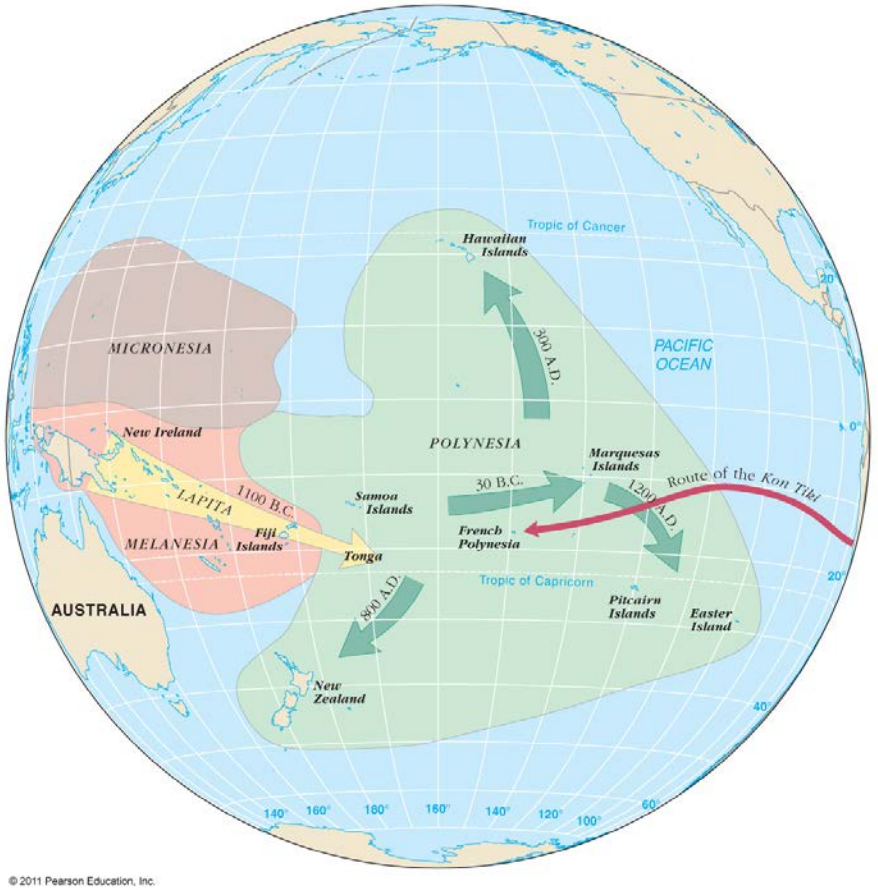
Lecture 2. Ocean Exploration

Early Exploration of the Oceans

- Early “explorers” used boats to seek new fishing grounds for food.
- The ocean facilitated trade and interaction between cultures.

Pacific Navigators

- The peopling of the Pacific Islands required extensive travel in open boats and exceptional navigation skills.
- It was difficult because islands are widely scattered.



Pacific People

- No written records exist of Pacific human history before the 16th Century.
- Archeological evidence suggests island occupation by people from New Guinea as early as 4000–5000 B.C.
- Thor Heyerdahl sailed on a balsa raft in 1947 – the *Kon Tiki* – to demonstrate migration of South Americans to Pacific Ocean islands.

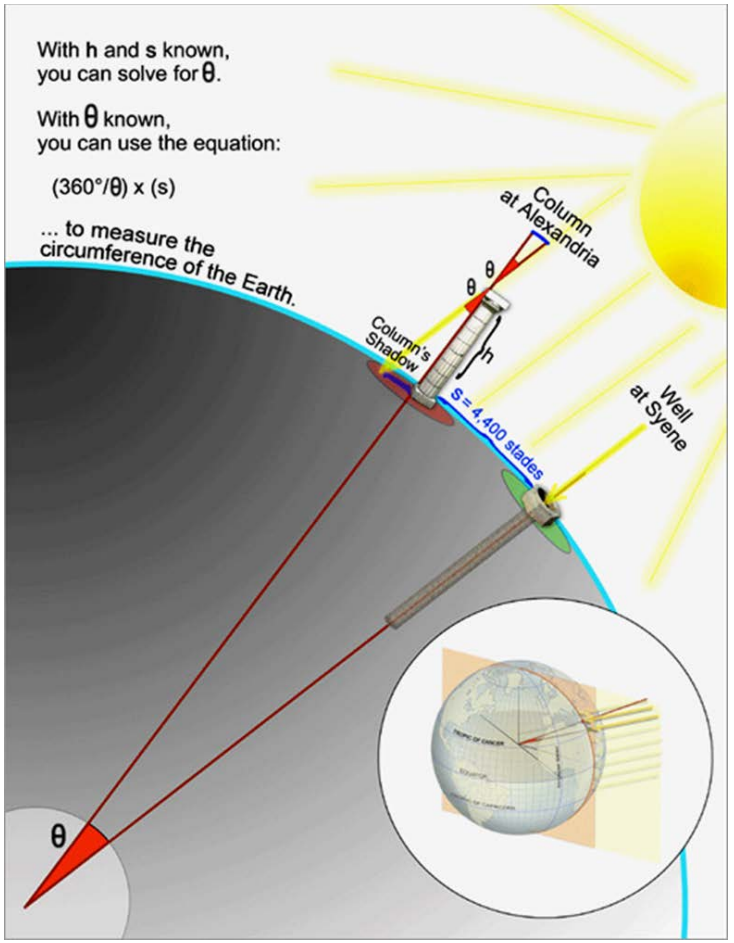
European Navigators

- Phoenecians – first from Western Hemisphere to develop navigation arts
  - Navigated circa 2000 B.C.
  - Explored Mediterranean Sea, Red Sea, and Indian Ocean
  - First circumnavigation of Africa
  - Reached the British Isles

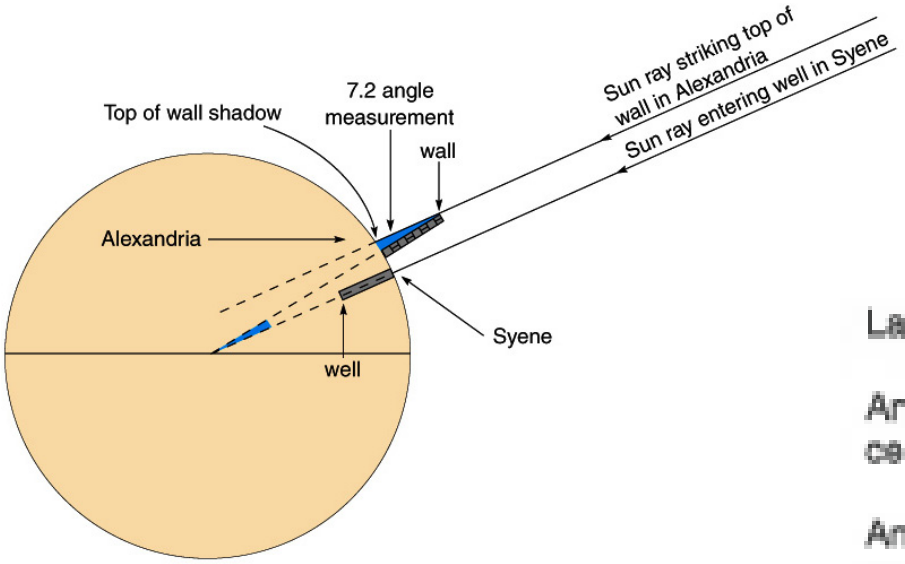
European Navigators

- Greek Pytheas
  - Sailed northward using a simple method to determine latitude in 325 B.C.
  - Navigated using the North Star
- Eratosthenes determined Earth's circumference fairly accurately.

1 stade = about 600 feet



Eratosthenes circumference (circa 250 B.C.)



$$\frac{\text{angle of the sun}}{360^0} = \frac{\text{distance to Tropic of Cancer}}{Earth\ \ circumference}$$

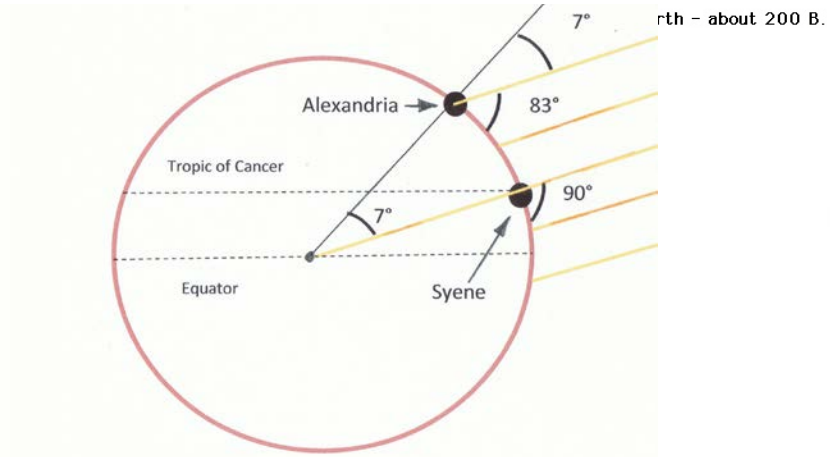
Land distance between Alexandria and Syene = 800 km (500 mi)

Angle formed by lines dropped from Alexandria and Syene to center of the earth = 7.2°

An angle of 7.2° with its vertex at the center of Earth cuts an arc of 800 km on Earth's surface. Thus:

$$\frac{7.2^\circ}{800 \text{ km (500 mi)}} = \frac{360^\circ}{\text{Circumference of Earth}}$$

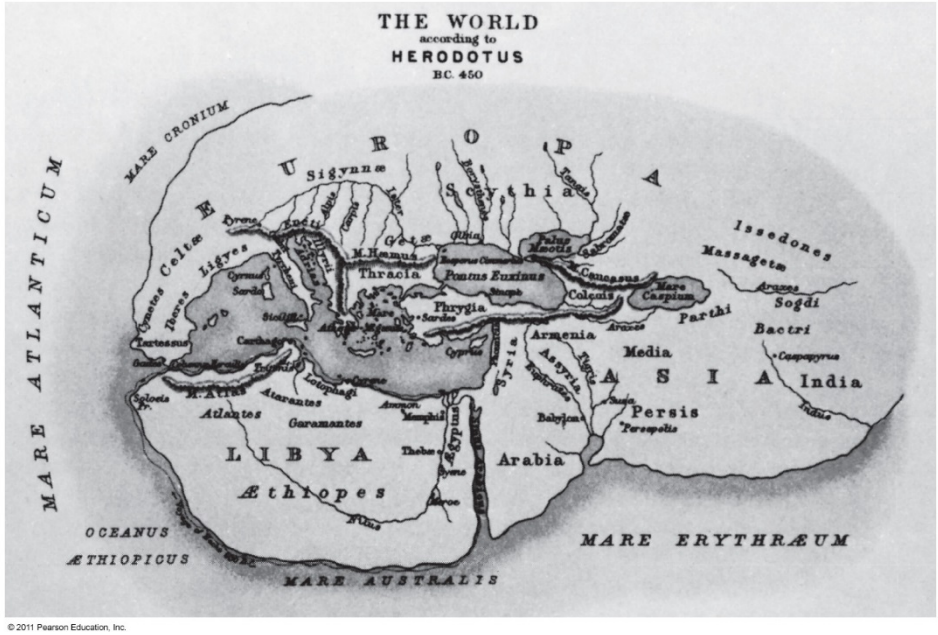
Circumference of Earth = 40,000 km (24,855 mi)
Value known today = 40,032 km (24,875 mi)



rth – about 200 B.

Europeans

- Herodotus produced inaccurate world map around 450 B.C.



Why “Earth”?

It seems perplexing that our planet is called “Earth” when 70.8% of its surface is covered by oceans. Many early human cultures that lived near the Mediterranean (*medi* = middle, *terra* = land) Sea envisioned the world as composed of large landmasses surrounded by marginal bodies of water (Figure 1–1). How surprised they must have been when they ventured into the larger oceans of the world. Our planet is misnamed “Earth” because we live on the land portion of the planet. If we were marine animals, our planet would probably be called “Ocean,” “Water,” “Hydro,” “Aqua,” or even “Oceanus,” to indicate the prominence of Earth’s oceans.

Ecumene – the inhabited world

Claudius Ptolomy produced fairly accurate world map around 150 A.D.

Erroneously updated Eratosthenes' original circumference estimation, later causing Christopher Columbus to believe he had reached Asia

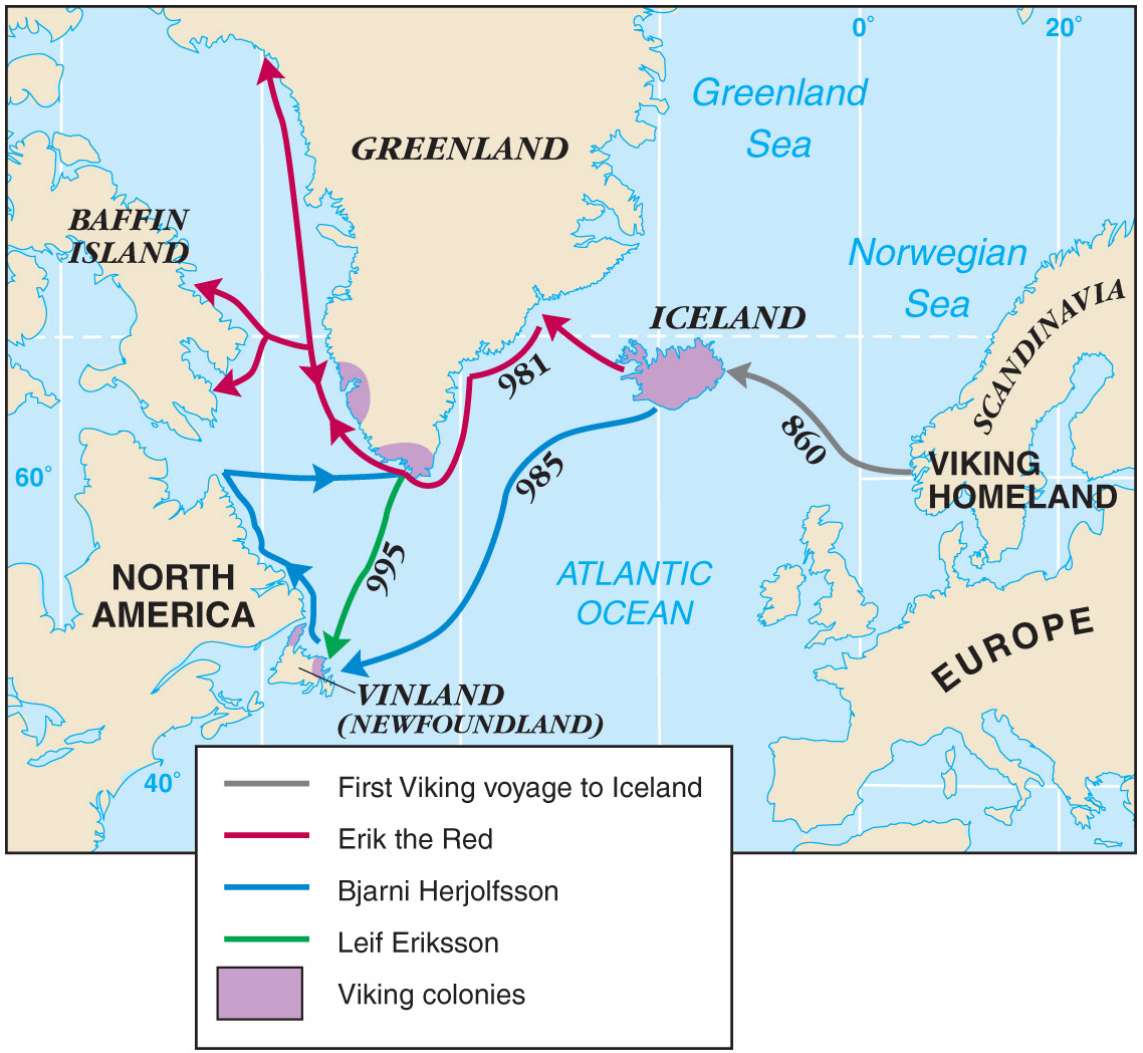
The Middle Ages

- Arabs dominant navigators in the Mediterranean Sea
- Traded extensively with East Africa, India, and Southeast Asia
- Learned to use Indian Ocean monsoon winds for travel

The Middle Ages

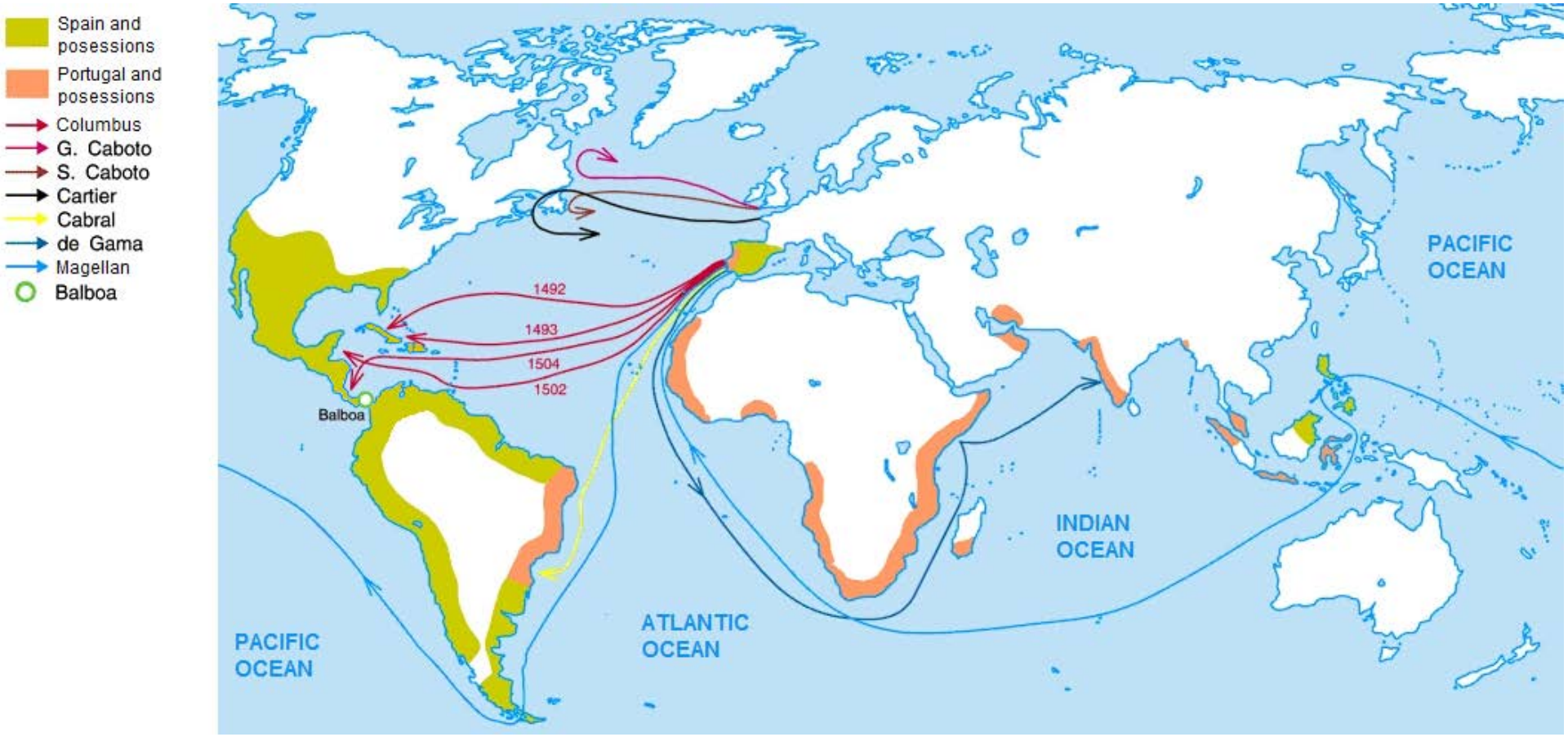
- Vikings explored North Atlantic Ocean
  - Settled Iceland and Greenland in 9th and 10th centuries A.D.
  - Leif Eriksson designated part of eastern Canada Vinland (now Newfoundland) in 995 A.D.
  - Greenland, Vinland settlements abandoned by 1450 A.D. due to climatic cooling

Viking Routes and Colonies



The Age of Discovery in Europe 1492–1522

The Europeans explored the continents of North and South America, and the globe was circumnavigated for the first time



The Age of Discovery in Europe 1492–1522

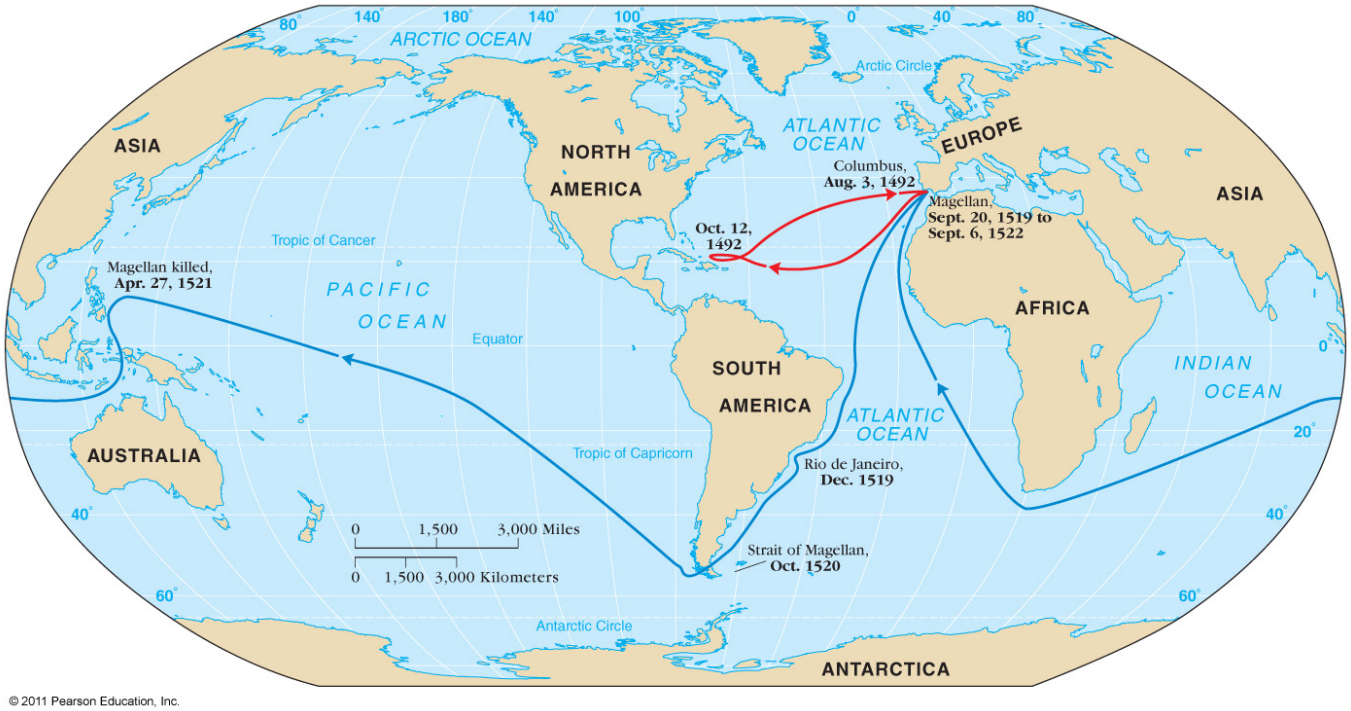
- Search for new Eastern trade routes by sea
  - Prince Henry the Navigator of Portugal sought trade routes around Africa.
  - Europeans explore North and South America
    - Christopher Columbus was financed by the Spanish to find new trade routes to Asia.
    - Englishman John Cabot arrived in northeast North America in 1497.

outside Europe. The prince established a marine institution at Sagres to improve Portuguese sailing skills. The treacherous journey around the tip of Africa was a great obstacle to an alternative trade route. Cape Agulhas (at the southern tip of Africa) was first rounded by **Bartholomeu Diaz** in 1486. He was followed in 1498 by **Vasco da Gama**, who continued around the tip of Africa to India, thus establishing a new Eastern trade route to Asia.

The Age of Discovery in Europe 1492–1522

- Spaniard Ferdinand Magellan circumnavigated the globe.
  - Was killed on a Pacific Island in 1521
- Juan Sebastian del Caño completed the circumnavigation in 1522.
- Voyages paved the way for the Spanish to take gold from the Incas and Mayas.
- Spain's maritime dominance ended when England defeated the Spanish Armada [ahr-**mah**-duh, -mey-] in 1588. – by Sir Francis Drake

Voyages of Columbus and Magellan



The Tropic of Cancer, also referred to as the Northern Tropic, is the most northerly circle of latitude on the Earth at which the Sun may appear directly overhead at its culmination.

Tropic of Capricorn is the southern hemisphere counterpart.

Voyaging for Science

- The English wanted to retain maritime superiority.
- Captain James Cook (1728 – 1779) undertook three scientific voyages.
  - Ships HMS *Endeavour, Resolution, Adventure*
  - Mapped many islands in Pacific
  - Systematically measured ocean characteristics
  - Marine chronograph (longitude)

Cook's Voyages

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Who discovered the Antarctic?

- The first landing was probably in 1821 when American Captain John Davis, a sealer, set foot on the ice.
- Several expeditions attempted to reach the South Pole in the early 20th century, during the 'Heroic Age of Antarctic Exploration'. Many resulted in injury and death. Norwegian Roald Amundsen finally reached the Pole on December 14, 1911, following a dramatic race with the Englishman Robert Falcon Scott.

Figure 1–12 The Ross Expedition in Antarctica (circa 1840).

Based on marine life brought up by dredges in Baffin Bay, Canada (by Sir John Ross in 1817–1818) and off Antarctica (by Sir James Clark Ross in 1839–1843), Sir James concluded that life existed at all levels in the ocean, including the deep-ocean floor.

Other key milestones in Oceanography

1770's: Ben Franklin refers to Gulf Stream as "river in the ocean"

1830's: Darwin's HMS Beagle expedition

1847: Maury & Prince Albert of Monaco generate first maps of ocean winds and currents

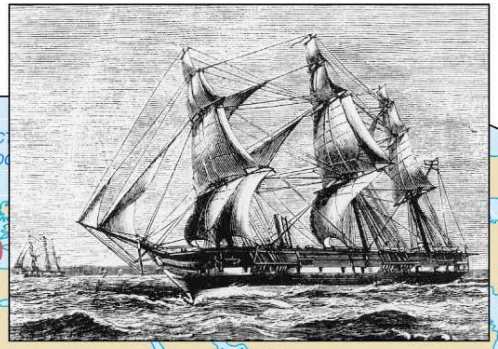
1830's: Darwin's HMS Beagle expedition

http://www.nhm.ac.uk/nature-online/science-of-natural-history/expeditions-collecting/beagle-voyage/

How was the ocean observed so far?

Lots of historical account of early explorations – (see book).

HMS *Challenger*



HMS *Challenger - some facts*

Crew: 243
Scientists: 6
Duration of Expedition: 4 years
Distance sailed: 127,000 km (68,890 miles)
Number of sampling stations: 362
Number of depth soundings made: 492
Number of dredges taken: 133
Number of new species of animals and plants discovered: 4,700

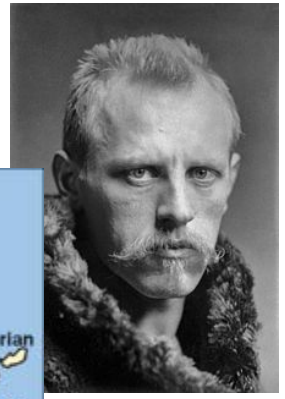
1895, almost a quarter of a century after the ship set sail.

The fifty thick tomes of the report, containing 29552 pages, were written by an international galaxy of scientists and many of these reports still form a starting point for specialist studies in oceanography.

4000 new species of animals taken by the trawls and dredges were documented and are still referred to by scientists from all over the world.

The reports were the tangible evidence of the achievements of the Challenger venture, but perhaps of much greater importance in the long term was the co-operation between scientists of many countries, inspired by Wyville Thomson's leadership, which set the young science of oceanography on the path to becoming the truly international discipline that it is today.

Fridtjof Nansen



Fridtjof Nansen (1861-1930)
-Nobel Award in 1922

Greenland expedition, July–October 1888
Dotted line shows approach of Jason, to 17 July. Continuous line shows drift of Nansen's party southward to 29 July, and the boat journey northward to Umivik
The originally planned crossing route, from Sermilik to Christianhaab
Actual crossing route to Godthaab, 15 August to 3 October

Routes taken during the 1893–1896 ***Fram*** **expedition: *Fram's* route eastward from Vardø along the Siberian coast, turning north at the New Siberian Islands to enter the pack ice, July–September 1893**

Fram's **drift in the ice from the New Siberian Islands north and west to Spitsbergen, September 1893 – August 1896**

Nansen and Johansen's march to Farthest North, 86° 13.6'N, and subsequent retreat to Cape Flora in Franz Josef Land, March 1895 – June 1896

Nansen and Johansen's return to Vardø from Cape Flora, August 1896

Fram's **voyage from Spitsbergen to Tromsø, August 1896**

Fridtjof Nansen and V. Walfrid Ekman (1874-1954)

Nansen bottle

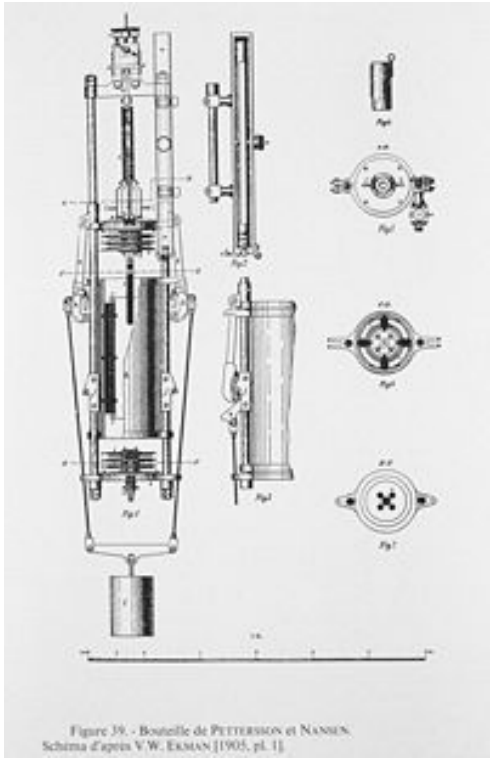
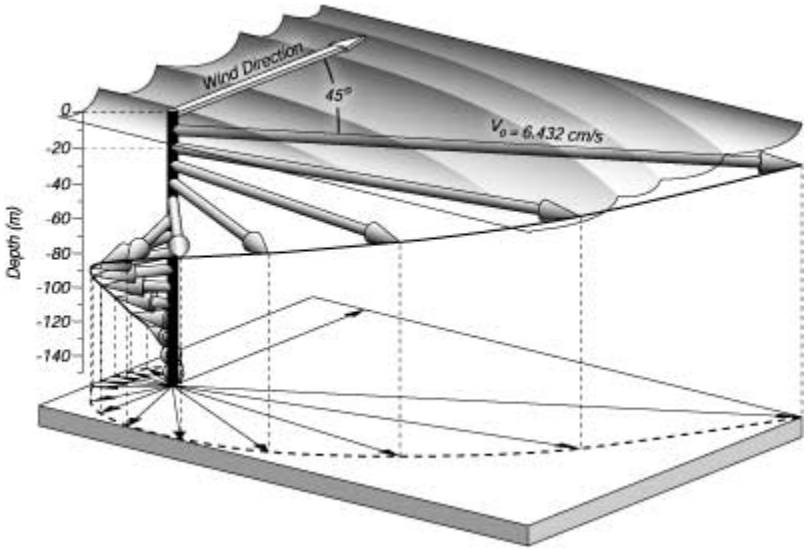


Figure 39. - Bouteille de Pettersson et Nansen.
Schéma d'après V.W. Ekman [1905, pl. 1].

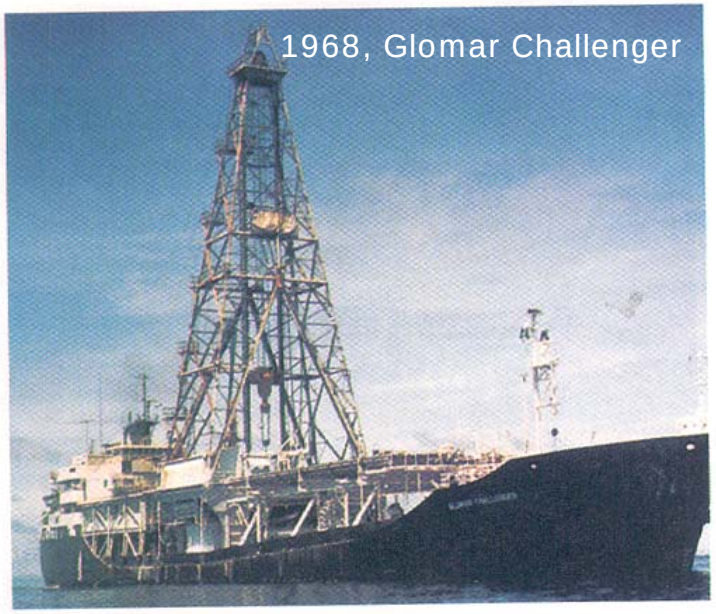


Ekman transport

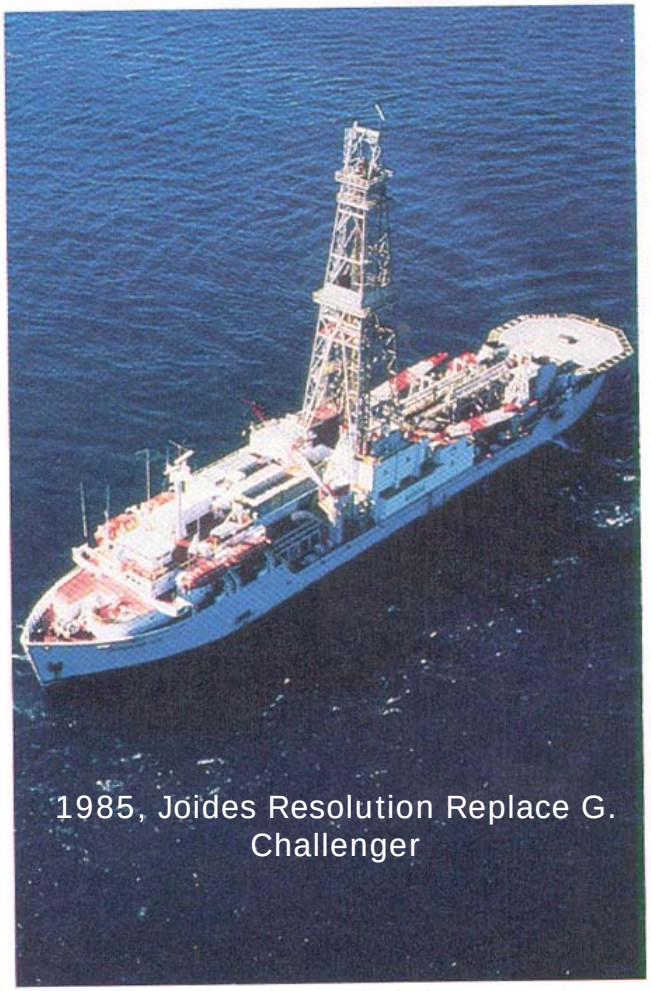
Fram

International Observational Programs

Deep Sea Drilling Project - DSDP



(a)



(b)

Figure 1-18

(a) The *Glomar Challenger* could produce 8800 continuous or 10,000 intermittent hp for propulsion and for operating drilling equipment. To remain over the drill site, the ship used dynamic positioning that could move the vessel in any direction. *(Photo courtesy of Victor S. Soleto, Deep Sea Drilling Project)*
(b) *JOIDES Resolution*, replaced the *Glomar Challenger* as the new drilling ship for the Ocean Drilling Program. *(Photo courtesy of the Ocean Drilling Program)*

Theory of Plate Tectonics and much more…

http://en.wikipedia.org/wiki/Soviet_submarine_K-129_(1960)

International Observational Programs

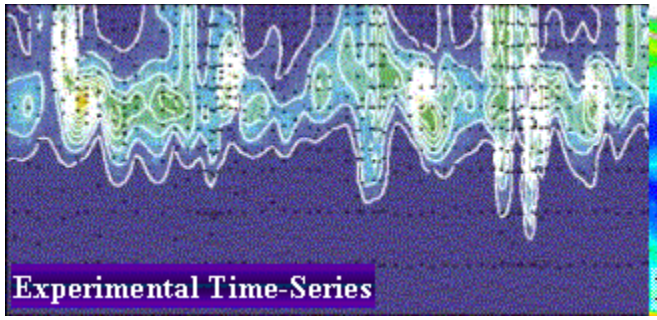
JGOFS

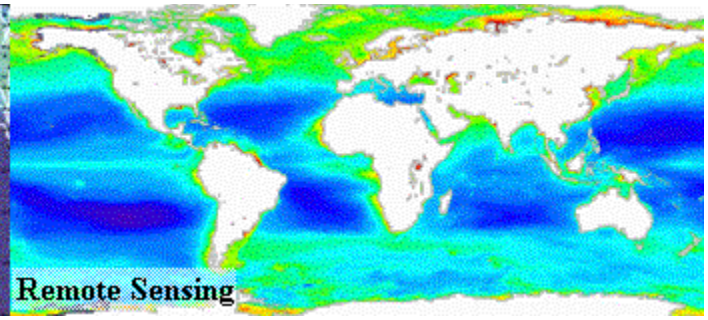
The Joint Global Ocean Flux Study (JGOFS)
was launched in 1987 at a planning meeting in Paris

The Operational Goal of JGOFS :

Spatial Scale: regional to global
Temporal Scale: seasonal to interannual

1) Fluxes of carbon between the atmosphere-surface ocean-ocean interior.
2) Sensitivity to climate changes





International Observational Programs

The World Ocean Circulation Experiment 1990-1998

http://woce.nodc.noaa.gov/wdiu/

http://www-pord.ucsd.edu/whp_atlas//pacific/p03/sections/printatlas/P03_OXYGEN_final.jpg

International Programme on Climate Variability and Predictability, 1995-present

http://www.clivar.org

http://www.clivar.org/publications/other_pubs/other_pubs.php

World Climate Research Programme

http://wcrp.wmo.int

US Programs sponsors

Incredible amount of resources!

National Science Foundation
WHERE DISCOVERIES BEGIN

http://www.nsf.gov/

e.g. GLOBEC http://www.pml.ac.uk/globec

National Oceanic & Atmospheric Administration
U.S. Department of Commerce

http://www.noaa.gov

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
EXPLORE. DISCOVER. UNDERSTAND.

http://nasascience.nasa.gov/earth-science/oceanography

Office of Naval Research

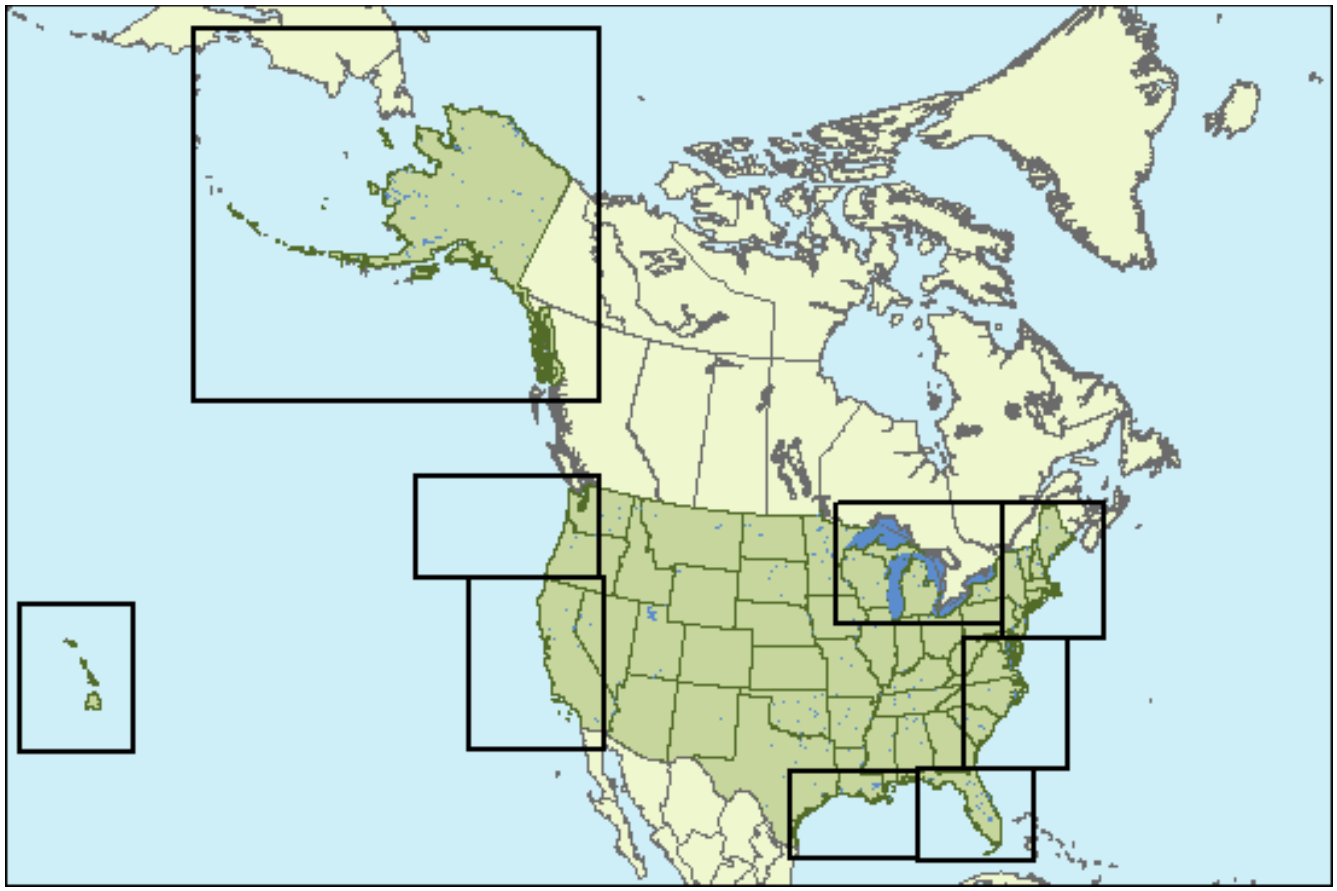
http://www.onr.navy.mil/focus/ocean/habitats/default.htm

U.S. Coastal Observing Systems

NOAA Coastal Services Center
LINKING PEOPLE, INFORMATION, AND TECHNOLOGY

National Science Foundation
WHERE DISCOVERIES BEGIN

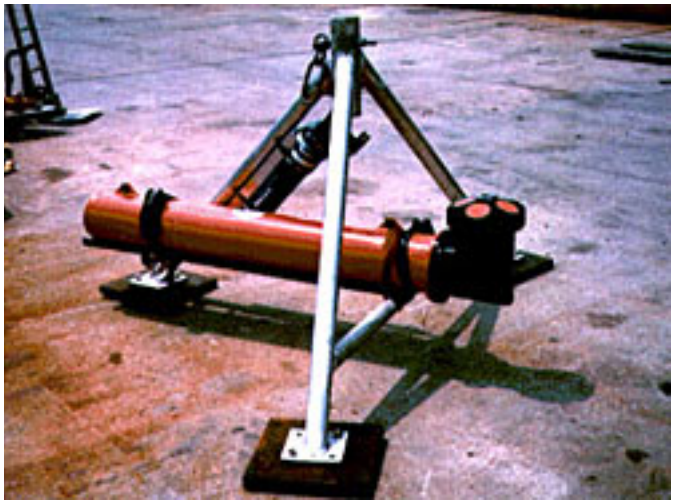
http://www.csc.noaa.gov/coos

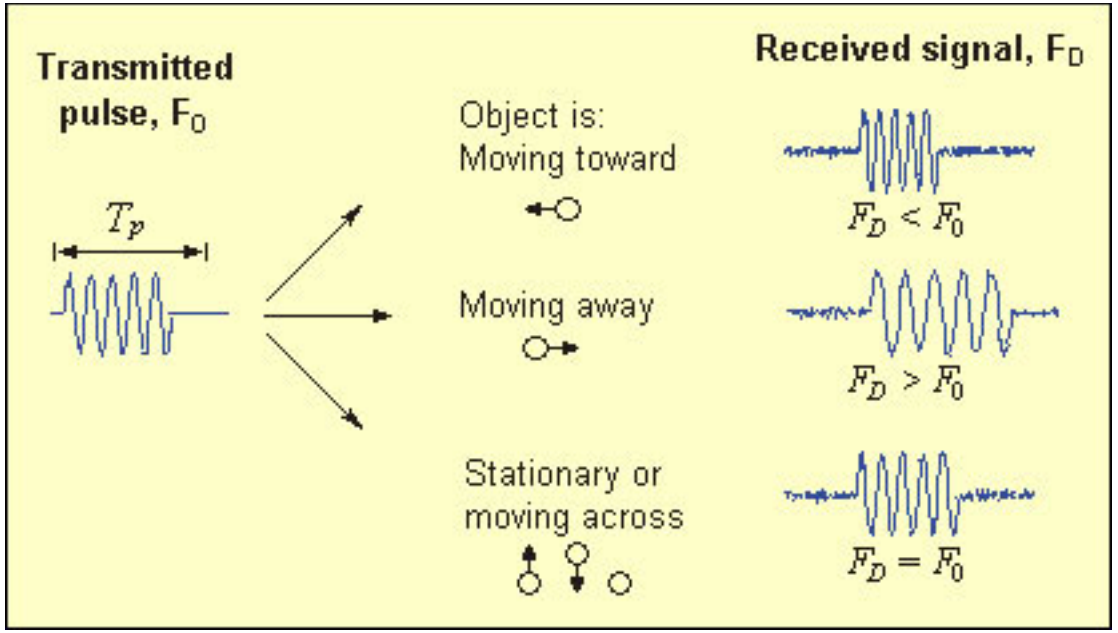


Tools for ocean observing

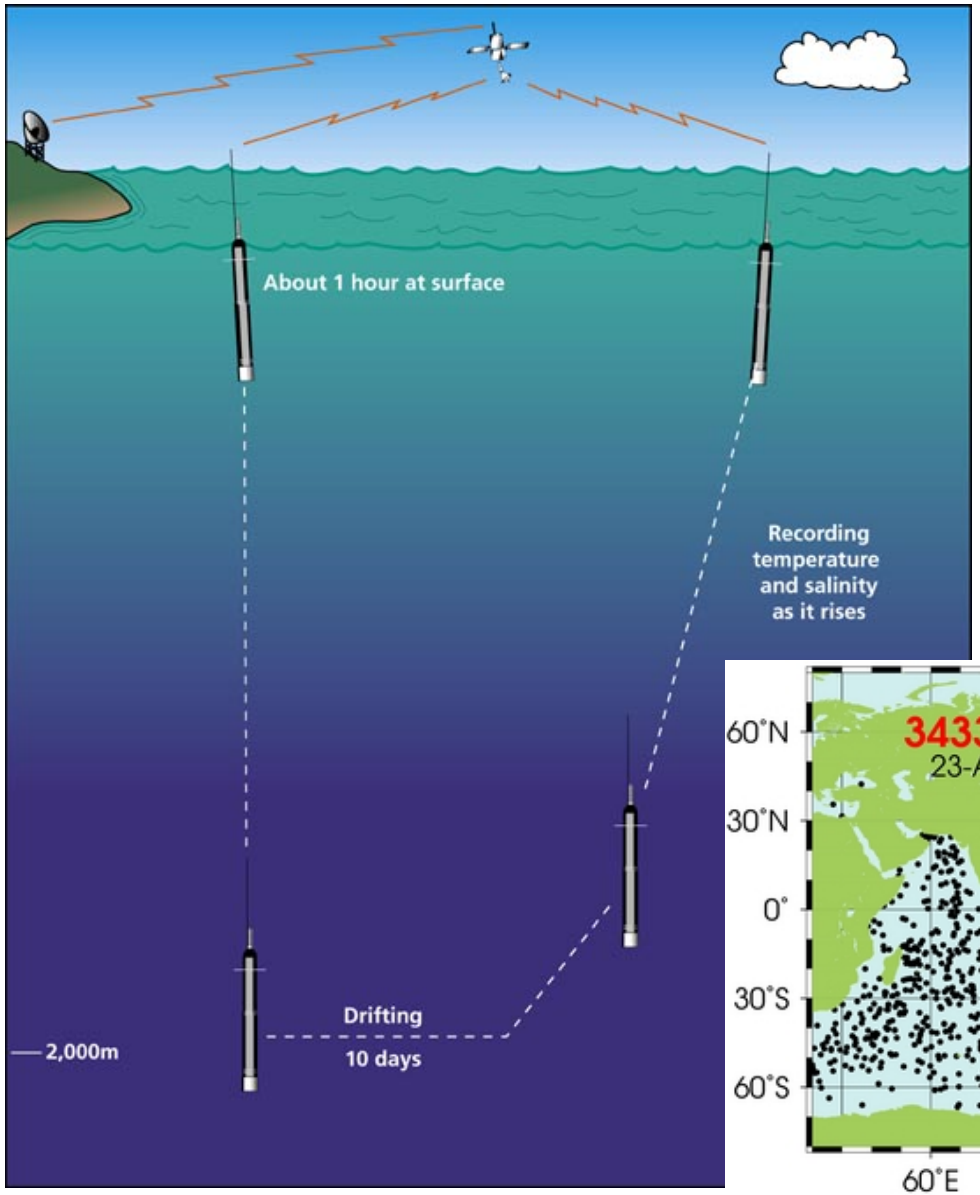
very good web-site→ http://www.whoi.edu/science/instruments/

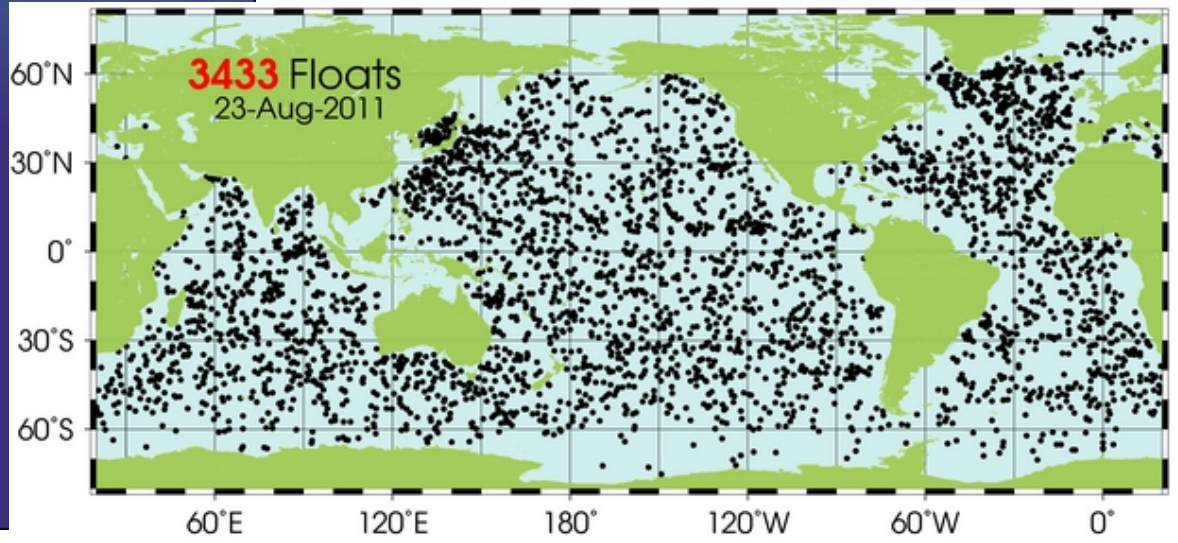
1) Acoustic Doppler Current Profiler (ADCP): measure velocity in ocean by pinging sound waves and analyzing the return wave



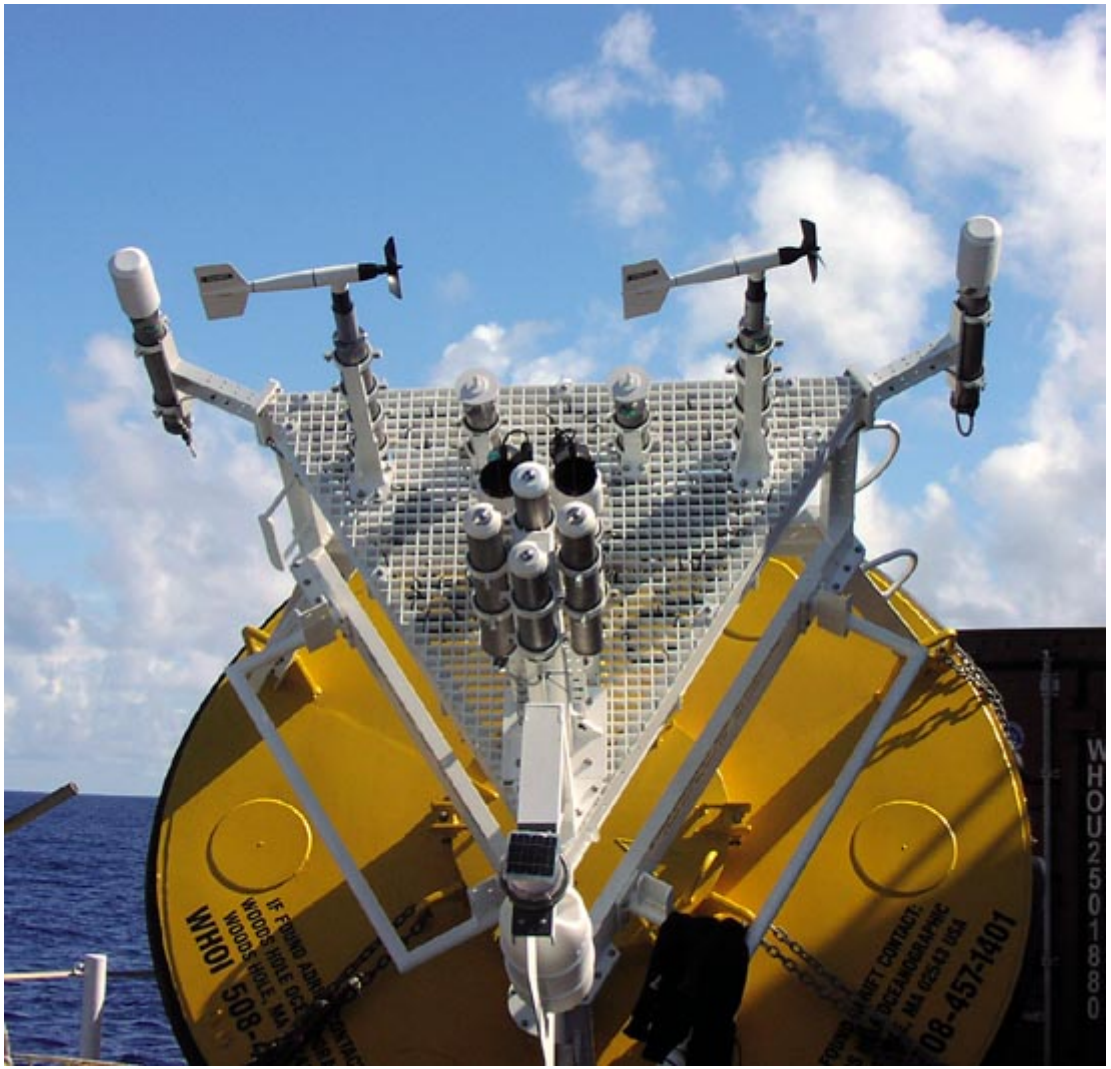


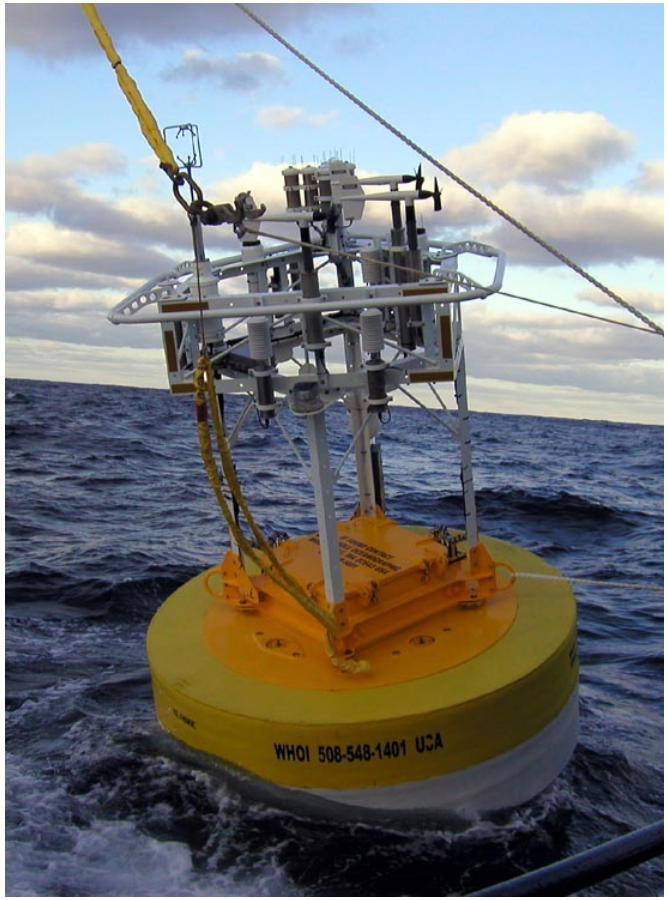
2) ARGO floats: measure ocean T and S while drifting with ocean currents, surface regularly to communicate with satellites to transmit data



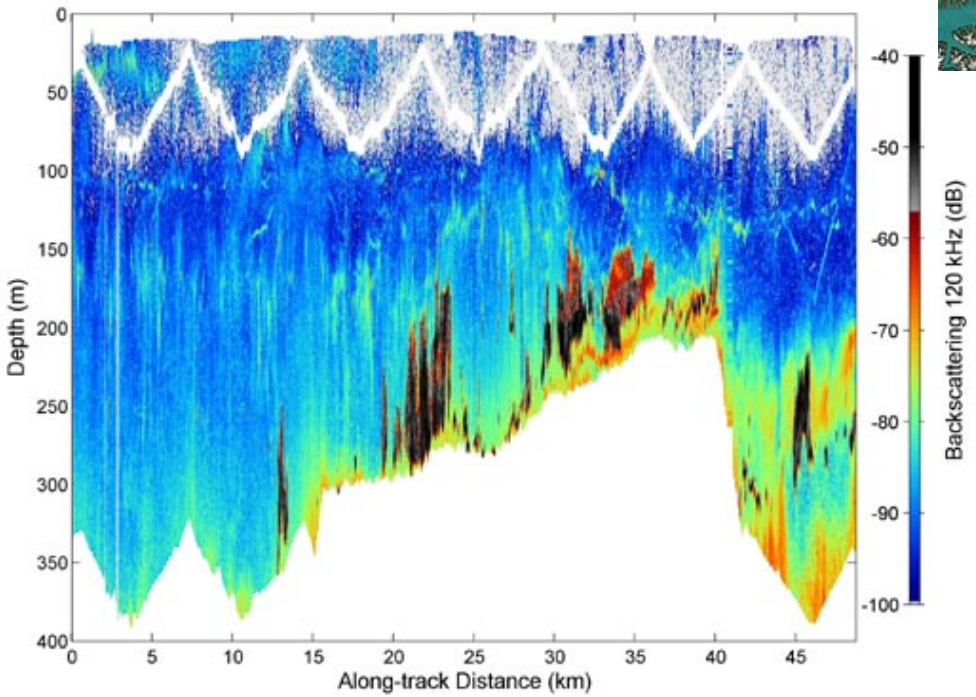


3) **Air-Sea Interaction Meteorology (ASIMET): measure ocean T and S, atmospheric wind, pressure, radiation, and precipitation; usually on oceanic buoys or research ship**

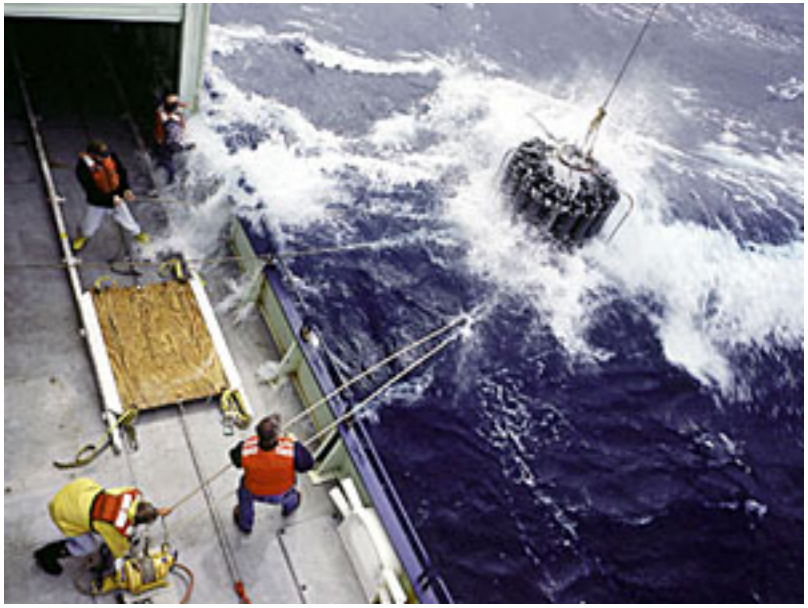




4) BIOMAPPER: studies plankton via sonar, video, and environmental measurements

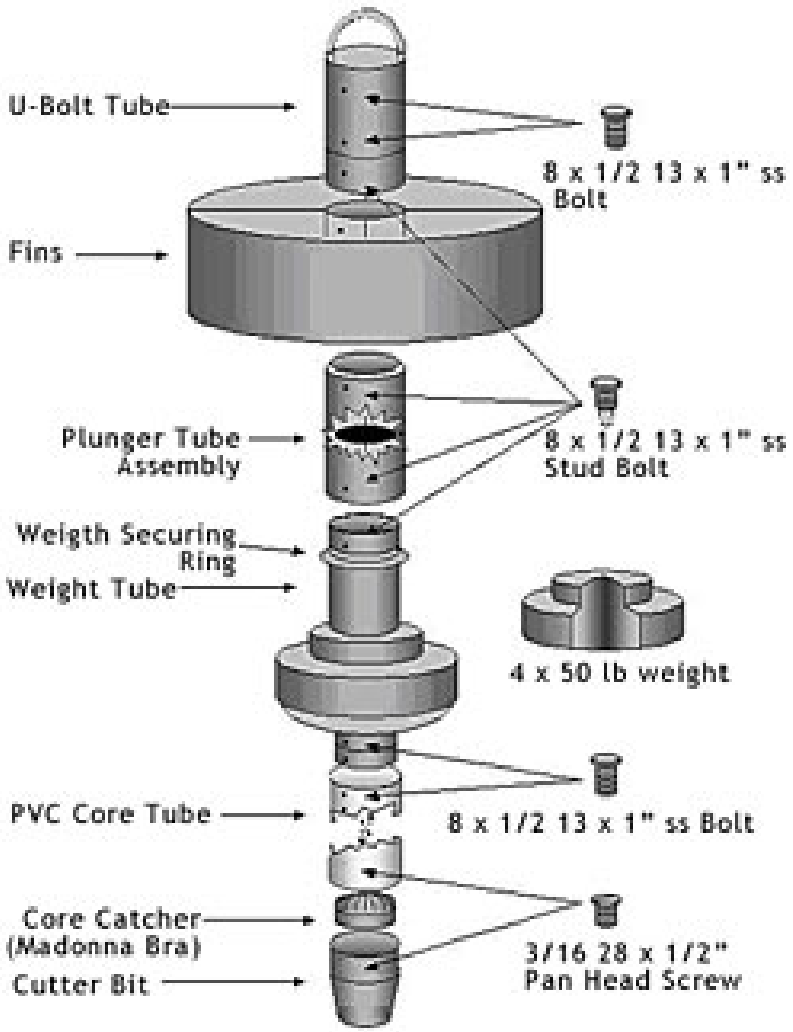


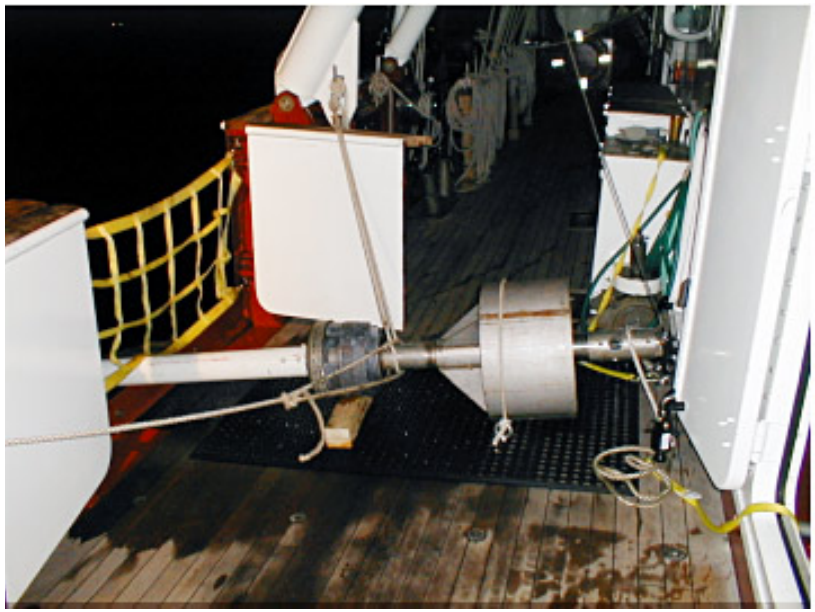
5) Conductivity-Temperature-Depth (CTD): measures T and S (density)in ocean



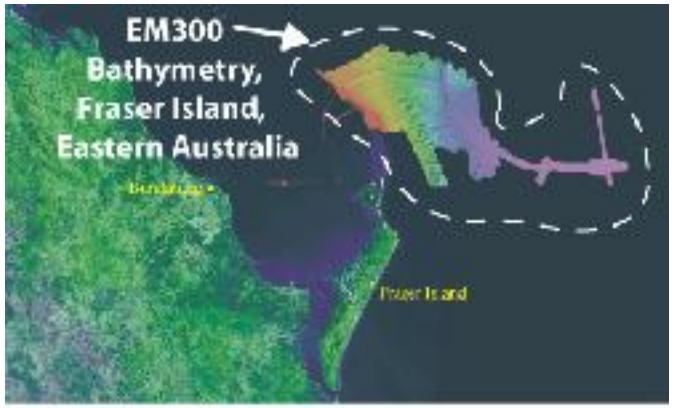
deployed off ship usually;
data fed back to ship in realtime
Niskin bottles sample ocean water at predetermined depths
“casts” can take many hours

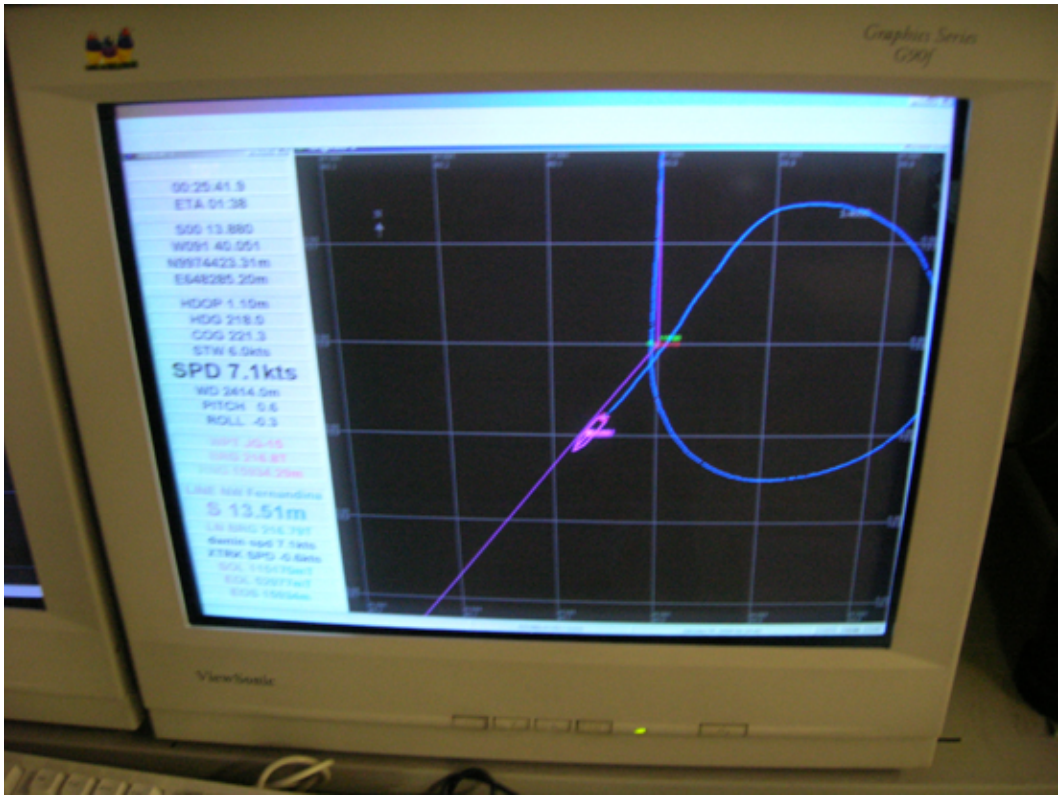
6) Gravity Corer: recover sediment core from ocean bottom





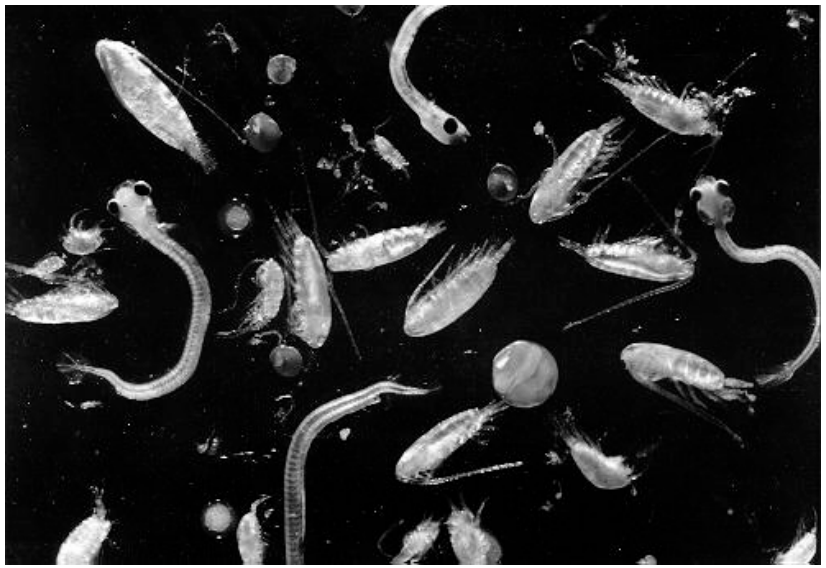
7) Multi-beam Echo Sounder: measure ocean bathymetry with ship (10-5000m)



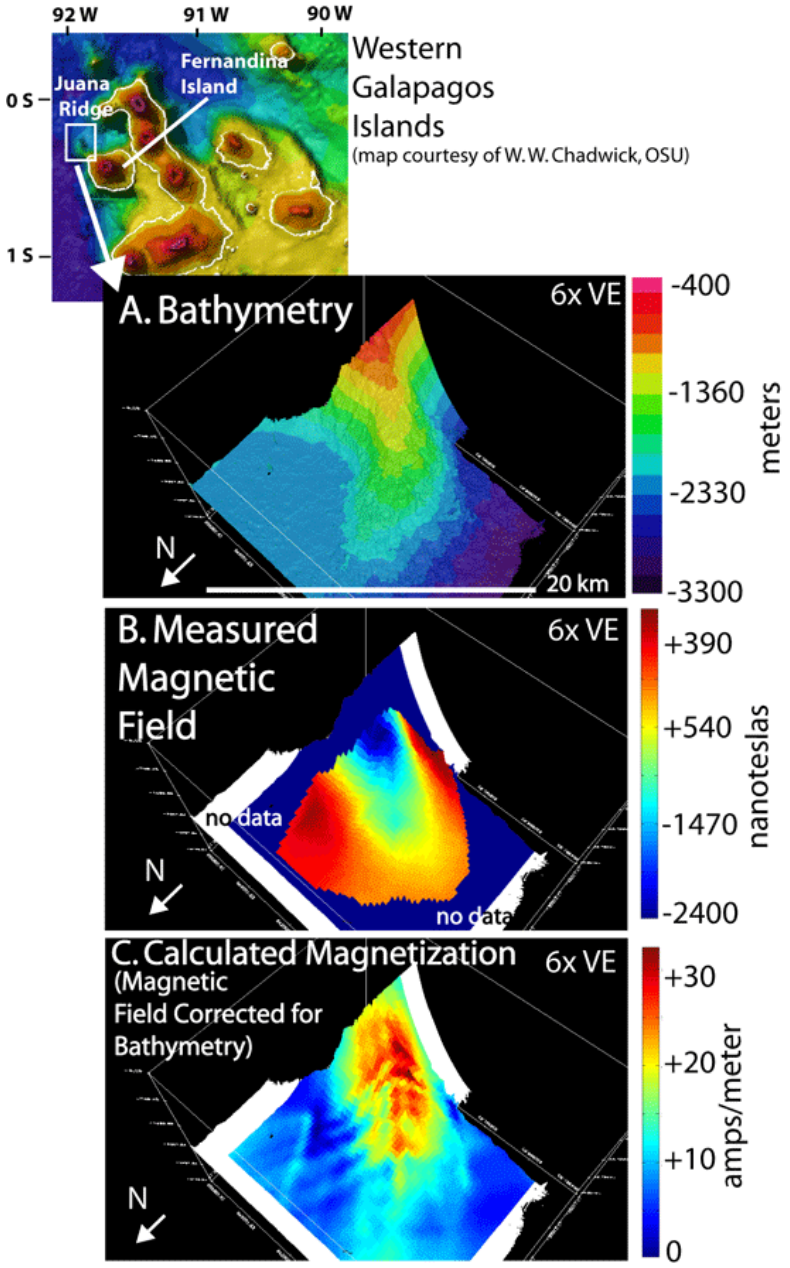


-like mowing the lawn: be sure you have overlapping “swathes”

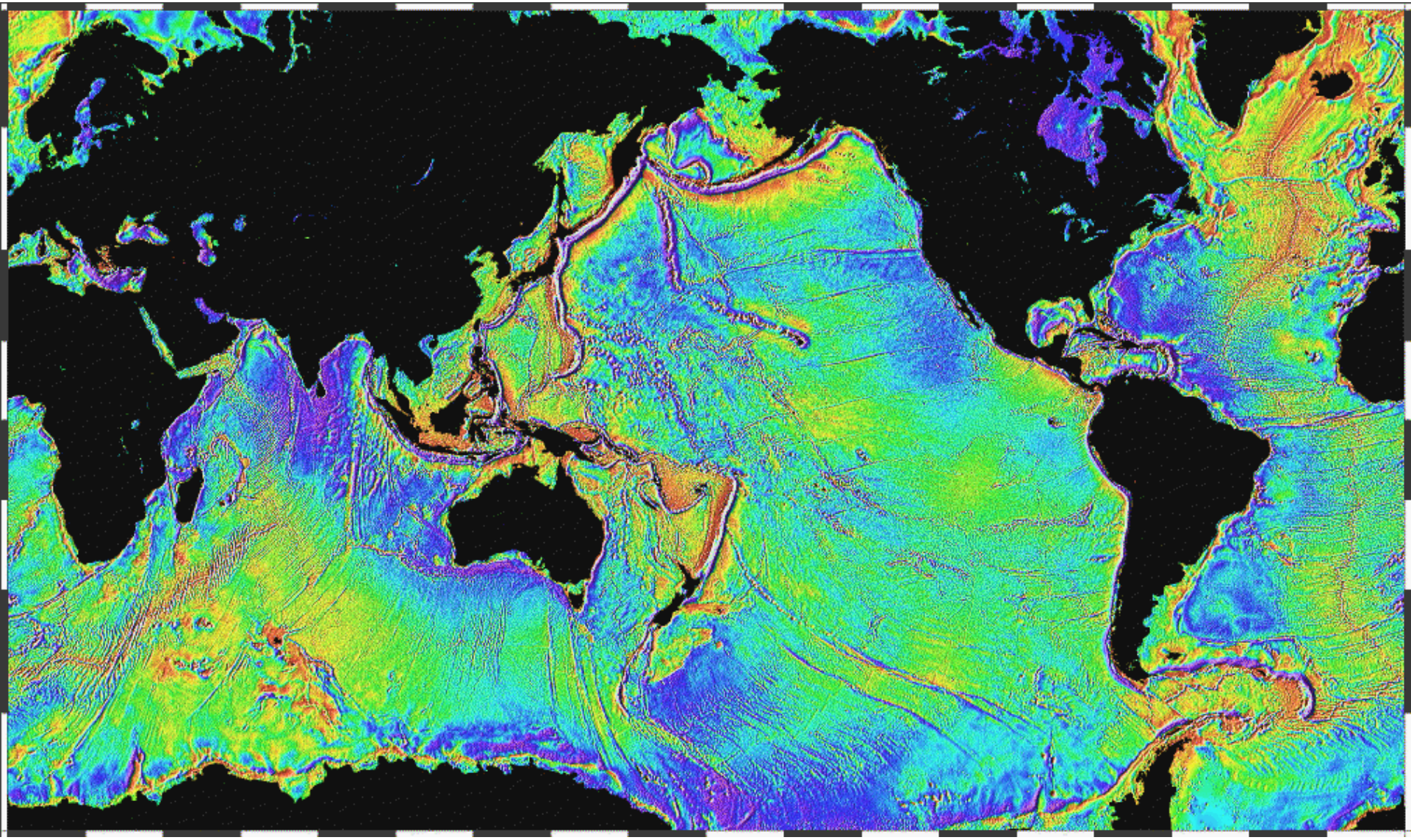
8) MOCNESS: multiple open and closing net with an environmental sampling system; used to collect plankton



9) Magnetometer: measure magnetic field in ocean

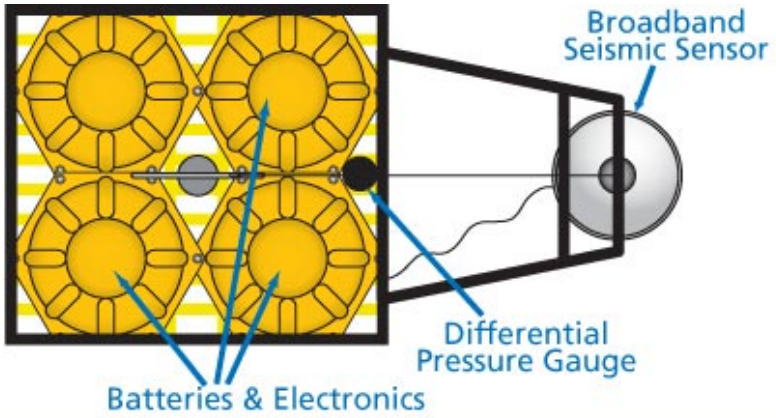


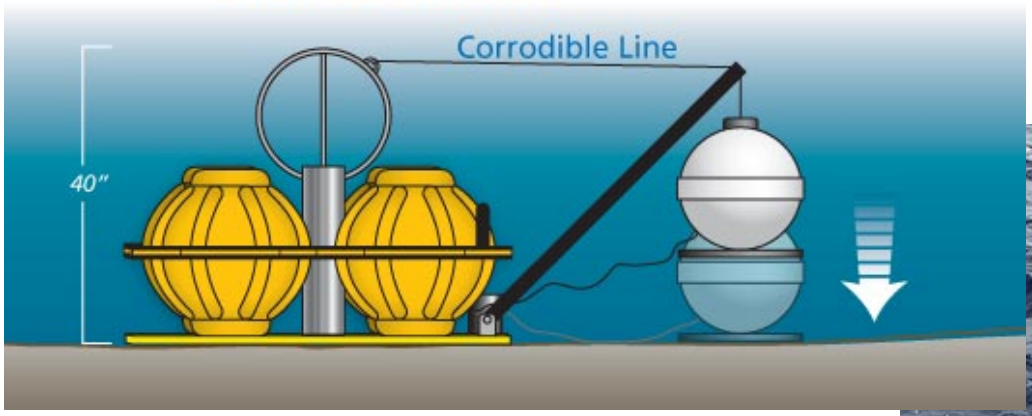
10) Seafloor mapping from satellite radar altimetry & ships soundings



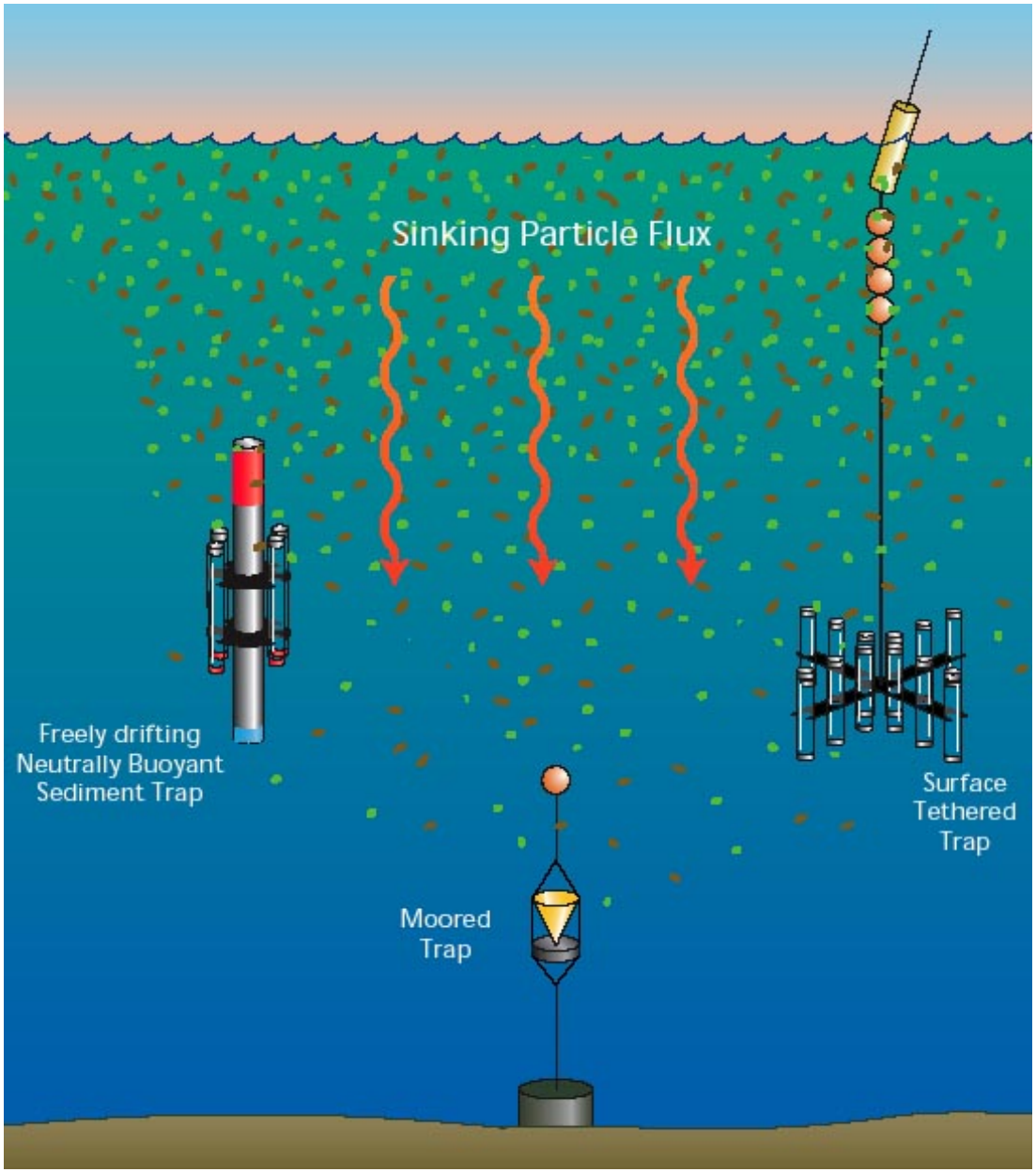
Smith and Sandwell, 1997

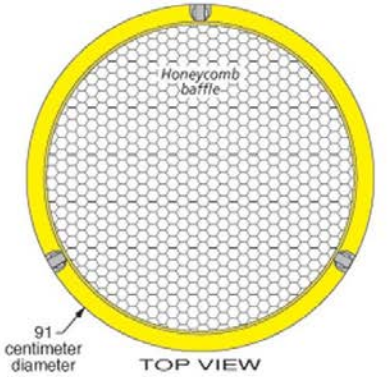
11) Ocean Bottom Seismometer: measure underwater earthquakes

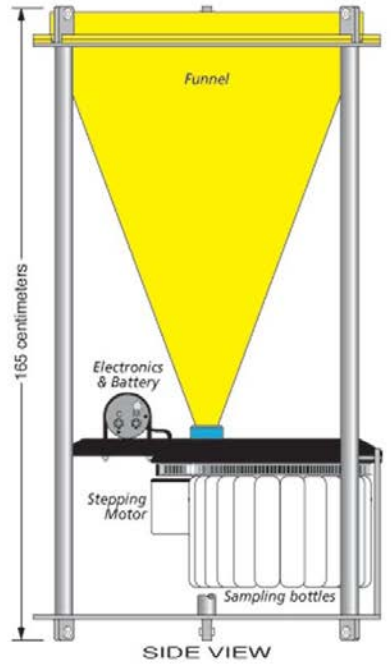


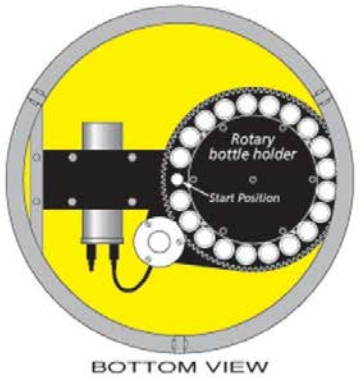


12) Sediment trap: collect falling sediments in ocean

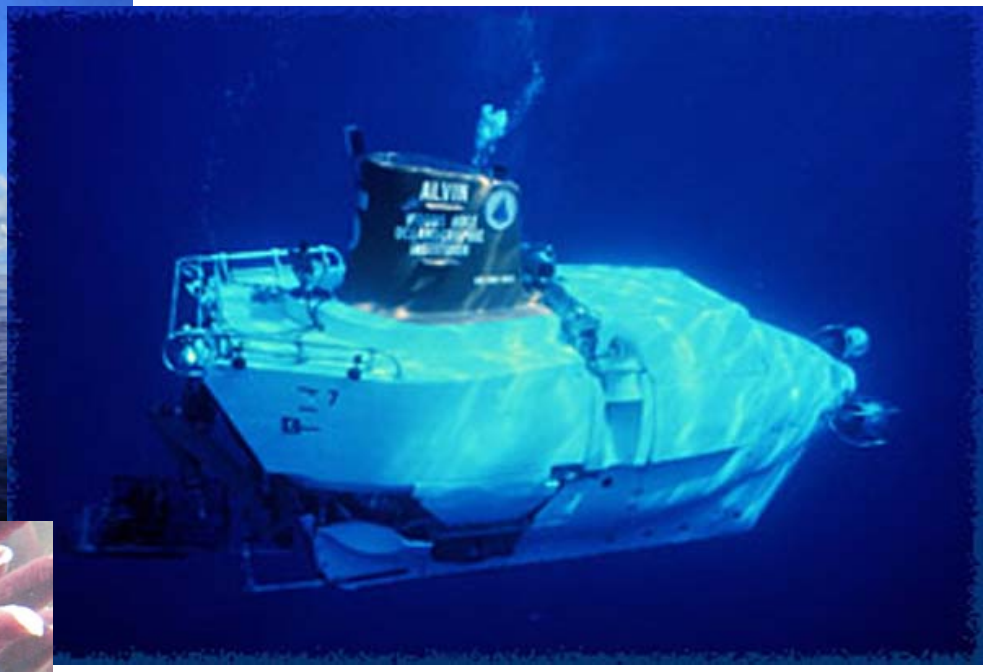








13) Alvin: a 3-person submersible that can dive to 4.5km



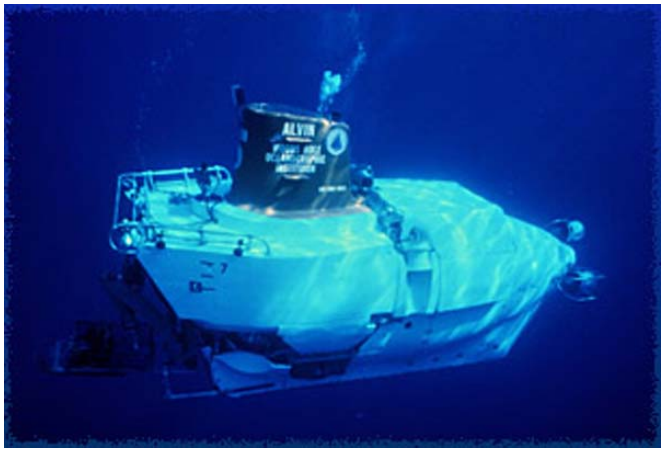
1977: discovered hydrothermal vents

Technologies for ocean observing

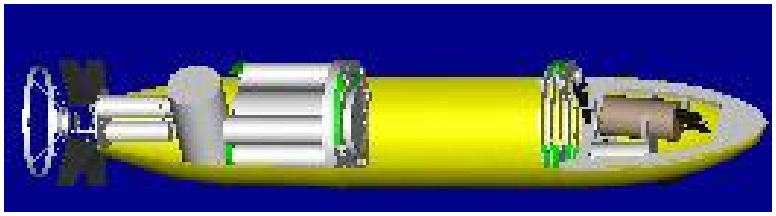
Remote Sensing / Satellite Imagery:
Geostationary Server - http://www.goes.noaa.gov
Satellite significant events: http://www.osei.noaa.gov
National Geophysical Data Center: http://www.ngdc.noaa.gov/ngdc.html

Floating devices in the ocean:
Argo FLoats - http://www.argo.ucsd.edu
Drifter Programs: http://www.aoml.noaa.gov/phod/graphics/pacifictraj.gif

Submarines &
Remotely Operated Vehicles (ROVs) :
Amazing discoveries…
http://oceanexplorer.noaa.gov/technology/subs/rov/rov.html



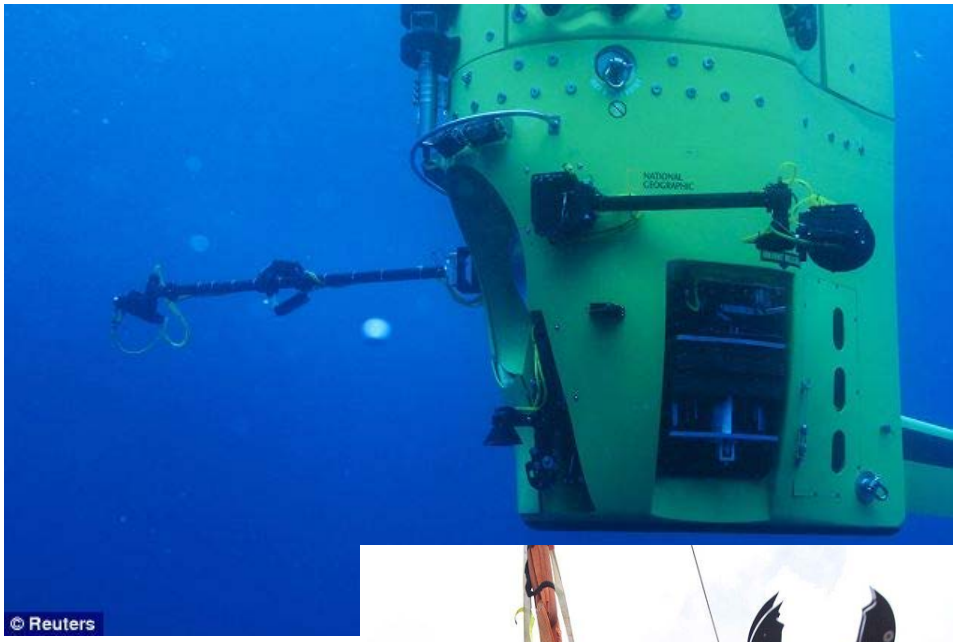
Automated Underwater Vehicles (AUVs) :



'To hell and back': James Cameron is first solo diver to reach deepest point on Earth - but has to race back to surface after hydraulic failure seven miles down

- Director becomes first human to visit bottom of trench since January 1960
- Cuts short dive after hydraulic failure
- Cameron descended 35,756 feet (6.77 miles/10.89km) to reach 'Challenger Deep' in the Mariana Trench
- Arnold Schwarzenegger, Richard Branson and Jessica Alba tweet support
- First of several competing missions to deepest point on Earth
- Mariana Trench is deeper than Mount Everest is high
- Returned to the surface in faster-than-expected 70 minutes
- Cameron filmed the journey for a feature-length documentary

By ROB WAUGH and THOMAS DURANTE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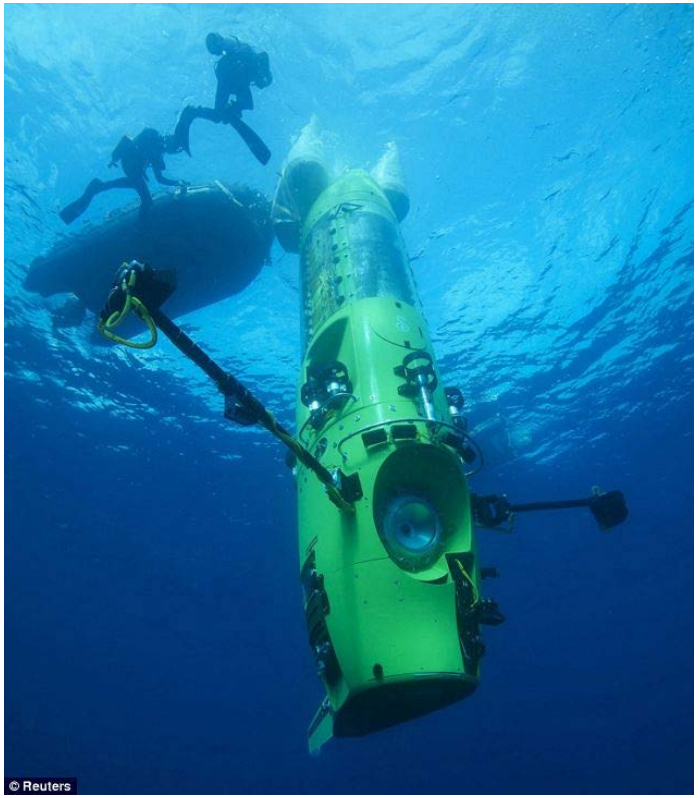
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Oceanography Continues

- More high-technology tools available today
  - Sonar
  - Robotics
  - Computers
  - Satellites

SO MUCH DATA!!!

How to synthesize it?

Homework #1

Korea's ocean observing systems?