Measuring Ocean Color: The Basics
Radiation of energy from the Sun and the Earth’s surface.

Recall from previous lectures that the Sun (6000°K), radiates energy in three portions of the energy spectrum:
- Ultraviolet
- Visible Light
- Short-wave Infrared

The Earth, being a cooler body (300°K), radiates energy only in the Long-wave Infrared portion of the energy spectrum.

The measurements of ocean color are based on Visible Light. This energy is emitted by the sun, transmitted through the atmosphere and then interacts with Earth’s surface.
Sunlight, however, is not merely reflected from the ocean surface. The color of the water surface results from sunlight that has entered the ocean, been selectively absorbed, scattered and reflected by phytoplankton and other suspended material in the upper layers, and then backscattered through the surface.
Interaction of Sunlight with Ocean Water – Energy Spectrum

Different materials in the water interact in different ways with the incoming energy. Thus measurement of ocean color can provide information about the type and amount of materials in the water.

Clean ocean water (Line A) has maximum emitted light in short (blue) wavelength and almost zero in yellow & red.

In phytoplankton, which contain chlorophyll and other plant pigments, maximum emitted light is more green color (Line B).

In coastal zones, with high concentration of dead organic and inorganic matter, light emitted is more red (Line C).
Interaction of Sunlight with Ocean Water – Energy Spectrum

Clean ocean water absorbs red light, i.e., sun radiation of long wavelength and transmits and scatters the light of short wavelength. That is why ocean surface looks blue.

Try this simple activity to see how it works: Dropping M&Ms in the ocean http://www.punaridge.org/doc/factoids/Light/Default.htm

Phytoplankton cells contain chlorophyll that absorbs other wavelengths and contributes green color to ocean water.

In coastal area suspended inorganic matter backscatters sunlight, contributing green, yellow and brown to water color.
Interaction of Sunlight with Ocean Water

The transparency of clean open ocean water is very high; the photic zone may extend as deep as 100 meters.

Thus, an upper layer of tens of meters of depth may contribute to ocean color (the contribution of light interaction will decrease with depth).

Overall, the color of the water is therefore regulated by the color of pure ocean water and the concentrations of different types of particles suspended in the upper water layer.
Interaction of Sunlight with Ocean Water

In coastal waters the depth of the photic zone decreases to few meters or less.

Coastal regions may have high concentrations of phytoplankton as well as suspended matter from coastal run-off. These contributions cause the water to appear turbid (cloudy) and will change the overall water color.
For most regions of the world, the color of the ocean is determined primarily by the abundance of living phytoplankton and associated photosynthetic pigments such as chlorophyll, which absorb energy in the red and blue portions of the energy spectrum and reflect energy in the green portion of the spectrum.
The sources of color change in ocean water

Dissolved organic material
• Colored Dissolved Organic Material (CDOM, or yellow matter) is derived from decaying phytoplankton and vegetable matter (land).

Suspended particulate matter
• The organic particulates (detritus) consist of phytoplankton and zooplankton cell fragments and zooplankton fecal pellets.
• The inorganic particulates consist of sand and dust created by erosion of land-based rocks and soils. These enter the ocean through:
  • River runoff.
  • Deposition of wind-blown dust.
  • Wave or current suspension of bottom sediments.

Both CDOM and particulates absorb sunlight strongly in the blue waveband, yielding a brownish yellow color to the water.
The Coastal Zone Color Scanner (CZCS), was a multi-spectral scanner developed by NASA to measure ocean color as a means of determining chlorophyll concentrations and the distributions of particulate matter and dissolved substances.

CZCS was launched aboard Nimbus-7 satellite platform in October 1978. Due to the power demands of the various on-board experiments, the CZCS operated on an intermittent schedule.
Coastal Zone Color Scanner (CZCS) measured reflected solar energy in five channels:

1. 433-453 nm (blue) - chlorophyll absorption
2. 510-530 nm (green) - chlorophyll concentration
3. 540-560 nm (yellow) - Colored Dissolved Organic Material conc.
4. 660-680 nm (red) - aerosol absorption
5. 700-800 nm (far red) - land and cloud detection
Coastal Zone Color Scanner (CZCS)

In one two-minute data segment, the CZCS covered approximately 1.3 million square kilometers of the ocean surface. CZCS collected about 60,000 images.

Monthly summaries provided realistic patterns of phytoplankton concentrations during the 7.5 years of the mission. (November 1978 to June 1986).
Coastal Zone Color Scanner (CZCS)

This image shows total surface plant pigment concentration in the world’s oceans averaged over the entire period of observations (November 1978 – June 1986).

CZCS Classic Scenes