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ABoVE: Corrected MODIS MAIAC Reflectance at Tower Sites, Alaska and Canada, 2000-2016

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Documentation Revision Date: 2019-07-31

Dataset Version: 1

Summary

This dataset provides angular corrections of MODIS Multi-Angle Implementation of Atmospheric Correction algorithm (MAIAC) surface reflectances by two methods at each of 62 flux tower sites (1 km x 1 km area) across the ABoVE domain in Alaska and western Canada from 2000 to 2015/2016. The original MAIAC reflectance data were corrected to consistent view and illumination angles (0 degree view zenith angle and 45 degree of sun zenith angle) using two independent algorithms: the first based on the original BRDF (Bidirectional Reflectance Distribution Function) parameters provided by the MAIAC team, and the second based on a machine learning approach (random forests). The corrected data preserve the original MAIAC data's sub-daily temporal resolution and 1 km spatial resolution with seven land bands (bands 1-7) and five ocean bands (bands 8-12). The resulting tower site sub-daily timeseries of angular corrected surface reflectances are suitable for long-term studies on patterns, processes, and dynamics of surface phenomena.

The 62 flux tower sites are located across the ABoVE domain (Figure 1) within 10 different Terra and Aqua satellite MODIS MAIAC tiles. The dataset includes the tile ID, latitude and longitude for the center of site located pixel, pixel index in the MAIAC tile for each site, and the distance in kilometers between site location and the pixel center. The dataset also includes the Ross-Thick Li-Sparse (RTLS) volumetric kernel function values (Fv), and geometric-optics kernel function values (Fg) originally provided by MCD19A1. The observation time, sun-view geometry, the cloud and land masks from MCD19A1, and International Geosphere-Biosphere Programme (IGBP) land cover class are also included.

This data set includes one data file in CSV (.csv) format, with the original MAIAC MODIS, BRDF corrected, and RF corrected reflectances plus the tower site characteristics for each of 62 flux tower sites.
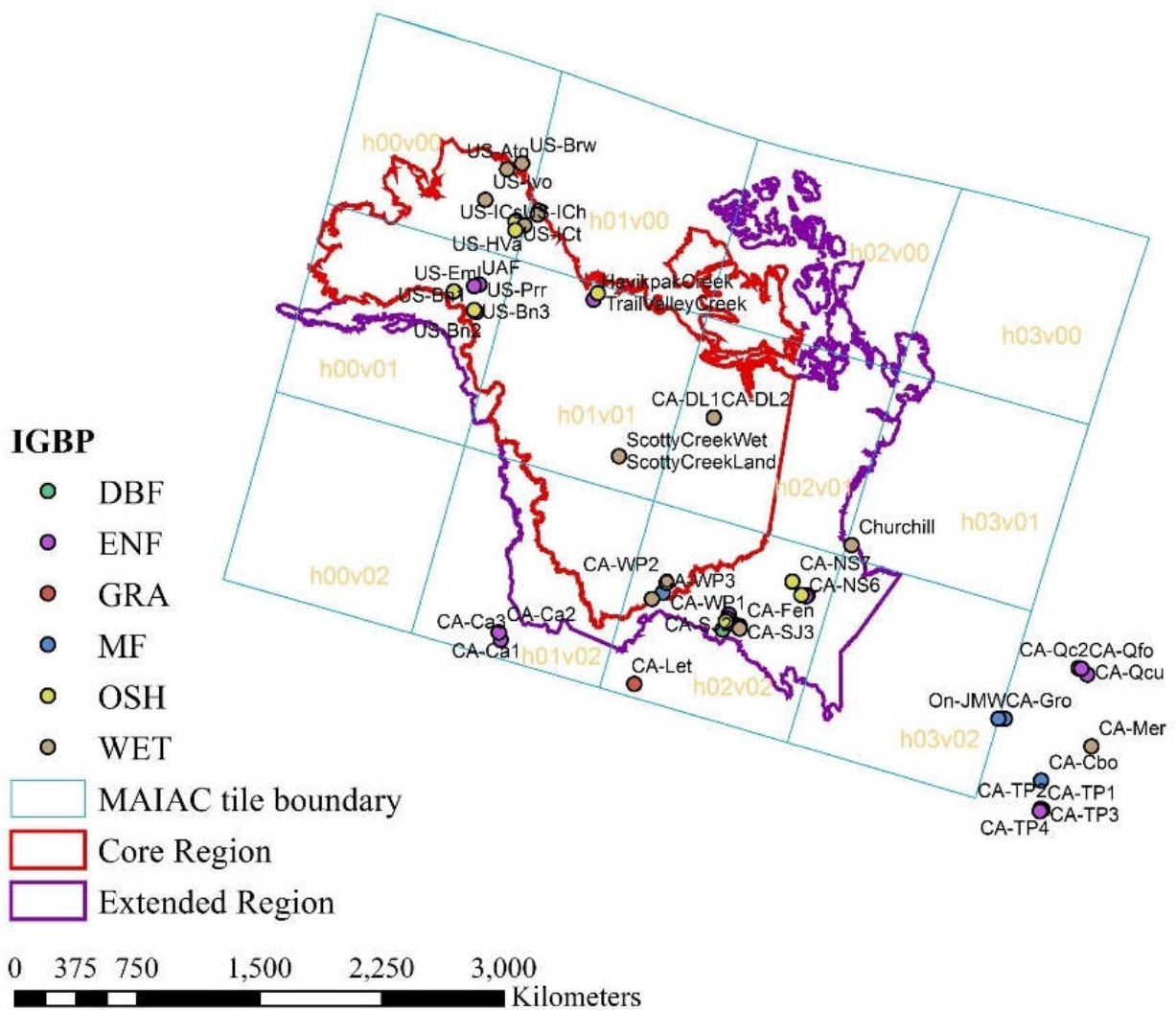
Figure 1. MAIAC tiles, flux sites with their IGBP classes, and ABoVE core and extended domain boundaries. IGBP classes: DBF-deciduous broadleaf forests; ENF-evergreen needleleaf forests; GRA-grasslands; MF-mixed forests; OSH-open shrubland; WET-permanent wetland; OSH-open shrubland; WET-permanent wetland (Yu et al., 2019, in preparation).

Citation

Yu, R., G. Hmimina, K.F. Huemmrich, D.P. Billesbach, A. Lyapustin, Y. Wang, and J.A. Gamon. 2019. ABoVE: Corrected MODIS MAIAC Reflectance at Tower Sites, Alaska and Canada, 2000-2016. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/1700

Table of Contents

1. Dataset Overview

This data set provides angular corrections of MODIS Multi-Angle Implementation of Atmospheric Correction algorithm (MAIAC) surface reflectances (Lyapustin et al., 2018; product MCD19A1) by two methods at each of 62 flux tower sites (1 km x 1 km area) across the ABoVE domain in Alaska and western Canada from 2000 to 2015/2016. The original MAIAC reflectance data were corrected to consistent view and illumination angles (0 degree view zenith angle and 45 degree of sun zenith angle) using two independent algorithms: the first based on the original BRDF (Bidirectional Reflectance Distribution Function) parameters provided by the MAIAC team, and the second based on a machine learning approach (random forests). The corrected data preserve the original MAIAC data's sub-daily temporal resolution and 1 km spatial resolution with seven land bands (bands 1-7) and five ocean bands (bands 8-12). The resulting tower site sub-daily timeseries of angular corrected surface reflectances are suitable for long-term studies on patterns, processes, and dynamics of surface phenomena since angular effects in bands have been reduced.

The 62 flux tower sites are located across the ABoVE domain (Figure 1) within 10 different Terra and Aqua satellite MODIS MAIAC tiles. The dataset includes the tile ID, latitude and longitude for the center of site located pixel, pixel index in the MAIAC tile for each site, and the distance in kilometers between site location and the pixel center. The dataset also includes the Ross-Thick Li-Sparse (RTLS) volumetric kernel function values (Fv), and geometric-optics kernel function values (Fg) originally provided by MCD19A1. The observation time, sun-view geometry, the cloud and land masks from MCD19A1, and International Geosphere-Biosphere Programme (IGBP) land cover class are also included.

Project: Arctic-Boreal Vulnerability Experiment

The Arctic-Boreal Vulnerability Experiment (ABoVE) is a NASA Terrestrial Ecology Program field campaign based in Alaska and western Canada between 2016 and 2021. Research for ABoVE links field-based, process-level studies with geospatial data products derived from airborne and satellite sensors, providing a foundation for improving the analysis and modeling capabilities needed to understand and predict ecosystem responses and societal implications.

Related Publication:

Acknowledgments:

2. Data Characteristics

Spatial Coverage: Flux tower sites across Alaska and Canada

ABoVE Reference Locations:

Domain: Core and extended ABoVE

State/territory: Alaska and Western Canada

Grid Cells:

Ah1Av0Bh6Bv5Ch36Cv33,Ah1Av0Bh8Bv1Ch50Cv7, Ah1Av0Bh7Bv1Ch46Cv8, Ah1Av0Bh7Bv2Ch42Cv15, Ah1Av0Bh8Bv2Ch53Cv17, Ah1Av0Bh8Bv3Ch53Cv18, Ah1Av0Bh8Bv3Ch48Cv19, Ah1Av0Bh8Bv3Ch50Cv20, Ah1Av0Bh8Bv3Ch48Cv21, Ah1Av0Bh6Bv5Ch40Cv32, Ah1Av0Bh6Bv5Ch41Cv32, Ah1Av0Bh10Bv5Ch65Cv34, Ah1Av0Bh10Bv5Ch64Cv35, Ah1Av1Bh6Bv6Ch40Cv37, Ah1Av1Bh11Bv11Ch69Cv67, Ah1Av2Bh7Bv17Ch45Cv103, Ah1Av2Bh7Bv17Ch45Cv105, Ah2Av1Bh14Bv9Ch89Cv59, Ah2Av2Bh13Bv15Ch79Cv93, Ah2Av2Bh13Bv15Ch78Cv95, Ah2Av2Bh12Bv16Ch76Cv96, Ah2Av2Bh15Bv16Ch92Cv99, Ah2Av2Bh17Bv15Ch105Cv93, Ah2Av2Bh17Bv15Ch107Cv95, Ah2Av2Bh15Bv16Ch92Cv100, Ah2Av2Bh15Bv16Ch91Cv101, Ah2Av2Bh15Bv16Ch93Cv101, Ah2Av2Bh15Bv17Ch91Cv102, Ah2Av2Bh15Bv17Ch94Cv102, Ah2Av3Bh12Bv19Ch73Cv114, Ah3Av2Bh18Bv15Ch108Cv95, Ah3Av2Bh19Bv14Ch117Cv85, Ah3Av2Bh18Bv16Ch108Cv96, Ah4Av3Bh27Bv18Ch163Cv110, Ah4Av3Bh27Bv18Ch164Cv110, Ah4Av3Bh27Bv18Ch165Cv112, Ah4Av3Bh24Bv20Ch147Cv121, Ah4Av3Bh24Bv20Ch148Cv121, Ah4Av3Bh27Bv21Ch166Cv126, Ah4Av3Bh26Bv22Ch156Cv133, Ah4Av3Bh26Bv23Ch156Cv139, Ah4Av3Bh26Bv23Ch156Cv140

Spatial Resolution: Data are provided for 1 km^2 pixels at each tower site

Temporal Coverage: 2000-02-24 to 2016-07-31 (Please note: only 12 southern sites have data until 2016-07-31, the rest of sites have data until 2015-04-30)

Temporal Resolution: The number of MAIAC observations within each day varied from 0 to 12, and most sites had one to four observations per day.

Study Areas (All latitude and longitude are given in decimal degrees)

Site	Westernmost Longitude	Easternmost Longitude	Northernmost Latitude	Southernmost Latitude
Alaska and Canada	-157.409	-74.0365	71.3225	42.6353

Data File Information

This data set includes one data file in .csv format: **MAIAC_site_reflectance.csv .**

This file provides original MODIS MAIAC bidirectional reflectances, BRDF angular corrected reflectances, and RF angular corrected reflectances plus the site characteristics for 1-km x 1-km pixels located at 62 flux tower sites across Alaska and western Canada.

User Notes:

- Occasionally, BRDF or RF angular corrections give extreme outliers. It is recommended that the interval [0,1] be applied as a filter on corrected reflectances.
- Data are provided from both Terra and Aqua satellites. Variable sat 1 means Terra and 2 means Aqua. Both MODIS "land" bands (1-8) and "ocean" bands (9-12) are included.
- Tower sites US-ICt, US-ICs, and US-ICh are located in the same 1km^2 pixel.
- Tower sites CA-NS1 and CA-Man are located in the same pixel.
- Tower sites CA-NS3 and CA-NS4 are located in the same pixel.

Table 1. Variables in the data file

Decimal Degrees

Column #	Variable	Units	Description
1	year	YYYY	Year (MODIS)
2	j_date	DD	DOY (MODIS)
3	hour	hh	Hour (MODIS)
4	minute	mm	Minute (MODIS)
5	site_id		Flux site name (AmeriFlux, https://ameriflux.lbl.gov)

6	canada_id		Canada flux site name (if there is one, AmeriFlux, https://ameriflux.lbl.gov)
7	igbp		International Geosphere-Biosphere Programme land cover classes: DBF-deciduous broadleaf forests, ENF-evergreen needleleaf forests, GRA- grasslands, MF-mixed forests, OSH-open shrubland, and WET-permanent wetland
8	latitude	Decimal Degrees	Tower site latitude
9	longitude	Decimal Degrees	Tower site longitude
10	tile_id		The corresponding MODIS MAIAC tile ID for each flux site
11	pixel_latitude	Decimal Degrees	Latitude for the center of site located pixel
12	pixel_longitude	Decimal Degrees	Longitude for the center of site located pixel
13	pixel_index		Pixel index in the MAIAC tile for each site
14	min_dist_square	km	Minimal distance in kilometer between site location and the pixel center
15	pixel_row		Pixel row index in the MAIAC tile for each site
16	pixel_col		Pixel column index in the MAIAC tile for each site
17	relative_az	Degrees	Relative azimuth
18	scattering_angle	Degrees	Scattering angle
19	cos_sza		Cosine of Solar Zenith Angle
20	cos_vza		Cosine of View Zenith Angle
21	fv		Volumetric kernel
22	fg		Geometric kernel
23-34	brf_b1 to brf_b12		Original MODIS MAIAC surface bidirectional reflectance for bands 1 to 12: band 1 data is column 23; band 12 is column 34
35	cloud_mask		Cloud mask values inherited from the original MCD19A1 data file: 0 --- Undefined 1--- Clear 2 --- Possibly Cloudy (detected by AOT filter) 3 --- Cloudy (detected by cloud mask algorithm) 5 -- - Cloud Shadow 6 --- hot spot of fire 7 --- Water Sediments
36	land_water_snow_ice_mask		Land water snow/ice mask values inherited from the original MCD19A1 data file: 0 --- Land 1 --- Water 2--- Snow 3 --- Ice
37	saz	Degree	Solar Azimuth Angle
38	vaz	Degree	View Azimuth Angle
39	satellite		Satellite: Terra or Aqua
40-51	brdf_ref1 to brdf_ref12		BRDF corrected surface bidirectional reflectance for bands 1 to 12: band 1 data is column 40; band 12 is column 51
52-63	rf_ref1 to rf_ref12		Random forest corrected surface bidirectional reflectance for bands 1 to 12: band 1 data is column 52; band 12 is column 63

3. Application and Derivation

This dataset provides angular corrected sub-daily surface land and ocean band reflectances at flux tower sites in boreal and Arctic regions over the ABoVE domain. These data can help interpret ground observations, can provide a better understanding long-term processes and dynamics of surface phenomena at these flux towers locations in high latitudes, and can be used for developing upscaling approaches from flux tower sites using MODIS data (Yu et al., 2019, in preparation.).

4. Quality Assessment

Two quality assessment variables (cloud mask and land mask) are provided, which are inherited from the original MAIAC dataset.

User note: Occasionally, BRDF or RF angular corrections give extreme outliers. It is recommended that the interval [0,1] be applied as a filter on corrected reflectances.

5. Data Acquisition, Materials, and Methods

Input MODIS MAIAC Data

This angular correction dataset was based on the MODIS MAIAC BRF product. The pre-Collection 6 data were obtained directly from the MAIAC team and were slightly different from the currently-available MCD19a1v006 product from Lyapustin and Wang (2018).

All original MAIAC reflectances were extracted from 1-km x 1-km pixels centered at each flux tower in 10 MODIS tiles. Please note flux tower sites (US-ICt, US-ICs, and US-ICh), (CA-NS1 and CA-Man), and (CA-NS3 and CA-NS4) are located in the same pixels, respectively.

The MODIS MAIAC BRF product improves accuracy of cloud detection, aerosol retrievals and atmosphere correction by integrating space and time in the image process and provides additional MODIS ocean bands (8-12). The BRDF parameters in original MAIAC data sometimes are missing or have a low quality during winter and seasonal transitions at high latitudes. Our new angular correction dataset used a random forests (RF) approach to reduce solar-view geometry effects on satellite measurements and provided a new kind of angular corrected reflectance product (Yu et al., 2019, in preparation).
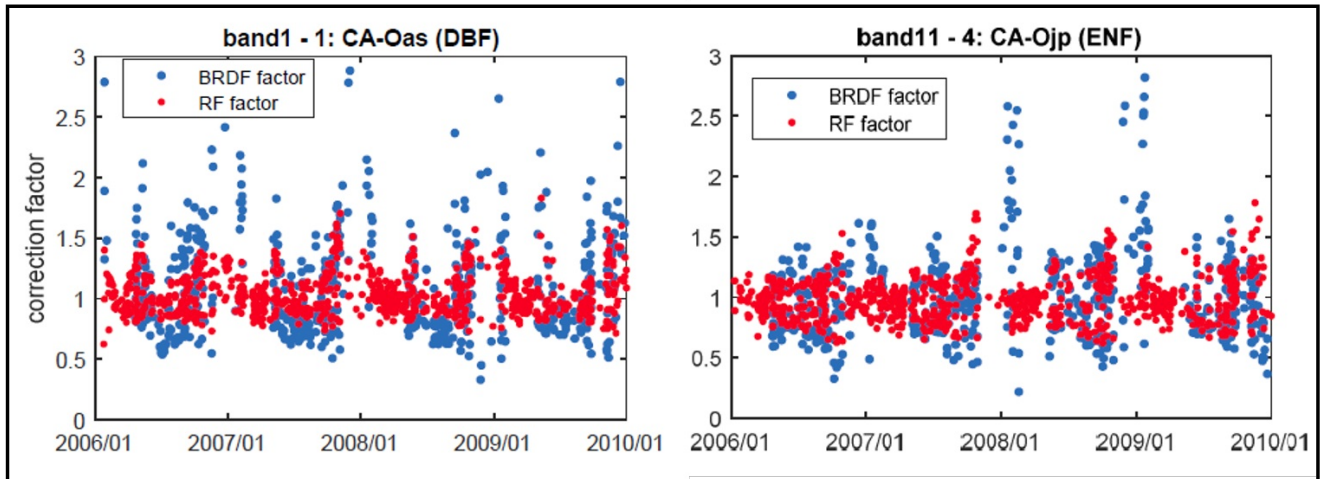

Figure 2. Examples of angular correction factors (BRDF and RF-derived) calculated for MAIAC MODIS band 1 for a deciduous broadleaf forest flux tower site (1 x 1 km^2 pixel), and band 11 for an evergreen needleleaf forest flux tower site (1 x 1 km^2 pixel). These examples illustrate that the RF approach resulted in fewer missing values and outliers (>=2) across bands and ecosystems relative to BRDF (Yu et al., 2019, in preparation).

BRDF based angular correction

Angular correction factor was defined as a ratio of reflectances for a fixed viewing geometry to that for measured viewing geometry. In this dataset, normalized geometry represents nadir view (0°) and 45° degree sun zenith angle (SZA). For BRDF based angular correction, only original MAIAC BRDF model parameters were used to ensure the correction quality. The BRDF based angular correction factors were calculated as equation (1) (e.g., see Lyapustin et al., 2018), and BRDF corrected reflectances were calculated as equation (2). When the BRDF based angular correction factors were out of range [0 2], they were removed as outliers.

$$F_n = (kL - 0.0458621*kV - 1.1068192*kG)/(kL + Fv*kV + Fg*kG) \quad (1)$$

$$BRF_n = F_{BRDF} * BRF \quad\quad\quad\quad (2)$$

Where:

F_n is BRDF based angular correction factor

Fv and Fg are Ross Thick Lee Sparse (RTLS) volumetric and geometric-optics kernel function values, respectively

kL, kV, kG are RTLS isotropic, volumetric, and geometric kernel parameters, respectively

BRF_n is BRDF based angular corrected reflectance

BRF is original bidirectional reflectance

The MODIS MAIAC provided BRDF model parameters for bands 1-8, thus, for ocean bands 9-12, the parameters from the nearest land bands were used, which were bands 3, 3, 4, and 4, respectively.

RF based angular correction

Across the MODIS tiles, 2,683 randomly sampled pixels among a total of 9,601,890 vegetated pixels were used in a "local" random forest model (LRF) for building a "global" random forest model (GRF), which was then applied across the entire study region. LRF derived correction factors were compared to BRDF correction factors. There were good agreements between the two during summer and LRF derived correction factors performed better during seasonal transitions and winter.

For the LRF, all MODIS bands were used as prediction (dependent) variables. The input (independent) variables include time variables, which are year and day of year; the spectrum variable, which is band wavelength; the viewing geometry variables including solar zenith angle (SZA), view zenith angle (VZA), solar azimuth angle (SAZ), view azimuth angle (VAZ), scattering angle, as well as the earth surface condition and vegetation structure and greenness indices NDVI (normalized difference vegetation index), NDSI (normalized difference snow index), NDWI (normalized difference water index for plant canopy water content), and NDWI_2 (normalized difference water index for surface water). The LRF was applied to each individual sampled pixel.

The GRF was created based on angular correction factors of all sampled pixels. Here, the dependent variable was F_{RF} and the independent variables were reflectances (bands 1-12), the viewing geometry variables, and two RTLS parameters, Fv and Fg. Angular
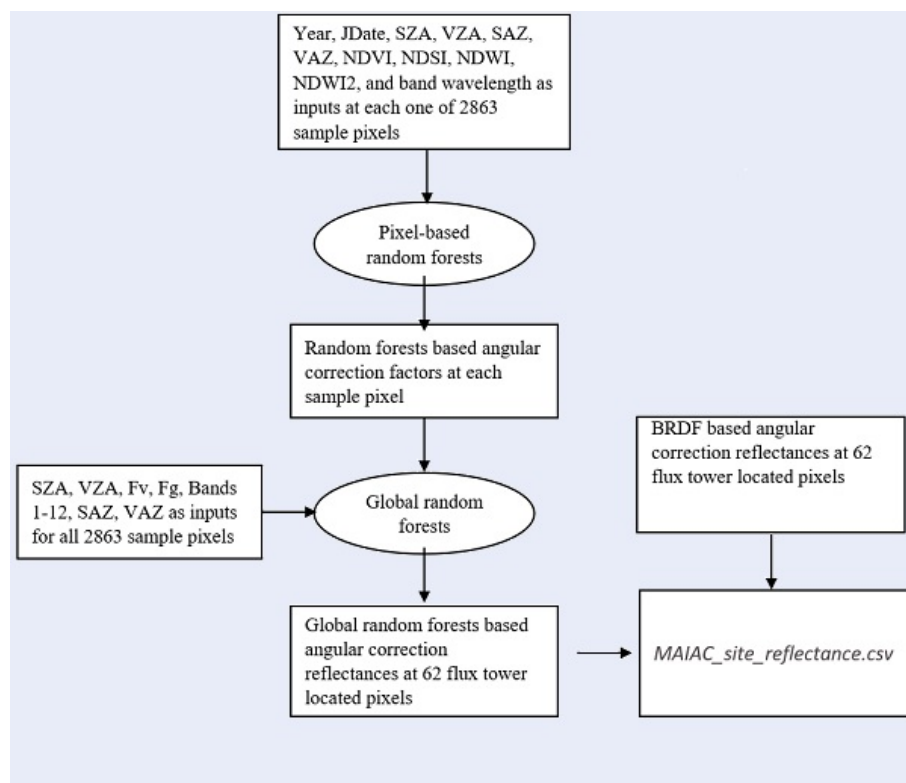
Figure 3. A general workflow chart on achieving angular corrected reflectances with BRDF and RF approaches at 1-km resolution for 62 flux tower sites. Year: observation year; JDate: observation day of year; SZA: solar zenith angle; VZA: view zenith angle; NDVI: normalized difference vegetation index, (band2 – band1)/ (band2 + band1); NDSI: normalized difference snow index, (band4 – band6)/ (band4 + band6); NDWI: normalized difference water index (vegetation water), (band2 – band5)/ (band2 + band5); NDWI2: normalized difference water index (surface water), (band4 – band2)/ (band4 + band2); Fv: RTLS volumetric kernel; Fg: RTLS geometric kernel; SAZ: solar azimuth angle; VAZ: view azimuth angle (Yu et al., 2019, in preparation).

6. Data Access

These data are available through the Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC).

ABoVE: Corrected MODIS MAIAC Reflectance at Tower Sites, Alaska and Canada, 2000-2016

Contact for Data Center Access Information:

- E-mail: uso@daac.ornl.gov
- Telephone: +1 (865) 241-3952

7. References

A. Lyapustin, Y. Wang (2018). *MCD19A1 MODIS/Terra+Aqua Land Surface BRF Daily L2G Global 500m and 1km SIN Grid V006*. NASA EOSDIS Land Processes DAAC. https://doi.org/10.5067/MODIS/MCD19A1.006.

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