The VIIRS Cloud Mask

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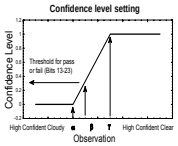
VIIRS Cloud Detection Approach

The VIIRS Cloud Mask (VCM) uses a series of tests to establish a confidence that any pixel is cloud-free and other tests to create a pixel-level cloud phase (discussed below).



Each cloud test returns a confidence (F) ranging from 0.0 to 1.0. Tests for similar cloud types (water vs ice) are grouped together and a minimum clear-sky confidence is selected [min (F_i)] for each of N groups. Final confidence (Q) is:

$$Q = \sqrt[N]{\prod_{i=1}^{N} \min(F_i)}$$

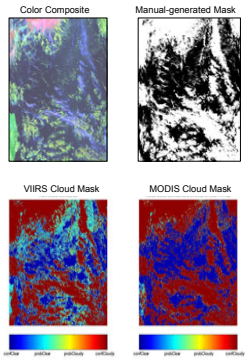
VCM has its heritage in many algorithms, especially MODIS, which produces four cloud confidences:" Confidently Cloudy" (Q=0), "Probably Cloudy" (0<Q<.5), "Probably Clear" (.5≤Q<.99), and "Confidently Clear" (Q≥0.99).

The VCM also includes new tests developed to exploit the unique aspects of the VIIRS sensor design. Spatial tests with imagery channels (375-m) are used over ocean surfaces to detect cloud edges that elude detection in the moderate resolution (750-m) channels.

The VCM has modified many spectral tests found in heritage algorithms by implementing thresholds that vary with viewing conditions and land classification.

The VCM also uses unique tests to discriminate heavy aerosols from clouds. (separate poster)

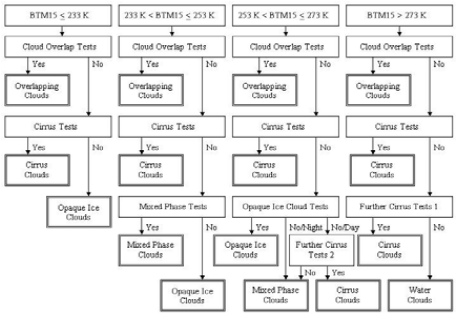
Pre-launch performance of the VCM is based upon comparisons with MODIS Collection 4 results and manually-generated cloud masks as shown for MODIS granule MODA2001.213.1220.



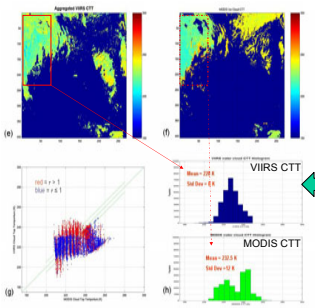
VIIRS Cloud Top Phase Approach

The VCM cloud phase algorithm was developed by Pavolonis and Heidinger (2004) and produces classes that include (1) water, (2) opaque ice, (3) mixed phase, (4) cirrus, and (5) overlap (ice and water clouds in the same pixel) in addition to (6) partly cloudy (edges) and (7) clear. The logic for the daytime algorithm is shown herein.

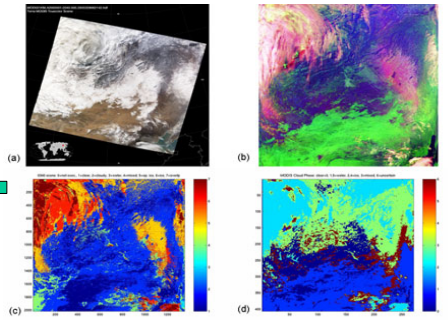
Accurately differentiating single from overlap cirrus results in improved quality of clouds products that rely upon the VCM. Differentiating these cloud types helps examine differences between VIIRS and MODIS cloud top temperature (CTT) products and establish VIIRS quality.



This schematic of the VIIRS cloud top phase algorithm used to retrieve the seven cloud classes in the VCM. (From Pavolonis et al., 2005 Figure 5)



Overlap in VCM cloud phase helps explain differences between (a) VIIRS CTT product and the (b) MODIS product. MODIS CTT are inferred to be too warm in overlap conditions. (See Wong et al., separate poster)



Cloud phase analysis for MODIS granule MOD2002.001.0340 over China. True color image (a), false color composite (b), VCM cloud phase (d) shows overlap (brown) and cirrus (red) while MODIS analysis (d) shows only ice phase.

Dynamic VIIRS M5 (0.672-µm) and M1 (0.412-µm) Cloud Detection Thresholds

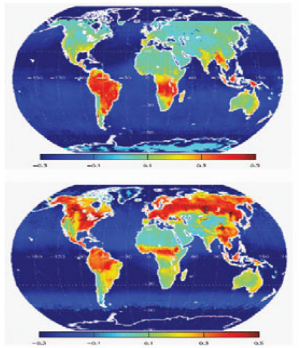
Early testing of the VCM at NGST in January 2003 determined the VIIRS algorithm generated too many false alarms over land surfaces, i.e. confidently cloudy in the VCM but cloud-free in the manually-generated cloud mask.

These false alarms arose because single-valued detection thresholds were used with a static land class database; thus, NGST sought to modify tests to use variable thresholds.

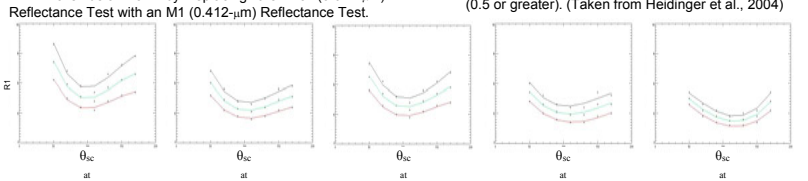
For example, NGST worked closely with NOAA/NESDIS, CIMSS, and Aerospace to modify the original M5 Reflectance Test, of MODIS heritage, with a variable threshold, similar to the one used in CLAVR-X. The thresholds for this test now vary with scattering angle and NDVI to compensate for seasonal variations in global precipitation patterns as shown in these NDVI images.

The TOC NDVI is updated every 16-days based upon the VIIRS surface albedo intermediate product thus becoming a dynamic database that shows current vegetative growth patterns.

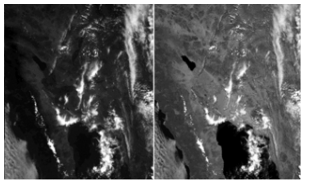
However, improved cloud detection is realized when TOC NDVI falls below 0.2 by replacing the M5 (0.672-µm) Reflectance Test with an M1 (0.412-µm) Reflectance Test.



Typical seasonal changes in global NDVI fields during January (top) and July (bottom) due to variations in precipitation patterns: Blue(0.0) to red (0.5 or greater). (Taken from Heidinger et al., 2004)

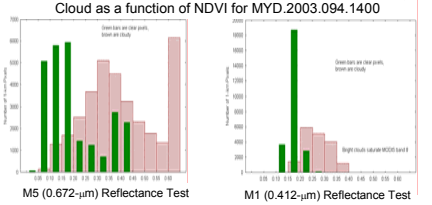


VIIRS M5 thresholds as functions of NDVI (0.2-0.3 left to 0.6-0.7 right) and scattering angle. Red, green, and black are 1.0, 0.5, and 0.0 confidence of clear sky, respectively. For NDVI < 0.2, the M1 band is used instead of the M5 band in the reflectance test.



Two images of the southwest USA taken by Sea-WIFS on 13 July, 2001, 0.41 µm (left) and 0.86 µm (right) (From Hutchison and Cracknell, 2005 Figures 5.23 & 5.24.)

Frequency of Occurrence in Confidently Clear and Confidently Cloud as a function of NDVI for MYD.2003.094.1400

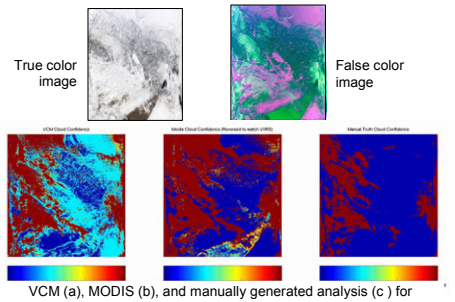


The histograms show distributions of clear and cloudy Aqua MODIS reflectances at 0.66-µm and 0.41-µm from the African Sahel. Less overlap in the in the 0.412-mm band means fewer false alarms in the VCM analysis at TOC NDVI values below 0.2 (From Hutchison et al., 2005, Figure 14)

Preliminary VCM Performance Results

Scene Number	Granule ID MODIS Terra	MODIS Cloud Mask Leakage Rate	MODIS Cloud Mask False Alarm Rate	MODIS Cloud Mask Probability of Correct Typing	VIIRS Cloud Mask Leakage Rate	VIIRS Cloud Mask False Alarm Rate	VIIRS Cloud Mask Probability of Correct Typing
#1	2002.032.1750	0.52%	9.50%	81.43%	0.31%	7.00%	89.40%
#2	2002.001.0340	0.39%	31.78%	49.63%	0.07%	13.60%	81.81%
#3	2003.194.0905	3.26%	2.91%	90.15%	2.07%	3.26%	89.14%
#4	2002.001.0435	0.74%	15.64%	78.53%	2.18%	0.06%	89.65%
#5	2003.299.1835	0.16%	6.35%	85.01%	0.12%	9.49%	88.34%
#6	2001.213.1210	4.48%	21.21%	67.33%	0.96%	8.27%	84.90%
#7	2001.196.1755	0.74%	2.56%	93.07%	1.21%	10.56%	85.69%
#8	2002.032.2210	3.18%	4.72%	79.76%	1.00%	0.55%	97.47%
#9	2001.152.1600	1.05%	5.14%	87.86%	1.45%	2.85%	85.77%
#10	2001.213.1220	0.70%	2.25%	93.75%	0.24%	2.08%	88.78%
#11	2002.118.0215	0.01%	15.16%	80.47%	0.03%	10.88%	84.97%
#12	2002.032.1745	0.17%	26.51%	70.29%	0.07%	13.68%	82.18%
#13	2002.032.0220	3.44%	4.75%	82.2%	1.67%	5.23%	87.83%
#14	2003.299.1840	0.49%	5.17%	91.66%	0.11%	5.66%	88.72%

VCM and MODIS Collection 4 performance for several MODIS granules analyzed recently at NGST. (Results are based upon comparisons with manually-generated cloud masks.)



VCM (a), MODIS (b), and manually generated analysis (c) for Scene #12, MODIS granule MOD.2002.032.1745