Ocean Color Lesson II: Data Processing and Imagery

Ocean color observations made from an Earth orbit allow an oceanographic viewpoint that is impossible from ship or shore -- a global picture of biological activity in the world's oceans. In this lesson we will discuss how the data collected by the satellite sensor are processed to obtain useful products for researchers.

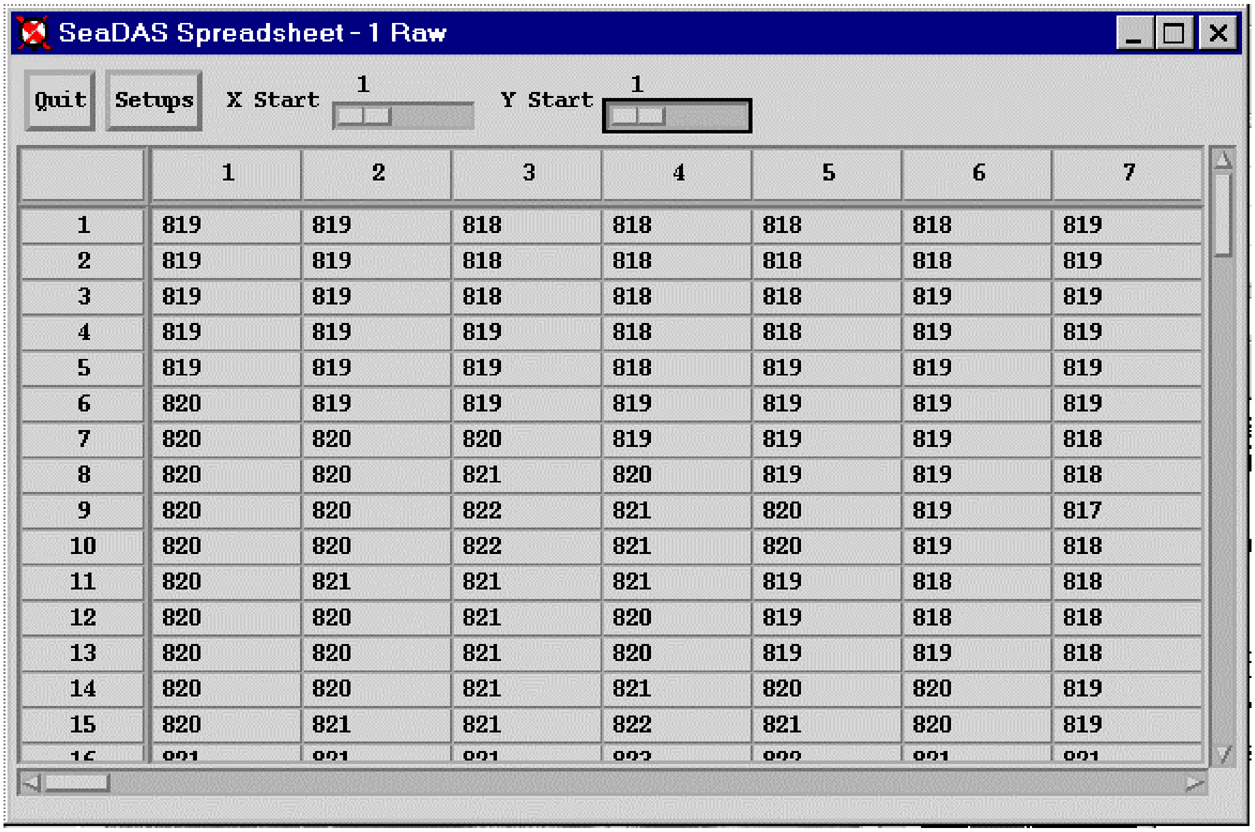
Ocean Color Viewed from Space: What Does the Satellite See?

The satellite radiometer "sees" light entering the sensor. In the case of ocean color measurements, the satellite is viewing some portion of the earth's surface and measuring the amount and color (wavelength) of sunlight reflected from the earth's surface. As ocean color intensity is related to the amount of each of the constituents in seawater, data from the satellite sensor may therefore be used to calculate the concentrations of particulate and dissolved materials in surface ocean waters. The sensor has the capability of making measurements at several visible and infra-red (IR) wavelengths, corresponding to different bands of electromagnetic energy. These are called the spectral bands of the sensor. The earliest ocean color sensor had 6 bands, SeaWiFS (Sea-viewing Wide Field-of-view Sensor) has 8 bands, or channels. Future sensors are planned with many more spectral bands, which will allow scientists to determine more seawater constituents and to do so more accurately.

What data do the satellite collect?

Data received from an ocean color satellite like the Sea-viewing Wide Field-of view Sensor (SeaWiFS), a global ocean color mission launched in August 1997, is stored and transmitted in several forms. Global Area Coverage (GAC) data are stored in the satellite's computers and transmitted to receiving stations on earth during the period the satellite is in the dark. (Remember that passive data can only be collected during daylight because sunlight is required for measurements.) Local Area Coverage (LAC) data are transmitted in real-time (as soon as it is collected) to other receiving stations on land where it is stored in land-based computers. Scientists who routinely work with the SeaWiFS data have real-time High Resolution Picture Transmission (HRPT) receivers to collect this LAC data and use it in their research.

One other difference between GAC and LAC data is that they are at different resolutions. Each data point is taken in a particular area of the ocean. This area is called a pixel. LAC data pixels cover an area which is 1 km by 1 km in size. GAC data pixels are larger, and cover an area of 4 km by 4 km. Actual pixel sizes differ slightly, because the earth's surface is curved, and because the satellite is sometimes looking down at the earth at an angle. We say that LAC data have higher resolution than GAC data. However, GAC data have lower computer storage requirements.



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2	819	819	818	818	818	818	819
3	819	819	818	818	818	819	819
4	819	819	819	818	818	819	819
5	819	819	819	818	819	819	819
6	820	819	819	819	819	819	819
7	820	820	820	819	819	819	818
8	820	820	821	820	819	819	818
9	820	820	822	821	820	819	817
10	820	820	822	821	820	819	818
11	820	821	821	821	819	818	818
12	820	820	821	820	819	818	818
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15	820	821	821	822	821	820	819
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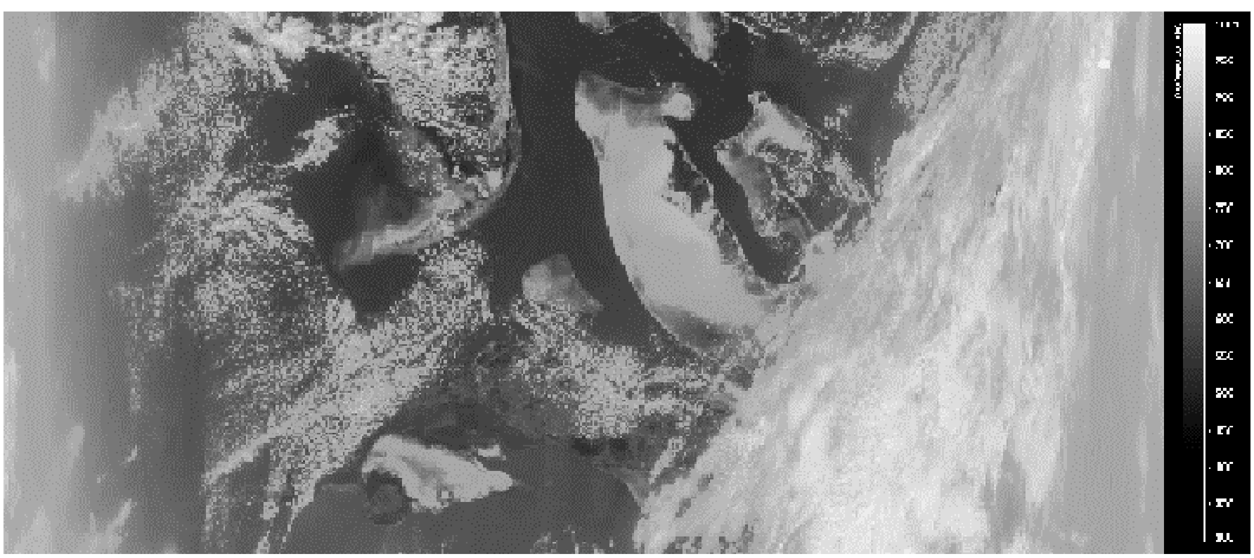


Data Processing from Level 0 to Level 3

At the time when LAC and GAC data are transmitted and stored on computer, they consist of a string of numbers. Each number represents a single reading of one of the sensors onboard the satellite. For example, one number corresponds to the amount of red light reflected from a single pixel. The raw data are classified as Level 0. Fully processed scenes available for you to view on the NASA websites are Level 3 data.

The raw, or unprocessed, Level 0 data include total radiances for ocean, land, clouds, and ice measured by the satellite. It also includes actual SeaWiFS spectral responses, saturation responses, telemetry data, global positioning data and other data.

Data processing is complicated, but it is greatly facilitated by the use of SEADAS, a software package developed by NASA scientists for processing and viewing ocean color data. All the data for a Level 0 scene are stored as a single file. Each scene consists of many pixels, which define a rectangular area of the ocean. A typical scene may be thousands of pixels on a side.

Using SEADAS, Level 0 data are converted to Level 1 data by transforming the string of numbers into a data table, or matrix. The data matrix has columns corresponding to each pixel in a scene and rows which correspond to a scan line. There are 8 of these data matrices for each scene--one for each color band of SeaWiFS. Each number, or element, in the matrix represents a raw radiance value. Other data such as latitude and longitude for each pixel, date, time, and all the other information required to calibrate and process the data, are stored separately for each scan line.

The table on page 17 is a very small part of an actual Level 1 data file. The raw radiance values only vary between 817-822 in this portion of the scene. Level 1 data can be plotted on a map using SEADAS. Each radiance value in the matrix can be displayed as a shade of gray corresponding to the magnitude of the number. High numbers are light, low numbers dark, and intermediate numbers are some shade between these two. One map can be made for each color of light measured, that is for each radiance channel. The values on the map correspond to the intensity of radiance measured for each individual pixel.

On page 17 is an actual Level 1 image taken over the southern tip of Florida. The brightest areas are clouds. Can you find Florida and the Bahamas in this scene? Level 1 data still largely consist of light scattered by atmospheric components, and this must be removed to study ocean color. Level 2 processing applies the atmospheric correction algorithms, and also applies other algorithms to convert the Level 1 data to concentrations of substances of interest, for example chlorophyll concentration. Algorithm development is still an active area of research, since many of the correction factors are not well known, and can vary due to environmental factors.

Level 2 images often contain black areas, where all the radiance was removed from pixels after atmospheric corrections. These are areas where clouds, ice or land were present. The area and shape of individual pixels in Level 1 and Level 2 data may also be distorted because of the angle at which the satellite views the earth's curved surface. Level 3 data processing by SEADAS removes the distortions and also combines multiple scenes in a given area to reduce the cloud cover. This is called "binning" the data, and is similar to taking the average of several numbers. Scenes can be binned over time intervals, or over intervals of space. Spatial binning is used to combine incomplete scenes of a particular area of interest.

True Color and False Color Images

Since white light is a combination of different colors, we can add SeaWiFS data collected in single bands to get a true color image of the ocean. There are 3 blue bands, 2 green bands, and a red band. One of each color of Level 1 data can be added in SEADAS to get a true color image.

One other way to enhance images for easier interpretation is to make false color images. This is similar to grayscale images, except that several colors are used to scale the data. How do we assign colors to the data? For temperature, it might seem logical to let blue represent cold (low temperatures), green intermediate, and red hot (high temperatures), but any scheme could be used. Usually color is chosen to make the image easy to interpret. A scale or legend by the figure defines the meaning of the colors. Depending on the circumstances, the colors may look real; that is, they may look like we imagine the scene appears to the eye. False color results when some scheme other than natural color is used for displaying images.

The term "false color" does not mean that the data are wrong or that the picture is deceiving you. It only means, don't be deceived; this figure is not a color photograph. You should look at the scale or legend to interpret it.

Ground Truth Measurements and Instruments

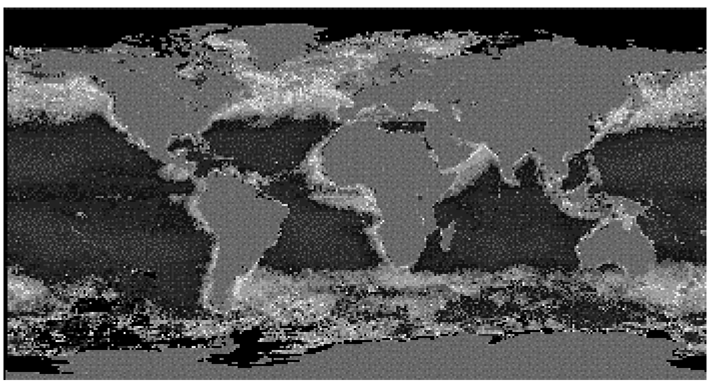
While the advent of ocean color satellites has revolutionized the way ocean scientists study the ocean, it has not totally eliminated the need to study the ocean from ships. In fact, the measurement of ocean color parameters in and just above the water is now more important than ever to be sure that data from the satellite are interpreted correctly. Data collected in the field to verify and calibrate data from satellite ocean color sensors is called "ground truth." Without ground truth data, scientists could not develop the algorithms they use to calculate such parameters as chlorophyll concentration.

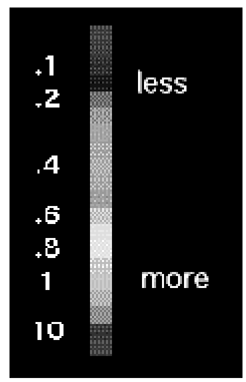
A variety of instruments have been developed to collect the required ground truth data. The basic measurements needed are absorption and scatter of the main substances responsible for ocean color, namely phytoplankton, detritus particles, and dissolved organic substances; water-leaving radiance; and incident solar irradiance (the amount of sunlight striking the sea surface). These properties change with seasons, with depth in the water column, and from one area of the ocean to another. So, scientists must make their measurements at different times and places. They are constantly trying to verify that chlorophyll concentrations calculated from satellite sensors accurately represent chlorophyll concentrations in the ocean.

Activity III. Analyzing the Satellite Image

Use the world wide web (www) to find a false color image of the entire ocean.
Sites: **http://seawifs.gsfc.nasa.gov/SEAWIFS.html**
http://ltpwww.gsfc.nasa.gov/MODIS/MODIS.html
http://observe.ivv.nasa.gov/nasa/education/reference/main.html

False Color Images of Ocean Color





Since phytoplankton are just tiny microscopic plants they need the same things to grow that the plants in your house or outside need. Your favorite houseplant needs water, sunlight, carbon dioxide and nutrients (these come from the soil it grows in) in order to grow through the process of photosynthesis. In some parts of the ocean there are a lot of these things that plants need to grow and other places which lack one or more of these important ingredients. Now for the fun stuff: remember what you read about using satellites to study the phytoplankton concentrations in the ocean? Now you are going to use one of these REAL satellite images to conduct your own investigation!
1. Analyzing the satellite image...

Take a look at the image above. It shows the entire world and the concentrations of phytoplankton in the world's oceans. Next take a look at the color scale beside the image; this tells you what the colors on the map mean. The purple color indicates very low amounts of phytoplankton, the green indicates medium amounts and the red indicates very high amounts or concentrations of phytoplankton. Now scroll down below the images and see if you can answer the questions.

Adapted from: ***http://k12science.stevens-tech.edu/curriculum/oceans/seawifs.html***

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Questions

1. There are areas of the ocean with relatively large concentrations of nutrients that animals and plants use as food substances. In these areas you see a lot of phytoplankton, especially in the spring. Why do some areas have greater amounts of phytoplankton? Where would be the best place for deep-sea fishing?

2. If a zooplankton, a very small animal type of plankton, eats a phytoplankton, generally speaking, what happens to the carbon that was in the phytoplankton? What happes to the carbon in the zooplankton when it dies?

3. What is an example of the lowest level of the "food chain" on land?

4. Scientists use two types of satellites to study the environment. A geostationary satellite remains above the same spot on the Earth's equator from an altitude of about 22,500 miles and can "see" an entire hemisphere all the time. A polar-orbiting satellite travels in a circular orbit, passing above the North and South Poles while the Earth rotates beneath it. This type of satellite can "see" details as small as a mile or less. Which of these satellites probably would be better for our ocean color instrument? Would one prove better than the other to track hurricanes and other large weather systems?

5. How do the atmosphere and the ocean interact?

6. How could global warming affect sea level? Why is global warming important?

7. Where do plankton grow?

ANSWERS:

1. When wind-driven surface currents carry water away from continents, an upwelling of deep ocean water occurs. These cold waters have high concentrations of nutrients, leading to phytoplankton growth and creating a highly productive fishing area. Ocean plants live within 200 meters from the surface where there is sunlight.

2. Most zooplankton migrate to the surface at night to feed on phytoplankton and then sink to greater depths during the day. The phytoplankton carbon they eat is connected to carbon dioxide incorporated into their bodies, are excreted as fecal pellets which sink to the ocean floor. When zooplankton die, they carry carbon with them as they sink to the bottom of the ocean.

3. Plants and bacteria are at the bottom of the food chain. Animals that eat grass, such as sheep, belong to higher food web levels.

4. A polar-orbiting satellite potentially can "see" everywhere in the world in about two days, and its orbit is low enough so that it can detect smaller details than a geostationary satellite. It will pass over a certain area once daily at the same time of day, which is important for instruments that use sun illumination for measurements of ocean color or land vegetation. A geostationary orbit can view almost an entire hemisphere at the same time, is able to track hurricanes and weather systems by making measurements every half hour or so, and also is used for meteorological purposes.

5. Differences in the heating and cooling rates of land and ocean affect air circulation. Land and water temperatures rise and fall at different rates because land absorbs and loses heat faster than water does. During the day, hot air rises and is replaced by cooler air. This small-scale circulation is called a sea breeze, and usually starts three or four hours after sunrise, reaching its peak by early afternoon. At night, the land is cooler than the water because the land has given up its heat to the atmosphere. The cool air flows over the warmer water and rises as it is warmed. This circulation

is called a land breeze, and usually starts to form in the late evening. It reaches its peak intensity near sunrise.

6. Global warming may cause sea levels to rise by several mechanisms. Temperature increases may cause some of the ice in the polar regions to melt, which would raise sea levels. Higher water temperatures also may cause the oceans to expand. This expansion would cause a sea-level rise. Scientists are studying how global warming would affect sea levels, because a substantial rise in the sea level may flood coastal cities and other low-lying areas.

6. Plankton (microscopic drifting plants and animals) live near the ocean surface where there is sunlight. Satellites will see changes in the color of water that indicates growth of ocean plants. ***Adapted from:*** **http://seawifs.gsfc.nasa.gov/SEAWIFS/LIVING_OCEAN/LIVING_OCEAN.html**

Student Information Sheet Lesson 2

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