BOUSSOLE DATA PROCESSING

D. Antoine, B. Gentili, E. Leymarie V. Vellucci

21-23 February 2017 – FRM4SOC

OUTLINE

> Preprocessing
  - conversion to physical units
  - dark subtraction
  - data reduction

> Processing
  - conversion to physical units
  - depth correction
  - cosine correction
  - shading correction
  - extrapolation
  - *Rrs*

> Quality Control
  - biofouling
  - intercalibration

APPLICATION OF FACTORY CALIBRATION

> Satlantic, NIST traceable, every 6-12 months

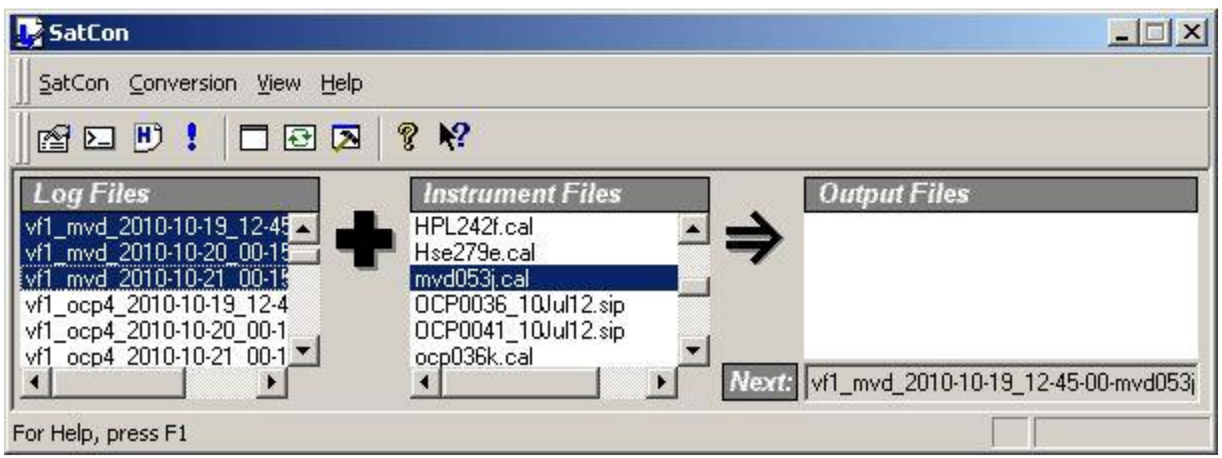
- $E_s(t',\lambda)_{Dd} = \left[E_s(t',\lambda)_{Volt} - Dark_{Cal\_Es}(\lambda)\right] \cdot Lin_{Cal\_Es}(\lambda)$
- $L_u(z',t',\lambda)_{Dd} = \left[L_u(z',t',\lambda)_{Volt} - Dark_{Cal\_Lu(z)}(\lambda)\right] \cdot Lin_{Cal\_Lu(z)}(\lambda) \cdot Imm_{Cal\_Lu(z)}(\lambda)$
- $E_d(z',t',\lambda)_{Dd} = \left[E_d(z',t',\lambda)_{Volt} - Dark_{Cal\_Ed(z)}(\lambda)\right] \cdot Lin_{Cal\_Ed(z)}(\lambda) \cdot Imm_{Cal\_Ed(z)}(\lambda)$
- $E_u(z',t',\lambda)_{Dd} = \left[E_u(z',t',\lambda)_{Volt} - Dark_{Cal\_Eu(z)}(\lambda)\right] \cdot Lin_{Cal\_Eu(z)}(\lambda) \cdot Imm_{Cal\_Eu(z)}(\lambda)$

```
#
#  MVDS s/n 053 with OCI-200 s/n 095
#
# Final calibration file  valid 13 November, 2014
# Villefranche / Project 2007-503

INSTRUMENT SATMVD '' 6 AS 0 NONE
SN 0053 '' 4 AI 0 NONE
RATE 6 'Hz' 0 BU 0 NONE

# Optical data updated by Jennifer

#ES sensor OCI-200 S/N 095 calibrated for LO GAIN in IN AIR
# by Jenn on 11/13/14 at 10:38:11
# LO GAIN calibration, LAMP: f1304 at DIST: 50.0 cm
ES 412.3 'uW/cm^2/nm' 2 BU 1 OPTIC2
   32774.3 9.72971e-003 1.00
ES 442.3 'uW/cm^2/nm' 2 BU 1 OPTIC2
   32775.2 9.45316e-003 1.00
ES 489.5 'uW/cm^2/nm' 2 BU 1 OPTIC2
   32775.6 9.08008e-003 1.00
ES 510.6 'uW/cm^2/nm' 2 BU 1 OPTIC2
   32775.9 9.79014e-003 1.00
ES 560.2 'uW/cm^2/nm' 2 BU 1 OPTIC2
   32775.1 9.09505e-003 1.00
ES 669.5 'uW/cm^2/nm' 2 BU 1 OPTIC2
   32776.7 8.61297e-003 1.00
ES 682.3 'uW/cm^2/nm' 2 BU 1 OPTIC2
   32773.0 9.35531e-003 1.00
```



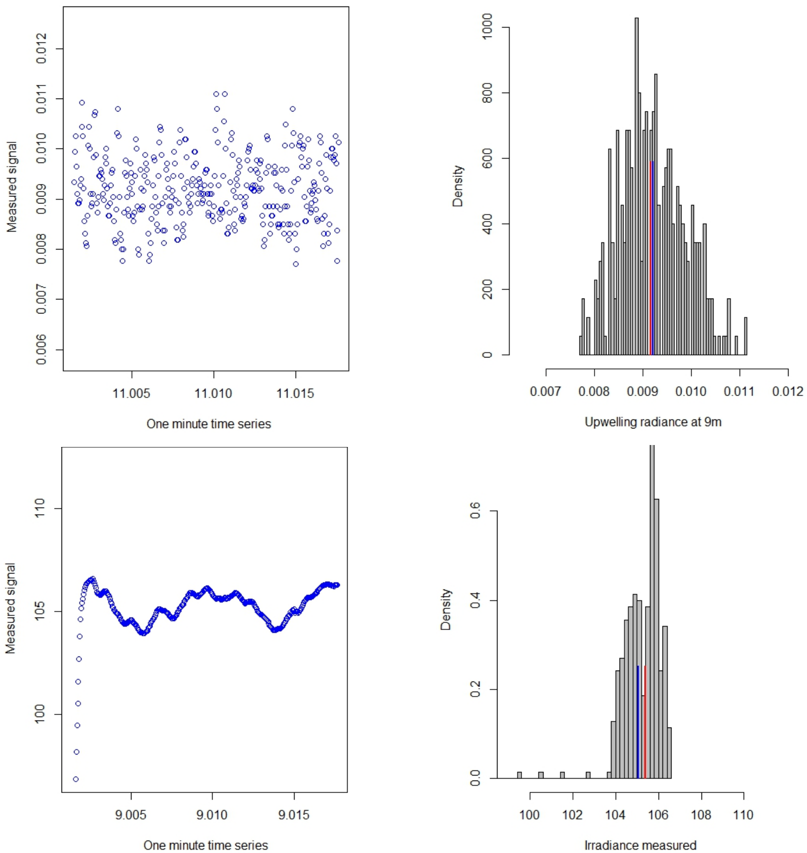
MULTISPECTRAL INSTRUMENTS (NO INTERNAL SHUTTER)

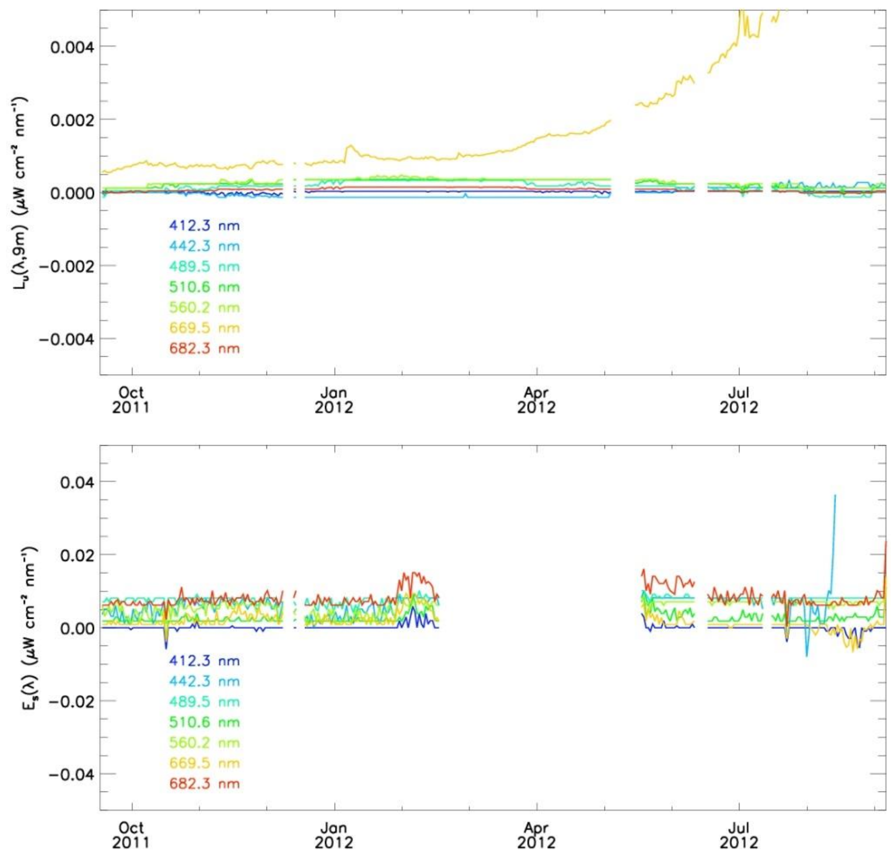
> The median value of 1' records is retained as representative of each quarter (same for ancillary)

- $\overline{E_s(t,\lambda)_{Dd}} = median[E_s(t',\lambda)_{Dd}]_{t'=0s}^{60s}$
- $\overline{L_u(z,t,\lambda)_{Dd}} = median[L_u(z',t',\lambda)_{Dd}]_{t'=0s}^{60s}$

> An average daily dark is calculated from night binned measurements and subtracted

- $\overline{E_s(t,\lambda)'} = \overline{E_s(t,\lambda)_{Dd}} - mean\left[\overline{E_s(t,\lambda)_{Dd}}\right]_{t=22h}^{3h}$
- $\overline{L_u(z,t,\lambda)'} = \overline{L_u(z,t,\lambda)_{Dd}} - mean\left[\overline{L_u(z,t,\lambda)_{Dd}}\right]_{t=22h}^{3h}$





Mean and median not significantly different when the measurement is not affected by environmental variability (e.g. clouds)

Hyperspectral Instruments (Internal Shutter)

> The mean of two consecutive dark measurements is subtracted to light measurements in between

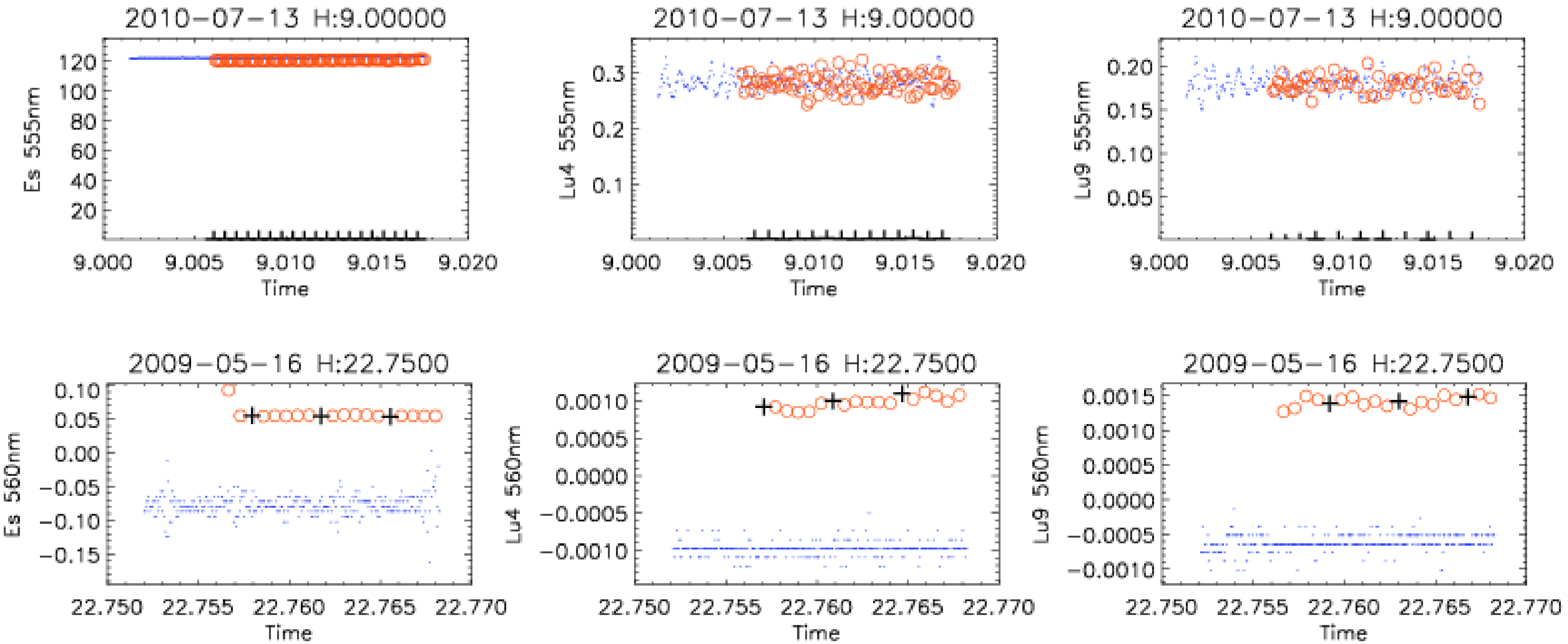
– $E_s(t',\lambda) = E_s(t',\lambda)_{Dd} - \frac{E_s(t'-1,\lambda)_{Shutter} + E_s(t'+1,\lambda)_{Shutter}}{2}$

– $L_u(z',t',\lambda) = L_u(z',t',\lambda)_{Dd} - \frac{L_u(z',t'-1,\lambda)_{Shutter} + L_u(z',t'+1,\lambda)_{Shutter}}{2}$

> Then the median value is kept for each quarter

– $\overline{E_s(t,\lambda)'} = median[E_s(t',\lambda)]_{t=0}^{60s}$

– $\overline{L_u(z,t,\lambda)'} = median[E_s(z',t',\lambda)]_{t=0}^{60s}$



Tilt Correction

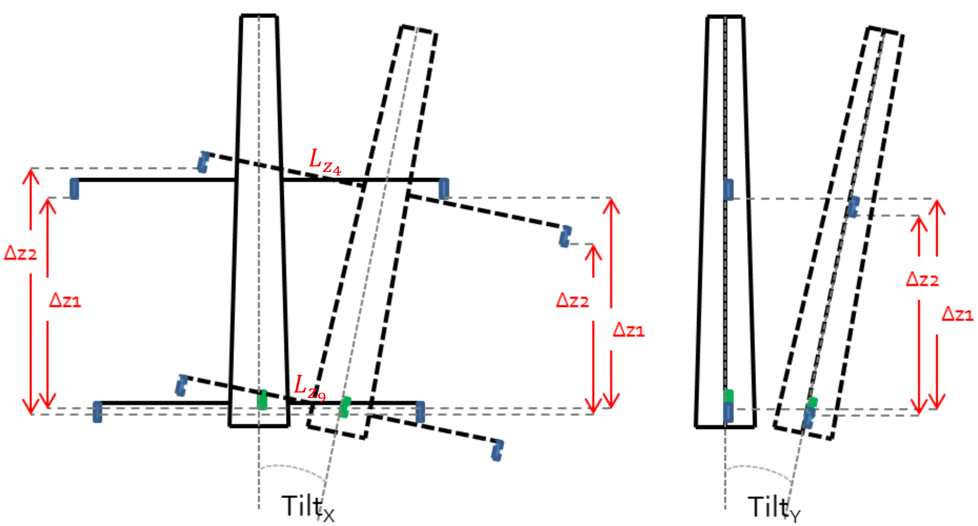
Correction of Instrument Depth

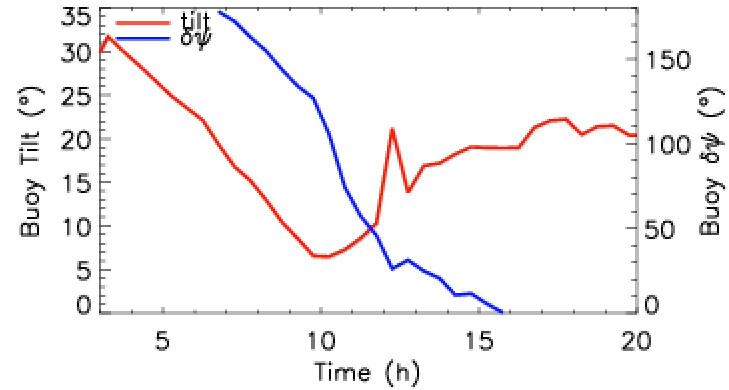
> Depth, $Tilt_x$ and $Tilt_Y$ are measured in the core of the buoy

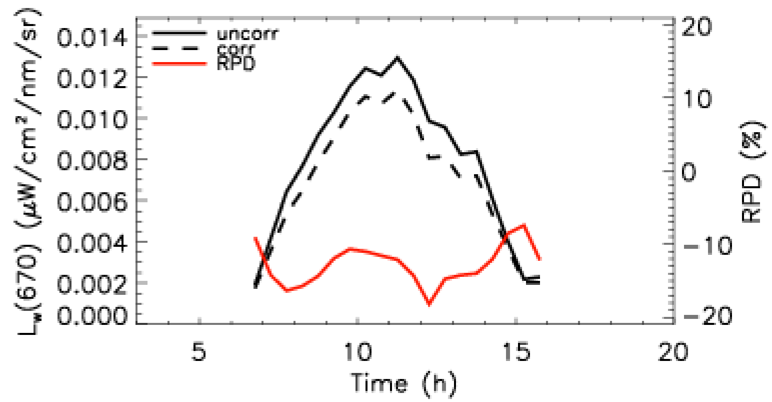
> The distance of each radiometer from the CTD along the buoy principal axis is known, so its depth when *Tilt*=0

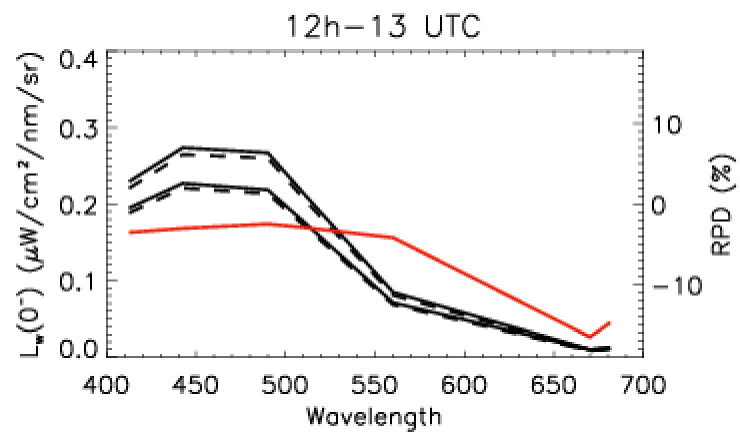
> A correction factor for depth each instrument and measurement is derived from the buoy Tilt and applied

- $z_{rad}(t) = [z_{CTD}(t) - \Delta z_{rad}] \cdot f_{depth}(t, Tilt_x, Tilt_y)$
- $f_{depth}(t) = \left(1 - \cos Tilt_y(t)\right) \cdot \left(1 - \cos Tilt_x(t)\right) - L_{z_{rad}} \sin Tilt_x(t)$

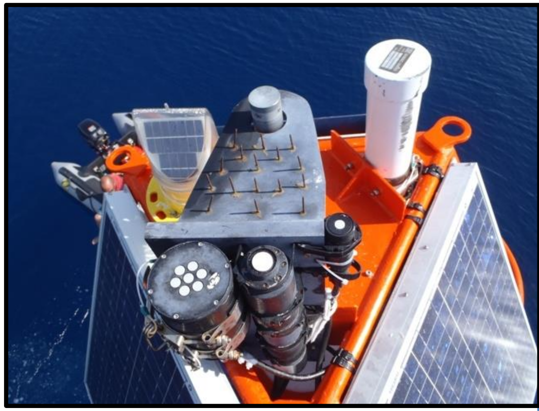


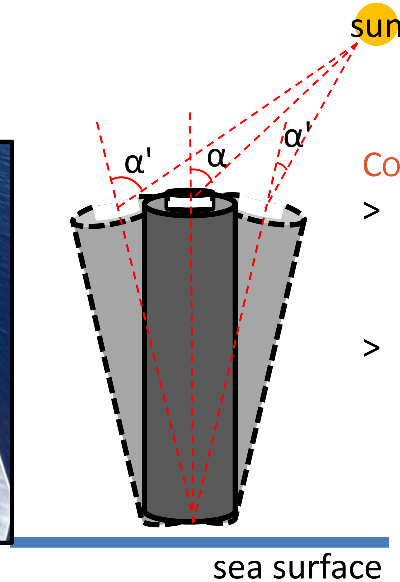






Tilt Correction

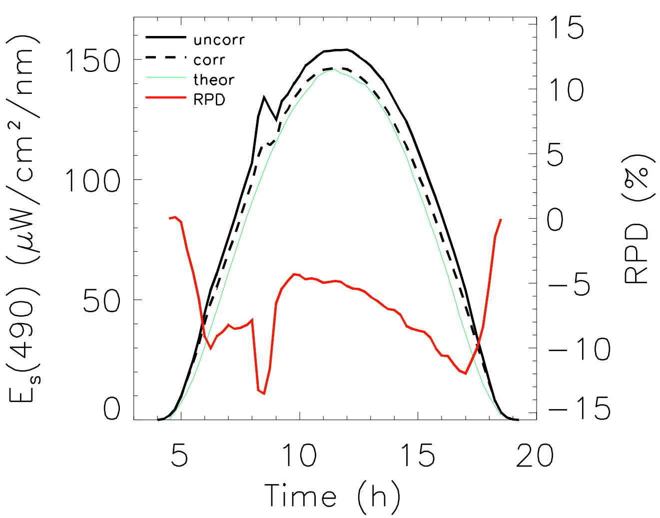


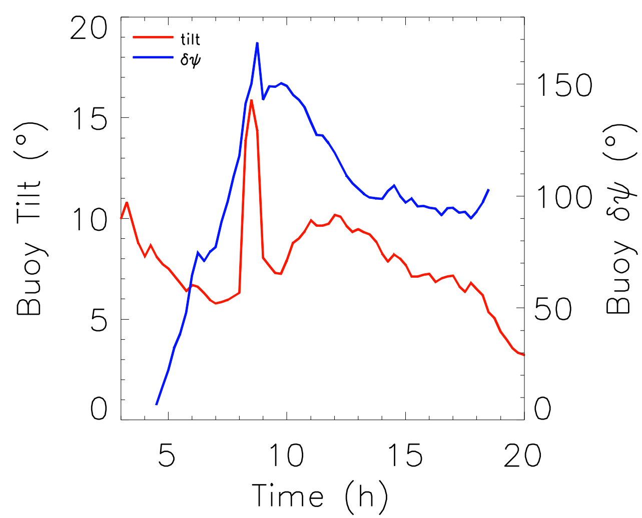


Cosine Correction of Surface Irradiance

> First the direct fraction of *Es* is estimated following *Gregg & Carder, 1990*
  - $\overline{E_S(t,\lambda)}' = \overline{E_S(t,\lambda)}' \cdot f_{dir} + \overline{E_S(t,\lambda)}' \cdot (1 - f_{dir})$

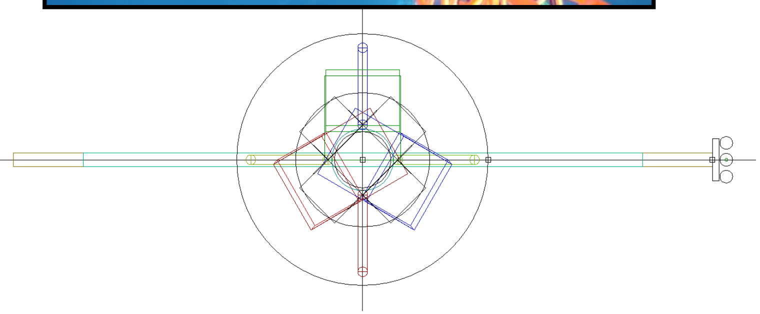
> The correction is then applied to the direct fraction of *Es*
  - $E_S(t,\lambda) = \overline{E_S(t,\lambda)}' \cdot f_{dir} \cdot f_{tilt} + \overline{E_S(t,\lambda)}' \cdot (1 - f_{dir})$
  - Where $f_{tilt} = \frac{\cos(\alpha')}{\cos(\alpha)}$

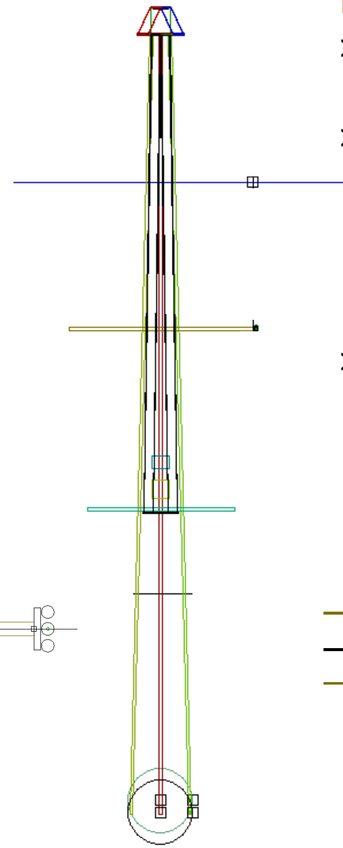


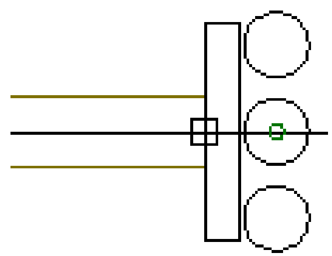


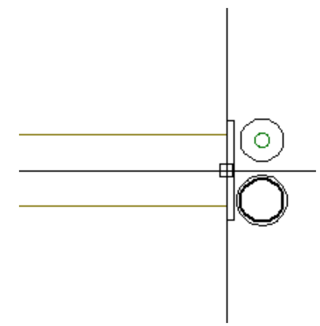
BUOY STRUCTURE SHADING AND INSTRUMENT SELF-SHADING

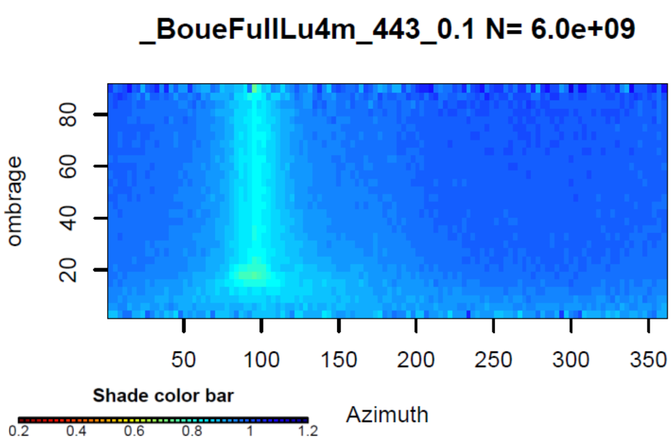
> Backward 3D *Montecarlo* simulation (*SimulO*) replaces the *Gordon & ding (1992)* correction scheme
> Simulation for each underwater instrument
  - Chl = 0.1, 0.5, 1.0, 5.0 µg l-1
  - Azimuth angle from 0° to 360°, with 5° step
  - Zenith angle from 0° to 90°, with 5° step
  - 7 wavelengths (412, 443, 490, 510, 555, 670 nm)
> A correction factor from LUTs is applied
  - $\overline{L_u(z_4,t,\lambda)}=\overline{L_u(z_4,t,\lambda)'}\cdot f_{s4}$
  - $\overline{L_u(z_9,t,\lambda)}=\overline{L_u(z_9,t,\lambda)'}\cdot f_{s9}$

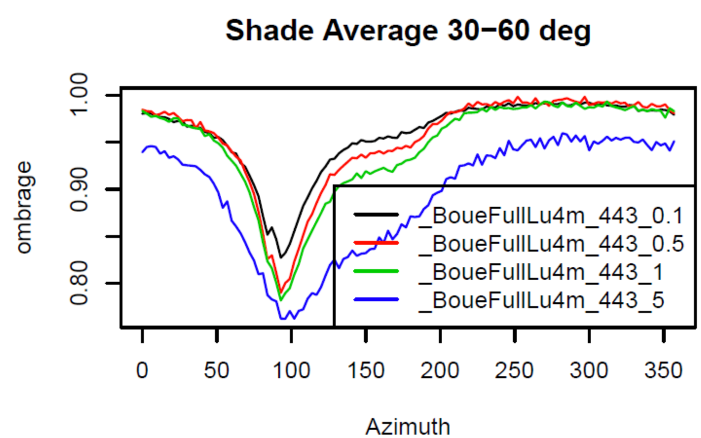


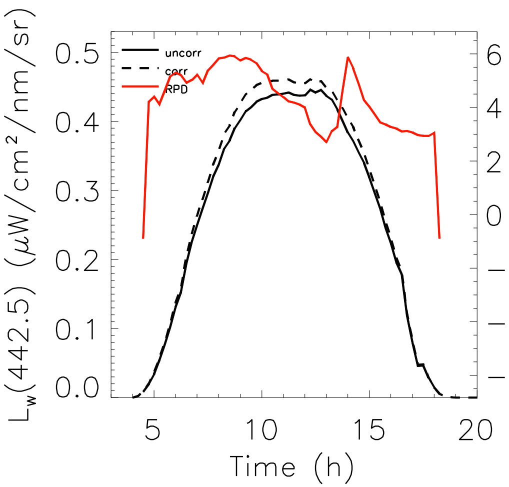


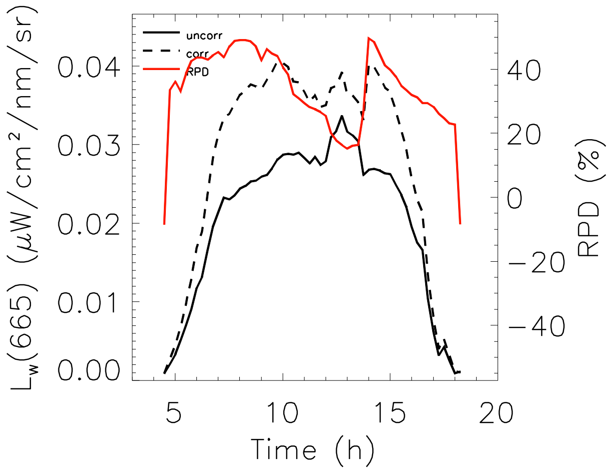


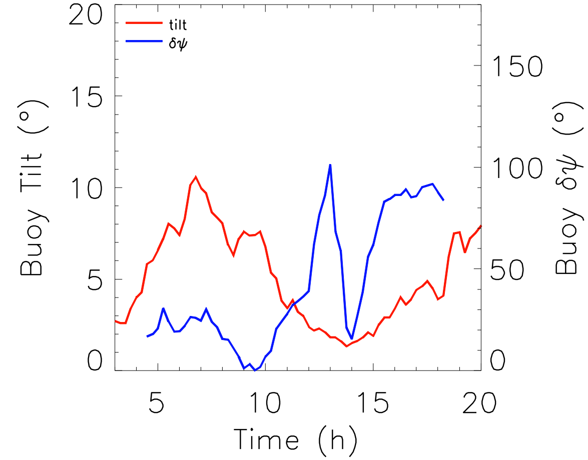


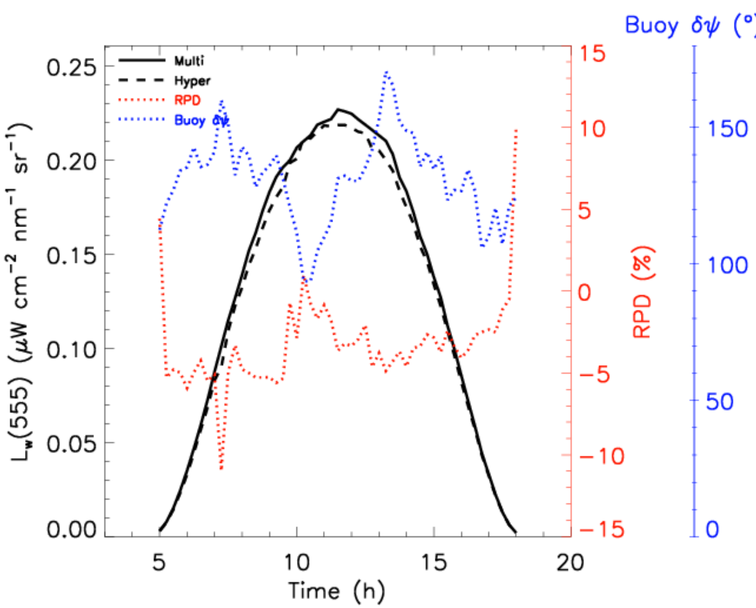


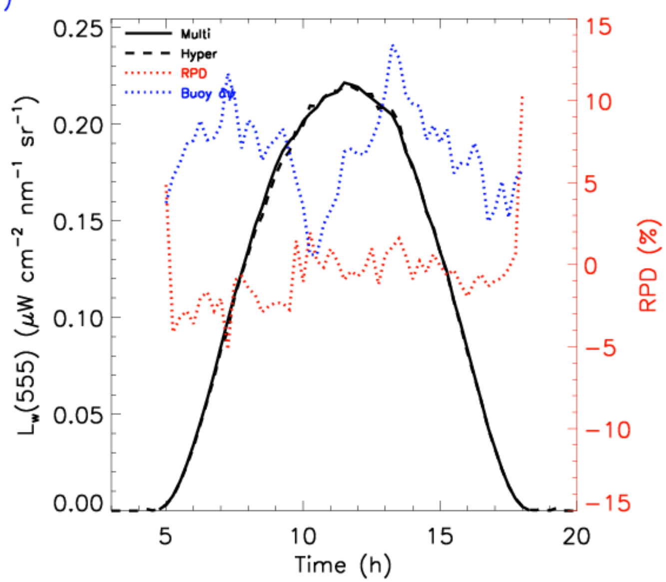



uncorr
corr
RPD
L_w(442.5) (μW/cm^2/nm/sr)
RPD (%)
Time (h)


uncorr
corr
RPD
L_w(665) (μW/cm^2/nm/sr)
RPD (%)
Time (h)


tilt
$\delta\psi$
Buoy Tilt (°)
Buoy $\delta\psi$ (°)
Time (h)


Multi
Hyper
RPD
Buoy $\delta\psi$
Buoy $\delta\psi$ (°)
L_w(555) (μW cm^{-2} nm^{-1} sr^{-1})
RPD (%)
Time (h)

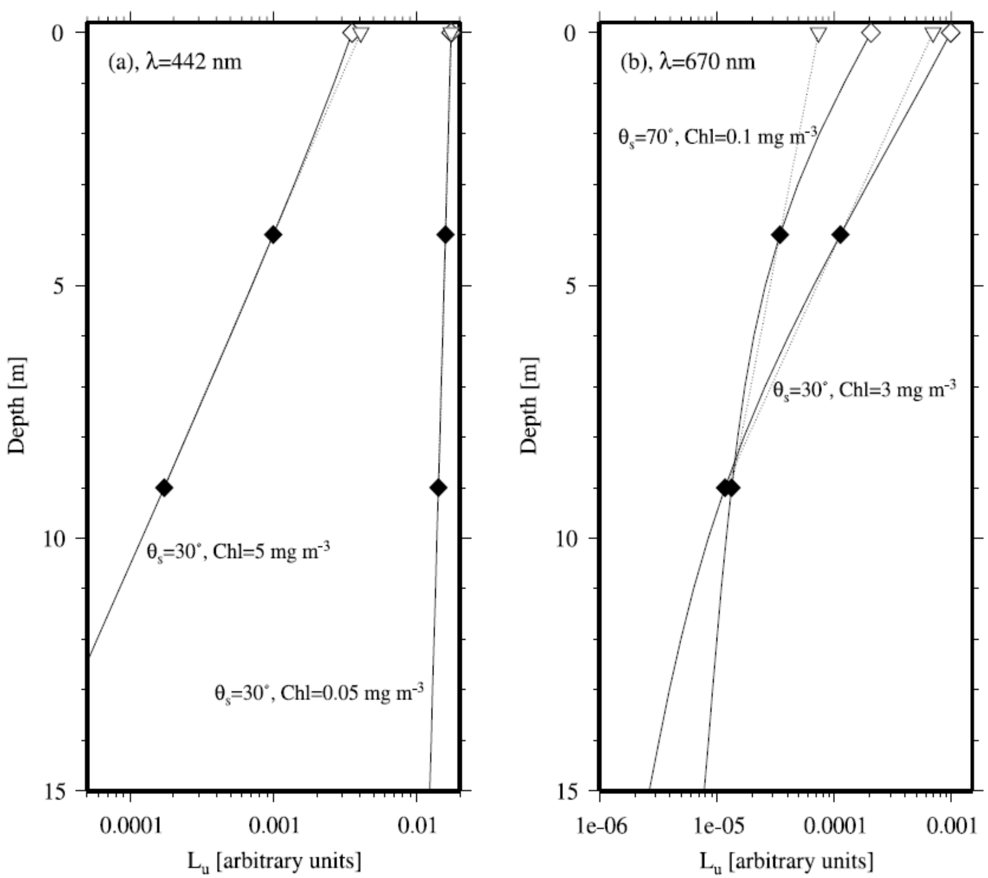

Multi
Hyper
RPD
Buoy $\delta\psi$
L_w(555) (μW cm^{-2} nm^{-1} sr^{-1})
RPD (%)
Time (h)

EXTRAPOLATION OF LU TO SURFACE

> Diffuse attenuation coefficient for radiance is estimated from the L_u measurements at 4 m and 9 m
  - $K_L = -\frac{\ln[\overline{L_u(z_9,t,\lambda)}/\overline{L_u(z_4,t,\lambda)}]}{z_9 - z_4}$

> L_u at 4 m is then lognormally extrapolated to surface (below water) and a correction factor is applied*
  - $L_u(0^-,t,\lambda) = \overline{L_u(z_4,t,\lambda)}\ e^{-z_4 \cdot K_L} \cdot f_H$

> Finally water leaving radiance is calculated as
  - $L_{w(t,\lambda)} = L_u(0^-,t,\lambda) \cdot \frac{1-\rho}{n^2}$; where $\frac{1-\rho}{n^2} = 0.543$



*HYDROLIGHT CORRECTION

> Radiative transfer simulation of $L_u(z, Chl, \theta_s, \lambda)$
  - Chl = 0.1, 0.5, 1.0, 5.0 µg l-1
  - Zenith angle from 0° to 90°, with 5° step
  - 7 wavelengths (412, 443, 490, 510, 555, 670 nm)

> Generation of a LUT of the ratio between $L_u(0^-,t,\lambda)$ as estimated from radiative transfer simulations and lognormal extrapolation of simulated $L_u(Chl, \theta_s, \lambda)$ at 4 and 9 m

$$R_{rs}(t,\lambda) = \frac{L_{w}(t,\lambda)}{E_S(t,\lambda)}$$

⇕

$$R_{rs} = \frac{\overline{L_{u4}} f_{cal} f_{s4} exp\left[z_4\left(\frac{-\ln\left(\overline{L_{u9}} f_{cal} f_{s9} / \overline{L_{u4}} f_{cal} f_{s4}\right)}{z_9 - z_4}\right)\right] f_H f_{\rho n}}{\overline{E_s} f_{cal} f_{cos} f_{tilt} f_{dir} + (1 - f_{dir})\overline{E_s} f_{cal}}$$

Keep in Mind for the Next Talk

- $\overline{E_s} = \overline{E_s(t,\lambda)'}$
- $\overline{L_{u4}} = \overline{L_u(4,t,\lambda)'}$
- $\overline{L_{u9}} = \overline{L_u(9,t,\lambda)'}$
- $f_{cal} = 1$ next talk for more details

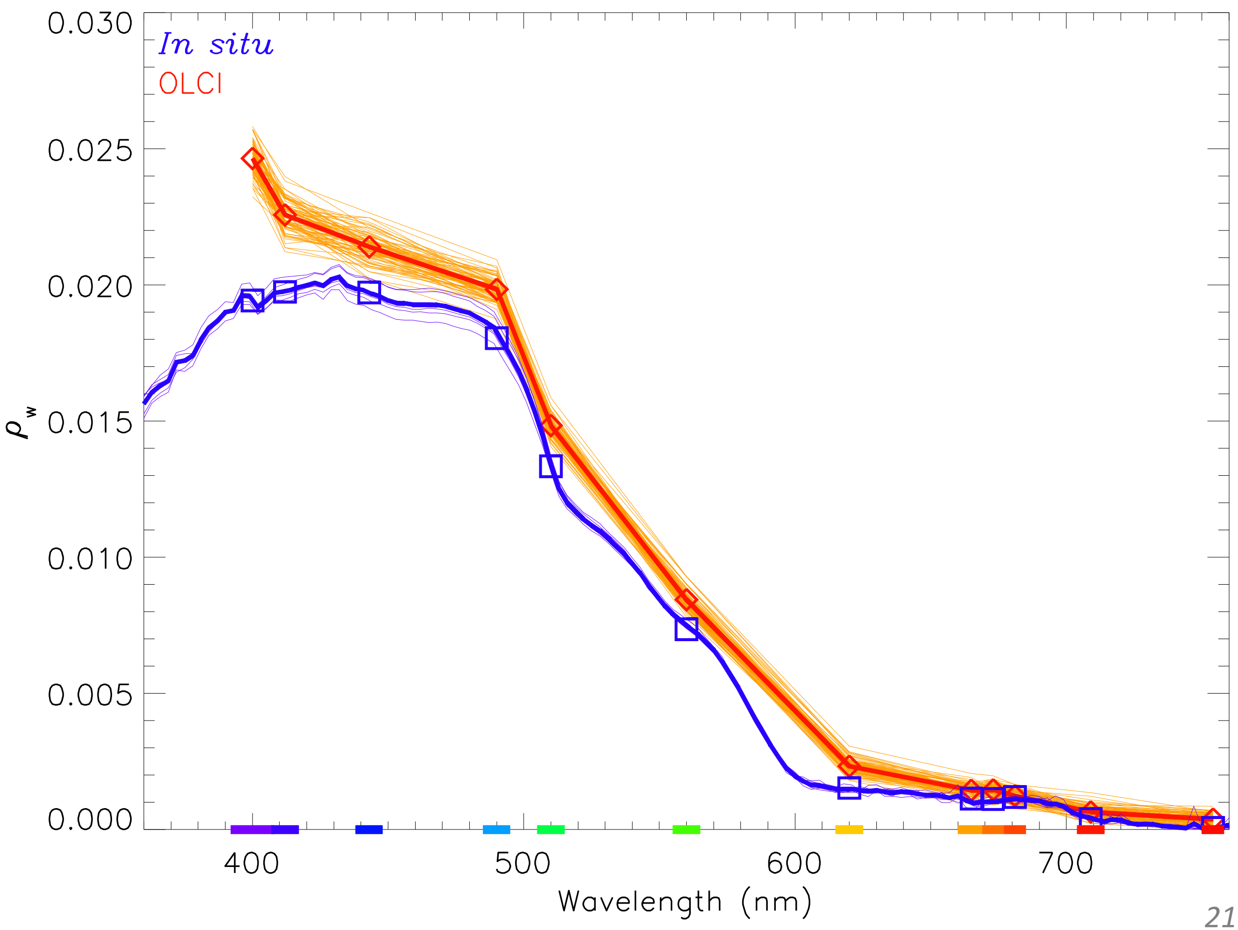
(first three:) Median of 1' records corrected for dark drift

\> Product delivered to space agencies, from here data processing for match-up analysis might differ

HYPERSPECTRAL INSTRUMENTS

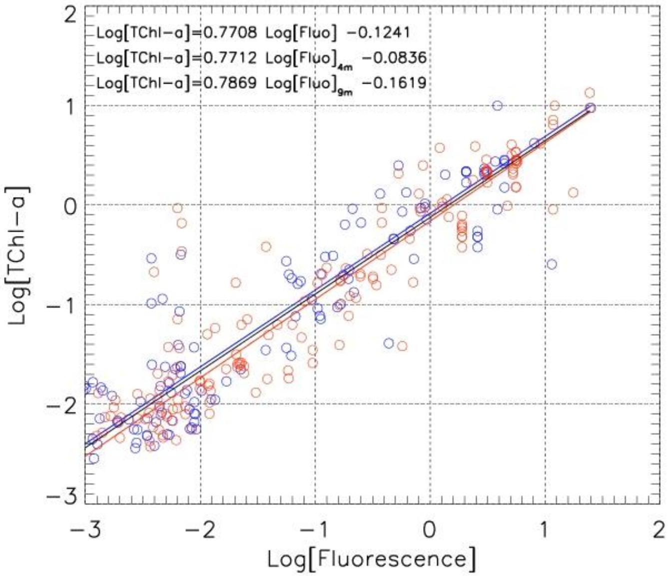
- $$R_{rs}(t,\lambda_i)_{sat} = \frac{\frac{\int_{\lambda_{i\_0}}^{\lambda_{i\_n}} L_{w(t,\lambda_i)} \cdot SRF(\lambda_i)_{sat}\, d\lambda}{\int_{\lambda_{i\_0}}^{\lambda_{i\_n}} SRF(\lambda_i)_{sat}\, d\lambda}}{\frac{\int_{\lambda_{i\_0}}^{\lambda_{i\_n}} E_{s(t,\lambda_i)} \cdot SRF(\lambda_i)_{sat}\, d\lambda}{\int_{\lambda_{i\_0}}^{\lambda_{i\_n}} SRF(\lambda_i)_{sat}\, d\lambda}}$$

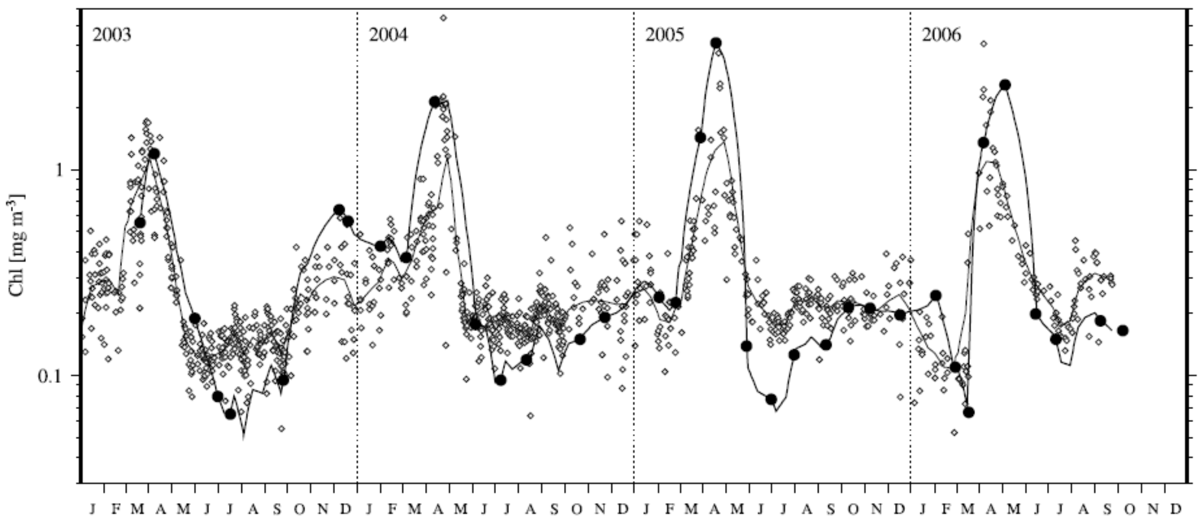
$SRF(\lambda_i)_{sat}$ are the spectral response functions of SeaWiFS, MERIS, MODIS, VIIRS, MSI, OLCI



TCHL-A TIME SERIES

- TChl-a values are needed for LUTs of shading and *Hydrolight* corrections (a single value per day is used)
- For recent data TChl-a values comes from calibrated Fluorescence calibrated (linear regression of an historical data set VS HPLC, mean night value are used to eliminate data affected by non-photochemical quenching)
- For assessed data a time-series from satellite data calibrated on monthly HPLC is used.





Quality Control

Some Criteria Generally Used for QC

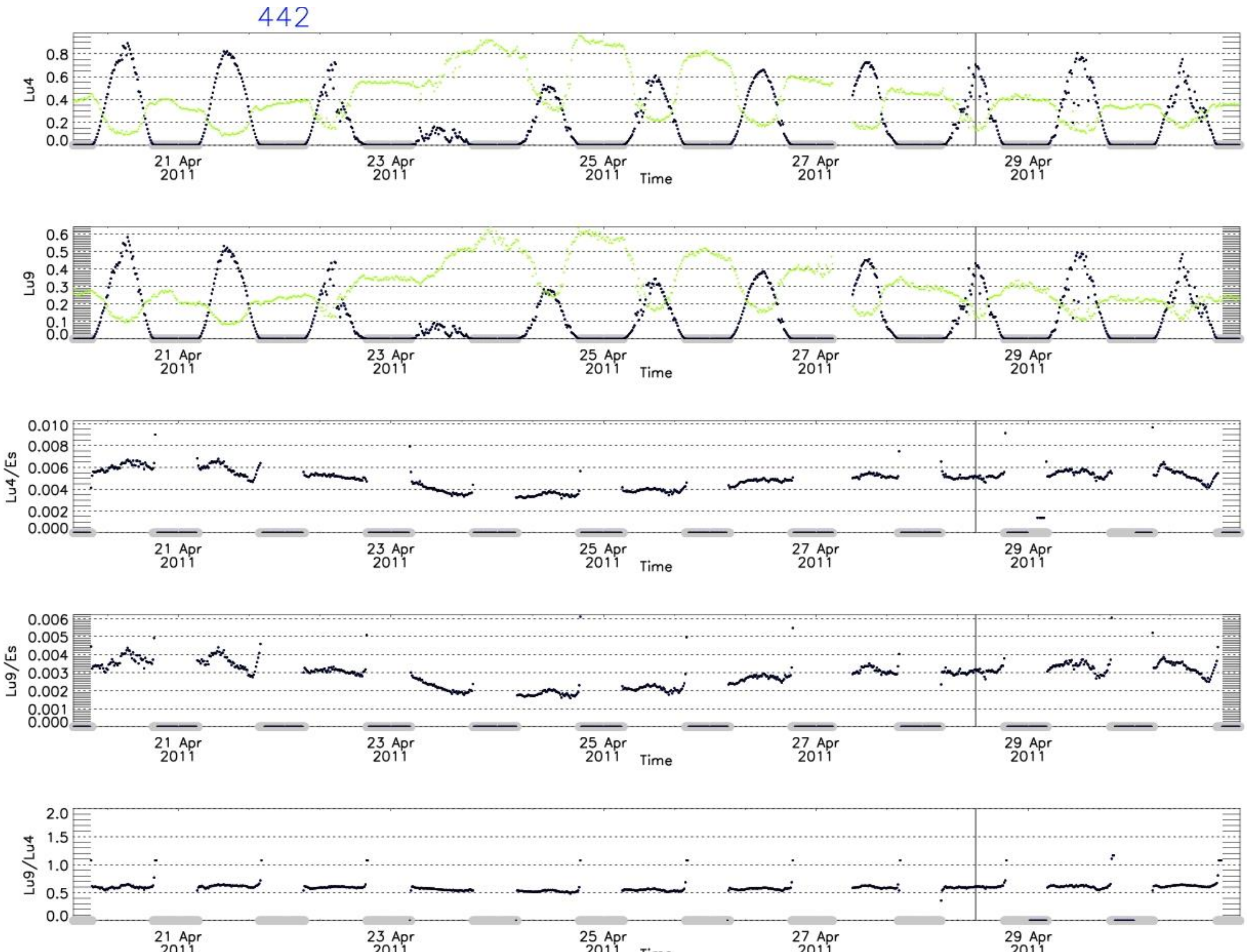
- Buoy depths < 11 m are discarded (*Es* too close to sea surface)
- Buoy Tilt > 10°
- 0.8 < Es/Theoretical Es < 1.2

Finer Criteria not Routinely Used

- Standard deviation of Es < 2%
- Azimuth angle (i.e. shading correction)
- Further QC is performed case per case on specific data sets

BIOFOULING

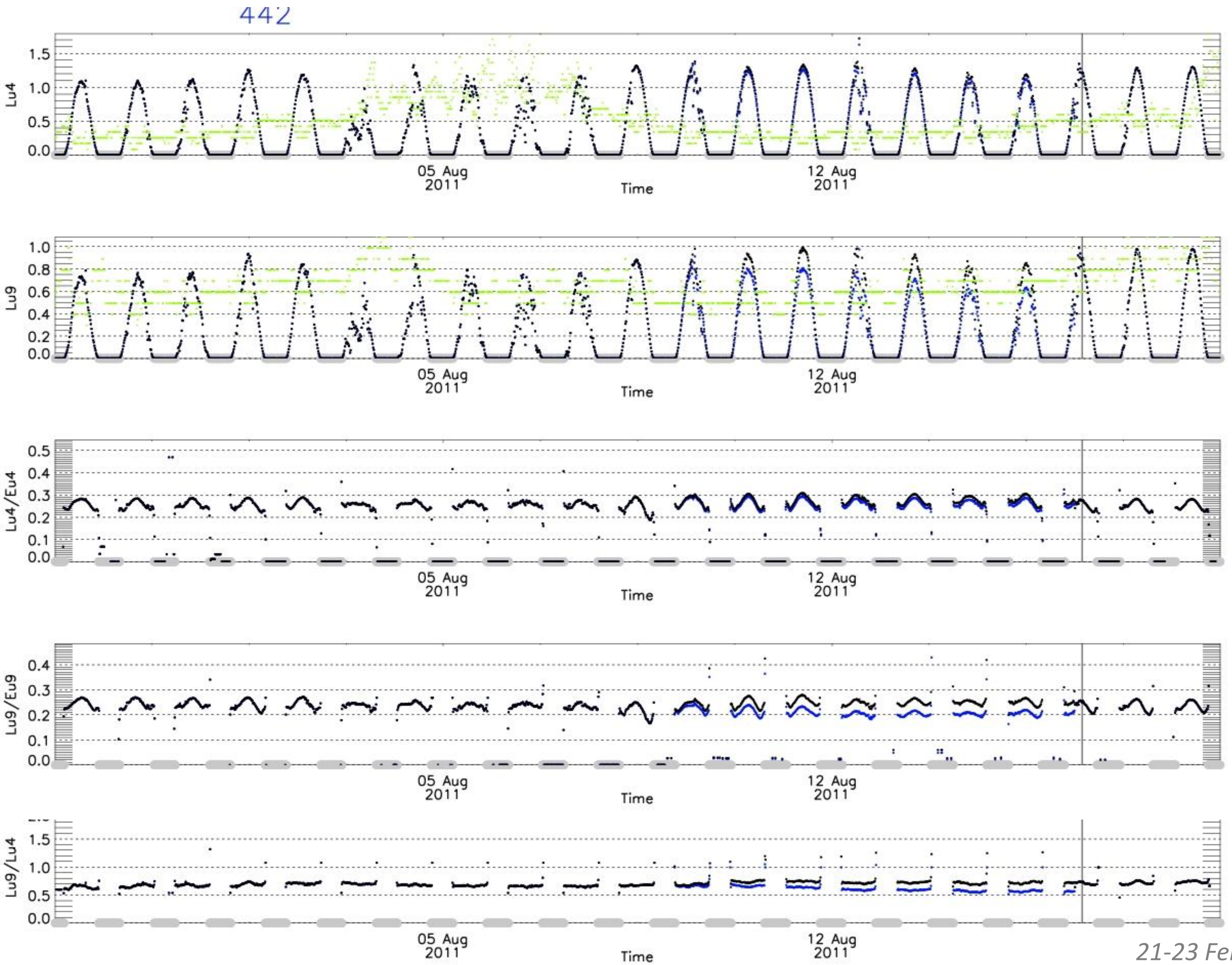
> Data screening for possible presence of biofouling (sensor cleaning helps)
> Elimination or correction whenever possible

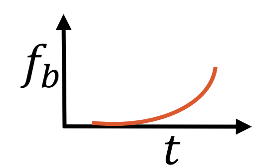


Biofouling

> Data screening for possible presence of biofouling (sensor cleaning helps)

> Elimination or correction whenever possible





DYNAMIC CLIMATOLOGY CORRECTION

> Data from deployments (or partial deployments from known issues) are compared to the rest of data from the same period of the year in terms of median ratio

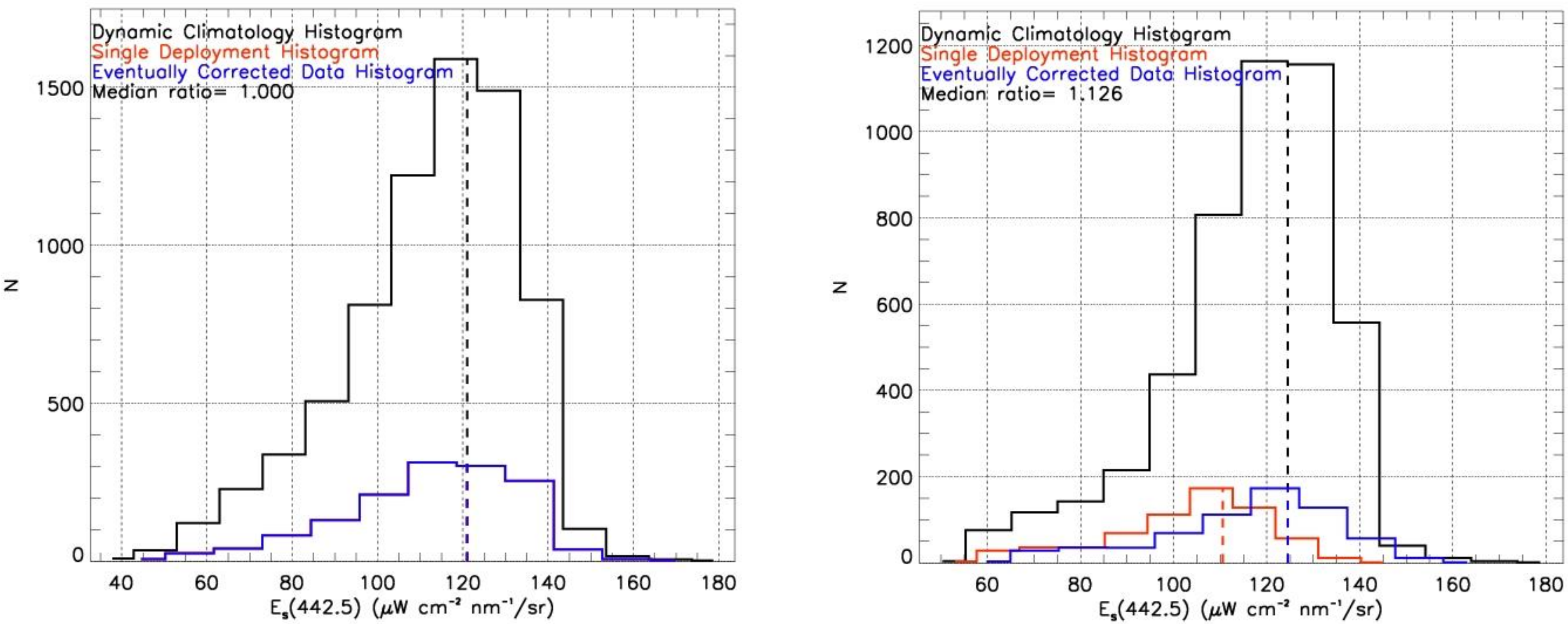
> Data whose median ratio is within a threshold are retained in the "good" data set

> Thresholds are *Log(median ratio)*<|0.1| for *Es, Log(median ratio)*<|0.2| for *Lu, Ed, Eu*

> A "good" data set is established for each wavelength, instrument, depth

> "Bad data" are compared to its corresponding "good" dynamic climatology and a correction factor estimated

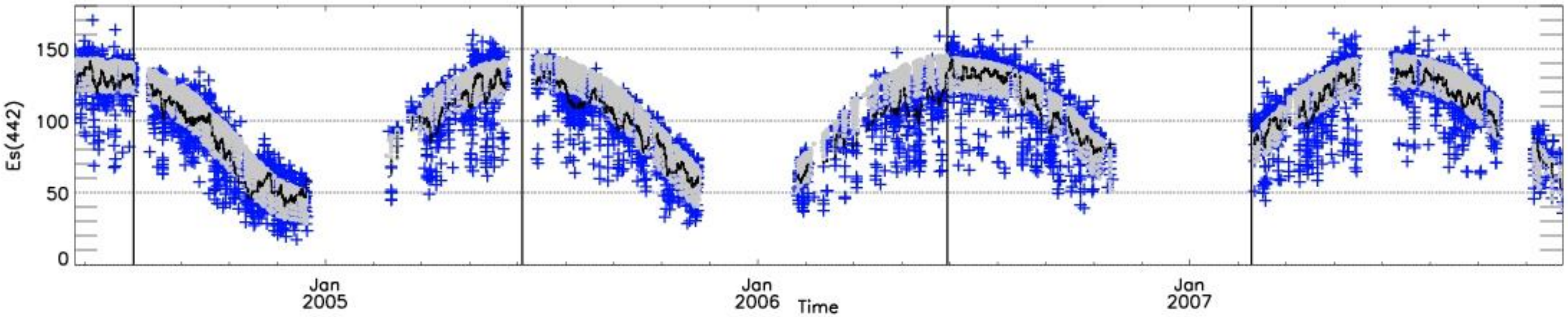
> Keep in mind that in most cases 1/few wavelengths of one of three instruments used to derive *Rrs* are concerned

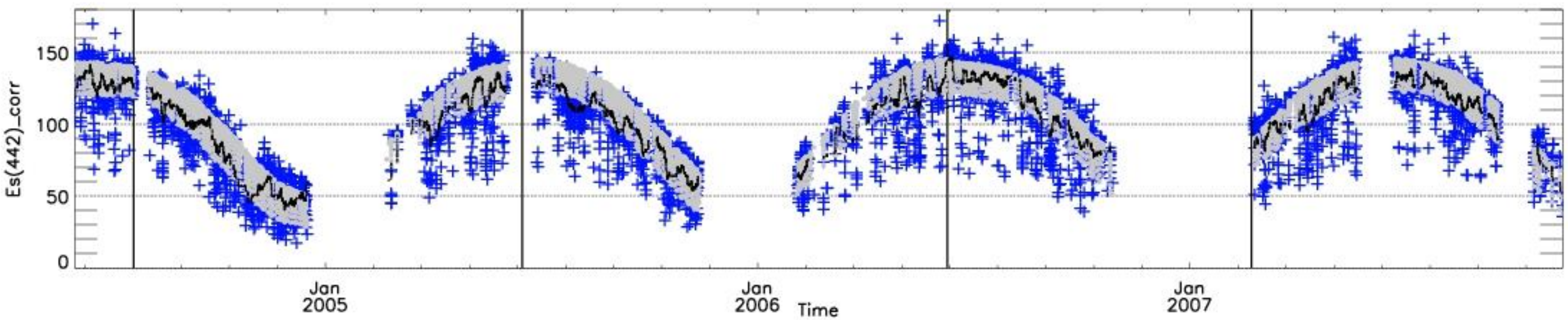


DYNAMIC CLIMATOLOGY CORRECTION

> How does it looks like in a time series?

> The procedure still need to be settled (*i.e.*: definition of the thresholds and N of observations needed in the dynamic climatology to asses stable "gains")





PURPOSE OF THESE CORRECTIONS

> Biofouling and Intercalibration corrections are not intended for SVC use
> Still valuable data for science (eg: seasonal variability, modelling assimilation,…)
> Debatable use for validation : the definitive answer can be given after assessment of their uncertainties (to do list)

THANKS FOR ATTENTION

D. Antoine – PI
V. Vellucci – Project Manager
M. Golbol, E. Soto, E. Diamond – Cruises
V. Taillander – CTD processing
C. Dimier, J. Ras – HPLC
B. Gentili – Code development
A. Bialek – Uncertainties
E. Leymarie – Montecarlo simulations
Bricaud – CDOM
G. De Liege, D. Luquet, D. Robin – Diving
S. Marty – Calibrations
J. Uitz, H. Claustre, F. D'Ortenzio – Expertise
L. Fere, C. Poutier, I. Courtois – Administration