

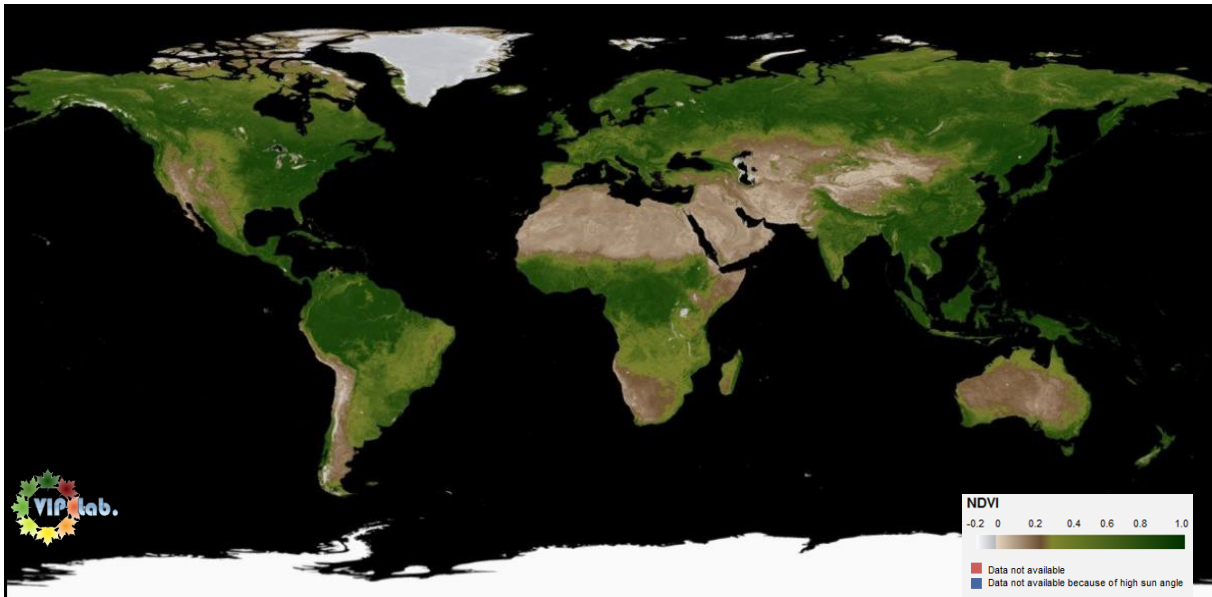
# **MODIS Collection 6.1 (C61) Vegetation Index Product User Guide**

The C61 MCD12 product is identical in format to the C6 product. This (C61) reprocessing does not contain any change to the science algorithm used to make this product. Any improvement or change in the C61 product compared to the product from the prior major collection reprocessing (C6) is from changes and enhancements to the calibration approach used in generation of the Terra and Aqua MODIS L1B products and changes to the polarization correction used in this collection reprocessing. For further details on C61 calibration changes and other changes user is encouraged to refer to the Collection 6.1 specific changes that have been summarized here: [https://landweb.modaps.eosdis.nasa.gov/QA\\_WWW/forPage/MODIS\\_C61\\_Land\\_Proposed\\_Changes.pdf](https://landweb.modaps.eosdis.nasa.gov/QA_WWW/forPage/MODIS_C61_Land_Proposed_Changes.pdf)

# MODIS Vegetation Index User's Guide (MOD13 Series)

Version 3.10, September 2019  
(Collection 6.1)

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This is a live document that serves as the User Guide for the MODIS Vegetation Index Product series  
Last Update September, 2019

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# 1 Introduction

One of the primary interests of the Earth Observing System (EOS) program is to study the quantity and role of terrestrial vegetation in large-scale global processes with the goal of understanding how the Earth functions as a system. This requires an understanding of the global distribution of vegetation types as well as their biophysical and structural properties and spatial/temporal variations. Vegetation Indices (VI) are robust, empirical measures of vegetation activity at the land surface. They are designed to enhance the vegetation reflected signal from measured spectral responses by combining two (or more) wavebands, often in the red (0.6 - 0.7  $\mu\text{m}$ ) and NIR wavelengths (0.7-1.1  $\mu\text{m}$ ) regions.

## 1.1 The MODIS vegetation index (VI) products

The MODIS VI products (MOD13) provide consistent, spatial and temporal time series comparisons of global vegetation conditions that can be used to monitor the Earth's terrestrial photosynthetic vegetation activity in support of phenology, change detection, and biophysical interpretations. Gridded vegetation index maps depicting spatial and temporal variations in vegetation activity are derived at 16-day and monthly intervals in support of accurate seasonal and inter-annual monitoring of the Earth's terrestrial vegetation.

Two VI products are made globally for land regions. The first product is the standard Normalized Difference Vegetation Index (NDVI), which is referred to as the "continuity index" to the existing NOAA-AVHRR derived NDVI. There is currently a ~35-year NDVI global data set (1981 - 2015) from the NOAA-AVHRR series, which in conjunction with MODIS data provide a long term data record for use in operational monitoring studies. The second VI product is the Enhanced Vegetation Index (EVI), with improved sensitivity over high biomass regions and improved vegetation monitoring capability through a de-coupling of the canopy background signal and a reduction in atmosphere influences. The two VIs complement each other in global vegetation studies and improve upon the extraction of canopy biophysical parameters. To further make these indices more useful a new compositing scheme that reduces angular, sun-target-sensor variations is also utilized. The gridded VI maps use MODIS surface reflectances corrected for molecular scattering, ozone absorption, and aerosols, as input to the VI algorithm equations. The gridded vegetation indices include quality assurance (QA) flags with thematic information about the quality of the VI product and input data.

The MODIS VI products are currently produced at 250 m, 500 m, 1 km and a special 0.05 deg. spatial resolutions. For data processing purposes, MODIS VIs are generated in square tile units that are approximately 1200-by-1200 km (at the equator), and mapped in the Sinusoidal (SIN) grid projection (equal area projection). Only tiles containing land features are processed. When mosaicked, all tiles cover the Earth landmass and the global MODIS-VI can thus be generated each 16 days and each calendar month.

## 1.2 Theoretical Description of Vegetation Indices

The theoretical basis for empirical-based vegetation indices is derived from examination of typical spectral reflectance signatures of leaves. The reflected energy in the visible is very low as a

result of high absorption by photosynthetically active pigments, with maximum absorption values in the blue (470 nm) and red (670 nm) wavelengths. Nearly all of the near-infrared radiation (NIR) is scattered (reflected and transmitted) back with very little absorption, in a manner dependent upon the structural properties of a canopy (LAI, leaf angle distribution, leaf morphology). As a result, the contrast between red and near-infrared responses (called the red shift) is a sensitive measure of vegetation amount, with maximum red–NIR differences occurring over a full canopy and minimal contrast over targets with little or no vegetation. For low and medium amounts of vegetation, the contrast is a result of both red and NIR changes, while at higher amounts of vegetation, only the NIR contributes to increasing contrasts as the red band becomes saturated due to chlorophyll absorption.

The red-NIR contrast can be quantified through the use of ratios (NIR/red), differences (NIR–red), weighted differences (NIR–k·red), linear band combinations ( $x_1 \cdot \text{red} + x_2 \cdot \text{NIR}$ ), or hybrid approaches of the above. Vegetation indexes are measures of this contrast and thus are integrative functions of canopy structural (%cover, LAI, LAD) and physiological (pigments, photosynthesis) parameters.

### 1.2.1 Theoretical basis of the NDVI

The NDVI is a normalized transform of the NIR to red reflectance ratio,  $\rho\text{NIR}/\rho\text{red}$ , designed to standardize VI values to between –1 and +1. It is commonly expressed as:

$$NDVI = \frac{NIR - Red}{NIR + Red} \quad (1)$$

As a ratio, the NDVI has the advantage of minimizing certain types of band-correlated noise (positively-correlated) and influences attributed to variations in direct/diffuse irradiance, clouds and cloud shadows, sun and view angles, topography, and atmospheric attenuation. Ratioing can also reduce, to a certain extent, calibration and instrument-related errors. The extent to which ratioing can reduce noise is dependent upon the correlation of noise between red and NIR responses and the degree to which the surface exhibits Lambertian (angle independent) behavior.

The main disadvantage of ratio-based indices tend to be their non-linearity exhibiting asymptotic behaviors, which lead to insensitivities to vegetation variations over certain land cover conditions. Ratios also fail to account for the spectral dependencies of additive atmospheric (path radiance) effects, canopy-background interactions, and canopy bidirectional reflectance anisotropies, particularly those associated with canopy shadowing.

### 1.2.2 Theoretical basis of the EVI

To minimizing atmospheric effect the difference in blue and red reflectances can be used as an estimator of the atmosphere influence level. This concept is based on the wavelength dependency of aerosol scattering cross sections. In general the scattering cross section in the blue band is larger than that in the red band. When the aerosol concentration is higher, the difference in the two bands becomes larger. This information is used to stabilize the index value against variations in aerosol concentration levels.

The EVI incorporates this atmospheric resistance concept in a similar fashion to the Atmospheric Resistant Index (ARVI), along with the removal of soil-brightness induced variations in VI based on the Soil Adjusted Vegetation Index (SAVI). The EVI additionally decouples the soil and atmospheric influences from the vegetation signal by including a feedback term for simultaneous correction. The EVI formula is written as:

$$EVI = G \frac{NIR - Red}{NIR + C1Red - C2Blue + L} \quad (2)$$

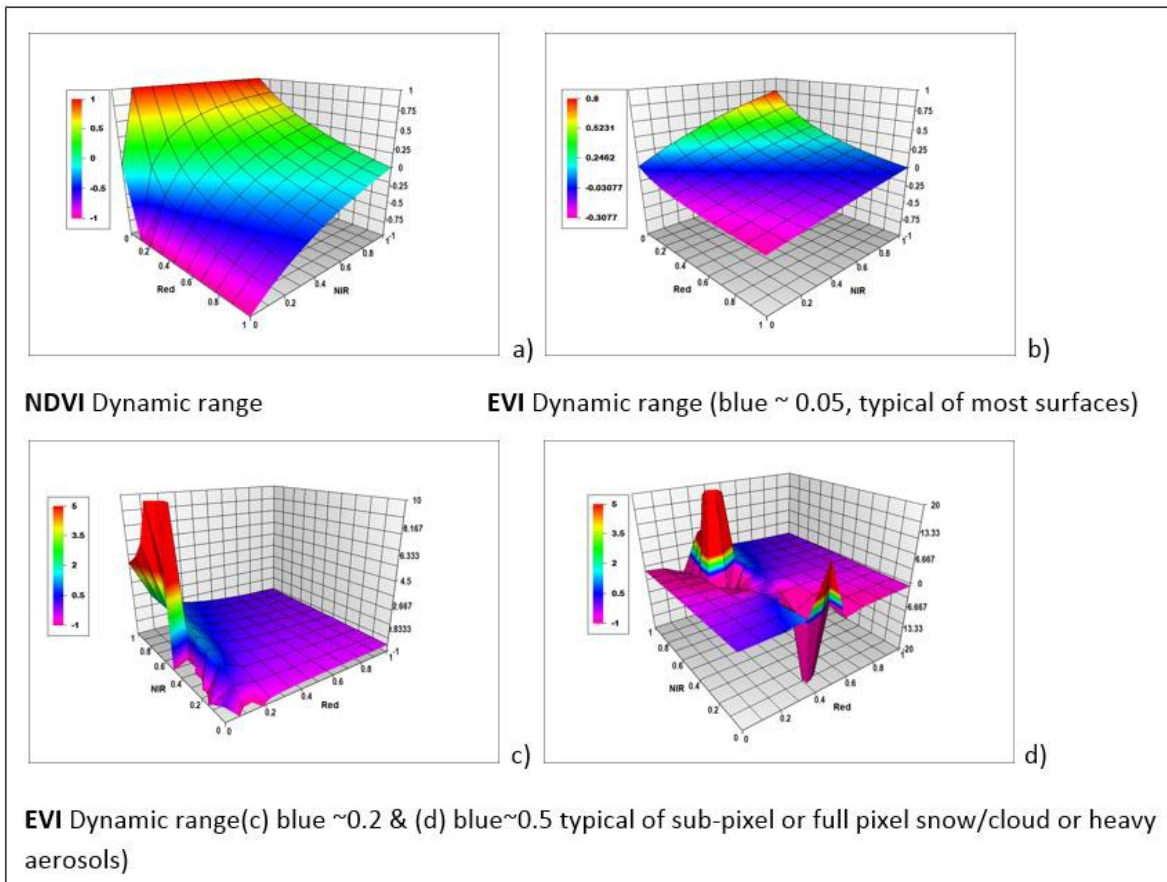
where NIR, Red, and Blue are the full or partially atmospheric-corrected (for Rayleigh scattering and ozone absorption) surface reflectances; L is the canopy background adjustment for correcting the nonlinear, differential NIR and red radiant transfer through a canopy; C1 and C2 are the coefficients of the aerosol resistance term (which uses the blue band to correct for aerosol influences in the red band); and G is a gain or scaling factor. The coefficients adopted for the MODIS EVI algorithm are, L=1, C1=6, C2=7.5, and G=2.5.

### 1.2.3 EVI backup algorithm

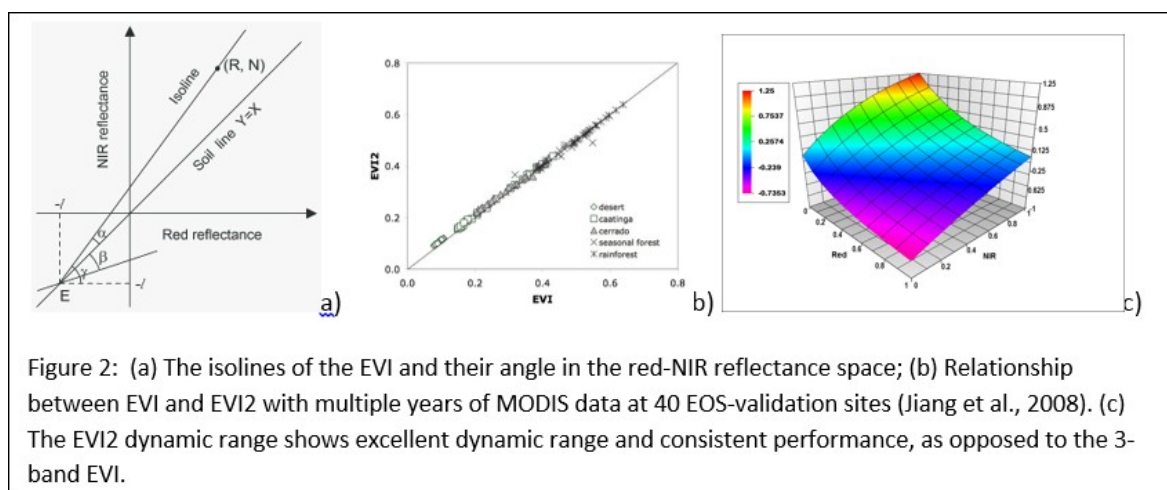
Per Figure 1, EVI exhibits erratic behavior over bright targets (heavy clouds, and snow/ice). This is mostly due to the inability of the blue band (saturates) to convey any useful atmosphere information which inhibits the EVI formulation leading to extremely high EVI values over bright targets. To address this issue starting Collection 5.0 the standard 3-band EVI is replaced by a modified 2-band EVI (does not use the blue band) over high-reflectance surfaces such as clouds and snow/ice. This situation is further exacerbated by an imperfect atmospheric correction procedure that further promotes anomalous EVI values. Because the 2-band EVI does not use the blue band, it becomes insensitive to these effects, while maintaining the other advantages of the EVI (Fig. 2).

The 2-band EVI equation used for the MODIS VI products is:

$$EVI 2 = 2.5 \frac{NIR - Red}{NIR + 2.4Red + 1} \quad (3)$$



**Figure 1:** (a). NDVI dynamic range illustrating the saturation problems. b,c, & d) the 3-band EVI works fine with blue band below 0.1 (typical of most surfaces), but becomes very unstable when the blue  $\geq 0.2$ , typical of under canopy snow, sub-pixel clouds or heavy aerosols. These conditions render EVI useless (f, 3-band EVI over Greenland). Because in most cases the 3-band EVI values stay within the acceptable range [-1. to 1] these problems are usually undetected. Note the different scales.



**Figure 2:** (a) The isolines of the EVI and their angle in the red-NIR reflectance space; (b) Relationship between EVI and EVI2 with multiple years of MODIS data at 40 EOS-validation sites (Jiang et al., 2008). (c) The EVI2 dynamic range shows excellent dynamic range and consistent performance, as opposed to the 3-band EVI.

For a more detailed and theoretical description please consult the “MODIS Vegetation Index (MOD 13) Algorithm Theoretical Basis” document ([https://modis.gsfc.nasa.gov/data/atbd/atbd\\_mod13.pdf](https://modis.gsfc.nasa.gov/data/atbd/atbd_mod13.pdf)).

## 2 What is new in Collection 6

A number of improvements have been proposed and implemented in the MODIS VI algorithm and product suite. The most important and major change to the VI algorithm is the use of pre-composited (8-day) surface reflectance data as opposed to daily data. Previous improvements in the quality-based compositing scheme were kept even when using this pre-composited data.

Since Collection 5.0 the Terra and Aqua data streams are processed 8 days out of phase at 16-day interval, which provides a quasi-8-day VI product time series when the two stream are used together, thus improving the change detection capabilities of the products.

Overall the changes in the C6 were:

- Use of precomposited data
- Modified the Constrained View angle Maximum Value Composite (CV- MVC) compositing method to work with this new input stream
- Updated the EVI backup algorithm from SAVI to a new robust 2–band EVI
- Adjusted the necessary SDS to reflect the new input data stream, in particular the RelativeAzimuth angle, which now uses a new dynamic range (-180 to 180 deg.)

## 3 File Format of the MODIS VI Products

The MODIS production and science team uses the NASA Hierarchical Data Format-Earth Observing System (HDF-EOS) format, which is the standard archive format for all EOS Data Information System (EOSDIS) products. Each MODIS-VI file contains two separate structures:

1. Scientific data sets (SDS) which are the actual data stored in array format (2-D, 3-D and even 4-D).
2. Three sets of metadata:
  - Structural metadata that describes the actual content of the file,
  - Core metadata that describes the projection and grid name,
  - Archive metadata that describes various aspects of the file in terms of dates, times, statistics about quality, useful for archiving and searching the products.

All MODIS VI products are in a grid structure, which are defined as projected, fixed-area files with a 10x10 deg. Geographic extent. The use of metadata is meant to enhance the self-describing characteristics of HDF files and is useful to the end user during archiving and searching of granules/files. Parameter Value Language (PVL) is used to write the various metadata to the product file as:

PARAMETER = VALUE

There are two types of metadata attributes: 1) global attributes which are general to all MODIS products and 2) product specific attributes (PSA). Metadata provides general information about the file contents, characteristics, overall quality (through the QA PSA), and information about the input data, algorithm, processing used to derive the products. The actual data is stored in scientific data sets (SDS) that are pixel base.



## 4. MODIS VI Product Suite

There are 6 products in the MODIS VI suite<sup>1</sup>:

1. MOD13Q1: 16-day 250m VI
2. MOD13A1: 16-day 500m VI
3. MOD13A2: 16-day 1km VI
4. MOD13A3: Monthly 1km VI
5. MOD13C1: 16-day 0.05deg VI
6. MOD13C2: Monthly 0.05deg VI

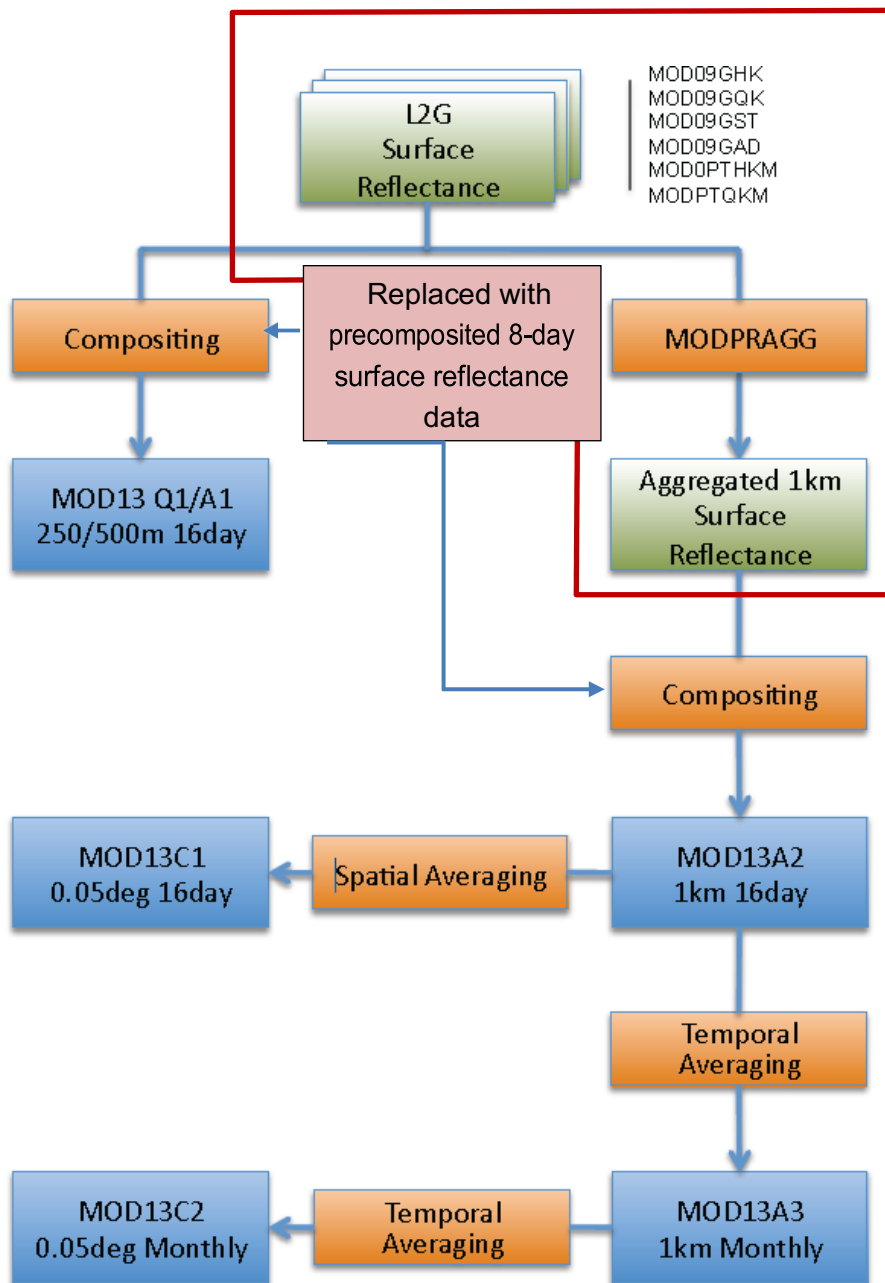
The first three products directly ingest daily level 2 gridded (L2G) product surface reflectance (MOD09 series). The last three products use the finer resolution VI products and aggregate through time or space. The 1-km VI product (MOD13A2), however, must use aggregated native finer resolution MODIS 250m and 500m pixel into 1 km, and this done by the surface reflectance algorithm (in prior collection a utility algorithm (MODAGG) handle the data aggregation. The CMG products, MOD13C1 is generated using a spatial averaging and reprojection of the 1-km data MOD13A2. The MOD13A3 and MOD13C2, are temporal averages of their 16-day versions (Fig. 3).

## 5 MOD13Q1/MOD13A1 (16-day 250/500-m) VI

Starting Collection 6.0 this product started ingesting precomposed 8-day MODIS Level-2G (L2G) surface reflectance (Fig. 4).

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<sup>1</sup> Even though we make reference in this document to mostly MODIS VI product as “MOD13”, it is implicit that we mean the full MODIS VI product suite from both MODIS sensors onboard Terra and Aqua platforms (i.e. MOD13 and MYD13 respectively)



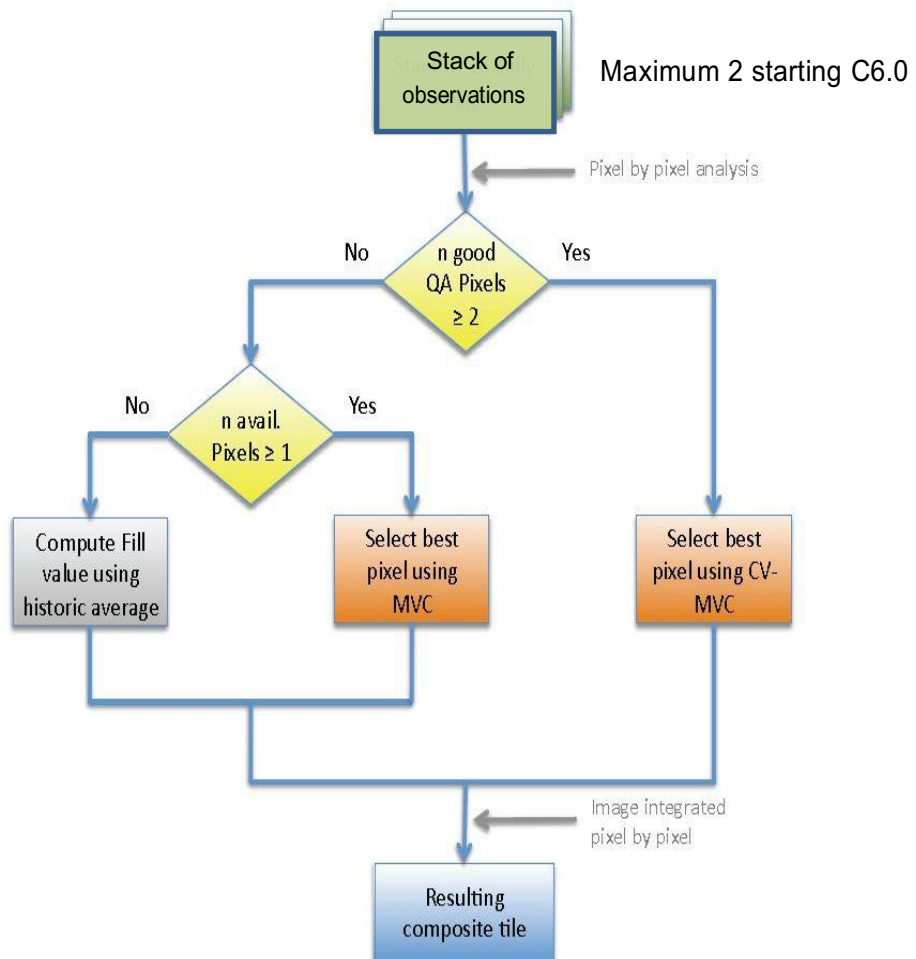
**Figure 3:** Overview of MODIS VI product suite and processing algorithms

## 5.1 Algorithm Description

These algorithms operate on a per-pixel basis and requires multiple observations (days, or precomposed as in collection 6.0) to generate a composited VI value that will represent the full period. Due to orbit overlap, multiple observations may exist from the same day and same pixel. However, due to the persistence of clouds and the sensor spatial coverage, the number of useful observations is rather small and less so as we get close to the equator due to the orbital gap resulting from the satellite having to cover more land (these are polar orbiters). Because in C6.0 we started using precomposed data, once all 8 days are collected, the surface reflectance algorithm applies a set of filters based on quality, cloud, and viewing geometry (Fig. 4). Cloud-

contaminated pixels and extreme off-nadir sensor views are considered lower quality. A cloud-free, nadir view pixel with no residual atmospheric contamination represents the best quality pixel. Only the higher quality cloud free data are retained for further compositing. The current surface reflectance employs a minimum BLUE band approach to minimize aerosols and other contaminants. The resulting 8-day composited surface reflectance data is then ingested by our VI algorithm. The goal of the compositing methodology is to extract a single value per pixel from all the retained filtered data, which will represent the pixel for the particular 16-day period. The VI compositing technique uses an enhanced criteria for normal-to-ideal observations, but switches to an optional backup method when conditions are less than ideal.

1. Main approach: Constrained View angle - Maximum Value Composite (CV-MVC)
2. Backup: Maximum Value Composite (MVC) only which is used to the simple AVHRR MVC approach (pixel with highest NDVI).



**Figure 4:** MODIS VI Compositing algorithm data flow.

The CV-MVC is an enhanced MVC approach, in which the number of observations  $n$  ( $n$  being set to 2) with the highest NDVI are compared and the observation with the smallest view angle, i.e. closest to nadir view, is chosen to represent the 16-day composite cycle. This was done to

minimize the BRDF effects.

All compositing methods inevitably result in spatial discontinuities due to the fact that disparate days can always be chosen for adjacent pixels over the 16-day period. Thus, adjacent selected pixels may originate from different days, with different sun-pixel-sensor viewing geometries and different atmospheric and residual cloud/smoke contamination.

## 5.2 Scientific Data Sets

The 250m/500-m VI product contains the following SDSs:

**Table 1:** Product MOD13A1: 16-day 250/500-m VI.

| Science Data Set                                | Units      | Data type | Valid Range   | Fill Value | Scale factor |
|---|------------|-----------|---------------|------------|--------------|
| 250/500m 16 days NDVI                           | NDVI       | int16     | -2000, 10000  | -3000      | 0.0001       |
| 250/500m 16 days EVI                            | EVI        | int16     | -2000, 10000  | -3000      | 0.0001       |
| 250/500m 16 days VI Quality detailed QA         | Bits       | uint16    | 0, 65534      | 65535      | NA           |
| 250/500m 16 days red reflectance (Band 1)       | Reflectanc | int16     | 0, 10000      | -1000      | 0.0001       |
| 250/500m 16 days NIR reflectance (Band 2)       | Reflectanc | int16     | 0, 10000      | -1000      | 0.0001       |
| 250/500m 16 days blue reflectance (Band 3)      | Reflectanc | int16     | 0, 10000      | -1000      | 0.0001       |
| 250/500m 16 days MIR reflectance (Band 7)       | Reflectanc | int16     | 0, 10000      | -1000      | 0.0001       |
| 250/500m 16 days view zenith angle              | Degree     | int16     | 0, 18000      | -10000     | 0.01         |
| 250/500m 16 days sun zenith angle               | Degree     | int16     | 0, 18000      | -10000     | 0.01         |
| 250/500m 16 days relative azimuth angle         | Degree     | int16     | -18000, 18000 | -4000      | 0.01         |
| 250/500m 16 days composite day of the year      | Day of     | int16     | 1, 366        | -1         | NA           |
| 250/500m 16 days pixel reliability (summary QA) | Rank       | int8      | 0, 3          | -1         | NA           |

250/500m corresponds to either MOD13Q1 or MOD13A1

## 5.3 Product Specific Metadata

An example listing of the metadata fields used in the MOD13Q1/A1 VI product is shown in Table 2.

## 5.4 Global and Local Metadata Attributes

As in all MODIS products, the global metadata is written to the output file during the generation process and could be used for searching the archive about the product. This metadata provides product wise information useful during product identification and search.

## 5.5 Quality Assurance

The quality of the MOD13Q1/A1 product is assessed through the quality assessment (QA) metadata objects and per-pixel QA science data sets (SDS's). The QA metadata objects summarize tile-level (granule) quality with several single words and numeric numbers, and thus are useful during data searching/ordering and screening processes. The QA SDS's, on the other hand, document product quality on a pixel-by-pixel basis and thus are useful for data analyses, filtering, and application.

**Table 2:** Metadata fields for QA evaluation of MOD13 Q1/A1.

---

|  |   |
|--|---|
| <b>I. Inventory Metadata fields for all VI products (searchable)</b> |   |
| QAPERCENTINTERPOLATEDDATA QAPERCENTMISSINGDATA                       |   |
| QAPERCENTOUTOFBOUNDSDATA QAPERCENTCLOUDCOVER                         |   |
| QAPERCENTGOODQUALITY QAPERCENTOTHERQUALITY                           |   |
| QAPERCENTNOTPRODUCEDCLOUD  |   |
| QAPERCENTNOTPRODUCEDOTHER  |   |
| <b>II. Product specific metadata (searchable)</b>                    |   |
| Product  | Specific Metadata variable name (Best Quality)            |
| MOD13Q1  | NDVI250M16DAYQCLASSPERCENTAGE                             |
| MOD13Q1  | EVI250M16DAYQCLASSPERCENTAGE                              |
| MOD13A1  | NDVI500M16DAYQCLASSPERCENTAGE                             |
| MOD13A1  | EVI500M16DAYQCLASSPERCENTAGE                              |
| <b>III. Archived Metadata (not searchable)</b>                       |   |
| Product  | Metadata variable name (Array of QA usefulness histogram) |
| MOD13Q1  | QAPERCENTPOORQ250M16DAYNDVI                               |
| MOD13Q1  | QAPERCENTPOORQ250M16DAYEVI                                |
| MOD13A1  | QAPERCENTPOORQ500M16DAYNDVI                               |
| MOD13A1  | QAPERCENTPOORQ500M16DAYEVI                                |

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### 5.5.1 QA Metadata

There are 18 QA metadata objects in the MOD13 Q1/A1 product. These objects (Table 3) are defined by the following four attributes:

1. Object name: Uniquely identifies and describes the content of each object.
2. Object type: Describes the object as either an ECS mandatory, MODLAND mandatory, or VI product specific metadata object, and also as either text or numeric.
3. Description: Briefly describes the object, its valid value or format, and its sample value(s).
4. Level: Describes whether the object value is given for each SDS or not.

The ECS QA metadata are mandatory to all of the EOS products (the first 10 objects in Table 3), all of which are given for each SDS of the MOD13 Q1/A1 product. The first 6 objects are called QAFlags, including AutomaticQualityFlag, OperationalQualityFlag, ScienceQualityFlag, and their explanations. The AutomaticQualityFlag object indicates a result of an automatic QA performed during product generation and the following criteria are used to set its value:

1. Set to 'Passed' if QAPercentMissingData  $\leq$  5%
2. Set to 'Suspect' if QAPercentMissingData  $>$  5% or  $<$  50%
3. Set to 'Failed' if QAPercentMissingData  $>$  50%

where the 'QAPercentMissingData' is also an ECS QA metadata object and is described below. Explanation of the result of the AutomaticQualityFlag is given in the AutomaticQualityFlagExplanation metadata object.

The OperationalQualityFlag indicates the results of manual, non-science QA performed by processing facility personnel (MODAPS, LDOPE, or PI), i.e., if data are not corrupted in the

transfer, archival, and retrieval processes. The flag has the value of 'Not Being Investigated' if no non-science QA is performed. If the flag has the value other than 'Passed' or 'Not Being Investigated', explanation is given in the OperationalQualityFlagExplanation object.

The ScienceQualityFlag indicates the results of manual, science-QA performed by personnel at the VI Science Computing Facility (SCF). As for the OperationalQualityFlag, the flag has the value of 'Not Being Investigated' if science QA is not performed. Explanation is given in the ScienceQualityFlagExplanation object if the flag has the value other than 'Passed' or 'Not Being Investigated'.

The last 4 ECS QA metadata objects are called 'QAStats'. The QAStats indicate the percentages of pixels in the tile of which values are either interpolated (QAPercentInterpolatedData), missing (QAPercentMissingData), out of a valid range (QAPercentOutOfBoundData), or contaminated by cloud cover (QAPercentCloudCover).

There are 4 MODLAND mandatory QA metadata objects, all of which are designed to complement the ECS QA metadata objects. These indicate the percentages of pixels in the tile that are either good quality (QAPercentGoodQuality), unreliable quality (QAPercentOtherQuality), covered by cloud (QAPercentNotProducedCloud), or not produced due to bad quality other than cloud cover (QAPercentNotProducedOther). Different from the ECS QA metadata, only one set of values are given per tile.

The last 4 QA metadata objects in Table 3 are designed specifically for the MODIS VI product(s) (Product Specific Attributes, PSAs). Both NDVI500M16DAYQCLASSPERCENTAGE and EVI500M16DAYQCLASSPERCENTAGE objects indicate the percentages of pixels with good quality in the tile and, thus, should be equal to the QAPercentGoodQuality value unless there is a significant difference between the NDVI and EVI performance for the same tile.

The QAPERCENTPOORQ500M16DAYNDVI and QAPERCENTPOORQ500M16DAY-NDVI indicate, respectively, the percent frequency distributions of the NDVI and EVI quality. Their values are computed as sums of the NDVI and EVI usefulness indices (described in the QA Science Data Set section) and, thus, include 16 integer numbers. The 16 numbers are ordered in the descending qualities from left to right and a sum of 16 numbers is always equal to 100. The first numbers in the QAPERCENTPOORQ500M16DAYNDVI and QAPERCENTPOORQ500M16DAYNDVI objects are equal to the values given in the NDVI500M16DAYQCLASSPERCENTAGE and EVI500M16DAYQCLASSPERCENTAGE objects, respectively.

**Table 3:** List of the QA Metadata Objects for the MOD13 Q1/A1 products (XYZ refers to either 250 or 500 m).

| <b>Object Name</b>                 | <b>Object Type</b>             | <b>Description</b>  | <b>Level</b>      |
|------------------------------------|--------------------------------|---|-------------------|
| AutomaticQuality Flag              | ECS Mandatory QAFlags, Text    | Result of an automatic quality assessment performed during product generation. Valid value: 'Passed', 'Suspect', or 'Failed'  | Per-SDS, Per-Tile |
| AutomaticQuality FlagExplanation   | ECS Mandatory QAFlags, Text    | Explanation of the result of the automatic quality assessment. Valid value: Up to 255 characters. Sample value: 'Run was successful. But no land data found/processed'  | Per-SDS, Per-Tile |
| OperationalQuality Flag            | ECS Mandatory QAFlags, Text    | Result of a manual, non-science quality assessment performed by production facility personnel after production. Valid value: 'Passed', 'Suspect', 'Failed', 'Inferred Passed', 'Inferred Failed', 'Being Investigated', or 'Not Being Investigated' | Per-SDS, Per-Tile |
| OperationalQuality FlagExplanation | ECS Mandatory QAFlags, Text    | Explanation of the result of the manual, non-science quality assessment. Valid value: Up to 255 characters  | Per-SDS, Per-Tile |
| ScienceQuality Flag                | ECS Mandatory QAFlags, Text    | Result of a manual, science quality assessment performed by production facility personnel after production. Valid value: 'Passed', 'Suspect', 'Failed', 'Inferred Passed', 'Inferred Failed', 'Being Investigated', or 'Not Being Investigated'     | Per-SDS, Per-Tile |
| ScienceQuality FlagExplanation     | ECS Mandatory QAFlags, Text    | Explanation of the result of the manual, science quality assessment. Valid value: Up to 255 characters  | Per-SDS, Per-Tile |
| QAPercent InterpolatedData         | ECS Mandatory QAStats, Numeric | Percentage of interpolated data in the tile. Valid value: 0 100. Sample value: 12   | Per-SDS, Per-Tile |
| QAPercent MissingData              | ECS Mandatory QAStats, Numeric | Percentage of missing data in the tile. Valid value: 0 100. Sample value: 8   | Per-SDS, Per-Tile |
| QAPercent Out-OfBoundData          | ECS Mandatory QAStats, Numeric | Percentage of data in the tile of which values are out of a valid range. Valid value: 0 100. Sample value: 2  | Per-SDS, Per-Tile |

**Table 3:** (cont.)

| <b>Object Name</b>                        | <b>Object Type</b>                    | <b>Description</b>  | <b>Level</b>         |
|---|---------------------------------------|---|----------------------|
| QAPercent<br>CloudCover                   | ECS Mandatory<br>QASStats,<br>Numeric | Percentage of cloud covered data in the tile. Valid value: 0 100. Sample value: 15  | Per-SDS,<br>Per-Tile |
| QAPercent<br>GoodQuality                  | MODLAND<br>Mandatory,<br>Numeric      | Percentage of data produced with good quality in the tile. Valid value: 0 100. Sample value: 4  | Per-Tile             |
| QAPercent<br>OtherQuality                 | MODLAND<br>Mandatory,<br>Numeric      | Percentage of data produced with un- reliable quality in the tile. Valid value: 0 100. Sample value: 56   | Per-Tile             |
| QAPercent Not-<br>ProducedCloud           | MODLAND<br>Mandatory,<br>Numeric      | Percentage of data produced but contaminated with clouds in the tile. Valid value: 0 100. Sample value: 32  | Per-Tile             |
| QAPercent Not-<br>ProducedOther           | MODLAND<br>Mandatory,<br>Numeric      | Percentage of data not produced due to bad quality in the tile. Valid value:0 100. Sample value: 8  | Per-Tile             |
| NDVIXYZM16DAYVI<br>QCLASS PER-<br>CENTAGE | Product<br>Specific,<br>Numeric       | Percentage of NDVI data produced with good quality in the tile. Valid value: 0 100. Sample value: 4   | Per-Tile             |
| EVIXYZM16DAY<br>QCLASS PER-<br>CENTAGE    | VI Product<br>Specific,<br>Numeric    | Percentage of EVI data produced with good quality in the tile. Valid value: 0 100. Sample value: 4  | Per-Tile             |
| QAPERCENT<br>POORQ<br>XYZM16DAYNDVI       | VI Product<br>Specific,<br>Numeric    | Summary statistics (percent frequency distribution) of the NDVI usefulness index over the tile. Valid format: (N, N, N, N, N, N, N, N, N, N, N, N, N, N), where N = 0 100. Sample value: (4,0,0,0,44,6,18,15,5,0,0,0,0,0,8) | Per-Tile             |
| QAPERCENT<br>POORQ<br>XYZM16DAYEVI        | VI Product<br>Specific,<br>Numeric    | Summary statistics (percent frequency distribution) of the NDVI usefulness index over the tile. Valid format: (N, N, N, N, N, N, N, N, N, N, N, N, N, N), where N = 0-100. Sample value: (4,0,0,0,44,6,18,15,5,0,0,0,0,0,8) | Per-Tile             |



### 5.5.2 QA Science Data Sets

A summary Quality layer is included in each MOD13 file, the pixel reliability index. This layer contains simplified ranking of the data that describes overall pixel quality (Table 4).

**Table 4:** MOD13Q1/A1 Pixel Reliability.

| Rank Key | Summary QA    | Description                              |
|----------|---------------|--|
| -1       | Fill/No Data  | Not Processed                            |
| 0        | Good Data     | Use with confidence                      |
| 1        | Marginal data | Useful, but look at other QA information |
| 2        | Snow/Ice      | Target covered with snow/ice             |
| 3        | Cloudy        | Target not visible, covered with cloud   |

Because an SCF evaluation of the full MODIS VI record prior to C5 (C3 and C4) revealed insignificant differences between the Quality assignments for NDVI and EVI, starting C5 we decided to combine them into a single Quality layer pertinent to both indices, rather than one layer for each (Table 5). This reduces data volume as well as user confusion with multiple Quality layers

The QA bits/fields are designed to document conditions under which each pixel was acquired and/or processed.

**Table 5:** Descriptions of the VI Quality Assessment Science Data Sets (QA SDS).

| <b>Bits</b> | <b>Parameter Name</b>           | <b>Value</b>   | <b>Description</b>   |
|-------------|---------------------------------|--|--|
| 0-1         | VI Quality<br>(MODLAND QA Bits) | 00<br>01<br>10<br>11   | VI produced with good quality<br>VI produced, but check other QA<br>Pixel produced, but most probably cloudy<br>Pixel not produced due to other reasons than clouds  |
| 2-5         | VI Usefulness                   | 0000<br>0001<br>0010<br>0100<br>1000<br>1001<br>1010<br>1100<br>1101<br>1110<br>1111 | Highest quality<br>Lower quality<br>Decreasing quality<br>Decreasing quality<br>Decreasing quality<br>Decreasing quality<br>Decreasing quality<br>Lowest quality<br>Quality so low that it is not useful<br>L1B data faulty<br>Not useful for any other reason/not processed |
| 6-7         | Aerosol Quantity                | 00<br>01<br>10<br>11   | Climatology<br>Low<br>Intermediate<br>High   |
| 8           | Adjacent cloud detected         | 0<br>1   | No<br>Yes  |
| 9           | Atmosphere BRDF Correction      | 0<br>1   | No<br>Yes  |
| 10          | Mixed Clouds                    | 0<br>1   | No<br>Yes  |
| 11-13       | Land/Water Mask                 | 00<br>01<br>010<br>011<br>100<br>101<br>110<br>111                                   | Shallow Ocean<br>Land (Nothing else but land)<br>Ocean coastlines and lake shorelines<br>Shallow inland water<br>Ephemeral water<br>Deep inland water<br>Moderate or continental ocean<br>Deep ocean   |
| 14          | Possible snow/ice               | 0<br>1   | No<br>Yes  |
| 15          | Possible shadow                 | 0<br>1   | No<br>Yes  |

The first two bits are used for the MODLAND mandatory per-pixel QA bits that summarize the VI quality of the corresponding pixel locations. This field exist in all MODIS land products and is meant as a simple quality assessment metric. Percentages of sums of its four possible values (bit combinations) over a tile will give the MODLAND mandatory QA metadata object values (Table 6).

**Table 6:** Relationship between the MODLAND Mandatory per-pixel QA Bits and QA Metadata Objects.

| <b>VI Quality Bit Combination</b>                       | <b>Corresponding QA Metadata Object</b> |
|---|---|
| 00: VI produced, good quality                           | QAPercentGoodQuality                    |
| 01: VI produced, but check other QA                     | QAPercentOtherQuality                   |
| 10: Pixel produced, but most probably cloudy            | QAPercentNotProducedCloud               |
| 11: Pixel not produced due to other reasons than clouds | QAPercentNotProducedOther               |

The 2nd QA bit-field is called the VI usefulness index. The usefulness index is a higher resolution quality indicator than the MODLAND mandatory QA bits (16 levels) and its value for a pixel is determined from several conditions, including 1) aerosol quantity, 2) atmospheric correction conditions, 3) cloud cover, 4) shadow, and 5) sun-target-viewing geometry (Table 7). There is a specific score that is assigned to each condition and a sum of all the scores gives a usefulness index value for the pixel. An index value of 0000 corresponds to the highest quality possible, while the lowest quality is equal to a value of 1100 (i.e., 13 levels). The three last values are reserved for three specific conditions which are shown in Table 5. There are relationships between the VI usefulness index and the MODLAND mandatory QA bits. Pixels with the index value of 0000 and 1111 always have the MODLAND QA bit values of 00 and 11, respectively.

The next three QA bit-fields document atmospheric correction scenarios of each pixel. The bits 6-7 are used to indicate aerosol quantity, and the bits 8 and 9 indicate whether an adjacency correction and atmosphere-surface BRDF coupled correction, respectively, are applied or not. While these fields are listed in the product in practice no adjacency correction or BRDF correction is applied and hence they are always set to 0.

Bit 10 indicates a possible existence of mixed clouds. As the original spatial resolutions of the red and NIR bands are 250 m, these two bands were spatially aggregated to a 500 m resolution before the computations of VIs. The mixed cloud QA bit is flagged if any of the 250 m resolution pixels that were used for the aggregations were contaminated with cloud.

**Table 7:** VI Usefulness Index Scaling Method for the MOD13 Q1/A1 products.

| Parameter Name                  | Condition  | Score |
|---------------------------------|--|-------|
| Aerosol Quantity                | If aerosol climatology was used for atmospheric correction (00)<br>If aerosol quantity was high (11) 3 | 2     |
| Atmosphere Adjacency Correction | If no adjacency correction was performed (0)   | 1     |
| Atmosphere BRDF Correction      | If not atmosphere surface BRDF coupled correction was performed (0)                                    | 2     |
| Mixed Clouds                    | If there possibly existed mixed clouds (1)   | 3     |
| Shadow                          | If there possibly existed shadow (1)   | 2     |
| View zenith angle ( $q_v$ )     | If $q_v > 40^\circ$  | 1     |
| Sun zenith angle ( $q_s$ )      | If $q_s > 60^\circ$  | 1     |

Bits 11-13 are used for the land/water mask. The input land/water mask to the MOD13 Q1/A1 VI product has 7 land/water classes. The VIs are not computed for pixels over the ocean/inland water class. And finally Bits 14 and 15 indicate possible existences of snow/ice and shadow, respectively.

## 6 MOD13A2 (16-day 1-km) VI

Starting C6.0 this product is generated using 8-day precomposed surface reflectance data. Similar to the MOD13Q1/A1 the output of this algorithm also contains 12 SDS (Table 8).

### 6.1 Algorithm Description

The MOD13A2 VI algorithm, like MOD13Q1/A1, operates on a per-pixel basis and requires multiple observations (days or precomposed) to generate a single composited VI value to represent the composite period. The information in section 5.1 “MOD13Q1/A1 Algorithm Description” provides detail on how the algorithm operates.

### 6.2 Scientific Data Sets

The 1-km VI product has 12 Science Data Sets (Table 8):

**Table 8:** Product MOD13A2: 16-day 1-km VI.

| Science Data Set   | Units       | Data type | Valid Range   | Fill Value | Scale factor |
|--|-------------|-----------|---------------|------------|--------------|
| 1km 16 days NDVI   | NDVI        | int16     | -2000, 10000  | -3000      | 0.0001       |
| 1km 16 days EVI  | EVI         | int16     | -2000, 10000  | -3000      | 0.0001       |
| 1km 16 days VI Quality detailed QA                           | Bits        | uint16    | 0, 65534      | 65535      | NA           |
| 1km 16 days red reflectance (Band 1)                         | Reflectance | int16     | 0, 10000      | -1000      | 0.0001       |
| 1km 16 days NIR reflectance (Band 2)                         | Reflectance | int16     | 0, 10000      | -1000      | 0.0001       |
| 1km 16 days blue reflectance (Band 3)                        | Reflectance | int16     | 0, 10000      | -1000      | 0.0001       |
| 1km 16 days MIR reflectance (Band 7)                         | Reflectance | int16     | 0, 10000      | -1000      | 0.0001       |
| 1km 16 days view zenith angle                                | Degree      | int16     | 0, 18000      | -10000     | 0.01         |
| 1km 16 days sun zenith angle                                 | Degree      | int16     | 0, 18000      | -10000     | 0.01         |
| 1km 16 days relative azimuth angle                           | Degree      | int16     | -18000, 18000 | -4000      | 0.01         |
| 1km 16 days composite day of the                             | Day of year | int16     | 1, 366        | -1         | NA           |
| 1km 16 days pixel reliability ( <a href="#">summary QA</a> ) | Rank        | int8      | 0, 3          | -1         | NA           |

### 6.3 Product Specific Metadata

An example listing of the metadata fields used for QA evaluations of the MOD13A2 VI product is shown in Table 9.

### 6.4 Global and Local Metadata Attributes

As in all MODIS products, the global metadata is written to the output file during the generation process and could be used for searching the archive. A listing of relevant metadata is provided.

**Table 9:** Metadata fields for QA evaluation of MOD13A2.

|  |   |
|--|---|
| <b>I. Inventory Metadata fields for all VI products (searchable)</b> |   |
| QAPERCENTINTERPOLATEDDATA  |   |
| QAPERCENTMISSINGDATA   |   |
| QAPERCENTOUTOFBOUNDSDATA   |   |
| QAPERCENTCLOUDCOVER QAPERCENTGOODQUALITY                             |   |
| QAPERCENTOTHERQUALITY  |   |
| QAPERCENTNOTPRODUCEDCLOUD  |   |
| QAPERCENTNOTPRODUCEDOTHER  |   |
| <b>II. Product specific metadata (searchable)</b>                    |   |
| Product  | Specific Metadata variable name (Best Quality)            |
| MOD13A2  | NDVI1KM16DAYQCLASSPERCENTAGE                              |
| MOD13A2  | EVI1KM16DAYQCLASSPERCENTAGE                               |
| <b>III. Archived Metadata (not searchable)</b>                       |   |
| Product  | Metadata variable name (Array of QA usefulness histogram) |
| MOD13A2  | QAPERCENTPOORQ1KM16DAYNDVI                                |
| MOD13A2  | QAPERCENTPOORQ1KM16DAYEVI                                 |

### 6.5 Quality Assurance

Overall the QA metadata objects and QA SDS's of the MOD13A2 product are the same as those of the MOD13 Q1/A1 product. In this section, we only describe the specific MOD13A2 QA.

## 6.5.1 QA Metadata

As the spatial resolution of the MOD13A2 product differs from that of the MOD13A1 product, the 4 VI PSA object names differ correspondingly. Table 10 lists the correspondences between these object names.

**Table 10:** Correspondence of the VI PSA QA Metadata Object Names between MOD13A2 and MOD13A1 products.

| Object Name in the MOD13A2   | Object Name in the MOD13A1    |
|------------------------------|-------------------------------|
| NDVI1KM16DAYQCLASSPERCENTAGE | NDVI500M16DAYQCLASSPERCENTAGE |
| EVI1KM16DAYQCLASSPERCENTAGE  | EVI500M16DAYQCLASSPERCENTAGE  |
| QAPERCENTPOORQ1KM16DAYNDVI   | QAPERCENTPOORQ500M16DAYNDVI   |
| QAPERCENTPOORQ1KM16DAYEVI    | QAPERCENTPOORQ500M16DAYEVI    |

## 6.5.2 QA Science Data Sets

VI usefulness index computation is performed according the criteria showed in Table 11. VI Pixel reliability is described in 'Pixel reliability summary QA' SDS (Table 4), and de-tailed QA bit fields are described in 'VI Quality detailed QA' SDS (Table 5).

**Table 11:** VI Usefulness Index Scaling Method for the MOD13A2 Product.

| Parameter Name                     | Condition               | Score |
|------------------------------------|-------------------------|-------|
| Aerosol Quantity (bits 6-7)        | Low or average aerosols | 0     |
|                                    | Climatology aerosols    | 2     |
|                                    | High aerosols           | 3     |
| Atmosphere BRDF Correction (bit 9) | Performed               | 0     |
|                                    | Not performed           | 2     |
| Mixed Clouds (bit 10)              | No mixed clouds         | 0     |
|                                    | Possible mixed clouds   | 3     |
| Shadows (bit 15)                   | No shadows              | 0     |
|                                    | Possible shadows        | 2     |
| View zenith angle ( $q_v$ )        | If $q_v > 40^\circ$     | 1     |
| Sun zenith angle ( $q_s$ )         | If $q_s > 60^\circ$     | 1     |

## 7 MOD13A3 (monthly 1-km) VI

This product is generated using the 16-day 1-km MODIS VI output using a temporal compositing algorithm based on a weighted average scheme to create a calendar-month composite. The output file contains 11 SDS's (Table 12)

### 7.1 Algorithm Description

This algorithm operates (Fig. 5) on a per-pixel basis and ingest all 16-day VI products that overlap with the calendar month. Once all 16-day composites are collected, a weigh factor based on the degree of temporal overlap is applied to each input. In assigning the pixel QA, a worst case

scenario is used, whereby the pixel with the lowest quality determines the final pixel QA

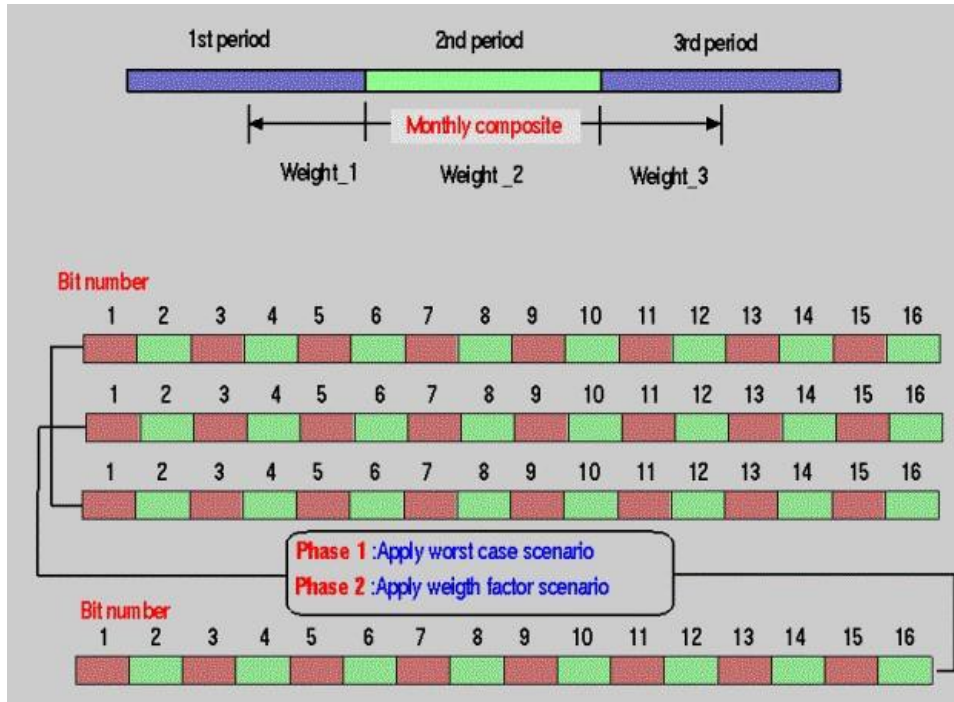


Figure 5: Monthly MODIS VI flow diagram.

## 7.2 Scientific Data Sets

The monthly 1-km MOD13A3 VI product has 11 SDS's, as listed in Table 12. Compared with MOD13A2, the only difference (besides the temporal aggregation) is the lack of the composite day of the year SDS, since this uses composited data.

Table 12: Product MOD13A3: monthly 1-km VI.

| Science Data Set                      | Units       | Data type | Valid Range   | Fill Value | Scale factor |
|---------------------------------------|-------------|-----------|---------------|------------|--------------|
| 1km monthly NDVI                      | NDVI        | int16     | -2000, 10000  | -3000      | 0.0001       |
| 1km monthly EVI                       | EVI         | int16     | -2000, 10000  | -3000      | 0.0001       |
| 1km monthly VI Quality                | Bits        | uint16    | 0, 65534      | 65535      | NA           |
| 1km monthly red reflectance (Band 1)  | Reflectance | int16     | 0, 10000      | -1000      | 0.0001       |
| 1km monthly NIR reflectance (Band 2)  | Reflectance | int16     | 0, 10000      | -1000      | 0.0001       |
| 1km monthly blue reflectance (Band 3) | Reflectance | int16     | 0, 10000      | -1000      | 0.0001       |
| 1km monthly MIR reflectance (Band 7)  | Reflectance | int16     | 0, 10000      | -1000      | 0.0001       |
| 1km monthly view zenith angle         | Degree      | int16     | 0, 18000      | -10000     | 0.01         |
| 1km monthly sun zenith angle          | Degree      | int16     | 0, 18000      | -10000     | 0.01         |
| 1km monthly relative azimuth angle    | Degree      | int16     | -18000, 18000 | -4000      | 0.0          |
| 1km monthly pixel reliability         | Rank        | int8      | 0, 3          | -1         | NA           |

## 7.3 Product Specific Metadata

A listing of the metadata fields used for QA evaluations of the MOD13A3 VI product is shown in Table 13.

**Table 13:** Metadata fields for QA evaluation of MOD13A3.

---

|  |   |
|--|---|
| <b>I. Inventory Metadata fields for all VI products (searchable)</b> |   |
| QAPERCENTINTERPOLATEDDATA  |   |
| QAPERCENTMISSINGDATA   |   |
| QAPERCENTOUTOFBOUNDSDATA   |   |
| QAPERCENTCLOUDCOVER QAPERCENTGOODQUALITY                             |   |
| QAPERCENTOTHERQUALITY  |   |
| QAPERCENTNOTPRODUCEDCLOUD  |   |
| QAPERCENTNOTPRODUCEDOTHER  |   |
| <b>II. Product specific metadata (searchable)</b>                    |   |
| Product  | Specific Metadata variable name (Best Quality)            |
| MOD13A3  | NDVI1KMMONTHQCLASSPERCENTAGE                              |
| MOD13A3  | EVI1KMMONTHQCLASSPERCENTAGE                               |
| <b>III. Archived Metadata (not searchable)</b>                       |   |
| Product  | Metadata variable name (Array of QA usefulness histogram) |
| MOD13A3  | QAPERCENTPOORQ1KMMONTHNDVI                                |
| MOD13A3  | QAPERCENTPOORQ1KMMONTHEVI                                 |

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## 7.4 Global and Local Metadata Attributes

MOD13A3 Metadata attributes are identical to the MOD13A2 (16-day 1-km VI), so please refer to the corresponding MOD13A2 description.

## 7.5 Quality Assurance

Each MOD13A3 output pixel has a ranked summary quality SDS (Table 4), and a single QA SDS for both NDVI and EVI quality assurance (Table 5).

### 7.5.1 QA Metadata

While similar to the MOD13Q1/A1 To the QA metadata of the MO13A3 product reflect the difference in temporal and spatial resolutions. Table 14 shows these QA metadata.

**Table 14:** Correspondence of the VI PSA QA Metadata Object Names between the MOD13A3 and MOD13A1 Products.

| Object Name in the MOD13A2   | Object Name in the MOD13A1    |
|------------------------------|-------------------------------|
| NDVI1KMMONTHQCLASSPERCENTAGE | NDVI500M16DAYQCLASSPERCENTAGE |
| EVI1KMMONTHQCLASSPERCENTAGE  | EVI500M16DAYQCLASSPERCENTAGE  |
| QAPERCENTPOORQ1KMMONTHNDVI   | QAPERCENTPOORQ500M16DAYNDVI   |
| QAPERCENTPOORQ1KMMONTHEVI    | QAPERCENTPOORQ500M16DAYEVI    |

### 7.5.2 QA Science Data Sets

MOD13A3 QA SDS are the same as described in all MOD13 products (Table 5)

## 8 MOD13C1 CMG (16-day 0.05-deg) VI

The VI CMG series is a seamless global 3600x7200 pixel data product with 13 SDS's, at approximately 100 MB per composite period (using internal compression). This is a higher quality climate product useful for modelling and spatial time series analyses of Earth surface processes. It incorporates a QA filter scheme that removes lower quality and cloud-contaminated pixels in aggregating and reprojecting the input 1-km pixels into the 0.05-deg geographic (lat/lon) CMG

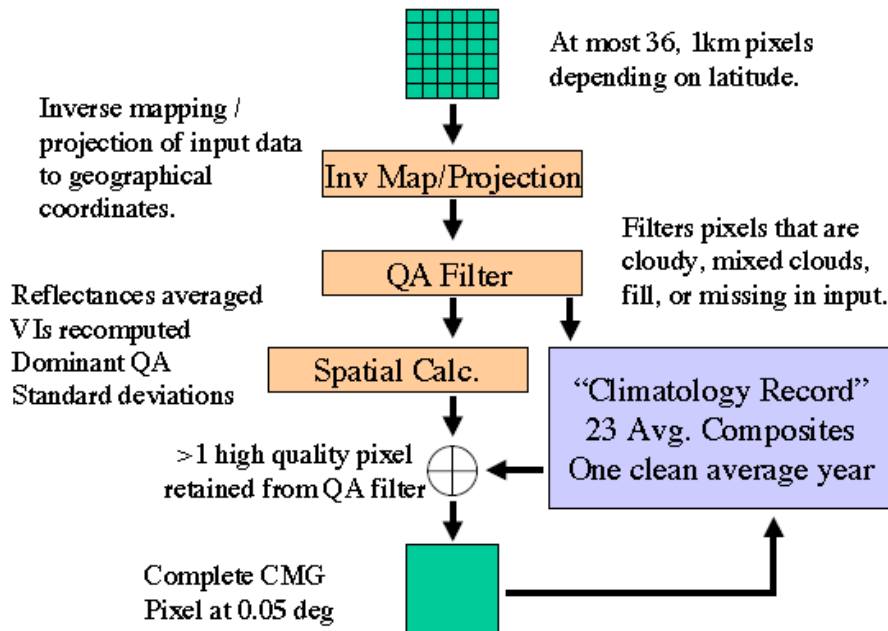


product. It also uses a spatial gap filling scheme, based on historic long term average data records, to produce a continuous, gap free and reliable product for ready ingestion by biogeochemical, carbon, and climate models.

### 8.1 Algorithm Description

Global MOD13C1 data are cloud-free spatial composites of the gridded 16-day 1-km MOD13A2, and are provided as a level-3 product projected on a 0.05 degree (5600-meter) geographic Climate Modeling Grid (CMG).

#### Processing Flow



**Figure 6:** MOD13C1 Algorithm and data processing flow

The algorithm eliminates all clouds in the output product. To do so, it employs three different averaging schemes. All input 1-km pixels (nominally 6x6) will either be all clear, all cloudy, or mixed. These averaging schemes work as follows: If all input pixels are clear, they will be all averaged to produce one output value; If all input pixels are cloudy, the pixel will be computed from the historical database; and, If the input pixels are mixed, only the clear pixels are averaged to produce one output value.

The MOD13C1 uses the entire MODIS data record to calculate a high fidelity VI fill value in case input data is missing or deemed cloudy. The fill value is calculated from the average of good data from all previous years CMGs of that composite period. It is mainly used for replacing completely cloudy data, but is powerful enough to reliably fill in a whole missing tiles. This database is regularly updated to ingest new data. And while this works fine for most pixels, it does have serious disadvantages in case of disturbance as the pixel will be replaced with data prior to the disturbance.

Certain highly dynamic areas may show discrepancies when filled from the long term database. However, for pixels missing due to cloud contamination, the fill strategy performs well on average. While, the algorithm gap fills the two VI layers with data, the other layers will contain their respective fill values, except data layer 11 (#1 km pix used), which is set to 0, i.e., no good input data.

## 8.2 Scientific Data Sets

The 16-day 0.05-deg MOD13C1 VI product has 13 SDSs, listed in Table 15

**Table 15:** List of SDS's from 16-day 0.05-deg MOD13C1 VI.

| Science Data Set                           | Units       | Data type | Valid Range  | Fill Value | Scale factor |
|--|-------------|-----------|--------------|------------|--------------|
| CMG 0.05 Deg 16 days NDVI                  | NDVI        | int16     | -2000, 10000 | -3000      | 0.0001       |
| CMG 0.05 Deg 16 days EVI                   | EVI         | int16     | -2000, 10000 | -3000      | 0.0001       |
| CMG 0.05 Deg 16 days VI Quality            | Bits        | uint16    | 0, 65534     | 65535      | NA           |
| CMG 0.05 Deg 16 days red reflectance       | Reflectance | int16     | 0, 10000     | -1000      | 0.0001       |
| CMG 0.05 Deg 16 days NIR reflectance       | Reflectance | int16     | 0, 10000     | -1000      | 0.0001       |
| CMG 0.05 Deg 16 days blue reflectance      | Reflectance | int16     | 0, 10000     | -1000      | 0.0001       |
| CMG 0.05 Deg 16 days MIR reflectance       | Reflectance | int16     | 0, 10000     | -1000      | 0.0001       |
| CMG 0.05 Deg 16 days Avg sun zenith angle  | Degree      | int16     | 0, 18000     | -10000     | 0.01         |
| CMG 0.05 Deg 16 days NDVI std dev          | NDVI        | int16     | 0, 10000     | -3000      | 0.0001       |
| CMG 0.05 Deg 16 days EVI std dev           | EVI         | int16     | 0, 10000     | -3000      | 0.0001       |
| CMG 0.05 Deg 16 days #1km pix used         | Pixels      | uint8     | 0, 36        | 255        | 1            |
| CMG 0.05 Deg 16 days #1km pix +/- 30deg VZ | Pixels      | uint8     | 0, 36        | 255        | 1            |
| CMG 0.05 Deg 16 days pixel reliability     | Rank        | int8      | 0, 4         | -1         | 1            |

## 8.3 Quality Assurance

Like all other MODIS VI products, the QA metadata objects summarize global level quality with several single words and numeric values, and thus are useful for data archiving, indexing, searching, and ordering.

Each MOD13C1 output pixel has a ranked summary quality SDS (Table 4), and a single QA SDS for both NDVI and EVI quality assurance (Table 5).

### 8.3.1 QA Metadata

A listing of the QA metadata fields used in the MOD13C1 and MOD13C2 VI product is shown in Table 16.

**Table 16:** Metadata fields for QA evaluation of MOD13C1 and MOD13C2 products.

|  |   |
|--|---|
| <b>I. Inventory Metadata fields for all VI products (searchable)</b> |   |
| QAPERCENTINTERPOLATEDDATA  |   |
| QAPERCENTMISSINGDATA   |   |
| QAPERCENTOUTOFBOUNDSDATA   |   |
| QAPERCENTCLOUDCOVER QAPERCENTGOODQUALITY                             |   |
| QAPERCENTOTHERQUALITY  |   |
| QAPERCENTNOTPRODUCEDCLOUD  |   |
| QAPERCENTNOTPRODUCEDOTHER  |   |
| <b>II. Product specific metadata (searchable)</b>                    |   |
| Product  | Specific Metadata variable name (Best Quality)            |
| MOD13C1  | EVICMG16DAYQCLASSPERCENTAGE                               |
| MOD13C1  | NDVICMG16DAYQCLASSPERCENTAGE                              |
| MOD13C2  | EVICMGMONTHQCLASSPERCENTAGE                               |
| MOD13C2  | NDVICMGMONTHQCLASSPERCENTAGE                              |
| <b>III. Archived Metadata (not searchable)</b>                       |   |
| Product  | Metadata variable name (Array of QA usefulness histogram) |
| MOD13C1  | QAPERCENTPOORQCMG16DAYEVI                                 |
| MOD13C1  | QAPERCENTPOORQCMG16DAYNDVI                                |
| MOD13C2  | QAPERCENTPOORQCMGMONTHEVI                                 |
| MOD13C2  | QAPERCENTPOORQCMGMONTHNDVI                                |

### 8.3.2 QA Science Data Sets

Like in all VI products, the VI Usefulness rank (bits 2-5 in the QA SDS) computation is performed for MOD13C1 according to the criteria showed in Table 11. Detailed QA bit 0-13 are kept the same as for MOD13A2 (Table 5); bits 14-15 are replaced as stated in Table 17.

**Table 17:** Bits 14-15 of the MOD13C1 VI Quality Assessment SDS.

| Bits                     | Parameter Name | Value | Description  |
|--------------------------|----------------|-------|--|
| 14-15 Geospatial quality |                | 00    | ≤25% of the finer 1-km resolution contributed to this CMG pixel          |
|                          |                | 01    | >25% and ≤50% of the finer 1-km resolution contributed to this CMG pixel |
|                          |                | 10    | >50% and ≤75% of the finer 1-km resolution contributed to this CMG pixel |
|                          |                | 11    | >75% of the finer 1-km resolution contributed to this CMG pixel          |

VI Pixel reliability has an additional rank compared with other VI product, which is used to describe if pixels were generated using the historical filling criteria (Table 18).

**Table 18:** MOD13C1 Pixel Reliability.

| Rank Key | Summary QA    | Description                              |
|----------|---------------|--|
| -1       | Fill/No Data  | Not Processed                            |
| 0        | Good Data     | Use with confidence                      |
| 1        | Marginal data | Useful, but look at other QA information |
| 2        | Snow/Ice      | Target covered with snow/ice             |
| 3        | Cloudy        | Target not visible, covered with cloud   |
| 4        | Estimated     | From MODIS historic time series          |

## 9 MOD13C2 CMG (monthly 0.05-deg) VI

Global MOD13C2 data are cloud-free temporal composites of the 16-day MOD13C1 product. MOD13C2 is a level-3 product projected on a 0.05 degree (5600-meter) geographic (lat/lon) Climate Modeling Grid (CMG). Cloud-free global coverage is achieved by replacing clouds with the historical MODIS time series climatology record in the input data from the 16-day MOD13C1 product.

### 9.1 Algorithm Description

The Algorithm uses a simple temporal averaging scheme similar to the Monthly 1km MOD13A3 product algorithm. Each 16-day period is adjusted by its weight computed from the overlap with the month in consideration.

### 9.2 Scientific Data Sets

MOD13C2 VI product has 13 SDSs, listed in Table 19.

**Table 19:** List of SDS's from monthly 0.05-deg MOD13C2 VI.

| Science Data Set                          | Units       | Data type | Valid Range  | Fill Value | Scale factor |
|---|-------------|-----------|--------------|------------|--------------|
| CMG 0.05 Deg Monthly NDVI                 | NDVI        | int16     | -2000, 10000 | -3000      | 0.0001       |
| CMG 0.05 Deg Monthly EVI                  | EVI         | int16     | -2000, 10000 | -3000      | 0.0001       |
| CMG 0.05 Deg Monthly VI Quality           | Bits        | uint16    | 0, 65534     | 65535      | NA           |
| CMG 0.05 Deg Monthly red reflectance      | Reflectance | int16     | 0, 10000     | -1000      | 0.0001       |
| CMG 0.05 Deg Monthly NIR reflectance      | Reflectance | int16     | 0, 10000     | -1000      | 0.0001       |
| CMG 0.05 Deg Monthly blue reflectance     | Reflectance | int16     | 0, 10000     | -1000      | 0.0001       |
| CMG 0.05 Deg Monthly MIR reflectance      | Reflectance | int16     | 0, 10000     | -1000      | 0.0001       |
| CMG 0.05 Deg Monthly Avg sun zenith angle | Degree      | int16     | 0, 18000     | -10000     | 0.01         |
| CMG 0.05 Deg Monthly NDVI std dev         | NDVI        | int16     | 0, 10000     | -3000      | 0.0001       |
| CMG 0.05 Deg Monthly EVI std dev          | EVI         | int16     | 0, 10000     | -3000      | 0.0001       |
| CMG 0.05 Deg Monthly #1km pix used        | Pixels      | uint8     | 0, 36        | 255        | 1            |
| CMG 0.05 Deg Monthly #1km pix +- 30deg VZ | Pixels      | uint8     | 0, 36        | 255        | 1            |
| CMG 0.05 Deg Monthly pixel reliability    | Rank        | int8      | 0, 4         | -1         | 1            |

### 9.3 Quality Assurance

Like in MOD13C1, QA metadata objects summarize the global level quality with several single words and numeric numbers, and thus are useful for data indexing, searching, ordering and screening.

QA SDSs document product quality on a pixel-by-pixel basis and thus are useful for data analyses and application uses of the data. Each MOD13C2 output pixel has a rank summary quality SDS (Table 4), and a single QA SDS for both NDVI and EVI quality assurance (Table 5)

### 9.3.1 QA Metadata

A listing of the metadata fields used for QA evaluations of the MOD13C2 VI product is shown in Table 16.

### 9.3.2 QA Science Data Sets

QA SDS for MOD13C2 are the same as for MOD13C1 (See Section 8.3.2 for details).

## 10 Related Web Sites

- MODIS VI Theoretical Basis document: [https://vip.arizona.edu/MODIS\\_ATBD.php](https://vip.arizona.edu/MODIS_ATBD.php)
- MODIS VI User's Guide: [https://vip.arizona.edu/MODIS\\_UsersGuide.php](https://vip.arizona.edu/MODIS_UsersGuide.php)
- MOD13 VI C6 Changes Document: [http://landweb.nascom.nasa.gov/QA\\_WWW/forPage/MODIS\\_Land\\_C6\\_Planning.doc](http://landweb.nascom.nasa.gov/QA_WWW/forPage/MODIS_Land_C6_Planning.doc)
- Data Access Sites and Tools: [https://lpdaac.usgs.gov/data\\_access](https://lpdaac.usgs.gov/data_access)
- MODIS Reprojection Tool: Utilities to convert from Sinusoidal projection, sub-setting, band extracting and format change from HDF-EOS (and more): [https://lpdaac.usgs.gov/tools/modis\\_reprojection\\_tool](https://lpdaac.usgs.gov/tools/modis_reprojection_tool)
- MODIS Land Discipline: <https://modis-land.gsfc.nasa.gov>
- MODIS Project: <http://modis.gsfc.nasa.gov/>
- MODIS Products: [http://lpdaac.usgs.gov/dataset\\_discovery/modis/modis\\_products\\_table](http://lpdaac.usgs.gov/dataset_discovery/modis/modis_products_table)
- MODIS Land Data Discipline Team: <https://landweb.nascom.nasa.gov/>
- HDF: <http://www.hdfgroup.org/>
- HDF-EOS: <http://www.hdfgroup.org/hdfEOS.html>

## 11 FAQ

### Frequently Asked Questions about MODIS VI Products

**Q.** *What is the difference between NDVI and EVI?*

**A.** The Enhanced Vegetation Index differs from NDVI by attempting to correct for atmospheric and background effects. EVI appears to be superior in discriminating subtle differences in areas of high vegetation density, situations in which NDVI tends to saturate. NDVI has been used for several decades, which is advantageous for studying historical changes. Please refer to our page on vegetation indices for more information.

**Q.** *What spatial resolutions are available?*

**A.** 250 m (MOD13Q1), 500 m (MOD13A1), 1 km (MOD13A2), and 0.05 deg (MOD13C1 and MOD13C2).

**Q.** *What temporal resolutions are available?*

**A.** Base products are 16-day (MOD13Q1, MOD13A1, MOD13A2 and MOD13C1). Monthly products (MOD13A3 and MOD13C2) are generated from their 16-day counterparts.

**Q.** *How often are images acquired?*

**A.** MODIS images are collected daily, however the vegetation products are composites of the best pixels from 16 consecutive days. These composites are produced on 16-day cycles. Monthly products are generated by using a weighted-average scheme on corresponding 16-day products.

**Q.** *Where can I order the data from?*

**A.** There are several sources of data, each providing different ways to access the data pool. Please see section "Related Web Sites" (Sec. 10), bullet "Data Access Tools" for detailed information.

**Q.** *How can I order MODIS data from VIPLab?*

**A.** The VIPLab does not keep complete archives of MODIS data due to space limitations. MODIS data may be ordered through the sites listed before.

**Q.** *How much does MODIS data cost?*

**A.** MODIS data are free.

**Q.** *What is a "tile"?*

**A.** Global data from MODIS are organized as units that are 10deg by 10deg at the Equator, but vary according to the latitude. These units are called tiles. The tile coordinate system starts at (0,0) in the UL corner and proceeds right (horizontal) and downward (vertical). The tile in the bottom right corner is (35, 17). See <http://modis-land.gsfc.nasa>.

gov/MODLAND\_grid.htm for more information.

**Q.** *How can I determine the tile and pixel coordinates for a specific site with known geographic coordinates?*

**A.** You can use the MODIS Tile Calculator (<http://landweb.nascom.nasa.gov/cgi-bin/developer/tilemap.cgi>).

**Q.** *What is the file format of MODIS data?*

**A.** HDF-EOS. Please see Section “Related Web Sites” for links to further details.

**Q.** *How can I read HDF/HDF-EOS data?*

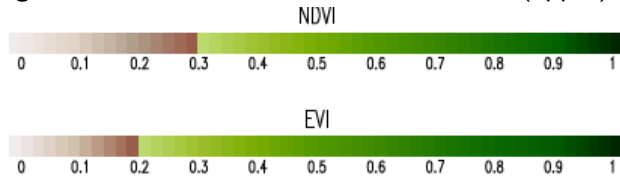
**A.** Some image processing programs, such as ENVI and PCI Geomatics, can read the format directly. If needed, free MODIS tools for converting the data format are available at [https://lpdaac.usgs.gov/lpdaac/tools/modis\\_reprojection\\_tool](https://lpdaac.usgs.gov/lpdaac/tools/modis_reprojection_tool)

**Q.** *My software does not recognize the MODIS map projection. What is the projection and how can I change it?*

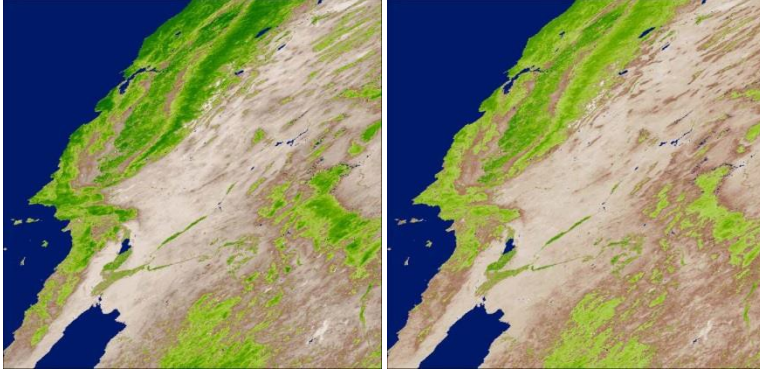
**A.** The projection is called Sinusoidal (SIN). Use the MODIS Tools, available at [https://lpdaac.usgs.gov/lpdaac/tools/modis\\_reprojection\\_tool](https://lpdaac.usgs.gov/lpdaac/tools/modis_reprojection_tool) to reproject your data to a more common projection.

## 12 Sample images

**Figure 7:** MODIS VI Color Palettes for NDVI (upper) and EVI (lower) products as used in this

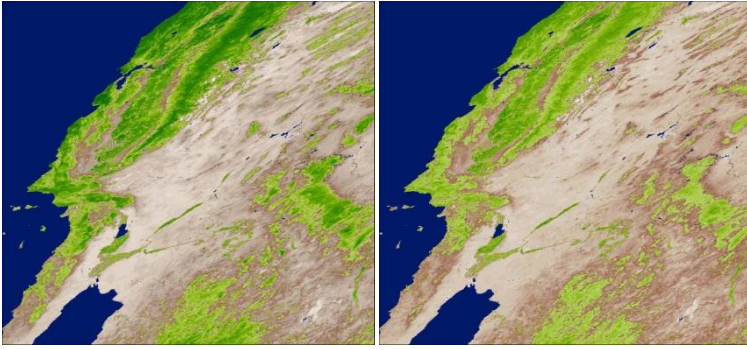


document.

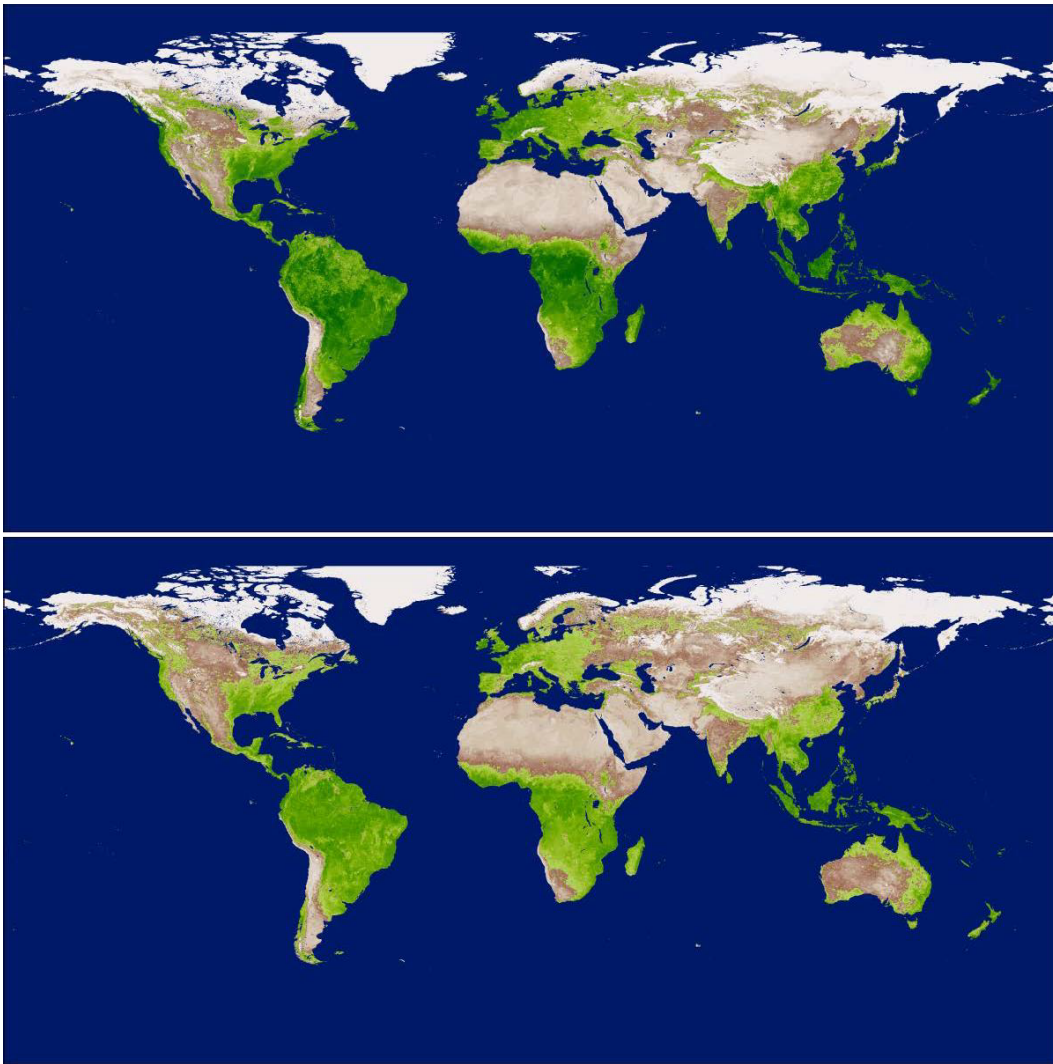


**Figure 8:** Colored 16-day 250-m MOD13Q1 NDVI and EVI images (left and right respectively). Data from the western United States (tile h08v05), corresponding to the period from June 25 to July 10, 2000.





**Figure 9:** Colored 16-day 500-m MOD13A1 NDVI and EVI images (left and right respectively). Data from the western United States (tile h08v05), corresponding to the period from June 25 to July 10, 2000.



**Figure 10:** 0.05-deg 16-day MOD13C1 NDVI (upper) and EVI (lower) sample images. The VI values have been pseudo-colored to represent biomass health across the globe using data acquired during April 6-22, 2000.