Ocean Color Remote Sensing
-Selected Applications

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Sun glint or sun glitter

- Sun light reflected from the water surface, which does not penetrate in the water column
- Sun glint strongly depends on viewing direction as well as surface roughness
Example of glint correction by Hochberg’s technique: QuickBird image over NE Coringa Herald

QuickBird: 2.6m pixel size, image size:~1km by 1km
AVIRIS image over Kaneohe Bay, Hawaii (before glint correction)
AVIRIS image over Kaneohe Bay, Hawaii (after glint correction)
Glint **improves** the oil spill visibility

Oil rig exploded on 2010.04.20

2010.04.26 MODIS-A

2010.04.29 MODIS-T
Ocean Color Applications

Uses of Satellite Ocean Color

Climate research

Elemental cycles
- Carbon
- Nitrogen
- Others

Physical Oceanogr.
- Current
- Front

Biogenic gases
- DMS
- Methyl chloride

Operational use

Fisheries
- Harvesting
- Aquaculture

Management

Environ. Monitoring and prediction
- Water Quality
- Hypoxia
- HAB
- Other Apps
Applications of Suspended Particulate Matter (SPM)
Suspended Particulate Matter (SPM)

Å Sediment transport study
   • Study on the dispersion of SPM following the dredging/dumping activities
   • SPM maps: boundary, initial and validation data
   • Ex) Fettweis et al., 2007. An estimate of the suspended particulate matter (SPM) transport in the southern North Sea using SeaWiFS images, in situ measurements and numerical model results, Continental Shelf Research 27: 1568-1583.

Å Underwater visibility
   • Maritime defense and security operation
   • Alteration of benthic habitat
   • Phytoplankton bloom timing (light availability)
Example of SPM time series

A 5-year time series of SPM for Thornton Bank (51°33.14´N, 2°59.55´E) in Belgian waters. Data from the 3 sensors is highly coherent. A strong seasonal cycle is seen which is related to wind-driven resuspension. (Adapted from Ruddick et al. 2008)
Applications
Chlorophyll concentration
Eutrophication monitoring

Chlorophyll *a* P90 derived from MERIS data for the 2005 growing season (March-October). The color scale corresponds to various eutrophication problem thresholds used by the OSPAR member states. (Adapted from Ruddick et al., 2008)
Optimization of seaborne monitoring

Location of the seaborne measurement stations of the Belgian water quality monitoring network (left) before 2007 and (right) after optimization for EU-WFD and OSPAR requirements. (adapted from Ruddick et al. 2008, courtesy of the Belgian Marine Data Centre)
Chl time series at aquaculture sites

Time series of satellite chlorophyll $a$ data at the location of two experimental mussel farms. Data supplied for an assessment of spatial variation of mussel growth. (Adapted from Ruddick et al., 2008)
Ecosystem model validation

Monthly mean chlorophyll a derived from (left) MERIS data, (middle) from MIRO&CO-3D model and (right) relative difference of model output from MERIS data. (adapted from Lacroix et al., 2007)
Biogeochemical cycles

The ocean contains the largest active pool of carbon near the surface of the Earth. Important carbon-related processes includes exchange of CO$_2$ with the atmosphere through the sea surface; conversion of CO$_2$ into organic carbon by phytoplankton photosynthesis in the upper layers; and sequestration of carbon into the deeper aphotic zone, either by settling of particulate matter or by diffusive or advective transport of carbon in organic and inorganic form. An inorganic long-term cycle driven by water alkalinity and the formation of calcium carbonate is also a component of the overall oceanic carbon cycle. (from IOCCG report number 7)

- Particulate organic carbon (POC): POC-SPM ratio
- Phytoplankton carbon: C:Chl ratio
- Particulate Inorganic Carbon (Calcium Carbonate)
- Colored dissolved organic matter
- Carbon fluxes
- Primary production function of biomass (chl or bbp) x photosynthetic_rate, function of PAR and SST
- Photochemistry in the upper ocean- CDOM
- Nitrogen sources: upwelling, nitrogen fixation
Coccolithophore

Emiliana Huxleyi, the main species of coccolithophore

MERIS image of 15-Jul-2006
Air-sea carbon flux

Algorithms for $pCO_2$ and air-sea $CO_2$ flux in the southern North Sea are developed to use

- a) satellite chlorophyll data,
- b) satellite Sea Surface temperature, and
- c) modelled/climatological sea surface salinity distribution
Seasonal mean water column net primary production (mg C m\(^2\) d\(^{-1}\)) calculated from satellite phytoplankton carbon and chlorophyll-based model, and their difference. (Adapted from Behrenfeld et al., 2005)
Trichodesmium bloom

MODIS false color (R859,G645,B469) image of Dec 18, 2008
showing a massive Trichodesmium bloom
near the southern Great Barrier Reef, Australia:
(left) before and (right) after atmospheric correction, (bottom right) photo.
Algal Bloom Detection Service (EU -MARCOAST project)
Algal bloom detection service

Schematics of data flow for algal bloom detection using MERIS and MODIS data (adapted from Park 2010)
Chl P90

Chl 90th percentile map from 2005 MERIS data: (left) pixel-by-pixel and (right) spatially averaged.
Output: AB flag map  
(18-Apr-2007)

Classification from previous day's data  
+ 
Recent information (within 7 days)  
→  
better representation of spatial extent of algal blooms
AB timing : First day AB detected

1. AB timing largely depends on latitude (solar irradiation),
2. Early blooms in the MED. Sea, and latest blooms in North western waters
Spring algal bloom and larval fish survival (Platt, 2003)

Relationship between haddock larval survival index and local anomalies in bloom timing off the eastern Nova Scotian shelf.
(Harmful) Algal Bloom detection
Bloom of cyanobacteria submerged and floating

MODIS false color (R859,G645,B469) image of July 2, 2006 showing a massive cyanobacteria bloom in the Baltic Sea: (left) before and (right) after atmospheric correction. Green patches are submerged; red are floating algae.

Source: http://www.icbm.de/~gmb/21184.html
Harmful algae detection

The Minimum Spectral Distance mapping technique applied for detection of C. polykrikoides blooms in. (Adapted from Ahn et al., 2006)
Floating algae detection using MODIS b1-b5

Intense blooms of the brown algae, *Hincksia sordida* in Southeast Queensland recently have substantially reduced the recreational value. Wide spread algal blooms confirmed by aerial overflights and in situ observations were not visible in true colour image from the MODIS Rapidfire website.

*Hincksia Sordida*
Non-toxic filamentous brown algae
(E. Abal et al., 2006)
Top Of Atmosphere MODIS reflectance spectra for bloom and non-bloom (=ocean water) pixels

Spectra from Terra image of Oct 3 2006

- Blue curves for non-bloom pixels and red curves for bloom pixels.
- Reflectance at 869nm should indicate the bloom intensity if the atmosphere and sea surface conditions are same.
MODIS-Aqua 2006 Oct 2 (275) 13:30

TOA RGB
R - 645nm
G - 555nm
B - 469nm

TOA RGB FA
R - 859nm
G - 645nm
B - 469nm

Rw RGB normal
R - 645nm
G - 555nm
B - 469nm

Rw RGB FA
R - 859nm
G - 645nm
B - 469nm
Potential Fishing Zone

Chlorophyll image of northwest India on 29 Feb 2006 from the Indian OCM sensor. Oceanic features such as cyclonic eddies (1 and 2) and fronts (3 and 4) are known to be productive sites. (Credit: R. M. Dwivedi, Indian Space Research Organisation)
Shallow water bathymetry
The analytical model for optically shallow waters

For an optical shallow water body part of the reflectance is composed of a substrate signal:

\[ R(0-, H) = R_\infty + \exp(-K_d H)[A \exp(-\kappa_B H) - R_\infty \exp(-\kappa_C H)] \]

where

- \( R_\infty \) = subsurface irradiance reflectance over a hypothetical optically deep water column;
- \( H \) = water depth;
- \( A \) = bottom albedo (substrate reflectance);
- \( K_d \) = vertical attenuation coefficient for diffuse downwelling light;
- \( \kappa_B \) = vertical attenuation coefficient for diffuse upwelling light originating from the bottom; and
- \( \kappa_C \) = vertical attenuation coefficient for diffuse upwelling light originating from each layer in the water column.
Remote Marine Parks Remote Sensing project for Department of Environment and Water Resources

Environmental Remote Sensing Group
CSIRO Land and Water
May, 2007
Han River mud flat area bathymetry derived from HICO image

HICO Image off Korean Peninsula

Relative Bathymetry Map Retrieved from HICO Image

Submerged Mud Flat

Water Channel

Scene ~ 42 km x 192 km Imaged October 21, 2009

Charles Bachmann bathymetry algorithm
And many other applications

Å Phytoplankton size class, function types
Å Ecological provinces
Å Physical processes and ocean biology

Å Aerosol type, optical thickness
Å Monitoring of storms and yellow dust
Å Detection of fire, snow, and sea ice
Å Volcano monitoring

Å Shallow water bathymetry and benthic habitat mapping with high resolution data
Å In-land water monitoring
Some slides are taken from IOCCG website, MUMM, Belgium, HyspIRI sunglint working group, CSIRO RS group, Australia, etc.