Aerosol Characterization Studies Using SKYNET and AERONET Radiometers in India

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Outline

- Importance of Aerosols in Air Quality, Environmental Health and Climate Change from Optical Remote Sensing Techniques
- Air Pollution is the most complex type, mainly because it is more dynamic and originates from multiple sources/sinks, transformation and transport processes.
- Albeit several advanced monitoring and diagnosis tools exist, mitigation and alternative processes are highly stringent.
- Estimation of Columnar Aerosol Optical, Microphysical and Radiative Properties under different environmental and meteorological conditions – A Challenge.
- Cimel- AERONET Vs Prede-SKYNET
- Evaluation of Products – Development and updating of Algorithms
- Satellite Validation and Calibration

Some Major Facts

Major Source "Automobile Activity" Automobile Emissions, one of the most dominant pollution sources in India

Biomass Burning (Parali / Pallari, Stubble or Crop-Waste/Residue Burning) Activity during October – November in North India

Automobile and Industrial Pollution Effects on Human Health

Brief History

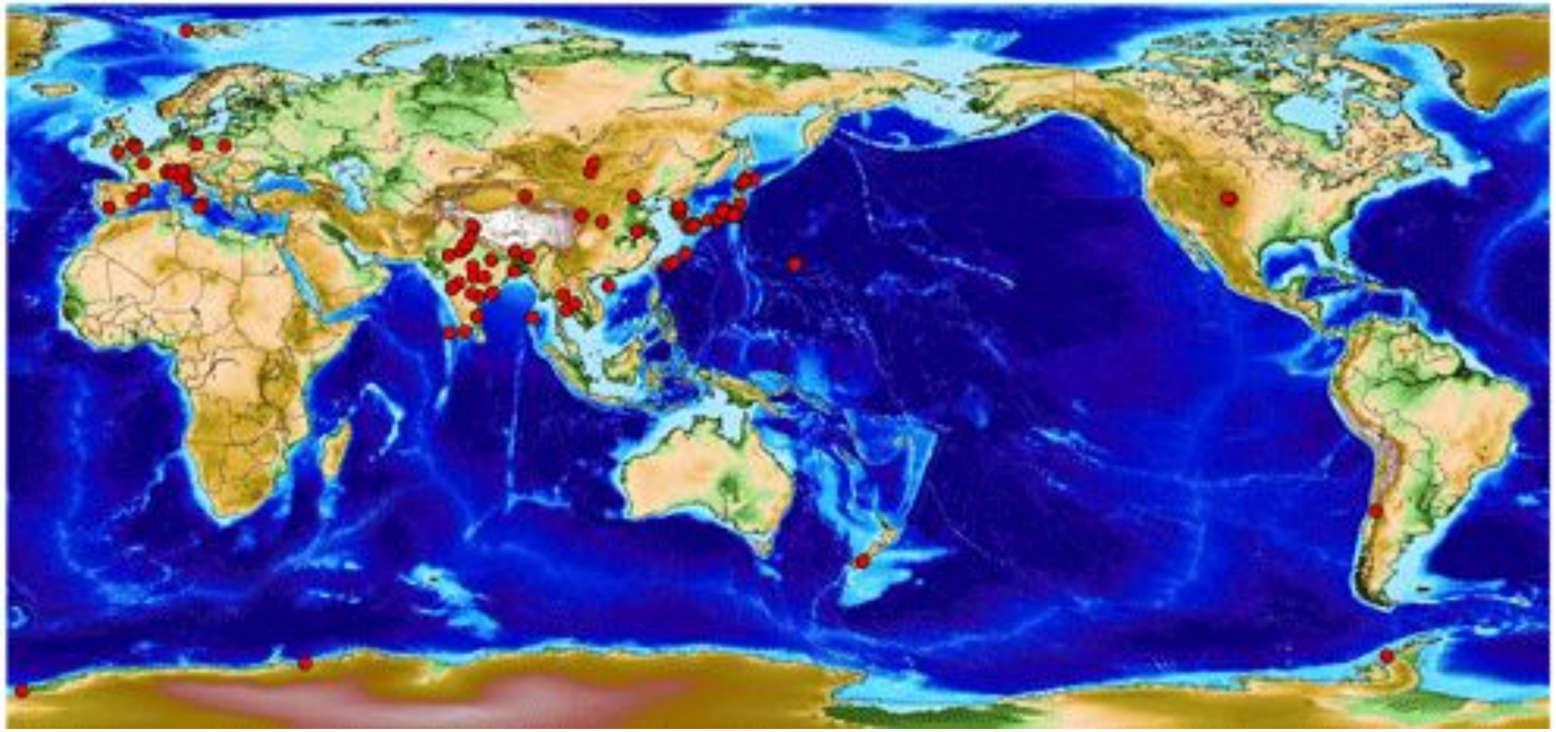
* A sun–sky radiometer is a narrow-band filter photometer that measures direct solar and diffuse sky radiation at selected wavelengths and at several scattering angles. Observed data contains information content for aerosol, cloud, and gaseous constituents. This requires complete understanding of the full radiative transfer equation to quantify single- and multiple-scattered radiation. By the 1980s, analyses of combined sun and sky radiation data became comprehensive.

* Networks of radiometers have been developed to utilize sun and sky measurement data for various applications, such as satellite remote sensing validation, air pollution monitoring, and the study of the climate effects of atmospheric constituents,

* The largest network is NASA **AERONET** (Holben et al., 1998) developed in the early 1990s and currently with more than 500 sun–sky photometers.

* Later, in the 2000s **SKYNET** was formed with sky radiometers (Nakajima et al., 2007). Compared to the **AERONET** technology, **SKYNET** has several differences in measurement and analysis methods.

* **SKYNET** is for research purposes without a centralized data analysis system and its information is scattered in independent papers and documents, which makes **SKYNET** difficult to understand for the science community, whereas the **AERONET** follows centralized centralized analysis protocol to remove individual site biases.



A map of the **Skynet radiometer Sites**, more than 60 sites, of which India covers about 20 sites

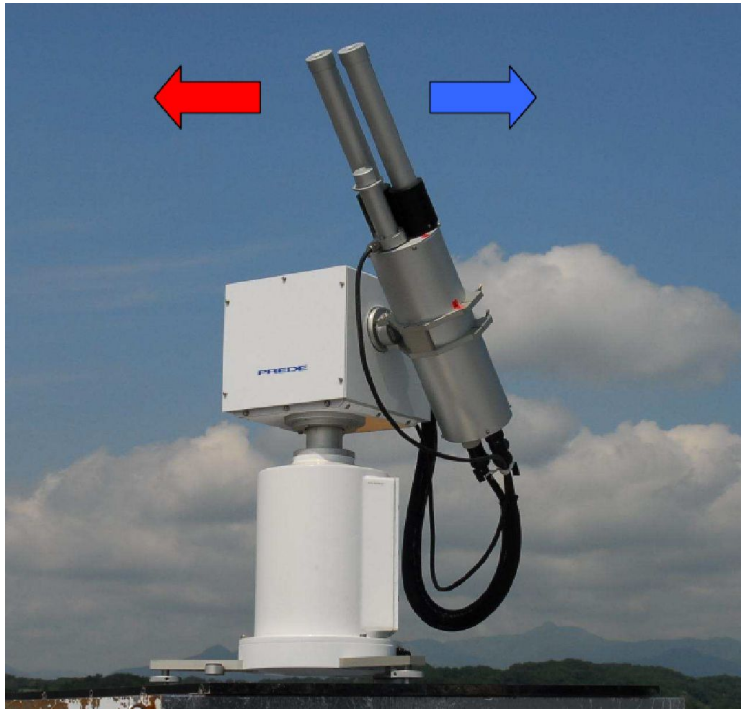
❖Direct Sun Parameters

- ❖Spectral fluxes (Wm^{-2})
- ❖Aerosol Optical Depth
- ❖Angstrom Exponent (α)
- ❖Single Scattering Albedo

Retrieved Parameters

- •Aerosols size distribution,
- •Spectrally dependent complex Refractive Index,
- •Partition of spherical/non-spherical particles
- •Phase Function
- •Asymmetry Parameter.
- •Extinction efficiency
- •Radiative Forcing

Skyradiometer Monitoring Network in India



VERTICAL

ANGULAR

The Sun Skyradiometer is a scanning spectral radiometer able to perform routine And long-term automated measurements of direct and scattered solar radiations at Seven wavelengths from 315 to 1020 nm (POM-01) or eleven wavelengths from 315 to 2200 nm (POM-02).

(315, 340, 380,400,500,675,870,940,1020,1627 and 2200nm) (POM-02)
315,400,500,675,870,940 and 1020nm) (POM-01)

PM02 Specifications

Half view angle	**0.5°**
Min scattering angle	**3°**
Wavelengths	**315, 340, 380, 400, 500, 675, 870, 940, 1020, 1627, 2200nm, 940nm is channel for water vapor (POM-02) 1627 to 2200nm channel is used for cloud analysis.**
Detector	**Short wave（315nm～1020nm） Si photodiode**
	Long Wave（1627nm, 2200nm） InGaAs photodiode
Temperature control	**20°C, option ： cooler, built-in Heater**
Tracking control	**Stepping Motor：2 way, Azimuth and Zenith, Stepping angle 0.0036°/pulse**
Sun sensor	**Si photodiode**
Potential tracking area	**Azimuth ±300°（South 0°）**
	Zenith -60 ～ 170°（Horizon 0°）

Skyradiometer POM-01 Specifications

Measurement method	Filter wheel, photo-diode detector
Sun tracker	tripod base, sun sensor and rain sensor included
Wavelength	315, 400, 500, 675, 870, 940, 1020 nm
Wavelength accuracy	2 nm
View half-angle	0.5 º
Power supply	230 / 115 VAC, optional 24 VDC
Operational temperature range	-10 ºC to +45 °C
Low temperature option	-30 ºC to +45 °C
High temperature option	-10 ºC to +70 ºC

Sun Skyradiometer Monitoring Network Products

- ❖ Aerosol optical thickness (AOT) at wavelengths of 340,380,400,500,675,870 & 1020nm.
- ❖ Single Scattering Albedo (SSA) of aerosols at same wavelengths of AOT.
- ❖ Refractive Index (RI) at same wavelengths of AOT.
- ❖ Volume size distributions of aerosols.
- ❖ Angstrom Exponent.
- ❖ Scattering Phase Function.
- ❖ Asymmetry Parameter
- ❖ DARF

(315, 340, 380,400,500,675,870,940,1020,1627 and 2200nm)
(11 Wavelengths, POM-02)
(315,400,500,675,870,940 and 1020nm) **(7 Wavelengths POM-01)**

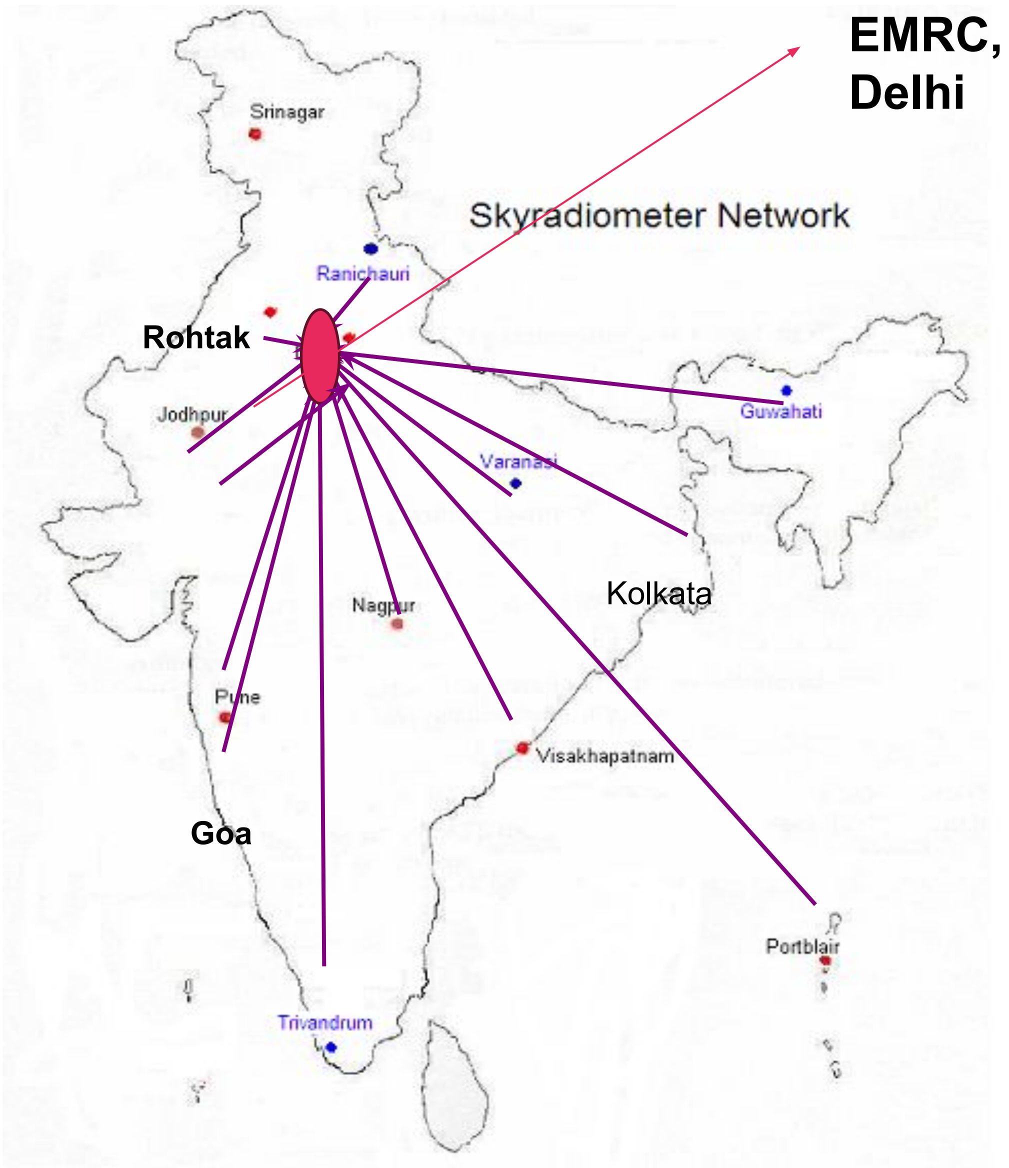
Sky-radiometer Network of IMD

Online Data Transfer on real time

Data processing at Central Data Processing System, EMRC, New Delhi

Data Processing Procedure done by SKYRAD ver 5.1 software

Windows based userfriendly Data Acquisition Software SRM450 is installed in the PC



Collocated and Synchronous Operation of Multi-Spectral AERONET & PREDE Sky Radiometers at IITM, Pune, India

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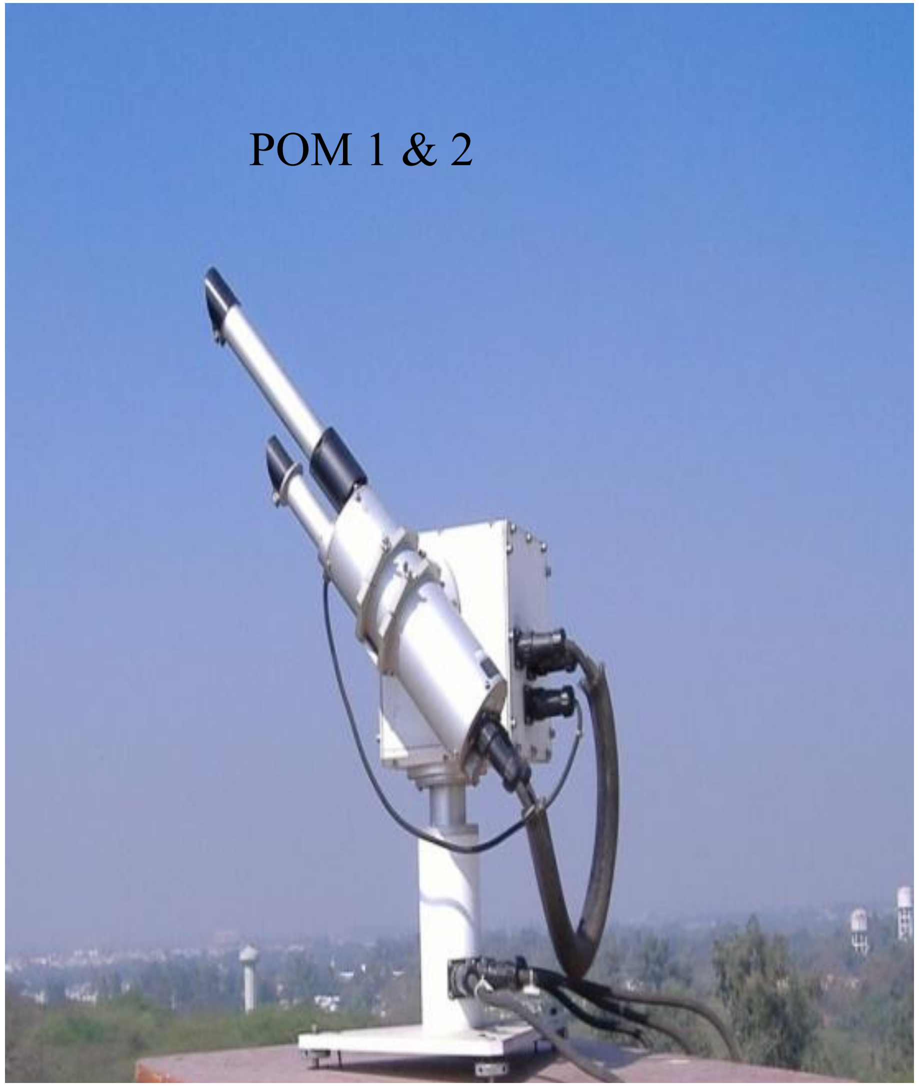

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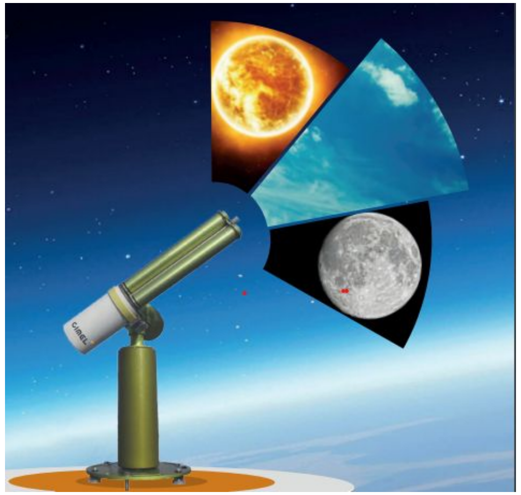
World-Wide NASA Aeronet Sites

AERONET consists of approximately **500 sites in 55 countries on all 7 continents**. The red squares on the map indicate the locations of AERONET sites. Credit: NASA

CE378-T Sun-Sky-Moon-Polarized Multispectral Radiometer installed at AUH, Gurugram in May 2023

From August 2017
To June 2022

From June 2022 Onwards



- Multi-spectral Aerosol Optical Depth (340, 380, 440, 500, 675, 870, 1020nm, 1046 nm)
- Aerosol Size Distribution
- Single Scattering Albedo
- Asymmetry Parameter
- Phase Function
- Total, Fine and Coarse-mode Fractions
- Water vapor
- Aerosol Refractive Index
- Ozone Optical Depth
- Lidar Ratio
- Lidar Depolarization Ratio
- MODIS-Aqua and Terra AOD
- HYSPLIT Airmass Trajectories
- TOMS/OMI TCO

Current Status and *Future Perspectives*

- **Several researchers have operated the Prede-SKYNET and Cimel-AERONET Radiometers, in collocated and/or stand-alone mode for aerosol characterization studies over diverse environments associated with different meteorological conditions.**
- SKYNET-AERONET comparison experiments have been conducted independently w.r.t the system development, and their performance w.r.t different processes associated with several episodic situations under extreme weather conditions to evaluate their sensitivity estimations.
- The results of SKYNET and AERONET agree well with better accuracy in the case of direct solar products, while they differ in the case of inversion products. These deviations are attributable mainly to difference in the data retrieval algorithms and their standardization.
- The results have been implemented in satellite CAL-VAL Programs & model development and evaluations, successfully.
- The centralized instrument updates, data analysis protocol developments and high-density network of AERONET show better compatibility with reasonable accuracy from local to global aerosol analyses while the research-mode data analysis with region-specific limited network in the case of SKYNET yields better picture more of regional nature. The data cleaning processes such as cloud-screening and sensing wavelength coverage with narrower filter bandwidth will improve the data quality and product accuracy. Comparison with *in-situ* measurements employing different platforms, and augmentation of both AERONET and SKYNET products will further improve the situation.

Some Important Research Journal Publications, So Far

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2. Devara P.C.S., Sumit Kumar, Pandithurai G., Safai P.D. and Dipu, S., 2013: Comparison between urban aerosol products retrieved from collocated Cimel and Prede Sun/sky radiometers at Pune, India, *Meteorology and Atmospheric Physics*, 119, DOI: 10.1007/s00703-013-0246-8.

3. Devara, P.C.S., K. Vijayakumar, S.M. Sonbawne, D.M. Giles, B.N. Holben, S.V.B. Rao and C.K. Jayasankar 2019: Study of aerosols over Indian subcontinent during El Nino and La Nina events: Inferring land-air-sea interactions, International Journal of Environmental Sciences & Natural Resources, 16(5), 1-10.

4. Devara, P.C.S., Sumit Kumar, K. Vijayakumar and G. Pandithurai, 2014: Sun-Sky Radiometer Synthesis of Interplay between Aerosols and Monsoon Activity Over Pune, India, *Pure and Applied Geophysics,* 171, 2501–2517.

5. Khatri, P., T. Takamura, T. Nakajima, V. Estellés, H. Irie, H. Kuze, M. Campanelli, A. Sinyuk, S. -M. Lee, B. J. Sohn,G. Padhithurai, S. -W. Kim, S. C. Yoon, J. A. M. Lozano, M. Hashimoto, **P. C. S. Devara**, and N. Manago 2016: Factors for inconsistent aerosol single scattering albedo between SKYNET and AERONET, *Journal of Geophysical Research: Atmospheres*, 121, 1859-1877.

6. More S., Pradeep Kumar, P., Gupta P., **Devara P.C.S**., Aher G.R., 2013: Comparison of aerosol products retrieved from AERONET, MICROTOPS and MODIS over a tropical urban city, Pune, India, *Aerosol and Air Quality Research*, 13, February 2013, DOI:10.4209/aaqr.2012.04.0102, 107-121.

7. Pandithurai, G., Dipu, S., Dani, K.K., Tiwari, S., Bisht, D.S., **Devara, P.C.S**. and Pinker, R. T., 2008: Aerosol radiative forcing during dust events over New Delhi, India, *Journal of Geophysical Research-Atmospheres*, 113, D13209, doi:10.1029/ 2008JD009804.

8. Pandithurai, G., Pinker R.T., **Devara, P.C.S.,** Takamura T. and Dani K.K., 2007: Seasonal Asymmetry in Diurnal Variation of Aerosol Optical Characteristics over Pune, Western India, *Journal of Geophysical Research – Atmospheres*, 112, doi:10.1029/2006JD007803, 2007.

9. Pandithurai, G., Pinker, R.T., Takamura, T. and **Devara, P.C.S.**, 2004: Aerosol radiative forcing over a tropical urban site in India, *Geophysical Research Letters*, 31, L12107, doi: 10.1029/2004GL019702, 20.

10. Pawar, G.V., **Devara, P.C.S.,** More, S.D., Pradeep Kumar, P., Aher, G.R., 2012, Determination of aerosol characteristics and direct radiative forcing at Pune, *Aerosol and Air Quality Research*, 12, DOI:10.4209/aaqr.2011.09.0157, 1166-1180.

12. Pawar, G.V., **P.C.S. Devara** and G.R. Aher, May 2015: Identification of aerosol types over an urban site based on air-mass trajectory classification, *Atmospheric Research*, 164-165, 142-155.

13. Varpe, S.R., A.R. Kolhe, G.C. Kutal, G.V. Pawar, S. Payra, K.B. Budhavant, G.R. Aher, and P.C.S. Devara 2018: Heterogeneity in aerosol characteristics at the semi-arid and island AERONET observing sites in India and Maldives, *International Journal of Remote Sensing,* 1–33.

14. Vijayakumar, K., **P.C.S. Devara,** D.M. Giles, B.N. Holben, S.V.B. Rao, C.K. Jayasankar, 2018: Validation of satellite and model aerosol optical depth and precipitable water vapour observations with AERONET data over Pune, India, *International Journal of Remote Sensing*, 1–21.

15. Vijayakumar, K., **P.C.S. Devara,** S.M. Sonbawne, D.M. Giles, B.N. Holben, S.V.B. Rao and C.J. Shankar 2020: Solar radiometer sensing of multi-.year aerosol features over a tropical urban station: direct-Sun and inversion products, *Atmos. Meas. Tech.,* 13, 5569–5593, 2020 https://doi.org/10.5194/amt-13-5569-2020.

Thank You all for Attention