CENTRE NATIONAL D'ETUDES SPATIALES

CNES
Ocean-colour related programmes & activities

E. Thouvenot
CNES, Toulouse, France

CENTRE NATIONAL D'ETUDES SPATIALES

Summary

- **POLDER-2**
- **Other activities**
  - **cal/val (SimbadA, Boussole)**
  - **MERCATOR and value added products**

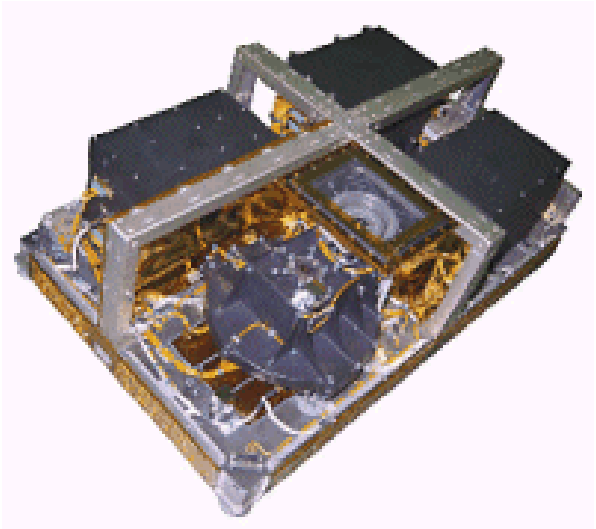
CENTRE NATIONAL D'ETUDES SPATIALES

POLDER-2

- **Integrated on ADEOS II**
- **Launched on Dec 14, 2002**
- **First image : Feb 1, 2003**

CENTRE NATIONAL D'ETUDES SPATIALES

POLDER-2 Technical features (1/2)



The POLDER instrument is a camera composed of a two-dimensional CCD detector array, wide field of view telecentric optics and a rotating wheel carrying spectral and polarized filters.

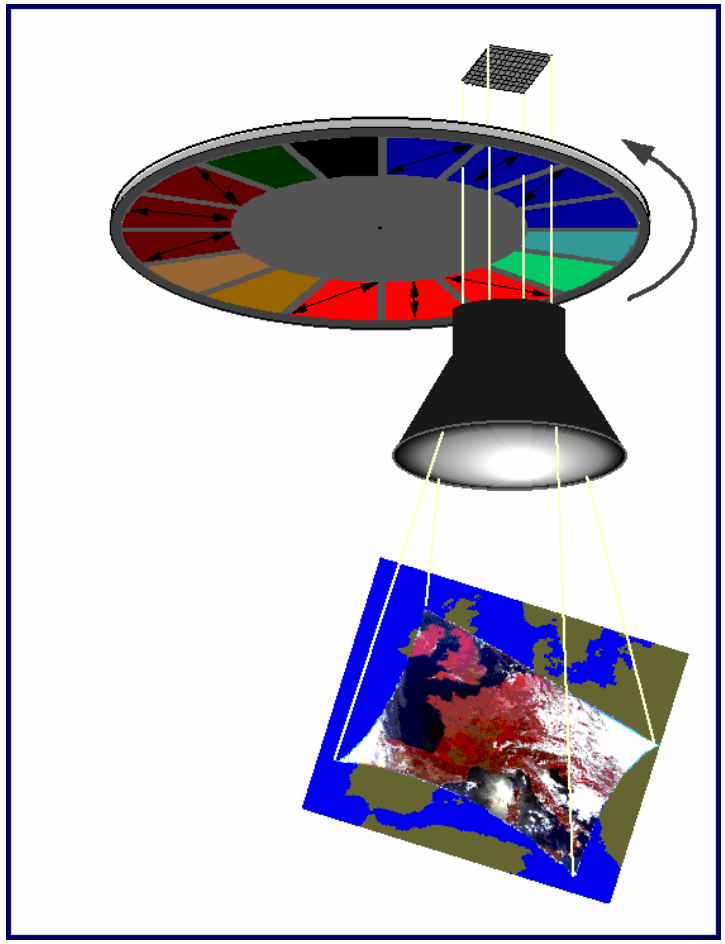
Mass	**32 kg**	
Volume	**0.8 x 0.5 x 0.25 m^3**	
Power Consumption	**50 W (image mode)**	
Encoding	**12 bits**	
Data rate	**883 kbps**	
Field of View	**± 43° along track**	**± 51° cross track**
Swath	**2400 km**	
Pixel (at nadir)	**6 km x 7 km**	
Mission Lifetime	**3 years**	

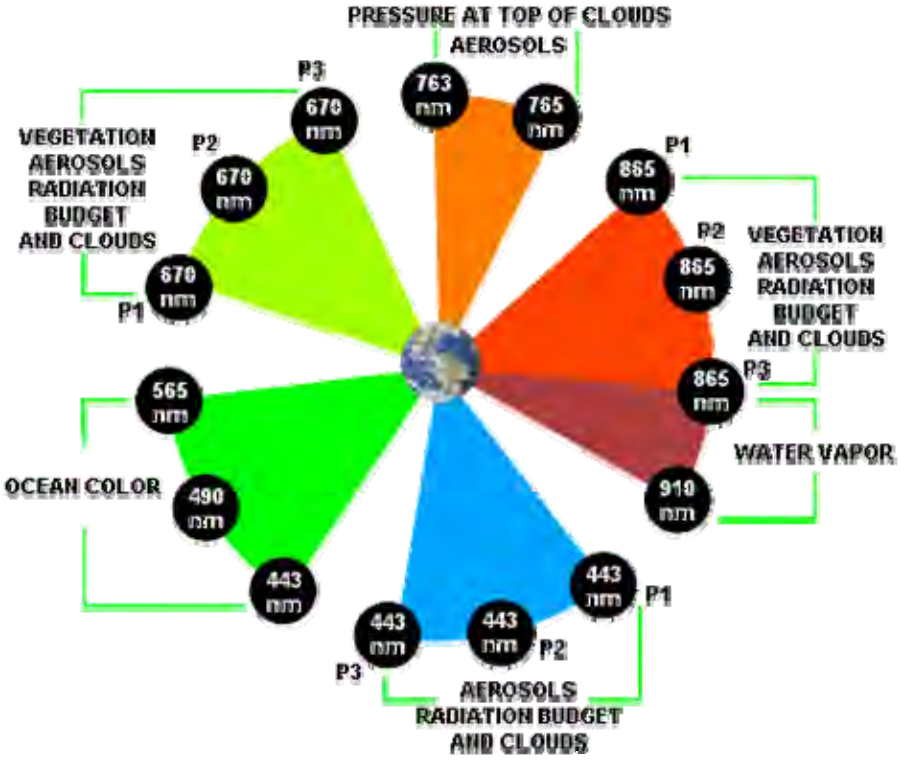
POLDER has 15 spectral bands which range from 443 nm to 910 nm. Two of these spectral bands are centered on molecular absorption bands : 763 (O2) and 910 (H2O).

POLDER band	443P	443NP	490NP	565NP	670P	763NP	765NP	910NP	865P
Central Wavelength	444.5	444.9	492.2	564.5	670.2	763.3	763.1	907.7	860.8
Approximate Band Width	20	20	20	20	20	10	40	20	40
Polarization	Yes	No	No	No	Yes	No	No	No	Yes
Saturation level	1.1	0.97	0.75	0.48	1.1	1.1	1.1	1.1	1.1

CENTRE NATIONAL D'ETUDES SPATIALES

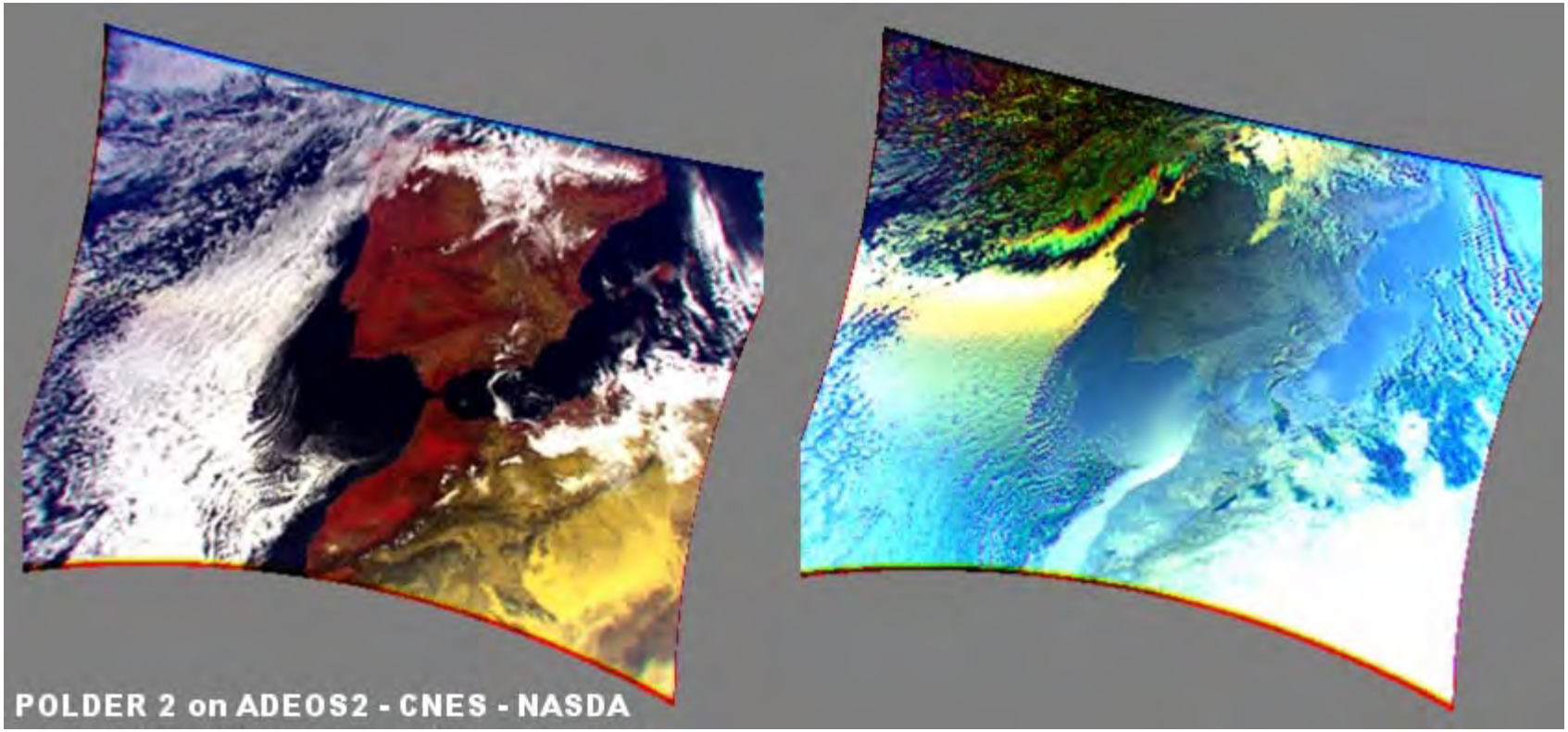
POLDER-2 Technical features (2/2)





CENTRE NATIONAL D'ETUDES SPATIALES

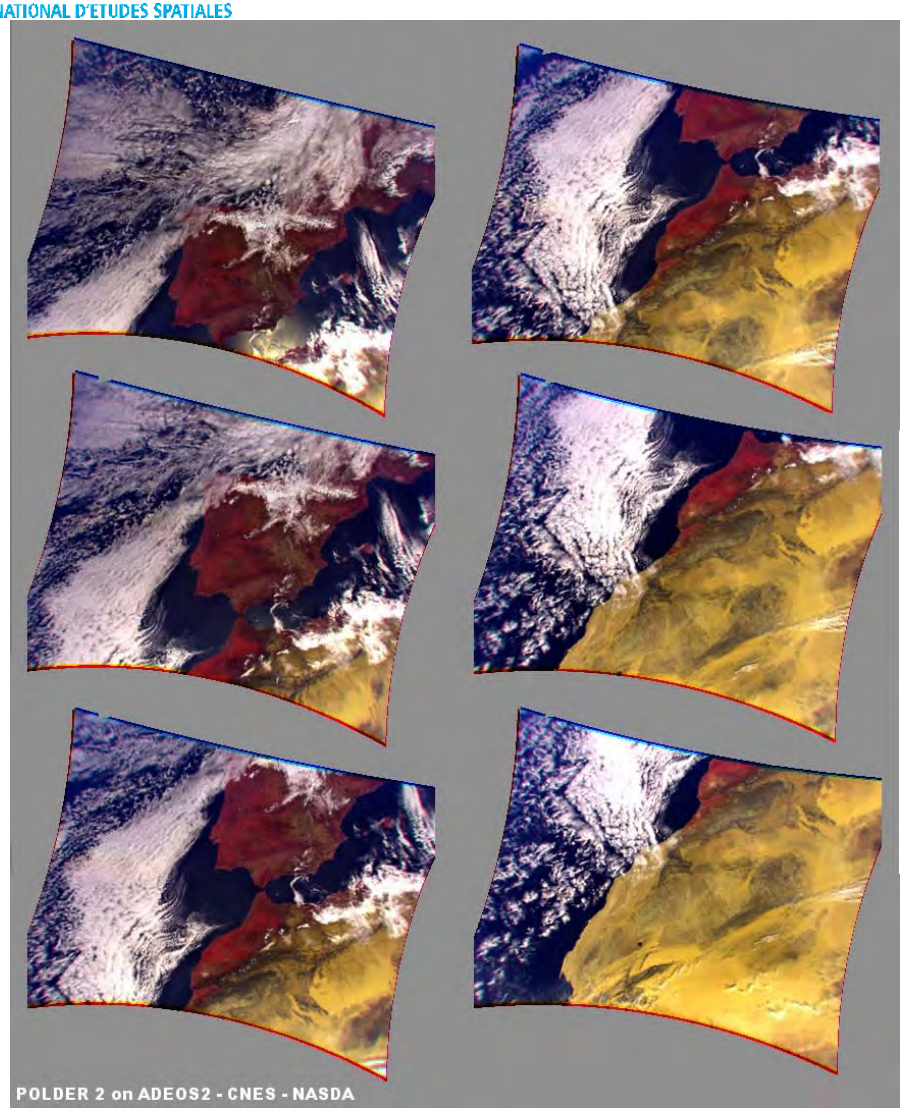
POLDER-2 First image : Feb. 1, 2003 (Spain & North Africa)



(443, 670, 865) nm colour images
with non polarized (left) and polarized (right) channels

CENTRE NATIONAL D'ETUDES SPATIALES

POLDER-2 First image : Feb. 1, 2003 (Spain & North Africa)



First sequence of images

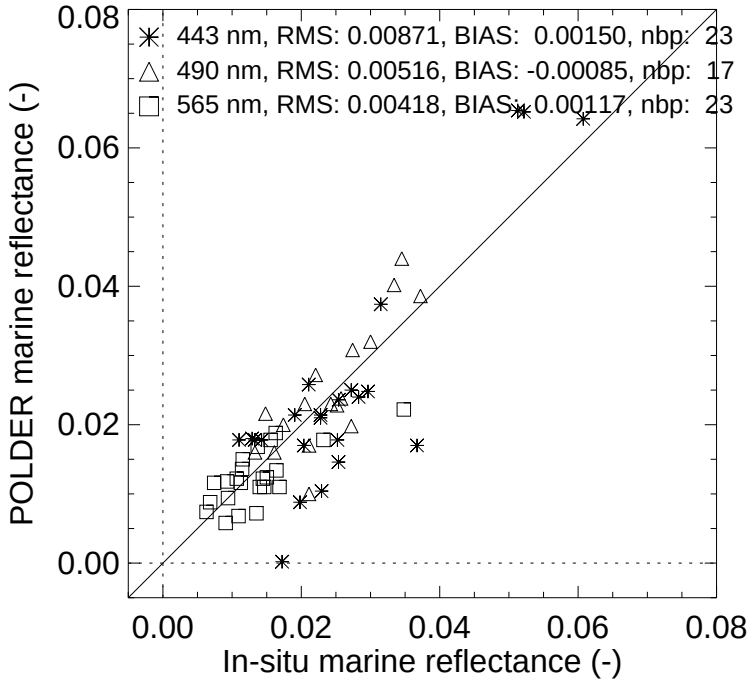
The instrument's wide of field of view combined with the forward motion of the satellite enables it to observe the same site from different viewing angles

(443, 670, 865) nm colour images with non polarized channels

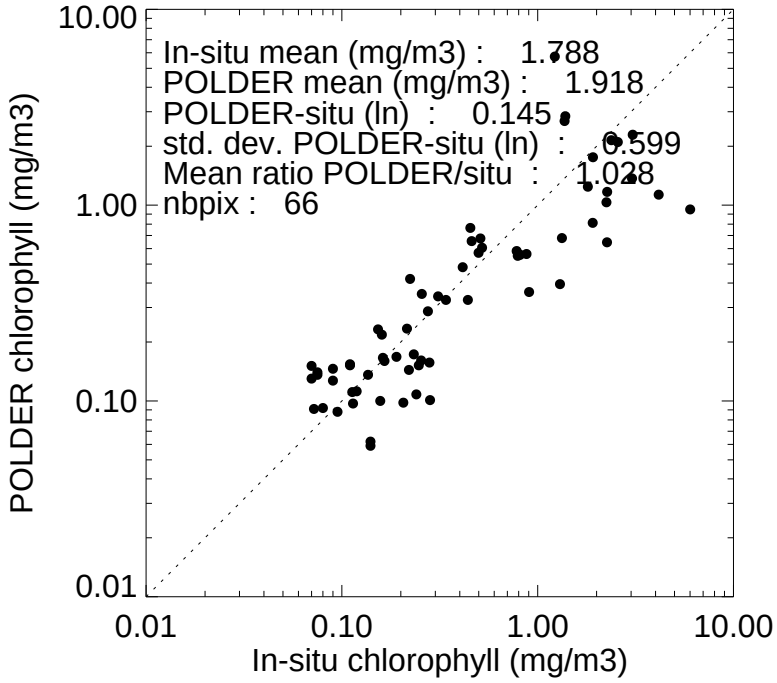
CENTRE NATIONAL D'ETUDES SPATIALES

POLDER-1 validation results

Validation results for marine reflectance (under the surface)



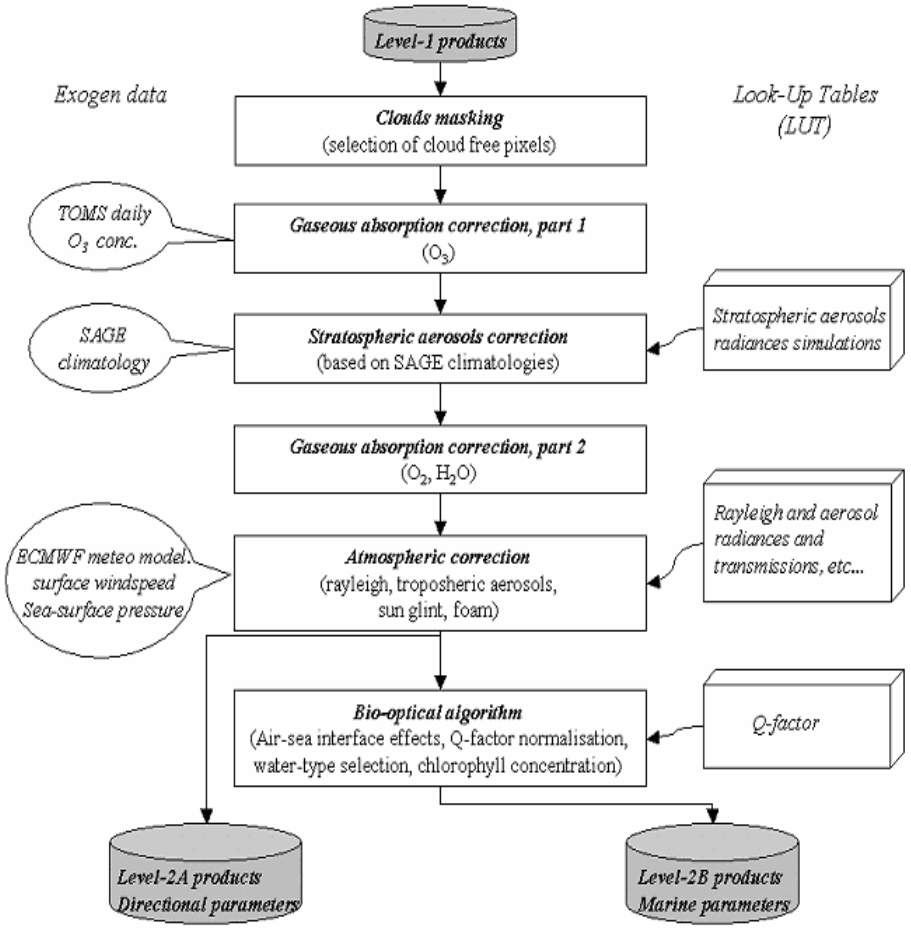
Validation results for chlorophyll-*a*



◎ **Insufficient number of in-situ measurements during the 8 months of acquisitions**

CENTRE NATIONAL D'ETUDES SPATIALES

POLDER-2 processing algorithms



POLDER-2 algorithm improvements :

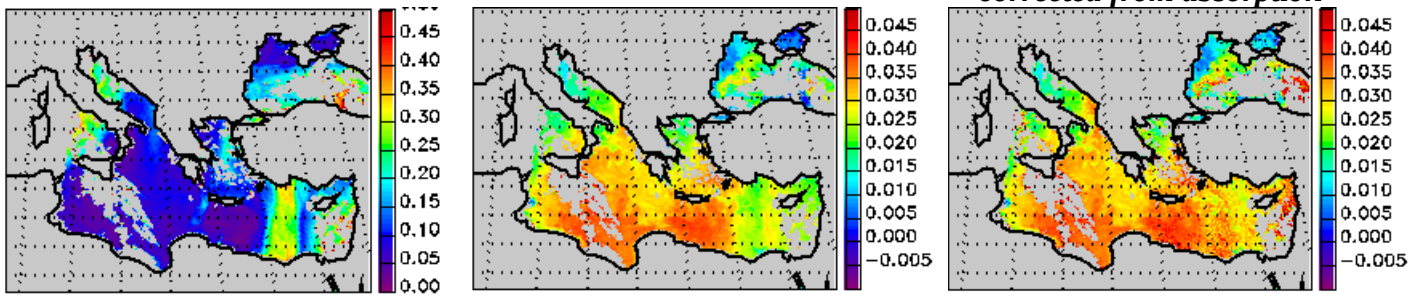
- Correction for absorbing aerosols using directional effects
- Correction of the "black pixel assumption" effects
- New parameters, including :
  - two chlorophyll-*a*
  - water particles backscattering coefficient
  - water particles and dissolved matters absorption coefficient

CENTRE NATIONAL D'ETUDES SPATIALES

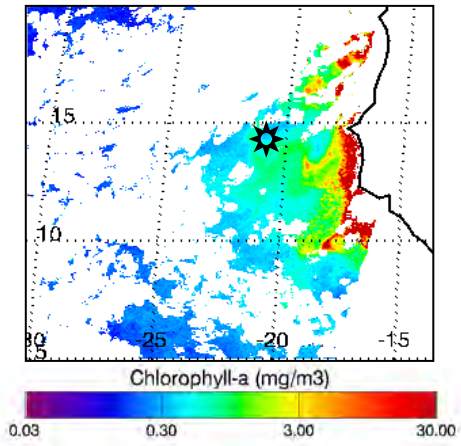
Application to POLDER-1 data : atmospheric corrections

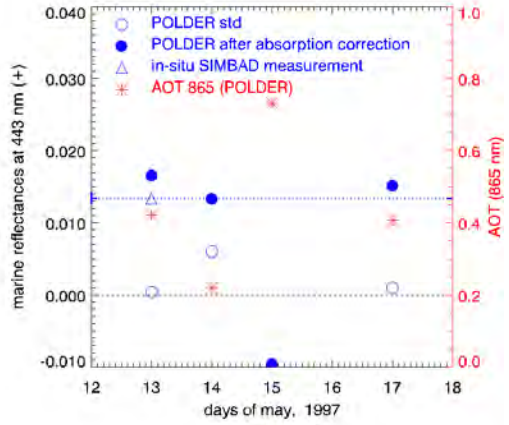
- **Correction from absorption by the aerosols**

AOT (865 nm) | *Marine reflectance (+) at 443 nm* | *Marine reflectance (+) at 443 nm* ***corrected from absorption***



- **Preliminary validation using SIMBAD *in-situ* measurements during AMT-4**





CENTRE NATIONAL D'ETUDES SPATIALES

POLDER-2 bio-optical algorithm

Five bio-optical parameters are retrieved from the spectral marine reflectances:

- The chlorophyll concentration as estimated from SeaWiFS-OC2 algorithm: **Chl1**
- The chlorophyll concentration estimated from a new empirical algorithm: **Chl2**
- The absorption coefficients at 443 and 490 nm: **a(443)** and **a(490)**
- The backscattering coefficient at 565 nm: **b_b(565)**

Chl1, the chlorophyll concentration estimated by a SeaWiFS-like bio-optical algorithm, OC2v4 (O'Reilly et al., 2000), using the ratio of the POLDER derived marine reflectances at 490 and 565 nm. Chl1 is the same product than the previously delivered by POLDER 1.

$Chl1 = a4 + 10^{(a0 + a1R + a2R^2 + a3R^3)}$; $R = \ln(R490/R565)$

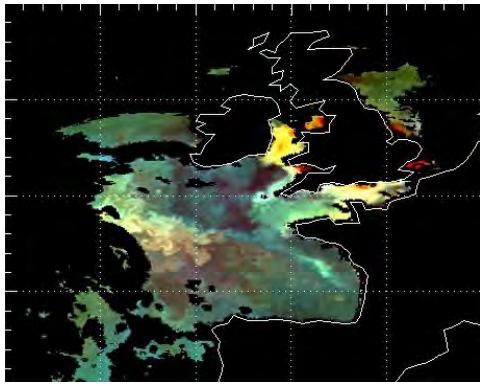
Chl2, the chlorophyll concentration estimated with a 3 wavelengths biooptical algorithm, at 443, 490 and 565 nm, customized for POLDER data (Deschamps, 2003). The use of the marine reflectance at 443 nm allows to increase the sensitivity of the biooptical algorithm at low chlorophyll concentration, together with the quadratic combination of channels. Chl2 should be more accurate and should be used preferably to Chl1 after its validation. The two algorithms tend to the same estimate for high chlorophyll concentration.

$\ln(Chl2) = a + b\ R'$; $R' = \ln[\{(R443^2 + R490^2)/(Ro565^2 + R565^2)\}^{0.5}]$

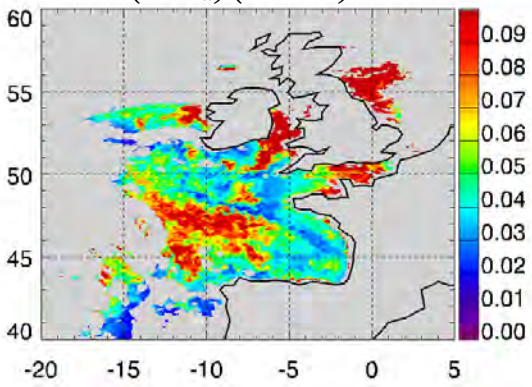
Ro565 is a constant, the marine reflectance at 565 nm for low chlorophyll concentration.

Application to POLDER-1 data : bio-optical algorithms (1/2)

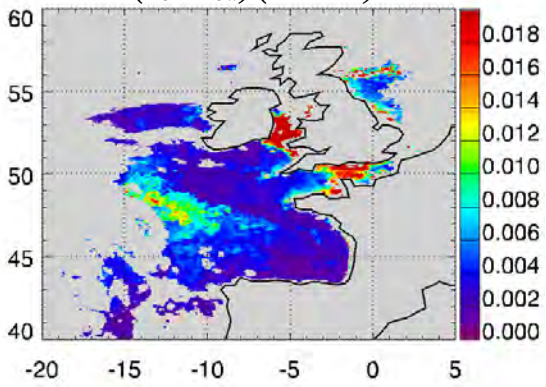
RGB POLDER image using marine reflectance at 443, 490 and 565 nm



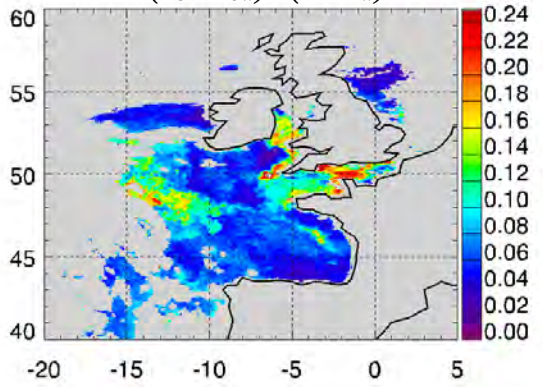
$(a - a_w)$ (490 nm)



$(b_b - b_{bw})$ (565 nm)

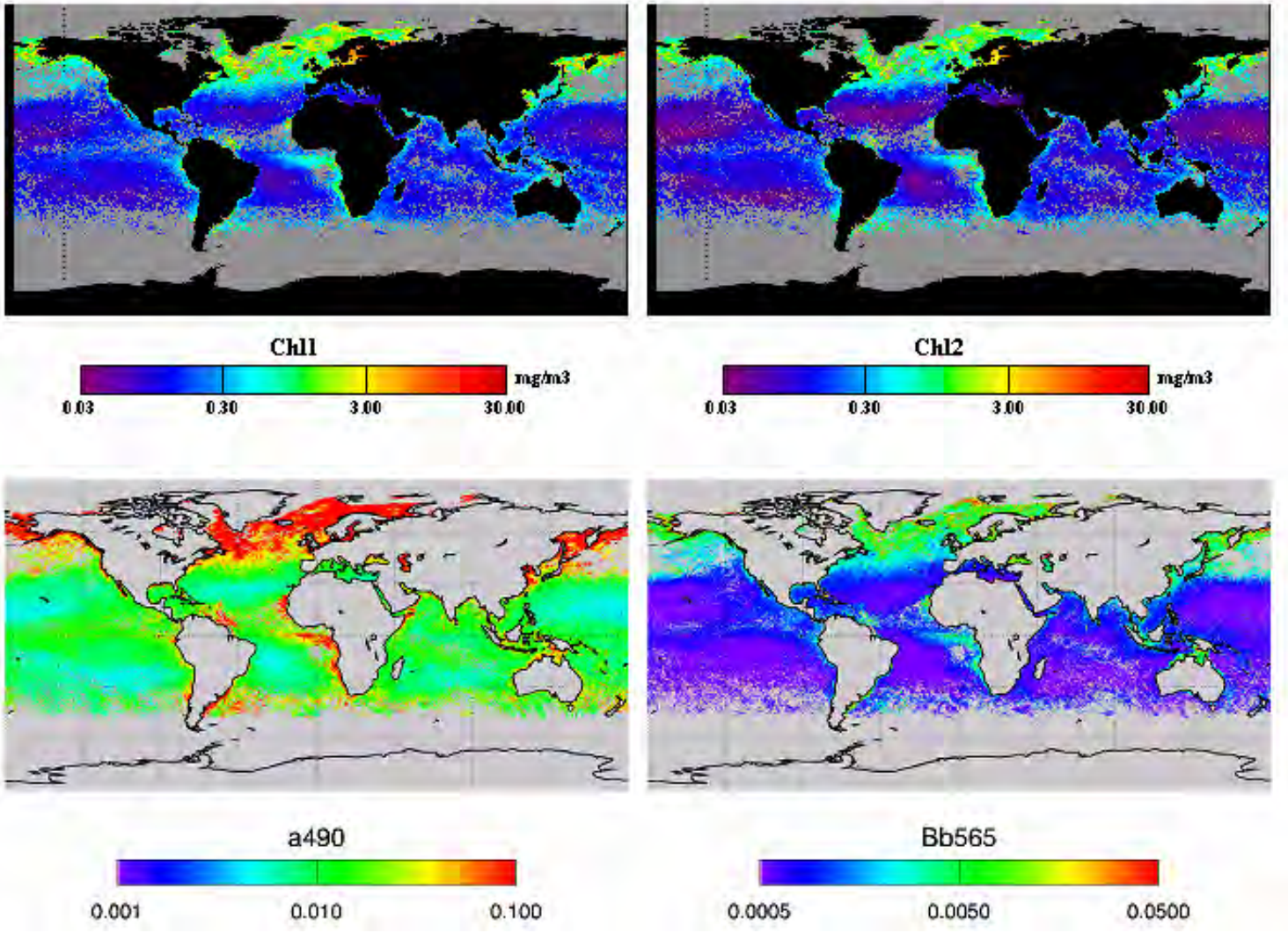


$(b_b - b_{bw}) / (a - a_w)$



CENTRE NATIONAL D'ETUDES SPATIALES

Application to POLDER-1 data : bio-optical algorithms (2/2)



CENTRE NATIONAL D'ETUDES SPATIALES

POLDER-2 planned activities

- Start of POLDER-2 continuous acquisition : April 2003
- 6-month calibration phase
- Start of validation of scientific products (level 2 & 3) : June 2003
- Start of level 1 product distribution : October 2003
- Level 2 & 3 data distribution :
  - Preliminary by LOA : October 2003
  - Final by CPP/CNES : 2004

CENTRE NATIONAL D'ETUDES SPATIALES

POLDER data availability

POLDER-1 data available :

- on-line (for chlorophyll synthesis) at :
  http://smsc.cnes.fr/POLDER/A_produits_scie.htm

- after ordering (for L1, L2, L3 data) at :
  http://smsc.cnes.fr/POLDER/A_p1_user_services.htm

CENTRE NATIONAL D'ETUDES SPATIALES

CAL/VAL Activitities

- **SIMBADA**
  - **set of ground radiometers for characterisation of atmospheric & ocean surface optical properties**
  - **operated on opportunity vessels: extensive sampling**
  - **multisensor cal/val: MERIS, POLDER, SeaWiFS (SIMBIOS)**
  - **design & operation funded by CNES with ESA contribution**
- **BOUSSOLE**
  - **buoy located on DYFAMED site (about 30 miles from Nice) for subsurface profiles of marine optical parameters**
  - **multisensor cal/val: MERIS, POLDER, SeaWiFS, MODIS (SIMBIOS)**
  - **design & implementation co-funded by ESA & CNES**

CENTRE NATIONAL D'ETUDES SPATIALES

SIMBADA Radiometers

CENTRE NATIONAL D'ETUDES SPATIALES

SIMBADA radiometers

1 Instrument concept

• optical radiometer allowing 2 measurements modes in 11 wavelengths (350 - 870 nm)

- solar mode : Sun viewing to measure aerosol optical thickness

- marine mode : Sea viewing to retrieve (above) water-leaving radiance/reflectance

• hand-held radiometer, measuring from a ship desk

2 Network concept

• 18 instruments (funded by CNES/CNRS, ESA, ...)

• lent to many scientific investigators doing measurements campaigns in almost every ocean and sea

CENTRE NATIONAL D'ETUDES SPATIALES

SIMBADA radiometers

Technical characteristics

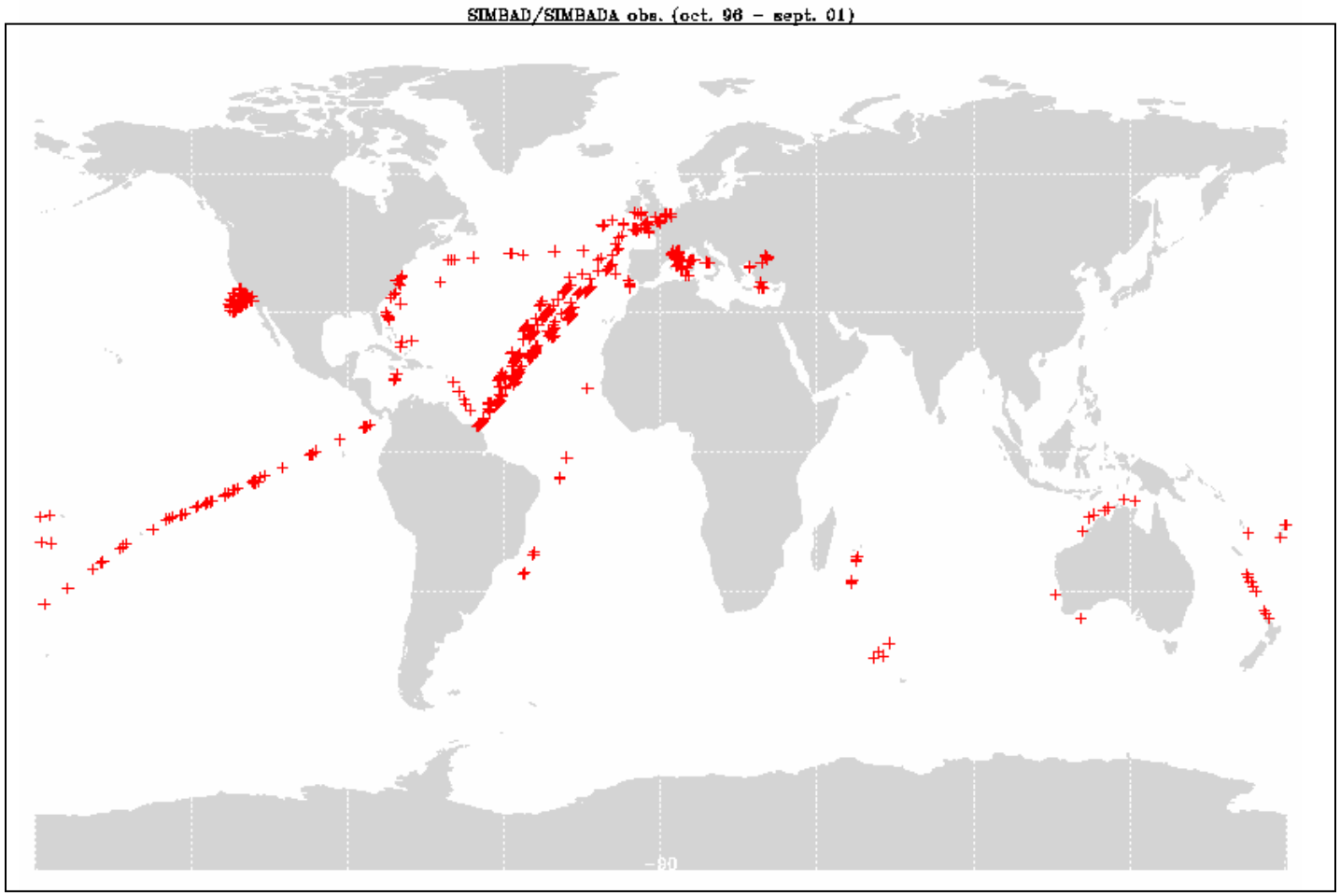
- **reflected skylight cut by polarizer and viewing at Brewster incidence angle**
- **10 Hz recording frequency**
- **GPS antenna**
- **rechargeable batteries**
- **internal memory**

band	1	2	3	4	5	6	7	8	9	10	11
λ_c (nm)	350.8	380.9	411.4	443.0	492.6	511.2	561.6	622.1	671.9	752.5	871.6
$\Delta\lambda$ (nm)	9.8	9.7	8.6	11.2	10.1	8.3	8.6	9.9	9.1	10.1	10.0

CENTRE NATIONAL D'ETUDES SPATIALES

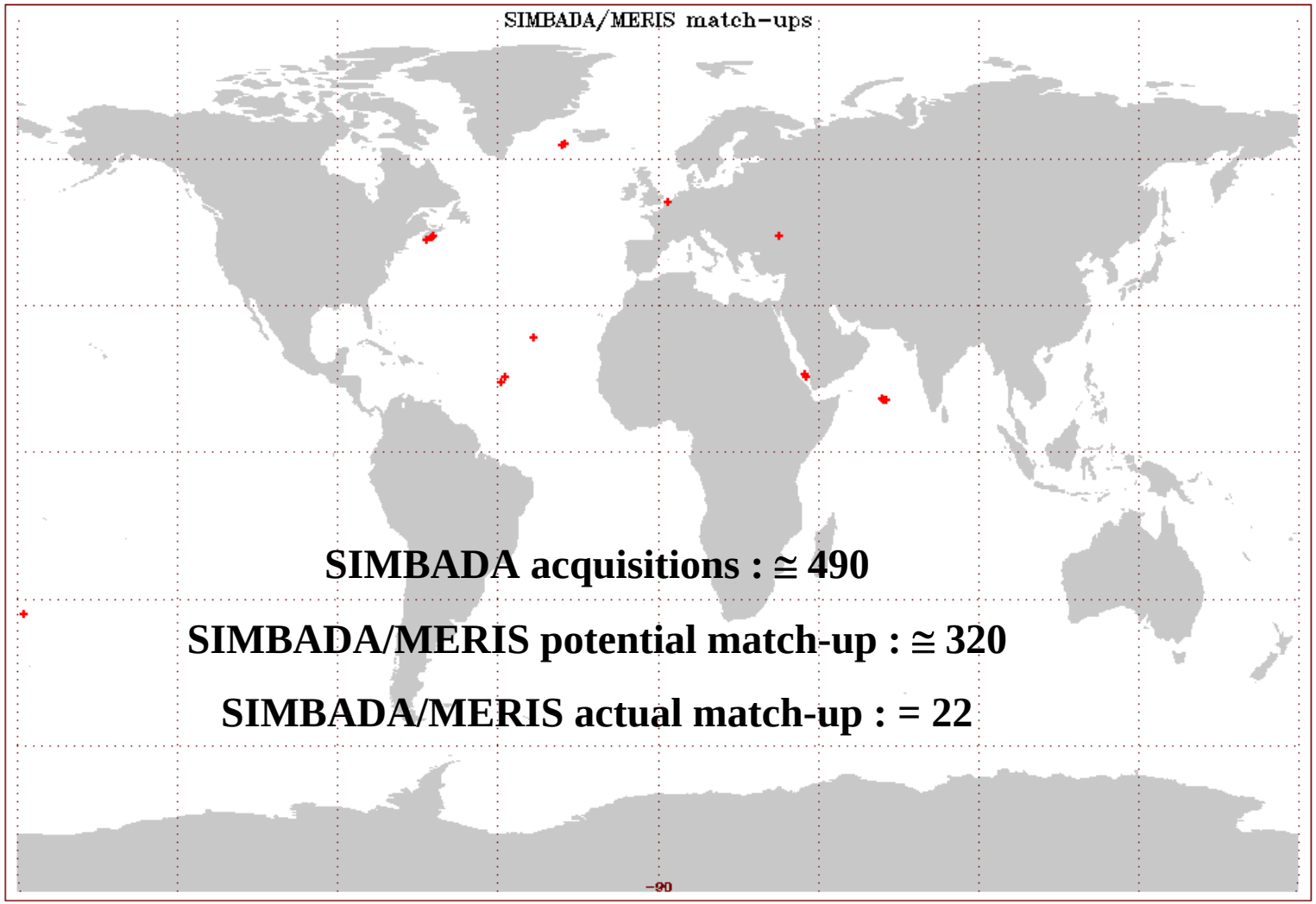
SIMBADA radiometers

SIMBADA stations from beginning (Sept. 01, 2000)



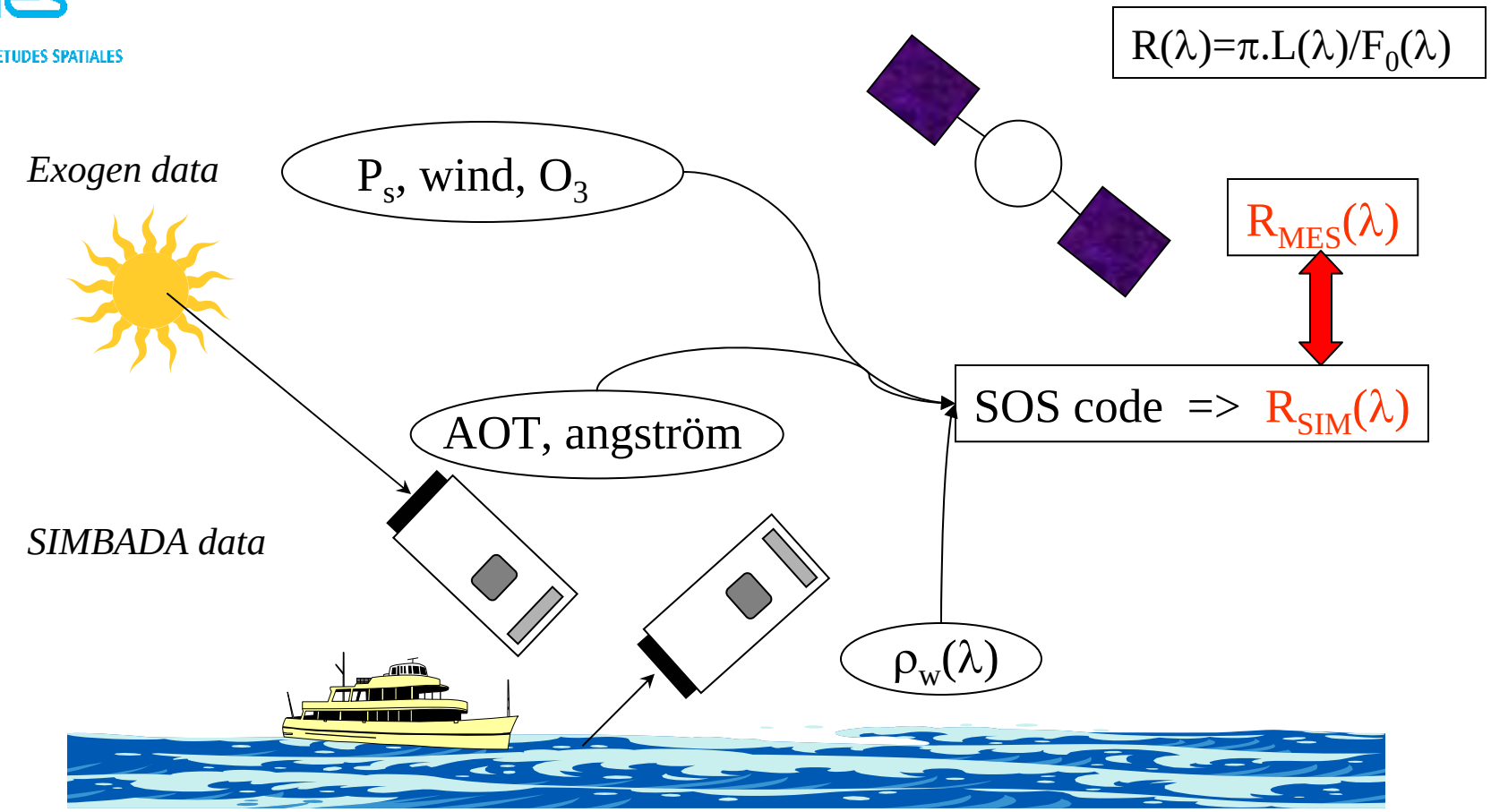
SIMBADA radiometers

SIMBADA/MERIS obtained match-up



Vicarious calibration with SIMBADA radiometers

CENTRE NATIONAL D'ETUDES SPATIALES



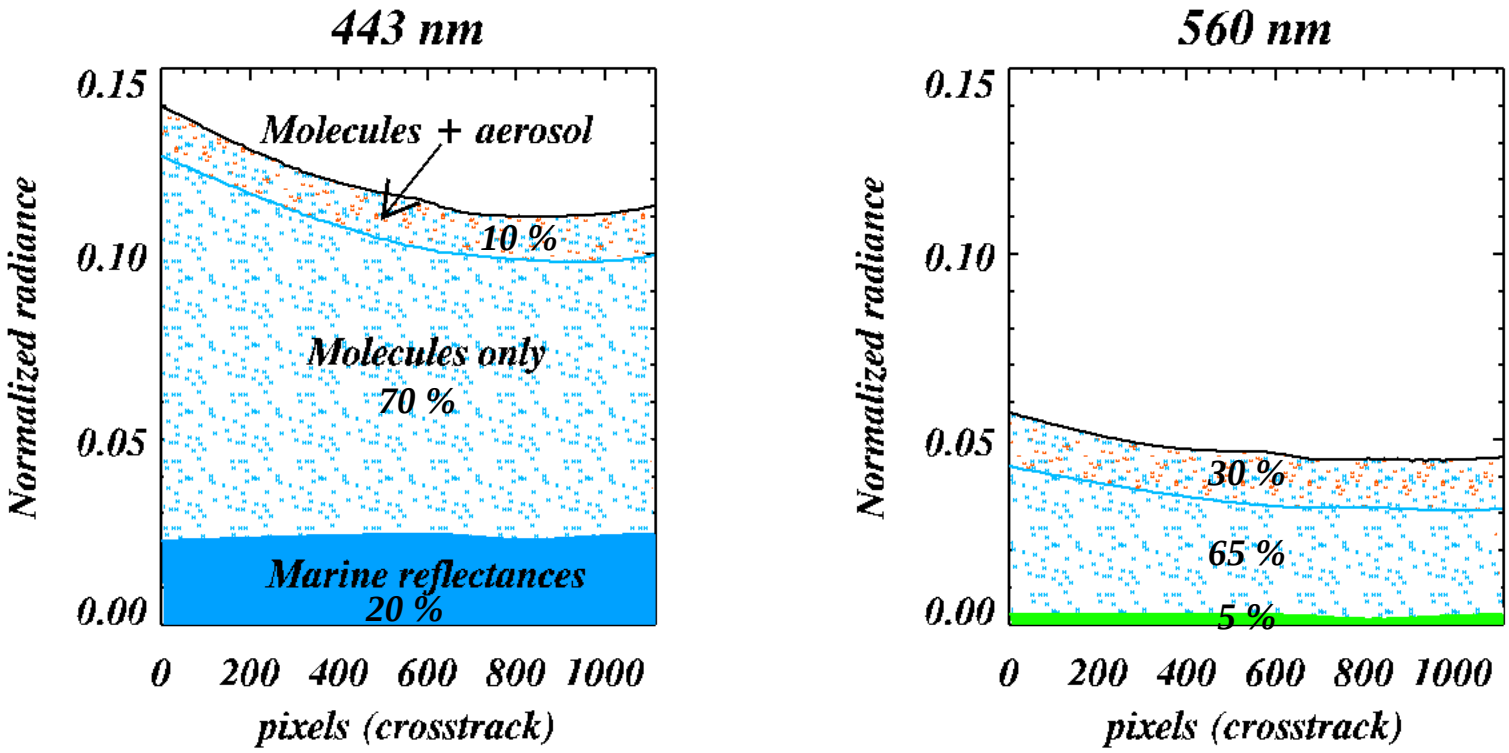
- Successive Order of Scattering (SOS) code from LOA/CNES
- Threshold :
  - AOT(865 nm) < 0.1
  - Measurement within +/- 3 hours from satellite overpass
  - Open ocean

Vicarious calibration with SIMBADA radiometers

CENTRE NATIONAL D'ETUDES SPATIALES

Error budget

- Atmospheric and Ocean Contributions to the signal observed by MERIS



Case I waters (30°N, march, maritime aerosol model, aerosol optical thickness : 0.2, chlorophyll concentration : 0.03 mg/m3)

CENTRE NATIONAL D'ETUDES SPATIALES

Vicarious calibration with SIMBADA radiometers

Error budget

- **Errors associated with scattering terms :**
  - Molecular scattering : 0.70 %
    - 0.50 % from Rayleigh optical thickness
    - 0.20 % from sea-surface pressure
  - Aerosol scattering : 10 %
    - about 10 % on simulated scattering term, from :
      - absolute precision of 0.01 on Aerosol Optical Thickness
      - absolute precision of 0.1 on angström coefficient
      - standard conditions for calibration
  - Diffuse marine reflectance : 5 %
    - About 5 % on marine reflectance measured by SIMBADA
- **Errors associated with absorption factors**
  - Ozone contents : 0.30 % (maximum) on total signal for affected bands
- **Global budget :**

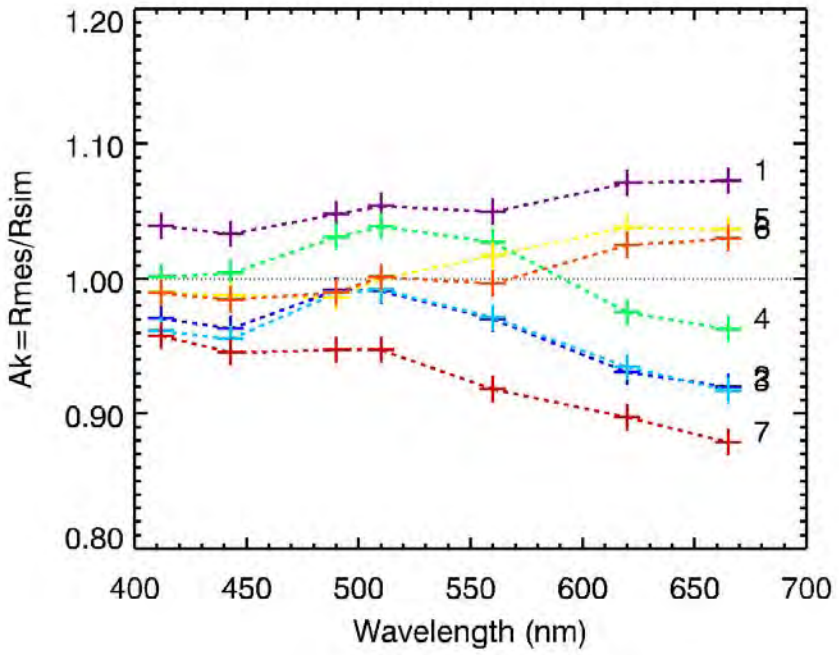
the errors of the method on A_k run from 1.5 % (412 nm) to 5 % (665 nm)

Vicarious calibration with SIMBADA radiometers

CENTRE NATIONAL D'ETUDES SPATIALES

Presentation of the results

- **For each band k, $A_k = R^{mes}_k / R^{sim}_k$**



• Good agreement for mean calibration coefficients (within 2 %)

• But there is not enough pixels for definitive conclusions

• Missing aerosol parameters for pixel 1 :

⇒ Using pure molecular atm.

⇒ Refinement of the method is needed for that case

bands	Ak (mean)	Std. Dev on Ak
412	0.987	0.028
443	0.982	0.030
490	0.998	0.033
510	1.004	0.035
560	0.993	0.044
620	0.982	0.065
665	0.974	0.073

CENTRE NATIONAL D'ETUDES SPATIALES

Vicarious calibration with SIMBADA radiometers

Conclusions and further developments

- Very good agreement for these preliminary results
- Much more MERIS data (past, present and future) are needed to increase the number of match-ups and the accuracy of the calibration :
  - Most of our pixels are located on camera 3, more data are required to check camera 4 and 5
  - More data are needed to evaluate time degradation
- SIMBADA network proved very valuable, providing measurements over different geographic locations and various geophysical conditions
- Work will continue in 2003 with the perspective of sensor comparison (POLDER-2, SeaWiFS, …)

CENTRE NATIONAL D'ETUDES SPATIALES

BOUSSOLE

CENTRE NATIONAL D'ETUDES SPATIALES

Acquisition of optical data at high frequency, for the calibration/validation of ocean color satellite sensors (MERIS, SeaWiFS, POLDER-2) : Deployment of an optical mooring in the Mediterranean sea

The «BOUSSOLE» project

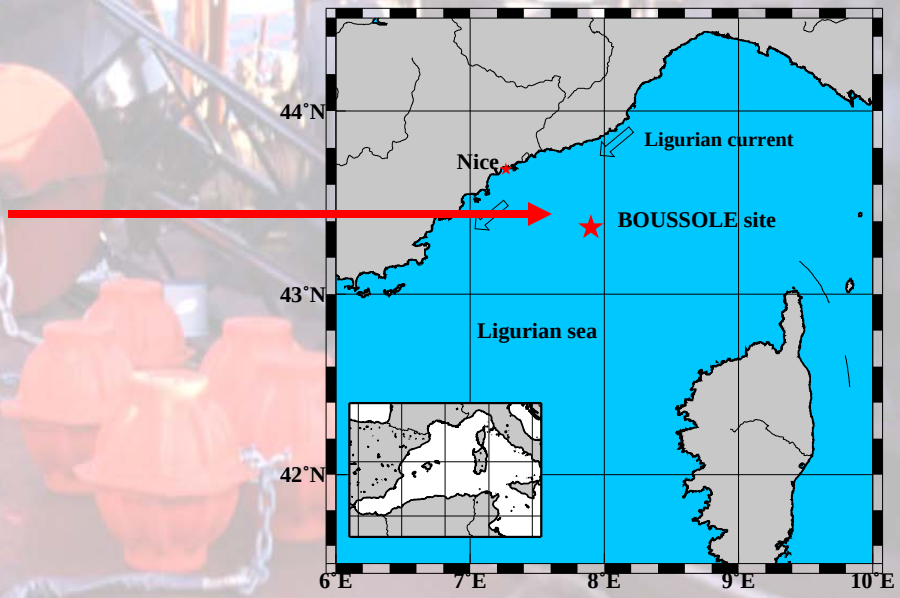
(« **BOU**ée pour l'acqui**S**ition de **S**éries **O**ptiques à **L**ong t**E**rme »)

CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE

BOUSSOLE : general objectives

Goals : **Fundamental marine optics and bio-optics**
Calibration of the MERIS and POLDER-2 observations
Validation of level 2 products (e.g., nLw's, Chlorophyll)

Means :
Development and deployment of an optical mooring in the Mediterranean sea



We aim at the progressive set up of a permanent station **for a long-term track** of the instrument and algorithms, which is mandatory for the use of MERIS and POLDER data over the long-term in the frame of global change studies.

General frame : MERIS & POLDER cal/val activities, SIMBIOS
Collaborations : NASA/GSFC, Ispra JRC, LOA, MERIS ESL's

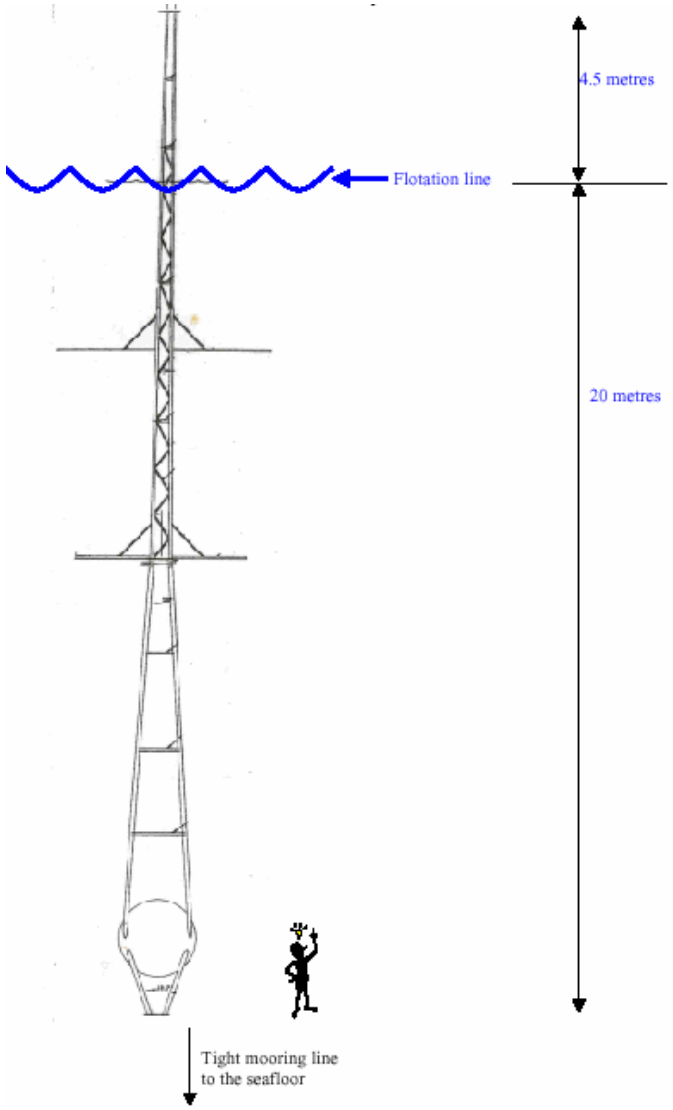
BOUSSOLE : project achievements

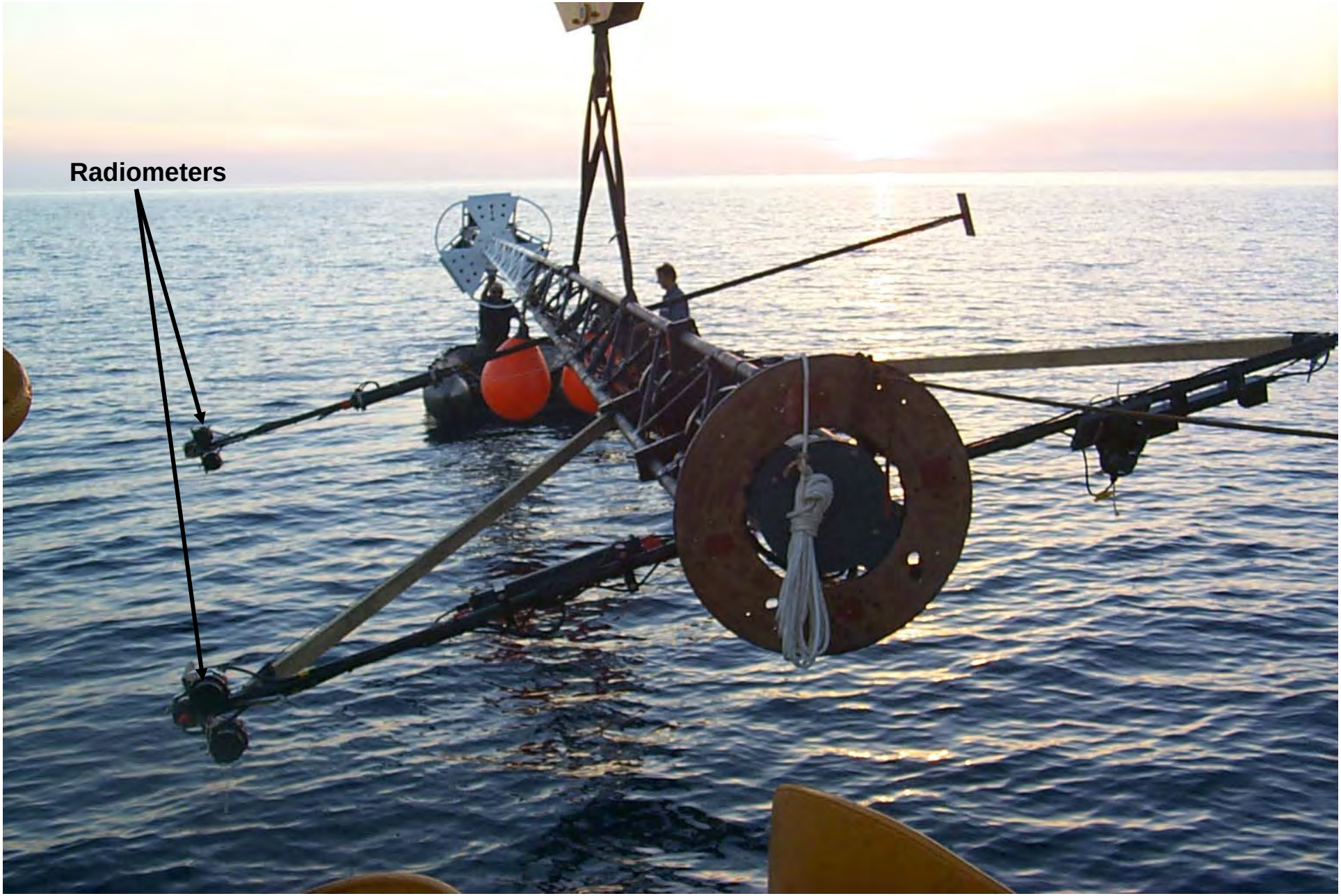
CENTRE NATIONAL D'ETUDES SPATIALES

- Conception of a new type of optical mooring, specifically designed for collecting radiometric data in deep ocean Case 1 waters

- ✔ 1999 : design, and first tests on a reduced-scale model
- ✔ 2000 (summer) : 3-month qualification deployment (full scale buoy version 1)
- ✔ 2000-2001 : conception and realization of the instrument suite
- ✔ 2002 (spring) : operational deployment (full scale version 2)
- ✔ 2002 (June) : the buoy sinks
- ✔ 2002 (fall) : further engineering studies are performed : design is confirmed
- ✔ 2002 (winter) : new construction solution is adopted
- ✔ 2003 (June) : buoy version 3 will be deployed

- Set up of a time series of ocean inherent and apparent optical properties, phytoplankton pigments, and atmosphere aerosols : 19 3-day monthly cruises on the BOUSSOLE site since July 2001.
- Set up of characterization (immersion coefs.) and relative calibration (SQM-II) facilities.
- Progressive set up of data processing procedures



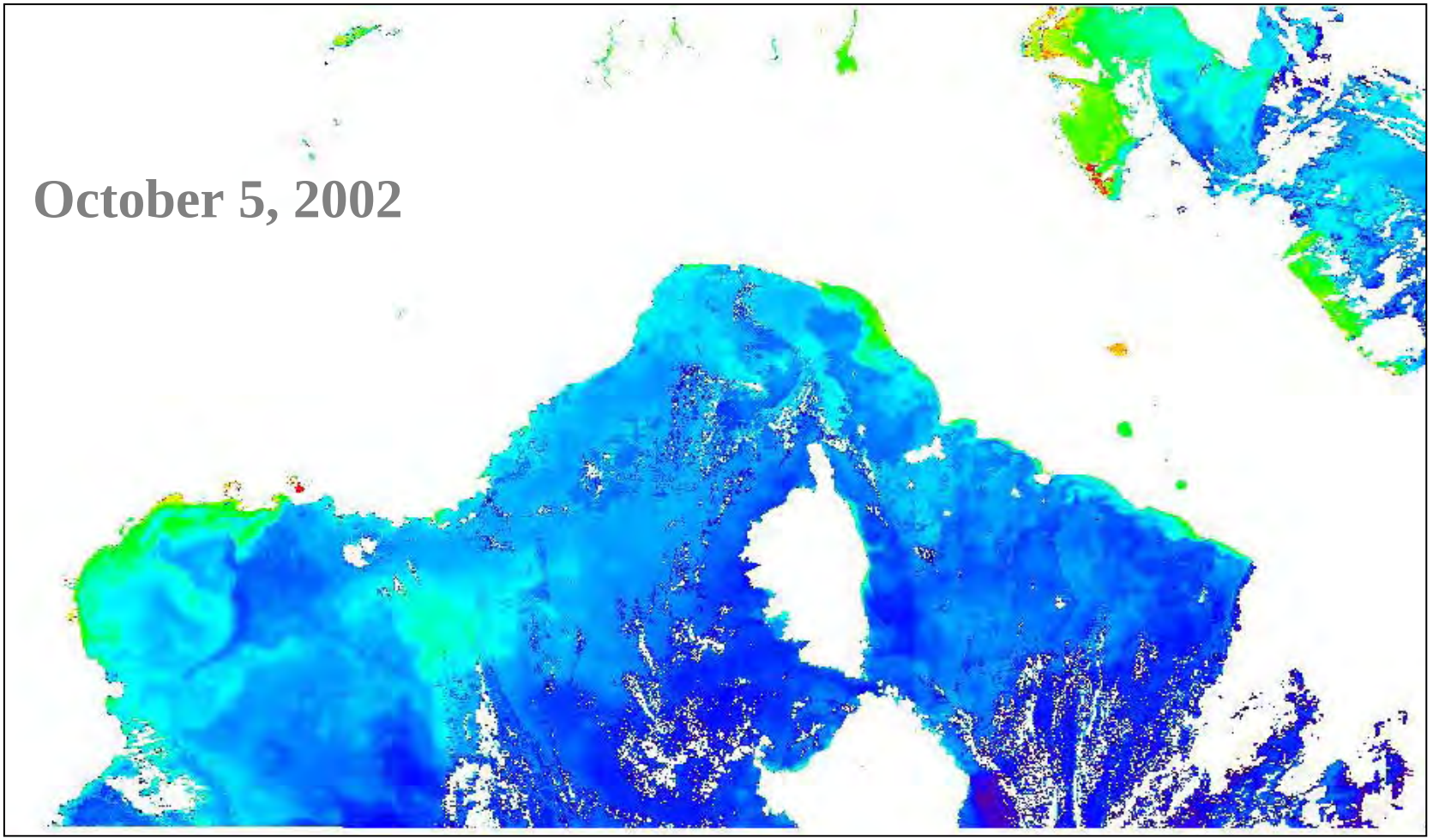


Deployment of the upper, instrumented, part of the buoy


INSU
INSTITUT NATIONAL
DES
SCIENCES DE L'UNIVERS
TETHYS II
MARSEILLE
20 10:56

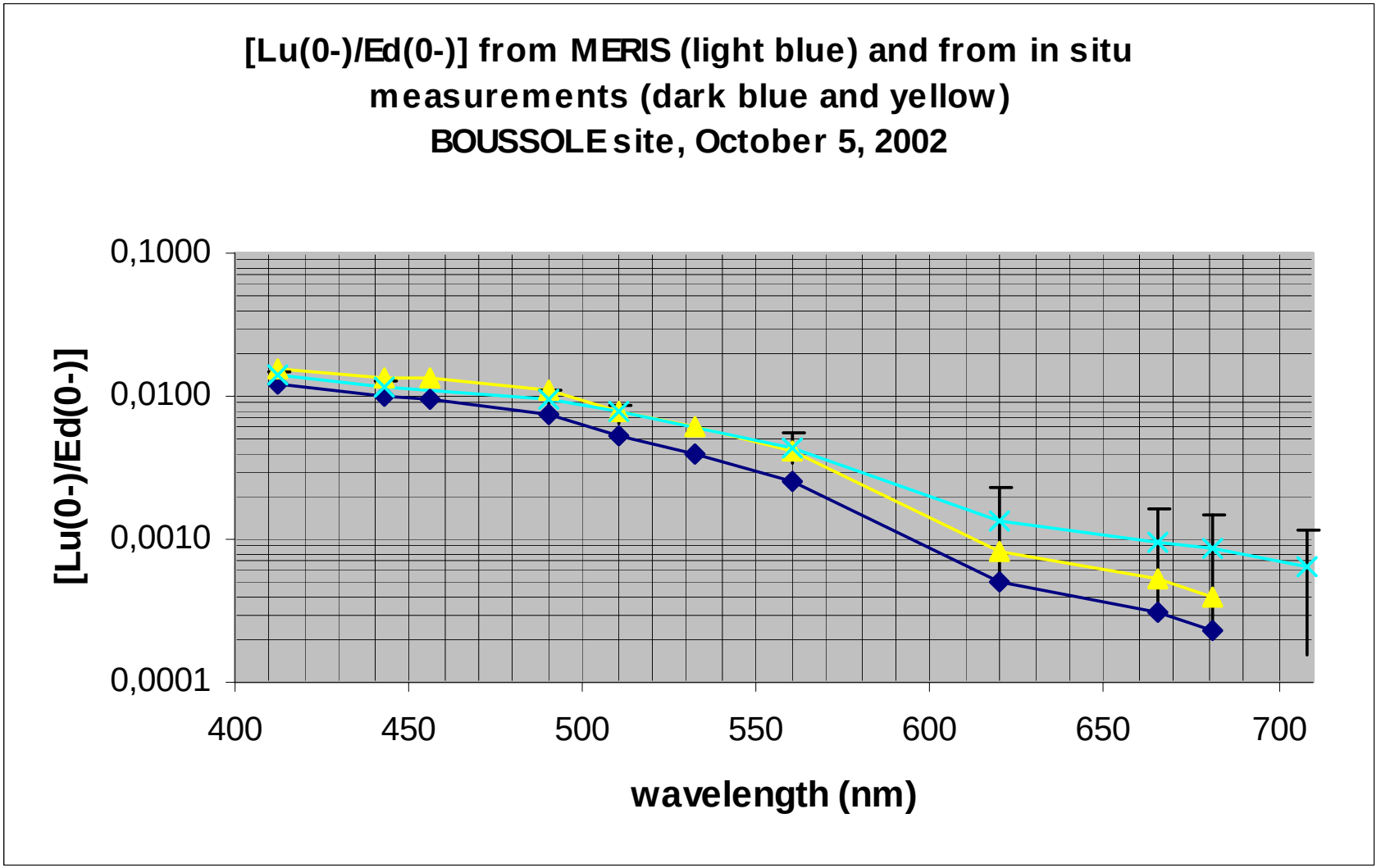
CENTRE NATIONAL D'ETUDES SPATIALES

A MERIS image over the eastern Med. sea
(processing through the LOV "breadboard" data processing code)



CENTRE NATIONAL D'ETUDES SPATIALES

An example of a matchup between MERIS and in situ measurements



CENTRE NATIONAL D'ETUDES SPATIALES

MERCATOR and value added products :

Towards an integrated, multi-parameter approach of ocean modelling and forecasting

The MERCATOR mission was defined in 1996 by six partner organizations. The project is pursuing three goals:

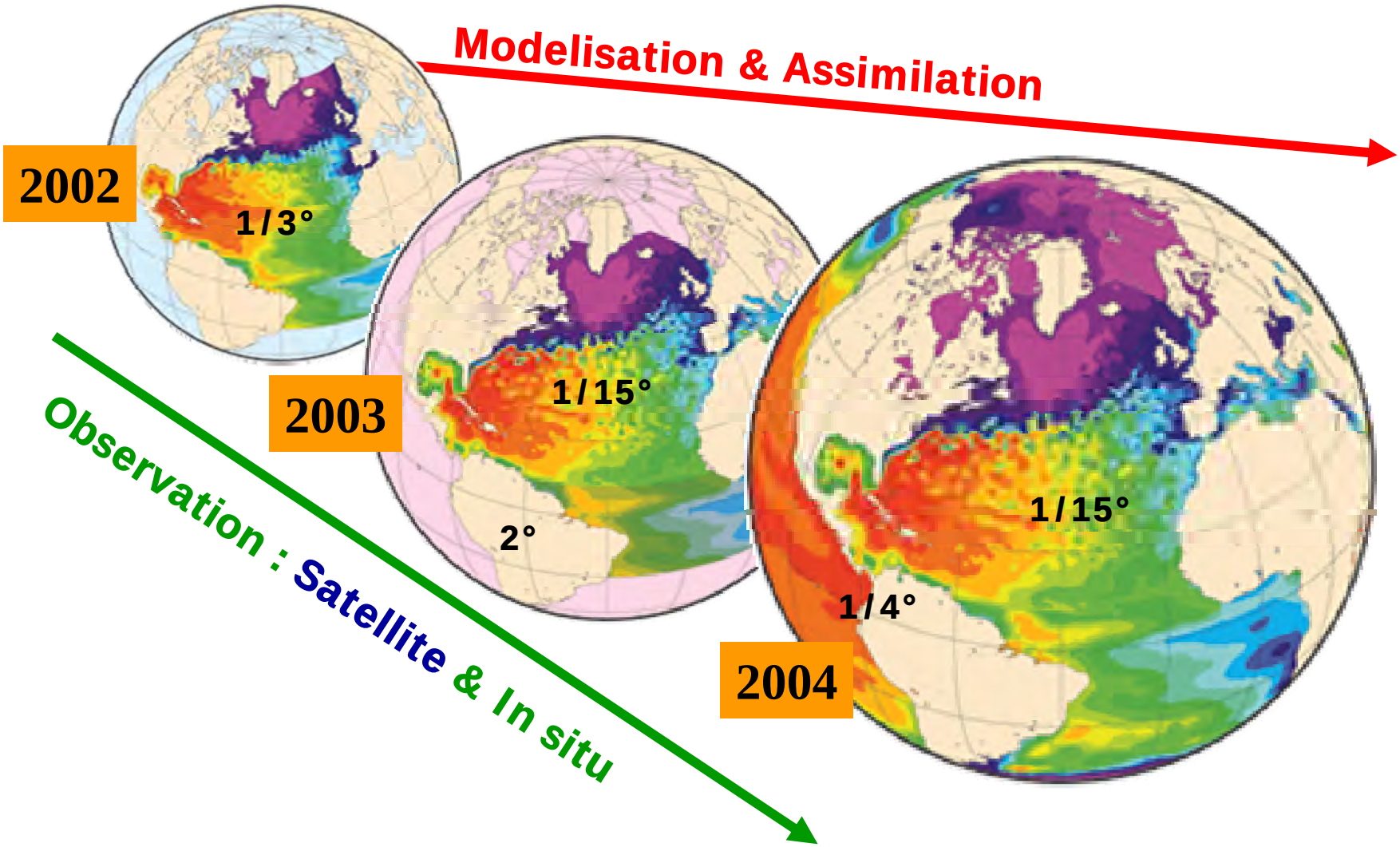
- **Develop an operational oceanography system**
- **Develop downstream oceanography applications**
- **Contribute to the international GODAE project**

Mercator Users :

- **« Sea people »**
- **« Science people »**
- **« Climate people »**
- **« Coastal people »**

CENTRE NATIONAL D'ETUDES SPATIALES

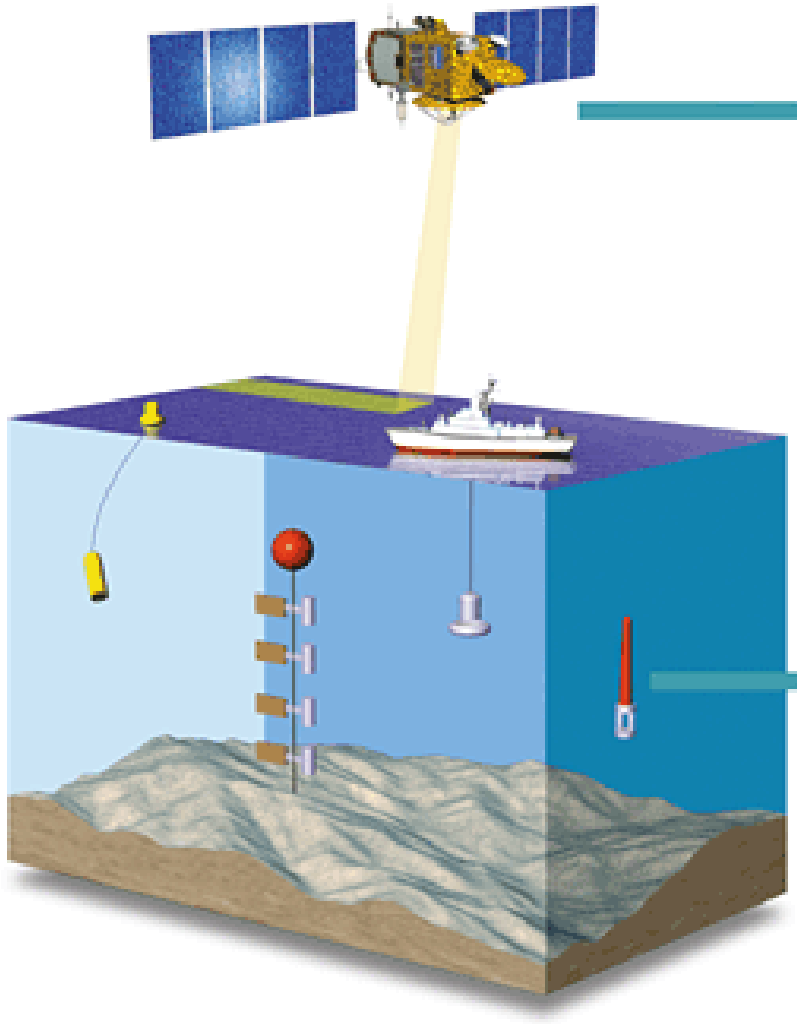
Mercator, towards operational oceanography



CENTRE NATIONAL D'ETUDES SPATIALES

MERCATOR system

TOPEX, JASON, ...



Satellite Observations

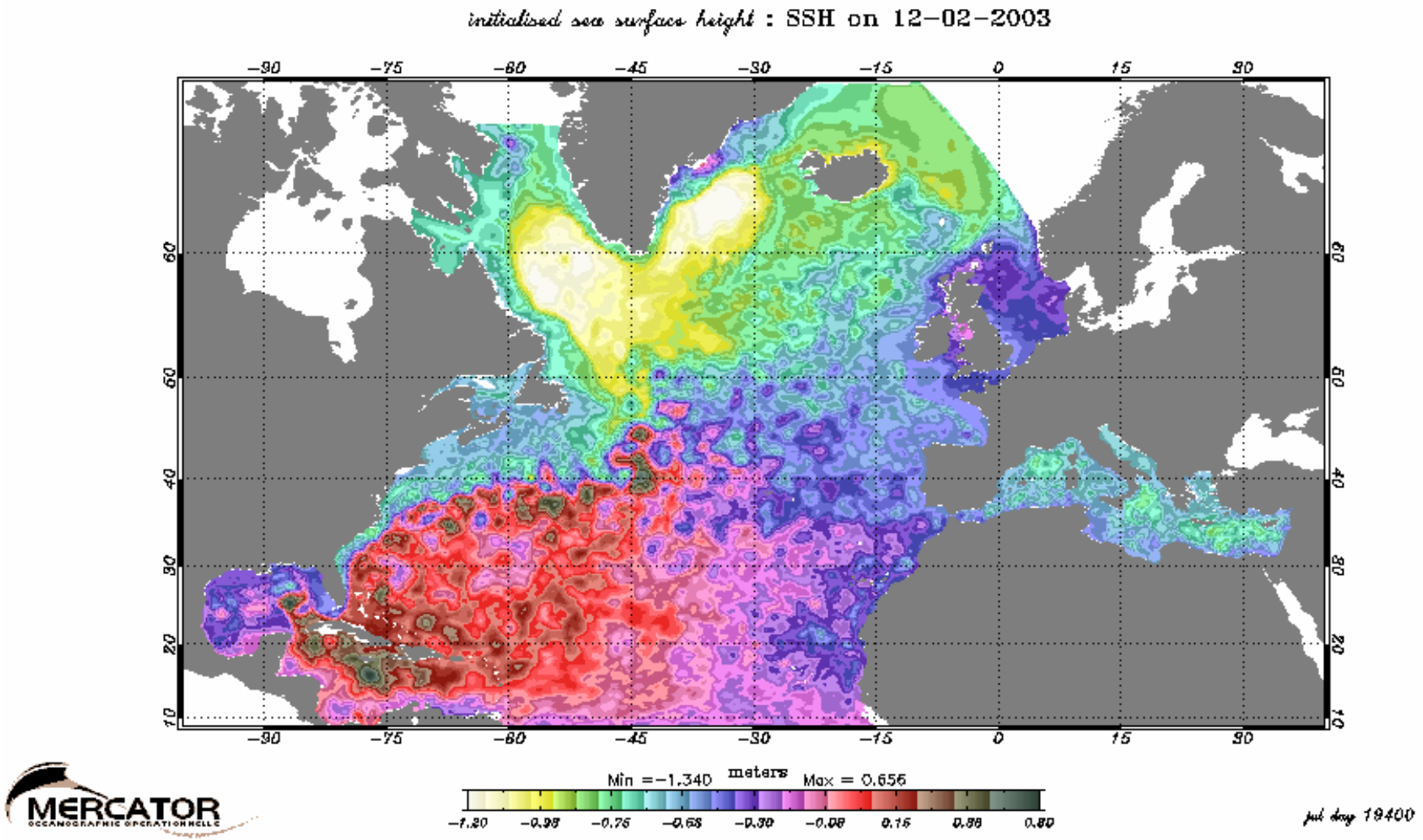
Model

Forecasts

In situ observations

CORIOLIS

CENTRE NATIONAL D'ETUDES SPATIALES



CENTRE NATIONAL D'ETUDES SPATIALES

MERCATOR : future activities

The MERCATOR mission seeks to develop and deploy a truly **operational oceanography** system over the next five years capable of analyzing and predicting ocean conditions around the globe : the Center for Operational Oceanography (C2O)

This system will describe and predict ocean conditions over the whole ocean column continuously and in real time, at scales ranging from global phenomena to regional eddies.

Example of value added product : CATSAT

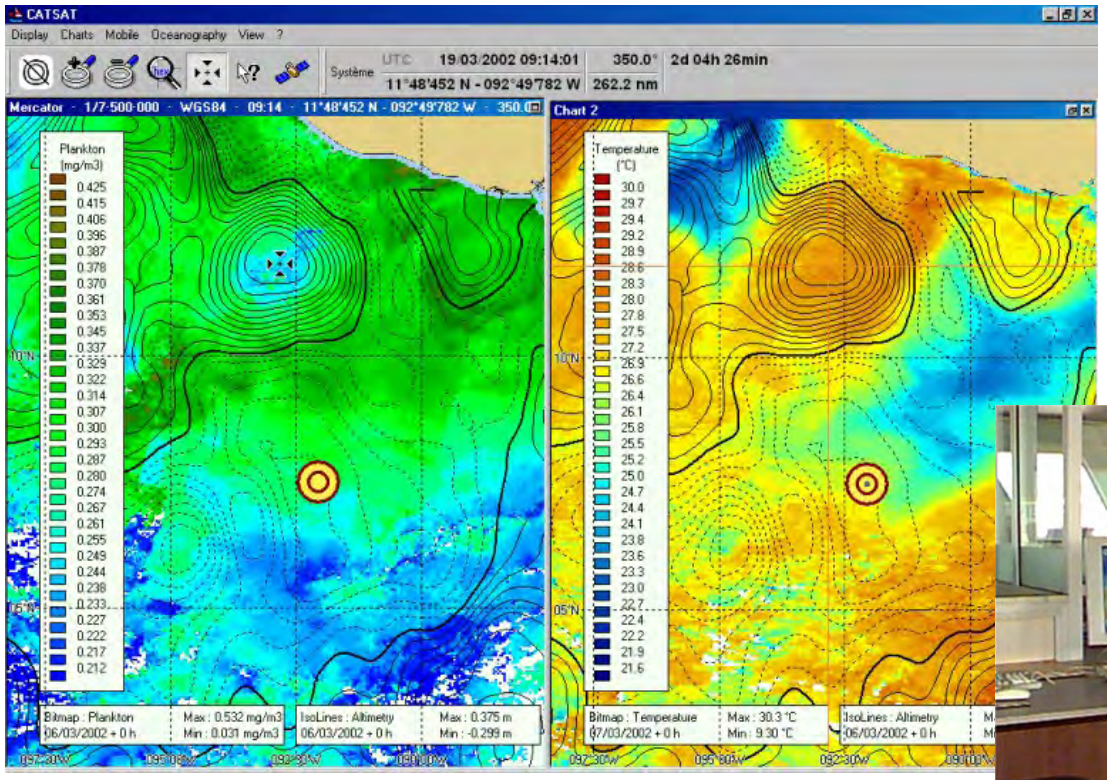
CENTRE NATIONAL D'ETUDES SPATIALES

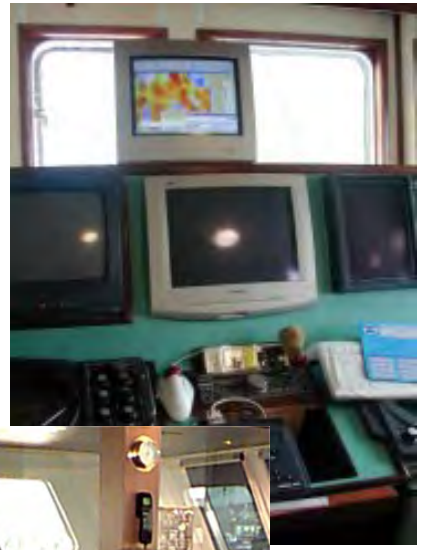
A worldwide satellite system to support fishing through oceanography

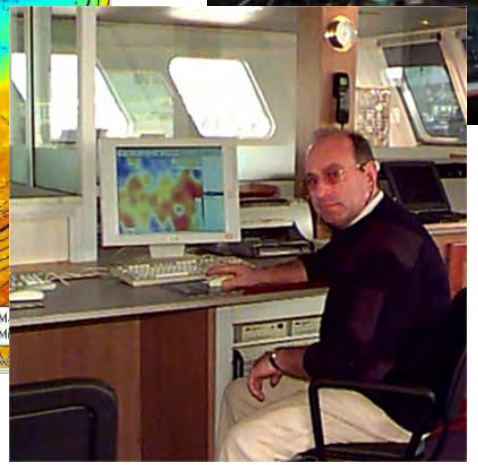
CLS
COLLECTE LOCALISATION SATELLITES

THALOS™
A GEOLINK GROUP COMPANY

CatSat







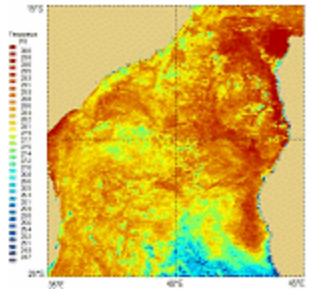
CATSAT : rationale

Ocean-observing satellites and marine meteorology can help fishermen to:

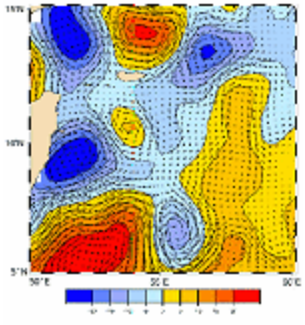
- **locate favorable fishing grounds**
- **reduce operating costs**
- **improve safety during fishing operations**
- **meet their quotas more efficiently**

CATSAT offers oceanographic data acquired by satellites and marine meteorology data, including:

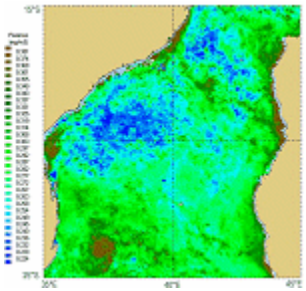
sea surface temperature



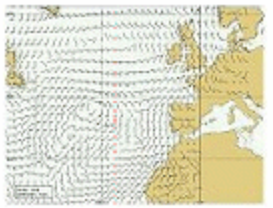
altimetry/sea level anomaly maps (SLA)



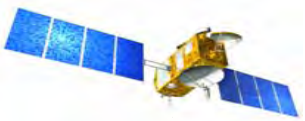
ocean color

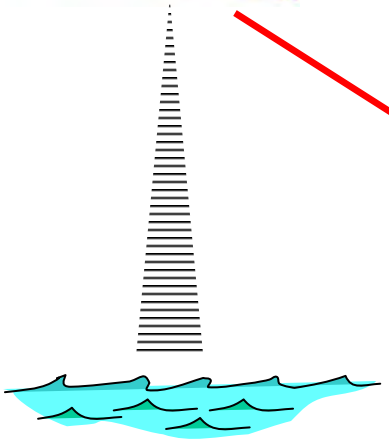


weather forecasts:



CATSAT System





ACQUISITION OF DATA

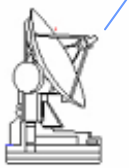
PRODUCTION

DISTRIBUTION OF PRODUCTS

ENCRYPTION

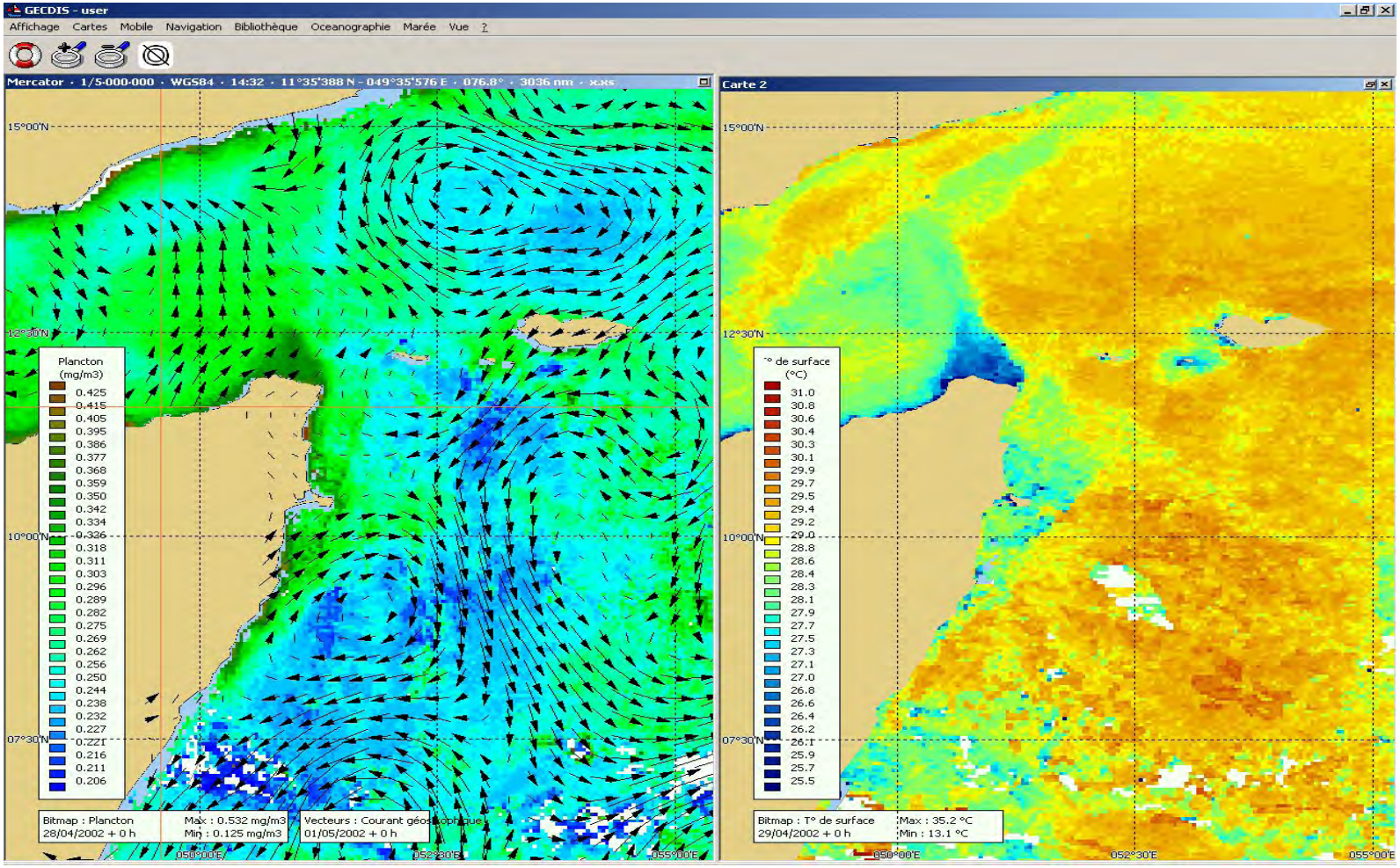
TRANSMISSION

ASSISTANCE



CENTRE NATIONAL D'ETUDES SPATIALES

CATSAT : example of combination of data products



Current vectors + plancton

SST (AVHRR)

CENTRE NATIONAL D'ETUDES SPATIALES

Conclusions

- POLDER-2 on-board ADEOS-2 is ON !

- Cal/Val activities will now go on with new or existing tools
  (SimbadA, BOUSSOLE, …)

- Pre-operational applications :
  - combination of data sets
  - value-added products