Ocean Color Remote Sensing: a primer

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OUTLINE

1. Overview
   2. Satellite facts and the light field
   3. The basic chlorophyll algorithm
Today we routinely study the land, atmosphere, and oceans from platforms in space …
Ocean Color Remote Sensing

- Water “color” depends on
  - phytoplankton
  - dissolved & particulate matter

- Can be used to estimate
  - biological productivity
  - water movements
  - sediment load
  - human impact on environment
QuickTime™ and a GIF decompressor are needed to see this picture.
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Current NASA ocean color satellites

• MODIS on Terra (launched Dec. 1999):
  10:30 am descending orbit
• SeaWiFS (launched Aug. 1997):
  12:00 pm descending orbit
• MODIS on Aqua (launched May 2002):
  1:30 pm ascending orbit

• Altitude of 705 km
• 99 minute orbital period
• 14 orbits for global coverage
SeaWiFS makes about 14 orbits per day and can acquire complete global coverage within two days … but cloudiness limits the view.
The size of the pixels is known as the spatial resolution of the image. Ocean color and infrared (SST) sensors typically have ~ 1 km spatial resolution. You can’t resolve (focus) any better than this.

Land remote sensors generally have much higher spatial resolution (smaller pixels).

Landsat data has 30 meter resolution.
Scientists use satellites to study plankton... But satellites measure LIGHT not the actual species.

One view of these images is the 'True color' view.

True Color = R+G+B
The light path

• 90% of light is reflected from the atmosphere

• 10% is reflected from the ocean

• Removing the atmosphere from these images is referred to as “atmospheric correction”.

• This must be done to get to the chlorophyll data.
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Photosynthesis in the ocean is carried out by microalgae (phytoplankton)
What are phytoplankton?

Diatoms

Dinoflagellates

Coccolithophores

Small flagellates
Phytoplankton Cell: Chlorophyll a Pigment

Chlorophyll a collects light

CO2

Chlorophyll a collects light
This is **NOT** a phytoplankton

This is a copepod
(they eat phytoplankton)
Do you know what an algorithm is?
An “algorithm” is a mathematical formula that derives a property of interest from satellite data.

A “bio-optical” algorithm is used to derive the upper ocean chlorophyll concentration from the spectral reflectance measured above the ocean surface.

Reflectance is the ratio of upwelling radiance to the downwelling solar irradiance. It is calculated for each spectral band of the satellite sensor.
Effect of Chlorophyll on Water-leaving Radiance

**443 nm**

clear blue water

**550 nm**

green water
Multispectral Capabilities

The ratio of the blue band (443 nm) to the green band (555 nm) is used to derive the chlorophyll concentration in the ocean.
SeaWiFS Chlorophyll Algorithm (OC4.V4, O’Reilly et al., 2000)

- in situ data
- SeaWiFS (OC4)
“Atmospheric correction”

Original image (Level 1A true color)  ▶  Processed image (Level 2 chlorophyll a)
This is a montage of chlorophyll images for 8 consecutive days in June 2005. Clouds and land are colored white!
To get around the problem of clouds, satellite images are averaged over a period of time. Such average images are called “composites.”

Here are two 8-day composite images from June 2005.
QuickTime™ and a GIF decompressor are needed to see this picture.
Today’s research is focusing on the coastal ocean…

Unlike the open ocean, where phytoplankton are the only substance affecting the color of the water, there are numerous substances affecting the color of coastal waters…

- dissolved organic matter
- suspended sediment
- phytoplankton pigments
Summary

- Ocean color satellites measure the spectral light field reflected back to space.
- Algorithms transform the measured light field to more usable products such as chlorophyll a concentration.
- Satellites can be used to observe daily levels in phytoplankton biomass for the entire globe.
- Changes in the ocean environment will lead to changes in phytoplankton dynamics, and on marine ecosystems and global biogeochemical cycles.
August 1, 1941 - August 9, 1995

August 1, 1997 - ?

...there are no coincidences...