

User Guide for MOD09PHN and MOD15PHN

Version 3.0

Bin Tan
Jeff M o r r i s e t t e
Robert Wolfe
Feng Gao
Joanne M. Nightingale
Jeff Pedelty
Greg Ederer

Contact: Bin Tan (bin.tan@nasa.gov)

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Note:

This Guide is a living document that describes the phenology metrics estimated from MODIS VIs (LAI from MOD15A2 [1], and EVI/NDVI calculated from MOD09A2 and MOD09Q2 [2][3]). It is revised as progress is made in the development of these products. The purpose of the document is to give the potential user an understanding of the MOD09PHN and MOD15PHN products and the current state of the data in those products.

Introduction:

Land surface phenology is defined as the seasonal pattern of variation in vegetated land surfaces observed from remote sensing [4]. Because the seasonal pattern of vegetations are sensitive to small variations in climate, phenological records can be a useful proxy in the study of climate change. Land surface phenology is distinct from the traditional definition of phenology, which is the study of the times of recurring natural phenomena, i.e. the date of emergence of leaves and flowers, and the date of leaf coloring and fall in deciduous trees. The traditional definition refers to specific life cycle events using in-situ observations of individual plants or species, while the land surface phenology observed from remote sensing is aggregated information at the spatial resolution of satellite sensors

(e.g. 250-m for the Moderate Resolution Imaging Spectroradiometer (MODIS) sensor). Currently, satellite sensors with a frequent repeat cycle provides synoptic information to study land surface phenology across large areas. Both the temporal frequency of the data and the moderate spatial resolution make this sensor well suited for studying continental/global phenology related to the timing of vegetation greenup, browndown and associated land surface phenomena at seasonal and interannual time scales.

Algorithm and Methodology:

Jonsson and Eklundh developed the TIMESAT program [5] for analyzing time-series satellite sensor data. This program provides three different smoothing functions to fit time-series data: asymmetric Gaussian, double logistic, and adaptive Savitzky-Golay filtering. The adaptive Savitzky-Golay filtering approach uses local polynomial functions in fitting. It can capture subtle and rapid changes in the time-series but is also sensitive to noise. Both asymmetric Gaussian and double logistic approaches use semi-local methods. Less sensitive to the noise provides a better description on the beginning and end of the growing season. We found that both asymmetric Gaussian and double logistic approaches in the TIMESAT program produced similar results, with the exception that the asymmetric Gaussian approach is less sensitive to the incomplete time-series data. This is a significant advantage considering many data gaps exist in satellite observations due to clouds etc. The asymmetric Gaussian method was selected for temporally smoothing data and estimating phenological metrics.

The base function of Asymmetric Gaussian is:



(1)

For this function x_1 determines the position of the maximum or minimum with respect to the independent time variable t , while x_2 and x_3 determine the width and flatness (kurtosis) of the right function half. Similarly, x_4 and x_5 determine the width and flatness of the left half. The details of the algorithm could be found at [5] [6].



There are 11 phenological parameters for each successfully fitted pixel[7]:

1. **time for the start of the season;** time for which the first local maximum is detected on the 3rd derivative curve (“start of greenup”, as shown in the plot above).
2. **time for the end of the season;** time for which the second local minimum is detected on the 3rd derivative curve (“end of browndown”, as shown in the plot above).
3. **length of the season;** time from the start to the end of the season.
4. **base level;** given as the average of the left and right minimum values.

5. **time for the mid of the season**; computed as the mean value of the times of the second local maximum (end of greenup) and first local minimum (start of browndown) on the 3rd derivative curve (as shown in the plot above).
6. **largest data value for the fitted function during the season**;
7. **seasonal amplitude**; difference between the maximal value and the base level.
8. **rate of increase at the beginning of the season**; calculated as the VI ratio evaluated between end of greenup and start of greenup divided by the corresponding time difference.
9. **rate of decrease at the end of the season**; calculated as the VI ratio evaluated between start of browndown and end of browndown divided by the corresponding time difference.
10. **large seasonal integral**; integral of the function describing the season from the start of greenup to end of browndown.
11. **small seasonal integral**; integral of the difference between the function describing the season and the base level from start of greenup to end of browndown.

Three additional parameters are added into the phenological metrics:

12. **annual maximum value**; the maximum data value for the selected year.
13. **annual minimum value**; the minimum data value for the selected year.
14. **annual mean value**; the mean data value for the selected year.

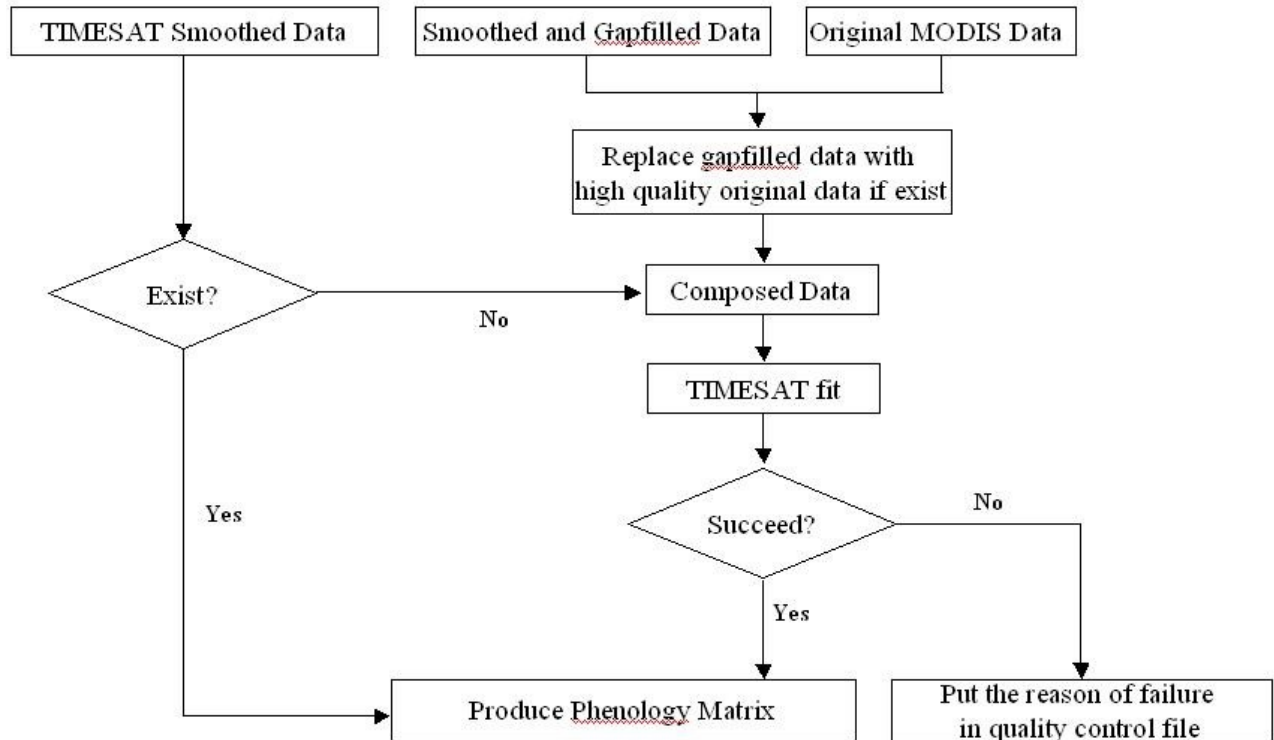
Besides phenological metrics, three ancillary layers are included in phenology products:

1. **RMSE**: the root mean square error of high quality original VI and fitted VI.
2. **Quality Flag**: indicate the quality of phenology estimations.
3. **Landcover**: provide IGBP landcover map.

If a pixel is 'failed' in the TIMESAT fitting process due to a large missing data gap, it may still be filled through a spatial gap filling process. All pixels with the same landcover type falling into an adaptive window are compared and a best pixel is selected. This best value is used to fill the processed pixel, which is the center of the adaptive window. The size of the window increases from 5 x 5 to 100 x 100 until a mean value is available. If the mean value is not available, all pixels with the same landcover type within the processing tile are used to calculate the mean value.

After the spatial filling, irretrievable pixels in previous TIMESAT process are re-processed by TIMESAT again with the spatial-filled data. The phenological metrics estimated by the first TIMESAT process and the second TIMESAT process are distinguished according to the quality flag, which is stored as an individual layer in MOD09PHN and MOD15PHN data.

The data flow of the phenology algorithm is as the following chart [8]:



Scientific data set:

MOD09PHN refers to four data sets – MOD09A1_EVI, MOD09A1_NDVI, MOD09Q1_EVI, and MOD09Q1_NDVI. “EVI” phenology products are derived from EVI, while “NDVI” phenology products are from NDVI. “A1” products are provided at 500-m resolution, and “Q1” products are provided at 250-m resolution. MOD15PHN is estimated from MCD15A2 8-day LAI products. The spatial resolution is 1-km. MOD09PHN and MOD15PHN are stored in Hierarchical Data Format (HDF) with sinusoidal projection, same as other standard MODIS land products.

For the first 11 phenology parameters, only the first two seasons (marked as s1 and s2) are stored if there are more than one valid seasonal cycles detected. Valid seasonal cycles should begin within the year of interest and end before the end of the second year. There are 27 Science Data Sets (SDS) in the available phenology product.

The details of the SDS for phenology products estimated from the NDVI is outlined as an example:

Layer-1 01greenups1 (short 16-bits):

```

long_name = "Greenup Date s1" ;
data_description = "At the beginning of the growing season, time for which the vegetation index begins to increase."
scale_factor = 1. ;
valid_range = 1s, 366s ;
unit = "day (from Jan 1st)" ;
FillValue = -3000s ;
  
```

fill value legend = "-3000: _Fillvalue: not computed, check QA layer for details.",

Layer-2 01greenups2 (short 16-bits):

long name = "Greenup Date s2" ;

data description = "At the beginning of the growing season, time for which the vegetation index begins to increase."

scale factor = 1. ;

valid range = 1s, 366s ;

unit = "day (from Jan 1st)" ;

FillValue = -3000s ;

fill value legend = "-3000: _Fillvalue: not computed, check QA layer for details.",

Layer-3 02browndowns1 (short 16-bits):

long name = "Browndown Date s1" ;

data description = "At the end of the growing season, time for which the vegetation index ends to decrease.";

scale factor = 1. ;

valid range = 1s, 732s ;

unit = "day (from Jan 1st)" ;

FillValue = -3000s ;

fill value legend = "-3000: _Fillvalue: not computed, check QA layer for details.",

Layer-4 02browndowns2 (short 16-bits):

long name = "Browndown Date s2" ;

data description = "At the end of the growing season, time for which the vegetation index ends to decrease.";

scale factor = 1. ;

valid range = 1s, 732s ;

unit = "day (from Jan 1st)" ;

FillValue = -3000s ;

fill value legend = "-3000: _Fillvalue: not computed, check QA layer for details.",

Layer-5 03seasonlengths1(short 16-bits):

long name = "Length of Growing Season s1" ;

data description = "Time from the start to the end of the season" ;

scale factor = 1. ;

valid range = 1s, 732s ;

unit = "day" ;

FillValue = -3000s ;

fill value legend = "-3000: _Fillvalue: not computed, check QA layer for details.",

Layer-6 03seasonlengths2(short 16-bits):

long name = "Length of Growing Season s2" ;

data description = "Time from the start to the end of the season" ;

scale factor = 1. ;

valid range = 1s, 732s ;

unit = "day" ;

FillValue = -3000s ;

fill value legend = "-3000: _Fillvalue: not computed, check QA layer for details.",

Layer-7 04baselevels1(short 16-bits):

long name = "Minimum NDVI in Growing Season s1" ;
data description = "Given as the average of the left and right minimum NDVI values";
scale factor = 0.0001 ;
valid range = -2000s, 10000s ;
unit = "NDVI unit" ;
FillValue = -3000s ;
fill value legend = "-3000: _Fillvalue: not computed, check QA layer for details.",

Layer-8 04baselevels2(short 16-bits):

long name = "Minimum NDVI in Growing Season s2" ;
data description = "Given as the average of the left and right minimum NDVI values";
scale factor = 0.0001 ;
valid range = -2000s, 10000s ;
unit = "NDVI unit" ;
FillValue = -3000s ;
fill value legend = "-3000: _Fillvalue: not computed, check QA layer for details.",

Layer-9 05peakdates1(short 16-bits) ;

long name = "Date of Peak NDVI s1" ;
data description = "Computed as the mean NDVI value of the time for which, respectively, the left edge ends to increase and right edge begins to decrease" ;
scale factor = 1. ;
valid range = 1s, 732s ;
unit = "day (from Jan 1st)" ;
FillValue = -3000s ;
fill value legend = "-3000: _Fillvalue: not computed, check QA layer for details.",

Layer-10 05peakdates2(short 16-bits) ;

long name = "Date of Peak NDVI s2" ;
data description = "Computed as the mean NDVI value of the time for which, respectively, the left edge ends to increase and right edge begins to decrease" ;
scale factor = 1. ;
valid range = 1s, 732s ;
unit = "day (from Jan 1st)" ;
FillValue = -3000s ;
fill value legend = "-3000: _Fillvalue: not computed, check QA layer for details.",

Layer-11 06maxpeakvalues1(short 16-bits):

long name = "Peak NDVI in Growing Season s1" ;
data description = "Largest NDVI value for the fitted function during the season" ;
scale factor = 0.0001 ;
valid range = -2000s, 10000s ;
unit = "NDVI unit" ;
FillValue = -3000s ;
fill value legend = "-3000: _Fillvalue: not computed, check QA layer for details.",

Layer-12 06maxpeakvalues2(short 16-bits):

long name = "Peak NDVI in Growing Season s2" ;
data description = "Largest NDVI value for the fitted function during the season" ;
scale factor = 0.0001 ;
valid range = -2000s, 10000s ;
unit = "NDVI unit" ;
FillValue = -3000s ;
fill value legend = "-3000: _Fillvalue: not computed, check QA layer for details.",

Layer-13 07amplitudes1(short 16-bits):

long name = "Seasonal Amplitude s1" ;
data description = "Difference between the maximum NDVI value and the base level" ;
scale factor = 0.0001 ;
valid range = 0s, 12000s ;
unit = "NDVI unit" ;
FillValue = -3000s ;
fill value legend = "-3000: _Fillvalue: not computed, check QA layer for details.",

Layer-14 07amplitudes2(short 16-bits):

long name = "Seasonal Amplitude s2" ;
data description = "Difference between the maximum NDVI value and the base level" ;
scale factor = 0.0001 ;
valid range = 0s, 12000s ;
unit = "NDVI unit" ;
FillValue = -3000s ;
fill value legend = "-3000: _Fillvalue: not computed, check QA layer for details.",

Layer-15 08greenuprates1(short 16-bits):

long name = "Greenup Rate s1" ;
data description = "Calculated as the ratio between the NDVI values evaluated when NDVI begins to increase and ends increasing divided by the corresponding time difference" ;
scale factor = 0.0001 ;
valid range = 0s, 32767s ;
unit = "NDVI unit per day" ;
FillValue = -3000s ;
fill value legend = "-3000: _Fillvalue: not computed, check QA layer for details.",

Layer-16 08greenuprates2(short 16-bits):

long name = "Greenup Rate s2" ;
data description = "Calculated as the ratio between the NDVI values evaluated when NDVI begins to increase and ends increasing divided by the corresponding time difference" ;
scale factor = 0.0001 ;
valid range = 0s, 32767s ;
unit = "NDVI unit per day" ;
FillValue = -3000s ;
fill value legend = "-3000: _Fillvalue: not computed, check QA layer for details.",

Layer-17 09browndownrates1(short 16-bits):

long name = "Browndown Rate s1" ;
data description = "Calculated as the ratio between the NDVI values evaluated when NDVI begins to decrease and ends decreasing divided by the corresponding time difference" ;
scale factor = 0.0001 ;
valid range = 0s, 32767s ;
unit = "NDVI unit per day" ;
FillValue = -3000s ;
fill value legend = "-3000: _Fillvalue: not computed, check QA layer for details.",

Layer-18 09browndownrates2(short 16-bits):

long name = "Browndown Rate s2" ;
data description = " Calculated as the ratio between the NDVI values evaluated when NDVI begins to decrease and ends decreasing divided by the corresponding time difference " ;
scale factor = 0.0001 ;
valid range = 0s, 32767s ;
unit = "NDVI unit per day" ;
FillValue = -3000s ;
fill value legend = "-3000: _Fillvalue: not computed, check QA layer for details.",

Layer-19 10largeintegrals1(short 16-bits):

long name = "Seasonal Integrated NDVI s1" ;
data description = "Integral of the function describing the season from the season start to the season end" ;
scale factor = 0.01 ;
valid range = 0s, 32767s ;
unit = "NDVI unit" ;
FillValue = -3000s ;
fill value legend = "-3000: _Fillvalue: not computed, check QA layer for details.",

Layer-20 10largeintegrals2(short 16-bits):

long name = "Seasonal Integrated NDVI s2" ;
data description = "Integral of the function describing the season from the season start to the season end" ;
scale factor = 0.01 ;
valid range = 0s, 32767s ;
unit = "NDVI unit" ;
FillValue = -3000s ;
fill value legend = "-3000: _Fillvalue: not computed, check QA layer for details.",

Layer-21 11smallintegrals1(short 16-bits):

long name = "Seasonal Integrated (NDVI - baseleve_NDVI) s1" ;
data description = "Integral of the difference between the function describing the season and the base level from season start to the season end" ;
scale factor = 0.01 ;
valid range = 0s, 32767s ;
unit = "NDVI unit" ;
FillValue = -3000s ;
fill value legend = "-3000: _Fillvalue: not computed, check QA layer for details.",

Layer-22 11smallintegrals2(short 16-bits):

long name = "Seasonal Integrated (NDVI - baseleve_NDVI) s2" ;
data description = "Integral of the difference between the function describing the season and the base level from season start to the season end" ;
scale factor = 0.01 ;
valid range = 0s, 32767s ;
unit = "NDVI unit" ;
FillValue = -3000s ;
fill value legend = "-3000: _Fillvalue: not computed, check QA layer for details.",

Layer-23 AnnualMaximumValue(short 16-bits):

long name = "The maximum NDVI value during the year" ;
data description = "Largest NDVI value for the fitted function during the year" ;
scale factor = 0.0001 ;
valid range = -2000s, 10000s ;
unit = "NDVI unit" ;
FillValue = -3000s ;
fill value legend = "-3000: _Fillvalue: not computed, check QA layer for details.",

Layer-24 AnnualMinimumValue(short 16-bits):

long name = "The minimum NDVI value during the year" ;
data description = "Smallest NDVI value for the fitted function during the year" ;
scale factor = 0.0001 ;
valid range = -2000s, 10000s ;
unit = "NDVI unit" ;
FillValue = -3000s ;
fill value legend = "-3000: _Fillvalue: not computed, check QA layer for details.",

Layer-25 AnnualMeanValue(short 16-bits):

long name = "The mean NDVI value during the year" ;
data description = "Mean NDVI value for the fitted function during the year" ;
scale factor = 0.0001 ;
valid range = -2000s, 10000s ;
unit = "NDVI unit" ;
FillValue = -3000s ;
fill value legend = "-3000: _Fillvalue: not computed, check QA layer for details.",

Layer-26 RMSE(short 16-bits):

long name = "The RMSE for the fitting" ;
data description = "The RMSE value between high quality original VI data and corresponding fitted VI data" ;
scale factor = 0.0001 ;
valid range = 0s, 10000s ;
unit = "NDVI unit" ;
FillValue = -3000s ;
fill value legend = "-3000: _Fillvalue: not computed, check QA layer for details.",

Layer-27 QualityFlag(byte 8-bits):

long name = "Quality Control Flag for Phenology parameters" ;
data description = "Quality Control Flag for Phenology parameters" ;
data legend =
 "For land area:\n",
 "0: Produced\n",
 "1: Produced - spatial gap filled data\n",
 "2: Not produced - no seasonal cycle started within the center
 year\n",
 "3: Not produced - insignificant seasonal cycle over entire
 interval\n",
 "4: Not produced - other reason\n",
 "\n",
 "5: Not produced - ocean/deep inland water\n",
 "\n",
 "For shallow inland water/ocean coastline/lake shoreline/ephemeral
 water area:\n",
 "10: Produced\n",
 "11: Produced - spatial gap filled data\n",
 "12: Not produced - no seasonal cycle started within the center
 year\n",
 "13: Not produced - insignificant seasonal cycle over entire
 interval\n",
 "14: Not produced - other reason\n",

Layer-28 Landcover(byte 8-bits):

long name = "Land cover map" ;
data description = "Quality Control Flag for Phenology parameters" ;
data legend =
 "0: Water\n",
 "1: Evergreen Needleleaf Forest\n",
 "2: Evergreen Broadleaf Forest\n",
 "3: Deciduous Needleleaf Forest\n",
 "4: Deciduous Broadleaf Forest\n",
 "5: Mixed Forest\n",
 "6: Closed Shrublands\n",
 "7: Open Shrublands\n",
 " 8: Woody Savannas \n",
 "9: Savannas\n",
 "10: Grasslands\n",
 "11: Permanent Wetlands\n",
 "12: Croplands\n",
 "13: Urban and Built-up\n",
 "14: Cropland/Natural Vegetation Mosaic\n",
 "15: Snow and Ice\n",
 "16: Barren or Sparsely Vegetated\n",
 "254: Unclassified\n",
 "255: Fill Value\n",

The details of SDS for phenology product estimated from the LAI is

Layer-1 01greenups1 (short 16-bits):

long name = "Greenup Date s1" ;

data description = "At the beginning of the growing season, time for which the vegetation index begins to increase" ;
scale factor = 1. ;
valid range = 1s, 366s ;
unit = "day (from Jan 1st)" ;
FillValue = -3000s ;
fill value legend = "-3000: _Fillvalue: not computed, check QA layer for details.",

Layer-2 01greenups2 (short 16-bits):

long name = "Greenup Date s2" ;
data description = "At the beginning of the growing season, time for which the vegetation index begins to increase" ;
scale factor = 1. ;
valid range = 1s, 366s ;
unit = "day (from Jan 1st)" ;
FillValue = -3000s ;
fill value legend = "-3000: _Fillvalue: not computed, check QA layer for details.",

Layer-3 02browndowns1 (short 16-bits):

long name = "Browndown Date s1" ;
data description = "At the end of the growing season, time for which the vegetation index ends to decrease";
scale factor = 1. ;
valid range = 1s, 732s ;
unit = "day (from Jan 1st)" ;
FillValue = -3000s ;
fill value legend = "-3000: _Fillvalue: not computed, check QA layer for details.",

Layer-4 02browndowns2 (short 16-bits):

long name = "Browndown Date s2" ;
data description = "At the end of the growing season, time for which the vegetation index ends to decrease " ;
scale factor = 1. ;
valid range = 1s, 732s ;
unit = "day (from Jan 1st)" ;
FillValue = -3000s ;
fill value legend = "-3000: _Fillvalue: not computed, check QA layer for details.",

Layer-5 03seasonlengths1(short 16-bits):

long name = "Length of Growing Season s1" ;
data description = "Time from the start to the end of the season" ;
scale factor = 1. ;
valid range = 1s, 732s ;
unit = "day" ;
FillValue = -3000s ;
fill value legend = "-3000: _Fillvalue: not computed, check QA layer for details.",

Layer-6 03seasonlengths2(short 16-bits):

long name = "Length of Growing Season s2" ;
data description = "Time from the start to the end of the season" ;
scale factor = 1. ;
valid range = 1s, 732s ;

unit = "day" ;
FillValue = -3000s ;
fill value legend = "-3000: _Fillvalue: not computed, check QA layer for details.",

Layer-7 04baselevels1(short 16-bits):

long name = "Minimum LAI in Growing Season s1" ;
data description = "Given as the average of the left and right minimum LAI values";
scale factor = 0.1 ;
valid range = 0s, 100s ;
unit = "LAI unit" ;
FillValue = -3000s ;
fill value legend = "-3000: _Fillvalue: not computed, check QA layer for details.",

Layer-7 04baselevels2(short 16-bits):

long name = "Minimum LAI in Growing Season s2" ;
data description = "Given as the average of the left and right minimum LAI values";
scale factor = 0.1 ;
valid range = 0s, 100s ;
unit = "LAI unit" ;
FillValue = -3000s ;
fill value legend = "-3000: _Fillvalue: not computed, check QA layer for details.",

Layer-9 05peakdates1(short 16-bits) ;

long name = "Date of Peak LAI s1" ;
data description = "Computed as the mean NDVI value of the time for which, respectively, the left edge ends to increase and right edge begins to decrease" ;
scale factor = 1. ;
valid range = 1s, 732s ;
unit = "day (from Jan 1st)" ;
FillValue = -3000s ;
fill value legend = "-3000: _Fillvalue: not computed, check QA layer for details.",

Layer-10 05peakdates2(short 16-bits) ;

long name = "Date of Peak LAI s2" ;
data description = "Computed as the mean NDVI value of the time for which, respectively, the left edge ends to increase and right edge begins to decrease" ;
scale factor = 1. ;
valid range = 1s, 732s ;
unit = "day (from Jan 1st)" ;
FillValue = -3000s ;
fill value legend = "-3000: _Fillvalue: not computed, check QA layer for details.",

Layer-11 06maxpeakvalues1(short 16-bits):

long name = "Peak LAI in Growing Season s1" ;
data description = "Largest LAI value for the fitted function during the season" ;
scale factor = 0.1 ;
valid range = 0s, 100s ;

unit = "LAI unit" ;
FillValue = -3000s ;
fill value legend = "-3000: _Fillvalue: not computed, check QA layer for details.",

Layer-12 06maxpeakvalues2(short 16-bits):

long name = "Peak LAI in Growing Season s2" ;
data description = "Largest LAI value for the fitted function during the season" ;
scale factor = 0.1 ;
valid range = 0s, 100s ;
unit = "LAI unit" ;
FillValue = -3000s ;
fill value legend = "-3000: _Fillvalue: not computed, check QA layer for details.",

Layer-13 07amplitudes1(short 16-bits):

long name = "Seasonal Amplitude s1" ;
data description = "Difference between the maximum LAI value and the base level" ;
scale factor = 0.1 ;
valid range = 0s, 100s ;
unit = "LAI unit" ;
FillValue = -3000s ;
fill value legend = "-3000: _Fillvalue: not computed, check QA layer for details.",

Layer-14 07amplitudes2(short 16-bits):

long name = "Seasonal Amplitude s2" ;
data description = "Difference between the maximum LAI value and the base level" ;
scale factor = 0.1 ;
valid range = 0s, 100s ;
unit = "LAI unit" ;
FillValue = -3000s ;
fill value legend = "-3000: _Fillvalue: not computed, check QA layer for details.",

Layer-15 08greenuprates1(short 16-bits):

long name = "Greenup Rate s1" ;
data description = "Calculated as the ratio between the NDVI values evaluated when NDVI begins to increase and ends increasing divided by the corresponding time difference" ;
scale factor = 0.1 ;
valid range = 0s, 32767s ;
unit = "LAI unit per day" ;
FillValue = -3000s ;
fill value legend = "-3000: _Fillvalue: not computed, check QA layer for details.",

Layer-16 08greenuprates2(short 16-bits):

long name = "Greenup Rate s2" ;
data description = "Calculated as the difference between the NDVI values evaluated when NDVI begins to increase and ends increasing divided by the corresponding time difference" ;
scale factor = 0.1 ;
valid range = 0s, 32767s ;

unit = "LAI unit per day" ;
FillValue = -3000s ;
fill value legend = "-3000: _Fillvalue: not computed, check QA layer for details.",

Layer-17 09browndownrates1(short 16-bits):

long name = "Browndown Rate s1" ;
data description = "Calculated as the ratio between the NDVI values evaluated when NDVI begins to decrease and ends decreasing divided by the corresponding time difference" ;
scale factor = 0.1 ;
valid range = 0s, 32767s ;
unit = "LAI unit per day" ;
FillValue = -3000s ;
fill value legend = "-3000: _Fillvalue: not computed, check QA layer for details.",

Layer-18 09browndownrates2(short 16-bits):

long name = "Browndown Rate s2" ;
data description = "Calculated as the ratio between the NDVI values evaluated when NDVI begins to decrease and ends decreasing divided by the corresponding time difference" ;
scale factor = 0.1 ;
valid range = 0s, 32767s ;
unit = "LAI unit per day" ;
FillValue = -3000s ;
fill value legend = "-3000: _Fillvalue: not computed, check QA layer for details.",

Layer-19 10largeintegrals1(short 16-bits):

long name = "Seasonal Integrated LAI s1" ;
data description = "Integral of the function describing the season from the season start to the season end" ;
scale factor = 0.1 ;
valid range = 0s, 32767s ;
unit = "LAI unit" ;
FillValue = -3000s ;
fill value legend = "-3000: _Fillvalue: not computed, check QA layer for details.",

Layer-20 10largeintegrals2(short 16-bits):

long name = "Seasonal Integrated LAI s2" ;
data description = "Integral of the function describing the season from the season start to the season end" ;
scale factor = 0.1 ;
valid range = 0s, 32767s ;
unit = "LAI unit" ;
FillValue = -3000s ;
fill value legend = "-3000: _Fillvalue: not computed, check QA layer for details.",

Layer-21 11smallintegrals1(short 16-bits):

long name = "Seasonal Integrated (LAI - baseleve_LAI) s1" ;
data description = "Integral of the difference between the function describing the season and the base level from season start to the season end" ;
scale factor = 0.1 ;

valid range = 0s, 32767s ;
unit = "LAI unit" ;
FillValue = -3000s ;
fill value legend = "-3000: _Fillvalue: not computed, check QA layer for details.",

Layer-22 11smallintegrals2(short 16-bits):

long name = "Seasonal Integrated (LAI - baseleve_LAI) s2" ;
data description = "Integral of the difference between the function describing the season and the base level from season start to the season end" ;
scale factor = 0.1 ;
valid range = 0s, 32767s ;
unit = "LAI unit" ;
FillValue = -3000s ;
fill value legend = "-3000: _Fillvalue: not computed, check QA layer for details.",

Layer-23 AnnualMaximumValue(short 16-bits):

long name = "The maximum LAI value during the year" ;
data description = "Largest LAI value for the fitted function during the year" ;
scale factor = 0.1 ;
valid range = 0s, 100s ;
unit = "LAI unit" ;
FillValue = -3000s ;
fill value legend = "-3000: _Fillvalue: not computed, check QA layer for details.",

Layer-24 AnnualMinimumValue(short 16-bits):

long name = "The minimum LAI value during the year" ;
data description = "Smallest LAI value for the fitted function during the year" ;
scale factor = 0.1 ;
valid range = 0s, 100s ;
unit = "LAI unit" ;
FillValue = -3000s ;
fill value legend = "-3000: _Fillvalue: not computed, check QA layer for details.",

Layer-25 AnnualMeanValue(short 16-bits):

long name = "The mean LAI value during the year" ;
data description = "Mean LAI value for the fitted function during the year" ;
scale factor = 0.1 ;
valid range = 0s, 100s ;
unit = "LAI unit" ;
FillValue = -3000s ;
fill value legend = "-3000: _Fillvalue: not computed, check QA layer for details.",

Layer-26 RMSE(short 16-bits):

long name = "The RMSE for the fitting" ;
data description = "The RMSE value between high quality original LAI data and corresponding fitted LAI data" ;
scale factor = 0.1 ;
valid range = 0s, 200s ;

```
unit = "LAI unit" ;  
FillValue = -3000s ;  
fill value legend = "-3000: _Fillvalue: not computed, check QA layer  
for details.",
```

Layer-27 QualityFlag(byte 8-bits):

```
long name = "Quality Control Flag for Phenology parameters" ;  
data description = "Quality Control Flag for Phenology parameters" ;  
data legend =  
    "0: Produced\n",  
    "1: Produced - spatial gap filled data\n",  
    "2: Not produced - water class\n",  
    "3: Not produced - non-vegetated class\n",  
    "4: Not produced - no seasonal cycle started within the center  
year\n",  
    "5: Not produced - insignificant seasonal cycle over entire  
interval\n",  
    "6: Not produced - other reason\n",
```

Layer-28 Landcover(byte 8-bits):

```
long name = "Land cover map" ;  
data description = "Quality Control Flag for Phenology parameters" ;  
data legend =  
    "0: Water\n",  
    "1: Grasses/Cereal Crops\n",  
    "2: Shrubs\n",  
    "3: Broadleaf Crops\n",  
    "4: Savannas\n",  
    "5: Broadleaf Forest\n",  
    "6: Needleleaf Forest\n",  
    "7: Unvegetated\n",  
    "8: Urban\n",  
    "254: Unclassified\n",  
    "255: Fill Value\n",
```

Reference

- [1] R.B. Myneni, s. Hoffman, Y. Knyazikhin, J. L. Privette, J. Glassy, Y. Tian, Y. Wang, X. Song, Y. Zhang, G. R. Smith, A. Lotsch, M. Friedl, J. T. Morisette, P. Votava, R. R. Nemani, and S. W. Running. Global products of vegetation leaf area and fraction absorbed PAR from year one of MODIS data. Remote Sens. Environ., vol 83, 214-231, 2002.
- [2] E. F. Vermote, N. Z. EL Saleous, and C. O. Justice. Atmospheric correction of MODIS data in the visible to middle infrared: first results. Remote Sens. Environ, vol 83, 97-111, 2002.
- [3]A.Huete, K. Didan, T. Miura, E. Rodriguez, X. Gao, and L. Ferreira. Overview of the radiometric and biophysical performance of the MODIS vegetation indices, Remote Sens. Environ. 83:195-213, 2002.

[4] M. Friedl, G. Henebry, B. Reed, A. Huete, M. White, J. T. Morisette, R. Nemani, X. Zhang, and R. Myneni. Land Surface Phenology. Earth System Data Records” (ESDR) white paper – Land surface phenology.

ftp://ftp.iluci.org/Land_ESDR/Phenology_Friedl_whitepaper.pdf

[5] P. Jonsson and L. Eklundh, “TIMESAT - a program for analyzing time-series of satellite sensor data,” Computers & Geosci., vol. 30, pp. 833–845, 2004.

[6] F. Gao, J. T. Morisette, R. E. Wolfe, G. Ederer, J. Pedelty, E. Masuoka, R. Myneni, B. Tan, and J. Nightingale. An algorithm to produce temporally and spatially continuous MODIS-LAI time series. IEEE Geosci. Remote Sens. Lett., vol. 5, 2008

[7] Tan, B., Morisette, J. T., Wolfe, R. E., Gao, F., Ederer, G. A., Nightingale, J., Pedelty, J. A., An Enhanced TIMESAT Algorithm for Estimating Vegetation Phenology Metrics From MODIS Data. IEEE J. Sel. Topics Appl. Earth Observ. DOI: 10.1109/JSTARS.2010.2075916, 2010.

[8] B. Tan, J. T. Morisette, R. E. Wolfe, F. Gao, G. Ederer, J. Nightingale, and J. Pedelty. Vegetation phenology metrics derived from temporally smoothed and gap-filled MODIS data. [Geoscience and Remote Sensing Symposium, pp. 593-596, 2008.](#)