Provisional 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 Provisional Data Quality
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Provisional Maturity Status Report and README for Data Users

The Joint Polar Satellite System (JPSS) Algorithm Engineering Review Board approved the Provisional level quality 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) as of the Mx8.5 installation (will be updated once software is operational). **Provisional** quality is defined as:

- Product quality may not be optimal - Optimal would be attaining all of the requirements of the 'Validated' maturity.
- Incremental product improvements still occurring
- General research community is encouraged to participate in the QA and validation of the product, but need to be aware that product validation and QA are ongoing
- Users are urged to contact JPSS and SNPP Cal/Val Team representatives prior to use to understand issues.

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. Note that the pixel level products are not currently available to the public. 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 at nadir) and gridded cell-level Cloud EDRs (approximately 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 these IPs are direct input to the subsequent algorithms in the cloud chain. *Therefore in the filtering for the "good quality" pixels the user must also filter out the "bad quality" pixels identified in these two upstream input IP products.*

To determine if a retrieval is "good quality" the user needs to consider the following: (1)by itself, e.g. CTH, check if CTH has converged; (2) CTH is retrieved based on input from its predecessor algorithm COP, therefore one should also check if COT/EPS converged; (3) check if the pixel is in degraded condition, e.g. in sun glint region, multi-layer cloud or mixed phase clouds, in day-night transition region, etc.; (4) under night time condition the user should always check if night time CTT (therefore COT/EPS) has converged. This is because CTT is retrieved simultaneously with COT and EPS in the COP algorithm and they all impact every IP downstream, say CTH, CTP, CTT, CBH etc.

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	3	1=converged; 0=not

	ice" cloud algorithm converged		
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 its cloud properties, to a new pixel location intercepted by the vertical line from the cloud as stated by the L1RD 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 in the cloud chain, as well as all the cloud EDRs, are "corrected" products, corrected in the sense that the clouds are geo-located based on 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 Provisional Maturity:** The VIIRS Cloud EDRs and VIIRS Cloud RIPs beta maturity effectivity date is TBD – will align with the Mx8.5 installation..

2. **Product Evaluation Description:** Validation of the cloud EDRs is focused on using RIPs as these products provide the finer spatial resolution than the aggregated 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 with established products if available, or comparable products generated under conditions under which no established products are available, such as night time COP.

   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 of 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 $\tau > 1$). The performance of CTT is ~ 5 K in accuracy for water clouds, the performance of which is larger than the L1RD requirement threshold. However, with the marine layer cloud code update operationalized by IDPS, June 27, 2013 the CTH performance for these clouds has improved

   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.
   For the Provisional Maturity status request we have expanded the nighttime COP validation to include pixel-level SSF products from CERES scientist team, Night Lunar Cloud Optical and Microphysical Properties, NLCOMP products, and finally Calipso Infrared Imaging Radiometer, IIR

cloud products. These products provide direct comparison to NPP night COT and EPS products. For the comparison we have selected NPP data from three "golden days", the day in which there is significant lunar illumination and Calipso near simultaneous overpass occurs. These 3 days are 02/01/13, 03/29/13 and 08/22/13 spanning 3 seasons of the year. In general, the NPP night COT and EPS retrievals are quite different from the SSF and NLCOMP products. However, NPP night products seems to compare better with the Calipso COT and IIR EPS product.

According to the JPSS Level 1 Requirements Document (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.

3. User Precautions/Known Deficiencies:

a) We do feel nighttime COP (including COT and CEPS) and cloud base meet Provisional but are less mature than the other algorithms.
b) Due to inherent limitation in retrieving COT and EPS using thermal IR bands the VIIRS nighttime water and ice COP algorithms are not expected to perform well for thick clouds, e.g. COT > 6.
c) After introducing an accurate k-ratio parameterization equation for day and night ice cloud retrievals the low bias in CTH retrievals in comparison with CALIPSO data is reduced but not completely eliminated. We suspect the error likely come from the clear sky radiances calculated using Pfaast fast RTM in which the VIIRS spectral response functions for the IR bands are only approximately accounted for. This error will be further analyzed and new methods, such as the use of Community RTM will be examined. Other errors such as the land surface emissivity could also contribute significantly to the error in clear sky radiances. This error will be further examined and remedy will be devised to reduce or eliminate the error. .
d) We also noticed that NPP daytime EPS algorithm shows significant differences between NOAA NCOMP and MODIS in the full range EPS while NPP returns all small EPS. The differences are much more prominent for land pixels than ocean leading to the belief that the NPP algorithm and other outside algorithms probably use significantly different surface albedos. This error will be further examined and remedy will be devised to reduce or eliminate this error.
e) 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).
f) Due to insufficient testing and evaluation the night time water cloud COT and EPS is currently still in Beta Maturity state.

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 Provisional Data Quality is also available at the CLASS Homepage.

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