Study of Variation of aerosols on High Mountain, Jomsom

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Abstract

The daily aerosol optical depth (AOD) data are derived from AERONET over Jomsom (lat.:28.47°N, long.:83.83°E, alt.: 2,700 m above sea level) for a period of one year 2012.Annual mean of parameters of aerosols are calculated. The effect of different physical as well as meteorological parameters on Angstrom exponential (α) were analyzed. Annual mean of Angstrom exponential (α), Angstrom turbidity coefficient (β) and curvature of AOD (a_2) are 1.24 ± 0.54, 0.05 ± 0.04,4.06 ± 1.44 respectively. Annual average of visibility is 18.48 ± 1.093km. Result of this research work is beneficial for the further identification, impact and analysis of aerosols at different places.

Keywords: Aerosol, Angstrom turbidity coefficient, Angstrom exponential, curvature of AOD, visibility.

1.Introduction

Main source of energy of Sun is thermonuclear fusion reaction. A helium nucleus if form by combination of four hydrogen nucleiby emitting 26.7 MeV energy. $6.2\text{x } 10^{11}$ kg of hydrogen converts into helium every second. Sun radiates $4\text{x}10^{26}$ J energy per second. In form of electromagnetic wave of wavelength 300 nm to 3000 nm (Poudyal et al., 2011). Average solar radiation 1367 W/m^2(solar constant, Isc) (Duffie and Beckman, 2013) incidents on outer layer of atmosphere when earth is at mean distance 1.49 $\text{x}10^8$ km from Sun. As orbit of Earth around Sun is elliptical with eccentricity (ε), solar energy incident on specific point of outer layer of atmosphere at specific time is extraterrestrial solar radiation(H_o).Extraterrestrial solar energy passing through the atmosphere is scattered and absorbed by molecules and particles. Solar energy interacts

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with large particle of atmosphere such as water droplets, dust and aerosols. So H_o decreases exponentially with extinction coefficient (K) and optical air mass (m) in atmosphere. By Beer Lambert's law, direct normal solar irradiance on ground (H_g) is (Iqbal, 1983).

$$H_g = H_o e^{-Km}$$

Extinction of solar radiation is sum of extinction due to gas mixture, water vapor, ozone, aerosol and Rayleigh scattering. Extinction coefficient due to aerosol is aerosol optical depth (AOD).Aerosols is suspension solid and liquid particle with size 1 nm to 10 μ m. Both natural and anthropogenic aerosols influence three ways on the solar radiation: in direct way is by affecting the scattering and absorption of solar radiation, indirect way is by altering cloud microphysics and lifetime, and semi-direct way is by affecting cloud formation or evaporation (Kaufman et al., 2002; Ramanathan and Carmichael, 2008). One of anthropogenic aerosols, black carbon is emitted by vehicles and kilns, produces Green House effect. It melts ice on mountain. Vehicle also emits particular matter (such as PM10, PM2.5), are responsible for respiratory illness.
Nepal is a land locked mountainous country with a large area coved by beautiful landscape in south East Asia. Nepal cover area 1, 47,181sq.km with length about 800 km and breadth about 200 km, divided into three geographical regions along south to north direction: Terai region (tropical zone), Hilly region (temperate zone) and Himalayan region (coldest zone). Within this small and beautiful setting it possesses diversity in biosphere and variation of climate. Nepal lies in sunbelt (latitude 15^o to 35^o). Annual solar isolation is 3.6 to 6.2 kWh/m^2/day and 300 sunshine days in Nepal (Shrestha et al., 2003). In FY 2016/017, 538.6TJ energy is consumed in which tradition fuel is 73%, commercial fuel is 25% and renewable energy is 2% (MoF, 2016/017). 4,37,614 vehicle register in Nepal in BS 2074/075 (DTM, BS 2075). Large foreign currency is used to export petroleum product. Due to petroleum fuel based vehicle, air pollution increases. Nepal lies between two big industrial countries Indian and China. Study of aerosols is needed.

Jomsom (lat.:28.47^o N, long.: 83.83^o E, alt.: 2,700 m above sea level) is the center of Mustang district in Gandaki Pradesh of western Nepal. It has population 1,370 (CBS, 2011). It is hub to Upper Mustang Kagbeni, and Muktinath. The houses in Jomsom are designed to protect the strong wind (annual average wind speed is 5 km/h south west). These winds are caused by differences in atmospheric pressure between the Tibetan plateau and the lower part of the valley. Map of Jomsom is shown in figure1.

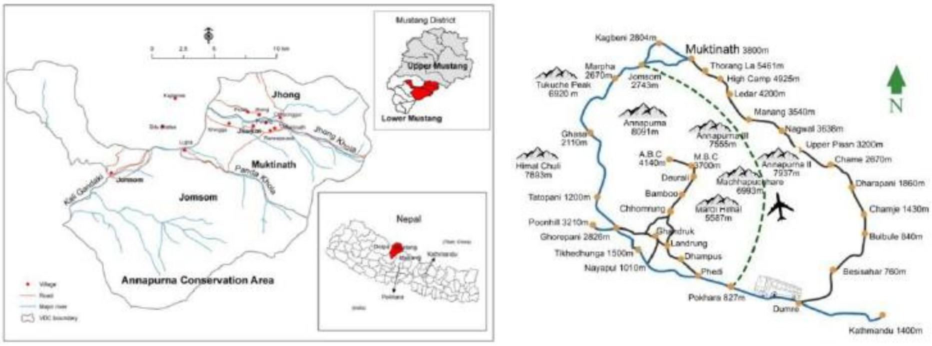


Figure 1: *Map of Jomsom [source: Research Gate]*

2. Methodology and material

Opacity of atmosphere for solar radiation is atmospheric turbidity. There various type of atmospheric turbidity index. Angstrom turbidity is one of index.

According to Angstrom relation (Angstrom, 1961) , AOD ($K_{A\lambda}$) is

$$K_{A\lambda} = \beta \lambda^{-\alpha}$$

Angstrom turbidity coefficient (β)measures the aerosol concentration and scattering constituents other than Rayleigh. Angstrom exponential (α) is particle size distribution. α and β are calculated by linear regression method. Spectral bands 675,500,440,380 and 340nmis used.

$$\ln(K_{A\lambda}) = ln\beta - \alpha\ ln(\lambda)$$

According to Koschmier (1924) (Koschmieder, 1924), visibility in km is

$$V_m = \frac{0.693}{b_{ext}}$$

Here b_{ext} is AOD for 550nm wavelength.

In Angstrom's formula, the errors in α and β arises due to error in AOD and the choice of wavelength(λ).Then second order polynomial equation between $\ln(K_{A\lambda})$ and $\ln(\lambda)$ can be used to get precise information of aerosol size distribution(Schuster et al., 2006).

$$\ln(K_{A\lambda}) = a_0 + a_1\ ln(\lambda) + a_2 ln(\lambda)^2$$

Here coefficients a_0, a_1 and a_2 are constant. a_2 gives curvature of AOD. It gives information about the domination of fine mode aerosols and coarse mode aerosols in the air.

The spectral aerosol optical depth data of Jomsom for year 2012 measured by CIMEL - 318 sun photometer are available in the AERONET homepage of Nasality is multichannel radiometer which measures direct solar irradiance. Spectral bands are 675 nm, 500 nm, 440 nm, 380 nm and 340nm.

Figure 2: *CIMEL -318 sun photometer*

Open source software Python 3.7 software is used to analysis data and plot graph. Mean standard deviation (σ), correlation coefficient(r) are used as Statistical tool. Standard error (SE) is used as error bar in graph. Data is presented in form mean ± standard deviation.

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}}$$

$$SE = \frac{\sigma}{\sqrt{n}}$$

$$r = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2 \sum_{i=1}^{n}(y_i - \bar{y})^2}}$$

Here n is no. of data. Correlation coefficient is used to find relation between two variables. Its value ranges from -1 to +1.

3. Results and Discussion

Figure3 indicates daily variation of spectral AOD. Maximum value of AOD for 675 nm ,500nm,440nm,380nm and 340 nm are in 58th,90th,90th,90th and 90^{th} day of year(DOY)respectively. Minimum value of AOD for 675 nm is in 165^{th} and for 500nm,440nm,380nm and 340 nm are in 194^{th} day of year(DOY). Smaller wavelength has large value of AOD. So radiation with smaller wavelength is absorbed more in atmosphere. That absorbed solar energy by atmosphere, are converts into radiation with large wavelength with is form of thermal radiation. That produces greenhouse effect. Statistics of those parameters are shown in Table 1.

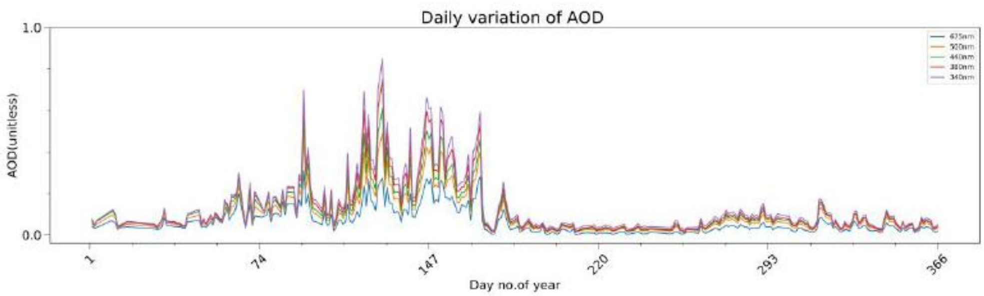
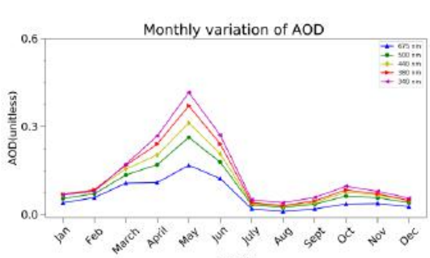


Figure 3: *Daily variation of AOD*

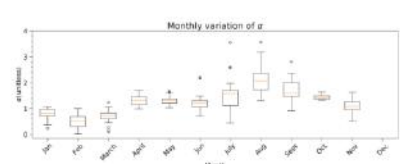
Table1: *Statistics of parameters*

Parameters	Max.	Min.	Mean	sd
AOD for 675nm	0.3105	0.0018	0.0677	0.0655
AOD for 500nm	0.4931	0.0112	0.1017	0.0984
AOD for 440nm	0.6106	0.0132	0.1198	0.1166
AOD for 380nm	0.7491	0.0125	0.1361	0.1400
AOD for 340nm	0.8505	0.0203	0.1513	0.1560

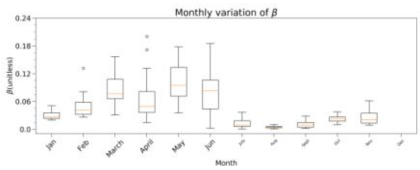
Figure4 (a) shows monthly variation of AOD. AOD for 675nm, 500nm, 440nm, 380nm and 340nm have maximum value on May. Smaller wavelength has large value vice versa. AOD for 675nm, 500nm, 440nm, 380nm and 340nm have minimum value on July. Figure4(b) shows monthly variation of Angstrom exponential(α) .Maximum value of α is 0.78 ± 0.53 in August due to rainy season and minimum of 0.52 ± 0.26 in February.Figure4(c) shows monthly variation of Angstrom turbidity coefficient(β) .Maximum value of β is 0.10 ± 0.037 in May and minimum value of 0.01± 0.00 in August.Figure4(d) shows monthly variation of curvature of AOD(a_2) .Maximum value of a_2 is 6.44 ± 1.17 in August and minimum value of 2.82 ± 0.49 in March.Figure4(e) shows monthly variation of visibility. Maximum value of visibility is 48.57 ± 18.31km in August and minimum value of 3.60 ± 1.50km in May.



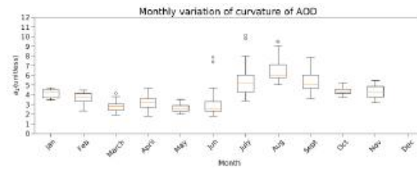
a)AOD



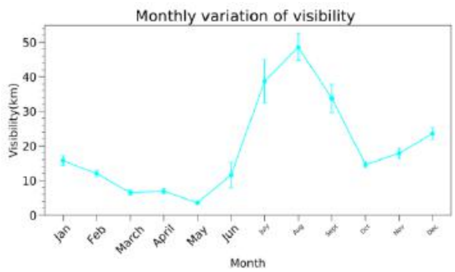
b)Angstrom exponential



c) *Angstrom turbidity coefficient*



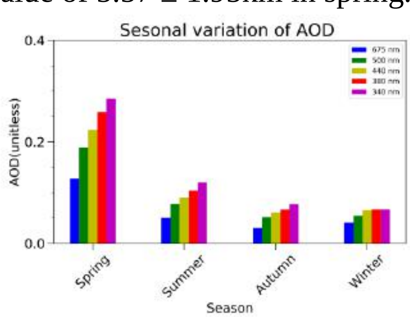
d) *curvature of AOD*



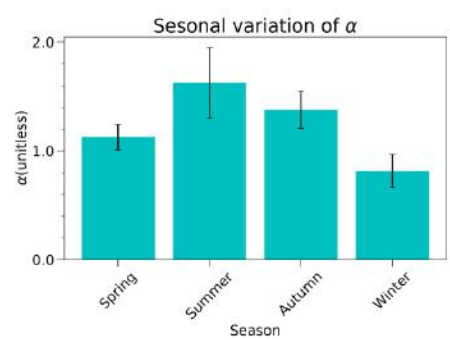
e) Visibility

Figure 4: *Monthly* **v***ariation of parameters*

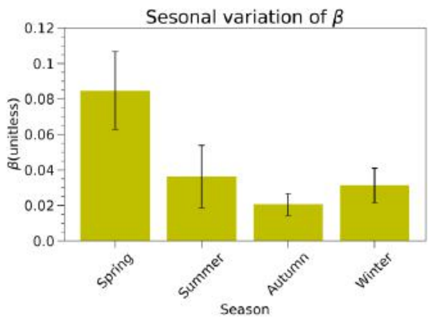
Figure5(a) shows seasonal variation of AOD.AOD for 675nm,500nm,440nm,380nm and 340nm has maximum value on Spring and minimum value on Autumn.Figure5(b) shows seasonal variation of Angstrom exponential(α).Maximum value of α is 1.62 ± 0.56 in summer and minimum value of 0.81 ± 0.24 in Winter.Figure5(c) shows variation of Angstrom turbidity coefficient(β) .Maximum value of β is 0.08 ± 0.03 in spring and minimum value of 0.02 ± 0.01 in autumn.Figure5(d) shows seasonal variation of curvature of AOD(a_2).Maximum value of a_2 is 4.88 ± 1.47 in summer and minimum value of 2.83 ± 0.50 in spring.Figure5(e) shows seasonal variation of visibility. Maximum value of visibility is 31.16± 13.00km in summer and minimum value of 5.57 ± 1.95km in spring.



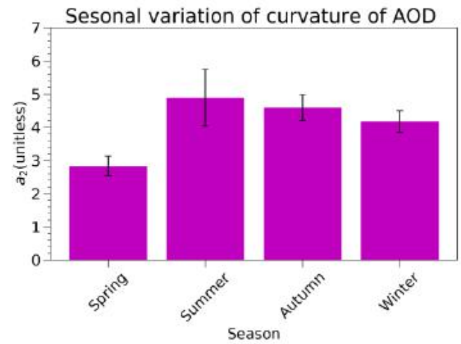
a)AOD



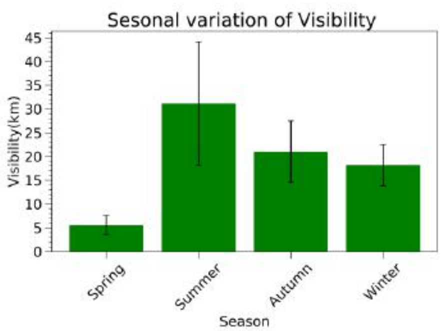
b) Angstrom exponential



c) *Angstrom turbidity coefficient*



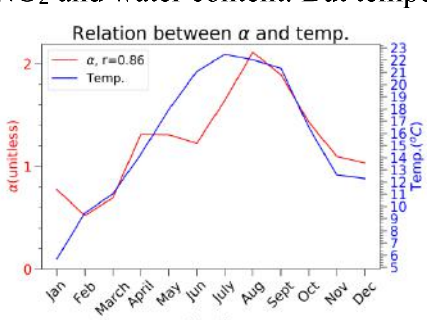
d)curvature of AOD



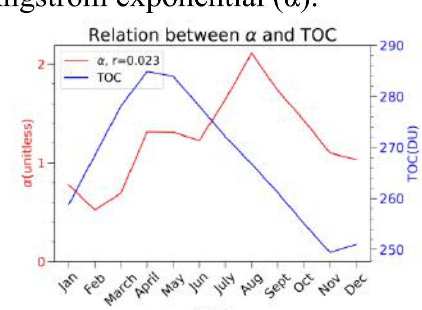
e)Visibility

Figure 5: *Seasonal variation of parameters*

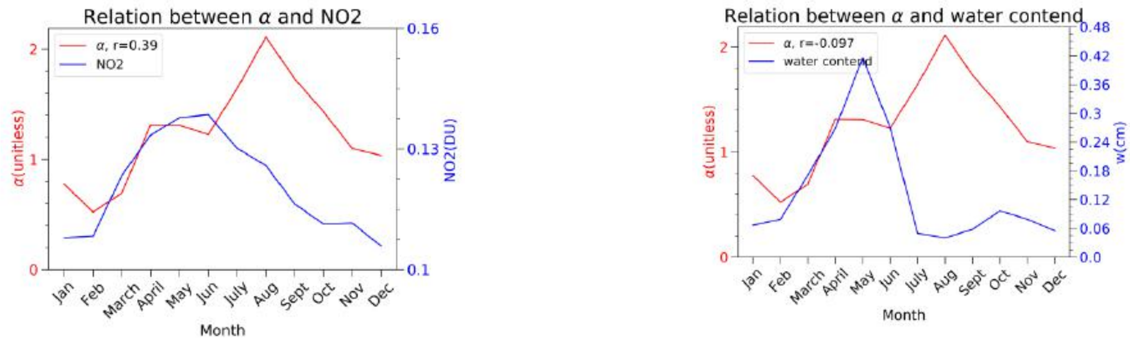
Figure6 (a) shows variation of Angstrom exponential (α) with temperature. Correlation coefficient is 0.86. Annual mean of temperature is 21.2 ±4. 1oC.Figure6 (b) shows variation of Angstrom exponential (α) with total ozone column (TOC). Correlation coefficient is 0.01. Annual mean of TOC is 267.3 ± 12.37DU. Figure6(c) shows variation of Angstrom exponential (α) with NO_2.Correlation coefficient is 0.3. Annual mean of NO_2 is0.12± 0.01 DU. Figure6 (d) shows variation of Angstrom exponential (α) with water content. Correlation coefficient is -0.11. Annual mean of water content is 0.80 ± 0.6cm. There is no significant relation of Angstrom exponential (α) with TOC, NO_2 and water content. But temperature affects the Angstrom exponential (α).



a)Temperature



b)TOC



c)NO$_2$ *d)water content*

Figure 6: *Relation of αwith of parameters*

4. Conclusions

In study period, the annual mean of Angstrom exponential(α), Angstrom turbidity coefficient(β), curvature of AOD(a_2) and visibility are 1.24 ± 0.54,0.05 ± 0.04, 4.06 ±1.44 and 18.48 ±0.09km respectively for Jomsom. Angstrom coefficient of turbidity(β) found to vary from 0.16 ± 0.03 to 0.35 ± 0.15 from December 2011 to March 2013 in Kathmandu Valley (lat.:27.7^{o}N, long.:85.5^{o}E, alt.:1350 ma.s.l.) (Thapa et al., 2017). Those data show that Angstrom turbidity coefficient (β) for Jomsom is smaller than that at Kathmandu Valley. So it is environmentally good place.

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References

Angstrom, A. (1961). Techniques of determinig the turbidity of the atmosphere. *Tellus*, 13(2):214–223.

CBS (2011). *National population and housing census 2011*.Central Bureau of Statistics, National Planning Commission Secretariat, Government of Nepal

DTM (BS 2075). Register vehicles till fiscal year BS 2074/075.Department of Transport

Management, Ministry of physical infrastructure and transport, Government of Nepal.

Iqbal, M. (1983). *An introduction to solar radiation*. New York: Academic Press.

John A Duffie, J. A. and Beckman, W. A. (2013). *Solar engineering of thermal processes*. John Wiley & Sons.

JN Shrestha, JN., Bajracharya, TR., S hacky, SR. and Giri, B. (2003). Renewable energy in

Nepal-progress at a glance from 1998 to 2003. In *Proceedings of the International Conference on Renewable Energy Technology for rural Development (RETRUD- 03)*, pages 12–14.

Kaufman, Y. J., Tanre, D. and Boucher, O. (2002). A satellite view of aerosols in the climate system. *Nature*, 419(6903):215–223.

Koschmieder, H. (1924). Theorie der horizontalensichtweite. *BeitragezurPhysik der freien atmosphere*, pages33–53.

MoF (2017). *Economic Survey 2016/017*.Ministry of Finance, Government of Nepal.

Poudyal, K.N., Bhattarai, B.K., Sapkota, BK. and Kjeldstad, B. (2011). Solar radiation potential at four sites of Nepal. *Journal of the Institute of Engineering*, 8(3):189–1971.

Ramanathan, V. and Carmichael, G. (2008). Global and regional climate changes due to black carbon. *Nature geoscience*, 1(4):221–227.

Schuster, G.L., Dubovik, O. and Holben, B.N. (2006). Angstrom exponent and bimodal aerosol size distributions. *Journal of Geophysical Research: Atmospheres*, 111(D7).

Thapa, M.K., Bhattarai, B.K., Gurung, S., Sapkota, BK., Poudyal, K.N, and Karki, NR. (2017).

Effects of aerosol on the solar radiation in mid-hill of Nepal: a case study in the Kathmandu Valley. *International Journal of System Assurance Engineering and Management*, 8(1):54–62.