Committee on Earth Observation Satellites	**Analysis Ready Data *For Land***	**Product Family Specification Aquatic Reflectance (CARD4L-AR)**

Document Status

Product Family Specification, Aquatic Reflectance

This Specification should next be reviewed on: March 2021, or no later than 2 weeks before LSI-VC-10 meeting.

Proposed revisions may be provided to: lsi@lists.ceos.org

Document History

Version	Date	Description of Change	Author
1.0	30.10.2020	Initial draft	*Barnes*
1.1.	4 Feb 2021	Edits	*Arnold Dekker (SatDek) reconciling edits by Barbara Bulgarelli (JRC-EC), and Carsten Brockmann (Brockmann Consulting)*
1.2	23 Feb 2021	Edits (sent to A. Dekker 20 to 23 Feb 2021)	*Daniela Gurlin (Wisconsin DNR), Joseph D. Ortiz (Kent State), Igor Ogashawara (IGB Berlin) and Anthony Vodacek (RIT); Barbara Bulgarelli (JRC-EC), Nima Pahlevan (NASA), Liesbeth de Keukelare (VITO)- ingested and reconciled by Arnold Dekker(SatDek) on 23 Feb 2021*
1.3	28 Feb 2021	Final version after edits by Water-ForCE and GEO-AW subgroup on adjacency, sun glint, sky glint etc.	*Joseph D. Ortiz (Kent State), Anthony Vodacek (RIT); Barbara Bulgarelli (JRC-EC), Liesbeth de Keukelare & Ils Reusen (VITO), Steef Peters (WaterInsight), Claudia Giardino (CNR), Tiit Kutser (WaterForCE),), Igor Ogashawara (IGB Berlin), Carsten Brockmann (Brockmann Consulting) ingested and reconciled by Arnold Dekker(SatDek) on 28 Feb 2021.*
1.4	29 April	Final version after discussion C.	*Arnold Dekker (SatDek) on 29 April*

	2021	with C. Barnes and A.G. Dekker	*2021.*

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Description

Product Family Title: Aquatic Reflectance (CARD4L-AR)

Applies to: Data collected with multispectral and hyperspectral sensors operating in the VIS/NIR/SWIR wavelengths over water bodies. These typically operate with ground sample distance and resolution in the order of 10-1000 m however the specification is not inherently limited to this resolution.

Definitions

AR	Aquatic Reflectance
Ancillary Data	Data other than instrument measurements, originating in the instrument itself or from the satellite, required to perform processing of the data. They include orbit data, attitude data, time information, spacecraft engineering data, calibration data, data quality information, and data from other instruments.
Auxiliary Data	The data required for instrument processing, which does not originate in the instrument itself or from the satellite. Some auxiliary data will be generated in the ground segment, whilst other data will be provided from external sources.
Metadata	Structured information that describes other information or information services. With well-defined metadata, users should be able to get basic information about data, without the need to have knowledge about its entire content.
MTF	Modulation Transfer Function
Spectral Resolution	Defines the narrowest spectral feature that can be resolved by a spectrometer.
Spatial Resolution	The highest magnification of the sensor at the ground surface.
Spectral Sampling Distance	Spectral sampling is the interval, in wavelength units, between discrete data points in the measured spectrum.
Spatial Sampling Distance	Spatial sampling distance is the barycentre-to-barycentre distance between adjacent spatial samples on the Earth's surface.

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 overall suitability of the dataset, and must meet the following requirements:

#	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements	Threshold Self-Assessment	Target Self-Assessment	Self-Assessment Explanation/ Justification	Comments
1.1	**Traceability**	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.*				
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 accordance with a community endorsed standard that facilitates machine-readability, such as ISO 19115-2.				
1.3	**Data Collection Time**	The product 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.				
1.4	**Geographical Area**	The surface location to which the data relates is identified, typically as a series of four corner	The geographic area covered by the observations is identified specifically, such as through a set of coordinates of				

		points, expressed in an accepted coordinate reference system (e.g., WGS84).	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 metadata lists the coordinate reference system– if any - that has been used. Satellite coordinates are acceptable.	As threshold.				
1.6	**Map Projection**	The metadata lists the map projection that has been used and any relevant parameters required in relation to use of data in that map projection.	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 methods should be available in the metadata as a single DOI landing page, including reference database and auxiliary data such as elevation model(s) and reference chip-sets.				
1.8	**Geometric Accuracy of the Data**	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 the data should be available in the metadata as a single DOI landing page.*				
1.9	**Instrument**	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.				
1.10	**Spectral Bands**	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. Central wavelength and bandwidth at full-width half maximum value of the relative spectral response function are provided at least. *Note 1: Information on spectral bands should be available in the metadata as a single DOI landing page.*				
1.11	**Sensor Calibration**	Not required. The general metadata does not include sensor calibration details. However, it is essential to know if the sensor has been calibrated (Yes/No).	Sensor calibration parameters are applied and 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.				
1.12	**Radiometric Accuracy**	Not required. But the number of bits is required (e.g. 8, 10, 12, 14, 16 etc.)	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.) *Note 1: Information on radiometric accuracy should be available in the metadata as a single DOI landing page.*				
1.13	**Algorithms**	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. *Note 1: Information on algorithms should be available in the metadata as a single DOI landing page.*	As threshold, but only algorithms that have been published in a peer-reviewed journal. *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.* *Note 2: Information on algorithms should be available in the metadata as a single DOI landing page.*				
1.14	**Auxiliary Data**	The metadata identifies the sources of auxiliary data used in the generation process,	As threshold, but information on auxiliary data should be available in the metadata as a single DOI landing page and is				

		ideally expressed as a single DOI landing page. *Note 1: Ancillary data includes DEMs, aerosols, land mask, bathymetry, NO2, etc. data sources.*	also 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 in the metadata as a single DOI landing page containing 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 referenced in the metadata.	As threshold.				
1.17	**Overall Data Quality**	Machine-readable metrics describing the overall quality of the data are included in the metadata, at minimum the pixels containing water information i.e.: • Proportion of observations over land (c.f. water) affected by non-target phenomena, e.g., cloud and cloud shadows.	As threshold.				

Per-Pixel Metadata

The following minimum metadata specifications apply to each pixel. Whether the metadata are 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 discriminate between (choose) observations on the basis of their individual suitability for application.

#	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements	Threshold Self-Assessment	Target Self-Assessment	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 observation/below noise floor') are flagged.	As threshold.				
2.3	**Per-pixel Assessment**	The metadata identifies pixels for which the per-pixel tests (below) have not all been successfully completed. *Note 1: This may be the result of missing ancillary data for a subset of the pixels.*	The metadata identifies which tests have, and have not, been successfully completed for each pixel.				
2.4	**Saturation**	Metadata indicates where one or more spectral bands are below detection level, or over-saturated.	Metadata indicates where each pixel is below detection level, or over-saturated.				
2.5	**Cloud**	Metadata indicates whether a pixel is flagged as being cloud by the	As threshold, information on cloud detection should be available in the metadata as				

		atmospheric correction algorithm.	a single DOI landing page along with the confidence in this assessment. Cloud and cirrus clouds are differentiated, if possible. Clouds and cirrus clouds are differentiated if possible.				
2.6	**Cloud Shadow**	Metadata indicates whether a pixel is assessed as being cloud shadow.	As threshold, but information on cloud shadow detection should be available in the metadata as a single DOI landing page.				
2.7	**Land/Water Mask**	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 but information on mixels handling is included. Mixels can be identified based on spectral, spatial and radiometric criteria. Provide mixel selection criterion or criteria. If available, provide % of land and % of water per pixel.				
2.8	**Sea/Lake/River Ice Mask**	The metadata indicates whether a pixel is assessed as being sea/lake/river ice or not. Information on snow/ice mask should be available in the metadata as a single DOI landing page.	As threshold.				
2.9	**Sun Glint**	The metadata indicates whether a pixel is assessed as of negligible (low), correctable (medium), or uncorrectable (strong) sun glint.	The metadata indicates the amount of sun glint and the associated uncertainty in percent is provided for each pixel.				
2.10	**Sky Glint Mask**	Per pixel amount of sky glint.	As threshold.				

2.11	**Whitecap/ Foam Mask**	The metadata indicates whether a pixel is assessed as affected by whitecaps or foam as a function of the wind speed.	As threshold.				
2.12	**Solar and Viewing Geometry**	The metadata provides average solar and sensor viewing azimuth and zenith angles.	As threshold.				
2.13	**Adjacency Effects**	When available provide risk of per-pixel adjacency effects contamination, through flagging to denote per-pixel minimum – medium – high adjacency effects contamination. *Note: The present state-of-the-art might not yet be mature for it. The wording "best guess" might be added to account for it.*	The metadata indicates the amount of per-pixel adjacency effects contamination. (Note: danger of often occurring increased turbidity or optically shallow water near shorelines to confuse this assessment).				
2.14	**Floating Vegetation/ Surface Scum Mask**	The metadata indicates whether a pixel is assessed as affected by floating vegetation/surface scum.	As threshold.				
2.15	**Aerosol Optical Depth Parameters**	Either per-pixel spectral AOD, or per-pixel AOD (550nm) and Angstrom exponent.	As threshold.				This might be an input or an output parameter.

2.16	**Deep/shallow water**	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.				
2.17	**Optically deep or optically shallow assessment**	The metadata indicates, based on likelihood (bathymetry maps and average Kd (preferred) or based on Turbidity or Secchi Disk Transparency), whether water pixels are 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.				Optically deep = there is no measurable reflectance or radiance signal from the substratum at the water surface; optically shallow= there is a measurable signal from the substratum in the above surface radiance or reflectance
2.18	**Turbid water flag**	The metadata indicates whether a pixel is assessed as being turbid or not. Information on turbid water mask should be available in the metadata as a single DOI landing page.	As threshold.				Problem: who determines at which value water is classified as "turbid" and where it applies?
2.19	**Bidirectional Reflectance Distribution Function Applied**	Not required.	Metadata indicates which pixels are corrected for BRDF effects.				
2.20	**Altitude (ASL)**	The metadata indicates approximate altitude (ASL) of water body pixels is required for atmospheric correction (range = -430 to ~6500m)	Metadata indicates approximate altitude (ASL) per pixel for atmospheric correction (range = -430 to ~6500m).				

Radiometric and Atmospheric Corrections

The following requirements must be met for all pixels in a collection. The requirements indicate 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.

#	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements	Threshold Self-Assessment	Target Self-Assessment	Self-Assessment Explanation/ Justification	Comments
3.1	**Measurement**	Pixel values that are expressed as a measurement of the Aquatic Reflectance ($AR=pi*R_{rs}$) 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).				
3.2	**Measurement Uncertainty**	Not required. *Note 1: 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.*	An estimate of the uncertainty of the values is provided in measurement units. Following Guide to the Expression of Uncertainty in Measurement (GUM). *Note 1: This is a requirement for SI traceability. See also 1.1.* *Note 2: Information on*				

			measurement uncertainty should be available in the metadata as a single DOI landing page.				
3.3	**Measurement Normalisation**	Not required.	Measurements are normalized for solar and viewing conditions, including BRDF Correction (see also 3.15) *Note 1: Information on measurement normalisation should be available in the metadata as single DOI landing page.*				
3.4	**Atmospheric Reflectance Correction**	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; 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.				

3.5	**Water Vapour Corrections**	Corrections are applied for water vapour if spectral bands are affected. Metadata contains a single DOI landing page with references to a citable peer-reviewed algorithm, technical documentation regarding the implementation of that algorithm *Note 1: Examples of technical documentation include an Algorithm Theoretical Basis Document, product user guide, etc.*	As threshold.				
3.6	**Ozone Corrections**	Required if spectral bands are affected.	Data is corrected for ozone. 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 ozone correction algorithm.				
3.7	**Other Trace Gaseous Absorption Corrections**	Required if spectral bands are affected.	As threshold				

3.8	**Sun Glint Correction**	Not required; where possible flag pixels that are sun glint affected	The metadata indicates surface contributions from Sun glint are removed from the data if a pixel is assessed as of correctable Sun glint.				
3.9	**Sky Glint Correction**	Contribution from sky glint to be removed.	The metadata indicates surface contributions from sky glint are removed from the data.				
3.10	**Whitecap and Foam Correction**	The water leaving reflectance or radiance is corrected for the contribution from surface whitecaps and the water leaving reflectance or radiance is corrected for the contribution from surface whitecaps and foam if a pixel is assessed as affected by whitecaps or foam. foam if a pixel is assessed as affected by whitecaps or foam.	As threshold.				
3.11	**Adjacency Effects Correction**	Whenever possible pixels affected by non-negligible Adjacency Effects are identified and flagged.	The metadata indicates the data are corrected for Adjacency Effects (citable peer-reviewed algorithms, technical documentation and sources of ancillary data should be provided).				
3.12	**Surface Reflected Vegetation Spectral Correction**	Not required.	The metadata indicates the data are corrected for surface reflected vegetation spectral effects.				

3.13	**Floating Vegetation/ Surface Scum Correction**	The metadata indicates whether a pixel is assessed as affected by floating vegetation/surface scum	As threshold				
3.14	**Turbid Water Correction**	The metadata indicates whether a pixel has been corrected for being turbid or not. In that case information on turbid water mask should be available in the metadata as a single DOI landing page.	As threshold				
3.15	**Bidirectional Reflectance Distribution Function Correction**	Not required.	Data is corrected for BRDF effects (see also 3.3.).				

Geometric Corrections

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.

#	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements	Threshold Self-Assessment	Target Self-Assessment	Self-Assessment Explanation/ Justification	Comments
4.1	**Geometric Correction**	Sub-pixel accuracy is achieved in relative geolocation, that is, the pixels from the same instrument and platform are consistently located, and in thus comparable, through time. 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. A consistent gridding/sampling frame is used, including common cell size, origin, and nominal sample point location within the cell (centre, ll, ur). Relevant metadata must be provided under 1.8 and 1.9. *Note 1: The threshold level*	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. Relevant metadata must be provided under 1.8 and 1.9. *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.*				Maybe it is useful to note if the sensor is used at its native resolution even before geometric correction or that some resampling has to be done (as will be the case for Sentinel-2 bands at 10, 20 and 60 m resolution)

		will not necessarily enable interoperability between data from different *sources as the geometric corrections for each of the sources may differ.*					

Summary Self-Assessment Table

	Threshold	Target
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2.20 Altitude (ASL)		
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3.3 Measurement Normalisation		
3.4 Atmospheric Reflectance Correction		

3.5 Water Vapour Corrections		
3.6 Ozone Corrections		
3.7 Other Trace Gaseous Absorption Corrections		
3.8 Sun Glint Correction		
3.9 Sky Glint Correction		
3.10 Whitecap and Foam Correction		
3.11Adjacency Effects Correction		
3.12 Surface Reflected Vegetation Spectral Correction		
3.13 Floating Vegetation/ Surface Scum Correction		
3.14 Turbid Water Correction		
3.15 Bidirectional Reflectance Distribution Function		
4. Geometric Corrections		
4.1 Geometric Correction		

Guidance

This section aims to provide background and specific information on the processing steps that can be used to achieve analysis ready data. This Guidance material does not replace or over-ride the specifications.

Introduction to CARD4L

What is CEOS Analysis Ready Data for Land (CARD4L) products?

CARD4L 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.

CARD4L 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 CARD4L?

The CARD4L branding is applied to a particular product once:

- that product has been assessed as meeting CARD4L requirements by the agency responsible for production and distribution of the product, and
- that assessment has been peer reviewed by the CEOS Land Surface Imaging Virtual Constellation in consultation with other CEOS working groups as appropriate, including the CEOS Working Group on Calibration and Validation.

Agencies or other entities considering undertaking an assessment process should contact the Land Surface Imaging Virtual Constellation.

A product can continue to use CARD4L branding as long as its generation and distribution remain consistent with the peer-reviewed assessment.

What is the difference between Threshold and Target?

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

Products that meet target 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.

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

Procedural Examples

Processes to produce Threshold Aquatic Reflectance CARD4L:

The following correction processes would typically be applied to produce CARD4L-AR Threshold:

- *No example processes are provided at this time.*

The following additional processes could be applied to produce CARD4L-AR Target:

- *No example processes are provided at this time.*

Specific Examples

Processes to produce Threshold Aquatic Reflectance CARD4L.

- *No example processes are provided at this time.*

Reference Papers

The following papers provide scientific and technical guidance:

Z. Ahmad, B. A. Franz, C. R. McClain, E. J. Kwiatkowska, J. Werdell, E. P. Shettle, and B. N. Holben, "New aerosol models for the retrieval of aerosol optical thickness and normalized water-leaving radiances from the SeaWiFS and MODIS sensors over coastal and open oceans," *Appl. Opt*, vol. 49, 2010.

S. W. Bailey, B. A. Franz, and P. J. Werdell, "Estimation of near-infrared water-leaving reflectance for satellite ocean color data processing," *Optics Express*, vol. 18, no. 7, pp. 7521–7527, 2010.

Brando, V.E., Anstee, J.M., Wettle, Dekker, A.G., Phinn, S.R., and Roelfsema, C (2009) "A Physics Based Retrieval and Quality Assessment of Bathymetry from Suboptimal Hyperspectral Data," Remote Sensing of Environment 113 (2009), pp. 755-770, 10.1016/j.rse.2008.12.003

B. Bulgarelli, V. Kiselev, and G. Zibordi, "Simulation and analysis of adjacency effects in coastal waters: a case study," Applied Optics, vol. 53, no. 8, pp. 1523–1545, 2014.

B. Bulgarelli, F. Mélin, and G. Zibordi, "On the minimization of adjacency effects in SeaWiFS primary data products from coastal areas," Optics Express, vol. 26, no. 18, pp. A709–A728, 2018.

B. Bulgarelli and G. Zibordi, "Adjacency radiance around a small island: implications for system vicarious calibrations," Applied Optics, vol. 59, no. 10, pp. C63–C69, 2020.

Dekker A.G., Phinn S.R., Anstee J.M., Bissett P. Brando V.E., Casey B. Fearns P., Hedley J., Klonowski, W., Lee Z.P., Lynch M., Lyons M., Mobley C. and Roelfsema C. (2011) Intercomparison of shallow water bathymetry, hydro-optics and benthos mapping techniques in Australian and Caribbean

coastal environments; *Limnology & Oceanography Methods.* 9:pp 396-425. | DOI: 10.4319/lom.2011.9.396

Feldman, G. “Level 2 Ocean Color Flags.” NASA Ocean Color Web, Ocean Biology Processing Group, Accessed https://oceancolor.gsfc.nasa.gov/atbd/ocl2flags/

Gao, Bo-Cai & Montes, Marcos & Davis, Curtiss & Goetz, Alexander. (2009). Atmospheric correction algorithms for hyperspectral remote sensing data of land and ocean. Remote Sensing of Environment. 113. 10.1016/j.rse.2007.12.015.

H. W. Gordon and M. Wang, “Retrieval of water-leaving radiance and aerosol optical thickness over the oceans with SeaWiFS: a preliminary algorithm,” vol. 33, no. 3, pp. 443–452, 1994.

H. R. Gordon and K. J. Voss, *MODIS normalized water-leaving radiance algorithm theoretical basis document*. NASA Technical Report Series, 1999.

Hochberg, E.J., Bruce, C.F., Green, R.O., Oaida, B.V., Muller-Karger, F.E., Mobley, C.D., Park, Y., Goodman, J., Knox, R.G., Middleton, E.M., Turpie, K.R., Ungar, S.G., Minnett, P.J., Gentemann, C., Zimmerman, R.C., Turner, W., and Gao, B.-C., 2011, HyspIRI sun glint report: National Aeronautics and Space Administration JPL Publication 11–4, 73 p., at https://hyspiri.jpl.nasa.gov/documentC. D. Mobley, J. Werdell, B. Franz, Z. Ahmad, and S. Bailey, “Atmospheric Correction for Satellite Ocean Color Radiometry,” NASA, NASA/TM–2016-217551, 2016.

N. Pahlevan, Z. Lee, J. Wei, C. Schaff, J. Schott and A. Berk, “On-orbit radiometric characterization of OLI (Landsat-8) for applications in aquatic remote sensing”, Remote Sensing of Environment, 154, pp. 272-284, 2014

M. Wang and S. W. Bailey, “Correction of sun glint contamination of the SeaWiFS ocean and atmosphere products”, Applied Optics, vol. 40, no. 27, pp. 4790-4798, 2001.