Uncertainties of Remote Sensing Reflectance

Synthesis of published methods
&
colocation approach

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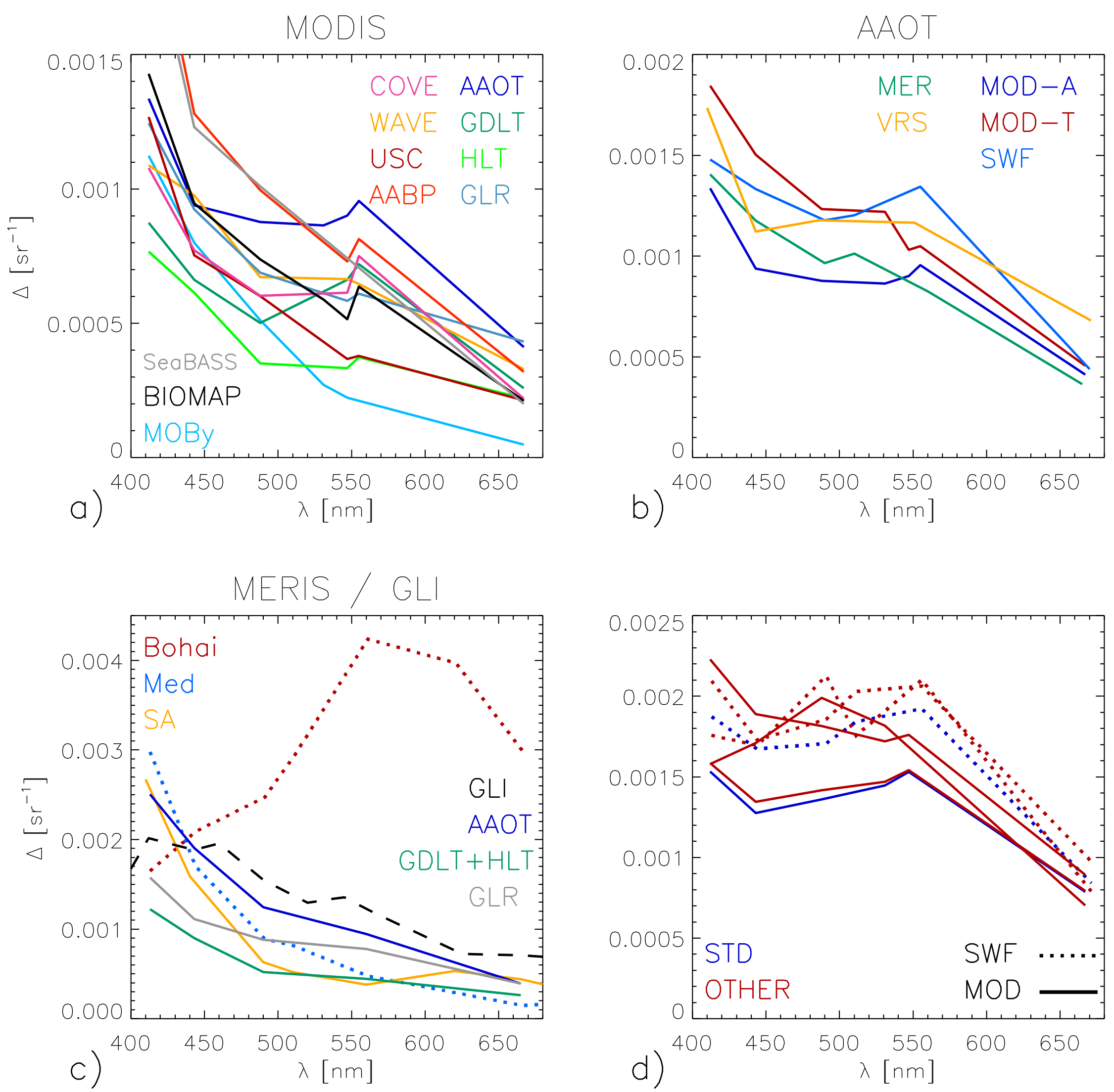
Comparison with in situ data (validation)

Gordon et al. *Appl. Opt.* 1983: comparison CZCS and ship L_w at 3 stations

MODIS-A

MERIS MEGS7/8 + GLI



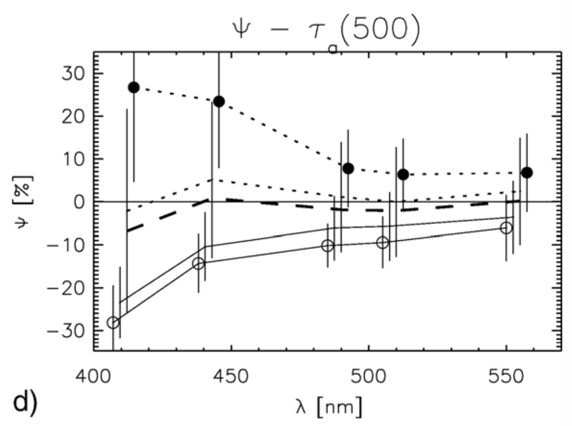
multiple sensors

different ACs

Δ: RMS difference

Mélin & Franz 2014

Jamet et al. *RSE* 2011
Goyens et al. *RSE* 2013

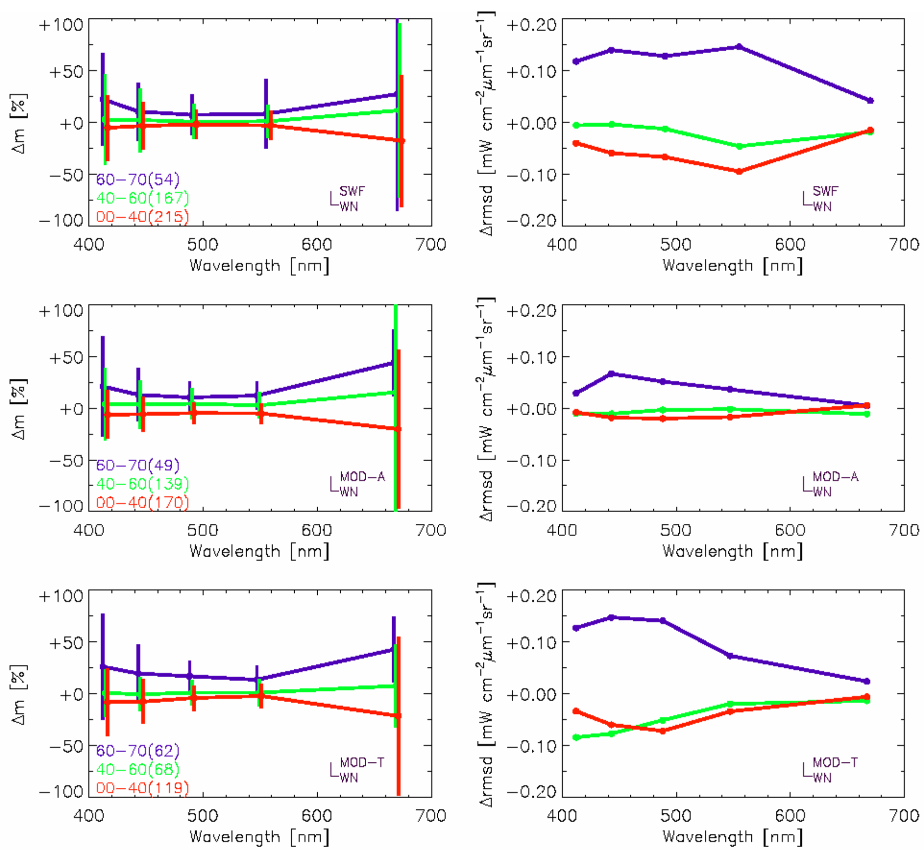


R_{RS} validation results f^n of Case1/Case2, ssa, τ_a, geometry…

Mélin et al. *RSE* 2007

R_{RS} validation results f^n season, geometry….

Zibordi et al. *RSE* 2012

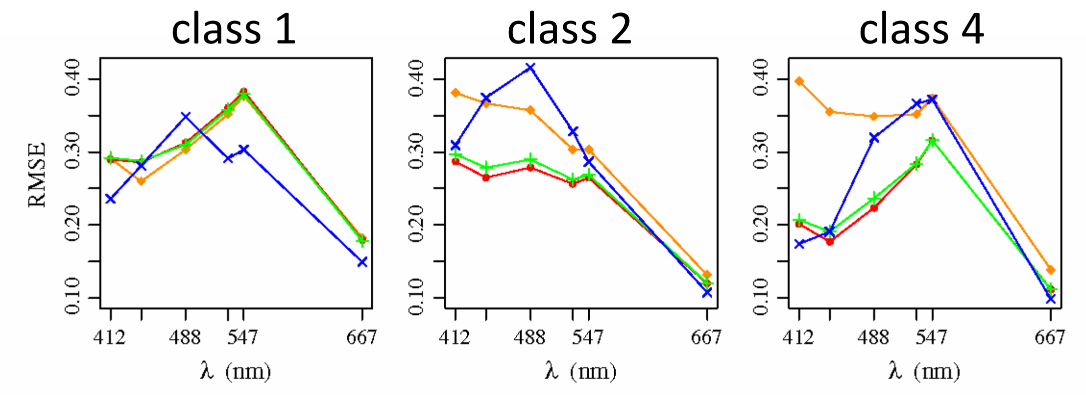


SeaWiFS

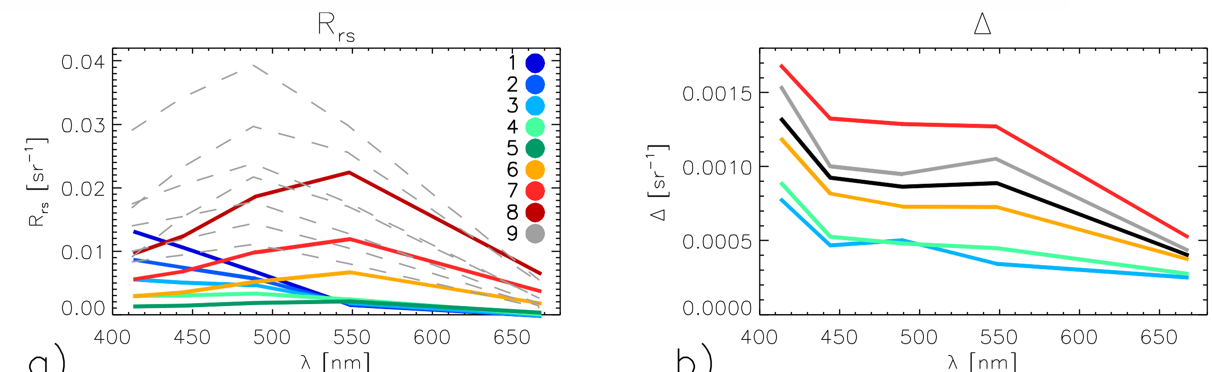
MODIS-A

MODIS-T

Validation results f^n of optical water types (classes)

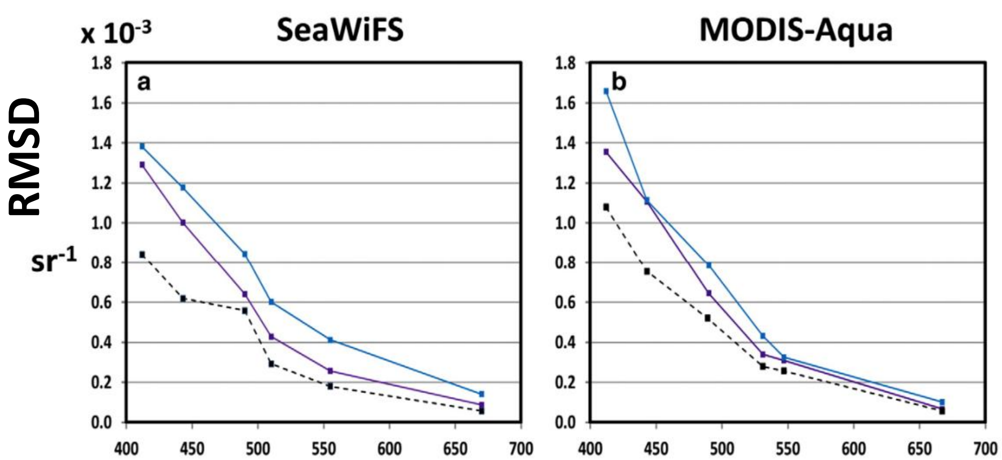


Goyens et al. *RSE* 2013
MODIS over coastal waters for 3 ACs



Moore et al. *RSE* 2009

Mélin & Franz 2014
MODIS at AAOT



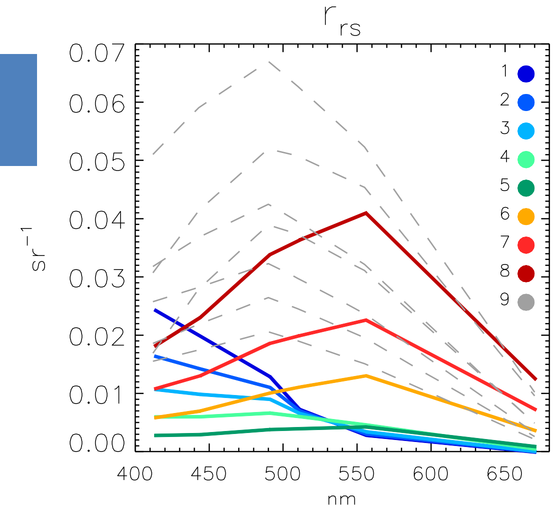
Moore et al. *RSE* 2015
SeaBASS

Application to the OC Climate Change Initiative (CCI)

Definition of uncertainty for each optical water type

Moore et al. (2009)

V1



Moore et al., *RSE* 2009

- **Compute class membership $w_{k,i}$ for each class k and each match-up i**

- **Compute validation stat for each class k:**

$$\Delta_k^{\,2} = \frac{\sum_{i=1}^{N} w_{k,i}\,(x_{i,s} - x_{i,f})^2}{\sum_{i=1}^{N} w_{k,i}}$$

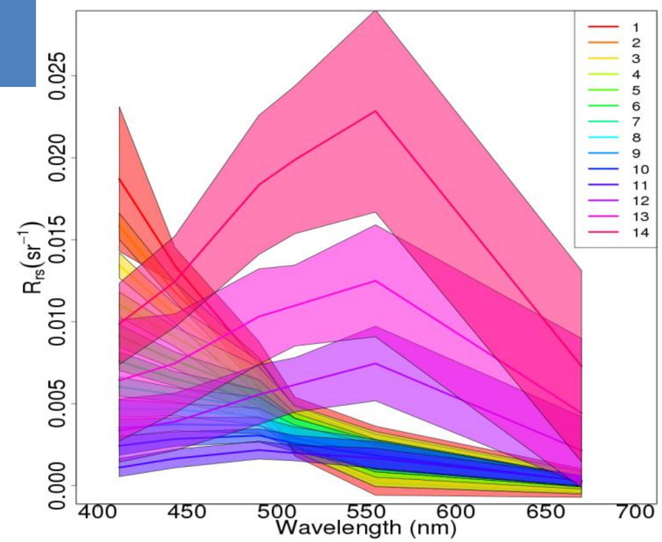
RMSD

$$\delta_k = \frac{\sum_{i=1}^{N} w_{k,i}\,(x_{i,s} - x_{i,f})}{\sum_{i=1}^{N} w_{k,i}}$$

BIAS

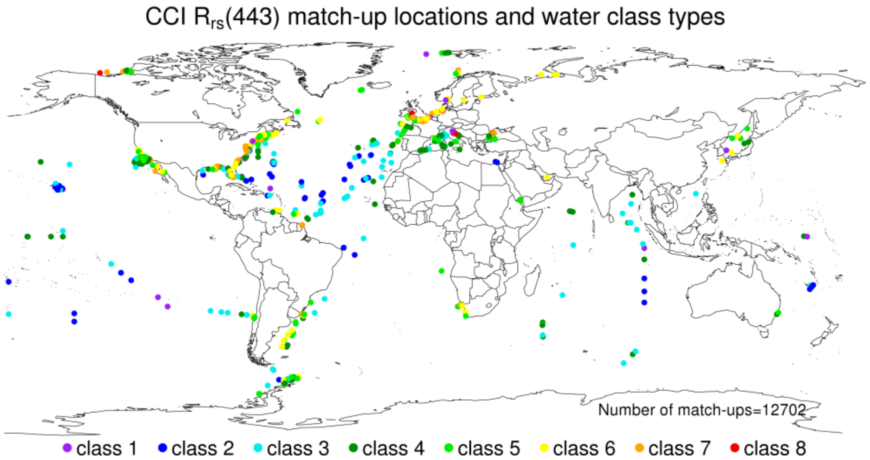
difference between satellite and field values

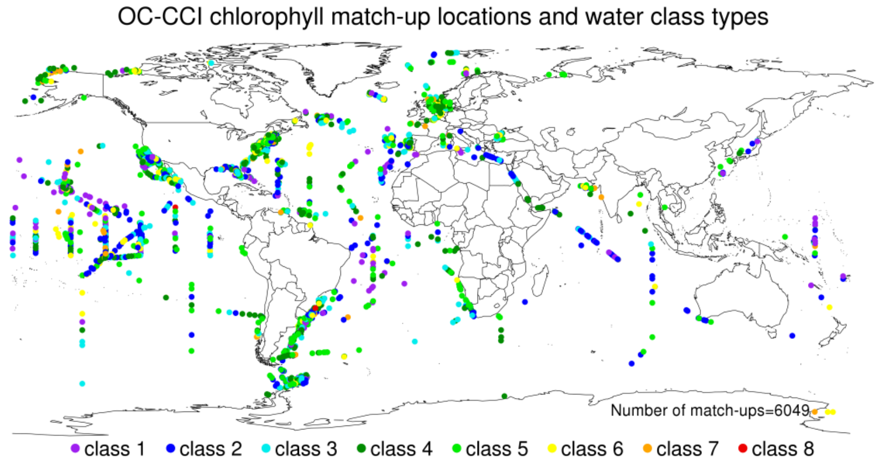
V2



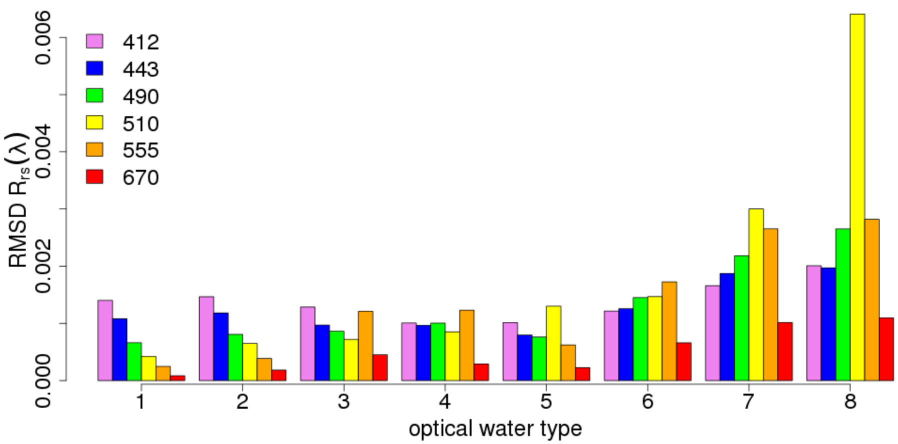
Jackson et al., *in prep*

V1

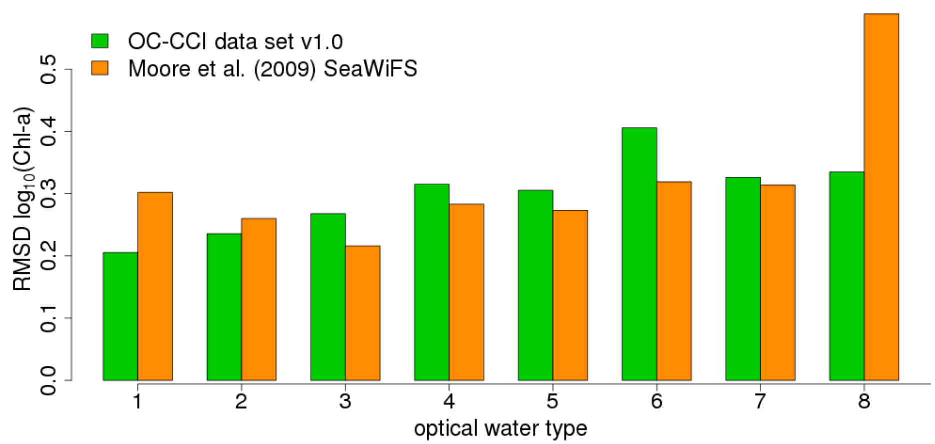




R_{RS}: RMSD per class and λ



Chla: RMSD per class

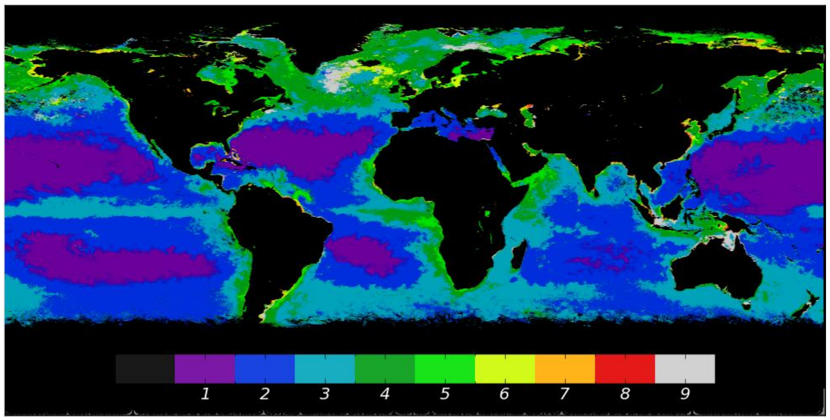


Application to any grid point:

- For pixel ***p***, compute class membership $w_{k,p}$ for each class ***k***

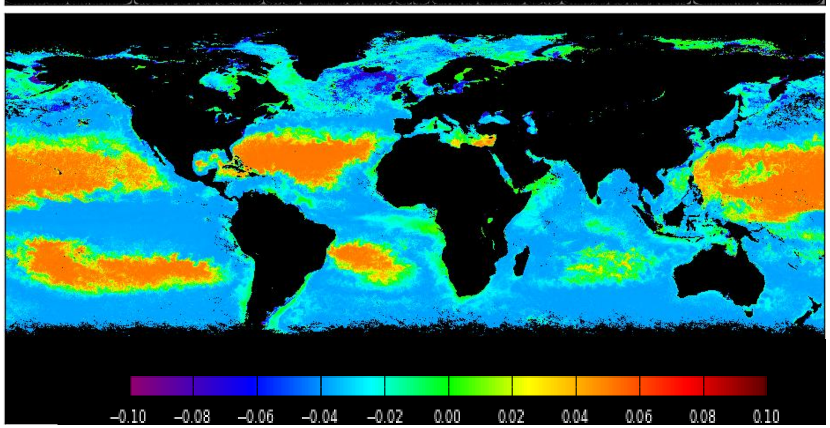
- Compute uncertainty for pixel ***p***:

$$\Delta_p^{\,2} = \frac{\sum_{k=1}^{M} w_{k,p} \Delta_k^{\,2}}{\sum_{p=1}^{M} w_{k,p}} \qquad \delta_p = \frac{\sum_{k=1}^{M} w_{k,p} \delta_k}{\sum_{k=1}^{M} w_{k,p}}$$



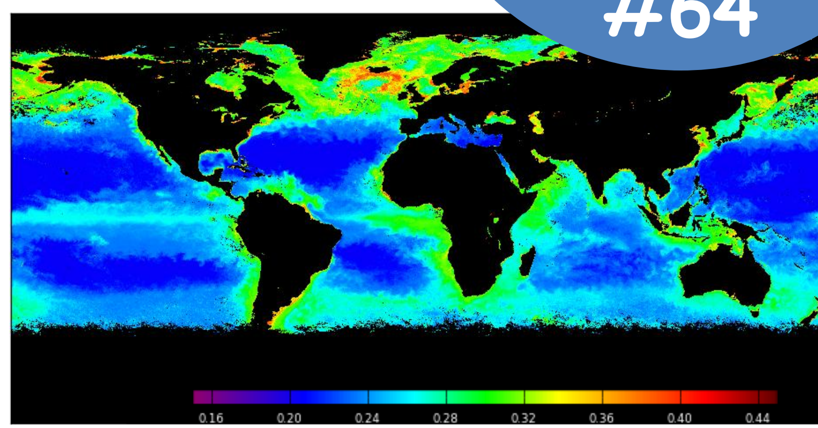
Dominant optical water type

See poster! Jackson et al. #64



bias – $\log_{10}$Chla

Jul. 2003



RMSD – $\log_{10}$Chla

Algorithm-based approach – Hu et al. *RSE* 2013

Based on the comparison of the outputs of 2 Chla algorithms: OC4v4 and OCI (3-band subtraction method)

Hypothesis: If ~identical outputs, then R_{RS} close to 'true' value

Uncertainties (relative and absolute): Standard deviation of differences with respect to these 'true' data, as f^n(Chla)

C. Hu et al. / Remote Sensing of Environment 133 (2013) 168–182

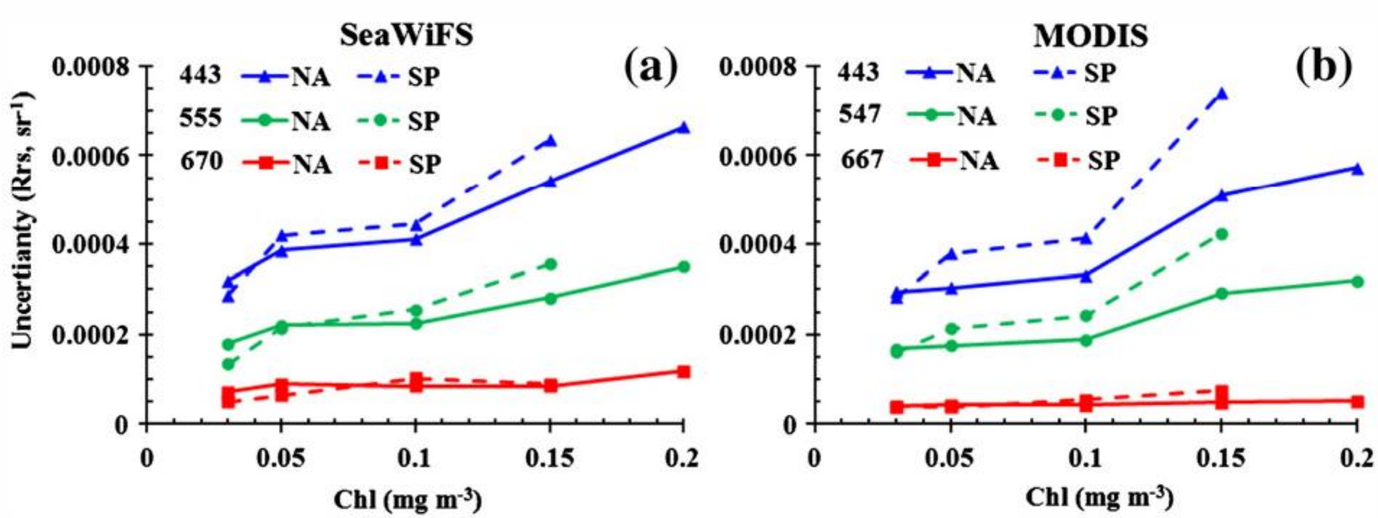


Fig. 7. Absolute uncertainties (in R_{rs} units, Ω of Eq. 3) of SeaWiFS and MODISA R_{rs} data for the North Atlantic (NA) and South Pacific (SP). The x-axis is Chl_{OCI}. About 68% of the non-flagged (i.e., valid) pixels have R_{rs} errors (gauged against the corresponding $R_{rs,true}$) less than the uncertainties. R_{rs} noise has been removed using a 3×3 median filter before uncertainty calculations. Data are listed in Table 3.

Other methods

- **Sensitivity analyses, simulated datasets, boot-strapping...**

  Gordon & Wang, *Appl. Opt.* 1994, Bulgarelli & Zibordi, *IJRS* 2003, Bulgarelli et al., *Ocean.* 2003, IOCCG #10, 2010, Steinmetz et al. OE 2011, etc…

This session:

- **Bayesian method** — **Frouin & Pelletier *RSE* 2015**
- **Uncertainty propagation** — **Neukermans et al. *OE* 2009, *RSE* 2012**
- **NN-based method**

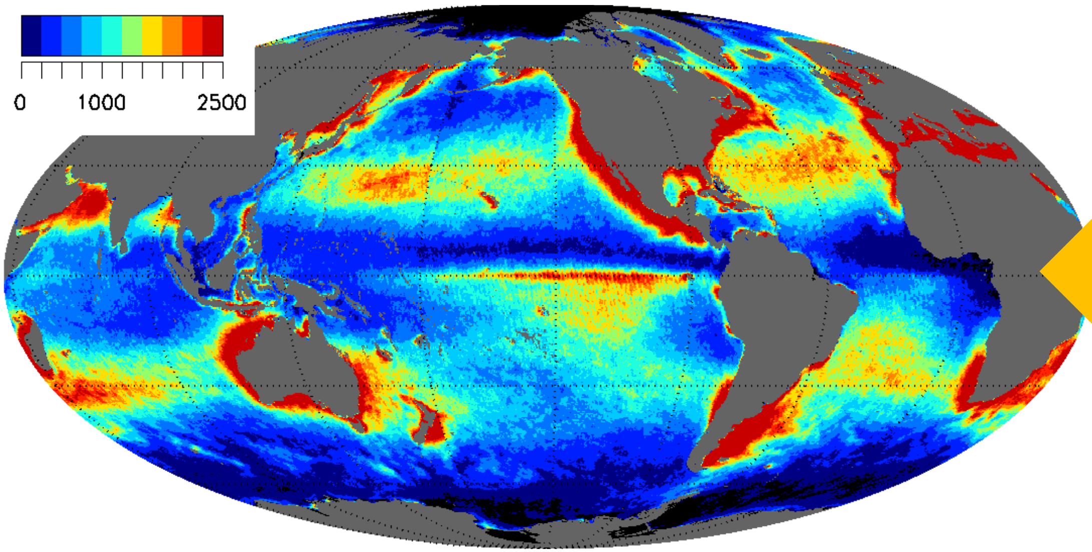
Uncertainty Estimates by Colocation

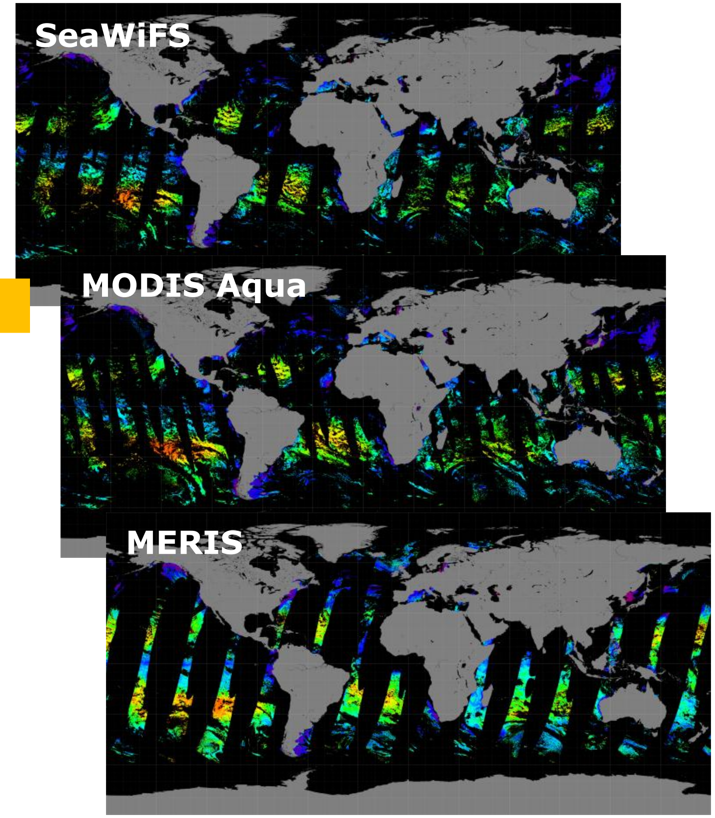
SeaWiFS, MODIS-A, MERIS data

Remote Sensing Reflectance $R_{RS}(\lambda)$ expressed on common λ's by a band-shifting process

Mélin & Sclep, *Opt. Exp.* 2015

Inter-Comparison per cell (1/3rd deg.) and day





Total number of match-ups SWF/MOD 2003-2007

Mélin et al., *RSE* submit

Sensor 1 $(x_i)_{i=1,N}$ and Sensor 2 $(y_i)_{i=1,N}$:

mean absolute relative difference

$$|\psi| = \frac{1}{N}\sum_{i=1}^{N}\frac{2|y_i - x_i|}{y_i + x_i}; \quad [\%]$$

mean relative difference (relative bias)

$$\psi = \frac{1}{N}\sum_{i=1}^{N}\frac{2(y_i - x_i)}{y_i + x_i}; \quad [\%]$$

mean difference (bias)

$$\delta = \frac{1}{N}\sum_{i=1}^{N}(y_i - x_i) \quad [sr^{-1}]$$

RMS difference

$$\Delta = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(y_i - x_i)^2} \quad [sr^{-1}]$$

unbiased RMS difference

$$\Delta_u = \sqrt{(\Delta^2 - \delta^2)} \quad [sr^{-1}]$$

} comparison metrics

Mélin & Franz 2014

random error σ [sr^{-1}] ⟷ Intrinsic property of each data set

(part of the uncertainty budget not affected by bias)

σ can be estimated by a colocation analysis

$$\begin{cases} x_i = r_i + \varepsilon_i \\ y_i = \alpha + \beta r_i + \zeta_i \end{cases}$$

α: additive bias
β: multiplicative
ε, ζ: random error

$$\Rightarrow \begin{cases} \sigma_\varepsilon^2 = \sigma_x^2 - \frac{1}{\beta}\sigma_{xy} \\ \sigma_\zeta^2 = \sigma_y^2 - \beta\sigma_{xy} \end{cases}$$

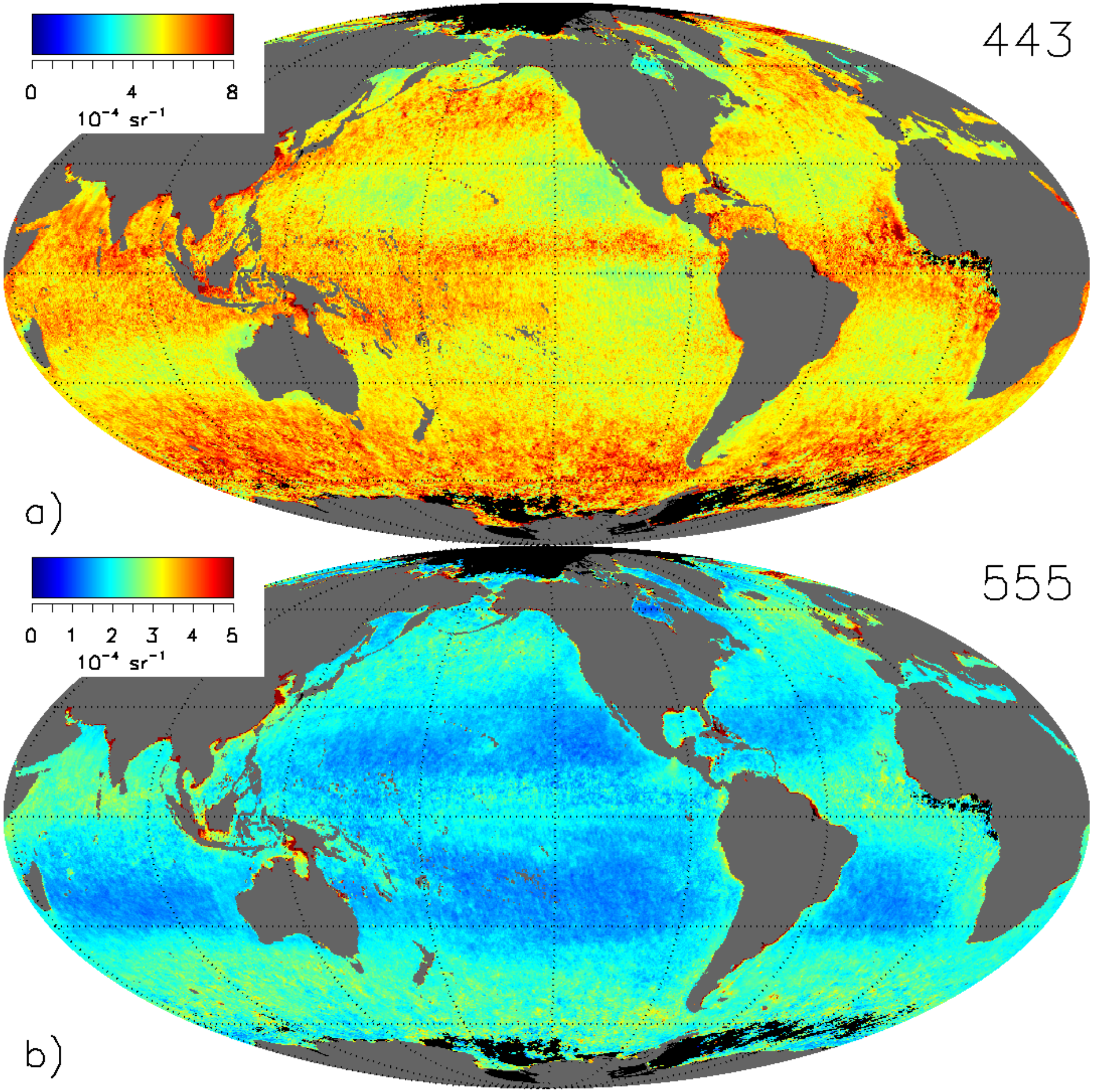
solved with the assumption:

$$\lambda = \frac{\sigma_\zeta^2}{\sigma_\varepsilon^2} = 1$$

Mélin, *IEEE GRSL*, 2010
Mélin & Franz 2014
Mélin et al. *RSE* submit

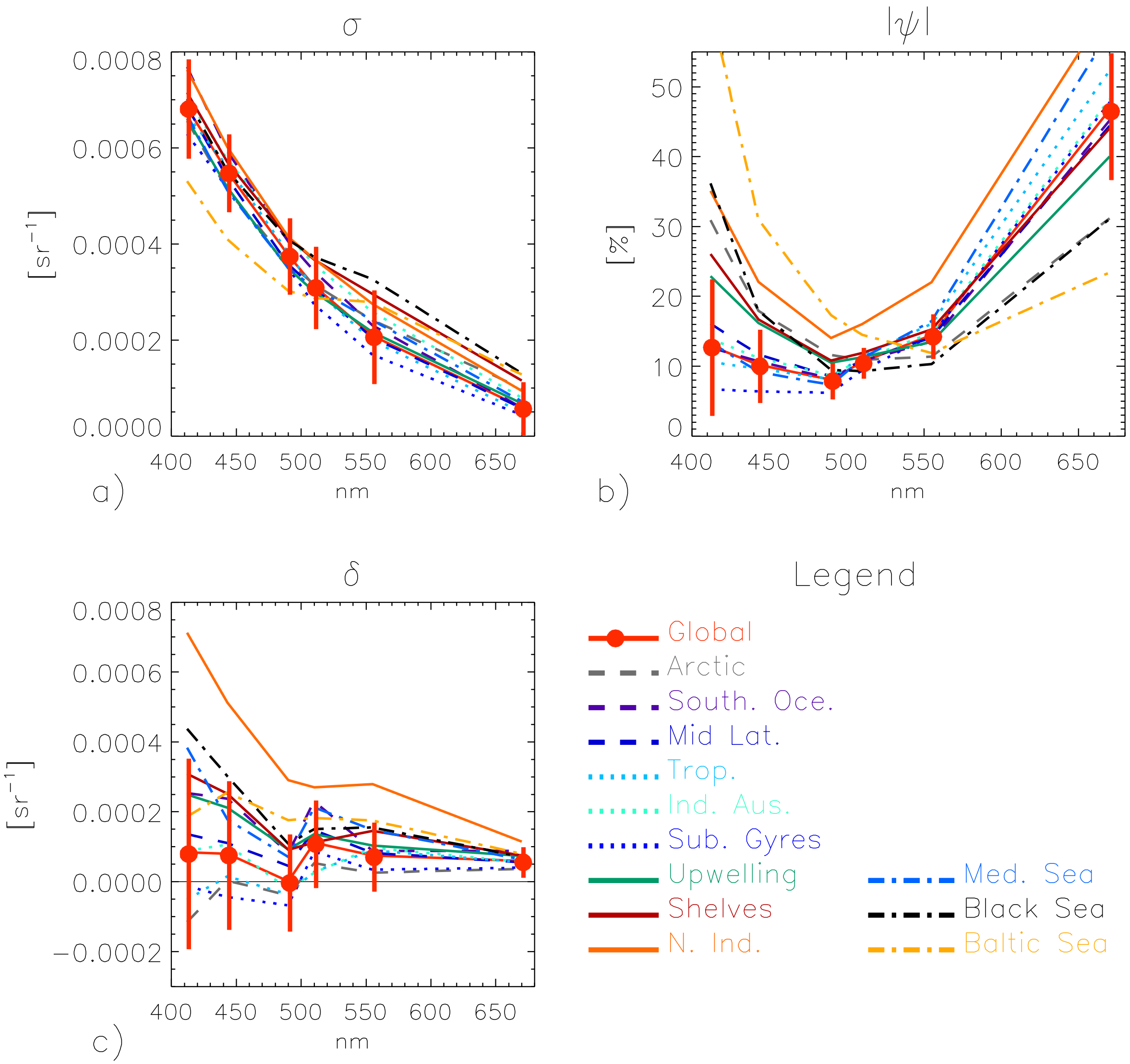
See poster! #95

σ



comparison SWF/MOD

Mélin et al., *RSE* submit



- **Characteristic U-shape for |ψ|**
- **Small spatial variability for σ**

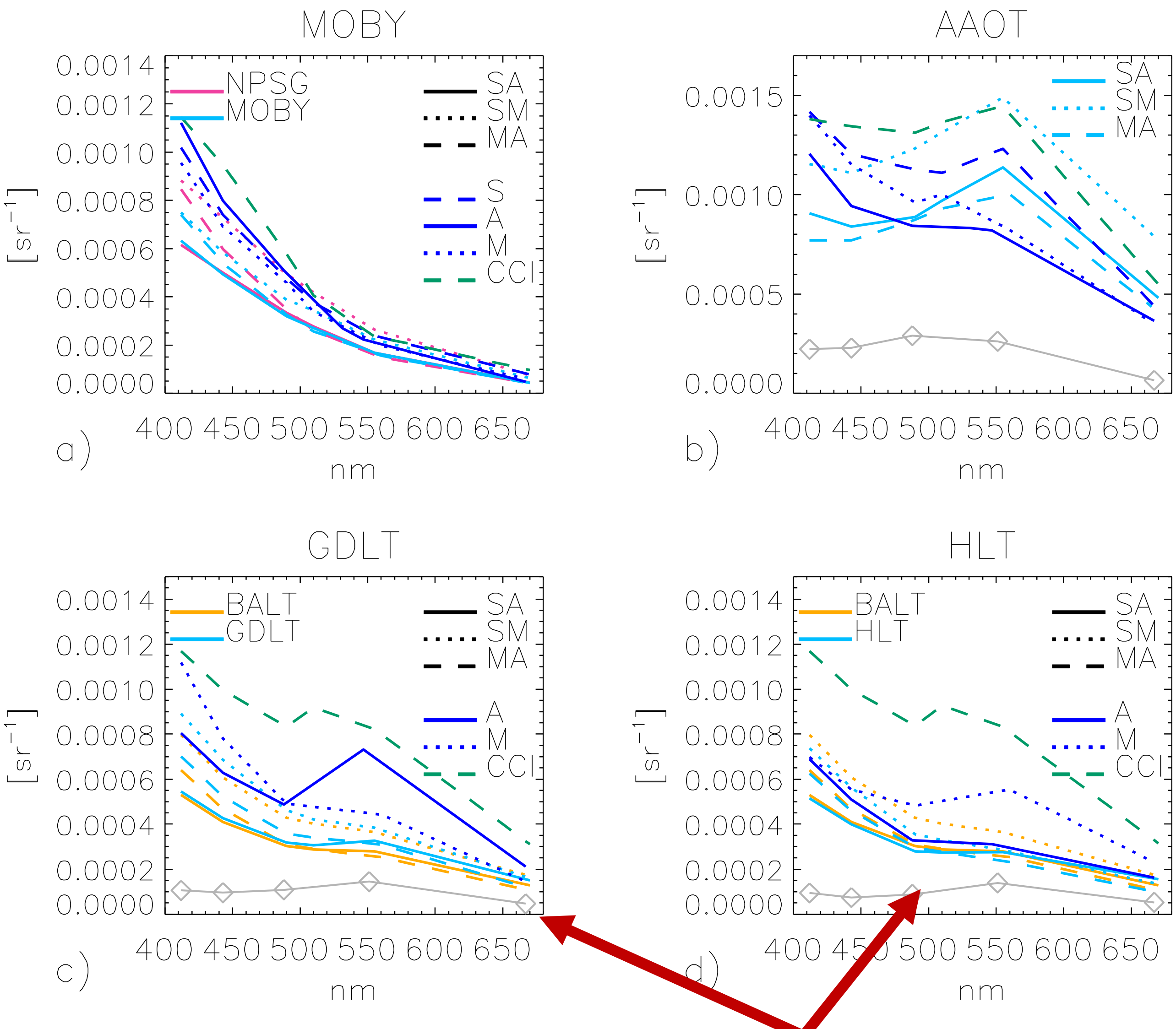
Mélin et al., *RSE* submit

Comparison with validation results and OC-CCI

σ

vs

Δ_u



AAOT

GDLT

HLT

Gergely & Zibordi *Metrology* 2014

Mélin et al., *RSE* submit

Comparison with OC-CCI and Hu et al. *RSE* 2013

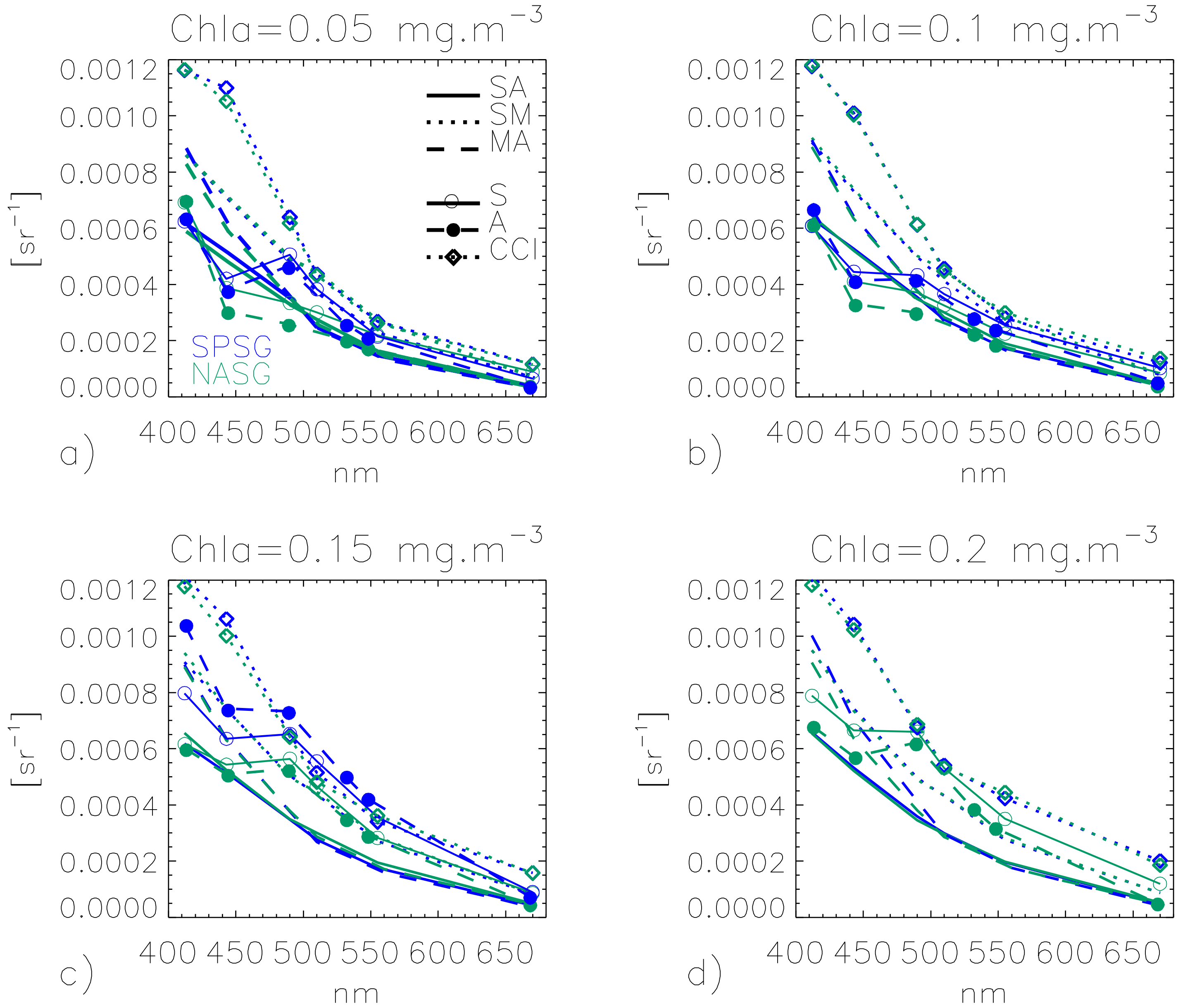
σ

vs

Δ_u

vs

Ω



Mélin et al., *RSE* submit

- σ between 0.9 10^{-3} sr^{-1} at 412 nm and 0.05-0.1 10^{-3} sr^{-1} at 670 nm in λ^{-n} with n~4-5

- Small variability for σ → express requirements in units of R_{RS}?

- $\sigma/\langle R_{RS}\rangle$ ~7% for 412-490 nm for Chla<0.3 mg m-3
  ~5% for 412-490 nm for Chla<0.1 mg m-3
  ~11% at 555 nm
  ~22% at 670 nm

- Coherence between σ and other estimates

General Conclusions

- Variety of methods for R_{RS} uncertainty estimates (should need to be clear about what they produce)
- General coherence of results, but differences should be understood
- Not many cases of methods ready to be applied on a grid-point basis
- Even less applied in actual processing

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