Alternative vicarious gain estimates for Sentinel-3 OLCI: Investigation of atmosphere-typed spectral optical thickness corrections for the processor vicarious calibration,

from the open ocean to the shore

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OLCI 250 m resolution image over Logan,
20170821 eclipse day !!

Why changing gain formulation in the future?

❖ **The classic (actual) gain formulation** :

OBS — **RTM** = Radiative Transfer Model

80% — 20%

$$G \,.\, rho_{gc}(\lambda) = rho_{path}(\lambda) + T_{\theta s}(\lambda) * T_{\theta v}(\lambda) * \boldsymbol{rho_w(\lambda)} + \varepsilon$$

with $\varepsilon \sim f(\varepsilon_m + \varepsilon_{TOA})$ $(\varepsilon_m = direct\ model\ errors, \varepsilon_{TOA}$ = TOA errors)

❖ **OLCI L2 processor estimates the total optical thickness Tau T= τa+ τr**. It is therefore natural to align (i.e. apply gains to) the model using an estimated correction on τ.

❖ A new gain formulation for (**Plan of the presentation**):

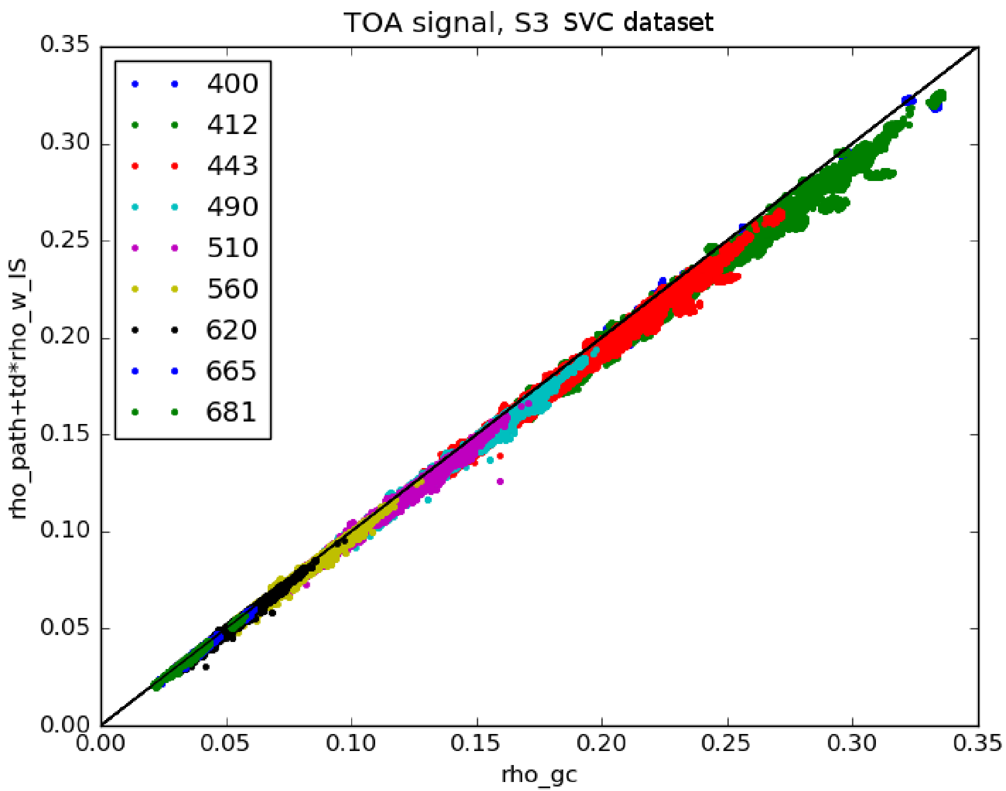
- ✓ **1/ Understand the OLCI level 2 errors** to enhance in the future the processor.
- ✓ **2/ Correct the estimated Tau** with the underlying idea that the non-linear correction **on Rhow(λ)** will be more generic, and therefore applicable in a more robust way to other areas, than the actual linear correction.
- ✓ **3/ Enhancements of the actual OLCI level 2 products , from open ocean to the shore,** with the introduction of conditional gains.

I/ Understand the significant sources of errors for the OLCI L2 processor

I/ Data alignment between OLCI L2 processor and the SVC dataset

Rho_gc = Rho_path + td * Rho_w

- Estimated by the processor
- In-Situ



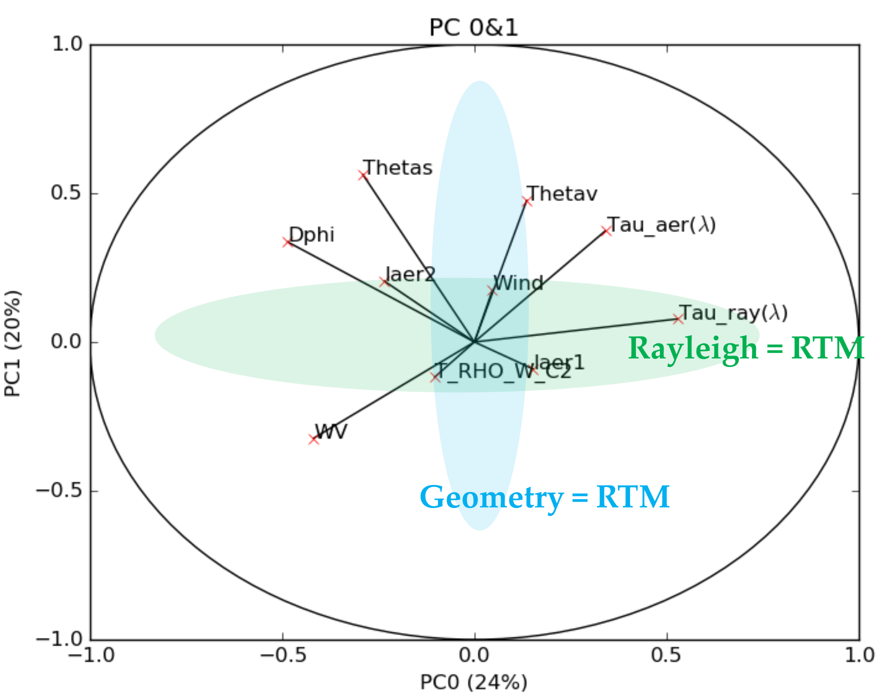
From what we see, to adjust the model:

- **Td is underestimated?**
- **Rho_path is underestimated?**

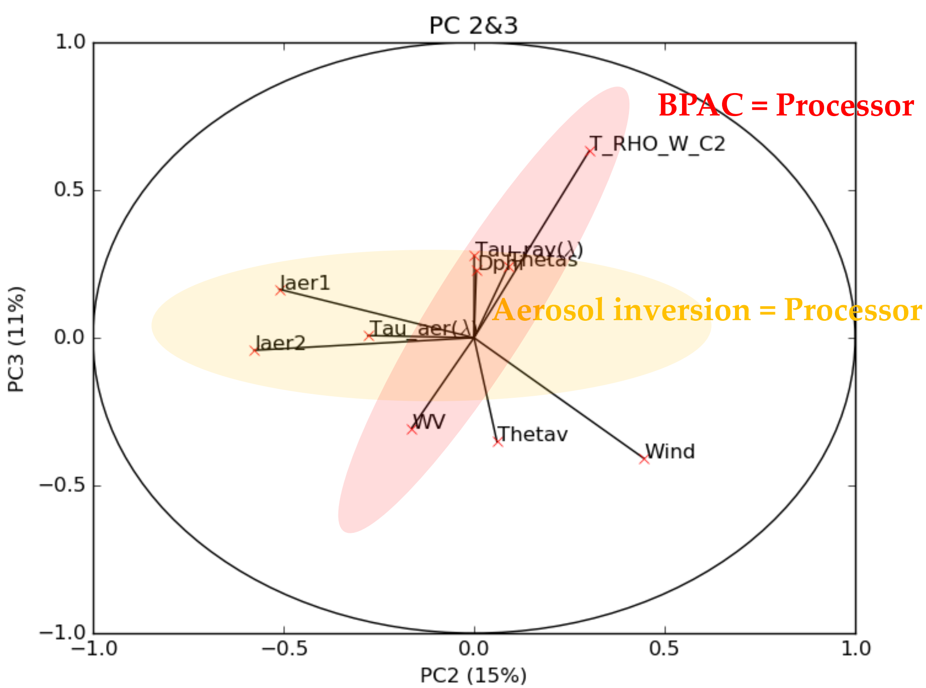
SVC dataset = 3150 **climatological measurements** + 350 **in-situ measurements**

I/ Understand the significant sources of errors for the OLCI L2 processor

PCA decomposition of forcing parameters (covariates) at Moby



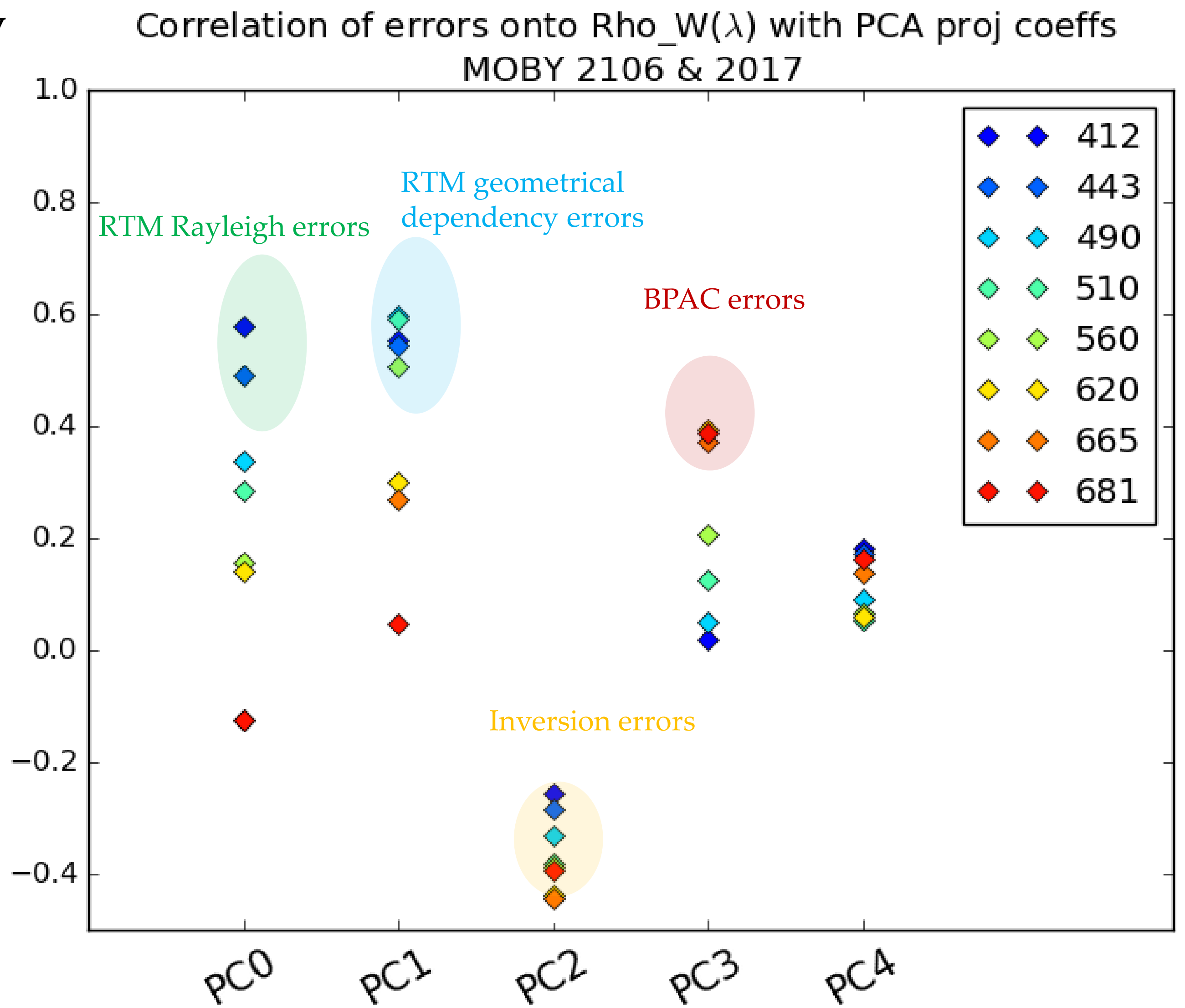
Modelling (RTM) covariates



Inversion covariates

I/ Understand the significant sources of errors of the OLCI processor

Moby



II/ Gains for OLCI in the visible onto the spectral optical thicknesses: Correct the estimated variable of the L2 processor

Classical formulation

$$G\,.rho_{gc}(\lambda) = rho_{path}(\lambda) + T_{\theta s}(\lambda) * T_{\theta v}(\lambda) * rho_w(\lambda)$$

- From OL2 processor
- In-Situ
- To be estimated

Proposed formulation:

Direct T / Diffuse T

$$T_{\theta s}(\lambda) = \underbrace{e^{-\tau(\lambda)*M_s(\lambda)}}_{\text{Direct T}} + \underbrace{e^{-\tau(\lambda)*M_s*coeffs(\lambda)}}_{\text{Diffuse T}}$$

Is the total downward transmittance

$$T_{G\theta s}(\lambda) = e^{-G(\lambda)*\tau(\lambda)*M_s(\lambda)} + e^{-G(\lambda)*\tau(\lambda)*M_s*coeffs(\lambda)}$$

Is the total downward transmittance with gains onto Tau

$$rho_{gc}(\lambda) = \left[\frac{1 - T_{G\theta s}(\lambda) * T_{G\theta v}(\lambda)}{1 - T_{\theta s}(\lambda) * T_{\theta v}(\lambda)}\right] * rho_{path}(\lambda) + T_{G\theta s}(\lambda) * T_{G\theta v}(\lambda) * rho_w(\lambda)$$

Where G is a vector of gains to be estimated for bands 400,412,443,490,510,560,620,665,670,681 given the inversion results of the OL2 processor and an in-situ dataset.

❖ **Estimation using a robust minimisation procedure on data from:**

1/ Radiometric In-situ dataset

MOBY	Kenneth Voss	University of Miami
	Kent Hughes	NOAA
BOUSSOLE	David Antoine	LOV
AAOT	Giuseppe Zibordi	JRC
	John Icely	University of Algarve
CASES	Selima Ben Mustapha	Fisheries and Oceans Canada
CoveSEAPRISM	Greg Schuster	NASA GSFC
Gloria	Giuseppe Zibordi	JRC
GustavDalenTower	Giuseppe Zibordi	JRC
HelsinkiLighthouse	Giuseppe Zibordi	JRC
LISCO	Alex Gilerson	City college of New York
MVCO	Annelies Hommersom	IVM
WaveCIS	Alan Weidemann	Naval Research Laboratory, NRLSSC
	Bill Gibson	Coastal Studies Inst. LSU

2/ Climatologcal radiometric dataset

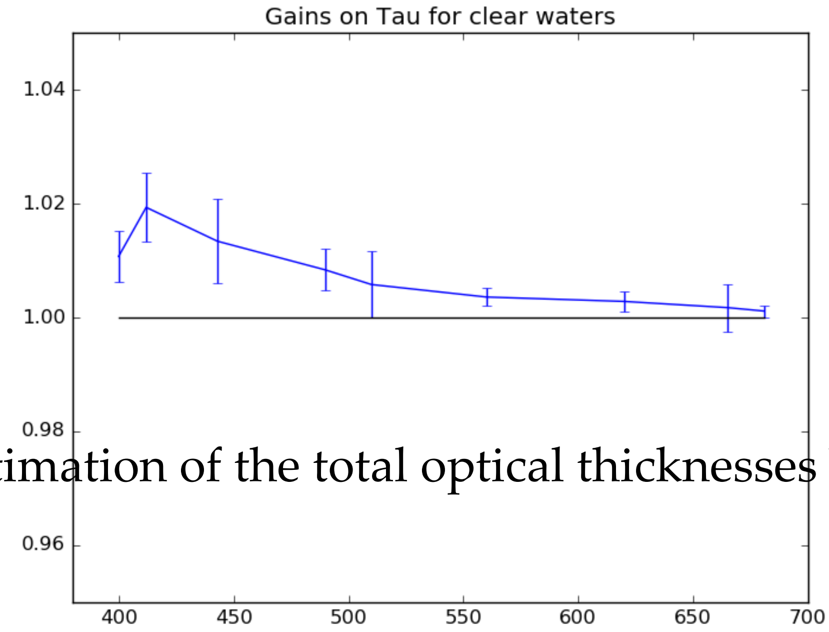
Daily Satelitte time-integrated average from 1997-now from **ESA Globcolor & NASA Oceancolor** datasets at global scale from 1997 no now

II/ Estimation of the gains for OLCI on Tau for clear waters

❖ **Estimation using a robust minimisation procedure**

Stations= MP15-SAGOPT-SPGOPT-SIOOPT-NWPOPT-NEPOPT-NAGOPT-HyBOUS-MOBY4O

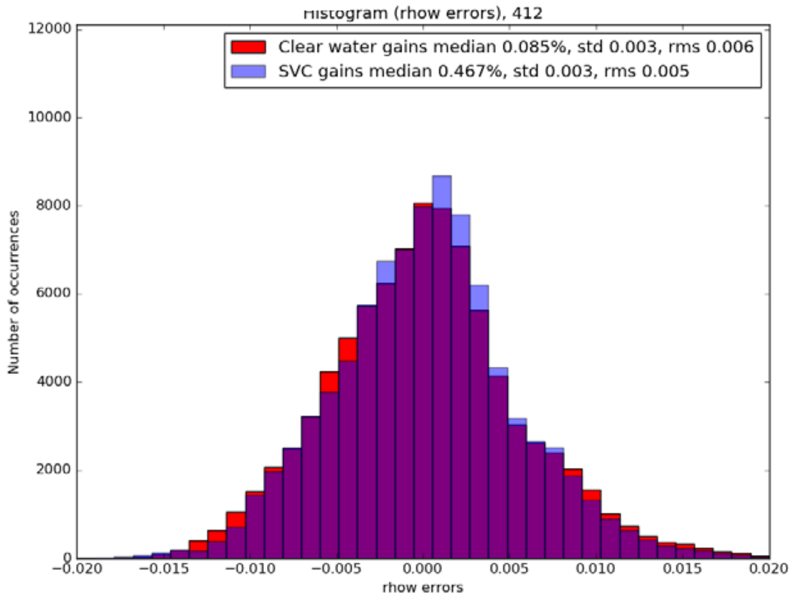
Gains on Tau= [1.00969002, 1.0181875 , 1.01301313, 1.00797925, 1.00522232, 1.00242976, 1.00128386, 1.00128386, 1.0006125]

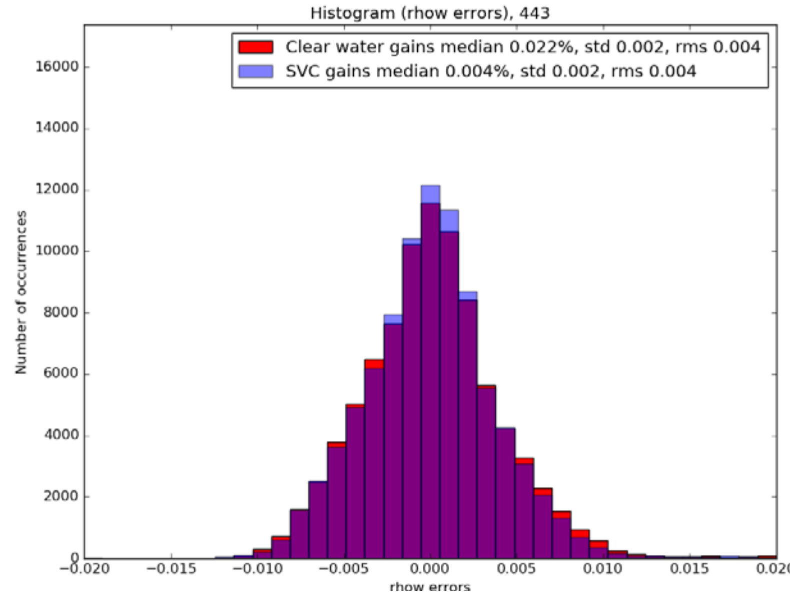


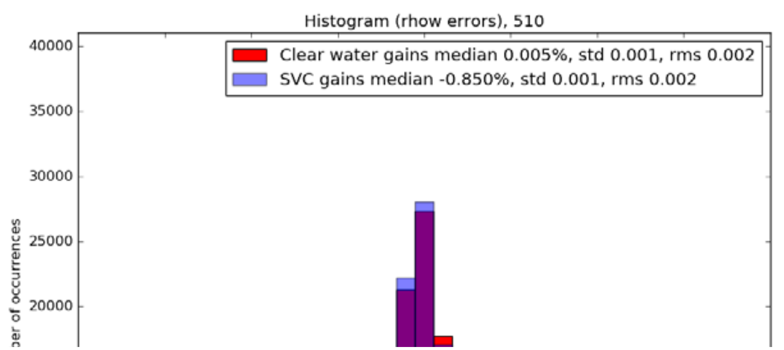
➢ Slight underestimation of the total optical thicknesses by the OLCI processor

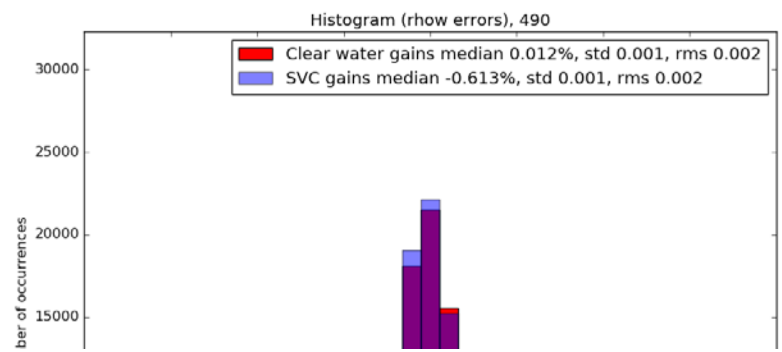
II/ Validation of the gains for OLCI on Tau for clear waters

❖ Rhow residuals





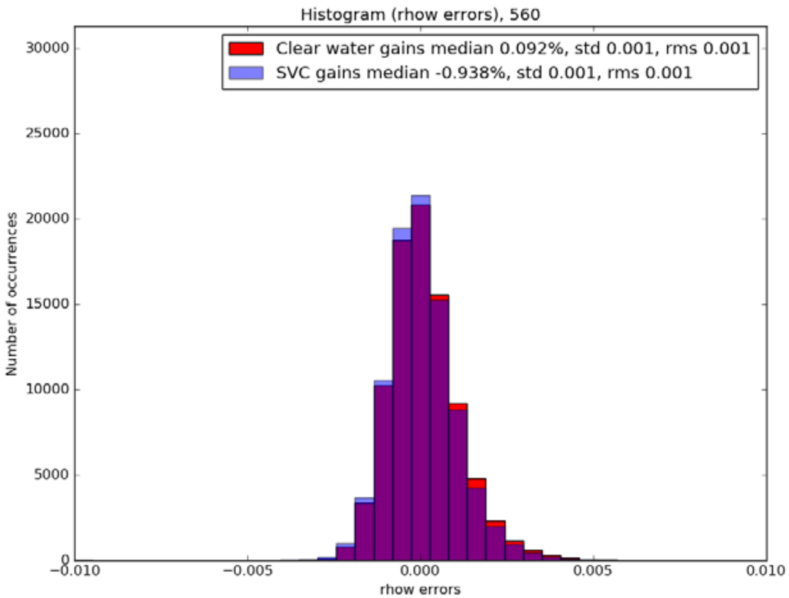


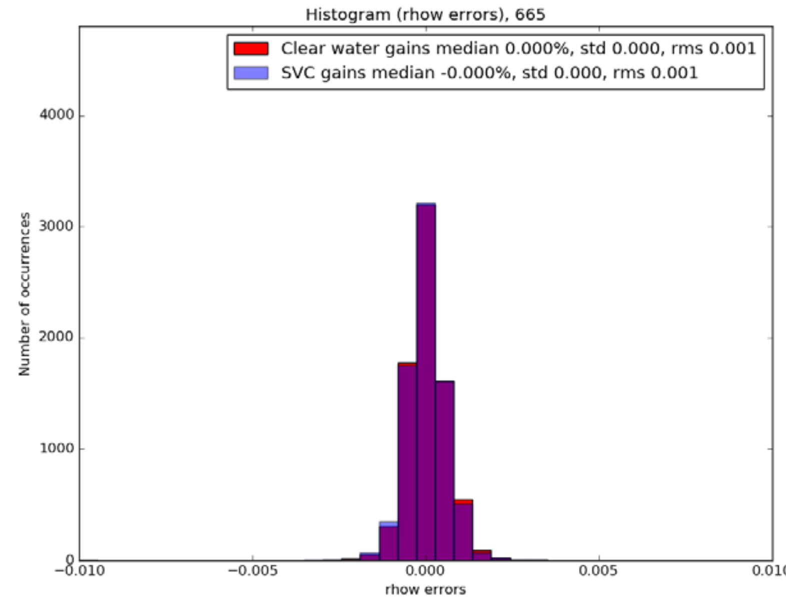


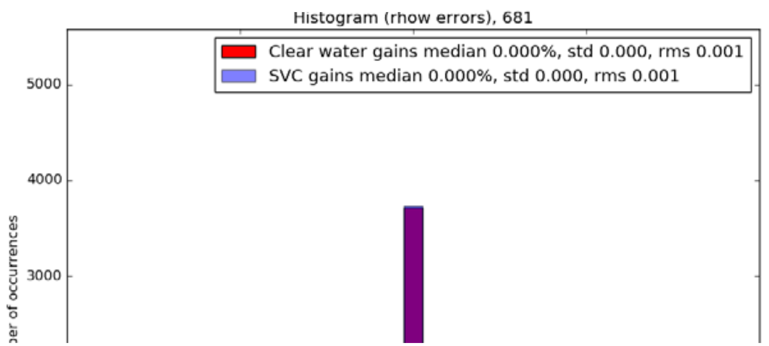
=> Same correction as performed by the S3 OLCI SVC but <u>correction of the OT and AOT products</u>

II/ Validation of the gains for OLCI on Tau for clear waters

❖ Rhow residuals



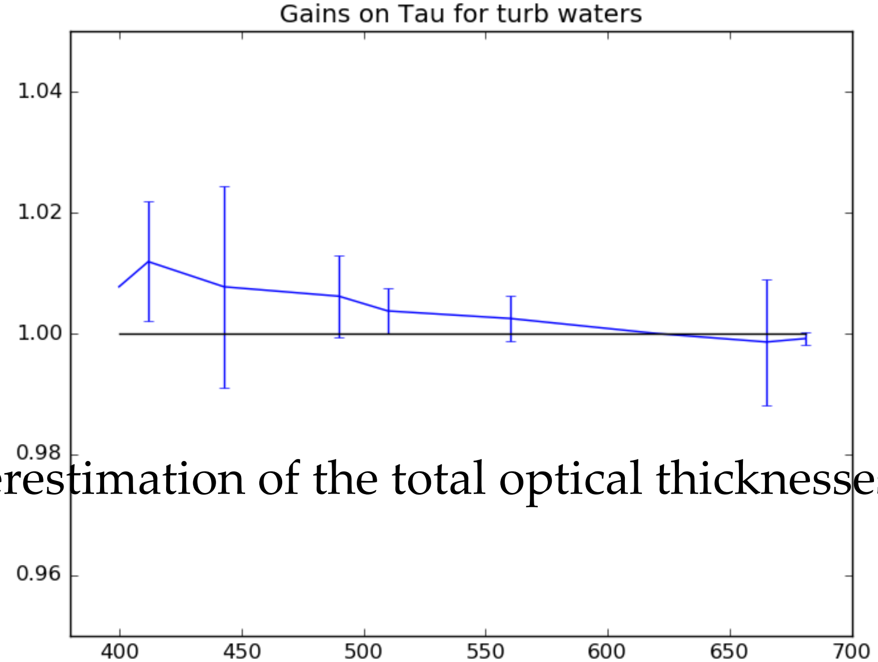




=> Same correction as performed by the S3 OLCI SVC but <u>correction of the OT and AOT products</u>

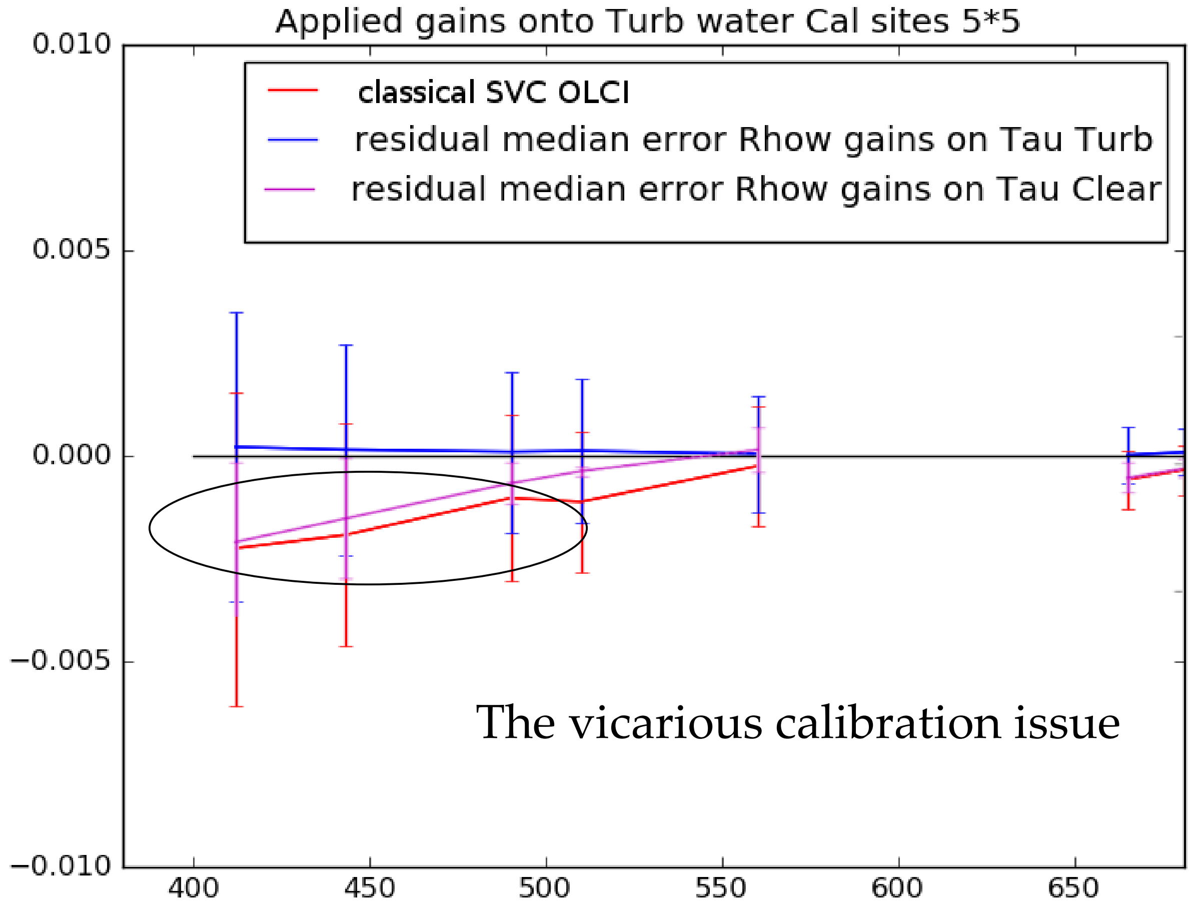
Stations='AAOT', 'GustavDalenTower', 'IML10', 'IML4', 'IML6', 'LISCO', 'MVCO', 'Thornton', 'UscSEAPRISM', 'WaveCIS', 'Zeebrugge'

Gains on Tau= 1.0077223 , 1.01188601, 1.0077223 , 1.00616707, 1.00373133, 1.00248754, 1. , 0.99859752, 0.99917006



- Slight underestimation of the total optical thicknesses by the OLCI L2 proc.

❖ Rhow residuals



⇒ Standard SVC leads to underestimate Rhows at the shore inc. negative reflectances

The vicarious calibration issue, from the open ocean to the shore

- Gains estimated on clear atmospheres & waters =>

  Good performance over clear waters BUT underestimation in coastal areas (including negative reflectance)

- Gains estimated on turbid atmospheres & waters =>

  Good performance over coastal waters BUT overestimation for clear waters

III/ Investigations for enhancements of the actual OLCI level 2 products with the introduction of conditional mixture of gains: to be better in every case

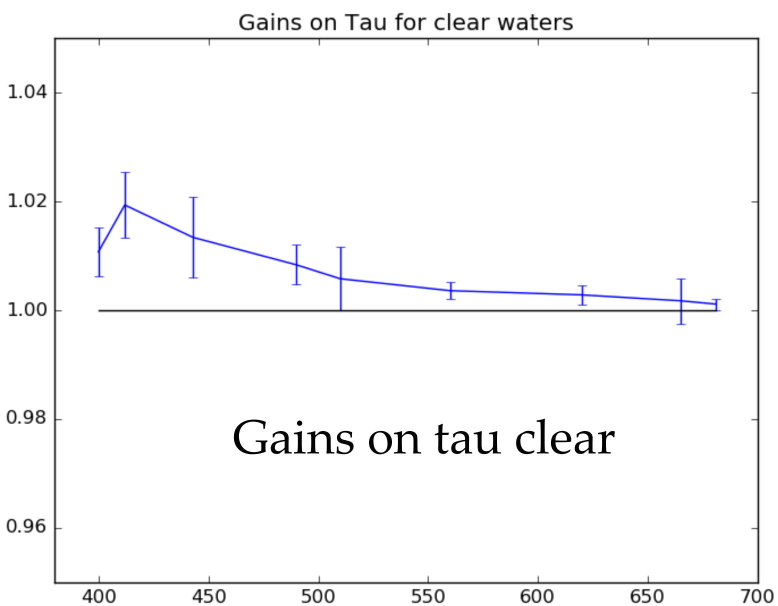
III Conditional mixture of gains

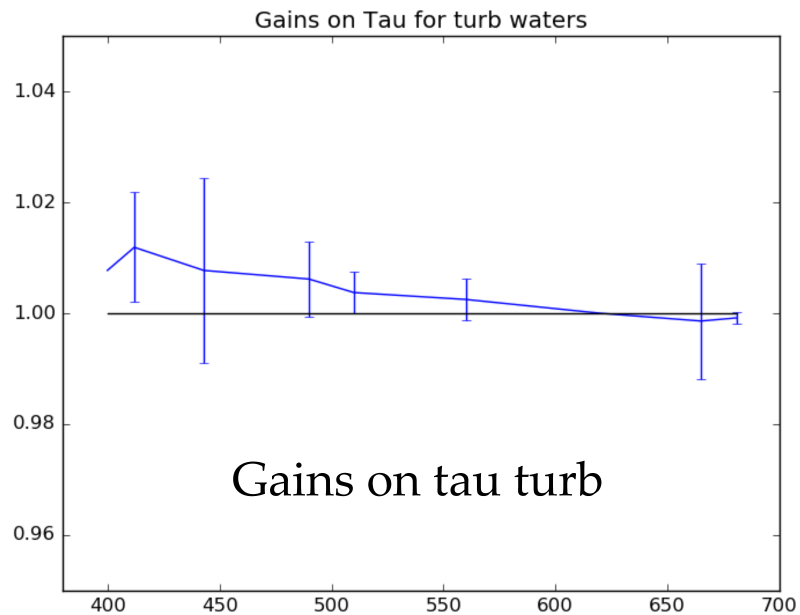
❖ **Introduction of conditional gains:**

Gains= $\sum_k P(i = k)$ Gains$_k$

The probability P being given by a robust TOA indicator to identify coastal and clear TOA observations

Gains= $\sum_k P(i = k)$ Gains$_k$





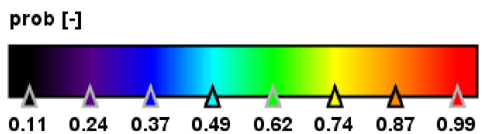
III Conditional mixture of gains

❖ **Seeking for robust TOA indicators** to characterise clear and coastal areas

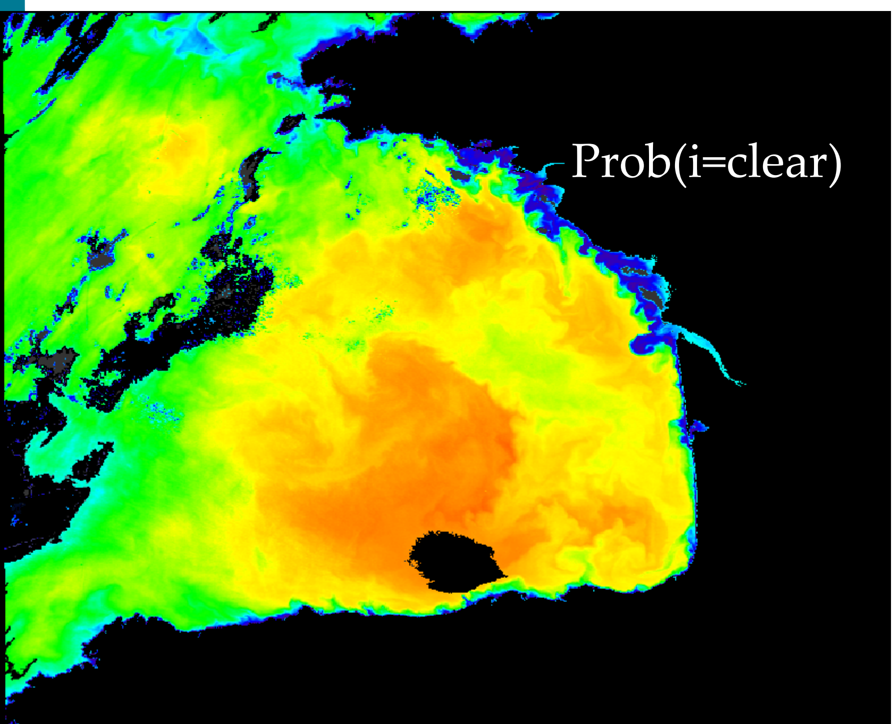
Example of the **Spectral Angle Mapper**:

$$\theta = \arccos\left(\frac{\overrightarrow{Rho\_GC(\lambda)}.\overrightarrow{Rho\_GC_{ref}(\lambda)}}{|Rho\_GC(\lambda)||Rho\_GC_{ref}(\lambda)|}\right)$$

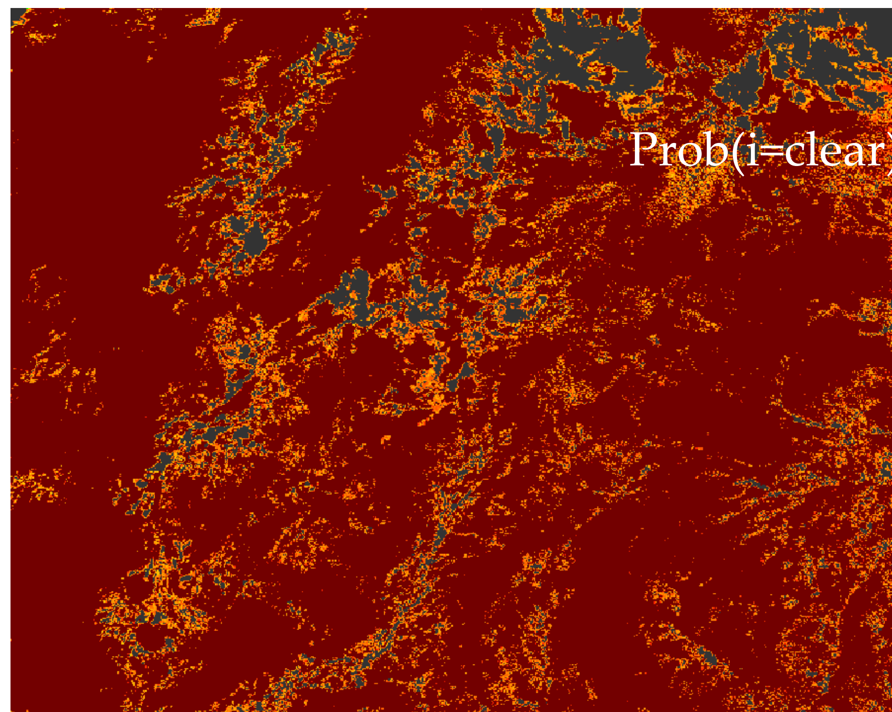
2 Refs={clear, coastal}



Coastal areas



Open ocean

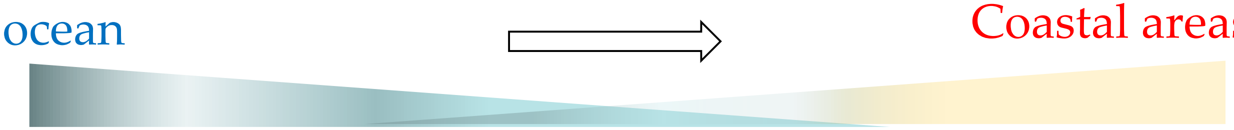


III Validation of mixed gains

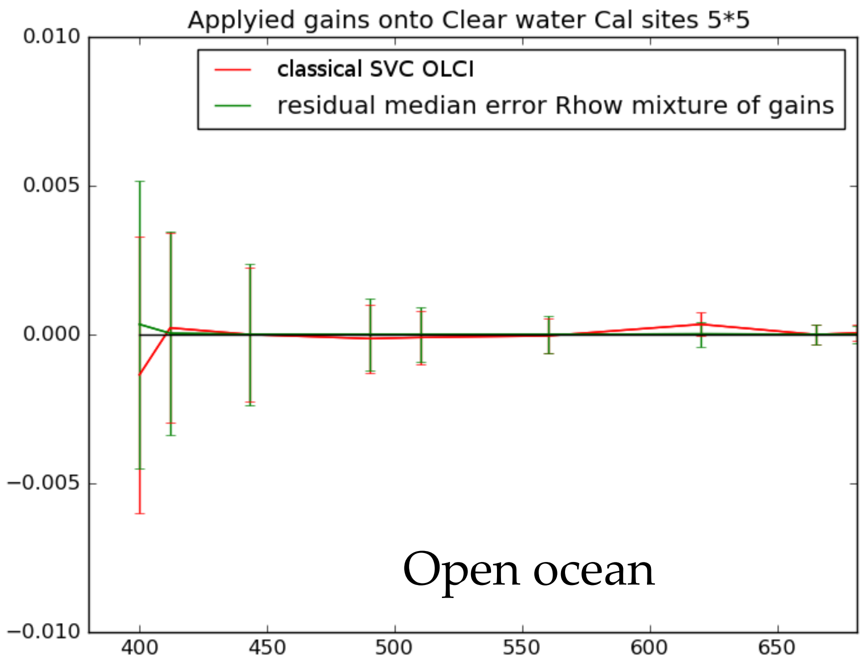
$$\text{Gains} = \sum_k P(i = k)\ \text{Gains}_k$$

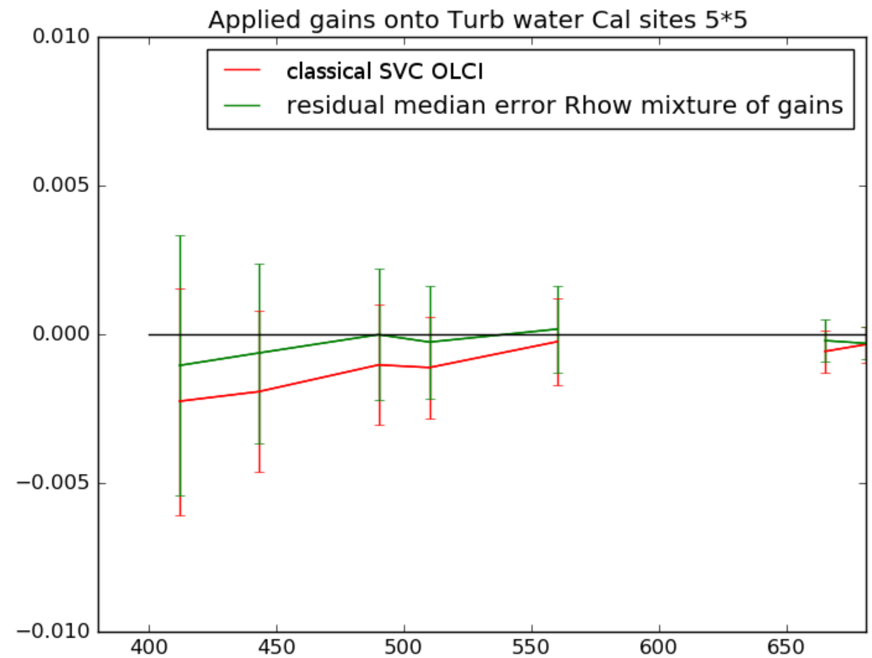
Open ocean

Coastal areas



Rhow residuals

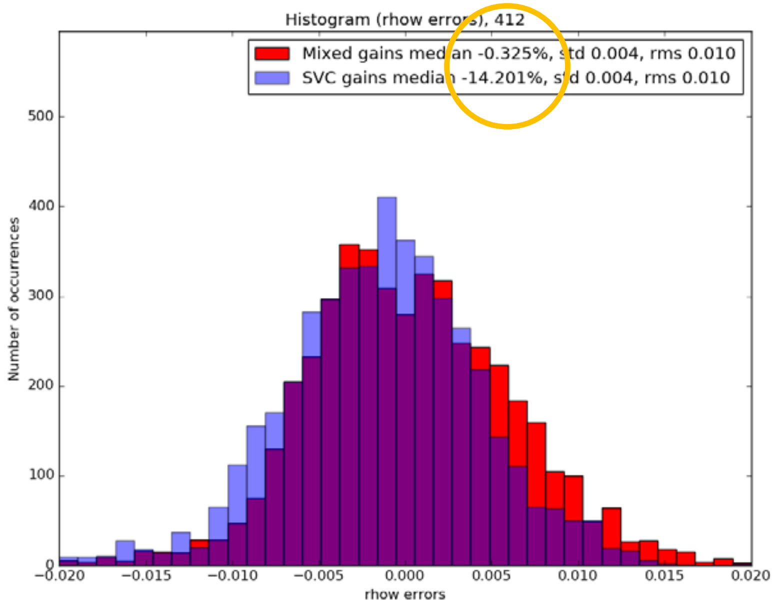


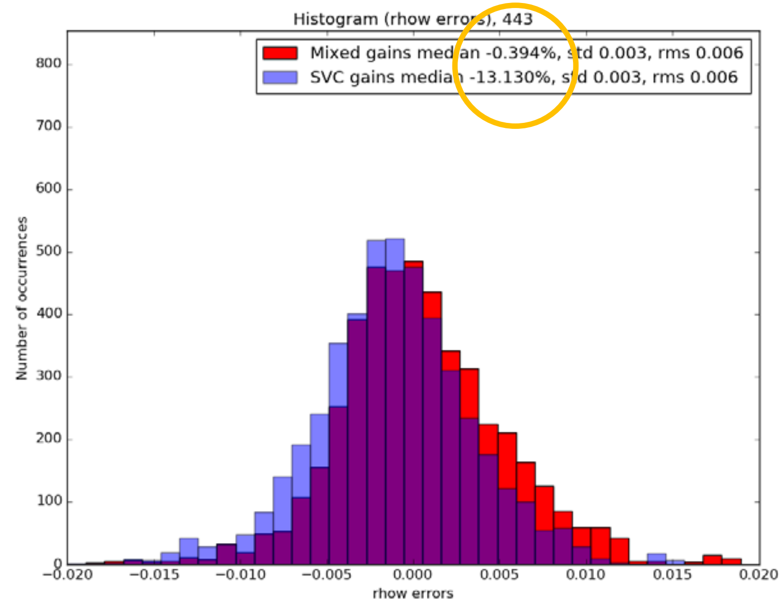


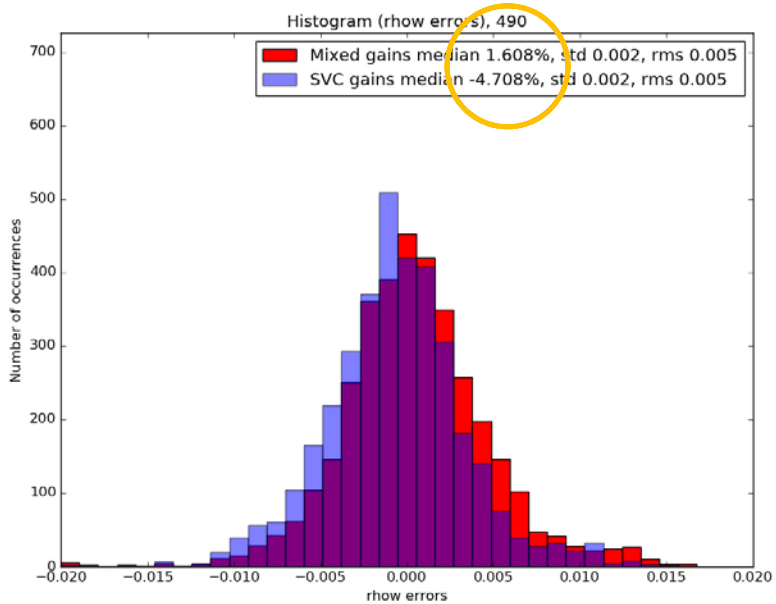
=> **Equivalent results as the S3 SVC**

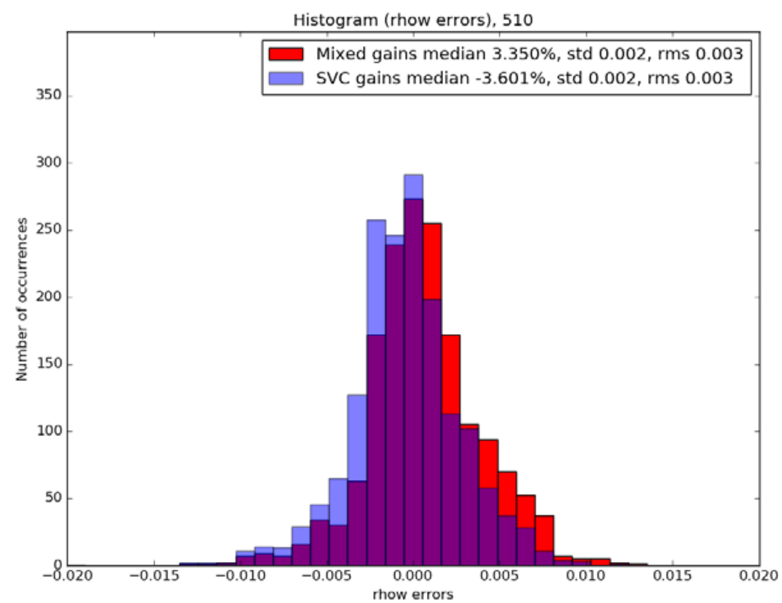
=> **Better results than the S3 SVC**

III Validation of mixed gains on coastal waters









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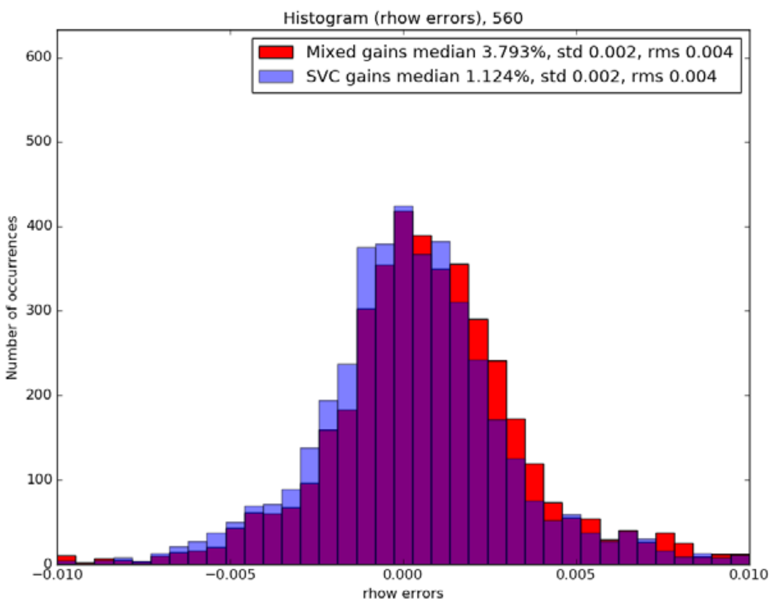
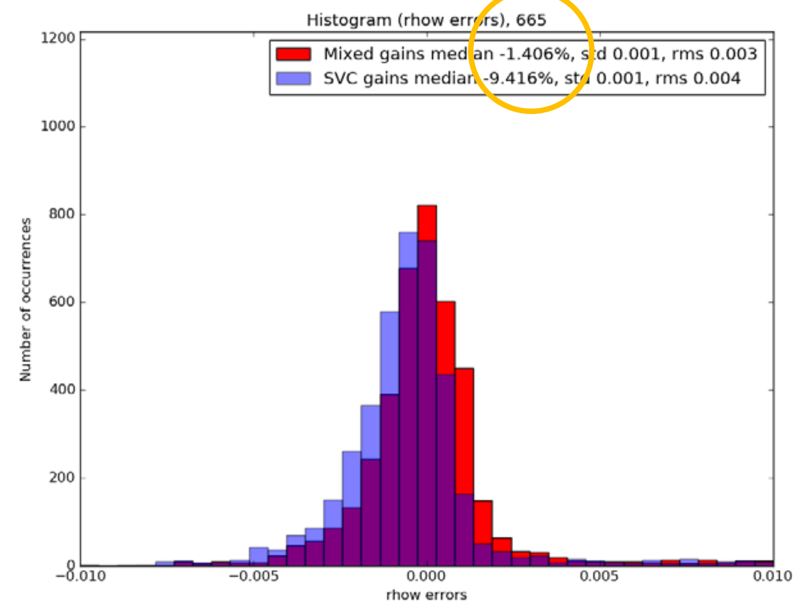
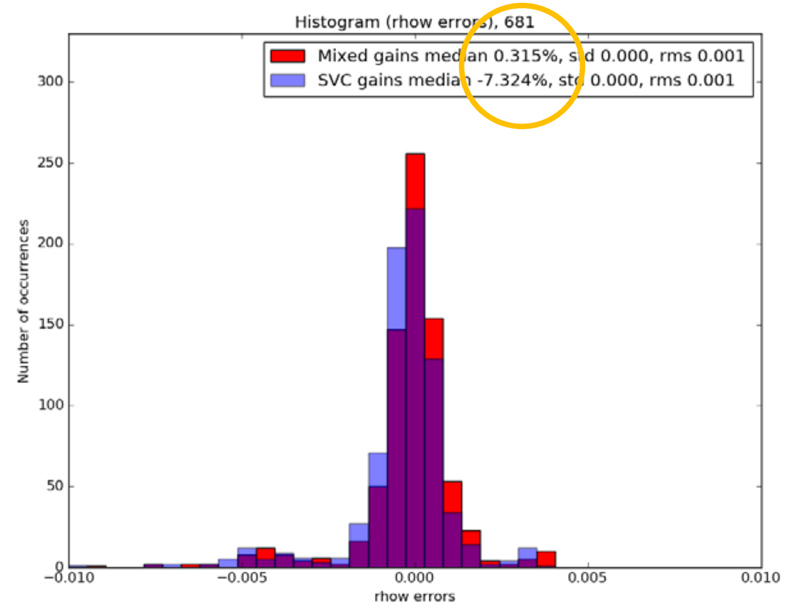


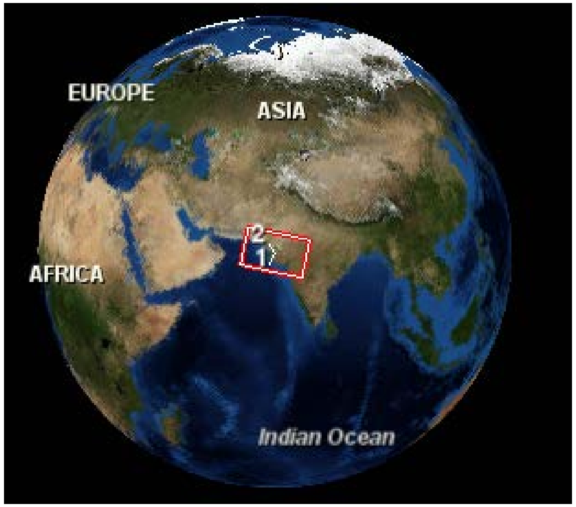




$\Rightarrow$ Improvements compared with the S3 SVC

III Mixed gains foe the OLCI L2 processor

❖ Less negative reflectances: level 2 coverage increase from 2 to 10% for coastal waters

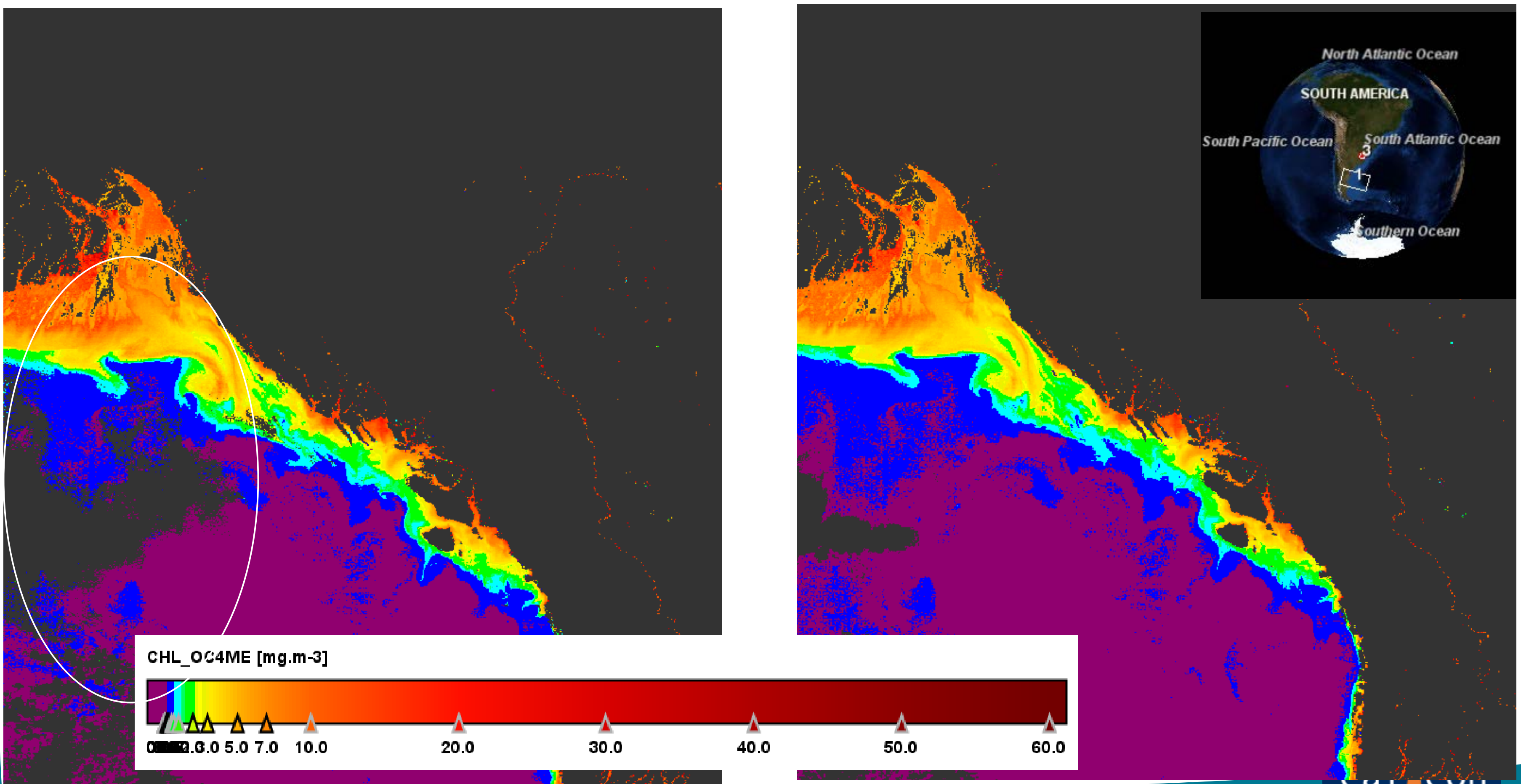


III Mixed gains foe the OLCI L2 processor

❖ **Less negative reflectances: level 2 coverage increase for coastal waters**

SVC OLCI Chl-a

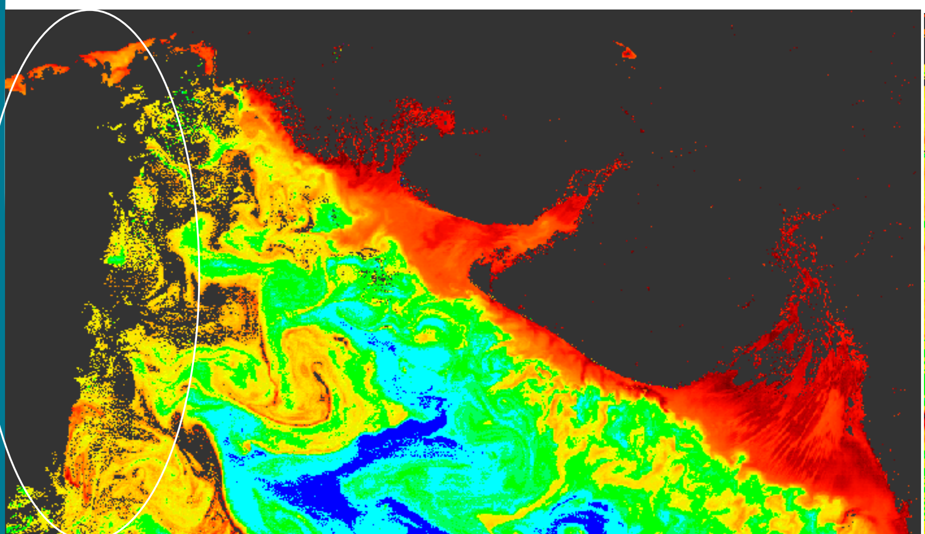
Mixed Gains Chl-a



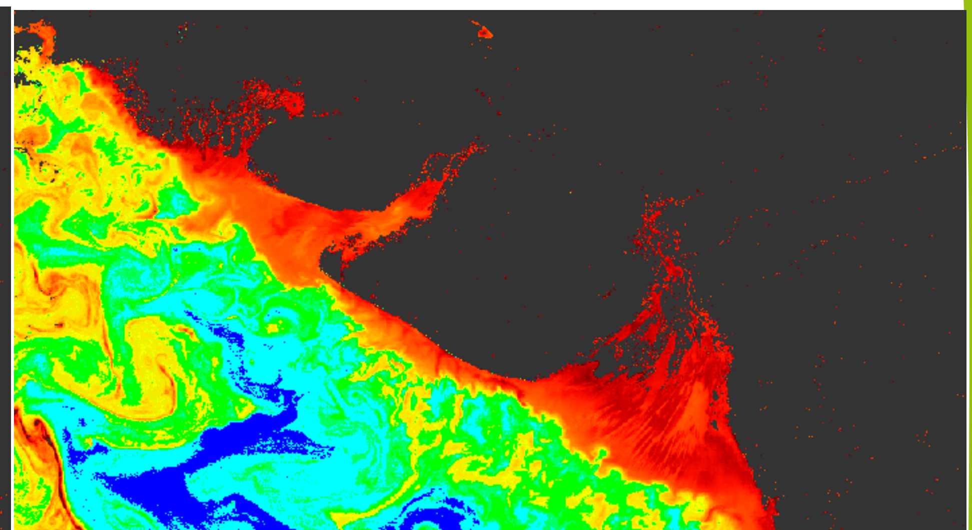
III Mixed gains foe the OLCI L2 processor

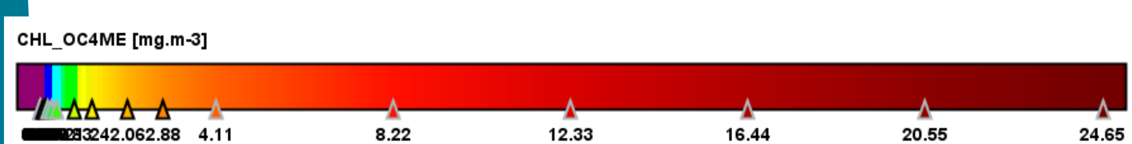
❖ **Less negative reflectances: level 2 coverage increase for coastal waters**

SVC OLCI Chl-a



Mixed Gains Chl-a





Preliminary conclusions

1/ Error analysis using PCA will provide soon ways to **quantify and discriminate the modelling errors and the inversion errors** => **returns towards the RTM designers**

2/ **Vicarious calibration on Tau**, the inversed variables, **correct the estimated Tau conversely to the gains onto rho_gc**.

=> **Soon, provision of the results of the correction onto Tau using the Aeronet in-situ data**

3/ **Conditional gains** provide a simple way to improve the Level 2 in coastal areas while preserving the atmosphere model's calibration in open ocean. We can increase the coverage from to 2 to 10 % at the shore of the OL2 processor.

=> L2 OLCI processor enhancements

=> Guide for a multi-model inversion scheme for OLCI

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Future improvements

Further major improvements of the L2 OLCI processor will be also soon proposed:

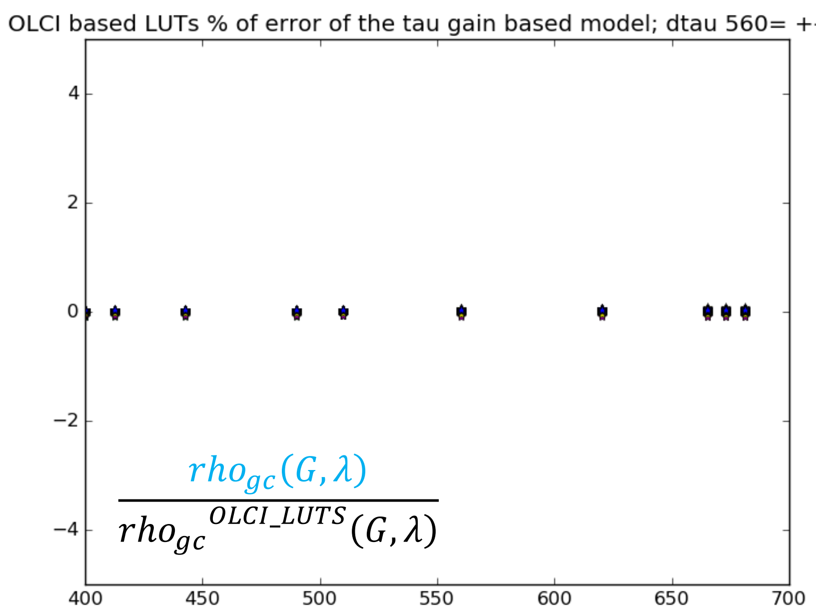
- **Correction of the BPAC including spatial regularisation terms.**
- **Optimisation** of the estimation of Tau_865 and the aerosol model selection to **avoid meaningless (incl. negative) Rhows**.
- **Inversion over block of pixels to minimize the noise** and introduce the existing **spatial continuity of the atmospheric variables (ongoing paper for Sentinel 2)**.
- Enhancement of the coupling between td_up and Rhow to take into account the BRDF of the water (**correction of the Lambertian hypothesis of the OL2 processor**).

Annex

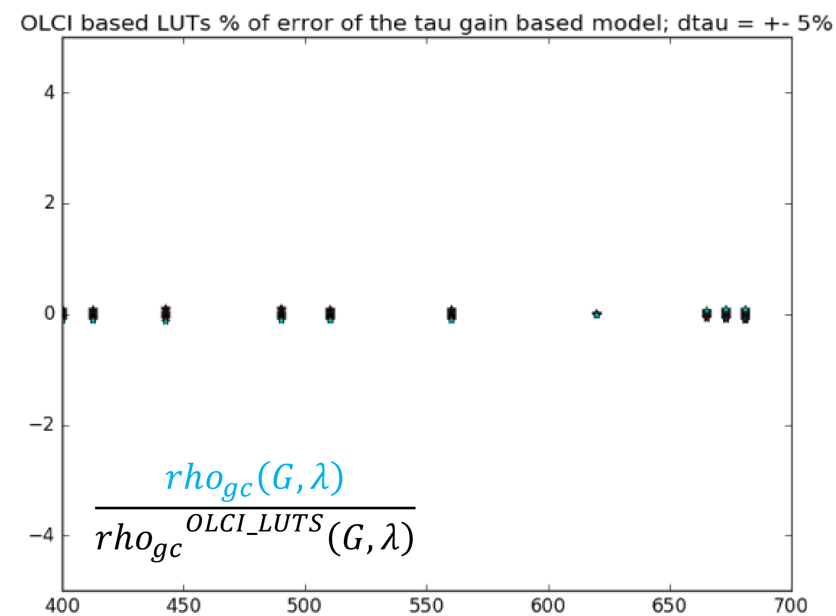
❖ Validation of the proposed formulation with the OLCI LUTS:

$$rho_{gc}(G,\lambda) = \left[\frac{1 - T_{G\theta s}(\lambda) * T_{G\theta v}(\lambda)}{1 - T_{\theta s}(\lambda) * T_{\theta v}(\lambda)}\right] * rho_{path}(\lambda) + T_{G\theta s}(\lambda) * T_{G\theta v}(\lambda) * rho_{w}(\lambda)$$

SZA=31, VZA=25, RAA=24, Tau_a=0.1, Aer=3



SZA=31, VZA=35, RAA=44, Tau_a=0.3, Aer=1



+- 5% dTau => Error performed TOA < 0,1% = < 1% BOA