**MODIS NDVI PRODUCTS AND METRICS**

**USER MANUAL**

**Version 1**

**Geographic Information Network of Alaska**

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**1. Introduction**

Moderate Resolution Imaging Spectroradiometer (MODIS) is used by the National Park Service (NPS), Alaska Region Inventory & Monitoring (I&M) Program and the University of Alaska-Geographic Information Network of Alaska (GINA) to monitor and study the interannual variability in growing season length, lake ice formation and breakup, and snow season across Alaska. MODIS-derived true color imagery, Normalized Difference Vegetation Index (NDVI) and snow products (2000-present) are now being acquired, processed, and distributed by GINA. This user manual briefly introduces how to acquire the standardized MODIS products obtained from existing archives at the USGS-EROS Data Center as well as how to deliver the processed results. It describes in detail the data process algorithm and its usage.

MODIS 7-day composite NDVI data are downloaded from the USGS-EROS Data Center ([http://dds.cr.usgs.gov/emodis/Alaska/historical/TERRA/](http://dds.cr.usgs.gov/emodis/Alaska/historical/TERRA/" \t "_blank)). The NDVI color imagery and NDVI metrics imagery are accessible through WMS.

**2. NDVI product and Metrics**

The MODIS 7-day composite NDVI data are downloaded from the eMODIS website. Each 7-day composite NDVI data are presented in color imagery though WCS. Yearly NDVI data are stacked, interpolated smoothed, then the yearly NDVI metrics are calculated. The yearly NDVI metrics product is delivered through the WCS (http://ndvi.gina.alaska.edu/metrics?). Figure 2.1 describes the NDVI data process and delivery procedure.

WCS

NDVI metrics Algorithm

Acquire eMODIS

NDVI data

NDVI imagery

Figure 2.1. MODIS NDVI data automatic process scheme

**2.1. Data Format of Input Data**

One 7-day composite eMODIS dataset includes six files. They are: band 1-7 reflectance, NDVI, quality, acquisition image, acquisition table, and metadata. NDVI data are used to produce colorful NDVI imagery. NDVI and quality data are used to calculate NDVI metrics.

NDIV data are in the range from -1999 to 10000, and the -2000 is fill value. Value "-1999" is assigned to any VI computation between "-1998" and "-10000". VI computation between "-1" and "-1997" are assigned face value. When surface reflectance input pixels contain negative fill values, the pixels will have a "-2,000" for NDVI and a corresponding "10" in the band quality layer. The scale factor is 0.0001. After applying the scale factor, valid NDVI values range from "0.0" to "1.0".

Quality layer includes flag values to indicate the quality of the corresponding NDVI values. The flag values are: 0—good, 1—cloudy, 2—bad data, 3—negative reflectance, 4—snow, and 10—fill value.

**2.2 NDVI Metrics**

The NDVI metrics algorithm is developed with IDL and ENVI language. The schema of the algorithm is illustrated in the Figure 2.2.

NDVI and quality data

Stack the NDVI and quality data

Smooth the interpolated data

Calculate the metrics

NDVI metrics and smoothed data files

Interpolate the stacked data

Figure 2.2. NDVI metrics algorithm schema

The yearly NDVI and quality data are inputs for the NDVI metrics algorithm. The algorithm stacks these data into a multiple-band data, then it interpolates and smooths the data, finally the algorithm calculates and output NDVI metrics as well as the smoothed NDVI data. The yearly NDVI metrics data includes 10 matrices. They are: day of onset of greenness (onp), NDVI value at onset day (onv), day of end of greenness (endp), NDVI value at the end day of greenness (endv), the duration of greenness season (durp), the day of the maximum NDVI value (maxp), maximum NDVI value (maxv), range of NDVI values (ranv), rate of green up (rtup), rate of senescense (rtdn), time-integrated NDVI (tindvi), NDVI metrics flag (mflg).

2.2.1 Installation, configuration, and execution of the MODIS NDVI metrics application

The algorithm codes are developed with IDL + ENVI programing language. They work on both Linux and Windows operational environment with IDL+ENVI installed. The instruction covers the installation, configuration, and execution of the algorithm codes in Linux environment.

Installation of the application

1. Download the algorithm zip file from <ftp://dds.gina.alaska.edu/public/modis_ndvi_metrics/modis_ndvi_metrics.zip>

We will assume you download it to your home directory ($HOME).

1. Unzip the file, the expanded files will be stored in the “modis\_ndvi\_metrics” directory ($HOME/modis\_ndvi\_metrics).

In the directory “modis\_ndvi\_metrics” you will find several subdirectorys; docs, bin, sav, codes, and scripts. The “doc” directory includes the documentation; the “~/bin” stores IDL library codes; the “~/codes” includes the IDL source codes; the “~/sav” stores the compiled IDL binary file; and the “~/scripts” includes script files used to execute the application in batch mode.

Configuration of the application

1. Edit the startup\_nps file and save to the $HOME/modis\_ndvi\_metrics directory

The file “startup\_nps” includes:

ENVI, /RESTORE\_BASE\_SAVE\_FILES

PREF\_SET,’IDL\_PATH’, ‘<IDL\_DEFAULT>:+$HOME/modis\_ndvi\_metrics/bin’,/COMMIT

1. edit .bashrc and add the following lines:

export ndvihome=$HOME/modis\_ndvi\_metrics

export IDL\_STARTUP=$HOME/modis\_ndvi\_metrics/startup\_np

1. edit 1yr\_emodis\_250\_env.bash

export rawdata\_dir=$HOME/emodis/distribution/Alaska/historical/TERRA

export work\_dir=$HOME/modis\_ndvi\_metrics/work

export script\_dir=$HOME/modis\_ndvi\_metrics/scripts

export idlprog\_dir=$HOME/modis\_ndvi\_metrics/sav

export idl\_dir=/usr/local/idl-7.1/bin

export result\_dir=$HOME/results

Execution of the application

There are two options for running the application. The first is to run it in batch mode and the second is to run the application step by step.

1. Run the application in batch mode

>cd $HOME/modis\_ndvi\_metrics/scripts

>./1yr\_emodis\_250\_main\_v2.bash yyyy

The parameter yyyy is the year that you want to process, such as 2007. It will automatically complete all steps to produce the NDVI metrics data file and smoothed data file in the $result\_dir.

1. Run the application step by step

Assume the eMODIS raw data are stored in the $rawdata\_dir/YYYY, where YYYY represents year (such as 2007).

Step1. unzip the raw data files

>cd $rawdata\_dir/yyyy

>gunzip \*.gz

>ls $PWD/\*NDVI\*>yyyy\_flist\_ndvi

>ls $PWD/\*QUAL\*>yyyy\_flist\_bq

Step2. create ndvi file list and quality file list.

>./1yr\_emodis\_250\_flist.bash unzipped\_data\_file\_dir, year

Step3. stack the one-year data

>./1yr\_emodis\_250\_stack\_v2.bash flist\_ndvi,flist\_bq, ul\_lon, ul\_lat, lr\_lon, lr\_lat

The flist\_ndvi and flist\_bq are file lists which include the full path of ndvi and quality file names, respectively. The ul\_lon,ul\_lat, lr\_lon and lr\_lat are upper left and low right location of the rectangular zone in longitude and latitude. They are used to subset the data. Set all four values as 0 for not doing data sunset.

Step4. calculate ndvi metrics

>./1yr\_emodis\_250\_calmetrics\_v2.bash one\_year\_stacked\_data\_file

2.2.2 NDVI metrics algorithm Description

As described in Figure 2.2, NDVI metrics algorithm includes: stacking one year of NDVI data, interpolating the data, smoothing the data, and calculating the yearly metrics.

1. Stacking the NDVI and quality data

The stacking process includes several steps. Figure 2.3 is the flowchart of stack process

Convert the NDVI value range of the I th file pair from [-10000, 10000] to [0, 200]

one-year-ndvi-file list and

one-year-qual-file list

Save the I th NDVI and quality data in the temporary files.

Stack the temporary NDVI files and quality files together to get a one-year-stack file

one-year-stacked file

Is the I th file pair is processed?

Figure 2.3. Flowchart of sctocking processing

The one-year-ndvi-file list and the one-year-qual-file list include the full-path formatted NDVI and quality data file names, respectively. Each NDVI file has a corresponded quality file. The stacking program goes through each pair of files and reads them into a temporary memory space, coverts the raw NDVI data from [-10000, 10000] to [0, 200], and stacks these data together. Finally, outputs the stacked data.

1. Interpolate the stacked-data time series (interpol\_noextention\_1y\_verctor\_ver9.pro)

The algorithm goes through each pixel and its corresponded time series. Figure 2.4 describes the interpolation process for the time series.

raw-data time series

Number of valid points >= 5 and the maximum value >=100+25%\*100

Assign random values from 100 or 101 to negative and bad points

Interpolate data segment from first point with 20% of maximum value to last point with 20% of maximum value

Get rid of one or two consecutive odd points

interpolated-time series

Figure 2.4. Flowchart of interpolation of time series

A raw-data time series for a pixel includes 42 weekly composite data points, starting with the 5th week of the year, and ending with 46th week. The value range of the raw-data time series is [0, 200], where the valid data range is [100,200], fill value=80. The raw data are classified into 6 types: good, cloud, bad, negative reflectance, snow, and fill. Figure 2.5 gives an example of a time series. As you can see, there are two fill-value points (80) in the time series, and some no valid points with values in the range (80,100). Interpolation process will target these points.



Figure 2.5. A raw-data time series

First a time series is checked to determine if it is reasonable for the purpose of NDVI metrics calculation. Two conditions are applied to determine the reasonability. a) the time series has more than 5 valid points, or b) the maximum value of the time series must be greater than 25% of the valid raw data range of [100,200]. That is to say, the maximum value must be greater than 125. If the time series does not meet either of the conditions, the program stops. Otherwise, the program continues to process the time series. Only good and snow data points are kept, other points are either interpolated linearly or replaced randomly with 100 or 101. Negative NDVI value or band points are randomly assigned a 100 or 101 value to avoid false crossovers for start of season and end of season detection. Linear interpolation is applied to the segment from the first to last points with greater than or equal to 20% of the maximum value of the time series. Check if the time series includes one or two consecutive odd points which are extremely smaller than their adjective points, and replace these odd points with values determined by linear interpolation method.



Figure 2.6. Interpolated-data time series

1. Smoothing the interpolated data time series

A weighted-least-square smooth algorithm is applied to the interpolated time series. The algorithm is developed based on Daniel L. Swets (2001). Figure 2.7 shows the smoothed time series, the 31th point of the line is increased.



Figure 2.7. Smoothed-data time series

1. Calculating the smoothed-data time series

The NDVI metrics calculation method combines the delay moving window method and the threshold method. Figure 2.8 describes the processes of calculation of NDVI metrics of the time series.

Smoothed-data time series

Convert the time series from [0, 200] to [0.0, 1.0]

Fix or variable length of window for delayed moving average method

Calculate forward and backward moving average of time series, respectively

pick the earliest possible threshold day as threshold day; obtain the possible day, which is the closet to the threshold day, from the crossover days; choose later day between the possible SOS day and the threshold day as SOS day; if the SOS day is “snow” day, pick the next “no-snow” day as SOS day.

pick the latest possible threshold day as threshold day; obtain the possible day of end of season (EOS),which is the closet to the threshold day, from the crossover days; choose earlier day between the possible EOS day and the threshold day as EOS day; if the EOS day is “snow” day, pick the next “no-snow” day as EOS day.

Obtain the crossover days where time series crosses over its backward moving average from up; the possible threshold days where time series crosses over the 20% of maximum line from up, and the minimum slope day

Calculate other metrics such as up and down slope rates, integrated NDVI values.

NDVI metrics and smoothed data files

Obtain the crossover days where time series crosses over its forward moving average from down; the possible threshold days where time series crosses over the 20% of maximum line from down, and the maximum slope day

Figure 2.8. Flowchart of calculation of NDVI metrics

The calculation of NDVI metrics algorithm takes smoothed-data time series as the input. In step 1, it converts the time series from [0, 200] to [0.0, 1.0]. In step 2, it uses a fix or variable window length for delayed moving average method. Using fix length moving window for delay moving average method benefits us for comparison of multiple year NDVI metrics data. The algorithm uses a fix length window as default. The algorithm also provides a method to determine dynamically the moving window length according to the possible greenness season length . Step 3 calculates the forward and backward moving averages of the time series. Step 4 obtains the crossover days, possible threshold days, and maximum slope days in the time series. Step 5 chooses the earliest day from the possible threshold days as threshold day, and choose the day which is the most close to the threshold day as possible SOS, then pick the later day between the possible SOS and threshold day, and if the SOS day is “snow” day, choose the next “no-snow” day as SOS day. Figure 2.9 describes how to determine the SOS day. The solid line is smoothed time series, the dot line is forward moving average of the time series, the star is possible crossover, the triangle is threshold day, and the square is maximum slope day. In this case, the SOS day is equal to the threshold day.



Figure 2.9Determination of SOS day

Steps 6 and 7 determine the EOS day. They follow the similar logic as in steps 4 and 5. Figure 2.10 illustrates the process of determining the EOS day. In this case, the EOS day is equal to threshold day.



Figure 2.10. Determination of EOS day

Once the SOS day and EOS day are determined, it is easy to calculate the other metrics such as the maximum NDVI day and its NDVI value, up and down slope rates, and the integrated NDVI-day value.

Since Alaska covers such large area the window width in the delayed moving average method is critical in the NDVI metrics algorithm. Using a fixed window width will over or under estimate the SOS and EOS days. Dynamically determining the window width is more suitable for estimating the SOS and EOS days by the delayed moving average method. Figure 2.11 shows the process of determining the widow width.

Time series, ratio=0.2

Obtain maximum NDVI value (maxv20) and its indices (mxidxst, mxidxed) from Apr.1 to Sep.31 in the time series

Obtain the minimum NDVI value (sosmim) and its index (idx\_sosmin) from [0, mxidxst]. calculate SOS-threshold (sosv20) =0.2\*(maxv20-sosmin) and its index(idx\_sosv20)

Obtain the minimum NDVI (eosmin) and its index (idx\_eosmin) from [mxidxed:num-1], where num is the length of the time series. calculate EOS-threshold (eosv20)=0.2\*(maxv20-eosmin) and its index (idx\_eosv20)

Window width=num –eosv20

Window width, sosv20, idx\_sosmin, idx\_sosv20, eosv20, idx\_eosmin, and idx\_eosv20,

Figure 2.11. Flowchart of dynamic determination of window width

Appendix A. Program List for NDVI metrics Algorithm

1, smooth\_calculate\_metrics\_tile.pro

1.1, start\_batch.pro

1.2, time\_series\_process\_nps\_oneyear.pro

1.2.1, interpol\_noextension\_1y\_vector.pro

1.2.1.1 cutoff\_interp.pro

1.2.1.1.1 filter\_2odd.pro

1.2.2. wls\_smooth.pro

1.2.3. user\_metrics\_nps\_by1yr.pro

1.2.3.1. ComputeMetrics\_by1yr.pro

1.2.3.1.1 GetForwardMA.pro

1.2.3.1.2 GetBackwardMA.pro

1.2.3.1.3 GetCrossOver\_percentage\_extremeslope.pro

1.2.3.1.4 GetSOS.pro

1.2.3.1.5 GetEOS.pro

1.2.3.1.6 GetMaxNDVI.pro

1.2.3.1.7 GetTotNDVI.pro

1.2.3.1.8 GetNDVItoDate.pro

1.2.3.1.9 GetSlope.pro

1.2.3.1.10 GetRange.pro

1.2.3.2. findday.pro

2, oneyear\_data\_layer\_subset\_good.pro

2.1, start\_batch.pro

2.2, read\_ndvi.pro

2.2.1, subset.pro