VIIRS Cloud Mask (VCM) Provisional Status

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VCM Basics

- Fundamentally the VCM is a moderate band pixel-by-pixel determination of cloud cover
- As originally defined in the NPOESS system specification, it is “used in the processing of many EDRs, which classifies pixels as Confidently Clear, Confidently Cloudy, Probably Clear, and Probably Cloudy”
  - The original requirements broke down the VCM performance into various backgrounds (e.g. day/night, ocean/land/desert) and characteristics (e.g. probability of correct typing, leakage, false alarms)
    - Limits on probably conditions were added in 2006
  - The design of the VCM also breaks down the cloud identification process by condition and background
- This logic has continued into the S-NPP and JPSS programs
- The applicable System Specification section, which fell under the Cloud Cover/Layers EDR, is shown on the following slide
  - This is our “target”

VCM Requirements

l. Binary Map HCS	0.8 km @ Nadir
m. Binary Map Horizontal Reporting Interval	Binary Map HCS
n.	Cloudy/Not Cloudy
o. Binary Map Probability of Correct Typing	
2. Ocean, Day, COT > 1.0	94%
4. Day, Land, COT > 1	90%
5. Ocean, Night, COT > 1	85%
p. Cloud Leakage Rate	
1. Ocean, Day, COT > 1.0, outside Sun Glint region	1%
2. Land, Day, COT > 1.0	3%
3. Land, Ocean, Night, COT > 1.0	5%
q. False Alarm Rate	
1. Ocean, Day, COT > 1.0	5%
2. Land, Day, ToC NDVI < 0.2 or ToC NDVI > 0.4, or Desert, COT > 1.0	7%
3. Land, Ocean, Night, COT > 1.0	8%
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	
a. Land, Ocean outside Sun Glint Region, Day, COT ≤ 1.0	5%
c. Land, 0.2 ≤ ToC NDVI ≤ 0.4 and COT ≤ 1.0	7%
d. Land and Ocean Sun Glint Regions	7%
e. Night, Poleward of 60 deg N or 60 deg S	15%
3. False Alarm Rate	
a. Land, Ocean, Day, COT ≤ 1.0	8%
c. Land, 0.2 ≤ ToC NDVI ≤ 0.4 and COT ≤ 1.0	10%
d. Land and Ocean Sun Glint Regions	10%
e. Night, Poleward of 60 deg N or 60 deg S	25%

Definitions

- Probability of Correct Typing: The percentage of confidently clear or confidently cloudy pixels that are properly identified as such in each background type
- Leakage: The percentage of pixels identified as confidently clear that in reality contain cloud
- False Alarms: The percentage of pixels identified as confidently cloudy that are in reality contain no clouds (they may contain aerosols)
- PCPC: The percentage of pixels identified as Probably Cloudy or Probably Clear (hence PCPC)

VCM Cal/Val Approach

- The Cal/Val approach is basically a 3-legged pedestal with assistance from liaisons and program personnel
  - NOAA leads product development and performs large scale analyses such as match-up comparisons
  - Aerospace leads the validation effort and determines when and how threshold updates occur
  - Northrop Grumman leads the development of Golden Granules and provides fundamental software support and development
- Other key contributors are our JPSS Algorithm Manager, Raytheon (COAST) representative, and our liaisons

VCM Cal/Val Core Team

- NESDIS/StAR - A. Heidinger (Product Lead and Cloud Liaison)
- The Aerospace Corporation - T. Kopp (Validation Lead)
- UW/CIMSS - R. Frey, D. Botambekov
- Northrop Grumman - K. Hutchison, B. Iisager
- NASA/DPE - B. Thomas (JAM)
- Raytheon – K. Brueske (COAST)
- AFWA - J. Cetola
- NRL, Monterey - K. Richardson
- NESDIS/StAR - H. Cronk (Aerosol Liaison with L. Remer)
- UMBC - E. Vermote (Land Liaison)
- NRL, Stennis - D. May (Ocean Liaison with J-F. Cayula)

VCM Inputs

- The VCM relies upon 13 of the 16 M-bands and 4 of the 5 I-bands for all of its computations
  - The VCM can be tuned for known biases and noise
- It also depends upon ancillary data critical for accurate cloud identification
  - Background surface temperatures at night (GFS)
  - Water vapor content (GFS)
  - Snow and ice
  - NDVI

VIIRS Bands Used in the VCM

VIIRS Band	Central Wavelength (µm)	Bandwidth (µm)	Wavelength Range (µm)	Band Explanation	Spatial Resolution (m) @ nadir
M1	0.412	0.02	0.402 -0.422	Visible	750 m
M2	0.445	0.018	0.436 - 0.454		
M3 (blue)	0.488	0.02	0.478 - 0.488		
M4 (green)	0.555	0.02	0.545 -0.565		
M5 (red)	0.672	0.02	0.662 -0.682		
M6	0.746	0.015	0.739 - 0.754	Near IR	
M7	0.865	0.039	0.846 -0.885		
M8	1.240	0.02	1.23 –1.25	Shortwave IR	
M9	1.378	0.015	1.371 -1.386		
M10	1.61	0.06	1.58 –1.64		
M11	2.25	0.05	2.23-2.28		
M12	3.7	0.0155	3.61 –3.79	Medium-wave IR	
M13	4.05	0.02	3.97 –4.13		
M14	8.55	0.3	8.4 -8.7	Longwave IR	
M15	10.763	1.0	10.26 -11.26		
M16	12.013	0.95	11.54 -12.49		
DNB	0.7	0.4	0.5 - 0.9	Visible	750 m across full scan
I1	0.64	0.08	0.6 -0.68	Visible	375 m
I2	0.865	0.039	0.85 –0.88	Near IR	
I3	1.61	0.06	1.58 - 1.64	Shortwave IR	
I4	3.74	0.38	3.55-3.93	Medium-wave IR	
I5	11.45	1.9	10.5 –12.4	Longwave IR	

Bands highlighted in pale yellow are used within the VCM

Status at Beta

- Beta was declared after the 30-day spin-up set of threshold adjustments were implemented on the IDPS
  - 74 thresholds were adjusted during the 30 day spin up
- This implementation also opened up the VCM to analysis and critique by the other VIIRS EDR teams
- 1012 granules of VCM/MODIS/CALIPSO match-ups were produced for beta – April 2012
  - Quantitative analysis shown on the next slide

Results Matching VCM and CALIPSO

Global results (Beta stage)

Cloud Mask	Sample Size	Cloud fraction				Probability of		
		Active	Passive	Pr. Clear	Pr. Cloudy	Detection	False D.	Leakage
IDPS	88240	0.7513	0.6915	0.0920	0.0515	0.9012	0.0195	0.0793
SSEC Pre-tuned	85650	0.7555	0.7006	0.0971	0.0490	0.8994	0.0228	0.0777
SSEC Phase 2	85650	0.7555	0.6915	0.0638	0.0238	0.9063	0.0148	0.0789
NOAA PATMOS-x VIIRS	90358	0.7507	0.7122	0.0343	0.0348	0.9257	0.0179	0.0564
MODIS C6	272635	0.7217	0.7151	0.0808	0.0333	0.9407	0.0264	0.0329
NOAA PATMOS-x MODIS	272635	0.7217	0.6793	0.0321	0.0254	0.9446	0.0065	0.0489

Provisional Definition

- Product quality may not be optimal
  - Optimal would be VCM attains all of its requirements
- Incremental product improvements still occurring
  - DR history and future planned efforts will be shown
- Version control is in effect
- General research community is encouraged to participate
  - VCM team set up liaisons even before launch
- Users urged to consult the EDR product status
- May be replaced in the archive
- Ready for operational evaluation
  - This has already begun, hence the upcoming feedback from other VIIRS EDR teams

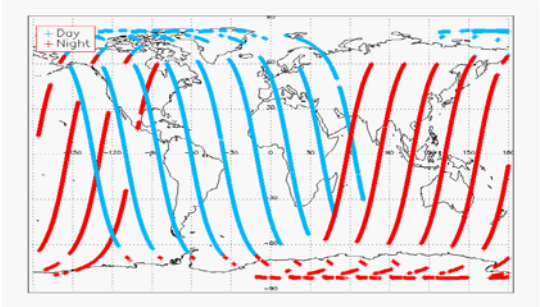
Product Quality

- Product quality was evaluated using two days of match-ups data between CALIPSO and the VCM over the month of November, and compared to results from May
  - The latest threshold update was implemented early November
  - Only one partial day was used for beta
  - Results for the first of the two November days are shown (the two November days contain similar results)
- Results were executed twice, one for all clouds observed by CALIPSO and one with thin clouds removed
  - Thin was defined as high cloud with an optical depth less than 0.3
- Current analysis tool assumes a binary cloud mask
  - Probably clear is counted as confidently clear, same for cloudy
  - This penalizes the VCM, recall actual definitions of leakage/false alarms is based on confident results only

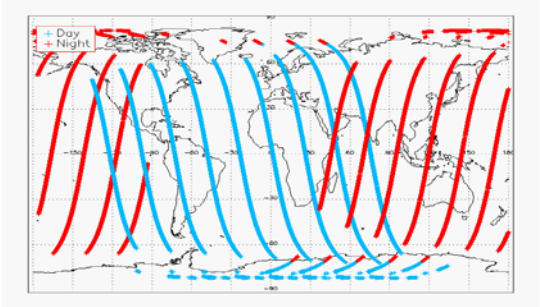
Product Quality – Global/All Clouds

90N – 90S, Ocean/Land, Day/Night, No Snow/Ice

CALIOP - VIIRS Matchup Pixels, 05/10/2012



CALIOP - VIIRS Matchup Pixels, 11/10/2012

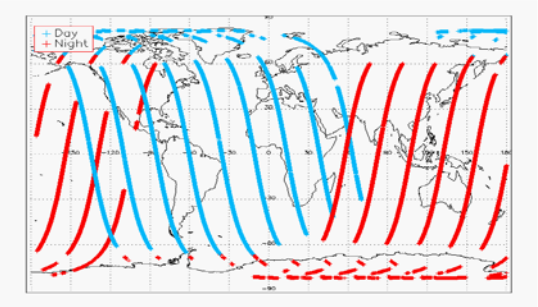


VIIRS Cloud Mask	Sample Size	Cloud fraction				Probability of		
		Active	Passive	Pr. Clear	Pr. Cloudy	Detection	False D.	Leakage
5/10/2012	257266	0.661	0.567	0.080	0.032	0.857	0.024	0.119
11/10/2012	304681	0.732	0.654	0.068	0.029	0.881	0.021	0.099

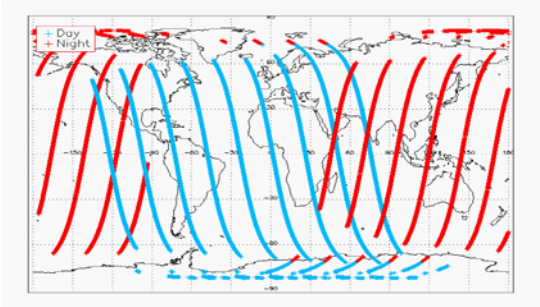
Product Quality – Global/No Thin

90N – 90S, Ocean/Land, Day/Night, No Snow/Snow/Ice

CALIOP - VIIRS Matchup Pixels, 05/10/2012



CALIOP - VIIRS Matchup Pixels, 11/10/2012

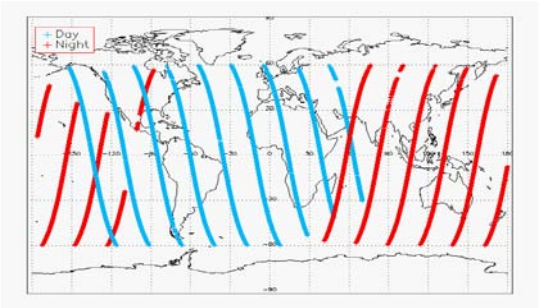


VIIRS Cloud Mask	Sample Size	Cloud fraction				Probability of		
		Active	Passive	Pr. Clear	Pr. Cloudy	Detection	False D.	Leakage
5/10/2012	206367	0.618	0.586	0.087	0.028	0.892	0.038	0.070
11/10/2012	258832	0.698	0.667	0.069	0.025	0.906	0.032	0.063

Product Quality – No Polar

60N – 60S, Ocean/Land, Day/Night, No Snow/No Ice

CALIOP - VIIRS Matchup Pixels, 05/10/2012



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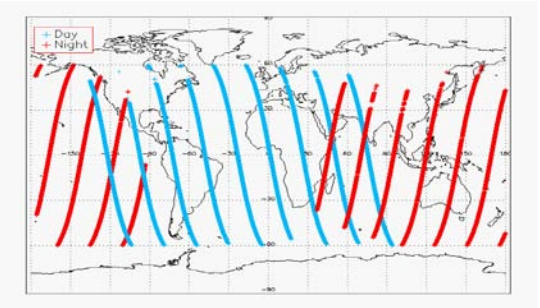
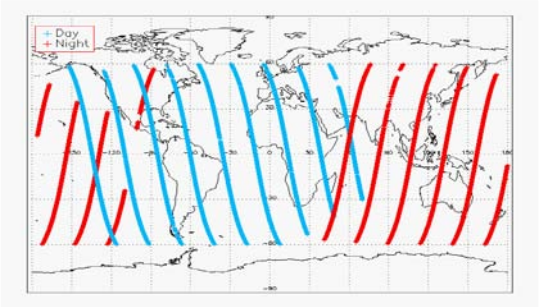


VIIRS Cloud Mask	Sample Size	Cloud fraction				Probability of		
		Active	Passive	Pr. Clear	Pr. Cloudy	Detection	False D.	Leakage
5/10/2012	218263	0.662	0.585	0.078	0.031	0.888	0.018	0.094
11/10/2012	237476	0.729	0.674	0.065	0.028	0.913	0.016	0.071

Product Quality – No Polar/No Thin

60N – 60S, Ocean/Land, Day/Night, No Snow/No Ice

CALIOP - VIIRS Matchup Pixels, 05/10/2012



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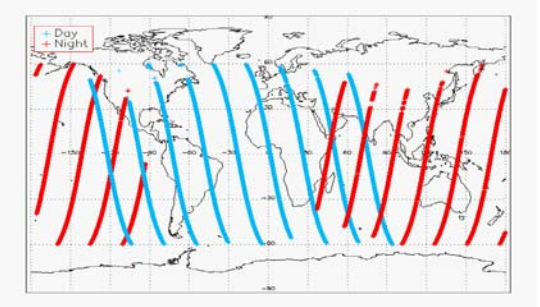
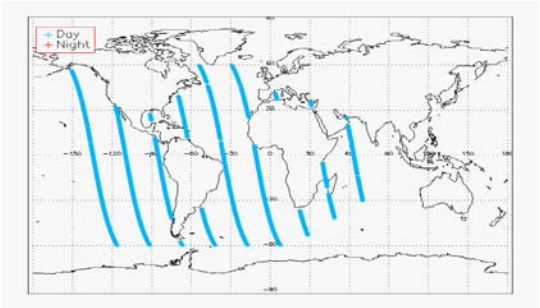


VIIRS Cloud Mask	Sample Size	Cloud fraction				Probability of		
		Active	Passive	Pr. Clear	Pr. Cloudy	Detection	False D.	Leakage
5/10/2012	178835	0.602	0.597	0.085	0.026	0.923	0.036	0.041
11/10/2012	203390	0.674	0.674	0.067	0.024	0.936	0.032	0.032

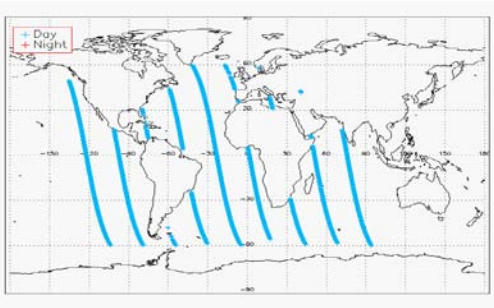
Product Quality – Ocean/Day

60N – 60S, Ocean, Day, No Snow/No Ice

CALIOP - VIIRS Matchup Pixels, 05/10/2012



CALIOP - VIIRS Matchup Pixels, 11/10/2012

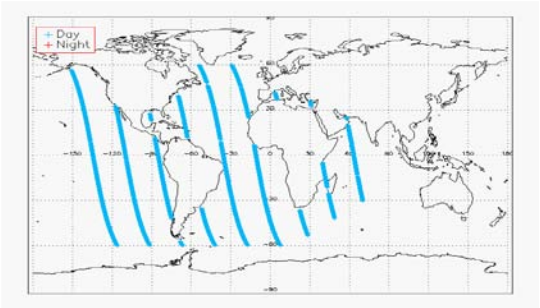


VIIRS Cloud Mask	Sample Size	Cloud fraction				Probability of		
		Active	Passive	Pr. Clear	Pr. Cloudy	Detection	False D.	Leakage
5/10/2012	71854	0.673	0.63	0.083	0.029	0.914	0.022	0.065
11/10/2012	79192	0.792	0.761	0.054	0.024	0.943	0.013	0.044

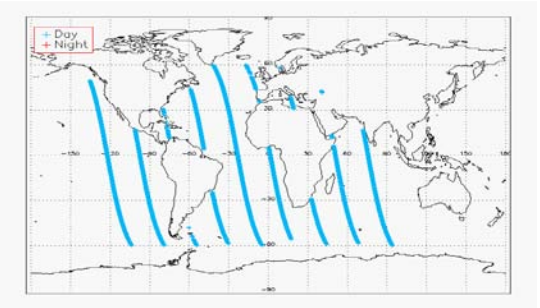
Product Quality – Ocean/Day/No Thin

60N – 60S, Ocean, Day, No Snow/No Ice

CALIOP - VIIRS Matchup Pixels, 05/10/2012



CALIOP - VIIRS Matchup Pixels, 11/10/2012

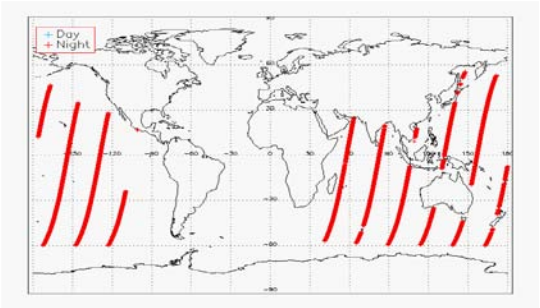


VIIRS Cloud Mask	Sample Size	Cloud fraction				Probability of		
		Active	Passive	Pr. Clear	Pr. Cloudy	Detection	False D.	Leakage
5/10/2012	63078	0.581	0.606	0.110	0.026	0.930	0.048	0.023
11/10/2012	68544	0.732	0.750	0.068	0.020	0.953	0.032	0.014

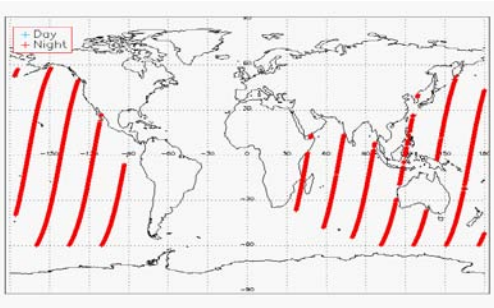
Product Quality – Ocean/Night

60N – 60S, Ocean, Night, No Snow/No Ice

CALIOP - VIIRS Matchup Pixels, 05/10/2012



CALIOP - VIIRS Matchup Pixels, 11/10/2012

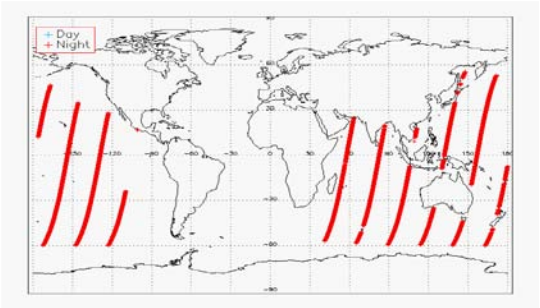


VIIRS Cloud Mask	Sample Size	Cloud fraction				Probability of		
		Active	Passive	Pr. Clear	Pr. Cloudy	Detection	False D.	Leakage
5/10/2012	74826	0.801	0.719	0.087	0.043	0.887	0.016	0.098
11/10/2012	91334	0.815	0.743	0.073	0.042	0.906	0.011	0.083

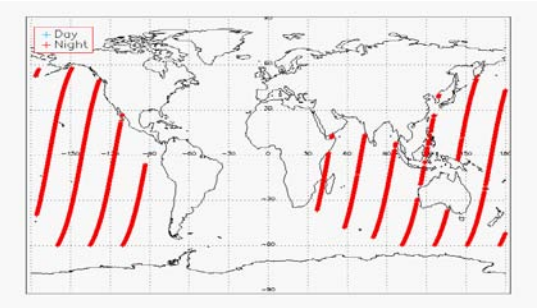
Product Quality – Ocean/Night/No Thin

60N – 60S, Ocean, Night, No Snow/No Ice

CALIOP - VIIRS Matchup Pixels, 05/10/2012



CALIOP - VIIRS Matchup Pixels, 11/10/2012

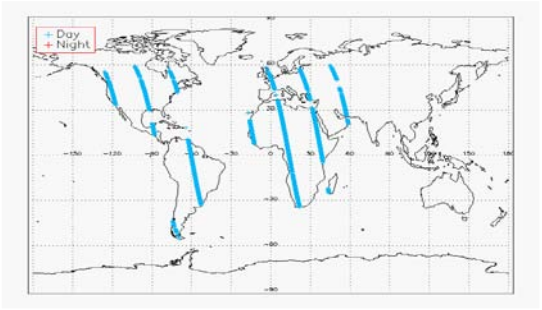


VIIRS Cloud Mask	Sample Size	Cloud fraction				Probability of		
		Active	Passive	Pr. Clear	Pr. Cloudy	Detection	False D.	Leakage
5/10/2012	61716	0.701	0.716	0.085	0.034	0.932	0.041	0.027
11/10/2012	80132	0.713	0.722	0.074	0.036	0.938	0.036	0.026

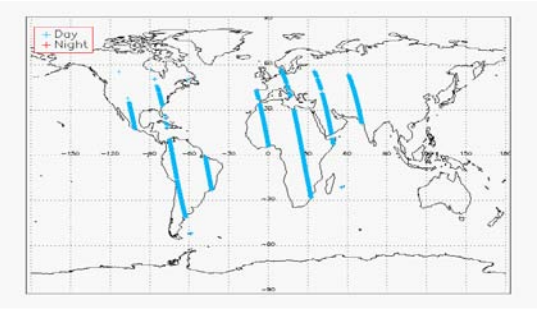
Product Quality – Land/Day

60N – 60S, Land, Day, No Snow/No Ice

CALIOP - VIIRS Matchup Pixels, 05/10/2012



CALIOP - VIIRS Matchup Pixels, 11/10/2012

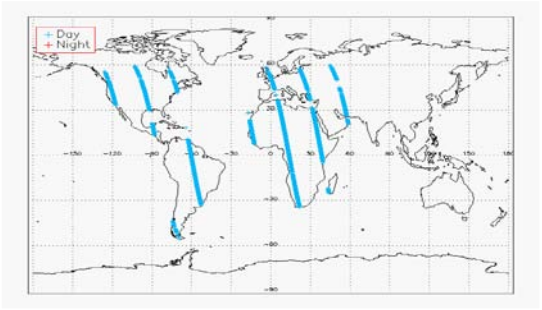


VIIRS Cloud Mask	Sample Size	Cloud fraction				Probability of		
		Active	Passive	Pr. Clear	Pr. Cloudy	Detection	False D.	Leakage
5/10/2012	34669	0.408	0.338	0.054	0.011	0.893	0.019	0.089
11/10/2012	36049	0.534	0.498	0.077	0.008	0.886	0.039	0.075

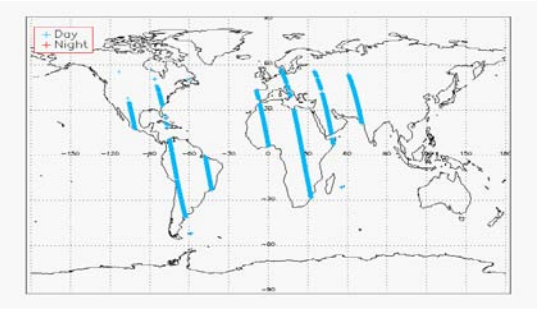
Product Quality – Land/Day/No Thin

60N – 60S, Land, Day, No Snow/No Ice

CALIOP - VIIRS Matchup Pixels, 05/10/2012



CALIOP - VIIRS Matchup Pixels, 11/10/2012

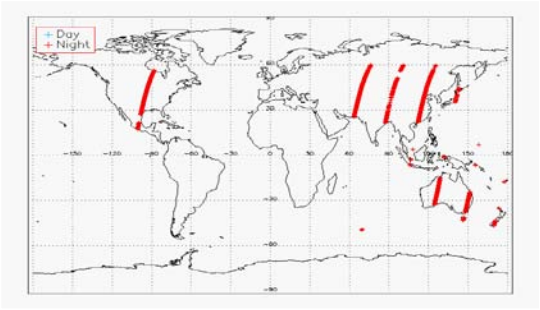


VIIRS Cloud Mask	Sample Size	Cloud fraction				Probability of		
		Active	Passive	Pr. Clear	Pr. Cloudy	Detection	False D.	Leakage
5/10/2012	28423	0.413	0.356	0.053	0.010	0.903	0.021	0.077
11/10/2012	29945	0.562	0.531	0.061	0.007	0.894	0.038	0.068

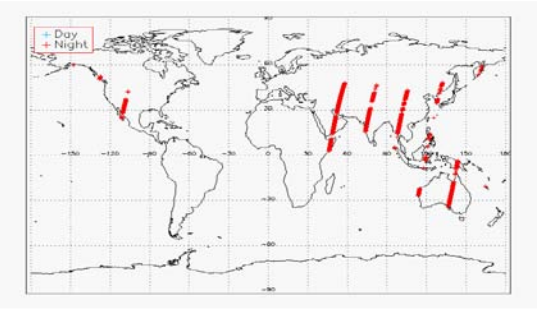
Product Quality – Land/Night

60N – 60S, Land, Night, No Snow/No Ice

CALIOP - VIIRS Matchup Pixels, 05/10/2012



CALIOP - VIIRS Matchup Pixels, 11/10/2012

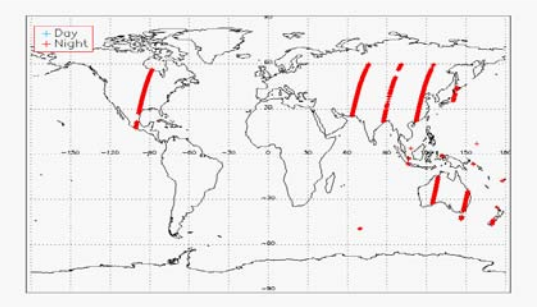


VIIRS Cloud Mask	Sample Size	Cloud fraction				Probability of		
		Active	Passive	Pr. Clear	Pr. Cloudy	Detection	False D.	Leakage
5/10/2012	23315	0.558	0.392	0.063	0.021	0.818	0.008	0.174
11/10/2012	17040	0.422	0.326	0.050	0.014	0.881	0.012	0.108

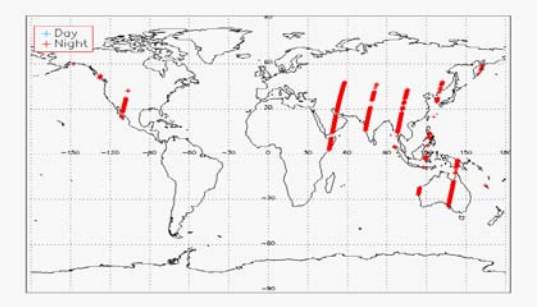
Product Quality – Land/Night/No Thin

60N – 60S, Land, Night, No Snow/No Ice

CALIOP - VIIRS Matchup Pixels, 05/10/2012



CALIOP - VIIRS Matchup Pixels, 11/10/2012

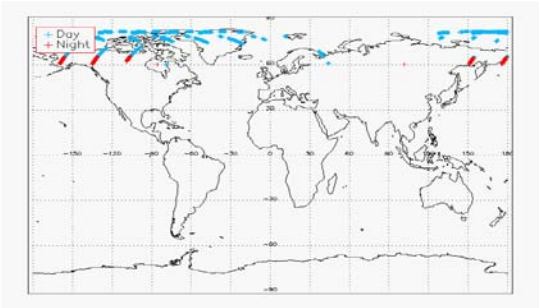


VIIRS Cloud Mask	Sample Size	Cloud fraction				Probability of		
		Active	Passive	Pr. Clear	Pr. Cloudy	Detection	False D.	Leakage
5/10/2012	15464	0.597	0.507	0.055	0.020	0.903	0.004	0.093
11/10/2012	13429	0.412	0.345	0.051	0.012	0.925	0.004	0.071

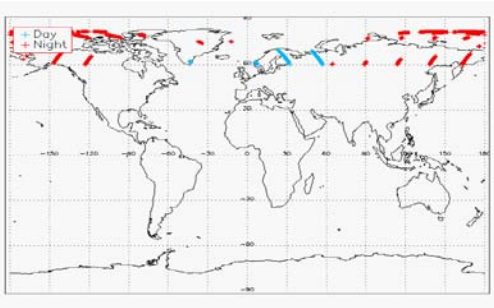
Product Quality – Polar/NH

60N – 90N, All

CALIOP - VIIRS Matchup Pixels, 05/10/2012



CALIOP - VIIRS Matchup Pixels, 11/10/2012

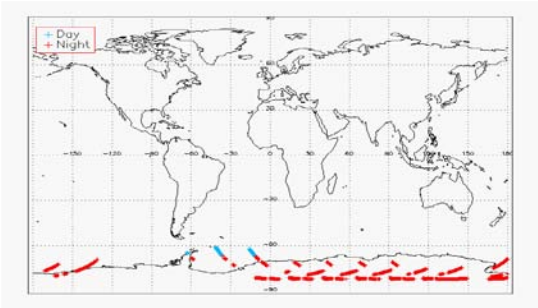


VIIRS Cloud Mask	Sample Size	Cloud fraction				Probability of		
		Active	Passive	Pr. Clear	Pr. Cloudy	Detection	False D.	Leakage
5/10/2012	13438	0.643	0.388	0.073	0.037	0.724	0.010	0.265
11/10/2012	13693	0.788	0.420	0.164	0.066	0.604	0.014	0.382

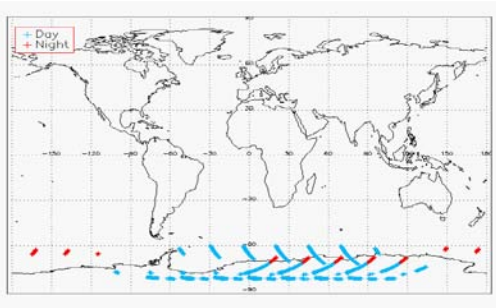
Product Quality – Polar/SH

60S – 90S, All

CALIOP - VIIRS Matchup Pixels, 05/10/2012



CALIOP - VIIRS Matchup Pixels, 11/10/2012



VIIRS Cloud Mask	Sample Size	Cloud fraction				Probability of		
		Active	Passive	Pr. Clear	Pr. Cloudy	Detection	False D.	Leakage
5/10/2012	12564	0.537	0.360	0.121	0.051	0.503	0.160	0.334
11/10/2012	22061	0.549	0.558	0.039	0.021	0.795	0.092	0.113

Product Quality Summary

- Global results show improvement for all evaluation criteria for the VCM
- Outside of the polar regions, both probability of detection and false alarms appear to be near requirements
- Leakage percentages are down 25-50% from May
  - However values still exceed requirements across the board
- Serious concerns exist to the results in polar locations
  - Daytime shows improvement but unquestionably short of requirements
  - Polar night is missing too many clouds
    - Note the requirements expected this

Incremental Product Improvement

- The VCM has had three software updates and three threshold updates since the declaration of beta
  - Software upgrades targeted shortfalls in the visual cloud detection test and consideration of scattering angles
  - Threshold updates aimed primarily at reducing leakage
- Seven Discrepancy Reports related to the VCM have been closed since the declaration of beta
- Longer term fixes for aerosol/cloud differentiation and high cloud identification over snow/desert in work for a February delivery

Incremental Product Improvement

- DRs considered critical at this time are:
  - DR 5039 – Water vapor consideration for M9
    - Software delivery scheduled for late February
  - DR 5038 – Cloud/Dust discrimination
    - Software delivery scheduled for late February
  - DR 4998 – Leakage feedback from Cal/Val teams
    - Ongoing but first threshold update directly addressing this DR approved by the AERB January 9
  - DR 4734 – Correct volcanic ash threshold
    - Feedback from aerosol and cloud teams indicate logic should be updated
  - DR 4577 – Cloud/snow discrimination in the VCM
    - Resolved over non-polar open water backgrounds but work continues on land and polar regions
- Ongoing efforts involving snow/ice and NDVI (gridding) will also improve the quality of the VCM

Incremental Product Improvement

- The VCM team has developed a list of activities either in progress or to be worked as priorities and resources allow
  - Threshold updates
    - NDVI impacts after gridding implementation, cloud phase, additional leakage issues, aerosol parameters
  - Software/code improvements
    - Low-light specific algorithms, cirrus logic expansion, snow/ice/cloud differentiation, Antarctica
  - Ongoing validation efforts
    - Additional Golden Granules, continued match-up analysis, ADA/ADL upgrades, continual presentation needs (AERB, conferences, TIMs)
- This list is updated monthly

Version Control

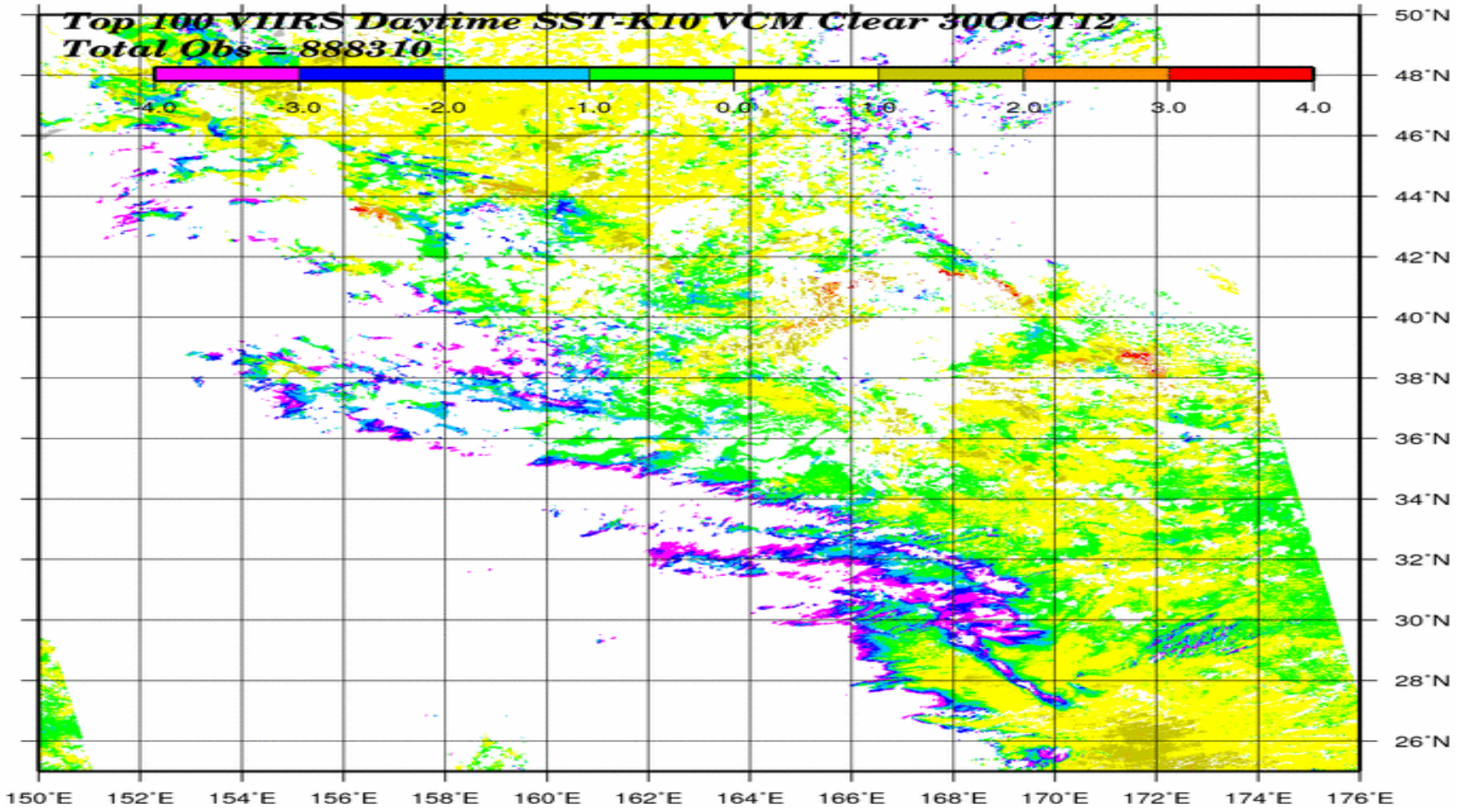
- All key documents are up-to-date
- ATBD, OAD, CDFCB-X all match operational VCM as of today
  - Note the VCM team uses configuration management of the associated Processing Coefficient Tables' XML files to maintain an up-to-date historical record of threshold changes
  - No document is expected to contain current operational values for all PCT thresholds
- Upcoming code deliveries will require updates to all three documents noted above

Community Interaction

- Many items, be they threshold or software updates, are now driven by feedback from other Cal/Val teams
- Consistent contact is maintained with all liaisons and others who have the capability to observe VCM impacts on their products
  - All threshold updates are now initiated either after specific feedback from a VIIRS Cal/Val team or after we have analyzed granules where issues have been identified
  - Two examples follow
- We will continue to use liaisons to communicate across the different Cal/Val teams
  - The VCM telecom, which generally meets bi-weekly, is open to anyone interested

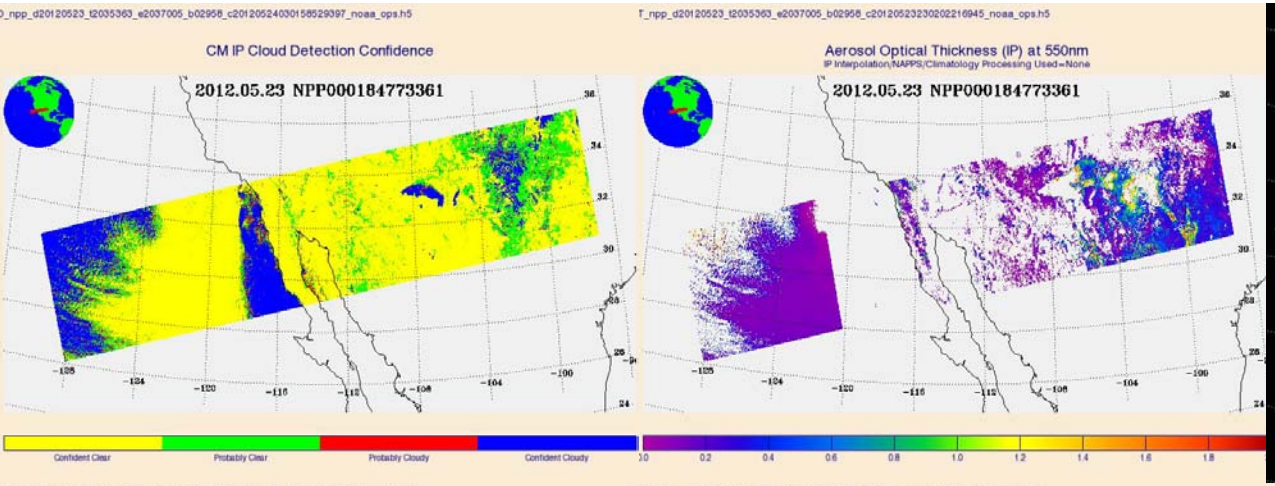
Community Interaction

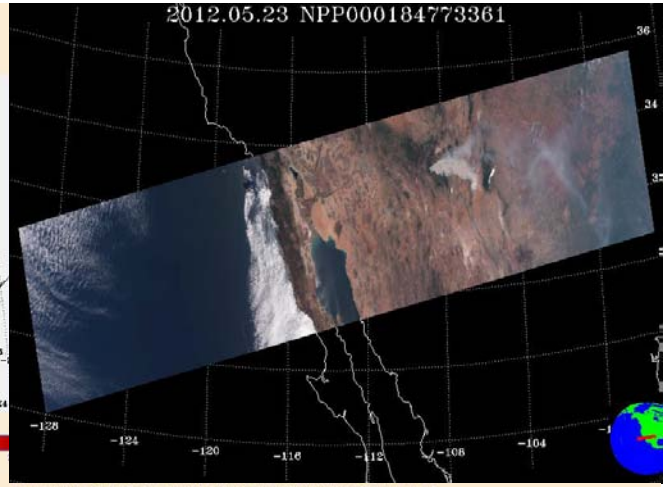
- Regional SST biases from NAVO

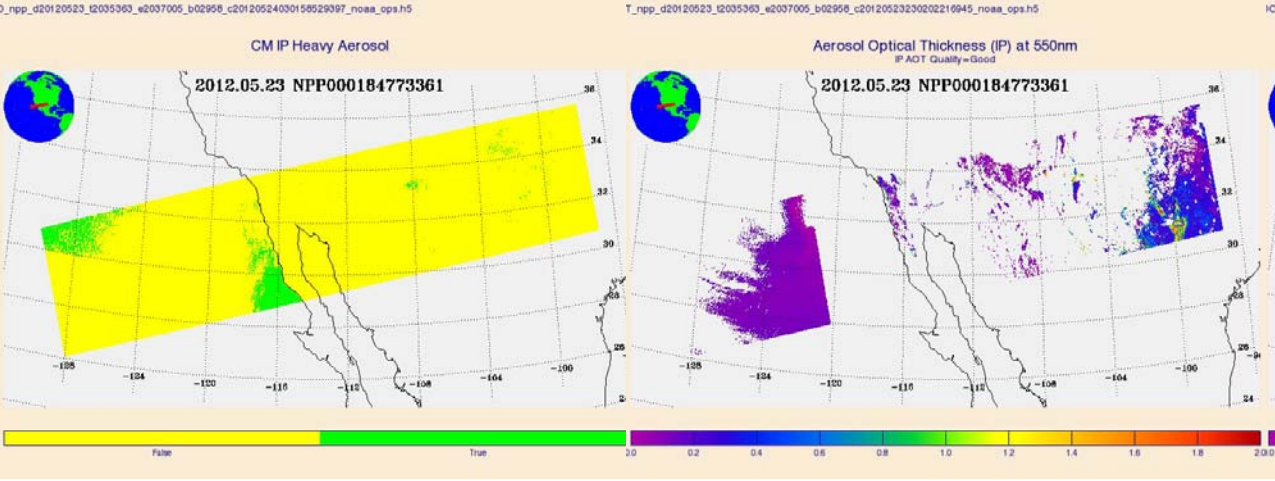


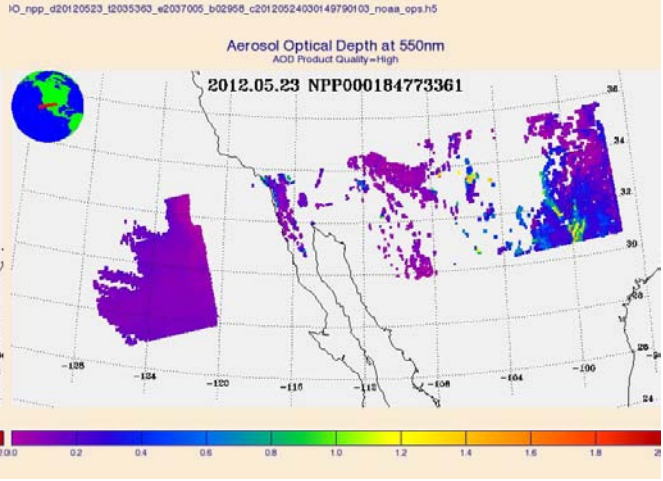
Community Interaction

- Aerosol/VCM displays from the aerosol team









Users and Product Status

- Bi-weekly telecoms are used, in part, to maintain open communication for both internal and external (liaison) VCM members with ongoing work and implementation dates
- Actual dates when thresholds are updated could be communicated better
  - No one on the VCM team receives notices when thresholds are actually placed on the system
  - Added member from Raytheon has improved this

Users and Product Status

- Five caveats may be found in the VCM "Read Me" file at the time beta was declared
  - Dependency on two external fields (snow and NDVI) that were fixed values from 2002
    - Snow now being updated monthly
    - NDVI no longer a fixed field, updates occurring but no known schedule as to how often
  - Difficulties differentiating low clouds from snow/ice
    - Resolved over open water away from polar regions, otherwise still present, as already discussed
  - Leakage, also already discussed
  - Results near edge-of-scan
    - Resolved with implementation of scattering angle curves
  - VCM performance at night over land/snow/ice
    - Improving over land, an open issue over snow/ice

Archive of the VCM

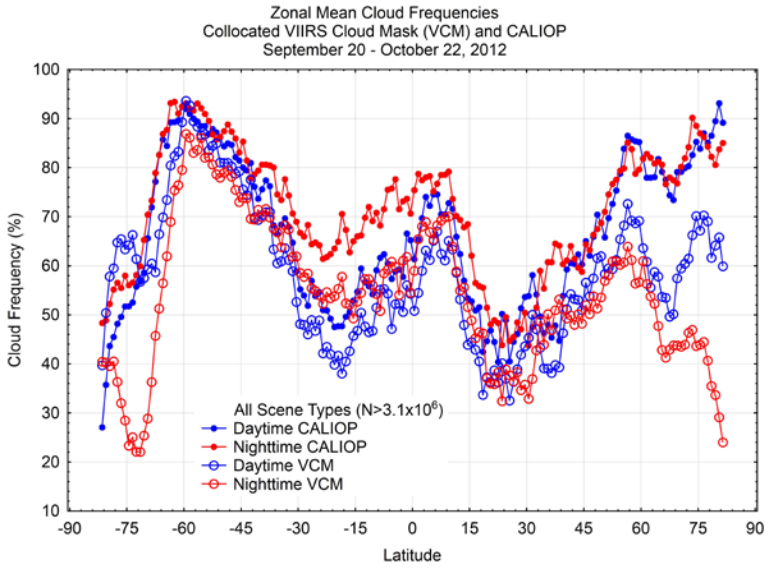
- The VCM, although it is considered an Intermediate Product (IP), is archived by CLASS
- There are no plans the VCM team is aware of to reproduce and replace what is in the archive
- Most downstream users, when reproducing products on a large scale, include the VCM as part of the software executed and not as an input
- The VCM team does not currently have any plans to reproduce the VCM in the archive

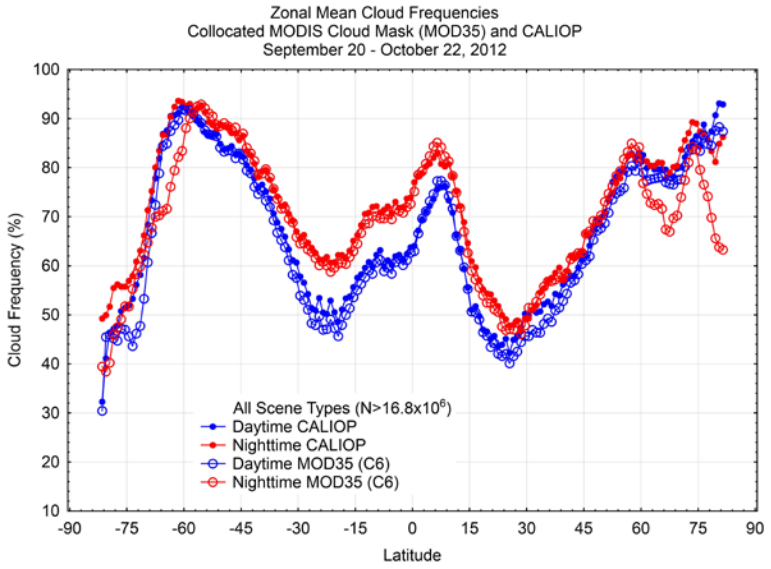
Ready for Operational Evaluation

- The VCM, as indicated by the feedback already received, has been evaluated by users for the past few months
- It had always been the intent, which has been met, that the VCM would be ready for outside evaluation after the 30-day spin-up (beta stage)
- The fact that this TIM includes presentations from downstream EDRs indicates this analysis has already been ongoing for months
- Even the climate community has already started to look at the VCM output

Ready for Operational Evaluation

- Chart showing VCM output with CALIOP over all latitude bands alongside MODIS results





Ready for Operational Evaluation

- Proposed caveats for the VCM at the provisional stage are:
  - External fields of snow and NDVI not updating at expected frequencies, older backgrounds will introduce additional errors
  - Nighttime performance above snow/ice backgrounds suspect
  - Leakage should be monitored and we ask significant areas be reported (widespread occurrences should be isolated)
  - All users should exploit available quality flags present in the VCM but not being used as they should
    - Snow/ice bit, thin cirrus bit, quality bit

Path Forward

- Primary function of the validation team in the next few months is twofold
  - Reduce leakage further
  - Address the cloud mask over snow/ice
- Evaluate additional Golden Granules to cover relevant scenes and backgrounds
- Pursue quantitative validation of cloud phase and aerosol quality flags
- Continue to interact and be responsive to other VIIRS EDR team needs

Conclusion

- VCM has shown marked improvement over the last few months
  - Probability of Correct Typing and False Alarms at or better than requirements
  - Leakage numbers are down but trend must continue
  - Polar regions need work
- The VCM has met all provisional criteria
  - Feedback from other VIIRS EDR teams and liaisons has been occurring since beta
    - And you will see some of this shortly
  - Documentation up-to-date