Using freeware tools for Sentinel5 - NetCDF files

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Session Contents

- Air Quality
- AEROTOX Project
- Particulate Matter and Dust Composition
- Desert Dust, Composition, and effects
- Measurement of air quality - Aerosol Optical Depth
- Measuring Aerosol Optical depth
- Sentinel 5p
- Tools and formats for Sentinel 5p
- Download and Extraction
- Post-Processing the data (Demo extracting relevant data, Creating Histograms)
- References
- Q&A session

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Air Quality

- Monitoring the type and quantity of pollutants in the atmosphere.
- It is a measure of a quality of life for the environment and people
- Provides a real time measure of chemicals present in the air
- Typical chemicals that are measured
  - PM2.5
  - PM10
  - Ozone (O3)
  - Nitrogen Dioxide (NO2)
  - Sulphur Dioxide (SO2)
  - Carbon Monoxide (CO)
- Dust is also a major contributor to air quality

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Atmospheric Toolbox (AEROTOX)Project

- There is adequate monitoring of particulate matter and chemicals using ground stations - Environmental Research Authority (ERA)
- Given the proximity of Malta to the Sahara desert, the contribution of desert dust to local air quality cannot be neglected
- Dust storm event occur on a regular basis, bringing
  - Reduced visibility
  - Reddish brown rain
  - Increased incidences of asthma and health related events
- Hence the need to monitor and forecast such events

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AEROTOX

- Objective – Provide a forecast for Saharan dust events over the Mediterranean especially Malta
- Project financed by the MCST Space Research Fund – €150,000
- Project managed by Malta College of Arts, Science and Technology (MCAST) and 4Sight Ltd
- Contact Details
  - Principal Investigator – Joseph A. Zammit – joseph.a.zammit@mcast.edu.mt
  - Co-investigator – Steve Zerafa – steve.zerafa@mcast.edu.mt

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Project Website

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Particulate matter

- Particulate matter is present in the atmosphere
- Coarse particles, size > 10um
- Fine particles, size < 2.5um
- Generation process
  - Chemical Reactions
  - Combustion processes
  - Mechanical generation (wind)

Mechanically Generated Matter

- Windborne matter
- Fine and Coarse Particles
- Sources
  - Mineral particles from soil erosion
  - Cement and fertilizer dust
  - Sea-Salt particles
  - Other sources, tires and brakes

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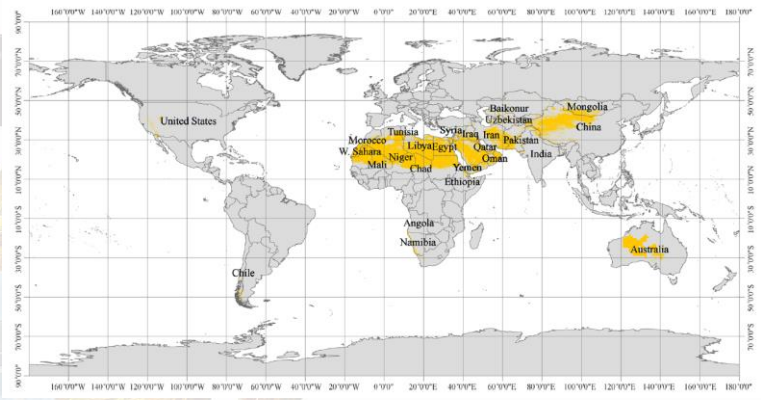
Mineral Particles

Name	Size
Gravel	2 – 16 mm
Very coarse sand	1 – 2 mm
Coarse Sand	**0.5 – 1 mm**
Medium Sand	**0.25 – 0.5 mm**
Fine Sand	**0.125 – 0.25 mm**
Very fine sand	**62.5 – 125 um**
Silt	3.9 – 62.5 um
Clay	0.1 – 39 um

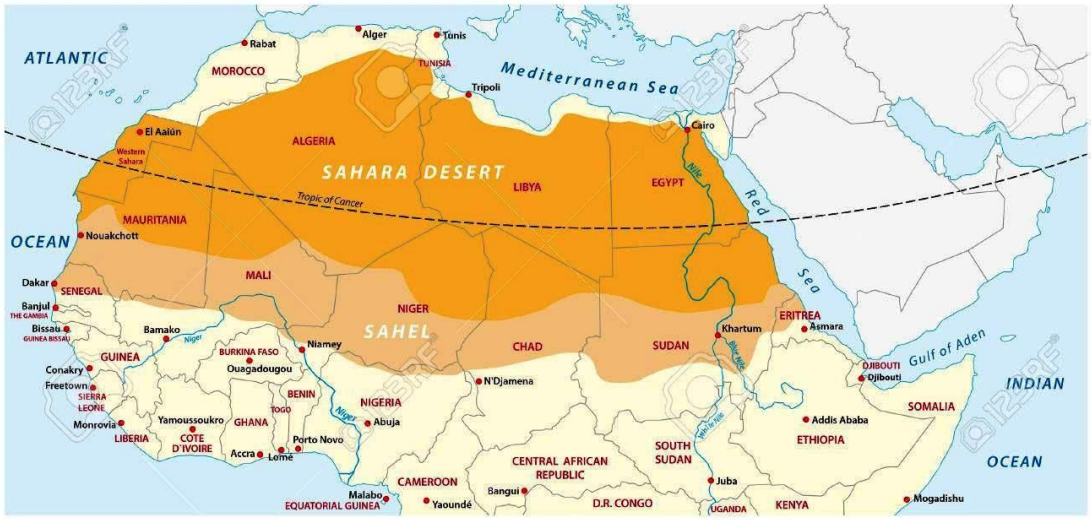
Sand generated in the Sahara Desert

Sources of global sand emission

- **Sahara Desert**
- Arabian Peninsula
- Euphrates river basin
- Qaidam Basin
- Taklamakan Desert



Sahara Desert



Composition of the Sahara Desert

- Largest Source of dust
- The process of dust generation is not fully known
- Bodélé depression - Chad

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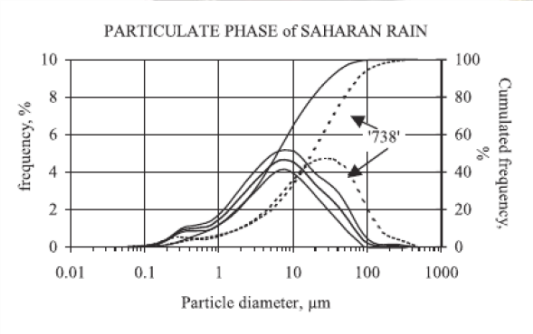
Particulate matter in the Sahara desert



- Coarse Grains < 63 um (Mica)
- Fine grain size < 1um
- Chemical Composition
  - Aluminum
  - Iron
  - Lead
  - Phosphorus
- Minerals
  - Quartz
  - Magnetite/Hematite
  - Carbonates

- Seasonal in nature

Effects of Saharan dust

- Negative
  - Health Effects
    - Allergies
    - Asthma and Upper Respiratory Tract (PM2.5)
    - Lower Respiratory Tract (< PM2.5)
    - Skin and Eye Irritation (PM10)
    - Cardiovascular Diseases
  - Visibility in Transportation
  - Reduction in Photovoltaic Electricity Generation
  - Seasonal Haze
- Positive
  - Reduce Hurricane development by drying up the air masses over the Atlantic
  - Acts as fertilizer for the Amazon rain forest

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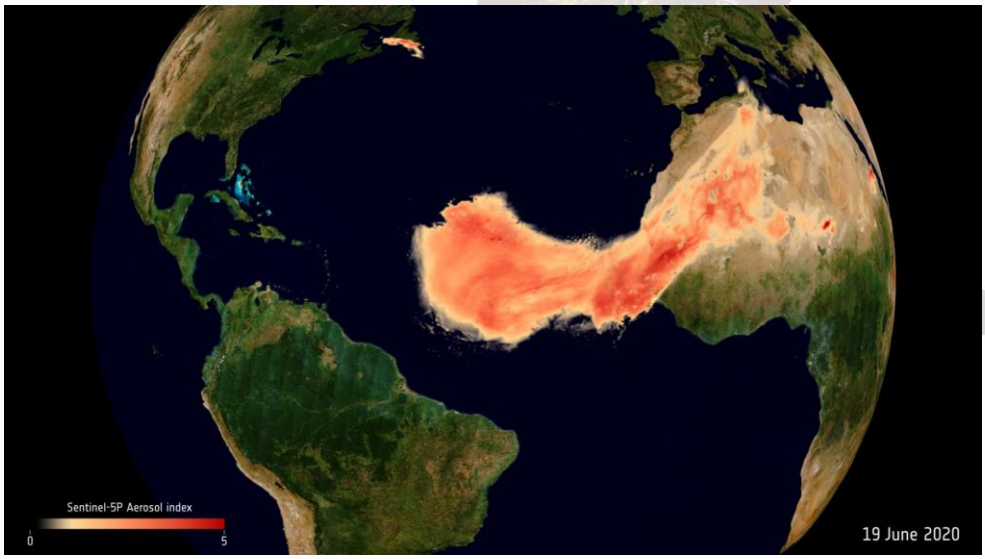
Reasons for monitoring Sahara dust storms

- With the generated dust, 70% of the daily PM10 limit value is exceeded
- Effects on nutrient dynamics in North Africa and beyond
- Transport of micro-organisms
- May induce long term change in atmospheric dynamics
- Frequency of dust events changes with climate

Typical Sahara dust plume trajectory



Aerosol Optical Depth

- Measurement of the amount of particles present in the atmosphere
- Describes the attenuation of the solar radiation as it passes through the atmosphere.
- $I(\lambda) = I_0(\lambda)e^{-T(\lambda)}$
- T = Transmittance of a material for a wavelength λ
- $I_0(\lambda)$ – Radiation Intensity of a wavelength λ at the top of the atmosphere
- $I(\lambda)$ - Resulting radiation Intensity

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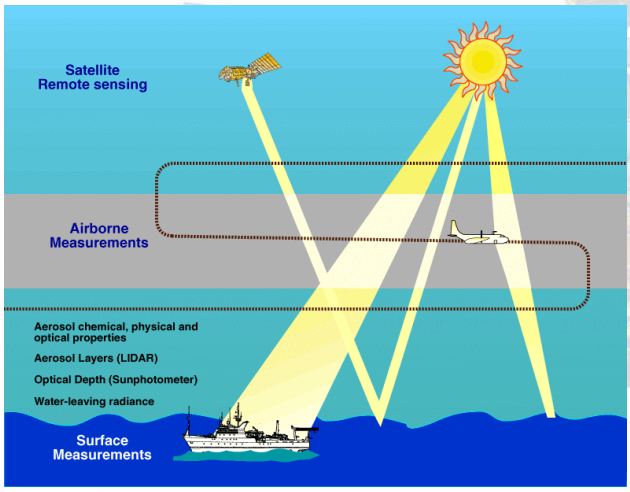
Measurement



Measurements are taken by :

- Land based (Photometers)
- Airborne
- Satellite remote sensing

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Sentinel 5p

- Launch Date: 13 October 2017
- Orbit: Polar, Sun-synchronous at altitude of 824 km and in flight forma National Oceanic and Atmospheric Administration
- Revisit time: Daily global coverage (13:30 local solar time)
- Life: Minimum of seven years (carries consumables for 10 years)
- Satellite: 3.35 m high, 5.63 m diameter and a mass of 820 kg (including 82 kg fuel)
- Instrument: **Tropospheric Monitoring Instrument (Tropomi) Swath width of 2600 km covering bands in ultraviolet and visible (270–495 nm), near infrared (675–775 nm) and shortwave infrared (2305–2385 nm) at a spatial resolution as high as 7 km x 3.5 km**
- Receiving stations: Scientific data: transmitted to Svalbard (NO) and Inuvik (CA)Telemetry data: transmitted to Kiruna (SE), Svalbard and Inuvik
- Data processing and dissemination: DLR German Aerospace Center
- Main applications: To provide global information on a multitude of atmospheric trace gases, aerosols and cloud distributions affecting air quality and climate
- Mission: Developed jointly by ESA and Netherlands Space Office, managed by ESA

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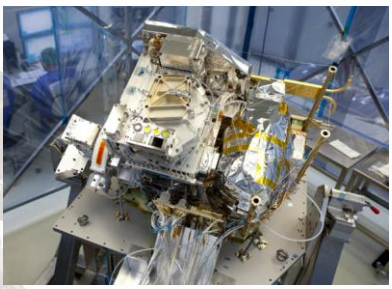
Tropomi Sensor



- Characteristics
- Type: passive grating imaging spectrometer
- Configuration: Push broom staring (non-scanning) in nadir viewing
- Swath width: 2,600 km
- Spatial sampling: 7x7 km2
- Spectral: 4 spectrometers, each electronically split in two bands (2 in UV, 2 in VIS, 2 in NIR, 2 in SWIR)
- Radiometric accuracy (absolute): 1.6% (SWIR) to 1.9% (UV) of the measured earth spectral reflectance.
- Overall mass: 204.3 kg not including ICU (16.7 kg) that is integrated on the platform, separated from the instrument.
- Dimensions: 1.40 x 0.65 x 0.75 m
- Design lifetime: 7 years
- Average power consumption: 155 W
- Generated data volume: 139 Gbits per full orbit.

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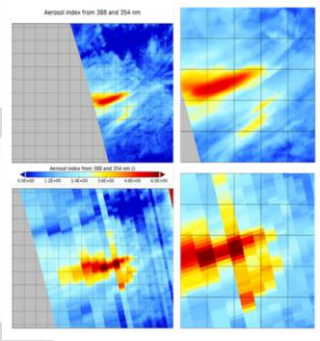
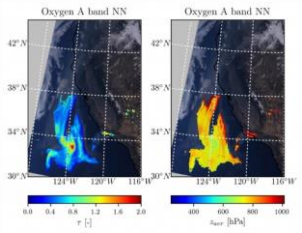
Sentinel 5p Products of interest



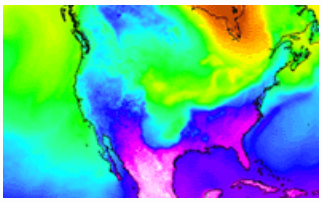
- Absorbing Aerosol Index
  - Indicates the presence of elevated layers of aerosols with significant absorption.
  - Detects
    - Desert dust
    - Biomass burning
    - Volcanic ash plumes.
  - May be derived for clear and partly cloudy ground pixels
  - Uses UV wavelength pairs 354/388nm and 340/380nm

Aerosol Layer Height



- Retrieves vertically localized aerosol layers in the free troposphere, such as
  - Desert dust,
  - Biomass burning aerosol
  - Volcanic ash plumes
- Applications include
  - Radiative forcing studies
  - Long-range transport modeling
  - Studies of cloud formation processes
- Retrieval of aerosol height is based on absorption in the O_2 A band in the near-infrared wavelength range (759 and 770 nm).
- Operates using a neural network methodology,

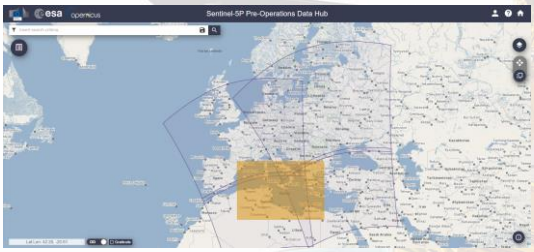
Sentinel 5p Data format

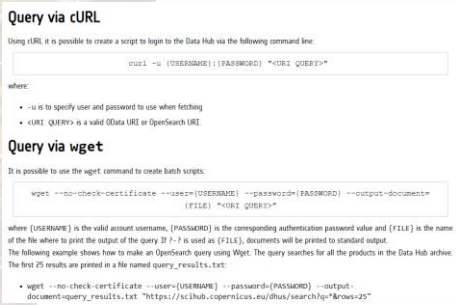


- Data is formatted in netCDF
- NetCDF Format - Generic Container for storing Multidimensional scientific data
- Advantages
  - **Self-Describing**
  - **Portable**
  - **Scalable**
  - **Appendable**
  - **Sharable**
  - **Archivable**
- Supported by a diverse number of packages – Python, Matlab

Downloading Data

Open Access Hub - https://s5phub.copernicus.eu/dhus





Query via cURL

Using cURL it is possible to create a script to login to the Data Hub via the following command line:

```
curl -u {USERNAME}:{PASSWORD} "<URI QUERY>"
```

where:

- -u is to specify user and password to use when fetching
- <URI QUERY> is a valid OData URI or OpenSearch URI.

Query via wget

It is possible to use the wget command to create batch scripts:

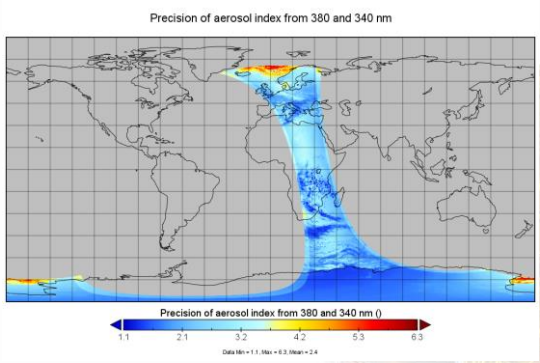
```
wget --no-check-certificate --user={USERNAME} --password={PASSWORD} --output-document=
                                {FILE} "<URI QUERY>"
```

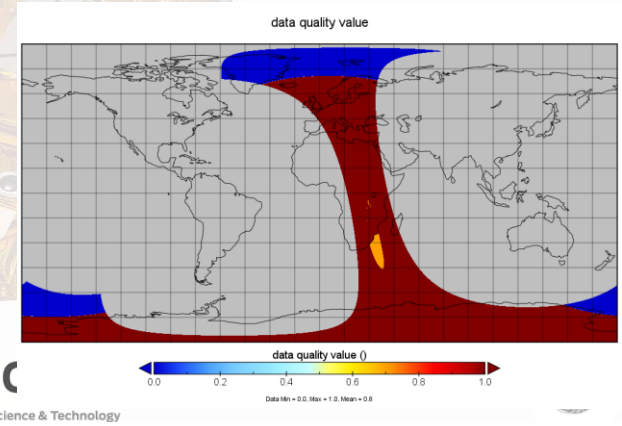
where {USERNAME} is the valid account username, {PASSWORD} is the corresponding authentication password value and {FILE} is the name of the file where to print the output of the query. If ?-? is used as {FILE}, documents will be printed to standard output.
The following example shows how to make an OpenSearch query using Wget. The query searches for all the products in the Data Hub archive. The first 25 results are printed in a file named query_results.txt:

- wget --no-check-certificate --user={USERNAME} --password={PASSWORD} --output-document=query_results.txt "https://scihub.copernicus.eu/dhus/search?q=*&rows=25"

Scripting

Aerosol Optical Index data





Data Extraction

- **Ncdump** is a utility to generate ASCII readable data from a netCDF file
- Example usage
  - `ncdump -h <Filename>` - Dumps the header information from the netcdf file to stdout
  - `ncdump -v <Variable> <Filename>` – Dumps the data from a specified variable to stdout

Conversion Script (Single File)

```
#!/bin/bash
{

f=$1 #nc flename
d=$( echo $f | cut -d'.' -f1 ) #Extract Directory

mkdir -p $d

ncdump -v aerosol_index_354_388 $f > $d/ai_354_388.txt
ncdump -v aerosol_index_340_380 $f > $d/ai_340_380.txt
ncdump -v longitude $f > $d/lon.txt
ncdump -v latitude $f > $d/lat.txt

echo done
}
```

The script will extract the Aerosol optical Index Variable at the wavelengths from **354nm to 388nm** and **340nm to 380nm**

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Conversion Script (Multiple Files)

```
#!/bin/bash
{
#echo on
echo "Creating Directories"

d_354="${PWD}"/ai_354_388
d_340="${PWD}"/ai_340_380

mkdir -p "$d_340"
mkdir -p "$d_354"

echo "Processing...."
for LINE in *$DOMAIN*
do
   printf "Processing ${LINE} ....\n"
            f=${LINE} #nc flename
            d=$( echo $f | cut -d'.' -f1 )

            PROCESS_STR_354=${f%%.*}_ai_354_388.txt
            PROCESS_STR_340=${f%%.*}_ai_340_380.txt

            #echo $d_354/$PROCESS_STR_354

            #mkdir -p $d

            ncdump -v aerosol_index_354_388 $f > "$d_354/$PROCESS_STR_354"
            ncdump -v aerosol_index_340_380 $f > "$d_340/$PROCESS_STR_340"
            ncdump -v longitude $f > "$d_354/lon.txt"
            ncdump -v latitude $f > "$d_354/lat.txt"
            ncdump -v longitude $f > "$d_340/lon.txt"
            ncdump -v latitude $f > "$d_340/lat.txt"
echo done
```

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Thank you for your attention!

Questions?

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