User's Guide for Albedo Data Sets

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NOTICE

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Revisions

Number	Date	Changes Made to Document
	6/28/2019	Initial release
1	9/12/2019	Added section 4.4 AmeriFlux Network
2	5/15/2020	Revised section 4.2 and added Section 4.2.2 Wuhai, Inner Mongolia
3	7/22/2020	Added sections 4.5 Technical University of Denmark Data and 4.6 7X Energy Data

Table of Contents

1 Introduction

This user's guide describes measurement data sets and summary information pertaining to the albedo for various ground surfaces and locations. The Department of Energy (DOE) initiated this work with the National Renewable Energy Laboratory (NREL) to provide a better understanding of albedo values and their characteristics, which had been identified at the 2018 Bifacial PV Workshop as needed by both the photovoltaic (PV) and financial communities to better estimate the performance and to reduce the risk of bifacial PV systems.

Albedo measurements are made with albedometers consisting of two horizontal pyranometers, one facing the sky and the other facing the ground. The albedo is the irradiance measured by the ground-facing pyranometer divided by the irradiance measured by the sky-facing pyranometer. The conventional name for the sky-facing measurement is the global horizontal irradiance (GHI). For consistency, we refer to the ground-facing measurement as the ground-reflected irradiance (GRI). Elsewhere, the GHI and GRI may be referred to as the downwelling and upwelling (reflected) irradiances, or the incoming and outgoing (reflected) irradiances. Albedo can also be measured using silicon reference cell irradiance sensors. Data for these sensors is denoted using the subscript "si" (GHI_{si} and GRI_{si}).

Besides GHI and GRI, other meteorological data useful for determining the performance of PV systems are included in the data sets, if available. This includes the direct normal irradiance (DNI), the diffuse horizontal irradiance (DHI), the dry bulb temperature (Tdry), the relative humidity (RH), the wind speed (Wspd), the wind direction (Wdir), the atmospheric pressure (Pres), and accumulated precipitation (PrecipAccum).

Sources of the albedo data sets include existing solar radiation and meteorological measurement networks and the PV industry. Section 2 lists the locations included in the albedo data base and their attributes, Section 3 discusses the data files and their formats and quality assessment, and Section 4 provides descriptions of the measurement networks and stations, data, and plots of the station albedos for various time scales.

This user's guide is a living document and will be updated as more albedo data becomes available.

2 Station Locations

Table 2-1 provides a list of measurement stations and their locations that are included in the albedo data base and the station identifier (*StationID*) assigned by NREL and used as part of the naming convention for the station's data files. The overall albedo is the average or mean yearly albedo. A yearly albedo is the sum of the GRIs during the year divided by the sum of the GHIs during the year. If measurements are for less than a year, the overall albedo represents the period of the measurements. The overall albedo includes the effects of snow if present.

Table 2-1. List of Measurement Stations

StationID	**Location**	**Data Source**	**Data Years**	**Ground Surface**	**Overall Albedo**
BondvilleIL	Bondville, IL, USA	SURFRAD	24	Native grasses	0.247
BoulderCO	Boulder, CO, USA	SURFRAD	23	Sandy with exposed rocks, sparse grass, desert shrubs and small cactus	0.199
DesertRockNV	Desert Rock, NV, USA	SURFRAD	20	Fine rock and scattered creosote bush	0.211
FortPeckMT	Fort Peck, MT, USA	SURFRAD	23	Native grasses	0.247
GoodwinCreekMS	Goodwin Creek, MS, USA	SURFRAD	24	Pasture grass and sparse deciduous trees	0.200
PennStateUnivPA	Penn State Univ, PA, USA	SURFRAD	20	¾ grass and ¼ crops	0.252
SiouxFallsSD	Sioux Falls, SD, USA	SURFRAD	15	Native grasses	0.238
ChangshuJiangsu	Changshu, Jiangsu, China	Canadian Solar, Inc	1.3	Concrete White-painted concrete	0.236 0.533
WuhaiInnerMongolia	Wuhai, Inner Mongolia, China.	Canadian Solar, Inc	1.1	Desert sand with wheat grass squares	0.282
DavisCA	Davis, CA, USA	SunPower Corp.	0.8	Gravel, light to medium gray White tarp	0.145 0.568
LethbridgeAlberta	Lethbridge, Alberta, Canada	AmeriFlux	1	Mixed grass prairie	0.250
MedfordOK	Medford, OK, USA	AmeriFlux	3	Hay pasture	0.211
WoodwardOK_1	Woodward, OK, USA	AmeriFlux	4	Switchgrass	0.186
WoodwardOK_2	Woodward, OK, USA	AmeriFlux	4	Switchgrass	0.204
AudubonRanchAZ	Audubon Research Ranch, AZ, USA	AmeriFlux	10	Native grasses	0.217

Table 2-1. List of Measurement Stations (Continued)

StationID	Location	Data Source	Data Years	Ground Surface	Overall Albedo
BouldinCA	Bouldin Island, CA, USA	AmeriFlux	3	Alfalfa	0.221
BrookingsSD	Brookings, SD, USA	AmeriFlux	7	Pasture grass	0.262
CanaanValleyWV	Canaan Valley, WV, USA	AmeriFlux	6	Grassland	0.294
CorralPocketUT	Corral Pocket, UT, USA	AmeriFlux	7	Semi-arid grassland with 38-80% bare ground from livestock grazing	0.238
CottonwoodSD	Cottonwood, SD, USA	AmeriFlux	4	Grassland	0.181
DiabloCA	Diablo, CA, USA	AmeriFlux	3	Grassland	0.206
DukeFieldNC	Duke Field, NC, USA	AmeriFlux	5	Tall fescue grass mowed annually	0.203
FlagstaffAZ	Flagstaff, AZ, USA	AmeriFlux	6	Post forest fire grasslands	0.219
FermilabIL	Fermilab – Batavia, IL, USA	AmeriFlux	14	Prairie grass	0.221
FieldStationKS	Kansas Field Station, KS, USA	AmeriFlux	8	Grassland	0.193
KonzaPrairieKS	Konza Prairie, KS, USA	AmeriFlux	6	Grassland	0.190
TurfgrassFieldMN	Turfgrass Field, MN, USA	AmeriFlux	4	Turfgrass lawn	0.322
ReynoldsCreekID_1	Reynolds Creek, ID, USA	AmeriFlux	3	Low sagebrush	0.179
ReynoldsCreekID_2	Reynolds Creek, ID, USA	AmeriFlux	3	Mountain big sagebrush	0.231
RosemountMN	Rosemount, MN, USA	AmeriFlux	5	Grassland	0.247
SonoranDesertCA	Sonoran Desert, CA, USA	AmeriFlux	7	Desert	0.245
SouthGrasslandCA	Southern Californian Grassland, CA, USA	AmeriFlux	9	Grassland	0.165
McKenzieFlatsNM	McKenzie Flats, NM, USA	AmeriFlux	12	Desert Grassland	0.219
ShidlerOK	Shidler, OK, USA	AmeriFlux	4	Tall grass prairie	0.217

Table 2-1. List of Measurement Stations (Continued)

StationID	Location	Data Source	Data Years	Ground Surface	Overall Albedo
SantaRitaAZ	Santa Rita, AZ, USA	AmeriFlux	11	Semidesert grassland	0.204
TwitchellCA	Twitchell Island, CA, USA	AmeriFlux	5	Alfalfa	0.223
WalnutGulchAZ	Walnut Gulch, AZ, USA	AmeriFlux	15	Grassland	0.182
SmileyburgKS	Smileyburg, KS, USA	AmeriFlux	3	Tall grass prairie	0.210
RoskildeDenmark	Roskilde, Denmark	Technical University of Denmark	1	Grass	0.222
FayetteOH	Fayette, OH, USA	7X Energy	1	Grass	0.230
PearsallTX	Pearsall, TX, USA	7X Energy	1	Native grass	0.194
SabinalTX	Sabinal, TX, USA	7X Energy	1	Native grass	0.210
CoyanosaTX	Coyanosa, TX, USA	7X Energy	1.5	Native grass and shrubs	0.256

3 Data Files and Format

All data files use a comma separated variables (CSV) format. Data files are available at the original temporal resolution provided by source of the data, and for an hourly temporal resolution. Hourly resolution data are derived from higher resolution original data, if needed. To facilitate the use of various sources of data, the time-series data files are formatted to a common format described in Section 3.1. The format includes the use of data quality assessment (QA) flags. The procedure for assigning the data QA flags is discussed in Section 3.2.

3.1 Time Series Data Format

Both the original temporal resolution data and the hourly resolution data use the same data format template. As viewed when imported into Excel, the first row is the station location header that contains text describing the station location values in the second row. Table 3-1 provides the column positions for the header text and values.

Table 3-1. Station Location Header Elements and Definitions

Column	Element	Definition
A	City	City or place where station located
B	State or Province	State or province where station located
C	Country	Country where station located
D	Latitude(deg N+)	Latitude in decimal degrees, north positive
E	Longitude(deg E+)	Longitude in decimal degrees, east positive
F	Elevation(m)	Elevation in meters above sea level
G	Time Zone(E+)	Time zone, positive for east longitudes
H	Time Step(min)	Temporal resolution of data in minutes
I	Begin Time(yyyy-mm-ddThh:mm)	Local standard time of first data row in file
J	End Time(yyyy-mm-ddThh:mm)	Local standard time of last data row in file
K	Data Source	Organization performing data measurements

For the hourly files, the Time Step element is always 60 minutes, but for the original temporal resolution files it depends on the original measurements, and which could have changed over time. For example, prior to 2009, SURFRAD data were measured as 3-minute averages (Time Step = 3), and for 2009 and after, SURFRAD data were measured as 1-minute averages (Time Step = 1).

The third row of the data file is the header for the data beginning in the fourth row and contains text describing the time stamp of the data and the data elements. Each data element has a QA flag associated with it that is in the next adjacent column. Table 3-2 provides the column positions for the header text and data elements that may be contained in a data file. The actual data elements included depend on their availability from the source of the data. As a minimum, GHI and GRI are included to permit albedo calculations. The header text in the third row of the file should be used to determine which data elements are present and their column locations.

Table 3-2. File Data Header Elements and Definitions that May Be Contained in a Data File

Column	Element	Definitions*
A	Year	Year, 4-digit
B	Month	Month of year (1-12)
C	Day	Day of month (1-31)
D	Hour	Hour of day in local standard time (0-23)
E	Minute	Minute of hour (0-59)
F	GHI(W/m2)	Global horizontal irradiance, the direct and diffuse irradiance in W/m^2 received by a sky-facing horizontal surface
G	Flag	QA flag for GHI
H	DNI(W/m2)	Direct normal irradiance, irradiance in W/m^2 received within a 5.7° field-of-view centered on the sun
I	Flag	QA flag for DNI
J	DHI(W/m2)	Diffuse horizontal irradiance, irradiance in W/m^2 received from the sky (excluding the solar disk) by a horizontal surface
K	Flag	QA flag for DHI
L	GRI(W/m2)	Ground reflected irradiance, irradiance in W/m^2 reflected by the ground and received by a ground-facing horizontal surface
M	Flag	QA flag for GRI
N	Tdry(deg C)	Dry bulb temperature in °C
O	Flag	QA flag for Tdry
P	RH(%)	Relative humidity in percent
Q	Flag	QA flag for RH
R	Wspd(m/s)	Wind speed in meters per second
S	Flag	QA flag for Wspd
T	Wdir(deg)	Wind direction in degrees from north
U	Flag	QA flag for Wdir
V	Pres(mBar)	Atmospheric pressure in millibars
W	Flag	QA flag for Pres
X	GHI_{si}(W/m2)	Global horizontal irradiance, the direct and diffuse irradiance in W/m^2 received by a sky-facing horizontal surface and measured with a silicon reference cell irradiance sensor
Y	Flag	QA flag for GHI_{si}
Z	GRI_{si} (W/m2)	Ground reflected irradiance, irradiance in W/m^2 reflected by the ground and received by a ground-facing horizontal surface and measured with a silicon reference cell irradiance sensor
AA	Flag	QA flag for GRI_{si}
AB	PrecipAccum(mm)	Amount of liquid precipitation in millimeters accumulated since the beginning of the day
AC	Flag	QA flag for PrecipAccum

*Solar irradiance and meteorological data are average or mean values for the time step interval preceding the time indicated, except wind direction is calculated as a wind vector average direction rather than a simple average.

3.2 Quality Assessment Flags

QA flags are assigned to data values to identify missing data and data that may not be suitable for use because it is outside an expected range. Missing data are indicated by a value of -9999 and a QA flag of 99. Otherwise, if within an expected range, a QA flag of 1 is assigned, if not, a QA flag of -1 is assigned. PrecipAccum values are not quality assessed and are assigned a QA flag of zero.

Expected ranges for meteorological data are:

- Tdry – Record low to record high dry bulb temperature for the location.
- RH – 3% to 100%.
- Wspd – 0 to 40 m/s.
- Wdir – 0° to 360°.
- Pres – Atmospheric pressure derived from elevation ± 90 mb.

Expected ranges for irradiance data during the night are from -15 W/m^2 to 10 W/m^2. Thermopile instruments radiate to the night sky, so negative readings are not unusual. Expected ranges for irradiance data during the day are:

- GHI – -15 W/m^2 to 1500 W/m^2.
- DNI – -15 W/m^2 to 1200 W/m^2.
- DHI – -15 W/m^2 to 900 W/m^2.

The GRI was checked by dividing by the GHI to see if the resulting albedo was within an expected range from 0.05 to 0.99. For GHI values below 50 W/m^2 where the quality of the measurement may suffer, the expected range was not more than 5 W/m^2 greater than GHI or less than -5 W/m^2. If the GHI was not within its expected range, the GRI was not checked and a QA flag of zero was assigned.

When GHI, DNI, and DHI are non-missing and are within their above expected ranges, their QA flags are reassigned to be the absolute value of the residual of DHI + DNI*cos(zenith) – GHI, where zenith is the zenith angle of the sun at the midpoint of the step interval, and with a minimum QA flag of 2 and a maximum QA flag of 98 to not conflict with other QA flag assignments. For instruments performing perfect measurements, the residual of the relationship between the three irradiances would be zero. Consequently, smaller flag values provide more confidence in the quality of the measurements.

4 Station Descriptions

This section provides descriptions of the measurement networks and stations and the available data files.

4.1 SURFRAD Network

The Surface Radiation budget (SURFRAD) network consists of seven stations and is operated by the National Oceanic and Atmospheric Administration (NOAA) to provide continuous and high-quality surface radiation budget measurements to support climate research, weather forecasting, satellite, and educational communities (Augustine et al., 2000). The GRI measurement is performed with a ground-facing pyranometer installed on a 10-m tower on the end of a 2.4-m horizontal cross arm 9 m above the ground. A cylindrical sun shield is used to shade the pyranometer body from unwanted solar radiation heating. Other data that we use from SURFRAD includes: GHI, DNI, DHI, Tdry, RH, Wspd, Wdir, and Pres. We did not include partial year data resulting from the timing of when the station operations began or data after December 31, 2018.

Irradiances are measured using Spectrolab SR-75 pyranometers for GHI and GRI, Eppley 8-48 pyranometers for DHI, and Eppley normal incidence pyrheliometers for DNI. All radiometers and other instruments are replaced annually with newly calibrated instruments. Stations are automated and maintenance is performed at least weekly to clean radiometer domes and lenses.
For more information on SURFRAD stations, including installation pictures, see Augustine et al. (2000) and the SURFRAD website (https://www.esrl.noaa.gov/gmd/grad/surfrad/index.html).

Data files for each location are stored in a file directory that uses the *StationID* for its naming convention. A subdirectory *OrigResData* contains yearly files of time series data using the original temporal resolution of the data and with the data reformatted as needed to comply with the data format described in Section 3.1. The naming convention for these files is *StationID_YYYY* where *YYYY* is the four-digit year. A subdirectory *HourlyData* contains yearly files of data using a one-hour temporal resolution. These files were created from the original temporal resolution data and use a naming convention of *StationID_Hourly_YYYY*.

The hourly data were used to determine statistics for monthly and annual albedos, including means, medians, minimums, maximums, and sample standard deviations. The albedo for a period of interest (hourly, monthly, yearly, etc.) was determined as the sum of the GRI values divided by the sum of the GHI values; and using only GRI and GHI data when they were both in their expected range as indicated by their QA flags. Locations subject to snowfall exhibit large variability in albedo during winter months because of seasonal and year-to-year variability of the snowfall.

The *StationID_SummaryResults* file contains four tables. The first table provides monthly and annual albedos for each month and year of the period of record, and minimum, maximum, mean, median, and standard deviation statistics by calendar month and annually. The second table provides the mean hourly albedo by hour of the day and calendar month using data for all years. This provides information on the diurnal variation of albedo. The third table provides information on the completeness of the data set for calculating the albedo values. The percent of total daytime hours with data not missing and that pass their QA is provided for each month and year. The fourth table is similar the third table, but for nighttime hours. Although these values are not used to calculate albedo, a low percentage passing QA may indicate that a zero offset exists that might also introduce errors in daytime values which would not be detected by the daytime QA checks.

The SURFRAD station information is provided in the following sections. The section headings are the station locations.

4.1.1 Bondville, Illinois, USA

StationID:	BondvilleIL
Latitude:	40.0516°N
Longitude:	88.3733°W
Elevation:	230 m
Time Zone:	-6
Period of Record:	1/1/1995 through 12/31/2018
Data Files:	Hourly and 3-minute for 2008 and earlier and 1-minute after 2008
Data Elements:	GHI, DNI, DHI, GRI, Tdry, RH, Wspd, Wdir, and Pres
Ground Surface:	Native Grasses
Overall Albedo:	0.247

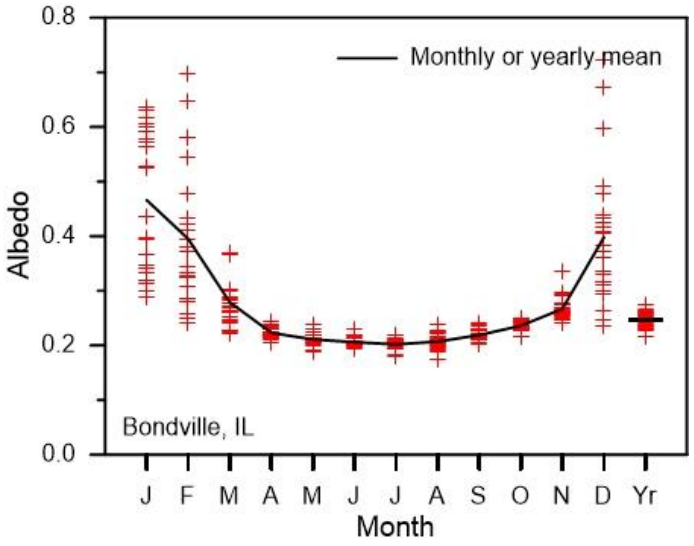

Figure 4.1.1-1. Monthly and yearly albedos and long-term means for Bondville, IL.

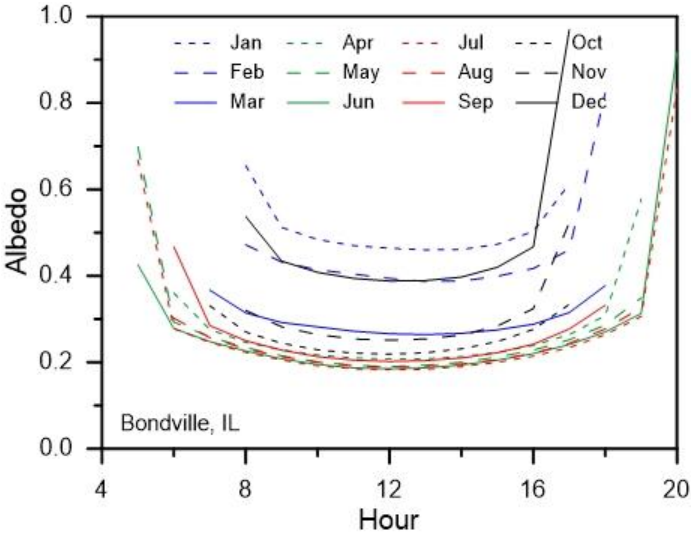

Figure 4.1.1-2. Mean hourly albedos by month for Bondville, IL.

4.1.2 Boulder, Colorado, USA

StationID:	BoulderCO
Latitude:	40.1256°N
Longitude:	105.2378°W
Elevation:	1689 m
Time Zone:	-7
Period of Record:	1/1/1996 through 12/31/2018
Data Files:	Hourly and 3-minute for 2008 and earlier and 1-minute after 2008
Data Elements:	GHI, DNI, DHI, GRI, Tdry, RH, Wspd, Wdir, and Pres
Ground Surface:	Sandy with exposed rocks, sparse grass, desert shrubs and small cactus
Overall Albedo:	0.199

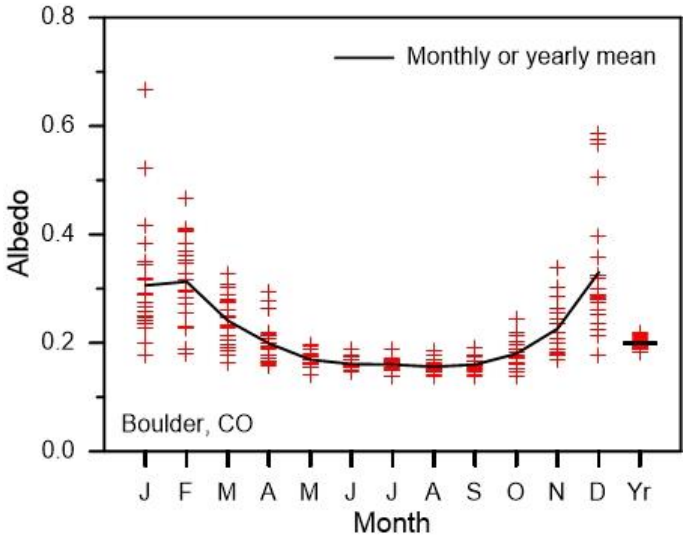

Figure 4.1.2-1. Monthly and yearly albedos and long-term means for Boulder, CO.

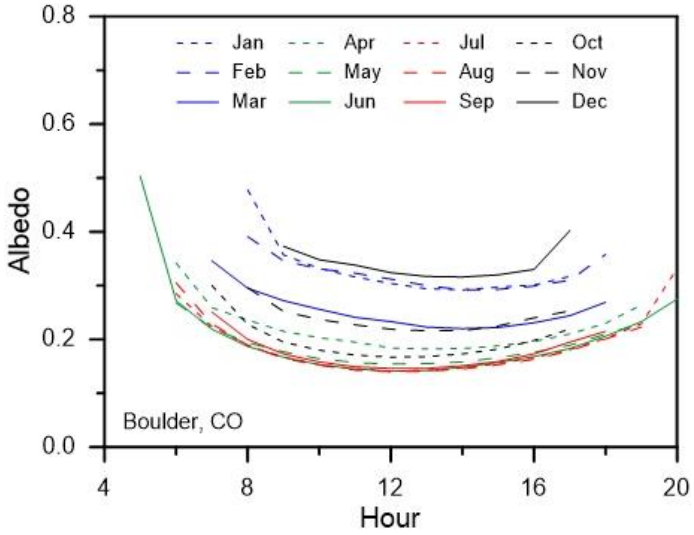

Figure 4.1.2-2. Mean hourly albedos by month for Boulder, CO

4.1.3 Desert Rock, Nevada, USA

StationID:	DesertRockNV
Latitude:	36.6232°N
Longitude:	116.0196°W
Elevation:	1007 m
Time Zone:	-8
Period of Record:	1/1/1999 through 12/31/2018
Data Files:	Hourly and 3-minute for 2008 and earlier and 1-minute after 2008
Data Elements:	GHI, DNI, DHI, GRI, Tdry, RH, Wspd, Wdir, and Pres
Ground Surface:	Fine rock and scattered creosote bush
Overall Albedo:	0.211

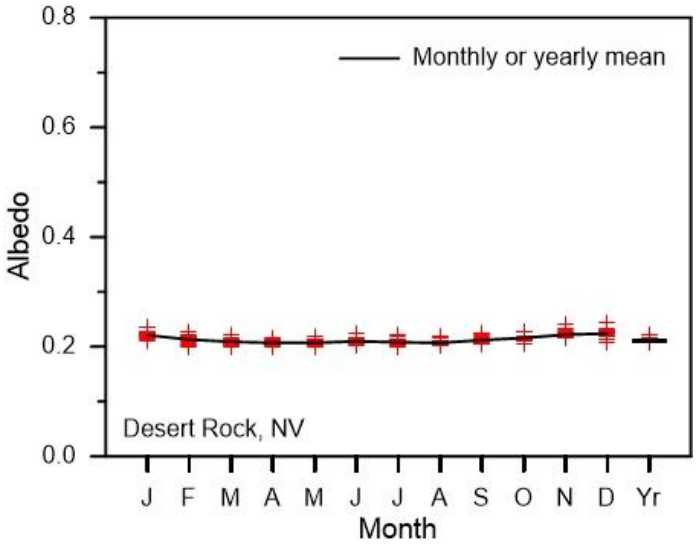

Figure 4.1.3-1. Monthly and yearly albedos and long-term means for Desert Rock, NV.

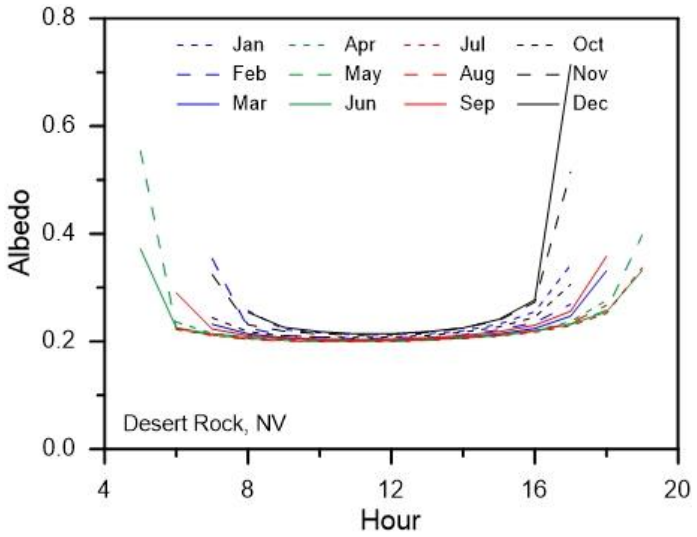

Figure 4.1.3-2. Mean hourly albedos by month for Desert Rock, NV.

4.1.4 Fort Peck, Montana, USA

StationID:	FortPeckMT
Latitude:	48.3080°N
Longitude:	105.1018°W
Elevation:	634 m
Time Zone:	-7
Period of Record:	1/1/1996 through 12/31/2018
Data Files:	Hourly and 3-minute for 2008 and earlier and 1-minute after 2008
Data Elements:	GHI, DNI, DHI, GRI, Tdry, RH, Wspd, Wdir, and Pres
Ground Surface:	Native grasses
Overall Albedo:	0.247

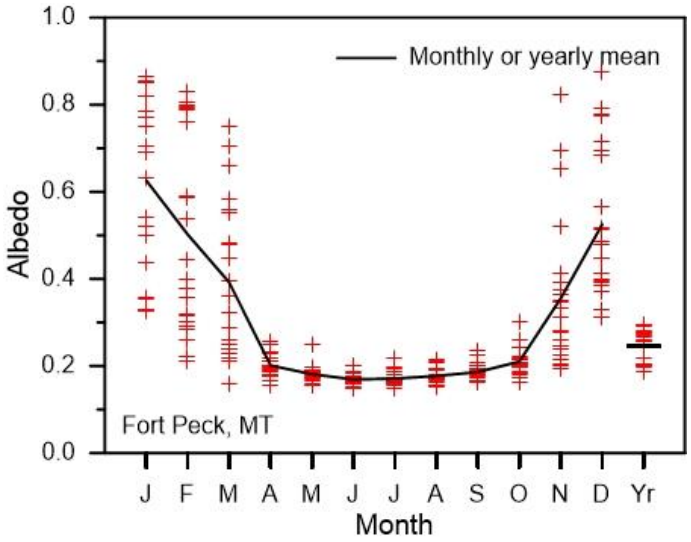

Figure 4.1.4-1. Monthly and yearly albedos and long-term means for Fort Peck, MT.

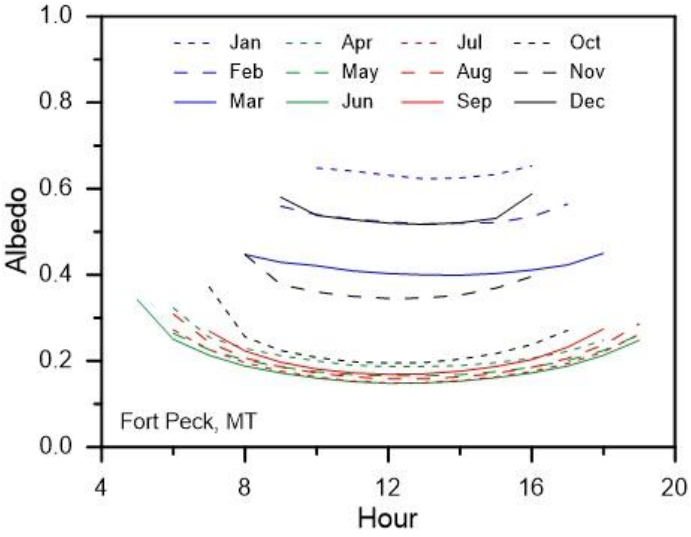

Figure 4.1.4-2. Mean hourly albedos by month for Fort Peck, MT.

4.1.5 Goodwin Creek, Mississippi, USA

StationID:	GoodwinCreekMS
Latitude:	34.2547°N
Longitude:	89.8729°W
Elevation:	98 m
Time Zone:	-6
Period of Record:	1/1/1995 through 12/31/2018
Data Files:	Hourly and 3-minute for 2008 and earlier and 1-minute after 2008
Data Elements:	GHI, DNI, DHI, GRI, Tdry, RH, Wspd, Wdir, and Pres
Ground Surface:	Pasture grass and sparse deciduous trees
Overall Albedo:	0.200

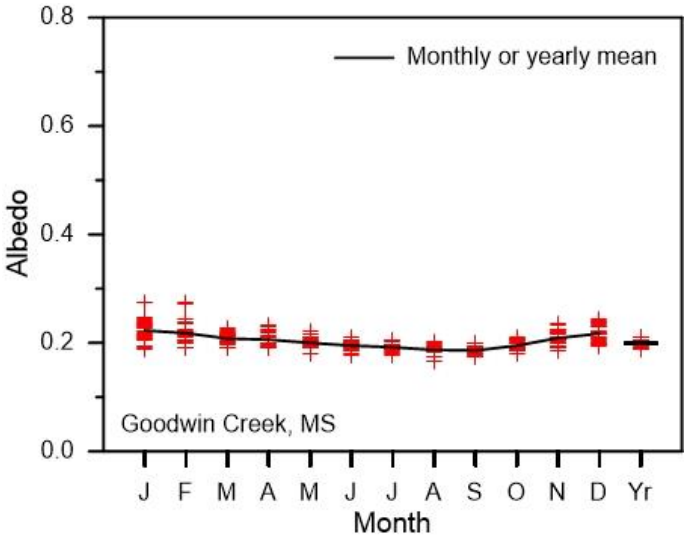

Figure 4.1.5-1. Monthly and yearly albedos and long-term means for Goodwin Creek, MS.

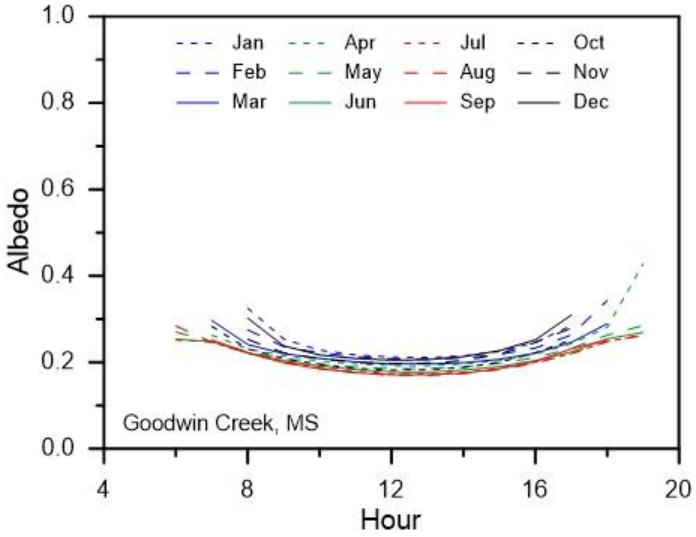

Figure 4.1.5-2. Mean hourly albedos by month for Goodwin Creek, MS.

4.1.6 Penn State University, Pennsylvania, USA

StationID:	PennStateUnivPA
Latitude:	40.7203°N
Longitude:	77.9310°W
Elevation:	376 m
Time Zone:	-5
Period of Record:	1/1/1999 through 12/31/2018
Data Files:	Hourly and 3-minute for 2008 and earlier and 1-minute after 2008
Data Elements:	GHI, DNI, DHI, GRI, Tdry, RH, Wspd, Wdir, and Pres
Ground Surface:	¾ grass and ¼ crops
Overall Albedo:	0.252

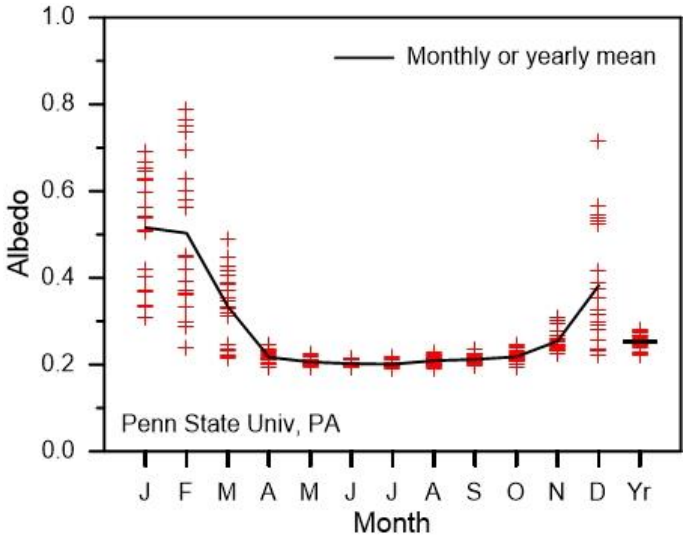

Figure 4.1.6-1. Monthly and yearly albedos and long-term means for Penn State University, PA.

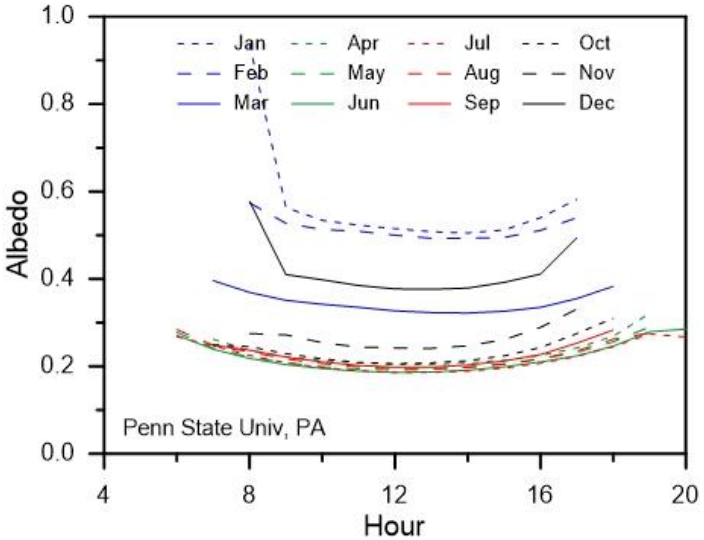

Figure 4.1.6-2. Mean hourly albedos by month for Penn State University, PA.

4.1.7 Sioux Falls, South Dakota, USA

StationID:	SiouxFallsSD
Latitude:	43.7343°N
Longitude:	96.6233°W
Elevation:	473 m
Time Zone:	-6
Period of Record:	1/1/2004 through 12/31/2018
Data Files:	Hourly and 3-minute for 2008 and earlier and 1-minute after 2008
Data Elements:	GHI, DNI, DHI, GRI, Tdry, RH, Wspd, Wdir, and Pres
Ground Surface:	Native grasses
Overall Albedo:	0.238

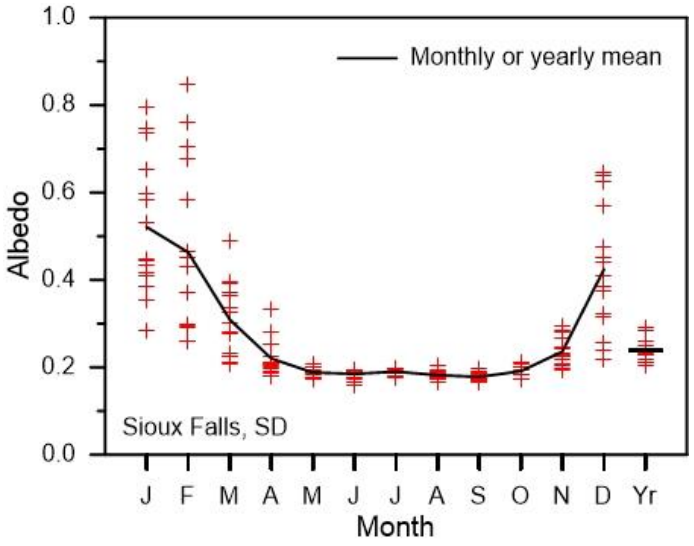

Figure 4.1.7-1. Monthly and yearly albedos and long-term means for Sioux Falls, SD.

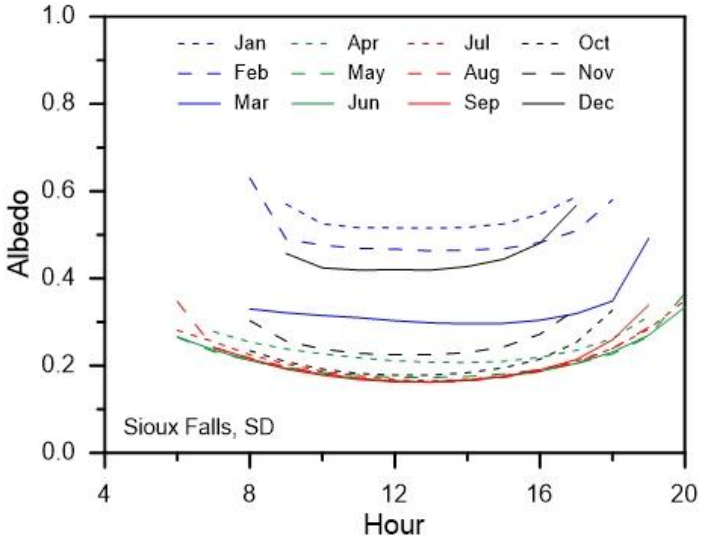

Figure 4.1.7-2. Mean hourly albedos by month for Sioux Falls, SD.

4.2 Canadian Solar, Inc. Data

Canadian Solar, Inc. provided albedo data for a concrete surface located at a PV system installation in Changshu, Jiangsu, China and for a desert location near Wuhai, Inner Mongolia, China.

For the Changshu, Jiangsu, China location, the concrete surface was installed in 2015. The albedo was measured with both thermopile and reference cell instruments. The GHI and GRI were measured with IMCDG model FSP10 pyranometers and the GHI_{si} and GRI_{si} were measured with Meteocontrol model SI-RS485TC-T-MB monocrystalline silicon irradiance sensors. The ground-facing pyranometer and reference cell are installed on the end of a 1.25-m horizontal cross arm 0.5 m above the concrete surface. The arm diameter is 0.032 m and the vertical stainless-steel mast diameter is 0.05 m. The arm and mast are south of the instruments. The instruments are calibrated every two years and cleaned depending on soiling level and rain frequency.

Figure 4.2-1 is an aerial view showing the location of the albedometers in the PV facility. A close-up view of the albedometers is shown in Figure 4.2-2. Figures 4.2-3 through 4.2-6 are images showing the horizontal view from the perspective of the albedometer for the four cardinal directions. Shadows from PV structures and the albedometer support masts likely reduced the measured albedos by a small, but relatively insignificant, amount. Figure 4.2-7 shows the ground surface after a rainfall. The presence of moisture darkens the concrete surface, resulting in a lower albedo. After approximately one year of measurements, the concrete surface was painted white to enhance the albedo. Figures 4.2-8 and 4.2-9 are images taken before and after painting.

Figure 4.2-1. Location of the pyranometer and reference cell albedometers in the PV facility is shown by the red arrow.

Figure 4.2-2. Close-up view of the albedometers and its support structure.

Figure 4.2-3. Horizontal view from the albedometer toward the north.

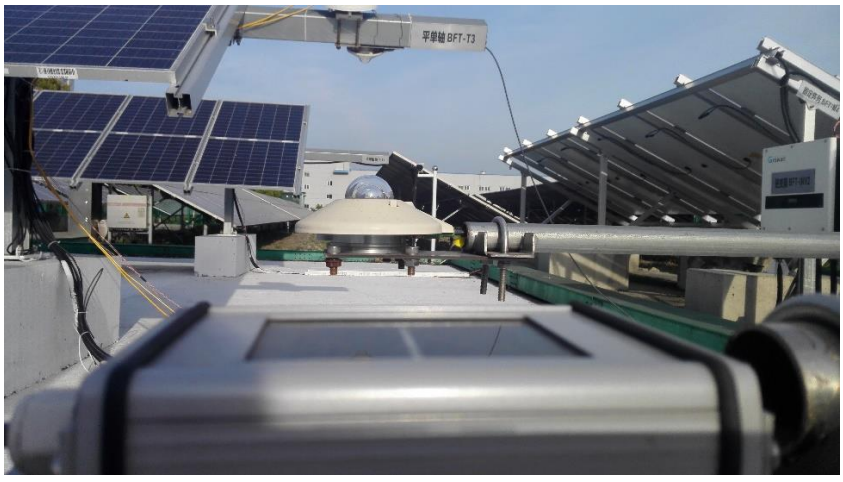

Figure 4.2-4. Horizontal view from the albedometer toward the east.

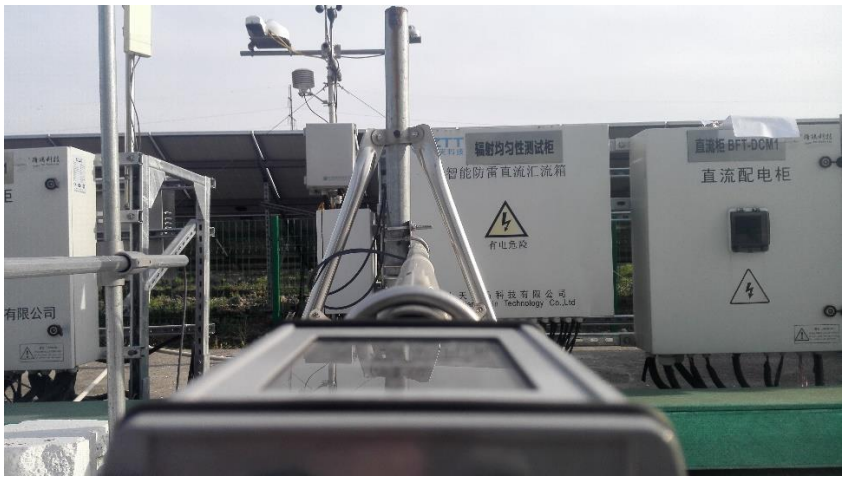

Figure 4.2-5. Horizontal view from the albedometer toward the south.

Figure 4.2-6. Horizontal view from the albedometer toward the west.

Figure 4.2-7. Concrete surface after rain showing darkening from the presence of moisture.

Figure 4.2-8. Concrete surface before painting white on March 12, 2019.

Figure 4.2-9. Concrete surface after painting white on March 12, 2019. The unpainted area on the right shows the contrast between painted and unpainted.

Canadian Solar, Inc. also provided albedo data for a desert location near Wuhai, Inner Mongolia, China. The surface is sand with wheat grass square vegetation. The GHI and GRI were measured with IMCDG model FSP10 thermopile pyranometers. The ground-facing pyranometer is installed on the end of a 1.3-m horizontal cross arm 0.5 m above the surface. The arm diameter is 0.032 m and the vertical stainless-steel mast diameter is 0.05 m. The arm and mast are north of the instruments. Instruments are calibrated every two years and cleaned every two months.

Figures 4.2-10 through 4.2-15 are views of the Wuhai albedometer from various directions and times of year. It appears that the view of sand was slightly more prevalent over time as it encroached on the wheat grass square vegetation. Snow is present in Figure 4.2-15.

Figure 4.2-10. View toward south-southwest of Wuhai albedometer on November 6, 2018.

Figure 4.2-11. Close-up view toward north of Wuhai albedometer on November 6, 2018.

Figure 4.2-12. Close-up view toward east of Wuhai albedometer on November 6, 2018.

Figure 4.2-13. View toward west-southwest of Wuhai albedometer on June 5, 2019.

Figure 4.2-14. View toward southwest of Wuhai albedometer on September 1, 2019.

Figure 4.2-15. View toward southwest of Wuhai albedometer on December 2, 2019.

The Canadian Solar, Inc. station information is provided in the following sections. The section headings are the station locations.

4.2.1 Changshu, Jiangsu, China

StationID:	ChangshuJiangsu
Latitude:	31.53°N
Longitude:	120.64°E
Elevation:	8 m
Time Zone:	+8
Period of Record:	2/6/2018 – 5/16/2019

Data Files:

ChangshuJiangsu_Pyranometer_30-sec.csv – Pyranometer albedometer data, instantaneous measurements every 30 seconds from 3/22/2018 to 12/8/2018.
ChangshuJiangsu_Pyranometer_1-min.csv – Pyranometer albedometer data, one-minute averages from measurements performed every 10 seconds from 12/13/2018 to 5/16/2019.
ChangshuJiangsu_Pyranometer_Hourly.csv – Pyranometer albedometer data, hourly averages determined from the 30-second and 1-minute data, from 3/22/2018 to 5/16/2019.
ChangshuJiangsu_Pyranometer_Monthly.csv – Pyranometer albedometer data, monthly values.

ChangshuJiangsu_RefCell_30-sec.csv – Reference cell albedometer data, instantaneous measurements every 30 seconds from 2/6/2018 to 12/8/2018.
ChangshuJiangsu_RefCell_1-min.csv – Reference cell albedometer data, one-minute averages from measurements performed every 10 seconds from 12/12/2018 to 5/16/2019.
ChangshuJiangsu_RefCell_Hourly.csv – Reference cell albedometer data, hourly averages determined from the 30-second and 1-minute data, from 2/6/2018 to 5/16/2019.
ChangshuJiangsu_RefCell_Monthly.csv – Reference cell albedometer data, monthly values.

Data Elements:	GHI and GRI, or GHI_{si} and GRI_{si}
Ground Surface:	Concrete prior to 3/12/2019, white-painted concrete after 3/12/2019. Testing of reflective materials from 9/14/2018 to 10/12/2018.
Overall Albedo:	Concrete – 0.236 with pyranometer albedometer, 0.238 with reference cell albedometer. White-painted concrete – 0.533 with pyranometer albedometer, 0.546 with reference cell albedometer

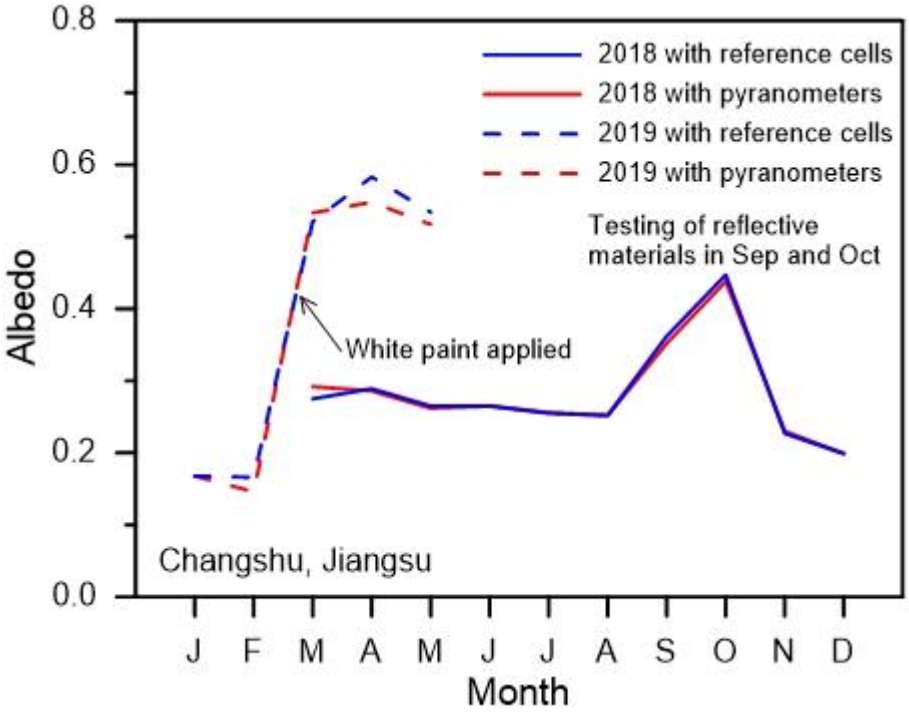

Figure 4.2.1-1. Monthly albedos for Changshu, Jiangsu, China for a concrete surface. Greater albedos in September and October are a result of testing reflective materials from 9/14/2018 to 10/12/2018. Data for these months not included when determining the overall albedo.

4.2.2 Wuhai, Inner Mongolia, China

StationID:	WuhaiInnerMongolia
Latitude:	39.76°N
Longitude:	106.84°E
Elevation:	1112 m
Time Zone:	+8
Period of Record:	12/1/2018 – 12/31/2019
Data Files:	*WuhaiInnerMongolia_1-min.csv* – Pyranometer albedometer data, one-minute averages from measurements performed every 3 seconds from 12/1/2018 to 12/31/2019. *WuhaiInnerMongolia_Hourly.csv* – Pyranometer albedometer data, hourly averages from measurements performed every 3 seconds from 12/1/2018 to 12/31/2019. *WuhaiInnerMongolia_SummaryResults.csv* – Pyranometer albedometer data, monthly albedos and mean hourly albedos by month.
Data Elements:	GHI and GRI
Ground Surface:	Desert sand with wheat grass squares
Overall Albedo:	0.282

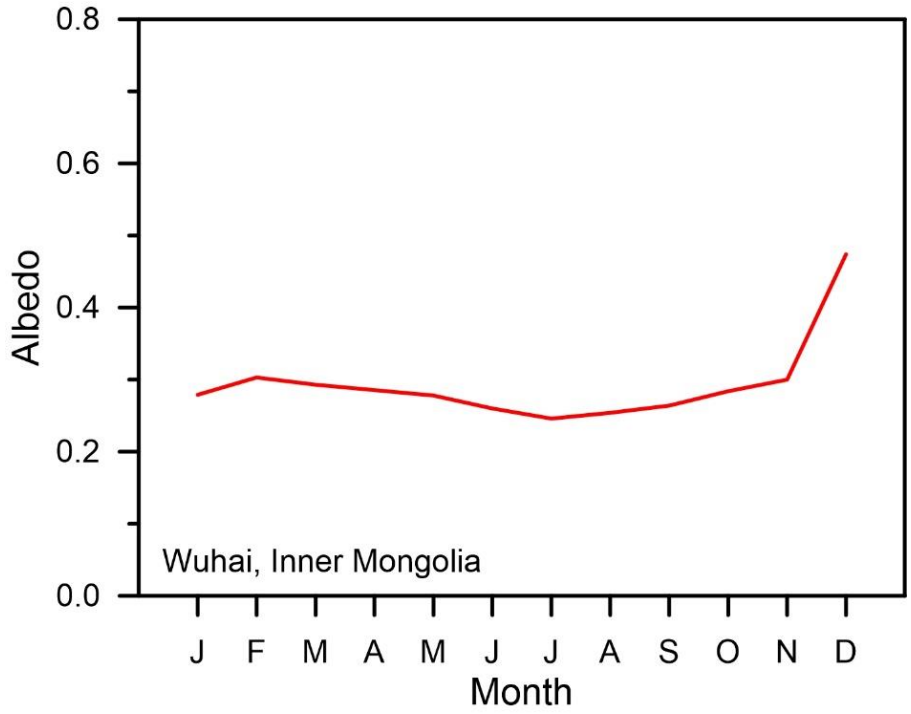

Figure 4.2.2-1. Monthly albedos for Wuhai, Inner Mongolia, China for a surface of desert sand with wheat grass squares for 2019.

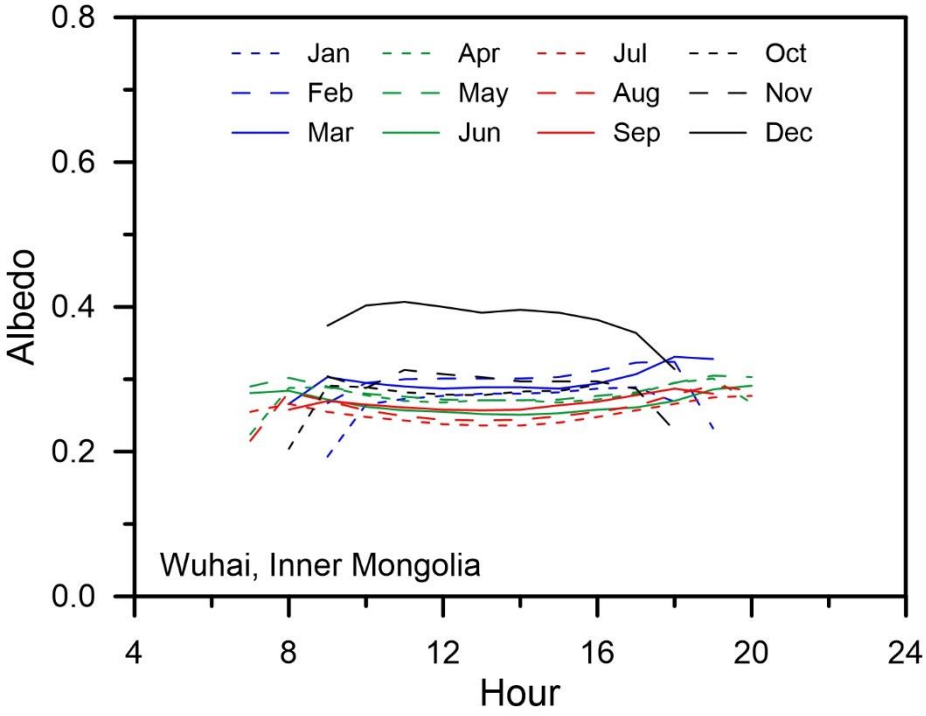

Figure 4.2.2-2. Mean hourly albedos by month for Wuhai, Inner Mongolia, China using data from December 1, 2018 through December 31, 2019.

4.3 SunPower Corporation Data

SunPower Corporation provided albedo data for a light to medium gray gravel surface located at a PV system installation in Davis, California, USA. Data for a white tarp placed on the ground on August 31, 2018 and removed on September 17, 2018 are included. The GHI and GRI were measured with Kipp and Zonen CMA11 pyranometers. The pyranometers are installed on the end of a 0.42-m horizontal cross arm 1.45 m above the gravel surface. The arm diameter is 0.016 m and the vertical gray mast diameter is 0.048 m. The arm and mast are north of these instruments. Other equipment measures the DNI with a Kipp and Zonen SHP1-V pyrheliometer; the DHI with a Kipp and Zonen CMP21 pyranometer; and the Tdry, RH, Wspd, Wdir, Pres, and PrecipAccum with a Vaisala WXT536 weather transmitter. Instruments are calibrated every two years and the radiometers are cleaned every two days.

Figure 4.3-1 shows the installation of the albedometer. Figure 4.3-2 is a close-up view of the gravel surface. Figures 4.3-3 through 4.3-6 are images showing the horizontal view from the perspective of the albedometer for the four cardinal directions. Figure 4.3-7 is a sketch of the local horizon and any obstacles viewed by the albedometer as a function of the azimuth.

Figure 4.3-1. Albedometer installation at SunPower's Davis, CA test site.

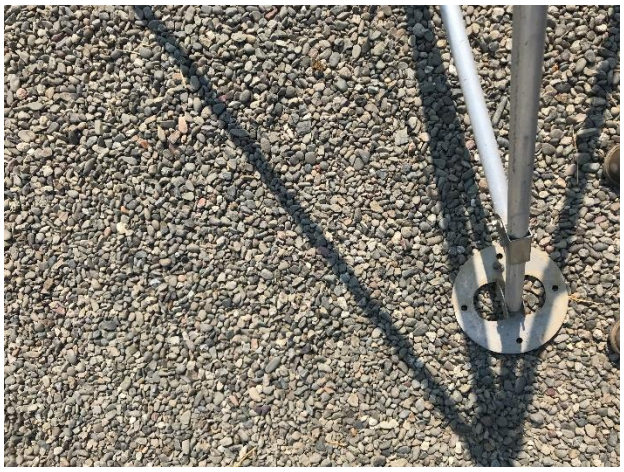

Figure 4.3-2. Close-up view of gravel surface viewed by albedometer

Figure 4.3-3. Horizontal view from the albedometer toward the north.

Figure 4.3-4. Horizontal view from the albedometer toward the east.

Figure 4.3-5. Horizontal view from the albedometer toward the south.

Figure 4.3-6. Horizontal view from the albedometer toward the west.

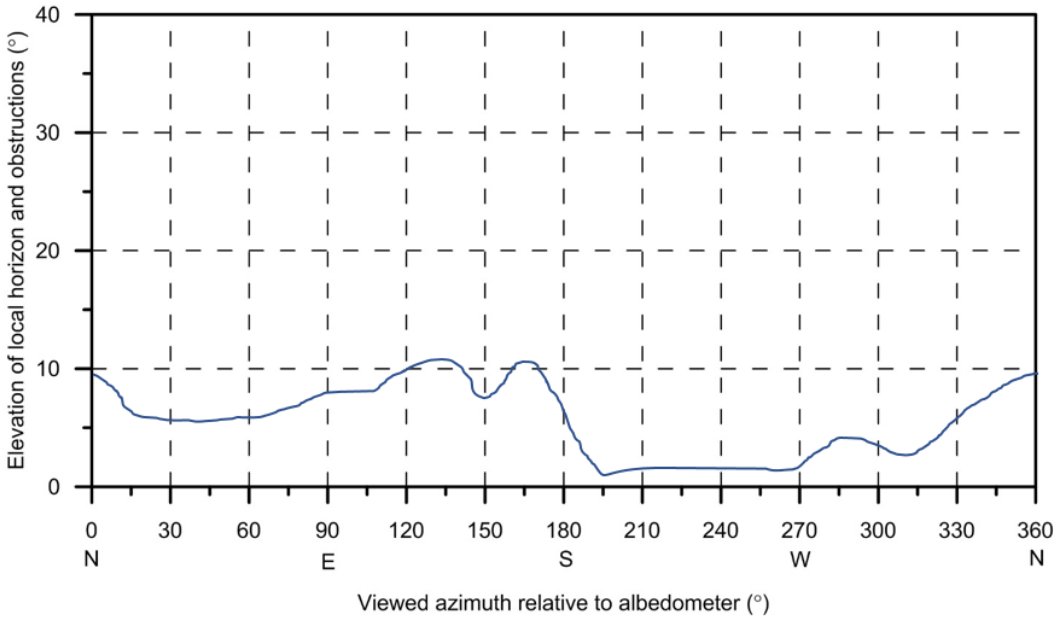

Figure 4.3-7. Sketch of local horizon and obstacles viewed by albedometer

The SunPower Corporation station information is provided in the following section. The section heading is the station location.

4.3.1 Davis, California, USA

StationID:	DavisCA
Latitude:	38.31°N
Longitude:	121.41°W
Elevation:	16 m
Time Zone:	-8
Period of Record:	8/5/2018 – 5/16/2019

Data Files: *DavisCA_1-min.csv* – One-minute averages from measurements performed every 15 seconds.
DavisCA_15-min.csv – Fifteen-minute averages from measurements performed every 15 seconds.
DavisCA_Hourly.csv – Hourly averages from measurements performed every 15 seconds.
DavisCA_Monthly.csv – Monthly albedo averages.

Data Elements: GHI, DNI, DHI, GRI, Tdry, RH, Wspd, Wdir, Pres, PrecipAccum

Ground Surface: Light to medium gray gravel, except white tarp placed on the ground on 8/31/2018 and removed on 9/17/2018.

Overall Albedo: Gravel – 0.145
White tarp – 0.568

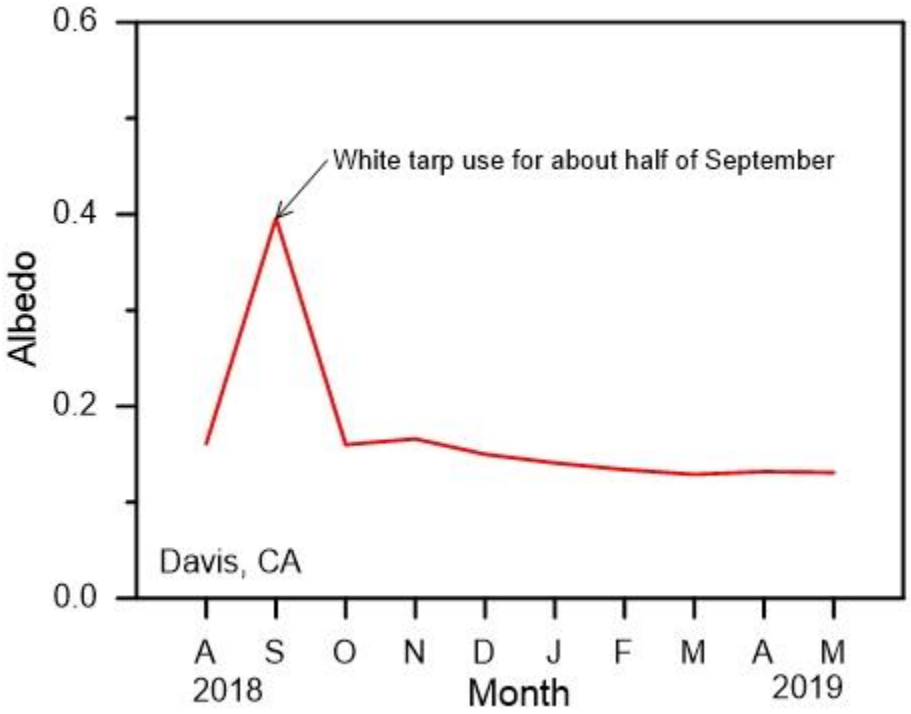

Figure 4.3.1-1. Monthly albedos for Davis, CA for a light to medium gray gravel surface, except white tarp placed on the ground on 8/31/2018 and removed on 9/17/2018 which contributed to an increase in the albedo for the month of September.

4.4 AmeriFlux Network

The AmeriFlux network data are contributed by individual scientists that operate measurement stations in North, Central, and South America for the purpose of measuring ecosystem CO2, water, and energy fluxes. Most of the sites are in the U.S., followed by Canada. The AmeriFlux network is managed by the Lawrence Berkeley National Laboratory with funding from the U.S. Department of Energy's Office of Science. For complete information, see the AmeriFlux website (https://ameriflux.lbl.gov/).

The AmeriFlux network is intended to represent major climate and ecological biomes, including tundra, grasslands, savanna, crops, and forests. For this user's manual, we used a subset of 28 stations with ground covers that might be present for PV installations (grasslands, deserts, low brush or crops; no forests or wetlands) and that had the required measurement of albedo.

Data files for each station are stored in a file directory that uses the *StationID* for its naming convention. A subdirectory *30MinData* contains yearly files of time series data using the original 30-minute temporal resolution of the data and with the data reformatted as needed to comply with the data format described in Section 3.1. The naming convention for these files is *StationID_YYYY_30Min* where *YYYY* is the four-digit year. A subdirectory *HourlyData* contains yearly files of data using a one-hour temporal resolution. These files were created from the original temporal resolution data and use a naming convention of *StationID_YYYY_Hourly*. (For the station CorralPocketUT, only hourly files are present because that is the original temporal resolution of the data.)

The hourly data were used to determine statistics for monthly and annual albedos, including means, medians, minimums, maximums, and sample standard deviations. The albedo for a period of interest (hourly, monthly, yearly, etc.) was determined as the sum of the GRI values divided by the sum of the GHI values; and using only GRI and GHI data when they were both in their expected range as indicated by their QA flags. Locations subject to snowfall exhibit large variability in albedo during winter months because of seasonal and year-to-year variability of the snowfall.

The *StationID_SummaryResults* file contains four tables. The first table provides monthly and annual albedos for each month and year of the period of record, and minimum, maximum, mean, median, and standard deviation statistics by calendar month and annually. The second table provides the mean hourly albedo by hour of the day and calendar month using data for all years. This provides information on the diurnal variation of albedo. The third table provides information on the completeness of the data set for calculating the albedo values. The percent of total daytime hours with data not missing and that pass their QA is provided for each month and year. The fourth table is similar the third table, but for nighttime hours. Although these values are not used to calculate albedo, a low percentage passing QA may indicate that a zero offset

exists that might also introduce errors in daytime values which would not be detected by the daytime QA checks.

The AmeriFlux station information is provided in the following sections. The section headings are the station locations. A link to an AmeriFlux website provides additional information on the station. The website tabs provide the DOI and associated publications. If images are not available, the satellite images from the "Windroses" tab may be useful. The "BADM" tab provides more information on vegetation and soil types.

Where provided by the station manager, additional information is included on the instrument maintenance and calibrations and related websites. Depending on available resources, maintenance activities may be at intervals of weeks or months, during an annual site visit, or none. If a station location experiences significant instrument soiling, the measured albedo values would be greater than actual because the sky-facing pyranometer would soil more than the ground-facing pyranometer.

Some of the albedo variation for a station may be the result of agricultural practices, such as mowing, grazing, burning, plowing, and herbicide or fertilizer applications.

For use of the AmeriFlux data in publications, see the AmeriFlux Data Use Policy (https://ameriflux.lbl.gov/data/data-policy/).

4.4.1 Lethbridge, Alberta, Canada

StationID: LethbridgeAlberta
AmeriFlux ID: CA-Let
Latitude: 49.7093°N
Longitude: 112.9402°W
Elevation: 960 m
Time Zone: -7
Period of Record: 2007
Data Files: 30-minute and hourly
Ground Surface: Mixed grass prairie
Annual Precipitation: 398 mm
Overall Albedo: 0.250
AmeriFlux Website: https://ameriflux.lbl.gov/sites/siteinfo/CA-Let#overview
AmeriFlux Description: *Mixed Grass Prairie that includes the following major species: Agropyron spp. (Wheat Grasses), Tragopogon dubius (Goat's Beard), Vicia americana (Wild Vetch), Koleria cristata (June Grass), Eurotia lanata (Winter Fat), Stipa comata (Spear Grass), Achillea millefolium (Yarrow); Artemisia frigida (Pasture Sage); Carex spp. (Sedges), Bouteloua gracilis (Blue Grama Grass). Maximum canopy height varies from year to year.*

Table 4.4.1-1. Data Elements, Mounting Height, and Instruments for Lethbridge, Alberta

Data Element	Mounting Height (m)	Instrument
GHI	-----	-----
GRI	-----	-----
Tdry	1.0	-----
RH	1.0	-----
Wspd	6.0	-----
Wdir	6.0	-----
Pres	-----	-----
PrecipAccum	-----	-----

Note: '-----' indicates that the information is not available.

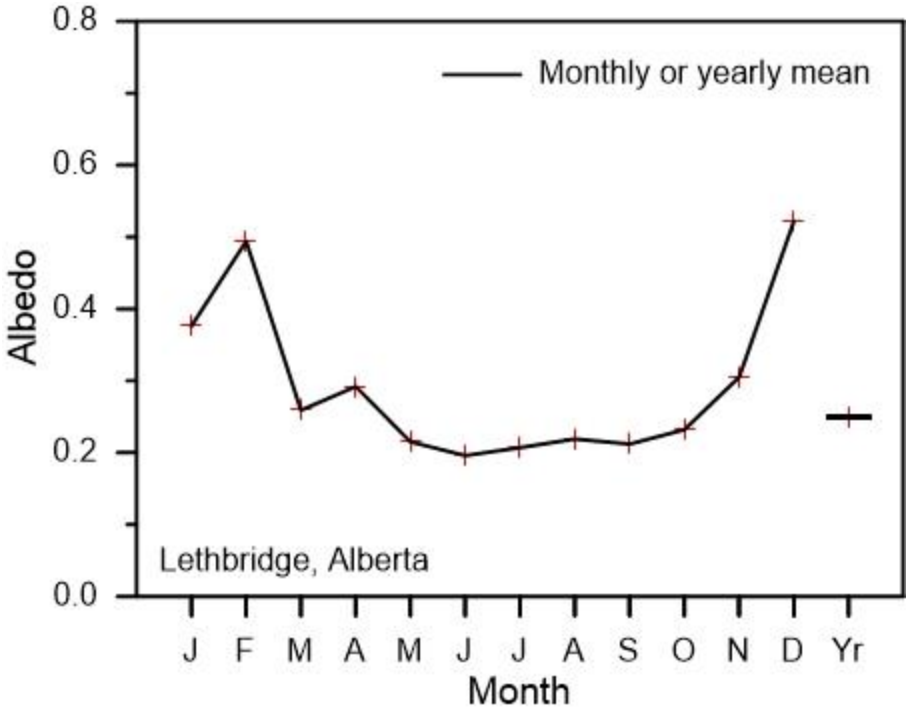

Figure 4.4.1-1. Monthly and yearly albedos and long-term means for Lethbridge, Alberta.

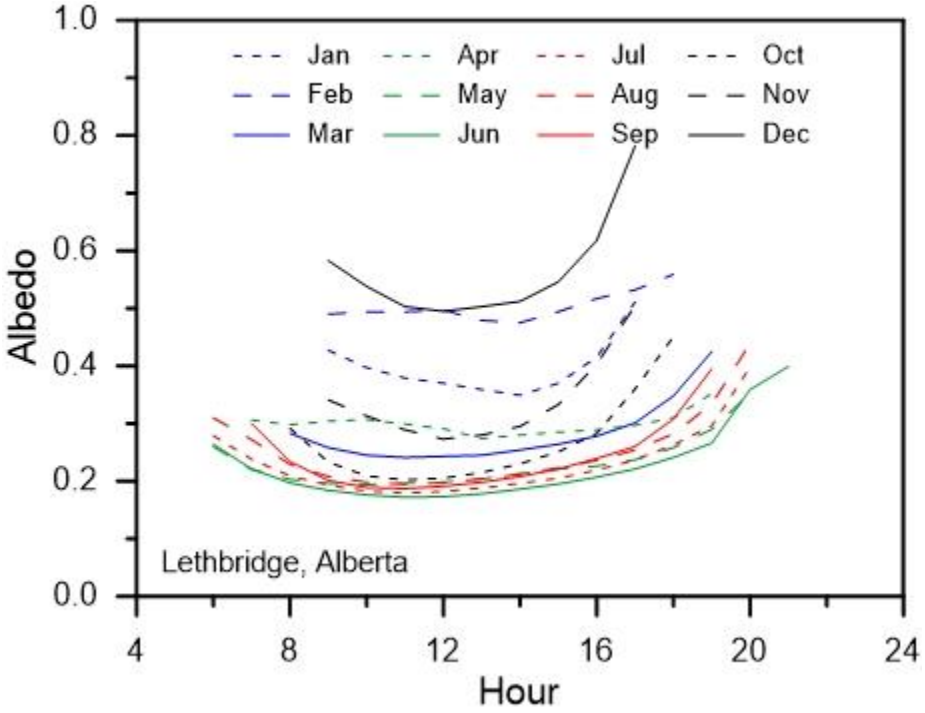

Figure 4.4.1-2. Mean hourly albedos by month for Lethbridge, Alberta.

4.4.2 Medford, Oklahoma, USA

StationID: MedfordOK
AmeriFlux ID: US-A32
Latitude: 36.8193°N
Longitude: 97.8198°W
Elevation: 335 m
Time Zone: -6
Period of Record: 2015-2017
Data Files: 30-minute and hourly
Ground Surface: Hay pasture
Annual Precipitation: 889 mm
Overall Albedo: 0.211
AmeriFlux Website: https://ameriflux.lbl.gov/sites/siteinfo/US-A32#overview
AmeriFlux Description: *This site is located at the ARM SGP Extended Facility E32, 8 km West of Medford, OK.*

Table 4.4.2-1. Data Elements, Mounting Height, and Instruments for Medford, OK

Data Element	Mounting Height (m)	Instrument
GHI	2.3	-----
DNI	2.3	-----
DHI	2.3	-----
GRI	2.3	-----
Tdry	2.9	-----
RH	2.9	-----
Wspd	3.8	Gill R3-50
Wdir	3.8	Gill R3-50
Pres	2.1	-----
PrecipAccum	1.0	-----

Note: '-----' indicates that the information is not available.

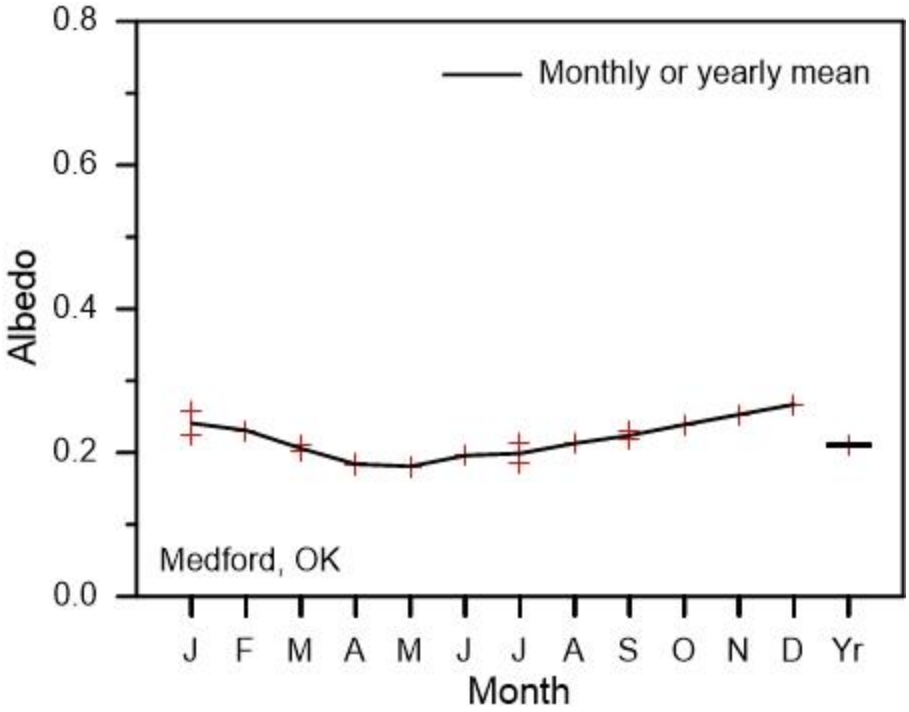

Figure 4.4.2-1. Monthly and yearly albedos and long-term means for Medford, OK.

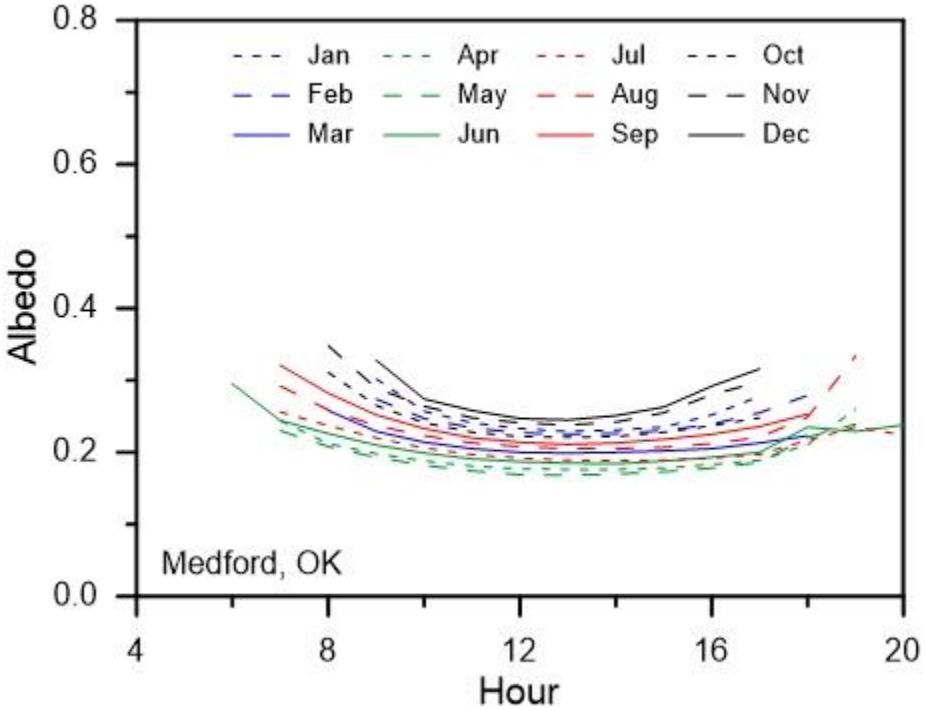

Figure 4.4.2-2. Mean hourly albedos by month for Medford, OK.

4.4.3 Woodward, Oklahoma, USA (1)

StationID: WoodwardOK_1
AmeriFlux ID: US-AR1
Latitude: 36.4267°N
Longitude: 99.4200°W
Elevation: 611 m
Time Zone: -6
Period of Record: 2009-2012
Data Files: 30-minute and hourly
Ground Surface: Switchgrass
Annual Precipitation: Not available
Overall Albedo: 0.186
AmeriFlux Website: https://ameriflux.lbl.gov/sites/siteinfo/US-AR1#overview
AmeriFlux Description: *The ARM USDA UNL OSU Woodward Switchgrass 1 tower is located on public land owned by the USDA-ARS Southern Plains Range Research Station in Woodward, Oklahoma. The site is on a former native prairie that is in the process of changing to switchgrass. A second companion site (ARM USDA UNL OSU Woodward Switchgrass 2) is on a former wheat field. In Spring 2009, the former native prairie site was burned, cattle were put on the pasture to graze down emergent grass, and broadleaf herbicide was sprayed. In Summer 2009, the cattle were removed from the pasture, and the site was sprayed with herbicide to kill all grass. In Spring 2010, prior to the planting of switchgrass, final herbicide was sprayed to kill cheat grass and to control broadleaf plants.*

Table 4.4.3-1. Data Elements, Mounting Height, and Instruments for Woodward, OK_1

Data Element	Mounting Height (m)	Instrument
GHI	2.2	-----
GRI	2.2	-----
Tdry	3.1	-----
RH	3.1	-----
Wspd	2.8	-----
Wdir	2.8	-----
Pres	2.0	-----
PrecipAccum	1.5	-----

Note: '-----' indicates that the information is not available.

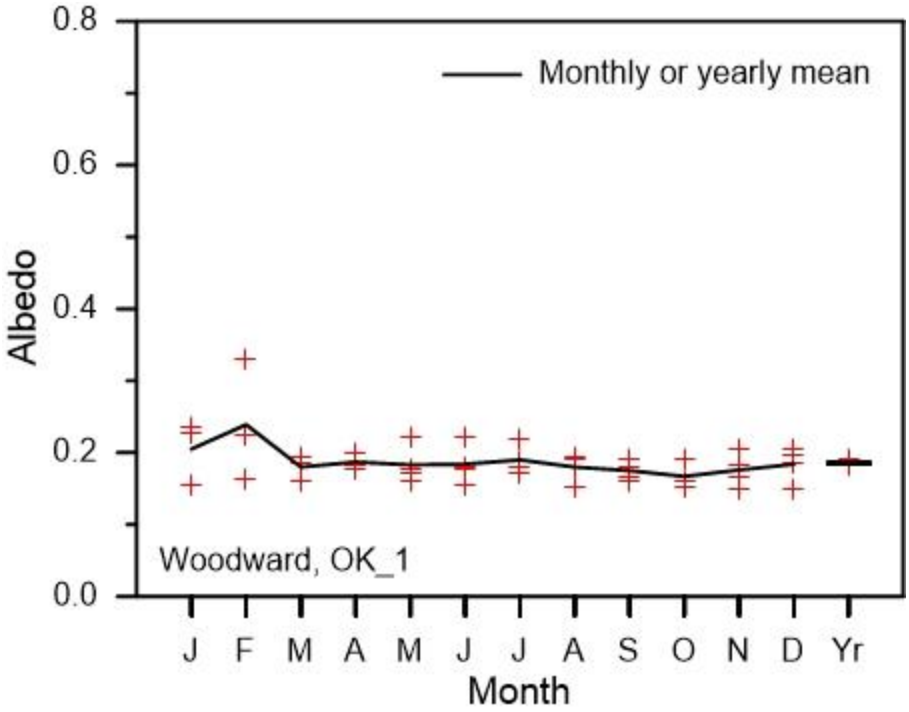

Figure 4.4.3-1. Monthly and yearly albedos and long-term means for Woodward, OK_1.

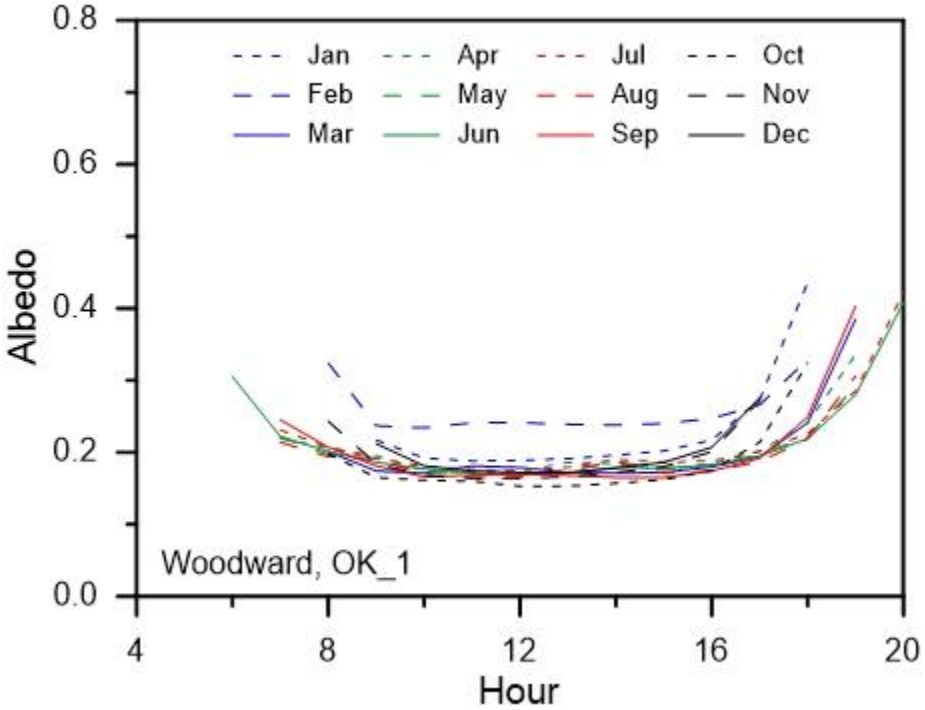

Figure 4.4.3-2. Mean hourly albedos by month for Woodward, OK_1.

4.4.4 Woodward, Oklahoma, USA (2)

StationID: WoodwardOK_2
AmeriFlux ID: US-AR2
Latitude: 36.6358°N
Longitude: 99.5975°W
Elevation: 646 m
Time Zone: -6
Period of Record: 2009-2012
Data Files: 30-minute and hourly
Ground Surface: Switchgrass
Annual Precipitation: Not available
Overall Albedo: 0.204
AmeriFlux Website: https://ameriflux.lbl.gov/sites/siteinfo/US-AR2
AmeriFlux Description: *The ARM USDA UNL OSU Woodward Switchgrass 2 tower is located on public land owned by the USDA-ARS Southern Plains Range Research Station in Woodward, Oklahoma. The site is on a former wheat field that is in the process of changing to switchgrass. A companion site (ARM USDA UNL OSU Woodward Switchgrass 1) is on a former native prairie. Previous wheat was planted in Fall 2008. In Spring 2009, herbicide was applied to kill the wheat prior to switchgrass planting. Later in the year, the site was sprayed with post-emergence herbicide. In 2010, fertilization occurred before herbicide was sprayed for broadleaf control.*

Table 4.4.4-1. Data Elements, Mounting Height, and Instruments for Woodward, OK_2

Data Element	Mounting Height (m)	Instrument
GHI	2.3	-----
GRI	2.3	-----
Tdry	3.3	-----
RH	3.3	-----
Wspd	3.0	-----
Wdir	3.0	-----
Pres	2.0	-----
PrecipAccum	1.5	-----

Note: '-----' indicates that the information is not available.

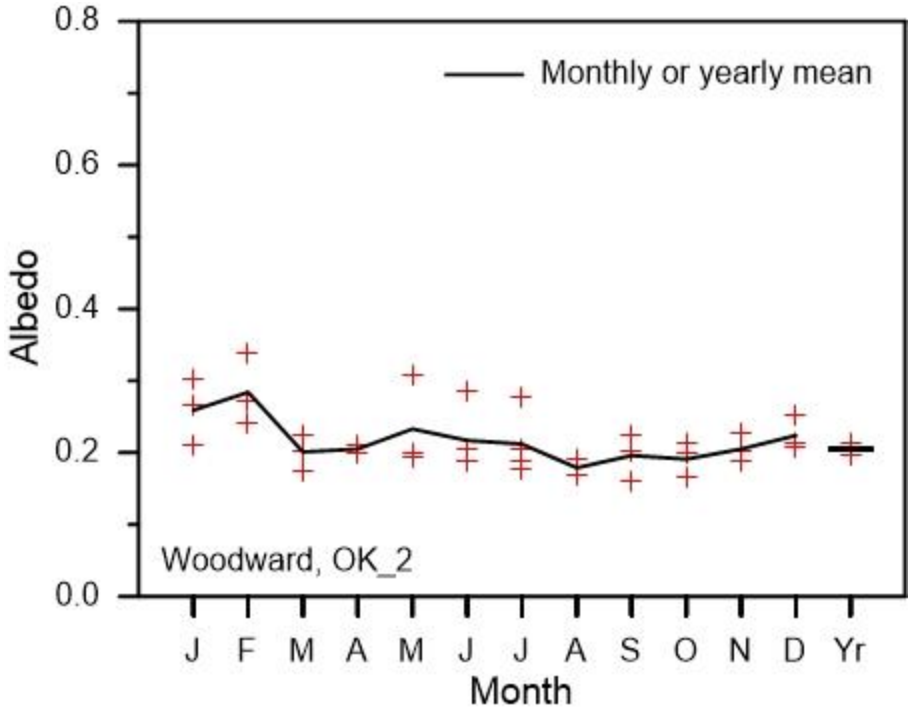

Figure 4.4.4-1. Monthly and yearly albedos and long-term means for Woodward, OK_2.

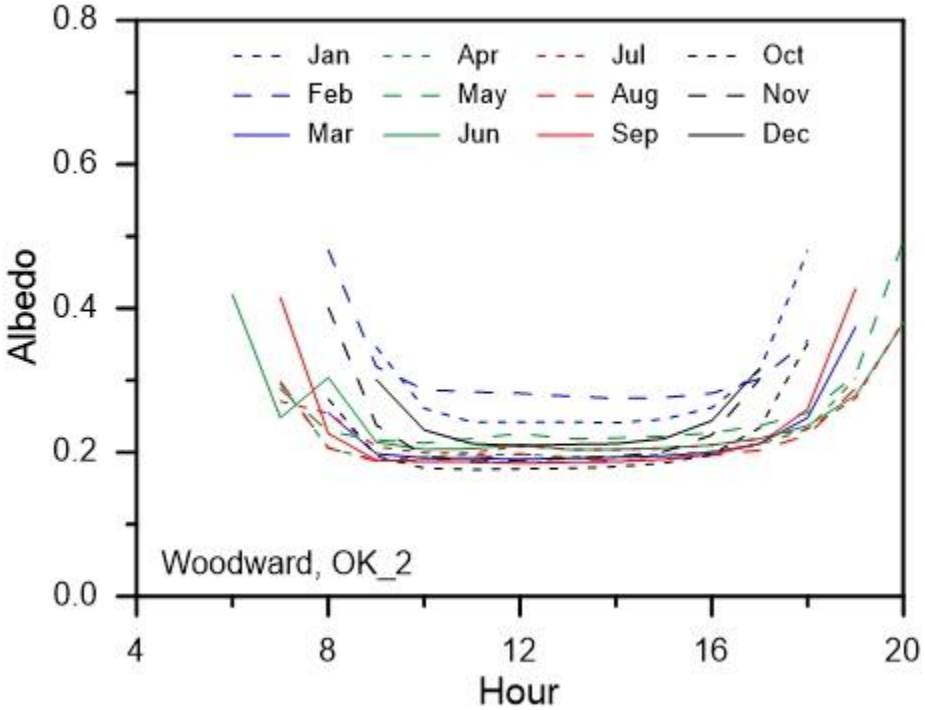

Figure 4.4.4-2. Mean hourly albedos by month for Woodward, OK_2.

4.4.5 Audubon Research Ranch, Arizona, USA

StationID: AudubonRanchAZ
AmeriFlux ID: US-Aud
Latitude: 31.5907°N
Longitude: 110.5104°W
Elevation: 1469 m
Time Zone: -7
Period of Record: 2002-2011
Data Files: 30-minute and hourly
Ground Surface: Native grasses
Annual Precipitation: 438 mm
Overall Albedo: 0.217
AmeriFlux Website: https://ameriflux.lbl.gov/sites/siteinfo/US-Aud
AmeriFlux Description: *Not available.*

Table 4.4.5-1. Data Elements, Mounting Height, and Instruments for Audubon Research Ranch, AZ

Data Element	Mounting Height (m)	Instrument
GHI	-----	-----
GRI	-----	-----
Tdry	-----	-----
RH	-----	-----
Wspd	-----	-----
Wdir	-----	-----
Pres	-----	-----
PrecipAccum	-----	-----

Note: '-----' indicates that the information is not available.

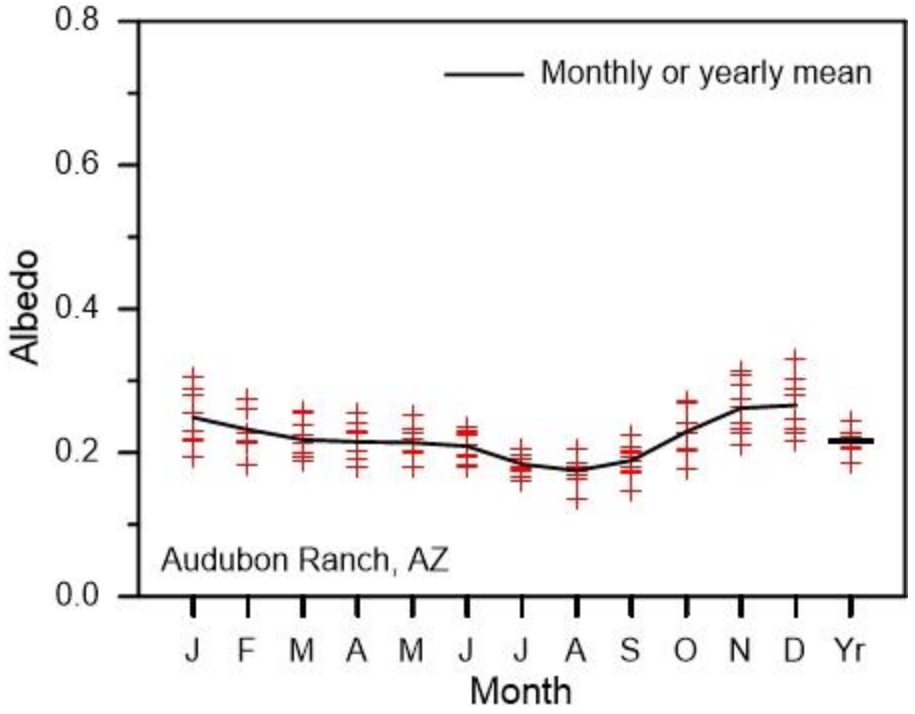

Figure 4.4.5-1. Monthly and yearly albedos and long-term means for Audubon Research Ranch, AZ.

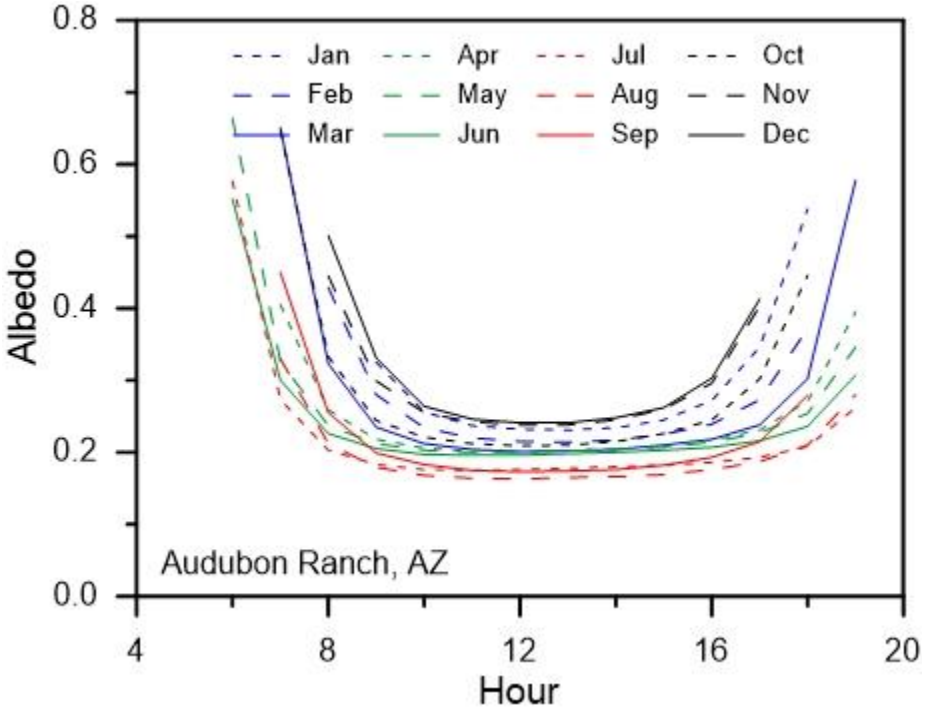

Figure 4.4.5-2. Mean hourly albedos by month for Audubon Research Ranch, AZ.

4.4.6 Bouldin Island, California, USA

StationID: BouldinCA
AmeriFlux ID: US-Bi1
Latitude: 38.0992°N
Longitude: 121.4993°W
Elevation: -3 m
Time Zone: -8
Period of Record: 2016-2018
Data Files: 30-minute and hourly
Ground Surface: Alfalfa
Annual Precipitation: 338 mm
Overall Albedo: 0.221
AmeriFlux Website: https://ameriflux.lbl.gov/sites/siteinfo/US-Bi1
AmeriFlux Description: *Agricultural field in the San Joaquin Sacramento Delta. The field is a mix of organic peat and sediments and minerals from old river channels.*
Maintenance: Sensors are cleaned every week or two and calibrated periodically (from email by station manager Dennis Baldocchi on 8/27/2019)
Station Websites:
https://nature.berkeley.edu/biometlab/bmetdata/sitedescriptions.php?screen=display&id=BA
https://nature.berkeley.edu/biometlab/bmetdata/photodb.php?screen=display&view=p&page=1&LL=Bouldin+Alfalfa&SN=Tower

Table 4.4.6-1. Data Elements, Mounting Height, and Instruments for Bouldin Island, CA

Data Element	Mounting Height (m)	Instrument
GHI	2.8	Hukseflux NR01
GRI	2.8	Hukseflux NR01
Tdry	3.5	Vaisala HMP45AC
RH	3.5	Vaisala HMP45AC
Wspd	3.9	Gill Windmaster
Wdir	3.9	Gill Windmaster
Pres	-----	-----
PrecipAccum	2.7	Texas Electronic TE525MM

Note: '-----' indicates that the information is not available.

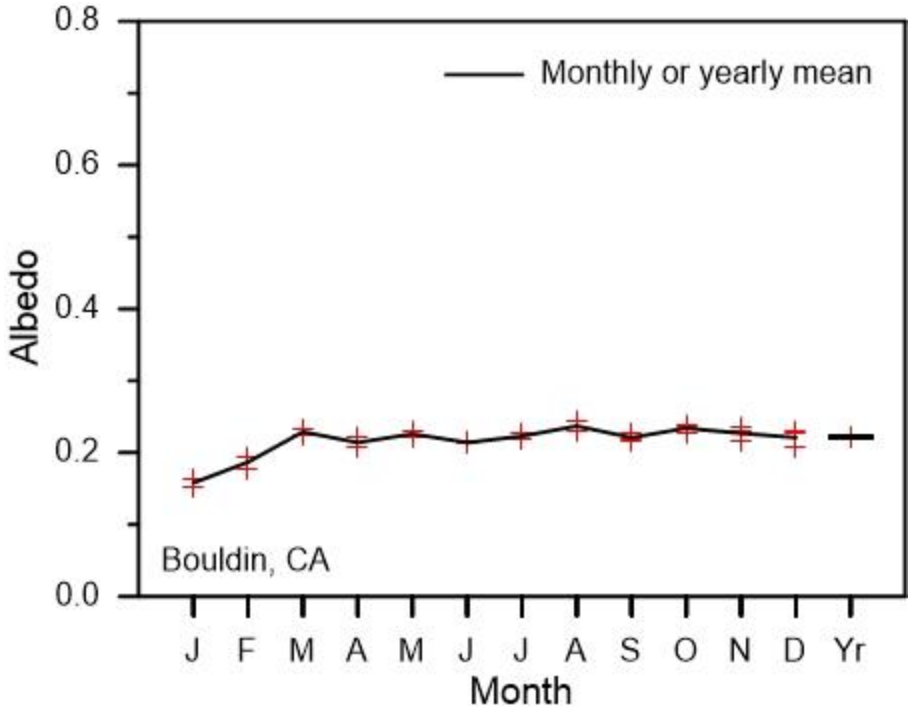

Figure 4.4.6-1. Monthly and yearly albedos and long-term means for Bouldin Island, CA.

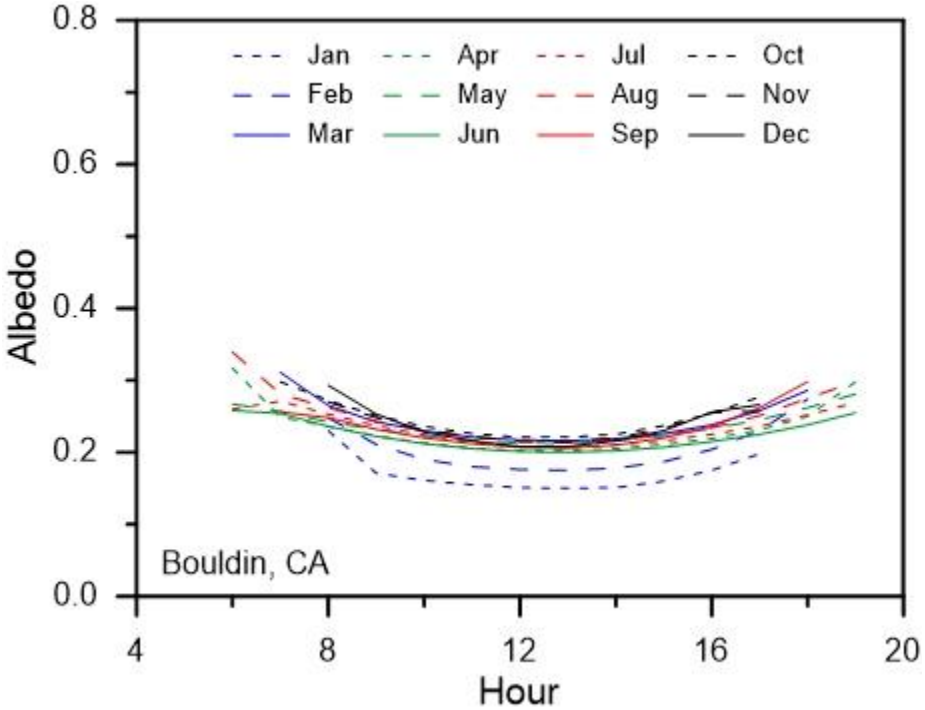

Figure 4.4.6-2. Mean hourly albedos by month for Bouldin Island, CA.

4.4.7 Brookings, South Dakota, USA

StationID: BrookingsSD
AmeriFlux ID: US-Bkg
Latitude: 44.3453°N
Longitude: 96.8362°W
Elevation: 510 m
Time Zone: -6
Period of Record: 2004-2010
Data Files: 30-minute and hourly
Ground Surface: Pasture grass
Annual Precipitation: 586 mm
Overall Albedo: 0.262
AmeriFlux Website: https://ameriflux.lbl.gov/sites/siteinfo/US-Bkg#overview
AmeriFlux Description: *The Brookings site is located in a private pasture, consisting of a mixture of C3 and C4 species actively used for grazing. Belonging to the Northern Great Plains Rangelands, the grassland is representative of many in the north central United States, with seasonal winter conditions and a wet growing season.*

Table 4.4.7-1. Data Elements, Mounting Height, and Instruments for Brookings, SD

Data Element	Mounting Height (m)	Instrument
GHI	-----	-----
GRI	-----	-----
Tdry	4.0	-----
RH	4.0	-----
Wspd	4.0	-----
Wdir	4.0	-----
Pres	-----	-----
PrecipAccum	-----	-----

Note: '-----' indicates that the information is not available.

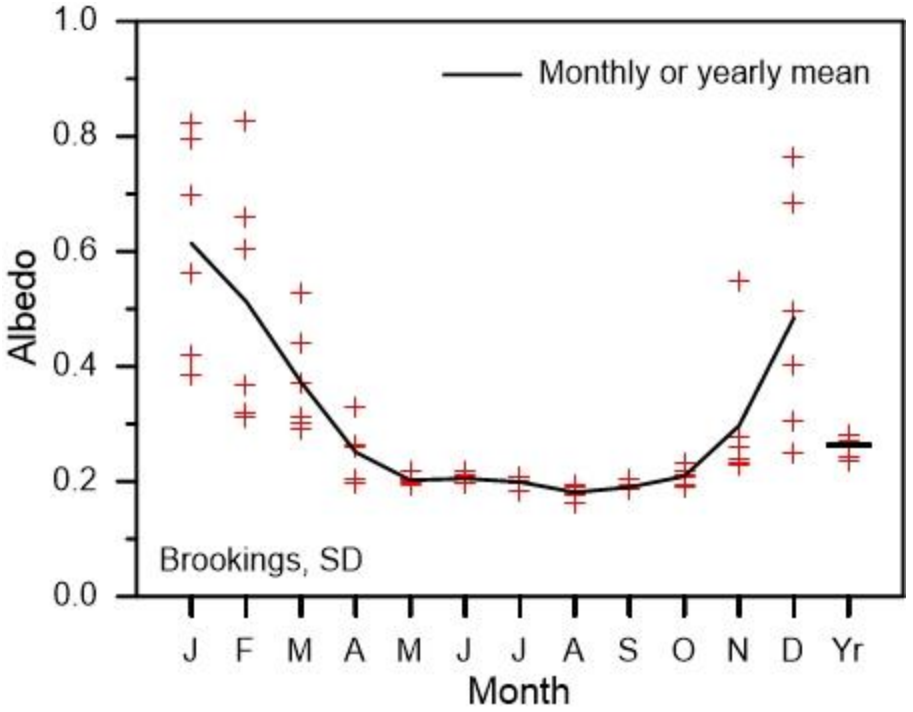

Figure 4.4.7-1. Monthly and yearly albedos and long-term means for Brookings, SD.

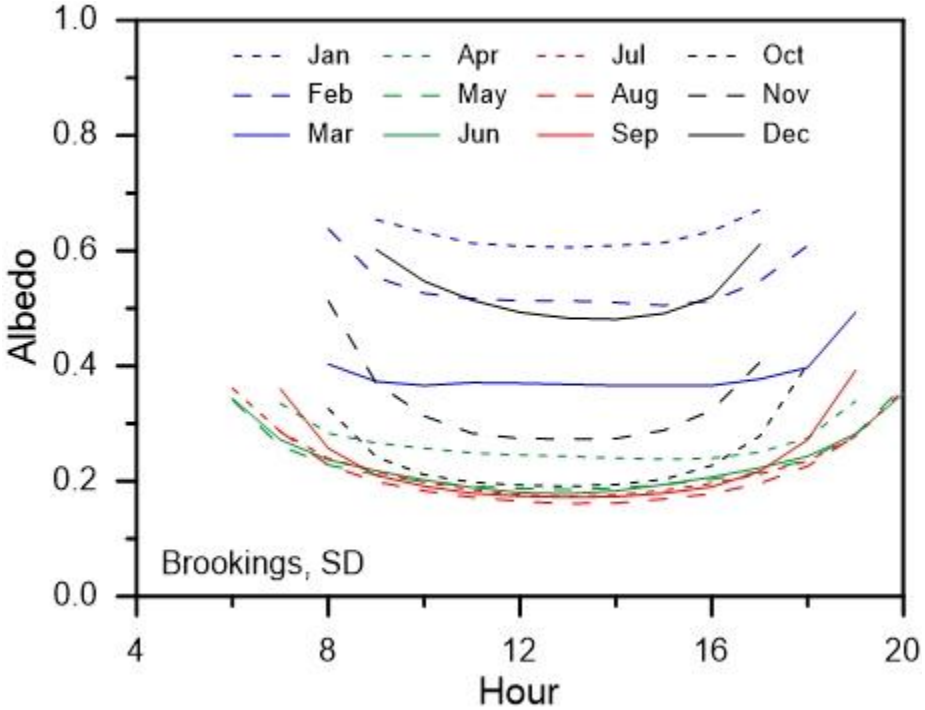

Figure 4.4.7-2. Mean hourly albedos by month for Brookings, SD.

4.4.8 Canaan Valley, West Virginia, USA

StationID: CanaanValleyWV
AmeriFlux ID: US-CaV
Latitude: 39.0633°N
Longitude: 79.4208°W
Elevation: 994 m
Time Zone: -5
Period of Record: 2004-2009
Data Files: 30-minute and hourly
Ground Surface: Grassland
Annual Precipitation: 1317 mm
Overall Albedo: 0.294
AmeriFlux Website: https://ameriflux.lbl.gov/sites/siteinfo/US-CaV
AmeriFlux Description: *Not available.*

Table 4.4.8-1. Data Elements, Mounting Height, and Instruments for Canaan Valley, WV

Data Element	Mounting Height (m)	Instrument
GHI	-----	-----
GRI	-----	-----
Tdry	-----	-----
RH	-----	-----
Wspd	4.0	-----
Wdir	4.0	-----
Pres	-----	-----
PrecipAccum	-----	-----

Note: '-----' indicates that the information is not available.

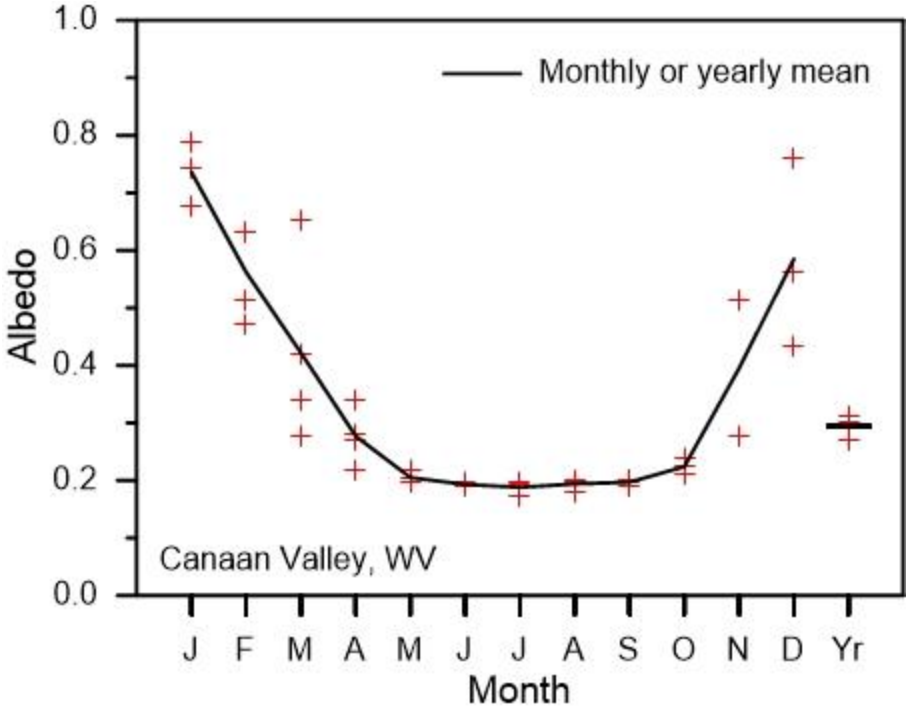

Figure 4.4.8-1. Monthly and yearly albedos and long-term means for Canaan Valley, WV.

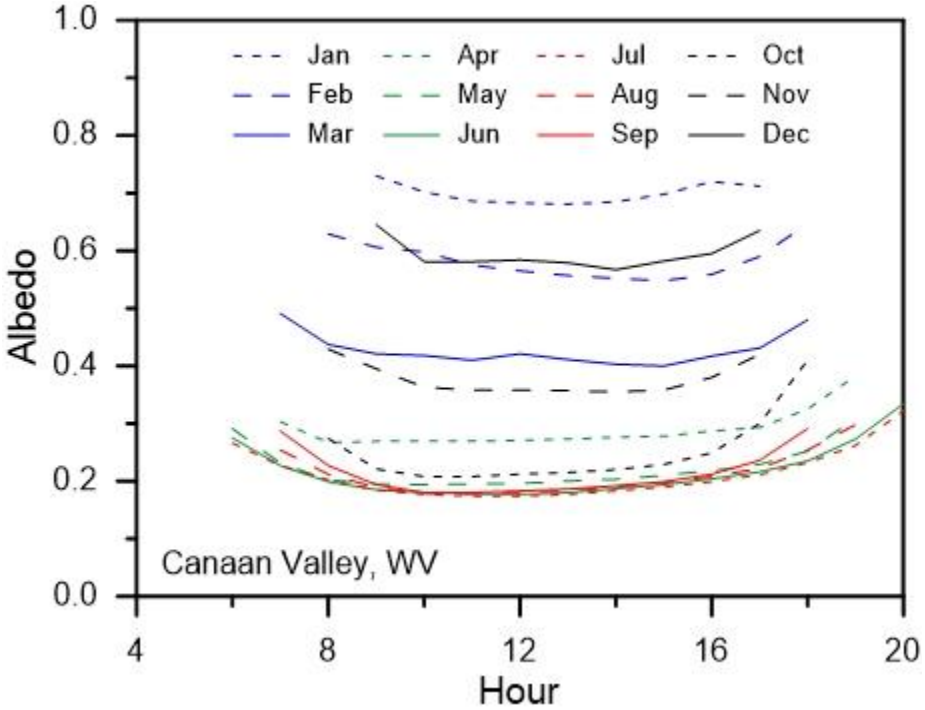

Figure 4.4.8-2. Mean hourly albedos by month for Canaan Valley, WV.

4.4.9 Corral Pocket, Utah, USA

StationID: CorralPocketUT
AmeriFlux ID: US-Cop
Latitude: 38.0900°N
Longitude: 109.3900°W
Elevation: 1520 m
Time Zone: -7
Period of Record: 2001-2009
Data Files: Hourly
Ground Surface: Semi-arid grassland with 38-80% bare ground from livestock grazing
Annual Precipitation: Not available
Overall Albedo: 0.238
AmeriFlux Website: https://ameriflux.lbl.gov/sites/siteinfo/US-Cop
AmeriFlux Description: *The Corral Pocket site is located in a semi-arid grassland in southeastern Utah, just east of Canyonlands National park. For the greater part of the year, 38-80% of the ground is essentially bare. Vegetation is primarily native perennial C3/C4 grasses with annual ground converge ranging from 8-35%. Leaving the remaining 0-15% coverage to interspersed annual grasses, the remaining 0-15% coverage is occupied by annual grasses. 6-8 weeks during the late fall or winter, Livestock grazing is responsible for the majority of aboveground vegetation loss and subsequent high variability of ground coverage.*
Maintenance: The focus was not on high-quality radiation measurements and the pyranometers were not cleaned (from email by station manager David Bowling on 8/27/2019)

Table 4.4.9-1. Data Elements, Mounting Height, and Instruments for Corral Pocket, UT

Data Element	Mounting Height (m)	Instrument
GHI	3.0	Licor LI-200X
GRI	3.0	Licor LI-200X
Tdry	3.0	Vaisala HMP35C
RH	3.0	Vaisala HMP35C
Wspd	3.0	RM Young 5103
Wdir	3.0	RM Young 5103
Pres	-----	Omega PX137
PrecipAccum	1.0	Texas Electronics 525 tipping bucket

Note: '-----' indicates that the information is not available.

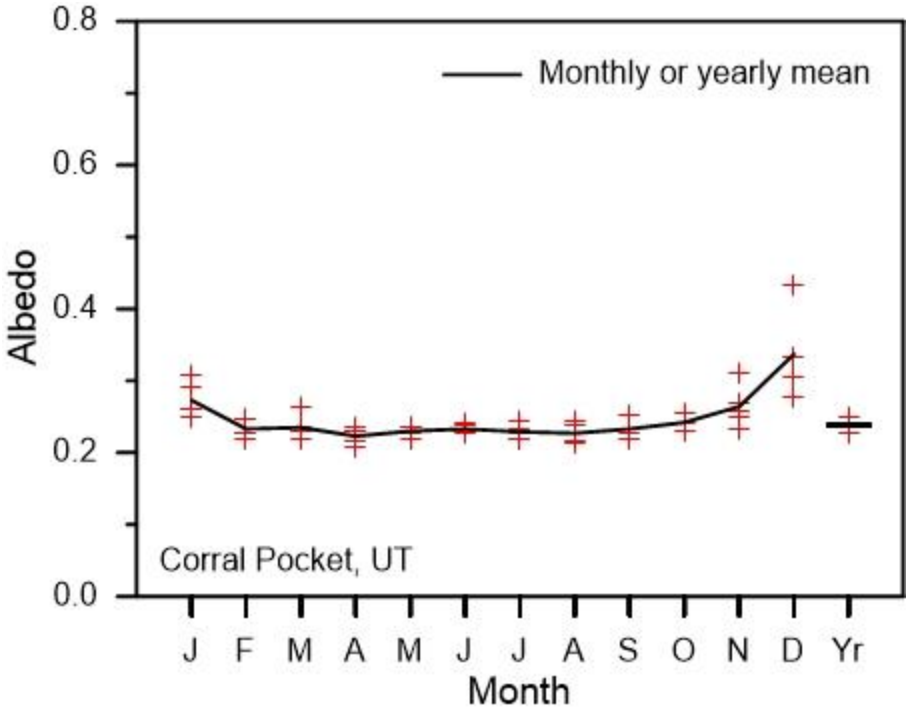

Figure 4.4.9-1. Monthly and yearly albedos and long-term means for Corral Pocket, UT.

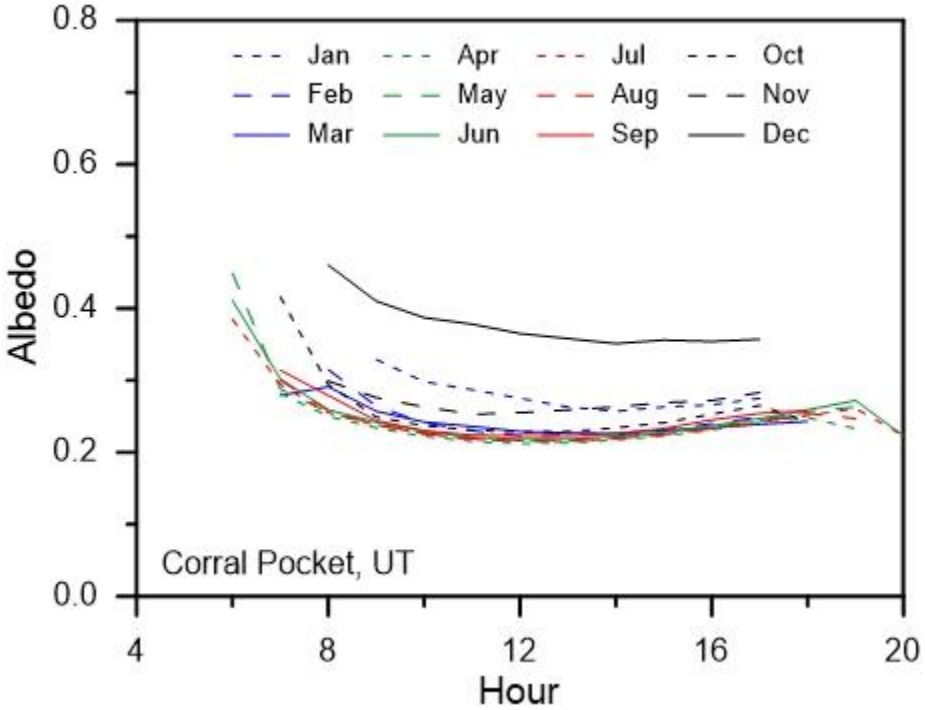

Figure 4.4.9-2. Mean hourly albedos by month for Corral Pocket, UT.

4.4.10 Cottonwood, South Dakota, USA

StationID: CottonwoodSD
AmeriFlux ID: US-Ctn
Latitude: 43.9500°N
Longitude: 101.8466°W
Elevation: 744 m
Time Zone: -7
Period of Record: 2006-2009
Data Files: 30-minute and hourly
Ground Surface: Grassland
Annual Precipitation: Not available
Overall Albedo: 0.181
AmeriFlux Website: https://ameriflux.lbl.gov/sites/siteinfo/US-Ctn
AmeriFlux Description: *Not available.*

Table 4.4.10-1. Data Elements, Mounting Height, and Instruments for Cottonwood, SD

Data Element	Mounting Height (m)	Instrument
GHI	-----	-----
GRI	-----	-----
Tdry	-----	-----
RH	-----	-----
Wspd	-----	-----
Wdir	-----	-----
Pres	-----	-----
PrecipAccum	-----	-----

Note: '-----' indicates that the information is not available.

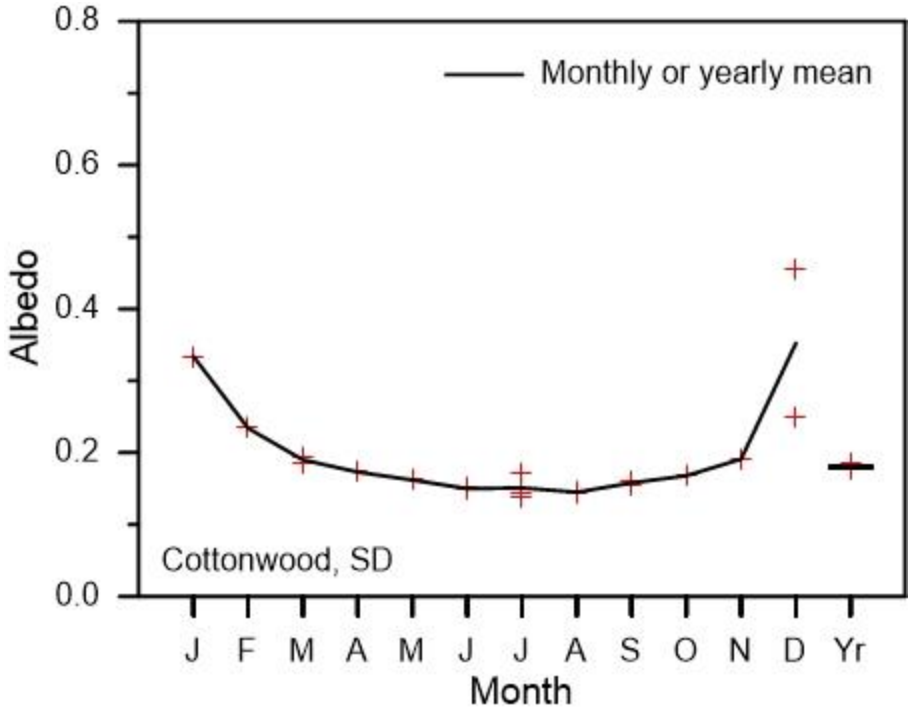

Figure 4.4.10-1. Monthly and yearly albedos and long-term means for Cottonwood, SD.

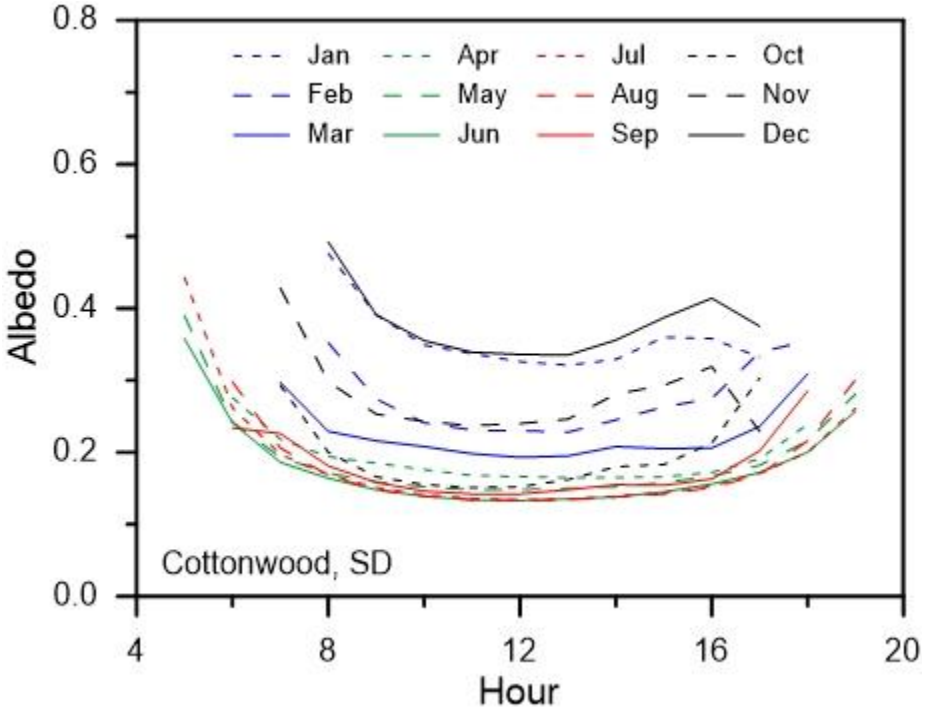

Figure 4.4.10-2. Mean hourly albedos by month for Cottonwood, SD.

4.4.11 Diablo, California, USA

StationID: DiabloCA
AmeriFlux ID: US-Dia
Latitude: 37.6773°N
Longitude: 121.5296°W
Elevation: 323 m
Time Zone: -8
Period of Record: 2010-2012
Data Files: 30-minute and hourly
Ground Surface: Grassland
Annual Precipitation: 265 mm
Overall Albedo: 0.206
AmeriFlux Website: https://ameriflux.lbl.gov/sites/siteinfo/US-Dia
AmeriFlux Description: *The site is on land owned by Lawrence Livermore National Laboratory (Site 300) and has no grazing or management history since the 1950's except for summer-time burning of selected acres for fire management (not included in the tower footprint).*
Maintenance: Pyranometers are cleaned once a year. From May through October the area is pretty dusty with little to no precipitation (from email by station manager Sonia Wharton on 8/28/2019).

Table 4.4.11-1. Data Elements, Mounting Height, and Instruments for Diablo, CA

Data Element	Mounting Height (m)	Instrument
GHI	2.2	Kipp & Zonen CNR1
GRI	2.2	Kipp & Zonen CNR1
Tdry	2.2	Vaisala HMP45
RH	2.2	Vaisala HMP45
Wspd	2.1	Campbell Scientific CSAT3A
Wdir	2.1	Campbell Scientific CSAT3A
Pres	2.2	-----
PrecipAccum	0.0	NovaLynx Corp. 260-2500-12

Note: '-----' indicates that the information is not available.

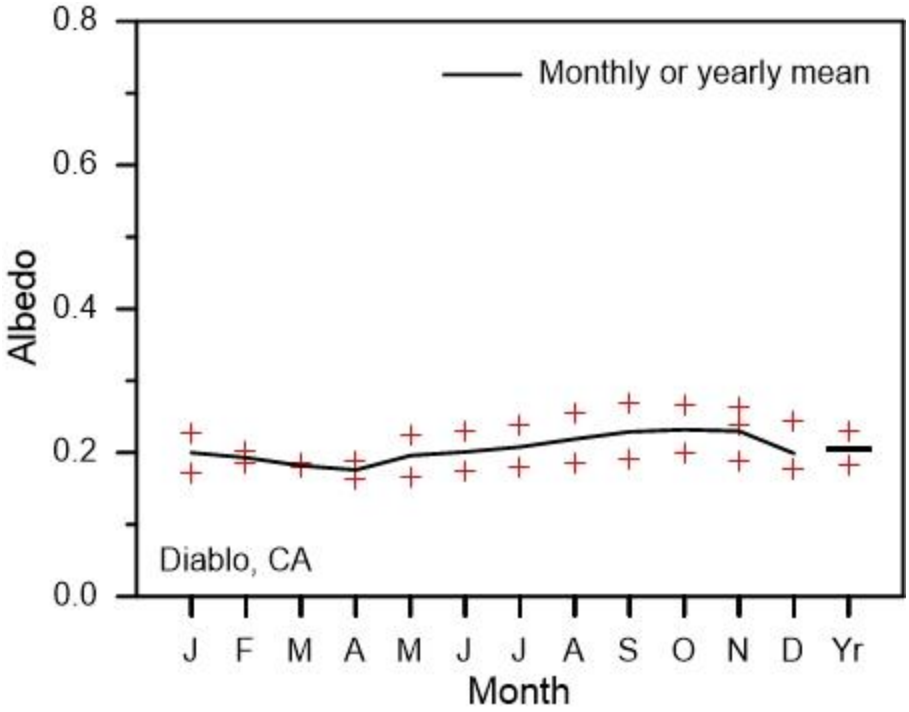

Figure 4.4.11-1. Monthly and yearly albedos and long-term means for Diablo, CA.

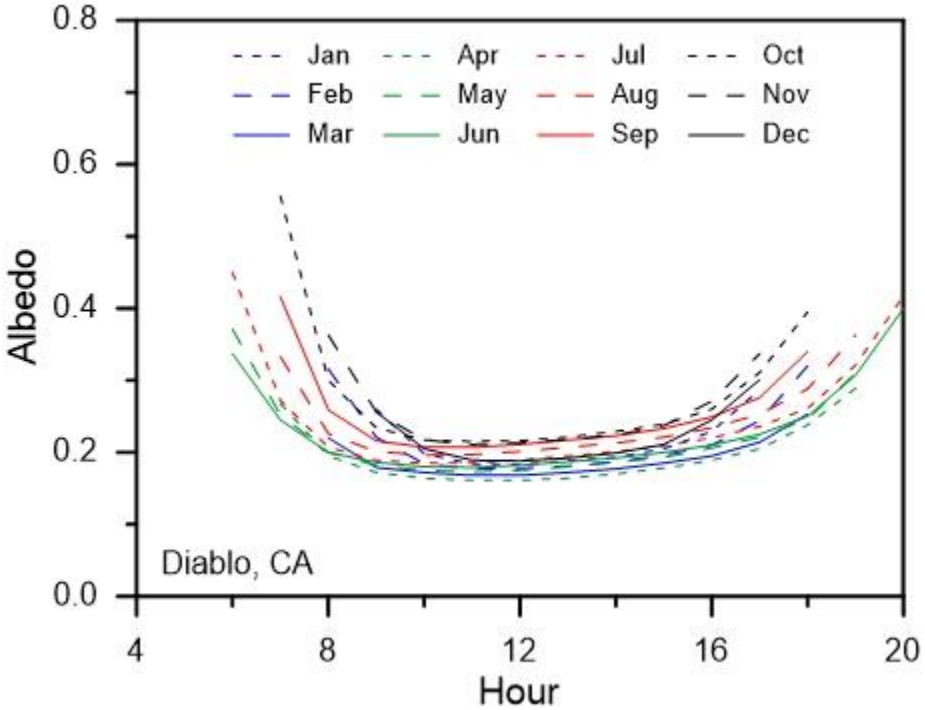

Figure 4.4.11-2. Mean hourly albedos by month for Diablo, CA.

4.4.12 Duke Field, North Carolina, USA

StationID: DukeFieldNC
AmeriFlux ID: US-Dk1
Latitude: 35.9712°N
Longitude: 79.0934°W
Elevation: 168 m
Time Zone: -5
Period of Record: 2004-2008
Data Files: 30-minute and hourly
Ground Surface: Tall fescue grass mowed annually
Annual Precipitation: 1170 mm
Overall Albedo: 0.203
AmeriFlux Website: https://ameriflux.lbl.gov/sites/siteinfo/US-Dk1
AmeriFlux Description: *The Duke Forest grass field is approximately 480×305 m, dominated by the C3 grass Festuca arundinacea Shreb. (tall fescue) includes minor components of C3 herbs and the C4 grass Schizachyrium scoparium (Michx.) Nash, not considered here. The site was burned in 1979 and is mowed annually during the summer for hay according to local practices.*

Table 4.4.12-1. Data Elements, Mounting Height, and Instruments for Duke Field, NC

Data Element	Mounting Height (m)	Instrument
GHI	-----	-----
GRI	-----	-----
Tdry	2.8	-----
RH	2.8	-----
Wspd	2.8	-----
Wdir	-----	-----
Pres	-----	-----
PrecipAccum	1.9	-----

Note: '-----' indicates that the information is not available.

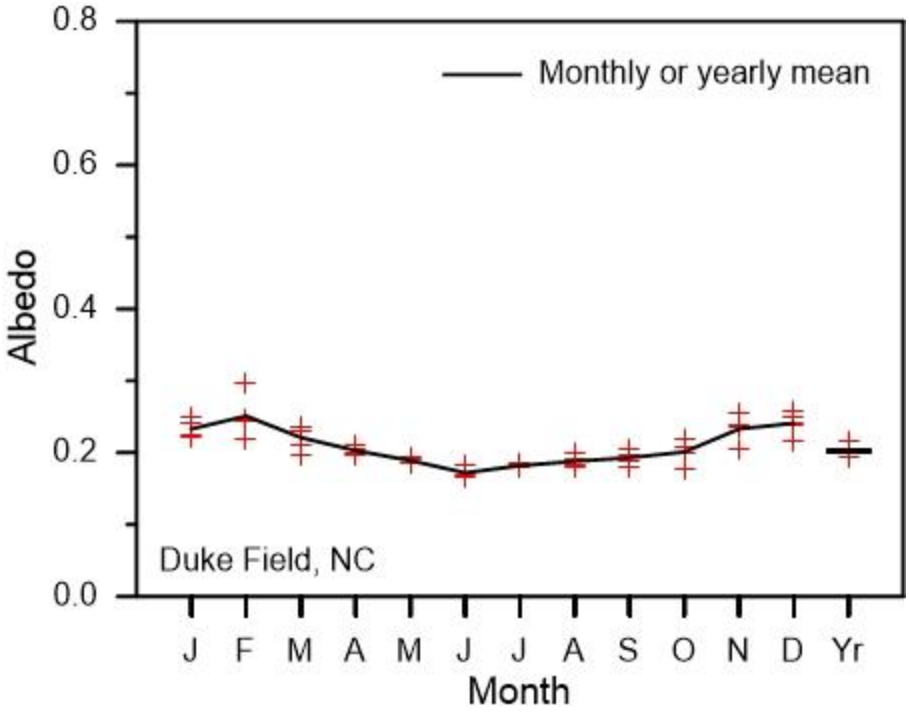

Figure 4.4.12-1. Monthly and yearly albedos and long-term means for Duke Field, NC.

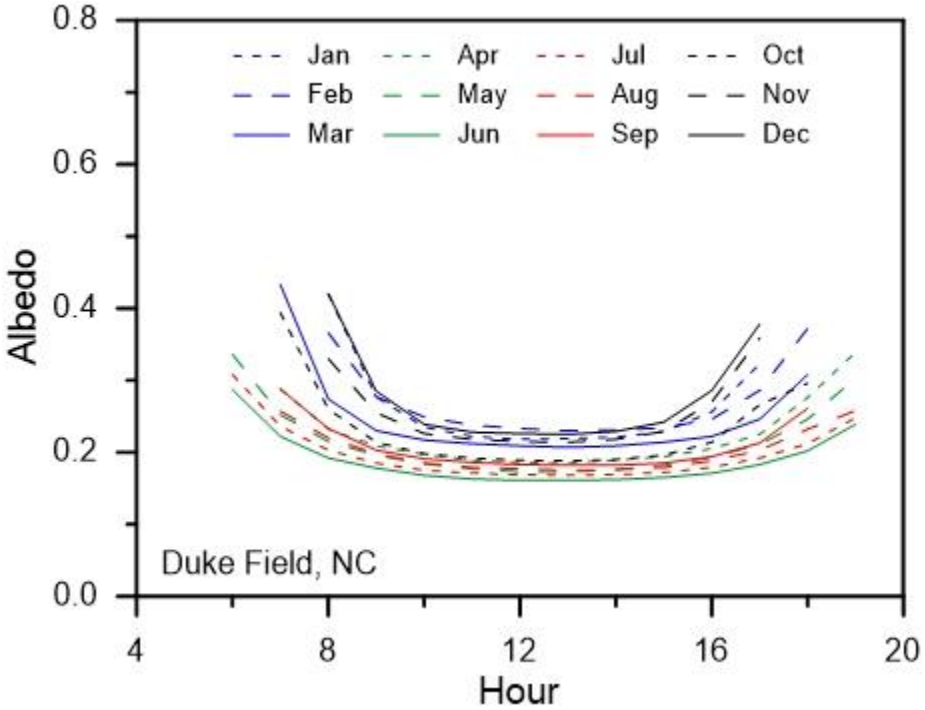

Figure 4.4.12-2. Mean hourly albedos by month for Duke Field, NC.

4.4.13 Flagstaff, Arizona, USA

StationID: FlagstaffAZ
AmeriFlux ID: US-Fwf
Latitude: 35.4454°N
Longitude: 111.7718°W
Elevation: 2270 m
Time Zone: -7
Period of Record: 2005-2010
Data Files: 30-minute and hourly
Ground Surface: Post forest fire grasslands
Annual Precipitation: 557 mm
Overall Albedo: 0.219
AmeriFlux Website: https://ameriflux.lbl.gov/sites/siteinfo/US-Fwf
AmeriFlux Description: *Ponderosa pine forest subject to high severity stand replacing wildfire in 1996.*

Table 4.4.13-1. Data Elements, Mounting Height, and Instruments for Flagstaff, AZ

Data Element	Mounting Height (m)	Instrument
GHI	2.0	-----
GRI	2.0	-----
Tdry	2.0	-----
RH	2.0	-----
Wspd	2.0	-----
Wdir	2.0	-----
Pres	-----	-----
PrecipAccum	-----	-----

Note: '-----' indicates that the information is not available.

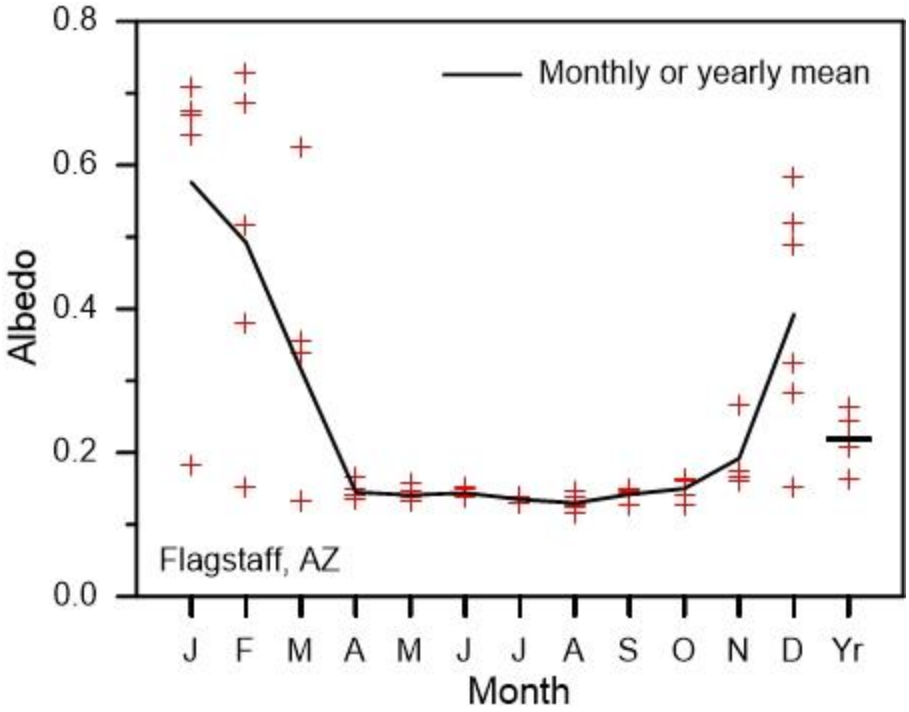

Figure 4.4.13-1. Monthly and yearly albedos and long-term means for Flagstaff, AZ.

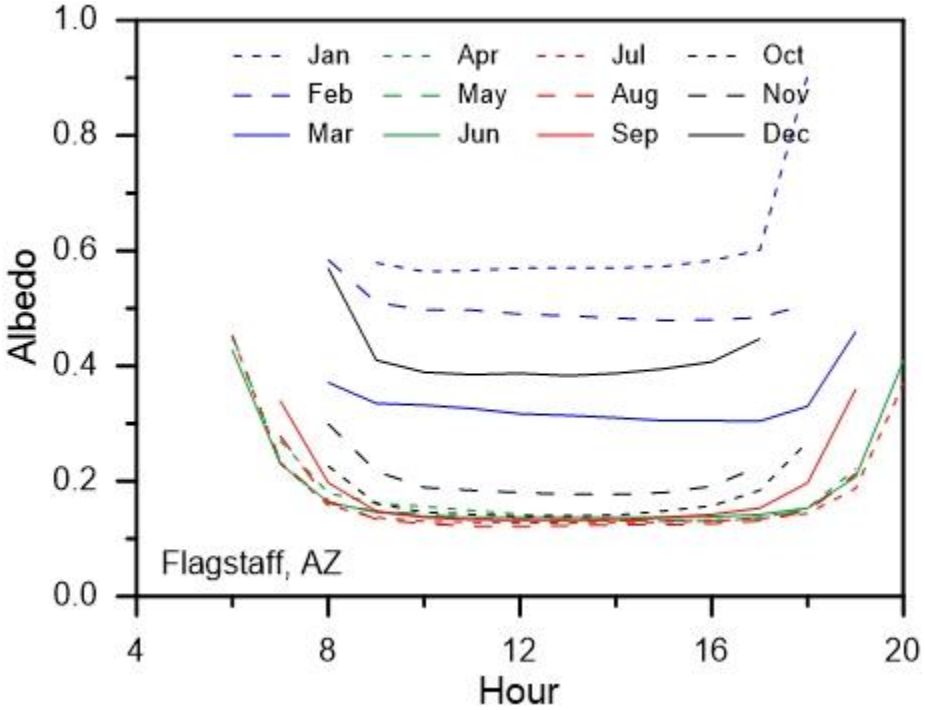

Figure 4.4.13-2. Mean hourly albedos by month for Flagstaff, AZ.

4.4.14 Fermilab - Batavia, Illinois, USA

StationID: FermilabIL
AmeriFlux ID: US-IB2
Latitude: 41.8406°N
Longitude: 88.2410°W
Elevation: 226 m
Time Zone: -6
Period of Record: 2004-2017
Data Files: 30-minute and hourly
Ground Surface: Prairie grass
Annual Precipitation: 930 mm
Overall Albedo: 0.221
AmeriFlux Website: https://ameriflux.lbl.gov/sites/siteinfo/US-IB2
AmeriFlux Description: *Two eddy correlation systems are installed at Fermi National Accelerator Laboratory: one on a restored prairie (established October 2004) and one on a corn/soybean rotation agricultural field (established in July 2005). The prairie site had been farmed for more than 100 years, but was converted to prairie in 1989. April annual to bi-annual prescribed burns have taken place from 1994 - 2007.*

Table 4.4.14-1. Data Elements, Mounting Height, and Instruments for Fermilab - Batavia, IL

Data Element	Mounting Height (m)	Instrument
GHI	2.3	Eppley 8-48
GRI	2.3	Eppley 8-48
Tdry	3.8	Vaisala HMP45D
RH	3.8	Vaisala HMP45D
Wspd	3.8	Gill R3-100
Wdir	3.8	Gill R3-100
Pres	1.5	Met One 7120
PrecipAccum	2.0	Belfort OMC-212

Note: '-----' indicates that the information is not available.

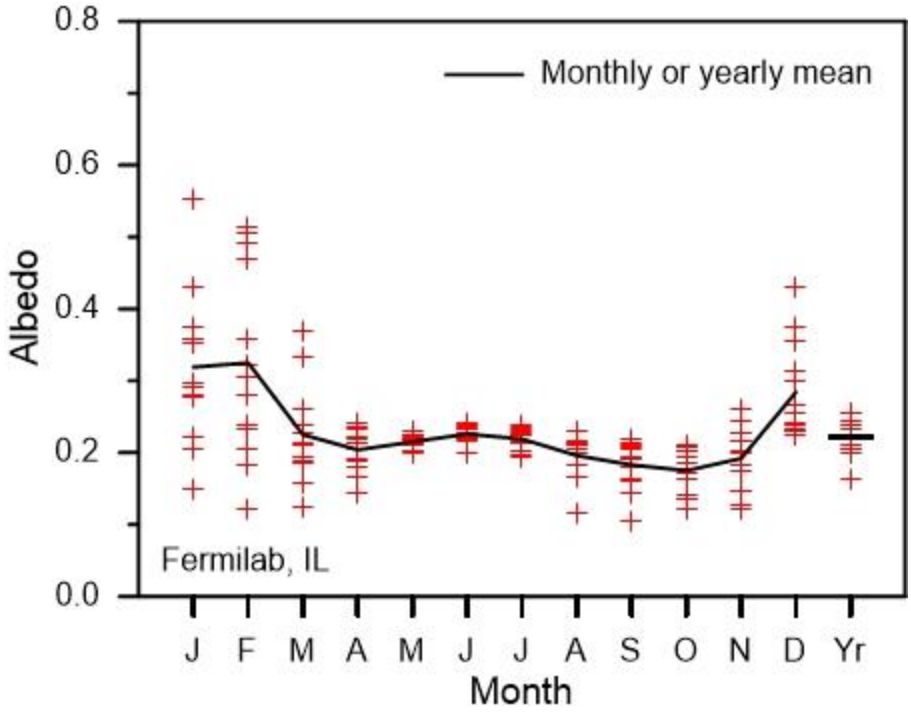

Figure 4.4.14-1. Monthly and yearly albedos and long-term means for Fermilab - Batavia, IL.

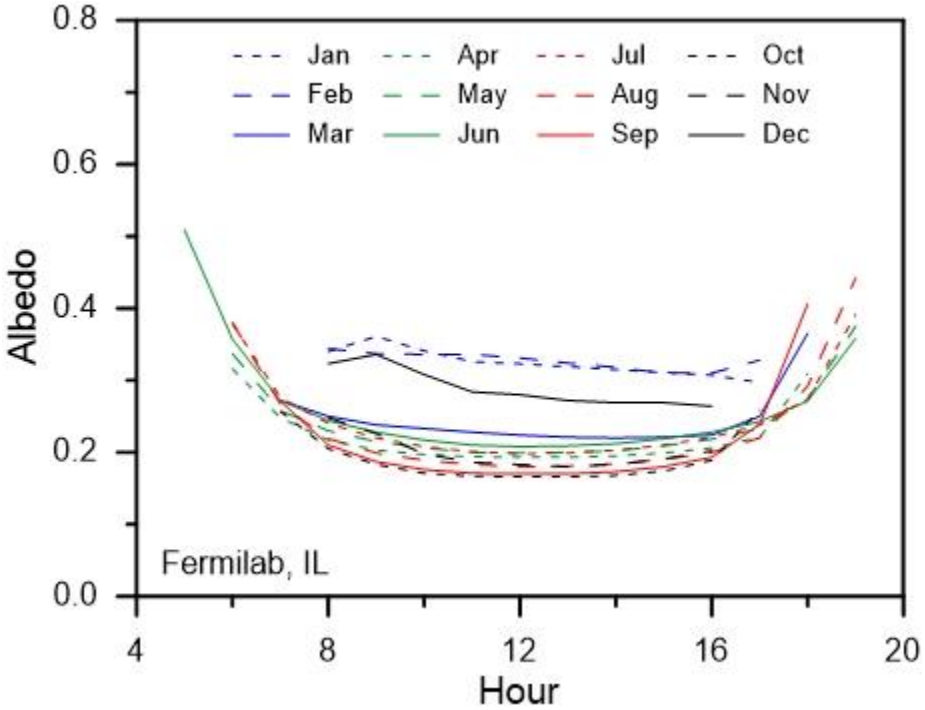

Figure 4.4.14-2. Mean hourly albedos by month for Fermilab - Batavia, IL.

4.4.15 Kansas Field Station, Kansas, USA

StationID: FieldStationKS
AmeriFlux ID: US-KFS
Latitude: 39.0561°N
Longitude: 95.1907°W
Elevation: 310 m
Time Zone: -6
Period of Record: 2010-2017
Data Files: 30-minute and hourly
Ground Surface: Grassland
Annual Precipitation: 1014 mm
Overall Albedo: 0.193
AmeriFlux Website: https://ameriflux.lbl.gov/sites/siteinfo/US-KFS
AmeriFlux Description: *The study is an abandoned grassland at the Kansas Field Station and Ecological Reserves. The site is located within the tallgrass prairie-deciduous forest ecotonal area. The site was subjected to intensive agriculture from the 1940s through the late 1960s. In the mid-1970s, the site was planted with the cool-season grass Bromus inermis and used as a hay meadow until 1987. Then, mowing and burning approximately every five years maintained it as a grassland until 2007, when the eddy flux tower was installed.*

Table 4.4.15-1. Data Elements, Mounting Height, and Instruments for Kansas Field Station, KS

Data Element	Mounting Height (m)	Instrument
GHI	3.0	-----
GRI	3.0	-----
Tdry	3.0	-----
RH	3.0	LI-COR LI-7500
Wspd	3.0	Campbell CSAT-3
Wdir	3.0	Campbell CSAT-3
Pres	3.0	-----
PrecipAccum	3.0	-----

Note: '-----' indicates that the information is not available.

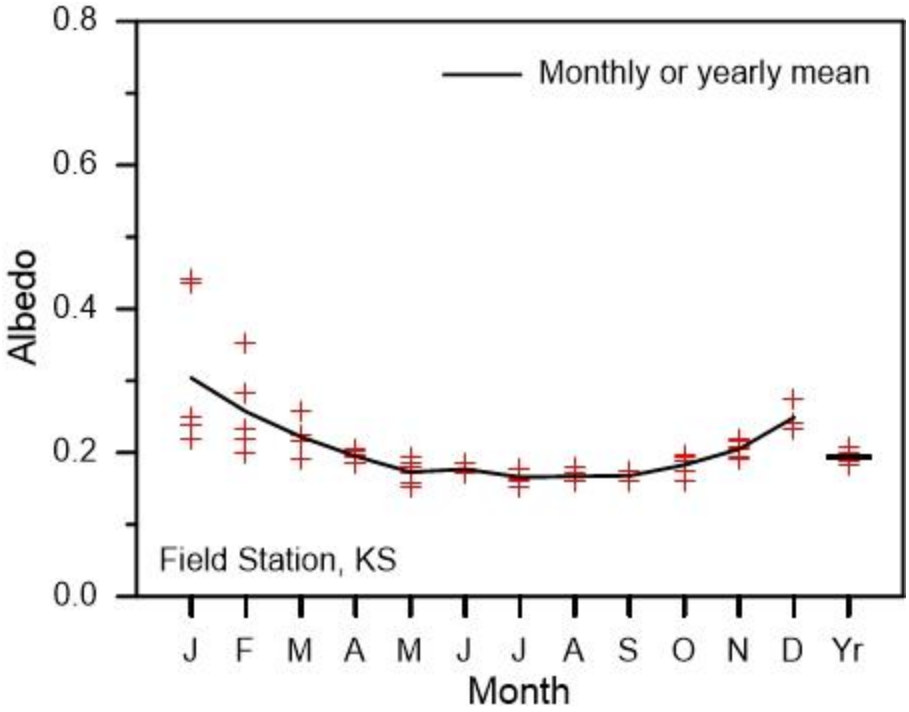

Figure 4.4.15-1. Monthly and yearly albedos and long-term means for Kansas Field Station, KS.

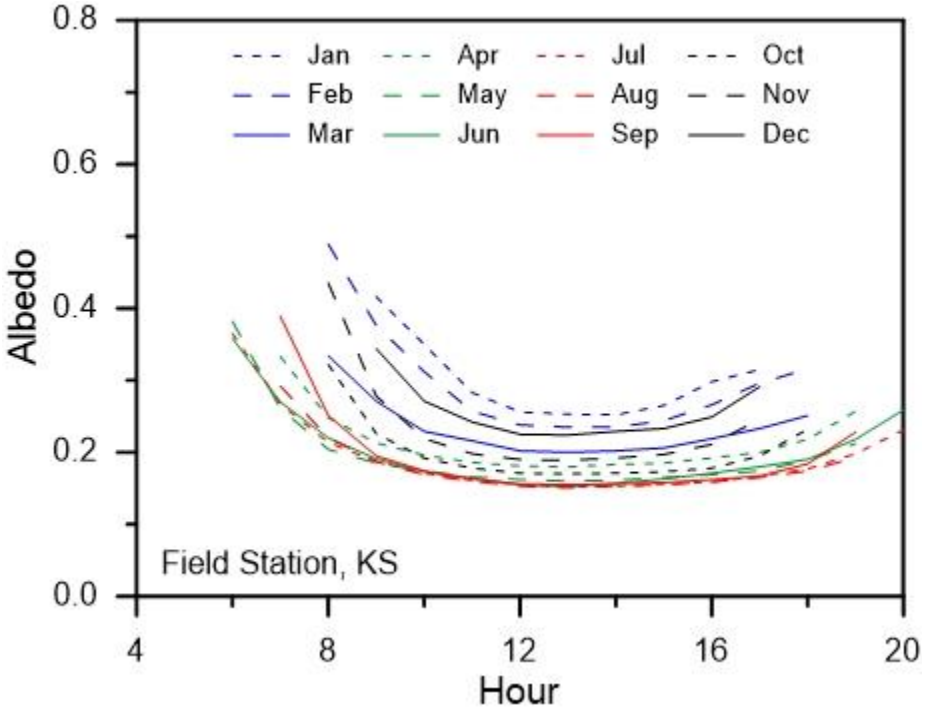

Figure 4.4.15-2. Mean hourly albedos by month for Kansas Field Station, KS.

4.4.16 Konza Prairie, Kansas, USA

StationID: KonzaPrairieKS
AmeriFlux ID: US-Kon
Latitude: 39.0824°N
Longitude: 96.5603°W
Elevation: 417 m
Time Zone: -6
Period of Record: 2007-2012
Data Files: 30-minute and hourly
Ground Surface: Grassland
Annual Precipitation: 867 mm
Overall Albedo: 0.190
AmeriFlux Website: https://ameriflux.lbl.gov/sites/siteinfo/US-Kon
AmeriFlux Description: *Burned on an annual basis. Bison reintroduced in 1987. Experimental cattle herds in 1992.*

Table 4.4.16-1. Data Elements, Mounting Height, and Instruments for Konza Prairie, KS

Data Element	Mounting Height (m)	Instrument
GHI	3.0	-----
GRI	3.0	-----
Tdry	3.0	-----
RH	3.0	LI-COR LI-7500
Wspd	3.0	Campbell CSAT-3A
Wdir	3.0	Campbell CSAT-3A
Pres	3.0	-----
PrecipAccum	-----	-----

Note: '-----' indicates that the information is not available.

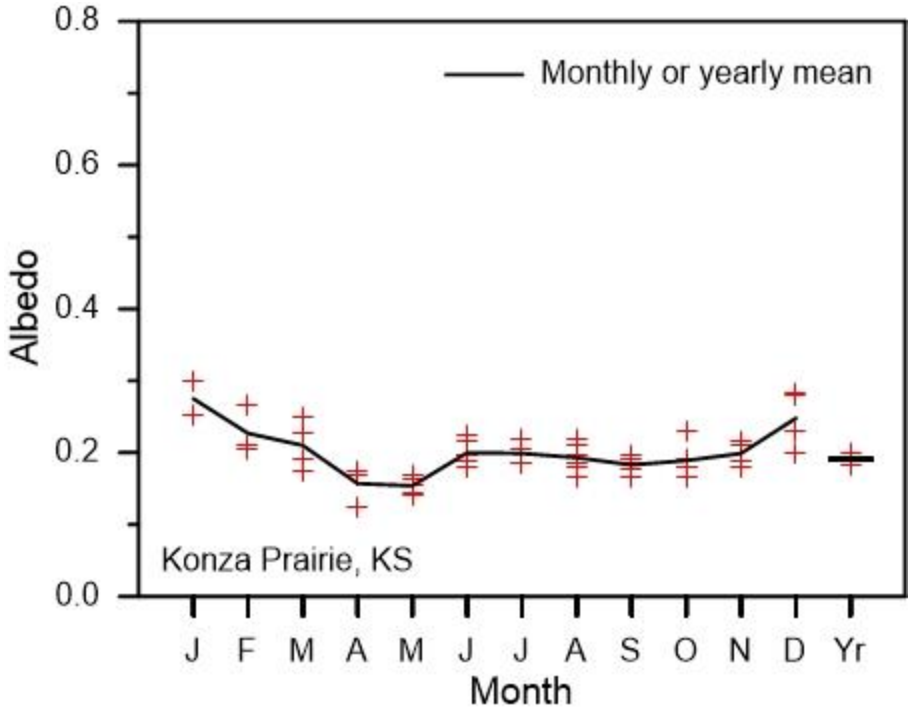

Figure 4.4.16-1. Monthly and yearly albedos and long-term means for Konza Prairie, KS.

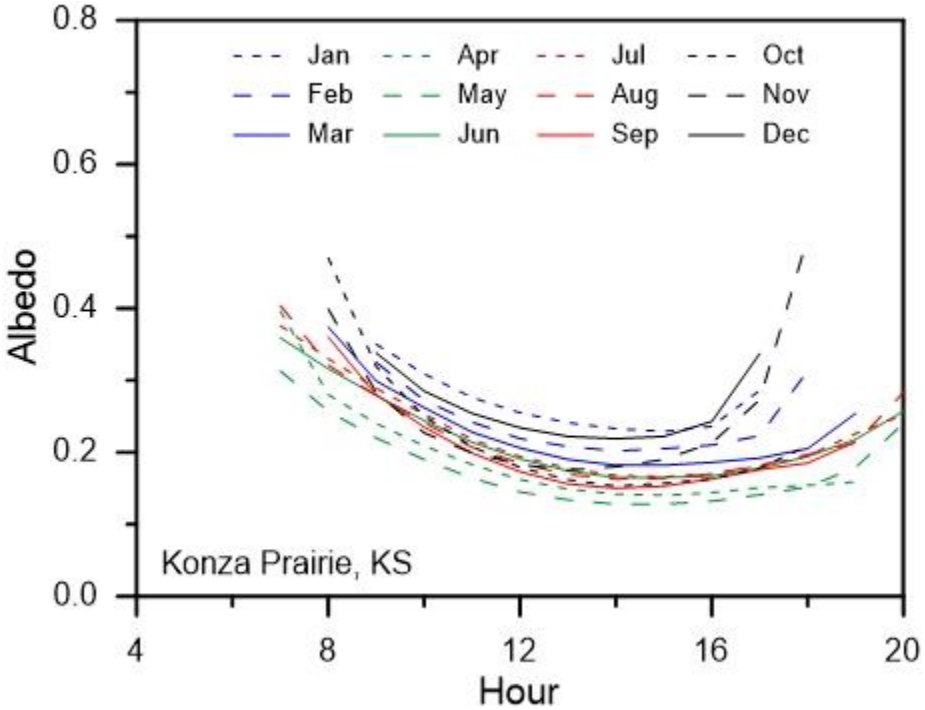

Figure 4.4.16-2. Mean hourly albedos by month for Konza Prairie, KS.

4.4.17 Turfgrass Field, Minnesota, USA

StationID: TurfgrassFieldMN
AmeriFlux ID: US-KUT
Latitude: 44.9950°N
Longitude: 93.1863°W
Elevation: 301 m
Time Zone: -6
Period of Record: 2006-2009
Data Files: 30-minute and hourly
Ground Surface: Turfgrass lawn
Annual Precipitation: 777 mm
Overall Albedo: 0.322
AmeriFlux Website: https://ameriflux.lbl.gov/sites/siteinfo/US-KUT
AmeriFlux Description: *The site was a low-maintenance lawn consisting of cool-season turfgrasses, typical of residential lawns or urban parks in the study area. It was mowed to a height of 70 mm approximately once per week with clippings left to decompose on the surface, was not irrigated, and received one application of inorganic N fertilizer per year. The surrounding suburban residential neighborhood experienced rapid residential development in the 1950s; prior to that time, farms and nurseries were the predominant land-use types. Note that the land management of the field site changed (removal of the turfgrass lawn and planting of trees) AFTER the flux study was completed--this means that imagery after 2009 does not show the land conditions during the flux study.*

Table 4.4.17-1. Data Elements, Mounting Height, and Instruments for Turfgrass Field, MN

Data Element	Mounting Height (m)	Instrument
GHI	2.0	-----
GRI	2.0	-----
Tdry	1.4	-----
RH	1.4	-----
Wspd	1.4	CSAT3
Wdir	1.4	CSAT3
Pres	2.0	-----
PrecipAccum	1.0	-----

Note: '-----' indicates that the information is not available.

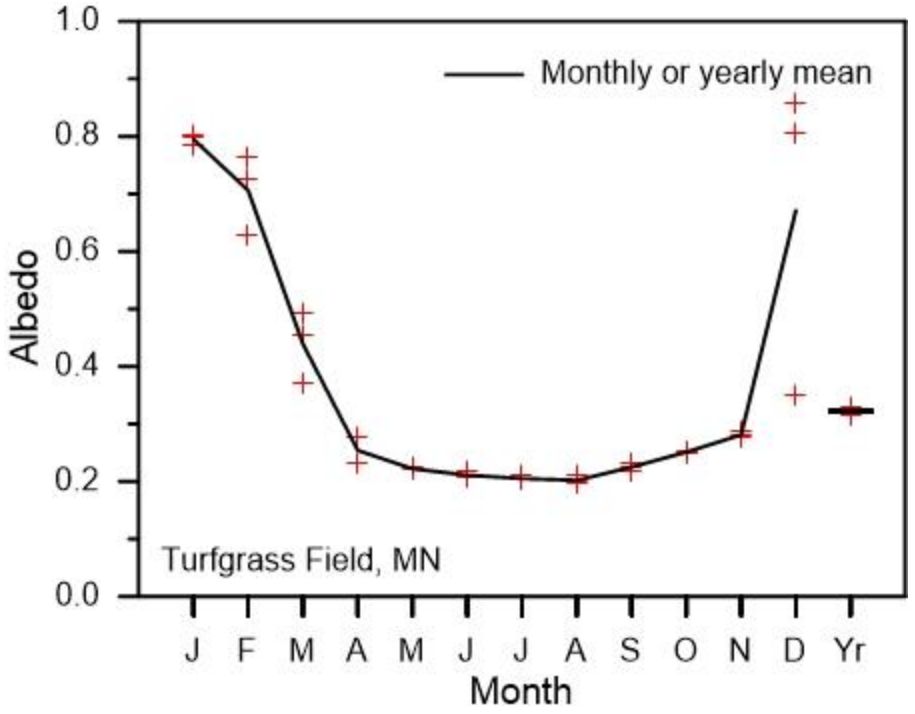

Figure 4.4.17-1. Monthly and yearly albedos and long-term means for Turfgrass Field, MN.

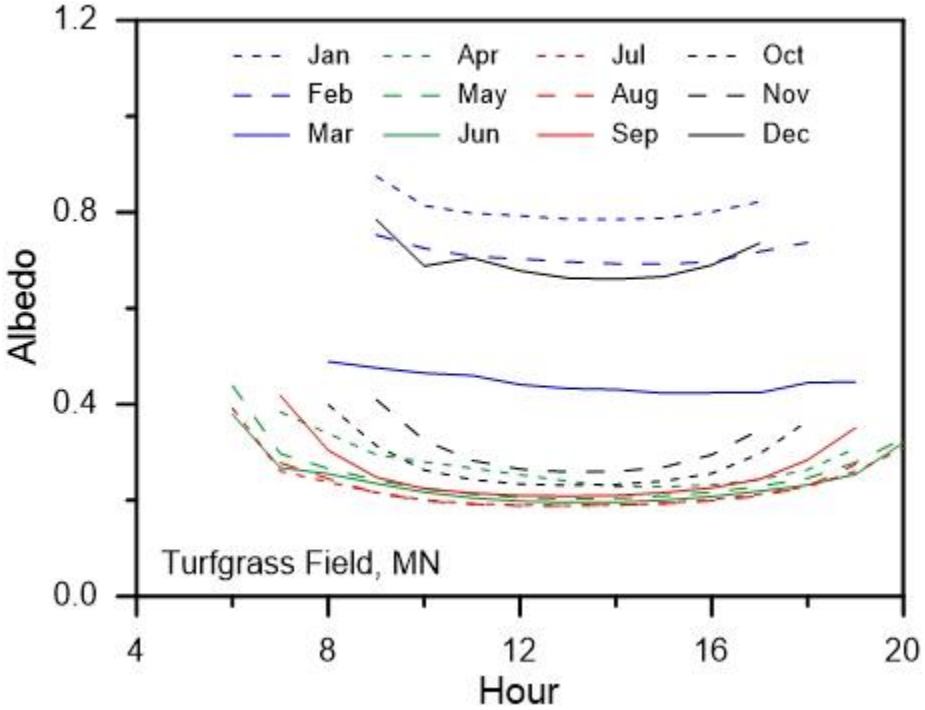

Figure 4.4.17-2. Mean hourly albedos by month for Turfgrass Field, MN.

4.4.18 Reynolds Creek, Idaho, USA (1)

StationID: ReynoldsCreekID_1
AmeriFlux ID: US-Rls
Latitude: 43.1439°N
Longitude: 116.7356°W
Elevation: 1608 m
Time Zone: -7
Period of Record: 2015-2017
Data Files: 30-minute and hourly
Ground Surface: Low sagebrush
Annual Precipitation: 333 mm
Overall Albedo: 0.179
AmeriFlux Website: https://ameriflux.lbl.gov/sites/siteinfo/US-Rls
AmeriFlux Description: *The site is located on the USDA-ARS's Reynolds Creek Experimental Watershed. It is dominated by low sagebrush on land managed by USDI Bureau of Land Management.*
Maintenance: The domes on the pyranometers are cleaned during annual maintenance; they do not seem to soil significantly and we have not noticed data deterioration. They were last calibrated during summer of 2015 (from email by station manager Gerald Flerchinger on 8/28/2019).

Table 4.4.18-1. Data Elements, Mounting Height, and Instruments for Reynolds Creek, ID_1

Data Element	Mounting Height (m)	Instrument
GHI	1.5	Kipp & Zonen CNR1
GRI	1.5	Kipp & Zonen CNR1
Tdry	2.1	Vaisala HMP155
RH	2.1	Vaisala HMP155
Wspd	2.1	Campbell CSAT-3
Wdir	2.1	Campbell CSAT-3
Pres	-----	Li-Cor 7550
PrecipAccum	-----	Bellfort dual gage system

Note: '-----' indicates that the information is not available.

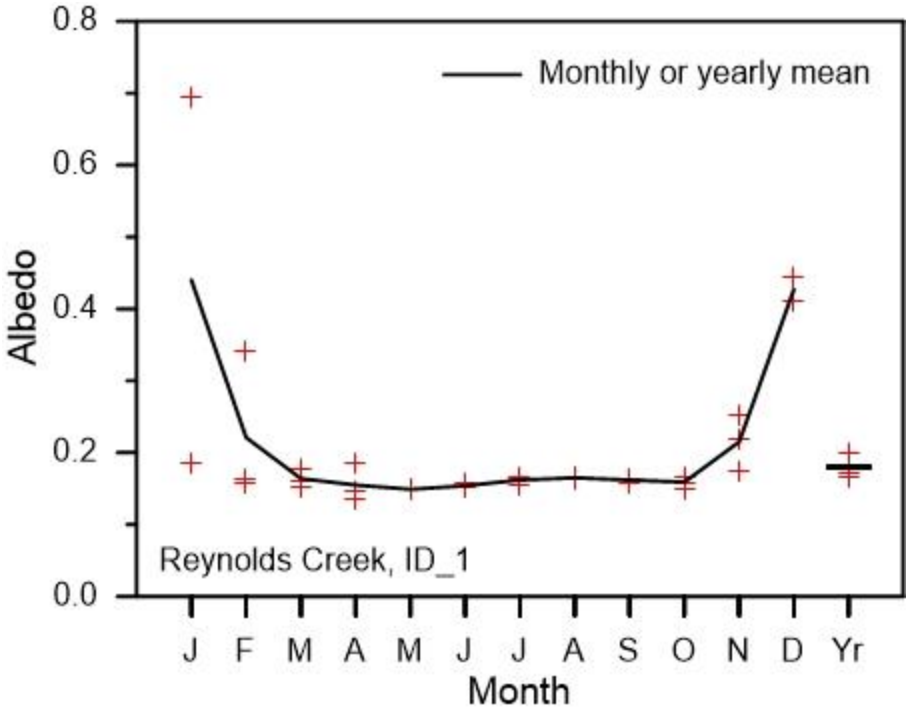

Figure 4.4.18-1. Monthly and yearly albedos and long-term means for Reynolds Creek, ID_1.

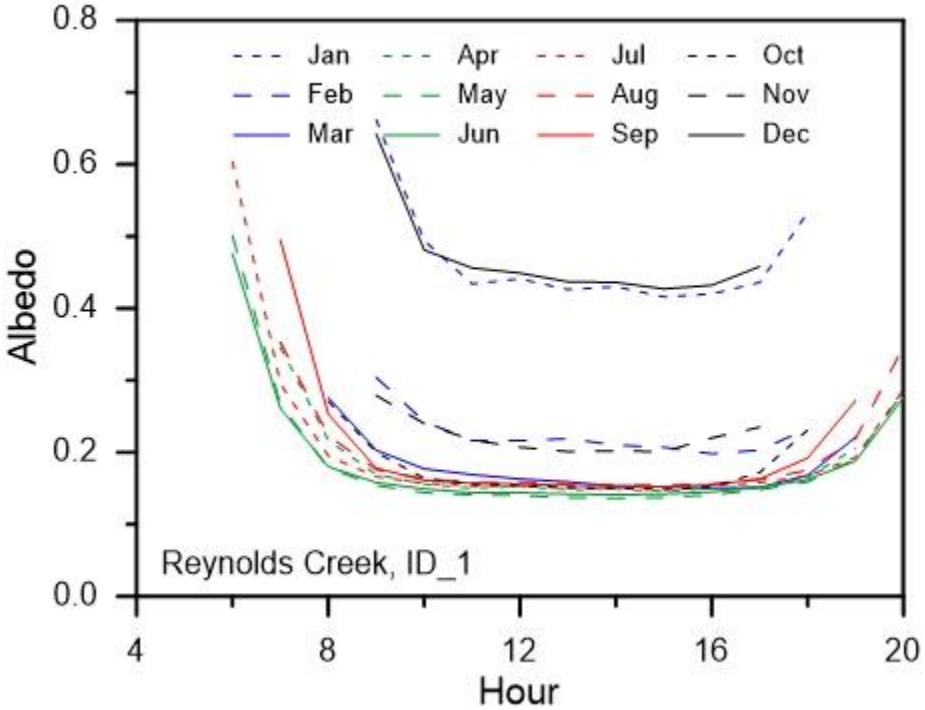

Figure 4.4.18-2. Mean hourly albedos by month for Reynolds Creek, ID_1.

4.4.19 Reynolds Creek, Idaho, USA (2)

StationID: ReynoldsCreekID_2
AmeriFlux ID: US-Rms
Latitude: 43.0645°N
Longitude: 116.7486°W
Elevation: 2111 m
Time Zone: -7
Period of Record: 2015-2017
Data Files: 30-minute and hourly
Ground Surface: Mountain big sagebrush
Annual Precipitation: 800 mm
Overall Albedo: 0.231
AmeriFlux Website: https://ameriflux.lbl.gov/sites/siteinfo/US-Rms
AmeriFlux Description: *The site is located on the USDA-ARS's Reynolds Creek Experimental Watershed. It is dominated by mountain big sagebrush on land managed by USDI Bureau of Land Management.*
Maintenance: The domes on the pyranometers are cleaned during annual maintenance; they do not seem to soil significantly and we have not noticed data deterioration. They were last calibrated during summer of 2015 (from email by station manager Gerald Flerchinger on 8/28/2019).

Table 4.4.19-1. Data Elements, Mounting Height, and Instruments for Reynolds Creek, ID_2

Data Element	Mounting Height (m)	Instrument
GHI	1.9	Kipp & Zonen CNR1
GRI	1.9	Kipp & Zonen CNR1
Tdry	2.5	Vaisala HMP155
RH	2.5	Vaisala HMP155
Wspd	2.5	Campbell CSAT-3
Wdir	2.5	Campbell CSAT-3
Pres	-----	Li-Cor 7550
PrecipAccum	-----	Bellfort dual gage system

Note: '-----' indicates that the information is not available.

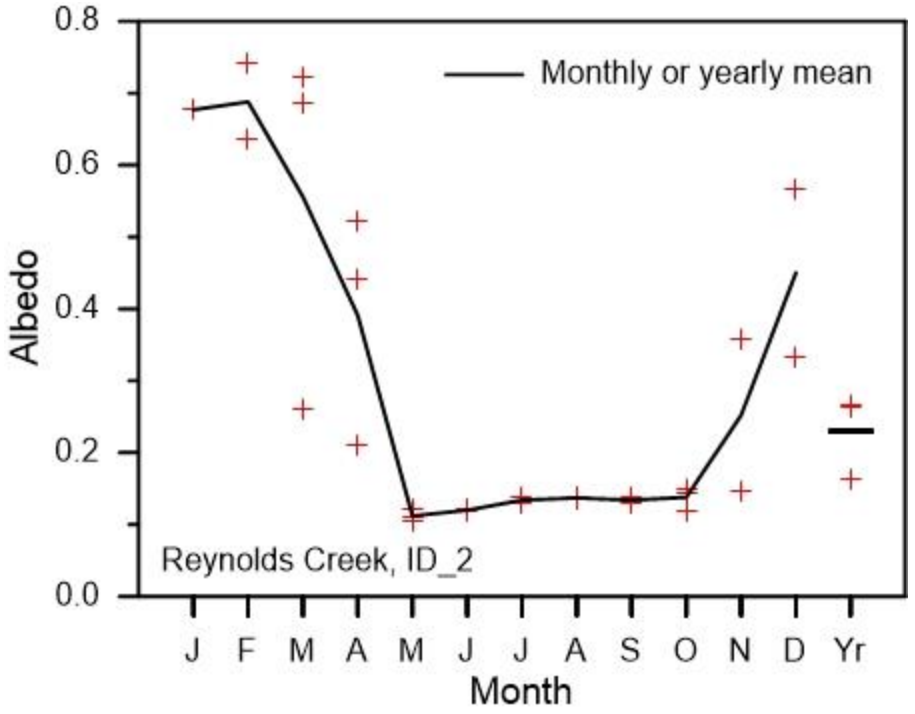

Figure 4.4.19-1. Monthly and yearly albedos and long-term means for Reynolds Creek, ID_2.

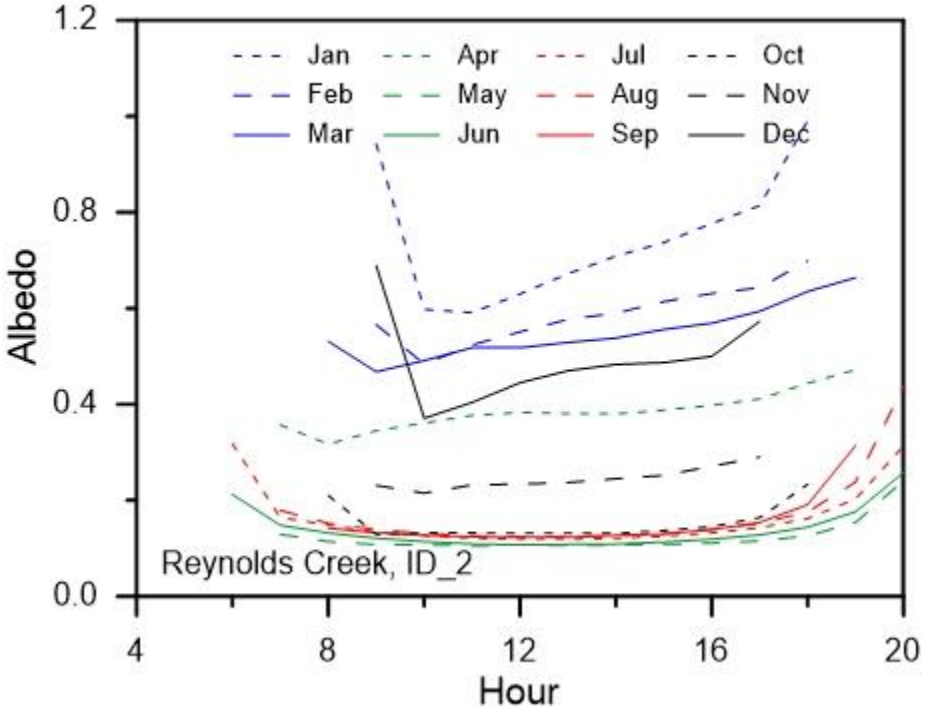

Figure 4.4.19-2. Mean hourly albedos by month for Reynolds Creek, ID_2.

4.4.20 Rosemount, Minnesota, USA

StationID: RosemountMN
AmeriFlux ID: US-Ro4
Latitude: 44.6781°N
Longitude: 93.0723°W
Elevation: 274 m
Time Zone: -6
Period of Record: 2014-2018
Data Files: 30-minute and hourly
Ground Surface: Grassland
Annual Precipitation: 879 mm
Overall Albedo: 0.247
AmeriFlux Website: https://ameriflux.lbl.gov/sites/siteinfo/US-Ro4
AmeriFlux Description: *This tower is located in restored prairie in a former agricultural area. Dominant species include Andropogon gerardii, Sorghastrum nutans and Elymus canadensis.*

Table 4.4.20-1. Data Elements, Mounting Height, and Instruments for Rosemount, MN

Data Element	Mounting Height (m)	Instrument
GHI	3.7	Eppley PSP
GRI	3.7	Kipp and Zonen CNR4
Tdry	3.0	Vaisala HMP35C
RH	3.0	Vaisala HMP35C
Wspd	2.6	Campbell CSAT-3
Wdir	2.6	Campbell CSAT-3
Pres	-----	Vaisala PTB-110
PrecipAccum	2.0	Geonor T200

Note: '-----' indicates that the information is not available.

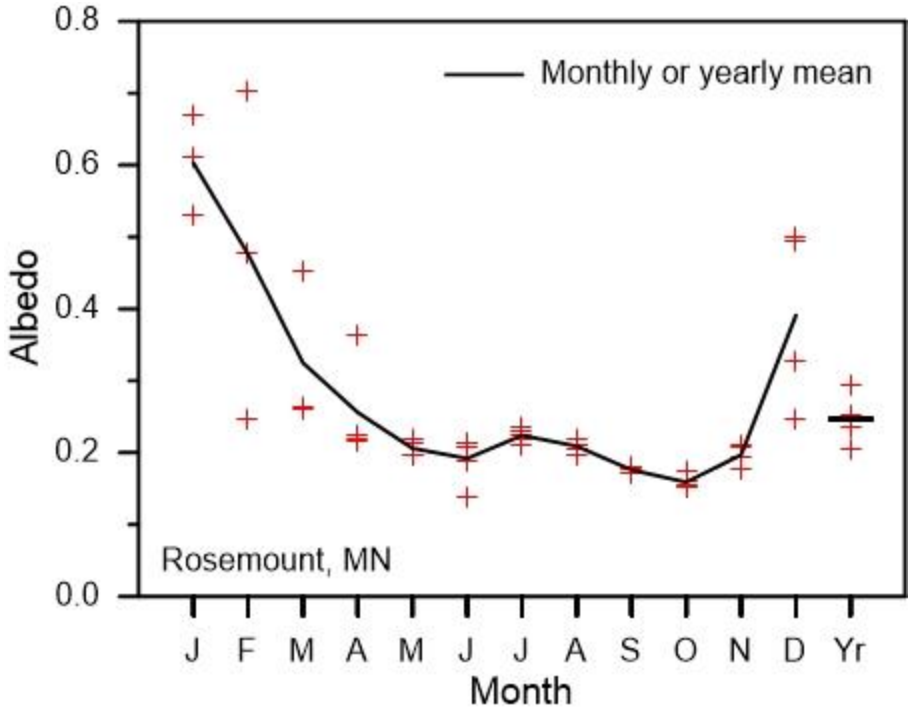

Figure 4.4.20-1. Monthly and yearly albedos and long-term means for Rosemount, MN.

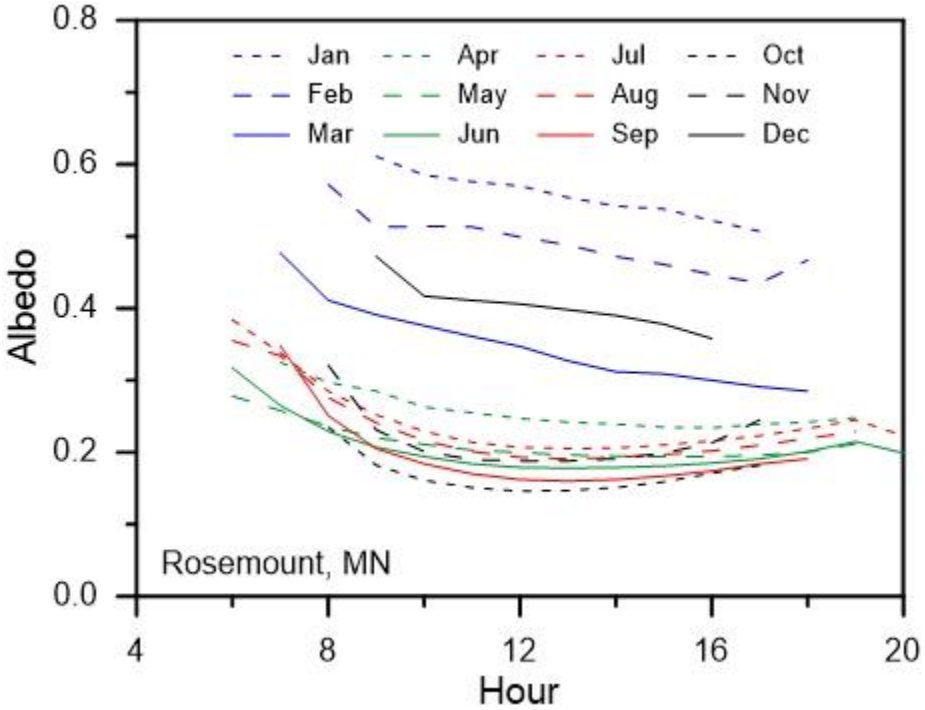

Figure 4.4.20-2. Mean hourly albedos by month for Rosemount, MN.

4.4.21 Sonoran Desert, California, USA

StationID: SonoranDesertCA
AmeriFlux ID: US-SCd
Latitude: 33.6518°N
Longitude: 116.3721°W
Elevation: 275 m
Time Zone: -8
Period of Record: 2006-2012
Data Files: 30-minute and hourly
Ground Surface: Desert
Annual Precipitation: Not available
Overall Albedo: 0.245
AmeriFlux Website: https://ameriflux.lbl.gov/sites/siteinfo/US-SCd
AmeriFlux Description: *This site is one of six Southern California Climate Gradient flux towers operated along an elevation gradient (sites are US-SCg, US-SCs, US-SCf, US-SCw, US-SCc, US-SCd). This site is a low desert site in Southern California''s rain shadow; the climate is extremely dry and hot. The site has experience repeated droughts, with negligible rainfall during several years of the record.*

Table 4.4.21-1. Data Elements, Mounting Height, and Instruments for Sonoran Desert, CA

Data Element	Mounting Height (m)	Instrument
GHI	-----	-----
GRI	-----	-----
Tdry	-----	-----
RH	-----	-----
Wspd	-----	-----
Wdir	-----	-----

Note: '-----' indicates that the information is not available.

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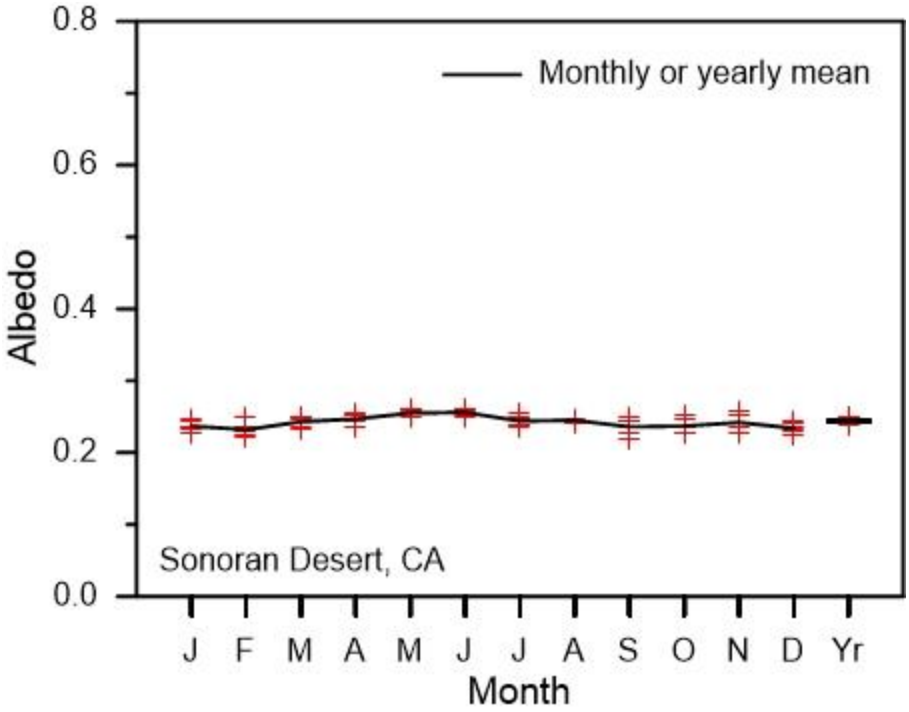

Figure 4.4.21-1. Monthly and yearly albedos and long-term means for Sonoran Desert, CA.

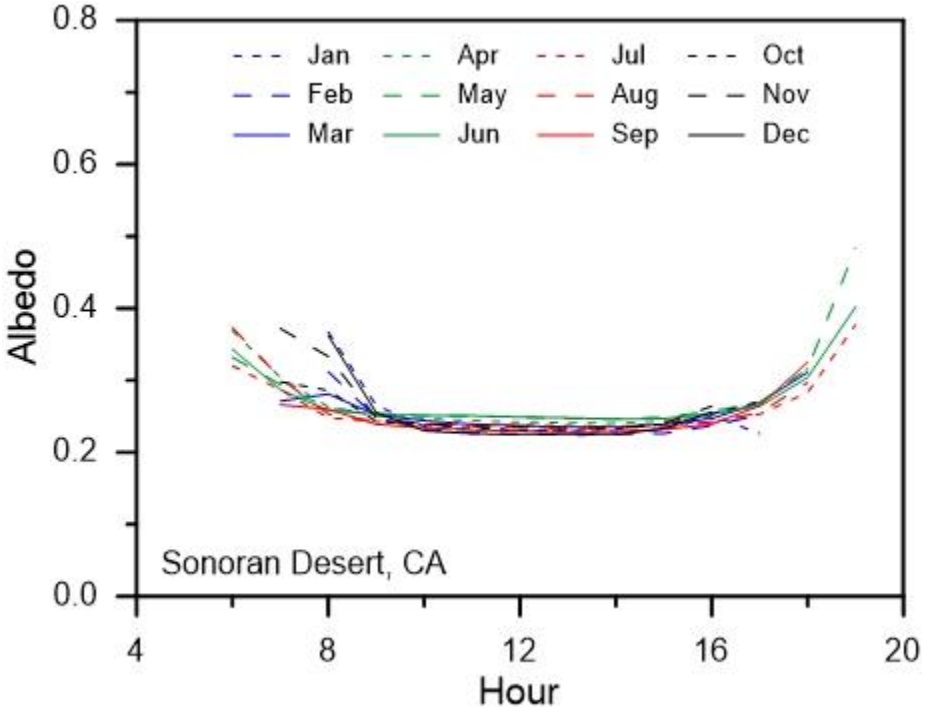

Figure 4.4.21-2. Mean hourly albedos by month for Sonoran Desert, CA.

4.4.22 Southern Californian Grassland, California, USA

StationID: SouthGrasslandCA
AmeriFlux ID: US-SCg
Latitude: 33.7365°N
Longitude: 117.6946°W
Elevation: 465 m
Time Zone: -8
Period of Record: 2006-2014
Data Files: 30-minute and hourly
Ground Surface: Grassland
Annual Precipitation: Not available
Overall Albedo: 0.165
AmeriFlux Website: https://ameriflux.lbl.gov/sites/siteinfo/US-SCg
AmeriFlux Description: *This site is one of six Southern California Climate Gradient flux towers operated along an elevation gradient (sites are US-SCg, US-SCs, US-SCf, US-SCw, US-SCc, US-SCd). This site is a grassland that was historically dominated by exotic annuals and that underwent restoration with a focus on native bunch grasses in the 2010s. The site has historically burned every 10-20 years, with a wildfire in October 2007. The restoration involved several years of mowing and herbicide application to suppress exotics followed by dense planting of Nasella bunch grasses.*

Table 4.4.22-1. Data Elements, Mounting Height, and Instruments for Southern Californian Grassland, CA

Data Element	Mounting Height (m)	Instrument
GHI	-----	-----
GRI	-----	-----
Tdry	-----	-----
RH	-----	-----
Wspd	-----	-----
Wdir	-----	-----

Note: '-----' indicates that the information is not available.

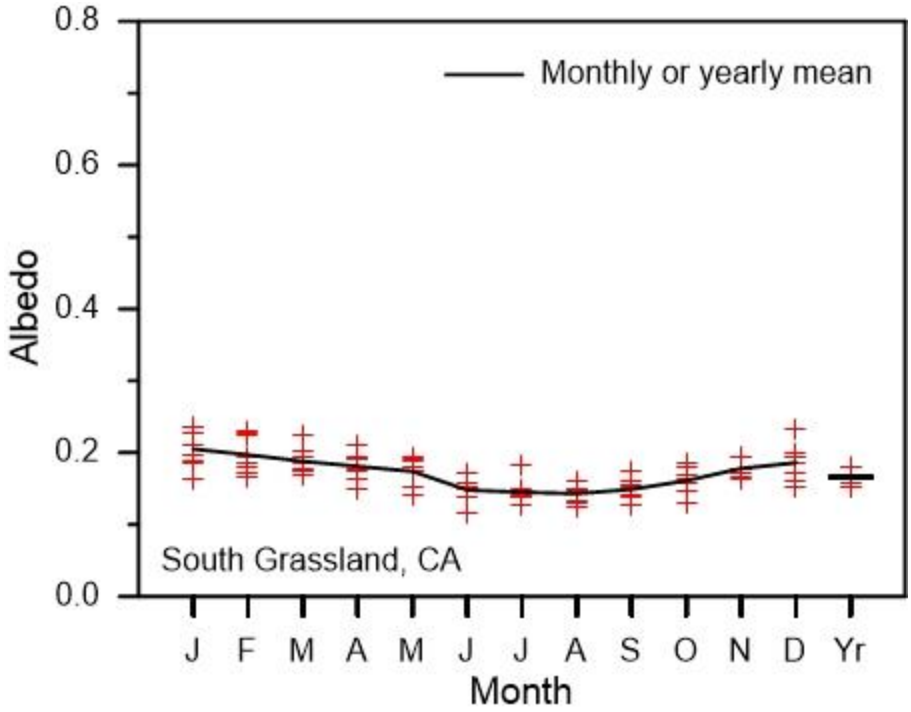

Figure 4.4.22-1. Monthly and yearly albedos and long-term means for Southern Californian Grassland, CA.

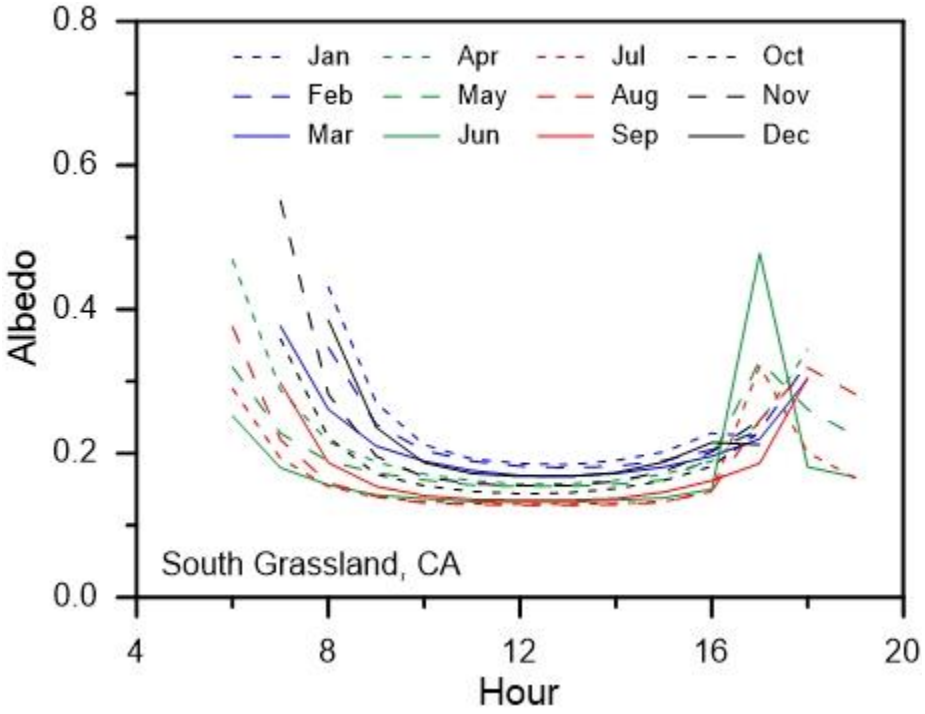

Figure 4.4.22-2. Mean hourly albedos by month for Southern Californian Grassland, CA.

4.4.23 McKenzie Flats, New Mexico, USA

StationID: McKenzieFlatsNM
AmeriFlux ID: US-Seg
Latitude: 34.3623°N
Longitude: 106.7020°W
Elevation: 1596 m
Time Zone: -7
Period of Record: 2007-2018
Data Files: 30-minute and hourly
Ground Surface: Desert Grassland
Annual Precipitation: 273 mm
Overall Albedo: 0.219
AmeriFlux Website: https://ameriflux.lbl.gov/sites/siteinfo/US-Seg
AmeriFlux Description: *The Sevilleta Desert Grassland site is located within the McKenzie Flats area of the Sevilleta National Wildlife Refuge (NWR), central New Mexico. Historically, this area has been used for livestock grazing; however, the McKenzie Flats have not been grazed since 1973 and the effects of this previous grazing are considered negligible for the purposes of this study. As the name suggests, McKenzie Flats is an extensive (~130 km^2), nearly flat, mixed-species desert grassland bounded on the east by Los Pinos Mountains and on the west by the Rio Grande. This site experienced a severe burn in August 2009.*
Maintenance: Pyranometers are cleaned every month (from email by station manager Marcy Litvak on 8/28/2019).
Station Website: http://www.litvaklab.org/new-mexico-elevation-gradient.html

Table 4.4.23-1. Data Elements, Mounting Height, and Instruments for McKenzie Flats, NM

Data Element	Mounting Height (m)	Instrument
GHI	2.9	Kipp & Zonen CNR1
GRI	2.9	Kipp & Zonen CNR1
Tdry	2.5	Vaisala HMP 45C
RH	2.5	Vaisala HMP 45C
Wspd	3.1	CSAT3
Wdir	3.1	CSAT3
Pres	-----	Licor 7500 IRGA
PrecipAccum	1.0	Texas Electronics Tipping Bucket

Note: '-----' indicates that the information is not available.

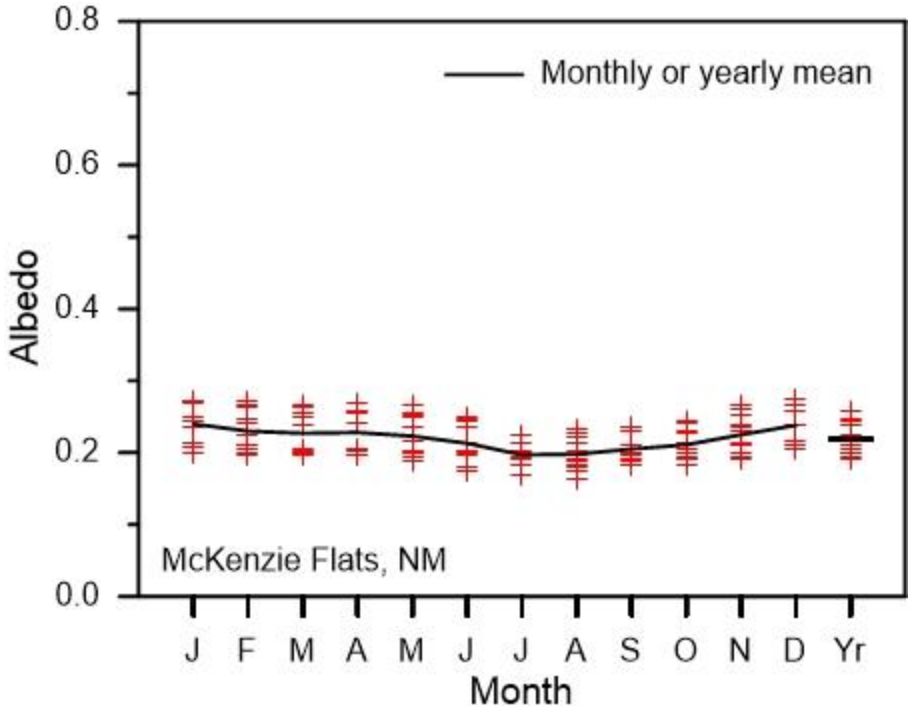

Figure 4.4.23-1. Monthly and yearly albedos and long-term means for McKenzie Flats, NM.

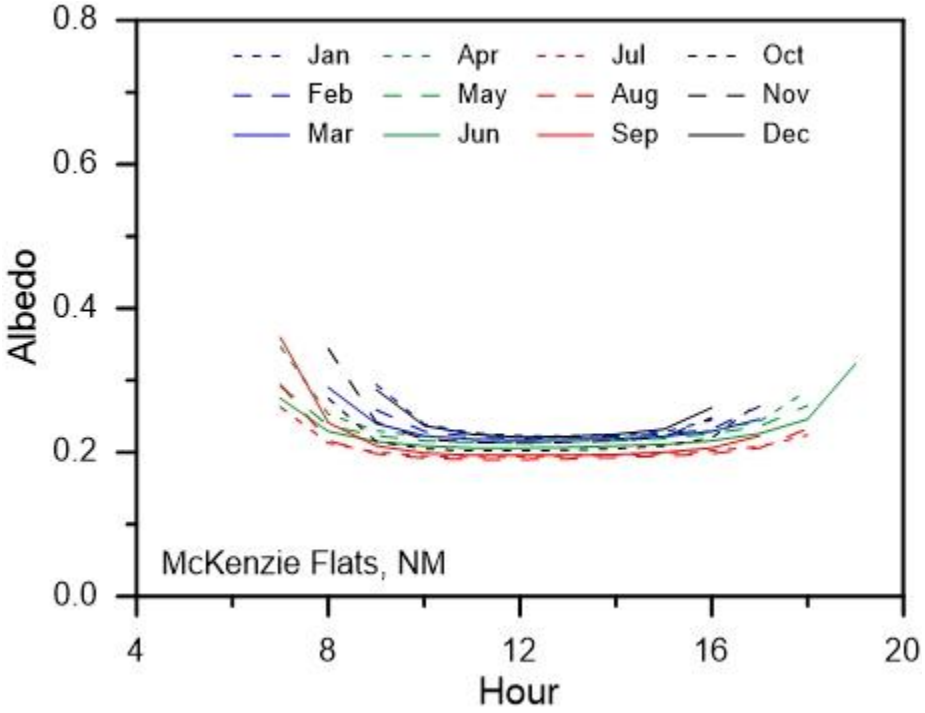

Figure 4.4.23-2. Mean hourly albedos by month for McKenzie Flats, NM.

4.4.24 Shidler, Oklahoma, USA

StationID: ShidlerOK
AmeriFlux ID: US-Shd
Latitude: 36.9333°N
Longitude: 96.6833°W
Elevation: 346 m
Time Zone: -6
Period of Record: 1997-2000
Data Files: 30-minute and hourly
Ground Surface: Tall grass prairie
Annual Precipitation: Not available
Overall Albedo: 0.217
AmeriFlux Website: https://ameriflux.lbl.gov/sites/siteinfo/US-Shd
AmeriFlux Description: *Native tall grass prairie. A prairie management prescribed burn was conducted in the spring of 1997, but not in 1996. The site was not grazed from early August 1996-September 1997. almost all plants are warm season C4 species, grasslands, temperate continental climate.*

Table 4.4.24-1. Data Elements, Mounting Height, and Instruments for Shidler, OK

Data Element	Mounting Height (m)	Instrument
GHI	3.5	-----
GRI	3.5	-----
Tdry	4.5	-----
RH	4.5	-----
Wspd	4.5	-----
Wdir	4.5	-----
Pres	3.5	-----
PrecipAccum	-----	-----

Note: '-----' indicates that the information is not available.

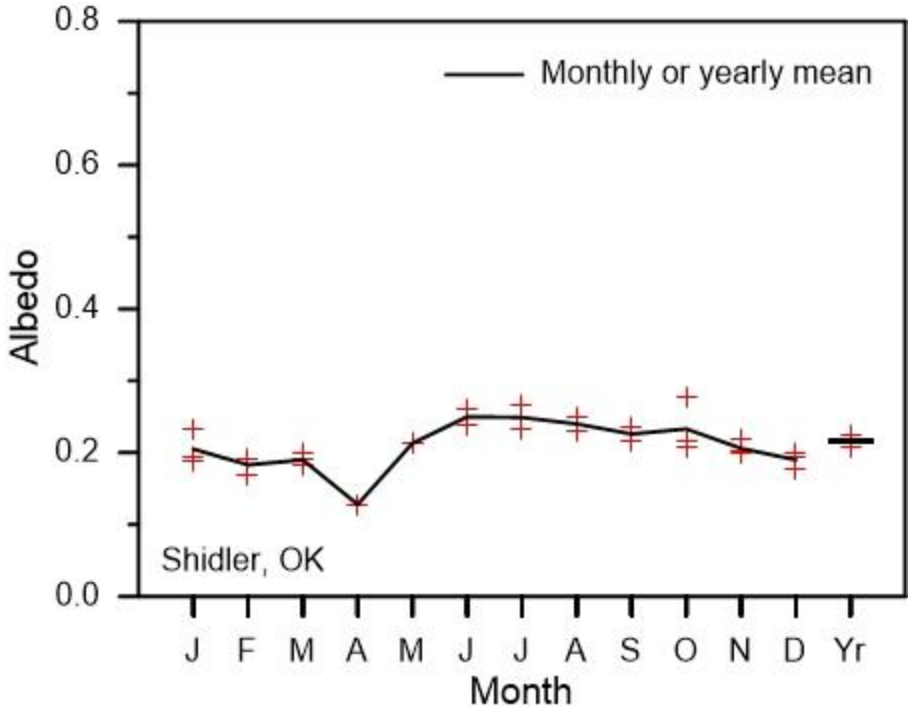

Figure 4.4.24-1. Monthly and yearly albedos and long-term means for Shidler, OK.

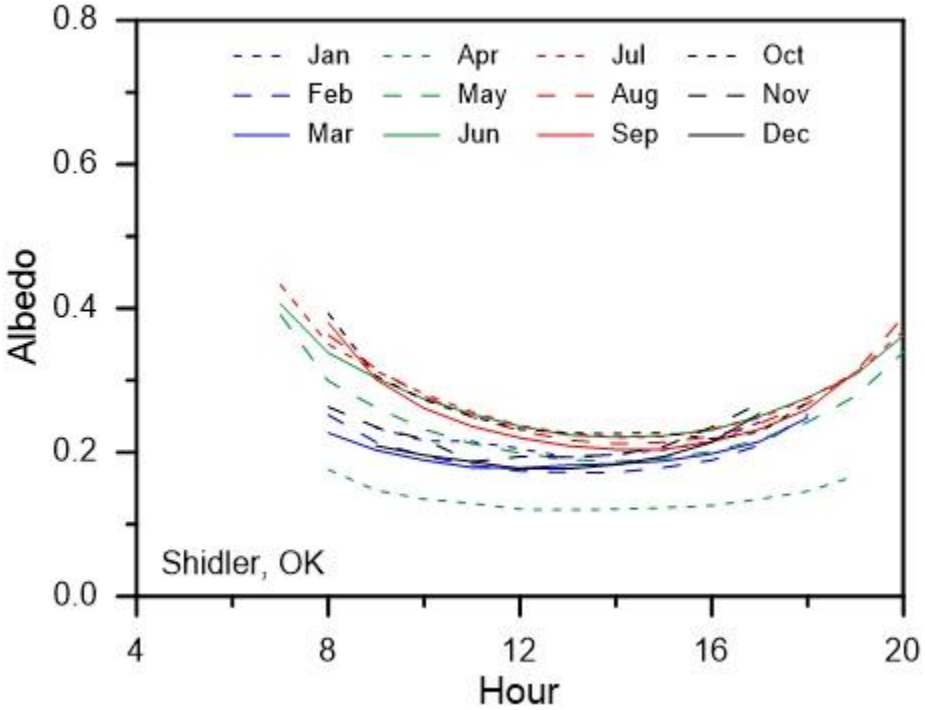

Figure 4.4.24-2. Mean hourly albedos by month for Shidler, OK.

4.4.25 Santa Rita, Arizona, USA

StationID: SantaRitaAZ
AmeriFlux ID: US-SRG
Latitude: 31.7894°N
Longitude: 110.8277°W
Elevation: 1291 m
Time Zone: -7
Period of Record: 2008-2018
Data Files: 30-minute and hourly
Ground Surface: Semidesert grassland
Annual Precipitation: 420 mm
Overall Albedo: 0.204
AmeriFlux Website: https://ameriflux.lbl.gov/sites/siteinfo/US-SRG
AmeriFlux Description: *Semidesert C4 grassland, lies in Pasture 1 on the Santa Rita Experimental Range. This is the companion site for US-SRM, but has much less mesquite encroachment.*
Maintenance: Pyranometers are cleaned and levels checked a couple of times a year and factory calibrated every three to five years. Instruments stay fairly clean at this site with no evidence of significant soiling (from emails by station operator Ross Bryant and manager Russ Scott on 8/28/2019).

Table 4.4.25-1. Data Elements, Mounting Height, and Instruments for Santa Rita, AZ

Data Element	Mounting Height (m)	Instrument
GHI	2.6	Kipp & Zonen CNR1
GRI	2.6	Kipp & Zonen CNR1
Tdry	2.9	Campbell HC2-S3L
RH	2.9	Campbell HC2-S3L
Wspd	3.3	Campbell CSAT-3
Wdir	3.3	Campbell CSAT-3
Pres	3.3	LI-COR LI-7500
PrecipAccum	1.0	Texas Electronics TR525

Note: '-----' indicates that the information is not available.

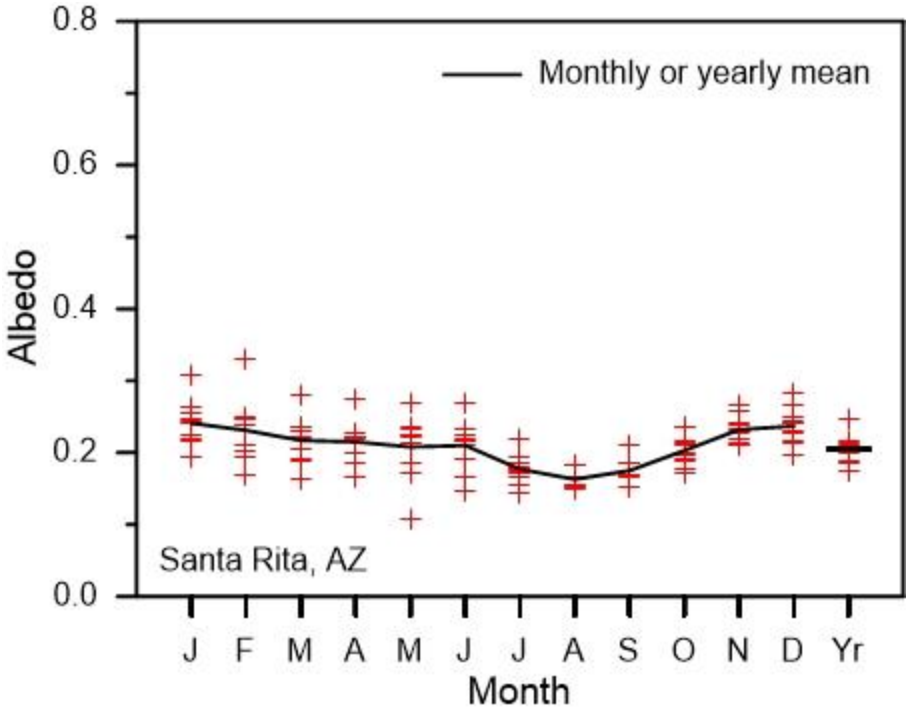

Figure 4.4.25-1. Monthly and yearly albedos and long-term means for Santa Rita, AZ.

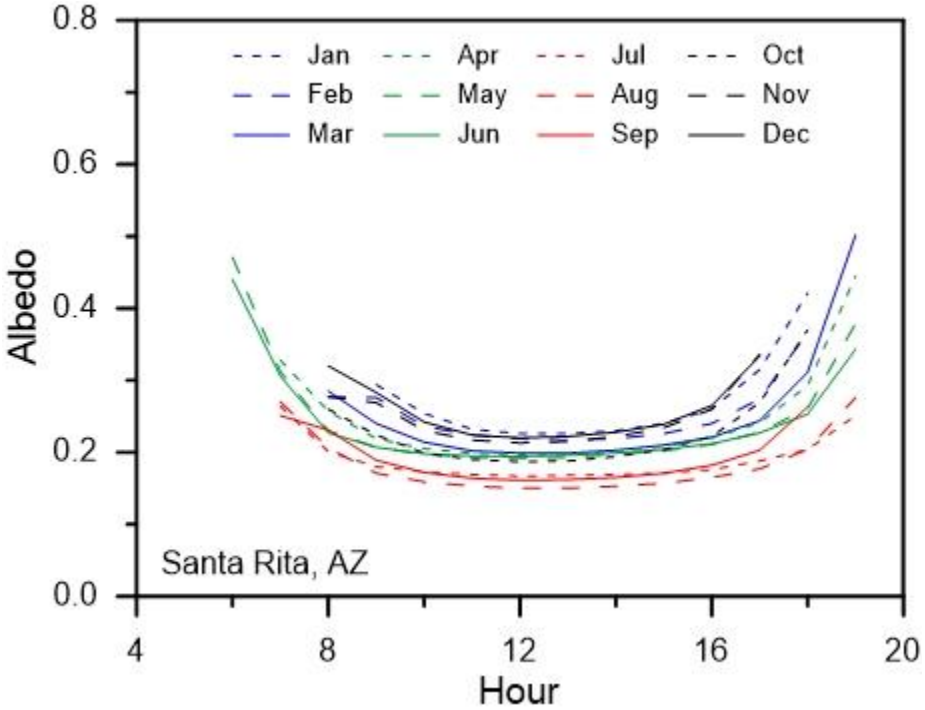

Figure 4.4.25-2. Mean hourly albedos by month for Santa Rita, AZ.

4.4.26 Twitchell Island, California, USA

StationID: TwitchellCA
AmeriFlux ID: US-Tw3
Latitude: 38.1159°N
Longitude: 121.6467°W
Elevation: -9 m
Time Zone: -8
Period of Record: 2013-2017
Data Files: 30-minute and hourly
Ground Surface: Alfalfa
Annual Precipitation: 421 mm
Overall Albedo: 0.223
AmeriFlux Website: https://ameriflux.lbl.gov/sites/siteinfo/US-Tw3
AmeriFlux Description: *The Twitchell Alfalfa site is an alfalfa field owned by the state of California and leased to third parties for farming. The tower was installed on May 24, 2013. This site and the surrounding region are part of the San Joaquin - Sacramento River Delta drained beginning in the 1850"s and subsequently used for agriculture. The field has been alfalfa for X years…., Crop rotation occurs every 5-6 years. The site is harvested by mowing and bailing several times per year. The field is fallow typically between November and February. The site is irrigated by periodically-flooded ditches surrounding the field. The site is irrigated by raising, and subsequently lowering the water table?*
Maintenance: Sensors are cleaned every week or two and calibrated periodically (from email by station manager Dennis Baldocchi on 8/27/2019)
Station Websites:
https://nature.berkeley.edu/biometlab/bmetdata/sitedescriptions.php?screen=display&id=TA
https://nature.berkeley.edu/biometlab/bmetdata/photodb.php?screen=display&view=p&page=1&LL=Twitchell+Alfalfa&SN=Tower

Table 4.4.26-1. Data Elements, Mounting Height, and Instruments for Twitchell Island, CA

Data Element	Mounting Height (m)	Instrument
GHI	1.5	-----
GRI	1.5	-----
Tdry	2.6	-----
RH	2.6	-----
Wspd	2.8	Gill Windmaster
Wdir	2.8	Gill Windmaster
Pres	-----	-----
PrecipAccum	-----	-----

Note: '-----' indicates that the information is not available.

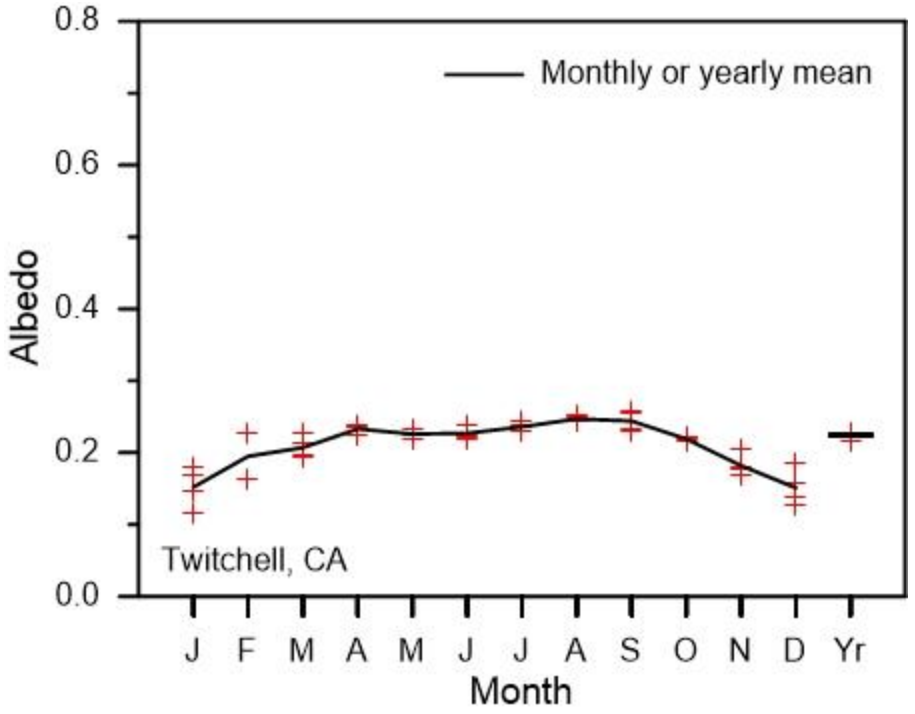

Figure 4.4.26-1. Monthly and yearly albedos and long-term means for Twitchell Island, CA.

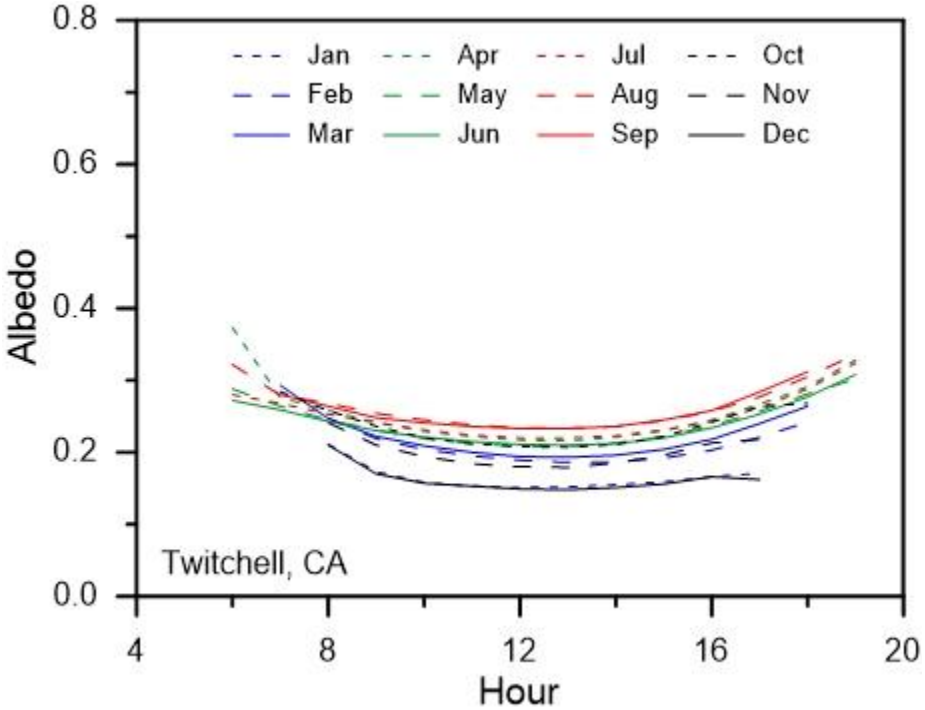

Figure 4.4.26-2. Mean hourly albedos by month for Twitchell Island, CA.

4.4.27 Walnut Gulch, Arizona, USA

StationID: WalnutGulchAZ
AmeriFlux ID: US-Wkg
Latitude: 31.7365°N
Longitude: 109.9419°W
Elevation: 1531 m
Time Zone: -7
Period of Record: 2004-2018
Data Files: 30-minute and hourly
Ground Surface: Grassland
Annual Precipitation: 407 mm
Overall Albedo: 0.182
AmeriFlux Website: https://ameriflux.lbl.gov/sites/siteinfo/US-Wkg
AmeriFlux Description: *This site is located in a small, intensively-studied, experimental watershed within USDA-ARS"s Walnut Gulch Experimental Watershed. Eddy covariance measurements of energy, water and CO2 fluxes began in the spring of 2004, though meteorological (including Bowen ratio) and hydrological measurements are available much further back.*
Maintenance: Pyranometers are cleaned and levels checked a couple of times a year and factory calibrated every three to five years. Instruments stay fairly clean at this site with no evidence of significant soiling (from emails by station operator Ross Bryant and manager Russ Scott on 8/28/2019).

Table 4.4.27-1. Data Elements, Mounting Height, and Instruments for Walnut Gulch, AZ

Data Element	Mounting Height (m)	Instrument
GHI	3.0	Kipp & Zonen CNR1
GRI	3.0	Kipp & Zonen CNR1
Tdry	2.0	Vaisala HMP-45C
RH	2.0	Vaisala HMP-45C
Wspd	3.5	RM Young 3001
Wdir	3.5	RM Young 3001
Pres	6.4	LI-COR LI-7500
PrecipAccum	1.0	Modified Belfort gage (8”)

Note: '-----' indicates that the information is not available.

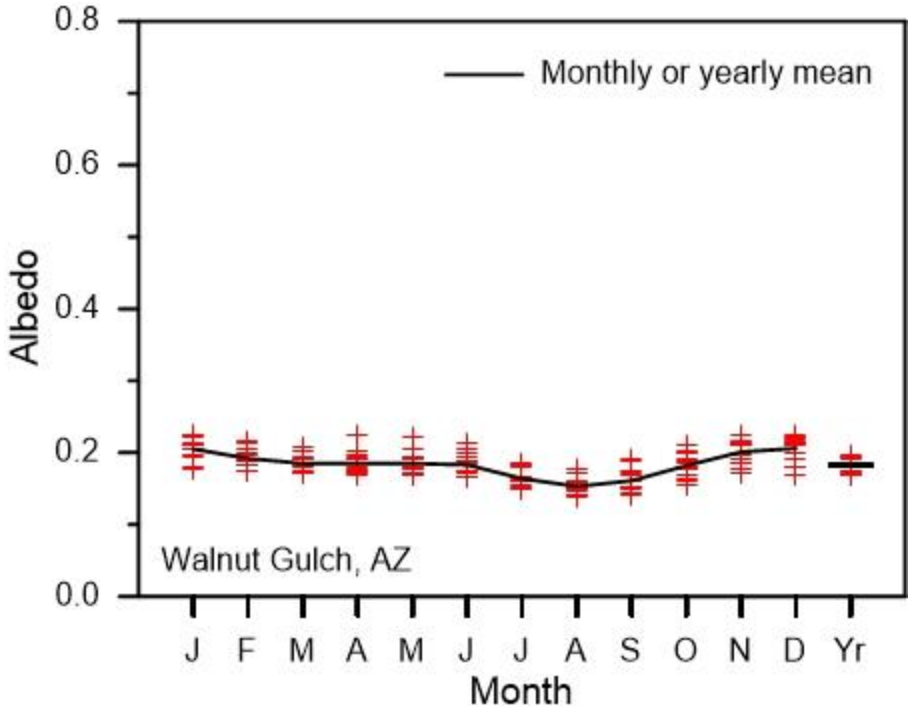

Figure 4.4.27-1. Monthly and yearly albedos and long-term means for Walnut Gulch, AZ.

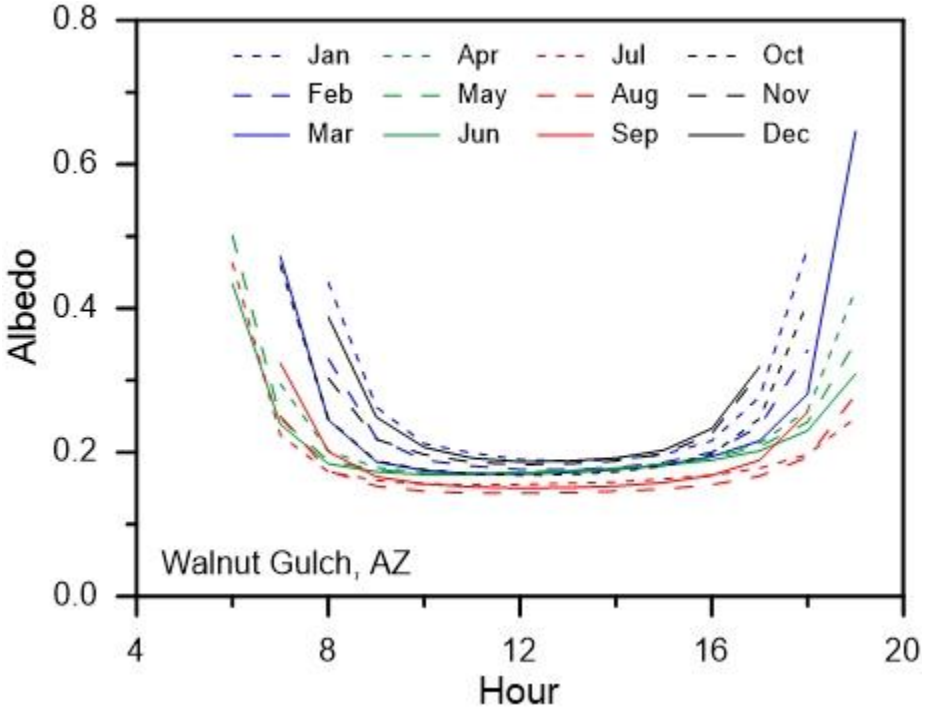

Figure 4.4.27-2. Mean hourly albedos by month for Walnut Gulch, AZ.

4.4.28 Smileyburg, Kansas, USA

StationID: SmileyburgKS
AmeriFlux ID: US-Wlr
Latitude: 37.5208°N
Longitude: 96.8550°W
Elevation: 408 m
Time Zone: -6
Period of Record: 2001-2003
Data Files: 30-minute and hourly
Ground Surface: Tall grass prairie
Annual Precipitation: 881 mm
Overall Albedo: 0.210
AmeriFlux Website: https://ameriflux.lbl.gov/sites/siteinfo/US-Wlr
AmeriFlux Description: *The Walnut River Watershed site rests on a C3/C4 mixed grassland, tallgrass prairie grazed by cattle. The land is owned by a local farmer and the land is leased on a year-to-year basis.*

Table 4.4.28-1. Data Elements, Mounting Height, and Instruments for Smileyburg, KS

Data Element	Mounting Height (m)	Instrument
GHI	1.5	Schenk Dual-Pyranometer Type 8194
GRI	1.5	Schenk Dual-Pyranometer Type 8194
Tdry	1.5	Vaisala HMP45A
RH	1.5	Vaisala HMP45A
Wspd	2.1	Gill R3-100
Wdir	2.1	Gill R3-100
Pres	1.5	Vaisala PTB201A
PrecipAccum	1.5	Met One 385 heated

Note: '-----' indicates that the information is not available.

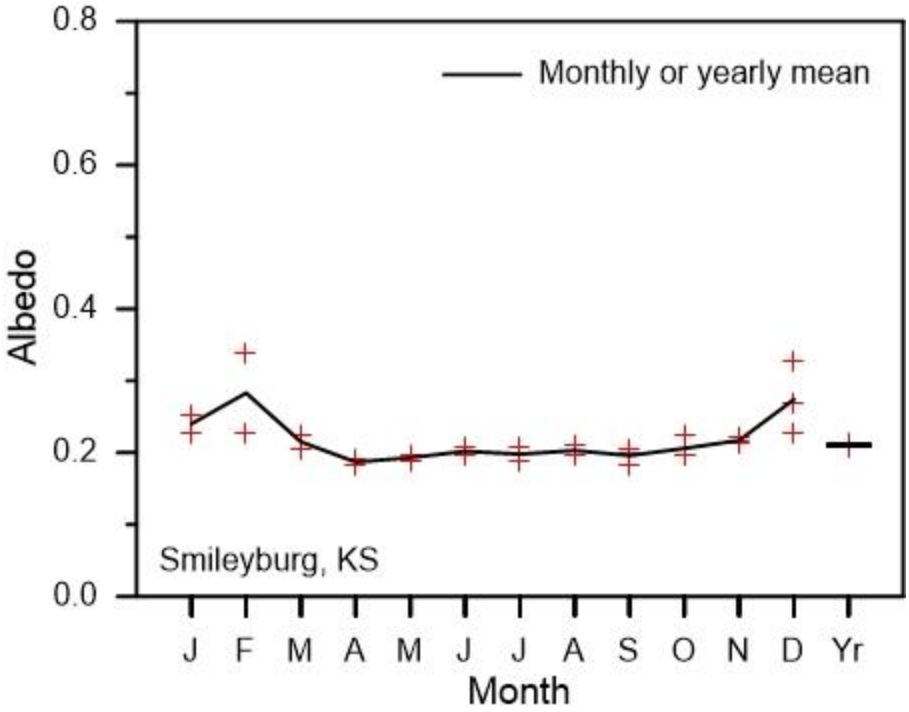

Figure 4.4.28-1. Monthly and yearly albedos and long-term means for Smileyburg, KS.

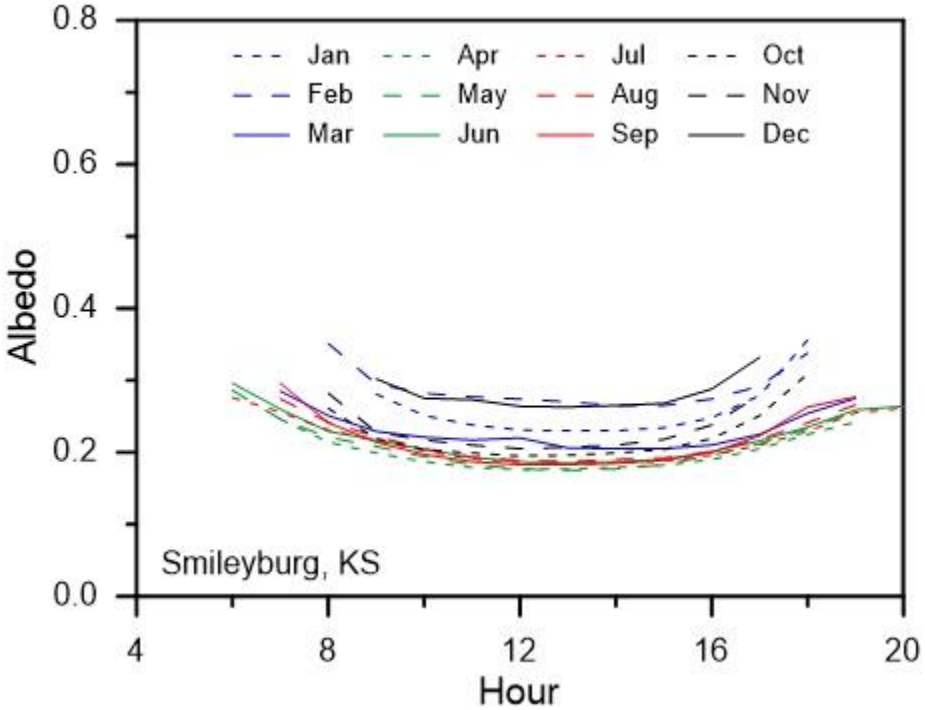

Figure 4.4.28-2. Mean hourly albedos by month for Smileyburg, KS.

4.5 Technical University of Denmark Data

The Technical University of Denmark provided albedo data for a grass surface in Roskilde, Denmark for the period May 1, 2019 through April 30, 2020. The albedometer is installed on the end of a 0.675 m horizontal cross arm 1.75 m above the grass surface. The arm diameter is 0.02 m and the semi-gloss black mast diameter is 0.02 m. The arm and mast are north of the albedometer which is shown in Figure 4.5.1. The tripod base permits relocating, but for the period of measurements it remained in one location. The views from the albedometer in the four cardinal directions are shown in Figures 4.5-2 through 4.5-5.

The Technical University of Denmark estimates that PV array to the east (see Figure 4.5-3) may shadow the ground under the albedometer when the solar azimuth is between approximately 80° and 90° and the solar elevation is less than 10°. The building south of the albedometer (Figure 4.5-4) may shadow the ground under the albedometer when elevation is less than 12°. At solar noon on the winter solstice the solar elevation is about 12°.

GHI and GRI were measured with Kipp and Zonen SMP10 pyranometers; DNI was measured with an EKO MS 56; DHI was measured with an EKO MS 802F; and Tdry, RH, Wspd, Wdir, and Pres were measured with a Lufft UMB 600 weather sensor. The instruments were new when installed and calibrations are planned for every two years. The EKO instruments were cleaned approximately every week and the albedometer was cleaned every two or three months.

Snowfall was observed on six days – November 29, 2019, December 14, 2019, January 4, 2020, February 11, 2020, February 22, 2020, and February 26, 2020. Because of the temperate climate, snow accumulations on the ground rarely remain for more than one day.

Figure 4.5-1. Albedometer installation at the Technical University of Denmark's PV test facility located in Roskilde, Demark (April 2019).

Figure 4.5-2. View from the albedometer toward the north (April 2020).

Figure 4.5-3. View from the albedometer toward the east (April 2020).

Figure 4.5-4. View from the albedometer toward the south (April 2020).

Figure 4.5-5. View from the albedometer toward the west (April 2020).

4.5.1 Roskilde, Denmark

StationID:	RoskildeDenmark
Latitude:	55.696°N
Longitude:	12.105°E
Elevation:	10 m
Time Zone:	+1
Period of Record:	5/1/2019 – 4/30/2020
Data Files:	*RoskildeDenmark_Hourly.csv* – Hourly averages from measurements performed every 5 minutes from 5/1/2019 to 9/4/2019 and every 1 minute from 9/5/2019 to 4/30/2020. *RoskildeDenmark_SummaryResults.csv* – Monthly albedos and mean hourly albedos by month.
Data Elements:	GHI, DNI, DHI, GRI, Tdry, RH, Wspd, Wdir, and Pres
Ground Surface:	Grass
Overall Albedo:	0.222

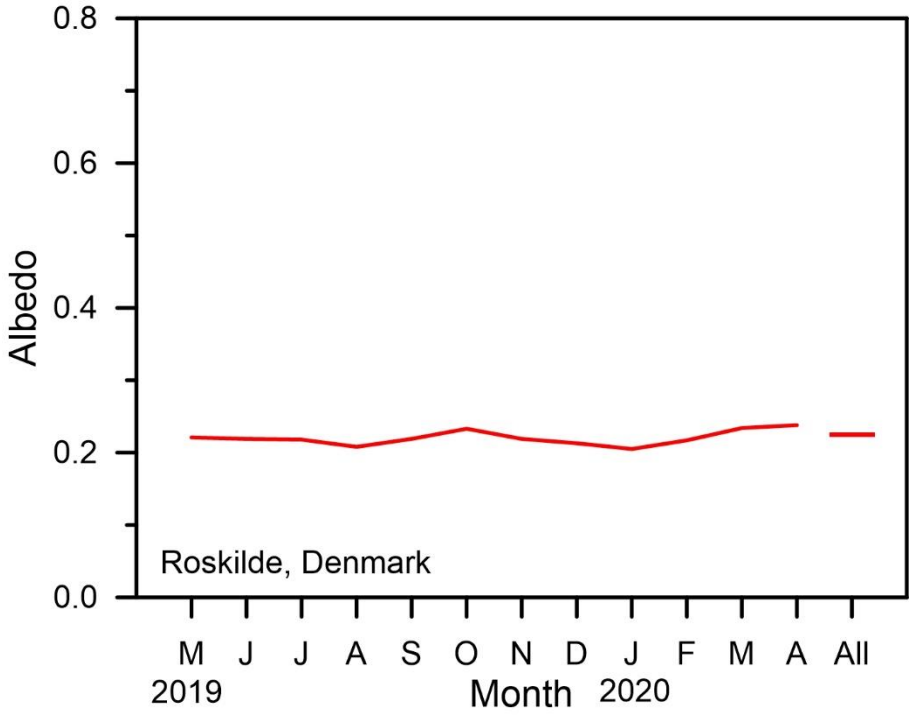

Figure 4.5.1-1. Monthly albedos for Roskilde, Denmark for a grass surface.

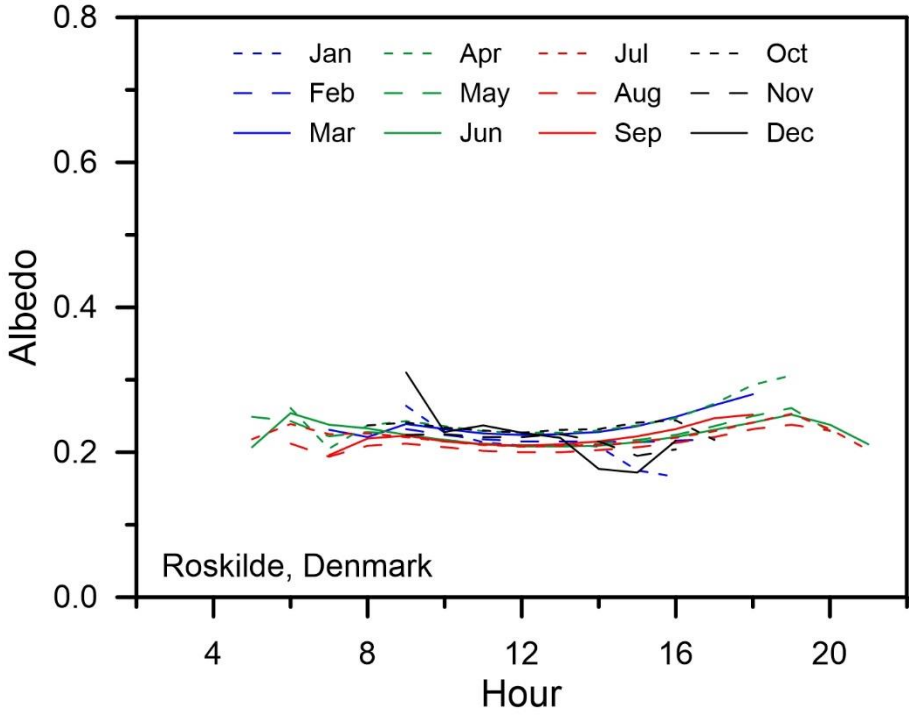

Figure 4.5.1-2. Mean hourly albedos by month for Roskilde, Denmark for a grass surface.

4.6 7X Energy Data

7X Energy provided one year of albedo data for a grass surface grown in silty clay soil near Fayette, Ohio; native grass grown in clay loam soil near Pearsall, Texas; native grass grown in clay loam soil near Sabinal, Texas; and native grass and shrubs grown in Dalby clay soil near Coyanosa, Texas. The albedometers for these locations were installed on the end of a 1.9 m horizontal cross arm 1.6 m above the surface. The arm diameter is 0.048 m and the black mast diameter is 0.033 m. The arms and masts are north of the albedometers.

GHI and GRI were measured with Hukseflux SR30-D1 pyranometers for the locations near Fayette, Pearsall, and Sabinal; and with Hukseflux SR20-T2 pyranometers for the location near Coyanosa. Tdry, RH, Wspd, Wdir, and Pres were measured with Lufft WS500 weather sensors. PrecipAccum was measured with Campbell Scientific TE525WS rain gages. For Coyanosa, DNI and DHI were also provided using a Delta-T SPN1 sunshine pyranometer. The instruments were cleaned every week and the calibration frequency is every two years. For Fayette, Sabinal, and Coyanosa, albedometer data from approximately mid-August through mid-September are not available.

Figures 4.6-1 through 4.6-4 show the albedometers and the nature of the ground surfaces for the four locations.

Figure 4.6-1. Albedometer installation at the Fayette, Ohio location (September 17, 2019).

Figure 4.6-2. Albedometer installation at the Pearsall, Texas location (September 16, 2019).

Figure 4.6-3. Albedometer installation at the Sabinal, Texas location (September 16, 2019).

Figure 4.6-4. Albedometer installation at the Coyanosa, Texas location (January 2019).

4.6.1 Fayette, Ohio, USA

StationID:	FayetteOH
Latitude:	41.6636°N
Longitude:	84.2782°W
Elevation:	228 m
Time Zone:	-5
Period of Record:	5/16/2019 – 4/30/2020
Data Files:	*FayetteOH_1-min.csv* – One-minute averages from measurements performed every three seconds. *FayetteOH_Hourly.csv* – Hourly averages determined from the one-minute data. *FayetteOH_SummaryResults.csv* – Monthly albedos and mean hourly albedos by month.
Data Elements:	GHI, GRI, Tdry, RH, Wspd, Wdir, Pres, and PrecipAccum.
Ground Surface:	Grass surface grown in silty clay soil
Overall Albedo:	0.230

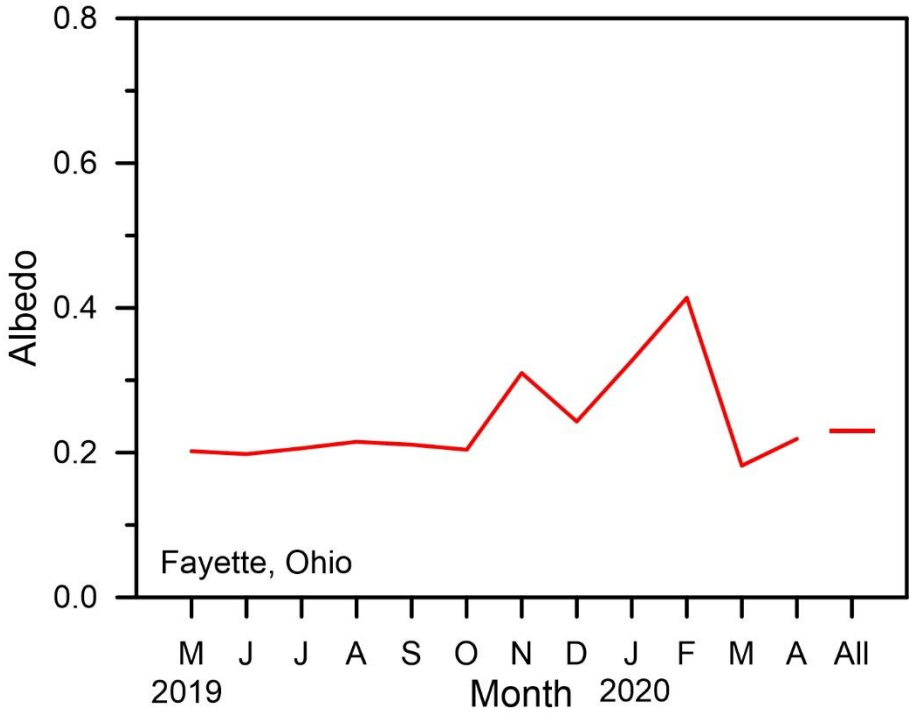

Figure 4.6.1-1. Monthly albedos for Fayette, Ohio.

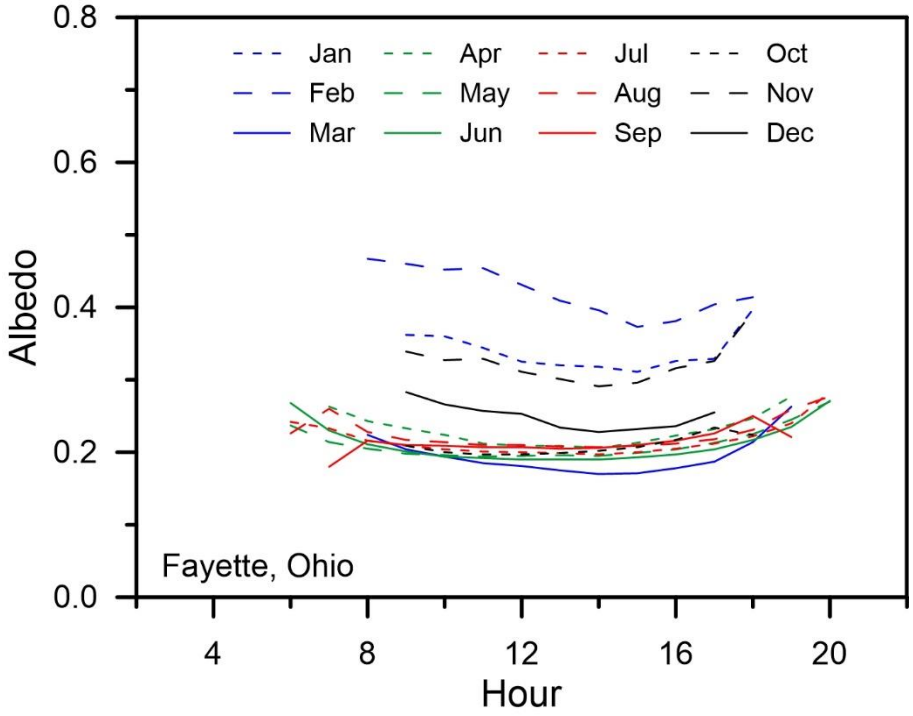

Figure 4.6.1-2. Mean hourly albedos by month for Fayette, Ohio.

4.6.2 Pearsall, Texas, USA

StationID:	PearsallTX
Latitude:	28.9149°N
Longitude:	99.1605°W
Elevation:	281 m
Time Zone:	-6
Period of Record:	5/14/2019 – 4/30/2020
Data Files:	*PearsallTX_1-min.csv* – One-minute averages from measurements performed every three seconds. *PearsallTX_Hourly.csv* – Hourly averages determined from the one-minute data. *PearsallTX_SummaryResults.csv* – Monthly albedos and mean hourly albedos by month.
Data Elements:	GHI, GRI, Tdry, RH, Wspd, Wdir, Pres, and PrecipAccum.
Ground Surface:	Native grass surface grown in clay loam soil
Overall Albedo:	0.194

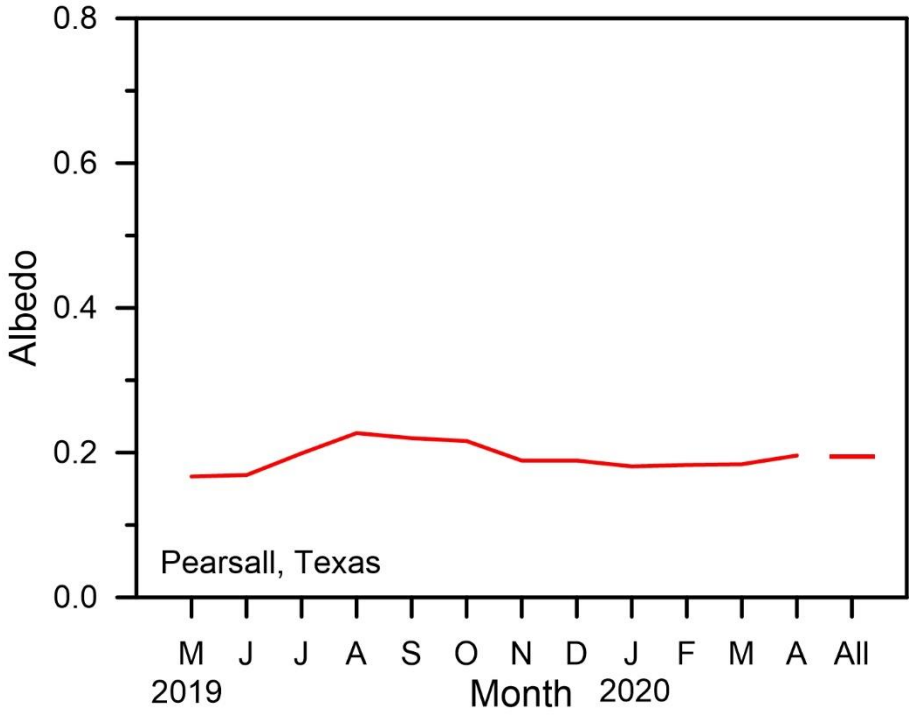

Figure 4.6.2-1. Monthly albedos for Pearsall, Texas.

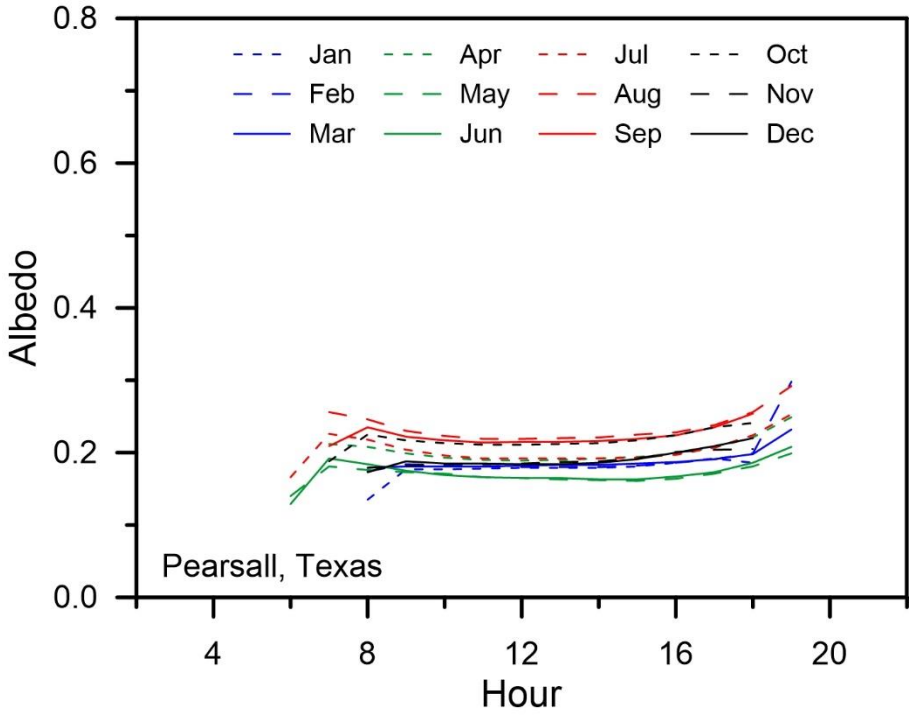

Figure 4.6.2-2. Mean hourly albedos by month for Pearsall, Texas.

4.6.3 Sabinal, Texas, USA

StationID:	SabinalTX
Latitude:	29.2588°N
Longitude:	99.5429°W
Elevation:	278 m
Time Zone:	-6
Period of Record:	5/16/2019 – 4/30/2020
Data Files:	*SabinalTX_1-min.csv* – One-minute averages from measurements performed every three seconds. *SabinalTX_Hourly.csv* – Hourly averages determined from the one-minute data. *SabinalTX_SummaryResults.csv* – Monthly albedos and mean hourly albedos by month.
Data Elements:	GHI, GRI, Tdry, RH, Wspd, Wdir, Pres, and PrecipAccum.
Ground Surface:	Native grass surface grown in clay loam soil
Overall Albedo:	0.210

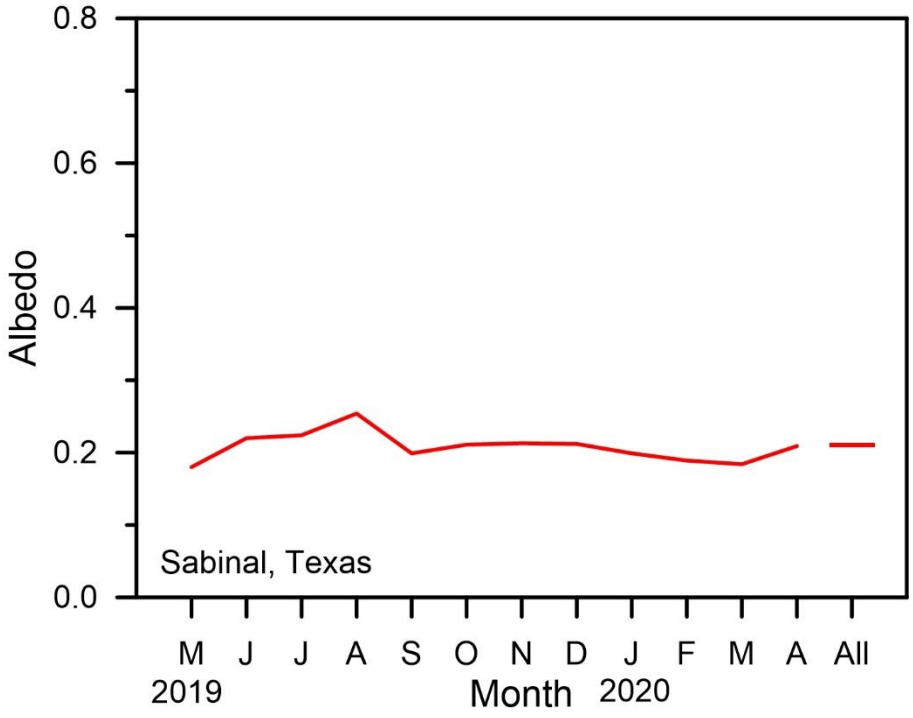

Figure 4.6.3-1. Monthly albedos for Sabinal, Texas.

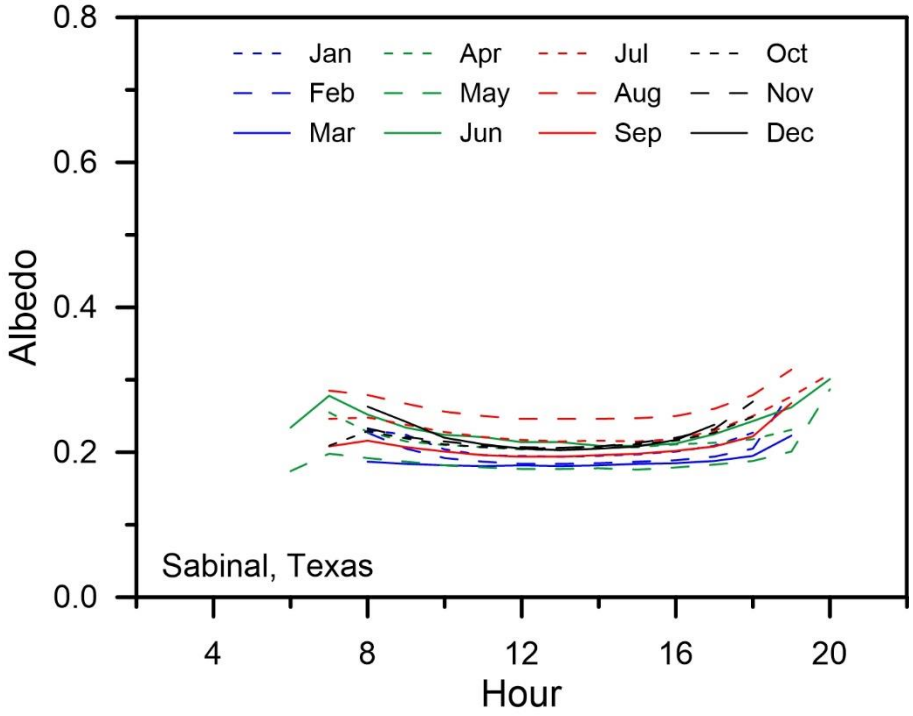

Figure 4.6.3-2. Mean hourly albedos by month for Sabinal, Texas.

4.6.4 Coyanosa, Texas, USA

StationID:	CoyanosaTX
Latitude:	31.1860°N
Longitude:	103.1530°W
Elevation:	835 m
Time Zone:	-6
Period of Record:	11/17/2018 – 4/30/2020
Data Files:	*CoyanosaTX_1-min.csv* – One-minute averages from measurements performed every three seconds. *CoyanosaTX_Hourly.csv* – Hourly averages determined from the one-minute data. *CoyanosaTX_SummaryResults.csv* – Monthly albedos and mean hourly albedos by month.
Data Elements:	GHI, DNI, DHI, GRI, Tdry, RH, Wspd, Wdir, Pres, and PrecipAccum.
Ground Surface:	Native grass and shrubs grown in Dalby clay soil. Trimmed and mowed to maintain height of one foot or less.
Overall Albedo:	0.256

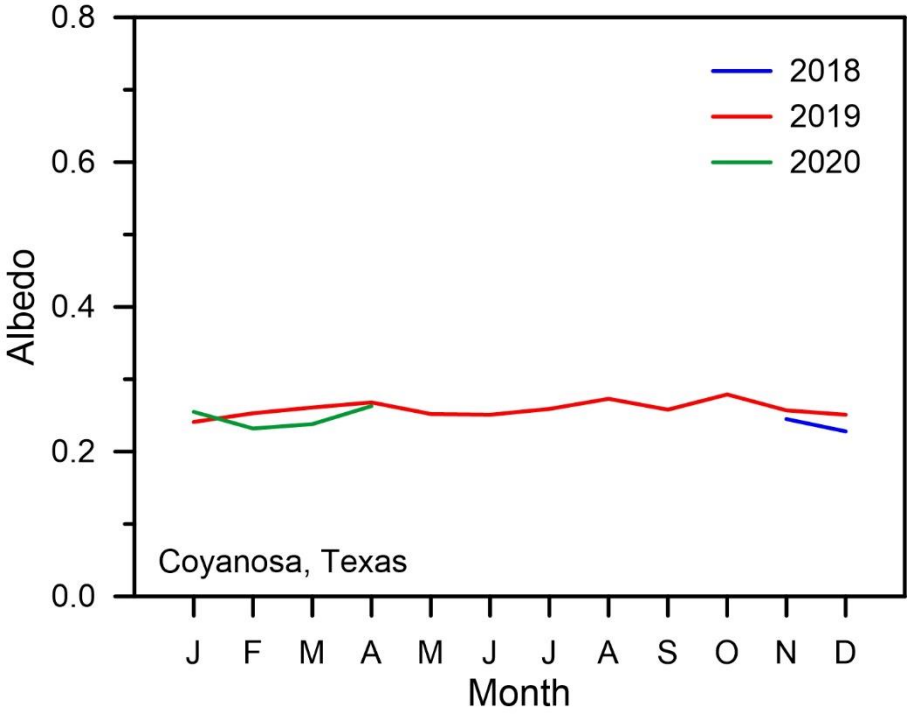

Figure 4.6.4-1. Monthly albedos for Coyanosa, Texas.

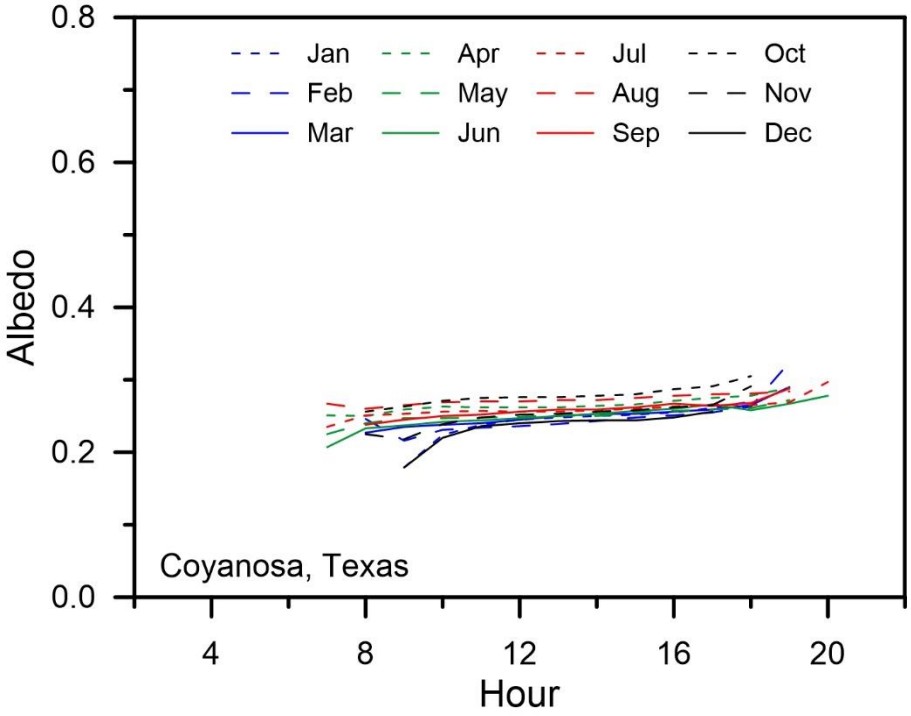

Figure 4.6.4-2. Mean hourly albedos by month for Coyanosa, Texas.

References

Augustine, John & J. DeLuisi, John & N. Long, Charles. (2000). SURFRAD—A national Surface Radiation Budget Network for atmospheric research. Bulletin of The American Meteorological Society 81, 2341-2357.