

OCES5001 Introduction to Oceanography

- Time: Mon. 19:00-21:50
- Venue: Rm 2503, Lift 25-26
- 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 interdisciplinary 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:

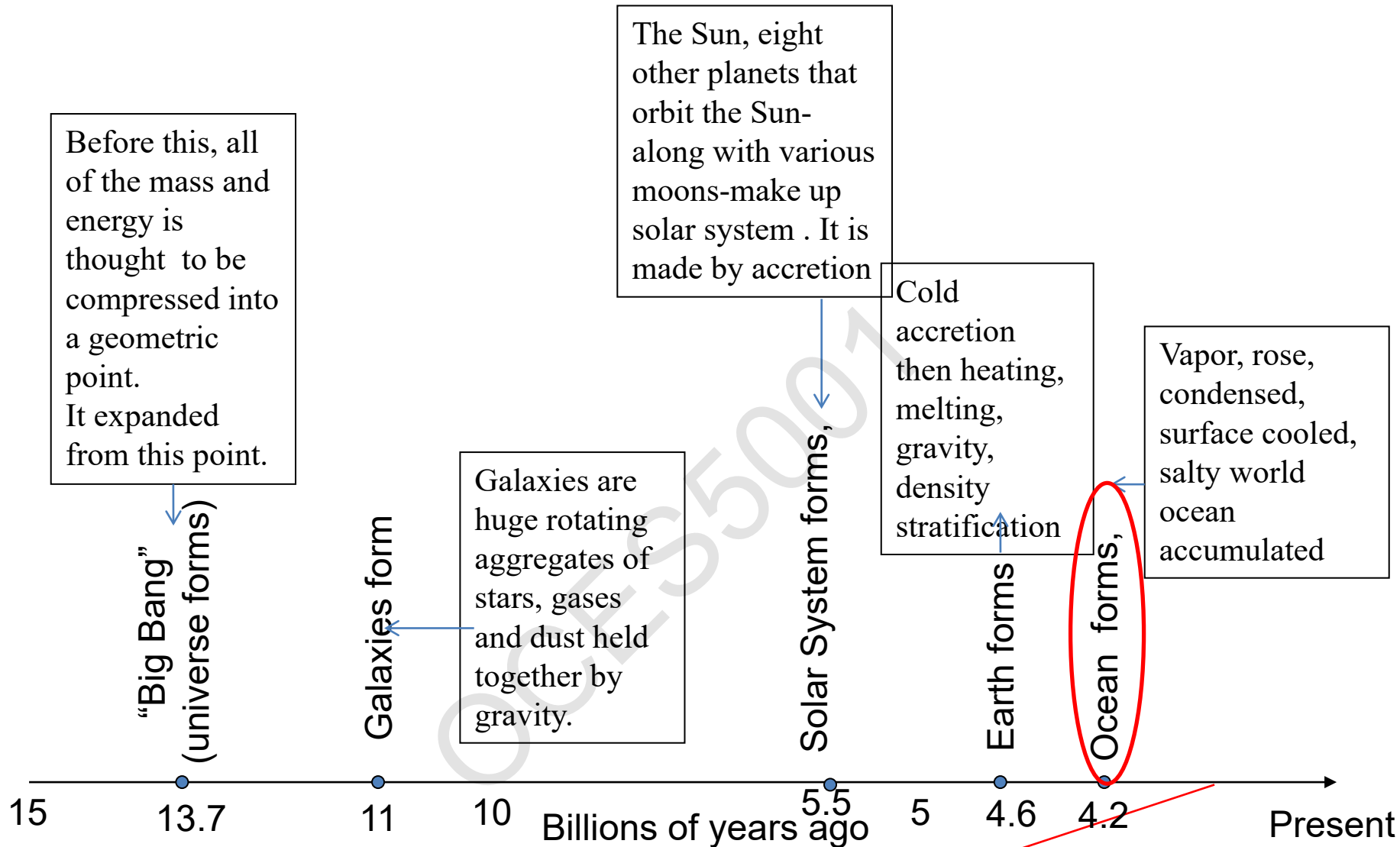
- Class participation: 10%
- Mid-term (Oct. 21) Exam: 35%
- Final Exam: 55%

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

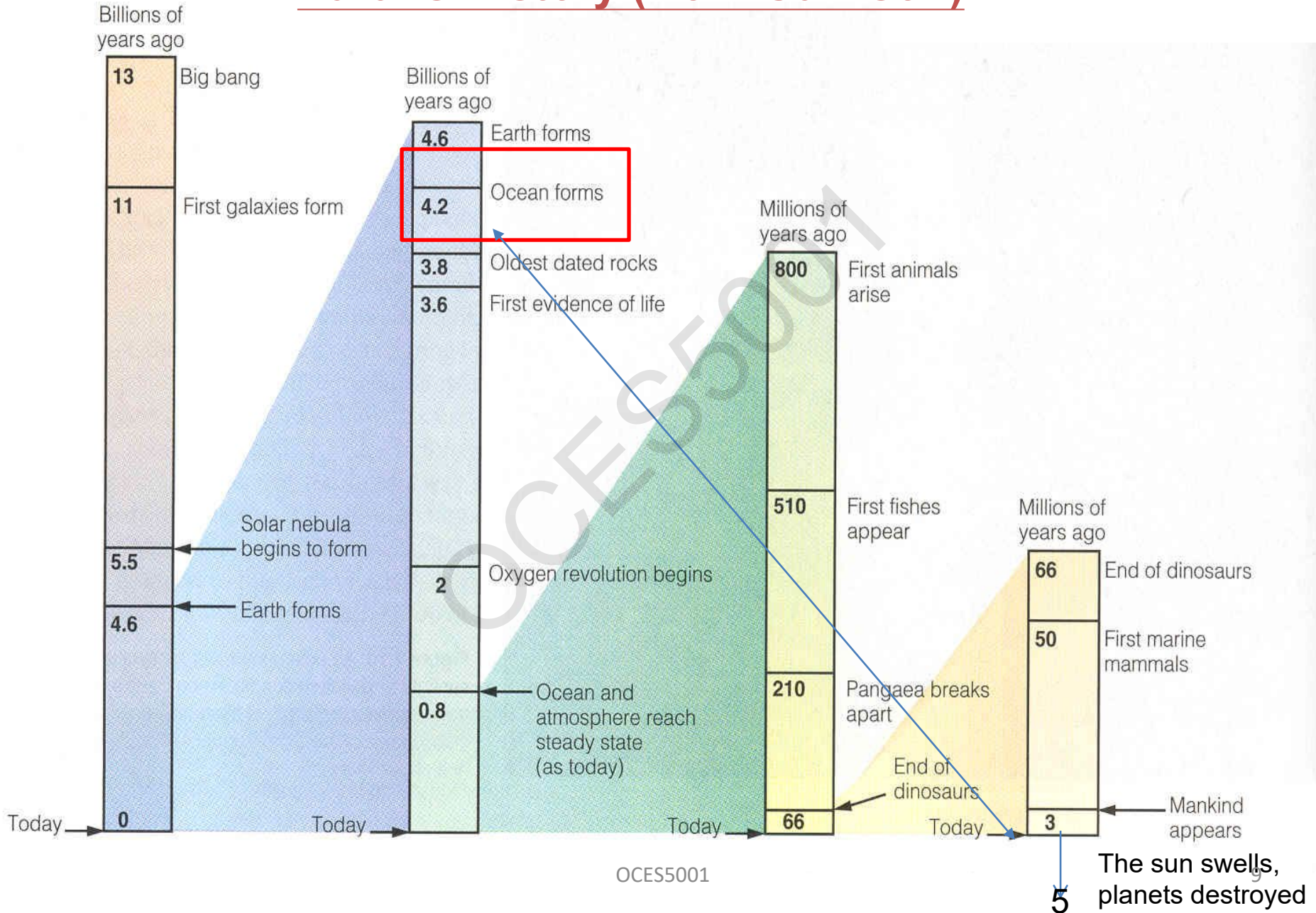
1.1 Timeline for the development of the universe, the solar system and life

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?

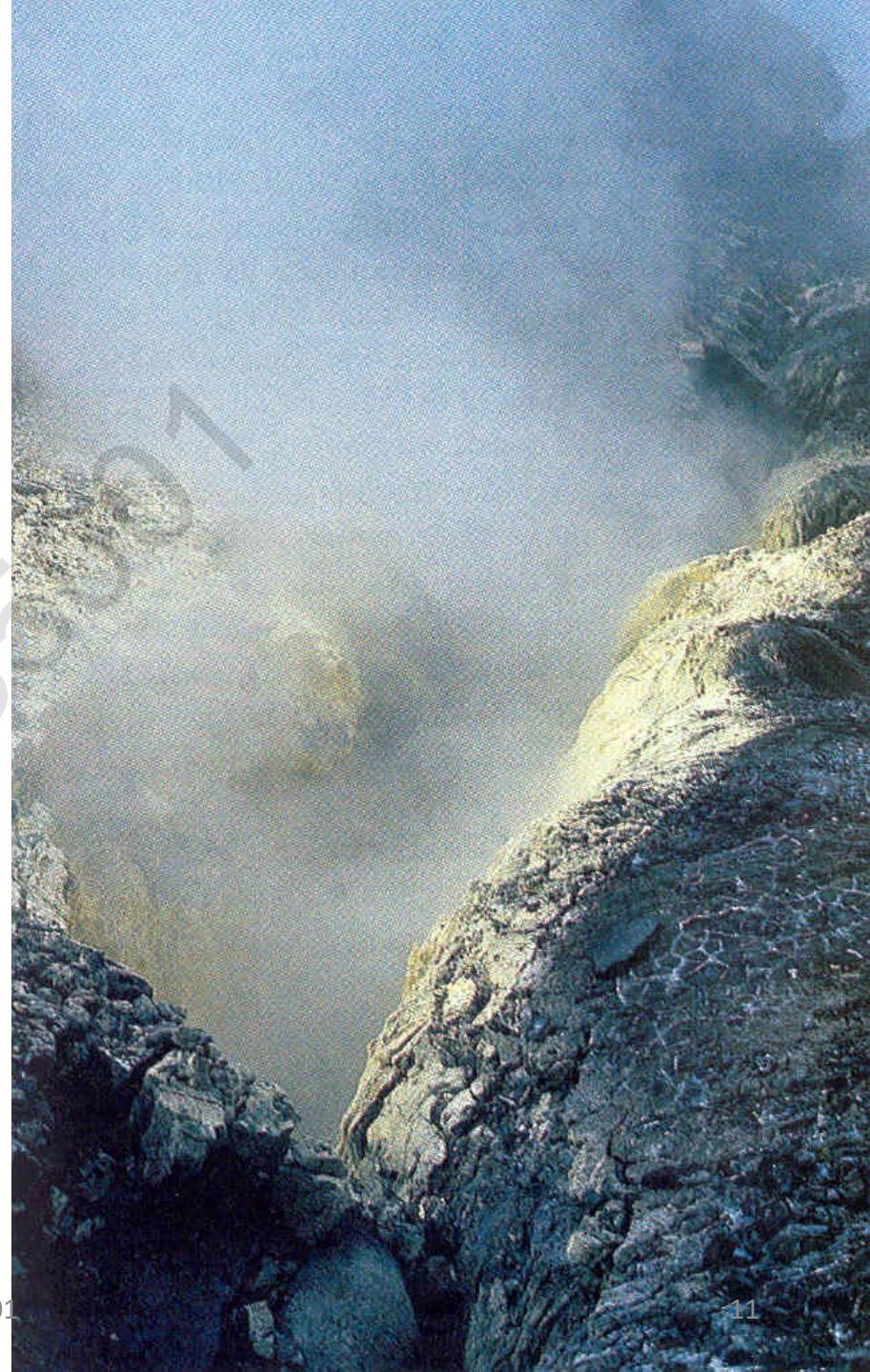
- The water on Earth stayed in **gaseous** form until the planet's surface cooled below 100 degrees Celsius.
- 4.2 billion years ago, water **condensed** into rain and poured onto the land. Water collected in low lying areas which gradually became the primitive oceans.
- As water entered the oceans from 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

Volcanic gases – H_2O , CO_2 , nitrogen

From Garrison

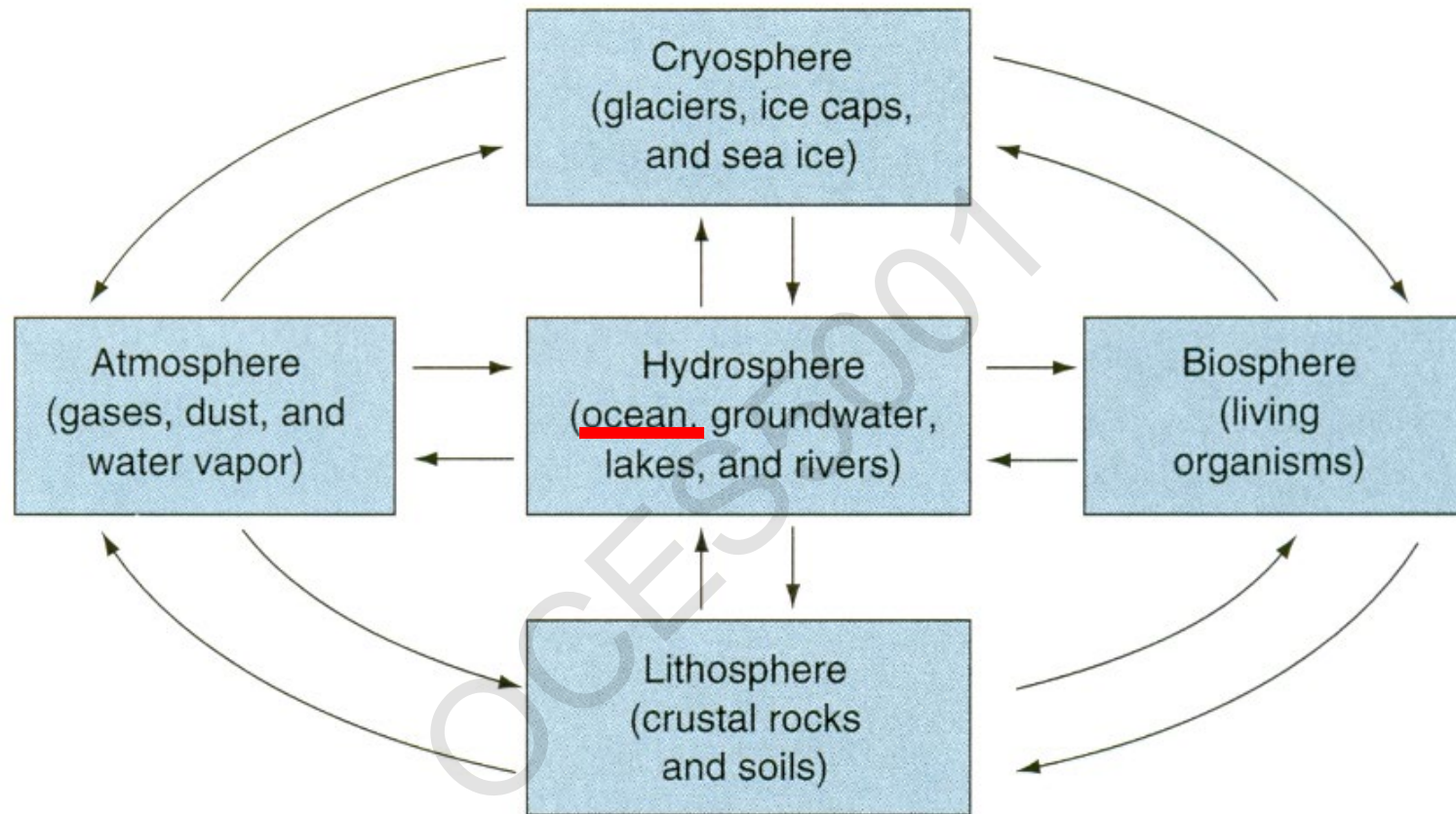


Intense bombardment of early Earth by large bodies of icy comets or asteroids from the outer space reaches the solar system.



Comets May Have Delivered Some Water (Fig 1.9b)

Subsystem in the Earth System



→ Feedback +, -
←

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. $T \nearrow, CO_2 \nearrow T$.

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 and 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)

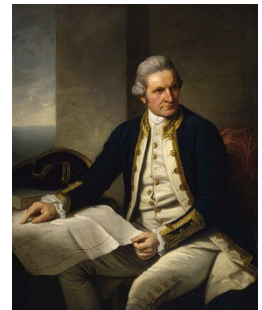
- credited with discovering the 'new world' (North America)
- wanted to find a route to Asia (for trading goods)

Ferdinand Magellan (1480-1521)

- sailed into the Orient
- his crew circumnavigated the globe

James Cook (1728-1779)

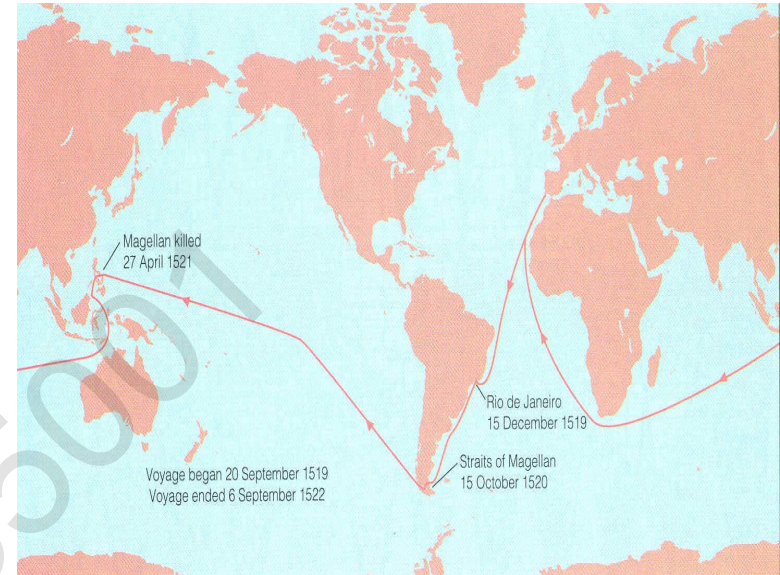
- began the study of scientific oceanography – took many samples
- sailed into Antarctica, and charted coastlines from Newfoundland to New Zealand



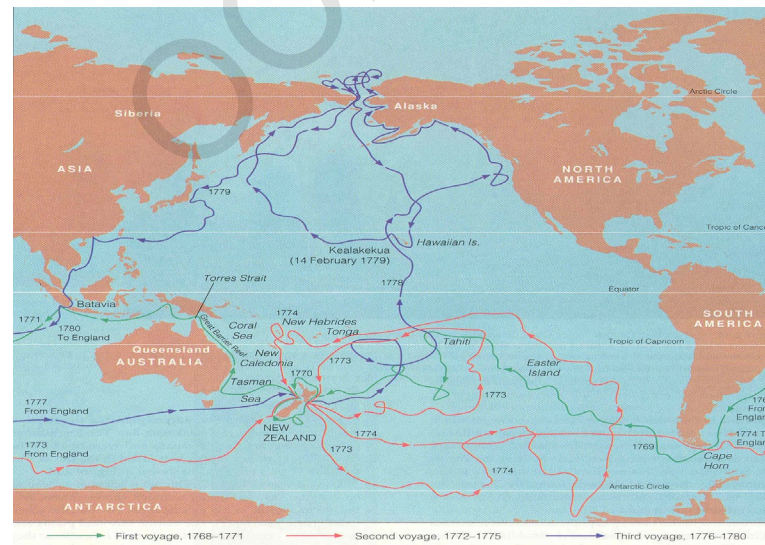
Zheng He's Expedition Map



Magellan's Voyages



Cook's Three Voyages Exploring the Pacific



(Garrison, 1996)

Scientists and Expeditions

Charles Wilkes

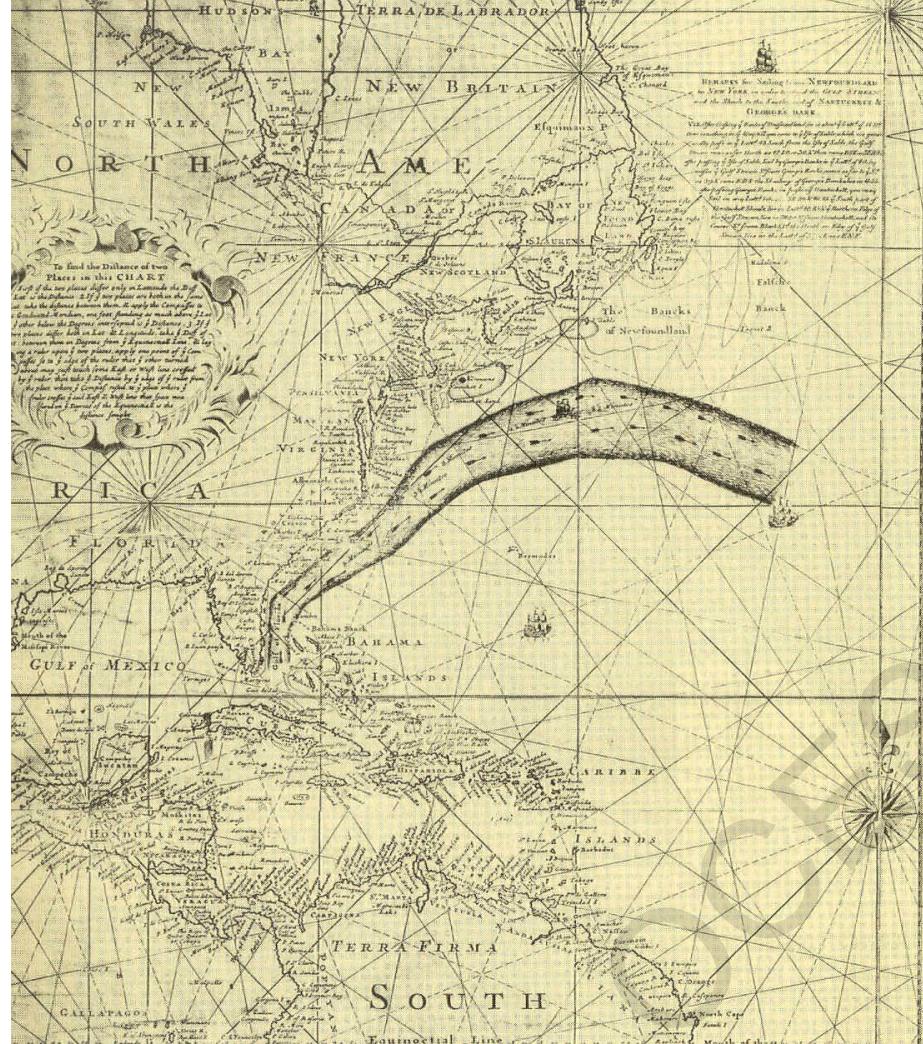
- explored the Antarctic coast and the Hawaiian Islands
- took many samples

Matthew Maury

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

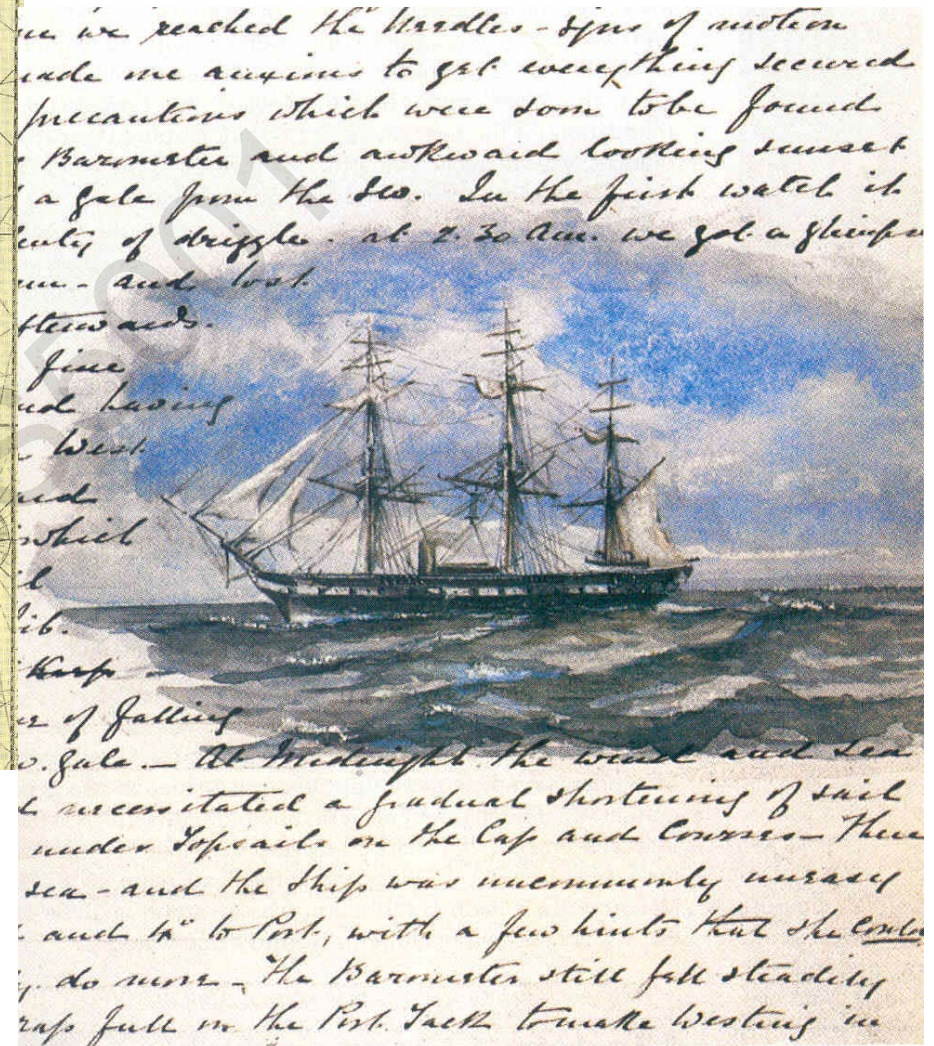
Benjamin Franklin

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

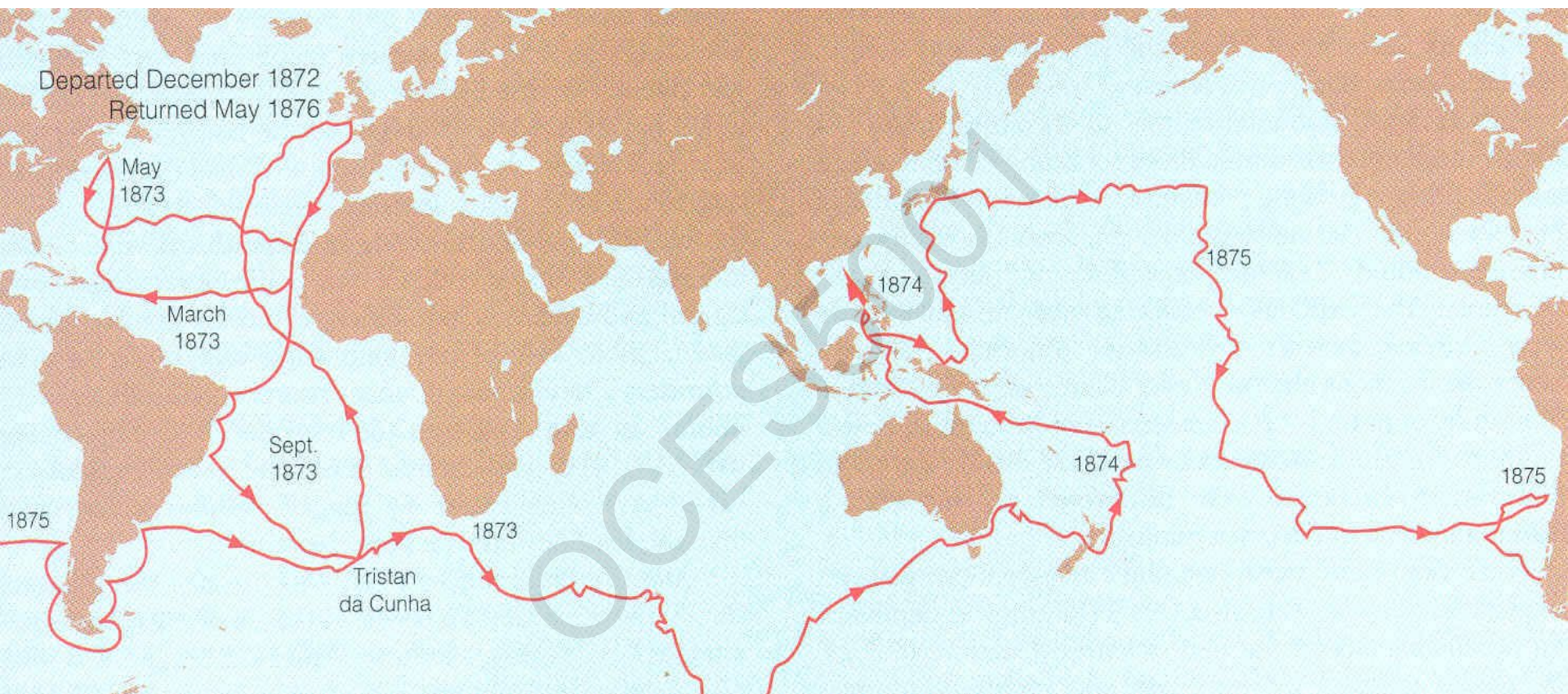


Benjamin Franklin's Chart of the Gulf Stream (1769)
(Fig 2.15)

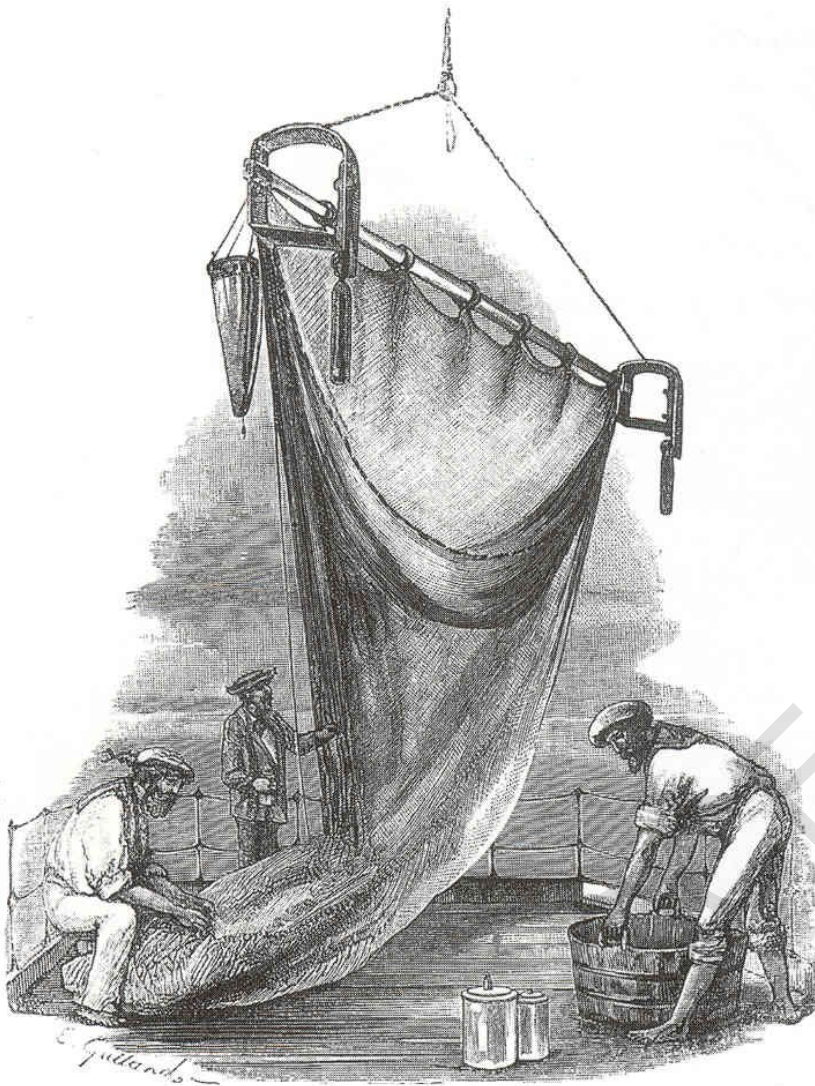
H.M.S. Challenger (Fig 2.16)



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.



Emptying a Trawl Net on the Challenger



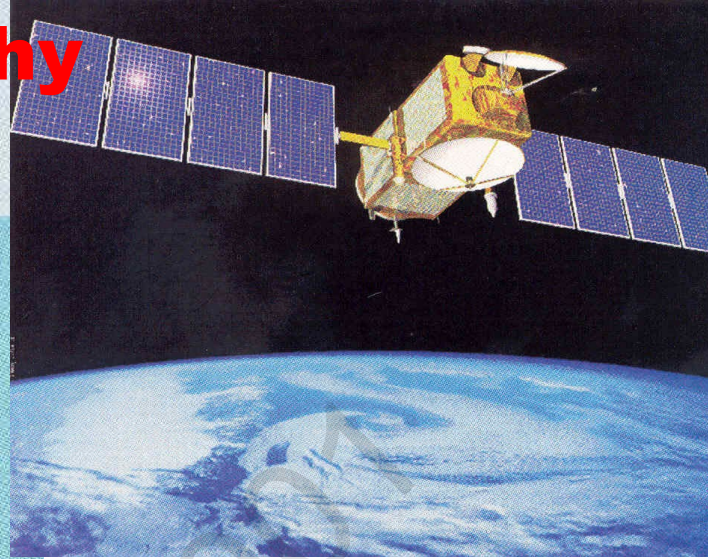
First Oceanographic Institution in Monaco 1906

Modern Oceanography

Beam of sound waves travels to bottom and is reflected back to ship

$$\text{Depth} = V \left(\frac{T}{2} \right)$$

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

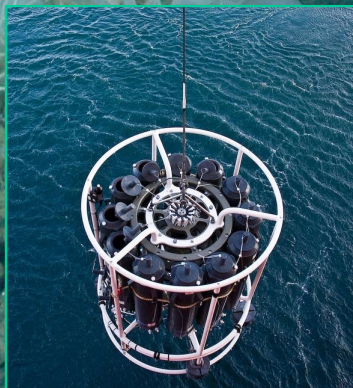
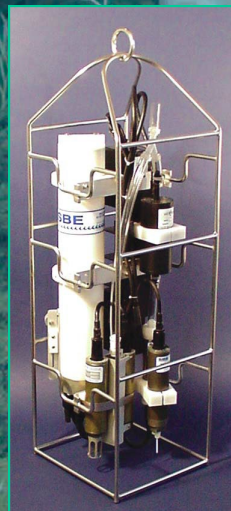
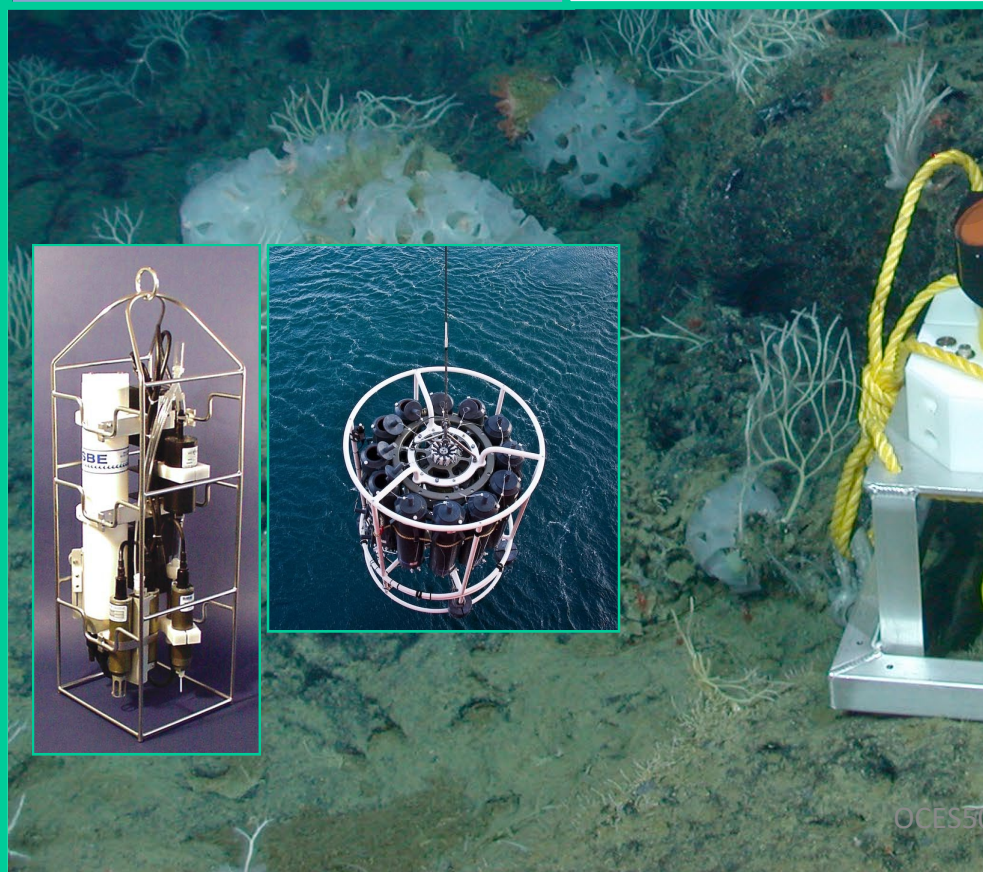
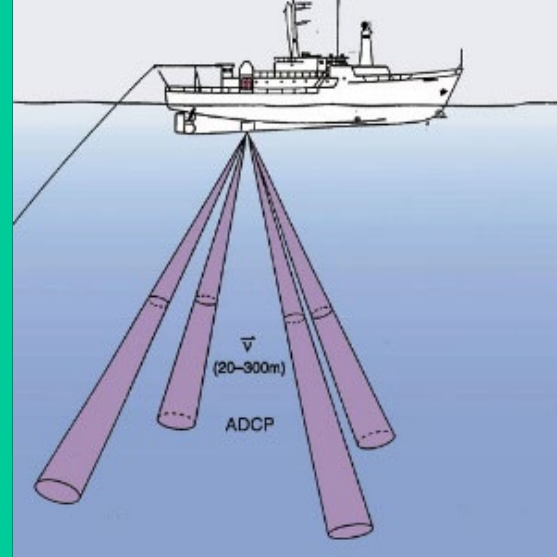


JASON – a satellite that covers all of oceans every 10 days. Measures sea surface height

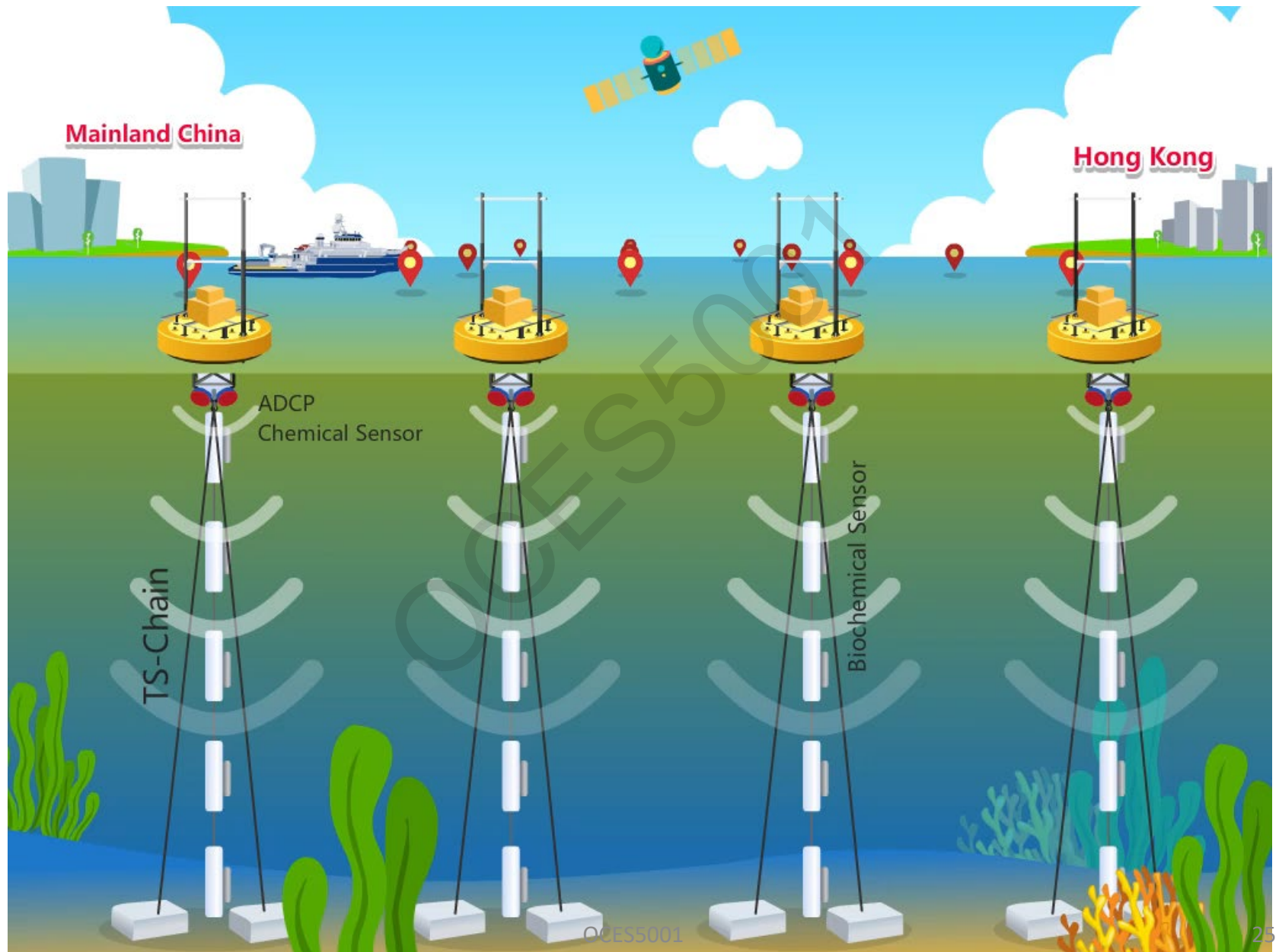


Kaiko – Deepest diving remotely operated vehicle (ROV) to 10,914 m





Interdisciplinary *in situ* measurement

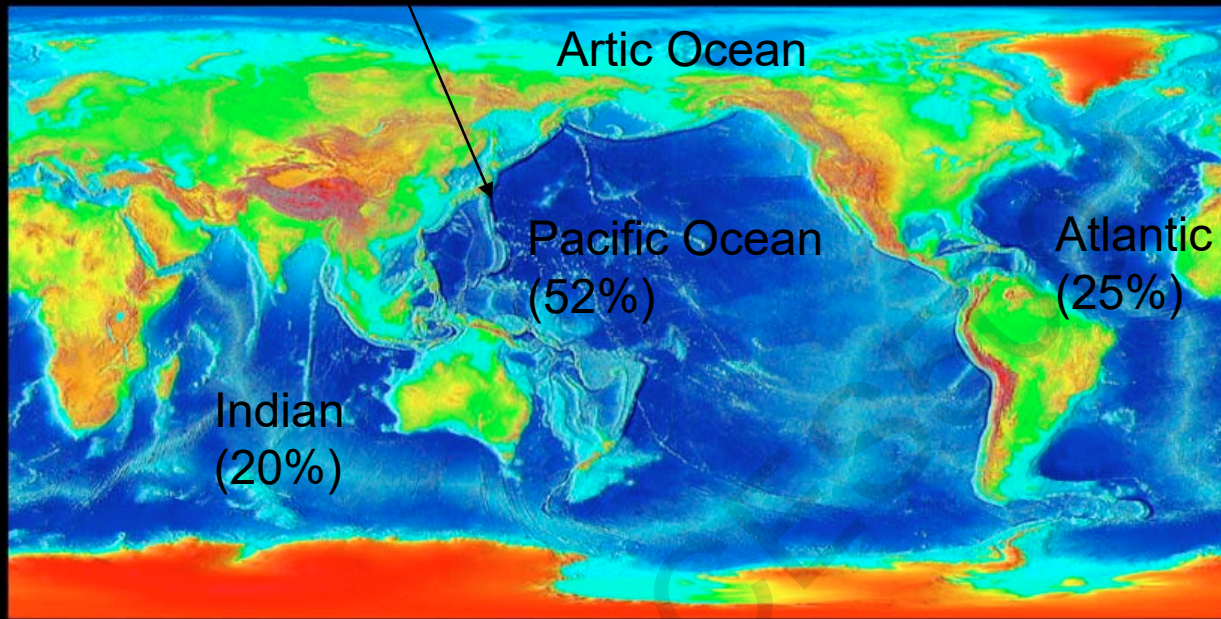


1.3 The ocean basins their characteristics

Oceans, bathymetry, continental margins

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

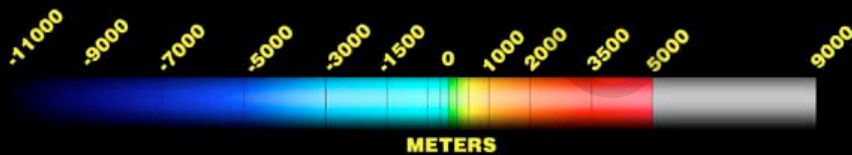
2. World's Ocean



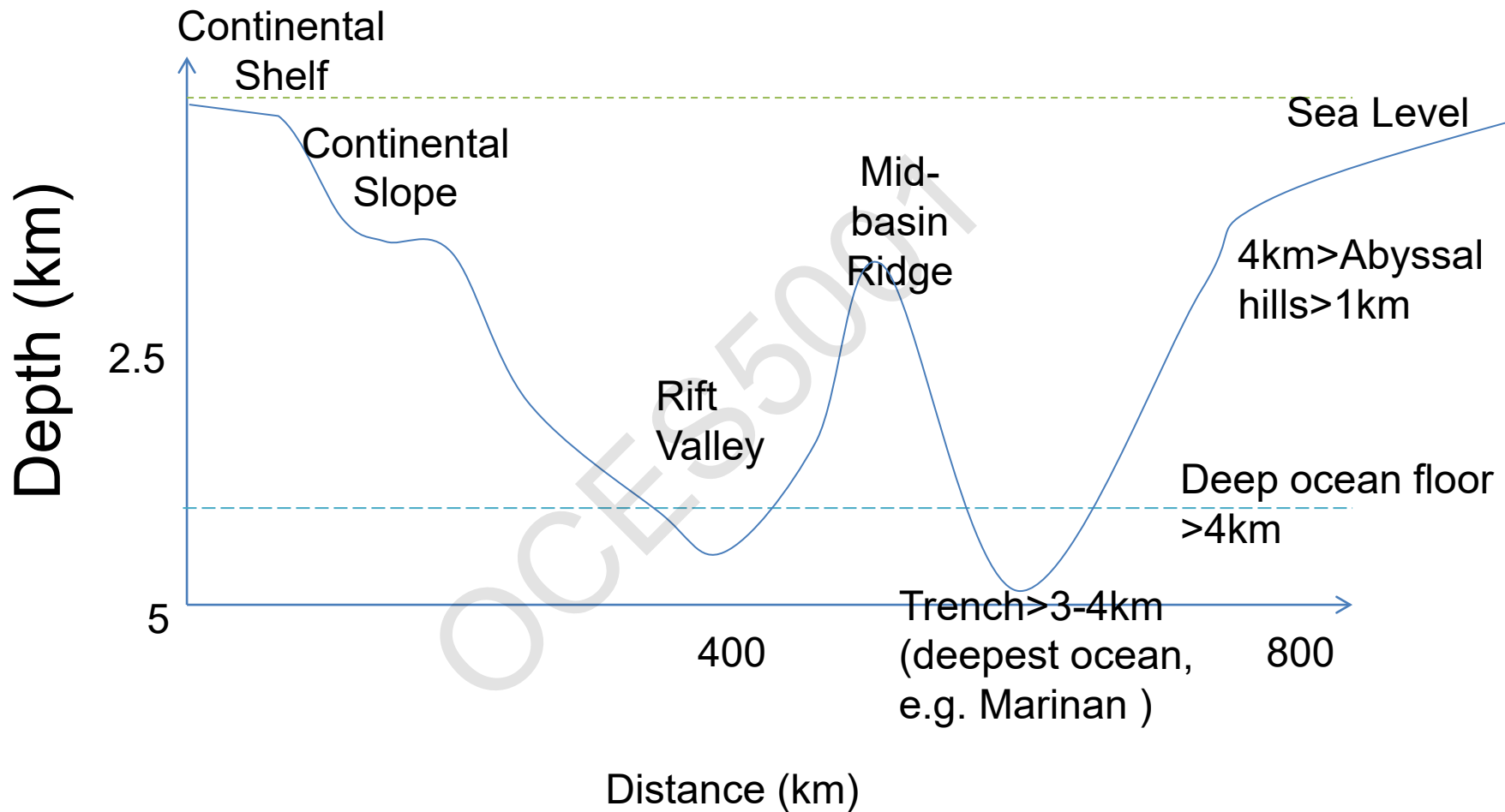
Ocean: 70.8%

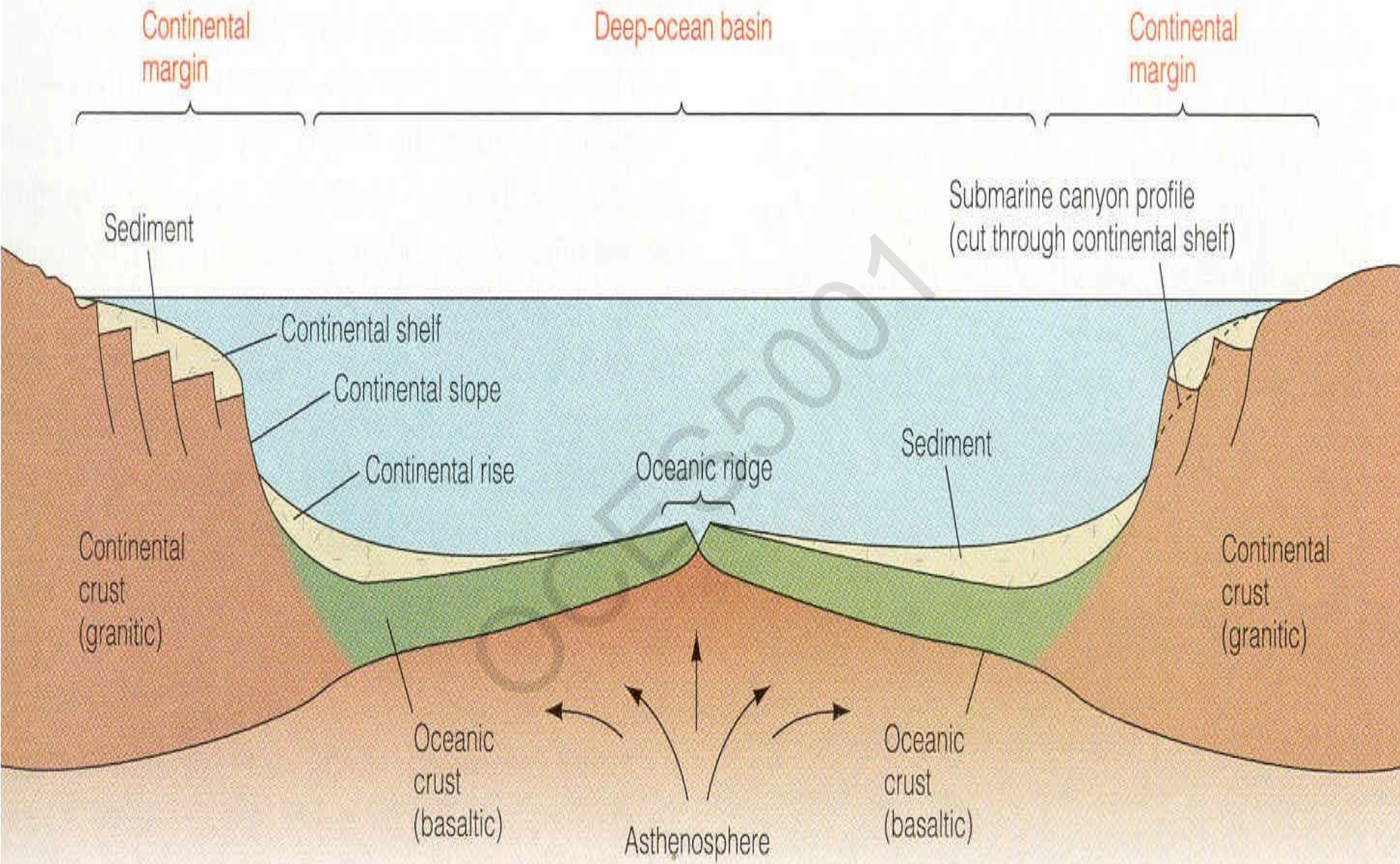
Northern Hemisphere:
60.7% sea, 39.3% land;

Southern Hemisphere:
80.9% sea, 19.1% land.



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





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

Mid-Ocean Ridges

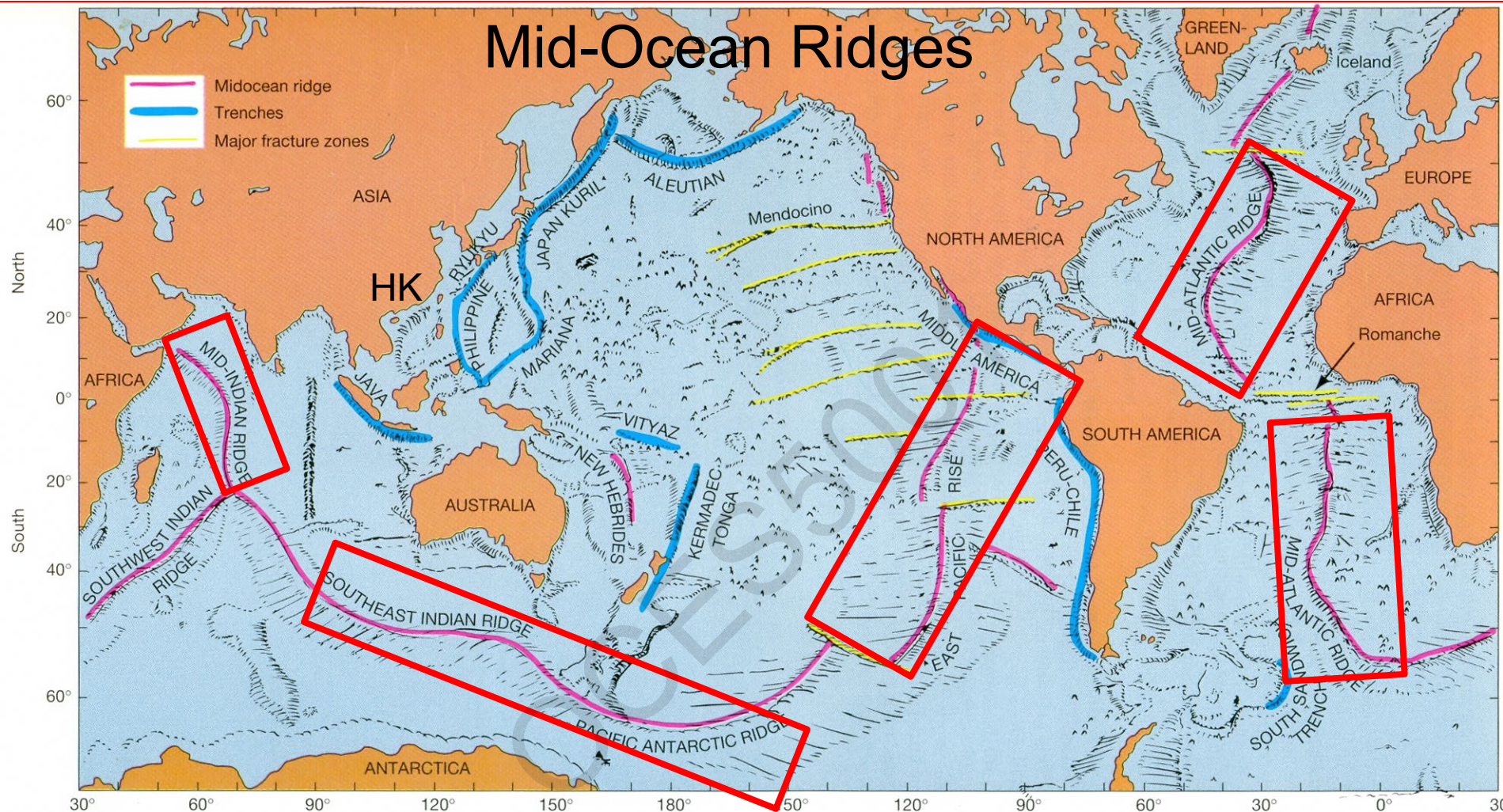


Figure 2-16

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

- Mid-ocean ridges exist 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.

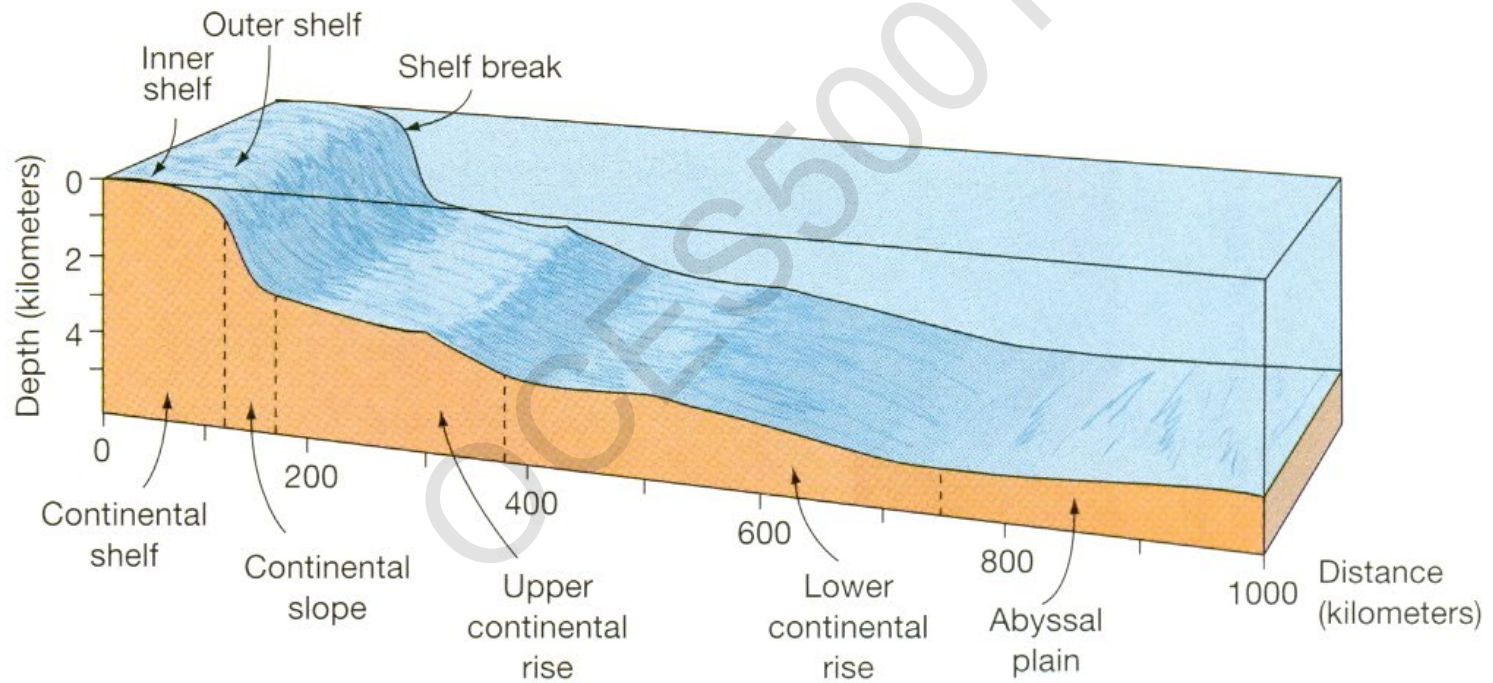
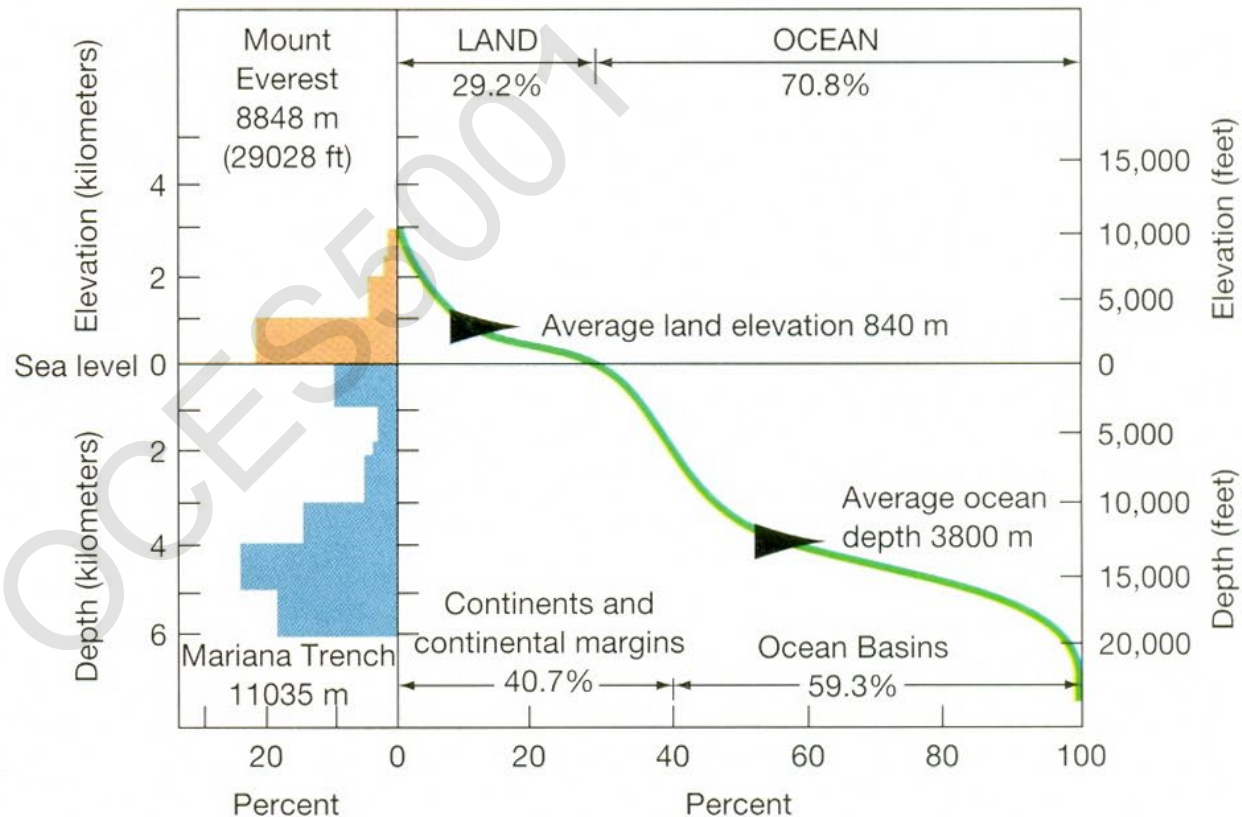


Figure 2-14

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.

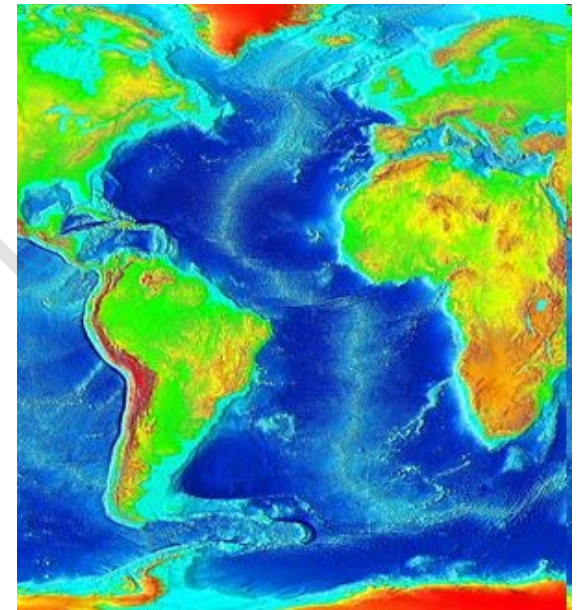


Pacific ocean bathymetry



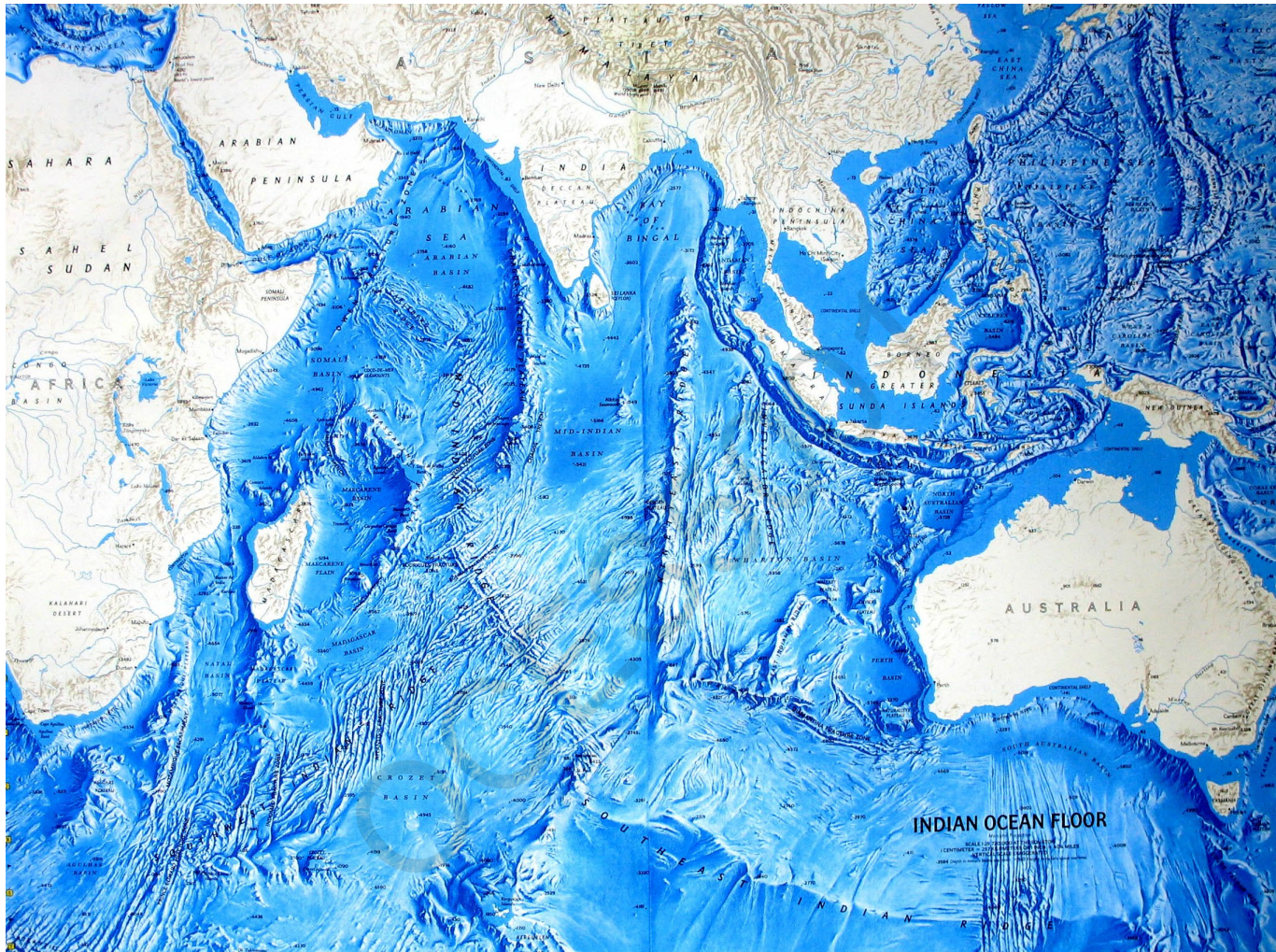
- Deepest and largest basin;
- 1/3 of earth surface;
- Narrow continental margin;
- Relatively less affected by land
- Island-abundant

Atlantic Ocean



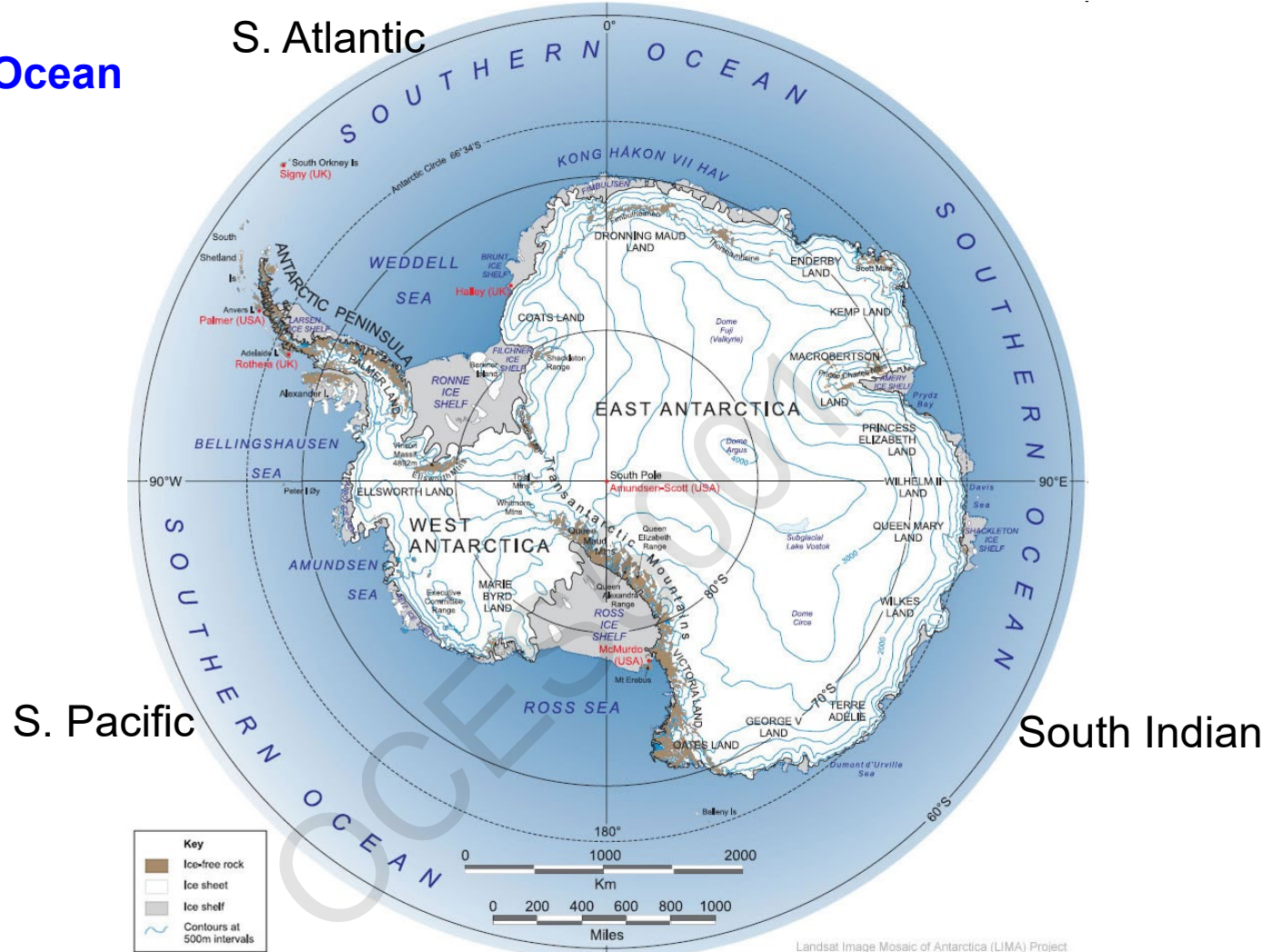
- Relatively narrow connecting the Arctic and Antarctic Oceans;
- Relatively shallow
- Wide continental margins

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

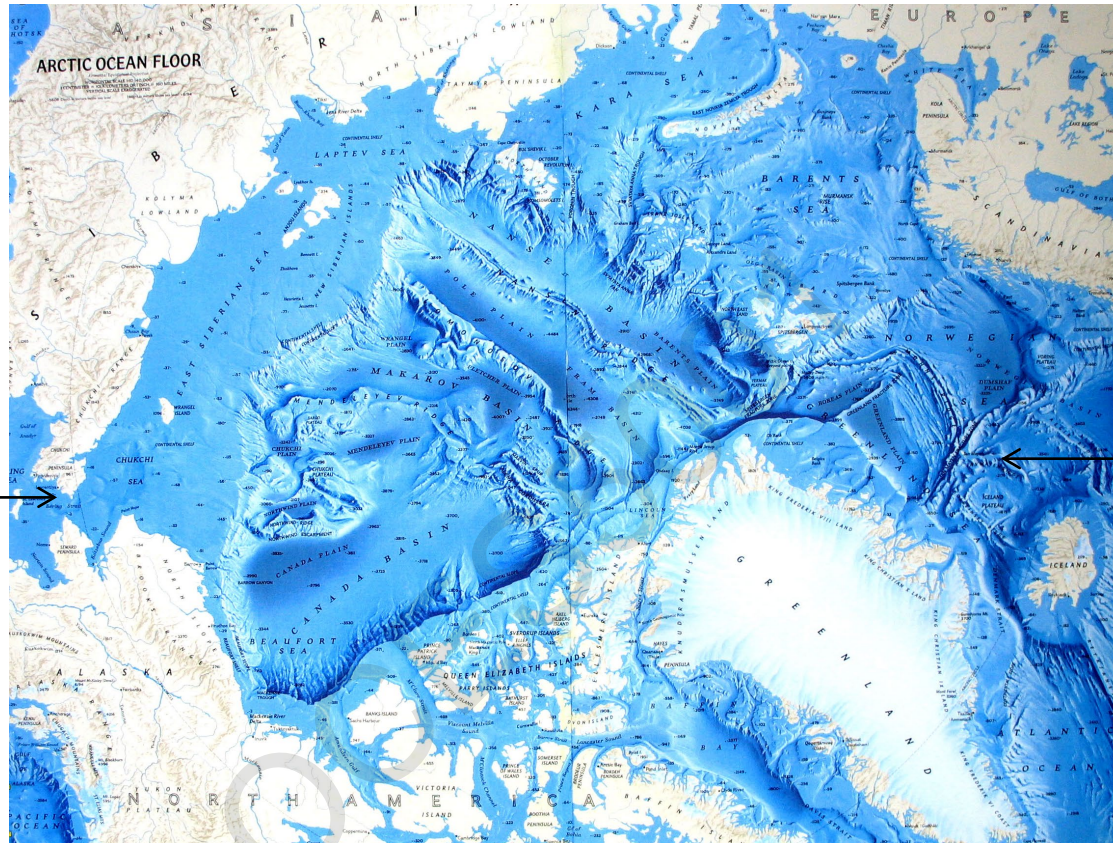
Southern Ocean



- 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

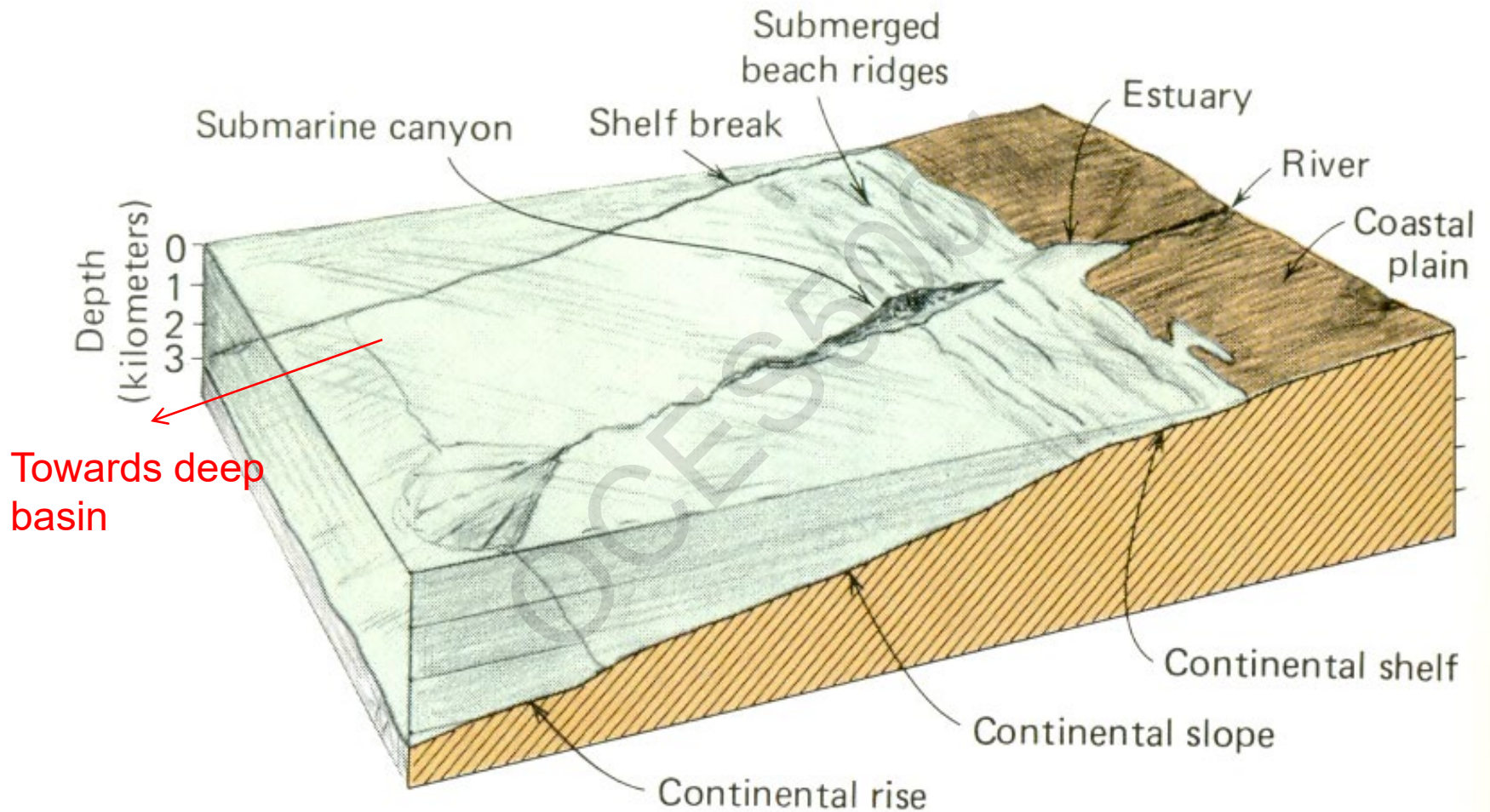


Fram Strait

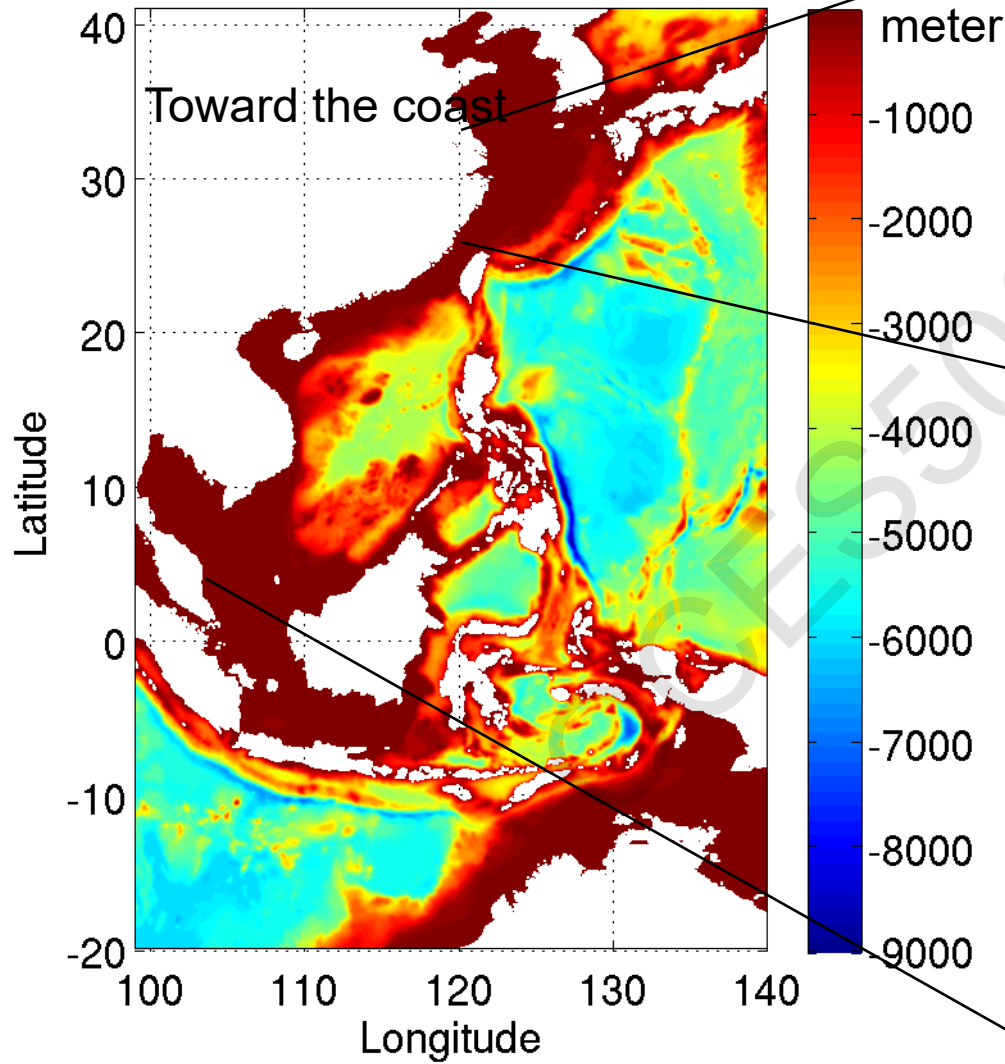
- Connect with Atlantic via Fram Strait and Pacific via Bering Strait;
- Large amount of freshwater discharge from several rivers;
- Continental shelves make up almost half of the Arctic Ocean;
- 80% percent of ice cover in summer and 90% in winter.

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

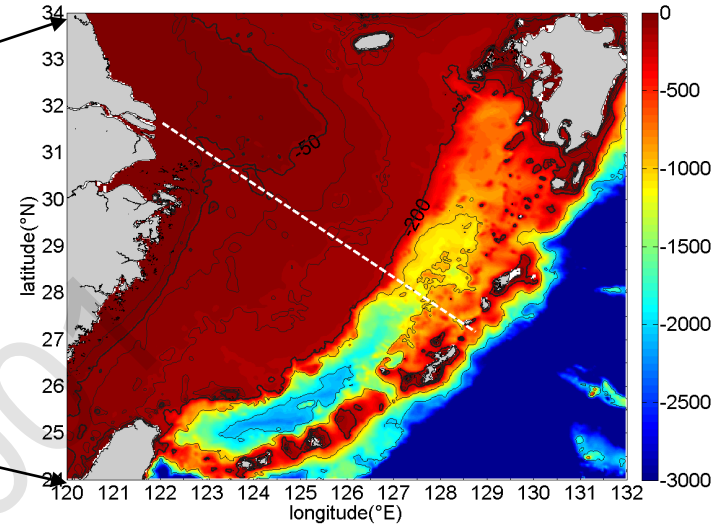
From land, sea to ocean



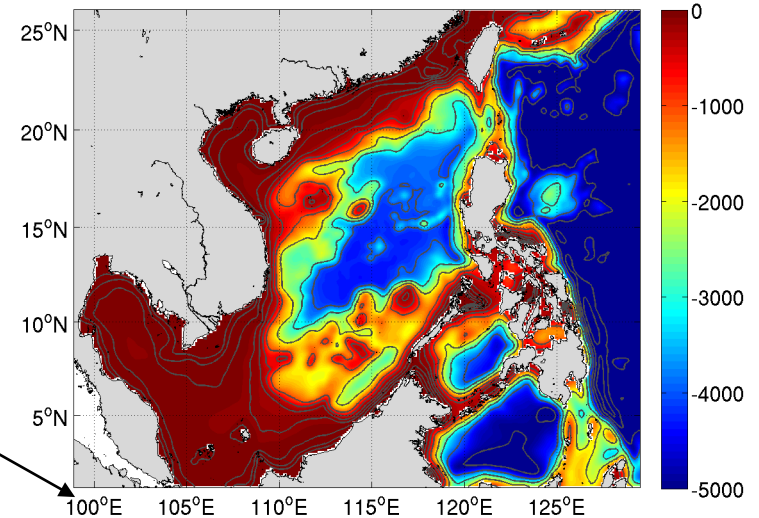
Bathymetry in Western Pacific and China Seas



East China Sea



South China Sea



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

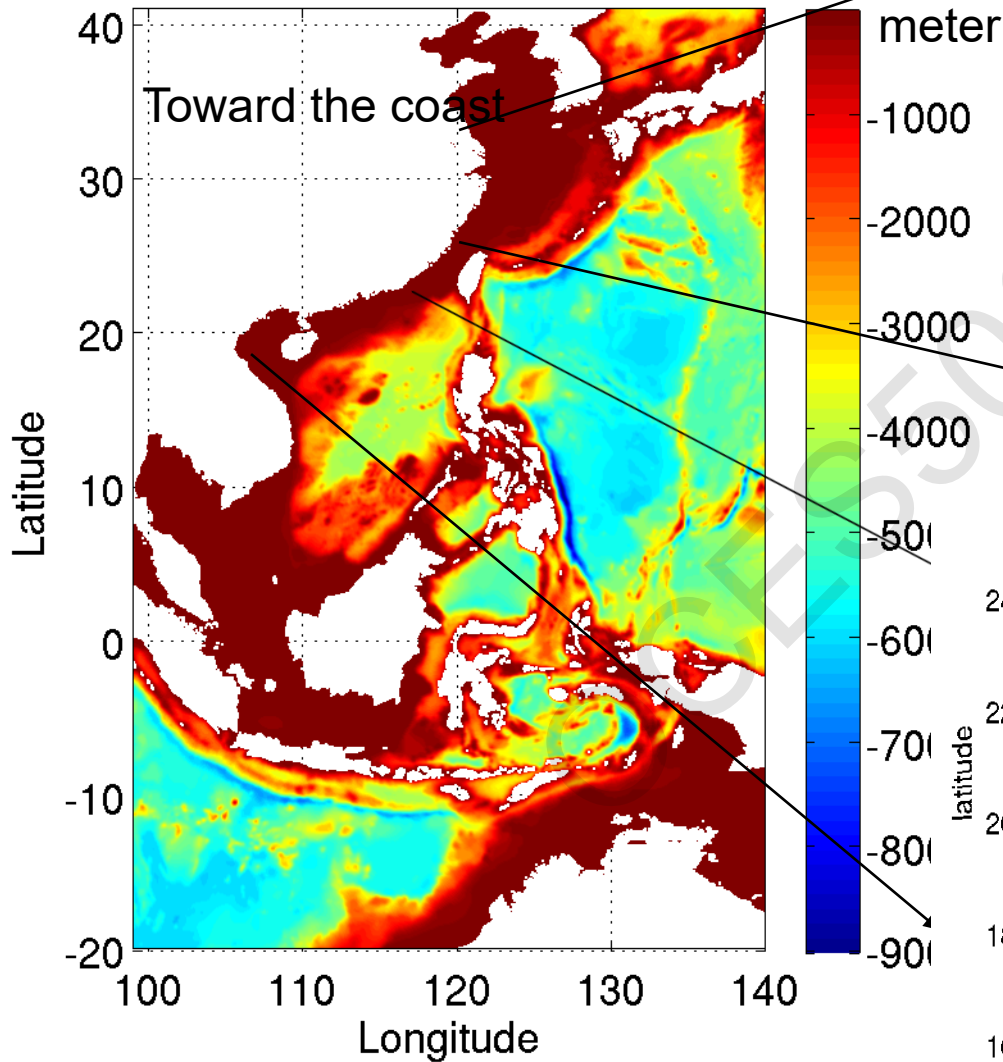
Coastal Ocean

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.

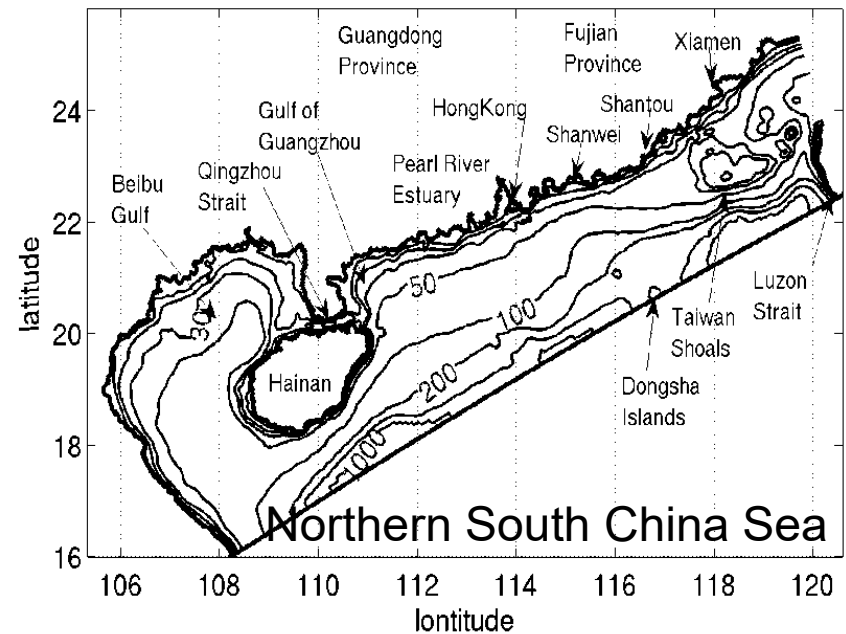
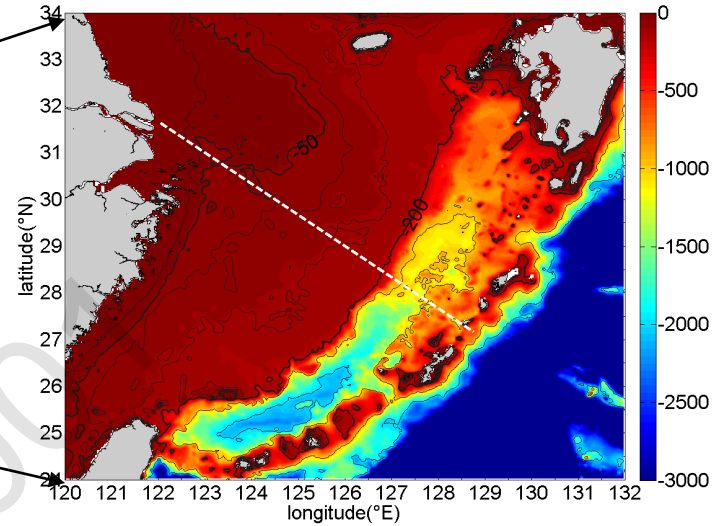
Shelf Break

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

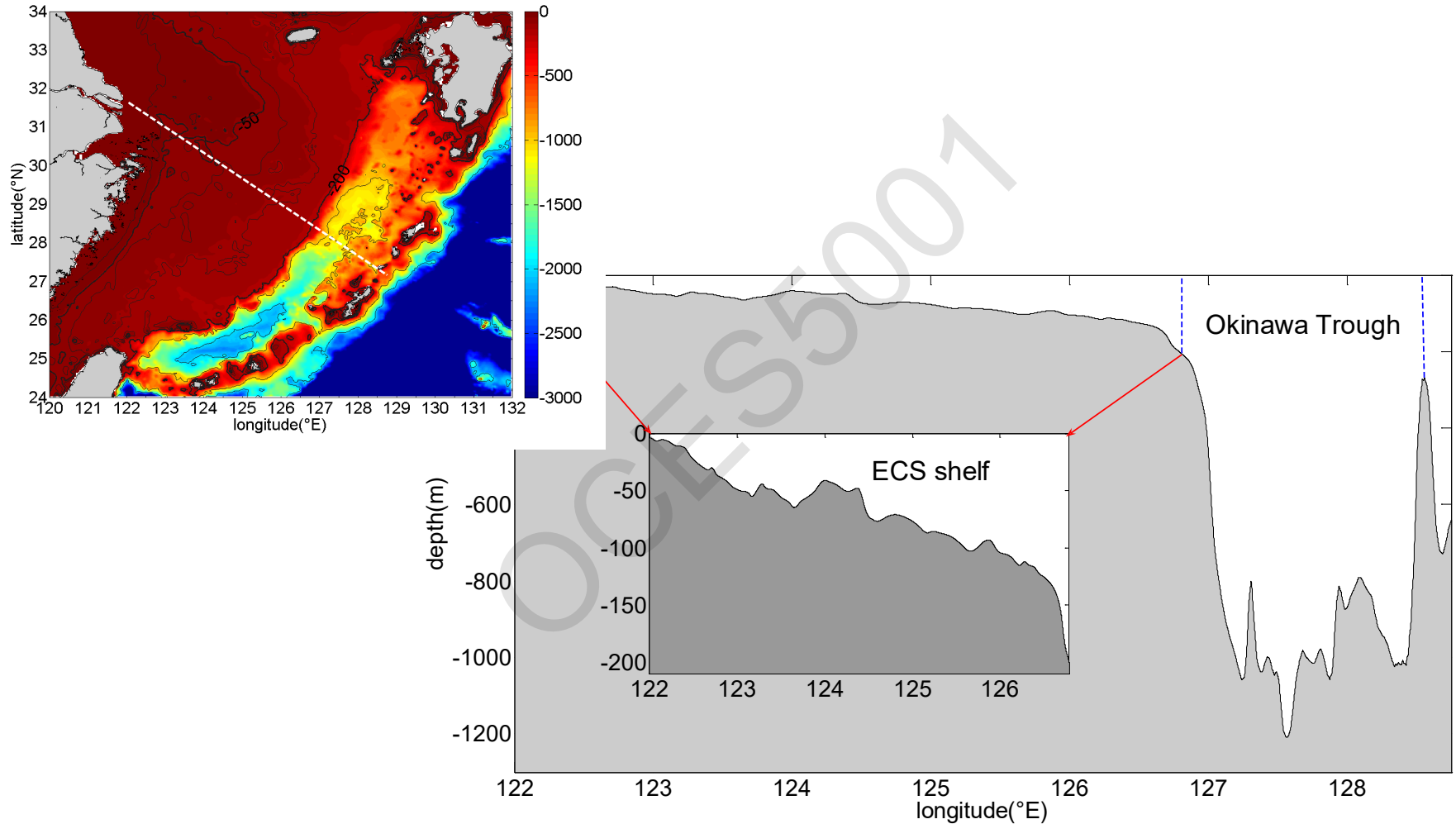
Examples of Shelf Seas



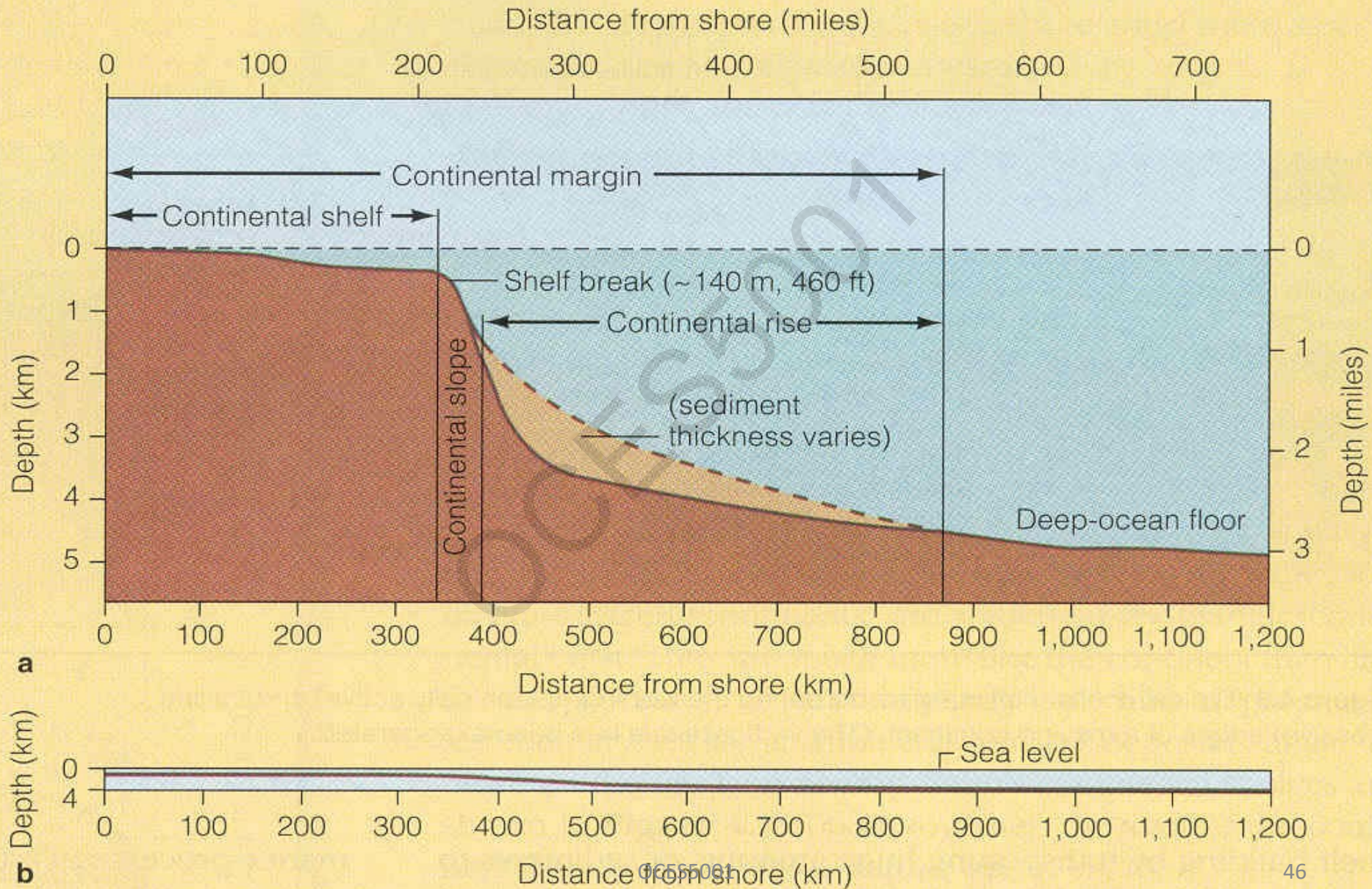
East China Sea



Cross-shelf topography in East China Sea

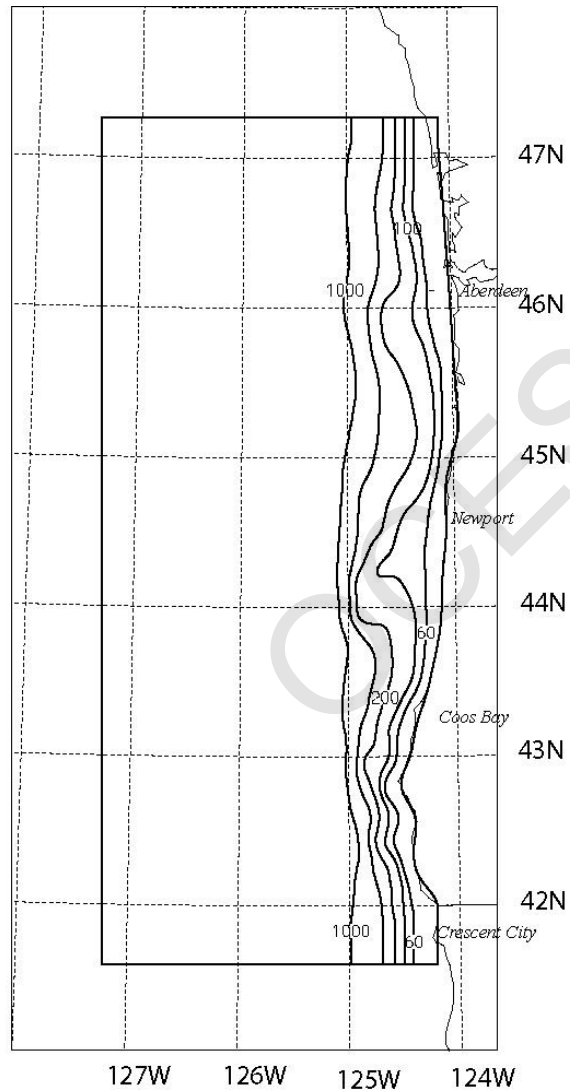


Components of the Continental Margin (Garrison)

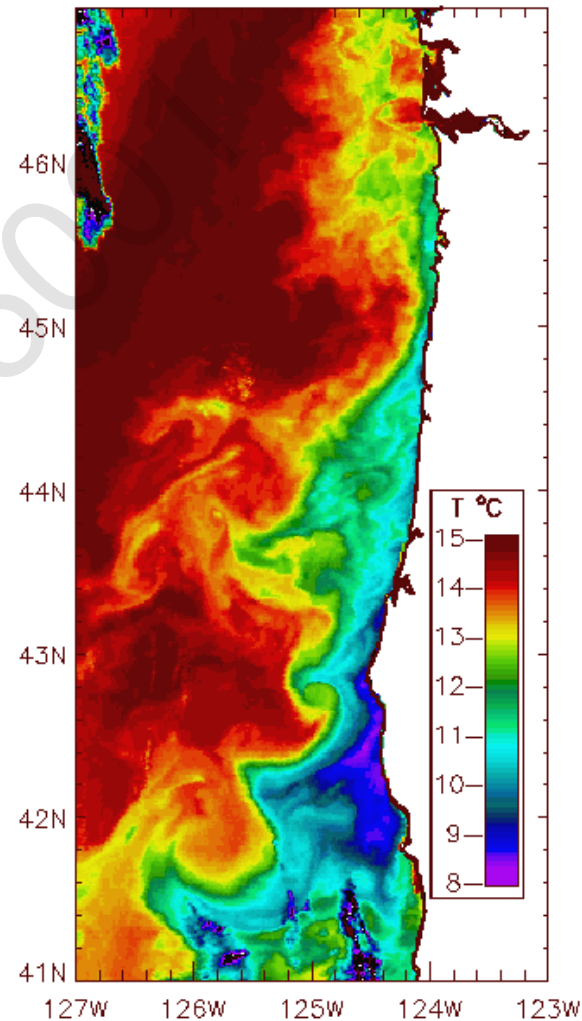


Effect of topography on oceanic condition (example: west coast of US)

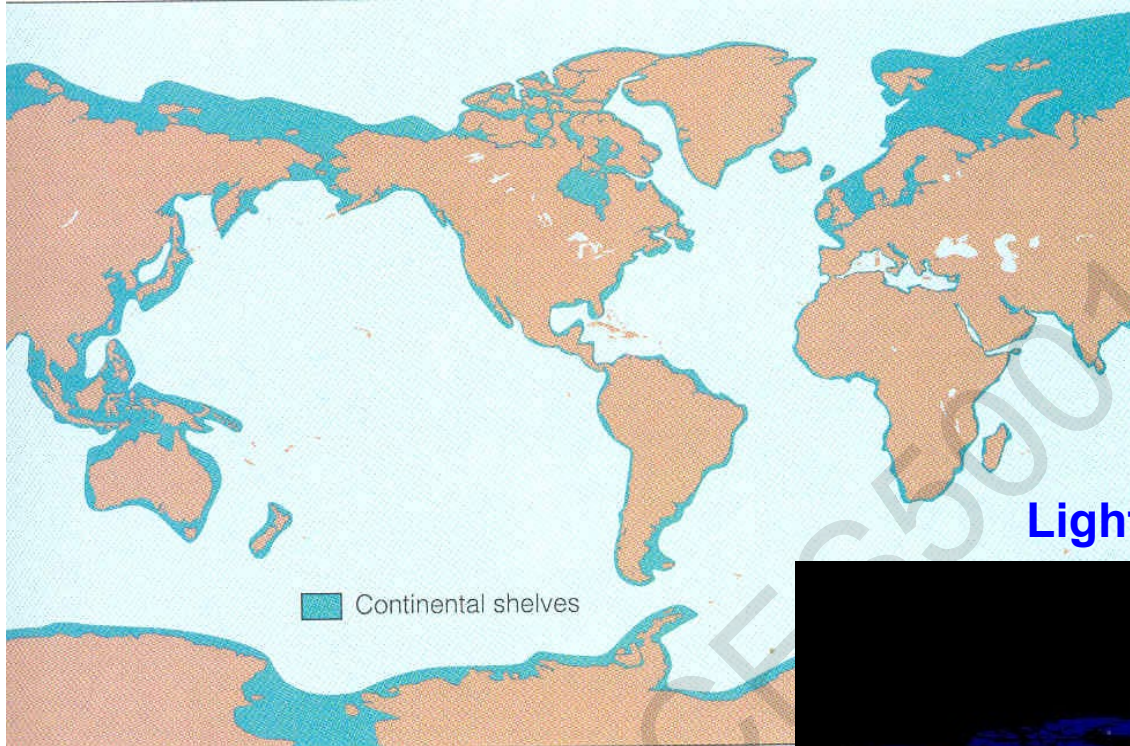
Shelf Sea in US west coast



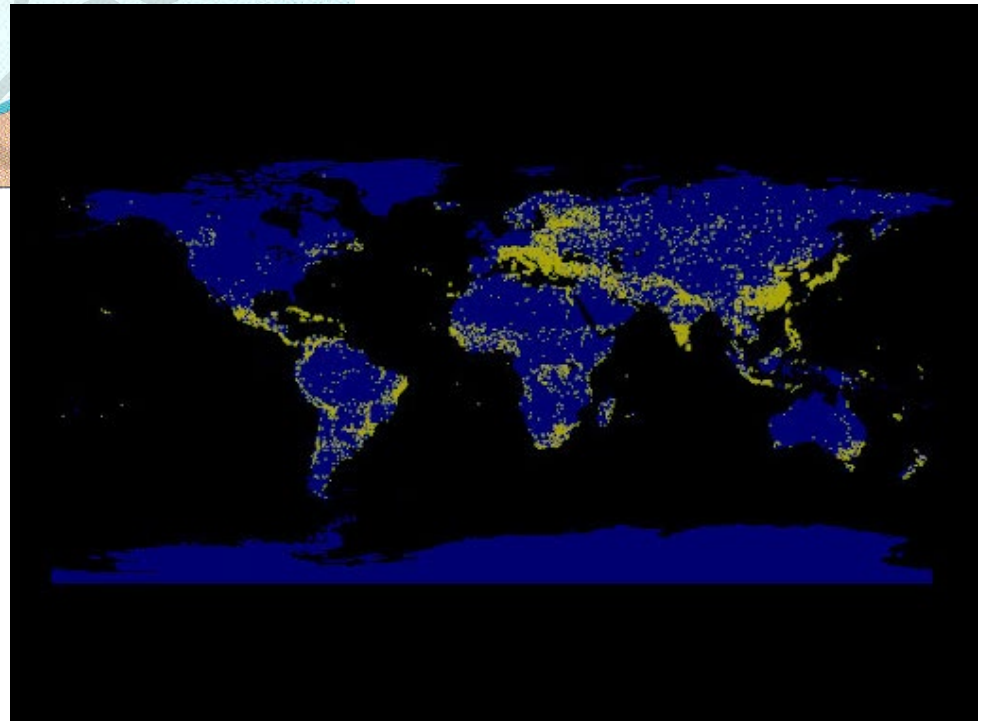
Sea Surface Temperature



Distribution of Continental Shelves (Garrison)



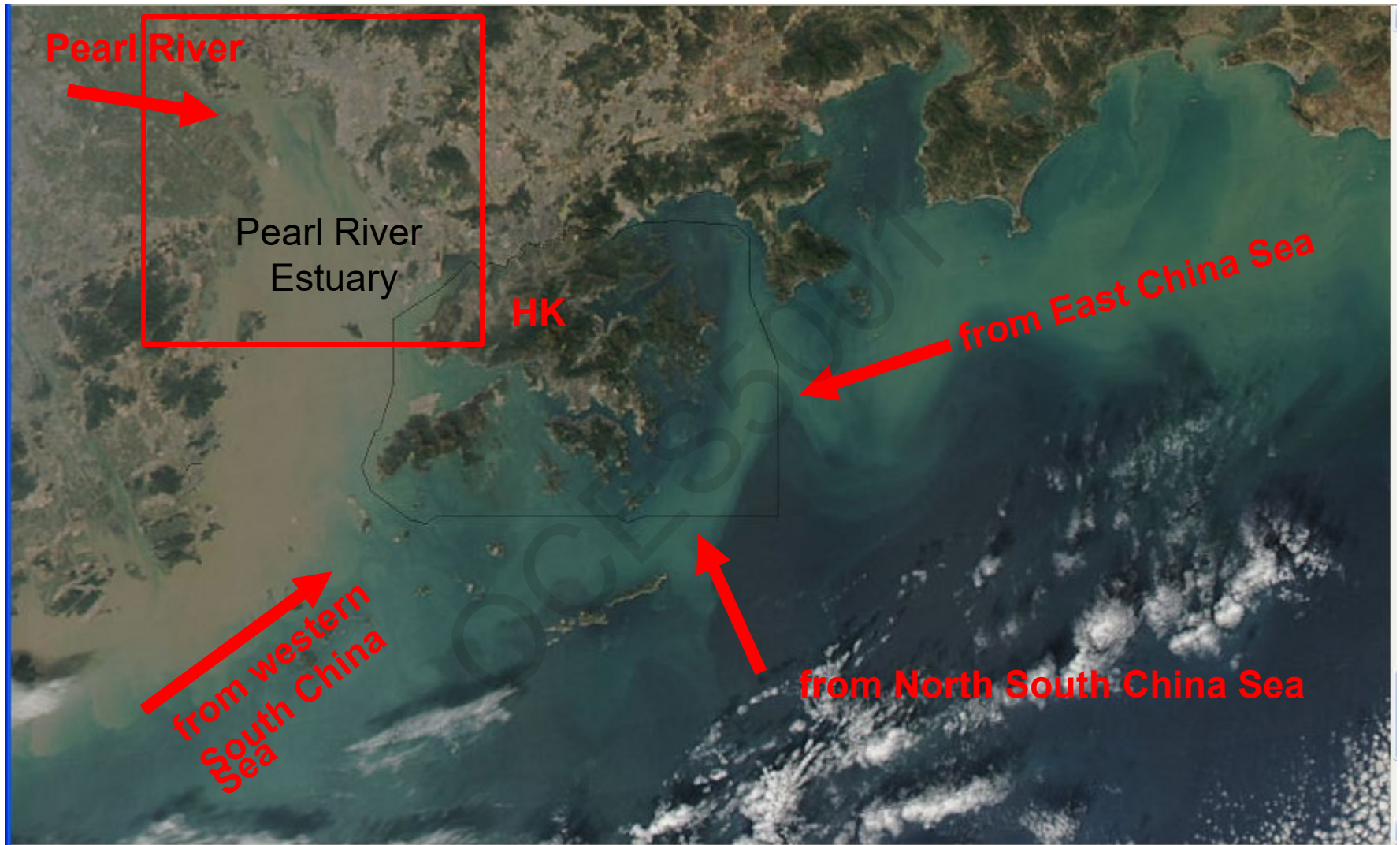
Lights over the world



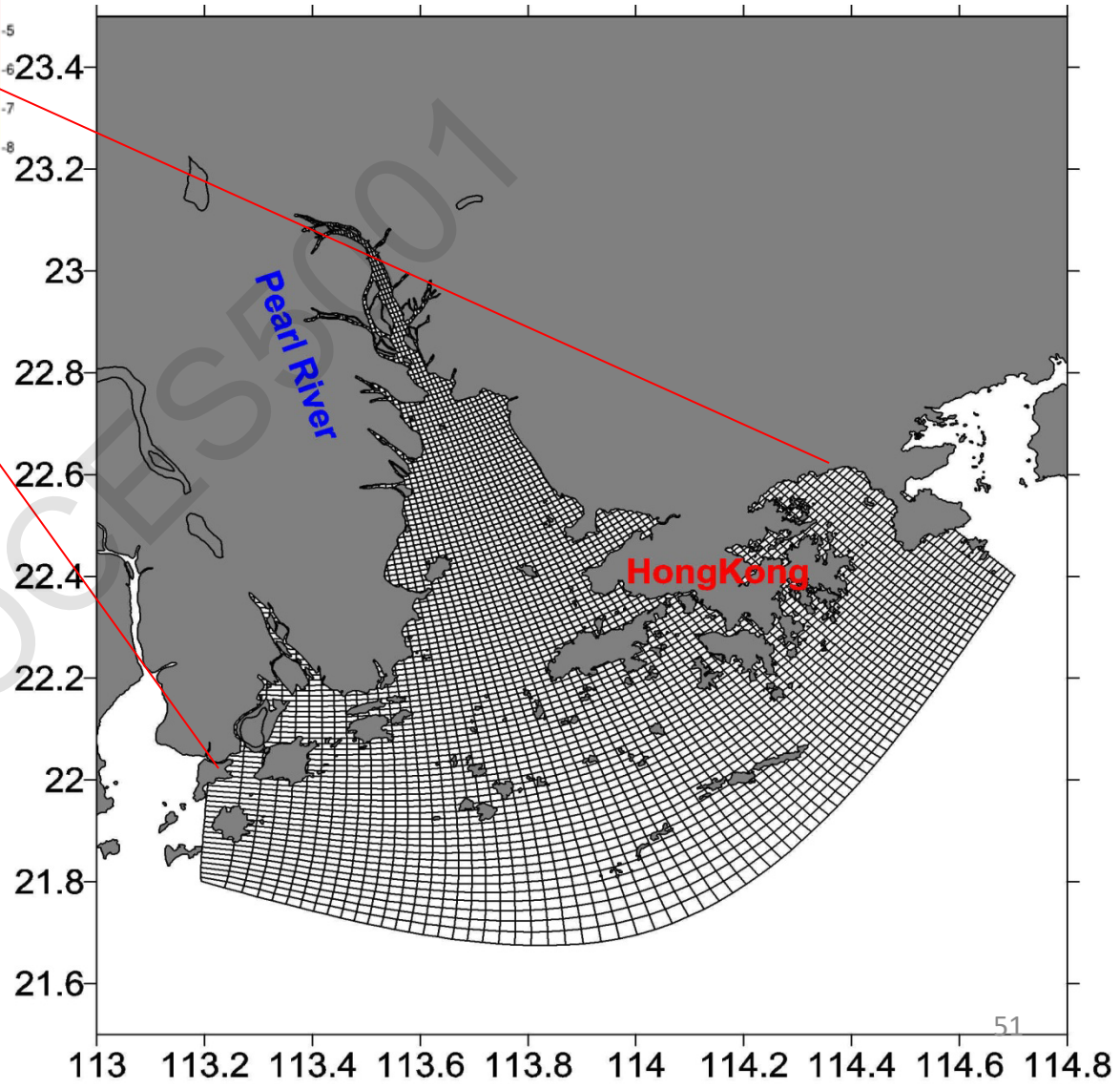
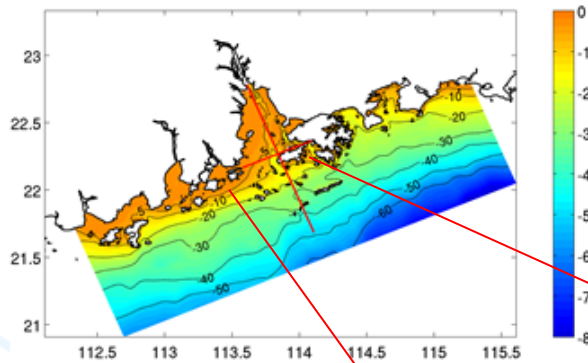
Estuary:

- 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

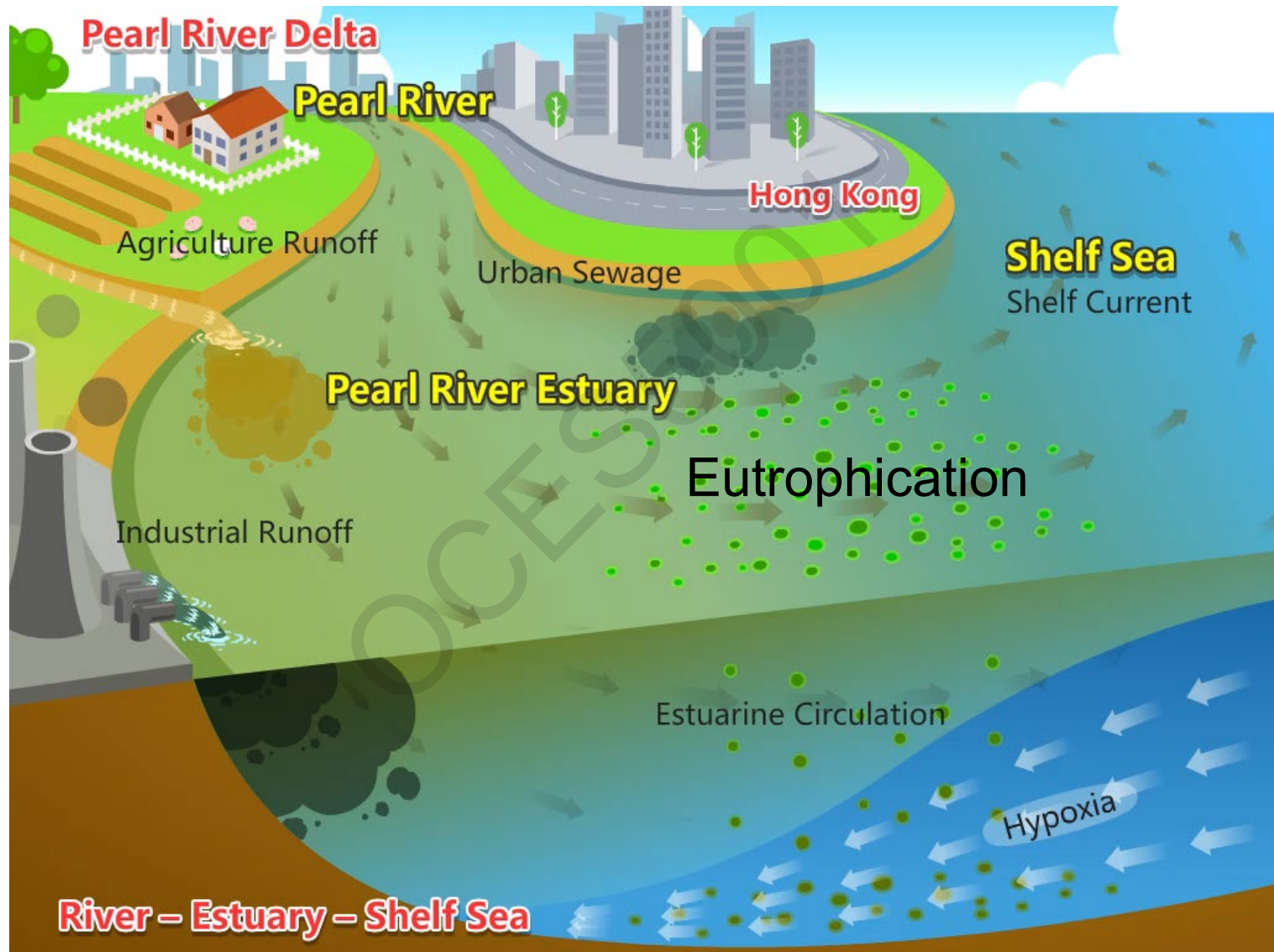
The Greater Bay Ocean

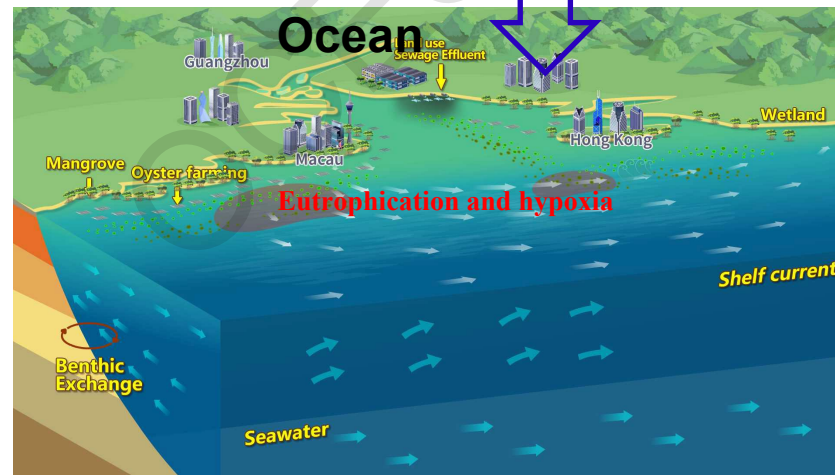
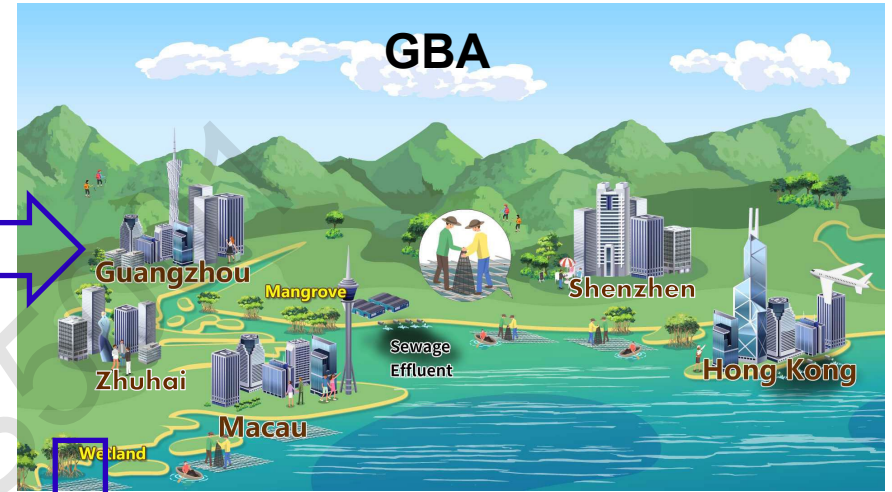


Pearl River Estuary

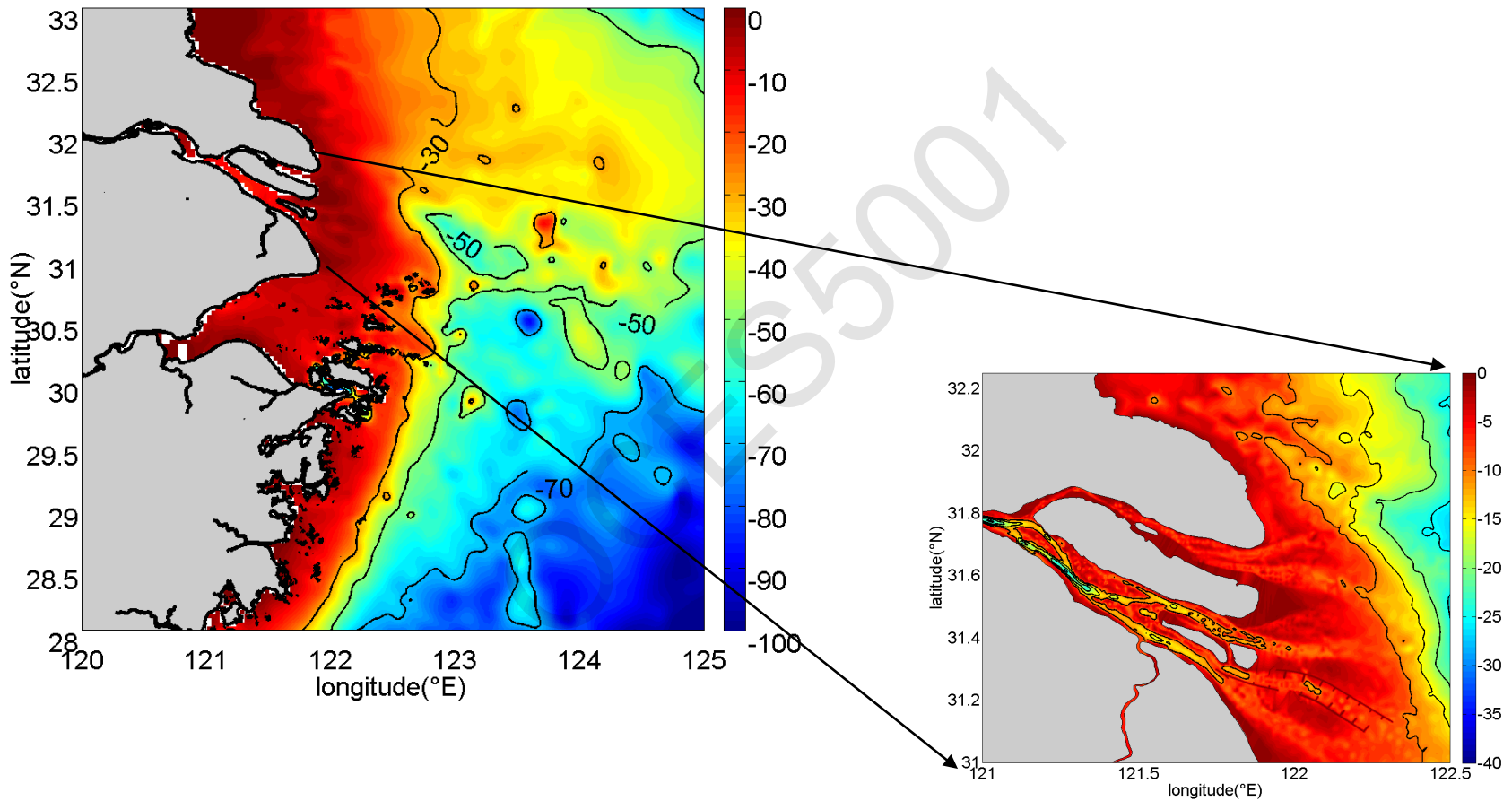


The River, Estuary and Shelf Coupled system around Hong Kong





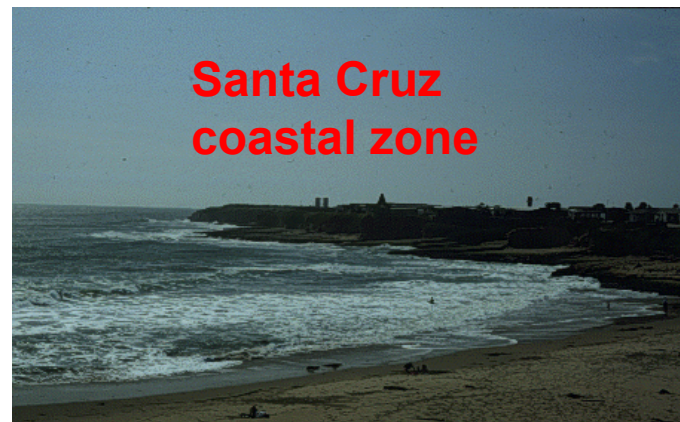
Changjiang Estuary and adjacent shelf



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

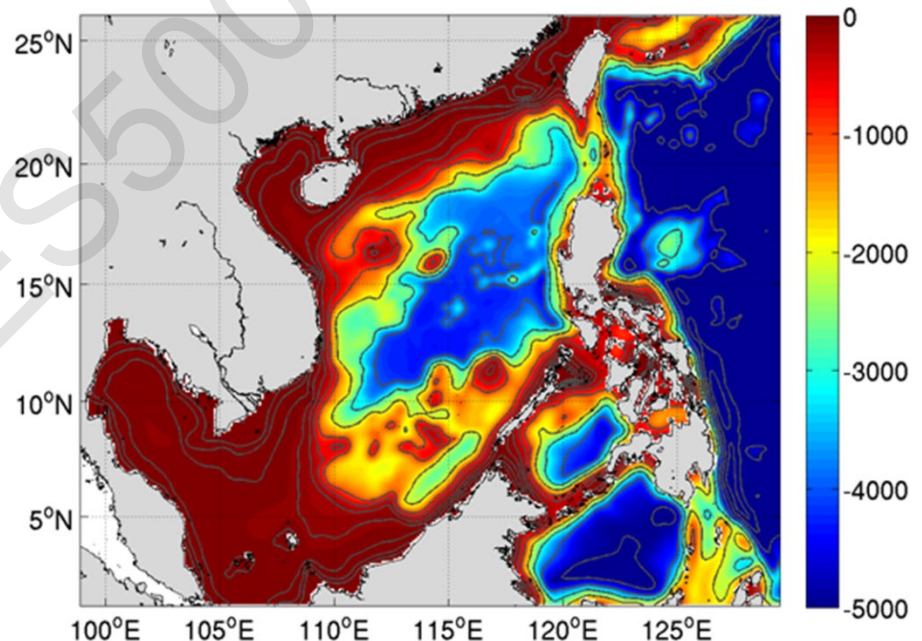


Marginal (Adjacent) Sea:

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

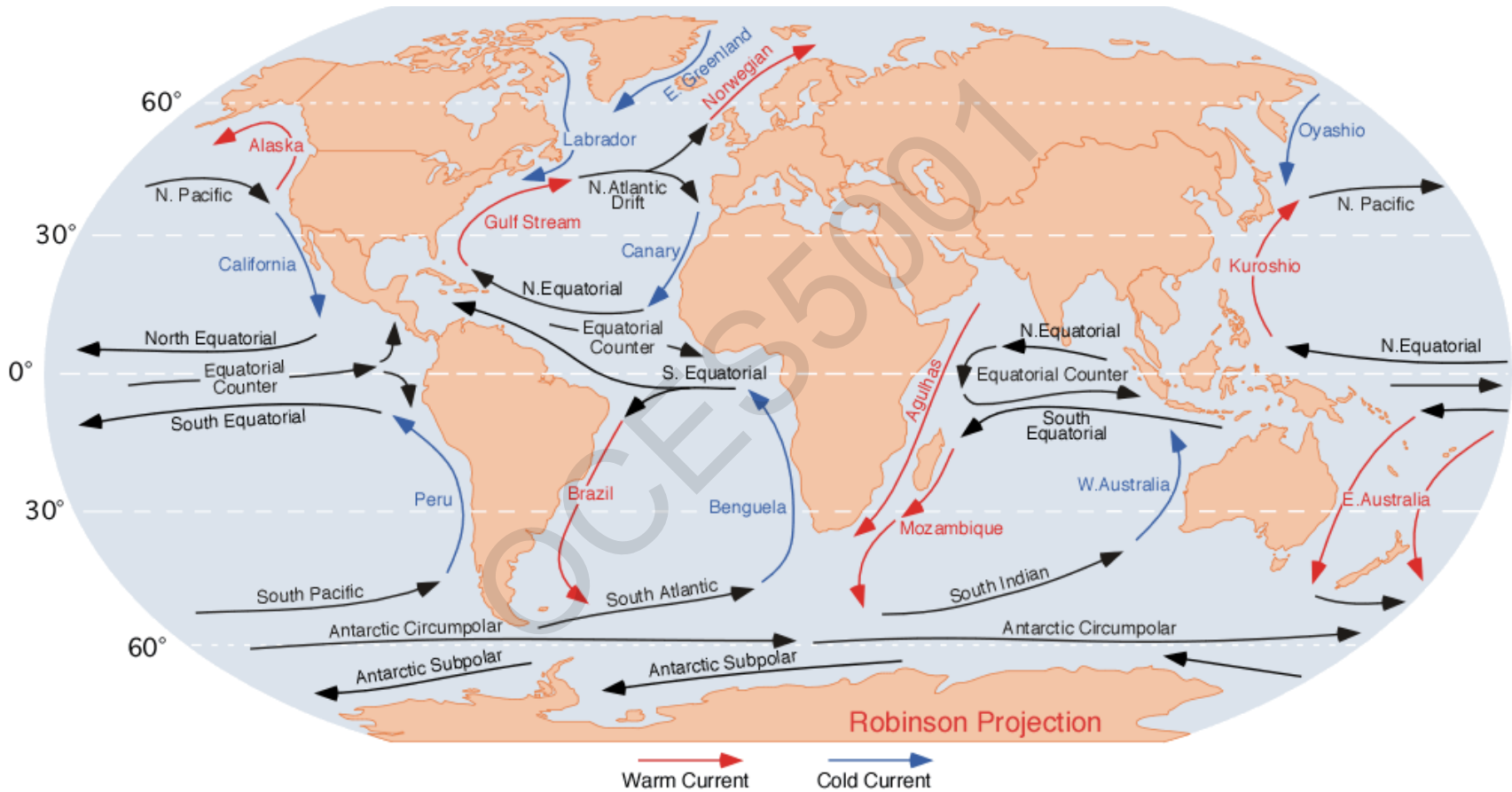


- 1.5 Inter-disciplinary and multi-scale oceanography

Physical Oceanography

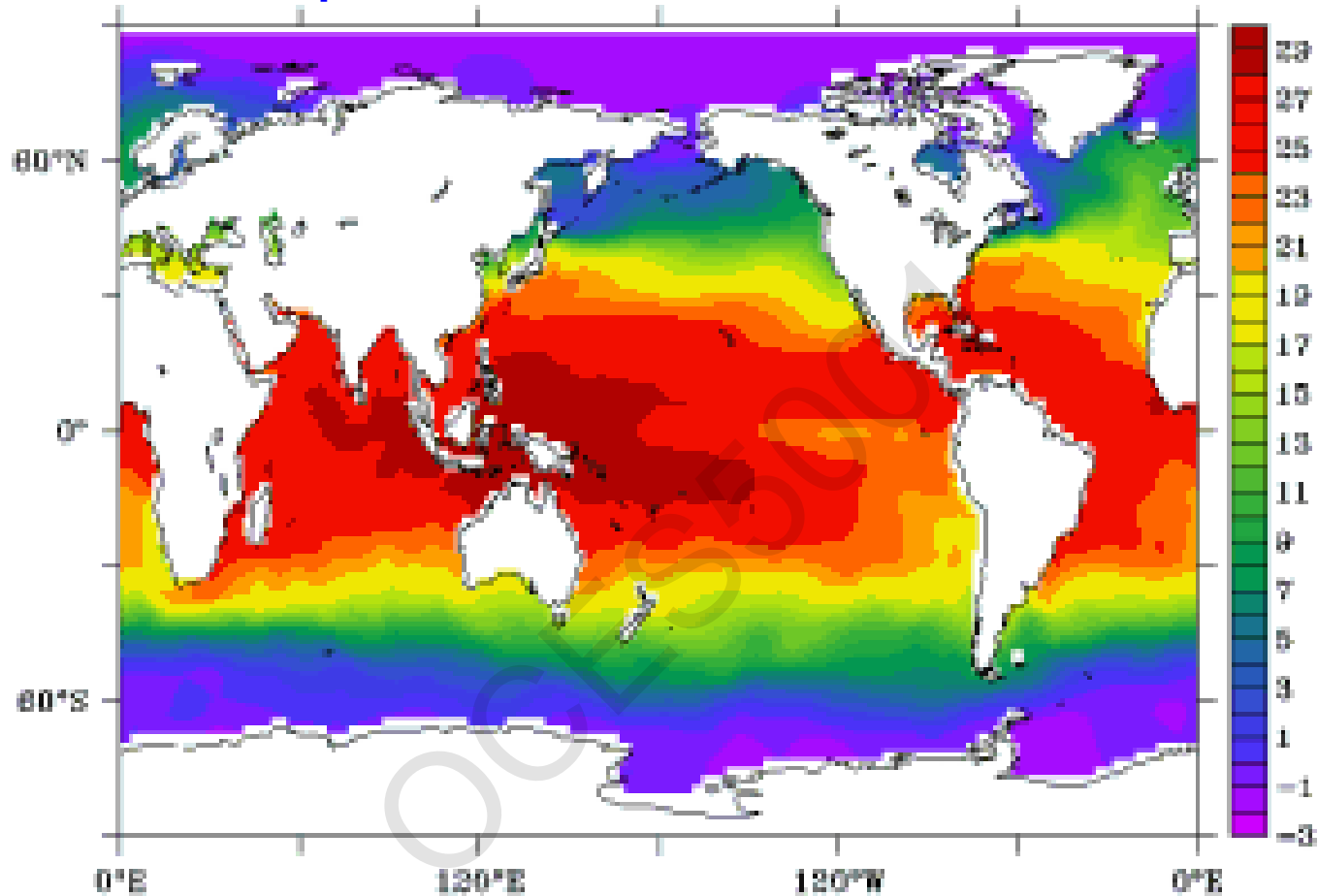
- Study physical properties and processes that control the ocean motion, e.g. ocean currents, waves, and geophysical fluid dynamics;
- Investigate the major forcing that transport momentum, heat, material, and biogeochemical substances in the ocean;

Global Ocean Circulation



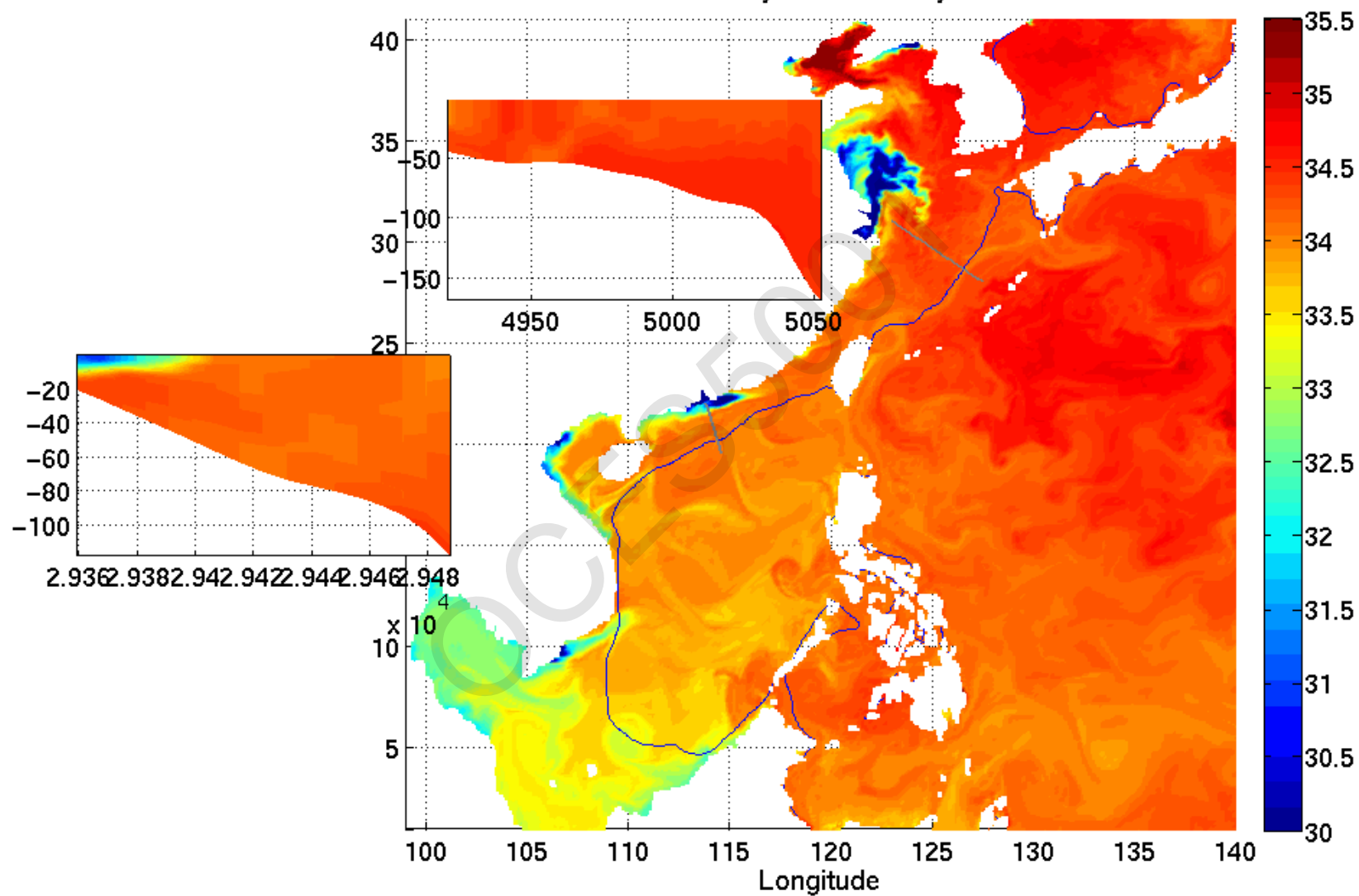
From Wikipedia

Variability of the western Pacific Warm pool in the Pacific Ocean

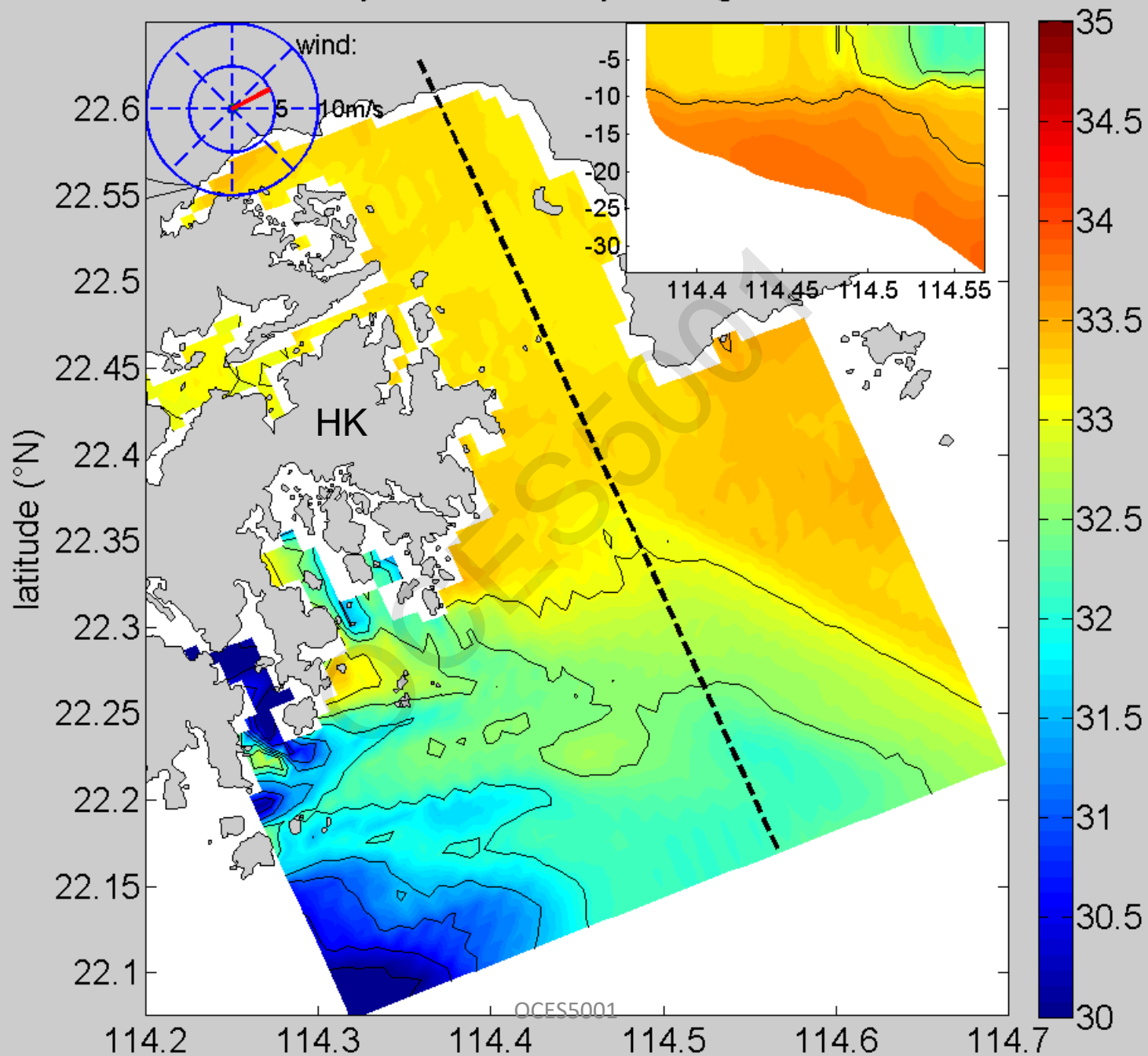


Sea surface temperature (SST) showing variability of the western Pacific Warm Pool in the Pacific Ocean. The Warm Pool and the variability greatly control the regional climate.

Surface salinity in June1 of cycle 2008

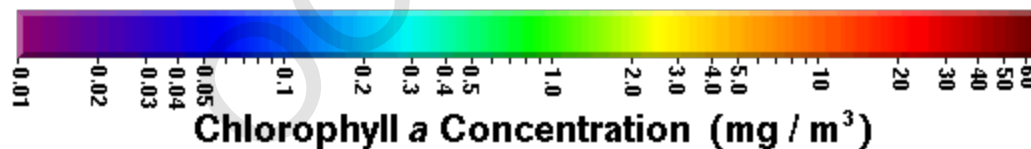
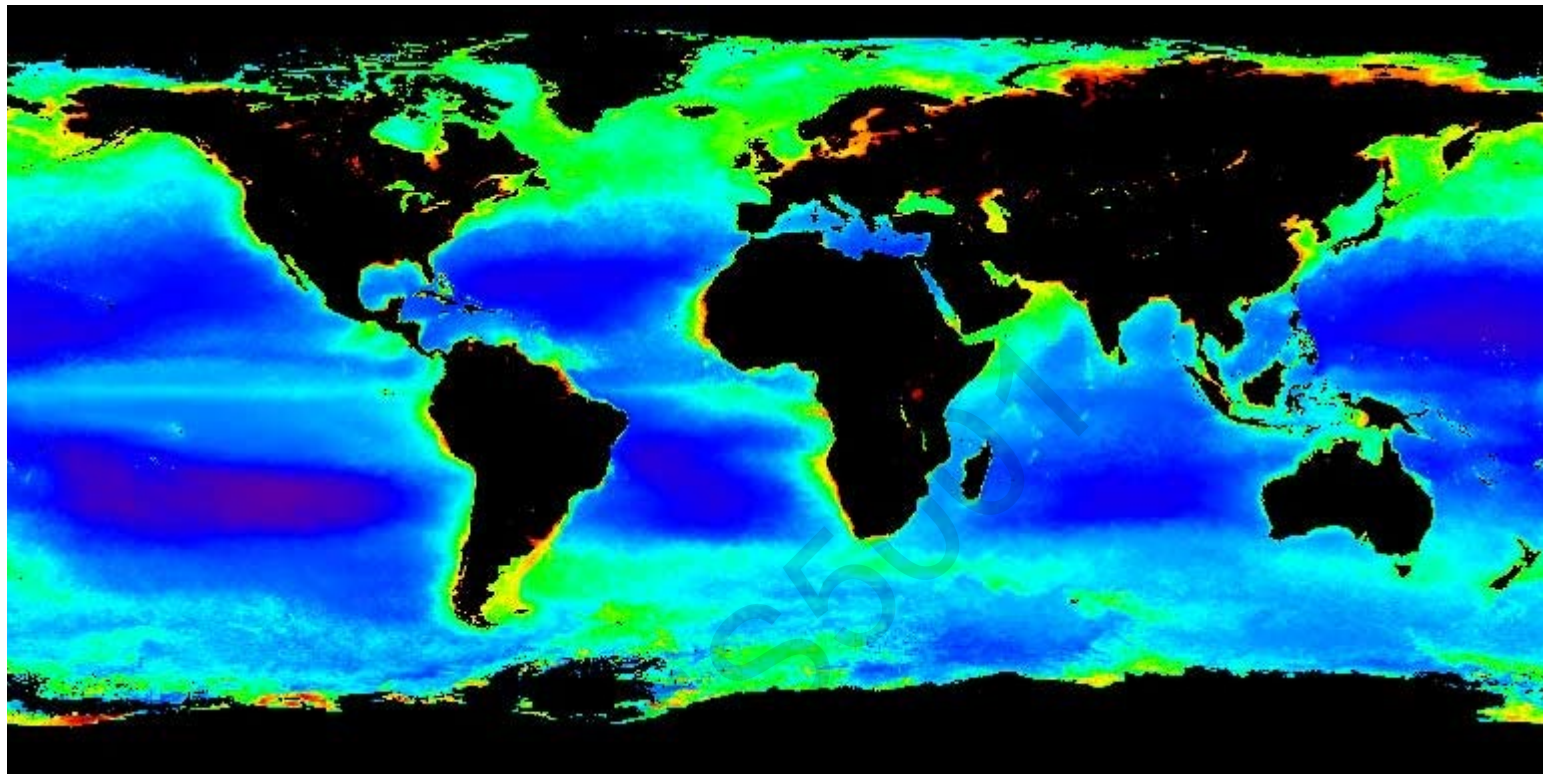


Surface Salinity of the Mirc Bay on Aug. 10 2000 00:00:00



Biological Oceanography

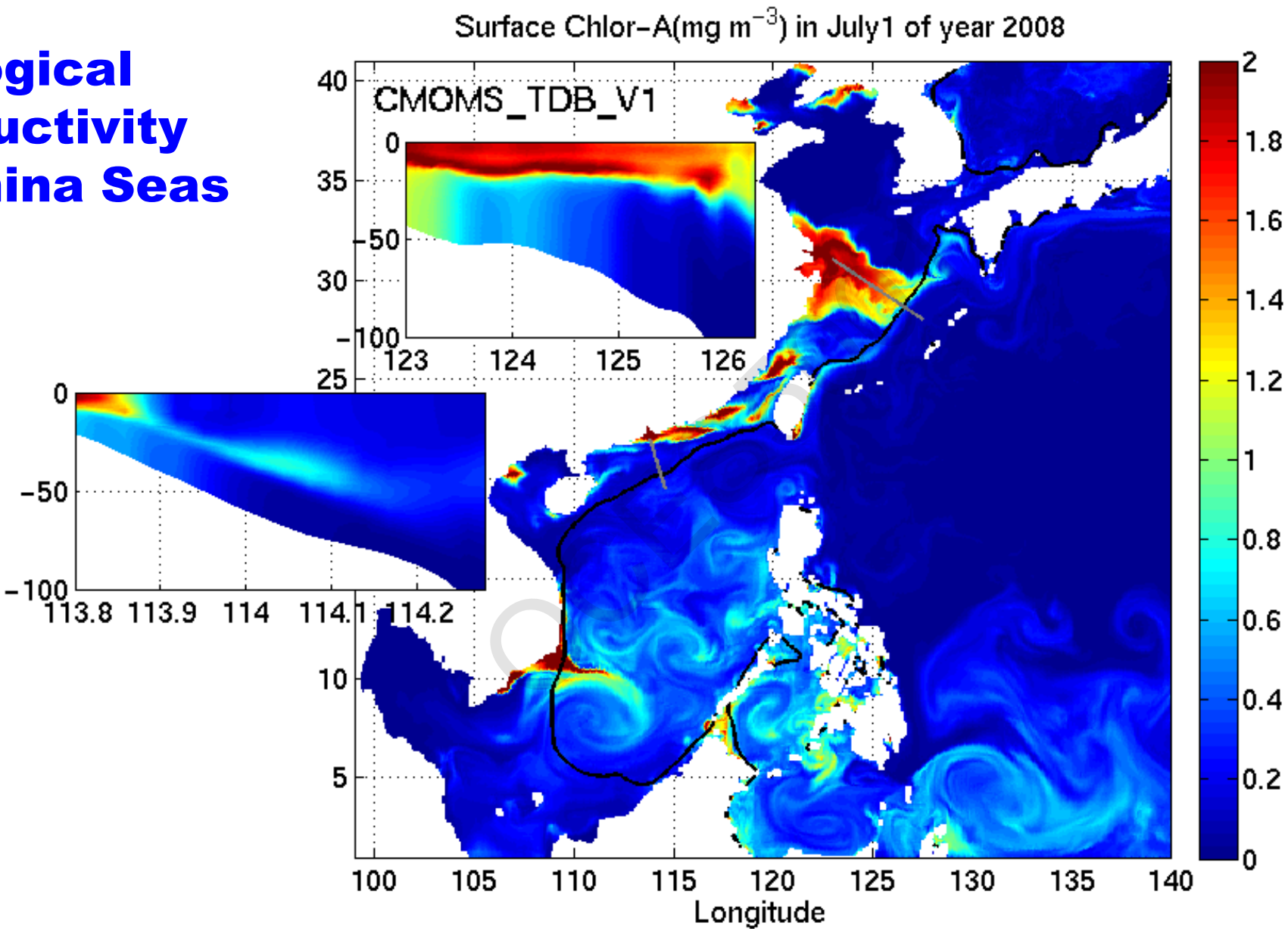
- Concerns the biology and ecology of oceanic, marine, coastal and estuarine organisms.
- The organism range from viruses and bacteria to microbes and phytoplankton, from zooplankton and benthic invertebrates to shellfish, fish and marine mammals.



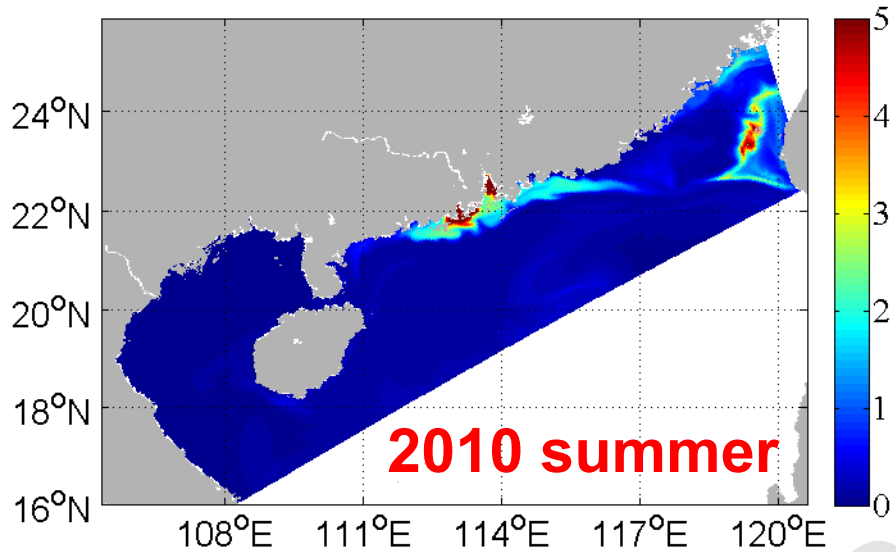
From NASA

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.

Biological Productivity in the Seas

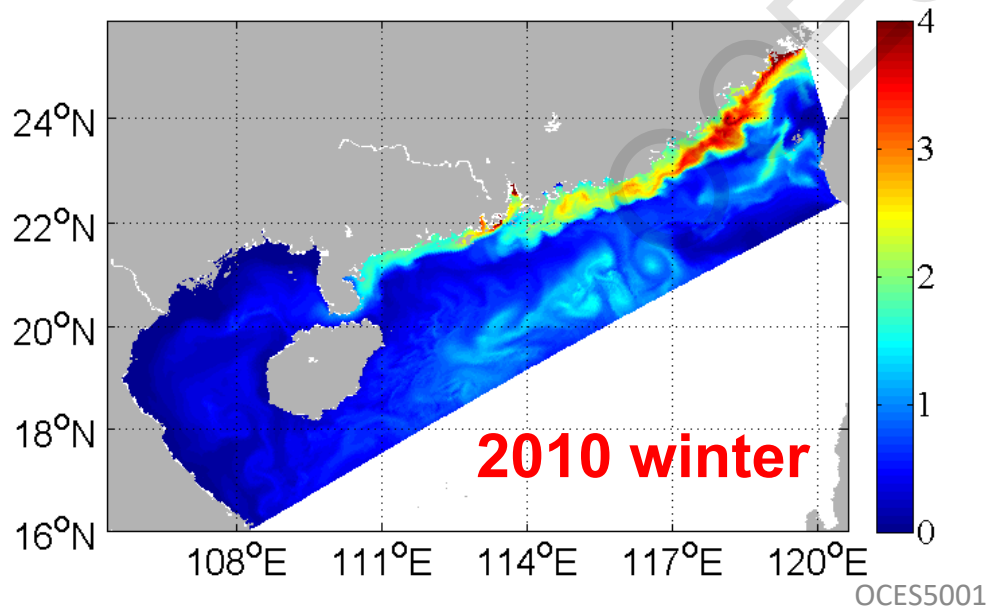


NSCS surface chl on 2010 Jun-01



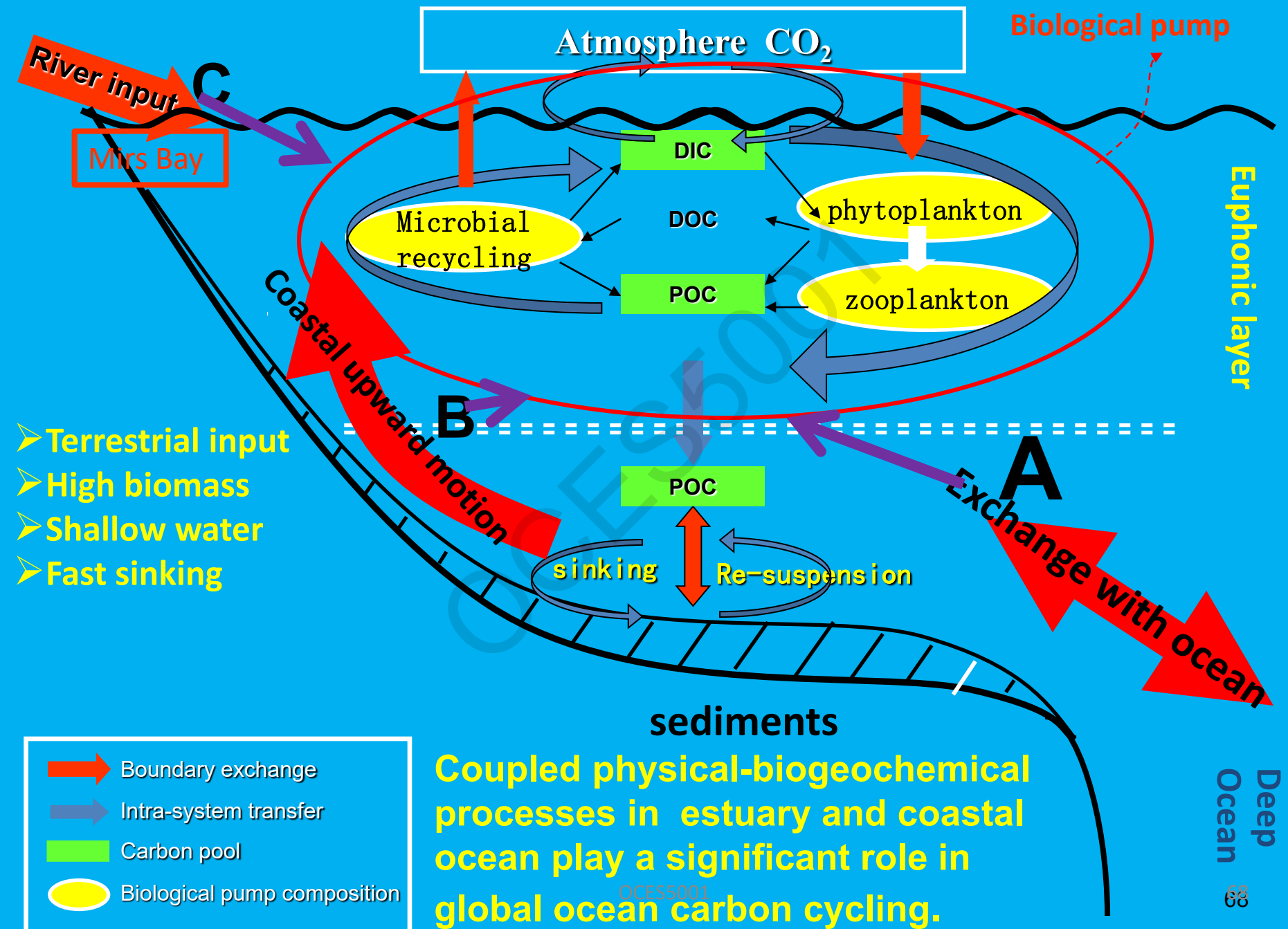
**Biological
productivity over
continental shelf in
the northern South
China Seas**

NSCS surface chl on 2010 Dec-01



Chemical oceanography:

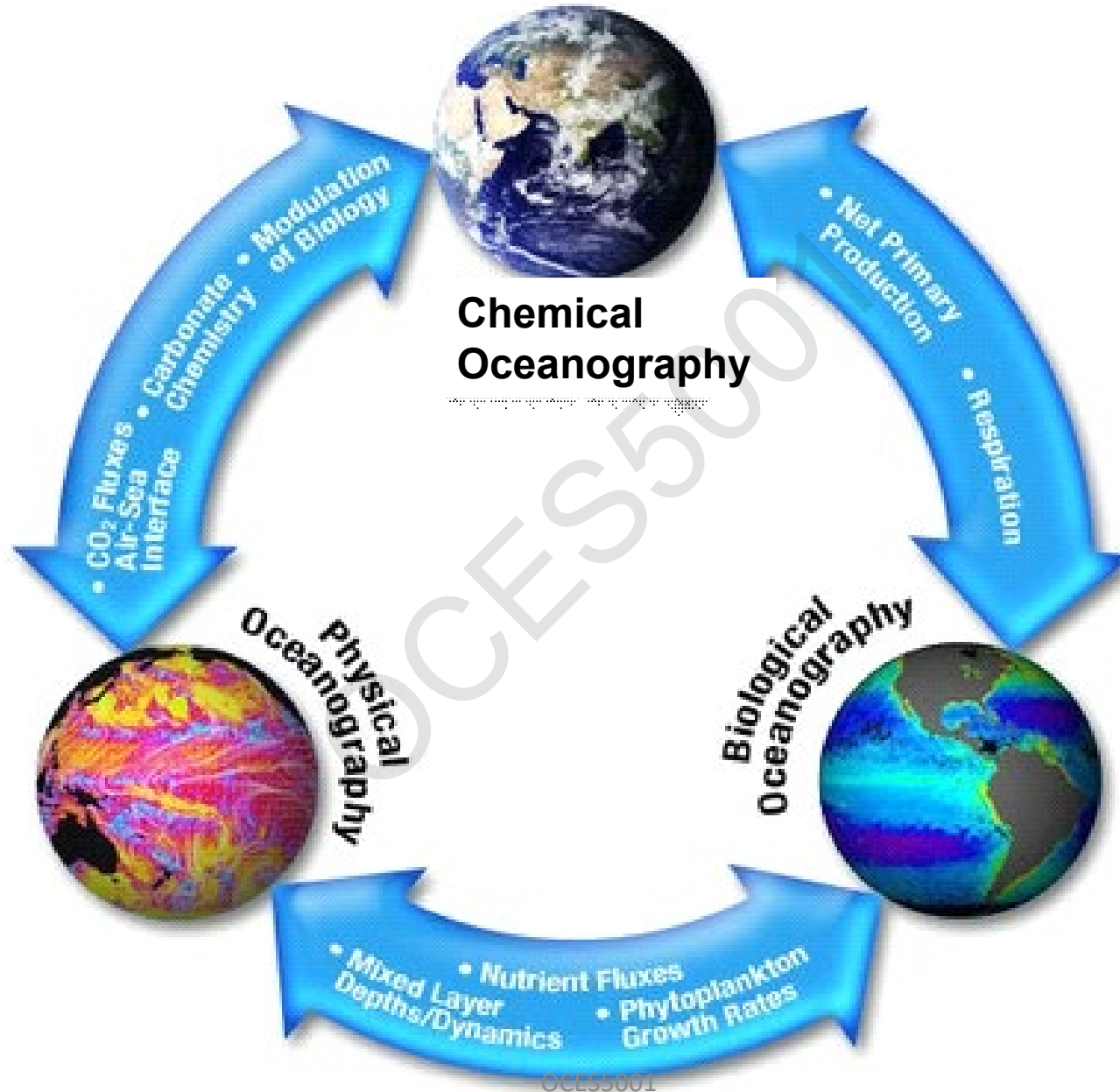
- The behavior of the ocean's dissolved solids and gases and their relationships to the geology and biological of the ocean as a whole.
- Cycling of these elements both within the ocean and with the other spheres of the Earth system



Geological Oceanography:

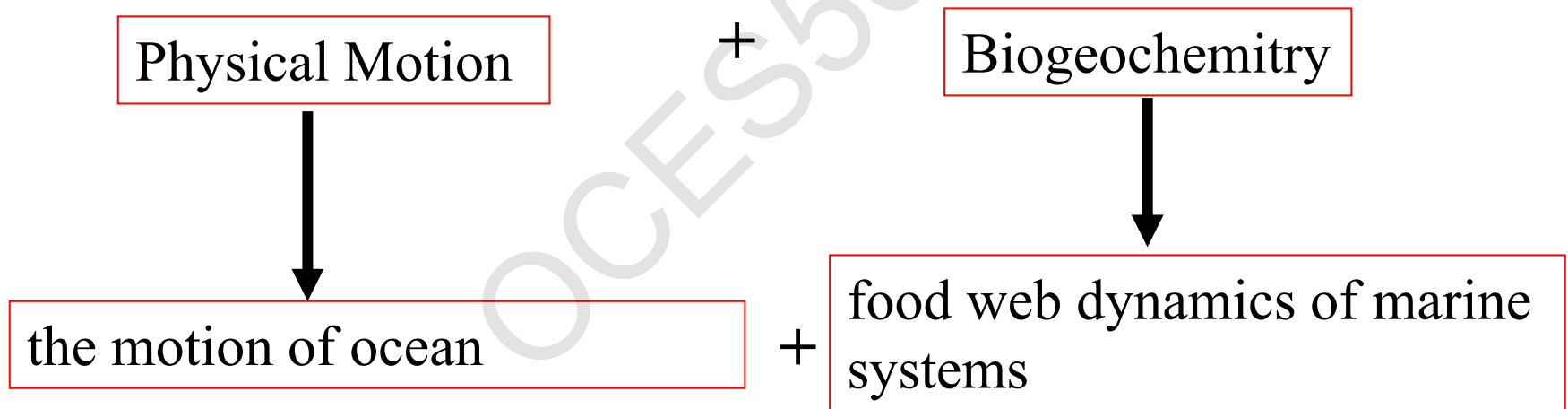
Study the composition of inner Earth, the mobility of the crust, topography, structure and geological processes of the ocean floor.

Interdisciplinary Oceanography

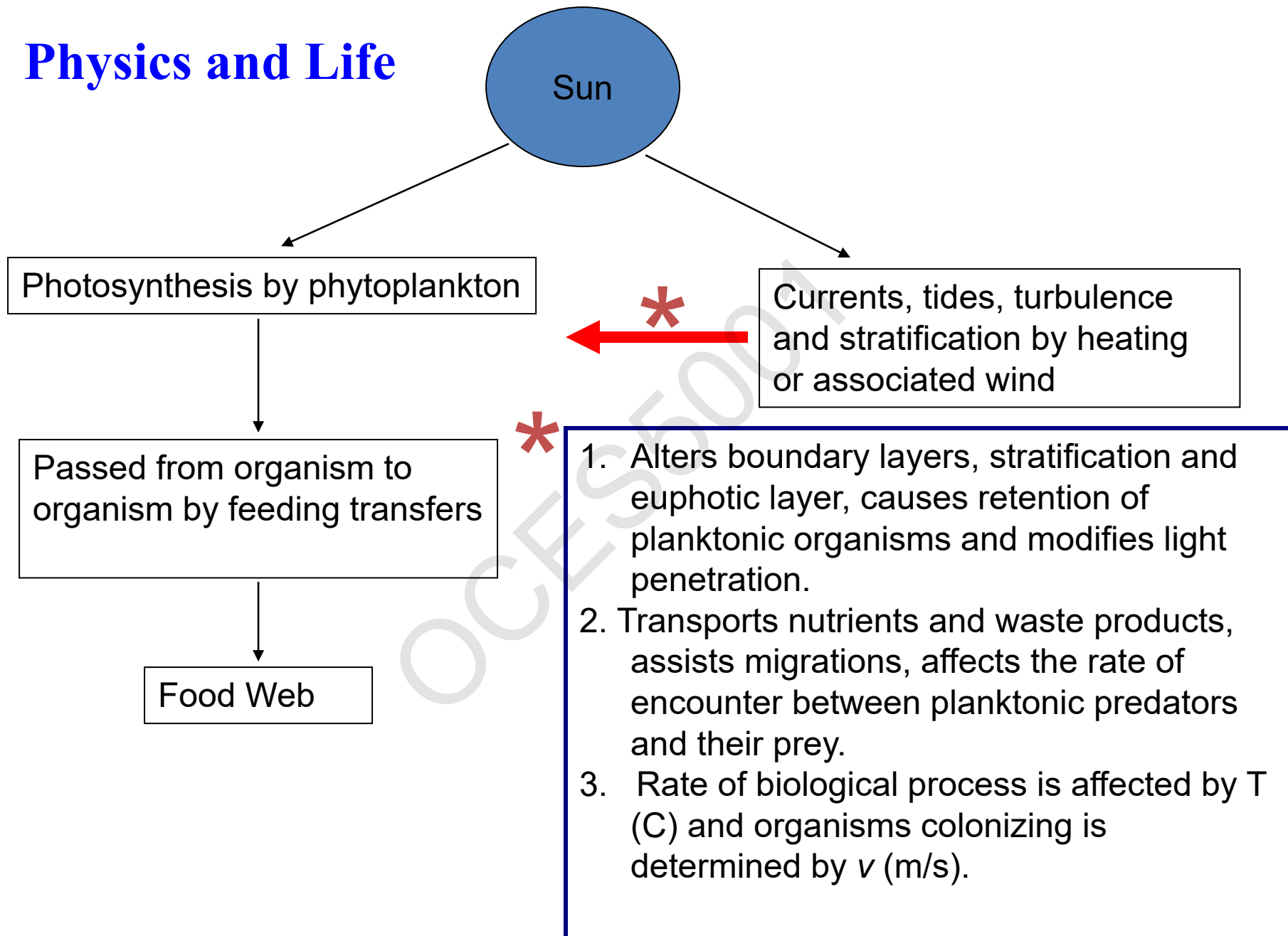


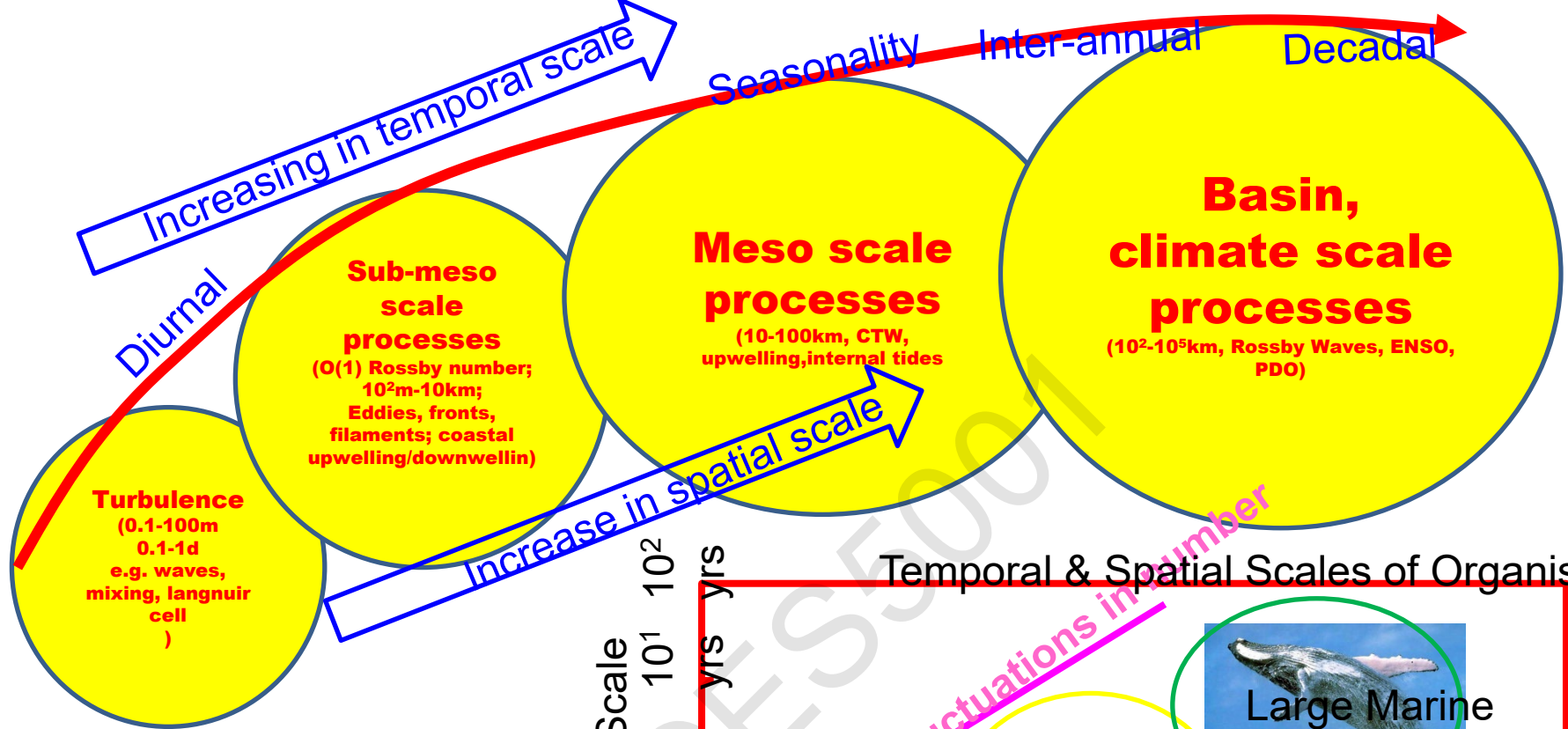
Ecosystem: Coupled Physical-Biogeochemical Oceanography

The Oceanography for the 21st Century

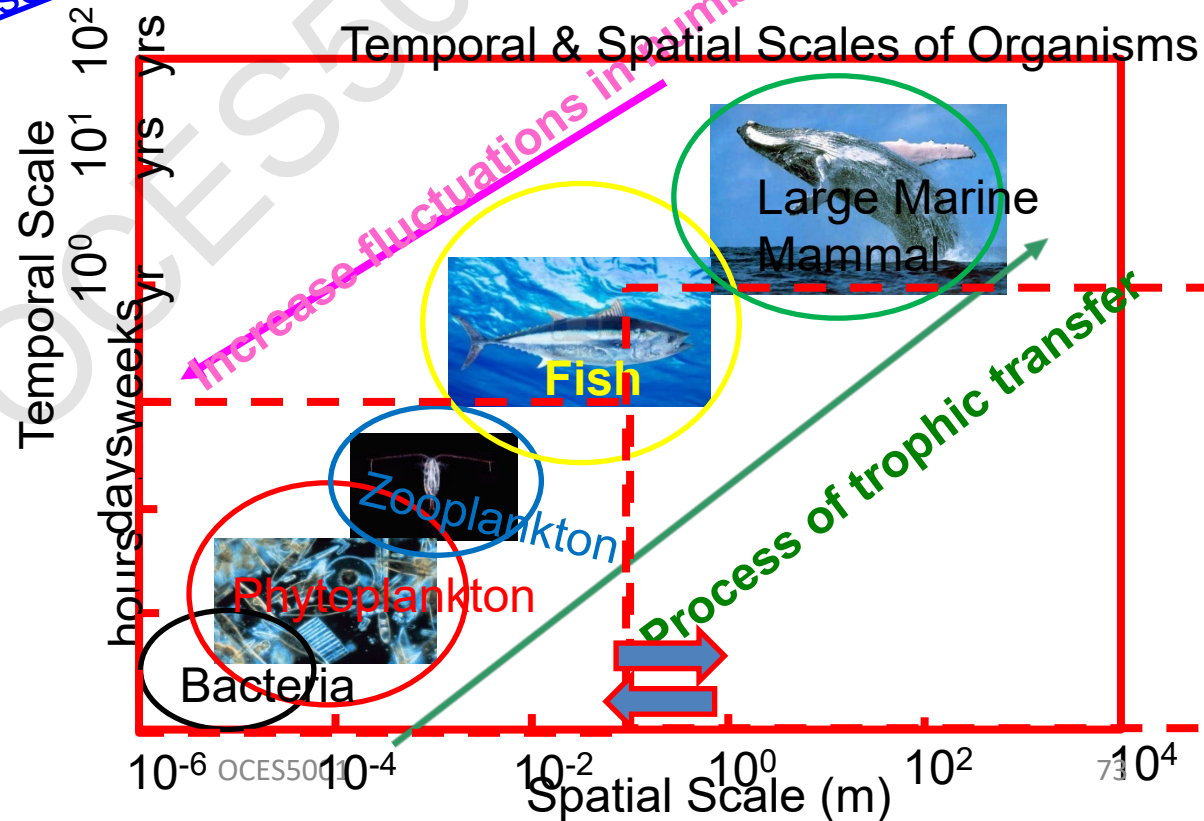


Physics and Life





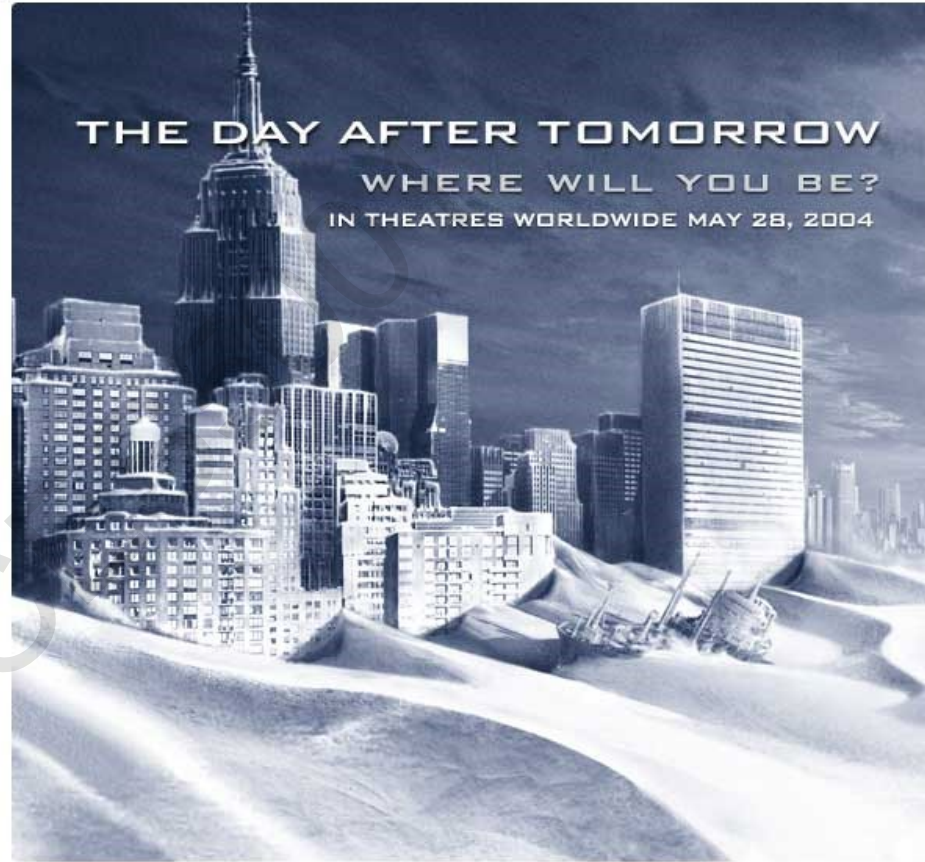
Multi-scale (in space and time), multi-discipline



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

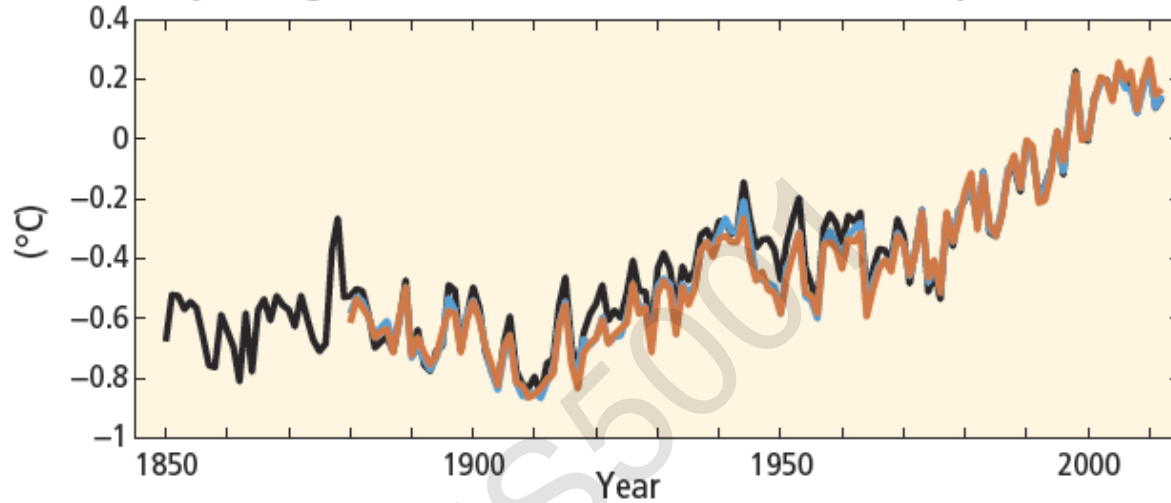
Slowing Gulf Stream current to boost warming for 20 years

BBC

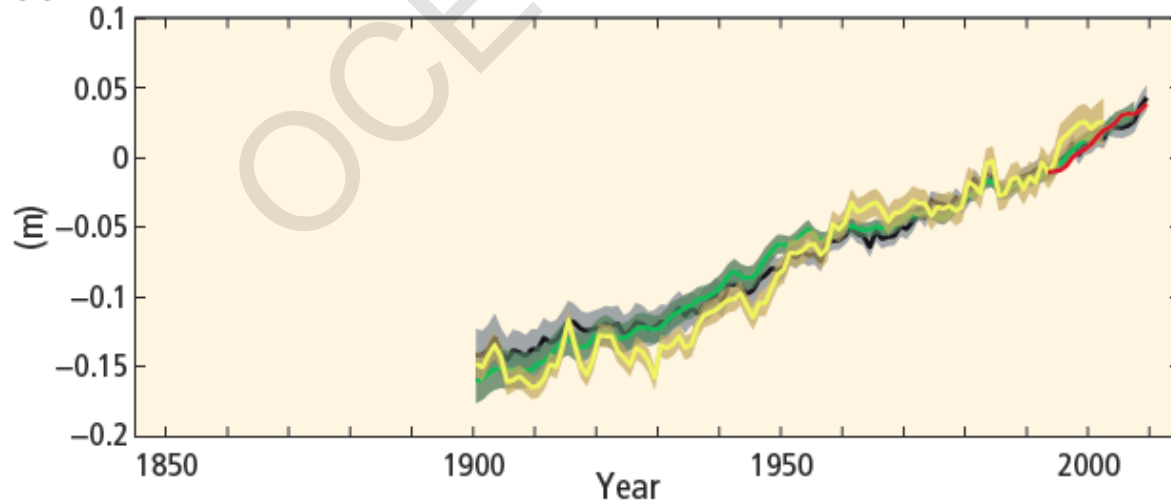
...

Changing trend of climate

(a) Globally averaged combined land and ocean surface temperature anomaly



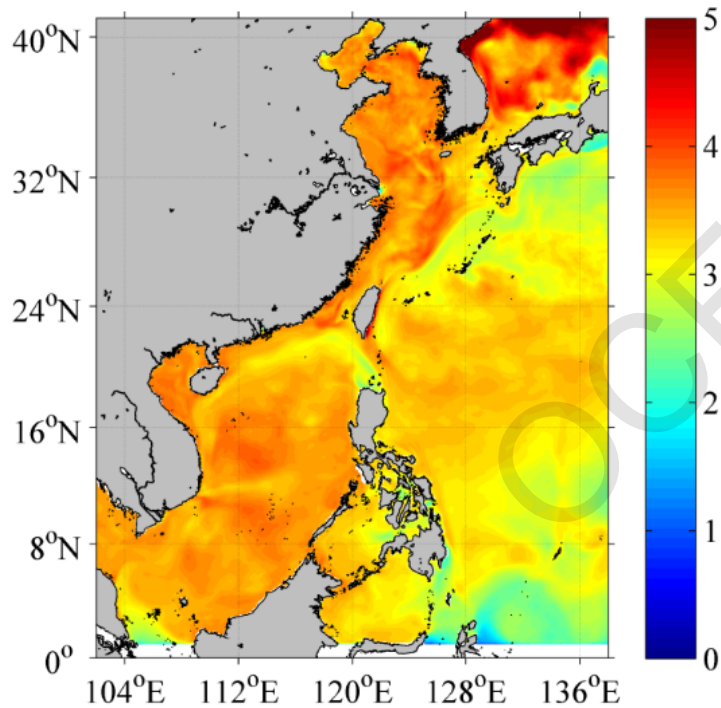
(b) Globally averaged sea level change



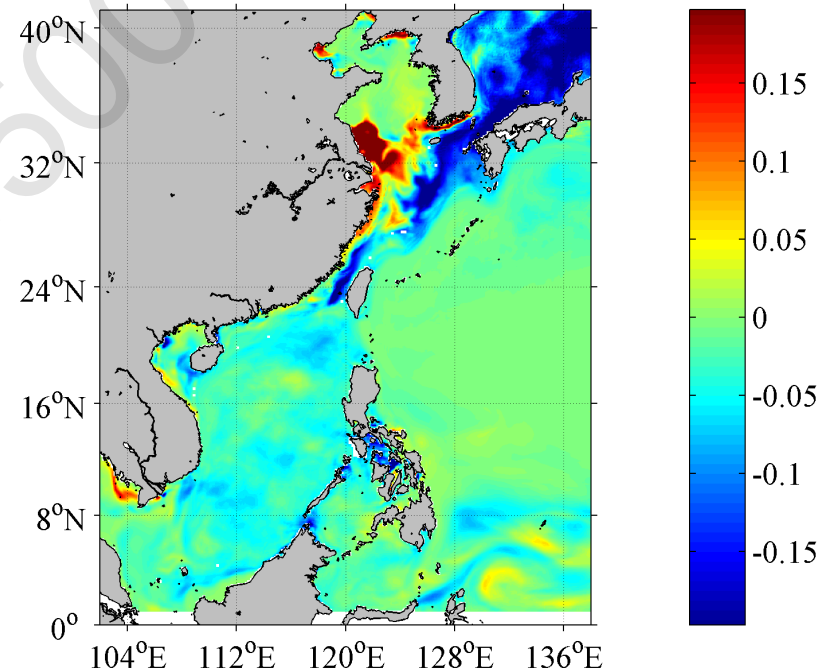
From IPCC

Net changes in China Seas from now to 2100

Sea Surface Temperature

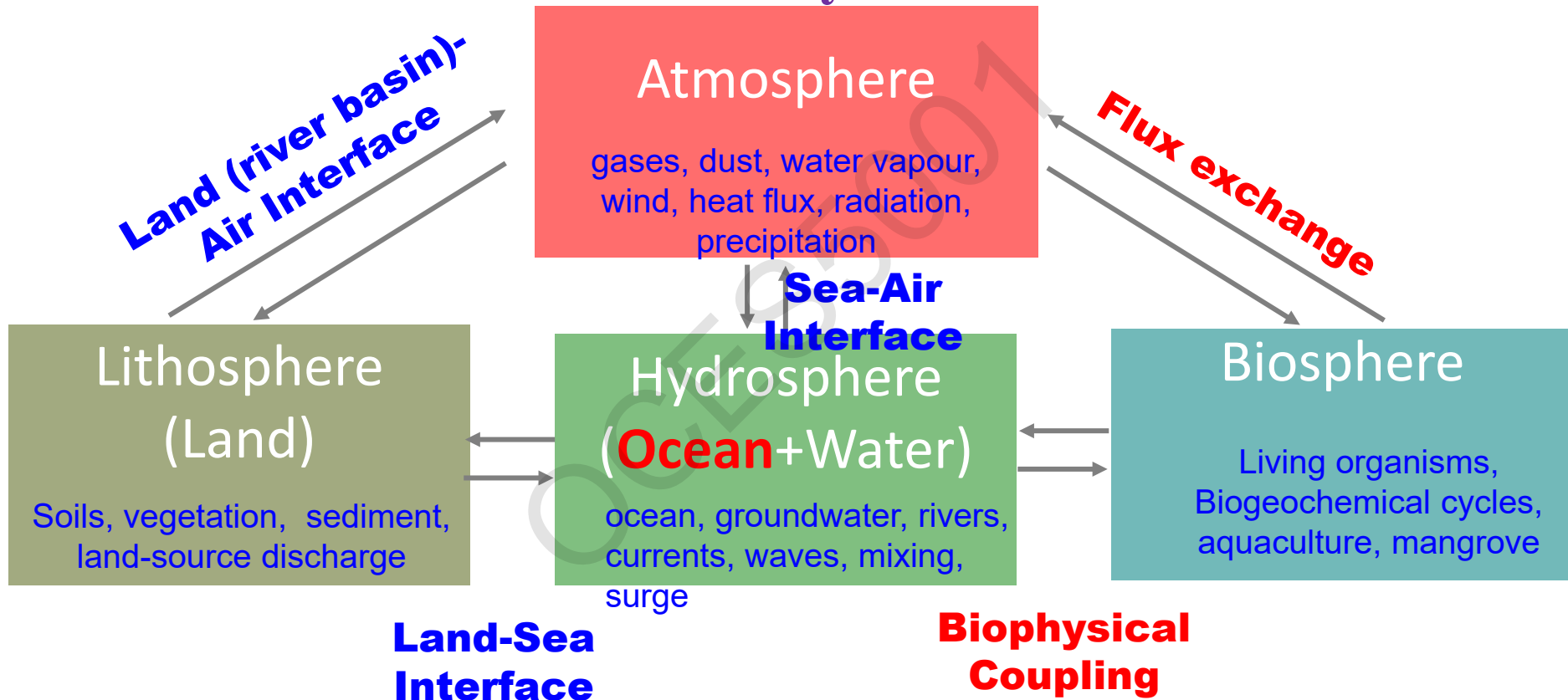


Biological Productivity



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

Hydrology

- Hydrodynamics
- Groundwater

Sedimentology

- Transport
- Deposition
- Lithification
- Soil science
- Geomorphology

Land-sea interaction

- Gas exchange
- Nutrient exchange

Oceanography

Earth Science

