

Department of the Interior
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**LANDSAT
FRACTIONAL SNOW COVERED AREA (FSCA)
ALGORITHM DESCRIPTION DOCUMENT (ADD)**

Version 1.0

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Executive Summary

This U.S. Geological Survey (USGS) fractional Snow Covered Area (fSCA) Algorithm Description Document (ADD) defines the algorithms used for the creation of fSCA data products at the USGS Earth Resources Observation and Science (EROS) Center.

This document is under Landsat Data Processing and Archive System (DPAS) Configuration Control Board (CCB) control. Please submit changes to this document, as well as supportive material justifying the proposed changes, via Change Request (CR) to the Process and Change Management Tool.

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Section 1 Introduction

1.1 Background

The fractional Snow Covered Area (fSCA) Level 3 algorithm determines the fraction of snow cover for each pixel in a Landsat scene. This algorithm was created at the U.S. Geological Survey (USGS) Alaska Science Center in cooperation with USGS Earth Resources Observation and Science (EROS) Software Engineers.

The algorithm is currently being applied only to scenes in the United States but is designed to be applicable worldwide.

1.2 Purpose and Scope

The primary purpose of this document is to provide technical details about how the fSCA algorithm is applied to Landsat data.

1.3 Document Organization

This document contains the following sections:

- Section 1 introduces the fSCA algorithm.
- Section 2 provides technical details on the inputs and outputs of fSCA.
- Section 3 provides details on the fSCA algorithm procedures.
- Appendix A provides information specific to the fSCA algorithm auxiliary inputs.
- The References section contains a list of reference documents and supporting webpages.

Section 2 Fractional Snow Covered Area Algorithm Details

2.1 Fractional Snow Covered Area Algorithm Details

The fSCA algorithm determines the fraction of snow for each pixel in a Landsat scene.

The algorithm is currently applied to Landsat 4-5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper Plus (ETM+), and Landsat 8 Operational Land Imager (OLI) scenes.

The fSCA algorithm involves the following steps:

1. Revise the cloud mask.
2. Pre-process the input data (and prepare for modeling).
3. Model fractional snow cover.
4. Post-process the output fSCA and Quality Assessment (QA).
5. Zero out the water pixels.
6. Optional post-processing adjustments attempt to correct for snow covered pixels, which exist in heavy tree canopy areas.

The canopy cover adjustment currently can only be applied to scenes in the U.S., because the inputs needed are only generated for the U.S.

2.2 Fractional Snow Covered Area Algorithm Inputs

The fSCA algorithm requires the following inputs:

- Landsat Level 2 pixel QA mask
- Top-of-Atmosphere (TOA) reflectance
- Surface reflectance
- Dynamic Surface Water Extent (DSWE)
- Several static inputs as described in Appendix A

2.3 Fractional Snow Covered Area Algorithm Outputs

The procedure creates the following bands:

- Revised cloud mask – unsigned 8-bit integer
The final cloud mask output also includes water pixels; however, these water pixels are handled in the zero_water_pixels application using DSWE products
- Fractional snow cover band – 16-bit integer

Section 3 Fractional Snow Covered Area Algorithm Procedure

The fSCA algorithm procedure contains the steps detailed in the following sections (these are listed in Section 2.1).

3.1 Revised Cloud Mask

The Landsat Level 2 QA cloud mask application (based on CFmask) flags many snow pixels as cloud pixels (particularly in the conifer forests with snow cover), which is problematic for identification of snow.

This revised cloud mask process uses a rule-based model to clean up the cloud mask to correctly identify snow pixels and unmask them as clouds. The model is based on TOA reflectance values. The code was set up to support TOA or surface reflectance values; however, the rule-based model currently only has values for TOA reflectance. This mask is provided for mapping glaciers.

Input

1. Landsat Level 2 pixel QA mask
2. Landsat TOA reflectance bands (1-5, 7 for TM / ETM+ and 2-7 for OLI)

This process flags pixels, which are less than seven percent reflectance in the green and Near Infrared (NIR) bands. These pixels are flagged as priority over any other QA value. When reflectance is that low in both bands, it is possible that flagged pixels are shadowed – usually by terrain, but possibly from clouds. (When running an algorithm, which maps glaciers and perennial snowfields as only those pixels where snow cover is retrieved in every cloud-free instance over a certain period, it might be desirable to exclude cases where snow may have been missed due to shadowing.)

The model uses the input QA mask to look at pixels identified as cloud. If the pixel is identified as a “true cloud”, it is flagged as cloud in the revised cloud mask. It uses the reflectance bands, along with Normalized Difference Vegetation Index (NDVI) and Normalized Difference Snow Index (NDSI) indices.

The cloud pixels are then run through a 5x5 erosion filter, followed by a 5x5 dilation filter, to obtain the final output. Any pixel determined clear in the QA mask is clear in the revised cloud mask. Any pixel determined cloud in the revised mask is flagged as such. Pixels flagged as cloud in the QA mask but not in the revised mask are also flagged. Fill pixels in the QA mask are flagged as fill in the revised cloud mask.

The revised cloud mask is an unsigned 8-bit integer with the following values:

- 0 – clear
- 1 – cloud in Level 2 QA cloud mask
- 2 – cloud

- 3 – water (flagged at a later time by zero_water_pixels)
- 4 – reflectance in green and NIR bands is less than seven percent
- 255 – fill

Output

1. Revised cloud mask (unsigned 8-bit integer)

3.2 Pre-Processor

This step performs the necessary preprocessing of the input Landsat scene (and associated inputs) to prepare the data for Landsat Thematic Mapper-based fractional Snow Covered Area and Grain size (TMSCAG) modeling. TMSCAG requires one or more saturation models to identify pixels that are saturated, which are then not modeled.

Input

1. Revised cloud mask
2. Landsat surface reflectance bands (1-5, 7 for TM / ETM+ and 2-7 for OLI)

These saturation files specify the pixels, which are modeled in TMSCAG and/or the TMSCAG emulator. All saturation files skip modeling for fill (from the revised cloud mask), high confidence clouds (from the revised cloud mask), and low NDSI values ($NDSI < -0.3$). The base file for these is the no saturation file (nosat), which represents the general information for modeling pixels, ignoring any saturation.

If processing TM / ETM+, then a saturation 1 (sat1) and saturation 1&3 (sat13) file are also needed as input to TMSCAG:

- sat1 turns modeling off when band 1 is saturated, and bands 2 and 3 are not saturated.
- sat13 turns modeling off when bands 1 and 3 are saturated, and band 2 is not saturated.
- Although it is currently not needed, this application also generates a sat123 file, which turns off modeling if bands 1, 2, and 3 are all saturated. A value of 1 in these saturation files indicates the pixel is to be modeled.

These saturation files are needed for TM / ETM+ because pixels in the visible range tend to saturate over snow covered areas. The OLI instrument has a higher range of represented values, and saturation is generally not an issue over snow covered areas.

TMSCAG also requires the surface reflectance to be input as Band Interleave by Pixel (BIP). The input ESPA single-band reflectance bands are stacked into a single BIP output file to be read by TMSCAG. The surface reflectance values in the BIP file are written the same as they appear in the input reflectance files, except as BIP. The data are scaled 16-bit integers, with a scale factor of 10,000.

Output

1. Surface reflectance bands in BIP, 6-bit integer, 1-5,7 for TM / ETM+ and 2-7 for OLI
2. No-saturation mask (unsigned 8-bit integer)
3. Saturation band 1 mask (unsigned 8-bit integer)
4. Saturation bands 1 and 3 mask (unsigned 8-bit integer)
5. Saturation bands 1, 2, and 3 mask (unsigned 8-bit integer)

3.3 Thematic Mapper- Based Fractional Snow Cover and Grain Size (TMSCAG)

This model performs spectral mixture analysis to identify various spectra at the pixel level.

Input

1. Landsat surface reflectance bands in BIP, 16-bit integer, 1-5, 7 for TM / ETM+ and 2-7 for OLI
2. No-saturation mask (unsigned 8-bit integer)
3. Saturation band 1 mask (unsigned 8-bit integer) – for TM / ETM+
4. Saturation bands 1 and 3 mask (unsigned 8-bit integer) – for TM / ETM+
5. Spectral libraries for 30°, 45°, and 60° solar zenith angles (4-byte floats in BIP format for each of the 6 TM / ETM+ and OLI reflectance bands)
6. Model control files – contain information on the spectral library, endmember models, grain size table

The back-end spectral libraries are integral for this process. The libraries are 2-endmember and 3-endmember linear spectral signatures created from in-situ measurements and laboratory-generated signatures. The last endmember in each library is shade. The first endmember is commonly snow; however, there are a few libraries that do not include snow and instead include another endmember such as granite or vegetation. This means that for any pixel, the results do not include all the possible endmembers (e.g., snow, rock, vegetation, lake / ice, etc.)

Each pixel will be limited to the number of endmembers represented (two or three). The libraries include vegetation, granite, lake ice, volcanics, metamorphics, soils derived from glacial till, snow, and shade.

The model being used was originally called tmscagSAT, which handles the saturation in the visible bands for TM / ETM+ as it is a well-known issue that TM / ETM+ frequently saturate over snow in the visible bands. As Painter, et. al. documented, “ETM+ and TM frequently saturate over snow in bands 1 through 3, resulting in a spectrum with artificially low apparent reflectance in the visible wavelengths. Landsat TM has a larger dynamic range in bands 2 and 3 than ETM+, resulting in fewer saturated pixels in bands 2 and 3. Raw spectral mixture analyses of these saturation-afflicted reflectance spectra result in erroneously low estimates of snow fraction. Therefore, when the three visible bands are saturated, assume 100 percent snow cover. This assumption can represent an overestimate if subpixel rock or vegetation is present, but this is the most reasonable

assumption with the given information. In the scenarios of bands 1 and 3 saturated or band 1 only saturated, perform spectral mixture analysis on the remaining bands.”

The fractions modeled by TMSCAG are shade-normalized fractions. When the spectral signature of the current pixel is matched to the spectral library signature, the library with the lowest Root Mean Square Error (RMSE) is selected. Furthermore the 3-endmember results are selected as higher-priority over the 2-endmember results. The fractions for each endmember are then calculated. Those fractions are divided by the shade fraction, which then allows the sum of the non-shade fractions to add to 1.0.

The spectral libraries are generated for three solar zenith angles (30°, 45°, and 60°) as the solar illumination heavily affects the spectral signature of the pixel. The source code identifies the desired spectral library by using the solar zenith angle at the scene center, and uses the closest library to that solar zenith angle. The values in the spectral library represent surface reflectance for each endmember.

The spectral libraries have been scaled by 10,000. This scaling matches the scaling on the Landsat surface reflectance products. These spectral libraries are for TM / ETM+; however, the same spectral libraries are also being used for OLI with reasonable results. If OLI-specific spectral libraries are generated in the future, the current libraries in the OLI subdirectory can be replaced.

Each spectral library is run through the model using tight constraints, then again with loose constraints. The results from the tight constraints are prioritized over the loose constraints, if the RMSE is reasonable (based on model constraints from a control file). A total of 15 model sets are each run twice for the constraints. The 2-endmember and 3-endmember models have a tight constraints control file and a loose constraints control file. Therefore, overall, TMSCAG is run a total of 30 times to cover the 15 model sets at each constraint level.

Each mode has a model constraint file that applies to all 2-endmember or 3-endmember models (separate constraint files for both as well as tight and loose parameters). These constraint values include the fraction minimum / maximum values (to be used for each endmember), the RMSE threshold, and the residual threshold. When running TMSCAG, these constraint values are used to indicate if the results for the current pixel and model are within the constraints. If they are, then those values are written to the output images, including the RMSE. If they fall outside the constraints, then that pixel remains unmodeled in the output images for that model.

The original TMSCAG constraint files used a loose RMSE threshold and a residual threshold of 30.0 for 2-endmember and 50.0 for 3-endmember models. Given that these thresholds often left pixels in the snow region unmodeled, those loose threshold constraints were increased to 2500.0. The goal with such a large increase was to model the pixel, regardless of any thresholds. For comparison, the tight constraints for these thresholds are 15.0.

After all the models are run, then TMSORT is called to iterate through the 30 different model and constraint results, sorting according to the priorities (3-endmember models over 2-endmember models, tight constraints over loose constraints, and the highest RMSE model value), to create the optimized results for that set of models.

Due to the common saturation in the visible bands for TM / ETM+, the spectral signature of snow with the saturated pixels does not model well. Therefore, TM / ETM+ scenes are run through the TMSCAG models three different times, using the saturation mask generated in the pre-processor. The first model set run is with the no saturation mask, which ignores saturation, using all reflective bands. The second run is with the saturation band 1 mask, and not using TM / ETM+ band 1. The third model set run is with the saturation bands 1 and 3 mask, and not using TM / ETM+ bands 1 and 3. For each of these runs, the TMSORT application is used to generate optimized results for that saturation model run. The final output from the TMSCAG model runs then include TMSCAG results for each of the saturation levels. When processing OLI scenes, saturation is not an issue and therefore TMSCAG modeling is only applied at the no saturation level.

Due to the saturation levels, modeling TM / ETM+ becomes quite time-consuming. There are 30 models run for each saturation level, which means a total of 90 “model runs”.

The 15 different models currently used by TMSCAG include gr (granite), grveg (granite-vegetation), lkice (lake ice), met (metamorphics), metveg (metamorphics-vegetation), till (soils largely derived from glacial till), veg [1-4] (four different vegetation models), vlc [1-3] (three different volcanics models), and vlcvveg (volcanics-vegetation). In most cases, snow is the first endmember, then the next endmember is dependent upon the model name, and shade is the third endmember. In the models where there are two endmembers described in the model name (e.g., grveg), then the model name describes the first two endmembers (in this example granite and vegetation) and shade is the third endmember.

The spectral libraries used by each model are stored as band interleave by pixel; the first 6 pixels are the first spectra values for all 6 bands. Next are the spectra values for all 6 bands of the next spectra, etc. There are 165 spectra listed in each spectral library, and the data are each four-byte floats (and are scaled by 10,000). Each of the control files specifies which spectral library should be used, based on the solar zenith angle. The control file also includes a TM.LIB.EMTYPE file that describes the endmember type of each of the spectra in the library. This file lists 0-snow, 1-veg, 2-rock, 3-other, and shade is always the last endmember.

Output

1. TMSCAG fractional products for each of the saturation levels (snow, vegetation, rock, shade, other, grain size, RMS) (16-bit scaled integer)
2. TMSCAG mask files for each of the saturation levels (8-bit integer)

3.4 Post-Processor

This application handles the TMSCAG post-processing to:

- Mosaic the results of each of the saturation levels into one product
- Address fractional snow covered area results for fully saturated pixels
- Emulate TMSCAG results for pixels that were not modeled
- Zero out fractional snow covered area for values less than a predefined snow cutoff value

The post-processor emulates TMSCAG values if emulation-only was specified, in which case the TMSCAG results are not needed.

Input

1. Landsat surface reflectance bands (1-5, 7 for TM / ETM+ and 2-7 for OLI)
2. TMSCAG fractional products for each of the saturation levels
3. TMSCAG mask files for each of the saturation levels
4. No-saturation model mask

If TMSCAG modeling is used, the output TMSCAG model masks are used from each saturation level to determine the final mosaic of TMSCAG values. If the mask for the saturation level (in order of no saturation, saturation band 1, and saturation bands 1 and 3) indicates the pixel was modeled, then the TMSCAG results from that saturation level are used. If the pixel was not modeled in any of the saturation levels, then the results for that pixel remain unmodeled.

When processing OLI scenes, the mosaic is simply the TMSCAG results from the no saturation run, given that multiple saturation levels do not exist. In the case of emulation-only modeling, then all pixels are marked as unmodeled so that they will be emulated in the following steps.

The overall model mask is an unsigned 8-bit integer with the following values:

- 0 – unmodeled in all saturation levels (also used for emulation-only)
- 1 – used the results from the no-saturation level
- 2 – used the results from the saturation 1 level
- 3 – used the results from the saturation 1 and 3 level

Based on the modeling mask generated for the mosaicking of the TMSCAG products, each of the TMSCAG fractional outputs are mosaicked from the various saturation levels into one overall product. The TMSCAG results for fractional snow covered area are mosaicked into one overall fractional snow covered area product, based on the saturation levels identified in the overall model mask. The same goes for grain size, rock, vegetation, other, and shade fractional area products. The RMS is also mosaicked. Each of these fractional products and RMS are written as a 16-bit integer that maintains the original scaling from TMSCAG.

The fractional snow covered area values are then further refined (if using the TMSCAG values and not emulating), and the associated model mask is updated. For any fractional snow covered area pixel values modified in the post-processor after the original merging of the saturation levels, the output model mask values are 99 (representing the value was assigned in the post-processor).

If the pixel is saturated in TM / ETM+ bands 1, 2, and 3, then the fractional snow cover is reset to 100 percent if the band 5 value is below 0.2 (band 5 snow low threshold). If the fractional snow covered area is below the minimum snow cutoff of 15 percent, then the fraction is set to 0 percent.

At this time, any unmodeled pixels that were masked to be modeled in the no-saturation mask are emulated for fractional snow covered area using a rule-based model developed to emulate the TMSCAG fractional snow covered area. Any pixels that were marked to not be modeled are left as unmodeled. Any pixels masked to be modeled, but were not able to be emulated remain unmodeled.

All fractional snow covered area values are clipped to be between 0 and 100 percent and are output (overall TMSCAG fractional snow covered area values are updated) as scaled 16-bit integers using the original scaling from TMSCAG. All unmodeled pixels are set to 0 percent as well. The overall TMSCAG model mask is also updated.

Output

1. Fractional snow covered area (16-bit integer)
2. TMSCAG model mask (unsigned 8-bit integer)

3.5 Zero Water Pixels

As TMSCAG tends to mark water (lakes and rivers / streams) as snow covered, this procedure uses the DSWE product to identify water pixels, and then zeros out the fractional snow covered-area for pixels that are water.

Input

1. Revised cloud mask
2. Fractional snow covered area
3. DSWE interpreted band
4. DSWE percent-slope, hillshade, cloud, cloud shadow, and snow filtered

The DSWE Percent Slope, Hillshade, Cloud, Cloud Shadow, and Snow Filtered (PSHSCCSS) band is used to first identify water pixels. With this band, water-high confidence (value of 1) and water-moderate confidence (value of 2) are marked as water pixels in the updated revised cloud mask. This band tends to miss rivers; however, those river areas are flagged as high-confidence in the DSWE interpreted band.

Another pass through the pixels is made to find snow covered pixels that are also high-confidence water pixels in the DSWE interpreted band. These pixels are also flagged

as water in the revised cloud mask. A 3x3 filter is applied to the pixels identified as snow, in order to buffer them slightly. The revised cloud mask values are written back to the existing revised cloud mask file, using a value of 3 to identify water.

The next step is to identify which pixels in the fractional snow covered area were falsely identified and should be zeroed out as water pixels. A count of the non-zero snow fractions in a 15x15 window is determined for each pixel, followed by the algorithm passing through the fSCA pixels to zero out the fractional snow covered area if:

1. The pixel is water in the revised cloud mask
2. The snow count for this pixel is less than 50
3. The snow covered fraction for this pixel is non-zero

The updated fractional snow covered area values are written back to the existing fractional snow covered area band.

Output

1. Revised cloud mask – updated to flag water pixels
2. Fractional snow covered area – updated to zero out any pixel deemed water

3.6 Adjustment for Canopy Cover

This application adjusts the fractional snow covered area values for canopy cover, and adjusts zero-valued pixels of high canopy cover to match similar pixels in the surrounding area.

Input

1. Fractional snow covered area (16-bit scaled integer)
2. Revised cloud mask
3. Solar radiation (10-day intervals) datasets
4. National Land Cover Database (NLCD) landcover (unsigned 8-bit integer) *
5. NLCD tree canopy percent cover (unsigned 8-bit integer)
6. Elevation file (16-bit integer)

* NLCD is only available for the United States so the canopy cover adjustment cannot currently be applied to scenes outside the United States.

Similar pixels are determined from accumulated solar radiation, snow cover, and elevation. The accumulated solar radiation is based on the current Day of Year (DOY) for the scene – and is the sum of the solar radiation starting on October 1 (DOY 274) up through the current DOY (wrapping around at the start of the year for scenes before DOY 274). Currently, the application expects the solar radiation bands to be available starting with DOY 274 and in 10-day increments for the remaining days in the year through DOY 189, for a total of 29 solar bands. The actual solar radiation for each day is interpolated between the 10-day intervals.

This process first calculates the accumulated solar radiation for each pixel, and sets the canopy cover to 0 for deciduous forest pixels and half the original canopy cover value for mixed forest pixels. It then loops through the scene looking for clear pixels (not cloud or fill) that have a fractional snow cover of 0.

These pixels are assessed to determine if they may be snow covered, but obscured by the canopy. If such a pixel is found, the 31x31 surrounding window is checked for snow covered pixels. If one or less snow covered pixels exist, then this pixel is not snow covered. Otherwise, the mean of the canopy values is computed for the 3x3 surrounding window.

If the canopy value of the current pixel meets the threshold and the 3x3 canopy mean also meets the threshold, then the 11x11 window is assessed for "similar pixels". Similar pixels are identified as those having lower canopy values, slightly higher solar loading (greater than or equal to 1.01 times the solar radiation of the current pixel), an elevation less than 75 meters above the current pixel, and not obscured by clouds. If the pixel is found to be similar, then it is also checked if it is snow. If enough similar pixels can be found within the search window, based on a threshold, then the ratio of similar snow covered pixels to the total similar pixels is computed. If that ratio meets the threshold criteria, then the pixel is marked as new snow.

If not enough similar pixels were found, then the search window is expanded to a 31x31 window. This time "similar pixels" are assessed, based on the previously identified criteria. If enough similar pixels are found, based on a new threshold, and the ratio of similar snow covered pixels to the total similar pixels meets another threshold, then the pixel is marked as new snow. If not enough fractional snow covered pixels were found, then the pixel is flagged as not snow.

Now that pixels are flagged as not snow or new snow, another loop is made through the pixels. If a pixel is not new snow and the fractional snow cover is non-zero, then the fractional snow cover value is adjusted based on the canopy cover. Otherwise, for newly identified snow cover pixels, their fractional snow cover is estimated based on the canopy cover. All other fractional snow cover values remain unmodified.

All fractional snow covered area values are clipped to be between 0 and 100 percent and are output (overall TMSCAG fractional snow covered area values are updated) as scaled 16-bit integers using the original scaling from TMSCAG.

Output

1. Fractional snow covered area, updated for canopy cover (16-bit scaled integer)

3.7 fSCA Statistics

This procedure processes the N-year fSCA mean fractions (monthly and annual) using the clear pixels (non-fill and non-cloud) from each scene in the stack.

Input

1. Stack of fractional snow covered area products, including the revised cloud mask and XML file

When processing Landsat path/rows, the user can specify that Level 1 Systematic (L1GS), high RMSE, and/or high cloud cover scenes be excluded. If excluded, those products are moved to an `exclude_l1g`, `exclude_rmse`, or `exclude_cloud_cover` subdirectory to prevent the scene from being processed and to document which scenes were excluded for which reason. Because of the high accuracy of Landsat Analysis Ready Data (ARD), these exclusion options are not available when processing temporal stacks of tiles.

For path/rows, the minimum bounding box for the stack is used for statistics. For the ARD tiles, the tile geographic extents are used. Monthly and annual fractions for fractional snow cover are generated, using the N-year date ranges. The mean fractions are values between 0 and 100.

Monthly and “annual” statistics are generated for the following 5-year, 10-year, and 35-year periods:

5-year (7): 1986-1990, 1991-1995, 1996-2000, 2001-2005, 2006-2010, 2011-2015, 2016-2020

10-year (4): 1986-1995, 1996-2005, 2006-2015, 2016-2025

35-year (1): 1986-2020

Output

1. Monthly and “annual” mean fractions generated as 5-year, 10-year, and 35-year periods (unsigned 8-bit scaled integer)
2. Count of the number of clear pixels used for the fractions (unsigned 16-bit integer)

3.8 Scripts to Assist with Landsat ARD Tile and Path/Row Stack Processing

The `process_tmescag_stack.py` and `process_tmescag_stack_ard_tiles.py` scripts are available to handle the end-to-end processing for an entire stack of path/row Landsat Collections or ARD tiles. Different command line options can be specified to include canopy-adjustment or to use the local scratch space, identified by the `LOCAL_SCRATCH` environment variable.

The stack of TOA reflectance and surface reflectance products are processed one at a time, and the resulting fractional snow cover and revised cloud masks are packaged for delivery.

Appendix A fSCA Algorithm Static Inputs

fSCA processing is based on various inputs to the algorithm that needs to be processed and made available prior to running the fSCA algorithm. These include the following:

- Spectral libraries for 30°, 45°, and 60° solar zenith angles
- Model control files
- NLCD landcover
- NLCD tree canopy percent cover
- Elevation dataset
- Solar radiation datasets

The spectral libraries (currently only available for Landsat 4-7; however, these libraries are used for Landsat 8) and model control files were provided as part of the TMSCAG software and are static products, not related to the path/row or tile/region being processed. The TMSCAG_CONFIG environment variable is used to identify the directory that contains these libraries and control files.

The ESPA_LANDCOVER_CONUS environment variable is used to identify the current location of this conterminous U.S. dataset. This dataset is resampled and cropped to the current scene extents for input into the fSCA algorithm. The current product is the 2011 NLCD edition from 2014, which is the most recent. If processing ARD tiles, this product needs to be available for the ARD tile/region being processed.

The ESPA_TREE_CANOPY_CONUS environment variable is used to identify the current location of this conterminous U.S. dataset. This dataset is resampled and cropped to the current scene extents for input into the fSCA algorithm.

The current product is the 2011 NLCD edition from 2014, which is the most recent. If processing ARD tiles, this product needs to be available for the ARD tile/region being processed.

The elevation dataset is generated for the maximum extent of the entire path/row stack. The ESPA-elevation project is used to generate the elevation dataset, based on the user-specified extents for the path/row or the preset extents of the ARD tile/region. One of the scenes from the path/row or ARD tile need to be fed to the ESPA-elevation executable along with the maximum extents of the stack to override the scene-based extents (if processing path/row).

The solar radiation bands are generated via the Geographic Resources Analysis Support System (GRASS) Geographical Information System (GIS) Application Programming Interface (API), using the Digital Elevation Model (DEM) as input. Solar radiation bands need to start at DOY 274, wrap into the beginning of the year, and continue through DOY 189. These solar radiation bands are in 10-day intervals (274, 284, 294, 304, ... 364, 009, 019, 029, ... 189) for a total of 29 bands. The ESPA_SOLAR_RADIATION_DIR environment variable is used to identify the directory

containing the solar radiation bands. These bands need to be available for each path/row or ARD tile/region.

There are two scripts available that assist in generating the canopy-adjustment inputs needed prior to canopy adjustment.

The `generate_canopy_adjust_inputs.py` script produces the inputs needed for canopy adjustment for the current path/row stack, using a pre-determined maximum geographic extent for that path/row. Elevation files are written to the path/row directory under `ESPA_DEM_DIR`. That elevation product is then passed into the GRASS application to generate the solar radiation files, which are written to the path/row directory in `ESPA_SOLAR_RADIATION_DIR`.

The `generate_canopy_adjust_inputs_ard_tiles.py` script produces the inputs needed for canopy adjustment for the specified ARD tile and region (CU, AK, etc.). Elevation files are written to the region and ARD tile directory under `ESPA_DEM_DIR`. That elevation product is then passed into the GRASS application to generate the solar radiation files, which are written to the path/row directory in `ESPA_SOLAR_RADIATION_DIR`.

Given that all the scenes in the tile are the same geographic extent (versus the path/row processing), the landcover and canopy cover products are also generated for this tile. These products are stored in the ARD tile/region directory under `ESPA_LANDCOVER_DIR` and `ESPA_TREE_CANOPY_DIR` directories.

References

Please see <https://landsat.usgs.gov/glossary-and-acronyms> for a list of acronyms.

CFMask

<https://landsat.usgs.gov/what-cfmask>

USGS NLCD Landcover

<http://www.mrlc.gov>

USGS EROS Science Processing Architecture (ESPA) Elevation Project

<https://github.com/USGS-EROS/espa-elevation>

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