Ocean Colour Remote Sensing in Turbid Waters

Lecture 2:
Introduction to computer exercise
“The Colour of Water”

by Kevin Ruddick

Overview of this lecture

- Objective: introduce the HYPERTEACH ocean colour model as basis for exercise session

- NB. This is an approximate model for educational purposes only
- NOT for ocean colour data processing
- NOT for research grade publications
- JUST for understanding first order variability of marine reflectance

- CONDITIONS of USE:
  - I will not hold anyone responsable for mis-use, etc.
  - I will not use this for ocean colour data processing or research grade publications - for that I will use accurate radiative transfer models such as HYDROLIGHT (water) or 6SV (atmosphere)
  - I will use this model for quickly understanding ocean colour variability
  - I will not cheat and go straight to the answers
  - I will think of ways this could be improved for educational purposes and help by providing suggestions

We Accept

Variation of reflectance with IOPs

- Gordon-Morel type approximate reflectance model

$$R_{rs}(\lambda) = \gamma' \frac{b_b(\lambda)}{a(\lambda) + b_b(\lambda)}$$

- For all but most reflective water, relation is linear:

$$b_b << a \quad \Rightarrow \quad R_{rs}(\lambda) = \gamma' \frac{b_b(\lambda)}{a(\lambda)}$$

- (NB This model is not appropriate for high reflectance)

Decomposition of IOPs: absorption

- The total absorption can be decomposed into a <u>linear</u> sum of (mutually exclusive) components:

(total) yellow substance $a_Y(\lambda)$

$$a(\lambda) = a_w(\lambda) + a_\phi(\lambda) + \overbrace{a_{CDOM}(\lambda) + a_{NAP}(\lambda)}$$

Pure water

Phytoplankton

Coloured Dissolved Organic Matter

Non-algae particles

Decomposition of IOPS: backscatter

- The total backscatter can be decomposed into a linear sum of (mutually exclusive) components:

$$b_b(\lambda) = b_{bw}(\lambda) + \overbrace{b_{b\phi}(\lambda) + b_{bNAP}(\lambda)}^{\text{(total) particulate } b_{bp}(\lambda)}$$

Pure water

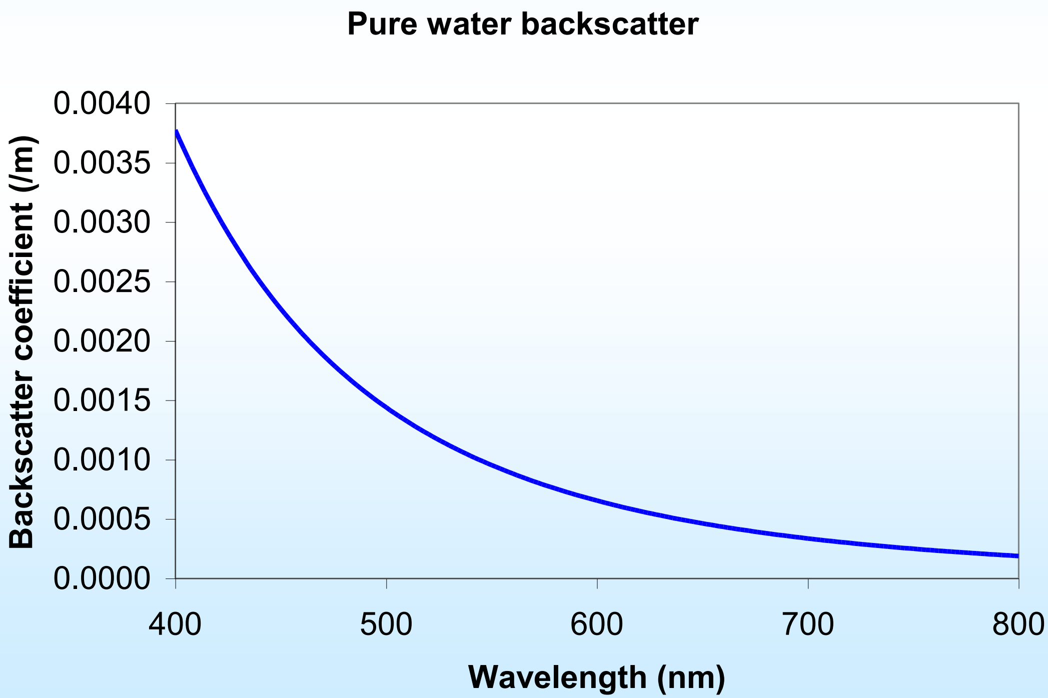
Phytoplankton

Non-algae particles

Optical properties of pure sea water (1/3)

- Backscatter of pure sea water (includes bubbles?):
  - Generally low, especially for green-red

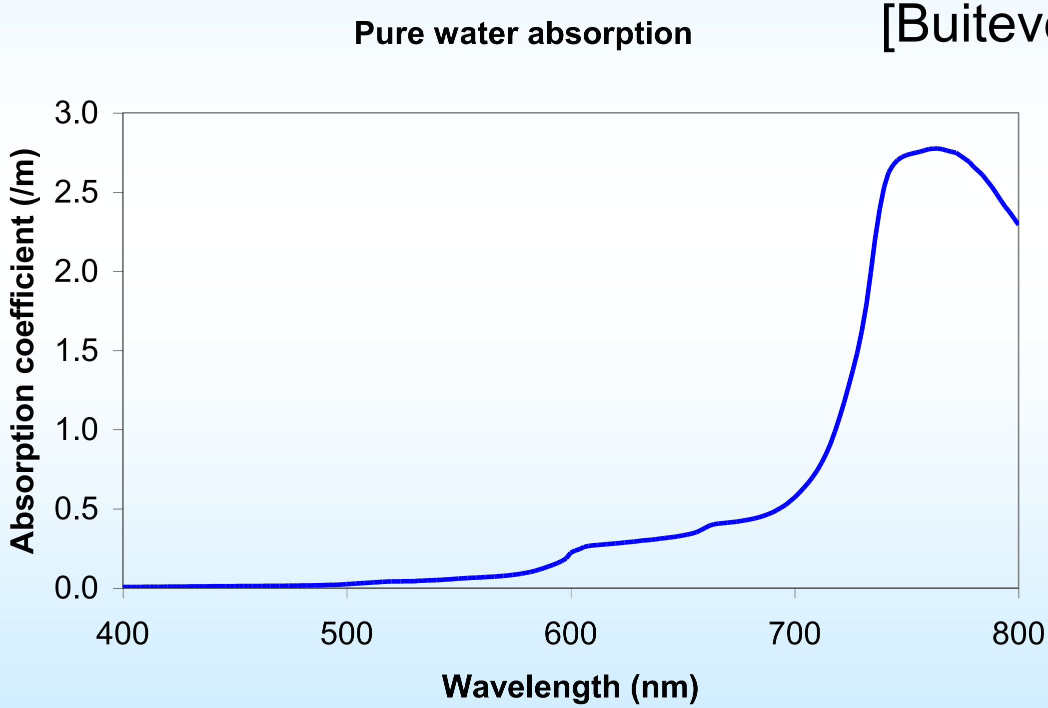
$$b_{bw} = 0.5 * 0.00288 * \left(\frac{\lambda}{500nm} \right)^{-4.32}$$ [Morel, 1974]



Optical properties of pure sea water (2/3)

- Absorption of pure sea water:
  - Dominant absorber (except in very turbid waters) for red and especially near infrared

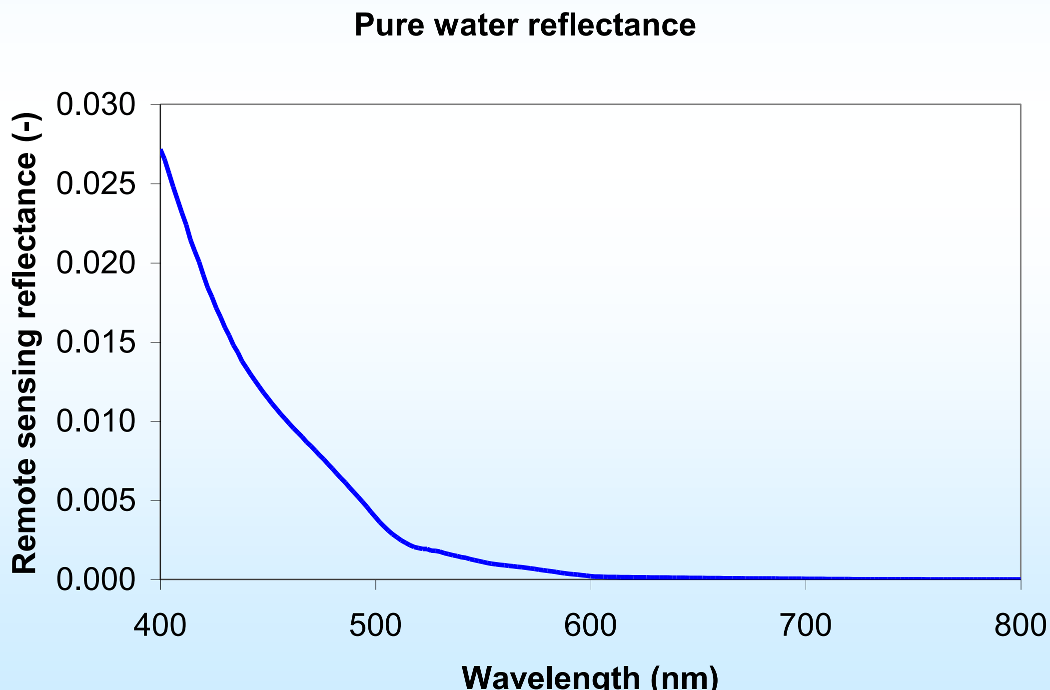
[Buiteveld et al, 1994]



Optical properties of pure water (3/3)

- If water contains no other constituents (no phytoplankton or other particles, no coloured dissolved organic matter) then:

$$R_{rs}(\lambda) = \gamma' \frac{b_b(\lambda)}{a(\lambda)} \approx 0.069 \frac{b_{bw}(\lambda)}{a_w(\lambda)}$$



- Not a realistic case, but useful extreme case (blue/violet water)

Optical properties of phytoplankton (1/2)

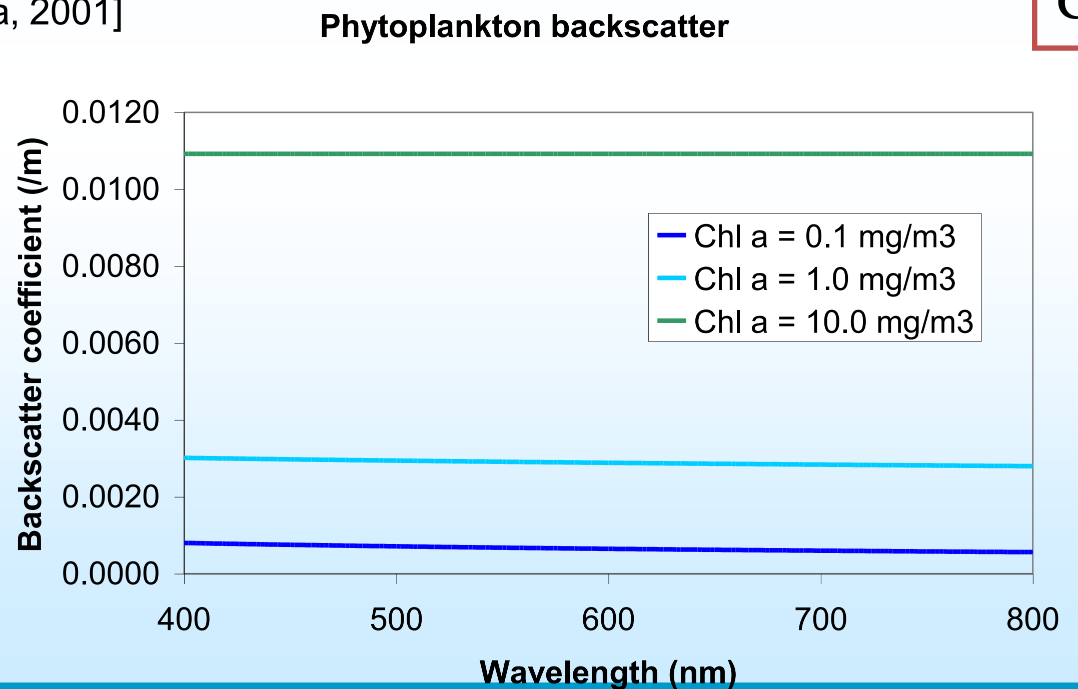
- Backscatter of phytoplankton:
  - Main backscatterer in open ocean, relatively flat spectrum

$$\nu \in (-0.65, 0)$$

$$b_{b\phi} = \left\{ 0.002 + 0.01 * \left[0.50 - 0.25 \log_{10} C \right] \left(\frac{\lambda}{550nm} \right)^{\nu} \right\} * 0.416 * C^{0.766}$$

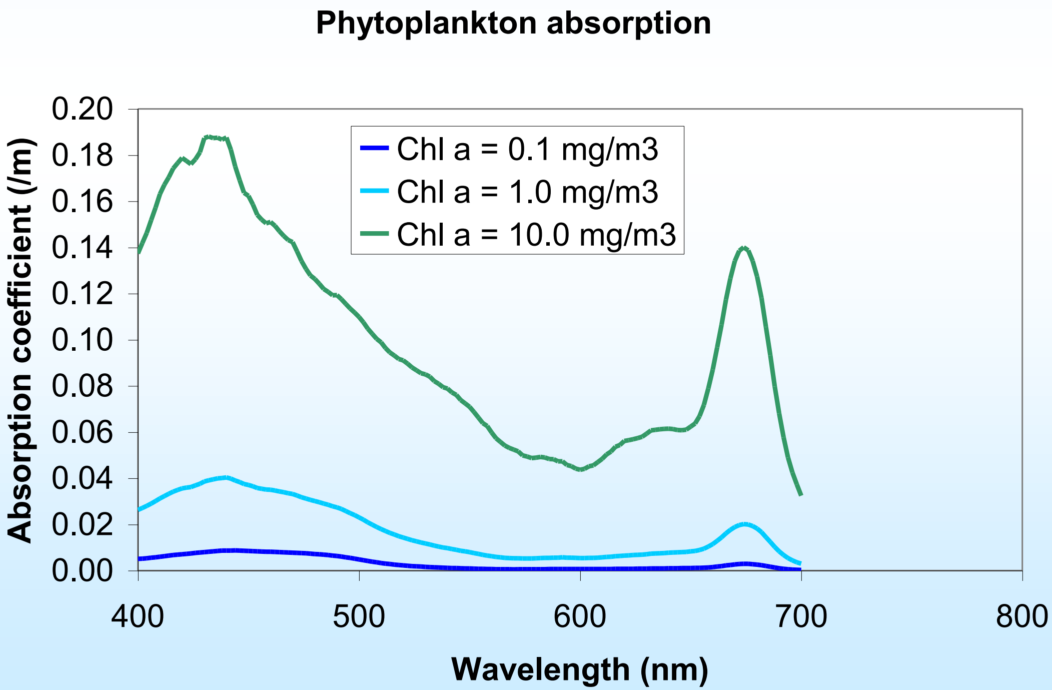
C=Chl a

[Morel and Maritorena, 2001]



Optical properties of phytoplankton (2/2)

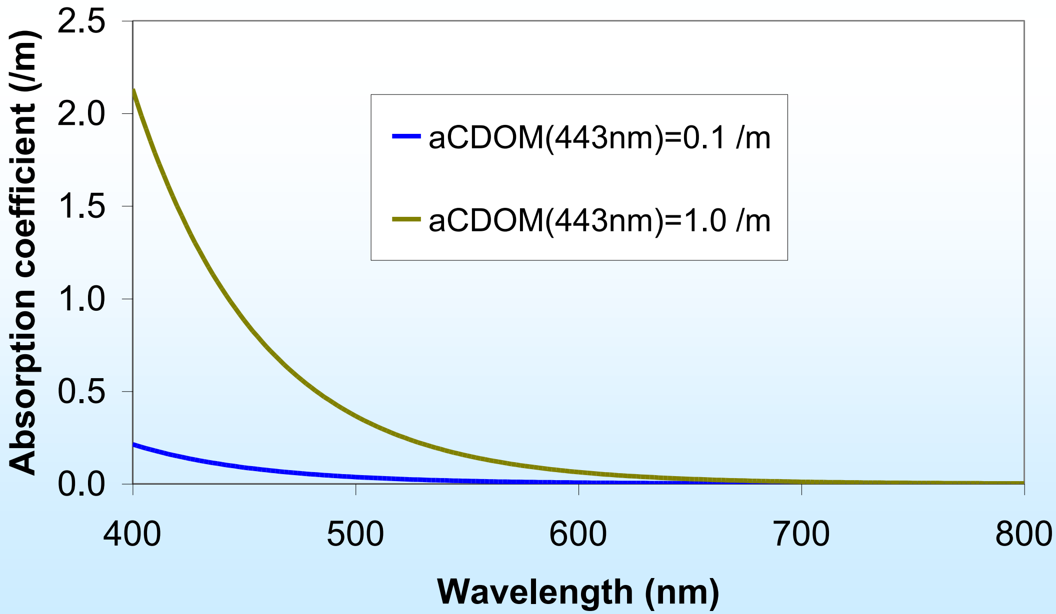
- Absorption of phytoplankton:
  - Main absorber in open ocean, spectral features in blue and red
  - Phyto absorption proportional to Chl *a* (first approximation)
  - Tabulated spectra given as function of Chl a [Bricaud et al, 1995]



Coloured Dissolved Organic Matter (CDOM)

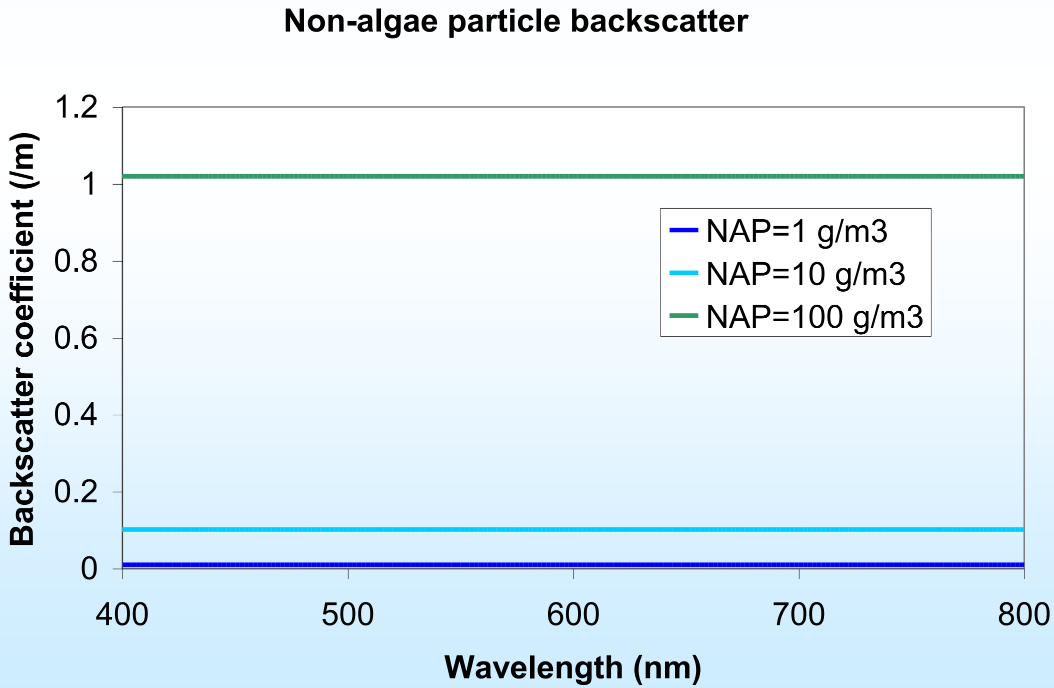
- CDOM=humic/fulvic acids from degradation of terrestrial or marine vegetation (correlated with salinity or phytoplankton)
  - neg. backscatter, absorbs strongly in blue: « yellow » substance
  - can be main absorber in coastal waters with high river input but low suspended matter e.g. parts of Baltic Sea, Black Sea

Coloured Dissolved Organic Matter (CDOM) absorption



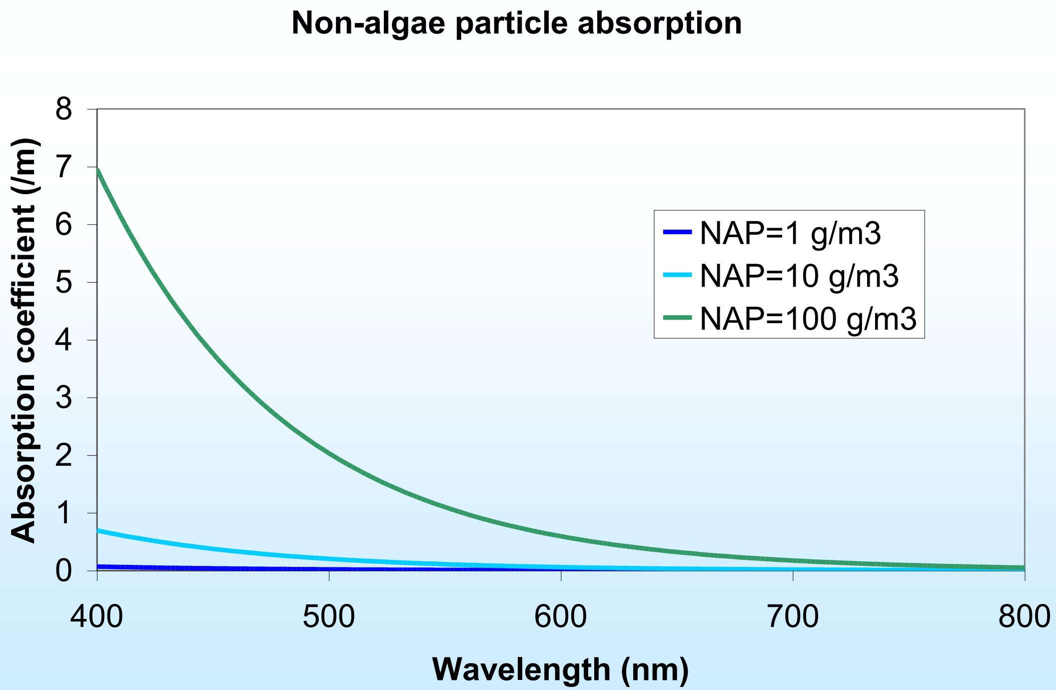
Optical propeties of non-algal particles (1/2)

- Non-algal particles (NAP) may have diverse nature and origin: e.g. mineral particles (coastal/bottom erosion, river outflow), detrital particles (decayed phytoplankton)
- Backscatter relatively flat spectrally, α NAP concentration, can be main backscatterer in coastal and estuarine waters

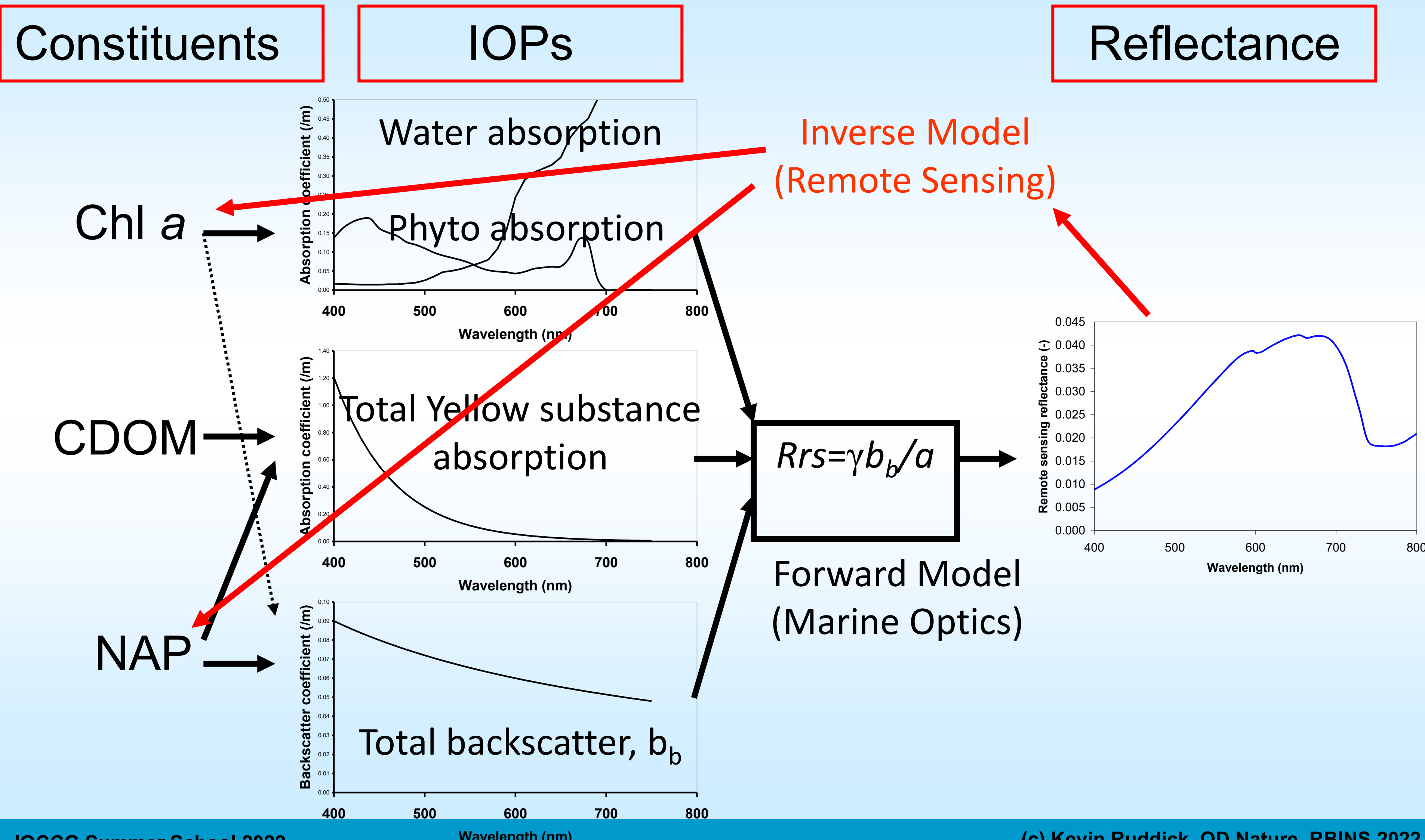


Optical propeties of non-algal particles (2/2)

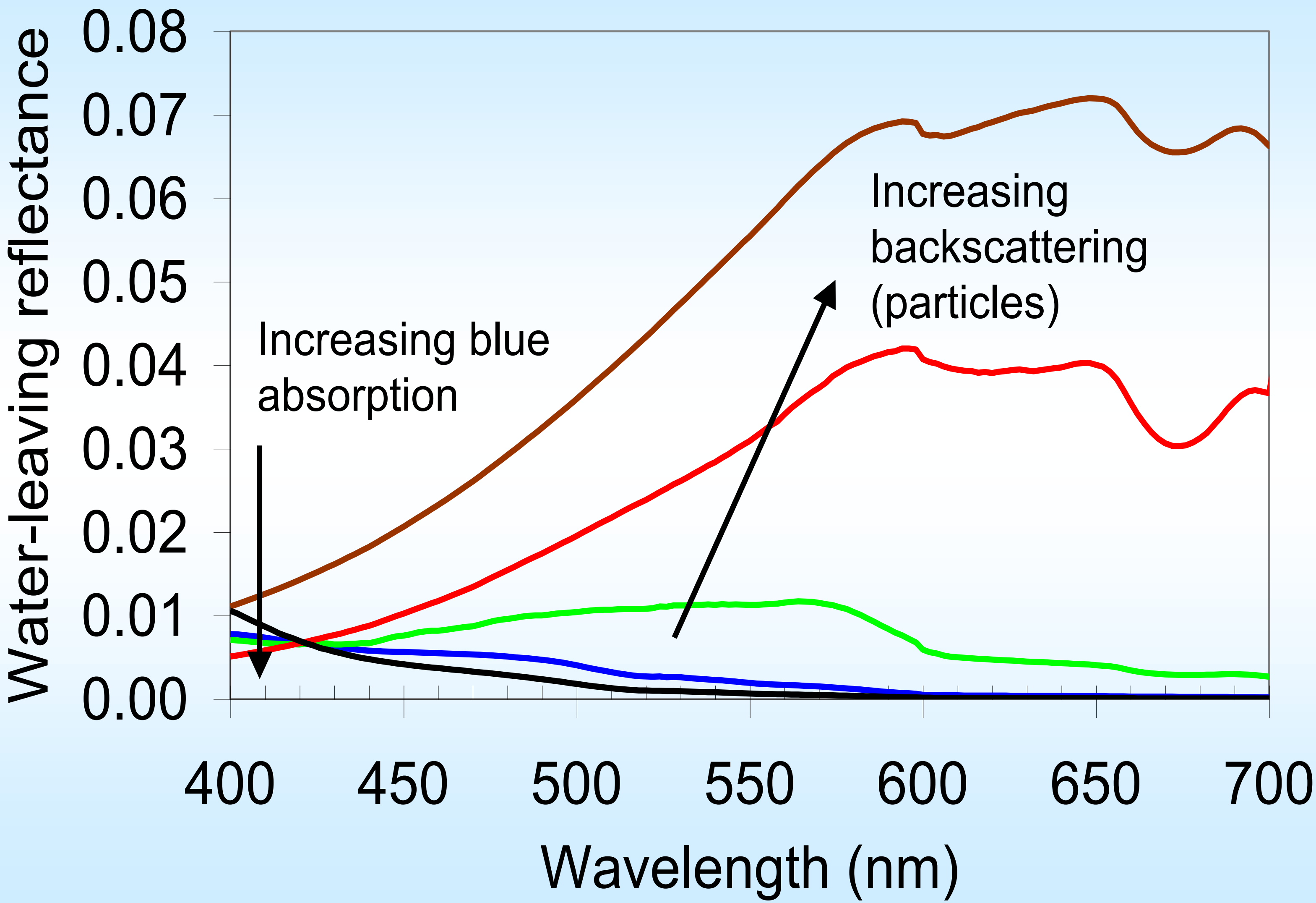
- Absorption of non-algal particles is strong in blue (like CDOM) with exponential decrease to higher wavelengths: « particulate » yellow substance
- Proportional to conc. of non-algae particles



From water constituents to reflectance via IOPs



Example reflectance spectra



Exceptions

- Assumes:
  - No bottom reflectance
  - No inelastic scattering (fluorescence, Raman, bioluminescence)
  - Vertically homogeneous (no stratification, no deep CHL max, etc.)

Make your own reflectance spectra

- Now follow the exercises and make your own reflectance spectra …

Please take notes on what is good/easy/broken!

We will distribute this online and develop further the project with extra lessons, YOU are our beta-testers!