

CEOS-ARD Aquatic Reflectance Product Family Specification Version 2.0

Summary of updates

In the effort to expand the Aquatic Reflectance PFS to cover the oceans, the team responsible has also considered some more fundamental aspects of the existing AR and Surface Reflectance PFS. Some changes have been agreed by this group as being sensible changes not only to the AR PFS, but the PFS more broadly. These changes are summarised below as a reference and input to the broader discussions on a combined optical PFS. Each of these will also be raised as an issue in the CEOS-ARD GitHub, to ensure these inputs are fully considered in future evolution of the CEOS-ARD specifications.

Editorial suggestions

- Throughout the PFS, 'accuracy' is changed to 'uncertainty' where applicable, to avoid confusion and incorrect use between the two terms.
- Addition of the following at the top of each metadata section: *"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."* This reduces the redundancy of the DOI landing page requirement in every metadata requirement.
- Redundant mentions of the term 'metadata' are removed from the data requirement specifications, given that the section titles specify it, e.g. 'General metadata' and 'Per-pixel metadata'.
- 'Target' requirement renamed to 'Goal'.
- Removed 'if possible' and 'when possible' throughout. Such language makes a specification mean less.
- 'Mask' vs 'Flag' nomenclature - Flag retains the pixel information and leaves the user to make a mask if they wish, so specification of 'Mask' was removed. Furthermore, 'flag' was removed from each associated metadata title, e.g. 'Cloud Mask' became 'Cloud,' for conciseness.

Definitions

Definitions section removed, instead referring to the [CEOS Terms and Definitions Wiki](#)

Justification: This section lies outside of the scope of the document, and it is more sustainable to refer to a single credible source.

General Metadata

1.0 Version of CEOS-ARD AR PFS Compliance Version

Addition of new metadata requirement to specify the CEOS-ARD PFS version to which the product complies.

Justification: It should be stated in the PFS what version is used in compliance with a CEOS-ARD product, such that a product's compliance can be tied to a specific PFS version. This would ensure that PFS updates do not invalidate compliance.

Threshold (Minimum) Requirements	Goal (Desired) Requirements
Version of the CEOS-ARD PFS with which the product is complying is identified.	As threshold.

1.1 Traceability

Update to Threshold requirement, removal of DOI landing page in parameter description

Justification: The aquatic reflectance measurement should be given in the appropriate and agreed units at the threshold level. SI traceability is reserved as a goal requirement.

Old requirement		Updated requirement	
Threshold (Minimum) Requirements	Goal (Desired) Requirements	Threshold (Minimum) Requirements	Goal (Desired) Requirements
Not required.	Data must be traceable to SI reference standard. Note 1: Relationship to 3.2. Traceability requires an estimate of measurement uncertainty. Note 2: Information on traceability should be available in the metadata as a single DOI landing page.	Aquatic Reflectance (dimensionless) or the Remote Sensing Reflectance (sr-1) of the water bodies ($AR = \pi \cdot R_{rs}$) is given.	Data must be traceable to SI reference standard. <i>Note: Relationship to 3.2. Traceability requires an estimate of measurement uncertainty.</i>

1.3 Data Collection Time

Suggest that the requirement be updated to specifically require identification of a beginning and end of a data collection time period, expressed in the ISO 8601 format. The goal requirement calls for the provision of additional information to allow derivation of when the individual observation/sample was taken.

Justification: The ISO 8601 format is an internationally recognised and unambiguous date/time format, so using it across PFSs would aid in establishing consistency.

Old requirement		Updated requirement	
Threshold (Minimum) Requirements	Goal (Desired) Requirements	Threshold (Minimum) Requirements	Goal (Desired) Requirements
The data collection time is identified in the metadata, expressed in date/time, to the second, with the time offset from UTC unambiguously identified.	Acquisition time for each pixel is identified (or can be reliably determined) in the metadata, expressed in date/time at UTC, to the second.	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.

1.8 Geometric Uncertainty of the Data

Removal of the second half of the final sentence of the Goal description.

Justification: Reduction in stringency of error specification across different sensors.

Old requirement		Updated requirement	
Geometric Accuracy of the Data		Geometric Uncertainty of the Data	
Threshold (Minimum) Requirements	Goal (Desired) Requirements	Threshold (Minimum) Requirements	Goal (Desired) Requirements
Not required. The user is not provided with results of geometric accuracy assessments pertaining to the dataset.	The metadata includes metrics describing the assessed geodetic accuracy of the data, expressed units of the coordinate system of the data. Accuracy is assessed by independent verification (as well as internal model-fit where applicable). Uncertainties are expressed quantitatively, for example, as root mean square error (RMSE) or Circular Error Probability (CEP90, CEP95), etc. Note 1: Information on geometric accuracy of	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.

	the data should be available in the metadata as a single DOI landing page.		
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1.9 Instrument

Requirement should make clearer reference to the CEOS MIM database.

Justification: Requirement description had unnecessary ‘metadata’ mentions, and a DOI landing page is not strictly required. MIM database reference clarified.

Old requirement		Updated requirement	
Threshold (Minimum) Requirements	Goal (Desired) Requirements	Threshold (Minimum) Requirements	Goal (Desired) Requirements
The instrument used to collect the data is identified in the metadata.	As threshold, but information should be available in the metadata as a single DOI landing page with references to the relevant CEOS Missions, Instruments, and Measurements Database record.	The instrument used to collect the data is identified.	As threshold, with references to the relevant “ <i>CEOS Missions, Instruments, and Measurements Database</i> ” record. (database.eohandbook.com)

1.10 Spectral Bands

Suggest making the provision of spectral response functions a threshold requirement.

Justification: Spectral band plus FWHM is not sufficient for ocean sensors. Need a spectral response function.

Old requirement		Updated requirement	
Threshold (Minimum) Requirements	Goal (Desired) Requirements	Threshold (Minimum) Requirements	Goal (Desired) Requirements
The central wavelength and full width at half maximum for each spectral band for which data is included is identified in the metadata, expressed in SI units.	As threshold, with instrument spectral response details (e.g., full spectral response function) also included or directly accessible using details in the metadata. Note 1: Information on spectral bands should be available in the	Full spectral response function is provided.	As threshold.

	metadata as a single DOI landing page.		
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1.11 Sensor Calibration

Updated Threshold and Goal descriptions, addition of “including history of onboard calibrations where available.”

Justification: Updated for clarity and conciseness, making requirement for sensor calibration details explicit.

Old requirement		Updated requirement	
Threshold (Minimum) Requirements	Goal (Desired) Requirements	Threshold (Minimum) Requirements	Goal (Desired) Requirements
Not required. The general metadata does not include sensor calibration details.	Sensor calibration parameters are identified in the metadata or can be accessed using details included in the metadata. Ideally this would support machine-to-machine access. Note 1: Information on sensor calibration should be available in the metadata as a single DOI landing page.	Binary description of calibrated / not calibrated only.	Specification of sensor calibration parameters including history of onboard calibrations where available.

1.12 Radiometric Uncertainty

Requirement name changed from ‘Radiometric Accuracy’ to ‘Measurand Radiometric Uncertainty’. Accuracy requires knowledge of the true value. The metadata requirement was split into two components, Radiometric Uncertainty and Radiometric Accuracy.

Justification: If we want an aquatic or remote sensing reflectance, radiometric uncertainty needs to be specified. Flexibility is given to providers by making ‘absolute’ uncertainty a Goal requirement.

Old requirement		Updated requirement	
Radiometric Accuracy		Measurand Radiometric Uncertainty	
Threshold (Minimum) Requirements	Goal (Desired) Requirements	Threshold (Minimum) Requirements	Goal (Desired) Requirements

The metadata provides the number of bits required (e.g., 8, 10, 12, 14, 16, etc.).	<p>The metadata includes metrics describing the assessed absolute radiometric uncertainty of the version of the data or product, expressed as absolute radiometric uncertainty relative to appropriate, known reference sites and standards (for example, pseudo-invariant calibration sites, rigorously collected field spectra, PICS, Rayleigh, DCC, etc.)</p> <p>Note 1: Information on radiometric accuracy should be available in the metadata as a single DOI landing page.</p>	Metrics describing the assessed radiometric uncertainty of the version of the data or product are provided. Method of determination of radiometric uncertainty is specified.	As threshold, but the absolute radiometric uncertainty of the data is provided.
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1.12a Radiometric Encoding

Suggest addition of a new data requirement. This replaces the requirement for the number of bits in 1.12 Radiometric Uncertainty, which is not necessarily related to bit depth.

Justification: The range and bit depth together yield the radiometric theoretical resolution which could define a minimum resolution outside without creating requirements on data quality. So the range and bit depth are required but don't fit in Radiometric Uncertainty, so a new requirement 'Radiometric Encoding' was created.

Threshold (Minimum) Requirements	Goal (Desired) Requirements
Range and bit depth are provided.	As threshold.

1.13 Algorithms

Requirement descriptions simplified, and the previous goal requirement is now a threshold requirement.

Justification: The openness of an algorithm is not the ultimate requirement for ARD. Checking the validity and traceability of an algorithm is important to evidence that it works and adheres to standards. A source does not need to be peer reviewed, only identified. The requirement would be satisfied as long as the algorithm is published and validated.

Old requirement		Updated requirement	
Threshold (Minimum) Requirements	Goal (Desired) Requirements	Threshold (Minimum) Requirements	Goal (Desired) Requirements
<p>All algorithms, and the sequence in which they were applied in the generation process, are identified in the metadata. For example, these may be available through Algorithm Theoretical Basis documents.</p> <p>Note 1: Information on algorithms should be available in the metadata as a single DOI landing page.</p>	<p>As threshold, but only algorithms that have been published in a peer-reviewed journal.</p> <p>Note 1: It is possible that high-quality corrections are applied through non-disclosed processes. CARD4L does not per-se require full and open data and methods.</p> <p>Note 2: Information on algorithms should be available in the metadata as a single DOI landing page.</p>	<p>All algorithms and the sequence in which they were applied in the generation process are identified.</p> <p>Algorithms must be published and validated, and a description of the validation process is included.</p> <p><i>Note: It is possible that corrections are applied through non-disclosed processes. CEOS-ARD does not require full and open data and methods.</i></p>	<p>As threshold.</p>

1.14 Auxiliary Data

Removal of DOI landing page requirements

Justification: Redundant DOI landing page requirements added to to the top of each metadata section.

Old requirement		Updated requirement	
Threshold (Minimum) Requirements	Goal (Desired) Requirements	Threshold (Minimum) Requirements	Goal (Desired) Requirements
<p>The metadata identifies the sources of auxiliary data used in the generation process, ideally expressed as a single DOI landing page.</p> <p>Note 1: Auxiliary data includes DEMs, aerosols, land mask,</p>	<p>As threshold, but information on auxiliary data should be available in the metadata as a single DOI landing page and is also available for free online download, contemporaneously with the product or</p>	<p>Lists the sources of auxiliary data used in the generation process.</p>	<p>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.</p>

bathymetry, NO2, etc. data sources.	through a link to the source.		
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1.17 Valid Pixels

‘Overall Data Quality’ renamed to ‘Valid Pixels’ and simplified.

Justification: Simplified for conciseness, and removed ‘machine readable’ from description as we already have a dedicated metadata requirement related to machine readability (1.2).

Old requirement		Updated requirement	
Overall Data Quality		Valid Pixels	
Threshold (Minimum) Requirements	Goal (Desired) Requirements	Threshold (Minimum) Requirements	Goal (Desired) Requirements
Machine-readable metrics describing the overall quality of the data are included in the metadata, at minimum the cloud cover extent, i.e.: <ul style="list-style-type: none"> Proportion of observations over land and over water affected by non-target phenomena, e.g., cloud and cloud shadows. 	As threshold.	Percentage of valid pixels based upon the applied masks from Section 2 (per-pixel metadata).	As threshold.

Per-Pixel Metadata

2.4 Saturation

Threshold requirement description updated to better define saturation in terms of a level 1 product. ‘As threshold’ was introduced to the Goal requirement, and grammatical edits were made alongside the removal of irrelevant ‘metadata’ mentions.

Justification: The initial requirement did not define what constituted the saturation of a spectral band, introducing uncertainty to compliance conditions.

Old requirement	Updated requirement
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Threshold (Minimum) Requirements	Goal (Desired) Requirements	Threshold (Minimum) Requirements	Goal (Desired) Requirements
Metadata indicates where one or more spectral bands are saturated.	Metadata indicates which pixels are saturated for each spectral band.	Specification of whether there is pixel saturation at Level 1 in one or more spectral bands.	As threshold, with specification of which pixels are saturated for each spectral band.

2.5 Cloud

Threshold description updated to 'cloud or cloud-affected,' Goal description simplified.

Justification: Redundant DOI landing page information removed from Goal requirement.

Identification of cloud-affected pixels are important to specify. This also applies to ice and cloud shadow affected pixels.

Old requirement		Updated requirement	
Threshold (Minimum) Requirements	Goal (Desired) Requirements	Threshold (Minimum) Requirements	Goal (Desired) Requirements
Metadata indicates whether a pixel is assessed as being cloud.	As threshold, information on cloud detection should be available in the metadata as a single DOI landing page along with the confidence in this assessment. Clouds and cirrus clouds are differentiated.	Specification of whether a pixel is cloud or cloud-affected.	As threshold, but clouds and cirrus clouds are differentiated.

2.6 Cloud Shadow

Threshold description updated to 'cloud shadow or cloud shadow-affected,' Goal description simplified.

Justification: Redundant DOI landing page information removed from Goal requirement.

Identification of cloud shadow-affected pixels are important to specify.

Old requirement		Updated requirement	
Threshold (Minimum) Requirements	Goal (Desired) Requirements	Threshold (Minimum) Requirements	Goal (Desired) Requirements
Metadata indicates whether a pixel is	As threshold, but information on cloud shadow detection	Specification of whether a pixel is cloud shadow or	As threshold.

assessed as being cloud shadow.	should be available in the metadata as a single DOI landing page.	cloud shadow-affected.	
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2.7 Land

Parameter title shortened, Threshold requirement updated to define pixels less than 100% water covered due to land.

Justification: Addresses ambiguity of what classifies a ‘water pixel’ without discounting pixels affected not by land but by surface scum ect.

Old requirement		Updated requirement	
Land/Water Mask		Land	
Threshold (Minimum) Requirements	Goal (Desired) Requirements	Threshold (Minimum) Requirements	Goal (Desired) Requirements
The metadata indicates whether a pixel is assessed as being land or water. Information on land/water mask should be available in the metadata as a single DOI landing page.	As threshold.	Specification of whether a pixel is less than 100% water covered due to land.	As threshold.

2.8 Ice

‘Sea/Lake/River Ice Mask’ changed to ‘Ice’, removing dependency of ice classification at the threshold and goal level.

Justification: Differentiating ice by location is not necessary and too strict for a threshold or goal requirement. In terms of ARD, we want to know at threshold a binary ‘ice’ or ‘no ice’ indication.

This change also touches on the notion that the PFS should not use ‘if possible’ statements in their requirements, which blurs the line of compliance. It is left up to the data provider to decide the degree to which a pixel is considered ice-affected. Information on the ice mask definition shall be available in the metadata as a single DOI landing page.

Old requirement	Updated requirement
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2.9 Sun Glint

'Absent' changed to 'negligible', and the addition of 'spectral' in the Goal description. Also added a link to the respective correction in section 3.

Justification: Updated terminology for clarity and conciseness.

Old requirement		Updated requirement	
Threshold (Minimum) Requirements	Goal (Desired) Requirements	Threshold (Minimum) Requirements	Goal (Desired) Requirements
The metadata indicates whether a pixel is assessed as absent or correctable (moderate), or uncorrectable (severe) Sun glint. Note 1: Sun glint is deemed uncorrectable if the upper limit of the dynamic range of a sensor is reached (i.e., saturation occurs).	The metadata indicates the amount of Sun glint for each pixel and band.	Specification of whether sun glint in a pixel is negligible, correctable (moderate), or uncorrectable (severe). <i>Note: Sun glint is deemed uncorrectable if the upper limit of the dynamic range of a sensor is reached (i.e., saturation occurs).</i>	Specification of the amount of sun glint for each pixel and spectral band. <i>Note: An additional product must be provided to specify the amount.</i> <i>Note 2: (See Correction 3.8)</i>

2.12 Whitecap / Foam

Both the Threshold and Goal requirements were updated for the Whitecap / Foam Mask metadata requirement, making it not required at the threshold level. The phrasing at the Goal level was refined.

Justification: The previous requirement for whitecap/foam was not in line with the approach typically taken by ocean colour algorithms, in which coarse resolution systems apply corrections on an assumption basis. High resolution systems with the ability to delineate foam per-pixel can do so at the Goal level, as long as they provide the applied method.

Old requirement		Updated requirement	
Threshold (Minimum) Requirements	Goal (Desired) Requirements	Threshold (Minimum) Requirements	Goal (Desired) Requirements
The metadata indicates whether a pixel is assessed as affected by whitecaps or foam as a function of the wind speed or other.	As threshold.	Not required.	Specification of whether a pixel is affected by whitecaps or foam. If affected, detail the method applied. <i>Note: (see Correction 3.10)</i>

2.13 Aerosol Optical Depth Parameters

Threshold and Goal requirements switched

Justification: Not necessary at the Threshold level.

Old requirement		Updated requirement	
Threshold (Minimum) Requirements	Goal (Desired) Requirements	Threshold (Minimum) Requirements	Goal (Desired) Requirements
The metadata indicates either per-pixel spectral Aerosol Optical Depth (AOD), or per-pixel AOD (550nm) and Angstrom exponent.	As threshold.	Not required.	Either per-pixel spectral AOD or per-pixel AOD (550 nm) and Angstrom exponent are provided. <i>Note: This might be an input or an output parameter.</i>

2.14 Adjacency Effects

Updated Goal requirement to lessen the requirement for adjacency effects details provision

Justification: The inclusion of minimum, medium, and high AE contamination is subjective. If the amount of AE correction is given it can also be uncorrected for any data provider with their own "better" method.

Old requirement		Updated requirement	
Threshold (Minimum) Requirements	Goal (Desired) Requirements	Threshold (Minimum) Requirements	Goal (Desired) Requirements
Not required.	<p>The metadata provides the risk of per-pixel adjacency effects contamination, through flagging to denote per-pixel minimum, medium or high adjacency effects contamination.</p> <p><i>Note 1: This effect often occurs in increased turbid or optically shallow waters near shorelines that may confuse this assessment.</i></p>	Not required.	<p>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.</p> <p><i>Note: An additional product must be provided to specify the amount.</i></p>

2.16 Bathymetry

The previous metadata requirement 2.16 'Deep / Shallow Water' was replaced by 'Bathymetry', along with a corresponding Goal requirement description.

Justification: A binary flag of deep / shallow water is not necessary, and any definition would be subjective. A coarse bathymetry measurement would be a better tool for users. Open ocean data without bathymetry are accounted for this being solely a goal requirement.

Old requirement		Updated requirement	
Deep/ Shallow Water		Bathymetry	
Threshold (Minimum) Requirements	Goal (Desired) Requirements	Threshold (Minimum) Requirements	Goal (Desired) Requirements

Not required.	The metadata indicates where available: the bottom depth referenced to the mean sea level for the oceans and referenced to mean levels for lakes. Information on bathymetry should be available in the metadata as a single DOI landing page.	Not required.	Water surface to bottom substratum depth (i.e., water column depth) at the specific pixel location is specified. <i>Note 1: Specify whether a recalculation to a mean sea level has taken place for oceanic waters.</i> <i>Note 2: Specify whether a recalculation to a mean water surface level has taken place for any non-oceanic waters.</i>
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2.17 Optically Deep or Optically Shallow Assessment

The threshold requirement was simplified and made stricter, requiring providers to state optically deep or shallow, along with any assumptions made, if any. The goal requirement was reduced to provision of a mask.

Justification: The previous requirement specified the goal requirement only by inversion modelling, and the threshold requirement was not stringent enough considering the importance of knowing whether water is classified as optically deep or shallow.

Old requirement		Updated requirement	
Threshold (Minimum) Requirements	Goal (Desired) Requirements	Threshold (Minimum) Requirements	Goal (Desired) Requirements
The metadata indicates, based on likelihood (bathymetry maps and average K _d (preferred) or based on turbidity or Secchi disk transparency), whether water pixels may be optically deep or optically shallow. This will most likely be bathymetry map contour based.	Based on an assessment from an inversion algorithm that estimates the optically deep or optically shallow per-pixel status.	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 or shallow waters is provided.

2.18 Optical Water Type

Addition of a new metadata requirement 'Optical Water Type,'

Justification: A dedicated requirement for water type information would benefit users given the increasing use of water typing for algorithm blending and relevance for global products.

New requirement	
Threshold (Minimum) Requirements	Goal (Desired) Requirements
Specification of optical water type, when applicable (for optically deep waters).	As threshold.

2.19 Bidirectional Reflectance Distribution Function Applied

The BRDF metadata requirements were removed, and will be factored into 3.3 Measurement Normalisation.

Justification: Removing the BRDF requirement places the Aquatic Reflectance PFS more in line with the other PFS documents.

Old requirement	
Threshold (Minimum) Requirements	Goal (Desired) Requirements
The metadata indicates, based on likelihood (bathymetry maps and average Kd (preferred) or based on turbidity or Secchi disk transparency), whether water pixels may be optically deep or optically shallow. This will most likely be bathymetry map contour based.	Based on an assessment from an inversion algorithm that estimates the optically deep or optically shallow per-pixel status.

2.20 Elevation

This was renamed 'Elevation' - previously Altitude

~~Radiometric and Atmospheric Corrections Metadata Products and Algorithms~~

3.1 Measurement

Simplified descriptions, referencing 1.1 and 3.3

Justification: See 1.1 Traceability

Old requirement		Updated requirement	
Threshold (Minimum) Requirements	Goal (Desired) Requirements	Threshold (Minimum) Requirements	Goal (Desired) Requirements

Pixel values are expressed as a measurement of the Aquatic Reflectance ($AR = \pi \cdot R_{rs}$) or the Remote Sensing Reflectance (sr^{-1}) of the water bodies. This is a dimensionless value.	Aquatic Reflectance or Remote Sensing Reflectance measurements are SI traceable (see also 1.1).	Pixel values that are expressed as a measurement of the Aquatic Reflectance (dimensionless) or the Remote Sensing Reflectance (sr^{-1}) of the water bodies ($AR = \pi \cdot R_{rs}$).	As threshold. <i>Note: (see also 1.1 and 3.3).</i>
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3.3 Measurement Normalisation

Goal requirement updated, nadir normalisation added, removal of DOI landing page specification.

Justification: reduce implicitness, simplification

Old requirement		Updated requirement	
Threshold (Minimum) Requirements	Goal (Desired) Requirements	Threshold (Minimum) Requirements	Goal (Desired) Requirements
Not required.	Measurements are normalised for solar and viewing conditions, including BRDF correction (see also 3.14). Note 1: Information on measurement normalisation should be available in the metadata as single DOI landing page.	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 Correction

The 'Atmospheric Reflectance Correction' parameter was renamed 'Directional Atmospheric Scattering'.

Justification: The existing parameter title was too broad as it applied to ozone, water vapour, and other trace gases, which are necessary as standalone metadata requirements. This is also more in line with the surface reflectance PFS.

Old requirement		Updated requirement	
Atmospheric Reflectance Correction		Directional Atmospheric Scattering	
Threshold (Minimum) Requirements	Goal (Desired) Requirements	Threshold (Minimum) Requirements	Goal (Desired) Requirements

Metadata indicates corrections are applied for molecular (Rayleigh) scattering and aerosol scattering and absorption. Metadata contains a single DOI landing page with references to a citable peer-reviewed algorithm, technical documentation regarding the implementation of that algorithm and the sources of ancillary data used to make corrections. Note 1: Examples of technical documentation include an Algorithm Theoretical Basis Document, product user guide, etc.	As threshold.	Specification of corrections applied for molecular (Rayleigh) scattering and aerosol scattering and absorption.	As threshold.
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3.7 Other Gaseous Absorption Corrections

‘Trace’ was removed from the metadata requirement title, requirement was changed to Goal only and simplified.

Justification: Corrections for the absorption of ozone and water vapour should be threshold requirements, and any other gaseous absorption correction should be Goal requirements.

Old requirement		Updated requirement	
Other Trace Gaseous Absorption Corrections		Other Gaseous Absorption Corrections	
Threshold (Minimum) Requirements	Goal (Desired) Requirements	Threshold (Minimum) Requirements	Goal (Desired) Requirements
Data is corrected for other trace gaseous absorption if spectral bands are affected. Relevant metadata must be provided under 1.8 and 1.9. Metadata contains a single DOI landing page with references to a citable peer-reviewed algorithm, technical documentation regarding the implementation of the other trace gaseous	As threshold.	Not required.	Data is corrected for other trace gaseous absorption for affected spectral bands. <i>Note: Relevant metadata must be provided under 1.8 and 1.9.</i>

absorption correction algorithm.			
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3.8 Sun Glint Correction

Goal requirement simplified

Justification: Simplification, removal of redundant 'metadata.'

Old requirement		Updated requirement	
Other Trace Gaseous Absorption Corrections		Other Gaseous Absorption Corrections	
Threshold (Minimum) Requirements	Goal (Desired) Requirements	Threshold (Minimum) Requirements	Goal (Desired) Requirements
Not required.	The metadata indicates the surface contributions from Sun glint removed from the data if a pixel is assessed as being of correctable (moderate) Sun glint.	Not required.	Sun glint is removed from the data if a pixel is of correctable (not radiometrically saturating) Sun glint. <i>Note 1: Sun glint removal methods can only partially remove sun glint from a pixel. Over or under correction may occur.</i> <i>Note 2: (see Flag 2.9)</i>

3.10 Whitecap / Foam Correction

The Goal requirement was updated to specify a per-pixel correction.

Justification: The new requirements accounts for coarse resolution corrections at the Threshold level, and per-pixel corrections at the Goal level.

Old requirement		Updated requirement	
Threshold (Minimum) Requirements	Goal (Desired) Requirements	Threshold (Minimum) Requirements	Goal (Desired) Requirements
The water leaving reflectance or radiance is corrected for the contribution from surface whitecaps and foam if a pixel is assessed as	As threshold.	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. <i>Note: (see Flag 2.12)</i>

affected by whitecaps or foam.			
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3.11 Adjacency Effects Correction

Goal description updates

Justification: Simplification, more detail is provided in 2.13

Old requirement		Updated requirement	
Threshold (Minimum) Requirements	Goal (Desired) Requirements	Threshold (Minimum) Requirements	Goal (Desired) Requirements
Not required.	Information on adjacency effects correction (for example, citable peer-reviewed algorithm approach, technical documentation of the implementation, sources of ancillary data) should be available in the metadata as a single DOI landing page.	Not required.	The data are corrected for adjacency effects.

3.12 Floating Vegetation/Surface Scum Correction

Metadata requirement for floating vegetation was removed.

Justification: Scum cannot be corrected for, just as for ice or ice-affected pixels.

Old requirement	
Threshold (Minimum) Requirements	Goal (Desired) Requirements
The metadata indicates whether a pixel has been corrected for floating vegetation/surface scum or not. In that case information on floating vegetation/surface scum water mask should be available in the metadata as a single DOI landing page.	As threshold.

3.14 Bidirectional Reflectance Distribution Function Correction

The BRDF metadata requirements were removed, and will be factored into 3.3 Measurement Normalisation. Whether BRDF becomes a requirement or suggestion is in discussion,

Justification: Removing the BRDF requirement places the Aquatic Reflectance PFS more in line with the other PFS documents.

Old requirement	
Threshold (Minimum) Requirements	Goal (Desired) Requirements
Not required.	Data is corrected for BRDF effects (see also 3.3.).

Geometric Corrections Metadata (Co-Registration and Ortho-Rectification)

Addition of (Co-Registration and Ortho-Rectification) to the section title

4.1 Geometric Correction

Split of previous requirement 4.1 into '4.1 Geometric Correction for land, and Geometric Correction for inland waters where an independent terrestrial referencing system is available;' for coastal and ocean waters where no terrestrial referencing system is available, 4.2 'Co-registration and Ortho rectification' applies.

Old requirement	
Threshold (Minimum) Requirements	Goal (Desired) Requirements
Sub-pixel accuracy is achieved in <u>relative</u> geolocation, that is, the pixels from the same instrument and platform are consistently located, and are thus comparable, through time.	Sub-pixel accuracy is achieved relative to an identified absolute independent terrestrial referencing system (such as a national map grid). A consistent gridding/sampling frame is necessary to meet this requirement.

<p>Sub-pixel accuracy 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.</p> <p>A consistent gridding/sampling frame is used, including common cell size, origin, and nominal sample point location within the cell (centre, ll, ur).</p> <p>Relevant metadata must be provided under 1.8 and 1.9.</p> <p><i>Note 1: 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.</i></p>	<p>Relevant metadata must be provided under 1.8 and 1.9.</p> <p><i>Note 1: 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.</i></p>
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Updated Requirements

4.1 Geometric Correction

Threshold (Minimum) Requirements	Goal (Desired) Requirements
<p>Sub-pixel uncertainty is achieved in <u>relative</u> geolocation, that is, the pixels from the same instrument and platform are consistently located, and are thus comparable, through time.</p> <p>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.</p> <p>A consistent gridding / sampling frame is used, including common cell size, origin, and nominal sample point location within the cell (centre, ll, ur).</p> <p>Relevant metadata must be provided under 1.8 and 1.9.</p> <p><i>Note 1: 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.</i></p> <p><i>Note 2: It is useful to note if the sensor is used at its native resolution before geometric correction or that some resampling has to be done.</i></p>	<p>Sub-pixel uncertainty is achieved relative to an identified absolute independent terrestrial referencing system (such as a national map grid).</p> <p>Relevant metadata must be provided under 1.8 and 1.9.</p> <p><i>Note: 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.</i></p>

4.2 Co-Registration and Ortho rectification

Threshold (Minimum) Requirements	Goal (Desired) Requirements
<p>Co-registration is performed to ensure consistency of pixel location in each spectral band of one image at 0.5 GSD.</p> <p>Ortho rectification specifies the pointing accuracy related to a geographic reference grid. The associated uncertainty is pixel size dependent and therefore cannot be given an a priori measure of uncertainty.</p> <p>The specifications of the co-registration and ortho-rectification processing (including parameterisation data) must be provided, including the estimated uncertainty of each processing, in publicly available documentation.</p> <p><i><u>Note:</u> Including but not limited to ocean-to-sea to coastal, estuarine, deltaic, lagoonal waters and inland water bodies such as canals, rivers, lakes and reservoirs.</i></p>	<p>Co-registration is performed to ensure consistency of pixel location in each spectral band of one image at 0.2 GSD.</p> <p>Ortho rectification specifies the pointing accuracy related to a geographic reference grid. The associated uncertainty is pixel size dependent and therefore cannot be given an a priori measure of uncertainty.</p> <p>The specifications of the co-registration and ortho-rectification processing (including parameterisation data) must be provided, including the estimated uncertainty of each processing, in publicly available documentation.</p>

References section:

The decision to update the next PFS version with a revised references section organised by parameter number. A number of up-to-date references were provided for each metadata requirement.