Climatological aspects of size-resolved column aerosol optical properties observed over a rural site in the southern peninsular India

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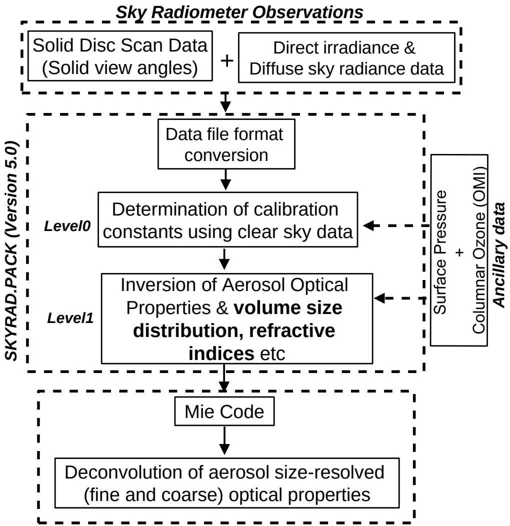
Sky Radiometer at Gadanki & Objectives of this Study

Figure : Location of Gadanki with Climate Observatory tower and Sky Radiometer

Data Period: April 2008 – November 2018

- Size-resolved approach based on a fixed particle size threshold
- Examine the climatological aspects of size resolved column aerosol optical properties
- Evaluate the size-resolved AOD with those retrieved using the extended spectral deconvolution algorithm (SDA+)

Methodology - Retrieve Column Aerosol Optical Properties



- Flow chart illustrating
  - the main processing steps, and
  - extended step for deconvolution.
- SKYRAD package (SKYRAD.PACK, version 5.0) → **400, 500, 675, 870 and 1020** nm

> - Aerosol Optical Depth (AOD)
> - Single Scattering Albedo (SSA)
> - normalized phase function
> - Asymmetry parameter (ASY)
> - Volume size distribution (dV/dlnr)
> - Complex refractive indices

Separation of Fine and Coarse aerosol optical properties

- Aerosol size distribution is mostly bimodal - fine (r $< 0.6\ \mu$m) and coarse (r $> 0.6\ \mu$m)
- This convention is followed for AERONET retrievals.

Aerosol Optical Depth (AOD or τ) is related to the columnar aerosol size distribution through the Mie integral equation as below:

$$\tau(\lambda) = \int_{r_a}^{r_b} \pi r^2 Q_{ext}(m, r, \lambda) N(r) dr = \int_{r_a}^{r_b} \frac{3Q_{ext}(m, r, \lambda)}{4r} \frac{dV}{dlnr} dlnr$$

Q_{ext} is the Mie extinction efficiency,

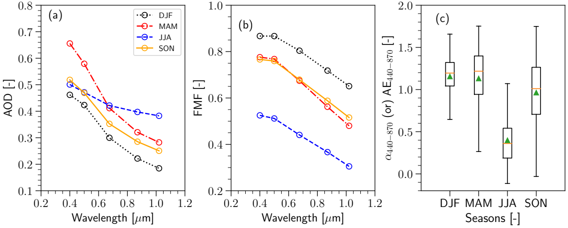
$N(r)$ is the columnar aerosol number density in the radius range dr centered at r

r_a and r_b correspond to the lower (0.012 μm) and upper (16.54 μm) cut-off radii

Extended Spectral Deconvolution Algorithm (SDA+)

- Developed by O'Neill et al. (2003) to separate fine and coarse mode contributions to AOD at reference wavelength (at 500 nm) using spectral AODs ← Spectral Deconvolution Algorithm (SDA).
- O'Neill et al. (2008) extended to fine and coarse AOD spectra ← Extended Spectral Deconvolution Algorithm (SDA+)
- Kaku et al. (2014) demonstrated SDA+ accurate prediction of fine and coarse partitioning in global data sets representing a range of aerosol regimes.
- Both SDA and SDA+ methods ...
  - does not require the assumption of minimum cutoff size between modes.
  - based on spectral AODs alone.

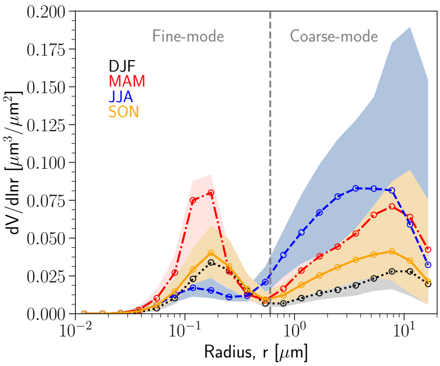
Seasonal variation - Spectral AOD, FMF, $AE_{440-870}$



- Steeper spectral slope of total AOD $\rightarrow$ DJF, MAM, SON
- Almost flat spectral behaviour of total AOD $\rightarrow$ JJA
- Attributed to changes in the columnar aerosol size distribution

- Angstrom (1929): $\tau_\lambda = \beta\ \lambda^{-\alpha}$
- Distinct spectral variability and seasonal heterogeneity observed

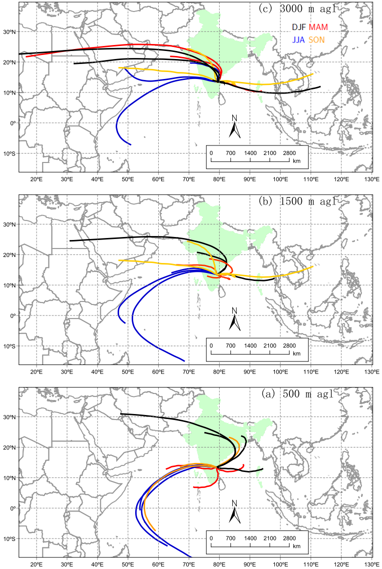
Seasonal variation - Volume size distributions



- Biomodal aerosol size distributions.
- A clear dip between the two modes.

- Fine mode dominated → DJF, MAM
- Significant coarse mode → JJA
- Fine mode radii for peak values →
  - 0.17 μm (DJF, SON)
  - 0.12 μm (JJA)
  - 0.12–0.18 μm (MAM)
- Correspond to *water-soluble component*
- Coarse mode radii for peak values →
  - 2.4–7.7 μm (JJA)
  - 7.7–11.3 μm (DJF)
  - 7.7 μm (MAM, SON)
- Mix of *insoluble* (6.0 μm), *sea-salt coarse* (7.9 μm), *mineral coarse* (11.0 μm), and *mineral transported* (3.0 μm)

Seasonal variation - Air mass history



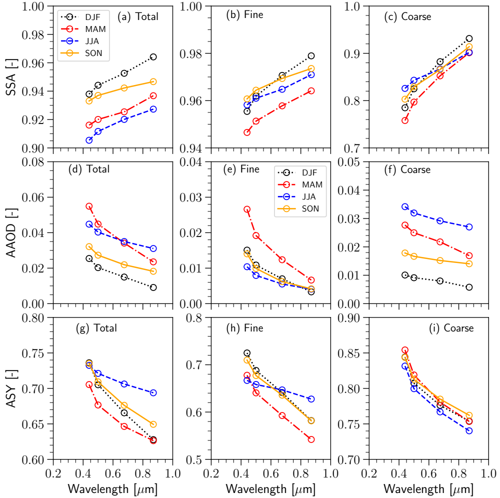
DJF *African region & Arabian peninsula ($<$ 30%); Southern tip of Indo-Gangetic outflow region & West of India ($>$ 50%); BoB and SE Asia ($\sim$ 20%)* $\Rightarrow$ **localized biomass burning, coated fine-mode aerosols dominate**

MAM *Continental air masses from peninsular India (60%); Saharan desert region ($\sim$14%), Oceanic region (26%)* $\Rightarrow$ biomass-burning aerosols from forest fires & localized burning; coarse-mode aerosols

JJA *SW & Oceanic (100%)* $\Rightarrow$ coarse mineral dust & marine aerosols

SON *SE & SW Asia, Oceanic region, Indo-Gangetic outflow region & West of India* $\Rightarrow$ coarse-mode sea-salt, marine and anthropogenic

Seasonal variation - Spectral SSA, AAOD, ASY



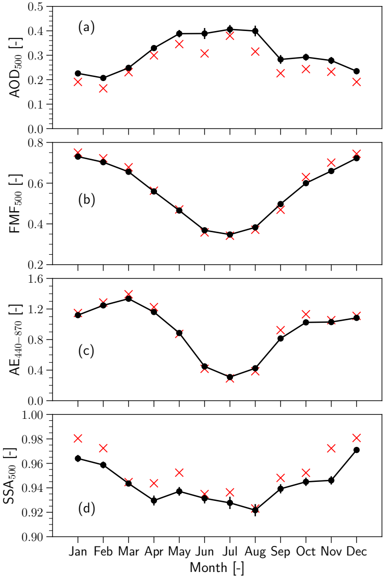
SSA Increasing trend → Pronounced spectral dependence of scattering at shorter wavelengths by fine mode in comparison to the scattering due to coarse mode aerosols.

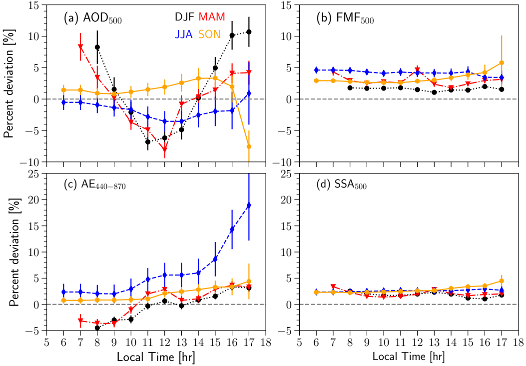
AAOD Decreasing trend of total/fine mode with wavelength & almost flat spectral behavior of coarse mode aerosols.

ASY Decreasing trend of total/fine & coarse mode

Weaker rate of decrease in total/fine mode during JJA (indicate dominance of coarse particles causing strong forward scattering)

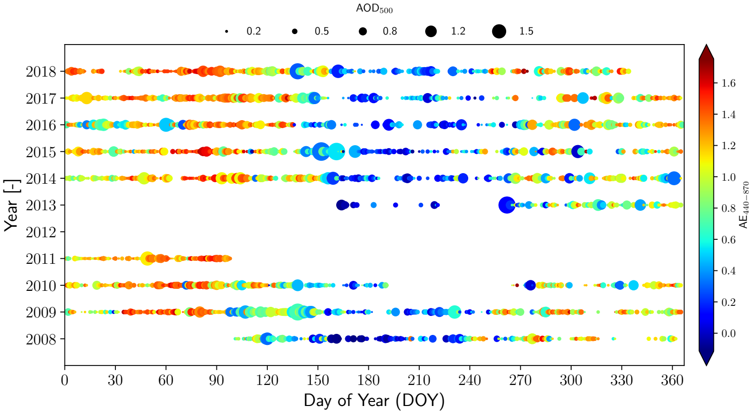
Monthly & Diurnal variation





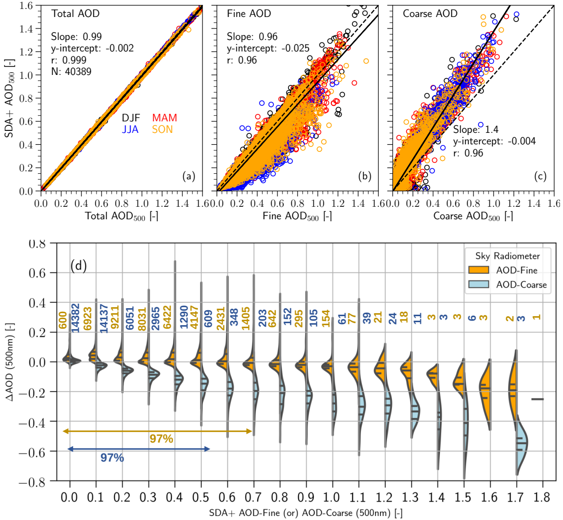
- Seasonal asymmetry → AOD, AE
- Practically insignificant ($< 5\%$) → FMF, SSA

Intra-annual variation



- Higher daily mean AOD_{500} (> 1.0) $\rightarrow$ Occur more frequently from May to September.
- Large number of days in any particular year are mostly dominated by fine mode aerosols or emission sources contributing them.

Comparison between size-resolved AOD and SDA+ retrievals



- Total AOD highly correlated (> 0.99)
- Fine and coarse AODs (r $\sim$ 0.96) with remarkable scatter and deviation from 1:1 line.
- Fine AODs (62%) overestimated w.r.t SDA+ retrievals for bins 0.0 to 0.3 in AOD, thereafter a clear underestimation.
- Coarse AODs exhibit zero difference centered at 0.0 bin (around 36%)
- Coarse AODs systematically decreased to -0.15 at 0.5 in AOD bin.

Conclusions

- Strong seasonal and spectral dependence $\Rightarrow$ Presence of varied contributions of natural and anthropgenic aerosols in the atmospheric column.
- Spectral behavior of SSA and AAOD $\Rightarrow$ Increased contribution of organic aerosol (absorption at shorter wavelengths) + highly absorbing coarse particles (in the blue spectral band ($\sim$ 440 nm)).
- High $FMF_{500} > 0.6$ and $AE_{440-870} \gtrsim 1.0$ $\Rightarrow$ Air masses coming from Indian subcontinent
- Low $FMF_{500} < 0.4$ and $AE_{440-870} < 1.0$ $\Rightarrow$ Coarse mode dominance associated with airmasses from the oceanic region.
- Intra-annual variability $\Rightarrow$ Prevalence of distinct fine and coarse mode dominance periods in any particular year.
- Diurnal variation $\Rightarrow$ Seasonal asymmetry in AOD and $AE_{440-870}$ while practically insignificant variation in FMF and SSA during the day.
- Evaluation of fine and coarse AOD_{500} with those from SDA+ method $\Rightarrow$ Differences resulting because of fixed cutoff radius (0.6 μm), and partly due to the mixed contributions from dominant fine and aloft mineral dust aerosols.

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Thank You