Introduction to Remote Sensing Air Quality

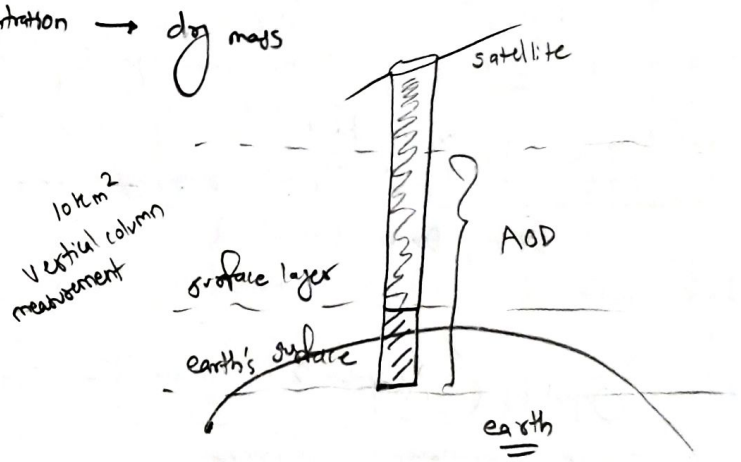
Satellites provides → aerosol optical thickness

AERONET measurements of aerosol optical depth are considered ground truth and are used to validate satellite aerosol retrievals.

AOD: aerosol optical depth (AOD) (measured at a particular wavelength)
- ↳ column integrated value (top of atmosphere to surface)
- ↳ optical measurement of aerosol loading
- ↳ unitless
- ↳ fn of shape, size, type, and no of concentration of aerosols

$PM_{2.5}$ → mass per unit volume of aerosol particles less than 2.5 μm in aerodynamic diameter at surface level.

$PM_{2.5}$ mass concentration → dry mass ($\mu g\, m^{-3}$)



Correlation of (0.7, 0.82) has been found for ($PM_{2.5}$, PM_{10})

Optical depth:- the optical depth expresses the quantity of light removed from a beam by scattering and absorption during its path through a medium.

$$\tau = \tau_{rayl} + \tau_{aer} + \tau_{gas}$$

(τ_{rayl}: air molecules; τ_{aer}: ↑ turbid; τ_{gas}: NH_3, water vapor, CO_2)

$$m = \sec \theta_0$$

$$I = I_0 e^{-m\tau}$$

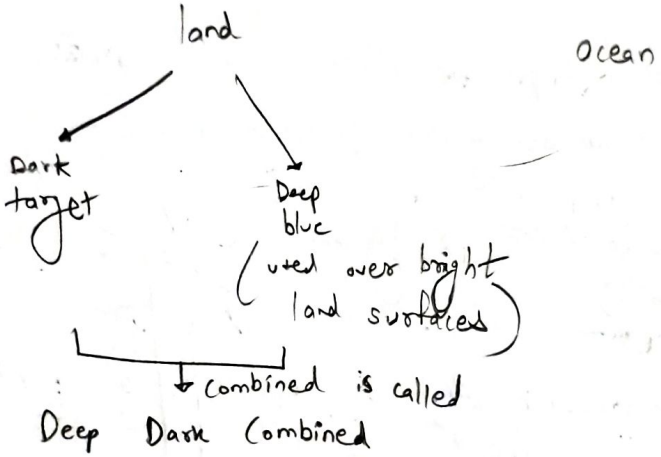
MODIS

moderate resolution imaging spectroradiometer

- 2000 - present
- Spatial resolution :— 250m, 500m, 1 km
- Platform - Terra and Aqua
- Temporal resolution — Daily, 8-day, 16-day, monthly, quaterly, yearly
- Data format - Heirarchal Data format
- 36 bands (spectral resolution)

MODIS aerosol products

↳ three separate algorithms



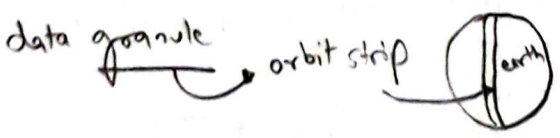
OMI (Almost 50% data loss since 2008 (row anomaly effect))

Ozone monitoring instrument

- launched in July, 2004
- 1:45 pm equatorial crossing line
- 13x24 km^2 at nadir
- daily global coverage

Products

- Total col^n O_3
- AOD (in UV)
- Total col^n SO_2, NO_2, formaldehyde



which cover entire globe for OMI

Quantification of gas abundances – Units

satellite tracer	Units
OMI O_3, SO_2	Dobson Unit (DU)
OMI NO_2	molecules/cm^2

thickness of a layer of pure gas which would be formed by the total column amount, but at standard temperature and pressure.

$1\ DU = 2.69 \times 10^{16}$ molec/cm^2

– L2 → 10km product
– 3k → 3 km product

Understanding a MODIS file name

Product name
- Terra: MOD04
- Aqua: MYD04

MOD04 – L2 . A 2001 079 . 0255 . 006 . 2006289012028 . hdf

- A2001: Year
- 079: Julian day (day of the year) → 029 will be 29th January
- 0255: time (2 digit hrs, 2 digit minutes) (GMT time or UTC time)
- 006: collection (version)
- 2006289012028: file processing information

(HDFlook, Panoply, IDL, Pyhton, Fortran, Matlab can be used to read the data)

– L2 → 10 km resolution
– 3k → 3km resolution

MODIS Aerosol Parameters (SDS)

Dark target is available for 10km
Deep blue is not available for 10km, only available for 3km

For quantitative analysis (over land): optical depths land and ocean
QA = 3 is recommended
→ factors involved:–
– no. of pixels
– error fitting
– surface reflectance

Relevant parameters :- for 3km (3k)

- latitude
- longitude
- land_sea_flag
- land_ocean_quality_flag → used to mask bad pixels
  (where 3 is best over land
  1,2,3 are best over ocean)

not to use:-
- mass_concentration_land
- aerosol_type_land (not much helpful)

Sheet to use:
- optical_depth_land_and_ocean
  (AOD at 3km at 550nm
  retrieved from MODIS dark target algorithm)
  ↓
  only includes data for highest quality (3 over land)

- image_optical_depth_land_and_ocean
  (AOD at 3km - - - same as above)
  ↓
  includes data for all quality flags (0,1,2,3)

for 10km (L2)

(difference is that 10km has a deep blue product)
↓
Also deep blue is ONLY available on land

deep_blue_spectral_aerosol_optical_depth_land → in 3 different channels

deep_blue_aerosol_optical_depth_550_land_QA_flag → varies from 0 to 2
Recommended to use: 2,3

AOD_550_dark_target_deep_blue_combined
↳ both the parameters have been combined for this product

Each MODIS data file contains data for 5 min of observations,

As satellite is passing, it continously makes measurements, and when 5min of measurements are combined together, we put together this file which is called granule.

∴ each granule has 5min worth of data

In 'read_and_and_calculate_pm25'

↓

We have to use our own slope and intercept } specific to the country and season

Understanding an OMI file name

OMI-Aura_L2-OMNO2-2008m0720t2016-o21357_v003-

- instrument Id
- data type (NO2, SO2)
- year
- month
- date
- observation date and time
- time in GMT (20 16) → hrs, minutes
- Orbit
- collection
- 2016m0820t102252.he5 → production date and time

SDS information (NO_2)

- ColumnAmountNO2Trop → estimated NO_2 tropospheric column amount
- ColumnAmountNO2Strat → estimated NO_2 stratosphere column amount
- use only rows 4–54 (where first row = 0)
- use only scenes with: (1) radiative cloud fraction < 0.5 (2) Solar zenith angle < 85° AND (3) terrain reflectivity < 0.3

for quality data

Terrain Reflectivity (Scale factor: 0.001)

↳ how reflective surface of earth is

- unitless
- must be multiplied by a scale factor of 0.001 to obtain the actual number.

Cloud Radiance Fraction

↳ is an estimate of no. of photons reaching the satellite instrument that come from cloud covered part of the scene

- Same as above

SolarZenithAngle → angle between zenith and center of sun's disc

Anomaly as seen in OMI is indicated with fill values :— high negative numbers $-2^{100} \approx -1.26 \times 10^{30}$

SDS information (SO_2)

PBL SO_2 → ColumnAmountSO2-PBL (SDS) (0.9 km) — estimate center of plume

↓

for near surface pollution

TRL SO_2 → ColumnAmount SO_2-TRL (SDS) (3km)

↓

volcanic degassing

Also :—

TRM SO_2 (8km) / STL SO_2 (18km)

There should NOT be added together

ColumnAmount SO_2 _PBL (only rows 4-54 first row = 0;

(DU)

scenes with
radiative cloud fraction < 0.3
solar zenith angle < 70°

Total column SO_2

for ColumnAmount SO_2 _TRL / TRM / STL

↳ solar zenith angle < 70°
All rows can be used

Radiative cloud fraction (unitless)
(No scale factor)

Other sensors :- VIIRS (no data gap, complete global coverage)