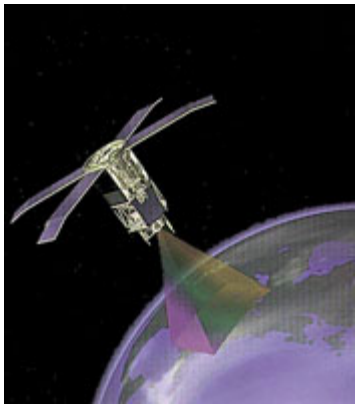
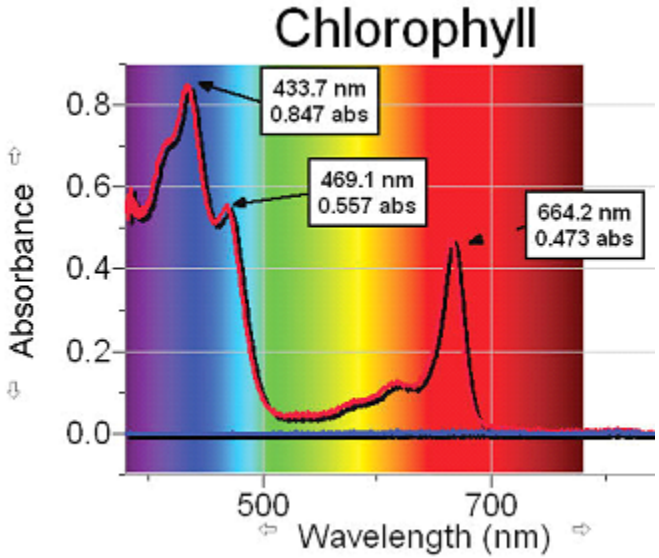
Remote Sensing of the Ocean and Coastal Waters

Freshwater and seawater boundary at Winyah Bay, South Carolina

Remote Sensing of Water Regions

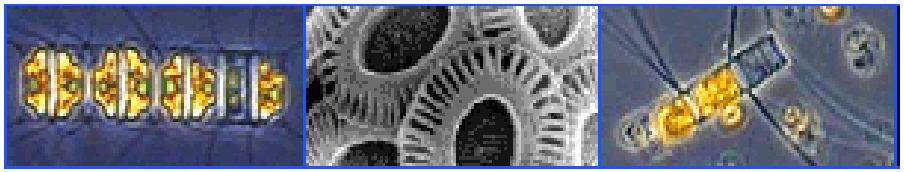


RS of water areas provides an efficient way of monitoring water quality, biomass in the ocean, sediment plumes, spatial and temporal scales of the water structures, sea surface temperature, etc.



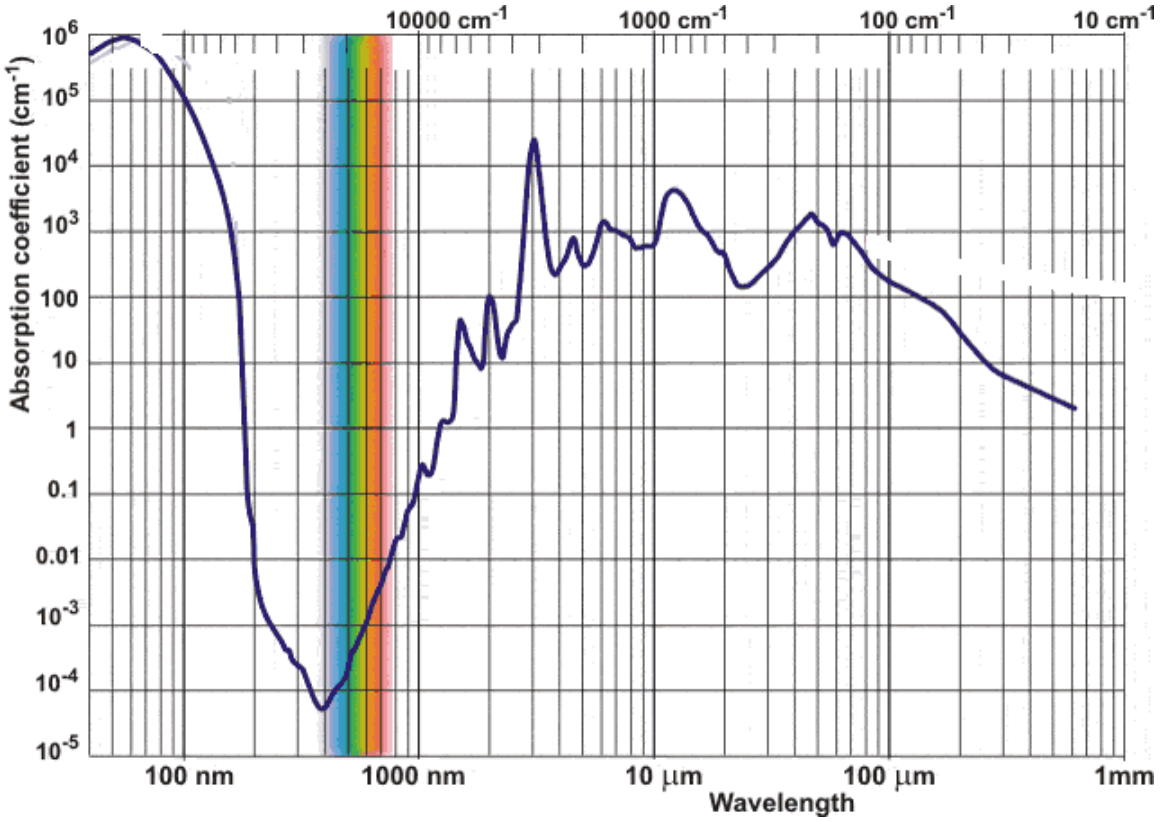
Phytoplankton are a very important part of ocean life:

- Phytoplankton are the first link in the food chain.
- Phytoplankton convert nutrients into plant material by using sunlight through photosynthesis and convert carbon dioxide from sea water into organic carbon and oxygen as a by-product and thus affect carbon balance.



Amount of phytoplankton in the ocean can be traced by the concentration of the optically active pigment chlorophyll [Chl]

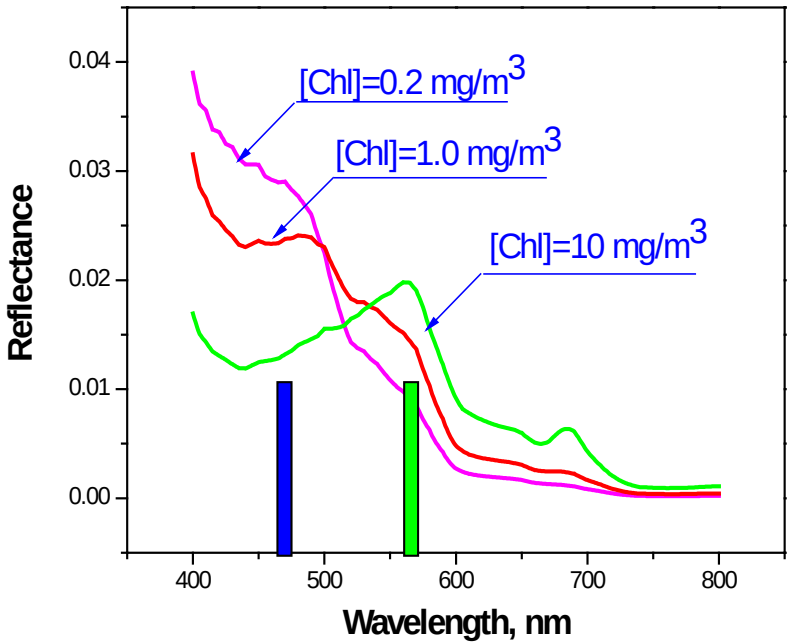
Water Absorption Spectrum



Water absorption is small only in VIS

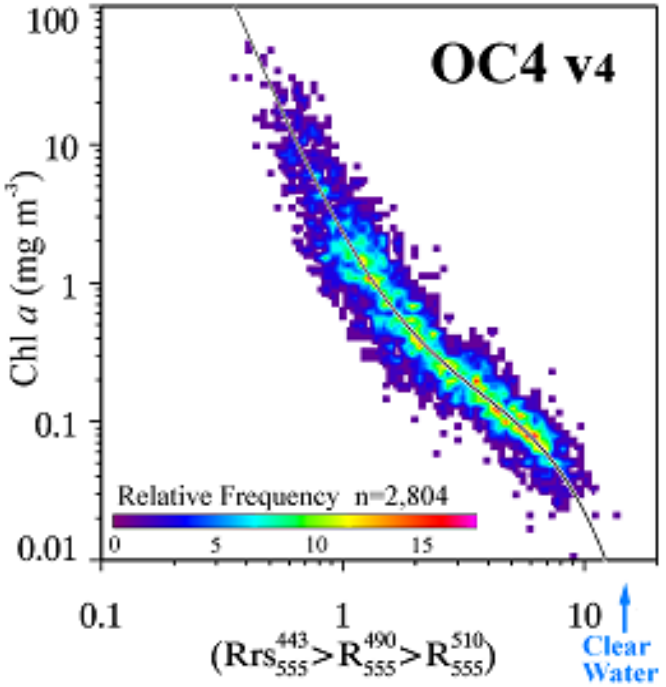
RS of water is often called Ocean Color

Reflectance spectra for the open ocean



[Chl] can be well characterized by blue-green ratio

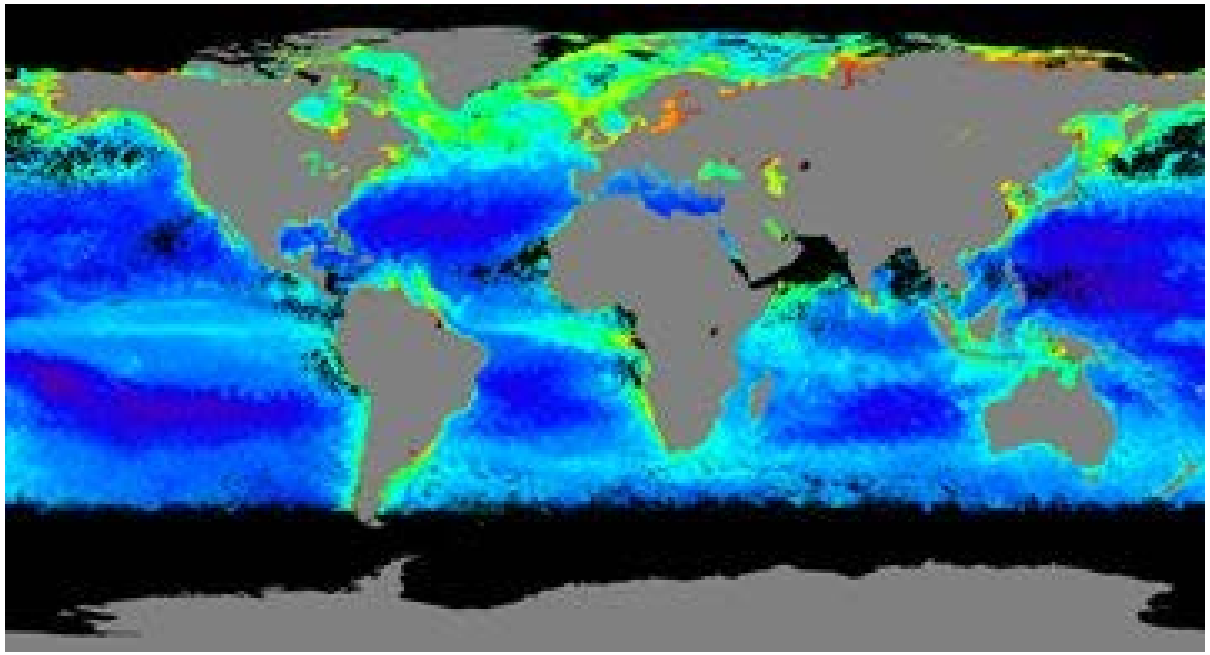
With increasing [Chl] water changes its color from blue to green

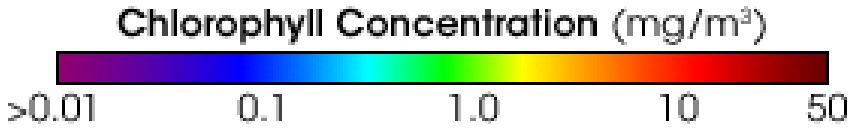


SeaWiFS Blue-Green Ratio Algorithm

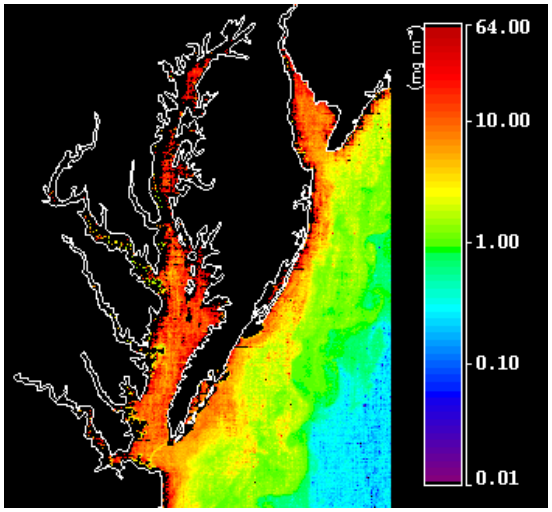
From K. Carder, et al. ,2003

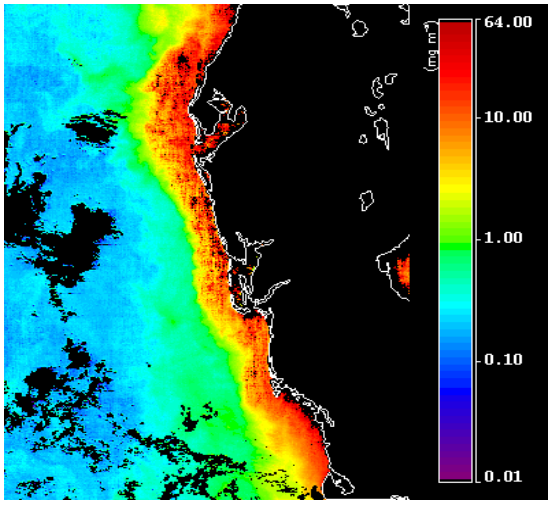
Chlorophyll Global and Regional Maps





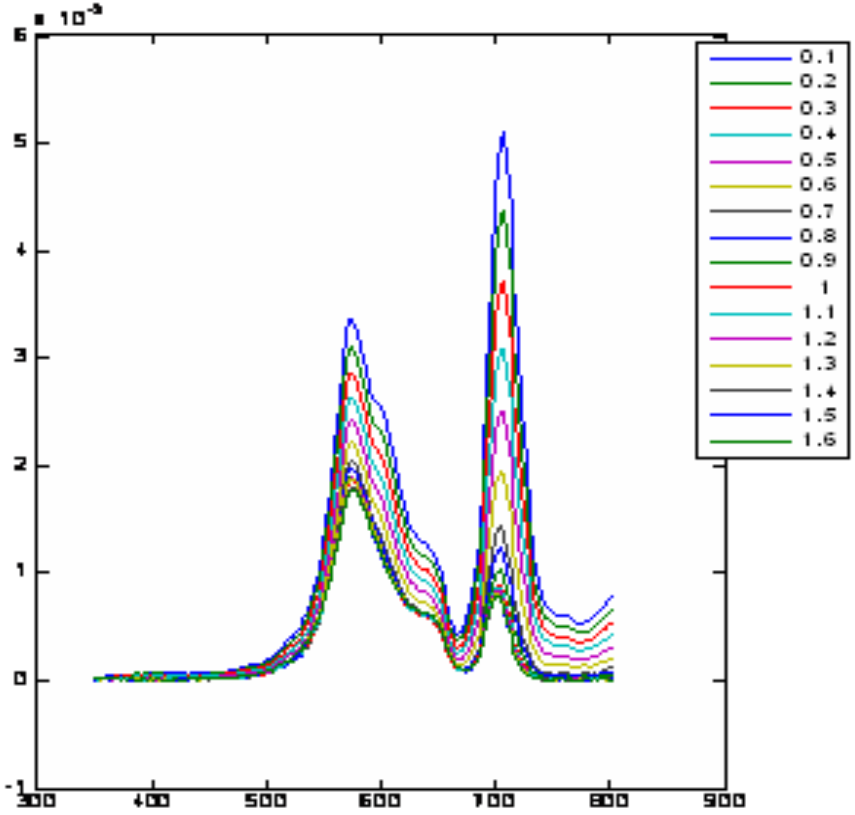
SeaWiFS, July 2006





MODIS, NE and Florida coasts

Spectra in conditions of Red Tide

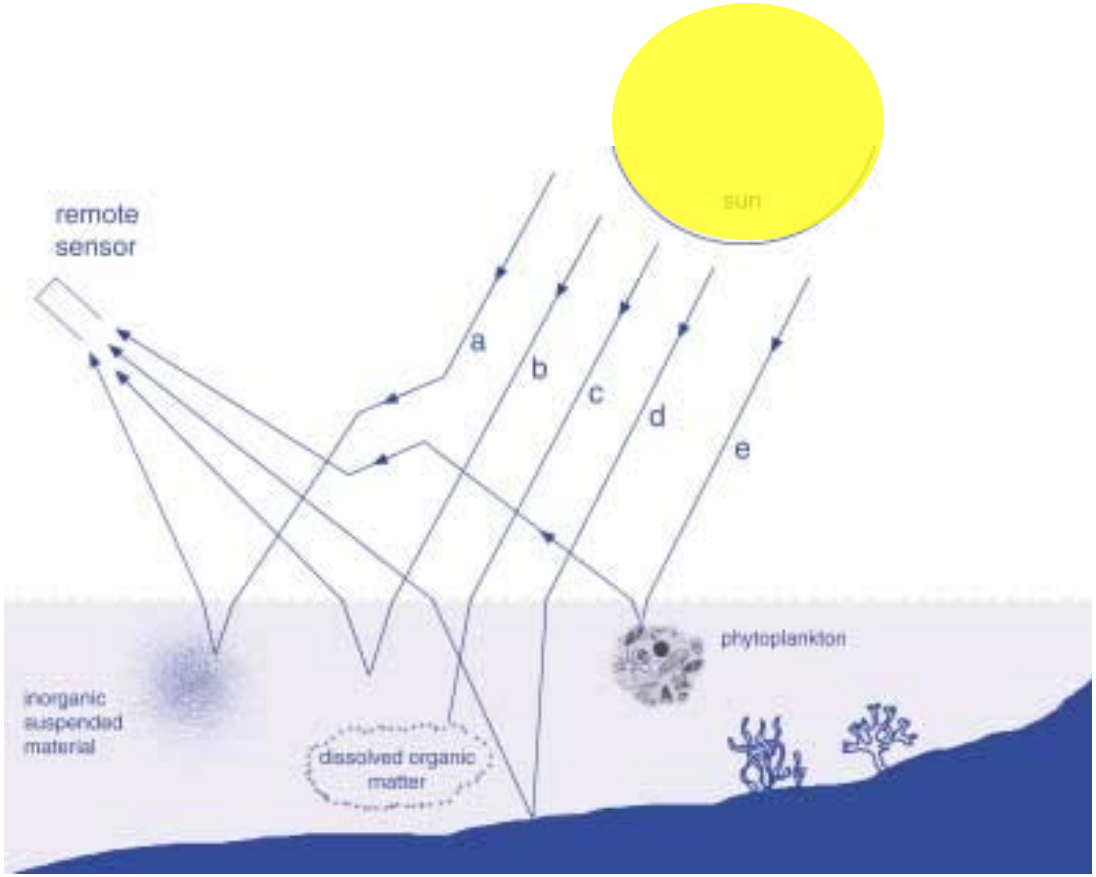


Red part of the spectra is very strong

Importance and Specifics of Coastal Water Remote Sensing

- Majority of human population lives near the coast
- Influenced by oceanic and terrestrial processes
- Account for nearly 90% of global fish
- Extreme events: hypoxia (deficit of oxygen), Harmful Algal Blooms
- Necessity of active coastal management

Water Composition for the Open Ocean and Coastal Waters



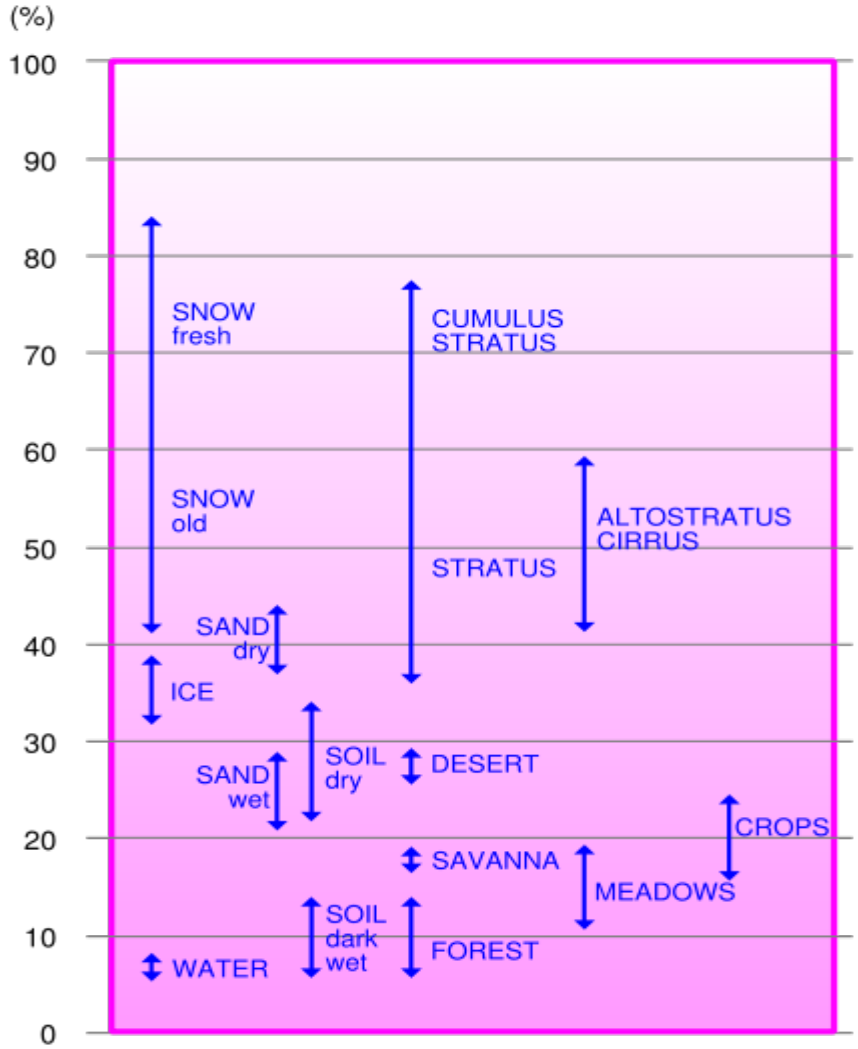
In the open ocean algae are the main component

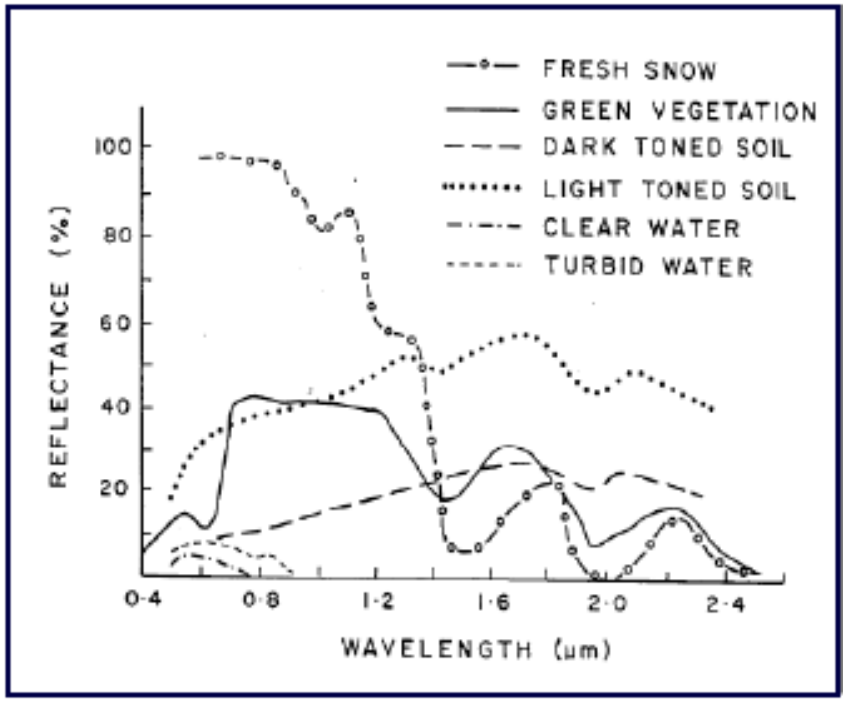
In coastal waters algae are mixed with CDOM and minerals

Algae CDOM* Minerals

*CDOM is the colored dissolved organic matter mostly of terrestrial origin

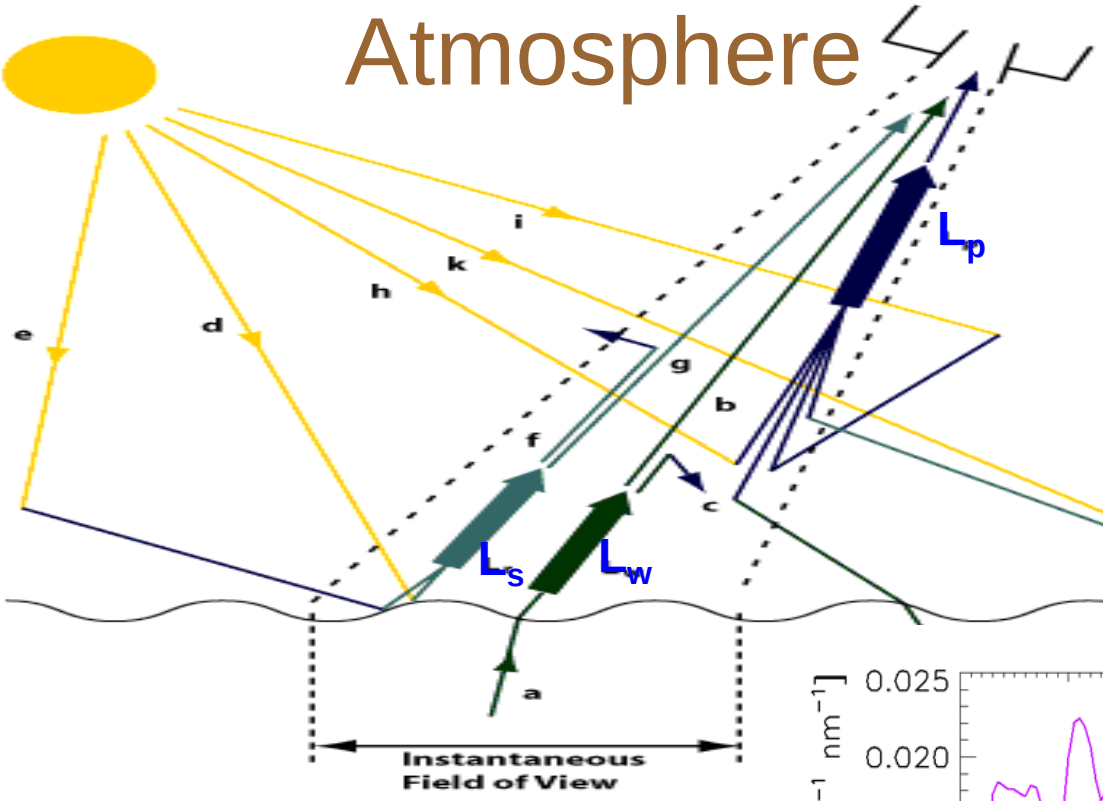
Reflectance of Various Surfaces





Signal from water is small in comparison with reflectance from other surfaces and atmosphere

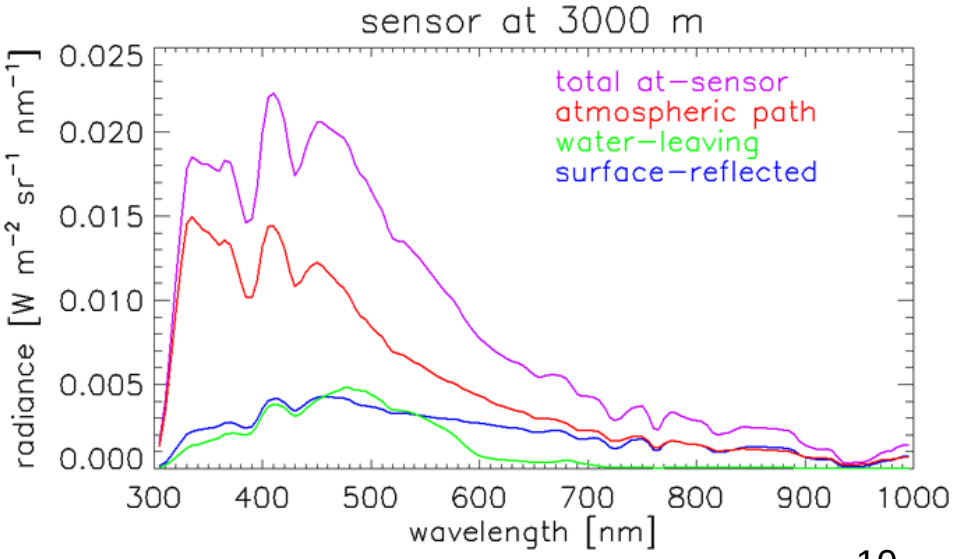
Total Radiance Signal at the Top of Atmosphere



L_w -Total water-leaving radiance. L_s - Radiance above the sea surface due to all surface reflection effects within the IFOV. L_p - Atmospheric path radiance.

Signal from the atmospheric scattering is about 10 times stronger than from water.

Atmospheric correction utilizes NIR bands (748, 865 nm)



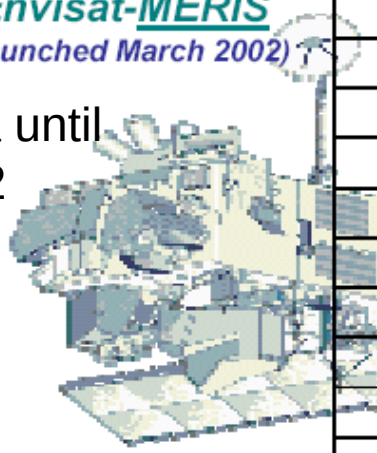
The total radiance curve at 3000 m sensor altitude partitioned into the contributions by water-leaving radiance, surface reflectance, and atmospheric pat radiance. Source: https://www.oceanopticsbook.info/view/

Super-Spectral Imaging System

A superspectral imaging sensor has many more spectral channels (typically >10) than a multispectral sensor. The bands have narrower bandwidths, enabling the finer spectral characteristics of the targets to be captured by the sensor. Examples: MERIS & MODIS

Envisat-MERIS
(Launched March 2002)

Data until 2012



MERIS Spectral Bands

Band	Band Centre (nm)	Bandwidth (nm)	Potential Applications
1	412.5	10	Yellow substance, turbidity
2	442.5	10	Chlorophyll absorption maximum
3	490	10	Chlorophyll, other pigments
4	510	10	Turbidity, suspended sediment, red tides
5	560	10	Chlorophyll reference, suspended sediment
6	620	10	Suspended sediment
7	665	10	Chlorophyll absorption
8	681.25	7.5	Chlorophyll fluorescence
9	705	10	Atmospheric correction, red edge
10	753.75	7.5	Oxygen absorption reference
11	760	2.5	Oxygen absorption R-branch
12	775	15	Aerosols, vegetation
13	865	20	Aerosols corrections over ocean
14	890	10	Water vapor absorption reference
15	900	10	Water vapor absorption, vegetation

Similar bands are available on Ocean and Land Color Instrument (OLCI) on recently launched ESA Sentinel 3A and B satellites

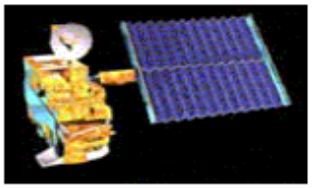
MODIS Spectral Bands for Ocean Color and Atmospheric Correction

MODIS Spectral Bands

(MODerate-resolution Imaging Spectroradiometer)

Primary Use	Band	Bandwidth (nm)	Spectral Radiance (W/m^2 -µm-sr)
Land/Cloud/Aerosols Boundaries	1	620 - 670	21.8
	2	841 - 876	24.7
Land/Cloud/Aerosols Properties	3	459 - 479	35.3
	4	545 - 565	29.0
	5	1230 - 1250	5.4
	6	1628 - 1652	7.3
	7	2105 - 2155	1.0
Ocean Color/ Phytoplankton/ Biogeochemistry	8	405 - 420	44.9
	9	438 - 448	41.9
	10	483 - 493	32.1
	11	526 - 536	27.9
	12	546 - 556	21.0
	13	662 - 672	9.5
	14	673 - 683	8.7
	15	743 - 753	10.2
	16	862 - 877	6.2
Atmospheric Water Vapor	17	890 - 920	10.0
	18	931 - 941	3.6
	19	915 - 965	15.0

Aqua satellite
(launched, May 2002)



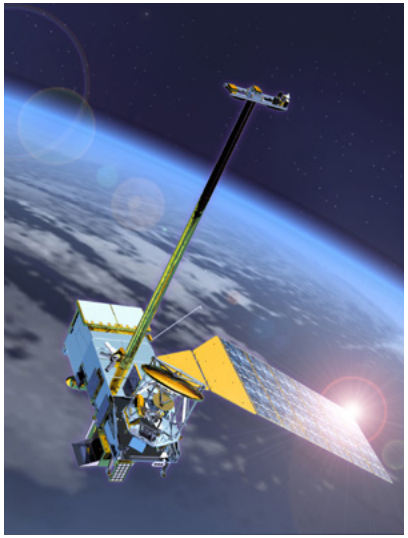
Primary Use	Band	Bandwidth (µm)	Spectral Radiance (W/m^2 -µm-sr)
Surface/Cloud Temperature	20	3.660 - 3.840	0.45
	21	3.929 - 3.989	2.38
	22	3.929 - 3.989	0.67
	23	4.020 - 4.080	0.79
Atmospheric Temperature	24	4.433 - 4.498	0.17
	25	4.482 - 4.549	0.59
Cirrus Clouds Water Vapor	26	1.360 - 1.390	6.00
	27	6.535 - 6.895	1.16
	28	7.175 - 7.475	2.18
Cloud Properties	29	8.400 - 8.700	9.58
Ozone	30	9.580 - 9.880	3.69
Surface/Cloud Temperature	31	10.780 - 11.280	9.55
	32	11.770 - 12.270	8.94
Cloud Top Altitude	33	13.185 - 13.485	4.52
	34	13.485 - 13.785	3.76
	35	13.785 - 14.085	3.11
	36	14.085 - 14.385	2.08

Band Name	λ(nm)	(nm) **	Wavelength Type
M1	412	20	VIS
M2	445	18	VIS
M3	488	20	VIS
M4	555	20	VIS
M5	672	20	VIS
M6	746	15	NIR
M7	865	39	NIR
M8	1240	20	SWIR
M9	1378	15	SWIR
M10	1610	60	SWIR
M11	2250	50	SWIR
M12	3700	180	MWIR
M13	4050	155	MWIR
M14	8550	300	LWIR
M15	10763	1000	LWIR
M16	12013	950	LWIR
DNB	700	400	VIS
I1	640	80	VIS
I2	865	39	NIR
I3	1610	60	SWIR
I4	3740	380	MWIR
I5	11450	1900	LWIR

VIIRS

Launched in October 2011
The Visible/Infrared Imager/Radiometer Suite is a part of JPSS project. It collects visible/infrared imagery and radiometric data. Data types include atmospheric, clouds, earth radiation budget, clear-air land/water surfaces, sea surface temperature, ocean color, and low light visible imagery.

It combines MODIS and AVHRR (for sea surface temperature) capabilities.



Main goals in retrieval from ocean color imagery

CHL concentration

In addition, especially in coastal waters:

CDOM concentration

Concentration of minerals

Particle size distributions

Types of phytoplankton species

Applications

Field Measurements

Physical properties ⟷ Optical properties ⟷ Reflectance spectra ⟷ Satellite sensor data

Water sampling (Chl, TSS and mineral concentrations, CDOM absorption)

Instrumentation for Field Measurements

Water optical properties:

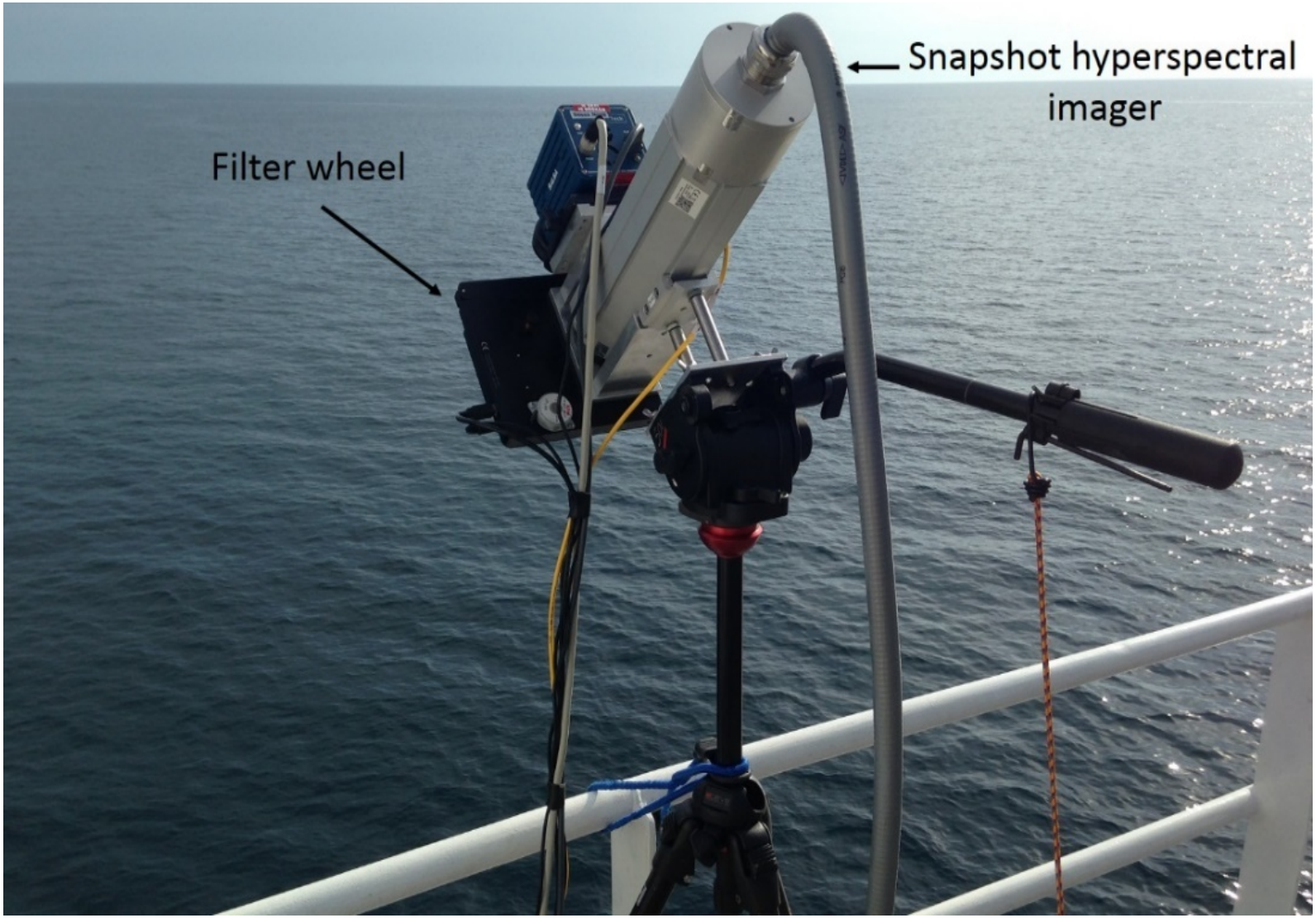
- WET Labs package: absorption, attenuation, scattering (82 channels 400-750 nm), backscattering (7 channels), Chl, CDOM fluorescence, temperature, salinity, depth

- CDOM absorption with 0.2 um filter on absorption tube

Reflectance measurements

GER spectroradiometer measures reflectance above and below water surface (512 channels between 300 and 1100 nm).
It is usually used to measure below surface reflectance in the fiber-optic mode

Above surface imaging

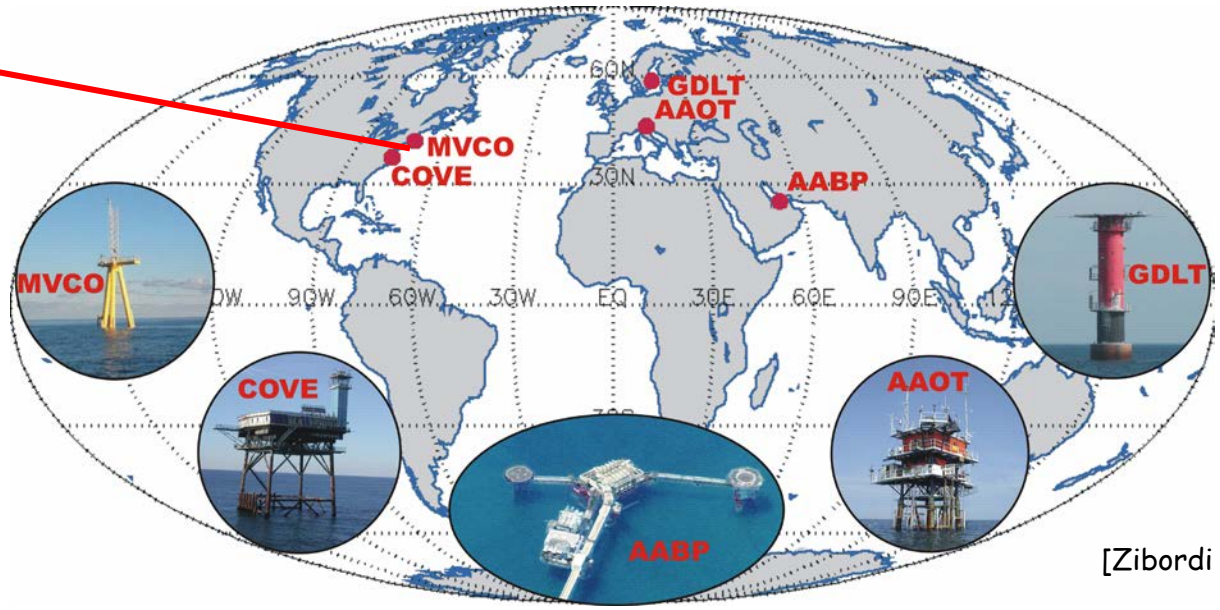


Validation of OC satellites by comparison with AERONET-OC data

AERONET: AErosol RObotic NETwork

LISCO Site Characteristics

LISCO Multispectral SeaPRISM system
as part of AERONET – Ocean Color network



[Zibordi et al., 2006]

- Identical measuring systems and protocols, calibrated using a single reference source and method, and processed with the same code;

→ **Standardized products of exact normalized water-leaving radiance and aerosol optical thickness**

Above Water Signal decomposition

Total radiance

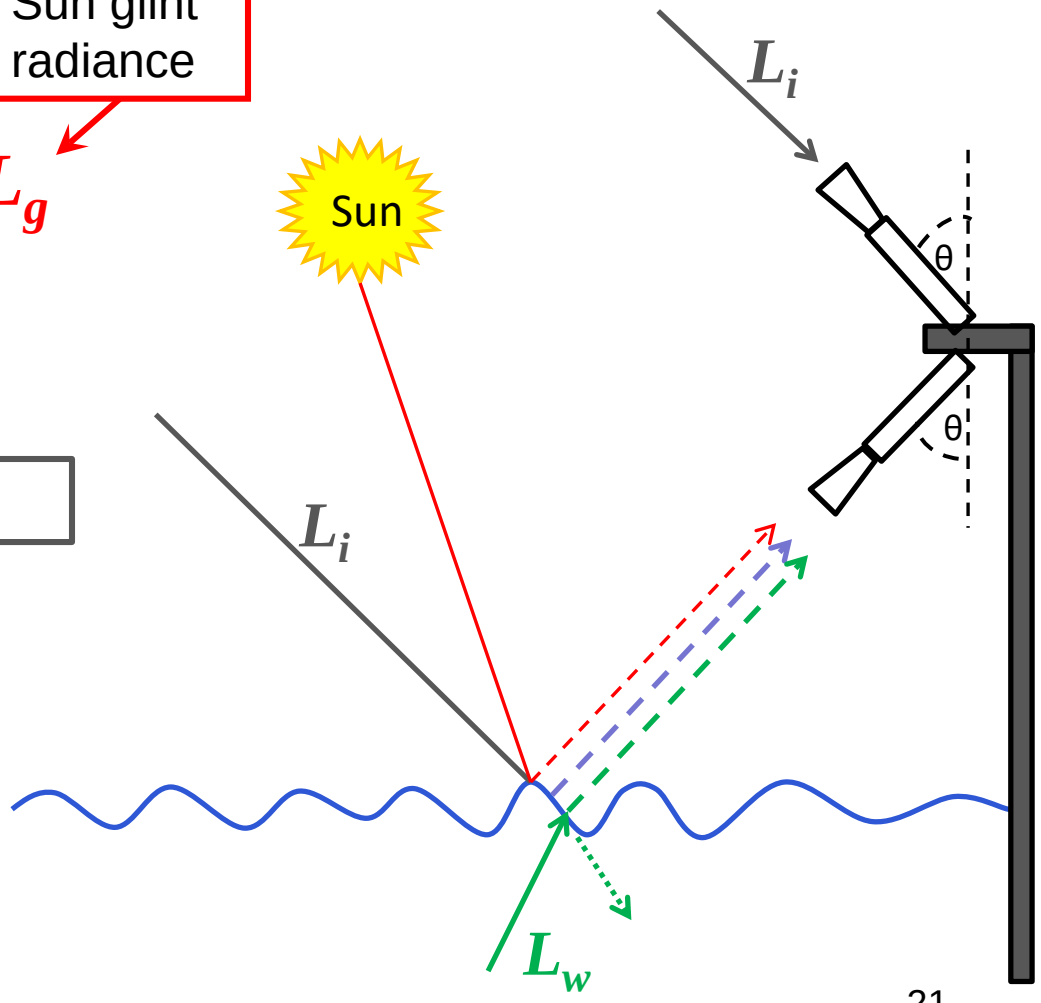
Sky radiance

Sun glint radiance

$$L_T = L_w + \rho(W)\, L_i + L_g$$

Water leaving radiance

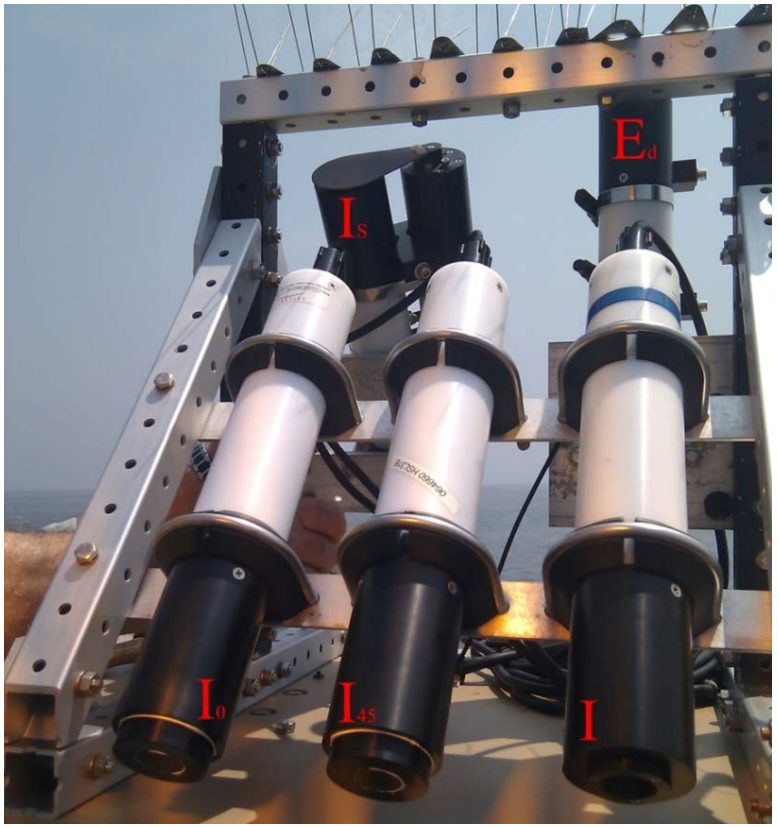
Sea surface reflectivity



Tower with the instruments and solar panels on the platform in LIS

SeaPRISM and HyperSAS instruments installed on the tower

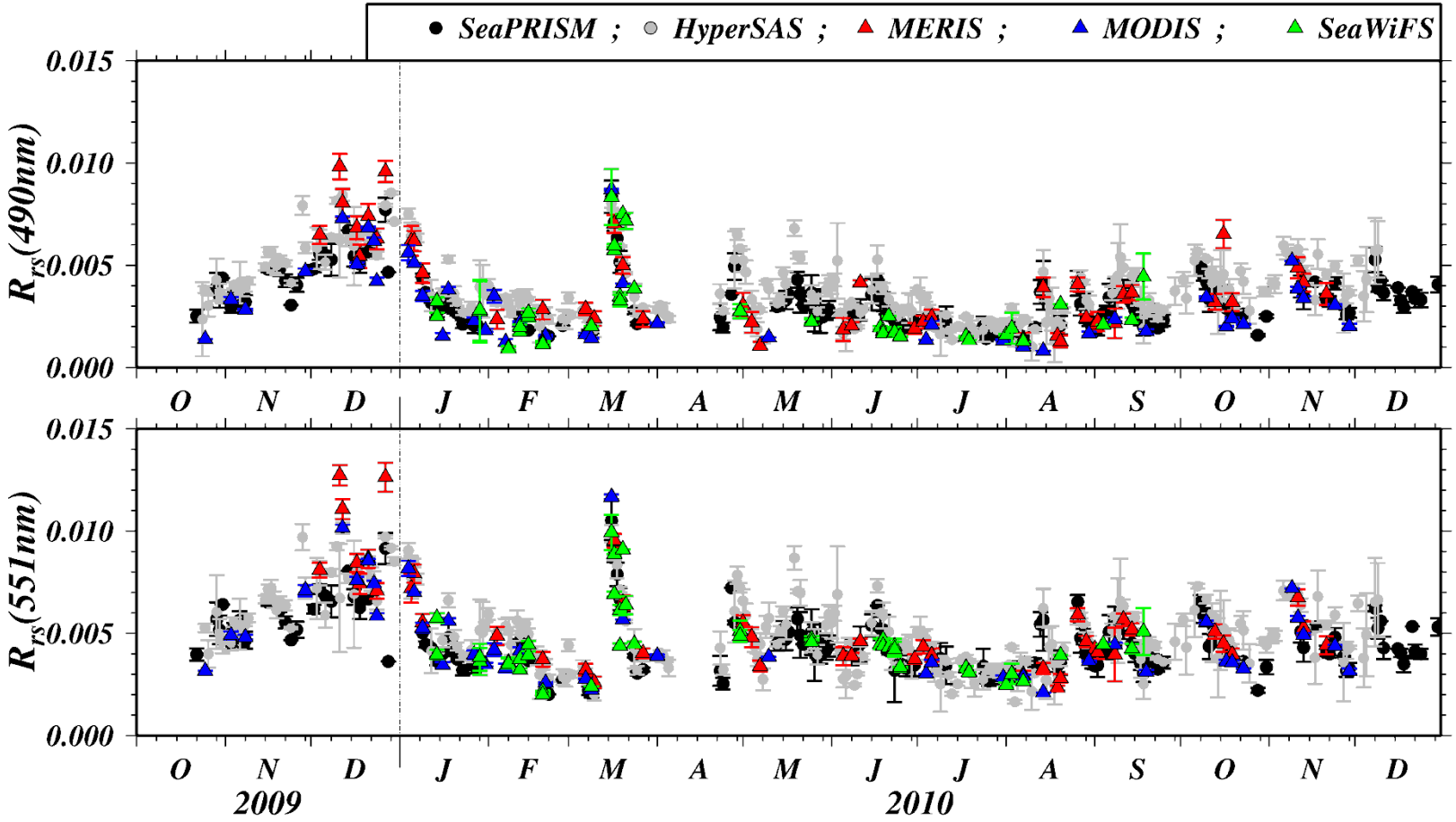
SeaPRISM data are transmitted through the satellite to NASA AERONET group. Processed data are posted on AERONET site



HyperSAS data are transmitted through broadband over IP to the CCNY server

Satellite Validation

Time Series Remote Sensing Reflectance (R_{rs}) [sr^{-1}]



→ **Consistency in seasonal variations observed from the platform and from space**

Estimation of uncertainties of OC satellites by comparison with AERONET-OC data

Prof. Alexander Gilerson
Dept of Electrical Engineering

gilerson@ccny.cuny.edu

Eder Herrera, PhD candidate
eherrera@gradcenter.cuny.edu