# OCES5001 Introduction to Oceanography

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| Time: | Mon. 19:00-21:50 |
| Venue: | Rm 4502 |
| Instructor: | Jianping Gan; Tel. x7421, rm 3451, email: magan@ust.hk |
| TA: | Yanning Liu, yliuln@connect.ust.hk |
| Textbook: | Essentials of Oceanography, after 8th ed., by Tom Garrison, Thomson Brooks/Cole. (Please reserve your textbook in UST bookstore) |
| Reference: | Oceanography: A View of Earth, by M. Grant Gross and E. Gross, Prentice Hall |

**Course Description** Earth Is an Ocean World with 71% of its surface covered by ocean. The oceanography is the story and the processes of unifying principles in the ocean. It integrates the disciplines of *geology (Geological Oceanography)* that focuses on earth structure related to earthquake prediction and distribution of valuable resources, *physics (Physical Oceanography)* that studies ocean currents, waves, and air-sea interaction, long-term climate change, *biology (Biological Oceanography)* that works with the nature and distribution of marine organisms, marine species and fisheries, *chemistry (Chemical Oceanography)* that investigates ocean's dissolved solids and gases and their relationship to geology and biology of the ocean and *engineering (Ocean Engineering)* that designs and builds oil platforms, ships and harbors. These topics are directly associated with marine resources and pollution of our great concerns. This course covers the inter-disciplinary topics in oceanography that introduces process of science and astonishing story of global ocean as well as the ocean around us in the Southeast Asia.

Syllabus:

1. Introduction
2. Earth structure and plate tectonics
3. Seawater physical and chemical properties
4. Circulation of atmosphere
5. Ocean circulation, El Nino and climate
6. Oceanic life and ecosystem
7. Sediments
8. Plankton in surface water
9. Essentials of physical-biogeochemical balances in the ocean
10. Shelf, coastal and estuarine circulation
11. Tides, waves and mixing in the ocean
12. Coastal circulation and biological responses
13. Marine resources and pollution

## Grading:

- Class participation: 10%
- Mid-term (Oct. 20) Exam: 35%
- Final Exam: 55%

# Chapter 1: Origins, history, the world's ocean basin and regional characteristics

1.1 Timeline for the development of the universe, the solar system and life;

1.2 History of oceanography

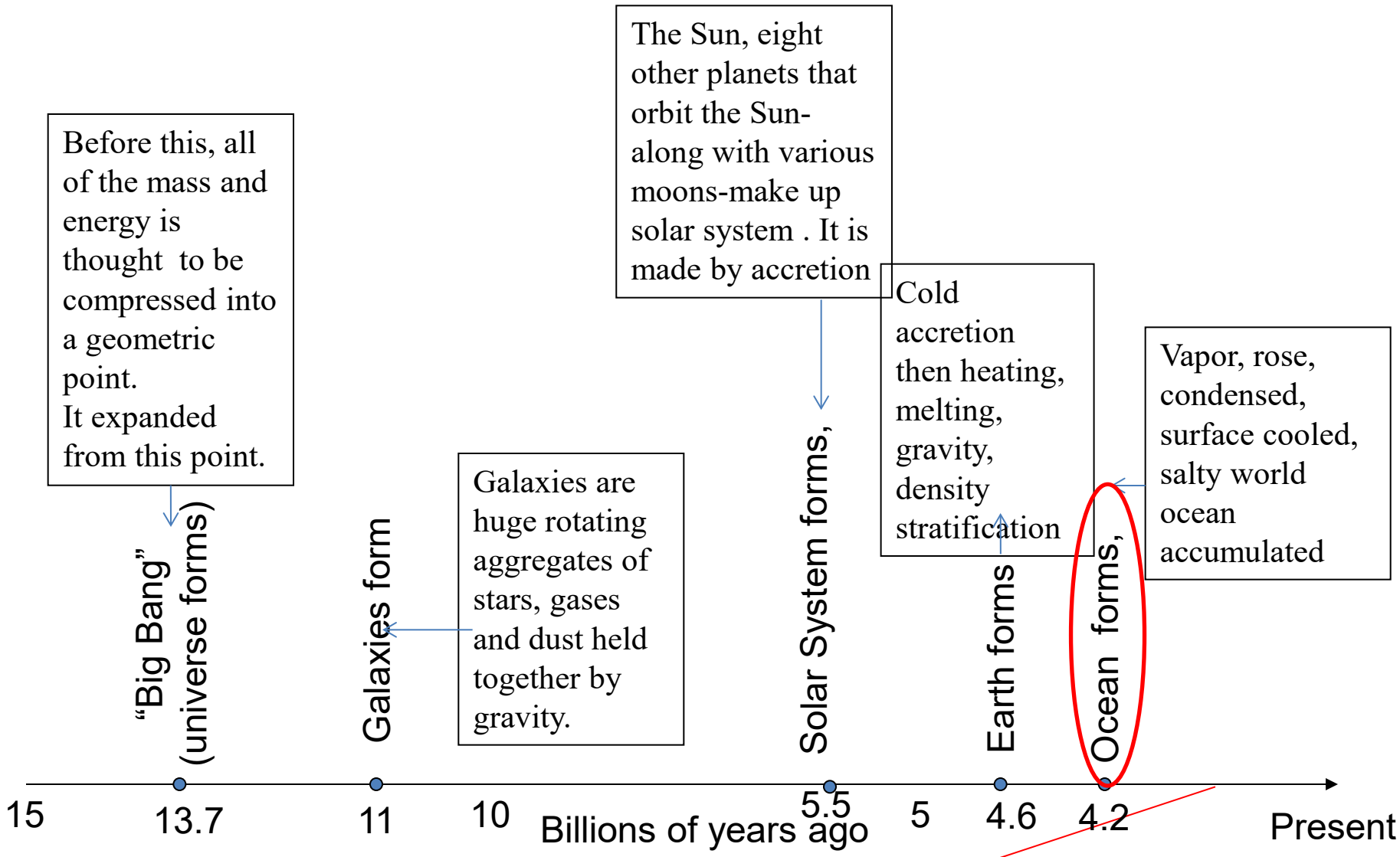
1.3 Ocean basins and their characteristics;

1.4 Regional ocean, continental shelf, coastal ocean and estuary;

1.5 Inter-disciplinary, multi-scale oceanography

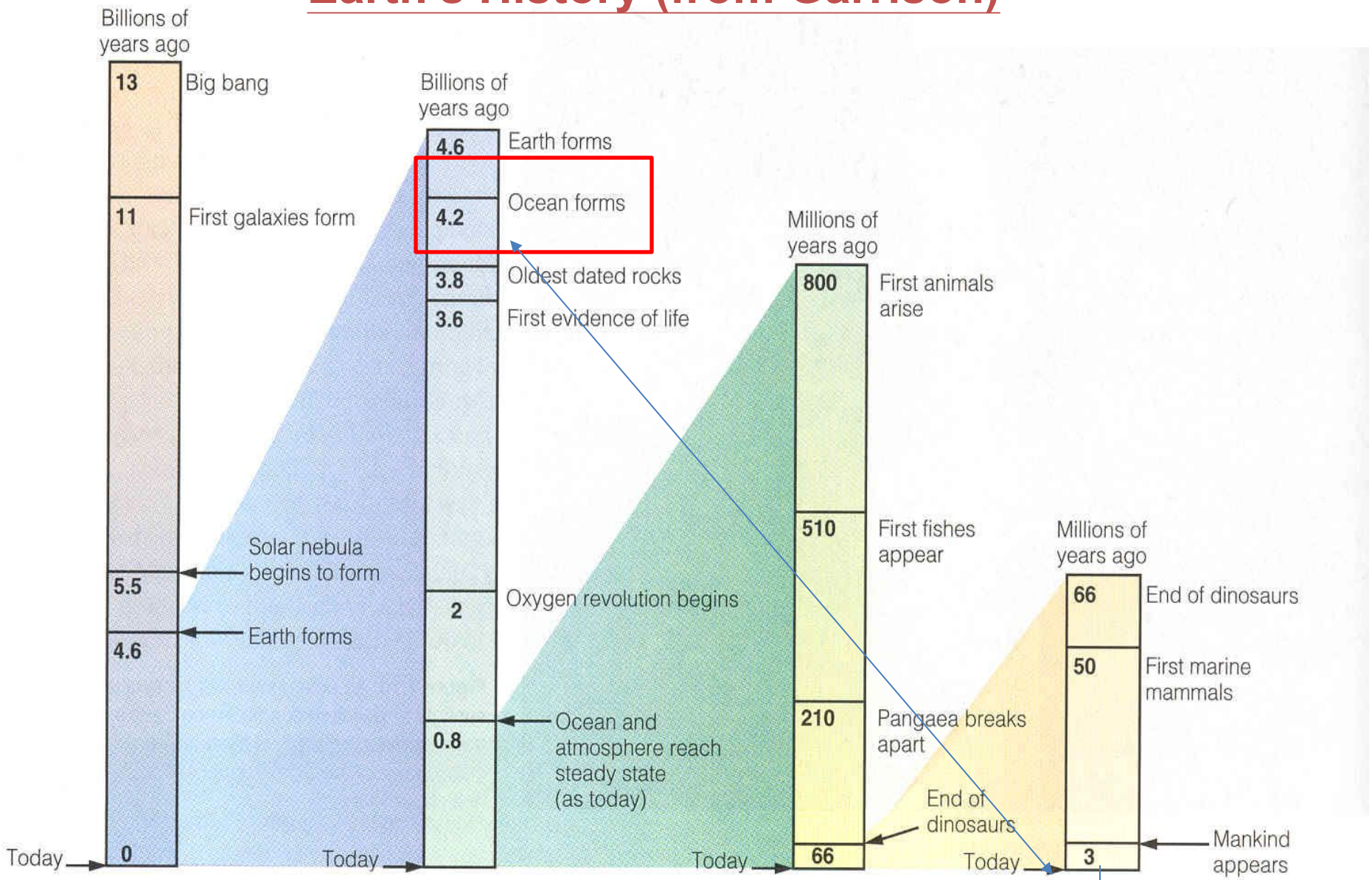
# 1.1 Timeline for the development of the universe, the solar system and life

*Formations and origins: universe, galaxies, solar system, life and ocean*




**Origin of Life**: One-celled organisms ➡ consume CO2, H2O, Sunlight organic matter ➡ O2 ➡ O2 breathing animals (surface) + O2-free animals (waters and below surface). Life begun about 3.5 b ago.

# Earth's History (from Garrison)



# How did the oceans form?

•The water on Earth stayed in gaseous form until the planet's surface cooled below 100 degrees Celsius.

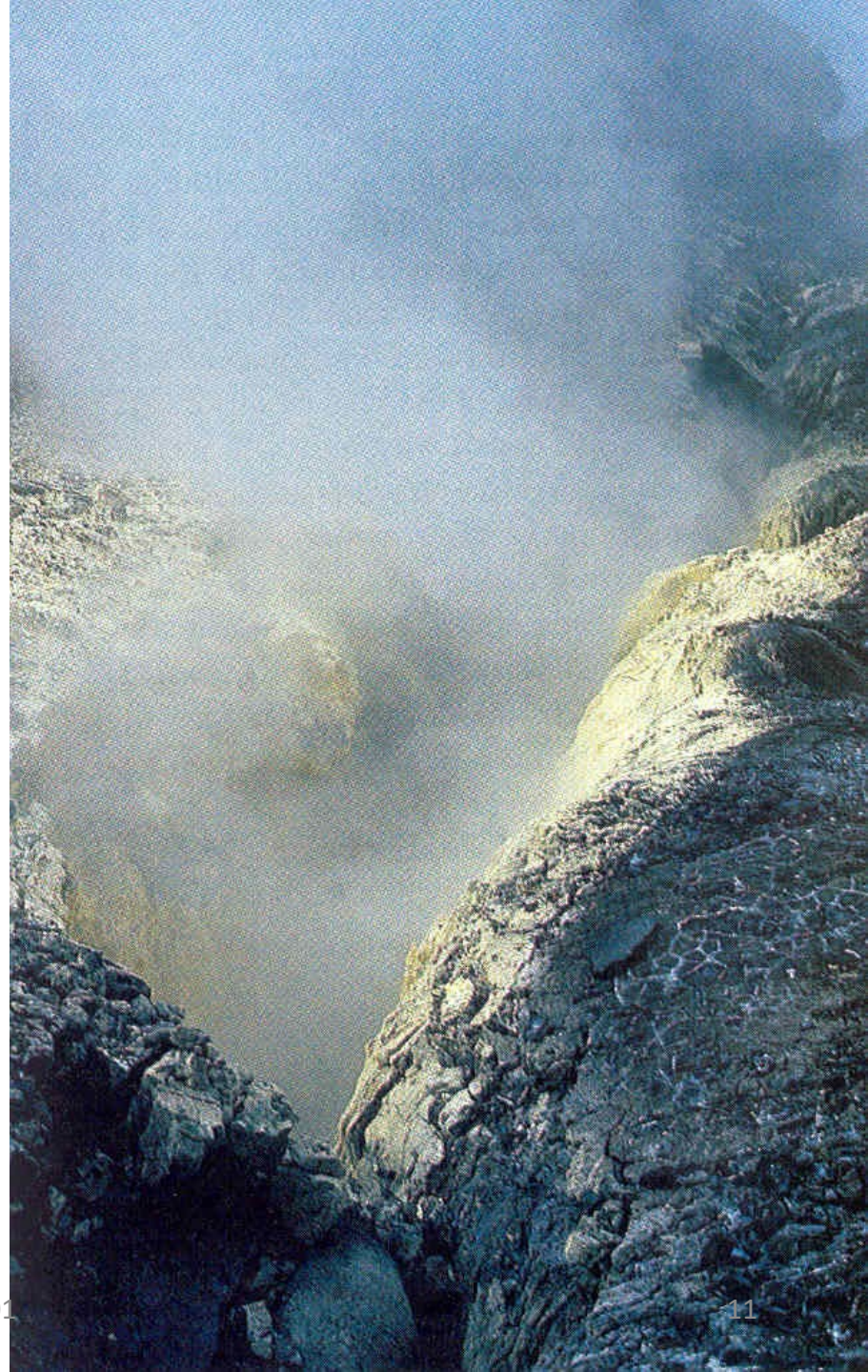
•4.2 billion years ago, water condensed into rain and poured onto the land. Water collected in low lying areas which gradually became the primitive oceans.

•As water entered the oceans from the atmosphere, it brought with it dissolved gasses released from the mantle by volcanoes and geysers. Water also flowed as runoff from the land, bringing in dissolved minerals from the rocks on the surface. These minerals include the salts which make seawater taste salty. Chemical properties of sea water were formed.

# Sources of Water for the Ocean

## Outgassing by Volcanoes Contributed to the Atmosphere

## Vocanic gases – $H_2O$, $CO_2$, nitrogen

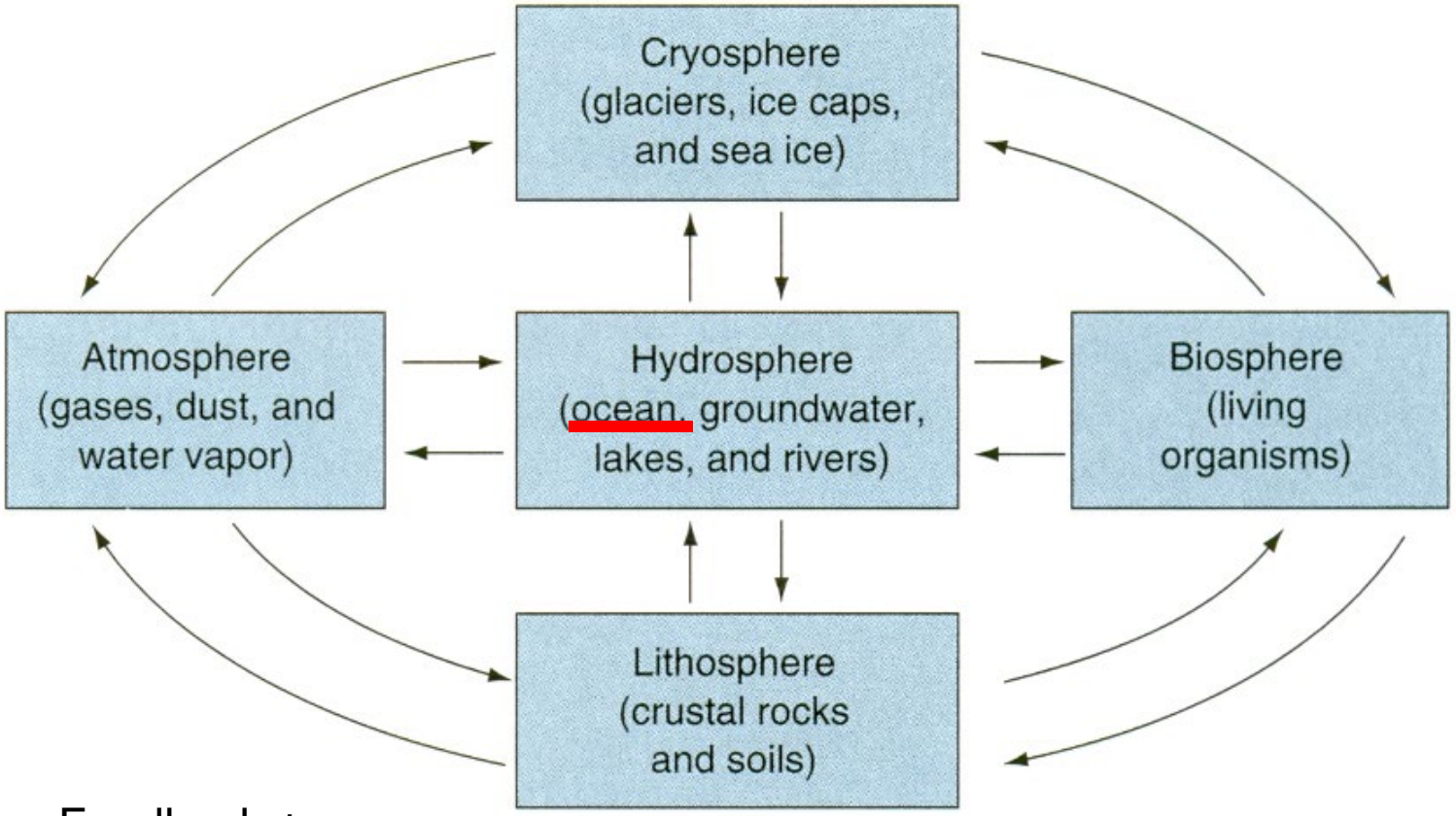


From Garrison

Intense bombardment of early Earth by large bodies of icy comets or asteroids from the outer space reaches the solar system.

# Comets May Have Delivered Some Water (Fig 1.9b)

# Subsystem in the Earth System




**Feedback:** a process that affects the flow of information from one part of the system to another.
**Positive feedback**: a change in some component results in the same sense of change in some other part of the system. e.g. T ↗, CO2 ↗ T.
**Negative feedback:** opposite to positive feedback


(from Earth Systems Digital Lab)

## History of early explorations:

- The earliest voyaging comes from records of trade in Mediterranean Sea about 1200 B.C.E
- Greeks began to explore outside the Mediterranean Sea into Atlantic Ocean around 900-700 B.C.E.
- Systematic study of the ocean began at the Library of Alexandria (~283 B.C or 246B.C)
- Eratosthenes (Greek scholar, 276 BC) calculated the size and shape of the earth.

# Highlights on pioneer explorations:

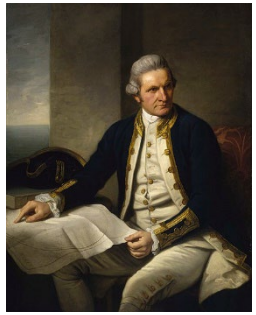
Prince Henry of Portugal (1394-1460)
– established a centre for the study of marine science & navigation
- explored the west coast of Africa an used the compass (Chinese invention)

Zheng He (1371 – 1433)
-Chinese, led by Zheng He, commanded the greatest fleet the world had ever known in 1405-1433

Christopher Columbus (1451-1506)
-credited with discovering the 'new world' (North America)
- wanted to find a route to Asia (for trading goods)

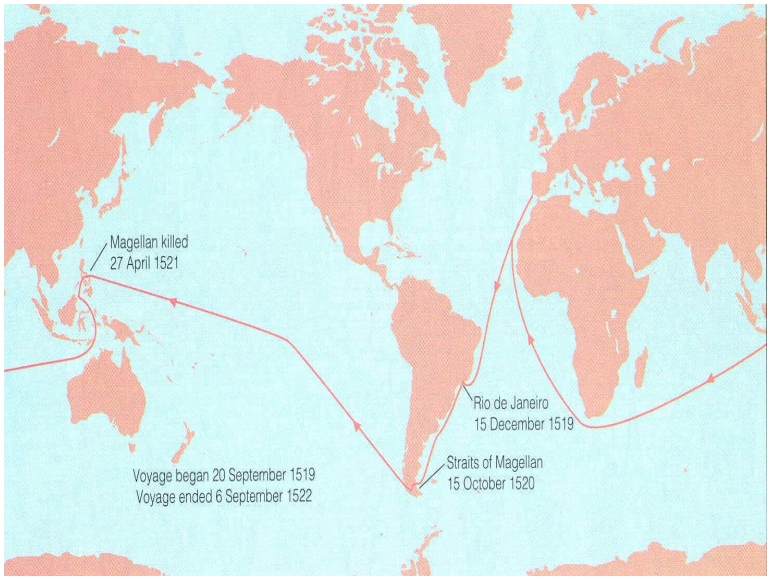
Ferdinand Megellan (1480-1521)
-sailed into the Orient
- his crew circumnavigated the globe

James Cook (1728-1779)
-began the study of scientific oceanography – took many samples
- sailed into Antarctica, and chartered coastlines from Newfoundland to New Zealand

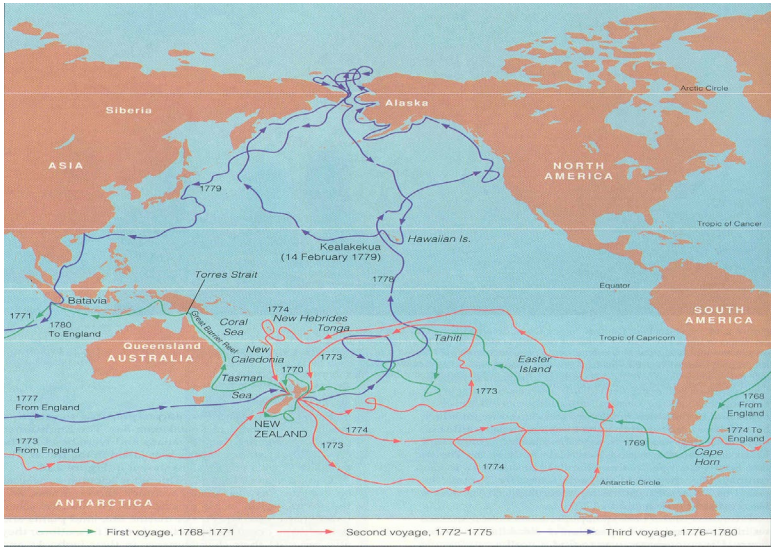


# Zheng He's Expedition Map


# Magellan's Voyages




# Cook's Three Voyages Exploring the Pacific




(Garrison, 1996)

# Scientists and Expeditions

**Charles Wilkes**

-explored the Antarctic coast and the Hawaiian Islands
- took many samples

**Matthew Maury**

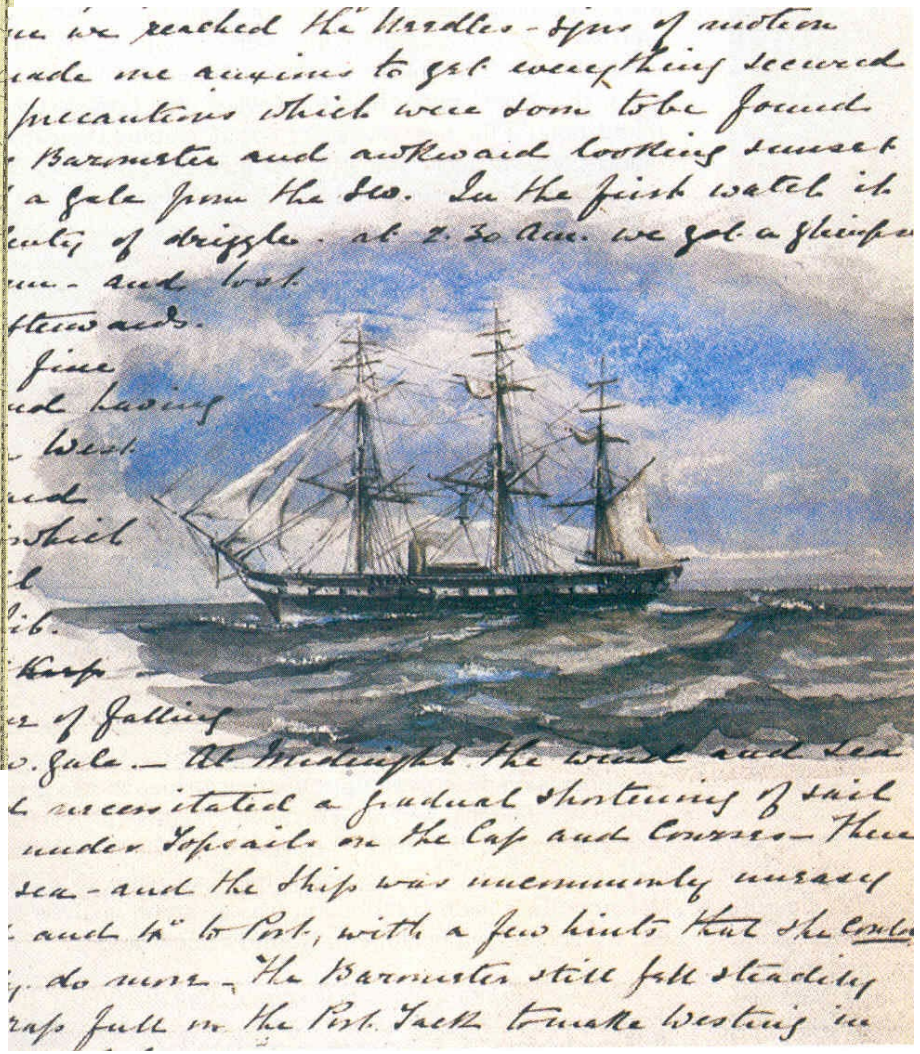
- 'father of Oceanography'
-Compiled wind and current charts from ships logs

**Benjamin Franklin**

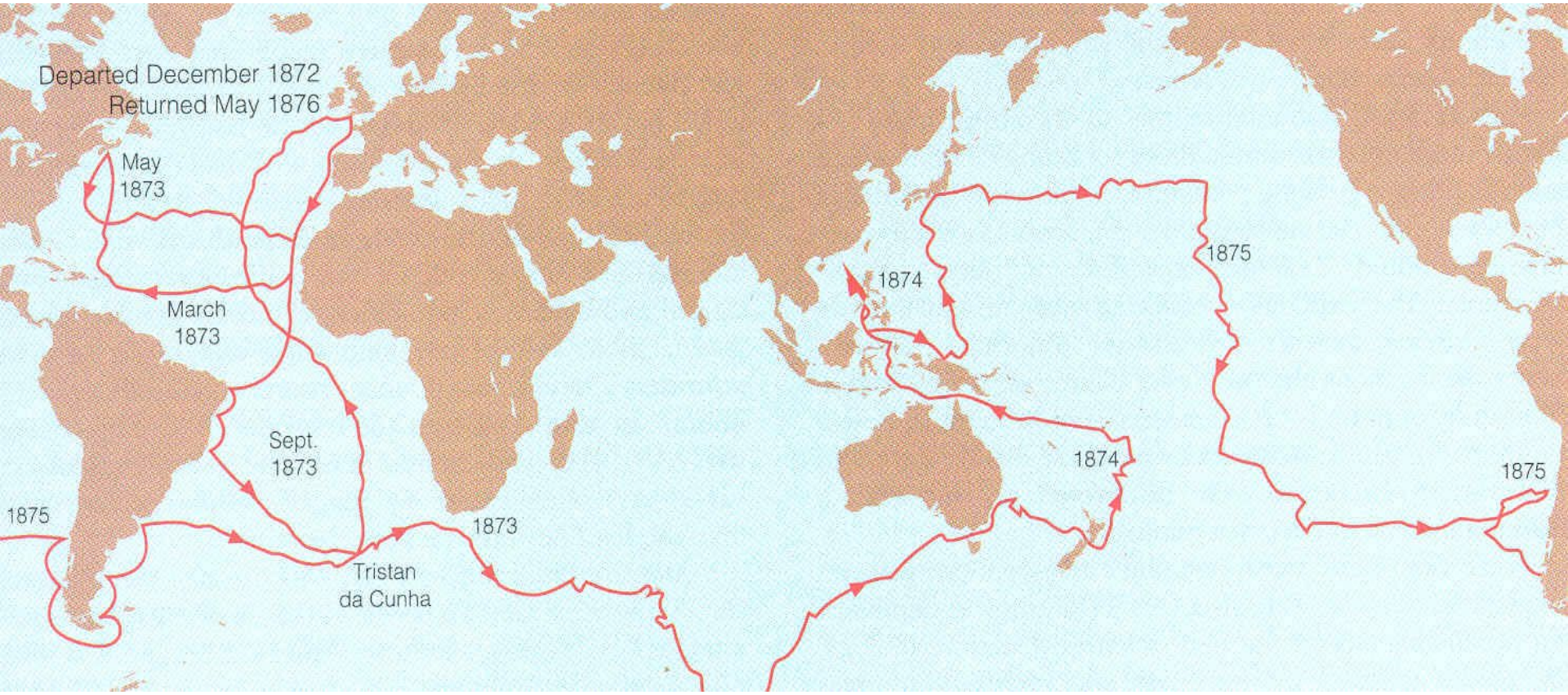
-discovered the Gulf Stream (1792)
- if sailing ships sailed in the Gulf Stream, passage to UK was faster.


**Benjamin Franklin's Chart of the Gulf Stream (1769) (Fig 2.15)**

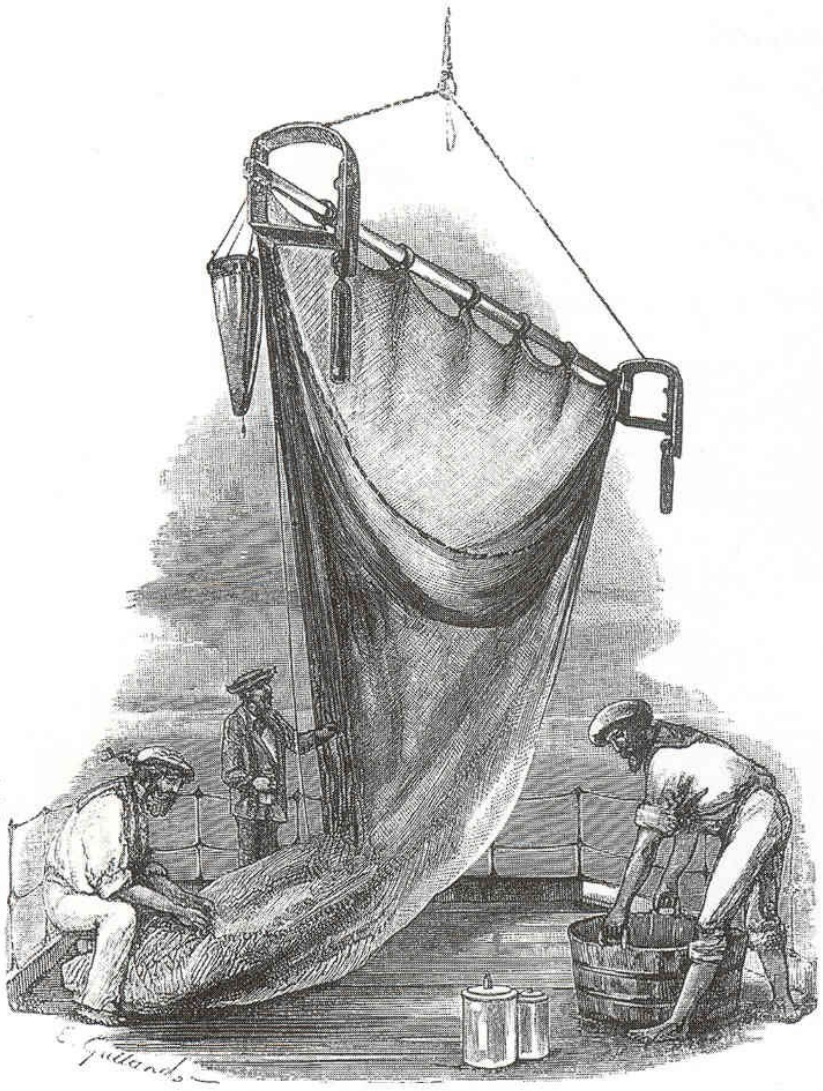
## H.M.S. Challenger (Fig 2.16)



# **H.M.S Challenger's Track** (1872-1876) Fig. 2.17




- **Findings recorded in 50 volume report – still used today.**
- **Found that there was life below 550 m – proved that Forbes was wrong**
- **Took sediment samples, trawls – discovered 4,717 new species**
- **It is the longest (4 yr) continuous oceanographic voyage.**

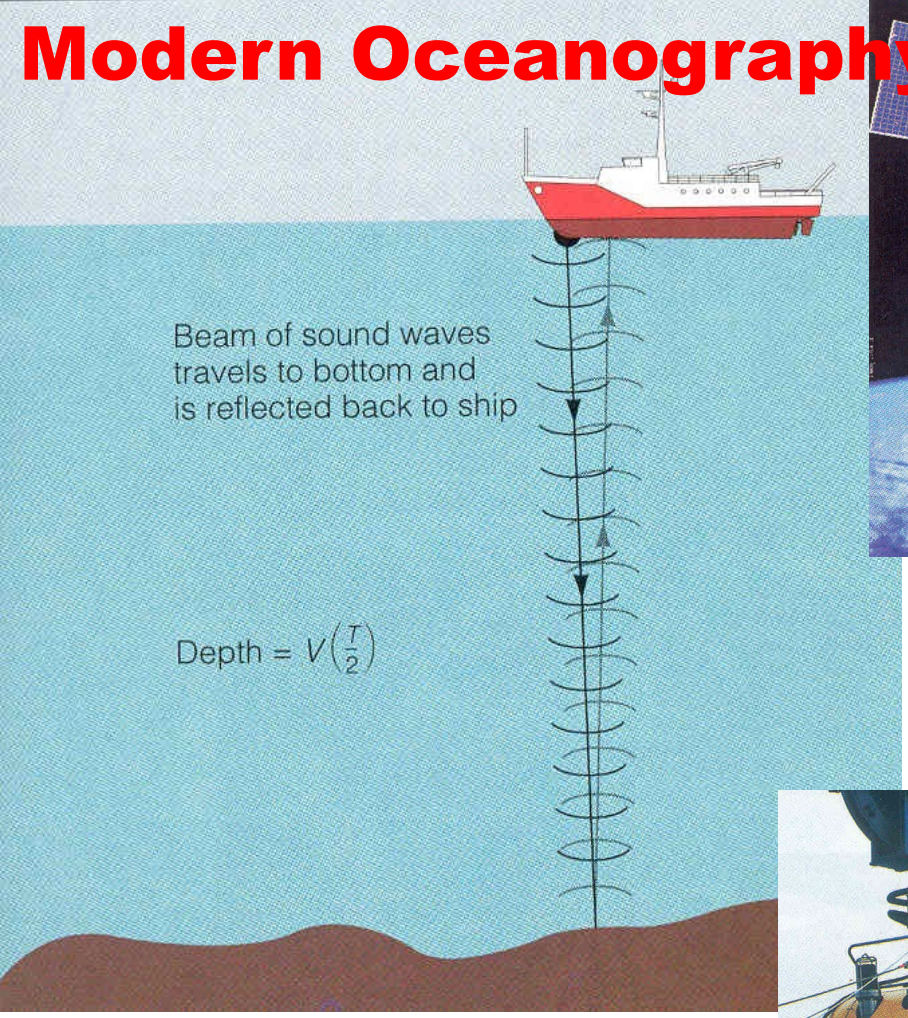


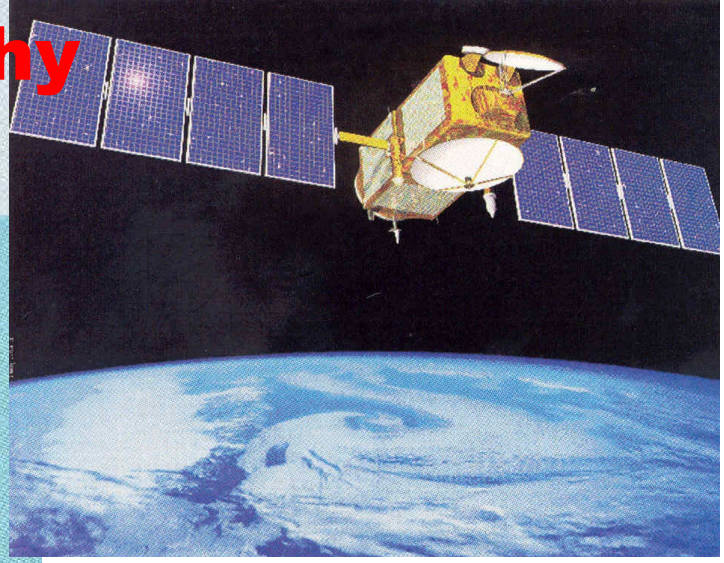
Archive, Scripps Institution of Oceanography

## Emptying a Trawl Net on the Challenger

## First Oceanographic Institution in Monaco 1906

# Modern Oceanography



**JASON – a satellite that covers all of oceans every 10 days. Measures sea surface height**

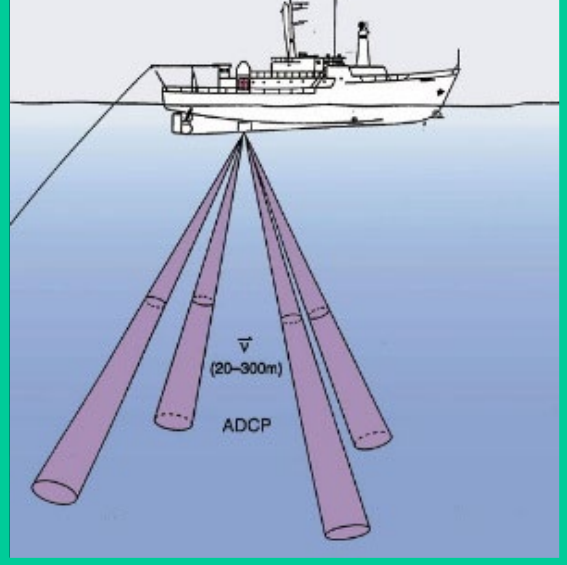
**Echo Sounder used to map the bottom topography of the ocean floor**


**Kaiko – Deepest diving remotely operated vehicle (ROV) to 10,914 m**


雪龍 2
XUE LONG 2

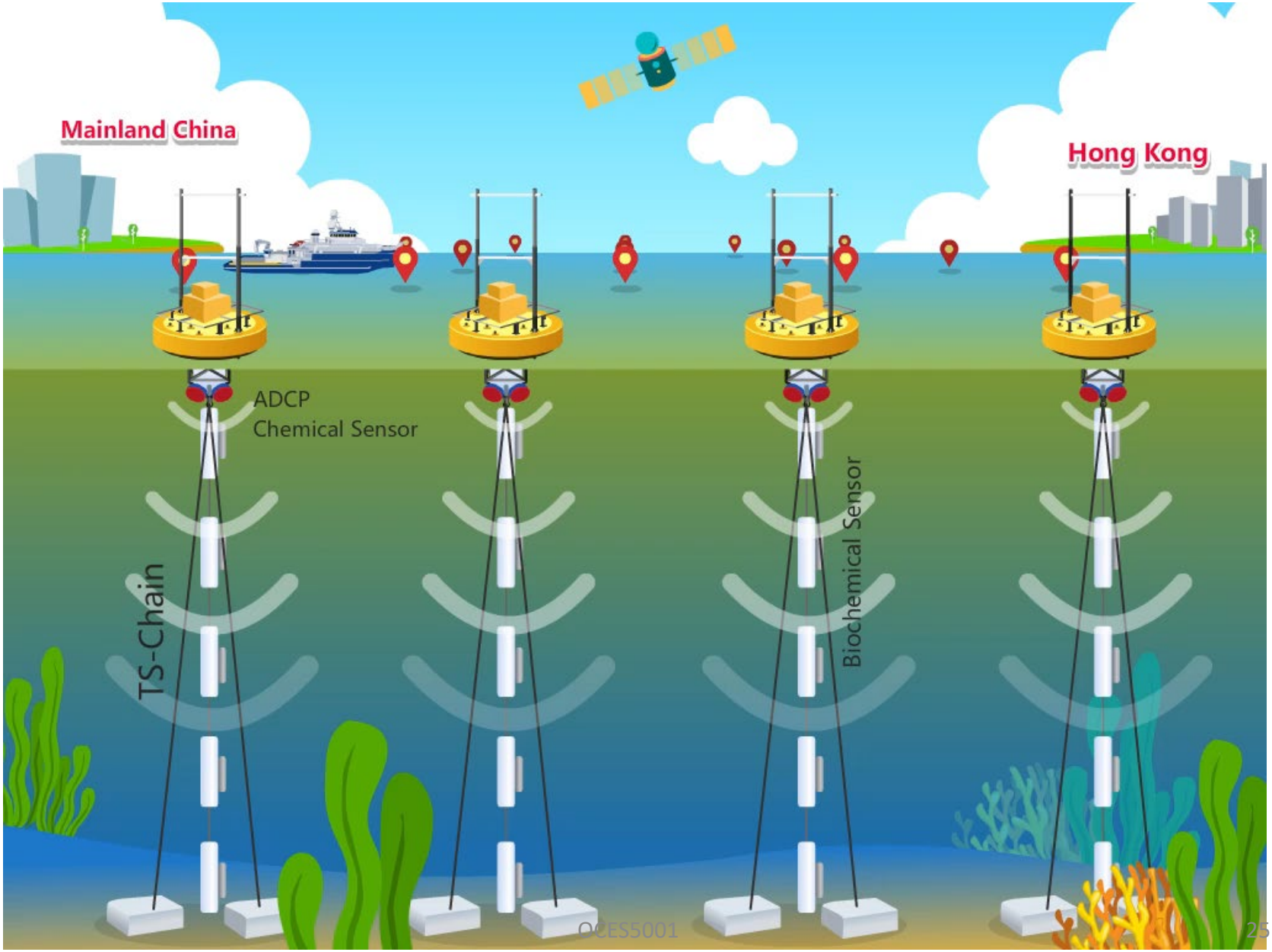

Buoy


EARTH-HK
“气候变化下粤港澳大湾区可持续发展的区域地球系统研究”
项目第一次科学考察航次
Earth-HK: 1st Field Survey in Ocean and Land of the GBA
(2024.07.11 – 08.03)


V
(20–300m)
ADCP


FLOTATION
TECHNOLOGIES

# Interdisciplinary *in situ* measurement

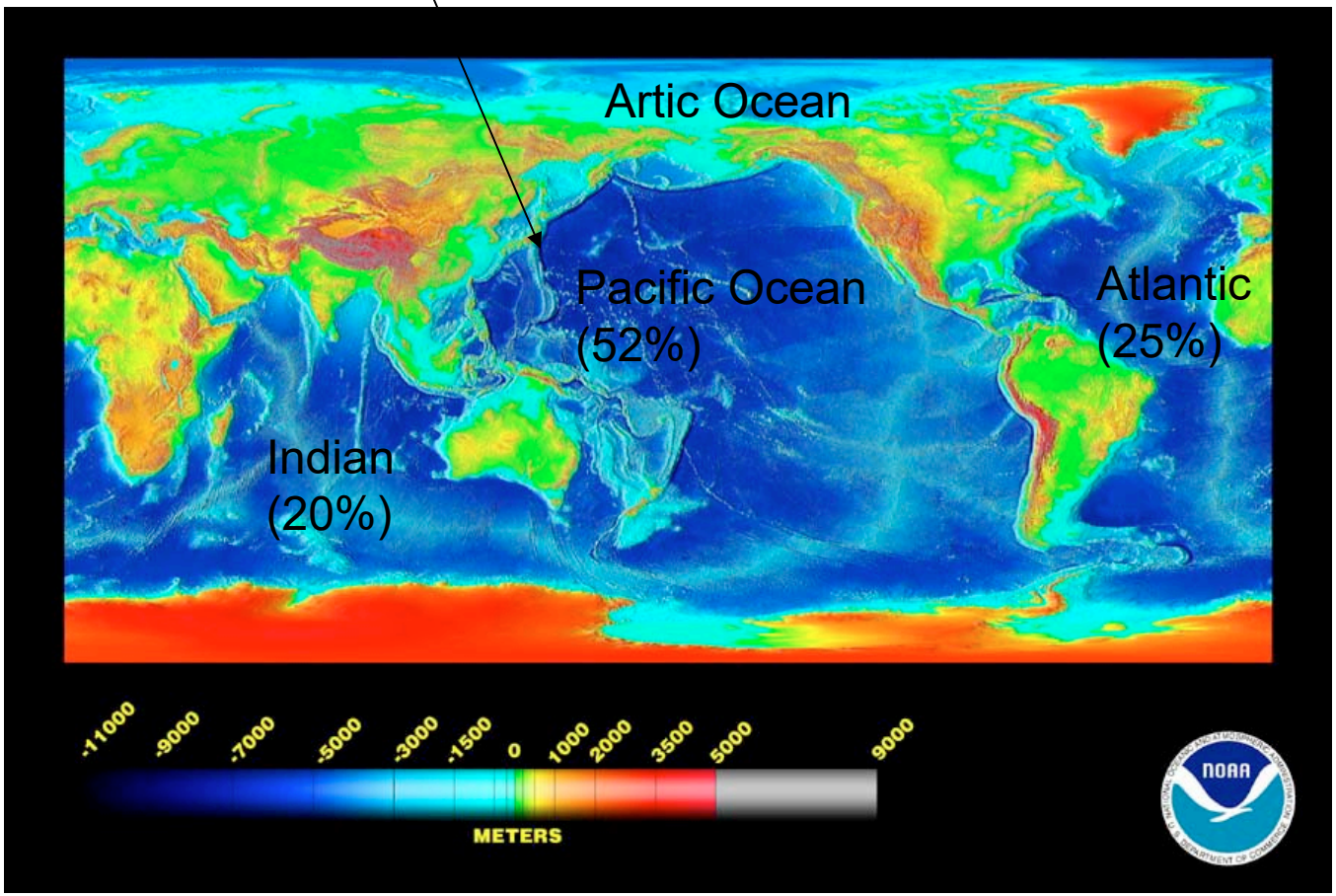


# 1.3 The ocean basins their characteristics

*Oceans, bathymetry, continental margins*

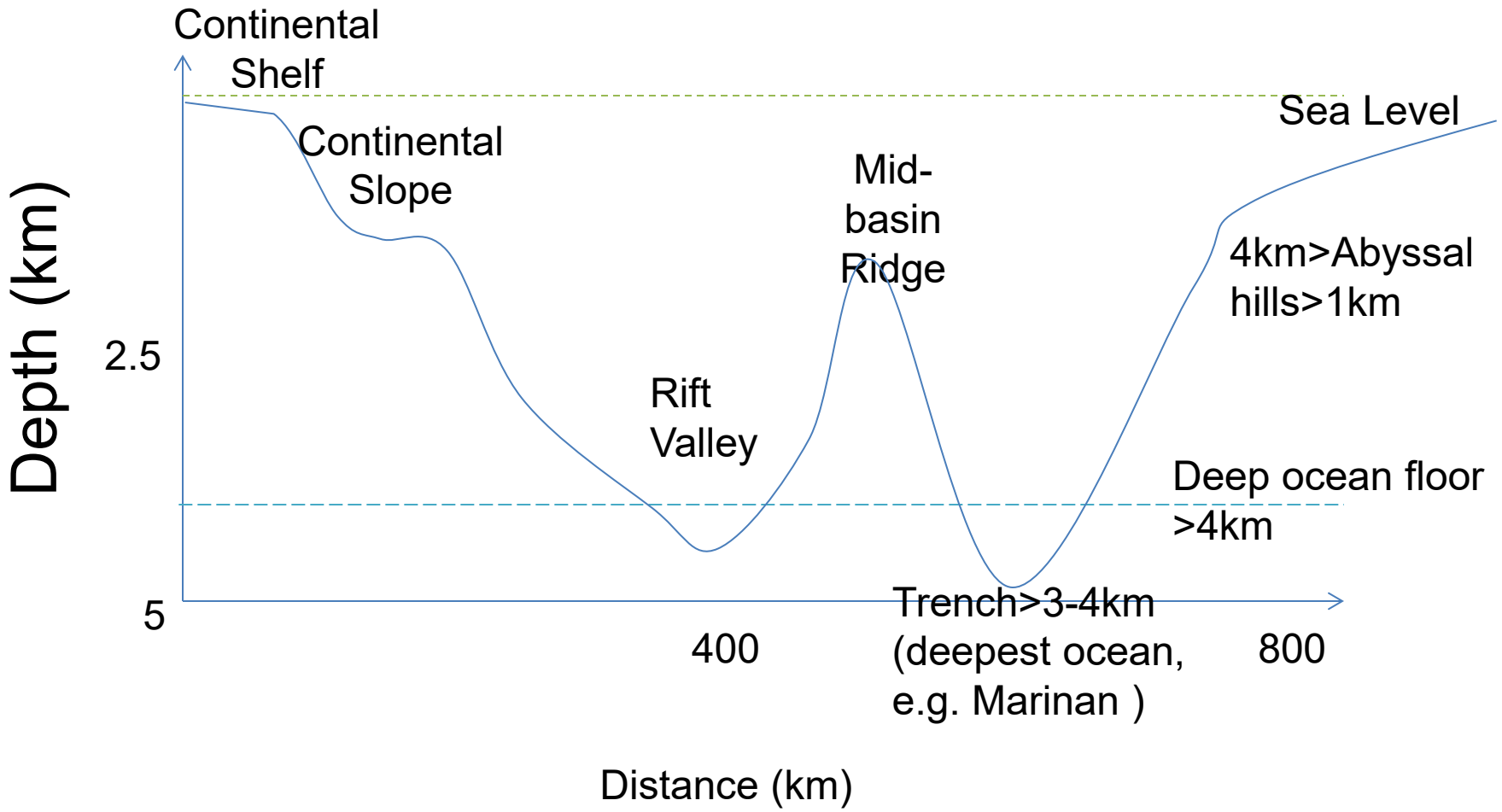
# 2. World's Ocean

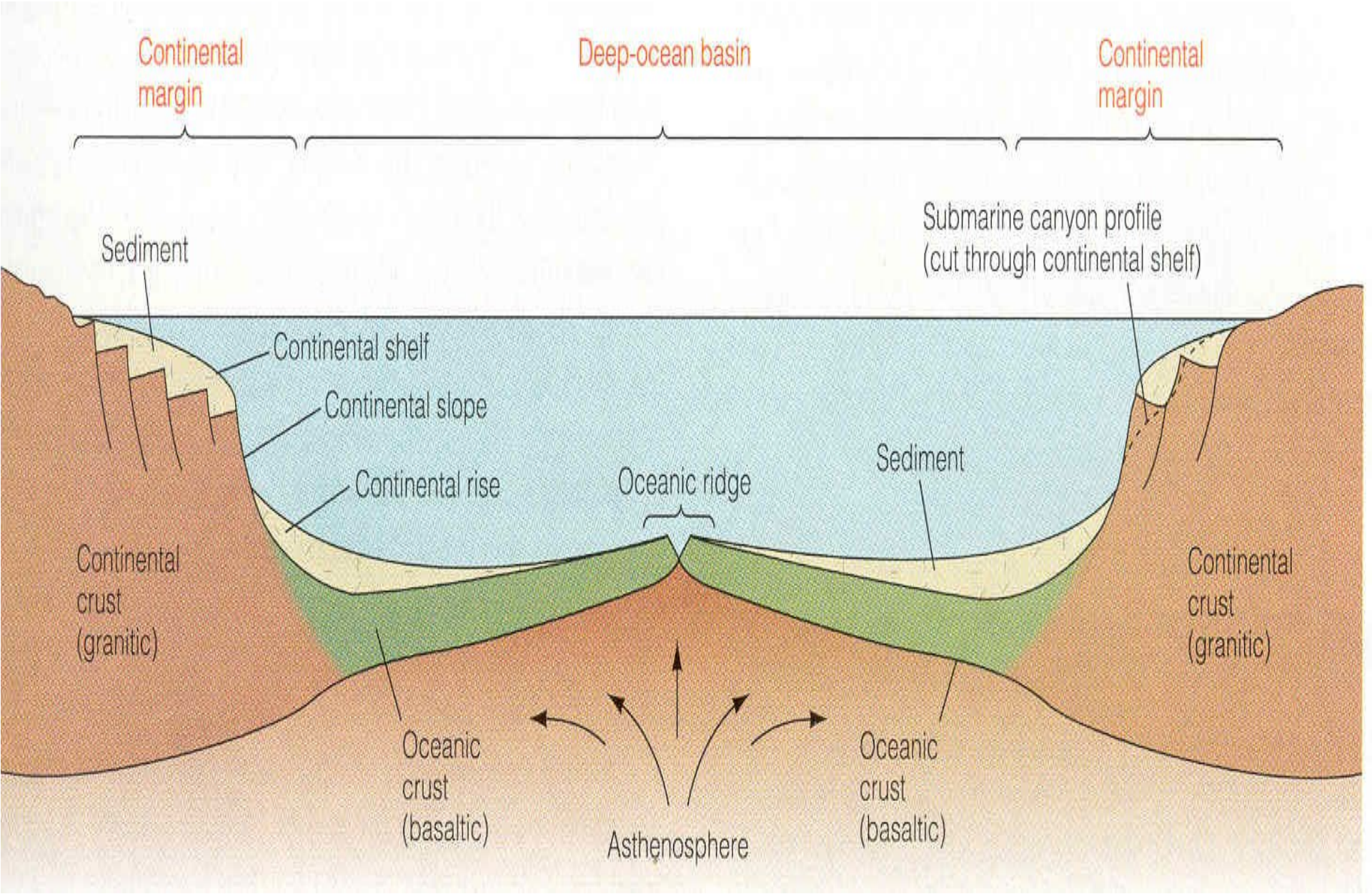
Ocean's deepest spot:
Marinan Trench
11,022 meters




Ocean: 70.8%
**Northern Hemisphere:**
60.7% sea, 39.3% land;
**Southern Hemisphere**:
80.9% sea, 19.1% land.

Elevation of the Earth: Elevation. Positive: Land, Negative: Ocean


Continental
Shelf
Continental
Slope
Mid-
basin
Ridge
Sea Level
4km>Abyssal
hills>1km
Depth (km)
2.5
Rift
Valley
Deep ocean floor
>4km
5
Trench>3-4km
(deepest ocean,
e.g. Marinan )
400
800
Distance (km)




**Cross-section of a Typical Ocean Basin and Continental Margin (Garrison)**

# Mid-Ocean Ridges

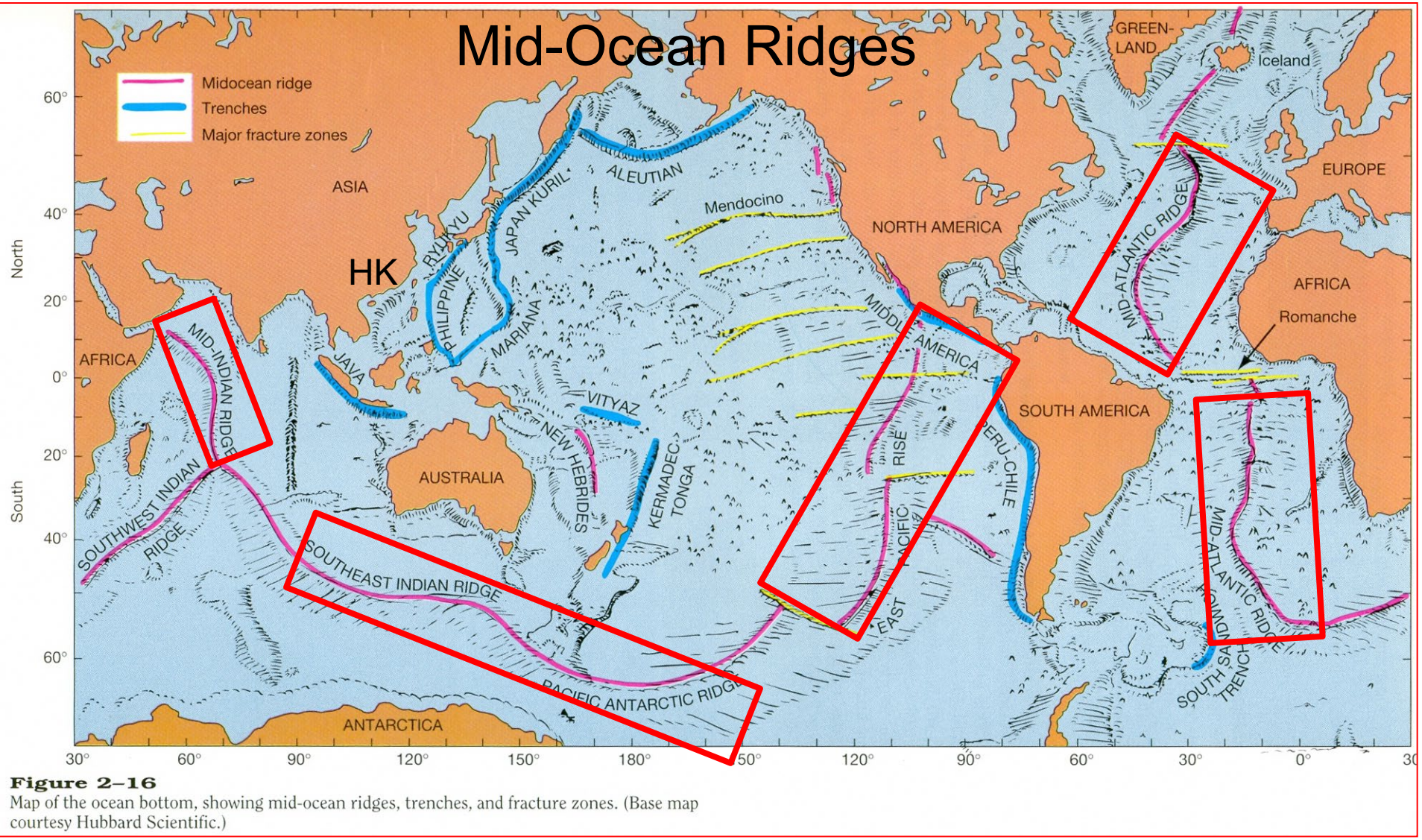
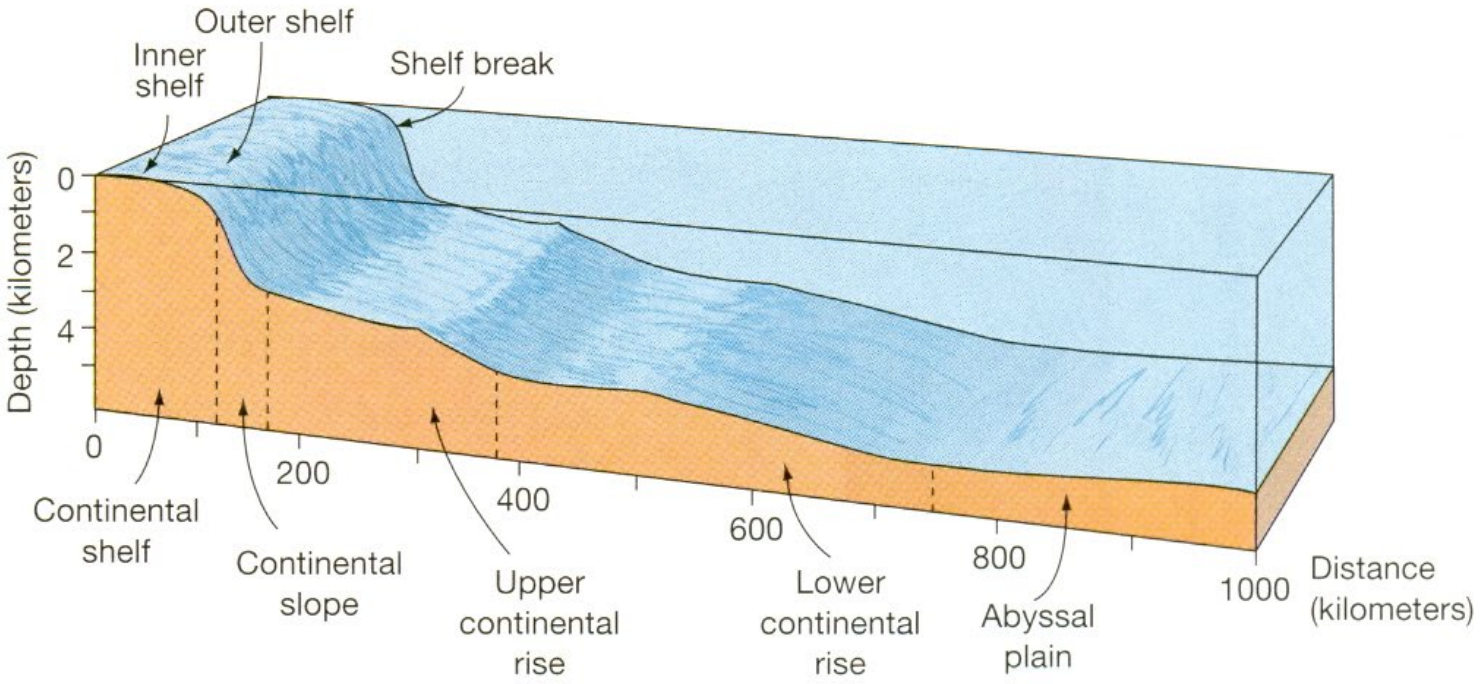



**Figure 2–16**
Map of the ocean bottom, showing mid-ocean ridges, trenches, and fracture zones. (Base map courtesy Hubbard Scientific.)

- Mid-ocean ridges exists in the deep-ocean basin;
- (a) Mid-Atlantic Ridge: rugged; (b) East Pacific Rise; less rugged; (c) Mid-Indian Ridge; (d) Pacific-Antarctic Ridge link Antarctic with Indian ridge
- Active earthquake; geothermal vent

**Figure 2–15**
Schematic diagram of the North Atlantic margin of North America, showing the change in the character of the ocean bottom going from the land to the deep-ocean bottom. Note the vertical exaggeration.



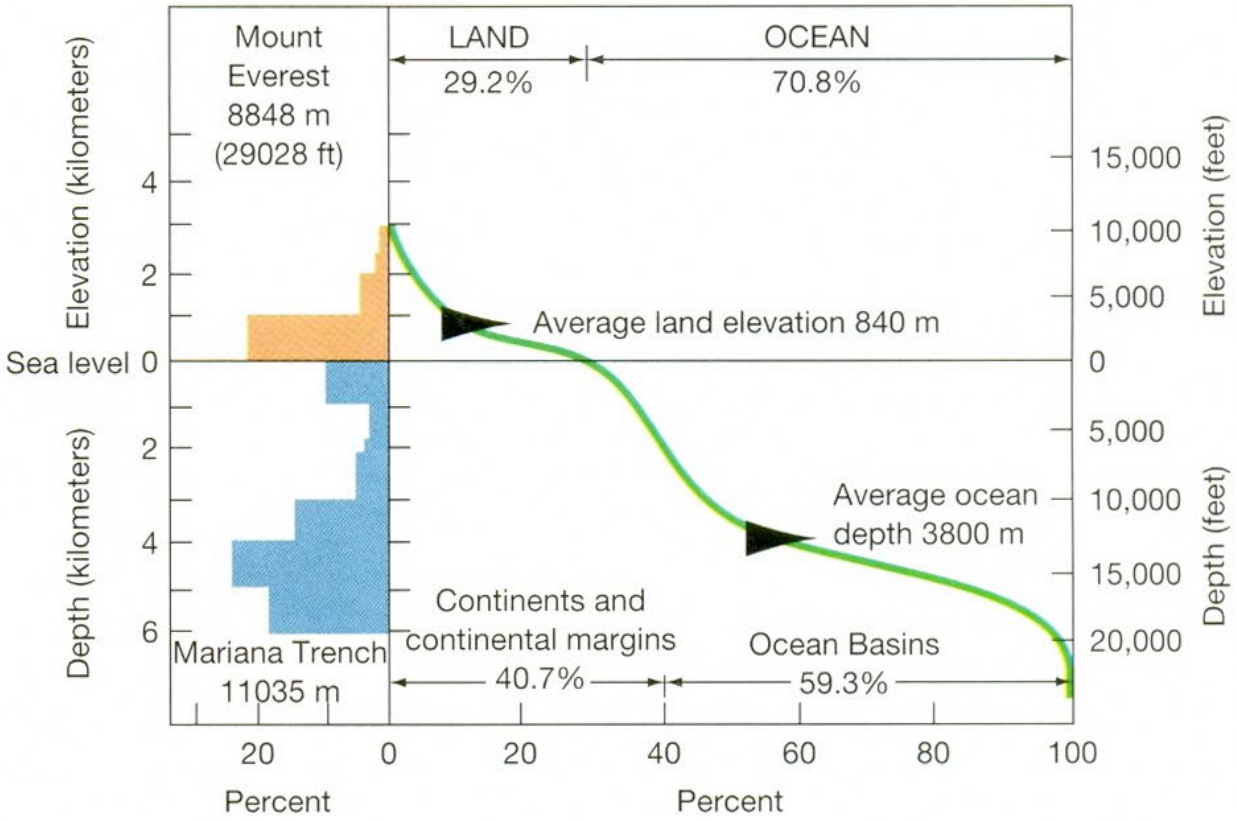
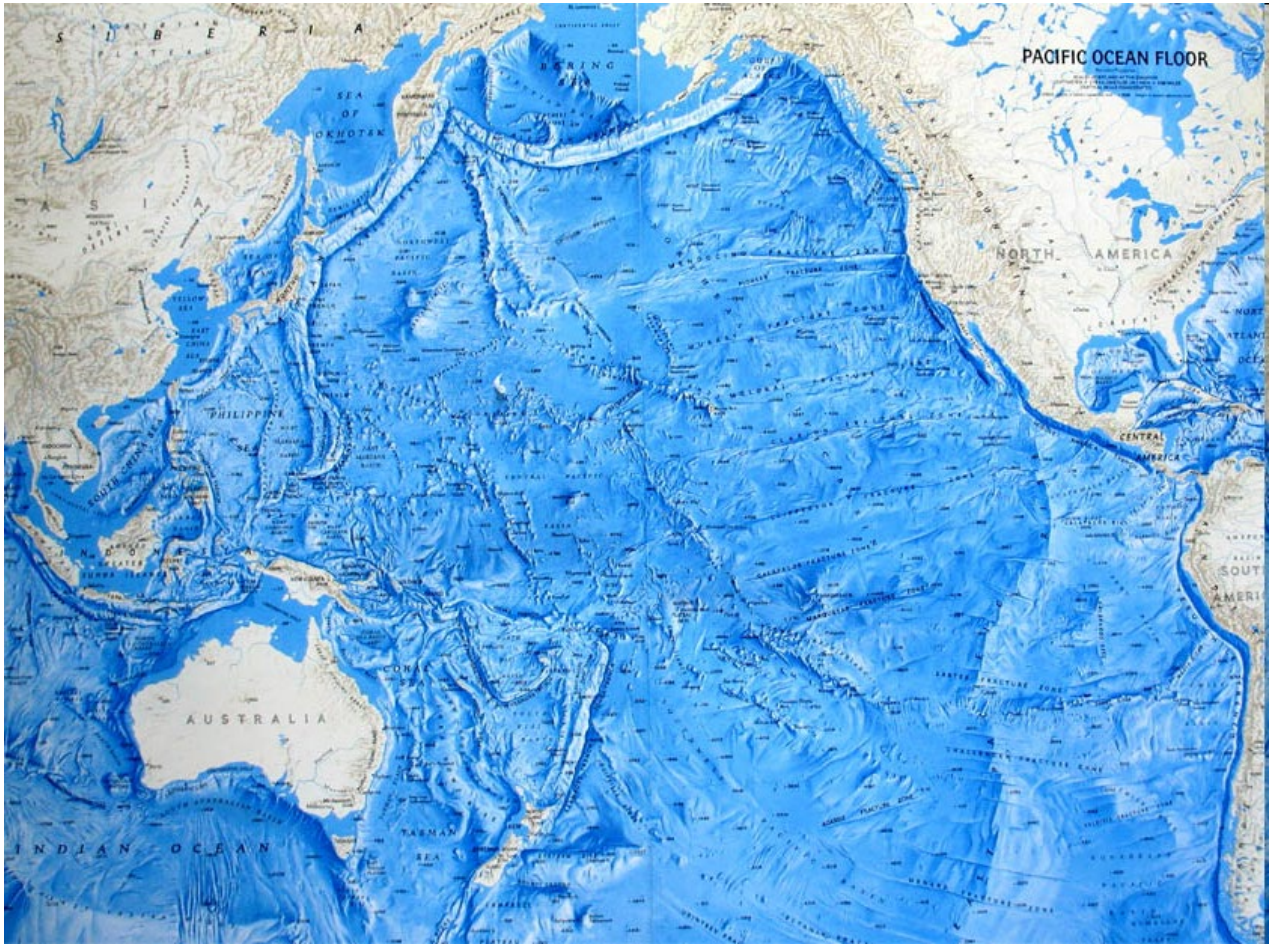
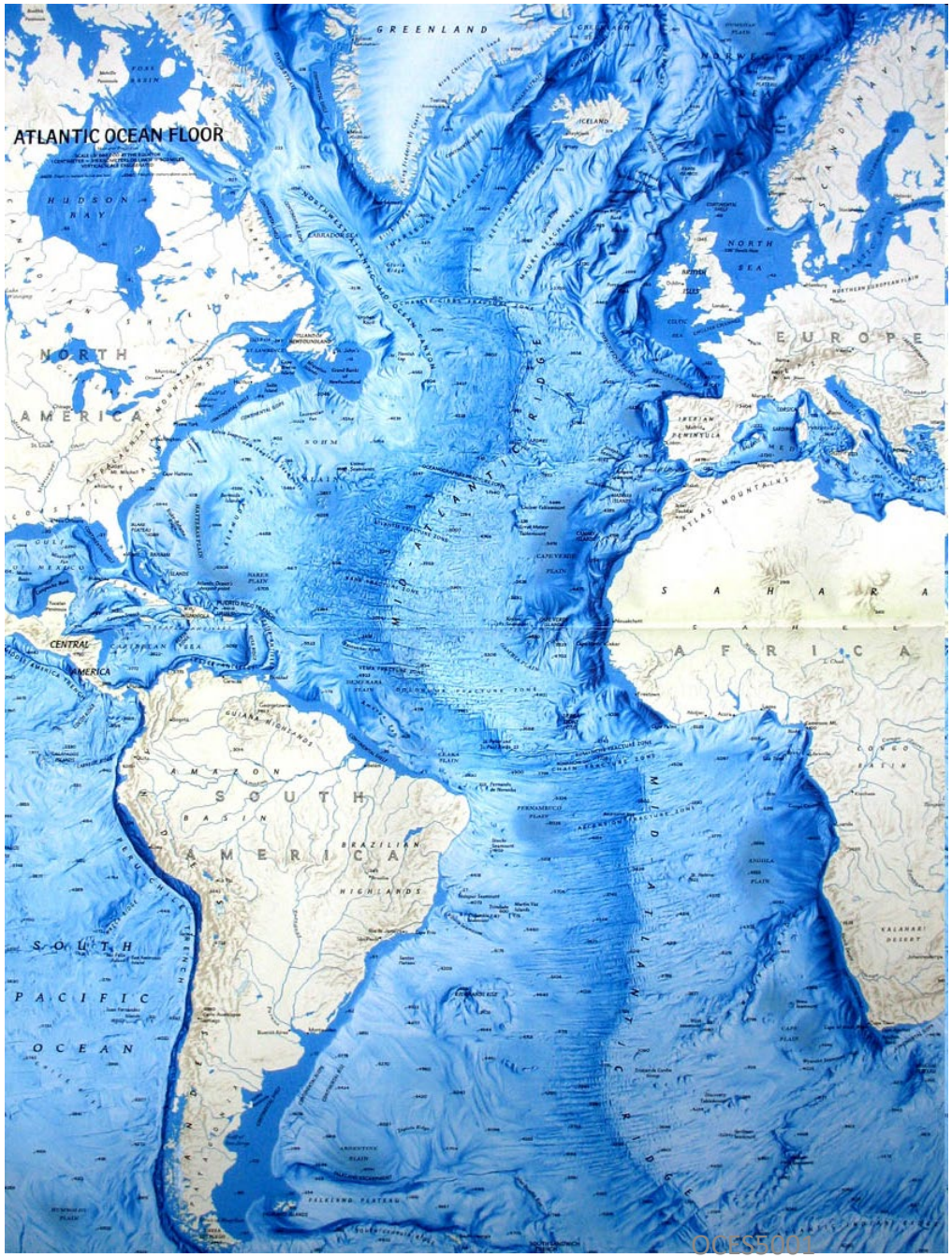



**Figure 2–14**
The fraction of Earth's surface in elevation or depth zones of 1 kilometer (left side). The right side shows the cumulative fraction of Earth's surface shallower than a given depth. Note that Earth has two dominant levels—one representing land and the other representing the ocean bottom.

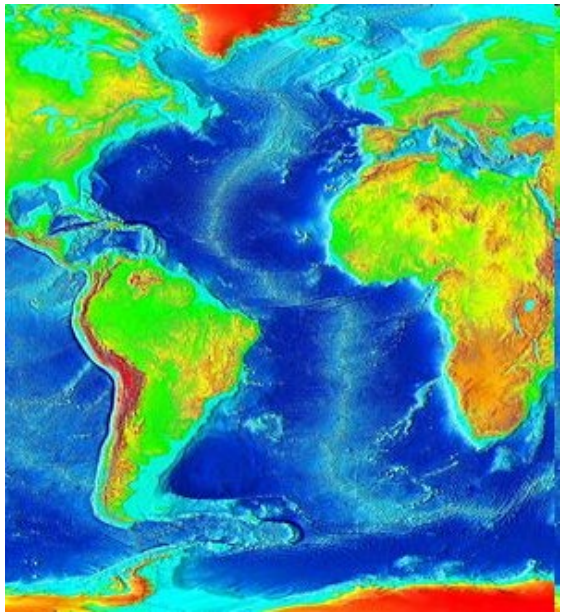
# Pacific ocean bathymetry




- Deepest and largest basin;
- 1/3 of earth surface;
- Narrow continental margin;
- Relatively less affected by land
- Island-abundant

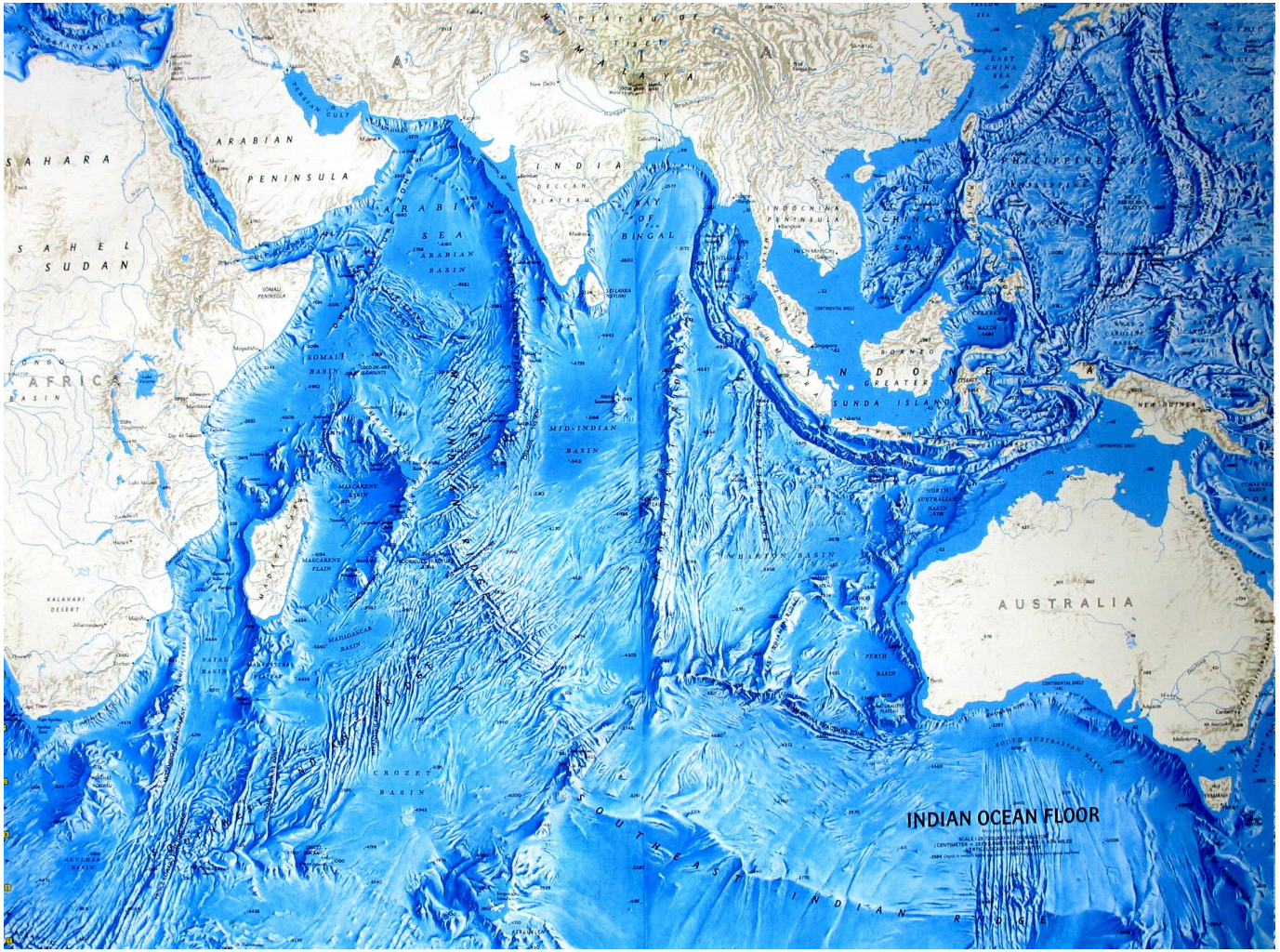



# Atlantic Ocean



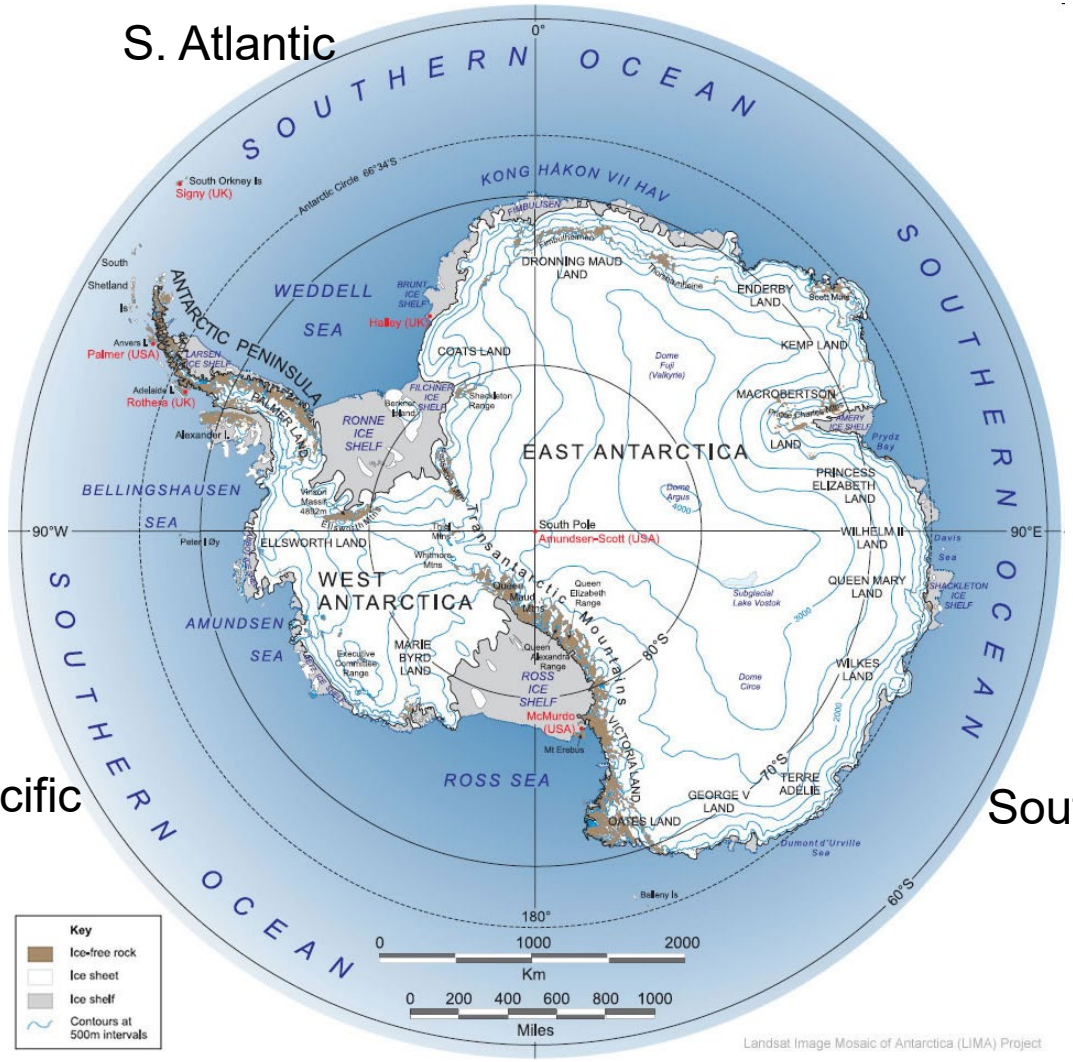
- Relatively narrow connecting the Artic and Antarctic Oceans;
- Relatively shallow
- Wide continental margins

# Indian Ocean




- Primarily in southern hemisphere; the smallest of the three major basins
- Most affected by land and receive 3 of the world's largest rivers (Ganges, Brahmaputra and Indus) discharge
- Intense evaporation with warm saline waters

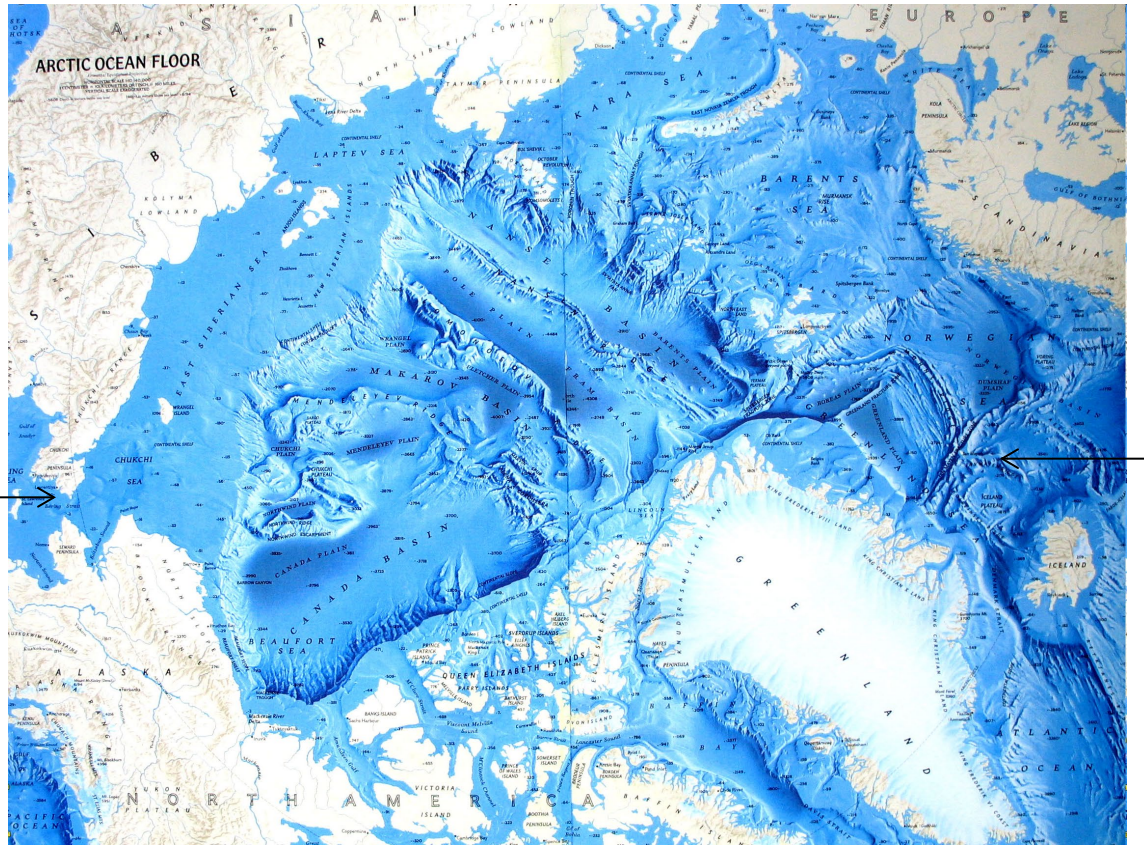
# Southern Ocean




- The ocean that the three major ocean basins connect on their southern end;
- Absence of land permits strong wind and ocean current, Antarctic Circumpolar
- Current, or ACC;
- The Weddell Sea forms the coldest and densest water for global ocean circulation;
- 100-200 meters thick of ice sheets

# Arctic Ocean

Bering Strait

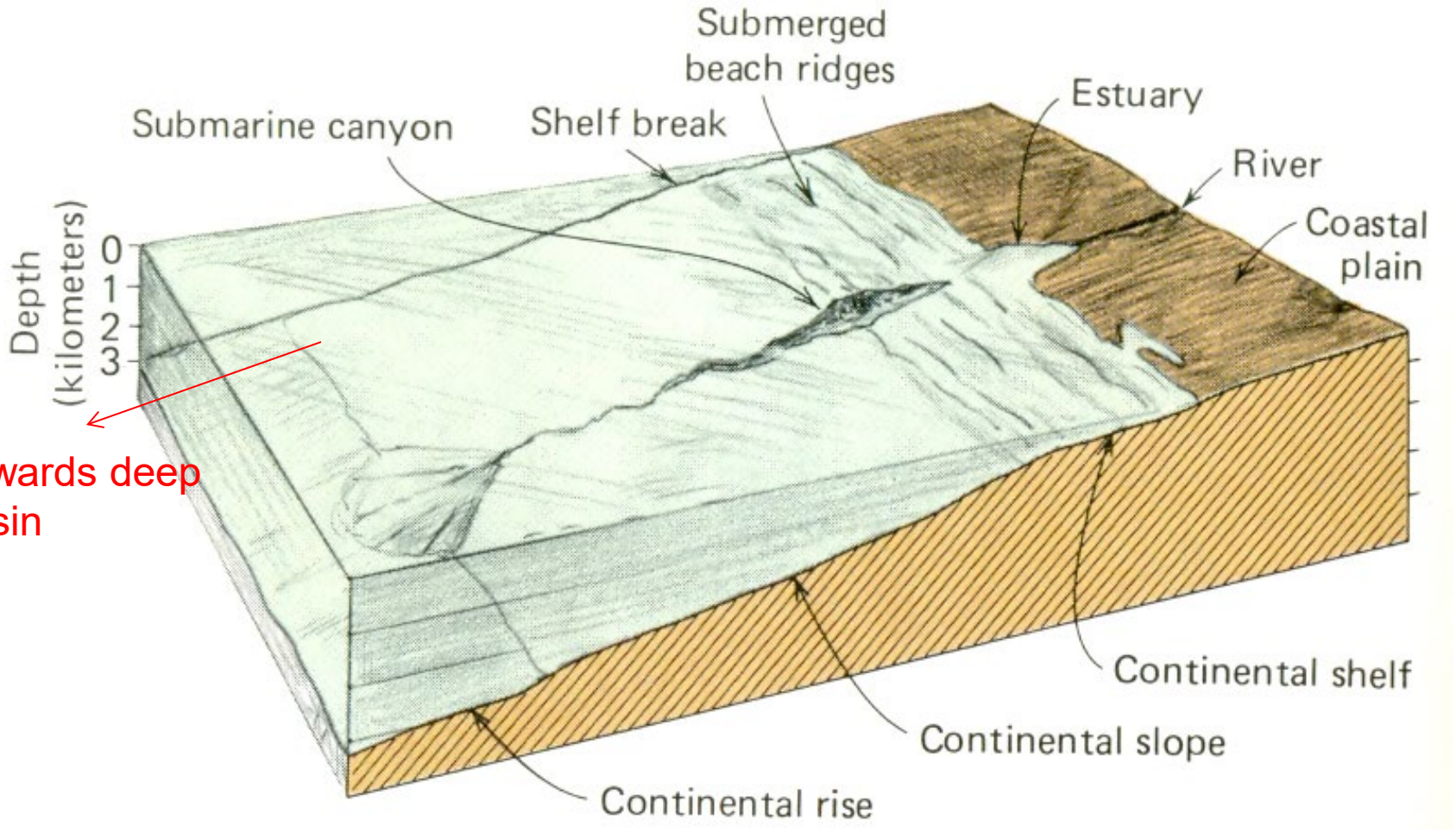



Frame Strait

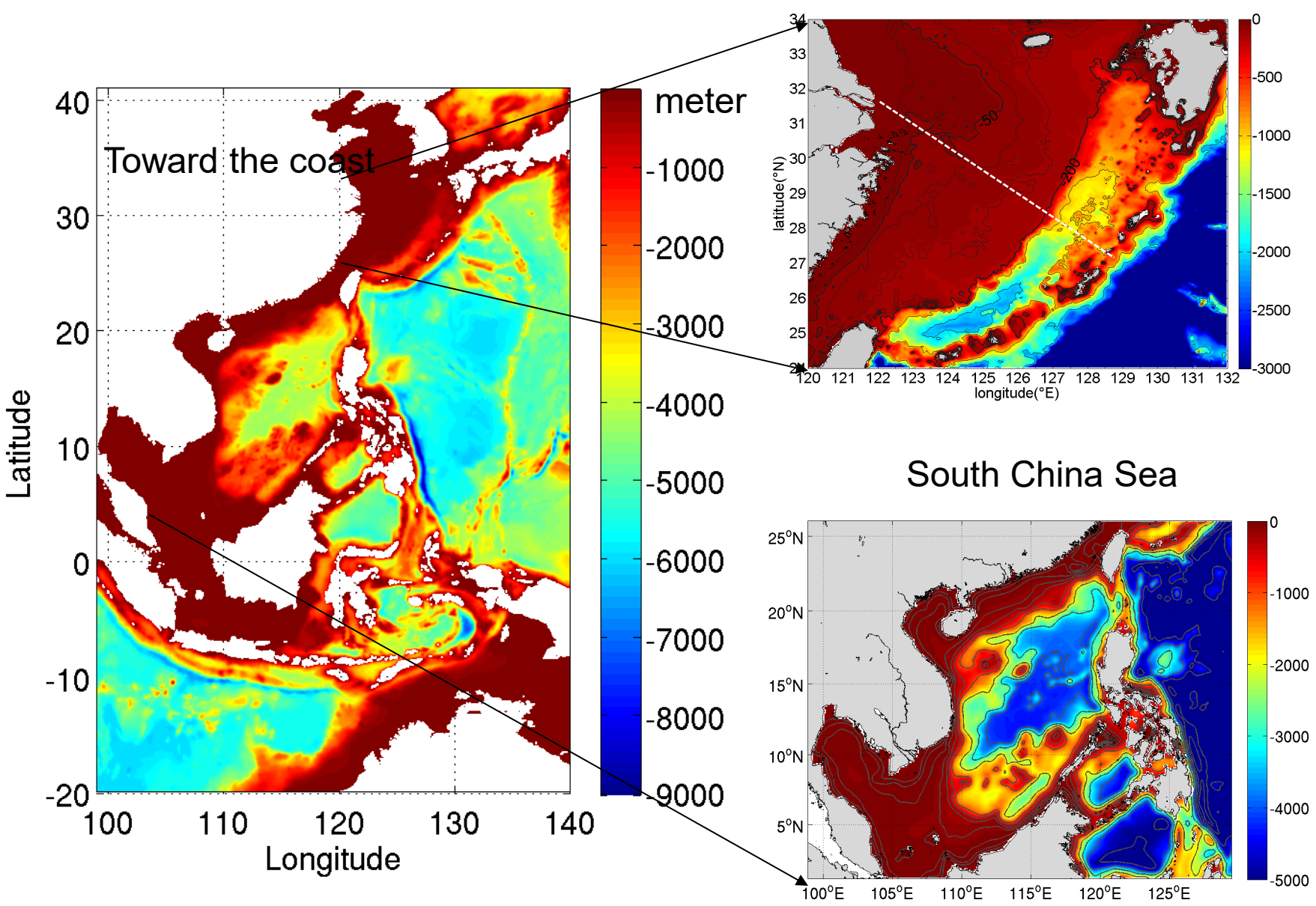
- Connect with Atlantic via Frame Strait and Pacific via Bering Strait;
- Large amount of freshwater discharge from several rivers;
- Continental shelves make use almost half of the Arctic Ocean;
- 80% percent of ice cover in summer and 90% in winter.

# 1.4: Features of ocean in regional ocean, continental shelf, coastal ocean and estuary

# From land, sea to ocean



# Bathymetry in Western Pacific and China Seas



# Definitions of regional ocean

- Shelf sea
- Coastal ocean
- Shelf break, shelf slope
- Estuary
- Coastal zone
- Marginal sea
- Mediterranean Sea

## Shelf Sea:

- A sea area between a continental shelf break with a water depth of about 200 m and the land shore.
- About 70% of global fish resources spend part of their life cycle in the coastal seas.
- Accounts for 90% of marine biomass yield
- Great influence of freshwater and nutrients from the land
- Chemical reactions occur there rapidly between substances from the land as they encounter substances from the ocean
- Boundary layer of kinetic energy exchange with open ocean

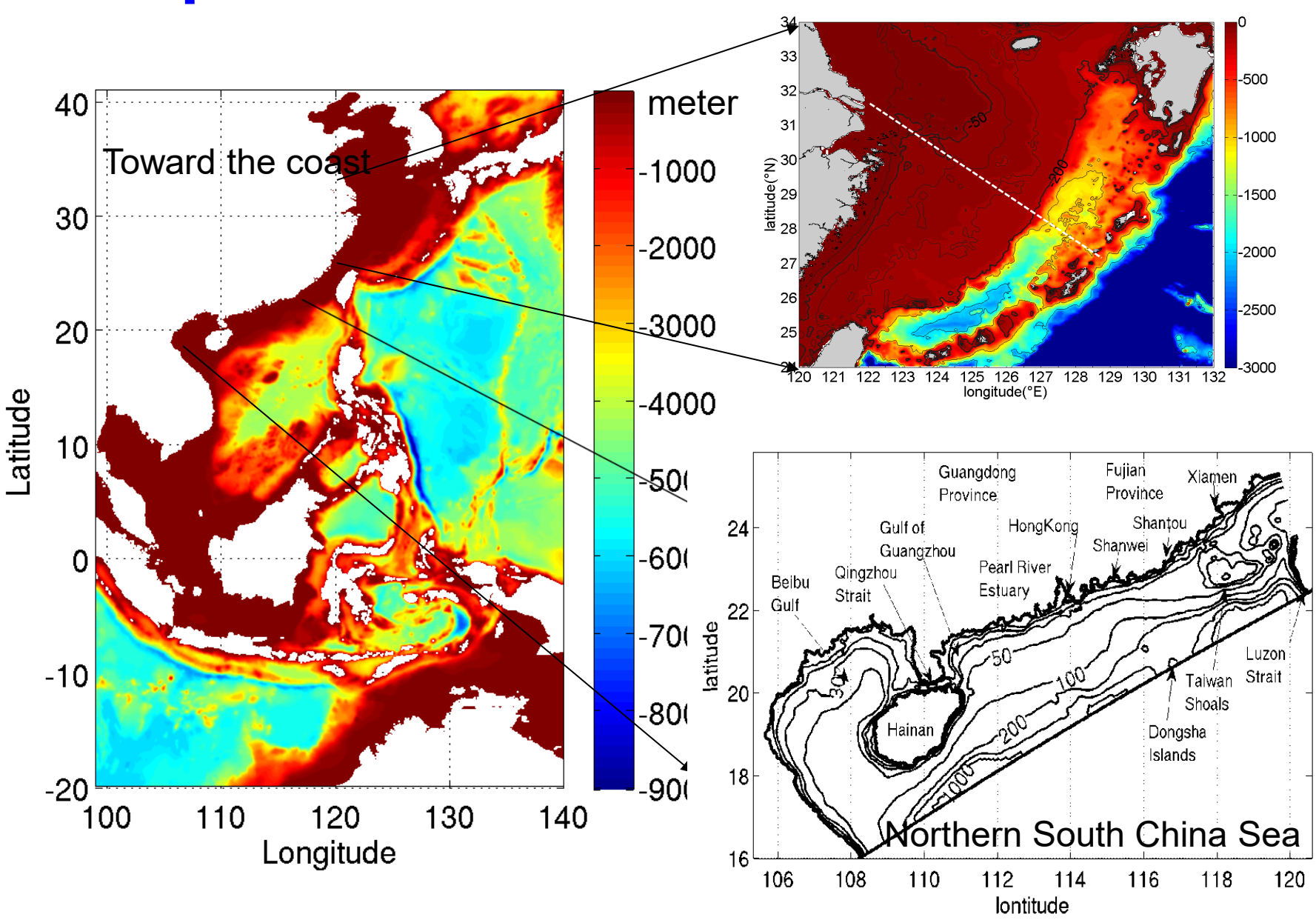
## Coastal Ocean

Coastal ocean as those shelf sea regions that display the dynamics of the deep ocean, modified by shallow water depth and the presence of the coast.

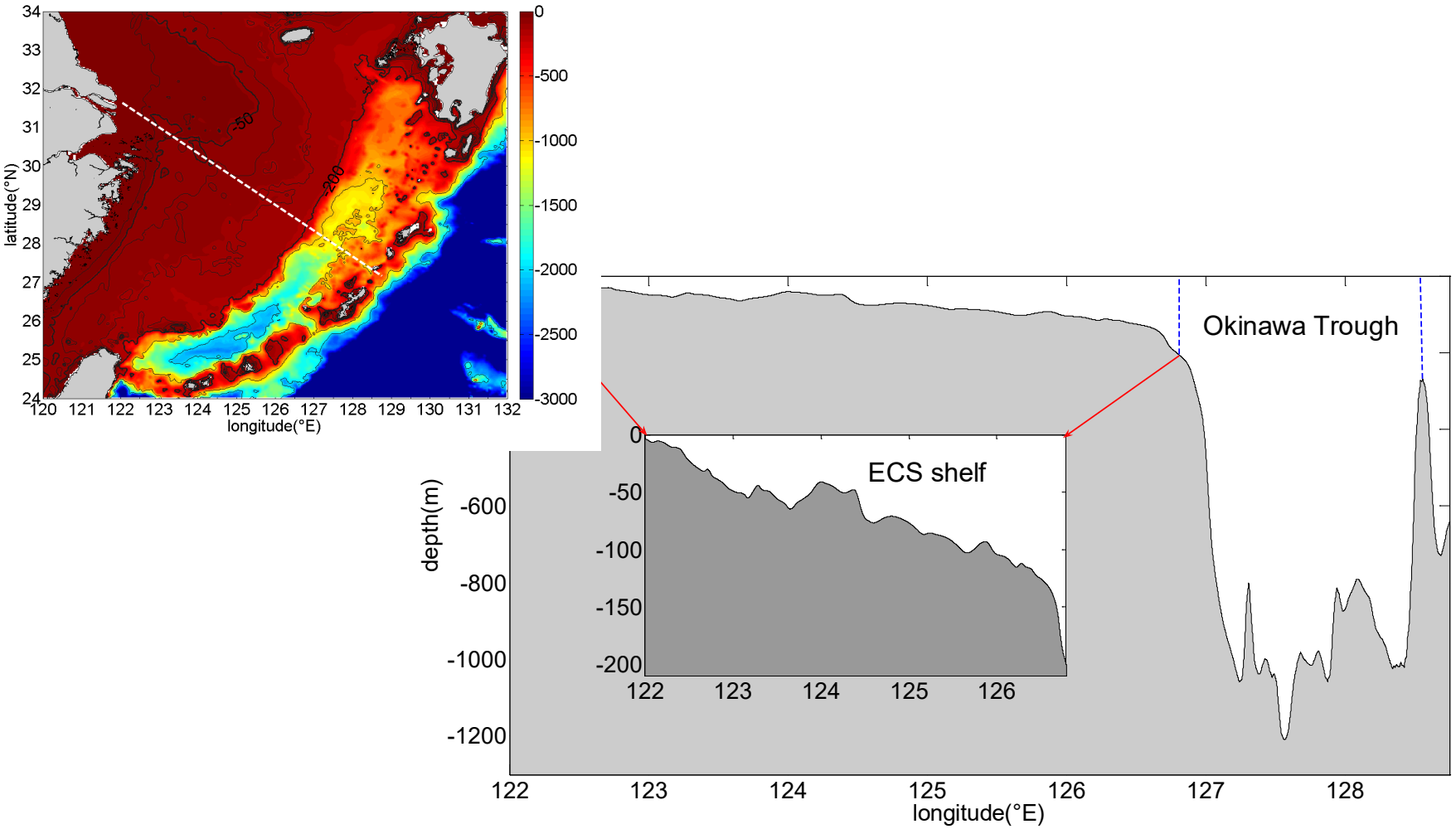
## Shelf Break

The location where the continental shelf joins the flanks of the continents near the 200 m depth

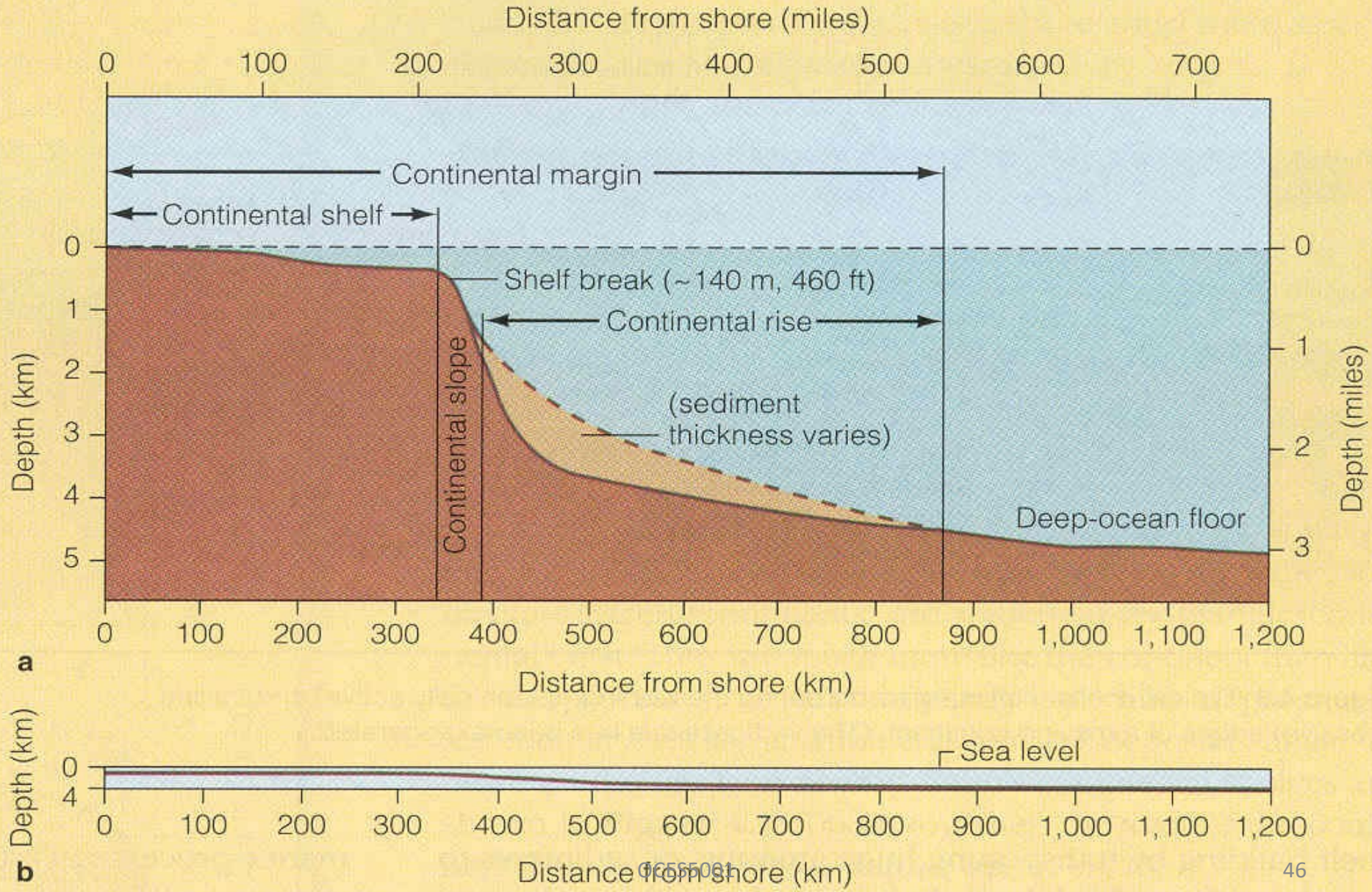
# Examples of Shelf Seas



# Cross-shelf topography in East China Sea

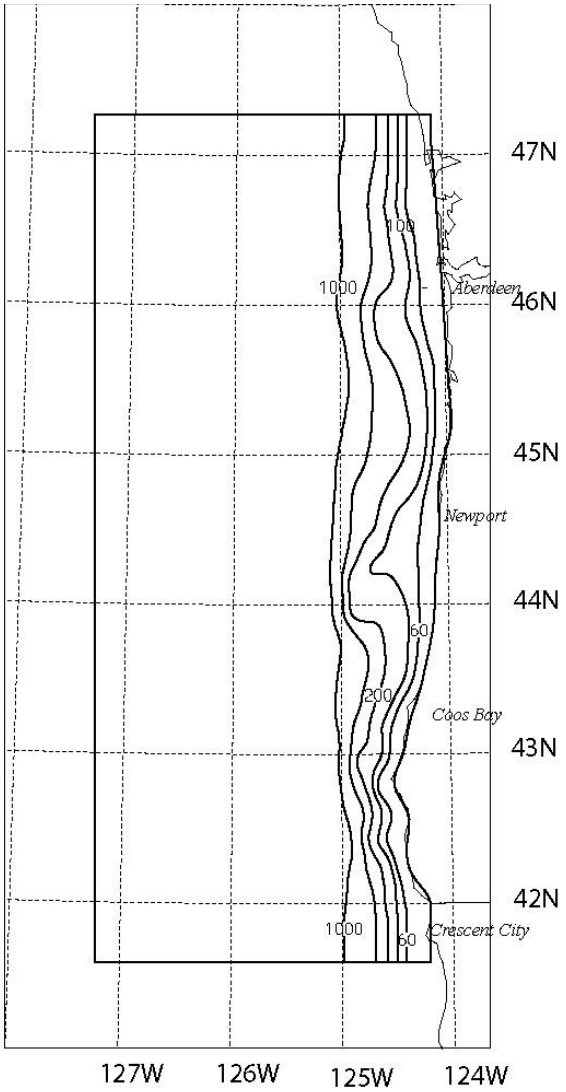


# Components of the Continental Margin (Garrison)

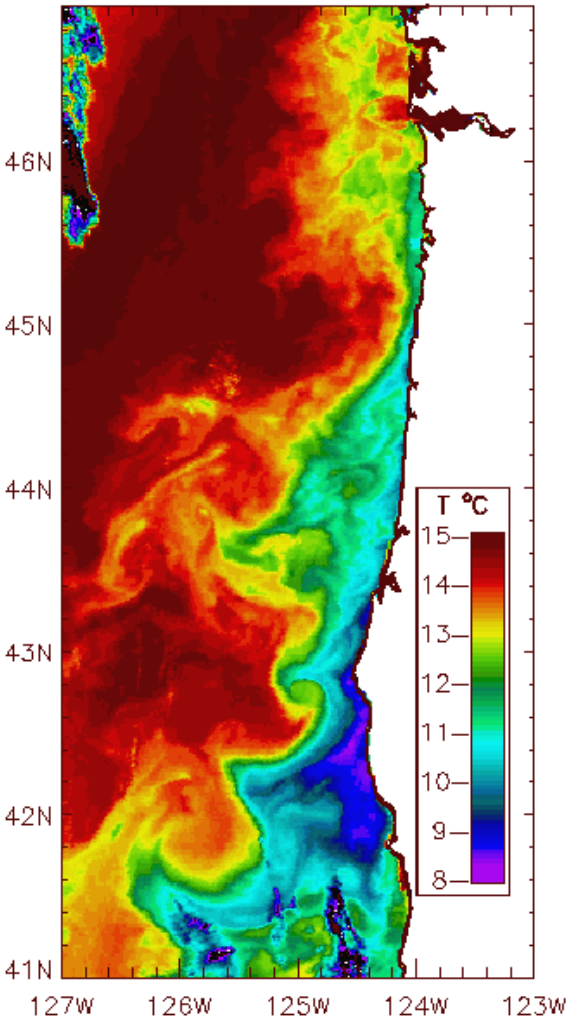


# Effect of topography on oceanic condition (example: west coast of US)

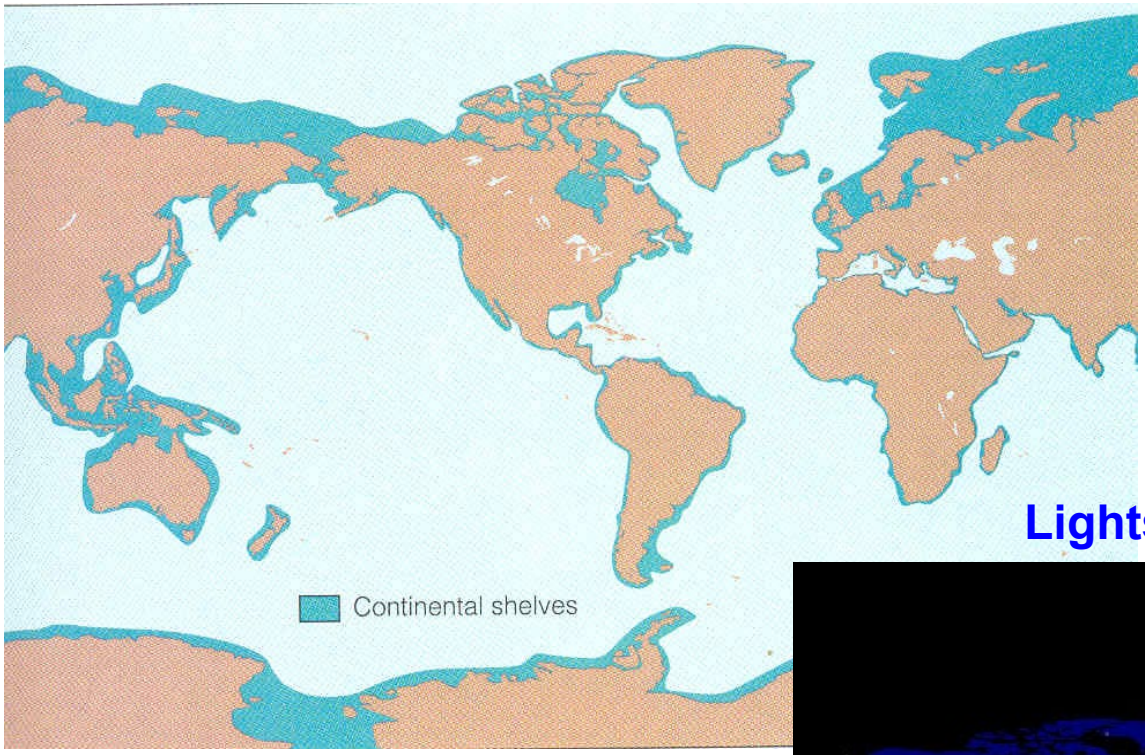
Shelf Sea in US west coast



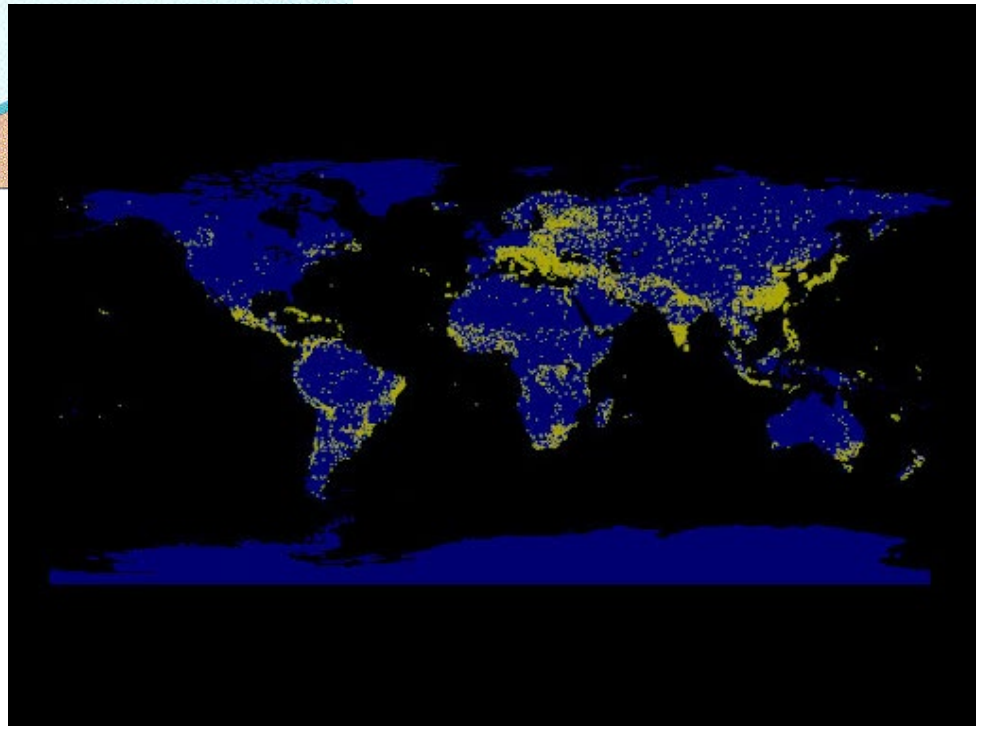

Sea Surface Temperature



# Distribution of Continental Shelves (Garrison)



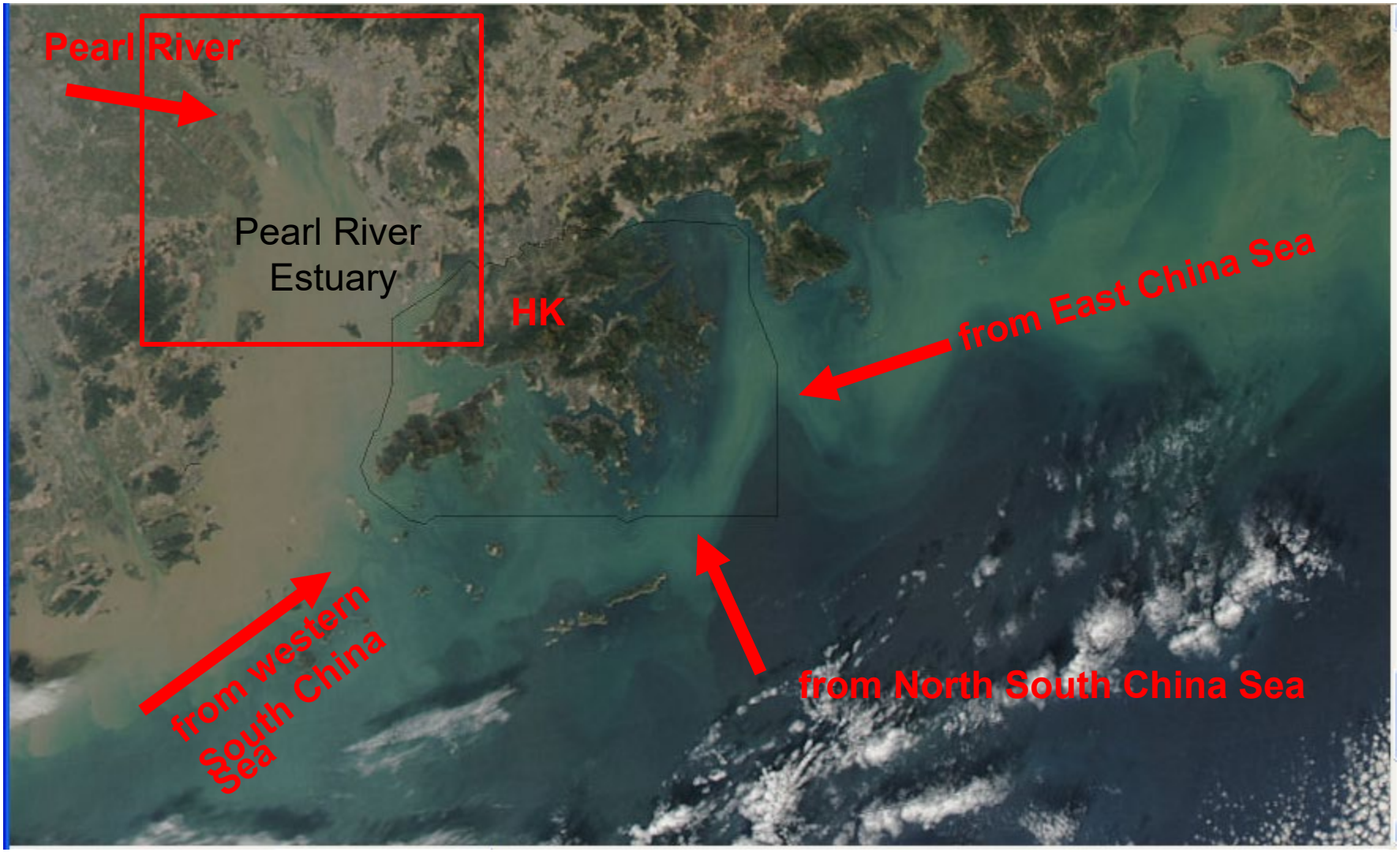

## Lights over the world



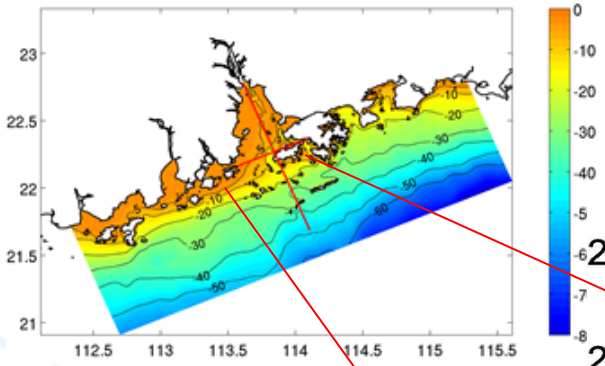
## Estuary:

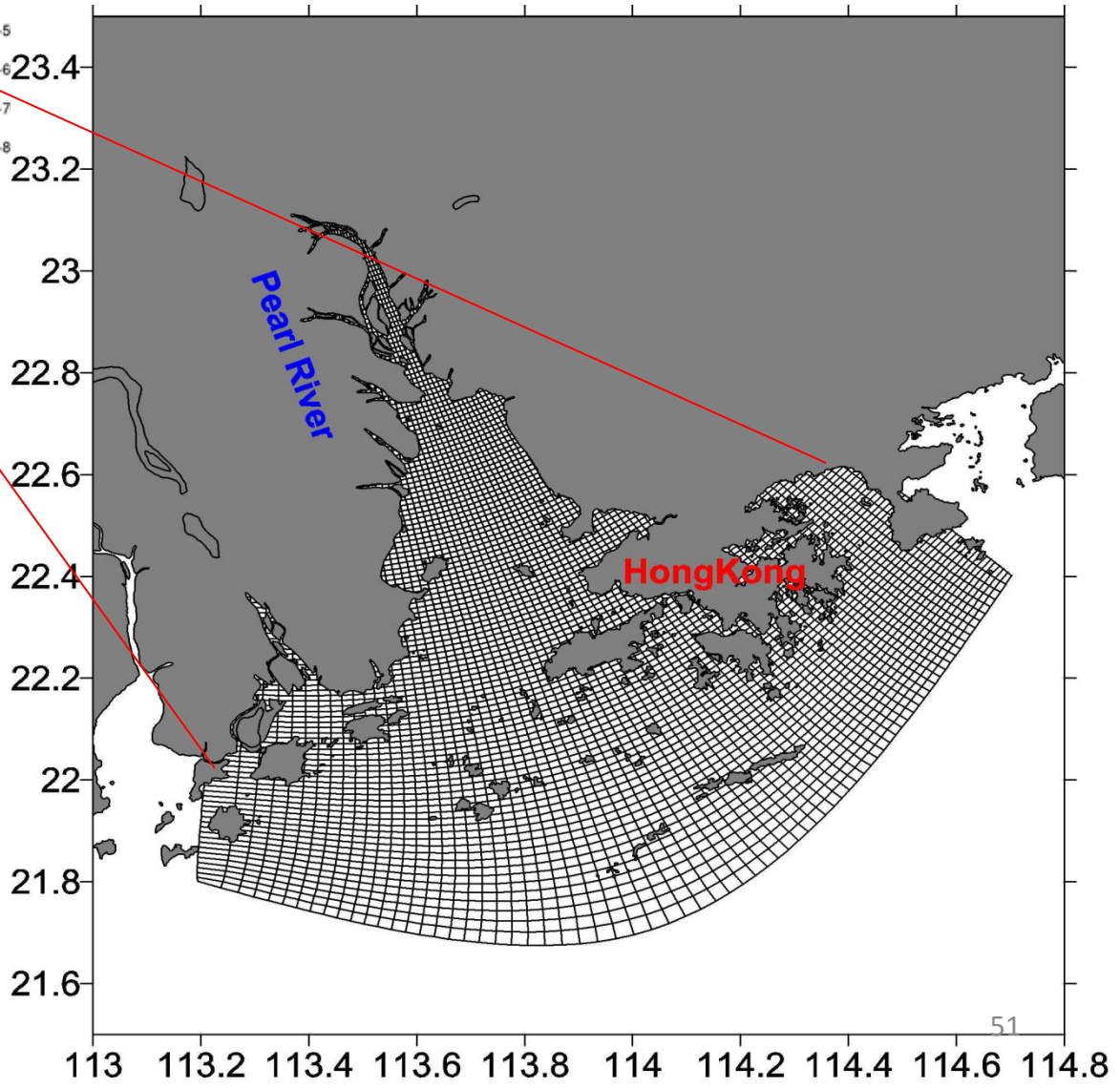
- A semi-enclosed coastal body of water which has a free connection with the open sea and within which seas water is measurably diluted with fresh water derived from land drainage
- The place where land and sea meet.
- Water movement is controlled primarily by thermohaline forcing
- Freshwater from land sends salt water upstream far beyond the river mouth
- Vigorous mixing

# The Greater Bay Ocean

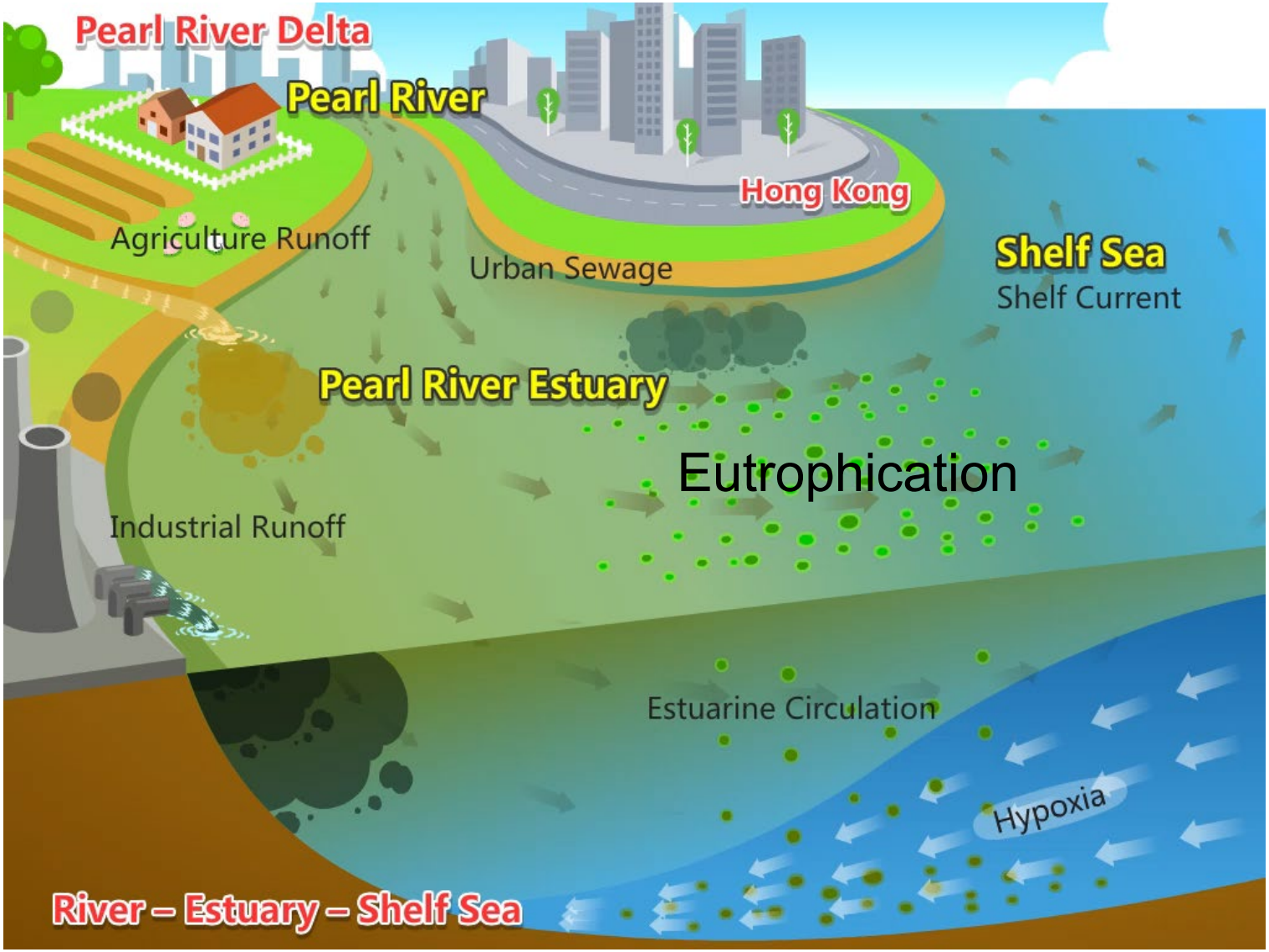


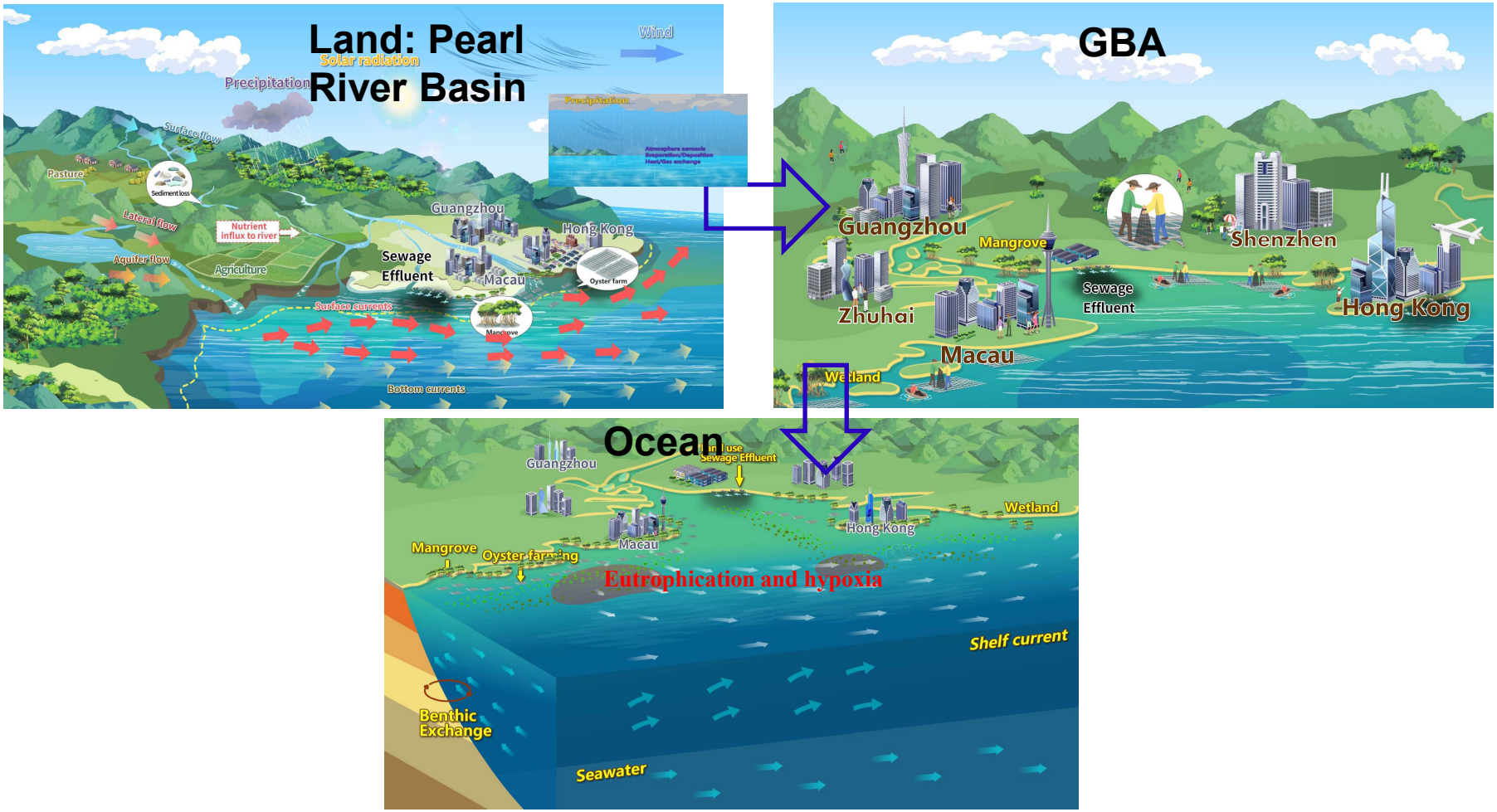
# Pearl River Estuary



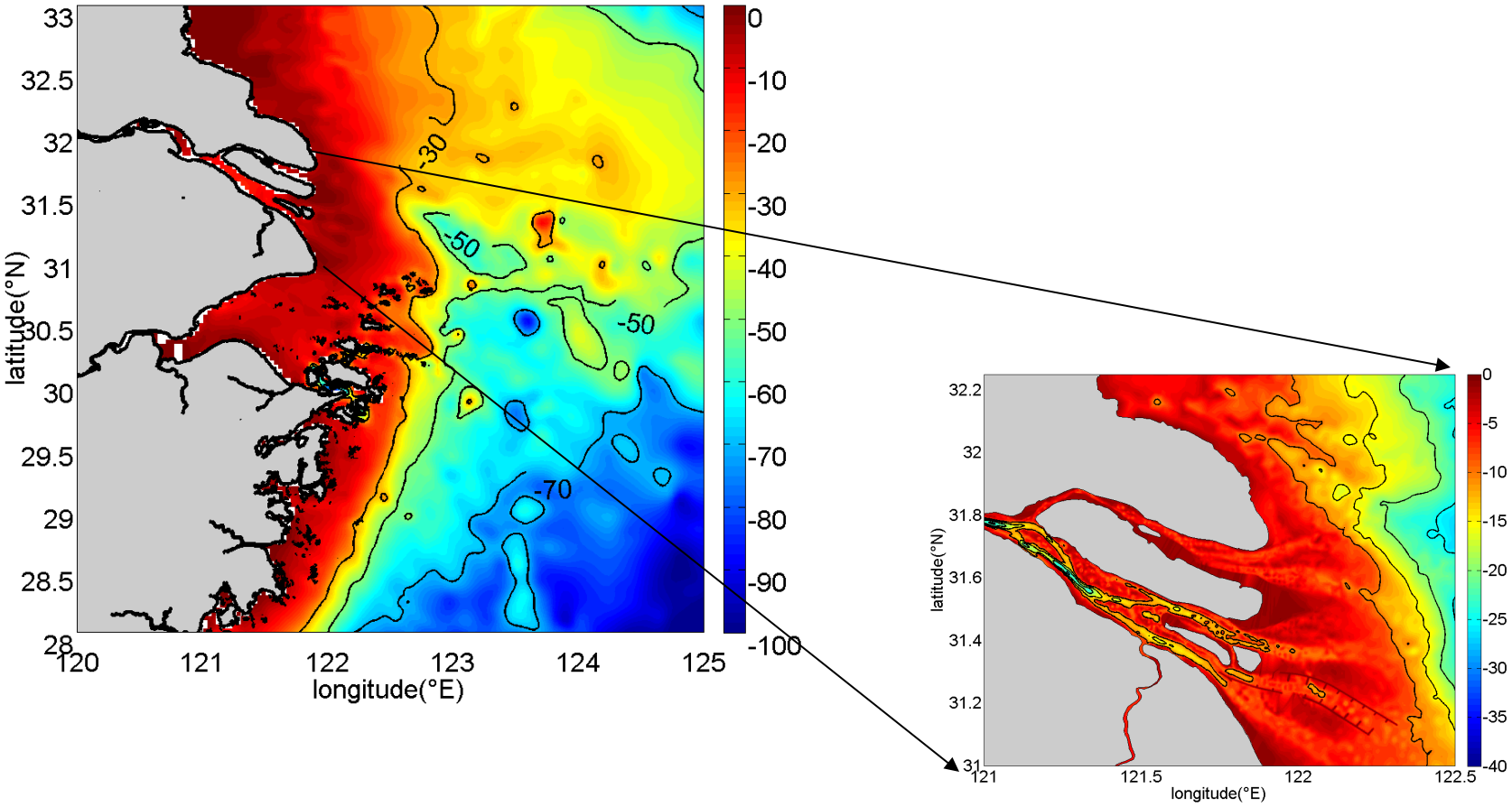



# The River, Estuary and Shelf Coupled system around Hong Kong




Land: Pearl River Basin
Solar radiation
Precipitation
Wind
Surface flow
Pasture
Sediment loss
Lateral flow
Nutrient influx to river
Aquifer flow
Agriculture
Guangzhou
Hong Kong
Sewage Effluent
Macau
Oyster farm
Mangrove
Surface currents
Bottom currents
Precipitation
Atmosphere aerosols
Evaporation/Deposition
Heat/Gas exchange
GBA
Guangzhou
Mangrove
Shenzhen
Sewage Effluent
Zhuhai
Hong Kong
Macau
Wetland
Ocean
Guangzhou
Land use
Sewage Effluent
Wetland
Hong Kong
Macau
Mangrove
Oyster farming
Eutrophication and hypoxia
Shelf current
Benthic Exchange
Seawater

# Changjiang Estuary and adjacent shelf



## Coastal Zone:

- Shallowest part of the shelf sea (immediate vicinity of the coastline). It is the interface between the land and water
- Strong sediment movement
- Strong effect from bottom friction, boundary layer dynamics
- Wave breaking


From; James F. Tait

# Marginal (Adjacent) Sea:

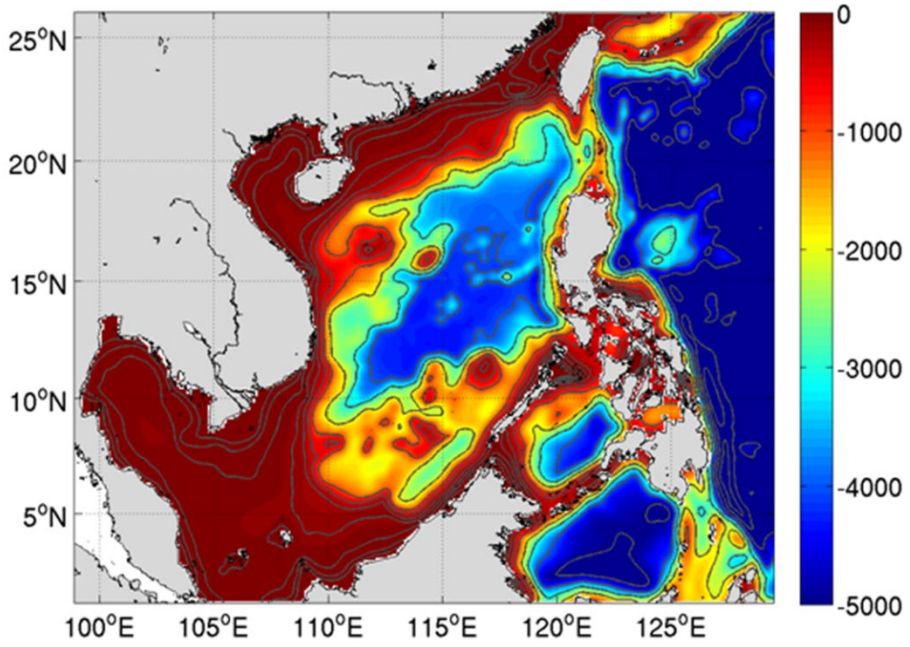
A part of the ocean that is separated from the major ocean basins by topographic features; It is a large ocean depression that occurs near continents.

Three types:

- Basin surrounded by island arcs
- South China Sea; Bering Sea

- Long, narrow marginal sea such as Red Sea and Gulf of California

- Marginal sea lied between two continents: Mediterranean Sea, Gulf of Mexico and Caribbean Sea



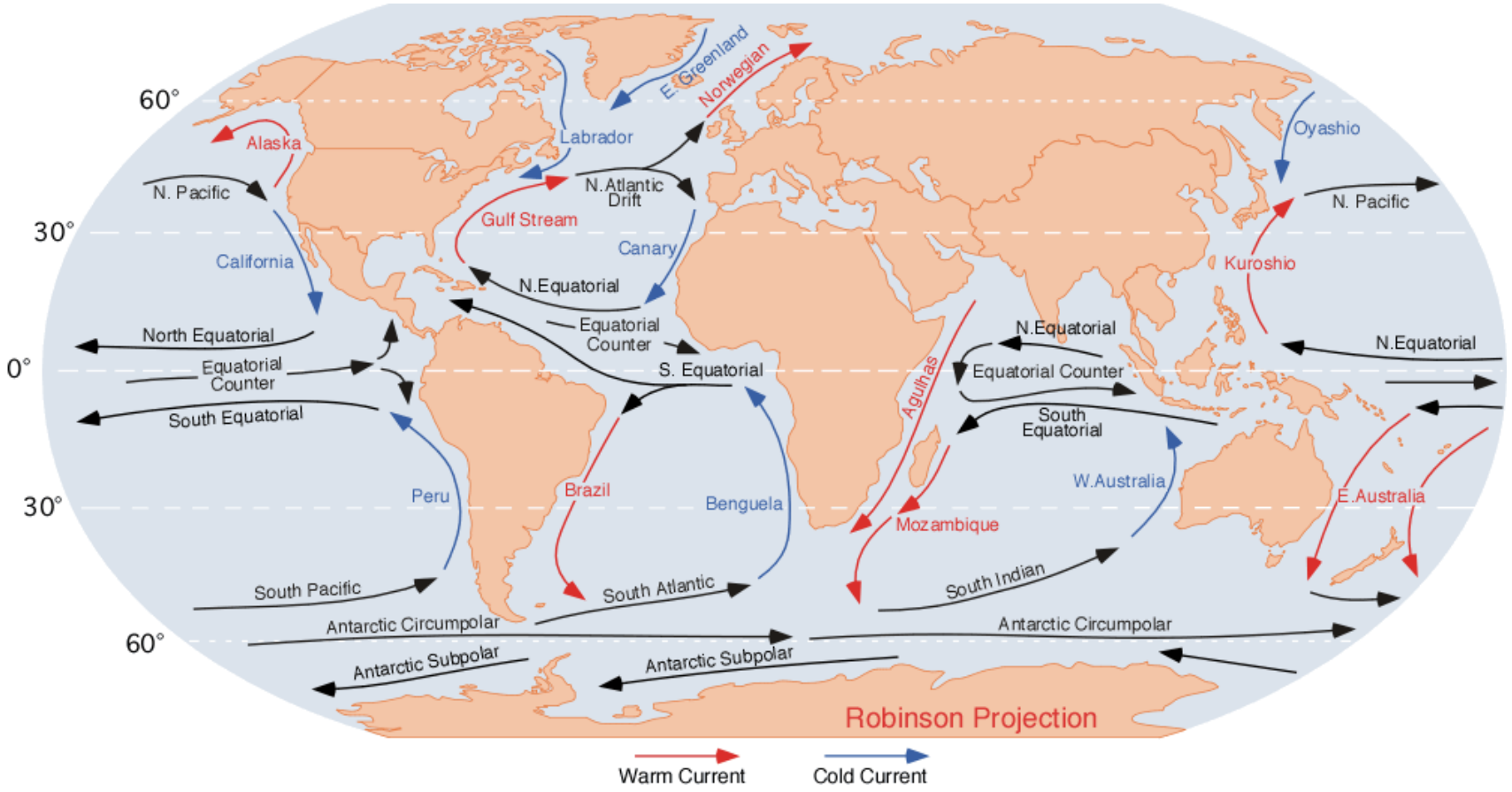
- 1.5 Inter-disciplinary and multi-scale oceanography

# Physical Oceanography

- Study physical properties and processes that control the ocean motion, e.g. ocean currents, waves, and geophysical fluid dynamics;

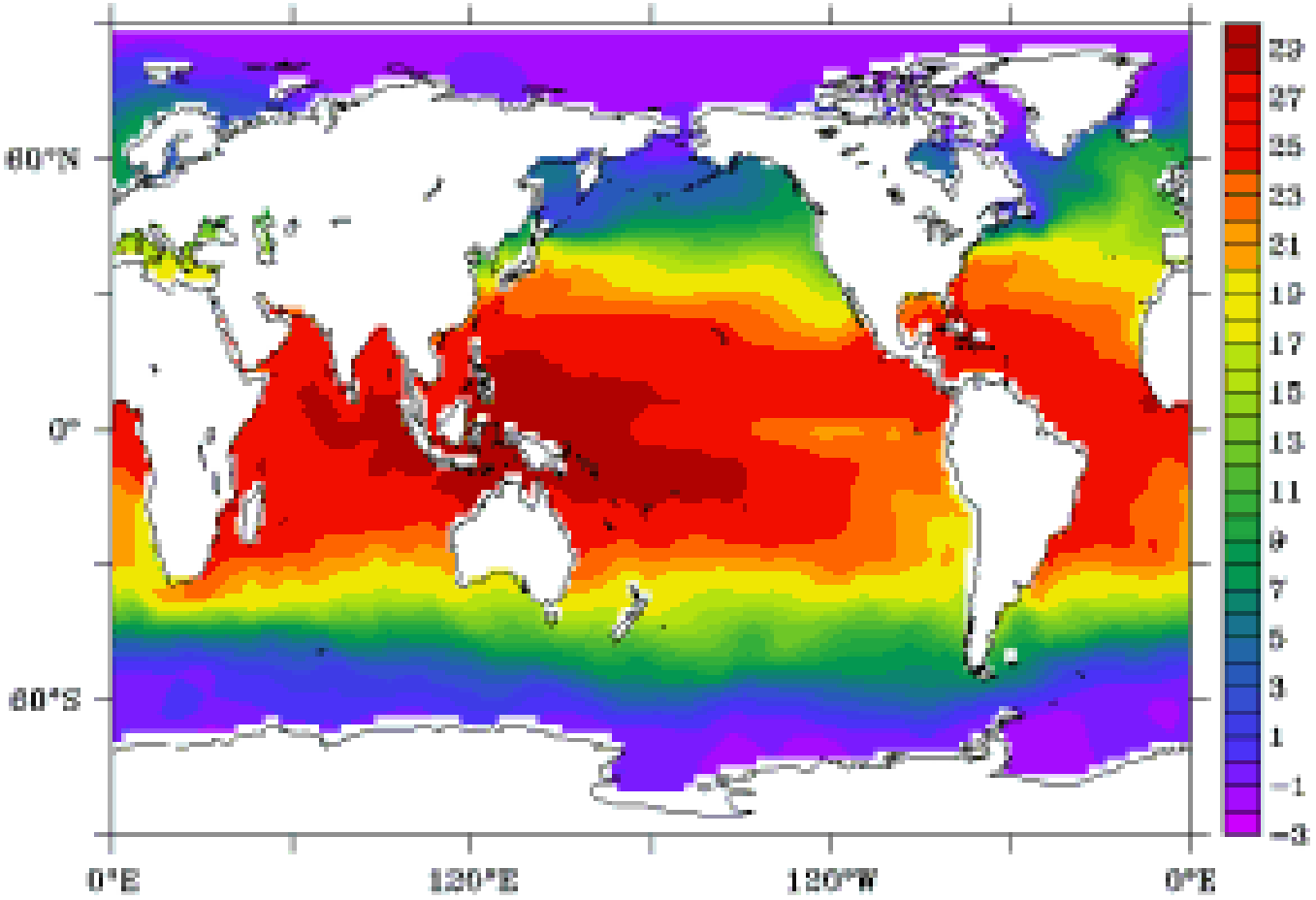
- Investigate the major forcing that transport momentum, heat, material, and biogeochemical substances in the ocean;

# Global Ocean Circulation

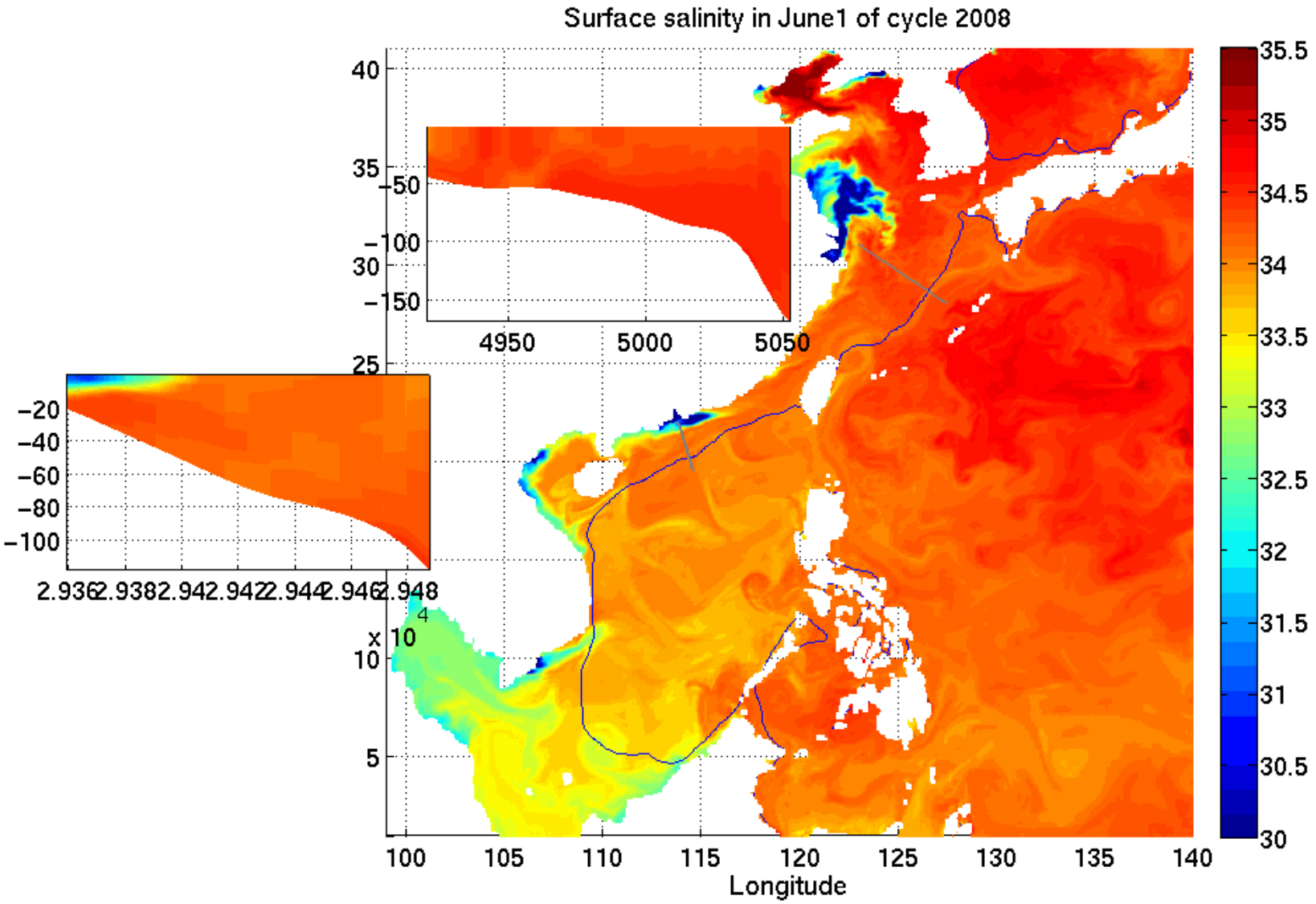


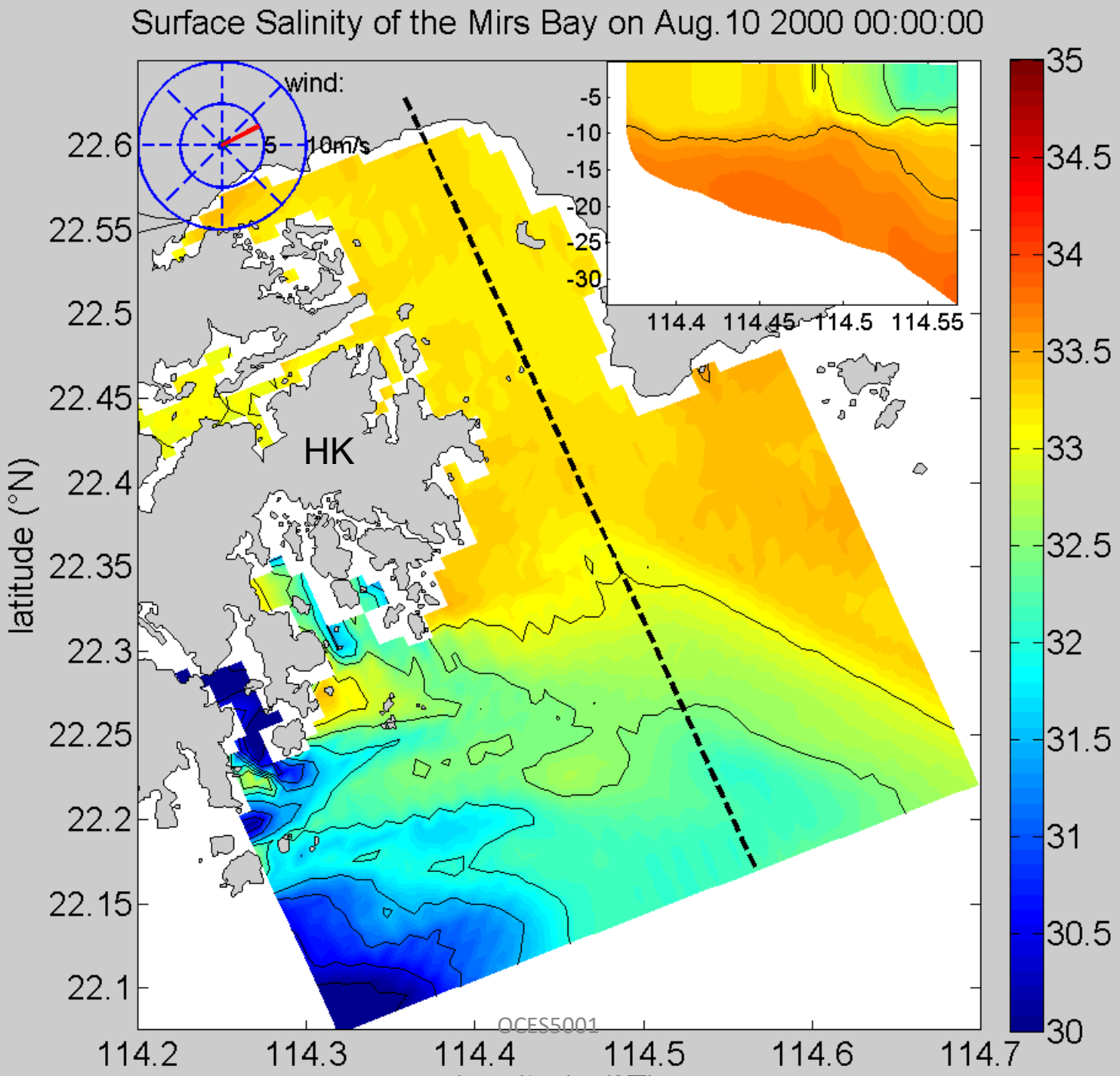

From Wikipedia

# Variability of the western Pacific Warm pool in the Pacific Ocean




Sea surface temperature (SST) showing variability of the western Pacific Warm Pool in the Pacific Ocean. The Warm Pool and the variability greatly control the regional climate.

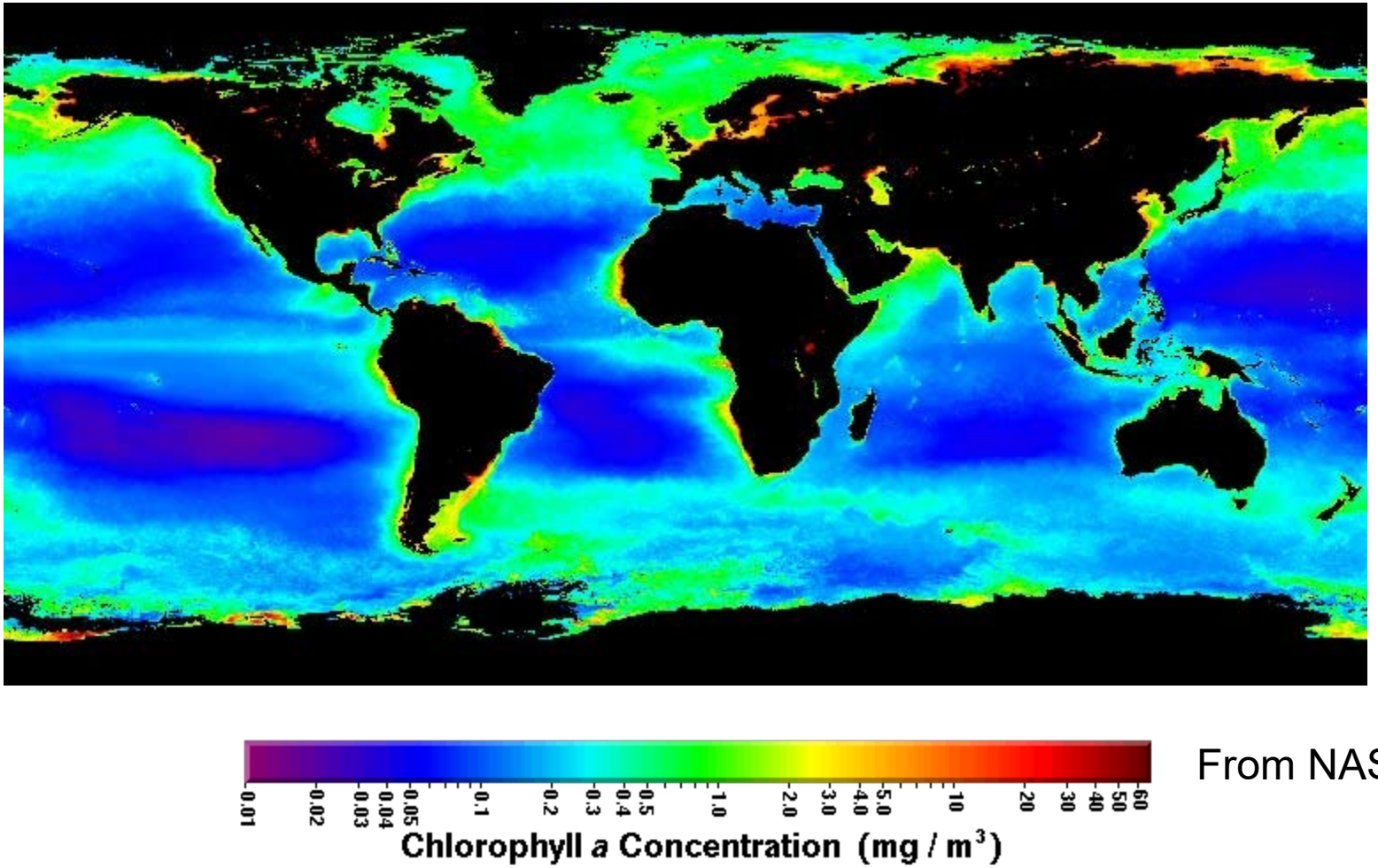

Surface salinity in June1 of cycle 2008
40
35
30
25
5
10
100
105
110
115
120
125
130
135
140
Longitude
35.5
35
34.5
34
33.5
33
32.5
32
31.5
31
30.5
30
4950
5000
5050
−50
−100
−150
−20
−40
−60
−80
−100
2.936
2.938
2.94
2.942
2.944
2.946
2.948
x 10^4


Surface Salinity of the Mirs Bay on Aug.10 2000 00:00:00
wind:
5
10m/s
HK
latitude (°N)
22.6
22.55
22.5
22.45
22.4
22.35
22.3
22.25
22.2
22.15
22.1
114.2
114.3
114.4
114.5
114.6
114.7
-5
-10
-15
-20
-25
-30
114.4
114.45
114.5
114.55
35
34.5
34
33.5
33
32.5
32
31.5
31
30.5
30

## Biological Oceanography

- Concerns the biology and ecology of oceanic, marine, coastal and estuarine organisms.

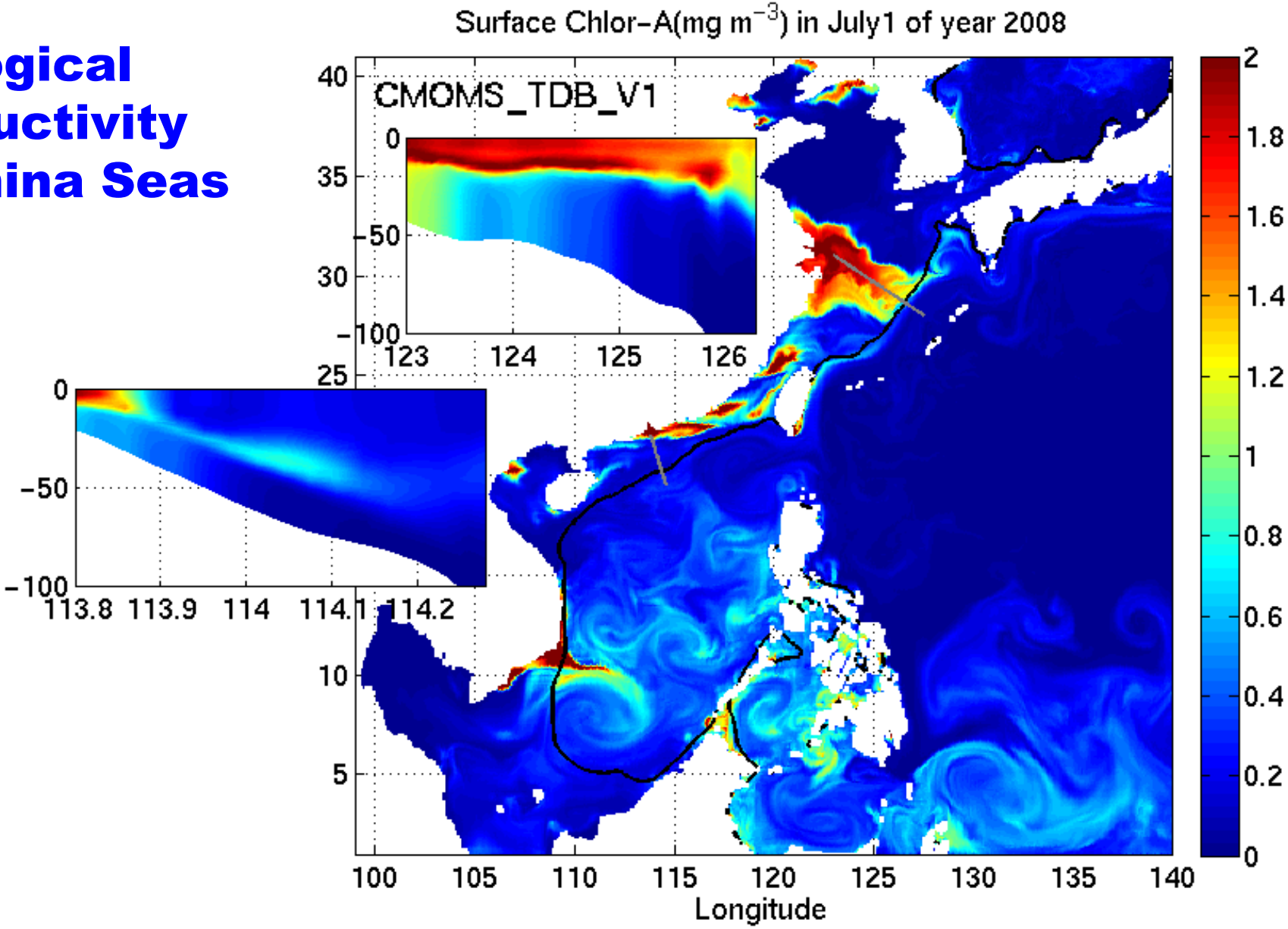
- The organism range from viruses and bacteria to microbes and phytoplankton, from zooplankton and benthic invertebrates to shellfish, fish and marine mammals.

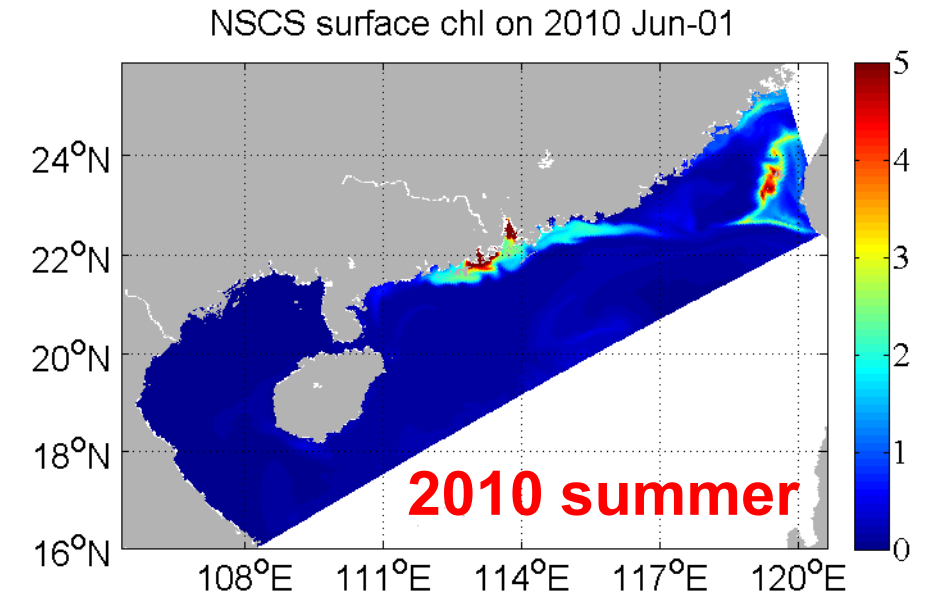


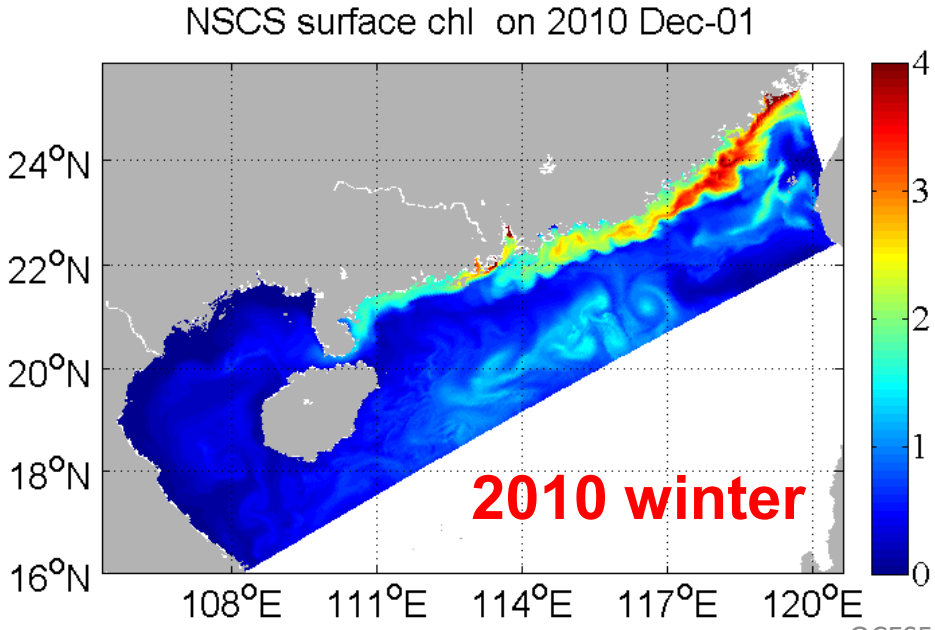

From NASA

**Global distribution of chlorophyll** averaged over the period from 1 January 2002 to 28 February 2005 using data collected from MODIS on the Aqua satellite. Chlorophyll values range from 0.01 mg/m3 (purple) to 60 mg/m3 (red). From NASA Goddard Space Flight Center.

# gical uctivity ina Seas





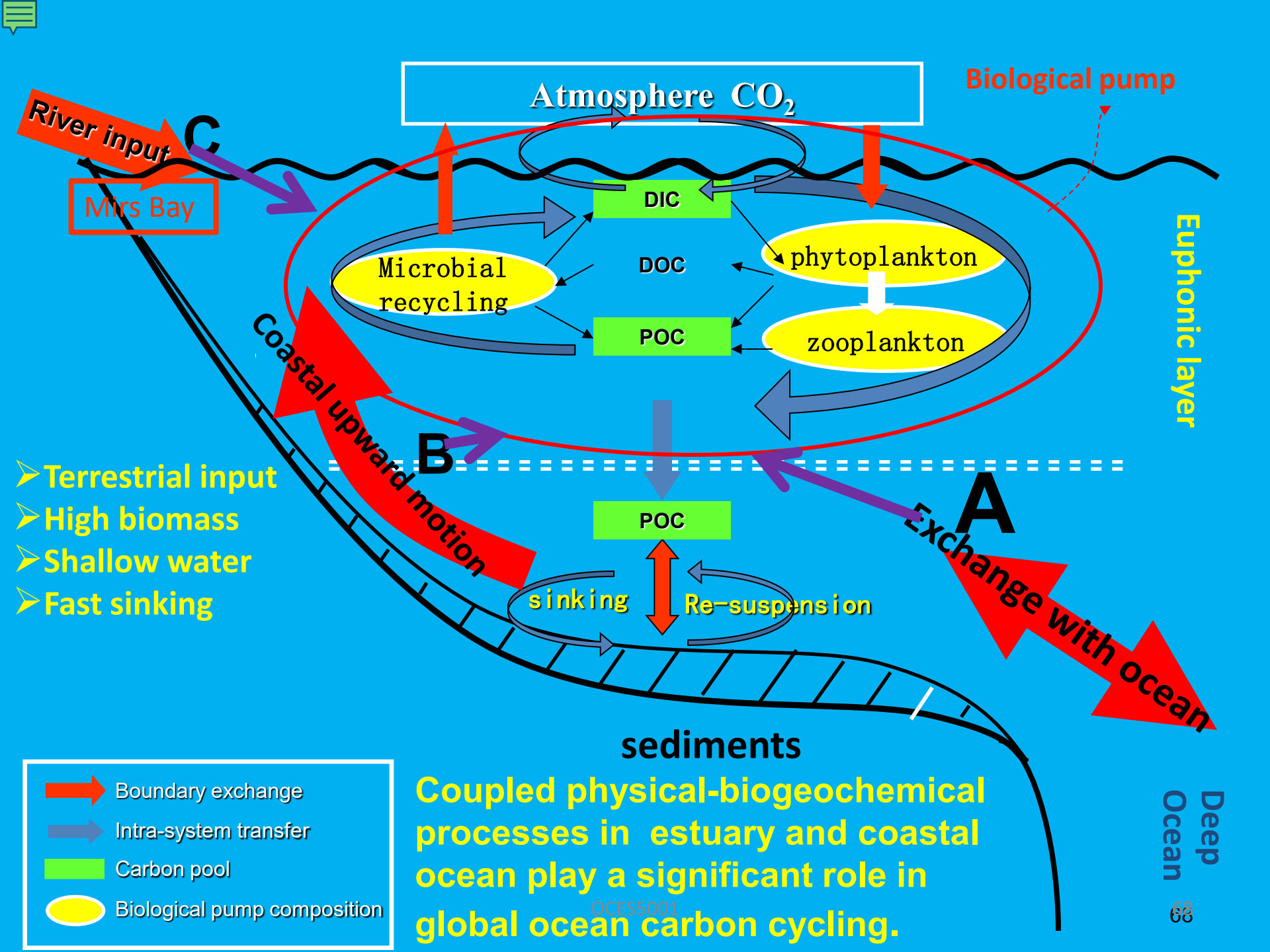




**Biological productivity over continental shelf in the northern South China Seas**

## Chemical oceanography:

- The behavior of the ocean's dissolved solids and gases and their relationships to the geology and biological of the ocean as a whole.

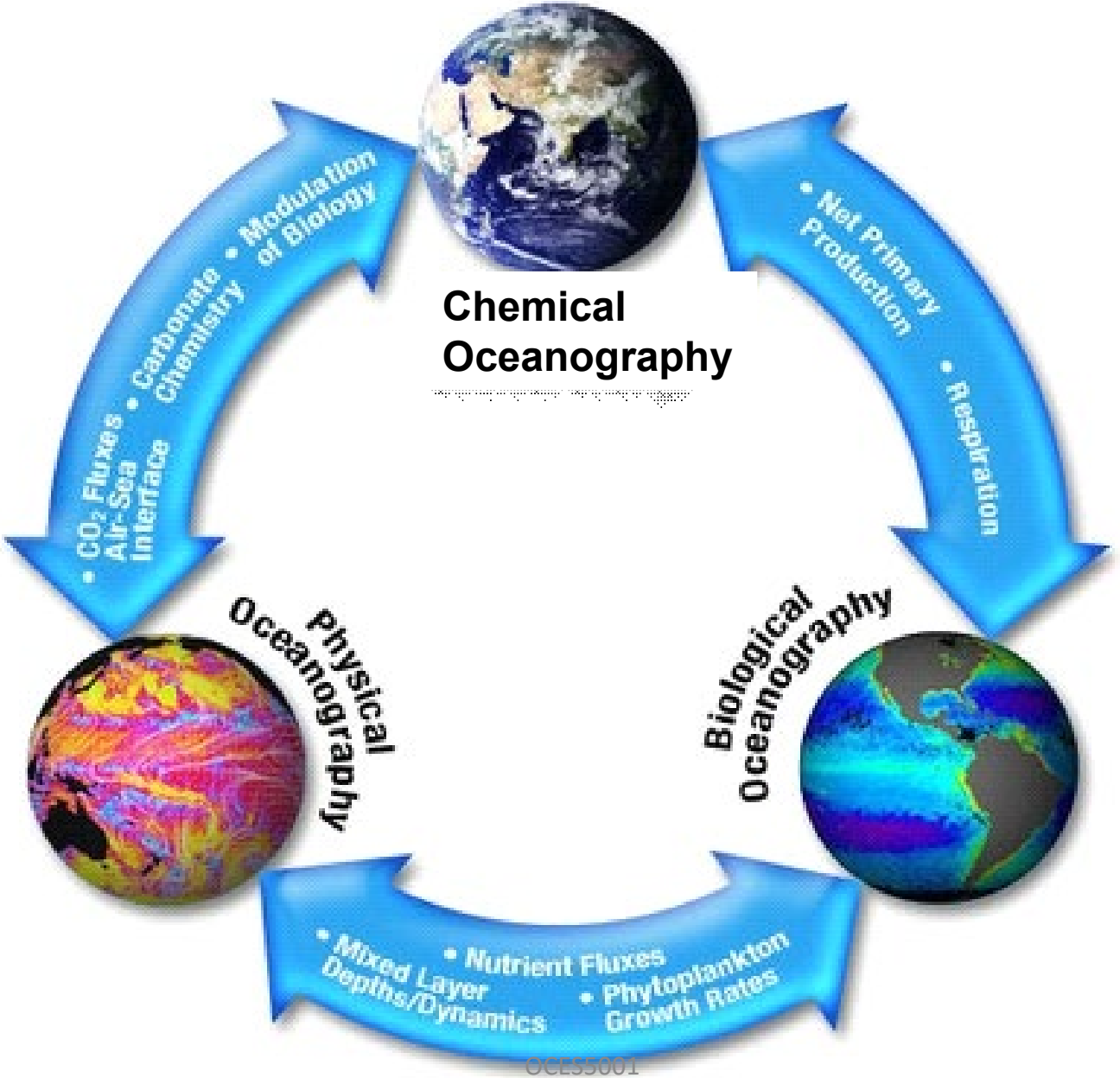
- Cycling of these elements both within the ocean and with the other spheres of the Earth system


Atmosphere $CO_2$
Biological pump
River input
C
Mirs Bay
DIC
DOC
POC
Microbial recycling
phytoplankton
zooplankton
Euphonic layer
Coastal upward motion
B
A
Exchange with ocean
POC
sinking
Re-suspension
sediments
Terrestrial input
High biomass
Shallow water
Fast sinking
Boundary exchange
Intra-system transfer
Carbon pool
Biological pump composition
Coupled physical-biogeochemical processes in estuary and coastal ocean play a significant role in global ocean carbon cycling.
Deep Ocean

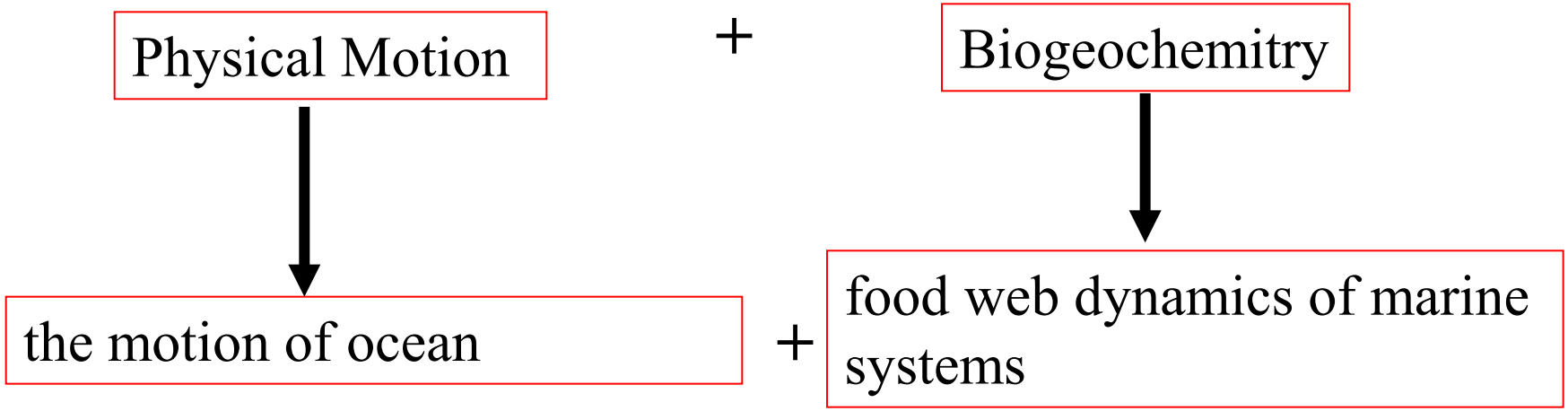
## Geological Oceanography:

Study the composition of inner Earth, the mobility of the crust, topography, structure and geological processes of the ocean floor.

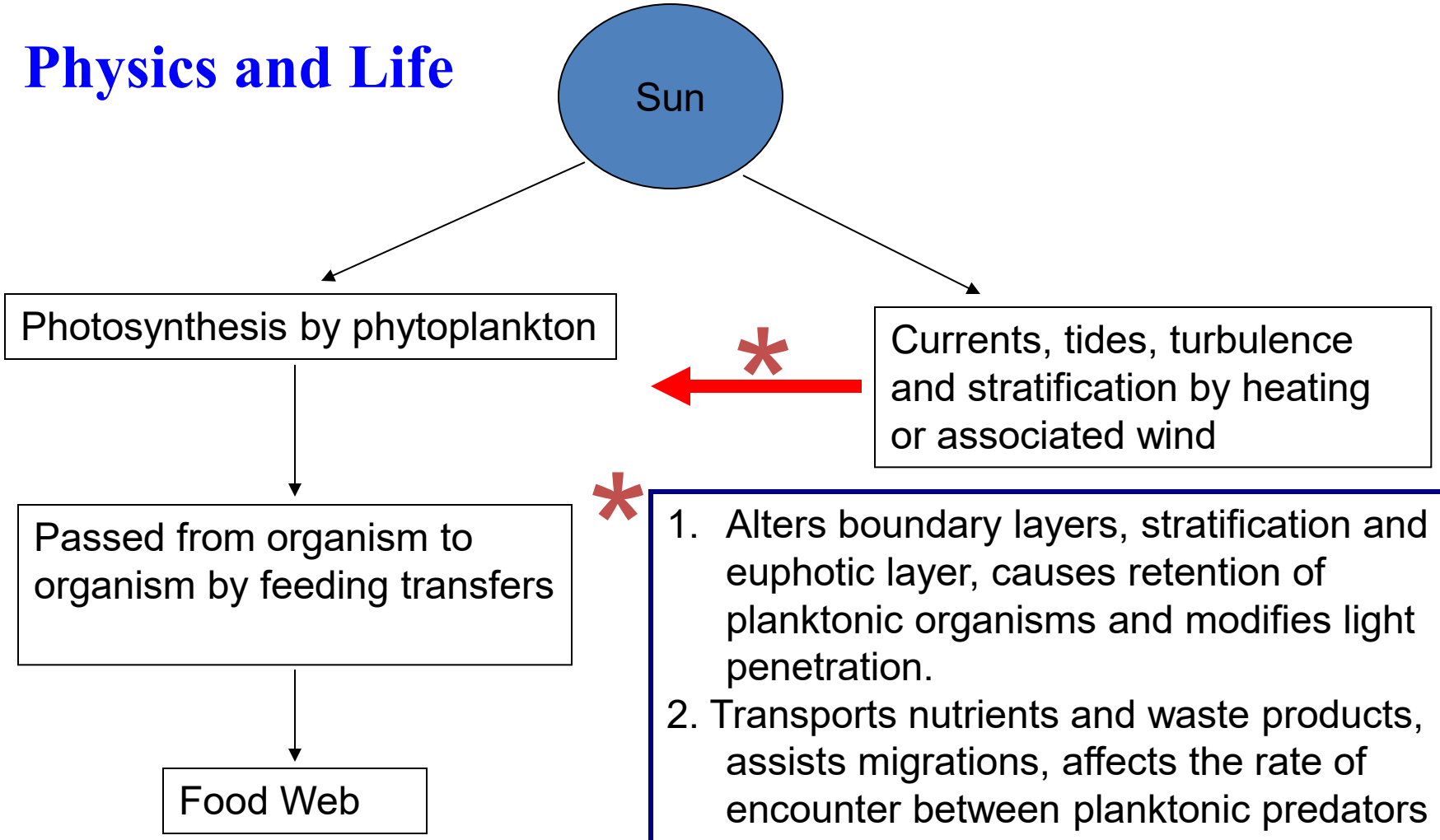
# Interdisciplinary Oceanography

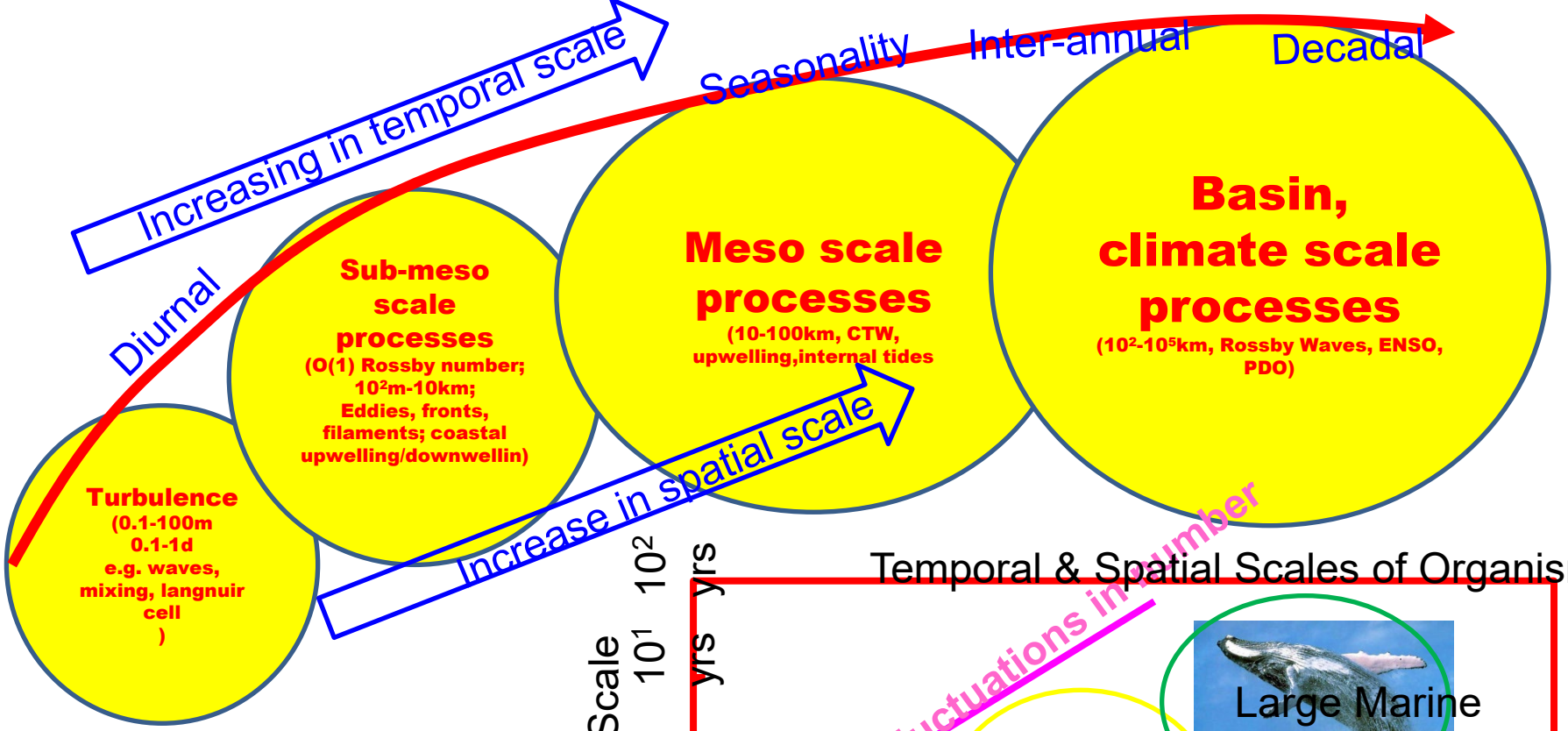


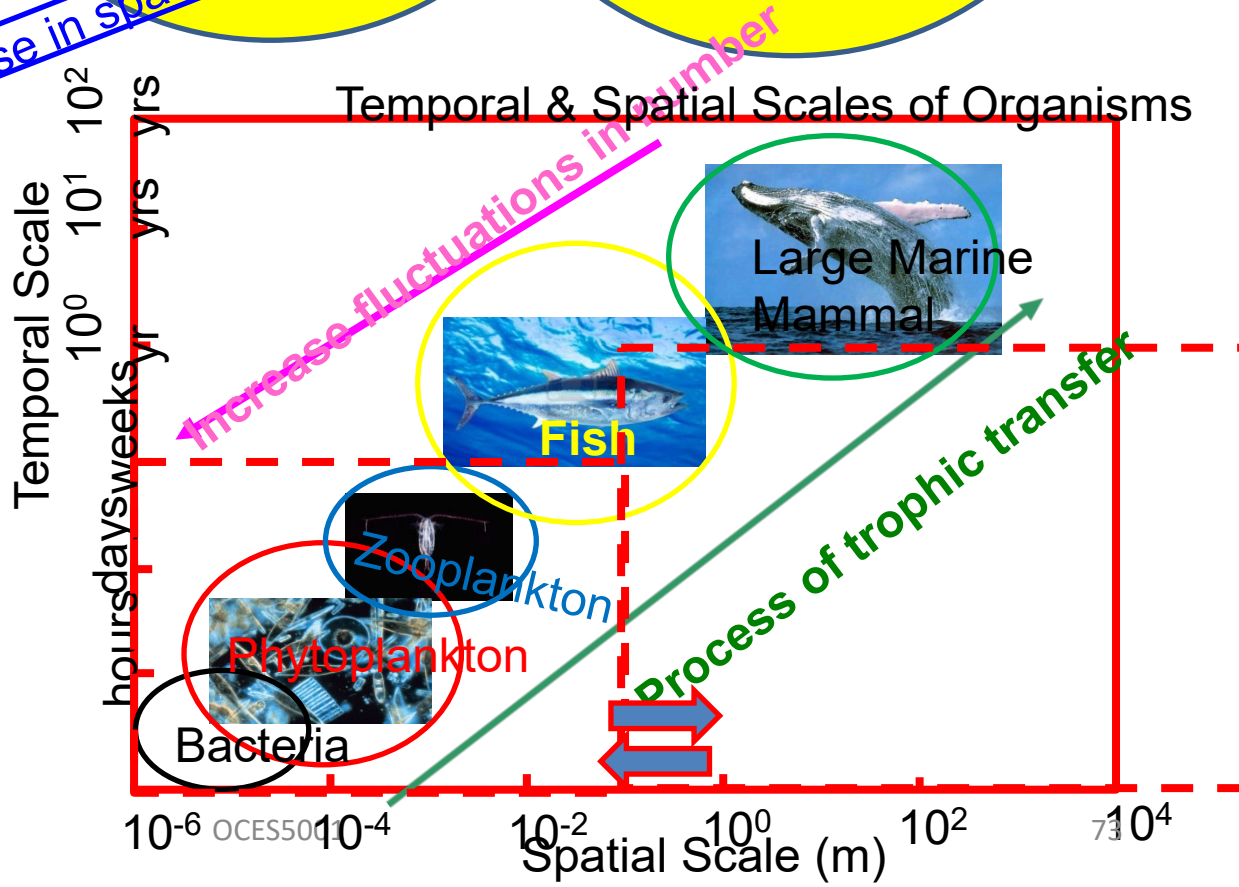
# Ecosystem: Coupled Physical-Biogeochemical Oceanography
# The Oceanography for the 21st Century



# Physics and Life





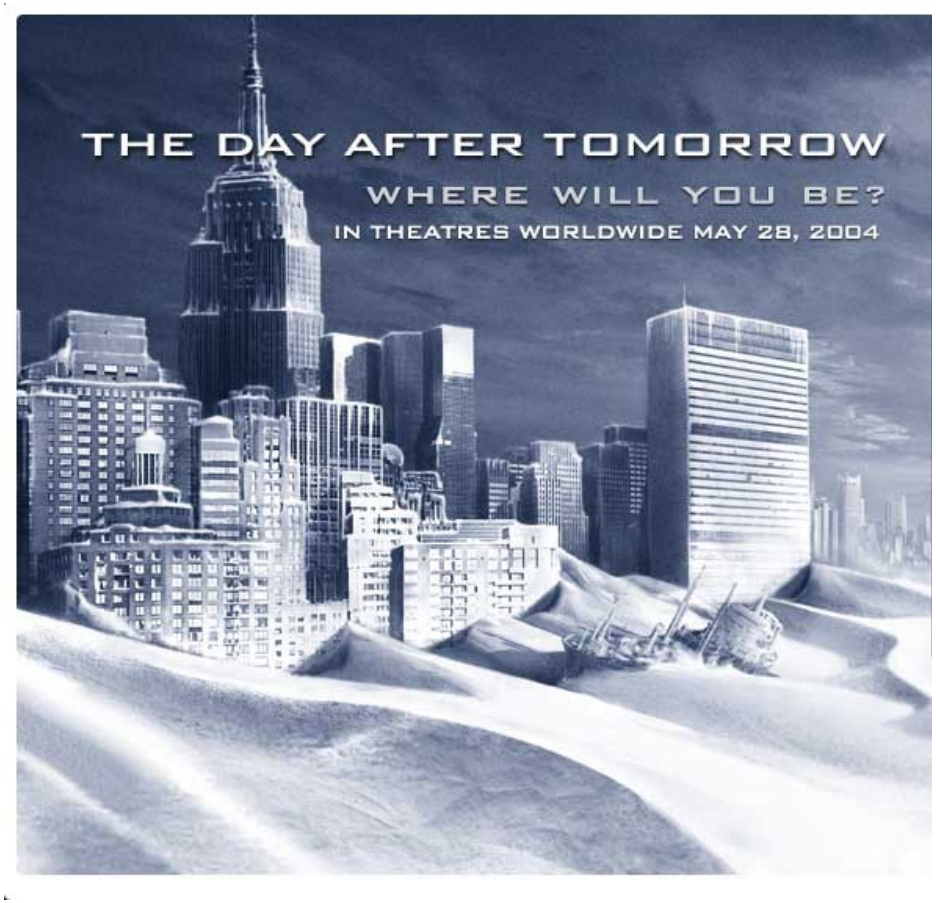




**Multi-scale (in space and time), multi-discipline**

# Importance of ocean study:

1. Almost 2/3 of earth surface is covered b the ocean;
2. It is the major engine that drives climate change
3. Fisheries and sustainable resources
4. Coastal environment and pollution
5. Coastal engineering, coastal erosion
6. Navigation
7. Defense and political issues
8. ….

# Climate scenario of The Day after Tomorrow



# Headline News in August, 2021

*A critical ocean system may be heading for collapse due to climate change, study finds 'The consequences of a collapse would likely be far-reaching'*
***The Washington Post***

*Atlantic Ocean circulation is the weakest in at least 1,600 years, study finds – here's what that means for the climate*
***CBS***

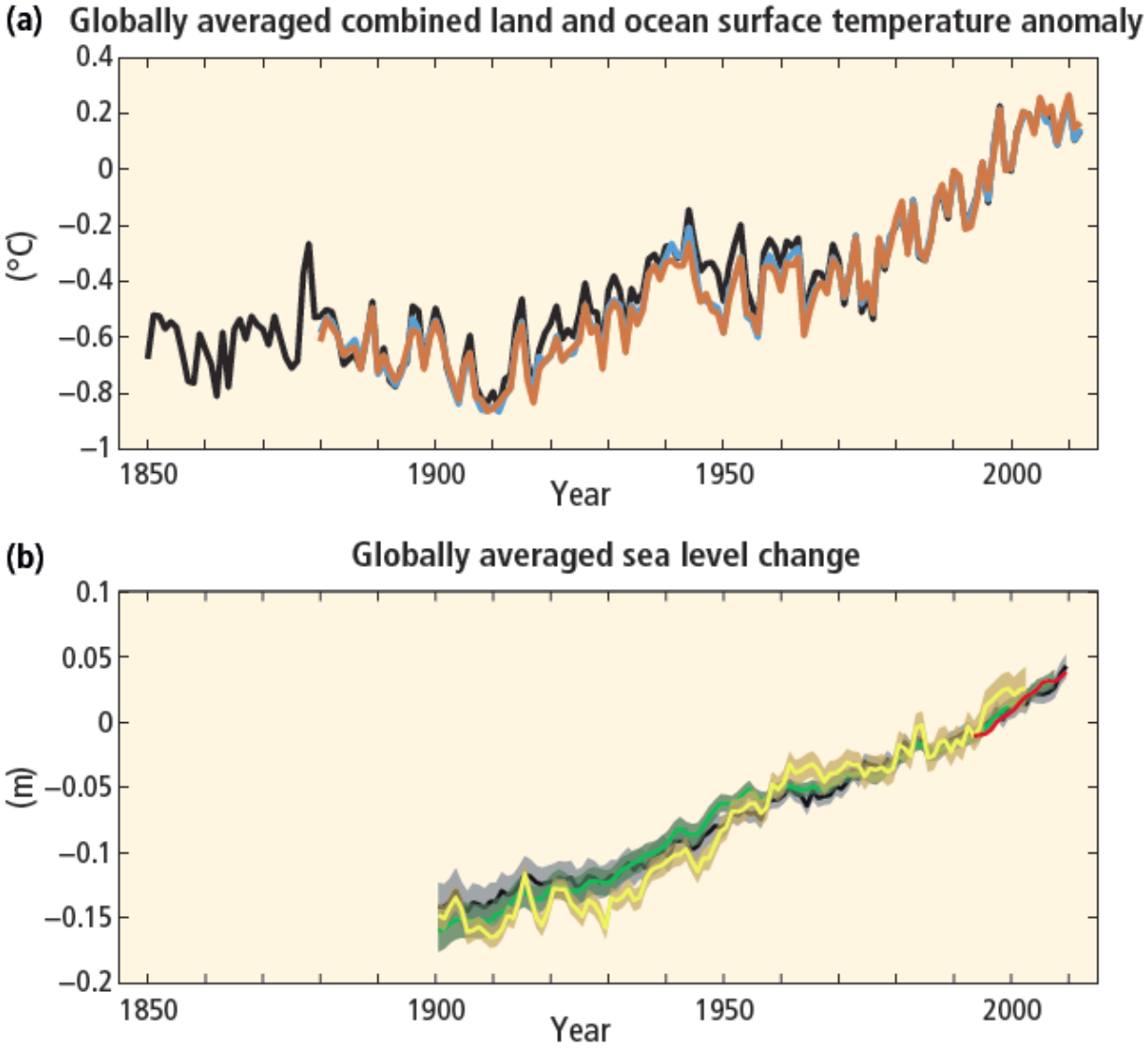
*Climate crisis: Scientists spot warning signs of Gulf Stream collapse: A shutdown would have devastating global impacts and must not be allowed to happen, researchers say*
***Gradian***

*Major Atlantic Current May Be On The Verge Of Collapse, Scientists Warn*
***Forbes***

*Slowing Gulf Stream current to boost warming for 20 years*
***BBC***

***…***

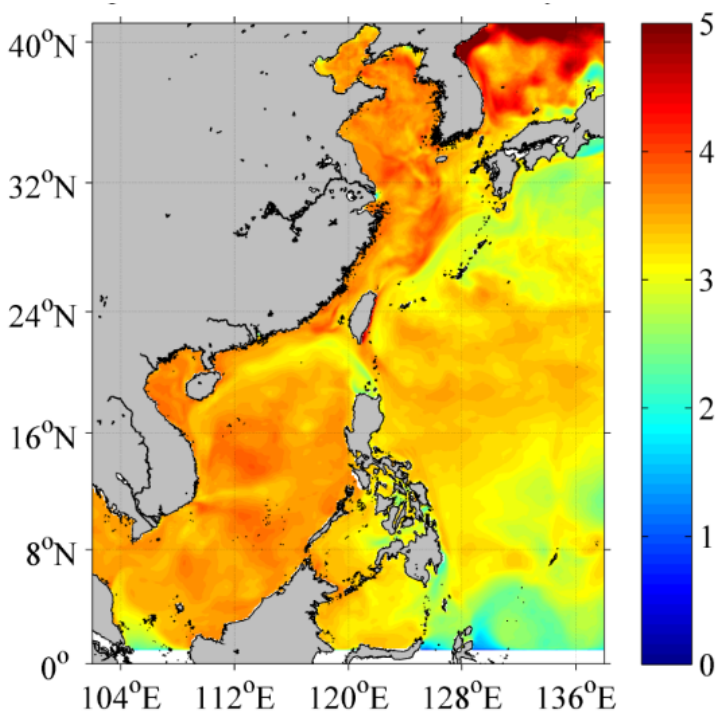
# Changing trend of climate



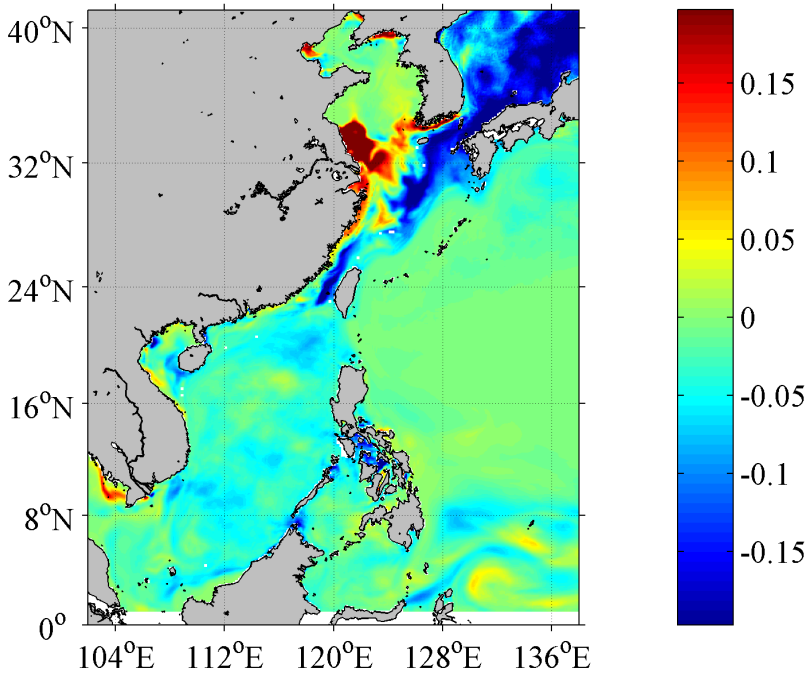

From IPCC

# Net changes in China Seas from now to 2100

## Sea Surface Temperature

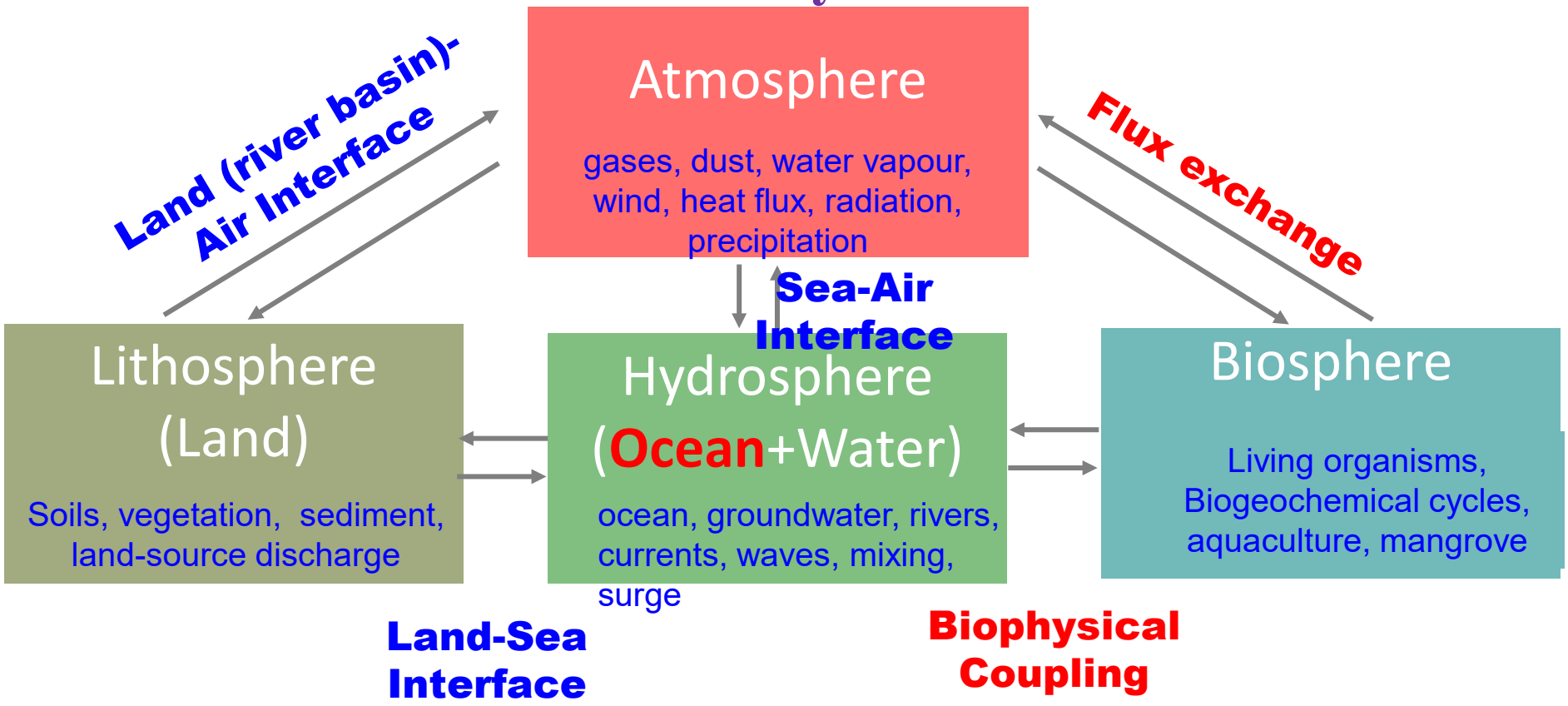


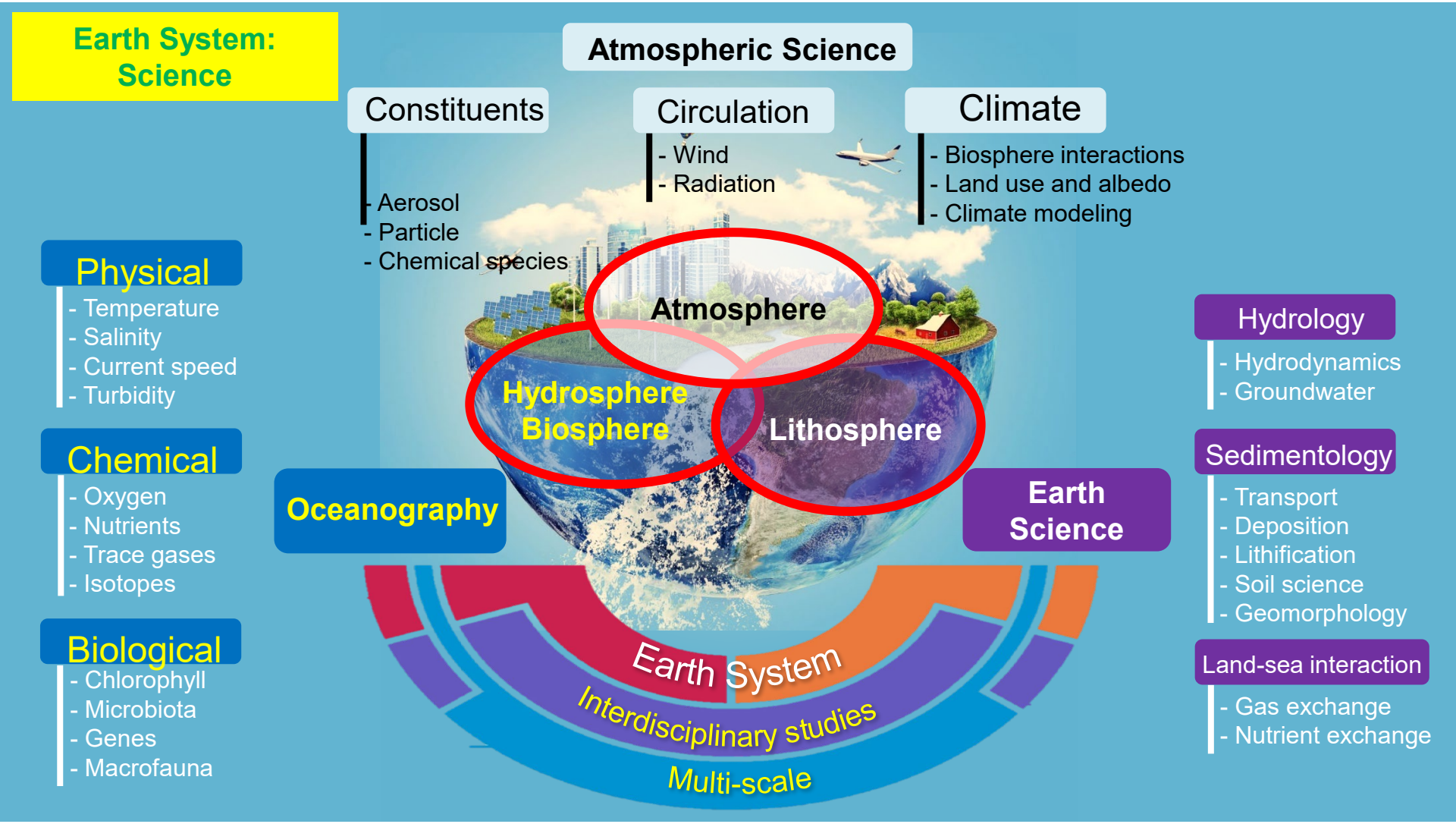

## Biological Productivity



# Summary

# Role of ocean in the multi-spheric and interdisciplinary study of the regional earth system




Earth System: Science
Atmospheric Science
Constituents
- Aerosol
- Particle
- Chemical species
Circulation
- Wind
- Radiation
Climate
- Biosphere interactions
- Land use and albedo
- Climate modeling
Physical
- Temperature
- Salinity
- Current speed
- Turbidity
Chemical
- Oxygen
- Nutrients
- Trace gases
- Isotopes
Biological
- Chlorophyll
- Microbiota
- Genes
- Macrofauna
Atmosphere
Hydrosphere
Biosphere
Lithosphere
Oceanography
Earth Science
Hydrology
- Hydrodynamics
- Groundwater
Sedimentology
- Transport
- Deposition
- Lithification
- Soil science
- Geomorphology
Land-sea interaction
- Gas exchange
- Nutrient exchange
Earth System
Interdisciplinary studies
Multi-scale