# Basics of Oceanography

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**Oceanography is a multi-discipline science studying the World ocean.**

**It includes:**

- **Physical oceanography**
- **Marine geology**
- **Marine chemistry**
- **Marine biology**
- **Marine technology**
- **etc.**

In this course, we discuss on topics that include instruments, measuring ocean properties and earth-orbiting satellites.

Another topic of satellite oceanography is the measurements of ocean color, which can be used as assessments of phytoplankton biomass and are of great interest to marine biologists.

## What drives ocean currents?

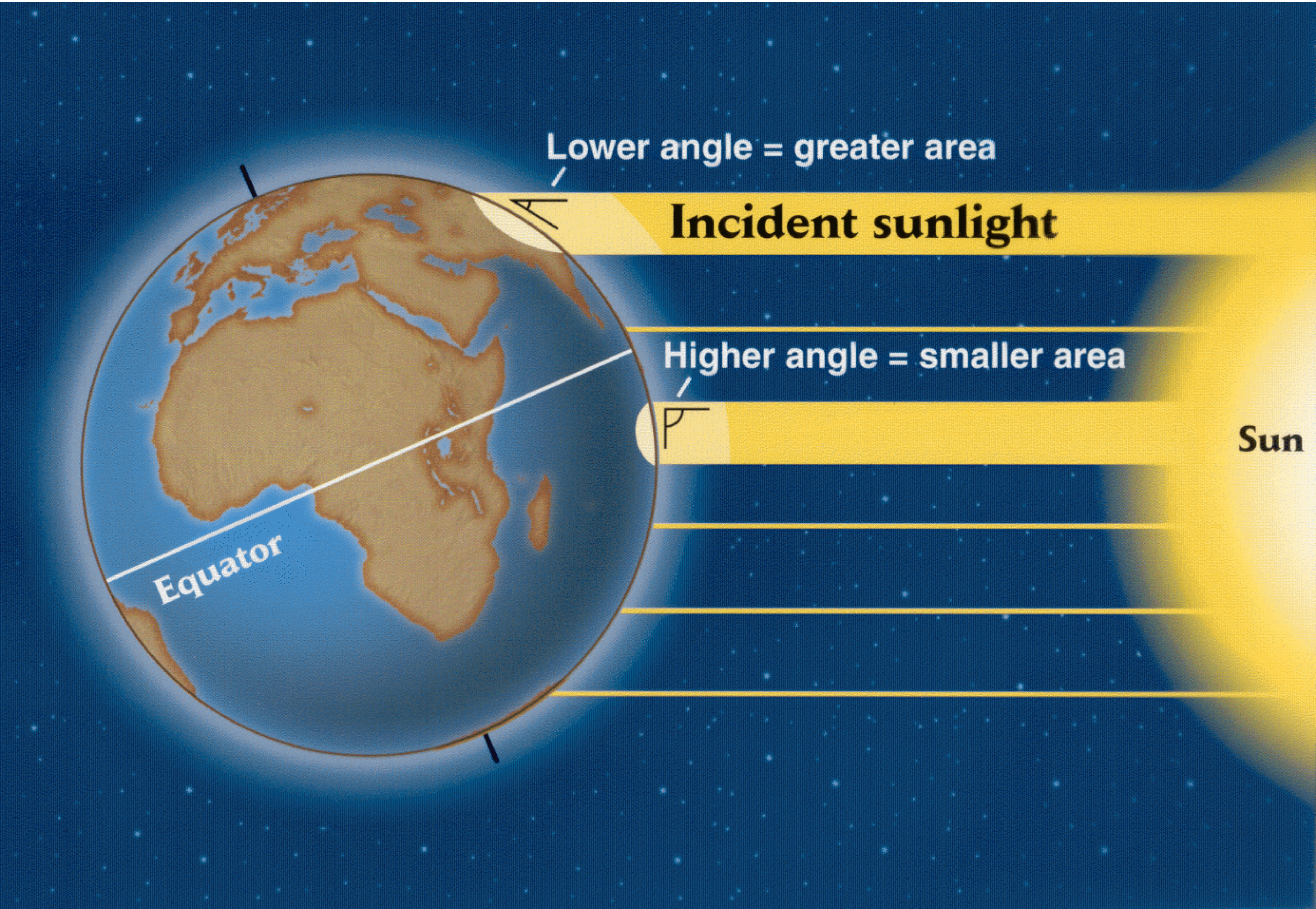
Two external forces influence the World Ocean generating ocean currents - gravitation and the energy flux from the sun.

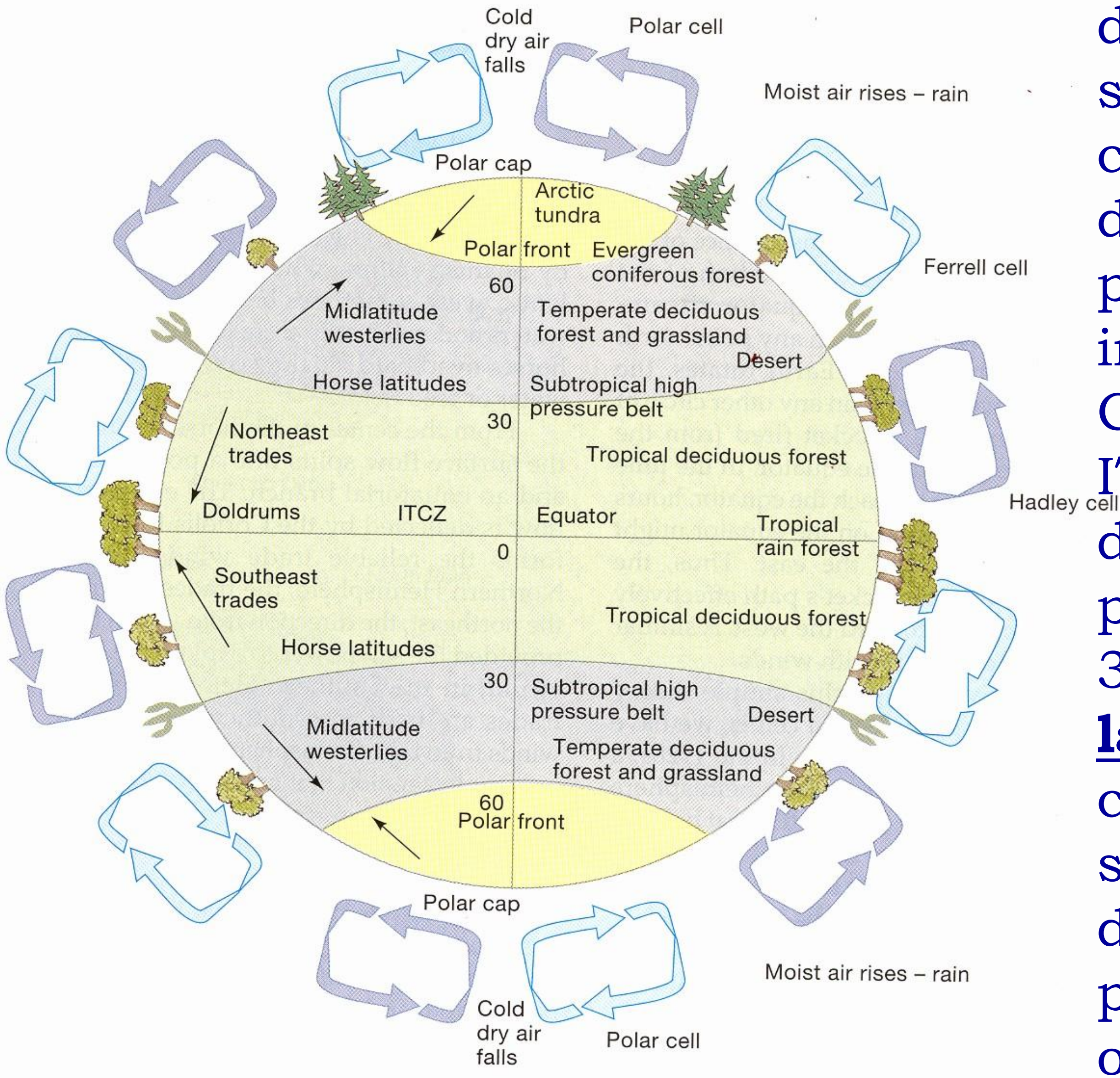
Gravitation includes tidal forces resulting from the interaction of water mass with the moon and the sun, and rotation of the Earth.

The radiation flux from the sun results in wind stress, heating and cooling of the ocean surface, and evaporation and precipitation of water.

A complex process of interaction between these forces results in a complex and variable pattern of ocean circulation.

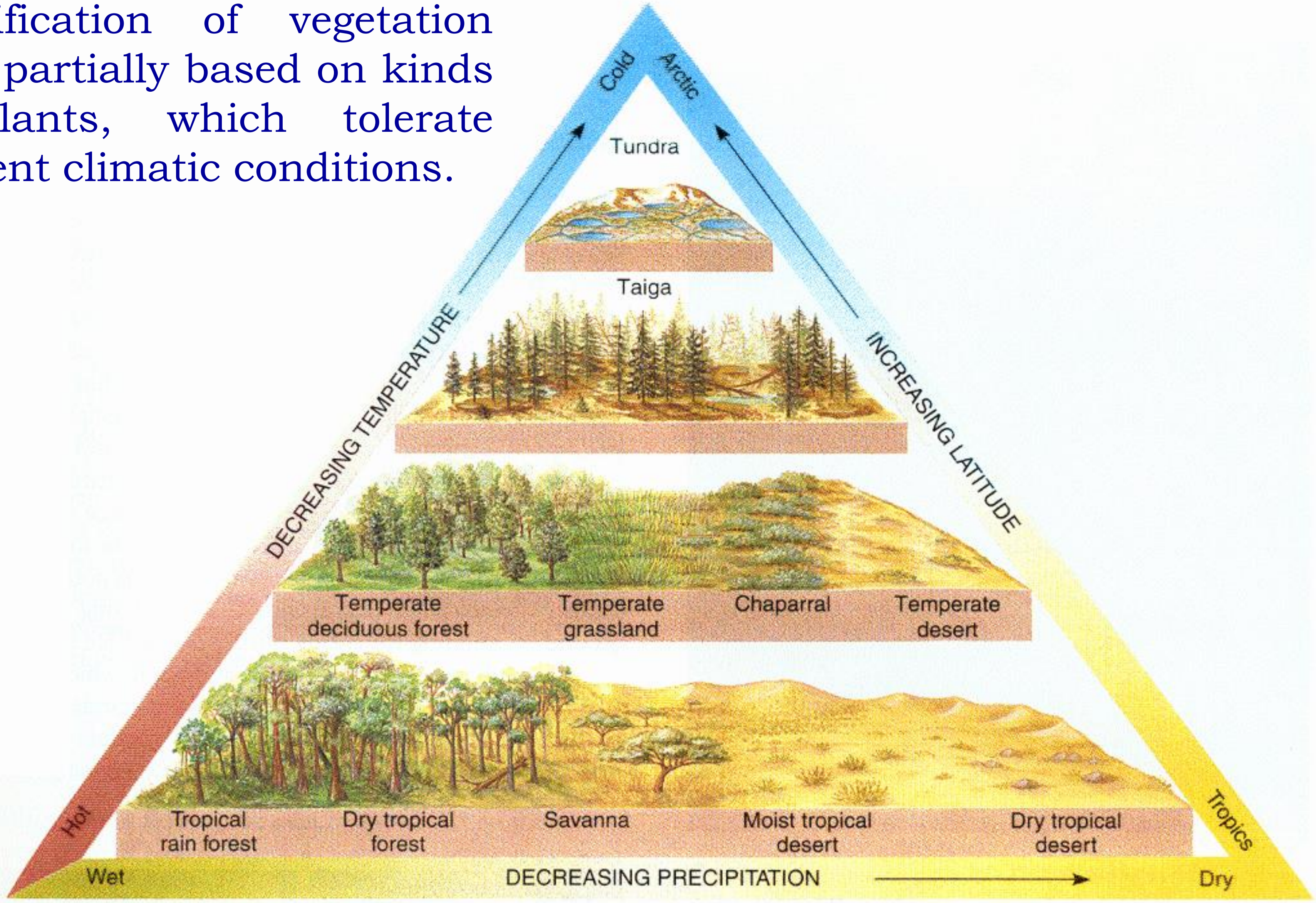
# Visual illustration of latitudinal gradient of insolation





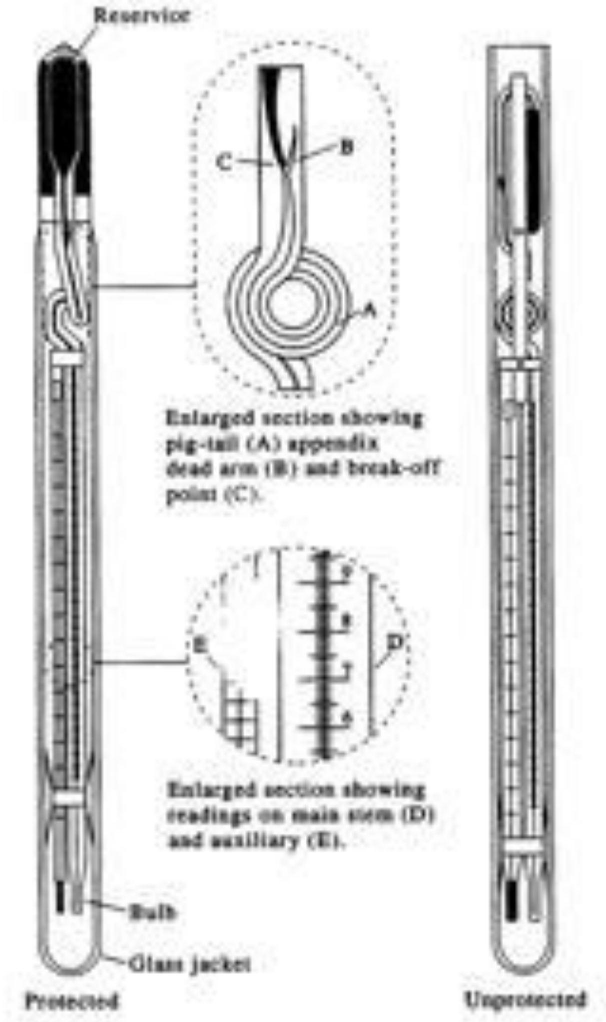

Major latitudinal displacements of surface air currents: convection currents drive **Hadley cells**, pulling air at surface into Inter-Tropical Convergence Zone, ITCZ); **Ferrel Cells** driven by low pressure zone at 20°-30° lat.; **Mid-latitude westerlies** converge into jet stream; **polar cells** driven by high pressure (cold) flows out of polar region along Earth's surface towards south.

Classification of vegetation types partially based on kinds of plants, which tolerate different climatic conditions.



# Temperature Measurements

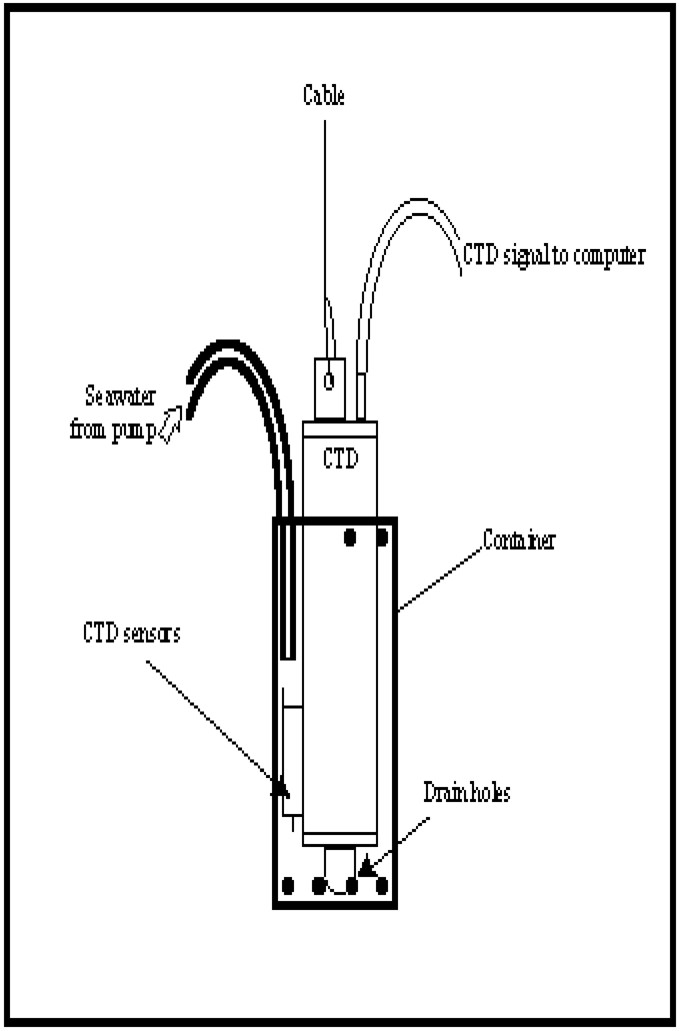
## Reversing Thermometer

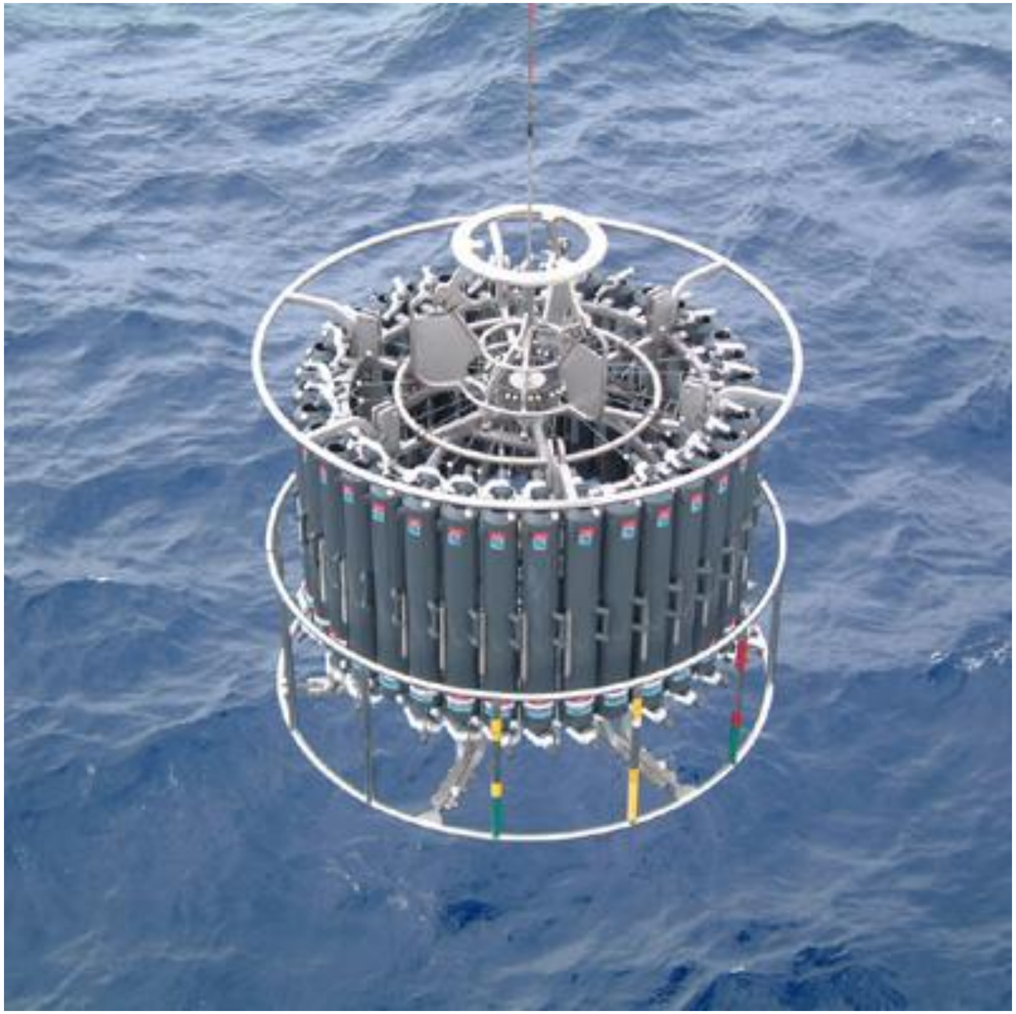



Unlike most conventional mercury thermometers, a reversing thermometer is able to record a given temperature to be viewed at a later time. If the thermometer is flipped upside down, the current temperature will be shown until it is turned upright again. This was the primary device used by oceanographers to determine water temperatures below the surface of the ocean from around 1900 to 1970.

# Temperature Measurements

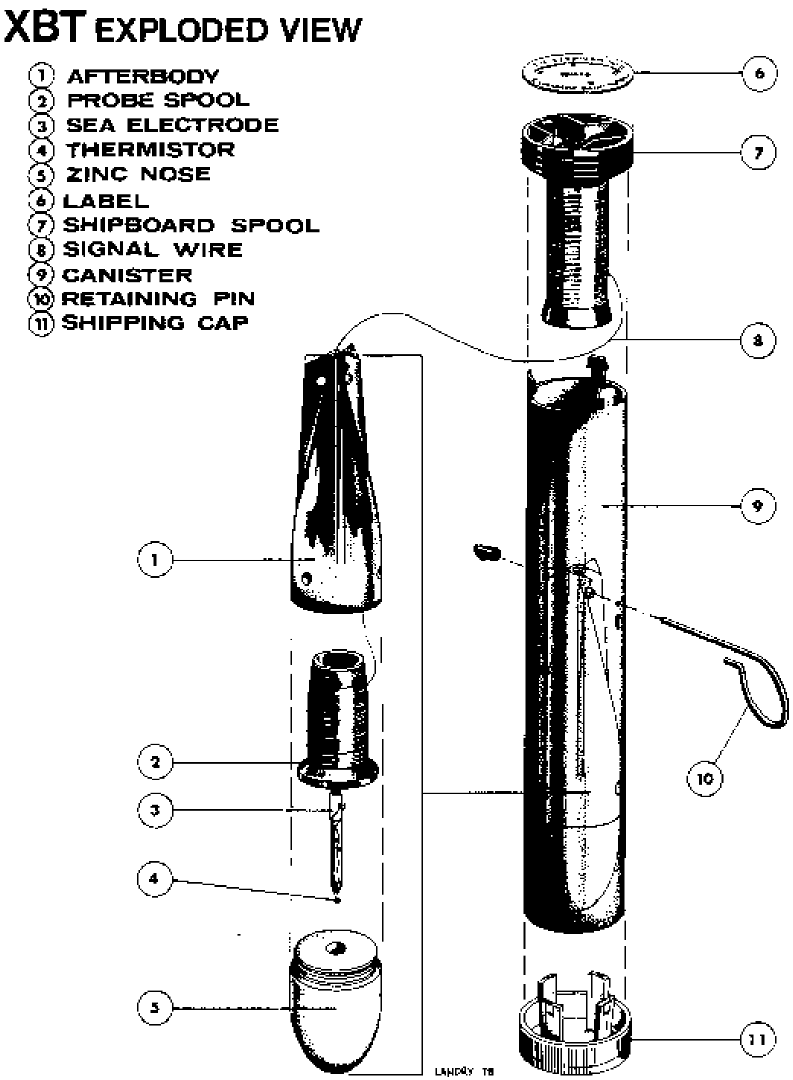
## CTD

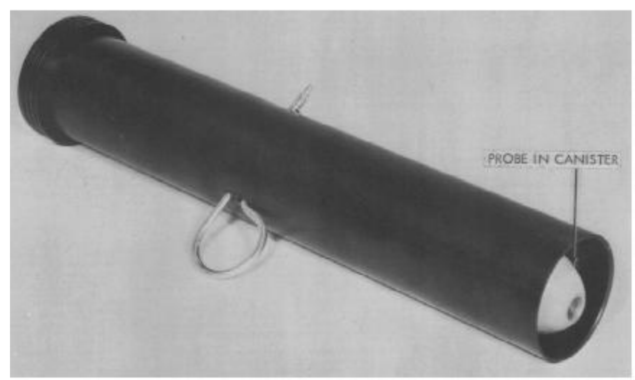


# Temperature Measurements

## XBT



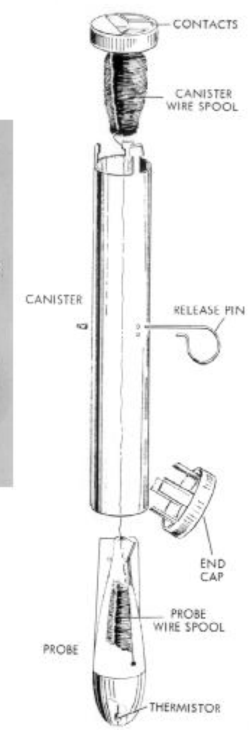




Fig. 1: XBT diagrams: Bathythermograph (probe) and exploded view.

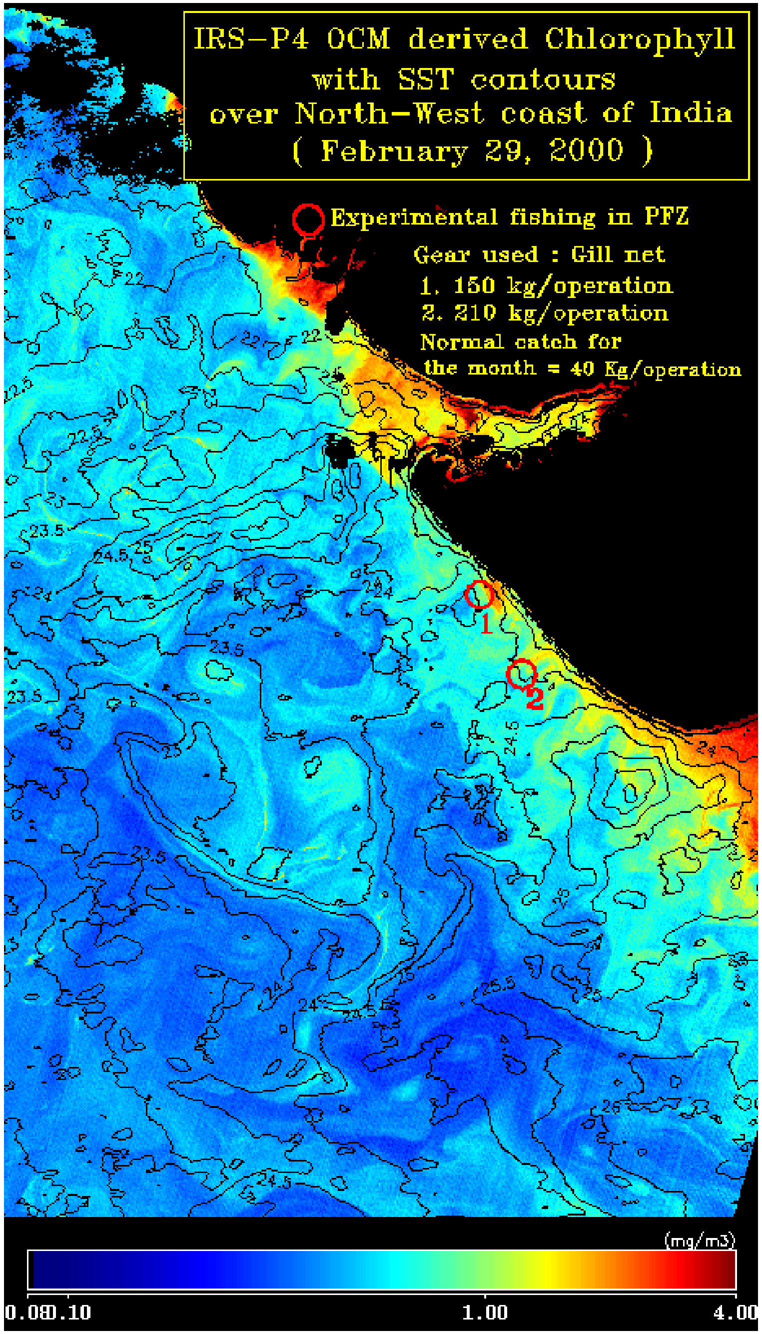
# Temperature Measurements

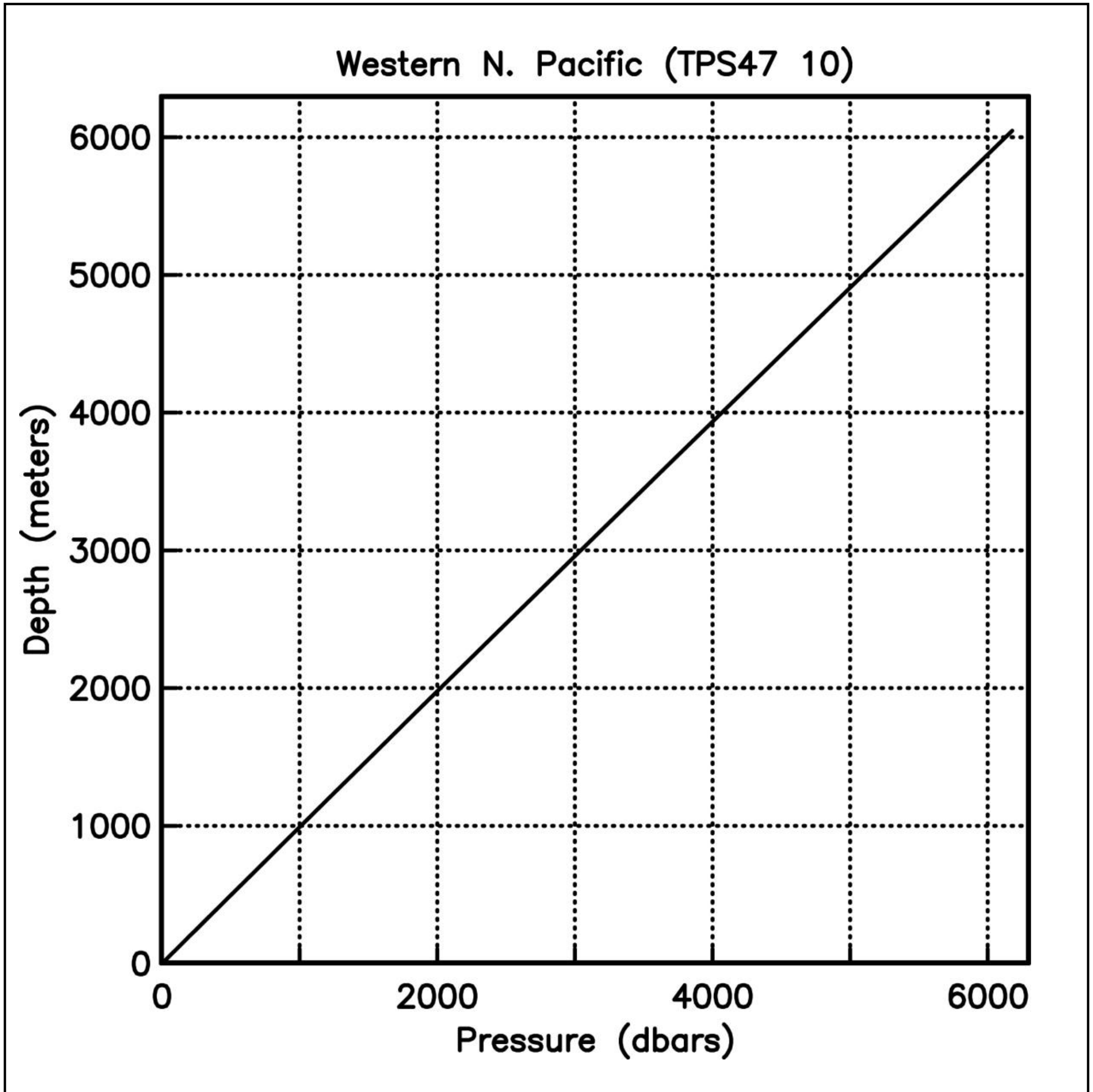
## NOAA AHVRR

## SST

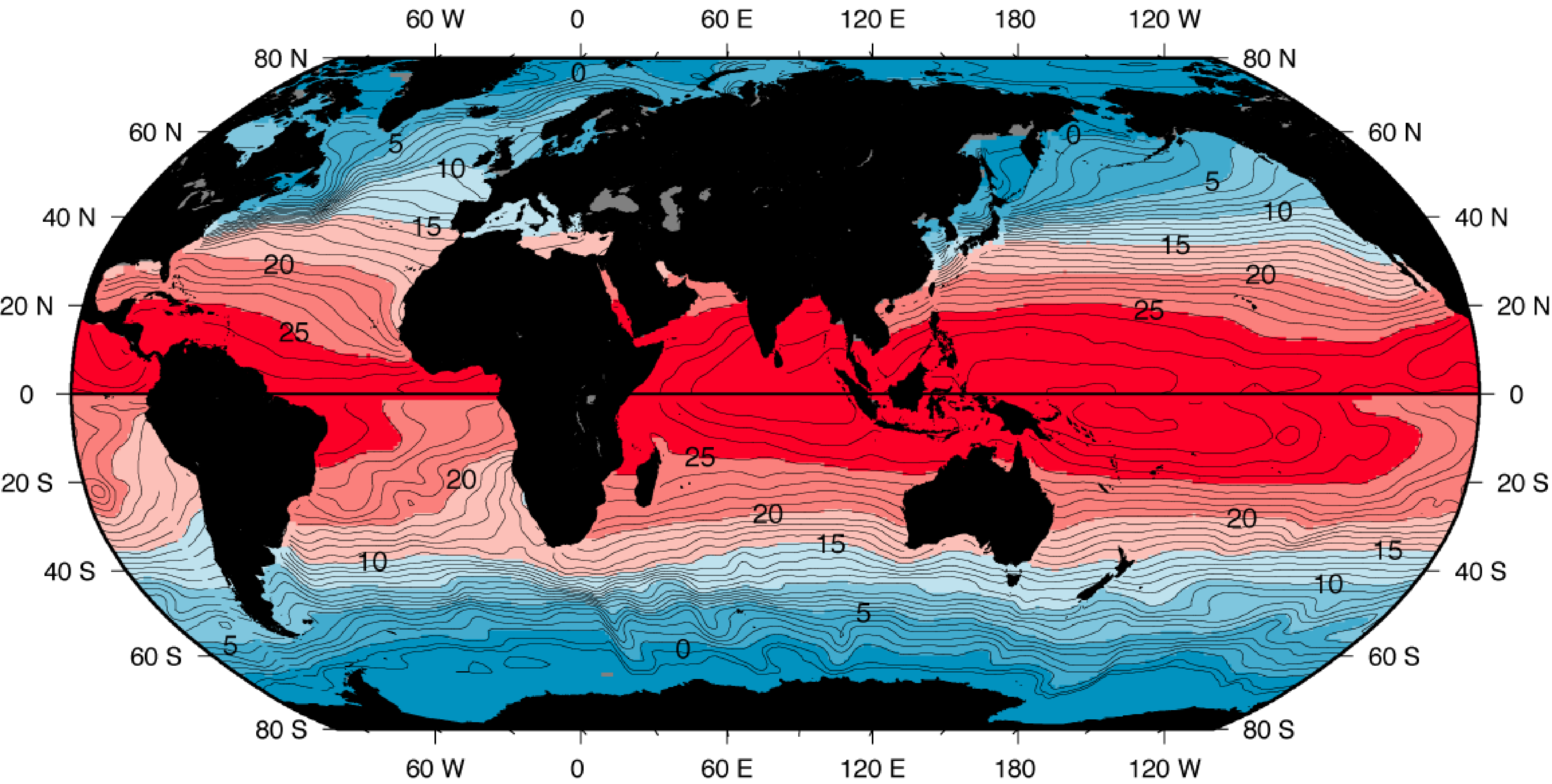
## Applications to

## Potential Fishing Zones



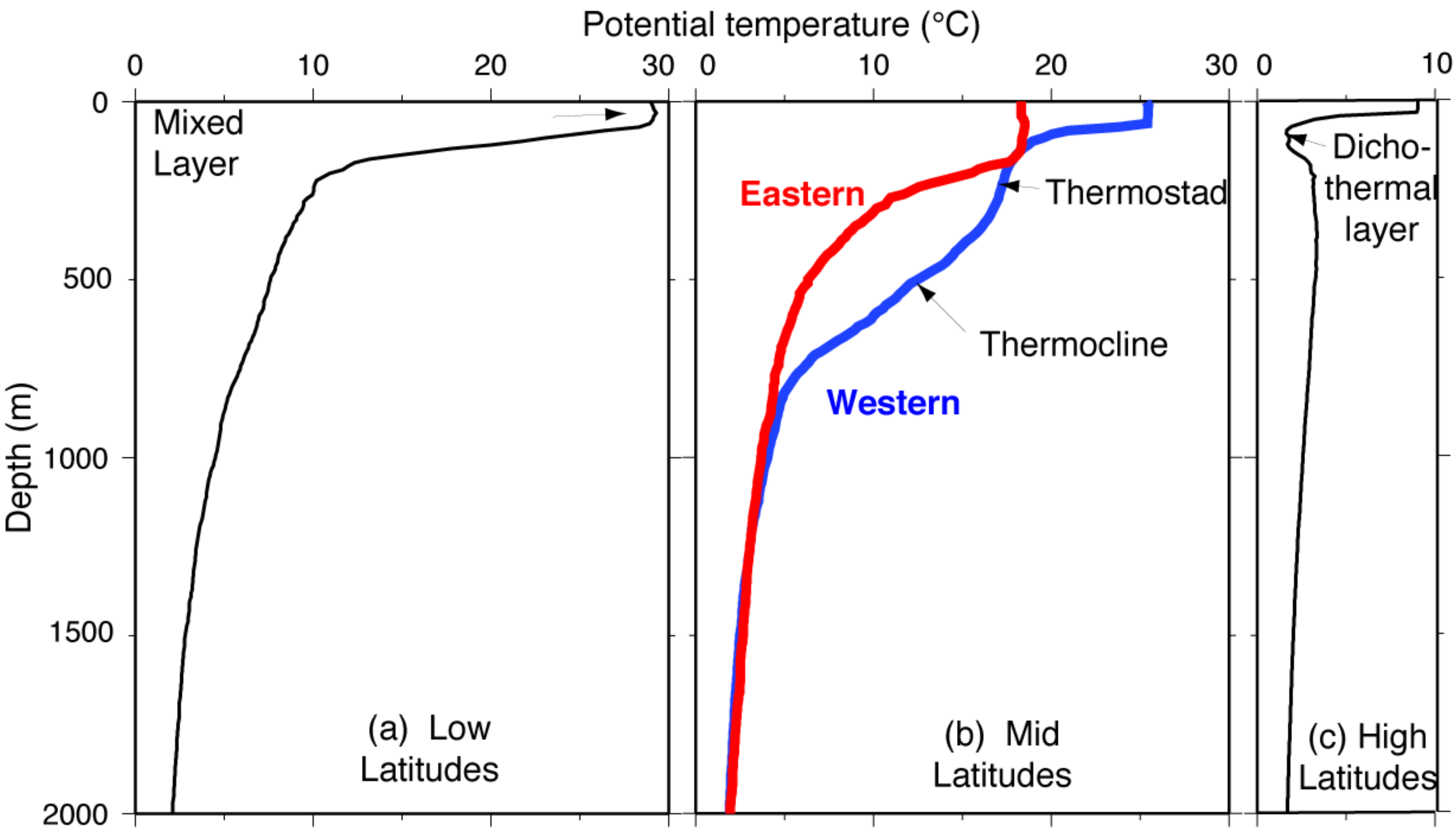

Western N. Pacific (TPS47 10)
6000
5000
4000
3000
2000
1000
0
Depth (meters)
0
2000
4000
6000
Pressure (dbars)

# Sea Surface Temperature

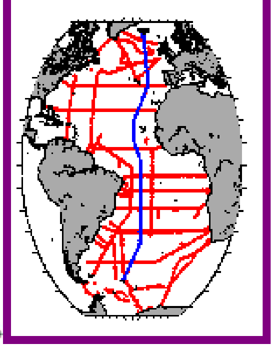


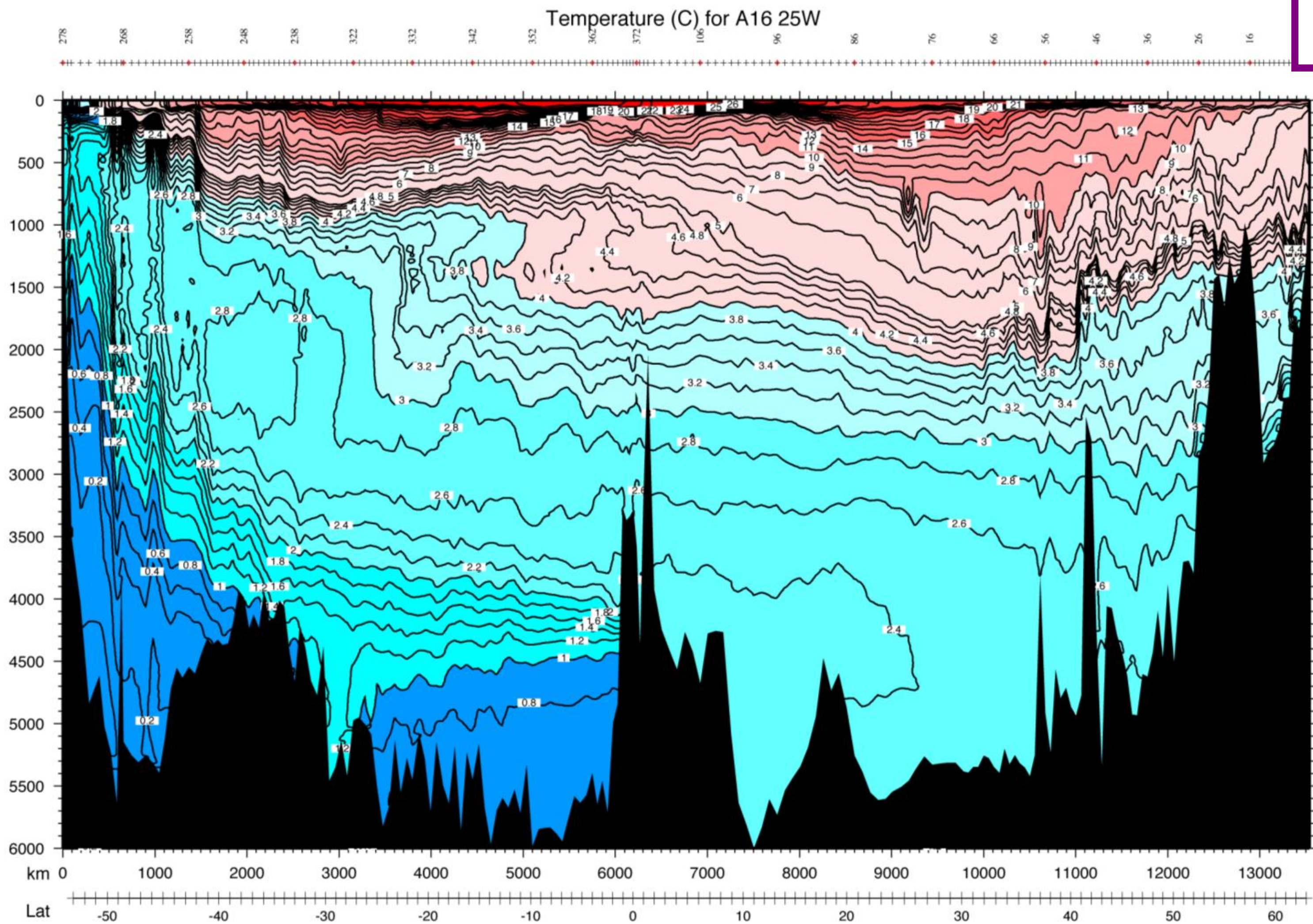

Winter data from Levitus and Boyer (1994)

# Temperature profiles: definitions



# Temperature section





# Seawater properties affected by Radiation, Flux and Diffusion

**Radiation, Advection & Diffusion → three processes which change things physically inside the ocean.**

**Radiation** → how heat and light (electro-magnetic waves) radiates.

- more important to atmosphere than oceans.
- penetration effects seen till euphotic zone.
- Ocean also radiates back heat to the atmosphere.

**Advection** → movement of parcel carrying heat and salt with it.

- Volume transport = V.A (where, V=velocity; A=area of surface)
- Mass transport = $\rho VA$ (where, $\rho$ = water density)
- Transport of dissolved materials = $C\rho VA$ (where, C = concentration of mass (or) molecules of matter unit mass).

**Flux** → directly related to transport (transport per unit area).

- Heat flux (Watts/$m^2$).
- Change in flux is related to change in properties within a closed box.

**An Example** → Let us consider there is a large flux of heat INTO a  box that OUT of the box.

- This implies water coming out of box is cooler and must have cooled inside the box.
- Where has this heat lost and by what process??
- Loss of heat out of sea-surface if one face of box is at sea-surface.

**Another Example** → Let us consider there is higher flux of oxygen into a box that outside the box.

- This implies oxygen is consumed within the box by bacteria.

**Change of flux through box** → flux divergence (more comes out than goes in)

Flux convergence → less comes out than goes in.

**Advection** → is similar to flux → refers to what happens at a point rather than side of a volume.

Fluid Mechanics → Advective terms → explains how convergence or divergence of flux occurs at that point.

**Diffusion** → similar to flux convergence/divergence → at extremely small spatial scales.

# Ficks Law of Diffusion

$$N_x = AD\left(\frac{\Delta C}{\Delta X}\right)$$

where, $N_x$ = mass flux ; A = area of plane of diffusion ($m^2$)

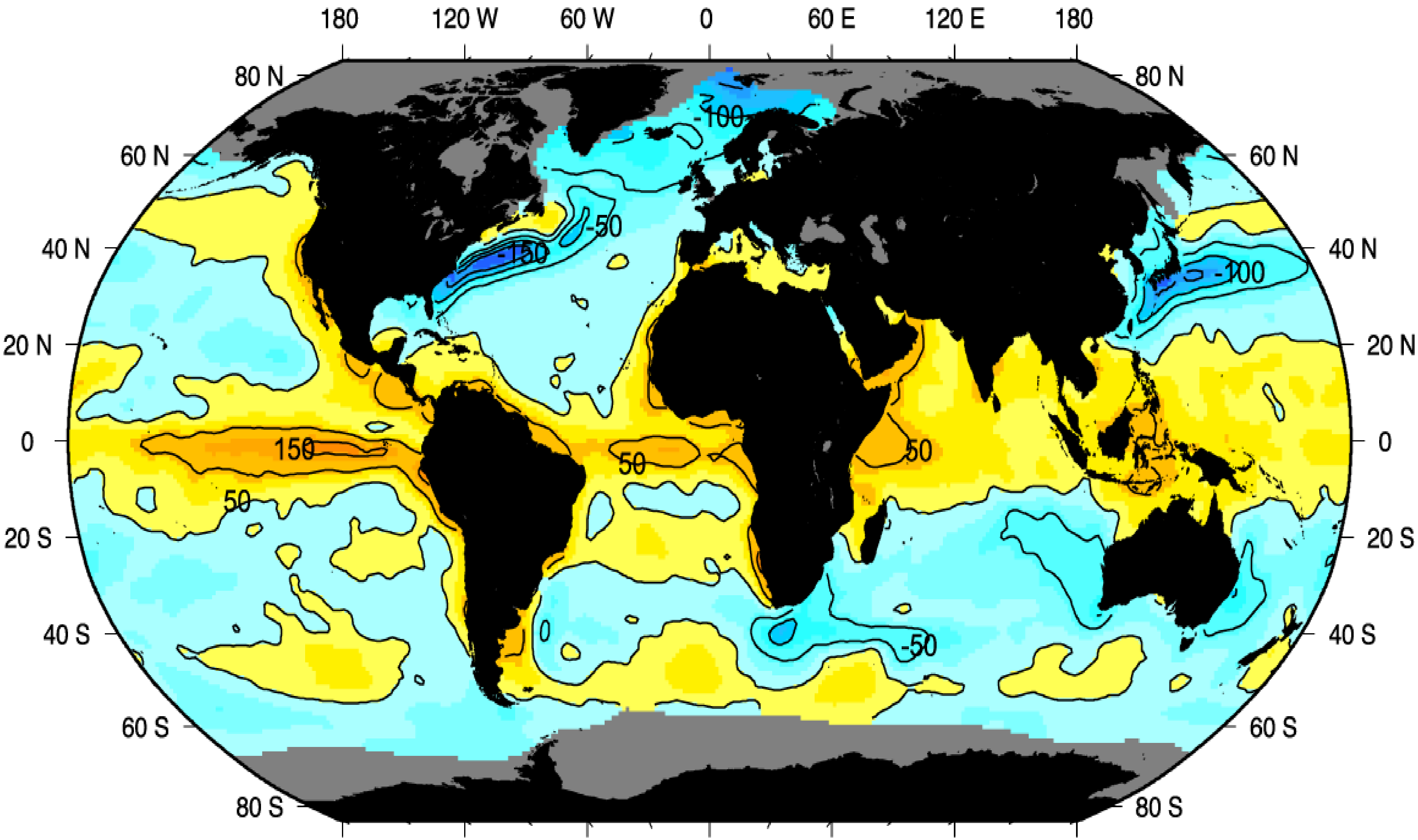
D = diffusion coefficient (molecular/turbulent) in $m^2/min$

$\Delta C$ = concentration difference (mg $m^{-3}$)

$\Delta X$ = distance over which concentration gradient exists (L)

$\Delta C/\Delta X$ = concentration gradient

# Surface heat flux ($W/m^2$) into ocean



# Density of Seawater

- Density of pure water is 1000 $kg/m^3$.
- Ocean water is more dense because of the presence of salt. Density of ocean water at the sea-surface is about 1027 $kg/m^3$.
- Two main factors that make ocean water more or less dense than 1027 $kg/m^3 \rightarrow$ the temperature of sea-water and its salinity.
- Ocean water gets denser as temperature goes down. Hence, cold water are more denser.
- Increasing salinity also increases the density of sea water.

# Density of Seawater

Less dense water floats on top of more dense water. Given two layers of water with the same salinity, the warmer water will float on top of the colder water.

Temperature has a greater effect on the density of water than salinity does → Layer of water with higher salinity can actual float on top of water with lower salinity if the layer with higher salinity is quite a bit warmer than the lower salinity layer.

The temperature of the ocean decreases as one go down vertically. Hence, the density of ocean water increases as one go to the bottom of the ocean → The deep ocean is layered with the densest water on bottom and the lightest water on top → Circulation in the depths of the ocean is horizontal. This means that water moves along the layers with the same density.

# Density of Seawater

- The density of ocean water is rarely measured directly. If one want to measure the density of ocean water, one need to collect the sample of sea water and bring it back to the laboratory to be measured.

- Density is usually calculated using an equation. One need to measure the salinity, temperature and pressure to be able to find density. These measurements are often made with a CTD instrument, where the instrument is placed in the ocean water from a ship or a platform.

A CTD recorder, which stands for Conductivity-Temperature-Depth recorder, measures the physical properties of seawater.

As the CTD instrument is lowered through the water measurements of conductivity, temperature and depth are recorded continuously. General data acquisition for a CTD profiler is up to 24 Hz, which means that each parameter could be measured up to 24 times each second. This provides a very high resolution description of the water being tested.

CTD instruments measure three important parameters directly - conductivity, temperature and pressure. By measuring conductivity scientists can get a measurement of that water sample's salinity. This is because electric current passes much more easily through water with a higher salt content. So if we know the conductivity of the water, we know how much salt is in the water. Accuracy of the measurement is generally better than 0.005 psu for a standard CTD profiler.

# CTD

CTD instrument usually uses a thermistor, a platinum thermometer, or a combination of these to measure the temperature of the water. Temperature as measured by a CTD instrument has an accuracy of greater than 0.005 degrees Celsius.

Finally, a CTD instrument measures pressure using either a strain gauge pressure monitor or a quartz crystal-based digital pressure gauge. Pressure is recorded in decibars, and since depth and pressure are directly related, a measurement in decibars can be converted to depth in meters.

For example the pressure in "X" decibars is almost exactly equal to the pressure found at "X" meters of depth. For instance, at about 500 meters below the surface, the pressure is almost around 500 dbars. The CTD instrument can measure pressure to within an error margin of about 1%.

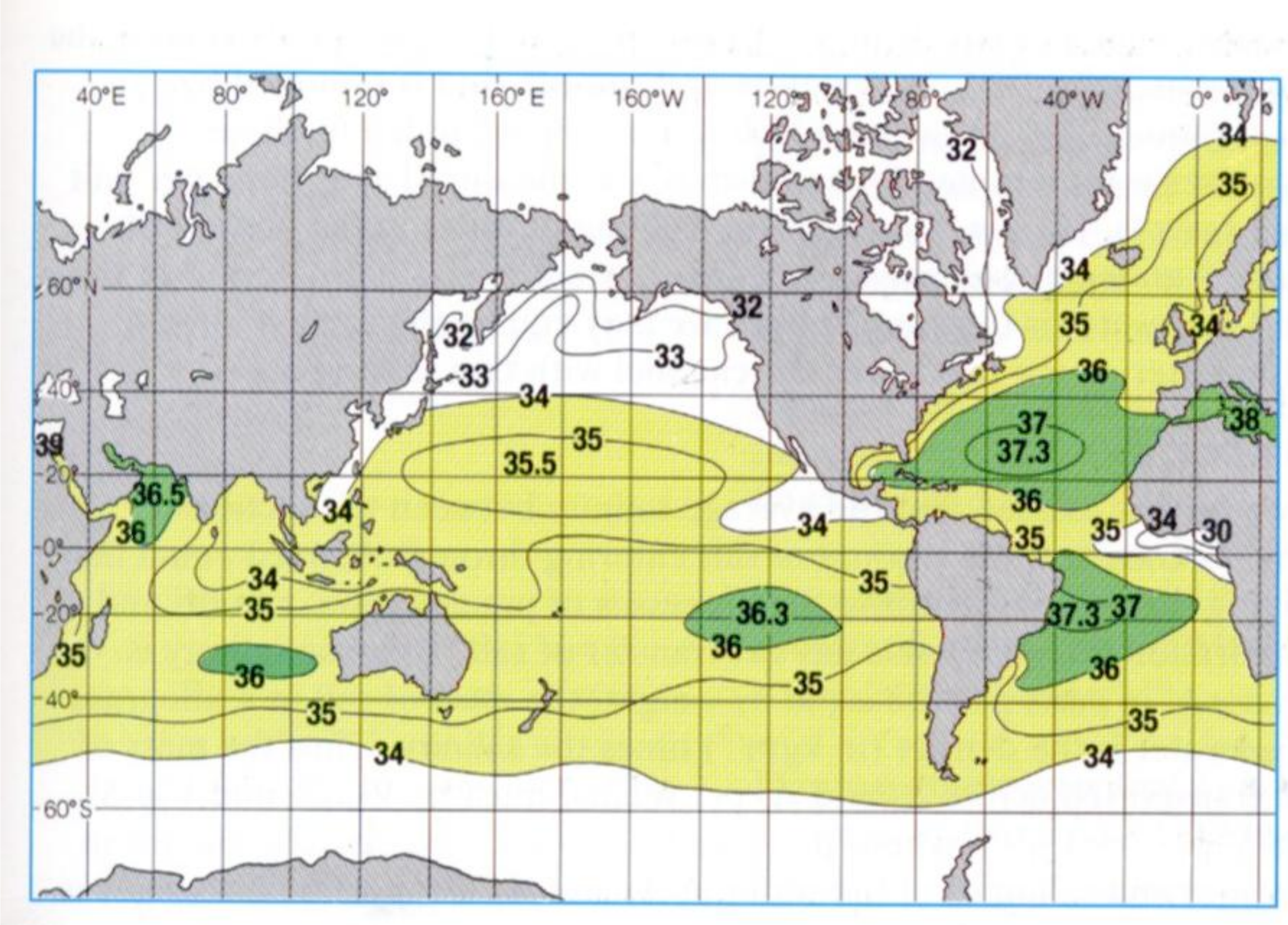
# The Global Salinity Budget

- There is a riverine source ...BUT... salinity of the ocean is nearly constant.
- Salinity is altered by air-sea exchanges and sea ice formation.
- Useful for budgeting water mass

# The Global Salinity Budget

- $3.6 \times 10^{12}$ kg salts are added to ocean each year from rivers.
- Mass of the oceans is $1.4 \times 10^{21}$ kg
- IF only riverine inputs, increase in salinity is $\Delta S \sim 1000 * 3.6 \times 10^{12}$ kg/y / $1.4 \times 10^{21}$ kg $= 2.6 \times 10^{-6}$ ppt per year
- Undetectable, but not geologically…
- Salinity is therefore constant (at least on oceanographic time scales)

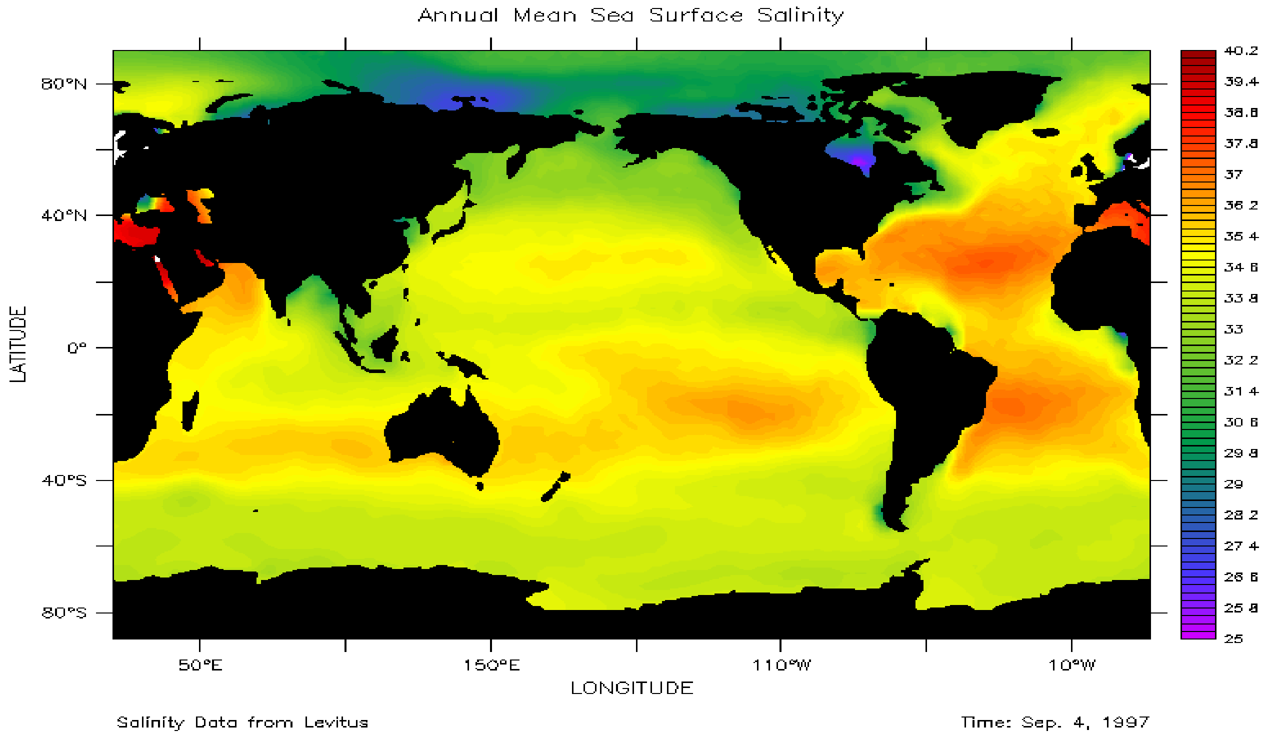
# Global Salinity Distribution

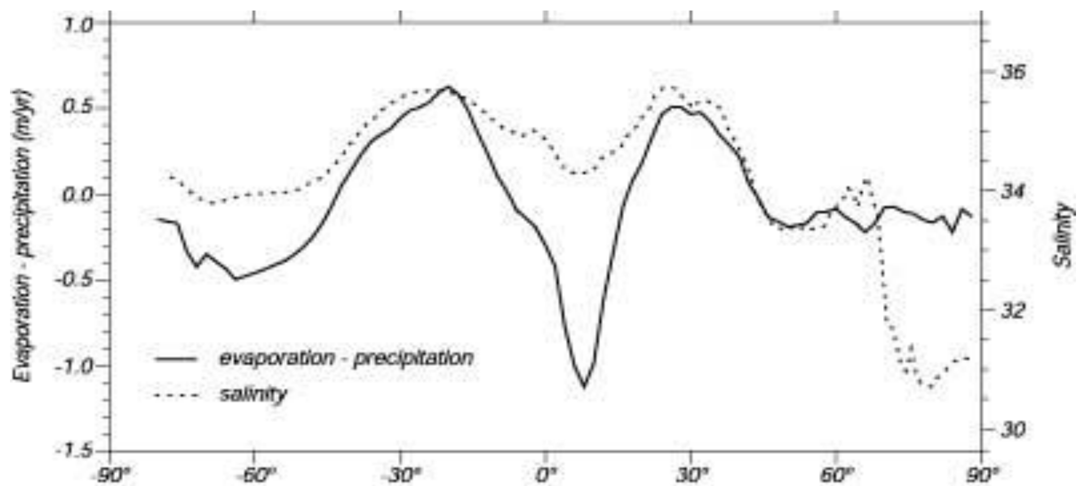


# The Global Salinity Budget

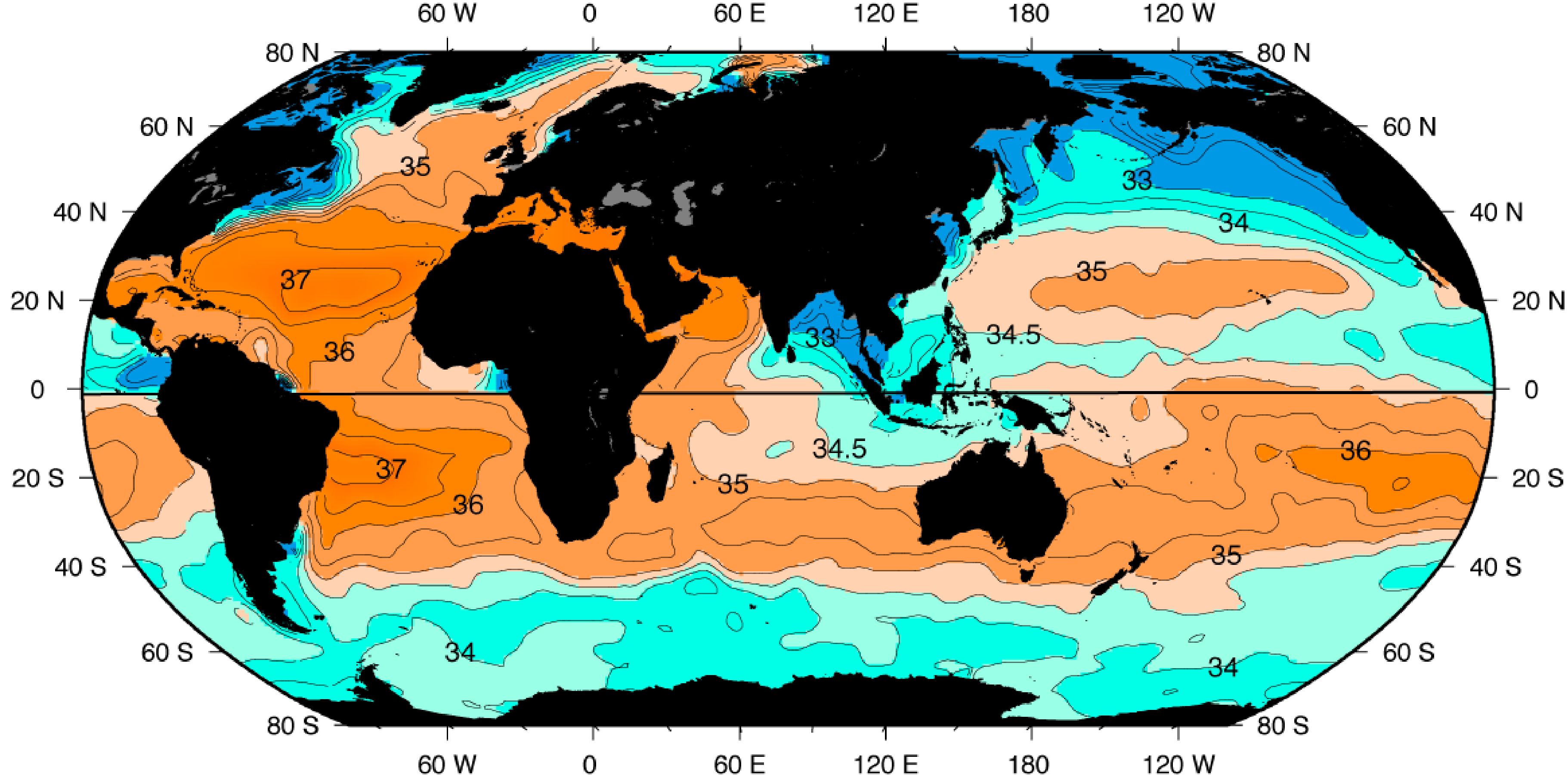
- Salinity follows (E-P) to high degree through tropics and subtropics.
- Degree of correspondence falls off towards the poles (sea ice…).
- Atlantic salinities are much higher than Pacific or Indian Oceans.

# Global Salinity Distribution

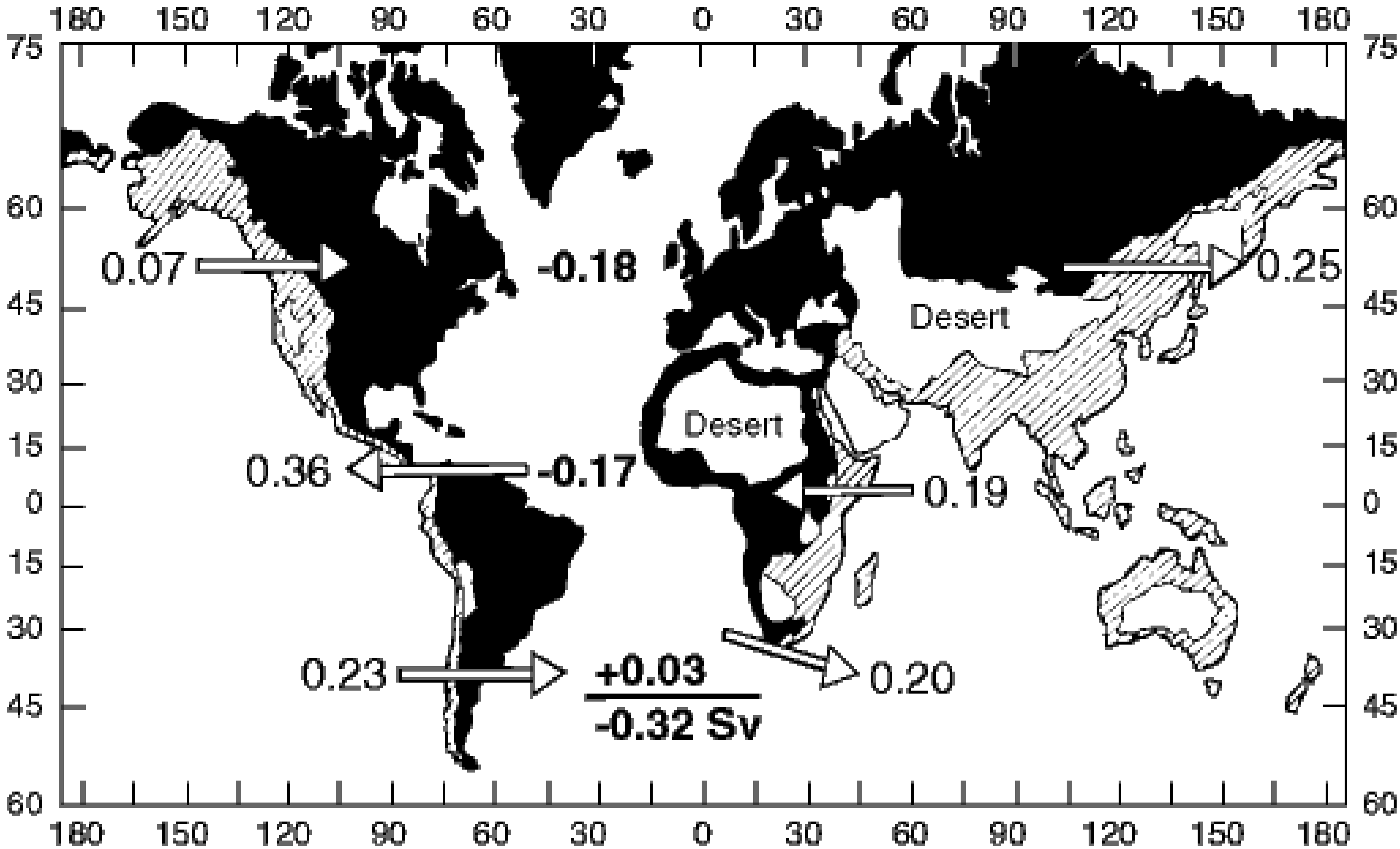


# Surface salinity

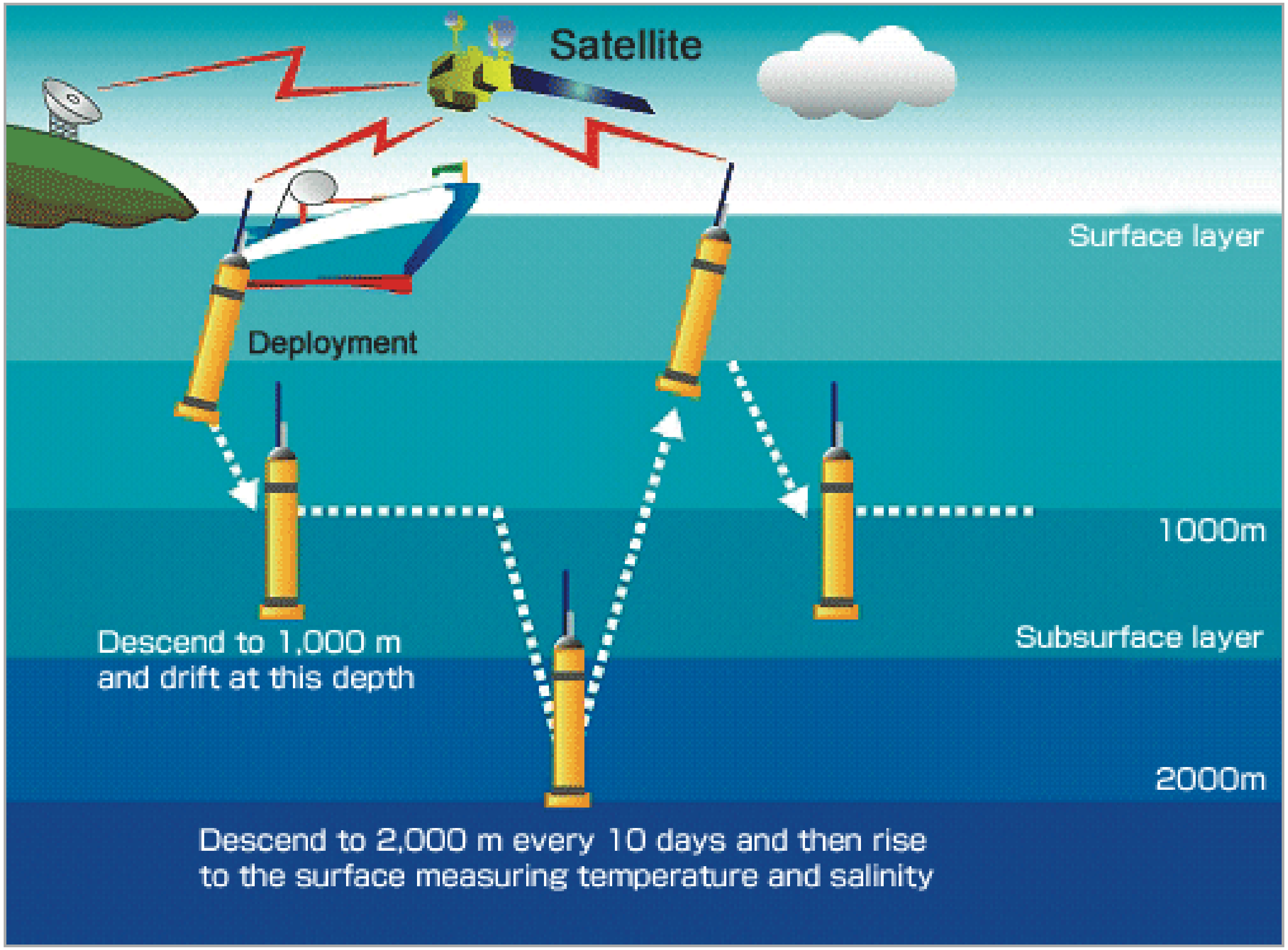


# Why is the Atlantic so salty?

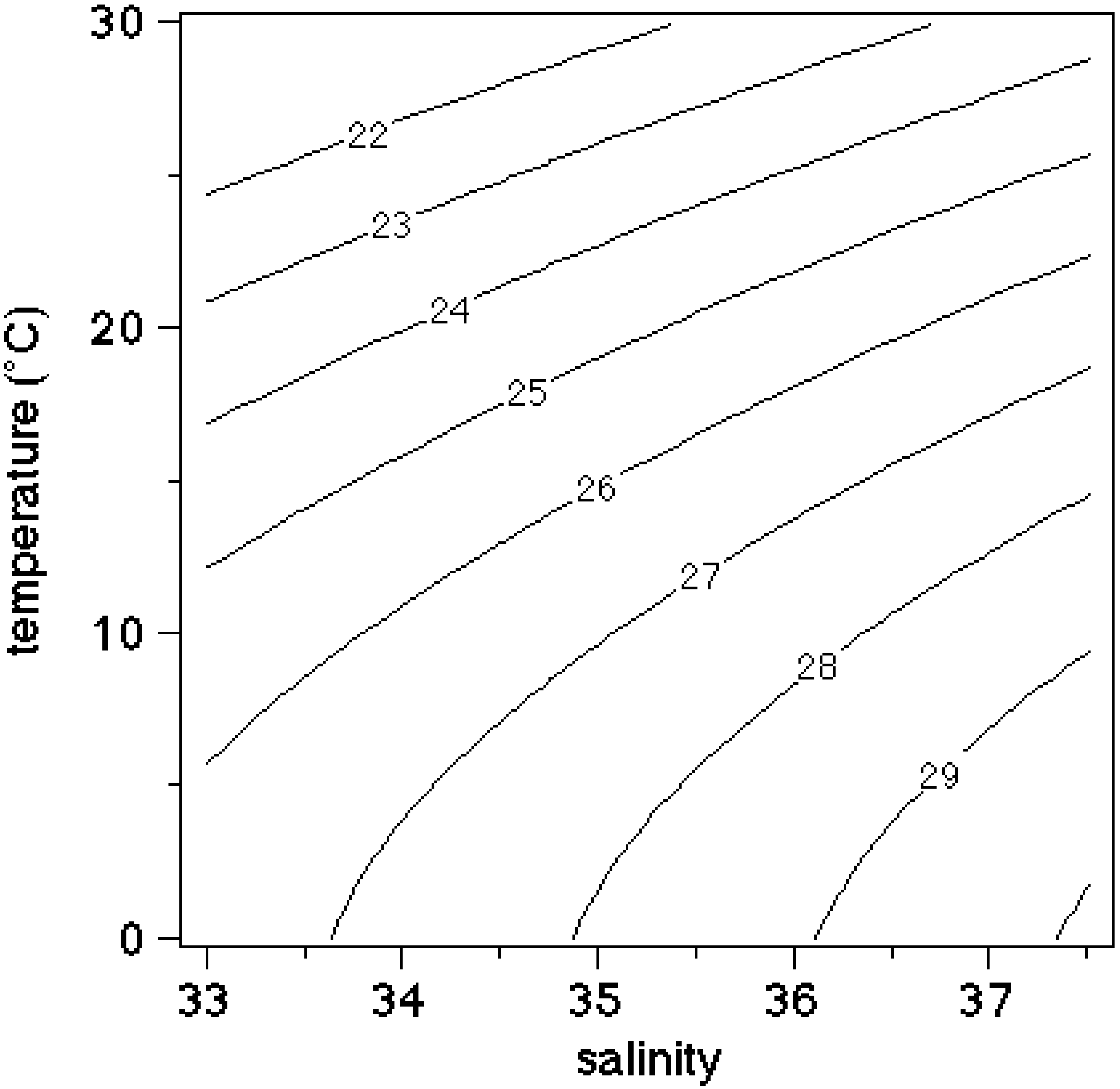



1 Sverdrup = $10^6$ $m^3$ $s^{-1}$

# Salinity Measurements – ARGO Floats

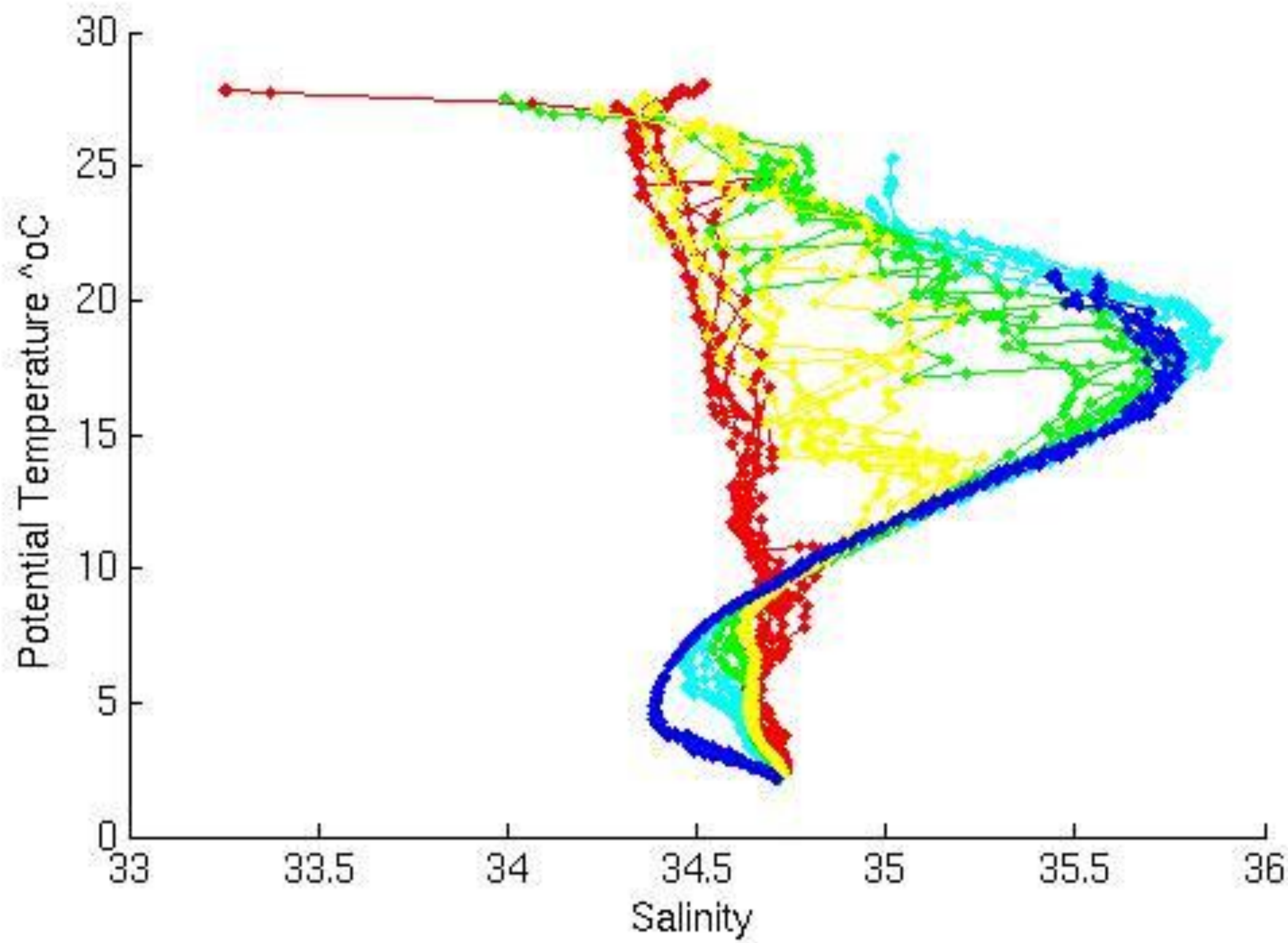


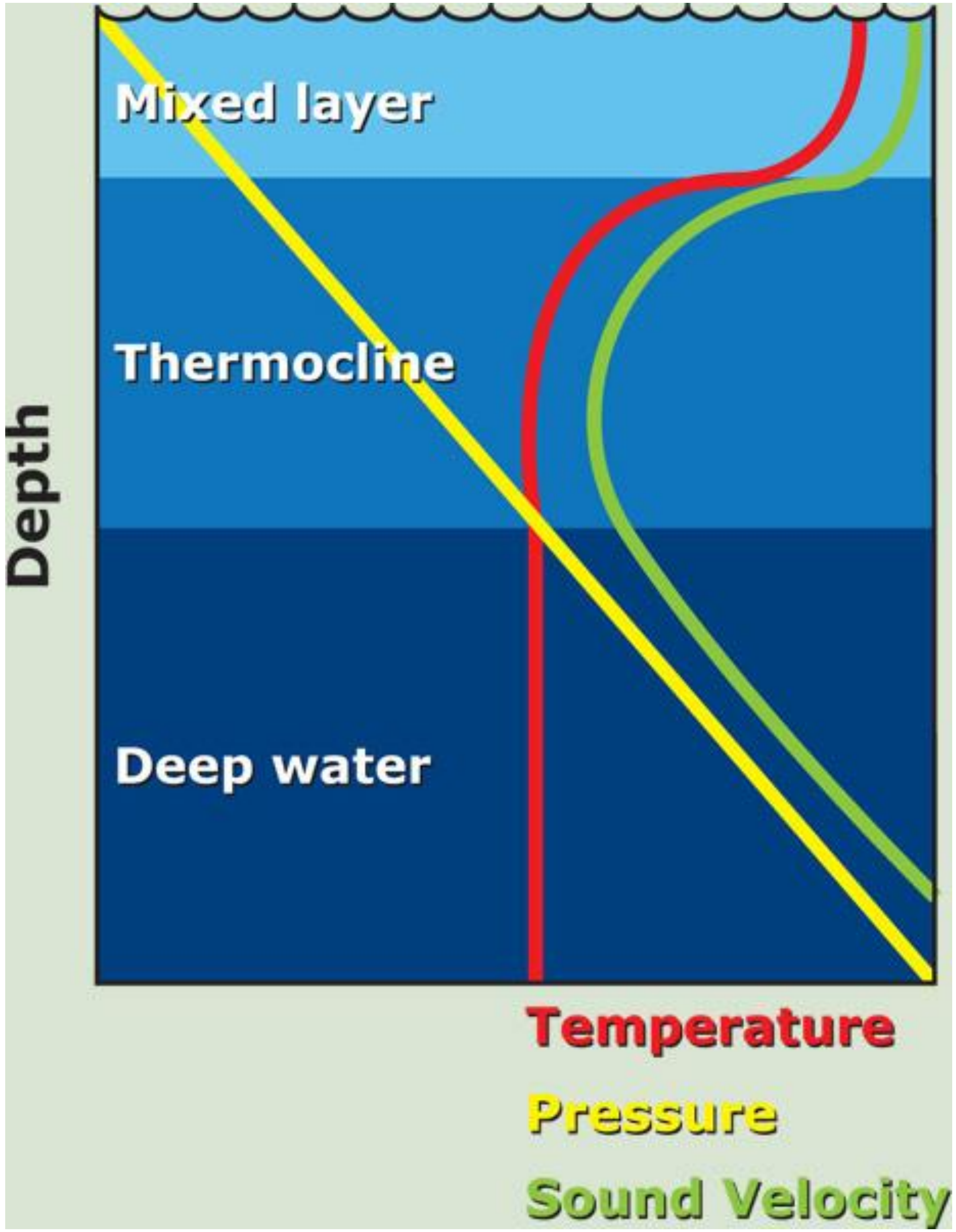
# T-S Diagram



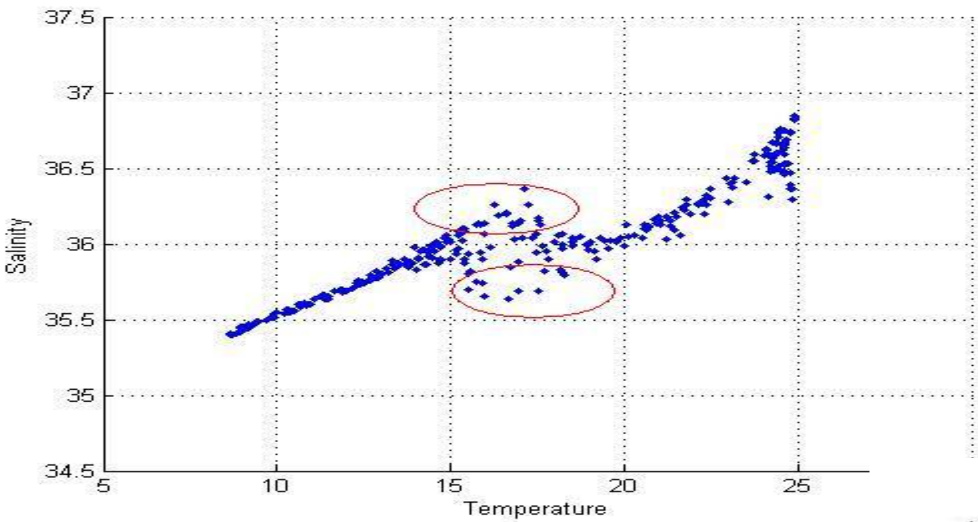
30
20
10
0
temperature (°C)
22
23
24
25
26
27
28
29
33
34
35
36
37
salinity

# Water Mass – T/S diagram



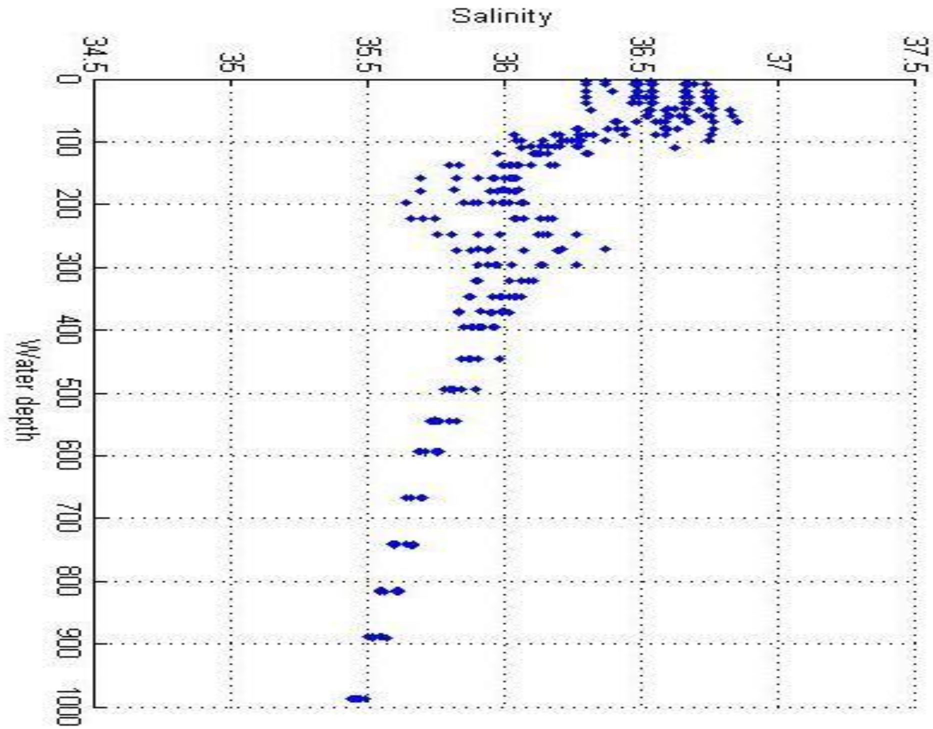

Mixed layer
Thermocline
Deep water
Depth
Temperature
Pressure
Sound Velocity

# Water Masses in Persian Gulf

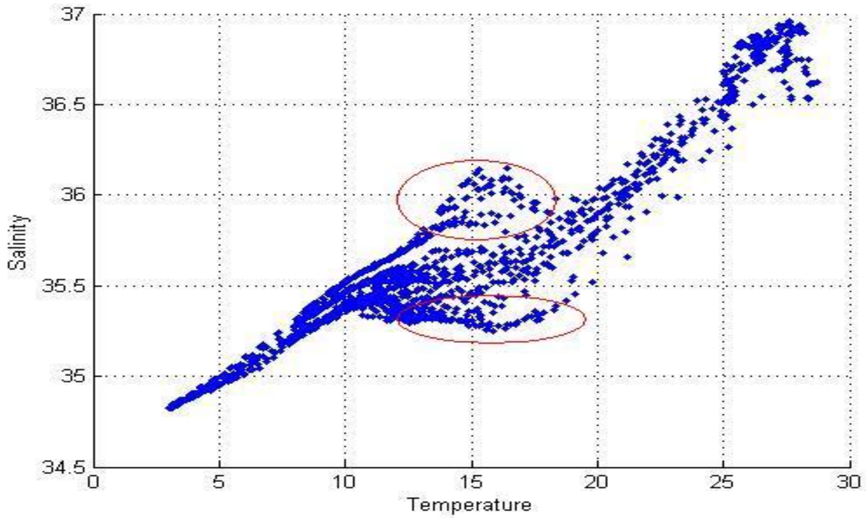



(Salinity - Temperature) graph for month of January
(Near the Strait of Hormuz)

(Salinity - Depth) graph for month of January (Near the Strait of Hormuz)

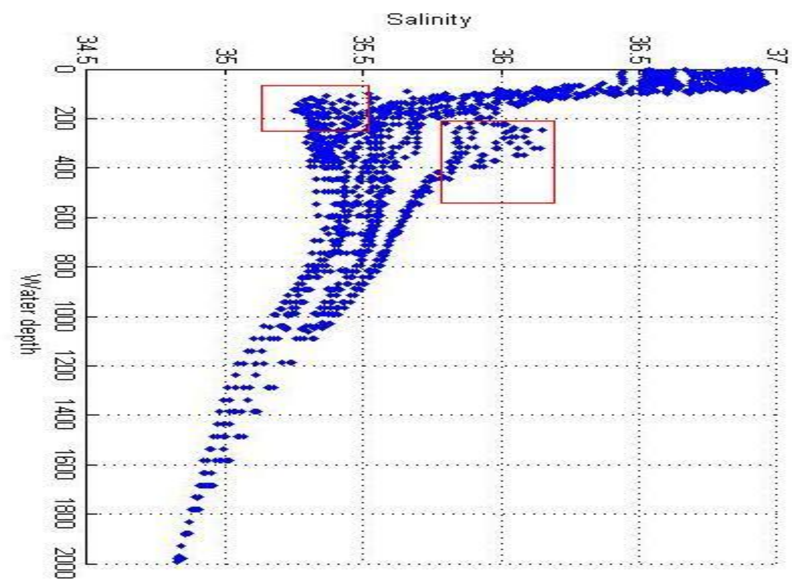


# Water Masses in Persian Gulf

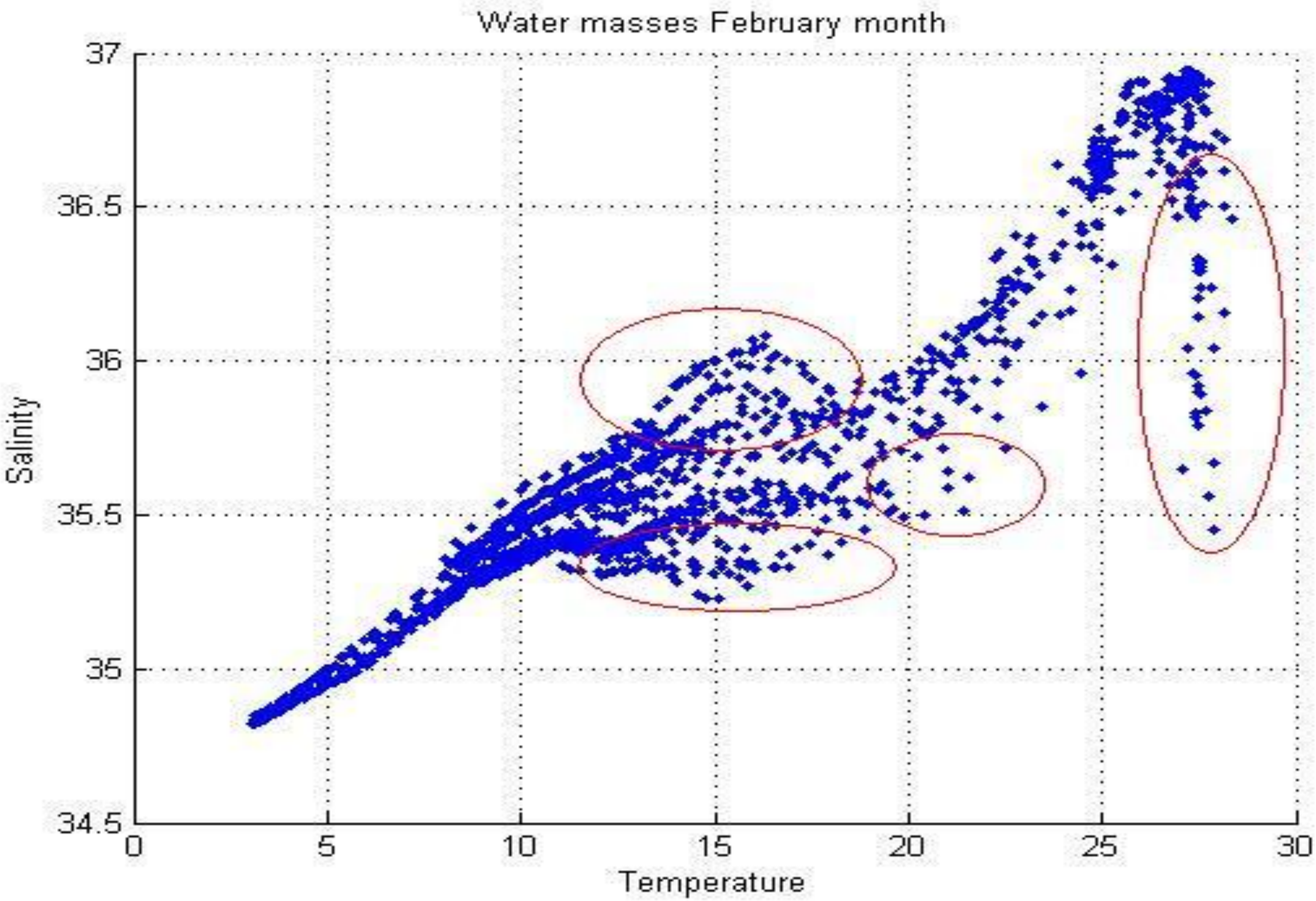



(Salinity - Temperature) graph for month of January (1000Km away from the Strait of Hormuz)

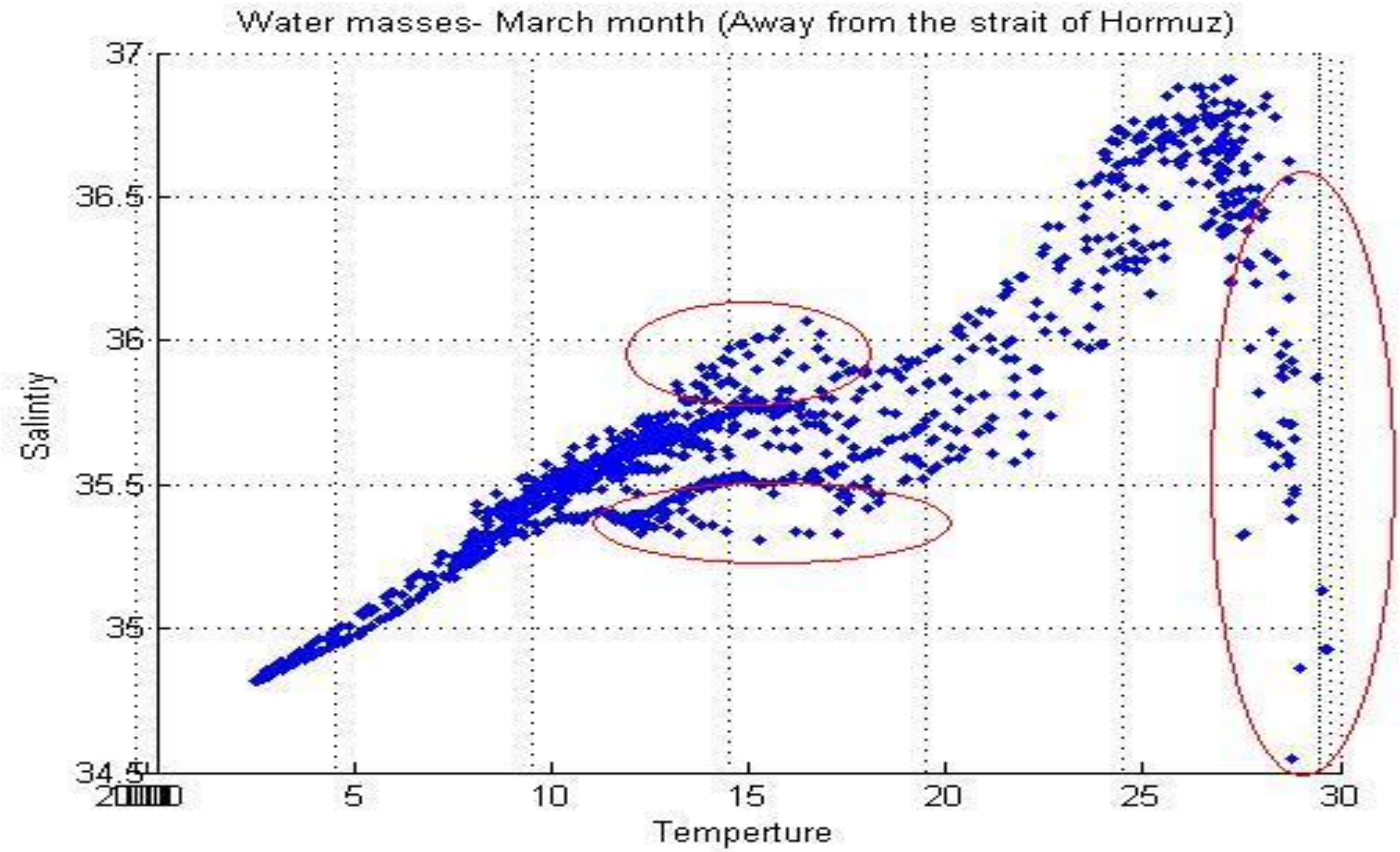
(Salinity - Depth) graph for month of January (1000Km away from the Strait of Hormuz)



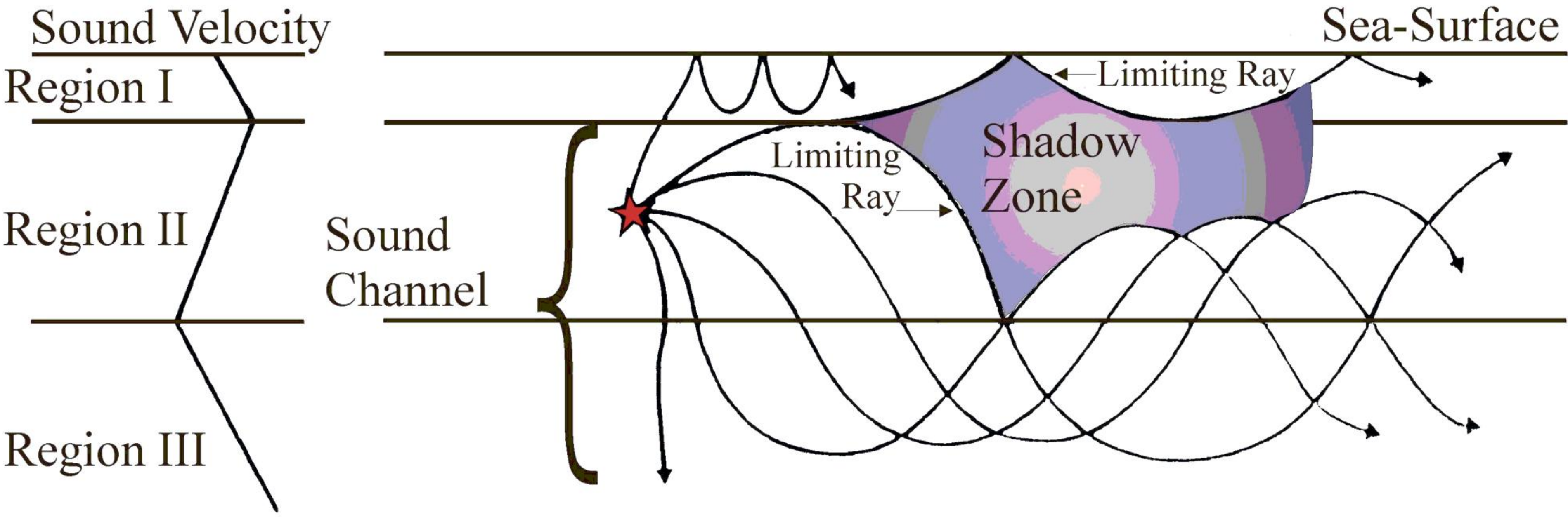
# Water-mass for the month of February (1000Km away from the Strait of Hormuz)



# Water-mass for the month of March (1000Km away from the Strait of Hormuz)

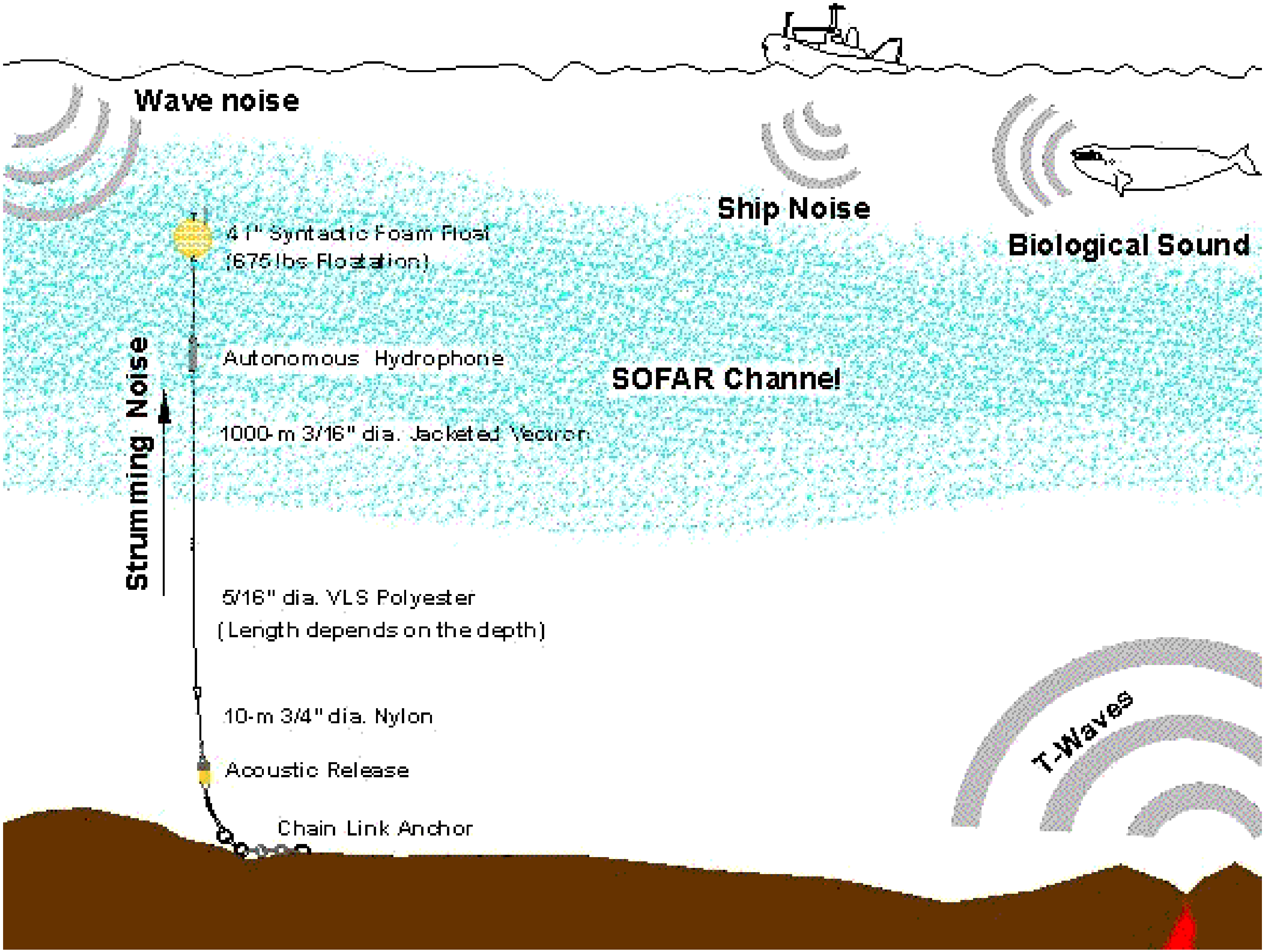


# Waveguides

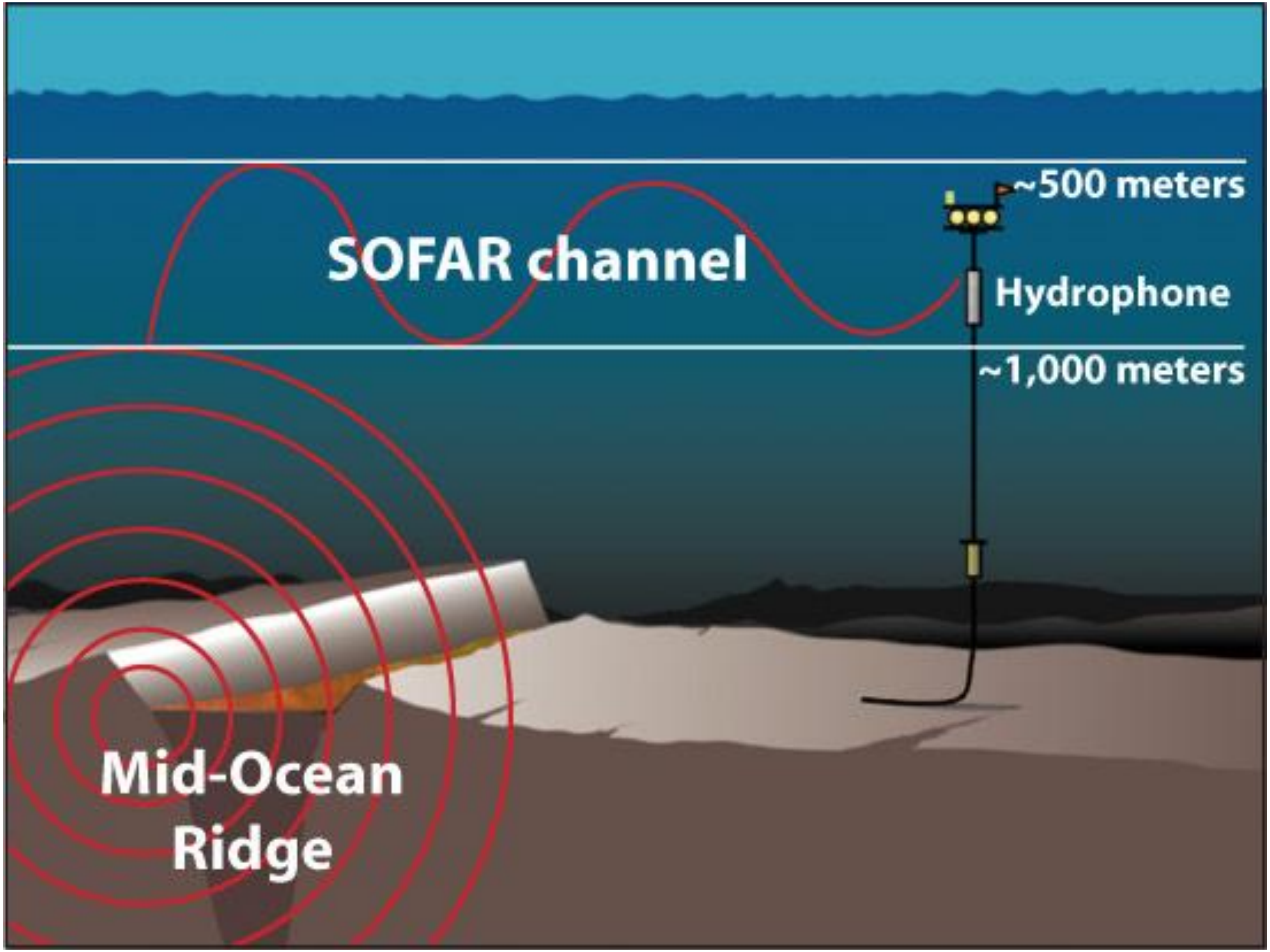


Sound Velocity
Region I
Region II
Region III
Sound Channel
Sea-Surface
Limiting Ray
Limiting Ray
Shadow Zone

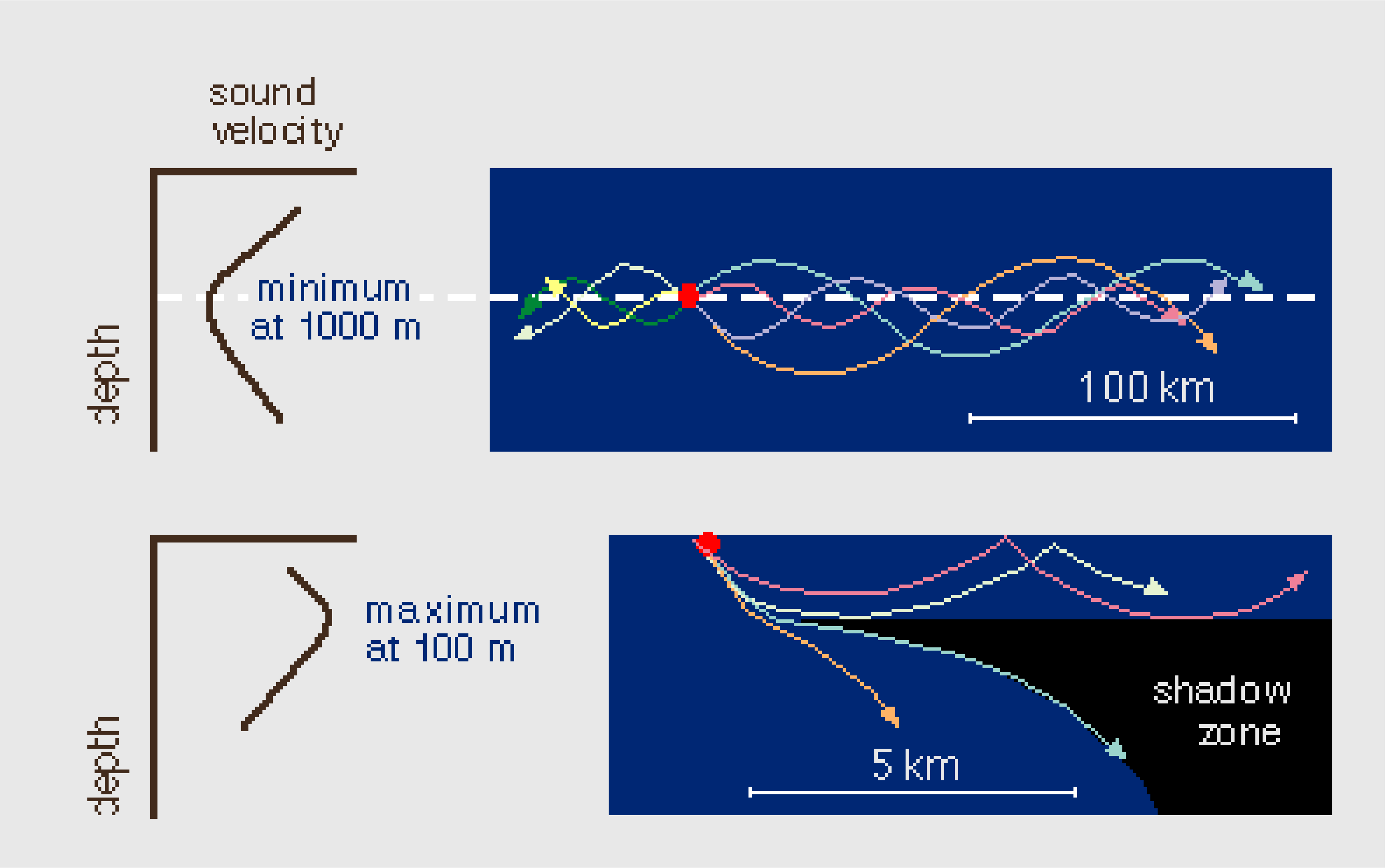
# Sound in the Oceans



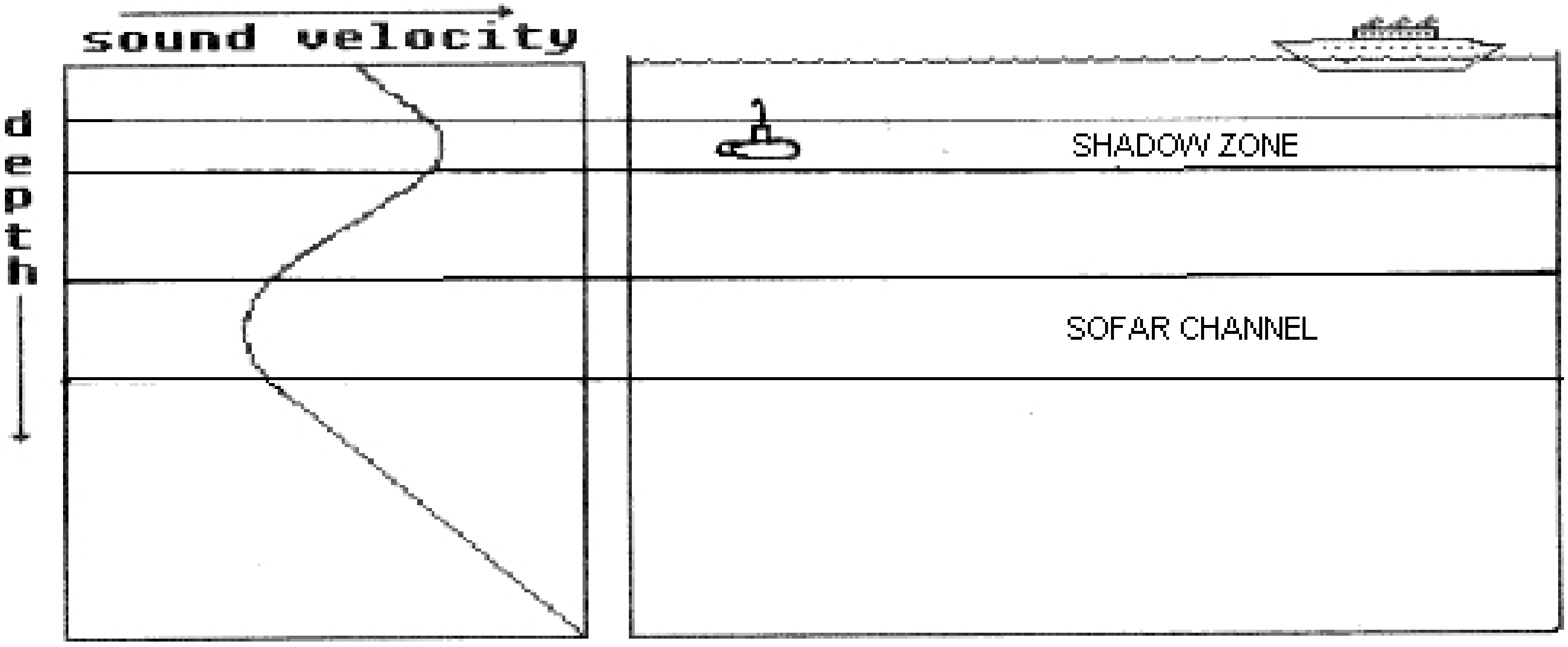
# SOFAR Channel

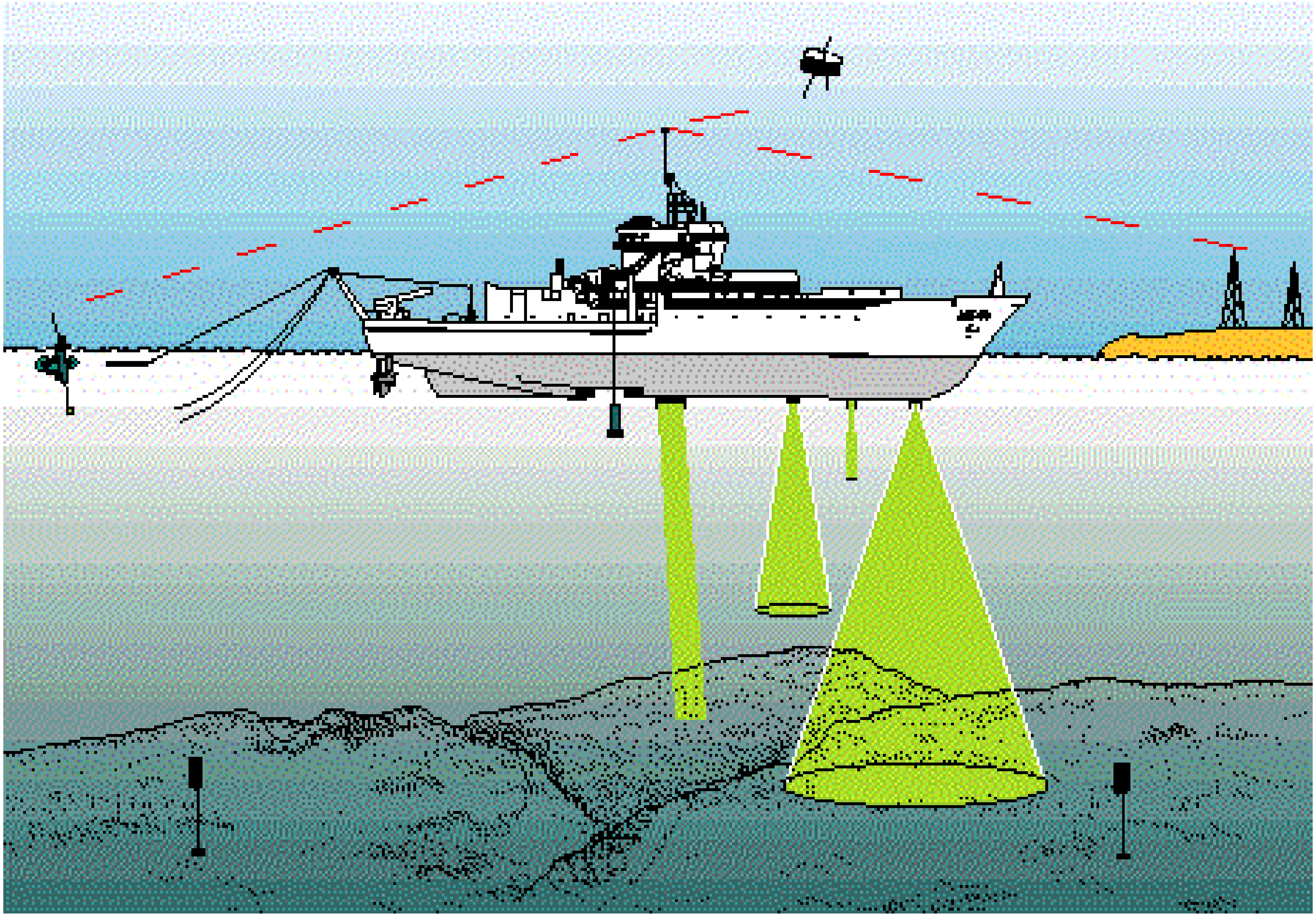


# Gradients – Sound Propagation

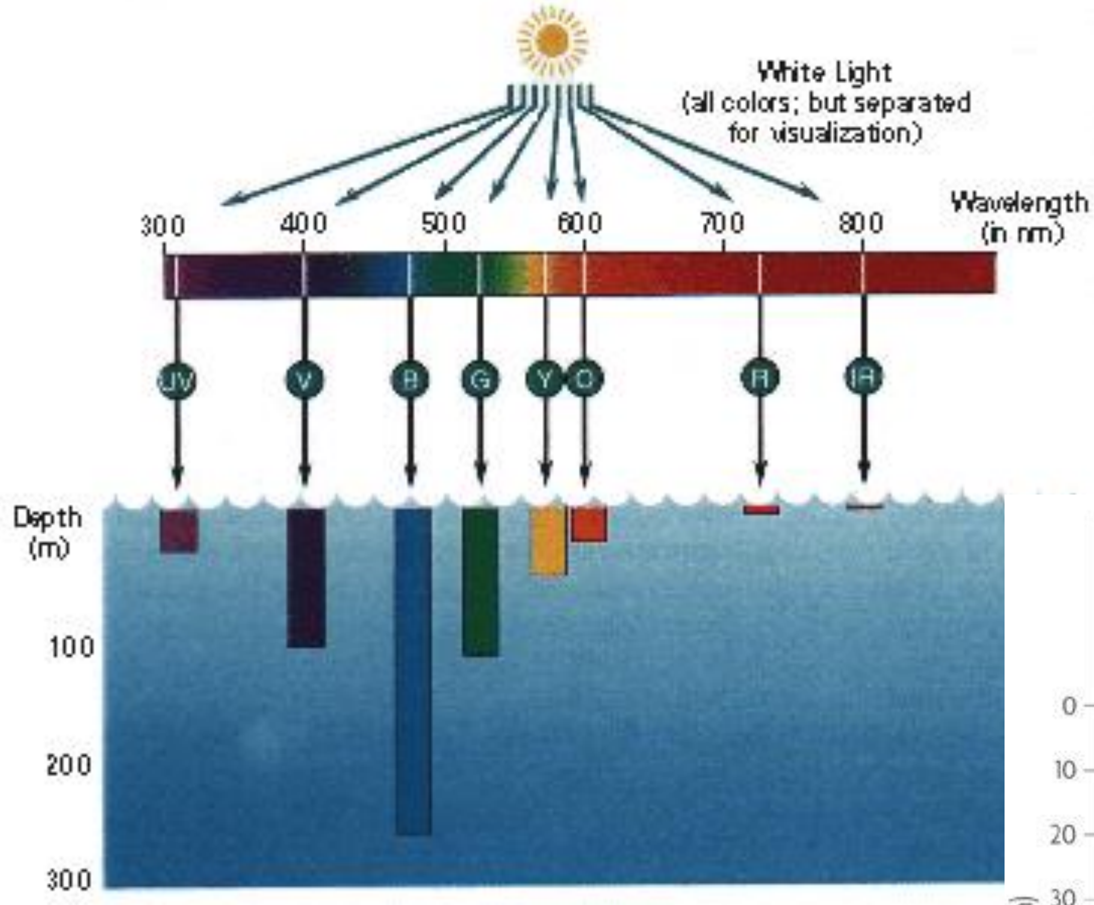


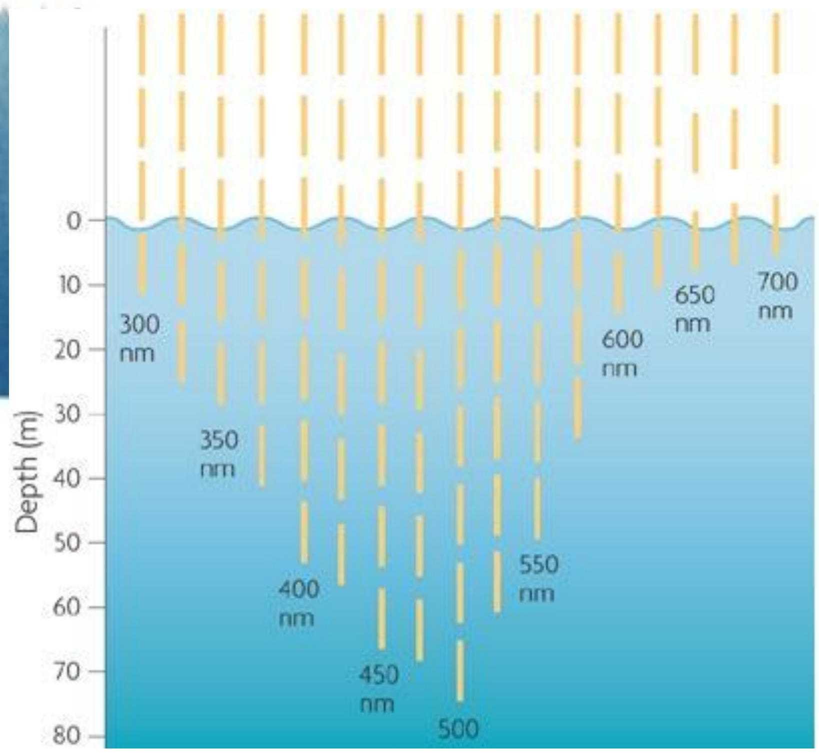
# Shadow Zones





# Optical properties of seawater



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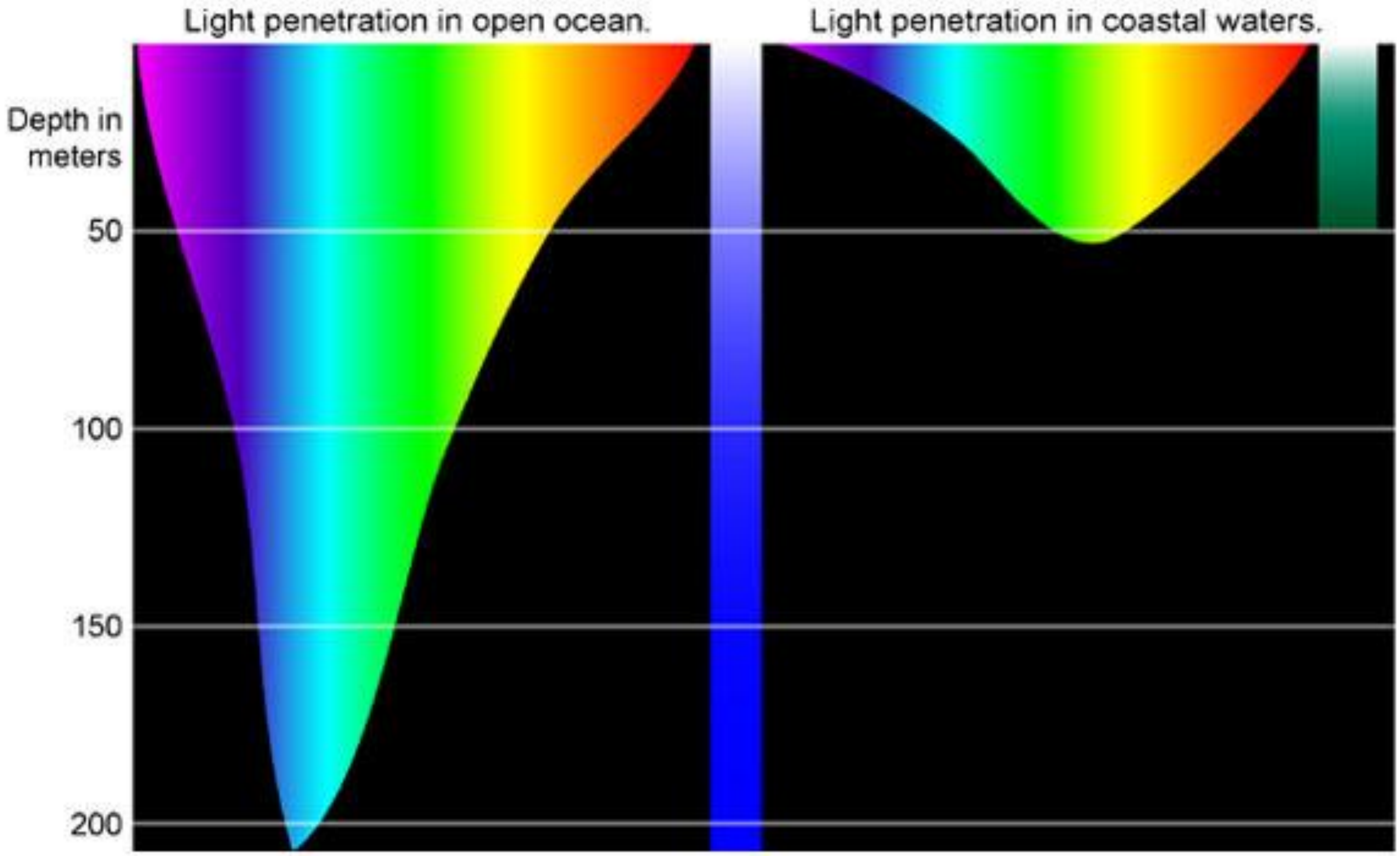
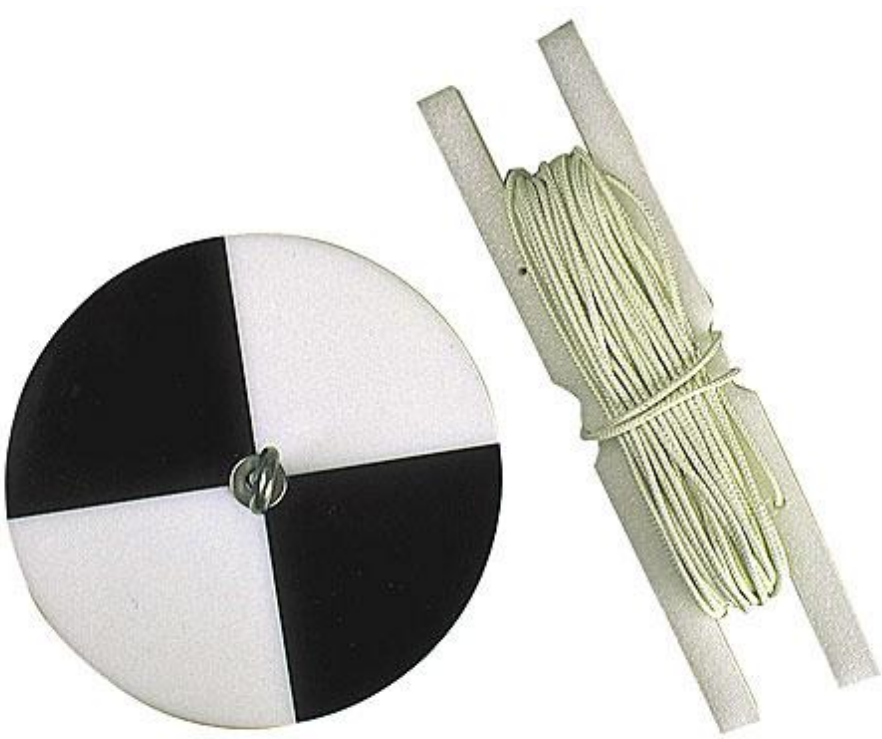
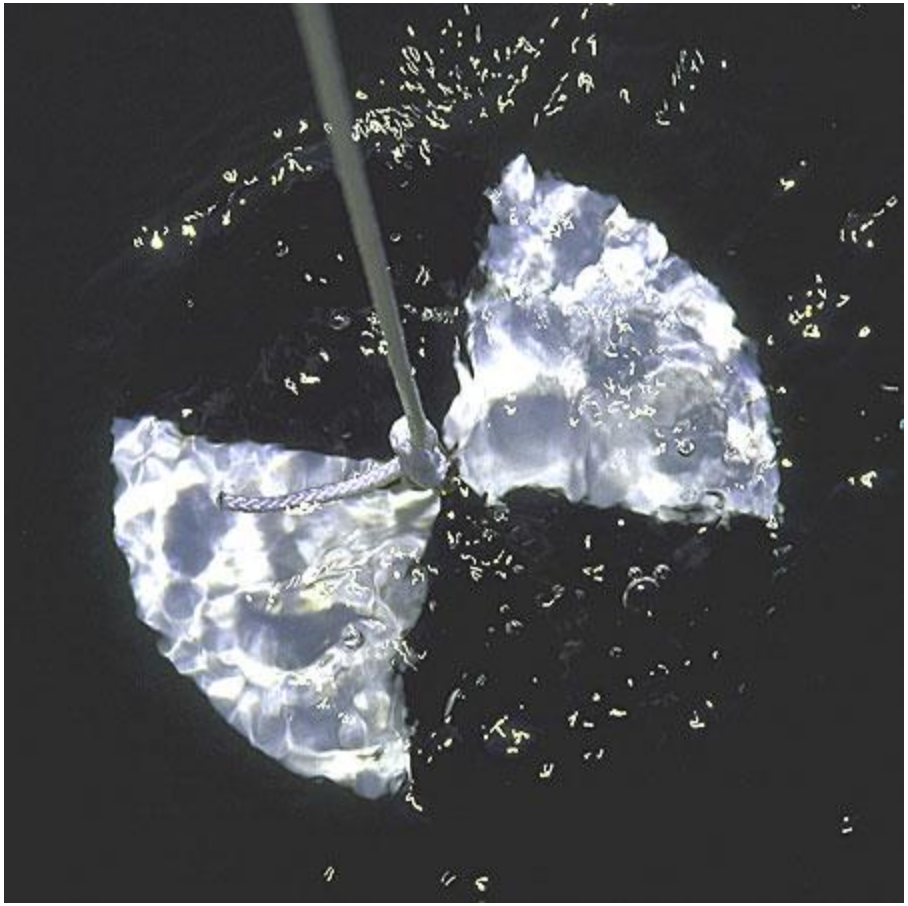


# Secchi Disk – Transparency of seawater





# MicroSAS

# Thank You