

CEOS Analysis Ready Data (CEOS-ARD) Product Family Specification: Aquatic Reflectance (AR)

### **Document Status**

#### Product Family Specification: Aquatic Reflectance

Proposed revisions may be provided to:

ard-contact@lists.ceos.org

## **Document History**

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1.5	15 Oct 2021	Edits and addition of references.	Gurlin, Greb, Ortiz, Sterckx, Bulgarelli, Keukelare, Ogashawara, Dekker, Giardino, Brando
2.0	29 May 2025	Major update to accommodate the oceans, increasing scope beyond initial coastal and inland waters focus. A summary of updates is available <u>here</u> .	Bailey, Barnes, Brando, Brockmann, Bulgarelli, Costa, Dekker, Dierssen, Evers-King, Gege, Giardino, Gurlin, Harrison, Jones, Kwiatkowska, Lovindeer, Mélin, Murakami, Page, Pinnel, Siqueira, Steventon, Strobl, Thankappan

#### Technical Leads

Arnold Dekker (CSIRO)

Daniela Gurlin (Independent Consultant)

#### **Organisational Leads**

Matt Steventon (CEOS-ARD Oversight Group Secretariat)

Harvey Jones (CEOS-ARD Oversight Group Secretariat)

#### Contributors

Carsten Brockmann (Brockmann Consult)

Vittorio Brando (CNR)

Claudia Giardino (CNR)

Nicole Pinnel (DLR)

Peter Gege (DLR)

Barbara Bulgarelli (EC)

Peter Strobl (EC)

Frédéric Mélin (EC)

Ewa Kwiatkowska (EUMETSAT)

Hayley Evers-King (EUMETSAT)

Andreia Siqueira (GA)

Medhavy Thankappan (GA)

Peter Harrison (GA)

Igor Ogashawara (IGB Berlin)

Raisha Lovindeer (IOCCG)

Hiroshi Murakami (JAXA)

Joseph D. Ortiz (Kent State)

Sean Bailey (NASA)

Nima Pahlevan (NASA)

Anthony Vodacek (RIT)

Heidi Dierssen (University of Connecticut)

Maycira Costa (University of Victoria)

Ben Page (USGS)

Chris Barnes (USGS)

Liesbeth de Keukelare (VITO)

## Description

### Product Family Specification Title: Aquatic Reflectance (CEOS-ARD AR)

**Applies to:** Data collected with multispectral and hyperspectral imaging sensors operating in the VIS/NIR/SWIR wavelengths over water bodies (including oceans, seas, coastal zones, and inland waters). These typically operate with ground sample distance and resolution in the order of 1-4000 metres however the specification is not inherently limited to these resolutions.

## Definitions

See: CEOS Terms and Definitions Wiki

## Requirements

### **General Metadata**

These are metadata records describing a distributed collection of pixels. The collection of pixels referred to must be contiguous in space and time. General metadata should allow the user to assess the <u>overall</u> suitability of the dataset and must meet the following requirements.

Information should be available in the metadata as a single DOI landing page, which may include links to further detailed documents and references to citable peer-reviewed algorithms or technical documentation.

#	Item	Threshold (Minimum) Requirements	Goal (Desired) Requirements	Threshold Self-Asses sment	Goal Self-Asses sment	Self-Assessment Explanation/ Justification	Comments
1.0	CEOS-ARD AR PFS Compliance Version	Version of the CEOS-ARD PFS with which the product is complying is identified.	As threshold.				
1.1	Traceability	Aquatic Reflectance (dimensionless) or the Remote Sensing Reflectance (sr <sup>-1</sup> ) of the water bodies (AR=pi*R <sub>rs</sub> ) is given.	Data must be traceable to SI reference standard. <u>Note:</u> Relationship to 3.2. Traceability requires an estimate of measurement uncertainty.				
1.2	Metadata Machine Readability	Metadata is provided in a structure that enables a computer algorithm to be used consistently and to automatically identify and extract each component part for further use.	As threshold, but metadata should be provided in a community endorsed standard that facilitates machine-readability, such as ISO 19115-2.				

1.3	Data Collection Time	The beginning and end of the data collection time is expressed in date/time and identified in the metadata consistent with ISO 8601. The time is expressed with the time offset from UTC unambiguously identified.	As threshold, but information required to determine, within a stated uncertainty, when the individual observations were taken is available.		
1.4	Geographical Area	The surface location to which the data relates is identified, typically as a series of four corner points, expressed in an accepted coordinate reference system (e.g., WGS84).	The geographic area covered by the observations is identified specifically, such as through a set of coordinates of a closely bounding polygon. The location to which each pixel refers is identified (or can be reliably determined) with the projection system (if any) and reference datum provided.		
1.5	Coordinate Reference System	The coordinate reference system that has been used is detailed.	As threshold.		
1.6	Map Projection	The map projection that has been used and any relevant parameters required in relation to use of data in that map projection is detailed.	As threshold.		

1.7	Geometric Correction Methods	Not required. The user is not explicitly advised of the geometric correction source and methods.	Information on geometric correction source and methods are provided, including reference database and auxiliary data such as elevation model(s) and reference chip-sets.		
1.8	Geometric Uncertainty of the Data	Not required. The user is not provided with results of geometric uncertainty assessments pertaining to the dataset.	Inclusion of metrics describing the assessed geodetic uncertainty of the data, expressed in units of the coordinate system of the data. Uncertainty is assessed by independent verification (as well as internal model-fit where applicable). Uncertainties are expressed quantitatively.		
1.9	Instrument	The instrument used to collect the data is identified.	As threshold, with references to the relevant "CEOS Missions, Instruments, and Measurements Database" record (database.eohandbook.com).		
1.10	Spectral Bands	Full spectral response function is provided.	As threshold.		
1.11	Sensor Calibration	Binary description of calibrated / not calibrated only.	Specification of sensor calibration parameters including history of onboard calibrations where available.		
1.12	Measurand Radiometric Uncertainty	Metrics describing the assessed radiometric uncertainty of the version of the data or product are provided. Method of determination of	As threshold, but the absolute radiometric uncertainty of the data is provided.		

		radiometric uncertainty is specified.			
1.12a	Radiometric Encoding	Range and bit depth are provided.	As threshold.		
1.13	Algorithms	All algorithms and the sequence in which they were applied in the generation process are identified. Algorithms must be published and validated, and a description of the validation process is included. <u>Note:</u> It is possible that corrections are applied through non-disclosed processes. CEOS-ARD does not require full and open data and methods.	As threshold.		
1.14	Auxiliary Data	Lists the sources of auxiliary data used in the generation process.	As threshold, but information on auxiliary data should be available for free online download, contemporaneously with the product or through a link to the source.		

1.15	Processing Chain Provenance	Not required.	Information on processing chain provenance should be available with a detailed description of the processing steps used to generate the product, including the versions of software used, giving full transparency to the users.		
1.16	Data Access	Information on data access should be available as a single DOI landing page. <u>Note:</u> Manual and offline interaction action (e.g., login) may be required.	As threshold.		
1.17	Valid Pixels	Percentage of valid pixels in a specified area based on the applied flags from Section 2 (per-pixel metadata).	As threshold.		

### **Per-Pixel Metadata**

The following minimum metadata specifications apply to each pixel. Whether the metadata is provided in a single record relevant to all pixels, or separately for each pixel, is at the discretion of the data provider. Per-pixel metadata should allow users to <u>discriminate between</u> (choose) observations on the basis of their individual suitability for application.

Information should be available in the metadata as a single DOI landing page, which may include links to further detailed documents and references to citable peer-reviewed algorithms or technical documentation.

#	Item	Threshold (Minimum) Requirements	Goal (Desired) Requirements	Threshold Self-Assess ment	Goal Self-Assess ment	Self-Assessment Explanation/ Justification	Comments
2.1	Metadata Machine Readability	Metadata is provided in a structure that enables a computer algorithm to be used to consistently and automatically identify and extract each component part for further use.	As threshold.				
2.2	No Data	Pixels that do not correspond to an observation (e.g., empty pixels / invalid observations / below noise floor) are masked.	As threshold.				
2.3	Per-pixel Assessment	Identifies pixels for which the per-pixel tests (below) have not all been successfully completed. <u>Note:</u> This may be the result of missing ancillary data for a subset of the pixels.	Identifies which tests have and have not been successfully completed for each pixel.				

2.4	Saturation	Specification of whether there is pixel radiometric saturation at Level 1 in one or more spectral bands.	As threshold, with specification of which pixels are radiometrically saturated for each spectral band.		
2.5	Cloud	Specification of whether a pixel is cloud or cloud-affected.	As threshold, but clouds and cirrus clouds are differentiated.		
2.6	Cloud Shadow	Specification of whether a pixel is cloud shadow or cloud shadow-affected.	As threshold.		
2.7	Land	Specification of whether a pixel is less than 100% water covered due to land.	As threshold.		
2.8	lce	Specification of whether a pixel is ice or ice-affected.	As threshold.		
2.9	Sun Glint	Specification of whether sun glint in a pixel is negligible, correctable (moderate), or uncorrectable (severe). <u>Note:</u> Sun glint is deemed uncorrectable if the upper limit of the dynamic range of a sensor's spectral band is reached (i.e., radiometric saturation occurs).	Specification of the amount of sun glint for each pixel and spectral band. <u>Note:</u> An additional product must be provided to specify the amount. <u>Note 2:</u> See correction 3.8.		

2.10	Sky Glint	Not required.	Specification of the amount of sky glint for each pixel and spectral band. <u>Note 1:</u> An additional product must be provided to specify the amount. <u>Note 2:</u> Sky glint is the at-water-surface reflected component of the diffuse downwelling irradiance. <u>Note 3</u> : See correction 3.9.		
2.11	Solar and Viewing Geometry	Specification of the solar and sensor viewing azimuth and zenith angles.	As threshold.		
2.12	Whitecap / Foam	Not required.	Specification of whether a pixel is affected by whitecaps or foam. If affected, detail the method applied. <u>Note:</u> See correction 3.10.		
2.13	Aerosol Optical Depth Parameters	Not required.	Either per-pixel spectral AOD or per-pixel AOD (550 nm) and Angstrom exponent are provided. <u>Note:</u> This might be an input or an output parameter.		

2.14	Adjacency Effects	Not required.	Depending on the adjacency effects correction method (embedded in the atmospheric correction or separate from the atmospheric correction) the metadata specifies the amount of per-pixel adjacency effect contamination. <u>Note:</u> An additional product must be provided to specify the amount.		
2.15	Floating Vegetation / Surface Scum	Specification of whether a pixel is affected by floating vegetation / surface scum.	As threshold.		
2.16	Bathymetry	Not required.	Water surface to bottom substratum depth (i.e., water column depth) at the specific pixel location is specified. <u>Note 1:</u> Specify whether a recalculation to a mean sea level has taken place for oceanic waters. <u>Note 2:</u> Specify whether a recalculation to a mean water surface level has taken place for any non-oceanic waters.		
2.17	Optically Deep or Optically Shallow Assessment	Information regarding whether pixels are optically deep or shallow is provided if there is an assumption during the processing that a pixel is optically deep or optically shallow.	A flag that indicates optically deep and shallow waters is provided.		

2.18	Optical Water Type	Specification of optical water type, when applicable (for optically deep waters).	As threshold.		
2.19	Turbid Water	Specification of whether a pixel is assessed as being turbid.	As threshold.		
2.20	Elevation	Specification of approximate elevation (above mean sea level) of the surface of the water body pixels is required for atmospheric correction (range = -430 m to approx. 6500 m)	As threshold.		

### **Products and Algorithms**

The following requirements must be met for all pixels in a collection. The requirements specify both the necessary outcomes (3.1-3.3) and the minimum steps necessary to be deemed to have achieved those outcomes (3.4 onwards). Radiometric corrections must lead to a valid measurement of aquatic reflectance.

Metadata must contain a single DOI landing page with relevant information to support each requirement. For corrections, references to a citable peer-reviewed algorithm or technical documentation regarding the implementation of that algorithm and the sources of ancillary data used to make corrections / provision of parameterisation data are required. Examples of technical documentation include an Algorithm Theoretical Basis Document, product user guide, etc.

#	ltem	Threshold (Minimum) Requirements	Goal (Desired) Requirements	Threshold Self-Assess ment	Goal Self-Assess ment	Self-Assessment Explanation/ Justification	Comments
3.1	Measurement	Pixel values that are expressed as a measurement of the Aquatic Reflectance (dimensionless) or the Remote Sensing Reflectance (sr <sup>-1</sup> ) of the water bodies (AR=pi* $R_{rs}$ ).	As threshold. <u>Note:</u> See also 1.1 and 3.3.				
3.2	Measurement Uncertainty	An estimate of the uncertainty of the values is provided in measurement units, following the BIPM Guide to the Expression of Uncertainty in Measurement (GUM). <u>Note:</u> In current practice, users determine fitness for purpose based on knowledge of the lineage of the data, rather than on a specific estimate of measurement uncertainty.	As threshold.				

3.3	Measurement Normalisation	Not required.	Measurements are normalised (to nadir) to remove the effect of bidirectional dependence of the upwelling radiance on observation and solar-illumination geometries.		
3.4	Directional Atmospheric Scattering	Specification of corrections applied for molecular (Rayleigh) scattering and for aerosol scattering and absorption.	As threshold.		
3.5	Water Vapour Corrections	Corrections are applied for water vapour if spectral bands are affected.	As threshold.		
3.6	Ozone Corrections	Data is corrected for ozone if spectral bands are affected. <u>Note:</u> Relevant metadata must be provided under 1.8 and 1.9.	As threshold.		
3.7	Other Gaseous Absorption Corrections	Not required.	Data is corrected for other trace gaseous absorption for affected spectral bands. <u>Note:</u> Relevant metadata must be provided under 1.8 and 1.9.		

3.8	Sun Glint Correction	Not required.	Sun glint is removed from the data if a pixel is of correctable (i.e., not radiometrically saturating) sun glint. <u>Note 1:</u> Sun glint removal methods can only partially remove sun glint from a pixel. Over or under correction may occur. <u>Note 2</u> : See flag 2.9.		
3.9	Sky Glint Correction	Specification of whether or not sky glint is implicitly corrected for in the atmospheric correction procedure. <u>Note:</u> Sky glint is often modelled in forward models explicitly. It is also often measured with above surface spectroradiometers. However, sky glint is seldom corrected for separately in atmospheric and air-water interface correction methods.	Sky glint is separately assessed and corrected for in the data processing. The metadata indicates the surface contributions from sky glint removed from the data. <u>Note: See flag 2.10.</u>		
3.10	Whitecap / Foam Correction	Specification of whether the water leaving reflectance or radiance is corrected for the contribution from surface whitecaps and foam.	The data are corrected for the contribution from surface whitecaps and foam and reported on a per-pixel basis.		
3.11	Adjacency Effects Correction	Not required.	The data are corrected for adjacency effects.		

3.12	Turbid Water Reflectance Correction	Specification of whether the atmospheric correction accounted for a pixel being turbid or not.	As threshold.				
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### Geometric Corrections Metadata (Co-Registration and Ortho-Rectification)

Geometric corrections must place the measurement accurately on the surface of the Earth (that is, geolocate the measurement) allowing measurements taken through time to be compared. Ocean and coastal imagery do not have an independent terrestrial referencing system and therefore 4.2 applies to that imagery.

#	ltem	Threshold (Minimum) Requirements	Goal (Desired) Requirements	Threshold Self-Assess ment	Goal Self-Assessment	Self-Assessment Explanation/ Justification	Comments
4.1	Geometric Correction 1) for land 2) for inland waters where an independent terrestrial referencing system is available	Sub-pixel uncertainty is achieved in relative geolocation, that is, the pixels from the same instrument and platform are consistently located, and are thus comparable, through time. Sub-pixel uncertainty is taken to be less than or equal to 0.5-pixel radial root mean square error (rRMSE) or equivalent in Circular Error Probability (CEP) relative to a defined reference image. A consistent gridding / sampling frame is used, including common cell size, origin, and nominal sample point location within the cell (centre, II, ur). Relevant metadata must be provided under 1.7 and 1.8. <u>Note 1:</u> The threshold level will not necessarily enable interoperability between data from <u>different</u> sources as the geometric corrections for each of the sources may differ. <u>Note 2:</u> It is useful to note if the sensor is used at its native resolution before geometric correction or that some resampling must be done.	Sub-pixel uncertainty is achieved relative to an identified absolute independent terrestrial referencing system (such as a national map grid). Relevant metadata must be provided under 1.7 and 1.8. <u>Note:</u> This requirement is intended to enable interoperability between imagery from different platforms that meet this level of correction and with non-image spatial data such as GIS layers and terrain models.				

# Summary Self-Assessment Table

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3.3 Measurement Normalisation	
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3.11 Adjacency Effects Correction	
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## Guidance

This section aims to provide background and specific information on the processing steps that can be used to achieve CEOS Analysis Ready Data. This guidance material does not replace or override the specifications.

## Introduction to CEOS-ARD

#### What are CEOS Analysis Ready Data (CEOS-ARD) products?

CEOS-ARD products have been processed to a minimum set of requirements and organized into a form that allows immediate analysis with a minimum of additional user effort. These products would be resampled onto a common geometric grid (for a given product) and would provide baseline data for further interoperability both through time and with other datasets.

CEOS-ARD products are intended to be flexible and accessible products suitable for a wide range of users for a wide variety of applications, including particularly time series analysis and multi-sensor application development. They are also intended to support rapid ingestion and exploitation via high-performance computing, cloud computing and other future data architectures. They may not be suitable for all purposes and are not intended as a 'replacement' for other types of satellite products.

#### When can a product be called CEOS-ARD?

The CEOS-ARD branding is applied to a particular product once:

- That product has been self-assessed as meeting CEOS-ARD requirements by the agency responsible for production and distribution of the product, and
- That self-assessment has been peer reviewed by the CEOS Working Group on Calibration and Validation (WGCV).

Entities considering undertaking an assessment should contact ard-contact@lists.ceos.org and review the <u>Guide to CEOS-ARD Self-Assessments</u>.

A product can continue to use CEOS-ARD branding as long as its generation and distribution remain consistent with the peer-reviewed assessment.

#### What is the difference between Threshold and Goal?

Products that meet all Threshold requirements should be immediately useful for scientific analysis or decision-making.

Products that meet Goal requirements will reduce the overall product uncertainties and enhance broad-scale applications. For example, the products may enhance interoperability or provide increased accuracy through additional corrections that are not reasonable at the *Threshold* level.

Goal requirements anticipate continuous improvement of methods and evolution of community expectations, which are both normal and inevitable in a developing field. Over time, *Goal* specifications may (and subject to due process) become accepted as *Threshold* requirements.

## **Procedural Examples**

#### Processes to produce Threshold Aquatic Reflectance CEOS-ARD:

The following correction processes would typically be applied to produce CEOS-ARD-AR Threshold:

• No example processes are provided at this time.

The following additional processes could be applied to produce CEOS-ARD-AR Goal:

• No example processes are provided at this time.

## **Specific Examples**

#### Processes to produce Threshold Aquatic Reflectance CEOS-ARD.

• No example processes are provided at this time.

## References

The following papers provide scientific and technical guidance for each requirement.

#### **Requirement Specific References**

#### 2.5 Cloud

Goal references: Foga et al., 2017; Skakun et al., 2022; Zhu & Woodcock, 2012; Zhu et al., 2015

- Foga, S., Scaramuzza, P.L., Guo, S., Zhu, Z., Dilley, R.D., Beckmann, T., Schmidt, G.L., Dwyer, J.L.,
  Hughes, M.J., & Laue, B., 2017. Cloud detection algorithm comparison and validation for operational Landsat data products. Remote Sens. Environ. 194, 379-390,
  <a href="https://doi.org/10.1016/j.rse.2017.03.026">https://doi.org/10.1016/j.rse.2017.03.026</a>.
- Skakun, S., Wevers, J., Brockmann, C., Doxani, G., Aleksandrov, M., ..., & Žust, L., 2022. Cloud Mask Intercomparison eXercise (CMIX): An evaluation of cloud masking algorithms for Landsat 8 and Sentinel-2, Remote Sens. Environ. 274, 112990, <u>https://doi.org/10.1016/j.rse.2022.112990</u>.

Zhu, Z. & Woodcock, C.E, 2012. Object-based cloud and cloud shadow detection in Landsat imagery. Remote Sens. Environ. 118, 83-94, <u>https://doi.org/10.1016/j.rse.2011.10.028</u>.

Zhu, Z., Wang, S., & Woodcock, C.E., 2015. Improvement and expansion of the Fmask algorithm: cloud, cloud shadow, and snow detection for Landsats 4-7, 8, and Sentinel 2 images. Remote Sens. Environ. 159, 269-277, <u>https://doi.org/10.1016/j.rse.2014.12.014</u>.

#### <u>2.7 Land</u>

Threshold references: Brockmann et al., 2015; Jones, 2019; Mikelsons et al., 2021; Pekel et al., 2016

Brockmann, C., Kirches, G., Militzer, J., & Stelzer, K., 2015. SENTINEL 3 – LAND-WATER MASK, Version 1.2. Technical Note S3\_LandWaterMask\_v1\_2.docx, Brockmann Consult GmbH, 14.08.2015.

Jones, J.W., 2019. Improved automated detection of subpixel-scale inundation - Revised Dynamic Surface Water Extent (DSWE) partial surface water tests. Remote Sens. 11(4), 374, https://doi.org/10.3390/rs11040374.

Mikelsons, K., Wang, M., Wang, X.L., & Jiang, L., 2021. Global land mask for satellite ocean color remote sensing. Remote Sens. Environ. 257, 112356, <u>https://doi.org/10.1016/j.rse.2021.112356</u>.

Pekel, J.-F., Cottam, A., Gorelick, N., & Belward, A.S., 2016. High-resolution mapping of global surface water and its long-term changes. Nature 540, 418-422, <u>https://doi.org/10.1038/nature20584</u>.

#### <u>2.8 lce</u>

Threshold references: Bourg, 2014; C-GLOPS-2, 2018; Dworak et al., 2021; Liu & Key, 2019; Liu et al., 2016; Robinson et al., 2003

Bourg, L., 2014. Sentinel-3 OLCI Level-0 and Level-1B ATBD. Algorithm Theoretical Basis Document S3-ACR-TN-007, Issue 5.0, ACRI, 10 December 2014. Accessed from: <u>https://sentinel.esa.int/documents/247904/2702575/Sentinel-3-OLCI-Level-0-and-1B-ATBD.pdf/4bdc</u> <u>6566-09ce-4604-b722-3ddec1beda8f?t=1595589452000</u> on 13. March 2025.

C-GLOPS-2, 2018. Lake Ice Extent (LIE) collection 250m Baltic Sea region, Version 1.0.1. Algorithm Theoretical Basis Document CGLOPS2\_QAR\_LIE-250m-V1.0.1, I1.03, Copernicus Global Land Service, 09.11.2018.

Dworak, R., Liu, Y., Key, J., & Meier, W.N., 2021. A blended sea ice concentration product from AMSR2 and VIIRS. Remote Sens. 13(15), 2982, <u>https://doi.org/10.3390/rs13152982</u>.

Liu, Y. & Key, J.R., 2019. Ice Surface Temperature, Ice Concentration, and Ice Cover, Version 1.2. Algorithm Theoretical Basis Document ATBD\_GOES-R\_IceConcentration\_v1.2\_Feb2019, NOAA NESDIS Center for Satellite Applications and Research, February 8, 2019.

Liu, Y., Key, J., & Mahoney, R., 2016. Sea and freshwater ice concentration from VIIRS on Suomi NPP and the future JPSS satellites. Remote Sens. 8(6), 523, <u>https://doi.org/10.3390/rs8060523</u>.

Robinson, W.D., Franz, B.A., Patt, F.S., Bailey, S.W., & Werdell, P.J., 2003. Masks and Flags Updates. Chapter 6 In: Patt, F.S., et al., 2003: Algorithm Updates for the Fourth SeaWiFS Data Reprocessing. NASA Tech. Memo. 2003--206892, Vol. 22, Hooker, S.B. & Firestone, E.R, Eds., NASA Goddard Space Flight Center, Greenbelt, Maryland.

#### 2.9 Sun Glint

Threshold references: Botha et al., 2016; Bourg, 2014; Kay et al., 2013

Botha, E.J., Brando, V.E., & Dekker, A.G., 2016. Effects of per-pixel variability on uncertainties in bathymetric retrievals from high-resolution satellite images. Remote Sens. 8(6), 459, <u>https://doi.org/10.3390/rs8060459</u>.

Bourg, L., 2014. Sentinel-3 OLCI Level-0 and Level-1B ATBD. Algorithm Theoretical Basis Document S3-ACR-TN-007, Issue 5.0, ACRI, 10 December 2014. Accessed from:

https://sentinel.esa.int/documents/247904/2702575/Sentinel-3-OLCI-Level-0-and-1B-ATBD.pdf/4bdc 6566-09ce-4604-b722-3ddec1beda8f?t=1595589452000 on 13. March 2025.

Kay, S., Hedley, J., & Lavender, S., 2013. Sun glint estimation in marine satellite images: a comparison of results from calculation and radiative transfer modeling. Appl. Opt. 52(23), 5631-5639, https://doi.org/10.1364/AO.52.005631.

Goal references: Colin, 2014

Colin, F.M., 2014. Glint Avoidance and Removal in the Maritime Environment. Thesis. Rochester Institute of Technology, accessed from <u>https://scholarworks.rit.edu/theses/8301/</u> on 27. September 2021.

2.10 Sky Glint

Goal references: Colin, 2014; Water-ForCE, 2022

Colin, F.M., 2014. Glint Avoidance and Removal in the Maritime Environment. Thesis. Rochester Institute of Technology, accessed from <u>https://scholarworks.rit.edu/theses/8301/</u> on 27. September 2021.

Water-ForCE, 2022. Atmospheric corrections Review document on inland waters atmospheric correction methods. Accessed from <a href="https://files.lobelia.earth/web-waterforce/d-9-23-atmospheric.pdf">https://files.lobelia.earth/web-waterforce/d-9-23-atmospheric.pdf</a> on 13. March 2025.

#### 2.12 Whitecap / Foam

Threshold references: Dierssen, 2019; Dierssen, 2021; EUMETSAT, 2021; Frouin et al., 2019; Koepke, 1984; Moore et al., 2000; Wang et al., 2017

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