Uncertainties in Ocean Color Products: Context

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Bojinski et al. *BAMS* 2014
Generating ECV datasets:
"Quality assessment and peer review of datasets are very important.
Providers of climate datasets should, where possible, meet community-specific needs for representing data, such as in suitable gridded formats with information on uncertainty to facilitate model–observation comparisons."

GCOS Climate Monitoring Principles
GCOS-143 (2010)

Effective monitoring systems for climate should adhere to the following principles:
4. The quality and homogeneity of data should be regularly assessed as a part of routine operations.

satellite systems for climate monitoring should adhere to the following specific principles:
20. Random errors and time-dependent biases in satellite observations and derived products should be identified.

NB: New status report and implementation plan being prepared

http://gcos.wmo.int

GCOS-154, 2011; "Systematic Observation requirements for satellite-based data products for climate" → **2 Ocean Color ECVs (Chla, L_W)**

	Horizon. Res.	Temp. Res.	Accuracy	Stability$
Water-leaving radiance	4km	Daily	5% (*)	0.5%
Chla concentration	30km	Weekly	30%	3%

not in GCOS 107

(*) specifically for blue and green wavelengths (not in GCOS 107)
$: over a decade

Accuracy: indicative of acceptable overall levels for the uncertainties of product values. Uncertainty can be influenced by factors such as spatial/temporal sampling, biases introduced by the retrieval method, biases introduced by interpolation methods, calibration errors, geo-location errors, and instrument noise. It may be quantified by the root mean square (or other measure) of the estimated distribution of errors in product values over a spatial domain, a time interval or a set of similar synoptic situations. Uncertainty may accordingly vary in space and time.

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"The accuracy of 5% for water leaving radiances for the blue and green wavelengths and 30% for chlorophyll is intended for the concentration range 0.01-10 mg m^{-3} in waters in which chlorophyll-a dominates. These are termed Case-1 waters, i.e., those whose inherent optical properties can be adequately described by phytoplankton (represented by chlorophyll-a concentration)…."

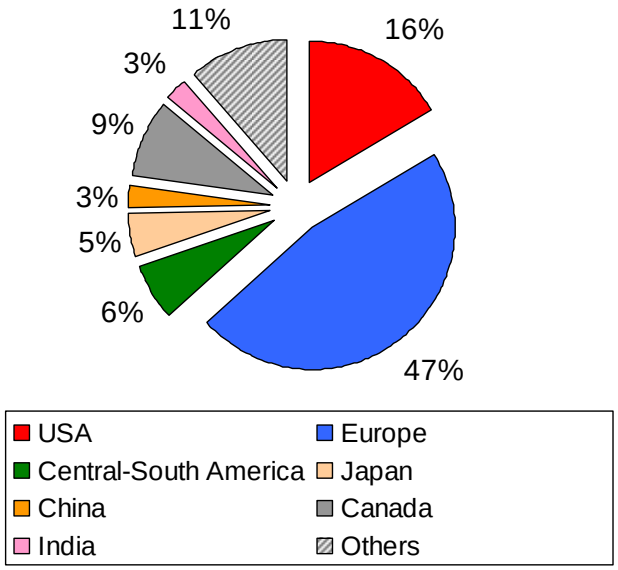
Current performance:
"Accuracy: 5-15% for water leaving radiances (for the blue and green wavelengths) and 30-70% for Chla in the concentration range 0.01-10 mg m^{-3} in Case 1 waters. For coastal waters and regional seas, which are typically Case 2, these errors are considerably higher, typically on the order of 60-70% for chlorophyll-a, but in areas of extreme optical-complexity as high as 200-300%."

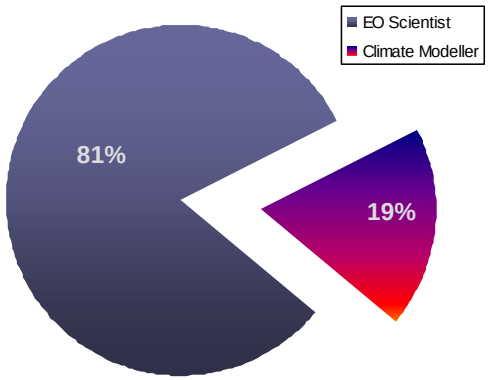
ESA Climate Change Initiative → Users Requirements Document

Users Consultation (survey-based) with the goal of identifying requirements of ocean-colour data for climate studies at present, and in the near future

→ **GCOS**

Users (78) pooled into 2 broad categories: climate modellers and EO scientists





ESA Climate Change Initiative

Requirements for Chla

	Accuracy			Precision		
	goal	breakthrough	threshold	goal	breakthrough	threshold
CCI modellers	<10%	10-25%	10-25%	<10%	<10%	10-25%
CCI EO scientists	<10%	10-25%	25-50%	<10%	10-25%	25-50%

Minimum requirements (threshold)

	L_{WN}		K_d		IOP		CDOM		SPM	
	Acc.	Prec.	Acc.	Prec.	Acc.	Prec.	Acc.	Prec.	Acc.	Prec.
modelers	10-25%	>25%	10-25%	10-25%	10-25%	10-25%	25-50%	10-25%	10-25%	10-25%
EO scientists	>10%	>10%	>10%	>10%	>10%	>10%	>10%	>10%	10-25%	>10%

OC_CCI URD 2011

Mission requirements

"In the case of SeaWiFS and MODIS, the primary parameter to be derived was chlorophyll-a and an accuracy goal of 35% in the open ocean (range of 0.5-50 mg m^{-3}) was set by community consensus primarily because uncertainties in the *in situ* measurements and physiological variability precluded a more accurate goal. The accuracy really was not associated with a scientific question requiring a particular accuracy."

***IOCCG* #13 2012**

➢ SeaWiFS requirements

1. Radiometric accuracy to within 5% absolute and 1% relative
2. Derivation of water-leaving radiances to within 5% absolute
3. Derivation of chlorophyll-a concentration to within 35% over the range 0.05-50 mg m^{-3}
4. Derivation of global PP to within 50% absolute with a precision to within 10%

McClain et al. 1992, Hooker et al. 1992, Hooker & Esaias *EOS* 1993

"The most important goals … are to produce water-leaving radiances with an uncertainty of 5% in clear-water regions and chlorophyll *a* concentrations within ±35% over the range of 0.05–50 mg m^{-3}."

Hooker & McClain *PO* 2000 (abstract)

"To recover $[\rho_w]_N$ in the blue (443 nm) for these waters with an error <5% requires an atmospheric correction of ±0.001 to ±0.002 in reflectance… This is our goal for MODIS band 9."

Gordon *JGR* 1997

➢ Sentinel-3 Copernicus requirements

Accuracy for Climate monitoring in global Case-1 waters:
Chla: 10-30%, K: 5%, PAR: 5%
Accuracy L_w: 5%

Donlon 2011

➢ PACE Science Definition:

ρ_{wN}=400-600nm, maximum of 0.001 or 5% (VIS)
ρ_{wN}=350-400nm, maximum of 0.004 or 20% (NUV)

Are we doing well for uncertainty assessment?

Bates & Privette (EOS 2012)
Maturity model for assessing the completeness of Climate Data Records:
Software readiness, metadata, document, product validation, public access, utility

Product Validation

1. **Little or none**
2. **Minimal**
3. **Uncertainty estimated for select locations/times**
4. **Uncertainty estimated over widely distributed times/location by multiple investigators; Differences understood.**
5. **Consistent uncertainties estimated over most environmental conditions by multiple investigators**
6. **Observation strategy designed to reveal systematic errors through independent cross-checks, open inspection, and continuous interrogation; quantified errors**

Bates & Privette EOS 2012

discussed in Mélin & Franz 2014
for R_{RS}: level 3-4? 5?

CDR Maturity evaluation guidelines

Level 6:

- **Independent validation:**
  At least 10 comparisons to models, in-situ data, or other independent products as available and appropriate to particular CDR; observation strategy designed to reveal systematic errors through independent cross checks, open inspection, and continuous interrogation
- **Uncertainty for TCDR:**
  Biases and errors minimized
- **Quality flag:**
  Masks applied as appropriate (e.g., land masks, cloud masks); algorithm failures identified; instrument degradation flags applied. Additional flags or modification of flag algorithms as a result of additional validation and user feedback
- **Operational monitoring:**
  Operational monitoring in place with results fed back to quality flags

Bates & Privette EOS 2012

International Network for Sensor Inter-comparison and Uncertainty assessment for Ocean Color Radiometry

The INSITU-OCR initiative was developed within the Ocean Colour Radiometry - Virtual Constellation (OCR-VC) developed in the context of the Committee on Earth Observation Satellites (CEOS). The INSITU-OCR initiative aims at integrating and rationalizing inter-agency efforts on satellite sensor inter-comparisons and uncertainty assessment for remote sensing products with particular emphasis on requirements addressing the generation of ocean colour Essential Climate Variables as proposed by the Global Climate Observing System (GCOS)

http://www.ioccg.org/insitu_ocr.html

INSITU-OCR White Paper

Metrology for Climate workshop
(hosted at NPL, UK)

- How can Metrology help the EO and FCDR/CDR community?
- What can the EO/CDR community do to ensure successful integration of metrological principles into the monitoring of ECVs and the formation of CDRs?

One pick: ensure rigor in analyses, in language and mathematics

→ **JCGM 100, 2008**

IOCCG Working Group on Uncertainties (meet 19/06/15)