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Introduction to
Ocean Colour Remote Sensing

SG Remote Sensing Workshop 2023

Rakesh Kumar Singh, PhD
Research Scientist
Centre for Remote Imaging, Sensing and Processing
National University of Singapore

What is Ocean?

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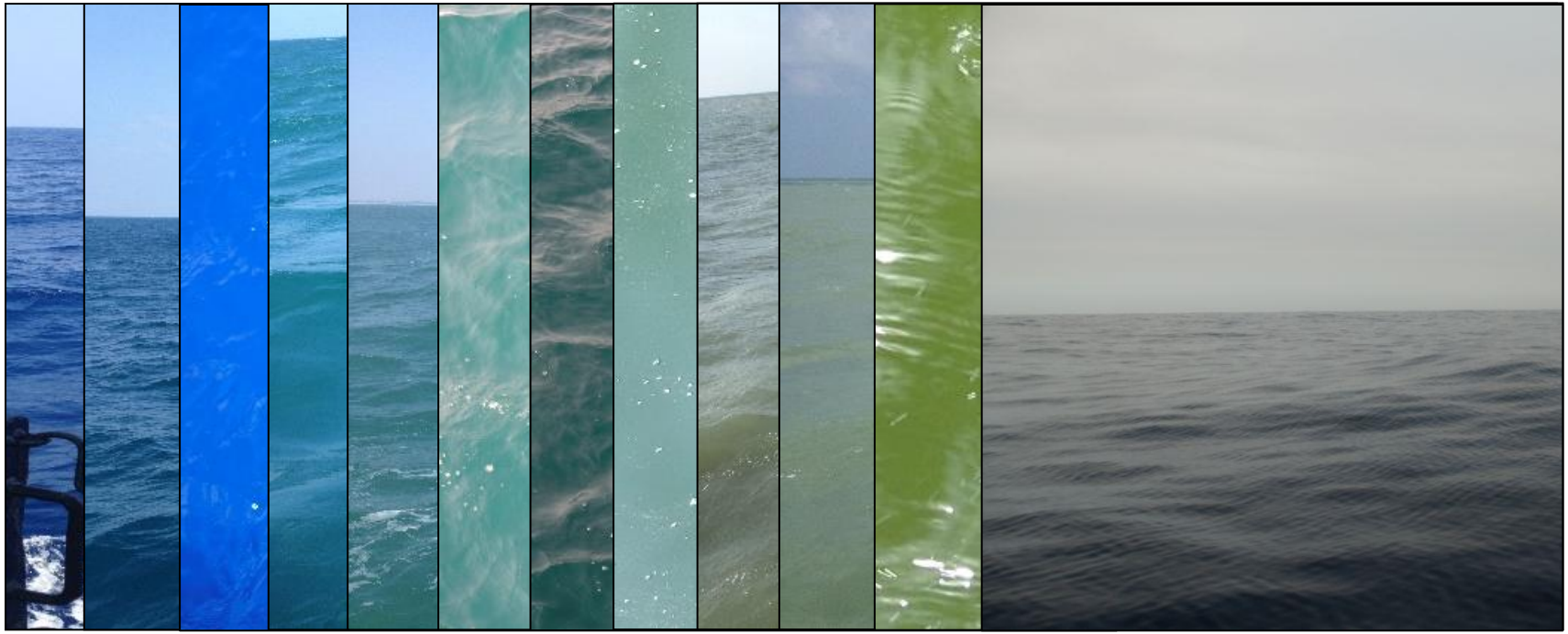
What is Ocean Colour?



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Why these colours?

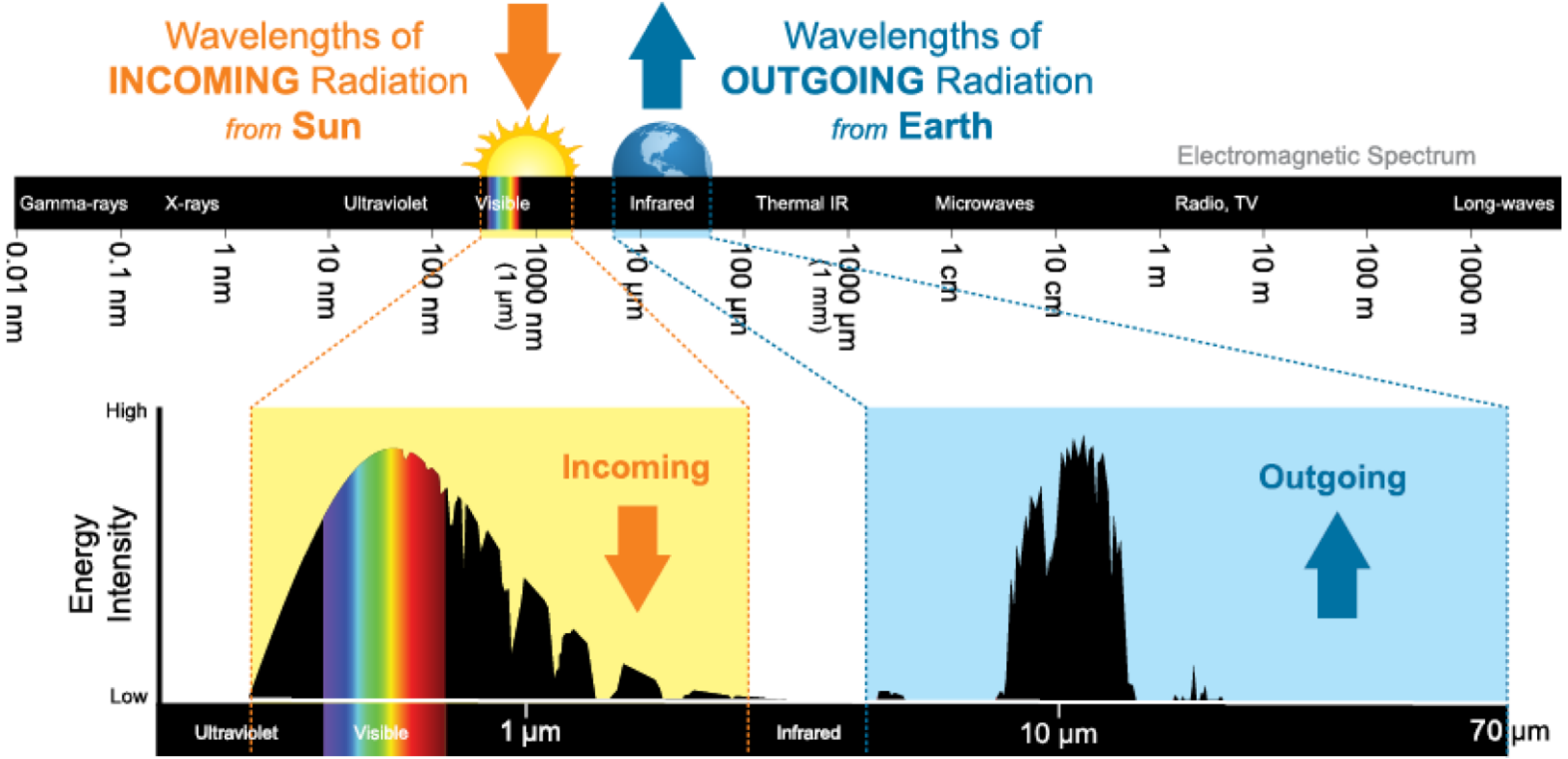

Image source: https://www.noaa.gov/jetstream/satellites/absorb

Why these colours?

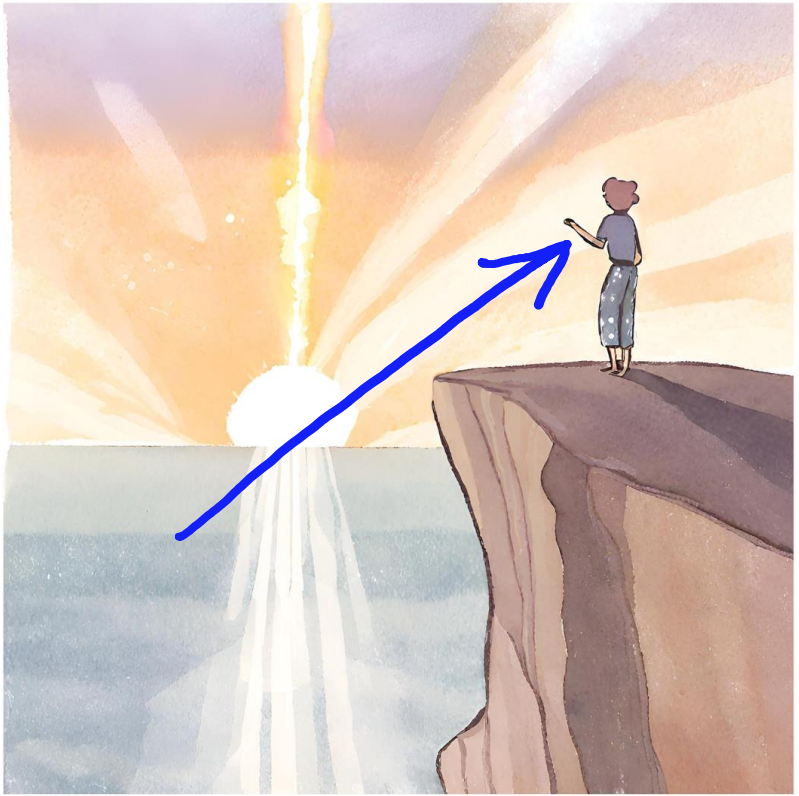

Image Source: Wikipedia

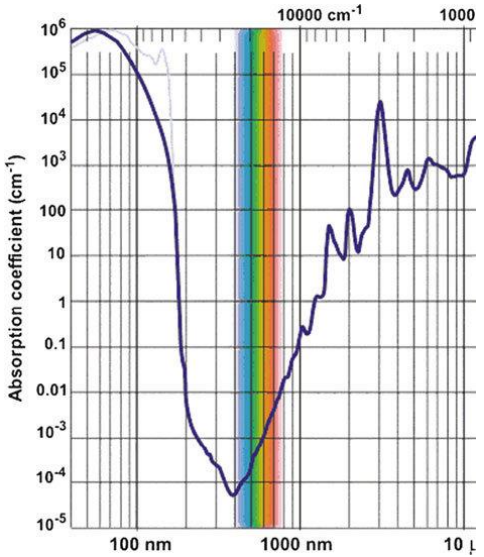

Image Source: Subhash, H.M., Wang, R.K. (2013). Optical Coherence Tomography: Technical Aspects. In: Liang, R. (eds) Biomedical Optical Imaging Technologies. Biological and Medical Physics, Biomedical Engineering. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-28391-8_5

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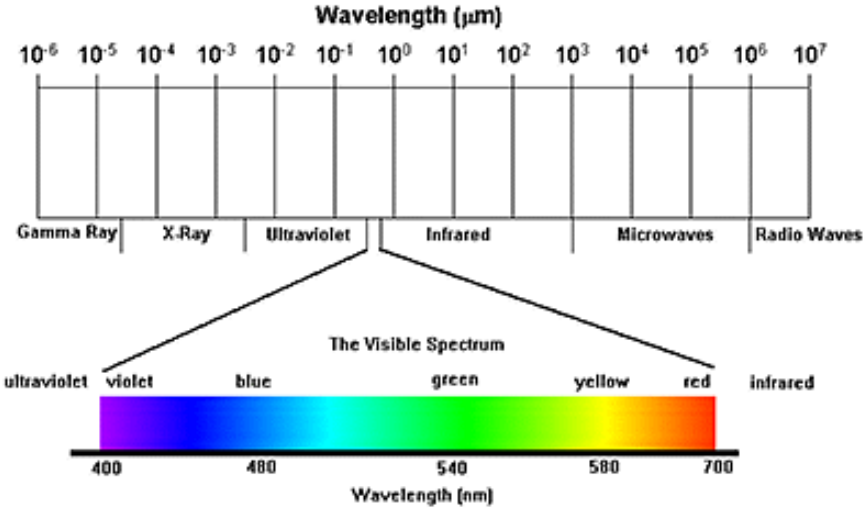

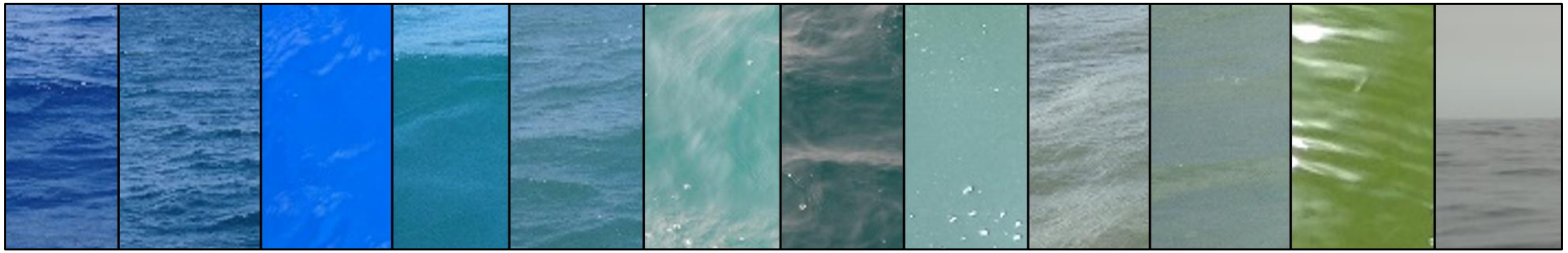

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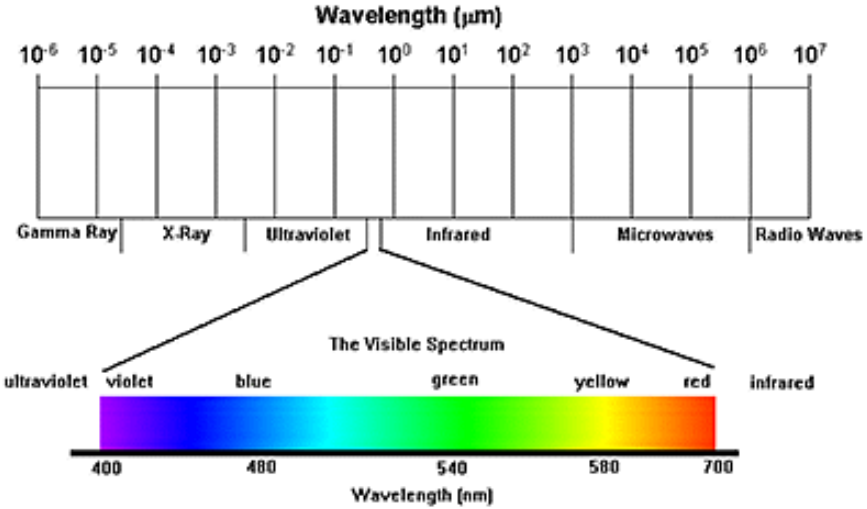
Why these colours?



Red + Blue = Pink

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Why these colours?

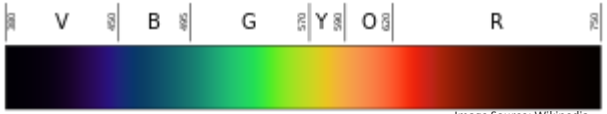
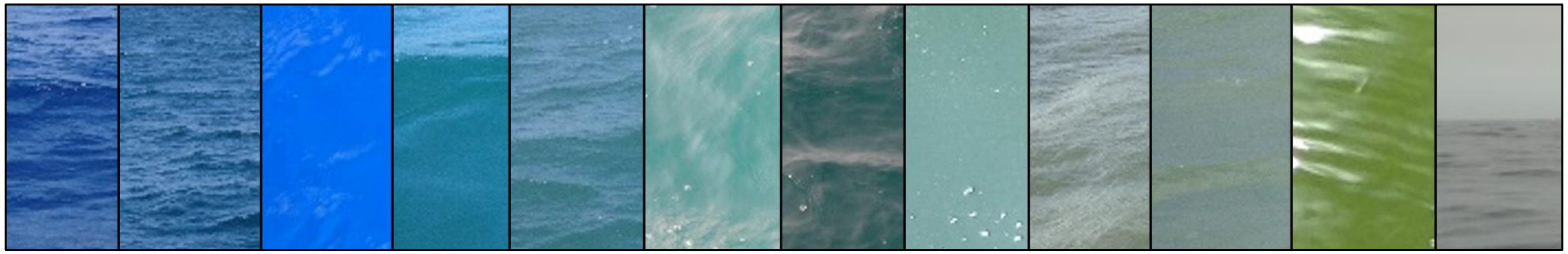


Image Source: Wikipedia

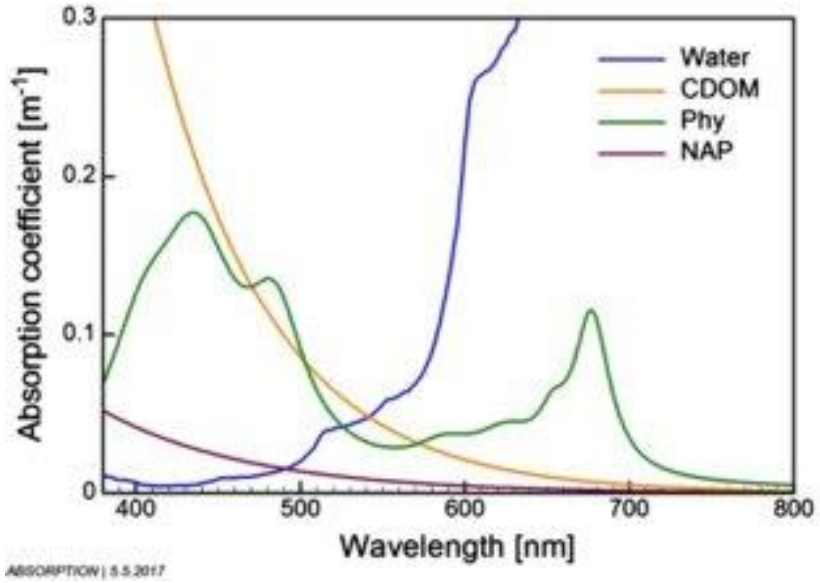


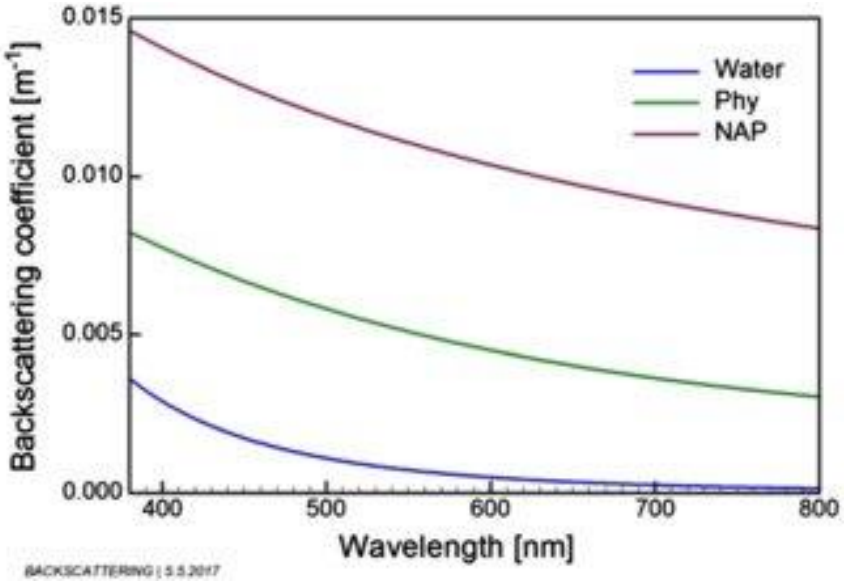
Different scattering and absorption spectrum

Absorption and scattering are Inherent Optical Properties.

How can we use these Inherent Optical Properties to do any analysis of these water bodies?

Inherent Optical Properties

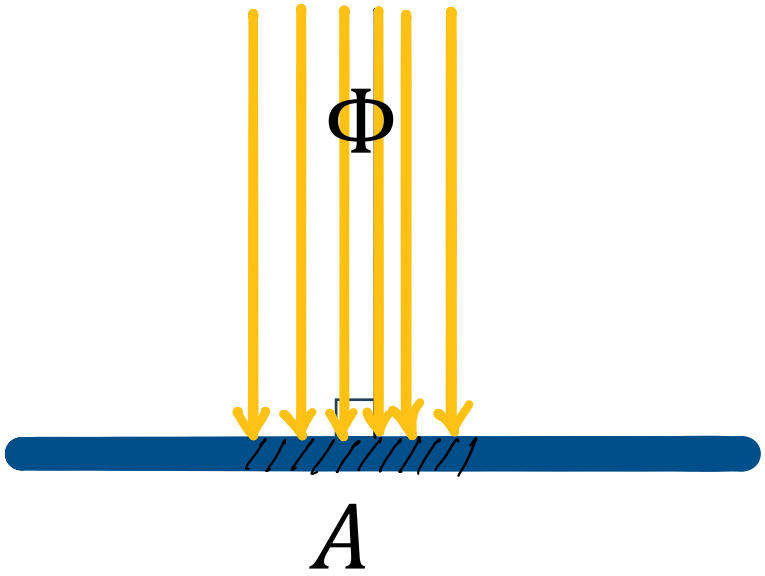




Giardino, C., Brando, V.E., Gege, P. et al. Imaging Spectrometry of Inland and Coastal Waters: State of the Art, Achievements and Perspectives. Surv Geophys 40, 401–429 (2019). https://doi.org/10.1007/s10712-018-9476-0

Basic Radiometric Quantities

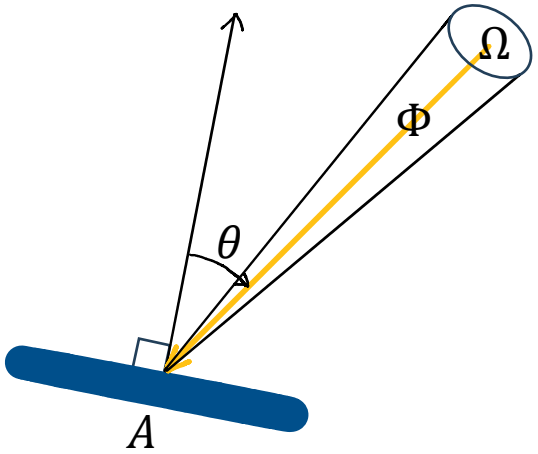
Irradiance (W m^{-2} nm^{-1})



$$E = \frac{\Phi}{A \cdot \lambda}$$

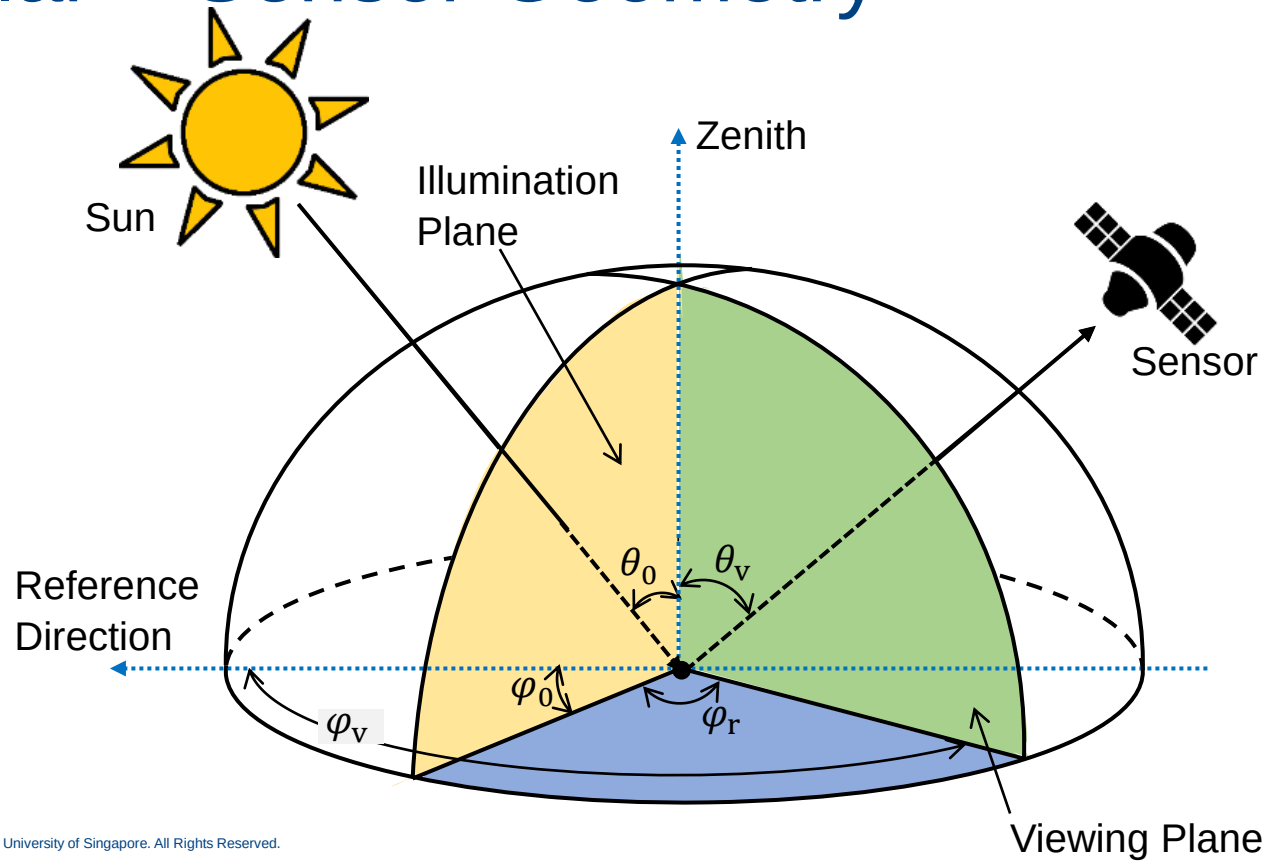
Basic Radiometric Quantities

Radiance (W m^{-2} nm^{-1} sr^{-1})



$$L = \frac{\Phi}{A \cdot \lambda \cdot \Omega}$$

Solar – Sensor Geometry

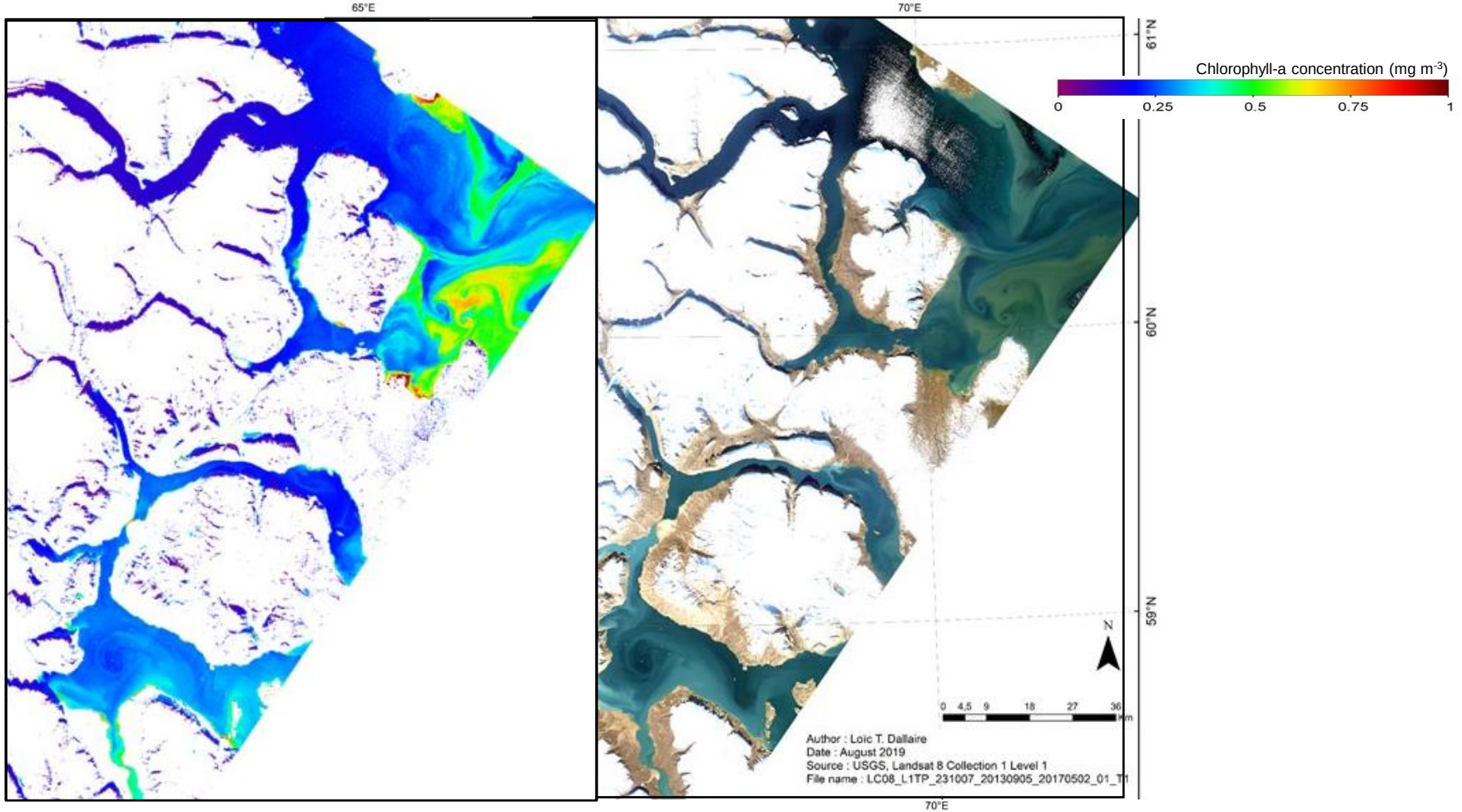


Apparent Optical Properties

(1) Depend both on the medium (the IOPs) and on the geometric (directional) structure of the radiance distribution, and

(2) Display enough regular features and stability to be useful descriptors of a water body.

Read https://www.oceanopticsbook.info for more information



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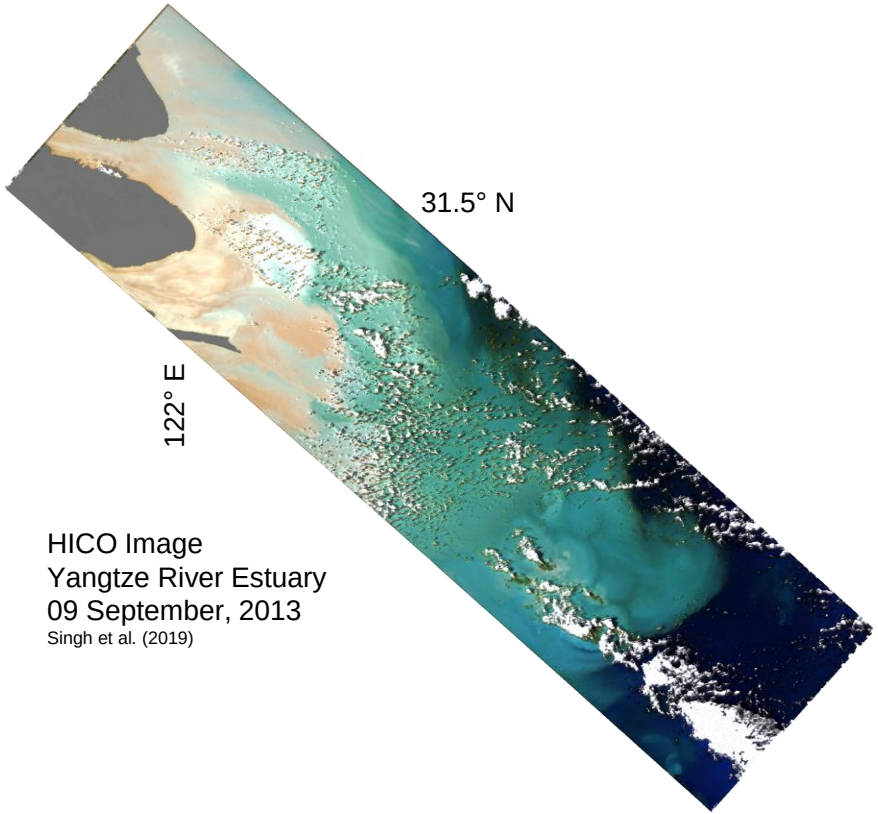
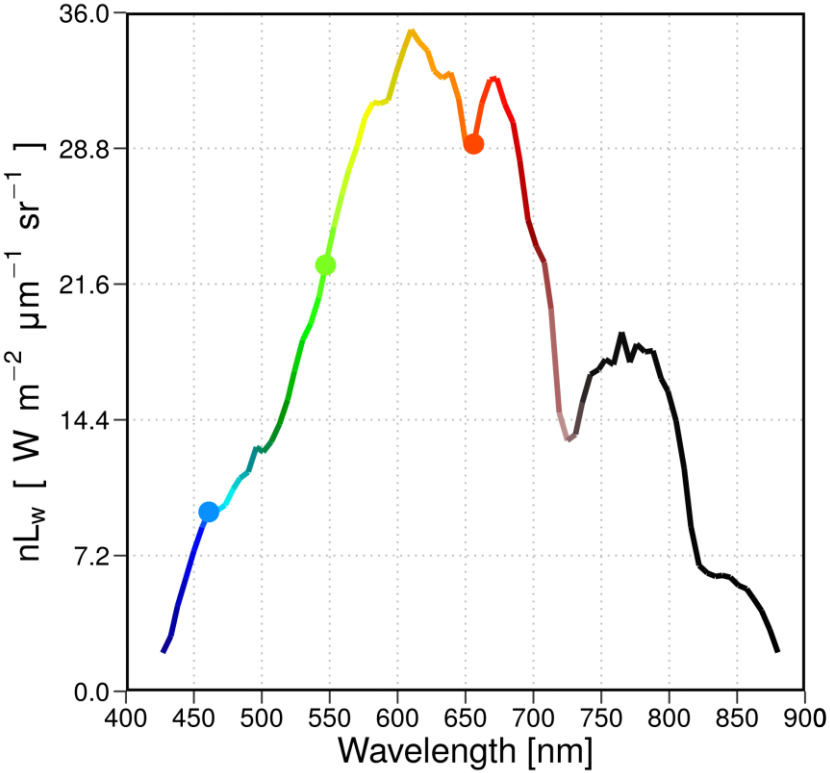


HICO Image
Yangtze River Estuary
09 September, 2013
Singh et al. (2019)



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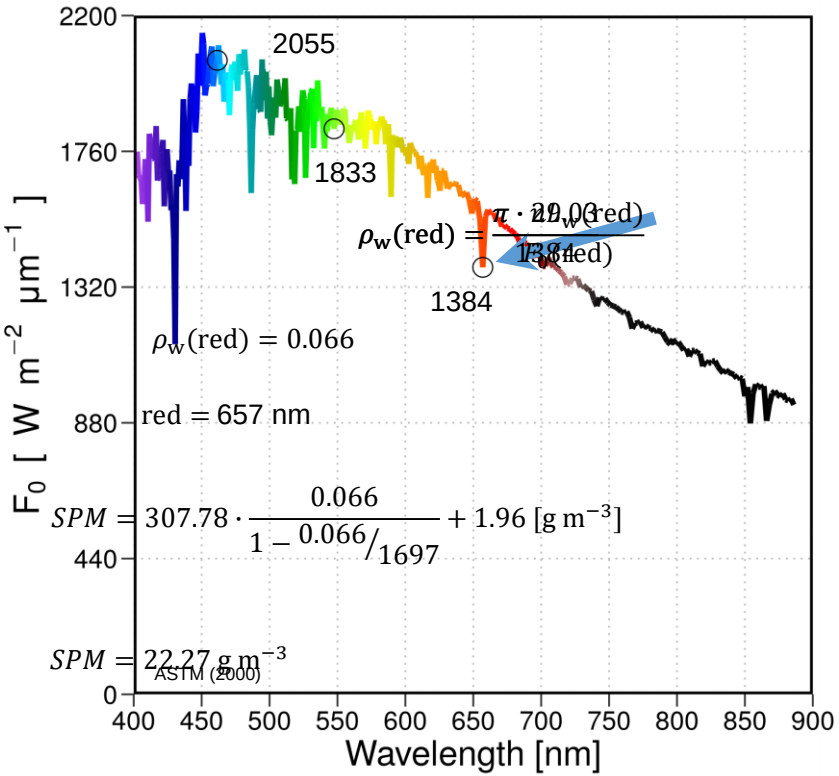

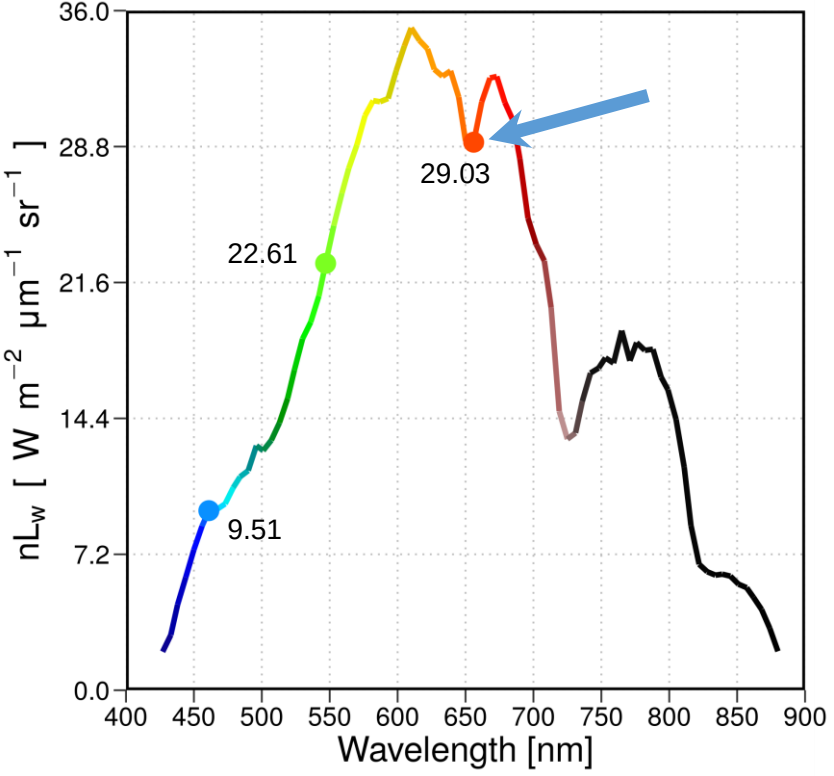

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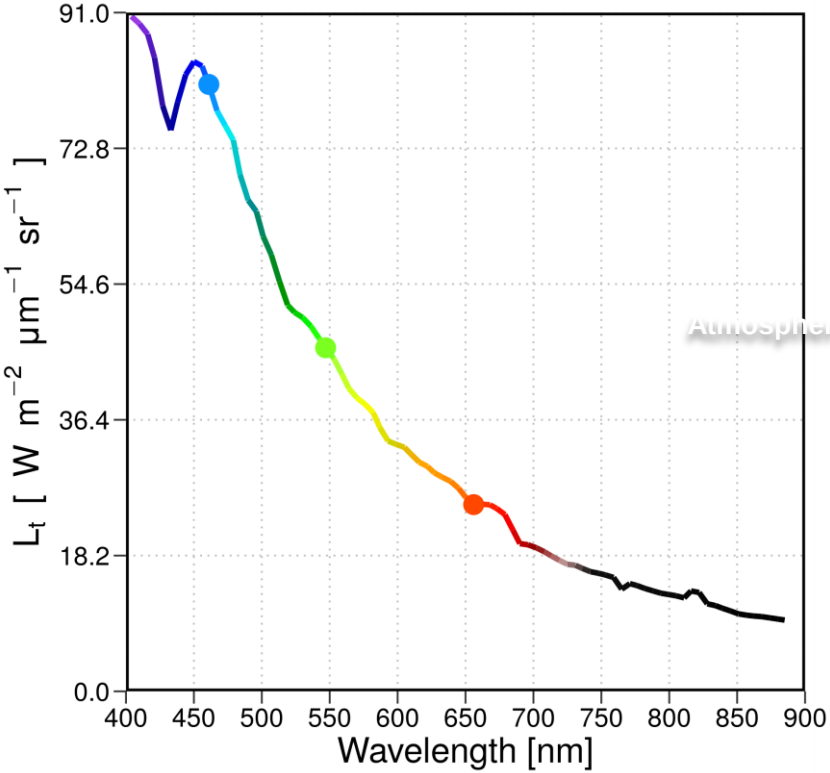
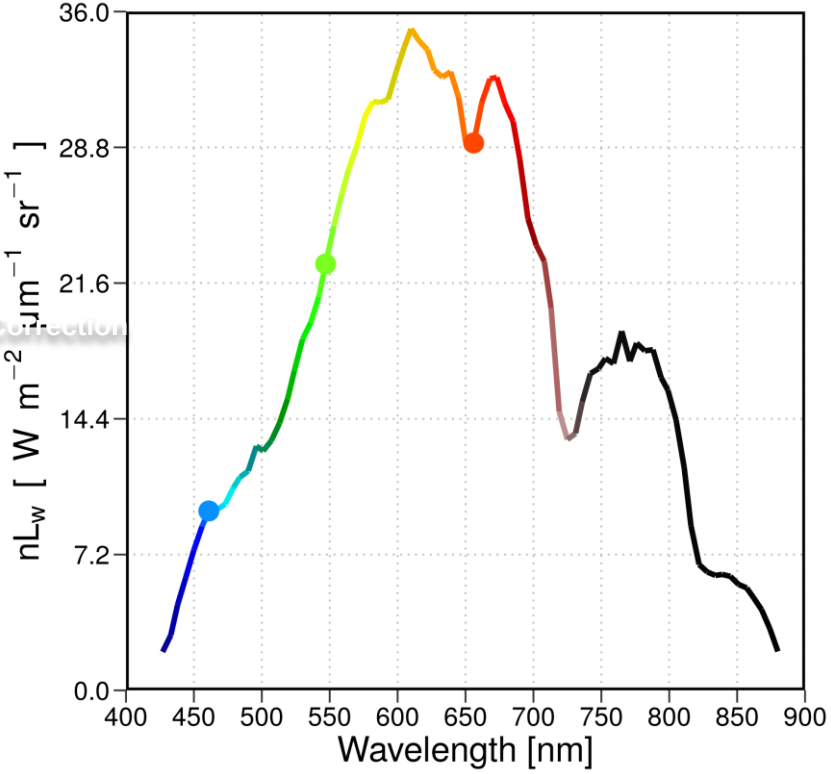
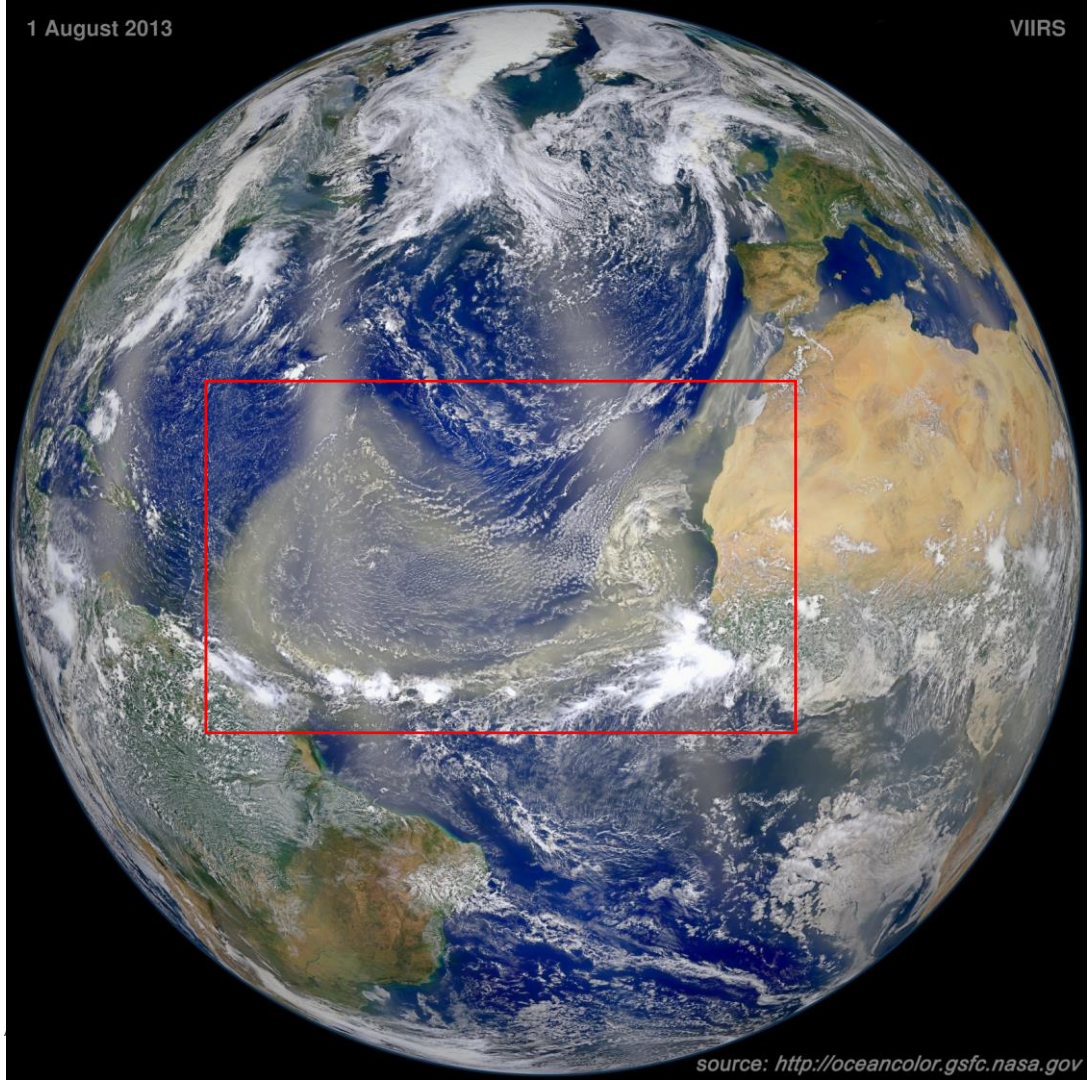
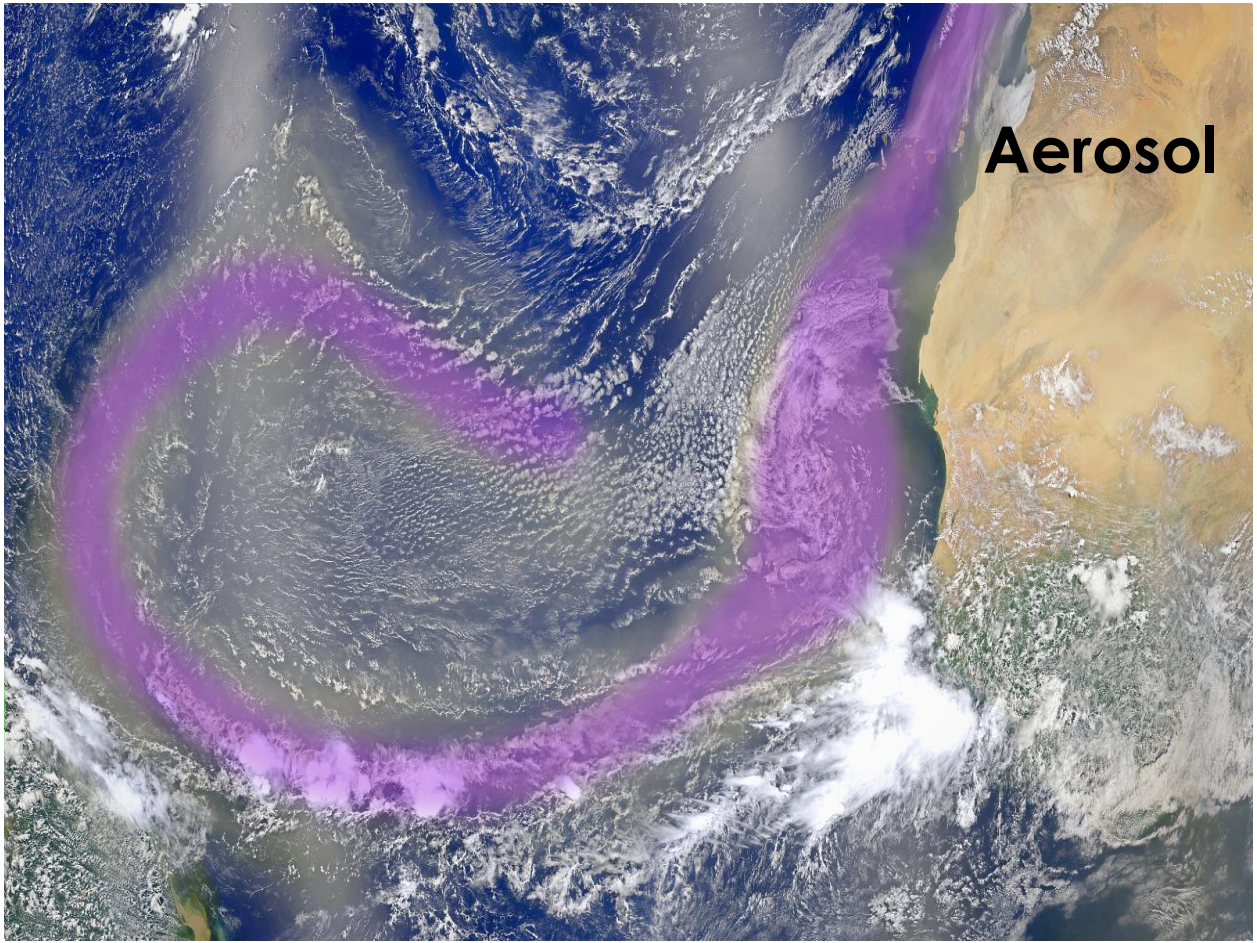


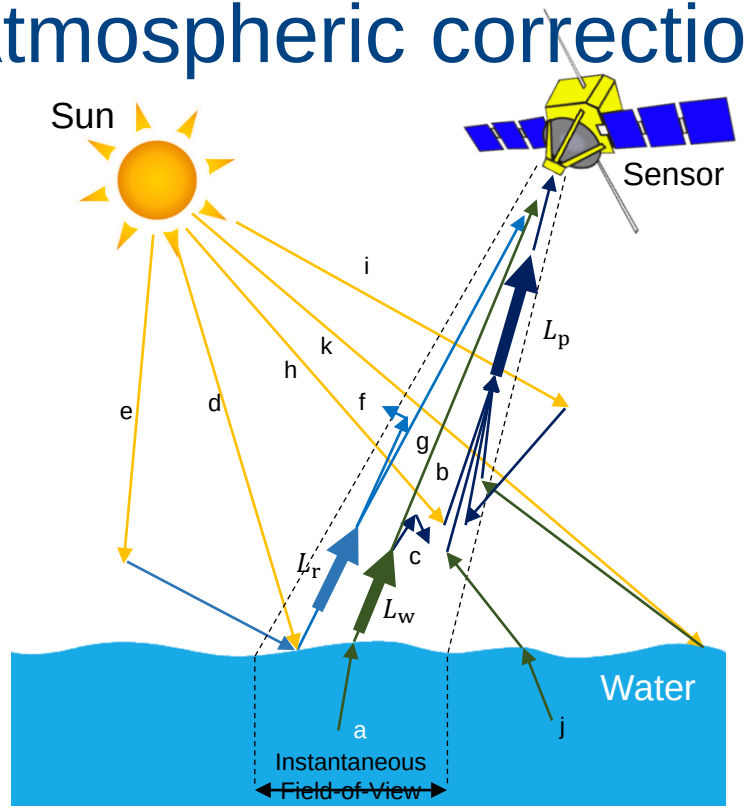
Atmospheric Correction







Atmospheric correction



L_w Water-leaving radiance,
L_r All reflected radiances within the IFoV,
L_p Atmospheric path radiance

a) The light path of the water-leaving radiance,
b) The attenuation of the water-leaving radiance,
c) Scattering of the water-leaving radiance out of the sensor's FOV,
d) Sun glint (reflection from the water surface),
e) Sky glint (scattered light reflecting from the surface),
f) Scattering of reflected light out of the sensor's FOV,
g) Reflected light is also attenuated towards the sensor,
h) Scattered light from the sun which is directed toward the sensor,
i) Light which has already been scattered by the atmosphere which is then scattered toward the sensor,
j) Water-leaving radiance originating out of the sensor FOV, but scattered toward the sensor,
k) Surface reflection out of the sensor FOV which is then scattered toward the sensor

Source: disc.sci.gsfc.nasa.gov

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Atmospheric correction

Path effects:

The scattering of light by the atmospheric molecules/particles while it passes through the atmosphere.

Rayleigh Scattering

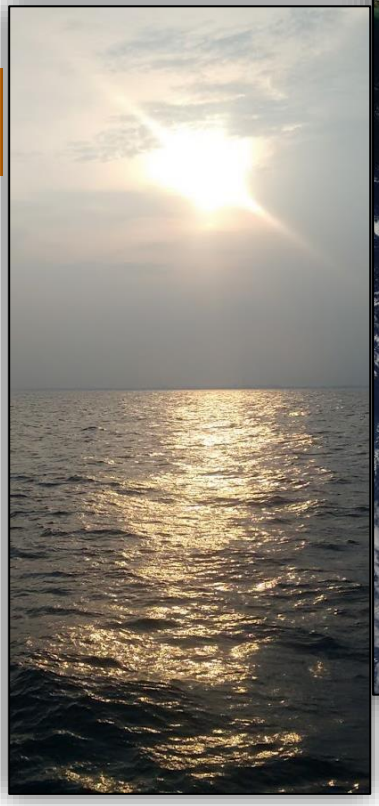
Aerosol Scattering

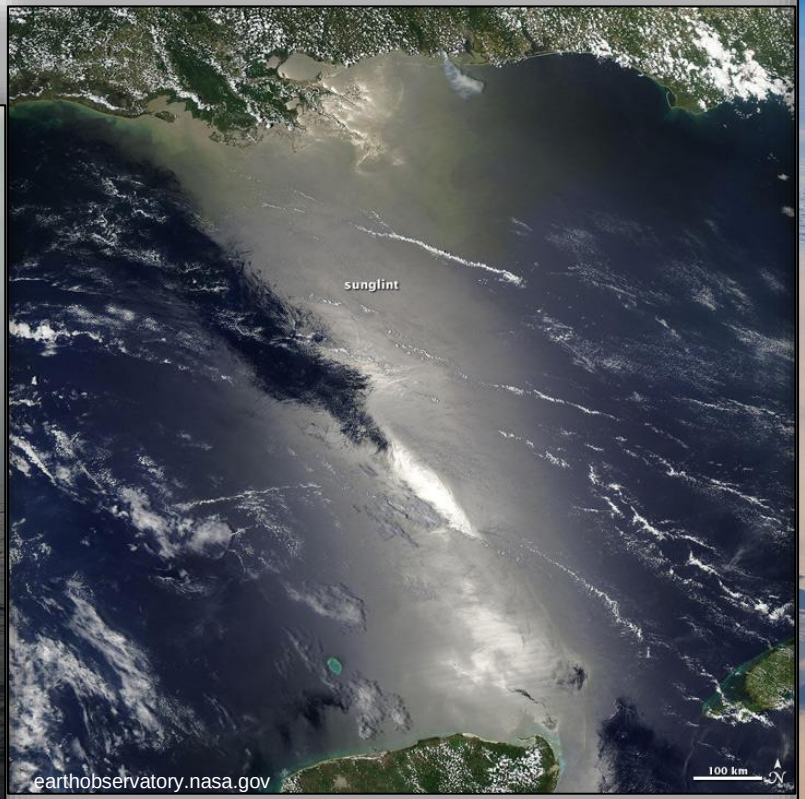
Surface effects:

The part of sunlight reflected from the water surface.

- Sunglint
- Whitecaps

Sunglint



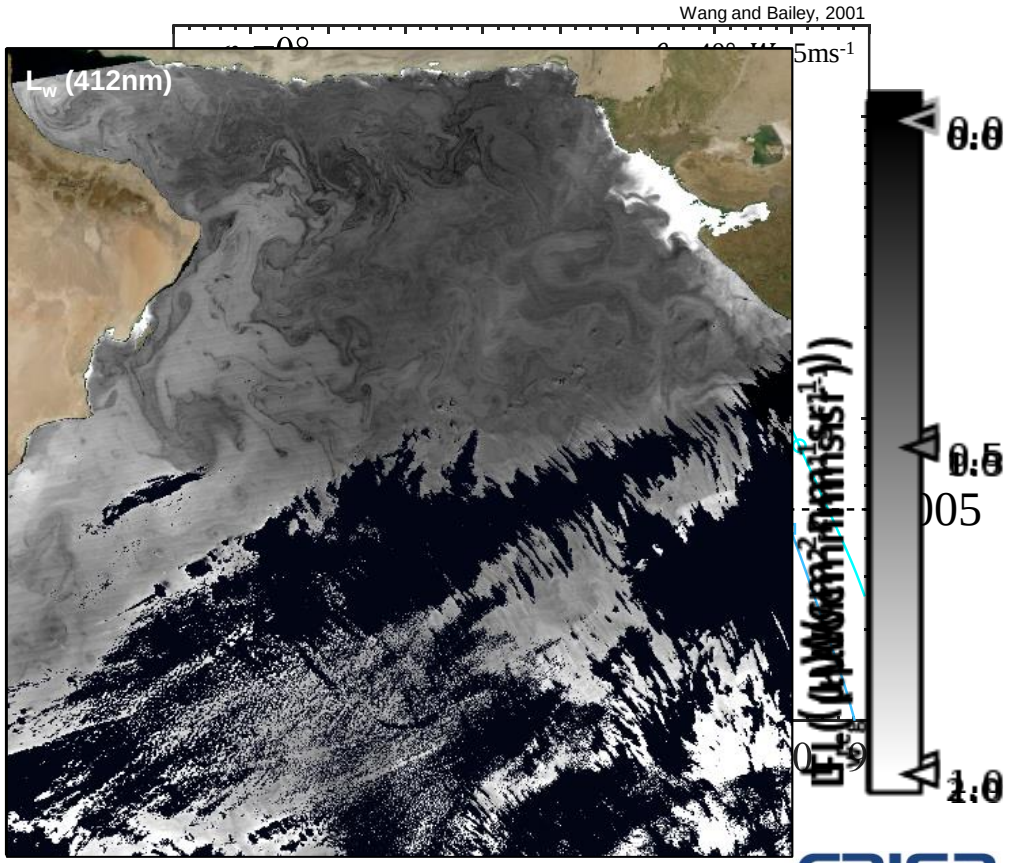


Sunglint

$$L_g(\lambda, \theta_0, \theta_v, \varphi_r, W)$$

Cox and Munk, 1954

λ = Wavelength
θ_0 = Solar zenith angle
θ_v = Sensor zenith angle
φ_r = relative azimuth angle
W = Windspeed



Singh and Shanmugam, 2014a

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Whitecaps

$$L_{wc}(\lambda, \theta_0, W, \Delta T)$$

Gordon and Wang, 1994a

λ = Wavelength

θ_0= Solar zenith angle

ΔT = difference in air-water temperature

W= Windspeed

https://manoa.hawaii.edu/exploringourfluidearth/physical/waves/sea-states

Rayleigh Scattering

Responsible for blue colour of the atmosphere

$L_r(\lambda, \theta_0, \theta_v, \varphi_r, P)$

(Gordon et al., 1988) (Wang, 2005)

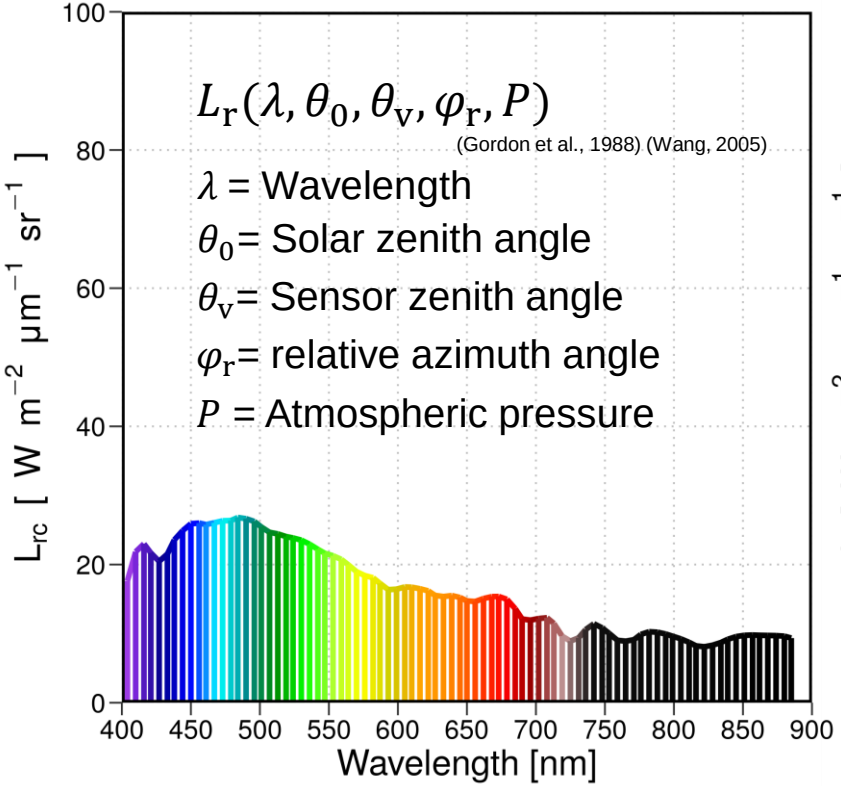
λ = Wavelength

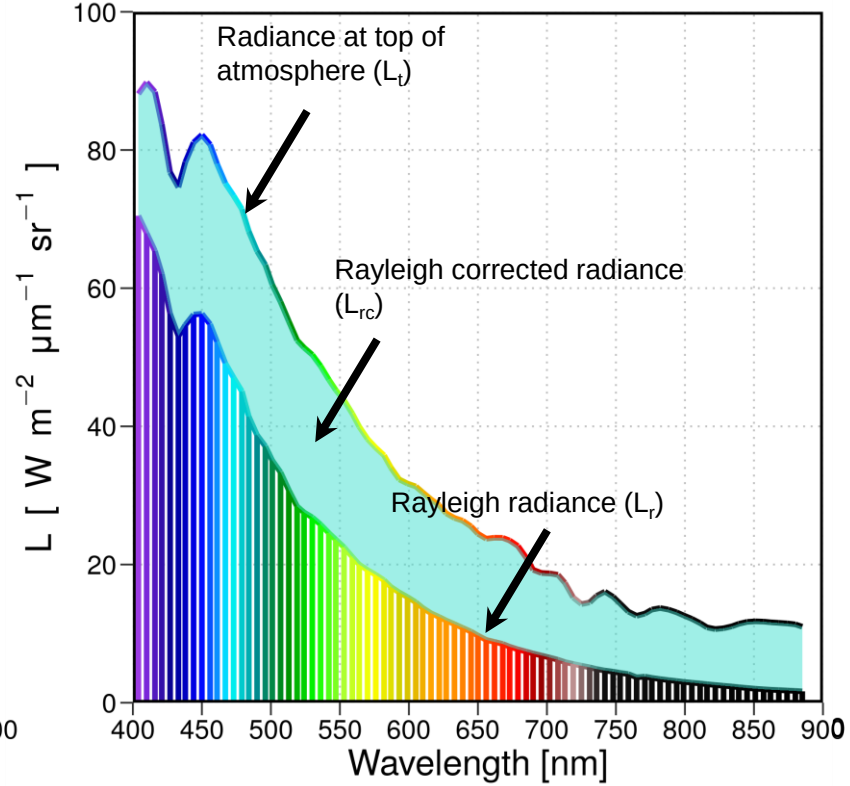
θ_0 = Solar zenith angle

θ_v = Sensor zenith angle

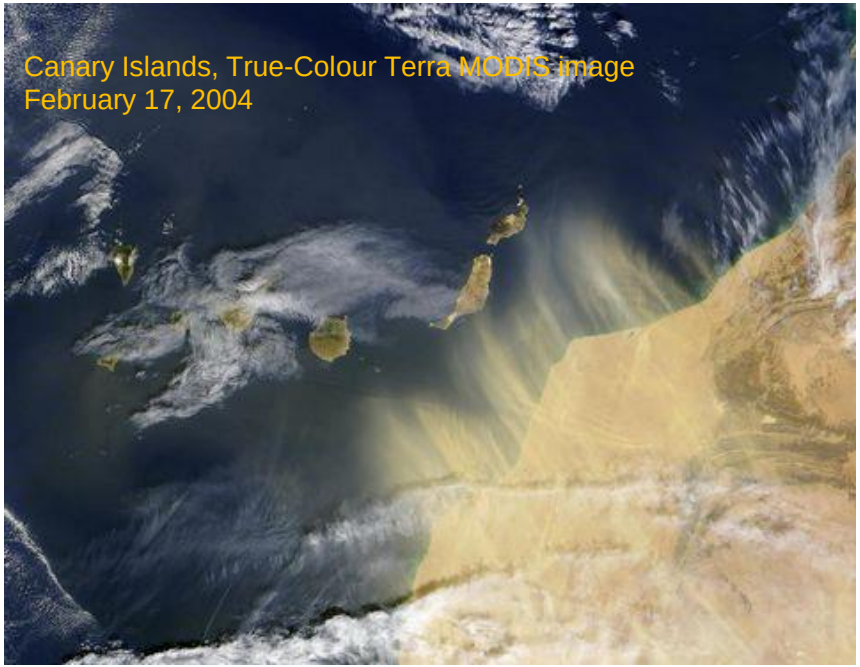
φ_r = relative azimuth angle

P = Atmospheric pressure





Aerosol Scattering



Source: NASA http://visibleearth.nasa.gov/view.php?id=70054

- Variable in time and space.
- Variable in shape and size.
- Variable in chemical composition (absorbing & non absorbing).
- Variable concentration.

Aerosol Scattering

$L_a(\lambda, \theta_0, \theta_v, \varphi_r, AM)$

(Gordon and Wang, 1994b)

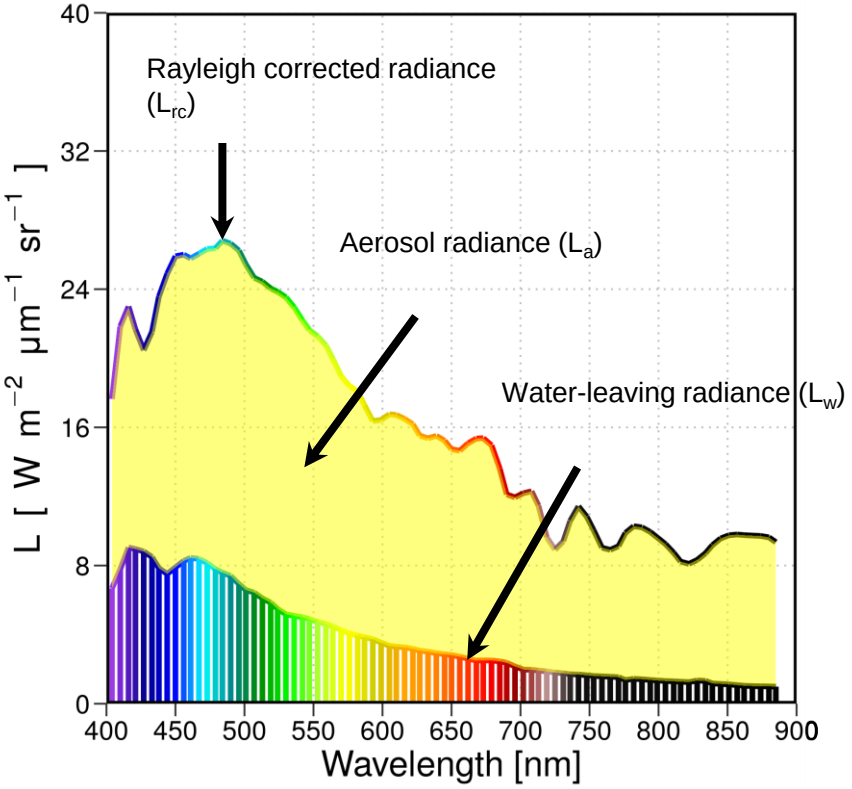
λ = Wavelength

θ_0 = Solar zenith angle

θ_v = Sensor zenith angle

φ_r = relative azimuth angle

AM = Aerosol model



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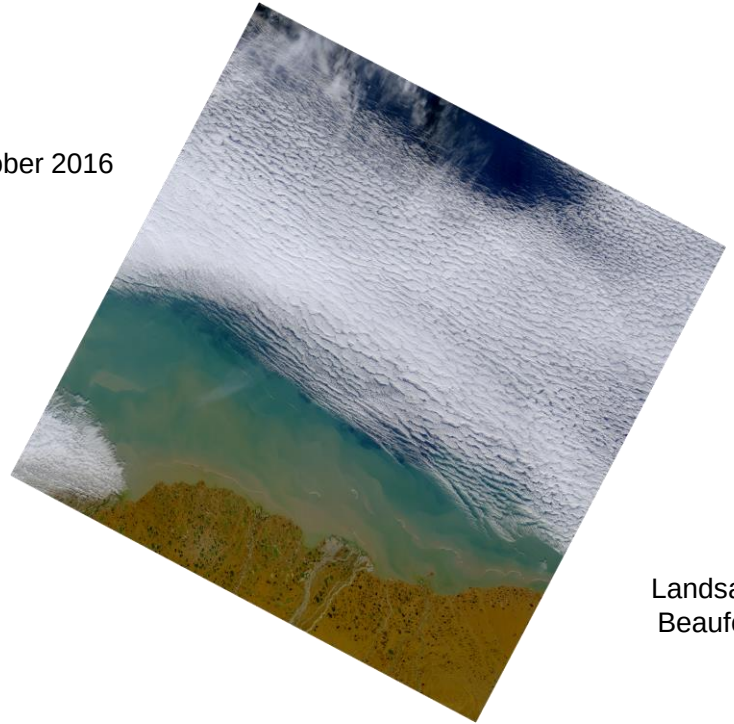
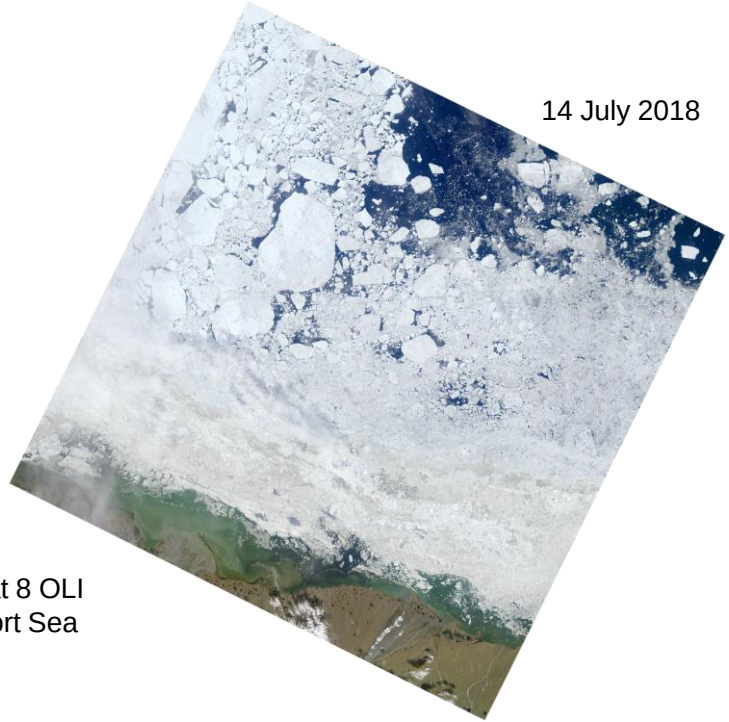
Clouds and other masks

03 October 2016



14 July 2018



Landsat 8 OLI
Beaufort Sea

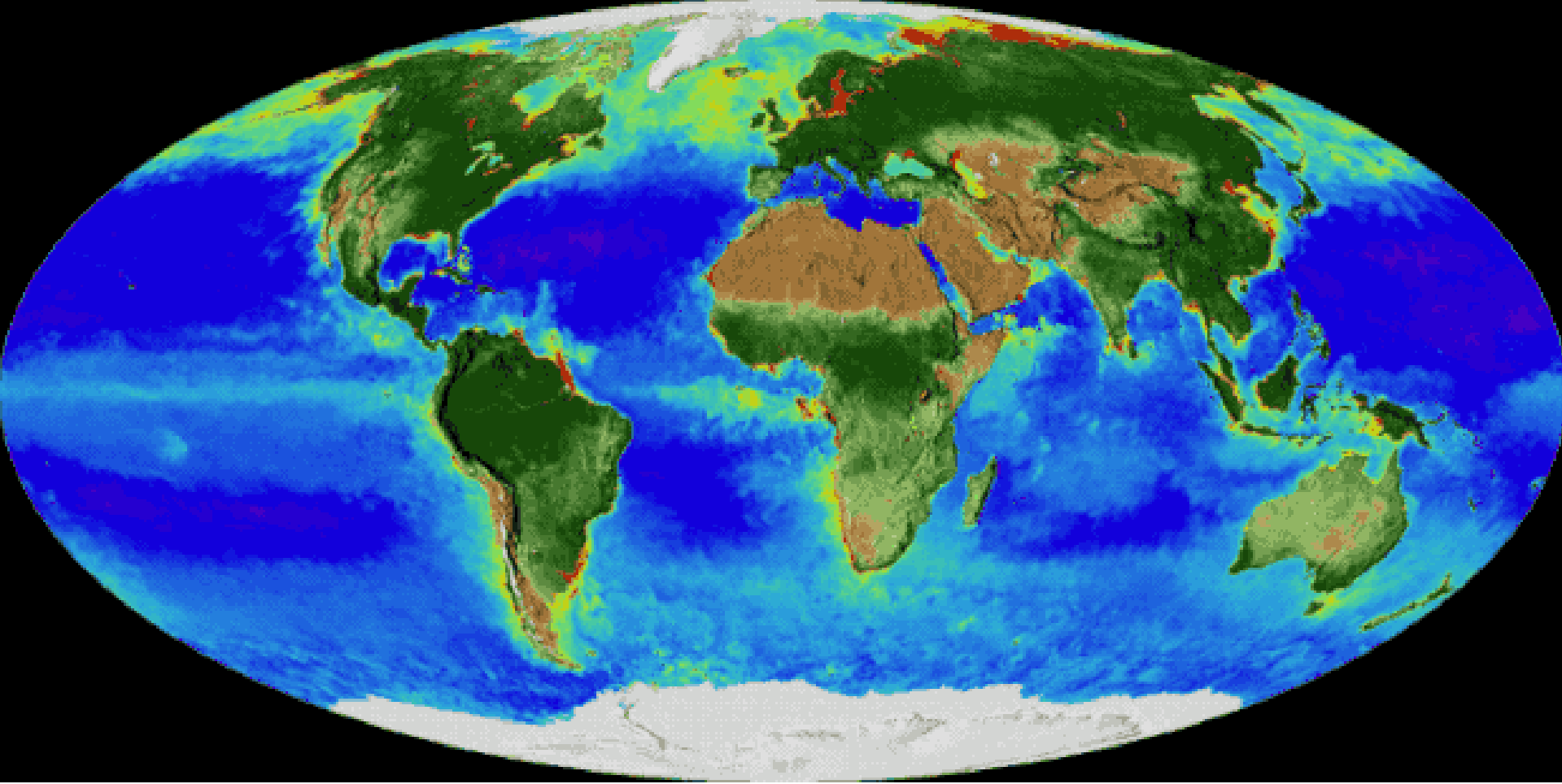


Image Source: NASA

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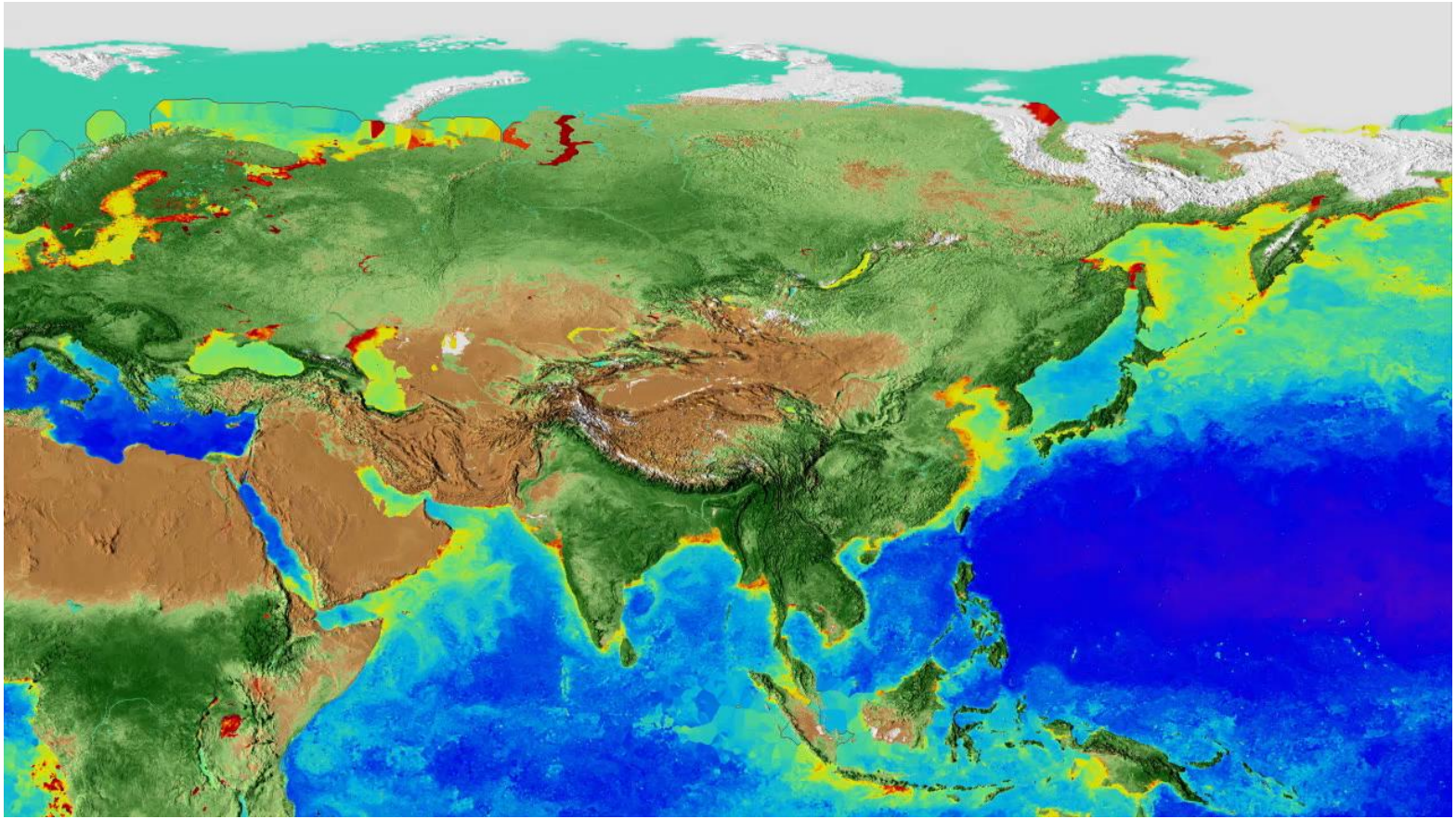

Image Source: NASA

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