CLOUD OPTICAL DEPTH MEASUREMENTS FROM MIE LIDAR AND EL NIÑO OCCURRENCE IN MANILA (14.64N, 121.07E), PHILIPPINES

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ABSTRACT

Regular lidar operation and data acquisition were done in Manila at the Manila Observatory (14.64N, 121.07E), Ateneo de Manila University from 1997 to 1998. These years coincided with the occurrence of the El Niño episode that started in the first quarter of 1997 and ended in the first half of 1998. From the lidar data gathered during this time interval, the optical depth of clouds was measured using Klett's algorithm [1]. The results showed that the computed average cloud optical depth values in 1998 were 7% to 76% smaller compared to 1997 values. The smaller values can be deduced as the effect of the El Niño event based on the rainfall rate and southern oscillation index (SOI) data.

1. INTRODUCTION

In recent years, there has been a growing interest in atmospheric and oceanic research. These studies are aimed at understanding the earth's weather and climate. Climactic events such as El Niño or La Niña strengthen the need to comprehend the physics behind these phenomena. The El Niño phenomenon refers to the warming of the sea surface in the equatorial and central Pacific. This produces warm current appearing along the coast of Ecuador and Peru. La Niña is the cooling counterpart of El Niño. Since the effects of these episodes on land are on the large scale level, the effects of these events on the atmosphere are worth investigating. This can be done by investigating the optical characteristics of scatterers (clouds or aerosols) in the atmosphere through the use of lidar.

In the field of ground remote sensing, lidar data contain important optical information in the atmosphere. These are the extinction and the backscattering coefficients. When regular monitoring of the atmosphere is performed, the seasonal variations of the scattering coefficients and aerosol motions in the atmosphere can be studied and characterized [2].

During El Niño, convective clouds do not form well in the Philippines since they are shifted eastward as the warming of the water in the coasts of Ecuador and Peru persist. In this condition, the Philippine islands experience less rainfall that can sometimes lead to drought. According the National Oceanic and Atmospheric Administration (NOAA), the El Niño event in 1997 to 1998 was the strongest in record (http://www.pmel.noaa.gov/tao/elnino/faq.html#fact). In the Philippines, this event caused some forest fires, low water supply and a dry spell that lingered until June of 1998 (http://www.ccb.ucar.edu/un/philippines.html). This climatological event can therefore be studied to investigate its effects on the atmosphere using lidar.

The main objective of this study is to investigate the effects of El Niño occurrence on the optical depth of clouds in Manila. To carry out this research, the optical depth of clouds from lidar data from 1997 to 1998 were calculated and characterized.

2. THE LIDAR SYSTEM

The lidar system in the Manila Observatory is a fixed, vertically pointing system. The second harmonic wavelength (532nm) of a Nd:YAG Q-switched laser is used for regular monitoring [3]. The laser emits a 120mJ nominal 5ns output pulse that is spatially expanded three times resulting to a well collimated beam with a repetition rate of 20Hz. The backscattered signal is collected and focused by a 28cm diameter Schmidt-Cassegraine telescope onto a photomultiplier tube (PMT) through a collimating lens and a 1nm bandpass filter. The analogue voltage output of the PMT is digitized and averaged by a digitizing storage oscilloscope and automatically stored in the computer via a computer program. Table 1 summarizes the specifications of the lidar system at the Manila Observatory.

2.1 The lidar data

From 1997 to 1998, regular lidar operations were conducted for the purpose of boundary layer height observations and aerosol monitoring. The data were acquired every Tuesday and Thursday of the week from 06:30 to 09:00, 13:00 to 15:30 and 18:00 to 21:00 (Philippine local time). Because the receiving section of the lidar system was exposed to the atmosphere, data acquisition was suspended during rainy days. The time intervals were initially selected for the purpose of characterizing the boundary layer height in a day.

Table 1. Specification of the lidar system at the Manila Observatory

Transmitter	
Laser	Q-Switched Nd:YAG laser
Wavelength	532 nm
Energy per pulse	150 mJ
Pulse width	5 ns
Repetition rate	20 Hz
Receiver	
Configuration	Schmidt-Cassegraine
Diameter	20 cm
Focal length	2 m
Bandpass filter	
Bandwidth	1 nm
Detector	PMT

2.2 The climate in Manila, Philippines

The Philippine archipelago is divided into three major sets of islands namely Luzon, Visayas and Mindanao. The Luzon and Mindanao group of islands are in the northern and southern part of the archipelago, respectively. The islands of Visayas are located between Luzon and Mindanao. These three groups of islands have similar climates but different rainfall rates (http://www.pagasa.dost.gov.ph/cab/climate.htm). In Manila, the climate can be divided into dry and wet seasons. The dry months are from December to May and the wet months are from June to November. The months from March to May are considered to be the hottest season while the months from August to October are the wettest season. Typhoons and heavy rains occur in these months.

2.3 The 1997-1998 El Niño event

The effects of the El Niño event in 1997-1998 were deeply felt in the southern portions of the Philippine islands. A significant decrease in rainfall was observed in the island of Mindanao and part of the Visayas region [4] that led to a short term drought, scarcity of water and forest fire. In the island of Luzon, the decrease in rainfall was not significant [4]. Fig. 1 shows the rainfall rate from the Science Garden Meteorological Station (14.63N, 121.01E) for the year 1997-1998. The distance between the lidar system in the Ateneo de Manila University and the meteorological station is about 6.75 km. The figure shows that the 1998 dry season rainfall rates are smaller compared to the 1997 dry season rainfall rates. Specifically, the months of February and April of 1998 had 0 and 1mm rainfall, respectively. These rainfall rates were way far lower compared to the rainfall rates of February and April of 1997 that had rainfall rates of 33 and 20mm, respectively. On March 1998, the rainfall rate was only around 5mm. This was only 15% of the rainfall rate in March 1997. Of the 24 months, the months worth considering are from August 1997 to April 1998. In these months, the measured rainfall decreased and had the lowest value in February 1998. These months can be considered as the months where the El Niño phenomenon had its greatest strength and effect in Metro Manila.

3. METHODOLOGY

The cloud optical depths were computed by inverting the lidar signal using Klett's method [1]. The algorithm by Klett [5] was used in determining the boundary value of the extinction coefficient. To facilitate the computation of the optical depth, a computer software was made. Each file is scanned for cloud signals. A file with a cloud signal is then processed for the extinction coefficient and optical depth. Signals from optically thick clouds often exhibit an abrupt drop or strong signal gradient after the peak implying that the laser has not fully penetrated throughout the cloud. These types of signals were excluded in the analysis.

To verify the results, the measured cloud optical depth values were compared to the southern oscillation index (SOI) (http://www/cru.uea.ac.uk/cru/data/soi.htm), [6], [7], [8] and cloud cover from the International Comprehensive Ocean-Atmospheric Data Set (ICOADS) (http://icoads.noaa.gov) from the NOAA-CIRES climate diagnostic center.

4. RESULTS AND DISCUSSIONS

Fig. 2 shows the computed optical thickness of clouds observed from the regular lidar observation done in the Manila Observatory. In 1997, when the El Niño started, the calculated cloud optical depth was higher compared to the computed cloud optical depth in 1998. When the optical depth values in a month are averaged, the result shows lower average optical depth in the same year, as shown in Fig. 3. No lidar observations were done in June and December 1997 and January 1998 due to problems in the system during these months.

In Fig. 3, the decreasing trend of optical depth in the middle of 1997 toward the middle of 1998 can be observed. This result shows that the maximum effect of the El Niño event must have taken place in Manila during the last quarter of 1997 and the first half of 1998. A comparison of the average cloud optical depths of same months in the years 1997 and 1998 shows that the average cloud optical depth values in 1998 are, in general, 7% to 76% smaller than the same months of 1997.

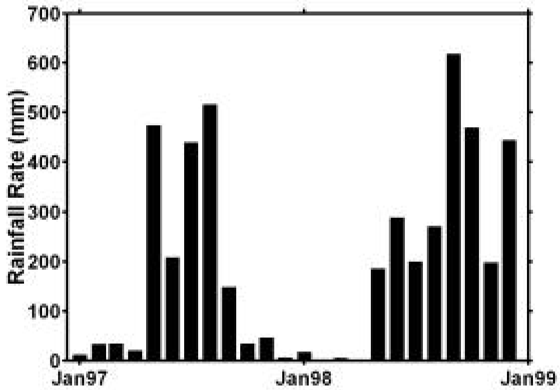

Fig. 1. The rainfall rate in Manila from 1997 to 1998 from the National Climactic Data Center of NOAA (http://www.ncdc.noaa.gov).

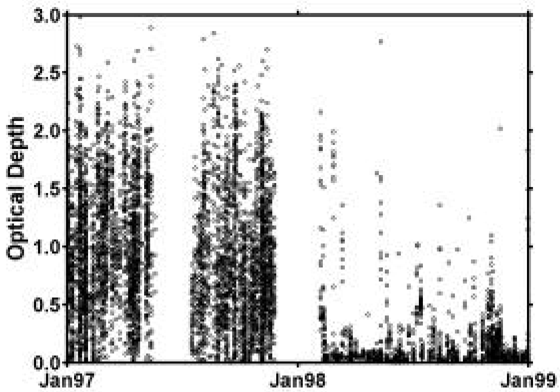

Fig. 2. Optical depth of clouds calculated from lidar data from 1997 to 1998.

From August 1997 to March 1998, the results in Fig. 3 show the same trend when compared to the SOI measurements. The SOI is defined as the normalized pressure difference between Tahiti and Darwin. During an El Niño occurrence, the eastern part of the Pacific Ocean has lower pressure compared to western side. Thus, the SOI becomes more negative. In this condition, the formation of clouds is increased in the eastern Pacific Ocean due to an intensified convection activity and higher humidity in the atmosphere. On the other hand, the western part of the Pacific Ocean experiences a decrease in both cloud formation and atmospheric humidity. As a result, rainfall rate in the western Pacific region decreases considerably.

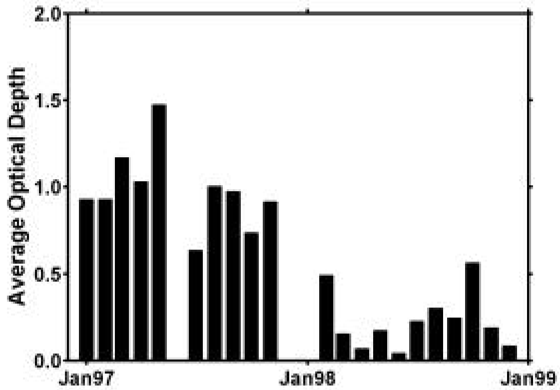

Fig. 3. Monthly average of cloud optical depth calculated from lidar data from 1997 to 1998.

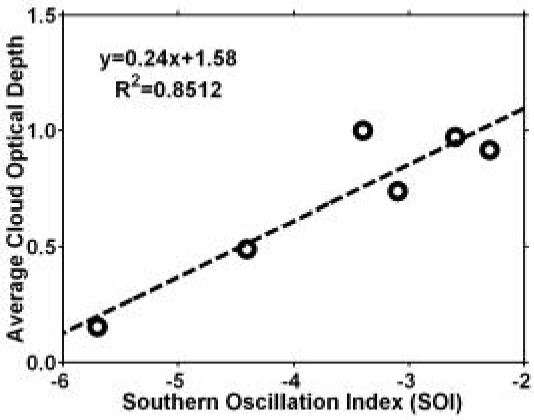

Fig. 4. The plot of the monthly average values of the cloud optical depth and the southern oscillation index (SOI) for the months of August 1997 to March 1998. No lidar data acquisitions were done from December 1997 to January 1998.

The lowest SOI values occurred from August 1997 to March 1998 [8]. The lowest SOI occurred on March 1998 registering an SOI value of -5.7. It was also during these months that rainfall rates were decreasing and were at the lowest. Fig. 4 shows the graph of the monthly average cloud optical depth values against the SOI from August 1997 to March 1998. In these months, a good correlation between the two quantities exists. This indicates that as the strength of the El Niño event increases, the convection activity in the western side, specifically in the Philippines, decreases resulting to low formation of clouds. Based on the linear regression result, clouds will not exist when the SOI value reaches -6.5. Thus, in these conditions, the cloud cover is virtually zero.

To relate the low cloud optical depth during these months to cloud cover, the average cloud optical depths are compared with the cloud cover data from ICOADS (http://icoads.noaa.gov). Since the ICOADS does not have land information, the cloud cover data were taken from sea at 14.64N, 119.5E. These latitude and longitude points are located on western part of Manila Bay. From August 1997 to March 1998, the ICOADS data set shows a similar trend with the average optical depth of clouds, i.e., there is a decrease in the cloud cover over 14.64N, 119.5E (Fig.5). The results in Fig. 5 show that the low cloud cover during these months is consistent with the idea that the formation of clouds in the western Pacific region is low during El Niño event resulting to low ground-measured precipitation values. Under this condition, cloud optical depths values measured from lidar are low.

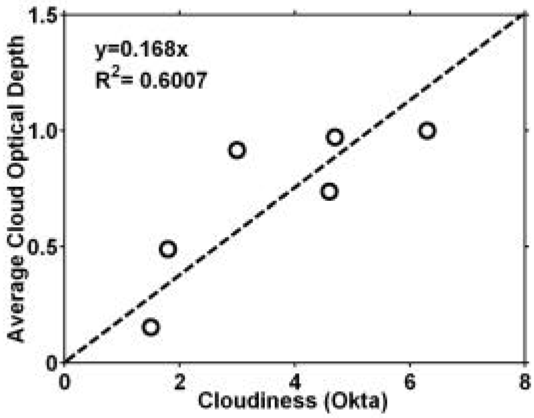

Fig. 5. The plot of the monthly average values of the cloud optical depth and the cloudiness for the months of August 1997 to March 1998.

5. CONCLUSION

The regular acquisition of lidar data is a valuable work in the field of atmospheric and climate studies. The acquired data will show the annual or seasonal changes of the optical characteristics of clouds and aerosols. With years of intensive data gathering, the measured optical characteristics of the clouds will confirm important climatologically occurring phenomenon like the El Niño.

In this study, the optical depth of clouds was computed from lidar data. The optical depth values showed a decreasing trend from second half of 1997 to first half of 1998. These results imply that the effects of El Niño on the atmosphere are measurable and can be estimated from the optical depth of clouds. During the El Niño event in the Philippines from 1997 to 1998, the annual precipitation also decreased. This is the result of the eastward shifting of the location of convection activity in the Pacific Ocean. The low values of cloud optical depth and rainfall rate values are consistent with the SOI and cloud cover data. In the months when the optical depth of clouds is low, the SOI and cloud cover also show minimal values.

The cloud optical depth measurements derived from the lidar data can be considered as values from a point in space. However, the changes in the optical depth values in time reflect certain direct relationships with climatic events such as the El Niño. This is an important result in the field of ground remote sensing and climate modelers. With this year revealed as the start of La Niña, regular lidar operation and data acquisition will be done in the Manila Observatory to study the effects of this event on the atmosphere from the point of view of remote sensing.

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