MODEL FOR IDENTIFICATION OF SEASONAL AEROSOLS WITHIN THE ENVIRONMENT FOR A PARTICULAR REGION USING REMOTE SENSING DATA

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ABSTRACT

Remote sensing methods for the understanding of physical phenomena has been used since the last 50 years. Satellite-based sensors and ground-based sun photometers provide quantitative and qualitative knowledge about the composition of different elements that exists within the atmosphere of the Earth. One of the current tasks relates to understanding the changes of the climate on different regions throughout the planet, where a particular problem is related to aerosol climate forcing. Improvement in measurement-based systems is necessary to identify remaining issues and improve quantification of aerosol effects on climate. Also the improvement in modeling is necessary to confidently extend estimates of forcing to prior times and to project future emissions. Achieving these capabilities will require a synergistic approach between observational systems and modeling. This paper describes how the study and analysis of satellite-based and ground-based measurements can be used to develop an innovative method, based in the existent methods to calculate some optical properties that will help in characterization of dominant temporal aerosols.

1. INTRODUCTION

Aerosols are minute which particles can be solid or liquid and suspended in the atmosphere, they have a short life on the troposphere, and can live long periods while travelling long distances at the top of the atmosphere. This is the main reason of its difficulty for them studying and understanding them, because each particle is totally unique. They have their own properties of change, size and composition, and play an important role in climate changing. The main natural sources of aerosols came from desert dust, wildfire smoke and sea salt particles [1]. The anthropogenic aerosols arising mainly from a variety of combustion sources (e.g. "smog") produced from sources like manufacturing, farming, and transportation among others.

In the last decades, researchers have identified and classified different types of aerosols, and investigated their spatial and temporal distribution. It is important to comprehend how aerosols affect the energy budget by scattering and absorbing radiation (direct effect).

The direct absorption of radiant energy by aerosols leads to heating of the troposphere and cooling of the surface, which can change the relative humidity and atmospheric stability, thereby influencing the clouds and precipitation (semi-direct effect) [2].

To gain this understanding, data records obtained from remote sensing measurements from two spaceborne systems and a multiangle imaging spectroradiometer are used. Moreover, data from the ground-based sun photometer instruments was used as well.

All the data is processed using mathematical models that are based on previously developed algorithms [3], and are used to understand the seasonal identification and behavior of the aerosol that are present throughout the Metropolitan Area of the city of Guadalajara (MAG) in Mexico.

2. AEROSOLS OPTICAL THICKNESS

Data records of aerosols optical thickness (AOT) are used in this study, for a period of time between March 2009 and December 2010, from the Sea-Viewing-Wide-Field-of view Sensor (SeaWiFS). The objective of the instrument carried in this mission (from 1997 thru 2010) was to create datasets by combining the long-running well-calibrated radiance data and a consistent algorithm to retrieve aerosol properties over the land and ocean. All the measurements information related to the MAG were obtained from references [4] and [5]. This time range of data was selected due to the availability of the information, and because there were datasets for all the months within that time range. Moreover, data related to AOT are provided by the Moderate Resolution Imaging Spectrometer (MODIS) and the Multiangle Imaging Spectroradiometer (MISR), both for the same period of time than SeaWiFS.

The instruments showed similar spatial and seasonal distributions of AOT, and it was the main reason to use the information about the results obtained from the analysis of these instruments, because those records are suitable for quantitative and scientific use. All this data is the basis for the development of the proposed methodology (based in existent methods) to calculate some optical properties that will help the process and mathematical characterization of the dominant aerosol types that are present within MAG.

	December 2009		January 2010		February 2010		March 2010	
Latitude 22.75	2.30E-02	2.10E-02	0.023	0.02	0.02	0.028	0.021	0.02
Latitude 22.25	2.60E-02	NaN	0.02	0.02	0.022	NaN	0.021	0.023

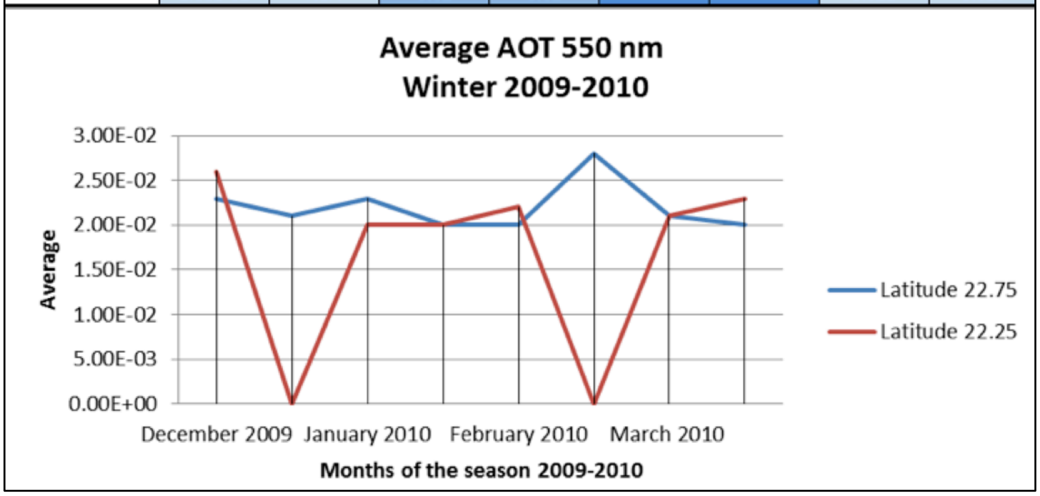


Figure 1. Average AOT estimated at 550nm over land during the winter of 2009-2010.

3. THE ANGSTRÖM EXPONENT

The Angström Exponent (AE) is used to describe the dependency of the AOT on wavelength, and provides some information regarding the size distribution of the particles.

The AE is mathematically defined by:

$$\alpha = \frac{ln\left(\frac{\tau_2}{\tau_1}\right)}{ln\left(\frac{\lambda_1}{\lambda_2}\right)} \quad (1)$$

where α is the AE, τ is the AOT, and λ represents the wavelength of the incident light.

The AE is inversely related to the average size of the particles present within the aerosol, this is, the smaller the particles, then the value of the exponent will be larger. Therefore, the AE is very useful to assess the particle size of atmospheric aerosols, and the wavelength dependence of their optical properties.

4. AEROSOLS OPTICAL THICKNESS

The AOT is the degree to which aerosols prevent the transmission of light by the absorption or scattering of light. Its study and application covers several areas, including atmospheric correction of remotely sensed surface features, monitoring of sources and sinks of aerosols, monitoring of volcanic eruptions and forest fire, radiative transfer models, air quality, health and environmental studies, Earth radiation budget, climate change, among others.

The calculation of AOT is mathematically defined by:

$$\tau_{\lambda A} = \frac{ln\left(\frac{V_0}{R^2}\right) - ln(V - V_{dark}) - a_R\left(\frac{p}{p_0}\right)m}{m} \quad (2)$$

where $\tau_{\lambda A}$ is the AOT made by the aerosols, V_0 is the calibration constant of the sun photometer, R is the distance between the Earth and the Sun expressed in astronomical units $[AU]$, p is the barometric pressure, p_0 is the standard sea level atmospheric pressure (1,013.25 millibars), m is the relative air mass, and a_R is the contribution to optical thickness of the molecular Raleigh scattering of light in the atmosphere.

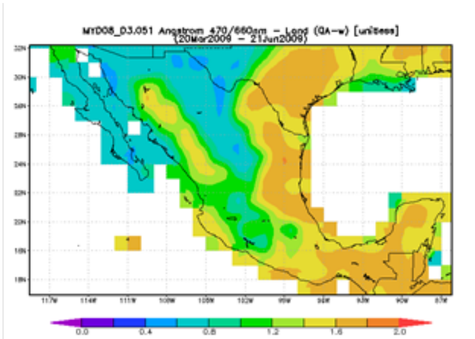
For the red channel, a_R is about 0.05793 and for the green channel a_G is about 0.13813.

The determination of transmission of the aerosols in percentage, also called solar intensity, is calculated expressing the percent of sunlight at a particular wavelength as described by:

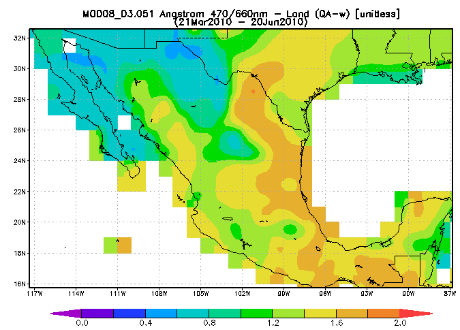
$$\%Transmision = 100e^{-\tau} \quad (3)$$

5. RESULTS AND DISCUSSION

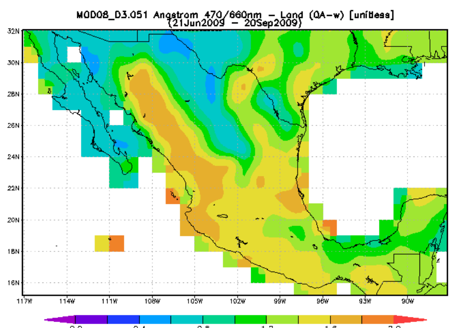
Data records of AOT were retrieved from the SeaWiFS portal instrument for the period of time between March 2009 and December 2010. As a sample of this information, Figure 1 shows a two-dimensional plot of the average AOT during the winter 2009-2010. During the month of December, the complete data was taken from latitude 22.75 and it had a maximum point of 2.60E-02.



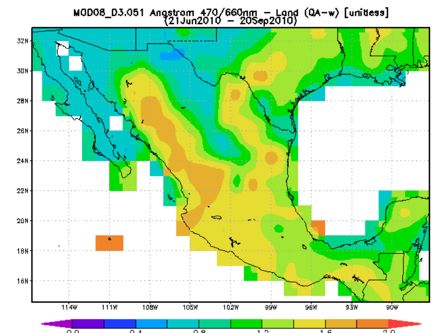
a. Angström exponent for Spring 2009, oscillating between 1.2 and 1.4 for MAG.



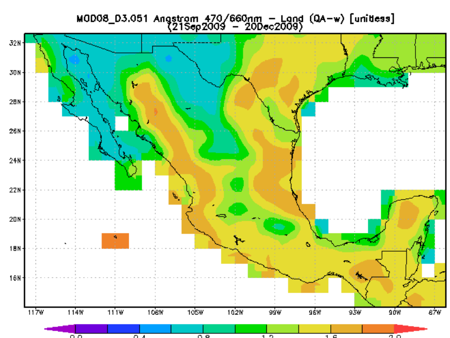
b. Angström exponent for Spring 2010, oscillating between 1.1 and 1.2 for MAG.



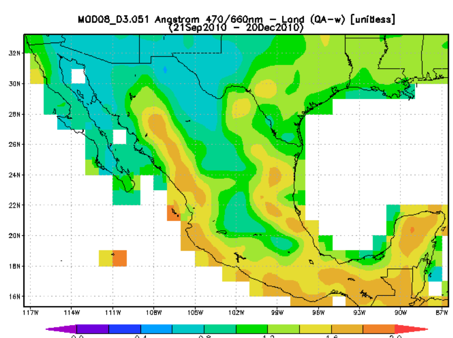
c. Angström exponent for Summer 2009, oscillating between 1.4 and 1.6 for MAG.



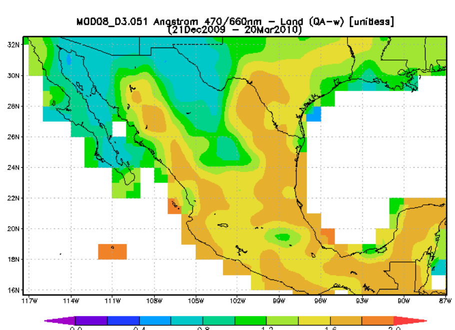
d. Angström exponent for Summer 2010, oscillating between 1.4 and 1.6 for MAG.



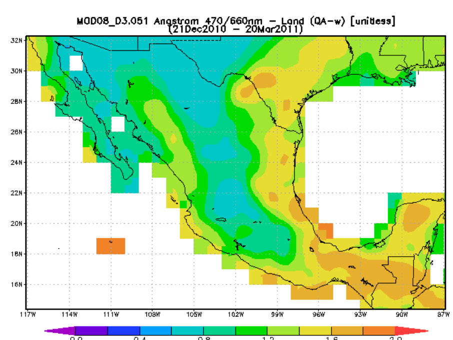
e. Angström exponent for Fall 2009, oscillating between 1.4 and 1.6 for MAG.



f. Angström exponent for Fall 2010, oscillating between 1.2 and 1.6 for MAG.



g. Angström exponent for Winter 2009, oscillating between 1.6 and 2.0 for MAG.



h. Angström exponent for Winter 2010, oscillating between 0.8 and 1.2 for MAG.

Figure 2. Angström exponent taken by seasons from December 2008 to December 2010 for the MAG.

Subsequently in January it is possible to identify a maximum point of 2.30E-02. During February the biggest measurement is 2.08E-02, and the values of the latitude 22.25 are not complete. March have a complete measurements from both latitudes where the maximum point was 2.30E-02.

With the information collected from SeaWiFS is possible to identify that the temporal AOT varies with respect of the season. The spring seasons of 2009-2010 had shown a small value of AOT, between 0.0325 and 0.0305. During both summers of 2009 and 2010 there are not existing data recorded, and the reason is that the rain season was present at MAG. During the fall of 2009 there is only data for November and December and the mean average value is 0.023. Comparing with the fall of 2010 is possible to observe a lower value 0.0215. During November and December, the AOT increased to 0.03. Finally, the winter seasons of 2008-2009 and 2009-2010 showed that the mean average optical thickness is 0.029 in comparison with the winter 2019-2010 that is 0.237. This is, a bigger AOT during the spring and winter in the region. The AOT have values between 0 and 1, therefore, the data recovered indicates a low concentration of aerosols.

Figure 2 shows different two-dimensional plots of the AE taken by seasons, from December 2008 to December 2010, and retrieved from the GIOVANNI portal for the TERRA-MODIS instrument [5].

The AE is typically defined as the relationship between aerosol optical extinction and wavelength, therefore, there is a relationship between the AE and the size distribution of the aerosols. As is was previously described, larger particles have a lower AE, and vice versa, this is because larger particles tend to be spectrally flat.

From figure 2.a until 2.h, the images are distributed in a vertical position by seasons in order to compare both seasons in two different years (2009 and 2010).

Finally, the AE provides the information related to size distribution of the aerosols using the TERRA-MODIS instrument, and describes that there are larger particles in the metropolitan zone of MAG.

6. CONCLUDING REMARKS

The results of this research provide a quantifiable knowledge about the temporal and regional optical properties of the existing aerosols in and around the metropolitan zone of MAG.

The presented analysis is a tool to identify the dominant aerosol size distribution, compute the AOT at different wavelength, and the aerosols effect on the radiation budget of the Earth for the specified region. In addition, these results will be the basis for future research related to environmental and atmospheric processes for any geographical zone worldwide.

Moreover, the quantifiable knowledge about the temporal and regional optical properties of the aerosols will contribute to future research related to their quantitative effects on atmospheric processes in the metropolitan zone of MAG. These effects include the alteration of weather, climate system change, variation of the tropospheric temperature, contribution to environmental ills, the formation and properties of the clouds, alteration on the ecosystems, local solar energy balance, and the impacts on human health among others.

7. ACKNOWLEDGEMENT

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8. REFERENCES

[1] T. M. Lilliesand and R. K. Kiefer, *Remote Sensing and Image Interpretation,* John Wiley & Sons, U.S.A., 2008.

[2] B. N. Holben, "An emerging ground-based aerosol climatology: Aerosol Optical Depth from AERONET", *Journal of Geophysical Research*, vol. 106, pp. 12067-12097, 2012.

[3] M. I. Mishchenko, "Monitoring of aerosol forcing of climate from space: analysis of measurement requirements", *Journal of Quantitative Spectroscopy and Radiative Transfer*, vol. 88, pp. 149-161, 2004.

[4] NASA Cloud-Aerosol Lidar and Infrared Pathfinder CALIPSO, http://www.nasa.gov/mission_pages/calipso, 2016.

[5] Angström Exponent Data from GIOVANNI System, http://gdata1.sci.gsfc.nasa.gov, 2016.