Ocean Color Lesson I: Energy and Color

Keywords: algorithm, photosynthetic organisms, chlorophyll, particulate matter, ocean color data, MODIS, global carbon cycle, backscatter, electromagnetic spectrum, water-leaving radiance

Why is Ocean Color Important?

The major reason scientists measure ocean color is to study phytoplankton, the microscopic ocean plants which form the base of the oceanic food web. Phytoplankton use sunlight and carbon dioxide to produce organic carbon. This process, called photosynthesis, is possible because plants contain chlorophyll, a green-colored compound which traps the energy from sunlight. Chlorophyll is also responsible for giving most marine and land plants a green color.

Because different types of phytoplankton have different concentrations of chlorophyll, measuring the color of an area of the ocean allows us to estimate the amount and general type of phytoplankton in that area.

Looking at ocean color also tells us about the health and chemistry of the ocean. In addition to light and carbon dioxide, phytoplankton also require nutrients such as nitrogen and phosphorus. The distribution of plants in the ocean also tells us where nutrient levels are high, and shows where pollutants poison the ocean and prevent plant growth. Other conditions can also affect phytoplankton growth, such as subtle changes in the climate due to seasons and variations in salinity in coastal areas. Since phytoplankton depend upon specific conditions for growth, they frequently become the first indicator of a change in their environment. Comparing images taken at different periods tells us about changes that occur over time. Because phytoplankton drift with the water, patterns in ocean color can also be used to study ocean currents.

Why are phytoplankton so important? These small plants are the beginning of the food chain for most of the planet. As phytoplankton grow and multiply, small fish and other animals eat them as food. Larger animals then eat these smaller ones. The ocean fishing industry finds good fishing spots by looking at ocean color images to locate areas rich in phytoplankton. Ocean color is therefore a valuable research tool for the study of ocean biology, chemistry, and physics.

What is Ocean Color?

The "color" of the ocean is determined by the interactions of incident light with substances present in the water. We see color when light is reflected by objects around us. White light is made up of a spectrum or combination of colors, as in a rainbow. When light hits the surface of an object, these different colors can be absorbed, transmitted through the substance, scattered, or reflected in differing intensities. The color we see depends on which colors are reflected. For example, a book that appears red to us absorbs more of the green and blue parts of the white light shining on it, and reflects the red parts of the white light. The light which is scattered or transmitted by most objects is usually not apparent to our eyes.

The substances in seawater which most affect the color reflected are the phytoplankton, inorganic particles, dissolved organic chemicals, and the water itself. Phytoplankton contain chlorophyll, which absorbs light at blue and red wavelengths and reflects green wavelengths. Particles can reflect and absorb light, which reduces the clarity (light transmission) of the water. Dissolved organic matter strongly absorbs blue light, and its presence can interfere with measurements of chlorophyll.

When we look at the ocean or observe it from space, we see that the ocean is blue because water absorbs red and reflects blue light. Using instruments that are more sensitive than the human eye, we can measure a wide array of blue shades, which reveal the presence of varying amounts of phytoplankton, sediments, and dissolved organic chemicals.

Excerpted from: http://daac.gsfc.nasa.gov/CAMPAIGN_DOCS/OCDST/seawifs_raq.html#Q1

Ocean Color and Global Warming

Besides acting as the first link in the food chain, phytoplankton are a critical part of ocean chemistry.

The carbon dioxide in the atmosphere is in balance with carbon dioxide in the ocean.

During photosynthesis phytoplankton remove carbon dioxide from sea water, and release oxygen as a by-product. This allows the oceans to absorb additional carbon dioxide from the atmosphere. If fewer phytoplankton existed, atmospheric carbon dioxide would increase.

Phytoplankton also affect carbon dioxide levels when they die and sink to the ocean floor. The carbon in the phytoplankton is soon covered by other material sinking to the ocean bottom. In this way, the oceans may store excess global carbon, which otherwise would accumulate in the atmosphere as carbon dioxide.

Carbon dioxide acts as a "greenhouse" gas in the atmosphere, and therefore may contribute to global warming. Sources of carbon dioxide in the Earth's atmosphere include decomposition of organic matter (such as trees), the carbon dioxide that animals and people exhale, volcanic activity, and human activities such as the burning of fossil fuels and wood.

No one yet knows how much carbon the oceans and land can absorb. Nor do we know how the Earth's environment will adjust to increasing amounts of carbon dioxide in the atmosphere. Studying the distribution and changes in global phytoplankton using ocean color and other tools will help scientists find answers to these questions. ***Excerpted from: http://daac.gsfc.nasa.gov/CAMPAIGN_DOCS/OCDST/seawifs_raq.html#Q1***

How is Ocean Color Measured?

The color of ocean water and its constituents (phytoplankton, particles, and dissolved organic matter) can be measured in a variety of ways, and many sensitive instruments have been designed for this purpose. Instruments which measure the light absorbed, transmitted, and scattered can be placed in the water, either lowered on a cable from a ship or moored in place on a buoy and left to collect data for long periods of time. Absorption and scatter measurements can also be made on discrete water samples, by either placing the sample in the sample chamber of the spectophotometer or by having the seawater flow continuously through the instrument while the ship is underway. Still other instruments which measure reflectance, called radiometers, are used above the sea surface, either from the deck of the ship, or from an airplane or satellite. This last type measures a property known as water-leaving radiance – the amount and color (spectral distribution) of light re-entering the atmosphere from the ocean surface.

Water-Leaving Radiance

The radiance received at spacecraft altitudes is actually controlled more strongly by the atmosphere than by the ocean. Solar irradiance (the full spectrum of light emitted by the sun) is scattered and absorbed by the gases in the atmosphere, including water vapor (molecular [Rayleigh] scattering), from particles suspended in the air (aerosol scattering), and ozone (selective absorption). It is this scattered light which is responsible for the blue color of the sky. Sea surface reflections (sun and sky glitter) also decrease the amount of sunlight which enters the ocean. The mathematical equations used to correct the water-leaving radiances for these interactions in the atmosphere are called "atmospheric correction **algorithms**."

After light enters the ocean, it interacts with the phytoplankton, dissolved organic matter, particles, and water molecules. Some of it is eventually scattered back up through the surface. This light is called the water-leaving radiance, and it can be detected from space. Generally, much less than 10% of the total light detected by a satellite sensor will be water-leaving radiance. Because such a large part of the radiance signal the satellite detects comes from the atmosphere, the atmospheric correction factors are extremely important for generating accurate ocean color data. In fact, the atmospheric effect is so large that if we were able to look at the ocean from the height of the satellite, it would appear to us to be blue even if the actual color of the ocean were black. Scientists are continuing to research how best to design the atmospheric correction algorithms.

Because there is a strong relationship between the color of most of the open ocean and the phytoplankton chlorophyll concentration, it is possible to develop a water-leaving radiance equation (algorithm) for calculating phytoplankton biomass in the ocean from satellite data. ***Excerpted from: http://daac.gsfc.nasa.gov/CAMPAIGN_DOCS/OCDST/seawifs_raq.html#Q1***

Activities

Activity I. Internet Ocean Productivity

Ocean color sensors measure the amount of plant biomass by measuring the color due to the presence of chlorophyll. The concentration of phytoplankton chlorophyll and other pigments is related to phytoplankton growth rate, also called productivity. Thus, ocean color gives us an indirect measure of ocean productivity. In this activity, you can use images and data available on the internet to draw some conclusions about where and why productivity is high or low.

1.Print out a blank map from internet **(http://seawifs.gsfc.nasa.gov/SEAWIFS/LIVING_OCEAN/LIVING_OCEAN.html)** and outline the ocean regions with higher productivity.
2. Consider the colors in the legend from green to red to be areas high in productivity. Color these areas red on your map using a colored pencil, pen or crayon.
3. Color the less productive areas on your map in blue.
4. Compare/contrast productivity near the coastal areas with that in the mid-ocean regions.
5. Compare the productivity of ocean water near the equator with that in the northern and southern latitudes in these areas:

- the mid-Atlantic
- the mid-Pacific
- eastern coastline of North and South America
- western coastline of North and South America
- western coastline of Asia

Discussion Questions:

1. In the region of the equatorial Pacific, where is the ocean most productive?
2. In the region of the equatorial Atlantic, where is the ocean most productive?
3. Compare/contrast the productivity in the oceans in the northern and southern hemispheres.
4. Can you think of any factors that cause the differences?

5. Predict at least three factors that affect the productivity of the oceans.

Activity II: Make a Greenhouse

Materials:

Two cardboard shoe boxes
Clear plastic wrap
Two regular "weather type" thermometers
Desk light with 75 watt or larger bulb.

Procedure:

Place some paper towels loosely in the bottom of each shoe box, then lay the thermometer on the towels. Cover the open top of one box with plastic wrap, taped to the side of the box; leave the other box with the top off (open). Place the boxes side by side, and move the desk light so it shines evenly into both boxes. Record the temperature in each box every minute for 10 minutes. Plot the temperatures on a graph with time as the "x" (horizontal) axis and temperature as the "y,' (vertical) axis.

Analysis:

Discuss the differences you see in the observed temperatures in the two boxes, and why this is happening.

Variation:
Try replacing the paper towels in each box with black paper. Repeat the experiment. What differences do you note? ***Adapted from:***
http://seawifs.gsfc.nasa.gov/SEAWIFS/LIVING_OCEAN/LIVING_OCEAN.html

Student Information Sheet Lesson 1

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