BHARATHIDASAN UNIVERSITY
Tiruchirappalli - 620 024
Tamil Nadu, India

Programme : 6 year Integrated M.Tech in Geological Technology and Geoinformatics

Course title : Marine Geology and Geoinformatics in Sea bed Exploration
Course code : MTIGT 0607

UNIT – IV
Physical and Chemical Oceanography

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Oceanography is an interdisciplinary science where maths, physics, chemistry, biology and geology intersect.

Traditionally, we discuss oceanography in terms of four separate but related branches: ***physical oceanography, chemical oceanography, biological oceanography and geological oceanography***.

Physical oceanography involves the study of the properties (temperature, density, etc.) and movement (waves, currents, and tides) of seawater and the interaction between the ocean and the atmosphere.

Chemical oceanography involves the study of the composition of seawater and the biogeochemical cycles that affect it..

Biological oceanography involves the study of the biological organisms in the ocean such as phytoplankton, zooplankton and extending to the more traditional of fish and marine mammals.

Geological oceanography focuses on the structure, features, and evolution of the ocean basins.

Oceanography is greater than the sum of these specific branches. Oceanographers use a variety of tools to study the ocean, and many of these studies involve more than one branch.

Oceanographers collect water, sediment and biological samples using ships. They deploy autonomous sampling systems such as buoys and gliders to collect data over time and space scales that cannot be done with a ship.

Remote sensing allows oceanographers to get a global view of some parameters. Modeling allows oceanographers to look at the past and predict the future state of the ocean (e.g ocean circulation, air-sea interactions, quality of water, etc.).

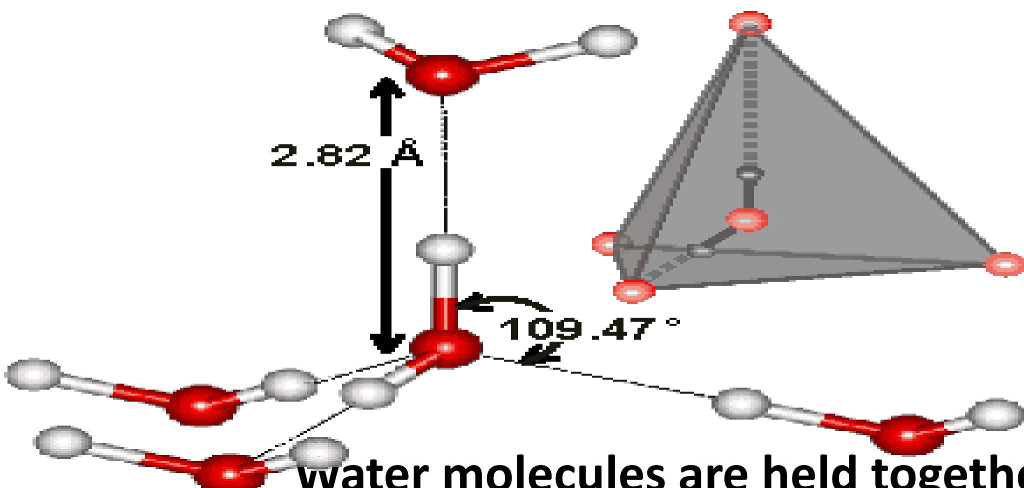
The knowledge gained from all of these types of measurements allows oceanographers to do many things:

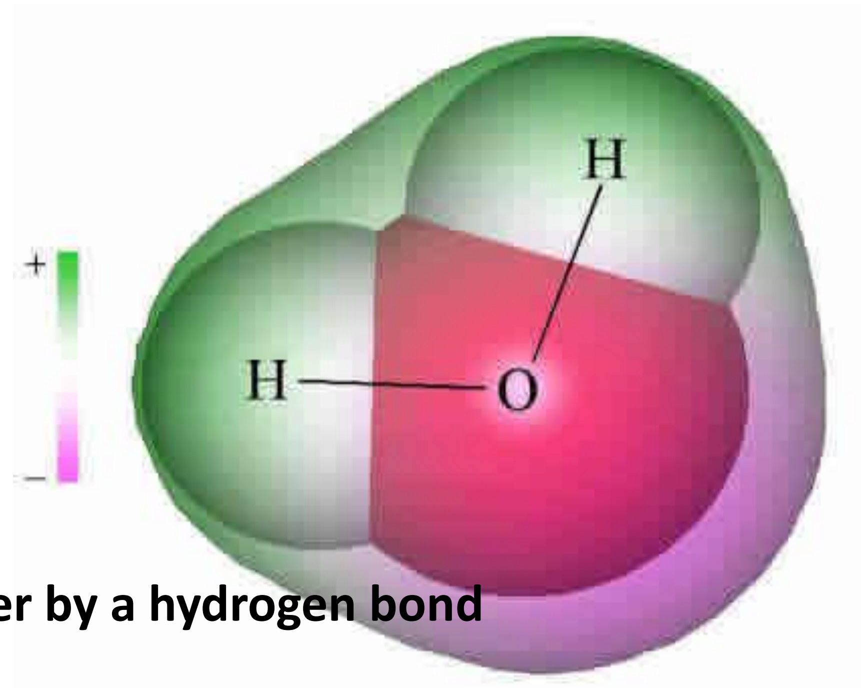
better predict (using models) changes in weather and climate improve the forecast for hazards; natural (e.g. hurricanes, tsunamis) or man-made (e.g. oil spills).

assess the impact of pollutants on the quality of sea water and protect the quality of the water in the ocean in the face of increasing human demands (e.g. fisheries, tourism, shipping, offshore oil & gas mining etc.).

The Water Molecule

- Water is formed when two hydrogen atoms bond to one oxygen atom.
- Not symmetrical
- Electrons spend more time near the (O) and less time near the (H)
- Water molecule is polar



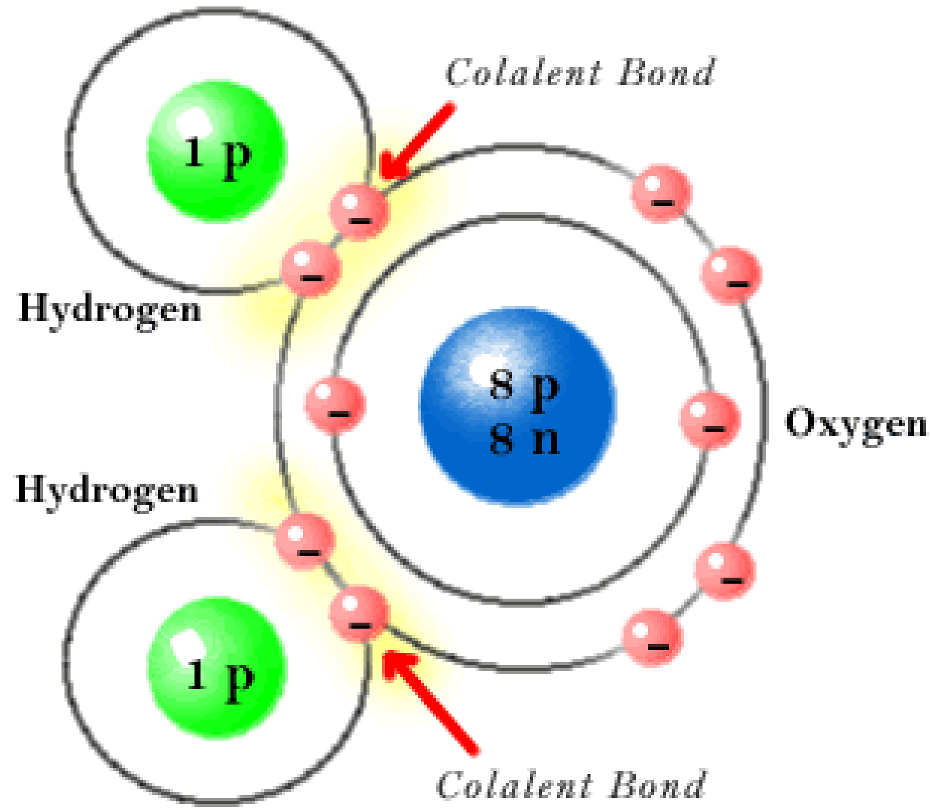


water molecules are held together by a hydrogen bond

- There is a greater concentration of electrons around the nucleus of the oxygen than around the hydrogen.

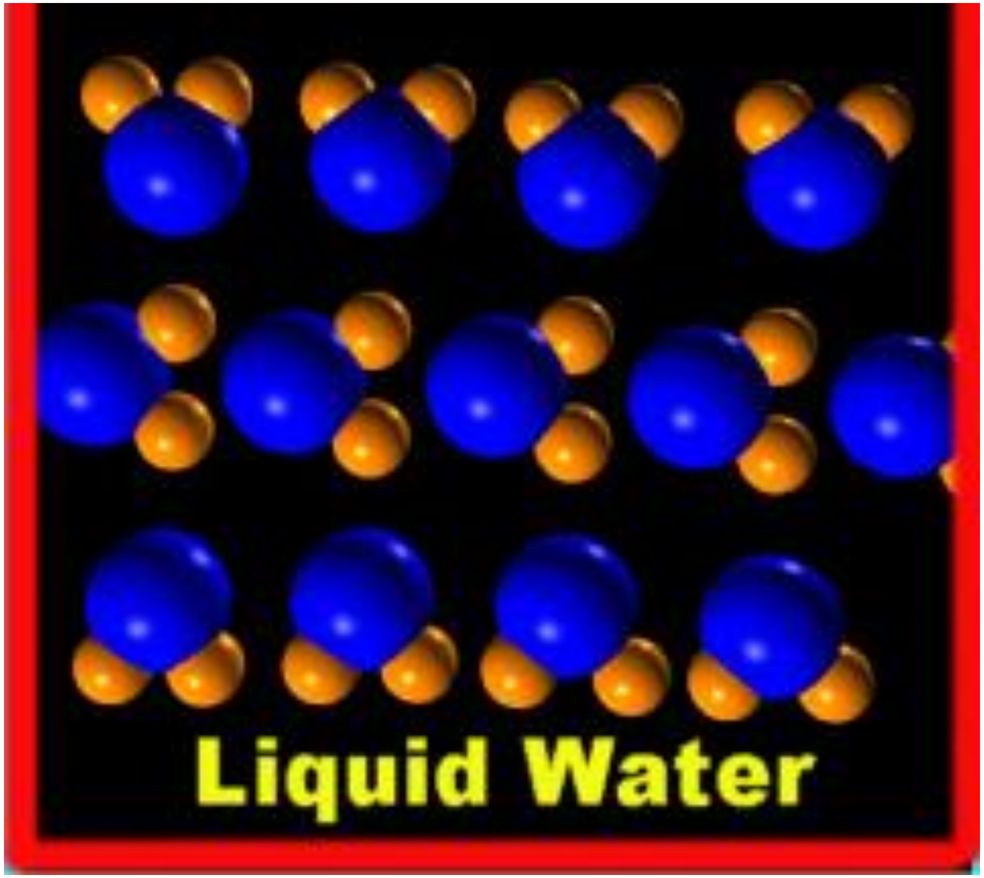
- Therefore, the **hydrogen** end is slightly positive and the **oxygen** end is **negative**..

Dipolar



Bohr Model of H_2O

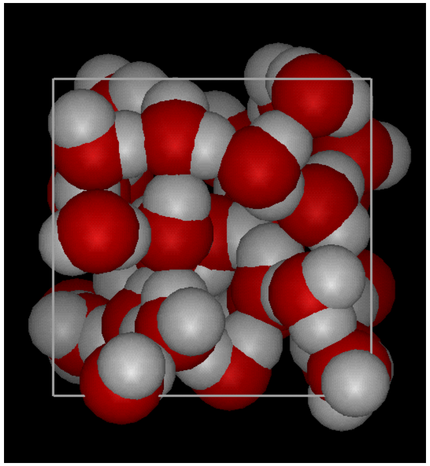
When water molecules attract to one another, the hydrogen end of one molecule is attracted to the oxygen end of another.

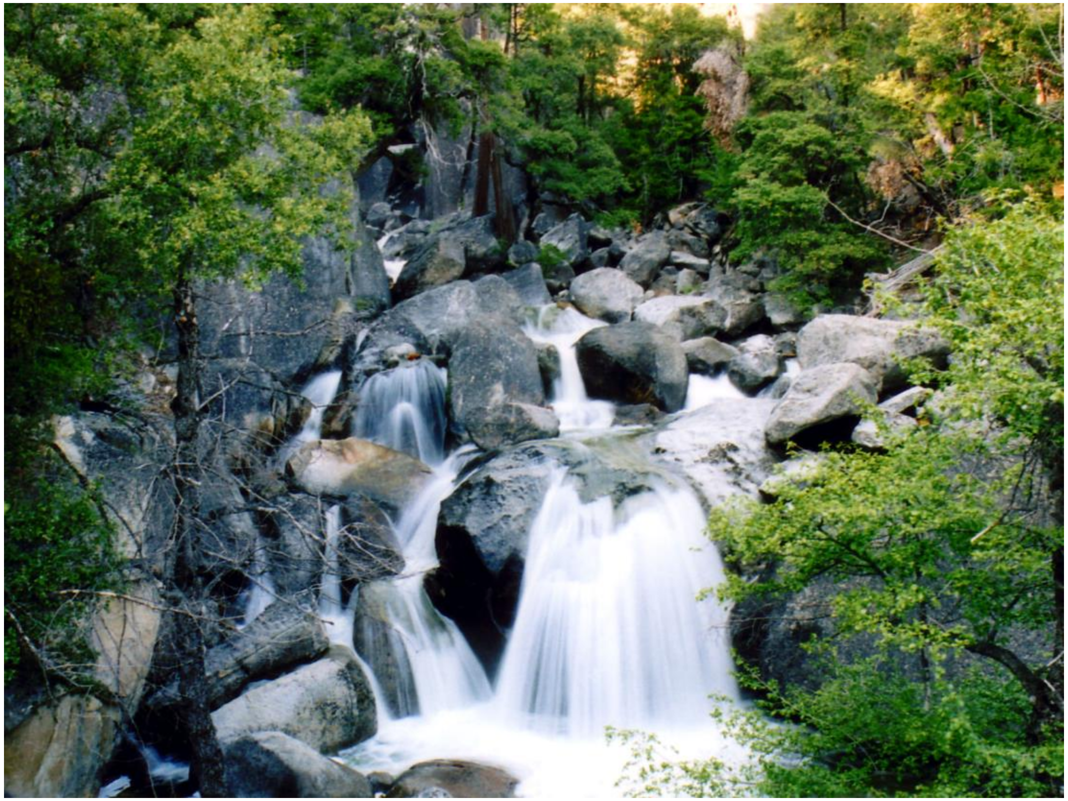


States of Water

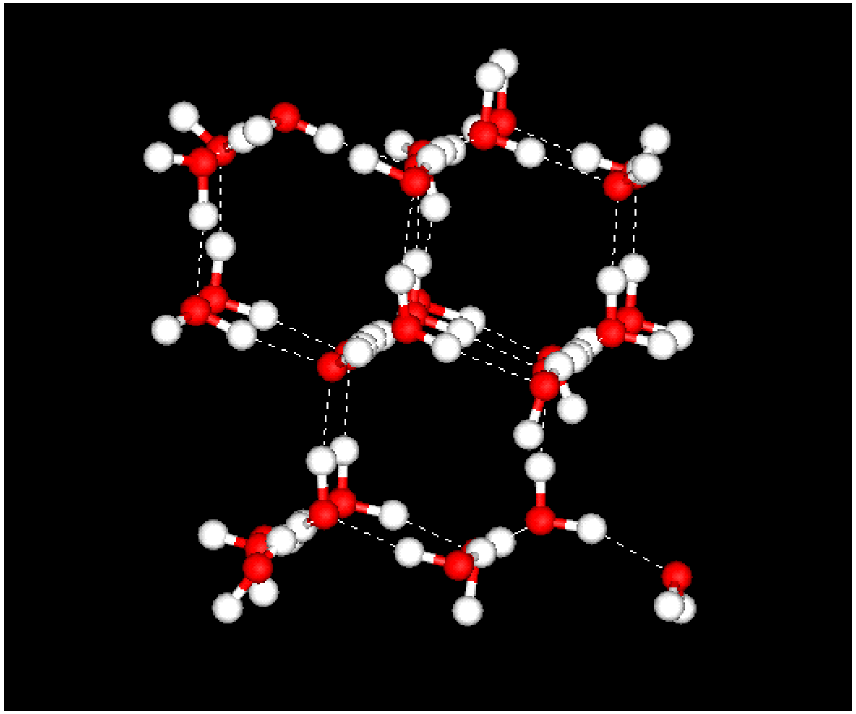
- Water is the only substance found on Earth in all three states (phases):

1. Liquid





States of Water



2. Solid (Ice)

States of Water

3. Gas (Steam or Vapor)

States of Water

- **Water molecules are constantly moving**

- Temperature increase = Increase in movement

States of Water

- When water molecules move faster, they tend to break their hydrogen bonds.

This is called

Evaporation

Credit: Kidzone Fun Facts

States of Water

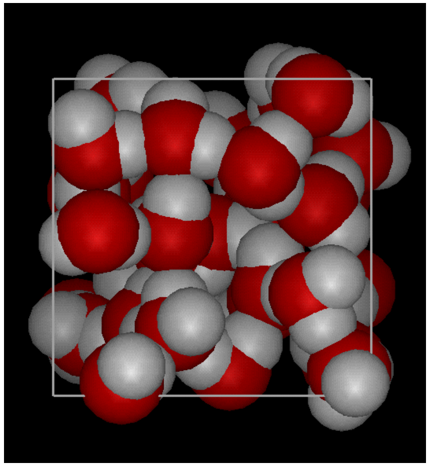
- When gas or vapor molecules slow down, they clump or join together.

This is called
Condensation

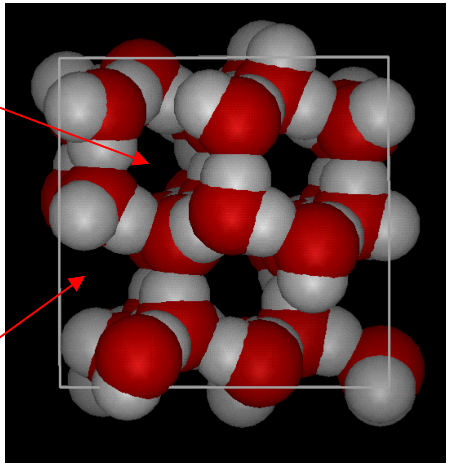
States of Water

- As water changes from a liquid to a solid, molecules form crystals.

  In ice crystals, molecules are spaced further apart.



Liquid



Solid (Ice)

States of Water

- Since molecules are spaced further apart, ice is less dense than water (it floats)

  Helpful for aquatic organisms; forms a "blanket"

    If ice was more dense than water, lakes would freeze from the bottom upwards.

Thermal Properties of Water

- Water has a high specific heat, or heat capacity (the amount of heat needed to raise 1g of a substance 1C°.)

- This quality of water is important for several reasons:

Thermal Properties of Water

1. Regulates rate at which air temperature changes.

July 9,2005

Las Vegas, NV		Miami, FL	
High	Low	High	Low
103	76	87	79
27		8	
Humidity: 14%		Humidity: 82%	

Affects global climate (milder temperatures in coastal regions)

Thermal Properties of Water

2. Aquatic organisms face less temperature variation than terrestrial organisms.

Surface Tension

- Next to mercury, water has the highest surface tension of all liquids.

This is a result of the tendency of water molecules to attract to one another, or cohere, at the surface of any accumulation of water.

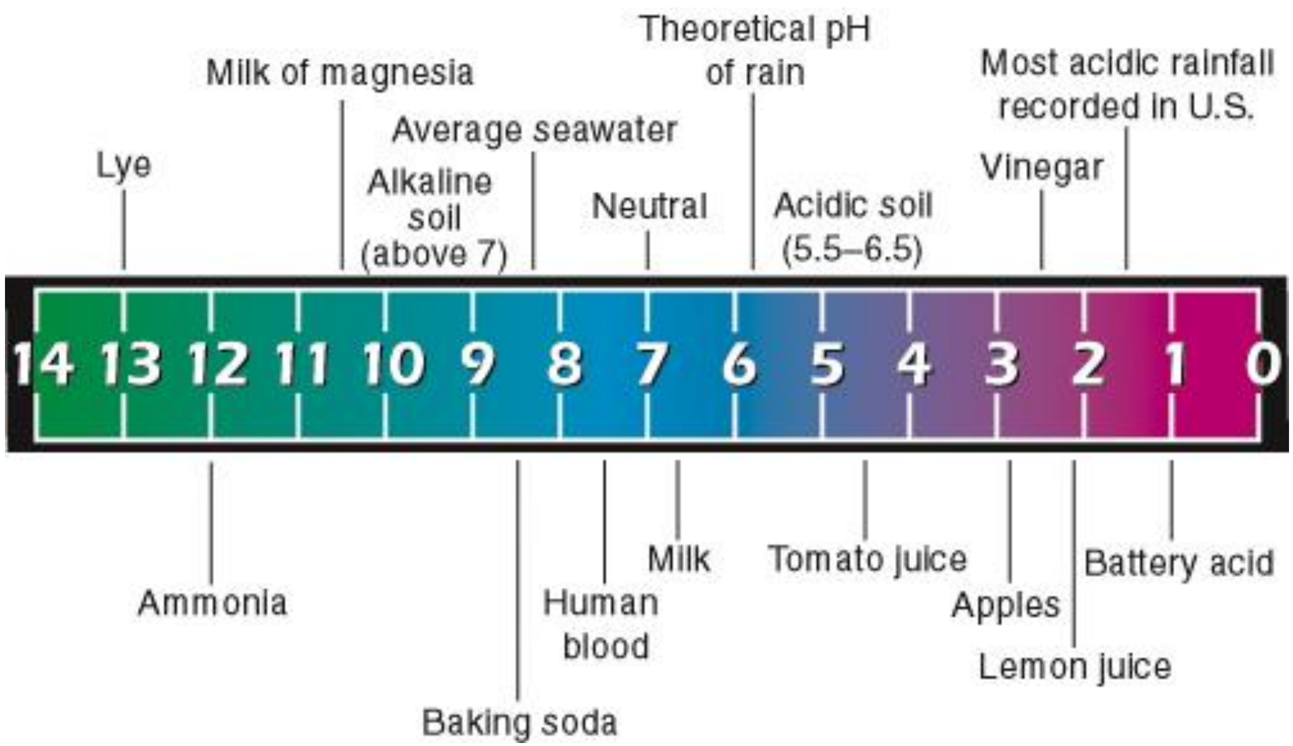
Surface Tension

- Surface tension allows insects to walk on water.

pH: Alkalinity/Acidity

- The measurement of the H+ ions found in that particular substance
- The scale goes from 0 to 14
- 7 is neutral
- Below 7 is acidic
- Above 7 is alkaline (or basic)
- One pH unit represents a ten-fold change in H+ concentration

The pH Scale


Theoretical pH of rain
Milk of magnesia
Most acidic rainfall recorded in U.S.
Average seawater
Lye
Alkaline soil (above 7)
Neutral
Acidic soil (5.5–6.5)
Vinegar
14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
Ammonia
Milk
Tomato juice
Battery acid
Human blood
Apples
Lemon juice
Baking soda

Water as a Solvent

- Since water can dissolve more things than any other natural substance, it is known as the " **Universal Solvent**"

Properties of Solvents include:

- Interacts with other polar compounds
- Is repelled by non-polar compounds
- Small size allows it to saturate areas
- Can convey other substances in solutions

Water as a Solvent

- Water is especially good at dissolving salts

Salts form from the combination of particles with opposite electrical charges (or ions)

Ex. $Na^{+} + Cl^{-} = NaCl$

Water as a Solvent

- When salt is placed in water, the strongly charged salt ions attract to the weaker charged water molecules.
- Water molecules surround each ion.
- Salt crystals fall apart, or dissociates, and the salt dissolves.

Salt Water and Salinity

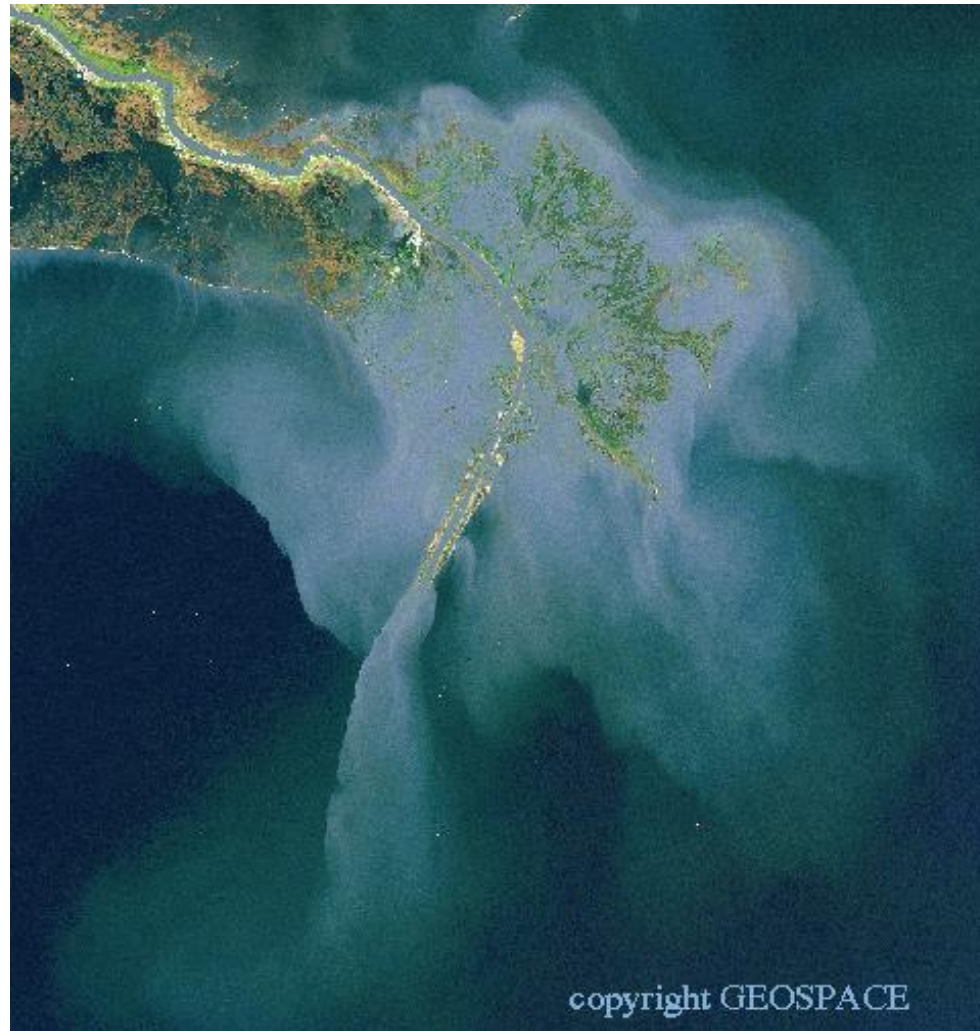
- **Solids found in seawater come from 2 main sources:**
  1. Chemical/Mechanical weathering of rocks on land.

     Carried to sea by rivers
  2. Come from the Earth's interior

     Released into oceans by hydrothermal vents

Salt Water and Salinity

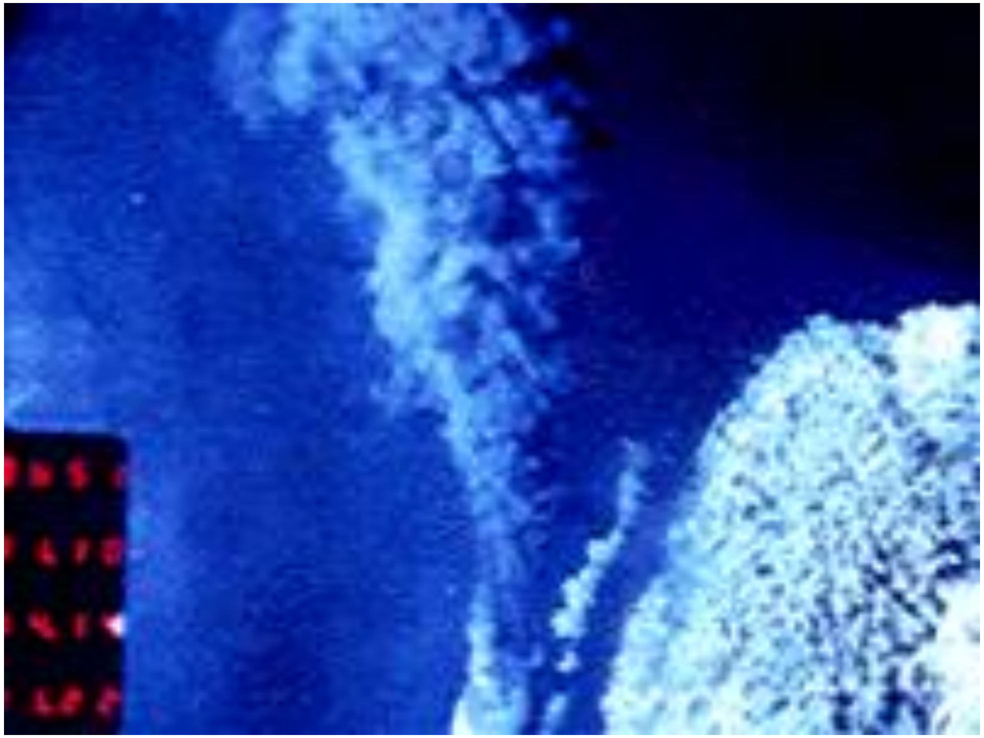
Chemical/Mechanical weathering

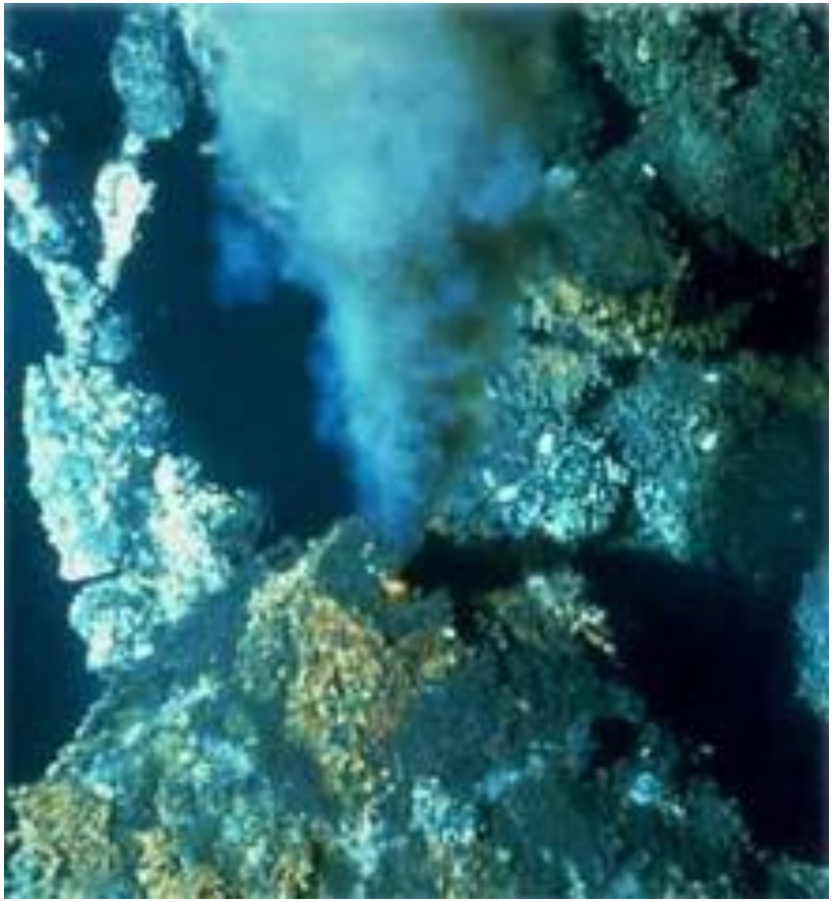


Mississippi Delta

Salt Water and Salinity

Hydrothermal Vents





Salt Water and Salinity

- Seawater contains most all elements found on Earth
- Most of the solutes are made of a small group of common ions

Solute- the substance being dissolved by the solvent

Salt Water and Salinity

Chloride (Cl^-)	55.03%
Sodium (Na^+)	30.59%
Sulfate (SO_4^{-2})	7.68%
Magnesium (Mg^{+2})	3.68%
Calcium (Ca^{+2})	1.18%
Potassium (K^+)	1.11%

- Six (6) ions compose over 98% of solids in seawater.

Na^+ and Cl^- = 85%
(This is why seawater tastes salty)

Salt Water and Salinity

- Salinity- total amount of salt dissolved in seawater.

Expressed as the number of grams of salt left when 1000g of seawater evaporates

Ex. 35 grams left over = salinity of 35 parts per thousand (35 ppt or $35^{0}/_{00}$).

Salt Water and Salinity

Salinity varies by the addition or deletion of pure water (***not salts***)

Pure water is added by **precipitation**.

Pure water is removed by **evaporation** or **freezing**.

Salt Water and Salinity

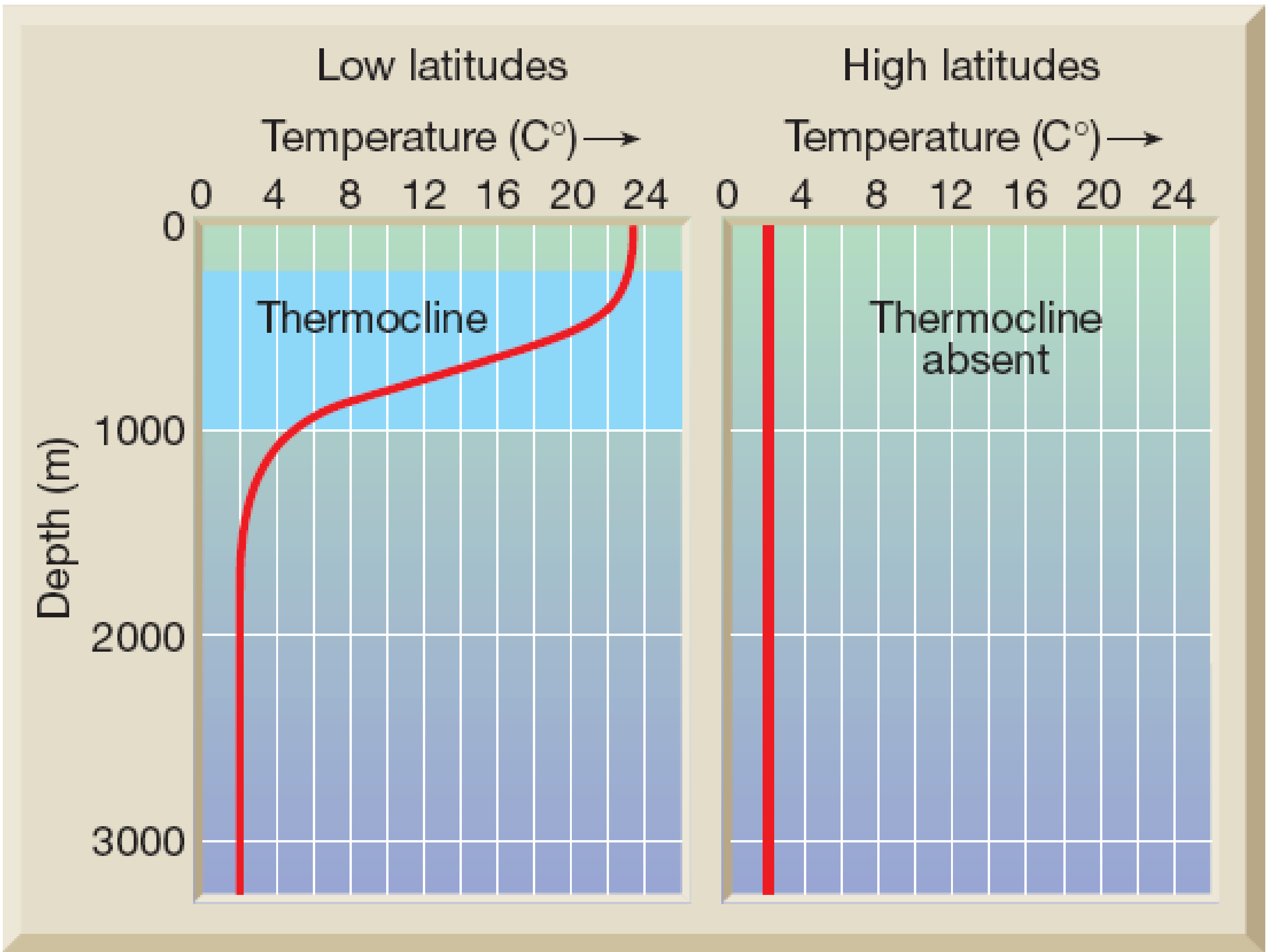
Average salinity:

Ocean:	35 ppt	
Red Sea:	40 ppt	**hot, dry climate;** **evaporation > precipitation**
Baltic Sea:	7 ppt	**excess river runoff;** **evaporation < precipitation**

Ocean Temperature Variation

- The ocean's surface water temperature varies with the amount of solar radiation received, which is primarily a function of latitude
- Surface waters generally have higher temperatures than deeper waters; however, the observed temperature pattern varies with latitude
- **Thermocline** – the layer of ocean water between about 300 meters to 1000 meters, where there is a rapid change of temperature with depth
- Below the *thermocline*, water remains just a few degrees above freezing and is relatively constant to the bottom.

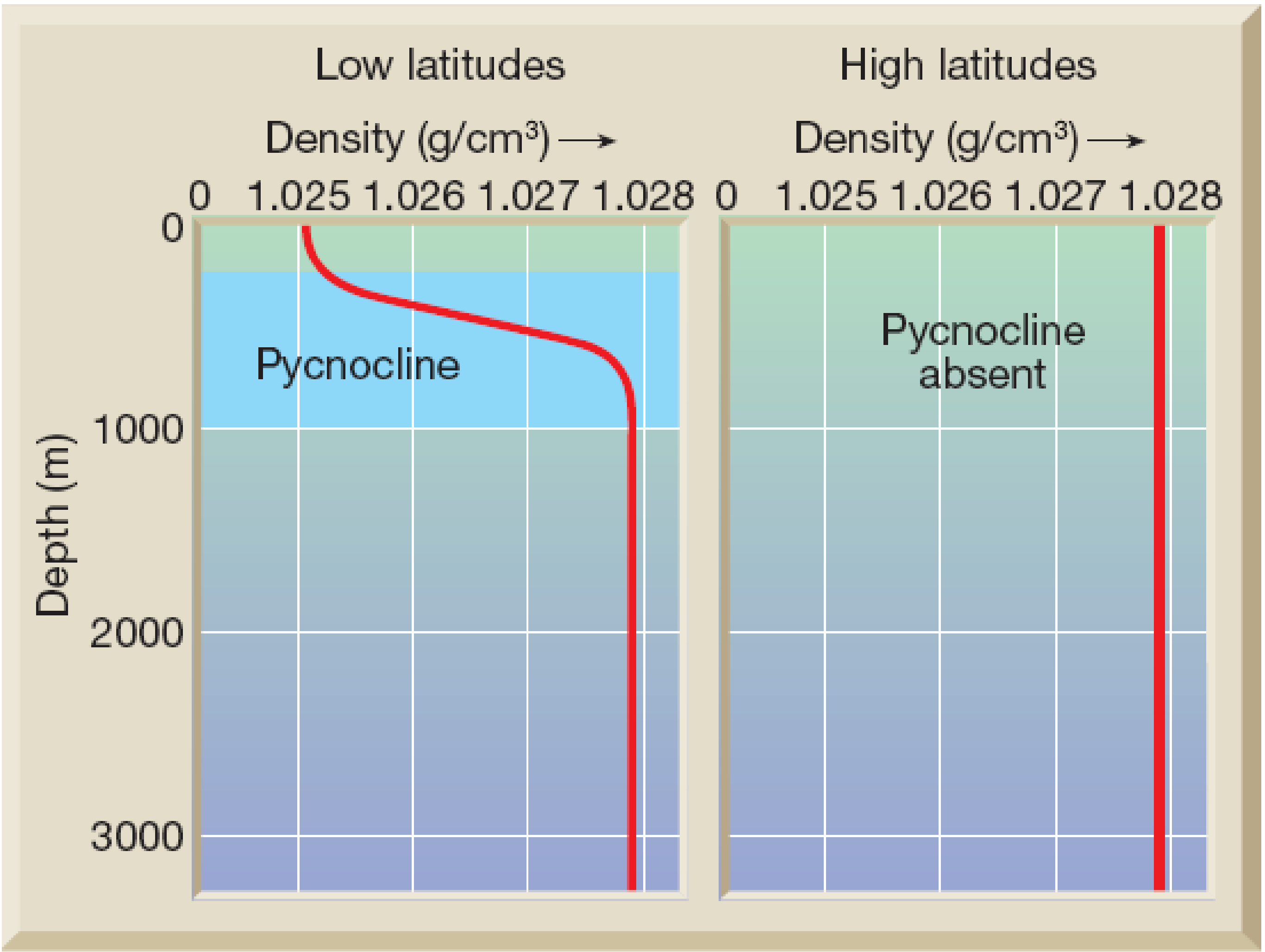
Variations in Ocean Water Temperature with Depth



Ocean Density Variation

- **Density** – mass per unit volume. Density is an important property for ocean water because it determines the water's vertical position in the ocean
- Seawater density is influenced by two main factors: **salinity** and **temperature**
- Temperature has the greatest influence on density, with salinity only becoming a major factor in extreme polar regions
- Temperature and salinity vary with depth
- **Pycnocline** – layer of ocean between about 300 meters and 1000 meters where there is a rapid change of density with depth
- The pycnocline represents a barrier to mixing between low-density water above and high-density water below

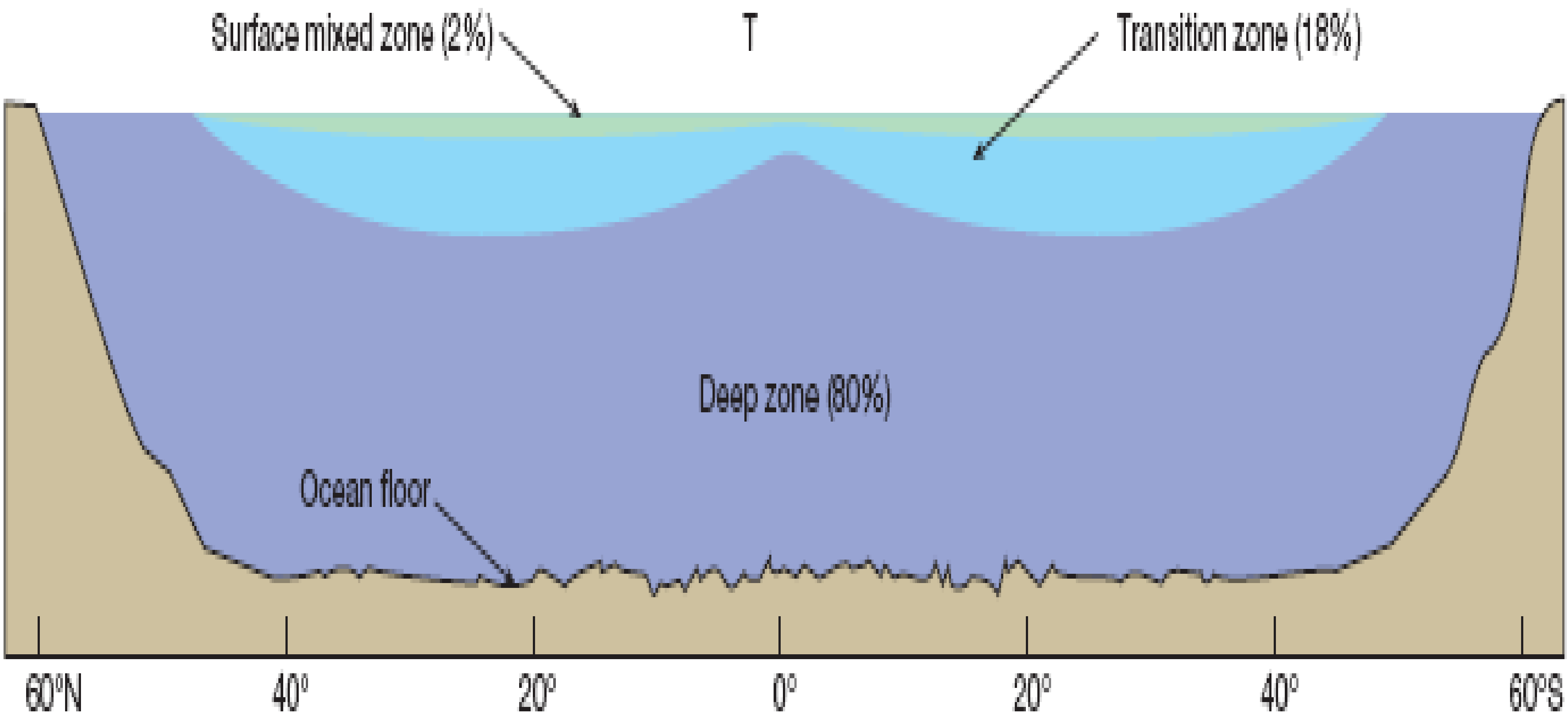
Variations in Ocean Water Density with Depth



Ocean Layering

- Oceanographers generally recognize a three-layered structure in most parts of the open-ocean: a shallow surface mixed zone, a transition zone, and a deep-zone
- **Mixed Zone** – the area of the ocean's surface created by the mixing of water by waves, currents, and tides
- The mixed zone has a nearly uniform temperature, and only accounts for ~2% of ocean water
- The **transition zone** exists between the warm surface and the deep zone
- The transition zone includes a *thermocline* and associated *pycnocline* (~18% of ocean water)
- In the **deep zone**, sunlight never reaches and temperatures are only a few degrees above freezing all the time
- Water density remains high and constant within the deep zone, this zone accounts for ~80% of ocean water

Three Layers of the Ocean



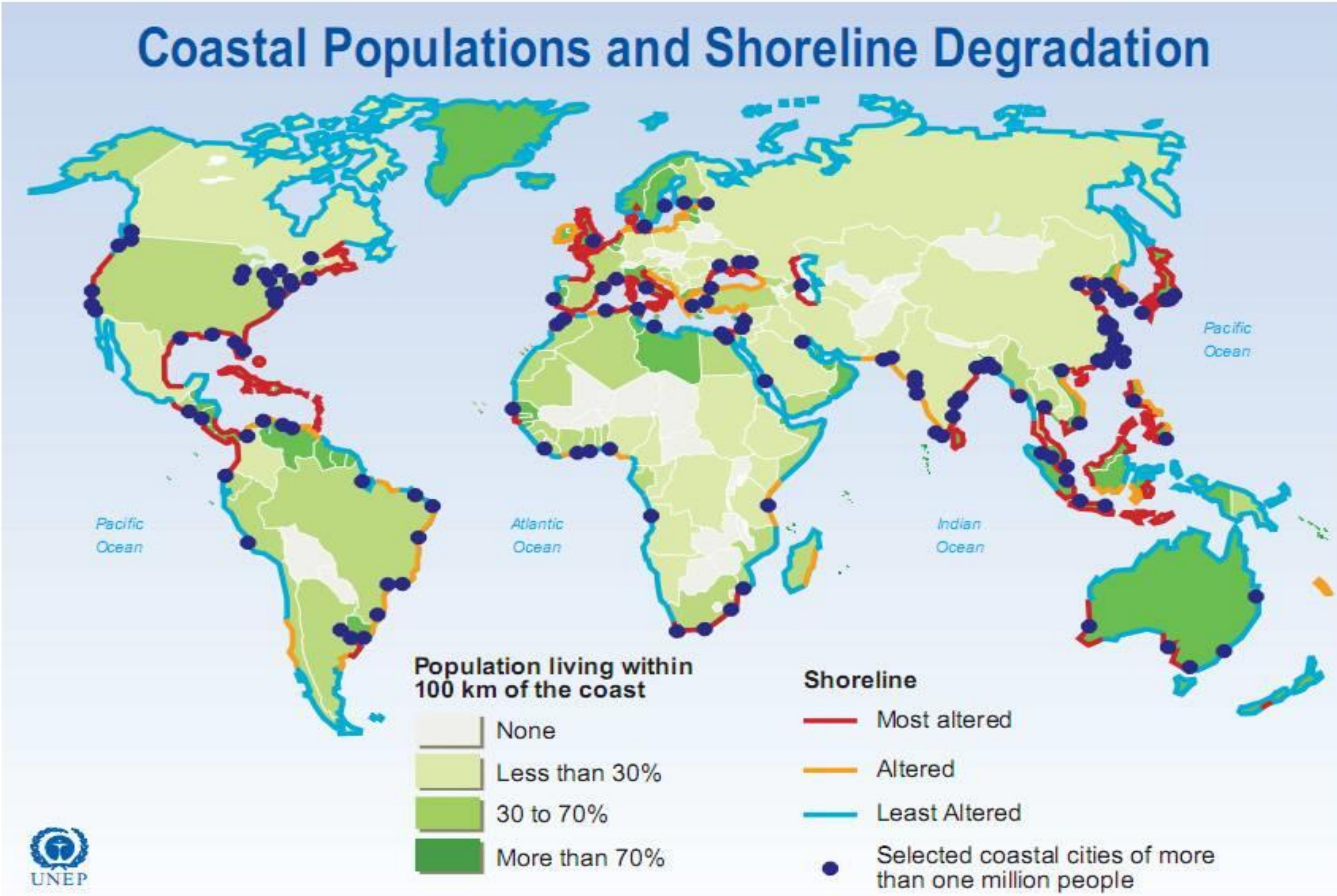
What is Marine Pollution?

- **It is a change in the physical, chemical and biological characteristics of water & sediments.**
- **It causes degradation of the natural quality of the coastal environments.**
- **It affects the health and survival of all forms of life.**
- **It is a major problem in developing countries--- and the trends are expected to increase.**

Marine pollution: A definition

- The introduction by man, directly or indirectly, of substances or energy into the marine environment, including estuaries, which results or is likely to result in such deleterious effects as harm to living resources and marine life, hazards to human health, hindrance to marine activities, including fishing and other legitimate uses of the sea, impairment of quality for use of sea water and reduction of amenities. (World Health Organization, WHO).

Marine pollution defined as contamination of oceans or seas, due to presence of unwanted materials or pollutants. The most common pollutants include chemicals, oils, toxic bio-matter, plastics etc.

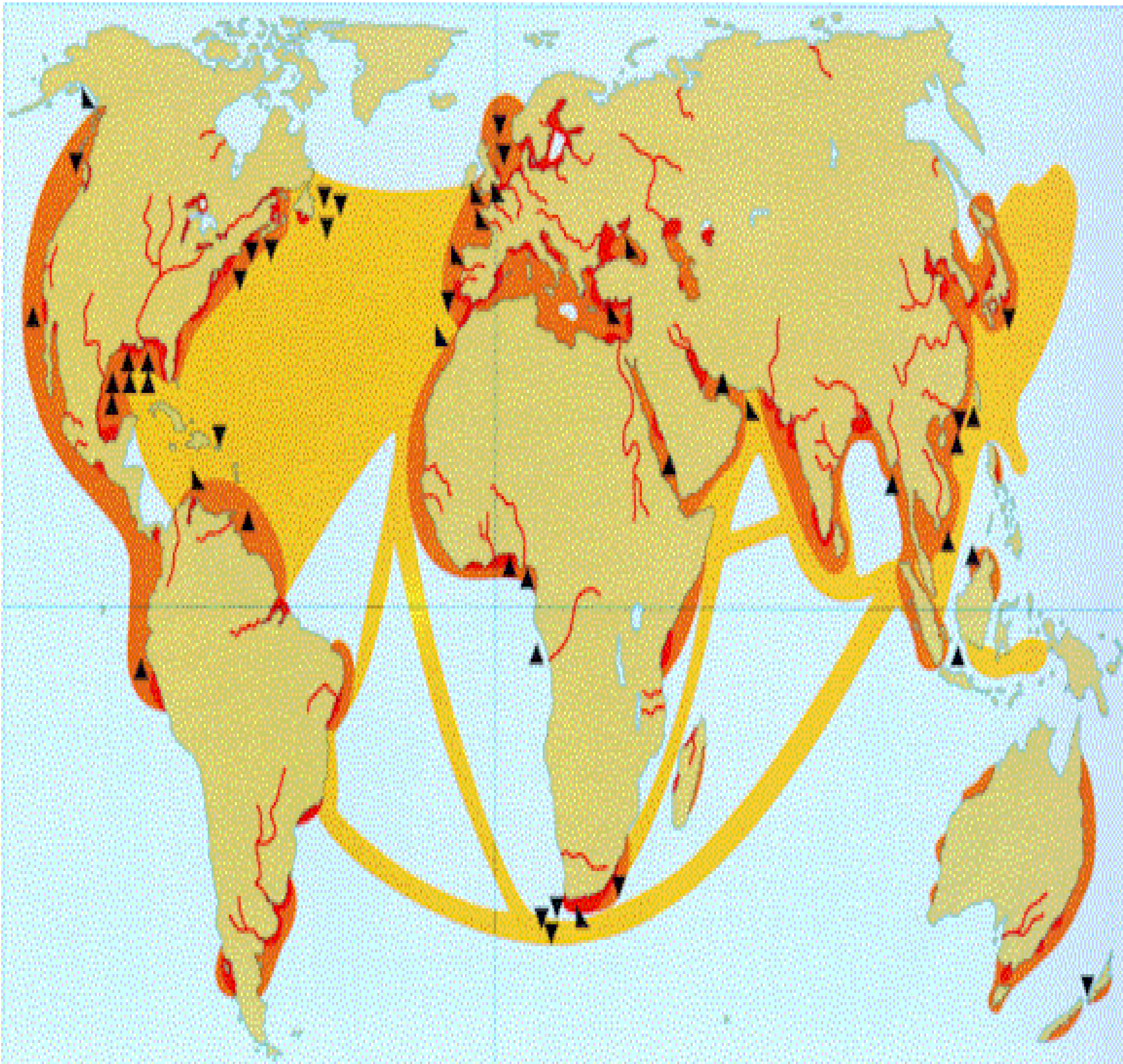


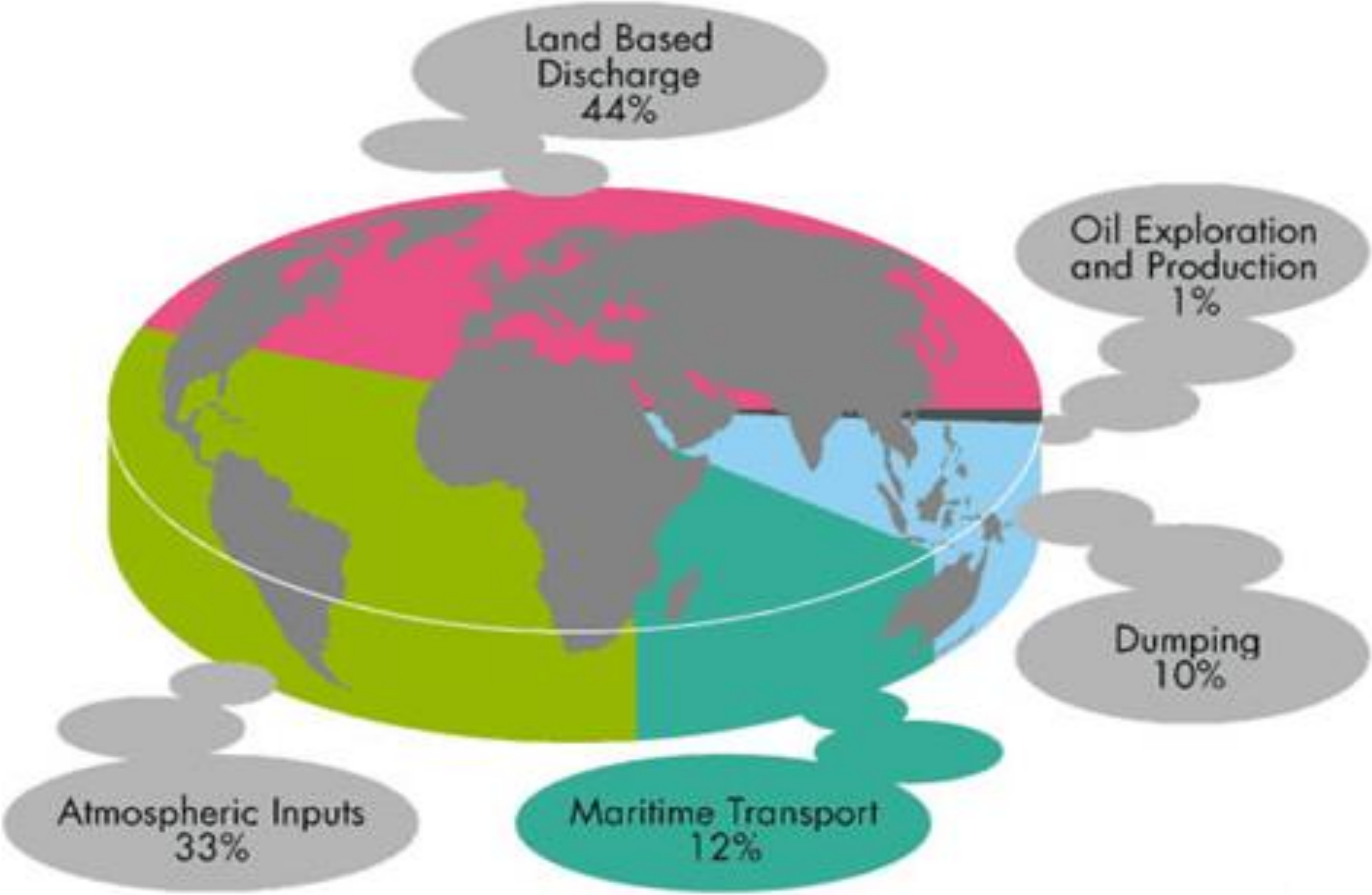
Source: Burke et al., World Resources Institute, Washington DC, 2001; Paul Harrison and Fred Pearce, *AAAS Atlas of Population and Environment 2001*, American Association for the Advancement of Science, University of California Press, Berkeley.

Water Pollution

- Severely polluted sea areas and lakes
- Polluted sea areas and lakes
- Areas of frequent oil pollution by shipping
- Major oil tanker spills
- Major oil rig blow-outs
- Offshore dumpsites for industrial and municipal waste
- Severely polluted rivers and estuaries

The most notorious tanker spillage of the 1980s occurred when the *Exxon Valdez* ran aground in Prince William Sound, Alaska, in 1989, spilling 267,000 barrels of crude oil close to shore in a sensitive ecological area. This rates as the world's 28th worst spill in terms of volume.



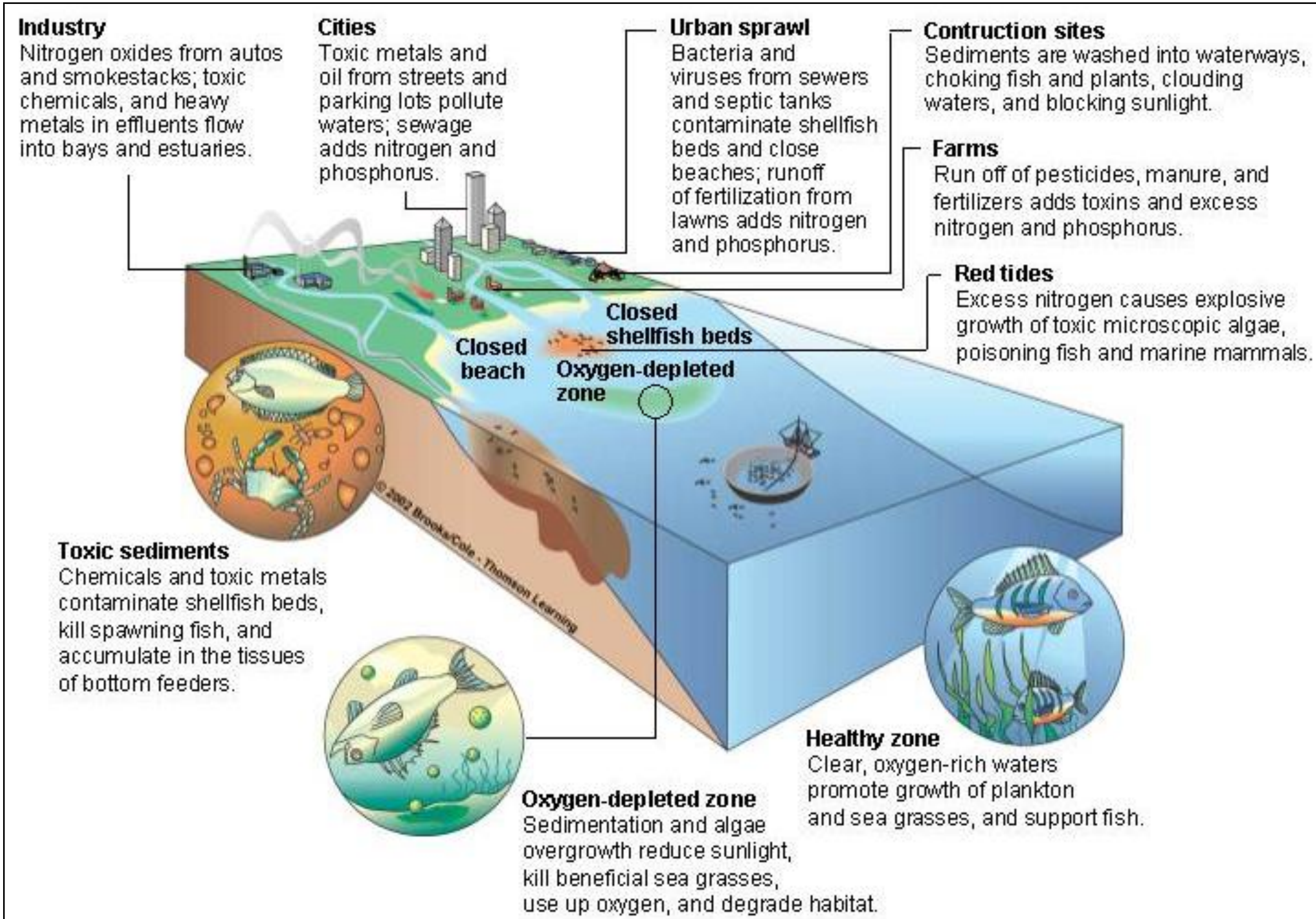


Marine Pollution Chart

Major industries in India responsible for coastal pollution

- Fertilizers
- Sugar
- Textiles
- Chemicals
- Mines and minerals
- Pulp and paper
- Leather tanneries

Causes



Industry
Nitrogen oxides from autos and smokestacks; toxic chemicals, and heavy metals in effluents flow into bays and estuaries.
Cities
Toxic metals and oil from streets and parking lots pollute waters; sewage adds nitrogen and phosphorus.
Urban sprawl
Bacteria and viruses from sewers and septic tanks contaminate shellfish beds and close beaches; runoff of fertilization from lawns adds nitrogen and phosphorus.
Contruction sites
Sediments are washed into waterways, choking fish and plants, clouding waters, and blocking sunlight.
Farms
Run off of pesticides, manure, and fertilizers adds toxins and excess nitrogen and phosphorus.
Red tides
Excess nitrogen causes explosive growth of toxic microscopic algae, poisoning fish and marine mammals.
Closed shellfish beds
Closed beach
Oxygen-depleted zone
© 2002 Brooks/Cole - Thomson Learning
Toxic sediments
Chemicals and toxic metals contaminate shellfish beds, kill spawning fish, and accumulate in the tissues of bottom feeders.
Oxygen-depleted zone
Sedimentation and algae overgrowth reduce sunlight, kill beneficial sea grasses, use up oxygen, and degrade habitat.
Healthy zone
Clear, oxygen-rich waters promote growth of plankton and sea grasses, and support fish.

Pathways of pollution

There are many ways to categorize and examine the inputs of pollution into marine ecosystems. There are three main types of inputs of pollution into the ocean: direct discharge of waste into the oceans, runoff into the waters due to rain, and pollutants released from the atmosphere.

Pollution is often classed as point source or nonpoint source pollution.

Point source pollution occurs when there is a single, identifiable, localized source of the pollution. An example is directly discharging sewage and industrial waste into the ocean. Pollution such as this occurs particularly in developing nations.

Nonpoint source pollution occurs when the pollution is from ill-defined and diffuse sources. These can be difficult to regulate. Agricultural runoff and wind blown debris are prime examples.

1. **Direct Discharge**: From urban sewerage and industrial waste discharges, sometimes in the form of hazardous and toxic wastes. The wastes often contain toxic materials such as mercury, PCBs, PAHs and radioactive materials, which contaminate the water of ocean.

2. **Mining of sand** from the sea bed results in an increase in turbidity in the coastal water, which affects ecosystem and primary productivity of fauna and flora by limiting the availability of sunlight.

3. **Land Runoff:** Surface runoff from farming, as well as urban runoff from the construction can carry soil laden with carbon, nitrogen, phosphorus, and minerals. This nutrient-rich water can cause fleshy algae and phytoplankton to thrive in coastal areas, known as algal blooms, which use all available oxygen.

4. **Ship Pollution:** Oil spills can have devastating effects. Very difficult to clean up, and last for years in the sediment and marine environment. Discharge of cargo residues from bulk carriers are also a cause (intentional discharge). Ships also create noise pollution that disturbs natural wildlife, and water from ballast tanks can spread harmful algae and other invasive species.

5. **Atmospheric Pollution:** Wind blows dust and debris, including plastic bags, seaward from landfills and other areas. Climate change is raising ocean temperatures and raising levels of carbon dioxide in the atmosphere. These rising levels alter the aquatic ecosystems and modify fish distributions.

6. **Also Carbon dioxide**, emitted by automobiles, due to the burning of fossil fuels, leads to air pollution. This results in acid rain.

7. **Eutrophication-** The enrichment of water by nutrients, especially compounds of nitrogen and phosphorus, causes an accelerated growth of algae and higher forms of plant life to produce an undesirable disturbance to the balance of organisms and the quality of the water

8. **Trash** washed into the ocean after heavy rain or floods gives rise to marine debris, which pollutes the water body. Marine debris is mainly discarded human rubbish which floats on, or is suspended in the ocean.

9. **Dumping** of human wastes, plastic and disposal of untreated or partially treated sewage water into the ocean is called 'garbage dumping. This is one of the leading causes of marine pollution.

10. Population growth and urbanisation are also reasons.

The water quality of a system depends crucially on the retention of pollutants within the system and its ability to flush them out.

Transport time scales are often compared with the pollutant source time scales or biogeochemical processes to evaluate the relative importance of physical and water quality processes. They are also used to understand population dynamics and to serve as indicators to classify and compare estuarine systems.

Residence time is the "time it takes for any water parcel of the sample to leave the lagoon through its outlet to the sea". It can be used to analyse the spatial variation of flushing properties and the variation of renewal for different environmental conditions. These detailed properties makes residence times very useful for comparative analyses of the effects of several engineering interventions (dredging, hard-struture building), and also to characterize changes in the system's contaminant inputs (changes in the nature, location and frequency of the sources of contaminants). The specific way to define "the time to leave the system" can also lead to different concepts of residence times which can be very important for water quality analyses.

EFFECTS!

- A reduction in biodiversity
- Stress on marine animals / populations that are already threatened or endangered.

Algal blooms

Red tides

Addition of nutrients & pathogens

- Organic matter - when in the sea/ocean, absorbs dissolved oxygen, which reduces level of oxygen in water, which marine life requires to survive

- Feed algal blooms & stimulate their growth-These algal blooms can also release toxins that can kill fish and poison people

- Algae blooms that feed on human sewage also causes discoloration of water due to the decomposition of matter, can choke fish gills and even poison them with the chemicals created from the decomposition process.

- Human sewage also contain bacteria and pathogens that contaminate the coastal areas by accumulating on shores and beaches. This might even enter the food chain or spread diseases like cholera, typhoid, or other dangerous diseases.

- Ocean organisms like mussels, oysters and clams that are consumed as food have a tendency of concentrating pathogens in their gut. Consumption of these foods will increase the possibility of food poisoning, creating possible health risks to many people around the world.

Sediments and Plastics

- Sediments from dredging and mining makes the sea water turbid, preventing sunlight to reach the marine plants for photosynthesis (much like oil spills).
- When heavy sediments settle on the ocean floor can bury fish and other delicate species such as coral reefs. These sediments can also be detrimental to a large part of the marine ecosystem.
- Sources of plastics include landfills, waste disposal from plastic industries, plastic garbage from ships, and litter on beaches. Plastics can stick to marine life and affect their breathing or swimming. Small plastic fragments can be mistaken as food by fish or other sea life which can kill them by filling up or damaging their stomach or other digestive organs.
- Another common piece of plastic that holds together packs of soda cans are infamous for getting stuck around the necks of birds, sea turtles, and other marine life.

Chemical, radioactive and thermal pollution

- Discarded radioactive materials from nuclear submarines and military waste have been a major source of radioactivity in the oceans, which causes fatal harm to marine life. They can also enter the food chain as some organisms like shellfish concentrate radioactivity in their bodies which are later consumed by humans.

- Pesticides like Dichlorodiphenyltrichloroethane (DDT) can enter the oceans through city waste water and industrial discharges from farms. Pesticides are easily absorbed by marine organisms causing numerous defects and reproductivity problems

- When high or low temperature water is discharged from an industrial source. The difference in temperatures can kill corals and other sensitive marine organisms that are not developed to handle the different temperatures.

Oil Pollution

- Oil spills are not the only source of oil pollution. Oil finds its way into the sea through many ways such as automobiles, waste discharge of heavy industries. Even the slightest type of contamination can kill the larvae of marine animals and also spread diseases. Larger oil spills are the worst type of marine pollution.

- The oil sticks to the body of marine organisms making them incapable of performing some necessary functions. Sea birds are the ones most affected by oil spills as the oil sticks to their wings, rendering them flightless.

- Density of oil is less that water, it floats on the top, forming a thick impermissible membrane. This thick layer prevents marine organisms to come to the surface for sunlight and oxygen, and eventually kills them. As the layer is black and opaque. The sunlight cannot pass through the surface. This prevents the marine plants to photosynthesize sunlight into energy.

- Tar balls formed due to the coagulation of oil, water, and other debris is washed onto the shore, causing harm to human and coastal life that relies on the water and beaches for food.

MANAGEMENT ISSUES

- Sustainable use and conservation of Marine resources has been a major issue
- Pollution from use of persistent organic pollutants- such as DDT for crop protection
- Effect of antifouling paints used on ships on marine organisms and adoption of the ban targeted for by IMO (International Maritime Organisation).
- Adequate support from developed countries to ocean related capacity building in developing countries.

- Need for some form of International involvement in management of the high seas fishery resources, as observed by UN conference on Straddling and Highly Migratory fish stocks

- Release of persistent hydrocarbons through ship traffic and their effect of global warming and climate change

- Oil Spills

Global conventions to mitigate marine pollution

- Since 1954 a number of global agreements dealing with marine pollution have been adopted:
  - International Convention for the Prevention of Pollution of the Sea by oil (OILPOL), 1954;
  - Convention on the Prevention of Marine Pollution by Dumping of Wastes and other Matter (London-Dumping Convention), 1972;
  - International Convention for the Prevention of Pollution from Ships, 1973, as modified by the protocol of 1978 (MARPOL 73/78);
  - United Nations Convention on the Law of the Seas, 1982; and
  - International Convention on Oil Pollution Preparedness, Response and Cooperation, 1990.

The International Convention for the Prevention of Pollution from Ships (Marpol)

- One of the important international marine environmental conventions. It was adopted on 02.11.1973 at International Maritime Organisation (IMO) and covered pollution by oil, chemicals, harmful substances in packaged form, sewage and garbage.

- The MARPOL Convention is the main international convention covering prevention of pollution of the marine environment by ships from operational or accidental causes.

- It is a combination of two treaties adopted in 1973 and 1978 respectively and updated by amendments through the years.

- The Convention includes regulations aimed at preventing and minimizing pollution from ships - both accidental pollution and that from routine operations - and currently includes six technical Annexures.

Annex I	**Regulations for the Prevention of Pollution by Oil**
Annex II	**Regulations for the Control of Pollution by Noxious Liquid Substances in Bulk**
Annex III	**Prevention of Pollution by Harmful Substances Carried by Sea in Packaged Form**
Annex IV	**Prevention of Pollution by Sewage from Ships**
Annex V	**Prevention of Pollution by Garbage from Ships**
Annex VI	**Prevention of Air Pollution from Ships**

(

- The Indian Merchant Shipping Act, 1958, reinforces the International Convention for the prevention of pollution of the sea by oil, 1954, as amended in 1962.
- Prevention of such oil pollution is tackled by International Convention, Merchant Shipping Act, 1958
  - ➢ The rules specify the limits of the prohibited zones, the equipment to be carried on board the ship.
  - ➢ General precautions to be taken for prevention of leakage and accidental discharges as well as precautions to be taken while loading, transferring and unloading oil by tankers.
  - ➢ The rules also require all vessels to maintain oil records book to indicate any operations carried out on board with respect to oil.
  - ➢ A Contingency Plan of action is prepared so that in the event of any spillage whether accidental or otherwise, the same can be dealt with.
- The authorities in the major ports viz. Kandla, Mumbai, Goa, Mangalore, Cochin, Chennai. Tuticorin, Vishakapatnam, Paradip and Calcutta, shall form and co-ordinate the Local Action Group.
- It is expected that the local action group shall equip their organization with dispersants, dispersants spraying equipment, crafts, skimmers, off-shore books and other such material required for the purpose.

Some major international shipping conventions, adopted by the International Maritime Organization (and the International Labour Organization) concerning safety and pollution prevention are:

- **SOLAS** (International Convention for the Safety of Life at Sea, 1974) lays down a comprehensive range of minimum standards for the safe construction of ships and the basic safety equipment (e.g. fire protection, navigation, lifesaving and radio) to be carried on board. SOLAS also requires regular ship surveys and the issue by flag states of certificates of compliance.

- **COLREG** (Convention on the International Regulations for Preventing Collisions at Sea, 1972) lays down the basic "rules of the road", such as rights of way and actions to avoid collisions.

- **LOADLINE** (International Convention on Loadlines, 1966) sets the minimum permissible free board, according to the season of the year and the ship's trading pattern.

- **ISPS** (The International Ship and Port Facility Security Code, 2002) includes mandatory requirements to ensure ships and port facilities are secure at all stages during a voyage.

RS and GIS for Marine Pollution

Increasing concerns about pollution levels in the oceans and coastal regions have led to multiple approaches for measuring and mitigating marine pollution, in order to achieve sustainable marine water quality.

Satellite remote sensing is considered useful for detecting and monitoring marine pollution. Recent developments in sensor technologies have transformed remote sensing into an effective means of monitoring marine areas.

Different remote sensing platforms and sensors have their own capabilities for mapping and monitoring marine pollution of different types, characteristics, and concentrations.

The oceans act as a natural sink for carbon dioxide and other greenhouse gases. However, anthropogenic activities have severely polluted the marine environment in the past few decades. Pollutants including plastic, oil, toxic chemicals, radioactive waste, and domestic and industrial sewage can be found in marine waters.

Marine pollution is also caused by the discharge of sewage into rivers and excessive nutrients entering marine waters from agricultural fertilizers and pesticides.

These pollutants have adverse impacts on marine ecosystem including coral reefs, mangroves, and aquaculture. Therefore, in addition to reducing pollutant flow into oceans, it is essential to map and monitor marine pollutants to ensure a sustainable marine ecosystem.

The most common approach for marine pollution measurements is collecting insitu water samples using boats/ships from different depths of water with water samplers. The water samples are analyzed in the laboratory to determine the physical and chemical properties of the water.

Such methods are accurate but time-consuming and geographically constrained and require trained professionals and laboratory analysis.

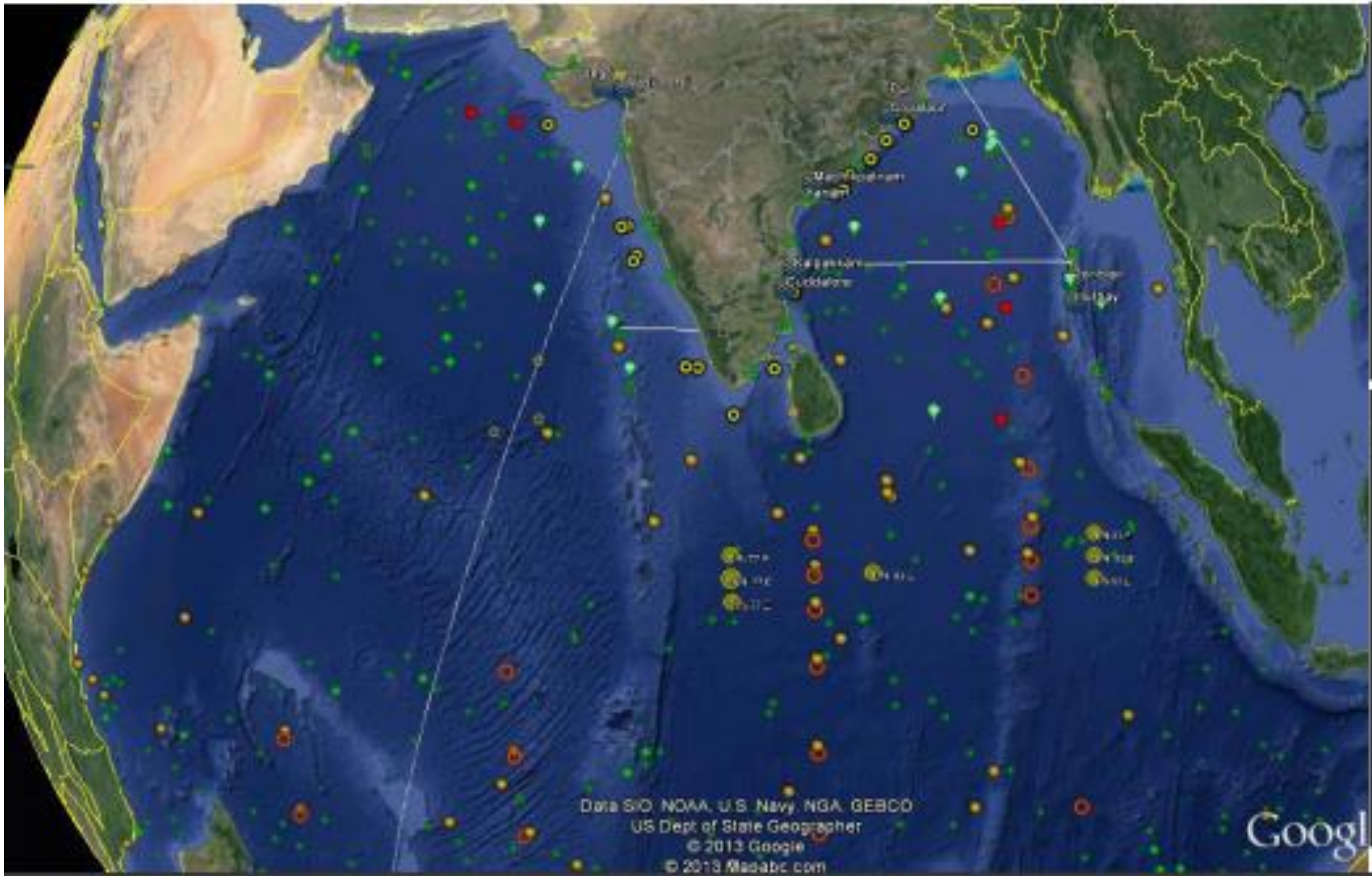
However, real-time or near real-time measurements of marine pollutants across a range of spatial scale are necessary for monitoring and managing the environmental impacts and understanding the processes governing their spatial distribution.

In-situ Observation Systems

Observations are important for understanding the vast expanse of our Oceans

Early Attempts:
322 BC – Aristotle - Charted currents in Euripus Strait
1777 – Benjamin Franklin – Charted currents in the Atlantic
1849 – Mathew Maury - Worldwide Current & Wind Atlas
1872 – 1876 – Challenger Expedition

Developments in 20th Century:
Acoustic Sounding for Bathymetry
Instruments for measuring T & S
Instruments for monitoring for Deep Currents
Global Experiments (IIOE, TOGA, WOCE)



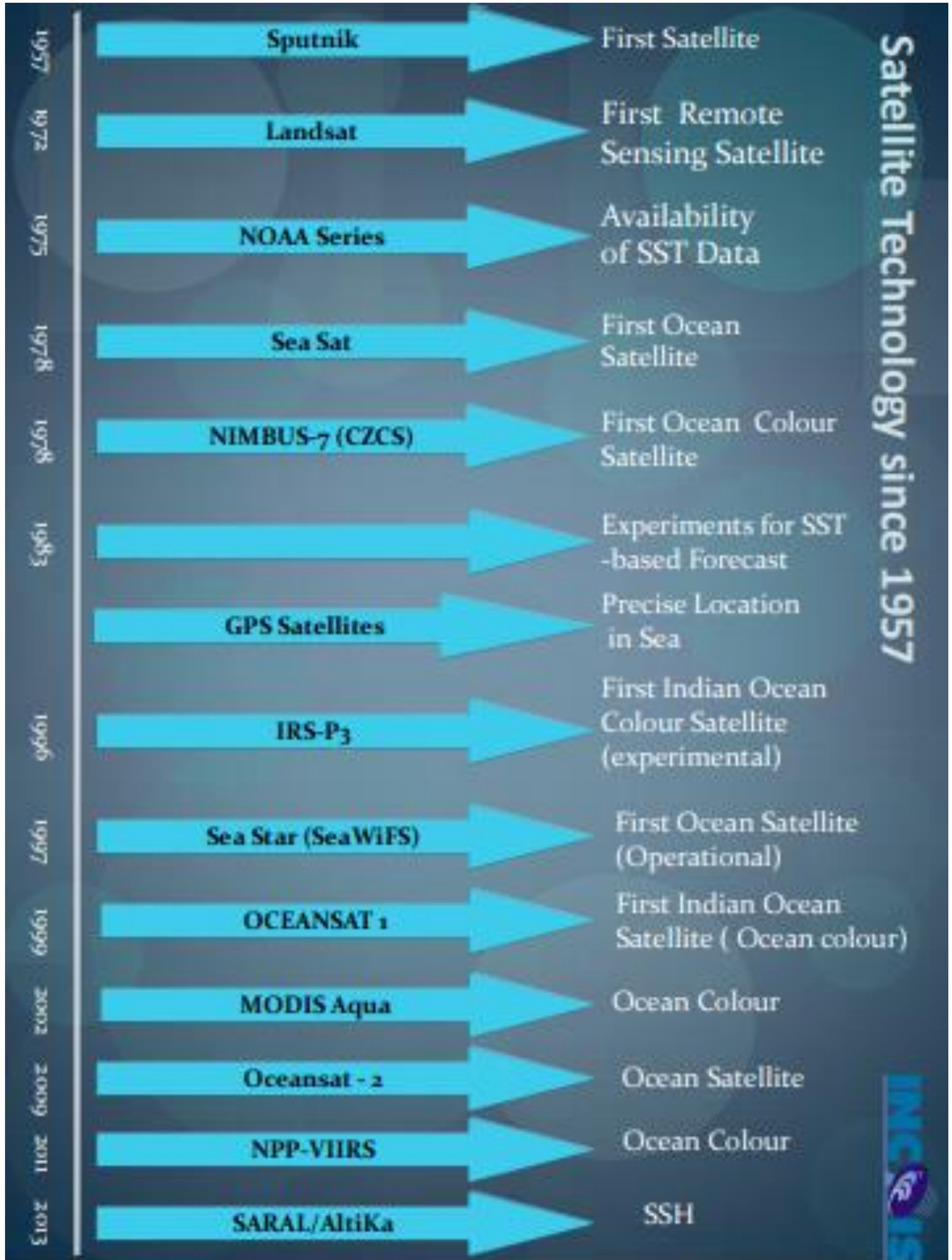
Last Decade:
Argo, Moorings, ADCP, drifters, RAMA buoys, Current meter moorings, XBT, CODAR, Tsunami buoys, wave rider buoys, Tide Gauges

Limitations:
- Point observations
- Limited spatial & temporal resolutions
- High Cost
- Sensor Degradation
- Inability to maintain systems at desired locations
- Geo-political considerations

In-situ Observation Systems by India

Remote sensing technology provides spatially synoptic and near real-time measurements that can be effectively used to detect, map and track many pollutants such as oil and chemical spills, algal blooms, and high suspended solid concentrations.

Aerial and satellite remote sensing has been demonstrated as an effective tool in detecting and mapping pollutant spills and for providing useful input data for oil spill models, to track pollutants through space and time.


Satellite Technology since 1957
1957
Sputnik
First Satellite
1972
Landsat
First Remote Sensing Satellite
1975
NOAA Series
Availability of SST Data
1978
Sea Sat
First Ocean Satellite
1978
NIMBUS-7 (CZCS)
First Ocean Colour Satellite
1983
Experiments for SST -based Forecast
GPS Satellites
Precise Location in Sea
1996
IRS-P3
First Indian Ocean Colour Satellite (experimental)
1997
Sea Star (SeaWiFS)
First Ocean Satellite (Operational)
1999
OCEANSAT 1
First Indian Ocean Satellite (Ocean colour)
2002
MODIS Aqua
Ocean Colour
2009
Oceansat - 2
Ocean Satellite
2011
NPP-VIIRS
Ocean Colour
2013
SARAL/AltiKa
SSH

Remote Sensing Observations – Some Recent Missions

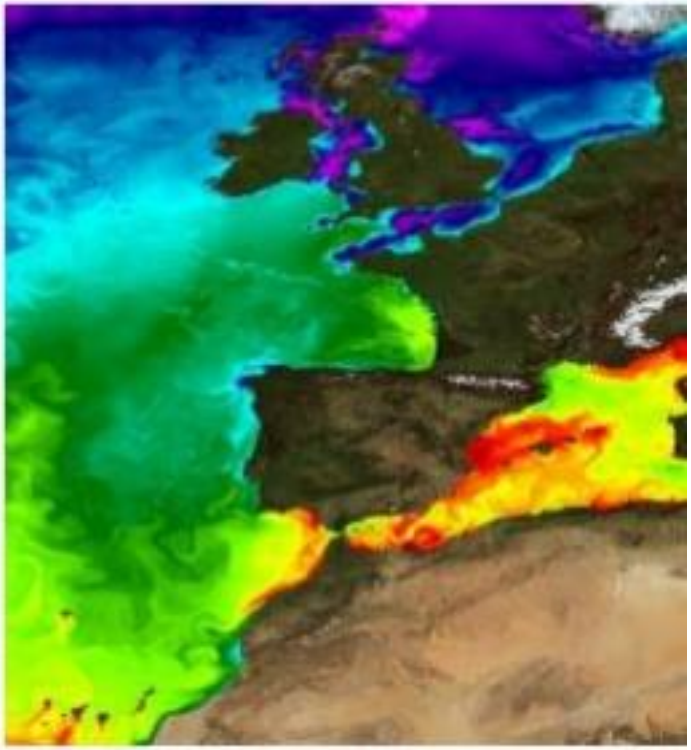
TOPEX
Jason-1
ERS
NPOESS
Oceansat3
METOP (ASCAT)
Jason-2 SARAL
RADARSAT RISAT
Megha Tropiques
Land RS Satellites
Oceansat-2 (OCM, OSCAT)
SMOSS Aquarius
INSAT (VHRR)
Aqua/Terra (MODIS)
NOAA (AVHRR)
TRMM
Oceansat-1 (OCM)

Advent of Satellite Observing Systems in 1960s

- Synoptic Observations even over large inaccessible areas
- High resolution in spatial, spectral, temporal and radiometric domains
- Reasonable accuracy & reliability
- Development of accurate, up-to-date and comprehensive scientific data base.
- **Operational Oceanography - Coastal & Ocean Information Services**

Radiometer (VIS, IR)	Radiometer (MW)	Altimeter (MW)	Scatterometer (MW)	SAR (MW)	Imaging Radiometer (MW)
•Ocean Colour •SST •Coastal Processes	•Wind Speed •SST •Sea Ice Extent	•Wave Ht. •Sea Level •Sea Ice	•Surface Wind Vector	•Wave Spectrum •Sea Mounts	• SSS

How SST is measured



- **By satellite**
  •Infrared radiometers
  •Microwave radiometers

  In-situ techniques
  •Ships of opportunity
  •Drifting buoys
  •Argo profiling floats
  •Moored buoys
- **Numerical models**
  Numerical atmospheric or oceanic models are also capable of calculating sea surface temperature. Models are calibrated by comparing the sea surface temperature produced by the model with that measured by different sensors.

Which Satellite Instruments are used for monitoring SST ?

- MODIS (or Moderate Resolution Imaging Spectroradiometer) is a key instrument aboard the Terra (EOS AM) andAqua (EOS PM) satellites.
- Terra's orbit around the Earth is timed so that it passes from north to south across the equator in the morning, while Aqua passes south to north over the equator in the afternoon.
- Terra MODIS and Aqua MODIS are viewing the entire Earth's surface every 1 to 2 days, acquiring data in 36 spectral bands, or groups of wavelengths. These data improve our understanding of global dynamics and processes occurring in the oceans, and in the lower atmosphere. MODIS is playing a vital role to predict global change accurately.