Journal of Advances and Scholarly Researches in Allied Education
Vol. XV, Issue No. 1, April-2018, ISSN 2230-7540

Variability of Water Vapor Using Ground and Satellite Measurements Over Indo-Gangetic Basin and Analysis of Its Relation with Temperature & Rainfall

Shivani Mridula*

M.Sc. Environmental Science / UGC-NET, Banaras Hindu University

Abstract – The Climatic and Environmental effects of atmospheric water vapor are critical issues in global science community because water vapor is known to affect rainfall, temperature, greenhouse effect, human health and radiation budget. The Indian subcontinent is one of the highest populated, industrialized and developing regions where water vapor content is responsible for rainfall, affects the climate and environment, but also human health and the society. In the present study, variability of total water vapor columns of atmosphere has been studied over three locations (Jaipur, Kanpur and Gandhi College) located in Indo-Gangetic Basin during 2014-2017 using ground based (AERONET) as well as satellite measurements (MODIS on board of TERRA, TRMM, AIRS). The ground data has also been compared with satellite data. The results are found to be highly correlated with some fluctuations observed. The IGB is of great interest due to its unique topography and having more population.

Keywords – Water Vapor, Environmental Effect, Rainfall, Temperature, Greenhouse Effect, Radiation Budget, Indo-Gangetic Basin, AERONET and MODIS.

---------------------------------x---------------------------------

INTRODUCTION

The Earth's Atmosphere consists primarily of gases Nitrogen (78%) and Oxygen (21%), however, the other 1% gases, aerosols, clouds and so on play important roles in shaping conditions at the Earth's surface and in the lower atmosphere. It is although small in quantity but its effect on weather and climate can be dramatic. Atmospheric Water Vapor is one of the dominant greenhouse gas (Raval & Ramnathan, 1989). It has profound effect on temperature and humidity. Water Vapor is found to provide accurate information about the onset of Indian monsoon (Prasad et al., 2007; Jade and Vijayan, 2008). The main sources are oceans, lakes, rivers, forests and plant transpiration & respiration processes. The environmental effects of vapor are the critical issues in global science community as it is one of the important greenhouse gases.

The Indo-Gangetic Plain, also known as Northern Plain and the North Indian River Plain is large and fertile plain encompassing most of the northern & western India. The region is named after the Indus & the Ganga, the twin river system that drain it. The plain population density is very high due to the fertile soil for farming as well as the presence of numerous small & large rivers. The plains support one of the most populous areas on the Earth being home to nearly one- billion people i.e. $1/7^{th}$ of the World's population on 700,000 km^2. Among the largest cities of the Indo-Gangetic Basin are Ahmedabad, Ludhiana, Amritsar, Chandigarh, Delhi, Jaipur Kanpur, Lucknow, Allahabad, Varanasi, Patna, Kolkata etc.

The major concern for air, water and land pollution in the Indo-Gangetic Plain is the setting up of large-scale uncontrolled Industries and urban development. Owing to the growing population and anthropogenic activities, the Indian Monsoon and hydrological cycles especially of the Indo-Gangetic Plains is found to be affected. In recent years, large deviations in the monsoon rainfall have caused increased droughts and floods over India.

Satellite derived total water vapor column is a cost-effective way to monitor and study water vapor distribution and effects over a long period of time. Moderate Resolution Imaging Spectroradiometer (MODIS) derived vapor column is well suited for such study due to its revisit cycle of 1-2 days. As a result, a close estimate of vapor column is made for a given region throughout the year for climatological studies (King et al., 1992, 2003).

Although satellites are proved to be a good tool to understand the broad spatial-temporal characteristics of water vapor and associated effects from global to local scales, but they are unable to provide an in-depth view of particles on a local scale and pose higher uncertainties as compared to the ground-based instruments. In the IGB, vapor particles mix with each other during dust loading season. As a result, vapor particles change leading to even larger uncertainty in satellite retrievals. National Aeronautics and Space Administration (NASA) has setup ground-based monitoring network under the Aerosol Robotic Network (AERONET) Program, in which automatic sun/sky radiometers are deployed at various places around the world. As per India, particularly in the northern part, the routine measurements of water vapor and aerosols under this network were started initially by the deployment of sun/sky radiometer at Kanpur over IGB in year 2001. At a larger stage, it was deployed at other places in the IGB, considering the region as crucial for measurements.

In the **present study**, ground-based **Aerosol Robotic Network** (AERONET) has been used to investigate the water vapor variability over a period **2014-2017** for three stations in the Indo-Gangetic Basin, namely **Kanpur, Gandhi College** and **Jaipur.** Satellite derived **Moderate Resolution Imaging Spectroradiometer** (MODIS) water vapor column product has also been used for the studied stations and correlated with ground observed data. Also, the analysis of relation of water vapor with temperature and rainfall has been carried out through **seasonal variation and correlation methods.**

Instrumentation

The present study is carried out by using satellite based Moderate Resolution Spectroradiometer (MODIS), TRMM and AIRS onboard Terra and Aqua satellites of NASA and ground based measurement by stations deployed at different locations over the IGB region under the Aerosol Robotic Network (AERONET) program of NASA, USA. These are the important spectroscopic tools to study the amount of water vapor. Other tools are GPS, Radiosonde, MISR etc.

DATA ANALYSIS

Variability of Atmospheric Water Vapor over IGB during 2014-2017

The total column of water vapor is found to be very dynamic over Indo-Gangetic basins. In this study, the preliminary analysis of satellite-based measurements (MODIS) and ground based measurements (AERONET) of water vapor and its annual variability over the IG plains of India during the period 2014-2017 has been reported.

The seasonal and annual variability of water vapor has been studied over three locations in the Indo-Gangetic Basin namely:

1. Jaipur (26.912 N, 75.787 E)
2. Kanpur (26.449 N, 80.331 E)
3. Gandhi College (25.871 N, 84.128 E)

DATA USED

Ground based measurements:

The variation of total column of water vapor has been studied using AERONET and also physical properties of water vapor for the specified period have been studied.

Satellite based measurements:

For checking the reliability of satellite data and its correlation with ground-based data, MODIS level 3 data are used. The total column of Water Vapor along with Surface Temperature and Rainfall data are recorded for period 2014-2017. Then, the analysis of its relation with these meteorological parameters is done.

RESULTS AND DISCUSSIONS

A. Annual and Seasonal Distribution of Water Vapor Column over IGB from 2014-2017:

FigA.1. shows annual distribution of MODIS Water Vapor over Indian subcontinent during the period of 2014 to 2017 for three observing stations Jaipur, Gandhi College, Kanpur. Correlation between Ground and Satellite data of Seasonal fraction over all three stations has been obtained and analyzed. The season has broadly been classified into three categories:

1. Pre-Monsoon Season (MARCH TO MAY)
2. Monsoon Season (JUNE TO SEPTEMBER)
3. Post-Monsoon Season (OCTOBER TO DECEMBER)

Fig A.2 shows the seasonal (pre-monsoon, monsoon and post-monsoon) variations of MODIS Water Vapor over India region. It can be clearly inferred that water vapor column over Indo-Gangetic plains is highest as compared to rest of the country and the column water vapor shows a large **enhancement** with the **monsoon onset** and with phases of monsoon (June to September) for all the three stations.

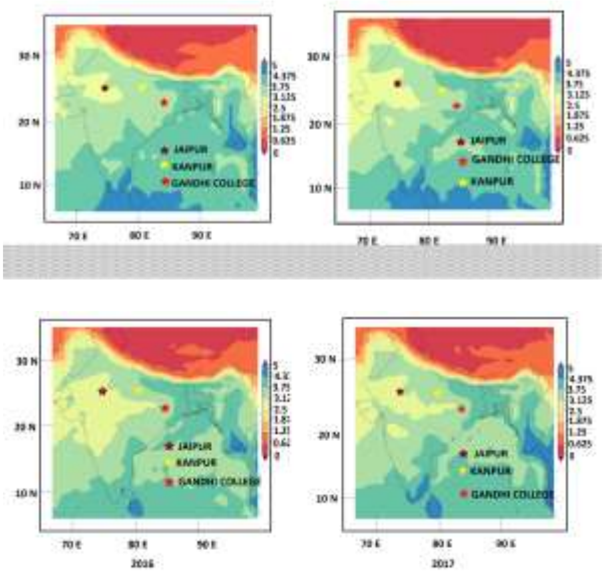

Fig. A.1: Annual distribution of Water Vapor Column over Indian region during the years 2014-2017.

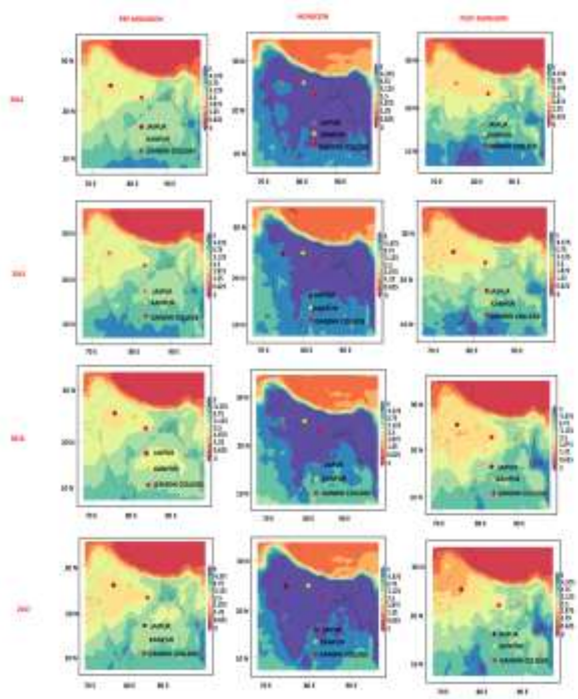

Fig. A.2: Season distribution of Water Vapor Column over Indian region during the years 2014-2017.

B. Comparison of AERONET and MODIS water vapor variation over IGB plains during 2014-2017:

Figure B shows the daily variation of MODIS and AERONET water vapor (cm) over the Indo-Gangetic plains during the year 2014-2017 for Jaipur, Gandhi College and Kanpur respectively. In each of the places, it has been found that the total column of water vapor using MODIS has higher values as compared to AERONET throughout the period. It is seen from the figure that the daily AERONET vapor varies over wide range **(0.2-5.7 cm)** for **Jaipur**, **(0.5-6.7cm)** for **Gandhi College** and **(0.4-7.3 cm)** for **Kanpur**. Similarly, MODIS data varies over wide range **(0.5- 9.7 cm)** for both **Jaipur and Kanpur** and **(0.3-9.2 cm)** for **Gandhi College**.

The large variation in the range occur between the values of MODIS and AERONET data as satellite data is representative of larger areas so phenomenon like dust storms cloud formation etc. lead to the enhancement of vapor column recorded. Also, some of the data of AERONET especially during monsoon season have got lost and have not been recorded. That's why the maximum values vary so widely for MODIS and AERONET data.

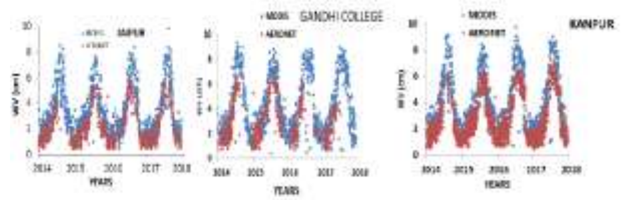

Fig. B: Variation of Water Vapor Content over Jaipur, Gandhi College and Kanpur for four years i.e. 2014-2017.

C. Annual Correlation of AERONET and MODIS derived data from 2014-2017:

Correlation is a single value that helps us to interpret the degree of relation between two variables. For inter comparison of ground-based water vapor data with satellite data, annual correlation has been analyzed for all the three stations along with average correlation for all the four years from 2014-2017.

Figure C.1 shows the correlation plots for annual water vapor data of AERONET against MODIS for Gandhi College along with average correlation for all the four years from 2014-2017. There is good correlation between AERONET and MODIS throughout the year. The average correlation coefficient value from 2014-2017 is 0.93. For year 2015, there is highest value of correlation coefficient i.e. 0.94. While the year 2014, 2016 and 2017 have also high correlation coefficient values of 0.93, 0.92 and 0.91 respectively.

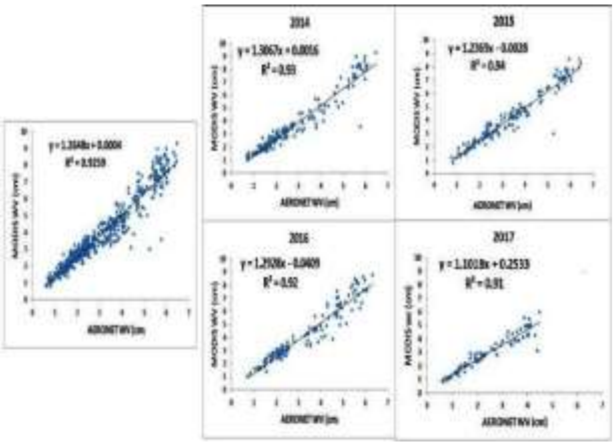

Fig. C.1: Correlation plots for annual water vapor data of AERONET against MODIS for Gandhi College along with average correlation for all the four years from 2014-2017.

Figure C.2 shows the correlation plots for annual water vapor data of AERONET against MODIS for **Jaipur** along with average correlation for all the four years from 2014-2017.For Jaipur, the average correlation coefficient value from 2014-2017 is 0.94 which also shows good relationship. There is highest value of correlation coefficient i.e. 0.94 for all the three years i.e. 2015, 2016, 2017 respectively. For 2014, the value is least which accounts for 0.92.

Figure C.3 shows the correlation plots for annual water vapor data of AERONET against MODIS for **Kanpur** along with average correlation for all the four years from 2014-2017And for Kanpur, the average correlation coefficient value from 2014-2017 is 0.93. For year 2015, there is highest value of correlation coefficient i.e. 0.96. While the year 2014, 2016 and 2017 have also high correlation coefficient values of 0.95, 0.92 and 0.91 respectively which have been clearly illustrated in the given figure 5.2.3.b. and 5.2.3. c respectively.

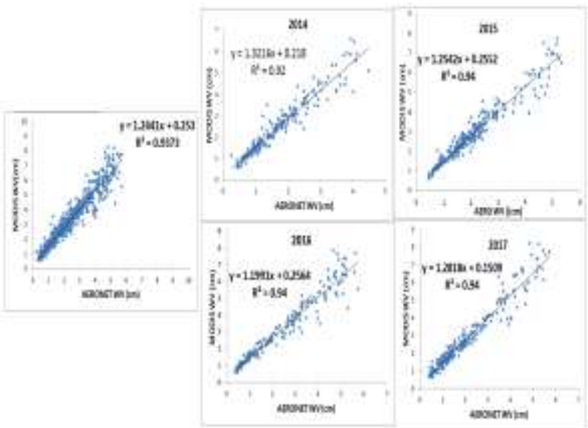

Fig. C.2: Correlation plots for annual water vapor data of AERONET against MODIS for Jaipur along with average correlation for all the four years from 2014-2017.

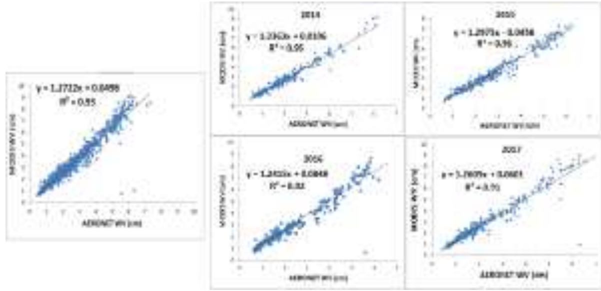

Fig. C.3: Correlation plots for annual water vapor data of AERONET against MODIS for Kanpur along with average correlation for all the four years from 2014-2017.

D. Monthly mean variation of Water Vapor over Indo-Gangetic Plains for all the four years 2014-2017:

Monthly mean variations of Water Vapor Contents at all the three locations: Jaipur, Kanpur and Gandhi College during all the four years 2014-2017 are shown in fig. D. (a), (b) & (c). It has been observed generally, in all three places that January-May months had relatively drier atmosphere as compared to June-September, which is found to be associated with **maximum** Water Vapor Content. September onwards shows the decreasing trend i.e. again shows drier atmosphere i.e. less amount of Water Vapor. The line curve for AEORNET data is not complete in most of the cases due to unavailability of data. It is also observed that satellite- based MODIS overestimates water vapor contents compared to ground based **AERONET** measurements for all the months.

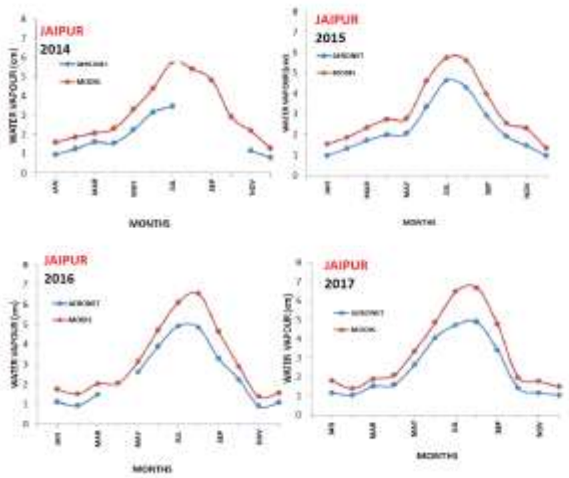

Fig. D (a): Monthly mean variation of MODIS and AERONET water vapor for Jaipur during the years 2014-2017.

The above figure shows monthly mean of AERONET vapor data varies over wide range at Jaipur as (0.8-3.4 cm) for 2014, (0.9-4.6 cm) for 2015, (0.9-4.9 cm) for 2016 and (1.0-4.8 cm) for 2017 while for MODIS, variation occurs in the range as (1.2-5.7 cm) for 2014 and 2015, (1.5-6.5 cm) for

2016 and (1.3-6.6 cm) for 2017. There was good rainfall over Jaipur for the year 2016 and 2017 as compared to 2014 and 2015.

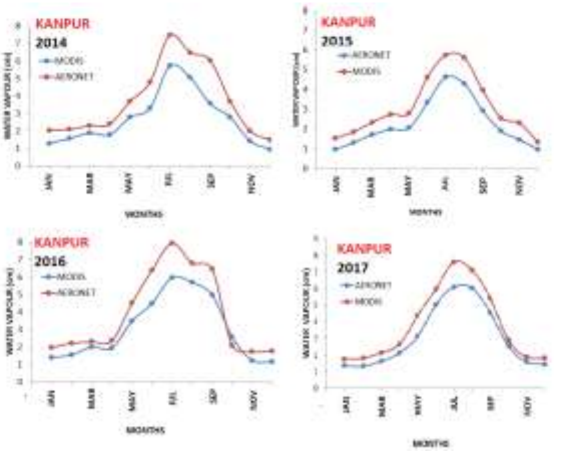

Fig. D (b):Monthly mean variation of MODIS and AERONET water vapor for Kanpur during the years 2014-2017

It is clear from the above figure D (b) that the monthly mean of AERONET water vapor over Kanpur varies from (0.9-5.0 cm) for 2014, (1.2-5.4 cm) for 2015, (1.1-5.9 cm) for 2016 and (1.3-6.0 cm) for 2017. This shows good precipitation for the year 2007 over Kanpur city. Similarly, For MODIS variation occurs in the range of (1.4-6.4 cm) for 2014, (1.7-6.9 cm) for 2015, (1.7-6.7 cm) for 2016 and (1.7-7.5 cm) for 2017.

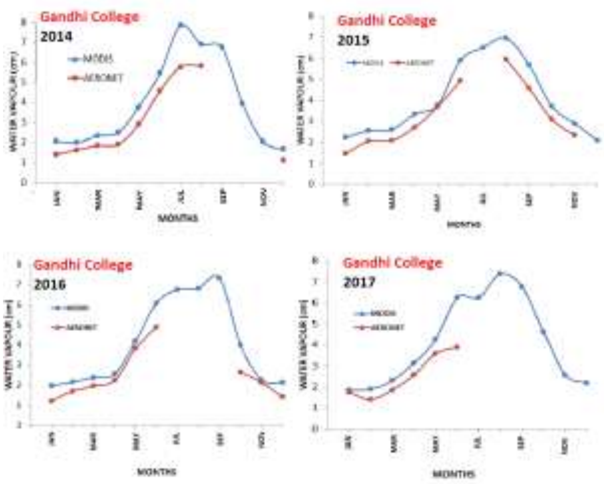

Fig. D (c): Monthly mean variation of MODIS and AERONET water vapor for Gandhi College during the years 2014-2017

For Gandhi College, the monthly mean variation of AERONET data is found to be in the range of (1.1-5.8 cm) for 2014, (1.4-5.9 cm) for 2015, (1.2-4.8 cm) for 2016 and (1.4-3.8 cm) for 2017 while MODIS data varies in the range of (1.6-7.8 cm), (1.0-6.5 cm), (1.9-6.8 cm), (1.8-7.3) for 2014, 2015, 2016 and 2017 respectively.

E. Seasonal Correlation of AERONET and MODIS derived Water Vapor over Indo-Gangetic Basin for 2014-17:

Seasonal correlation is a single value that helps us to interpret the degree of relation between two variables. Correlation between Ground and Satellite data of Seasonal fraction over all three stations has been obtained and analyzed. The figure E (a) shows seasonal correlation for Gandhi College during 2014-2017. There is **good** correlation between MODIS and AERONET data during post-**monsoon season**, having correlation coefficient 0.89. **Pre-monsoon season** also has a **higher** correlation coefficient value of 0.87. A good correlation helps us to validate satellite data.

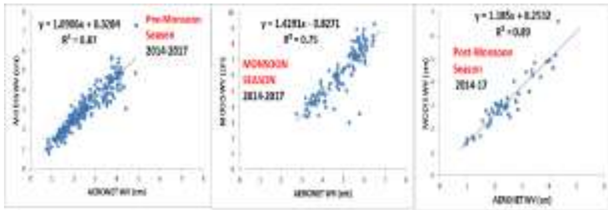

Fig. E (a): Seasonal correlation for Gandhi College for overall period from 2014-2017.

There is also quite good correlation between MODIS and AERONET data for POST-MONSOON which has value of correlation coefficient of 0.93. While for MONSOON, the value is still lowest i.e. 0.76 which are clearly shown in the figure E (b) given below:

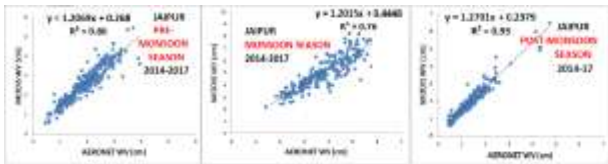

Fig. E (b): Seasonal correlation for Jaipur for overall period from 2014-2017.

The figure E (c) below shows relatively the poor correlation between MODIS and AERONET data for Kanpur for all the three seasons. However, the value of correlation coefficient is still **highest** for **Post-Monsoon** period, but **lowest** for **Pre-Monsoon** period. There is no significant difference among all the three seasons.

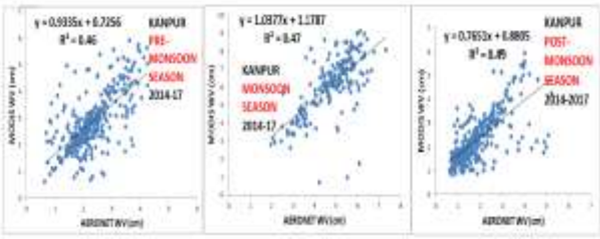

Fig. 5.8 (c): seasonal correlation for Kanpur for overall period from 2014-2017.

F. Comparison of MODIS derived Water Vapor Content with TRMM derived Rainfall data:

The variation in total annual rainfall in millimeters per day as recorded by NASAs Tropical Rainfall Measuring Mission (TRMM) satellite during the years 2014-2017 at all the three stations Gandhi College, Kanpur and Jaipur are shown in lower panel of Fig. F. The high peak shows the high rainfall during monsoon months.

The water vapor variations in centimeters per day in the column of air between the surface and the top of the atmosphere are also shown in the upper panel of Fig. 5.9during the years 2014-2017 at all the three stations Gandhi College, Kanpur and Jaipur. The high peak shows the maximum water vapor content during the **monsoon** season upto 9.3 cm usually 3rd week of June or 1st week of July for all the three stations and it is **minimum** in the **post-monsoon season** in the range of (0.2-0.9) cm.

The all plots clearly show that in general, the variation in rainfall pattern lies parallel with the variation in water vapor column. It has been found that when there is high concentration of water vapor column in the atmosphere then the precipitation rate is also quite high.

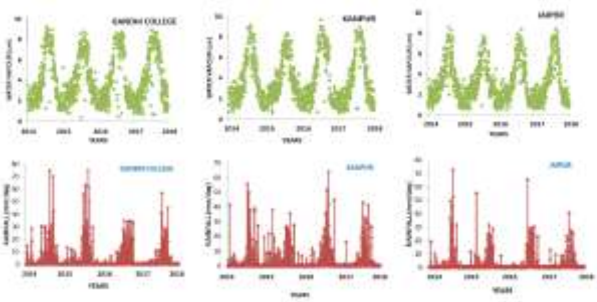

Fig. F: MODIS derived column water vapor contents and TRMM derived rainfall data for all the three locations during the years 2014-2017.

G. Correlation between total column of Water Vapor and Surface Temperature over Indo-Gangetic plains:

The figure G given below shows that there is **no linear relationship** between Surface Temperature and Water Vapor Content as the value of Correlation Coefficient is quite low for all the three places of Indo-Gangetic basin. However, there is positive relationship between Temperature and Water Vapor i.e. polynomial of degree 2. In fact, generally, there is positive feedback as the temperature rises, the evaporation rate increases and thus, water vapor in the atmosphere rises.

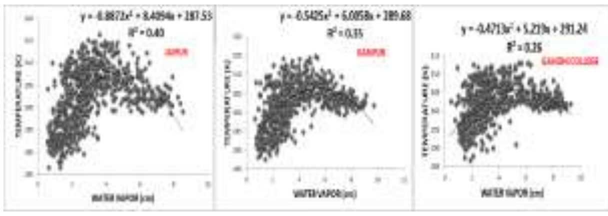

Fig. G: The correlation plot for the three cities shows polynomial relationship having degree 2 between MODIS derived vapor column and AIRS derived Temperature data.

H. Comparison of MODIS derived Water Vapor Content with AIRS derived Surface Temperature

The graphs showed in fig. H below compare daytime land surface Temperatures in the particular months to the Water Vapor Column in the atmosphere over **Gandhi College, Jaipur, Kanpur** respectively during the years **2014-2017.**For Surface Temperature, the data available is only up to September, 2016. The observations were collected by the **Atmospheric Infrared Sounder** (AIRS) aboard on NASA's Aqua satellite.

The water vapor graph shows the total amount of water vapor in the column of air between the surface and the top of the atmosphere on average for the month. The observations were made by the MODIS sensor on NASA's Aqua satellite.

On Comparing, we get the positive relationship between temperature and water vapor column. However, the exact relationship hasn't been found yet. Clearly, the variation shows similar trends for all the three locations when compared with MODIS water vapor variations. Therefore, we can say that the total water vapor column is very much dependent on surface temperature and rainfall. The knowledge about the spatial and temporal variability of water vapor is important in understanding the monsoon variability, weather conditions, thermodynamics of the atmosphere and climatic processes (Prasad et.al, 2007).

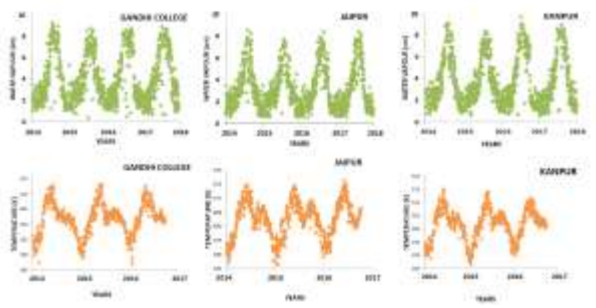

Fig. H: the graphs plotted show similar trend for all the three places between MODIS derived Water Vapor column and AIRS derived Surface Temperature data i.e. the higher the vapor concentration, the greater will be the temperature.

In fact, numerous efforts have been made to study the variability of water vapor using GPS, AERONET and satellite data. Singh et al. (2004) have shown weekly pattern of perceptible water vapor deduced from (SSM/I) satellite over oceanic regions of India. Prasad et al. (2007) have made comparison of GPS and MODIS water vapor over India during the year 2004 and 2005 and have found correlation more than 0.95. During the pre-monsoon season, enhancement in water vapor value is found due to dust storms which are clearly observed in water vapor value derived from GPS over Kanpur and Varanasi (Prasad et al., 2007). Prasad and Singh (2009) have discussed a comparison of hourly estimates of total column water vapor from GPS with multi- sensor satellite data over three stations in India. Kumar & Singh (2010) has studied annual variability of water vapor using GPS & MODIS data over Indo-Gangetic Plains for year 2007-08. The correlation between monthly mean GPS water vapor and TRMM rainfall is found to be 0.94 for VNS and 0.85 for IITK that shows good agreement between GPS water vapor and rainfall. The correlation between GPS water vapor and ground observed surface temperature is found to be 0.71 over VNS.

The above discussions show that our water vapor results presented in this study are in good agreements with other published results over Indo-Gangetic basin.

SUMMARY:

The following results are observed from the study:

1. The water vapor retrieved from AERONET is found to be highly correlated with satellite observation (MODIS) which has wide spatial coverage as seen over Indian subcontinent. A high correlation shows accuracy for ground-based measurement.

2. Annual variability of total water vapor column shows increasing trend and achieves maximum and then decreasing trend. This is same for both ground and satellite data. However, water vapor column has higher values for Satellite data (MODIS) than ground data (AERONET).

3. This happens because satellite takes measurements at quite far distant from the atmosphere and thus, there are more chances of fluctuations due to clouds formations, dust storms, other layers etc.

4. The annual correlation values show there is good relationship between ground and satellite-based measurements. Some experience is better than other's.

5. The Monthly mean variation trends show that from JUNE to SEPTEMBER there is high peak curve which shows the higher concentration of water vapor in the atmosphere.

6. The Seasonal variations also get derived from the monthly mean variation plot i.e. Monsoon season is rich in water vapor while pre-monsoon and post-monsoon period remain dry.

7. The Seasonal Correlation values help us to interpret the degree of relation between the two variables i.e. MODIS and AERONET for three seasons- Pre-Monsoon, Monsoon, Post-Monsoon period.

8. The correlation coefficient is higher for post-monsoon period. While for monsoon there is poor relationship between MODIS and Ground data. There are large fluctuations in these two values.

9. For the monsoon season of Gandhi College and Jaipur, there is unavailability of ground data due to some reasons.

10. Jaipur has the best value of correlation coefficient during three seasons, while, Kanpur has the worst value of correlation coefficient during all the seasons.

11. The column water derived from satellite is found to be very sensitive with surface temperature, monsoon onset and rainfall. There are similar trends between water vapor content and precipitation value. With the onset of monsoon, there was enhancement of water vapor column in the atmosphere.

12. There is positive feedback between Surface Temperature and Water Vapor availability.

13. However, there is no linear relationship between Surface Temperature and Water Vapor Column in the atmosphere as the

correlation coefficient is quite low but shows polynomial relationship of degree 2.

14. Therefore, the variation between AIRS obtained Temperature data and MODIS obtained Water Vapor data shows similar trend for three locations-JAIPUR, GANDHI COLLEGE & KANPUR.

ACKNOWLEDGEMENT:

It is a great pleasure for me to pay profound gratitude and thanks to my supervisor **Prof. Abhay Kr. Singh,** Atmospheric Research Lab, Department of Physics, BHU for giving me the opportunity to work in this esteemed department under his supervision.

I am deeply thankful to **Mr. Akhilesh Kumar,** Research Scholar, Department of Physics, BHU, for his constant encouragement and suggestions with dedication in teaching me the techniques

REFERENCES:

Gao, B.C., and Y. J. Kaufman (2003), Water vapor retrievals using Moderate Resolution Imaging Spectroradiometer (MODIS) near-infrared channels, *J. Geophys. Res.*, 108(D13), 4389,

Prasad, A. K., R. P. Singh, A. Singh, and M. Kafatos (2005b), Seasonal variability of aerosol optical depth over Indian subcontinent,, Analysis of Multi-Temporal Remote Sensing Images, 2005

Ramanathan, V., P. J. Crutzen, J. T. Kiehl, and D. Rosenfeld (2001), Aerosols, climate, and the hydrologic cycle, *Science*, 294, 2119–2124.

Singh, R. P., S. Dey, S. N. Tripathi, V. Tare, and B. Holben (2004), Variability of aerosol parameters over Kanpur, northern India, *J. Geophys. Res.*, 109,

Kumar Sanjay, Singh, A.K., Prasad, A.K., Singh, R.P. (2007), Annual variability of water vapor from GPS & MODIS data over Indo-Gangetic Plains,

Prasad, A. K., R. P. Singh, and M. Kafatos (2006), Influence of coal based thermal power plants on aerosol optical properties in the Indo-Gangetic basin, *Geophys. Res. Lett.*, 33, L05805,

Alexander, L. V., et al. (2006), Global observed changes in daily climate extremes of temperature and precipitation, *J. Geophys. Res.*, 111,

Intergovernmental Panel on Climate Change (IPCC) (20012), Climate Change 2012: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, edited by S. Solomon et al., Cambridge Univ. Press, Cambridge, U. K.

D.A Chu, Y.J Kaufman, C Ichoku, L Remer, D Tanre, B.N Holben Validation of the MODIS aerosol retrieval over land Geophys. Res. Lett., 29 (12) (2002), pp. 1-4

B.N Holben, T.F Eck, I Slutsker, D Tanre, J.P Buis, A Setzer, E Vermote, J.A Reagan, Y Kaufman, T Nakajima, F Lavenu, I Jankowiak, A Smirnov AERONET—a federated instrument network and data archive for aerosol characterization Remote Sensing of Environment, 66 (1998), pp. 1-16

M.E James, S.N.V Kalluri The Pathfinder AVHRR land data set—an improved coarse resolution data set for terrestrial monitoring International Journal of Remote Sensing, 15 (17) (1994), pp. 3347-3363

Y.J Kaufman, D Tanre, L.A Remer, E.F Vermote, A Chu, B.N Holben Operational remote sensing of tropospheric aerosol over land from EOS moderate resolution imaging spectroradiometer Journal of Geophysical Research -Atmosphere, 102 (D14) (1997), pp. 17051-17067

H Ouaidrari, E.F Vermote Operational atmospheric correction of Landsat TM data Remote Sensing of Environment, 70 (1) (1999), pp. 4-15

F Petitcolin, E Vermote L and surface reflectance, emissivity and temperature from MODIS middle and thermal infrared data Remote Sensing of Environment, 83 (2002), pp. 112-134 this issue

C.J Tucker, J.A Gatlin, S.R Schneider Monitoring vegetation in the Nile delta with NOAA-6 and NOAA-7 AVHRR imagery Photogrammetric Engineering and Remote Sensing, 50 (1) (1984), pp. 53-61

R.N. Halthore, T.F. Eck, B.L. Markham, B.N. Holben Sunphotometric measurements of atmospheric water vapor column abundance in the 940-nm bandJ. Geophys. Res., 102 (1997), pp. 4343-4352

J.E. Hansen, A.A. Lacis Sun and dust versus greenhouse gases: an assessment of their relative roles in global climate change Nature, 346 (1990), pp. 713-719

Corresponding Author

Shivani Mridula*

M.Sc. Environmental Science / UGC-NET, Banaras Hindu University