Ocean Colour Remote Sensing in Turbid Waters

Lecture 2:
Introduction to computer exercise #1
“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

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

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

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

- For most reflective water, relation is asymptotic:

$$b_b >> a \quad \Rightarrow \quad R_{rs}(\lambda) \approx \gamma'$$

  - And reflectance is limited by a maximal value, which no longer depends on values of IOPs
  - BUT this doesn't happen often and model shouldn't be used there

Decomposition of IOPs: absorption

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

(total) yellow substance $a_Y \ \lambda$

$$a \ \lambda \ = a_w \ \lambda \ + a_\phi \ \lambda \ + \underbrace{a_{CDOM} \ \lambda \ + a_{NAP} \ \lambda}_{a_Y}$$

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:

(total) particulate $b_{bp} \;\; \lambda$

$$b_b \;\; \lambda \; = b_{bw} \;\; \lambda \; + b_{b\phi} \;\; \lambda \; + b_{bNAP} \;\; \lambda$$

Pure water

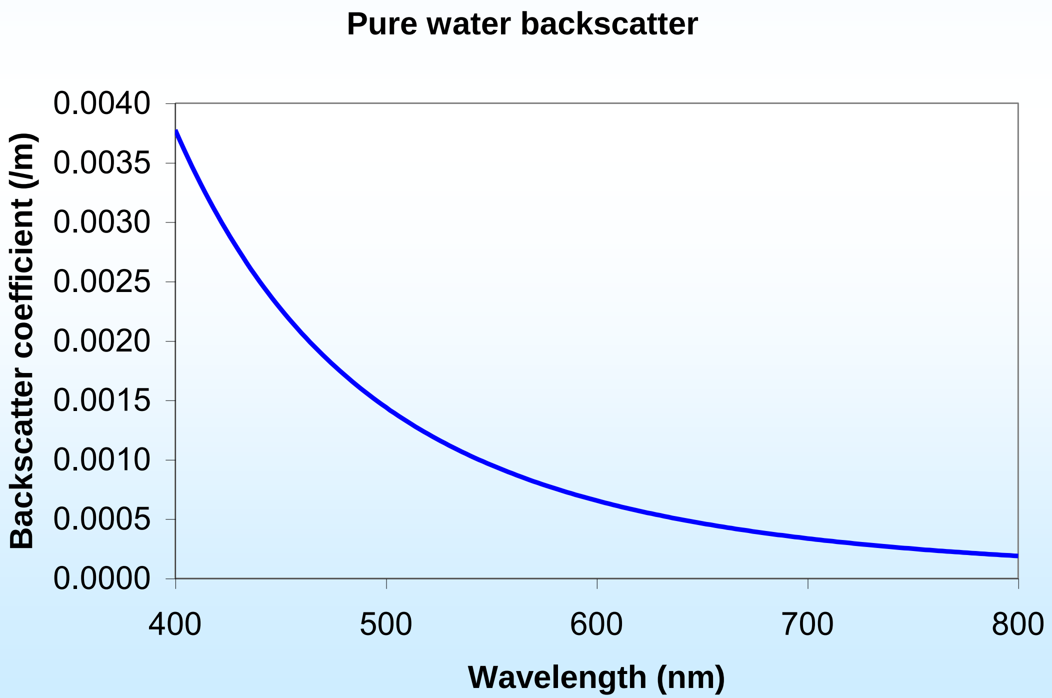
Phytoplankton

Non-algae particles

Optical properties of pure sea water (1/3)

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

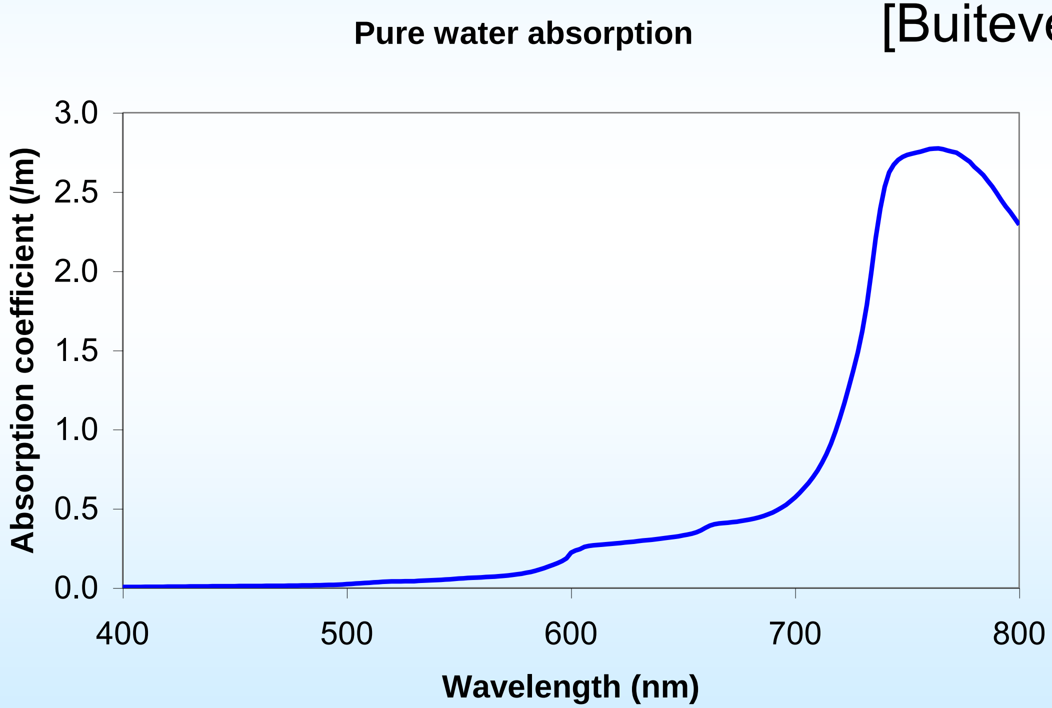
$$b_{bw} = 0.5 * 0.00288 * \left(\frac{\lambda}{500nm} \right)^{-4.32}$$ [Morel, 1974]



Optical properties of pure sea water (2/3)

- Absorption of pure sea water:
  - Dominant absorber for red and especially near infrared

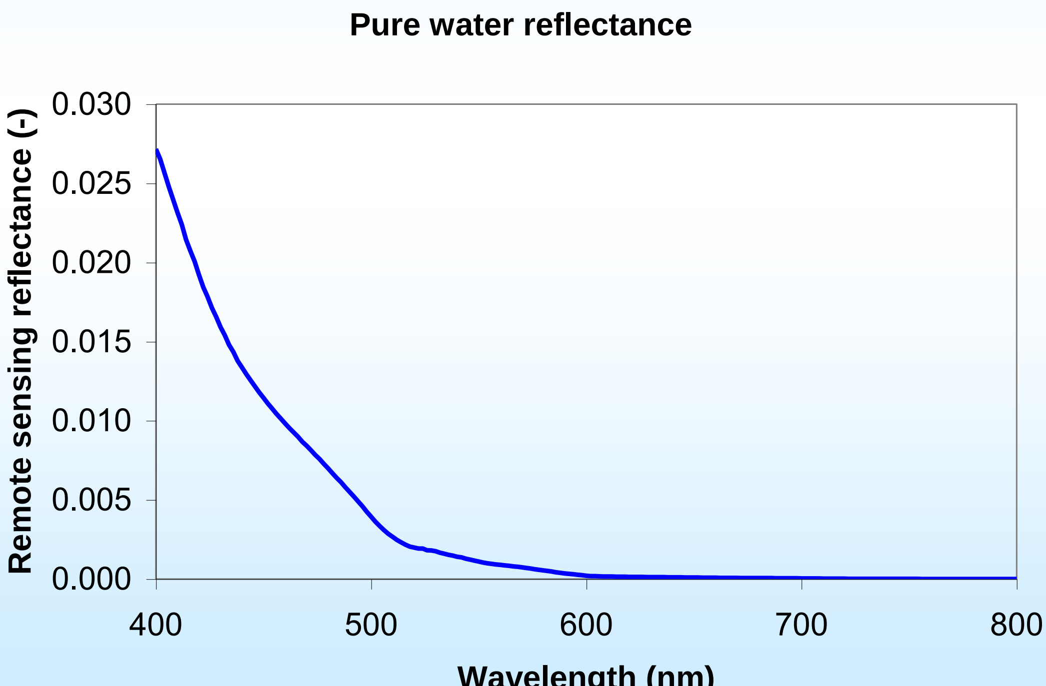
[Buiteveld et al, 1994]



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)

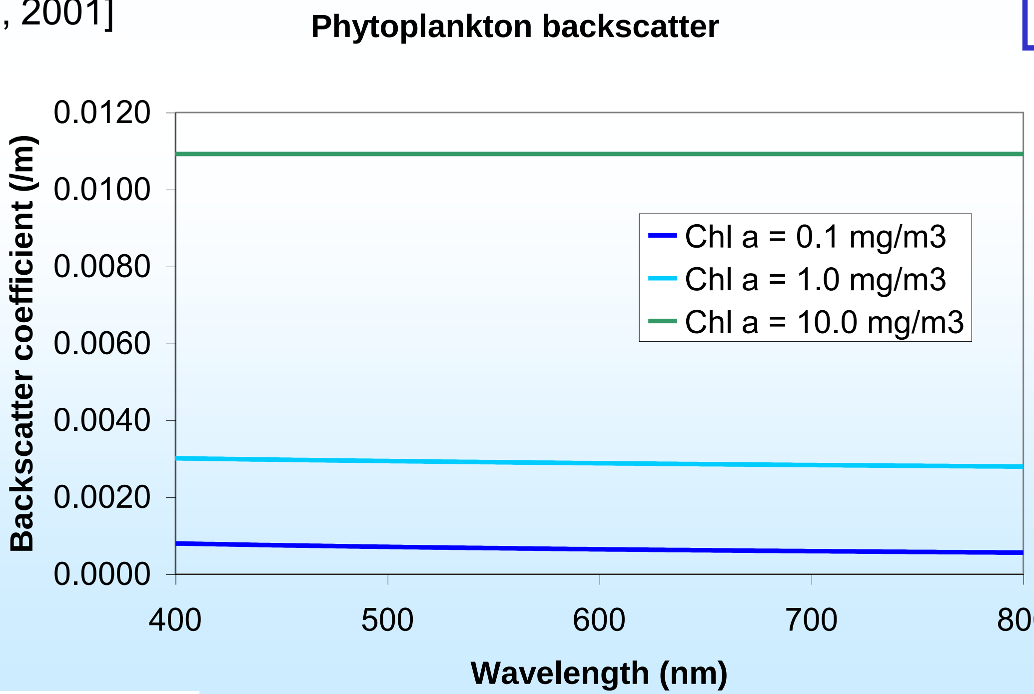
- Backscatter of phytoplankton:
  - Main backscatterer in open ocean, relatively flat spectrum

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

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

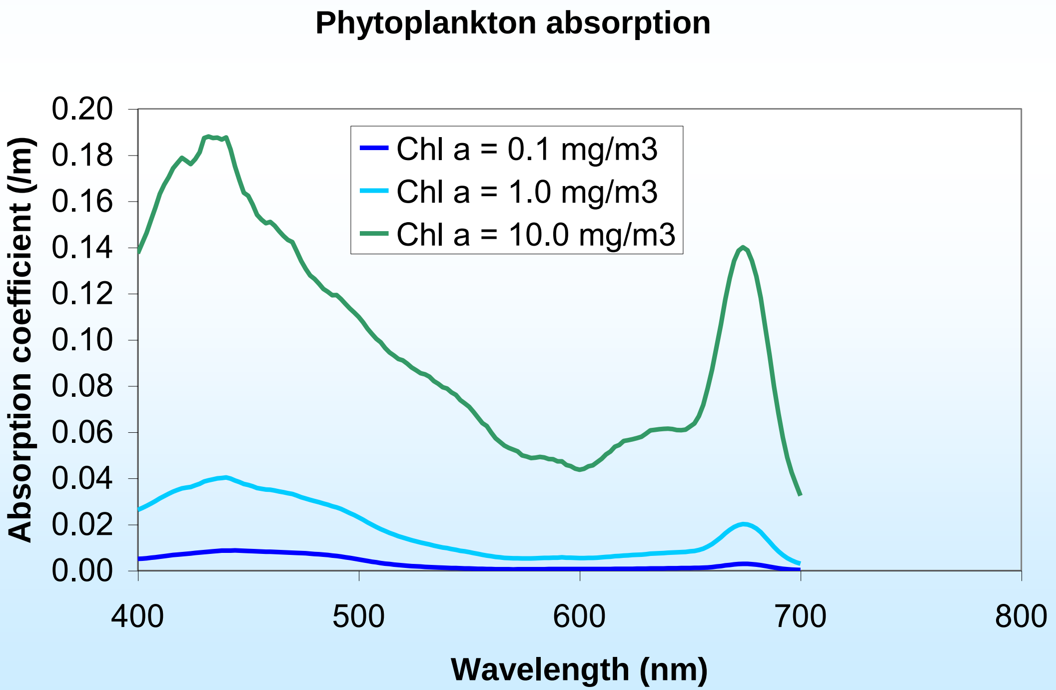
C=Chl a

[Morel and Maritorena, 2001]



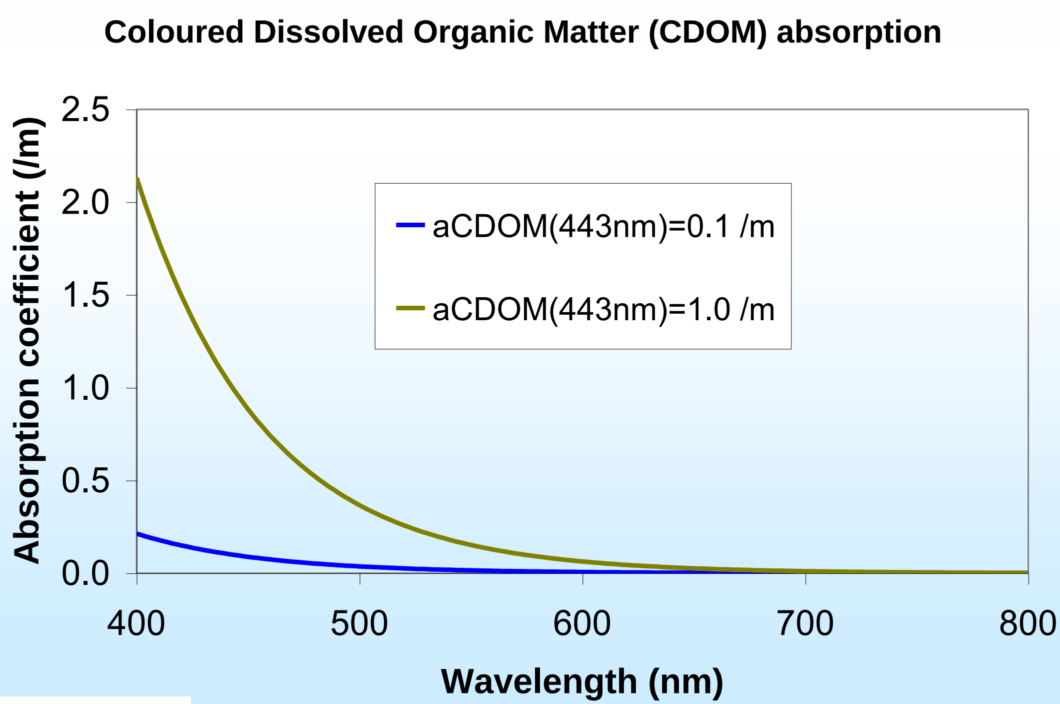
Optical properties of phytoplankton (2/2)

- 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]



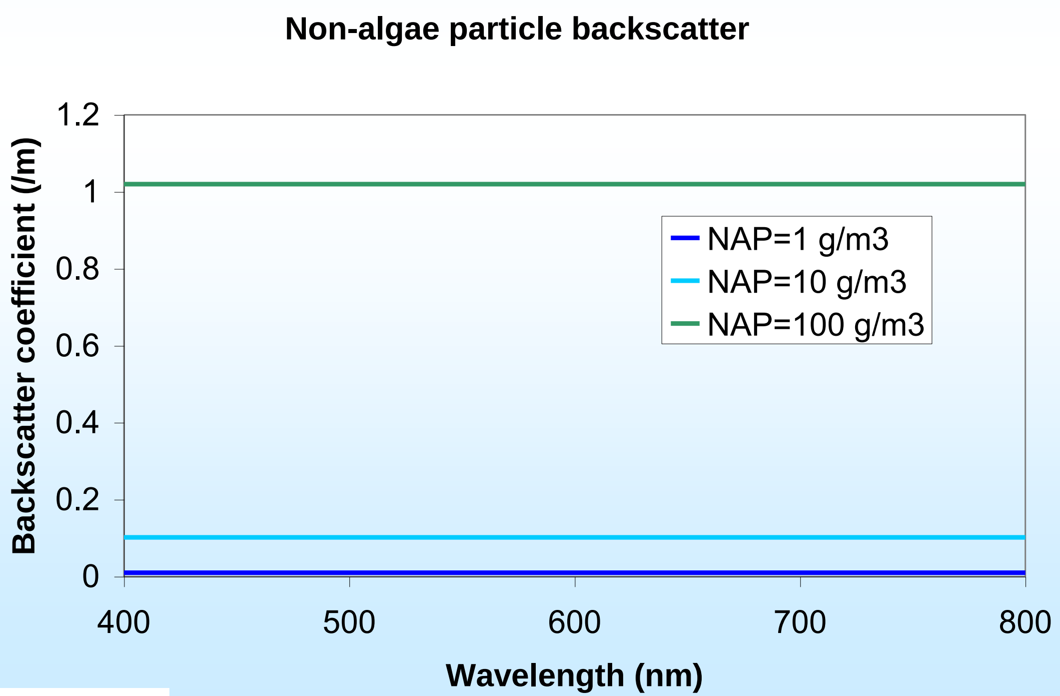
Coloured Dissolved Organic Matter (CDOM)

- 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



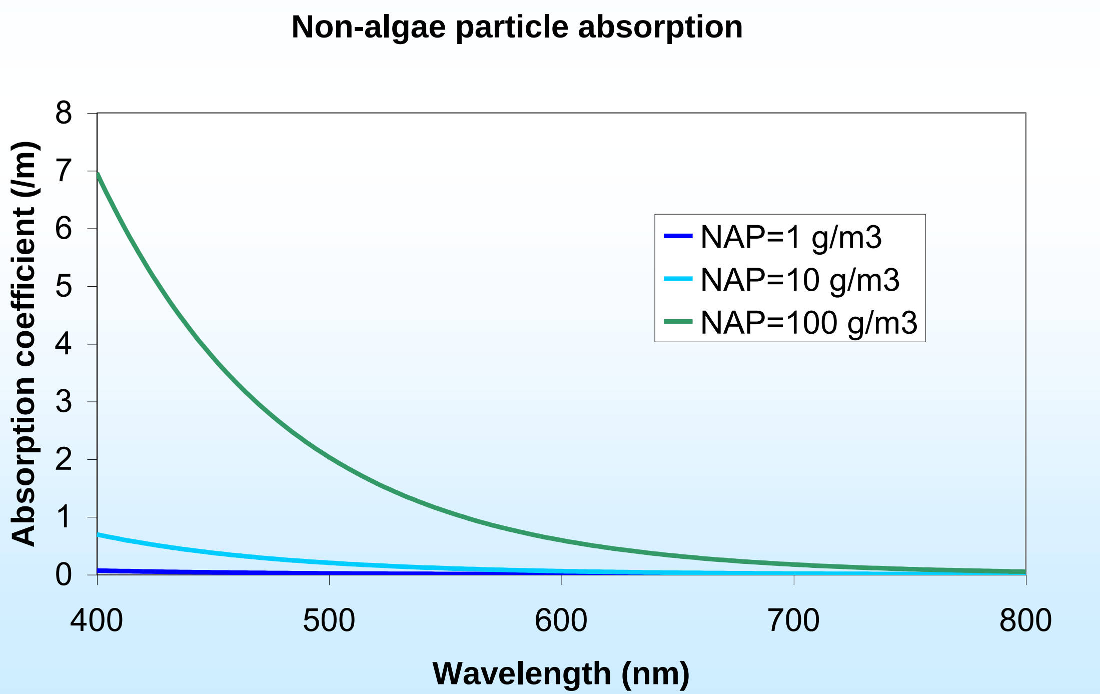
Optical propeties of non-algal particles (1/2)

- 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

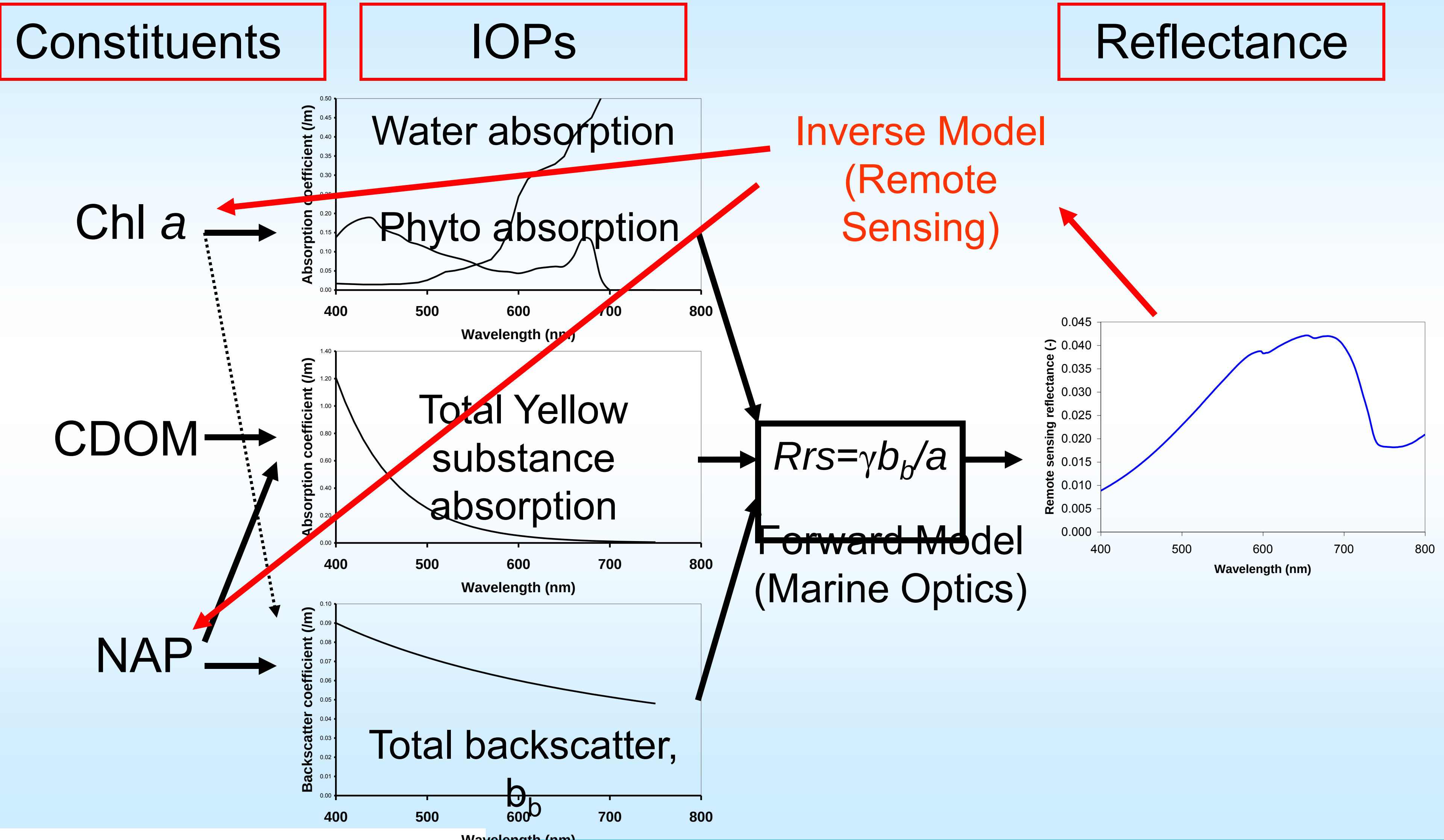


Optical propeties of non-algal particles (2/2)

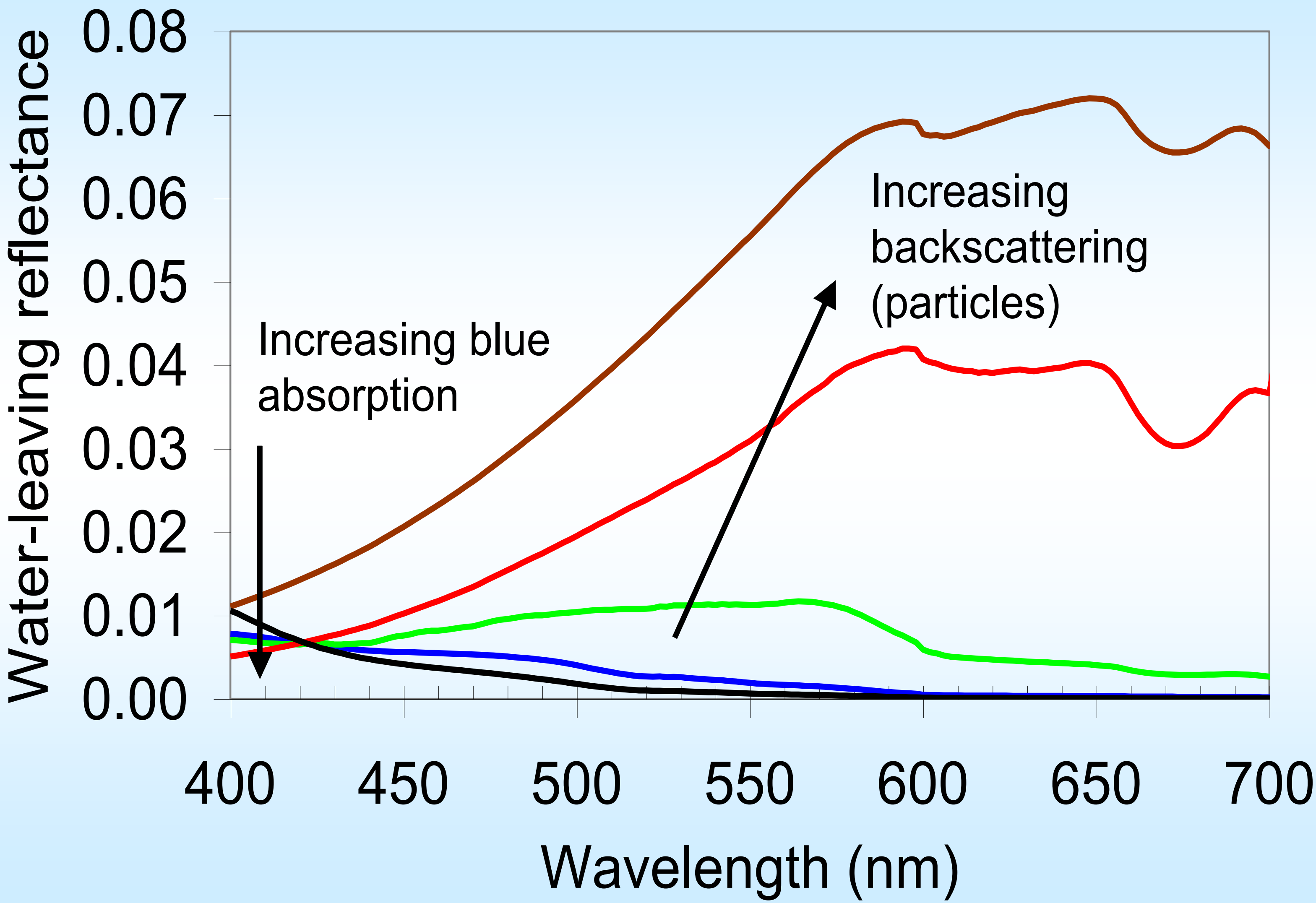
- Absorption of non-algal particles is strong in blue (like CDOM) with exponential decrease to higher wavelengths: « particulate » yellow substance
- Proportional to conc. of non-algae particles



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 …

