Comparison of the Aerosol Optical Properties over Durban using Sun-Photometer measurements

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Introduction

- **Earth's atmosphere consists of a mixture gases and particles, such as aerosols and clouds**
- **Aerosols have the following characteristics:**

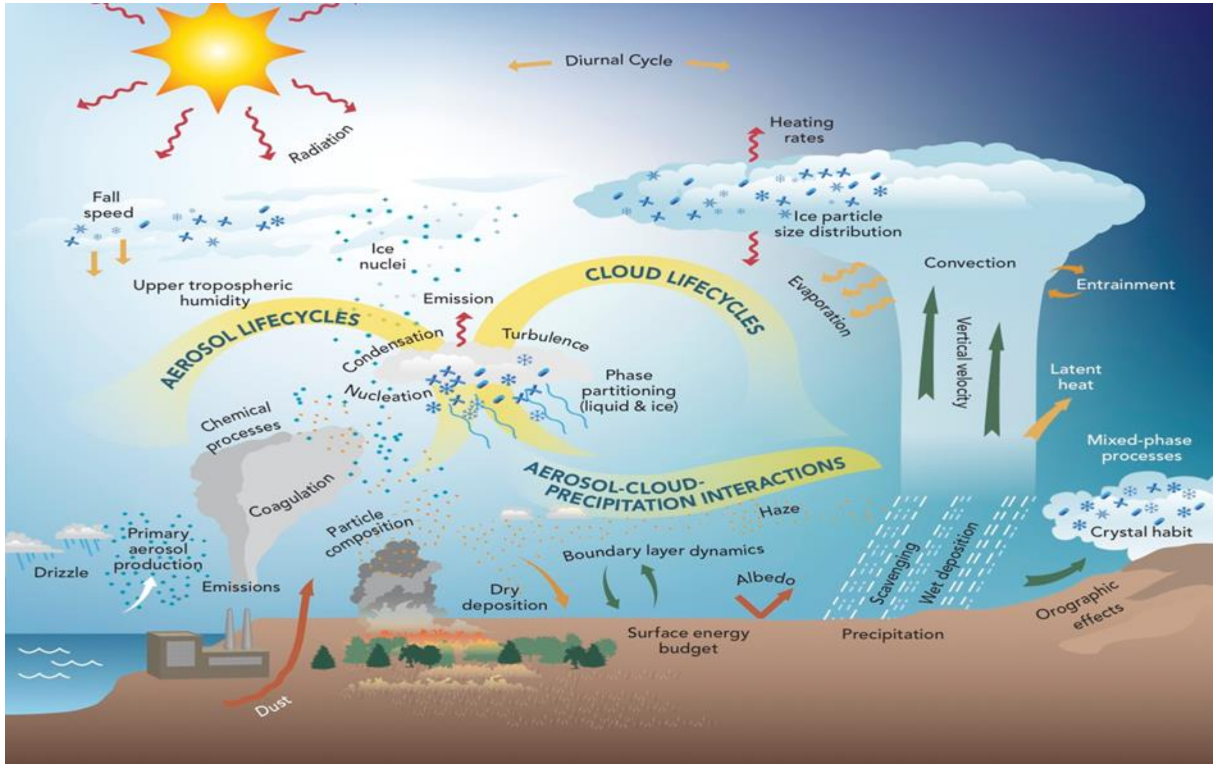
-Aerosols are suspended liquid or solid particles with varying diameters

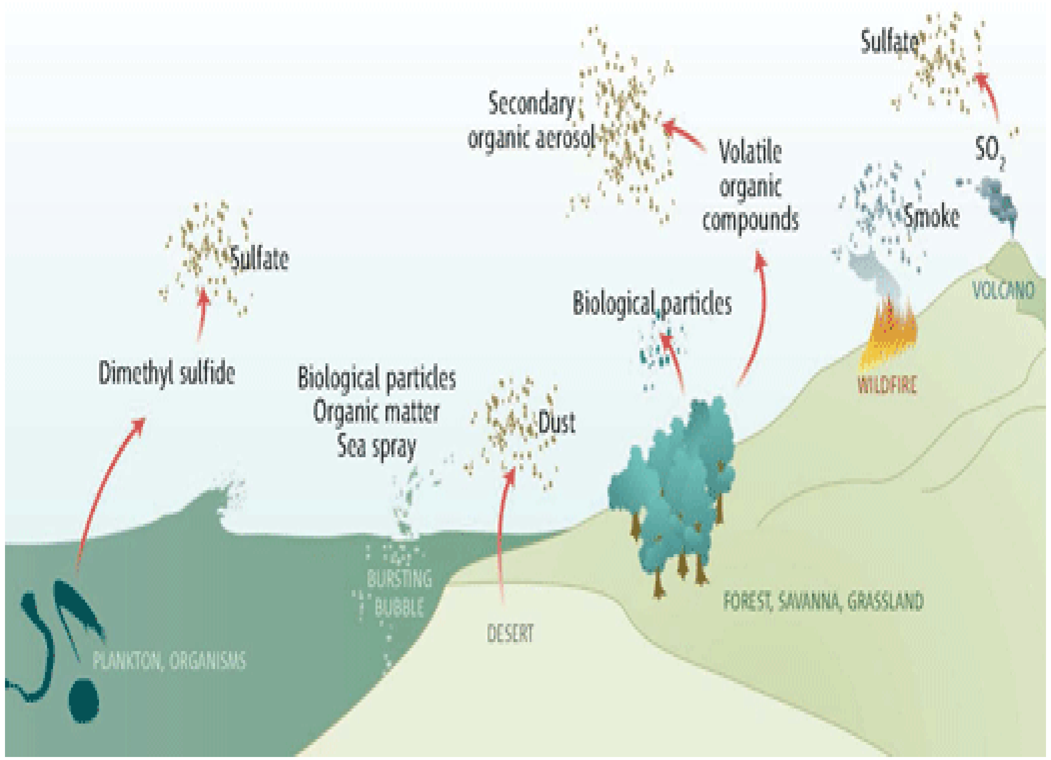
-They are both horizontally and vertically entrained in the atmosphere

-Aerosols also have a diverse spatial and temporal distribution

-Aerosols have a variety of important impacts on the environment.

Sources and life cycle of aerosols





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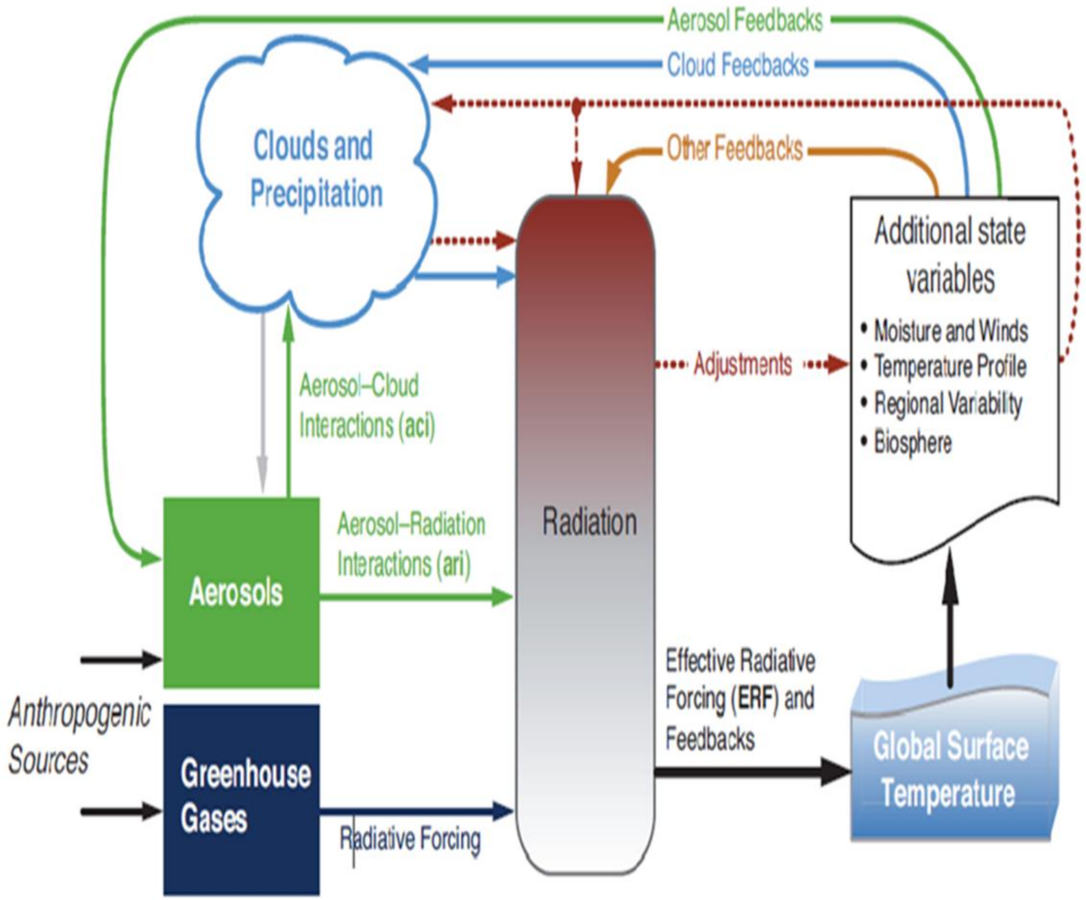
Aerosol climate effects

- Aerosol particles scatter and absorb solar radiation – thereby influencing Earth's radiation budget and climate.
- Aerosol's impact on climate is separated into **direct** and **indirect**
- **Direct effect**: Aerosols scattering sunlight directly back to space
- **Indirect effect**: Aerosols in the lower atmosphere changing the size of cloud particles
- Changes the amount of solar energy reaching earth's surface
- Therefore, aerosols are a radiative forcing agent
- RF is changes in the energy fluxes of solar radiation (short wave) and terrestrial radiation (long wave)



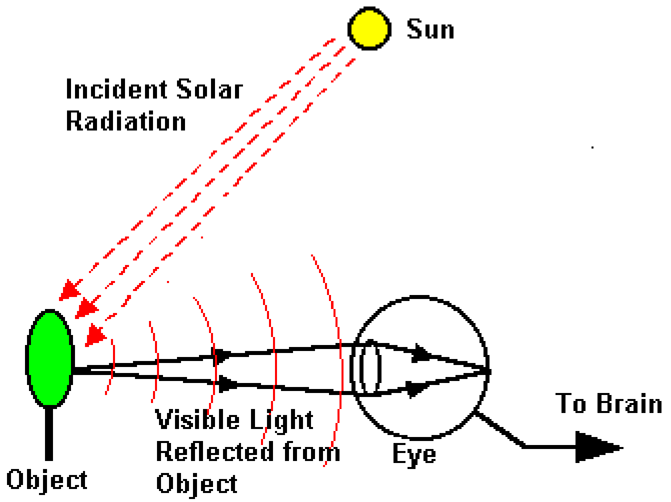
IPCC, 2013

Air Pollution in Durban

- Although South Africa does not have a national air quality problem, a number of air pollution “hot spots” exist around the country where severe air quality problems do occur.
- Due to Durban being home to the air pollution hot spot, the South Durban Industrial basin, and being the third largest economy in South Africa, aerosols in Durban need to be investigated to inform adaptation and mitigation measures.
- Durban also has extremely diverse aerosol sources that need to be investigated.
- Aerosols are extremely important to understanding our climate and has implications for climate change

Instruments used to measure aerosols

- We measure aerosols using remote sensing :
  - The science or the art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area, or phenomenon under investigation.



- Remote sensing refers to the activities of recording/observing/perceiving (sensing) objects or events at far away (remote) places.
- The information needs a physical carrier to travel from the objects/events to the sensors through an intervening medium.
- The electromagnetic radiation is normally used as an information carrier in remote sensing
- In a more restricted sense, remote sensing usually refers to the technology of acquiring information about the earth's surface (land and ocean) and atmosphere using sensors on-board airborne (aircraft, balloons) or space-borne (satellites, space shuttles) platforms.

Instruments used in this study: The sun photometer

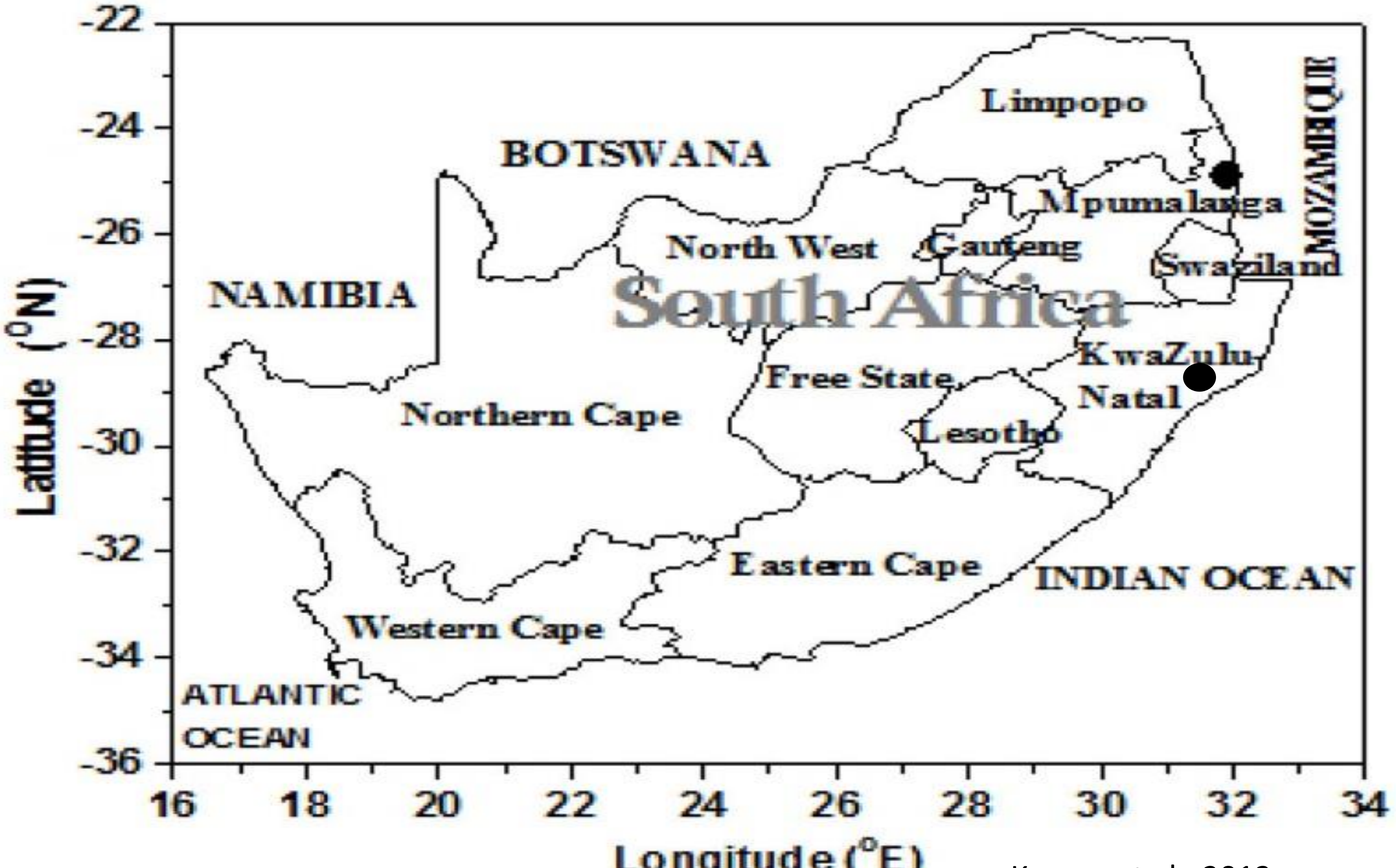
Multi-channel, automatic sun and sky scanning radiometer that measures the direct solar irradiance and sky radiance at the Earth's surface.

The Sun photometer

- The Cimel sun photometer is a multi-channel, automatic sun and sky scanning radiometer that measures the direct solar irradiance and sky radiance at the Earth’s surface. It is produced by Cimel Electronic in France and is part of the AERONET program
- Sun Photometers absorb direct sunlight energy to measure aerosols in the atmosphere.
- While the sunlight travels through the atmosphere, aerosols can dissipate the energy by scattering and absorbing the light.
- We can determine the amount of scattering, and thus, the amount of aerosols.

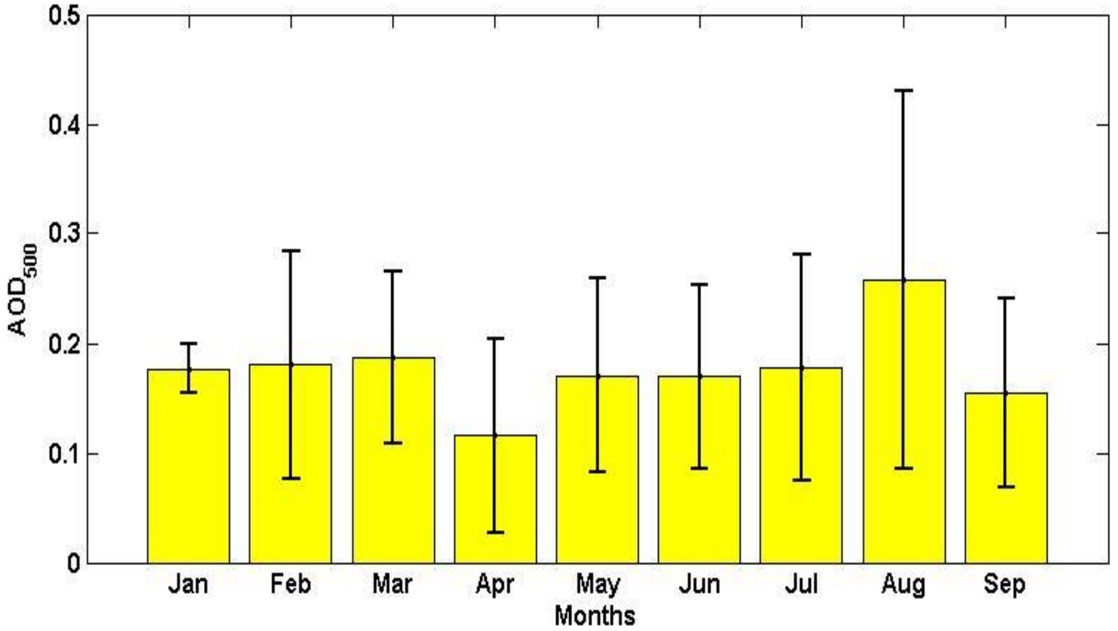
Method of proposed study

- Use the sun-photometer located in Skukuza to validate the preliminary results from the Durban sun-photometer:
  - The aerosol optical depth, the Ångström wavelength exponent (α440–870), particle volume size distribution, single scattering albedo (SSA), the asymmetry parameter (ASP), together with the real (Re) and imaginary (Im) parts of the complex refractive index (RI)

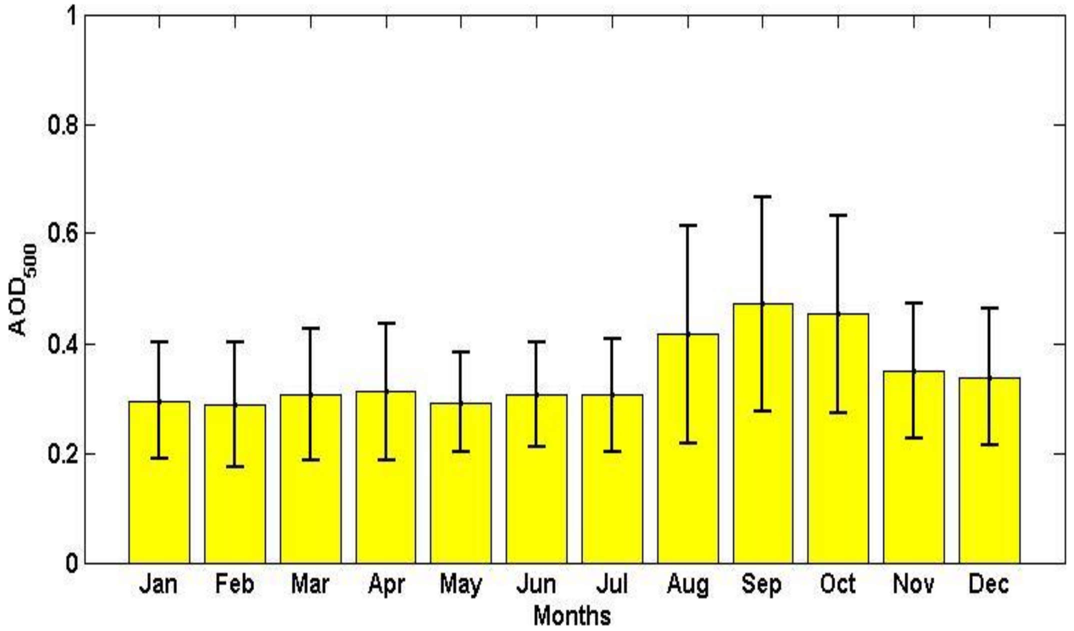


Kumar, et al., 2013

Aerosol Optical Depth



Monthly average aerosol optical depth (AOD) at 500nm at Durban from January to September, 2014.



Monthly average aerosol optical depth (AOD) at 500nm at Skukuza from July 1998 to July 2011.

AOD is a measure of the degree to which aerosols inhibit the transmission of light by absorption or scattering of light.

DURBAN

All months AOD <0,4

AOD greatest in August at 0,26 (Winter)

Onset of biomass burning

Stable weather conditions

AOD lowest in April, 0,12

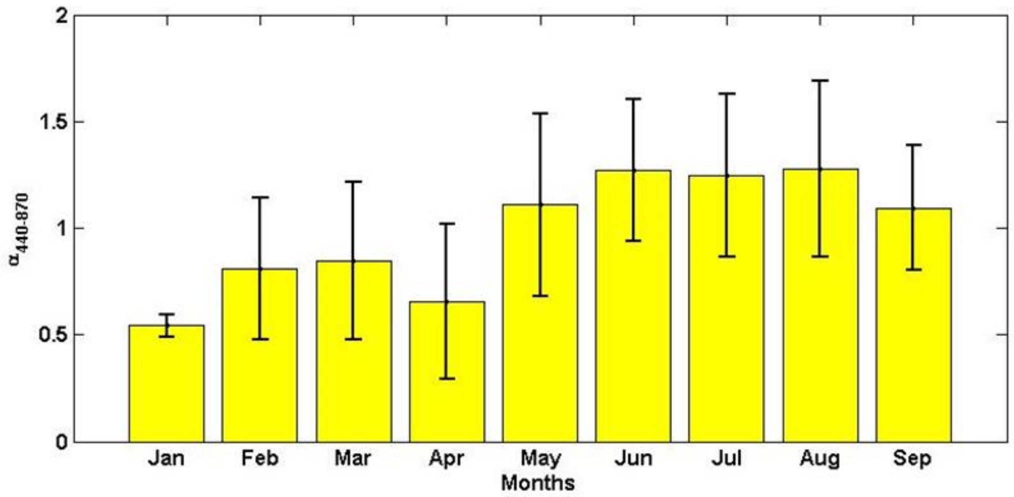
Increase in wind speeds

Low AOD (Jan- Apr) could be due to wet removal processes and rainout

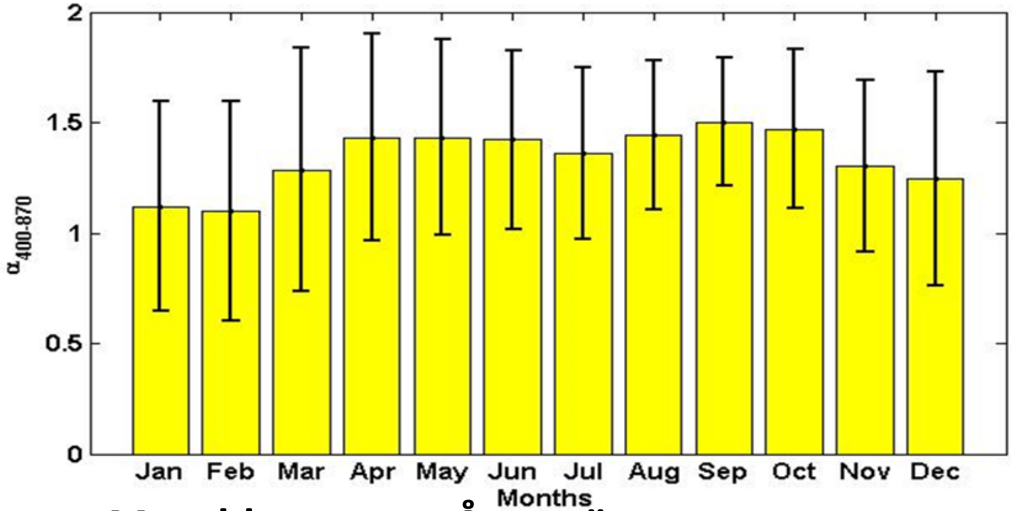
SKUKUZA

- Similar AOD values during all months except Aug – Oct
- Increase in biomass burning activities in the northern and eastern parts of South Africa
- Affect is more prominent in Skukuza, due to the location.

Ångström exponent ($\alpha_{440-870}$)



Monthly average Ångström exponent ($\alpha_{440-870}$) at Durban from January to September, 2014.



Monthly average Ångström exponent ($\alpha_{440-870}$) at Durban Skukuza from July 1998 – July 2011.

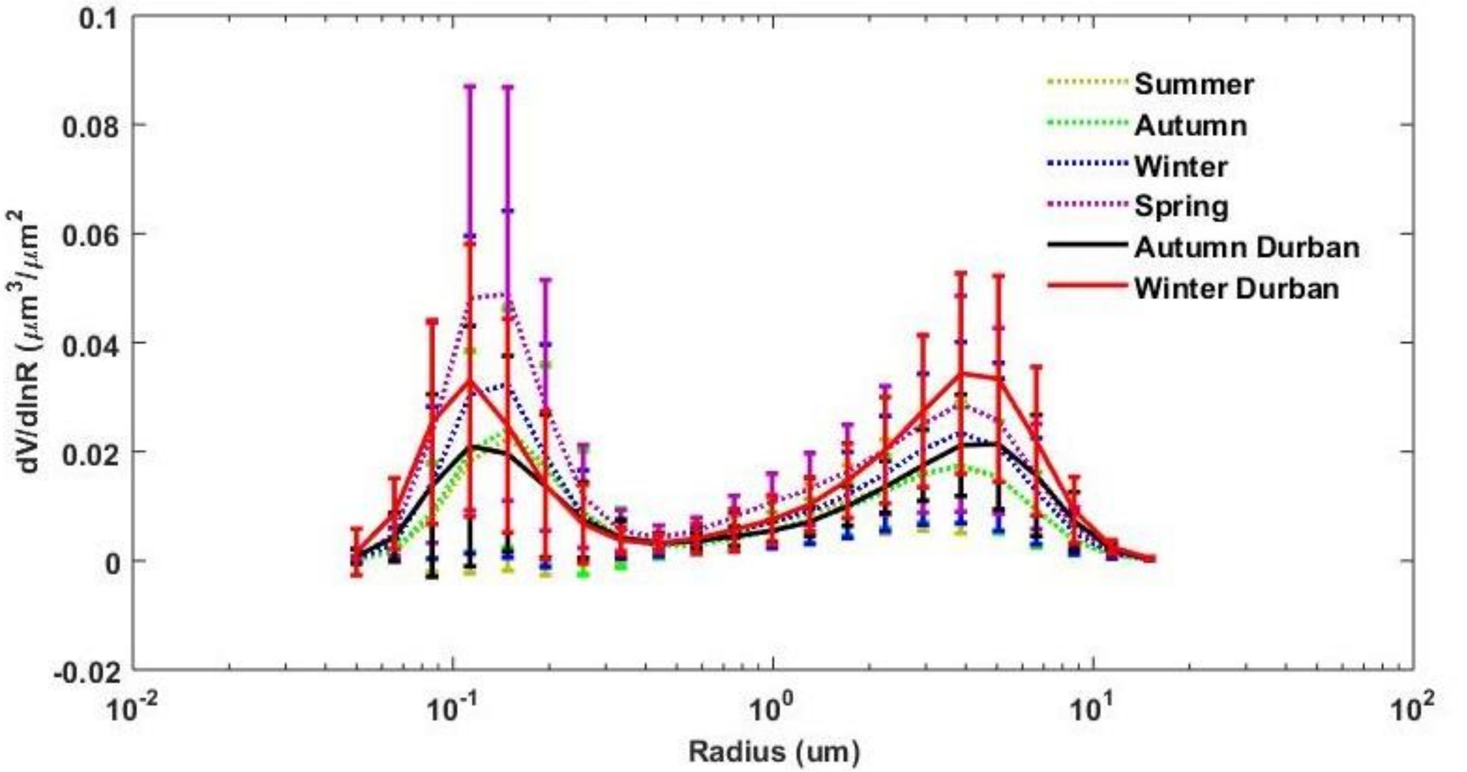
AE is often used as a qualitative indicator of aerosol particle size, values that are greater than two represent small particles associated with combustion by-products and values less than one represent large particles such as sea salt and dust.

- DURBAN
- AE < 1 from January – April
- Transport of soil and dust particles due to convective winds
- Dust transported from West and North parts of SA, sea-spray
- AE > 1 from May – September, increase in fine mode particles
- Due to forest fires, emitting smoke aerosol
- Urban industrial activities
- Stable weather conditions , therefore finer aerosols
- Therefore, mixed aerosol sizes

- SKUKUZA
- The $\alpha_{440-870}$ is below 1.5 for most months with the exception of September
- For Skukuza, monthly average of the Ångström Exponent $\alpha_{440-870}$, varied from 1.01 in February to 1.50 in September, during the study period.
- The high temperatures experienced during January/February aid in the formation of coarse mode aerosols by heating the ground and lifting the loose soil particles to be later entrained by wind

Aerosol Volume Size Distribution

- The VSD is a list of values that defines the relative amount of particles present within a volume of air.
- Aerosols are polydiserse
- Particle radii < 0,6 (course), >0,6 (fine)

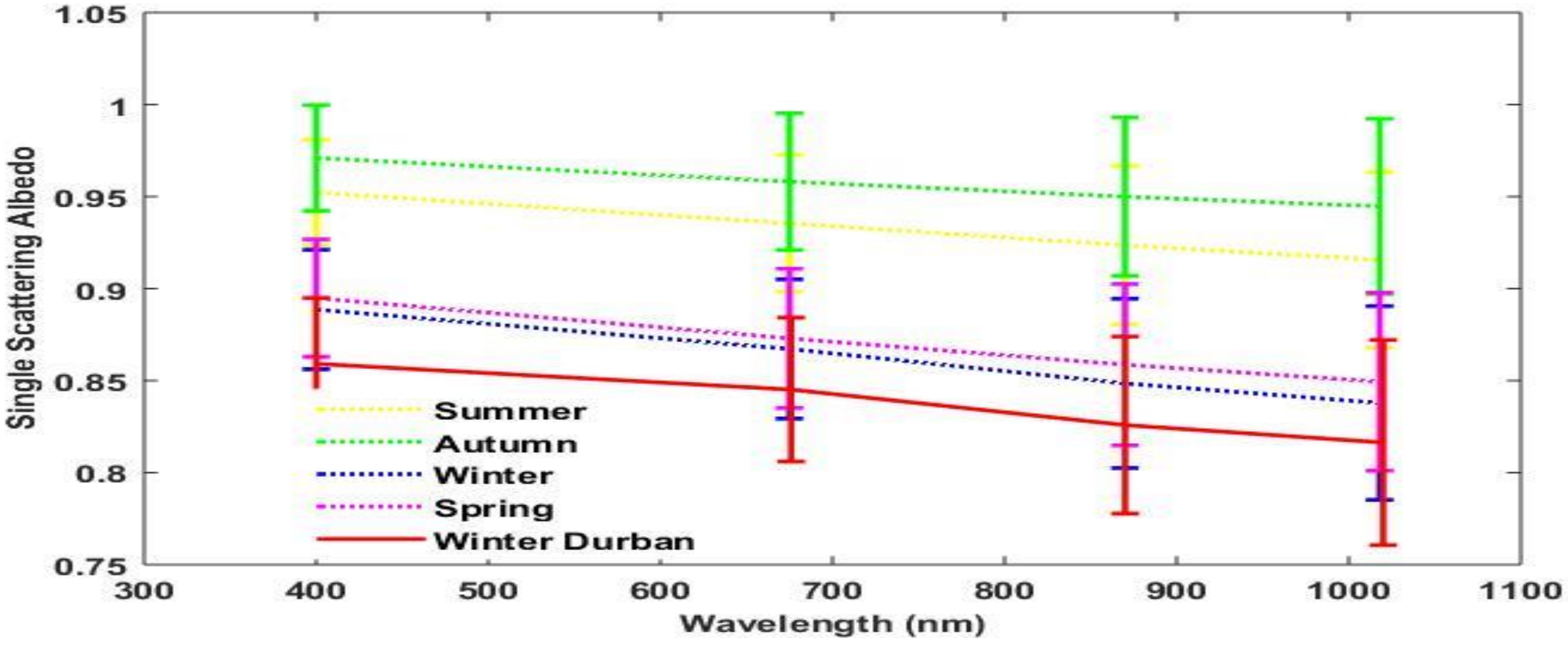


Seasonal variations with standard deviations of aerosol volume size distributions derived from sky radiance as a function of particle radiance for Durban for autumn and winter of 2014 and for Skukuza from July 1998 – July 2011 (summer, autumn, winter, spring).

- DURBAN
- VSD for both the fine and course mode are higher during the winter months than during the autumn months.
- Likely due to stable meteorological conditions, hindering dispersion of aerosols.
- VSDs for autumn and winter, appears to share similar peaks in both the fine and coarse modes
- The smaller distribution during autumn (for both Durban and Skukuza) and summer could be due to cloud scavenging and rain out processes
- The higher distribution during winter (for both Durban and Skukuza) could be due to a lack of cloud scavenging and rainout processes, as well as aerosols generated from many different sources

- SKUKUZA
- Greater VSDs in the fine mode than in the course mode.
- Suggests an increase in aerosol particles of anthropogenic origin
- The VSDs for Skukuza in the fine mode are highest in the spring, followed by the winter, then the autumn and last during summer
- High spring values = biomass burning season, high convective activity, long range transfer or dust, sea-spray aerosols.

Single Scattering Albedo (SSA)

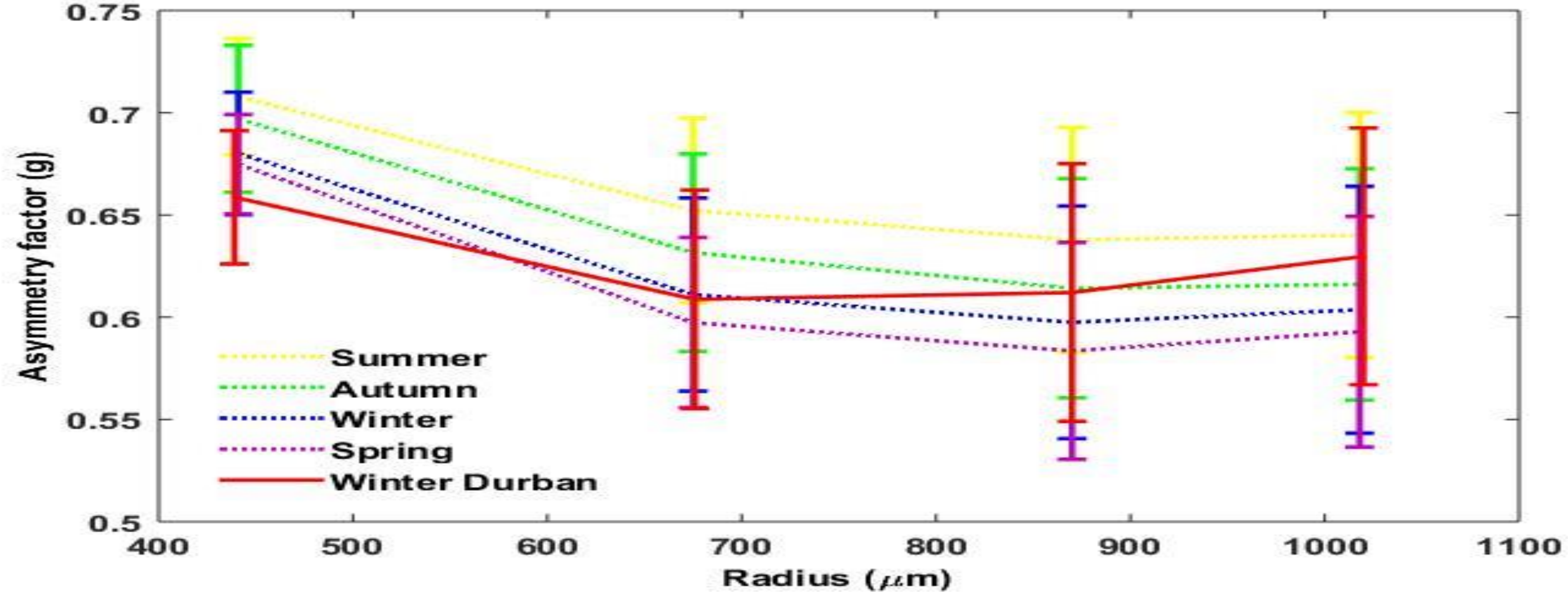


Aerosol microphysical and radiative properties over Durban, SSA, January to September 2014.

- SSA ratio of scattering efficiency to total extinction efficiency
- Dependent upon aerosol size and composition
- 0 for absorbing and 1 for scattering
- SSA<0,9 for winter, urban aerosols and biomass burning type

- SSA decreases with an increase in wavelength; therefore, it has a spectral dependence
- SSA is <0.9 for winter (for both Skukuza and Durban) and for spring (Skukuza only)
- Stable weather conditions associated with winter as well as the onset of the biomass burning season (in August), increasing the presence of carbonaceous absorbing type aerosols.
- The SSA is shown to be greater than 0.9 for all wavelengths during autumn and summer for Skukuza.
- This is characteristic of scattering aerosols.
- There exist high humidity during the summer and autumn months, with the growth of aerosols and makes it more scattering in nature.

Aerosol Asymmetry Parameter



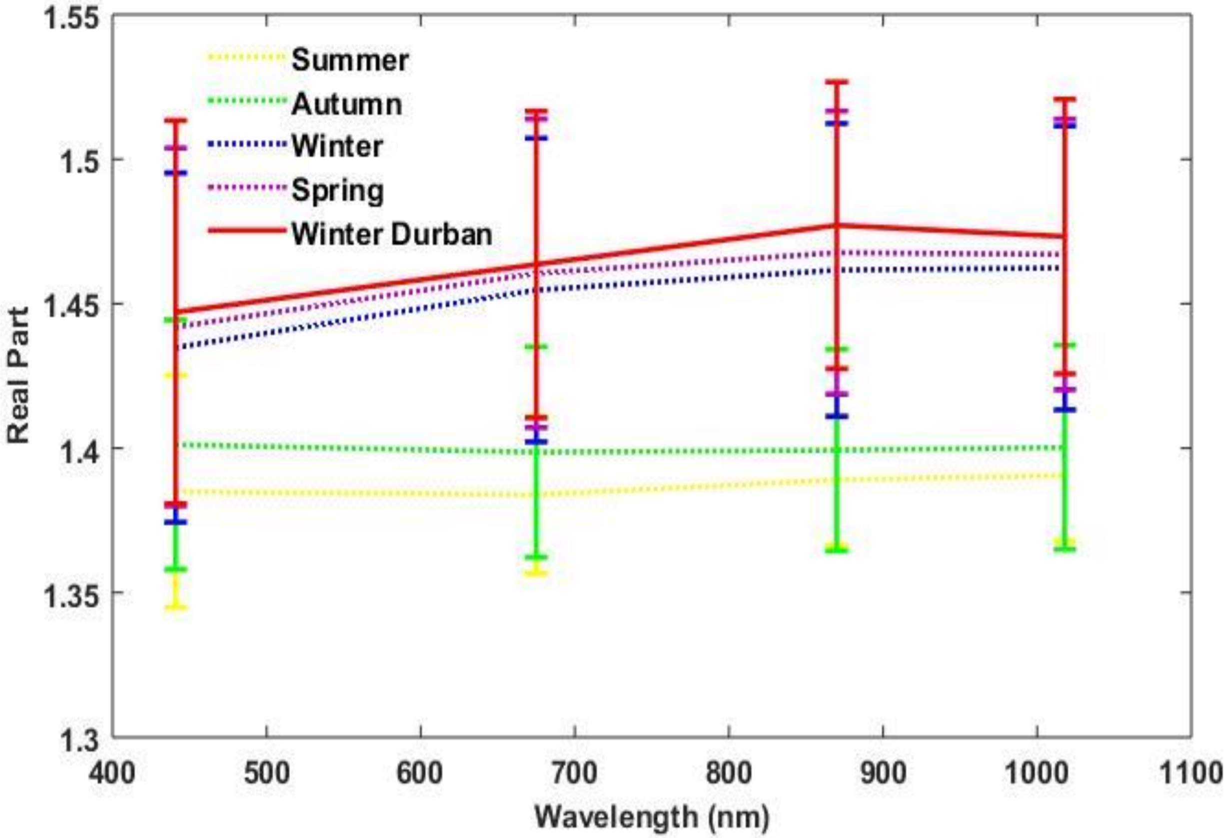
Spectral variation of the Asymmetry parameter (ASP) for the winter months, for Durban from January – September 2014 and for Skukuza from July 1998 – July 2011 for all seasons.

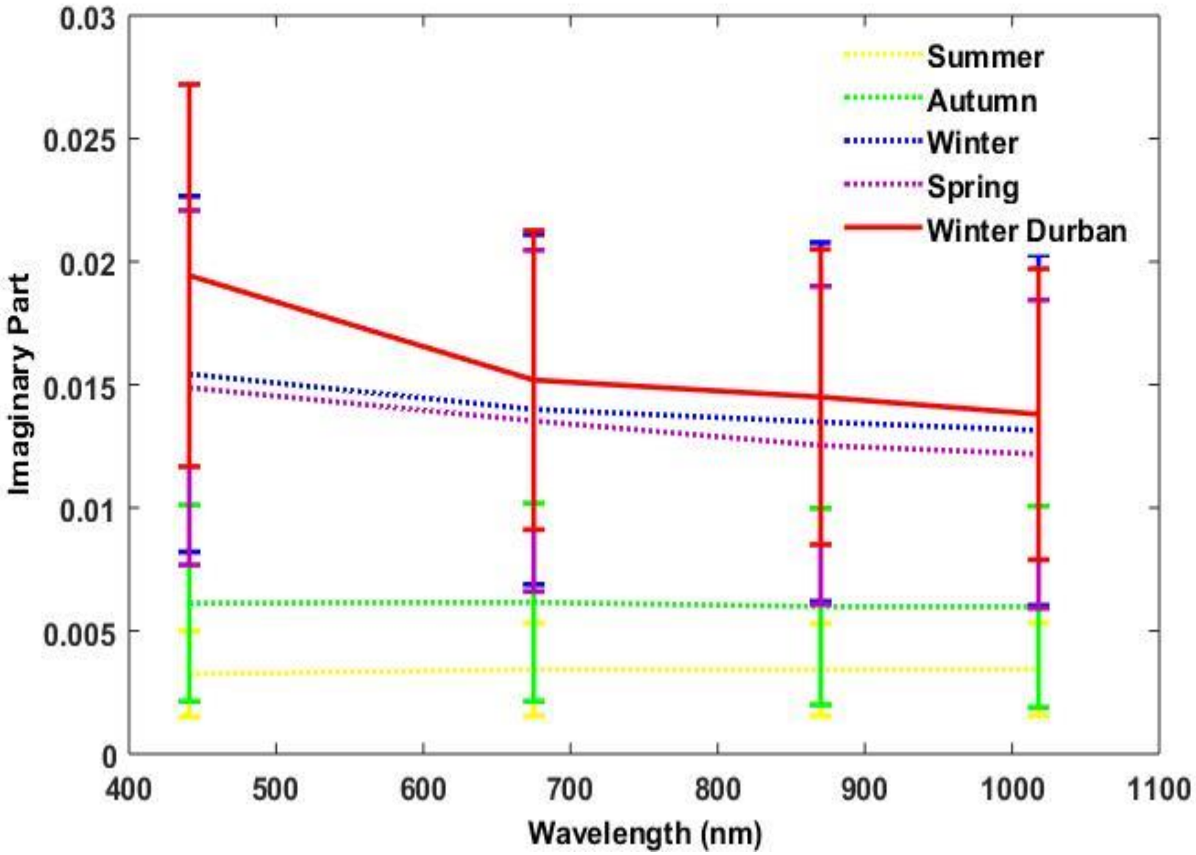
The Aerosol Asymmetry Parameter ASP (g) is a measure of the preferred scattering direction (forward or backward) for the light that reaches the aerosol. In terms of radiative forcing the ASP factor (g) is of extreme importance because it characterises the angular scattering. Angular scattering influences the variability of radiative forcing efficiency.

- DURBAN
- The g values tend to decrease with an increase in wavelength, similarly to the SSA.
- The value of g ranges from -1 for light that is completely back scattered to +1 for completely forward scattered light.
- Low g values reflected for winter

- SKUKUZA
- Low g values reflected for spring
- Suggest a greater abundance of fine anthropogenic (absorbing) pollutants.
- Lower g values during spring is characteristic of biomass burning aerosol
- Lower g values have been reported for smoke aerosol
- Higher value of g was calculated for summer and autumn.
- Increase scattering in the forward direction resulting in dominance of course mode particles during these seasons

Complex Refractive Index





- The complex index retrieval can only be obtained for aerosol optical thickness greater than 0.4 at 440nm
- The complex index of refraction consists of real (Re) and imaginary (Im) parts of the refractive index. The real part is a measure of how much the speed of light is decreased inside the medium relative to the speed of light within a vacuum
- The imaginary part which is an absorption parameter representative of the material itself.

- DURBAN
- For Durban during the winter season, the complex refractive index ranges from 1.45 to 1.47(Re) and from 0.01 to 0.02(Im)
- Dubovik et al., (2002), consistent with urban industrial aerosols and biomass burning aerosols

- SKUKUZA
- Winter: 1.44 – 1.46 (real part) and from 0.014 – 0.015 (imaginary part) also indicative of urban aerosol presence and biomass burning aerosol loads
- The low real and imaginary part values for autumn and summer and high SSA values, suggest low AOD. The low imaginary type values are also associated with dust aerosol types, together with the lower AE values noted for summer could attest to the presence of coarser, dust and maritime aerosol presence

Conclusion

The Aerosol Optical Properties, paints a picture as to the origins of aerosols in a particular region

- The AOD was highest during August (Durban) and during Spring and Winter for Skukuza, points to biomass burning and stable weather conditions
- AE was highest during winter for Durban, for Skukuza, the values were around 1,4 for all seasons, with the exception of summer (<1,2).

- VSDs are high for winter (Durban and Skukuza)and spring (Skukuza)
- Low VSDs for autumn and summer correspond to lower AOD values
- Low SSA and ASP for winter (Durban and Skukuza) and spring – alluding to smoke aerosol
- High SSA and ASP values for summer and autumn

- Low Re and Im values for summer and autumn for Skukuza (due to low AOD)
- High values in winter for Durban: suggesting mixed aerosol loads from both scattering and absorbing type aerosols
- High values during spring and winter for Skukuza, high aerosol content, from biomass burning and urban industrial aerosol sources.
- Effect of biomass burning is more prominent in Skukuza due to its location