Ocean Level-2 Data Products
March 22, 2010

1.0 Introduction

This document describes the specifications of Ocean Level-2 archive products that are produced and distributed by the NASA Goddard Space Flight Center's Ocean Data Processing System (ODPS). The products are implemented in the Hierarchical Data Format (HDF), and HDF terminology is used in this document.

These specifications are given in terms of the logical implementation of the products in HDF and are not a physical description of file contents. Therefore, HDF software must be used to create or read these products.

A Level-2 data product is generated from either a Level-1A (SeaWiFS, OCTS or CZCS) or Level 1B (MODIS or MERIS) product. The main data contents of the product are the geophysical values for each pixel, derived from the Level-1 radiance by applying the sensor calibration (for Level-1A), atmospheric corrections, and geophysical parameter algorithms. Each Level-2 product corresponds exactly in geographical coverage (scan-line and pixel extent) to that of its parent Level-1 product and is stored in one physical HDF file. Note that a number of fields were originally specified for the SeaWiFS data products and are not applicable to the other sensor products; these are indicated as SeaWiFS only.

2.0 Naming Convention

The form of a Level-2 file name is iyyyydddhhmmss.L2_rrr_ppp, where i is the instrument identifier (S for SeaWiFS, A for Aqua MODIS, T is for Terra MODIS, O for OCTS, C is for CZCS, M is for MERIS), yyyydddhhmmss are the UTC year, day of the year, hours, minutes, and seconds of the first scan line, rrr is the resolution, and ppp is the product identifier (OC for ocean color or SST for sea surface temperature. The resolution can be:

GAC for Global Area Coverage (i.e., subsampled image data, for SeaWiFS or OCTS)
LAC for Local Area Coverage (full-resolution, 1 km SeaWiFS, MODIS, OCTS or CZCS)
Hxxx for SeaWiFS HRPT direct-broadcast (where xxx is a station identifier, e.g., HNSG for the NASA SeaWiFS station)
MLAC for merged LAC (multiple scenes from a single orbit merged into a single product).

Examples of Level-2 file names are:

S1998001180514.L2_GAC_OC	SeaWiFS GAC (4 km subsampled) ocean color
A2004032163500.L2_LAC_OC	Aqua MODIS LAC (1 km) ocean color
T2006022172000.L2_LAC_SST	Terra MODIS 1 km SST
O1997001130032.L2_GAC	OCTS GAC (4 km subsampled)

3.0 Global Attributes

For global attributes that have constant values specific to this product type, the actual value is given.

3.1 Mission and Documentation

This section lists attributes that are common to all sensors, followed by sensor-specific attributes.

3.1.1 Common Attributes

Product Name (character): the name of the product file (without path).

Title (character): data product type, e.g., "SeaWiFS Level-2 Data".

Sensor Name (character): name of sensor, e.g., "MODISA""

Replacement Flag (character): "ORIGINAL" if this is the first version of this product delivered to the DAAC; otherwise, it is set to the name of the product to be replaced (superseded) by the present product.

Software Name (character): "l2gen"; name of the software used to create this product.

Software Version (character): version of the software used to create this product.

Processing Time (character): UTC of generation of this product; concatenated digits for year, day-of-year, hours, minutes, seconds, and fraction of seconds in the format of YYYYDDDHHMMSSFFF.

Processing Control (character): path and name of the file containing the control parameters. This information is simply stored in the product as part of its processing history.

Input Parameters (character): all input and processing control parameters used by the calling program to generate the product. Vertical bars or carriage return characters serve as parameter information delimiters. This information is simply stored in the product as part of its processing history.

Input Files (character): the names of the Level-1A or Level-1B file (without path; always listed first) from which the current product was created and of the ancillary (environmental) data files (without paths, each separated by one comma) used in the processing. This information is simply stored in the product as part of its processing history.

Calibration Data (character): the names of the calibration files (without paths, each separated by one comma) used in the processing. This information is simply stored in the product as part of its processing history.

3.1.2 SeaWiFS-Specific Attributes

Data Center (character): "NASA/GSFC SeaWiFS Data Processing Center".

Station Name (character): "Wallops Flight Facility".

Station Latitude (4-byte real): 37.9272.

Station Longitude (4-byte real): -75.4753.

Mission (character): "SeaStar SeaWiFS".

Mission Characteristics (character): "Nominal orbit: inclination = 98.2 (Sun-synchronous); node = 12 noon local (descending); eccentricity = <0.002; altitude = 705 km; ground speed = 6.75 km/sec".

Sensor (character): "Sea-viewing Wide Field-of-view Sensor (SeaWiFS)".

Sensor Characteristics (character): "Number of bands = 8; number of active bands = 8; wavelengths per band (nm) = 412, 443, 490, 510, 555, 670, 765, 865; bits per pixel = 10; instantaneous field-of-view = 1.5835 mrad; pixels per scan = 1285; scan rate = 6/sec; sample rate = 7710/sec".

Data Type (character): "GAC".

3.2 Data Time

Start Time (character): start UTC of the first scan line of the scene; concatenated digits for year, day-of-year, hours, minutes, seconds, and fraction of seconds in the format of YYYYDDDHHMMSSFFF.

End Time (character): start UTC of the last scan line of the scene; concatenated digits for year, day-of-year, hours, minutes, seconds, and fraction of seconds in the format of YYYYDDDHHMMSSFFF.

Scene Center Time (character): start UTC of the center scan line of the scene; concatenated digits for year, day-of-year, hours, minutes, seconds, and fraction of seconds in the format of YYYYDDDHHMMSSFFF.

Node Crossing Time (character): UTC of descending node crossing; concatenated digits for year, day-of-year, hours, minutes, seconds, and fraction of seconds in the format of YYYYDDDHHMMSSFFF (SeaWiFS only).

Start Year (2-byte integer): UTC year of first scan line of the scene.

Start Day (2-byte integer): UTC day-of-year of first scan line of the scene.

Start Millisec (4-byte integer): UTC milliseconds-of-day of start of the first scan line of the scene.

End Year (2-byte integer): UTC year of last scan line of the scene.

End Day (2-byte integer): UTC day-of-year of last scan line of the scene.

End Millisec (4-byte integer): UTC milliseconds-of-day of start of the last scan line of the scene.

Start Node (character): "Ascending" or "Descending"; describes node direction at the start of the scene.

End Node (character): "Ascending" or "Descending"; describes node direction at the end of the scene.

Orbit Number (4-byte integer): orbit number of the scene (SeaWiFS only).

3.3 Data Structure

Pixels per Scan Line (4-byte integer): number of pixels in each scan line.

Number of Scan Lines (4-byte integer): number of scan lines in the scene.

Number of Bands (4-byte integer): 8; number of channels/wavelengths.

LAC Pixel Start Number (4-byte integer): the LAC pixel number corresponding to the first pixel in scan lines of this product (SeaWiFS only).

LAC Pixel Subsampling (4-byte integer): the subsampling rate for the pixels in this product relative to LAC scan lines (SeaWiFS only).

Scene Center Scan Line (4-byte integer): number of the center scan line (1-relative) of the scene, relative to first scan line.

Number of Scan Control Points (4-byte integer): number of rows in the **latitude** and **longitude** control point arrays.

Number of Pixel Control Points (4-byte integer): number of columns in the **latitude** and **longitude** control point arrays.

Mask Names (character): list of algorithm names (each separated by one comma, from the values of the attributes **f01_name** to **f32_name** of the **l2_flags** SDS in the Geophysical Data Vgroup) for the flag bits that were used as masks when generating this product.

Flag Percentages (4-byte real, array size 32): percentages of pixels in the scene for which a bit in **l2_flags** is set; each of the 32 values corresponds to one of the 32 bits (from lowest to highest) in **l2_flags**.

3.4 Scene Coordinates

Latitude Units (character): "degrees North"; units used for all latitude values in this product.

Longitude Units (character): "degrees East"; units used for all longitude values in this product.

Scene Center Latitude (4-byte real): latitude of the midpoint of the scene center scan line.

Scene Center Longitude (4-byte real): longitude of the midpoint of the scene center scan line.

Scene Center Solar Zenith (4-byte real): solar zenith angle at the scene center.

Upper Left Latitude (4-byte real): latitude of the upper left scene corner.

Upper Left Longitude (4-byte real): longitude of the upper left scene corner.

Upper Right Latitude (4-byte real): latitude of the upper right scene corner.

Upper Right Longitude (4-byte real): longitude of the upper right scene corner.

Lower Left Latitude (4-byte real): latitude of the lower left scene corner.

Lower Left Longitude (4-byte real): longitude of the lower left scene corner.

Lower Right Latitude (4-byte real): latitude of the lower right scene corner.

Lower Right Longitude (4-byte real): longitude of the lower right scene corner.

Northernmost Latitude (4-byte real): northernmost latitude of all scan line end points.

Southernmost Latitude (4-byte real): southernmost latitude of all scan line end points.

Westernmost Longitude (4-byte real): westernmost longitude of all scan line end points.

Easternmost Longitude (4-byte real): easternmost longitude of all scan line end points.

Start Center Latitude (4-byte real): latitude of center pixel for first scan line.

Start Center Longitude (4-byte real): longitude of center pixel for first scan line.

End Center Latitude (4-byte real): latitude of center pixel for last scan line.

End Center Longitude (4-byte real): longitude of center pixel for last scan line.

Orbit Node Longitude (4-byte real): longitude of scene's orbit descending node (longitude at equatorial crossing of day-side node) (SeaWiFS only).

Earth-Sun Distance Correction (4-byte real): correction applied to radiance for irradiance changes caused by the annual Earth-Sun distance variation, computed as the square of the inverse of the distance in astronomical units.

4.0 Data Objects

Of the following data object groups, three (Scan-Line Attributes, Geophysical Data, and Navigation) contain data that are functions of scan lines. That is, each data object within these groups have data for each scan line and is therefore dimensioned by the value of the global attribute, **Number of Scan Lines**. Thus, to get all the data corresponding to a specific scan line, n, the n^{th} values of all data objects in these four groups would need to be read.

4.1 Scan-Line Attributes

The following data objects are SDSs belonging to the Vgroup "Scan-Line Attributes". Attributes of the SDSs are shown in **bold**.

year (4-byte integer, array size **Number of Scan Lines**): **long_name** = "Scan year"; **valid_range** = (1996, 2038); **units** = "years".

day (4-byte integer, array size **Number of Scan Lines**): **long_name** = "Scan day of year; **valid_range** = (1,366); **units** = "days".

msec (4-byte integer, array size **Number of Scan Lines**): **long_name** = "Scan-line time, milliseconds of day"; **valid_range** = (0,86399999), **units** = "milliseconds".

slat (4-byte real, array size **Number of Scan Lines**): **long_name** = "Scan start-pixel latitude"; **valid_range** = (-90.,90.); **units** = "degrees".

slon (4-byte real, array size **Number of Scan Lines**): **long_name** = "Scan start-pixel longitude"; **valid_range** = (-180.,180.); **units** = "degrees".

clat (4-byte real, array size **Number of Scan Lines**): **long_name** = "Scan center-pixel latitude"; **valid_range** = (-90.,90.); **units** = "degrees".

clon (4-byte real, array size **Number of Scan Lines**): **long_name** = "Scan center-pixel longitude"; **valid_range** = (-180.,180.); **units** = "degrees".

elat (4-byte real, array size **Number of Scan Lines**): **long_name** = "Scan end-pixel latitude"; **valid_range** = (-90.,90.); **units** = "degrees".

elon (4-byte real, array size **Number of Scan Lines**): **long_name** = "Scan end-pixel longitude"; **valid_range** = (-180.,180.); **units** = "degrees".

csol_z (4-byte real, array size **Number of Scan Lines**): **long_name** = "Scan center-pixel solar zenith angle"; **valid_range** = (0.,180.); **units** = "degrees".

4.2 Geophysical Data

4.2.1 Retrieved Geophysical Parameters

The retrieved geophysical parameters are stored in SDSs belonging to the Vgroup "Geophysical Data". A list of parameters included in the archive products is shown in Table 1, along with the values of the standard attributes: **long_name**, **slope**, **intercept**, **units**. All parameter SDSs have dimensions **Number of Scan Lines** x **Pixels per Scan Line**. Most parameters are stored as integers, which are scaled according to the attributes **slope** and i**ntercept** attached to each SDS. In addition, each parameter has attributes **bad_value_scaled** and **bad_value_unscaled**, which indicate the values stored for pixels in which the parameter could not be computed; for scaled integers, the former specifies the actual value stored and the latter, the equivalent parameter value.

Parameters that are wavelength-specific (e.g., water-leaving radiance) have separate SDSs for each band used to derive the parameter; a list of wavelengths for each sensor is given in Table 2. This section lists those parameters that are stored in the standard archive products. The SST and SST4 are stored in separate archive products with their respective quality fields. A complete list of parameters that can be output by the software is given in the L2gen User Guide.

Table 1. Summary of Level-2 geophysical parameters and attributes

Parameter	**Storage (bytes)**	**Approximate Range**	**Units**	**Long Name**
Rrs_WWW	2	-0.015 – 0.115	sr^{-1}	Remote sensing reflectance at WWW nm
chlor_a	4	0 – 100	mg m^{-3}	Chlorophyll Concentration, OC4 Algorithm
Kd_490	2	0 – 6.4	m^{-1}	Diffuse attenuation coefficient at 490 nm
aot_WWW	2	0 – 3.2	none	Aerosol optical thickness at WWW nm
angstrom	2	-0.7 – 5.7	none	Angstrom coefficient, 443 to 865 nm
pic	2	0 – 0.13	mol m^{-3}	Calcite Concentration
poc	2	0 – 12,800	mg m^{-3}	Particulate Organic Carbon
cdom_index	2	0 – 12.8	None	CDOM Index

par	2	0 – 131	Einsteins m^{-2} day^{-1}	Photosynthetically Available Radiation
ipar	2	0 – 131	Einsteins m^{-2} sec^{-1}	Instantaneous Photosynthetically Available Radiation
nflh	2	0 – 131	mW m^{-2} μm^{-1} sr^{-1}	Normalized Fluorescence Line Height
sst	2	-2 – 45	degrees C	Sea Surface Temperature
sst4	2	-2 – 45	degrees C	4um Sea Surface Temperature

Table 2. Band-center wavelengths by sensor (nm). These are used in the geophysical parameter names that are based on wavelength.

SeaWiFS	MODIS	OCTS	CZCS	MERIS
412 (1)	412 (1)	412 (1)		413 (1)
443 (1)	443 (1)	443 (1)	443 (1)	443 (1)
	469 (1),(3)			
490 (1)	488 (1)	490 (1)		490 (1)
510 (1)	531 (1)	520 (1)	520 (1)	510 (1)
555 (1)	547 (1)	565 (1)	550 (1)	560 (1)
	555 (1),(3)			
	645 (1),(3)			620 (1)
670 (1)	667 (1)	670 (1)	670 (1),(2)	665 (1)
	678 (1)			681 (1)
765	748	765	750	754
865 (2)	869 (2)	865 (2)		865 (2)

(1) Used for **Rrs_WWW**
(2) Used for **aot_WWW**
(3) Generated from MODIS 250m or 500m data aggregated to 1 km

4.2.2 Flags and Quality Levels

l2_flags (4-byte integer, array size **Number of Scan Lines** x **Pixels per Scan Line**):
long_name = "Level-2 Processing Flags"; **units** = "dimensionless"; 32 bilevel flags in four bytes used as indicators of certain conditions (see Table 3). This SDS has attributes **f01_name**, … **f32_name** that provide the names of the algorithms (also listed in Table 3) used in determining the setting of the corresponding bits in **l2_flags** (the least significant bit being the first bit). The algorithms associated with these names, and the use of the corresponding bits as masks or as flags, are described in volumes of the SeaWiFS TM Series. Note that for SST, only the LAND, SSTWARN and SSTFAIL flags are meaningful, as the quality indicators are stored in sst_qual and sst4_qual, respectively.

Table 3. Conditions indicated for the pixel associated with the setting of individual bits in l**2_flags**. These correspond to the algorithm names given by the attributes of **l2_flags**.

Bit Set = 1	**Condition Indicated**	**Algorithm Name**
1	atmospheric correction failure from invalid inputs	ATMFAIL
2	land	LAND
3	questionable value for one or more parameters	PRODWARN
4	severe Sun glint	HIGLINT
5	total radiance above knee in any band	HILT
6	satellite zenith angle above limit	HISATZEN
7	shallow water	COASTZ
8	not used	SPARE
9	stray light contamination	STRAYLIGHT
10	clouds and/or ice	CLDICE
11	coccolithophore	COCCOLITH
12	turbid, case-2 water	TURBIDW
13	solar zenith angle above limit	HISOLZEN
14	not used	SPARE
15	low water-leaving radiance at 555 nm	LOWLW
16	chlorophyll not calculable	CHLFAIL
17	questionable navigation (e.g, tilt change)	NAVWARN
18	absorbing aerosol index above threshold	ABSAER
19	not used	SPARE
20	maximum iterations of NIR algorithm	MAXAERITER
21	moderate Sun glint	MODGLINT

22	chlorophyll out of range	CHLWARN
23	epsilon out of range	ATMWARN
24	not used	SPARE
25	sea ice in pixel (based on climatology)	SEAICE
26	navigation failure condition indicated in nav flags	NAVFAIL
27	insufficient valid neighboring pixels for epsilon filtering	FILTER
28	sea surface temperature warning flag (MODIS only)	SSTWARN
29	sea surface temperature failure flag (MODIS only)	SSTFAIL
30	degree of polarization above limit (MODIS only)	HIPOL
31	one or more parameters could not be computed	PRODFAIL
32	not used	SPARE

qual_sst (SST product only) (byte, array size **Number of Scan Lines** x **Pixels per Scan Line**): **long_name** = "Quality Levels, Sea Surface Temperature"; **units** = "dimensionless"; byte array indicating SST quality with range of 0 (best) to 3 (invalid); used during generation of binned products to select best available data for a bin; specific quality levels are documented in TBD.

qual_sst4 (SST4 product only) (byte, array size **Number of Scan Lines** x **Pixels per Scan Line**): **long_name** = "Quality Levels, Sea Surface Temperature"; **units** = "dimensionless"; byte array indicating SST4 quality with range of 0 (best) to 3 (invalid); used during generation of binned products to select best available data for a bin; specific quality levels are documented in TBD.

4.3 Navigation

4.3.1 Navigation Control Points and Tilt

The following data objects are SDSs belonging to the Vgroup "Navigation". Attributes of the SDSs are shown in **bold**. The control point arrays **latitude** and **longitude** are used for Level-3 processing and display. The most accurate geolocation will be obtained for SeaWiFS using the navigation block fields with the SeaWiFS Project software (see 4.4.4, below), and for MODIS using the Geolocation product.

cntl_pt_cols (4-byte integer, array size **Number of Pixel Control Points**): **long_name** = "Pixel control points"; **units** = "none"; array of pixel indices corresponding to **latitude** and **longitude** SDSs.

cntl_pt_rows (4-byte integer, array size **Number of Scan Control Points**): **long_name** = "Scan control points"; **units** = "none"; array of scan line indices corresponding to **latitude** and **longitude** SDSs.

longitude (4-byte real, array size **Number of Scan Control Points** x **Number of Pixel Control Points**): **long_name** = "Longitudes at control points";**units** = "degrees"; **valid_range** =

"-180., 180."; **units** = "degrees"; longitudes of pixels indicated by **cntl_pt_cols** and **cntl_pt_rows**.

latitude (4-byte real, array size **Number of Scan Control Points** x **Number of Pixel Control Points**): **long_name** = "Latitudes at control points";**units** = "degrees"; **valid_range** = "-90., 90."; **units** = "degrees"; latitudes of pixels indicated by **cntl_pt_cols** and **cntl_pt_rows**.

tilt (4-byte real, array size **Number of Scan Lines**): **long_name** = "Tilt angle for scan line"; **valid_range** = (-20.1,20.1); **units** = "degrees"; positive values indicate aft tilts and negative values indicate forward tilts.

4.3.2 SeaWiFS Navigation Block (SeaWiFS only)

The following data objects are additional SDSs belonging to the Vgroup "Navigation" in SeaWiFS data products. Attributes of the SDSs are shown in **bold**. See the *SeaWiFS Postlaunch Technical Report Series*, volume 16 for a description of methods used for the operational navigation of SeaWiFS data.

orb_vec (4-byte real, array size **Number of Scan Lines** x 3): **long_name** = "Orbit position vector at scan line time"; orbit position vector interpolated to the time of the scan line; **valid_range** = (-7200.,7200.); **units** = "kilometers"; used to determine spacecraft position for geolocation.

sun_ref (4-byte real, array size **Number of Scan Lines** x 3): **long_name** = "Reference Sun vector in ECEF frame"; unit Sun vector in the Earth-centered, Earth-fixed (ECEF) frame; **valid_range** = (-1.,1.); used for computing solar zenith and azimuth angles.

att_ang (4-byte real, array size **Number of Scan Lines** x 3): **long_name** = "Computed yaw, roll, pitch"; **valid_range** = (-180.,180.); relates spacecraft position to orbit reference frame.

sen_mat (4-byte real, array size **Number of Scan Lines** x 3 x 3): **long_name** = "ECEF-to-sensor-frame matrix"; **valid_range** = (-1.,1.); relates sensor scan plane to Earth-fixed reference frame (3x3 matrix, in column-major order).

scan_ell (4-byte real, array size **Number of Scan Lines** x 6): **long_name** = "Scan-track ellipse coefficients"; defines scan-track geometry in sensor frame.

nflag (4-byte integer, array size **Number of Scan Lines** x 8): **long_name** = "Navigation flags"; in the 8-integer array, the integers represent, respectively: navigation failure flag; orbit flag; Sun sensor flag; Earth sensor flag; spacecraft attitude uncertainty flag; time code flag; tilt data flag; and navigation warning flag. All flags may have the value 0 for valid or 1 for invalid. The tilt data flag only may also have the value of 2 to indicate a changing tilt. Note that the failure flag is only to 1 if the orbit flag, time code flag or tilt data flag are set to 1.

4.4 Sensor Tilt (SeaWiFS only)

The following data objects are SDSs belonging to the Vgroup "Sensor Tilt" in the SeaWiFS data products. Attributes of the SDSs are shown in **bold**.

ntilts (4-byte integer): **long_name** = "Number of scene tilt states".

tilt_flags (2-byte integer, array size 20): **long_name** = "Tilt indicators"; **valid_range** = (-1,3); tilt flags corresponding to each tilt state in the scene; possible values are 0 for nadir tilt, 1 for forward tilt, 2 for aft tilt, and 3 to indicate a changing tilt angle; -1 indicates an unknown state; contains **ntilts** valid values.

tilt_ranges (2-byte integer, array size 20 x 2): **long_name** = "Scan-line number ranges of scene tilt states"; first and last scan line numbers (1-relative) corresponding to each tilt state in the scene; contains **ntilts** valid values.

4.5 Sensor Band Parameters

The following data objects are SDSs belonging to the Vgroup "Sensor Band Parameters". Attributes of the SDSs are shown in **bold**. These parameters are used in the Level 2 processing.

wavelength (4-byte integer, array size **Number of Bands**); **long_name** = "Wavelengths"; **units** = "nm"; band center wavelength for each band.

vcal_gain (4-byte real, array size **Number of Bands**); **long_name** = "Vicarious Calibration Gain"; **units** = "dimensionless"; vicarious calibration gain for each band.

vcal_offset (4-byte real, array size **Number of Bands**); **long_name** = "Vicarious Calibration Offset"; **units** = "mW cm^-2 um^-1 sr^-1"; vicarious calibration offset for each band.

F0 (4-byte real, array size **Number of Bands**); **long_name** = "Mean Solar Flux"; **units** = "mW cm^-2 um^-1 sr^-1"; mean solar flux for each band.

k_oz (4-byte real, array size **Number of Bands**); **long_name** = "Ozone Absorption Coefficient"; **units** = "cm^-1"; ozone absorption coefficient for each band.

Tau_r (4-byte real, array size **Number of Bands**); **long_name** = "Rayleigh Optical Thickness"; **units** = "dimensionless"; Rayleigh optical thickness for each band.