EARTH OBSERVATION CLIMATE INFORMATION SERVICE

Quick Start Guide

Swansea University Global Aerosol Optical Depth

Issued by:
Kevin Pearson and Peter North
Swansea University,
Date: 18th Sep 2024

Table of Contents

1. Quick Start: Swansea University Global Aerosol Optical Depth

The following will provide you with sufficient information to quickly get to grips with the Swansea University Global Aerosol Optical Depth dataset products and to gain some familiarity with the information available.

1.1 What products are available?

The data are grouped into two instrument families each with an associated daily and monthly product. The ATSR-2 and AATSR instruments have been grouped as (A)ATSR L3C v4.35.1 products. SLSTR-A and SLSTR-B are grouped as SLSTR L3C v1.14.1 products.

Product name and acronym	Filename example	Version
SU Daily Aerosol (A)ATSR L3C	19961231-C3S-L3C_AEROSOL-AER_PRODUCTS-ATSR2_ERS2-SU_DAILY-v4.35.1.nc 20061231-C3S-L3C_AEROSOL-AER_PRODUCTS-AATSR_ENVISAT-SU_DAILY-v4.35.1.nc	4.35.1
SU Monthly Aerosol (A)ATSR L3C	199612-C3S-L3C_AEROSOL-AER_PRODUCTS-ATSR2_ERS2-SU_MONTHLY-v4.35.1.nc 200612-C3S-L3C_AEROSOL-AER_PRODUCTS-AATSR_ENVISAT-SU_MONTHLY-v4.35.1.nc	4.35.1
SU Daily Aerosol SLSTR L3C	20171231-C3S-L3C_AEROSOL-AER_PRODUCTS-SLSTR_SENTINEL_S3A-SU_DAILY-v1.14.1.nc 20181231-C3S-L3C_AEROSOL-AER_PRODUCTS-SLSTR_SENTINEL_S3B-SU_DAILY-v1.14.1.nc	1.14.1
SU Monthly Aerosol SLSTR L3C	201712-C3S-L3C_AEROSOL-AER_PRODUCTS-SLSTR_SENTINEL_S3A-SU_MONTHLY-v1.14.1.nc 201812-C3S-L3C_AEROSOL-AER_PRODUCTS-SLSTR_SENTINEL_S3B-SU_MONTHLY-v1.14.1.nc	1.14.1

Table 1 Dataset Products covered in this document

1.2 Summary information

Product Name	**SU Daily Aerosol (A)ATSR L3C**
Main observed variable(s)	Aerosol Optical Depth at 550nm, Fine Mode Aerosol Optical Depth at 550nm
Geographical range of dataset	Global
Temporal range of dataset	ATSR-2: 1995/06/01-1995/12/22, 1996/07/01-2003/06/22 AATSR: 2002/05/20-2012/04/08
Spatial resolution / gridding	1°x1°

Temporal sampling characteristics	Daily
Level of processing	L3C Gridded Data
Main auxiliary content	AOD at 670, 870 and 1600nm, Uncertainty on AOD at 550, 670, 870 and 1600nm, FM AOD at 670, 870 and 1600nm, Surface Reflectance at 550, 670, 870 and 1600nm
Dataset citation	TBC
Dataset journal reference	TBC

Table 2 Summary Information for SU Daily Aerosol (A)ATSR L3C dataset

Product Name	SU Monthly Aerosol (A)ATSR L3C
Main observed variable(s)	Aerosol Optical Depth at 550nm, Fine Mode Aerosol Optical Depth at 550nm
Geographical range of dataset	Global
Temporal range of dataset	ATSR-2: 1995/06-1995/12, 1996/07-2003/06 AATSR: 2002/05-2012/04
Spatial resolution / gridding	1°x1°
Temporal sampling characteristics	Monthly
Level of processing	L3C Gridded Data
Main auxiliary content	AOD at 670, 870 and 1600nm, Uncertainty on AOD at 550, 670, 870 and 1600nm, FM AOD at 670, 870 and 1600nm, Surface Reflectance at 550, 670, 870 and 1600nm
Dataset citation	TBC
Dataset journal reference	TBC

Table 3 Summary Information for SU Monthly Aerosol (A)ATSR L3C dataset

Product Name	SU Daily Aerosol SLSTR L3C
Main observed variable(s)	Aerosol Optical Depth at 550nm, Fine Mode Aerosol Optical Depth at 550nm
Geographical range of dataset	Global
Temporal range of dataset	SLSTR-A: 2016/05/01-2022/12/31 SLSTR-B: 2018/05/09-2022/12/31
Spatial resolution / gridding	1°x1°
Temporal sampling characteristics	Daily
Level of processing	L3C Gridded Data
Main auxiliary content	AOD at 670, 870 and 1600nm, Uncertainty on AOD at 550, 670, 870 and 1600nm, FM AOD at 670, 870 and 1600nm
Dataset citation	TBC
Dataset journal reference	TBC

Table 4 Summary Information for SU Daily Aerosol SLSTR L3C dataset

Product Name	SU Monthly Aerosol SLSTR L3C
Main observed variable(s)	Aerosol Optical Depth at 550nm, Fine Mode Aerosol Optical Depth at 550nm

Geographical range of dataset	Global
Temporal range of dataset	SLSTR-A: 2016/05-2022/12 SLSTR-B: 2018/05-2022/12
Spatial resolution / gridding	1°x1°
Temporal sampling characteristics	Monthly
Level of processing	L3C Gridded Data
Main auxiliary content	AOD at 670, 870 and 1600nm, uncertainty on AOD at 550, 670, 870 and 1600nm, FM AOD at 670, 870 and 1600nm
Dataset citation	TBC
Dataset journal reference	TBC

Table 5 Summary Information for SU Monthly Aerosol SLSTR L3C dataset

1.2.1 Variables summary information

Variable name	Description	Units
latitude	Latitude	Degrees north
longitude	Longitude	Degrees east
pixel_count	Number of retrieved pixels in grid cell	Dimensionless
AOD<band>_mean	Mean aerosol optical thickness at <band>nm	Dimensionless
AOD<band>_sdev	Standard deviation of aerosol optical thickness at <band>nm	Dimensionless
FM_AOD550_mean	Fine model AOD	Dimensionless
FM_AOD550_sdev	Standard deviation aerosol optical thickness at 550nm	Dimensionless
AOD<band>_uncertainty	Propagated L2 uncertainty in aerosol optical thickness at <band>nm	Dimensionless
AOD<band>_uncertainty_mean	Mean of L2 uncertainty of AOD at <band>nm	Dimensionless
AOD<band>_uncertainty_mix	Minimum L2 uncertainty of AOD at <band>nm	Dimensionless
AOD<band>_uncertainty_max	Maximum L2 uncertainty of AOD at <band>nm	Dimensionless
AOD<band>_uncertainty_sdvev	Standard deviation of L2 uncertainty of AOD at <band>nm	Dimensionless
ANG550_870 mean	Angstrom exponent computed on AOD550 and AOD870	Dimensionless

ANG550_870_sdev	Standard deviation of the angstrom exponent computed on AOD550 and AOD870	Dimensionless
D_AOD550_mean	Mean non-spherical dust AOD at 550nm	Dimensionless
D_AOD550_sdev	Standard deviation of non-spherical dust AOD at 550nm	Dimensionless
AAOD550_mean	Mean Absorbing Aerosol Optical Depth at 550nm	Dimensionless
AAOD550_dev	Standard deviation of Absorbing Aerosol Optical Depth at 550nm	Dimensionless
SSA550_mean	Single-scattering albedo at 550nm	Dimensionless
SSA550_sdev	Standard deviation of single-scattering albedo at 550nm	Dimensionless

Table 6 Summary information for each variable included in all the datasets. <band> can take values of 550, 670, 870 or 1600.

Variable name	Description	Units
surface_reflectance<band>_mean	Mean bidirectional surface reflectance (nadir)	Dimensionless
surface_reflectance<band>_sdev	Standard deviation of mean bidirectional surface reflectance (nadir)	Dimensionless
cloud_fraction_mean	Mean fraction of cloud flagged pixels in 10km bin	Dimensionless
cloud_fraction_sdev	Standard deviation of mean fraction of cloud flagged pixels in 10km bin	Dimensionless
surface_type_number_mean	Mean land fraction	Dimensionless
surface_type_number_sdev	Standard deviation of mean land fraction	Dimensionless

Table 7 Summary information for additional variables included only in (A)ATSR Daily and Monthly datasets.

1.3 What can these products be used for?

These products form a long-term set of observations of global aerosol optical depth and associated quantities. Such observations are required to reduce the current large range in the estimated radiative forcing associated with aerosol effects. The products can be used to infer regional aerosol optical depth trends as part of climate monitoring. They can also be used as inputs to numerical weather and climate modelling seeking to include the radiative effects of aerosols.

1.4 Where to find these products for download

Evaluation versions of these datasets can be downloaded from https://gws-access.jasmin.ac.uk/public/cci_aerosol_su/ .

- CCI_v4.35.1_atsr2_ncdf – ATSR2 daily and monthly datasets
- CCI_4.35.1_ncdf – AATSR daily and monthly datasets
- SLSTR_AOD_v1.14.1_ncdf – SLSTR-A daily and monthly datasets
- SLSTRB_AOD_v1.14.1_ncdf – SLSTR-B daily and monthly datasets

To access the dataset products(s) navigate to the following locations using the links below:

- Data portal 1 – < enter the DOI or URL for the access location [top page / directory]>

- Data portal 2 – < enter the DOI or URL for the access location [top page / directory]>

<Add information about any login or registration requirements that may need to be met in order to access the data>

1.5 Using downloaded data

All data files are provided in NetCDF format and accessible with standard tools. Example python code to ingest, subset, regrid and display mapped data is given below.

1.5.1 Import Data

This sample code uses the xarray module to import a sample dataset and show the contents.

Example Code:

```
import xarray as xr

# Open an AOD Monthly dataset
filename = '202109-C3S-L3C_AEROSOL-AER_PRODUCTS-SLSTR_SENTINEL_S3A-SU_MONTHLY-
v1.14.1.nc'

d = xr.open_dataset(filename)
d
```

Illustrative Results:

```
<xarray.Dataset> Size: 10MB
Dimensions:                   (latitude: 180, longitude: 360)
Coordinates:
  * latitude                  (latitude) float32 720B -89.5 -88.5 ... 88.5 89.5
  * longitude                 (longitude) float32 1kB -179.5 -178.5 ... 179.5
Data variables: (12/39)
    pixel_count               (latitude, longitude) float64 518kB ...
    AOD550_mean               (latitude, longitude) float32 259kB ...
    AOD550_sdev               (latitude, longitude) float32 259kB ...
    AOD670_mean               (latitude, longitude) float32 259kB ...
    AOD670_sdev               (latitude, longitude) float32 259kB ...
    AOD870_mean               (latitude, longitude) float32 259kB ...
    ...                        ...
    AOD870_uncertainty_max    (latitude, longitude) float32 259kB ...
    AOD1600_uncertainty_mean  (latitude, longitude) float32 259kB ...
    AOD1600_uncertainty_sdev  (latitude, longitude) float32 259kB ...
    AOD1600_uncertainty       (latitude, longitude) float32 259kB ...
    AOD1600_uncertainty_min   (latitude, longitude) float32 259kB ...
    AOD1600_uncertainty_max   (latitude, longitude) float32 259kB ...
Attributes: (12/40)
    Conventions:                CF-1.6
    tracking_id:                764fe687-f5ca-456c-9989-ececff79adf4
    naming_authority:           uk.ac.su.aatsraerosol
    sensor:                     SLSTR
    platform:                   SENTINEL-S3A
    resolution:                 1x1 degrees
    ...                         ...
    project:                    Algorithm - European Space Agency Climate Cha...
    history:                    Level 3 product generated using Swansea Unive...
    license:                    Creative Commons Attribution 4.0  https://cre...
    inputfilelist:              ['20210901-C3S-L3C_AEROSOL-AER_PRODUCTS-SLSTR...
    acknowledgement:            The European Space Agency (ESA) funded the de...
    format_version:             EOCIS Data Standards v1.0
```

1.5.2 Data Reduction/Subsetting

This sample code makes a subset of the dataset loaded in the previous subsection, takes a subset and shows the contents of the new data structure.

Example Code:

```
subset = d.AOD550_mean.sel(latitude=slice(12,35), longitude=slice(-120,-80))
subset
```

Illustrative Results:

```
<xarray.DataArray 'AOD550_mean' (latitude: 23, longitude: 40)> Size: 4kB
[920 values with dtype=float32]
Coordinates:
  * latitude   (latitude) float32 92B 12.5 13.5 14.5 15.5 ... 32.5 33.5 34.5
  * longitude  (longitude) float32 160B -119.5 -118.5 -117.5 ... -81.5 -80.5
Attributes:
```

```
    long_name:      aerosol optical thickness at 550 nm
    standard_name:  atmosphere_optical_thickness_due_to_ambient_aerosol
    units:          1
    valid_range:    [0. 4.]
```

1.5.3 Re-Gridding/Formatting

This code takes the subset formed in the previous subsection, performs a coarsening by binning at 4 times the previous resolution and then shows the resulting data structure.

Example Code:

```
# Regridding to a coarser spatial resolution (4x coarser)
subset_coarse = subset.coarsen(lon=4, lat=4, boundary='pad').mean()
subset_coarse
```

Illustrative Results:

```
<xarray.DataArray 'AOD550_mean' (latitude: 6, longitude: 10)> Size: 240B
array([[0.09914041, 0.11219011, 0.12162341, 0.10869941, 0.12889022,
        0.1427731 , 0.16363764, 0.1921311 , 0.22160482, 0.19335517],
       [0.09982581, 0.12032932, 0.13449472, 0.14035141, 0.18461803,
        0.22009136, 0.21284157, 0.27843368, 0.17642054, 0.19784525],
       [0.1047129 , 0.13090579, 0.1434227 , 0.15296006, 0.23314755,
        0.24339572, 0.21455343, 0.2069033 , 0.19423398, 0.1833095 ],
       [0.1428014 , 0.1583708 , 0.18069965, 0.15517005, 0.15588146,
        0.23961101, 0.18391289, 0.19371954, 0.17694983, 0.18360274],
       [0.19241317, 0.16708739, 0.13925195, 0.13571121, 0.13887161,
        0.27275518, 0.24756318, 0.21678634, 0.1859371 , 0.15589866],
       [0.1692735 , 0.13231312, 0.1205624 , 0.14177537, 0.20551033,
        0.2793535 , 0.25784323, 0.1626115 , 0.18611021, 0.13954811]],
      dtype=float32)
Coordinates:
  * latitude   (latitude) float32 24B 14.0 18.0 22.0 26.0 30.0 33.5
  * longitude  (longitude) float32 40B -118.0 -114.0 -110.0 ... -86.0 -82.0
Attributes:
    long_name:      aerosol optical thickness at 550 nm
    standard_name:  atmosphere_optical_thickness_due_to_ambient_aerosol
    units:          1
    valid_range:    [0. 4.]
```

1.5.4 Forming a Time-series

The data files do not contain a time dimension but this can be deduced either from the file names or the metadata. The following code uses the numpy, xarray and matplotlib modules to read the 12 monthly data files for year, add a time dimension and then plot the mean AOD within a geographic sub-region against time.

Example Code:

```
import xarray as xr
import numpy as np
import matplotlib.pyplot as plt

# Set the year and filename parameters
yyyy='2021'
filebase = '-C3S-L3C_AEROSOL-AER_PRODUCTS-SLSTR_SENTINEL_S3A-SU_MONTHLY-v1.14.1.nc'

# Loop over months in the year
for m in np.arange(1,13):
    # Create the filename for this month
    mm="{:02d}".format(m)
    filename=yyyy+mm+filebase
    # Load the file
    d = xr.open_dataset(filename)
    #Add a "month" dimension of length 1 and make it a coordinate with this month's
value
    d=d.expand_dims(dim={"Month": 1 } )
    d=d.assign_coords(Month=("Month", [m] ) )
    #Append the new data along the Month dimension
    if (m == 1):
        d_total=d
    else:
        d_total=xr.combine_by_coords([d_total, d],combine_attrs='drop_conflicts')
#End the month loop

#Create a spatial subset of AOD from the datasets
AOD_region=d_total.AOD550_mean.sel(latitude=slice(12,35), longitude=slice(-120,-80))
#Find the mean value of AOD across the spatial dimensions
AODvTime=AOD_region.mean(dim=["latitude","longitude"])

#Make a figure and assign month names to the x-axis
fig=plt.figure()
ax=fig.add_subplot(1,1,1)
AODvTime.plot()
mnths=["Jan","Feb","Mar","Apr","May","Jun","Jul","Aug","Sep","Oct","Nov","Dec"]
ax.set_xticks(range(1,13),mnths)
plt.title("Mean SLSTR-A AOD in a sub-region during 2019")

#Display the figure
plt.show()
```

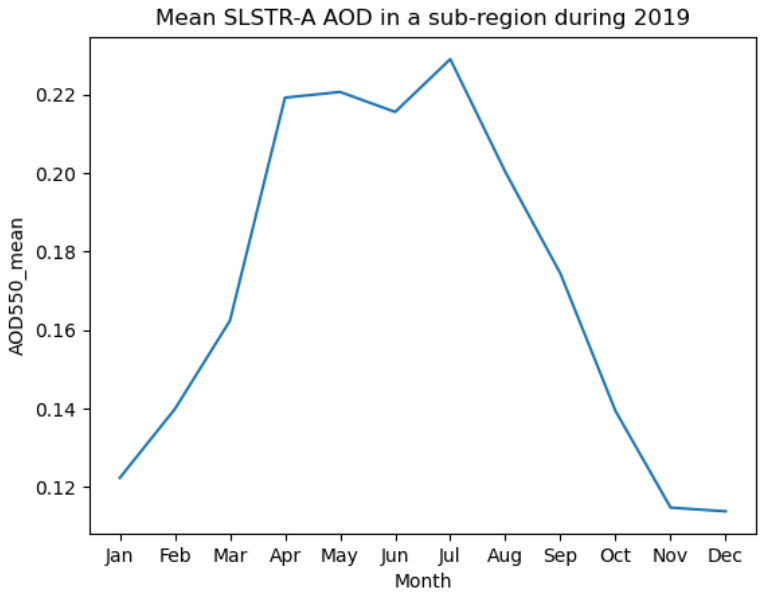

Figure 1 Time-series of mean AOD for a sub-region of SLSTR-A data during 2019

1.5.5 Displaying Data

This code makes use of the matplotlib, cartopy, pylab, netCDF4 and numpy python modules to produce a map of the global dataset with overlayed continents.

Example Code:

```
import matplotlib.pylab  as plt
import matplotlib.colors as colors
import cartopy.crs as ccrs
import netCDF4
import numpy as np

# A function to redefine the colormap to remove the darkest blues
def truncate_colormap(cmap, minval=0.0, maxval=1.0, n=256):
    new_cmap = colors.LinearSegmentedColormap.from_list(
        'trunc({n},{a:.2f},{b:.2f})'.format(n=cmap.name, a=minval, b=maxval),
        cmap(np.linspace(minval, maxval, n)))
    return new_cmap

# Load the data using the netCDF interface
filename='202109-C3S-L3C_AEROSOL-AER_PRODUCTS-SLSTR_SENTINEL_S3A-SU_MONTHLY-v1.14.1.nc'
aod=netCDF4.Dataset(filename).variables['AOD550_mean'][:]

# Increase the default font size and lighten the colour mapping
plt.rcParams.update({'font.size': 12})
cmap = plt.get_cmap('jet')
new_cmap=truncate_colormap(cmap,0.15,1.0)

# Create the plotting area
fig = plt.figure(figsize=(10,7))
ax=fig.add_subplot(1,1,1,projection=ccrs.PlateCarree())
```

```
ax.set_title('SLSTR-A Monthly Mean AOD 2021-09')
ax.coastlines('50m')

# Add the data to the map
# n.b. origin is used to the specify location of data array element [0,0]
im=ax.imshow(aod,origin='lower', transform=ccrs.PlateCarree(), extent=(-180,180,-
90,90), vmin=0.0, vmax=1.0, cmap=new_cmap)
plt.colorbar(im, label='Aerosol Optical Depth',orientation='horizontal')

# Display the figure
plt.show()
```

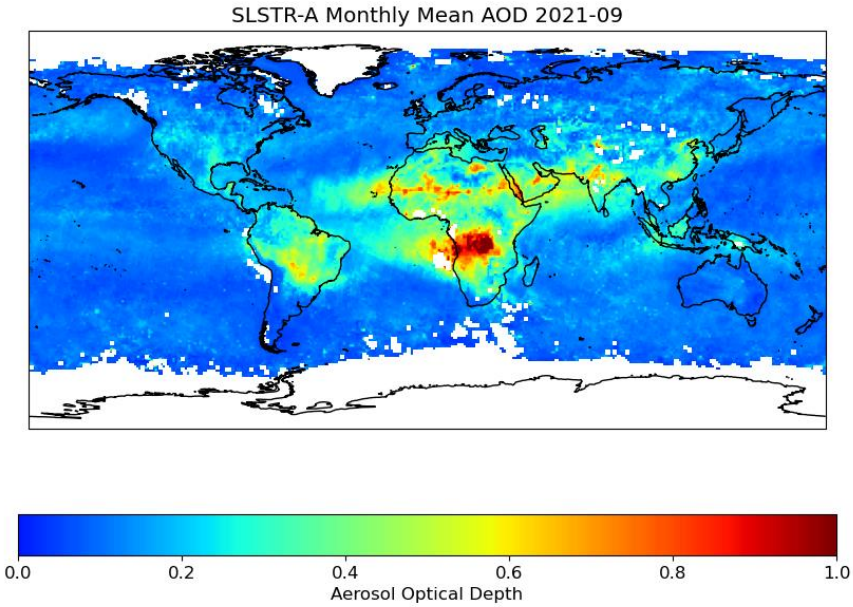

Figure 2 Example Monthly Mean AOD field from SLSTR-A

1.6 Interactive visualisation / data access

The monthly mean Aerosol Optical Depth data can be visualised interactively through the EOCIS data portal https://eocis.org/portal/viewer/?layer=AOD550_mean#

1.7 Your obligations when using these products

By accessing the Swansea University Aerosol Optical Depth products, you agree to cite the dataset digital object identifier (doi) and corresponding journal article describing the dataset every time you publish results obtained in whole or in part by use of UK EOCIS products. These citations are given under Summary Information.

The reference to the dataset should mention "created by the UK Earth Observation Climate Information Service". The product name and acronym in Table 1 should be used to avoid confusion and enable traceability.

1.8 Further Information

This data set currently runs from 1995-2012 for ATSR-2 and AATSR and from 2016-2022 for SLSTR-A and SLSTR-B. Ongoing processing will extend the SLSTR data shortly after release up to the present day with monthly data being generated by the middle of the following month.

History of modifications / Change Log

Version	Date	Changes	Person
1.1	28/6/24	Draft	KJP
1.2	18/9/24	Update with GLS comments	KJP

Related Documents / Reference Documents

Document	Author	Reference

Acronyms and/or Abbreviations

Acronym / Abbreviation	Definition
(A)ATSR	Either of the two Along-Track Scanning Radiometers ATSR-2 and AATSR
AATSR	Advanced Along-Track Scanning Radiometer
AOD	Aerosol Optical Depth
ATSR-2	Along Track-Scanning Radiometer 2
SLSTR	Sea and Land Surface Radiometer

General definitions

Term	Definition