Data QA/QC for the *BOUSSOLE* bio-optical time series project

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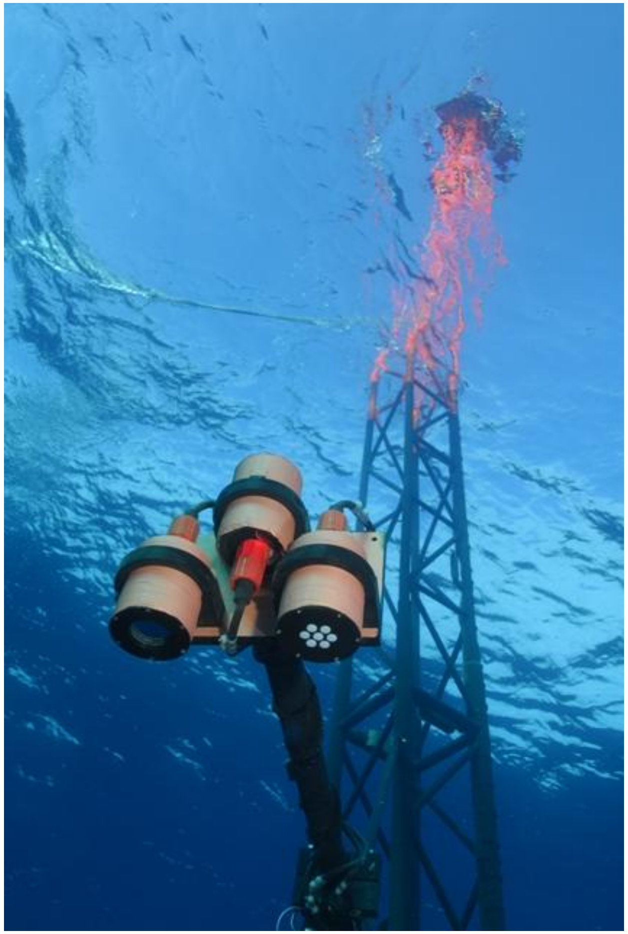
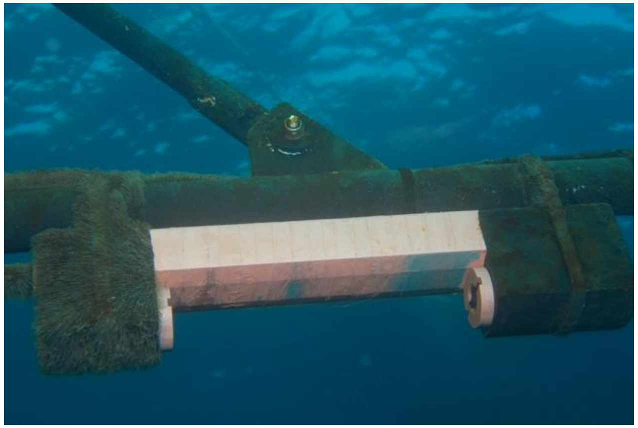
Quality assurance (QA)
in particular for radiometers

- Bi-yearly calibration/check: we rely entirely on the instrument manufacturers (Satlantic)
- Anti-fouling devices
- Bi-monthly cleaning by divers
- Monitoring of dark currents
- Inter calibrations of sensors before deployments
- Respecting measurement protocols ("SeaWiFS protocols")

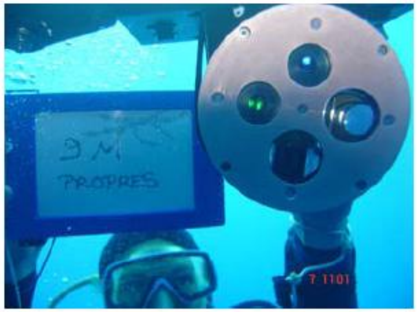
About biofouling in clear waters…

From good.. to… … not so good





Bio-fouling mitigation: antifouling devices

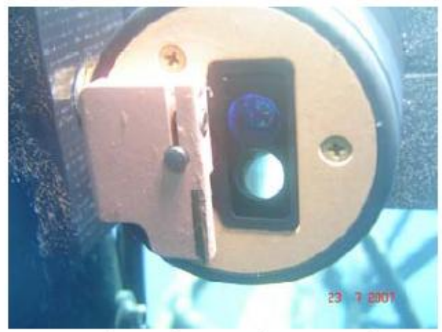


Copper face plate of the Hobilabs' Hydroscat-2 backscattering meter

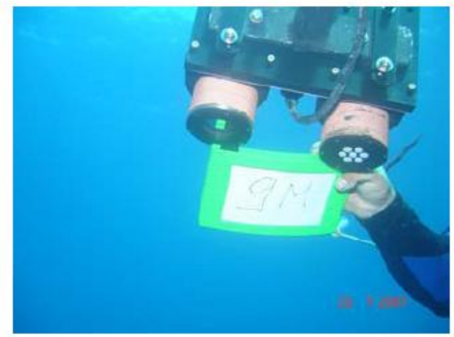
Copper rings around the emission and reception windows of the Wetlabs C-star beam transmissometers

Copper tape on the housings of the Wetlabs C-star beam transmissometers

Copper face plate and copper shutter including a wiper for the Wetlabs Eco-FLNTU fluorometers (shutter closed)



Copper face plate and copper shutter including a wiper for the Wetlabs Eco-FLNTU fluorometers (shutter opened, measuring)

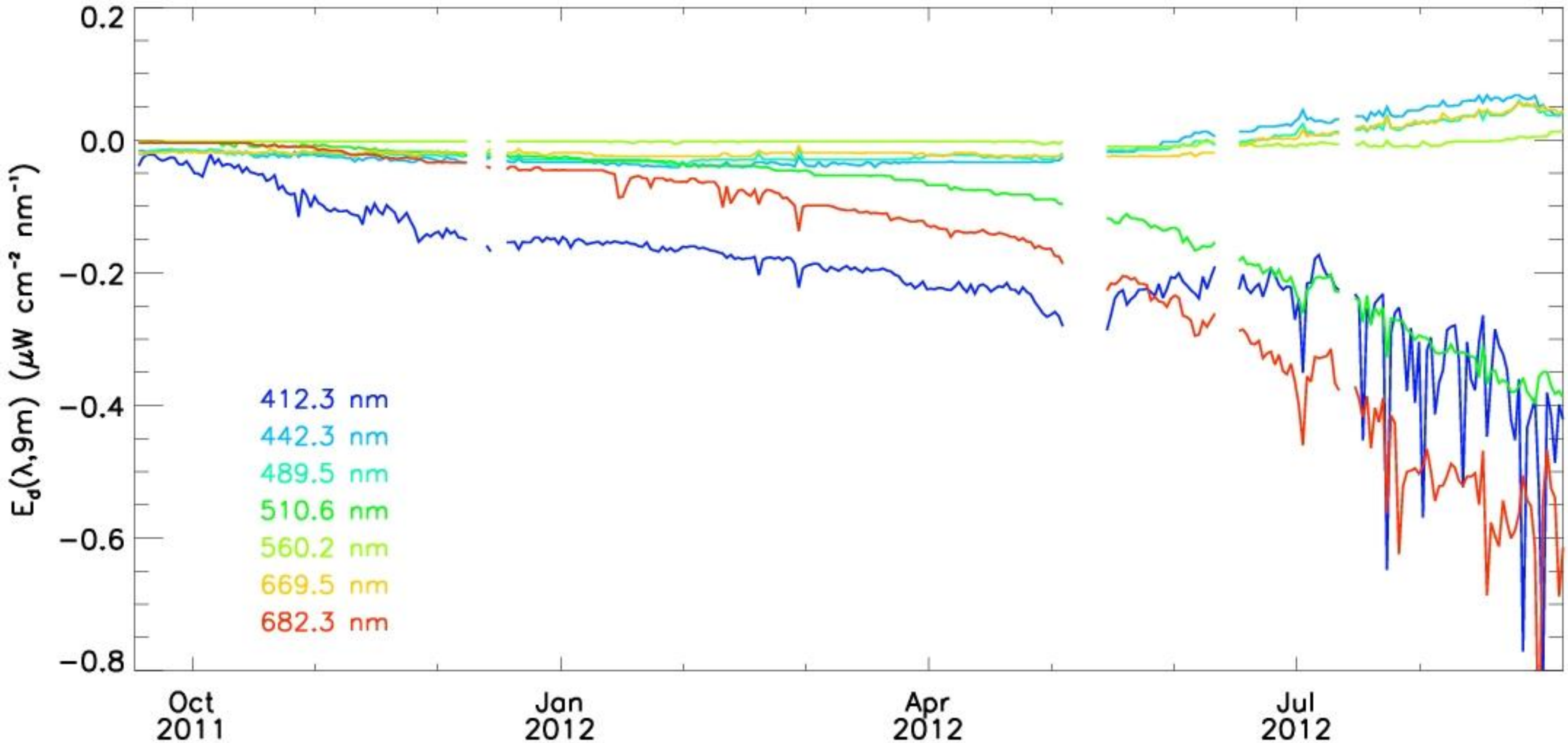


Copper tape on the instruments' housings for the Satlantic 7-band OCR-OCI/200 radiometers

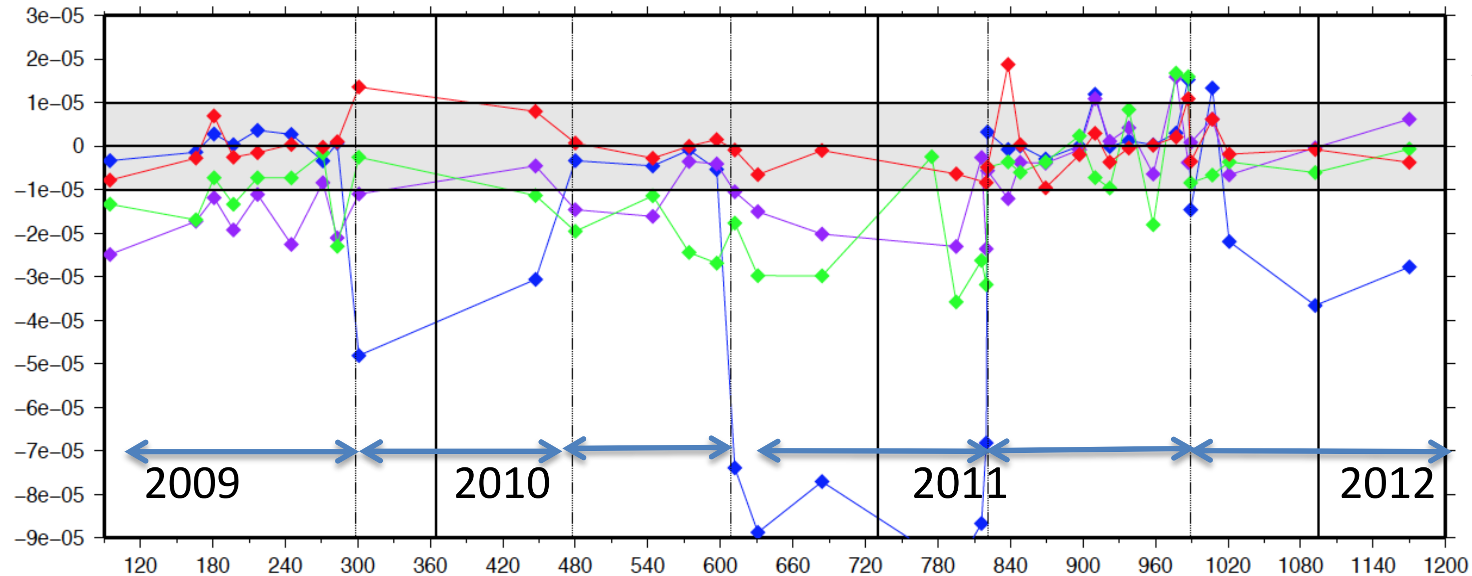
Copper tape on the instruments' housings and bio-shutter (Satlantic Hyperspectral radiometers)

Plus cleaning by divers about every 2 weeks

Monitoring dark currents of radiometers

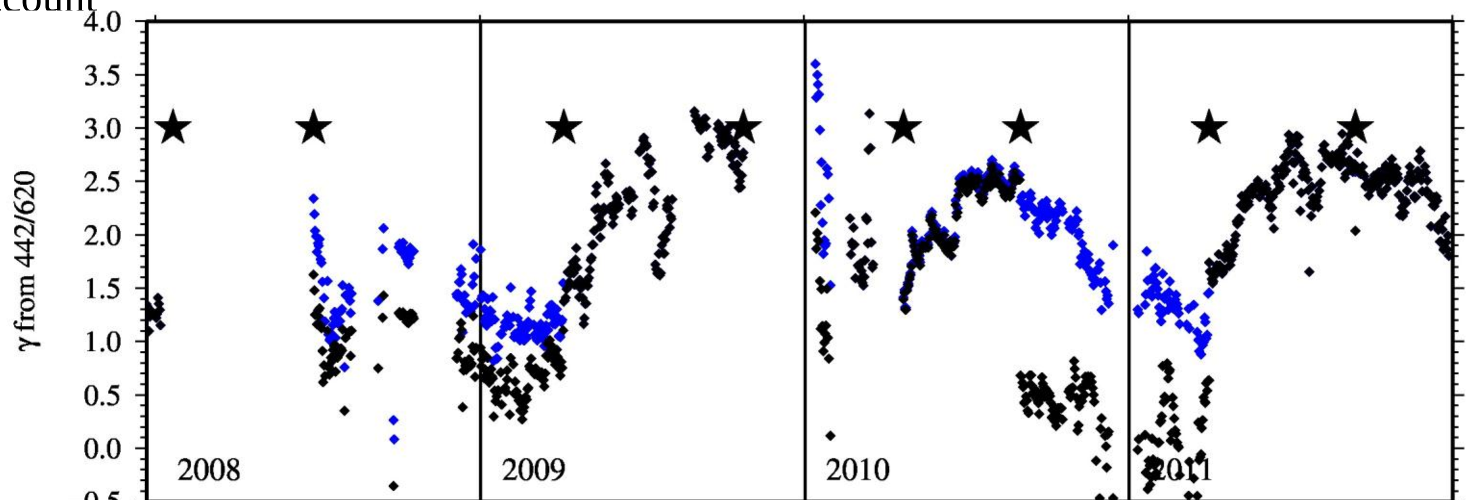


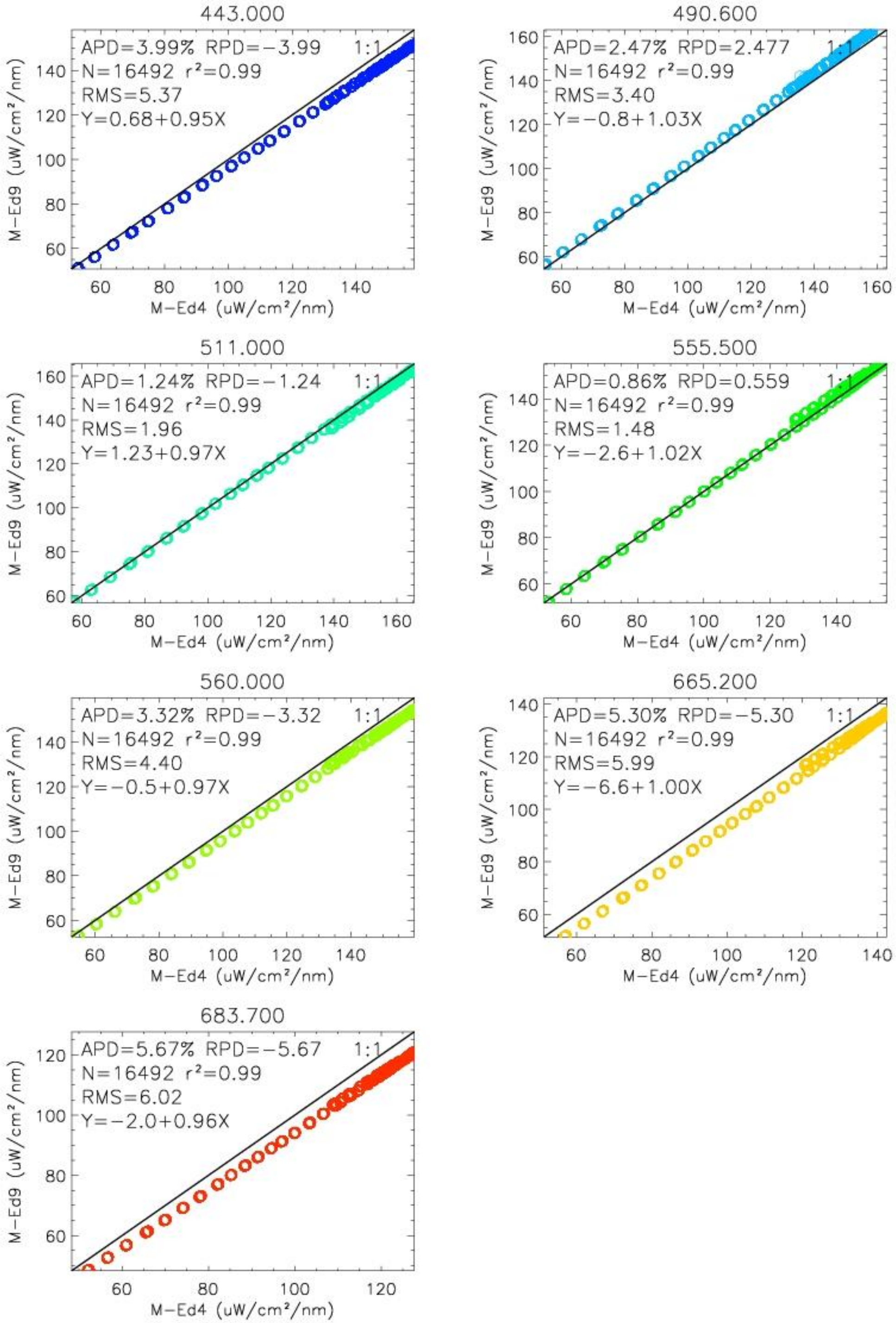
Dark currents for IOP instruments as well



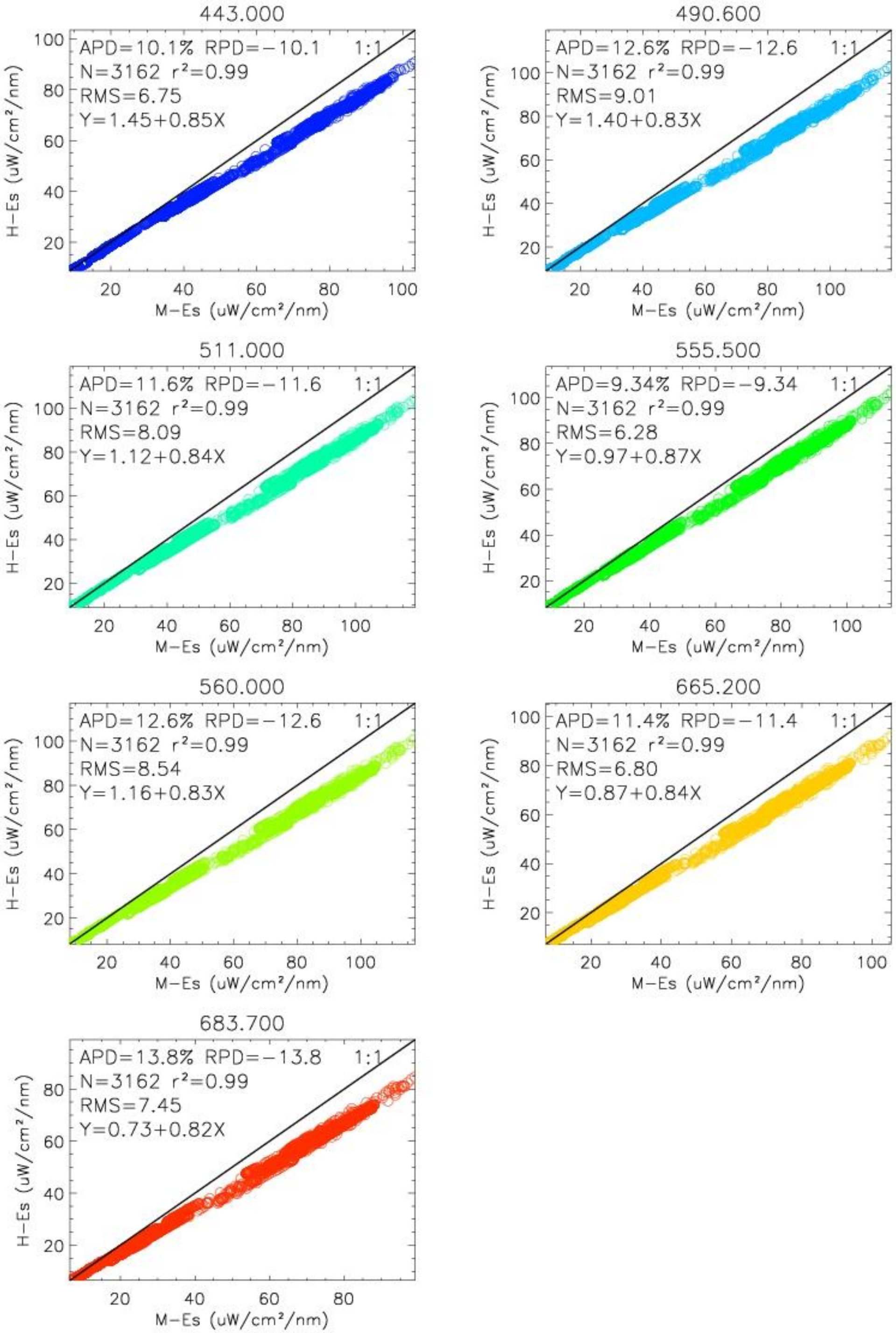
Dark records from two backscattering meters (m^{-1} sr^{-1})
443
488
550
620

Time series of the b_{bp} spectral dependency,before (black) and after (blue) darks have been taken into account





When everything's OK



When something's wrong…

Improving our “working conditions”

Challenges of data QC for BOUSSOLE

- Critical aspect, considering the huge amount of data (today we have ~220,000 acquisition sequences over ~8 years of buoy deployment), for IOPs (2 transmissometers , 2 chl fluorometers, 1 backscattering), and AOPs (12 radiometers – 7-band and hyper-spectal)

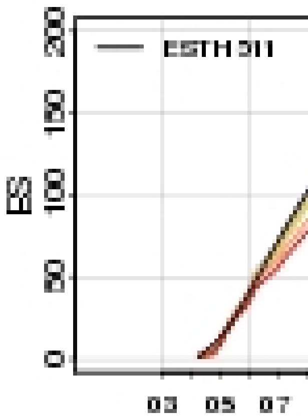
- Quite small team of technical staff

- QC mostly performed on a "case per case" basis for the moment (i.e., performed on subsets of data used for a particular purpose)

- More systematic procedures are what we would like to reach

- Identified issues: bioflouling, intercalibration of instruments, instruments instabilities/drifts, instrument design, dark records

Note: all instruments (radiometers and IOPs) are calibrated twice a year, i.e., before and after each buoy deployment. This is performed by manufacturers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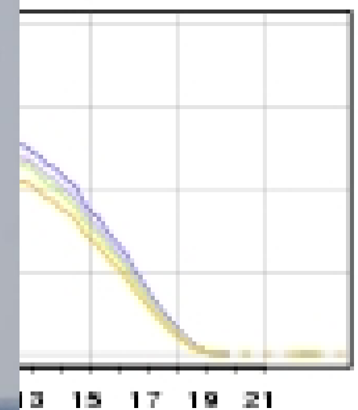
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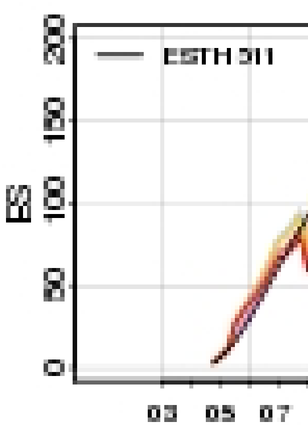
t 4m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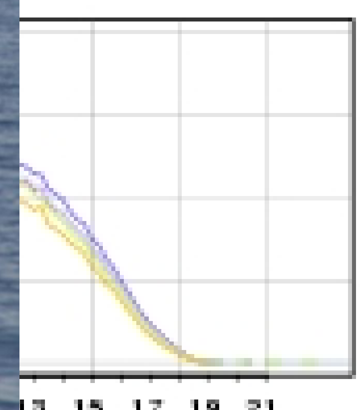
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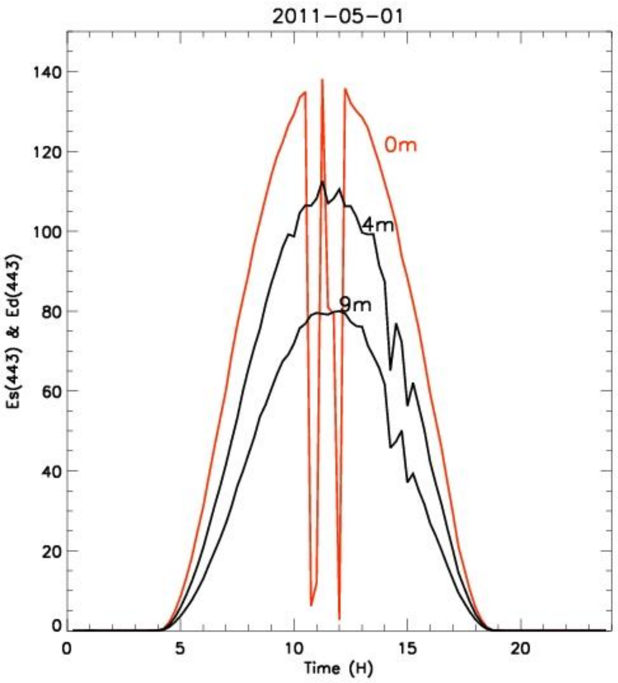
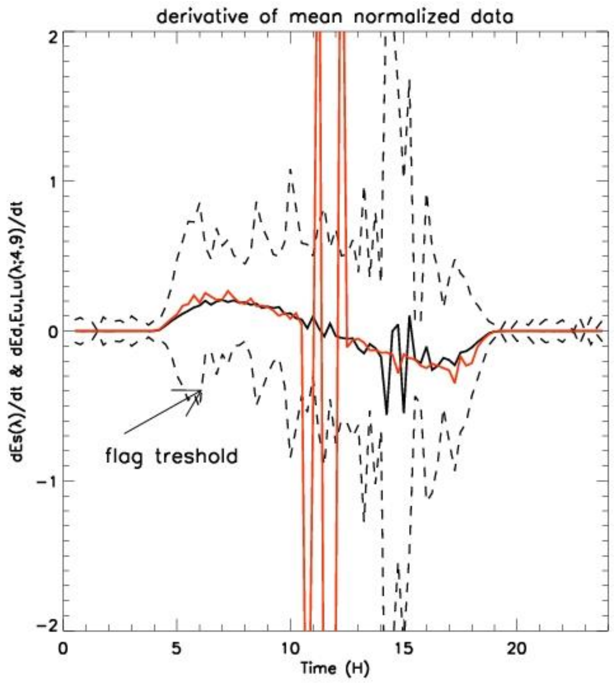
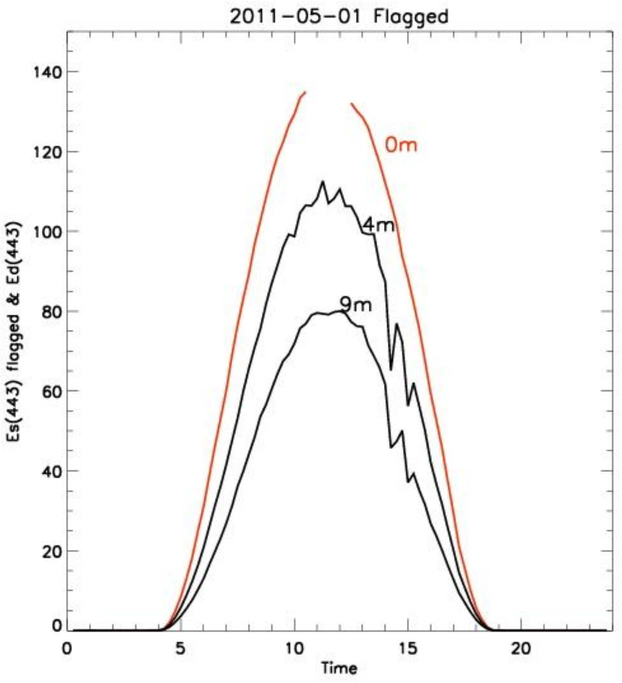
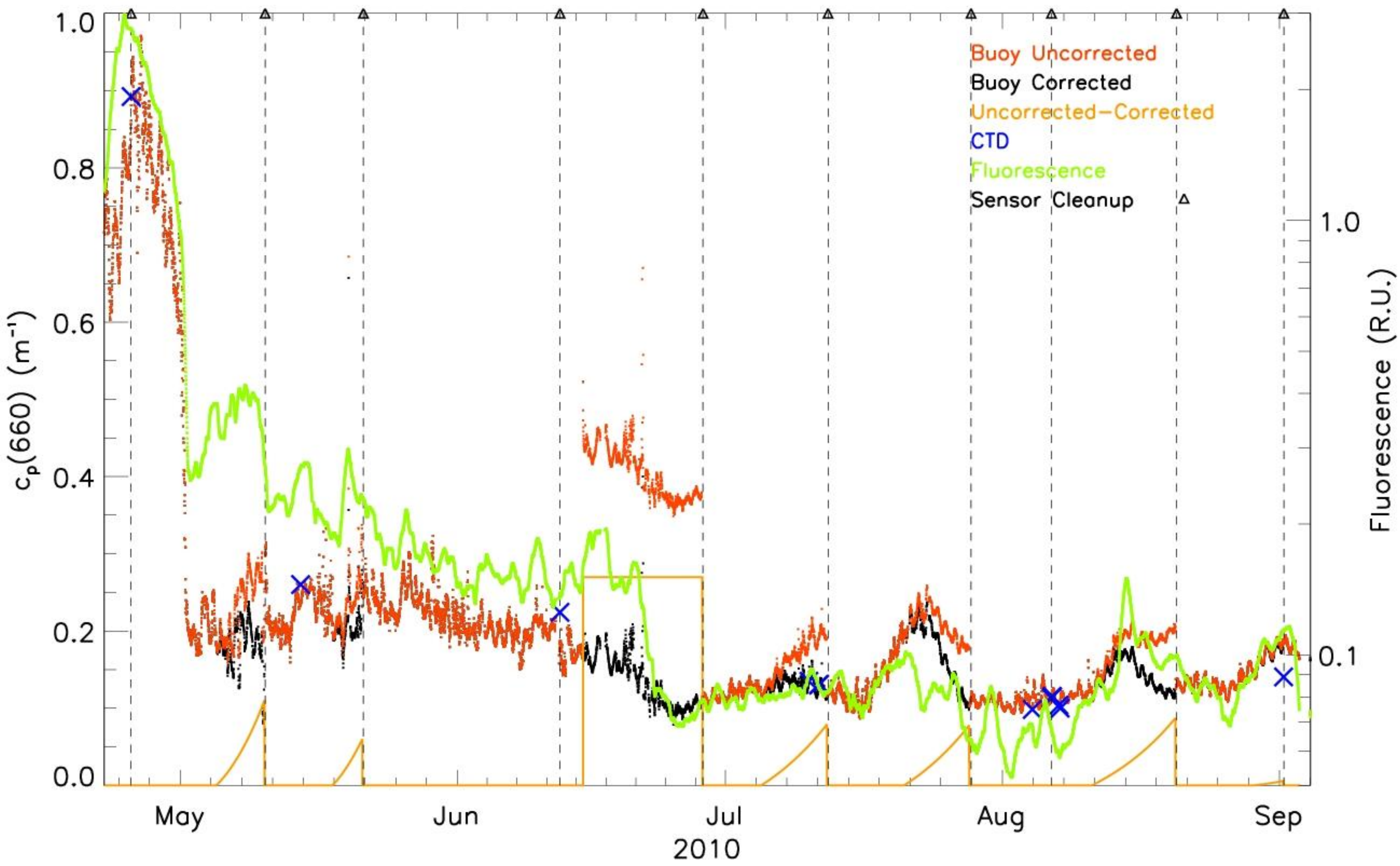
Small-scale problems



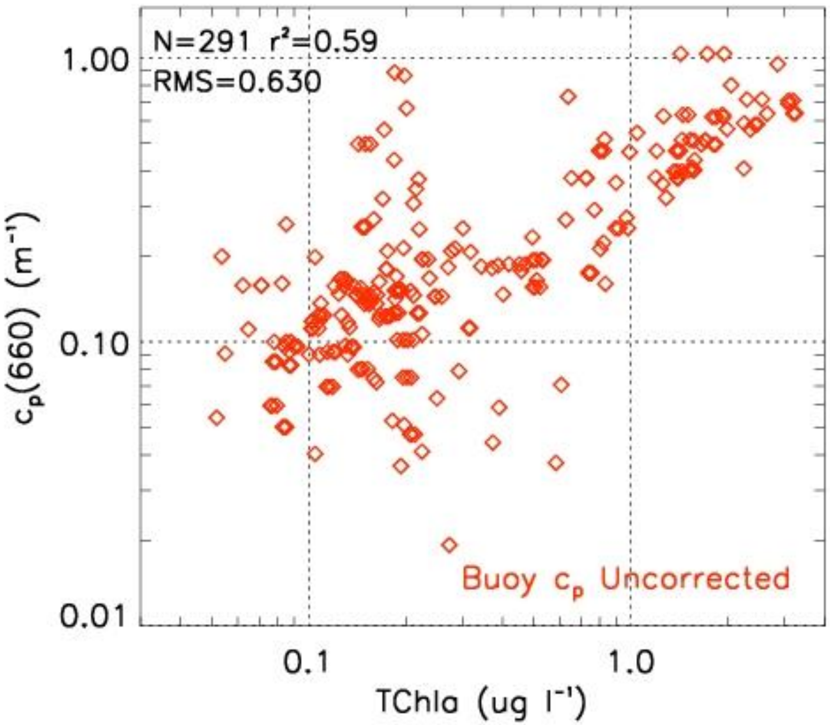




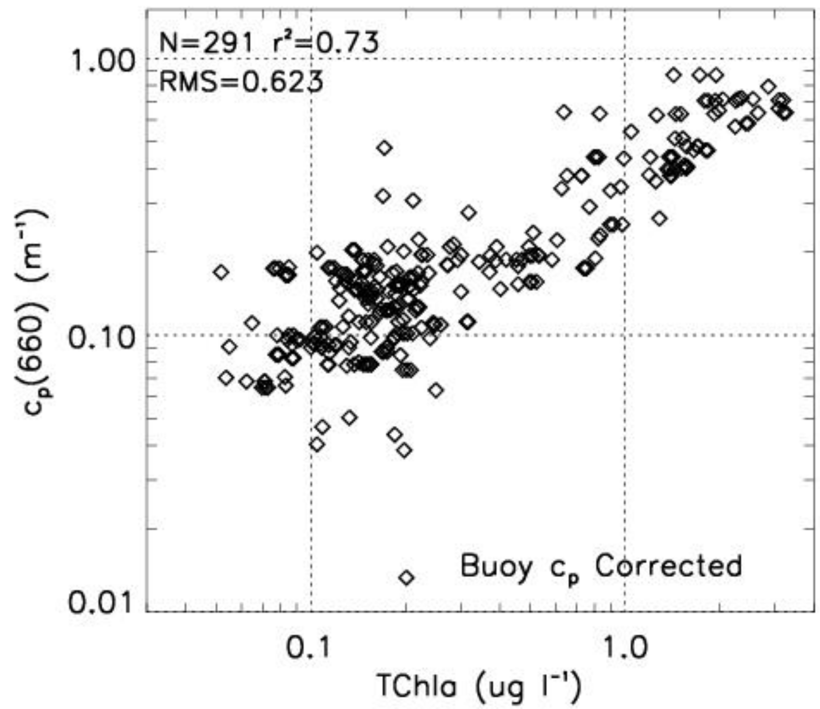
An example of corrections based on pre- and post-cleaning observations: c_p



Verification by post-analysis: c_p *versus* fluorescence

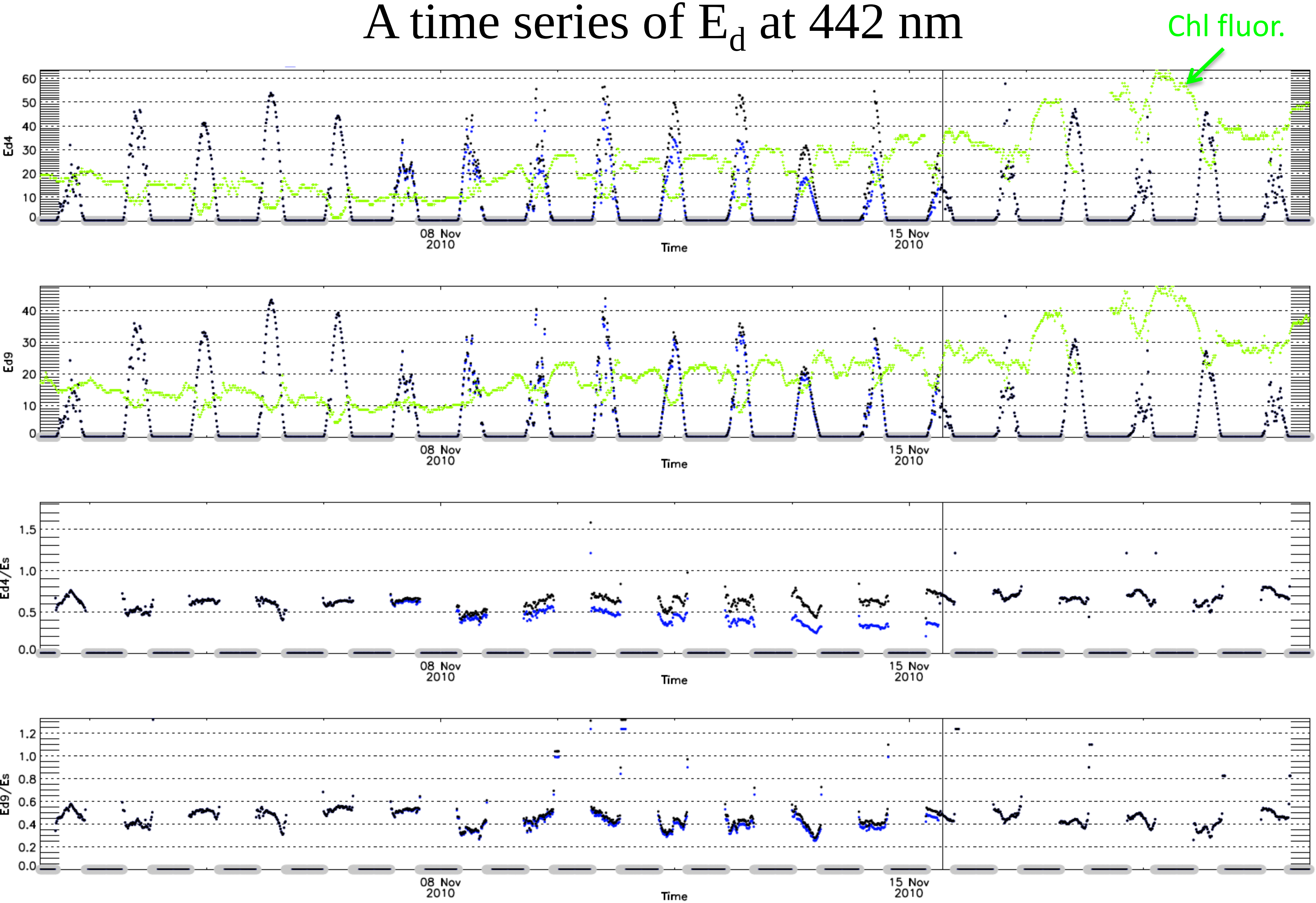


Before



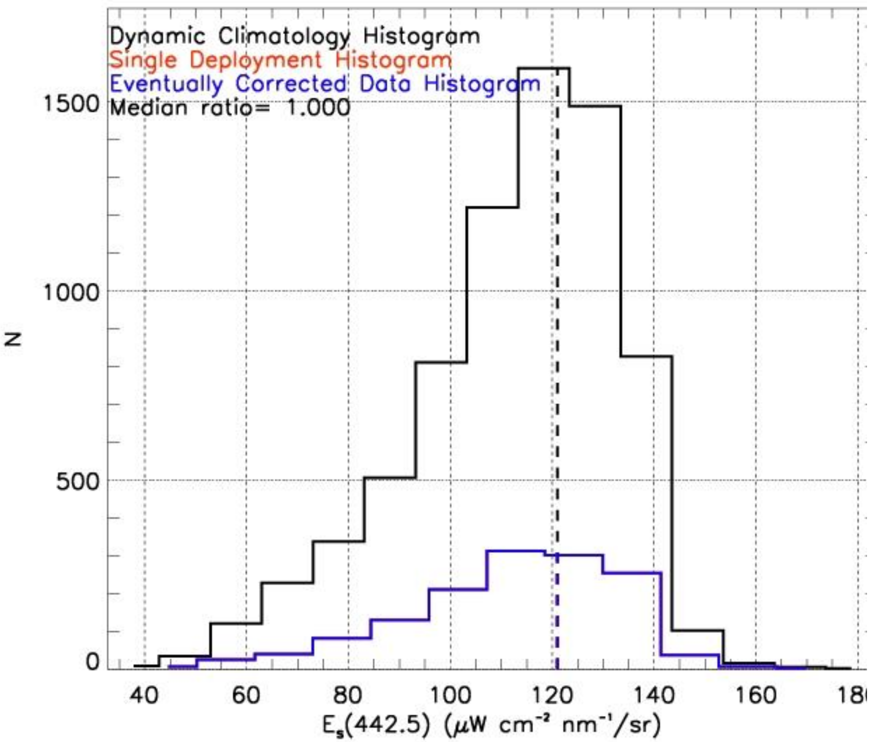
After

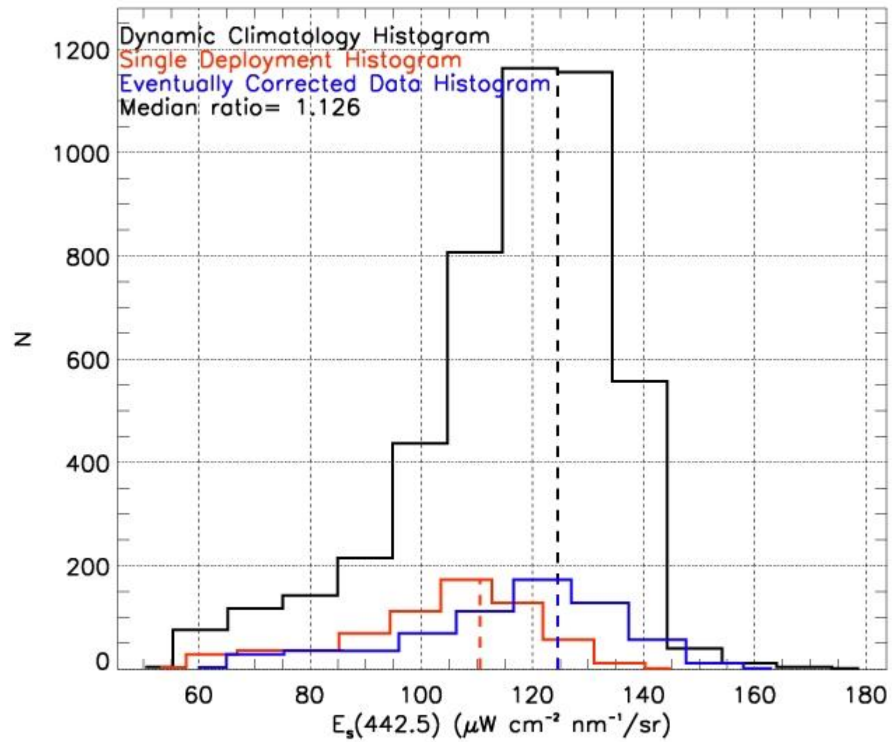
A time series of E_d at 442 nm



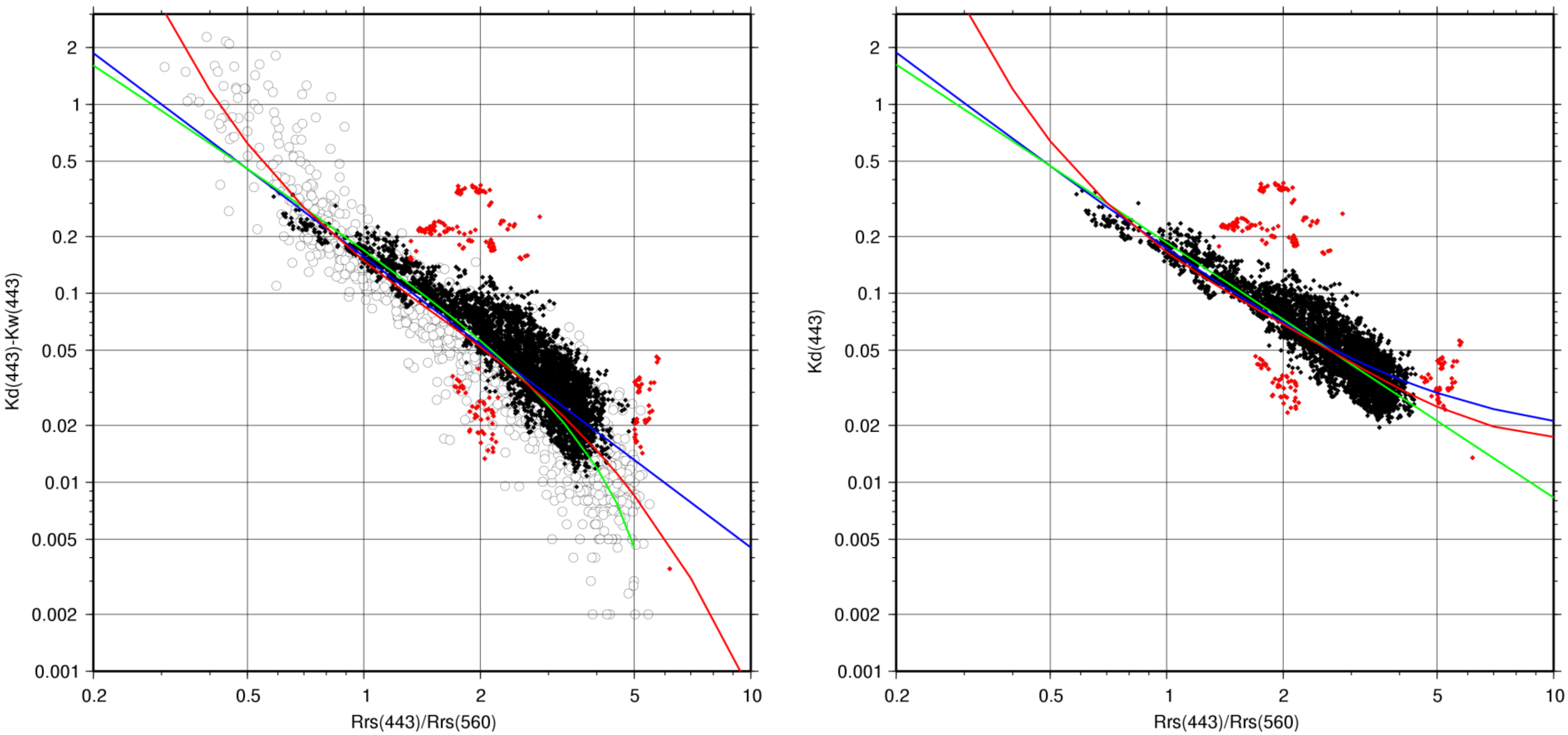
Blue: before correction. Black: after

"Dynamic climatology"





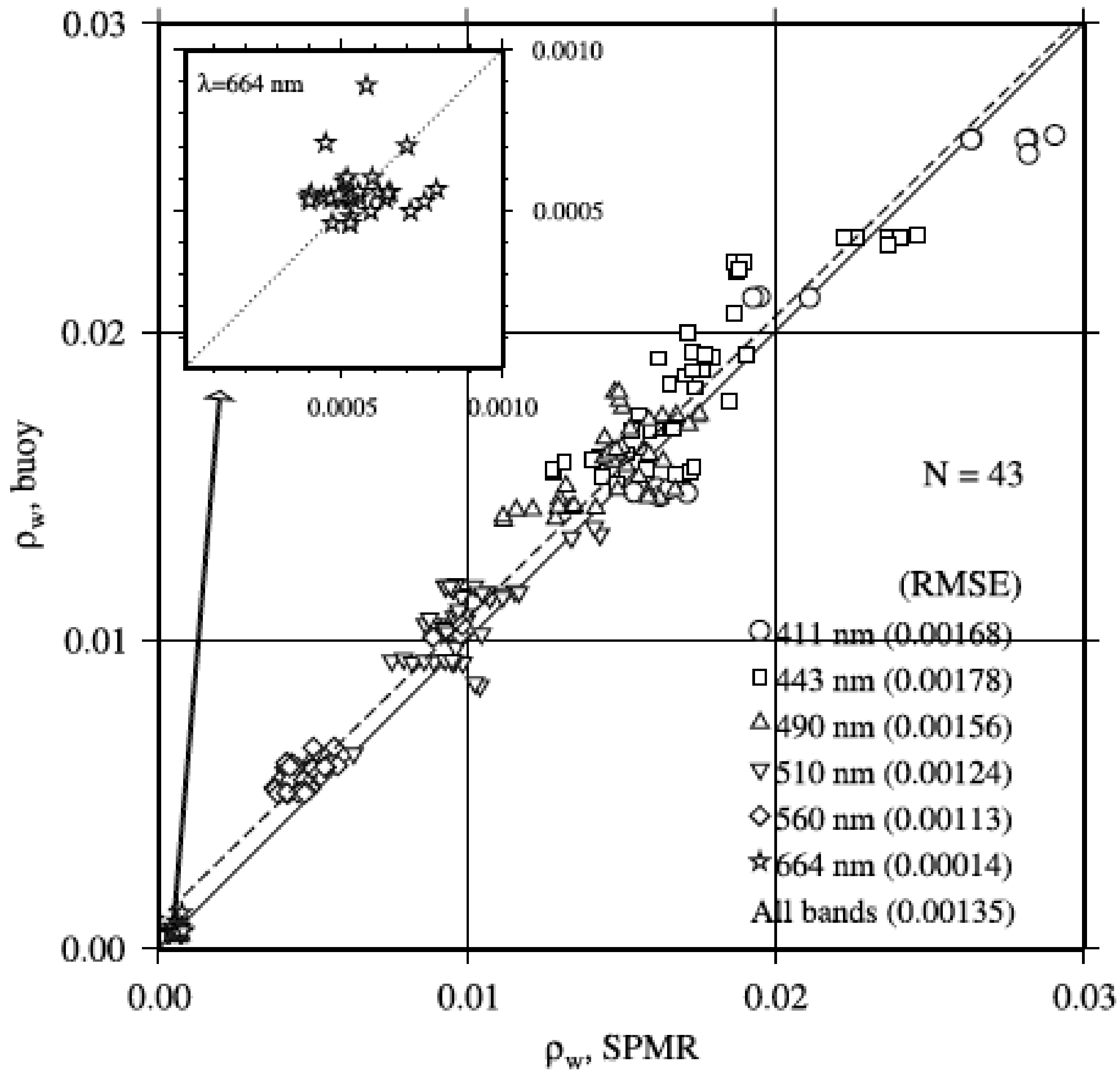
Using bio-optical relationships to 1) identify problematic data points and 2) verify data after corrections have been introduced



○ NOMAD
● BOUSSOLE

Curves: various bio-optical relationships (Muller, Werdell, Morel)

Intercomparison of instruments: buoy versus free-fall profiler



Error budget for the buoy radiometry measurements

(from Antoine et al., 2008, J. Geophys. Res., 2008, VOL. 113, C07013, doi:10.1029/2007JC004472)

Table 1. Summary of the Uncertainty Assessment for the Various Data Acquisition and Processing Steps[a]

Data Acquisition or Processing Step	Percent Uncertainty	Reference/Comment
Absolute radiometric calibration of radiometers	3	*Hooker et al.* [2002]
Decay over time	2	Linear interpolation between absolute calibrations (performed roughly every 6 months).
Computation of K_L	3	see text (section 4.1)
Bidirectionality corrections	2	*Morel et al.* [2002]
Air-sea interface	0	*Austin* [1974]
Illumination changes during the measurement sequences	0	The coefficient of variation within the 360 measurements must be <5% (see text).
IOP changes during the measurement sequences	0	The coefficient of variation of $c_p(660)$ is less than 3% in 95% of the cases (see text).
Spectral corrections	N/A	*Morel and Maritorena* [2001] reflectance model
Bio-fouling	N/A	Instrument cleaning every 2 weeks. Use of copper shutters, rings and tape. Data suspected of bio-fouling are not included in the validation process.
Self-shading	3	*Gordon and Ding* [1992]; *Zibordi and Ferrari* [1995]
Buoy shading	N/A	Minimized by virtue of the buoy design [*Antoine et al.*, 2008].
Quadratic error	6	

[a]N/A's indicate that no uncertainty estimate was possibly derived.

This 6% uncertainty is not a magic and frozen number

We have to derive uncertainties per band, whenever feasible (at least per wavelength range)

Ongoing actions:
- Better evaluation of self-shading effects
- Evaluation of the buoy shading

(3D backward Monte Carlo)

- Surface extrapolation procedures for profiling radiometry
- Bidirectionality (better characterization of the site through the use of a radiance camera)

NPL National Physical Laboratory | Centre for Carbon Measurement

QA4EO –PI WP4 Case Study: BOUSSOLE

Aga Bialek, Claire Greenwell, Javier Gorroño and
Nigel Fox

11th November 2013

QA4EO

QA4EO PI WP4 Objectives

1. Establish improved uncertainty and traceability for OC Radiometers and Obs-VLF in-house calibration facility

2. Detailed review and discussion of basis and potential for improvement of overall BOUSSOLE uncertainty budget.

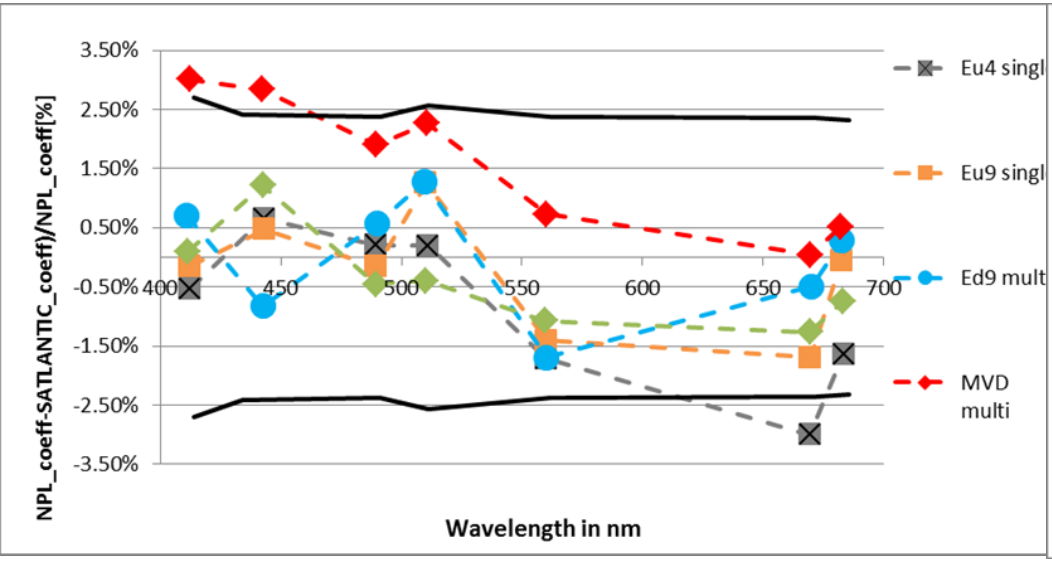
3. Strategy for long-term operational traceability

QA4EO

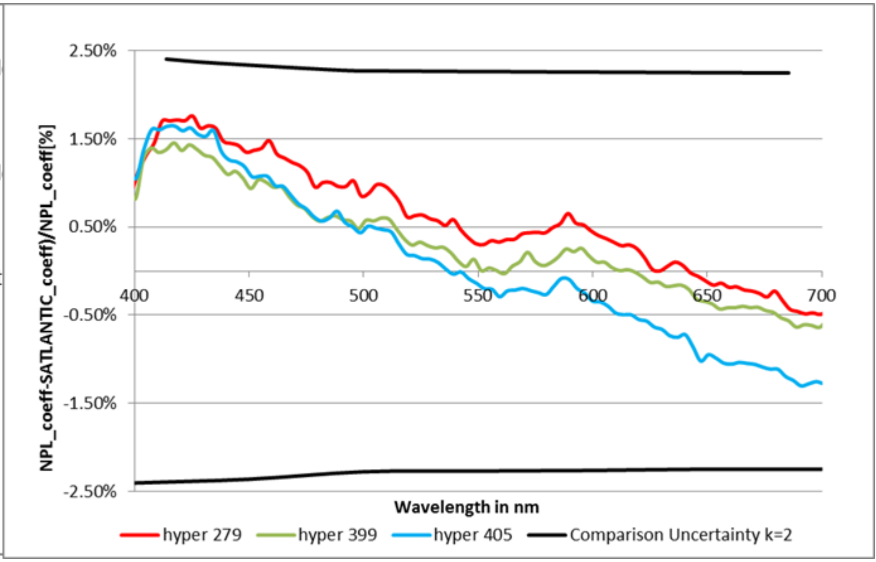
Irradiance mode

Absolute radiometric calibration

Multispectral



Hyperspectral

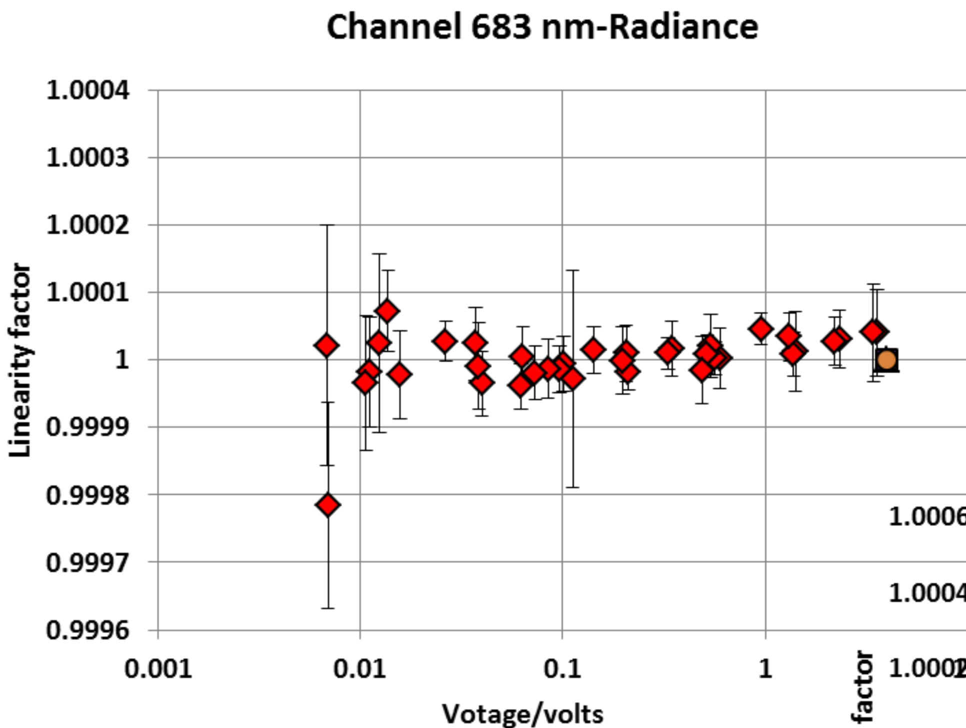


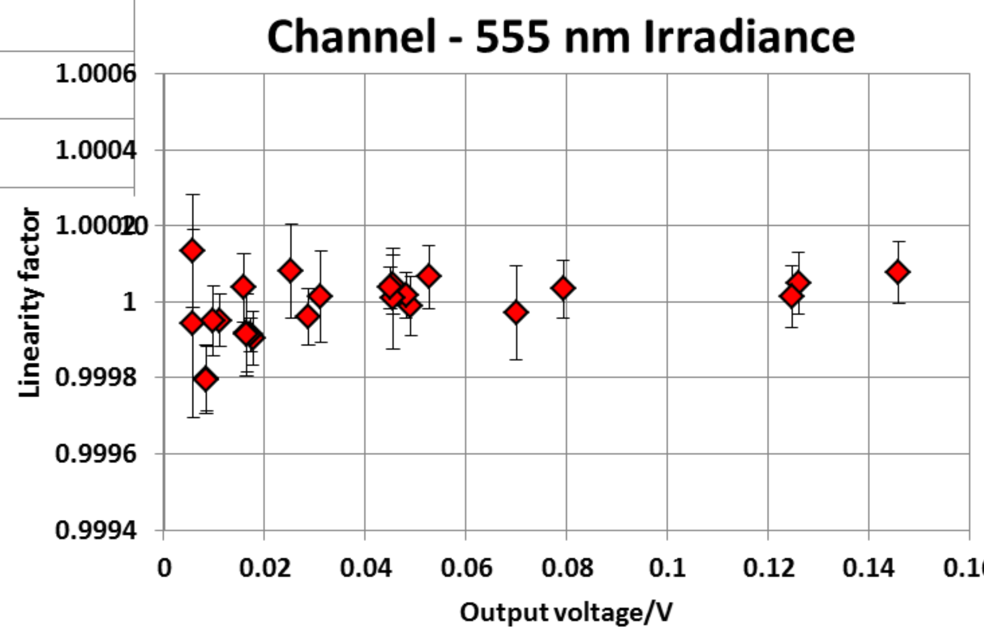
The black lines represent the k=2 limits of the comparison uncertainty.

QA4EO

Linearity tests

Multispectral – very good linearity

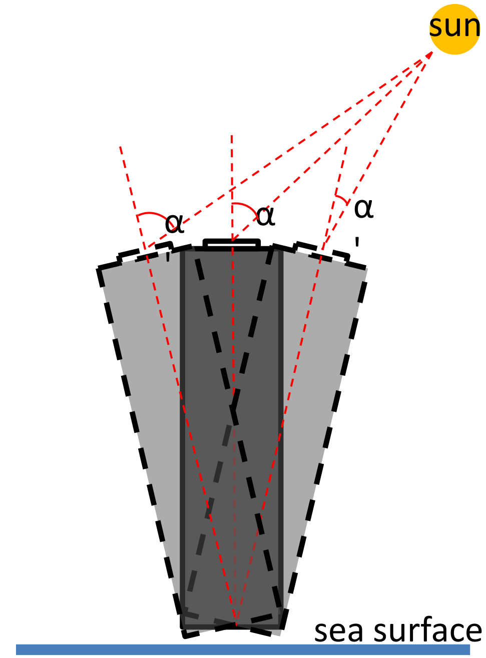


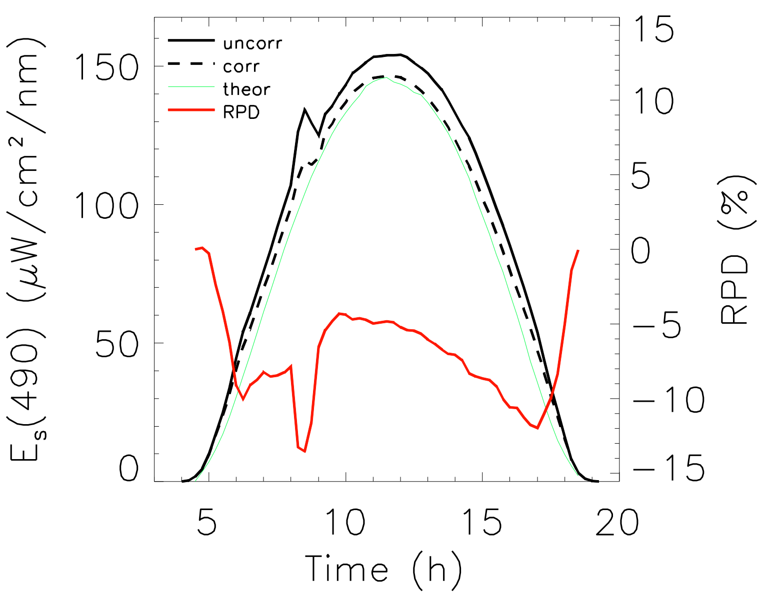


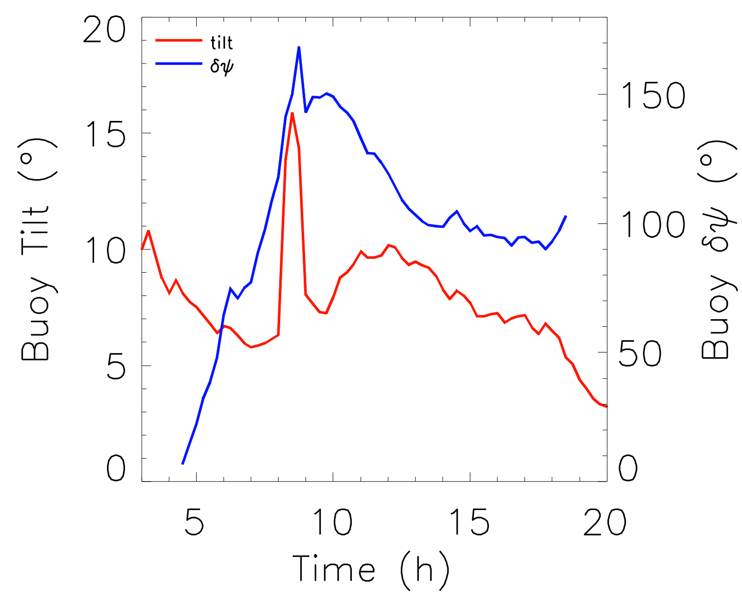
QA4EO

Latest data processing improvements for BOUSSOLE

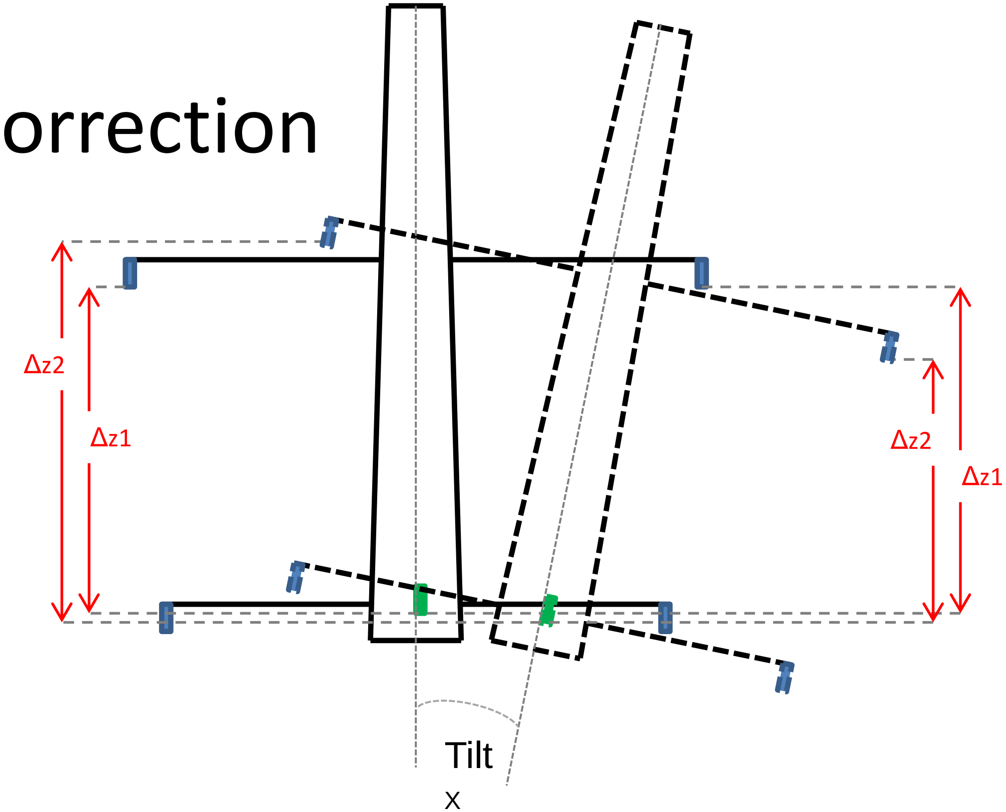
Es tilt (cosine) correction

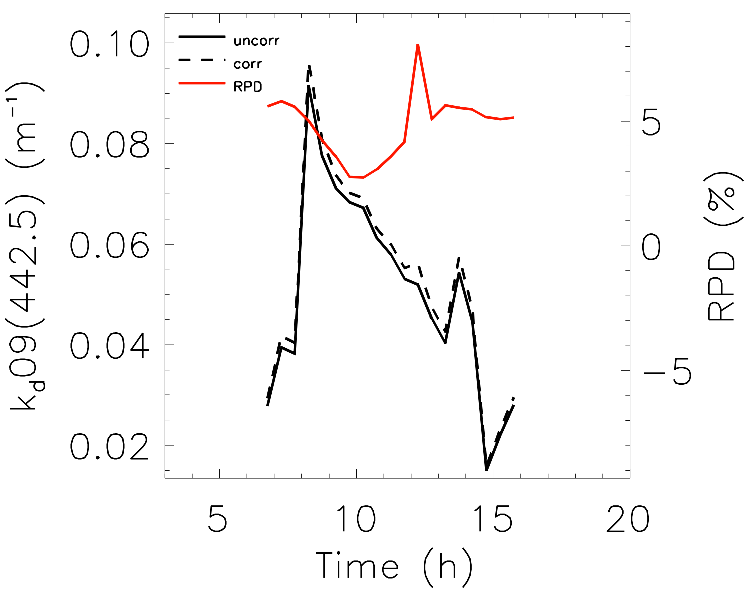


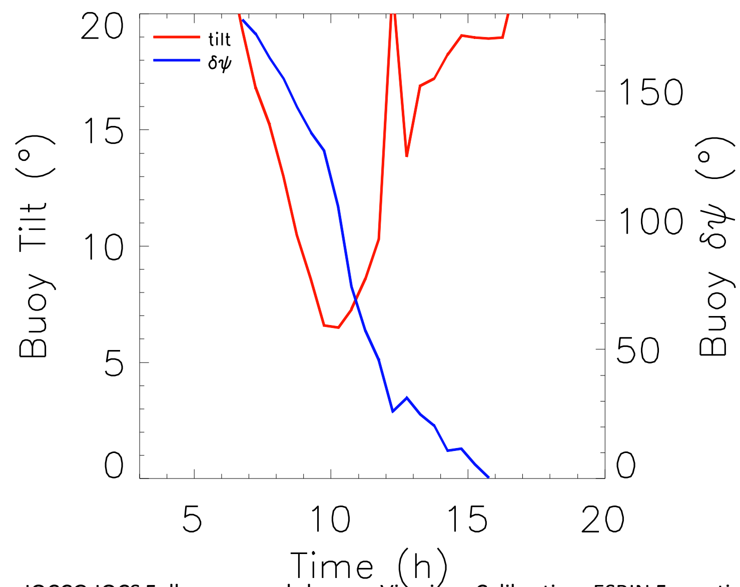




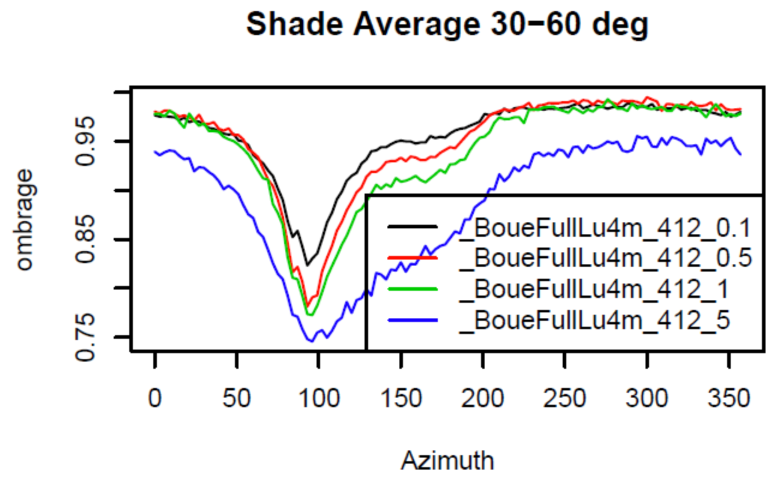
Underwater tilt (depth) correction

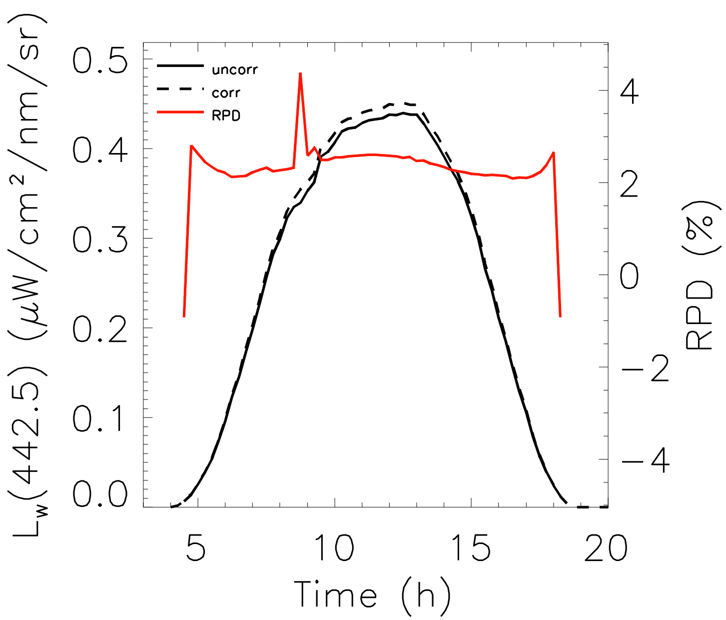


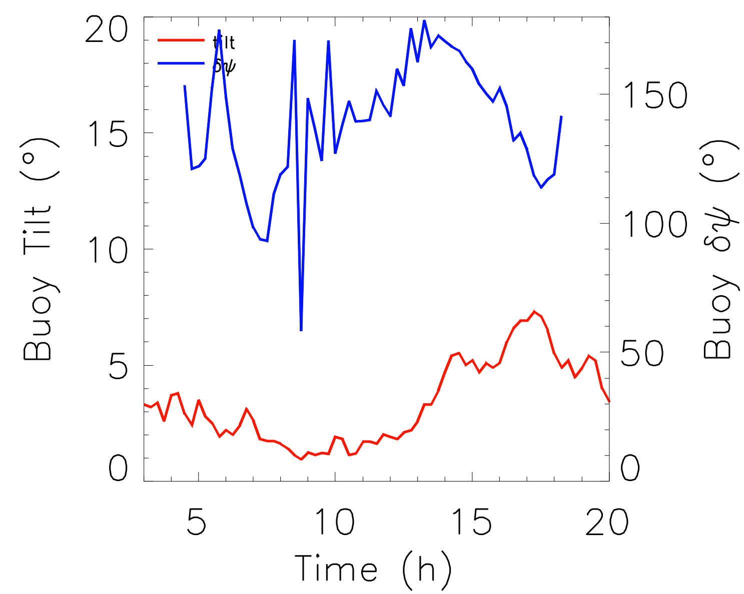




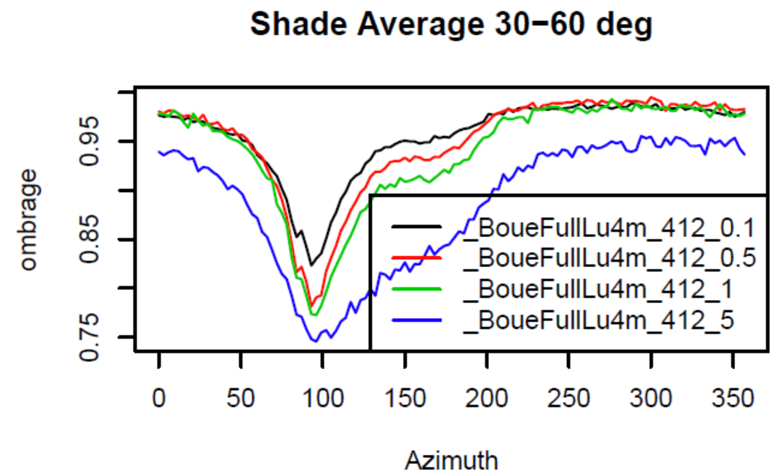
Underwater shadowing correction

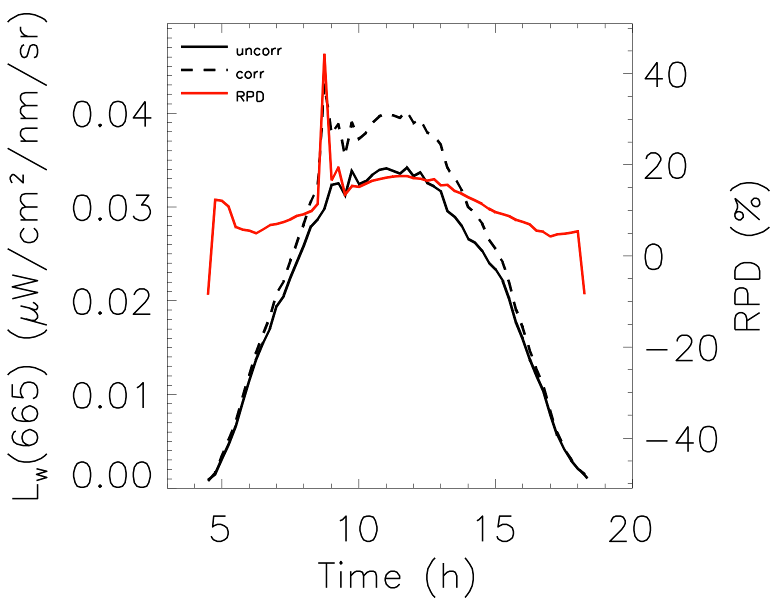


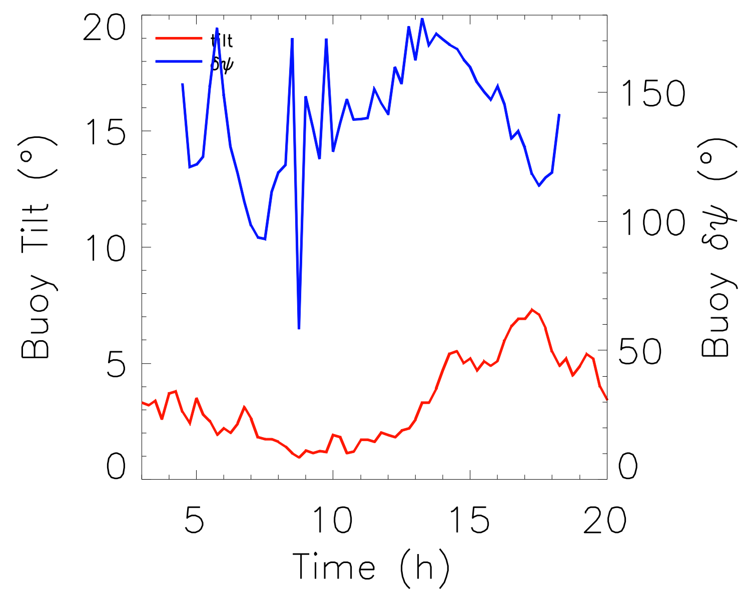




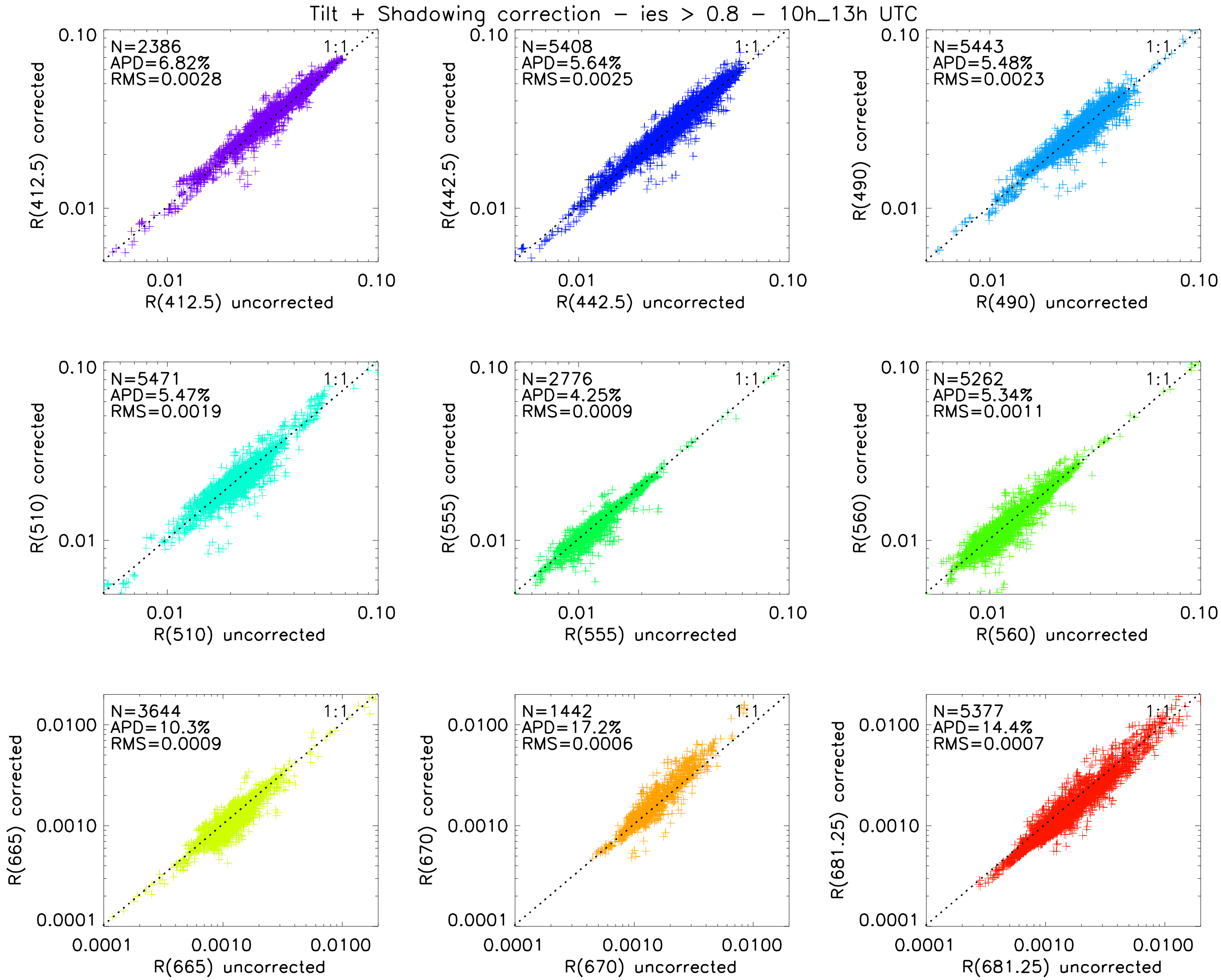
Underwater shadowing correction



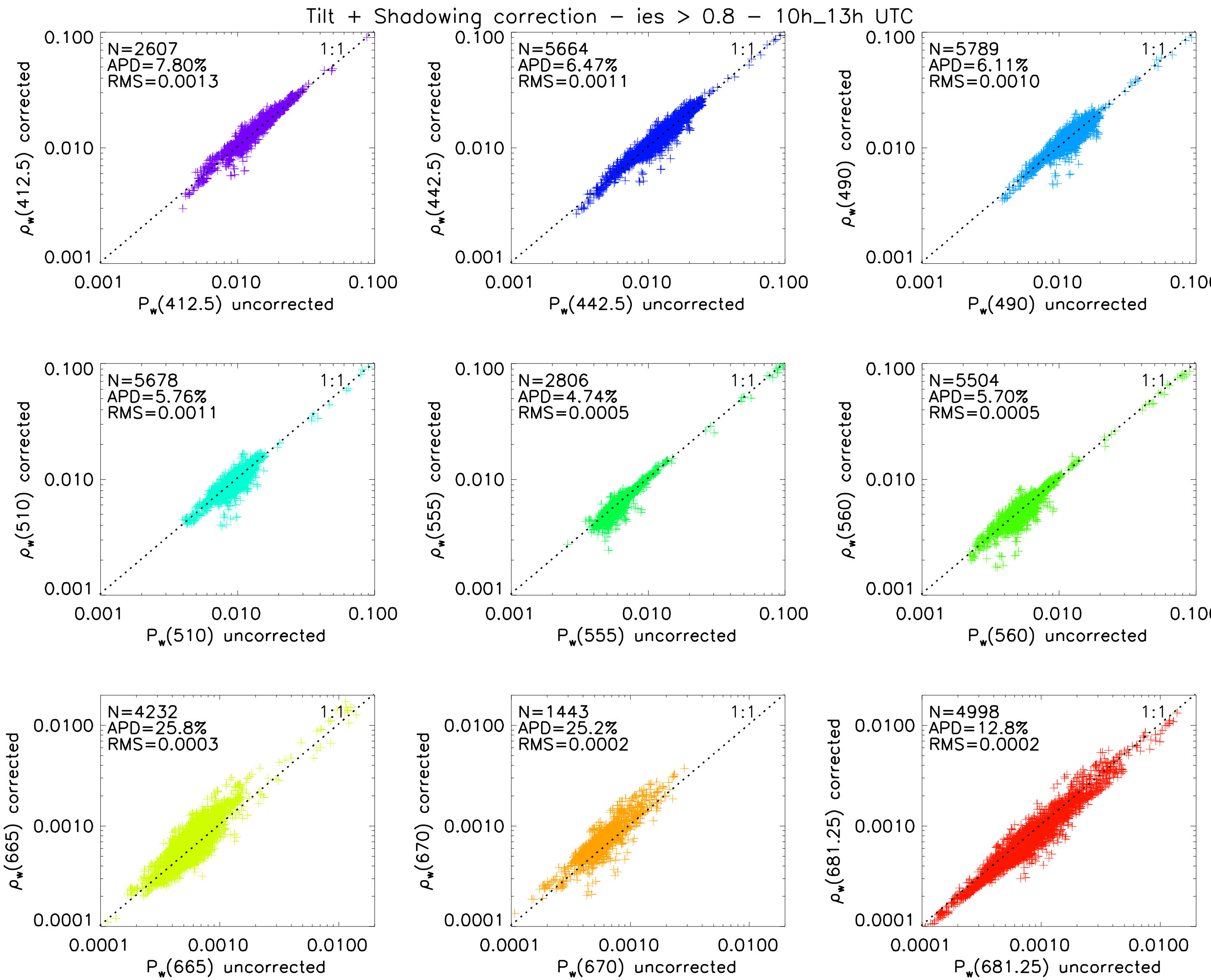




Tilt + shadowing correction



Tilt + shadowing correction




Thank you

SPARES

BOUSSOLE

means

"**BOU**ée pour l'acqui**S**ition d'une
Série **O**ptique à **L**ong term**E**"

"Buoy for the acquisition of
a long-term optical time series"

"Boussole" is the French word for "compass."

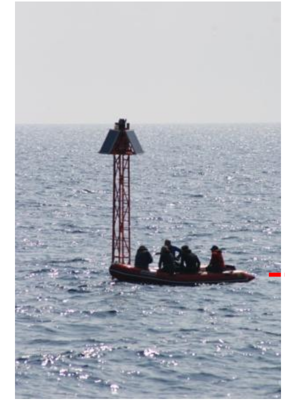
BOUSSOLE: rationale

Motivation, objectives: establishing a long-term time series of optical properties (IOPs and AOPs),
with two parallel objectives:

- Scientific objective: IOPs et AOPs documentation and understanding (bio-optics research), from short-time changes to seasonal variability and more long-term trends...

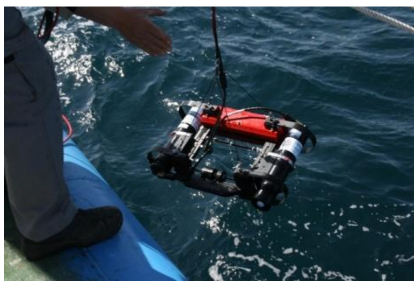
- Operational objective: vicarious calibration of ocean color satellite observations, and validation of the Level-2 geophysical products derived from these observations (*e.g.*, chlorophyll, reflectances, optical properties...).

Strategy



Combination of 3 elements :

- A deep-sea mooring, collecting data in a continuous mode

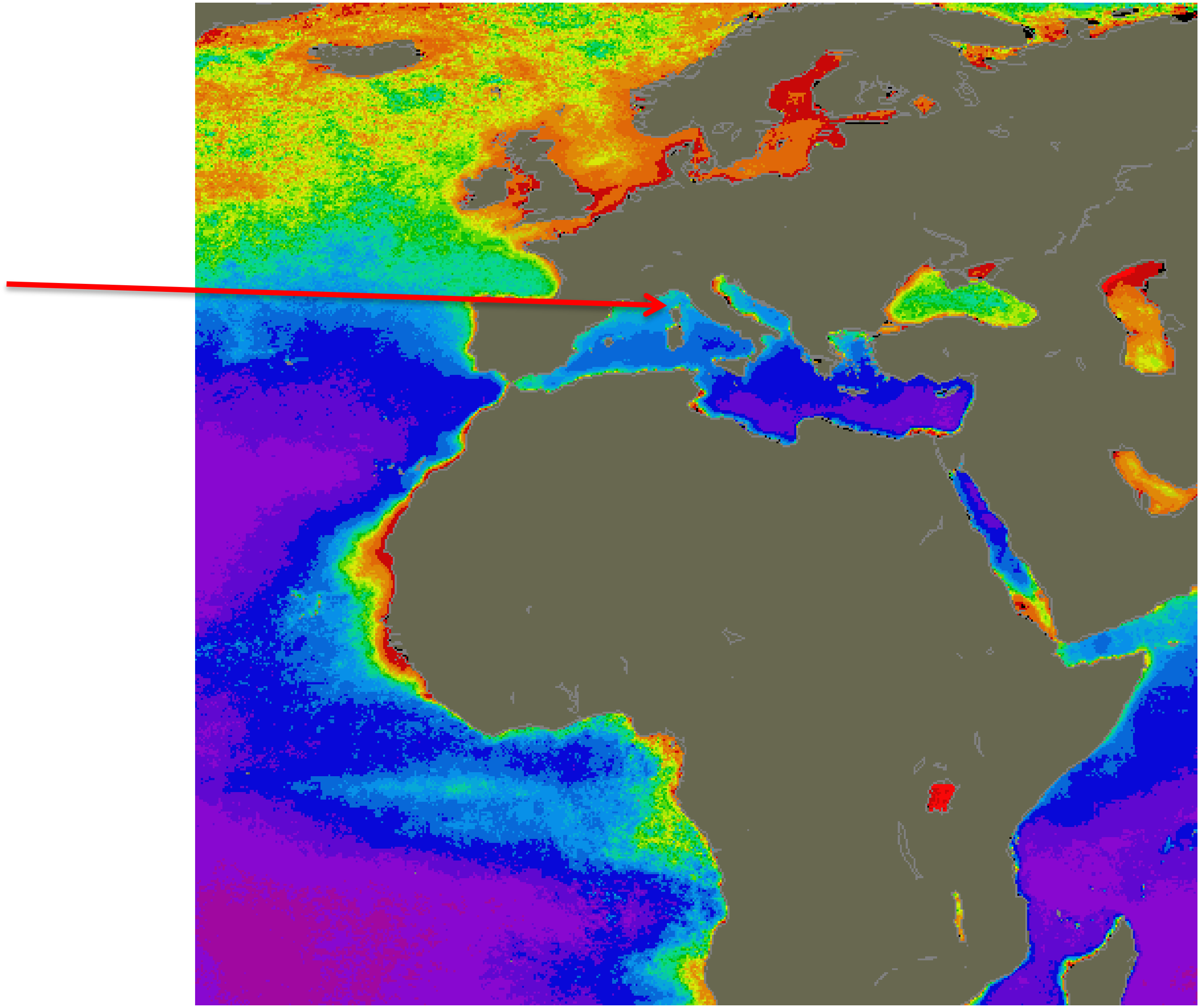


Monthly cruises for mooring servicing and acquisition of complementary data

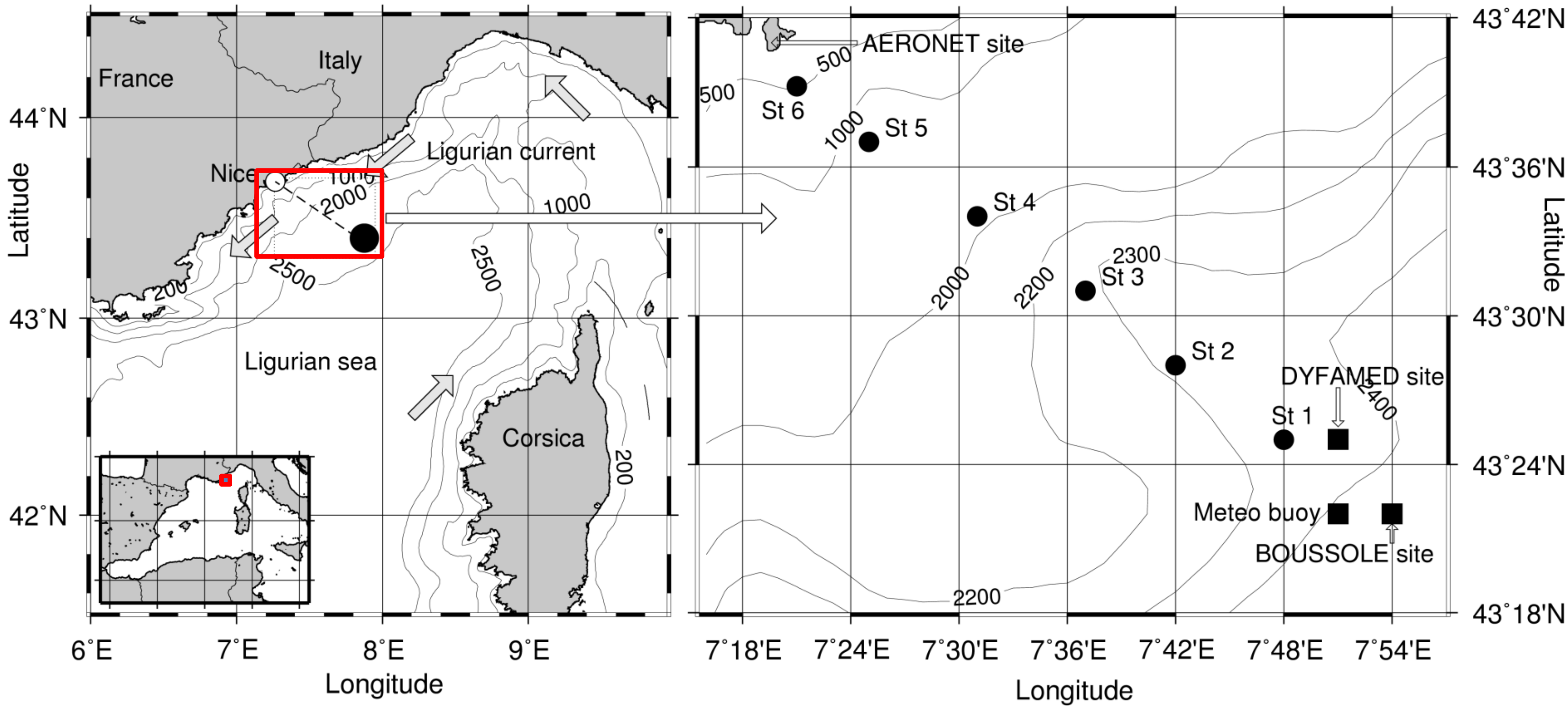
- An AERONET coastal station, providing information on the aerosols, which are an important element in the vicarious calibration

The measurement site

The BOUSSOLE site

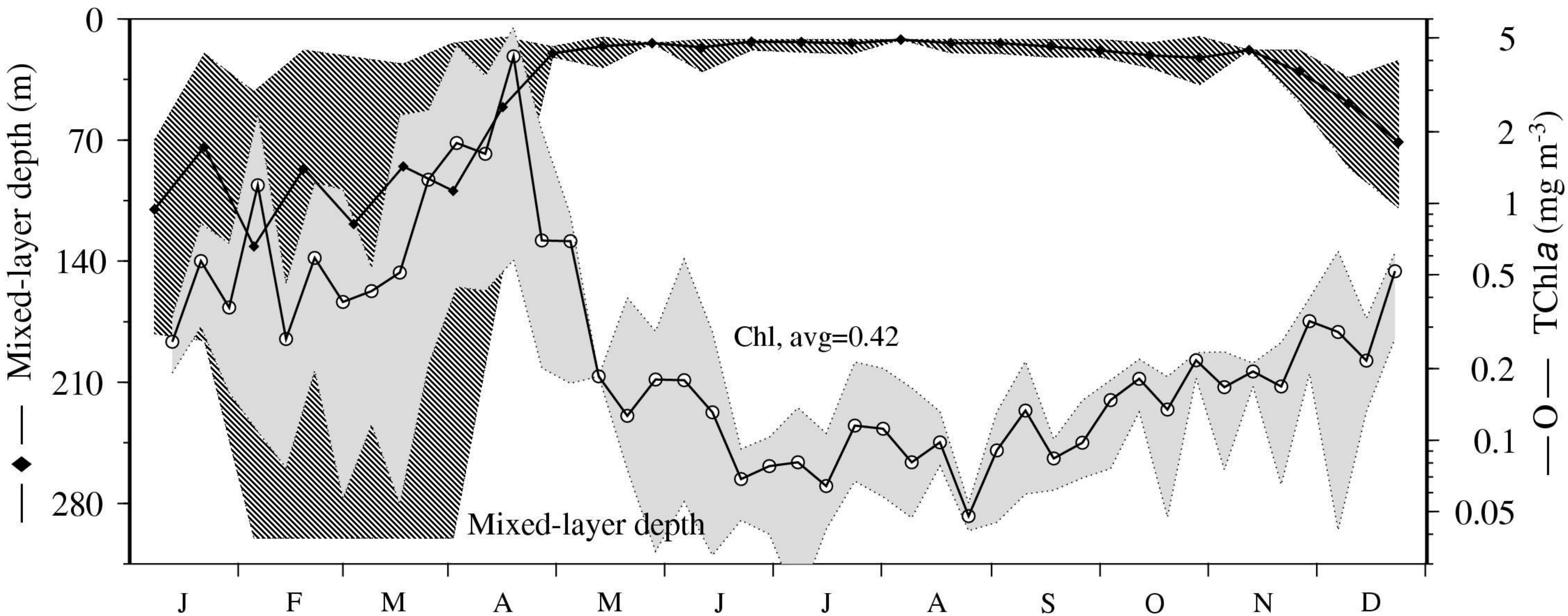


The BOUSSOLE site
in the Ligurian Sea (northwestern Mediterranean)
Water depth: 2440m; 60 km offshore



From: Antoine et al., 2008 JGR 113, C07013, doi:10.1029/2007JC004472

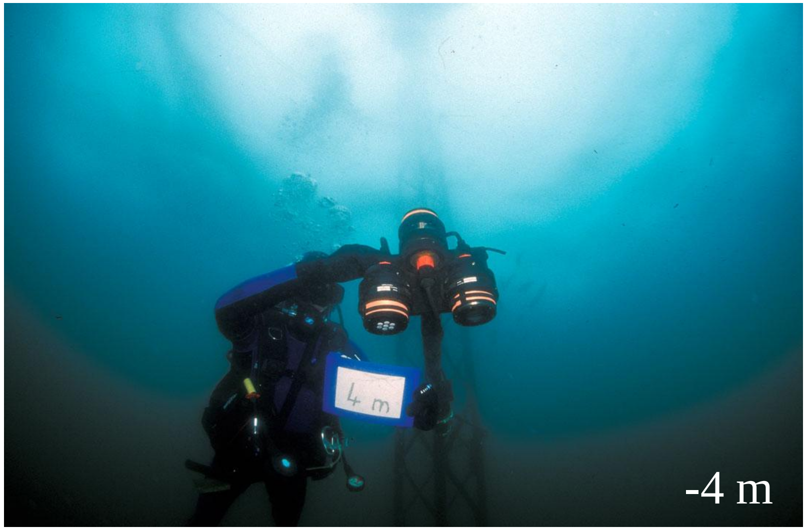
BOUSSOLE site:
10-year average cycles for the mixed-layer depth and the surface chlorophyll concentration



From: Antoine et al., 2008 JGR 113, C07013, doi:10.1029/2007JC004472

Range of variability in optical properties: *"a field look"*

Chl ~ 0.05 mg m^{-3} (march 2006)



Chl ~ 3 mg m^{-3} (April 2006)

Chl ~ 5 mg m^{-3} (March 2012)

The measurement suite

Instrumentation, measurements : buoy
(2 sister buoys, rotation about every 6 months)

✓ E_d, E_u, nadir L_u at 7 λ and at 4 and 9 m + above-surface reference, E_s (Satlantic 200 series)

✓ E_d, nadir L_u and above-water E_s, hyperspectral from 350 to 800 nm, resolution ~3 nm (Satlantic HyperOCR series)

✓ Above-surface PAR (Satlantic PAR sensor)

✓ Beam attenuation coefficient at 660 nm (4 and 9 m; Wetlabs' C-star)

✓ Phytoplankton fluorescence (4 and 9 m; Wetlabs EcoFLNTU)

✓ Backscattering coefficient at 442, 488, 555, and 620 nm (9m only; Hobilabs Hydroscat-4)

✓ Temperature, salinity, pressure (SeaBird SBE 37SI), at nominal depth of 9m

✓ Buoy tilt and compass

✓ Mooring cable tension (strain gauge)

All measurements taken as 1-min acquisition sequences every 15 minutes night and day

Instrumentation, measurements: Monthly cruises

CTD-rosette package:

✓ P, T, S, O_2, chlorophyll fluorescence (CTD), seabird 911

✓ Beam attenuation at 660 nm (Wetlabs' C-Star)

✓ Backscattering coefficient (Wetlabs' ecoBB3; 1 angle, 3 λ)

✓ CDOM fluorescence (Wetlabs' CDOM WetStar).

✓ Attenuation and absorption at 9 λ (Wetlabs' AC9)

Rosette sampling:

✓ Phytoplankton pigments (HPLC)

✓ Particulate and phytoplankton absorption (filters)

✓ CDOM absorption (ultrapath; 2-m capillary wave guide)

✓ Dry weight of particles (only surface samples)

Free-fall radiometry profilers:

✓ E_d and E_u at 13 λ (Satlantic SPMR/SMSR; until June 2011)

✓ E_d and E_u at 18 λ (Biospherical C-OPS; since March 2010)

Others:

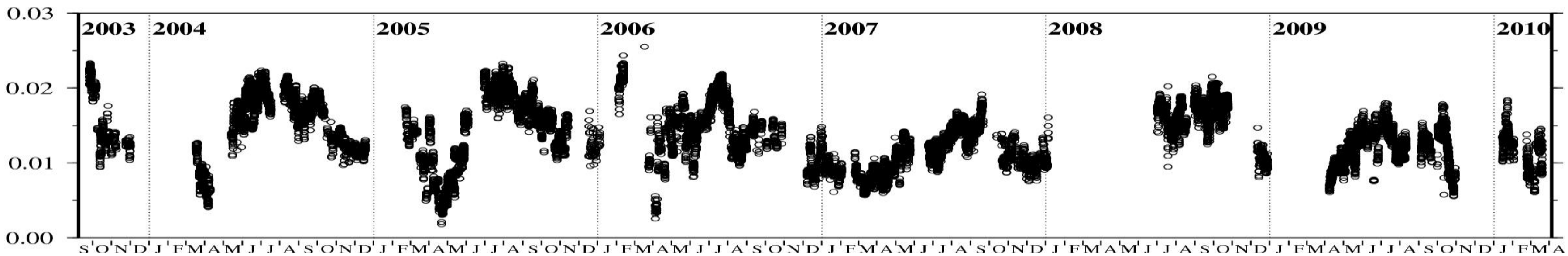
✓ AOT(CIMEL CE-317)

✓ Above-water L_w (SIMBADA); only from 2001 to 2004

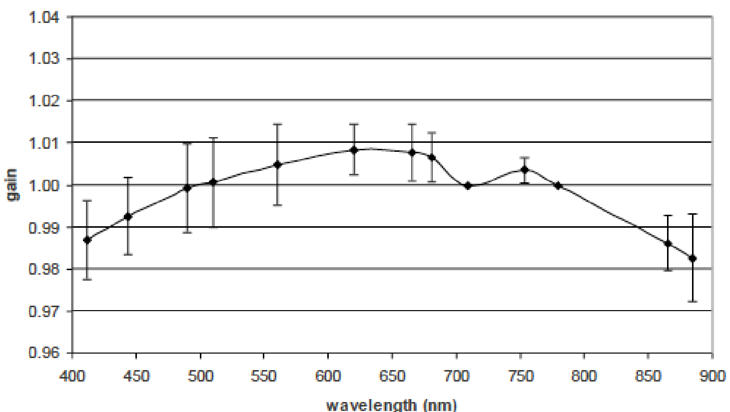
AERONET Station

✓ CIMEL CE-318 photometer : AOT, sky radiances & polarization (since July 2002)

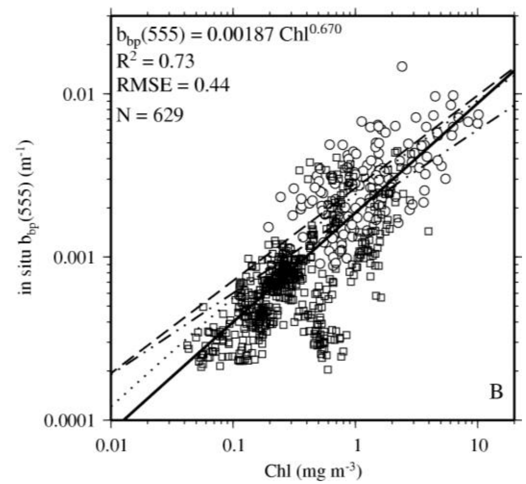
What are these data used for?



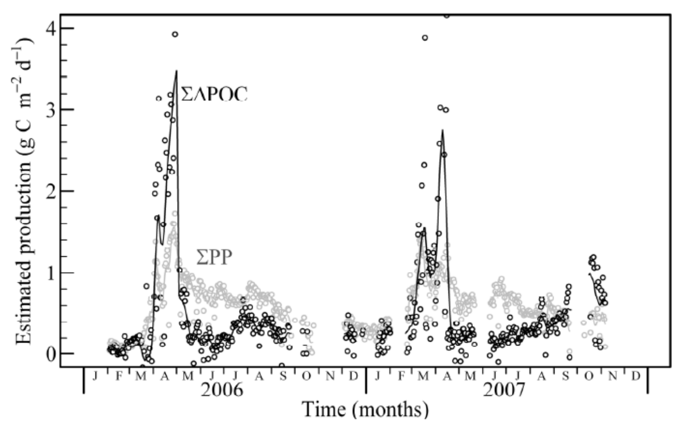
~7-year time series of $\rho_w(442)$; values from 10:00 – 14:00, buoy tilt<10°, clear sky only



MERIS vicarious calibration (3rd reprocessing)
Merging BOUSSOLE and MOBY[1] data



Antoine D, D.A. Siegel, T Kostadinov, S. Maritorena, N.B. Nelson, B. Gentili, V. Vellucci and N. Guillocheau, 2011, ***Limnology & Oceanography***, 56, 955–973.



Gernez P., D. Antoine and Y. Huot, 2011, ***Limnology & Oceanography***, 56, 17-36.

BOUSSOLE publications, as of Dec 2011

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•Antoine, D. M. Chami, H. Claustre, F. D'Ortenzio, A. Morel, G. Bécu, B. Gentili, F. Louis, J. Ras, E. Roussier, A.J. Scott, D. Tailliez, S. B. Hooker, P. Guevel, J.-F. Desté, C. Dempsey and D. Adams. 2006, BOUSSOLE : a joint CNRS-INSU, ESA, CNES and NASA Ocean Color Calibration And Validation Activity. **NASA Technical memorandum N° 2006–214147**, NASA/GSFC, Greenbelt, MD, 61 pp.

•Voss, K., Morel, A. and D. Antoine, 2007. Detailed validation of the bidirectional effect in various Case 1 waters for application to Ocean Color imagery. **Biogeosciences**, 4, 781-789.

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•Antoine, D., P. Guevel, J.-F. Desté, G. Bécu, F. Louis, A.J. Scott and P. Bardey, 2008. The « BOUSSOLE » buoy – A new transparent-to-swell taut mooring dedicated to marine optics : design, tests and performance at sea, **Journal of Atmospheric and Oceanic Technology,** 25, 968-989.

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•Dubuisson P., R. Frouin, L. Dufôret, D. Dessailly, K. Voss & D. Antoine, 2009, Estimating aerosol altitude from reflectance measurements in the O2 A-band, **Remote Sensing of Environment**, 113, 1899–1911

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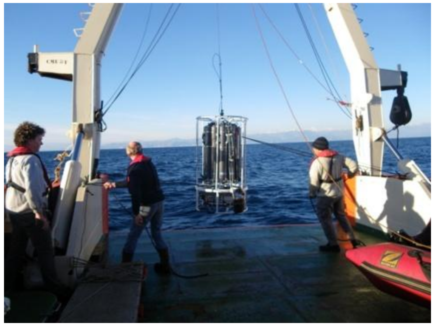
•Banzon V., H.R. Gordon, C. Kuchinke, D. Antoine, K. Voss, and R.H. Evans, 2009, Validation of a SeaWiFS dust-correction methodology in the Mediterranean Sea: Identification of an algorithm-switching criterion. **Remote sensing of environment,** 113 (2009) 2689–2700.

•Gernez P., D. Antoine and Y. Huot, 2011, Diel cycles of the particulate beam attenuation coefficient under varying trophic conditions in the northwestern Mediterranean Sea: observations and modeling. **Limnology & Oceanography**, 56, 17-36.

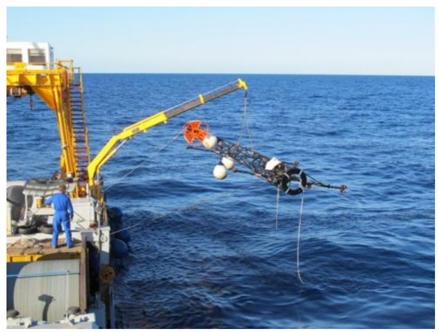
•Antoine D, D.A. Siegel, T Kostadinov, S. Maritorena, N.B. Nelson, B. Gentili, V. Vellucci and N. Guillocheau, 2011, Variability in optical particle backscattering in two contrasting bio-optical oceanic regimes, **Limnology and Oceanography**, 56, 955–973.

Quantitative summary at the end of 2011 (over ~10 years)

- ~**290** days at sea since July 2001 (monthly cruises on R/V Tethys-II)

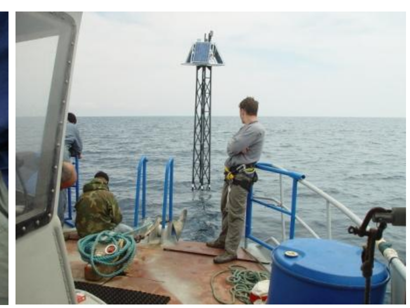



- ~**50** days at sea for buoy deployments / recoveries (47m dyn. Positioning ship)

- ~**70** days at sea for on-demand maintenance operations (cleaning, repairs etc..)






Photos: E. Diamond, LOV; D. Luquet, OOV, D. Antoine, LOV

Web site and data base

Open since 2006

All data available there

http://www.obs-vlfr.fr/Boussole

LOV radiometric calibration facility
(image below: during installation)