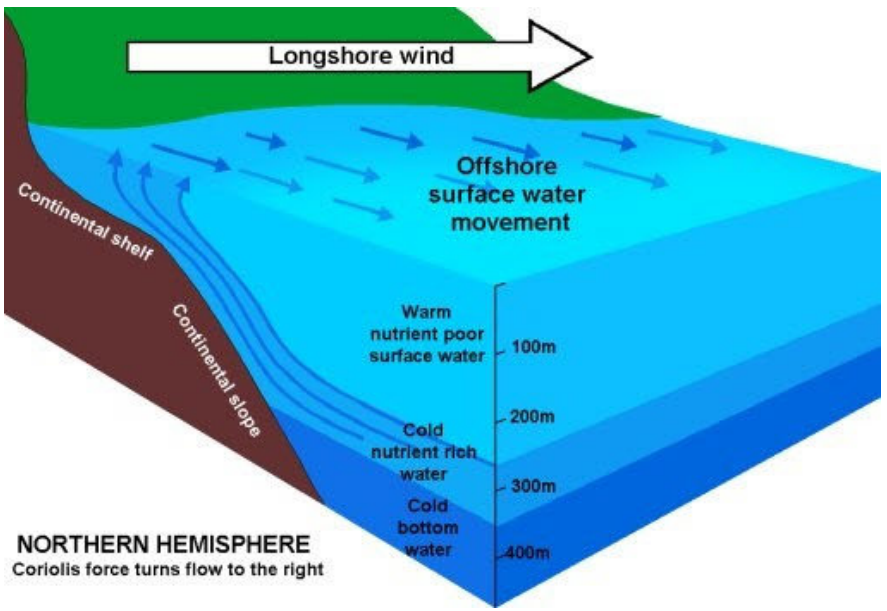
Upwelling

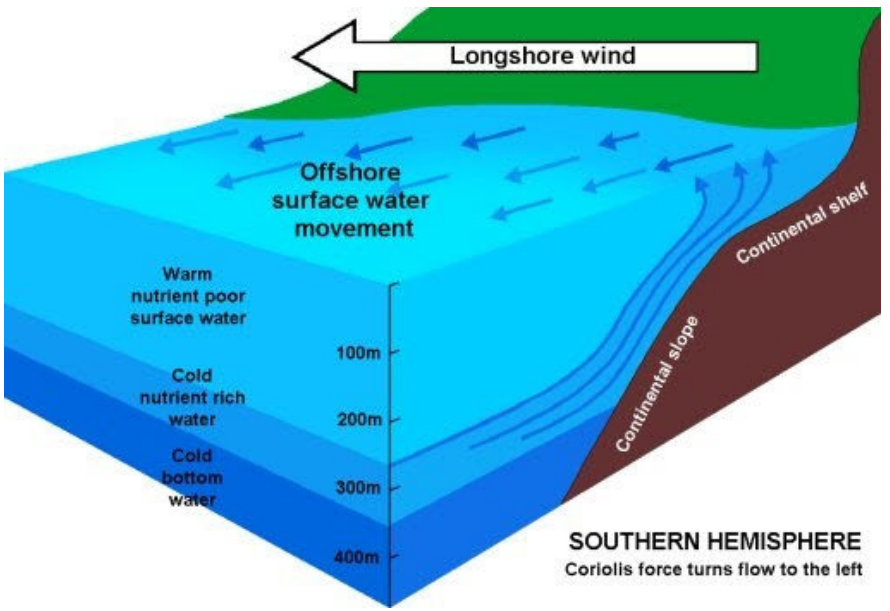
Can anyone explain ?

- Wind + Coriolis -> Ekman spiral

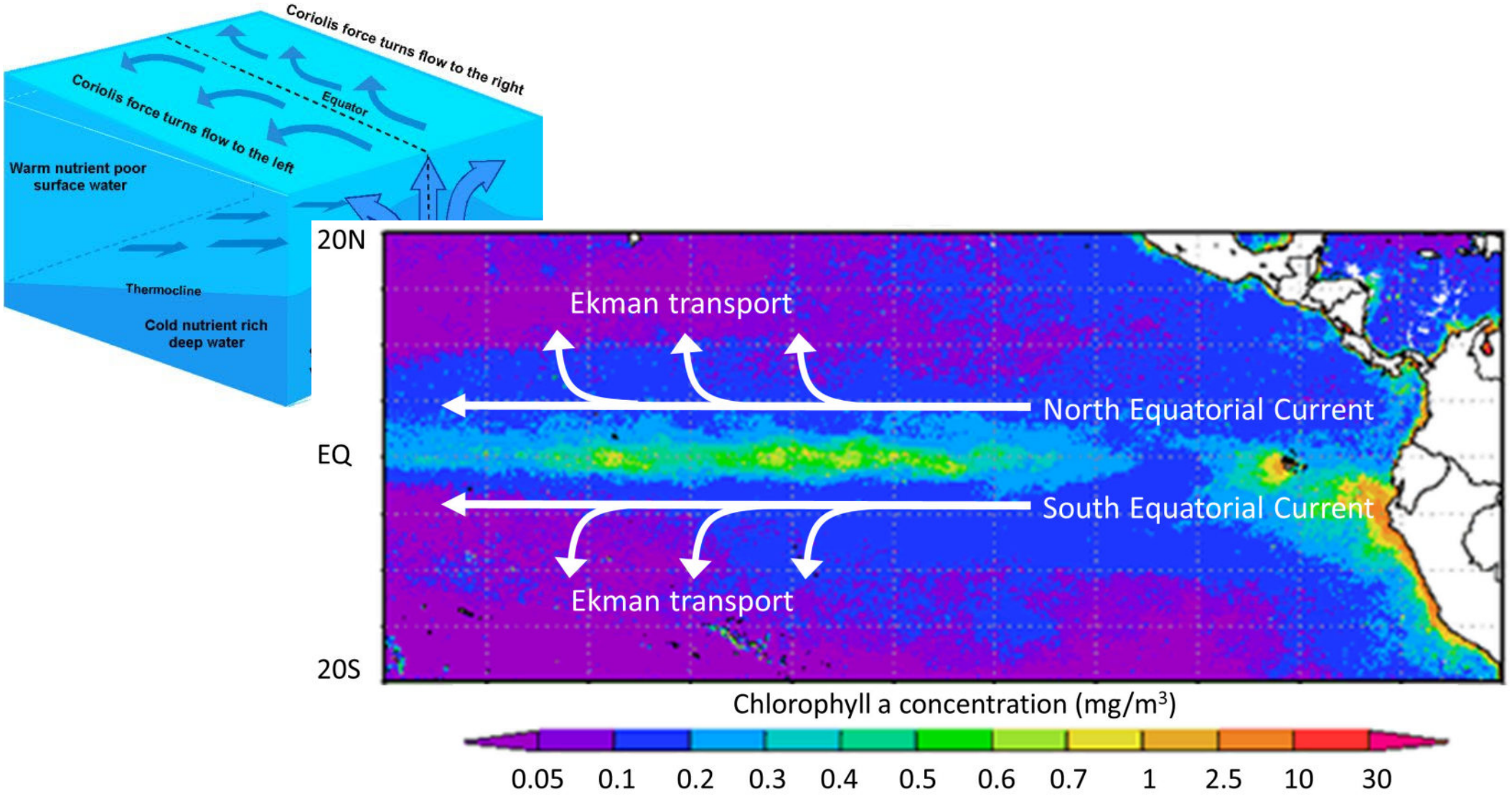


a The Ekman spiral model.





Equatorial upwelling



Downwelling

- Wind from South in Northern hemisphere

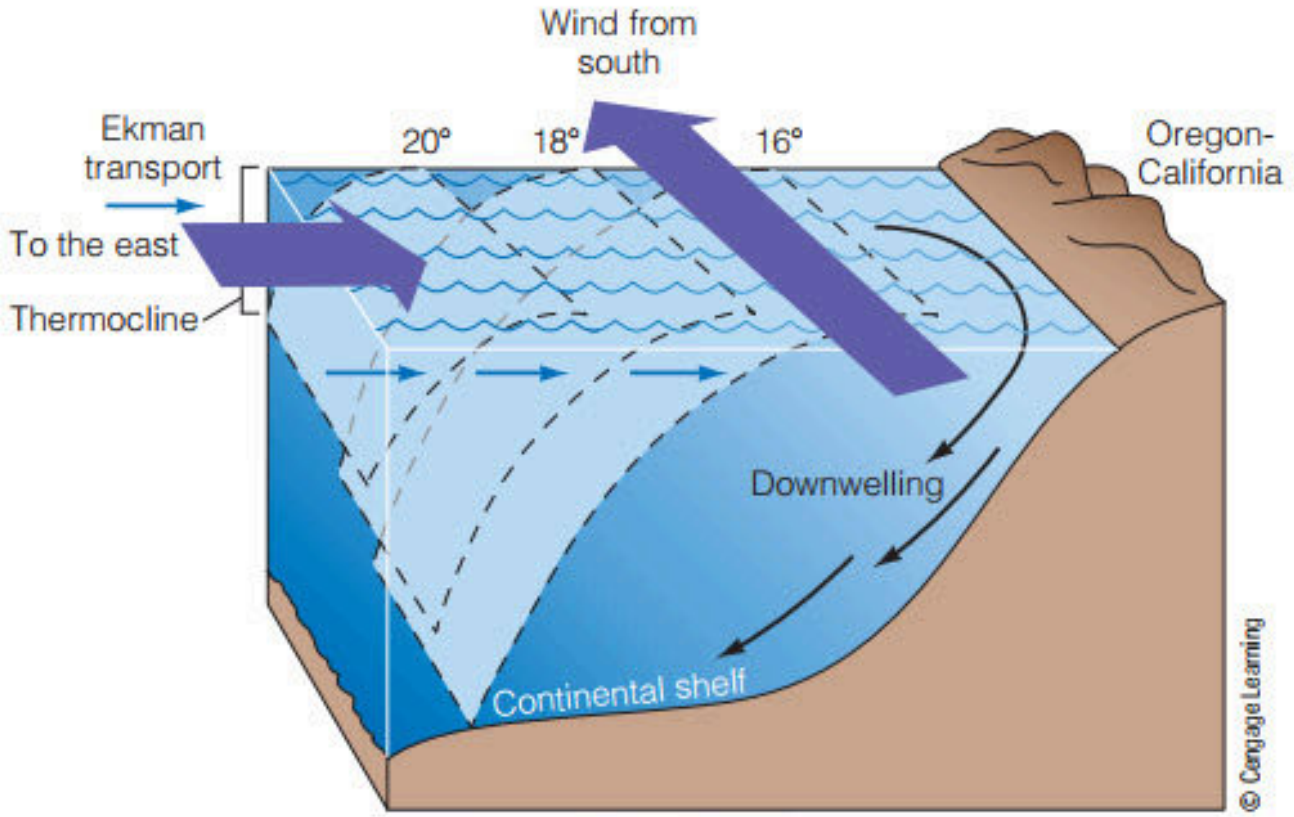
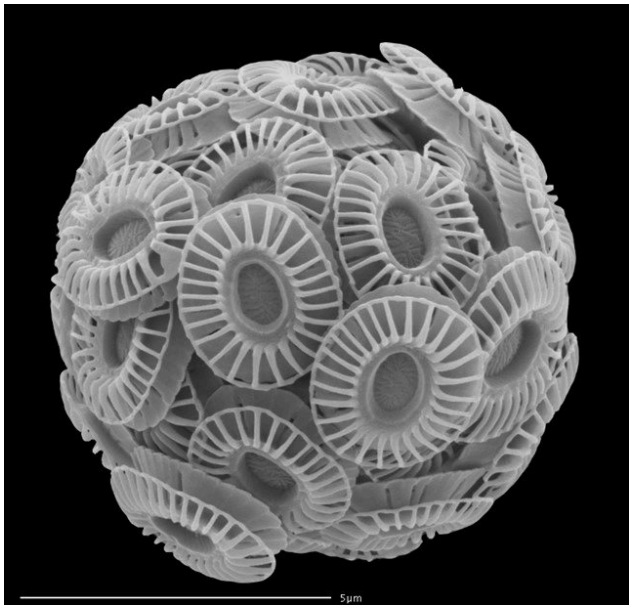


Figure 9.21 Wind blowing from the south along a Northern Hemisphere west coast for a prolonged period can result in downwelling. Areas of downwelling are often low in nutrients and therefore relatively low in biological productivity. (Vertical exaggeration ~100×.)

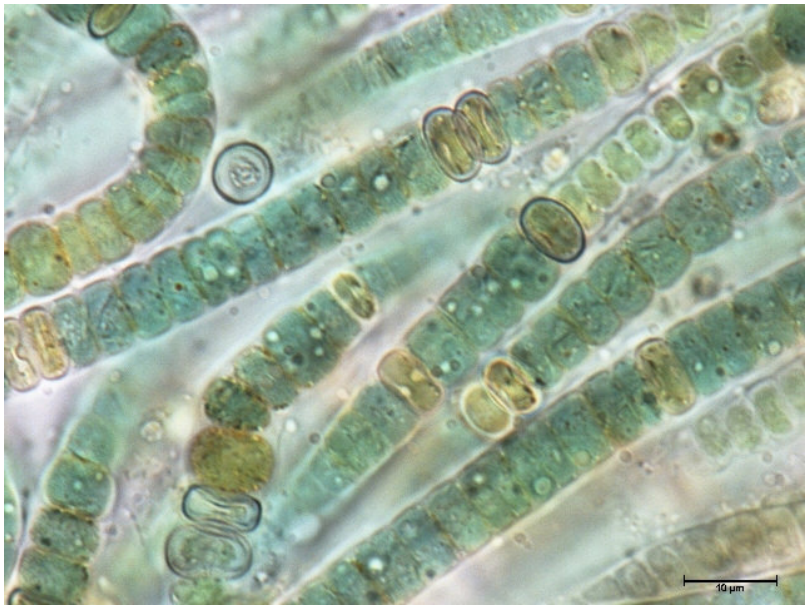
Mesoscale - English Channel

- Effect of turbulence
- Coccolithophorid bloom

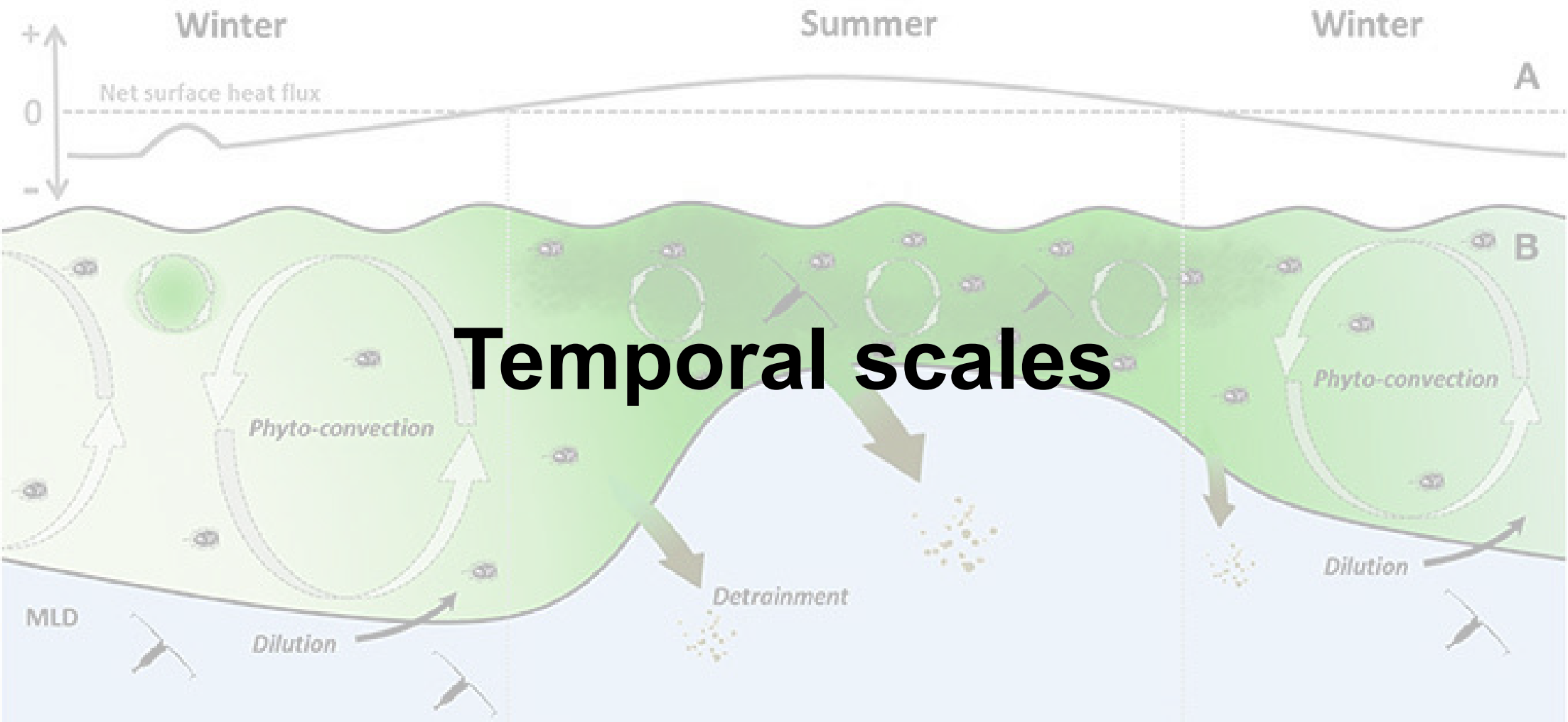


Mesoscale - Baltic

Cyanobacteria

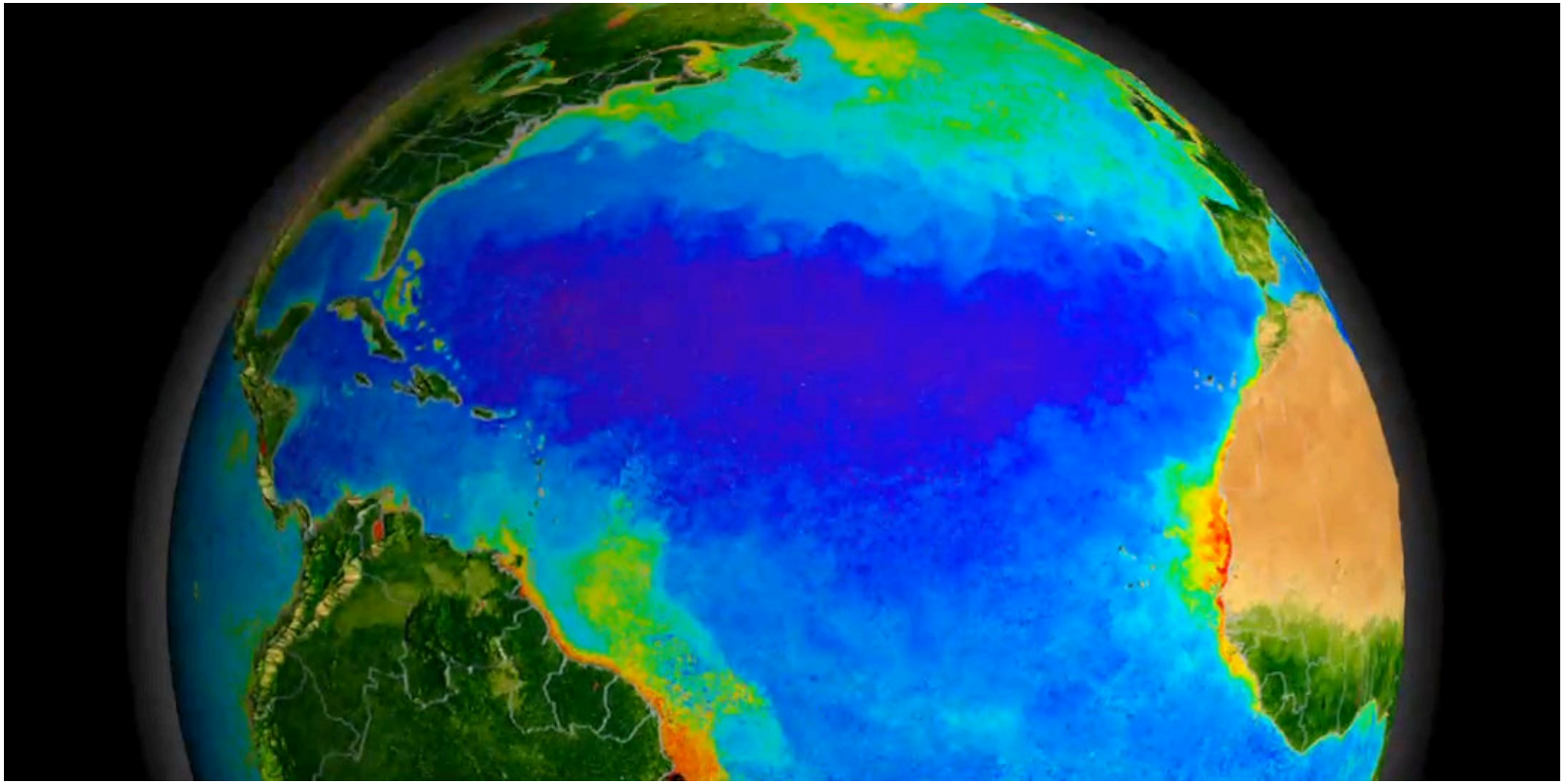


Temporal scales



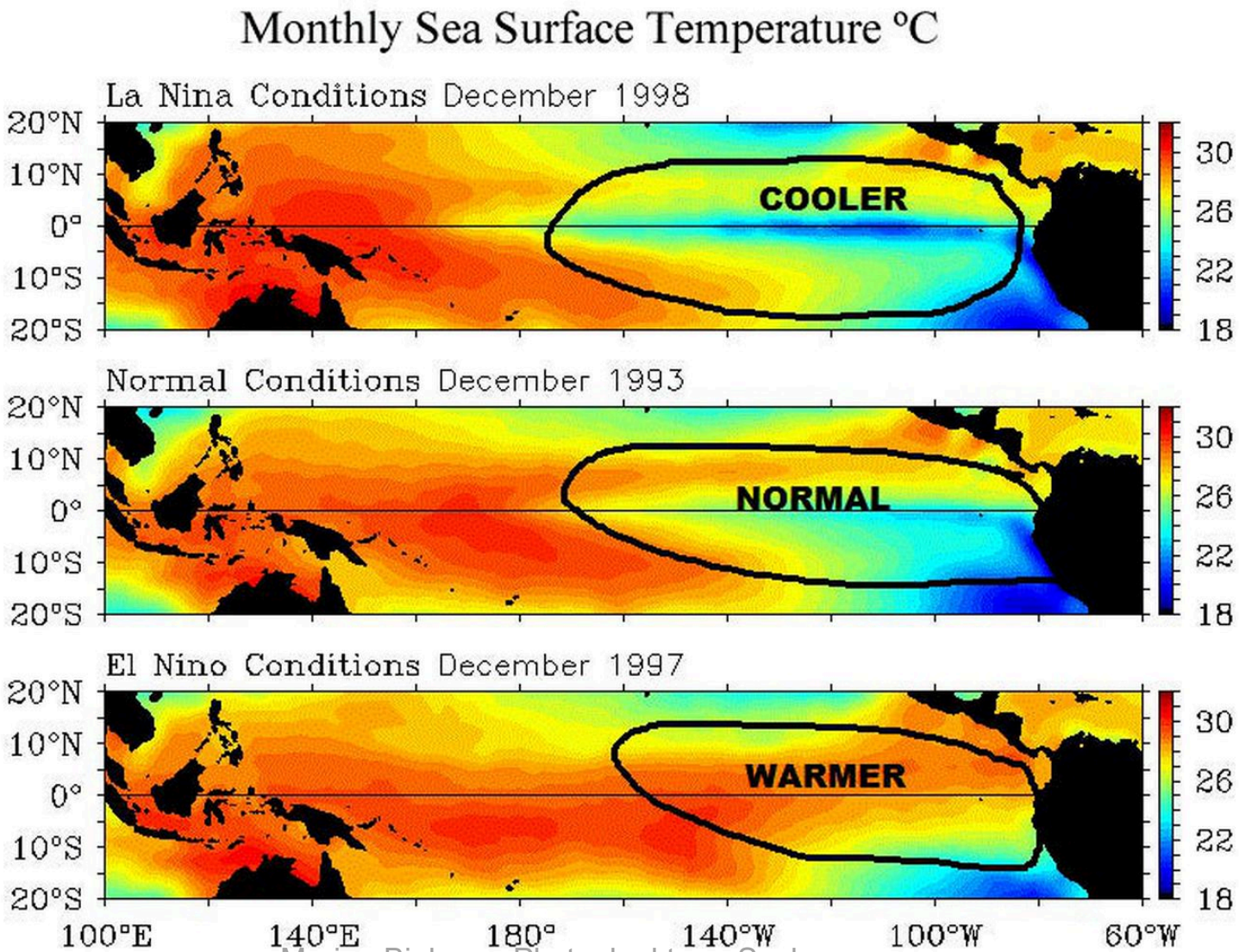
Temporal variations

North Atlantic and North Pacific oceans from March 2003 to October 2006



Multi-year scale - El Niño

Warm water accumulates over East Pacific



Multi-year scale - El Niño

Linked to trade wind changes

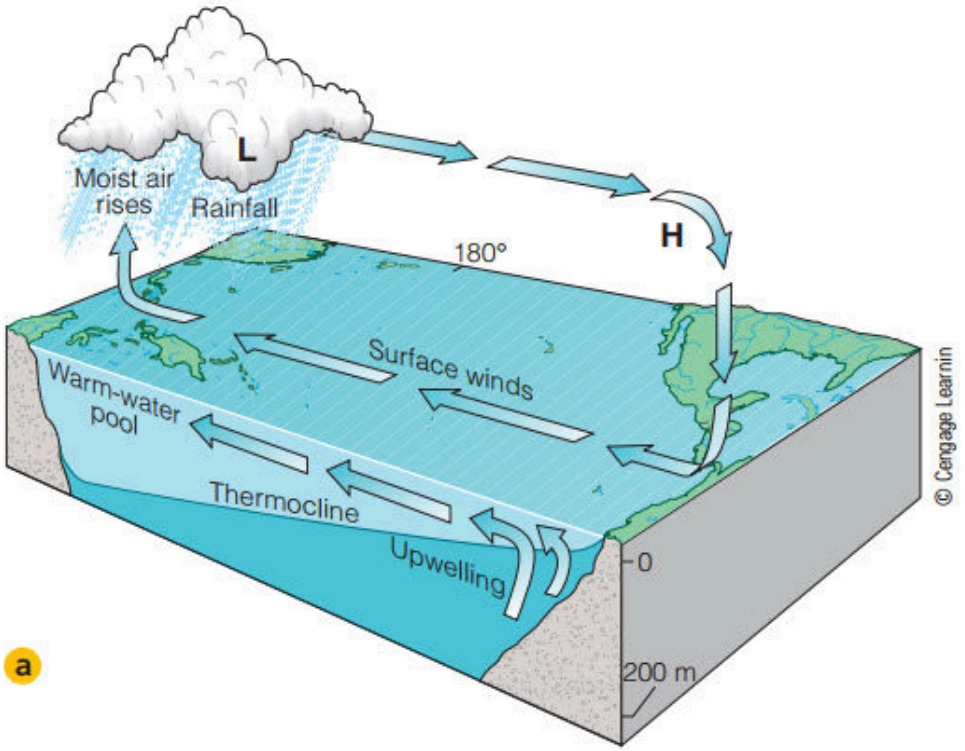


Figure 9.23 A non–El Niño year.
a Normally the air and surface water flow westward, the thermocline rises, and upwelling of cold water occurs along the west coast of Central and South America.

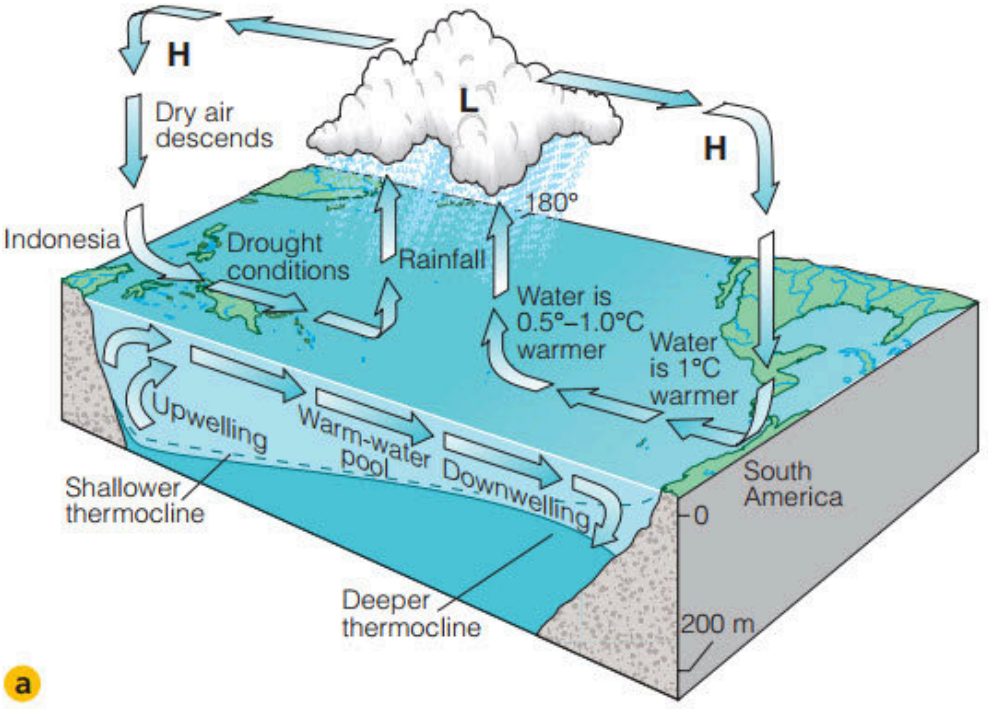
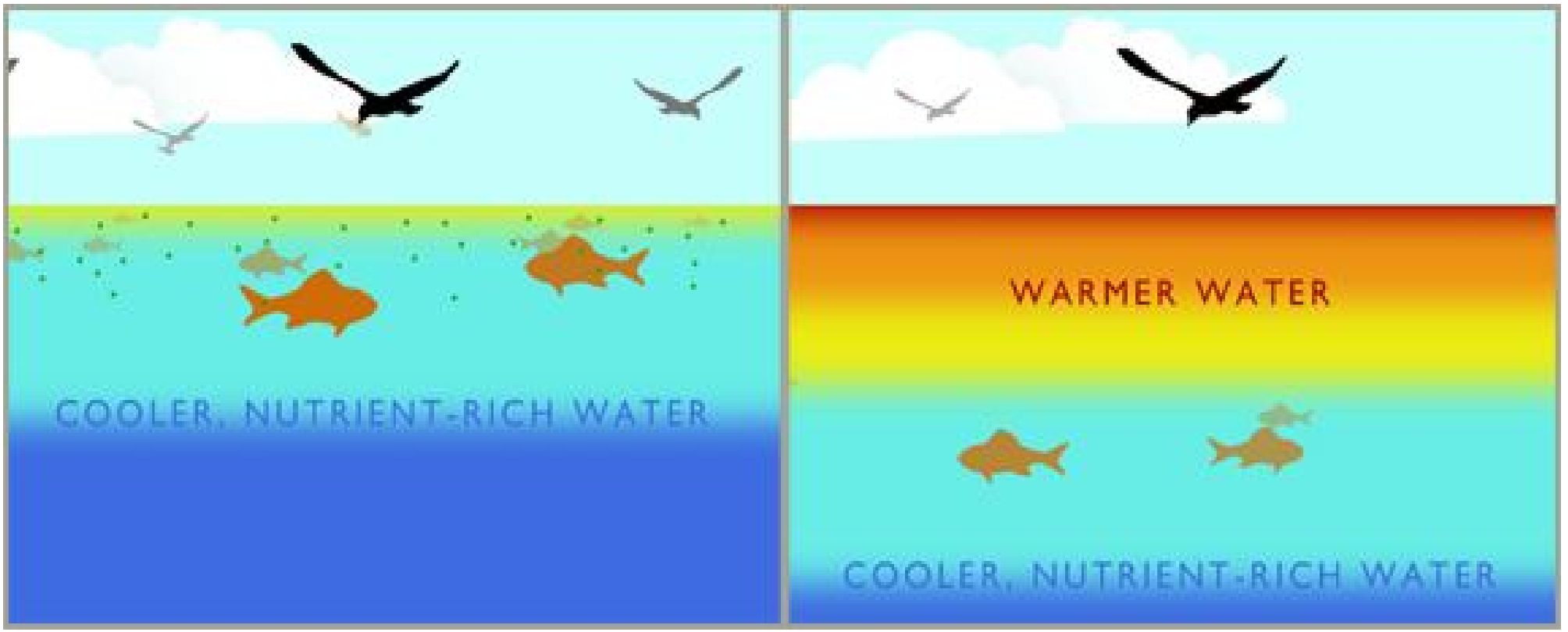


Figure 9.24 An El Niño year.
a When the Southern Oscillation develops, the trade winds diminish and then reverse, leading to an eastward movement of warm water along the equator. The surface waters of the central and eastern Pacific become warmer, and storms over land may increase.

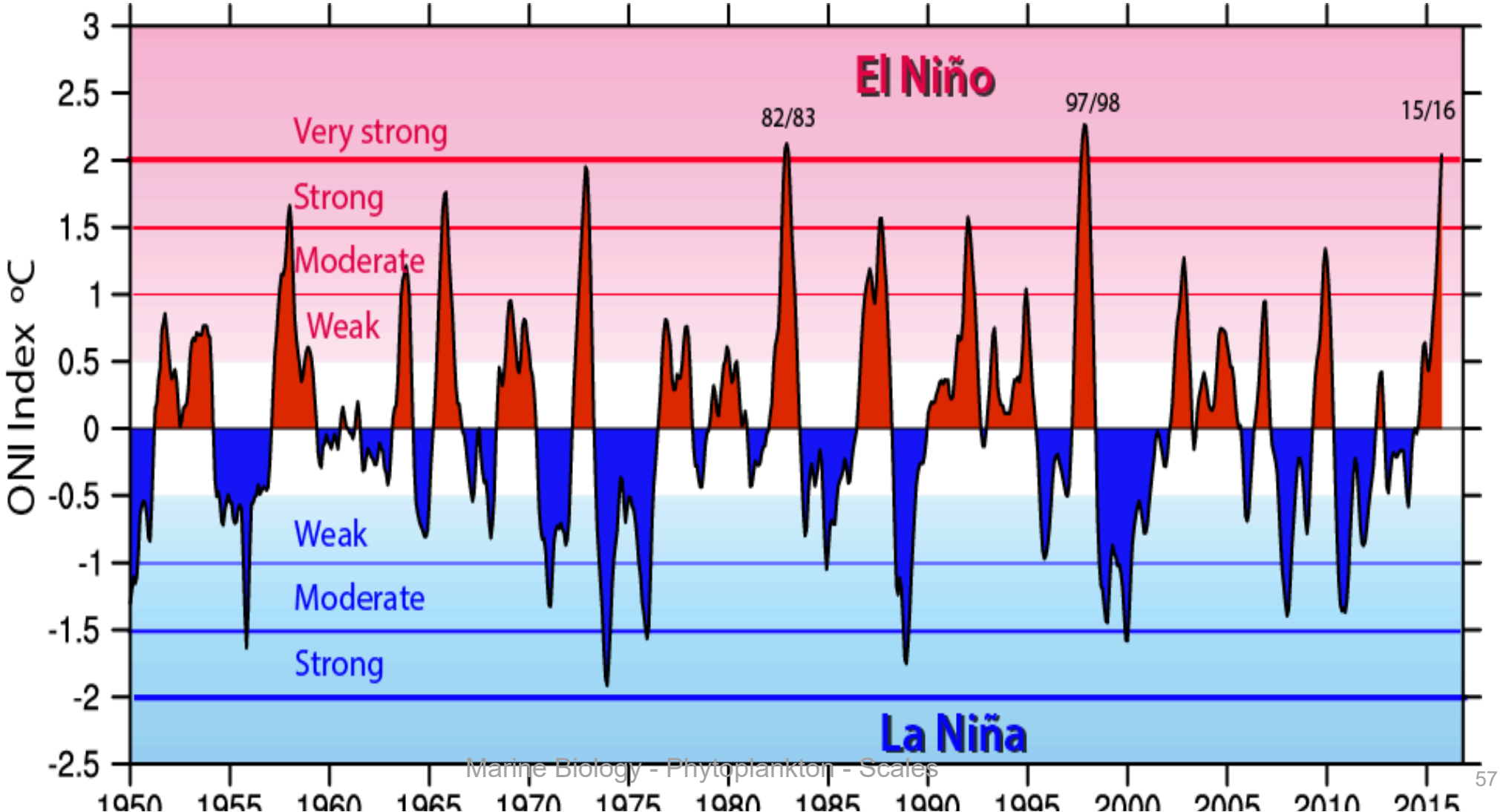
Multi-year scale - El Niño

- Blocks upwelling
- Phytoplankton decrease
- Lower fish capture (anchovy)



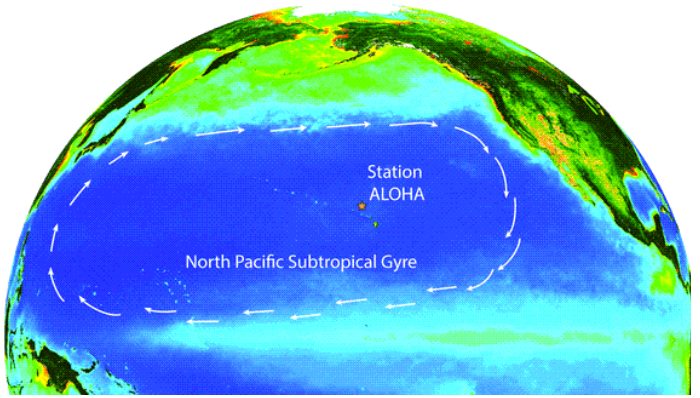
Multi-year scale - El Niño

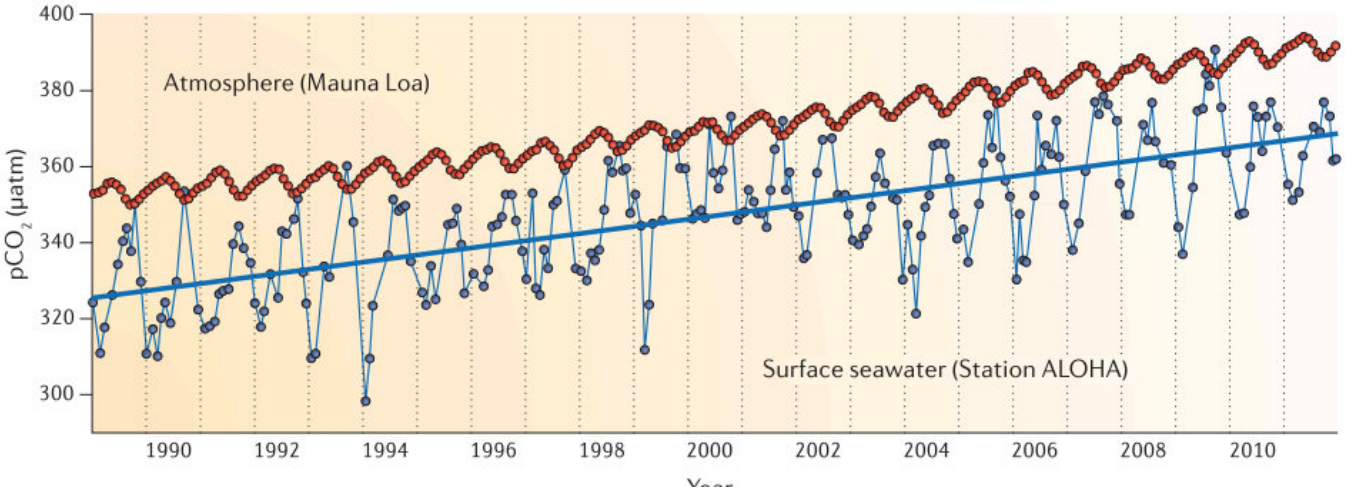
- Year to year change in intensity

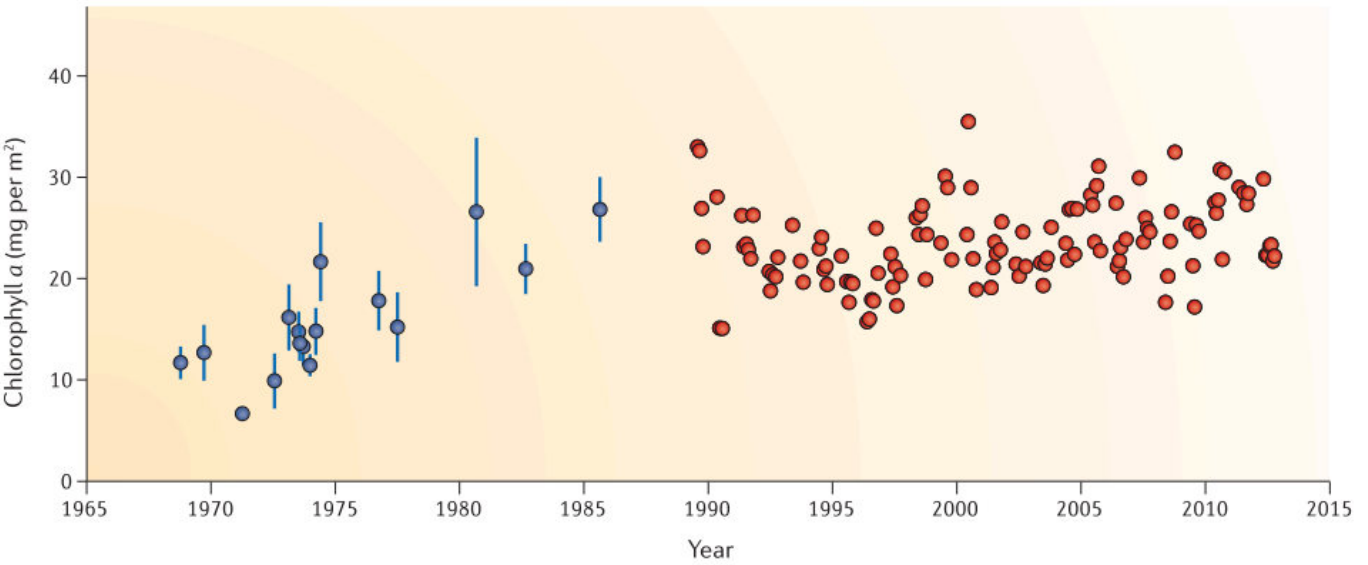


Climatic change

- ALOHA station

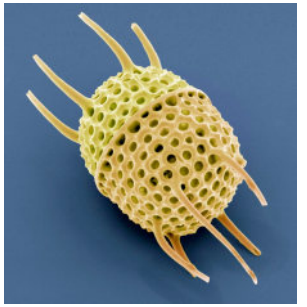


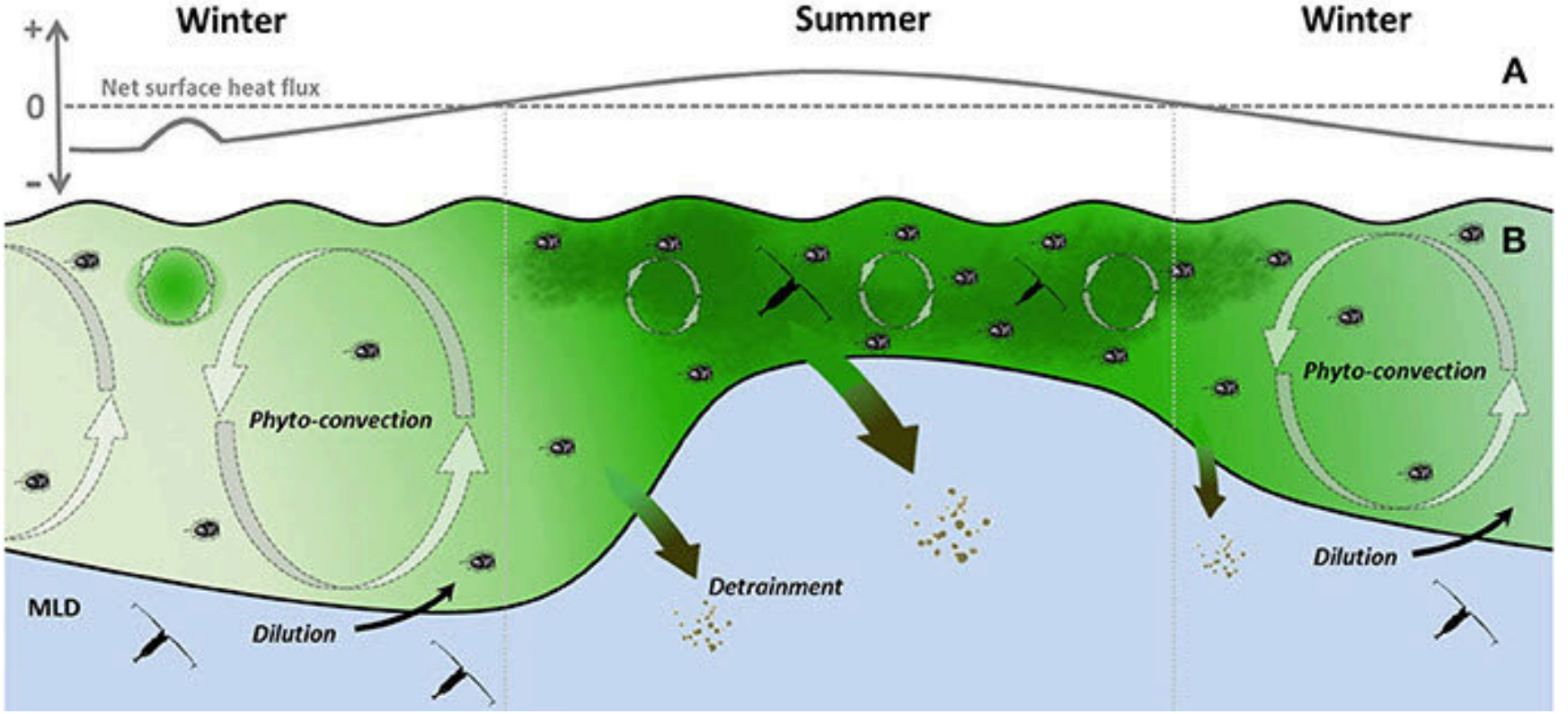




Annual scale - Spring bloom

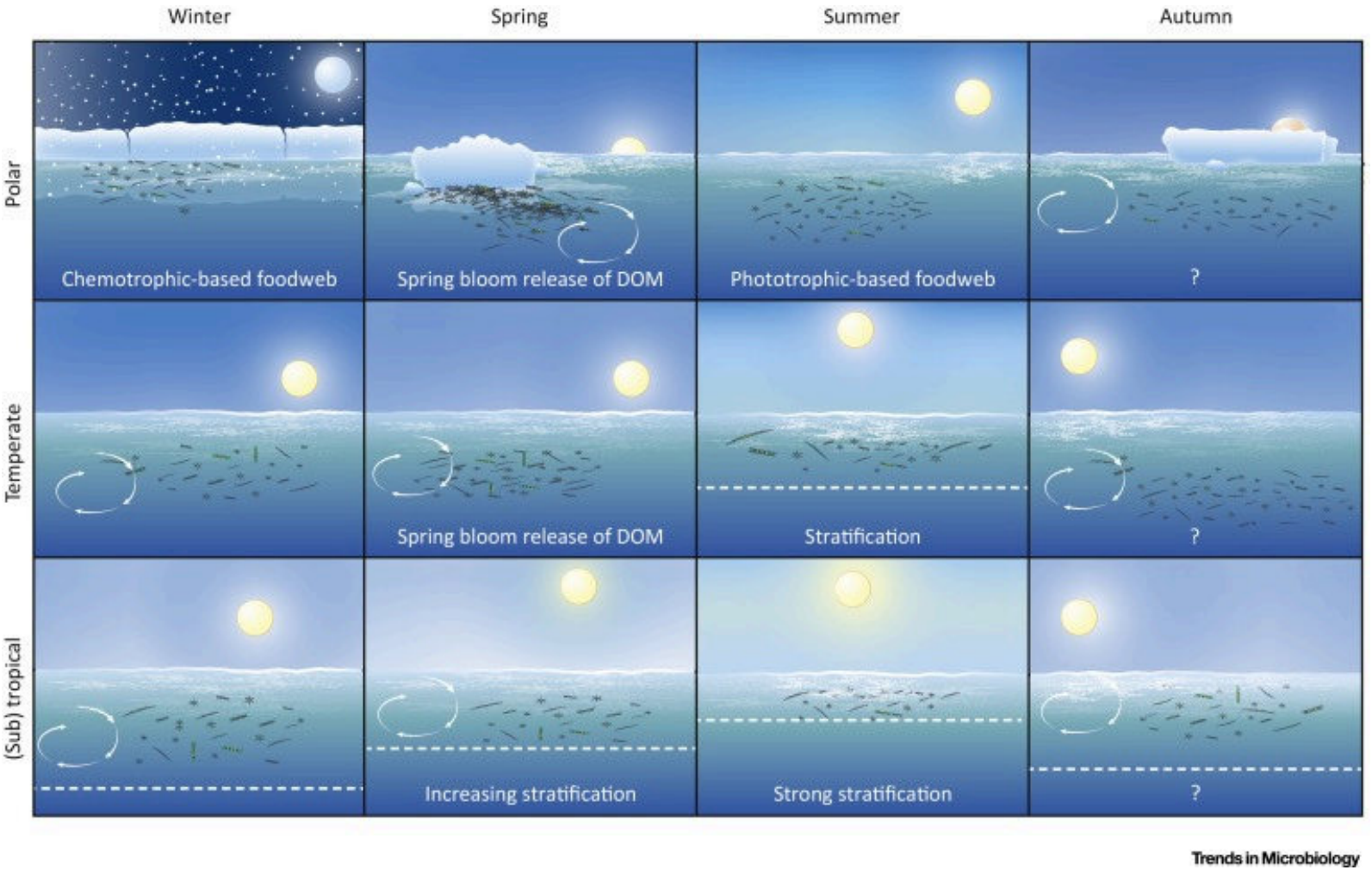
- Diatoms
- Dinoflagellates





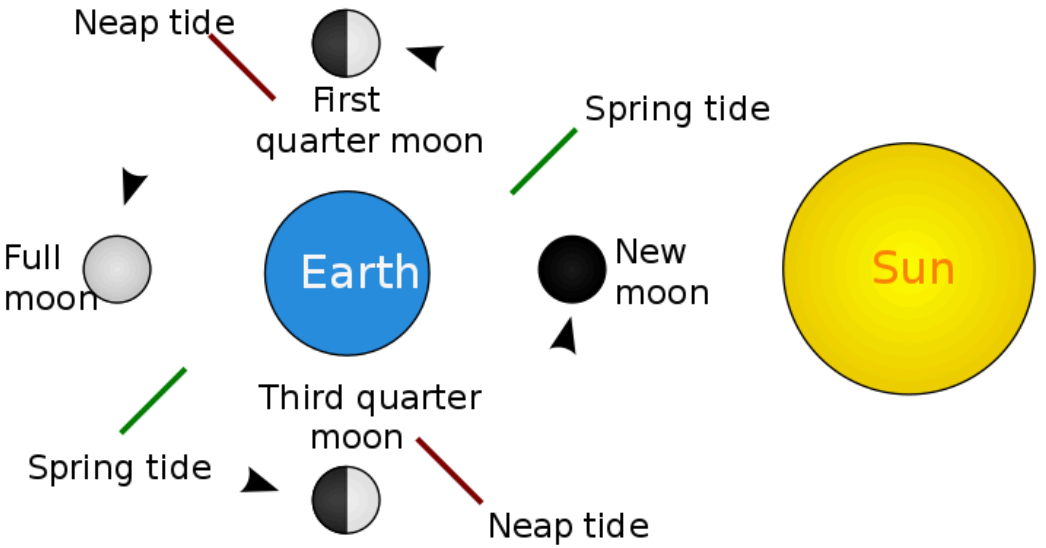
Annual scale - Spring bloom

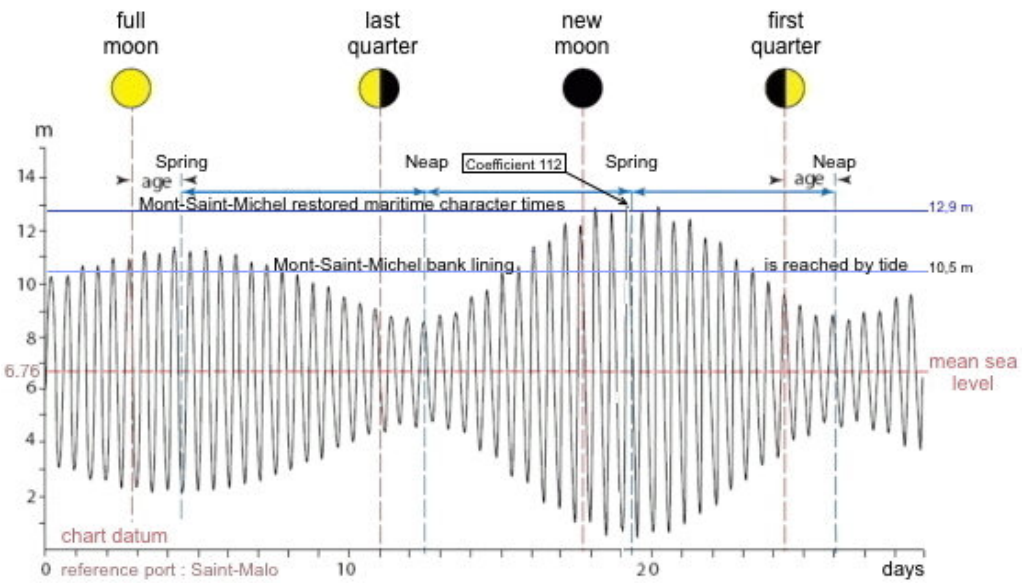
- Depends on latitude
  - Temperate
  - Tropical
  - Arctic



Monthly scale

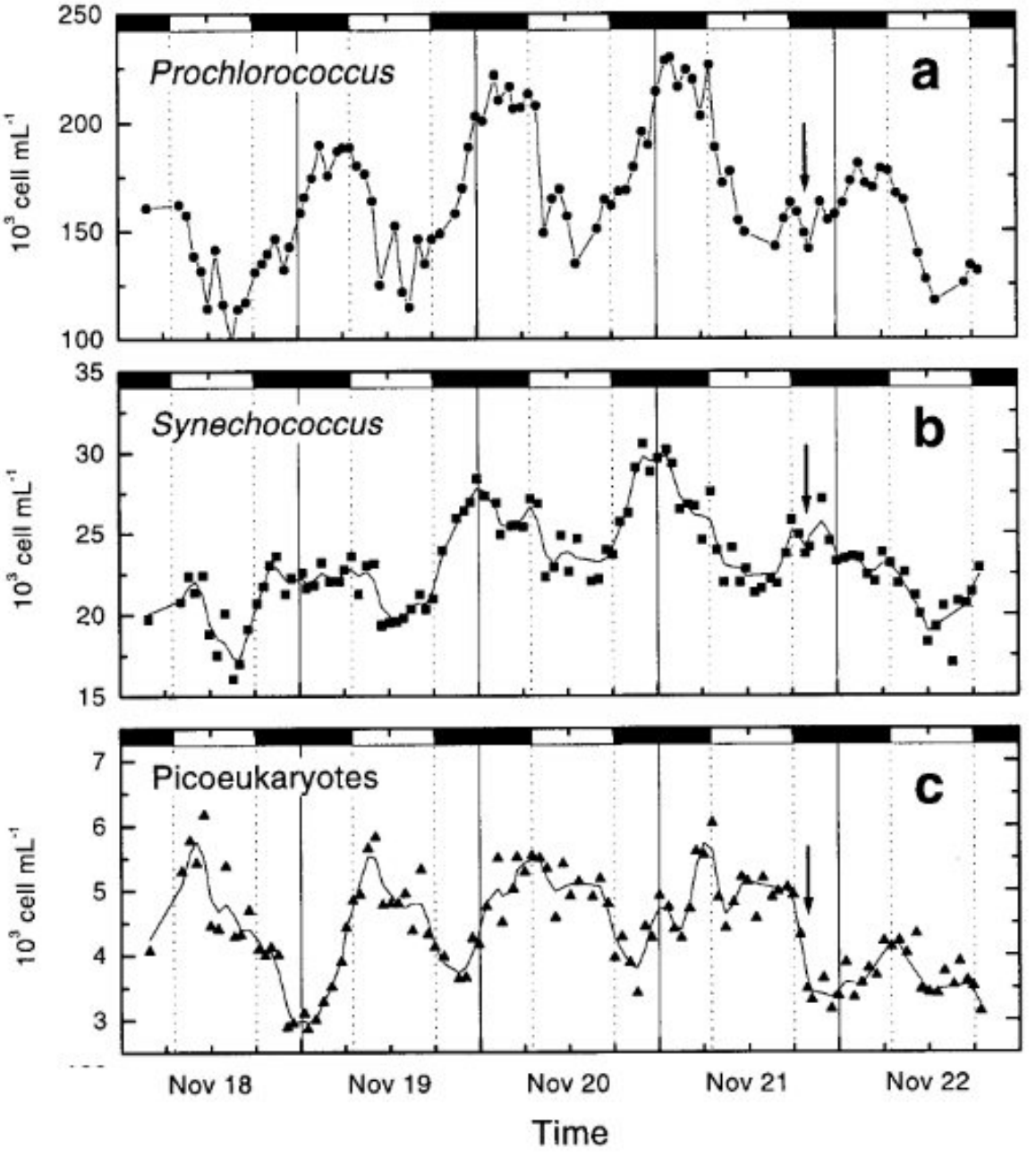
- Neap tide
- Spring tide





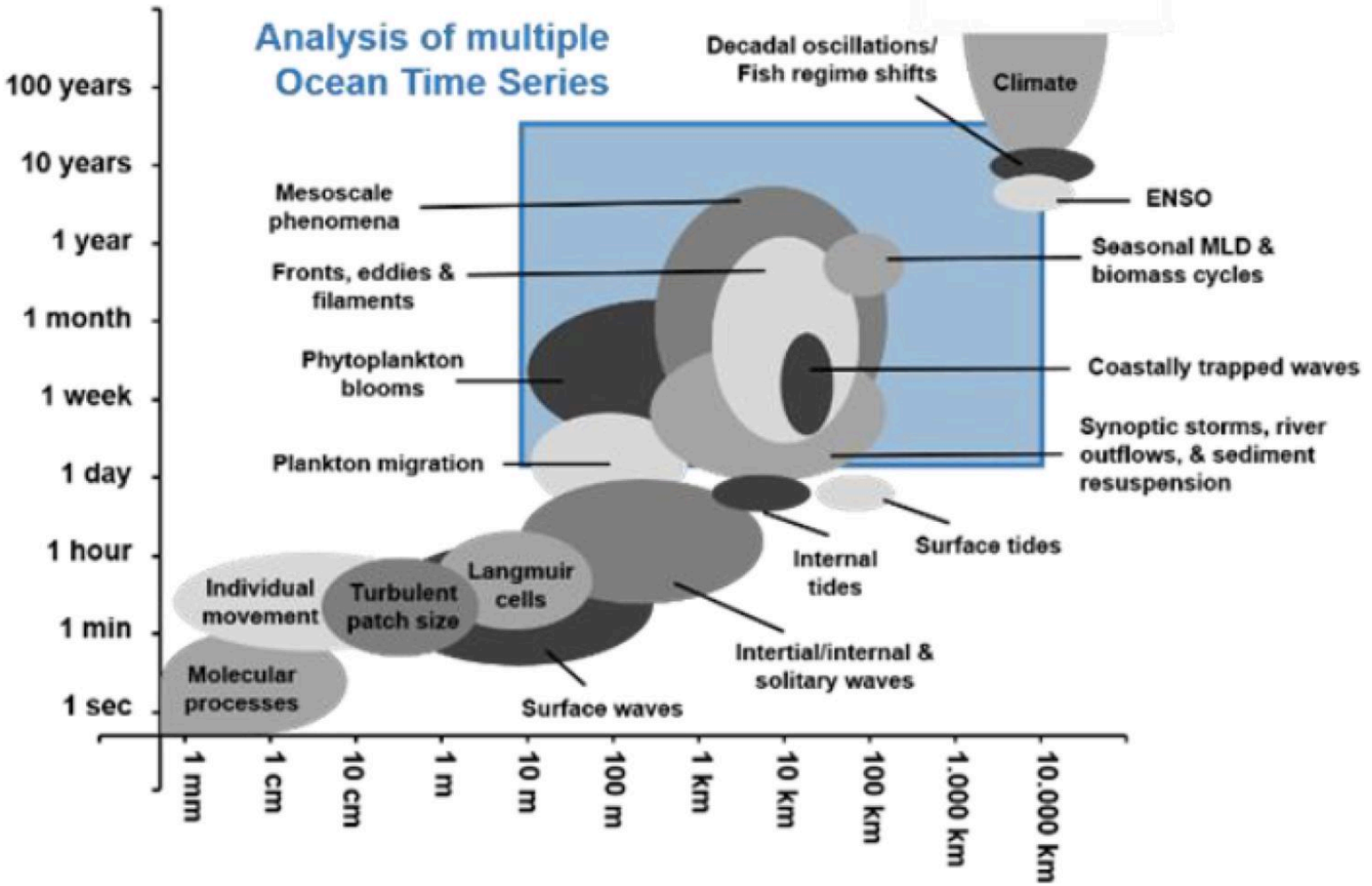
Daily scale

Unique to marine systems



Vaulot D., Marie D. 1999. Diel variability of photosynthetic picoplankton in the equatorial Pacific. Journal of Geophysical Research 104:3297.

Spatial and temporal scales



Benway HM. et al. 2019. Ocean Time Series Observations of Changing Marine Ecosystems. Front. Mar. Sci. 6:1–22.

Take home messages

- Phytoplankton reacts to a multitude of scales
- Spatial scales
- Vertical scale is very important (1D models)
- Spatial scales: from gyres to mesoscale
- Temporal scales: from centuries to hours

Questions ?