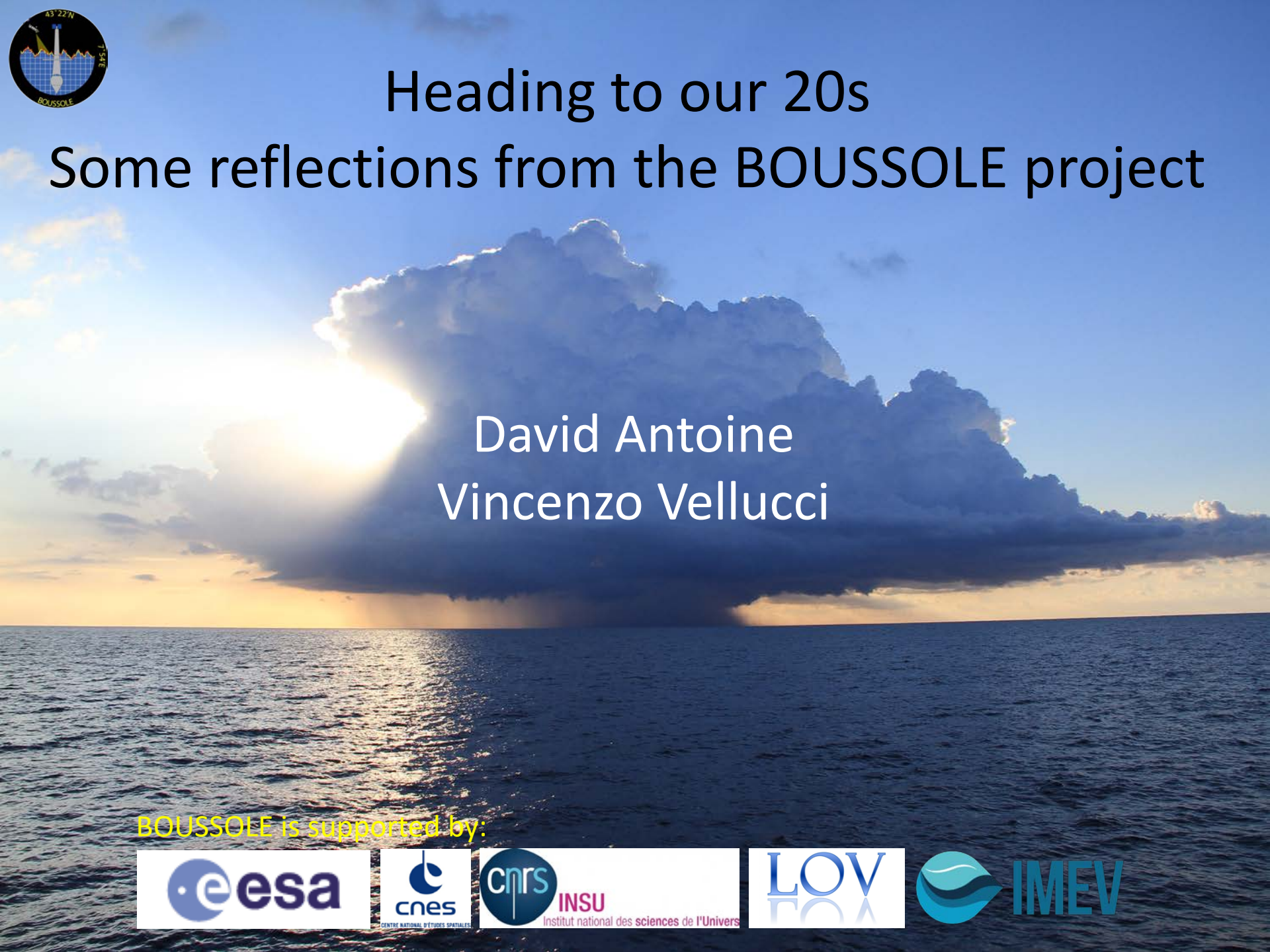


Heading to our 20s
Some reflections from the BOUSSOLE project

David Antoine
Vincenzo Vellucci

BOUSSOLE is supported by:

Let’s start with a celebration

On 6th September 2018,
BOUSSOLE buoys had been at sea and had been collecting data for an uninterrupted 15 years sequence

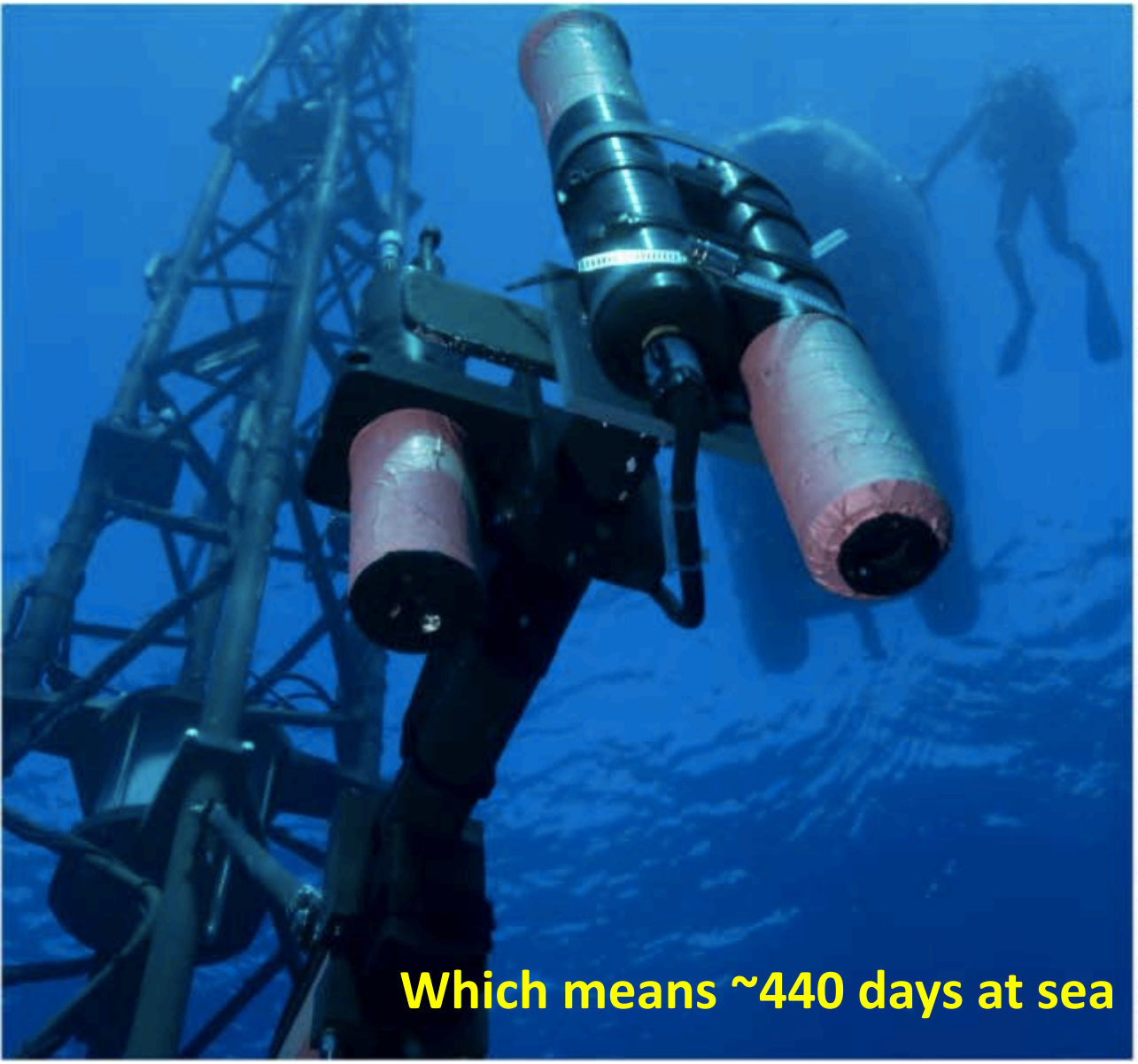
Totals, at the end of 2017:

- 5114 days total since 1st January 2004
- 4870 days with a buoy at sea (95%)
- 4206 days with data acquisition (86%)

This goes with:

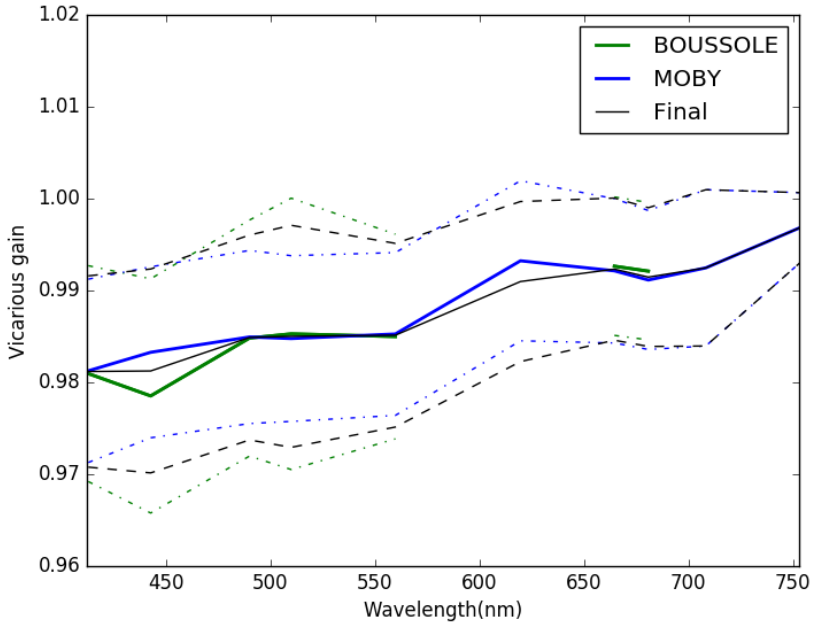
- ~64 days at sea for buoy deployments/recoveries
- ~135 days of on-demand, short maintenance operations

the 200th monthly cruise to the BOUSSOLE site was carried out on 18th-19th September 2018

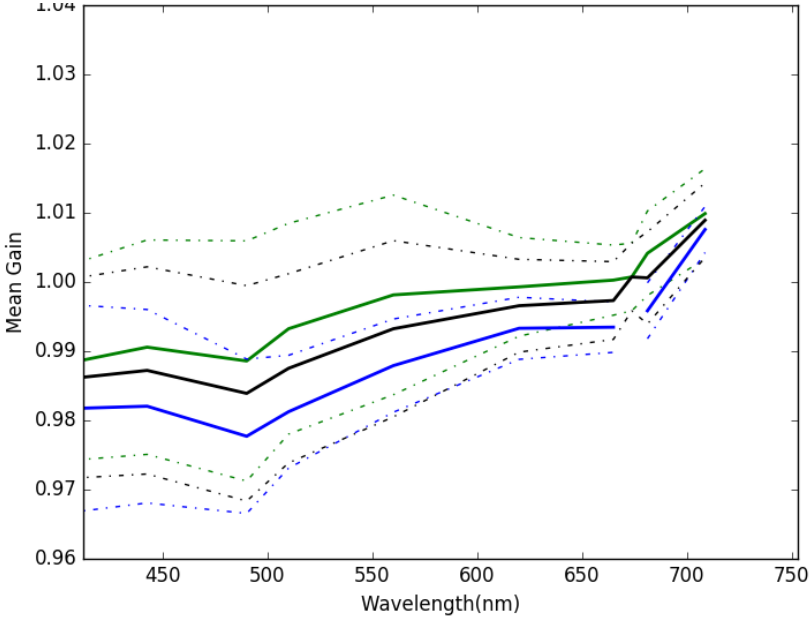


Why all this?

Calibration matters; most recent SVC results



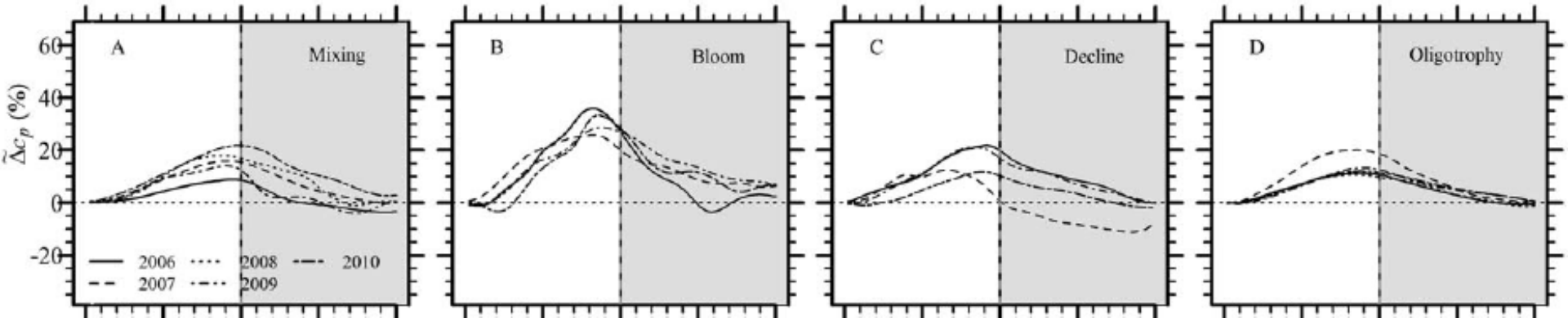
MERIS 4th reprocessing



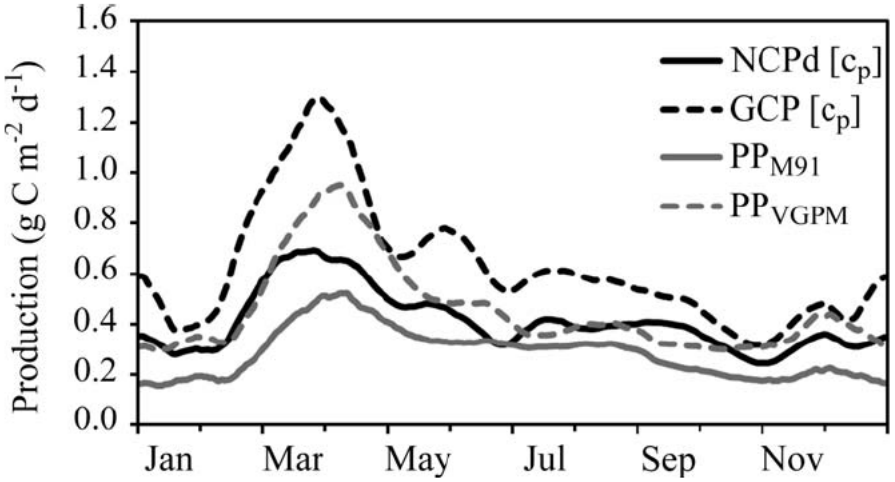
OLCI, preliminary SVC gains

Why all this?

Science matters; recent examples



Kheireddine M, Antoine D (2014) Diel variability of the beam attenuation and backscattering coefficients in the north-western Mediterranean Sea (BOUSSOLE site). ***Journal of Geophysical Research***, 119, 5465-5482



Barnes M, Antoine D (2014) Proxies of community production derived from the diel variability of particulate attenuation and backscattering coefficients in the northwest Mediterranean Sea. ***Limnology and Oceanography***, 59(6), 2133-2149.

How did we get there?

1998	First thoughts about developing an optics mooring
1999	Buoy conception & design (->engineering pool tests), in search of funding supports
	1st grant from CNES (TOSCA)
	Development essentially made from remainder money from past ESA contracts
2000	Construction buoy "v0", qualification deployment, still in search for funding
2001	Start of monthly cruises (July 2001). Hiring first technical staff.
	June 2001: signature of the UPMC/NASA LOA
	First specific ESA funding for BOUSSOLE
2002	1st deployment of the instrumented buoy → failed (total loss, construction defect)
	Reimbursement by our insurance: continuation of the project
	Complementary engineering studies (IFREMER/MARINTEK) → buoy version 2
	ENVISAT / MERIS launch
2003	Construction of the new buoy
	Operational deployment: September 2003
2003-..	Operational period (2 sister buoys & instrumentations; rotations every 6 months)
	Progressive development of scientific exploitation of the data
2006	Unsuccessful request to being "labelled" as a "SO" at INSU
2009	Long-term commitment from CNES (2019 at least) in the frame of Sentinel-3
2011	Start of the "BIOCAREX" project funded by ANR (2011-2014)
2016	S3A launch
2018	S3B launch
....	

PROJECT PRINCIPAL INVESTIGATOR	
David ANTOINE	**Chief Scientist**
Staff members (100% working for BOUSSOLE)	**Project responsibilities**
Vincenzo VELLUCCI	Responsible for buoy maintenance and data processing (October 2007 - ongoing)
Melek GOLBOL	Responsible for monthly cruises (March 2013 - ongoing)
Staff members (shared with other activities of our laboratory)	**Project responsibilities**
Edouard LEYMARIE	Radiance camera development
Joséphine RAS	HPLC and absorption measurements
Céline DIMIER	HPLC and absorption measurements
Edoardo SOTO GARCIA	Maintenance / deployment of the CTD
Vincent TAILLANDIER	Maintenance of the CTD / CDT data processing
Emilie DIAMOND	Responsible for DYFAMED monthly cruises
David LUQUET	Management of diving operations on site
Didier ROBIN	Management of diving operations on site
Guillaume DE LIEGE	Management of diving operations on site, servicing
Past staff members	**Project responsibilities**
Bernard GENTILI	Data processing codes
Francis LOUIS	Servicing, electronics, design
Grigor OBOLENSKY	Maintenance / deployment of the CTD/IOP package
Mustapha OUHSSAIN	HPLC and absorption measurements
Dominique TAILLIEZ	CTD + IOPs, all monthly cruises
Catherine BROWN	Web site design and data base development
Guislain BECU	Responsible for monthly cruises, data processing (2004-2007)
Alec SCOTT	Responsible for monthly cruises, data processing (2003-2004)

Who did this?

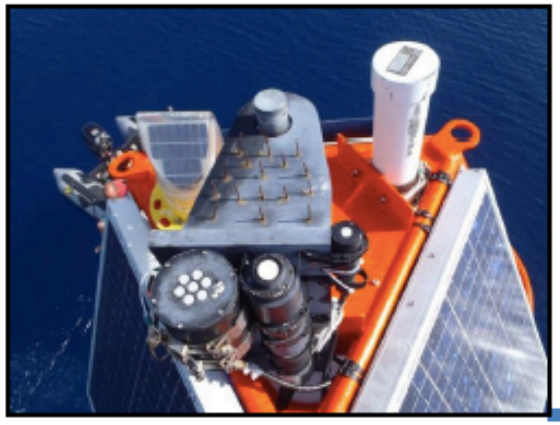
BOUSSOLE: fact sheet

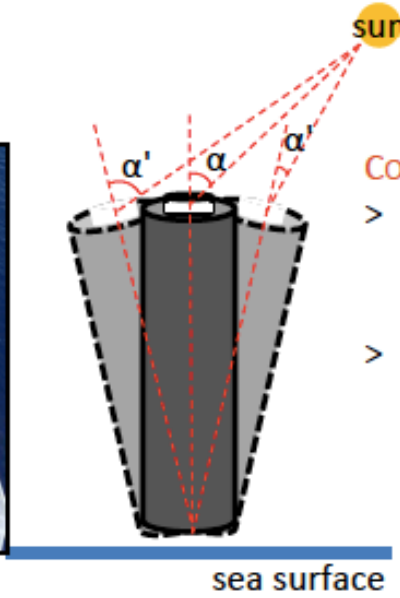
- 18+ years of existence
- 15+ years of operational data production (95% success rate for data acquisition in the 4 years before 2018)
- Currently one of the 2 sites used for vicarious calibration of satellite ocean colour, along with MOBY
- A unique radiometry + optics + BGC data set
- A model for how science & operational objectives come together for mutual benefits
- Permanent effort towards increased data quality (calibration, characterization, QA/QC in general etc…)
- A small, yet highly efficient, technical staff team
- A number of scientific users (publications)
- In good standing to continue for the coming decade

Progressive improvement in radiometric data quality

- Essentially rely on manufacturer calibration (Satlantic)
- SQM-II: we tried and abandoned
- Immersion coefficients: did some experiments
- Inter-comparison of sensors
- Extrapolation of underwater L_u/E_u measurements
- Identification and quantification of uncertainty sources
- Better bio-fouling mitigation
- Progressive move from multi- (7 λ's) to hyper-spectral
- Many incremental improvements in data processing (shading, tilt effects, changes of instruments depth, long-term corrections for instrument drifts or biofouling, short-term events identification..)
- Future improvements: cosine response correction, BRDF correction for tilt effects.

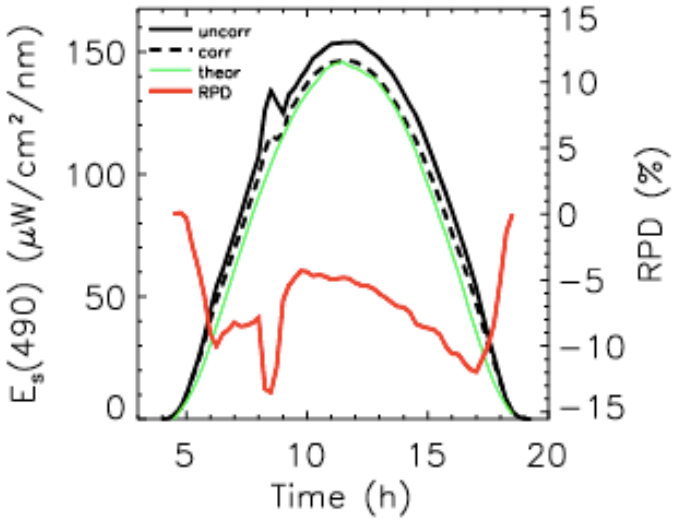
Correcting E_s for tilt

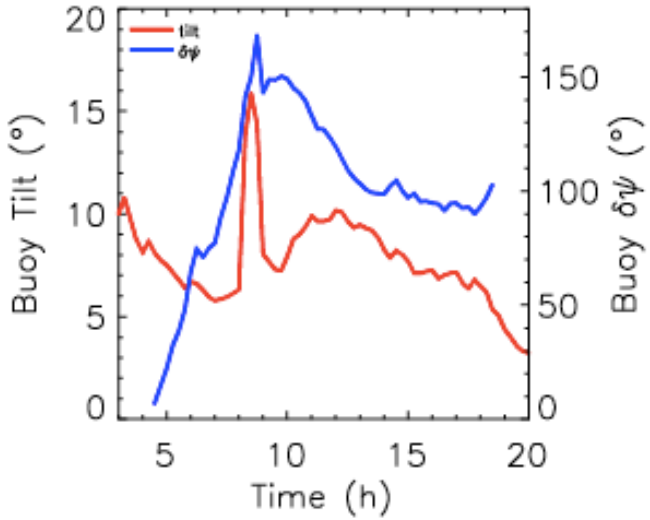




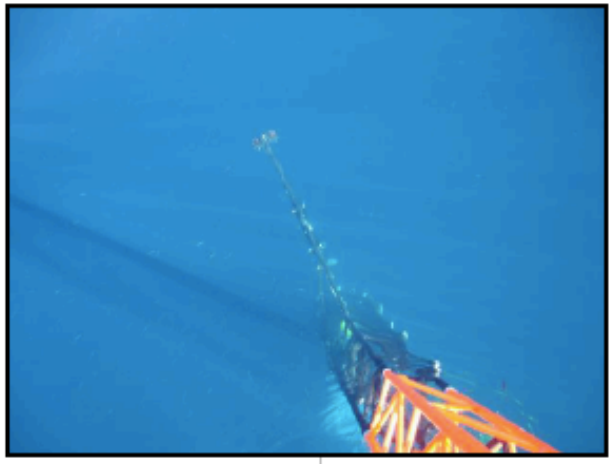
COSINE CORRECTION OF SURFACE IRRADIANCE

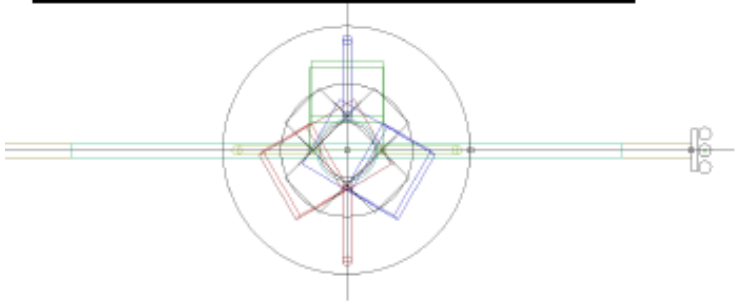
> First the direct fraction of *Es* is estimated following *Gregg & Carder, 1990*
  - $\overline{E_S(t,\lambda)'} = \overline{E_S(t,\lambda)'} \cdot f_{dir} + \overline{E_S(t,\lambda)'} \cdot (1 - f_{dir})$
> The correction is then applied to the direct fraction of *Es*
  - $E_S(t,\lambda) = \overline{E_S(t,\lambda)'} \cdot f_{dir} \cdot f_{tilt} + \overline{E_S(t,\lambda)'} \cdot (1 - f_{dir})$
  - Where $f_{tilt} = \frac{\cos(\alpha')}{\cos(\alpha)}$

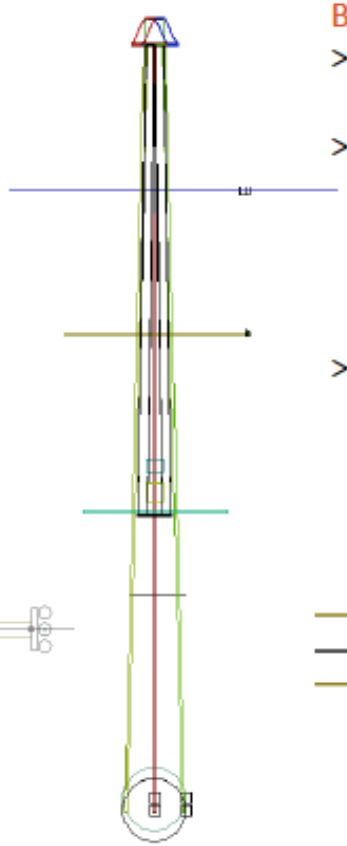




Shading corrections

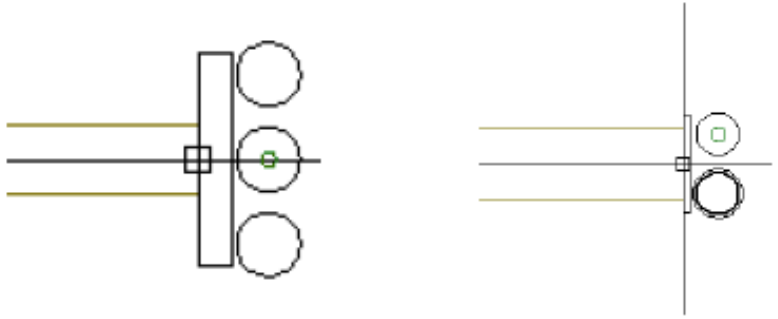




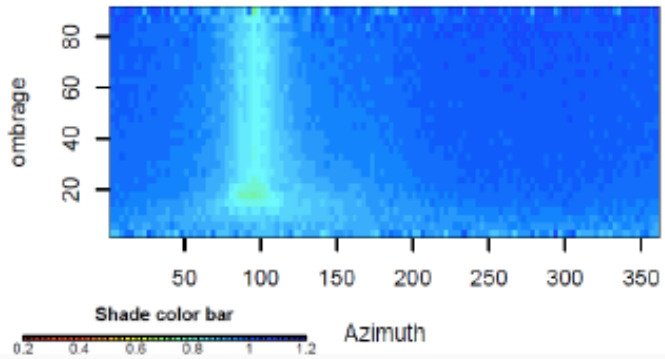


Buoy Structure shading and Instrument self-shading

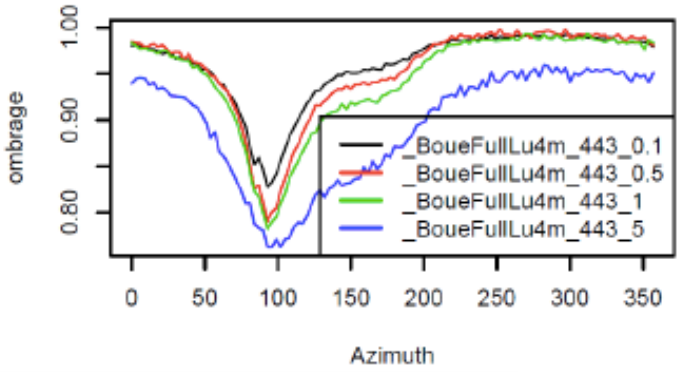
- Backward 3D *Montecarlo* simulation (*SimulO*) replaces the *Gordon & ding (1992)* correction scheme
- Simulation for each underwater instrument
  - Chl = 0.1, 0.5, 1.0, 5.0 µg l-1
  - Azimuth angle from 0° to 360°, with 5° step
  - Zenith angle from 0° to 90°, with 5° step
  - 7 wavelengths (412,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



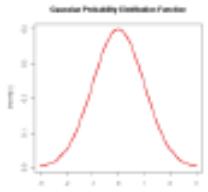
_BoueFullLu4m_443_0.1 N= 6.0e+09

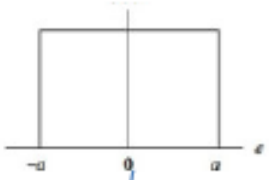


Shade Average 30–60 deg



Defining/quantifying uncertainties
The measurement equation





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

Preliminary error budget

$u\ in\ \%$ / $\lambda\ in\ nm$	E_s	L_{u4}	L_W	R_{rs}	$u_{abs}(R_{rs})$
412	2.1	2.6	3.1	3.7	0.000215
443	2.0	2.6	3.1	3.7	0.000225
490	2.0	2.6	3.0	3.7	0.000175
510	2.0	2.6	3.0	3.7	0.000155
560	2.0	2.6	3.1	3.7	0.0000725
665	2.1	3.9	5.9	6.3	0.00000410
681	2.1	4.0	5.9	6.3	0.00000195

Do we need an “error budget”?

What matters are the uncertainties

How we combine them into a “budget” might actually be confusing, and might be hardly comparable among different systems

What matters for SVC is the number of match-ups with the lowest uncertainty
What matters for validation is the N° of match-up with (maybe) a lightly higher threshold
What matters for science are data with uncertainties below that of the signals to study

The goal: each measurement comes with an uncertainty. Then, it is up to the users to set the uncertainty threshold above which data are rejected.

Where do we set the bar?

Full characterization and calibration of radiometers is a time consuming and expensive process.

Therefore the question is: can we find the right balance between the effort that we put on calibration/characterisation and the benefit in terms of improved data quality?

Example of the SQM-II: was way too much work for marginal benefit

Corollary: is this where the effort has to be put? Are protocols more important?

And, in the same vein: is a lot of this needed because we do not have the appropriate instruments?

What about science?

Since inception, BOUSSOLE was conceived as a sustained research activity, rather than as a truly “operational” system.

It has actually become very close to the latter, but still includes a significant research programme

You cannot do otherwise when you operate from a research environment, which in our case is CNRS-INSU-Sorbonne University

It is vital for the motivation of staff

Can provide additional Capex investment

The challenges we faced in 2018

Year 2018:

Month	Days with data																														
Jan	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	--	--	--	28	29	30	31
Feb	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	--	--	--	--	--	--	--	--	--	--			
Mar	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Apr	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
May	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Jun	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
Jul	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Aug	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Sep	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
Oct	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Nov	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
Dec	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Unfortunately, in 2018 the buoy has taken a “gap year”.

The DacNET (central data acquisition system) definitely died, and Satlantic/Seabird were in the process of transitioning their activity from Canada to the US. This has generated unusually long delays for the system maintenance, recalibration etc..

Why did we end up with this situation?

The DacNET (central data acquisition system) was conceived in the late 1990s, and our units built in 2001-2002.

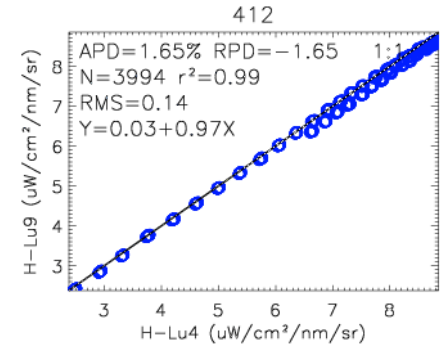
They have proven extremely reliable, but we warned many times about the need to prepare for replacement.

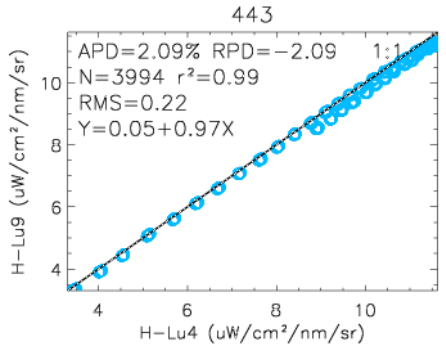
This was not feasible at constant funding, so it was not done.

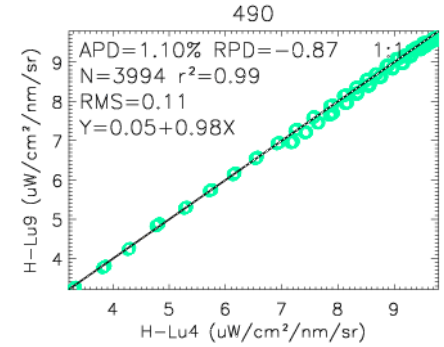
Lesson: regular capex investment has to be included at regular intervals in the life of such a long-term activity

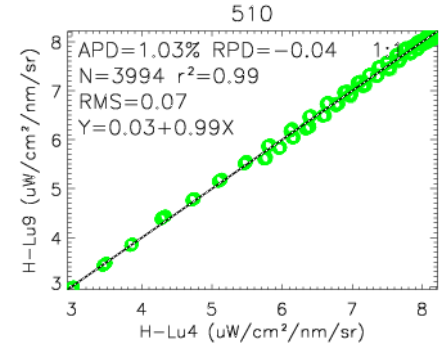
Operations will resume soon

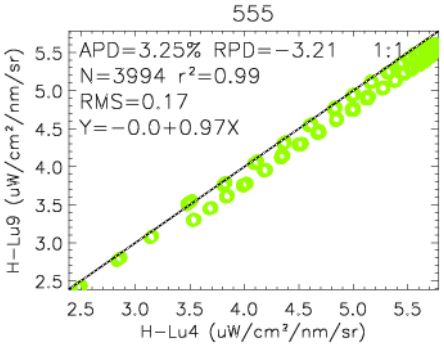
Inter-comparisons, pre-deployment

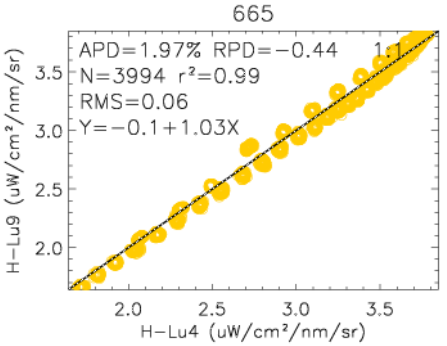












Where to now?

Radiometry for Ocean Colour SAtellites Calibration & Community Engagement

ROSACE

Laboratoire d'Océanographie de Villefranche,
Institut de la Mer de Villefranche

Hellenic Centre for Marine Research

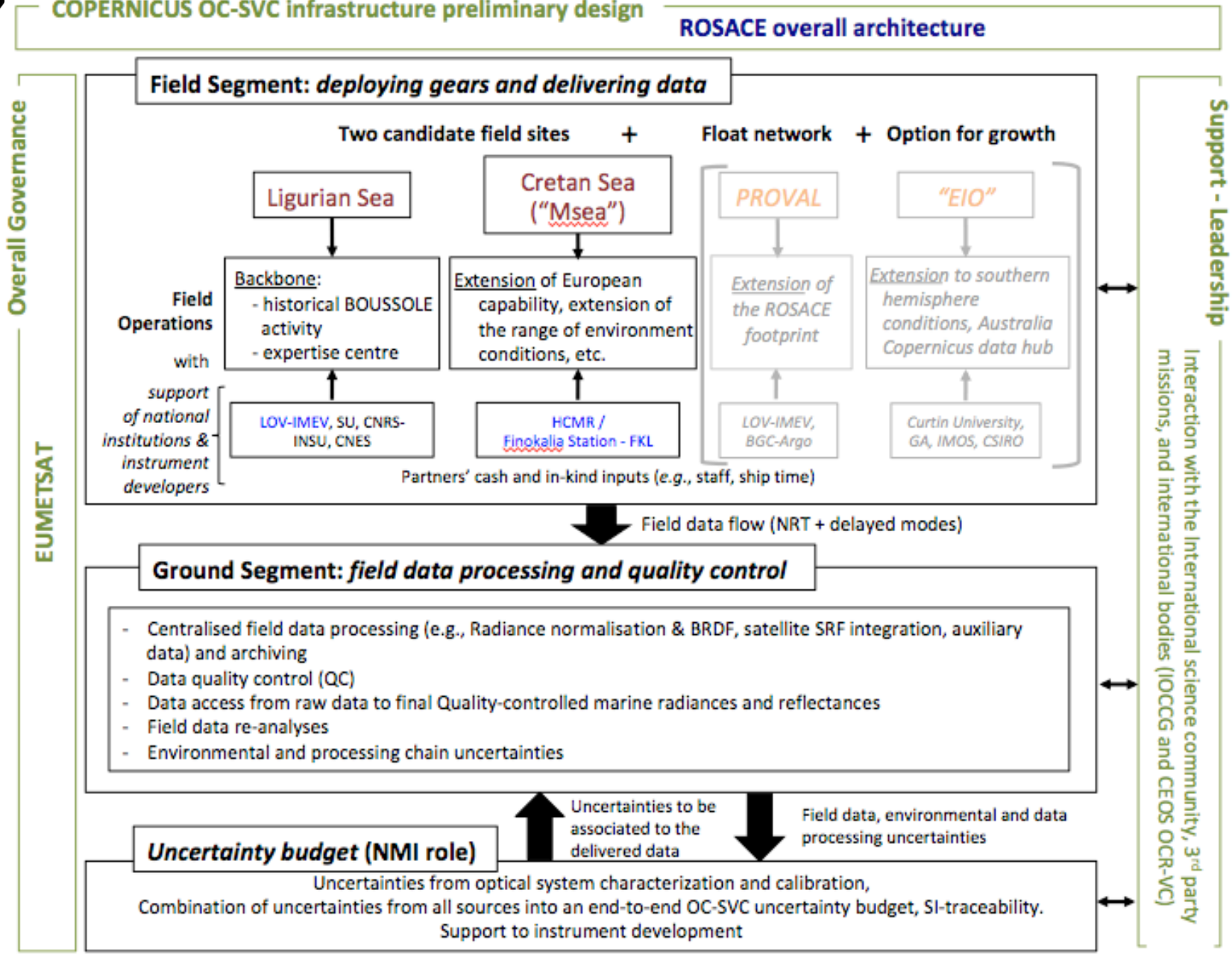
ACRI-ST

UK National Physical Laboratory

University of Tartu, Tartu Observatory

CIMEL Electronique

ROSACE overall logic



Thanks for your attention