International Ocean Colour Science Meeting 2017

Advancing Global Ocean Colour Observations

Ocean Colour Vicarious Calibration

Community requirements for future infrastructures

Report of Breakout Workshop#3

IOCS 2017

Goal of the workshop

- This workshop is a forum to discuss the **requirements** for the development & operation of future vicarious calibration infrastructures

- It is a **follow-up of the IOCS 2013 session** on System Vicarious Calibration (SVC) which expected to be *"the start for additional international actions aiming at detailing specific requirements and methods for SVC of new missions like PACE and Sentinel-3"*

- Expected outcome: **get consensus on the requirements, ensure international harmonisation and rationalise efforts for the next decades** (as part of the INSITU-OCR initiative).

Workshop agenda

Part I: On-going activities & existing/under-development infrastructures

14:15 - 14:25 On-going SVC activities in Space agencies (EUMETSAT, ESA & NASA)
C. Mazeran (Solvo), C. Lerebourg (ACRI-ST), S. Bailey (NASA/GSFC)

14:25 – 14:35 Overview and status of the HYPERNAV concept
Andrew Barnard (Sea-Bird Scientific)

14:35 – 14:45 Overview and status of the HARPOONS concept
Sean Bailey on behalf of Carlos Del Castillo (NASA/GSFC)

14:45 – 14:55 Overview and status of the MOBY-NET concept
Kenneth Voss (University of Miami)

14:55 – 15:05 Overview and status of the BOUSSOLE concept
David Antoine (CNRS-LOV & Curtin University)

Part II: Discussion on requirements for any future SVC programme

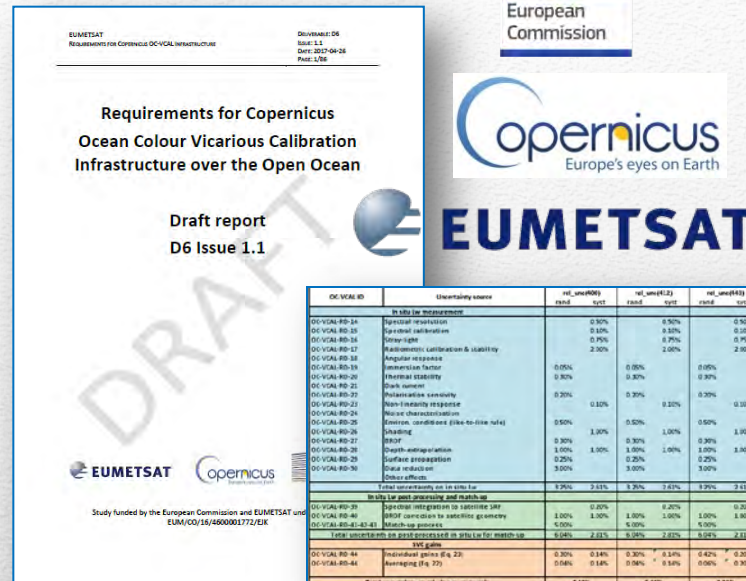
15:05 – 16:00 High level scientific and technical requirements (key aspects)

16:00 – 16:30 Operational requirements

16:30 – 17:00 Programmatic steps and international activities

On-going SVC activity at EUMETSAT

- In the frame of joint ESA-EUMETSAT effort to develop Copernicus SVC capability
- Study **"Requirements for Copernicus Ocean Colour Vicarious Calibration Infrastructure"** (OC-VCAL)
  - Clear justification of SVC for Copernicus missions
  - Listing of SVC science and high-level technical requirements
  - Listing of SVC operational and service requirement



Excel uncertainty budget:
- Sources of uncertainties
- Examples of values

- **Requirement report to be delivered to the European Commission in July 2017**
  - Report reviewed by an international Expert Review Team (10 members) and publicly available in advance to the workshop participants – draft available to anyone now

    → **community approved**

  - Next step at EUMETSAT: ITT to define a preliminary design

On-going activity at ESA: FRM4SOC

fiducial reference measurements for satellite ocean colour

- **Overall objective:** *establish and maintain SI traceability of Fiducial Reference Measurements (FRM) for satellite ocean colour radiometry (OCR) with accompanying uncertainty budgets.*
- **Project website:** https://frm4soc.org
- **Workshop on vicarious adjustment (Feb. 2017):**
  - *Options for future European satellite OCR vicarious adjustment infrastructure for the S-3 OLCI and S-2 MSI A/B/C and D instruments*
- **Key workshop conclusions (report under preparation):**
  - Sound metrological foundation with 'hands-on' involvement of NMIs
  - Increased effort on sensor characterisation, uncertainty budgets
  - At least two SVC sites in Europe:
    - In priority, BOUSSOLE should be maintained and strengthened
    - A second site should be created, possibly in Eastern Med (e.g. MOBY-net)
  - In complement for larger CalVal purposes:
    - Autonomous radiometric systems (ProVals/HyperNav) should be encouraged
    - AERONET-OC as a proven system should be maintained and further developed

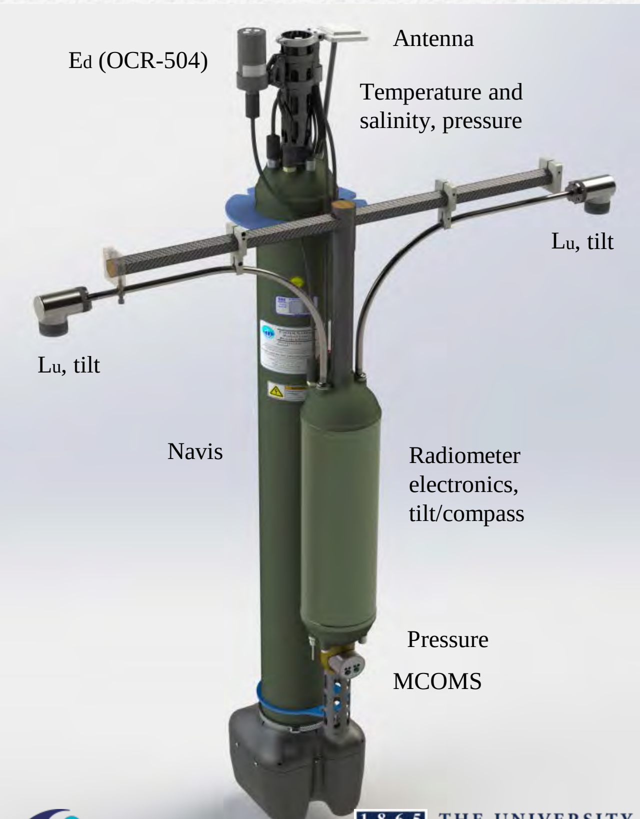
On-going activity at NASA

- **ROSES 2014 - Ocean Color Remote Sensing Vicarious (In Situ) Calibration Instruments**
  - Solicited proposals for the development of in situ instrumentation explicitly for vicarious calibration of satellite-based ocean color remote sensors
  - 3 proposals selected (presentations to follow)
  - 3-year award – ending this FY
  - A follow-on has yet to be announced
- **PACE Project Science Office has been focusing a lot of attention on overall measurement uncertainties, including the development of a complete uncertainty budget**

Status of HYPERNAV

Hyperspectral radiometric device for accurate measurements of water leaving radiance from autonomous platforms for satellite vic. cal.

- HyperNav autonomous float: rapid deployment, broader ranger of observation conditions, near surface measurement (10-20cm), biofouling limitation (1km)



- Radiometric characterization at NIST; field deployment
- Uncertainty budget

SOURCE	TARGET %@412nm	TARGET %@443nm	TARGET %@500nm	TARGET %@550nm	TARGET %@665nm	METHOD OF VALIDATION	MITIGATION
Calibration							
Irradiance standard	1.04	0.94	0.84	0.78	0.68	Provided by NIST	Use NIST calibrated lamp
Reflectance target	1.8	1.8	1.8	1.8	1.8	Provided by manufacturer	Use corrections for 0-45deg
Reproducibility	1.6	1.6	1.6	1.6	1.5	Repeated calibrations	Careful lab procedures
Instrument							
Immersion factor	0.3	0.3	0.3	0.3	0.3	Theory and experiment	Careful lab procedures
Linearity	0.3	0.3	0.3	0.3	0.3	NIST beam conjoiner	Characterize and correct
Stray light	0.10	0.09	0.06	0.04	0.09	NIST laser scanning	Characterize and correct
Thermal effects	0.01	0.00	0.01	0.02	0.07	At cal station over 4-30 C	Characterize and correct
Polarization effects	0.5	0.4	0.1	0.1	0.5	Int. sphere and polarizer	Depolarizer
Wavelength accuracy	0.4	0.4	0.4	0.4	0.4	Provided by mfr., verified w/ Fraunhofer lines	Quality control on spectrometers
Field							
Wave focusing	1.0	1.0	1.0	1.0	1.0	Field measurements	High frame rate at surface
Self-shading	0.5	0.5	0.5	0.5	0.5	Monte Carlo	Model corrections
Tilt effects	0.5	0.5	0.5	0.5	0.5	Tilt sensors in heads	Only send data w/ good tilts
Surface extrapolation	0.65	0.65	0.65	1.13	4.84	Modelling	High accuracy pressure
Biofouling (6 mnths)	0.5	0.5	0.5	0.5	0.5	Retrieval of floats, post cal	Park in aphotic zone
Total	3.1	3.1	3.0	3.1	5.6		

SEA·BIRD SCIENTIFIC

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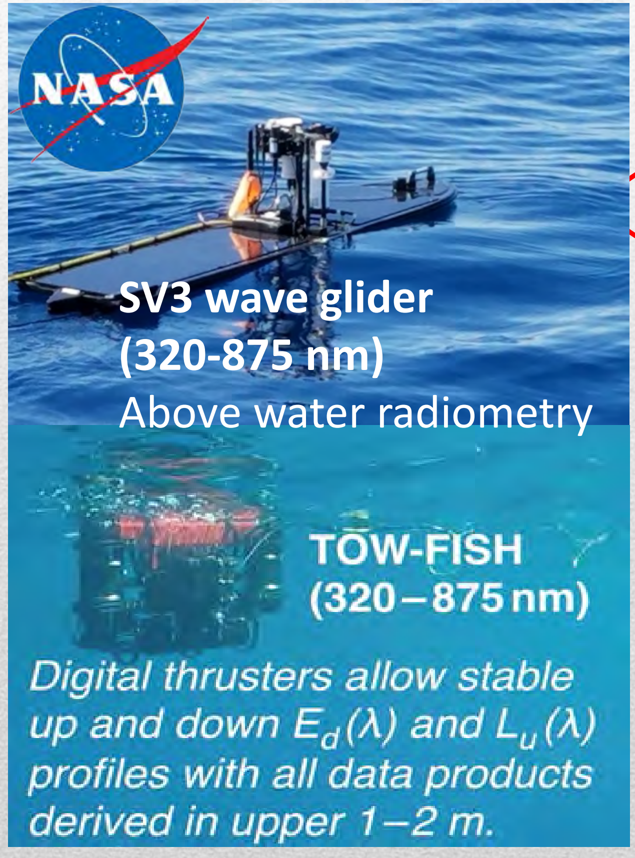
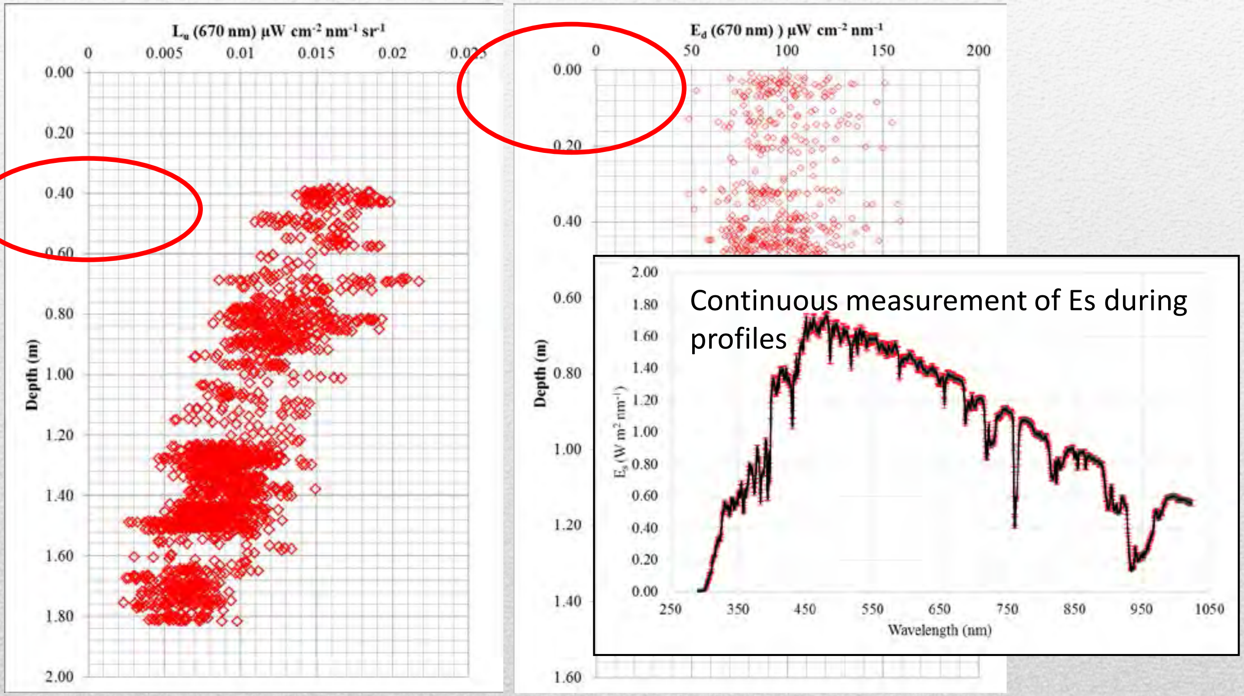
- Next steps: continued characterization, continued float testing (at MOBY), final report for Sept. 2017

Status of HARPOONS

Hybridspectral Alternative for Remote Profiling of Optical Observations for NASA Satellites

- Motivations: smaller, cheaper (COTS components) and more flexible than fixed buoys, deployed only when good weather



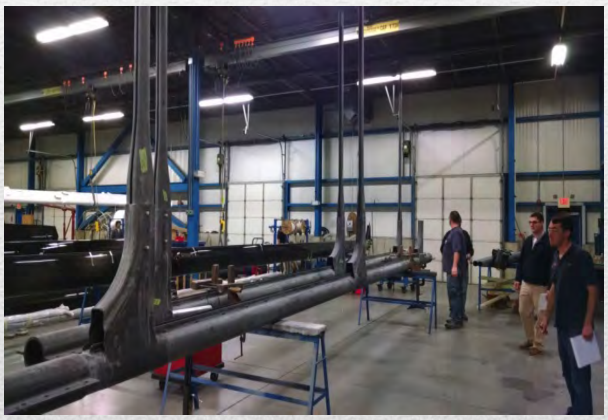


- Deployment South West Coast of Porto Rico
- Web site soon available (data, documentation software)
- Data to be submitted to SeaBASS by the end of Sept. 2017

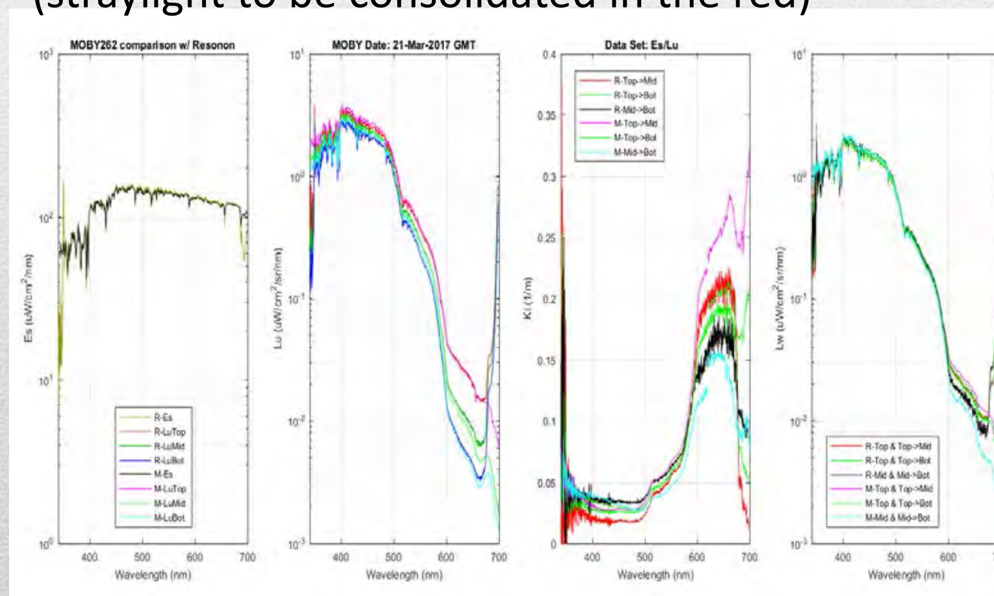
- Concept works as advertised; closing up in Sept. on time & budget (2.8 $M for 3 years)

Status of MOBY-NET Marine Optical Buoy network

- Built upon MOBY long experience at Hawaii, to support **additional sites** with same optical design, consistent calibration, consistent data reduction
- MOBY design but allows optical system to be removed intact



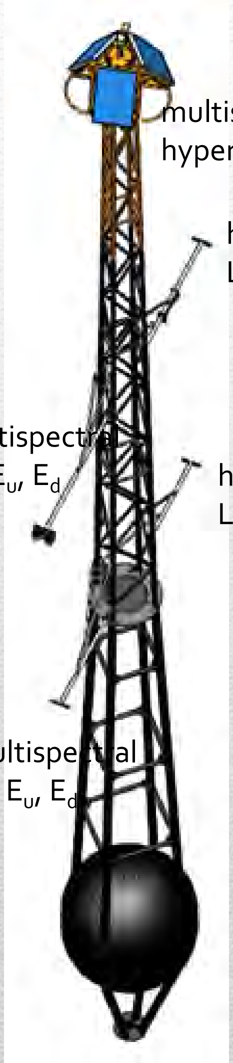
- Very good comparison of heritage and new system (straylight to be consolidated in the red)



- Goal is a yearlong cross-over between the new/old optical system completed in 2018
- Support for two sites (Hawaii + another on) in the future

Status of BOUSSOLE

Buoy for the acquisition of a long-term optical series



- Close to 20 years of experience, one of the 2 sites used today for SVC
- Recent evolutions:
  - Establishment of a thorough **uncertainty budget** for the radiometry measurements (NPL collaboration; Monte Carlo method)

u in % / λ 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

  - From May 2017: multi-spectral radiometry no longer maintained, and only **hyperspectral radiometry** will proceed
  - Extension of the **data use for SVC** through collaborations (S3-OLCI, S2-MSI, S-GLI, VIIRS)

Discussion: approach for requirements

- Focus on **System** Vicarious Calibration (system = sensor + algorithm) and on **standard** atmospheric correction (Gordon & Wang)

- Requirements on the SVC infrastructure should be driven by the **end-to-end uncertainty budget of the SVC gains** (without a priori infrastructure concept), itself driven by **requirements on OC products**

- **Focus on open ocean climate applications:**
  - **Targeted radiometric Lw uncertainty requirement** of 5% in the blue-green (clear waters) for CDRs (GCOS 2011)
  - **Stability requirements**: no real consensus on the GCOS requirements of 0.5% per decade. Recommendation to carry on investigations and to progress on a justified requirement

- **Coastal applications**: requirements unknown. Effort should focus on algorithm (atmospheric correction) and validation, not SVC

Discussion: some examples of requirements

- Choice or water type (**oligotrophic vs mesotrophic**) should be based on the **end-to-end uncertainty budget of the system**, including contribution of Lw to TOA, BRDF correction, spatial homogeneity, temporal stability, etc.

- If the system is calibrated in reflectance (NOAA requirement), and not radiance (NASA case), we need **concurrent measurement of Es with same spectral resolution**

- **Site selection: atmosphere** at the SVC site needs to be **characterized** using dedicated atmospheric space mission & field measurement (LIDAR, AERONET) at least for one year; during operation, measurement of AOT(λ) for quality control

- Can **multiple sites** be used? No perfect consensus. Redundancy is recommended from an operational point of view to limit impact of any failure; from a metrology point of view, multiple equivalent sites would be required for robustness (equivalence in terms of protocols for measurements & uncertainty, traceability; proof of equivalence of gains).

Discussion: example of uncertainty budget

- Excel tables publicly available with simplified uncertainty propagation
- Numbers to be adapted on a case by case basis

In this example: $\frac{t_g t C_Q L_w^t}{L_t}$ *= 5%,*

N=50

Note: uncertainty due to atmosphere is considered separately in the site selection

OC-VCAL ID	Uncertainty source	rand.	syst.
	In situ Lw measurement		
OC-VCAL-RD-14	Spectral resolution		0.50%
OC-VCAL-RD-15	Spectral calibration		0.10%
OC-VCAL-RD-16	Stray-light		0.75%
OC-VCAL-RD-17	Radiometric calibration & stability		2.00%
OC-VCAL-RD-18	Angular response		
OC-VCAL-RD-19	Immersion factor	0.05%	
OC-VCAL-RD-20	Thermal stability	0.30%	
OC-VCAL-RD-21	Dark current		
OC-VCAL-RD-22	Polarisation sensivity	0.20%	
OC-VCAL-RD-23	Non-linearity response		0.10%
OC-VCAL-RD-24	Noise characterisation		
OC-VCAL-RD-25	Environ. conditions (like-to-like rule)	0.50%	
OC-VCAL-RD-26	Shading		1.00%
OC-VCAL-RD-27	BRDF	0.30%	
OC-VCAL-RD-28	Depth-extrapolation	1.00%	1.00%
OC-VCAL-RD-29	Surface propagation	0.25%	
OC-VCAL-RD-30	Data reduction	3.00%	
	Other effects		
	Total uncertainty on in situ Lw	3.25%	2.61%
	In situ Lw post-processing and match-up		
OC-VCAL-RD-39	Spectral integration to satellite SRF		0.20%
OC-VCAL-RD-40	BRDF correction to satellite geometry	1.00%	1.00%
OC-VCAL-RD-41-42-43	Match-up process	5.00%	
	Total uncertainty on post-processed in situ Lw for match-up	6.04%	2.81%
	SVC gains		
OC-VCAL-RD-44	Individual gains (Eq. 23)	0.30%	0.14%
OC-VCAL-RD-44	Averaging (Eq. 22)	0.04%	0.14%
	Total uncertainty on mission average gain	**0.15%**	

Discussion: international harmonization

- New IOCCG working group: ***Long-term vicarious calibration of ocean colour sensors***
- Term of references: http://ioccg.org/group/vicarious-adjustment/
- Will benefit from the on-going activities (ESA FRM4SOC, EUMETSAT OC-VCAL, NASA ROSES …)
- **Co-chairs:**
  - Christophe Lerebourg, ACRI-ST, France
  - Carol Johnson, NIST, USA
  - Ewa Kwiatkowska, EUMETSAT, Germany
- **Members:**
  - David Antoine, Curtin Univ., Australia
  - Ken Voss, Univ. of Miami, USA
  - Nigel Fox, NPL, UK
  - Marlon Lewis, Dalhousie Univ., Canada
  - Bryan Franz, NASA GSFC, USA
  - Hiroshi Murakami, JAXA, Japan
  - Sean Bailey, NASA GSFC, USA
  - Andrew Banks, NPL, UK
  - Craig Donlon, ESA/ESTEC, Netherlands
  - Constant Mazeran , Solvo, France
  - Emmanuel Boss, Univ. of Maine, USA

Detailed requirements – short-term

- EUMETSAT report to be delivered to the European Commission in July 2017

- Draft version publicly available today

→ **Opportunity to express your opinion**

→ **Any feedback welcome until July 2017**:

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EUMETSAT
Requirements for Copernicus OC-VCAL Infrastructure

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Requirements for Copernicus Ocean Colour Vicarious Calibration Infrastructure over the Open Ocean

Draft report
D6 Issue 1.1

DRAFT

EUMETSAT
Copernicus
European Commission

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Main conclusion

Main priority for operational SVC is to ensure **sustainable resources (staff, knowledge, and infrastructure)** to build long-term data series over multi-mission lifetime