NATIONAL POLAR-ORBITTING OPERATIONAL
ENVIRONMENTAL SATELLITE SYSTEM (NPOESS)
INTEGRATED PROGRAM OFFICE
8455 Colesville Road
Suite 935
Silver Spring, MD 20910

NPOESS Community Collaborative Calibration/Validation Plan for the NPOESS Preparatory Project
VIIRS Cloud Mask Intermediate Product

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PREPARED BY: ____
Dr. Thomas J. Kopp, The Aerospace Company

ELECTRONIC APPROVAL SIGNATURES:

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1.0 Objectives

The VIIRS Cloud Mask (VCM) Intermediate Product (IP) is the first product in the chain of EDRs (outside of imagery) and hence virtually all other VIIRS EDRs depend on the VCM. The verification and validation of the VCM is therefore critical for success of the NPP/NPOESS program as a whole. There are a diverse set of users of cloud masks in general, with many of these users creating their own cloud masks. For each of these users, any new cloud mask must be at least as good as what they use today, so for them the benchmark is “heritage” performance. However the IDPS approach requires a single VCM for all EDRs, and to achieve a VCM that works for all products demands that it meet the numerous quantitative requirements in the System Specification (Sys Spec). The objective of this plan is to provide the actions necessary to prove if the VCM achieves the Sys Spec while also meeting or beating heritage performance.

The Sys Spec gives quantitative requirements regarding the cloud mask under the Cloud/Cover Layer EDR. These can be found in Table 40.4.2, paragraphs 14-18, of the Sys Spec (see Appendix B). Due to the nature and importance of the VCM, the IPO decided to detach the VCM from the other Atmosphere EDRs with respect to the Cal/Val effort. Verifying the VCM meets the Sys Spec however, is not sufficient to prove heritage. Heritage can be other cloud masks (i.e. Cloud Depiction and Forecast System II (CDFS II), Clouds From AVHRR (CLAVR)) or in some cases “heritage” is a loose term and the cloud mask employed is never evaluated directly, but only indirectly by noting errors in the EDR it supports (i.e. SST). It will take both direct evaluation of the cloud mask, which this plan will address, and the indirect evaluations from the supported EDRs, which this plan will not address in detail, to validate the VCM and its’ impact on downstream EDRs. Note the indirect support will be a factor in determining the success, or lack thereof, for the VCM, and furthermore that the coordination with the other EDR Cal/Val disciplines is discussed in this plan. The Centrals’ are also directly involved, as this document will show. It is this combined effort that will lead to the validation of the VCM.

Operational uses for the VCM vary widely, for some users it will be used directly as part of an automated cloud analysis or forecast, for others it is an input to the EDR of interest, whether by for a cloud property (i.e. COP) or for identifying clear scenes for further processing (i.e. SST). In both cases the VCM represents a fundamental input where poor performance would leave the final desired EDR unacceptable. The VCM, simply put, must work.

The VCM is expected to achieve the Sys Spec and be capable of supporting the EDRs produced on the IDPS. With regard to heritage, there are many concerns among the various communities as to whether or not the VCM will meet their needs. Current pre-launch evaluations of the VCM indicate it will be at least competitive with heritage cloud masks, though the proliferation of cloud masks across the user community may make this difficult to prove. Ultimately it is the impact on the downstream EDRs produced on the IDPS that drive the “indirect” validation of the VCM.

The following table list ties the VCM to the other Cal/Val disciplines and their related EDRs. A list of dependent users would take pages; given the use of the VCM it makes more sense to tie it to the products themselves. The VCM is produced under all conditions, and there are no exclusion conditions. There are four degraded conditions noted in the Sys Spec for the VCM that can be found under the Cloud Cover/Layer requirements, they are: daytime conditions with clouds present but their Cloud Optical Thickness is less than 1.0, land locations with Normalized Difference Vegetation Index (NDVI) values between 0.2 and 0.4 with clouds present but their COT is less than 1.0, sun glint, and nighttime conditions poleward of 60 degrees latitude. Even for these four conditions, there are quantified values in Appendix D of the Sys Spec for false alarms and leakage.

I.

CalVal Discipline	**EDRs dependent on VCM IP**
Atmosphere	Aerosol Optical Thickness, Aerosol Particle Size, all Cloud EDRs
Land	Albedo Products, Land/Ice Surface Temperatures, Surface Type, Suspended Matter, Active Fires, Sea Ice, Snow
Oceans	Ocean Color, Sea Surface Temperature

Table 1: Relation of VCM to other CalVal Disciplines and EDRs

2.0 Approach

The scope for evaluating VCM involves Subject Matter Experts (SME) in cloud detection algorithms and imagery interpretation, with significant coordination with SMEs for each of the VIIRS EDR products. The VCM Cal/Val effort will basically be two steps (simply referred to as Step 1 and Step 2 below). The critical Step 1 is a planned 30-day rapid tuning event to produce a VCM adequate for other EDR products to employ. This step commences when the SDR and Imagery is determined adequate for VCM evaluation (see the VIIRS Imagery and SDR Cal/Val plans) and is intended to allow for validation of the dependent downstream EDRs to begin earlier in ICV. Once this is completed, Step 2 will be comprised of a simultaneous set of studies performed to fully characterize the VCM's performance. The below covers this in more detail.

Pre-launch activity will focus on updating the so-called tuning parameters (i.e. the thresholds used to determine a pixels' level of cloudiness). The process of tuning will be demonstrated using global synthetic data, constructed using the MODIS spectral response functions, to tune the VCM. The updated VCM will then be used to analyze 14 granules of MODIS_proxy data and establish VCM performance through comparisons with the manually-generated truth data. Post-tuning improvement in VCM performance using these 14 granules validates the tuning process and helps define the impact of various thresholds on false alarms, leakage, and the percentage of "probably" criteria. After pre-launch VIIRS sensor characterization is complete, the process will be repeated using global synthetic data with the VIIRS spectral response functions to create a final set of pre-launch thresholds. These thresholds will be updated in the 30-day spin-up period using actual VIIRS sensor data. For a detailed discussion of the tuning process, please see the document "Tuning and Reprocessing of the VCM".

Remaining pre-launch activity will focus on analyzing the VCM via the use of MODIS as proxy data for VIIRS at the Atmosphere PEATE and Aerospace Omaha. The PEATE will focus on match ups between both the VCM and the MODIS cloud mask with CALIPSO, giving us early indication of VCM sensitivity to thin clouds and other potential problem areas. Aerospace Omaha will work with NGAS on establishing the pre-launch VCM tuning thresholds.

Very early in the ICV phase will come the 30-day spin-up mentioned above. Once this is completed, four different analyses will occur simultaneously, they are, in no particular order of importance; 1) a quantitative analysis using manual determination of cloud over a specified set of VIIRS granules 2) a quantitative comparison of other cloud algorithms with the VCM 3) a quantitative analysis comparing the VCM to other external sources of cloud measurements such as CALIPSO and 4) incorporating feedback from the other Cal/Val disciplines and EDRs, especially SST and surface reflectance, into tuning corrections that maximize the quality of the VCM. Some re-tuning will occur during step 2 as these additional results come in, though no “second” rapid tuning period is planned. Long Term Monitoring (LTM) of the VCM directly is not expected, but LTM of dependent EDRs will, at times, require changes to the VCM. The Air Force Weather Agency (AFWA) also employs a full time cloud analyst who will periodically analyze the VCM after ICV. LTM will not be addressed in this document.

A wide variety of tools currently exist to evaluate cloud masks, but they are scattered and serve widely different purposes. Tools for evaluating the required ancillary data also exist. The only new tool needed is that for quantitative evaluations of the VCM based on manual analysis of the granule, and that will be written by Northrop Grumman Advanced Sciences (NGAS). Aerospace will need to perform significant upgrades on their current analysis and tuning tools, but this work is an extension of a tool already in existence. The other tools primarily only need to adjust to the format of the VCM. The tools are described further in section 5.

SME expertise is a fundamental requirement throughout the ICV effort. Due to the nature of the VCM, and the need to coordinate with many different interests (19 other EDRs), good communication skills are also required. We have personnel who have worked within and with the VIIRS Operational Algorithm Team (VOAT) for almost 10 years, and do not foresee any problems in this regard. Some expertise with imagery is also required, as this is useful when comparing the VCM results with imagery.

The VCM depends upon ancillary data for 2-meter temperature (Global Forecast System or GFS) and two IDPS-produced intermediate products for NDVI and snow information. Match up data will be primarily comprised of cloud results from CALIPSO and CloudSat, assuming they are in good shape after the NPP launch. Other sources such as LIDAR and ARM sites also apply, though their benefits are of a more limited nature for the VCM. Comparisons to cloud masks created from MODIS and AVHRR are also planned, with more emphasis on their results if CALIPSO and CloudSat are no longer available. Processing VIIRS through other cloud mask algorithms requires additional hardware beyond that of the IDPS, but the Atmosphere PEATE covers this more than adequately. GRAVITE will need adequate resources to support multiple users of the VCM during ICV. We do not expect any “new” match up data sources to develop between now and NPP launch.

We have committed to a 30-day step 1 where the VCM will be tuned adequately for use by the VIIRS EDRs. The remaining activities, described above, will take approximately 6-9 months after the initial 30-day period. The items we expect to take the longest are the quantitative assessment through a manual analysis and the analysis via the impact to the downstream VIIRS EDRs. The latter could extend beyond the 9 month time frame, but we expect any major issues to have been discovered by then.

Given the criticality of step 1, the small team working this will be in one physical location. They will use tools built by Aerospace and NGAS employed on GRAVITE and the NPOESS Science Investigator Processing System (NSIPS). The initial VCM will come from the NESDIS IDPS into GRAVITE, where it will be stored for analysis and tuning. Tuning changes will be tested through GRAVITE. Actual implementation on the IDPS regarding tuning changes in this initial 30-day period will not occur until the end of that period. Hence only one configuration change of the operational software will be needed. GRAVITE will be used to maintain CM over the VCM thresholds during step 1.

Work relating the VCM to the KPP SST will be performed by NAVO. Our POC with NAVO is Doug May. NAVO has the ability to run the SST algorithm with different cloud masks and generate quantitative results. They also have the ability to focus on specific regions to isolate those types of clouds causing any undesired effects. They will run the SST using the VCM and report back to the VCM team any anomalies they find along with examples. The VCM team will alter thresholds as needed and inform NAVO when sufficient improvements are in place. NAVO will reprocess the SST algorithm over the same or similar datasets. Once the threshold changes are deemed appropriate and acceptable, they will be implemented into the IDPS.

The effects of the confidently clear mask also have significant impacts on Land EDRs. Working with the Land Cal/Val team, we have established a POC on the Land EDR team to coordinate issues they find that relate to the VCM. Eric Vermote will use surface reflectance as his primary product to determine the impact of the VCM on Land EDRs. Eric expects to use a time series of surface reflectance to detect adverse affects from potential errors in the VCM. Once they determine a sufficient time series to expose concerns with the VCM, expected to take on the order of 2-3 months, they will report both omissions and commissions (too much or too little cloud) of the VCM for our team to resolve. Using both scenes recommended by the Land team and our own, we will address and correct the VCM as necessary. The Land team will then need 2-4 weeks of rerunning their test cases to determine if the fix is suitable. If it is, we will work with NGAS to implement the improvement into the IDPS in accordance with the ICV algorithm update process defined by the IPO and NGAS. If it is not, we will work further iterations with the Land Team.

3.0 Schedule and Milestones within IPO-Defined Phases

At a high level, the exit criteria occurs when the Sys Spec has been met and the downstream EDRs, produced on the IDPS, are receiving a sufficient cloud mask for their needs. The first of these will take approximately one year, maybe slightly less, but the second has other dependencies that will take it to the end of ICV. Actual use of the VCM operationally can be gradual as each EDR's needs are met.

The rapid tuning during the 30-day spin-up will be performed by a small group of experts with extensive experience in working with cloud masks. At this time this team will be comprised of one member from the government, one from NGAS, and the VCM Cal/Val lead. The more significant second phase, with its' numerous activities, will occur at various organizations to include NSIPS, AFWA, GRAVITE, Aerospace – Omaha, Atmosphere PEATE, and NRL-Monterey. This does not include the organizations where individual EDRs under the other disciplines are evaluated. The coordination of all these efforts will be one of the greater challenges during the VCM validation process. Major science changes will not be addressed in step 1.

As indicated earlier, we foresee the actual work of step 1 to take approximately one month. Note this will focus only on tuning (threshold) changes and no new science will be considered at that time. Step 2 will take 6-9 months to complete the work that supports proving whether or not the VCM meets the Sys Spec, but the VCM itself cannot be considered finished until all of the downstream EDRs receive an adequate cloud mask.

The timing of when to begin step 1 has a strong dependence on the quality of the Imagery coming from NPP. Some coordination between the SDR Cal/Val team and the Imagery Cal/Val team will be required. Step 1 cannot wait until the Imagery work is fully completed, but neither can the VCM Cal/Val effort begin if the Imagery is not suitable for cloud analysis. As the Imagery and VCM team have common members, it should not be difficult to establish the point where Imagery is suitable for VCM work, although stating specific criteria will be a challenge. Our preference is to begin when step 1 of the Imagery plan is satisfied, but it must be recognized that if problems develop that drag out the time it takes to complete that phase of the Imagery plan, the VCM team will need to consider beginning work even if Imagery is only useful over limited scenes. Regarding support of the VCM, the Imagery only has to be “good enough” to determine cloud vs. surface or aerosol features, and not necessarily good enough to determine the exact nature of the cloud, although it is the latter that is the requirement on the Imagery EDR. There are no requirements that directly link Imagery with analysis of the VCM.

Step 2 formally begins immediately after step 1 is complete. Besides the need of the downstream EDRs, which step 1 is primarily designed to serve, some of our participating organizations intend to aggressively analyze the VCM as soon as we pass the Provisional Stage. Science changes, minor or major, that the team believes to be necessary, will be worked during step 2.

The 30-day rapid spin-up is a milestone in itself, but the other validation processes will require some tracking. The milestones for the VCM can be broken into three parts; 1) the completion of the various validation processes, i.e. comparisons with CALIPSO 2) Central’s such as AFWA acknowledging the cloud mask is good enough for operational use and 3) the SMEs for each EDR determining the cloud mask is adequate for their use. Note on the latter the EDRs are those from the IDPS, not EDRs produced off other non-related systems. The defined maturity levels listed below state the milestones associated with each level.

We plan to document the completion of each activity described in section II. This is necessary to show the broader community what was done and who performed the work. We will need to coordinate with the other disciplines on the appropriate deliverables that support VCM validation. GRAVITE is an ideal platform to record the responses from these other disciplines on their issues regarding the VCM. It will also serve as the location where specific EDRs can either record that the VCM suits their needs or the shortfalls they observe. This is additional to entering the completion of the levels discussed in the following paragaraph.

The definitions of the VCM with regard to the Data Product Maturity Levels are as follows:

- **Beta** – The VCM has been tuned by NGAS pre-launch after sensor characterization. The VCM should be at the Beta maturity level at launch.
- **Provisional** – The VCM has completed the rapid 30-day spin-up, having been analyzed through a minimum of 1000 granules by SME, and is ready to support production of the dependent downstream EDRs such that they may begin their own Cal/Cal activities. The granules used must reflect all possible conditions; essentially the VCM must be tuned on a global basis.
- **Validation Stage 1** – At least 500 granules of the VCM have been quantitatively compared to remote systems such as CloudSat or CALIPSO for performance validation. If these systems are not viable after the launch of NPP, then the comparisons will be performed against other cloud masks such as those from MODIS or CLAVR. In either case, tho pass this stage the VCM must also be quantitatively characterized via the manual analysis.
- **Validation Stage 2** – The VCM, as agreed by both NGAS and the government, meets or beats the Sys Spec.
- **Validation Stage 3 –** The VCM, as agreed to be the Atmospheres, Land, and Oceans Cal/Val teams, is suitable to support the downstream EDRs produced by the IDPS.

4.0 Resource Requirements

The current VCM Cal/Val team members include Andy Heidinger (NOAA/NESDIS), John Eylander (AFWA), Jeff Hawkins (NRL-Monterey), Jeff Tesmer (FNMOC), Keith Hutchison (NGAS), Mike Plonski (NGAS), and Thomas Kopp (Aerospace). The two primary contacts with the EDR Cal/Val teams dependent on the clear portion of the VCM are Doug May (Oceans) and Eric Vermote (Land). Any needed aerosol expertise will be coordinated with the Atmosphere Cal/Val team, which has the responsibility of validating the Aerosol EDRs. In some cases these personnel represent a POC for their organization and they may tap other personnel to perform the actual validation of the VCM.

The expertise required has been discussed previously. The initial SMEs for step 1 will require 1 SME from the government and NGAS, as well as the VCM Cal/Val lead. Step 2 will include all the organizations listed above, plus representatives from the other three VIIRS Cal/Val disciplines (Atmospheres, Land, Oceans).

Step 1 will require 3 Full Time Equivalents (FTE) for one month. Step 2 is more loosely organized, depending on the availability of personnel, but no doubt will be a much larger effort. At this time we estimate on the government side 5 FTEs over 9 months. NGAS will provide an estimate of their resources in a later draft.

The team members are identified above. All the government team members except Andy Heidinger are co-located with NPOESS customers (in this context, a customer is one who can directly access the VCM from the IDPS). Andy is co-located with the Atmosphere PEATE, and can access the VCM product via the Science Data Segment (SDS). Also see Table 2.

Many of the organizations involved have their own tools for evaluating the VCM, and our intent is to exploit these pre-existing tools to the maximum extent possible. NGAS will focus on tools showing the Sys Spec is met, the PEATE will compare the VCM to other space-based cloud detection sensors and comparison to other algorithms, AFWA will focus on tuning, GRAVITE will supply updated VCM corrections to the other EDR evaluation teams, and Aerospace – Omaha will work on addressing those concerns from the other Cal/Val teams. Thomas Kopp has broad expertise and will work with each customer and team member coordinating efforts and insuring all concerns are documented, prioritized, and worked by the appropriate party. Mike Plonski and other NGAS personnel will lead the quantitative analysis work with government assistance. All results will be aggregated by Thomas Kopp and Mike Plonski. The tools are described further in section 5.

Although NGAS has the responsibility to build the manual analysis tool, the application and analysis using this tool will be a coordinated effort among the VCM Cal/Val team. Selected manual scenes must address the different conditions spelled out in the Sys Spec. Besides the breakdown of ocean/land and day/night, special requirements can be found for specific NDVI backgrounds, sun glint, and polar night. The selected scenes must encompass this breakdown. The exact scenes will be chosen post–launch by the same team working the initial 30-day tuning effort. These scenes will be stored in GRAVITE and NGAS's NSIPS tool so any threshold changes can be evaluated for quantitative impacts on well understood scenes. The evaluation of the Sys Spec requirements will be heavily dependent on this data set. No other stratifications are planned at this time.

The manual analysis itself involves SMEs drawing, by hand, the location of all clouds in a VIIRS granule. This analyst may use any available VIIRS imagery, but may not look at the output of the VCM itself. If multiple SMEs are used on a granule, they would work together to maximize the quality of the manual analysis. This is a time consuming process, hence the number of granules chosen will be limited. We foresee approximately 20-30 granules for this effort. This type of analysis has heritage in the pre-launch evaluation of the VCM, and is used operationally at the AFWA. Other than ground truth such as CALIPSO, it is the only other technique that allows for quantitative evaluation of the VCM on a scale larger than a few pixels at a time.

Ground truth or match up data from CALIPSO or the ARM sites is already received by the Atmosphere PEATE. Negotiations are underway on how that data may be shared with NGAS. CloudSat data is now publically available and may be obtained through the open Internet. Note that not all of the organizations involved with the VCM Cal/Val effort require match up data. Depending on the resolution of the larger question of data sharing with the PEATEs, which covers data well beyond what is necessary for the VCM Cal/Val effort, we expect some storage of match up data on GRAVITE.

Allocation of funds will not be discussed in this document.

Significant coordination will be necessary for a successful VCM validation effort. Coordination is required among two different groups 1) the validation group itself and 2) the other Cal/Val disciplines. Coordination among the validation group is under the VCM Cal/Val discipline lead. However the coordination among the other Cal/Val disciplines will require joint collaboration to insure each EDRs concerns are documented, prioritized, and addressed in an efficient yet realistic context. There are more dependent

EDRs than there are VCM team members, and not everyone's concerns can be addressed at once. Because of this, among the NPP Cal/Val teams, we have agreed to use the points of contact given in the first paragraph of this section. Furthermore there will be a related coordination effort in terms of the versions of the VCM the Cal/Val community is using at one time. GRAVITE will be critical in controlling the configuration management of these versions, as changes in the VCM will likely outpace the ability of the IDPS system to implement them in a timely manner. As such, it is incumbent upon the IPO along with the VCM Cal/Val team to show the VCM produced by GRAVITE sufficiently matches the output from the IDPS when similar inputs are applied.

The amount of validation data for a cloud mask has significantly improved with the advent of CloudSat and CALIPSO. Provided these systems are still active after the NPP launch, they will play a large role in the validation effort. Other truth sources are sparse and of limited use, although we will still work with such sources as LIDAR and ARM. Traditionally cloud masks are evaluated in a qualitative manner by overlaying the mask on coincident imagery. We will do this as well. Quantitative analysis based on manual interpretation of imagery is also expected, and allows for quantitative analysis over targeted scenes. This work will be led by NGAS with assistance from the government.

No calibration data is employed by the VCM, although one could consider tuning as a calibration-type activity. The tuning parameters are all located in a single file, which should ease both access to the parameters and testing of the changes made. No formal LTM monitoring of the VCM is planned, however trends noted in other products, especially SST, often lead to additional tuning changes in the VCM. AFWA also uses a full time "tuner" who will analyze the VCM periodically once they employ the VCM operationally at AFWA.

The production of the VCM does not require substantial computing resources, but the 30-day spin-up requires sufficient resources to rerun and evaluate many granules simultaneously. At this time hardware is not expected to be an issue, however an additional GRAVITE terminal will be required at AFWA to support the VCM Cal/Val effort.

GRAVITE will be a centerpiece of the VCM work, and is the most critical system for step 1. We expect GRAVITE to perform configuration management functions as the VCM reacts to a large influx of comments and additional corrections. GRAVITE will serve as a test platform for these corrections during step 2, and as a method to disseminate either the updated VCM itself or the software to include these corrections to the wider Cal/Val community. Also during step 2, GRAVITE will also be the first test platform for science changes deemed necessary by the Cal/Val team. GRAVITE is the centerpiece around which the VCM software will revolve. See Appendix A for further details.

The team's resources begin with the cloud mask manipulation and evaluation tools already in place at each organization involved in the VCM Cal/Val effort. There is surprisingly little duplication among these tools, as they have been designed to serve the specific purposes of the associated organization. Hence NESDIS can compare cloud masks while AFWA evaluates the tuning process while NGAS deals with quantitative assessments and none are performing the same work. The total list of organizations involved for the VCM alone currently includes Aerospace – Omaha, AFWA, IPO (GRAVITE), NGAS, NASA (PEATE), NESDIS, and NRL-Monterey. Supporting work will also be performed by NAVO (Doug May) and the Land Cal/Val team (Eric Vermote). The resources/tools associated with each organization are:

- **Aerospace** – Adapt the pre-existing Aerospace Nephanalysis (ANEPH) that allow qualitative evaluation of the VCM from any granule, to include the evaluation of individual cloud detection tests and ancillary data input; produce the tool to update the VCM tuning parameters in real-time, and coordinate with the IPO/GRAVITE to develop a hardware/software environment conducive to rapid reproduction of individual granules and extensive analysis of many granules over a short time frame.
- **AFWA** – Provide their tuning personnel for analysis of the VCM during step 2, with a focus on the global performance of the VCM, and coordinate with the IPO/GRAVITE on establishing a Cal/Val working environment, to include a GRAVITE terminal, within AFWA.
- **NGAS** – Produce tools to allow for the quantitative analysis of the VCM in comparison to a manual analysis based on VIIRS imagery. Provide personnel to work with the government on said analysis during step 2, and to work with the government during the 30-day spin-up period as well. NGAS is expected to be involved during both steps.
- **NOAA/NESDIS** – Produce the tools to quantitatively compare the VCM to remote sensors such as CALIPSO and CloudSat. Also to provide quantitative comparisons between the VCM and other cloud mask algorithms such as CLAVR.
- **NASA/PEATE** – The Atmospheric PEATE hardware and software environment will be used to support the work performed by NOAA/NESDIS, which includes quantitative comparisons of the VCM to CALIPSO/CloudSat as well as quantitative comparisons to other cloud mask approaches.
- **NRL-Monterey** – Insert the VCM into their NexSat tool for evaluation relative to Navy support

Organization	Point of Contact(s)	Tool
Aerospace	Thomas Kopp	Visualize VCM and underlying imagery for tuning and qualitative analysis (ANEPH)
AFWA	John Eylander	Employ GRAVITE terminal to analyze VCM and potential impacts on real-time operations
IPO	Joe Zajic	Develop GRAVITE tools, especially for performing CM on the VCM and sharing results as needed
NGAS	Michael Plonski Keith Hutchison	Develop tool for manual analysis of VCM for quantitative evaluation
NOAA/NESDIS	Andrew Heidinger Richard Frey	Utilize PEATE to compare VCM to CALIPSO and other match up data sources. Also perform

		quantitative comparisons to other cloud masks
NASA/PEATE	Andrew Heidinger	Coordinate use of PEATE systems with other users
NRL-Monterey	Jeff Hawkins	Analyze VCM along with imagery on the NexSat platform for Navy support
NAVO	Doug May	Processing of the SST algorithm and evaluations of the impact from VCM threshold modifications
Land Cal/Val Team	Eric Vermote	Processing surface reflectance and evaluations of the impacts of threshold changes to the VCM

Table 2: Organizations and POCs for VCM Cal/Val

Any new hardware at this time would be the workstations that pull in data and software from GRAVITE and run the VCM at certain sites. As some of these sites may already have many of these resources, to include the Algorithm Development Environment of the IDPS, the number of workstations should be less than 5, but the exact number remains TBD. In of FY2009 only the need for one GRAVITE terminal has been identified, and that one is for AFWA. Most of the software needed would be an extension of tools already in place, though some coordination will be needed for some of those tools and their placement on GRAVITE. The major exception is the quantitative tool using manual analysis that will be developed by NGAS. Match up data will come from the PEATE and GRAVITE. If any synthetic data needs to be shared, something we do not expect at this time, it would be through the IPO's CasaNosa system. The source synthetic data would be NGAS.

The Cal/Val tools needed are those that address the tasks stated earlier in section 2. They include the tools in Table 2, and these tools will be used to accomplish the following:
1) a quantitative comparison of a manual analysis of cloud with the VCM
2) a quantitative analysis of differences between the VCM cloud mask algorithm and others on the same VIIRS granules
3) a quantitative comparison of the VCM with cloud determined from other sensors such as CloudSat or CALIPSO
4) a display of tuning thresholds and the ability to change and test them on the same set of granules in an efficient manner
5) a subjective evaluation of the VCM by overlaying the VCM on imagery, to include the visualization of each individual test result whether it is a cloud, aerosol, snow, or shadow component of the VCM and
6) the capability to track different versions of the VCM across different members of the Cal/Val community.
All but #1 and #6 currently exist in some form or another for MODIS. We currently plan for NGAS to create #1 and the IPO, through GRAVITE, to address #6. The others are handled by the team members and their organizations. Further note the NGAS tool will

be a combination of the needs to verify both the VCM and imagery; see the imagery Cal/Val plan for further details.

5.0 Reporting

We currently do not have a list of official "IPO-defined reports". At this time, it is expected that the discipline lead, Thomas Kopp, with help from Mike Plonski and Andy Heidinger, would write any performance reports, progress reports, and milestone documents required. Risks for the VCM at present can be found in the EDR assessment reports being prepared by the IPO. We expect many issues and concerns to come from the Cal/Val activities of the other disciplines. While the VCM Cal/Val team will be the "front door" for those items, given that we are responsible for entering and monitoring these items for resolution, we are expecting that the IPO has the lead in developing and maintaining the database as a whole.

With issues on the VCM as likely to come within the VCM Cal/Val team as outside of it, coordination of these issues into the Data Tracker Issues Database is critical. Only three personnel will be allowed to write to this database regarding VCM issues, Thomas Kopp (the lead), Andrew Heidinger (NOAA/NESDIS) and a representative from NGAS (TBD). However, the VCM team alone cannot enforce this, as other teams will have their own personnel who can write to this database, and they may discover cloud mask concerns via their EDR of interest. Nevertheless, we expect to coordinate with the IPO such that VCM items get referenced to the VCM Cal/Val team for placement into the database. If this does not occur, the VCM will be unaware of concerns only they can address.

Final determination of the Algorithm Change Process will play a major role on the communication of cloud mask concerns across the different teams. Provided this process includes interaction between the Cal/Val leads, we should be able to minimize potential disconnects on the status and performance of the VCM.

6.0 Areas of Concern

The very demanding requirements on the VCM are the source of its' greatest concerns. The most significant challenges with pre-existing cloud masks are the same as those for the VCM. This includes performance in polar night, low-light (terminator), and sun glint areas. Many users have also expressed concerns with the ability of the VCM to screen either thin cirrus or sub-pixel clouds. While the VCM algorithm does address those concerns, they will remain until we can prove the VCM adequately identifies those clouds (or a fix is in place if it does not). Other than the terminator, each of these challenges has specific criteria in the Sys Spec and will be stratified in the quantitative results. The performance of the VCM in the terminator (which is treated as night in the Sys Spec) will be a risk carried through NPP ICV.

The primary concerns with the sensor that may adversely affect the VCM are striping, Dewer ghosting, and crosstalk. As of the writing of this draft, none of these are expected to cause even a moderate level of impact on the VCM, though it must be monitored. Note any sensor issue that can be treated as noise can be dealt with by tuning, provided the overall percentage of probably cloudy and probably clear pixels after the "noise" has been dealt with is no more than 15%. Please see the "Tuning and Reprocessing of the VCM" document for further discussion.

The VCM plan would greatly benefit from the CloudSat and CALIPSO programs currently active (April, 2009) if they are still in operation after the launch of NPP. Given, however, that ICV will not begin until a few weeks after the launch of NPP, it is problematic these satellites will still be producing valid data. The VCM plan assumes they will be available, but the risk of either satellite no longer being viable clearly exists. The plan does account for this possibility, but the results will be degraded over what would exist if CloudSat and CALIPSO were available.

Finally, the method of the IDPS (using a single cloud mask for all EDRs) is directly opposite how it is handled by the MODIS community, which sets precedence that a single cloud mask is not a viable approach. Latency requirements for VIIRS products drove the design of the IDPS to use a single cloud mask. Discussions with early users of MODIS acknowledged a primary concern of theirs was a lack of responsiveness in changes needed to the primary cloud mask, as these changes were limited to formal builds occurring more than one year apart. The NPOESS system will allow for more frequent software upgrades. With specific points of contact with the other VIIRS Cal/Val teams, and coordinated efforts through the IPO to set appropriate priorities among competing interests, we have mitigated the concern of using a single mask. Users are asked to keep an open mind in this regard and allow the results of the VCM to speak for themselves.

Significant mitigation of VCM risks has already occurred by using MODIS data as a proxy for the VCM. The combined efforts of NGAS, NESDIS, and Aerospace – Omaha has resulted in many effective improvements to the VCM that have already been implemented into the algorithm. Earlier quantitative assessments by NGAS and recent work by NESDIS indicate the VCM has real promise to achieve its requirements. The early 30-day spin-up has been designed, in part, to identify and address any undesirable surprises discovered after launch and correct them before the VCM is employed by the greater NPOESS community.

The experience with MODIS has been invaluable, despite the impression that a single cloud mask has its' drawbacks. Much of the VCM logic is from the MODIS algorithms, and improvements to the MODIS algorithm have been incorporated by the VCM when practical. Experience by AFWA and Aerospace – Omaha in tuning the operational CDFS II will also prove useful post-launch. As MODIS and DMSP serve widely different communities, our joint effort favors resolving VCM challenges in a manner that supports both.

Some will take issue with the manual analysis approach, since it relies upon the expertise of a small number of SMEs. This is a consequence of the nature of the VCM, and its' historical lack of ground truth or match up data. The quantitative requirements from the Sys Spec force a capability of where different types of scenes can be evaluated, whereas even other platforms such as CALIPSO may not cover all possibilities. This approach insures all stratifications in the Sys Spec are addressed.

Another area of concern is setting priorities as multiple, and potentially contradictory, requests for tuning adjustments or software improvements come into the VCM Cal/Val team. Some of this is mitigated by the coordination with the other VIIRS Cal/Val teams and our agreement to use points of contact (Doug May and Eric Vermote) to communicate issues and observations of note with the other teams. As the VCM affects virtually all other VCM EDRs other than Imagery; the final process to set priorities in an item more for the IPO than the VCM Cal/Val team to resolve, and such an effort is in work. The Data Tracker Issues Database will be central to this process. Other mitigations lie in the structure of the VCM algorithms themselves. Because the VCM algorithms are structured using specific conditions (day/night, land/water, etc.) and given the thresholds for confidently clear and confidently cloudy can be tuned independently; different issues between say, the VCM over land and water, can be addressed without impacting each other. The “Tuning and Reprocessing of the VCM” document discussed this in more detail. The main challenge is therefore the distribution of limited resources, especially SMEs, available to work off discovered problems with the VCM. The final coordination procedures will be documented both in the Overall Cal/Val plan and the VCM Cal/Val plan.

Because of the nature of the VCM, there is a certain level of tolerance of the algorithm to SDR issues. The algorithm contains so-called “probably” cloudy/clear conditions to indicate to the users pixels that are indeterminate for some reason. Provided the number of “probable” pixels is not large, users can remain confident in using the identified cloudy and clear pixels for their applications. The primary SDR issue we are monitoring is that described in Engineering Failure Report (EFR) 2386, noncompliance of emissive radiometry. This may adversely affect band M12, a critical MWIR band for the VCM. Work up to this date indicates it does not greatly impact the VCM, but we will continue to monitor.

There are no specified “Watch Items” for VCM at this time. Such a list would incorporate the items noted in section 4. Unless there is an unexpected SDR issue coming from the upcoming TVAC testing, no new Watch Items are expected until post-launch evaluations of the VCM begin.

7.0 APPENDIX A: Coordination with other Cal/Val Teams and Use of GRAVITE

Regarding the VCM, coordination with the other VIIRS Cal/Val EDR discipline leads (Atmospheres, Land, Oceans) is fundamental in establishing a successful VCM effort. SST, as a KPP, is clearly a driver but all the VIIRS EDRs (other than imagery) have a dependence on the VCM and we must plan that any of their SMEs may find problems with the cloud mask. At a higher level, the IPO has the lead in coordinating issues through their Data Tracker Issues Database, as indicated in section 7. The Algorithm Change Process, as it evolves, will prove fundamental in coordinating among the different parties the status of each issue and its resolution. However communication among the Cal/Val teams will also be necessary; and our understanding of how that will be done varies with each team, as described below.

- **Atmospheres** – One clear link between the VCM work and that for the Atmosphere Cal/Val team is the Atmospheric PEATE. Interaction is fostered by the VCM lead's relationship with Andy Heidinger and Bryan Baum. While both work in the same building on the University of Wisconsin campus, it should be noted Andy is a member of the VCM Cal/Val team while Bryan is a member of the Atmosphere Cal/Val team. However both will be performing critical portions of the Cal/Val effort, and telecoms including the two leads (David Starr and Thomas Kopp) with these two should keep both sides aware of mutual concerns. The number and frequency of these telecoms is TBD, but it appears the best way to maintain communication among the two groups. It is also expected that NGAS will be interested in these conversations as well. Note the validation of the cloud phase results along with the aerosol tests embedded within the VCM must be coordinated with this team.
- **Land** – Our coordination with the Land Team will be through Eric Vermote. His main role is to pass on any concerns they have with the VCM to the VCM Cal/Val lead, while the VCM lead also has the responsibility to inform the Land POC of discoveries relevant to the Land EDR community. The effort to validate the cloud shadow results must also be coordinated with the Land Team. Also see section 2.
- **Oceans** – The SST community has well established processes for determining cloud contamination. Besides statistical measurements, some of the users (i.e. NAVO) also use qualitative displays of cloud masks to help identify areas of concern. As such, our POC for SST is Doug May of NAVO. Since SST is a KPP, it will generally get priority while working off the issues identified with the VCM. The Ocean Color (OC) community operates on much longer time frames than the SST community, and we (the VCM team) believe they will likely be the last EDR to verify the VCM suits their needs. Also see section 2 of this plan.

The single most important function of GRAVITE will be to maintain Configuration Management (CM) over the different versions of the VCM thresholds. Each threshold alteration, or set of threshold alterations, needs to be monitored and we will need to ability to determine which version each Cal/Val community is using. As different teams and SMEs report concerns with the VCM, our team must be able to determine the thresholds that particular team or SME was using at the time. Without CM, this capability is lost and the ability to determine the root cause of the concern will be severely compromised. This, in turn, will require the ICV community to obtain the thresholds through GRAVITE. Only after a certain set of thresholds have been adequately tested and approved will they be implemented on the IDPS.

Besides CM, GRAVITE will store up to 6 months of the VCM IP and produce Metadata that includes considerations for the predominate features of the granule. These features will include the primary geographical background (water, land, desert, snow/ice) upon which many of the thresholds are based. This will allow the VCM Cal/Val team to access a set of granules containing similar backgrounds, and allow testing of potential threshold improvements over scenes with similar backgrounds in an expedited manner. Simple statistics will also be generated to indicate the overall effects on the VCM. These statistics aid in determining the overall improvement achieved.

Efforts are underway between the IPO and AFWA to establish a GRAVITE terminal at AFWA. The GRAVITE terminal at AFWA will be used for “episodic” evaluations of the VCM. AFWA will use the terminal to evaluate the VCM in a manner consistent with their current operations for CDFS II. As they locate areas of concern, they will first determine thresholds that improve the VCM for those granules that, in near real-time, were identified as a problem. Afterward AFWA will investigate the impacts on similar scenes, using in part the features discussed in the previous paragraph. This work will be in conjunction with the Aerospace support. Thresholds found appropriate will then be routed through GRAVITE to undergo the CM procedure and be disseminated for testing by the other Cal/Val EDR teams. Aerospace will also employ the GRAVITE terminal at AFWA to investigate specific concerns identified by the SST and Land Cal/Val teams. Their use will be also episodic in nature, although the granules chosen will be guided by the locations noted by the dependent EDR teams.

GRAVITE will also be used to disseminate the manual analysis produced by NGAS to the rest of the VCM Cal/Val team. GRAVITE will be used as a central repository for any “golden” or episodic scenes that are used for repeated evaluation of various VCM threshold alternatives.

8.0 Appendix B: Validation Against the System Specification

Validation of the VCM includes the requirements with the Sys Spec Appendix D. To ensure that the plan properly considers the needs to accomplish this, this Appendix was added to the VCM plan to detail how that will occur. Note that as this Appendix is concerned solely with validation against the Sys Spec, there will be some duplication with what has been noted in the overall plan where both efforts use similar approaches and tools for validation efforts.

The VCM product classifies pixels as Confidently Clear, Confidently Cloudy, Probably Clear, and Probably Cloudy. A Binary Cloud Map is included as a subset of the VCM, comprising only those pixels that are Confidently Cloudy or Confidently Clear.

The Sys Spec states that “the probability for correct typing in the Binary Cloud Map may depend on a combination of the cloud optical depth and NDVI background to help distinguish between clouds and bright land surfaces. In the VCM (and the Binary Cloud Map), “leakage” occurs when a Confidently Clear pixel actually contains cloud, whereas “false alarm” is applied to pixels classified as Confidently Cloudy when the pixels are actually cloud-free. Consequently, for the Binary Cloud Map, probability of correct typing (PCT), leakage and false alarm rates will sum to 100% only when there are no Probably Cloudy or Probably Clear pixels classified by the VCM. Hence the Binary Cloud Map attributes represent optimum conditions, with the expectation that "probably clear" and "probably cloudy" pixels will be minimized through tuning procedures. The number of pixels identified as either Probably Clear or Probably Cloudy by the VCM will not exceed 15%. Cloud Cover/ Layers is produced using only pixels marked as "Confidently Cloudy" by the VIIRS Cloud Mask (and the Binary Cloud Map), which are included in the cell. This EDR will be produced from all nominal NPOESS orbits, but the measurement accuracy for a terminator orbit will be degraded due to VIIRS calibration limitations for a terminator orbit. The terminator orbit is not included in computing the maximum local average revisit time.” The specific VCM attribute requirements extracted from the Sys Spec Appendix D are shown in Table B.1 below.

Paragraph	Subject	Specified Value
	a. Horizontal Cell Size (HCS)	
40.4.2-1	1. Entire Swath	6 □ 1 km
40.4.2-2	b. Horizontal Reporting Interval	HCS
40.4.2-3	c. Vertical Reporting Interval	4 Layers
40.4.2-4	d. Horizontal Coverage	Global
40.4.2-5	e. Vertical Coverage	0 - 20 km
40.4.2-6	f. Measurement Range	0 - 1.0 HCS Area
	g. Measurement Accuracy	
40.4.2-7a	1. At Nadir	0.07 of HCS Area
40.4.2-7b	2. At Edge of Swath	0.4 of HCS Area
	h. Measurement Precision	
40.4.2-8a	1. At Nadir	0.07 of HCS Area
40.4.2-8b	2. At Edge of Swath	0.4 of HCS Area
40.4.2-9	i. Mapping Uncertainty, 3 Sigma	1.5 km

Paragraph	Subject	Specified Value
40.4.2-10	j. Max Local Average Revisit Time	12 hrs
40.4.2-13	k. Latency	NPP - 140 min. NPOESS - 28 min.
40.4.2-14	l. Binary Map HCS	0.8 km @ Nadir
40.4.2-15	m. Binary Map Horizontal Reporting Interval	Binary Map HCS
40.4.2-16	n. Binary Map Measurement Range	Cloudy/Not Cloudy
	o. Binary Map Probability of Correct Typing	
40.4.2-17b	2. Ocean, Day, COT > 1.0	94%
40.4.2-17d	4. Day, Land, COT > 1	90%
40.4.2-17e	5. Ocean, Night, COT > 1	85%
	p. Cloud Leakage Rate	
40.4.2-17i	1. Ocean, Day, COT > 1.0, outside Sun Glint region	1%
40.4.2-17p	2. Land, Day, COT > 1.0	3%
40.4.2-17q	3. Land, Ocean, Night, COT > 1.0	5%
	q. False Alarm Rate	
40.4.2-17l	1. Ocean, Day, COT > 1.0	5%
40.4.2-17m	2. Land, Day, ToC NDVI < 0.2 or ToC NDVI > 0.4, or Desert, COT > 1.0	7%
40.4.2-17r	3. Land, Ocean, Night, COT > 1.0	8%
40.4.2-17n	r. Differentiate heavy aerosols from clouds, Day (0 < OD < 2), dust/sand, smoke, volcanic ash.	85% (SYS-TBR-002)
	s. Degraded Measurements Conditions	
	2. Cloud Leakage Rate	
40.4.2-18c	a. Land, Ocean outside Sun Glint Region, Day, COT □ 1.0	5%
40.4.2-18e	c. Land, 0.2 ≤ ToC NDVI ≤ 0.4 and COT ≤ 1.0	7%
40.4.2-18f	d. Land and Ocean Sun Glint Regions	7%
40.4.2-18g	e. Night, Poleward of 60 deg N or 60 deg S	15%
	3. False Alarm Rate	
40.4.2-18h	a. Land, Ocean, Day, COT □ 1.0	8%
40.4.2-18j	c. Land, 0.2 ≤ ToC NDVI ≤ 0.4 and COT ≤ 1.0	10%
40.4.2-18m	d. Land and Ocean Sun Glint Regions	10%
40.4.2-18n	e. Night, Poleward of 60 deg N or 60 deg S	25% (SYS-TBR-003)

Table B.1: NPOESS Sys Spec requirements for the VCM

In the NPOESS program, the results from a single VCM algorithm are used to create all downstream algorithms. Thus, additional performance requirements have been included to ensure the VCM IP meets the requirements of all downstream EDR groups.

The VCM IP is used as an input field for all additional cloud products, and these are only created for pixels classified as confidently cloudy. The VCM generates a cloud phase IP that is used to select different processing paths in these cloud algorithms, depending upon whether water or ice clouds are present. Also, the VCM identifies instances where multiple cloud layers, i.e. consisting of ice and water clouds, are present in a single pixel. This is critically important since radiative transfer theory assumes that only one single cloud layer is present in any single FOV, as applied in the retrieval of other cloud products.

Additionally, the performance of many surface products are assessed only for pixels classified as confidently clear in the VCM, although some products may be generated for probably clear and probably cloudy conditions. Such products are flagged as lower quality. The VCM identifies sun-glint regions and identifies land types also for these downstream EDR applications.

Heritage algorithms typically are challenged to produce high values of Percentage of Correct Typing (PCT) without classifying heavy aerosols as clouds. The VCM IP is required to maintain high PCT performance while accurately differentiating between heavy aerosols and clouds, since no aerosol retrievals are completed for pixels classified as confidently cloudy. Failure to differentiate between heavy aerosols and clouds would mean loss of information for the aerosol products.

The VCM is also required to cast accurate cloud shadows for surface products. Many products are degraded in the presence of cloud shadows, e.g. Vegetation Index EDR. The VCM uses a geometric-base cloud shadow algorithm to accurately predict shadow location; therefore, the cloud shadow flag must be evaluate to ensure it satisfies downstream EDRs.

Clouds are more easily identified under some geophysical conditions than others. For example, VCM products are considered degraded in regions of latitudes higher than 60-degrees while in nighttime conditions. In addition, cloud signatures become complex in semi-arid regions and exclusions are applied if the TOC NDVI field is between 0.2-0.4. Finally, sub-visual clouds may go undetected if they have small optical thickness values. These cases are excluded from performance estimates in the VCM IP, and are identified in Table B.3.

It is assumed that the VIIRS sensor will produce SDRs that satisfy the sensor requirements for all I-bands and M-bands, any of which may be needed for use to evaluate cloud products by inspection or through the use of manually-generated binary cloud maps and/or cloud type analyses. Work validating the VCM with regard to the Sys Spec cannot begin until these SDRs have been vetted by the SDR Cal/Val team. See the Imagery and SDR Cal/Val plans for more detail.

Matchup correlative data sets will be provided and stored in GRAVITE or NSIPS for the evaluation of the VCM as they become available. A primary source of correlative data, as shown in Figure B.1, is derived from matchups of CloudSat with VIIRS data, which will fly in formation with the NASA A-Train, which a nodal time of the Aqua spacecraft. It is a critical assumption that the CloudSat mission will continue to function throughout the NPP Cal/Val period; else the amount of correlative data will be sharply reduced (see the main plan for further discussion).

Secondly, it is assumed that matchup data for CloudSat and VIIRS will be provided to GRAVITE or NSIPS on a regular (TBD) basis. The source of CloudSat is also TBD at this time, but could be from a public source or the Atmosphere PEATE. Note AFWA is already using CloudSat data to verify its' operational CDFS II cloud products. Actual

VIIRS-CloudSat matchups are expected to be approximately 2.4-km (along-track) by 4-km (across-track) box of VIIRS data centered on each CloudSat profile location, which is determined from the geolocation of each CloudSat profile by the definitive ephemeris after it arrives. This ephemeris contains the latitude, longitude and altitude of the satellite at 1-second intervals but has the disadvantage that it is only available once per day at approximately 16 UTC. Thus the standard CloudSat level-1B-CPR data product is not be available until 16-40 hours after the data are actually measured. These projections allow the VCM Cal/Val team to segment and archive correlative datasets for use as a “quicklook” into VCM performance. As a consequence, this provides a cost-effective approach to acquiring large sets of the globally representative data needed to complete the Cal/Val mission. An example of matchups between VIIRS and CloudSat is shown in Figure B.2.

The full list of ancillary data required to execute the VCM in a post-operational environment will be obtained routinely by GRAVITE/NSIPS from the IDPS and can be delivered based upon an ad-hoc request (see Table B.2). CM will be maintained by the IDPS on LUTs, thresholds, and other tunable parameters, i.e. changes will not occur on the operational system without the approval of the appropriate CM board.

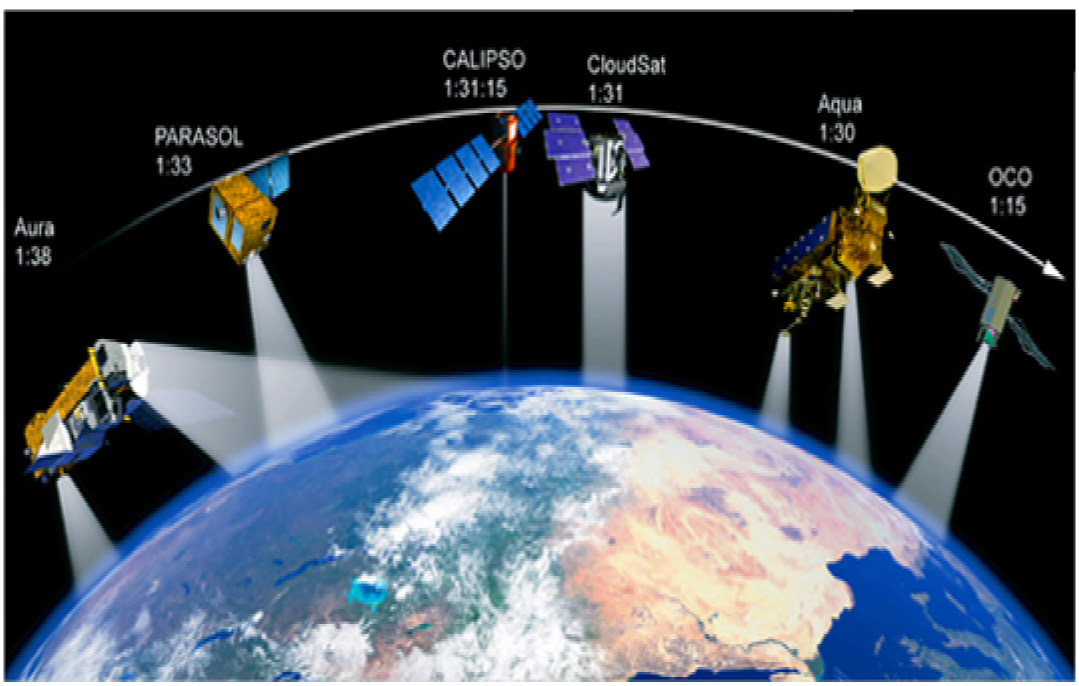

Figure B.1. A-train constellation.
(Source: www-calipso.larc.nasa.gov/about/atrain.php)

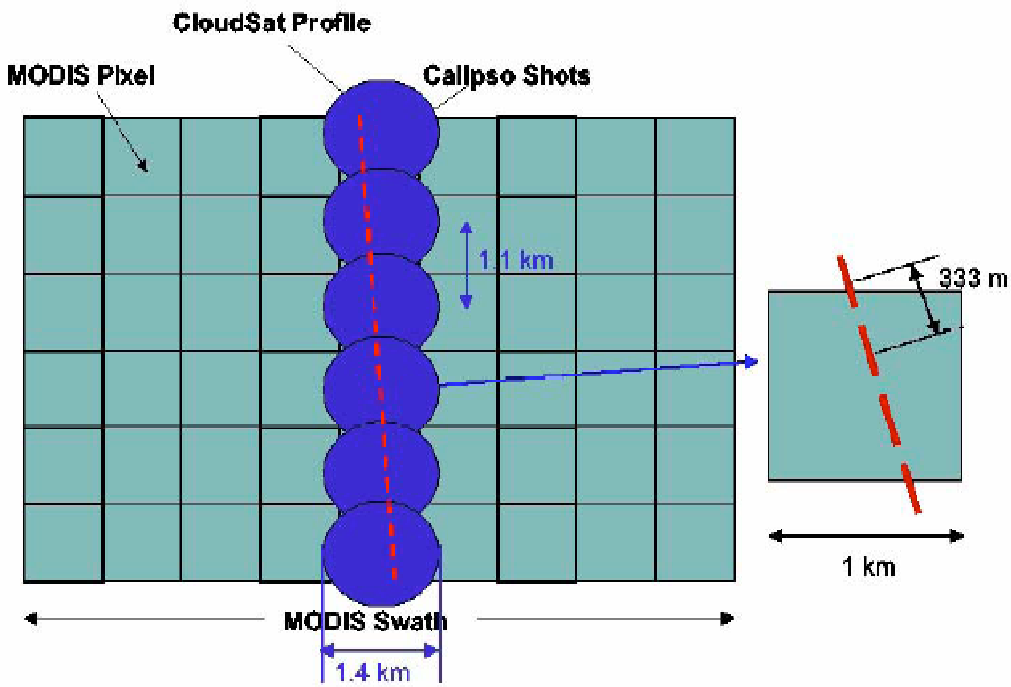

Figure B.2. Sample of correlative data based upon Cloudsat (Calipso) and MODIS. (Source:science.larc.nasa.gov/ceres/STM/200811/presentations/14_kato_col_c3m_status.pdf slide 3php)

The VCM algorithm must be tuned, before launch, to ensure an optimum product is created soon after NPP launch. This tuning is based upon global synthetic data and is first demonstrated using synthetic MODIS data to tune the VCM along with MODIS Proxy data to verify the success of the tuning process. A second tuning will occur before launch using VIIRS RSRs to construct the synthetic data. Once tuned against these synthetic data, the VCM is ready for post-launch analyses.

Additional tuning of tests used in the VCM algorithm will be performed soon after the VIIRS SDR has been approved by the SDR Cal/Val team for use in other EDRs. This tuning may be based upon inspection of VCM IP results compared with VIIRS images, by correlative matchup datasets, and/or through the use of manually-generated binary cloud maps and/or cloud type analyses. Please see the associated “Tuning and Reprocessing of the VCM” document for further details.

The performance of the VCM algorithm will be routinely examined to identify VIIRS granules where the VCM algorithm has performed both poorly and well. These routine analyses are based upon the correlative data obtained through a “subscription” service with GRAVITE/NSIPS to obtain matchup datasets of the parallax-corrected VCM IP and Cloudsat, These results will be processed automatically upon receipt. These near real-time VCM performance estimates over these relatively small regions of matchup data are considered a “quicklook” capability.

Results from quicklook analyses provide the methodology for obtaining the larger datasets of full VIIRS granules used in the Cal/Val process. These larger datasets are obtained through “ad-hoc” data requests to GRAVITE or NSIPS. The procedure will use quicklook analyses to identify regions where VCM performance is poorer and larger datasets are needed to conduct detailed post-analyses. In addition, regions of better performance will also be examined in more detail to ensure performance of the VCM is optimum. A (TBD) mixture of global, stressing and non-stressing scenes will be used to make the final assessment of VCM performance through comparison against manually-generated cloud data sets. The datasets to execute the VCM in this environment include auxiliary data, SDRs, EDRs and retained IPs. The complete list can be found in Table B.2. This ad-hoc method of obtaining complete datasets needed to execute the VCM algorithm in a post-operational environment will also be used to support anomaly resolution activities.

Data from a (TBD) number of VIIRS granules that were identified through the quicklook process just described will be maintained to assess performance after VCM algorithm enhancements are made to resolve problems. Quantitative performance against these or other “golden granules” will be established against manually-generated cloud truth to ensure each expected algorithm enhancement has the desired effect.

Once the VCM has been tuned to meet the full range of requirements outlined in the previous section, the product performance of the VCM cloud confidence flags will be established using an independent set of (TBD) manually-generated cloud products. Performance will be established using the following definitions.

- Leakage: ((VCM= conf. Clear) & (Truth=cloud)/total #pixels in the geographic class
- False alarms: ((VCM=conf. cloudy) & (Truth=clear))/total #pixels in the geographic class
- Binary Cloud Mask Error Rate (1- Probability of Correct Typing): ((VCM=conf. clear) & (Truth=cloud) *OR* ((VCM=conf. cloudy) & (Truth=clear))/((total #pixels in the geographic class – (VCM=prob. clear) OR (VCM=prob. Cloudy))
- Fraction of Pixel Classified Probably: ((VCM=prob. clear) *OR* (VCM=prob. cloudy))/total #pixels in the geographic class

Data	Description
SDR	MSDR (Moderate Resolution SDR bands)
	ISDR (Imagery Resolution SDR bands)
Ancillary Data	Sea Surface Winds
	Quarterly Land-Water Surface Types
	Snow fields
	Total Precipitable Water
	Top-of-Canopy NDVI
	2-m Air Temperature
Auxiliary Data	Fire Mask
Retained IP	VCM parallax corrected IP

Table B.2: Datasets required supporting execution of the VCM algorithm in a post-operational environment

Table B.4 (p. 28) shows an example of the results obtained using existing software at NGAS for VCM cloud confidence flag performance compared against 14-granules of correlative data matchups based upon manually-generated binary cloud masks. These results are stratified by the background class produced by the VCM algorithm, i.e. ocean and inland water, land, desert, coastal regions, and snow/ice. Results are stratified by background conditions, day versus night, and degraded conditions.

Once the VCM has been tuned to meet the full range of requirements outlined in the previous section, the product performance of other (non-cloud confidence) VCM flags will also be validated using imagery inspection and/or manually-generated cloud fields, including cloud phase analyses and heavy aerosol flags. Comparisons between these manually-generated cloud analyses and/or imagery will require use of the non-parallax-corrected VCM IP.

All manually-generated cloud products will be quality controlled by a team of imagery subject matter experts to ensure the veracity of these correlative data products.

In the absence of a cloud shadow truth dataset, adequacy of the VCM cloud shadow flag will be validated with assistance of the VIIRS Land/Ocean Cal/Val Teams, which uses this product in the generation of surface products. Also, the validity of the VCM cloud phase flag will be verified with assistance from the VIIRS Cloud Team which uses this information to determine processing branches for the VIIRS Cloud Optical Property retained IP.

The primary sources of correlative data are the matchup datasets of CloudSat and VCM described at length elsewhere in Appendix B. These data are needed in near-real time to provide a quicklook at VCM performance, support anomaly resolution, and identify golden granules for algorithm enhancements and performance verification. Other sources of correlative data are manually-generated binary cloud masks and cloud phase analyses derived from imagery subject matter experts.

The VCM IP is required to identify the degraded conditions that are listed in Table B.3. All but one of these conditions is identified by quality flags in the VCM output fields. The condition not identified by a quality flag is cloud optical thickness (COT) ≤1.0, since the VCM does not provide information on this cloud parameter. Consequently, this COT restriction is assumed to be a Cal/Val condition, i.e. lowering VCM performance when these optically-thin clouds are present.

Degraded Measurements Conditions	**Identification Method**
Cloud Leakage Rate	
a. Land, Ocean outside Sun Glint Region, Day, COT < 1.0	Absence of Quality Flag for Degraded Measurments
c. Land, 0.2 ≤ ToC NDVI ≤ 0.4 and COT ≤ 1.0	VCM Quality Flags
d. Land and Ocean Sun Glint Regions	VCM Quality Flags
e. Night, Poleward of 60 deg N or 60 deg S	VCM Quality Flags

False Alarm Rate	
a. Land, Ocean, Day, COT < 1.0	Absence of Quality Flag for Degraded Measurments
c. Land, 0.2 ≤ ToC NDVI ≤ 0.4 and COT ≤ 1.0	VCM Quality Flags
d. Land and Ocean Sun Glint Regions	VCM Quality Flags
e. Night, Poleward of 60 deg N or 60 deg S	VCM Quality Flags

Table B.3. VCM degraded conditions defined in the NPOESS Sys Spec.

VCM performance measures are leakage, false alarm, probability of correct typing, and percent pixels classified as probably cloudy or clear. The equations for these performance measures were shown earlier in this section. These performance measures are reported according to two major VCM quality groups: good quality retrievals and all quality. However, poor quality retrievals are not included in these QC metrics, i.e. pixels flagged to show that no VCM cloud detection test could be performed with the SDR data.

The approach outlined in this Appendix requires the completion of several tasks, and are summarized below. Note the below is concerned solely with the verification of the VCM Sys Spec requirements.

Pre-launch algorithm assessments:

- The VCM algorithm will be tuned, before launch, using global synthetic data generated with MODIS Raw Sensor Records (RSRs). This tuning will be followed by an assessment of performance against the manually-generated binary cloud mask for 14-MODIS Proxy datasets. Improved performance in each cloud test tuned in the process will confirm the validity of the procedures.
- A second tuning of the VCM algorithm will occur during pre-launch using updated RSRs from VIIRS. These will be the initial values used post-launch for the VCM algorithm.
- Procedures will be developed to ensure GRAVITE/NSIPS acquires all datasets needed to execute and evaluate the VCM in a post-operational environment. This list includes TOC NDVI, SDR calibration/geolocation data, tunable parameter files, ancillary/auxiliary data, and the parallax corrected binary cloud mask.
- Procedures will be developed to acquire VIIRS-CloudSat correlative datasets and these will be exercised with MODIS as proxy to VIIRS data during the pre-launch period.
- Pre-launch checks will be made to ensure that pre-launch tasks have been correctly implemented.
- Software and procedures will be developed to manage, store, archive, and analyze the quicklook data. The archive must be able to stratify the results, to include not just the parameters used for stratification, but quality control measures such as the truth source and time and distance for the matchups.

Post-launch algorithm assessments:

- Quicklook performance of the Parallax Corrected VCM IP will be made using correlative matchups based upon CloudSat, with the objective of doing so in near real-time (24-48 hours).
- Additional tuning of thresholds used in the VCM cloud algorithm detection tests will be performed soon after the VIIRS SDR has been approved for use in other EDRs.
- Manually-generated binary cloud mask and cloud phase analyses will be generated for (TBD) VIIRS granules.
- VCM algorithm (not parallax corrected) performance measures will be established in accordance with the Sys Spec using manually-generated cloud analyses.
  - Analyze Accuracy, Precision, and Uncertainty (APU) attribute performance according to Sys Spec for all major background grounds and conditions.
  - Cause/effect relations will be established for stratifications where the Sys Spec is not satisfied.
  - Correction to algorithmic logic and thresholds will be made, tested, and implemented in the operational system at IDPS.
  - Assessments will be made on the suitability of ancillary/auxiliary datasets.
- Characterize Degraded Performance as time available.

Analysis tool development:

- Tools are needed to calculate VCM APU performance of quicklook data collected by GRAVITE/NSIPS for matchup VCM-CloudSat datasets. These tools must support stratifications that allow differences between actual cloud cover and the VCM to be examined in detail. Conditions specified by the Sys Spec and derived Quality Flags will aid in sub-setting these matchups.
- Visualizations will be developed to identify and evaluate VIIRS granules in a sufficiently detailed manner to identify exactly the cloud detection tests which are not performing as necessary for the VCM to meet the Sys Spec. NGAS has already developed some of these tools, and additional work will extend their application to the validation of the Sys Spec by the post-launch time frame.
- NGAS will develop software allowing manual analysis and quantitative results using the VCM and VIIRS imagery.
- Interfaces to government furnished (GFI) datasets will be determined and documented, with appropriate software developed to make the outputs in the necessary formats for EDR matchup and storage.
- Existing tools are believed adequate for anomaly resolution but will require modification for inputting the VCM and VIIRS imagery, modifications that will be completed during the pre-launch period.

Cross-comparisons to other sensor, algorithm, and Cal/Val teams

- Cross–comparisons will be led by the government. Agreements have been reached with NESDIS to compare the VCM to other cloud mask approaches such as those from MODIS and CLAVR. See section 2.0 of the main document.

- No quantitative measures exist for the evaluation of VCM cloud shadow projections. Assistance from the Land/Ocean Cal/Val Team will ensure these quality flags are adequate to generate land/ocean surface products.
- Assistance will be obtained from the Land/Ocean Teams to ensure VCM leakage rates adequately address product requirements and with the Cloud Team members to ensure false alarms and cloud phase products satisfy cloud algorithm requirements. Such efforts may result in a greater number of Probably Clear or Probably Cloudy pixels, although we will work to insure the 15% limit identified in the Sys Spec is maintained.
- The analysis of the aerosol flags will be performed in coordination with the Atmosphere Cal/Val team. Data collection by the Atmosphere Cal/Val team along with the manual analysis performed by the VCM Cal/Val team will be combined to evaluate the capability of the aerosol flags within the VCM. The details of this coordination will be finalized during the pre-launch period.

Daytime VCM Chain 1.12 Performance Compared to Manually-Generated Cloud Truth Data															
	*_1755	*_1745	*_1600	*_1210	*_1220	*_0435	*_2210	*_0220	*_1750	*_0215	*_0905	*_1835	*_1840	*_0340	Total
nGran	2729664	2729664	2729664	2729664	2729664	2729664	2729664	2729664	2729664	2729664	2729664	2729664	2729664	2729664	38215296
nCat Snow	30510	1874434	321	13	349	0	0	0	797615	1678247	32	9561	731	846846	5238659
nCldTruth	2990	185269	320	13	349	0	0	0	38236	262838	1	2286	714	66055	559071
nClrTruth	27520	1689165	1	0	0	0	0	0	759379	1415409	31	7275	17	780791	4679588
nPrbCldy	329	15930	82	3	86	0	0	0	256	1317	1	63	188	3334	21589
nPrbClr	3493	996401	1	0	0	0	0	0	311870	902230	28	1414	3	435295	2650735
False Alarms	890	180371	0	0	0	0	0	0	67823	180931	0	5009	1	117311	552336
Leakage	341	12	19	0	0	0	0	0	4	0	0	61	14	127	578
Binary Error	0.04	0.096	0.059	0	0	0	0	0	0.085	0.108	0	0.53	0.02	0.139	0.105566
nCat Desert	133802	557	455	126156	308	10	662434	1625	57541	3319	132791	77607	28102	299018	1523725
nCldTruth	43453	350	424	76657	95	10	79434	1217	33554	3257	9805	2870	1769	1651	254546
nClrTruth	90349	207	31	49499	213	0	583000	408	23987	62	122986	74737	26333	297367	1269179
nPrbCldy	874	1	14	2973	15	0	1549	9	416	26	382	109	35	41	6444
nPrbClr	87425	28	6	952	170	0	4335	53	4774	14	7415	9870	461	63028	178531
False Alarms	1185	123	9	9	1	0	3541	286	4672	12	64	2677	16	45972	58567
Leakage	18307	1	24	13993	3	9	11698	98	1013	16	468	303	387	7	46327
Binary Error	0.146	0.022	0.072	0.111	0.013	0.9	0.023	0.237	0.099	0.01	0.004	0.038	0.014	0.0154	0.041626
nCat Land	1229174	719457	643388	92406	65751	1751	1701410	2358490	1688156	685893	1796752	2307295	217618	1523667	15031208
nCldTruth	475905	418290	608865	20680	28817	1113	52430	1824823	630623	440264	377877	507921	41492	428765	5857865
nClrTruth	753269	301167	34523	71726	36934	638	1648980	533667	1057533	245629	1418875	1799374	176126	1094902	9173343
nPrbCldy	4317	17417	1530	454	339	10	935	36527	7145	1033	7637	10725	785	7864	96718
nPrbClr	277813	151170	15307	50046	26430	106	102991	111232	534373	63488	696977	908311	81720	709379	3729343
False Alarms	47621	58265	11903	8444	7998	0	10789	160789	106520	81760	1976	134024	6409	148210	784708
Leakage	2224	572	490	29	49	130	2397	42609	2953	66	56738	2428	321	1382	112388
Binary Error	0.04	0.082	0.019	0.092	0.122	0.074	0.01	0.086	0.065	0.119	0.033	0.059	0.031	0.098	0.059857
nCat Inland Water	166843	69596	20178	2618	365	5	15678	50677	8357	5203	2338	22000	631	26181	390670
nCldTruth	85797	54708	18658	1373	67	0	89	36995	3229	4006	359	4342	138	20812	230573
nClrTruth	81046	14888	1520	1245	298	5	15589	13682	5128	1197	1979	17658	493	5369	160097
nPrbCldy	1246	52	7	0	8	0	0	962	23	0	34	45	4	265	2646
nPrbClr	33739	4554	418	618	127	2	2325	4703	2306	364	797	5029	235	2230	57447
False Alarms	7642	7228	473	438	25	0	628	522	901	544	19	6142	41	2542	27145
Leakage	32	0	0	0	0	0	6	1591	0	0	37	0	0	0	1666
Binary Error	0.046	0.104	0.023	0.167	0.068	0	0.04	0.042	0.108	0.104	0.024	0.279	0.065	0.097	0.073752
nCat Seawater	450705	7246	681024	1164995	1612626	2727784	343048	288266	158078	249169	790587	284833	1942728	23124	10724213
nCldTruth	150664	4455	398613	567335	871095	1825890	13430	159319	154728	34512	215981	17431	1160194	6893	5580540
nClrTruth	300041	2791	282411	597660	741531	901894	329618	128947	3350	214657	574606	267402	782534	16231	5143673
nPrbCldy	2593	0	7810	1050	19818	59354	808	4530	171	461	0	156	13227	0	109978
nPrbClr	33145	29	73024	188843	228687	45743	215212	90593	144	104067	57168	23254	310603	8793	1379305
False Alarms	24457	2762	25336	120224	35248	1374	55	7808	3015	25351	66032	3598	37008	5574	357842
Leakage	1378	0	11492	17	3757	69773	7469	47	95	37	0	153	790	0	95008
Binary Error	0.057	0.381	0.054	0.103	0.024	0.026	0.022	0.027	0.02	0.102	0.084	0.013	0.019	0.241	0.042087
nCat Coast	220341	58374	9356	14301	797	0	7094	30606	16605	8307	7164	28368	5873	10269	417455
nCldTruth	116795	45578	8029	11321	168	0	45	21925	6598	4848	2208	5005	1014	7583	231117
nClrTruth	103546	12796	1327	2980	629	0	7049	8681	10007	3459	4956	23363	4859	2686	186338
nPrbCldy	1413	2628	96	0	2	0	4	426	111	36	24	92	11	69	4912
nPrbClr	37024	4242	198	58	187	0	217	810	2561	290	477	5756	431	536	52787
False Alarms	8953	1934	57	58	40	0	90	6659	1261	133	65	2349	21	326	21946
Leakage	7119	1202	543	11142	66	0	12	370	1325	274	391	399	242	96	23181
Binary Error	0.073	0.054	0.064	0.783	0.133	0	0.014	0.23	0.156	0.049	0.064	0.097	0.045	0.041	0.257571

Table B.4. Performance summaries stratified by background class for the VCM IP analyses of 14 MODIS proxy granules compared to correlative data matchups of manually-generated binary cloud masks.