Inversion of a semi-analytical reflectance model to retrieve inherent optical properties of the marine environment

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Funding agency

Bedford Institute of Oceanography

Fisheries and Oceans Canada / Pêches et Océans Canada

CSA ASC

PML | PLYMOUTH MARINE LABORATORY

Interest in retrieving water optical properties (non exhaustive)

• Direct relationship between IOPs and radiative field (unlike chlorophyll-a concentration)

• Knowledge on IOPs infers information on the nature and concentration of particles and dissolved matter present in the water

- absorption of phytoplankton, yellow substances
- backscattering of mineral particles

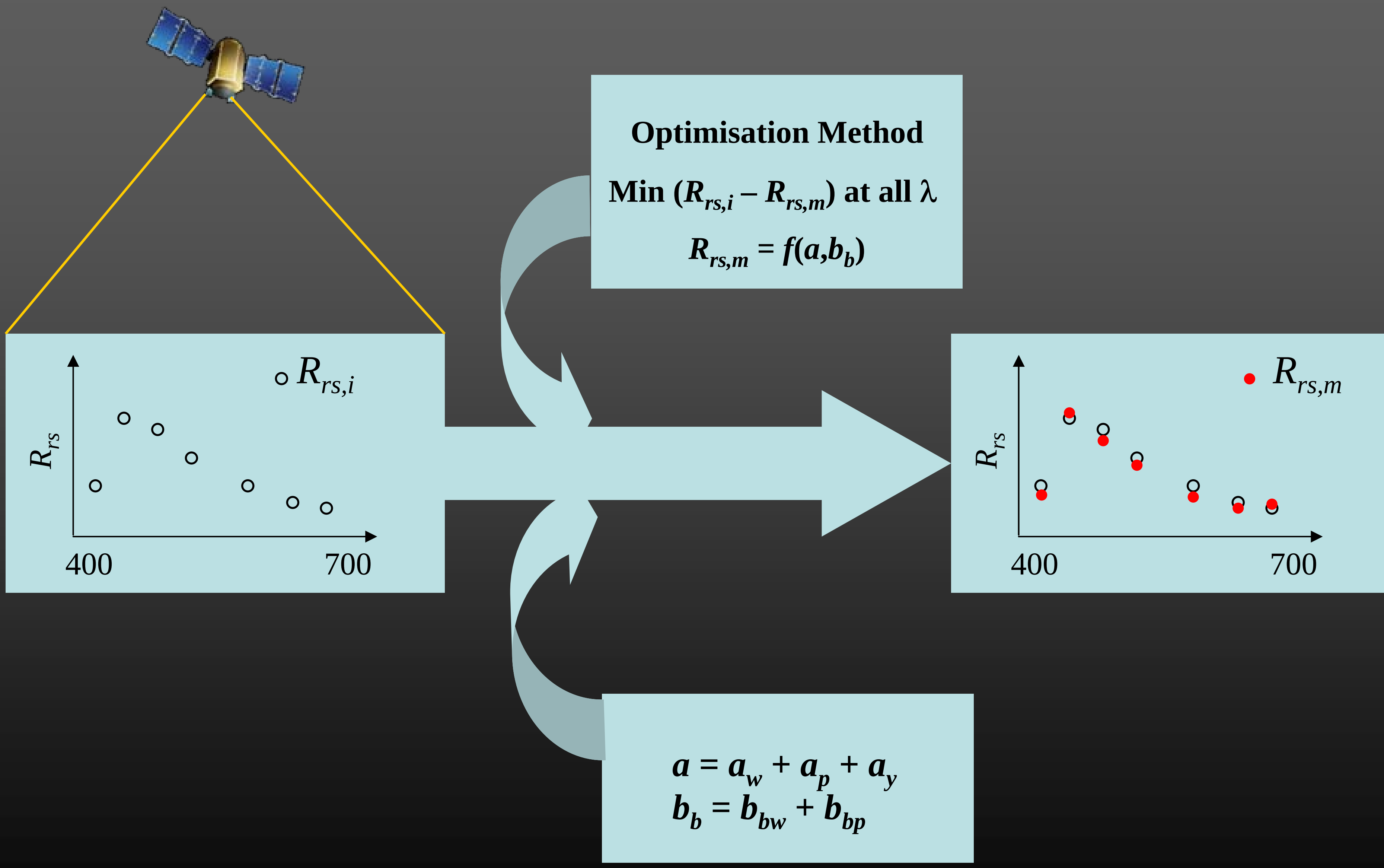
• Phytoplankton absorption can be used to retrieve chlorophyll biomass, phytoplankton size classes (i.e., pico, nano and micro)

• Computation of primary production

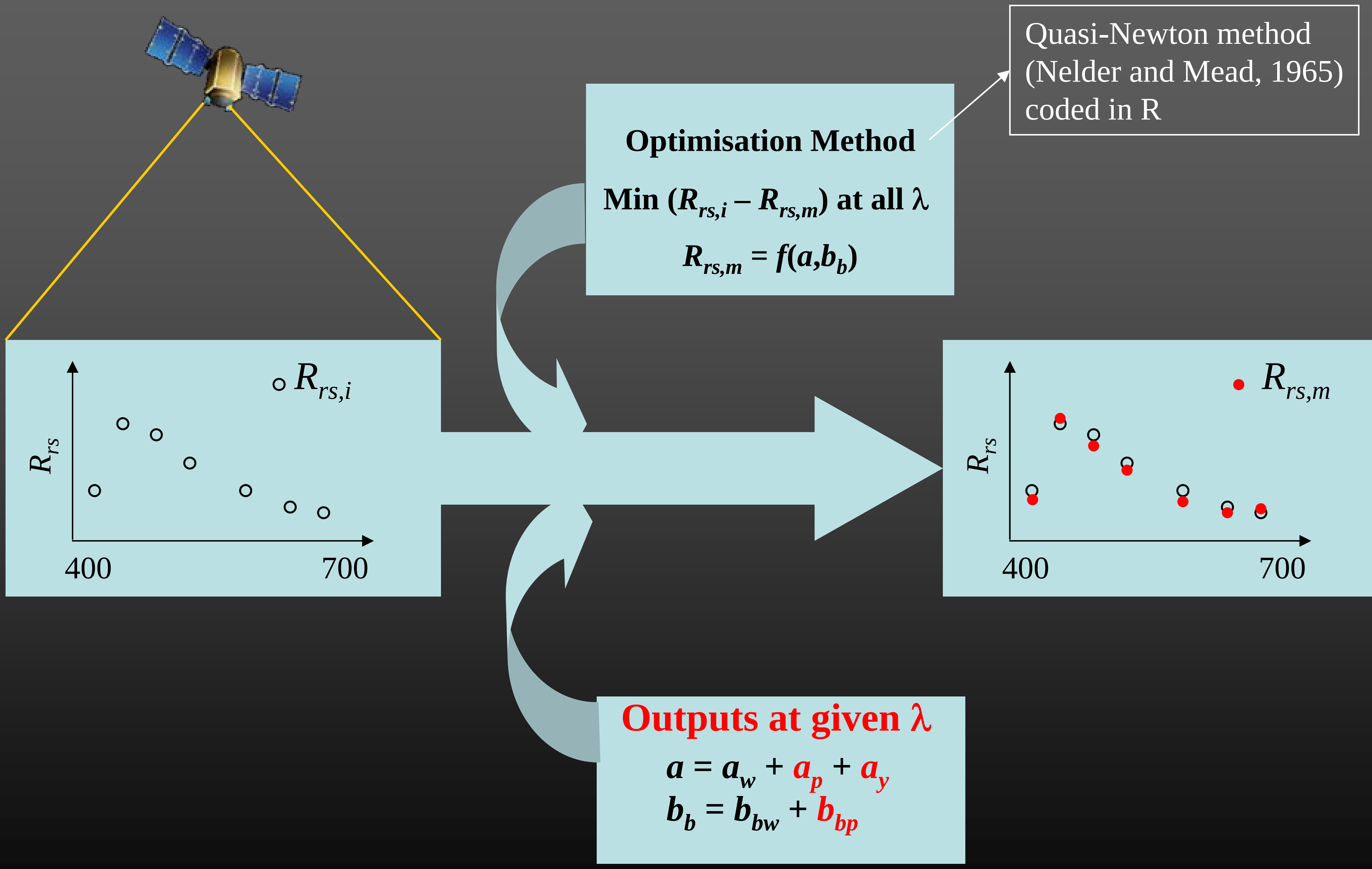
- Light field in the water column
- Phytoplankton absorption can be used to estimate wavelength-dependent photosynthetic parameters

• Assessment of organic carbon in the upper layer of the oceans

Inversion of IOPs: Principles



Inversion of IOPs: Principles



Reflectance model: *(Sathyendranath and Platt, 1997, 1998)*

$$s = b_u / b_b$$

$$R(0) = \frac{E_u(0)}{E_d(0)} = \frac{s b_b(\lambda)}{\mu_d (K(\lambda) + \kappa(\lambda))}$$

$$\mu_d = \frac{I_d \cos\theta_s}{I_0} + \frac{0.83 I_s}{I_0}$$

$$\kappa = \frac{a + b_b}{\mu_u}$$

with μ_u=0.5

$$K = \frac{a + b_b}{\mu_s}$$

$$\mu_s = \cos\theta_s$$

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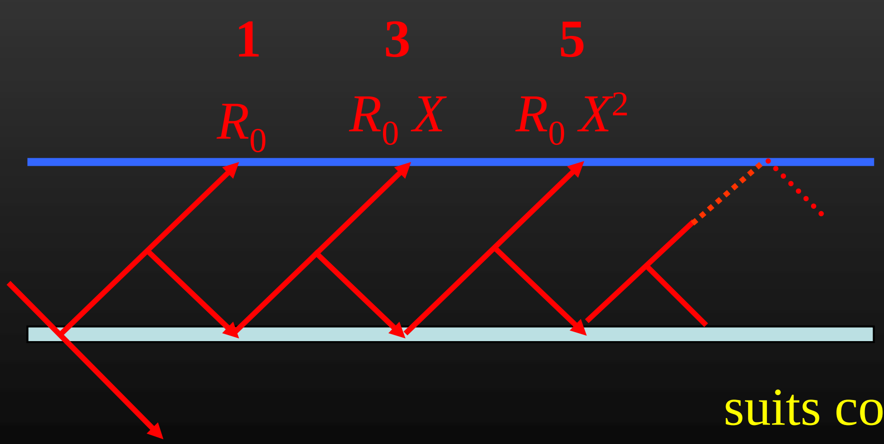
Second order reflectance:



$$X = \left(\frac{b_b}{K + \kappa}\right)^2 \approx \left(\frac{b_b}{2K}\right)^2$$

suits coastal applications

Spectral dependence of inherent optical properties

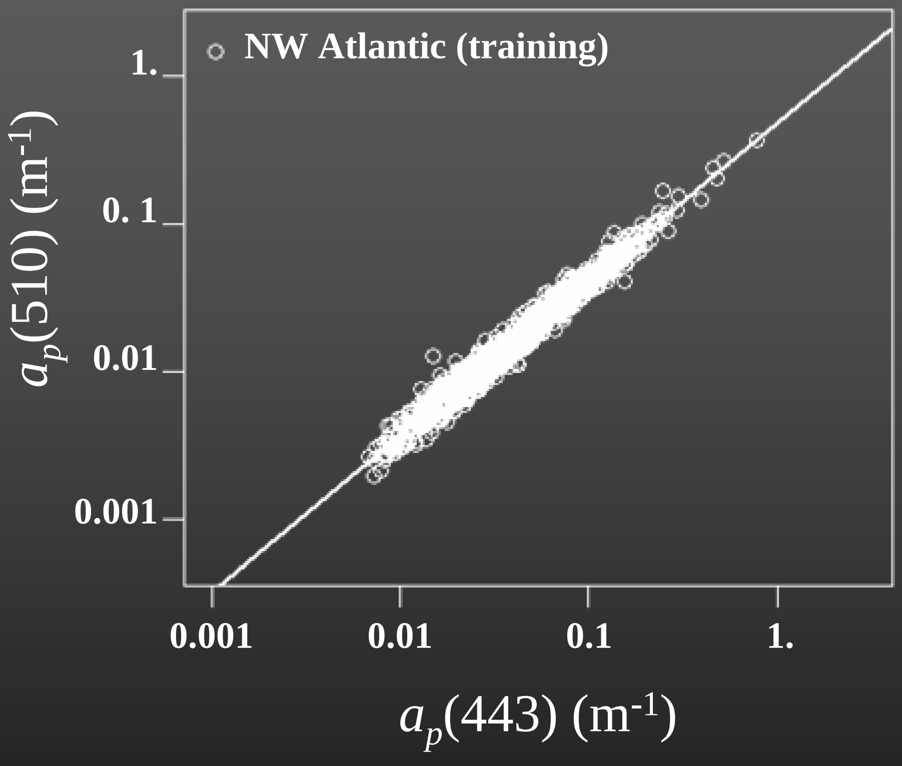
- Phytoplankton: $a_p(\lambda) = A(\lambda)\, a_p(443)^{B(\lambda)}$

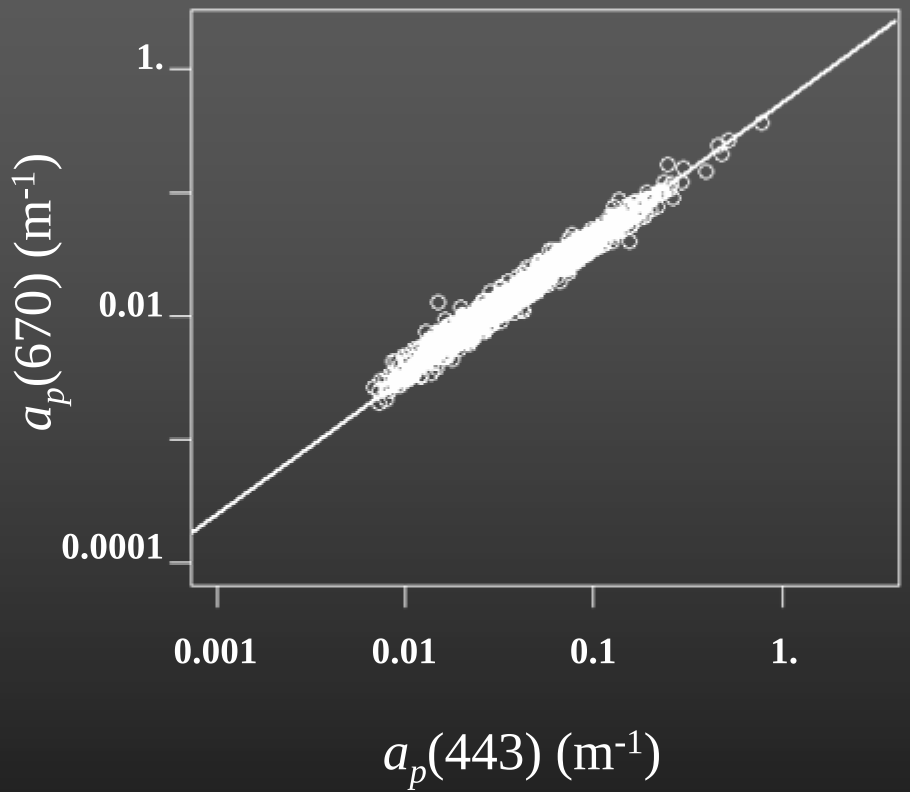
- Yellow substances: $a_y(\lambda)$ "usual" exponential law, $S_y = 0.018$

- Backscattering by particles: $b_{bp}(\lambda)$ usual power law with slope of 1.03 (Maritorena et al. 2002)

- Water absorption (Pope and Fry, 1997) and scattering (Morel, 1974)

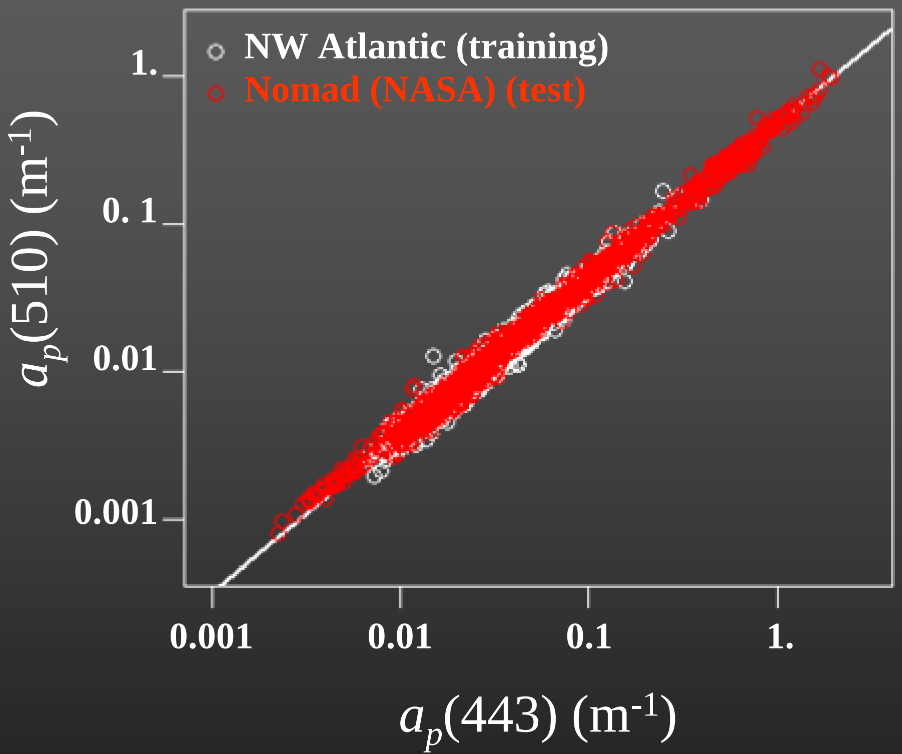
Spectral dependence of phytoplankton absorption| coefficient: power law

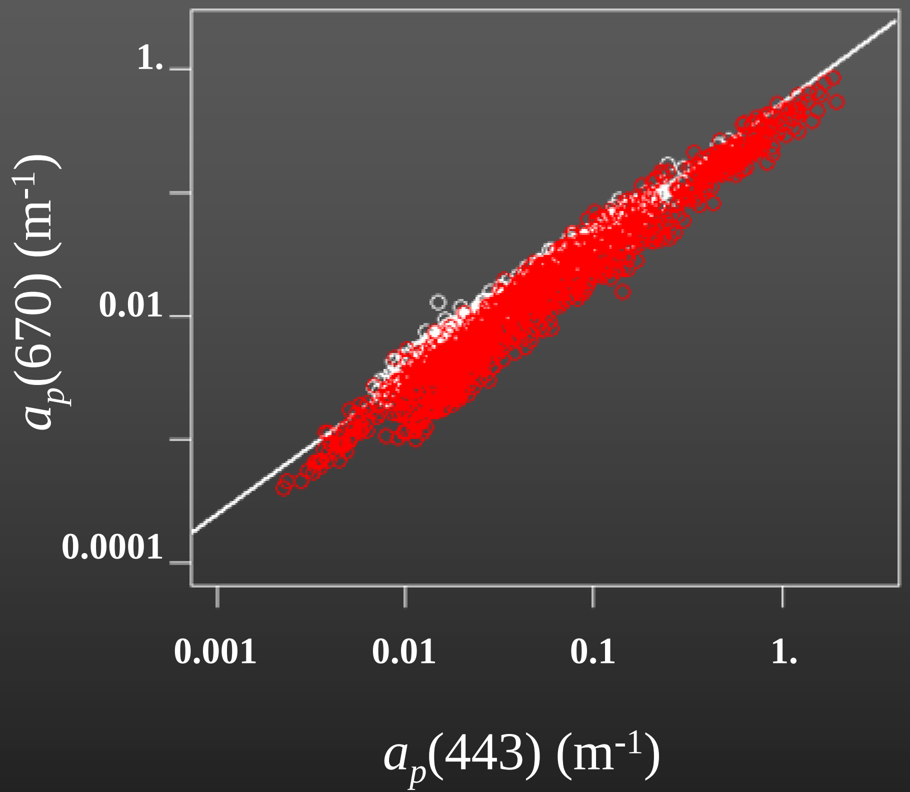




$$a_p(\lambda) = A(\lambda)\ a_p(443)^{B(\lambda)}$$

Spectral dependence of phytoplankton absorption| coefficient: power law





$$a_p(\lambda) = A(\lambda)\, a_p(443)^{B(\lambda)}$$

RESULTS

Validation Dataset: NOMAD

NASA bio-Optical Marine Algorithm Dataset (Werdell and Bailey, 2005)

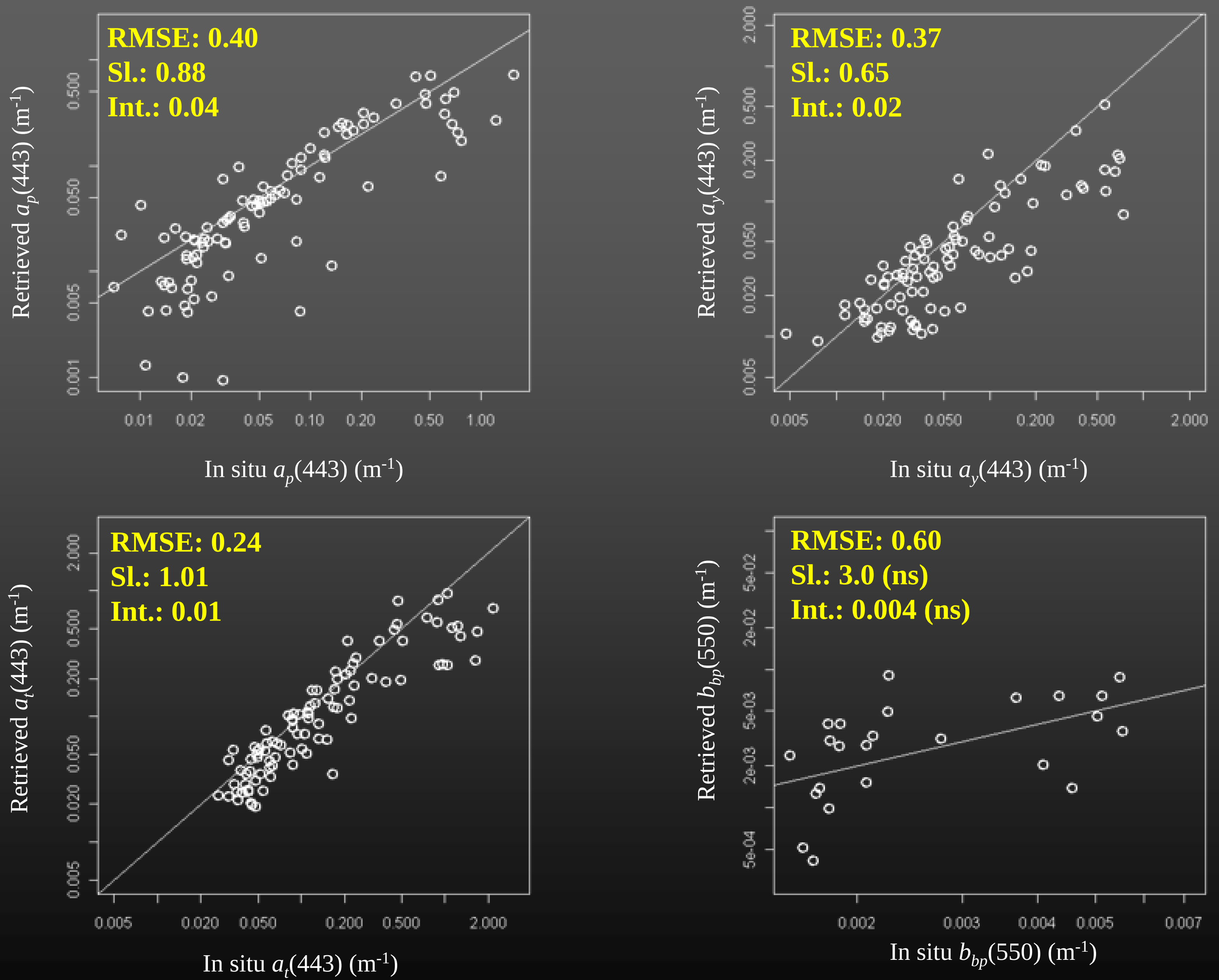
Phytoplankton absorption: N = 110

Yellow substances absorption: N = 95

Particle backscattering N = 24

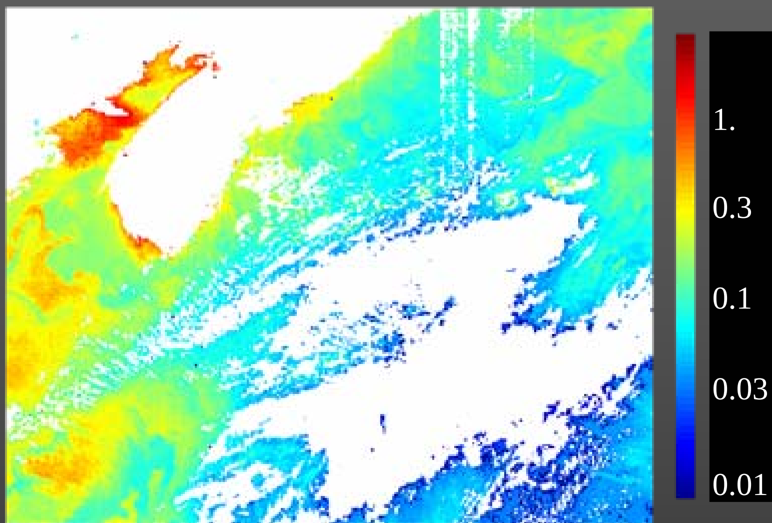
Number of wavebands (R_{rs}) available
4 wavelengths (412, 443, 490, 510): N = 6
5 wavelengths: N = 83
6 wavelengths: N = 12
7 wavelengths: N = 9

Comparison of retrieved versus measured IOPs: NOMAD dataset



Application to MERIS data: April 12 2009

$a_t(443)$ (m^{-1})



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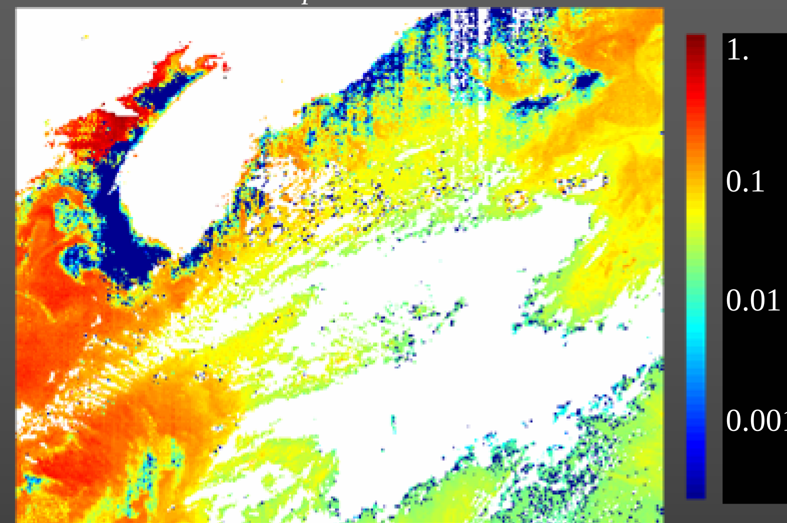
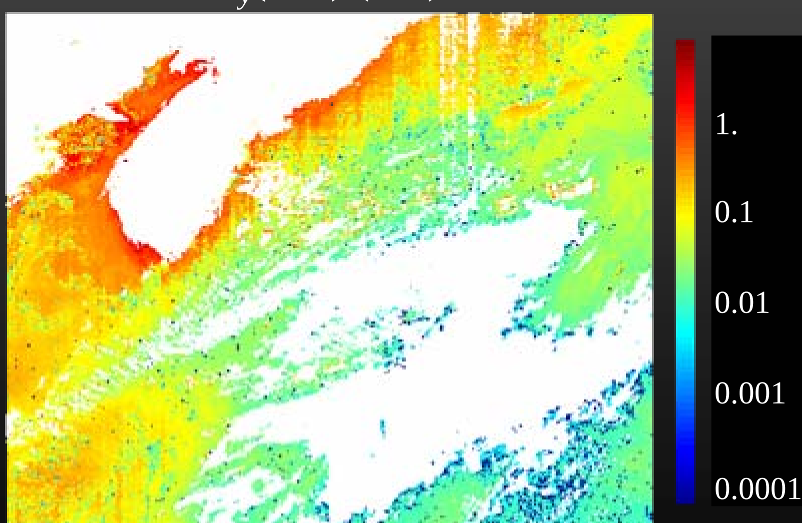
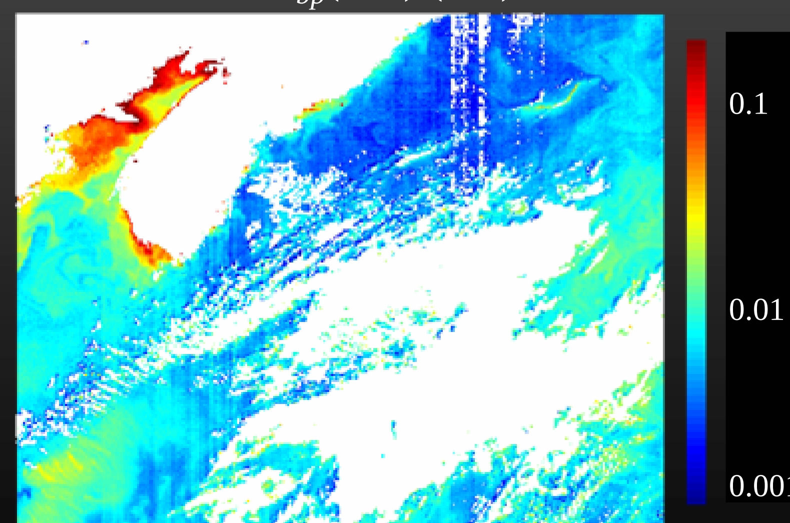


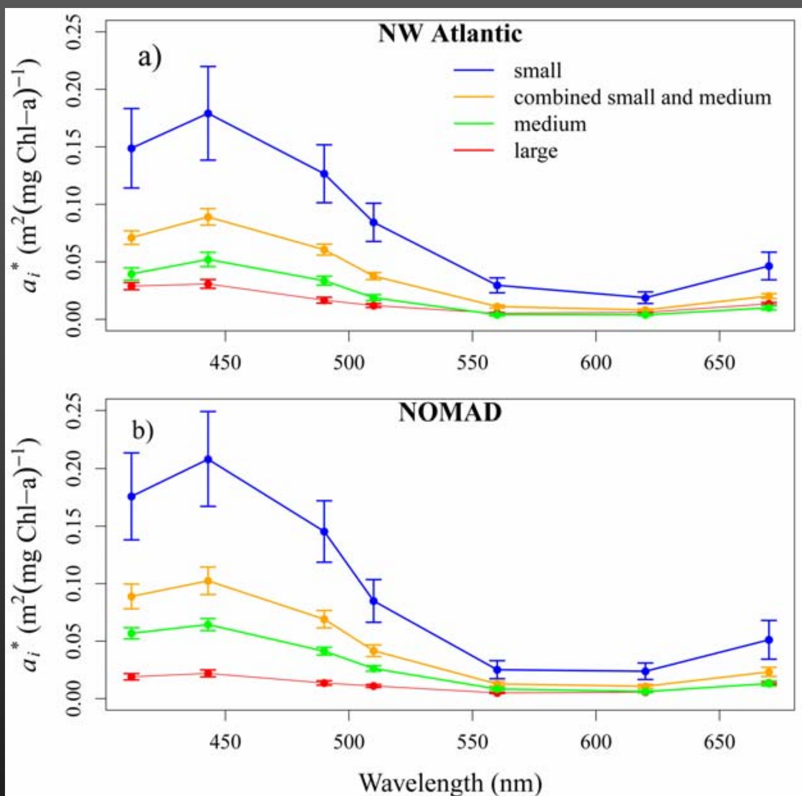
$a_y(443)$ (m^{-1})



$b_{bp}(550)$ (m^{-1})

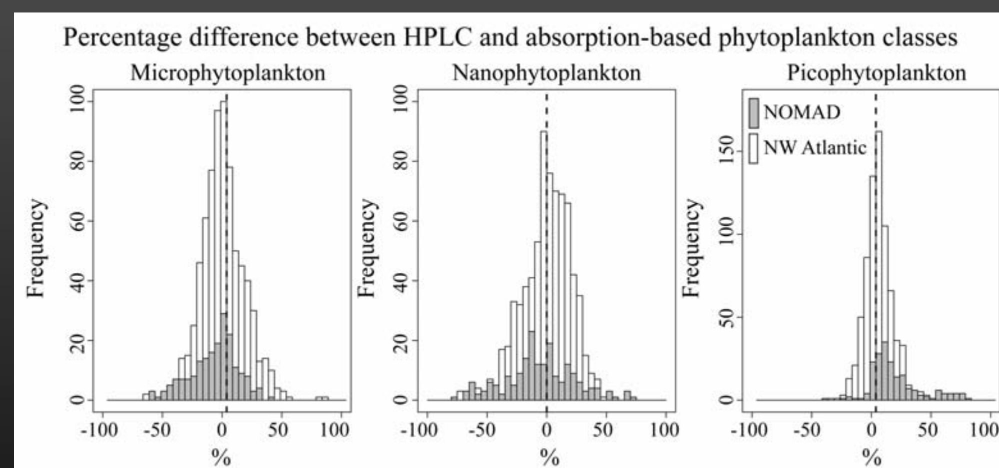


Application to MERIS data: April 12 2009
Phytoplankton size distribution



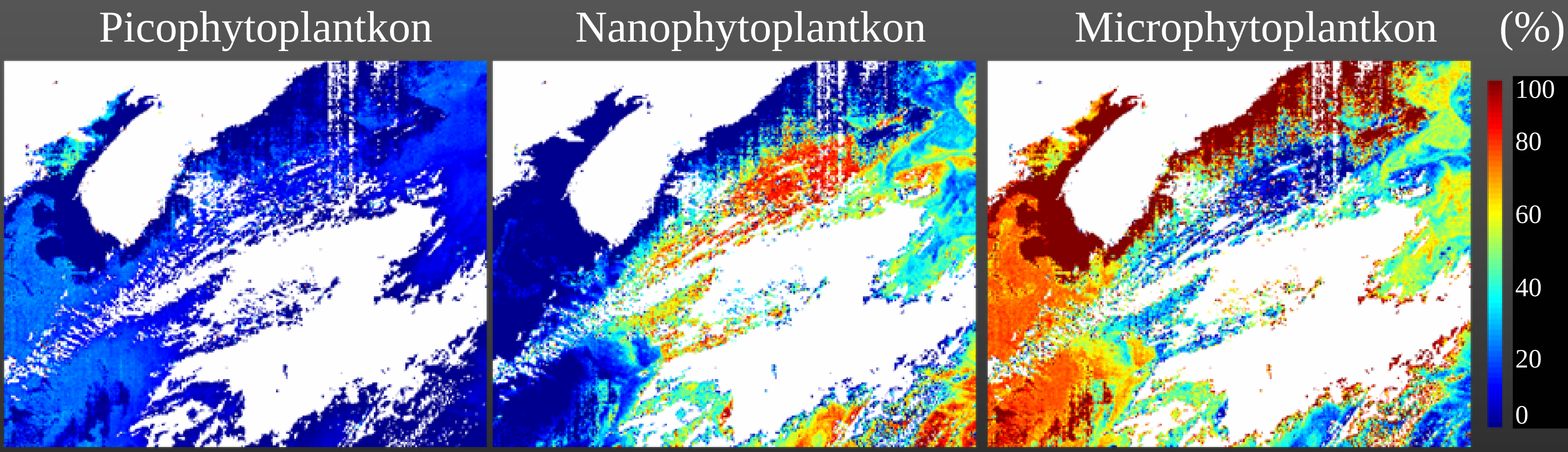
System of 5 equations with 3 unknows: C_s, C_m, C_l

$$
\begin{array}{ccccccc}
a_C(\lambda_1) & = & a_s^*(\lambda_1)C_s & + & a_m^*(\lambda_1)C_m & + & a_l^*(\lambda_1)\,C_l \\
\vdots & & \vdots & & \vdots & & \vdots \\
a_C(\lambda_5) & = & a_s^*(\lambda_5)C_s & + & a_s^*(\lambda_5)C_s & + & a_s^*(\lambda_5)C_s
\end{array}
$$



Devred et al. in revision

Application to MERIS data: April 12 2009
Phytoplankton size distribution



Conclusion

What has been achieved:

Implementation of an existing algorithm to retrieve IOPs (IOCCG reprot # 5), improvement of overall statistics

Retrieval of IOPs from MERIS data, ground-truth validation still required (participation in round-robin)

Ability to retrieve the three main phytoplankton size classes (potentially new product for MERIS and OCLI sensors)

What remains to be done (near future):

Extend parameterisation of Q-factor to more sun angles

Change code to more effective programming language (python, C)

Refine bio-optical models: e.g. variation of slope of backscattering with IOPs

LOOK FORWARD TO USE THE COASTCOLOUR VALIDATION DATASET