PONDER - Using metre scale optical satellite data for inland and coastal water applications

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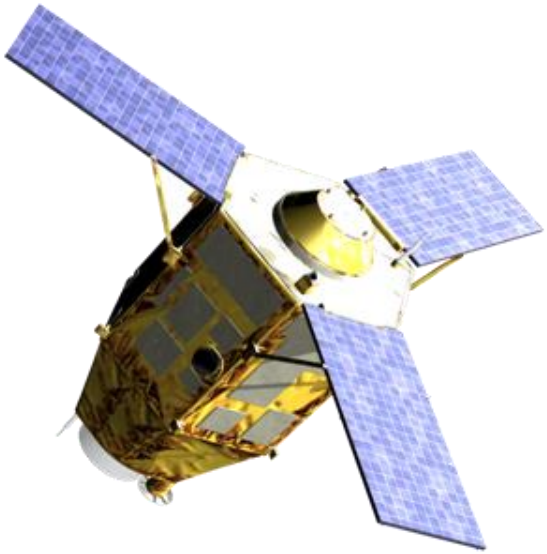
belspo PONDER SR/00/325

UNIVERSITEIT GENT

museum

LOV



Pléiades constellation

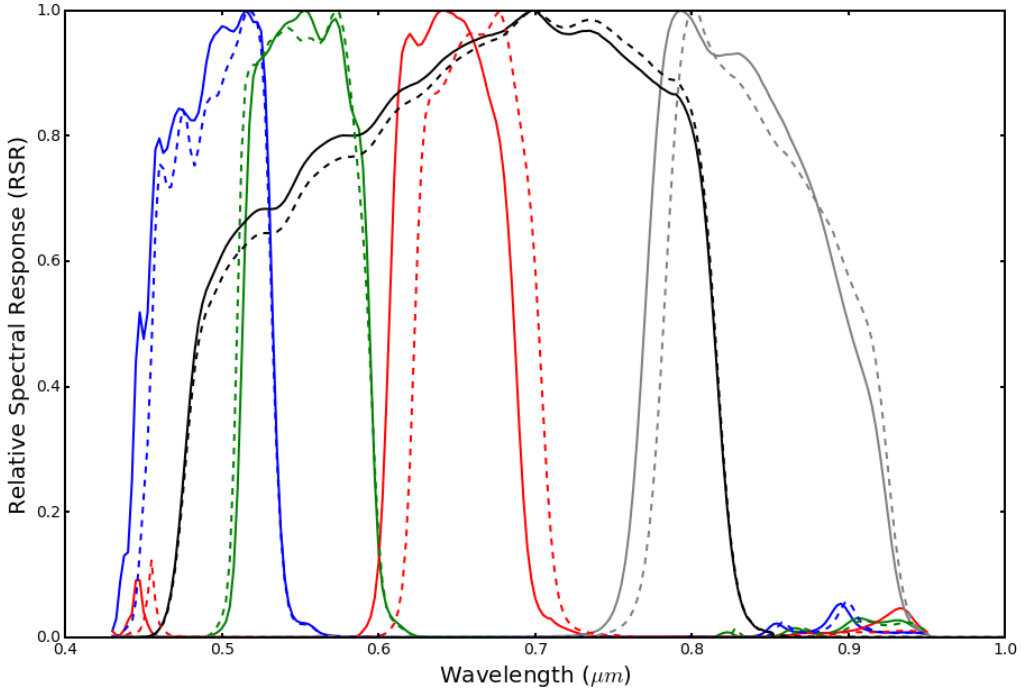
- 2 pointable very high resolution satellites
- four 2.8 m spectral bands, one 0.7 m pan
- very affordable for Belgian public institutions

Challenges

- Atmospheric correction must be performed to retrieve accurate water reflectances

- 4 broad bands (100 nm VIS) that are not always « black » for coastal and inland waters

- Lack of validation data in coastal and inland waters



Relative spectral response of the 4 bands on Pléiades-1A (solid lines) and 1B (dashed lines).

PONDER Project

RBINS museum

atmospheric correction and processor, validation and VHR coastal applications

UPMC/LOV LOV

opportunistic campaigns, validation and VHR coastal/river applications

UGent UNIVERSITEIT GENT

inland water campaigns: planning and measurements, validation and VHR applications

BELSPO/STEREO-3 exploration project, 3 years, 2016-2018

mainly staff costs, but 60 Pléiades images requested from the programme

Results (1)
Inland water dataset

Spuikom

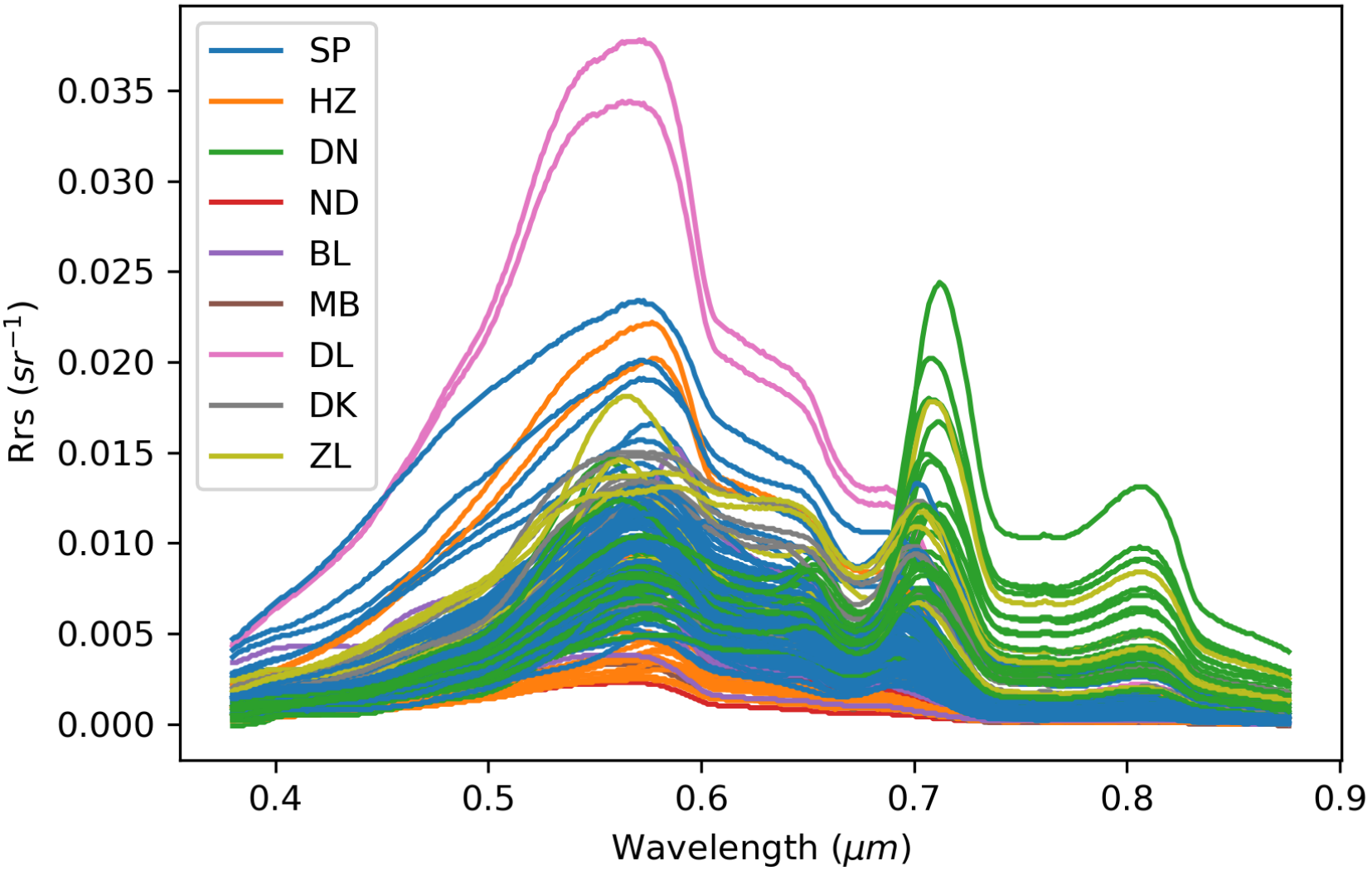
Donkmeer

Dikkebus & Zillebeke

Hazewinkel & De Bocht

Samples:

- SPM and mineral fraction;
- Particle size distribution;
- Turbidity and Secchi;
- HPLC of pigments;
- *In vivo* particle absorption;
- CDOM absorption;
- Particle scattering;
- Microscopy taxonomy;
- **Water spectroscopy;**
- Macrophyte reflectance.



144 SBA spectra across sites and seasons, self-shading correction using backward MC model

Results (2)
A/C algorithm

Dark Spectrum Fitting A/C

Assumptions -

a. the atmospheric conditions are homogeneous within the (sub)scene, and
b. a target with negligible signal in at least one spectral band exists in the scene.

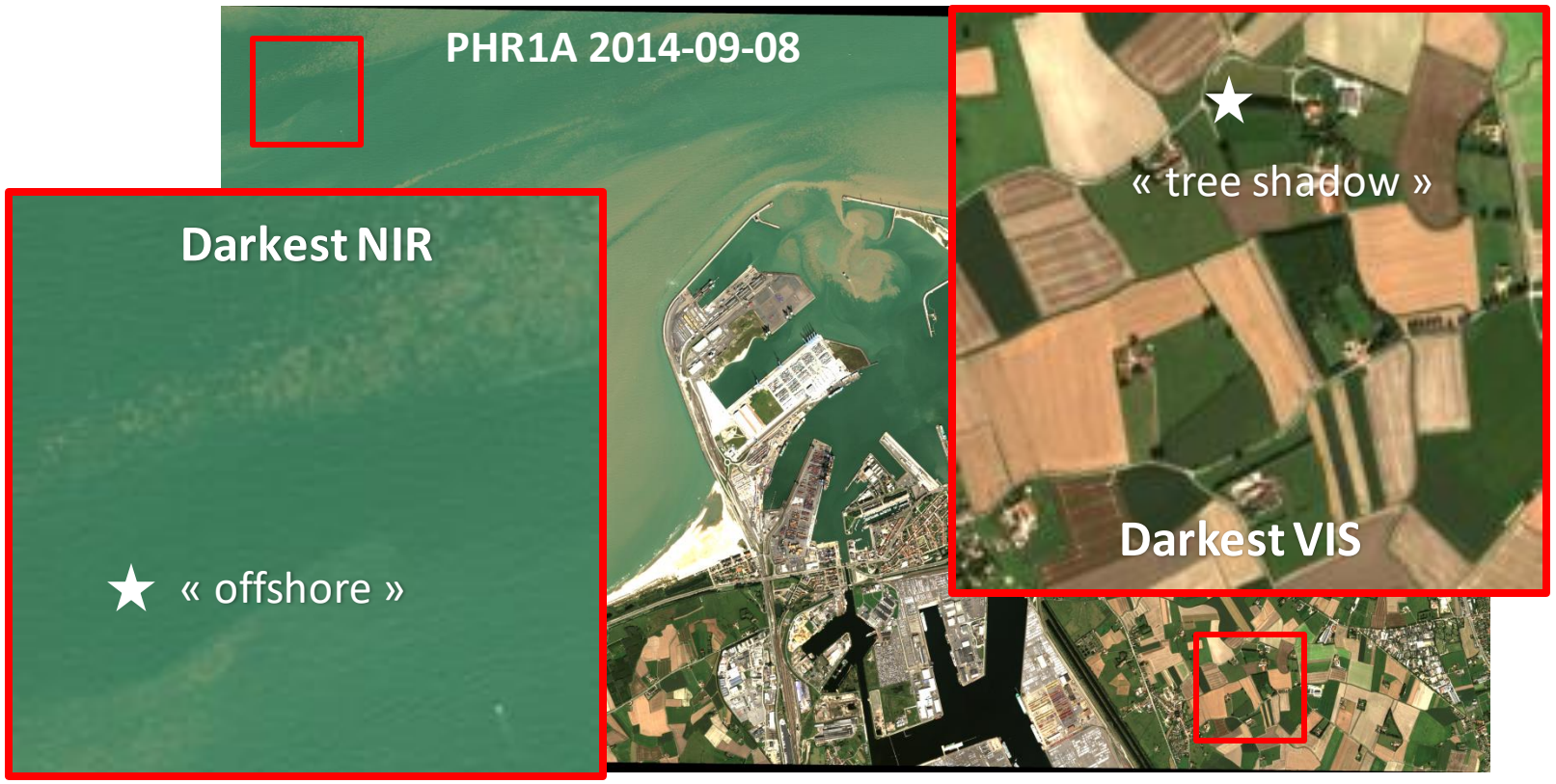
These exploit the main strength of the metre scale sensors: their resolution.

a. generally sensors have a narrow swath (20 km for Pléiades), and imagery can be tiled with enough pixels per tile (Pléiades has 250k pixels in a 1 km² tile)
b. suitable dark objects are more likely to be resolved: e.g. ground-level object shadows, clear or very absorbing water bodies – note that we are not a priori defining target types or bands to be used in the a/c

Vanhellemont & Ruddick (2018) **Atmospheric correction of metre-scale optical satellite data for inland and coastal water applications** https://doi.org/10.1016/j.rse.2018.07.015

Step 1: ρ_{dark} selection

A dark reflectance spectrum, ρ_{dark} (λ), is constructed to represent the darkest objects in the (sub)scene. The ρ_{dark} (λ) can represent different objects in different bands: e.g. ground-level object shadows, dense vegetation or highly absorbing waters in the Blue band, or clear waters in the red and NIR band.



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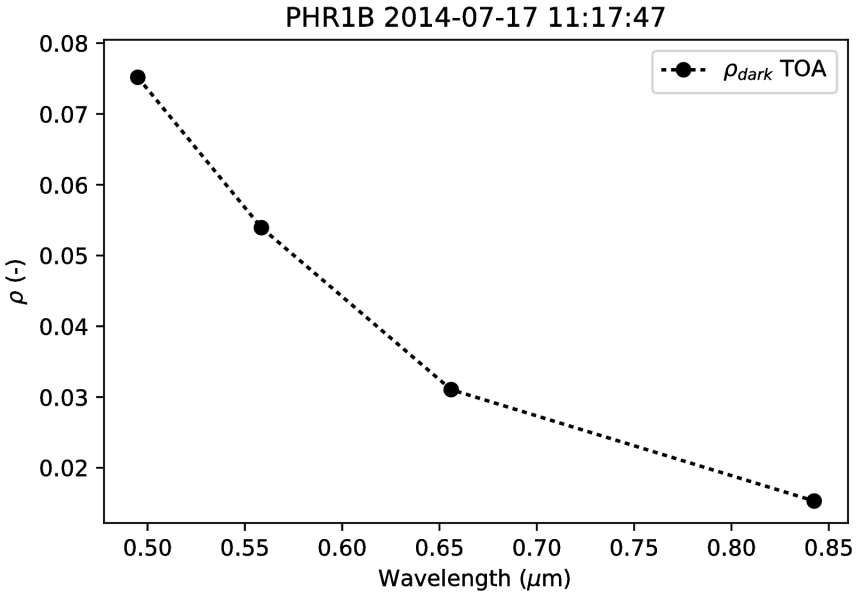
"dark spectrum"



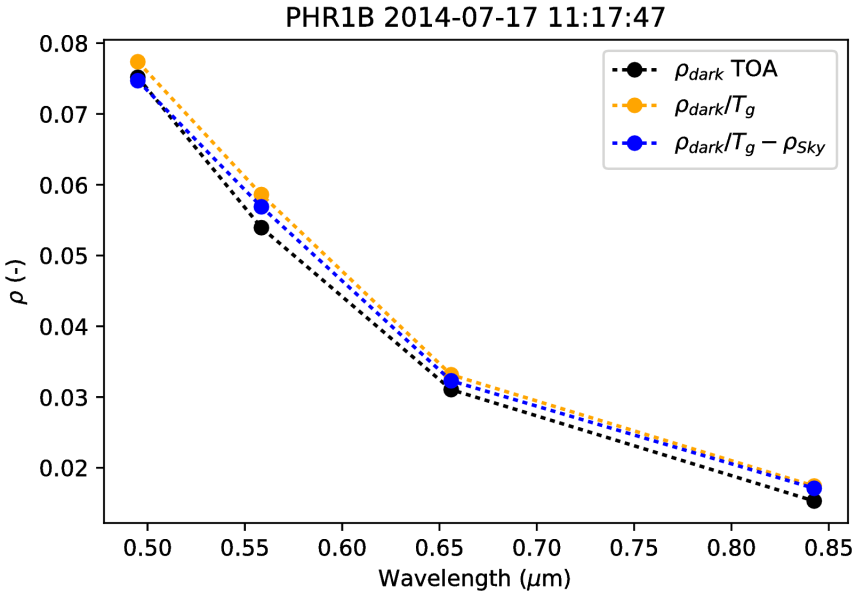
Step 2: Gas and Fresnel correction

The sky reflectance on the air-water interface (Fresnel reflectance) is computed based on the sun-sensor geometry using an analytical approximation, and is only subtracted for water scenes. (ρ_{sky} = 0 for land).

“dark spectrum”

gas corrected

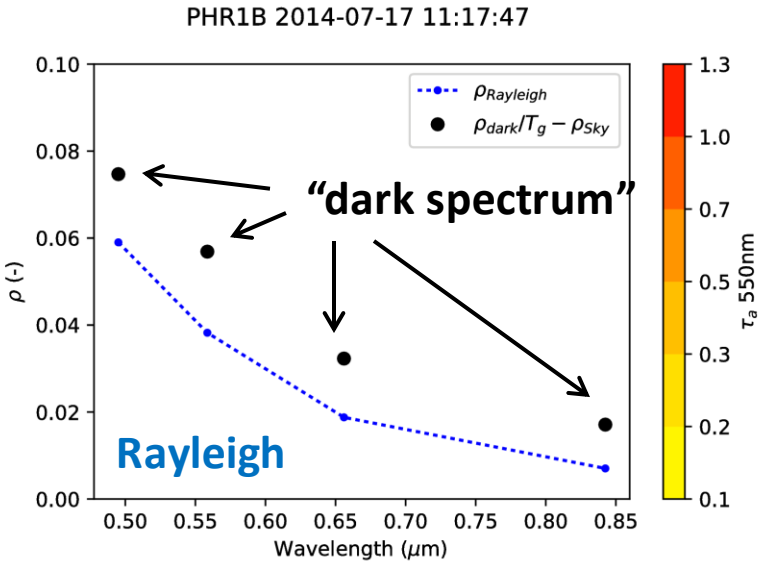
gas + sky corrected



Step 3: ρ_{dark} fitting

For each observation in the ρ_{dark}, a ρ_{path} is estimated for the sensor and sun geometry (θ_s, θ_v, $\Delta\phi$) for a number of aerosol models and optical thicknesses at 550 nm, $\tau_a 550$.

For every band λ, the two ρ_{path} (λ) values from the LUT, bounding the observed ρ_{dark} (λ) are located, and linearly interpolated to give a $\tau_a 550$ estimate per band, per model.



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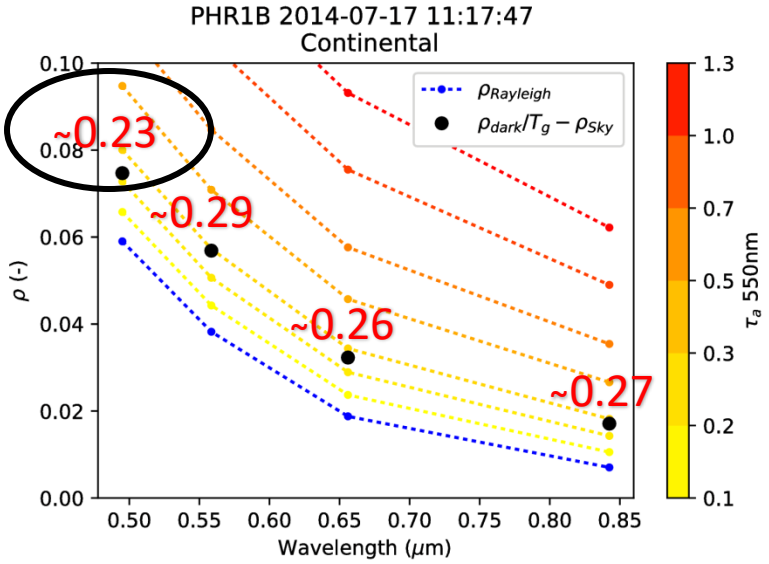
Continental aerosol: lowest $\tau_a 550$ for Blue



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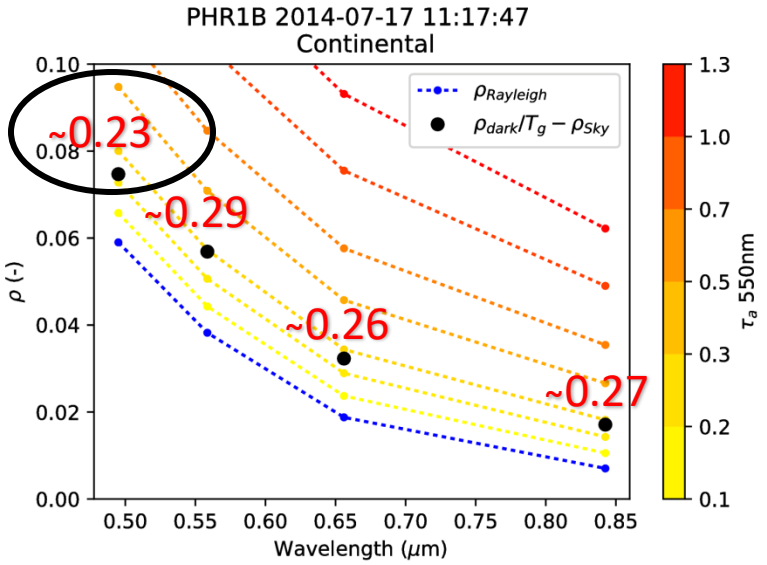
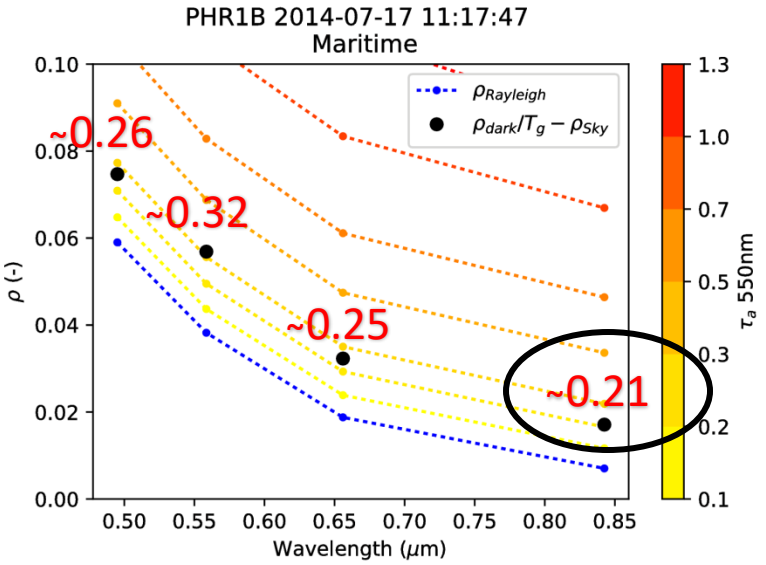


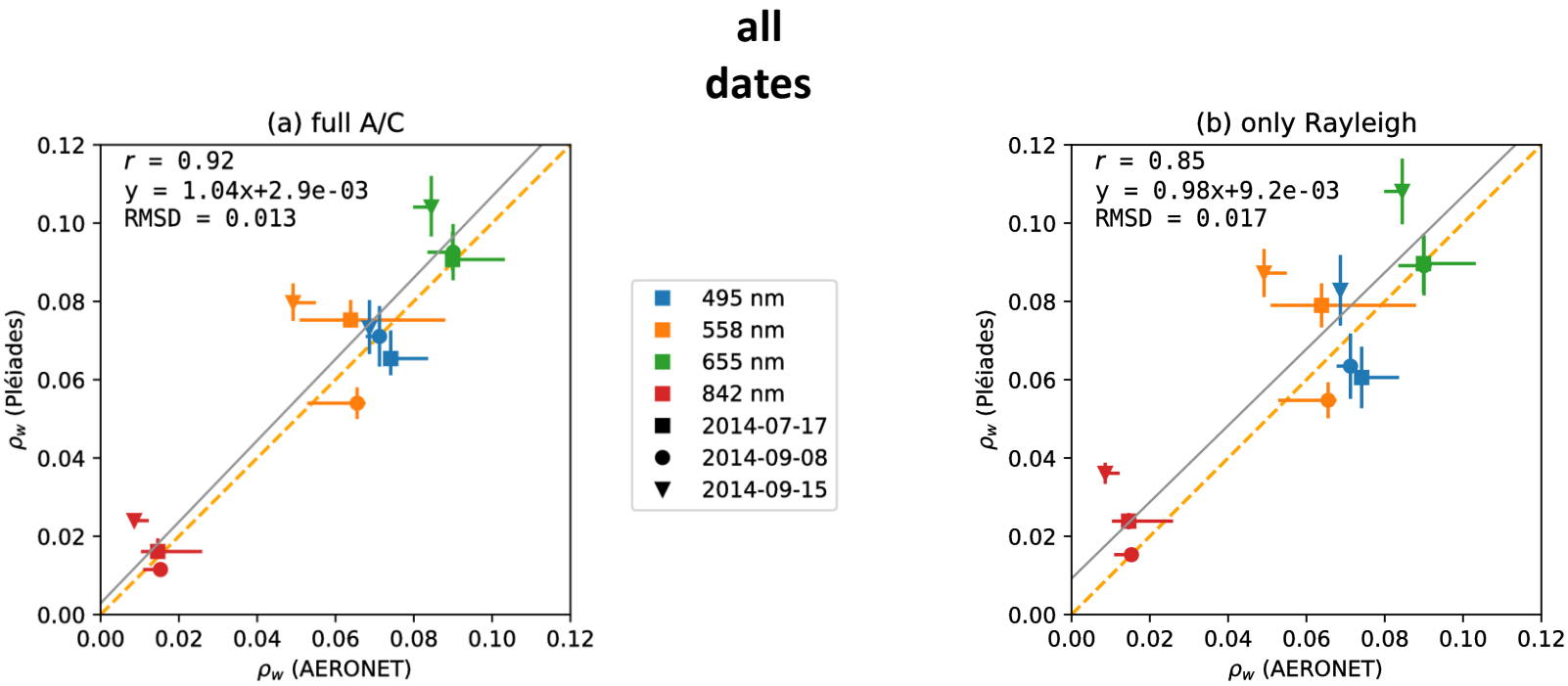


For Pléiades the **model and band combination giving the lowest $\tau_a 550$ is selected**. (This criterion avoids negatives values in the ρ_{dark} after aerosol correction.)

Validation - water

MOW1/Zeebrugge AERONET-OC
PHR1A 2014-09-08

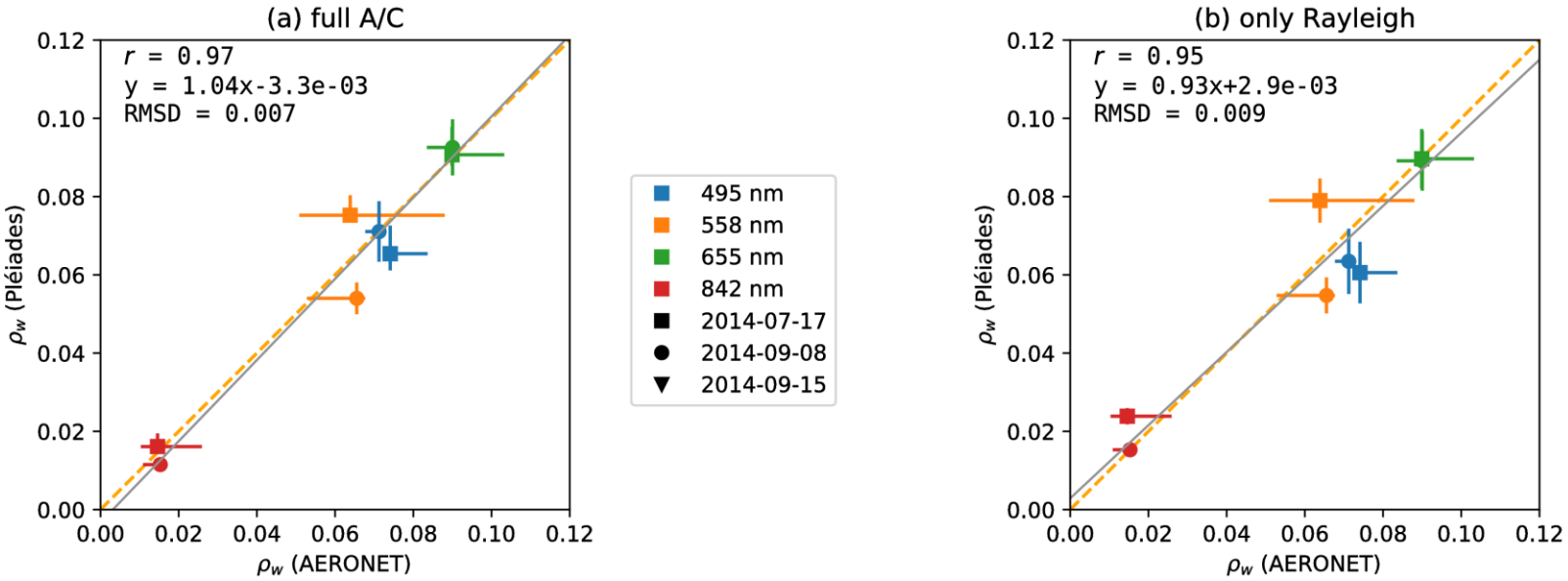
Validation - water



In situ AERONET-OC data (8 channels) resampled hyperspectrally and convoluted to Pléiades.

Validation - water

without 2014-09-15



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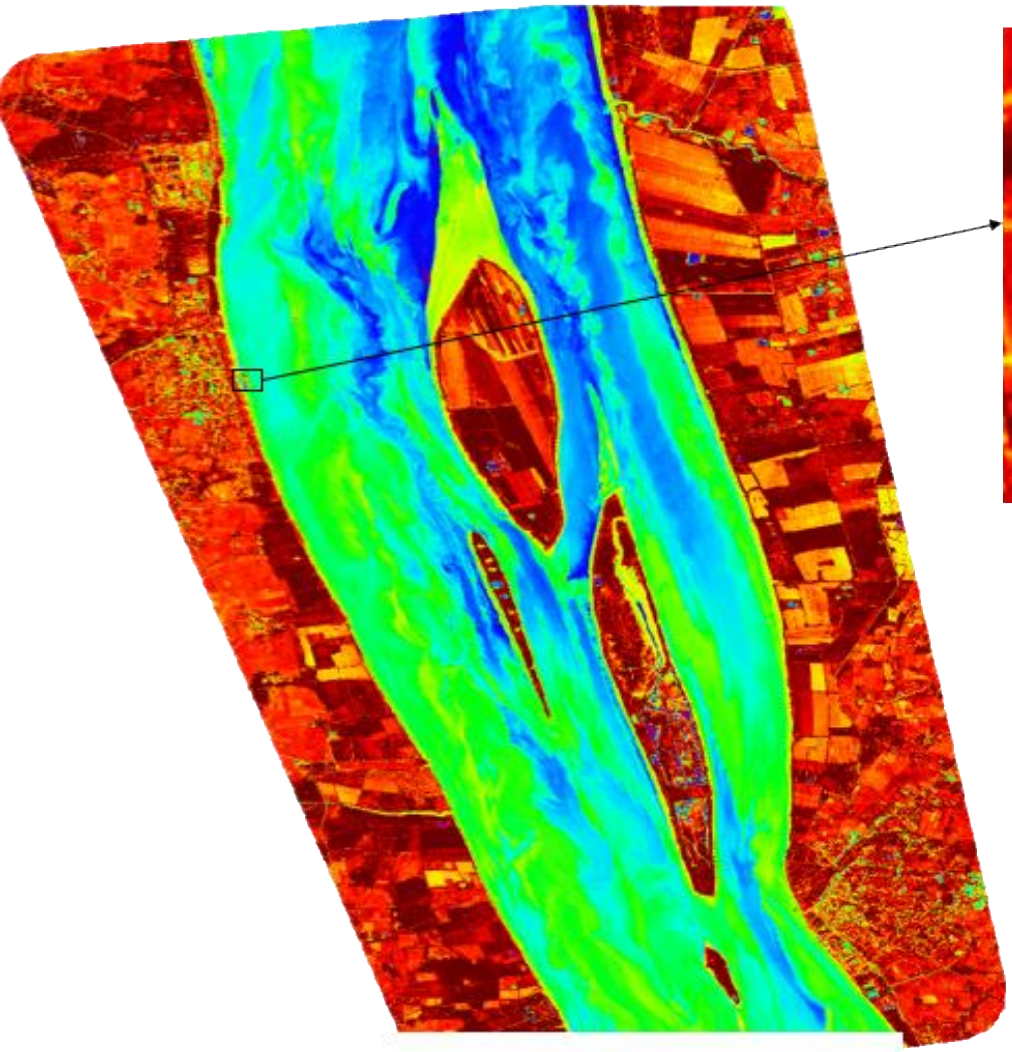
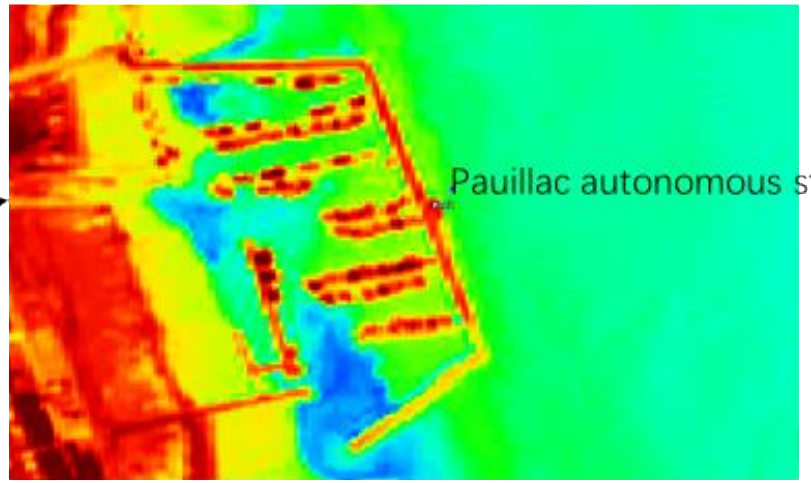
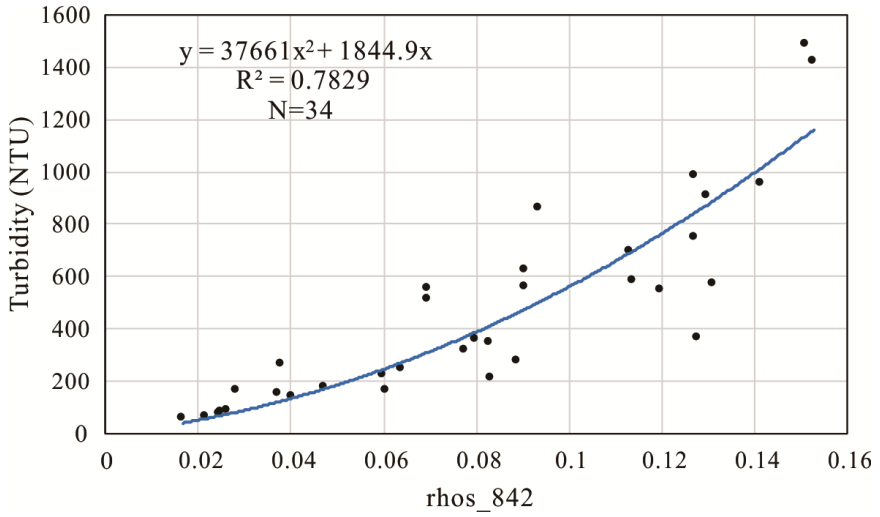
Results (3)
Turbidity retrieval

Applications - Gironde

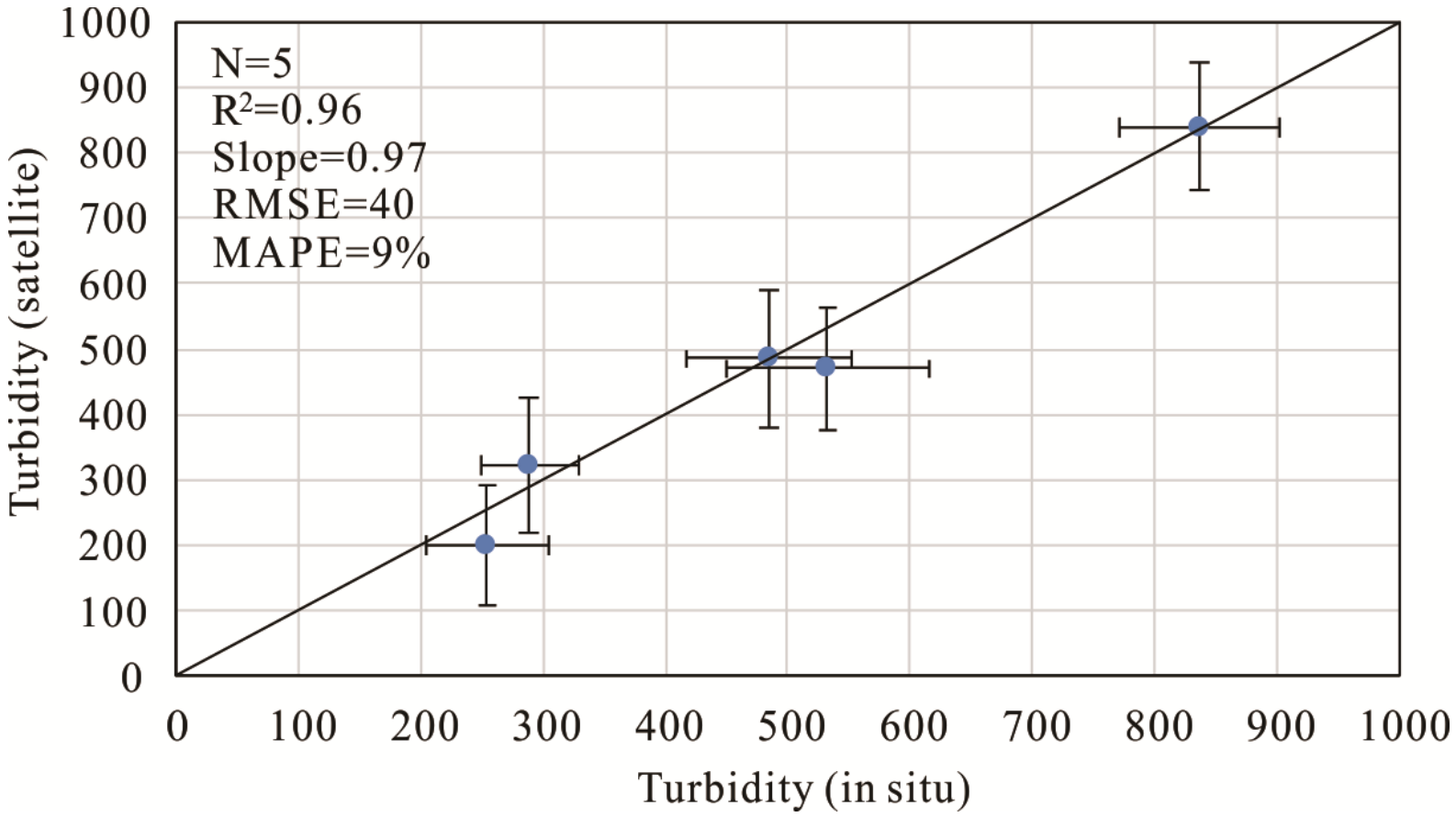






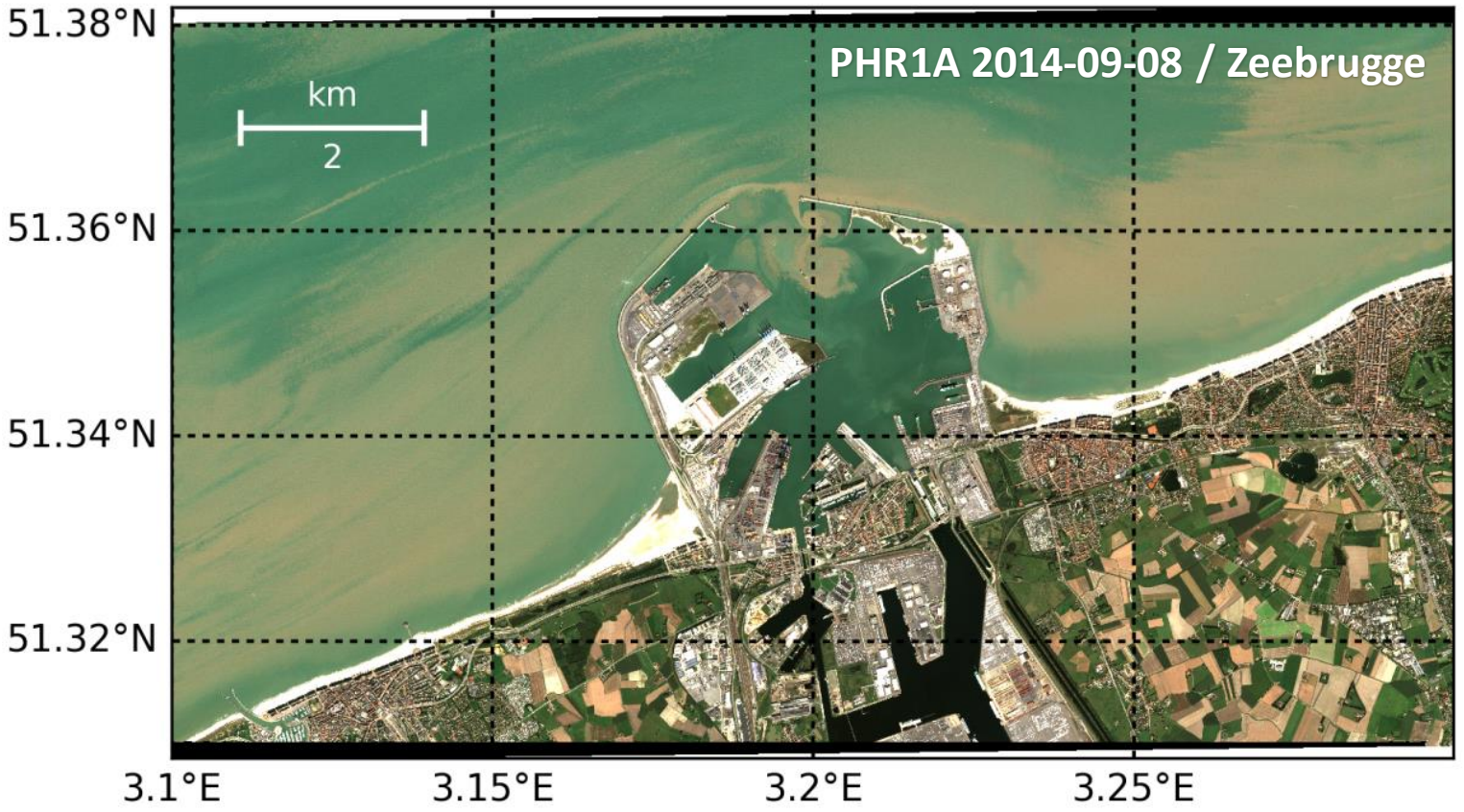
Turbidity map at 2 m spatial resolution & match-up with Pauillac turbidity station

Applications - Gironde



Match-up comparison of in situ turbidity (NTU) and turbidity derived from reflectance using the Pléiades band of 842 nm

Applications - Zeebrugge



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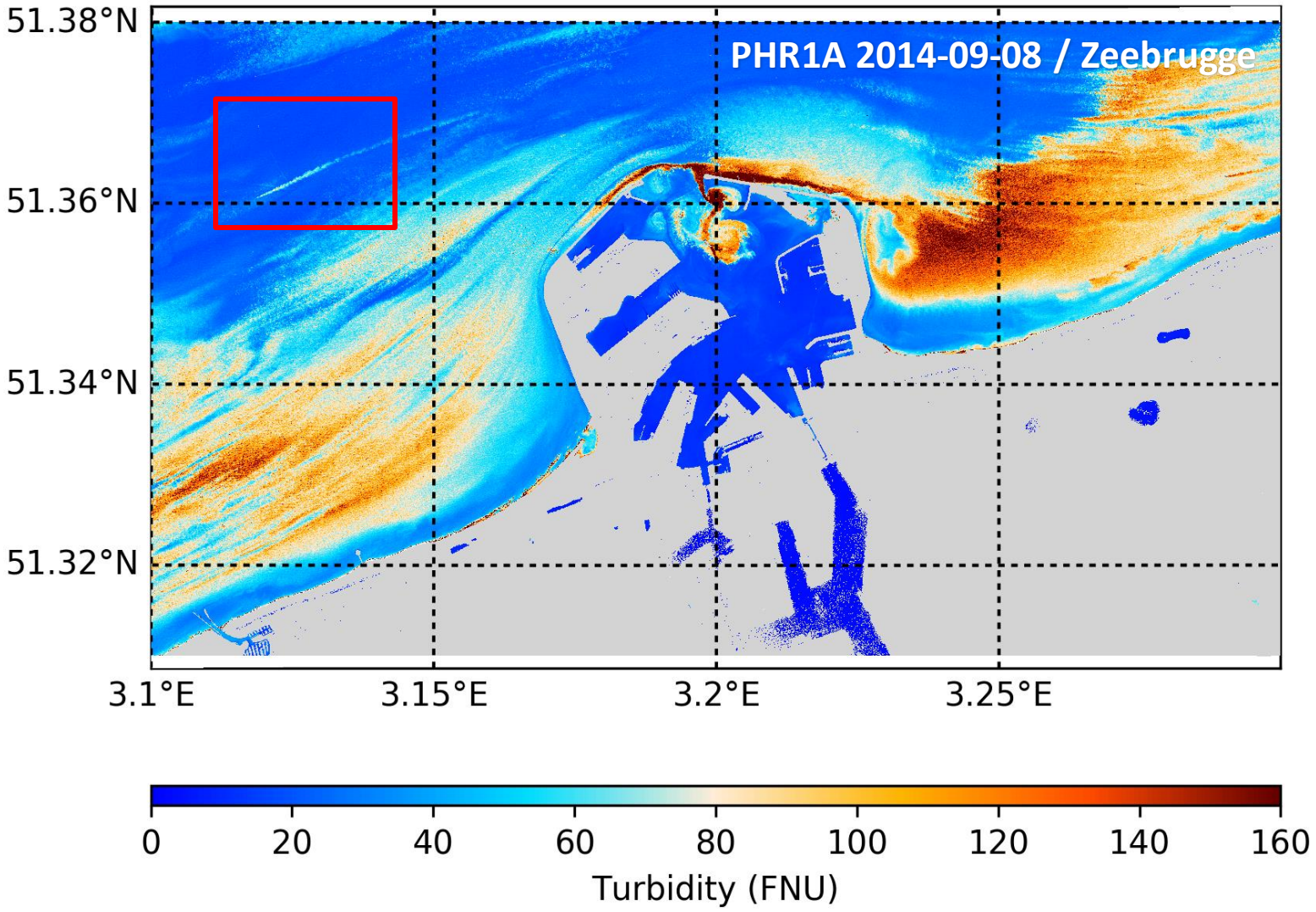
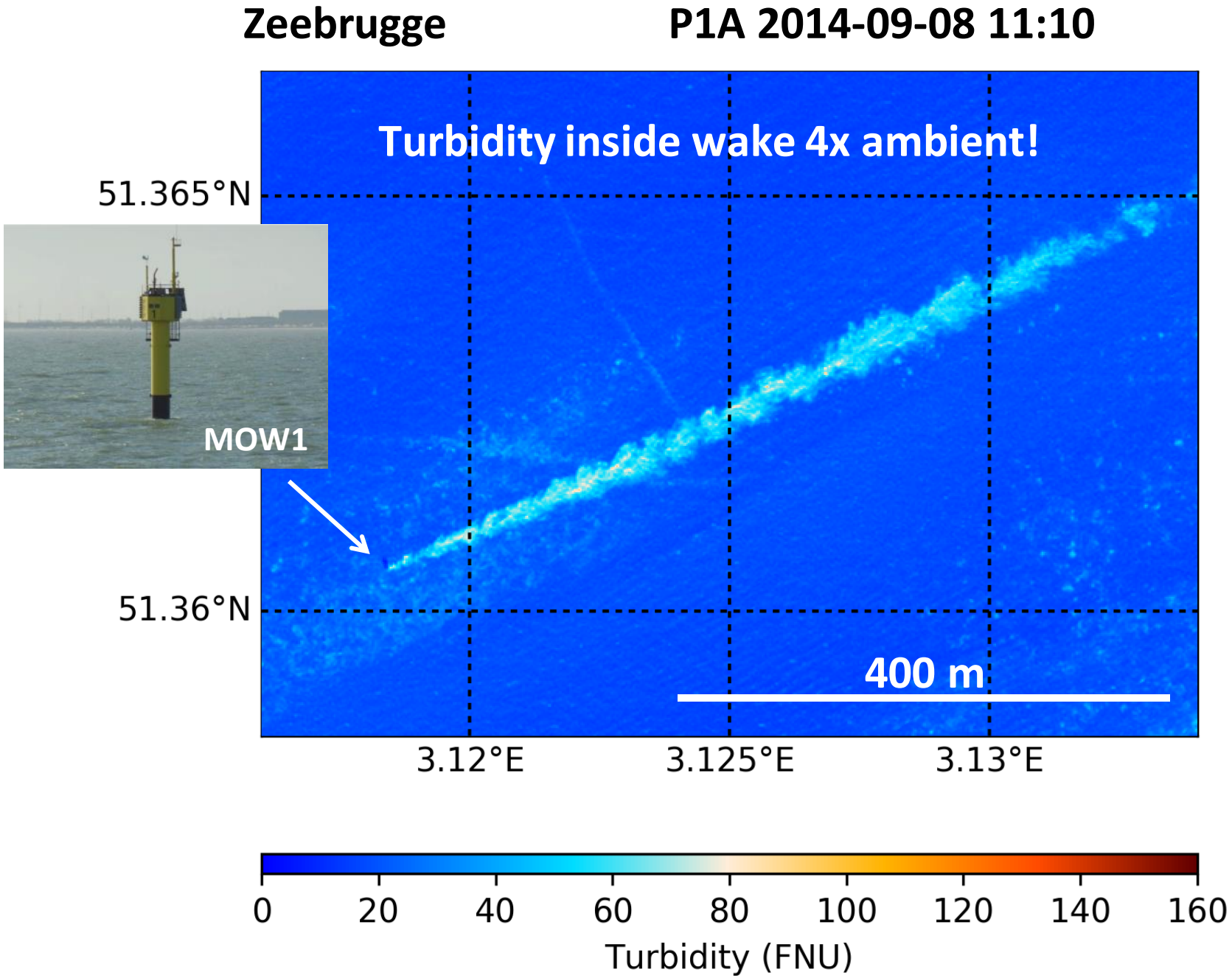
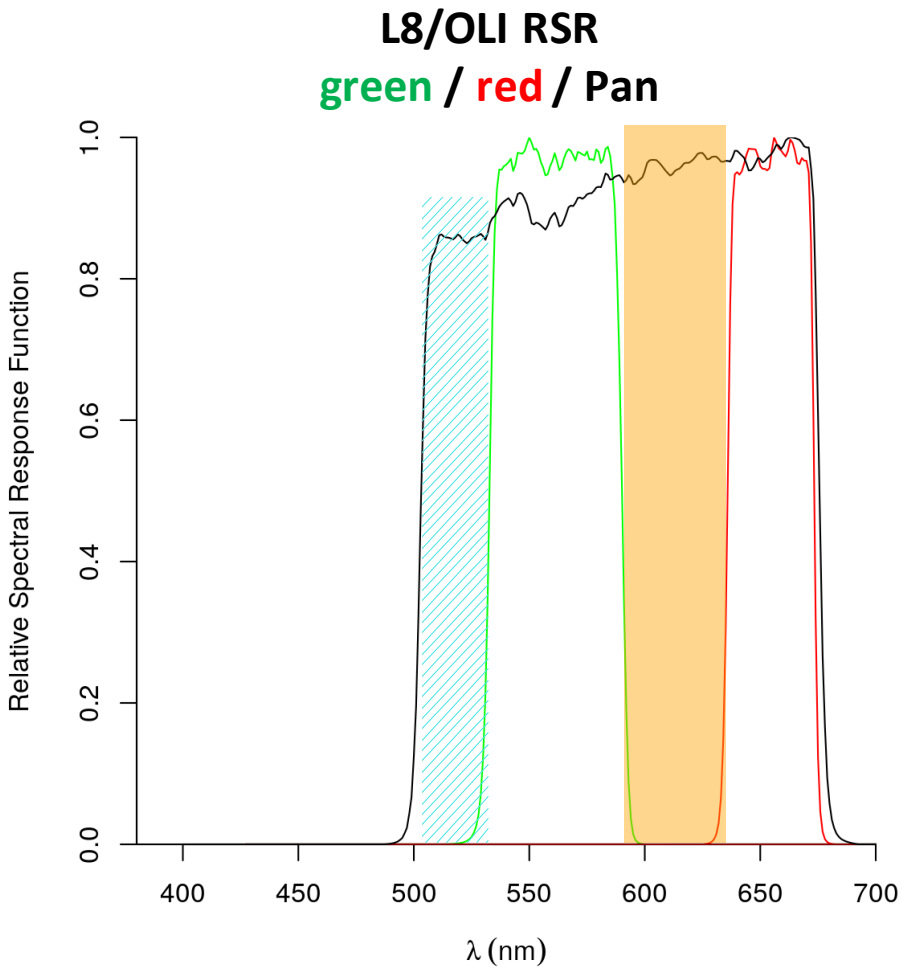
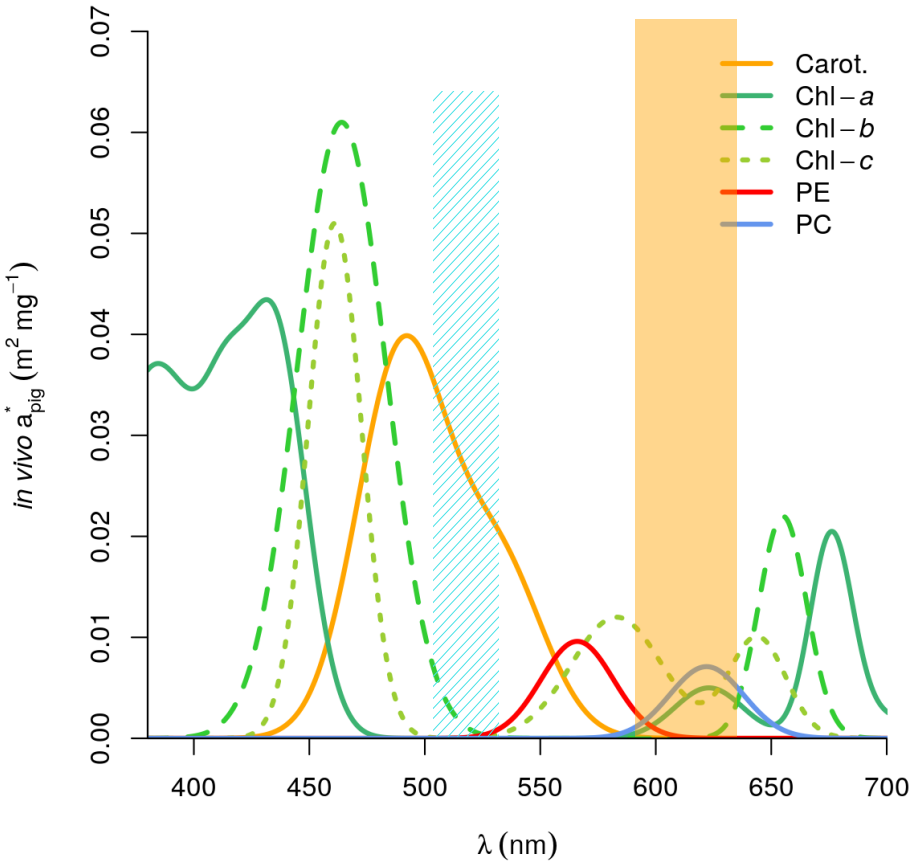



Zeebrugge
P1A 2014-09-08 11:10
Turbidity inside wake 4x ambient!
51.365°N
51.36°N
MOW1
400 m
3.12°E
3.125°E
3.13°E
0
20
40
60
80
100
120
140
160
Turbidity (FNU)

Results (4)
Orange band retrieval

L8/OLI Orange contra-band

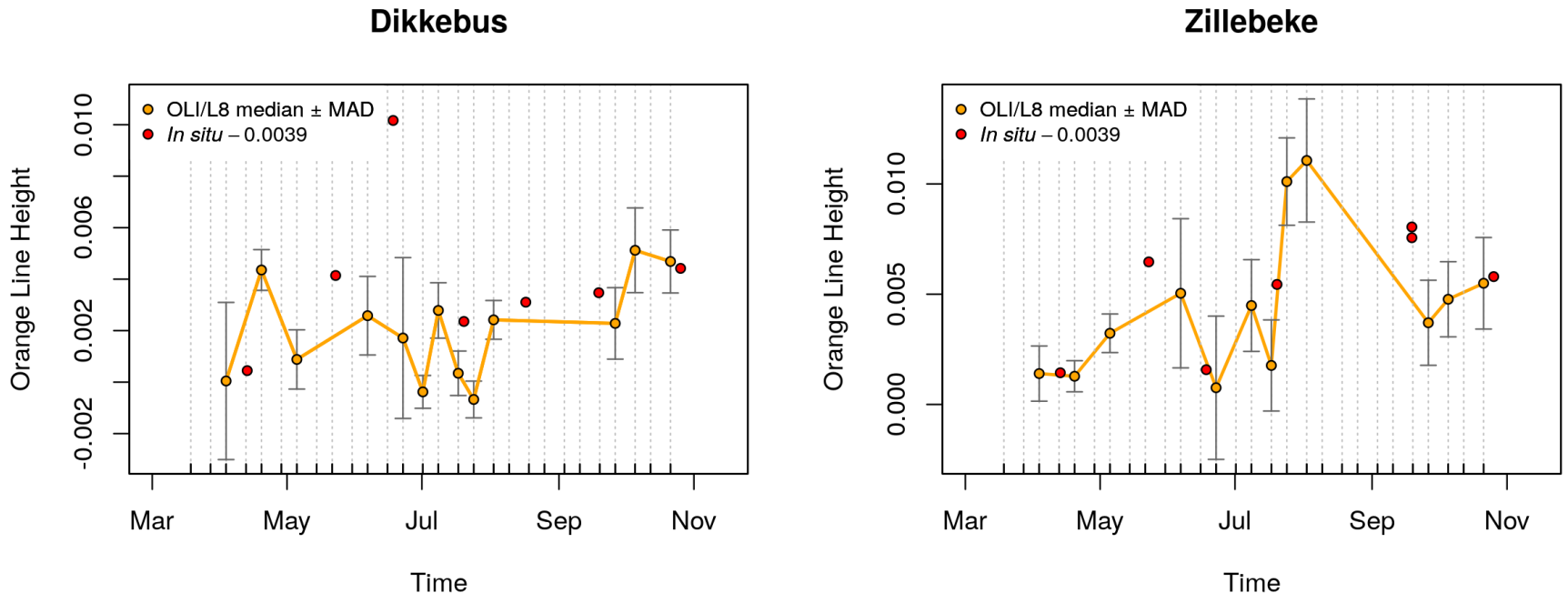




Castagne et al (in prep.) **Extending Landsat 8: Retrieval of an orange contra-band**

L8/OLI Orange contra-band

Applied to Landsat 8 time series



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Conclusions

- A large dataset of in situ measurements were collected in Belgian inland waters in 2017-2018. These measurements will be further examined with regards to satellite validation and site characterisation.

- A method was developed for retrieving "contraband" information from panchromatic bands overlapping multispectral bands. The orange band derived from Landsat 8 may further strengthen the OLI's use in inland waters.

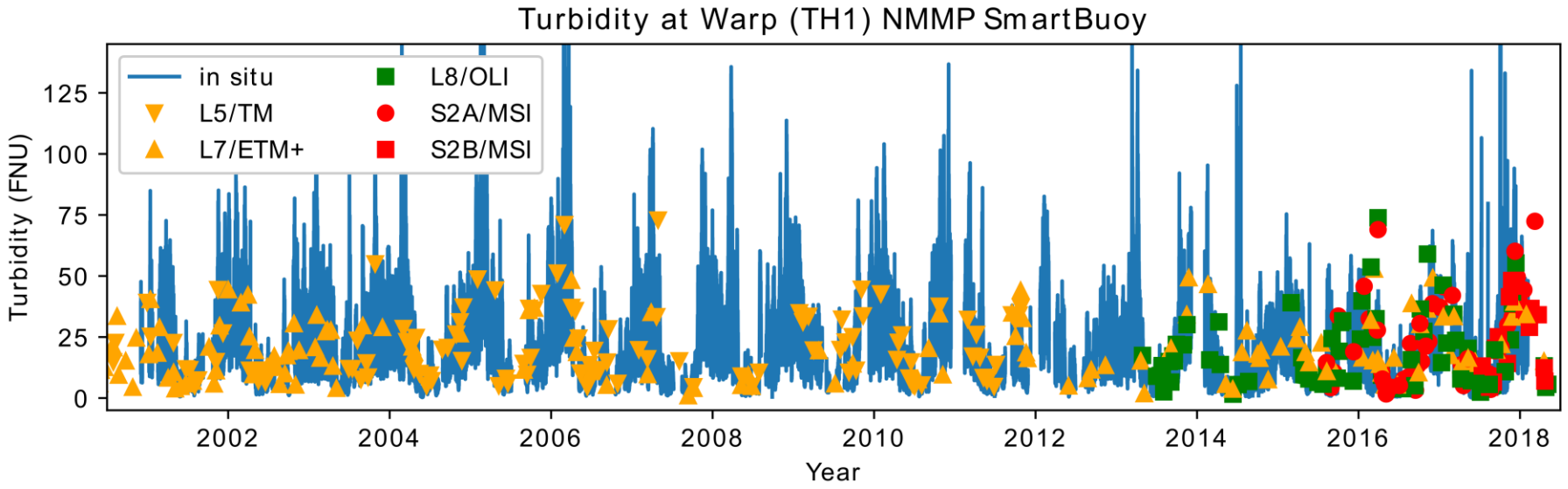
- A generic « dark spectrum fitting » aerosol correction approach was developed for metre scale sensors, which does not use a priori defined targets or ‘black’ bands. By switching bands the DSF avoids negative reflectances and shows promise for inland waters that are strongly affected by adjacency effects.

- The first validation results of the DSF look promising, in terms of τa, Lwn, and Turbidity retrieved from Pléiades. The DSF is since March 2018 the default algorithm in ACOLITE for Landsat/Sentinel-2 processing...

ACOLITE - DSF

- The Dark Spectrum Fitting algorithm was adapted for **Landsat 5/7/8 & Sentinel-2A/B** processing, and is now publicly available through ACOLITE

Water turbidity retrieved from > 30 years of Landsat and Sentinel-2 data



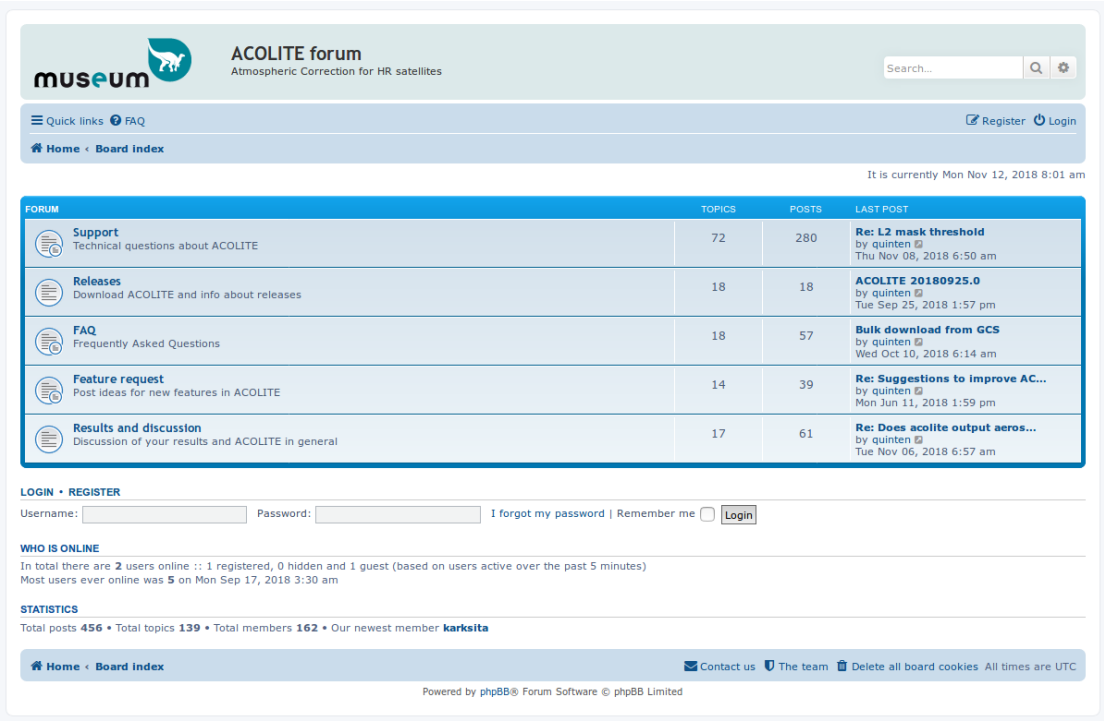
Vanhellemont (submitted) **Adaptation of the dark spectrum fitting atmospheric correction for aquatic applications of the Landsat and Sentinel-2 archives**

ACOLITE - DSF

ACOLITE for Landsat and Sentinel-2 is available at:

http://odnature.naturalsciences.be/remsem/acolite-forum/

https://github.com/acolite/acolite



S2A/MSI 2016-07-20

Grensmaas

ACOLITE – DSF + GC