SATELLITE MEASUREMENTS OF THE ANGSTROM EXPONENT USING AN INNOVATIVE MATHEMATICAL METHOD TO IDENTIFY SEASONAL AEROSOLS

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ABSTRACT

The remote sensing methods for understanding physical phenomena are being used since the last 50 years. Satellite-based sensors and ground-based sun photometers provides quantitative and qualitative knowledge about the composition of elements within the Earth's atmosphere. One actual problem is the changes on the climate of different regions of the Earth; one of them 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 the dominant temporal aerosols found in and around the city of Guadalajara in Mexico, based on previous algorithms. The quantifiable knowledge about the temporal and regional aerosols' optical properties will contribute to future investigations related to their quantitative effects on atmospheric processes in this region.

Index Terms — Satellite Measurements, Photometry, Remote Sensing, Seasonal Aerosols, Angstrom Exponent

1. INTRODUCTION

The aerosols are minute particles can be solid or liquid, suspended in the atmosphere, they have a short life on the troposphere, they can live long periods and travel long distances at the top of the atmosphere. It is the reason of why they are difficult to study and understand because each particle is unique. They have their own properties of change, size and composition. They play a mysterious and important role in the climate change. Aerosols principal natural sources are coming from: desert dust, wildfire smoke and sea salt particles [1]. The anthropogenic aerosols arising mainly from a variety of combustion sources (e.g. “smog”) like: manufacturing, farming, and transportation.

In the last 3 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 Earth's 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 (SeaWifis and MODIS-Terra) and Multiangle Imaging Spectroradiometer (MISR) 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], which are intended to use to improve and understand the seasonal aerosol's behavior in the Metropolitan Area of Guadalajara (MAG) in Mexico.

2. VERIFICATION PROTOCOLS

Data records of aerosols optical thickness (AOT) are used; from the period of time between March 2009 and December 2010, from the Sea-Viewing-Wide-Field-of view Sensor (SeaWiFS). The mission of this instrument (1997-2010) was to create a data set 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 was obtained from [4] and [5]. Moreover, data related to AOT is provided the Moderate Resolution Imaging Spectrometer (MODIS) and Multiangle Imaging Spectroradiometer (MISR), from the same period of time. The instruments displayed very similar spatial and seasonal distributions of AOT. It was the reason why it was decided to use the information about the results of these satellites instruments because those records are suitable for quantitative scientific use. This information will be the basis for the development of the innovative method, based in the existent methods to calculate some optical properties that will help to characterization of the dominant aerosol types of the MAG.

3. AEROSOLS OPTICAL THICKNESS

Data records of AOT were retrieved from the SeaWiFS portal instrument for the period of time between March 2009 and December 2010. The Figure 1 shows a two-dimensional plot of the average AOT during the winter 2009-2010 (as a sample). During December the complete data were taken from latitude 22.75 and it had a maximum point of 2.60E-02. 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 the season. The spring seasons of 2009-2010 had shown a small value of AOT, between 0.0325 and 0.0305. During both summer of 2009 and 2010 did not exist data files, the reason is that the rain season was present at MAG. During the fall 2009 exist only data file of the Months of 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 increase to 0.03. Finally the winter seasons on seasons 2008-2009 and 2009-2010 that the mean average optical thickness is 0.029 in comparison with the winter 2019-2010 that is 0.237. The information shows a bigger AOT during the spring and winter in the region. The AOT have values between 0 and 1, using this scale the data recovered indicates a low concentration of aerosols.

The measurements done with the MIMS Sun Photometer were taken from November 2010 to March 2012, were only suitable for calculating the AOT on the MAG from the surface.

The calculations for AOT are determined by the following equation:

$$\tau_{\lambda A} = \frac{[\ln(V_o / R^2) - \ln(V - V_{dark}) - a_R(p/p_o)m]}{m} \qquad (1)$$

Where $\tau_{\lambda A}$ is the AOT made by aerosols, V_o is the calibration constant of MIMS Sun Photometer, R is the Earth-Sun distance expressed in astronomical units $\left[AU\right]$, a_R is the contribution to optical thickness of 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, p is the barometric pressure, p_o is the standard sea level atmospheric pressure (1013.25 millibars), and m is the relative air mass.

	Aerosol optical thickness estimated at 550 nm over land							
	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

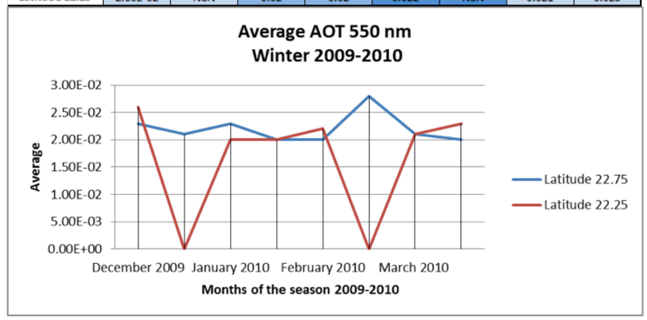


Figure 1. Average AOT during Winter (2009-2010).

The calculation of aerosol's percent transmission "Solar Intensity" are calculated expressing the percent of sunlight at a particular wavelength as follows:

$$\%\, Transmission = 100 e^{-\tau} \qquad (2)$$

4. THE ANGSTROM EXPONENT

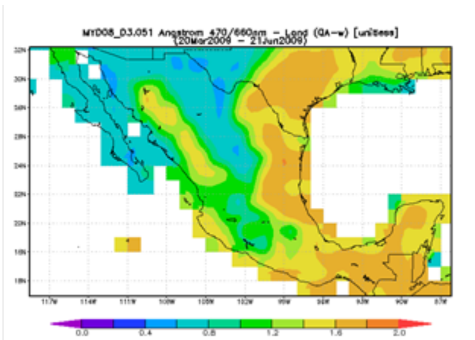
The Angstrom Coefficient provides some information regarding the size distribution of the particles, and it is defined by:

$$\alpha = \frac{\ln(\tau_2 \div \tau_1)}{\ln(\lambda_1 \div \lambda_2)} \qquad (3)$$

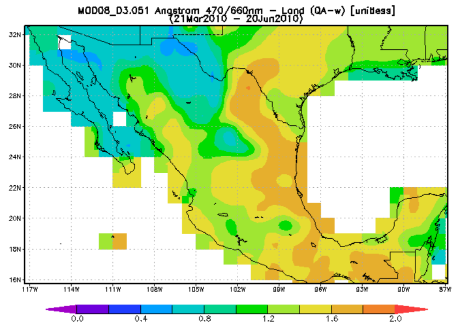
Where α is the Angstrom Coefficient, τ is the AOT, and λ is the wavelength of incident light.

Figure 2 shows different two-dimensional plots of the Angstrom exponent taken by seasons from December 2008 to December 2010, retrieved from the GIOVANNI portal for the TERRA-MODIS instrument. The Angstrom exponent is typically defined as the relationship between aerosol optical extinction and wavelength. There is a relationship between the Angstrom exponent and the size distribution of the aerosols. Usually, larger particles have a lower Angstrom exponent, and vice versa. This is because larger particles tend to be spectrally flat. The figures are distributed in a vertical position by seasons in order to compare both seasons in two different years (2009 and 2010).

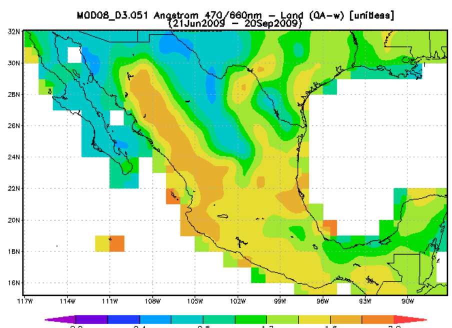
The Angstrom exponent give us the information related to size distribution of the aerosols using the TERRA-MODIS instrument, and describes that there are larger particles in the MAG. Figure 3 shows different plots from the Earth and distributed in a horizontal position in order to compare the same season in two different years (2009 and 2010).



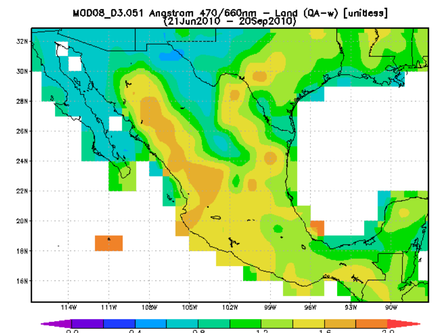
(a) Angstrom Exponent for Spring 2009, oscillating between 1.2 and 1.4 for the MAG.



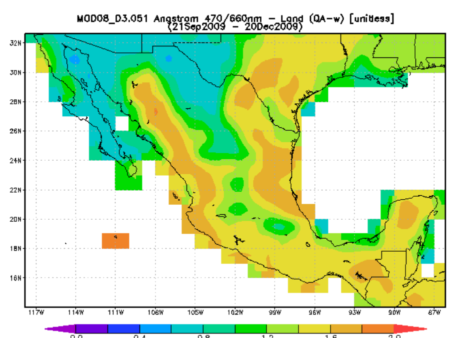
(b) Angstrom Exponent for Spring 2010, oscillating between 1.1 and 1.2 for the MAG.



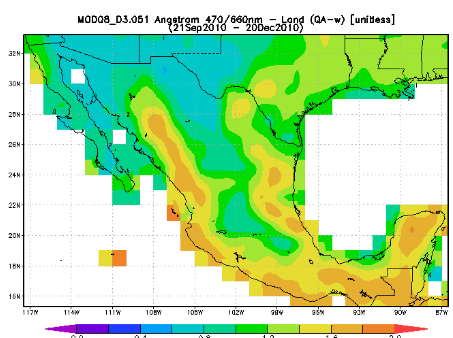
(c) Angstrom Exponent for Summer 2009, oscillating between 1.4 and 1.6 for the MAG.



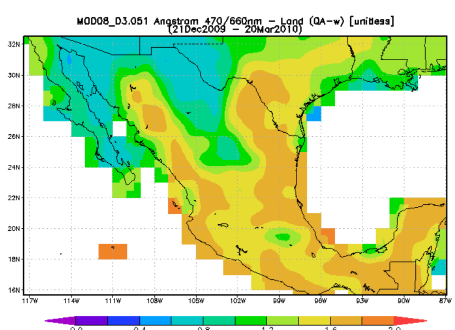
(d) Angstrom Exponent for Summer 2010, oscillating between 1.4 and 1.6 for the MAG.



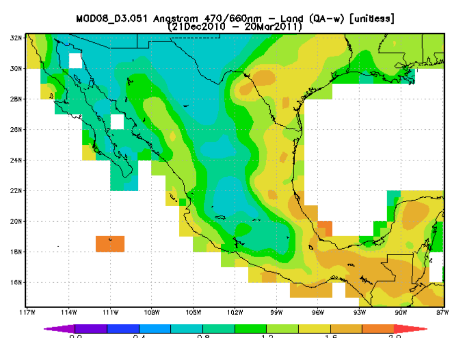
(e) Angstrom Exponent for Fall 2009, oscillating between 1.4 and 1.6 for the MAG.



(f) Angstrom Exponent for Fall 2010, oscillating between 1.2 and 1.6 for the MAG.



(g) Angstrom Exponent for Winter 2009, oscillating between 1.6 and 2.0 for the MAG.



(h) Angstrom Exponent for Winter 2010, oscillating between 0.8 and 1.2 for the MAG.

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

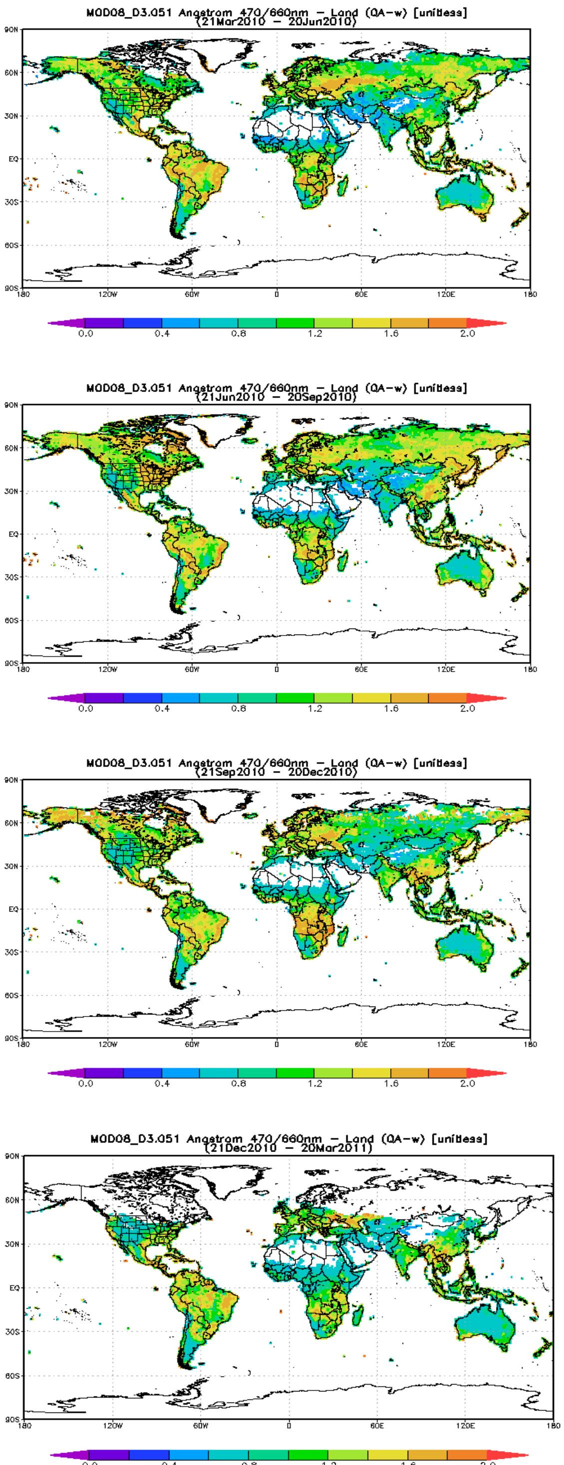


Figure 3. Angstrom exponent taken by seasons from December 2008 to December 2010 for the Earth.

5. CONCLUDING REMARKS

The results of this research provide a quantifiable knowledge about the temporal and regional aerosols' optical properties existing in and around the MAG. The analysis is a novel tool to identify the dominant aerosol size distribution, compute the AOT at different wavelength, and the aerosols effect on the earth radiation budget of the region. In addition, these results will be the support of future investigations related to environmental and atmospheric processes for any geographical zone.

The quantifiable knowledge about the temporal and regional aerosols' optical properties will contribute to future investigations related to their quantitative effects on atmospheric processes in the MAG. These effects include: 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.

6. ACKNOWLEDGMENT

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