

## **MODIS Global Land Cover Dynamics (MOD12Q2) User Guide**

The purpose of this document is to provide guidance to users of MOD12Q2 regarding the map layers included in this product, and regarding the procedure used to generate the MOD12Q2 product in MODIS collection 4 processing. This document is not meant to be exhaustive, but is intended to provide users with information regarding how the data is produced and how it is formatted.

### **1. Overview of the MOD12Q2 product.**

The MODIS Global Land Cover Dynamics product (MOD12Q2) provides estimates of the timing of vegetation phenology at global scales. As a supplement to this information, the product also includes information related to the range and summation of the enhanced vegetation index computed from MODIS surface reflectance data at each pixel. The product is produced twice per year globally at 1 km<sup>2</sup> spatial resolution, thereby allowing for hemispheric differences in the timing of growing seasons. Each product period includes data that spans a twelve month period and allows for two growth cycles.

### **2. Brief Description of Algorithm**

This section provides a brief description of the MOD12Q2 algorithm. Key elements of this description include: (1) the MODIS data used, and (2) the techniques used to create the SDS fields.

#### **2.1 Input data**

To estimate global phenology for any 12-month period the MOD12Q2 algorithm uses 24 months of data (i.e., the 12 months of interest, bracketed by six months on either side). Specifically:

1. The primary input is the enhanced vegetation index (EVI) computed from the MODIS BRDF/albedo product (MOD43B4; Schaaf et al., 2002). The MOD43B4 product provides nadir BRDF- (bi-directional reflectance distribution function) adjusted reflectance (NBAR) for MODIS bands 1-7. NBAR values are computed for the mean solar zenith angle of a 16-day period using daily multi-angle surface reflectances at a spatial resolution of 1 km. EVI values are computed using the formula provided by Huete et al. (2002), but using NBAR data in place of the MOD09 surface reflectance product.
2. The snow and ice flag is provided by the quality assurance (QA) field in the MODIS BRDF/albedo product. Using this flag, data points associated with snow-covered surfaces can be removed from the input time series. This is important because the presence of snow introduces a large source of temporal variation in EVI that is not associated with vegetation phenology.

3. Land surface temperature (LST) is obtained from the MODIS MOD11A2 LST product. LST data provide land surface skin temperatures for 8 day time periods by averaging daily LST measurements at a spatial resolution of 1 km. These data are used to screen for consecutive 16-day periods where the temperature is too low to support vegetation growth.

## 2.2. Phenology Detection Algorithm

Estimation of vegetation phenological parameters included in the MOD12Q2 product involves nine main steps as originally described in Zhang et al. (2003).

1. Enhanced vegetation index (EVI) values are computed from 16-day NBAR data.
2. Spurious values in the time series of NBAR EVI data at any pixel are eliminated by outlier detection and smoothing.
3. The background NBAR EVI value for each pixel is determined by combining the EVI trajectory, land surface temperature (LST) data, and snow flags. The background EVI at each pixel in a given 12-month period is defined as the minimum and approximately stable value for a pixel without flood or snow effects.
4. Periods with sustained EVI increase and decrease in a pixel are determined using moving windows composed of five 16-day NBAR EVI values.
5. Temporal variation in EVI data are modeled using piecewise sigmoidal models. Each growth cycle is modeled using two sigmoidal functions: one for the growth phase, one for the senescence phase. Specifically, temporal variation in EVI for a single growth or senescence cycle can be modeled using a function of the form:

$$y(t) = \frac{c}{1 + e^{a+bt}} + d \quad (1)$$

where  $t$  is time in days,  $y(t)$  is the EVI value at time  $t$ ,  $a$  and  $b$  are free parameters that are fitted using a non-linear least squares approach,  $c+d$  is the maximum EVI value, and  $d$  is the initial background EVI value.

6. To identify phenological transition dates, the rate of change in the curvature of the fitted logistic models is used (Figure 1). Specifically, transition dates correspond to the times at which the rate of change in curvature in the EVI data exhibits local minima or maximums. These dates indicate when the annual cycle transitions from one approximately linear stage to another. More formally, at any time  $t$  the curvature ( $K$ ) for the sigmoidal function given above can be computed using:

$$K = \frac{d\alpha}{ds} = - \frac{b^2 cz(1-z)(1+z)^3}{\left[ (1+z)^4 + (bcz)^2 \right]} \quad (2)$$

where  $z = e^{a+bt}$ ,  $\alpha$  is the angle (in radians) of the unit tangent vector at time  $t$  along a

differentiable curve, and  $s$  is the unit length of the curve. The rate of change of curvature ( $K'$ ) is then:

$$K' = b^3 cz \left\{ \frac{3z(1-z)(1+z)^3 [2(1+z)^3 + b^2 c^2 z]}{[(1+z)^4 + (bcz)^2]} \cdot \frac{z^2(1+2z-5z^2)}{[(1+z)^4 + (bcz)^2]} \right\} \quad (3)$$

During the growth period, when vegetation transitions from a dormant state to maximum leaf area, three extreme points in a EVI curve are estimated from Equation (3). These points correspond to the onset of leaf growth, the onset of maximum leaf area, and the inflection point between these two events (Figure 1). Transition dates indicating the onset of senescence and dormancy are estimated in a similar fashion.

7. For each growth cycle, four phenological transition dates are recorded based on the approach described above. The corresponding phenological transition dates are defined as the onset of greenness increase (A'), the onset of greenness maximum (B'), the onset of greenness decrease (C'), and the onset of greenness minimum (D') (Figure 1).

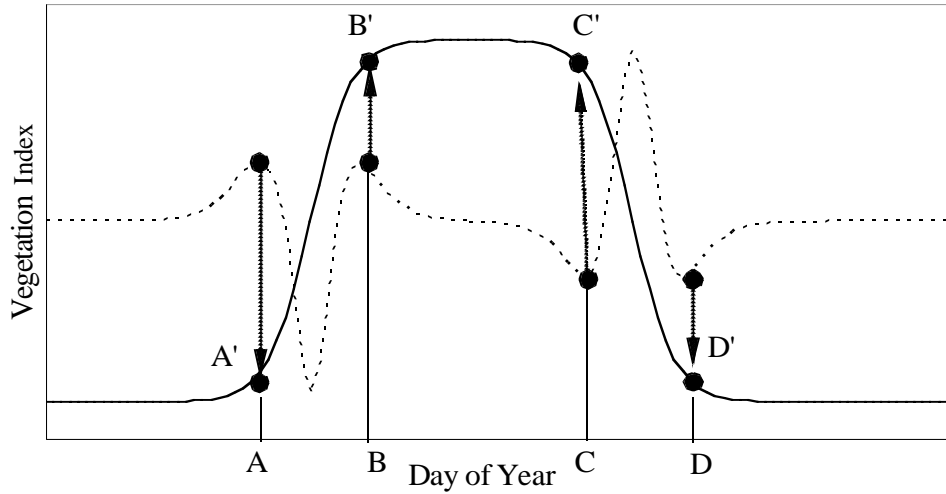


Figure 1. Schematic showing how phenological transition dates are defined using minimum and maximum values in the rate of change in curvature. The solid line is an idealized time series of NBAR EVI, and the dashed line is the curvature change rate derived from the EVI time series. The circles indicate phenological transition dates which are A: onset of greenness increase; B: onset of greenness maximum; C: onset of greenness decrease; and D: onset of greenness minimum.

8. Values for (1) NBAR EVI at the onset of greenness increase, (2) maximum NBAR EVI, and (3) NBAR EVI area during the growing season (the integral of daily EVI between A and D) are calculated from the estimated sigmoidal models.

9. Post-processing is applied to reduce the number of localized spurious values using a 3 by 3 moving window.

### 3. Limitations to MOD12Q2 Phenology Retrievals

Note that a variety of conditions limit the ability of the algorithm to provide globally complete estimates of all of the SDS fields included in the MOD12Q2 product. Specifically, phenology is not identified if there are no satellite observations for more than two consecutive 16-day periods during the vegetation growing season. This condition is referred to as "not processed, cloud" in the Dynamics\_QC field. If the EVI values are uniformly high within a given 12-month period (such as in some evergreen forests), no phenology is estimated. Similarly, if EVI values in an annual period are all less than 0.05 (such as in some deserts) no phenology is estimated.

### 4. Description of the Data Format Used to Record Phenological Metrics.

The MOD12Q2 product includes sixteen Science Data Sets (SDS) for each pixel. The long\_names and formats of these SDSs are:

DataField	Name	Format
DataField_1	Onset_Greenness_Increase	UINT16
DataField_2	Onset_Greenness_Maximum	UINT16
DataField_3	Onset_Greenness_Decrease	UINT16
DataField_4	Onset_Greenness_Minimum	UINT16
DataField_5	NBAR_EVI_Onset_Greenness_Minimum	UINT16
DataField_6	NBAR_EVI_Onset_Greenness_Maximum	UINT16
DataField_7	NBAR_EVI_Area	UINT16
DataField_8	Dynamics_QC	UINT16

Each DataField includes two 16-bit (UINT16) values, one for each of two possible growth cycles in the 12-month period included.

### 5. Accounting for Geographic Variability in the Timing of Growing Seasons

Phenological cycles within a specified 12-month period are recorded using the SDS fields identified above. Note that the timing of growing seasons varies geographically and that vegetation growth can have one or more cycles during any 12 month period. The algorithm allows for a maximum of two detectable growth cycles in any given period. To record this, the data is formatted into two "layers", which correspond to the first and second cycle at a pixel occurring in the period of interest. Further, depending on the location and period of interest any given pixel may possess an incomplete cycle (truncated at the beginning or end). The combination of these factors adds substantial complexity to the manner in which these data are

stored. Different scenarios in this regard are presented in Figure 2, below, and are discussed in the text that follows.

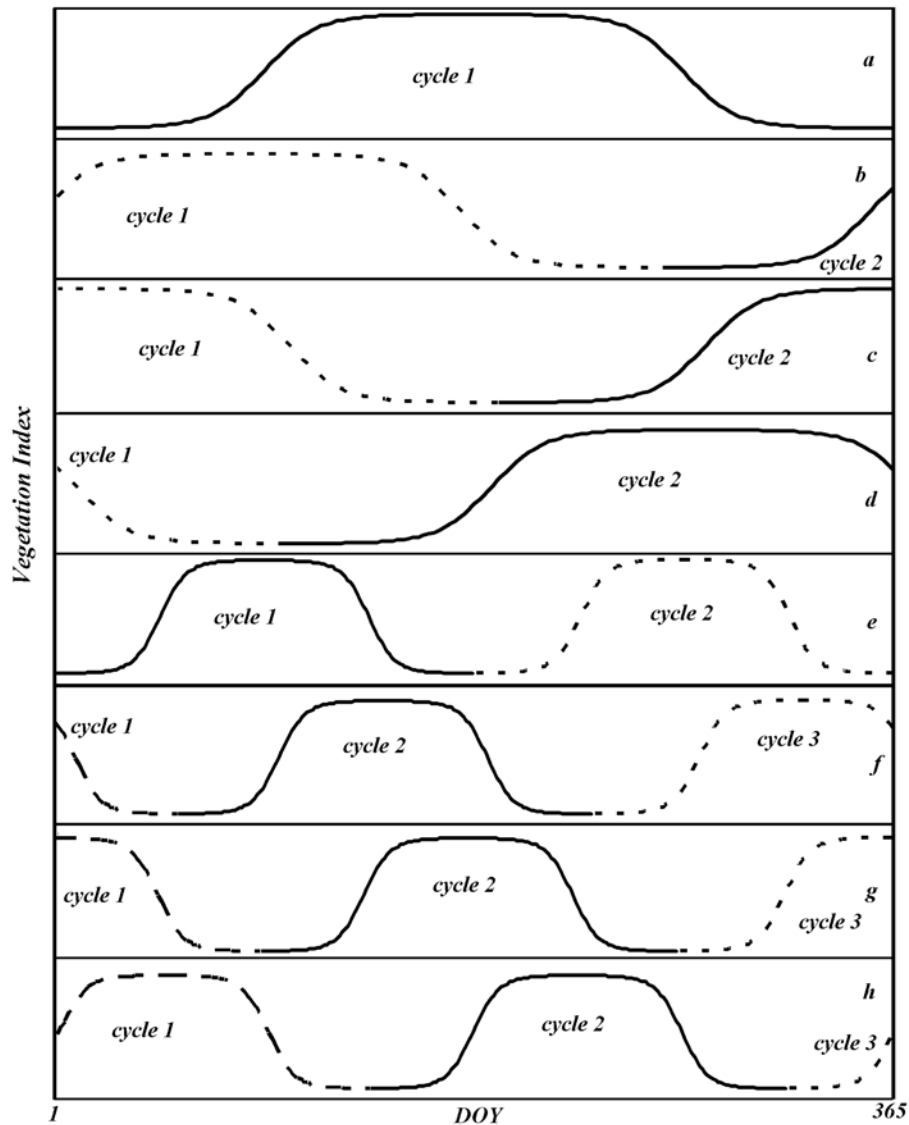


Figure 2. Characteristic forms of vegetation growth cycles within a 12-month period.

The MOD12Q2 algorithm is designed to allow for four distinct scenarios in regards to the timing of vegetation phenology:

1. Case a: A single, complete growth cycle centered at the mid-point of the 12-month period. In this case the phenological metrics are recorded in the first layer for each SDS, and fill values are used for the second layer.
2. Cases b, c, and d illustrate examples in which two partial cycles are present in the 12 month period of interest. In these cases, the phenological parameters are recorded when they appear,

fill values are used for the phenological events that occur outside of the 12-month period, and EVI area for both cycles is set equal to the fill value (32767).

3. Case e, two complete growth cycles are present and transition dates for each are provided in the two layers provided.
4. Cases f, g, h illustrate cases where there are two incomplete cycles and one complete cycle. In this situation, only the characteristics in the first two cycles are recorded. All parameters in the third cycle are recorded in the next period.

Note that the preceding and/or subsequent 12-month product period (produced six months later), will capture the complete cycle for those cases presented above with incomplete cycles (cases b, c, d, f, g, h).

## 6. Contact Information:

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## 7. Literature Cited

Huete A, Didan K, Miura T, Rodriguez EP, Gao X, Ferreira LG 2002. Overview of the radiometric and biophysical performance of the MODIS vegetation indices, *Remote Sensing of Environment*. 83 (1-2): 195-213.

Schaaf CB, Gao F, Strahler AH, Lucht W, Li XW, Tsang T, Strugnell NC, Zhang XY, Jin YF, Muller JP, Lewis P, Barnsley M, Hobson P, Disney M, Roberts G, Dunderdale M, Doll C, d'Entremont RP, Hu BX, Liang SL, Privette JL, Roy D. 2002 First operational BRDF, albedo nadir reflectance products from MODIS. *Remote Sensing of Environment*, 83 (1-2): 135-148.

Zhang XY, Friedl MA, Schaaf CB, Strahler AH, Hodges JCF, Gao F, Reed BC, Huete A 2003. Monitoring vegetation phenology using MODIS. *Remote Sensing of Environment*. 84 (3): 471-475