User Guide for the MODIS Land Cover Dynamics Product (MCD12Q2)
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1. Introduction

Vegetation phenological events such as the start of spring, onset of dormancy, and growing season length influence ecosystem processes such as carbon and water cycles and have implications for biosphere-atmosphere exchanges and the climate system. Phenology-climate interactions are also diagnostic of the integrated effects of climate change on ecosystems. Ground observations of phenological transitions in agriculture and culturally significant seasonal events have been collected for centuries (e.g., viticulture and cherry blossom observations), but the spatial scale of such observations, coupled with definitional differences across datasets has hampered their use in large-scale investigations of climate-phenology interactions.

Recently, remotely sensed images have emerged as a critical source of consistent, large-scale, and spatially-exhaustive data which may be used to track vegetation phenology at a variety of spatial scales. The temporal resolution and spectral configuration of the MODIS instruments make them an ideal source of such data. The MODIS Land Cover Dynamics Product (MCD12Q2) is designed to exploit this capability by providing information related to phenology in support of ecological and global change science. This document provides information related to the algorithm used to produce this product, the data format, relevant literature, and provides contact information for the production team should user's require further assistance.

2. Overview of the MCD12Q2 Land Cover Dynamics Product Algorithm

The MODIS Land Cover Dynamics algorithm (MLCD) identifies phenophase transition dates based on logistic functions fit to time series of the Enhanced Vegetation Index (EVI; Huete et al., 2002). Specifically, a time series of EVI is assembled for each pixel, the data undergo a gap-filling and smoothing process, periods of sustained EVI increase or decrease are identified, logistic models are fit to the time series, and transition dates are identified as local maxima and minima in the rate of change of curvature of the fitted logistic function. More complete details regarding algorithm implementation are provided in Zhang et al. (2003; 2006) and Ganguly et al. (2010). Four dates are calculated for a maximum of two full vegetation cycles at each pixel. These dates correspond to the onset of EVI increase (greenup), the onset of EVI maximum (maturity), the onset of EVI decrease (senescence), and the onset of EVI minimum (dormancy). In addition, the product also provides the minimum and maximum EVI in each cycle, along with the sum of daily EVI values during the growing period.

The MLCD product uses EVI calculated from composited 8-day Normalized BRDF-Adjusted Reflectance data (MCD43A4; Schaaf et al., 2002). Two full years of NBAR-EVI observations are assembled using a window that includes six months of data before and after the 12-month period of interest. MCD43A4 data are produced every

8-days using overlapping 16-day compositing windows. Thus, there are a maximum of 46 possible EVI values for any year, and an MLCD time series can include as many as 92 EVI observations. The standard product available to the user community uses a fixed start date of Jan 1, 2000 for all years. Users with other needs are invited to contact the production team.

In practice, the number of observations available in any MLCD two-year window is considerably less than the maximum possible because of cloud cover, aerosols, and other effects that prevent the production of NBAR data. Further, some NBAR-EVI values may be contaminated by the presence of snow or ice. The MLCD algorithm removes such observations using the snow/ice flag from the MCD43A2 BRDF-Albedo Quality product. Observations contaminated by snow or ice are replaced with the most-recent snow/ice free value. The Collection 5 MODIS Land Surface Temperature (LST) product (MOD11A2; Wan et al., 2002) is used to further filter the EVI time series by replacing those observations where LST is lower than 5° C with background, snow-free values. This step accounts for cases where the NBAR product fails to accurately identify snow or ice, and where vegetation is otherwise assumed to be biologically inactive. Remaining gaps in the time series are removed using a three-date moving window average, and the series are smoothed using a three-point median-value moving-window technique (Zhang et al., 2006).

Sustained periods of EVI increase and decrease are determined from the filtered, gap-filled, and smoothed EVI time series using moving windows composed of 5 consecutive observations. Transient variations in EVI, which may cause spurious detection of transitions, are excluded by requiring that the local maximum EVI value be at least 70% of the annual maximum, and that the change in EVI must exceed 35% of the annual amplitude. For each identified period of sustained EVI increase or decrease, sigmoid curves are fit to the corresponding EVI time series using non-linear least squares. Phenophase transition dates are then estimated by identifying local maxima and minima in the rate of change of curvature of the fitted logistic function (Zhang et al., 2003).

3. Product Overview and Science Data Sets:

Collection 5 of the MCD12Q2 Land Cover Dynamics product provides phenophase transition dates at annual time steps and 500-m spatial resolution for 2001-present. Seven separate SDS comprise the MCD12Q2 product. The first four SDS's provide the day of year for cardinal phenophase transition dates during the growing season:

- Onset_Greenness_Increase,
- Onset_Greenness_Maximum,
- Onset_Greenness_Decrease, and
- Onset_Greenness_Minimum

These dates correspond to the timing of vegetation greenup, maturity, senescence and dormancy, respectively. The next two SDS record the NBAR-EVI value corresponding to greenup and dormancy onset dates:

- NBAR_EVI_Onset_Greenness_Min, and
- NBAR_EVI_Onset_Greenness_Max.

The final SDS records the sum of fitted daily NBAR-EVI values during the identified vegetation cycle (i.e., Onset_Greenness_Increase to Onset_Greenness_Minimum):

- NBAR_EVI_Area

The product also provides an additional QA/QC SDS (Dynamics_QC), which records information related to the quality of phenophase transition date estimates. Note however, that because of an unidentified bug in the production codes used to generate the MCD12Q2 product, the QA/QC SDS is currently not meaningful. We are working to fix this.

Dates are recorded as 16-bit unsigned integers that measure the number of days since Jan 1, 2000. For example, for the Onset_Greenness_Increase SDS, a pixel value of 1595 corresponds to a greenup date of May 13, 2004. Pixels where the MLCD algorithm failed to produce an estimate are assigned the fill value of 32767. It is important to note that the MLCD algorithm is capable of recording phenophase transition dates for up to two full vegetation cycles at each pixel. Therefore, each of the SDS has two data layers, corresponding to the first full vegetation cycle, and the second (if one exists), respectively. Note that because the timing of seasons is variable across the planet, detection of cycles can be quite complicated. The algorithm, as currently structured, is best aligned with northern hemisphere dynamics. Users should be aware that cycles in the tropics and southern hemisphere may start in the middle of a cycle (i.e., the first detected transition date may correspond to the onset of senescence or dormancy); this can be especially complex in the tropics where multiple cycles can be present that are not in phase with the Northern Hemisphere.

The most recent version of the product is Collection 5, which makes the following important changes from the Collection 4 product:

- The product is now produced at 500-m spatial resolution instead of 1 km.
- Each pixel's phenological information is estimated using only data from that pixel rather than averaged values from the 3x3 pixel neighborhood.
- Collection 5 benefits from improvements in upstream products, particularly the NBAR data

Up-to-date information related to science data sets, data formats, and quality information can be found at:

https://lpdaac.usgs.gov/products/modis_products_table/mcd12q2

3.1. Data Formats and Projection

MODIS data are provided as tiles that are approximately 10° x 10° at the Equator using a sinusoidal grid in HDF4 file format. Information related to the MODIS sinusoidal projection and the HDF4 file format can be found at:

- MODIS tile grid: http://modis-land.gsfc.nasa.gov/MODLAND_grid.html
- MODIS HDF4: http://www.hdfgroup.org/products/hdf4/

3.2. Accessing and Acquiring Data

MCD12Q2 data can be acquired from the Land Processes Distributed Active Archive Center (https://lpdaac.usgs.gov/get_data). There are multiple portals for downloading the data. Reverb is the easiest to use and does not require a user account, but you only have the option to download the data in its original projection and HDF format. The MRTWeb portal enables more advanced options such as reprojection, subsetting, and reformatting but does require a user account.

4. Contact Information

Product PI: Mark Friedl (friedl@bu.edu)

Associate team member and primary contact for data users: Josh Gray (joshgray@bu.ed)

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