THE SURFRAD AEROSOL OPTICAL DEPTH DATA SET

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Use the following references in any publications that use SURFRAD Aerosol Optical Depth data:

Augustine, J. A., J. J. DeLuisi, and C. N. Long, 2000: SURFRAD—A national surface radiation budget network for atmospheric research. *Bull. Amer. Meteor. Soc.* **81**, 2341-2357.

Augustine, J. A., G. B. Hodges, C. R. Cornwall, J. J. Michalsky, and C. I. Medina, 2005: An update on SURFRAD—The GCOS surface radiation budget network for the continental United States, *J. Atmos. And Oceanic Tech.*, **22**, 1460–1472.

Augustine, J. A., C. R. Cornwall, G. B. Hodges, C. N. Long, C. I. Medina, and J. J. DeLuisi, 2003: An automated method of MFRSR calibration for aerosol optical depth analysis with application to an Asian dust outbreak over the United States, J. Appl. Meteor., **42**, 266-278.

Augustine, J. A., G. B. Hodges, C. R. Cornwall, J. J. Michalsky, and C. I. Medina, 2005: An update on SURFRAD-The GCOS surface radiation budget network for the continental United States, J. Atmos. And Oceanic Tech., **22**, 1460-1472.

See the end of this document for "Fair use" data practices and licensing policies that pertain to SURFRAD data.

DATA DISTRIBUTION

SURFRAD AOD files are distributed from the ftp site:

https://gml.noaa.gov/aftp/data/radiation/surfrad/aod/

For a particular station's data go to that station's subdirectory, where data are organized in year subdirectories, i.e.,

https://gml.noaa.gov/aftp/data/radiation/surfrad/aod/[sta]/[yyyy]/

where [sta] refers to the station 3-letter identifier (e,g, dra for Desert Rock) and [yyyy] is the 4-digit year

DATA DESCRIPTION

Aerosol optical depth (AOD) data for SURFRAD stations are generated from visible Multi-Filter Rotating Shadowband Radiometers (MFRSR). Nominal channels are 415nm, 500nm, 615nm, 670nm, and 870nm. During site maintenance trips of 2015 and 2016, new model MFRSRs were installed with a 1625nm channel in place of the 615nm channel.

CALIBRATION METHOD

Calibration of the MFRSR channels for AOD is obtained from 0-airmass linear extrapolations of Langley plots (the natural log of the output voltage versus air mass) that are derived from cloud-free MFRSR measurements. Because the total optical depth for a particular spectral channel is the slope of the Langley plot, absolute calibration of the MFRSR channels is unnecessary. To automatically identity pristine measurements for calibration Langley plots, the SURFRAD algorithm cross references times identified as cloud free by the Long Ackerman clear-sky identification (or RadFlux) method with the times of MFRSR measurements. The times of clear sky are determined from independent collocated SURFRAD broadband solar measurements. Such plots represent first-attempt Langley calibrations that are generally free of cloud contamination. The few bad calibration Langley points that survive the first attempt are rejected by deviation-from-linearity tests that follow. All calibration Langley plots are checked before being included.

Time series of Langley calibrations and associated errors are constructed for the duration of a particular MFRSR's deployment. To get a "representative Langley" calibration for each channel for a designated period, about two months of data are processed as described above. Channel specific Langley calibrations within that period are normalized to a circular orbit and then averaged to derive a "representative" calibration and error for that two-month period. Error is computed by a common propagation of error method. Outliers from the sample are rejected by standard statistical methods and the average and error is recalculated. After about two years of these "representative" ~2-month channel mean calibrations and associated error are ascertained, the time series of the representative calibrations for each channel is fit to a polynomial with linear, sine and cosine terms that describes the mean variation of a channel-specific calibration (normalized to a circular orbit) over the two-year period. The error time series for each channel are also fit to best-fit linear regression expressions that represent the variation of error for each channel over the 2-year period. Prior to the regression, the two-year time series are overlapped by about four months on either end of the 2-year period to ensure a smooth transition in the fits to the spectral calibrations and error time series between adjacent two-year periods. These calibration equations are loaded into files that are accessed by the algorithm that is used to compute aerosol optical depth.

AEROSOL OPTICAL DEPTH COMPUTATION

The total optical depth for each spectral MFRSR measurement is computed by first obtaining the calibration for the day of the measurement from the linear equations that have been fit to the time series of channel-specific 0-air mass Langley calibrations. That calibration is then corrected back to an elliptical orbit value for the day being processed. For each 2-minute MFRSR measurement, the appropriate channel calibration and measurement are plotted as a two-point Langley plot. The slope of that line is the total optical depth for that channel at that time. Aerosol optical depth is computed by subtracting the contributions of molecular scattering and absorption by ozone from the total optical depth. Ozone absorption coefficients are chosen based on the particular central measurement wavelengths of each MFRSR. Molecular scattering is also computed based the central wavelengths. Potential contributions by nitrogen dioxide and sulfur dioxide absorption are ignored because they are negligible (< 1%).

FILE STRUCTURE:

The SURFRAD AOD analysis program operates on one day and one station, and produces a one-day AOD product file for that station. The AOD files are named with the convention [sta]_yyyymmdd.aod, where [sta] is the three-letter

station identifier:

bon Bondville, Illinois
fpk Fort Peck, Montana
gwn Goodwin Creek, Mississippi
tbl Table Mountain, Colorado
dra Desert Rock, Nevada
psu Penn State, Pennsylvania
sxf Sioux Falls, South Dakota

For example, the AOD file for Table Mountain for April 13, 2001 would be named: tbl_20010413.aod. The data frequency in these files matches that of the MFRSR, which is typically two-minute.

Each SURFRAD AOD product file has six header records that are followed by data. An example of the header of such a file is shown below:

```
Table Mountain SURFRAD aerosol optical depth (nm)
13-apr-2001 13 04 2001 349 lines of data
 413.5 497.4 615.0 672.7 869.8 channel central wavelengths
 0.221  0.211  0.196  0.194  0.185 Daily average AODs (sample size = 236)
352 Dobson units of ozone
ltime 0=good AOD414 AOD497 AOD615 AOD673 AOD870 414E 497E 615E 673E 870E
p_mb ang_exp
(first line of data)
.
```

.
.
.
.
(last line of data)

The first header record contains the station name,

The second header record has the date in two forms followed by the number of lines of AOD data in the file. The first date is of the form: dd-mmm-yyyy, which is the same as that in the filename. To the right on that same line, the date is repeated in numeric format, i.e., day of the month (dd), month number (mm), and the 4-digit year (yyyy). The last numeric entry on that line is the number of lines of AOD data in the file.

The third header record contains the central wavelengths (nm) of the first five spectral channels of the MFRSR that was used to generate the AOD data in the file.

The fourth header record lists the daily average AODs for each spectral channel, in the order that they are listed on the previous line. Only AODs marked as "good," i.e., a 0 in the second column of the data block, are included in the daily average computation. At the end of the line, the sample size of data points that was used in the average calculation for each channel is listed.

The fifth header record lists the total column ozone (in Dobson units) that was derived from TOMS data for the location of the station on the day that the file represents. That value of total ozone was used to compute the channel-specific optical depth due to ozone that was removed from the total optical depth (not listed in the file) computed for each channel.

The sixth header line lists data column headers.

The data block consists of 13 columns.

The first column is the time in local standard time (LST) in hours and minutes (hhmm).

The second column is the cloud-screening indicator; either a 0 or 1 is entered. A "0" in column 2 indicates that that time period passed a cloud screen test and the AOD data listed on the line likely represent true aerosol optical depths. A "1" in column 2 indicates that the measurements on that line may be adversely affected by clouds and the AODs listed should be ignored. All data are included because the cloud-screening test is not perfect. The convention of using "0" as a good-data indicator and "1" for bad data is consistent with that used in SURFRAD data files.

Columns 3 through 7 are aerosol optical depths (AODs) for the first five spectral channels of the MFRSR. They are nominally 415 nm, 500 nm, 614 nm (or 1625 nm after 2015 or 2016, depending on the station), 670 nm, and 868 nm, but in practice they vary among visible MFRSRs. The unique values

for the MFRSR used to compute AOD for the current file are listed in header record 3. Missing values for AOD are indicated by -9.999.

Columns 8 through 12 are errors associated with the AODs in the columns 3 through 7, respectively. Missing errors are indicated by -9.9999.

The 13th and last column list the atmospheric station pressure in millibars measured at the SURFRAD station for the time of the measurement. These values were used to compute the optical depth due to molecular (Rayleigh) scattering that was subtracted from the total optical depth (not listed in the file) for each channel. The last column contains the Angstrom exponent which is computed from the AODs for the 500nm and 868nm channels.

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