User Guide for MOD09PHN and MOD15PHN
Version 1.0

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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, phonological 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:

$$g(t, x_1, x_2, ..., x_5) = \begin{cases} \exp\left[-(\dfrac{t - x_1}{x_2})^{x_3}\right] & if \quad t > x_1 \\ \exp\left[-(\dfrac{x_1 - t}{x_4})^{x_5}\right] & if \quad t < x_1 \end{cases} \tag{1}$$

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] and [6].

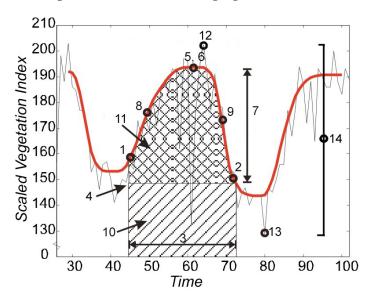The original TIMESAT algorithm provides 11 phenological parameters for each successfully fitted pixel:
1. **time for the start of the season**; time for which the left edge has increased to a user defined level (10% of the seasonal amplitude used here) measured from the left minimum level.
2. **time for the end of the season**; time for which the right edge has decreased to a user defined level measured from the right minimum level.
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 for which, respectively, the left edge has increased to the 90 % level and the right edge has decreased to the 90 % level.
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 ratio between the values evaluated at the season start and at the left 90 % level divided by the corresponding time difference.
9. **rate of decrease at the end of the season**; calculated as the ratio between the values evaluated at the season end and at the right 90 % level divided by the corresponding time difference.

10. **large seasonal integral**; integral of the function describing the season from the season start to the season end.
11. **small seasonal integral**; integral of the difference between the function describing the season and the base level from season start to season end.

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.
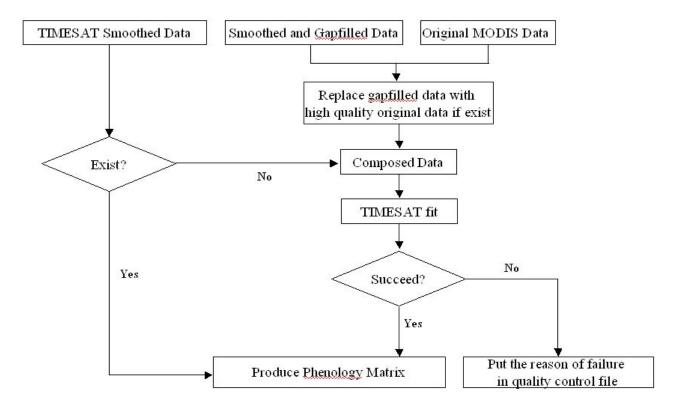14. **annual mean value**; the mean data value for the selected year.

These 14 metrics are represented in the following figure:

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 used to calculate a mean value. This mean 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:

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 MOD15A2 8-day LAI products. The spatial resolution is 1-km. MOD09PHN and MOD15PHN are stored in Hierarchical Data Format (HDF) with sinusodial 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 = "Time for which the left edge has increased to 10 percent of the seasonal amplitude measured from the left minimum level" ;
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 = "Time for which the left edge has increased to 10 percent of the seasonal amplitude measured from the left minimum level" ;
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 = " Time for which the right edge has decreased to 10 percent of the seasonal amplitude measured from the right minimum level";
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 = " Time for which the right edge has decreased to 10 percent of the seasonal amplitude measured from the right minimum level";
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 has increased to the 90 percent level and right edge has decreased to the 90 percent level" ;
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 has increased to the 90 percent level and right edge has decreased to the 90 percent level" ;
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 at the season start and at the left 90 percent level 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 at the season start and at the left 90 percent level 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 at the season end and at the right 90 percent level 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 at the season end and at the right 90 percent level 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 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-27 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 = "Time for which the left edge has increased to 10 percent of the seasonal amplitude measured from the left minimum level" ;
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 = "Time for which the left edge has increased to 10 percent of the seasonal amplitude measured from the left minimum level" ;
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 = " Time for which the right edge has decreased to 10 percent of the seasonal amplitude measured from the right minimum level";
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 = " Time for which the right edge has decreased to 10 percent of the seasonal amplitude measured from the right minimum level";
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 LAI value of the time for which, respectively, the left edge has increased to the 90 percent level and right edge has decreased to the 90 percent level" ;
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 LAI value of the time for which, respectively, the left edge has increased to the 90 percent level and right edge has decreased to the 90 percent level" ;
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 LAI values evaluated at the season start and at the left 90 percent level 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 ratio between the LAI values evaluated at the season start and at the left 90 percent level 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 LAI values evaluated at the season end and at the right 90 percent level 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 LAI values evaluated at the season end and at the right 90 percent level 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 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-27 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",
```

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