Status of MERIS validation activities at BOUSSOLE

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Outline

- Some acknowledgement slides
- Reminder about
  - The project objectives,
  - The site where we are working
  - The data we are collecting
- Why a new mooring type?
- Quantitative summary of data acquisition
- MERIS matchups & comparison with SeaWiFS and Aqua-MODIS
- Conclusions / recommendations
Funding Agencies / Supports

European Space Agency

Centre National d’Etudes Spatiales, France

National Aeronautics and Space Administration of the USA

Centre National de la Recherche Scientifique, France

Institut National des Sciences de l’Univers, France

Observatoire Océanologique de Villefranche sur mer, France
In addition to our supporting/funding Agencies, We also express our appreciation & thanks to

The **ACRI-in/Genimar** (Sophia Antipolis, France) and **Satlantic Inc.** (Halifax, NS Canada) for the buoy & instrument system designs

The **ACRI-st** company (Sophia Antipolis, France) for assistance in MERIS processing and data extraction for matchups (L. Bourg, G. Obolensky)

The **Brockmann Consult** company (Germany) for data distribution

The French institute **IFREMER** and the Norwegian **Marintek** company are also thanked for their help and fairness in the engineering studies that were ordered to them after the major failure of the buoy in spring of 2002.

The **crews and Captains** of:
the **Castor-02** vessel from the Fosevel Marine company (buoy/mooring operations),
the **INSU R/V Téthys-II** (regular monthly cruises),
the **GG-IX** from the Samar company (buoy servicing)

Pilots of the **Valair** and **Commerçair** helicopter companies, for their willingness in accomplishing for us unusual survey missions above the **BOUSSOLE** site.

The French weather forecast Agency, **“Meteo France”** (real time data that are of great help in the day-to-day management of the monthly cruises).

Emmanuel Bosc, Maria Vlachou, Guillaume Lecomte, Edouard Leymarie, Fanny Tièche, who are helping in data acquisition at sea.
People involved

RESEARCH STAFF (L.O.V., Villefranche sur mer) “Marine Optics & Remote Sensing Group”

David ANTOINE, Chief Scientist
Marcel BABIN, Natural phytoplankton fluorescence
Annick BRICAUD, IOPs
Malik CHAMI, Ocean colour vicarious calibration
Hervé CLAUSTRE, IOPs, Biogeochemical proxies
Fabrizio d’ORTENZIO, Associate project manager (starting 2006)
André MOREL, AOPs

TECHNICAL STAFF (L.O.V., Villefranche sur mer)

Alec SCOTT, Responsible for monthly cruises, data processing (2003-2004)
Guislain BECU, idem (2004 - ongoing)
Bernard GENTILI, Data processing codes
Francis LOUIS, Servicing, electronics, design
Joséphine RAS, HPLC and a_p measurements
Dominique TAILLIEZ, CTD + IOPs, monthly cruises
David LUQUET, Diving

PARTNERSHIP WITH COMPANIES

Pierre GUEVEL, ACRI-st-Genimar, Buoy design, hydrodynamics calculations
Jean-François DESTE, ACRI-st-Genimar, Engineering work (e.g., reduced scale model), testing
Philippe BARDEY, ACRI-st, Expertise
Ludovic BOURG, Grigor OBOLENSKY, ACRI-st, MERIS processing, matchups
Alpha CAMARA, “Avance Conceptuelle”, Buoy design, structure calculations
Cyril DEMPSEY Satlantic Inc.
Darrell ADAMS Satlantic Inc.
Motivations

Establish a time series of inherent and apparent optical properties (IOPs and AOPs), with two parallel objectives:

- **Science objectives**: short-term changes in IOPs and AOPs, relationships between both, role of CDOM, seasonal and inter-annual changes, bidirectionalism of the ocean reflectance...

- **Operational objective**: vicarious radiometric calibration of ocean color observations from space, and validation of the level-2 “geophysical products” (e.g., chlorophyll, normalized radiances).
Strategy

Combination of 3 elements:

- A **deep sea mooring**, collecting data on a “continuous” basis

- **Monthly cruises** for collecting data that are not accessible to the mooring (vertical profiles, water sampling), as well as for servicing the mooring

- A **coastal AERONET station**, providing the necessary information about the aerosol properties, which are a central element of the vicarious calibration process
Measurement suite, instrumentation

- **Buoy:** Surface irradiance \( (E_s) \), downwelling irradiance \( (E_d) \), upwelling irradiance \( (E_u) \) and upwelling radiance at nadir \( (L_u) \) at 4 and 9 meters (7 \( \lambda \)’s Satlantic’ OCR-OCI 200 Series), attenuation coefficient (Wetlabs C-star), backscattering coefficient (2 \( \lambda \)’s, Hobilabs’ Hydroscat), chlorophyll fluorescence (Chelsea MiniTracka). Temp., Pressure, Salinity at 9 meters (SeaBird’ SBE37), buoy tilt and compass.

- **Monthly cruises** In-water profiles of \( E_d \) and \( E_u \) at 13 \( \lambda \)’s (Satlantic’ SPMR/SMSR), above water determination of \( L_w \), phytoplankton pigments (HPLC), phytoplankton absorption (filtered water), CDOM absorption, total absorption, scattering and attenuation coefficients at 9 \( \lambda \)’s (Wetlabs’ AC9), backscattering profile (Wetlabs’ eco VSF) and CDOM fluorescence (Wetlabs’ CDOM WetStar). Aerosol optical thickness (CIMEL CE-317 or SIMBADA).

- **Coastal AERONET Station (CE-318 sun photometer)**: aerosol optical thickness, sky radiances (aerosol types) and polarization
The site where we collect data:
“BOUSSOLE” site & program
“Buoy for the acquisition of a long-term (bio)optical series”

Monthly cruises (started July 2001) + a new type of optical buoy (since Sept. 2003)

Marine optics, Bio-optics, Ocean color calibration / validation program (MERIS, SeaWiFS, MODIS, PARASOL)

Site BOUSSOLE
Nice
Courant Ligure
Mer Ligure

Mer Tyrrhénienne
St 2

MERIS/AATSR workshop, ESA-ESRIN, Frascati, 26-30 September 2005
Winter,  
Maximum of the water mixing  
Chl $\sim 0.2$-$0.5$ mg m$^{-3}$  
mixed layer down to 1000 meters

Spring,  
Bloom  
Chl up to $\sim 3$-$5$ mg m$^{-3}$

Summer,  
Maximum of the stratification. DCM is maximum, with surface Chl $\sim 0.05$-$0.1$ mg m$^{-3}$ (up to 1 in the DCM)

End of fall,  
Erosion of the thermocline,  
the DCM progressively disappears  
Chl $\sim 0.2$-$0.5$ mg m$^{-3}$
SeaWiFS chlorophyll 2001–2004
(in correspondence with our monthly cruises)

SeaWiFS/SIMBIOS « diagnostic data sets »
(http://seawifs.gsfc.nasa.gov/cgi/seawifs_region_extracts.pl?TYP=ocean)

MERIS/AATSR workshop, ESA-ESRIN, Frascati, 26-30 September 2005
Why a new mooring type? (1/2)

- All our radiative transfer (and derived algorithms): plane parallel assumption: horizontally-homogeneous ocean (horizontal gradient of irradiance \( E \) or radiance \( L \) is considered negligible)

- Satellite pixel size is \( \sim 1 \) km (at least several hundreds of meters)

- “Sea truth” data are made of individual profiles (scale \( \sim 1 \) m)

- In a homogeneous ocean (in terms of IOPs), this would not be a problem when the sea surface is perfectly flat

- Irradiance profilers provide however highly noisy data near the surface because of the effect of capillary and gravity waves \( \rightarrow \) the horizontal gradient in \( E \) or \( L \) is often an order-of-magnitude larger than the vertical gradient (see, e.g., Zaneveld et al., Appl. Opt., 40(9), 2001)
Why a new mooring type? (2/2)

The data near the surface are usually unusable whereas they are the ones that should be used when satellite validation is concerned.

One “solution”:
Integration over an “infinite” number of individual and simultaneous profiles covering a large area.

Another solution:
Integration over time with a sensor maintained at a fixed position and depth (w.r.t. the bottom).

This is what the BOUSSOLE buoy is making possible, by

1. maintaining verticality,
2. warranting the stability of the instruments, and
3. avoiding shading of the instruments by the buoy structure.

Taught mooring + « transparent-to-swell » tubular structure without a surface buoy.
Burst acquisition mode (1 minute at 6 Hz): Possibility of filtering the effects of the wavy interface to get closer to the true value of \( K_d \) or \( K_u \), and then achieve a better extrapolation to “just below the surface”.
Deployments summary

**Monthly cruises** started in July 2001, ongoing…

**Buoy deployments**:
- July to October 2000: qualification deployment
- May 2002: first, unsuccessful deployment
- Sept 6 - Dec 6, 2003: 3-month successful deployment
- Mid June 2005: full buoy+mooring rotation
- Data acquisition is ongoing

**AERONET site**, data collection periods:
- July 2002 to April 2003
- January to November of 2004
- February 2005, ongoing

**Project should extend at least throughout the MERIS life**
### Data summary: monthly cruises

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<th>CTD Profiles</th>
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<th>SimbadA measurements</th>
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</tr>
</tbody>
</table>

Data summary : AERONET
Matchups summary at BOUSSOLE

Obtained from:

buoy data: 3 months in fall 2003
8 months in 2004 (March, mid May-mid July, Aug - Dec)
1 ½ months in 2005 (Mid Feb. to end of March)

SPMR data: monthly cruises up to Sept 2004

MERIS data: Mid June 2002 to end of March 2005

very last reprocessing, “MEGS7.4” (summer 2005)

MERIS: \( N = 55 \) (48 + 7)

MODIS: \( N = 85 \) (77 + 8) (2005 reprocessing, fully normalized nLw’s)

SeaWiFS: \( N = 98 \) (79 + 19) (2005 reprocessing, fully normalized nLw’s)

Criteria: no glint, not at a cloud border, QC in situ data.

More selective criteria (low AOT, small \( \theta_s \), low wind speed etc...) leads to a reduction of these numbers by at least 50%
MERIS matchups results & Comparison with SeaWiFS and Aqua-MODIS
Matchups examples at BOUSSOLE (1/4) : March 22, 2004

**MERIS**

- Chl
- $\tau_a(865)$

**A-MODIS**

- Chl
- $\tau_a(869)$

**SeaWiFS**

- Chl
- $\tau_a(865)$
Matchups examples at BOUSSOLE (2/4) : May 29, 2004

MERIS

A-MODIS

SeaWiFS
Matchups examples at BOUSSOLE (3/4) : June 17, 2004

**MERIS**

- **Chl**
- **τ_a(865)**

**A-MODIS**

- **Chl**
- **τ(869)**

MERIS/AATSR workshop, ESA-ESRIN, Frascati, 26-30 September 2005
Matchups examples at BOUSSOLE (4/4) : October 6, 2003

MERIS

A-MODIS

SeaWiFS
MERIS matchups ($\rho_w's$) BOUSSOLE site

48 matchups from the buoy
7 from the SPMR (monthly cruises)

$y = 1.0113x + 0.0008$
$R^2 = 0.9473$

Linear scale

Log scale
SeaWiFS matchups (nLw's) BOUSSOLE site

\[ y = 0.9725x + 0.0073 \]
\[ R^2 = 0.9496 \]

79 matchups from the buoy
19 from the SPMR (monthly cruises)
Aqua-MODIS matchups (nL_w’s) BOUSSOLE site

77 matchups from the buoy
8 from the SPMR (monthly cruises)

\[ y = 0.9591x + 0.0219 \]

\[ R^2 = 0.975 \]
### Matchups statistics at BOUSSOLE (MERIS, SeaWiFS & A-MODIS)

#### MERIS

<table>
<thead>
<tr>
<th>(\lambda)</th>
<th>N</th>
<th>mean ratio</th>
<th>RPD</th>
<th>(r^2)</th>
<th>slope</th>
<th>interc.</th>
<th>RMS</th>
<th>in situ range</th>
<th>satellite range</th>
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<th>RPD</th>
<th>(r^2)</th>
<th>slope</th>
<th>interc.</th>
<th>RMS</th>
<th>in situ range</th>
<th>satellite range</th>
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#### A-MODIS

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<th>(r^2)</th>
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<th>interc.</th>
<th>RMS</th>
<th>in situ range</th>
<th>satellite range</th>
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<td>0,960</td>
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</table>
MERIS matchups at MOBY ($\rho_w$'s)

Linear scale

$y = 1.0556x + 0.0004$

$R^2 = 0.9897$

Log scale

24 points from the buoy (~ 5 months from August 2002 to January 2003)
### MERIS matchups statistics at MOBY

#### MERIS (Moby site)

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<tr>
<th>$\lambda$</th>
<th>N</th>
<th>mean ratio</th>
<th>RPD</th>
<th>$r^2$</th>
<th>slope</th>
<th>interc.</th>
<th>RMS</th>
<th>in situ range</th>
<th>satellite range</th>
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<td>0,000000</td>
<td>0,000000</td>
<td>0,000000</td>
</tr>
</tbody>
</table>
Chlorophyll matchups

MERIS

SeaWiFS

A-MODIS

All matchups

With the radiometry QC

MERIS Chl vs. SeaWiFS Chl vs. A-MODIS Chl

HPLC-TChl-a vs. HPLC-TChl-a vs. HPLC-TChl-a

MERIS/AATSR workshop, ESA-ESRIN, Frascati, 26-30 September 2005
Conclusions / Ongoing & future work (1/2)

- Quasi-operational system, including two complete moorings (mooring line + buoy + instrumentation)

==> Continuous sampling is at reach.
==> About 40 to 50 matchups per year for MERIS
     80 to 90 matchups per year for MODIS & PARASOL

==> MERIS shows a significant overestimation in the blue,
    and a problem in the red

   A-MODIS looks pretty good (low bias, low dispersion)
   SeaWiFS shows a slight underestimation and a slightly larger dispersion

So : should we now introduce a **vicarious calibration** for MERIS
    (not necessarily with the same methods than for other OC sensors)
    or should we concentrate on **algorithms** (in particular atmospheric corrections) ? Probably both.
Conclusions / Ongoing & future work (2/2)

- Still a lot of work to reduce satellite versus in situ scatter
  (1) Further interpret the matchups’ results
  (2) Further QC the buoy data,
  (3) Introduce corrections, e.g., for self-shadow and buoy shadow, tilt on Es
  (4) Improve the data processing, e.g., surface extrapolation
  (5) Introduce SQM-II relative calibrations
  (6) Improve bio-fouling elimination

- A dedicated person is needed in order to go further in the understanding of the problems we have, in particular with the blue bands.

- Vicarious radiometric calibration of MERIS
  (i.e., simulating the TOA total radiance and comparing with what MERIS is providing)
  The tools (inversion procedures & RT codes) & the data (AERONET) are nearly Ok ==> results by the end of 2005.

- A data base, including the full data set and some public-access data, is under construction (opening end of 2005).
Thank you for your attention
An example: reflectance time series (2005)
2001-2004 time series for $K_d(490)$
A web site is in preparation, where you will find all relevant information about the project, as well as some public-access data. Should be ready by the end of 2005.

Developed by C. Brown.
“blue-to-green” ratio : \( R(443)/R(560) \)
time series 2001-2004

Model

Data

“reconstructed” Chl

Chl \textit{in situ}
$K_d$ essentially determined by absorption

\[ K_d \approx \frac{a}{\mu_d} \]
R time series 2001-2004

R more depending on backscattering ($b_b$)

$$R = f \frac{b_b}{a + b_b}$$