Chapter 2

An Overview of Ocean Data Levels

Introduction

As mentioned, the OBPG is the designated NASA team responsible for the processing and distribution of ocean color and SST data acquired from the MODIS/Aqua, MODIS/Terra, SeaWiFS, OCTS, and CZCS sensors. This chapter discusses the standard NASA data levels used for storing ocean color satellite data. These data levels are distributed by the OBPG and/or are producible by the SeaDAS software package.

Goal

This chapter gives an introduction to the HDF file format and briefly describes the following standard OBPG satellite ocean data levels:

- Level-0
- Level-1A
- MODIS GEO
- Level-1B
- Level-2
- Level-3 Binned
- Level-3 Standard Mapped Images

2.1 HDF and HDF-EOS Data Formats

OBPG Level-1A to Level-3 data files are stored in the HDF file format. HDF can be thought of as a 'container' that can store a variety of data types and meta data in a single file (see Figure 2.1). From the NASA Atmospheric Science Data Center:

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Hierarchical Data Format (HDF) is a data file format designed by the National Center for
Supercomputing Applications (NCSA) to assist users in the storage and manipulation of
scientific data across diverse operating systems and machines.  NCSA developed a library
of callable routines and a set of utility programs and tools for creating and using HDF
files.  This work is now performed by The HDF Group (THG).
```

OBPG files are actually stored in the HDF-EOS format, a specialized form of HDF created by NASA in 1993 as a standard format for all data generated by instruments on the Earth Observing System (EOS) satellites.

TIP SeaDAS is fully compatible with all OBPG HDF-EOS data files.

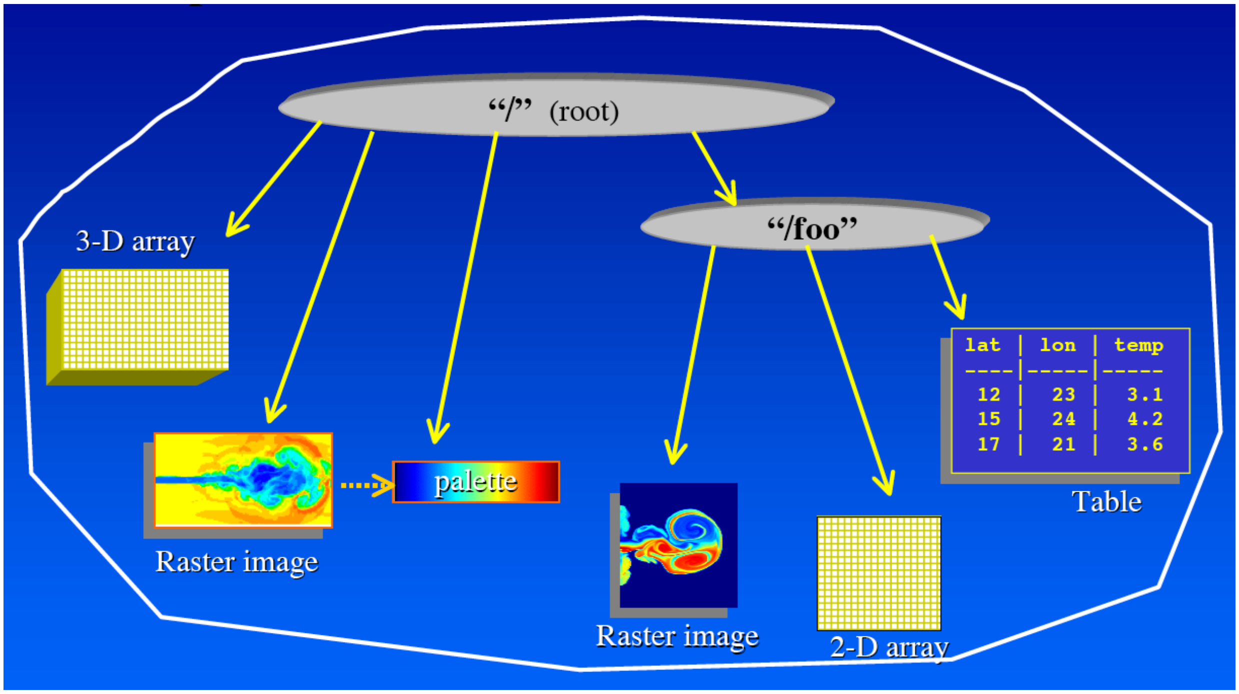

Figure 2.1: HDF File Example (Curtesy of The HDF Group)

2.2 Level-0 Data

Level-0 (L0) data files contain the raw radiance counts (digital numbers) and this is the lowest and most raw level of data normally available to end-users. **L0 data is rarely utilized by end-users since the Level-1A (L1A) data is usually a simple re-organization of the L0 data into the more friendly/standardized HDF-EOS format.** However, L0 data from MODIS Aqua and Terra may be desired because unlike MODIS L1A data (which has been ocean-band-subsetted), MODIS L0 data contains all 36 MODIS bands including the 7 high resolution bands, some of which may be useful for oceanic processing. As of July 2007, all MODIS L0 data is available from the single file selection page of the OBPG Level 1 and 2 Browser. A rolling 60-day archive of L0 MODIS Aqua and Terra data is also available via ftp://oceans.gsfc.nasa.gov/.

TIP SeaDAS has the ability to process L0 data to L1A for only the MODIS and SeaWiFS sensors, and can display only L0 SeaWiFS data.

2.3 Level-1A Data

L1A data files contain the sensor raw radiance counts (digital numbers) as well as spacecraft and instrument telemetry and calibration data. Navigation data is also included except for MODIS, in which case the geolocation data is contained in a separate file.

All L1A filenames use the SeaWiFS-like convention, which indicates sensor (e.g. S for SeaWiFS, A for MODIS-Aqua, T for MODIS-Terra), sampling rate (e.g. LAC for full 1-km sampling), and time of the first scan in the file (e.g. AYYYYDDDHHMMSS.L1A_LAC).

The entire mission archive of L1A ocean data for all sensors is maintained online, and all higher-level products are derived from this archive. **Due to the ever-changing nature of L1B calibration coefficients for active missions, it is recommended that researchers who intend to generate their own L2 products begin their processing using the L1A data (and an up-to-date version of SeaDAS).**

OBPG MODIS L0 to L1A processing is performed using the standard code developed by the MODIS Science Data Support Team (SDST) and all MODIS L0 and L1A files distributed by the OBPG are 5-minute granules. For file size and bandwidth reasons, MODIS L1A files are reduced (band-subsetted) by removing excess bands and data that are not utilized for oceanic processing. A standard MODIS L1A file is ∼575MB (∼220MB compressed), while a band-subsetted L1A file is ∼215MB (∼50MB compressed). The reduced Ocean L1A file format retains the bands shown in Figure 2.2).

MODIS Band	Wavelength (nm)	MODIS Band	Wavelength (um)
8	412	20	3.7
9	443	22	3.9
10	488	23	4.0
11	531	24	4.5
12	551	26	1.3
13lo	667	27	6.7
13hi	667	28	7.3
14lo	678	29	8.5
14hi	678	31	11
15	748	32	12
16	869		

Figure 2.2: MODIS Ocean Subset Band List

2.4 MODIS GEO Data

For the MODIS sensor only, a separate geolocation (GEO) file must be generated from an L1A file, and contains the navigation for that granule. L1B and L2 processing then requires the GEO file as an input. The naming convention for GEO files is similar to that of the L1A files, e.g. AYYYYDDDHHMMSS.GEO.

GEO files are not maintained in the long-term OBPG archive since they can be regenerated as needed using SeaDAS, so only a short-term rolling archive is made available for distribution by the OBPG. For the OBPG distribution's NRT stream, predicted attitude and ephemeris files are used to produce Quick-Look GEO files. Several days later, in the Refined processing stream, the definitive attitude and ephemeris files are used to create the final GEO version and refined data products.

2.5 Level-1B Data

Level-1B data files contain the calibrated at-aperture (top-of-atmosphere) radiances derived from L1A sensor counts by applying the sensor calibration. L1B files are named similarly to L1A files, e.g. AYYYYDDDHHMMSS.L1B_LAC or simply AYYYYDDDHHMMSS.L1B.

For non-MODIS sensors the end-user will rarely make use of L1B files since the processing software produces a L2 file directly from an L1A input. However, for MODIS processing, generating the L1B file is a required separate step. If the input MODIS L1A file is not band-subsetted, separate high resolution L1B files will also be produced, e.g. AYYYYDDDHHMMSS.L1B_HKM, AYYYYDDDHHMMSS.L1B_QKM.

There are differences between the MODIS L1B files produced by the OBPG and those from the MODIS Calibration Support Team (MCST). First, since ocean pixels are generally much darker than land and cloud pixels, a higher level of precision is required for ocean processing. Therefore the OBGP fine-tunes the MCST calibration coefficients for ocean data and so the ocean radiances will be slightly different (and hopefully improved). Second, the OBPG uses the ocean subsetted L1A files as input to the L1B processing so OBPG L1B files will contain only the bands listed in Figure 2.2. However, if SeaDAS is used to process a non-subsetted L1A file, all the non-high-resolution MODIS bands will be present in the L1B file (the high-resolution bands will exist in separate L1B HKM ad QKM files).

2.6 Level-2 Data

Level-2 data files contain calculated geophysical values for each pixel (e.g. nLw's, Chlorophyll-a, SST) derived from the L1B radiances by applying atmospheric corrections and bio-optical algorithms. L2 data files also contain geolocation data. Each L2 product corresponds exactly in geographical coverage (scan-line and pixel extent) to its parent L1A product and is stored in one physical HDF file. As with previous levels, the data has not been mapped and so is in "satellite view".

L2 filenames have the form AYYYYDDDHHMMSS.L2_LAC. MODIS SST products require different processing parameters than other ocean products, therefore MODIS SST L2 files are generated in a separate processing run and are named AYYYYDDDHHMMSS.L2_LAC_SST or TYYYYDDDHHMMSS.L2_LAC_SST.

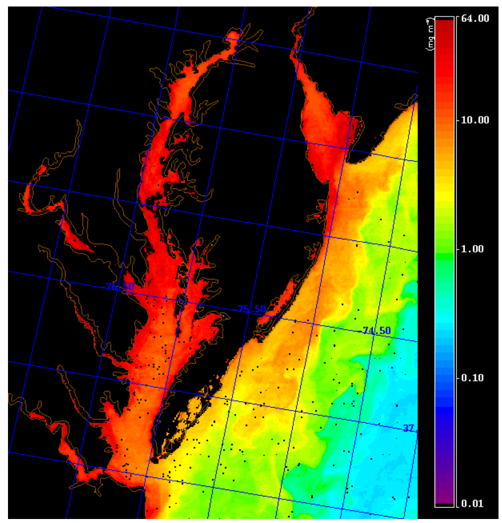

Figure 2.3: Level-2 Chlorophyll-a Product

The L2 files distributed by the OBPG contain a standard suite of products including water-leaving radiances, chlorophyll *a* concentration, the diffuse attenuation coefficient at 490nm, and a few other products. In addition, thirty-two flags are associated with each pixel indicating if any algorithm failures or warning conditions occurred for that pixel. These flags exist in the 'l2_flags' product. The separate standard MODIS SST files contain the 11μ and 4μ (night-time only) SST products. Five quality levels are associated with these SST products and are stored in the 'qual_sst' and 'qual_sst4' products. Using SeaDAS, L2 files can be creating that contain hundreds of pre-defined products and/or custom products.

Level-2 processing is performed using the Multi-Sensor Level-1 to Level-2 (`msl12`) code, which is developed and maintained by the OBPG. `msl12` is used for the standard processing of all ocean products distributed through the OBPG web browsers and ftp sites. This software is capable of retrieving oceanic optical properties and a multitude of derived products from the observed top-of-atmosphere (TOA) radiances. For non-MODIS sensors the L1A file is input to `msl12`, and for MODIS the L1B and GEO files are used as input. Full documentation, source code, and output product descriptions can be found at http://oceancolor.gsfc.nasa.gov/DOCS/MSL12/.

2.7 Level-3 Binned Data

Level-3 Binned (L3b) data files contain spatially and temporally binned L2 data products. In other words, an L3b data file consists of the accumulated L2 data statistics for the specified instrument, product(s), spatial resolution, and time period. Bins can be thought of as square grid elements or grid cells. (Prior to L3b, geophysical variables are derived only for individual satellite pixels.)

The statistical data provided in L3b files allow for the calculation of the mean, standard deviation, median, and mode for each L2 variable, and for certain other variables (e.g. primary productivity) which are functions of the L2 variables. The L3b data are stored in a representation of a global, sinusoidal equal-area grid (see Figure 2.4), and the standard OBPG-distributed bin resolutions are either 4.6km or 9.2km (certain regional products are 1km resolution). Only those bins containing data values are present in the L3b file; land bins and bins with no data are not stored. To create L3b files, the L2 files are spatially averaged into L3 Daily binned files using the `l2bin` program, and the Daily files are further composited into Weekly, Monthly, Annual, Seasonal, and Climatological time periods using the `l3bin` program.

TIP SeaDAS can be used to create an L3b composite for an arbitrary time period, and the available SeaDAS binning resolutions are 0.5, 1, 2, 4, 9, and 36 kilometers.

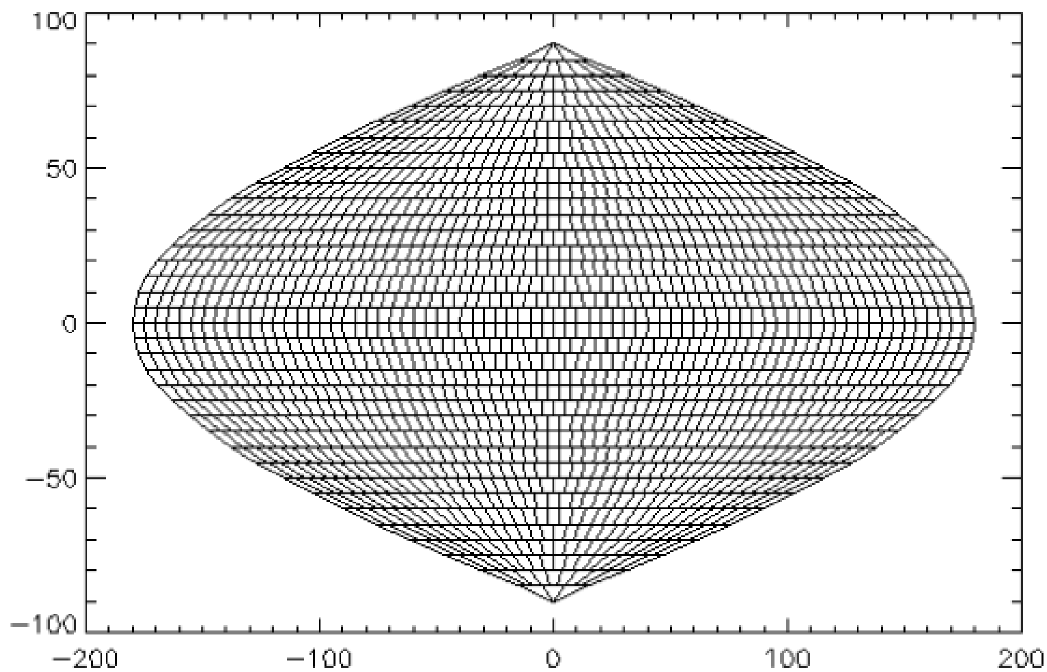

Figure 2.4: Square Bins Defined by a Sinusoidal Equal-Area Projection

The full suite of L2 ocean color parameters as well as three sea surface temperature parameters are available as standard temporal composites from the OBGP. Each product contains only data that has met data quality standards as indicated by a selected standard set of L2 flags and masks. SST products can contain data of varying data quality levels, but each bin will only contain the best quality data available for the time period.

L3b products are stored either in a single, self-contained file, or else in separate data files known as subordinates (for bandwidth and disk space considerations). Single-file L3b products have filenames of the form IYYYYDDDYYYYDDD.L3b_TTT, where I is the instrument identifier, YYYYDDDYYYYDDD are the concatenated digits for the GMT year and day of the start and end days of the binning period, and TTT is a code for the binning period length (DAY, 8D, MO, YR, etc.). For daily products, only the year and day of the data are used.

For the multi-file L3b products a 'main' file exists, containing all product-level metadata and other data common to all the binned geophysical parameters, along with the multiple subordinate files, each of which contains the data of one binned geophysical parameter. An example of the filenames used for a multi-file SeaWiFS L3b Daily product is:

S1998001.L3b_DAY.main
S1998001.L3b_DAY.x00
S1998001.L3b_DAY.x01
...
S1998001.L3b_DAY.x10

Although it is not necessary to know which subordinate file stores which product (SeaDAS automatically handles this), each extension number (x00, x11, etc.) is permanently assigned to a certain geophysical product. For example, the extension numbers for SeaWiFS are assigned as follows:

x00 ⟶ nLw_412
x00 ⟶ nLw_412
x01 ⟶ nLw_443
x02 ⟶ nLw_490
x03 ⟶ nLw_510
x04 ⟶ nLw_555
x05 ⟶ nLw_670
x06 ⟶ angstrom_510
x07 ⟶ chlor_a
x08 ⟶ K_490
x09 ⟶ eps_78
x10 ⟶ tau_865

TIP L3 Binned data products are stored as VDATA HDF objects within the data files, so any HDF utility such as *vshow* can be used to obtain information about the contents of the data files.

More L3b documentation including algorithms used for spatial and temporal binning are listed in the OBPG *Algorithms and Products* FAQ: http://oceancolor.gsfc.nasa.gov/forum/oceancolor/topic_show.pl?tid=1959

2.8 Level-3 Standard Mapped Images

A Level-3 Standard Mapped Image (SMI) is an equidistant cylindrical projection of the arithmetic means derived from the statistical data of one Level-3 Binned geophysical product. (The equidistant cylindrical projection is also called the equirectangular projection or geographic projection.) Therefore SMI products are image representations of binned data products over the period covered by the parent product.

The OBPG distributes global SMI maps at 4.6km (4320×2160) and 9.2km (8640×4320) resolution to match the L3b standard resolutions. Grid points for the entire globe are present in the data files, including an assigned fill value for land and missing data points. SMI files are distributed both as HDF files and as PNG (Portable Network Graphics) image files. The SMI HDF product files are created using the `smigen` program.

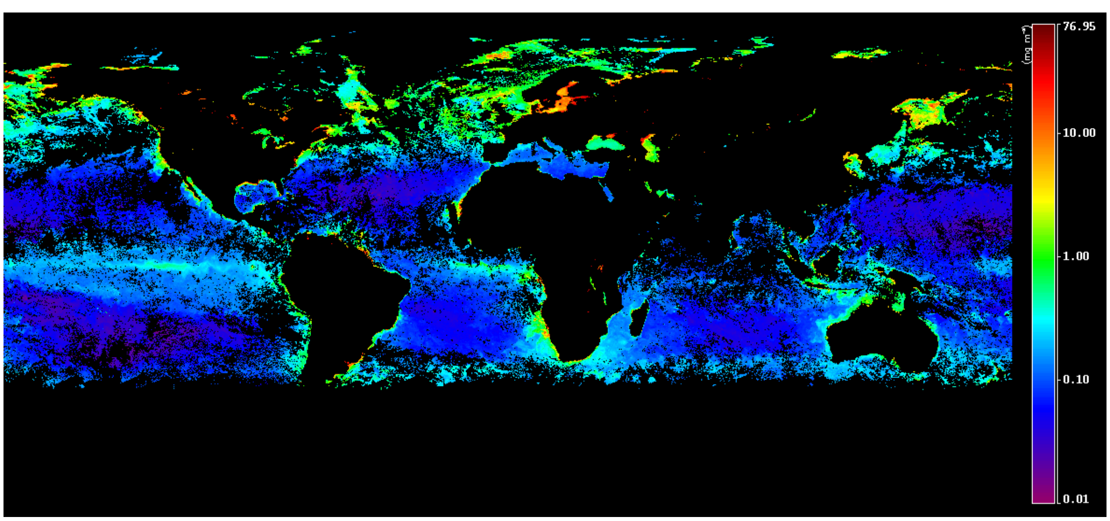

Figure 2.5: 8-Day Level-3 Standard Mapped Image (MODIS Aqua Chlorophyll-*a*, June 2007)

All of the OBPG-distributed SMI products are stored as 16-bit integers (scaled down from the 32-bit floating-point L3b products).

Due to scaling of the L3b data values and problems that may arise from mapping, researchers should fully understand the issues involved with the SMI format before using these maps for scientific purposes. Often using the L3 Binned data directly instead of mapping the bins may be the best approach.

TIP SeaDAS has the flexibilty to create SMI maps as 8-bit integer data, 16-bit integer data, or 32-bit floating-point data at 1, 2, 4, 4.6, 9, 9.2, or 36 kilometer resolutions.