Merged, Long-Term Ocean-Colour Products

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Introduction

This breakout session aimed to engage the broader ocean colour user and producer community in the activities of the newly established IOCCG Task Force on *Harmonizing Global Ocean Colour for Long-Term Climate and Ecosystem Monitoring*. The goal was to solicit community input to help shape the Task Force's priorities and activities, ensuring that the resulting multi-sensor, long-term ocean-colour products are scientifically robust, practically useful, and widely adopted.

The session was convened as a town hall to encourage an inclusive, international dialogue around the challenges and requirements for creating long-term, blended ocean-colour time series, with particular relevance for climate research, operational monitoring, and ecosystem applications.

The session began with a short presentation by members of the IOCCG Task Force, outlining its mandate, membership, scope, and current plans. This was followed by brief lightning presentations (5-10 minutes each) from selected participants outside the Task Force, intended to showcase user needs, relevant experiences and perspectives, and recent work related to long-term merged ocean-colour products. The remainder of the session was devoted to open discussion, providing participants with the opportunity to share input, voice concerns, and raise priorities directly with Task Force members. Interventions from both experienced practitioners and new users were encouraged to ensure broad representation across scientific, operational, and applied domains. Outcomes from the session will inform the Task Force's future recommendations and work plan.

Key Questions

1. What are the most pressing user needs for long-term, multi-mission ocean-colour products (e.g., for climate trend analysis, ecosystem monitoring, fisheries management, or disaster response)?
2. What are the critical gaps in current merged ocean-colour products in terms of spatial/temporal resolution, uncertainty quantification, sensor continuity, or product accessibility?
3. What criteria should define a "climate-quality" or "application-ready" long-term product?
4. What are the key methodological challenges in harmonizing and blending across sensors, including calibration, atmospheric correction, and algorithm consistency?

5. How can the community support efforts to sustain and improve merged data records (e.g., through shared tools, in situ observations, or collaborative validation activities)?
6. What do users envision as essential future capabilities or product features (e.g., uncertainty characterization, region-specific products, spectral harmonization)?

Session Summary

The discussion opened with a review of the historical context of ocean color missions and the challenges that persist despite decades of effort. Ocean colour is recognized as a climate data record because it captures key indicators such as phytoplankton biomass, productivity, and carbon cycling. These variables are essential for understanding climate variability, ecosystem responses, and supporting operational services like fisheries management and harmful algal bloom monitoring. However, no single mission can provide the continuity required for climate-scale analysis, making multi-mission synthesis indispensable.

Participants emphasized that inconsistencies across missions (arising from differences in radiometric calibration, spectral bands, atmospheric correction, and sensor drift) introduce artifacts and biases which obscure true climate signals. Even small calibration discrepancies can lead to significant errors in derived products and trends. Harmonization is therefore critical, but it remains technically and organizationally challenging. It requires cross-sensor radiometric consistency, standardized atmospheric correction, robust uncertainty propagation, and the integration of diverse in-situ datasets for system vicarious calibration. These challenges are further complicated by imperfect mission overlaps and the need for international coordination.

Elizabeth Atwood introduced the IOCCG Long-Term Time Series (LTTS) Task Force, established to address these issues. The Task Force aims to develop strategies for blending and harmonizing multi-sensor data, identify gaps in existing datasets, and provide guidance for calibration, infrastructure, and interagency coordination. Its activities are organized around four planned reports: (1) a comprehensive status review, (2) recommendations for blended products, (3) calibration and infrastructure strategies, and (4) proposals for sustainable interagency coordination and data management. Community engagement is central to the Task Force's mandate, as user input will help define priorities and clarify what constitutes a climate-quality record.

Several technical presentations illustrated current approaches and innovations. ZhongPing Lee described the GLOSS project, which uses AI-driven cross-satellite atmospheric correction to align data from multiple sensors to a MODIS-Aqua reference, improving consistency across missions and enhancing coverage in polar and coastal regions. Jing Tan discussed methods for achieving radiometric consistency through cross-calibration using geostationary sensors as stable references, and proposed hierarchical approaches to combine system vicarious calibration gains from multiple sites. Salem Salem presented updates on the OC-CCI project, which merges data from six sensors using standardized atmospheric correction and bias adjustment, supported by expanded in-situ datasets and improved uncertainty estimation. Lionel

Arteaga Quintero provided an overview of the data assimilation of NASA's Ocean Biogeochemical Model (NOBM) together with MODIS data to fill observational gaps and generate Level-4 products. Thomas Jackson outlined EUMETSAT's role in creating long-term, climate data records, emphasizing inter-agency collaboration, harmonized processing, and robust uncertainty characterization to support climate monitoring, trend detection, and application-ready products for diverse user needs. Myung-Sook Park presented evidence of ocean color shifts in ocean colour, with trends toward bluer waters in tropical/subtropical regions and greener waters at high latitudes, suggesting ocean desertification in low-latitude regions and increased productivity in polar areas, with significant implications for global carbon cycles and fisheries.

The open discussion reinforced several overarching themes. Participants stressed the need for clear definitions of climate-quality products, including explicit stability, traceability, and uncertainty thresholds. They noted that uncertainty should be smaller than the trends being detected and that comprehensive metadata documenting calibration history and algorithm versions is essential. Intercomparison exercises among merged products was viewed as valuable, given that no single method will satisfy all users. Sustained community support through shared tools, open data platforms, and sustained in-situ networks was identified as critical for success. Looking ahead, participants envisioned future capabilities such as hyperspectral missions, cautious use of machine learning for gap-filling, geostationary sensors for improved continuity, and cloud-based infrastructures for large-scale processing.

Overall, the session reaffirmed that harmonizing long-term ocean color records is both a scientific and organizational imperative. Achieving this goal will require coordinated international efforts, robust technical solutions, and active engagement with the user community. The LTTS Task Force will play a central role in guiding these efforts to ensure that future ocean color products meet the stringent requirements of climate research and operational applications.

Audience Slido Poll Statistics

Eighteen countries were represented across the audience: Australia, Belgium, Bulgaria, Canada, Chile, China, France, Germany, India, Korea, Portugal, South Korea, Spain, Sweden, Tanzania, the United Kingdom, the United States, and international organizations (e.g., EUMETSAT). Their research spanned 24 fields, with the top three common areas being ocean color remote sensing, climate change and trend analysis, and water quality monitoring.

When asked which LTTS products they currently use, the most frequently cited were OC-CCI (18 responses), GlobColour (8 responses), and None (6 responses), reflecting both the importance of existing merged products and the need to broaden adoption and accessibility.

Review of Existing IOCS Recommendations

List, and state any updates on the progress of, existing/open recommendations made on this topic. From https://iocs.ioccg.org/iocs-recommendations/

2023.04.1	The community should develop an open-access database of POC and DOC for inland and coastal waters	Community	Actioned*
2023.08.1	The community needs to conduct more research to identify all sources of discrepancies in merged datasets (beyond time and space, including geometry and other factors) and to quantify and correct them.	Community	OPEN
2023.08.2	The community needs to improve description of continuity metrics including reporting of possible extremes (tails), possibly using Probability Density Functions.	Community	OPEN
2023.08.3	Space agencies and distribution services (in collaboration with the ocean colour and metrology communities) need to prioritize calculating and distributing uncertainties associated with all products (pixel-based and composite), and including propagation through AC and algorithms following metrological practices.	Agency	OPEN
2023.08.4	The community and IOCCG need to consider revising/updating the 2006 IOCCG report on data merging.	IOCCG	OPEN
2023.08.5	Space agencies should advocate for mission design to ensure backwards compatibility to improve confidence in derived trends and ensure overlap between missions.	Agency	OPEN

At the time of the IOCS 2025 meeting, almost all IOCS 2023 recommendations relevant to long-term ocean-colour time series remain open. While progress has been made through individual projects, intercomparison studies, and emerging methodologies, no recommendation has yet been fully resolved at the community or agency level. Recommendation 2023.04.1 has been actioned through such open-access databases already existing. IOCCG suggests collating and adding POC and DOC data for inland and coastal waters to existing community databases, such as SeaBASS.

Several initiatives, such as multi-sensor merging efforts, advances in uncertainty estimation, geostationary-assisted cross-calibration, and expanded use of in situ networks, demonstrate partial progress toward these goals. However, these efforts remain fragmented, with approaches varying across agencies, regions, and products. In particular, consistent implementation of uncertainty propagation, standardized continuity metrics (including treatment of extremes), and formal mechanisms for cross-agency coordination are still lacking.

The establishment of the IOCCG LTTS Task Force directly responds to this situation. The Task Force provides a structured framework to consolidate ongoing efforts, translate existing IOCS recommendations into actionable guidance, and define measurable criteria for climate-quality long-term ocean-colour products.

New IOCS Recommendations

The new recommendations emerging from the LTTS Breakout Session are intended to operationalize and extend the IOCS 2023 guidance, moving the community from problem identification toward coordinated implementation. They define a pathway toward transparent, traceable, and climate-quality long-term ocean-colour records, grounded in robust calibration, explicit uncertainty characterization, regional awareness, cautious use of new technologies, and sustained international collaboration.

1. Deliver a Single Blended LTTS Product with Regionally Informed Adjustments

Develop one unified, blended long-term ocean-colour record that supports optional regional adjustments where required by physics and optics, while avoiding multiple competing global products. Regional tuning should be documented, traceable, and applied only where justified, without forcing artificial consistency across regions.

Responsibility: Agencies and Community

2. Define Climate-Quality Requirements with Quantified Uncertainty Thresholds

Establish explicit, variable-specific climate-quality criteria, including uncertainty thresholds that are demonstrably smaller than the trends being investigated. Define minimum record lengths required for robust trend detection (e.g., 35 years for chlorophyll), recognizing that requirements differ by variable and application.

Responsibility: Community

3. Provide Flexible Access to Intermediate and Derived Products

Ensure users can access intermediate products (e.g., pre-SVC, sensor-specific fields) alongside merged products, enabling users to apply application-specific uncertainty tolerances, regional analyses, or alternative merging strategies where appropriate.

Responsibility: Agencies

4. Strengthen Coordination Through Shared Calibration and Processing Infrastructure

Establish and sustain coordinated local-regional-global networks for calibration, validation, and processing, building on existing international frameworks. Support shared investments in calibration sites, matchup databases, processing tools, and documentation to ensure long-term continuity.

Responsibility: Agencies and Community

5. Expand and Qualify In Situ Observations for Validation

Address gaps in global in situ coverage, particularly in under-sampled regions (e.g., high latitudes, monsoonal systems, optically complex coastal waters). Explicitly quantify and document regions where in situ uncertainty exceeds satellite uncertainty, and incorporate this information into validation and uncertainty frameworks.

Responsibility: Agencies and Community

6. Ensure Traceable Cross-Calibration and Account for SVC Variability

Maintain traceable cross-calibration chains across missions, including assessment of gaps in geostationary coverage. Explicitly account for site-to-site variability in SVC gains in merged products rather than relying on indiscriminate averaging, and document how SVC differences are handled.

Responsibility: Agencies and Community

7. Implement Robust, Scalable Merging Frameworks

Design merging frameworks that explicitly accommodate different numbers of contributing sensors (e.g., two-sensor versus multi-sensor merges). Provide metadata indicating which missions contribute at each time step, and implement safeguards to avoid regional artifacts caused by gap-filling under aerosols, dust, or persistent cloud cover.

Responsibility: Agencies

8. Define Acceptable Temporal Gaps by Application

Develop community guidance on acceptable data gaps and compositing windows (e.g., daily versus 7-day products), recognizing that tolerance for gaps varies across climate, ecosystem, and operational applications.

Responsibility: Community

9. Integrate AI/ML Methods with Clear Physical and Uncertainty Constraints

Encourage innovation using AI/ML while requiring that such methods be traceable, physics-aware, and uncertainty-quantified. Ensure AI-based approaches do not introduce spurious or non-physical features, mask real variability, or create false temporal continuity in long-term records.

Responsibility: Agencies

10. Provide Multi-Scale Uncertainty Characterization

Deliver pixel-level uncertainty estimates alongside methods for deriving regional and ensemble uncertainties, recognizing that aggregation reduces random error. Provide uncertainty PDFs or ensemble-based representations to characterize extreme behavior (tails), and document impacts of data gaps or regional data-sharing constraints on uncertainty.

Responsibility: Agencies