**VIIRS-NPP Reprocessing 2013.0**

**1. Introduction**

An effort is currently underway to assess the capacity of the VIIRS instrument to support NASA Ocean Biology and Biogeochemistry Program science (e.g., [Turpie et. al 2012](http://oceancolor.gsfc.nasa.gov/WIKI/OCRef.html)). The NASA Ocean Biology Processing Group (OBPG) is applying calibration methods and algorithms based on lessons learned from SeaWiFS and MODIS with the goal of producing a suite of ocean color products from VIIRS that are consistent in content, format, and quality with heritage sensors. These products are being distributed as [evaluation products](http://oceancolor.gsfc.nasa.gov/WIKI/VIIRSdisclaimer.html) for assessment by the NPP Science Team and the research community. Some discussion on the differences between VIIRS products producted by NOAA and those producted by NASA can be found in the [initial NASA processing of VIIRS (V2012.0)](http://oceancolor.gsfc.nasa.gov/WIKI/OCReproc20120VN.html). This initial processing was followed by a calibration update, the introduction of a Level-1A format, and expansion of the evaluation products suite in [NASA VIIRS ocean color processing V2012.2](http://oceancolor.gsfc.nasa.gov/WIKI/OCReproc20122VN.html).

In this reprocessing, called V2013.0, several significant changes were made relative to [V2012.2](http://oceancolor.gsfc.nasa.gov/WIKI/OCReproc20122VN.html).

1. the temporal calibration was switched from solar-diffuser-based to lunar-based but using the solar-diffuser for detector-relative calibration.
2. the vicarious calibration was updated.

**2. Instrument Calibration**

NASA is deriving a continuous temporal calibration based on the on-board calibration measurements for the visible and near-infrared bands (M1-M7, 410-862), and then reprocessing the full mission to produce a continuously calibrated Level-2 product.

In Level-0 to Level-1A processing, the calibration is based on results from the prelaunch characterization (e.g. spectral response, polarization sensitivity, response versus scan angle, etc.). The prelaunch radiometric calibration is assumed to be a linear function of the measured counts after dark current subtraction. In Level-1A to Level-2 processing, the prelaunch-calibrated radiances are multiplied by trending coefficients that track the on-orbit change of the radiometric gains. In previous OBPG reprocessings of VIIRS, the temporal calibration was based entirely on measurements of the Sun through the solar diffuser ([Eplee et al. 2012](http://oceancolor.gsfc.nasa.gov/WIKI/OCRef.html)). These solar-based temporal trends were validated against less frequent observations of the moon. That validation showed increasing discrepancy beween the lunar and the solar trends, reaching as much as 2% in the shortest wavelengths.

This discrepancy is being investigated by both the VIIRS Calibration Support Team (VCST) and the OBPG. A complicating factor in the solar calibration is that the solar diffuser reflectance has degraded substantially since launch, with largest decrease of ~15% in the shortest wavelengths. Unlike MODIS, the solar diffuser on VIIRS is continuously exposed, so accelerated degradation is to be expected. Error in the correction for solar diffuser degradation may be the reason for the solar to lunar discrepancy.

In this reprocessing, the lunar trends provide the primary temporal calibration and the solar diffuser measurements are used only to account for detector and mirror-side relative variations.

The figure below shows the change in radiometric response for bands M1-M4 (410-551nm) and M4-M7 (551-862nm) as derived from the OBPG compined lunar and solar calibration.

**3. Vicarious Calibration**

As for SeaWiFS and MODIS, the OBPG applies an additional vicarious calibration to VIIRS during Level-2 processing ([Franz et al., 2007](http://oceancolor.gsfc.nasa.gov/WIKI/OCRef.html)). Band M7 (862nm) is assumed to be correctly calibrated from prelaunch measurements. Band M6 (748nm) is adjusted using match-ups from the South Pacific Gyre, to force the aerosol type retrievals to match, on average, the aerosol type observed at the Tahiti AERONET site. The calibration of bands M1-M5 (410nm to 671nm) is then adjusted to produce retrievals that match, on average, a surface reference.

In this 2013.0 reprocessing, the vicarious calibration is based on measurements from the Marine Optical Buoy (MOBY) near Lanai Hawaii (the same reference currently used for SeaWiFS and MODIS).

The vicarious calibration gains derived in this manner are:

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Wavelength (nm) | 410 | 443 | 486 | 551 | 671 | 745 | 862 | 1238 | 1601 | 2257 |
| Gain | 0.9656 | 1.007 | 1.0146 | 0.9799 | 1.0232 | 1.0448 | 1.0 | 1.0 | 1.0 | 1.0 |

It must be emphasized that these gains are only applicable to the OBPG instrument calibration and the standard NASA atmospheric correction algorithm. **If NOAA SDRs are processed through the NASA algorithms, it is recommended to set the vicarious calibration to unity, as the NOAA SDRs include an absolute calibration to the solar diffuser that may largely resolve the biases captured by NASA through vicarious calibration.**

No attempt has yet been made to calibrate the shortwave infrared (SWIR) bands.

**4. Processing Algorithms and Derived Products**

For the NASA SDR to Level-2 processing, the OBPG is using the [standard NASA atmospheric correction](http://oceancolor.gsfc.nasa.gov/WIKI/AtmoCor.html), i.e., the same algorithms and software that are currently used in standard processing of MODIS, SeaWiFS, and other ocean color sensors. See the [initial NASA processing of VIIRS](http://oceancolor.gsfc.nasa.gov/WIKI/OCReproc20120VN.html) for details.

For this reprocessing, the product suite has been expanded to include photosynthetically available radiation (PAR) and particulate organic and inorganic carbon (POC and PIC), which are currently standard MODIS and SeaWiFS products. The full list of products now contained in the NASA VIIRS Level-2 product includes:

1. remote sensing reflectance, Rrs, in 5 visible channels (410-671nm)
2. aerosol optical thickness at 862nm, aot\_862, using the models of [Ahmad et. al 2010](http://oceancolor.gsfc.nasa.gov/WIKI/OCRef.html)
3. aerosol Angstrom exponent at 443nm, angstrom, using the models of [Ahmad et. al 2010](http://oceancolor.gsfc.nasa.gov/WIKI/OCRef.html)
4. chlorophyll-a concentration, chlor\_a, using the [OC3 algorithm](http://oceancolor.gsfc.nasa.gov/REPROCESSING/R2009/ocv6/)
5. diffuse attenuation at 490nm, Kd\_490, using the [KD2 algorithm](http://oceancolor.gsfc.nasa.gov/REPROCESSING/R2009/kdv4/)
6. particulate organic carbon, POC, using the algorithm of [Stramski et al. 2008](http://oceancolor.gsfc.nasa.gov/WIKI/OCRef.html)
7. particulate inorganic carbon, PIC, using the combined algorithm of Balch and Gordon
8. photosynthetically available radiation, par, from the algorithm of [Frouin et al. 2003](http://oceancolor.gsfc.nasa.gov/WIKI/OCRef.html)

All derived product algorithms have been updated to account for the VIIRS spectral band-passes and effective band centers. Updates for PIC and PAR were provided by NASA NPP Science Team PIs Balch and Frouin, respectively.

**5. File Formats and Naming Conventions**

The NASA VIIRS pseudo Level-1A and Level-2 products are distributed through the [Level-1/2 Browser](http://oceancolor.gsfc.nasa.gov/cgi/browse.pl?sen=v0) and the via the online the [Ocean Color Archive](http://oceandata.sci.gsfc.nasa.gov/VIIRS/) for direct access and bulk download. As previously noted, the pseudo Level-1A products produced by NASA are similar to [standard NOAA SDR format](http://npp.gsfc.nasa.gov/science/sciencedocuments/ATBD_122011/474-00028_Rev-Baseline.pdf). The Radiance, Reflectance, and [BrightnessTemperature](http://oceancolor.gsfc.nasa.gov/WIKI/BrightnessTemperature.html) fields, however, are output as 32-bit floating-point values, and the associated scaling attributes (i.e., [RadianceFactors](http://oceancolor.gsfc.nasa.gov/WIKI/RadianceFactors.html), [ReflectanceFactors](http://oceancolor.gsfc.nasa.gov/WIKI/ReflectanceFactors.html), and [BrightnessTemperatureFactors](http://oceancolor.gsfc.nasa.gov/WIKI/BrightnessTemperatureFactors.html)) are therefore not included.

Each Level-1A or Level-2 file spans ~85-seconds of observation time, thus there are over 1000 granules in a day. This granularity may eventually be changed, but the OBPG is currently constrained to match the granularity of the source (RDR) data. Each band within an SDR is stored in a separate HDF5 file, as is the geolocation data. The NASA processing code requires all 16 M-bands and the geolocation file. To simplify the data distribution and ensure that all bands are present, the OBPG is distributing the Level-1A as a tar file that contains the full suite of bands for the granule (excluding higher resolution I-bands). The tar file mimics the standard naming convention used for other NASA ocean color missions: Vyyyydddhhmmss.L1A\_NPP.tar, where yyyy is year, ddd is day, hhh is hour, mm is minute, and ss is second, and the date/time indicates the observation time of the first line of the granule. An example is shown below.

% tar tf V2012145214452.L1A\_NPP.tar

1. README.txt
2. GMTCO\_npp\_d20120524\_t2144540\_e2146182\_b02972\_obpg\_ops.h5
3. SVM01\_npp\_d20120524\_t2144540\_e2146182\_b02972\_obpg\_ops.h5
4. SVM02\_npp\_d20120524\_t2144540\_e2146182\_b02972\_obpg\_ops.h5
5. SVM03\_npp\_d20120524\_t2144540\_e2146182\_b02972\_obpg\_ops.h5
6. SVM04\_npp\_d20120524\_t2144540\_e2146182\_b02972\_obpg\_ops.h5
7. SVM05\_npp\_d20120524\_t2144540\_e2146182\_b02972\_obpg\_ops.h5
8. SVM06\_npp\_d20120524\_t2144540\_e2146182\_b02972\_obpg\_ops.h5
9. SVM07\_npp\_d20120524\_t2144540\_e2146182\_b02972\_obpg\_ops.h5
10. SVM08\_npp\_d20120524\_t2144540\_e2146182\_b02972\_obpg\_ops.h5
11. SVM09\_npp\_d20120524\_t2144540\_e2146182\_b02972\_obpg\_ops.h5
12. SVM10\_npp\_d20120524\_t2144540\_e2146182\_b02972\_obpg\_ops.h5
13. SVM11\_npp\_d20120524\_t2144540\_e2146182\_b02972\_obpg\_ops.h5
14. SVM12\_npp\_d20120524\_t2144540\_e2146182\_b02972\_obpg\_ops.h5
15. SVM13\_npp\_d20120524\_t2144540\_e2146182\_b02972\_obpg\_ops.h5
16. SVM14\_npp\_d20120524\_t2144540\_e2146182\_b02972\_obpg\_ops.h5
17. SVM15\_npp\_d20120524\_t2144540\_e2146182\_b02972\_obpg\_ops.h5
18. SVM16\_npp\_d20120524\_t2144540\_e2146182\_b02972\_obpg\_ops.h5

The Level-2 files produced by NASA follow the same general naming convention (e.g., V2012145214452.L2\_NPP\_OC), and the format is the same HDF4 format used for all other NASA ocean color sensor products. The OBPG is also distributing VIIRS Level-3 products derived from the NASA Level-2 processing. The Level-3 products are binned to 4.6-km spatial resolution (identical to MODIS), composited to daily, 8-day, monthly, and seasonal products, and distributed in the same binned and mapped HDF4 formats as other NASA sensors. The Level-3 binned and mapped products are available from the evaluation tab of the [Level-3 Browser](http://oceancolor.gsfc.nasa.gov/cgi/l3?per=MO&prd=NPP_CHL_chlor_a&sen=V&ctg=Evaluation) and directly from the [Ocean Color Archive](http://oceandata.sci.gsfc.nasa.gov/VIIRS/).

NOTE: To support evaluation activities by the NASA NPP Science Team, the OBPG is also distributing a set of Level-3 products derived from the standard NOAA Level-2 (EDR) products. These files are clearly identified on the Level-3 browser, and the filenames contain NPPE in place of NPP.

**6. Results**

The V2013.0 reprocessing of VIIRS significantly improves agreement between the Rrs time-series of VIIRS and [MODIS/Aqua V2012.0](http://oceancolor.gsfc.nasa.gov/WIKI/OCReproc20120MA.html), especially at 443nm. VIIRS 2013.0 Rrs retrievals show very good correlation with in situ measurements from AERONET-OC sites. Changes in mean chlorophyll are generally within 10%, with largest changes at the end of the mission. Mean agreement in chlorophyll between MODISA and VIIRS is slightly degraded. See:

1. [VIIRS (2012.2) versus MODISA (2012.0)](http://oceancolor.gsfc.nasa.gov/ANALYSIS/global/vr2012.2m_ar2012.0m/)
2. [VIIRS (2013.0) versus MODISA (2012.0)](http://oceancolor.gsfc.nasa.gov/ANALYSIS/global/vr2013.0m_ar2012.0m/)
3. [VIIRS (2013.0) versus VIIRS (2012.2)](http://oceancolor.gsfc.nasa.gov/ANALYSIS/global/vr2013.0m_vr2012.2m/)
4. [VIIRS (2013.0) versus AERONET-OC](http://seabass.gsfc.nasa.gov/seabasscgi/search.cgi?search_type=val&id=1361305853689044)

**7. Additional Information**

1. [Documentation of NOAA operational algorithms and product formats](http://jointmission.gsfc.nasa.gov/science/documents.html)

[Access to NOAA operational data distribution (CLASS)](http://www.nsof.class.noaa.gov/saa/products/welcome)