# Tropical Oceanography OCN5003

## Course Outline

Co-funded by the Erasmus+ Programme of the European Union

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Physical

Tropical Oceanography

Chemical

Geological

Assoc. Prof Dr. Ong Meng Chuan

Dr. Fatin Izzati Minhat

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# Learning Outcomes

| |
|---|
| Explain the fundamentals of oceanography in the tropical oceans as an interactive system in which physical, chemical, and geological factors are inter-related through ocean processes, nutrient dynamics and ocean productivity |
| Evaluate the scientific findings through data and information from oceanographic data analysis. |
| Articulate scientific arguments in addressing past, present and future climate change issues on tropical ocean. |

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**Course Outline: Semester March 2021 (SEM II 2020/2021)**

| TYPE | DAY | TIME | LOCATION |
|---|---|---|---|
| Lectures | Wednesday | 2 – 4 pm | WEBEX |
| Discussion/Tutorial | Monday | 10 am – 1 pm | WEBEX |

**Lecture list**

| Week | Lecture | Subject* | Discussion/Tutorial |
|---|---|---|---|
| 1 | 12/4 | Introduction to Tropical Oceanography | Review GOSR 2021 and UN Ocean Decade |
| | 14/4 | Global Ocean Observation System | |
| 2 | 19/4 | Physical Processes of South China Sea | World Ocean Database Exploration |
| | 21/4 | Dynamics of Monsoon Circulation | |
| 3 | 26/4 | Air -Sea interaction and Climate | ODV – Field data analysis: Upwelling |
| | 28/4 | Upwelling Dynamics and Processes | |
| 4 | 3/5 | Seawater Chemistry | |
| | 5/5 | Nutrient Cycle | |
| **MID TERM BREAK - HARI RAYA AIDILFITRI** | | | |
| 5 | 17/5 | Ocean Productivity | |
| | 19/5 | Primary and Net Primary Productivity | |
| 6 | 24/5 | Marine Pollution | |
| | 26/5 | Impact of pollution to environment | |
| 7 | 7/6 | Introduction to geological oceanography | |
| | 9/6 | Cosmology theories: formation of Earth | |
| 8 | 14/6 | Climate Change from Geological Perspective (Major Geological Events) | |
| | 16/6 | Geomorphology of Ocean Basin | |
| 9 | 21/6 | Paleoceanography and global sea level changes | |
| | 23/6 | Future sea level | |
| 10 | 28/6 | Tropical Ocean and Climate Change | Review IPCC AR5 |
| | 5/7 | **FINAL ASSIGNMENT** | |
| | | **NO FINAL EXAM** | |

| Type | % of final marks |
|---|---|
| Tutorial/Discussion1 | 5 |
| Assignment 1 | 15 |
| Tutorial/Discussion2 | 5 |
| Assignment 2 | 15 |
| Tutorial/Discussion3 | 5 |
| Assignment 3 | 15 |
| Final Assignment | 40 |
| **Total** | **100** |

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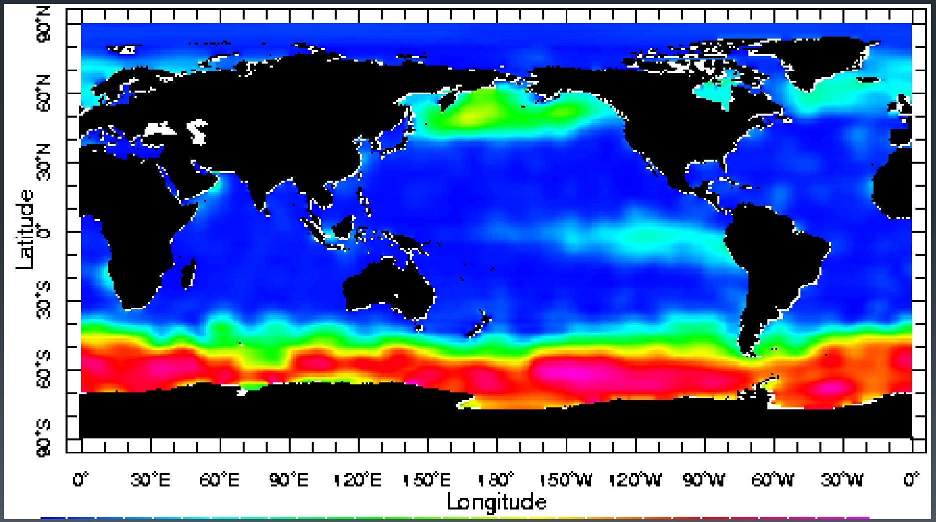
**Reading Lists**


| | |
|---|---|
| 1 | Tom Garrison. (2001). Essentials of Oceanography (2nd edition). USA. |
| 2 | John. H. Sampson and J. Sharples, 2012. Introduction to the Physical and Biological Oceanography of Shelf Seas. Cambridge University Press |
| 3 | Robert H. Stewart, 2007. Introduction To Physical Oceanography. Dept. of Oceanography, Texas A & M University. |
| 4 | Riley, J. P. and R. Chester, 1971. Introduction to Marine Chemistry. Academic Press. London. |
| 5 | R. Chester and T.D. Jickells, 2013. Marine Geochemistry. Wiley-Blackwell |
| 6 | Jim Murray, 2001. Chemical Oceanography Lecture Note. Univ. Washington. |
| 7 | Seibold, E. & Berger, W. H. 2010. The sea floor: An introduction to marine geology. Springer. |
| 8 | Global Ocean Scientific Report 2021, UNESCO |
| 9 | Intergovernmental Panel of Climate Change, Annual Report 6 |

# Oceanography

The study of the ocean, with emphasis on its character as an environment.
The goal is to obtain a description sufficiently quantitative to be used for predicting the future with some certainty.

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# What are the importance of oceanography to human being???

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# Oceanography

- Climate and Weather
  - Monsoon
  - ElNino
  - Hurricanes/Cyclones
- Resources
  - Fisheries
  - Oil and Gas
  - Toursim
- Pollution and Natural Disaster
  - HAB
  - Coastal Erosion
  - Hypoxia
- Climate Change/Global Warming
  - Ocean Acidification
  - CO2 sequestration

# What so special about the Tropics?

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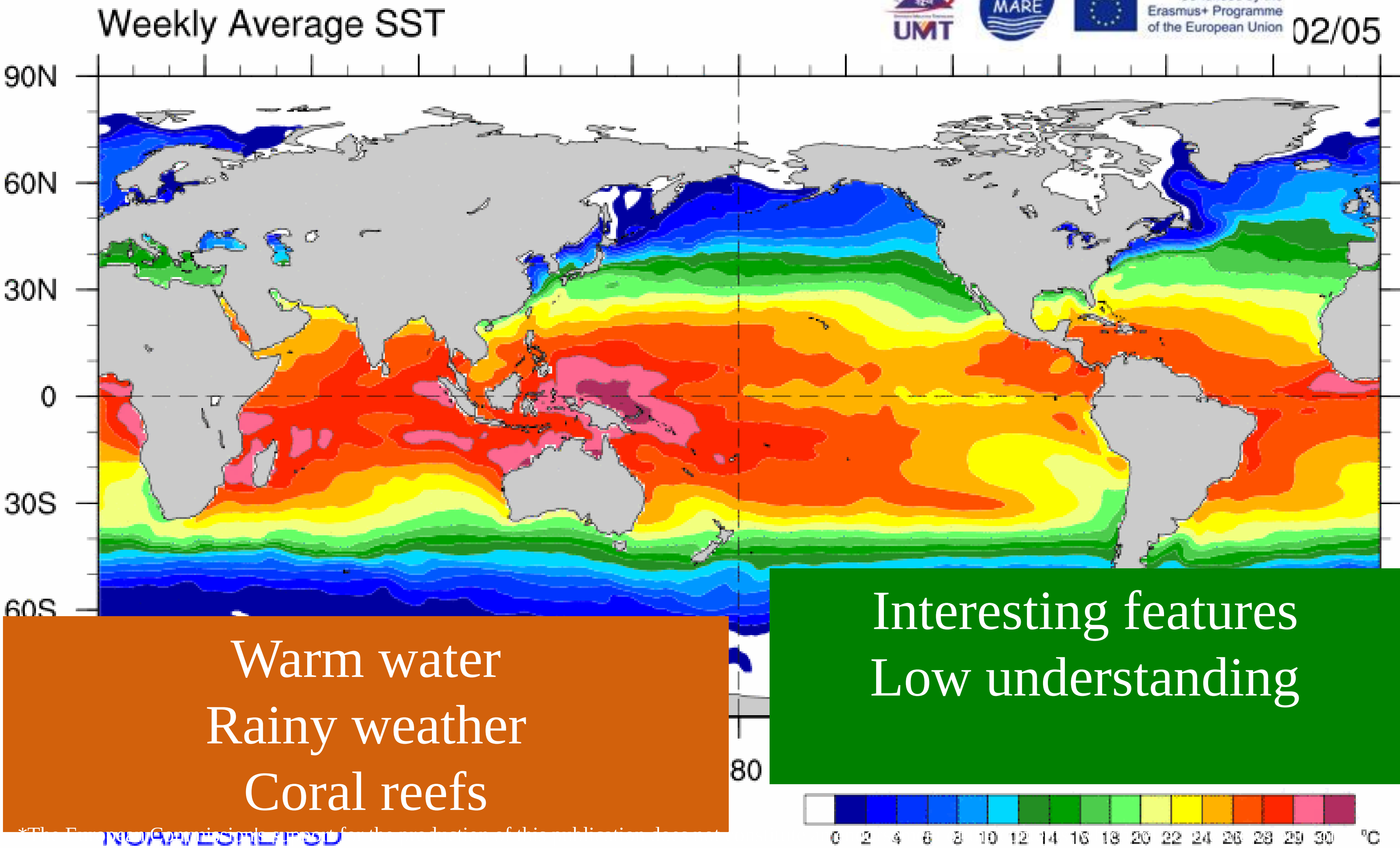


Warm water
Rainy weather
Coral reefs

Interesting features
Low understanding

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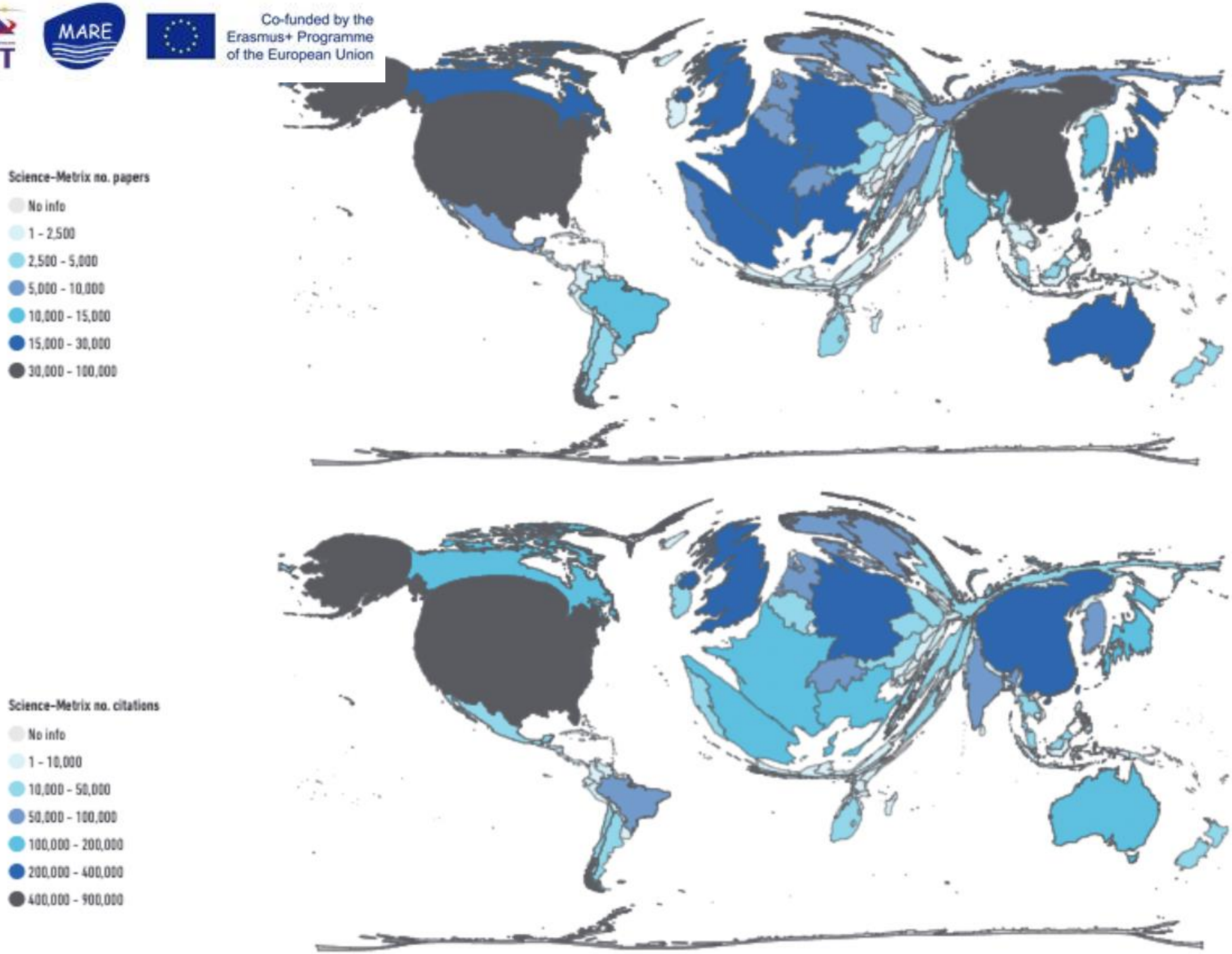


**Figure ES7.** Publication and citation map of the world. The area of each country is scaled and resized according to the number of ocean science publications (top) or citations received (bottom). Different colours indicate a different number of publications (top) or citations (bottom) (Annex F).

# OCEAN PRODUCTIVITY

UMT
MARE
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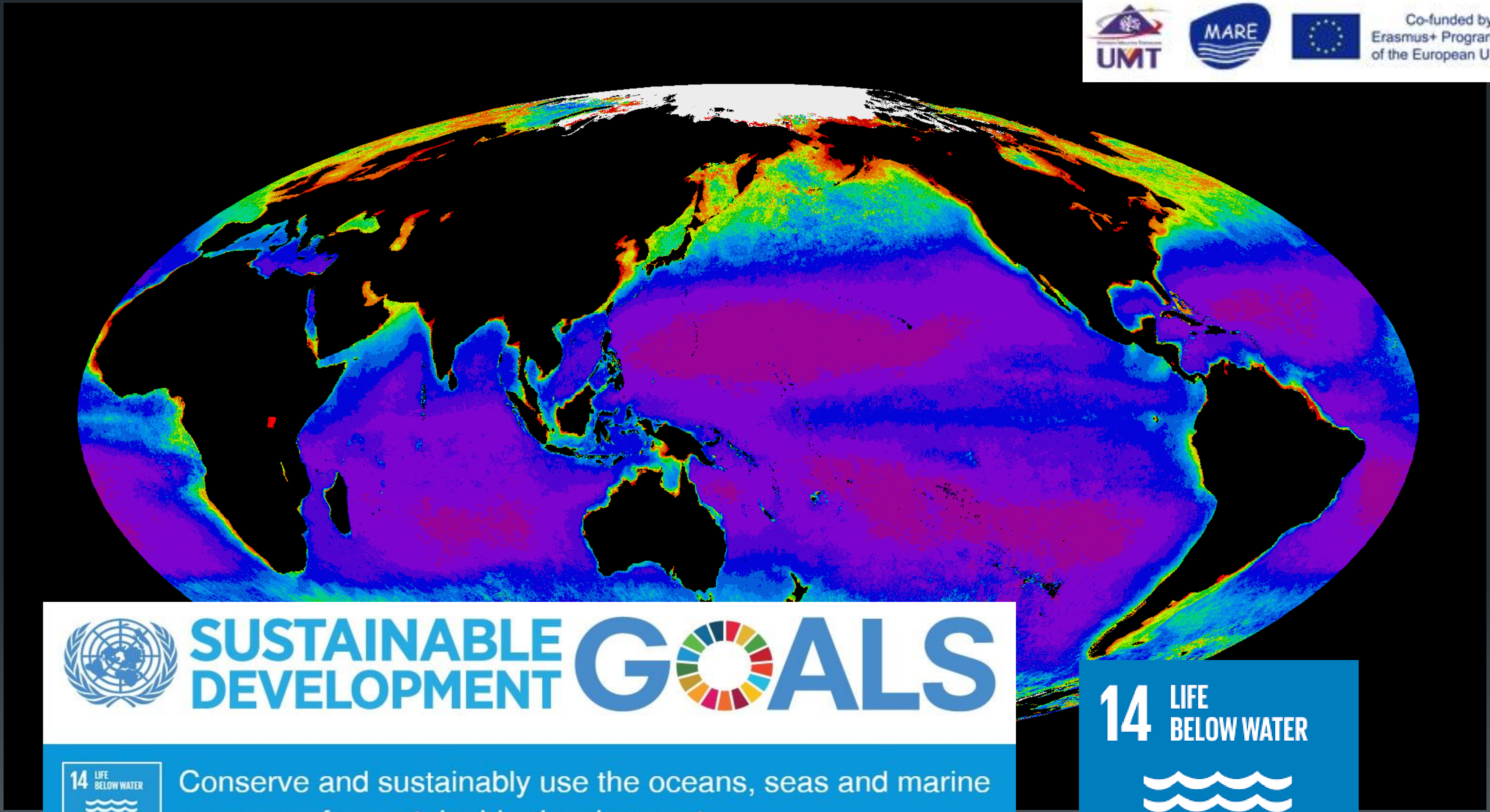

SUSTAINABLE DEVELOPMENT GOALS

14 LIFE BELOW WATER

Conserve and sustainably use the oceans, seas and marine resources for sustainable development

14 LIFE BELOW WATER

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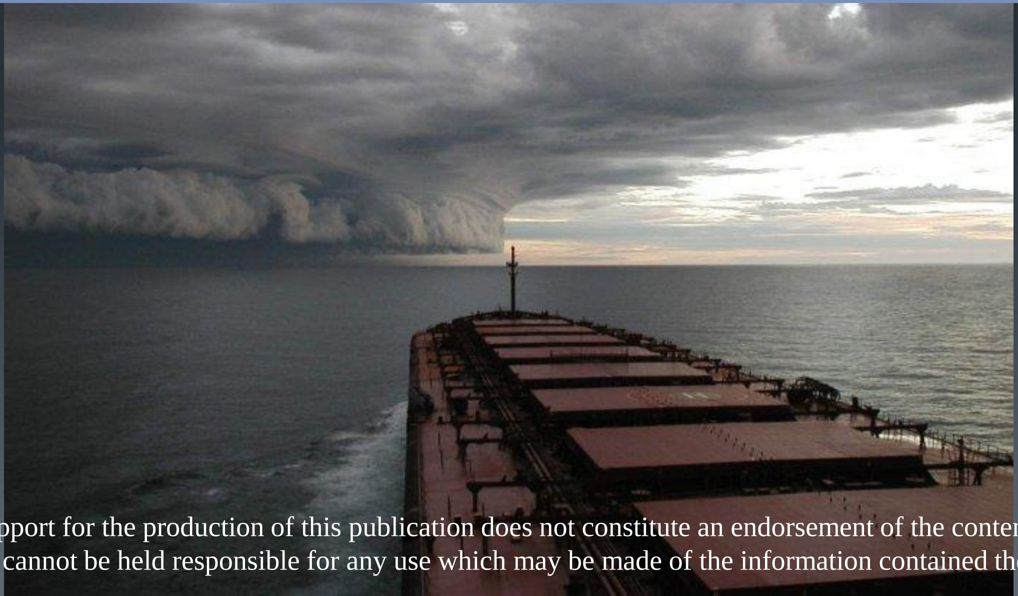
# What about Physical Oceanography???


These pictures share something in common

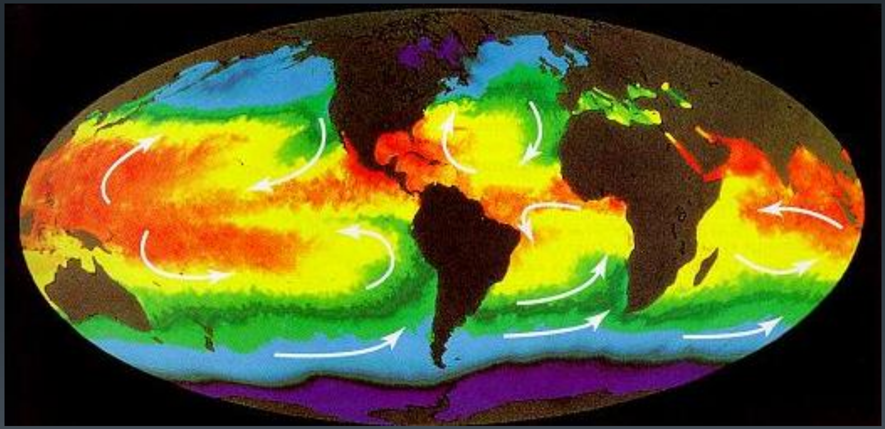
**It involves ocean dynamics**



# Physical Oceanography

The study of physical properties, mixing and dynamics of the oceans

The primary interests are the interaction of the ocean with the atmosphere, the oceanic heat budget, water mass formation, currents, and coastal dynamics



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# Why Study the Physics of the Ocean ?

- The oceans are a source of food. Hence, we are interested in processes which influence the sea even more than farmers are interested in the weather and climate

- The ocean not only has weather such as temperature changes and currents, but the oceanic weather fertilizes the sea

# Why Study the Physics of the Ocean ?

- The oceans are used by man. We build structures on the shore or just offshore, we use the oceans for transport.


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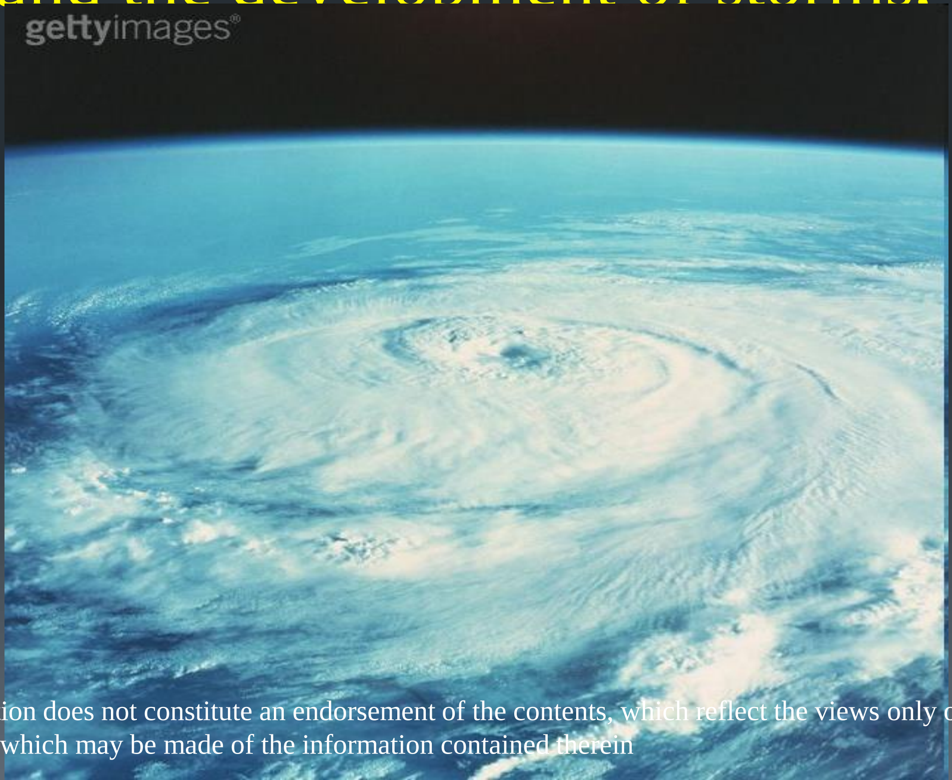
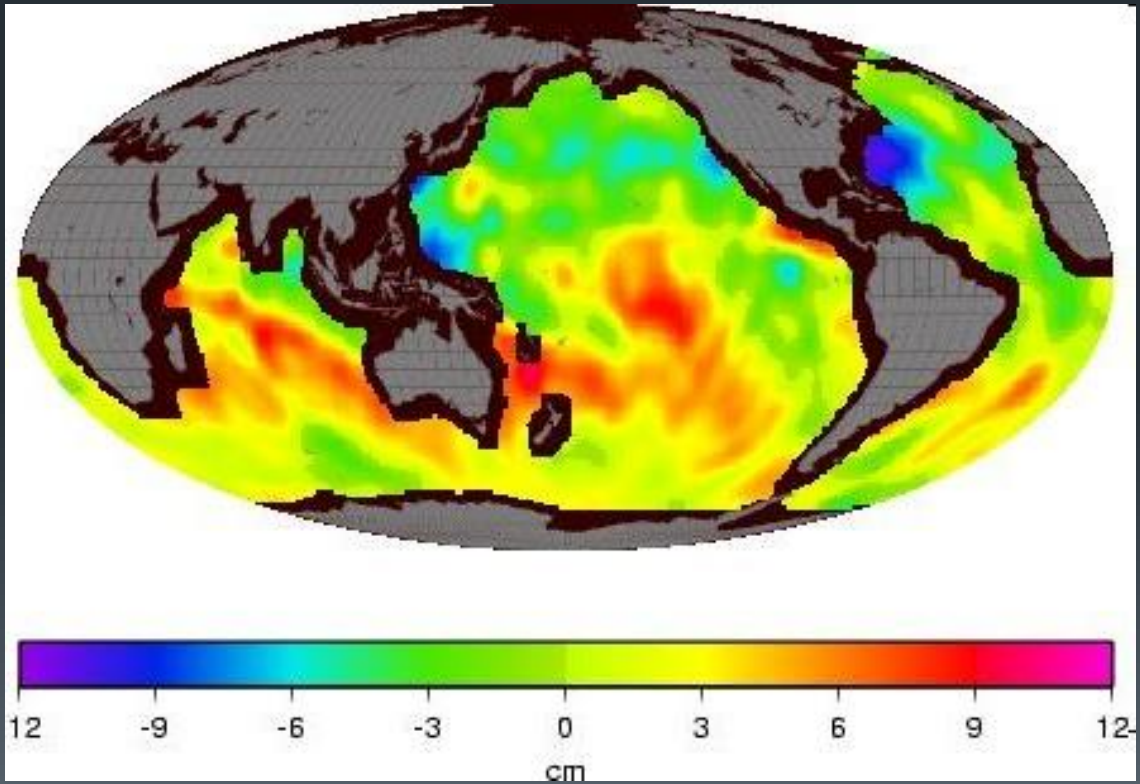
- Hence, we are interested in processes that influence these activities, especially waves, winds, currents, and temperature

# Why Study the Physics of the Ocean ?

- The oceans influence the atmospheric weather and climate
- The oceans influence the distribution of rainfall, droughts, floods, regional climate, and the development of storms, hurricanes and typhoons



- Hence we are interested in air-sea interactions, especially the fluxes of heat and water across the sea surface, the transport of heat by the oceans, and the influence of the ocean on climate and weather patterns



# Why the Ocean ?

Food Resources – Food Security!

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# Why the Ocean ?


## Recreational - Safety !!

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# Why the Ocean ?

# Transportation and Logistic: Safety !!

# Why the Ocean ?

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# Extreme erosion in our university during northeast monsoon (Dec 2014)

# Thank you

# 2.0 Physical Properties of Sea Water

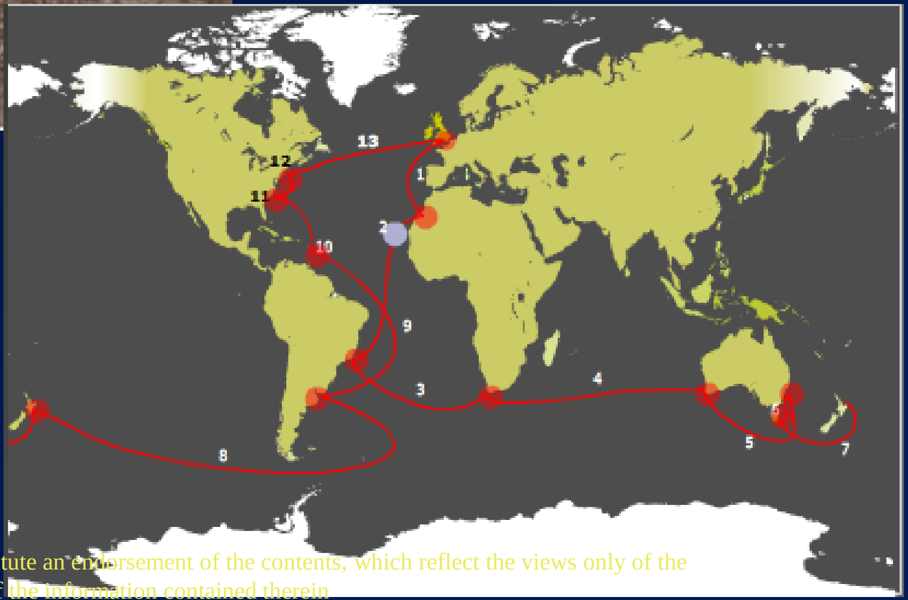
2.1 Temperature: in situ and potential Temperature
2.2 Salinity: Conductivity
2.3 Depth: Pressure
2.4 Density: Sigma

# Objectives

- Understand the vertical and horizontal distribution of ocean waters and how it changes
- Explore the importance of T-S in oceanography research

# HMS Challenger, 1872

- 127,500kms
- 3 ½ years
- 20years to compile data of 50 volumes books



# RV Discovery - UMT

## Explored the southern South China Sea

# Physical properties of sea water

Primary properties we need to look at are the following as they define the circulation and mixing of different waters

**Temperature:** in situ and potential Temperature
**Salinity:** Conductivity
**Depth:** Pressure
**Density:** Sigma-t, specific volume anomaly

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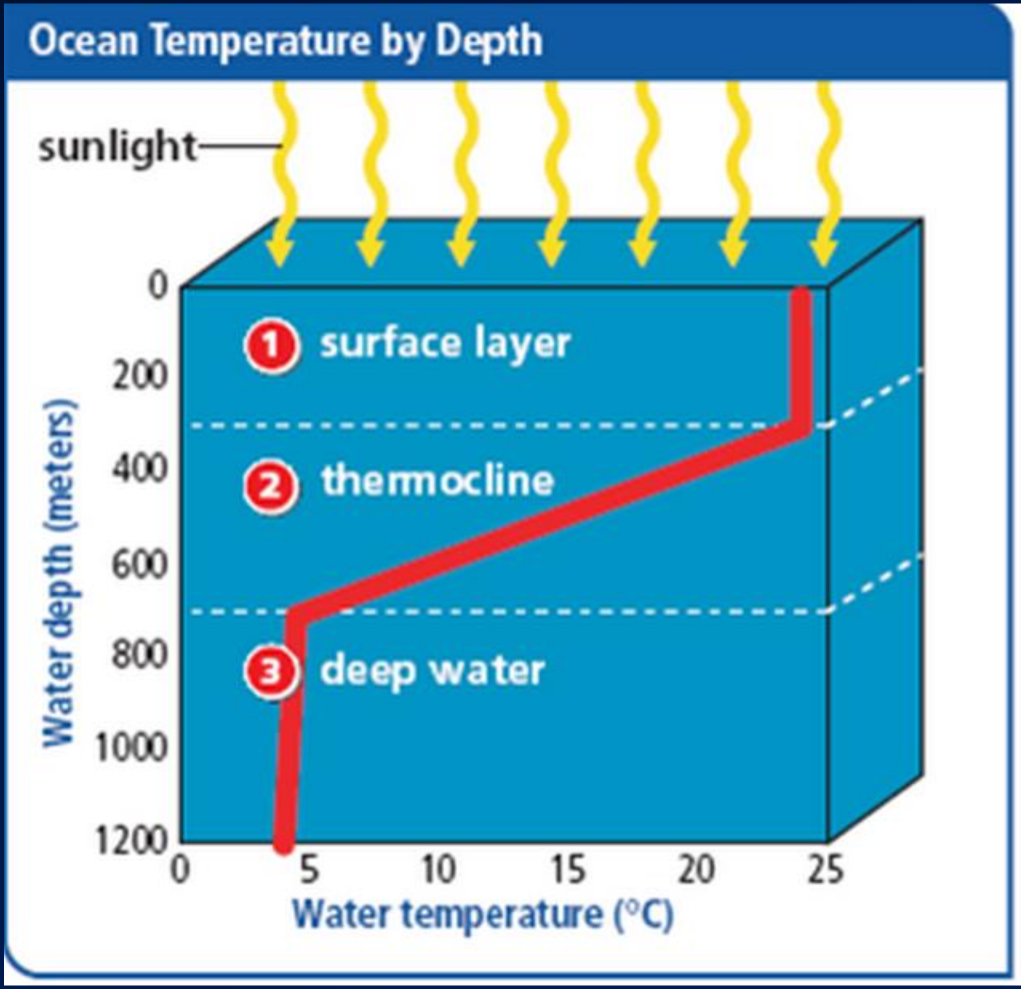
# Temperature

The ocean can be divided into three vertical zones, depending on temperature:

- The top layer is the surface layer, or mixed layer. This layer is influenced by solar energy, wind and rain.
- The second layer is the thermocline. Here, the water temperature drops as the depth increases.
- The third layer is the deep-water layer. Water temperature in this zone decreases slowly as depth increases. Water temperature in the deepest parts of the ocean averages about 2° Celsius.

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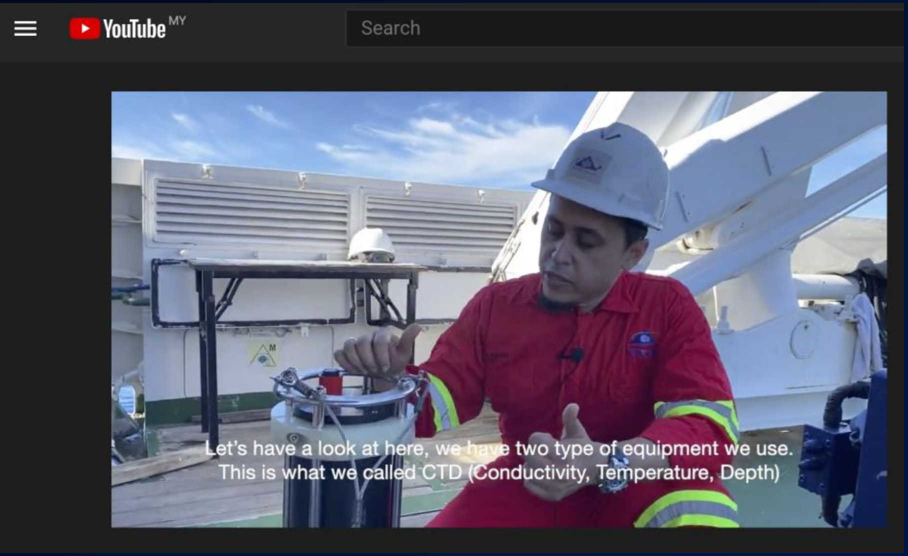
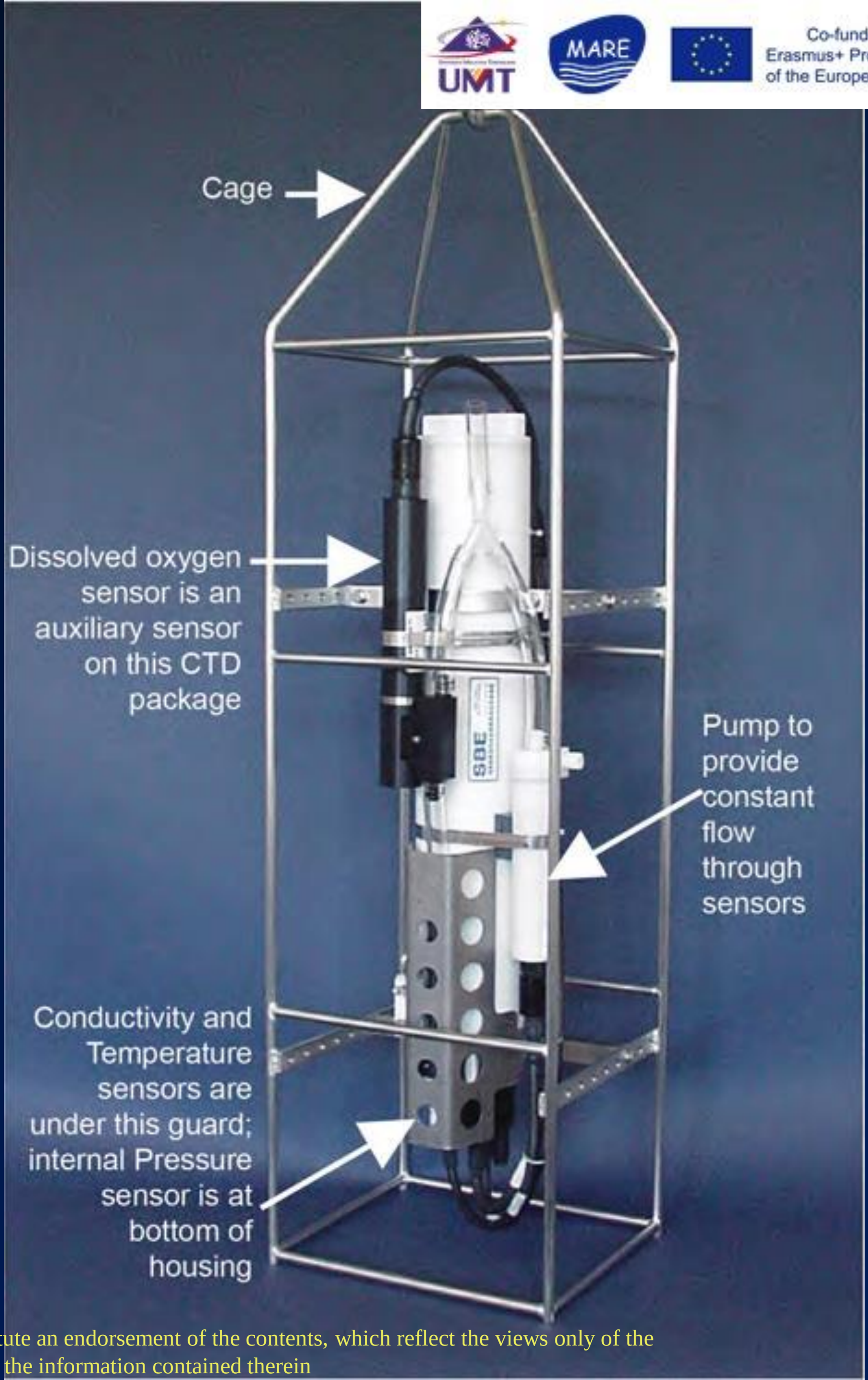
# CTD Equipment:
# Conductivity, temperature and depth




https://www.youtube.com/watch?v=rJGrDoR9NVM

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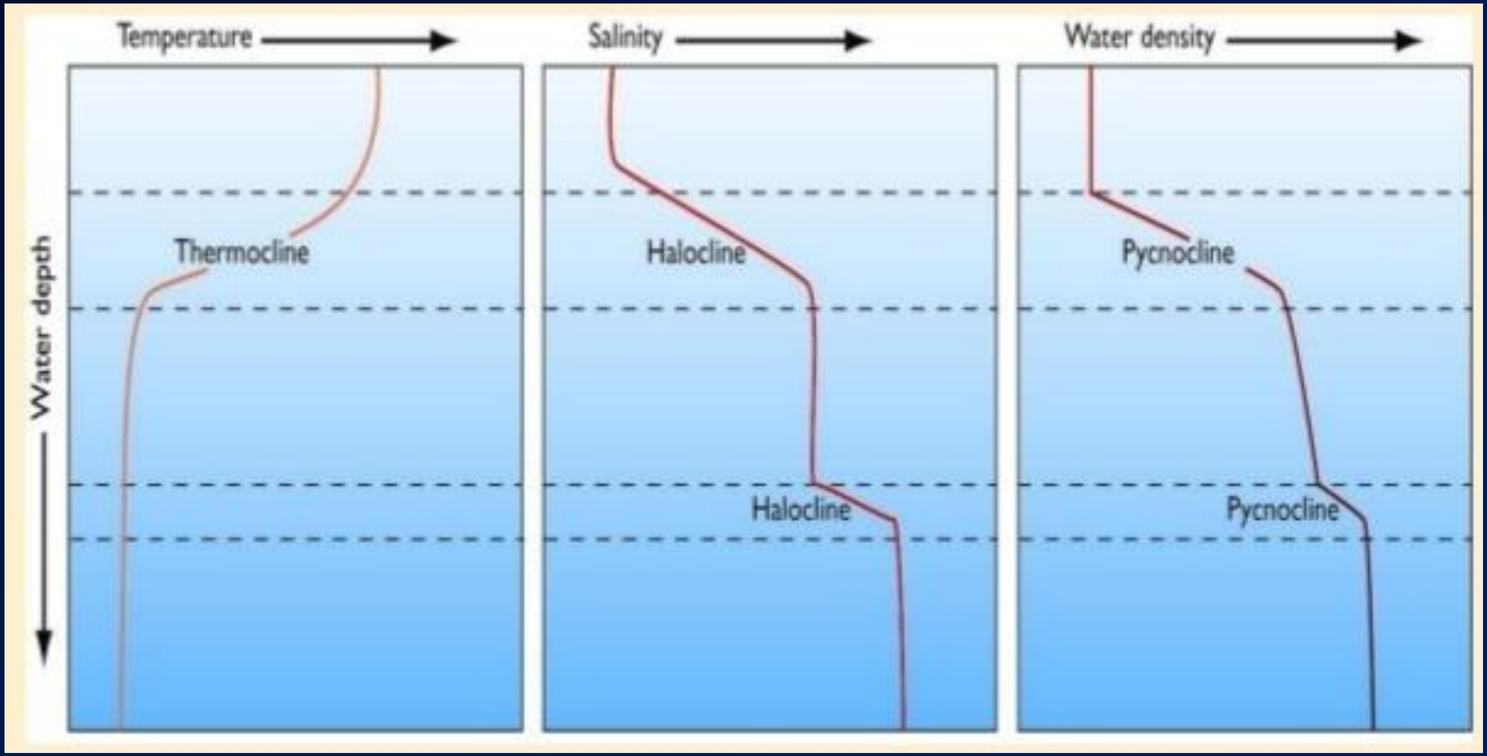
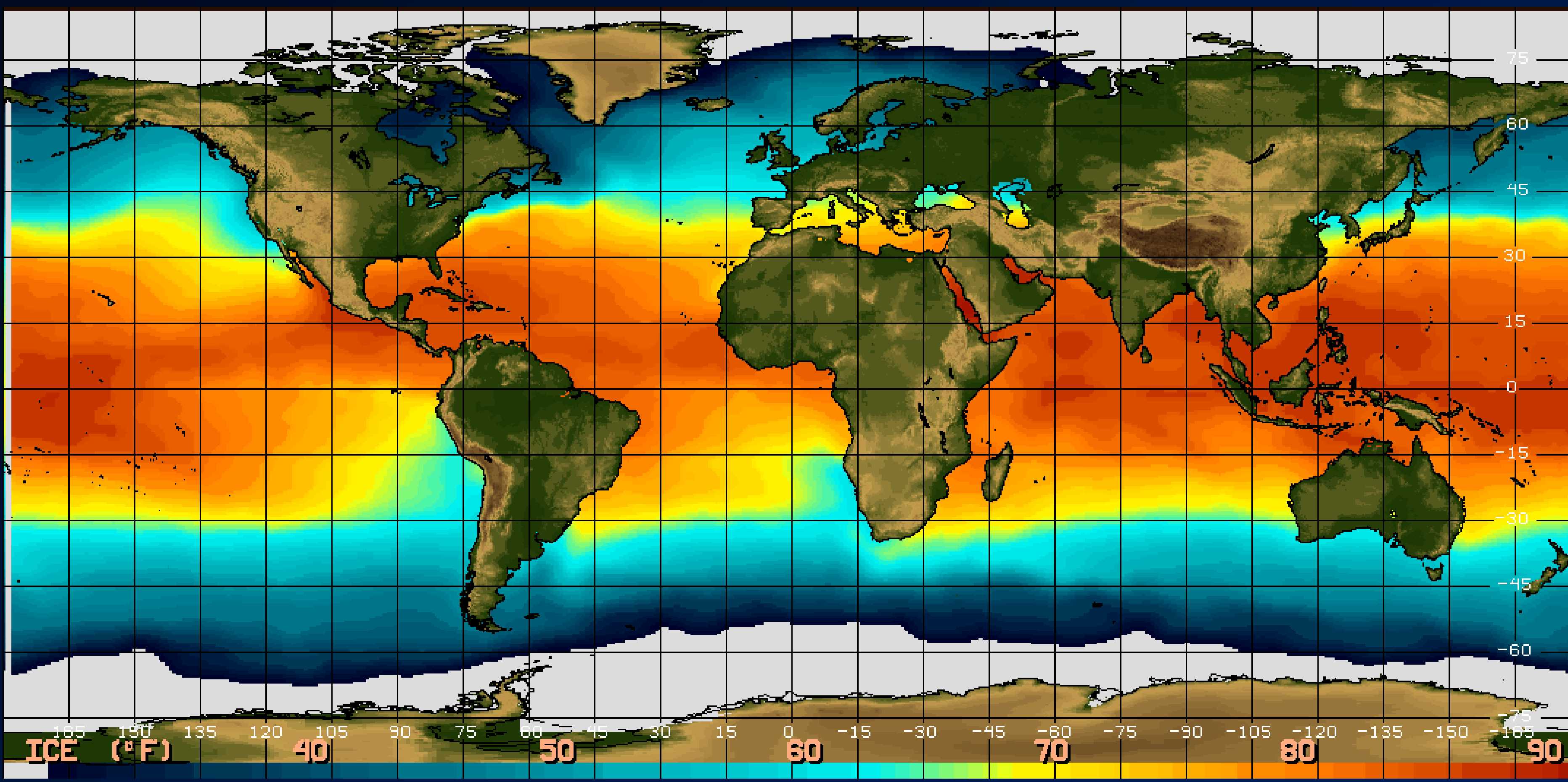
# Terminology: Gradients/ '-cline

Remember that thermocline refers to a 'gradient' where characteristic changes rapidly with depth

| | | |
|---|---|---|
| Thermocline | - | temperature |
| Halocline | - | salinity |
| Density | - | pycnocline |

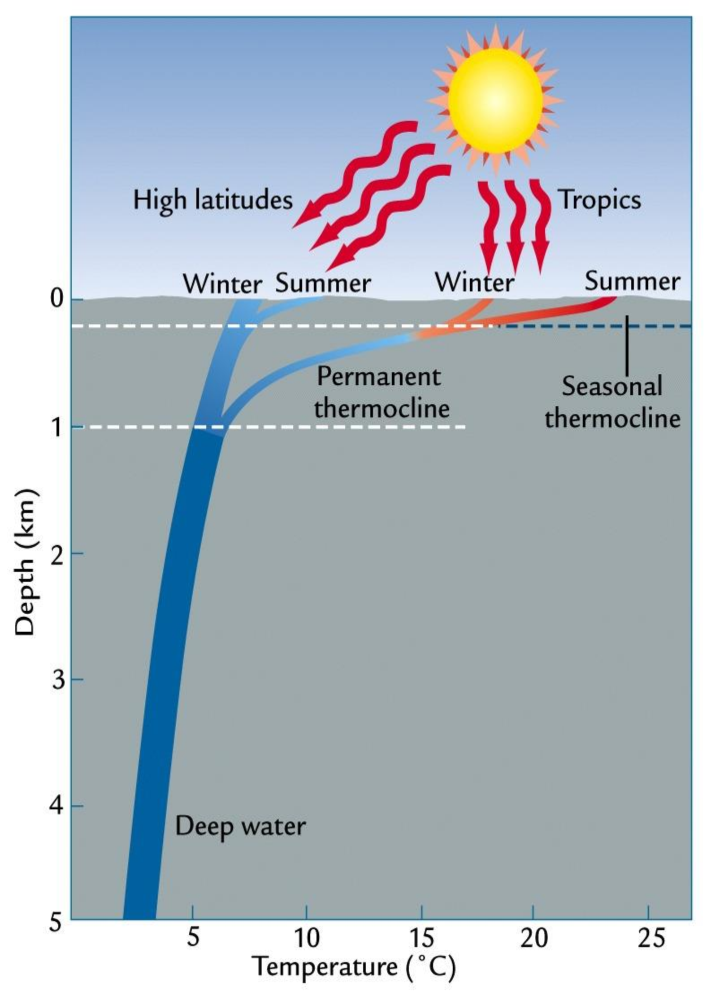


# Surface Temperature



# Vertical Structure of Ocean

- Surface Waters – well mixed
  - Wind, waves and currents
  - ~ Constant T and S, low density
  - Waves, surface currents, tides
- Pycnocline or Thermocline-Intermediate Waters (300-1000 m)
  - rapid decrease in temperature with depth
  - Stronger, shallower at low latitudes
  - Barriers to mixing, biological migration
- Deep Waters-
  - Cold, high density water below 1000m
  - Contains ~80% of all ocean water
  - Deep ocean currents



# Vertical Structure in shallow sea

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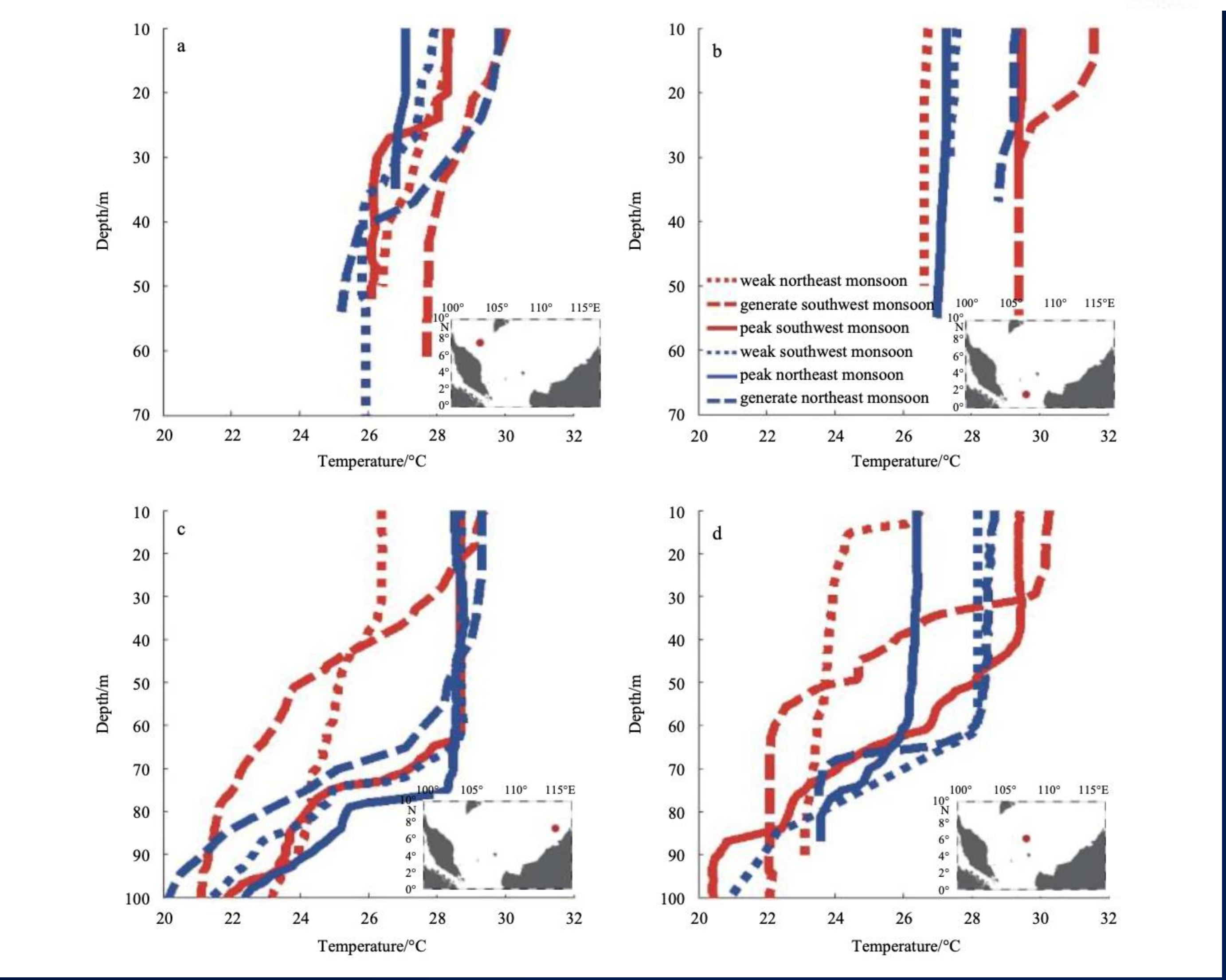


Data taken from South China Sea (Terengganu waters) - WOD

(Johari and Akhir, 2019)

# Temperature can change through:

- Heat input/loss at the surface
- Mixing with other waters
- With increasing pressure
- Friction (usually negligible)

Influences density, heat exchange

# Surface Salinity

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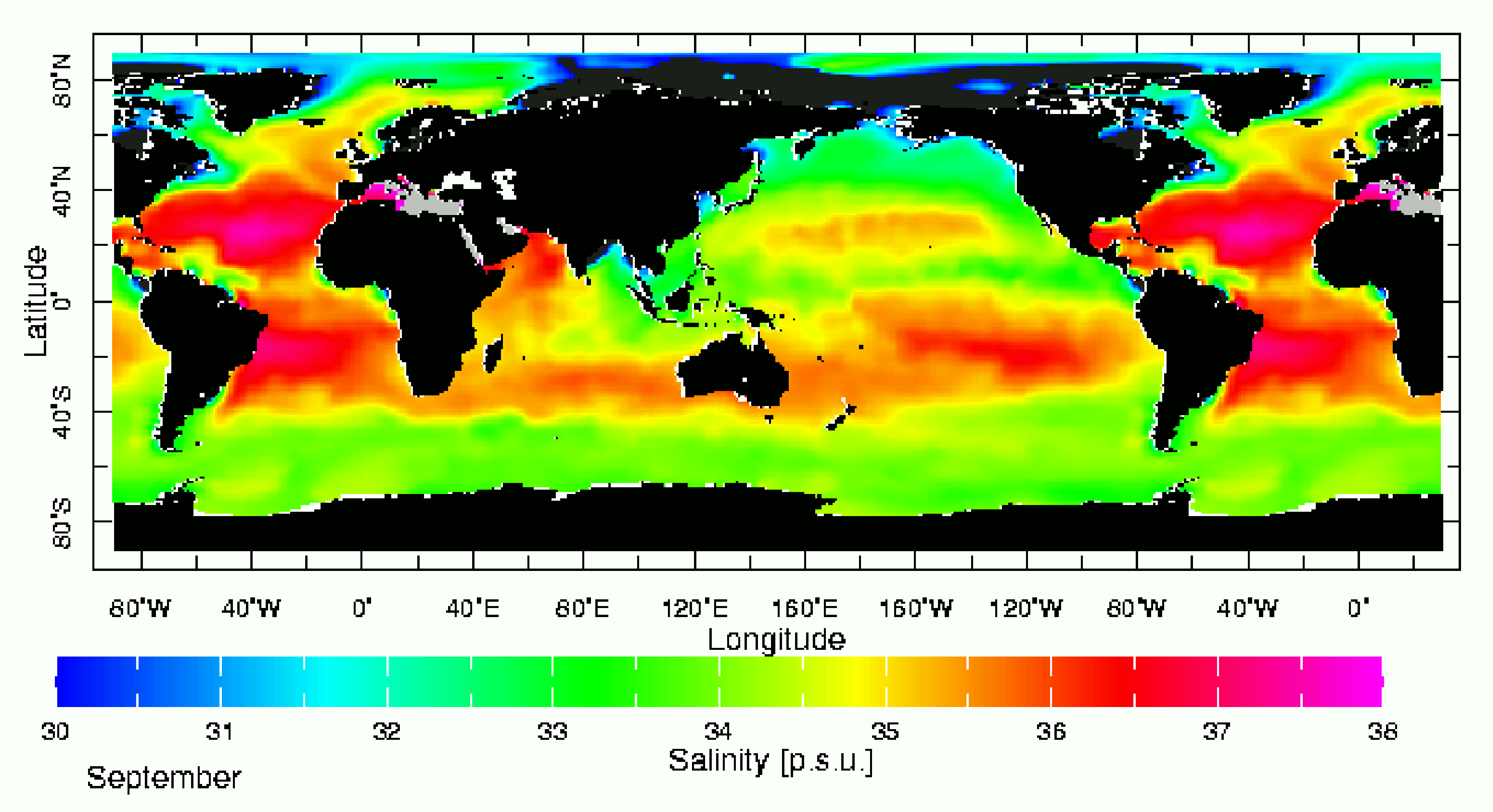

# Vertical Structure of Ocean - salinity

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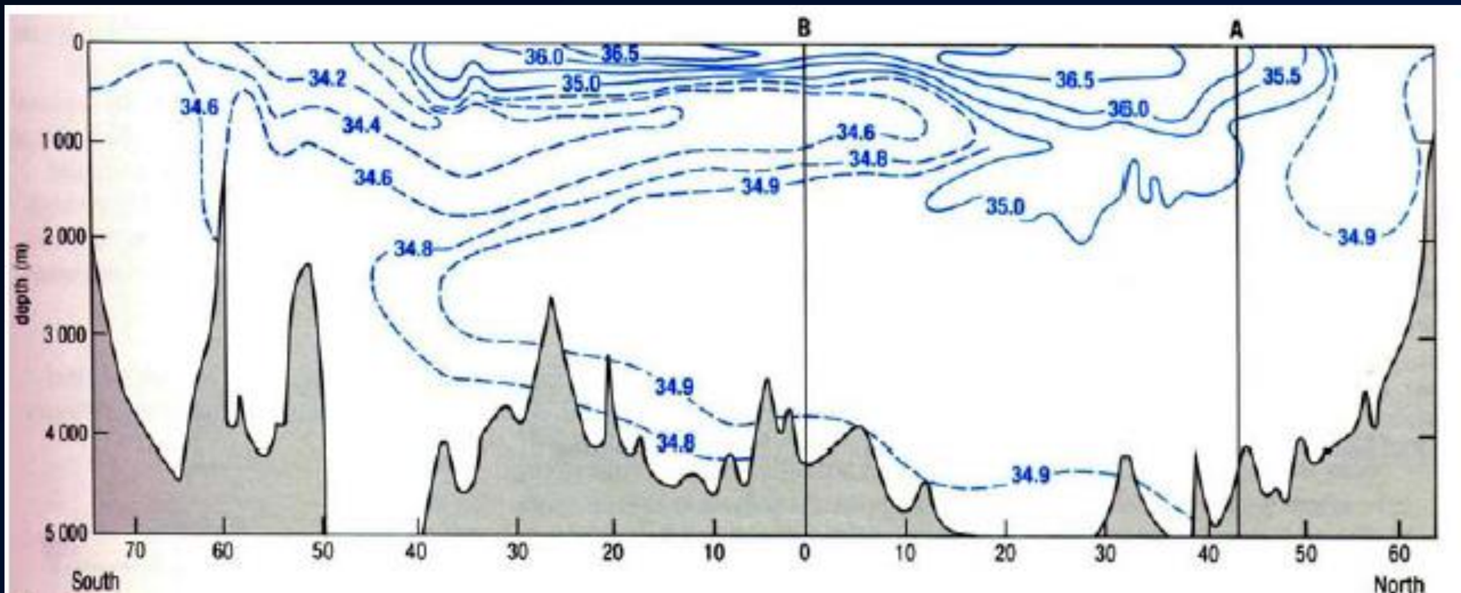


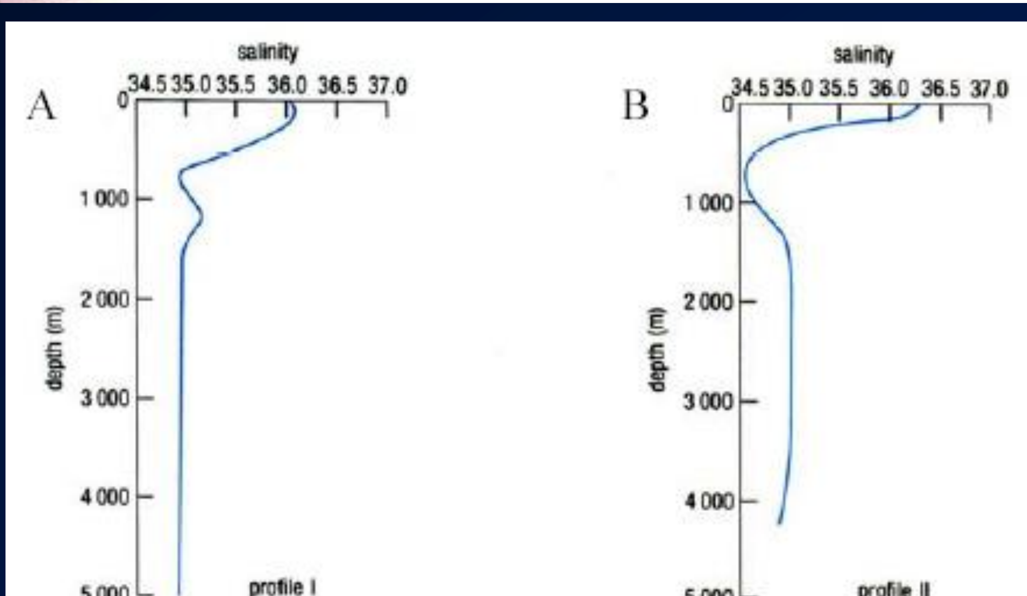



(b)

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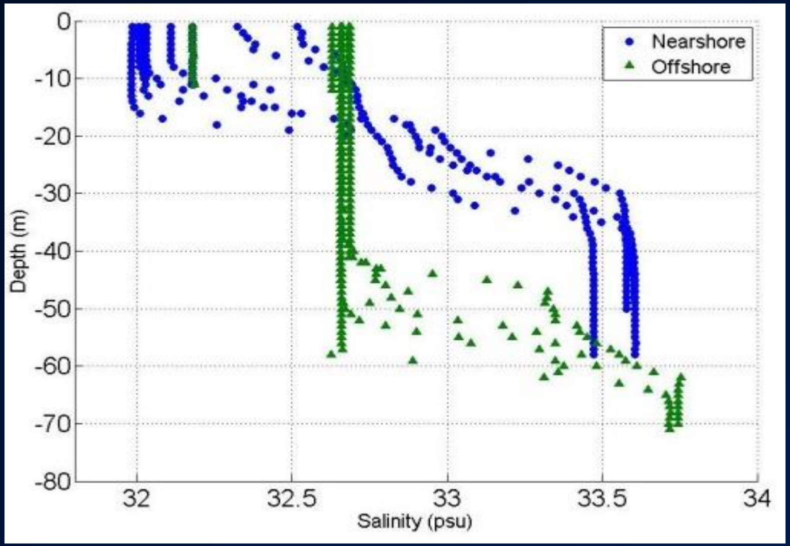
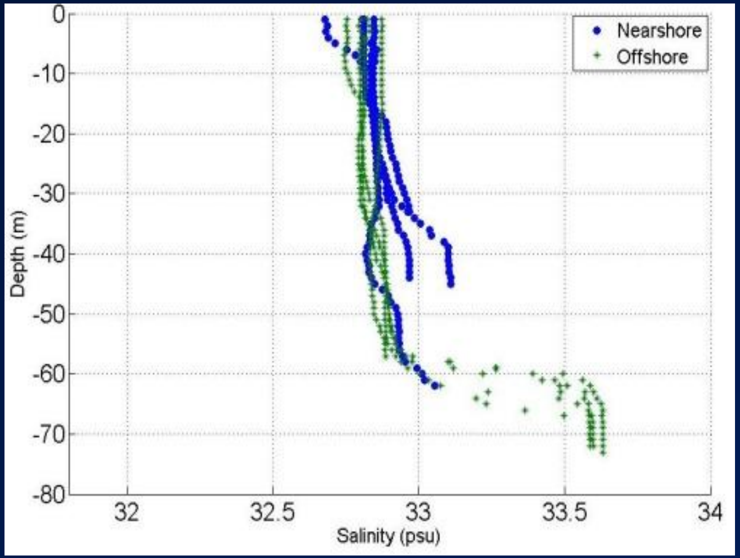
# Vertical Structure in shallow sea




Data taken from South China Sea (Terengganu waters)

# Salinity can change through:

- Evaporation/precipitation at the sea surface
- Ice formation
- Freshwater inputs (rivers, groundwater)
- Mixing with other waters

Influences density, freezing point, ice formation

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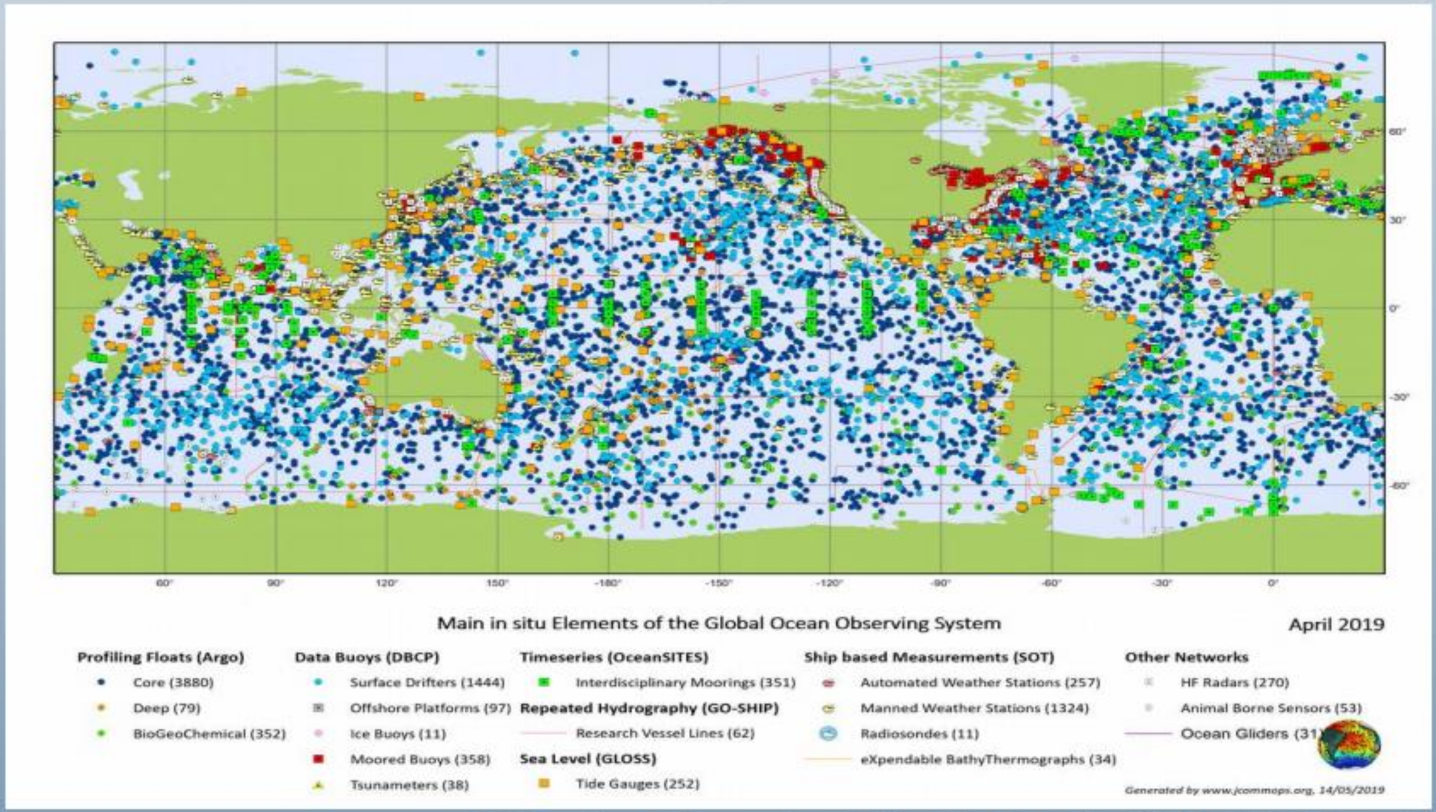
jcommops

# JCOMMOPS: FOCAL POINT FOR TECHNICAL COORDINATION

*Implementation, Data/Metadata exchange, Monitoring*

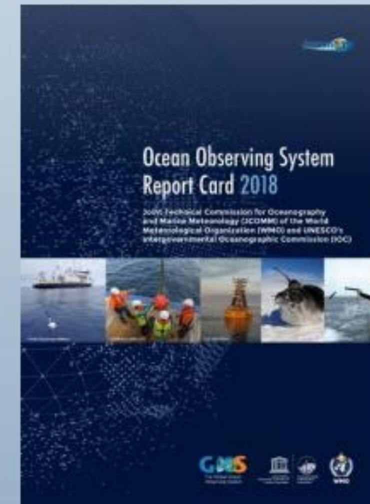


# JCOMMOPS : DISTRIBUTE METADATA AND MONITOR THE NETWORK

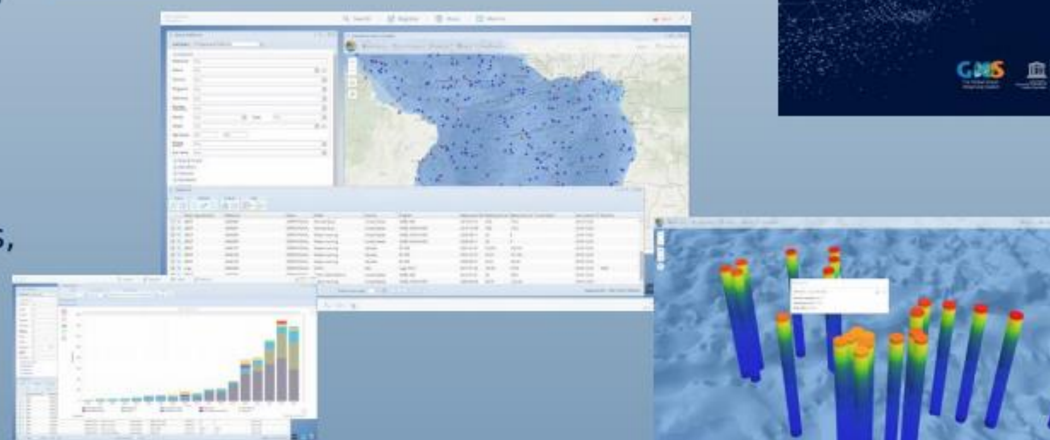
*What can we do with it?*

- Monthly authoritative status maps
  (www.jcommops.org/map)


- Annual JCOMM Report Card to inform ocean observing stakeholders, society and decision-makers about the status and value of the GOOS
  (www.jcommops.org/reportcard)




- Web application to make query, maps, graphs, stats, 3D data visualization
  (www.jcommops.org)



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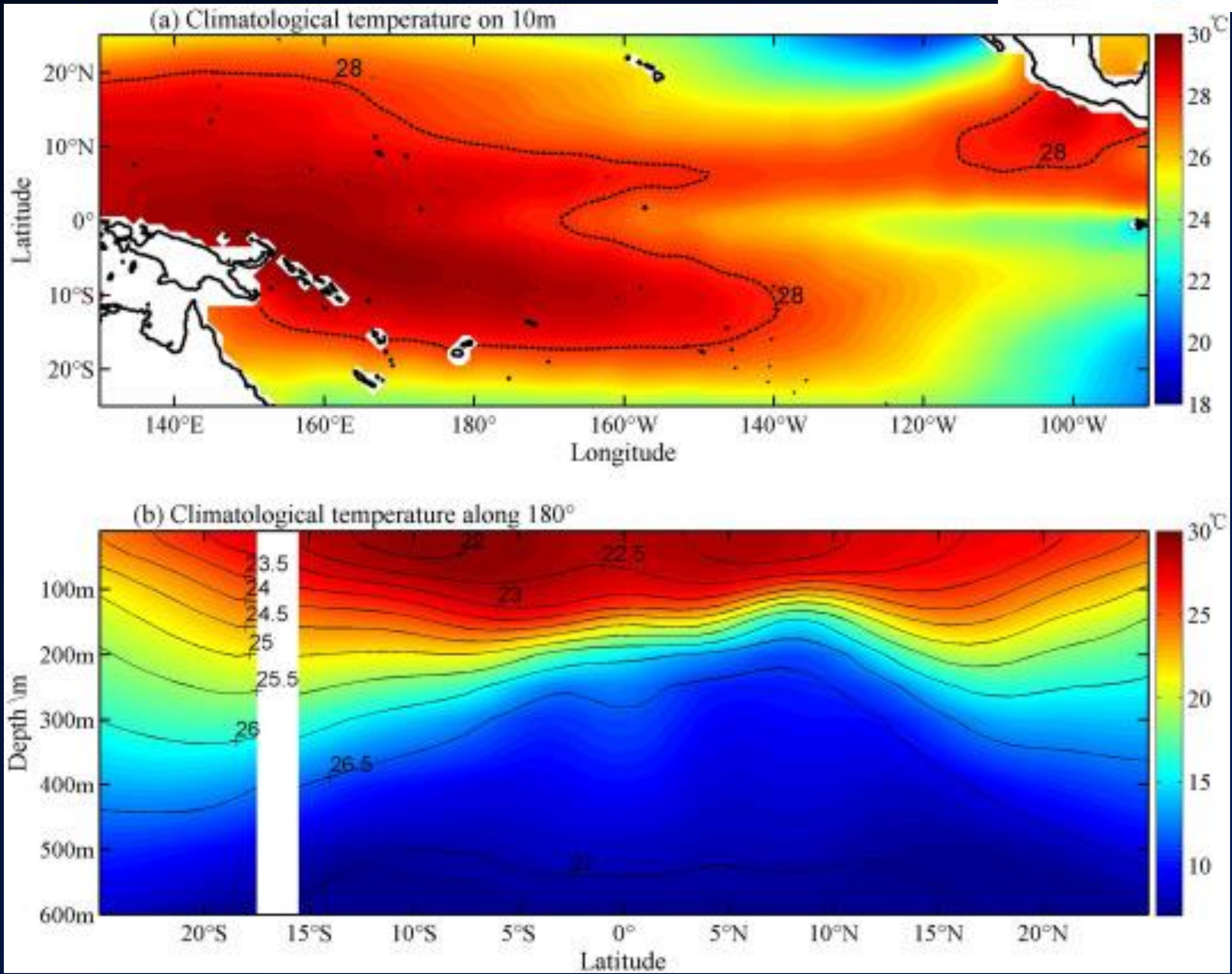
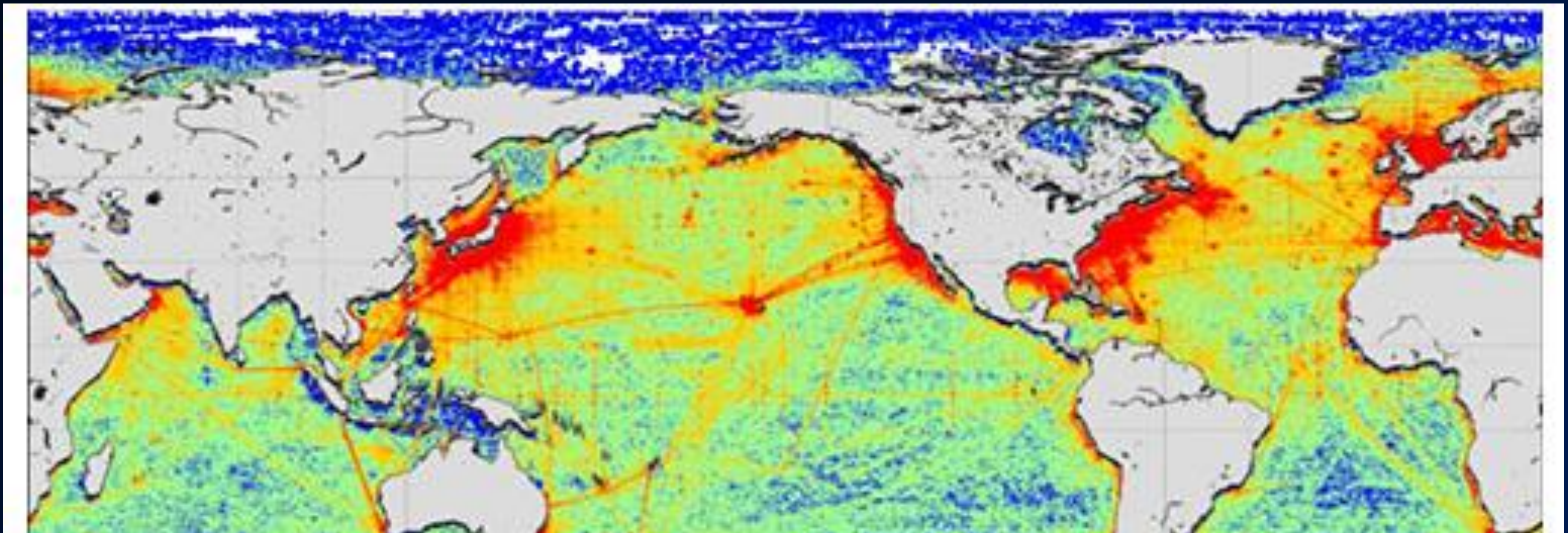



Climatological mean temperature on 10 m level (a) and along 180° meridional section (b) in the tropical Pacific derived from gridded Argo data (2001–2017). The dashed contour in (a) denotes the isotherm of 28 °C, and solid contours in (b) denote isopycnals.

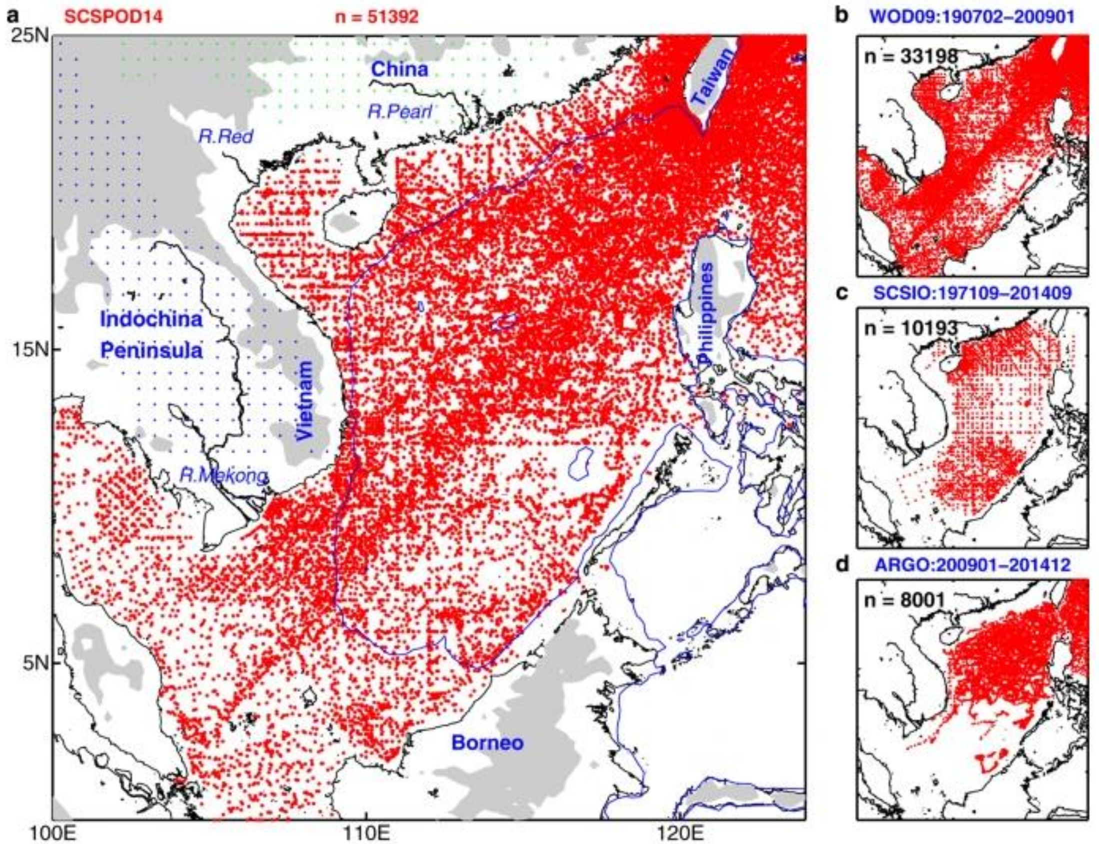
# WORLD OCEAN DATABASE (WOD)



- **The WOD is the largest available, online, free ocean database**
  - Data range from >200 years old to stations within the past few years
  - Constantly updated, includes a synchronizing option
  - In-situ only, no remote sensing
  - No instrumental time-series - e.g. tide gauge, current meter
  - About 30 parameters
  - 12 types, depending on measurement methods - ship stations, drifters, diving pinnipeds, etc.
  - Uses cruise/station/depth/date/time paradigm for data organization
  - Includes quality flags for all measurements

# WOD in South China Sea

**Figure 2: Hydrographic stations.**




Geographical distribution of hydrographic (temperature and salinity) stations in the South China Sea: (**a**) the merged dataset (SCSPOD14), (**b**) the World Ocean Database 2009 (WOD09), (**c**) South China Sea Institute of Oceanology (SCSIO), and (**d**) Argo profiling floats. The number of profiles (**N**) is shown at the top of each panel.



Zheng Lili, Wang Dongxiao, Chen Ju, et al. 2016. SCSPOD14, a South China Sea physical oceanographic dataset derived from in situ measurements during 1919-2014. Scientific Data, 3: 160029, doi: 10.1038/sdata.2016.29

# WOD in Southern South China Sea

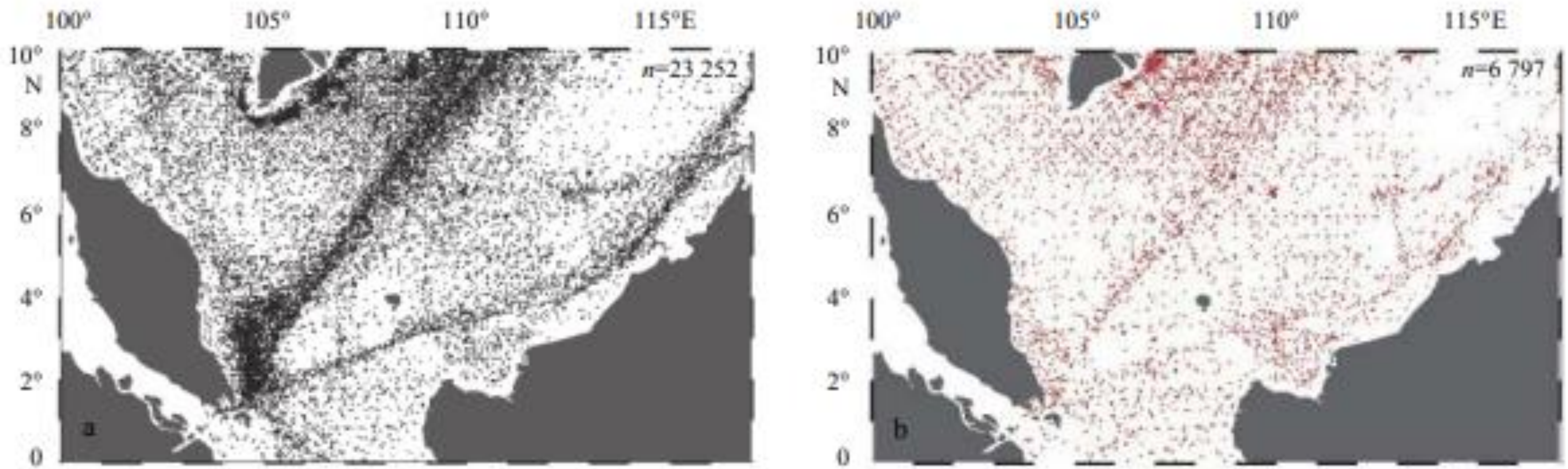
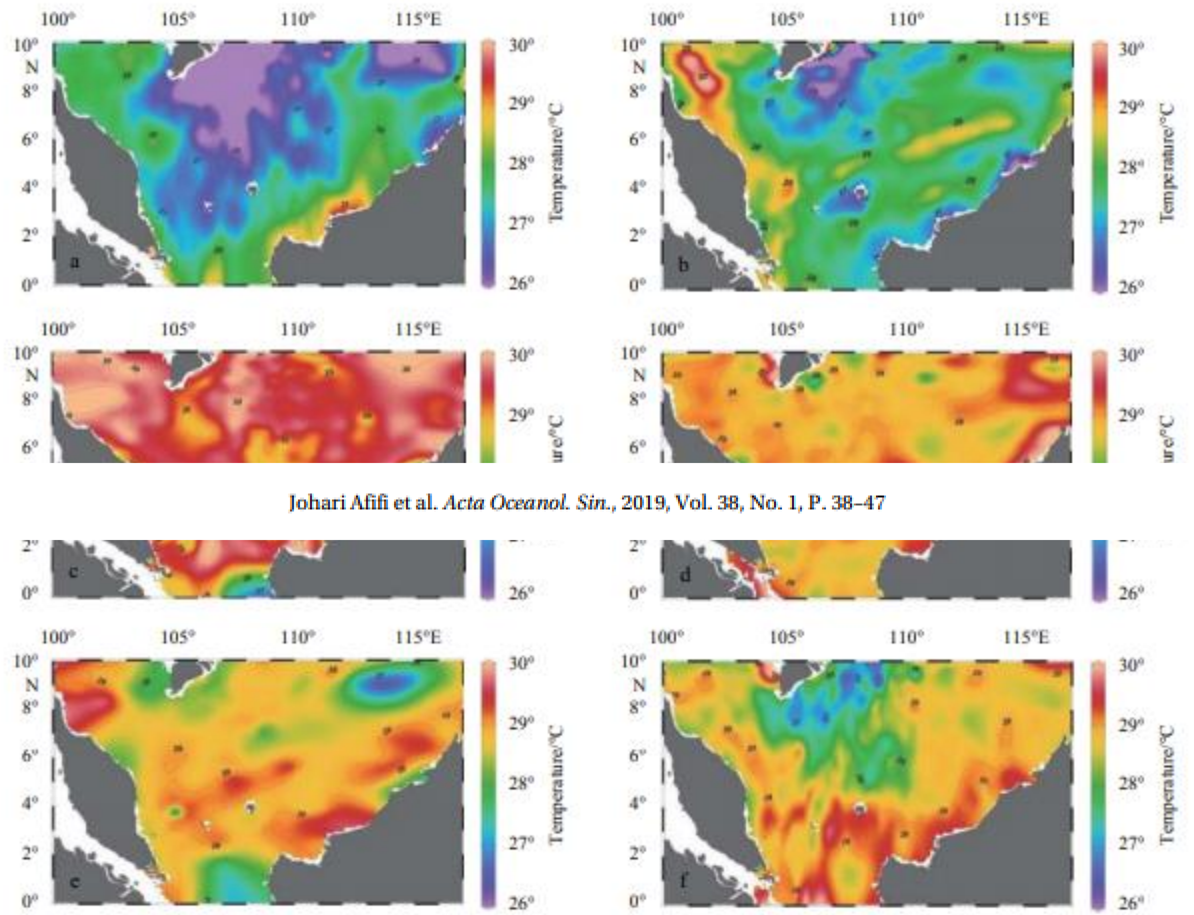



**Fig. 2.** Distribution of datasets present in SSCS (a, $n = 23\,252$), while (b) is the dataset which present both temperature–salinity data ($n = 6\,797$). Datasets compactness is high in particular region such as in east coast of Johor, Vietnam tip and across the SSCS.

Johari Afifi et al. *Acta Oceanol. Sin.*, 2019, Vol. 38, No. 1, P. 38–47




Johari Afifi et al. *Acta Oceanol. Sin.*, 2019, Vol. 38, No. 1, P. 38–47

**Fig. 9.** Upper layer temperature contour plot in SSCS according to seasonality. a. Peak northeast monsoon, b. weak northeast monsoon, c. generate southwest monsoon, d. peak southwest monsoon, e. weak southwest monsoon, and f. generate northeast monsoon.

# Air-Sea Interaction

I. Atmospheric circulation

II. Sea/Land breeze system

III. Monsoon system

IV. Upwelling

# Objectives

- Understand how wind influence ocean currents
- Explore the atmospheric cell system: Hadley, Ferrel and Polar cells. These cells result in the trade winds, roaring forties and polar easterlies
- Comprehend the concept of global atmospheric system and its influence on ocean current

# The 3 Cell Circulation

3 cells in each hemisphere.
4 surface high pressure and 3 surface low pressure.
**Hadley Cell** (thermally direct cell)
    Air rises near Equator and descends near 30 o S/N.
    Explains desert; trade wind; ITCZ.
**Ferrel Cell** (thermally indirect cell)
    air rises near 60 degrees and descends near 30 degrees.
    explains surface westerlies.
**Polar Cell** (weak thermally indirect cell)
    air descends near 90 degrees and rises near 60 degrees.
    Polar Easterlies at the surface.

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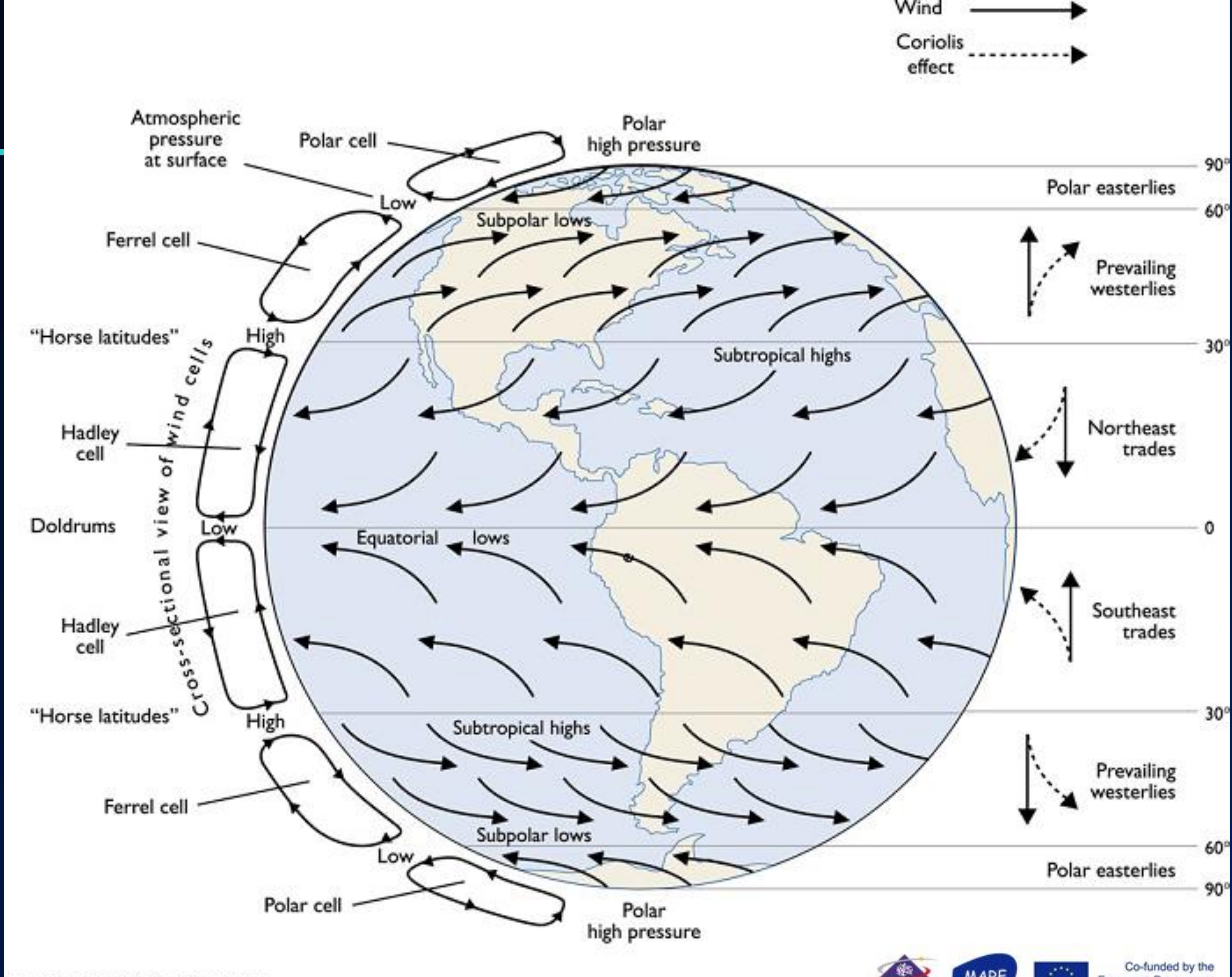


(a) GLOBAL WIND PATTERN

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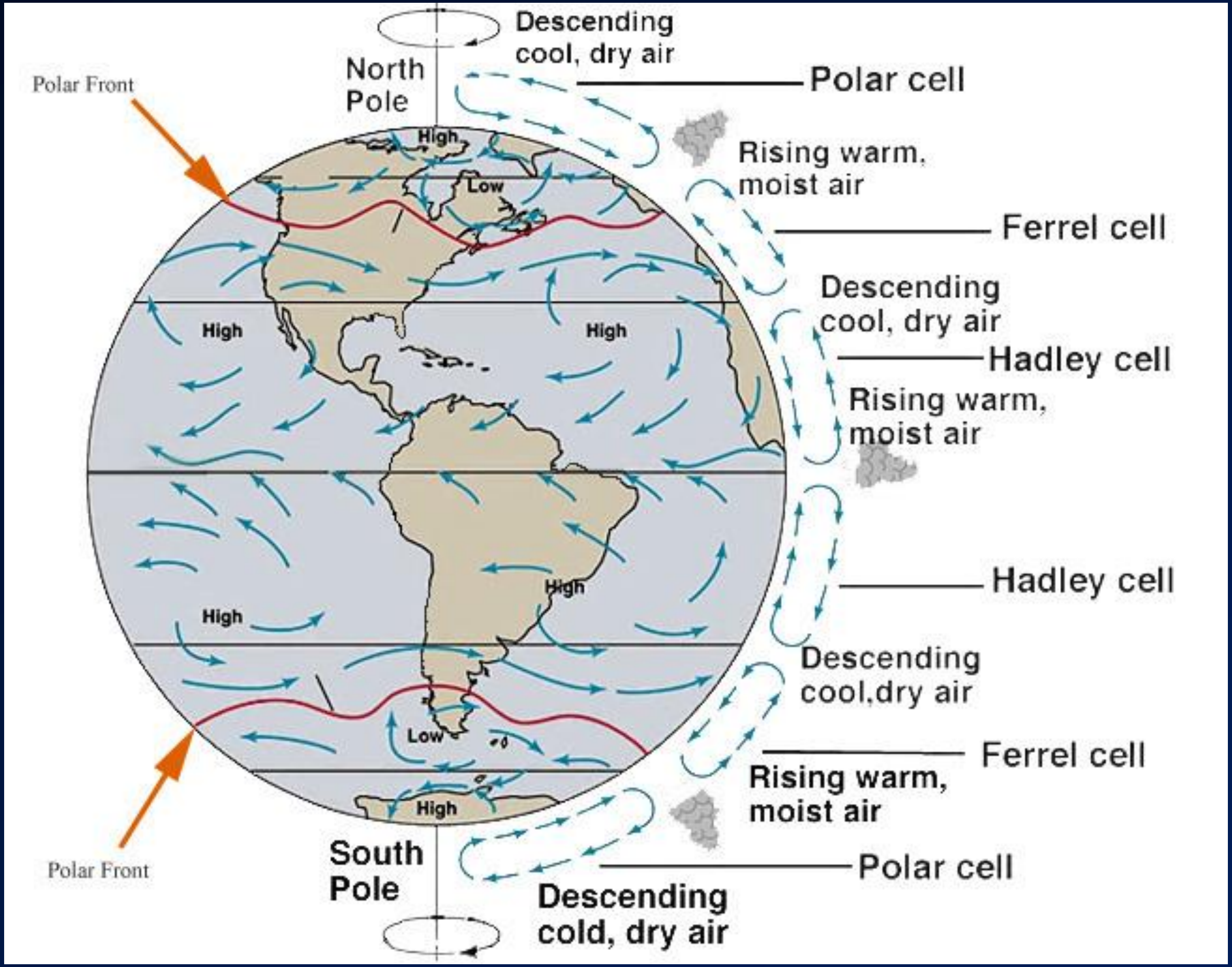
# General Circulation Model

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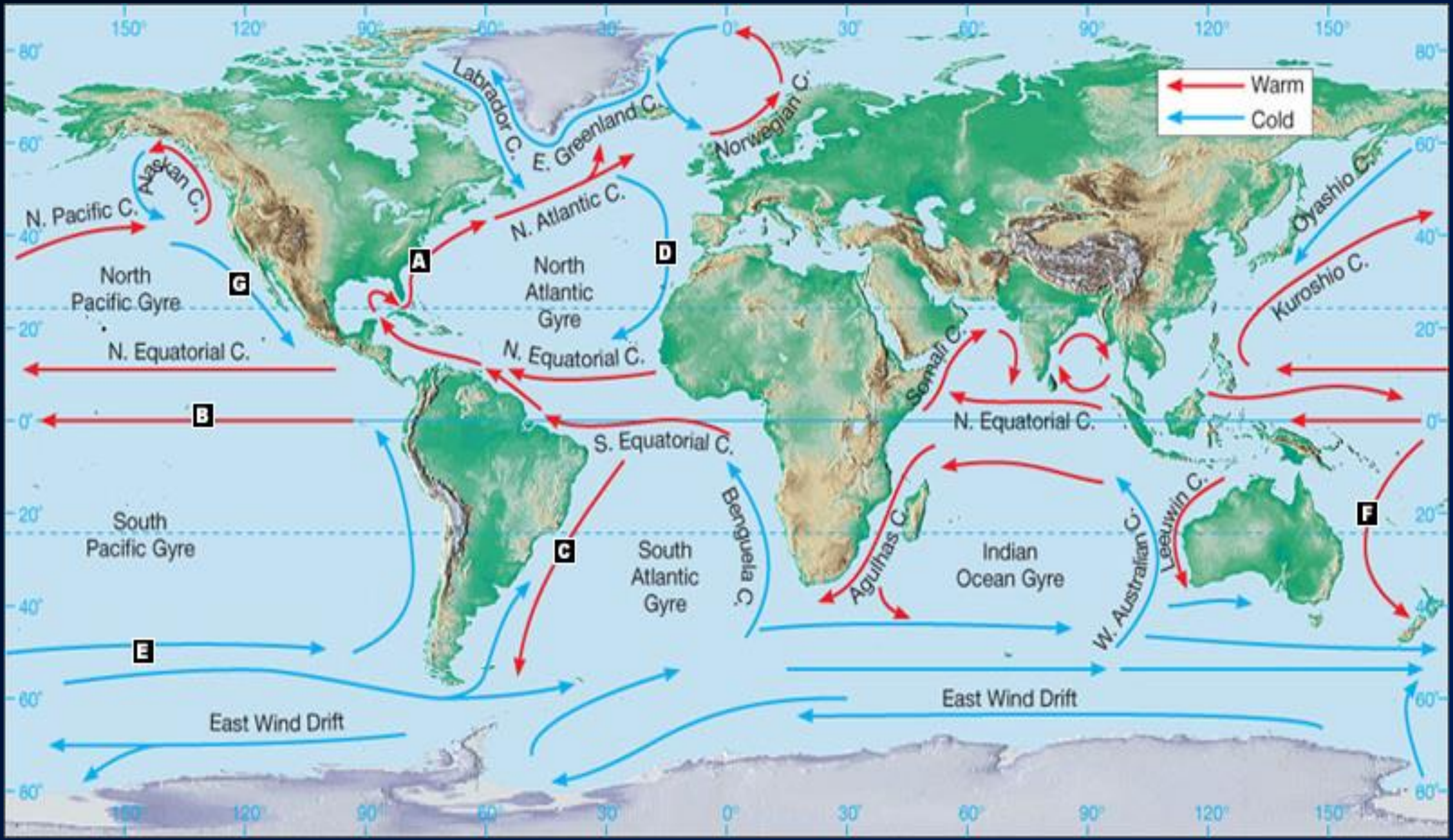
# Ocean Circulation

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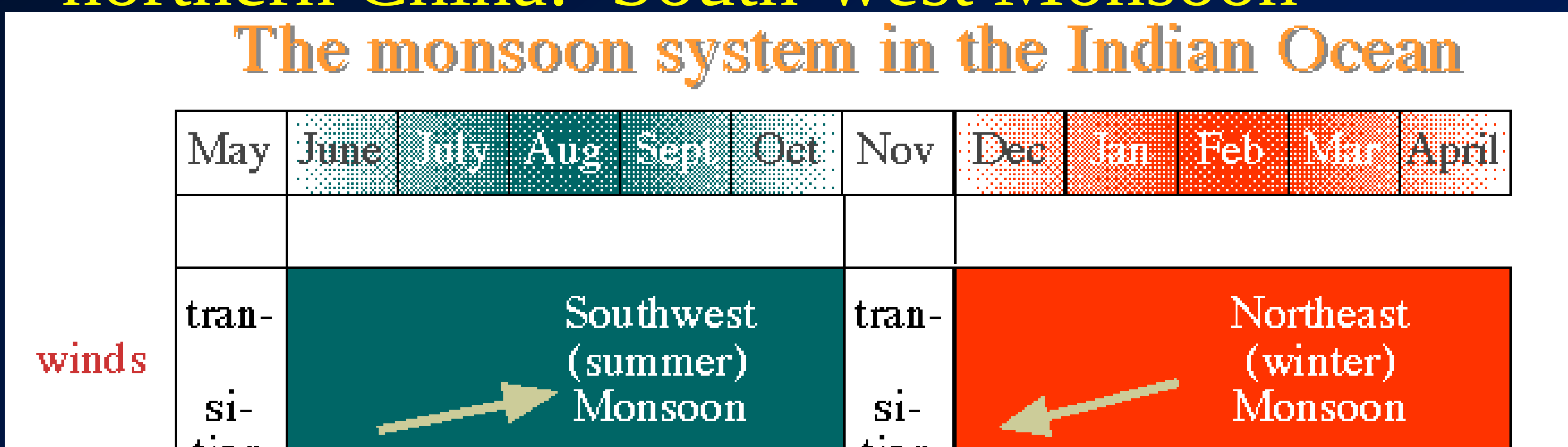
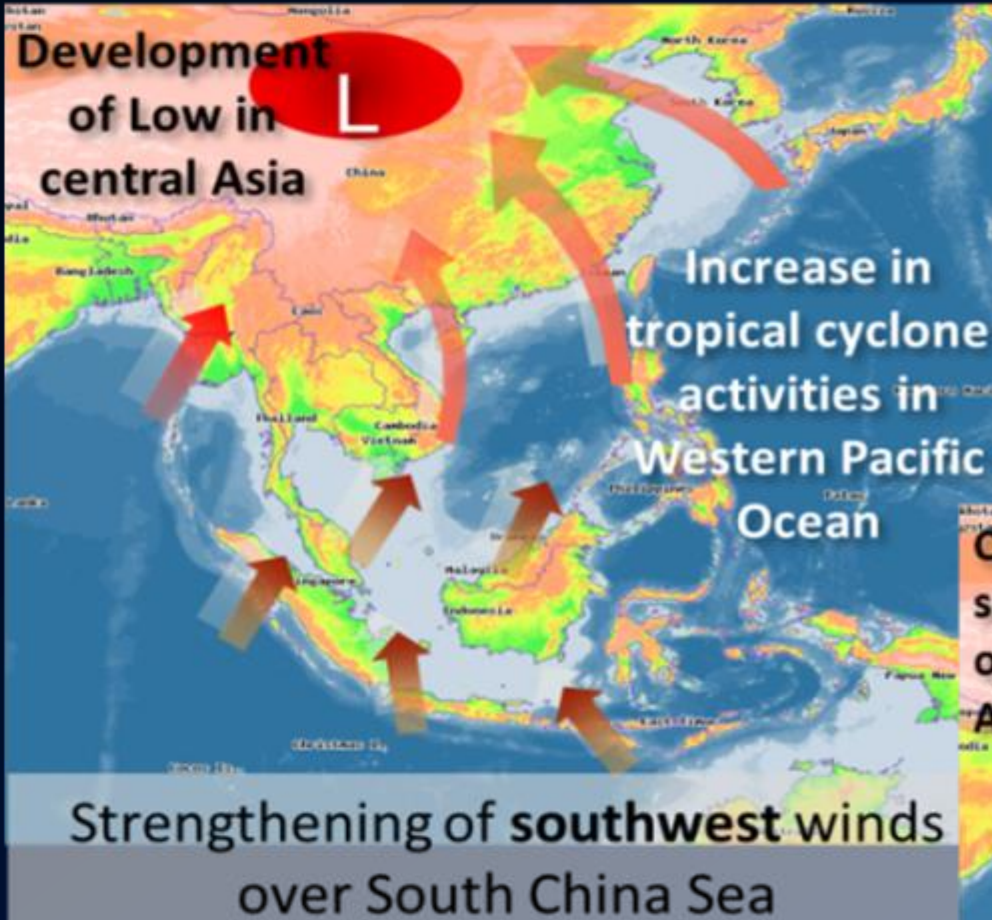
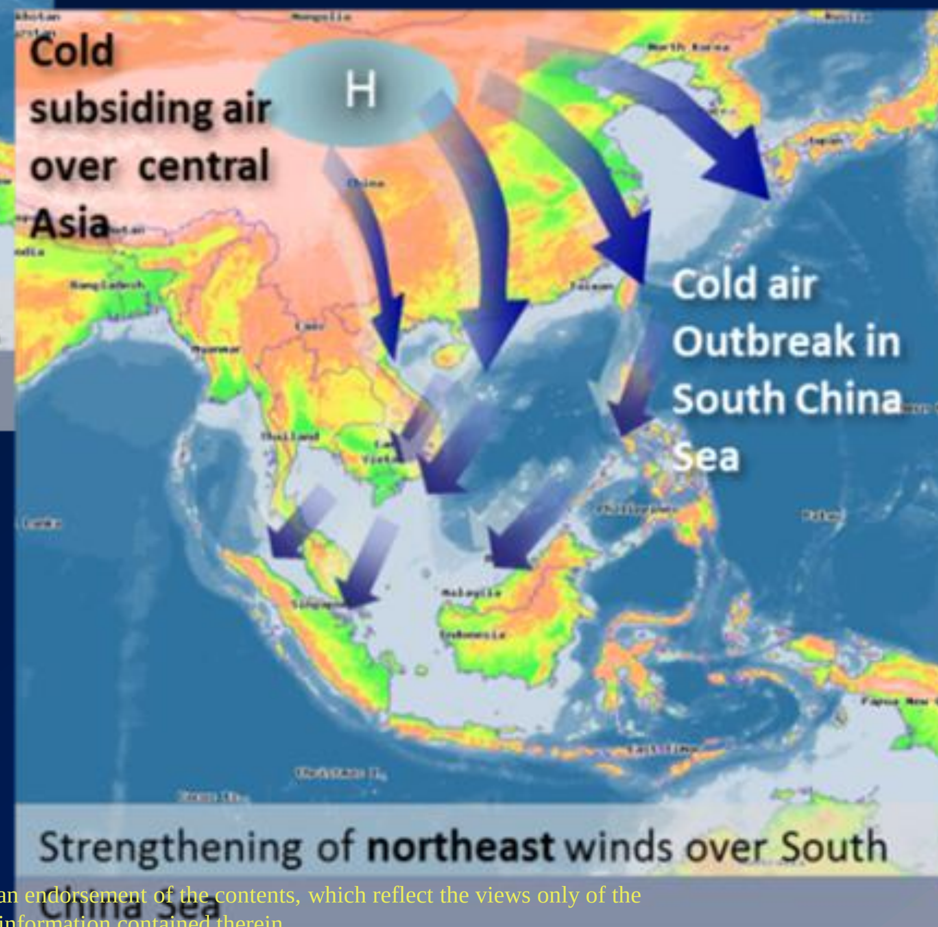
# The Monsoon System

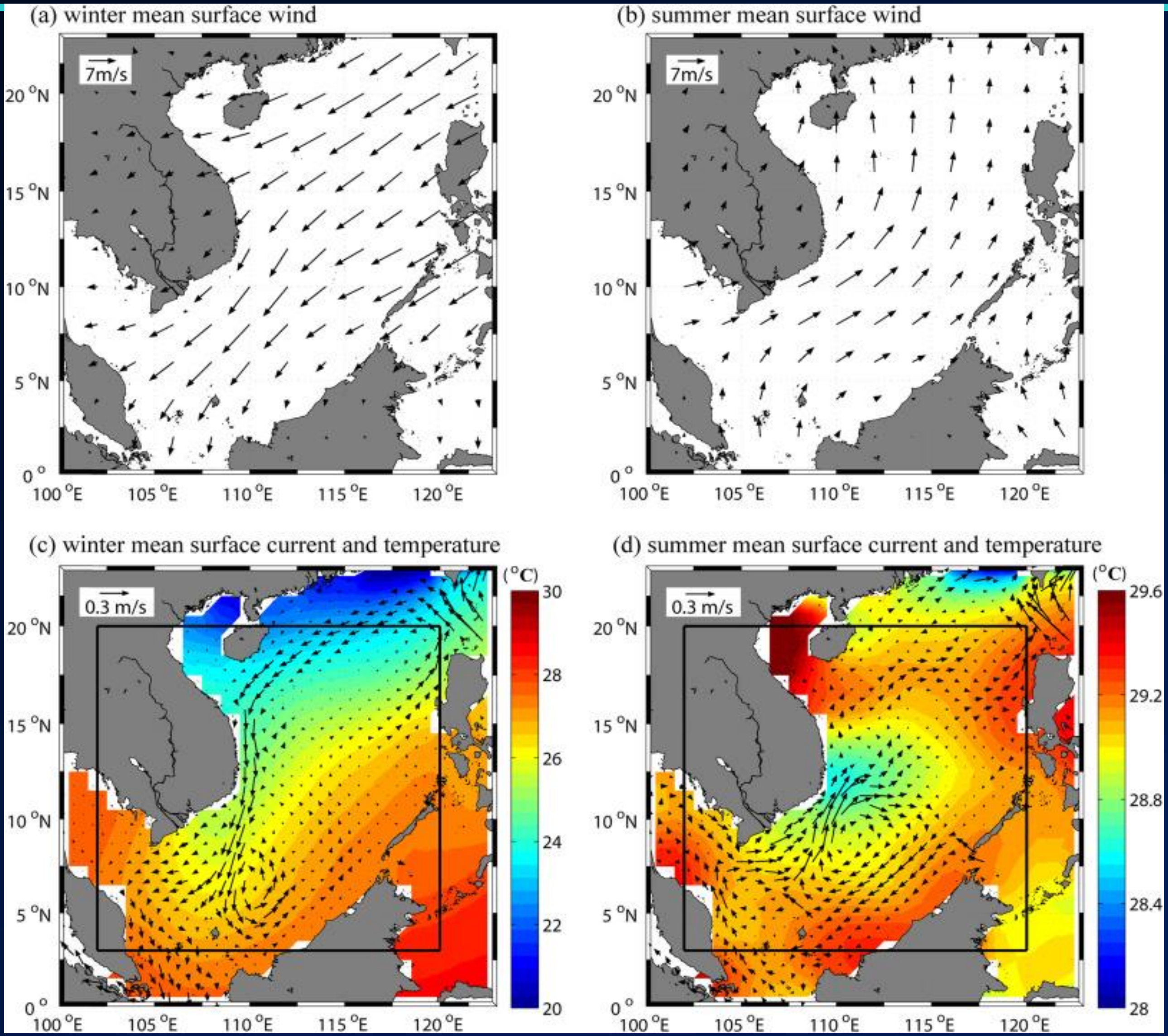
- Similar to the sea/land breeze system but on a seasonal time scale
- Northern hemisphere winter:  high pressure in northern China:  North-east Monsoon
- Northern hemisphere summer:  low pressure in northern China:  South-west Monsoon




Development of Low in central Asia
L
Increase in tropical cyclone activities in Western Pacific Ocean
Strengthening of **southwest** winds over South China Sea


Cold subsiding air over central Asia
H
Cold air Outbreak in South China Sea
Strengthening of **northeast** winds over South China Sea

# South China Sea

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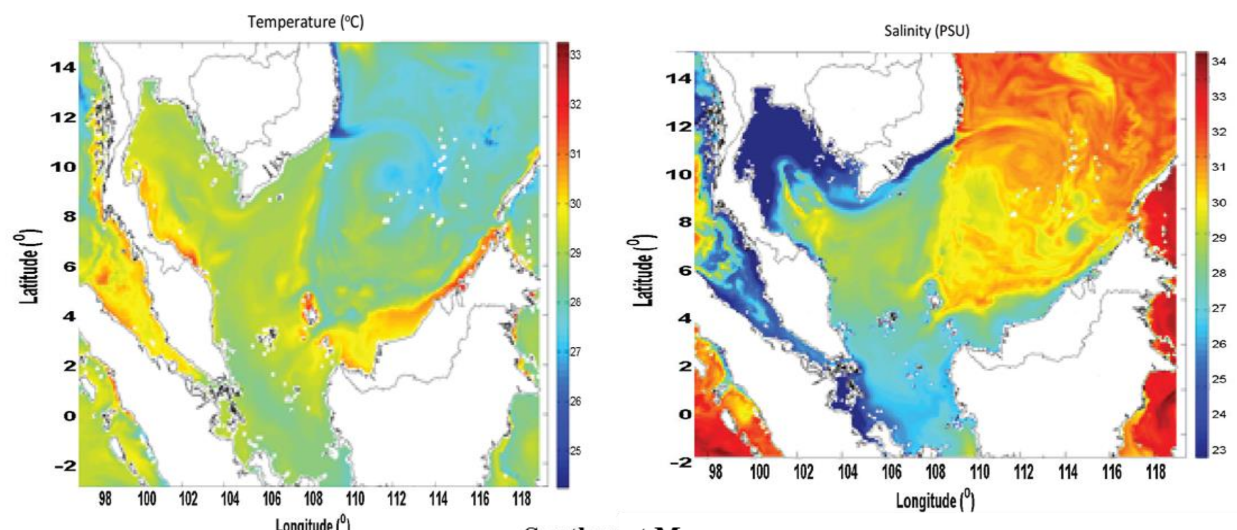
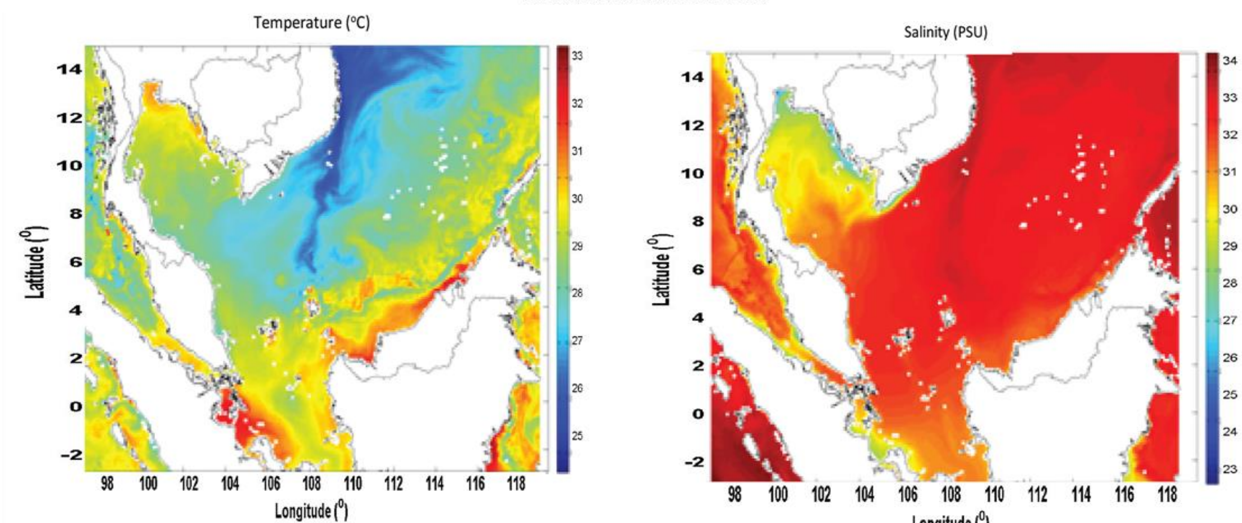
# SST and Salinity




**Southwest Monsoon**




**Northeast Monsoon**

# Currents with Friction

## Ekman Dynamics

Co-funded by the Erasmus+ Programme of the European Union

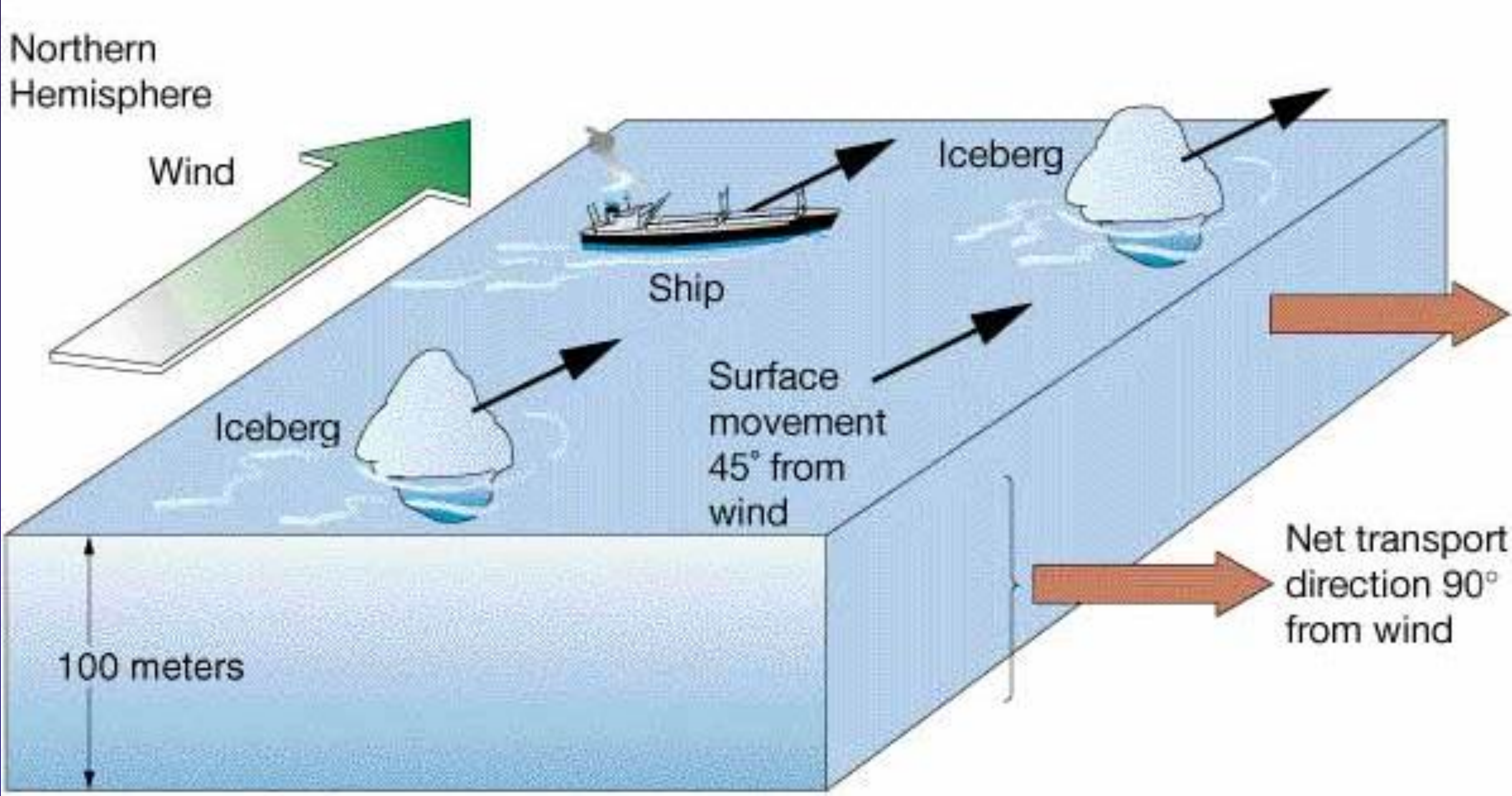
# Objectives

- Comprehend the mathematical equation of Ekman Dynamics
- Understand the concept of Ekman balance, Ekman dynamics and depth of frictional influence
- Apprehend the application of Ekman transport toward the upwelling system

# Ekman Dynamics

When the wind exert upon surface water, the coriolis effect caused the currents at the surface to deflect 45º to the right of wind stress in northern hemisphere and 45º to the left in southern hemisphere. The deflection continued downward until it reach the level of no motion.

# Ekman dynamics




Nansen noticed icebergs moving 20° - 40° to right of wind direction

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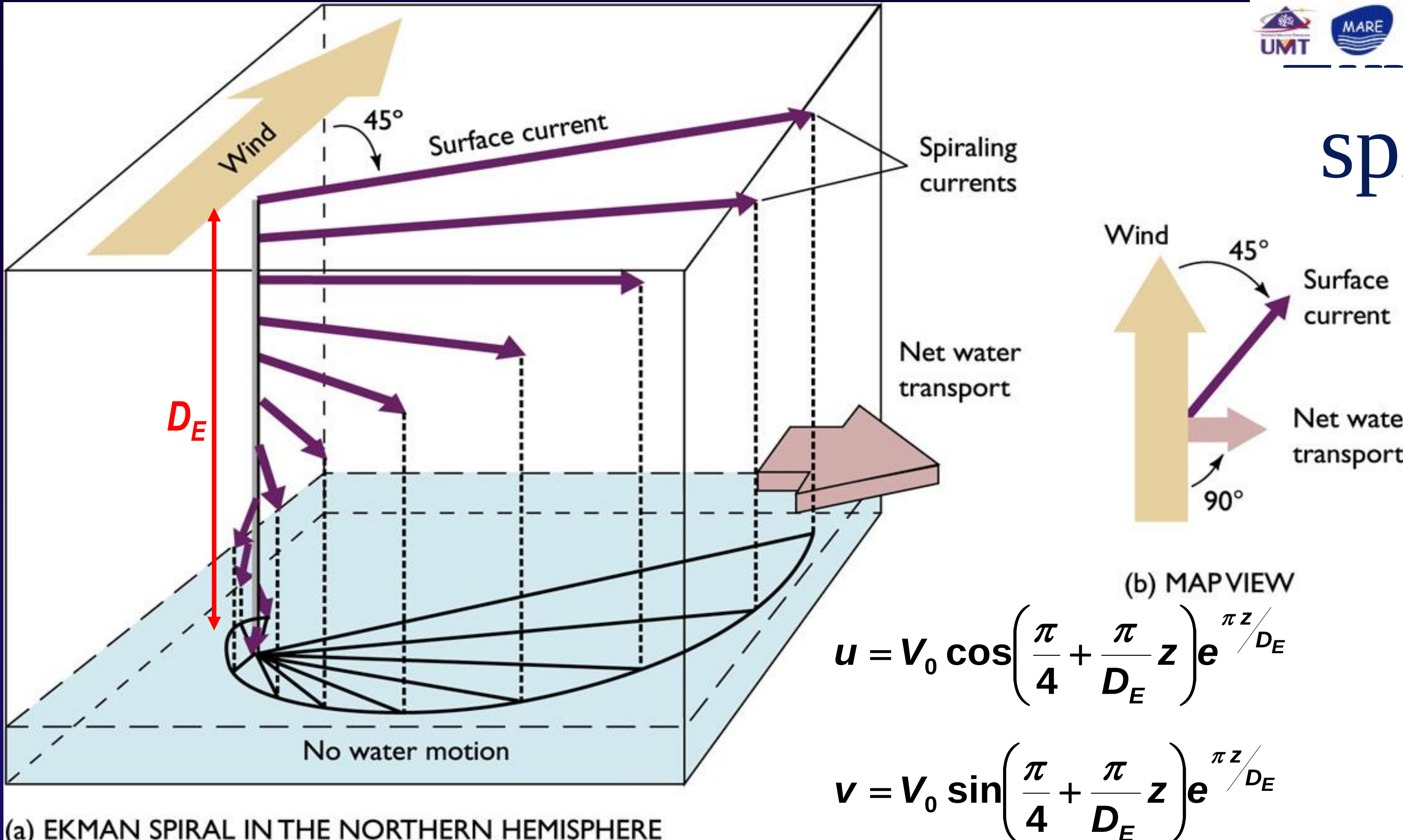
# spiral




$$u = V_0 \cos\left(\frac{\pi}{4} + \frac{\pi}{D_E} z\right) e^{\pi z / D_E}$$

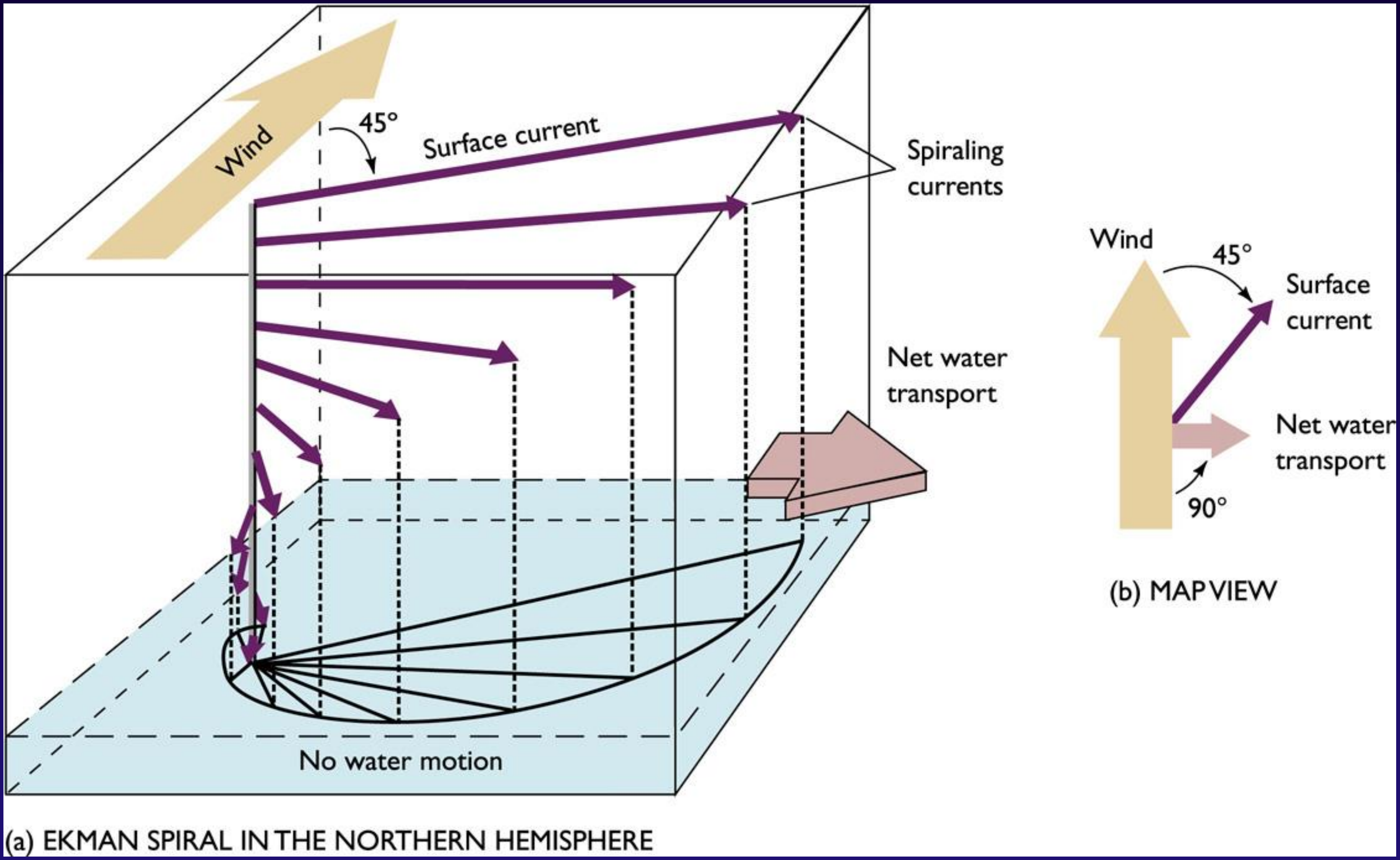
$$v = V_0 \sin\left(\frac{\pi}{4} + \frac{\pi}{D_E} z\right) e^{\pi z / D_E}$$

$V_0$ is 45° to the right of the wind (in the northern hemisphere)

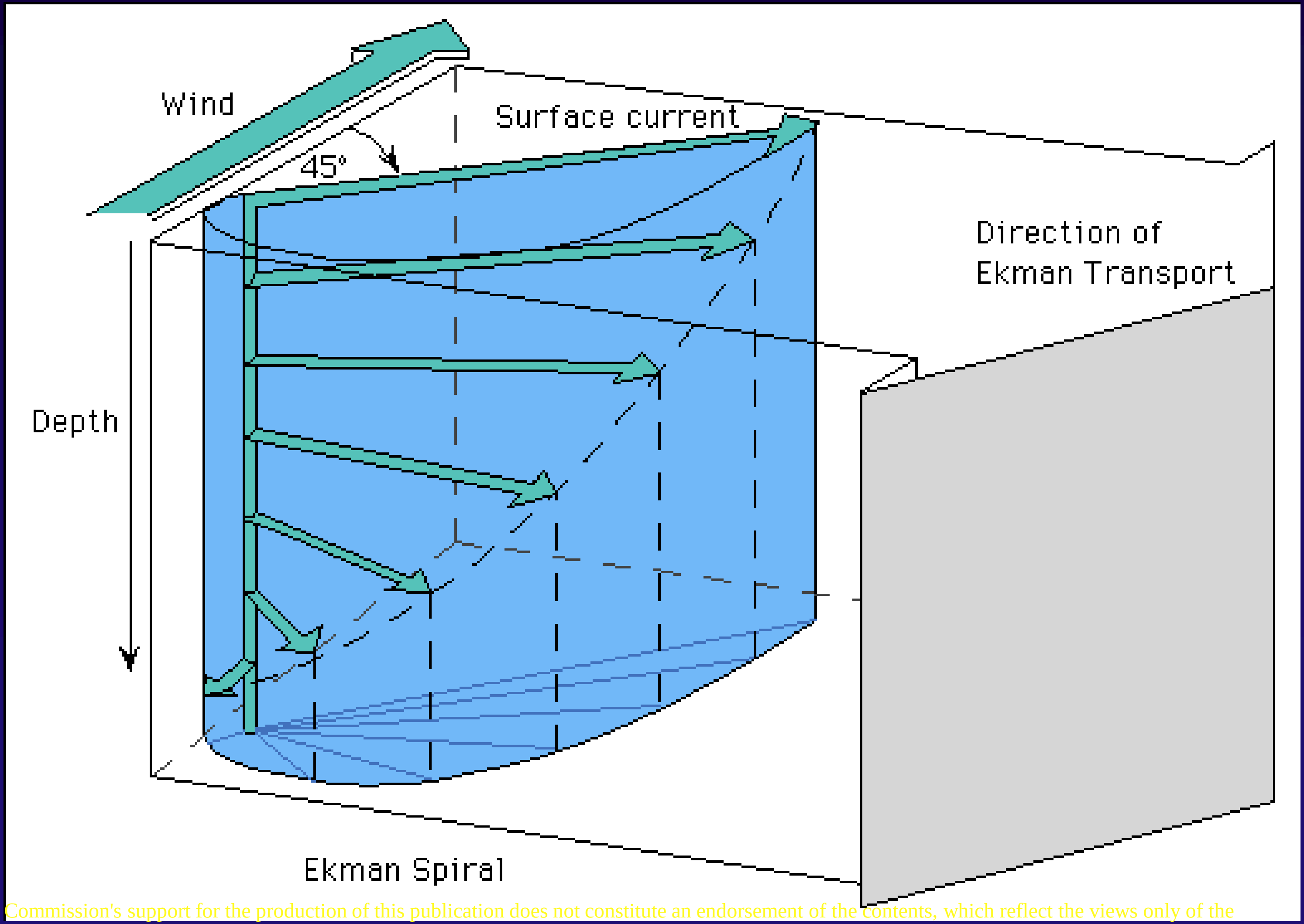
$V_0$ decreases exponentially with depth as it turns clockwise (NH)

At $z = -D_E$ the flow speed falls to $e^{-\pi} = 0.04$ that at the surface and in opposite direction

# Ekman Transport



# Ocean Surface Circulation
# Ekman dynamics



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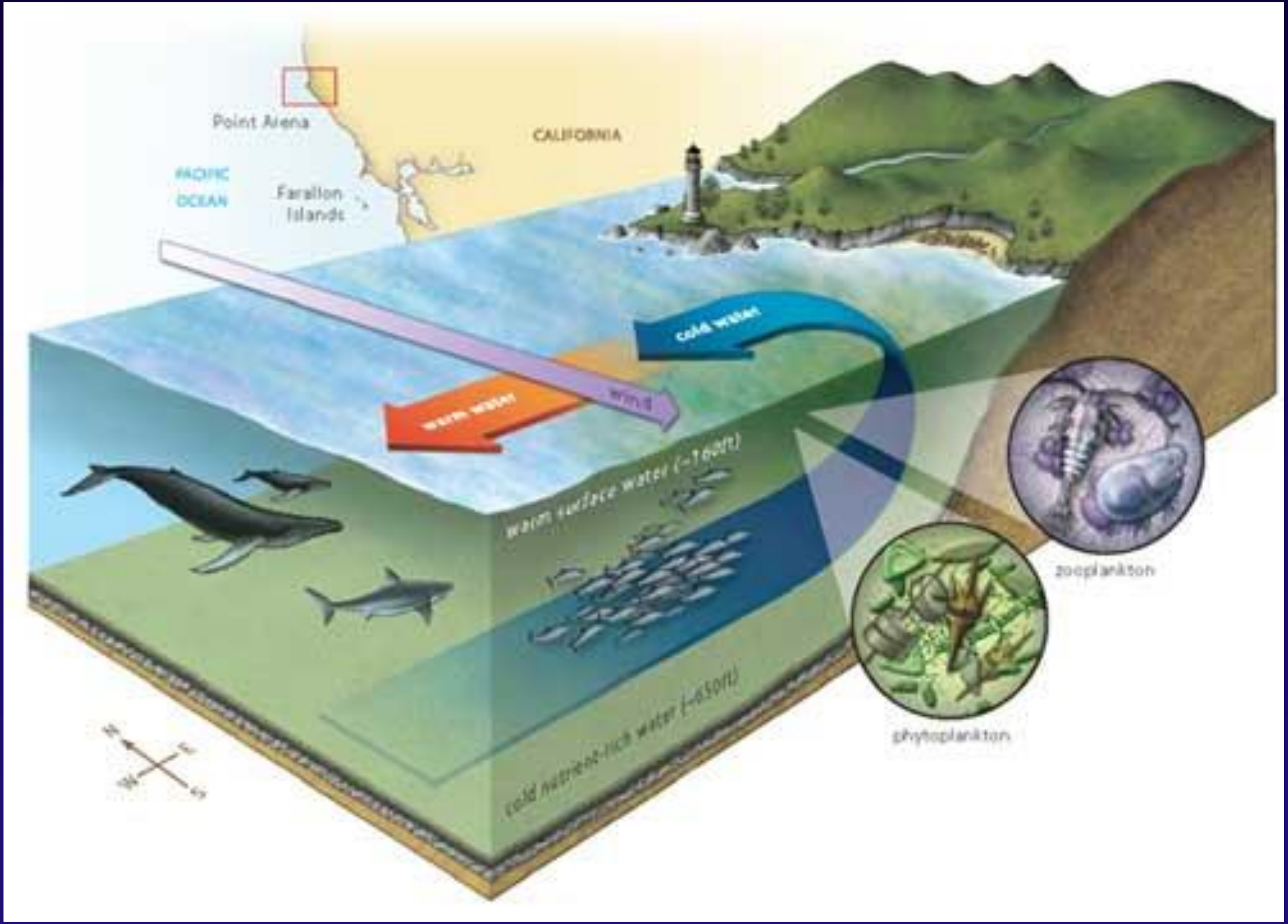
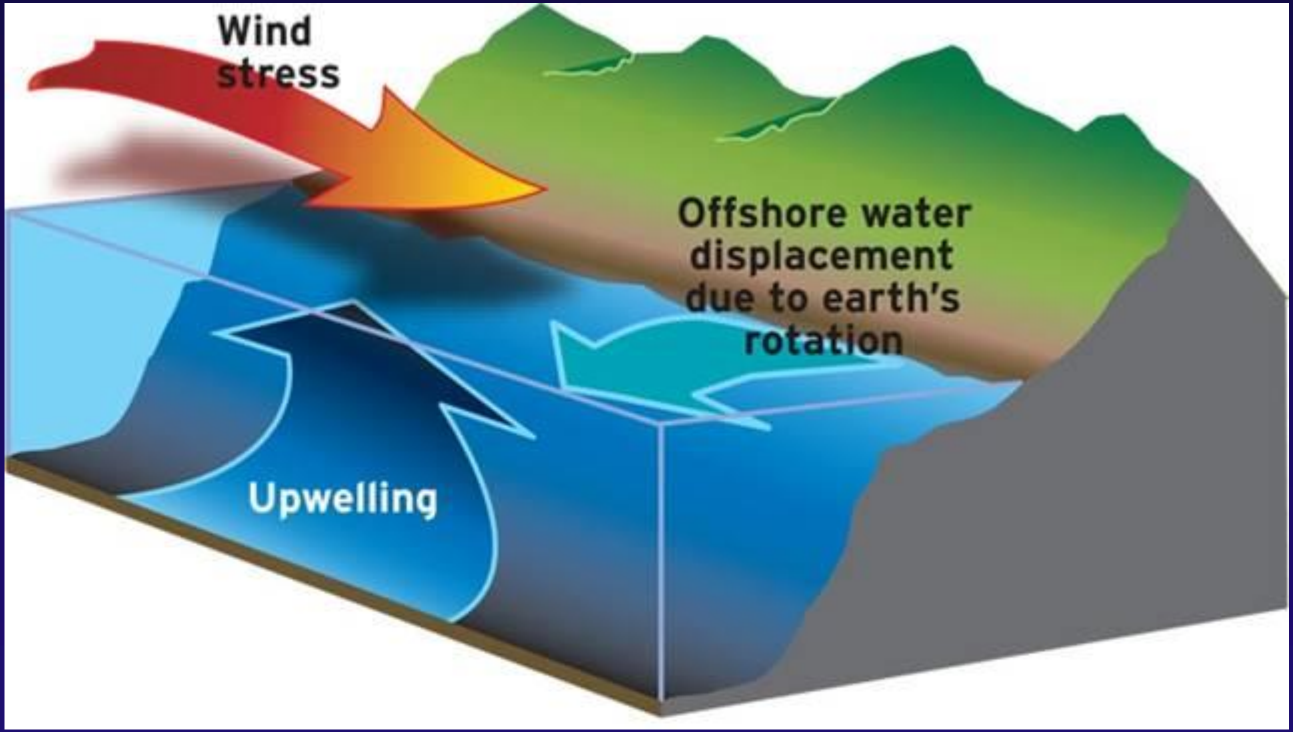
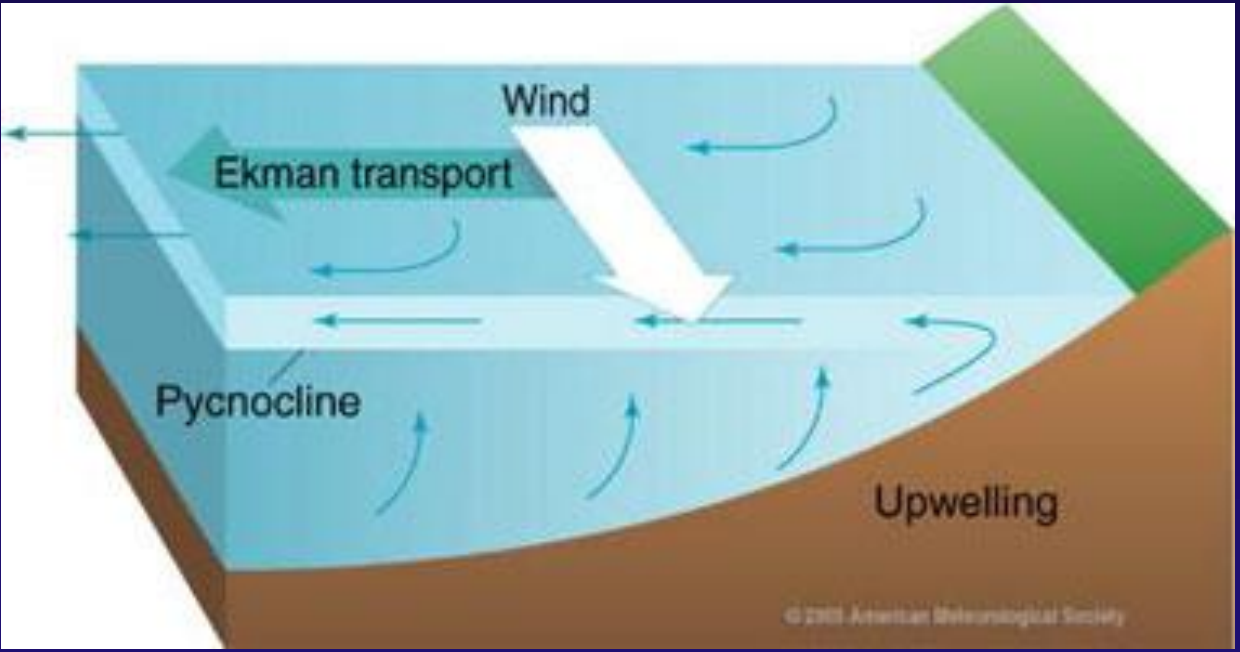


# Definition of Coastal Upwelling



# What is coasta upwelling?

- Coastal upwelling occurs where Ekman transport moves surface waters away from the coast; surface waters are replaced by water that wells up from below.

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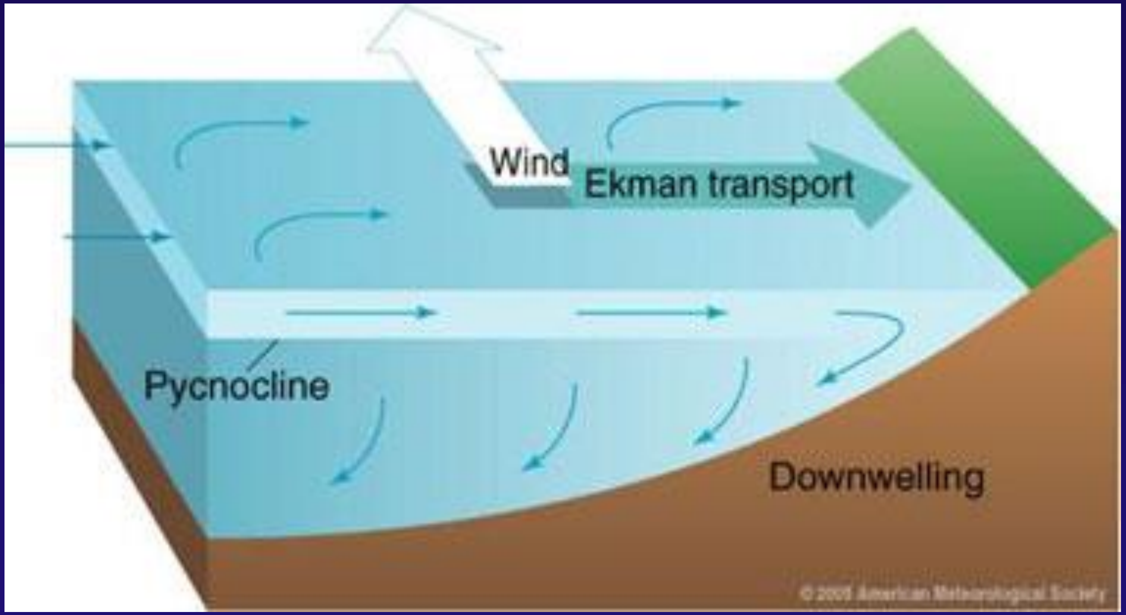
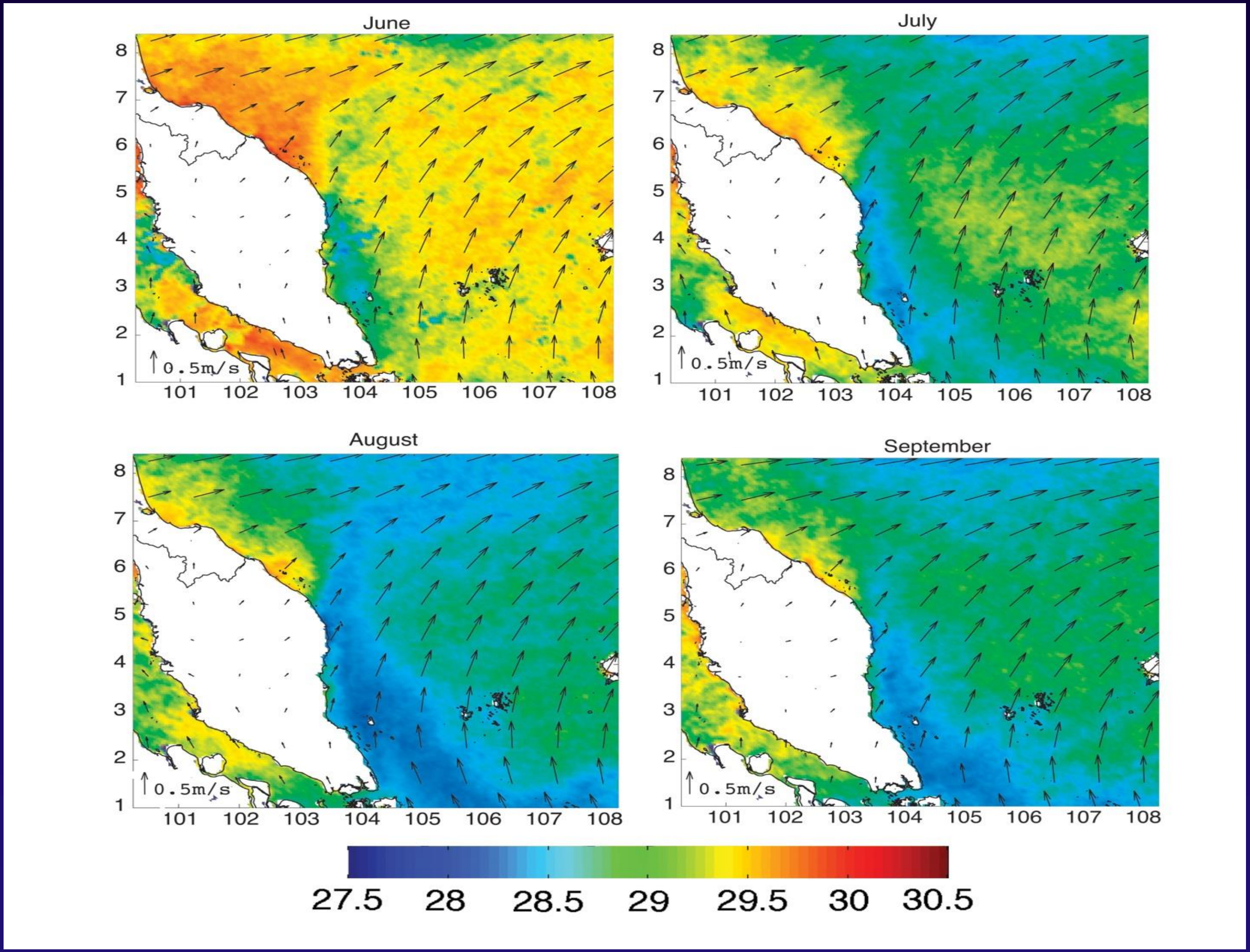
# What is coastal downwelling?

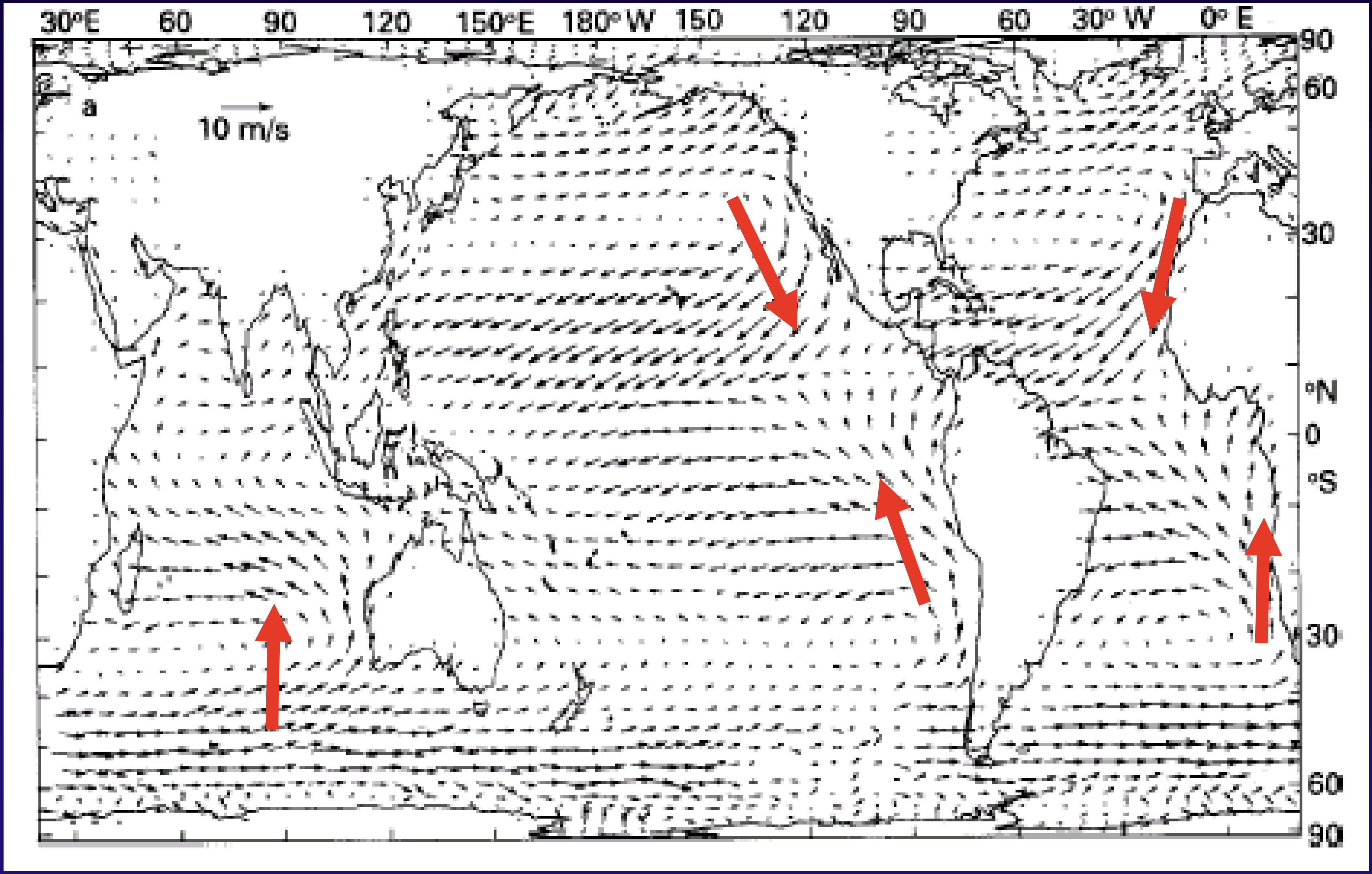
- Coastal downwelling occurs where Ekman transport moves surface waterstowards the coast; water piles up and sinks below the surface current



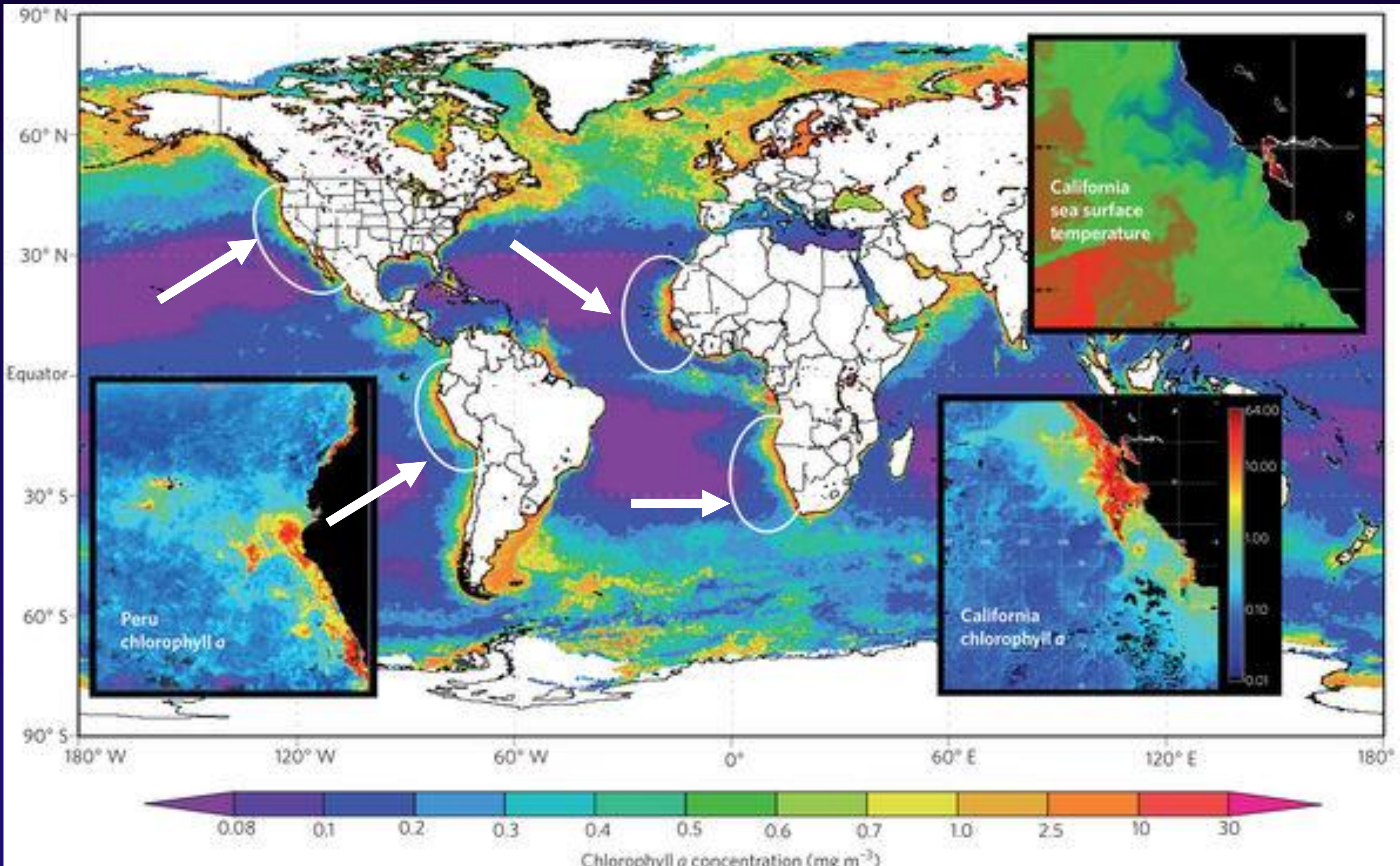
# Coastal Wind Driven Upwelling

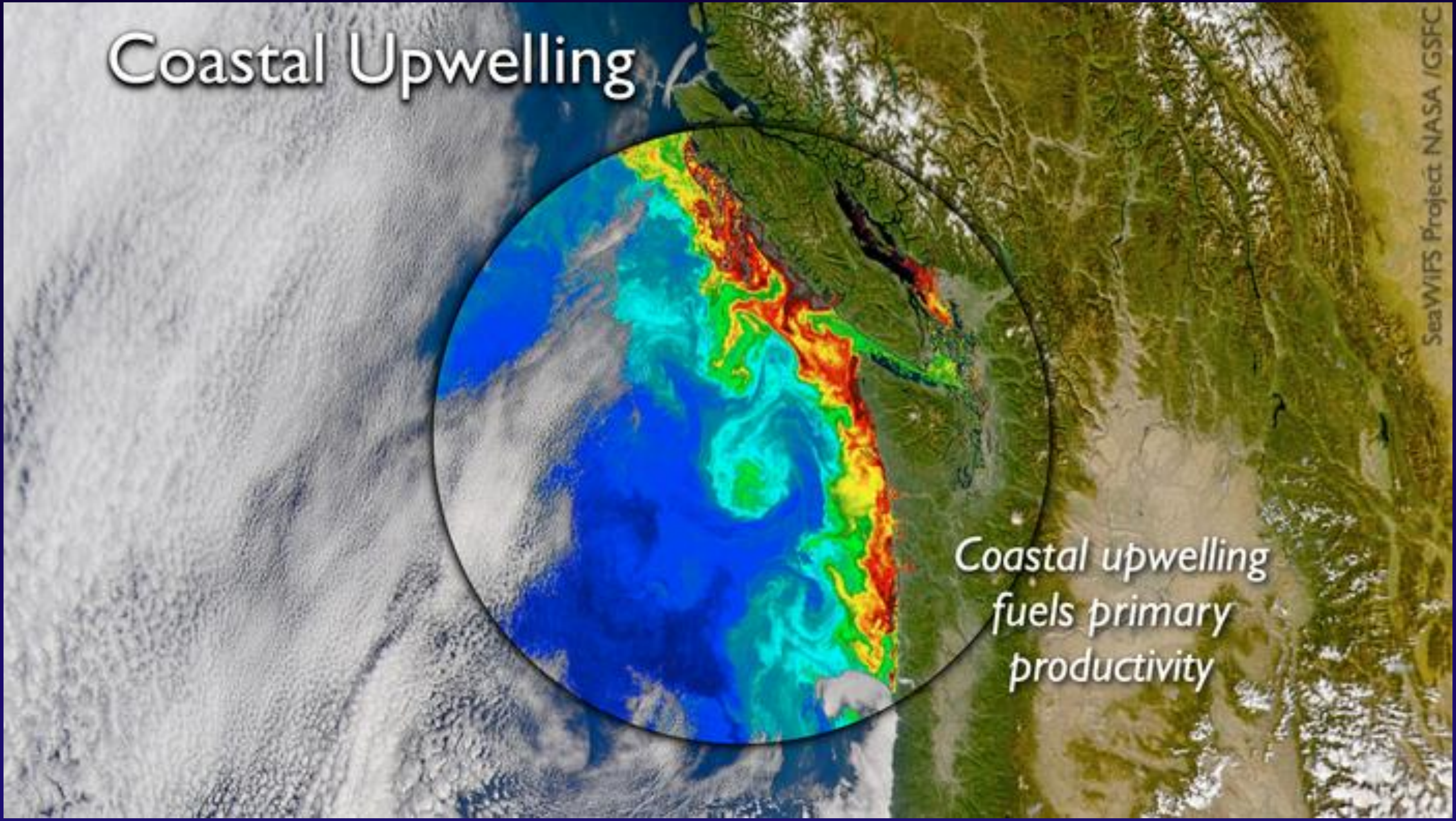


# Mean wind field



# Ocean Primary Productivity

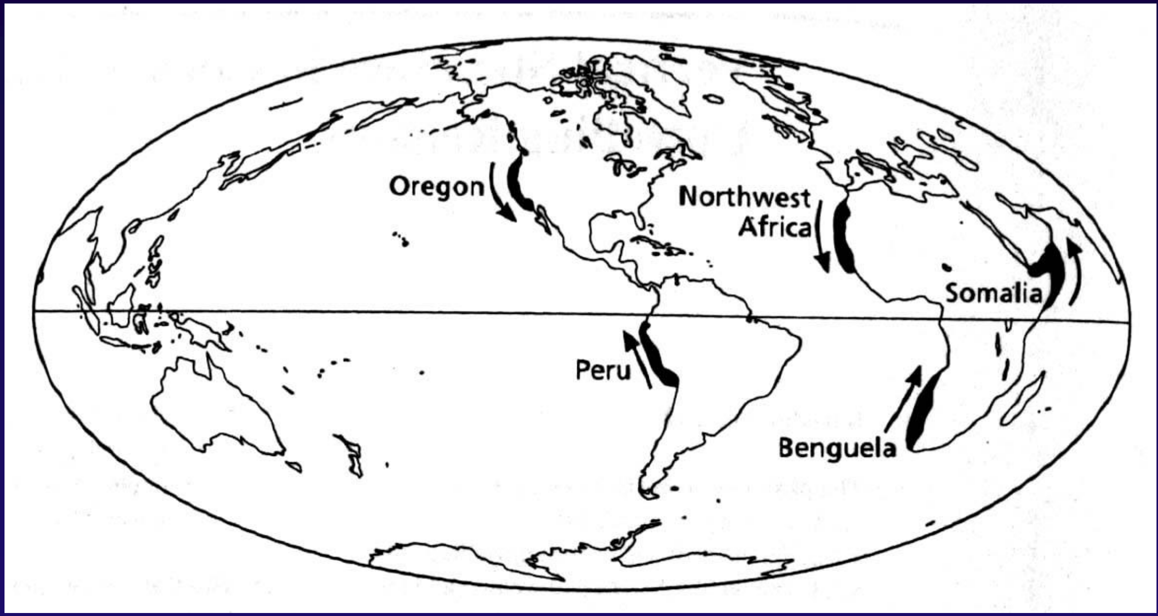



Coastal Upwelling
Coastal upwelling fuels primary productivity
SeaWIFS Project NASA /GSFC

Co-funded by the Erasmus+ Programme of the European Union

# Eastern Boundary Currents

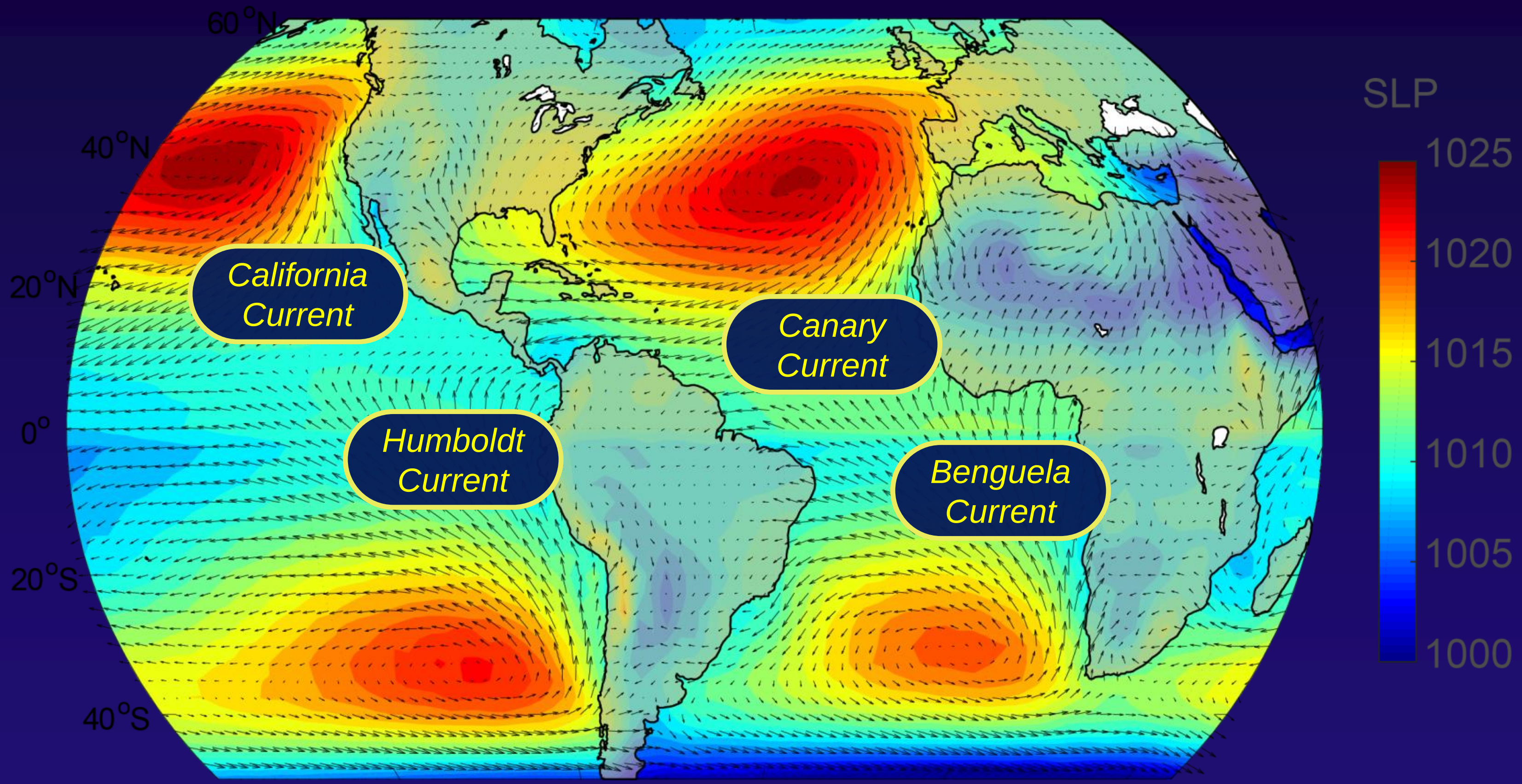
- Eastern portion of the oceanic gyres, located on the western coasts of continents
- Winds blow parallel to the coast, towards the equator
- Generates large-scale upwelling



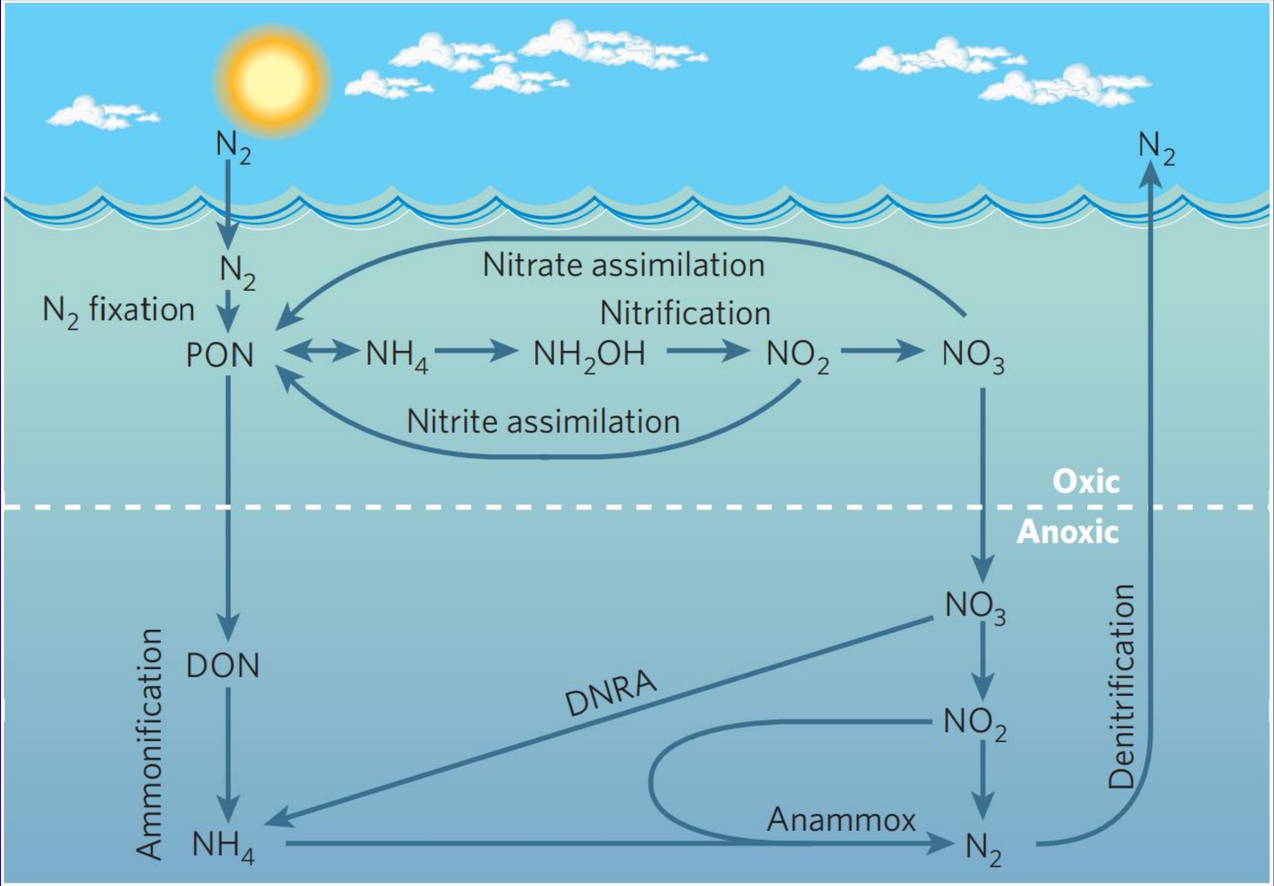

(Mann and Lazier 1996)

50 % of world fish production but only 1% of surface area of the oceans

# Eastern Boundary Upwelling Systems (EBUS)

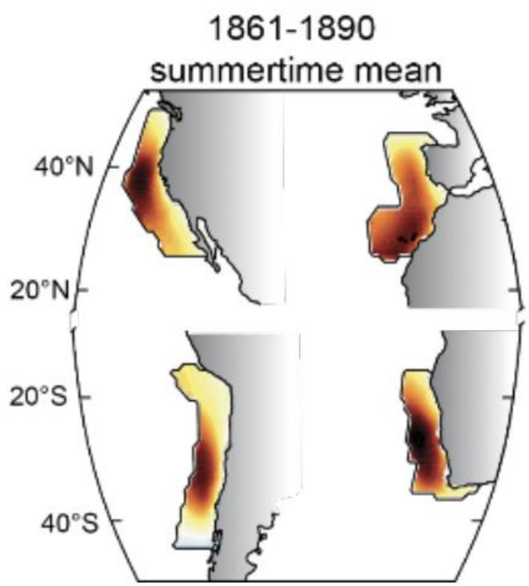


## *Nitrogen (and specifically nitrate) gets the most attention, at least classically…*




Arrigo (200

## Anthropogenic changes in wind intensity are fairly subtle...




# CLIMATE CHANGE IMPACT ON UPWELLING

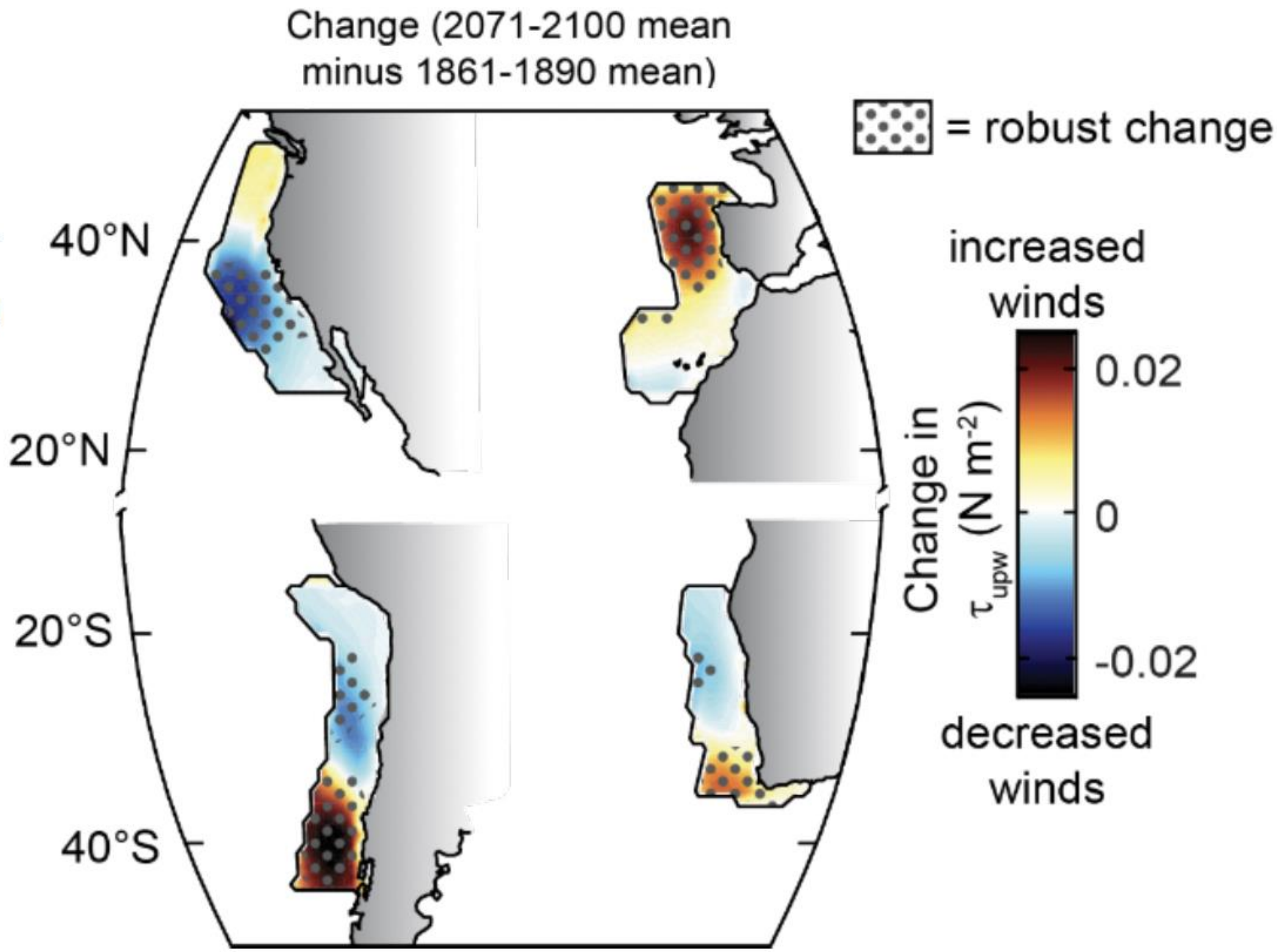


Rykaczewski *et al.* (2015)

# Anthropogenic changes in wind intensity are fairly subtle…

Upwelling intensity tends to increase in the poleward halves…

… but decrease in the equatorward portions of the upwelling systems.






Rykaczewski *et al.* (2015)

# Case Studies: Coastal Upwelling Variability


# Upwelling Area in South China Sea

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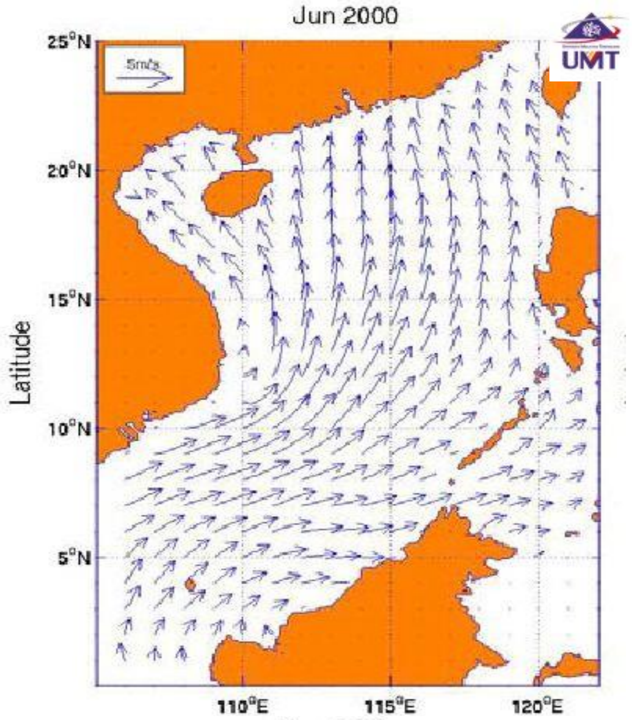


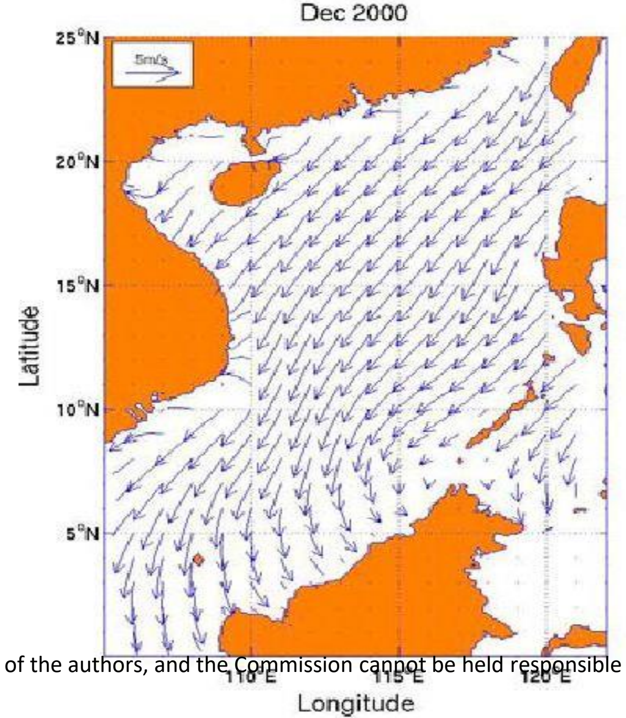

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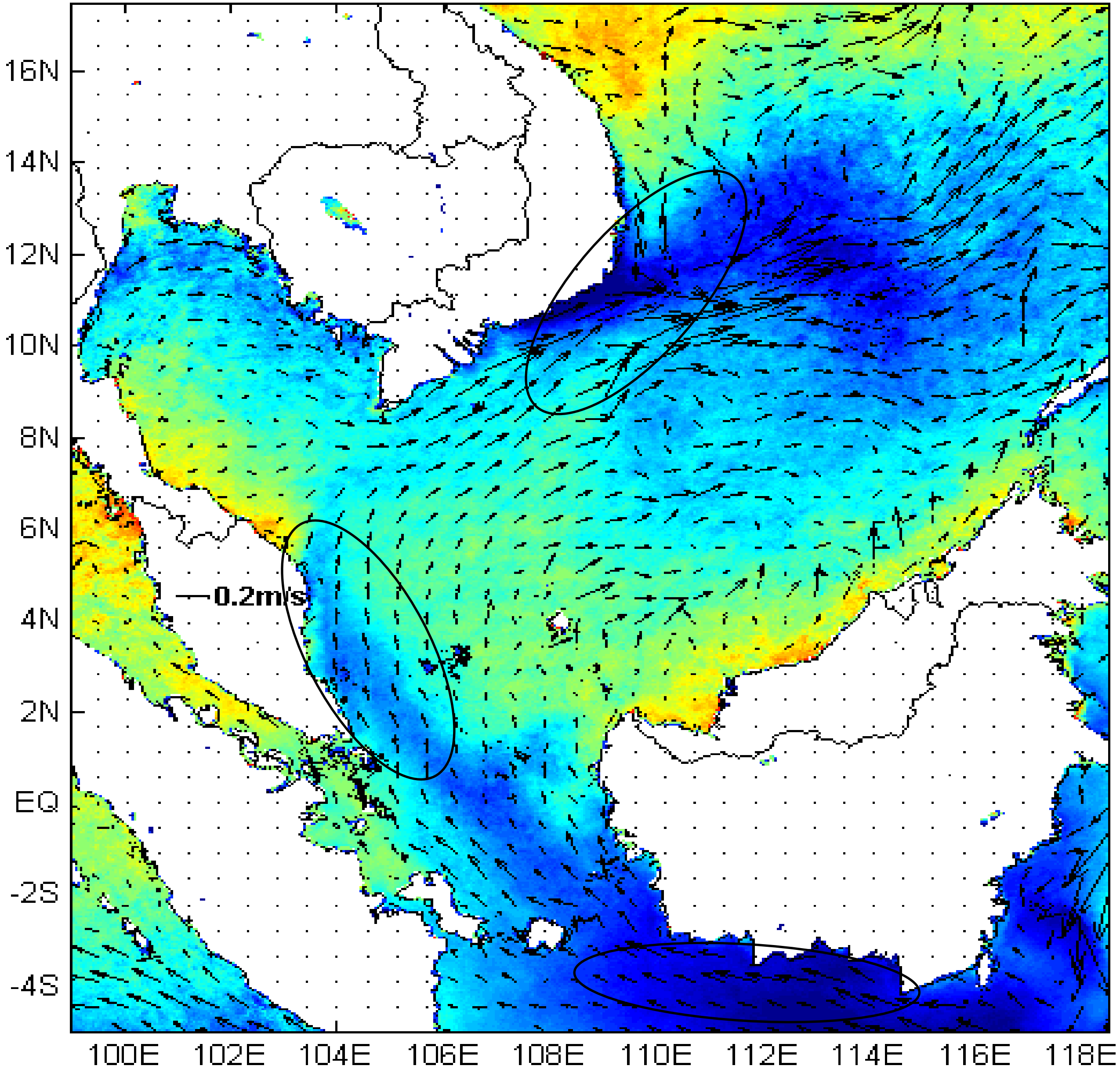
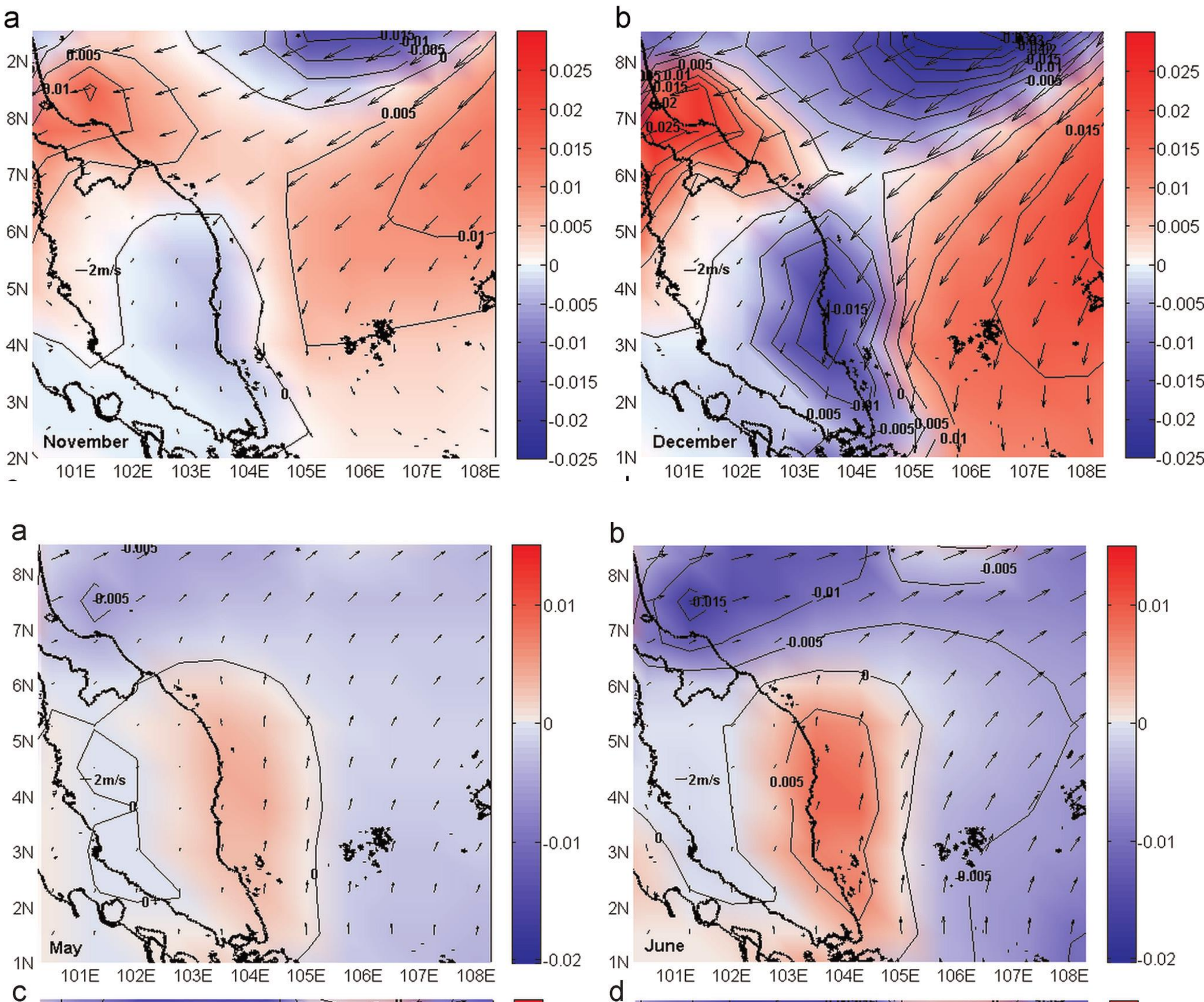
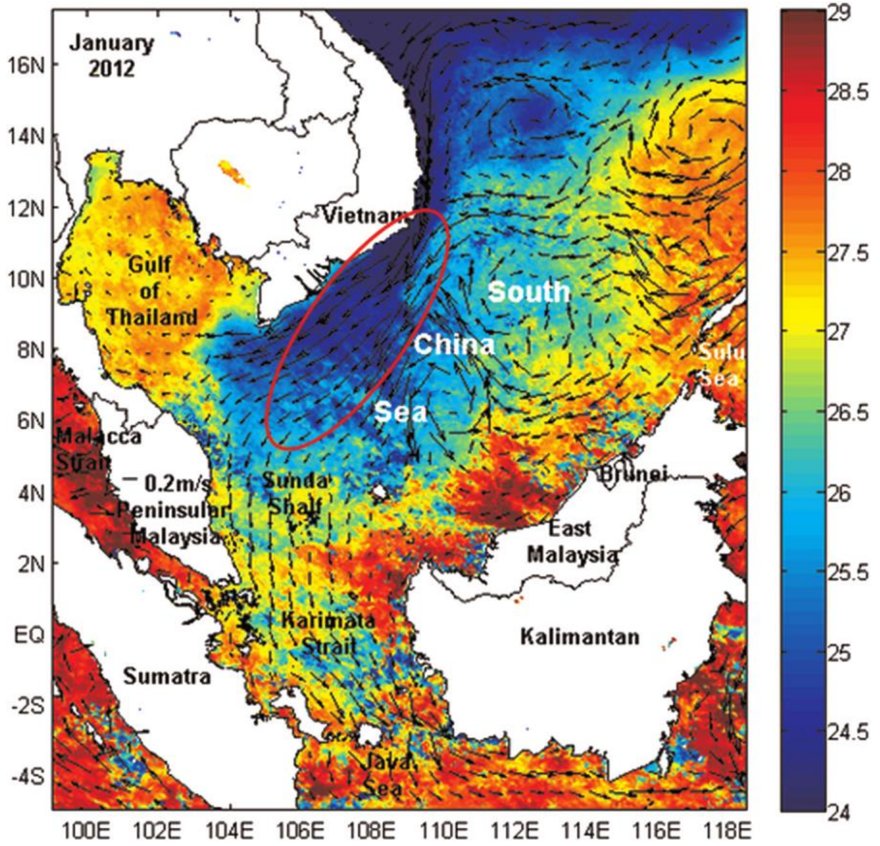
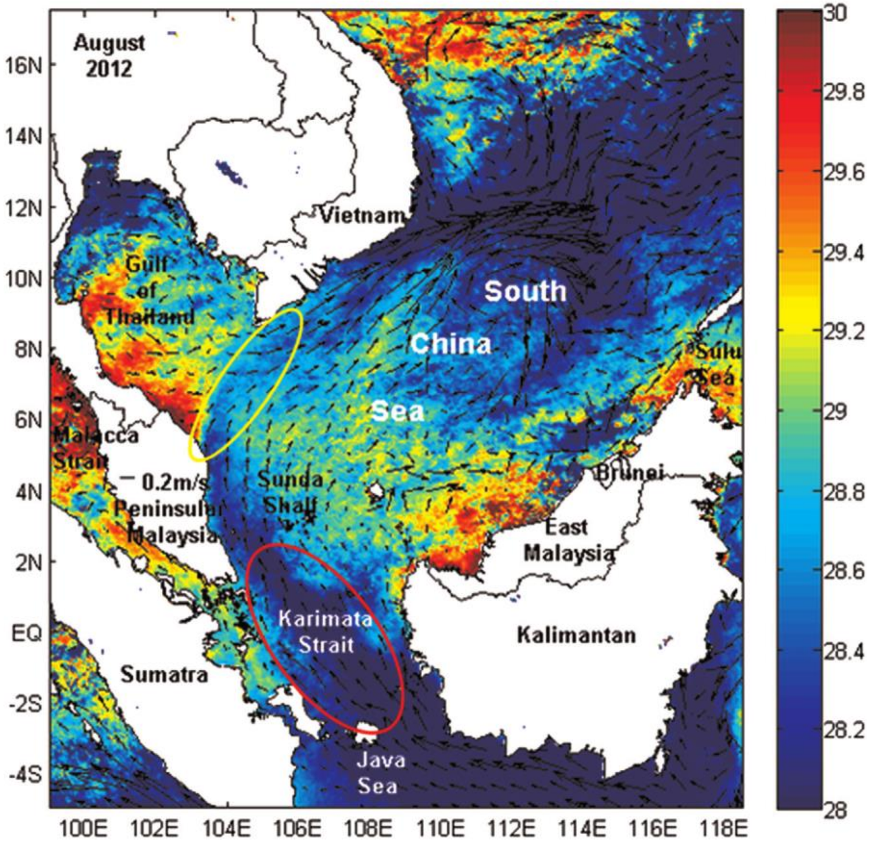


# Wind Stress

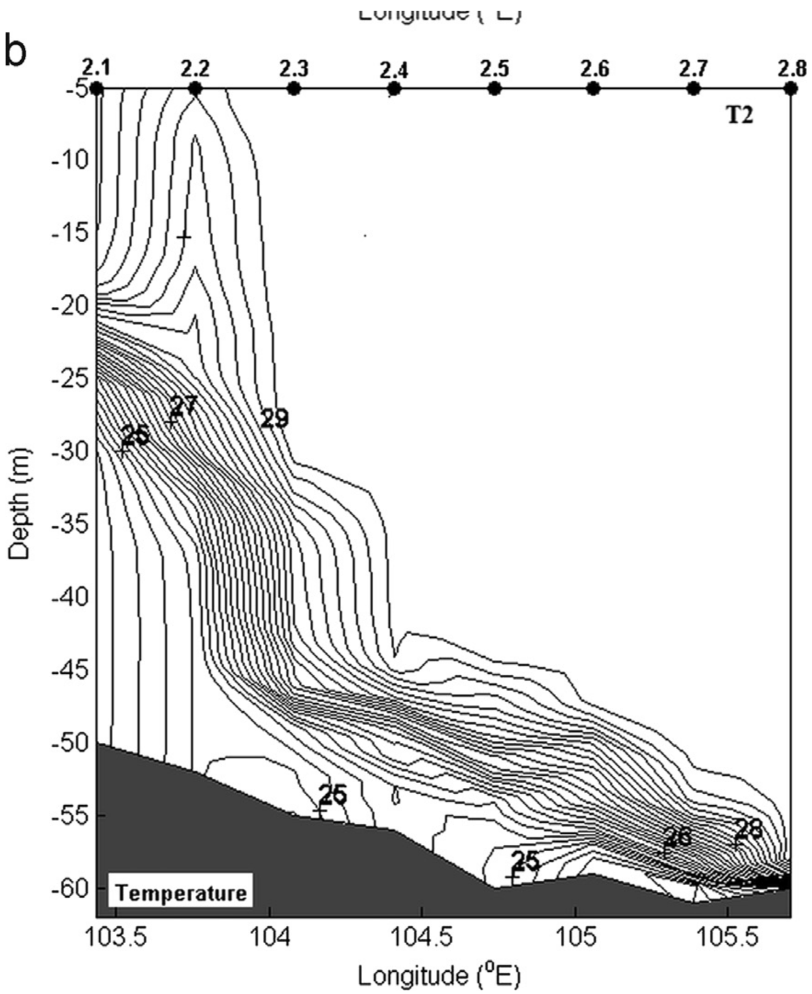

a
b
November
December
May
June
c
d
—2m/s
101E
102E
103E
104E
105E
106E
107E
108E
1N
2N
3N
4N
5N
6N
7N
8N
0.025
0.02
0.015
0.01
0.005
0
-0.005
-0.01
-0.015
-0.02
-0.025

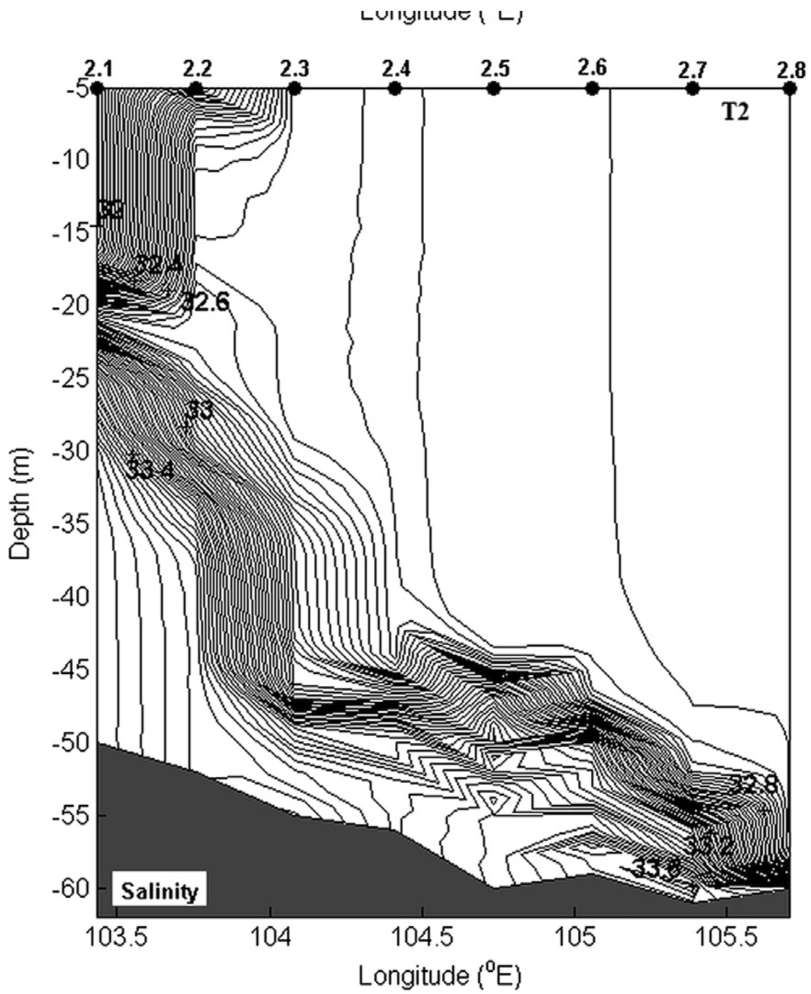
# Seasonality



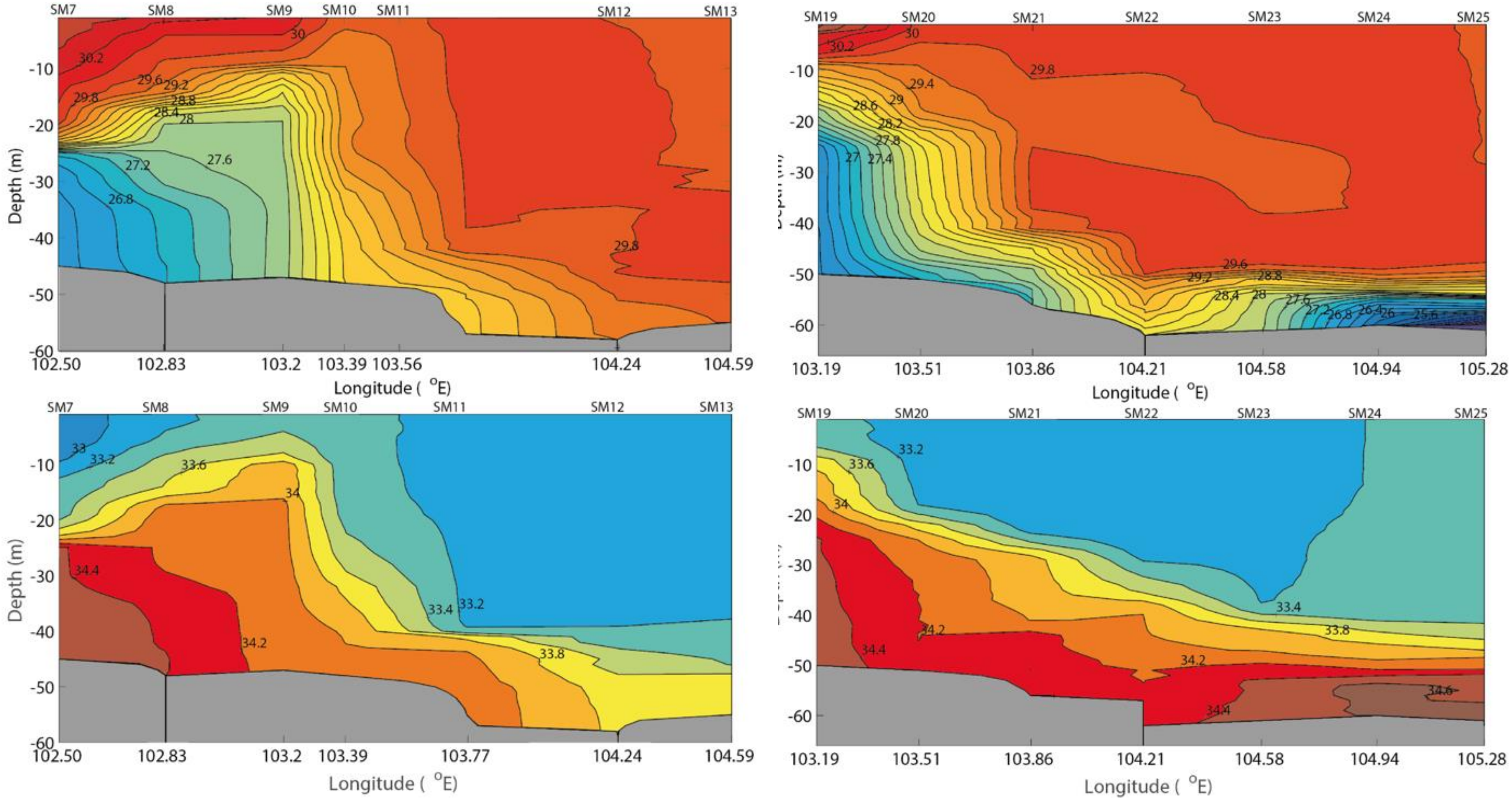



# Transect: Thermocline uplifting



# Upwelling transects

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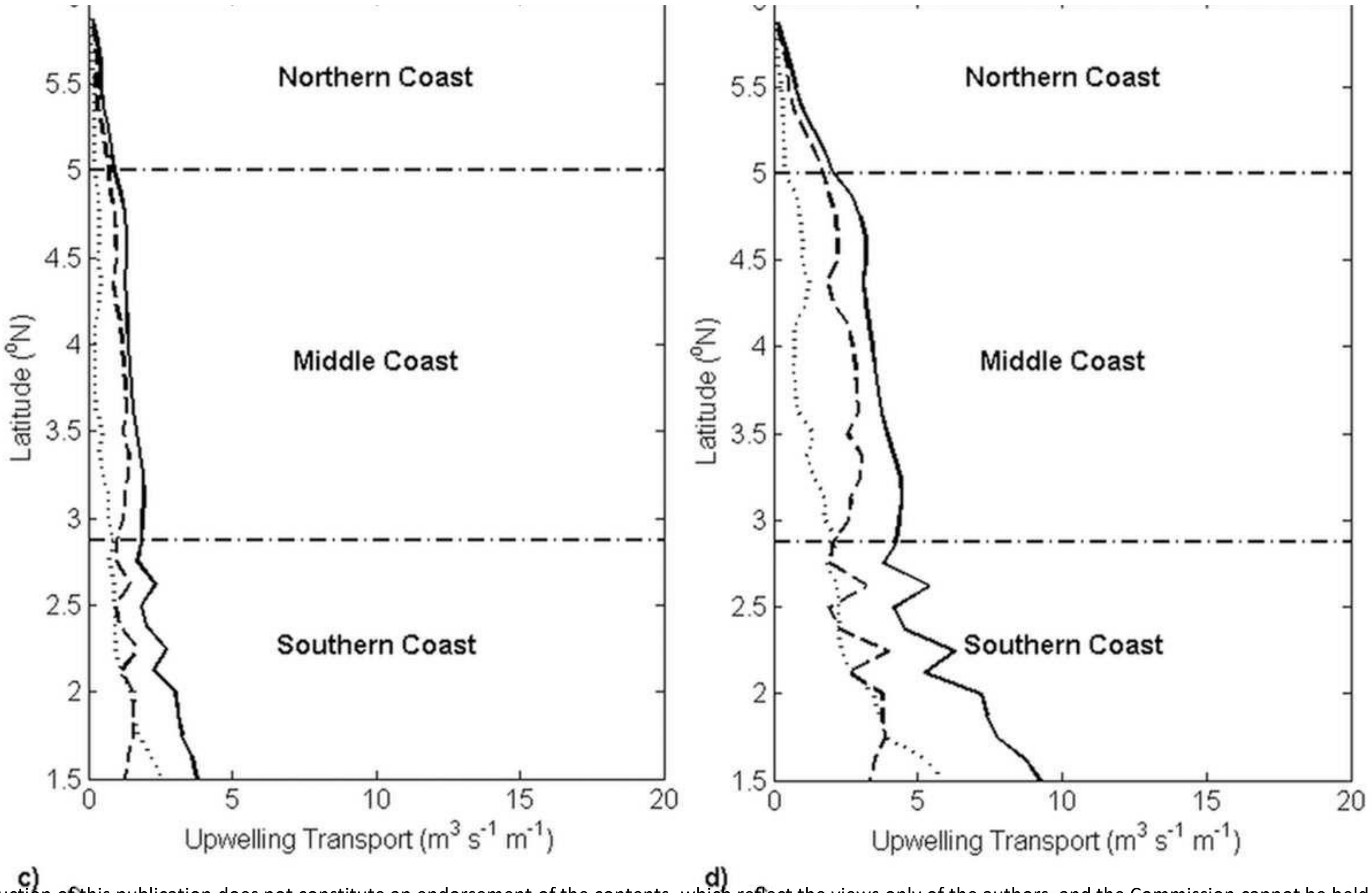
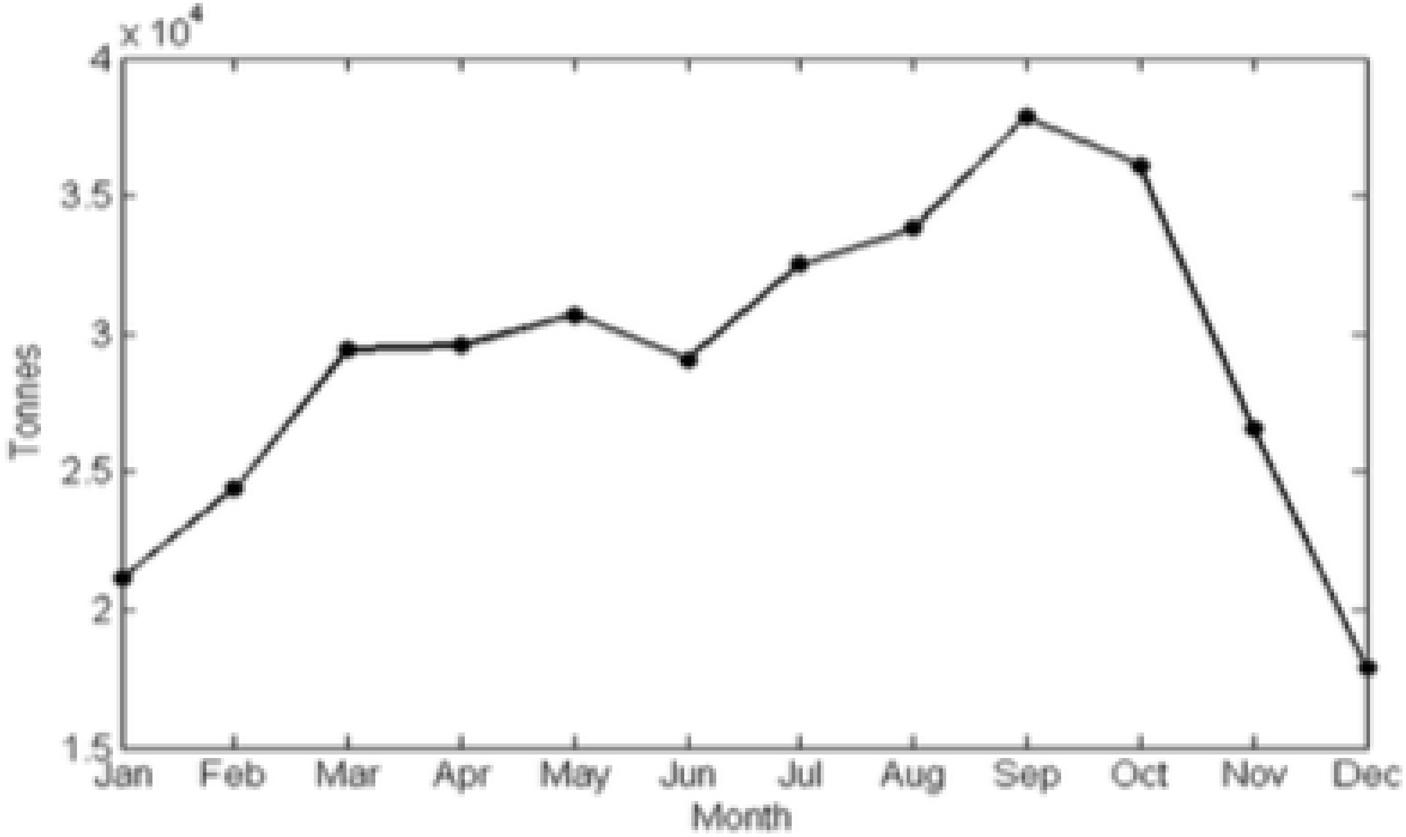
# Alongshore wind-induced upwelling estimates






Ionthly mean of marine fish landing in the period of 2003 – 2013 (unit: tones)

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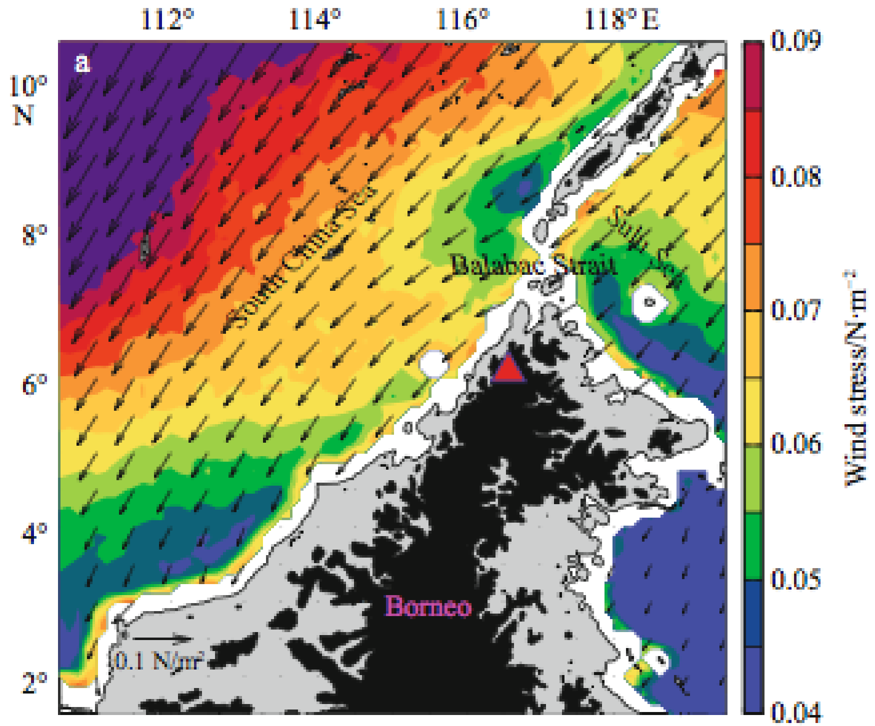
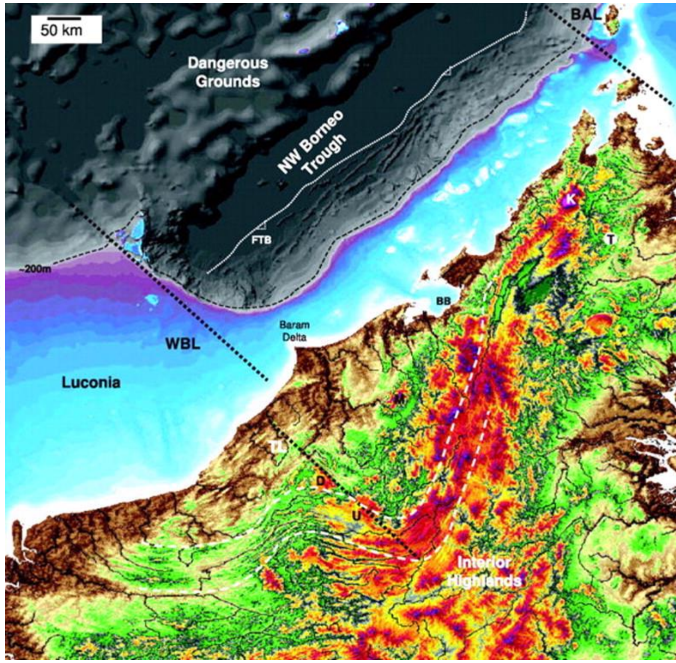
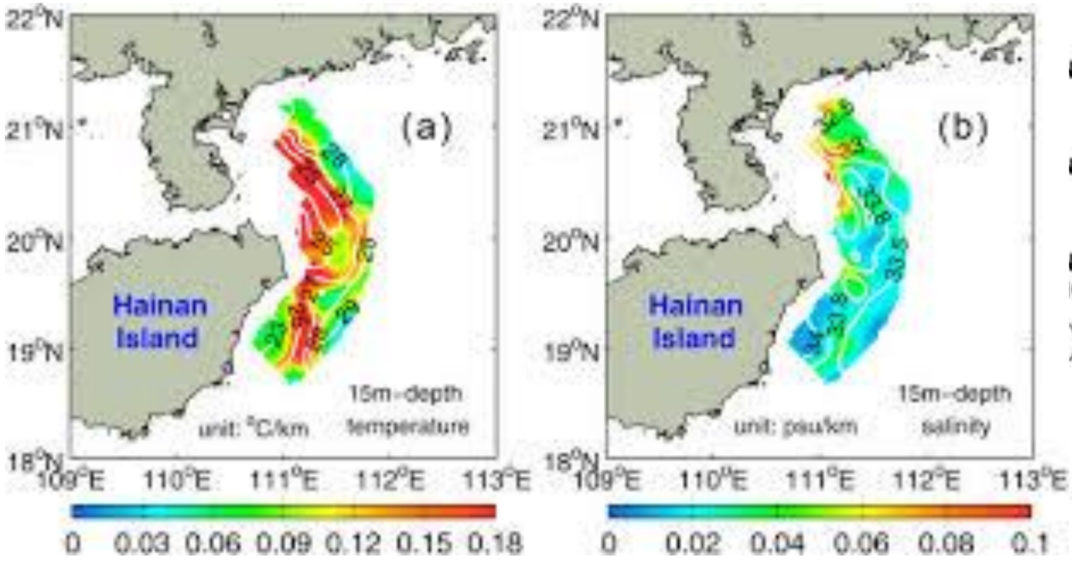


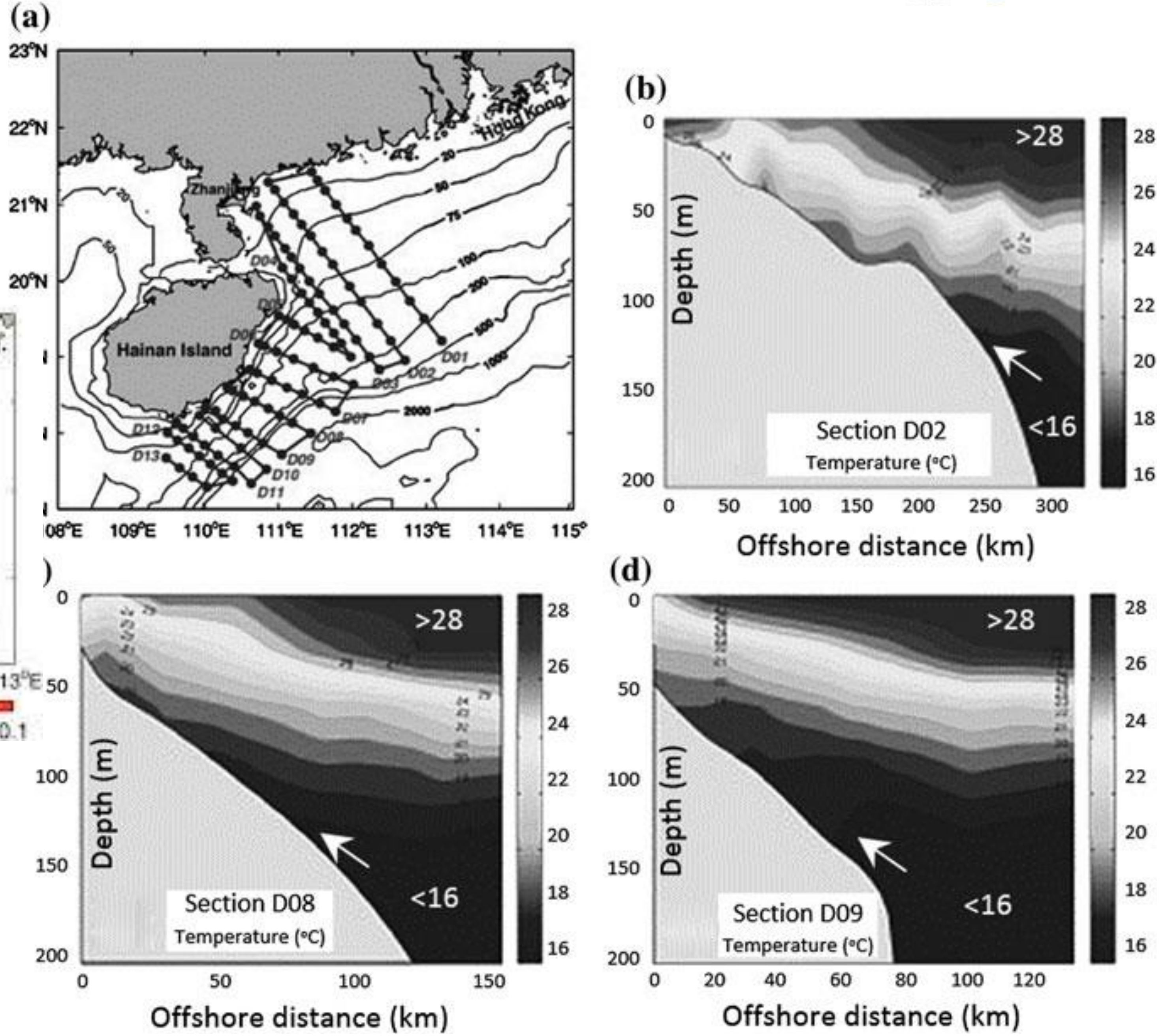

**Fig. 1.** QuickScat winter mean (a) wind stress (color), wind stress vector (arrow) and (b) wind stress curl. Land topography with elevations greater than 300 m is shaded in Black and the red triangle is the highest point Mount Kinabalu with an elevation of 4 095 m.



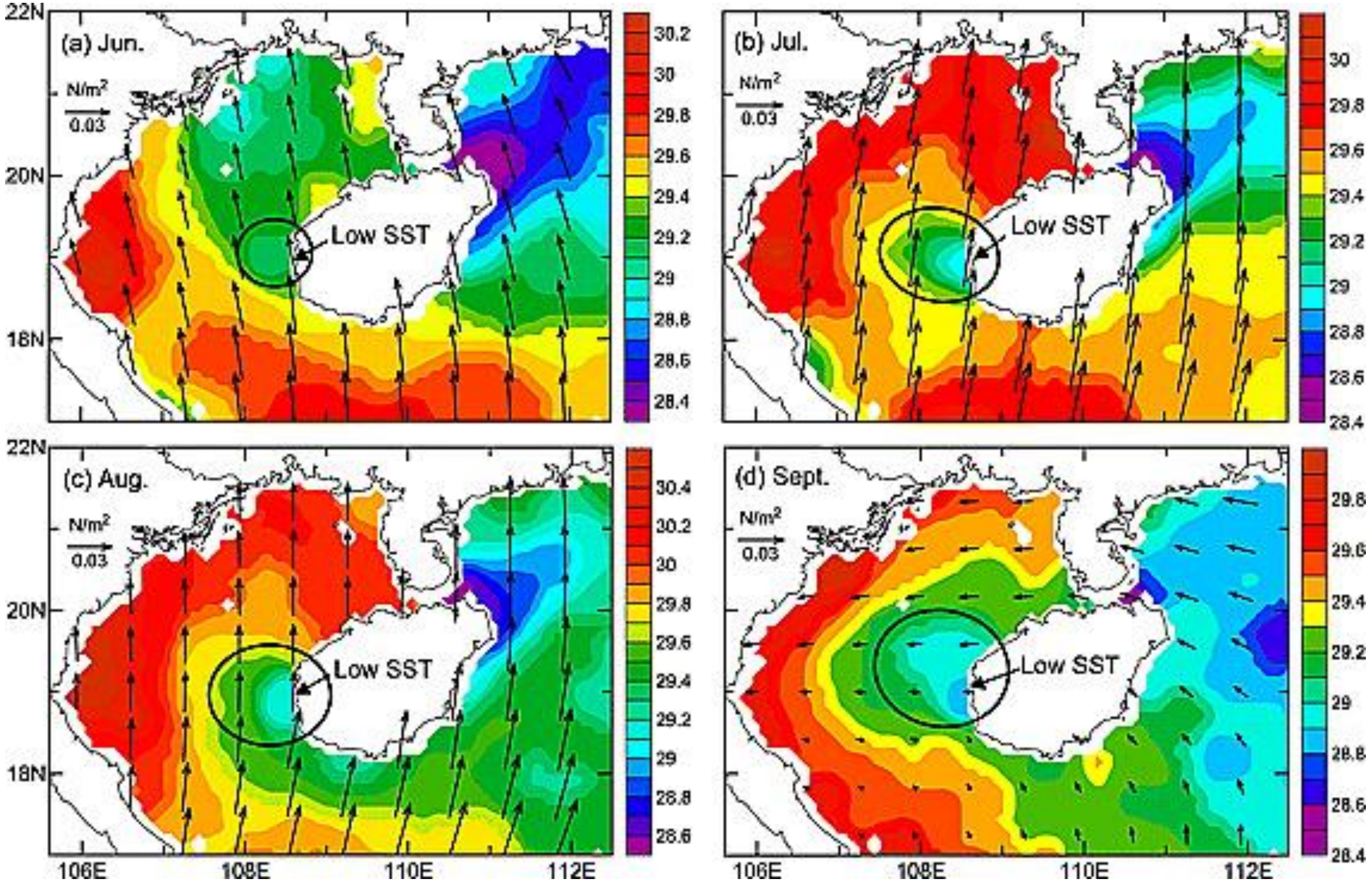

New upwelling site, North-west of Borneo

# Hainan Island Upwelling



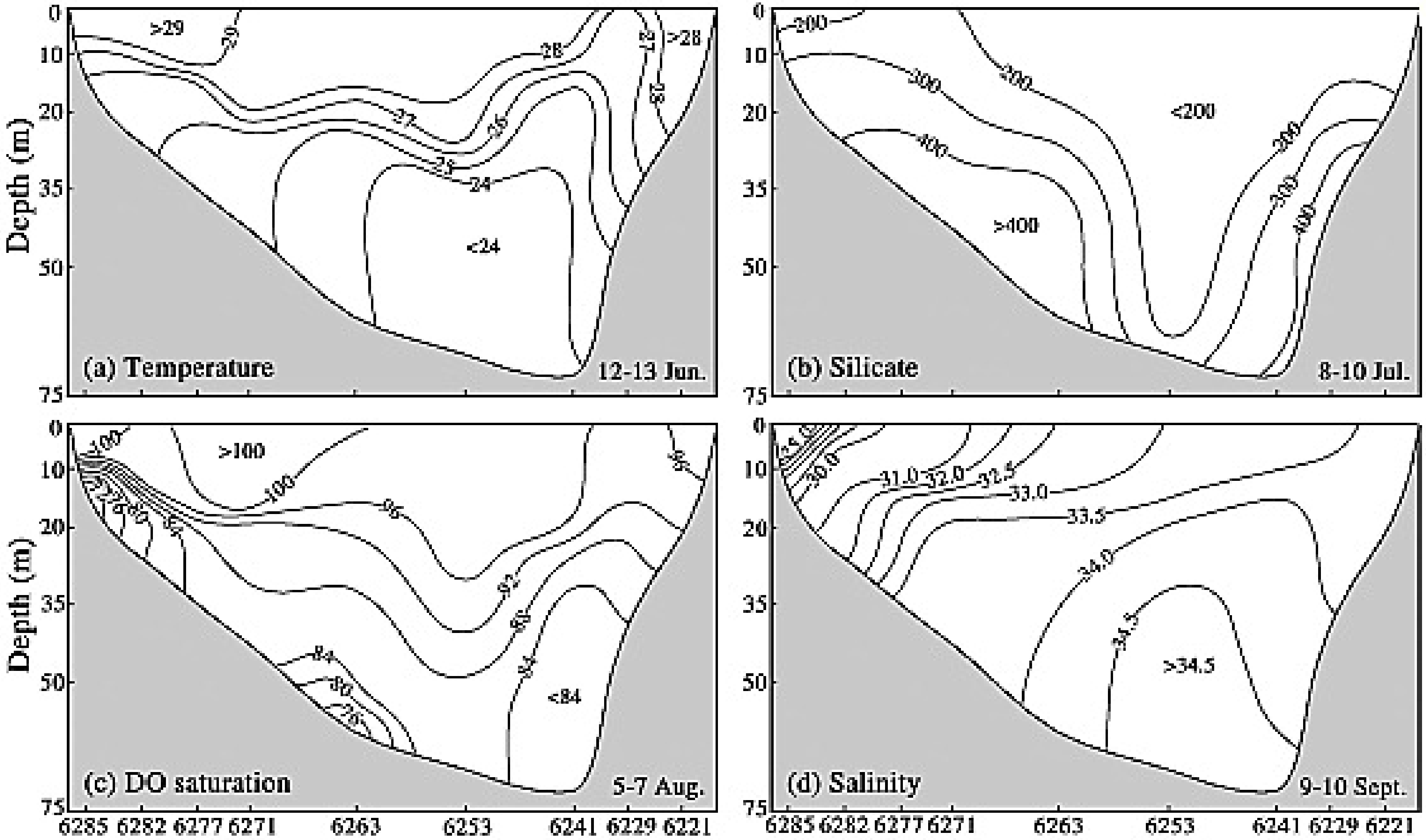



# Upwelling off the west coast of Hainan Island in summer



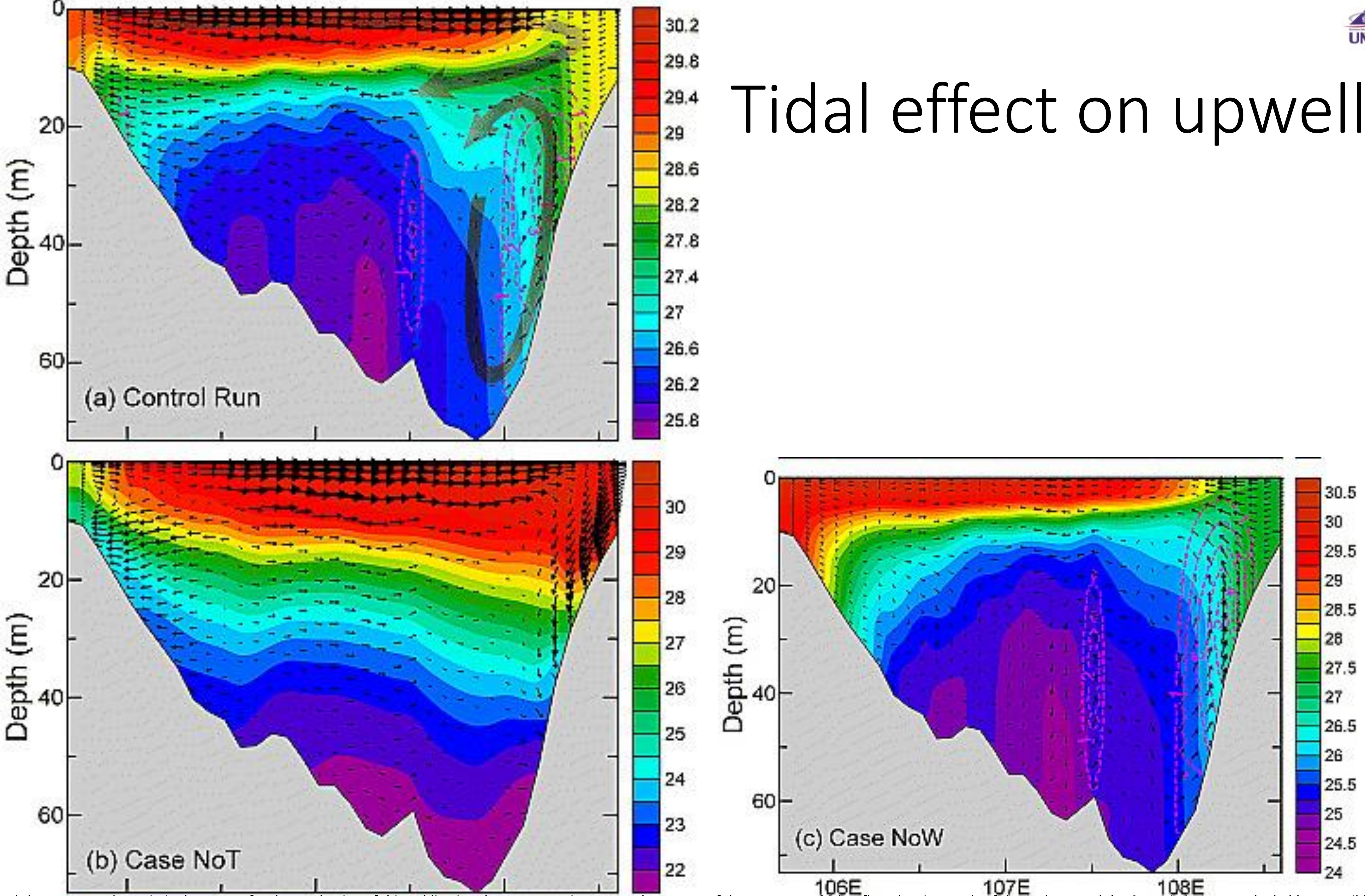


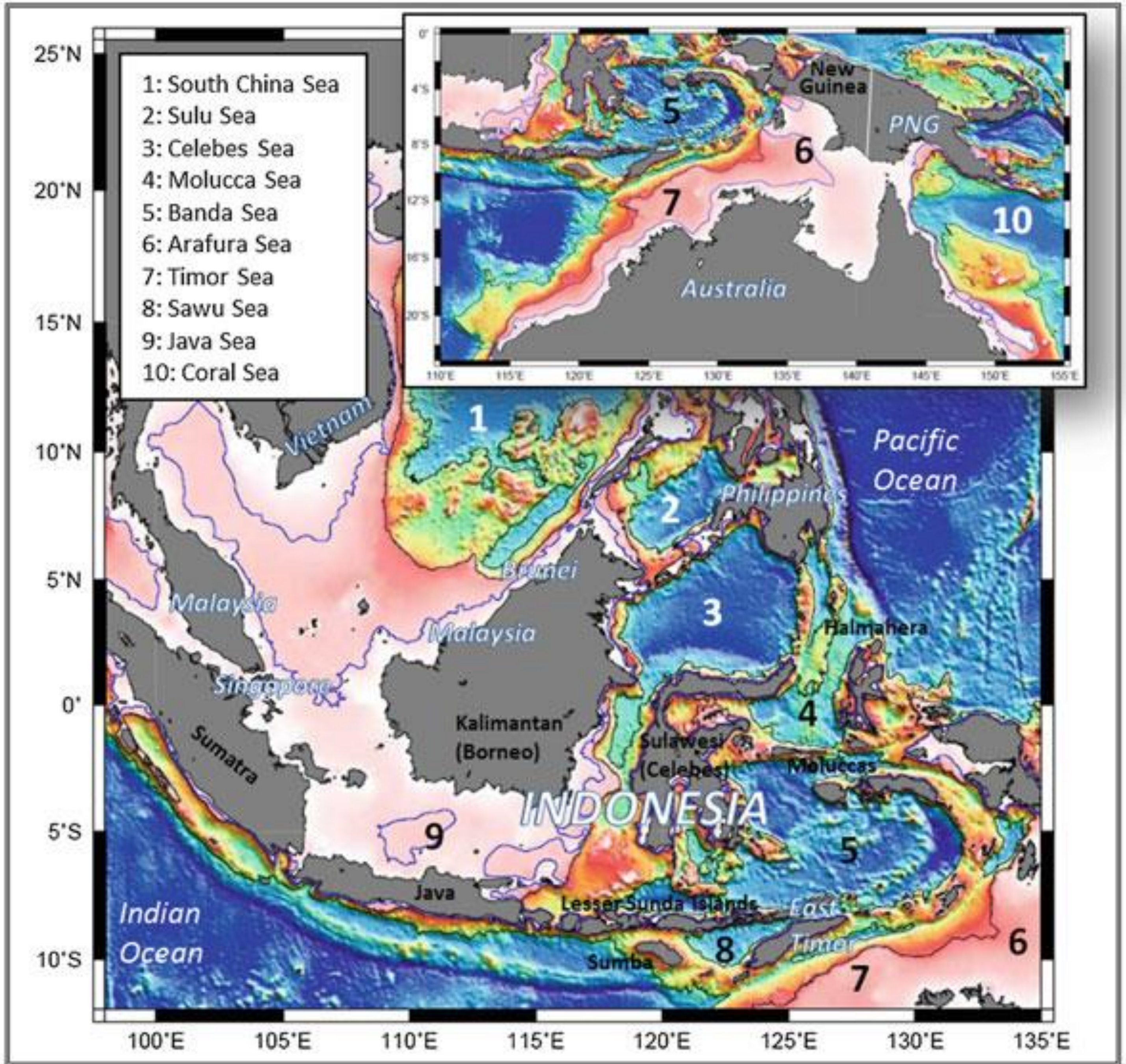
**Geophysical Research Letters**
Volume 35, Issue 2, L02604, 18 JAN 2008 DOI: 10.1029/2007GL032440
http://onlinelibrary.wiley.com/doi/10.1029/2007GL032440/full#grl24116-fig-0002

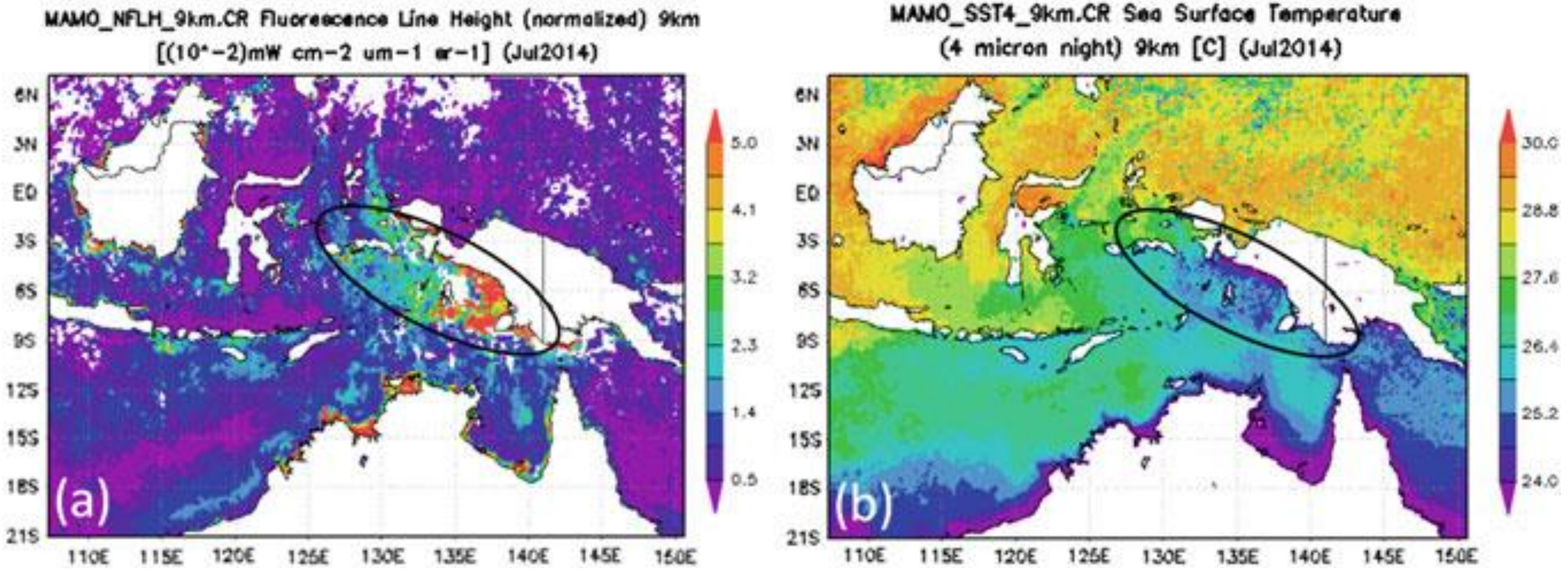



- Vertical distributions of (a) sea temperature (°C), (b) silicate ($\mu$g $L^{-1}$), (c) DO saturation (mL $L^{-1}$), and (d) salinity on cross section along 19°N (see Figure 1 for the transect location)

# Tidal effect on upwelling




1: South China Sea
2: Sulu Sea
3: Celebes Sea
4: Molucca Sea
5: Banda Sea
6: Arafura Sea
7: Timor Sea
8: Sawu Sea
9: Java Sea
10: Coral Sea
New Guinea
PNG
Australia
Vietnam
Pacific Ocean
Philippines
Brunei
Malaysia
Malaysia
Singapore
Halmahera
Sumatra
Kalimantan (Borneo)
Sulawesi (Celebes)
Moluccas
INDONESIA
Java
Lesser Sunda Islands
East Timor
Sumba
Indian Ocean
25°N
20°N
15°N
10°N
5°N
0°
5°S
10°S
100°E
105°E
110°E
115°E
120°E
125°E
130°E
135°E

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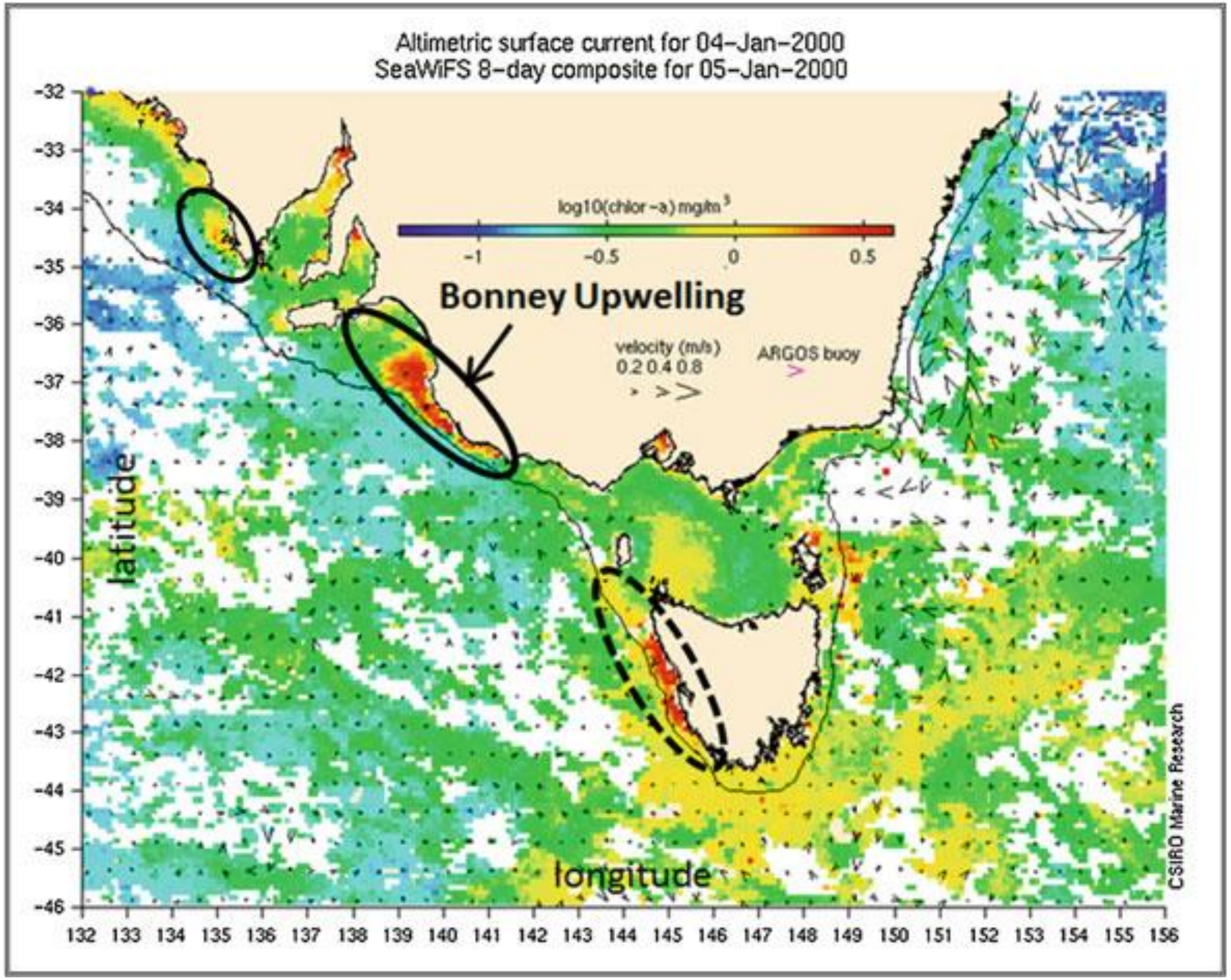
Altimetric surface current for 04-Jan-2000
SeaWiFS 8-day composite for 05-Jan-2000
log10(chlor-a) mg/m3
-1 -0.5 0 0.5
Bonney Upwelling
velocity (m/s)
0.2 0.4 0.8
ARGOS buoy
latitude
longitude
-32 -33 -34 -35 -36 -37 -38 -39 -40 -41 -42 -43 -44 -45 -46
132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156
CSIRO Marine Research

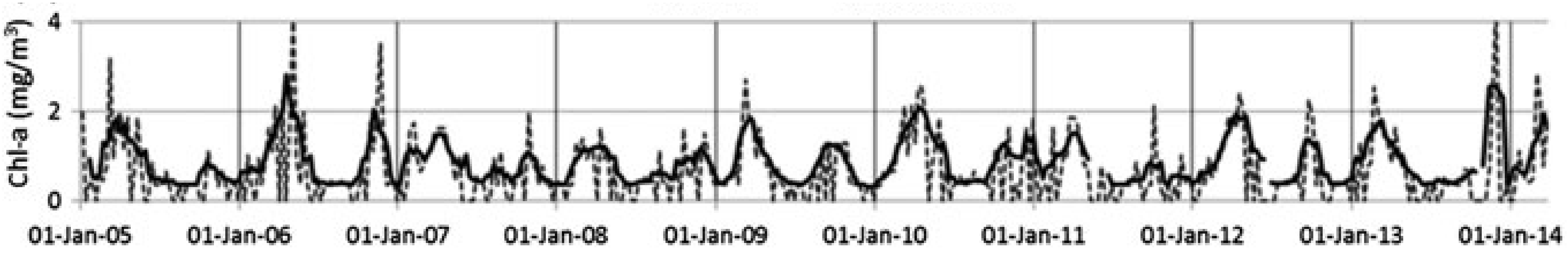


**Fig. 8.13** Reconstructed time series of chlorophyll-*a* concentrations for upwelling centres off the Bonney coast and the west Tasmanian coast (from Kämpf 2015)

# Upwelling Index

- The volume of water transported by time unit and distance unit through an along-shore transect.
- Upwelling indices was to develop simple time series that represent variations in coastal upwelling.
- UI has also been used extensively in biological oceanographic studies in the Galician region; in phytoplankton species distribution, mussel growth, micro plankton variability, on the study of the benthic regime and phytoplankton assemblages and in fisheries research.

https://www.tandfonline.com/doi/pdf/10.1080/1755876X.2014.11020152

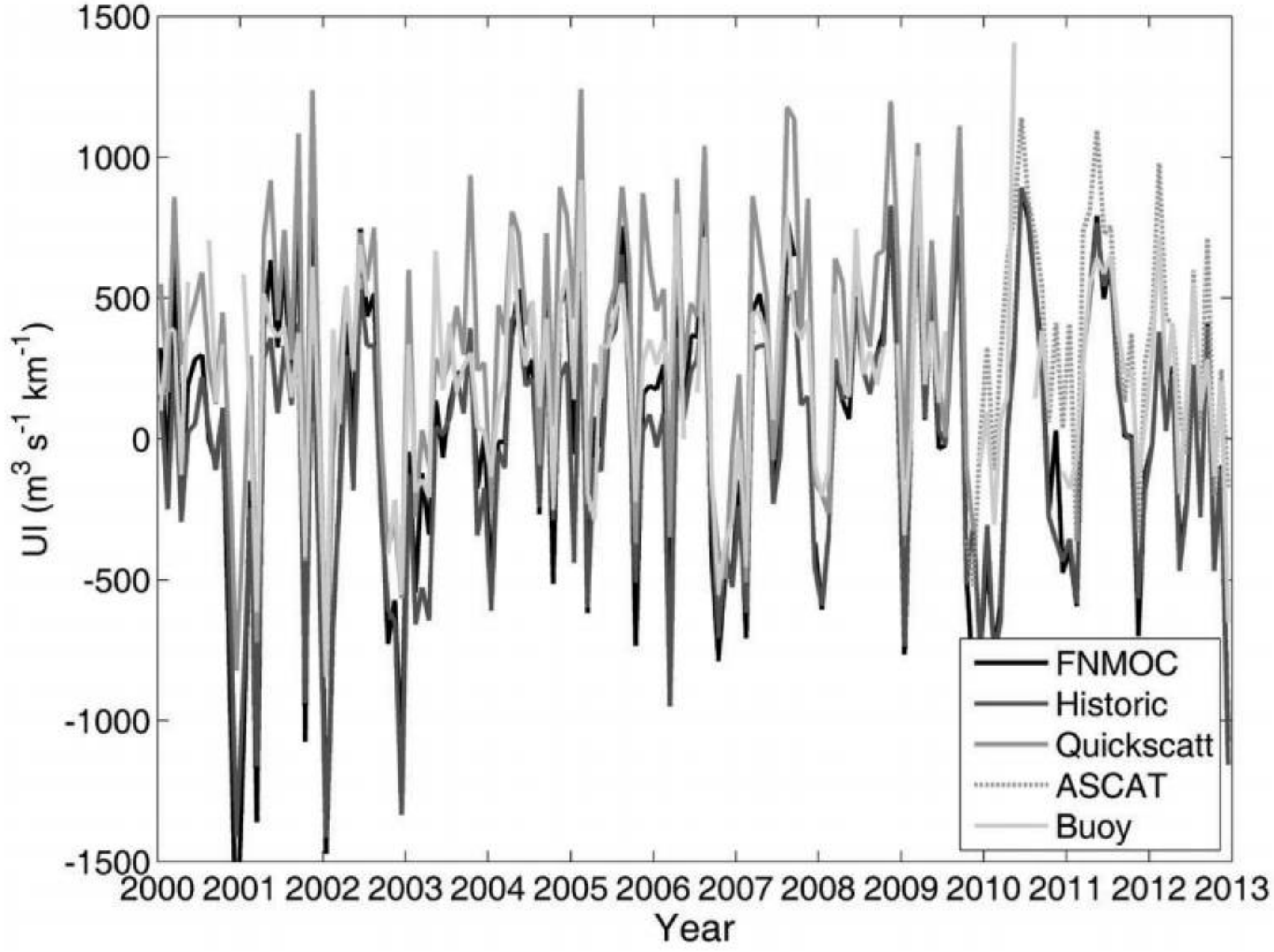


Fig 2: Monthly time series of UI derived from different data sources a) $UI_{FNMOC}$, b) $UI_{H}$, c) $UI_{SAT}$ and d) $UI_{buoy}$.

# Assignment: Scientific Article Review

Read all 3 papers;

Please write a short summary (1 page) on the upwelling forcing from all the 3 site, please highlights the similarity and distinguish the uniqueness of each upwelling site.


- Zhe-Wen Zheng, Quanan Zheng, Yi-Chun Kuo, Ganesh Gopalakrishnan, Chia-Ying Lee, Chung-Ru Ho, Nan-Jung Kuo, Shih-Jen Huang,(2016) Impacts of coastal upwelling off east Vietnam on the regional winds system: An air-sea-land interaction, Dynamics of Atmospheres and Oceans,Volume 76, Part 1

- Kämpf, J. (2016), On the majestic seasonal upwelling system of the Arafura Sea, *J. Geophys. Res. Oceans*, 121, 1218– 1228, doi:10.1002/2015JC011197.

- P.H.Kok, M.F. Akhir, F. Qiao. (2019) Distinctive characteristics of upwelling along the Peninsular Malaysia's east coast during 2009/10 and 2015/16 El Niños. Continental Shelf Research

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# CHEMICAL OCEANOGRAPHY

## Why This Field Is Important?

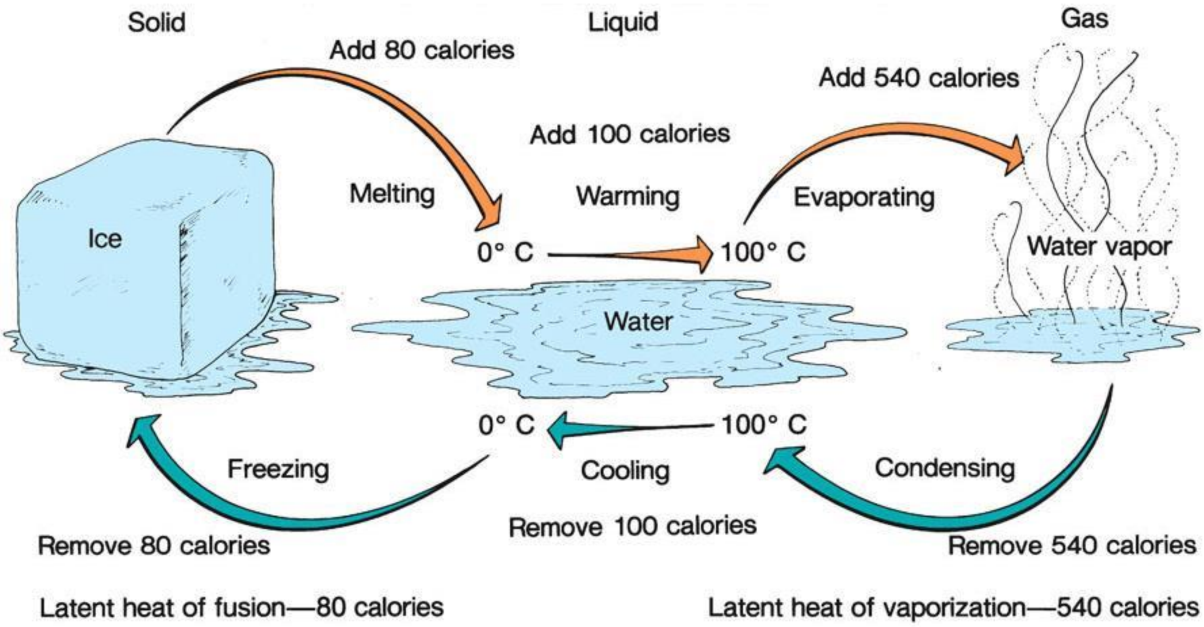
- Global Climate changes
- Key factor for the ocean primary production.
  - Photosynthesis
  - Respiration
- As the world enters the 21st century there was increased focus on carbon cycle
- $CO_2$ and other greenhouse gases are increasing in the atmosphere → Ocean acidification
- Marine pollutions issue

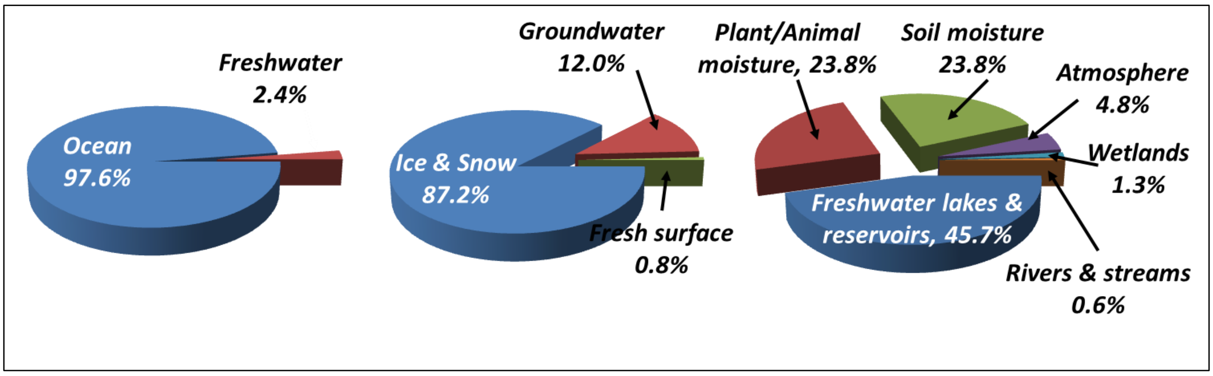
## Introduction

- Oceanography is the study of all aspects of the ocean.
- The study of oceanography is interdisciplinary.
- Oceanography covers a wide range of topics, from marine life and ecosystems, to currents and waves, to the movement of sediments, to seafloor geology.
- Chemical oceanography is the study of the origin and composition of seawater, relationships between chemical compounds, and how the chemistry of the ocean affects, or is affected by biological, geological and physical processes.

## Seawater Composition

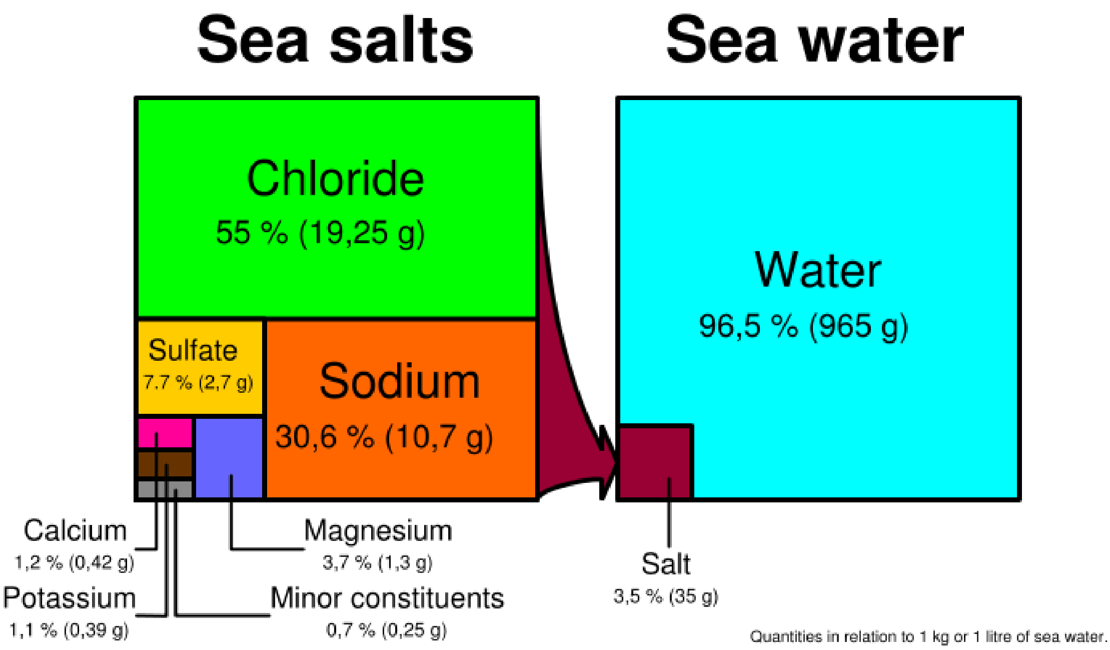
- Water is present on Earth in three phases – solid, liquid and gas






- Nearly all the world's water is the OCEANS.
- Only about 0.02% of the world's water is in a form accessible to human and organisms that rely on fresh water.

- Seawater is a complex mixture of 96.5% water, 3.5% salts, and smaller amounts of other substances, including dissolved inorganic and organic materials, particulates, and a few atmospheric gases.




- Seawater can be subdivided into 4 phases:
  1. Dissolved solutes (passes through a 0.7 µm filter)
     a) Inorganic solutes
        i. Major (> 1 ppm)
        ii. Minor (< 1 ppm)
     b) Organic solute

2. Colloids (passes through a 0.7 µm filter, but is not dissolved)
   a) Organic
   b) Inorganic

3. Solids (does not pass through a 0.7 µm filter)
   a) Particulate organic material (plants detritus)
   b) Particulate inorganic material (minerals)

4. Gases
   a) Conservative ($N_2$, Ar, Xe)
   b) Nonconservative ($O_2$ & $CO_2$)

- Chemical composition of seawater in order of abundance

| Category | Examples | Concentrations Range |
|---|---|---|
| Major ions | $Cl^-$, $Na^+$, $Mg^{2+}$, $SO_4^{2-}$, $Ca^{2+}$, $K^+$ | mM |
| Minor ions | $HCO_3^-$, $Br^-$, $Sr^{2+}$, $F^-$ | µM |
| Gases | $N_2$, $O_2$, Ar, $CO_2$, $N_2O$, $H_2S$, $H_2$, $CH_4$ | nM to mM |
| Nutrients | $NO_3^-$, $NO_2^-$, $NH_4^+$, $PO_4^{3-}$, $H_4SiO_4$ | µM |
| Trace metals | Ni, Li, Fe, Mn, Zn, Pb, Cu, Co, U, Hg | <0.05 µM |
| Dissolved organic compounds | Amino acids, humic acids | ng/L to mg/L |
| Colloids | Sea foam, flocs | ≤ mg/L |
| Particulate matter | Sand, clay, dead tissues, marine organisms, feces | µg/L to mg/L |

**Why is Seawater Salty?**

- The salts found in seawater originated from rocks and sediments on land.
- As rain fell on the land masses of the prehistoric earth, the minerals in the rocks dissolved in the rainwater and flowed into the sea.
- Once in the sea, evaporation takes water up into the air where it is recycled as rain, but the salts remain behind.
- As time progressed, more and more of these minerals were left behind in the sea as salt ions.
- Slowly over time the salinity of the sea increased to its present level.

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**Seawater Salinity**

- Variations of salinity in ocean occur due to several factors.
  1. The most common factor is the relative amount of evaporation or precipitation in an area.

     evaporation > precipitation → salinity increases

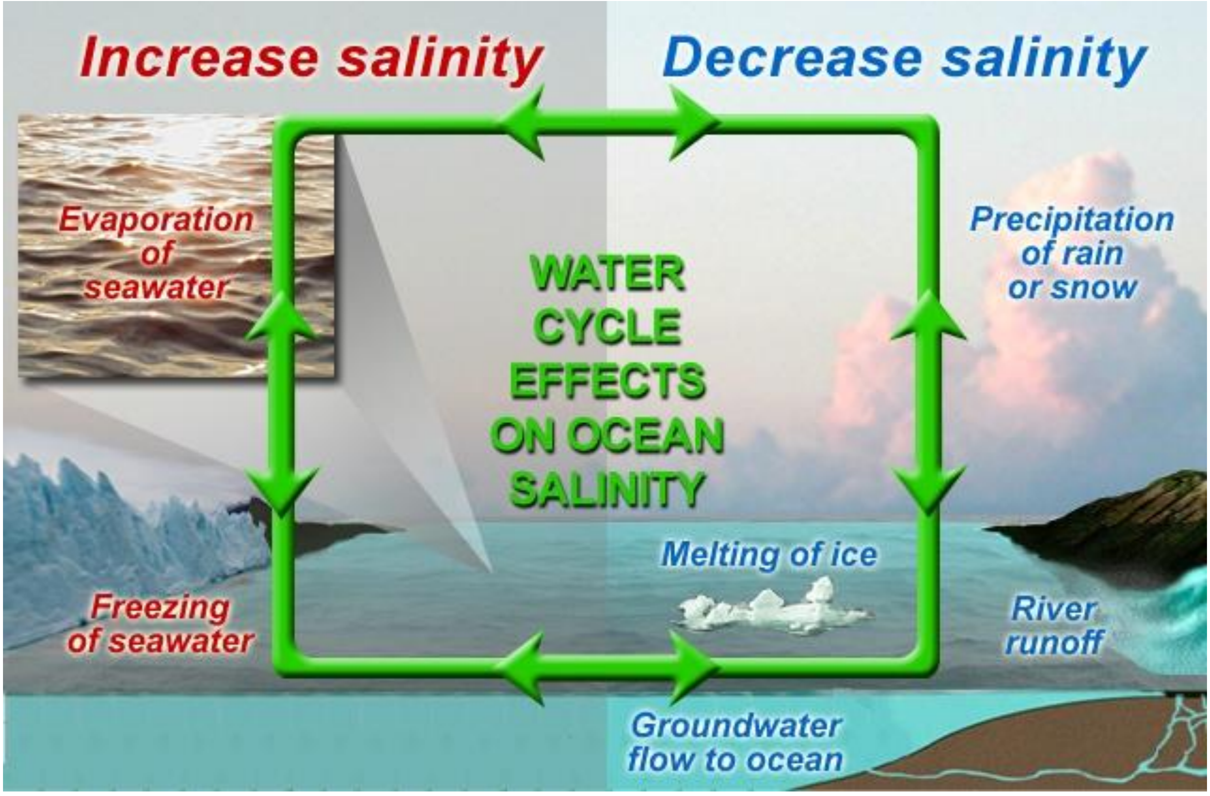
     evaporation < precipitation → salinity decreases

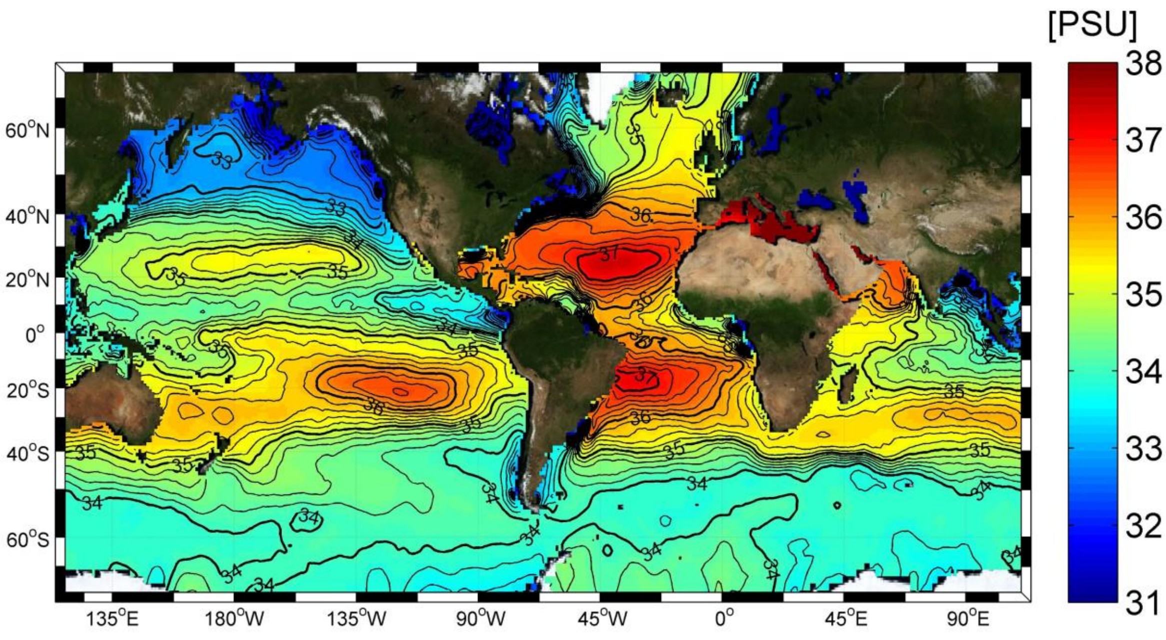
  2. The river that flows into the ocean.

     The runoff from most small streams/rivers is quickly mixed with ocean water by the currents and has little effect on salinity. Large rivers (e.g. Amazon River) may have little or no salt content for over a mile or more out to sea.

  3. The freezing and thawing of ice also affects salinity.

     The thawing of large icebergs (made of frozen freshwater and lacking any salt) will decrease the salinity while the actual freezing of seawater will increase the salinity temporarily.






- Low salinity is found in cold seas, particularly during the summer season when ice melts.
- High salinity is found in the ocean 'deserts' and due to cool dry air descending and warming up, these desert zones have very little rainfall, and high evaporation.
- The Red Sea located in the desert region but almost completely closed, shows the highest salinity of all (40ppt), Mediterranean Sea (38ppt).

**Seawater major Component**

- Major Ions in Seawater (>99% of ions):
  - Chloride ($Cl^-$) (55.1%)
  - Sodium ($Na^+$) (30.6%)
  - Sulfate ($SO_4^{2-}$) (7.7%)
  - Magnesium ($Mg^{2+}$) (3.7%)
  - Calcium ($Ca^{2+}$) (1.2%)
  - Potassium ($K^+$) (1.1%)

- Generally behave conservatively i.e. their concentrations vary little except at ocean boundaries, where they may be changed by input or output process (eg. In estuaries due to dilution by river discharges, atmospheric deposition).

**Seawater Trace Element**

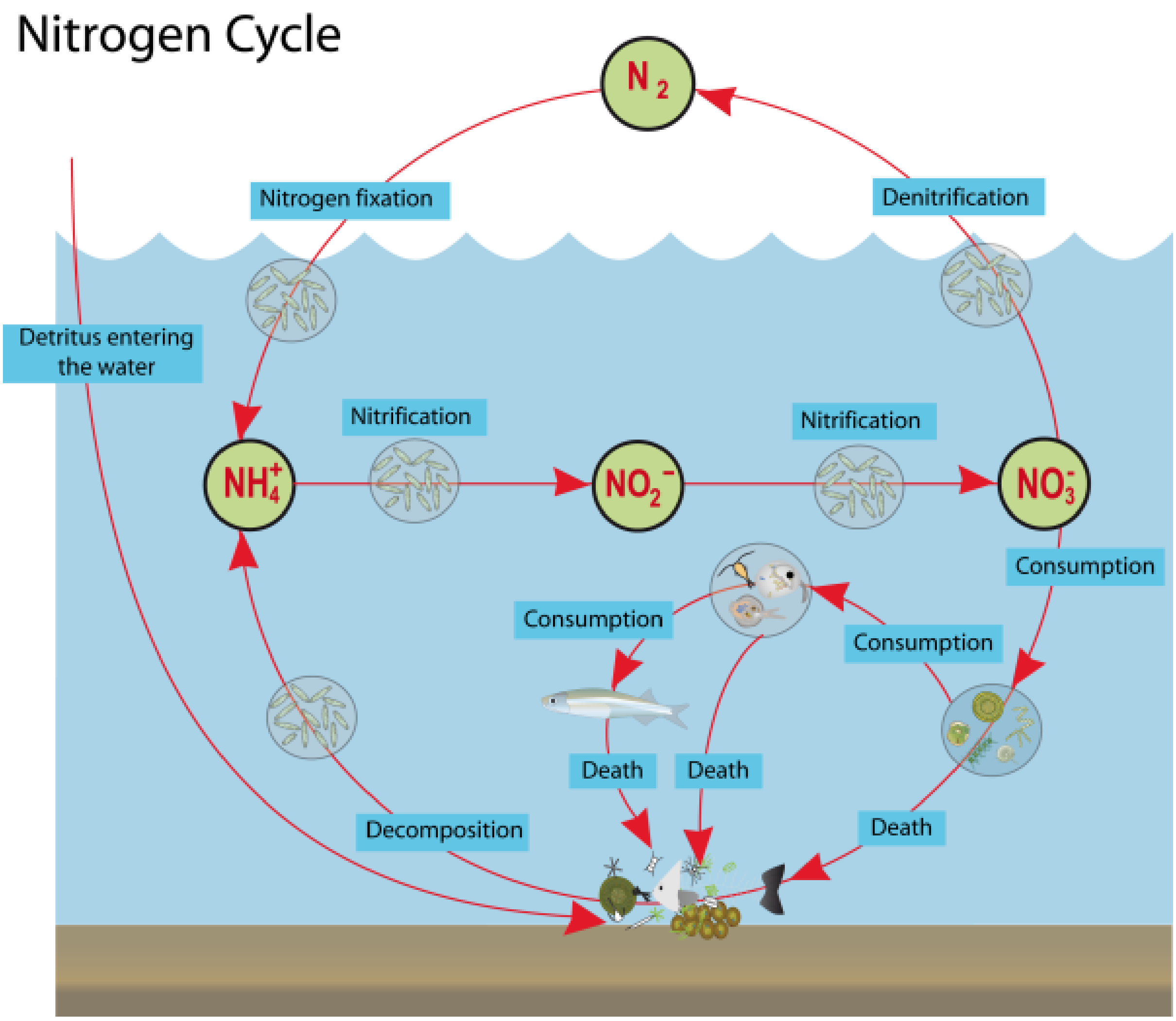
- Trace element → those elements (less than 1 mg/kg) that do not contribute to salinity.
  - alkali metal ions Li+ & Rb+
  - alkaline earth cation Ba2+
  - transition metal molybdenum (as MoO42-)
  - halogen iodine (as $IO_3$- & $I^-$)

- Sources
    i. riverine & atmospheric influx
    ii. anthropogenic input
    iii. hydrothermal activity at seafloor
- Estuaries act as a filter.
    - Bottom sediments serve as a reservoir for trace elements and may be released to overlying waters by dissolution, desorption & biological processes.
    - Trace metal mobilization is facilitated by changes in pH & redox potential in the sediment column.
    - Physical factors (eg. wave action, currents) also promote mobilization of the metals from bottom sediments.
- Trace elements important to the life processes of marine organisms:
    - Co, Cu, Fe, Mn, Mo, Va & Zn are essential elements for functioning of marine flora & fauna.
    - Co & Fe are required for N metabolism.
    - Fe, Mn, Va are needed for photosynthesis.
- Toxicity of trace elements

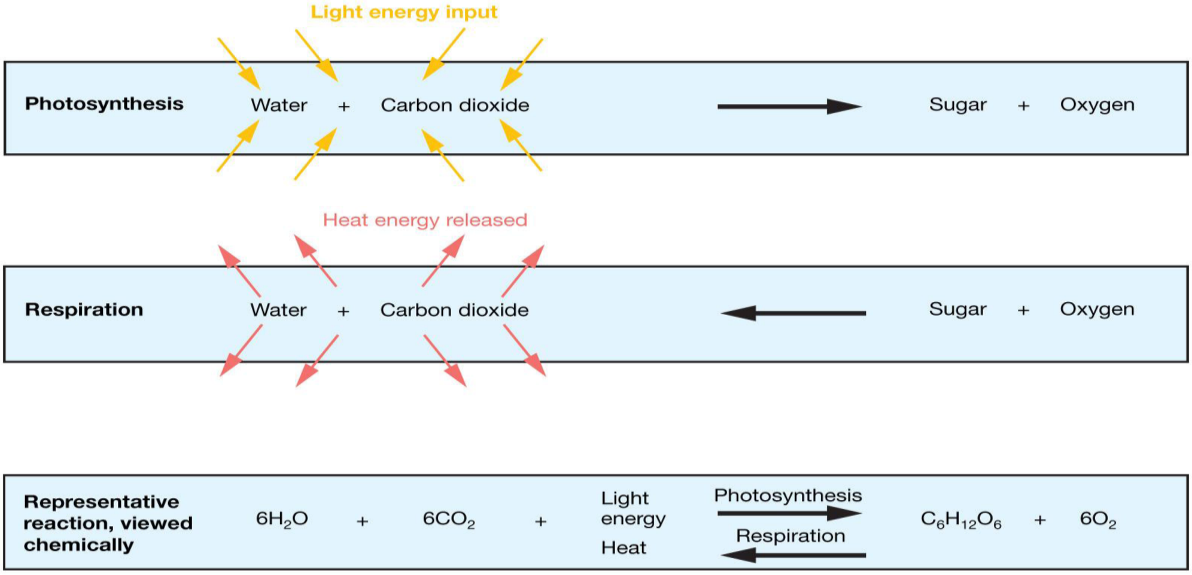
$$Co<Al<Cr<Pb<Ni<Zn<Cu<Cd<Hg$$

**Phytoplankton Nutrients**

- Inorganic sources of N, P, Si and other atoms required for phytoplankton growth
- Photosynthesis and respiration contributes in nutrient distribution
- The concentration of N, P & Si in near-surface waters of the ocean are 0.07, 0.5 & 3 ppm respectively.
- Especially important, because so much is needed, are N (nitrogen) and P (phosphorus).
- Si (silica) is also important for all the siliceous organisms : diatoms and siliceous sponges.
- N is necessary to make proteins.
- P is necessary to make new cells (it's part of the cell wall), and also genetic material, DNA and RNA.
- N is useful for plants only in these forms:
    i. $NO_3^-$ nitrate (1-500 μM)
    ii. $NO_2^-$ nitrite (0.1-50 μM)
    iii. $NH_4^+$ ammonium (1-50 μM)
- $N_2$, the gas, is not usable by most plants.
- Only a few bacteria can break this very strong molecule ($N_2$) apart and turn it into nitrate.
- These are 'nitrogen-fixing bacteria'.
- P is useful in the form of phosphate, $PO_4^{3-}$




**Photosynthesis vs Respirator**



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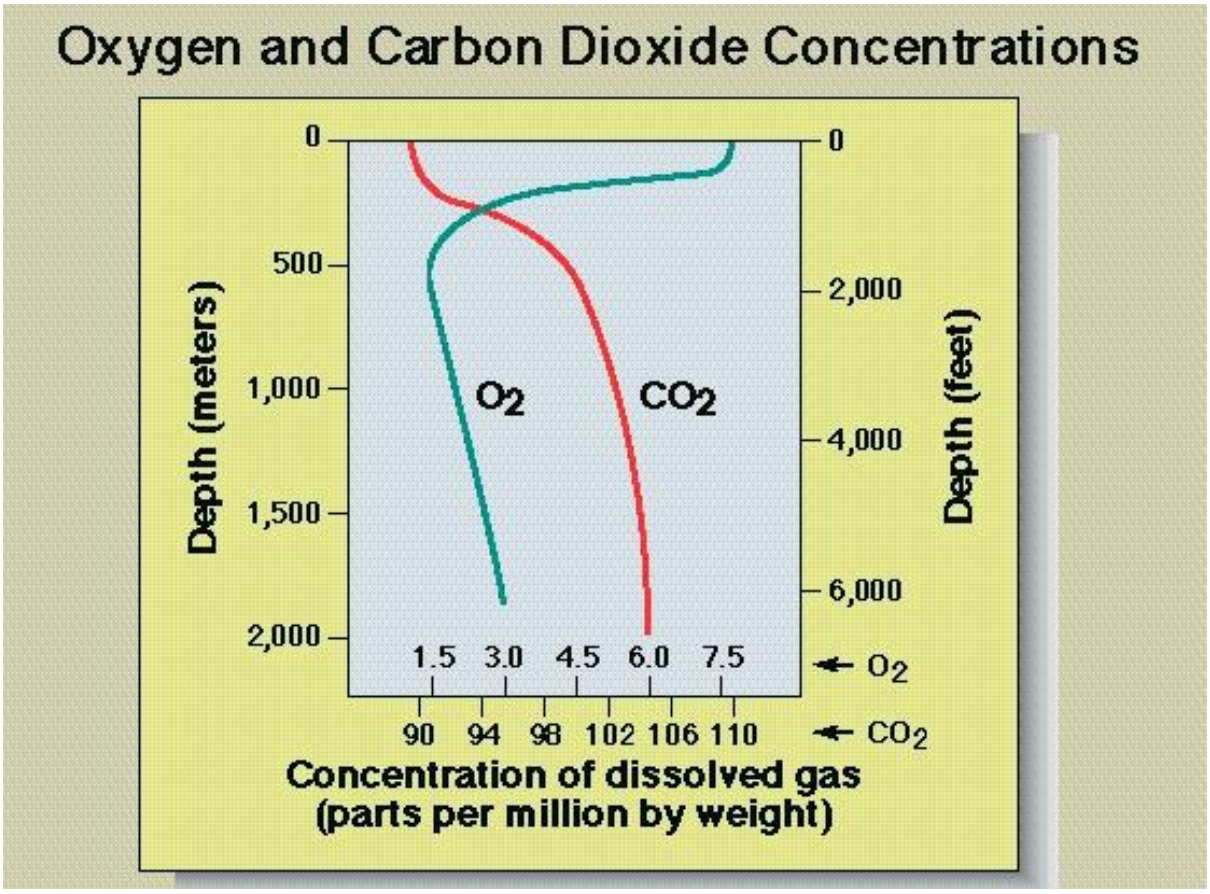
**Dissolve Gas**

- The proportions of gases in the atmosphere is not the same as their proportions in seawater.

$$N_2 = 48\%, O_2 = 36\%, CO_2 = 15\%$$

- There is less $N_2$ (nitrogen gas) in the ocean than in the atmosphere,
- Much more oxygen, and even more $CO_2$.
- All this $CO_2$ in the oceans keeps CO2 from being in the atmosphere and causing global warming.




- The colder the water, the more gas can dissolve in it.
  - When you leave your can of pop in the car in the sun, then open it, what happens?
  - Pop sprays all over you.
  - That's because the gas has exsolved (come out of solution); a lot has accumulated in the little space at the top of the can.
- Very active fish, such as trout and salmon, require very cold water to live in because they have high oxygen requirements.
- They literally suffocate when the water gets too warm, and the oxygen levels drop.
- This explain why these fish don't live down south.

**Carbon Dioxide**

- $CO_2$ is important because it is needed by plants so they can photosynthesis.
- $O_2$ is important because animals need it for respiration:
- photosynthesis

$$CO_2 + H_2O + \text{energy} \rightarrow O_2 + \text{sugar (organic matter)}$$

- respiration (the reverse of photosynthesis)

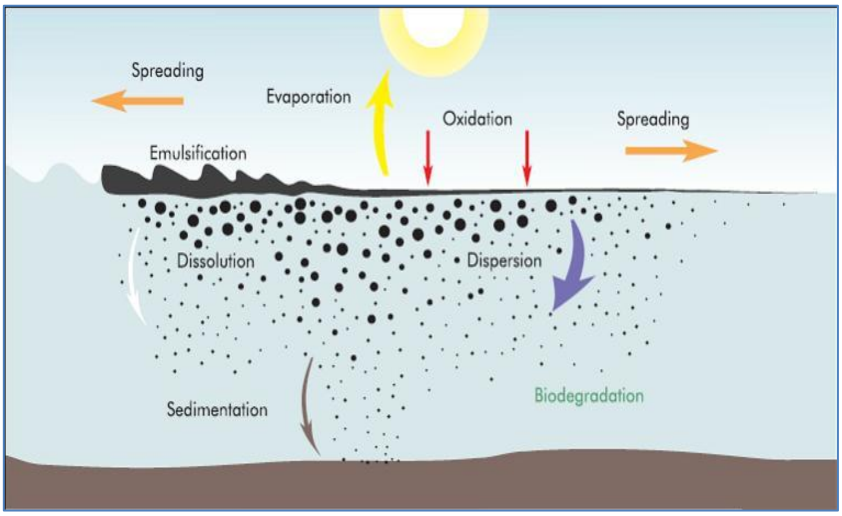
$$O_2 + \text{sugar} \rightarrow CO_2 + H_2O + \text{energy}$$

# OIL POLLUTION

## Oil Spill

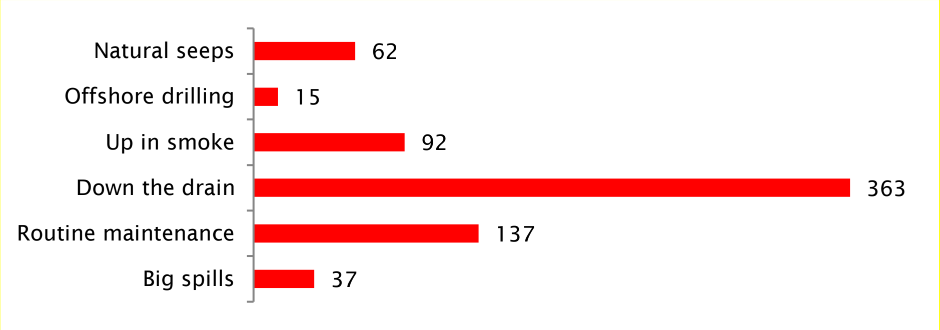
- Oil spill → release of a liquid petroleum hydrocarbon into the environment, especially marine areas, due to human activity and is a form of pollution
- The term is usually applied to marine oil spills, where oil is released into the ocean or coastal waters, but spills may also occur on land

## Fate of Oil in Water




## Source of Oil Pollution

- Although the major source of marine oil pollution might appear to be accidental oil spills but.....
- Tanker accidents account for less than 7% of the oil discharged into the ocean
- Nearly 43% of oil discharged into marine environment enters the oceans via urban storm drainage systems and industrial discharges
- EXAMPLE : Oil spills and leaks during car maintenance / illegal discharge and dumping of waste oil
- The graph below shows how many millions of gallons of oil each source puts into the oceans worldwide each year




**Municipal and industries waste**

- Domestic waste contain oils and greases
- During rains, iridescence caused by oil and petrol can be seen on the roads
- Spilled oil from garage – washed into the drains – reached the sea.

**Tanker ship operation**

- Segregated ballast – **ballast water** is carried in separate compartments
- At loading terminal, cargo is loaded on top of the oil in the slop tank

**Dry docking**

- All ship require periodic dry docking for servicing repairs cleaning etc→ ship repair yards should provide slop reception facilities

**Marine Terminal**

- Accidents through human error and pipeline failure during loading and discharging oil at terminal – care taken to minimize accident

**Bilge and fuel oils**

- Ballast water system : when pumped overboard it carries oil into the sea
- In addition, all shipping needs to pump out bilge water which contains oil from the ship's engine.

**Tanker ship accidents**

**Non-tanker ship accidents**

- Cargo ships - fuel oil lost to the sea.

### Offshore oil production

- Oil extracted from seabed contain some water, must be extracted on the platform before transported to the refinery
- Drilling oil well – oil-based mud is separate from drill cuttings - dumped on the seabed beneath platform
- Blow-outs are the uncontrolled release of oil from the well – need great precaution

### Atmosphere input

- Incomplete combustion of petrol or diesel in motor vehicles and gas flared-off at oil platforms – washed out in rain

### License dumping

- Shipping channels in estuaries and ports need regular dredging
- The dredging spoil which is usually dumped at sea is contaminated with oil

### Natural input

- Natural sources – oil deposits close to the earth surface seep out

### Oil Spill Impact

- Smaller spills have already proven to have a great impact on ecosystems – remoteness of the site or the difficulty of an emergency environmental response
- Oil spills at sea are generally much more damaging than those on land, since they can spread for hundreds of nautical miles in a thin oil slick which can cover beaches with a thin coating of oil
- This can kill sea birds, mammals, shellfish and other organisms it coats
- Seafood Safety with Oil Chemical
  - Oil spills can prompt concern about the seafood safety
  - Bioaccumulation in seafood (fish or shellfish) can occur through food items, water, sediment, or through skin and gills
  - Polycyclic aromatic hydrocarbons (PAHs) are the chemicals in petroleum - based oils most likely to bioaccumulate in seafood tissues
- Different Seafood Species Affected by Oil Spills
  - Fish – less likely to be exposed to oil than other marine organism

    Oil floats – fish usually don’t come into contact with oil
  - Crustacean (such as lobster, crabs) – can move away from oil

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- Mollusks (such as mussel, clams) – the most affected by oil spills

  Anchor themselves – can't avoid spilled oil

- Although only a small percentage of oil enters the ocean from major oil spills, it is from studies during those events that we understand the extreme toxicity oil has on marine animals
- A smaller spill at the sensitive environment may prove much more harmful than a larger spill

- EXAMPLE :
  - Year 1976, a spill estimated to have been less than 10 tons killed more than 60,000 long-tailed ducks in the Baltic Sea
  - Year 1989, 40,000 tons of Exxon Valdez oil spill in Alaskan waters killed more than 250,000 birds
- Oil penetrates into the structure of the plumage of birds and the fur, reducing its insulating ability, and making them more vulnerable to temperature fluctuations and much less buoyant in the water
- As they preen, birds may ingest the oil coating their feathers, irritating the digestive tract, altering liver function and causing kidney damage
- As they preen, birds may ingest the oil coating their feathers, irritating the digestive tract, altering liver function and causing kidney damage
- The thick, sticky oil coats the feathers on birds, inhibiting flight and the ability of those feathers to insulate the bird
- The gills of fish become clogged with oil, and the fish suffocate
- Marine mammals' bodies become coated in oil, and they cannot maintain their body temperatures
- Heavily furred marine mammals exposed to oil spills are affected in similar ways
- Oil coats the fur of sea otters and seals, reducing its insulating effect, and leading to fluctuations in body temperature and hypothermia
- Oil can also blind an animal, leaving it defenceless
- Animals can be poisoned, and may die from oil entering the lungs or liver
- Oil coated marine plants cannot obtain energy from the sun for photosynthesis
- Oil may also become trapped in sediments for many years and may become suspended again in storms or dredging.

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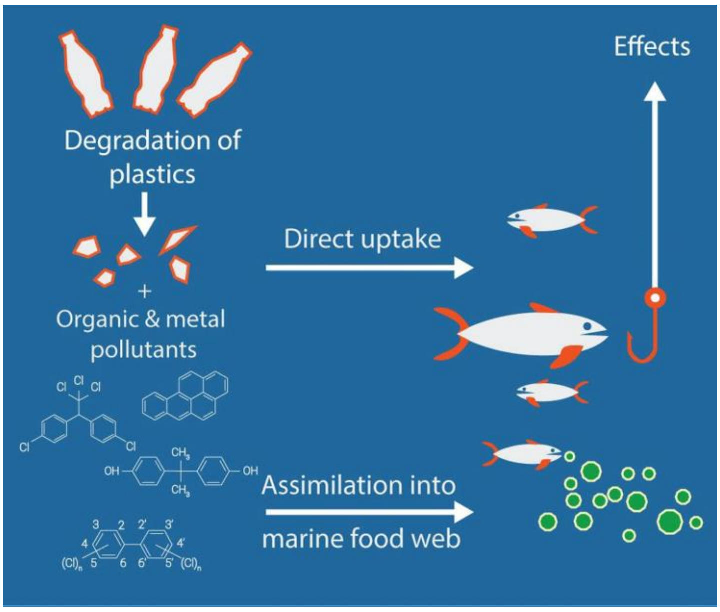
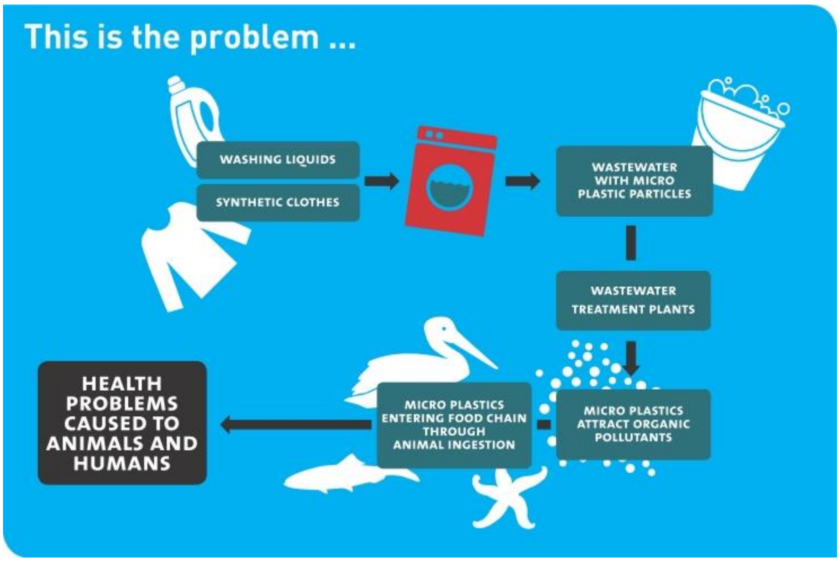
**MICROPLASTICS POLLUTION**

- Microplastics can come from a variety of sources including larger plastic pieces that have broken apart, resin pellets used for plastic manufacturing, or in the form of microbeads, which are small, manufactured plastic beads used in health and beauty products.
- Microplastics are small plastic pieces less than 5mm long which can be harmful to our ocean and aquatic life.
- Microplastics come from a variety of sources, including from larger plastic debris that degrades into smaller and smaller pieces.
- Microbeads, a type of microplastic, are very tiny pieces of manufactured polyethylene plastic that are added as exfoliants to health and beauty products, such as some cleansers and toothpastes.
- These tiny particles easily pass through water filtration systems and end up in the ocean posing a potential threat to aquatic life.






**DEBRIS POLLUTION**

- Marine debris is any man-made object intentionally or unintentionally discarded, disposed of or abandoned that enters the marine environment
- Also known as litter, is human created waste that has deliberately or accidentally been released in the ocean, lake and river.
- Marine environment : 80% of debris originates onshore and 20% from offshore sources
- Marine debris is something in the marine environment (ocean and beach) that does not naturally occur there
- More definition according to National Oceanic and Atmospheric Administration (NOAA) is :

  " any persistent solid material that is manufactured or processed and directly, intentionally or unintentionally, disposed of or abandoned into the marine environment "
- Aquatic debris is a problem with no geographical boundaries.
- Although various countries have had a more publicized problem, persistent aquatic debris can be found on just about every coast and waterway in the world

**Type of Marine Debris**

**<u>Plastic</u>**

- As society has developed new uses for plastics, the variety and quantity of plastic items found in the marine environment has **increased dramatically**

- These products range from common domestic material (bags, cups, bottles, balloons) to industrial products (strapping bands, plastic sheeting, hard hats, resin pellets) to lost or discarded fishing gear (nets, buoys, traps, lines).

## Glass, Metal, Styrofoam, and Rubber

- These materials are similar to plastic in that they are used for a wide range of products
- While they can be worn away – broken down into smaller and smaller fragments, they generally **do not biodegrade entirely**
- As these materials are used commonly in our society, their occurrence as marine debris is **overwhelming**

## Derelict Fishing Gear

- Derelict fishing gear (DFG) refers to **nets**, **lines**, **crab/shrimp pots**, and other recreational or commercial fishing equipment that has been **lost**, **abandoned**, or **discarded** in the marine environment.
- Modern gear is generally made of synthetic materials and metal, and lost gear can persist for a very long time.

## Derelict Vessels

- Thousands of **abandoned** and **derelict vessels** litter ports, waterways and estuaries, creating a threat to navigation, recreation, and the environment.
- Many vessels **end up sinking at moorings**, **semi-submerged in the intertidal zone**, or **stranding on shorelines**, **on reefs or in marshes**, and **breaking apart**

## Source of Marine Debris

- Land-based Sources – Indirectly when washed out to the ocean via rivers, streams and storm drains
  - Littering, Dumping, and Poor Waste Management Practices – Intentional or unintentional disposal of domestic or industrial wastes on land or in rivers or streams
  - Extreme Natural Events – Hurricanes, tsunamis, floods and mudslides have devastating effects on human life and property

- Ocean-based Sources – Directly by illegal dumping or accidental loss of debris from a ship and stationary platform
  - Fishing Vessels – Fishing gear may be lost from commercial fishing vessels as well as from recreational boats

  - Cargo Ships and Other Vessels – Cargo lost overboard from freighters, cruise ships and other vessels poses serious threats to marine navigation

- Estimated 10,000 containers at sea each year are lost by container ships, usually during storms
- One famous spillage occurred in the Pacific Ocean in 1992, when thousands of rubber ducks and other toys went overboard during a storm. The toys have since been found all over the world, providing a better understanding of ocean currents
- Similar incidents have happened before, such as when Hansa Carrier dropped 21 containers in 1990 (with one notably containing buoyant Nike shoes) – Great Shoe Spill of 1990

**Threats of Marine Debris**

- Each year, many species of marine animal, including sea birds, marine mammals and sea turtles die from becoming entangled in marine debris or ingesting marine debris they have mistaken for food
- Entanglement – an animal gets ensnared in the loops and opening of debris
- Ingestion – an animal can mistake marine debris for food, accidentally ingest it, and degraded debris can be ingested by filter-feeding organisms
- Smothering – marine debris may disrupt feeding, reproduction, movement or severely impair the health of sessile animals

- Entanglement can occur :
  - accidentally
  - when animal is curious about an object or using it for shelter

- Harmful to marine organism because it can :
  - cause drowning
  - disrupt or prevent feeding
  - restrict movement or ability to swim
  - increase vulnerability to predators
  - result in infection or loss of limbs

- Derelict fishing gear, rope and strapping bands are common items that entangle marine organism
- Ghost nets, lost or abandoned fishing nets hundreds of meters long, threaten protected species and other marine organism

- Ghost nets often become concentrated in relatively small areas by wind and currents and can continue ghost fishing for extremely long periods

- Ingestion can occur :
  - accidentally
  - when an animal feeds on debris that look like food
- Harmful to marine organism because it can :
  - Blockages of the esophagus and intestinal tract can kill organism
  - Sharp object can cause injuries and infections
  - Toxins can accumulate in an animal's tissue affecting the health and wellness of the organism

- Seabird and hatchling sea turtles may eat plastic debris that is toxic, resulting in reproductive failure or death
- Sea turtle may mistake floating debris for food, which can lead to suffocation or intestinal blockage
- Whale can ingest marine debris that can become entangled in the baleen, cause choking or interfere with digestion

## INDUSTRIAL POLLUTION

- Pollution which can be directly linked with industry, in contrast to other pollution sources
- This form of pollution is one of the leading causes of pollution worldwide; estimates that up to 50% of the nation's pollution is caused by industry.
- Industrial pollution is a serious problem for the entire planet, especially in nations which are rapidly industrializing
- Because of the nature of the global environment, industrial pollution is never limited to industrial nations
- EXAMPLE : Samples of ice cores from Antarctica and the Arctic both show high levels of industrial pollutants, illustrating the immense distances which pollutants can travel, and traces of industrial pollutants have been identified in isolated human, animal, and plant populations as well

### Industrial Accident

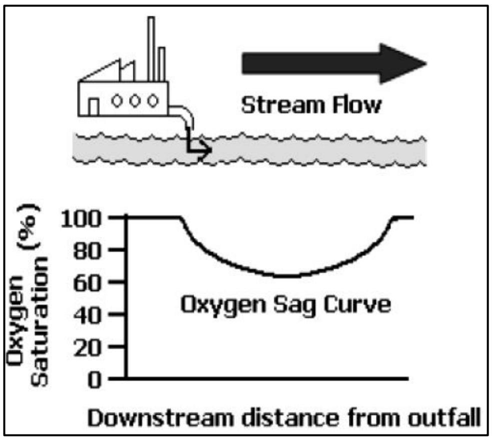
- Industrial accidents may result in extremely large releases of industrial water pollution
- EXAMPLE :
  1. Deep Horizon oil spill that occurred off the Louisiana Coast in the U.S. in 2010, which was the largest oil spill in U.S. history
  2. Union Carbide gas leak in Bhopal, India in 1984 – Pesticide industry
  3. Chernobyl disaster in Ukraine – Nuclear disaster
  4. Fukushima Daiichi in Japan – Nuclear disaster

### Wastewater

- Wastewater from industrial discharge may contain a combination of high BOD (organic substances), high level of suspended solid, and presence of toxic substances
  - Wastes with high BOD
  - Wastes with a high BOD and a significant level of toxic substances
  - Wastes with low (or no) BOD and high level of toxic substances

## Industrial Effluent

### Interaction of Oxygen with Industrial Effluent




- Wastewater from industrial activity may easily have **BOD** due to the **oxidation on organic matters by microorganism**
- If wastewater being discharged into the aquatic system; **oxygen level in water would drop**
- However, as the **distance from outfall increase**, the oxygen influx from atmospheric **will exceed the microbial respiration rate**
- Therefore, the oxygen level is **slowly back to virtually 100% as distance increase**

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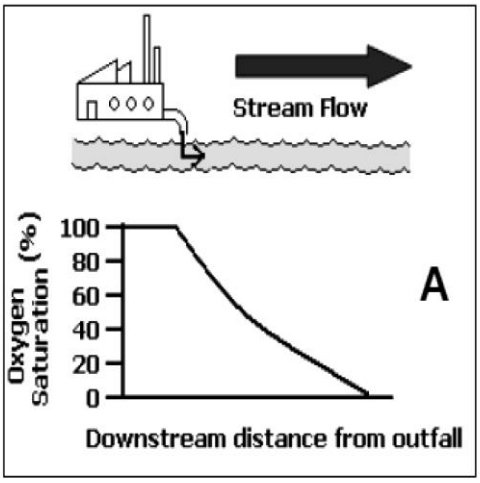


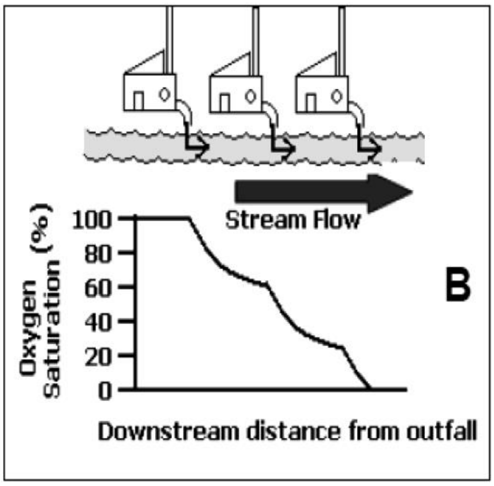


**Picture A**

- The discharge waste is **sufficient high in BOD**

**Picture B**

- There are **2 or more industrial activities**
- The phenomenon occur when the waste from the earlier out are still **apparent in water** and **combine with the new discharge**

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- The water quality along the discharge/river system may **undergoes a deleterious**
- Oxygen concentration may drop to **zero (anoxic)**
- Effect may extend **few kilometers** before the **oxygen raise up** again / back to normal concentration
- Natural fauna would be **completely displaced in the distance**

**AQUACULTURE POLLUTION**

- One of the huge industry, and the world's fastest growing food sector
- Worth a massive US$56 billion globally and provides one-third of the fish people consume
- Farming of fish, shrimp, and shellfish is often is viewed – and marketed – as a way to take pressure off wild fisheries and provide needed income to coastal communities
- But some types of aquaculture are actually increasing pressure on several already threatened marine species
- Those impacts depends upon the species being farmed
- Oyster and clam farms, for example, have fewer impacts than shrimp and salmon farms, which in turn have fewer impacts than tuna farms
- The detrimental impacts can be huge, and have even proven disastrous in some parts of the world
- Impacts on local marine biodiversity can in turn cause problems for local communities that rely on marine resources for their livelihoods
- As production rises, aquaculture's impacts on the environment and wild marine species :
    - Pollution
    - Eutrophication
    - Competition for space
    - Habitat damage & destruction
    - Escaped farmed fish
    - Parasites and disease
    - Wild-caught fish for fish feed
    - Wild-caught fish for farming
    - Predators conflict, such as
    - seabirds, seals, and starfish
    - Socio-economic effect

## Marine Pollution in Tropical Malaysia Aquatic Environment: A Review of Metallic Elements (MEs) in Sediments and Aquatic Organisms

### INTRODUCTION

- Unlike **other pollutants** which may **visibly build up in the environment**, trace metals in the environment may **accumulate unnoticed to toxic levels**
- **Heavy metals** → commonly defined as those having a **specific density of more than 5 g/cm$^3$**
- **Heavy metals** → serious **pollutants** in our natural environment due to their **toxicity**, **persistence** and **bioaccumulation problems**
- **Heavy metals** in aquatic systems can be from **natural** or **anthropogenic** sources
- Currently, **anthropogenic inputs of metals exceed natural inputs**
- **Organisms** require trace amounts of some heavy metals, including **cobalt**, **copper**, **iron**, **manganese** and **zinc**
- **Excess metal levels** in aquatic may pose a **health risk** to **humans** and to the **environment**
- **Excessive levels** of **essential metals**, however, can be **detrimental to the organism**
- **Non-essential heavy metals** of particular concern to surface water systems are **cadmium**, **chromium**, **mercury**, **lead** and **arsenic**
- Can be divided into **four major groups** according to their pollution potential
  1. **Very high pollution potential -** Ag, As, Cd, Cr, Cu, Hg, Pb, Sb, Sn, Te, Zn
  2. **High pollution potential -** Ba, Bi, Ca, Fe, Mn, Mo, Ti, U
  3. **Moderate pollution potential -** Ai, Au, B, Be, Br, Cl, Co, F, Ge, K, Li, Na, Ni
  4. **Low pollution potential -** Ga, I, La, Mg, Nb, Si, Sr, Ta, Zr
- **Metals pollution** has drawn increasing attention **worldwide** due to a dramatic **increase of anthropogenic contaminants** to the ecosystems through **air**, **water** and **soils**
- Pollution of the natural environment by metals is a **serious problem** because these chemical elements are **indestructible** and most of them have **toxic effects** on living organisms, when they **exceed a certain concentration**
- Some are **highly toxic and persistent**, and have a **strong tendency to become concentrated in marine food webs**
- **Accumulation** of heavy metals in **surficial sediments** from industrial effluents and urban sewage discharged into the aquatic environment without proper cleaning will easily be **identified** through **metals spatial variations** in sediments
- **Geochemical mapping** can be used as a tool for visualization which enhanced by computer–aided modelling using **GIS** to make it easier to **identify the possible locations of contaminated area**

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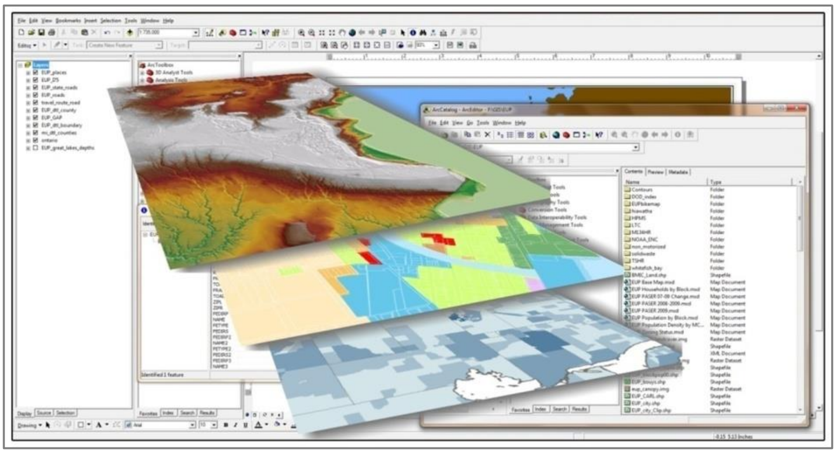


- **Heavy metal** concentrations in **harbour** or **estuarine sediments** usually are quite **high** due to significant anthropogenic contaminants loading carried by the **upstream of tributary rivers**
- **Sediments – serve** as a **metal pool** that can **release metals to the overlying water via natural** or **anthropogenic processes**, causing potential **adverse health effects** to the ecosystems



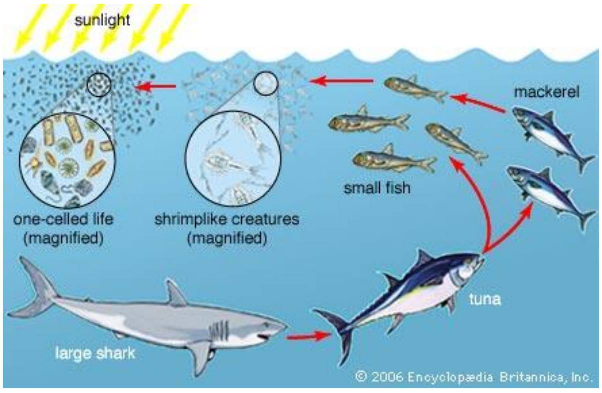
- Lying in the **second trophic level** in the aquatic ecosystem, **shellfish species** have long been known to **accumulate both essential and non–essential metals**
- Many researchers have reported the potentiality of using **molluscs**, especially mussel and oyster species, as **bio–indicators** or **bio–markers** for **monitoring the metals contamination** of the aquatic system
- Beside as a bio–marker for marine pollution studies, molluscs species also been used in **ecotoxicology** and **toxicity studies**

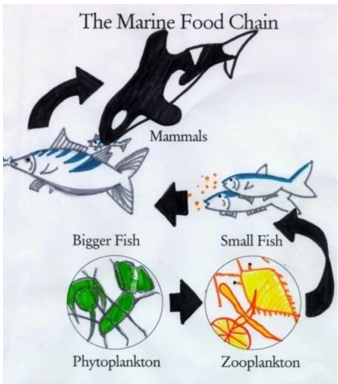
- **Safety of food** to the consumer is a major concern to **ensure the safety of consumers**
- Therefore, **metals analyses** of the aquatic organisms can provide important **information on the degree of environmental contamination**, and **potential impact of seafood**, especially fishes and shellfish consumption

**SOURCES OF HEAVY METALS**

- **Heavy metals** of **natural and/or anthropogenic origin** is transported by **rivers** and transferred to the coastal marine system through the **estuaries**
- **Enter the coastal environments** and oceans by two means:
  1. **Natural processes**
     Erosion of ore–bearing rocks, wind–blown dust, volcanic activity and forest fires
  2. **Human activities**
     Atmospheric deposition, rivers, and direct discharges or dumping, wastewater

- **Marine aquatic organisms** can accumulate heavy metals from **various sources** in their surrounding environment
- Once the heavy metals **enter the food chain**, they may accumulate to **dangerous levels** and be **harmful to human health**



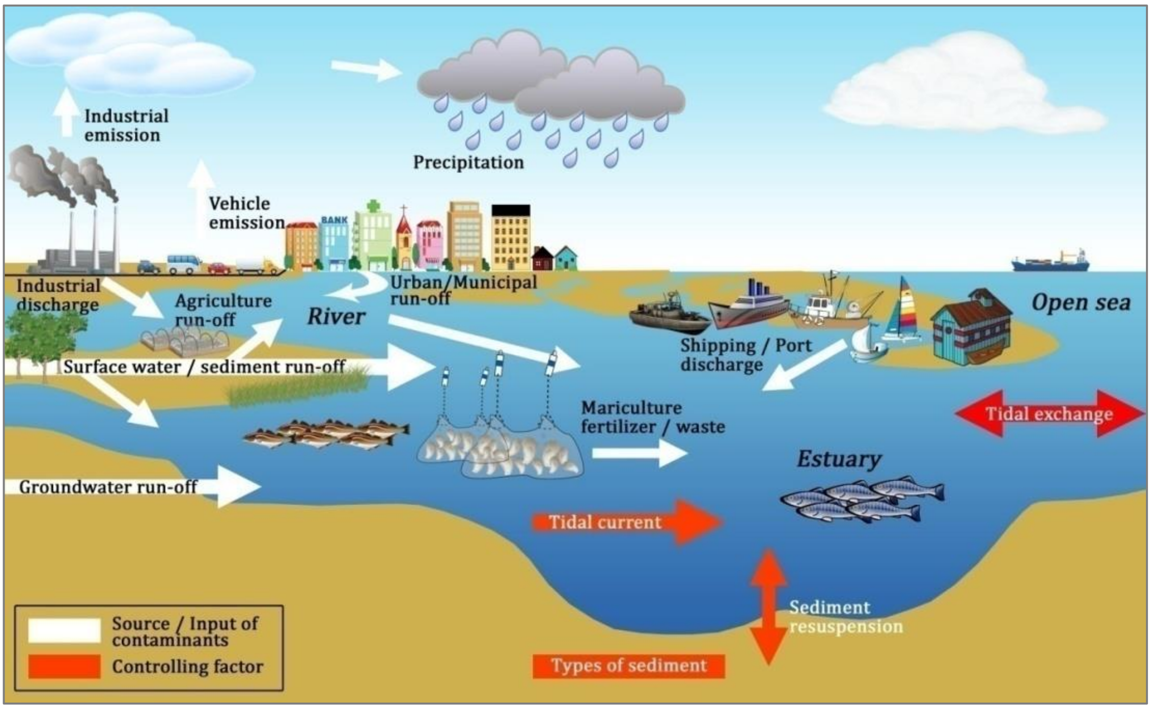



- **Heavy metals accumulation** depend on several factors, environmental **concentrations of metals** in water and sediments; **species of organisms**; **body size** and **age** of the marine organisms
- **Different** concentrations of metals can also be found in different **organs** (stomach, gill, muscle, liver) in the **same biological sample**


- Entry may be a result of **direct discharges** into both freshwater and marine ecosystems or through **indirect routes** such as dry and wet deposition and land run–off
- Important **natural sources** are volcanic activity, continental weathering and forest fires


- Major part of the metals compound in the water and the seabed sediments is **anthropogenic** and associated with:
  - terrestrial sources related to untreated municipal sewage
  - industrial wastewaters
  - intensive aquaculture
  - harbour activities
  - riverine fluxes loaded with urban and agricultural runoff
  - crude oil exploration and exploitation
  - emissions from vehicular traffic gas exhausts

- **Rivers flowing through urban areas**, may bring the **pollutants** to the downstream estuarine sediments, from where they are incorporated in the mudbank cycle
- This process may result **downstream** such as estuary ecosystem in **higher concentrations**




**MARINE SEDIMENT AS A MARKER**

- **Sediment** are widely used as **geo–markers** for **monitoring** and **identifying** the possible sources of pollution in the coastal environments since sediments are the **main sink for various pollutants**
- Most metals are **bound in the fine–grained fraction (<63 µm)** mostly because of its **high surface area–to–grain size ratio** and **humic substance content** where they have a potentially greater biological availability than those in the larger (2 mm – 63 µm) sediment fraction
- **Sediment cores** can provide **chronologies** of contaminant concentrations and a **record of the changes in concentration** of chemical indicators in the environment
- Metal accumulation rates in sediment cores can **reflect variations in metal inputs in a given system over long periods of time**

- Hence, the study of sediments core provides **historical record** of various influences on the aquatic system by indicating both **natural background levels** and the **man–induced accumulation** of metals over an extended period of time

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## BIO–MONITOR OF HEAVY METALS

- **Individual bio–monitors respond differently** to **different sources** of chemical elements for example, in **solution**, in **sediments** or in **foods**
- Therefore, to use a **correct bio–monitor** that can reflect the element bioavailability in all available sources
- Ideally, species to be chosen as bio–monitors should fulfil several criteria:
  - should be **sedentary**
  - easy to **identify**
  - **abundant**
  - **long lived**
  - **available for sampling** throughout the year
  - large enough to provide **sufficient tissue**
  - resistant to **handling stress** caused by laboratory studies of metal kinetics and/or field transplantations
  - **tolerant** of exposure to environmental variations in physico–chemical parameters such as salinity
- Living organisms can **transport pollutants** and **contaminants into**, **within**, and **out** of the marine aquatic ecosystem
- These organisms can **ingest** the pollutants via **water** and **food**, and **inhale** them as they **breathe** and **feeding**
- Once in the body, **some contaminants pass quickly** while others can be **retained for long periods** and **accumulate** in body tissues
- The choice of a suitable bio–monitor needs to consider the **potential sources of metals to the biota**
- **Seagrass not in contact with sediments** will take up MTEs from **dissolved sources only**
- **Suspension feeders** take up metals both directly from **seawater** and from the **suspended particles** collected during feeding


## ASSESSMENT OF POLLUTION STATUS

- To evaluate the **heavy metals contamination**, determined element concentrations were **compared background concentrations**

- Literature data on **average world shale** or **sediment cores** or sediments from **pristine, non–industrialized regions** were analyzed → **to establish the pollution status**

**Enrichment Factors**

$$\mathbf{EF} = \frac{\text{( Heavy metals / reference ) sample}}{\text{( Heavy metals / reference ) background}}$$

*Reference : Al, Li, Co, Fe, Sc, Cs, Th*

| EF range | Contamination category |
|---|---|
| EF < 2 | Deficiency to minimal enrichment |
| 2 < EF < 5 | Moderately enrichment |
| 5 < EF < 20 | Significant enrichment |
| 20 < EF < 40 | Very high enrichment |
| EF > 40 | Extremely high enrichment |

$$I_{geo} = \log_2 \frac{C_n}{1.5B_n}$$

*$C_n$ → concentration of the examined element (n)*
*$B_n$ → geochemical background concentration of the element (n).*
*1.5 → background matrix correction factor due to the lithogenic effects*

| Class | Value | Sediment quality |
|---|---|---|
| 0 | Igeo $\leq$ 0 | Practically uncontaminated |
| 1 | 0 < Igeo < 1 | Slightly contaminated |
| 2 | 1 < Igeo < 2 | Moderately contaminated |
| 3 | 2 < Igeo < 3 | Moderately to heavily contaminated |
| 4 | 3 < Igeo < 4 | Heavily contaminated |
| 5 | 4 < Igeo < 5 | Heavily to extremely contaminated |
| 6 | Igeo > 5 | Extremely contaminated |

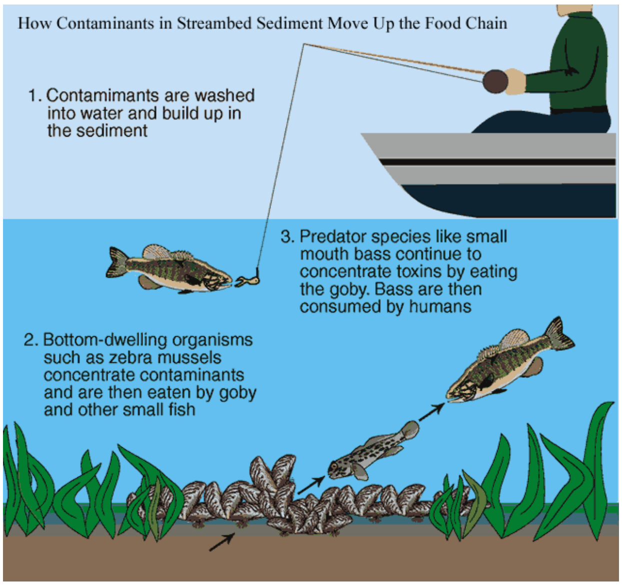
**Pollution Load Index**

$$\mathbf{PLI} = (CF_1 \times CF_2 \times CF_3 \times CF_4 \times CF_n)^{(1/n)}$$

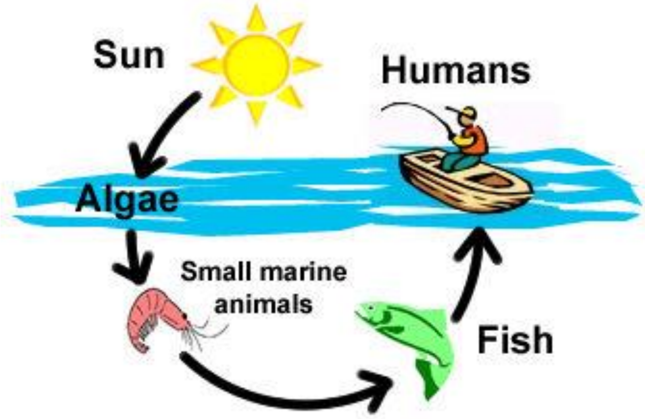
$$CF = \frac{\textbf{Heavy metals concentration in sample}}{\textbf{Heavy metals concentration in background}}$$

| Value | Sediment quality |
|---|---|
| PLI < 1 | Low contamination factor |
| 1 < PLI < 3 | Moderate contamination factor |
| 3 < PLI < 6 | Considerable contamination factor |
| PLI > 6 | High contamination factor |

**EFFECTS ON HUMAN HEALTH**




- Generally, **human health problems** associated with trace metal contamination have been well **highlighted** in the literature
- In spite of the relatively **low level of industrial activity** in **less developed regions**, there is nevertheless a high **potential of toxic heavy metal pollution**
- **Bioaccumulation**, another way in which pollution can **harm the environment**, is the **internal accumulation** of a pollutant that is very difficult to degrade or expel from the body
- **Every organism** accumulates pollutants during its **lifetime** and if it is **eaten**, the **pollutant are transferred to the predator**
- Hence, bioaccumulation especially targets the **top predators** of the food chain, including humans





EXAMPLE :

- **Oysters** can be "**swallowed**" or **masticated normally**, increasing the surface of contact between food and digestive fluids
- The consumer will **consume whole soft part** of the oyster, therefore metals content is examined **in–toto** or **oyster flesh**

# OCEAN PRODUCTIVITY

## Primary Productivity

- Primary Productivity → the production of organic compounds from inorganic substances through process of photosynthesis or chemosynthesis
- Primary production → the total amount of carbon (C) in grams converted into organic material per square meter of sea surface per year (gm C/m2/yr)
- Photosynthesis
  The use of light energy to convert water and carbon dioxide into energy-rich glucose molecules
- Chemosynthesis
  The process by which certain microorganisms create organic molecules from inorganic nutrients using chemical energy


- Two major factors influence a region's photosynthetic productivity:
  - the availability of nutrients and the amount of solar radiation (sunlight)
  - upwelling, turbulence, grazing intensity and turbidity as secondary factors.
- Only 0.1 to 0.2% of the solar radiation is employed for photosynthesis and its energy stored in organic compounds.
- Macronutrients and micronutrients are needed for survival, growth and reproduction.
- As the primary producers, phytoplankton require sunlight, nutrients and carbon dioxide for photosynthesis.

- Sunlight and nutrients are commonly the limiting factor.

- The formula for photosynthesis is:

$$\text{Sunlight} + 6\ CO_2 + 6\ H_2O \rightarrow C_6H_{12}O_6\ (\text{sugar}) + 6\ O_2$$

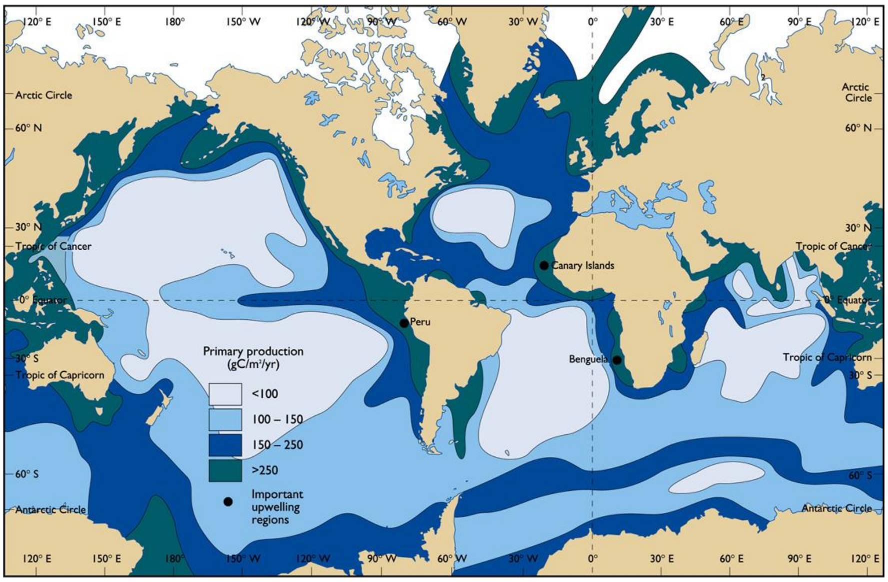
- Phytoplankton blooms are the rapid expansion of a phytoplankton population because light and nutrients are abundant.

**Bacteria**

- Bacteria are the decomposers; they break down organic material and release nutrients for recycling.
- Few bacteria are capable of completely degrading organic material into its inorganic components. Most operate in succession with other bacteria to decompose material in a series of stages.
- Bacteria also serve as food for other organisms either directly or indirectly.
- Two basic types of bacteria are
  - Aerobic bacteria
  - Anaerobic bacteria
- Most bacteria are heterotrophs, but two types are autotrophs:
  - Cyanobacteria (blue-green algae)
  - Chemosynthetic bacteria

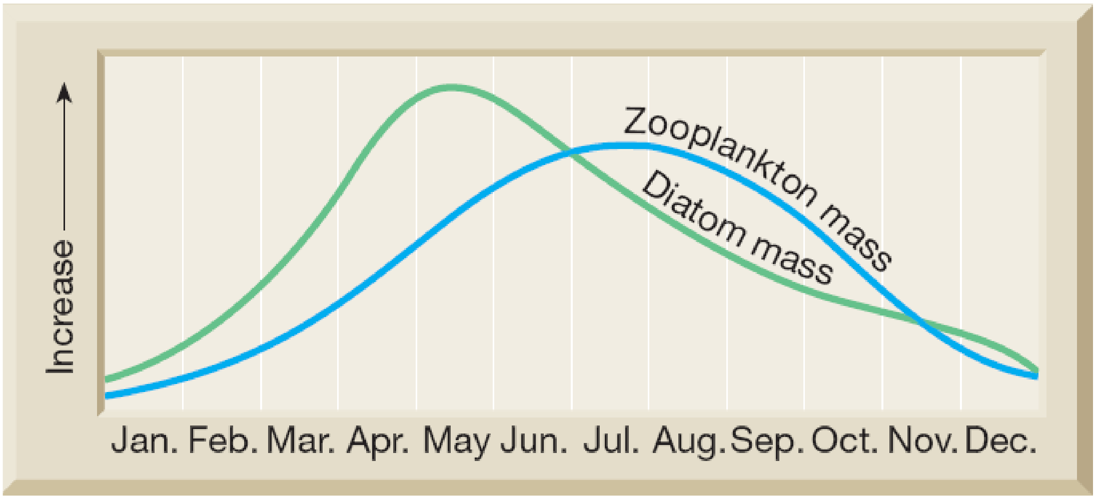
**Ocean Productivity**

- Productivity varies greatly in different parts of the ocean in response to the availability of nutrients and sunlight.
- In the tropics and subtropics sunlight is abundant, but it generates a strong thermocline that restricts upwelling of nutrients and results in lower productivity.
- High productivity locally can occur in areas of coastal upwelling.
- In temperate regions, productivity is distinctly seasonal.
- Polar waters are nutrient-rich all year but productivity is only high in the summer when light is abundant.




**Productivity in Polar Region**

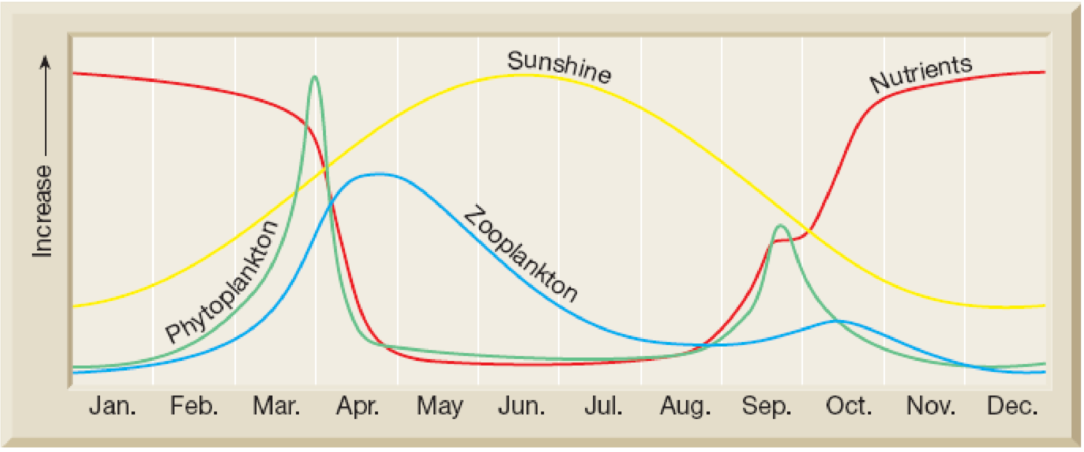
- Polar regions experience continuous darkness for about three months of winter and continuous illumination for about three months of during summer.
- Productivity of phytoplankton, mostly single-celled algae, peaks in May.
- As soon as the phytoplankton develop, zooplankton come in to eat them.
- The availability of solar energy is what limits photosynthetic productivity in polar areas.




**Productivity in Temperate Region**

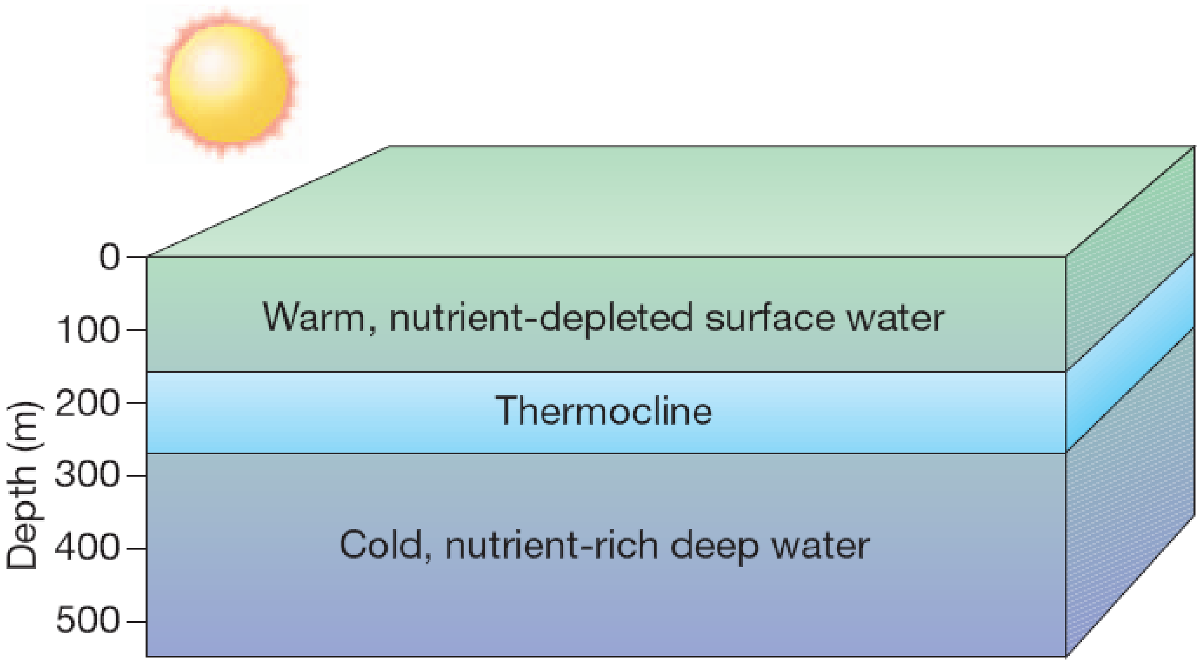
- In temperate regions, which are found at mid-latitudes, a combination of these two limiting factors, sunlight and nutrient supply, controls productivity
- Winter → productivity is low, due to the low angle of the sun and shallower sunlight penetration
- Spring → phytoplankton bloom due to an increase in nutrients and sunlight, nutrient supply is in greater demand and limits production

- Summer → nutrients depleted from spring "bloom" are not able to be replenished from deep waters due to a sharp thermocline, phytoplankton population will remain low
- Fall → nutrients return to the surface, as the summer thermocline breaks down, and another "bloom" of phytoplankton occurs (short-lived due to decreasing sunlight)




**Productivity in Tropical Region**

- Productivity is low in tropical regions of the open ocean
- Light penetrates much deeper into tropical oceans than in temperate and polar waters
- Solar energy is available year-round
- A permanent thermocline prevents mixing between surface waters and nutrient-rich deeper waters; it is a barrier that cuts off the supply of nutrients from deeper waters
- Productivity in tropical regions is limited by the lack of nutrients



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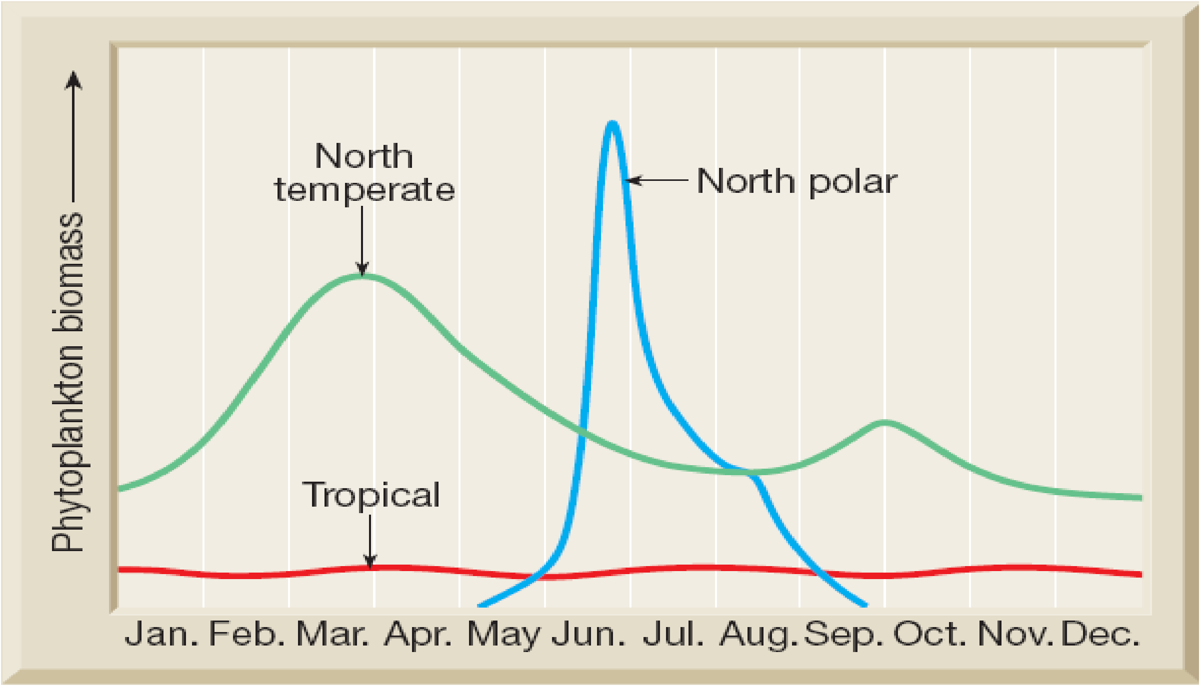
**Productivities Comparison**



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# THE CARBON CYCLE

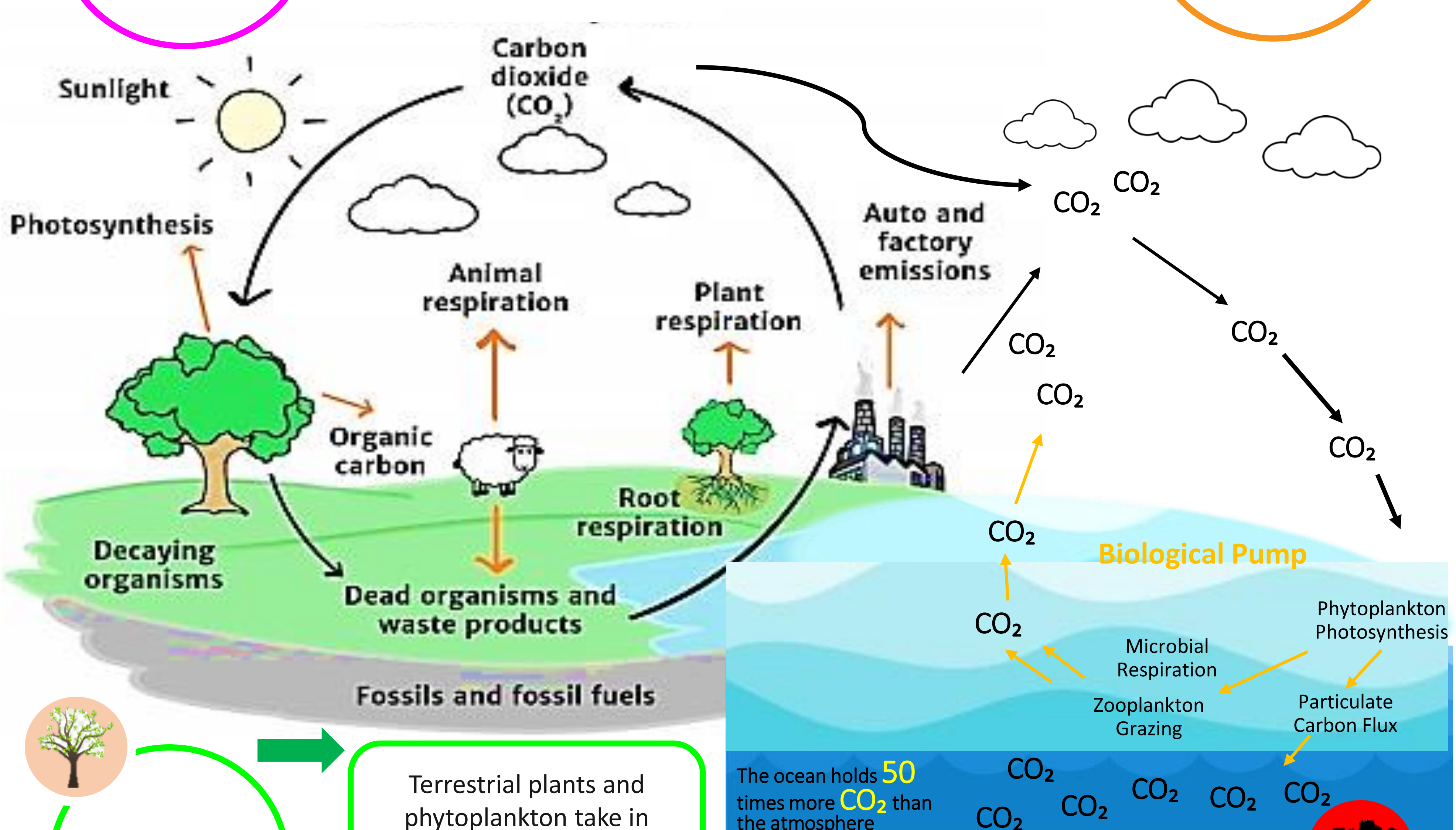
Carbon is transported and exchanged through atmosphere, hydrosphere and biosphere, the reusing of carbon atoms in the natural environment are known as the carbon cycle.
Carbon is main component in many biological compounds and some minerals.

**Decomposition**

When complex carbon compounds in dead organisms, urine and faeces are broken down into simpler carbon compounds by bacteria or fungi

**Respiration**

Animal and plants releases carbon dioxide to the atmosphere through cellular respiration




**Photosynthesis**

Terrestrial plants and phytoplankton take in carbon dioxide for photosynthesis

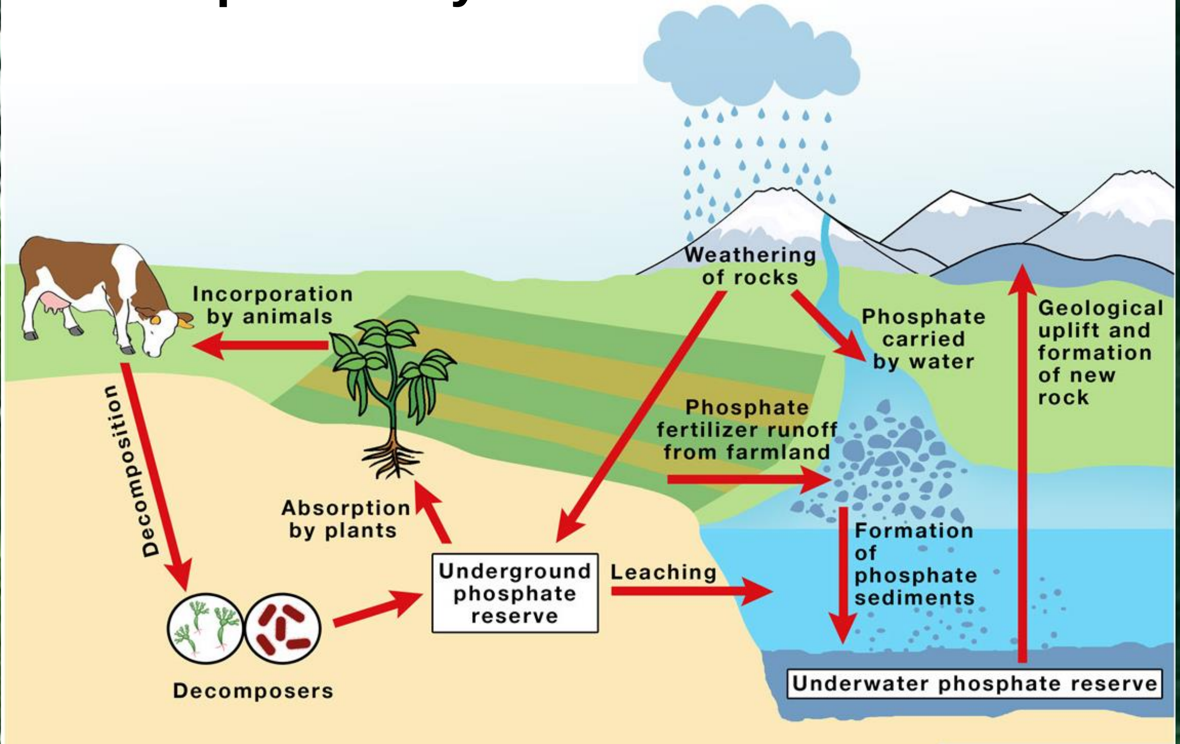
**Combustion**

The burning of fossils fuels, gas emissions from car and factory releases carbon dioxide into atmosphere

**References :**

https://earthhow.com/carbon-cycle/
https://www.lenntech.com/carbon-cycle.htm
https://www.iaea.org/topics/oceans-and-climate-change/the-ocean-carbon-cycle
https://www.britannica.com/science/biosphere/The-carbon-cycle

# Phosphorus Cycle




## Did you know?

### IMPORTANCE of PHOSPHORUS?

Phosphorus is essential for plant and animal growth, as well as the health of microbes inhabiting the soil, but is gradually depleted from the soil over time.

### However, EXCESSIVE in PHOSPHORUS LEAD to..

Eutrophication

Dead Zone


### PHOSPHORUS is widely USED in?


INSTITUTE OF OCEANOGRAPHY AND ENVIRONMENT

Envision Marine Future

## Summary of case study related to phosphorus cycle..

**1) Balance sheet for phosphorus in Malaysia by SFA.**
**By: Ghani, L. A., & Mahmood, N. Z. (2011)**

Case study of phosphorus in flow in Malaysia exemplifies how Material Flow Analysis can be used to investigate the flows and stocks of phosphorus in Malaysia. There is unbalance of phosphorus input-output in Malaysia region with the total input is 879 kt P/a and total output is 1151 kt P/a. In Malaysia, there is no actions have been done for banning phosphates from household detergent, food-product, fertilizer and other related goods. The level of P-recycling in Malaysia region is also very low especially in P-solid waste products and P-domestic wastewater. Only 3 to 7 % of that amount phosphorus is successfully be recycled back into the environment.

**2) Phosphorus cycle-possibilities for its rebuilding.**
**By: Gorazda, K., Wzorek, Z., Tarko, B., Nowak, A. K., Kulczycka, J., & Henclik, A. (2013)**

Phosphorus is potentially critical resource because its reserves are limited and is loss globally by erosion and runoff of mined phosphorus and animal waste. 9.7% of waste generated consist of phosphorus, which means around 3000 to 4000 tons of phosphorus can be recycled and introduced back into the environment per year. Hence, rebuilding the global and local phosphorus cycles will only be possible with the use of sustainable development rules and adequate phosphate-rich waste management.

# Nitrogen (N) Cycle


- Azyyati binti Abdul Aziz (P3408)
- Ku Nor Afiza Asnida binti Ku Mansor (P3661)
- Wan Amrul Jaahiz bin Wan Abd Razak (P4421)
- Nurul Hidayah binti Mat Zaki (P4709)


## Nitrogen is key to life

- A **component of protein, amino acids** - essential to life on earth for growth.
- **Abundant element in atmosphere** (78%) as nitrogen gas.

## What is N-Cycle?

The **cycle** between **different chemical form of N** moves through **both living & non-ling things** (the atm., soil, water, plants, animal, bacteria).

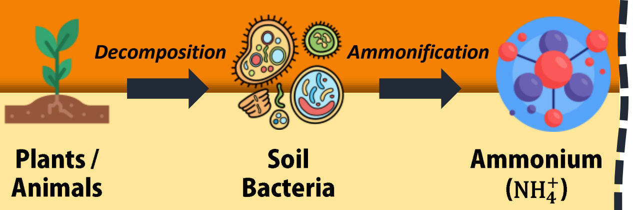
## Stage 1 - Nitrogen Fixation

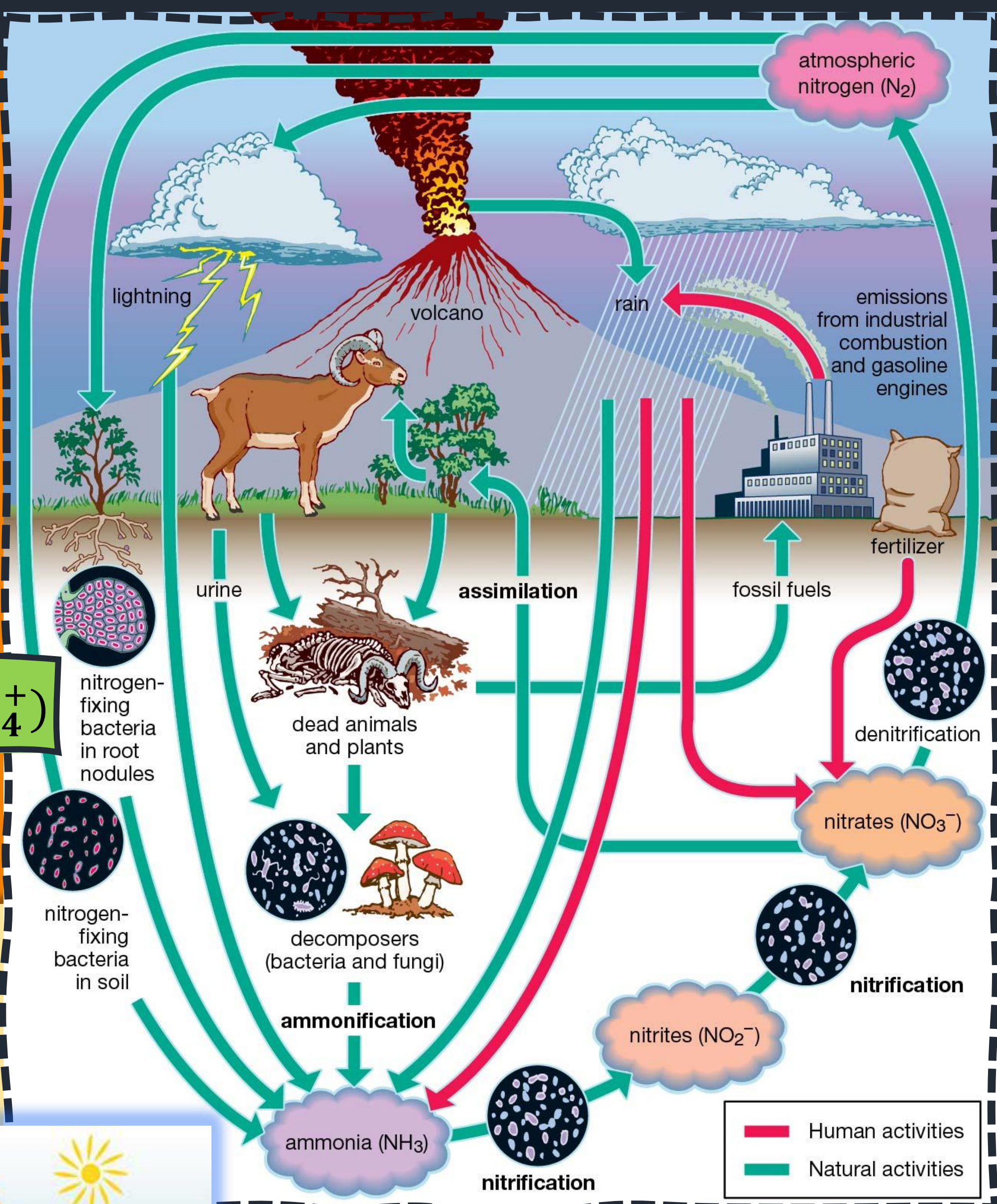
$N_2 \longrightarrow NH_3$ (Soil & root)

$N_2 \longrightarrow NH_4^+$ (Dissolved)

## Stage 2 - Ammonification

$NH_3 + H_2O \longrightarrow NH_2OH\ (NH_4^+)$




## Stage 5 - Denitrification

denitrifying bacteria

$NO_3^- \longrightarrow N_2^- / NO_x$

$NO_3^- \longrightarrow NO_2^- \longrightarrow NO \longrightarrow N_2O \longrightarrow N_2$

## Stage 4 - Assimilation

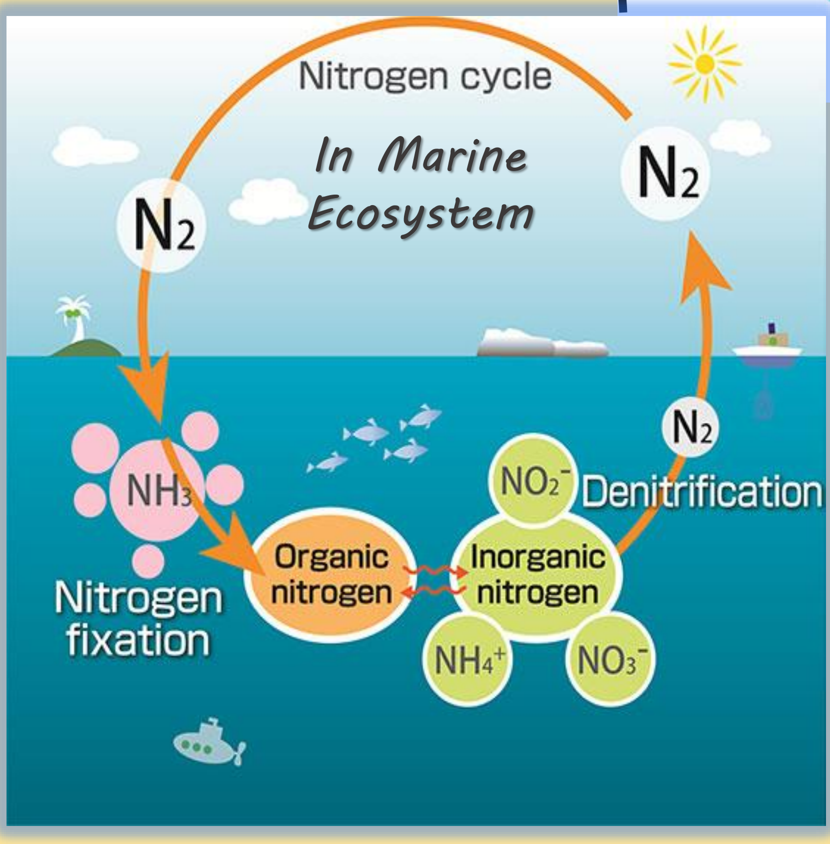
Step 1 : $NO_3^-$ (Uptake by plant / algae)

Step 2 : $NO_3^- \longrightarrow NO_2^-$

## Stage 3 - Nitrification

Step 1 : $NH_3 \longrightarrow NH_2OH\ (NH_4^+) \longrightarrow NO_2^-$

Step 2 : $NO_2^- \longrightarrow NO_3^-$




## Importance of N - Cycle

- **Food Chain**
  Play major role in regulating primary productivity.
- **As Limiting Nutrients**
  If less supply (would limit growth & lack of primary production).
- **Act as indicator for water quality**
  Prevention from eutrophication / Harmful algae bloom.

GROUP 4

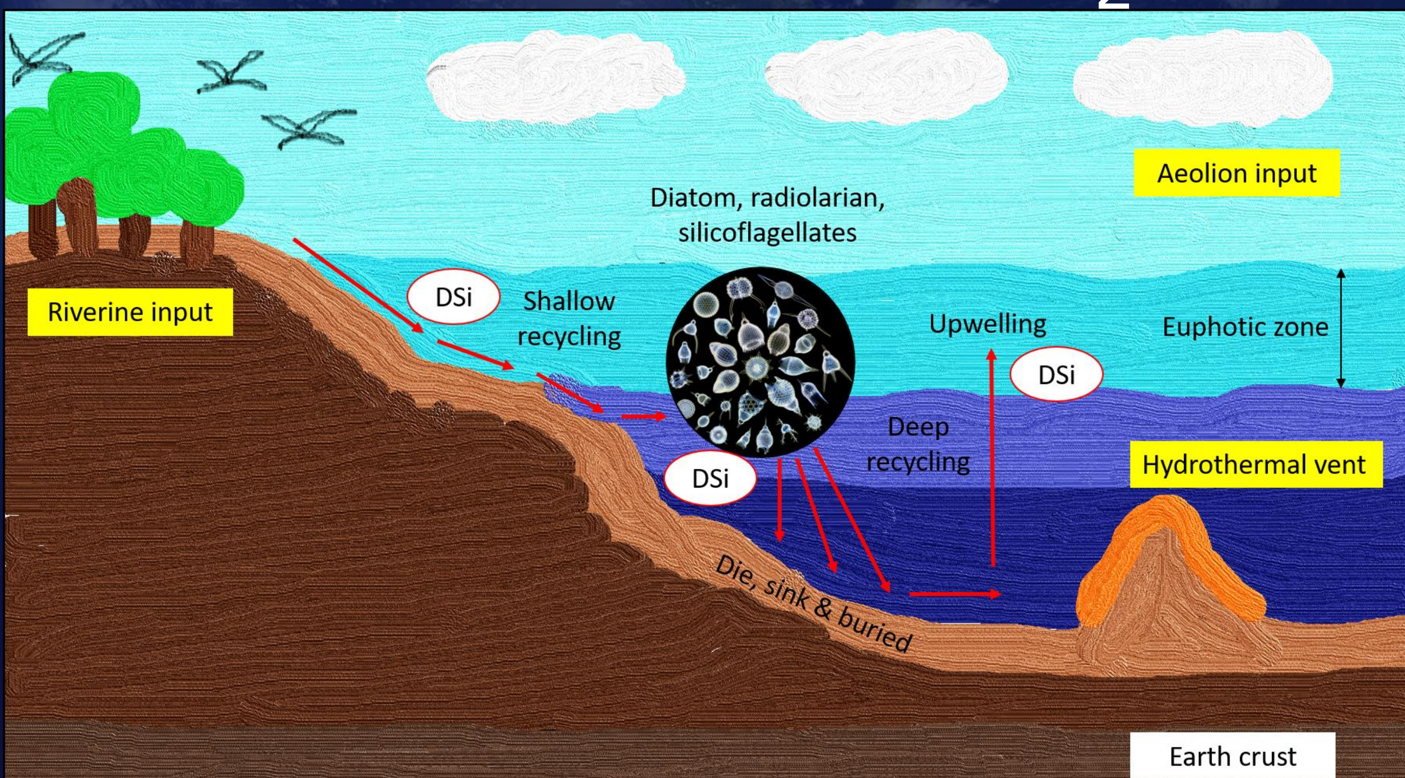
# SILICA CYCLE

Nur Hannah Abd Rahim, Nur Fazne Ibrahim, Che Engku Siti Mariam, Mrs Mushraat

**2nd** Most abundant element in the earth crust

**8th** Most common element in the universe

**$SiO_2$** Opal silica The chemical compound of silicon, and is also called silicon dioxide




## IMPORTANCES

- Silica cycle is strongly intertwined with other major biogeochemical cycles
- Essential ocean nutrient for the growth of silicified organisms in marine environments (*e.g.* diatoms)
- Silisifiers such as diatoms constitute >50% of ocean primary productivity

## MAIN SOURCES

TERRESTRIAL - Weathering

MARINE - Rivers, groundwater flux, seafloor weathering inputs, hydrothermal vents and atmospheric deposition

## ISSUES

- Agricultural activities change the N:Si:P ratio thus affecting coastal productivity.
- River damming caused significant decreases in dSi concentration downstream.
- Global warming will reduce the dSi inputs from the deep sea.


## Do you know..

About Terengganu's 1800 ha. "silicon valley"?

## References

Tréguer, P. J., Sutton, J. N., Brzezinski, M., Charette, M. A., Devries, T., Dutkiewicz, S., Ehlert, C., Hawkings, J., Leynaert, A., Liu, S. M., Llopis Monferrer, N., López-Acosta, M., Maldonado, M., Rahman, S., Ran, L., and Rouxel, O.: Reviews and syntheses: The biogeochemical cycle of silicon in the modern ocean, Biogeosciences, 18, 1269–1289, https://doi.org/10.5194/bg-18-1269-2021, 2021.

# Introduction to geology and oceanography

OCN 5003 TROPICAL OCEANOGRAPHY

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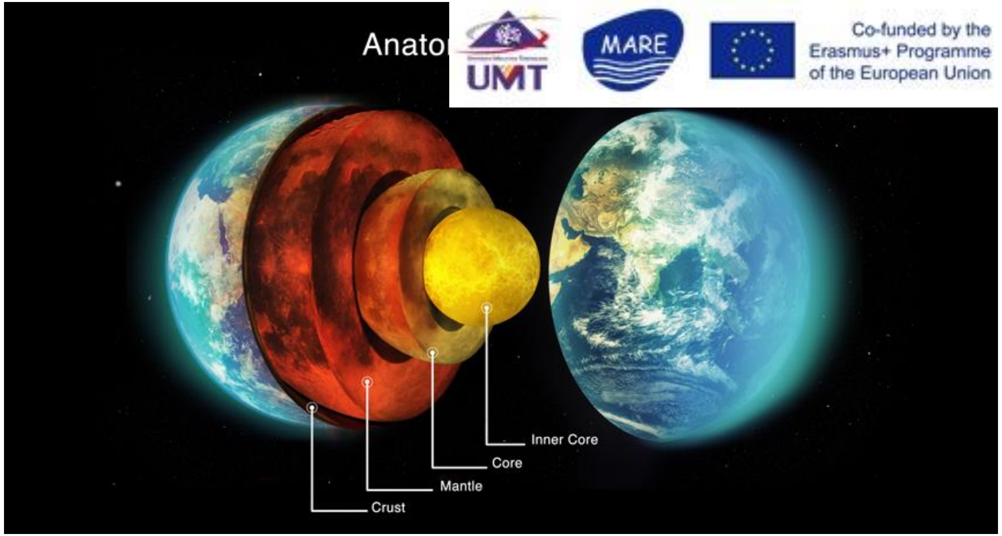


# What is geology?

**Geology** is the study of the Earth, the rocks of which it is composed, and the processes by which they change over time. Basically geologist try to understand the history and the formation of planet Earth.

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# What is oceanography?

Oceanography is the branch of Earth science that studies the ocean including sediments, currents, waves and geophysical fluid dynamics; plate tectonic as well as chemical, physical and biological properties of the ocean.

# Geological oceanography

Study that address questions regarding the formation of ocean basin, the deposition of sediment in the ocean. This study also address the formation of minerals and fossil fuel in the ocean.

# How does geology influence where and how we live?

Rainbow mountain in China

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1. Geologic features and processes constrain where people  can live because they determine whether a site is safe from landslides, floods or other natural hazard.
2. Geologic processes shape the surface of the planet and produce wonderful diversity of the landscapes and scenery.
3. Geologist look for clues in the rocks and landscapes to find the answers to the questions.

https://www.youtube.com/watch?v=uy9GFAOGGXU

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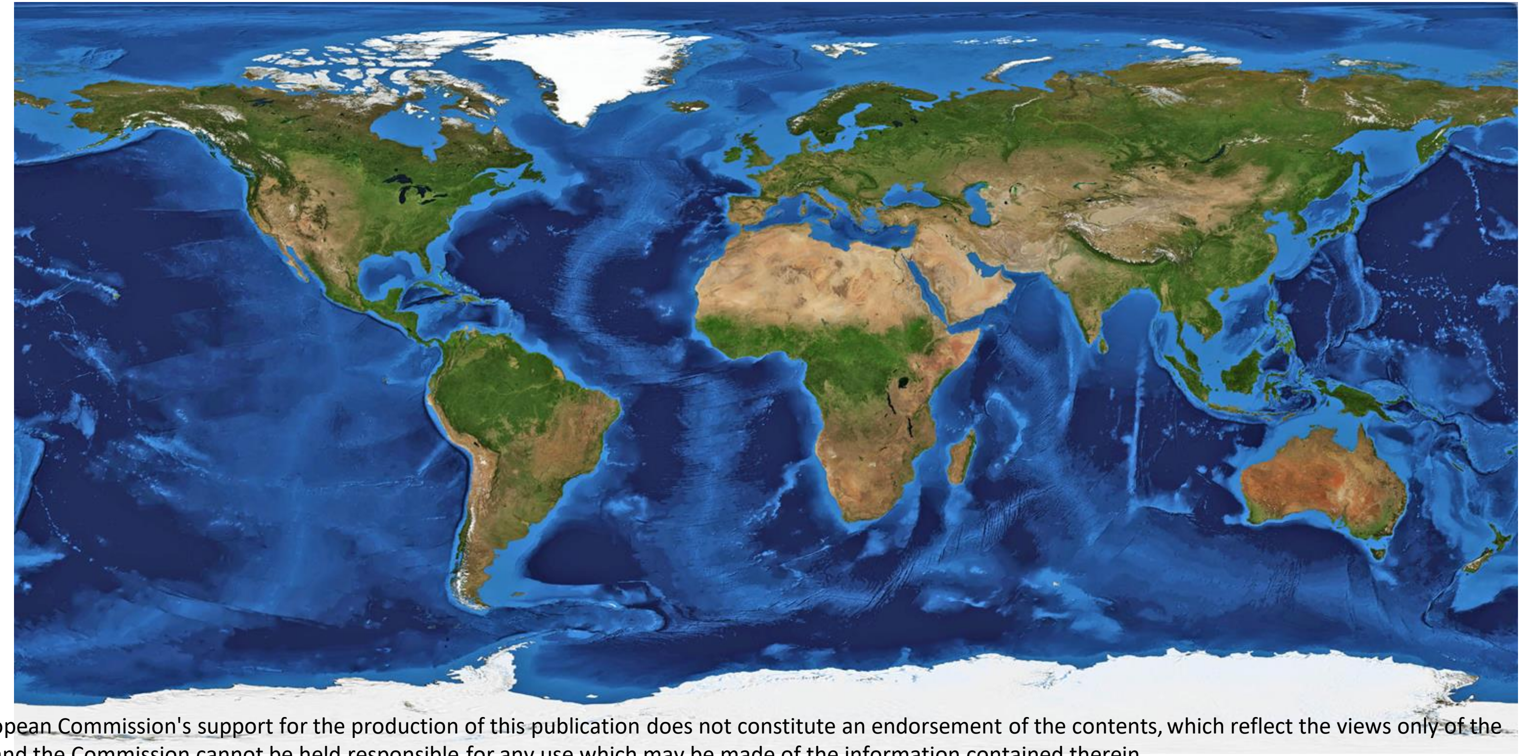
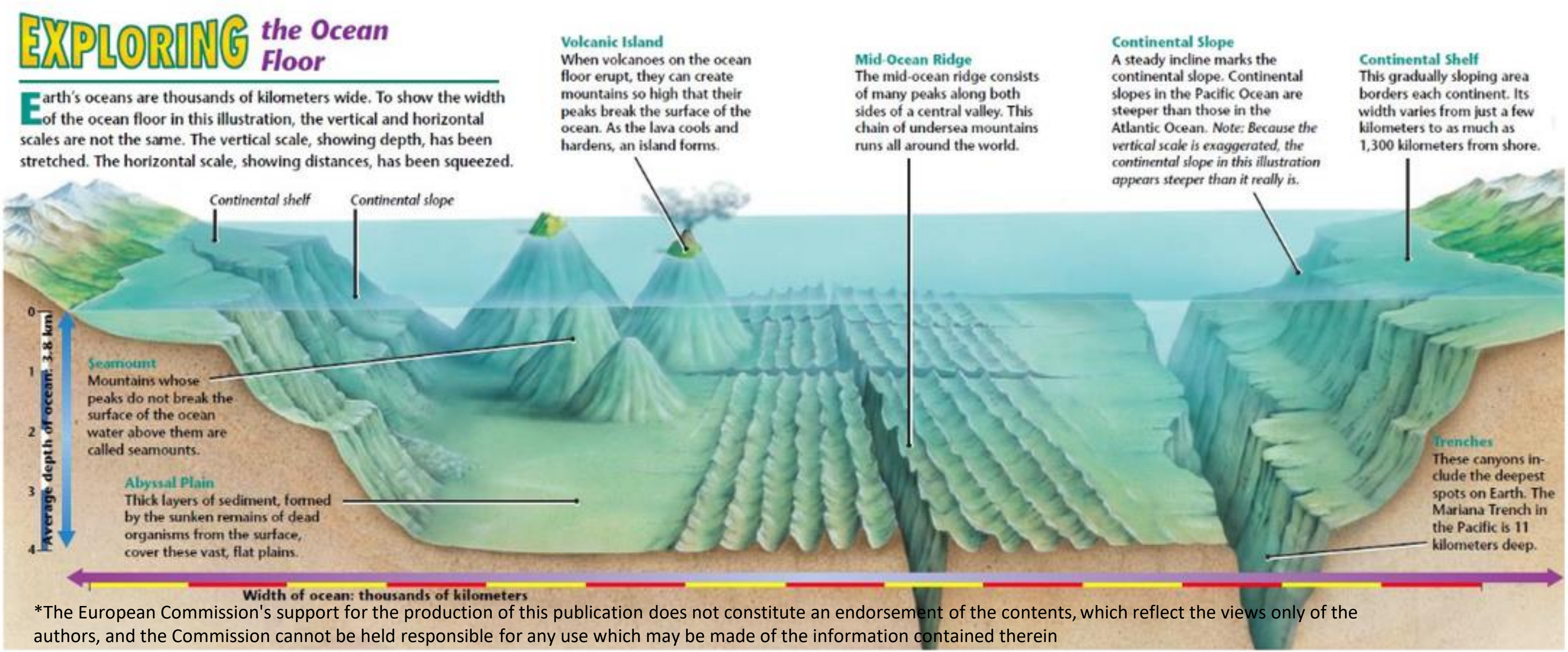
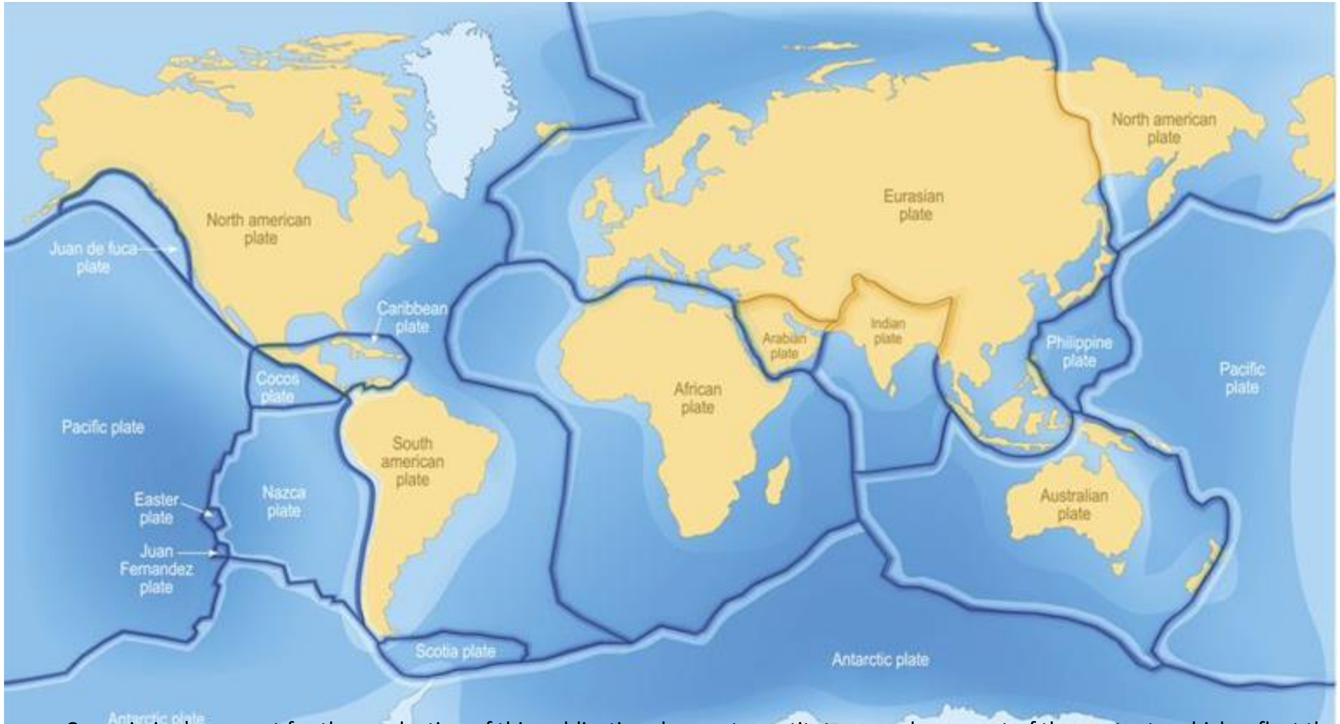
# How many continents and ocean basin on earth?



# How does geology help explain our world?



# The continents and ocean basin sits on jigsaw puzzle-like plates

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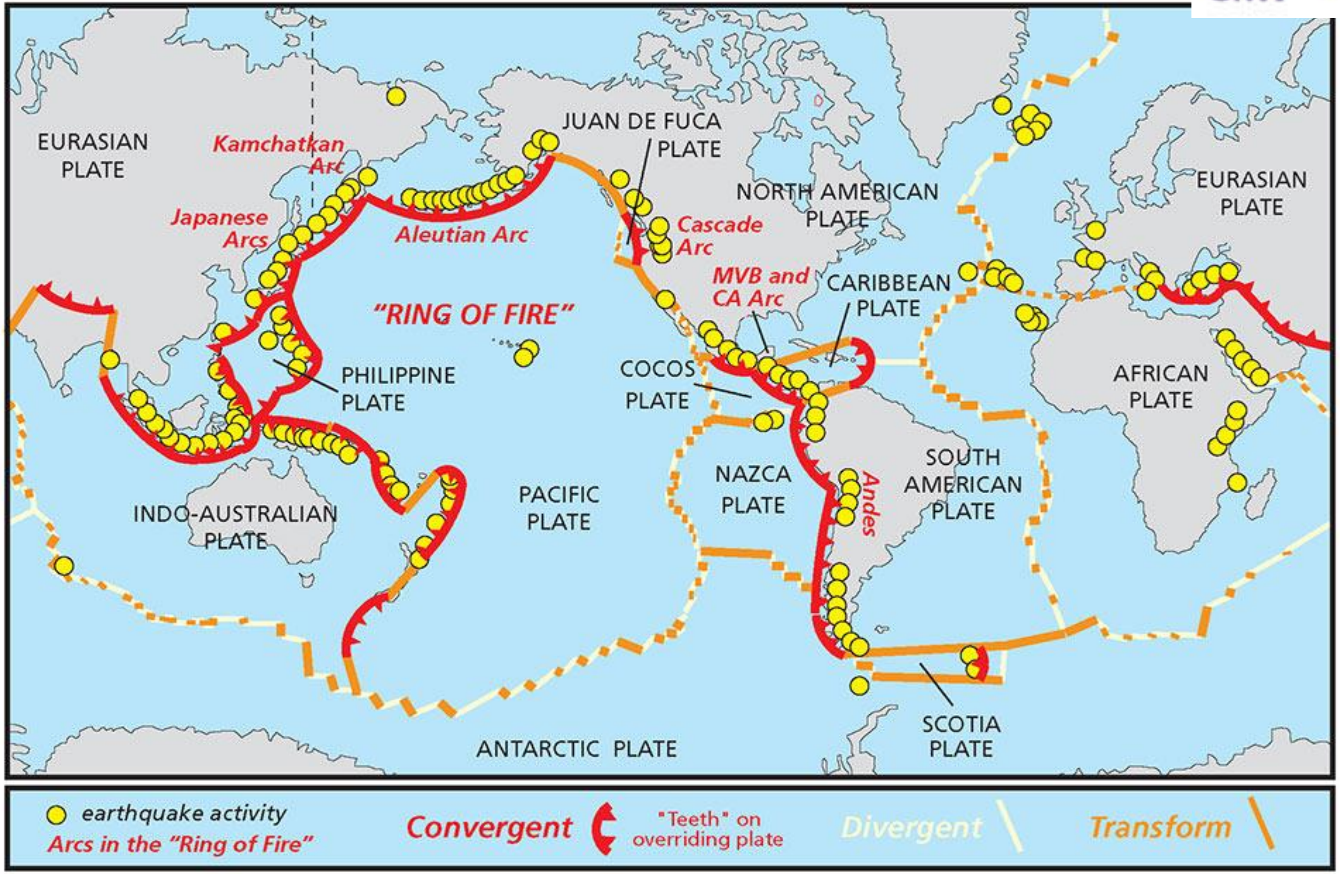


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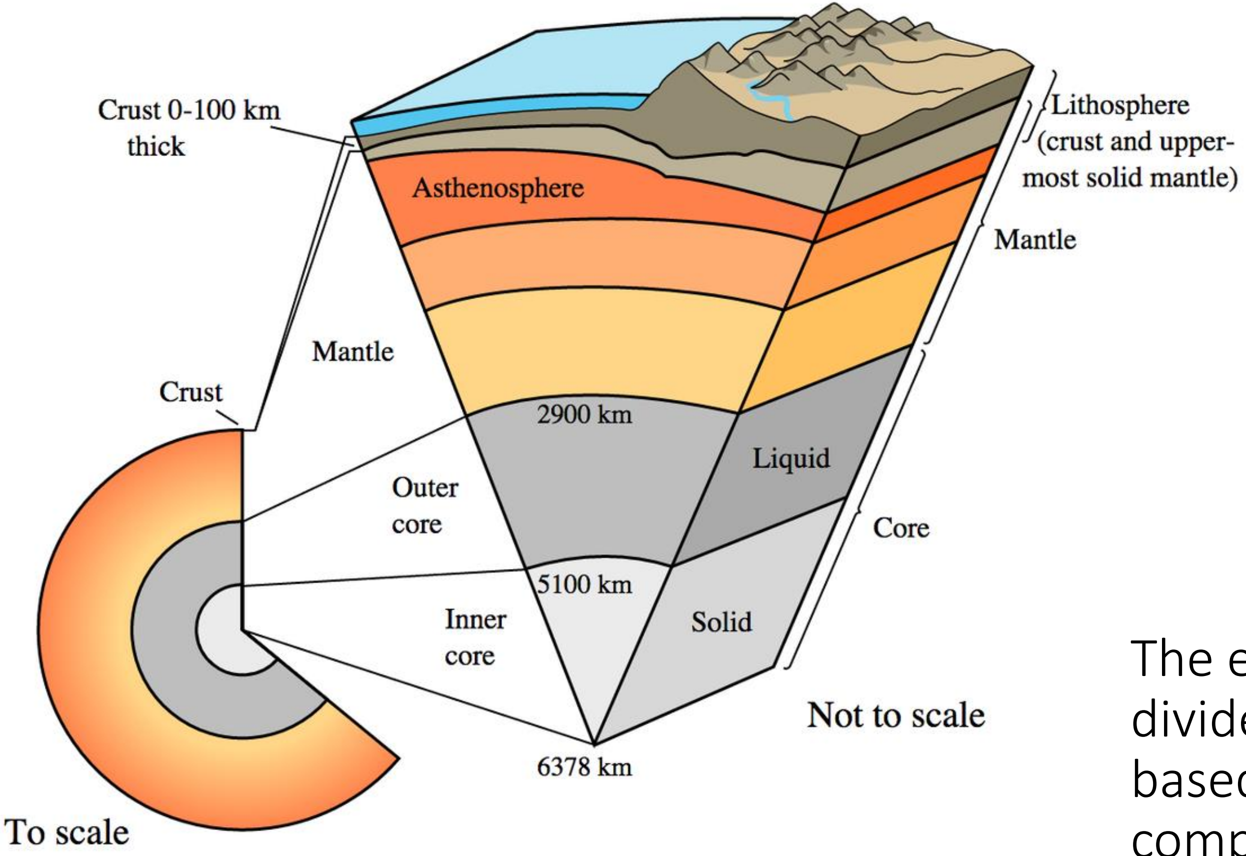
# Earth Structure

OCN 5003

# The planet

- Earth is estimated to be about 4.5 million years old.
- Through geological time, the planet slowly change form what we see today.
- Let’s take a journey inside the planet.




The earth structure is divided into three layers based on their chemical compositions

# The Crust

1. The thin, rocky outer skin which can be divided into
   a. Continental crust
   b. Oceanic crust
2. Oceanic crust is approximately 7 km thick, composed of dark igneous rock call basalt. Have relatively homogenous chemical composition. Average density of oceanic crust is 3.0 $g/cm^3$. relatively denser than continental crust.
3. Continental crust average thickness is 35 – 70 km. Consist of many rock types. The average density is 2.7 $g/cm^3$ .

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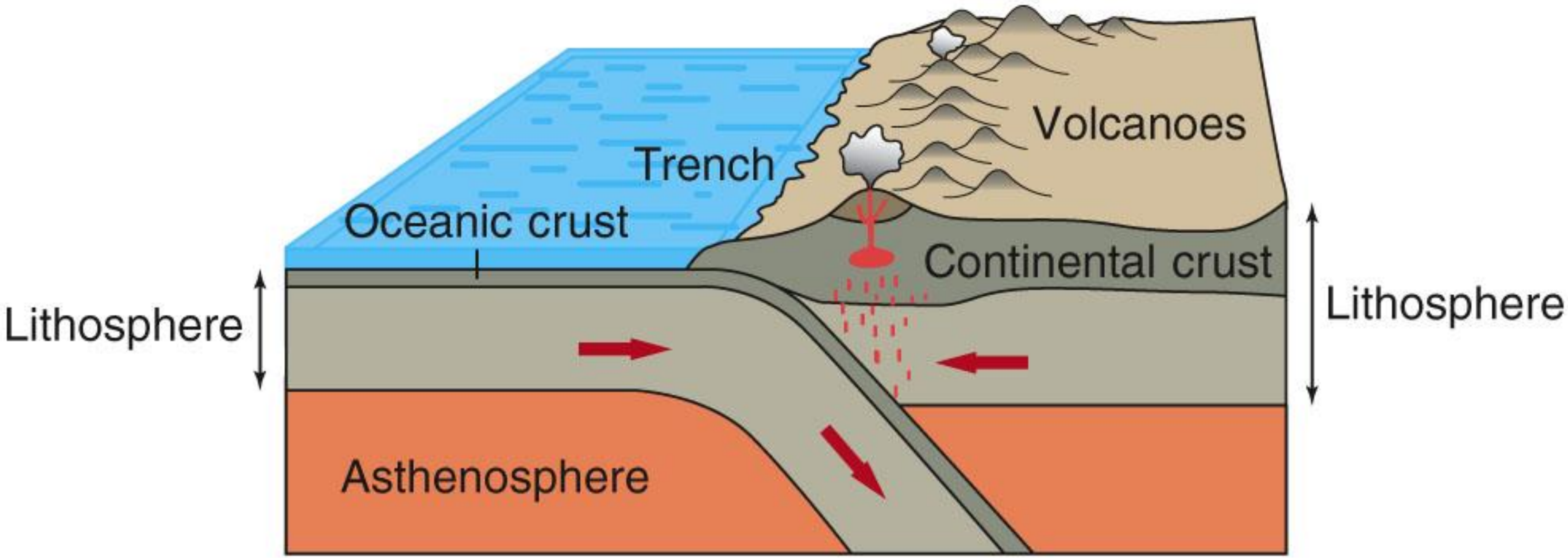

Oceanic-continental convergence

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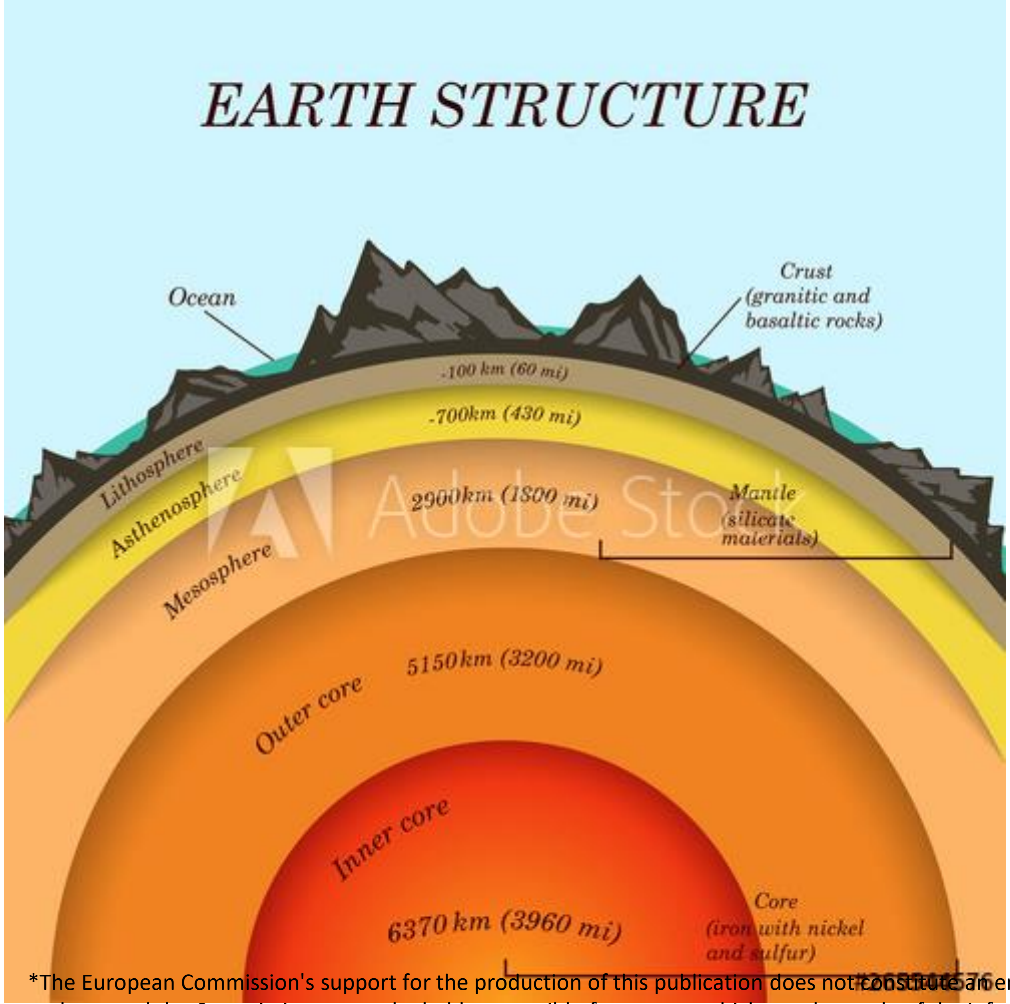
# Earth Mantle




1. Is divided into upper and lower mantle.
2. The upper mantle
   a. Extends from the mantle-crust boundary down to 660 km deep.
   b. The uppermost area is which consist of mantle and crust is known as the lithosphere.
   c. Below the lithosphere is asthenosphere
   d. Below the asthenosphere is the transition zones.
3. The Asthenosphere is solid but mobile.
4. The lower mantle (mesosphere) is in solid form. The pressure here increase with increase depth.

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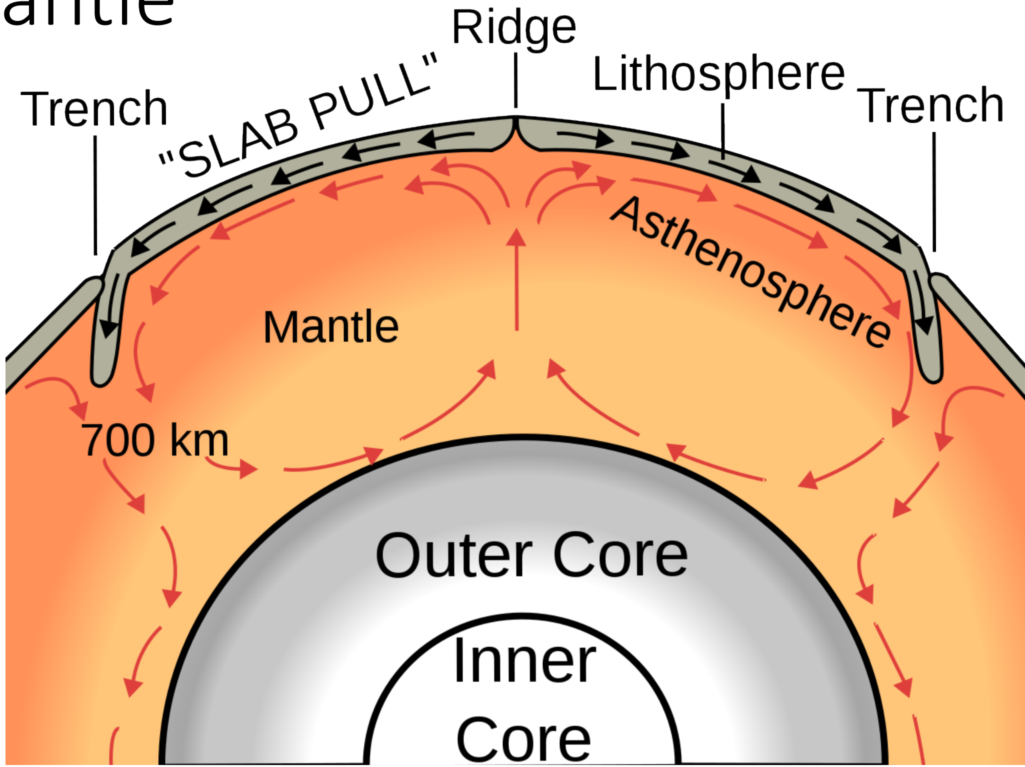
# Convection cells in mantle

1. The inner core heat drives currents of magma in the Earth's mantle.
2. These current form convection cells.
3. These currents drive the motion or movement of plates at the surface of the Earth.



# The outer and inner core.

1. The outer core which is about 2270 km thick is mostly composed of liquid iron and nickel with low viscosity.
2. The outer core can reach up to 5500 degree Celsius.
3. The movement of metallic iron in outer core generates Earth's magnetic field.
4. The inner core is made up mostly with iron.
5. The temperature here may reach 5200 degree Celsius.
6. However due to the intense pressure, the inner core is in the solid state.

http://www.bbc.com/future/bespoke/story/20150306-journey-to-the-centre-of-earth/

# Did you know?

- Scientist has never reached the center of the Earth. So how do they make up the condition within the earth structure?

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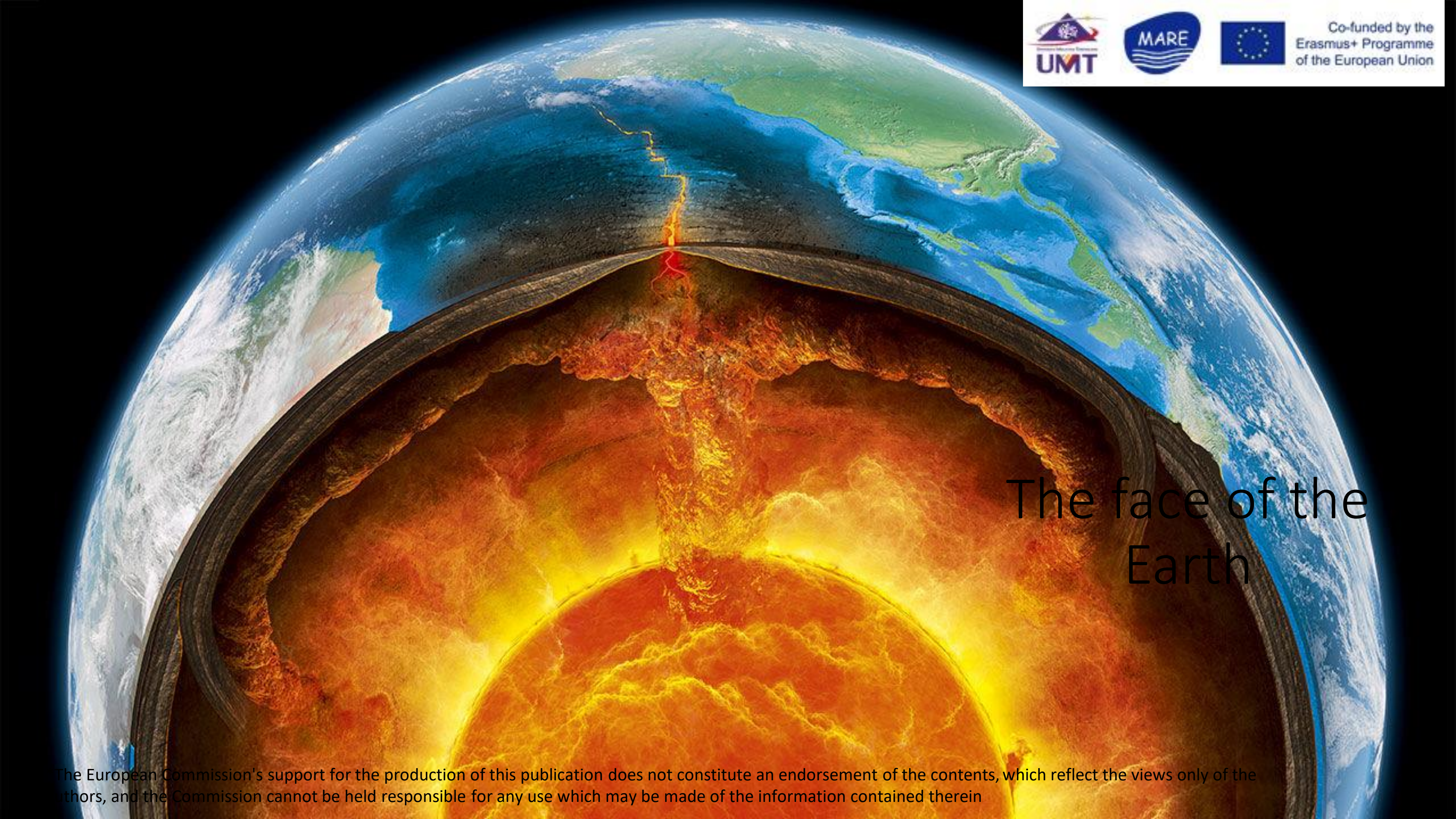

# The face of the Earth

# Ocean basins

1. Average depth of the ocean floor is 3.8 km.
2. The oceanic crusts comprises of basaltic rocks.
3. Have higher density compared to continental crust.
4. Major feature of ocean floor
    a. Continental margin
    b. Deep-ocean basin
    c. Oceanic ridges

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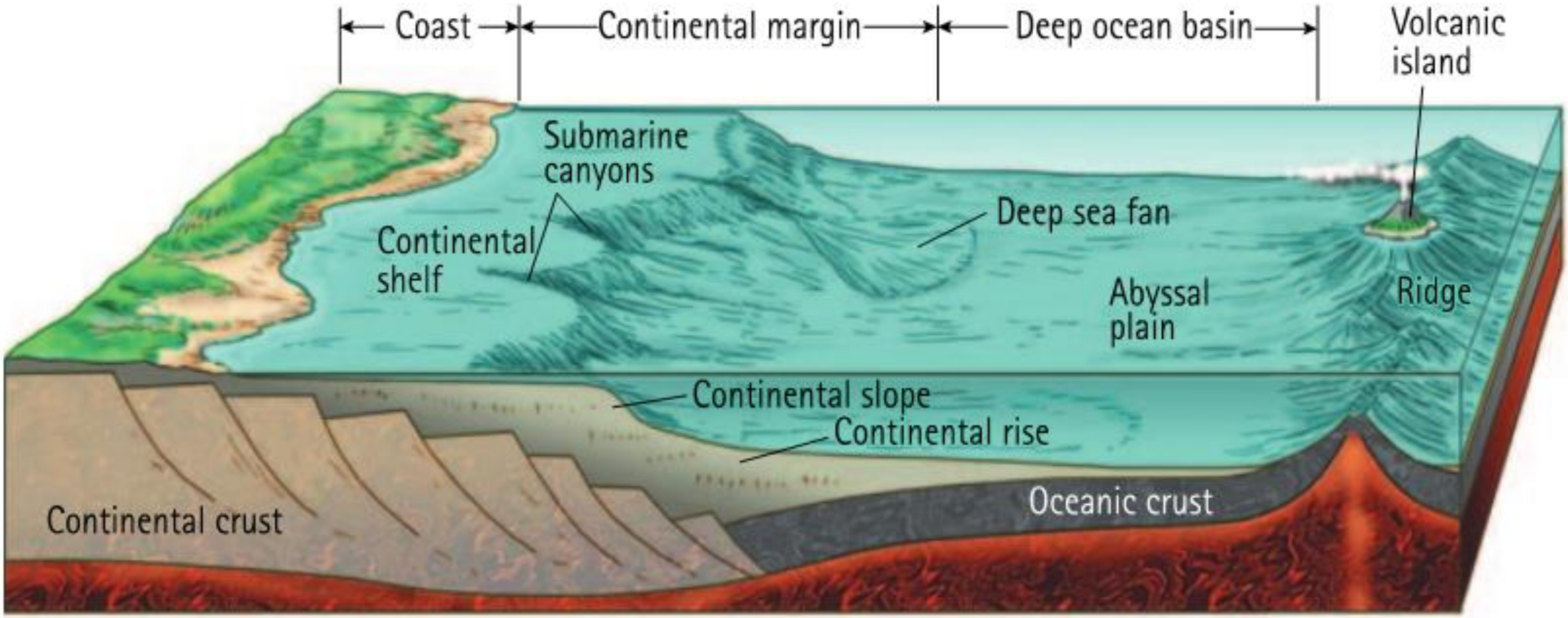


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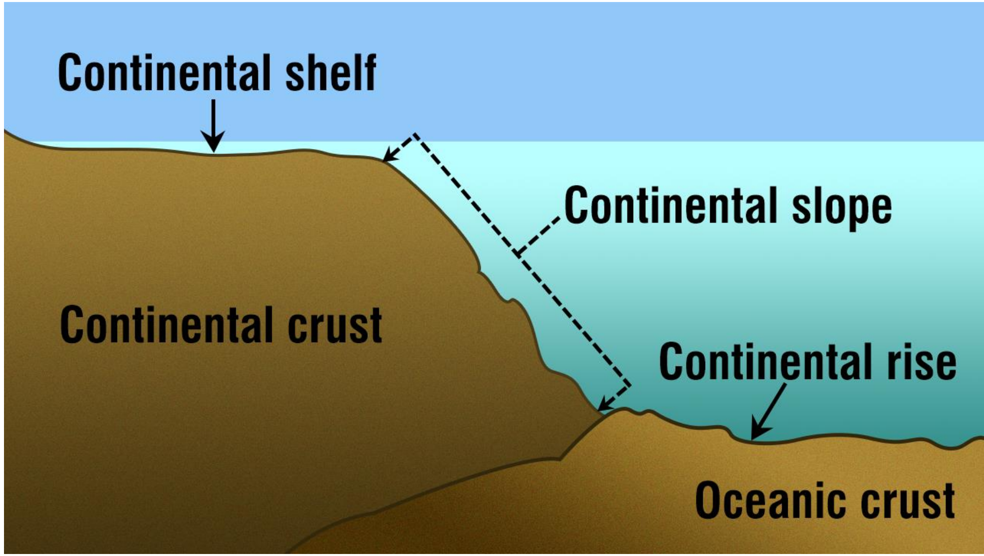
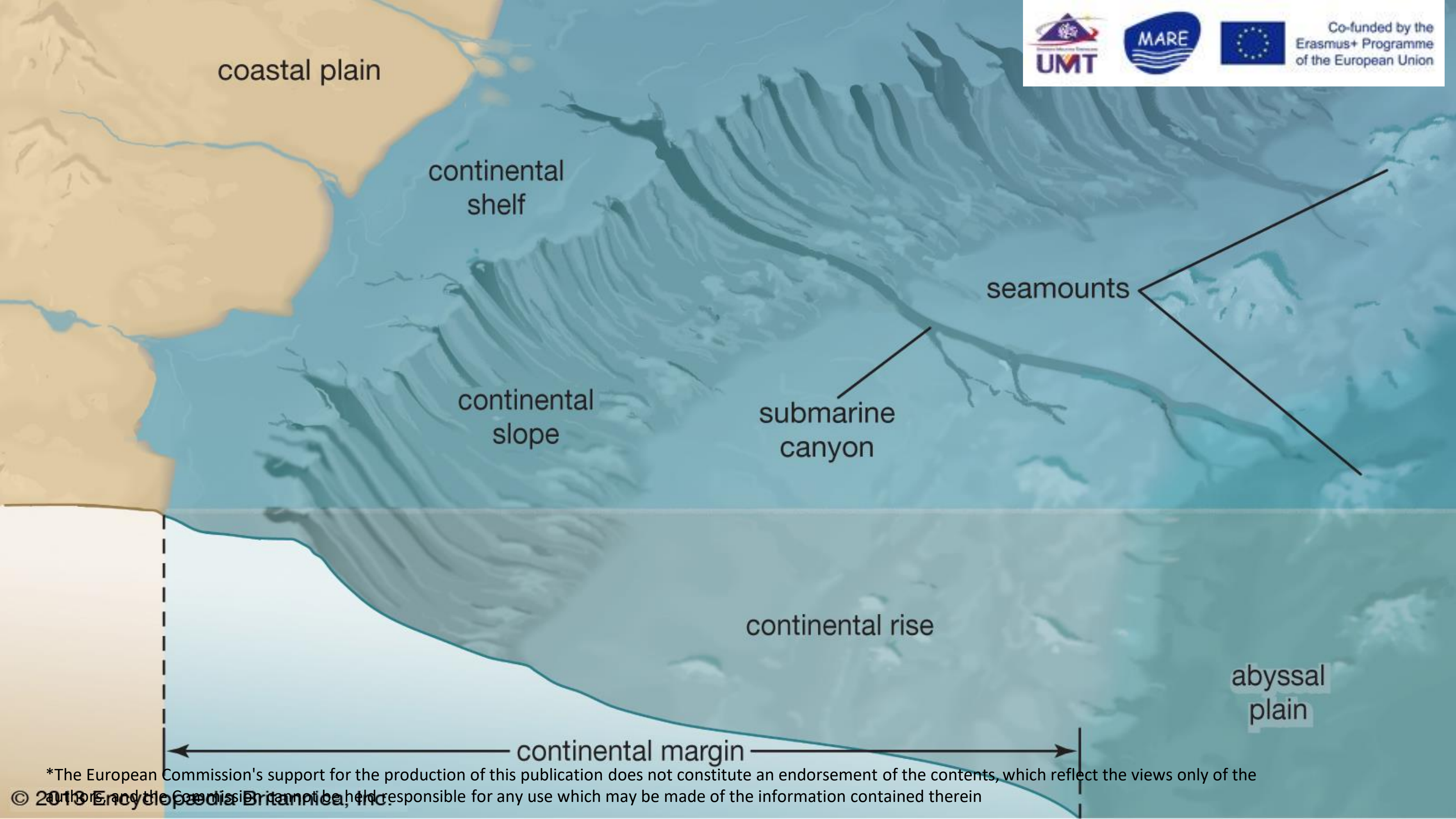
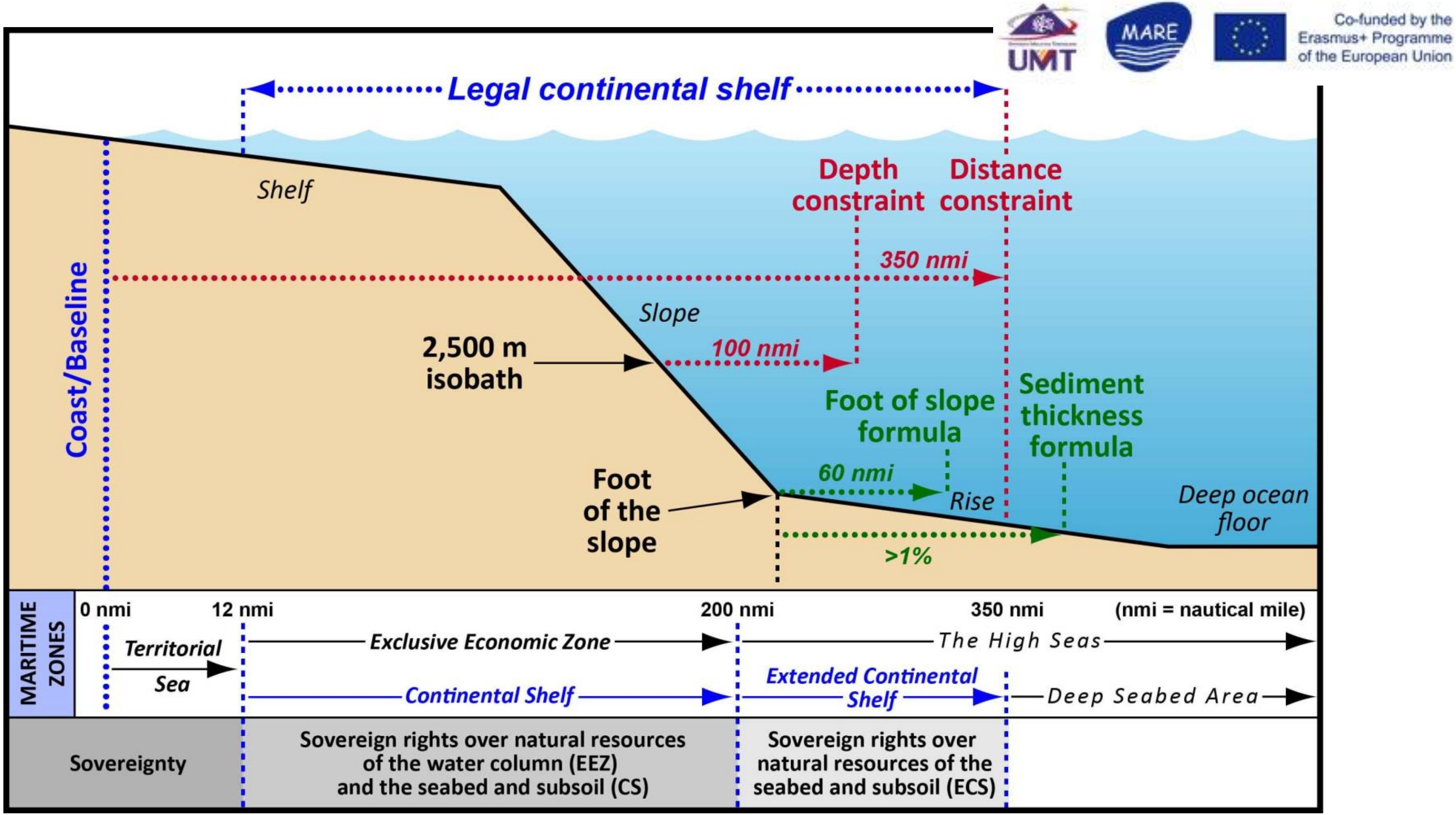
# 1. Continental margin

- The portion of seafloor adjacent to major landmasses.
- May include feature such as continental shelf, continental slope and continental rise.
- Continental shelf is a gentle sloping platform that extends seaward.
- Continental slope is relatively steep dropoff that extends from the outer part of continental shelf.
- Continental rise. In region where trenches do not exist, the continental slope will merge with gradual incline continental rise.





coastal plain
continental shelf
continental slope
submarine canyon
seamounts
continental rise
abyssal plain
continental margin

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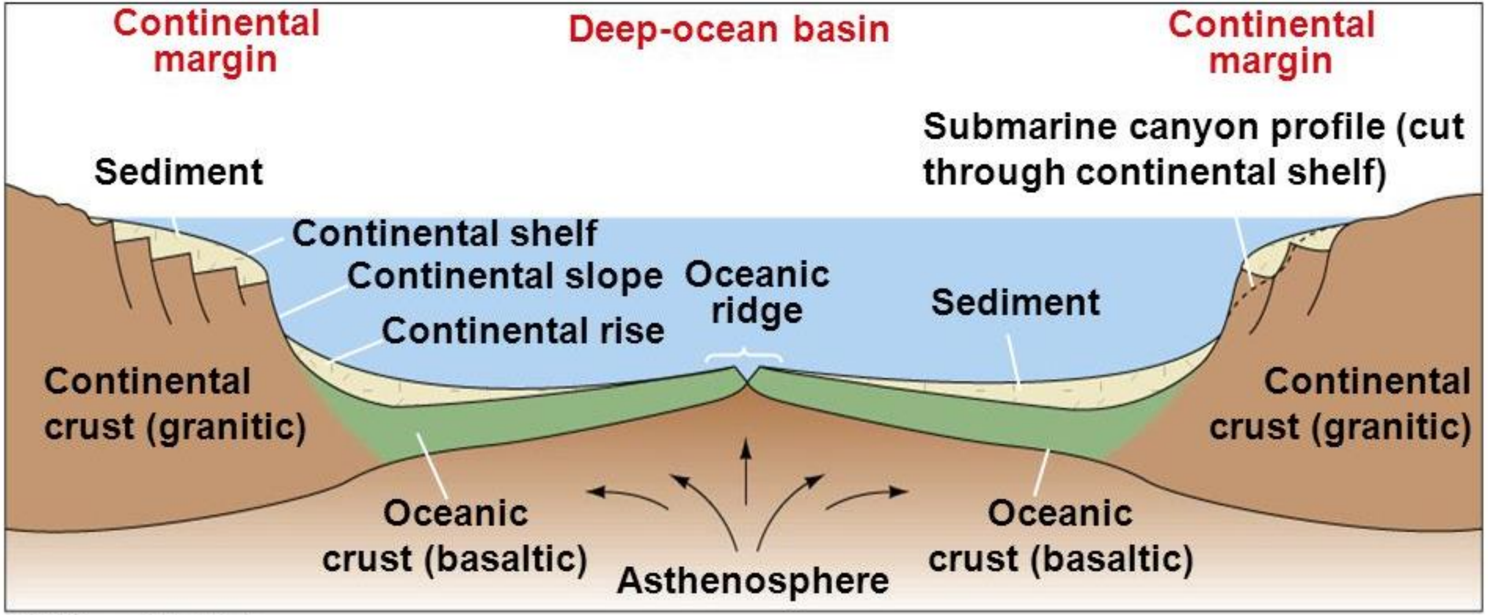
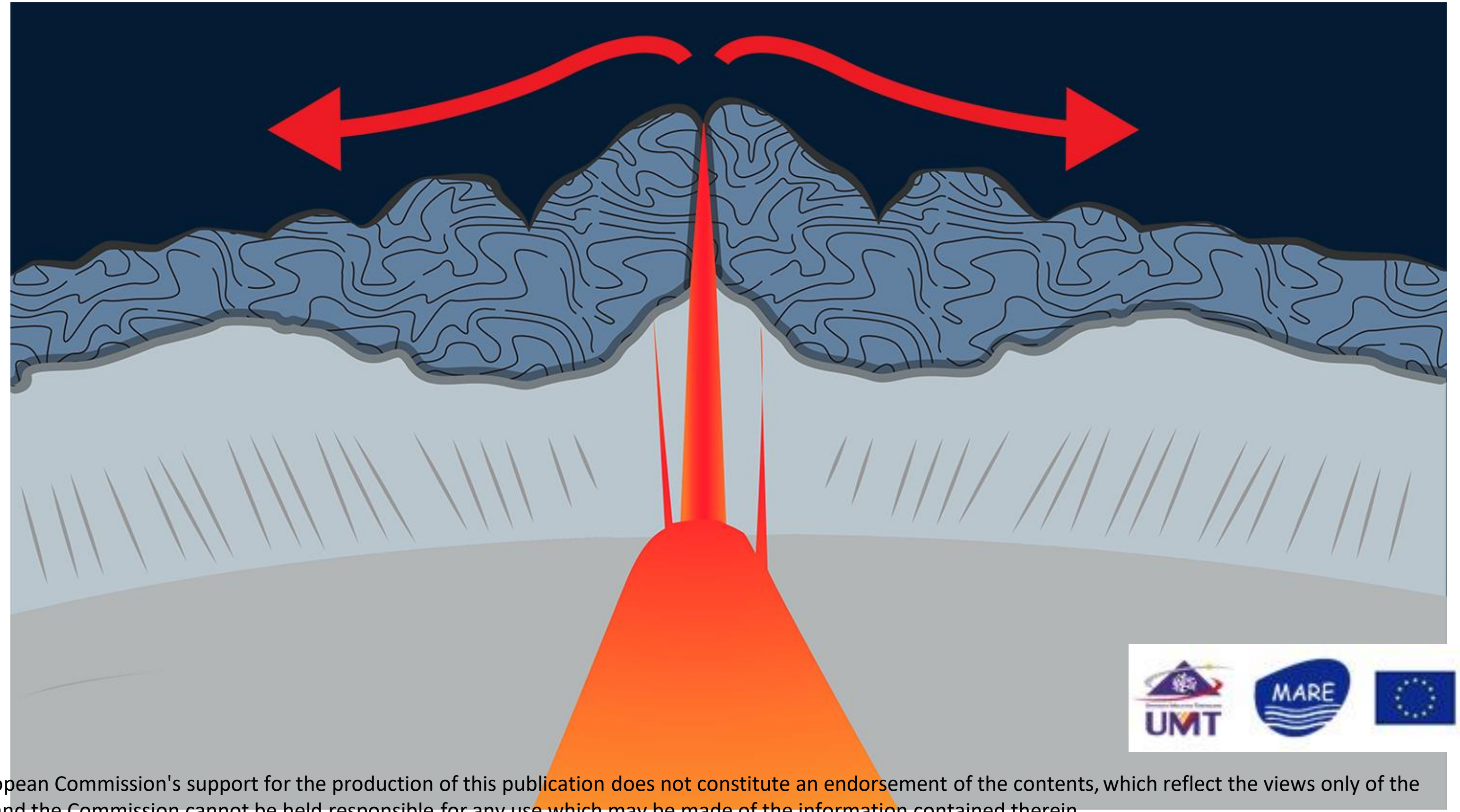
2. The deep ocean basin may include features such as
   a. Abyssal plains – flat feature of the basin
   b. Deep-ocean trenches – narrow and deep depression
   c. Seamounts- submerge volcanic structures



3. Oceanic ridge, is broad elevated feature that forms continuous belt. Consist of layers upon layers of igneous rock that has been uplifted.



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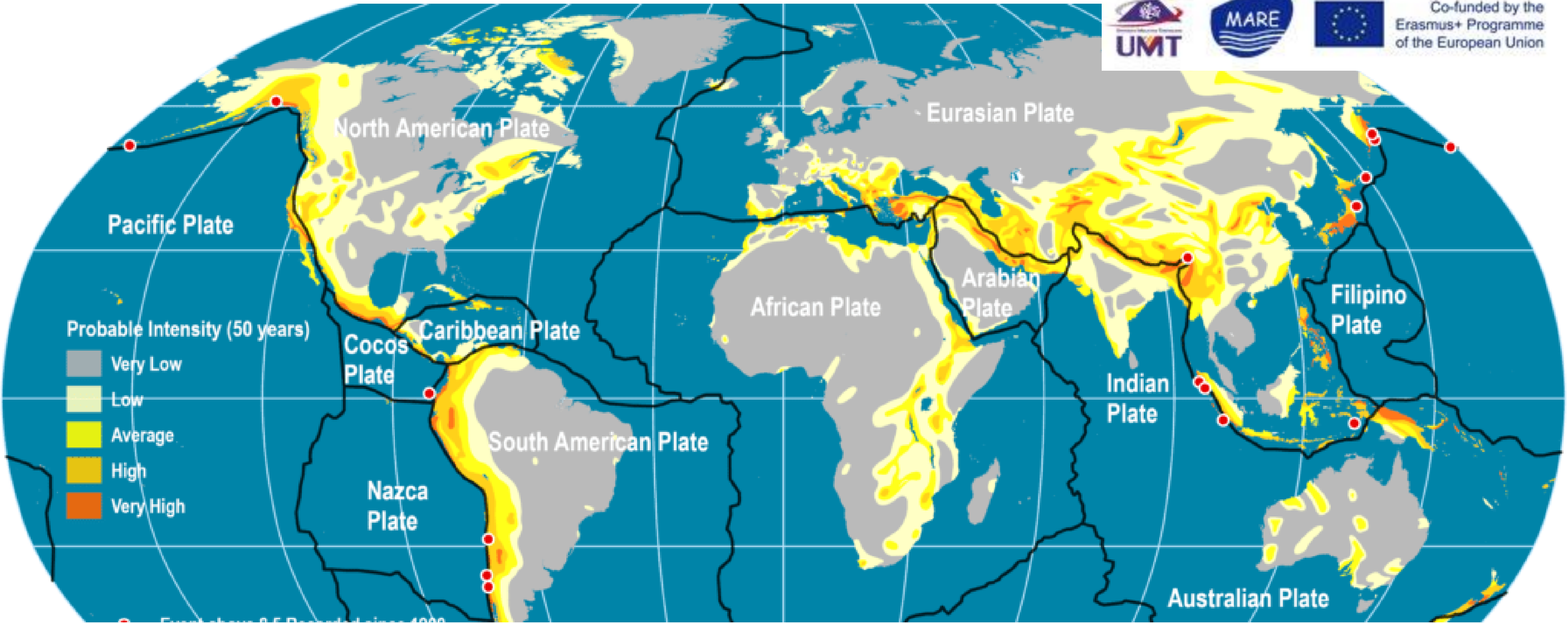


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https://www.youtube.com/watch?v=zbtAXW-2nz0

# The theory of plate tectonic

# The theory…

1. In 1924, Alfred Wegener suggested the drift hypothesis.
2. His hypothesis received much critics because he could not explain the force or mechanisms that lead to continental drift.
3. After world war II, scientific exploration has been more advanced.
4. So in 1968, they had accepted Wegener hypothesis and unfold the theory of plate tectonic

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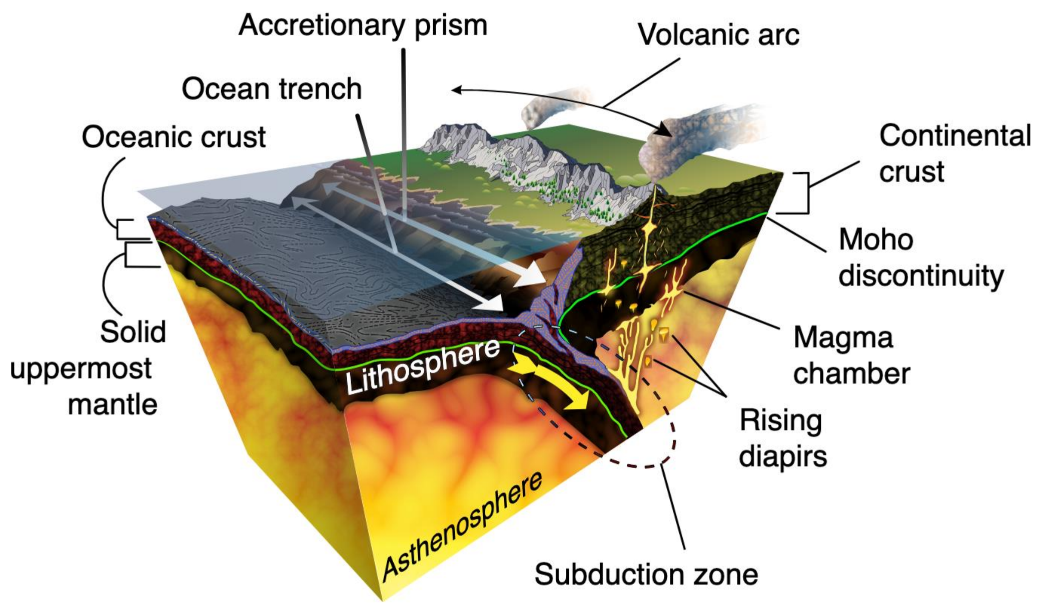


1. According to the plate tectonic model, the crust and the upper part of the mantle made up lithosphere, the strong outer layer.
2. The lithosphere vary in thickness and density depending on whether is is oceanic or continental.
3. The oceanic crust is composed of dense basalt, a rock rich in iron and magnesium.
4. The continental crust composed of less dense granitic rocks.
5. Because if this differences, the oceanic lithosphere has higher density.

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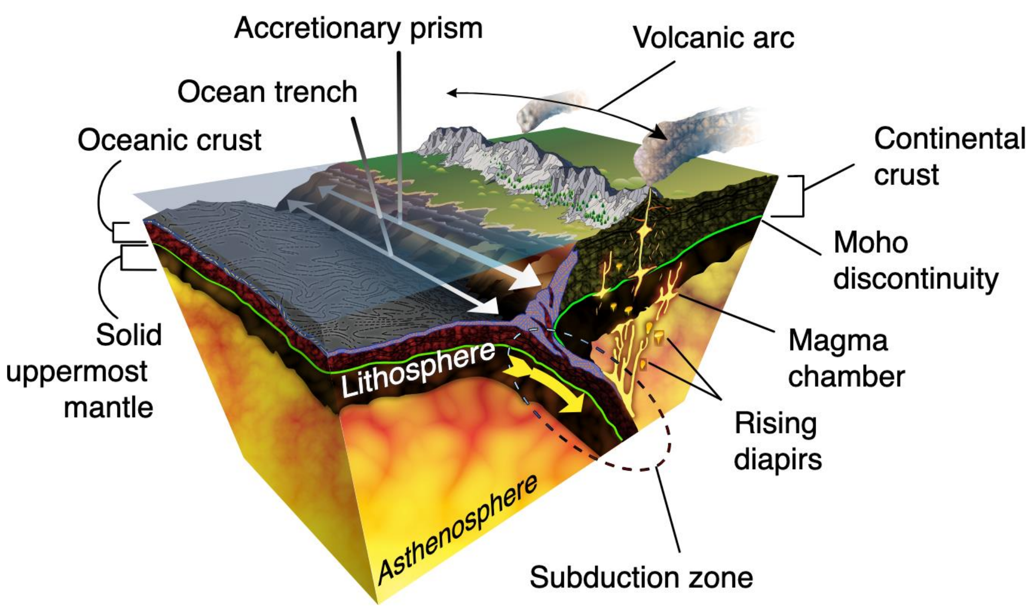


6. The asthenosphere (*asthenos*=weak) is a hotter weaker region of the mantle.
7. The pressure and temperature bring the rock to melting point in this layer.
8. Hence the rock appear to be flowing.
9. This allow the Earth lithosphere to effectively detached from the asthenosphere and move independently.

# Earth’s Major Plates

1. North American plate.
2. South American plate.
3. Pacific plate
4. African plate
5. Eurasian plate
6. Australian-Indian plate
7. Antarctic plate

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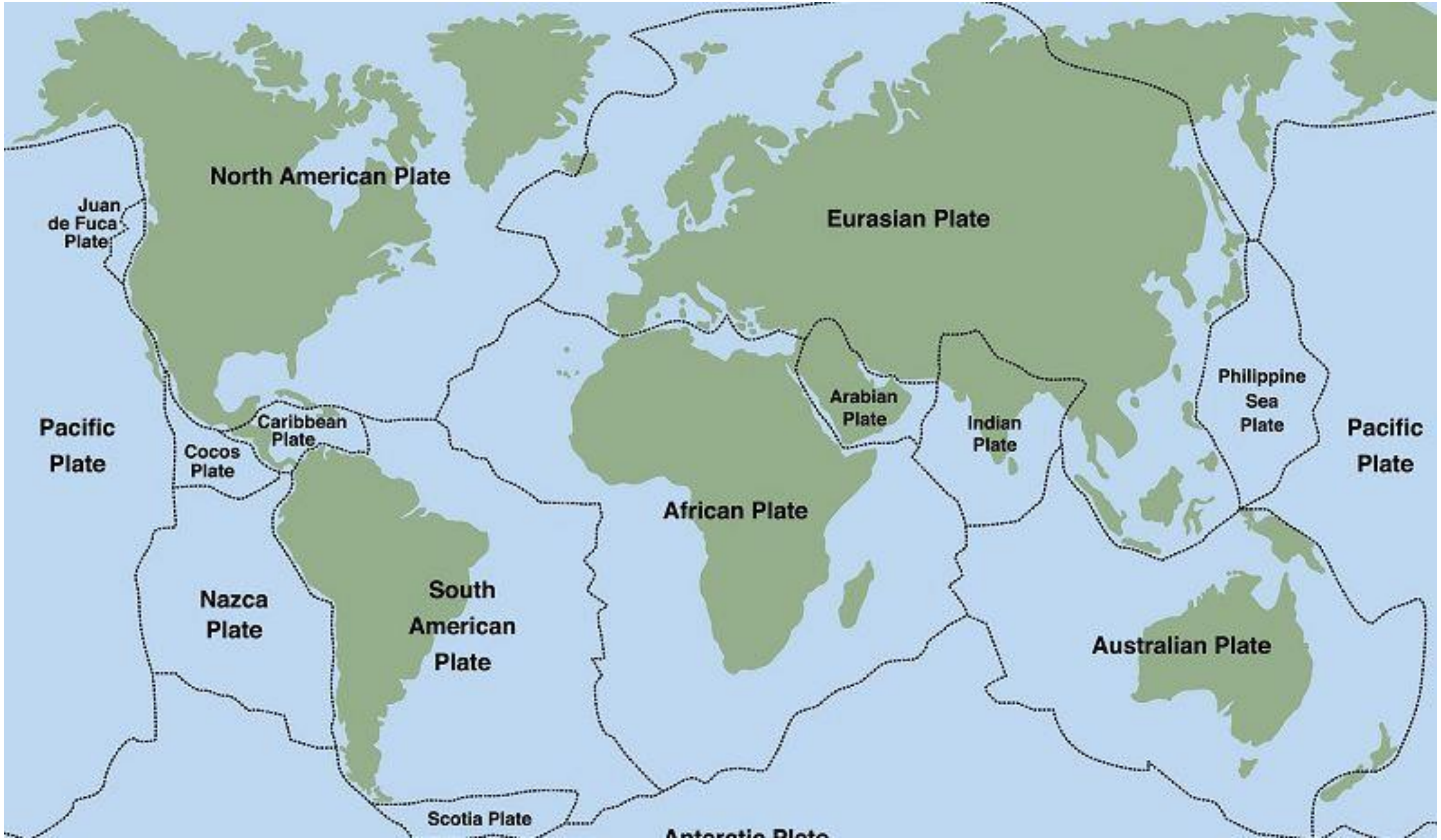
# Mircoplates

1. Philippine plate
2. Nazca plate
3. Cocos plate
4. Arabian plate
5. Caribbean plate
6. Scotia plate



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# GEOLOGIC TIME SCALE

https://www.youtube.com/watch?v=dI7SbZx_Qiw

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# CONTENTS

https://www.youtube.com/watch?v=veit8_NESxU

https://www.youtube.com/watch?v=rWp5ZpJAIAE

- Terminology
- Rationale
- History and nomenclature of the time scale
- Table of geologic time
- Proposed Precambrian timeline

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# TERMINOLOGY

- The geologic time scale is a system of chronological dating that relates geological strata to time. It is used by geologists, paleontologists, and other Earth scientists to describe the timing and relationships of events that have occurred during Earth's history. The table of geologic time spans, presented here, agree with the nomenclature, dates and standard color codes set forth by the International Commission on Stratigraphy.

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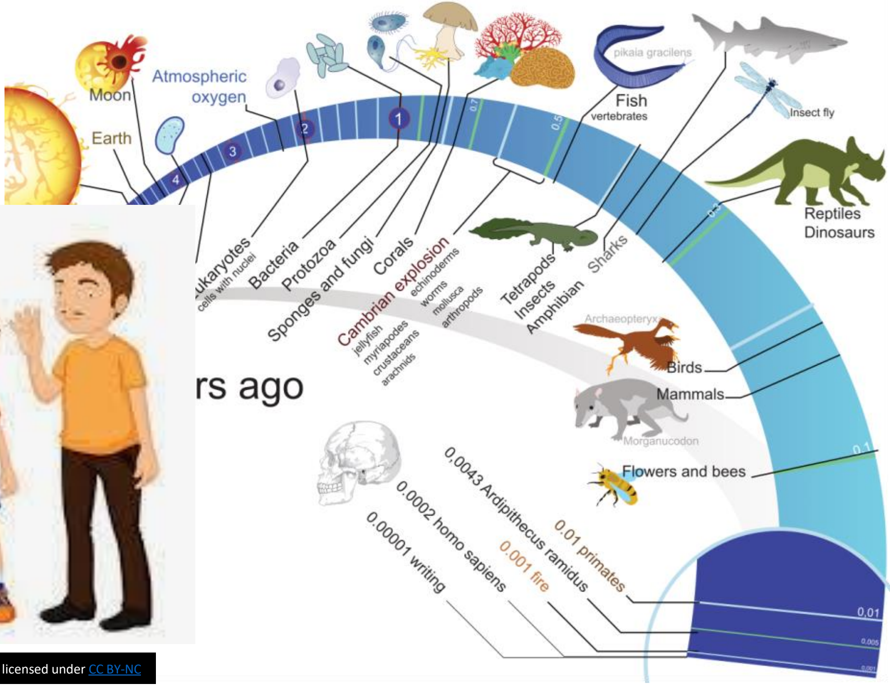
# COMPARE YOUR AGE AND LIFE TIME LINE TO THE GEOLOGICAL TIME ……



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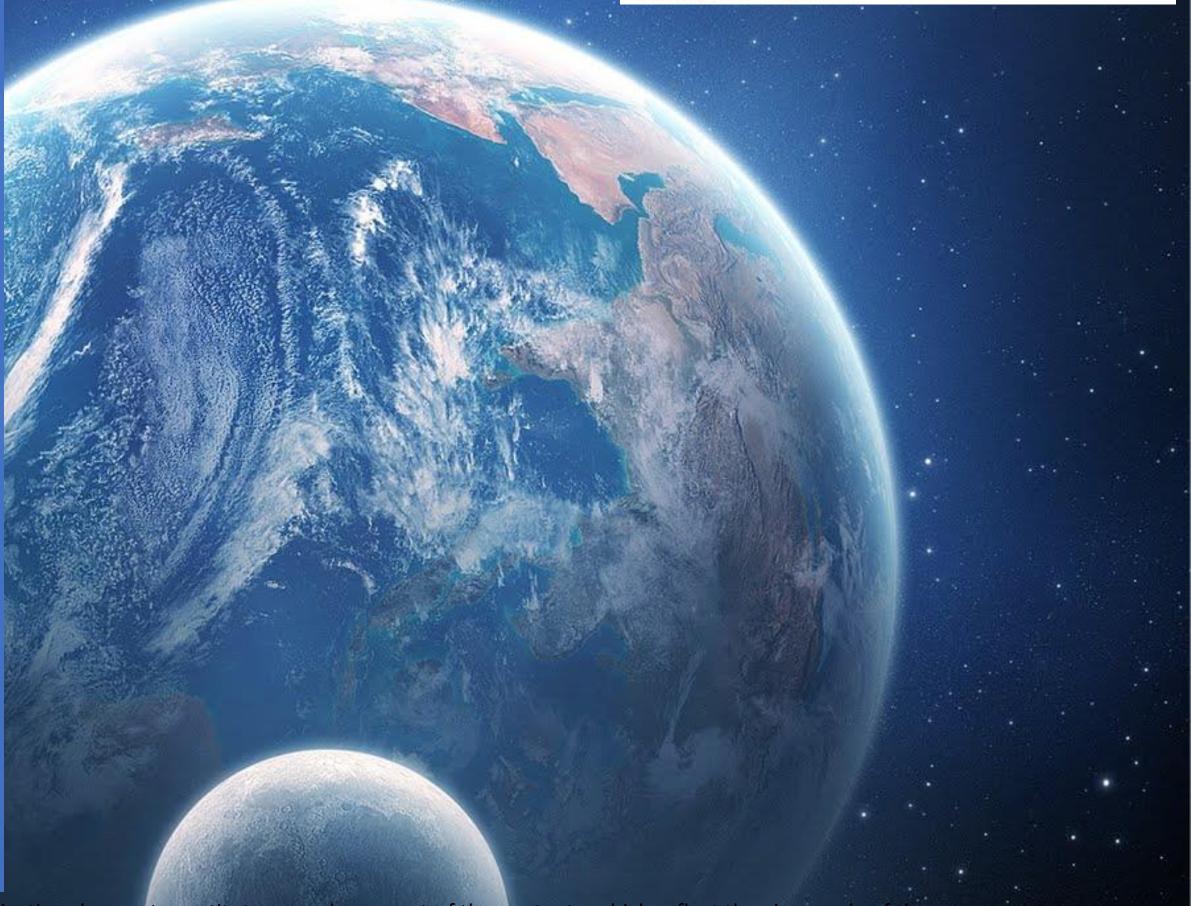
# RATIONALE

- The mystery age of planet Earth.
- Since the early formations of planet Earth, so many changes have occurred.
- The changes are recorded in rocks.
- When telling history of planet earth, scientist needs relative age or time.



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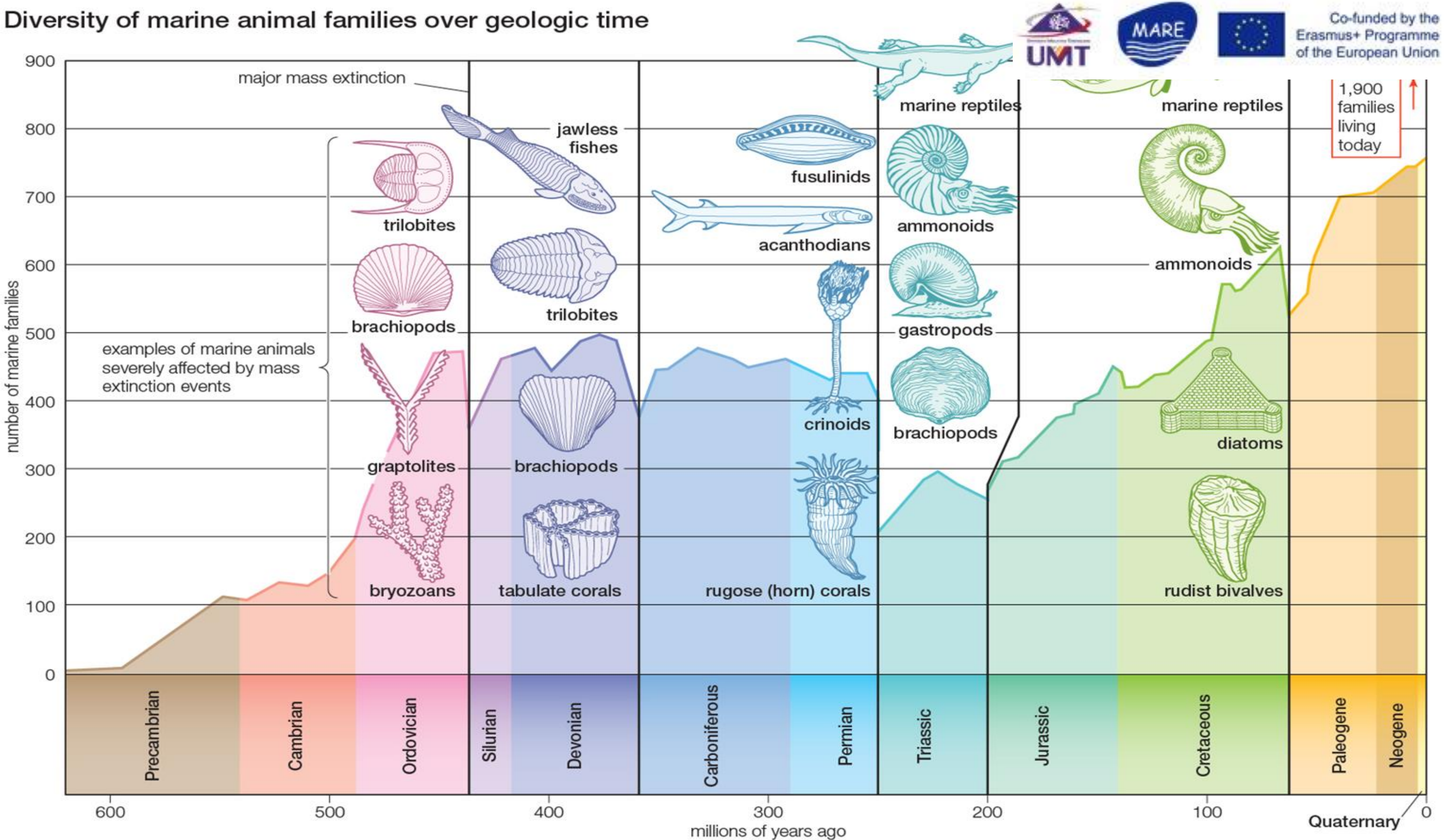
# RATIONALE

- Each of the layers, tells various chapters of Earth history.
- The story of first life on Earth to the wipe out of species, catastrophic events are told based on the chapters.
- Geological Time Scale - combined together the chronology / chapters of the stories.


Diversity of marine animal families over geologic time
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900
800
700
600
500
400
300
200
100
0
number of marine families
major mass extinction
examples of marine animals severely affected by mass extinction events
trilobites
brachiopods
graptolites
bryozoans
jawless fishes
trilobites
brachiopods
tabulate corals
fusulinids
acanthodians
crinoids
rugose (horn) corals
marine reptiles
ammonoids
gastropods
brachiopods
marine reptiles
ammonoids
diatoms
rudist bivalves
1,900 families living today
Precambrian
Cambrian
Ordovician
Silurian
Devonian
Carboniferous
Permian
Triassic
Jurassic
Cretaceous
Paleogene
Neogene
Quaternary
600
500
400
300
200
100
0
millions of years ago


NICOLAI STENONIS
DE SOLIDO
INTRA SOLIDVM NATVRALITER CONTENTO
DISSERTATIONIS PRODROMVS.
AD
SERENISSIMVM
FERDINANDVM II.
MAGNVM ETRVRIÆ DVCEM.
FLORENTIÆ
Ex Typographia sub signo STELLÆ MDCLXIX.
SVPERIORVM PERMISSV.



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- In 1669, Nicolas Steno (Danish Scientist) published the first law of stratigraphy. He suggested that the rock forms on top is usually younger than those below.
- “the further down you dig, the older the fossils are”

# NAMING THE ROCK LAYERS

- Based on the foundation set by Nicolas Steno, in year 1760s Giovanni Arduino (Italian) starts giving name to the rock layers.
- He studied the Italian Alps and start naming the layers based on composition and depth (height) of the layers.
- The lowest layer made out of metamorphic and volcanic rocks – Primary layers
- Above it is hard sedimentary rock – secondary layers
- And on top, are soft alluvial deposits known as tertiary and quaternary rocks.

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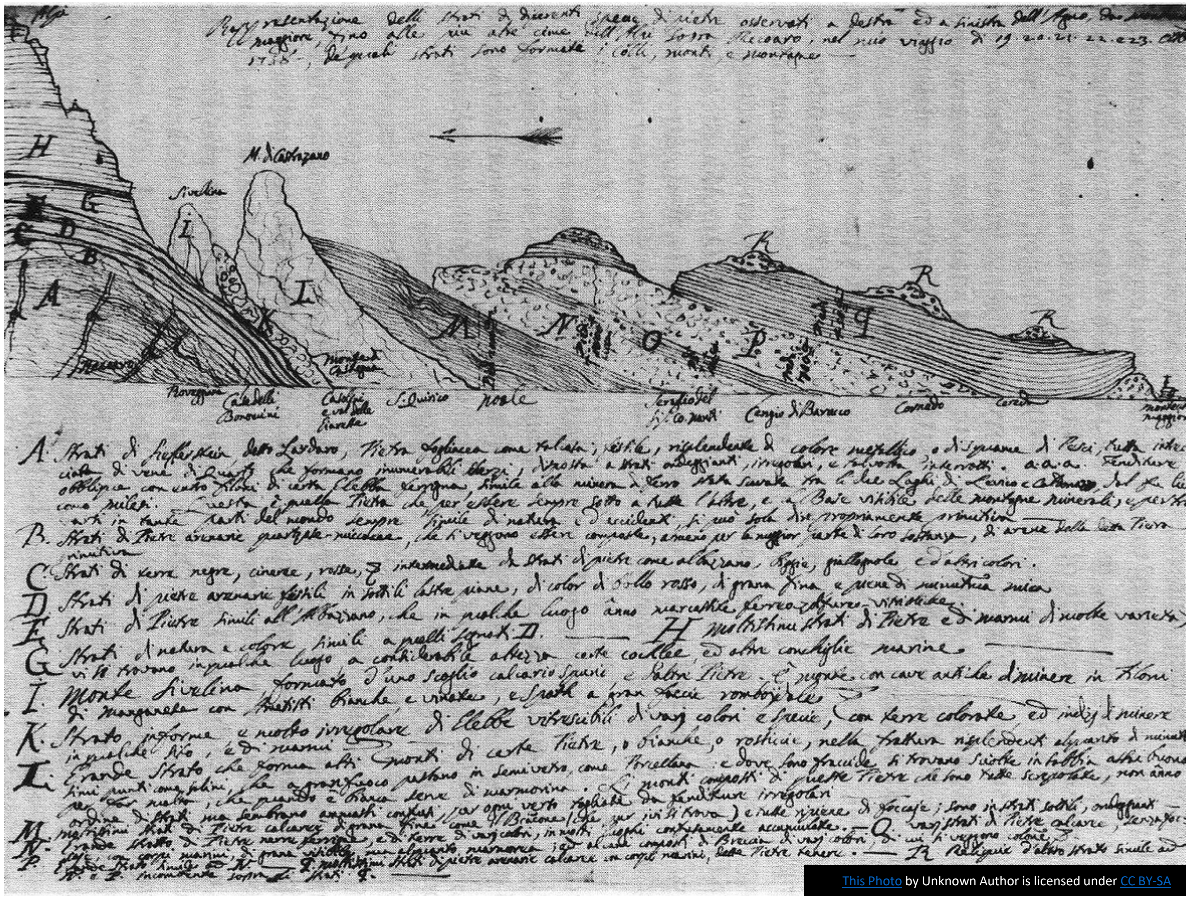

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# BUT COMPARING ROCK LAYERS ALL OVER THE WORLD IS IMPOSSIBLE DUE TO THE UNIQUE FORMATION OF EACH AREA. SO HOW DO YOU TELL STORY THAT RELATED?



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# FOSSIL AS AGE MARKER

- In 1819 English geologist, William Smith suggested the use of fossils found in rocks as age markers.
- He realized that fossils of trilobites usually are found bellow ammonites and ammonites below other molluscan species.
- The fossil all over the world relates based on these fossil distribution.

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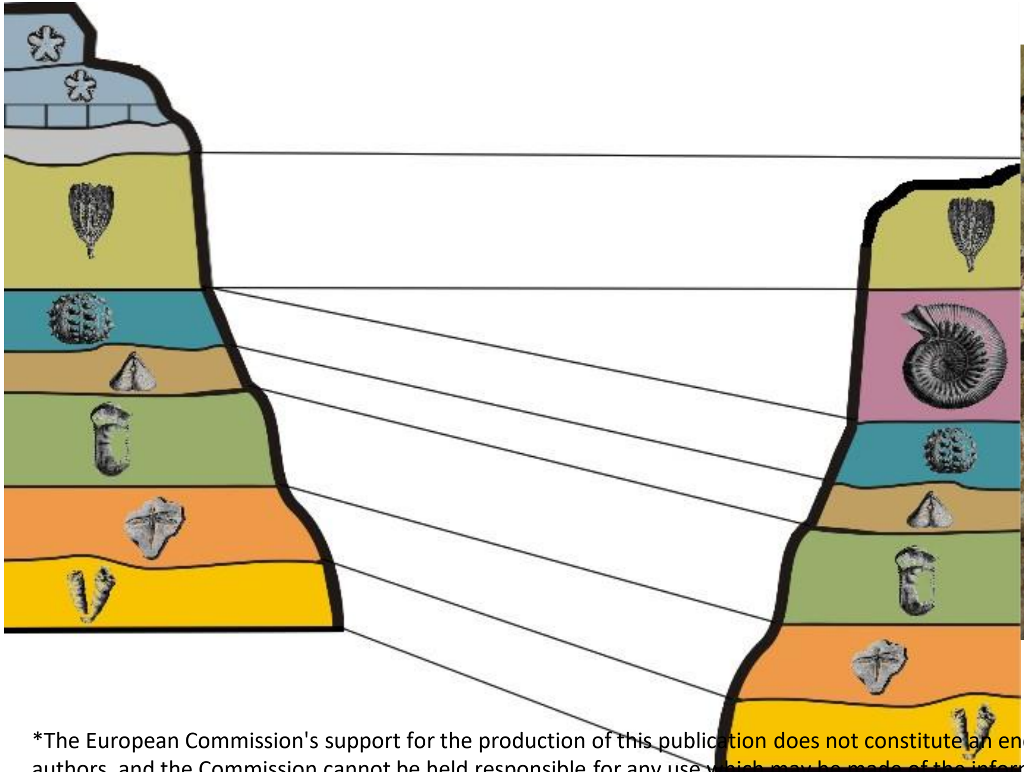
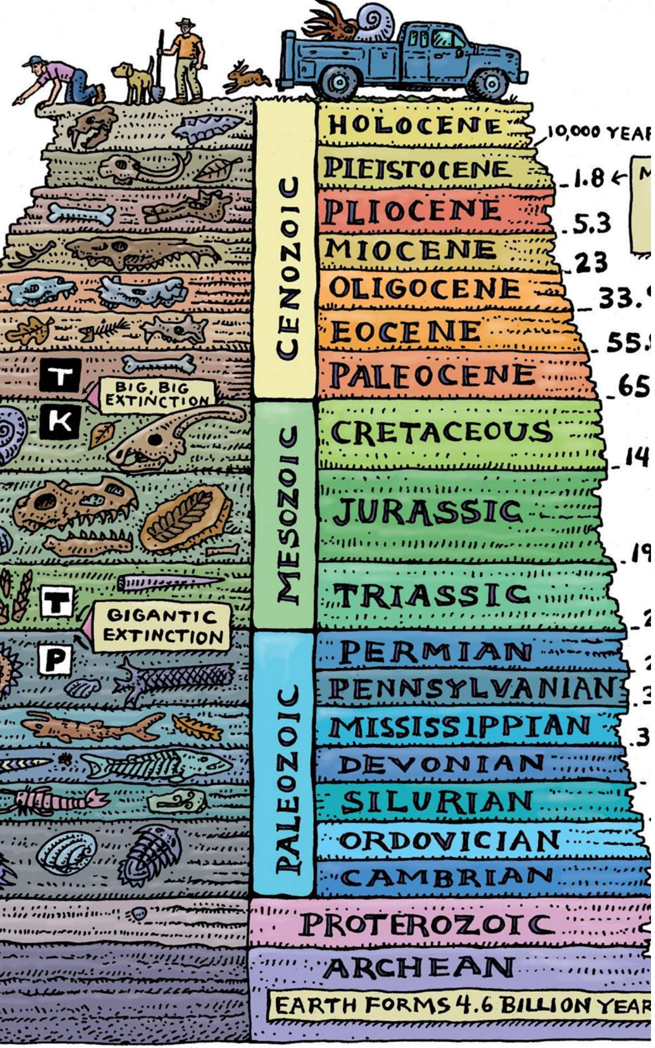
# EXAMPLES OF FOSSIL ARRANGEMENT AT TWO DIFFERENT OUTCROPS








# THE BIRTH OF GTS (GEOLOGICAL TIME SCALE)

- Combining both the relative placing of an events on the time line with the chronological numbers of rock samples, scientist has came out with Geological Time Scale.
- GTS- act like book chapters with stories/ episodes of events that happened on Earth

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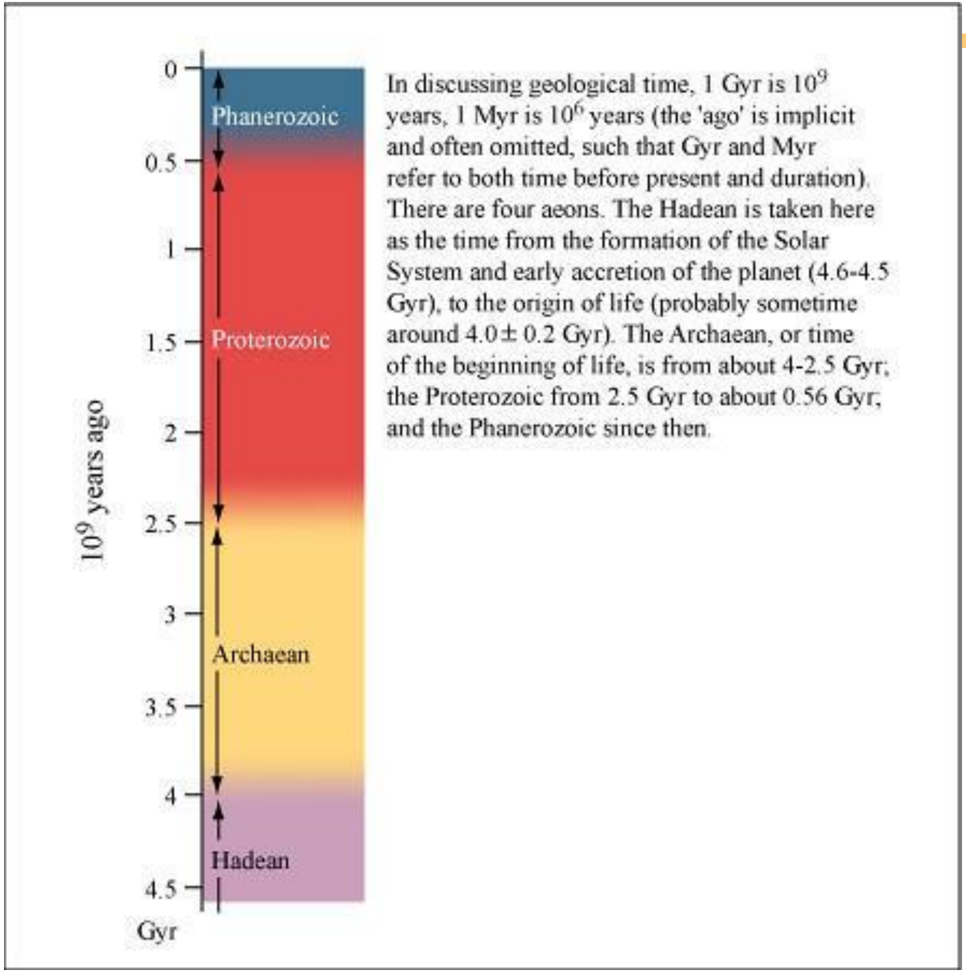
# TABLE OF GEOLOGIC TIME

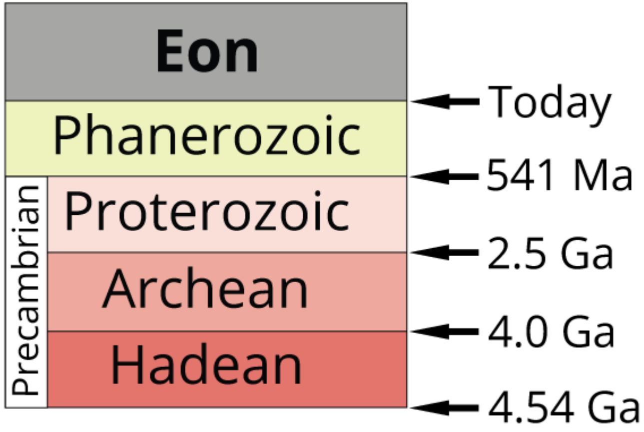
- The GTS has been organized into five subgroups
  - Eons
  - Eras
  - Periods
  - Epoch
  - Age

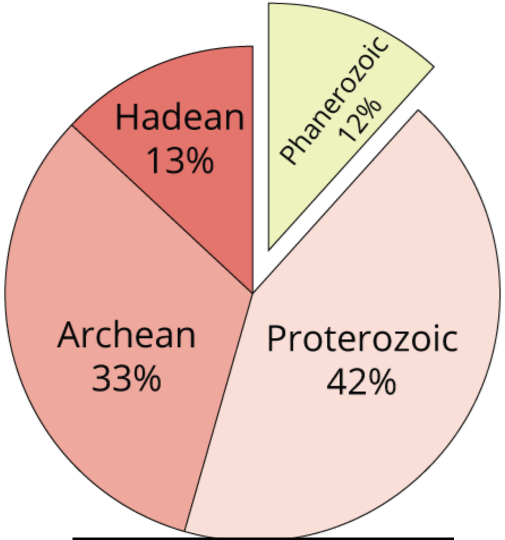



# LET US LOOK AT THE BIGGER GROUPS - EONS

- Eon was the largest slices of time. Range from ½ billions to 2 billions years ago.
- There are all together 4 Eons
  - **Hadean** (*4.6- 4 billion years ago*)
  - **Archean** (*4 – 2.5 billion years ago*)
  - **Proterozoic** (*2.5 -0.54 billion years ago*)
  - **Phanerozoic** (*541 million years ago - present*)

# THE RELATIVE PERCENTAGE OF EONS



# HADEAN EONS (4.6 – 4 BILLION YEARS AGO)– THE BEGINNING OF PLANET EARTH

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# WHAT WAS IT LIKE DURING HADEAN?

- The name Hadean came from Greek word “Hades” (the under world).
- There were no fossil found during this Hadean Eons – planet was on fire!
- Hadean Eon- begin with Earth formation and ended by cooling of planet Earth.

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## NO SIGN OF LIFE

- Intensive volcanic activities.
- Raging storms
- Meteor shower
- Flowing magma
- Absent of oxygen and atmosphere
- No water

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# THE ARCHEAN EON (4 – 2.5 BILLION YEARS AGO)

# THE FIRST SIGN OF LIFE



- Archean (Greek) means “the origin” .
- The cooling Earth set stage for microbe to develop.
- Most took refuge in the deep ocean
- Fossil of microbes (microscopic organisms) are in form of stromatolites.
- Oldest stromatolites were found in western Australia.
- No oxygen – most are anaerobic organisms.



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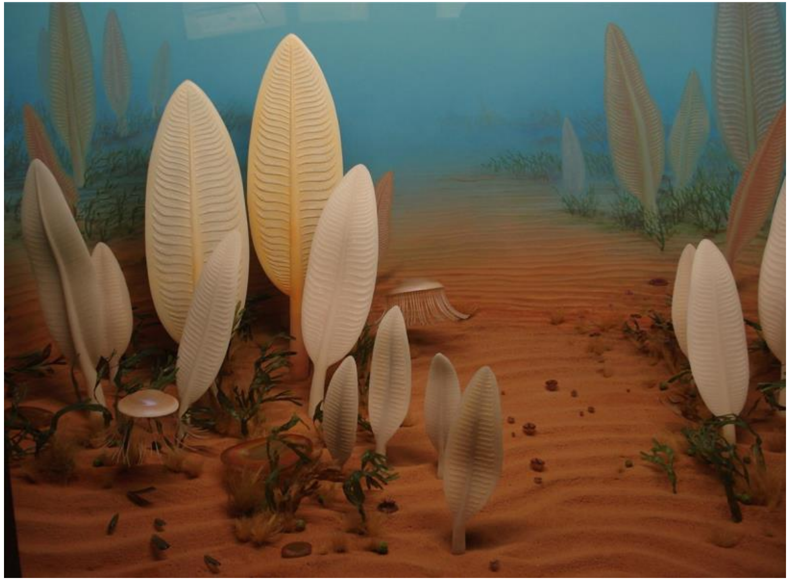
# EARLIER LIFE



- The word Proterozoic means “earlier life”
- Thanks to photosynthetic bacteria and microbes, oxygen started to fill the Earth’s atmosphere.
- This condition allow larger single cell and multi cell organisms to evolve.
- The condition also wipe out most of the anaerobic ancestors.

# THE VISIBLE LIFE STARTS TO DOMINATE EARTH

- The Phanerozoic is also known to mark the beginning of diverse organisms on Earth.
- This eon can be further divided into 3 Eras.
  - Paleozoic Era
  - Mesozoic Era
  - Cenozoic Era
- The cooling Earth now has oxygen, atmosphere and ozones.
- Continents formation allow various ecosystem to be developed on earth

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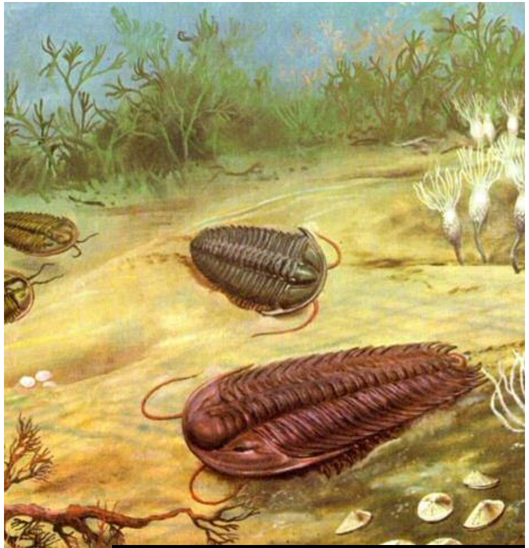
# LET US TAKE A CLOSER LOOK AT THE PALEOZOIC ERA

- Phanerozoic Eon >>> Paleozoic Era (541 – 252 million years ago)
- Paleozoic – “ancient life”
- This era mark the start of diversity explosion!!!
- During the early part of Paleozoic Era, marine fossil are found abundant in rocks all over the world!
- Paleozoic Era- divided into 6 periods
    - Cambrian, Ordovician, Silurian, Devonian, Carboniferous, Permian.

# PALEOZOIC ERA >> CAMBRIAN PERIOD (541 - 485.4 MILLION YEARS AGO)


This Photo by Unknown Author is licensed under CC BY-NC-ND

- The famous “Cambrian explosion” occurred.
- Many animals develop exoskeleton or ability to swim. The marine ecosystem were rich with prey and predator and plants.
- Trilobites were so successful during this era that their presence become age marker of early Paleozoic era (Early Cambrian period: 541 – 520 mya).
- However, the Cambrian ended 488 million years ago. Cambrian-Ordovician Extinction Event .
- During this mass extinction event, many trilobites and mollusk species disappeared.

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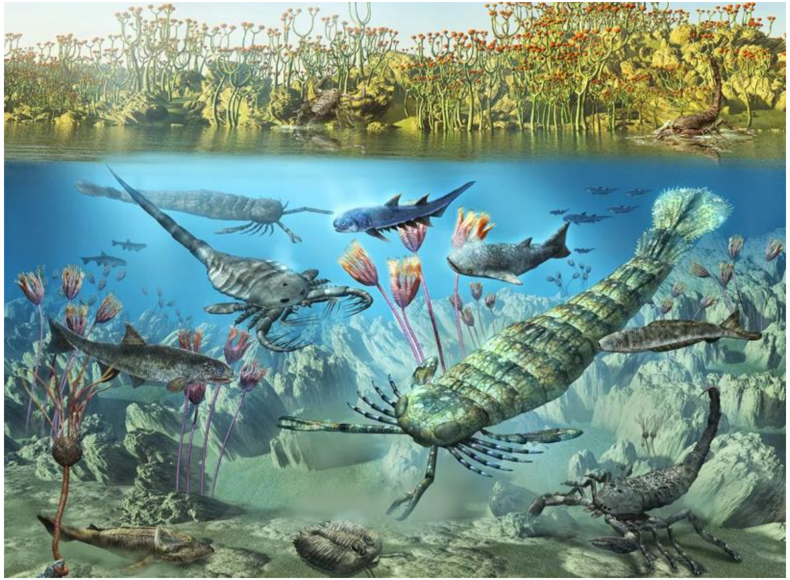
# PALEOZOIC ERA >> ORDOVICIAN PERIOD (485.4 – 443.8 MILLION YEARS AGO)

- The drift of continents, increase oxygen levels and changes of sea level has once again allow the burst of diversity during Ordovician period
- The first fish evolved –Ostracoderms (jawless and covered by bony plates) starts to dominate the oceans.
- The Ordovician periods also ended with mass extinction event- Ordovician-Silurian extinction event (wipe out 86% marine species)

# PALEOZOIC ERA >> SILURIAN PERIOD (443.8 – 419.2 MILLION YEARS AGO)



- Plant starts to take over the land.
- Insects were also very successful on land.
- Jawless fish now has evolved into jawed fish.

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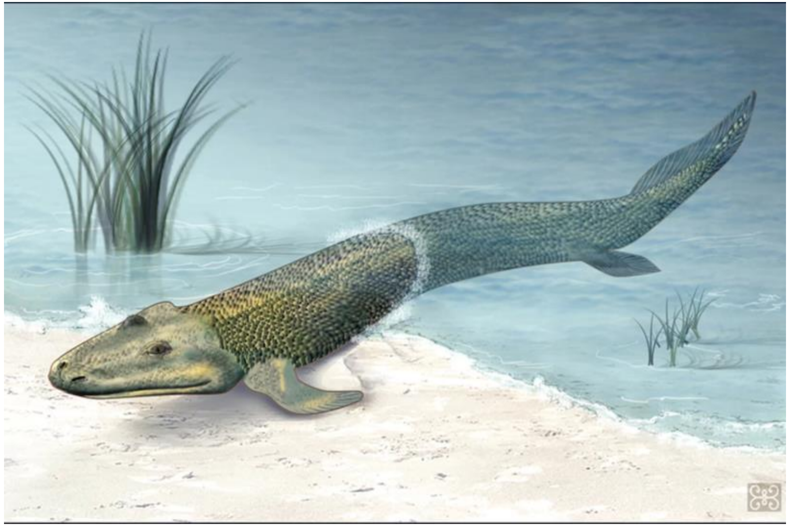
# PALEOZOIC ERA >> DEVONIAN PERIOD (419.2 – 358.9 MILLION YEARS AGO)



- Fish began to take over the seas. Early shark starts to roam the oceans.
- Things get pretty crowded on land too- insects diversify, trees are larger forming canopy of forests.
- By end of Devonian, fish evolved into Tetrapod and starts to take over the land. Amphibians was very successful during the late Devonian periods.
- This period ended with another mass extinction event – “The late Devonian Extinctions”

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# PALEOZOIC ERA >> CARBONIFEROUS PERIOD (358.9 – 298.9 MILLION YEARS AGO)

- This periods recorded an increase in global temperature, moisture and oxygen level. Allowing dense forest and swamp to spread all across the globe.
- Insects were very HUGE in this period.
- The continent starts to drift again and merge to become the supercontinent – Pangea.
- By end of Carboniferous period, most forest were replaced with giant grass land– humidity drop due to the formation of supercontinent.

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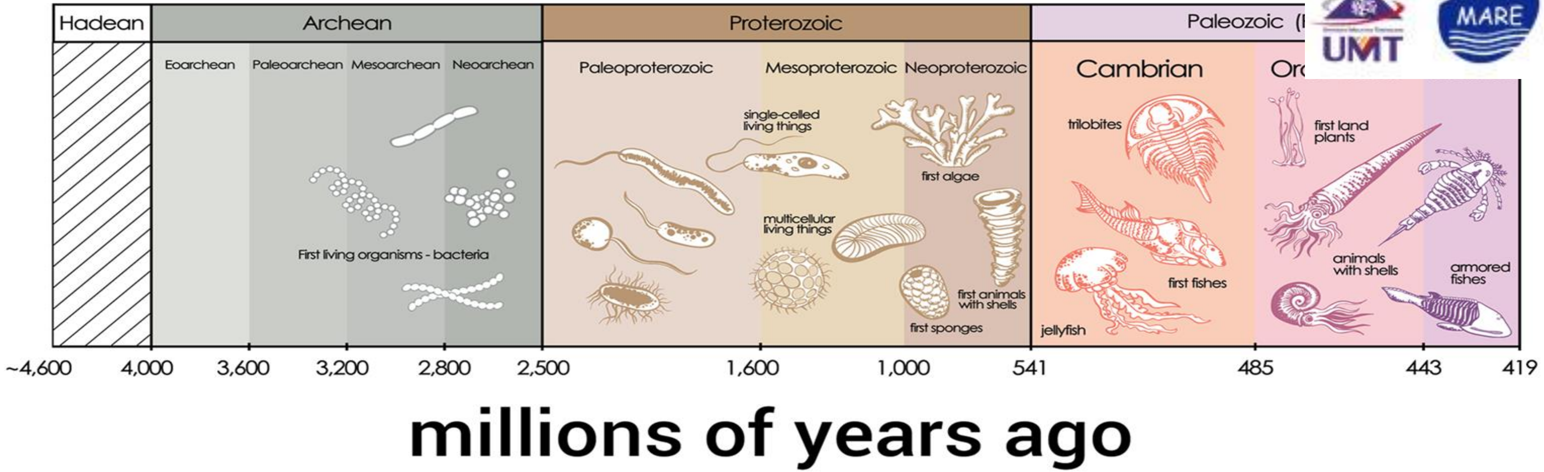
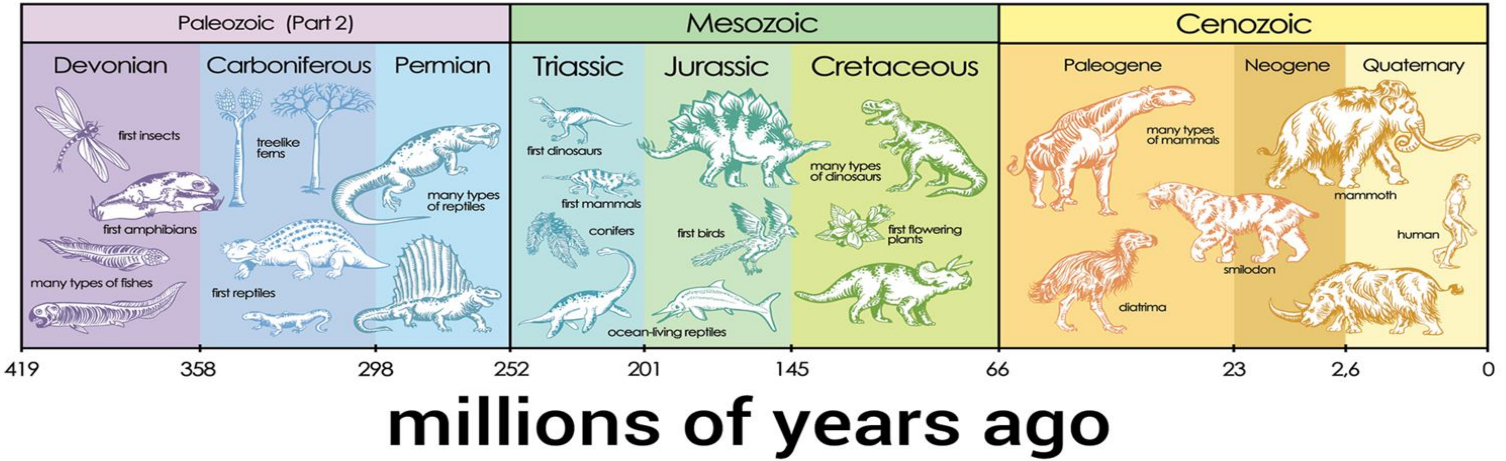
# PALEOZOIC ERA >> PERMIAN PERIOD (298.9 – 251.9 MILLION YEARS AGO)

- Reptiles were very successful during the early Permian period.
- But as the land get dryer and hotter, these reptiles were forced to evolved and adapt to harsh condition.
- The Permian came to an end with another mass extinction event "The Permian-Triassic Extinctions Event" (The Great Dying)
- Most marine and terrestrial species were wipe out during this mass extinction event.
- This is also mark an end to PALEOZOIC ERA.

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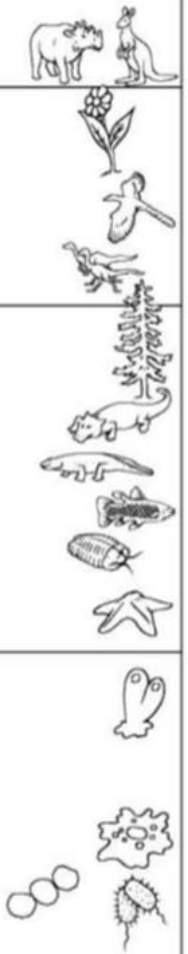
| ERA | PERIOD | MILLION YEARS AGO | MAJOR EVOLUTIONARY EVENTS |
|---|---|---|---|
| Cenozoic | Quaternary | | Humans evolve |
| | | 1.6 | |
| | Tertiary | | First placental mammals |
| | | 66 | |
| Mesozoic | Cretaceous | | Flowering plants dominant |
| | | 144 | |
| | Jurassic | | First birds<br>First mammals<br>First flowering plants |
| | | 208 | |
| | Triassic | | First dinosaurs |
| | | 245 | |
| Paleozoic | Permian | | Conifers dominant |
| | | 286 | |
| | Pennsylvanian | | First reptiles<br>Great coal deposits form |
| | | 320 | |
| | Mississippian | | First seed plants |
| | | 360 | |
| | Devonian | | First amphibians |
| | | 408 | |
| | Silurian | | First land plants<br>First jawed fishes |
| | | 438 | |
| | Ordovician | | Algae dominant<br>First vertebrates |
| | | 505 | |
| | Cambrian | | Invertebrates |
| | | 544 | |
| Precambrian Era | | | Life diversifies |
| | | 2000 | Eukaryotes |
| | | 3500 | Prokaryotes |
| | | 4000 | Life evolves |

MAJOR LIFE FORMS



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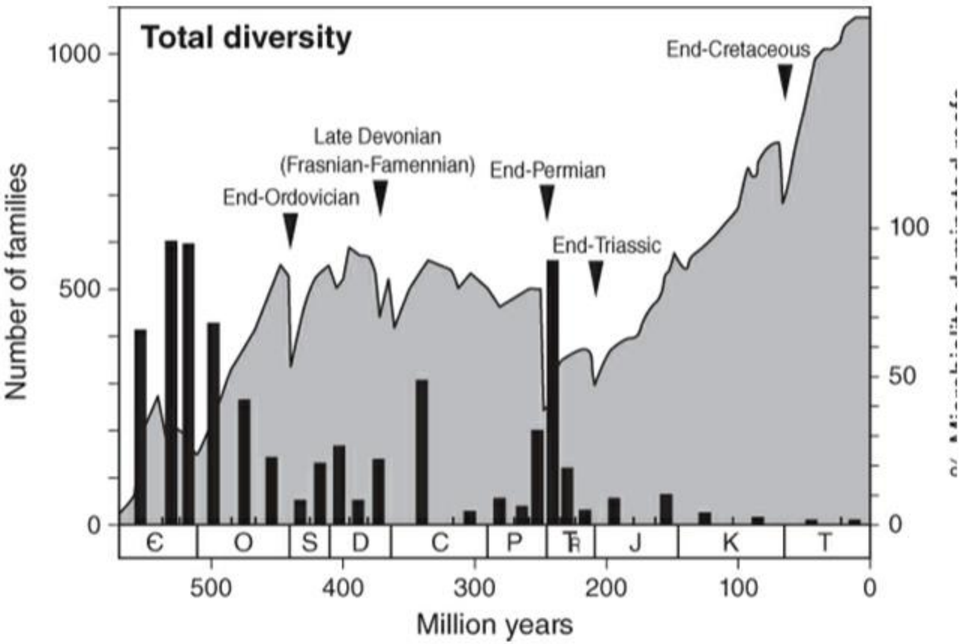
# Mass Extinctions- the big 5

- Mass extinctions are well known as biodiversity crises that affect wide geographic areas and affect a broad taxonomic spectrum in which extinction rates increase significantly from normal background rates.
- The most prominent mass extinctions in the **Phanerozoic** are the “Big Five,”
    - Ordovician- Silurian,
    - in the Late Devonian,
    - at the end of the Permian,
    - at the end of the Triassic,
    - and at the end of the Cretaceous




Bottjer, David J.. Paleoecology (p. 175). Wiley. Kindle Edition.

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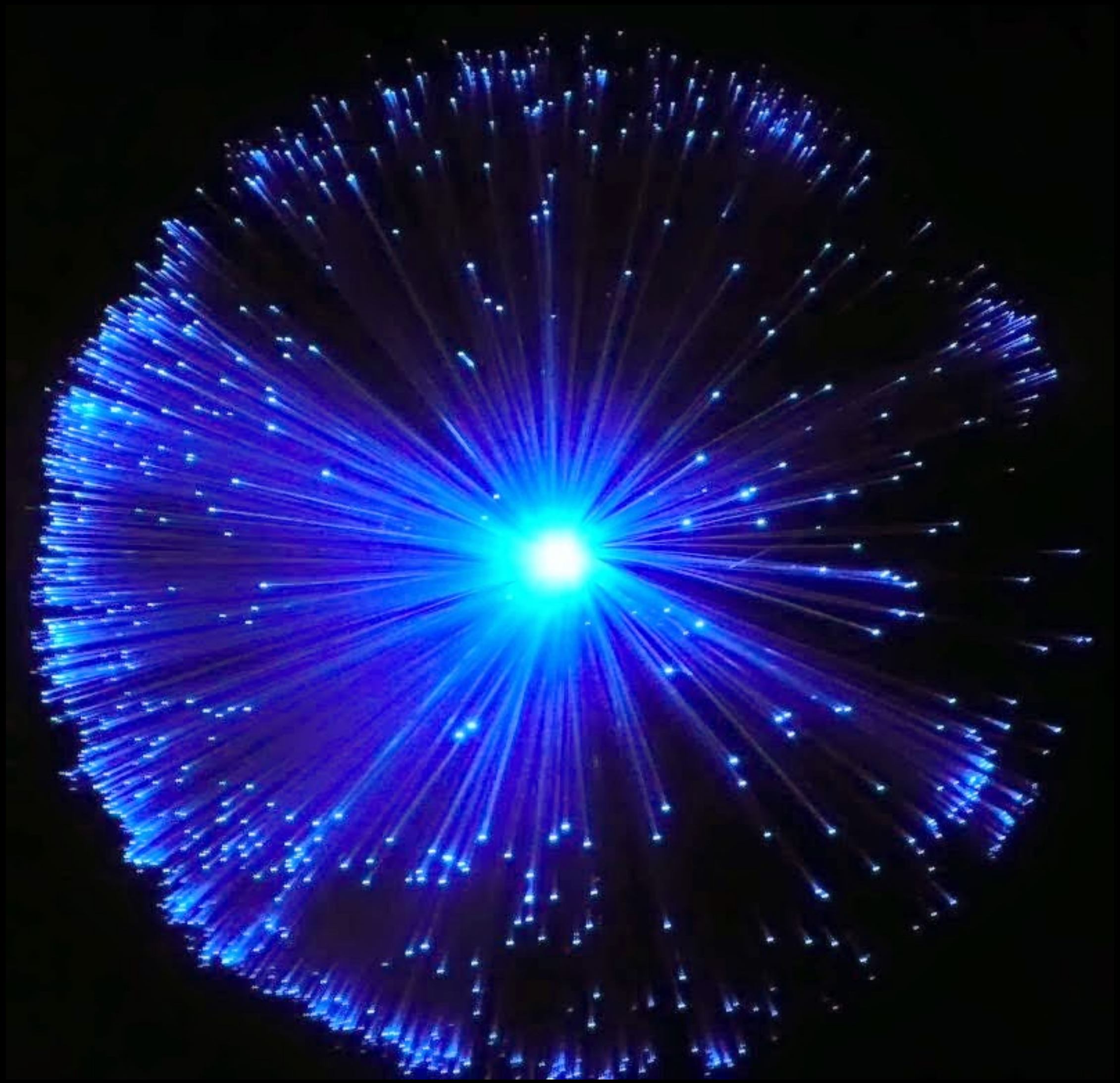
# SUMMARY

- Hadean, Archean and Proterozoic are also known as ‘Precambrian’.
- There were 5 mass extinction events.
- The Geological Time Scale always change due to the on going research and new finding. The International Commission on Stratigraphy (ICS) is the body that authorised or publish the GTS.

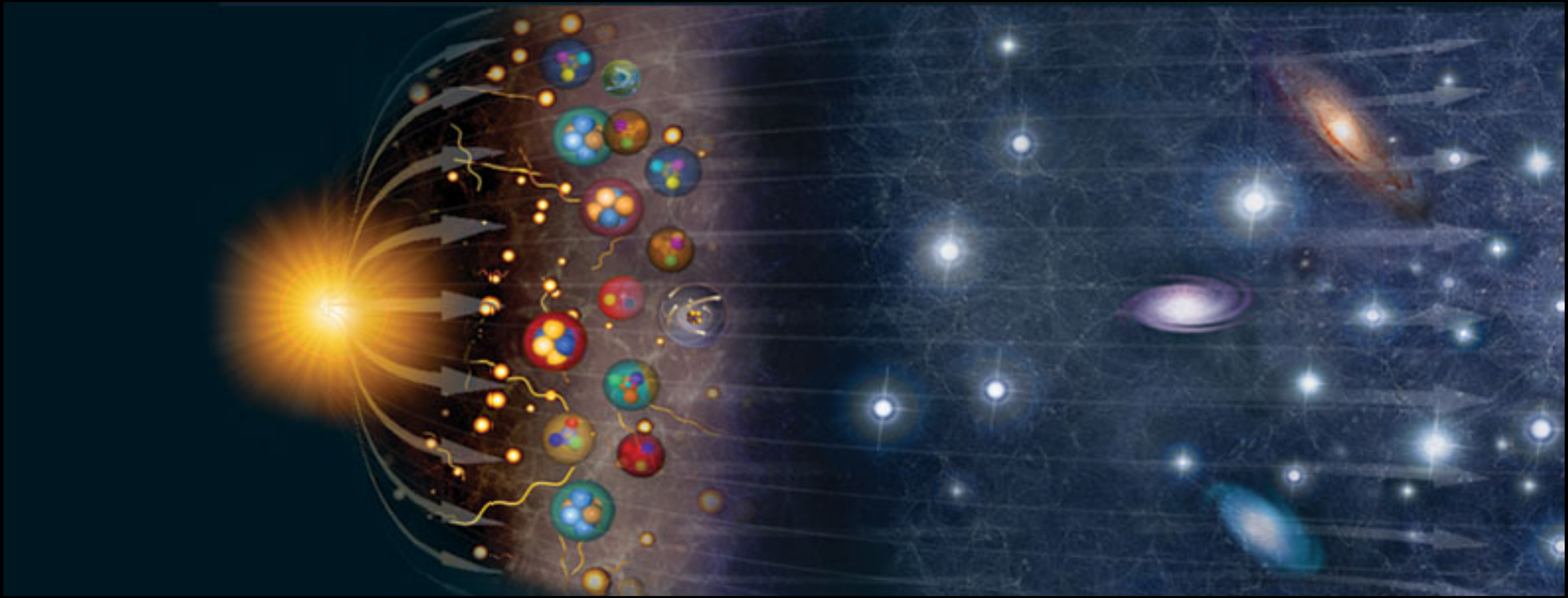
# Cosmology theories

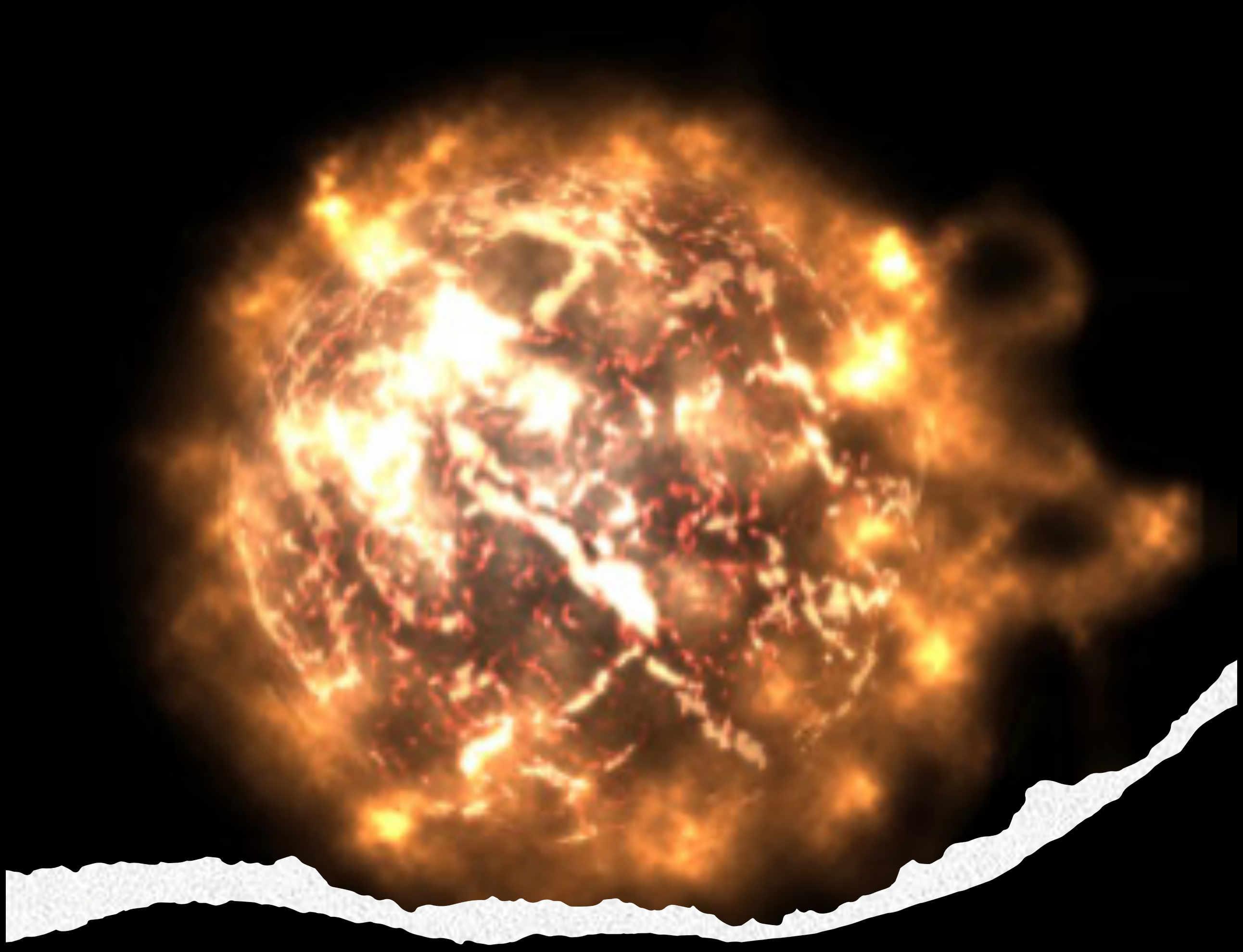
FATIN MINHAT (PhD)

# THE BIG BANG



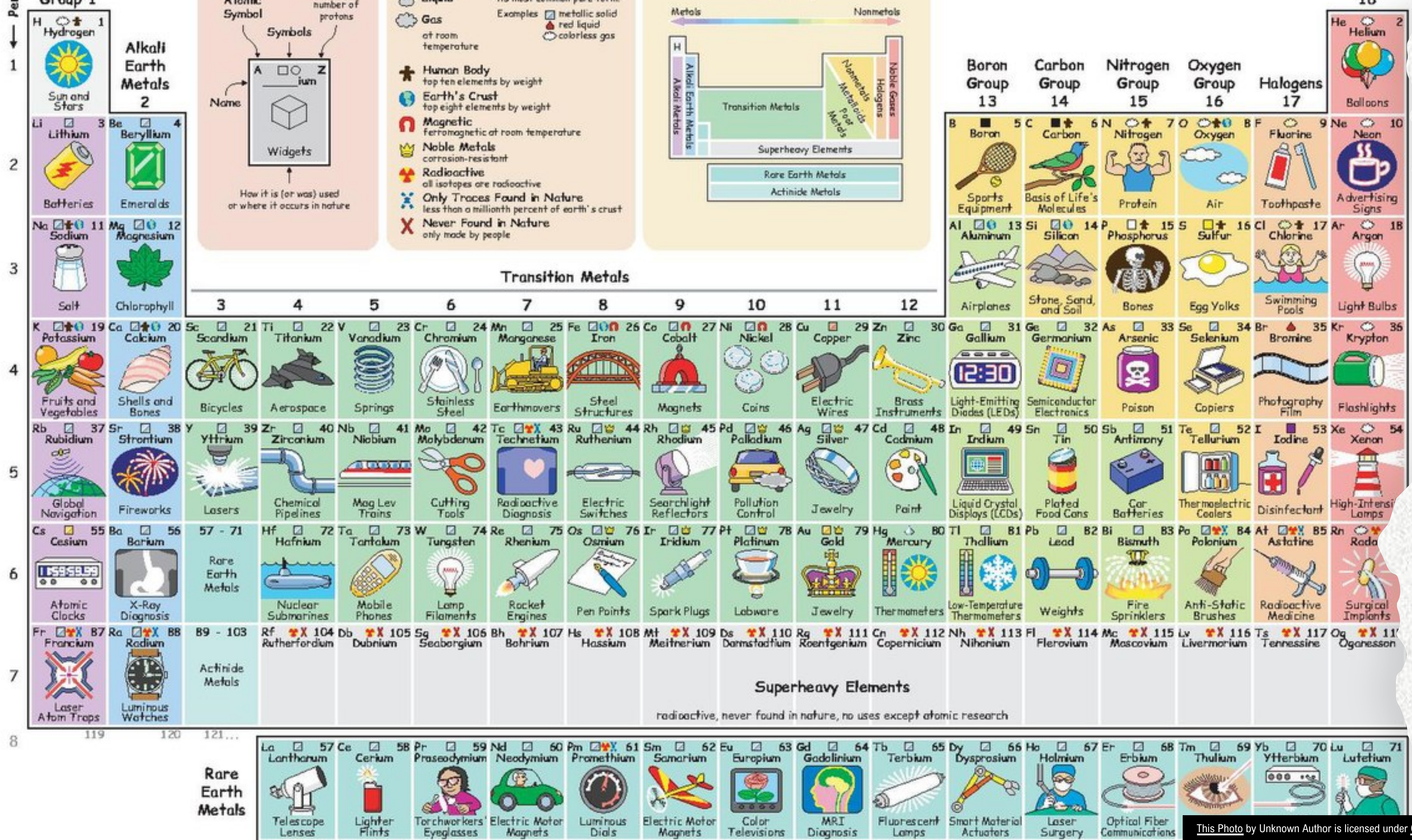
# THE BIG BANG





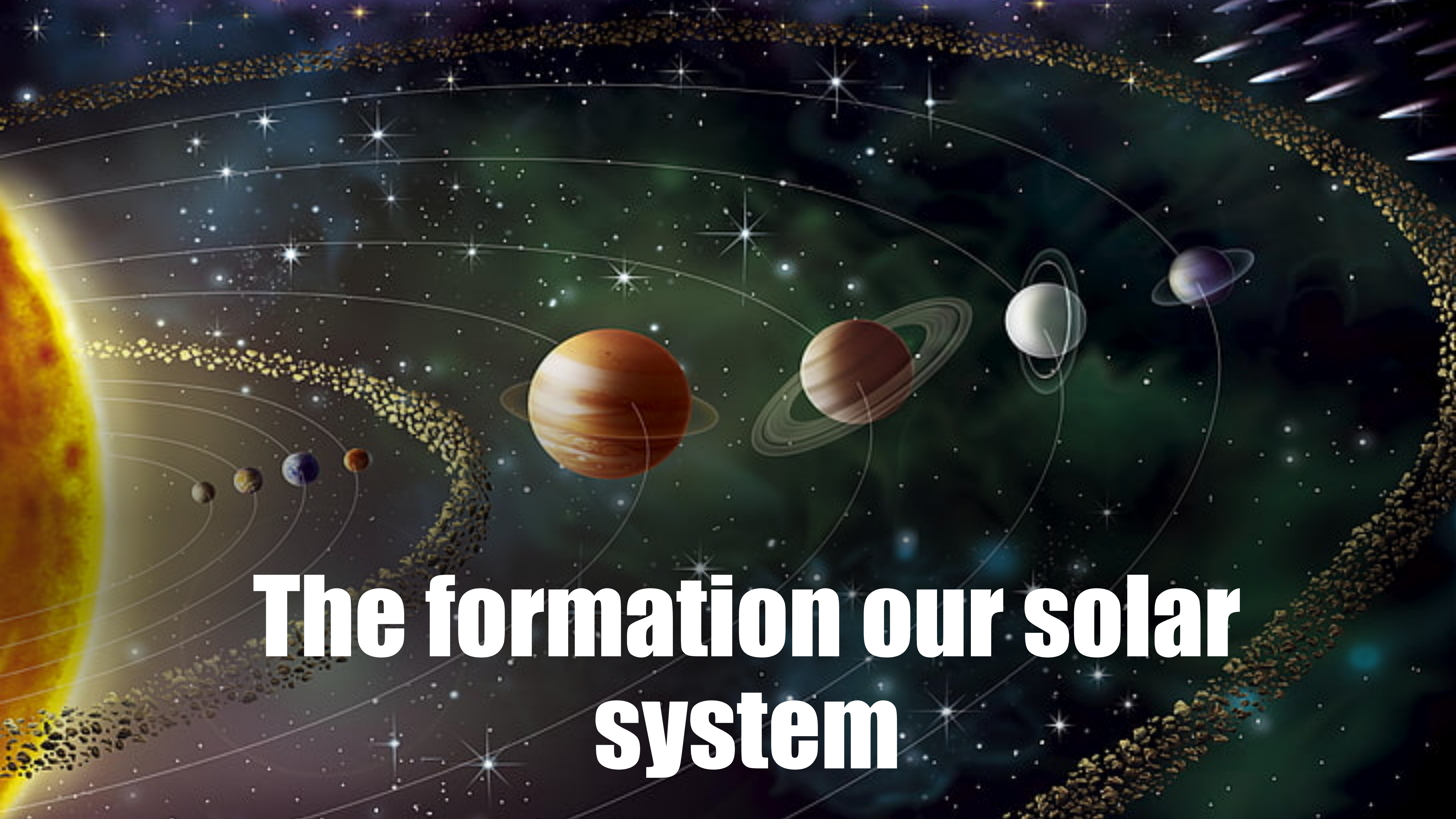
# The expansion and cooling down of the universe.

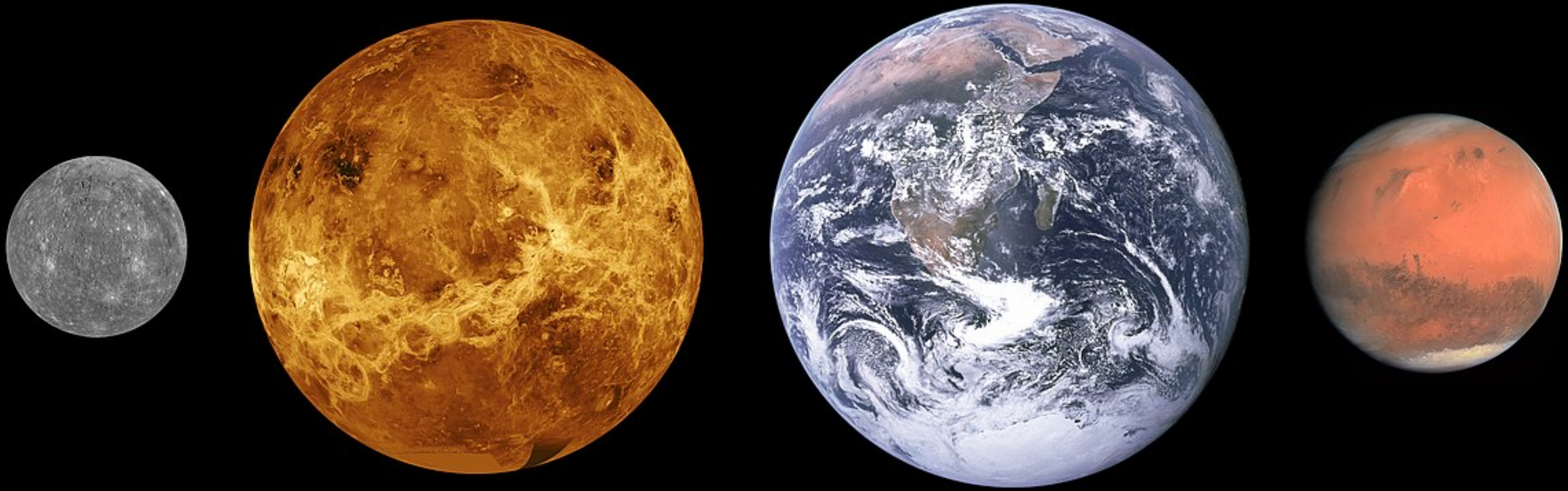
# The star is born

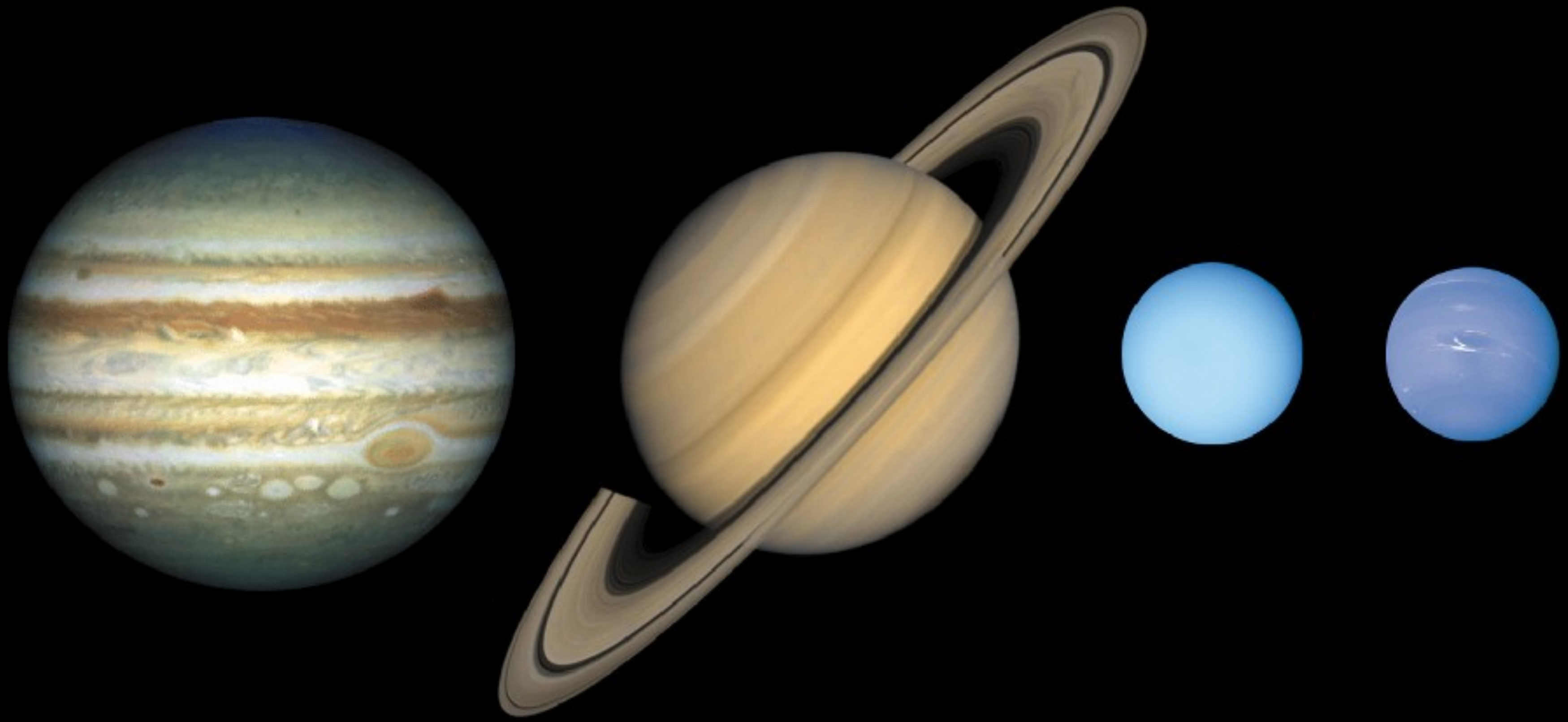


Group 1
Atomic Symbol
Symbols
number of protons
Name
A
ium
Z
Widgets
How it is (or was) used or where it occurs in nature
Gas at room temperature
Examples: metallic solid, red liquid, colorless gas
Human Body top ten elements by weight
Earth's Crust top eight elements by weight
Magnetic ferromagnetic at room temperature
Noble Metals corrosion-resistant
Radioactive all isotopes are radioactive
Only Traces Found in Nature less than a millionth percent of earth's crust
Never Found in Nature only made by people
Metals
Nonmetals
H
Alkali Metals
Alkali Earth Metals
Transition Metals
Nonmetals
Metalloids
Poor Metals
Halogens
Noble Gases
Superheavy Elements
Rare Earth Metals
Actinide Metals
1
2
3
4
5
6
7
8
H 1 Hydrogen Sun and Stars
Alkali Earth Metals 2
He 2 Helium Balloons
Boron Group 13
Carbon Group 14
Nitrogen Group 15
Oxygen Group 16
Halogens 17
Li 3 Lithium Batteries
Be 4 Beryllium Emeralds
B 5 Boron Sports Equipment
C 6 Carbon Basis of Life's Molecules
N 7 Nitrogen Protein
O 8 Oxygen Air
F 9 Fluorine Toothpaste
Ne 10 Neon Advertising Signs
Na 11 Sodium Salt
Mg 12 Magnesium Chlorophyll
Transition Metals
3 4 5 6 7 8 9 10 11 12
Al 13 Aluminum Airplanes
Si 14 Silicon Stone, Sand, and Soil
P 15 Phosphorus Bones
S 16 Sulfur Egg Yolks
Cl 17 Chlorine Swimming Pools
Ar 18 Argon Light Bulbs
K 19 Potassium Fruits and Vegetables
Ca 20 Calcium Shells and Bones
Sc 21 Scandium Bicycles
Ti 22 Titanium Aerospace
V 23 Vanadium Springs
Cr 24 Chromium Stainless Steel
Mn 25 Manganese Earthmovers
Fe 26 Iron Steel Structures
Co 27 Cobalt Magnets
Ni 28 Nickel Coins
Cu 29 Copper Electric Wires
Zn 30 Zinc Brass Instruments
Ga 31 Gallium Light-Emitting Diodes (LEDs)
12:30
Ge 32 Germanium Semiconductor Electronics
As 33 Arsenic Poison
Se 34 Selenium Copiers
Br 35 Bromine Photography Film
Kr 36 Krypton Flashlights
Rb 37 Rubidium Global Navigation
Sr 38 Strontium Fireworks
Y 39 Yttrium Lasers
Zr 40 Zirconium Chemical Pipelines
Nb 41 Niobium Mag Lev Trains
Mo 42 Molybdenum Cutting Tools
Tc 43 Technetium Radioactive Diagnosis
Ru 44 Ruthenium Electric Switches
Rh 45 Rhodium Searchlight Reflectors
Pd 46 Palladium Pollution Control
Ag 47 Silver Jewelry
Cd 48 Cadmium Paint
In 49 Indium Liquid Crystal Displays (LCDs)
Sn 50 Tin Plated Food Cans
Sb 51 Antimony Car Batteries
Te 52 Tellurium Thermoelectric Coolers
I 53 Iodine Disinfectant
Xe 54 Xenon High-Intensi Lamps
Cs 55 Cesium Atomic Clocks
Ba 56 Barium X-Ray Diagnosis
57 - 71 Rare Earth Metals
Hf 72 Hafnium Nuclear Submarines
Ta 73 Tantalum Mobile Phones
W 74 Tungsten Lamp Filaments
Re 75 Rhenium Rocket Engines
Os 76 Osmium Pen Points
Ir 77 Iridium Spark Plugs
Pt 78 Platinum Labware
Au 79 Gold Jewelry
Hg 80 Mercury Thermometers
Tl 81 Thallium Low-Temperature Thermometers
Pb 82 Lead Weights
Bi 83 Bismuth Fire Sprinklers
Po 84 Polonium Anti-Static Brushes
At 85 Astatine Radioactive Medicine
Rn Rado Surgical Implants
Fr 87 Francium Laser Atom Traps
Ra 88 Radium Luminous Watches
89 - 103 Actinide Metals
Rf 104 Rutherfordium
Db 105 Dubnium
Sg 106 Seaborgium
Bh 107 Bohrium
Hs 108 Hassium
Mt 109 Meitnerium
Ds 110 Darmstadtium
Rg 111 Roentgenium
Cn 112 Copernicium
Nh 113 Nihonium
Fl 114 Flerovium
Mc 115 Moscovium
Lv 116 Livermorium
Ts 117 Tennessine
Og 11 Oganesson
Superheavy Elements
radioactive, never found in nature, no uses except atomic research
119
120
121...
Rare Earth Metals
La 57 Lanthanum Telescope Lenses
Ce 58 Cerium Lighter Flints
Pr 59 Praseodymium Torchworkers' Eyeglasses
Nd 60 Neodymium Electric Motor Magnets
Pm 61 Promethium Luminous Dials
Sm 62 Samarium Electric Motor Magnets
Eu 63 Europium Color Televisions
Gd 64 Gadolinium MRI Diagnosis
Tb 65 Terbium Fluorescent Lamps
Dy 66 Dysprosium Smart Material Actuators
Ho 67 Holmium Laser Surgery
Er 68 Erbium Optical Fiber Communications
Tm 69 Thulium
Yb 70 Ytterbium
Lu 71 Lutetium

# Supernova


The formation our solar
system







# What are the associations?

- The cosmic theories provide clues on how life might have started on Earth instead of other planets in our solar systems.

# The late heavy bombardment

1. The event of 'Late Heavy Bombardment' were thought to take place between 4.1 to 3.8 billion years ago.
2. During this event, large number of asteroid has hit the Earth for over 200 million years time period.
3. Some scientist believe that the event was triggered by the re-arrangement of Jupiter inside our solar systems.

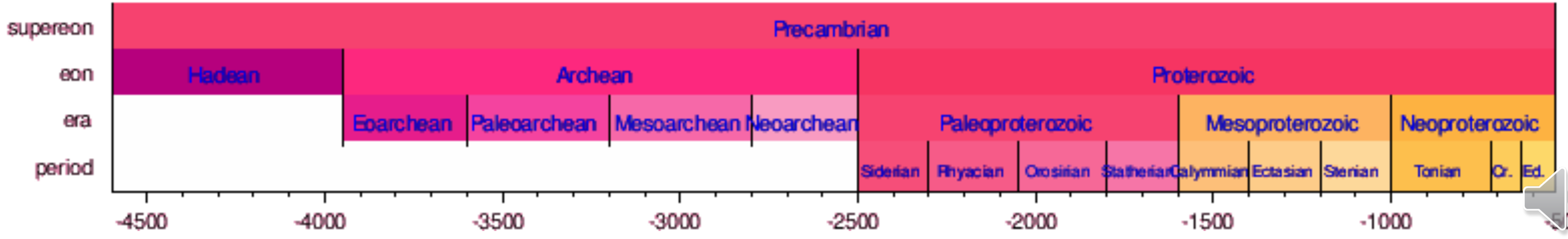


https://www.youtube.com/watch?v=JVboHupB8I0&ab_channel=NakedScience

# SNOWBALL EARTH

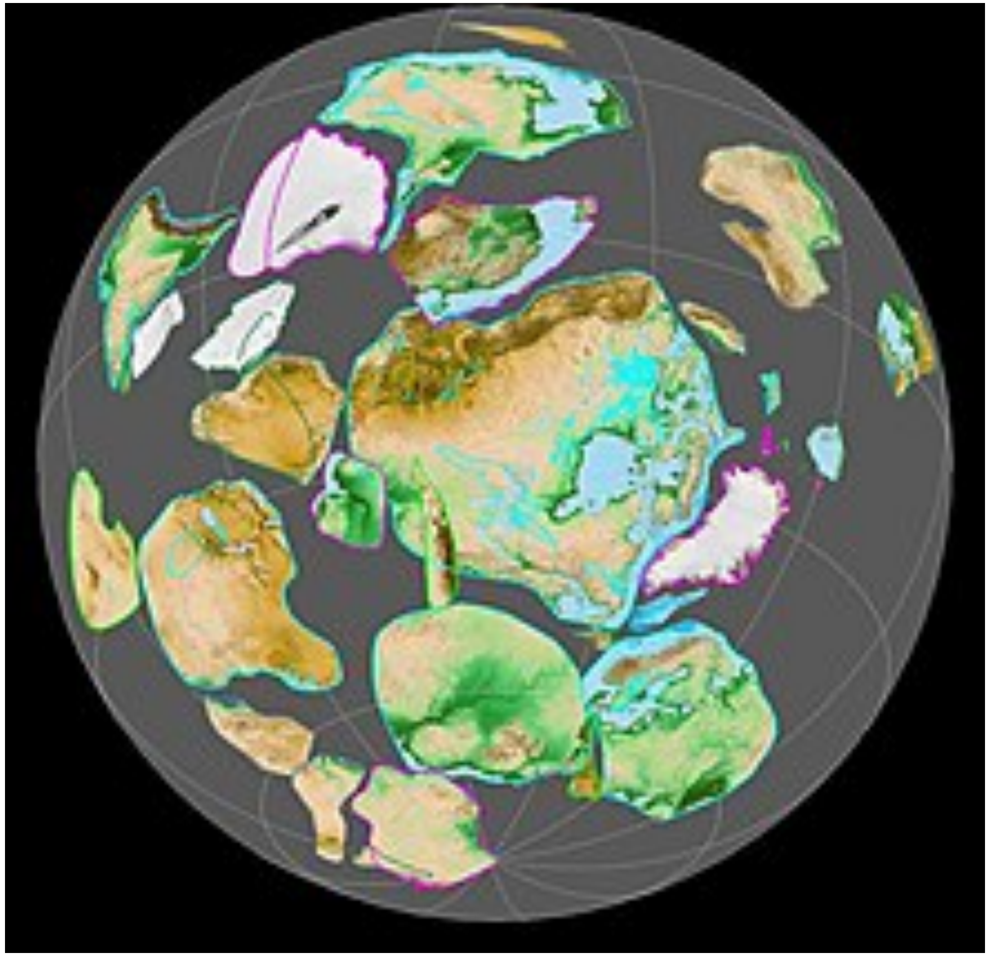
# What is a snowball Earth event?

1. The extreme glaciation event happened twice during the Neoproterozoic Era (716 million years and 635 million years ago).
2. The period of Cryogenian – "time of ice"
3. Poles temperature reach -130 °C.
4. Temperature at the equator reach 0 °C.
5. Glacier cover the land and sea-ice cover the ocean surfaces.
6. Below the surface of the ocean, water was very cold.



# What causes the snowball Earth event?

1. The breakup of Rodinia expose basalt to the Earth surface. Basalt is a good sink for $CO_{2.}$
2. The sun was 7% cooler than it is today. Hence the reduce of CO2 with the dimmer sun allowed the snowball Earth to happen.
3. Sulphur dioxide has been injected as part of the gasses produced by volcanic activities. The amount of sulfur in the ancient volcanic events were too great that it causes the global cooling.



# Evidences of Snowball Earth theory

1. Dropstones are found in ancient marine sediment all over the globe.
2. Carbonate rocks disappeared from the records during the Cryogenian period indicated that the Earth was covered by ice.



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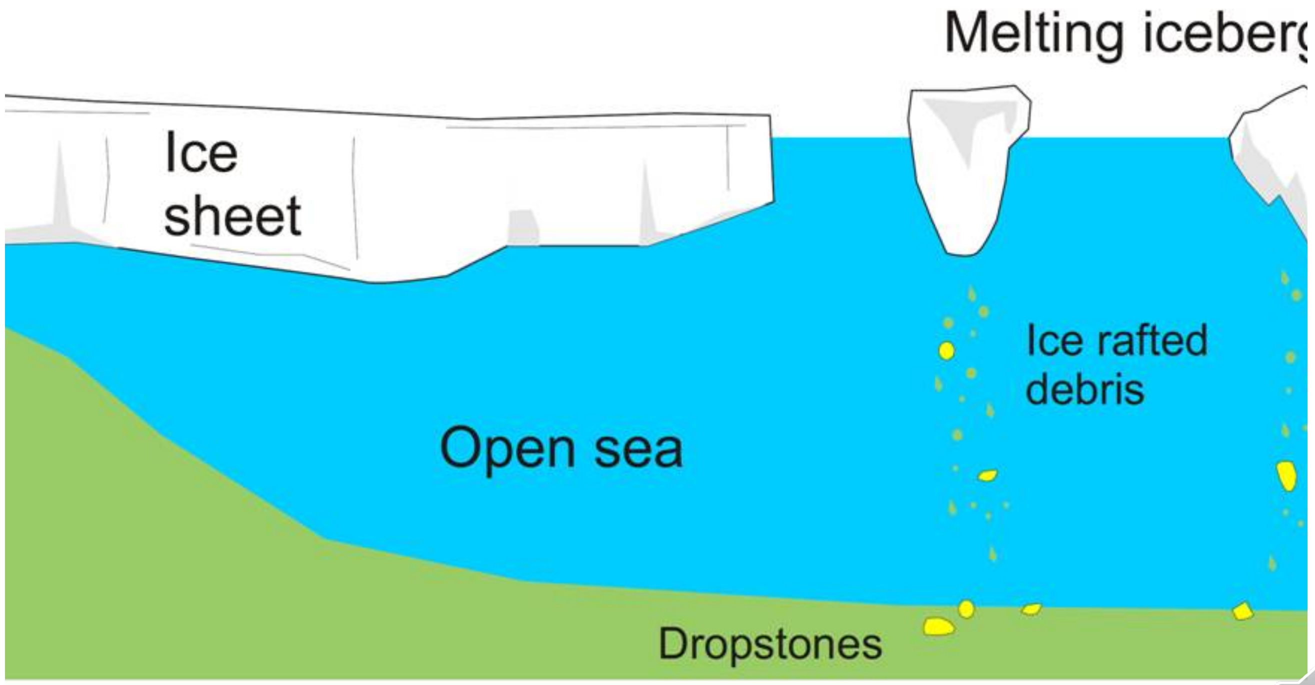
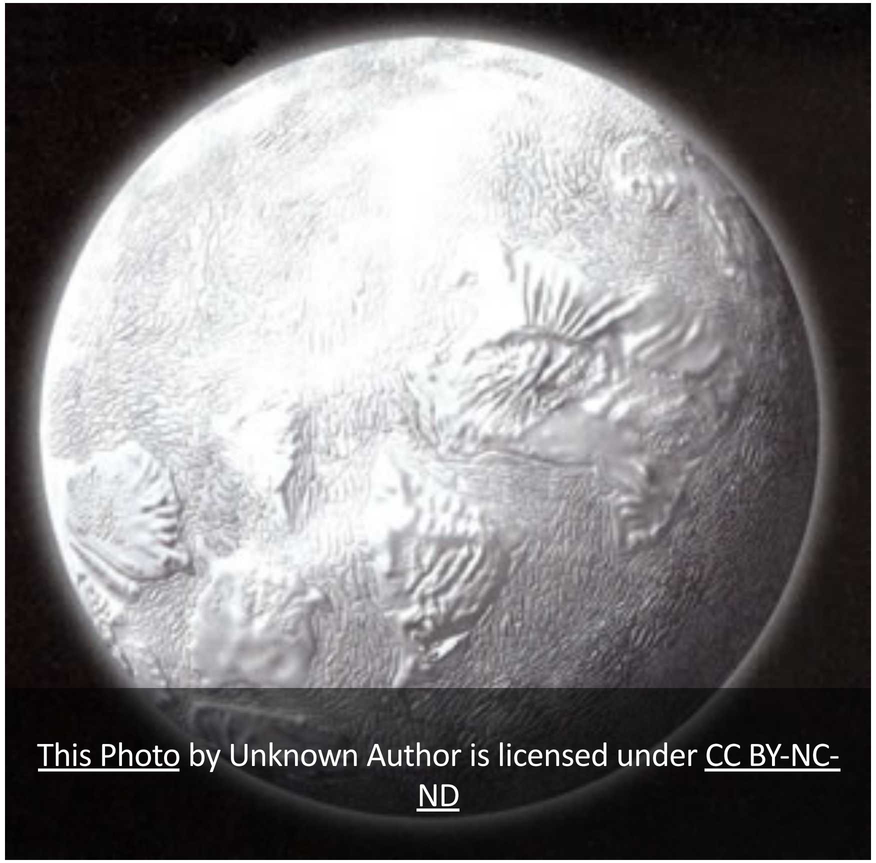


# Theory of the Slushball Earth

1. Although geological evidences suggested that all surfaces on Earth was covered with ice, it seems unreal to biologist.
2. By the time the Cryogenian period took place, many bacteria and archaea has evolved and live on Earth.
3. The theory of snowball Earth seems impossible for life in the ocean at that time.
4. The slushball Earth suggested that there was ice everywhere but at certain places, the ice was thin enough to allow light to shine into the ocean. This allow photosynthetic activity to happen.


# Why is there no more Snowball Earth during the Quaternary?

# How does it end?

- Volcanic activities continues to take place.
- The land has fully covered the ice- covering the basalt.
- The $CO_2$ can accumulate in the atmosphere allowing the global temperature to go up again.
- After 50 million years, the ice finally thawed, and it is the end of the snowball earth period.

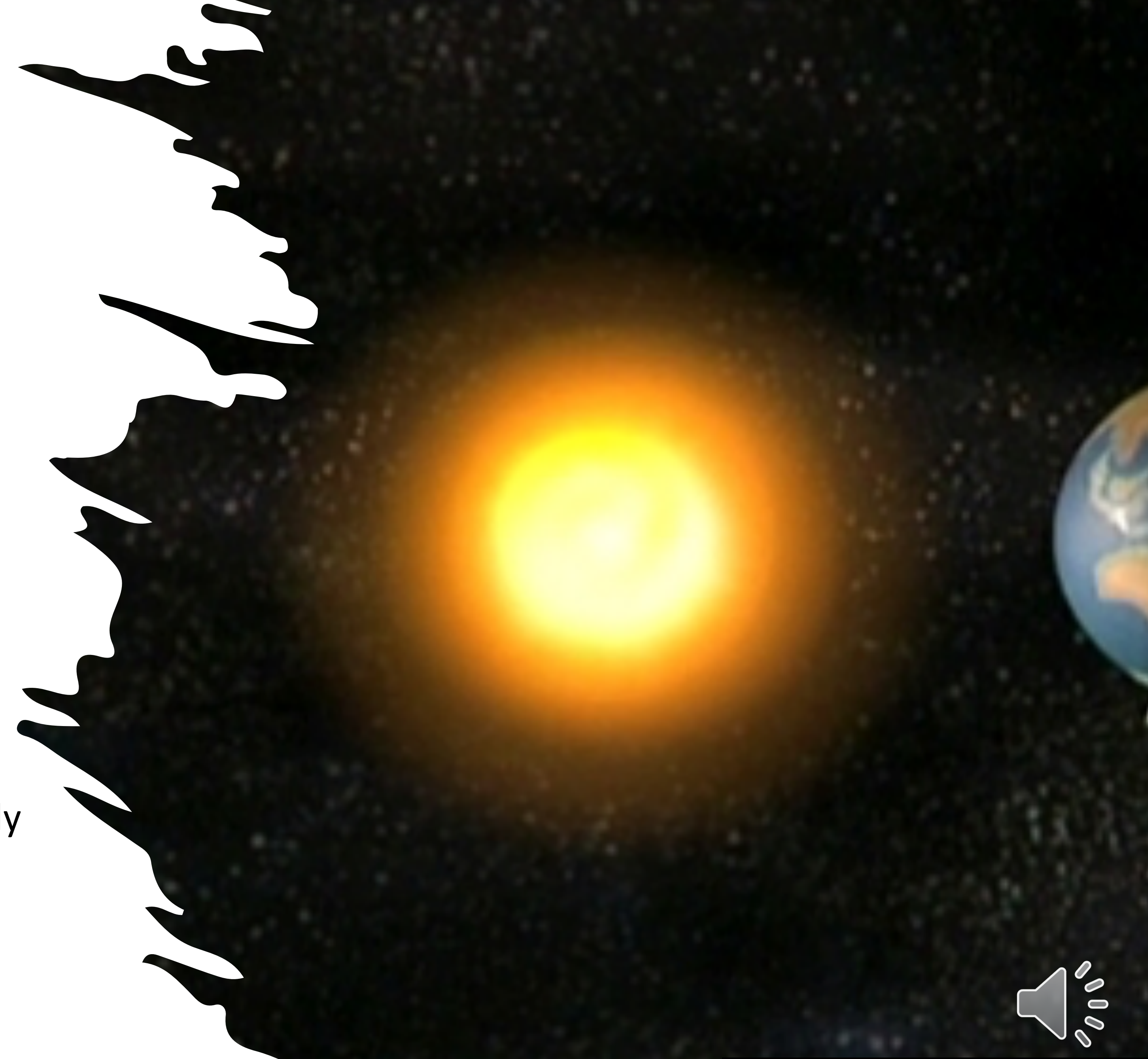


# The Great Oxygenation Event (GOE)

FATIN MINHAT (PhD)

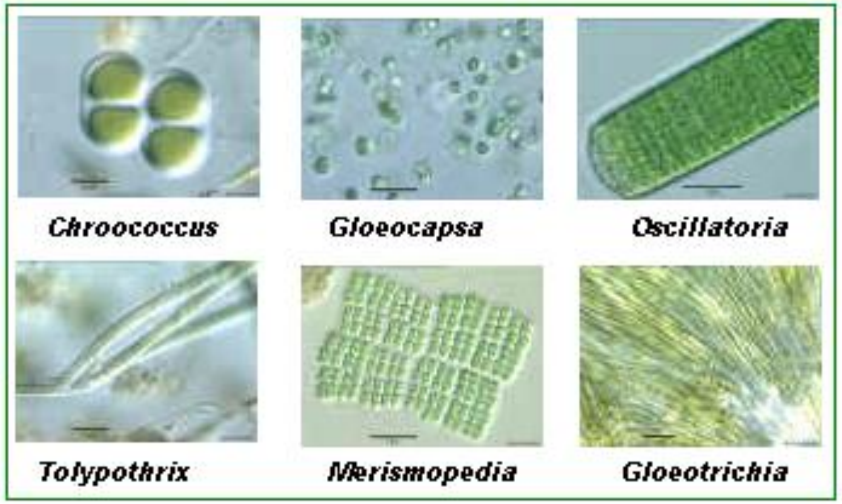
# The Ancient Earth's Atmosphere

- Before the GOE, the atmosphere of Earth was basically filled with
  a) Carbon dioxide
  b) Dinitrogen
  c) Hydrogen
  d) Carbon monoxide
  e) Methane
- During the first billion years of Earth formation, the sun was still young and only shine 70% of its brightness.
- Without these green house gases, Earth would be very cold. Too cold.



# What is The Great Oxygenation Events (GOE)?

1. The GOE is a geologic event that mark an increase amount of oxygen in the atmosphere.
2. The GOE at 2.35 billion years ago allowed the Earth's atmosphere to change from reducing to oxidizing atmosphere.
3. The second leap of oxygen occurred at 700 million years ago.





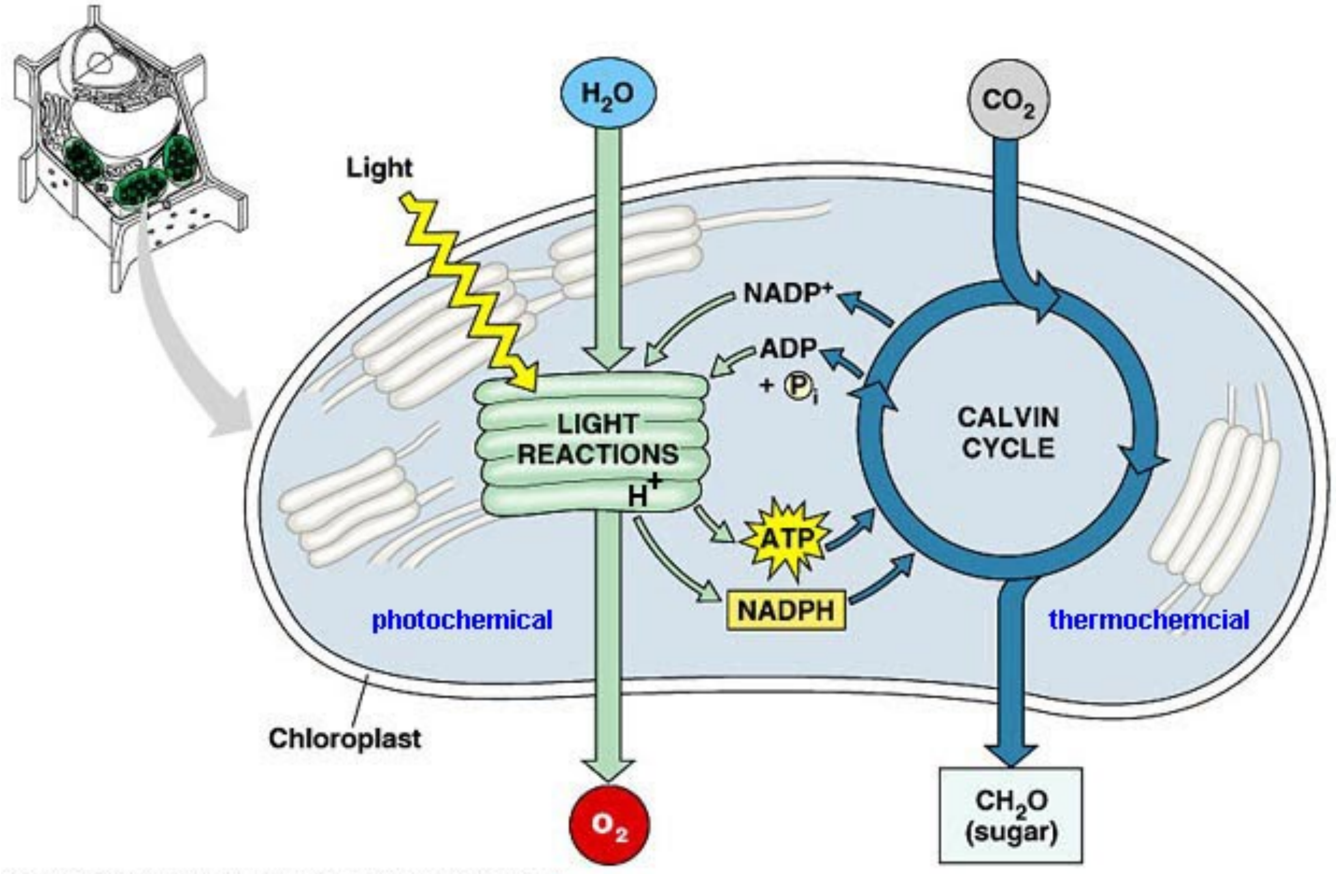



# What contributed to the GOE?

- The evolution of photosynthetic bacteria from non-oxygen producing to oxygen producing sources.
- Cyanobacteria – responsible in the production of oxygen some 3 billion years ago, before the peak of oxygen level was evidence in the atmosphere.

# Oxygenic photosynthesis (2.7 billion years ago)

- Photosynthesis do not always produce oxygen as their product.
- It was believed that the early bacteria that carried out photosynthesis was experimenting with the best way to harvest solar energy into organic energy.
- after trying for millions of years, some of these bacteria evolved and become the cyanobacteria.
- Cyanobacteria- groups of bacteria with the ability to carry out photosynthesis and produce oxygen

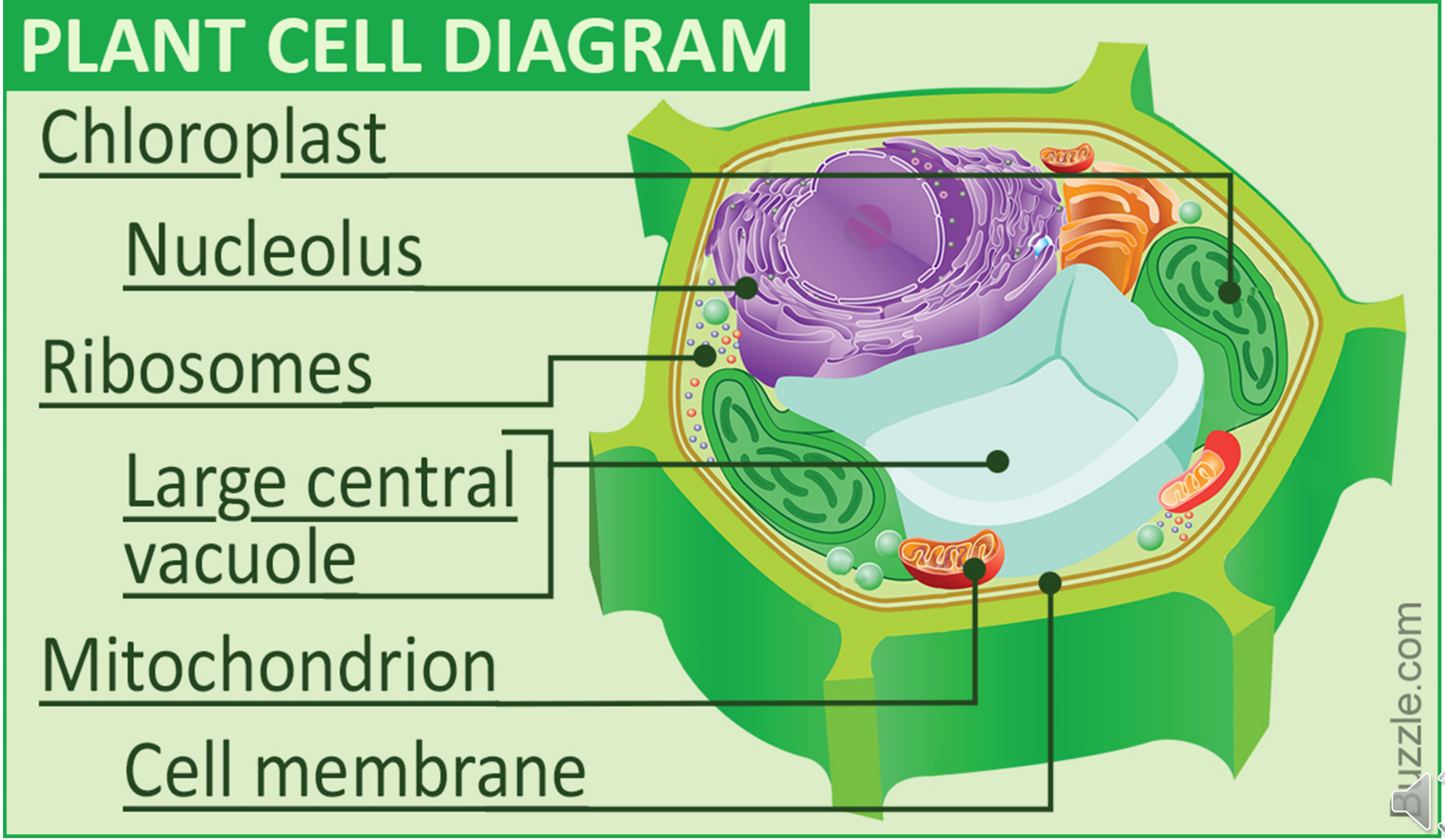


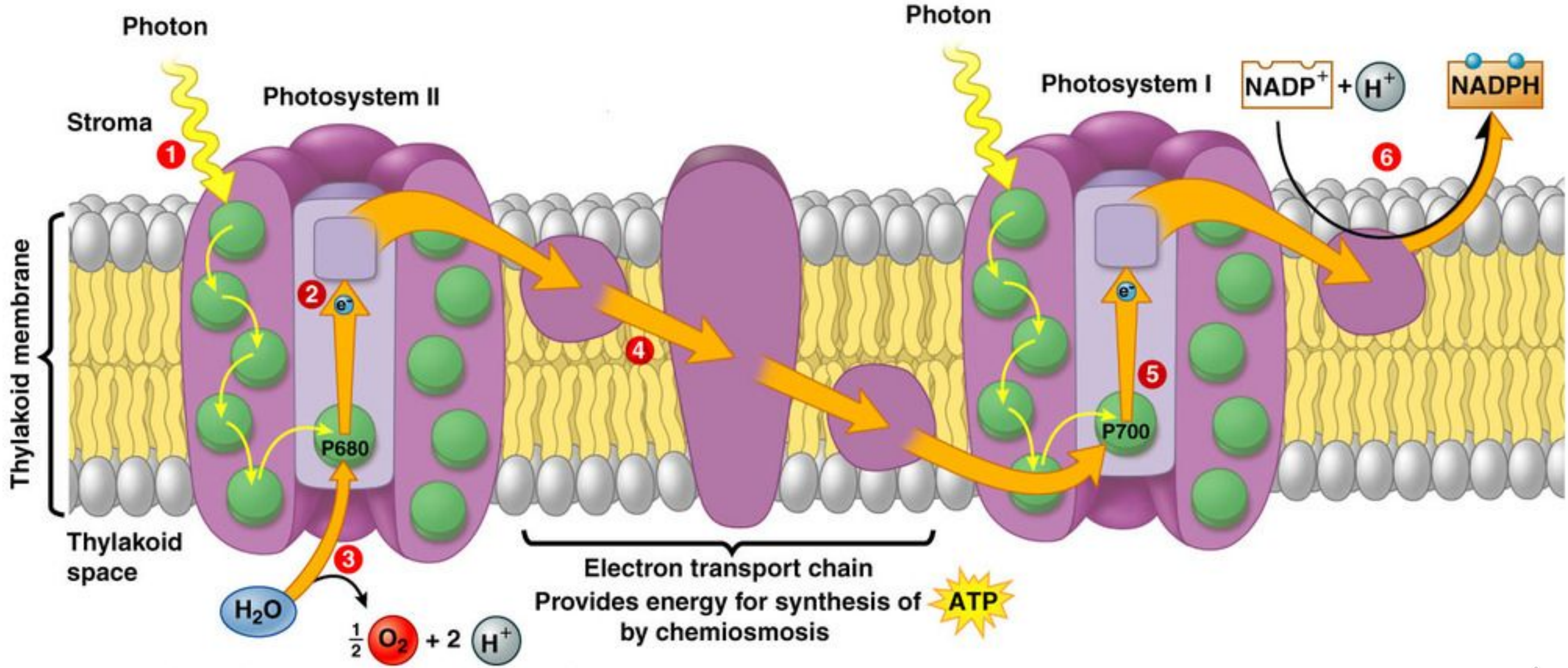





# Oxygenic photosynthesis (2.7 billion years ago)

- Oxygenic photosynthesis is more complex and productive compared with the anoxygenic photosynthesis.
- Cyanobacteria has two photosystems within its cell.
- Anoxygenic bacteria has one photosystem within its cell.

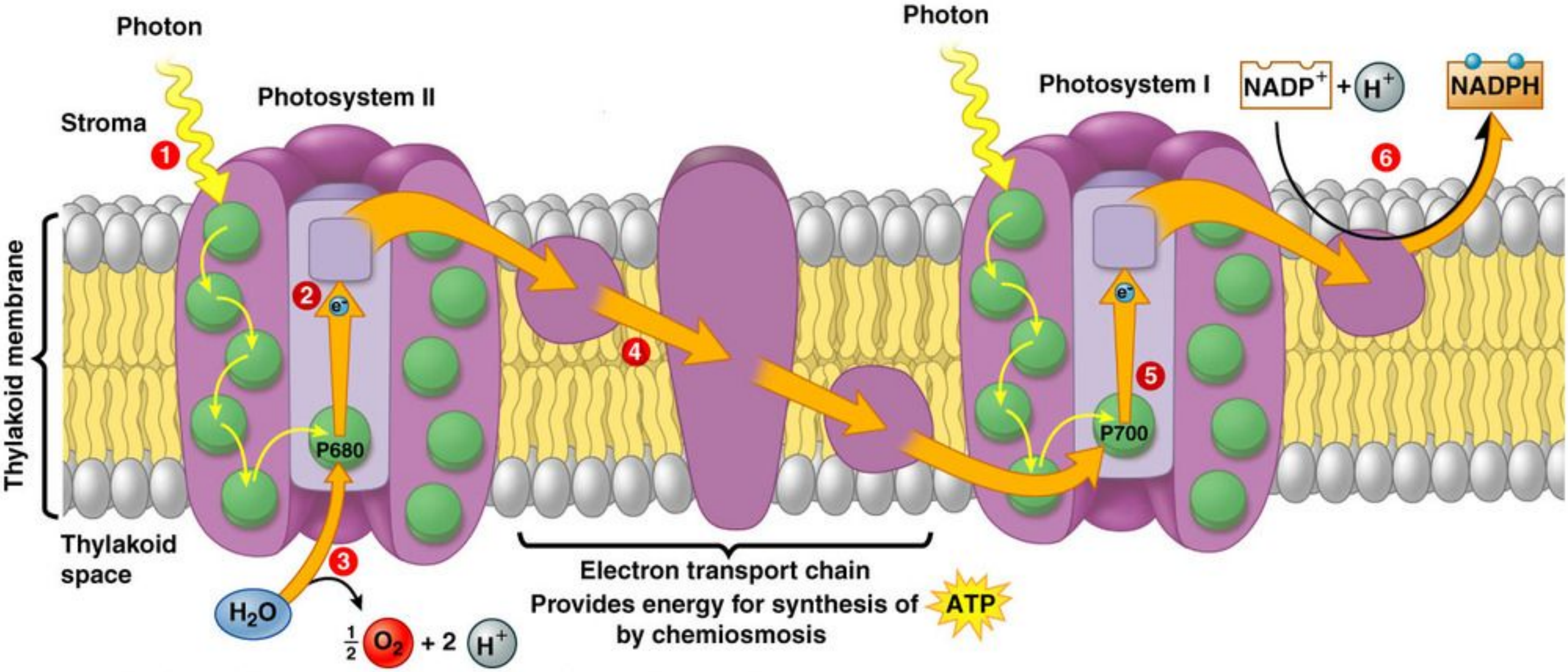

PLANT CELL DIAGRAM
Chloroplast
Nucleolus
Ribosomes
Large central vacuole
Mitochondrion
Cell membrane
Buzzle.com



Photon
Stroma
Photosystem II
1
Thylakoid membrane
2
$e^-$
P680
3
Thylakoid space
$H_2O$
$\frac{1}{2}$ $O_2$ + 2 $H^+$
4
Electron transport chain
Provides energy for synthesis of ATP by chemiosmosis
Photon
Photosystem I
$NADP^+$ + $H^+$
NADPH
6
$e^-$
5
P700

# The Great Oxygenation Event (GOE)

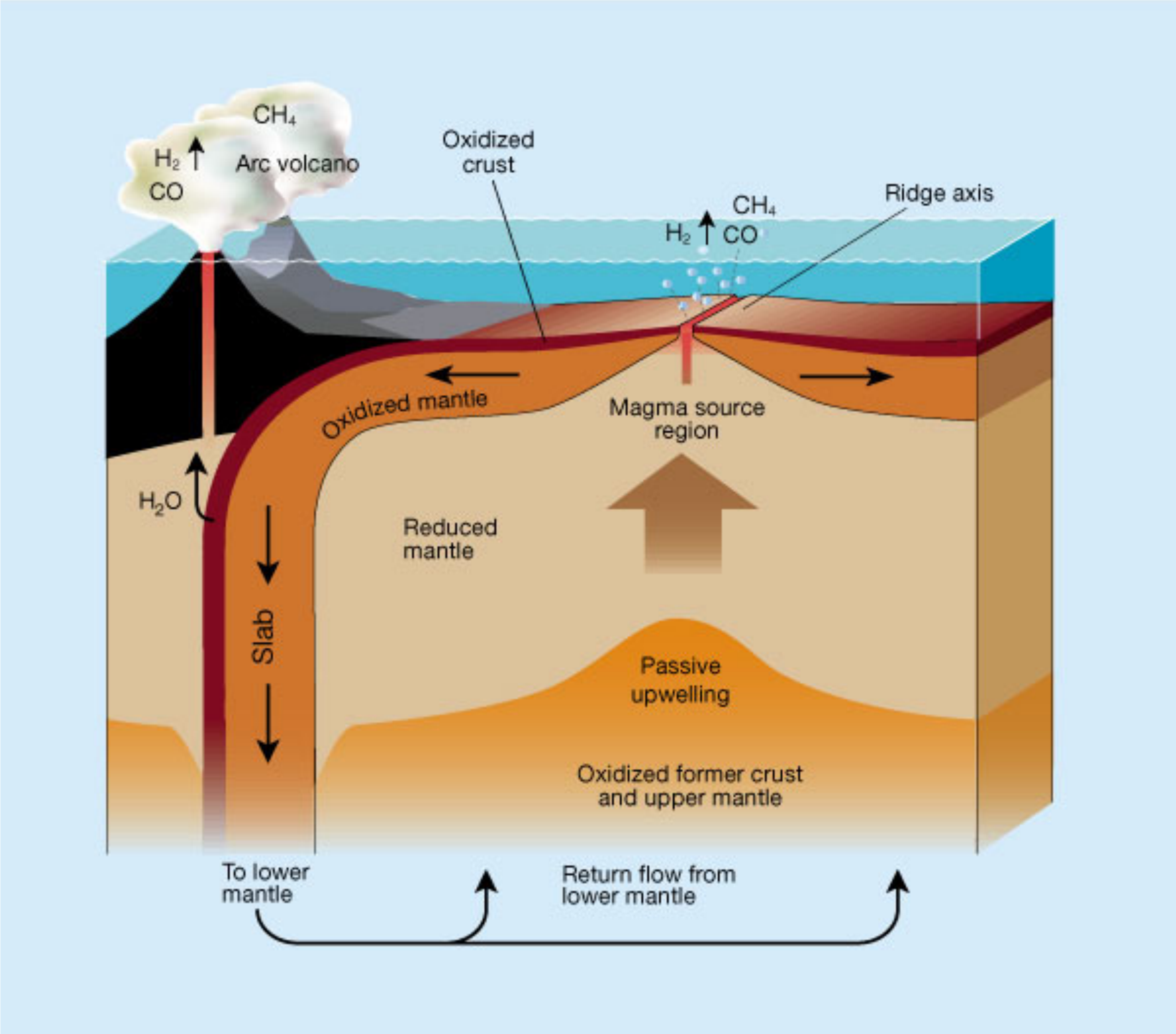
FATIN MINHAT (PhD)


Photon
Photosystem II
Stroma
1
Thylakoid membrane
2
e⁻
P680
Thylakoid space
3
$H_2O$
$\frac{1}{2}$ $O_2$ + 2 $H^+$
4
Electron transport chain
Provides energy for synthesis of ATP by chemiosmosis
Photon
Photosystem I
5
e⁻
P700
$NADP^+$ + $H^+$
NADPH
6

# The advantage of this evolution

- When cyanobacteria has mastered the ability to break water and use this reaction for their source of electron, they had made a big step in evolution.
- Oxidizing water means they do not have to worry if other electron sources, run out because water is very abundant.
- Oxygenic photosynthesis get maximum biochemical energy with more no of ATP.

*If oxygen-producing photosynthesis was occurring by 3.5- 2.7 Ga, why doesn't free $O_2$ appear until 2.3 Ga, a 1200-400 Myr delay?*

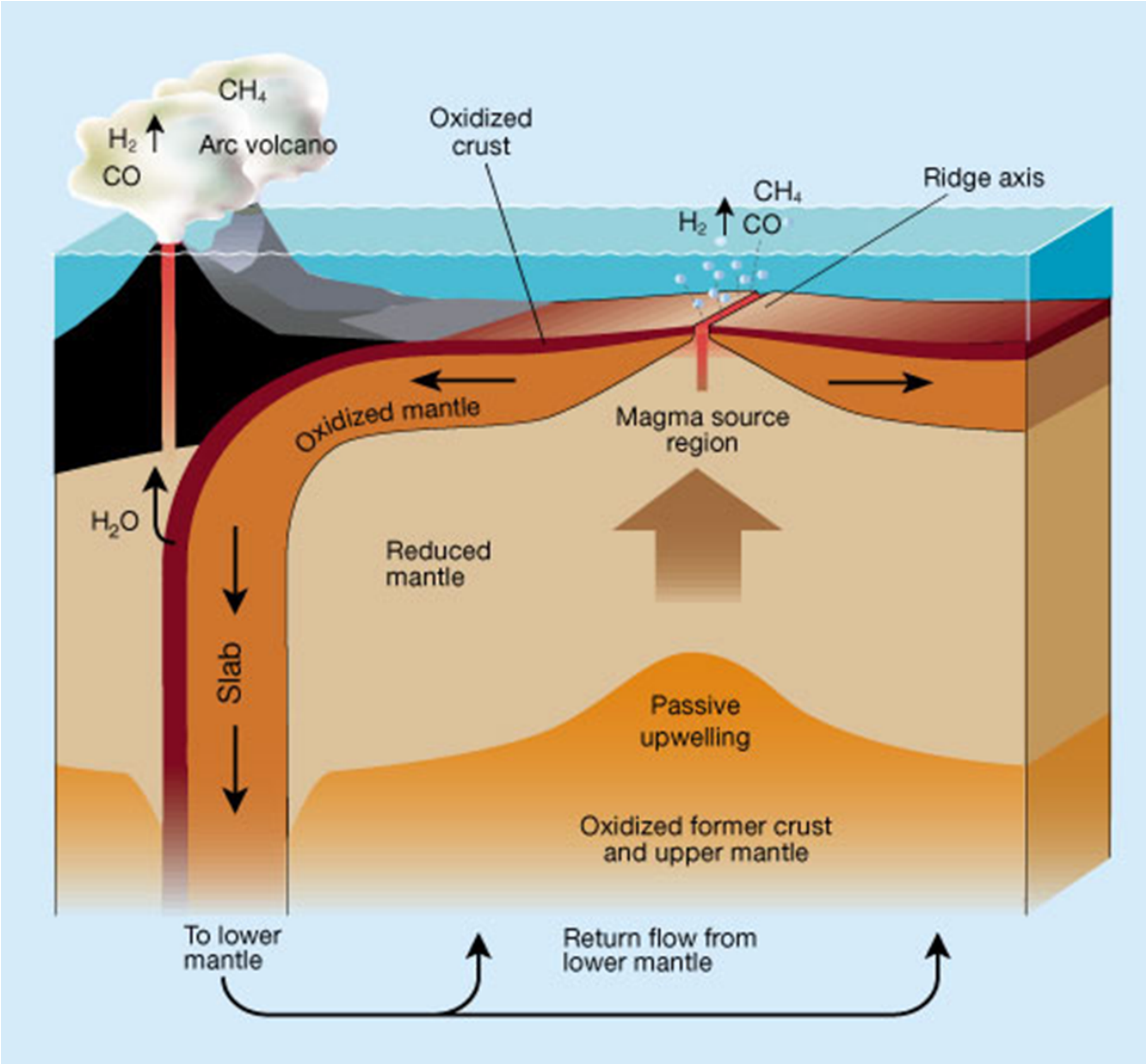


# The ancient mantels on Earth

- Race to absorb the oxygen from the atmosphere.
- Earth was a giant oxygen sinks.

# The oxygen delay

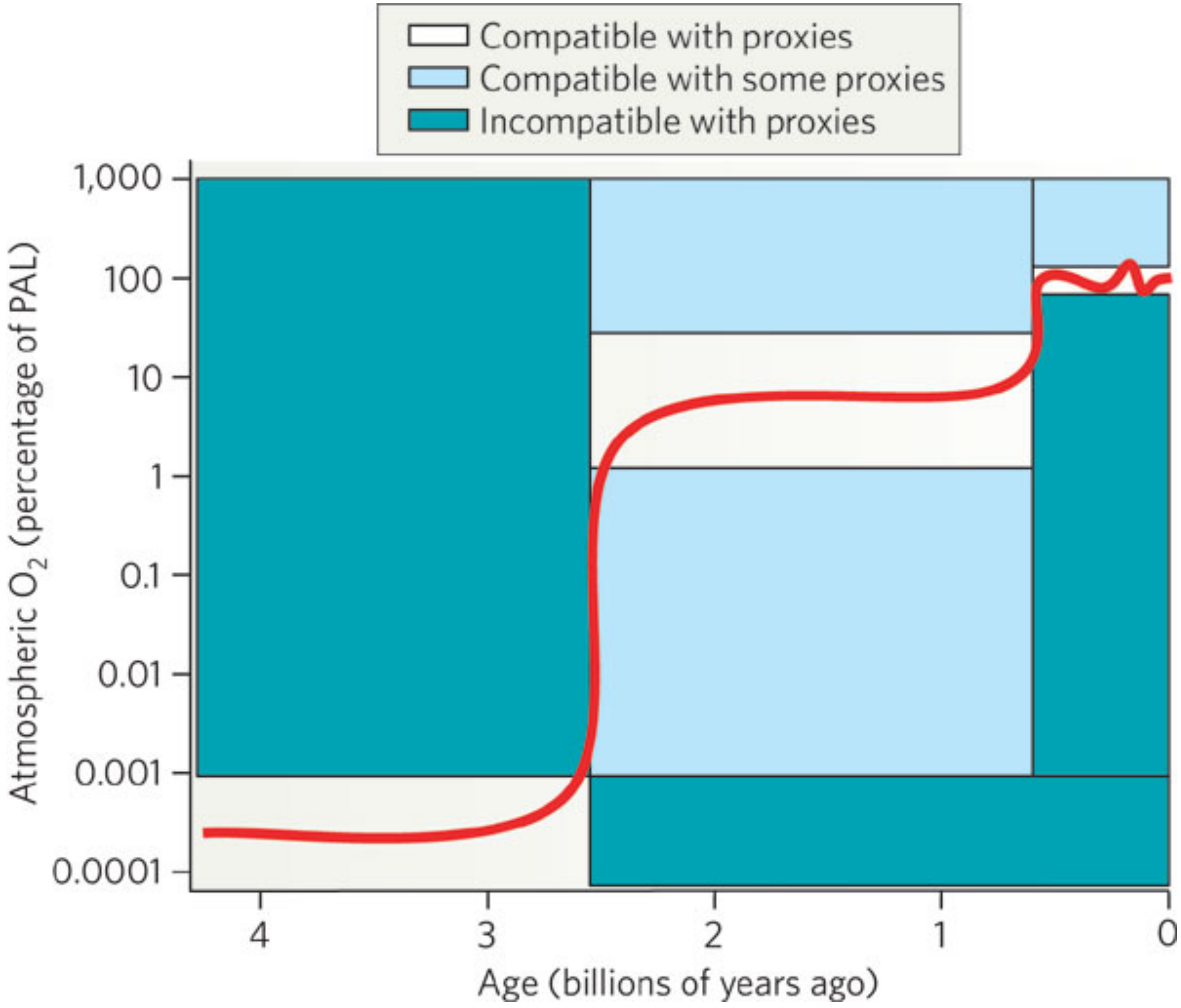
1. Oxidizable materials such as ferrous iron, sulfides, and organic compounds were abundant in the ancient environment. These materials are absent in our modern world.
2. The pre-GOE methane gasses, neutralize oxygen quickly.

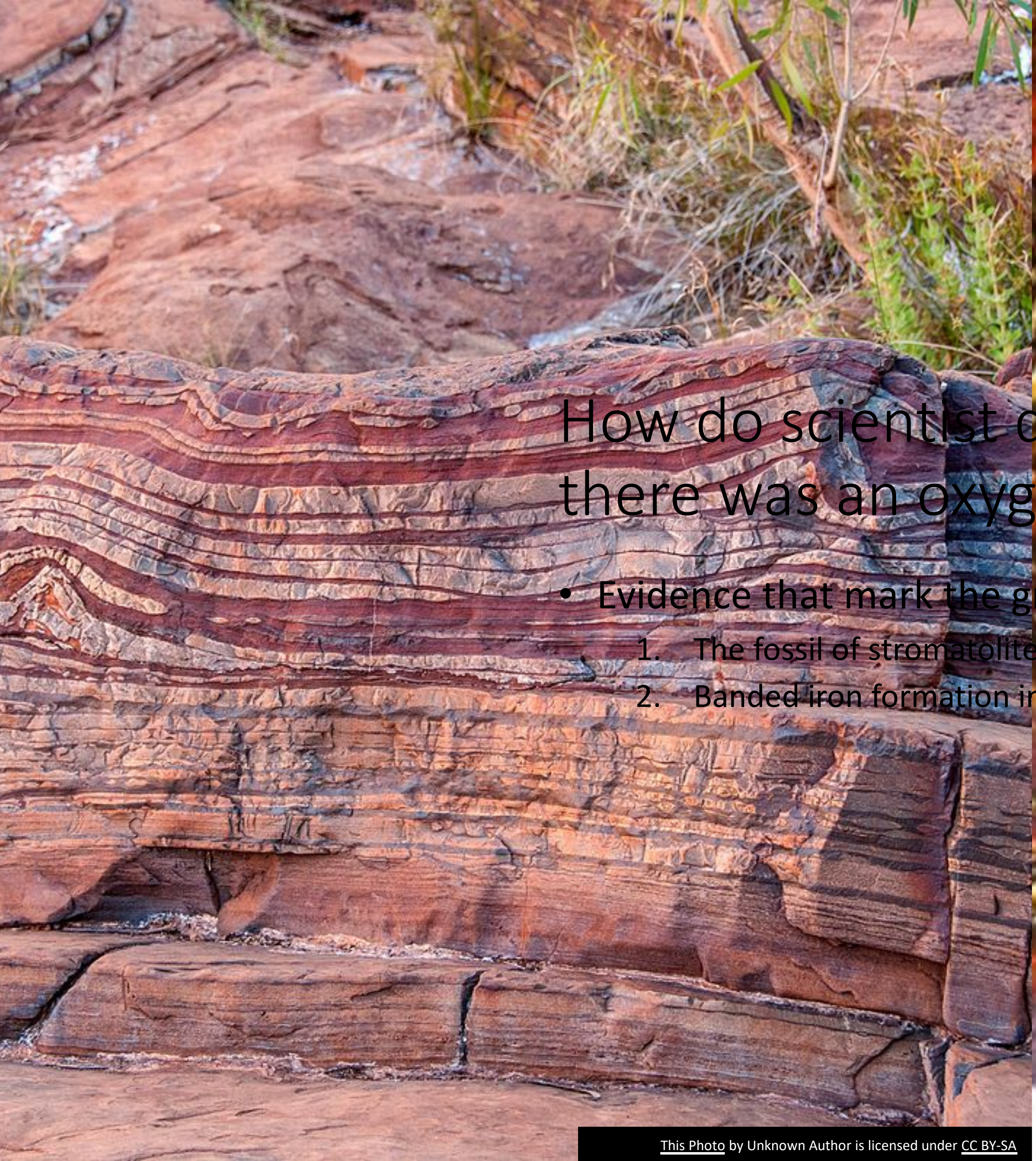


# The rise of oxygen 2.35 billion years ago.

Series of event that led to the GOE

1. Cyanobacteria (prokaryotes) develop ability to photosynthesize.
2. Oxidation of mantle overtime has reduced the oxygen sink.
3. The development of continental crust has changes some of the tectonic activities. Switch from mainly submarine to subaerial volcanoes. Subaerial volcanic activities absorb less oxygen.





# How do scientist determine that there was an oxygenation event?

- Evidence that mark the great oxygenation event:
  1. The fossil of stromatolite- biomarker found.
  2. Banded iron formation in many rocks.

# The importance of GOE

- The GOE changes earth atmosphere from reducing to oxidizing atmosphere.
- The formation of ozone.
- The leap in biological evolution- rise of the eukaryotic cells.
- Habitable planet in our solar systems.

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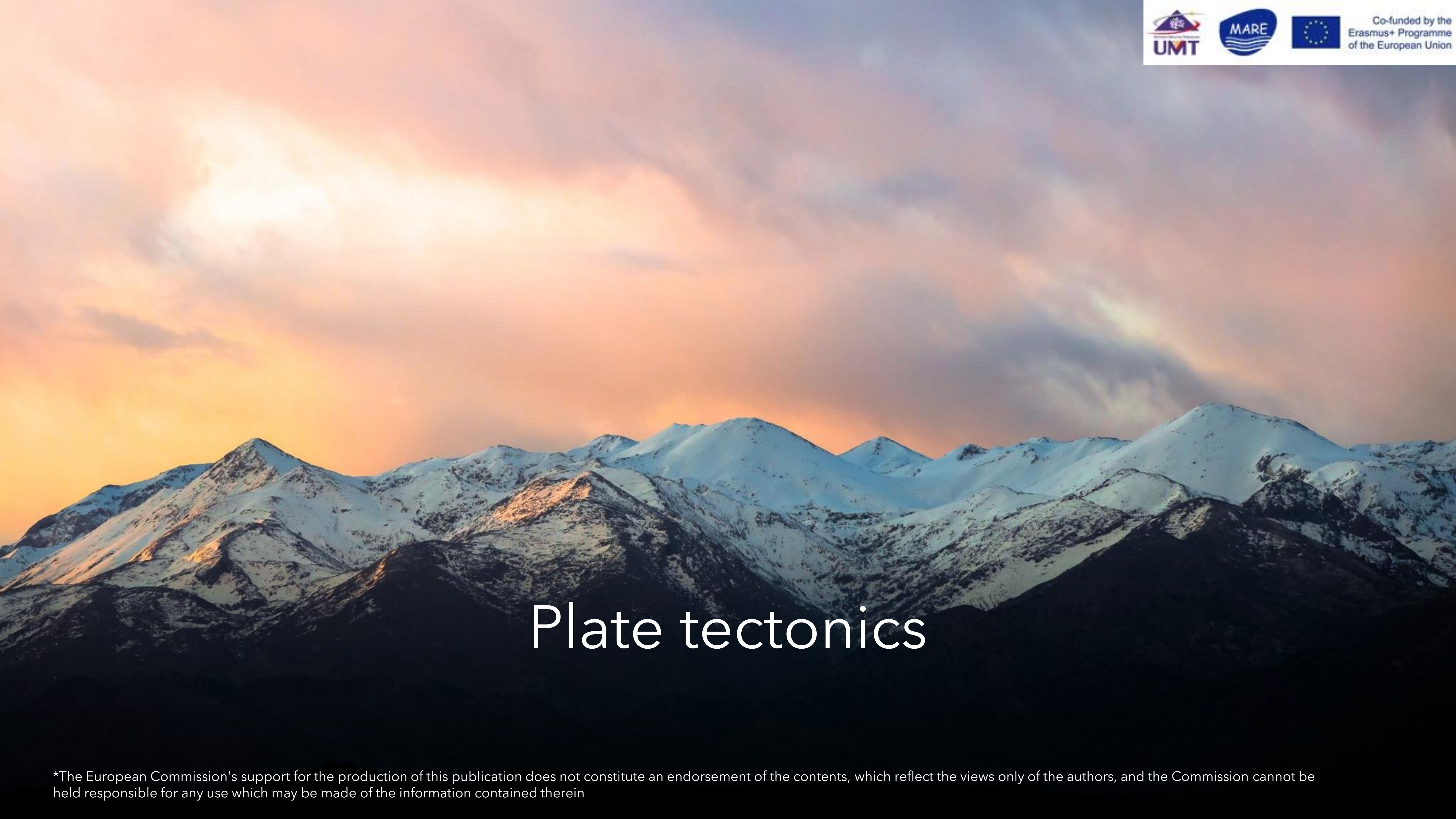

# Plate tectonics

# Do you know that the shapes of continents varies along the geological time?




# The theory…

1. In 1924, Alfred Wegener suggested the drift hypothesis.
2. His hypothesis received much critics because he could not explain the force or mechanisms that lead to continental drift.
3. After world war II, scientific exploration has been more advanced.
4. So in 1968, they had accepted Wegener hypothesis and unfold the theory of plate tectonic



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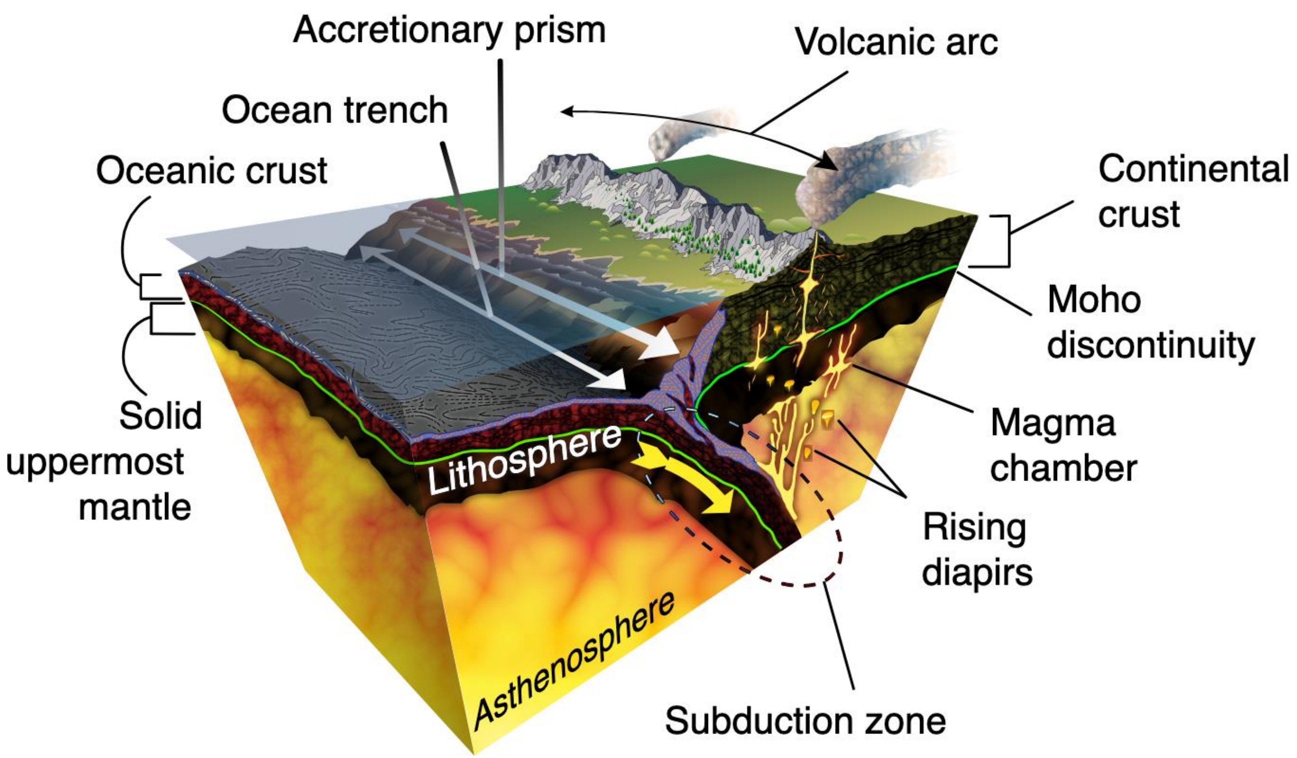
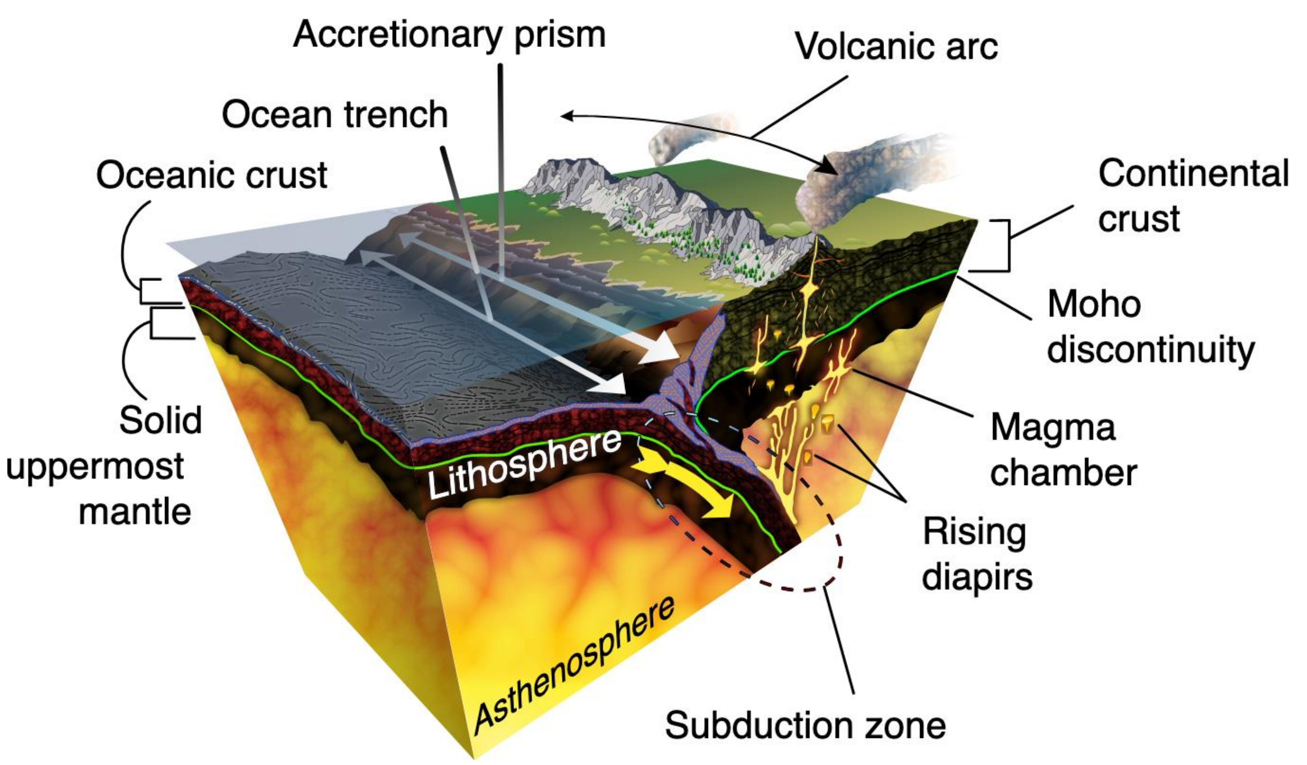
# Strong Lithosphere Overlies Weak Asthenosphere.

1. According to the plate tectonic model, the crust and the upper part of the mantle made up lithosphere, the strong outer layer.
2. The lithosphere vary in thickness and density depending on whether is is oceanic or continental.
3. The oceanic crust is composed of dense basalt, a rock rich in iron and magnesium.
4. The continental crust composed of less dense granitic rocks.
5. Because of this differences, the oceanic lithosphere has higher density.
6. Therefore, oceanic crust always sink when met with continental crust.



# Strong Lithosphere Overlies Weak Asthenosphere.

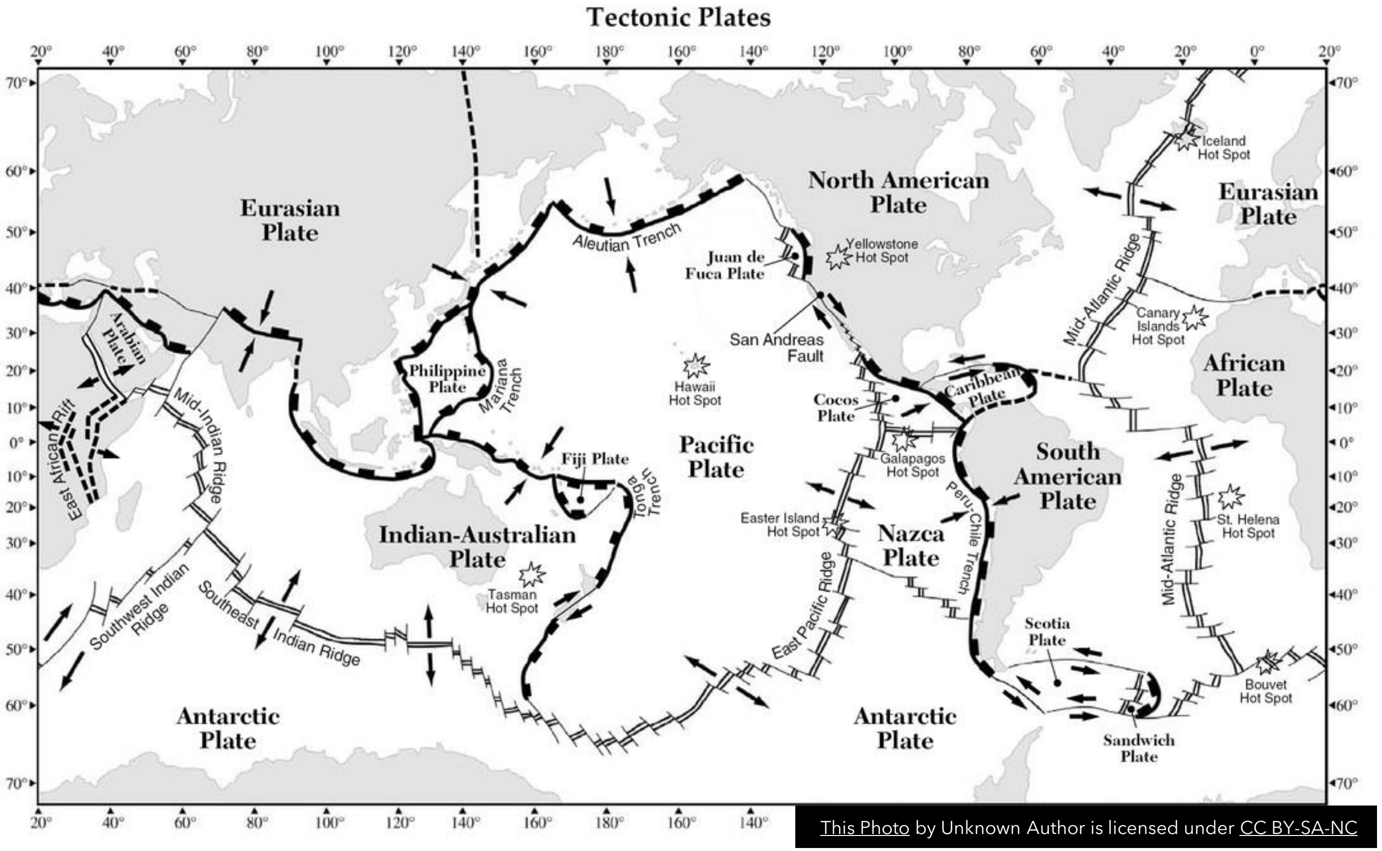
6. The asthenosphere (*asthenos*=weak) is a hotter weaker region of the mantle.
7. The pressure and temperature bring the rock to melting point in this layer.
8. Hence the rock appear to be flowing.
9. This allow the Earth lithosphere to effectively detached from the asthenosphere and move independently. Creating various features as they move.




https://www.youtube.com/watch?v=kwfNGatxUJI

# Earth's Major Plates

1. North American plate.
2. South American plate.
3. Pacific plate
4. African plate
5. Eurasian plate
6. Australian-Indian plate
7. Antarctic plate



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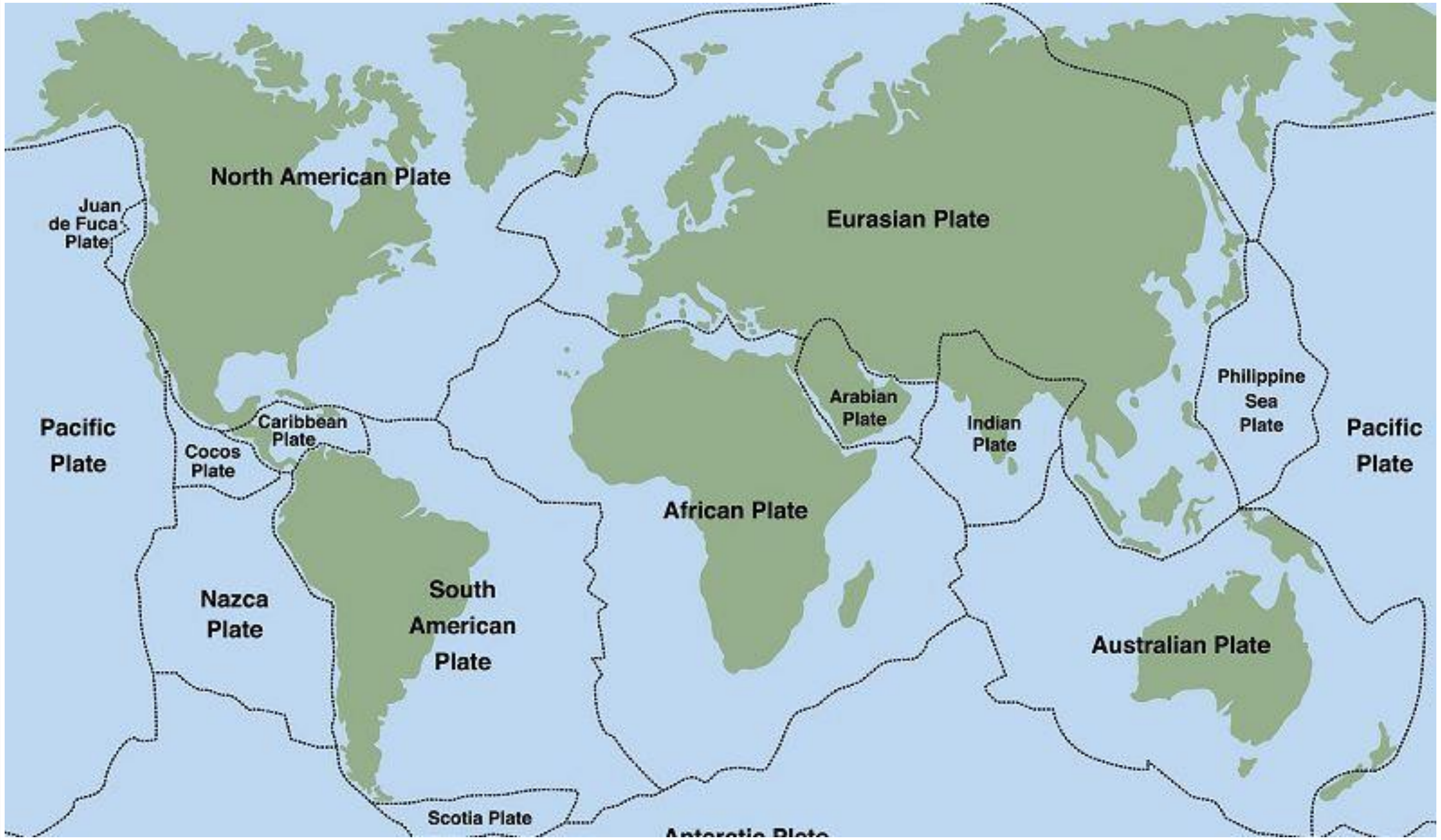
# Microplates

1. Philippine plate
2. Nazca plate
3. Cocos plate
4. Arabian plate
5. Caribbean plate
6. Scotia plate

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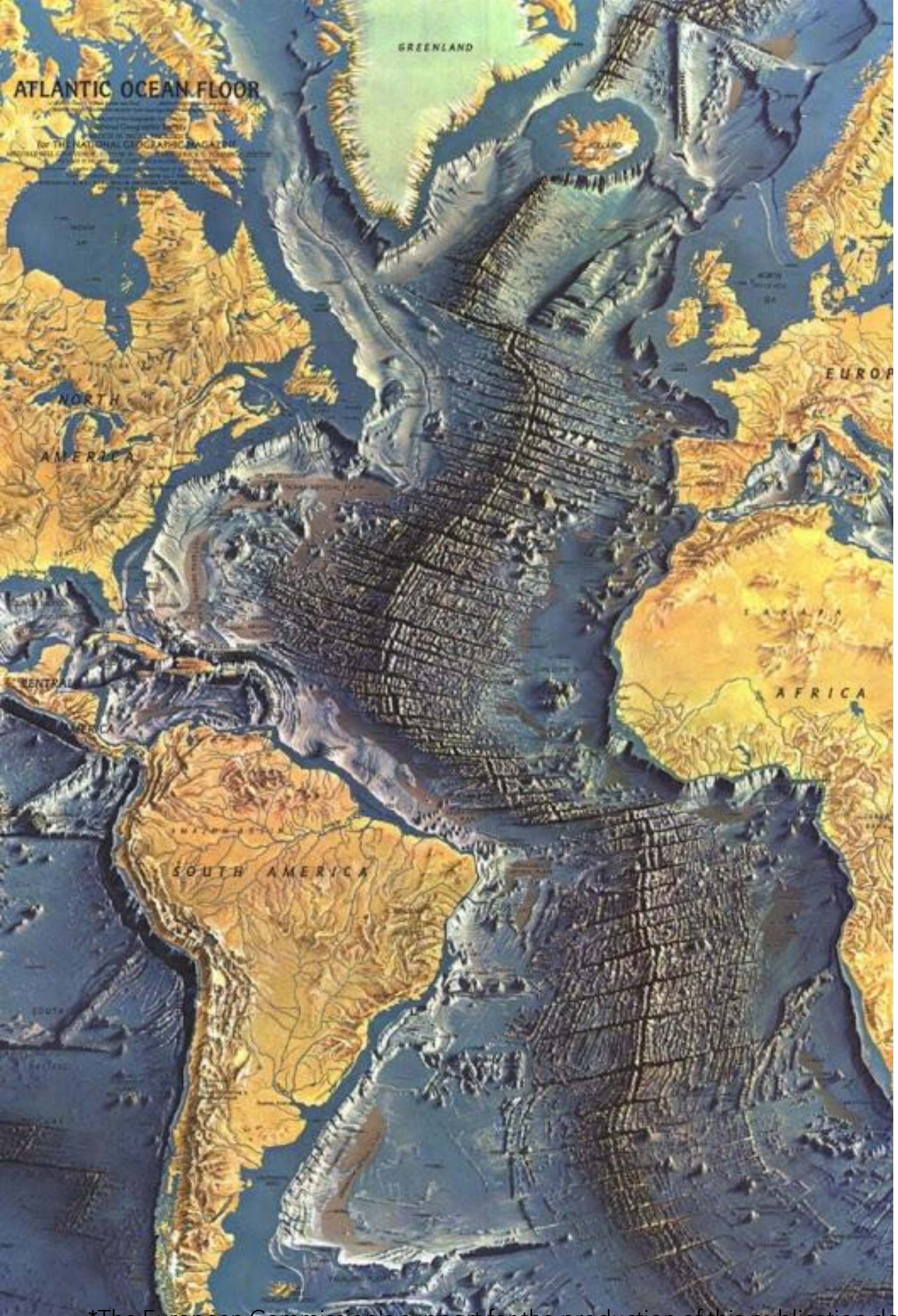
# Plate movement

1. **Divergent plate boundaries** – two plates move apart, resulting in upwelling of hot material from the mantle to create new seafloor.
2. **Convergent plate boundaries** – two plates move towards each other. Resulting in oceanic lithosphere decending beneath the overriding plate.
3. **Transform plate boundaries-** two plates grind past each other. https://www.youtube.com/watch?v=JmC-vjQGSNM





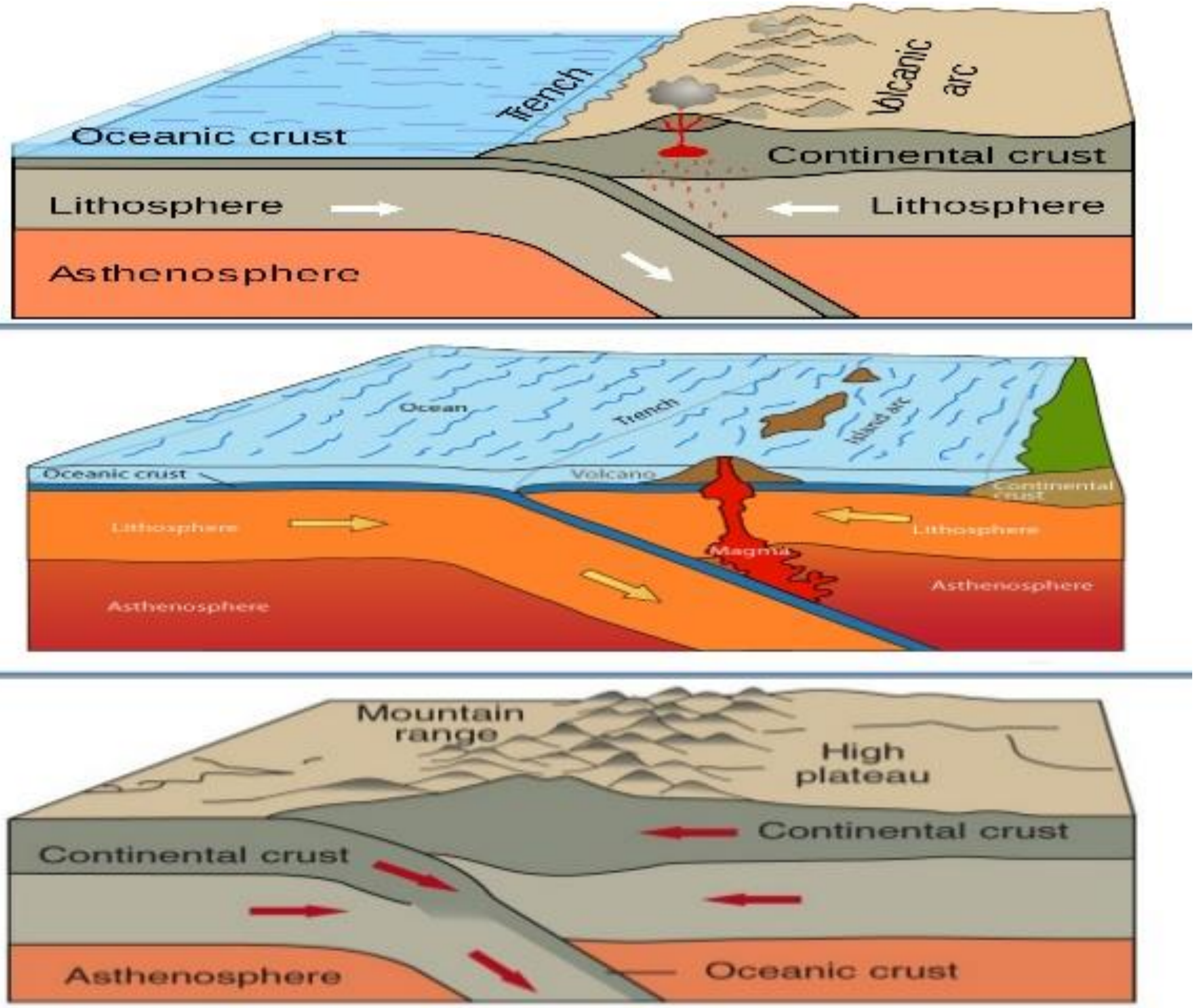

# Divergent plate boundaries.

1. A divergent plate boundary often forms mountain ranges known as ridges or **oceanic ridges**.
2. The ridges form as magma escapes into the space between the spreading tectonic plate.
3. The mechanisms that operates along the oceanic ridge system to create new sea floor is called **seafloor spreading**.
4. One example of ridge is the great Mid-Atlantic Ridge.
5. Forms when North American Plate and Eurasian Plate spread up north, and South American Plate and African Plate spread in the south.

# Convergent plate boundaries

1. The convergent boundaries are also called subduction zones because they are sites where the lithosphere is being subducted into the mantle.
2. The deep ocean trenches are feature form where oceanic lithosphere bends as it descends into the mantle along subduction zones.

CONVERGENT PLATES



# Types of convergent plate boundaries

1. Oceanic-continental convergence
   a) Example: the Andes mountain system is part of the process of subducting oceanic lithosphere into the continental lithosphere.
   b) The volcanoes here were produced by molten rock generated underneath as the oceanic lithosphere melted.
2. Continental-continental convergence
   a) The buoyancy of continental materials generally inhibits neither plates to be subducted.
   b) The collision will fold and deforms the sediment on the crust and form uplifted feature.
   c) The process usually form mountain belts such as the Himalayas

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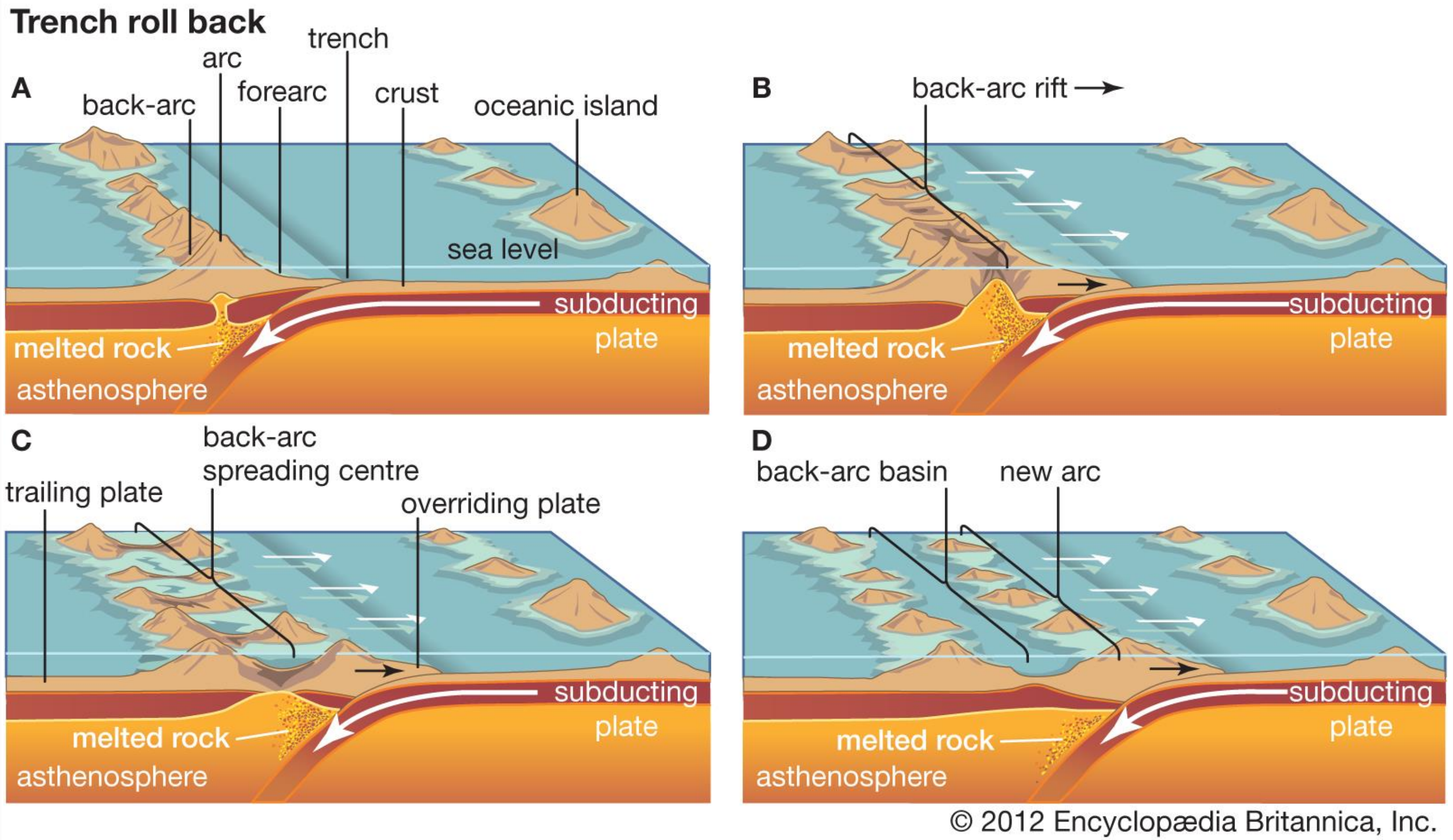
# Types of convergent plate boundaries

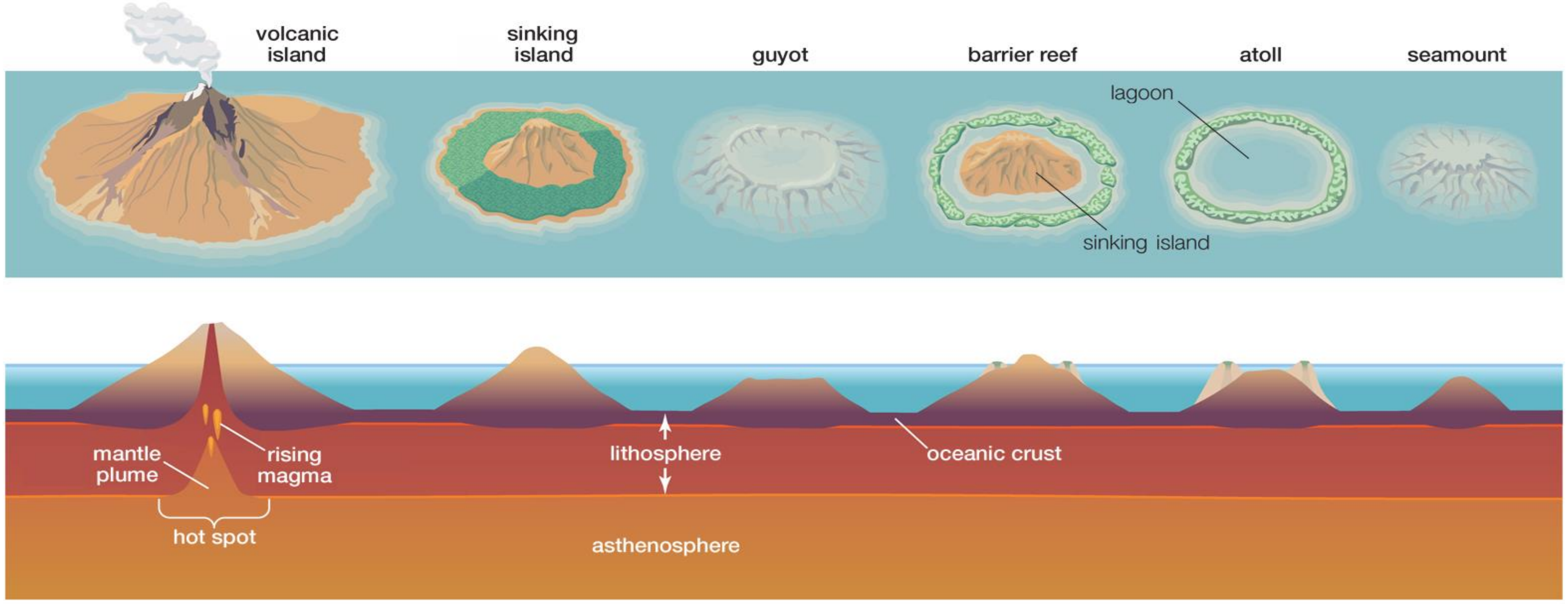
3. Oceanic-oceanic convergence
    a) When two oceanic plates meet, one descend beneath the other, initiating volcanic activity.
    b) Form volcanic island arc overtime



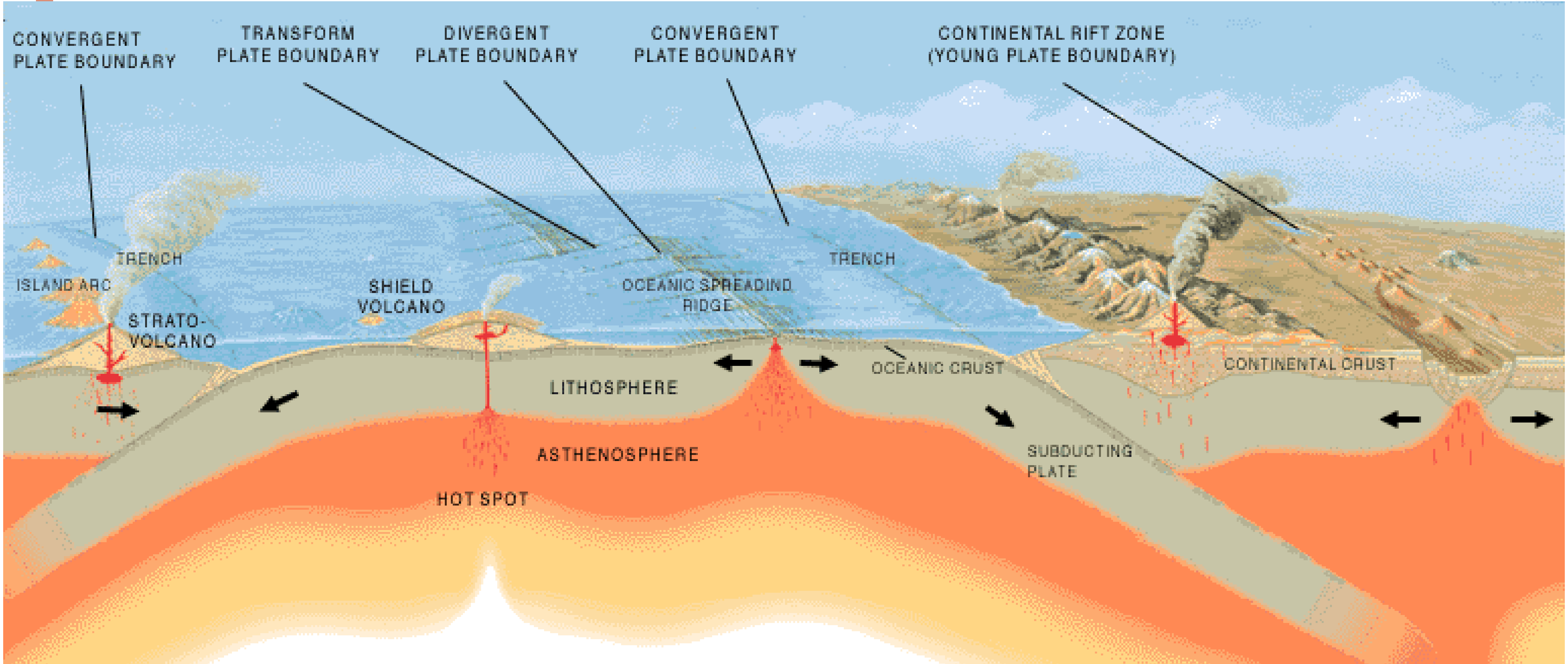
# Tectonic plates and atoll formation.

- Diagram depicting the process of atoll formation. Atolls are formed from the remnant parts of sinking volcanic islands.
- Examples of atolls:



# Transform boundries



# How would the world look in the future?

https://www.youtube.com/watch?v=VqjHmtZ9240

https://news.agu.org/press-release/study-proposes-link-between-formation-of-supercontinents-strength-of-ocean-tides/

UMT MARE Co-funded by the Erasmus+ Programme of the European Union

# Sea-level changes: Factors involved and implication

Fatin Izzati Minhat (PhD)

# What is sea level changes?

- The changes of water level relative to land elevation.
- The increase of water level (sea level rise) or the decrease of water level (sea level fall) happened numerous time throughout the geological time.

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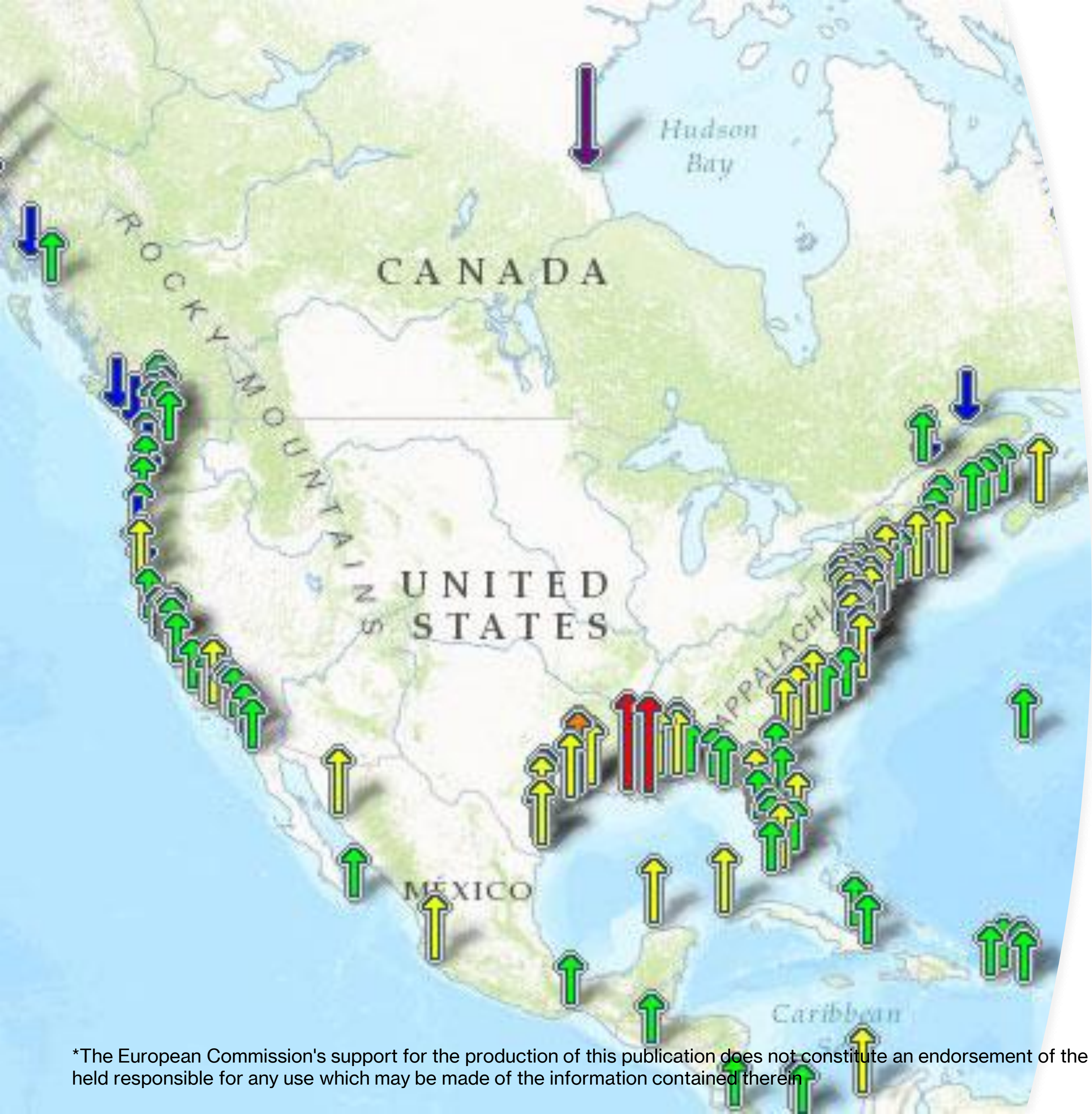


# Global mean sea level vs local sea level

- Global sea level trends and relative sea level trends are different measurements.
- Just as the surface of the Earth is not flat, the surface of the ocean is also not flat – in other words, the sea surface is not changing at the same rate at all points around the globe.
- Sea level rise at specific locations may be more or less than the global average due to many local factors such as land subsidence, ocean currents, variations in land height, and whether the land is still rebounding from the compressive weight of Ice Age glaciers.

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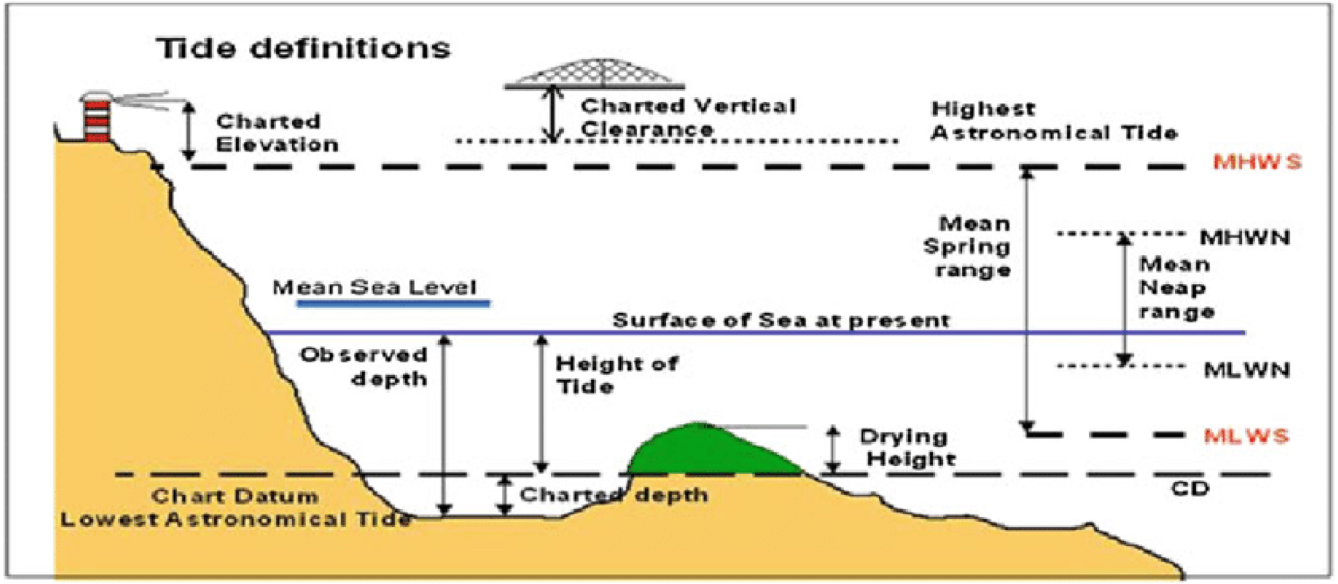
# How do we measure sea level changes?

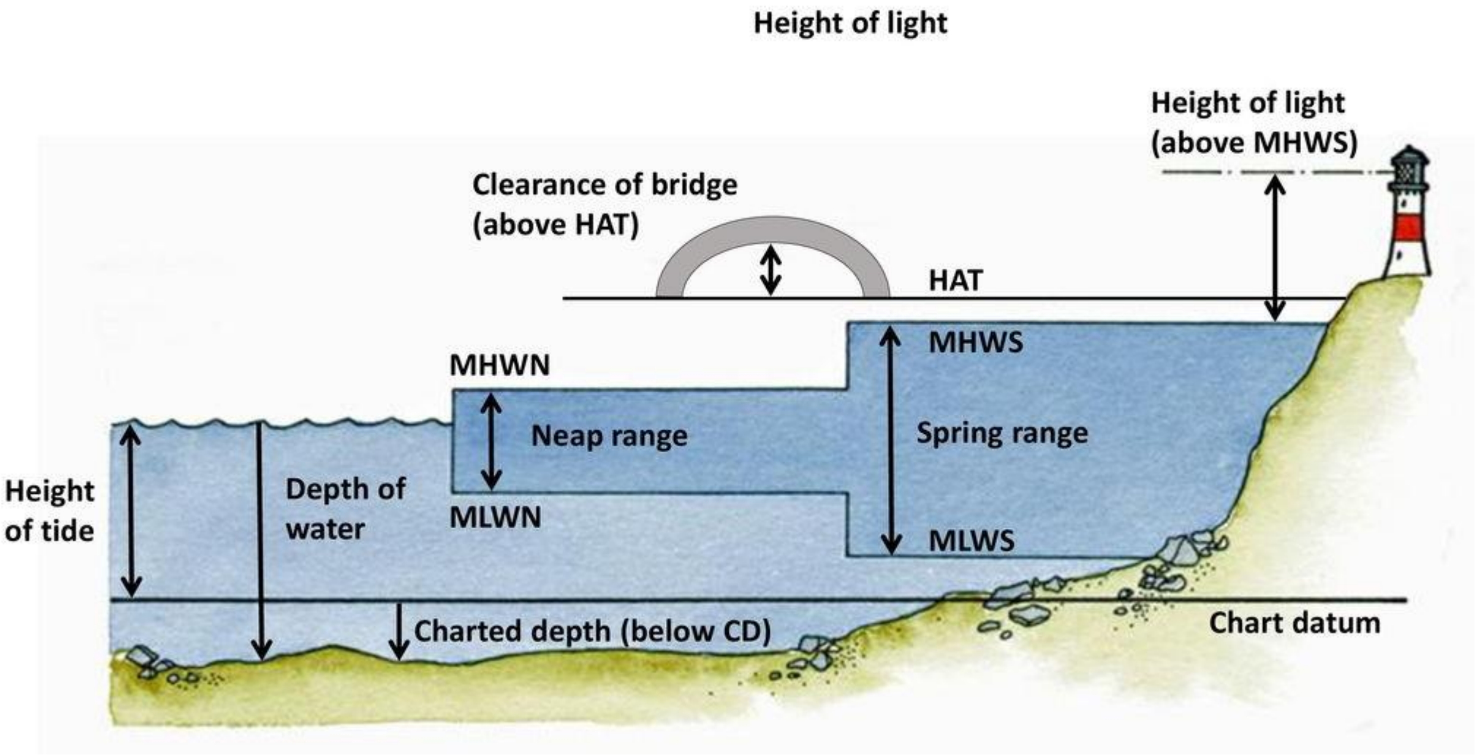
- Sea level is primarily measured using tide stations and satellite laser altimeters.
- Tide stations around the globe tell us what is happening at a local level – the height of the water as measured along the coast relative to a specific point on land.
- The point on land is known as geodetic datum.
- Satellite measurements provide us with the average height of the entire ocean. Taken together, these tools tell us how our ocean sea levels are changing over time.



# Geodetic datums

- A geodetic datum is an abstract coordinate system with a reference surface (such as sea level) that serves to provide known locations to begin surveys and create maps.
- Vertical datums are used as a reference level to which bathymetric soundings are referenced for nautical charts.

Tidal terms



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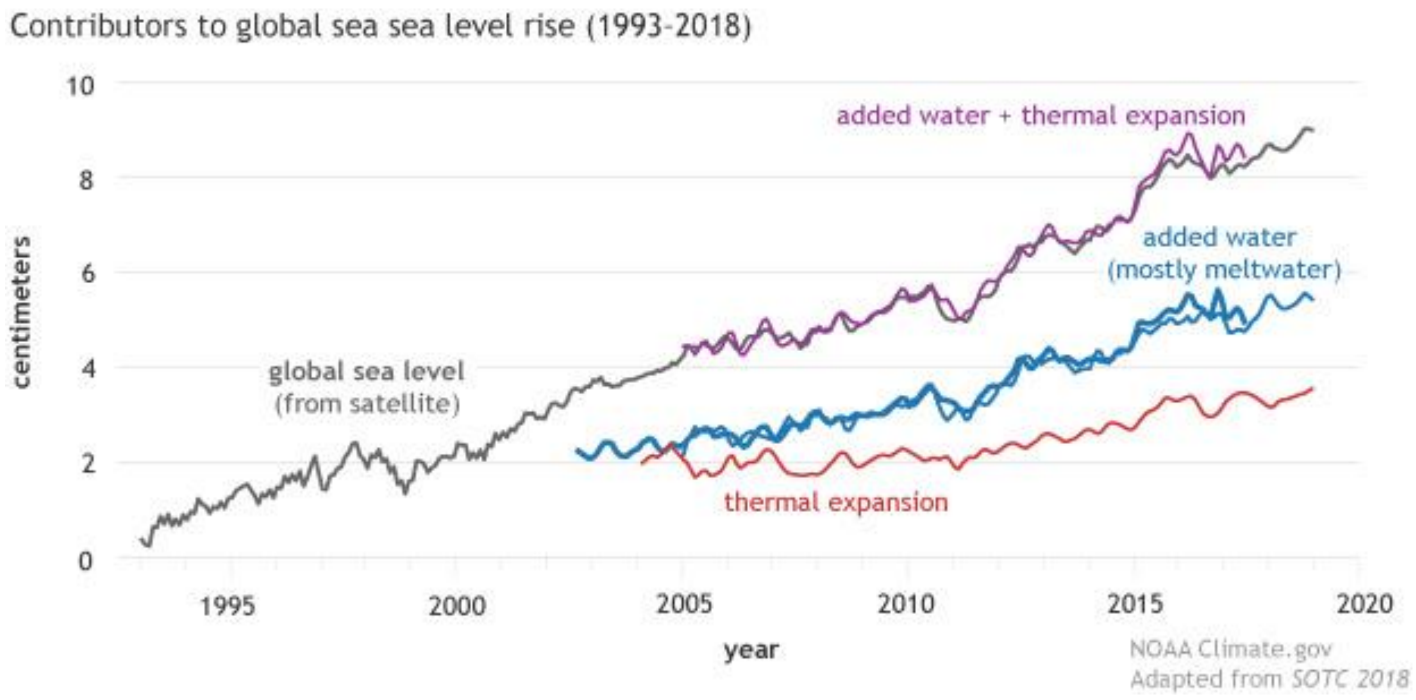
# Factors affecting global sea level changes

- Melting and building up of glacier.
- When glacier and ice-sheet melt, the water enter ocean basins.
- When glacier build up, lots of water store as ice.
- Thermal expansion. The heat absorbed by the ocean causes the water molecules to expand. Adding volume to the ocean.

# Global mean sea level rise




- Sea level has risen 8–9 inches (21–24 cm) since 1880.
- In 2019, global sea level was 3.4 inches (87.61 mm) above the 1993 average – the highest annual average in the satellite record (1993-present). This is an increase of 0.24 inches (6.1 mm) from 2018.

https://www.climate.gov/news-features/understanding-climate/climate-change-global-sea-level#:~:text=Global%20mean%20sea%20level%20has,of%20seawater%20as%20it%20warms.

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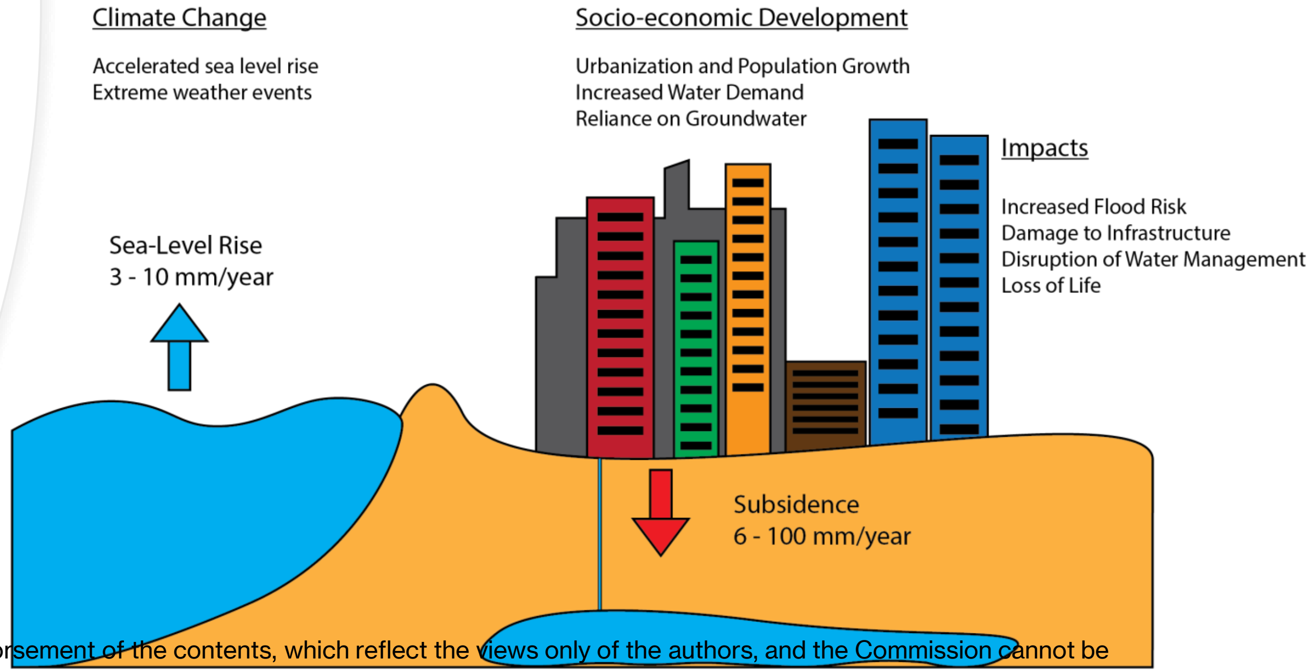
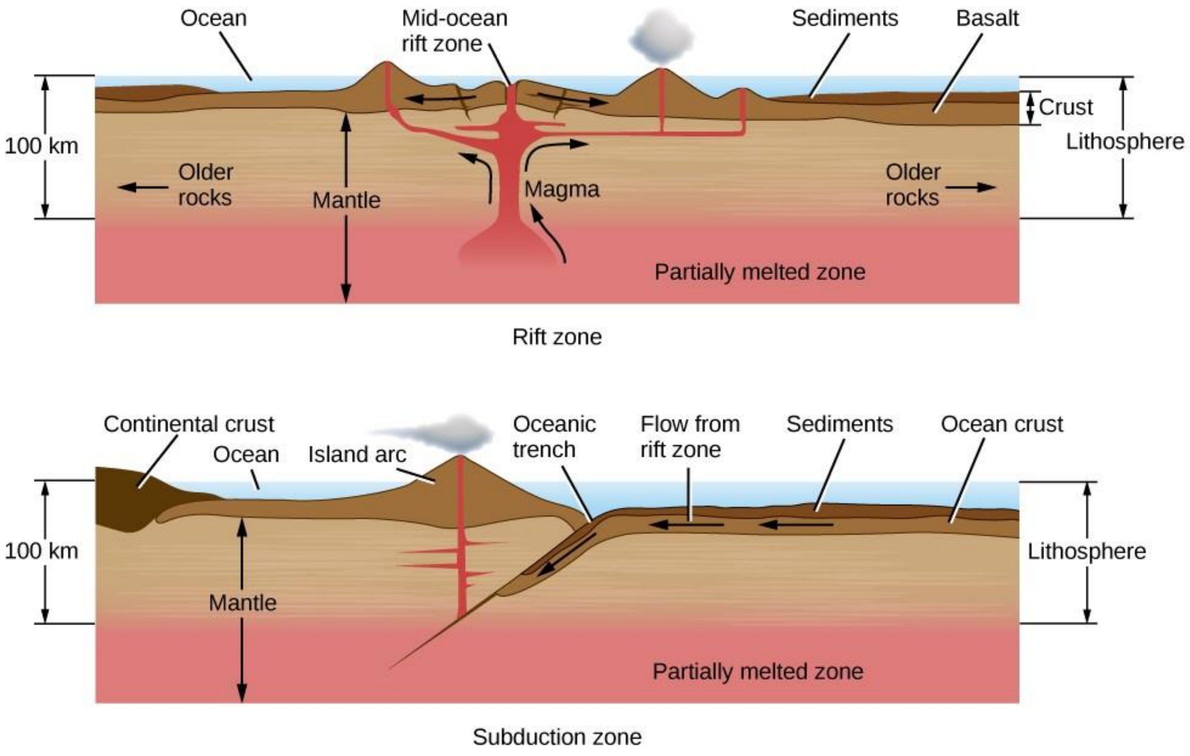
# Factors affecting local sea level changes

- Several local factors determine the rise and fall of local sea level pattern.
- These factors include land subsidence, ocean currents, tidal pattern, variations in land height and local climates.
- Land subsidence is the sinking of land area due to massive weight of cities and extraction of ground water.
- Ocean currents and tidal patterns changes with climate. Extreme climatic event such as typhoon and storm may cause higher local sea level.

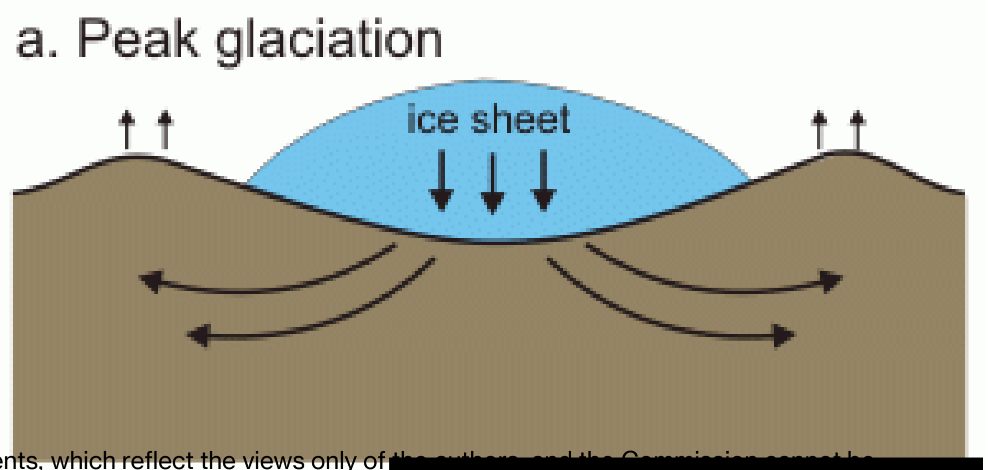



# Factors affecting local sea level changes

Variation in land height- vertical land movement and isostatic adjustment.





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# What are the implications of sea level changes?