**Beta Maturity Status Report/README for Data Users**

***VIIRS Cloud Optical Properties, Cloud Top Parameters, Parallax Correction, Cloud Cover and Layers, Cloud Base Height and Generate Cloud EDRs Beta Data Quality***

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***Beta Maturity Status Report and README for Data Users***

The Joint Polar Satellite System (JPSS) Algorithm Engineering Review Board approved the release of the Visible Infrared Imager Radiometer Suite Cloud Optical Properties, Cloud Top Parameters, Cloud Cover and Layers and Cloud Base Height Environmental Data Record (VIIRS COT EDR, VIIRS CEPS EDR, VIIRS CTP EDR, VIIRS CTH EDR, VIIRS CTT EDR, VIIRS CCL EDR, VIIRS CBH EDR) to the public with a Beta level quality as of April 27, 2013. Beta quality is defined as:

* Early release product
* Initial calibration applied
* Minimally validated and may still contain significant errors (additional changes are expected)
* Available to allow users to gain familiarity with data formats and parameters
* Product is not appropriate as the basis for quantitative scientific publications, studies and applications

The Board recommends that users be informed of the following product information and characteristics when evaluating all the VIIRS Cloud EDRs mentioned above.

**Product status:** The VIIRS Cloud EDRs (listed above) represent continuity with NASA EOS MODIS and NOAA POES AVHRR cloud products. VIIRS Cloud EDRs are produced by an algorithm suite containing Cloud Optical Properties (COP), Cloud top Parameters (CTP), Perform Parallax Correction (PPC), Cloud Cover and Layers (CCL), Cloud Base Height (CBH) and Generate Cloud EDRs (GCE). These algorithms are required to be processed sequentially as outputs from the predecessor algorithm(s) are required input to the downstream algorithm. The outputs from the first five algorithms are pixel level (or Retained Intermediate Products, RIP) products while the last algorithm, GCE, outputs 6x6 km cell level aggregated EDR products. Based on the extensive MODIS/AVHRR cloud product user base, the VIIRS cloud products will be used by numerical weather and climate prediction models. The current VIIRS Cloud EDRs were designed to satisfy the JPSS Level-1 Requirements Document (L1RD) requirements for VIIRS Cloud Properties Products.

As mentioned above the VIIRS cloud algorithms produce pixel-level cloud RIPs (750 m spatial resolution) and gridded cell-level Cloud EDRs (6 km spatial resolution). Each RIP includes quality flags derived from COP, CTP and CBH correspondingly. These are bit-level quality flags indicating in most cases either 1 or 0 corresponding to “yes” or “no” to the condition specified for the quality flag. For EDRs, however, the quality flags are divided into 2 types: (1) the overall or “average over all the pixels in the 6 km cell” quality; (2) the layered quality, each of which has 4-levels of good quality of 0-25%, 25-50%, 50-75% and 75-100%. Each 6 km-cell can have up to 4 layers of clouds and the quality of each layer also has 4-level of quality as mentioned above.

The qualities of most of the IP products are affected by the quality of COP and CTP IPs because they are products generated by the first 2 algorithms in the cloud chain and the products of which also serve as input to the downstream algorithms. *Therefore in the filtering for the “good quality” pixels from an IP product the user must also filter out the “bad quality” pixels identified as such for the upstream input IP products.*

In the following the quality flags directly related to the “goodness” of quality of the IP products are identified and described:

Table 1 - COT and CEPS IP (IVCOP\*) Quality Flags (Ref: COP OAD Table 13)

|  |  |  |  |
| --- | --- | --- | --- |
| IP Attribute | Description | Bit (0 base) | Comment |
| QF1\_VIIRSCOPIP | Indicates VIIRS cloud phases | 5-7 | 0: not executed; 1=cirrus; 2=Op. ice; 3=water; 4=mixed; 5=multilayered cloud |
| QF2\_VIIRSCOPIP | Indicates if “daytime water” cloud algorithm converged | 0 | 1=converged; 0=not |
| QF2\_VIIRSCOPIP | Indicates if “daytime ice” cloud algorithm converged | 1 | 1=converged; 0=not |
| QF2\_VIIRSCOPIP | Indicates if pixel in sun glint region | 6 | 1=in sun glint; 0=not |
| QF3\_VIIRSCOPIP | Indicates if radiance from SDR is bad | 1-2 | 0=good; 1=bad; 2=no calibration |
|  |  |  |  |

Table 2 – Night time and daytime ice CTT IP (IVIWT\*) Quality Flags (Ref: COP OAD Table 14)

|  |  |  |  |
| --- | --- | --- | --- |
| IP Attribute | Description | Bit (0 base) | Comment |
| cttQ | Indicates if “nighttime water” cloud algorithm converged | 2 | 1=converged; 0=not |
| cttQ | Indicates if “nighttime ice” cloud algorithm converged | 3 | 1=converged; 0=not |
| cttQ | Indicates if “daytime ice” cloud algorithm converged | 4 | 1=converged; 0=not |

The Quality flags for CTT described in Table 2 does not include “daytime water“ cloud condition because daytime water cloud algorithm is not in COP. It is however included in the cloud top parameter algorithms described in the following Table 3.

Table 3 – CTH, CTT and CTP IP (IVCTP\*) Quality Flags (Ref: CTP OAD Table 11)

|  |  |  |  |
| --- | --- | --- | --- |
| IP Attribute | Description | Bit (0 base) | Comment |
| QF1\_VIIRSCTPIP | Indicates if pixel in sun glint region | 5 | 1=in sun glint; 0=not |
| QF2\_VIIRSCTPIP | Indicates VIIRS cloud phases | 0-2 | 0: not executed; 1=water; 2=cirrus + Op. ice; 3=mixed |
| QF2\_VIIRSCTPIP | Indicates if “nighttime water” cloud algorithm converged | 5 | 1=converged; 0=not |
| QF2\_VIIRSCTPIP | Indicates if “nighttime ice” cloud algorithm converged | 6 | 1=converged; 0=not |
| QF2\_VIIRSCTPIP | Indicates if “daytime ice” cloud algorithm converged | 7 | 1=converged; 0=not |
| QF3\_VIIRSCTPIP | Indicates if “daytime water” cloud algorithm converged | 3 | 1=converged; 0=not |
|  |  |  |  |

Table 4 – CBH IP (IVCBH\*) Quality Flag (Ref: CBH OAD Table 12)

|  |  |  |  |
| --- | --- | --- | --- |
| IP Attribute | Description | Bit (0 base) | Comment |
| QF\_VIIRSCBHIP | Indicates if pixel in sun glint region | 2 | 1=in sun glint; 0=not |
|  |  |  |  |

\*Note: IVCOP, IVIWT, IVCTP AND IVCBH are Operational file names for IPs

Due to the interdependence of the cloud algorithms the 7 EDRs generated from the aggregation of IP values of pixels within a cell, all have common quality flags. Therefore, the COT EDR quality flags described below apply to other cloud EDRs.

Table 5 – COT EDR (VCOTO\*\*) Quality Flag (Ref: CCL & GCE OAD Table 23)

|  |  |  |  |
| --- | --- | --- | --- |
| IP Attribute | Description | Bit (0 base) | Comment |
| QF1\_VIIRSCOTLAYEREDR | Indicates the % (or level) of a given cloud phase, in 4 separate cloud layers | 2-7 | 2-3 bits: level or % of water cloud  4-5 bits: level or % of multilayer cloud  6-7 bits: level or % of mixed cloud |
| QF2\_VIIRSCOTLAYEREDR | Indicates overall quality, in 4 separate cloud layers | 0-1 | Good quality in 4 levels |
| QF3 \_VIIRSCOTAVGEDR | Indicates the % (or level) of a given cloud phase, over all cloud layers | 2-7 | 2-3 bits: level or % of water cloud  4-5 bits: level or % of multilayer cloud  6-7 bits: level or % of mixed cloud |
| QF4 \_VIIRSCOTAVGEDR | Indicates overall quality, over all cloud layers | 0-1 | Good quality in 4 levels |
| QF5 \_VIIRSCOTEDR | Indicates average % of snow ice pixels in cell | 0-1 | Snow ice pixels in 4 levels of percentage |
| QF5 \_VIIRSCOTEDR | Indicates average % of sun glint pixels in cell | 2-3 | Sun glint pixels in 4 levels of percentage |
| QF5 \_VIIRSCOTEDR | Indicates day, night and transition | 4-5 | 1: Day; 2: Night; 3: Transition |
| QF5 \_VIIRSCOTEDR | Indicates quality of radiance from SDR | 6-7 | Bad SDR data: 0=good, 1=bad, 2=no calibration |
|  |  |  |  |

\*\*Note: VCOTO is the Operational file name for COT EDR

The purpose of the PPC algorithm is to move or relocate a cloud, along with the cloud properties, to a new pixel location as required by the L1RD which states, e.g. “Cloud Optical Thickness is defined as ….. in a vertical column above a horizontal cell on the Earth’s surface”. PPC algorithm finds the new pixel on which the cloud is projected along a vertical line. Any RIP generated downstream of PPC, as well as all the cloud EDRs, are “corrected” products, corrected in the sense that the clouds are projected along a vertical line instead of a slant path. The “corrected” RIPs are designated as VIIRS Parallax Corrected Cloud RIPs at CLASS.

*The users must be reminded that when the “parallax corrected” IP products and cloud phase are used together one must use the cloud phase data in the relevant Quality Flag of the corrected IP, not from the regular VIIRS Cloud Mask IP, as the latter is not “parallax corrected”.*

1. **Effectivity Date of Beta Maturity:** The VIIRS Cloud EDRs and VIIRS Cloud RIPs beta maturity effectivity date is April 27, 2013.
2. **Product Evaluation Description:** Validation of the cloud EDRs is focused on using RIPs as these products provide the finest spatial resolution thus reducing errors due to aggregation, in the EDR products. The validation has included two basic components: first, verifying that the quality flags in the cloud RIP granule files are consistent with the algorithm and its inputs, e.g. VIIRS Cloud Mask (VCM); and secondly, quantifying the cloud RIP accuracy in view of the JPSS Level-1 Requirement Document (L1RD) requirements for the VIIRS cloud EDRs.

Based on comparisons of the VIIRS COP and CTP IP with MODIS cloud products for days, e.g. 08/14/2012 and 11/02/2012, and Calipso CALIOP cloud products for the period of November 2012 – April 2013 the quality flags appeared in the RIPs and EDRs are found to be consistent with the algorithm that generates them, and the algorithm’s input IPs. Many of the quality flags were also examined in details and found to be correct, in the verification of test results generated due to algorithm change.

Quantitative validation was based on the comparisons large number of pixels matched up with MODIS, NOAA, CloudSat and Calipso CALIOP cloud products. The most extensive comparisons were performed for CTH, CTP and CTT with MODIS, NOAA and CALIOP products, which include days of NPP granules. The performance of CTH and CTP are found to be meeting the L1RD accuracy requirement for ~ 64% of the matchup data points (for optically thick cloud at τ > 1 ). The performance of CTT is ~ 5 K in accuracy for water clouds, the performance of which is larger than the L1RD requirement threshold. However, the CTT performance is expected to improve when the marine layer cloud code update is operationalized by IDPS, June 27, 2013.

For VIIRS COP IP, extensive comparisons were made with MODIS and NOAA cloud products for the daytime conditions. Based on comparisons with NOAA products, the NPP COT and CEPS performance are: 68% and 64% within the L1RD accuracy requirements. There values were computed only for data where the cloud mask and cloud phase agreed with the NOAA and NASA data. Errors in the VCM cloud detection or cloud phase will reduce the actual level of agreement. Also, these numbers do not include snow or ice covered surfaces. These performance values were obtained based on NPP COP products generated with the March 2013 updated COP cloud Look-Up-Tables. MODIS does not provide nighttime COP products and therefore no direct comparisons can be made. However, VIIRS nighttime COT performance was estimated based on the cloud emissivity data generated by the MODIS cloud top products. This indirect COT comparison with MODIS nighttime products was possible because COT can be related to the cloud emissivity by taking in account of sensor zenith angle and scattering effects. From these indirect comparisons the nighttime COT performance is estimated to be ~ 40% of τ value, thus over the L1RD precision requirement limit.

According to the L1RD, the cloud cover (or fraction) uncertainty is listed as the only requirement to meet. Cloud cover is determined directly from the VCM cloud classification. Therefore the uncertainty of cloud cover is related to the error rates in the cloud classification. From VCM Provisional Review (January 2013) the cloud classification error rates (false alarm + leakage), therefore the cloud cover uncertainty, is estimated to be 0.143. With this performance value the cloud cover EDR is close to meeting the L1RD CCL requirement.

Comparisons of VIIRS CBH with CloudSat cloud products from 11:59:16 UTC to 12:00:40 UTC on 17 February 2012 were made. The VIIRS CBH overall performance was estimated to have an uncertainty = 2.8 km, the value of which is slightly over the L1RD uncertainty requirement limit. In general, the VIIRS CBH tends to over-predict the base height for low clouds, however, under-predicts the base for high clouds.

1. **User Precautions/Known Deficiencies:**
2. We do feel nighttime COP (including COT and CEPS) and cloud base meet beta but are less mature than the other algorithms.
3. Nighttime water COP software bugs have been identified and are being assessed. These bugs return nighttime water cloud COT and CEPS retrievals a factor of about 5 too high or low respectively (ADR 7231).
4. We also observed that for ice clouds, the CTH performance has a negative bias and the major error contribution has been found to be from the parameterization equation used to characterize the extinction coefficient ratio of 2 IR bands, known as the k-ratio in the COP ATBD. A more accurate representation of the k-ratio equation is being developed based on the Calipso IIR Track products in which the cloud emissivities for 2 IR bands are provided (ADR 7232).
5. VIIRS CBH tends to over-predict the base height for low clouds, however, under-predicts the base for high clouds. The major contributing factor is in the oversimplification of the use of constant liquid water content (LWC) for various cloud types. This issue is being assessed and better LWC characterizations will be developed for a future IDPS Build for CBH (ADR 7233).

Additional information on VIIRS and Cloud Algorithms Theoretical Basis Document (ATBD) are available at <http://www.star.nesdis.noaa.gov/jpss/ATBD.php>

The VIIRS Cloud EDRs Read-me for Beta Data Quality is also available at the CLASS Homepage.

Points of Contact:

Andrew Heidinger

JPSS VIIRS Cloud Cal/Val Lead

Email: [Andrew.Heidinger@noaa.gov](mailto:Andrew.Heidinger@noaa.gov)