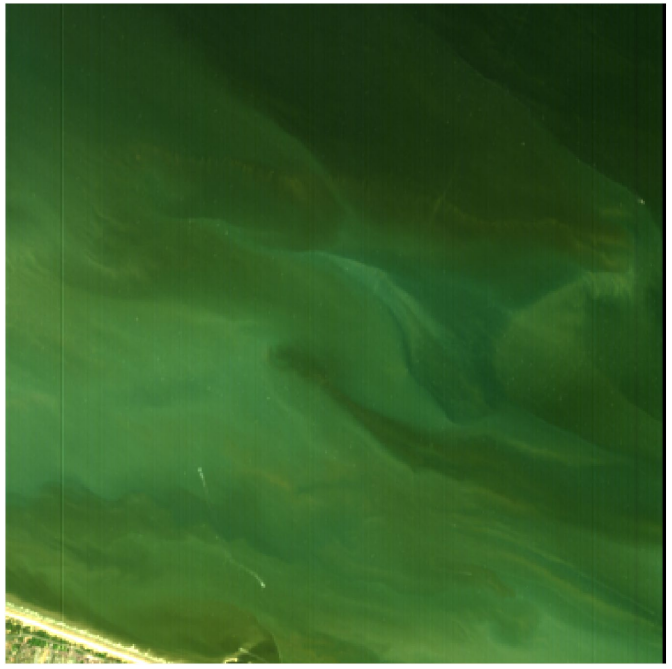
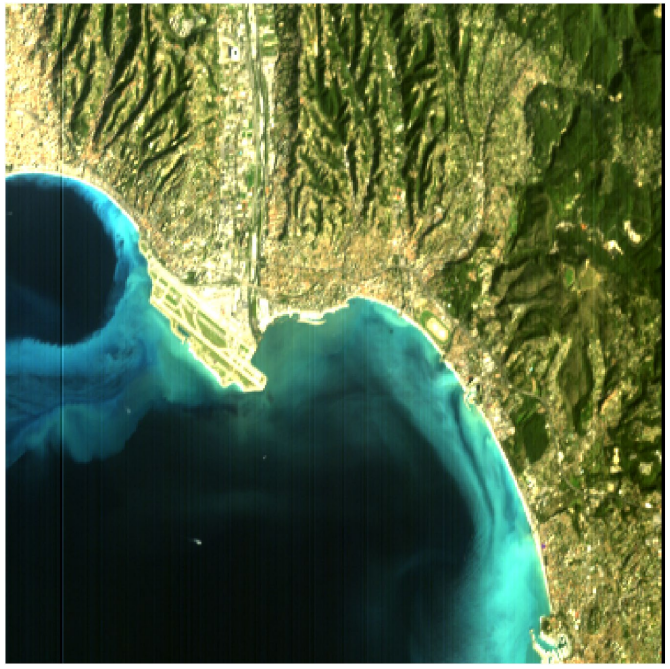
How CHRIS-PROBA images can be used for new aquatic applications?

Héloïse Lavigne, Kevin Ruddick, Quinten Vanhellemont

CHRIS-PROBA end of mission workshop 17-18 Jan. Gent





Outlines and objectives

A. Use of CHRIS-PROBA for aquatic applications

Hyperspectral advantages: Distinction of sediment types and phytoplankton group, retrieving chlorophyll-a in very challenging waters.

1. Development of a dedicated image processing and validation
2. Examples of applications

B. Future applications of hyperspectral sensors and limitations

The example of P. globosa blooms

Retrieving of P. globosa with in situ hyperspectral data

Which are the main requirements for hyperspectral sensors?

New CHRIS processor for water targets

Data correction

- Stripping correction (Gomez-Chova et al. 2008)
- Inter-band relative calibration (Lavigne and Ruddick, 2021 IGARSS proceeding)

Atmospheric correction

- Based on Dark Spectrum Function (ACOLITE, Vanhellemont et al., 2018)
- Assumes an homogeneous atmosphere over the image and at least one couple pixel/wavelength with no surface reflectance in the image.
- Maritime aerosol model is imposed
- A unique AOT is imposed for all five view angles.

Georeferencing

- Manually with the identification of 5 ground control points.

Interband relative calibration (methods)

Hypothesis: Top of atmosphere reflectance spectra above clear oligotrophic waters should be smoothed.

Water pixels

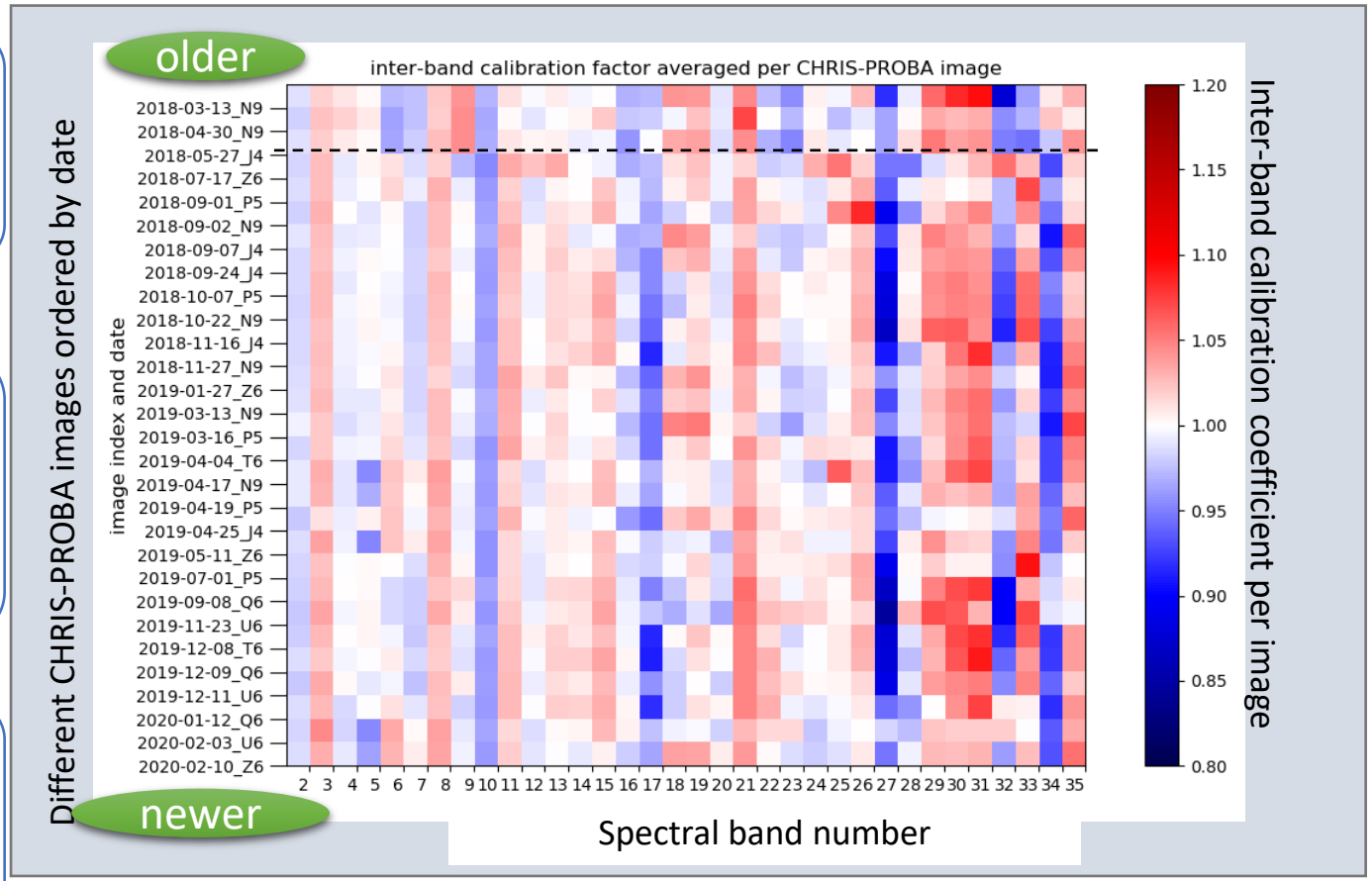
- Selection of images with possibly clear water pixels.

Fitting TOA spectra

- Fit TOA spectra with 8-degree polynomial from 440 to 730nm.
- Calculate $D = \frac{\sum_{i=1}^{36} |\rho_i - \rho_{smooth\,i}|}{\sum_{i=1}^{36} \rho_i}$

Final calibration coefficients

- Pixel based calibration coefficient:
- $CAL_{i\lambda} = \rho_{smooth\lambda i} / \rho_{\lambda i}$



Validation : against in situ measurements

1 match-up

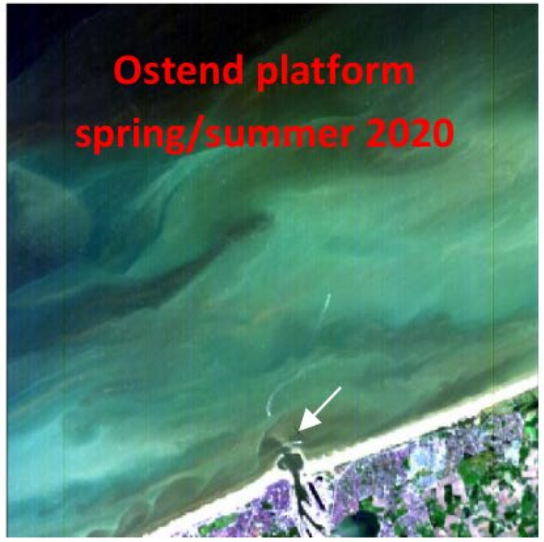
Argentina
Latitude : -35,58°N
Longitude: -58,08°W

Ponctual TriOS measurement

1 match-up

Belgium waters
Latitude : 54,24°N
Longitude: 2,92°W

Mutispectral aeronet OC station



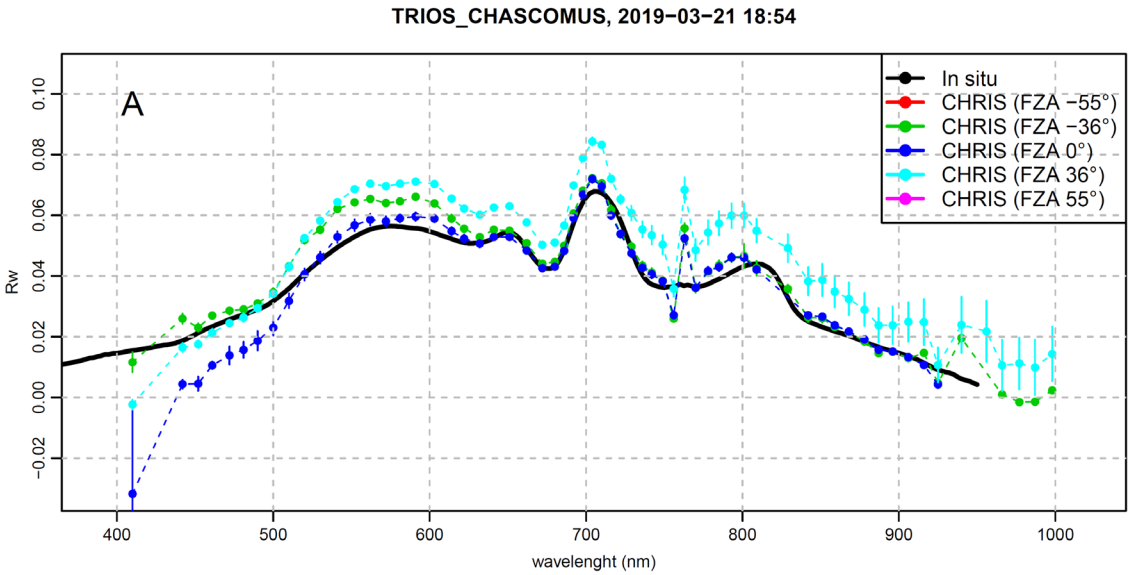
2 match-ups

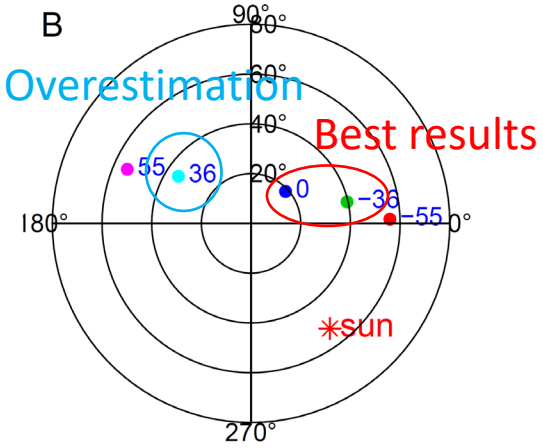
Belgium waters
Latitude : 51,35°N
Longitude: 3,17°W

Hyperspectral autonomous station (PANTHYR)

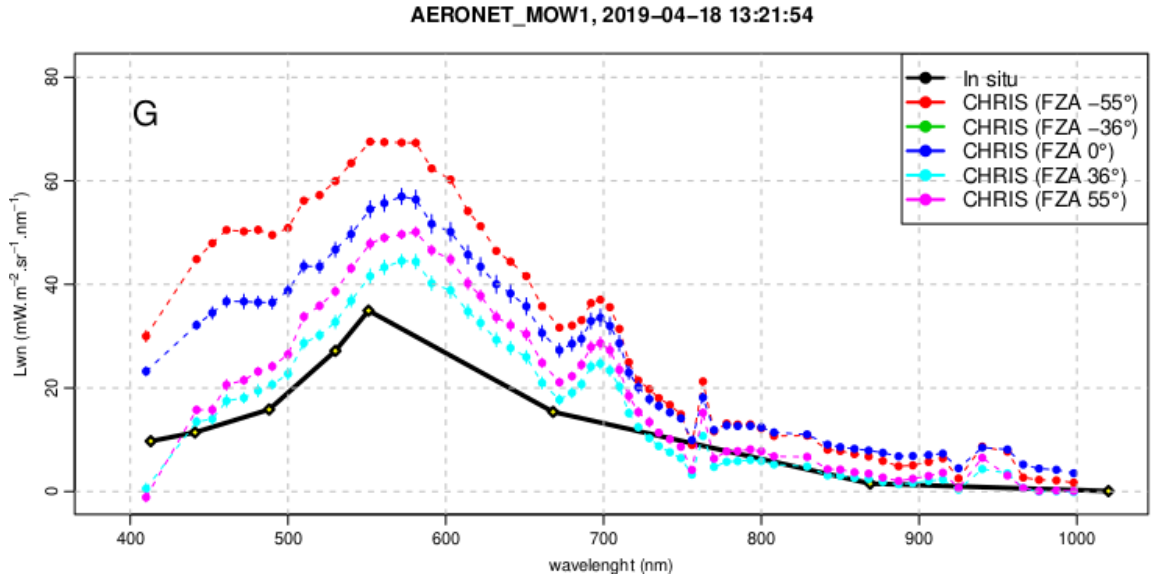
Validation : against in situ measurements (1/3)

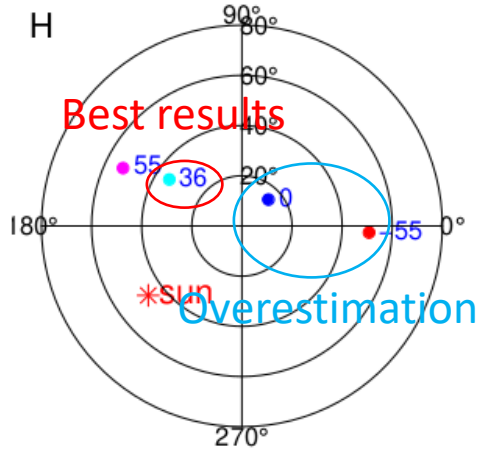
Chascomus
Argentina





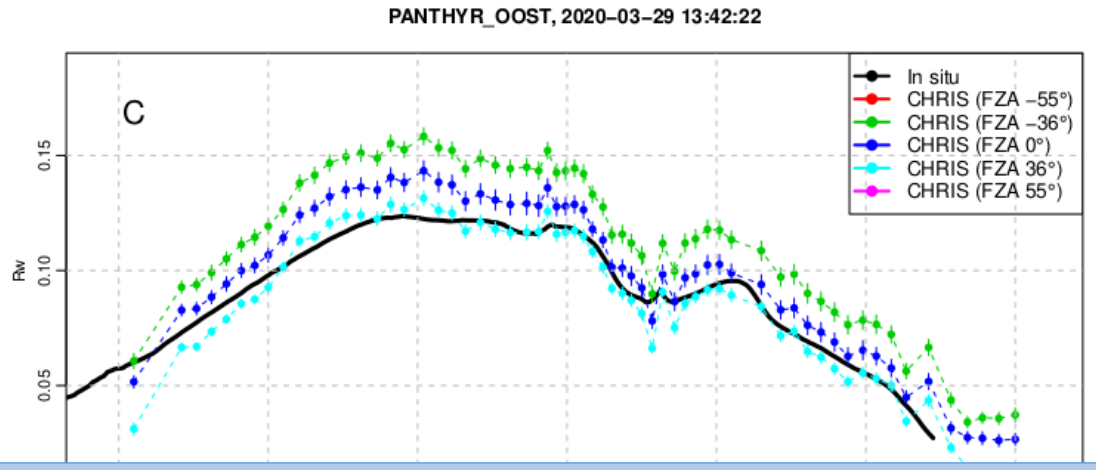
MOW-1
North Sea

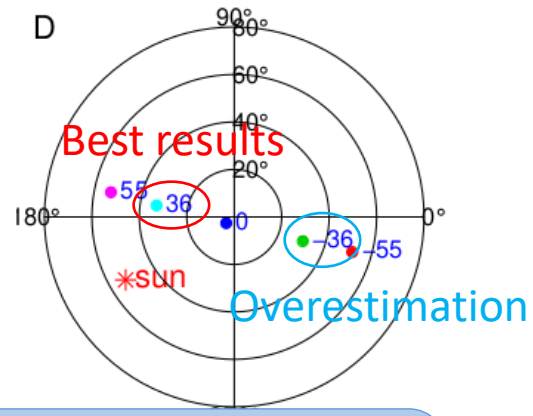




Validation : against in situ measurements (2/3)

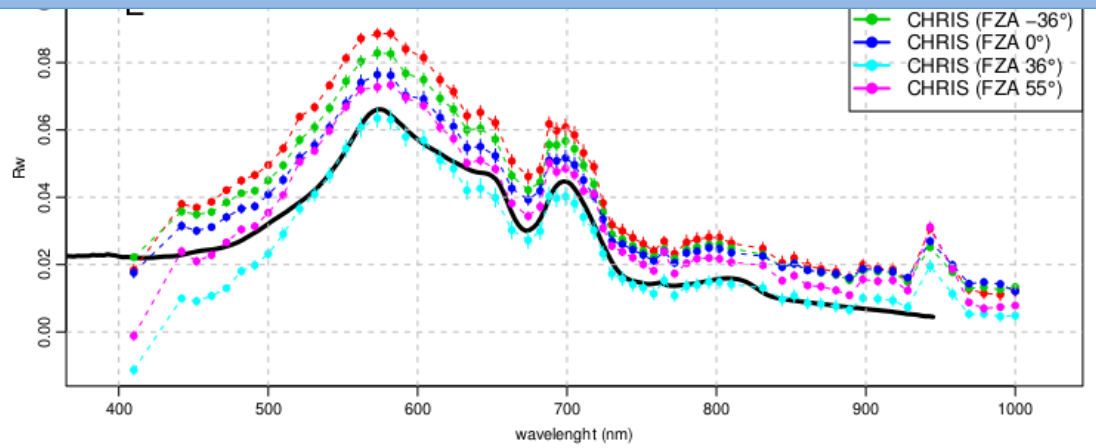
Ostend
North Sea

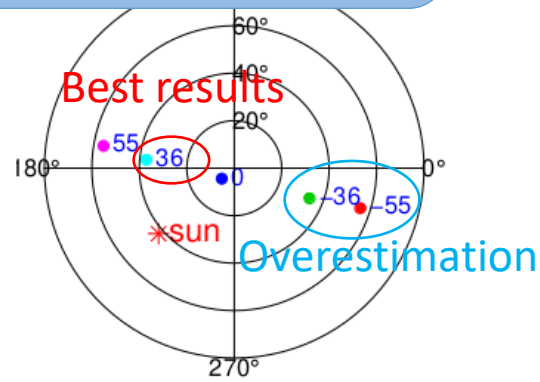




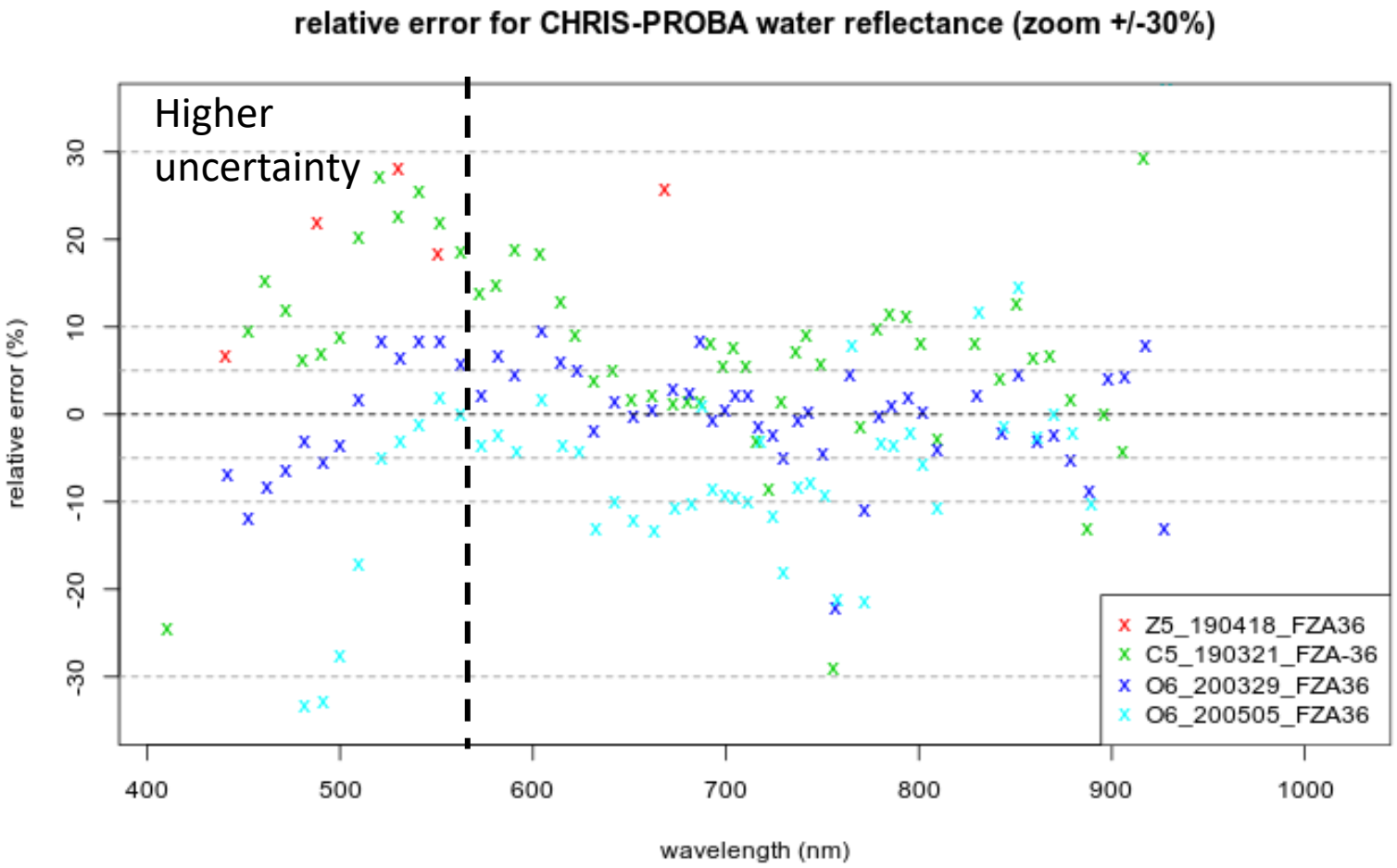
Best match-ups are always found for
with FZA = +/- 36° with an azimuth angle viewing away from
the sun

Ostend
North Sea





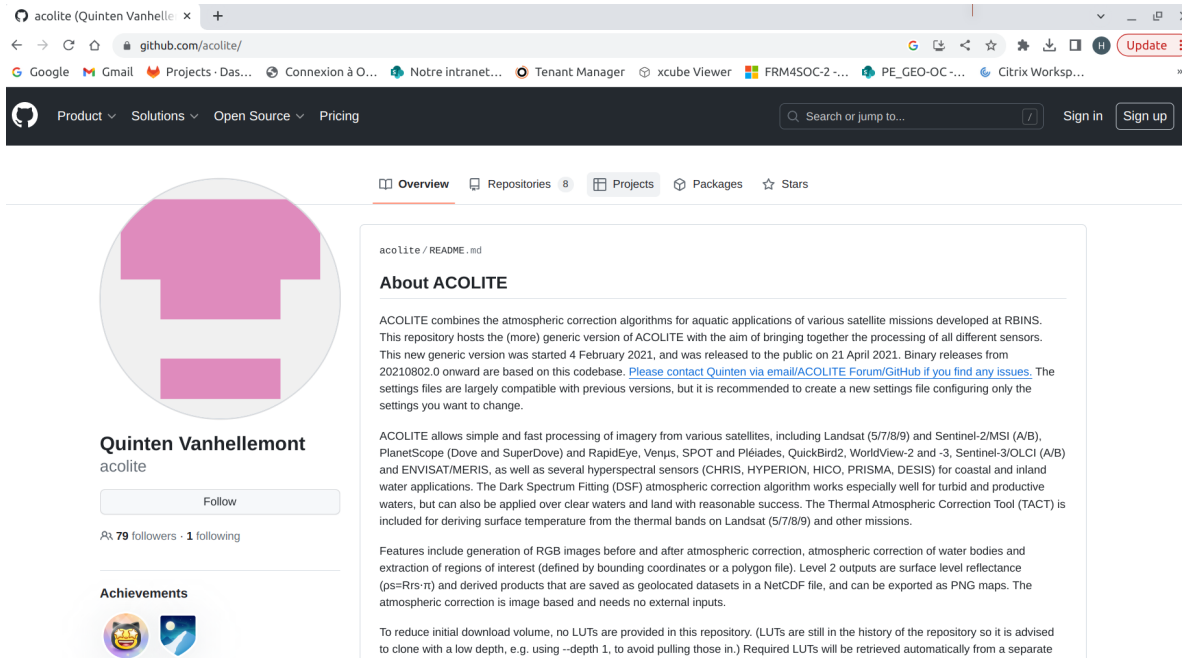
Validation : against in situ measurements (3/3)



ACOLITE processor for CHRIS-PROBA

https://github.com/acolite

Open source software for aquatic atmospheric correction
Includes many sensors (S2, S3, Landsat, Pléiades, superDove, PRISMA, etc.)
In 2021, CHRIS-PROBA has been added.

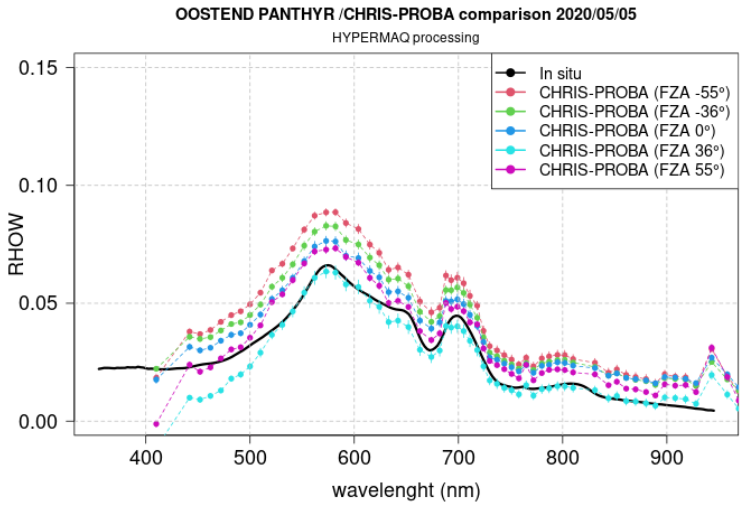


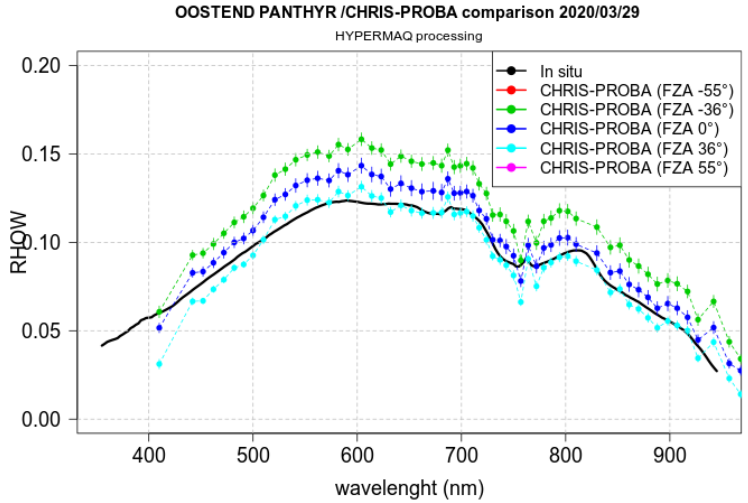
ACOLITE for CHRIS-PROBA

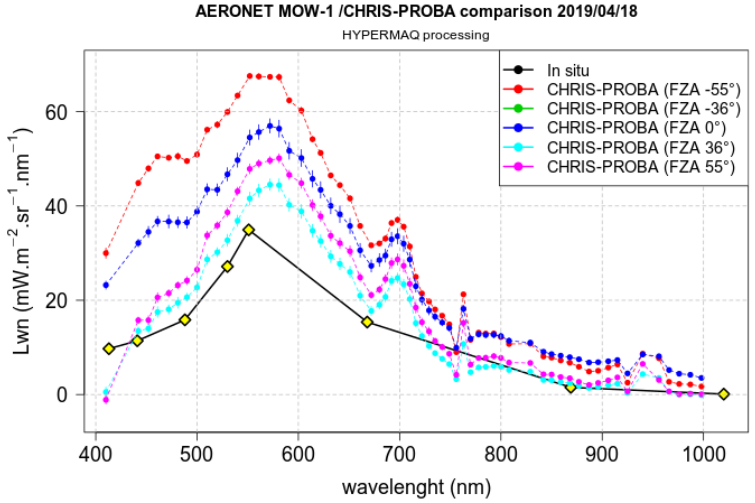
- Noise Reduction (Gomez-Chova et al. 2008)
- Inter-band relative calibration (Lavigne and Ruddick, 2021 IGARSS proceeding)
- AC is based on DSF atmospheric correction (Vanhellemont et al., 2018)

Comparison of ACOLITE and SNAP CHRIS tool box processing

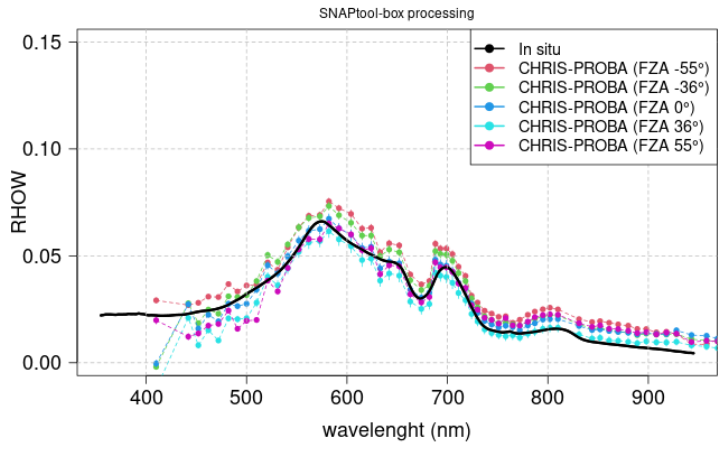
DSF - ACOLITE

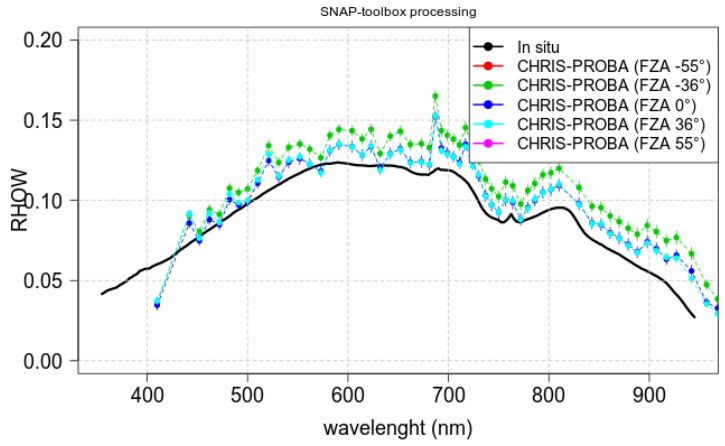


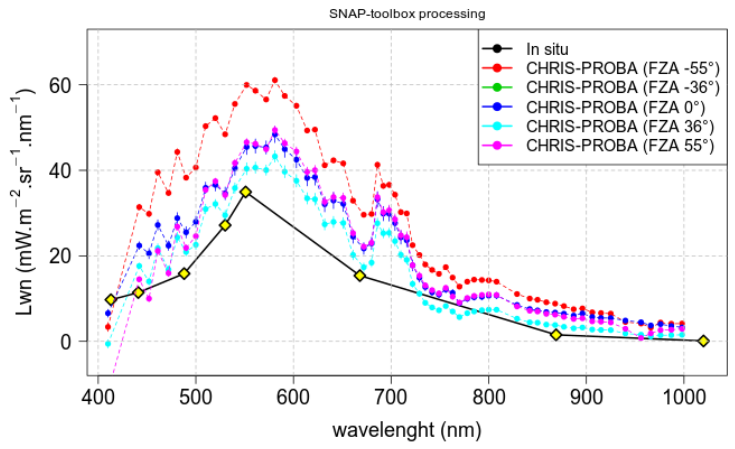




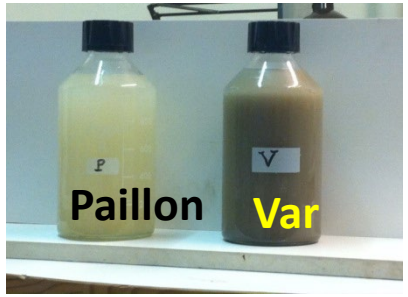
SNAP – CHRIS TOOL BOX

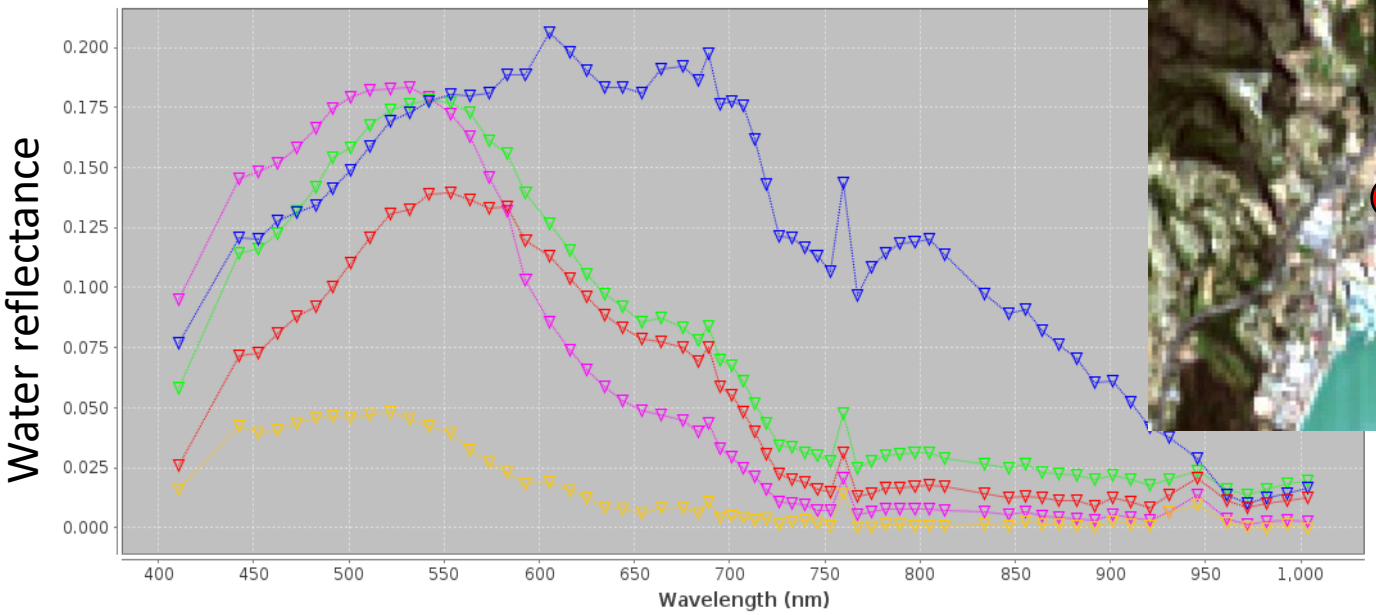


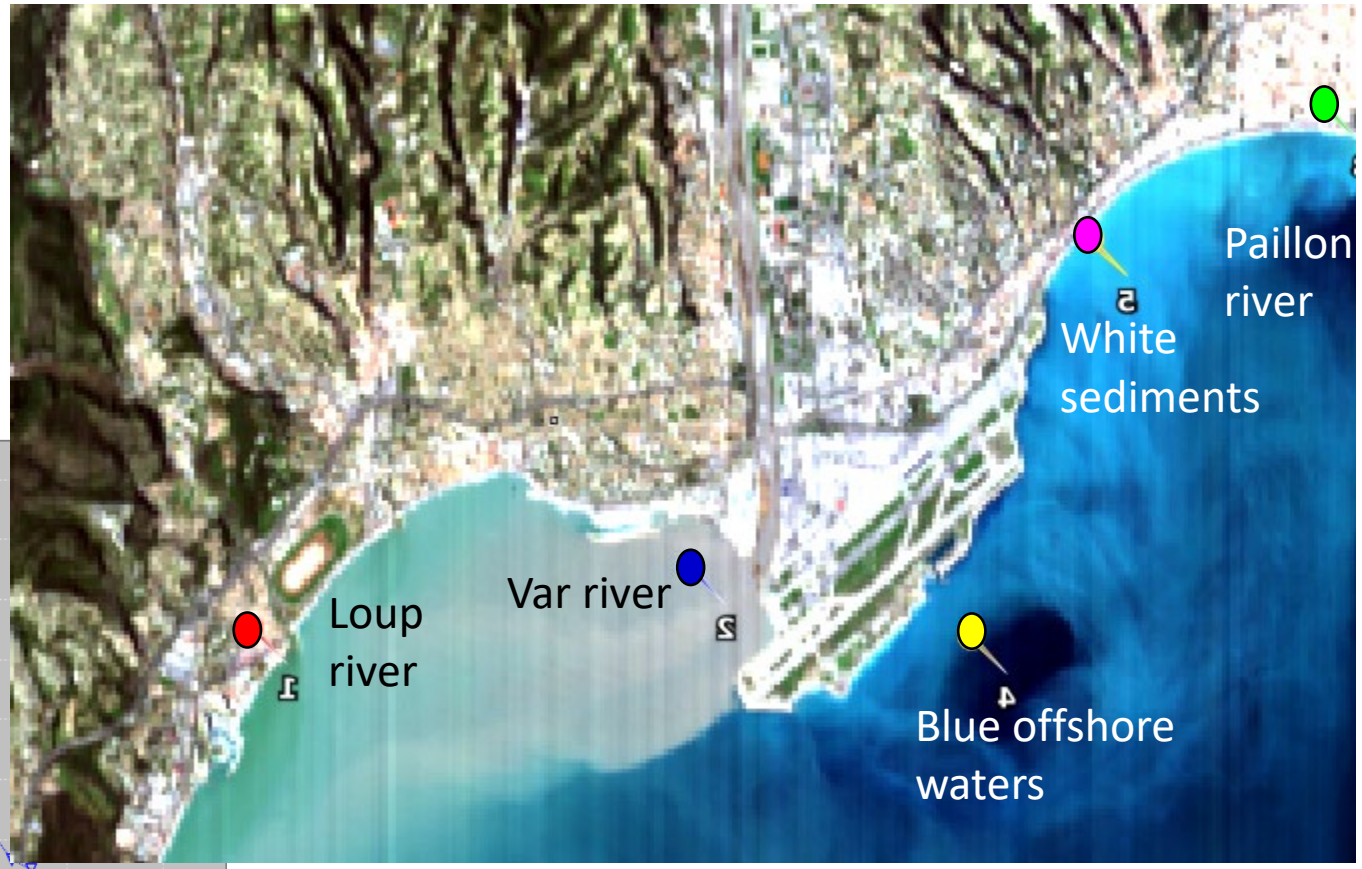




Retrieval of water constituents:
Suspended Particulate Matter (SPM)
Comparison of reflectance spectra for different rivers plume

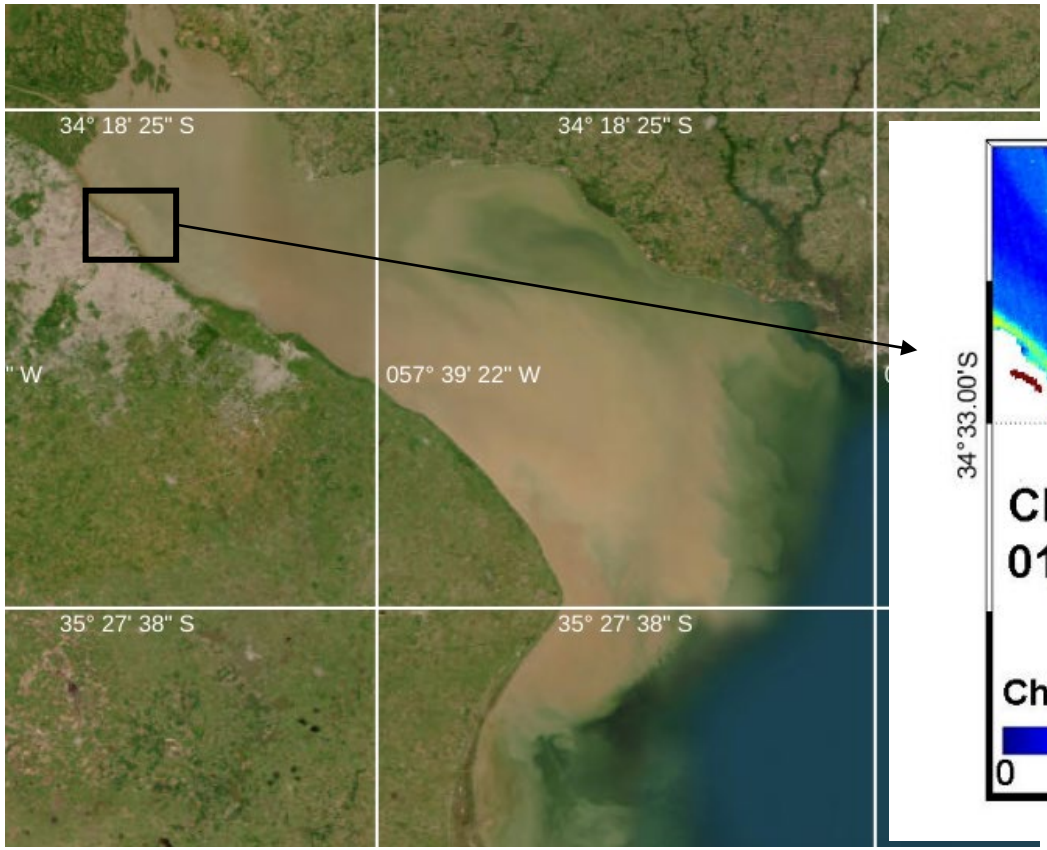


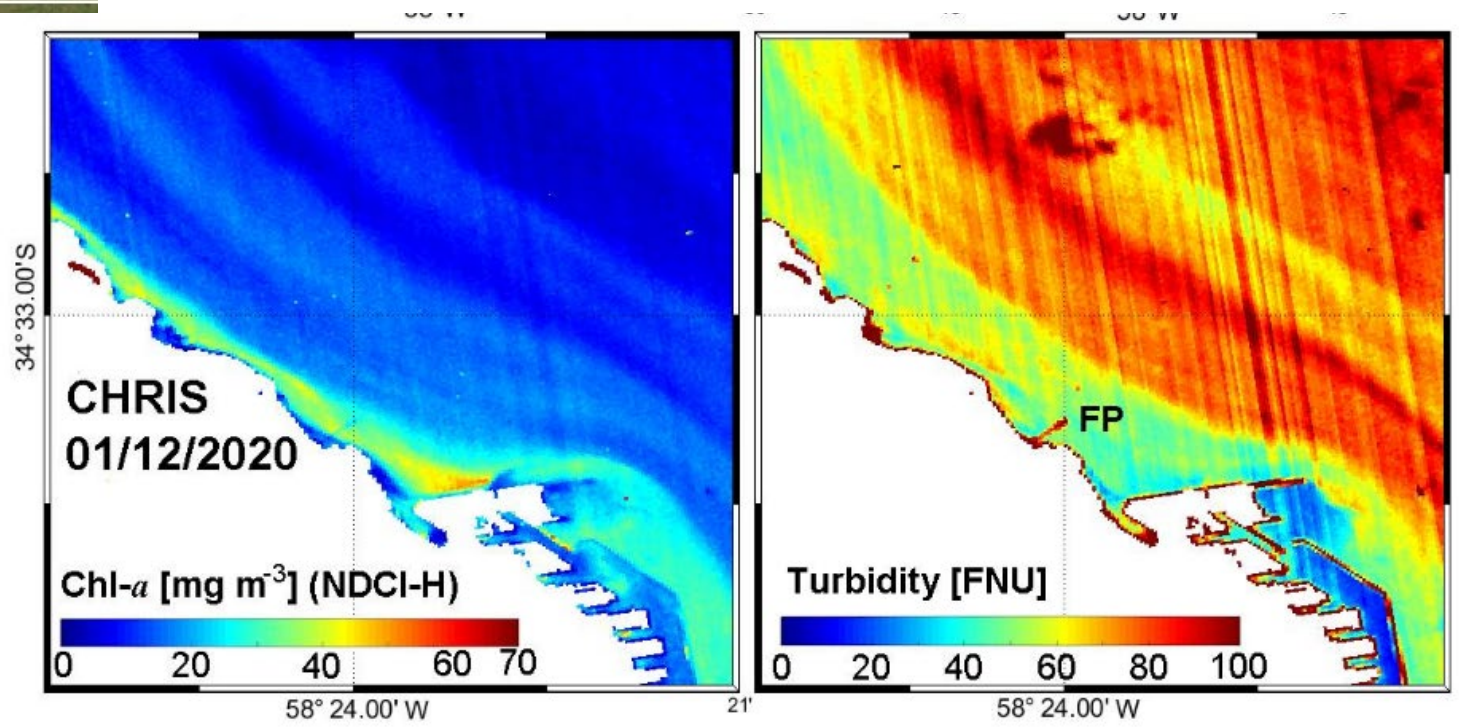




Retrieveing Chl-a in very complex waters (highly turbid waters of the Rio de la Plata Argentina)

Use of an hyperspectral algorithm (Dogliotti et al., 2021 IGARSS proceedings)





P. Globosa blooms in the Southern North Sea monitored with in situ hyperspectral system (PANTHYR)

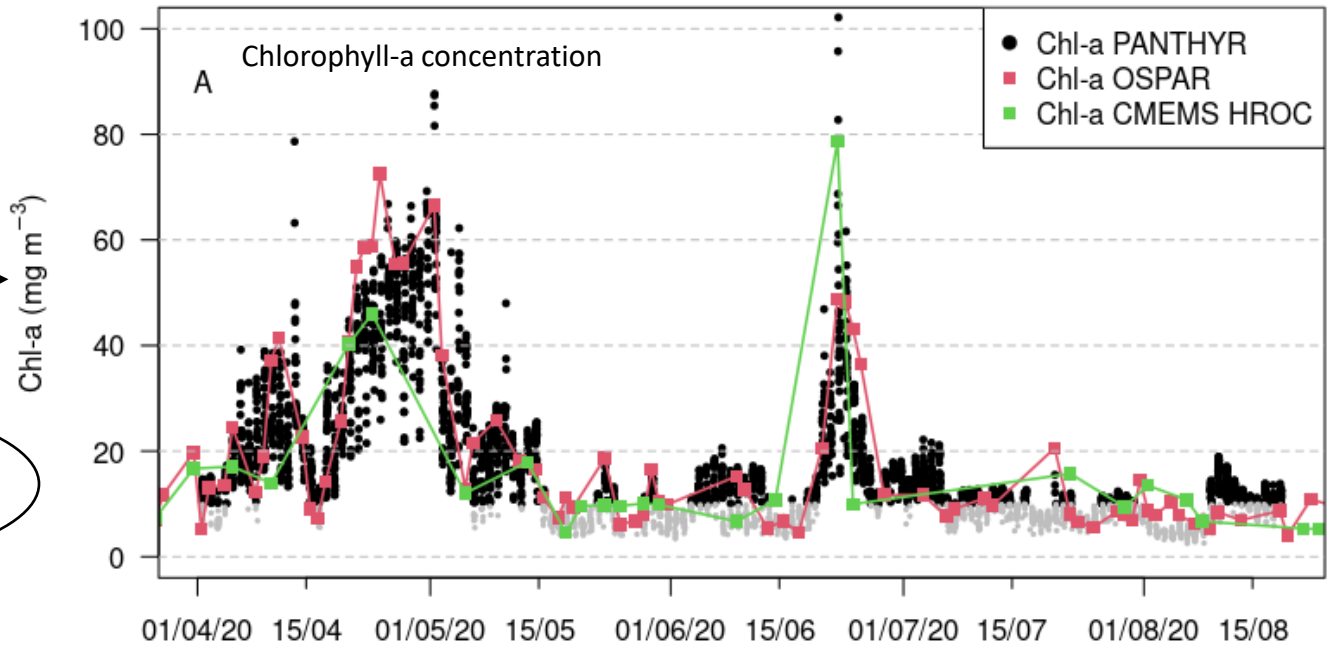
- Develop at spring after a diatom bloom in April-May
- Not toxic but produces a foam that accumulates on beaches (negative economic impact). This can lead to dramatic accidents.
- Monitored in the OSPAR program
- Monitored at spring 2020 with a PANTHYR System.
  - TRIOS acquisitions for water reflectance
  - Every 20 minutes
  - From sunrise to sunset.

P. globosa foam on the beach

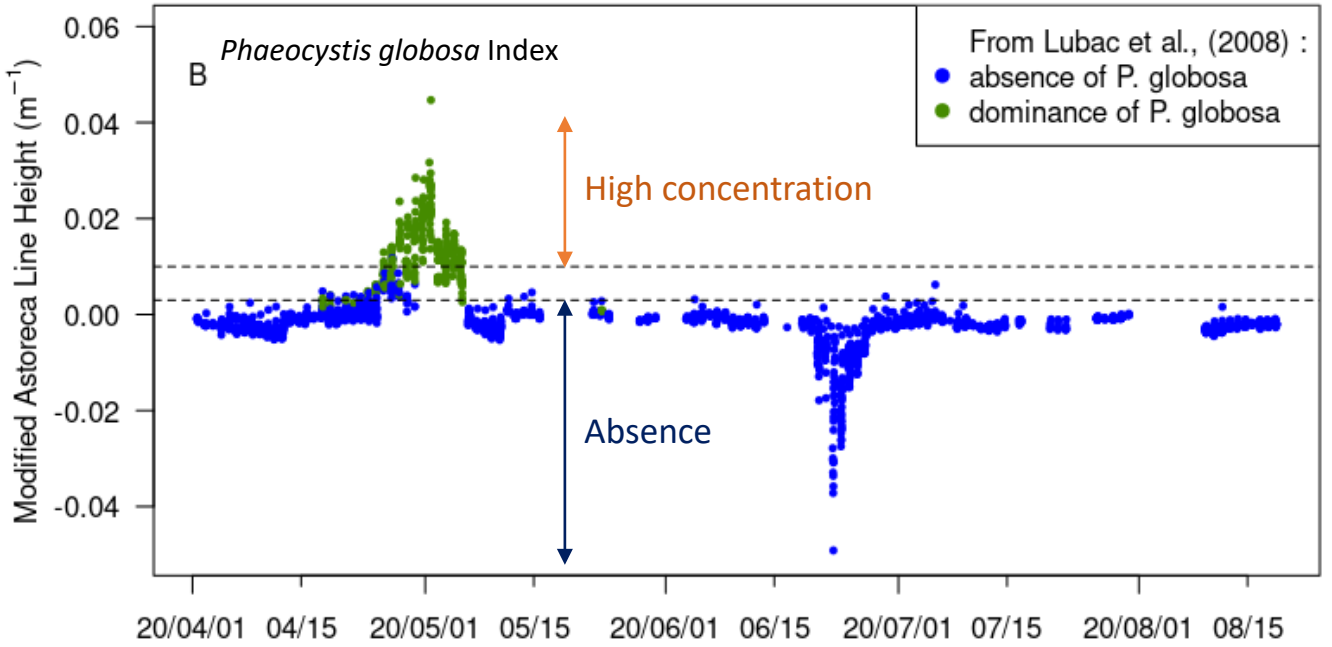
https://www.blueaccelerator.be/

Chl-a and *P. globosa* index time-series

Calculated from CRAT algo. (Ruddick et al., 2001)

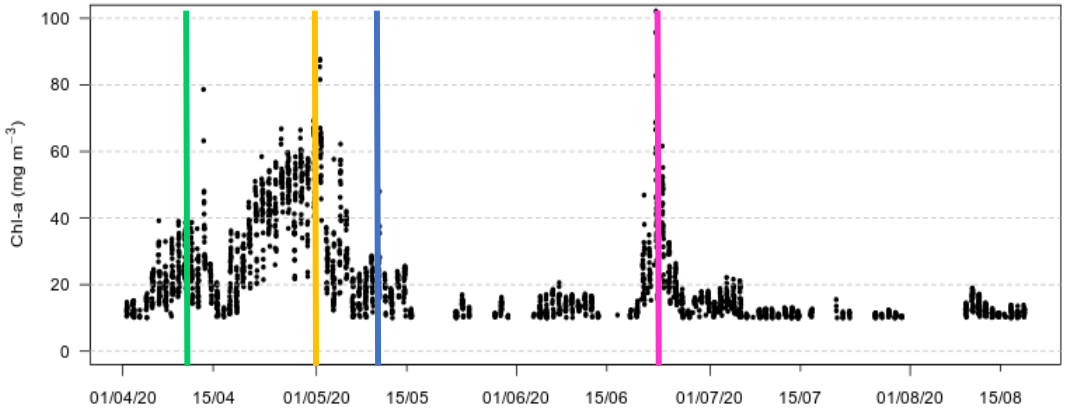


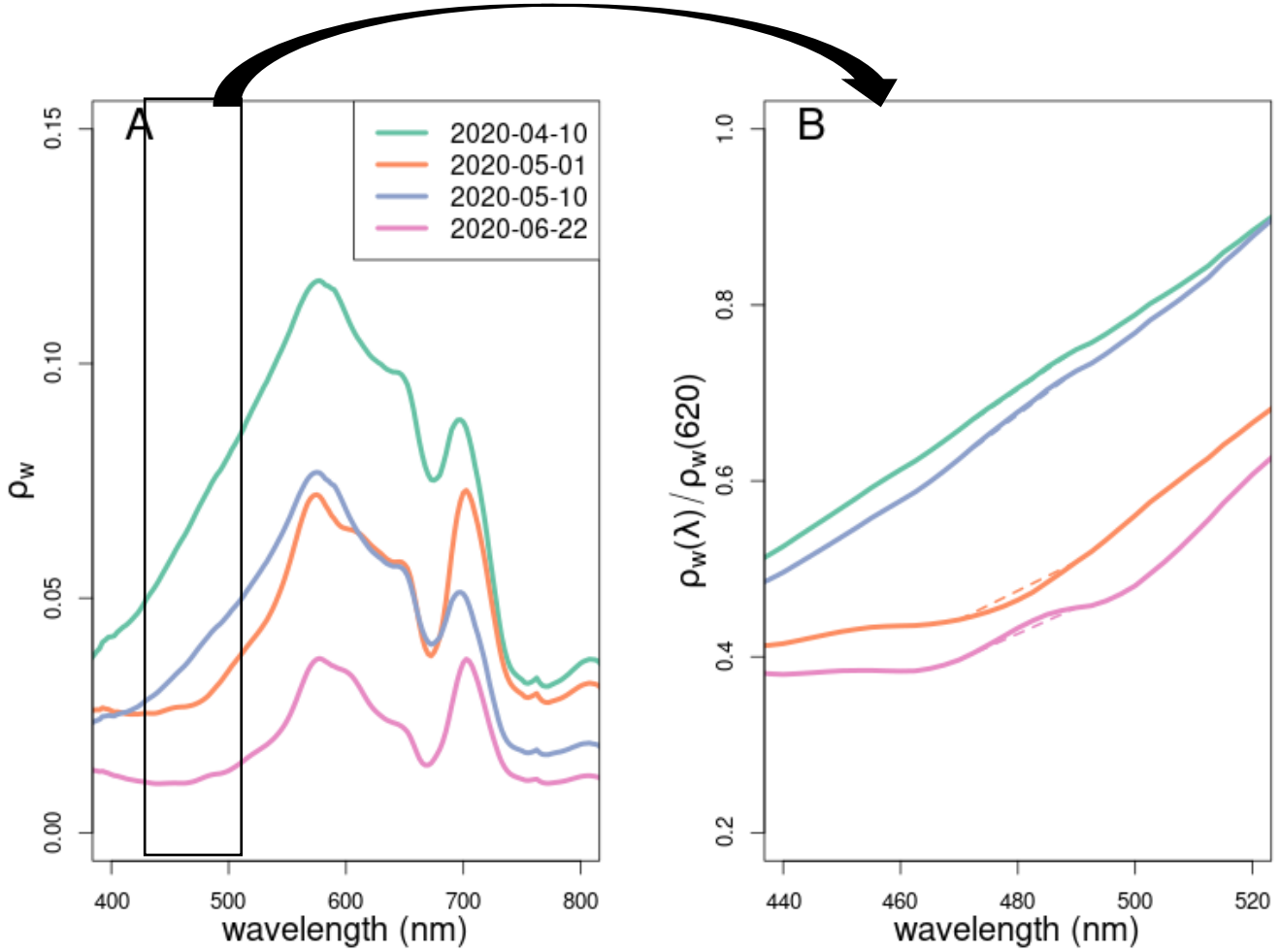
Adapted from Astoreca et al., 2008

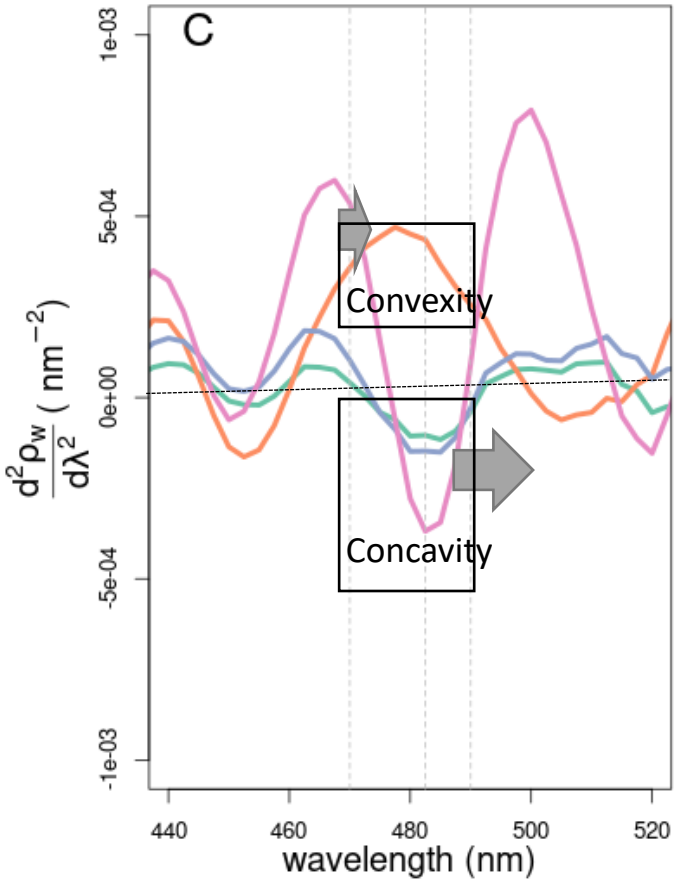


From Lavigne et al. 2022

Analysis of the second derivative for *P. globosa* indexes







Lubac et al. (2008)
Shift in second derivative minima and maxima

Lavigne et al., 2022
Line height algorithm in the 470 nm – 490 nm range, because of positive/negative second derivative

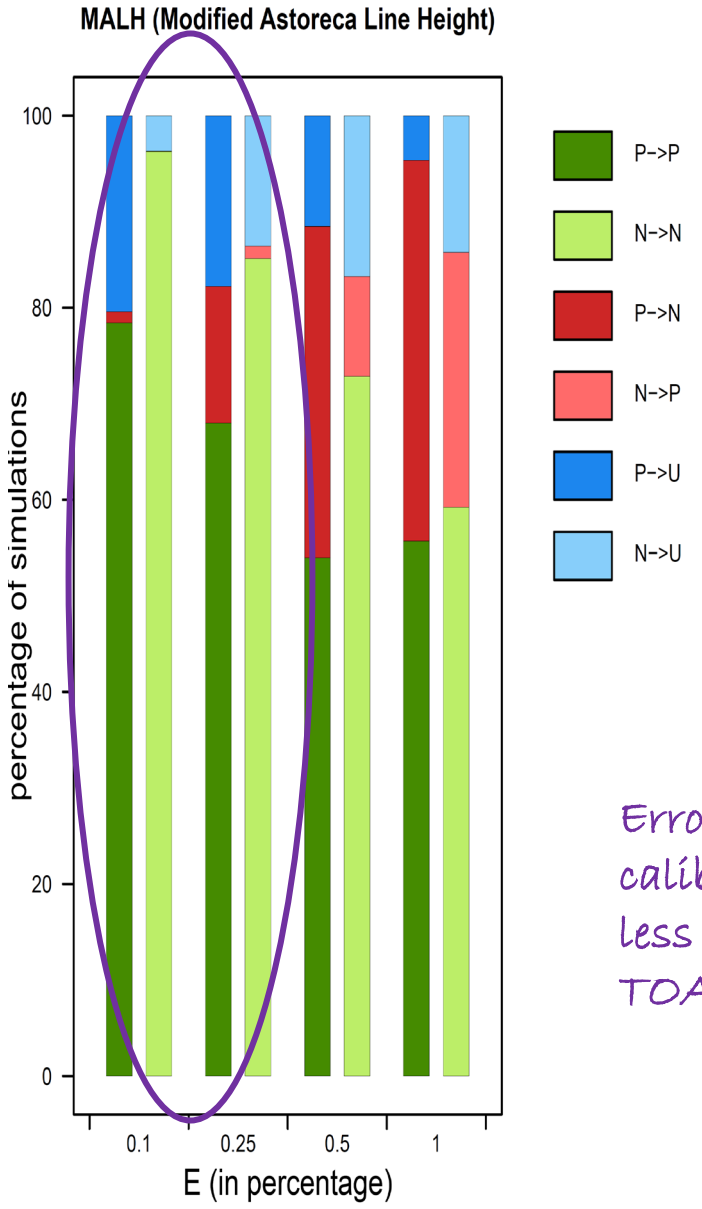
From Lavigne et al. 2022

Analysis of the impact of inter-band calibration uncertainties

Simulation of uncertainties due to inaccurate inter-band calibration.
Random uncertainty for each spectral band

$$\Delta\rho_{RCAL}(\lambda_i) = \rho^{TOA}(\lambda_i)\, x(\lambda_i)$$

with $x(\lambda_i)$ drawn in a uniform distribution centered on 0 with std E (E=0,1%, 0,25%, 0,5%, 1%)



Error on inter-band calibration need to be less than 0,25% at TOA

From Lavigne et al. 2022

summary

- Demonstrate the **CHRIS hyperspectral** mode (mode 1) can be **used for coastal and inland water** targets.
- Propose a **dedicated processing** based on Dark Spectrum Fitting atmospheric correction with **inter-band relative uncertainty correction**.
- **Validation** shows **good results in general** except an under-estimation in the 400nm-500nm range.
- **ACOLITE** processor will integrate **CHRIS processor** in its next released.
- Demonstrate the **utility** of hyperspectral **CHRIS images** for certain applications
- Show the **limitations** of CHRIS-PROBA for applications based on **second derivatives** and pigment retrieval.
- **High need** to provide **very good inter-band relative calibration**

Level 2 CHRIS sample dataset and processor

Open sample dataset of Level 2 CHRIS mode 1 (hyperspectral) images Netcdf format

Site name	code	date	latitude	longitude
Chascomus	C5	2018-03-19	-35.58°N	-58.02°E
Chascomus	C5	2019-03-21	-35.58°N	-58.02°E
Le-Verdon	J4	2018-09-07	45.55°N	-1.04°E
Nice	N9	2018-10-22	43.65°N	7.20°E
Ostend	O6	2018-05-04	51.24°N	2.92°E
Ostend	O6	2020-05-05	51.24°N	2.92°E
Port-St-Louis	P5	2018-09-01	43.32°N	4.88°E
Pauillac	P6	2018-09-08	45.20°N	-0.74°E
Shanghai	Q3	2018-10-29	31.47°N	121.77°E
Thornton	T6	2019-04-04	51.53°N	2.95°E
Buenos-Aires	U2	2019-01-11	-34.56°N	-58.40°E
Buenos-Aires	U2	2020-03-01	-34.56°N	-58.40°E
Zeebrugge	Z5	2018-08-31	51.35°N	3.17°E

ftp://ftp.rbins.be/heloise/IGARSS2021_DATA_SUP/L2_CHRIS_sample_dataset_IGARSS2021.zip

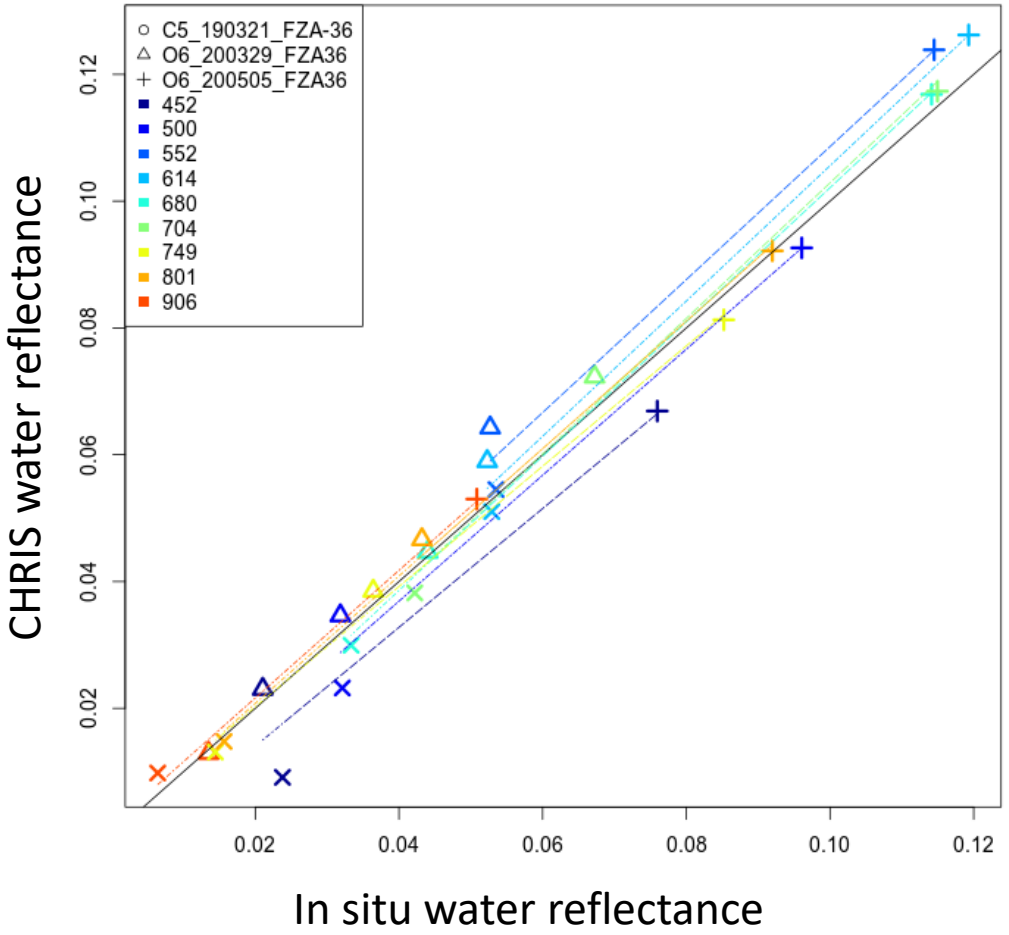
PROCESSOR

ACOLITE: https://github.com/acolite/acolite

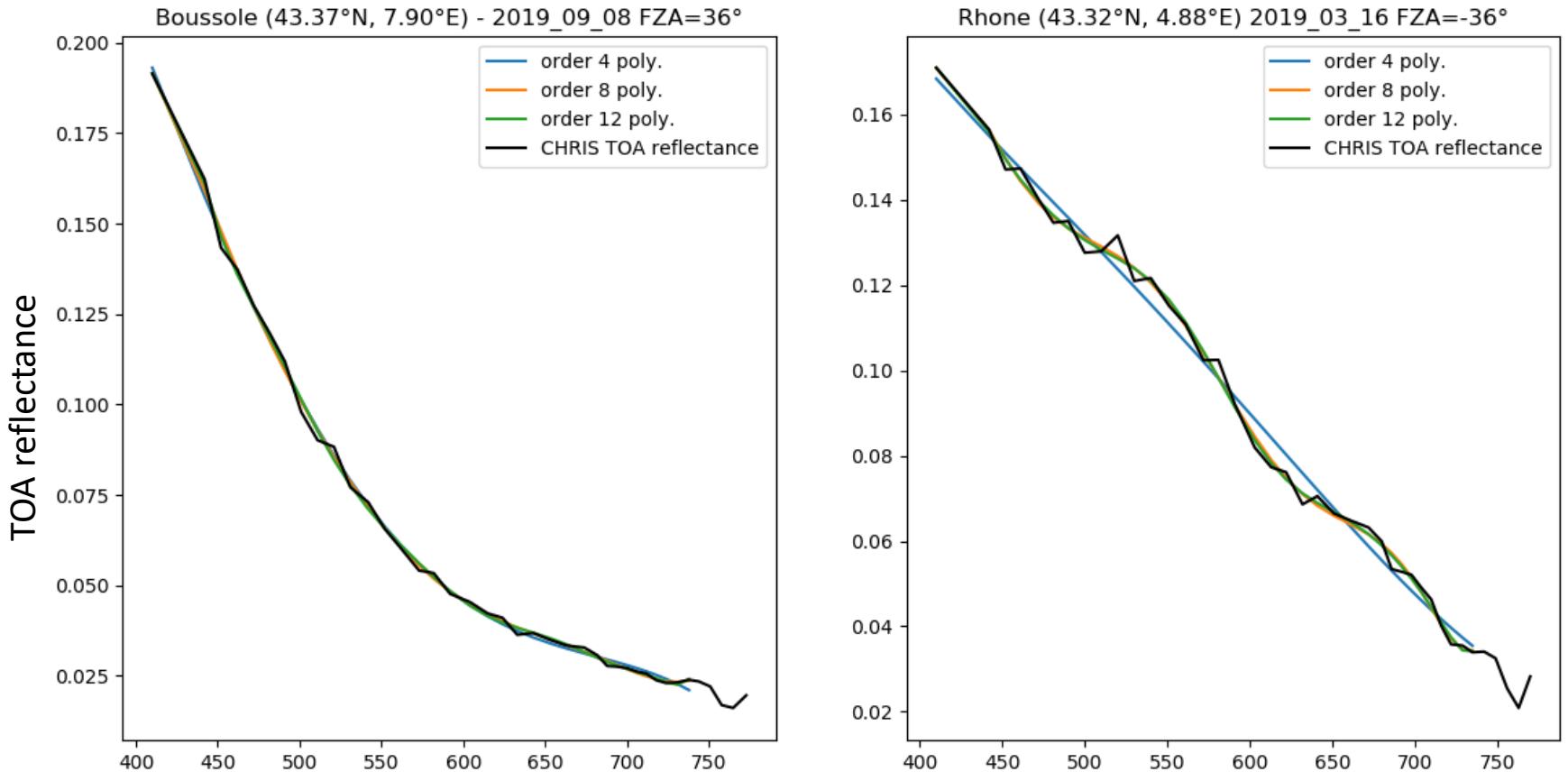
ACOLITE for CHRIS already available in the beta version

Very soon : release of the ACOLITE including CHRIS processor

Validation : against in situ measurements (summary)



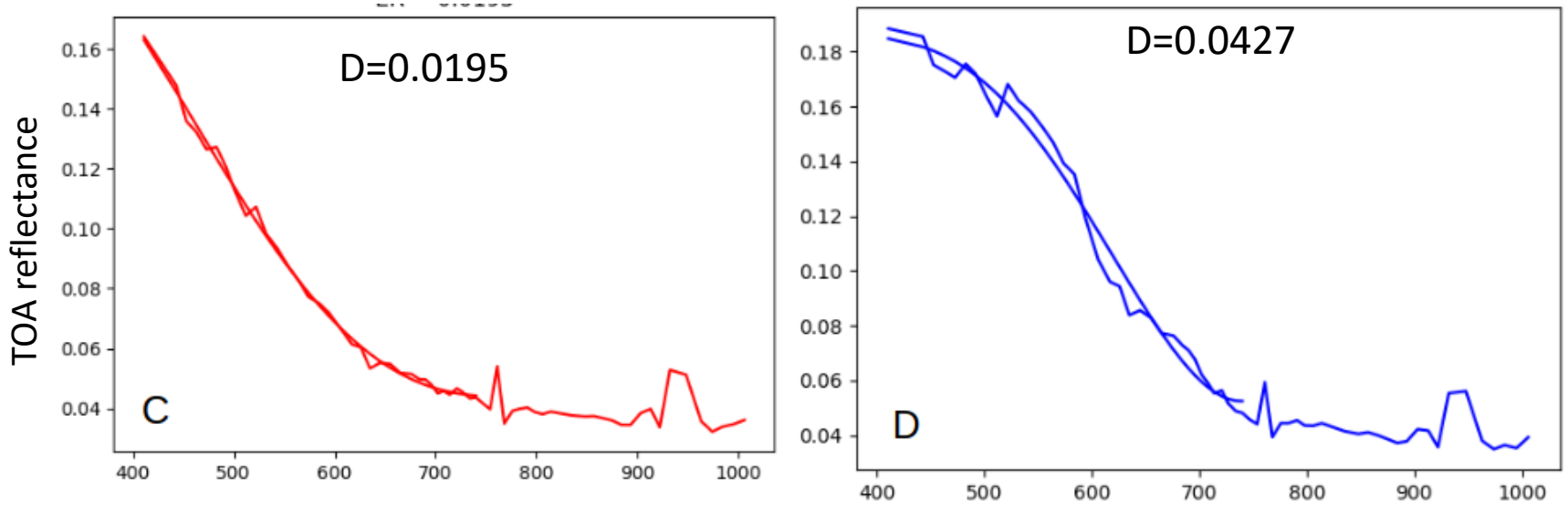
Inter-bands calibration : selection of polynomial degree



8 degree polynomial is the minimum polynomial degree which well fit different type of spectra

Inter-bands calibration : selection of fits (with D)

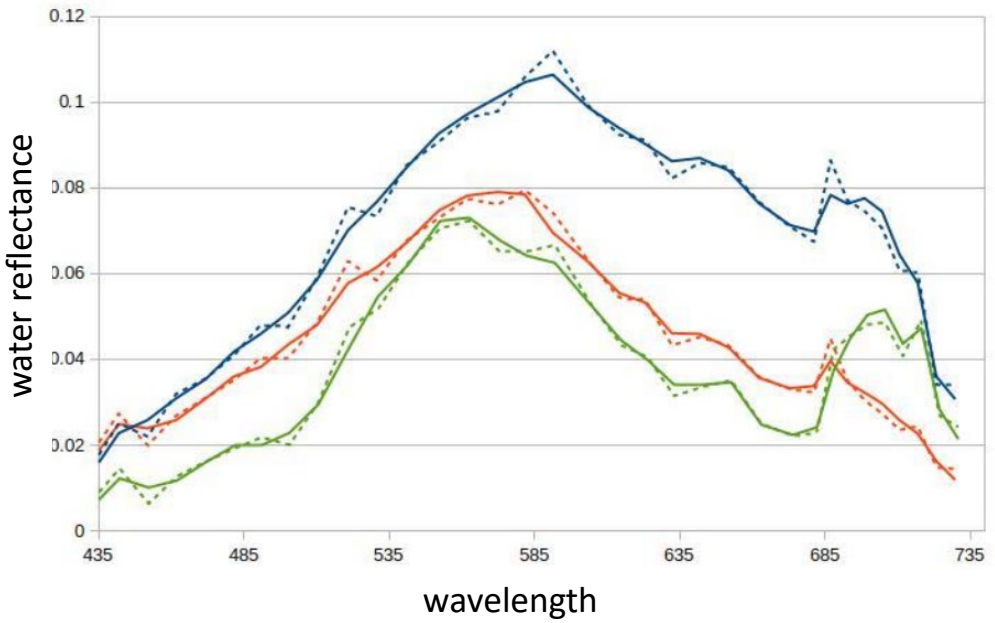
$$D = \frac{\sum_{i=1}^{36} |\rho_i - \rho_{smooth\,i}|}{\sum_{i=1}^{36} \rho_i}$$



D < 0.03
Spectra is well fitted
Spectra is retained for the computation of calibration coefficients

Spectral shape is too complex to be properly fitted. This spectra is not retained as D > 0.03

Validation

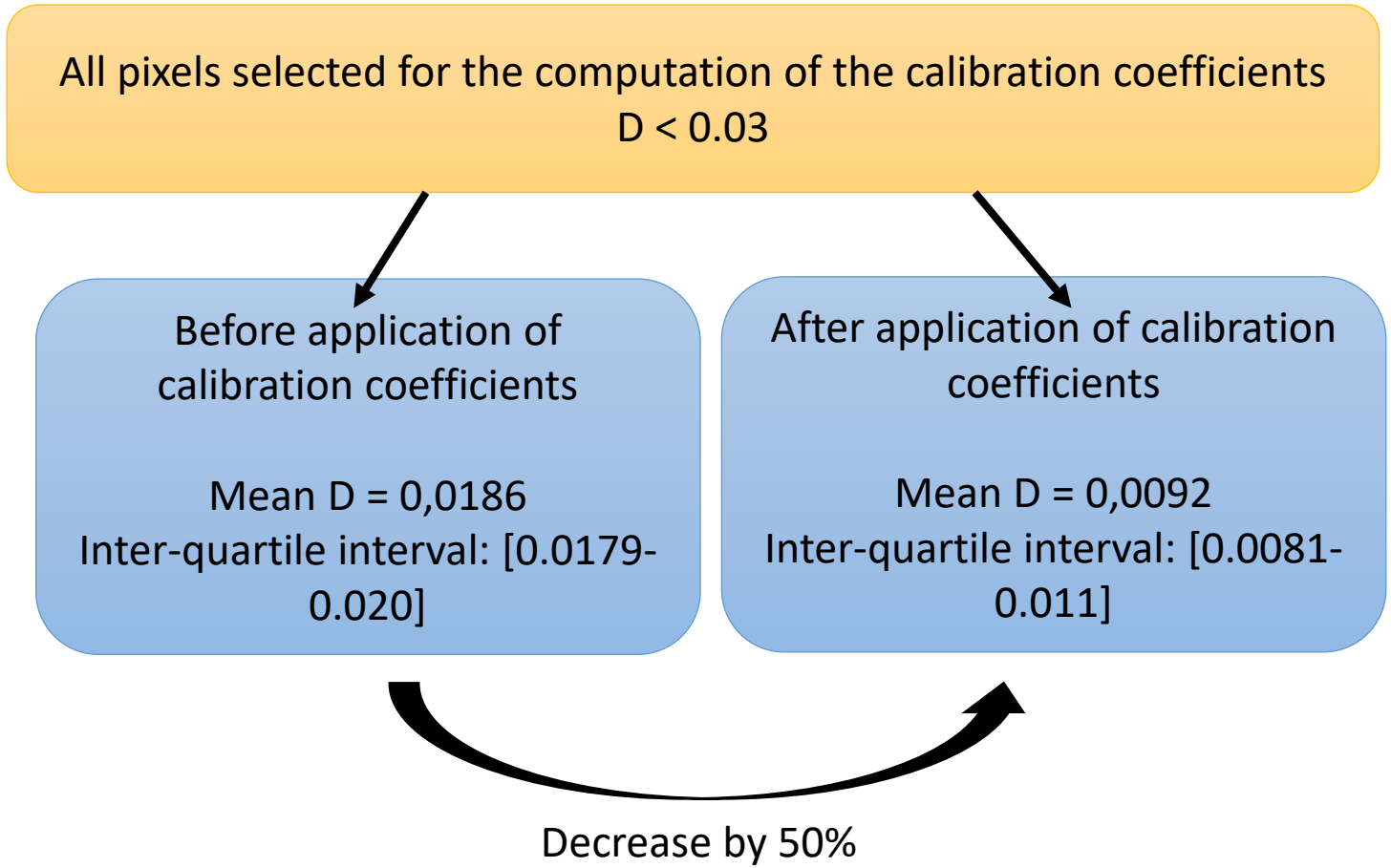


Buenos-Aires image on 2020-11-13 (-34.56°N, -58.40°E)

Etang de Berre image on 2019-09-11 (43.44°N, 5.10°E)

Ostend image on 2020-05-05 (51.24°N, 2.92°E)

Re-estimation on D parameter



Interband relative calibration (methods)