Radiometric data at BOUSSOLE: techniques for data collection, processing, and quality control

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Outline

- Reminder about BOUSSOLE and the deployment site
- Deployment platforms
- Sensors
- Data collection techniques
- Data processing techniques
- Quality control procedures
- Conclusions

A reminder about BOUSSOLE

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

- Scientific objectives: IOPs et AOPs documentation and understanding (bio-optics research), short-time changes...

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

Strategy: combination of 3 elements:

- A Deep-sea mooring, for continuous collection of data at the surface (started 5 years ago, September of 2003)
- Monthly cruises for the buoy servicing and the collection of data complementary to the buoy data (started in July 2001, next month cruise is #83)
- An AERONET coastal station, to provide the necessary aerosol parameters

Funding Agencies / Supports

esa **European Space Agency**

cnes CENTRE NATIONAL D'ETUDES SPATIALES **Centre National d'Etudes Spatiales, France**

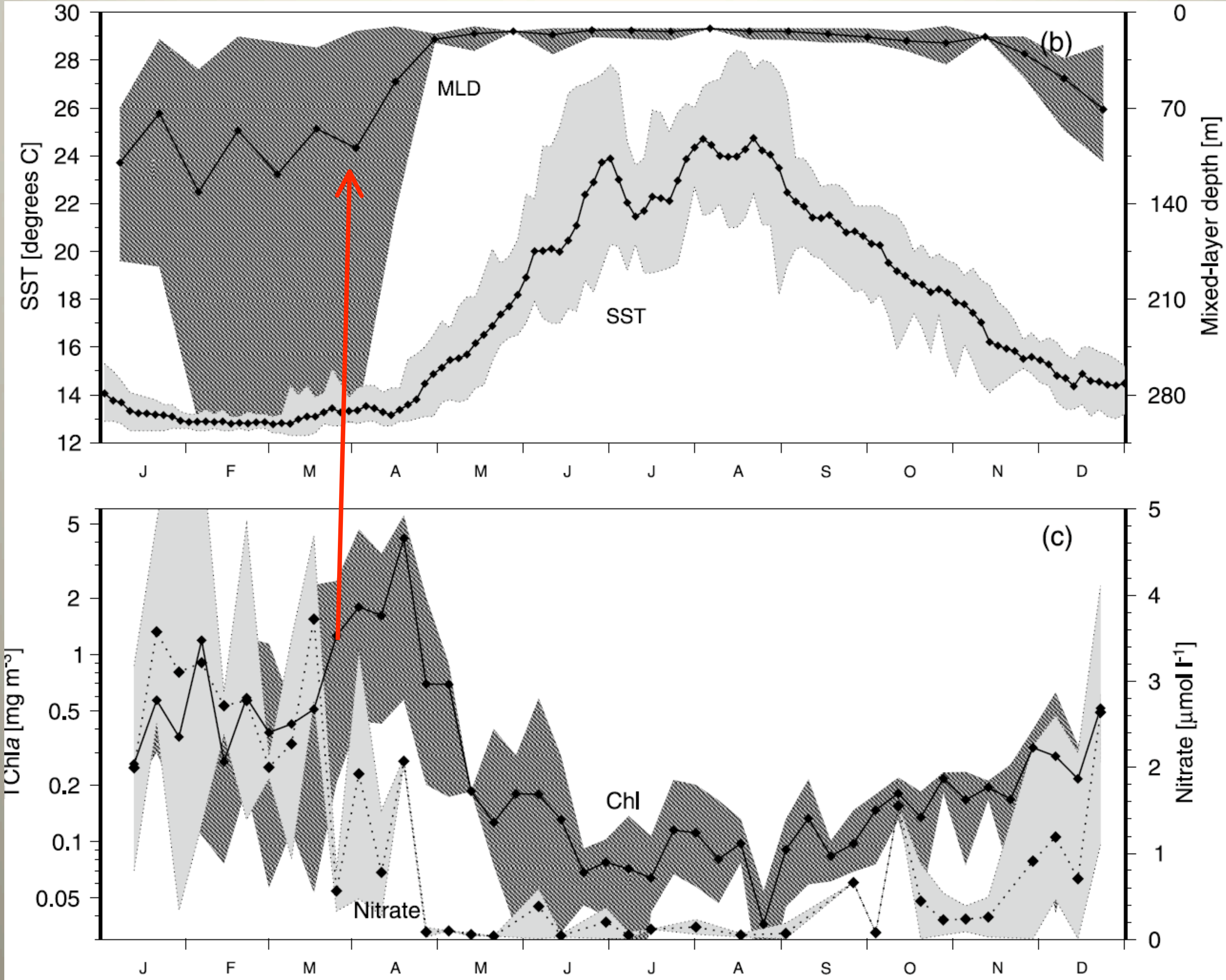
NASA **National Aeronautics and Space Administration of the US**

CNRS CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE **Centre National de la Recherche Scientifique, France**

INSU **Institut National des Sciences de l'Univers, France**

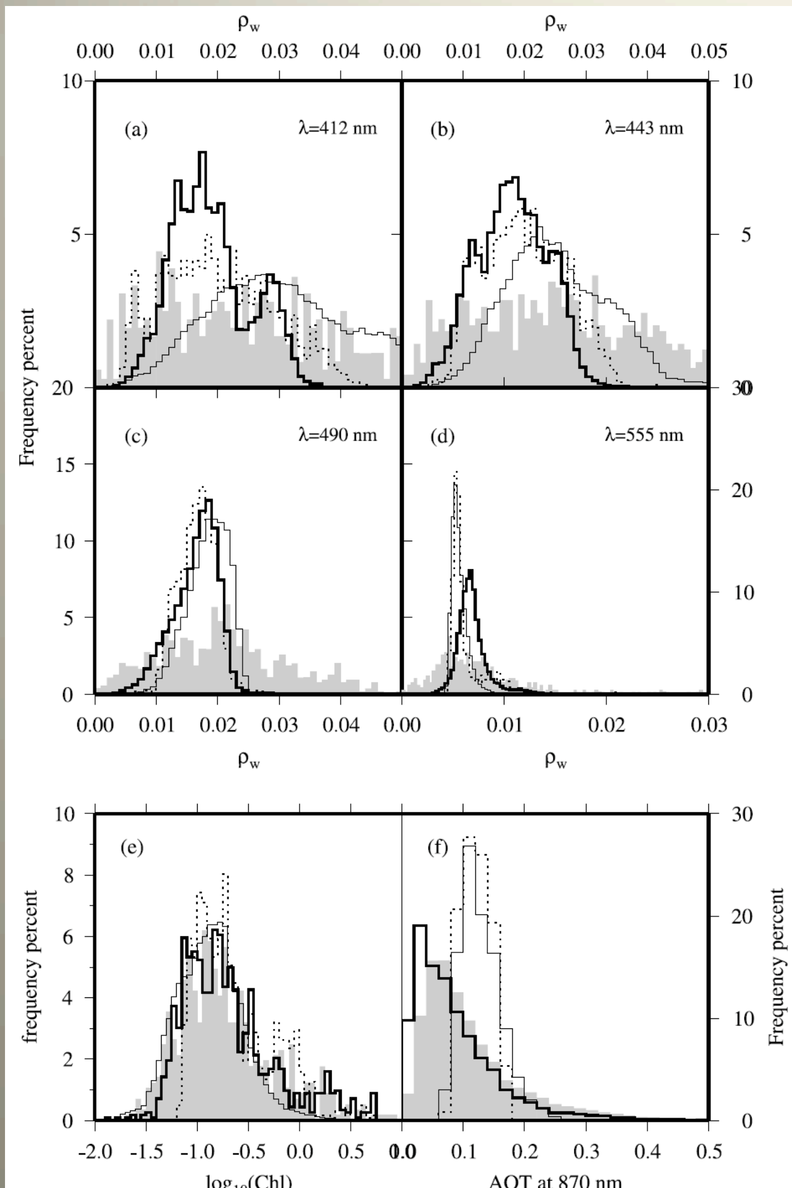
OBSERVATOIRE OCEANOLOGIQUE VILLEFRANCHE/MER **Observatoire Océanologique de Villefranche sur mer, Fra**

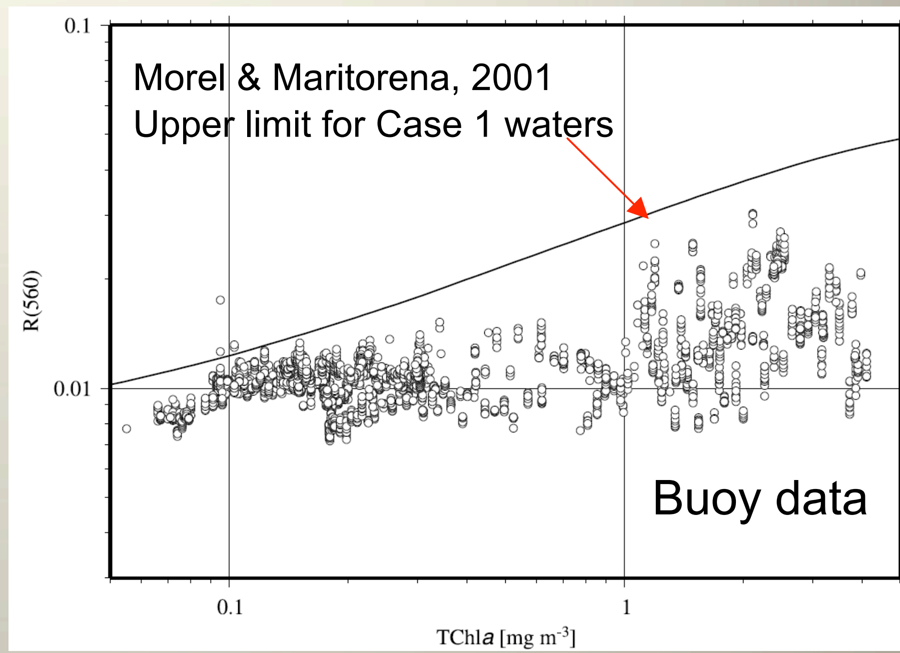
The BOUSSOLE site



Located in the Ligurian Sea (northwestern Mediterranean)

BOUSSOLE: Case 1 waters site, encompassing a significant range of global oceanic waters properties





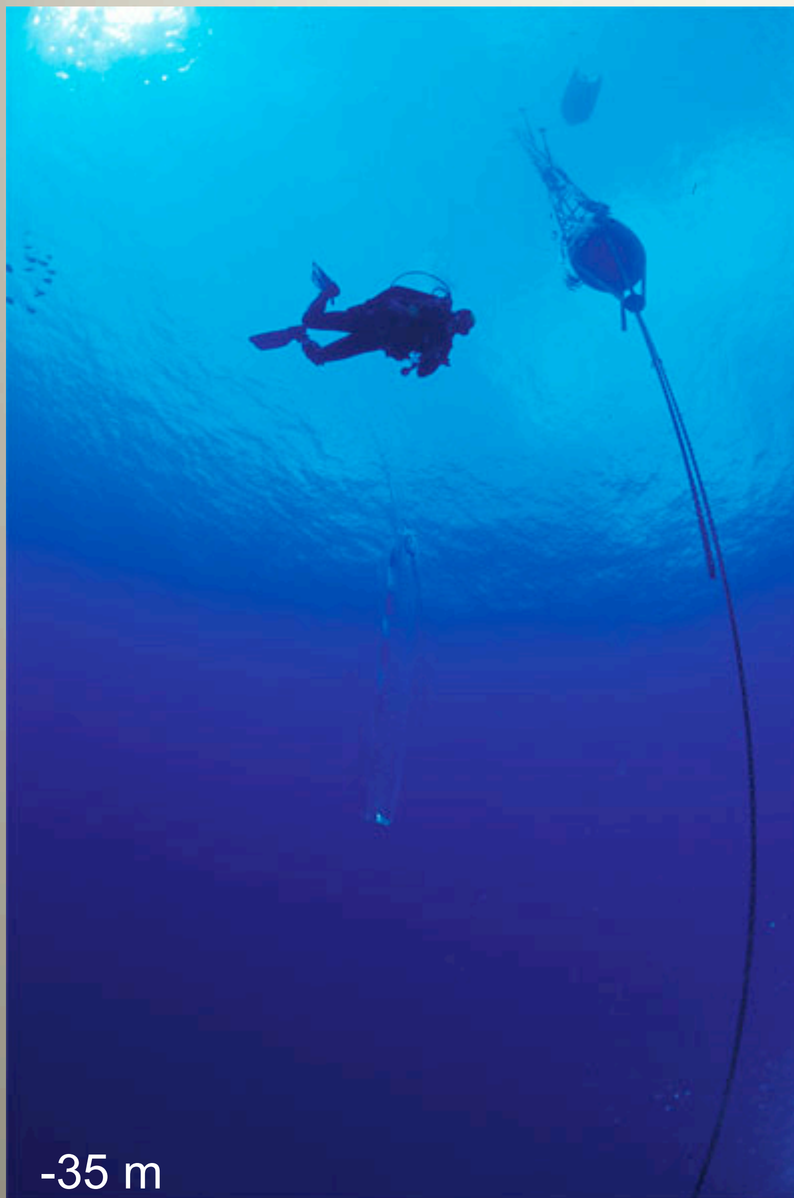
Boussole site (3 years of data)

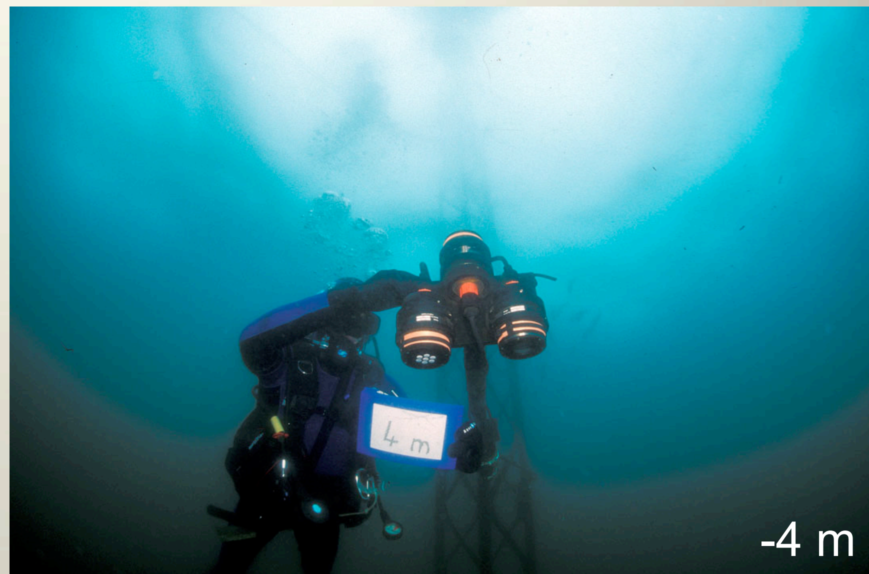
SeaWiFS, global, March, June, Sept, De

SeaWiFS, Mediterranean sea

NOMAD

Range of variability in optical properties:
"A field look"





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

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

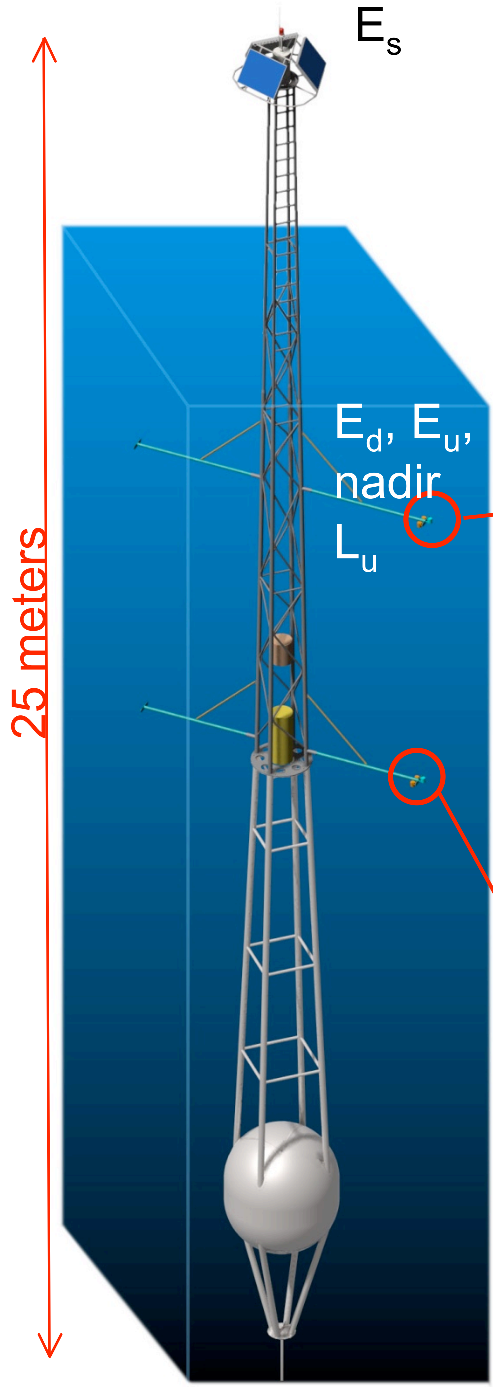
Platforms and instruments for AOPs

Ship (R/V Téthys-II), from which we deploy a Satlantic' SPMR/SMSR

13-l OCI-1000 series radiometers, data collection at 6H
Bands:
380, 412, 443, 455, 490, 510, 530, 560, 620, 665, 683, 705 nm

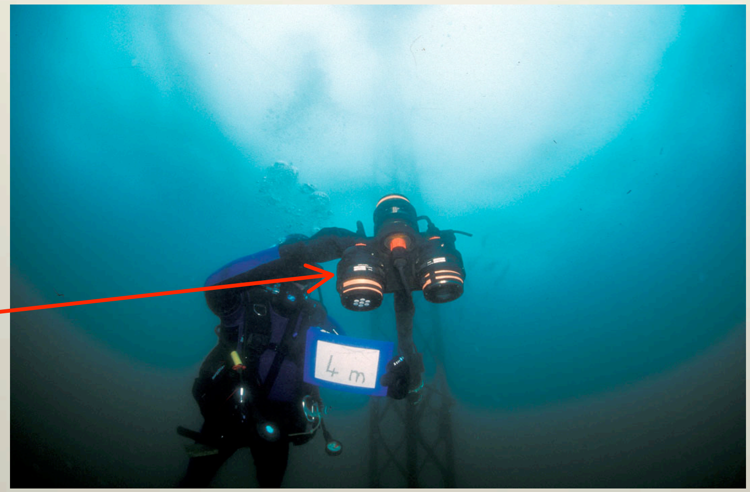
The absolute calibration of the SPMR and SMSR with respect to NIST-traceable standards is
performed every 6 months in the Satlantic optics calibration laboratory.

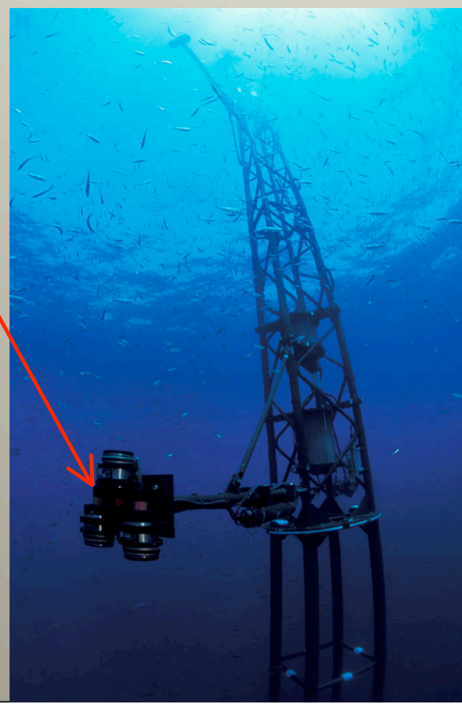
It was (2001-2004) tracked between these absolute calibrations using at the LOV the ultra-stable portable light source developed for that purpose by Stalantic, *i.e., the*



Platforms and instruments for AOPs

BOUSSOLE buoy, onto which are installed Satlantic' 200 Series 7-I radiometers, above the surface (E$_s$) and at 4 & 9





Bands:
412 (alternately 555), 443, 490, 510, 560, 665, 683 nm

Acquisition frequency 6 Hz

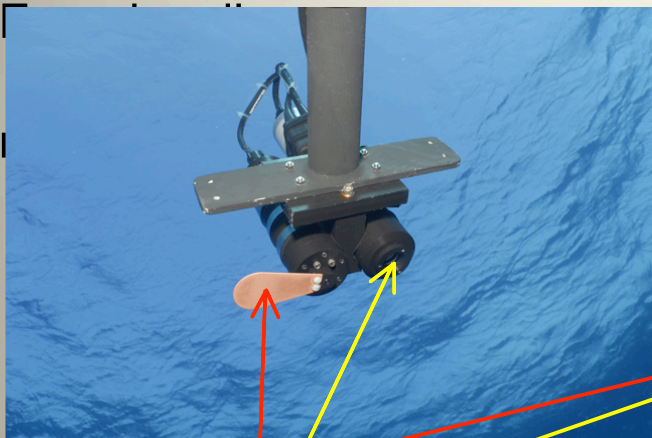
1-min acquisition sequences each 15 minutes

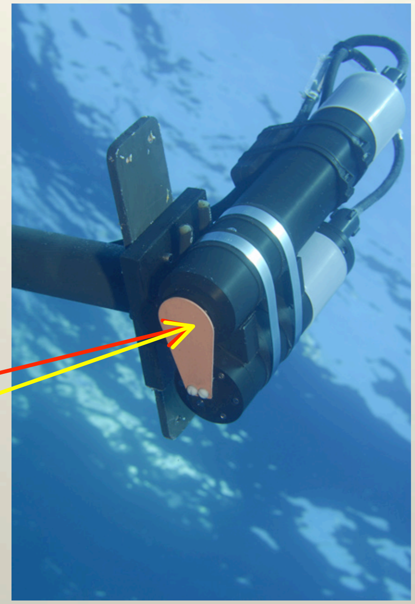
Calibration as for the SPMR/SMSR

Rotation ~every 6 months

Other LOV platforms and instruments for AOPs

Satlantic Hyperspectral sensors on the BOUSSOLE buoy (HOCR, HOCI), measuring



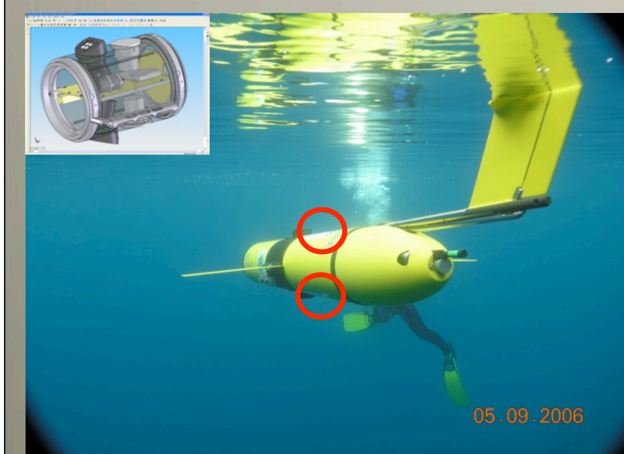


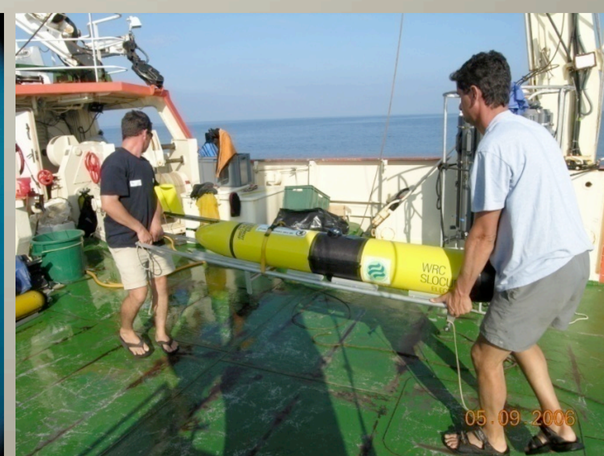
L_u at the 2 depths (350-800 nm; 2

Bio-shutters

Hyper-OCR's

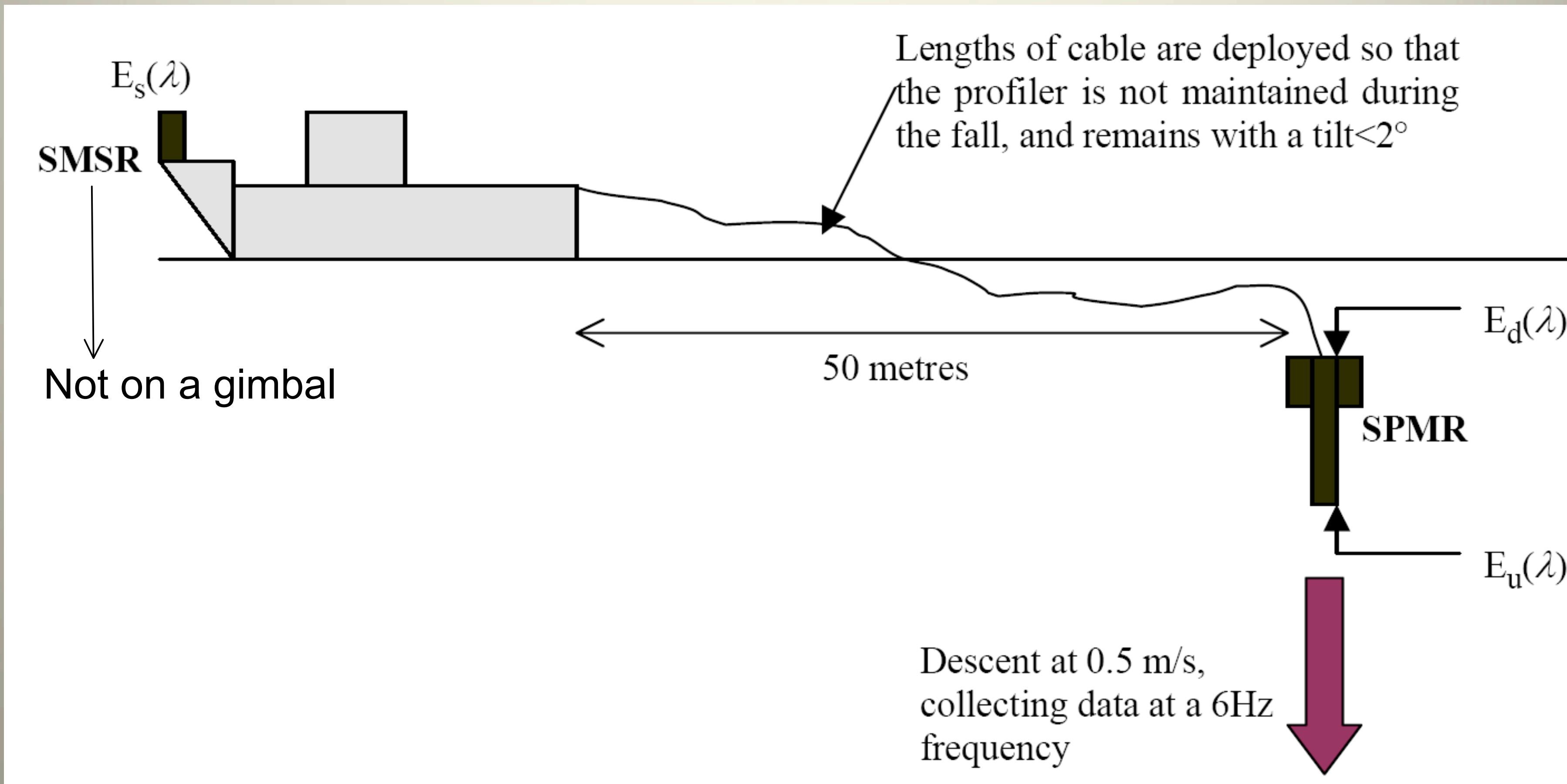
Satlantic 4-I sensors on gliders and floats, measuring E_d and L_u or E_u





Data processing for these is not part of today's prese

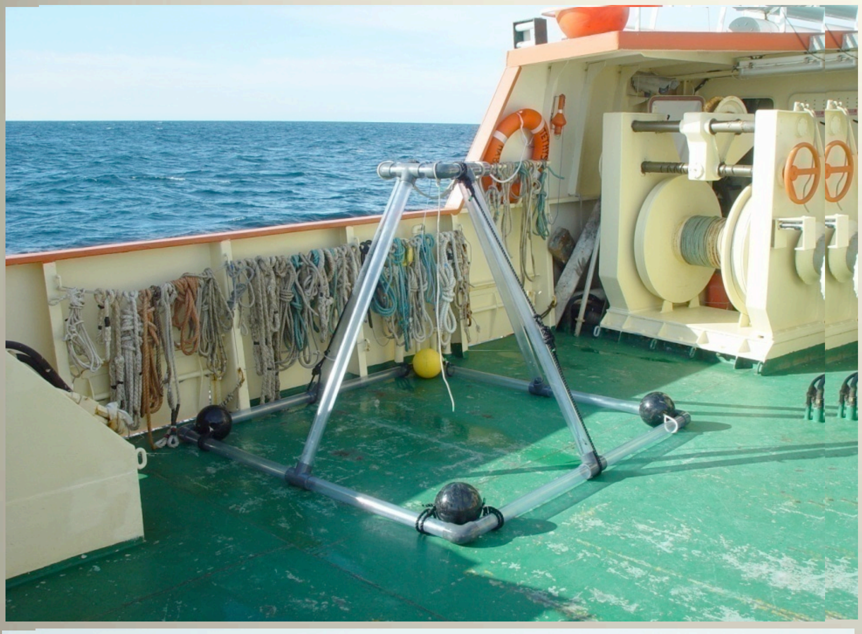
Deployment techniques/characteristics: SPMR/SMSR



Multiple casts (minimum 3) are performed during each optic session
Dark measurements (caps on) are taken before and after each session

Matchup with satellite passes is aimed at when feasible

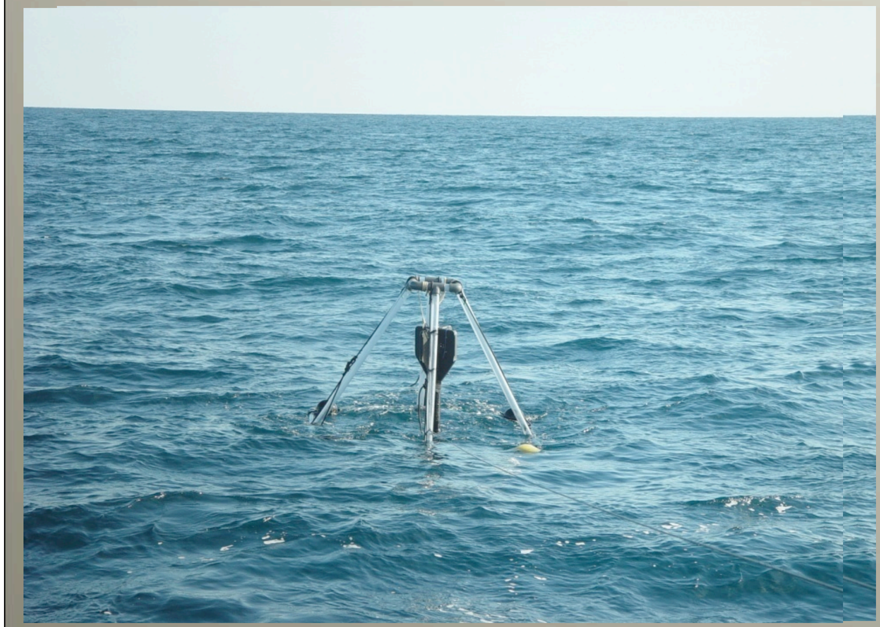
Deployment techniques/characteristics: SPMR/SMSR



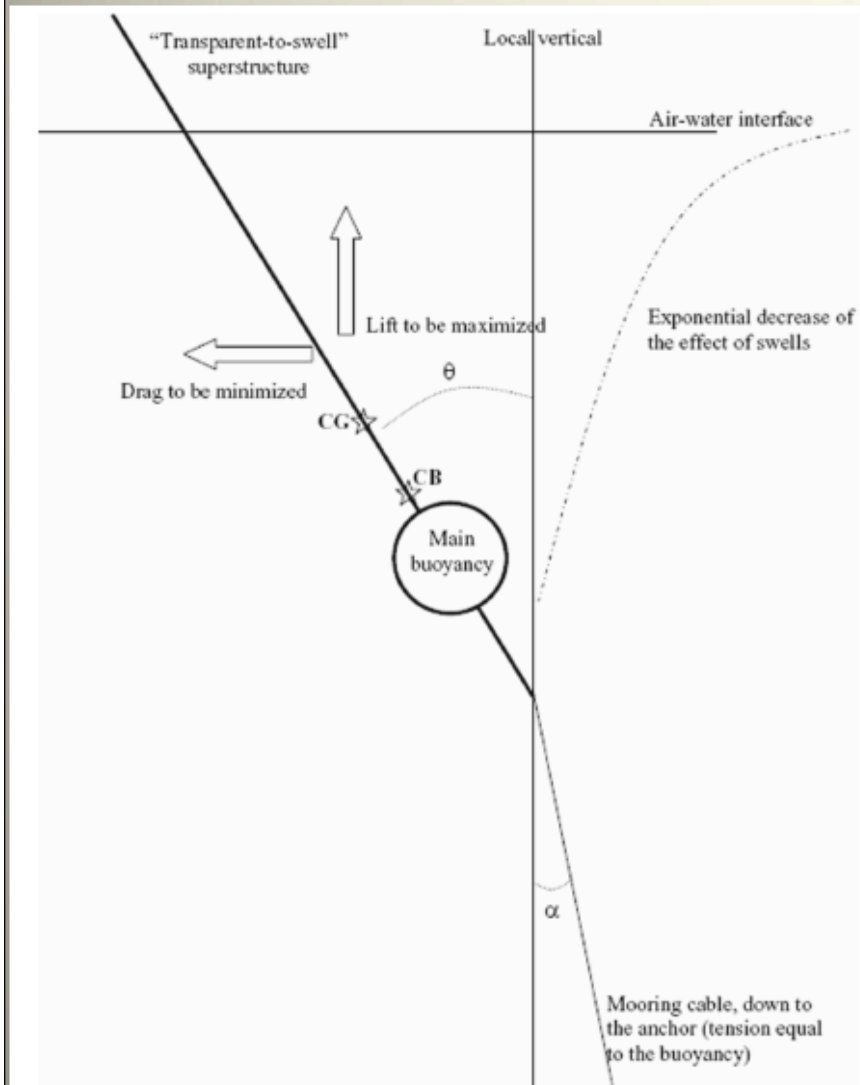
A tentative to get $E_u(0^-)$ without any need to extrapolate data from $E_u(z)$, in order to analyze the performance of various extrapolation techniques

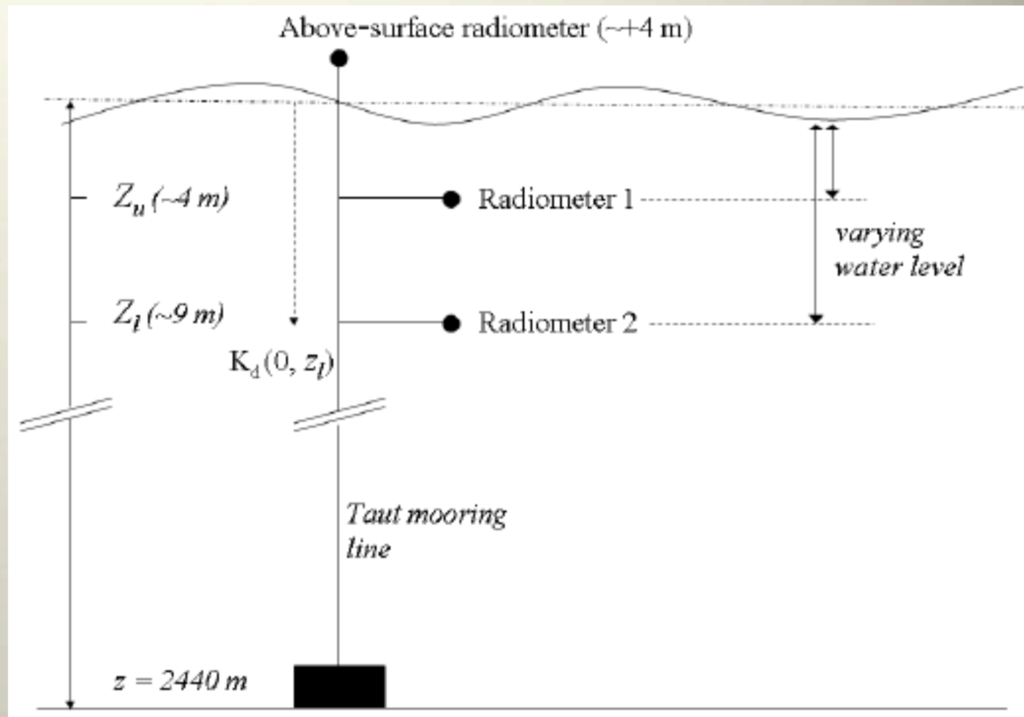
Uses a pyramidal floatation structure and a remote trigger to release the SPMR after he has taken minutes of $E_u(0^-)$ data just below (~20 cm) the sea surface

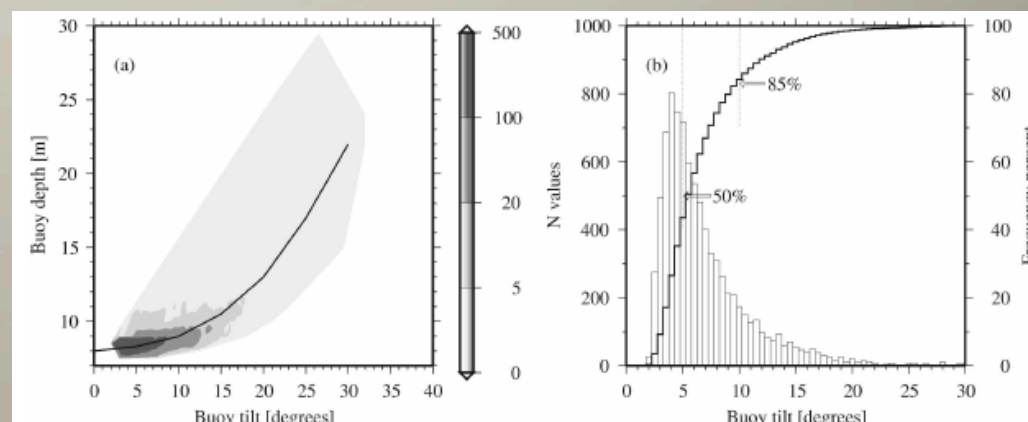
Analysis is underway…



Deployment techniques/characteristics: buoy







The "reversed pendulum" principle

Data collected:

SPMR/SMSR:
Above-surface E_s, and vertical profiles of E_d and E_u, at the 13 following nominal bands: 380, 412, 443, 455, 490, 510, 530, 560, 620, 665, 683, 705 nm

Buoy:
Above-surface E_s, and E_d, E_u, and nadir L_u at 4 & 9 m, at the 7 following nominal bands: 412 (alternately 555), 443, 490, 510, 560, 665, 683 nm

Note: actual central wavelengths are within 2 nm of the nominal values

In both cases, two-axis tilt is recorded, along with pressure (SeaBird SBE37-SI MicroCAT C-T-P on the buoy, and a paroscientific pressure sensor Model 8WD270-I for the SPMR).

For the buoy, we also have the buoy heading (EZ-COMPASS-DIVE / MAGNETOMETER Tilt Compensated Compass & linear Dual Axis Tilt System)

On the buoy: temperature and salinity at 9m, c(660) and chl fluorescence at the 2 measurement depths, b_b(442, 488, 550 et 620) at 9m.

SPMR/SMSR Data processing:

✓ Raw data are transformed into calibrated values using Satcon (Satlantic immersion coefficients)

✓ Dark measurements are subtracted (using the two that most closely bracket the collected data)

✓ A fit is applied to E_s in order to remove ship pitch and roll effects

✓ The in-water data are normalized by the E_s changes

✓ A quadratic fit is applied on $E_u(z)$ (when tilt<5°) to get $E_u(0^-)$

✓ Self shading correction (Gordon Ding 1992) is applied to $E_u(0^-)$ (diffuse/direct from Gregg and Carder 1990, and absorption from the Chl following Morel & Maritorena, 2001)

✓ R is determined as : $E_u(0^-)$ / $E_d(0^-)$, where $E_d(0^-) = E_s$*0.96

✓ K_d is derived as – ln [$E_d(z=20)$ / $E_d(0^-)$] / 20

✓ L_u (then nL_w) can be determined as far as a Q factor is derivable

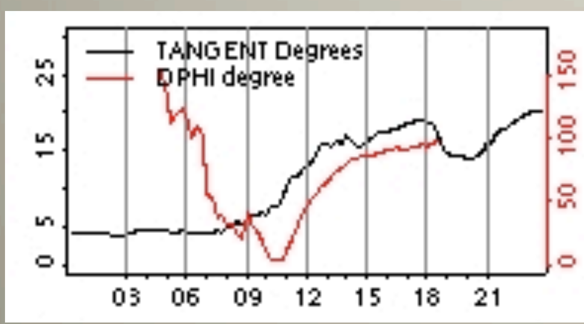
Buoy Data processing: general steps

- ✓ Raw data are transformed into calibrated values using Satcon (Satlantic immersion coefficients)
- ✓ The average dark measurements taken from 0 to 2 am is subtracted from the data
- ✓ The median value is taken in each of the 1-minute records that are taken every 15 minutes at 6 Hz (~360 measurements)
- ✓ $L_u(0^-)$ is determined as: $L_u(0^-) = L_u(z=4)\, e^{K_L z}\ \mathrm{fn}(z, \theta_s, \mathrm{Chl})$
- ✓ Where $K_L = -\dfrac{\log\left[L_u(z=9) / L_u(z=4)\right]}{\Delta z}$
- ✓ and “fn” is a function introduced to correct for curvature effects (see later)
- ✓ Self shading correction (Gordon Ding 1992) is applied (diffuse/direct from Gregg and Carder 1990, and absorption from the Chl following Morel & Maritorena, 2001).
- ✓ Then $L_w = L_u(0^-)\dfrac{1-\rho(\theta)}{n^2}$ and $nL_w = \dfrac{L_w}{t_d(\theta_s)\cos(\theta_s)} \dfrac{\Re_0}{\Re(\theta')} \left\{ \dfrac{f_0(\mathrm{Chl})}{Q_0(\mathrm{Chl})} \left[\dfrac{f(\theta_s, \mathrm{Chl})}{Q(\theta_s, \theta', \Delta\phi, \mathrm{Chl})} \right]^{-1} \right\}$
- ✓ R is determined as : $E_u(0^-) / E_d(0^-)$, where $E_d(0^-) = E_s*0.96$ and $E_u(0^-)$ is determined as $L_u(0^-)$

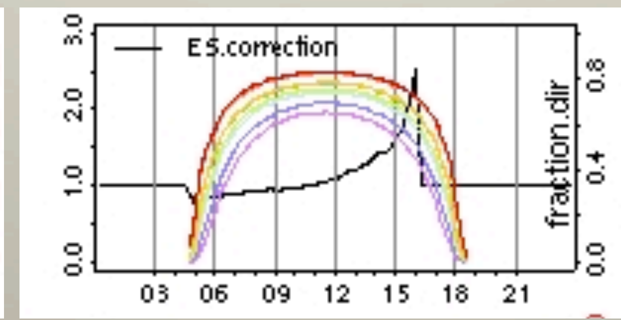
Buoy Data processing, cont'd

E_s correction for tilt: uses the 2-axis tilt + the compass:

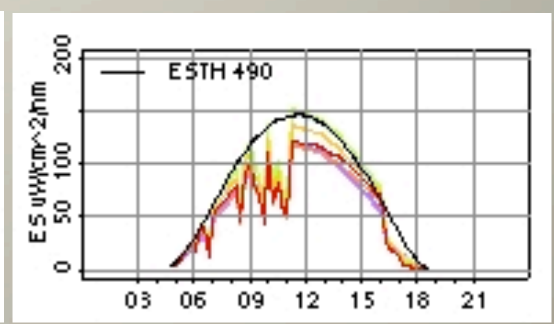
- ✓ The angle between the irradiance collectors and the sun is then determined
- ✓ The diffuse-to-direct ratio is determined following Gregg and Carder 1990
- ✓ The direct component is cosine-corrected
- ✓ The diffuse component is not modified



Tilt (black) and compass (red)

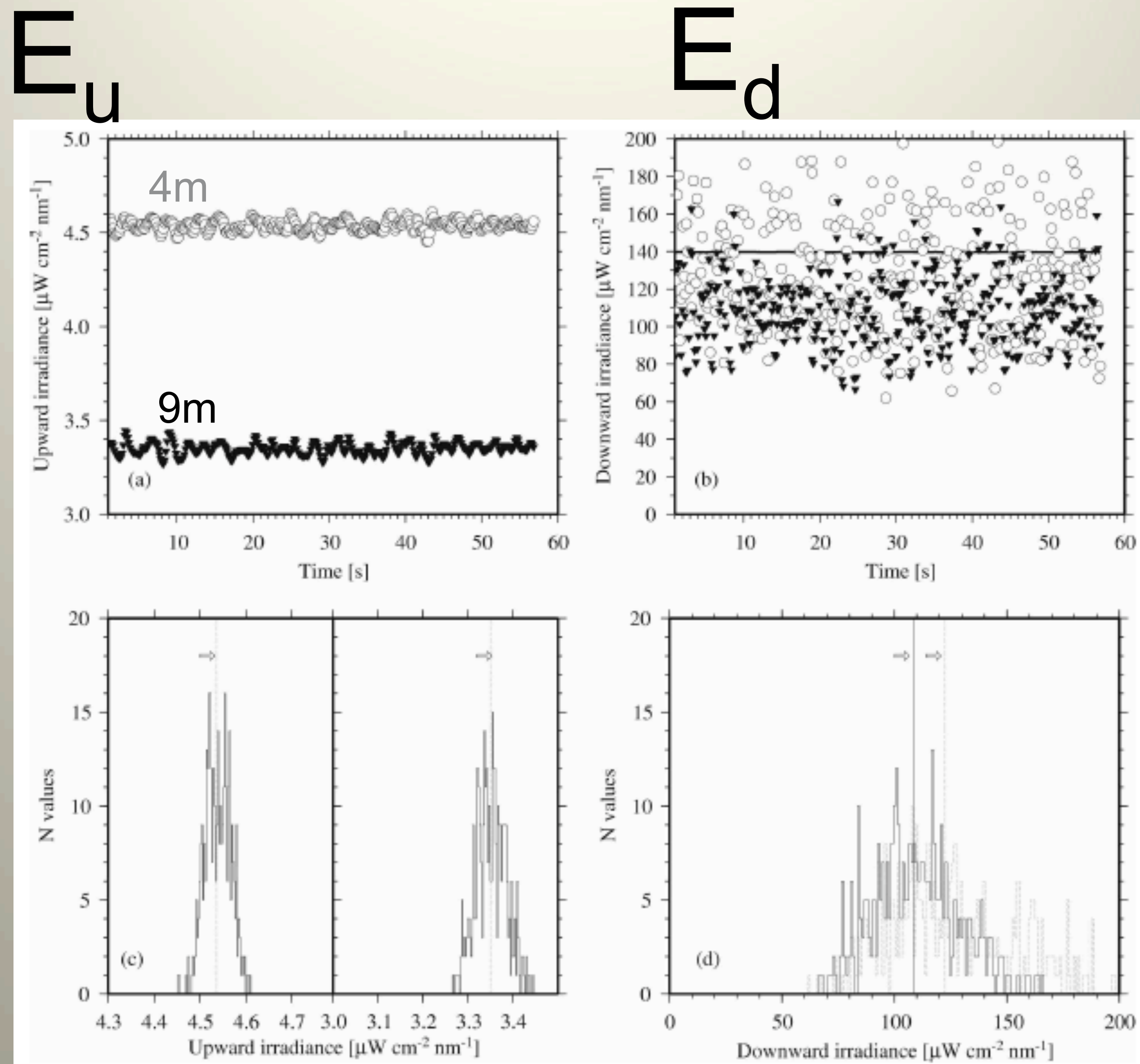


E_s correction (black) and Fraction of direct light (colors)



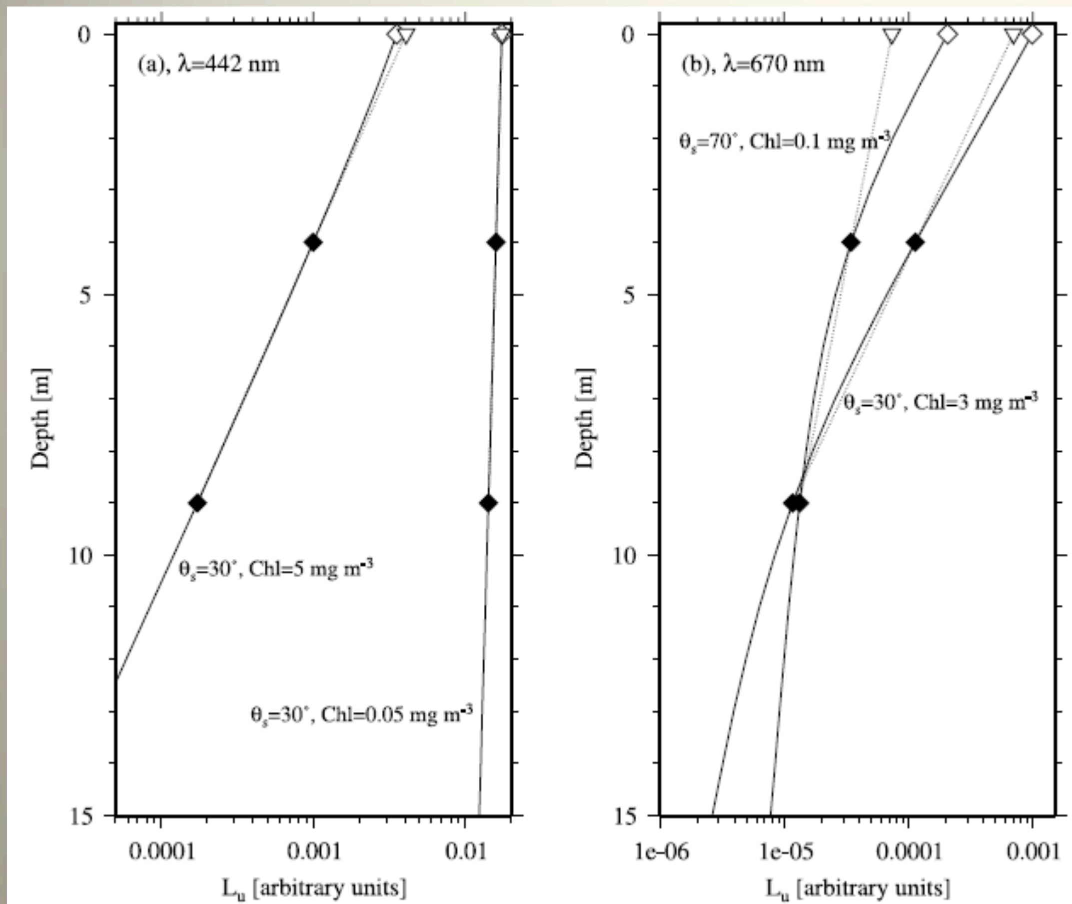
Theoretical clear-sky E_s (black) Tilt-corrected actual E_s (colors)

Buoy Data processing: filtering surface wave effects



An example at 490 nm (arrows are the median values)

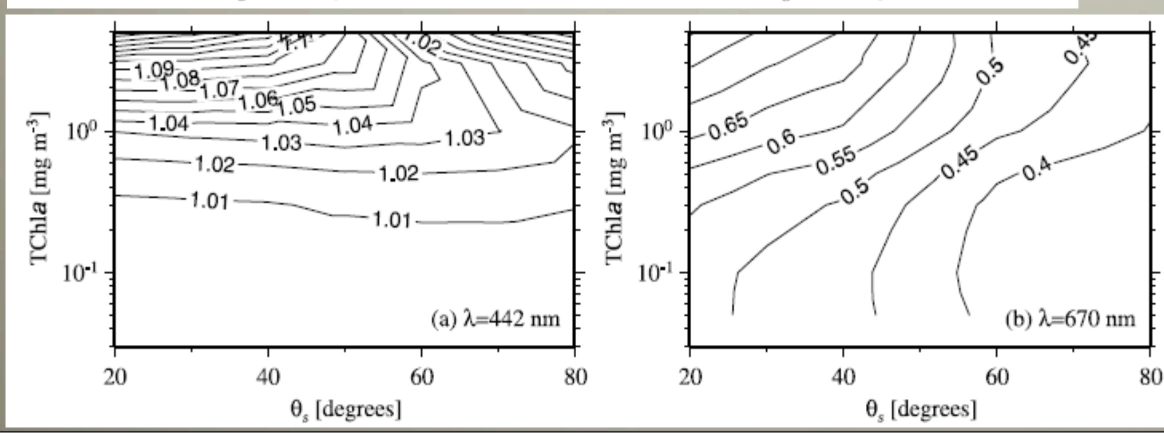
Buoy Data processing: extrapolation to the surface



RT calculations were performed to compare the $E_u(0^-)$ extrapolated from the diffuse attenuation coefficient computed from measurements at 4 & 9 m and the "true" value.

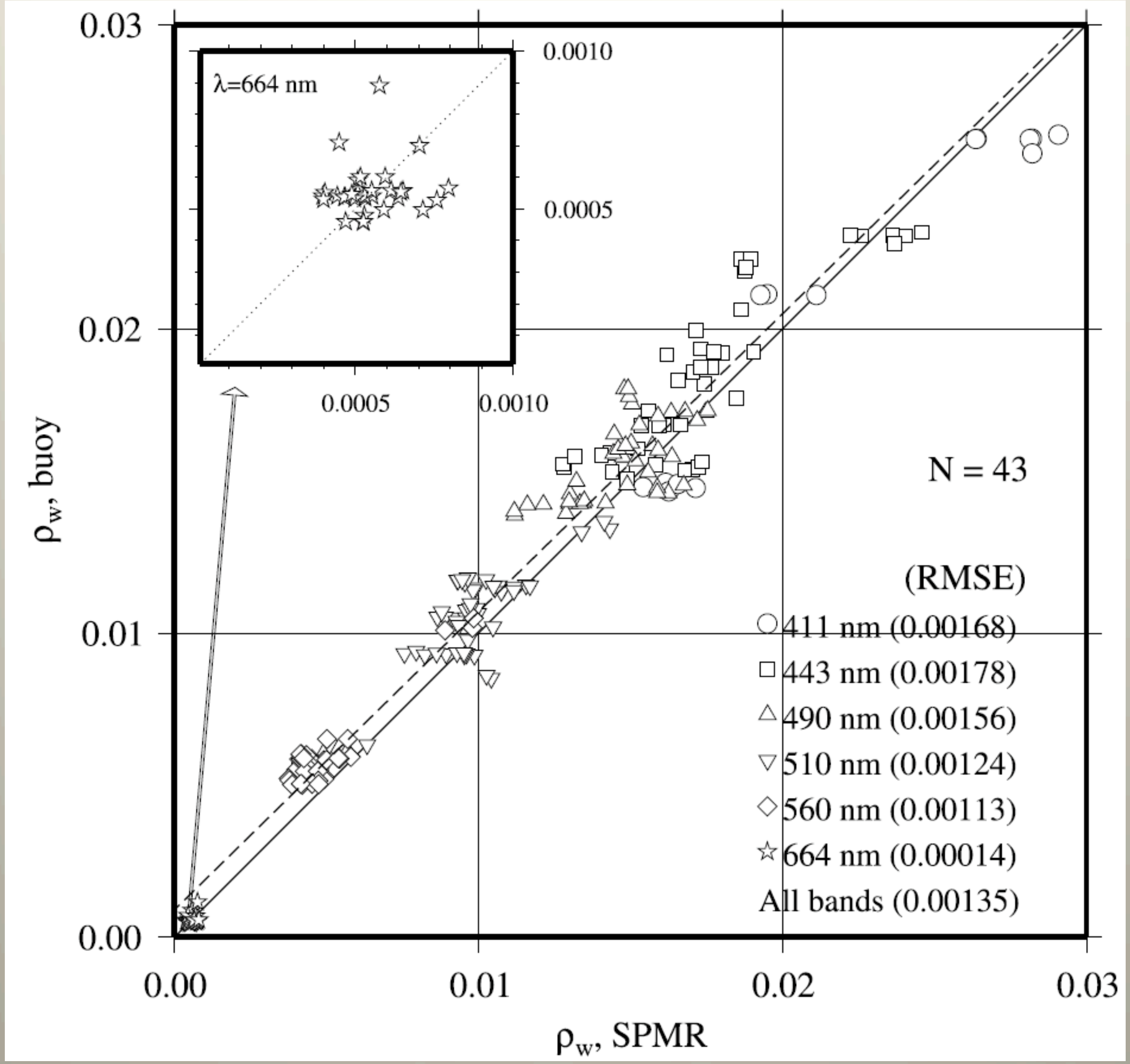
Very slight difference in the blue

Large difference in the red



The ratio of the two has been tabulated as a function of Chl and q_s

Buoy *versus* SPMR reflectances



Quality control procedures

SPMR/SMSR:

Individual examination of the reflectance spectra

Buoy:

Impossible to look at all data individually (~10000 reflectance spectra/year)

• Filtering of the data : data out of X% of a Y-day running average are eliminated.

X and Y are determined empirically, by trial and error

• Manual elimination of obvious outliers

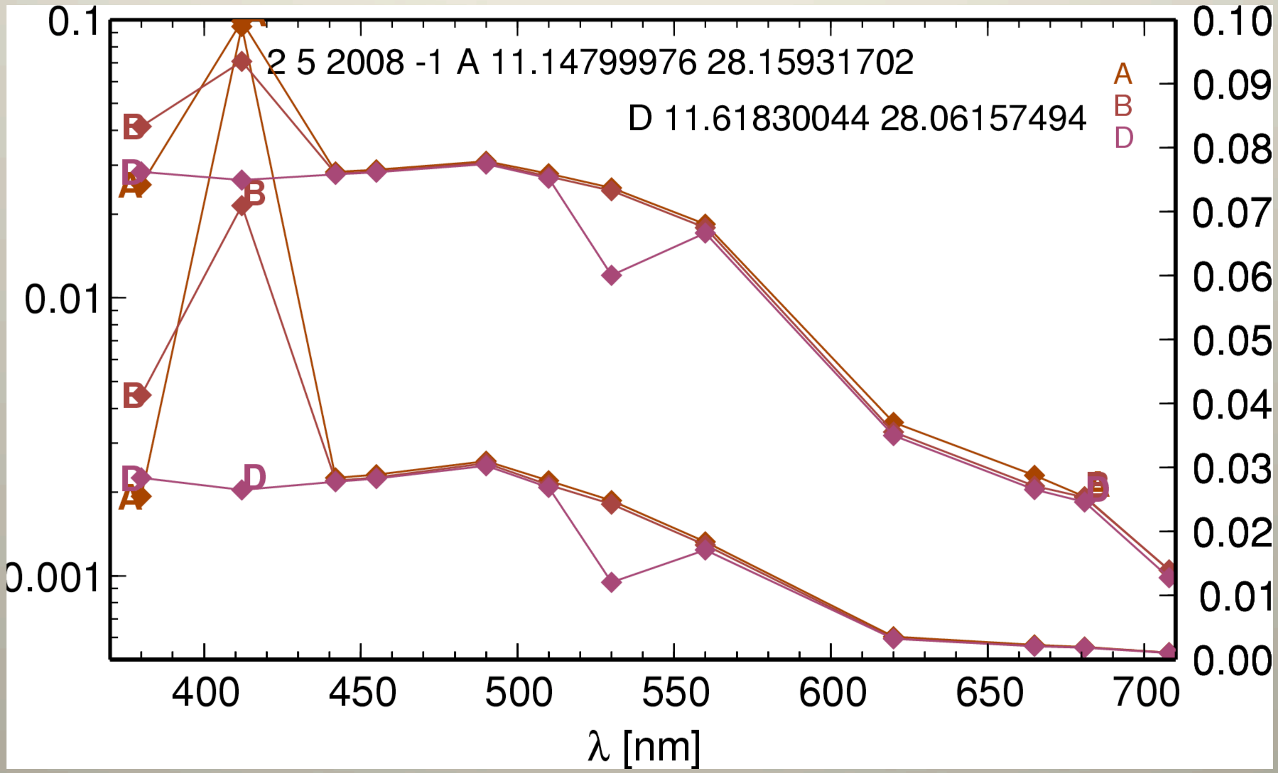
• Plot of K_d's *versus* reflectance ratios

• Plot of R_{rs}'s *versus* reflectance ratios

• ….

These checks apply to the final products (reflectances, K_d's..), not to the "raw" data, *i.e.*, profiles of the various radiometric quantities

Quality control procedures for the SPMR/SMSR data; one example



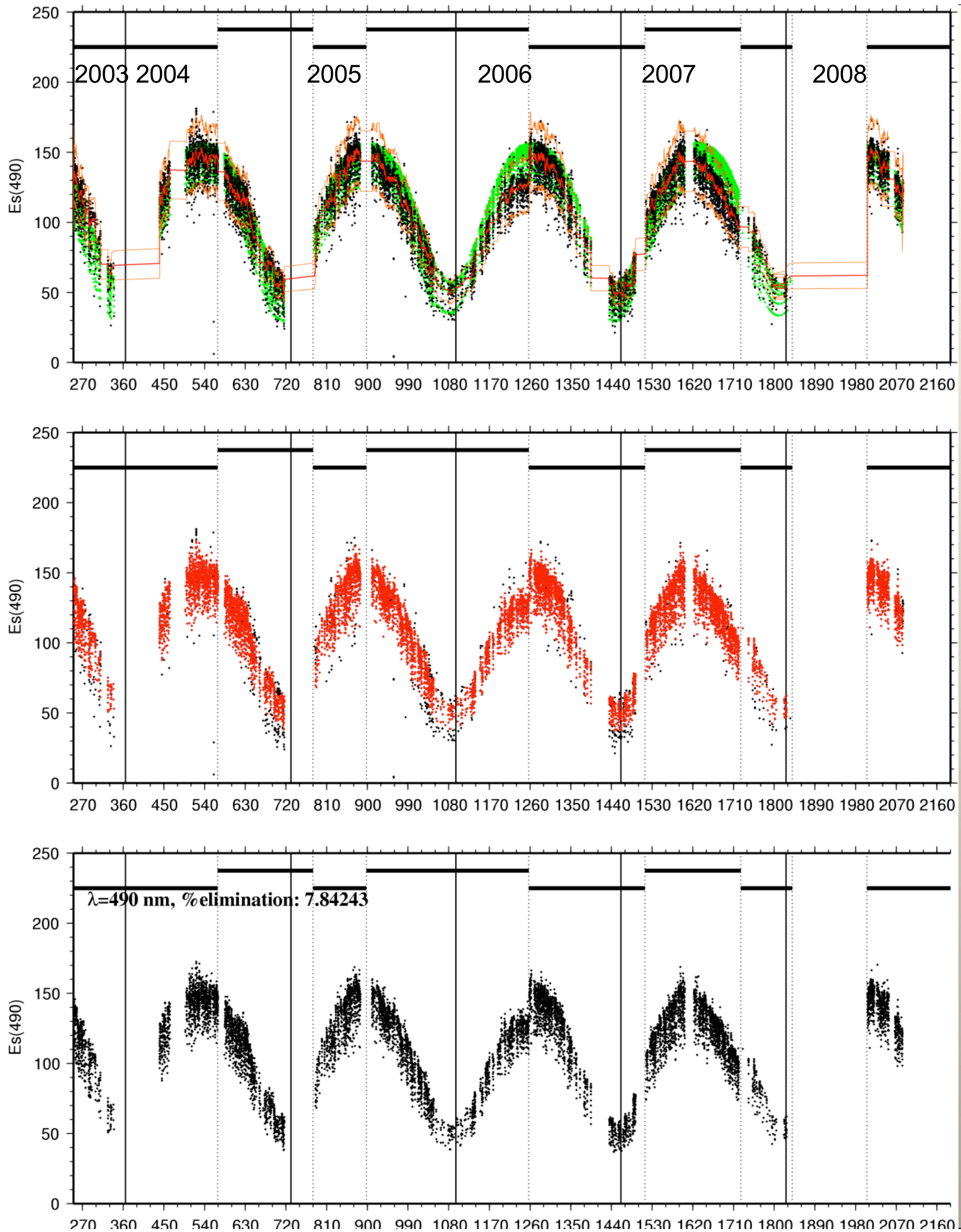
Quality control procedures for the buoy data;

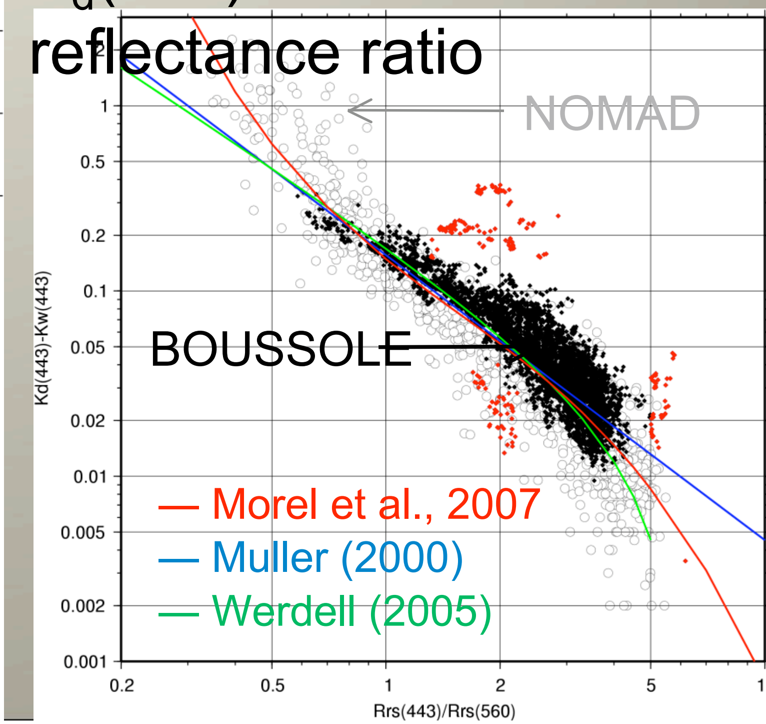
Examples:

$E_s(490)$ time series

and

$K_d(443)$ *versus* a reflectance ratio





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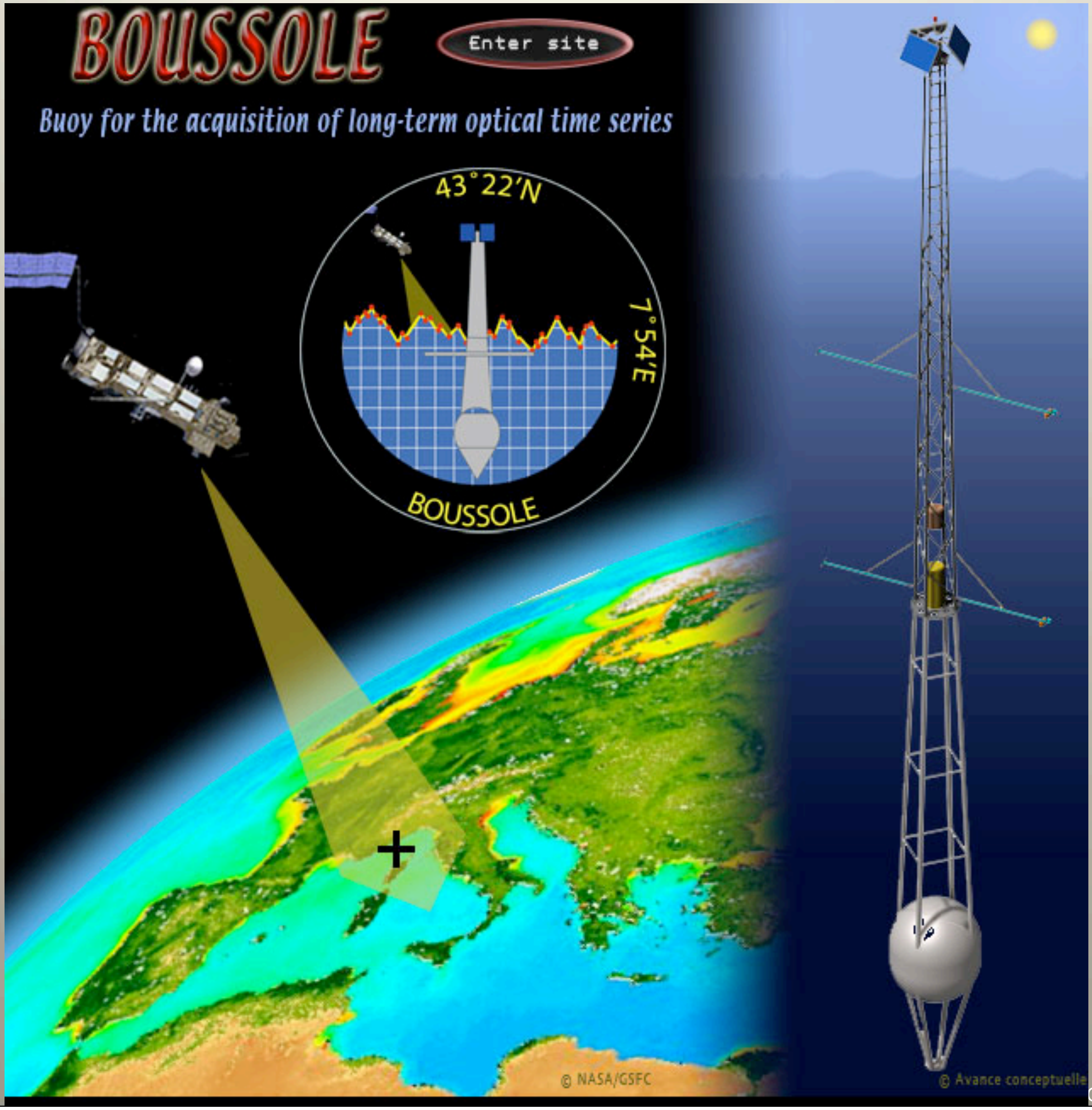
BOUSSOLE web site and data base

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



Interest and ideas for a web-based generic data processin System for AOPs

<u>Our view of what should be this processor</u>:

High interest, as far as the processing is flexible enough so that we can ingest data from our different platforms without too much pain and too much preprocessing steps

Architecture should incorporate a core processing, and modules should be added that allow transformation/adaptation of data from multiple platforms toward the standard data format requested by the core module.

Open source for permanent improvement through community-based inputs and comments

Fully documented

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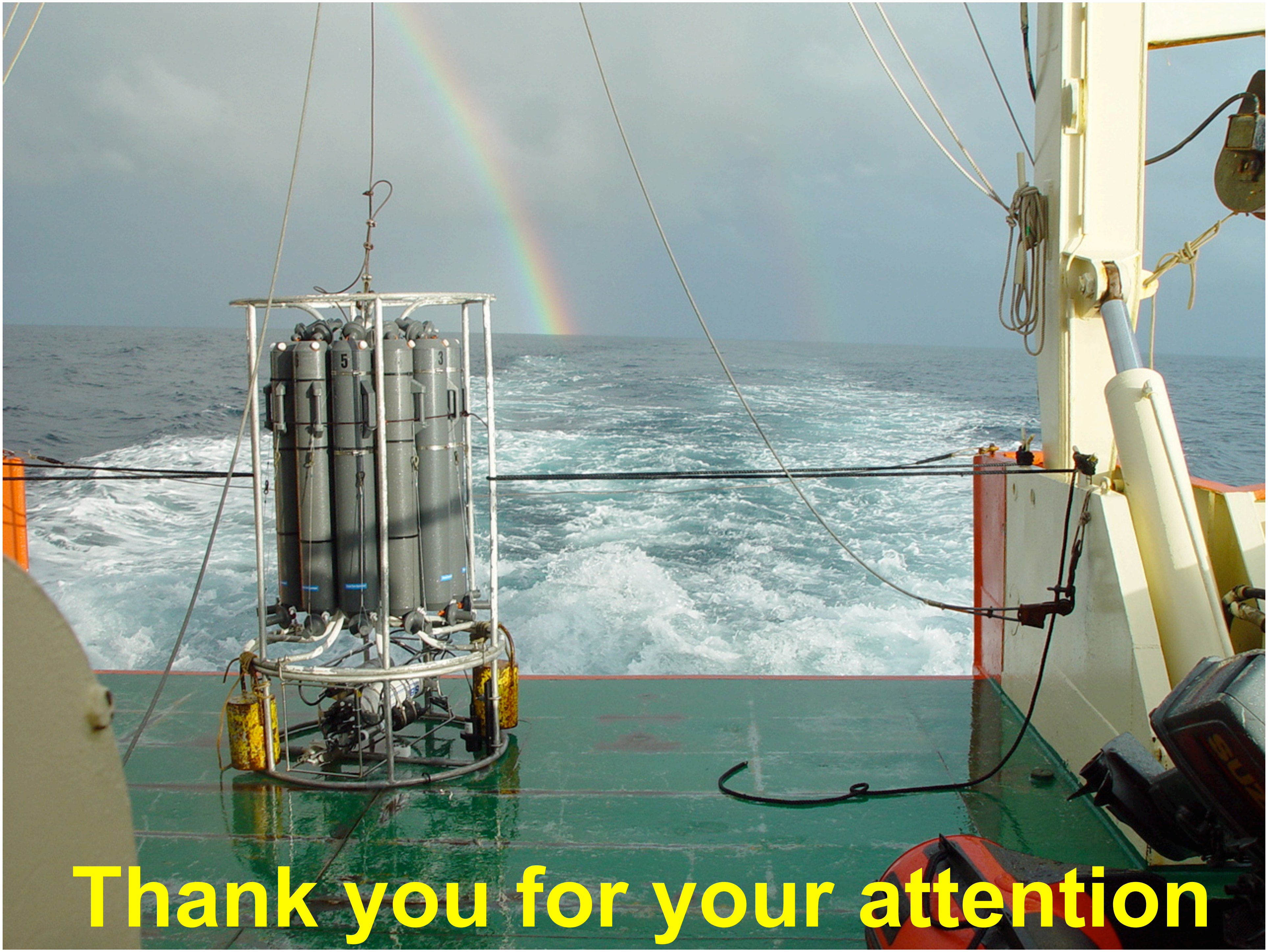
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