IDEAS-QA4EO

DEVELOPMENT OF ADVANCED NON-LINEAR MODEL FOR OCEAN COLOR APPLICATIONS

Constant Mazeran
solvo

esa IDEAS-QA4EO Cal/Val workshop #2 – 02.12.2020

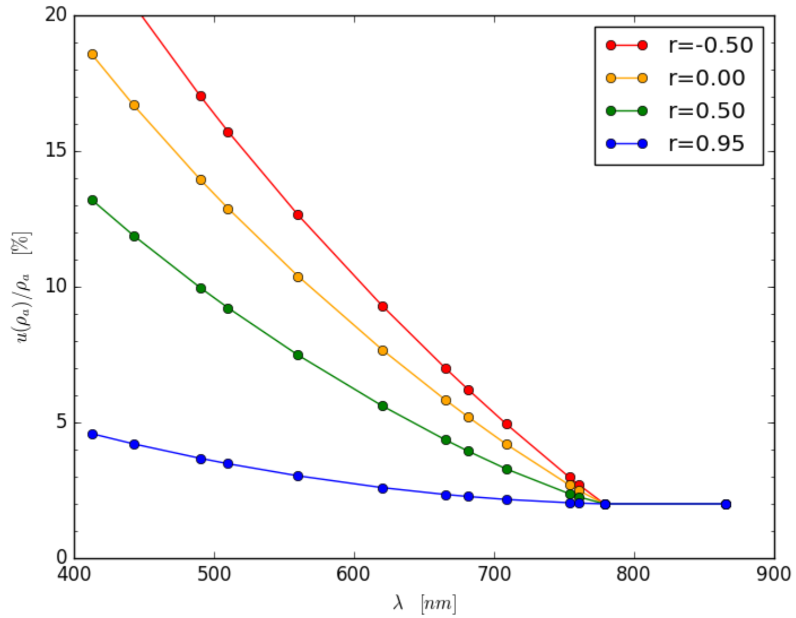
OBJECTIVE AND STATUS OF THE WORK-PACKAGE 2120

- **Objective: revisit the inverse problem of ocean colour, outside operational constraints (R&D)**
  - QA4EO: uncertainty formalism as a tool to develop algorithm (+ provide output uncertainties)
  - Robust algorithmic method to the ill-posed Atmospheric Correction problem: physical model, choice of bands, multi-pixel, a priori knowledge …
  - Develop a prototype, document in ATBD

- **Status since Cal/Val workshop #1:**
  - Litterature review
  - Analysis of the ill-posed inversion for some “linear” atmospheric models (PCA analysis)
  - New non-linear atmospheric model investigated, tested on RTM simulations
  - Prototype started to be implemented
  - Documentation in a first version of ATBD: on-going, delayed to end 2020

UNCERTAINTY PROPAGATION: STD VS NON-STD ATM. CORR.

- **Standard Atmospheric Correction (MERIS/OLCI baseline AC)**
  - **Two bands in the NIR** only to detect aerosol, then extrapolate to the VIS
  - **Strong uncertainty propagation** to the VIS: radiometric noise, possibly overcorrection (negative marine signal)…
  - **Modelling not totally physically justified**: aerosol mixing from NIR to VIS, impossibility to detect absorbing aerosol
  - Method **not robust for actual remote-sensing conditions** (variable gaseous absorption, residual Sun glint, absorbing aerosols, complex waters…)



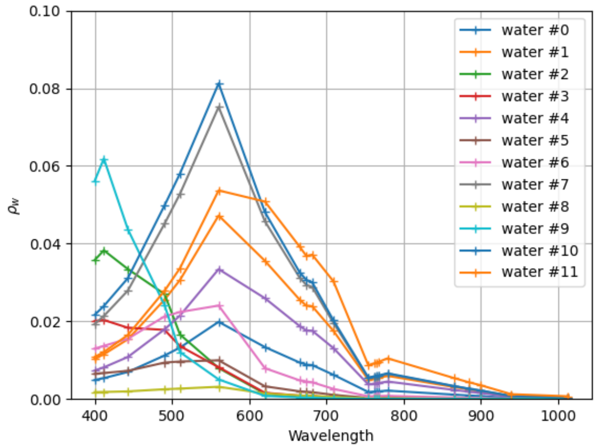
- **Alternative: use a spectral model over the full spectrum for aerosol detection; no extrapolation**
  - Introduce a **coupled ocean-atmosphere** problem, due to non-negligible marine signal in the VIS
  - Least-square minimisation **adapted to uncertainty formalism**: input/output uncertainties
  - Example of spectral model widely used in the OC community (OC-CCI…): POLYMER (Steinmetz et al., 2011)

$$\rho_a^{mod}(\lambda) = c_O * T(\lambda) + c_1 * \left(\frac{\lambda}{\lambda_0}\right)^{-1} + c_2 * \left(\frac{\lambda}{\lambda_0}\right)^{-4}$$

: linear with respect to three unknowns c_O, c_1, c_2

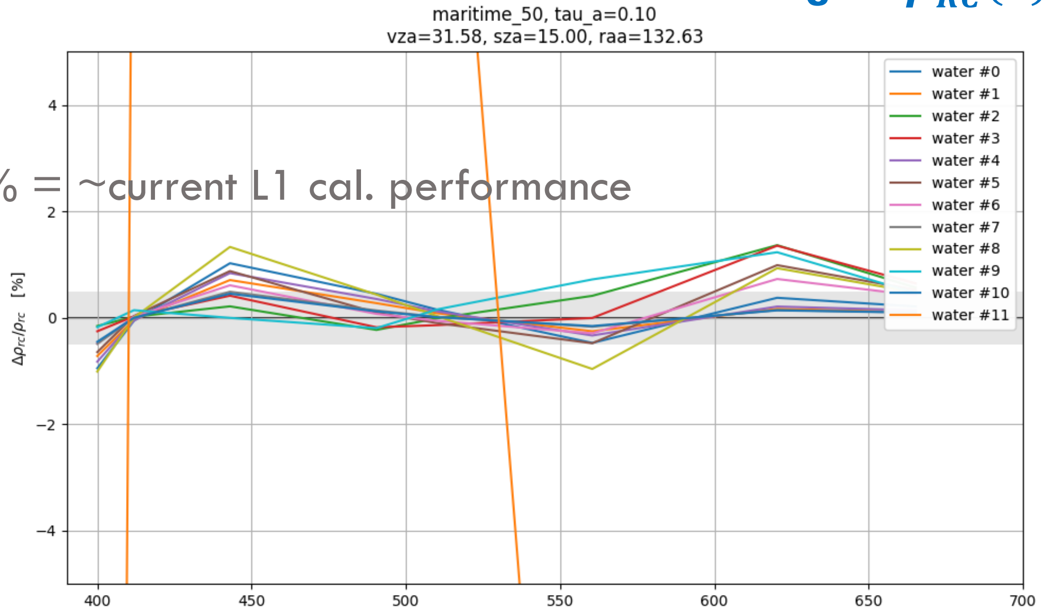
INVERSION ERROR WITH "LINEAR" ATMOSPHERIC MODEL

- **Simulated TOA signal $\rho_{RC}(\lambda)$ pre-corrected for Rayleigh:**
  - Ocean: various spectra $\rho_w^{mod}(\lambda)$ from clear blue to strongly scattering or absorbing waters
  - Atmosphere: $\rho_a(\lambda)$ from RTM for various aerosol models, AOTs, geometries
- **Inversion by spectral fitting (least-square minimisation)**

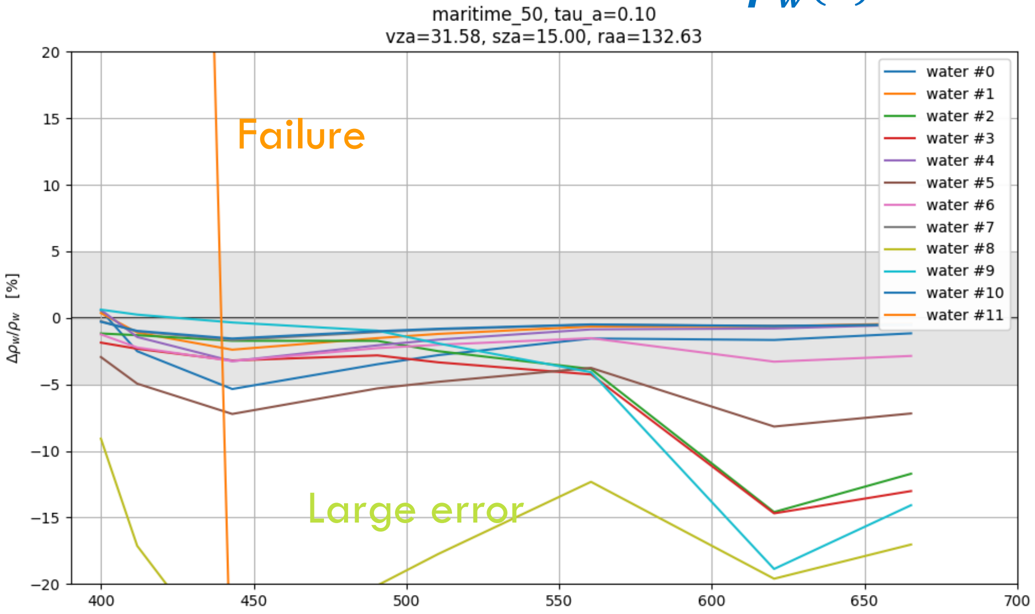


Relative error on re-constructed TOA signal $\rho_{RC}(\lambda)$

2% = ~current L1 cal. performance

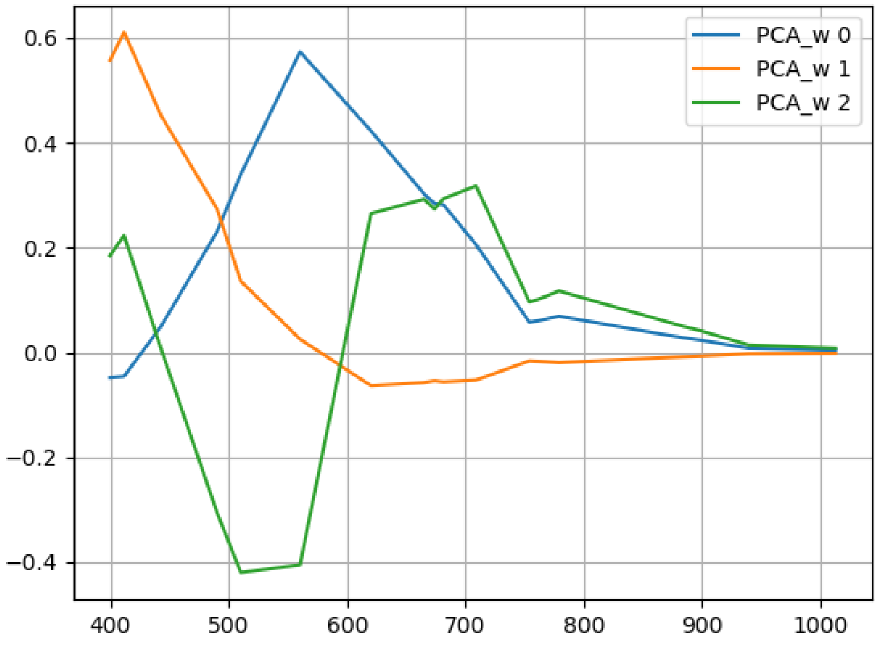


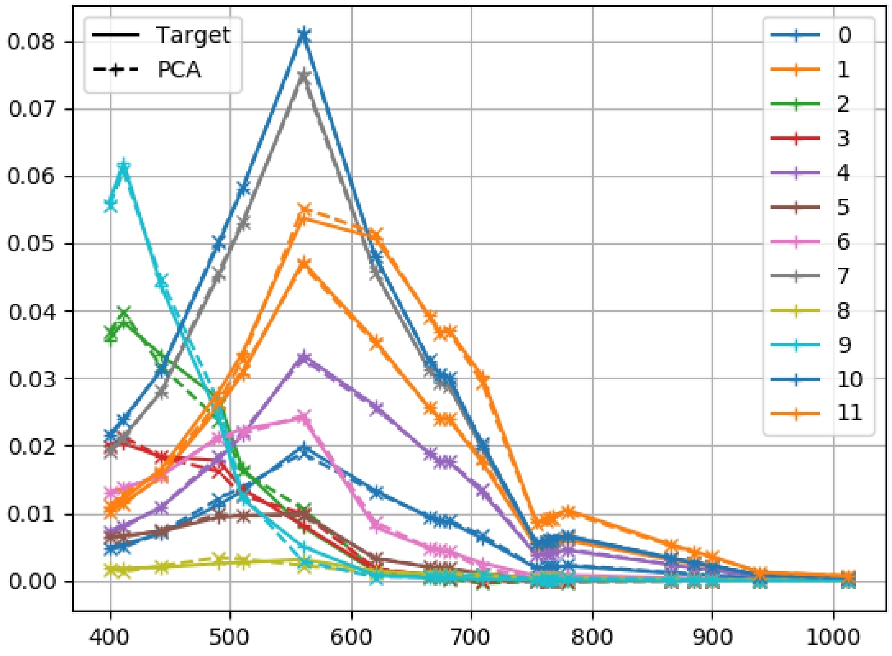
Relative error on retrieved $\rho_w(\lambda)$



AMBIGUITY BETWEEN “LINEAR” ATM. MODEL AND OCEAN

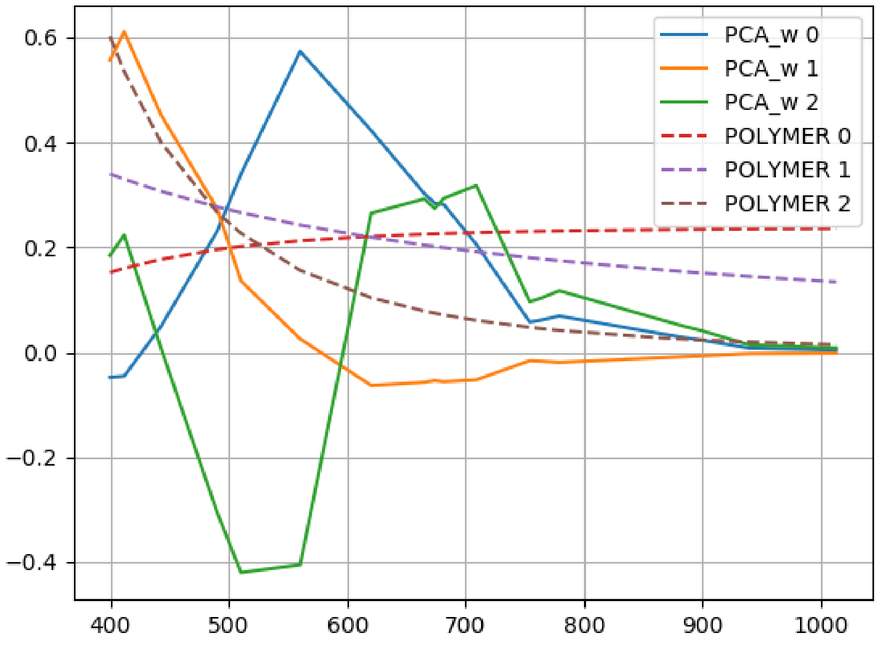
- **Principal Component Analysis on <u>marine spectra</u>**
  - Three linear components allow to construct very well the various marine spectra

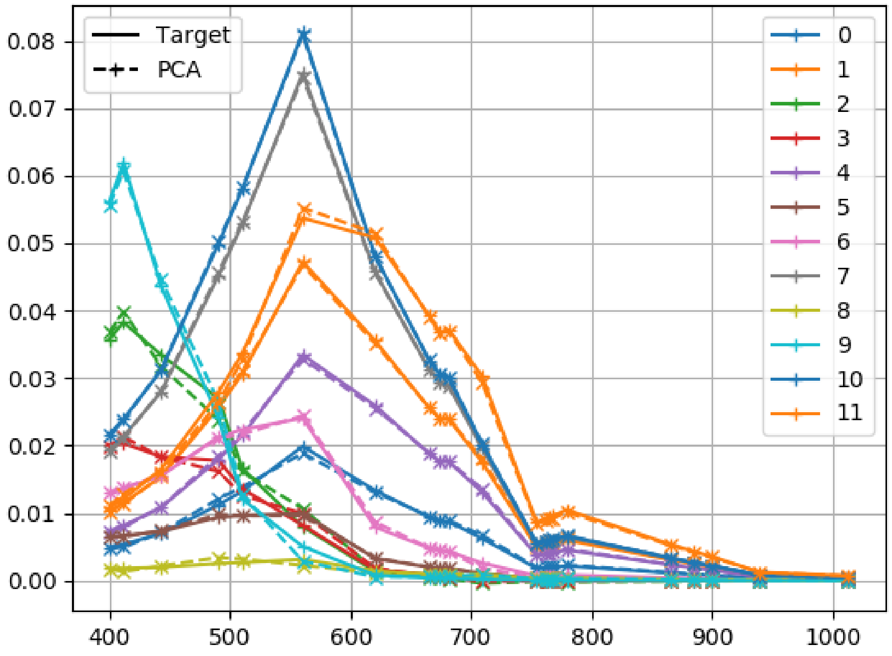




AMBIGUITY BETWEEN "LINEAR" ATM. MODEL AND OCEAN

- **Principal Component Analysis on marine spectra**
  - Three linear components allow to construct very well the various marine spectra





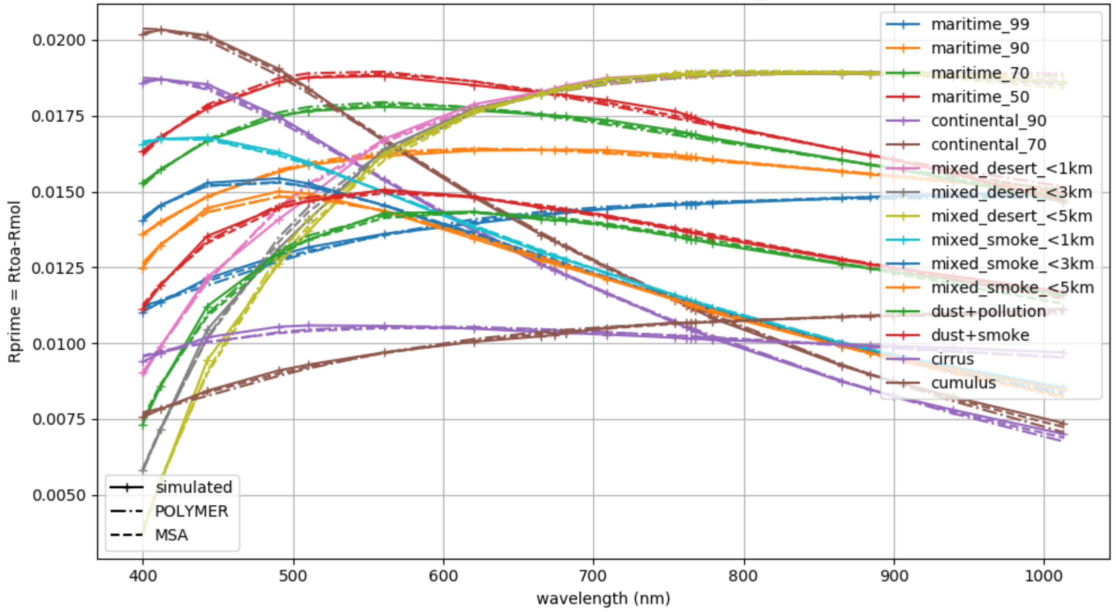
- **2nd component of the marine signal is very close to POLYMER λ^{-4} term**
  - "Linear" atmospheric model may absorb some marine components → ambiguity
  - Ideally, the eigenvectors of atmospheric and ocean linear decompositions should be orthogonal

INTRODUCING A NON-LINEAR SPECTRAL MODEL: MSA

- **Requirements:** 3 degrees of freedom, multiple-scattering, relevant for all aerosol types including absorbing
- **Starting from Single Scattering Approximation (SSA) → Multiple-Scattering Approximation (MSA)**

$$\rho_a(\lambda) = \rho_a(\lambda_0) * \left(\frac{\lambda}{\lambda_0}\right)^{\alpha} \left(\frac{1 + k * \left(\frac{\lambda}{\lambda_0}\right)^{\alpha}}{1 + k}\right)$$

Spectral fit of $\rho_a(\lambda)$ for various aerosol types



- Coefficient k is negative and adjust for multiple scattering and absorption (~single scattering albedo)
- Smooth function reaching a maximum at λ_L:

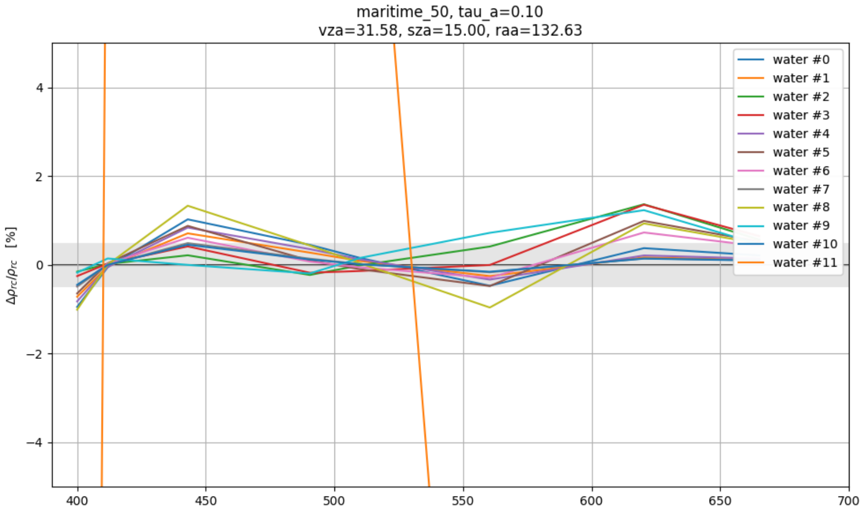
$$\rho_a(\lambda) = \rho_a(\lambda_0) * \left(\frac{\lambda}{\lambda_0}\right)^{\alpha} \left(\frac{1 - \frac{1}{2}\left(\frac{\lambda}{\lambda_L}\right)^{\alpha}}{1 - \frac{1}{2}\left(\frac{\lambda_0}{\lambda_L}\right)^{\alpha}}\right)$$

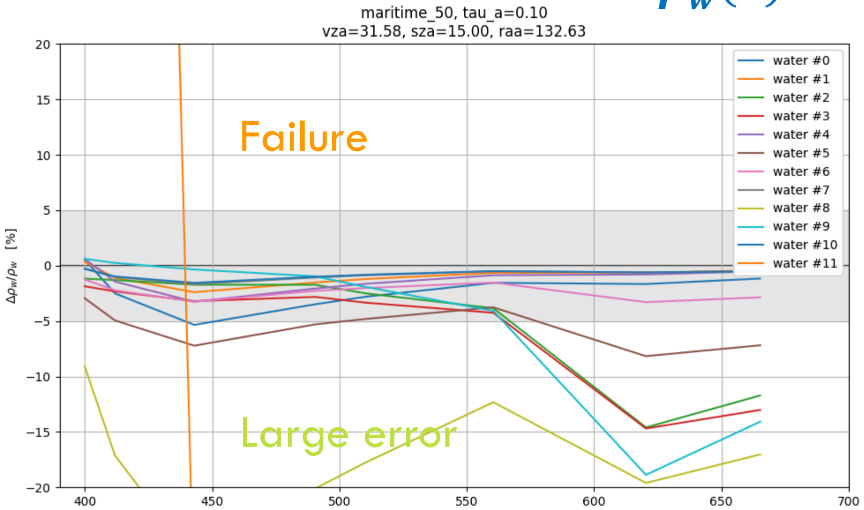
- Degrees of freedom $\rho_a(\lambda_0)$, α, λ_L have now a physical meaning and are bounded → **constraint on the inversion**

INVERSION ERROR: LINEAR VS MSA MODEL

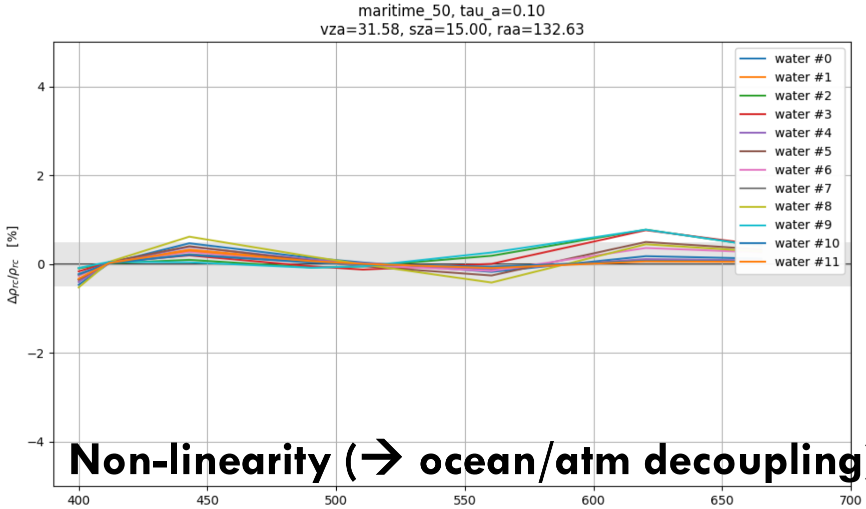
Relative error on re-constructed TOA signal $\rho_{RC}(\lambda)$

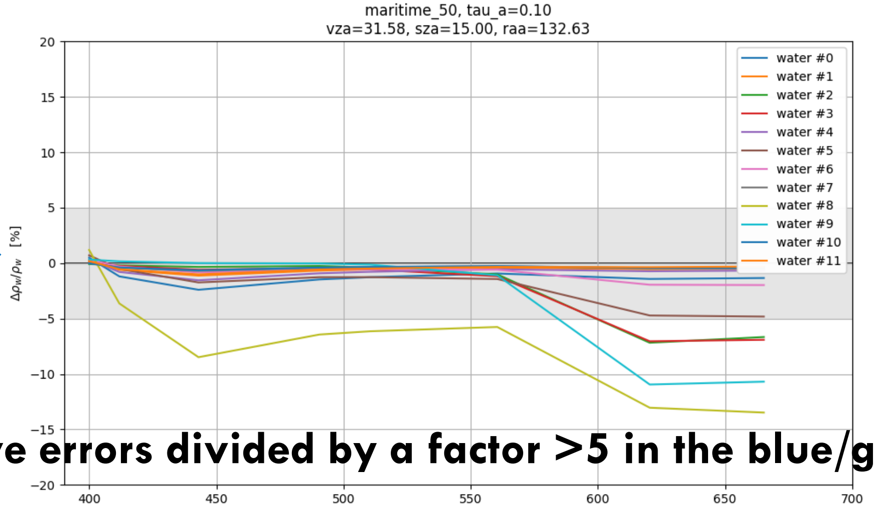
Relative error on retrieved $\rho_w(\lambda)$





Linear model





MSA

Non-linearity (→ ocean/atm decoupling) + constraint: relative errors divided by a factor >5 in the blue/green

CONCLUSION: ON-GOING & FUTURE WORK OF WP2120

- **On-going**
  - Document current status (draft ATBD, deliverable D.2.1.3-2)
  - Further work on the algorithmic inversion of the new model (speed up inversion of the 3 unknowns, first guess…). Model proposed to HYGEOS for POLYMER evolution, undergoes parallel investigation at EUMETSAT
  - Keep implementing the prototype: processing of OLCI scenes

- **Next step**
  - Select the most useful bands for ocean/atm decoupling with statistical approach & weight accordingly (uncertainty)
  - Study more robust inversion with multi-pixel processing (cf. GRASP)
  - Validation