# Ocean Structure

ES 383

Colby at Bigelow, September 2018

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**Aside:** Daily mixed layer

# Temperature diurnal cycle

- SST diurnal cycle: usually small(<0.4°C)
- Diurnal cycle is mainly in upper 10 meters
- Produce a “diurnal thermocline”
- Localized higher amplitude of SST: 1°C (occasionally 3°-4°C) in regions of high isolation + low wind, 2~3°C in shallow water along coast.

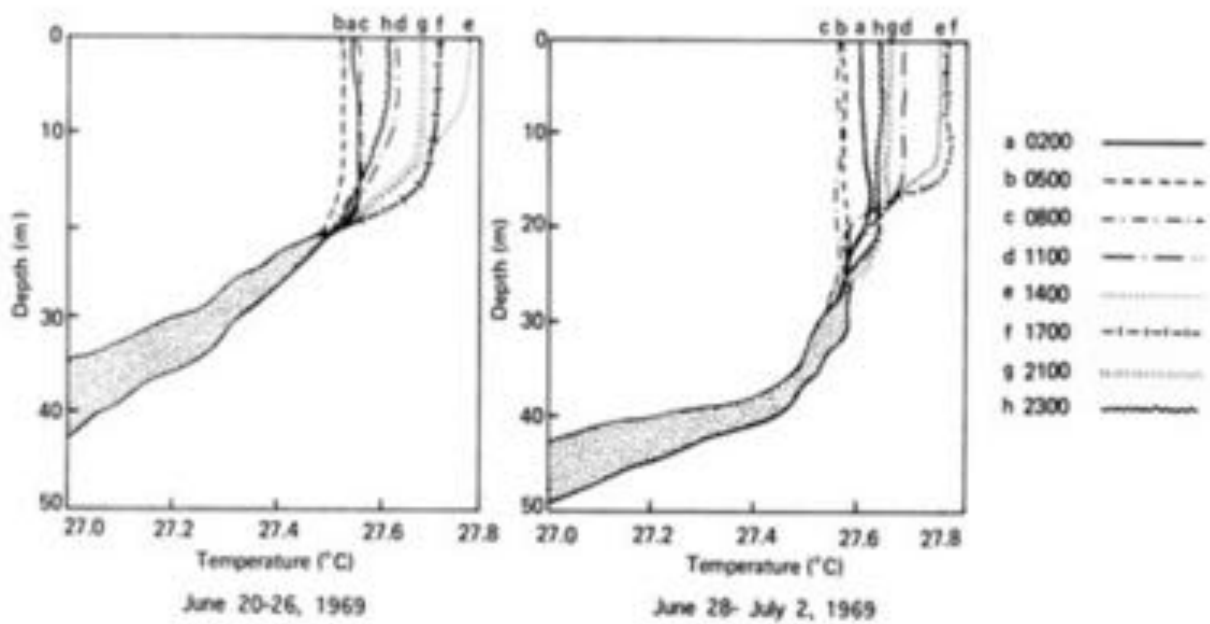


**Figure 3.10** Growth and decay of a diurnal thermocline in spring. In a given 24-h period, nearly all the heat that is gained during the day is lost at night. However, there is generally a small net heat gain each day in spring. As a consequence, the average heat content of the second period is greater than that of the first period. (After Delnore, *J. Phys. Oceanog.*, 2, 1972.)

**Gulf of Maine Water Masses**: Henry Bigelow 1924

One of the first modern oceanographers
Early oceanographic maps of the Gulf of Maine
- *Fishes of the Gulf of Maine*
- *Physical Oceanography of the Gulf of Maine*

WHOI archives

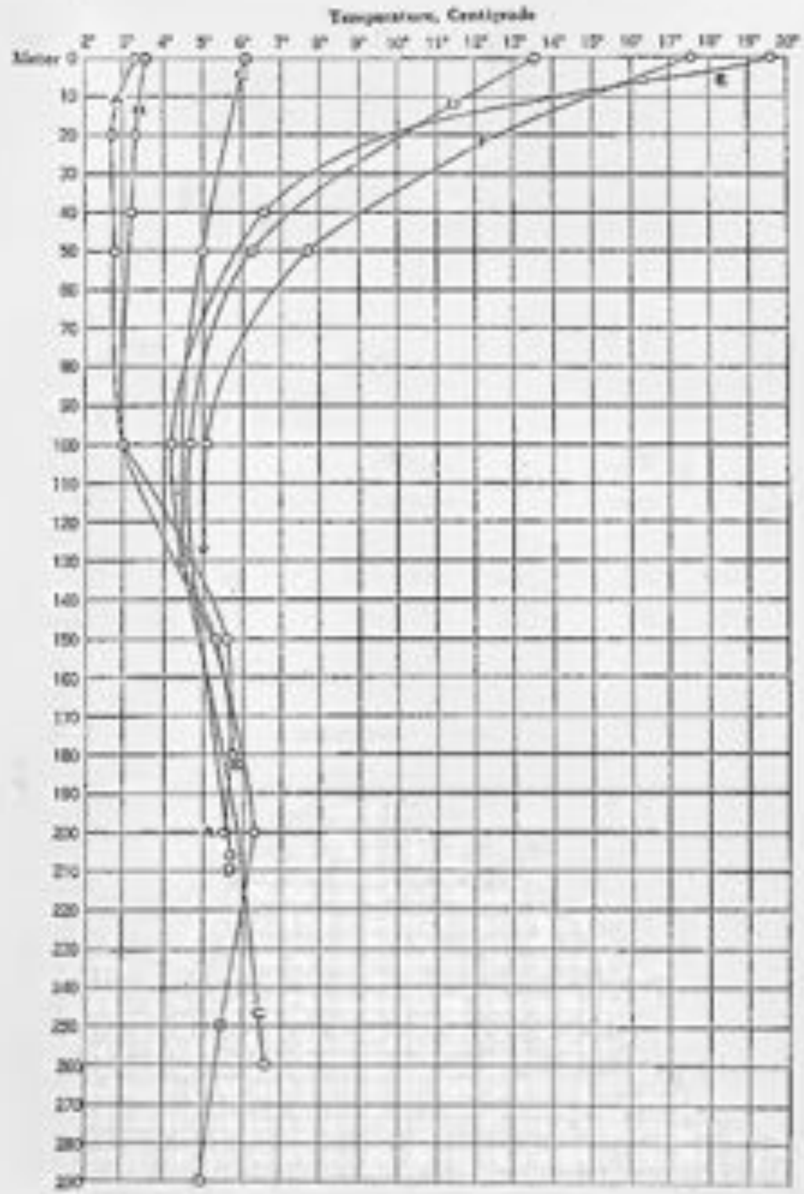


FIG. [illegible].—Vertical distribution of temperature in the western side of the basin, off Cape Ann, March to August. A, February [illegible], [illegible] (station [illegible]); B, April [illegible], [illegible] (station [illegible]); C, May [illegible], [illegible] (station [illegible]); D, June [illegible], [illegible] (station [illegible]); E, August [illegible], [illegible] (station [illegible])

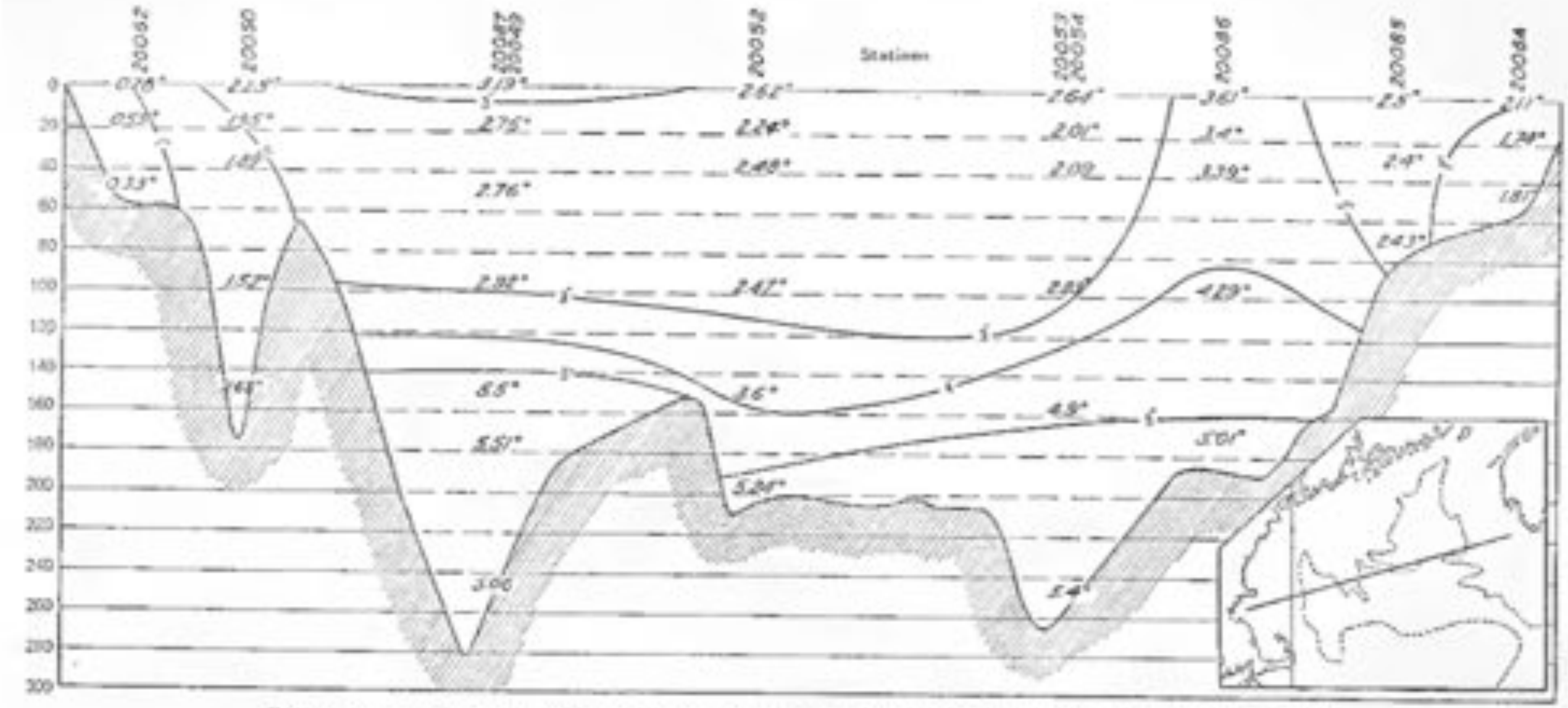


FIG. 14.—Temperature profile crossing the gulf from Massachusetts Bay to the vicinity of Cape Sable, March 8 to [illegible]

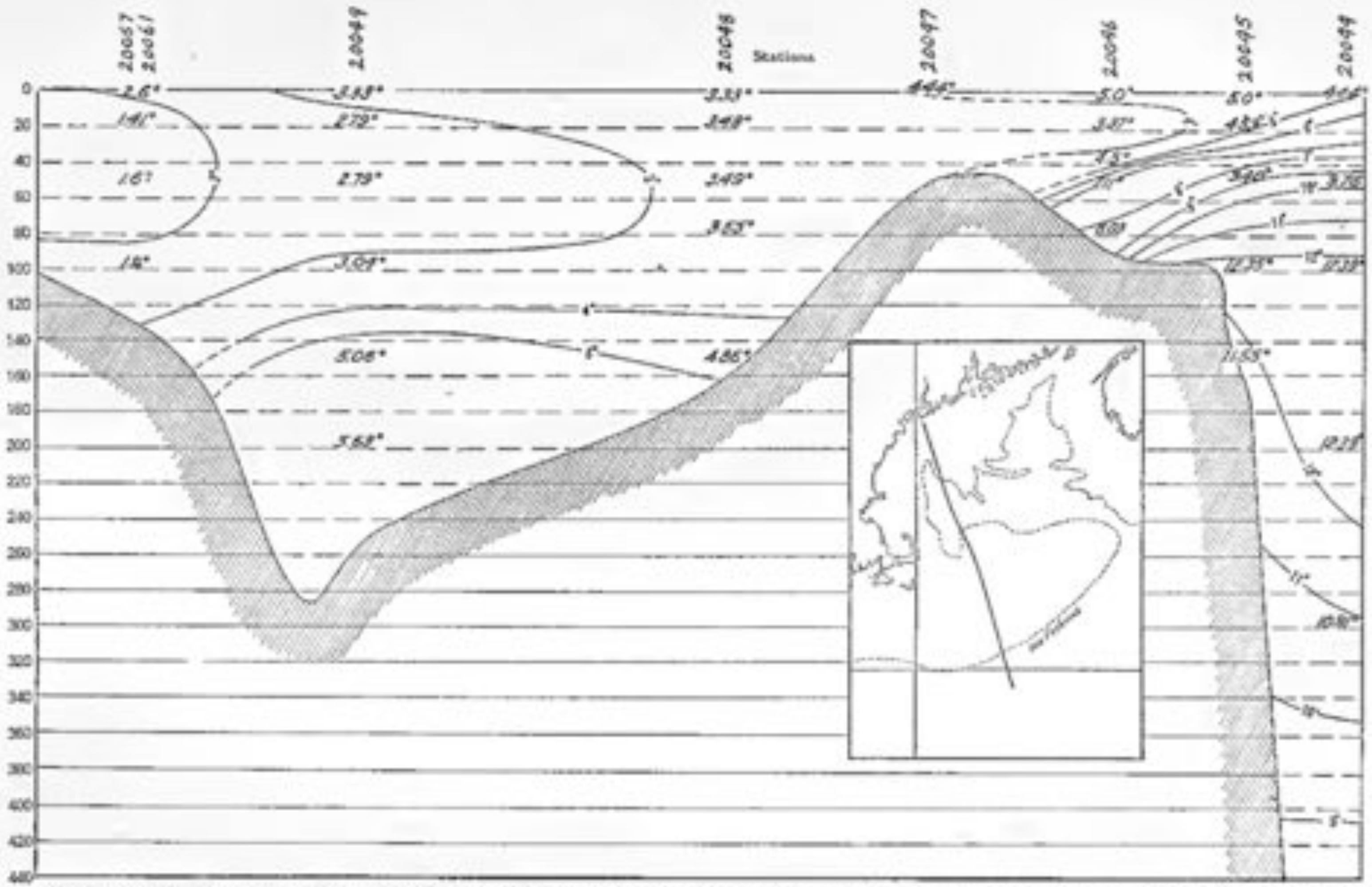


Fig. 18.—Temperature profile running southeasterly from the northwestern part of the gulf, off Cape Elizabeth, across Georges Bank to the continental slope, February 22 to March 4, 1920





Bi

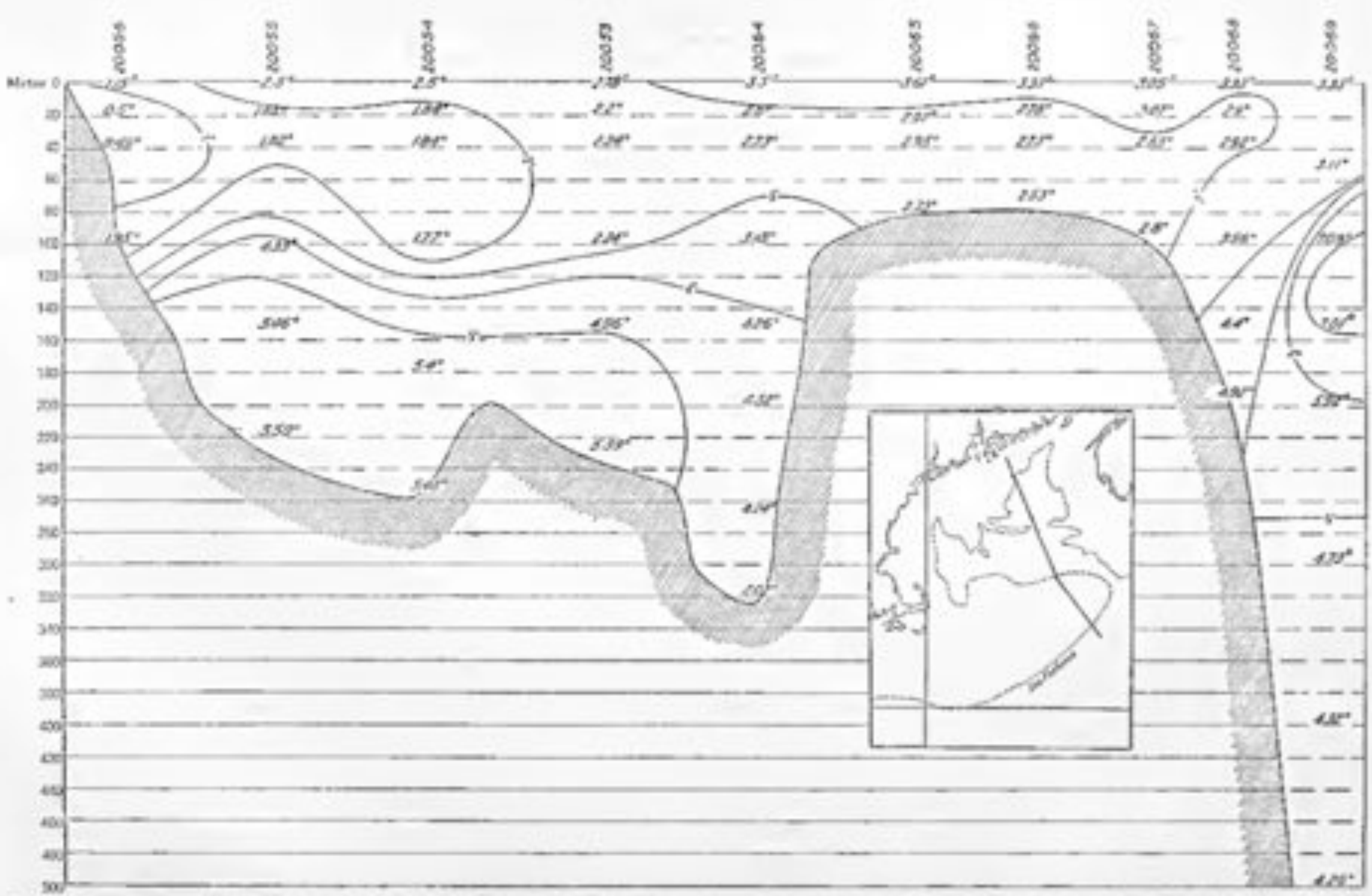

FIG. 15.—Temperature profile running from the vicinity of Mount Desert Island, southeasterly across the eastern part of Georges Bank to the continental slope, for March 3 to 12, 1920

grounds for haddock in North American waters, and at the height of the spawning

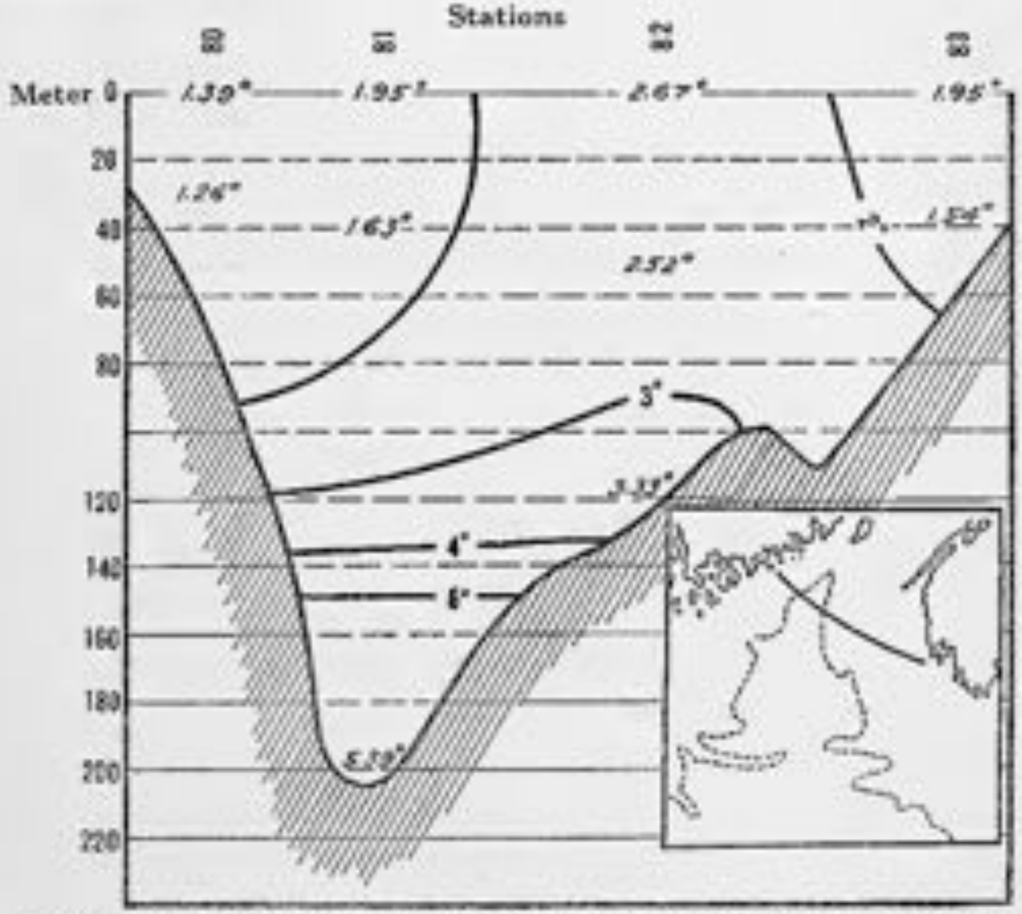


FIG. 17.—Temperature profile crossing the northeastern part of the gulf, off the mouth of the Bay of Fundy, for March 22 and 23, 1920 (stations 20080 to 20083)

season, lends biological interest to the temperatures at stations 20061 to 20068. Evidently the eggs were being set free in water of about 2.5° to 2.7°.

The boundaries of the comparatively warm (5°) bottom water in the eastern arm of the basin, for March, are outlined further by a profile from Maine to Nova Scotia, opposite the mouth of the Bay of Fundy (fig. 17, stations 20080 to 20083). Temperatures higher than 5° were confined to depths greater than 150 meters along this line, but the isotherm for 3° shows the warmer bottom water banking up against the into the Eastern Channel, on the other, is illustrated by a profile following the arc of the banks (fig 19). Bottom water of 6° to 7° in the Eastern Channel, banked

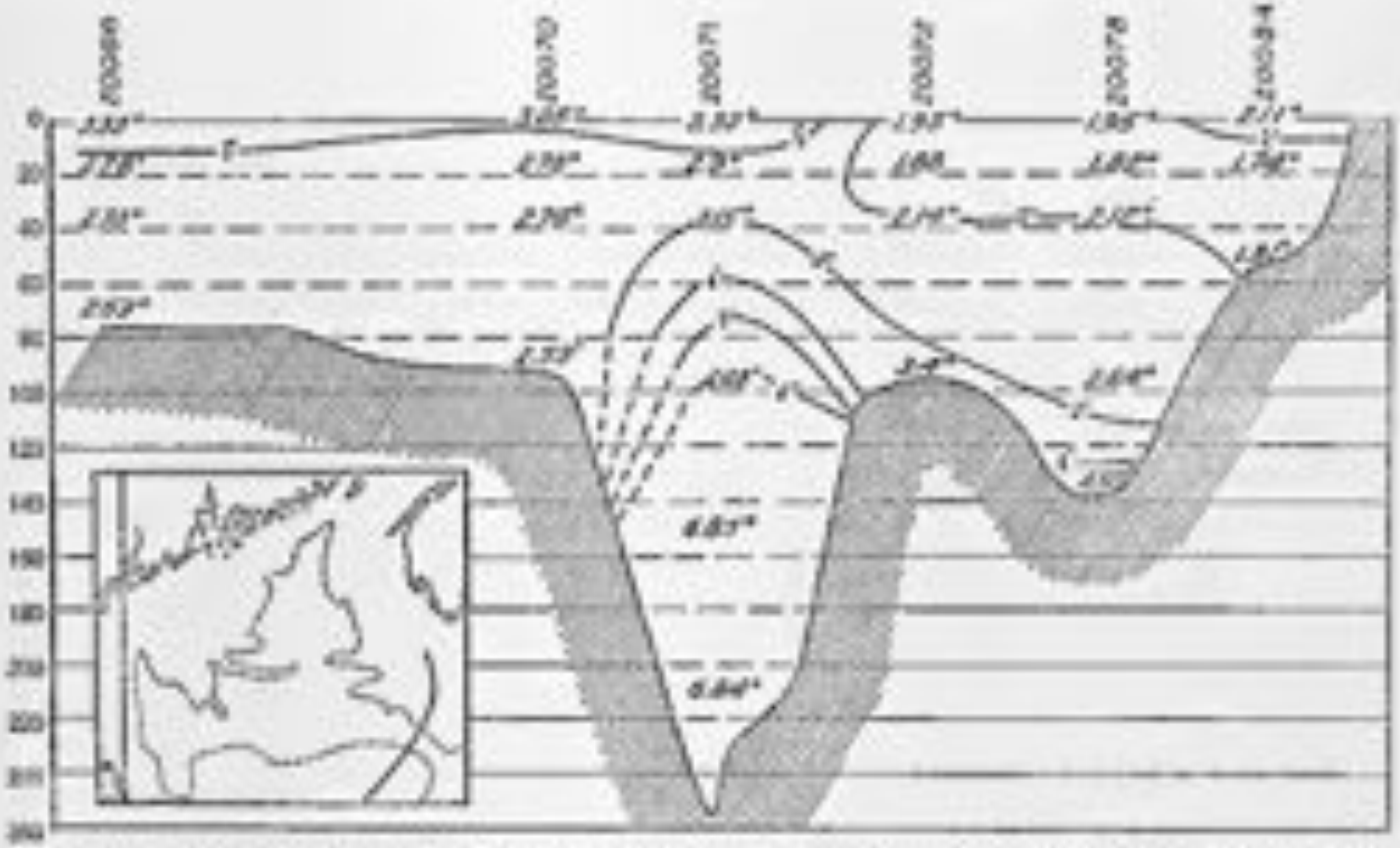

FIG. 2[illegible].—Temperature profile running from the eastern part of Georges Bank, across the Eastern Channel, Brown's Bank, and the Northern Channel, March 11 to [illegible], 1920

up like a ridge along its trough (isotherms for 3° to 6°), contrasts with 3° to 4.5° at equal depths in the Northern Channel, where temperatures higher than 4° were con-


FIG. 15.—Extent of bottom water warmer than 6°, last half of June, 1915

Cape Cod Bay, as outlined by the isotherm for 18°. Within this area readings of

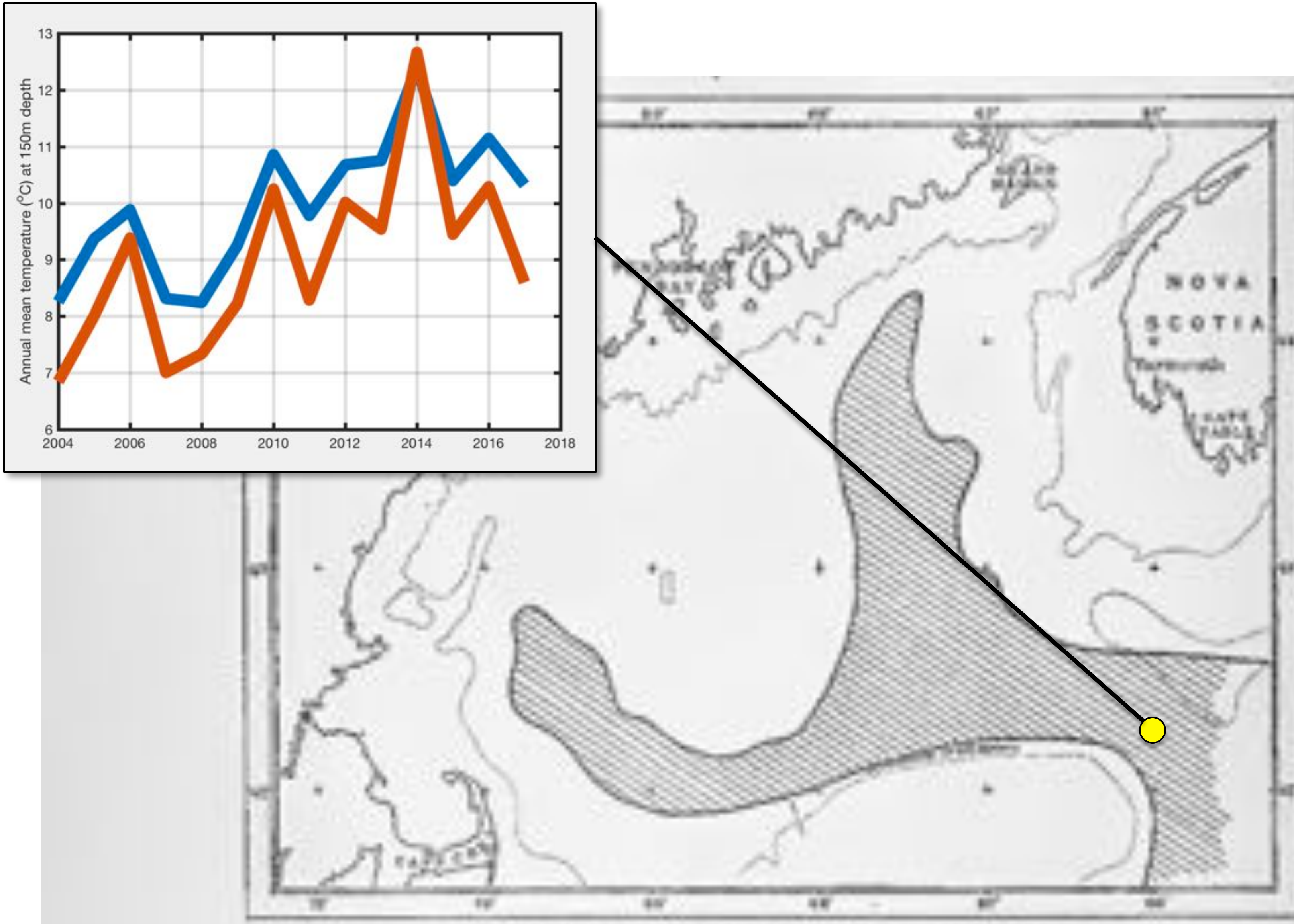


Fig. 15.—Extent of bottom water warmer than 6°, last half of June, 1915

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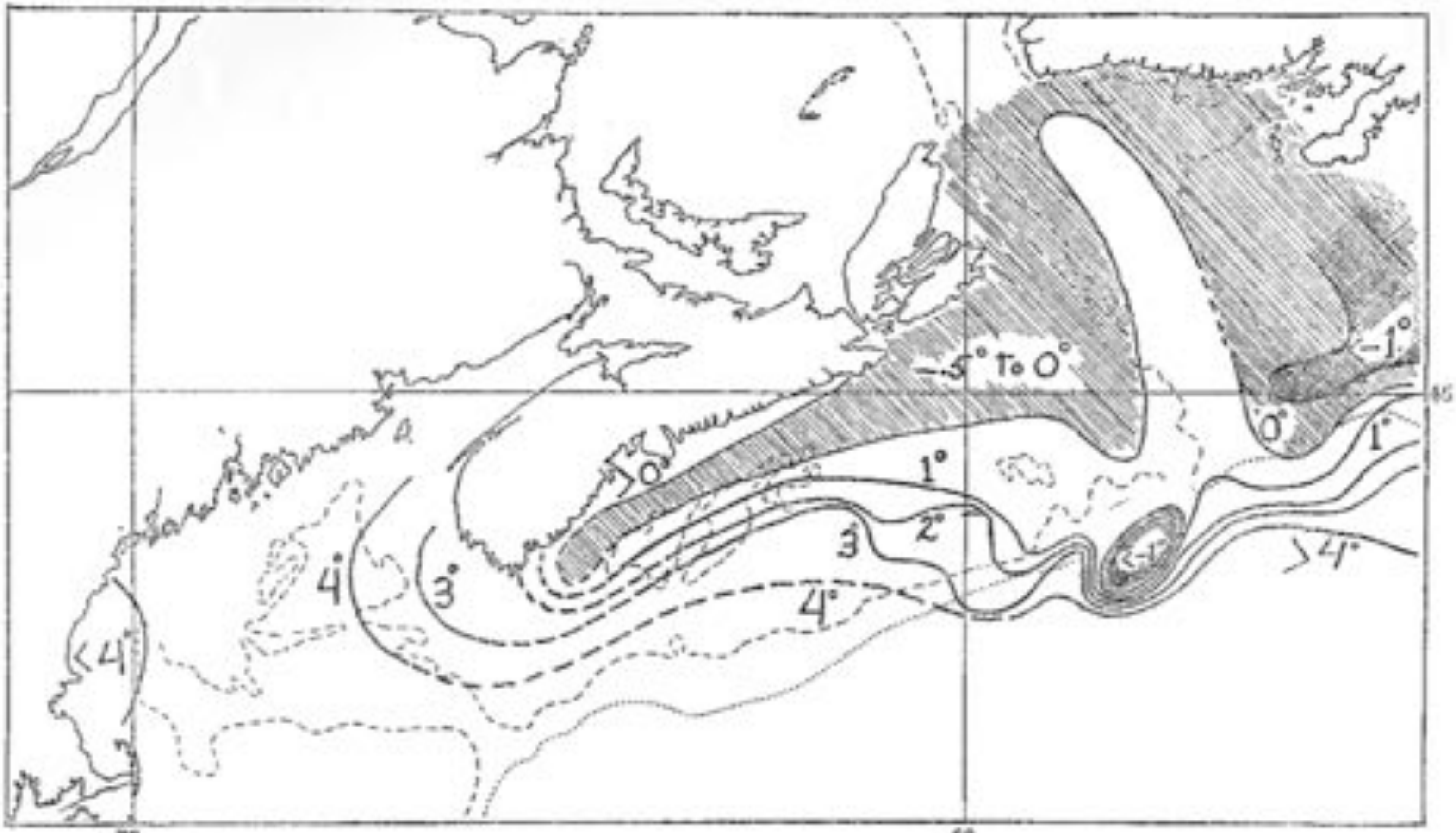
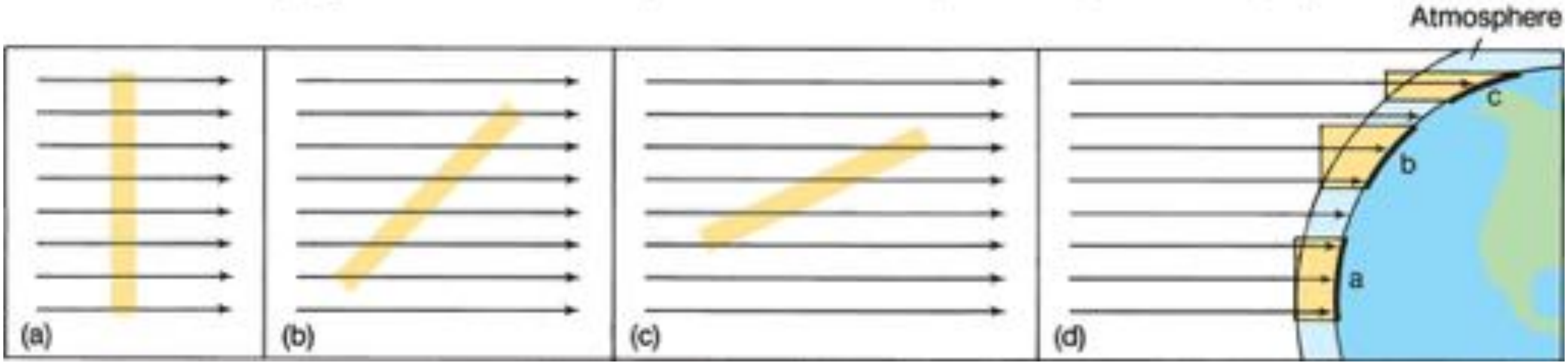



FIG. 167.—Distribution of the coldest water, irrespective of depth, from Newfoundland to the Gulf of Maine, for May, 1915, based on the records of the Canadian Fisheries Expedition (Bjerkan, 1919) and *Grampus* stations 10256 to 10279

# What controls ocean temperature?



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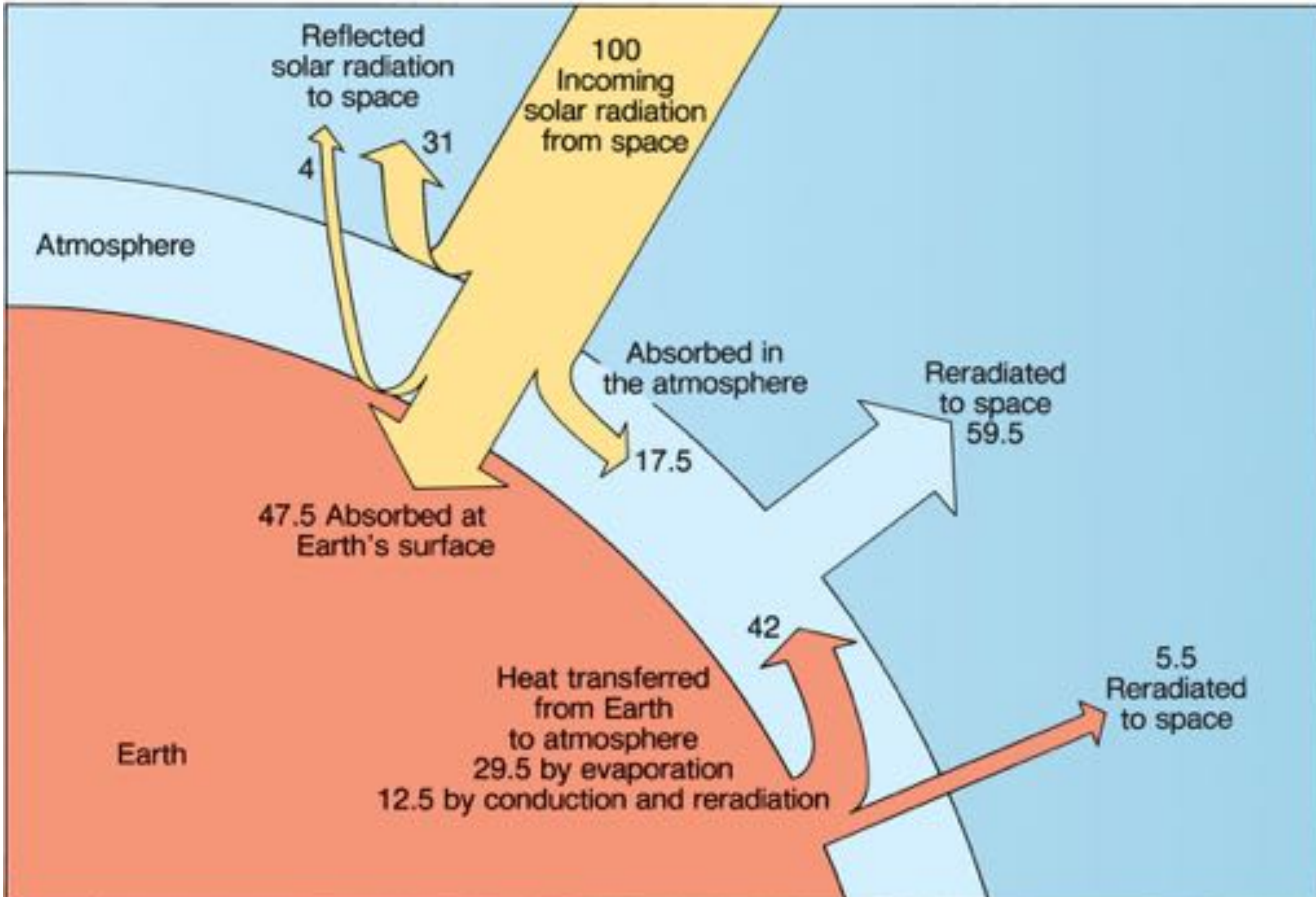
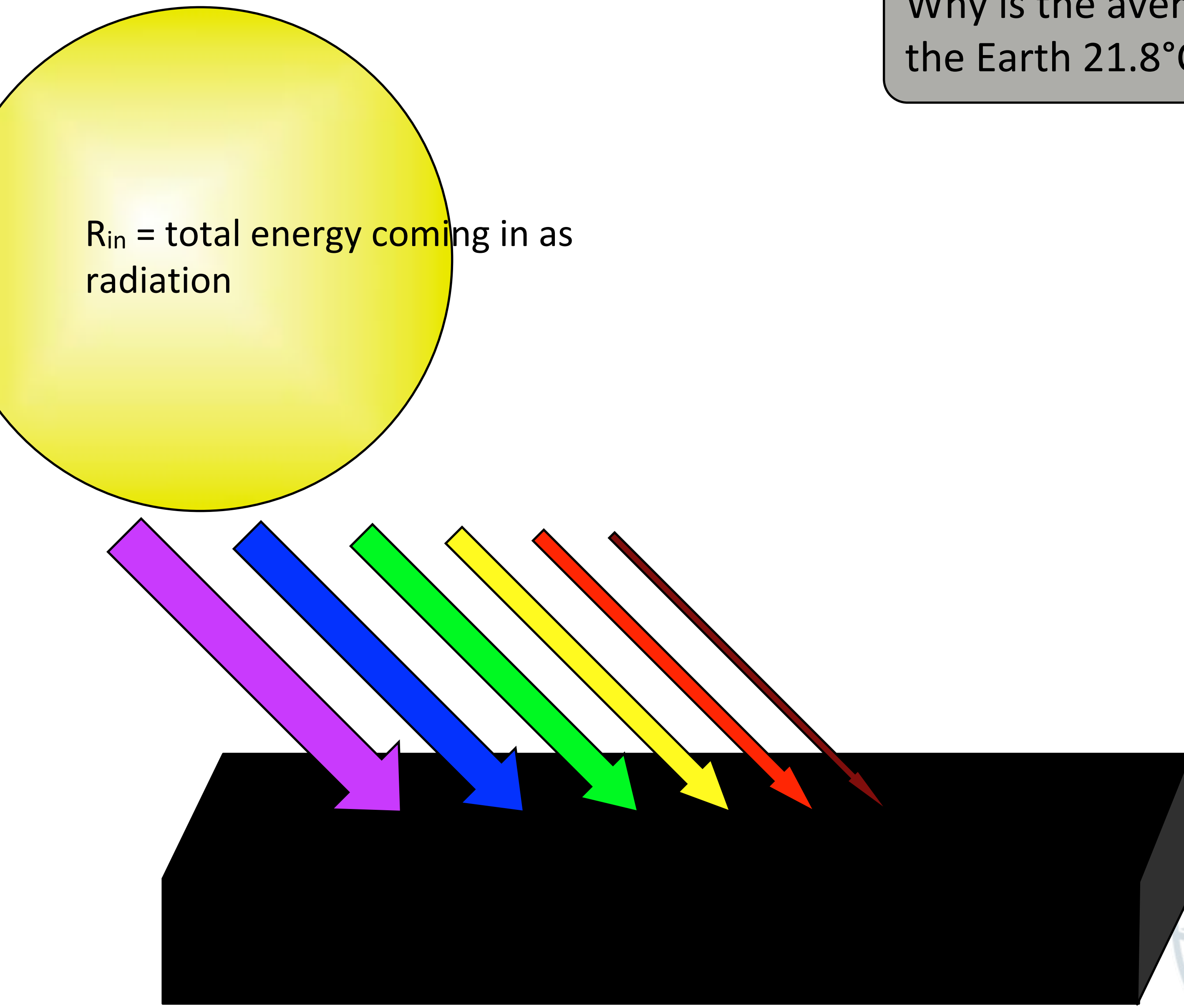

Reflected
solar radiation
to space
4
31
100
Incoming
solar radiation
from space
Atmosphere
Absorbed in
the atmosphere
17.5
Reradiated
to space
59.5
47.5 Absorbed at
Earth's surface
42
5.5
Reradiated
to space
Heat transferred
from Earth
to atmosphere
29.5 by evaporation
12.5 by conduction and reradiation
Earth

Why is the average temperature of the Earth 21.8°C?

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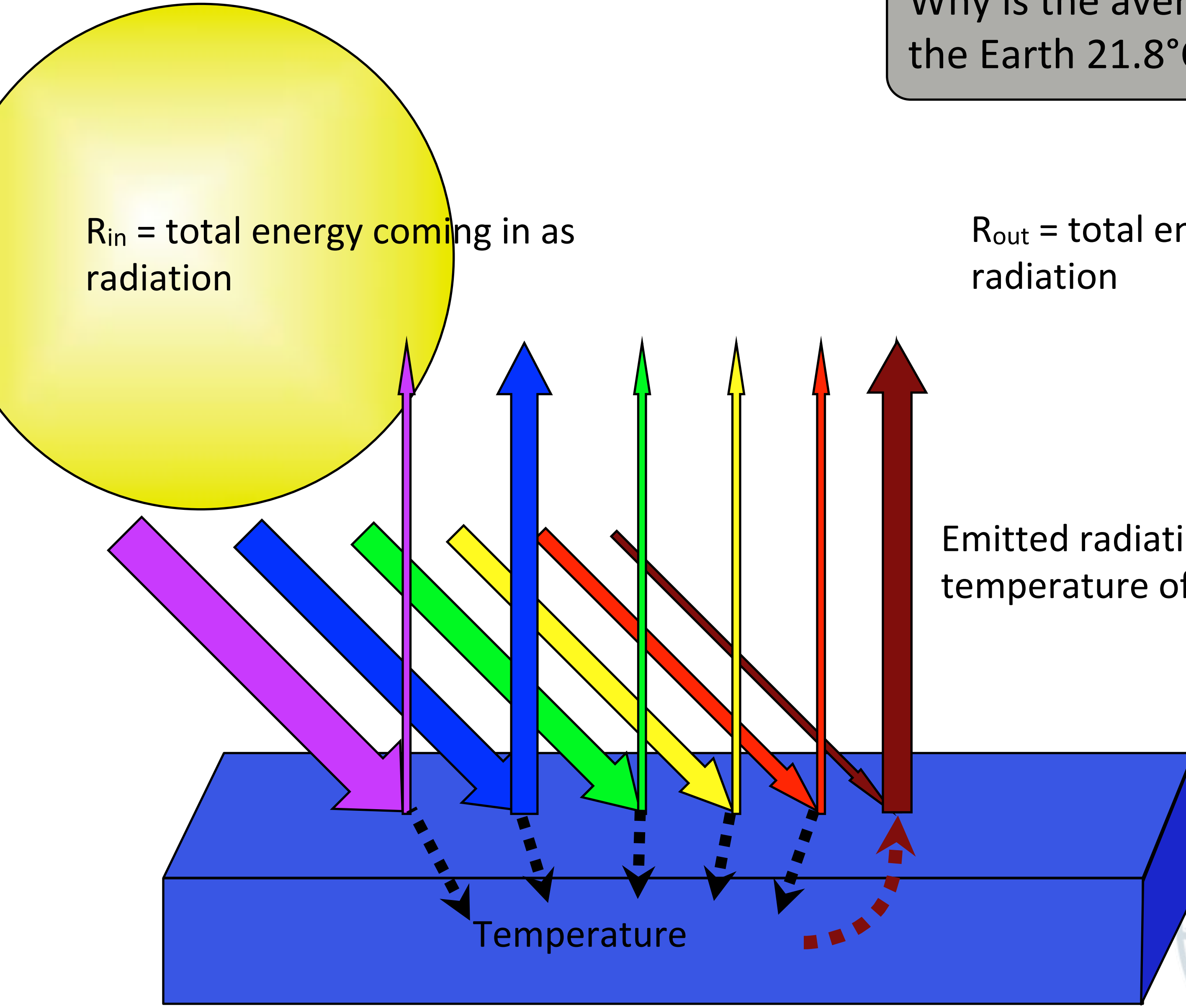
Slide credit: A. Pershing

Why is the average temperature of the Earth 21.8°C?

$R_{in}$ = total energy coming in as radiation

$R_{out}$ = total energy leaving as radiation




Emitted radiation depends on temperature of body

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Slide credit: A. Persing

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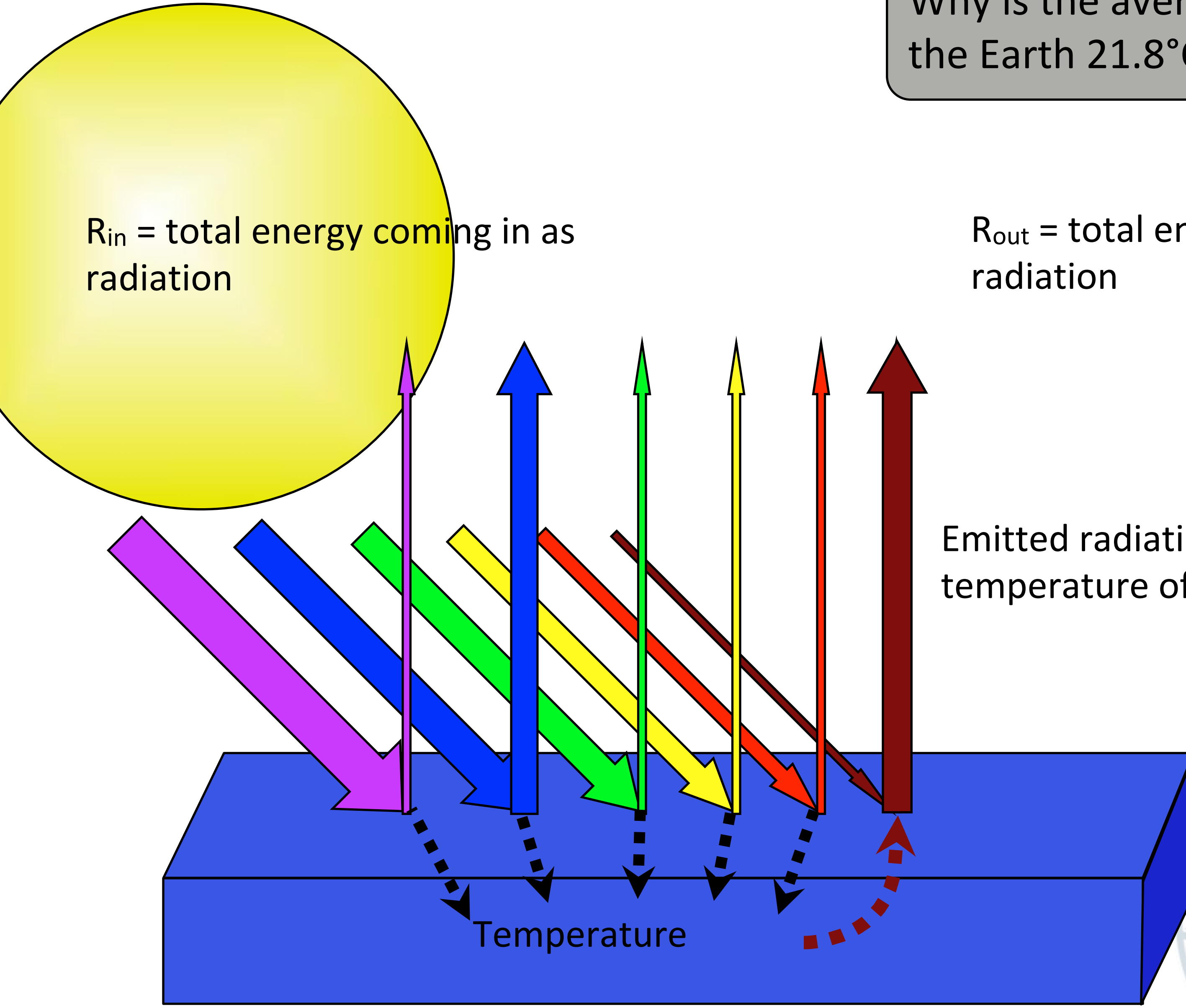


$R_{out}$ = total energy leaving as radiation

Emitted radiation depends on temperature of body

Temp. goes up until $R_{out}$=$R_{in}$



Slide credit: A. Pershing

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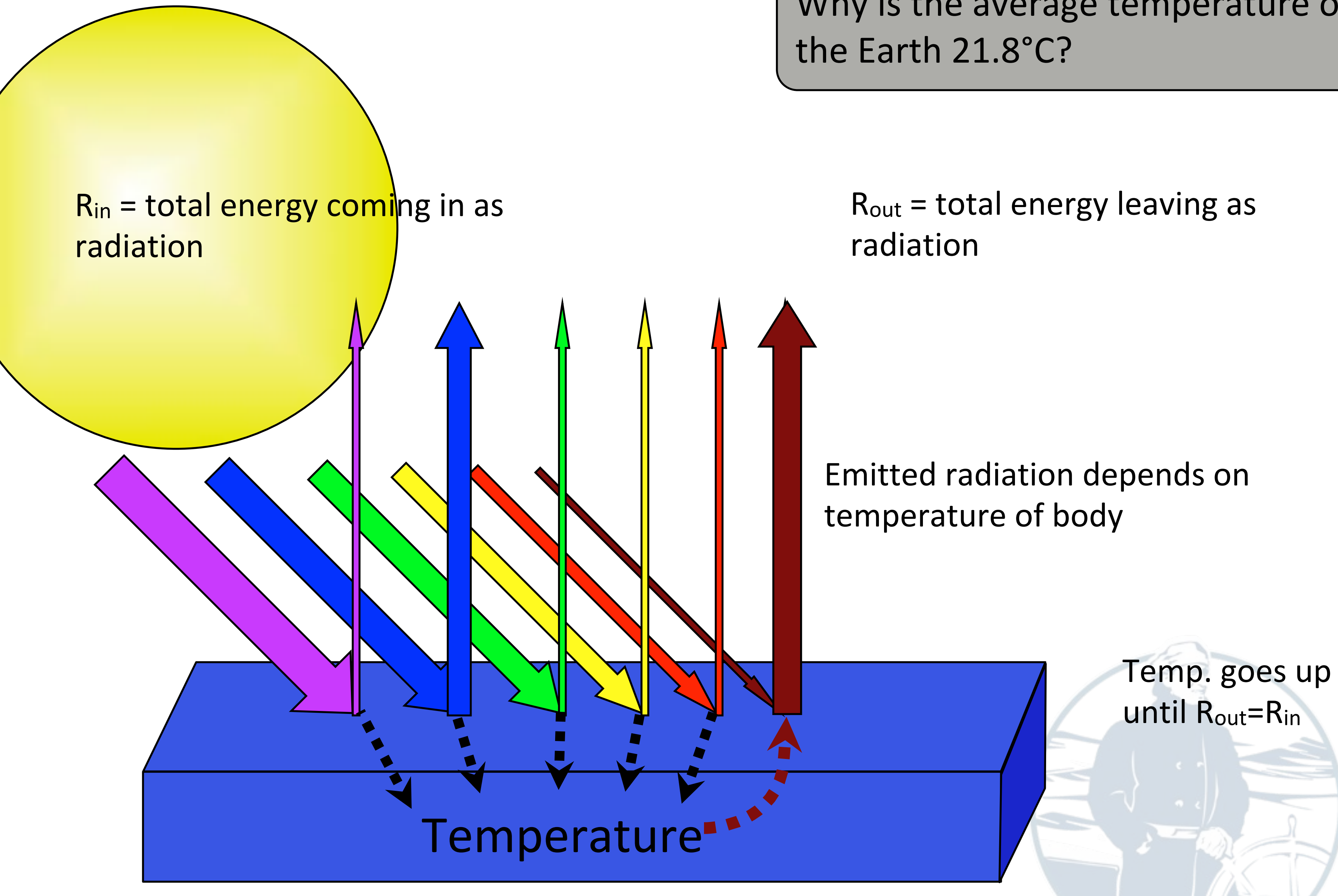


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Slide credit: A. Pershing

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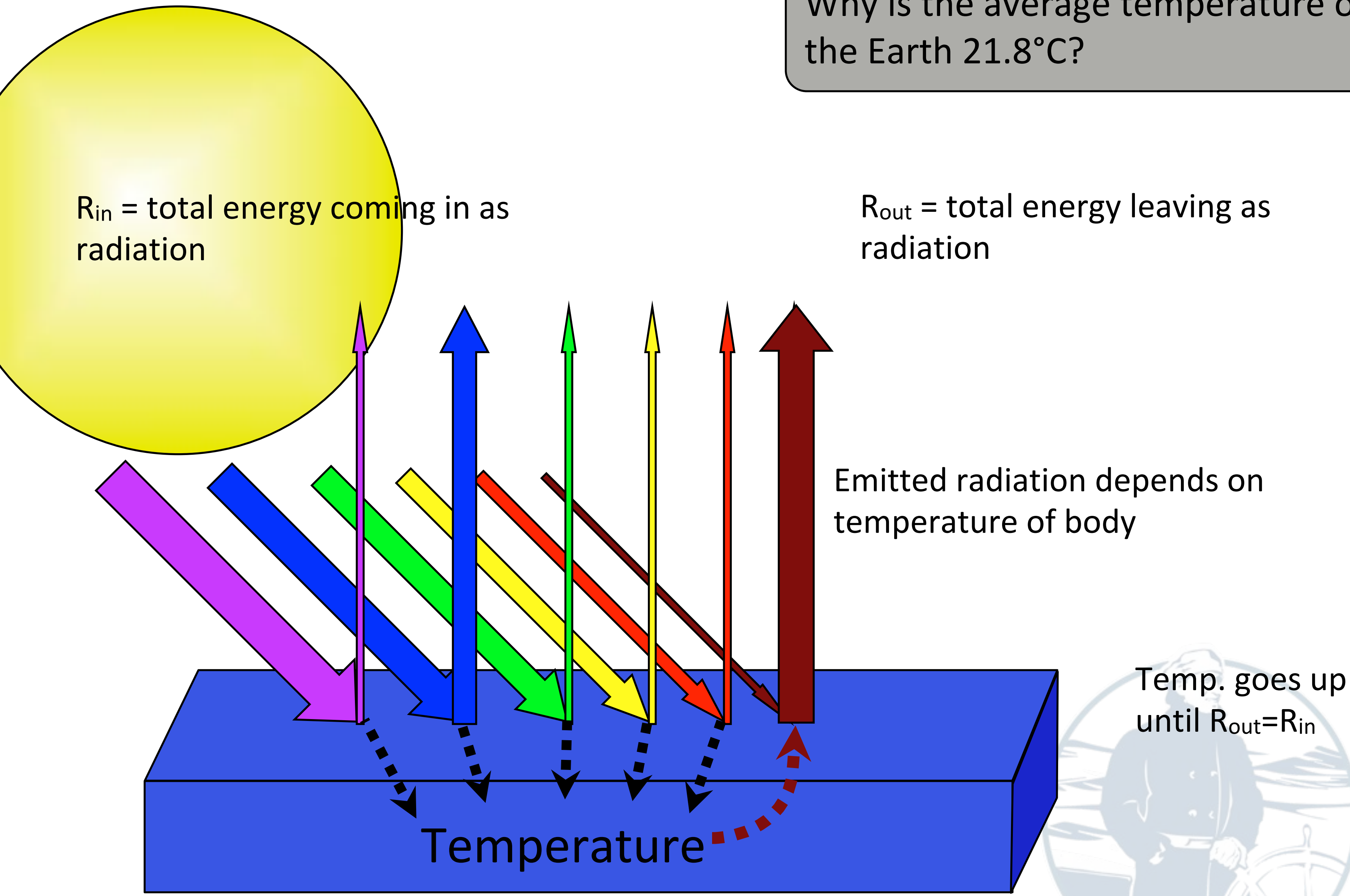


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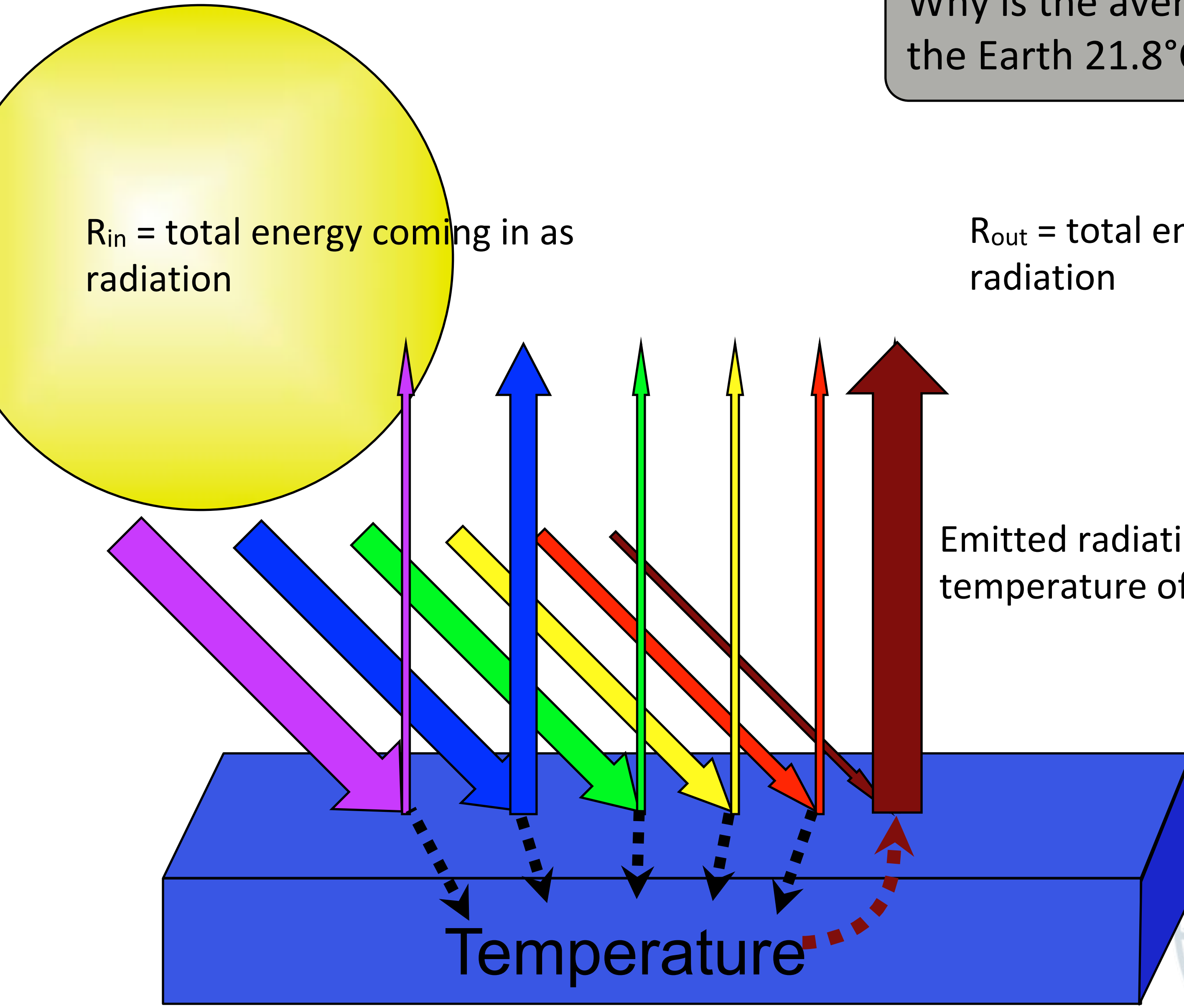


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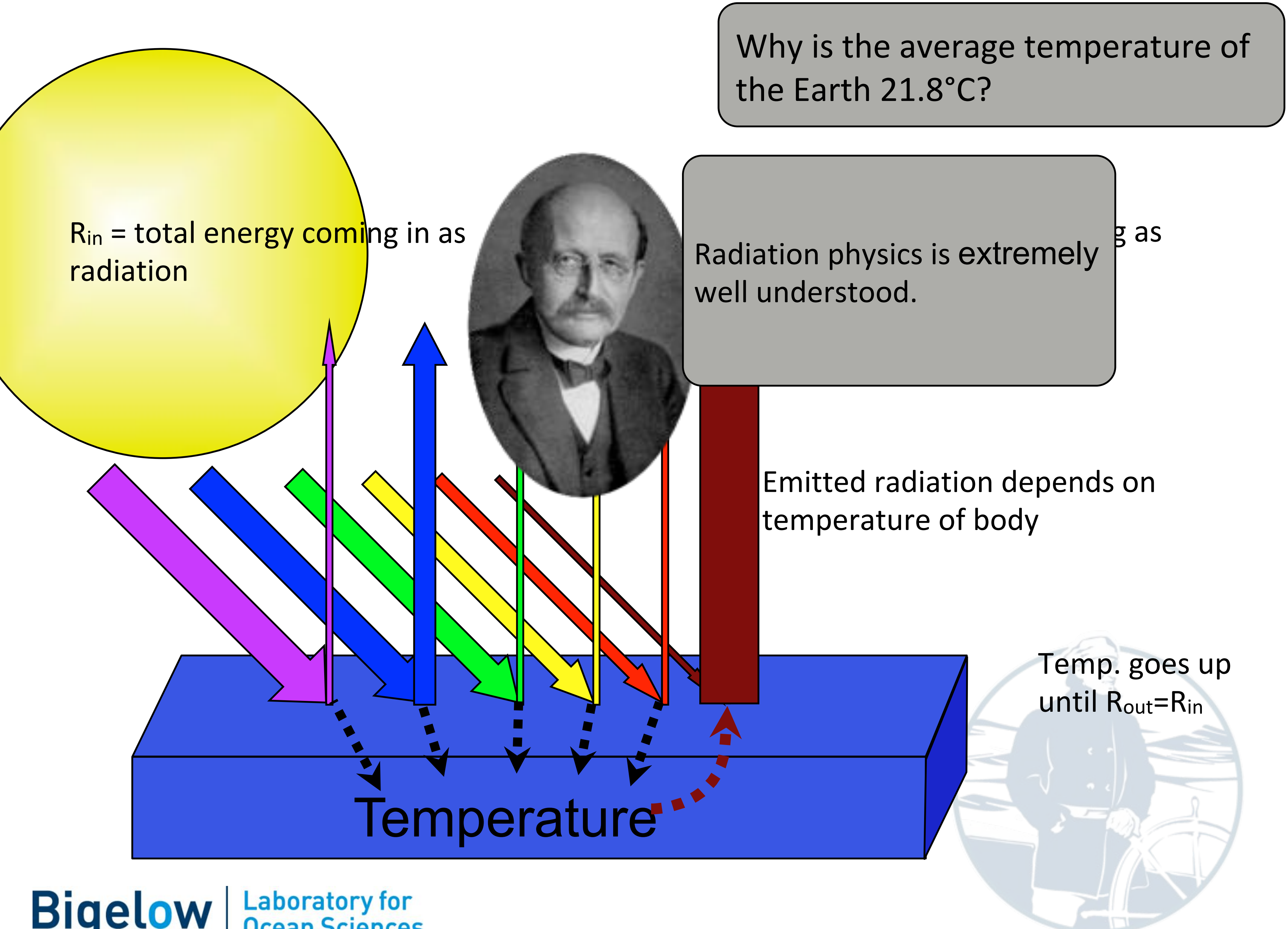
Slide credit: A. Pershing

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Slide credit: A. Pershing

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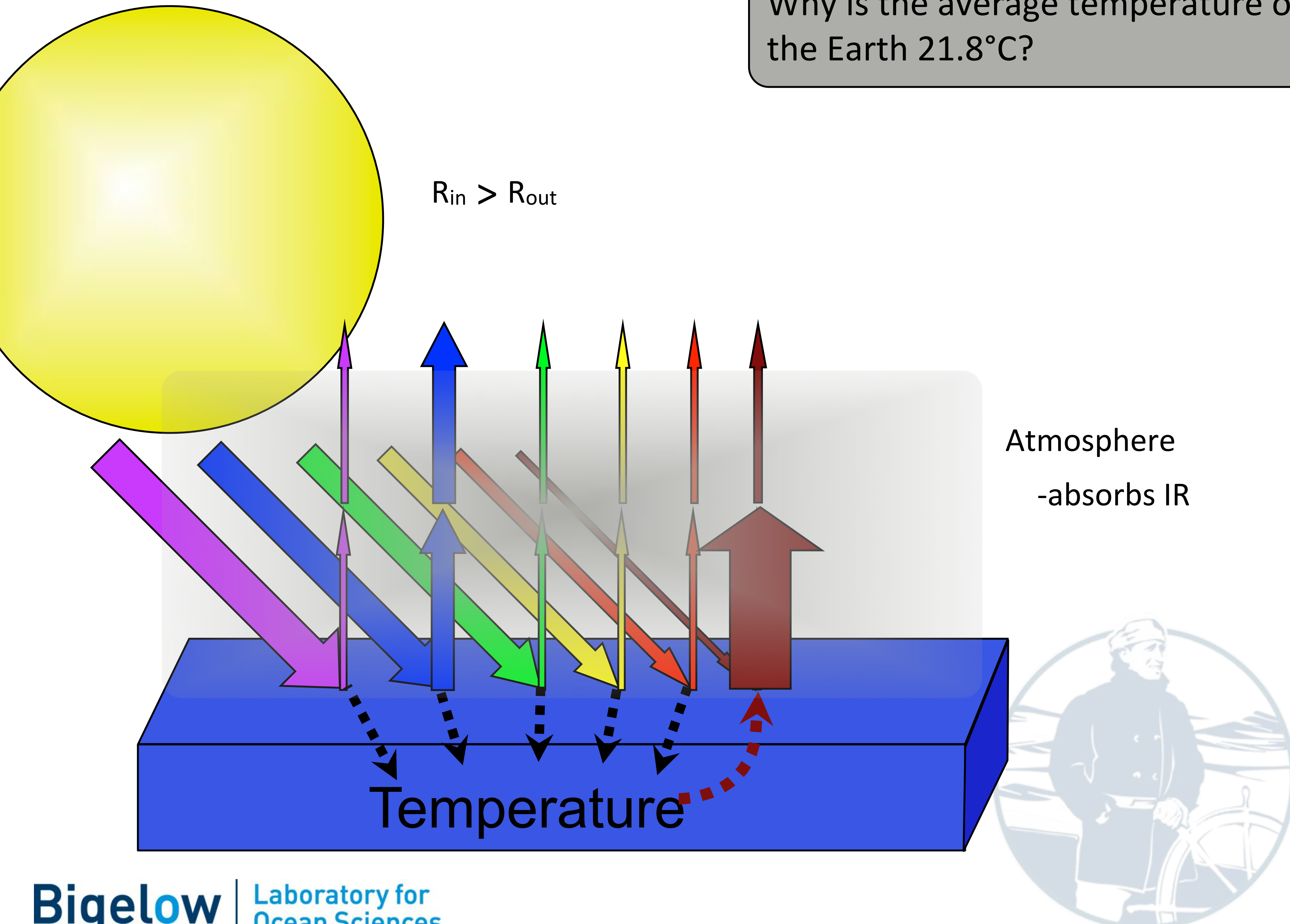


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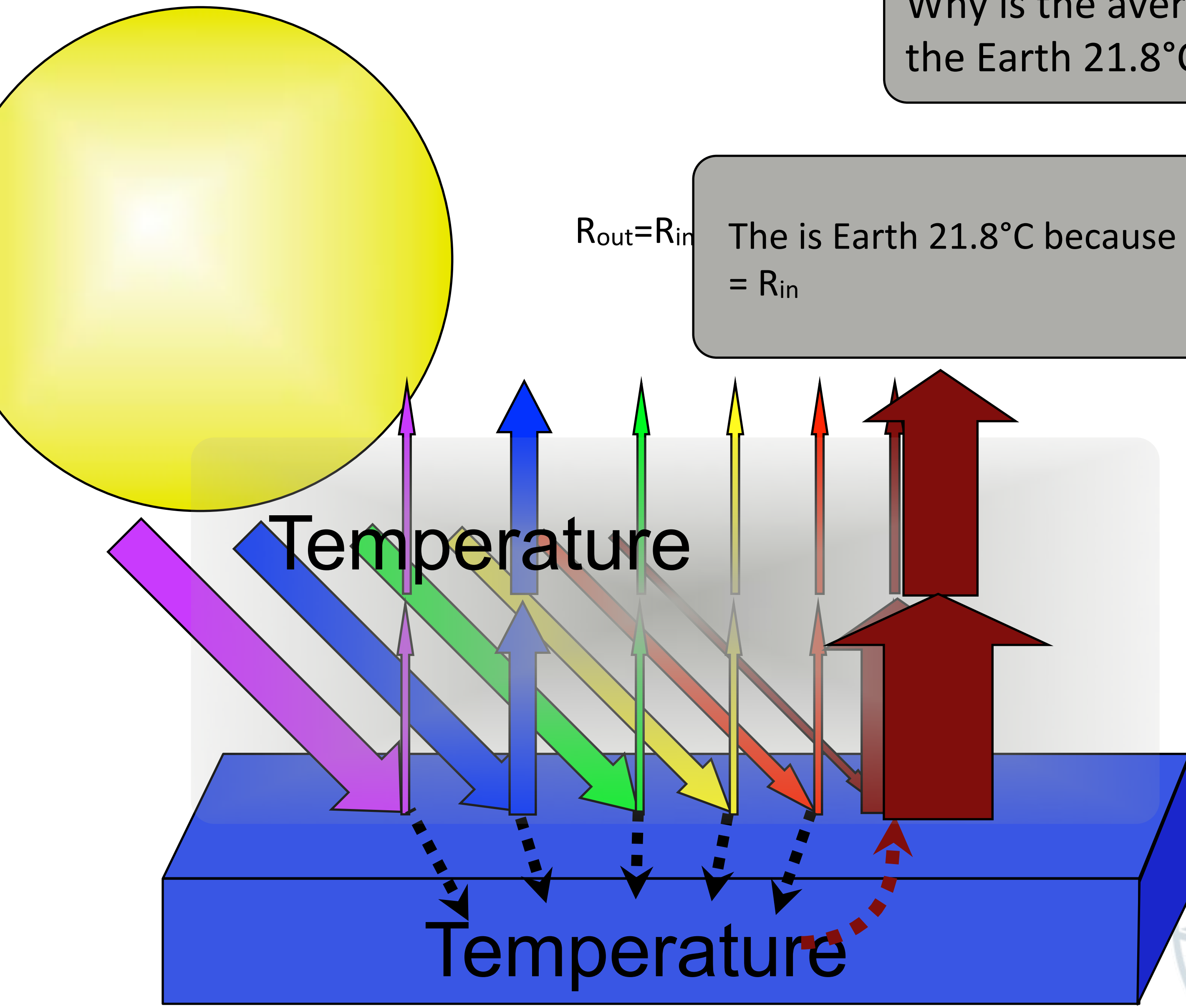
Slide credit: A. Pershing

Why is the average temperature of the Earth 21.8°C?

The is Earth 21.8°C because at that temp., $R_{out} = R_{in}$




Atmosphere

-absorbs IR

-temps go up until $R_{out}$=$R_{in}$



Slide credit: A. Pershing

# Heat budget of a body of water (in one place)

- Heat flow Q [joules/ sec/m$^2$]

$Q_{total} = Q_{solar\ S} - Q_{radiant\ B} - Q_{conduction\ H} - Q_{evap\ E} \pm Q_{advection\ V}$

$Q_T = 0$, temp does not change annually but $Q_S$, $Q_B$, $Q_H$, $Q_E$, $Q_V$ can.

$Q_V = 0$ over globe

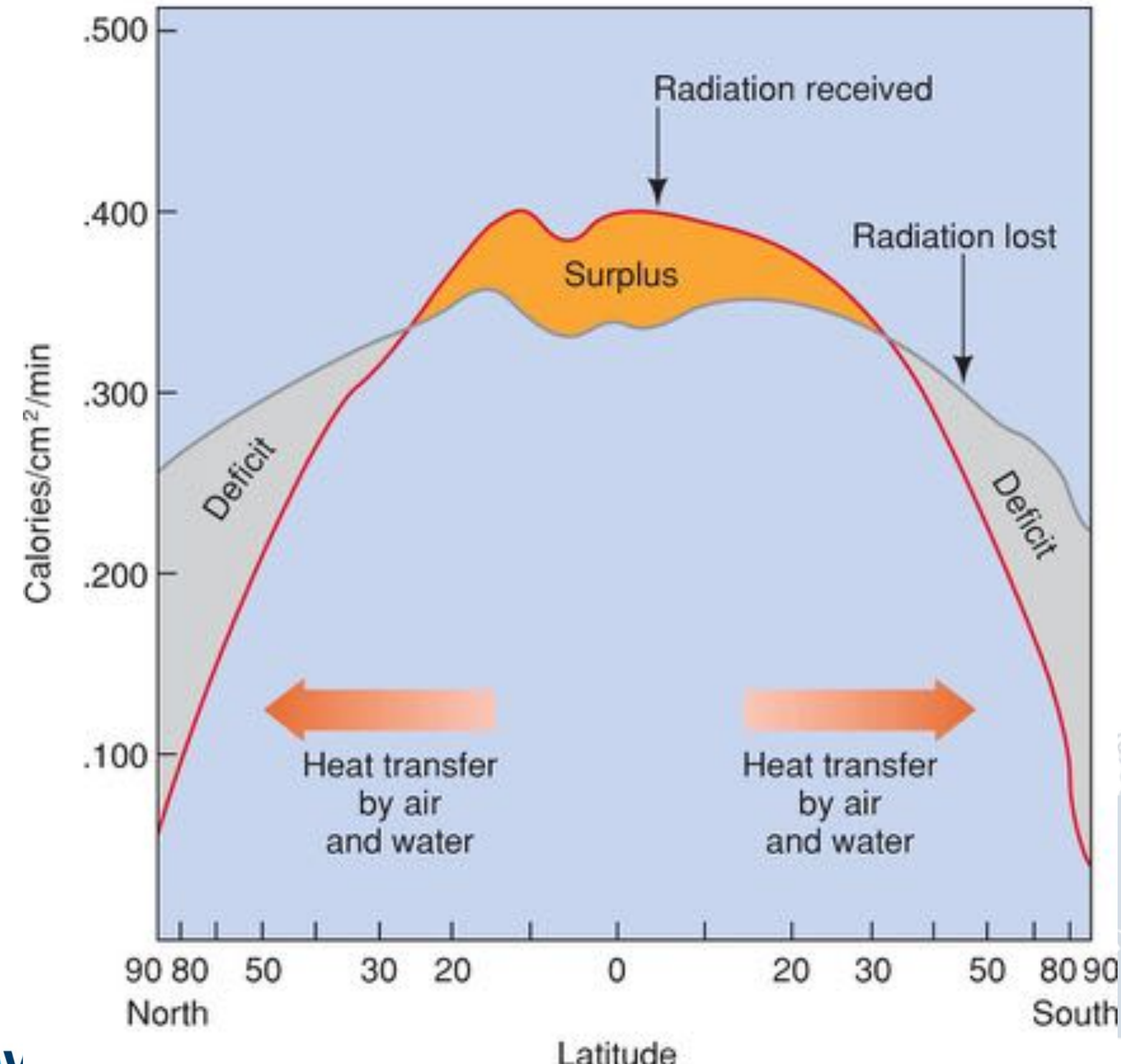
$Q_T = 0$ over year (ignoring climate change)

EVAP >> RADIATION > CONDUCTION

(IR, to space) (to atm)

(max@30$^o$ max@0$^o$ max@45$^o$)

- Thus, different heat losses are dominant at different latitudes
- There are also orbital, seasonal, day/night cycles
- Milankovitch cycles – changes in the properties of Earth's orbit that produce climate changes (e.g. ice age)




Source: NOAA Meteorological Satellite Laboratory.

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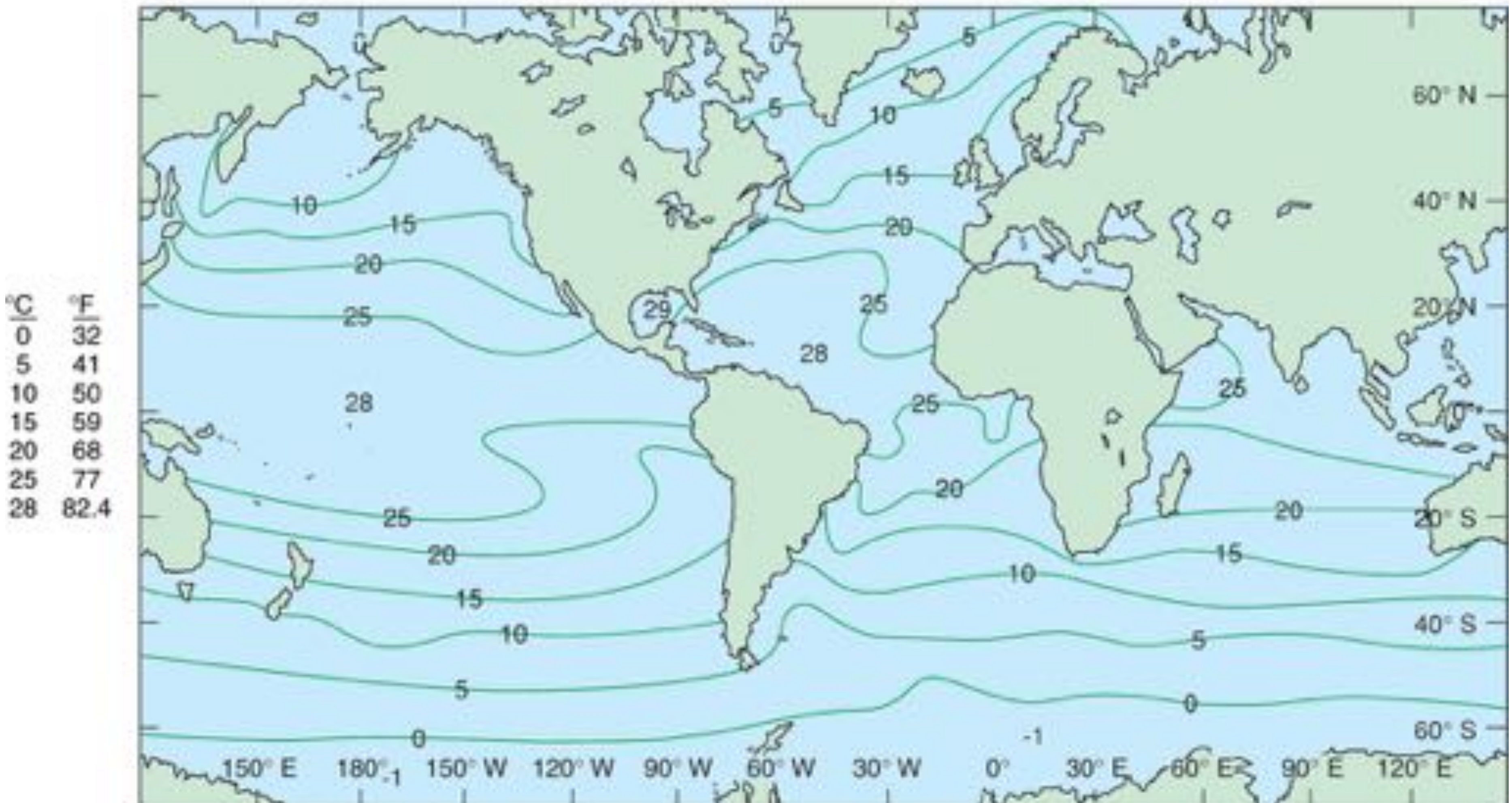
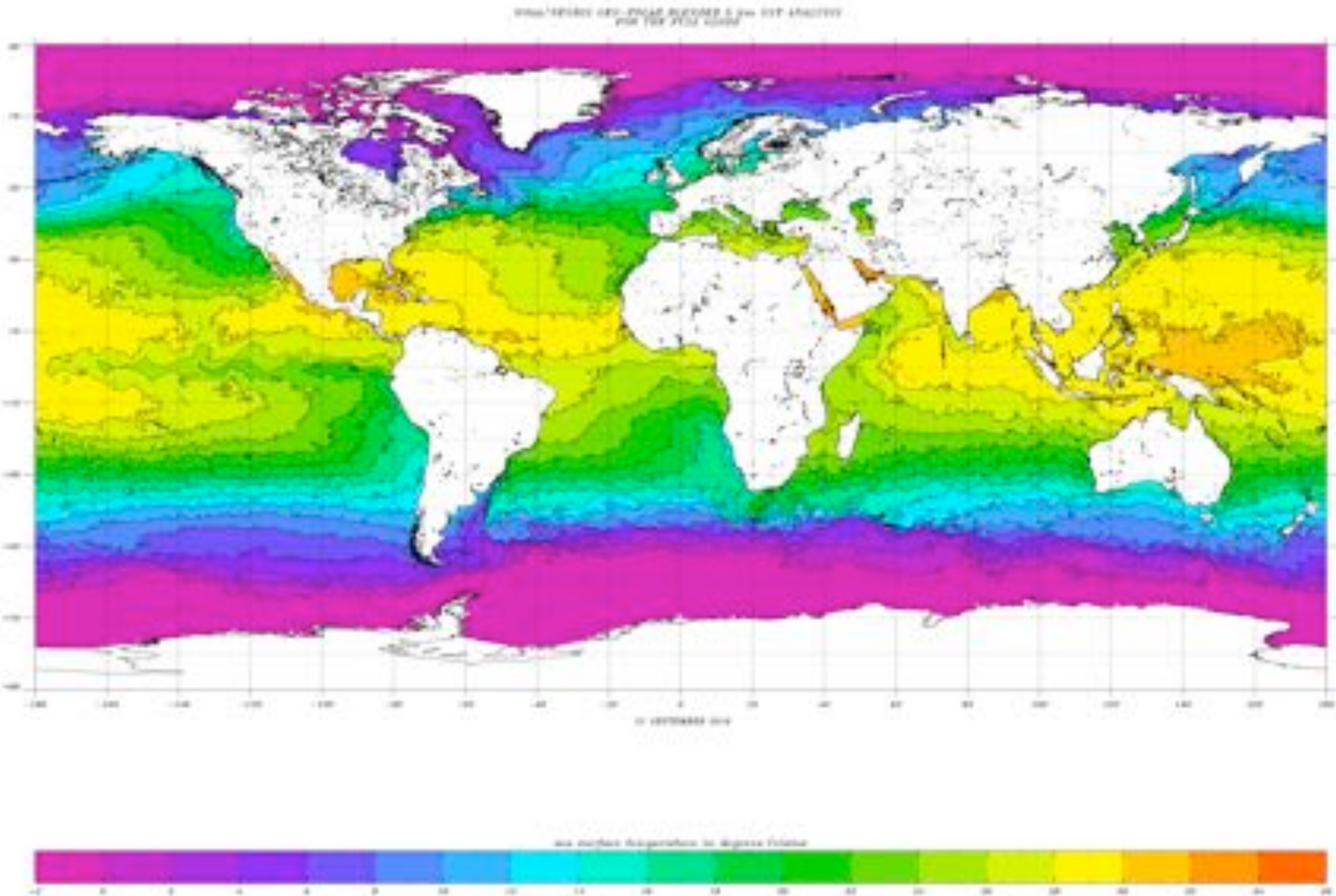
# Sea surface temperature (SST) (summer NH)

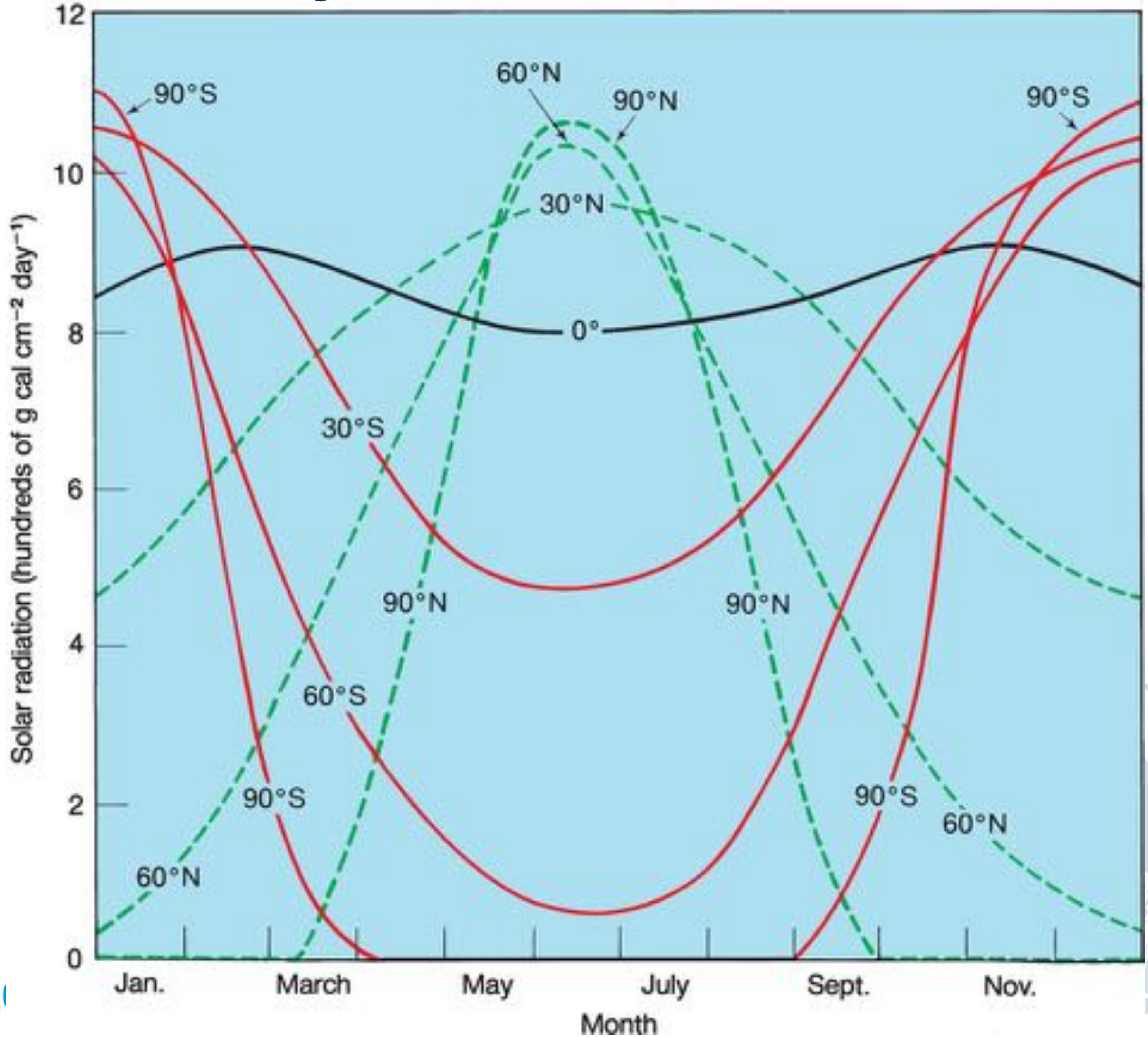




# Annual SST



# Average daily solar radiation

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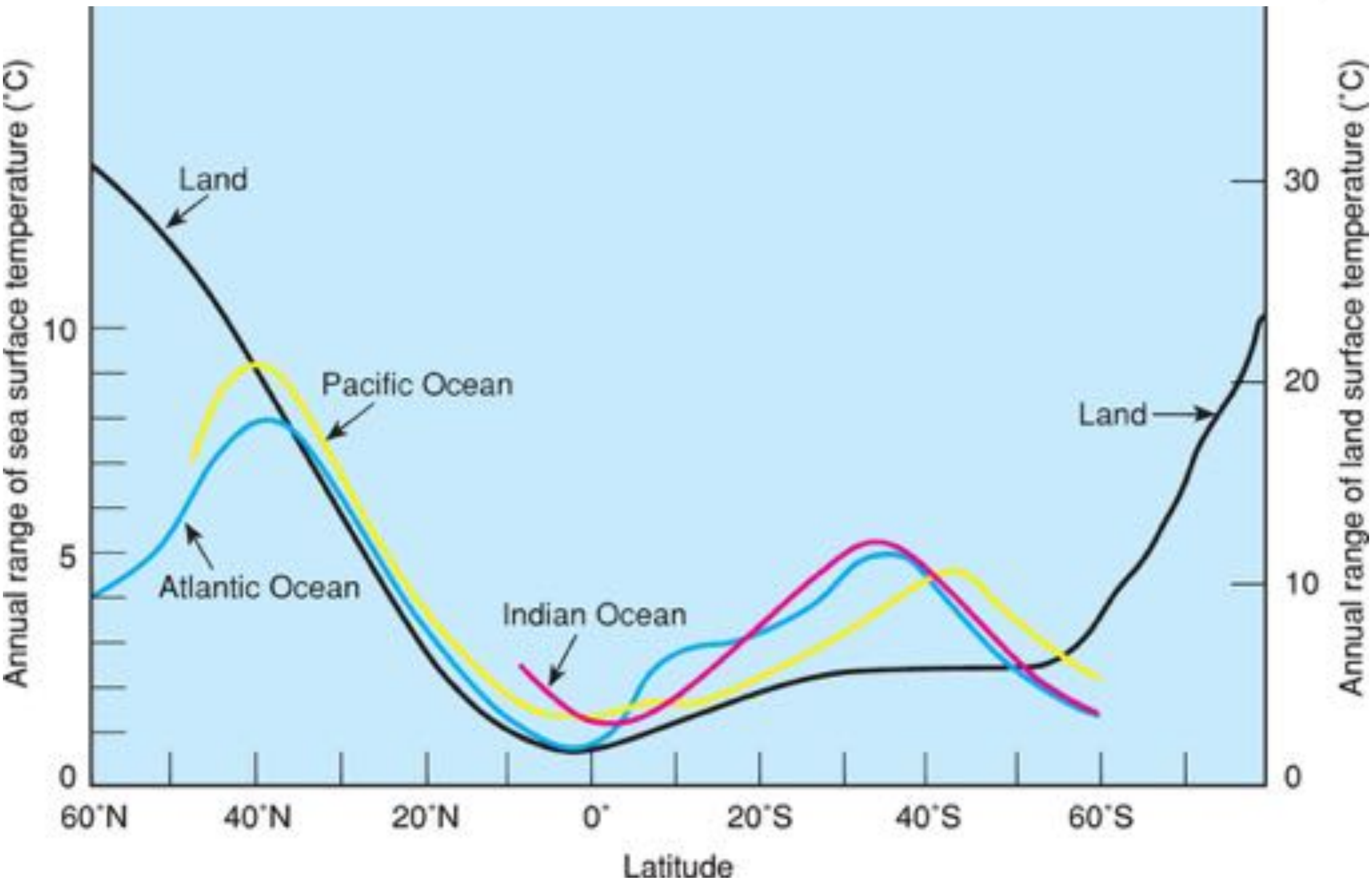
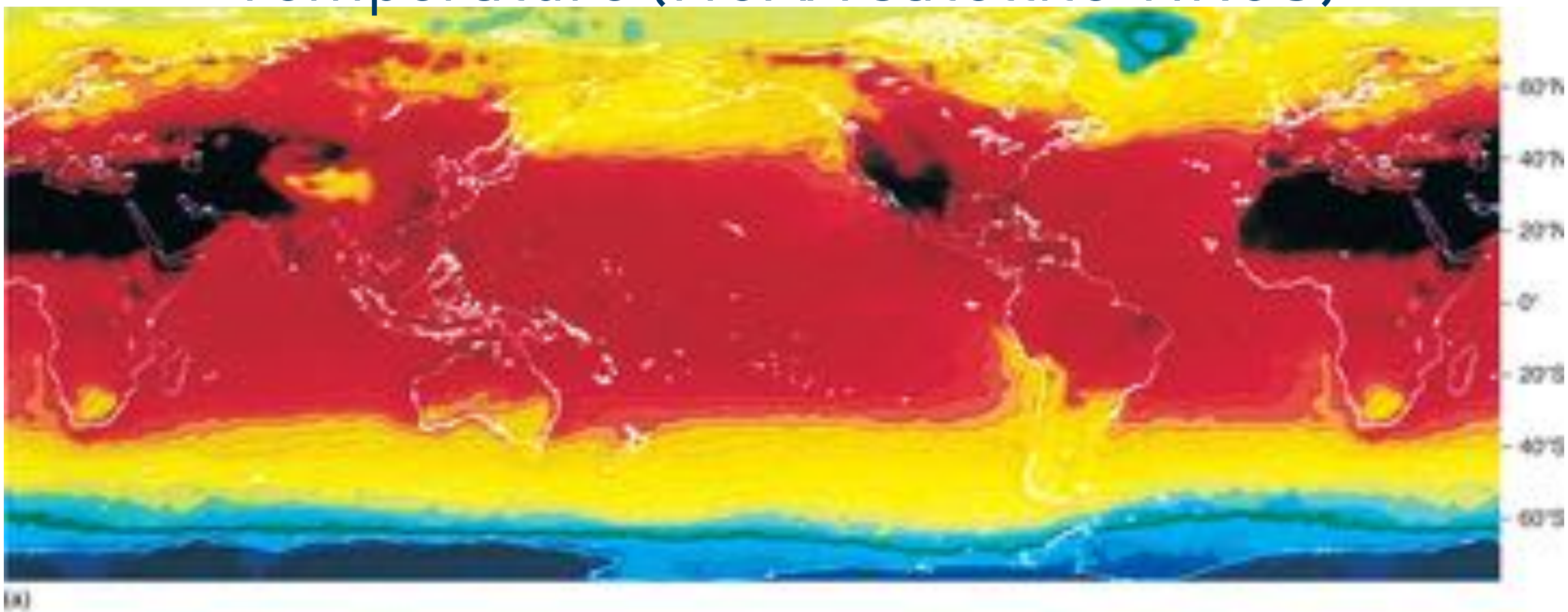
# Annual range of mid-ocean SST

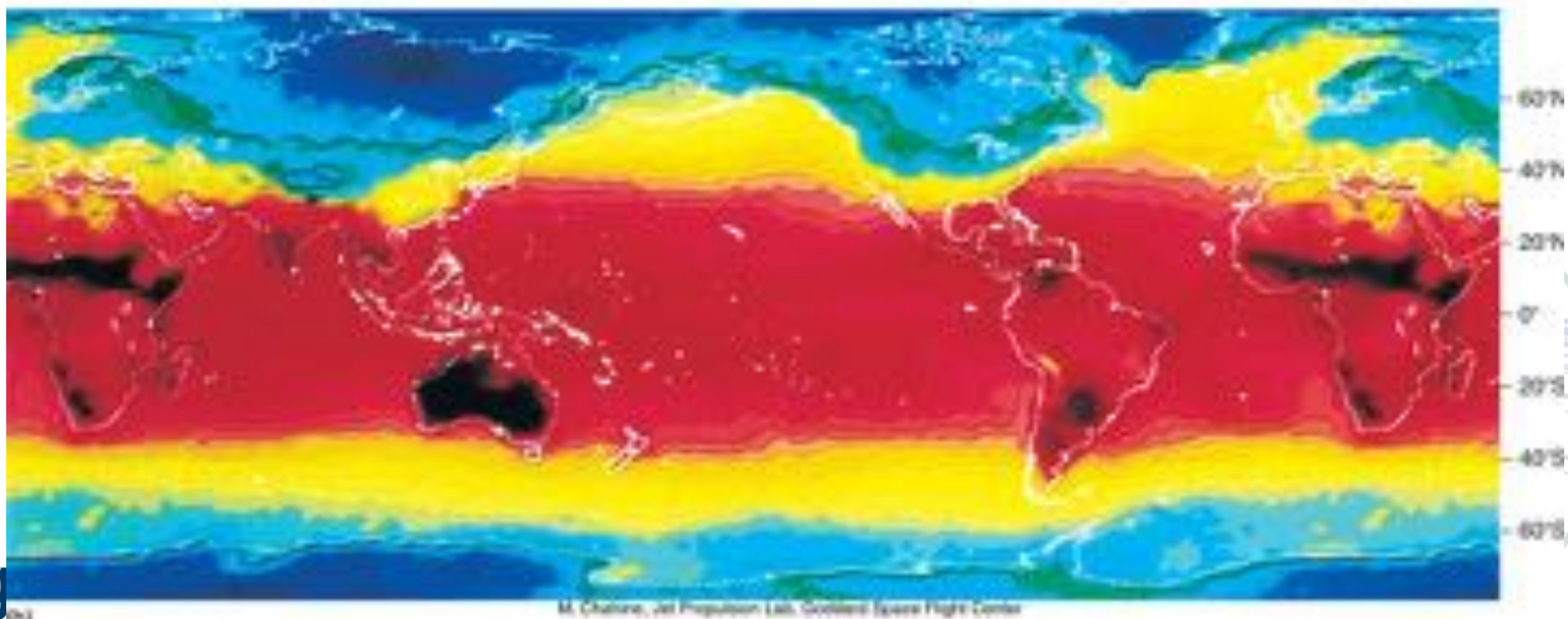


# Temperature (NOAA satellite TIROS)

July




Jan

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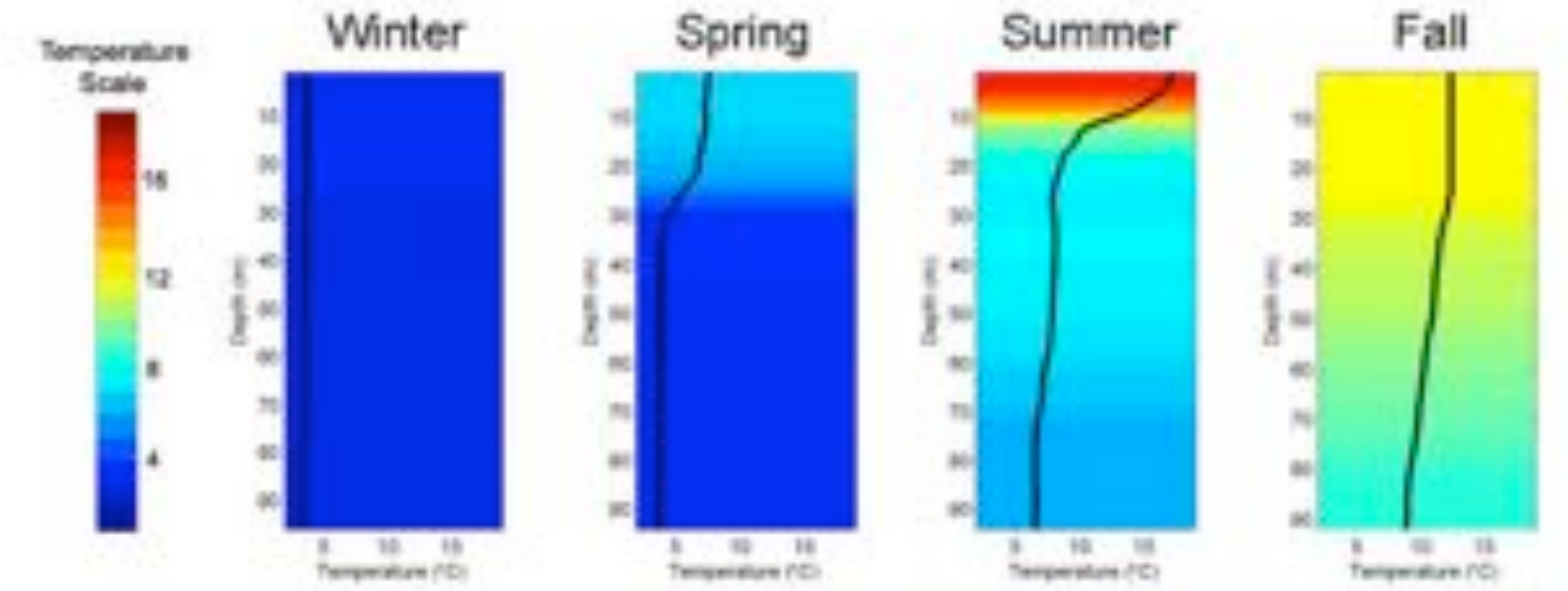
Seasonal cycle and distribution of solar energy shapes the water column



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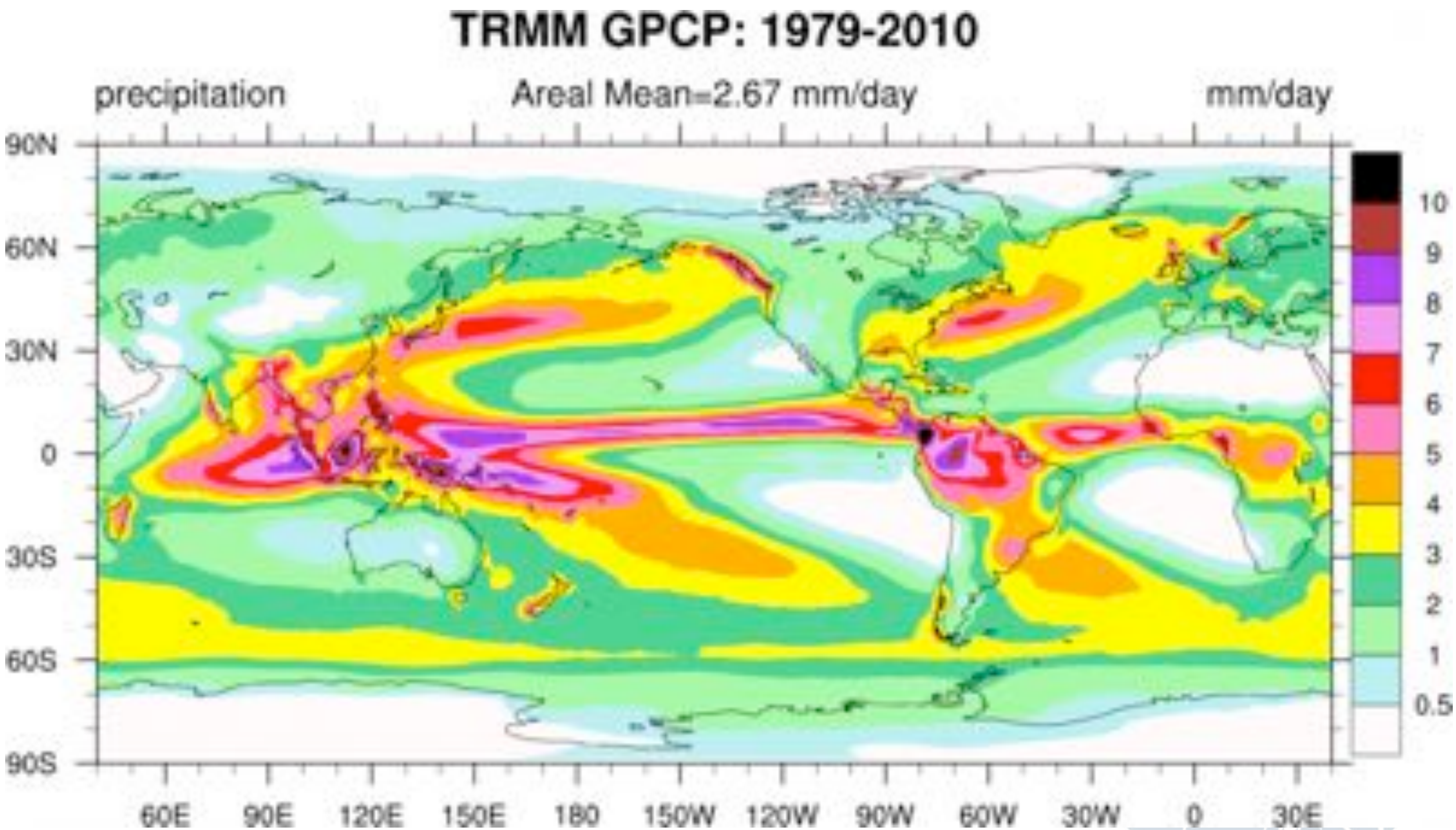
# What controls ocean salinity?

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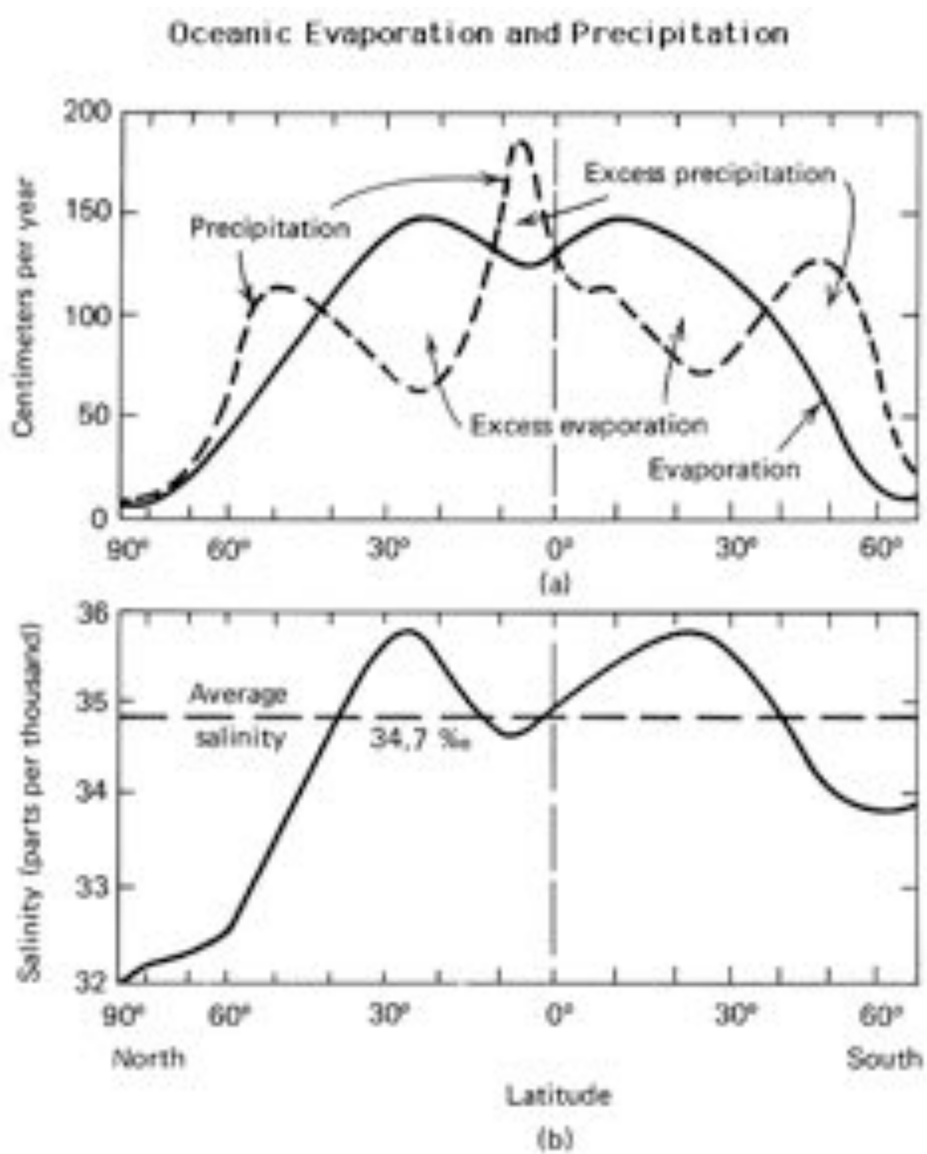

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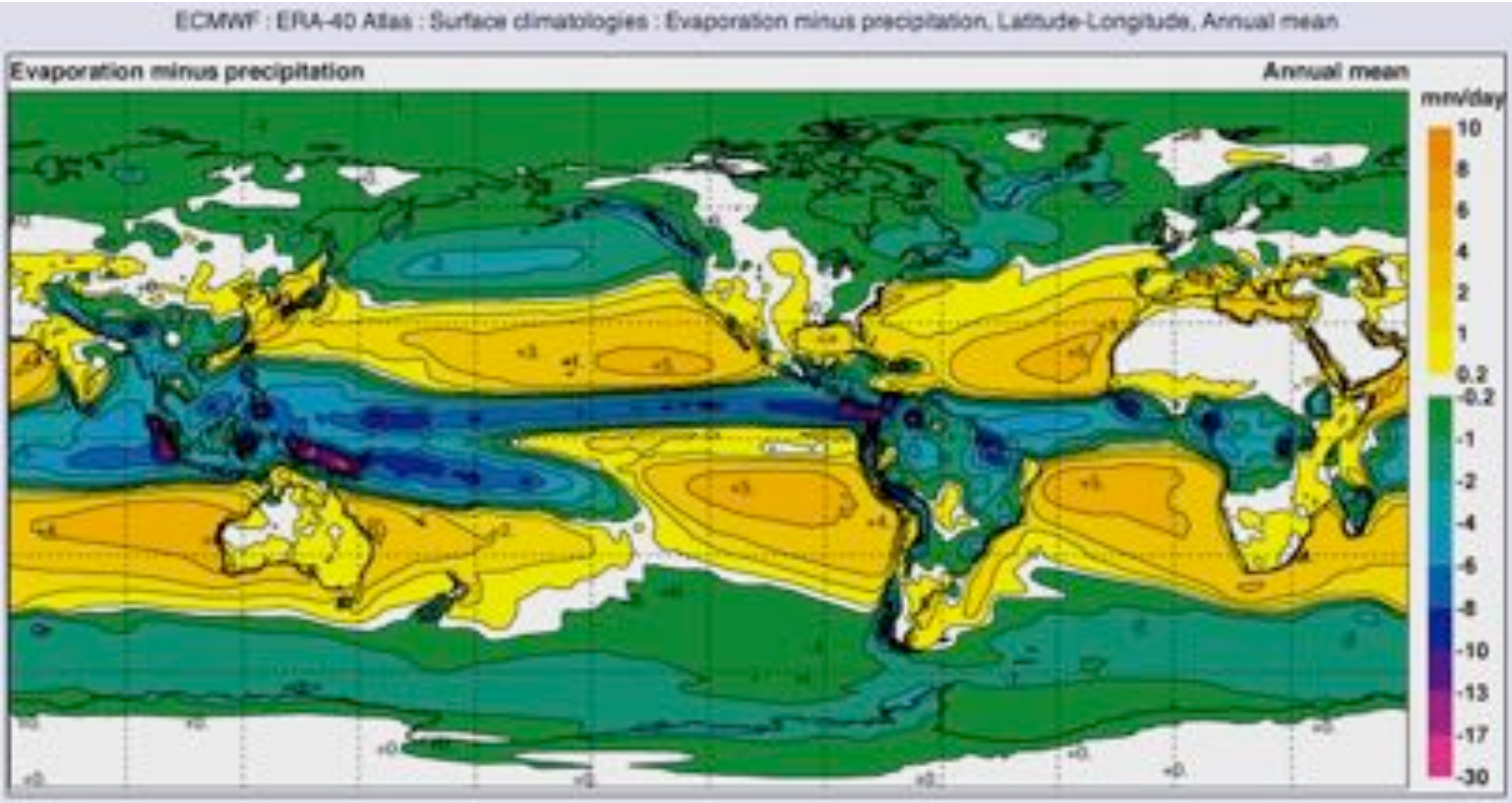


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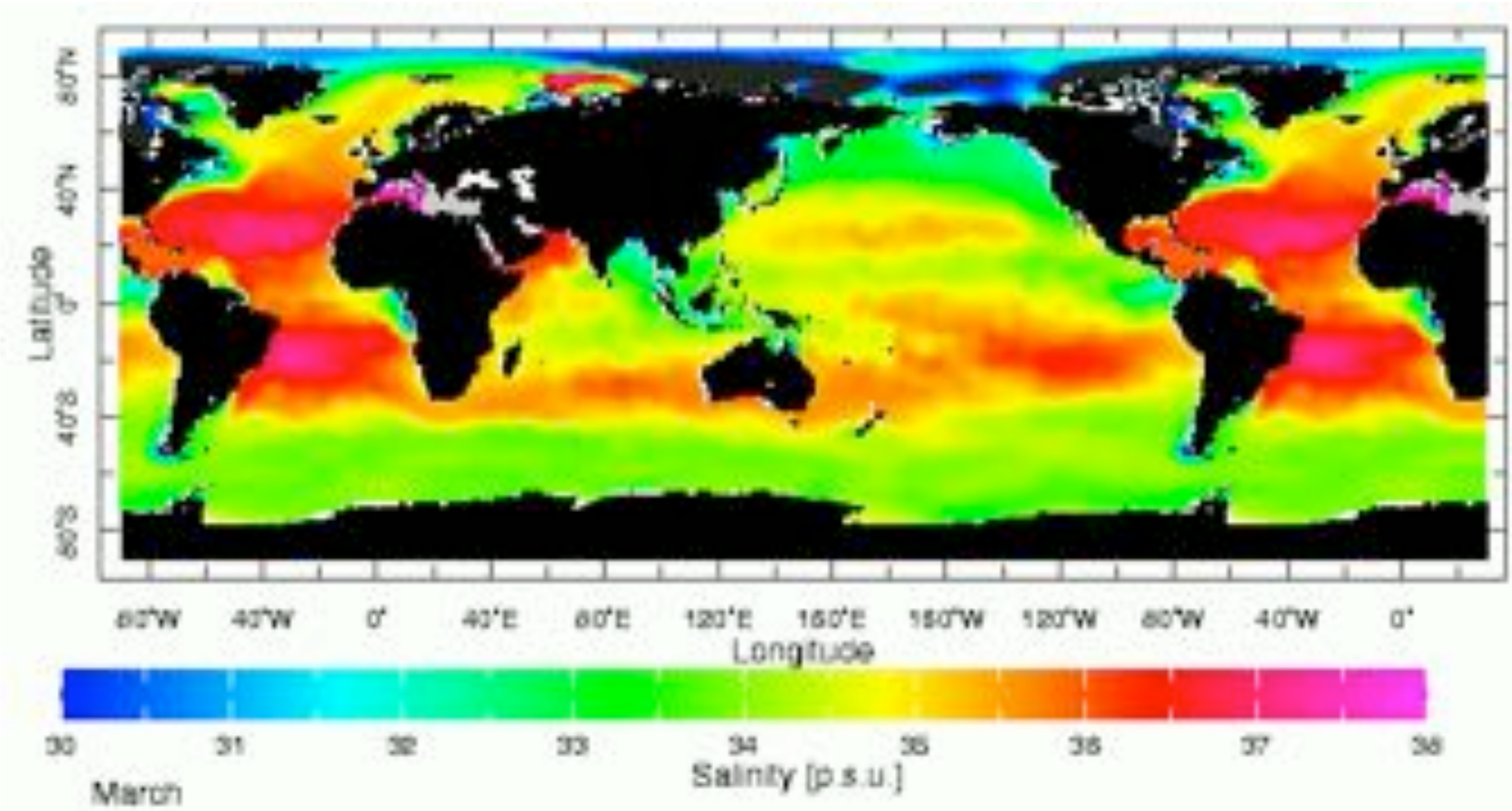


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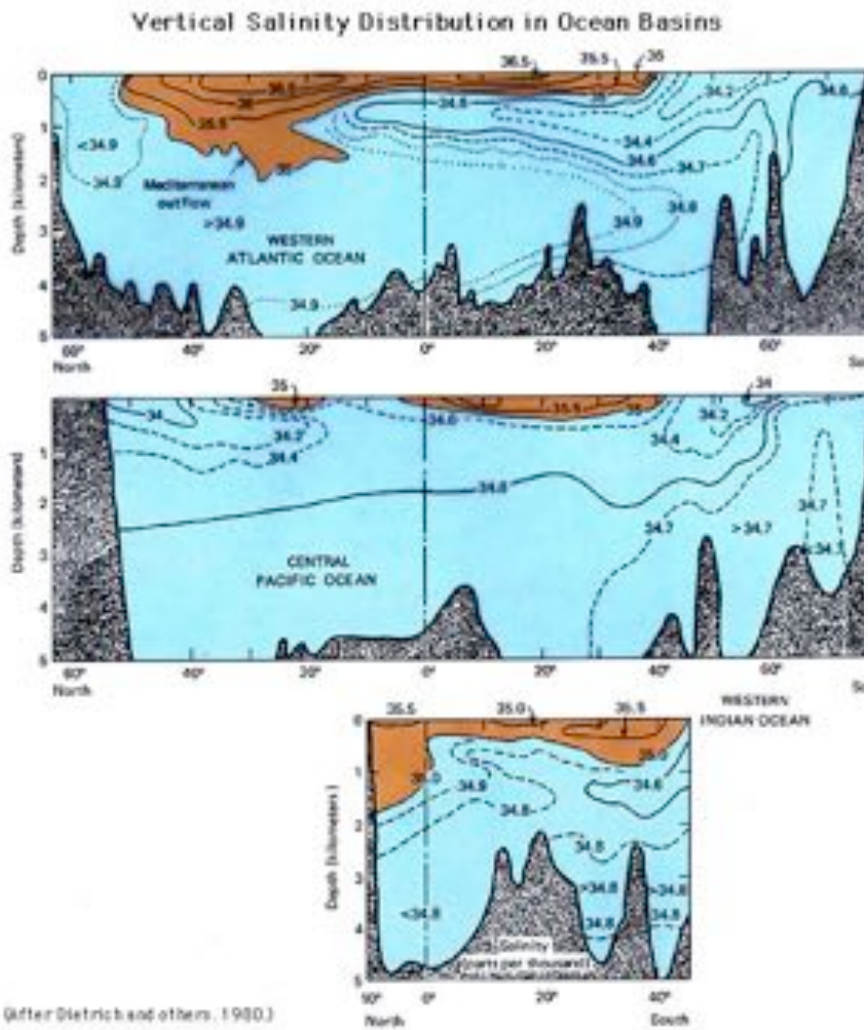
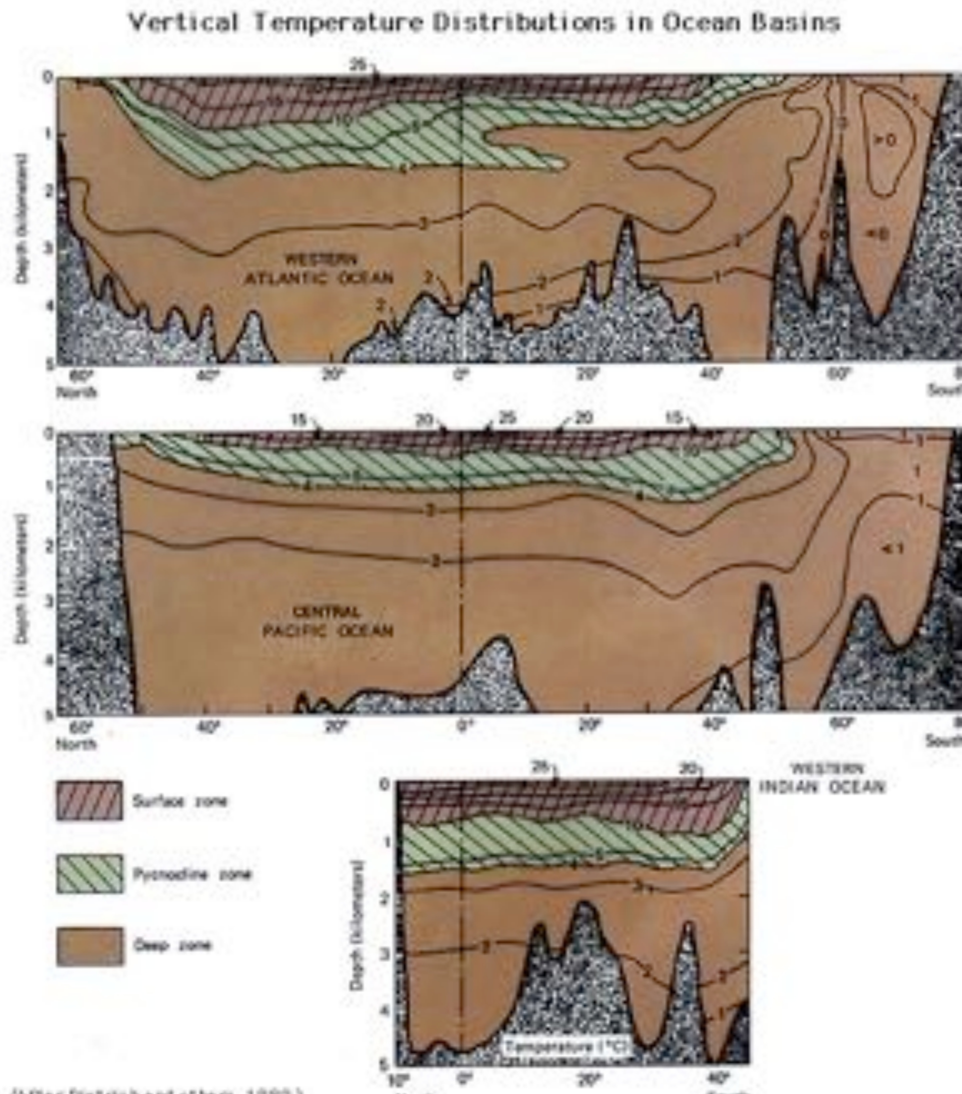



(After Dietrich and others, 1980.)

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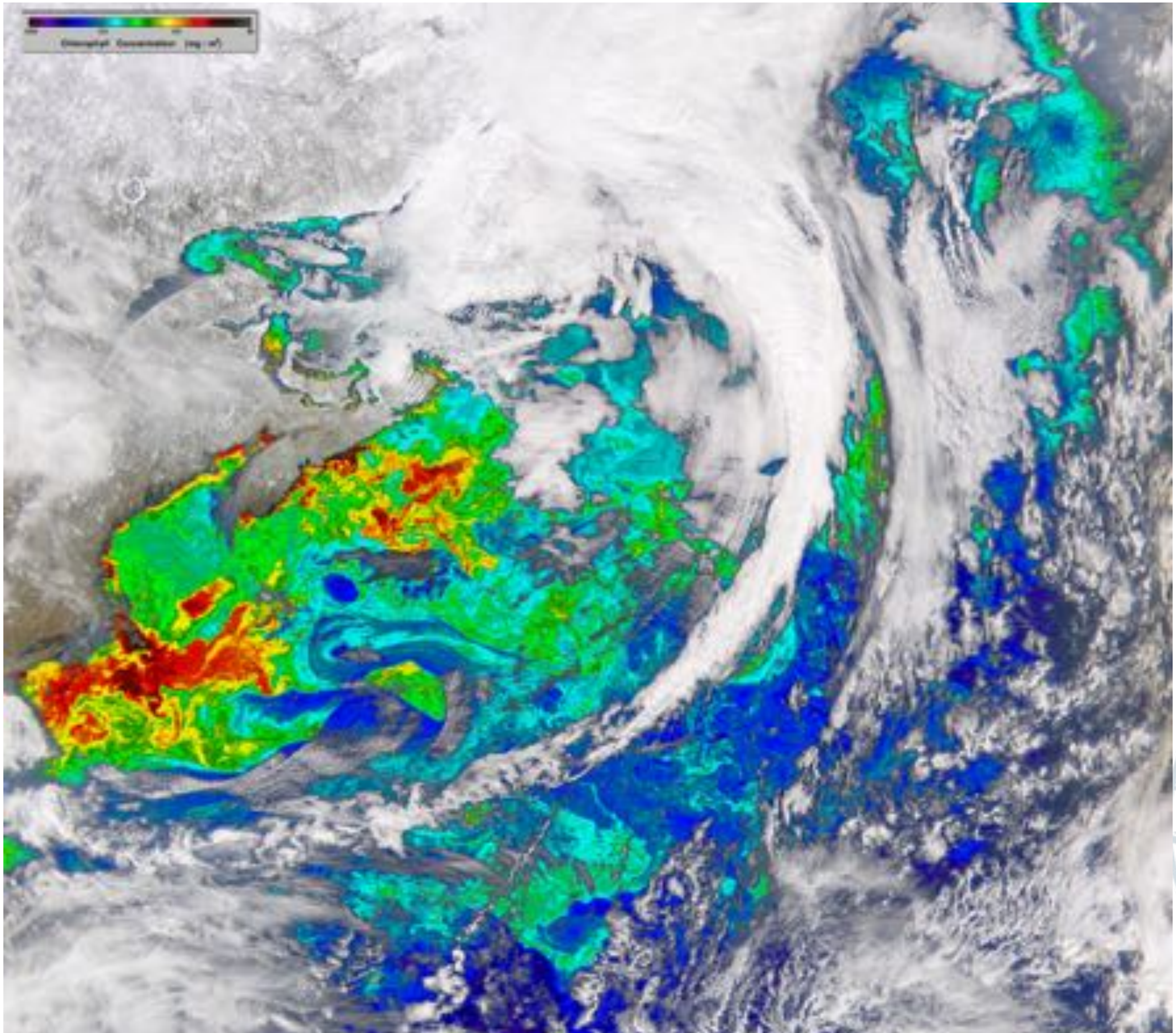
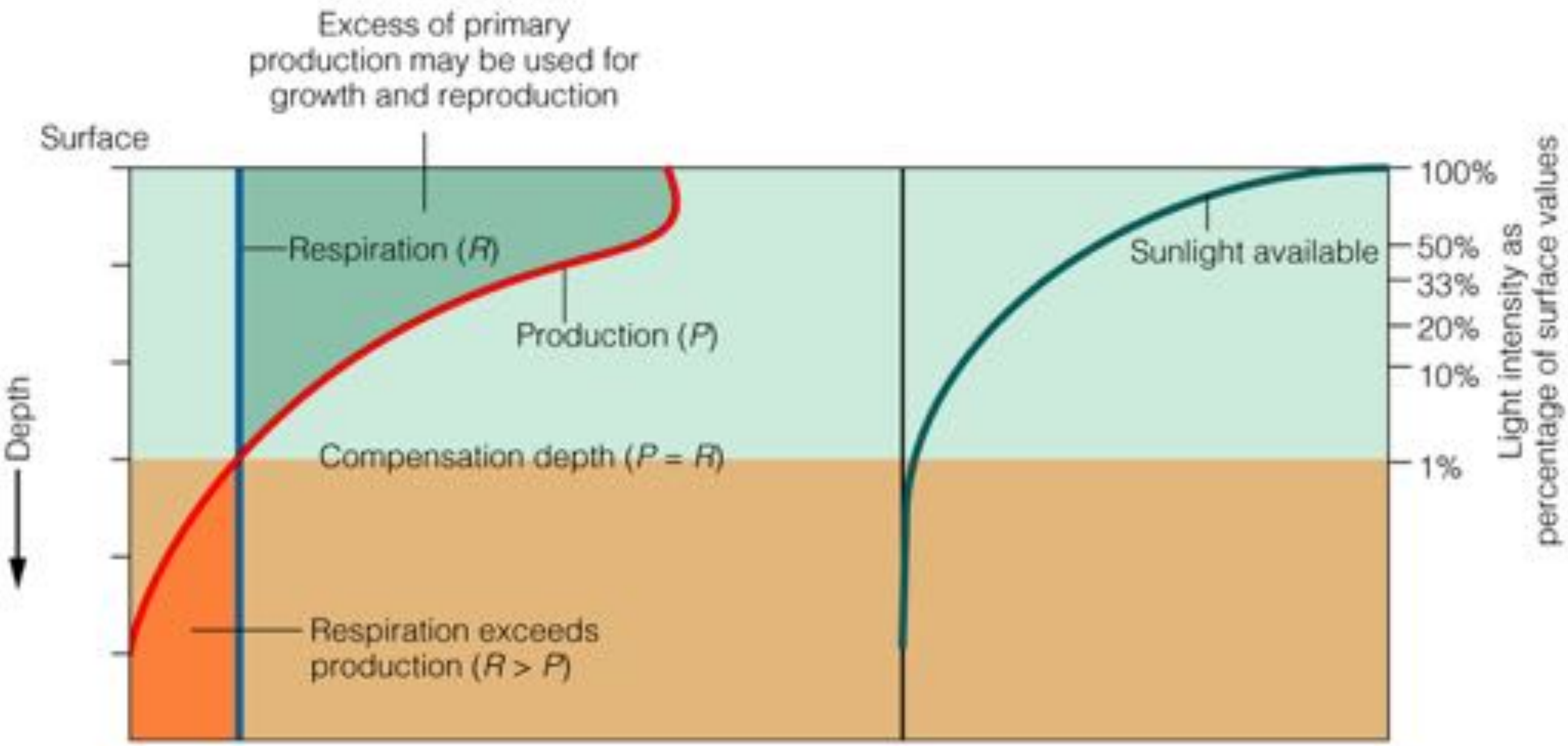
# What controls ocean chlorophyll?



# What controls ocean chlorophyll?

Figure 3.2.5 Coccolithophore bloom in the Barents Sea. © NASA/Goddard Space Flight Center.




$$I = I_0 \, e^{-kz}$$

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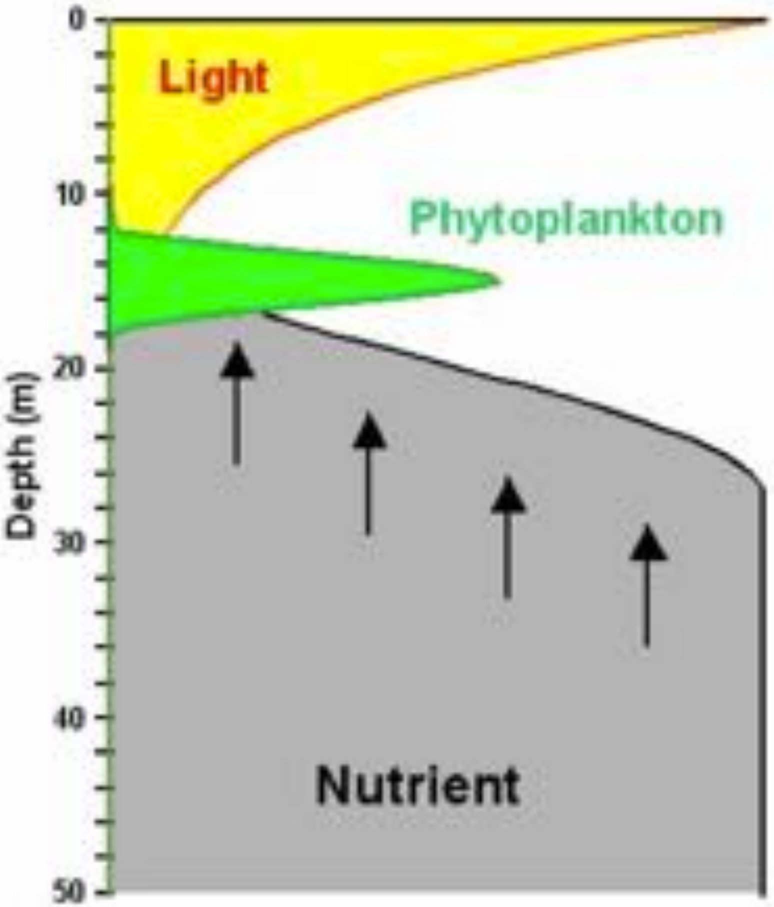
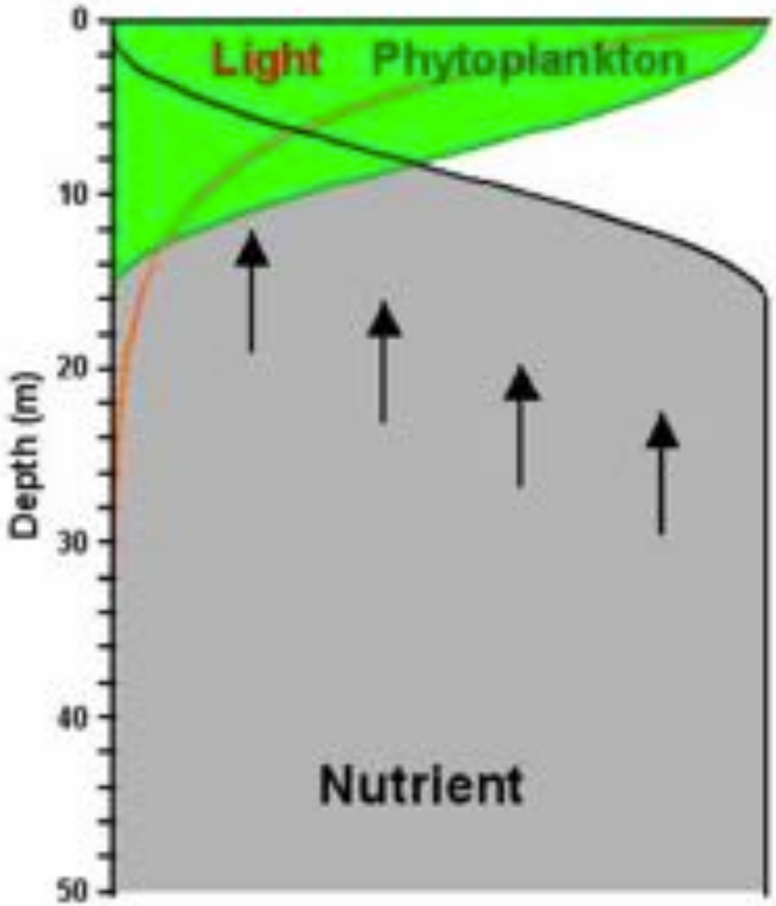
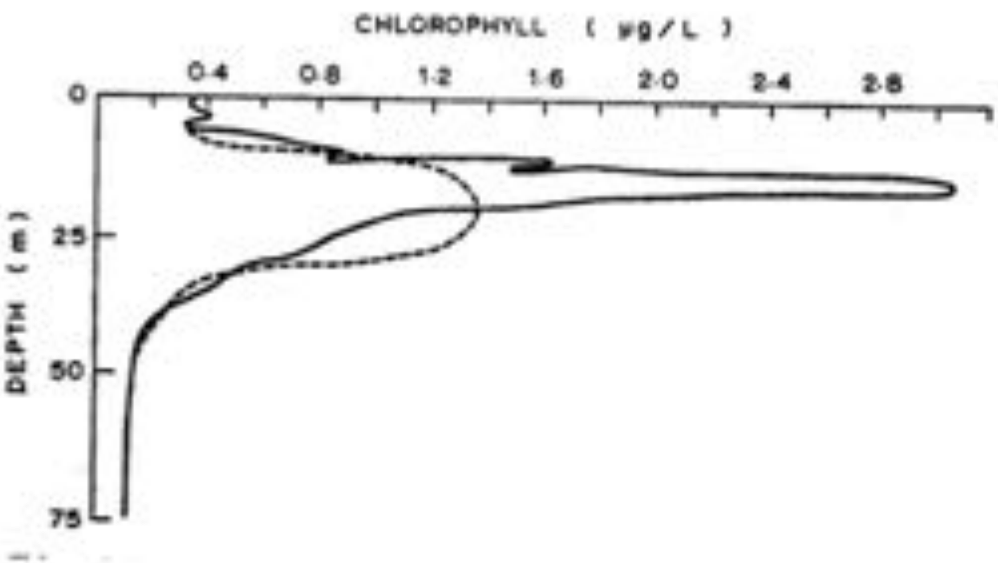
# Vertical profiles

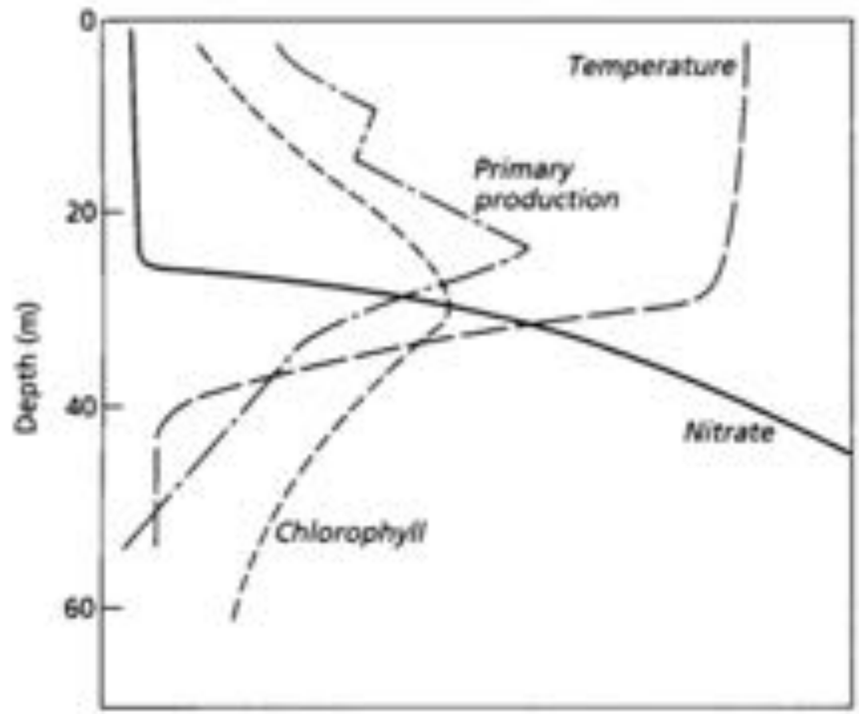



Stolen from UCLA web site

# Subsurface Chlorophyll Maxima

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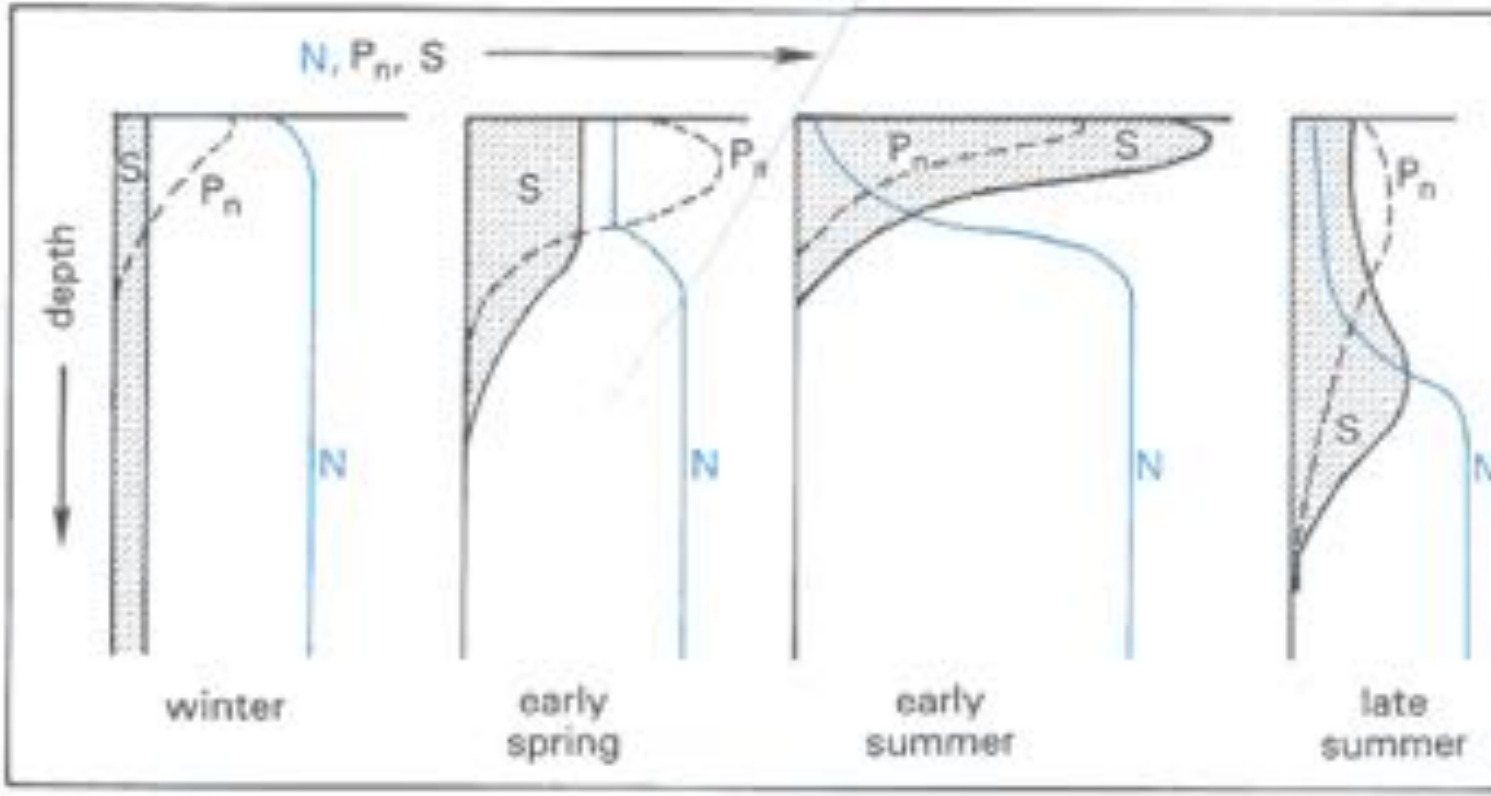


Figure 3.18 Schematic seasonal depth changes in phytoplankton biomass (S), daily net photosynthetic rate ($P_n$), and nutrient concentration (N) in stratified temperate water. S (shaded area), usually expressed in mg chl *a* $m^{-3}$, $P_n$ (broken line), usually expressed as mg C per mg Chl *a* per day, N (blue line), usually expressed as $\mu$M nitrate. The figure omits any changes caused by significant zooplankton grazing.

From Lalli & Parsons 1993

# Seasonal Development in spring

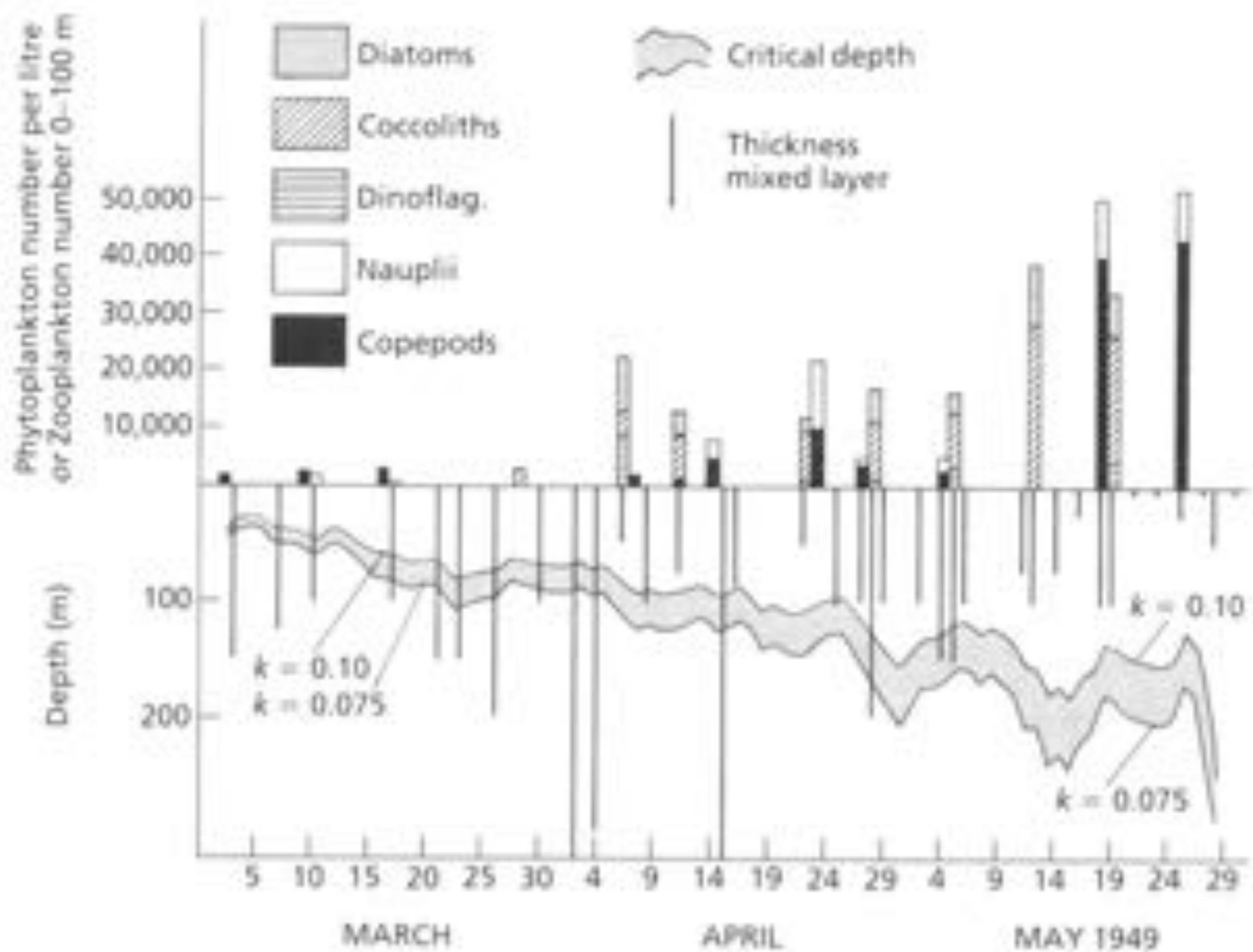


**Fig. 3.11** Data from ocean weather ship M in the Norwegian Sea on plankton, mixed layer thickness and critical depth. Note that the mixed layer is always deeper than the critical depth until early April, when a large increase in phytoplankton biomass occurs. From Sverdrup (1953).

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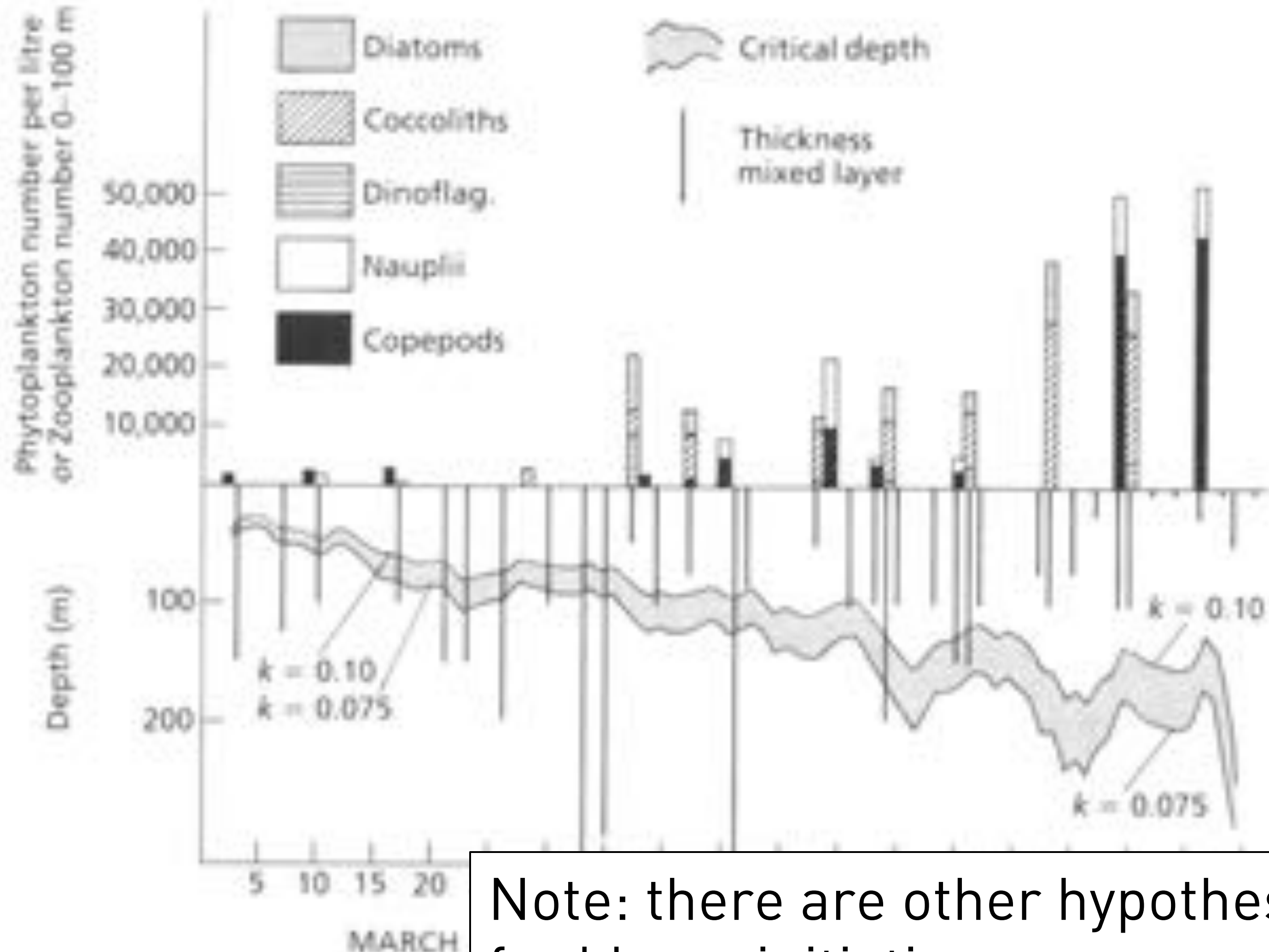
# Seasonal Development in spring




Note: there are other hypotheses for bloom initiation

**Fig. 3.11** Data from ocean weat[...] layer thickness and critical depth. Note that the mixed layer is always deeper than the critical depth until early April, when a large increase in phytoplankton biomass occurs. From Sverdrup (1953).

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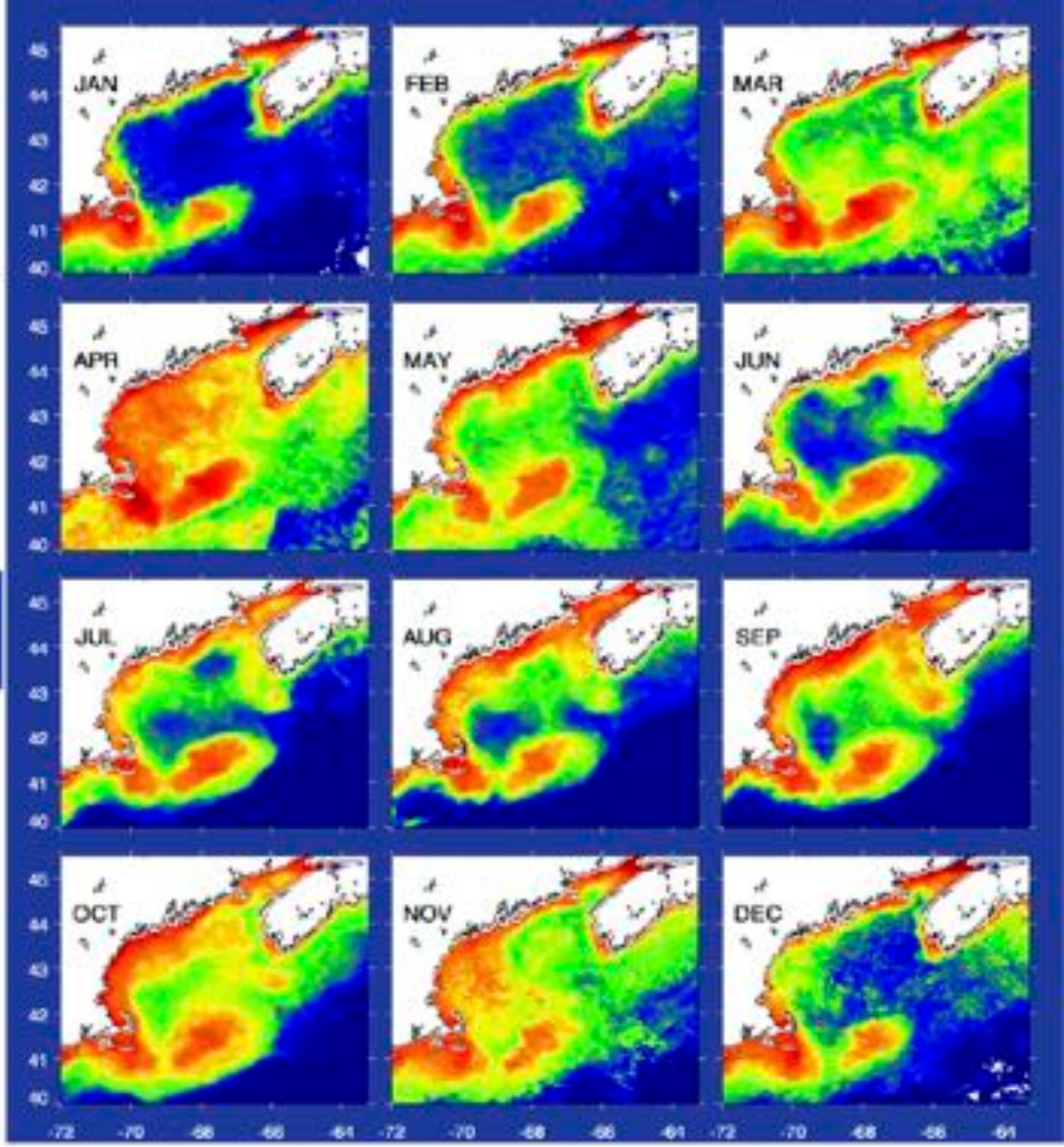
# Gulf of Maine Seasonal Cycle of Phytoplankton Biomass

# Seasonal Cycles

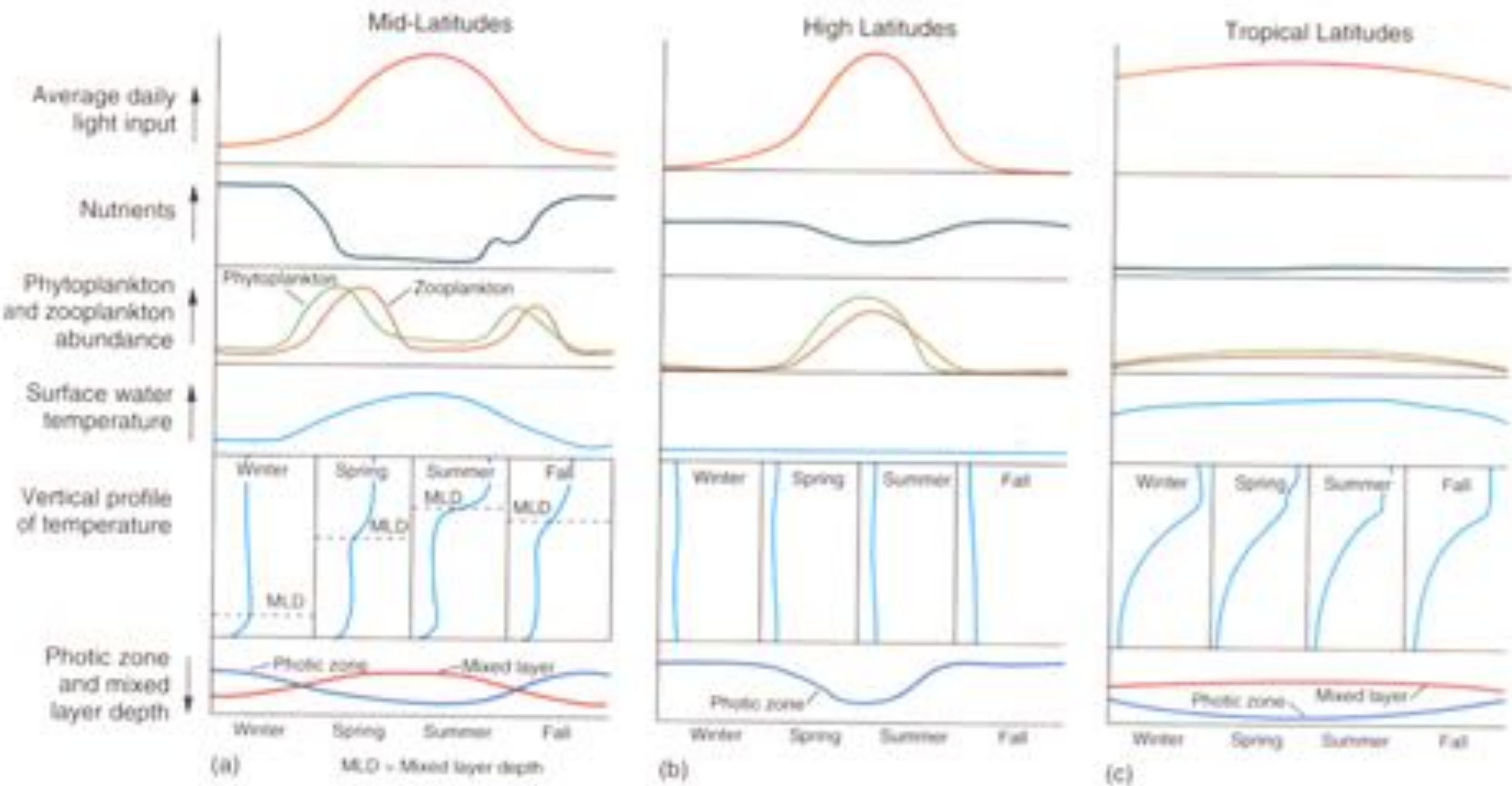



Fig 13-8

- Light
  - Insolation
  - Turbidity
  - Mixed layer
- Nutrients
  - Mixing from below
  - Input from coastal runoff
  - Phytoplankton depletion

Note: these processes aren't restricted to 1-D. We'll discuss more complex dynamics when we consider currents.

# Nutrients

- Eutrophic
  - Excess of nitrogen
  - Dense phytoplankton blooms
  - High rates of bacterial decomposition
    - → Hypoxic / anoxic

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# Nutrients

- Oligotrophic
  - Limited in nutrients
  - Oligotrophic gyres: Fe - limited
  - Post bloom oceans: N - limited