Research and Teaching approach to Environmental Studies

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Abstract: The GLOBE program was used to design an interactive Earth Science course for pre-service teachers. The main component of the course was a research project in which students used a handheld sun photometer to measure aerosol optical thickness of the atmosphere at a study site on campus. Results indicated that pre-service teachers valued their experiences in the class and were more confident in their ability to teach Earth sciences at the high school level.

1. Introduction: In the K-12 school system, many courses with interdisciplinary titles such as environmental science are taught by teachers with little formal training in the Earth sciences. To bridge this gap, in collaboration with the Education department, faculty from the department of Physics and Computer Science used GLOBE to design an interactive atmospheric aerosol research project for pre-service teachers. The focal point of this research project was to guide pre-service teachers in deepening their understanding of environmental concepts and to engage students in inquiry-based learning, which ultimately would help the pre-service teachers to make learning more meaningful to students in their classrooms.   Students used an inexpensive handheld sun photometer to measure atmospheric aerosols at a designated study site on campus. The handheld sun photometer is an ideal instrument for both the teaching of atmospheric science courses and for use in a global aerosol monitoring network. The Global Learning and Observations to Benefit the Environment (GLOBE) program offers the potential for such a network, through thousands of schools in all the 50 states of the United States and nearly 120 other countries. The primary idea of the GLOBE program is to use students all over the world to provide scientifically valuable measurements of environmental parameters using inexpensive equipment. The data presented here represents an example of how pre-service students can be organized and motivated to take long and sustained atmospheric aerosol measurements. In this study, students used two GLOBE handheld sun photometers to track the annual, daily and hourly variation of the aerosol optical thickness (AOT) of the atmosphere at the campus study site. The data was collected by two teams of pre-service students using two independently calibrated sun photometers.

2.Background: Teacher training, whether pre-service or continuous professional development, is an essential element needed to introduce environmental education in the K-12 system [1,2]. Studies have shown that pre-service teachers avoid teaching earth science classes because their knowledge of environmental issues and their preparation to teach them are inadequate [2]. Other studies have shown that there are no significant differences in knowledge of environmental issues between high school students and the pre-service teachers [3]. It is for these reasons that we designed the Advanced Earth Science class at Xavier University of Louisiana and made it mandatory to all pre-service teachers. The Advanced Earth Science course incorporates GLOBE protocols in the curriculum. The course is designed to prepare students not only to teach Earth Science at the high school level, but to be enthusiastic and passionate about environmental issues. The course emphasizes on applying inquiry-based teaching approaches and on developing deep understanding of basic Earth Science concepts. Activities include discussions, interactive lectures, hands-on, and field-based experiences. During the semester, students review major content areas in Earth Science within the context of the GLOBE program. Contents of the GLOBE program are related to the National Science Standards and to the State Science Benchmarks. The four major areas covered are atmosphere, hydrology, soils, and land cover. In addition to in-class activities, the students collect real time atmospheric data such as air temperature, humidity, rainfall, cloud cover, atmospheric pressure and atmospheric aerosols daily during the semester. Students are organized to work in teams and as individuals to ensure that data is collected every day. An essential part of the GLOBE program is that the students perform measurements that are of research quality and record their findings in the GLOBE data base to be accessed by anybody. In any given week, students spend more time outside doing field work than they spend inside. This experiential learning had a great impact on the pre-service teachers and has greatly improved their enthusiasm for the subject [4,5]

An essential component of the Advanced Earth Science class is the research project. For the research project, students work in teams on a given atmospheric investigation. The general topic for the research project is to investigate atmospheric aerosols in New Orleans. The specific focus undertaken by the students in the past two semesters was to investigate the yearly, seasonal and daily variation of atmospheric aerosols at our study site using a handheld sun photometer [6-9]. By building a data record that extends across several seasons, we will learn more about the variation of aerosols at the XULA site. This investigation offered students the opportunity to learn the scientific method, analysis of scientific data, presentation of scientific results, and utilization of national databases to compare, compliment and analyze experimental results. But above all it gave them the confidence to teach Earth science at the high school level. This paper presents student data for a 12-months period from September 2017 to August 2018.

3. Site, Instrument and Method

3.1. Site and Meteorology

The City of New Orleans is located on the Mississippi river in southeastern Louisiana. New Orleans has a subtropical climate with very hot and humid summers and mild, short-lived winters. Summers in New Orleans are relatively long with high temperatures hovering around 90°F from June to September. In winter, from December to February, temperatures average between 44°F and 62°F. New Orleans experiences high annual rainfall, most of it falling in late summer to early winter.

Figure1: *A map of the state of Louisiana in USA showing the study site in New Orleans.*

3.2. Instrument and Method

A sun photometer is an electronic device that measures direct sunlight over a narrow range of wavelengths [10-13]. The GLOBE sun photometer has two channels, one of which is sensitive to green light at wavelength 505nm and the other to red light at wavelength 625nm. The GLOBE sun photometer is an LED-based sun photometer. LEDs with smaller full-width half-maximum (FWHM) bandwidths are preferred over wider bandwidths. The FWHM bandwidth used in GLOBE sun photometers is about 75nm. The two Globe sun photometers used in this investigation were purchased from IESRE (Institute for Earth Science Research and Education. One had serial # RG8-989 and the other had serial #RG8-990.

Figure 2: *The GLOBE handheld sun photometer. The GLOBE sun photometer has two channels, green light at wavelength 505nm and red light at wavelength 625nm.*

Figure 2 above shows the GLOBE sun photometer. It is housed in a plastic case about 15×8×5 cm. On the top and bottom of the case, there are two alignment brackets. In use, the instrument is pointed at the sun so that light passes through the hole in the top bracket and makes a bright spot that shines on a piece of paper covering the bottom bracket. The two LED detectors in the GLOBE sun photometer respond to red or green light. When sunlight strikes one of the LEDs, it produces a very small current which is then amplified and turned into an output voltage. The output voltage is what is measured. The output voltage is affected by the concentration of particles (aerosols) in the atmosphere. The higher the concentration of aerosols, the smaller the amount of sunlight reaching the detector, and the smaller the sun photometer's output voltage. The sun photometers were calibrated using the Langley plot method [14,,15]. The Langley calibration was done by the Institute for Earth Science Research and Education (IESRE). In general, the calibration constant V_0 values of the GLOBE sun photometers vary by about 0.8% over a 10-year period [14,15], hence we did not have to recalibrate our instrument during this one-year period.

Measurements of AOT were done every day when the weather conditions permit. The measurements were done by two teams of students using two different sun photometers. Sun photometer measurements can be interpreted properly only when the sun is not obscured by clouds. The presence of cirrus clouds in front of the sun affect sun photometer readings. Low- and mid-altitude clouds near the sun are easy to see, but cirrus clouds pose a problem. Measurements that were done when there were cirrus clouds within the vicinity of the sun were excluded in the analysis. Table #1 shows the number of days in each month that we had completely clear skies. Altogether, about 47% of the data taken was excluded.

Month	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Number of days	18	20	16	15	15	15	16	15	18	15	15	16

Table#1: shows the number of days in each month that AOT measurements were taken. On average there were about 16.1 completely clear days in each month during the 12-month period

Most of the daily cloud observations were compared with NASA's cloud observation satellite. Ground observations that coincide with satellite observations receive a 'match' email which summarizes both ground and satellite observations. Overtime students became very good at accurately observing clouds.

AOT measurements were done 6 times a day (7:00am, 9am, 11am, solar noon, 3pm and 5pm). The data shown on the plots are the monthly average AOT values taken at solar noon. During each measurement time; at least five values of the voltage V and the dark voltage V_{dark} are taken for each channel. The mean for these five measurements is taken as the average for that measurement time. The error in these measurements is calculated as the standard deviations of these five measurements. The accuracy of measurements made carefully with a GLOBE sun photometer are comparable to measurements made with professional sun photometers [14]. Measurements taken with the GLOBE sun photometer are in units of volts. These values are then converted to AOT using the equation shown below.

$$AOT = \left[\frac{ln\left(V_0/R\,2\right) - ln(V - V_{dark}) - a_{R(P/P_0)}m}{m}\right] \qquad (1)$$

V_0 is the calibration constant of sun photometer, R is the earth-sun distance expressed in astronomical units, V and V_{dark} are the measured sunlight and dark voltages from the sun photometer, a_R is the contribution to optical thickness of Rayleigh scattering of light, in the atmosphere, P is the station pressure at the time of measurement, P_0 is the standard sea level atmospheric pressure, m is the relative air mass ($m = 1/\sin\Phi$, where Φ is the solar elevation angle). The solar elevation angle is calculated using the solar elevation calculator provided by the National Oceanic and Atmospheric Administration (NOAA). In the 12-month period from September 2017 to August 2018,

the solar elevation at solar noon changes by $\approx 15^0$. Other meteorological data such as temperature, atmospheric pressure, rainfall and relative humidity were also measured at the same time. The values of *V*, *V$_{dark}$* and other site meteorological data were entered into the GLOBE data base to obtain the GLOBE calculated AOT values as a corroboration of our calculations. Equation 1 as given above includes the contributions of optical thickness from ozone. Ozone has a variable but small effect which can be calculated based on tabulated values of the ozone absorption coefficient and assumptions about the ozone amount in the atmosphere [16]. Based on this calculation ozone reduces the AOT for the 505nm channel by ≈ 0.01 and that of the 625nm channel by ≈ 0.03. The XULA AOT data shown here has been corrected for ozone. The contribution due to Rayleigh scattering is derived from the fundamental physics of the atmosphere [17,18]. For the 505nm channel $a_R \approx 0.13813$ and for the 625nm channel it is ≈ 0.05793. Details of this derivation are given in references 12.
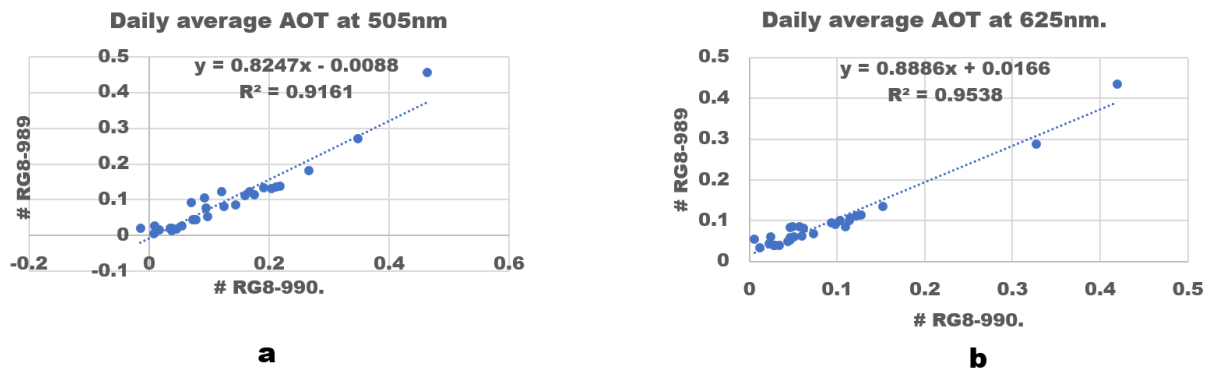
4. Results and Analysis

Figure 3: Two Linear regressions curves for AOT values from handheld sun photometer serial# RG-989 versus handheld sun photometer serial# RG-9990 at the XULA site. (a) 625 nm and (b) 505nm.The dotted line represents the linear equation.

To combine the data collected by the two teams using two independently calibrated instruments, we first made numerous simultaneous measurements with the two sun photometers. Figure 3 shows AOT data from the GLOBE sun photometer with serial #RG8-989 and another with serial #RG8-990 taken at the same time. The figure shows that the agreement between the two sun photometers is strong. The R-squared value for the 505nm channel is 95.3% and the slope of the linear regression line between the two sun photometers is 0.89. For the 625nm channel, R-squared is 91.6% and the slope linear regression line is 0.82. The agreement for both channels is improved by controlling the heating of the sun photometers during use. This analysis allows us to combine the data taken by the two sun photometers at different times.
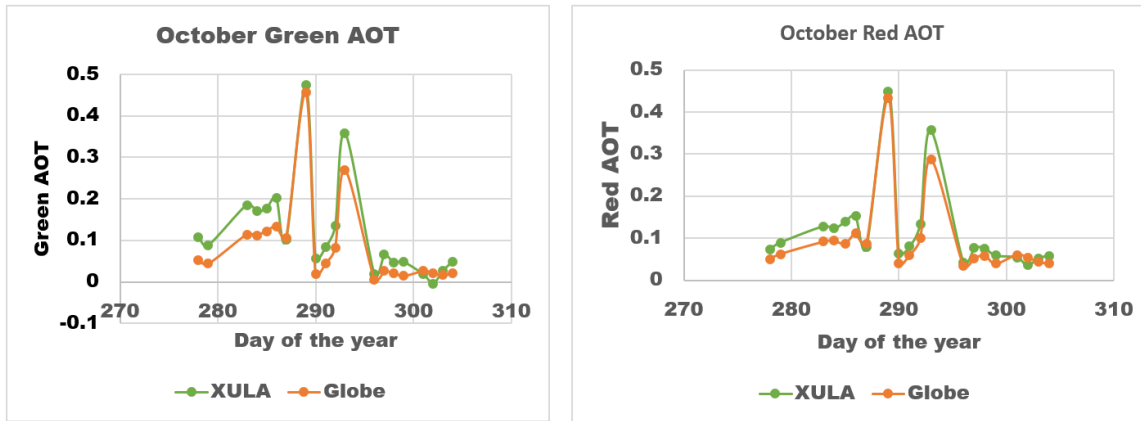
Figure 4: A sample of AOT values measured at XULA, calculated using equation 1 are compared with AOT values retrieved from GLOBE after entering the measured parameters at XULA. The figure shows data for October 2017 only. Data for the other months show the same similar agreement between our calculations and the GLOBE calculations.

Figure 4 shows a typical sample of how our calculated values of AOT compare with the AOT calculated by GLOBE. We see that our values and the GLOBE values agree in most cases, when they differ, the difference is less than 5%. This gave us confidence that our calculations are correct. Figure 5 shows variation of the average monthly AOT measured at XULA over the 12 months period. Average ozone optical thickness corrections of -0.01 and -0.03 are applied to the 505-nm and 625-nm optical thickness values respectively. The data shows that the AOT measured at wavelength 505nm (green light) drops continuously from September to January and then picks up in February. The AOT measured at wavelength 625nm (red light) follows a similar trend but reaches a minimum in December and starts going up for January and February. AOT measured at 505nm is higher than AOT measured at 625nm. The maximum value for green AOT is 0.176 (September) and the minimum value is 0.040 (January). For the red AOT the maximum value is 0.123 (September) and the minimum is 0.034 (December). Figure 6 shows the average AOT values per season. The seasons are categorized as follows: winter (December, January and February), spring (March, April and May), summer (June, July and August) and fall (September, October and November). Summer has the highest average AOT and winter has the lowest average AOT.
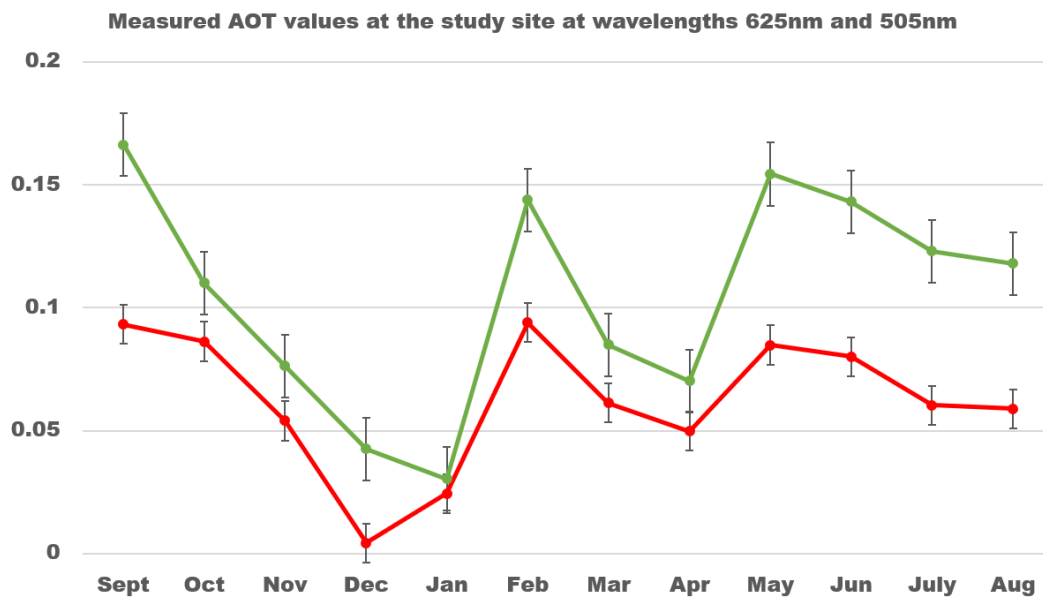
Figure 5: The variation of the monthly average AOT values measured at XULA over the 12-month period. AOT values were measured with two channels at wavelengths 625nm and 505nm and ozone correction was applied to this data.
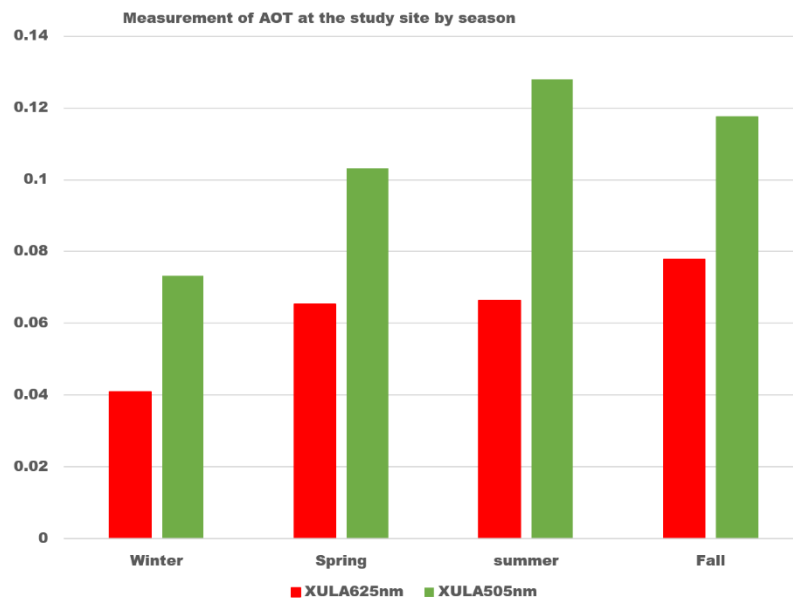

Figure 6: *The seasonal variation of AOT at the XULA site. Seasons were categorized thus: winter (Dec, Jan, Feb), spring (March, Apr, May), summer (Jun, July, Aug) and fall (Sept, Oct, Nov*
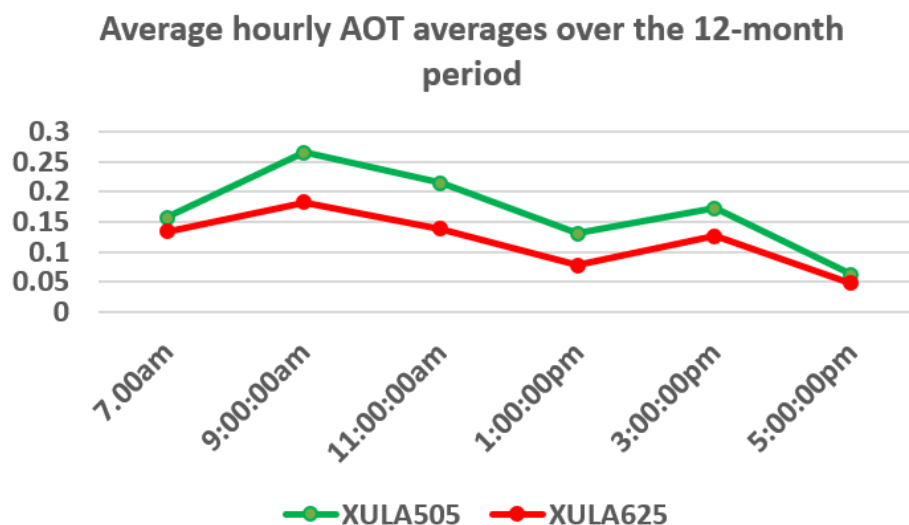
Figure 7: Diurnal variability of hourly mean values of AOT computed over the 12-month period. The time shown on the graph is local time

Figure 7 shows the hourly variation of AOT averaged over the 12-month period. Each data point is an average of 194 measurements. The daily variation is between 0.265 in the morning and 0.06 in the evening for the 505nm channel which corresponds to about 77% variation. The data shows a peak at 9:00am of 0.265 and another peak at 3:00pm of 0.182 for the 505nm channel. The 625nm channel show similar peaks.

5. Conclusion: The data above shows that students can be organized and motivated to take long and sustained measurements of atmospheric aerosols. Feedback from the students indicated that the course had provided them with new knowledge about environmental matters, improved their environmental awareness and allowed them to discover new teaching methods for their practice.

Conflicts of Interest: The authors declare no conflict of interest.

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