

LIDAR OBSERVATION OF THE 2014 KELUT VOLCANIC STRATOSPHERIC AEROSOLS AT KOTOTABANG, INDONESIA

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ABSTRACT

The Kelut (Kelud) volcano (7.9S, 112.3E) in the Java island of Indonesia erupted on 13 February 2014. The CALIOP observed that the eruption cloud reached 26km above sea level. We have observed this stratospheric aerosol from 28 February 2014 at equatorial lidar site located in the Sumatra island of Indonesia (0.2S, 100.3E). We observed the depolarization maximum to be up to 2km below the backscatter maximum in April 2014. We also observed the vertical transportation process of stratospheric aerosol to troposphere by equatorial Kelvin wave.

1. INTRODUCTION

Stratospheric aerosols play important roles in climate regulation and atmospheric chemistry. The volcanic eruption of Mt. Pinatubo (15.14N, 120.35E) on 15 June 1991 injected huge amounts of SO₂ and ash into the stratosphere. The Volcanic Explosivity Index (VEI) was 6. The eruption injected into the stratosphere an amount of SO₂ estimated to be about 20 Tg [1]. The injected SO₂ was oxidized to sulfuric acid particles through homogeneous nucleation [2]. Based on some satellite data, the stratospheric aerosol optical thickness (AOT) increased after 2000 as the result of a series of moderate but increasingly intense volcanic eruptions [3].

At 16:15 UTC, Mt. Kelut in East Java, Indonesia, erupted a mixture of gas, ash and water. The eruption was short lived and no subsequent explosions have been reported. VEI was 4. From CALIOP data, the inertial plume ejected material up to 26 km in the tropical stratosphere, but most of the plume remained at 19-20 km [4]. A number of sensors continued to track the plume over the next few days. As the plume continued to move west over the Indian Ocean, it thinned and spread out, following local atmospheric circulation. Aerosol index returns show that much of the ash

injected into the atmosphere was removed by three days after the eruption. The SO₂ plume remained more coherent and could still be seen clearly in OMI and OMPS data 4 days after the eruption. OMI estimates suggest that SO₂ is being removed from the plume at a rate of roughly 0.01 Tg per day. IASI data suggests that the removal is happening more rapidly, at a rate of 0.02 - 0.03 Tg per day, however IASI reported higher initial concentrations of SO₂ than OMI [5]. Although most of the SO₂ was injected into the stratosphere, the total SO₂ mass measured was ~0.2 Tg (confirmed by multiple sensors including OMI, AIRS and IASI), making this eruption fairly modest in terms of SO₂ release [6].

In this paper we report observations of stratospheric aerosols following the volcanic eruption of Mt. Kelut (7.9S, 112.3E) in February 2014 at lidar site in Kototabang (0.2S, 100.3E), Indonesia.

2. LIDAR SYSTEM

We had constructed the lidar facility for survey of atmospheric structure over troposphere, stratosphere, mesosphere and low thermosphere over Kototabang (100.3E, 0.2S), Indonesia in the equatorial region [7]. The lidar system consists of the Mie and Raman lidars for tropospheric aerosol, water vapor and cirrus cloud measurements, the Rayleigh lidar for stratospheric and mesospheric temperature measurements and the Resonance lidar for metallic species in the mesopause region. The most parts of this lidar system are remotely controlled via the Internet from Japan. The full lidar observations started from 2004. The routine observations of clouds and aerosol in the troposphere and stratosphere are continued now. We have installed DIAL (differential absorption lidar) system for high-resolution measurements of vertical ozone profiles in the equatorial tropopause region in 2013 and

532nm polarization lidar system for stratospheric aerosol monitoring in 2014.

A polarizer divided photons at 2 into components parallel (P) and perpendicular (S) to the transmitted laser polarization plane. The received photons were converted to electrical signals by photomultiplier tubes (PMT). A photon counter is used to process the output signals of the PMTs.

We used the nearest operational radiosonde data to calculate the atmospheric molecular density. The lidar backscattered signal was interactively normalized to unity around 27–32 km, where aerosol-free conditions could be assumed. The total linear depolarization ratio d is defined as

$$d = S / (P + S) \times 100(\%)$$

where P and S are the parallel and perpendicular components of the backscattered signals [8].

3. RESULTS

Over Kototabang, stratospheric aerosol layers were observed on 28 February 2014 about 15 days after the eruption (Figure 1(a)). The peak values of scattering ratio was 4 at 19 km and the values of depolarization ratio was 4% at 19 km. Non-spherical ash particles were probably included in the layers with sulfuric acid particles that were produced from SO₂ through chemical reactions. Non-spherical particles were also present in the lower region (13-17km) of the aerosol layer.

On 29 April 2014 (2 months after the eruption), the peak altitude of scattering ratio move upward to 21 km but the peak altitude of depolarization ratio was still at 19 km (Figure 1(b)). Light spherical sulfuric acid particles should be moved upward by the upwelling tropical branch of the Brewer-Dobson circulation but the non-spherical ash should not be moved upward.

On 26 June 2014 (4 months after the eruption), the peaked stratospheric aerosol layers could not seen (Figure 1(c)). On 20-26 June 2014, aerosol transportation from the stratosphere to the troposphere by Kelvin-Helmholtz instability in the tropical tropopause layer should be occurred over the Kototabang.

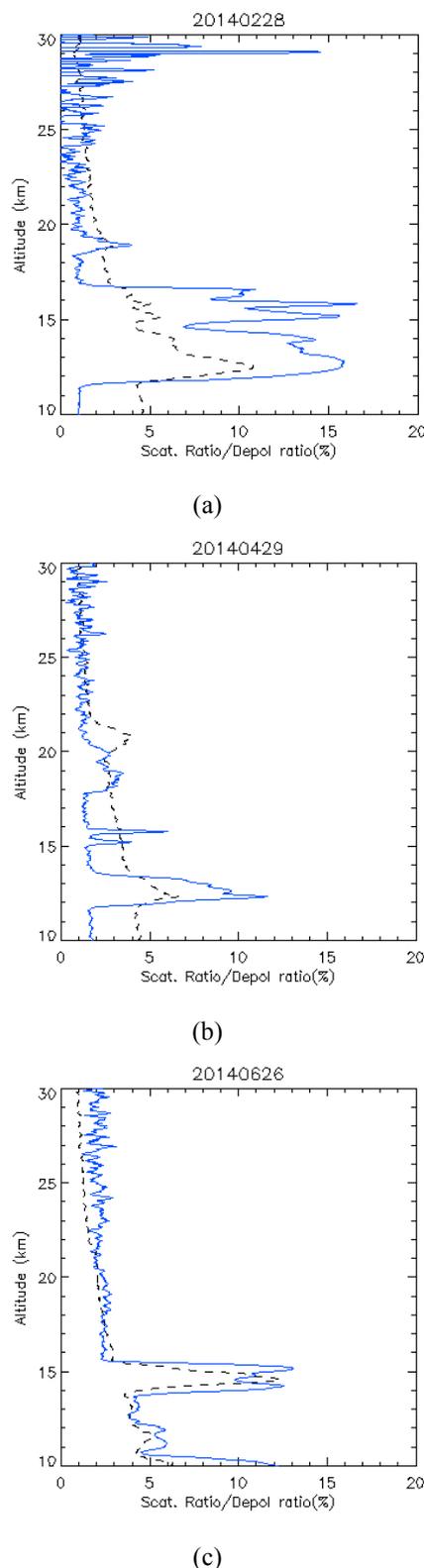


Figure 1 Profiles of scattering ratio (dotted) and depolarization ratio (solid) on (a) 15 days after the eruption, (b) 2 months after the eruption, (c) 4 months after the eruption.

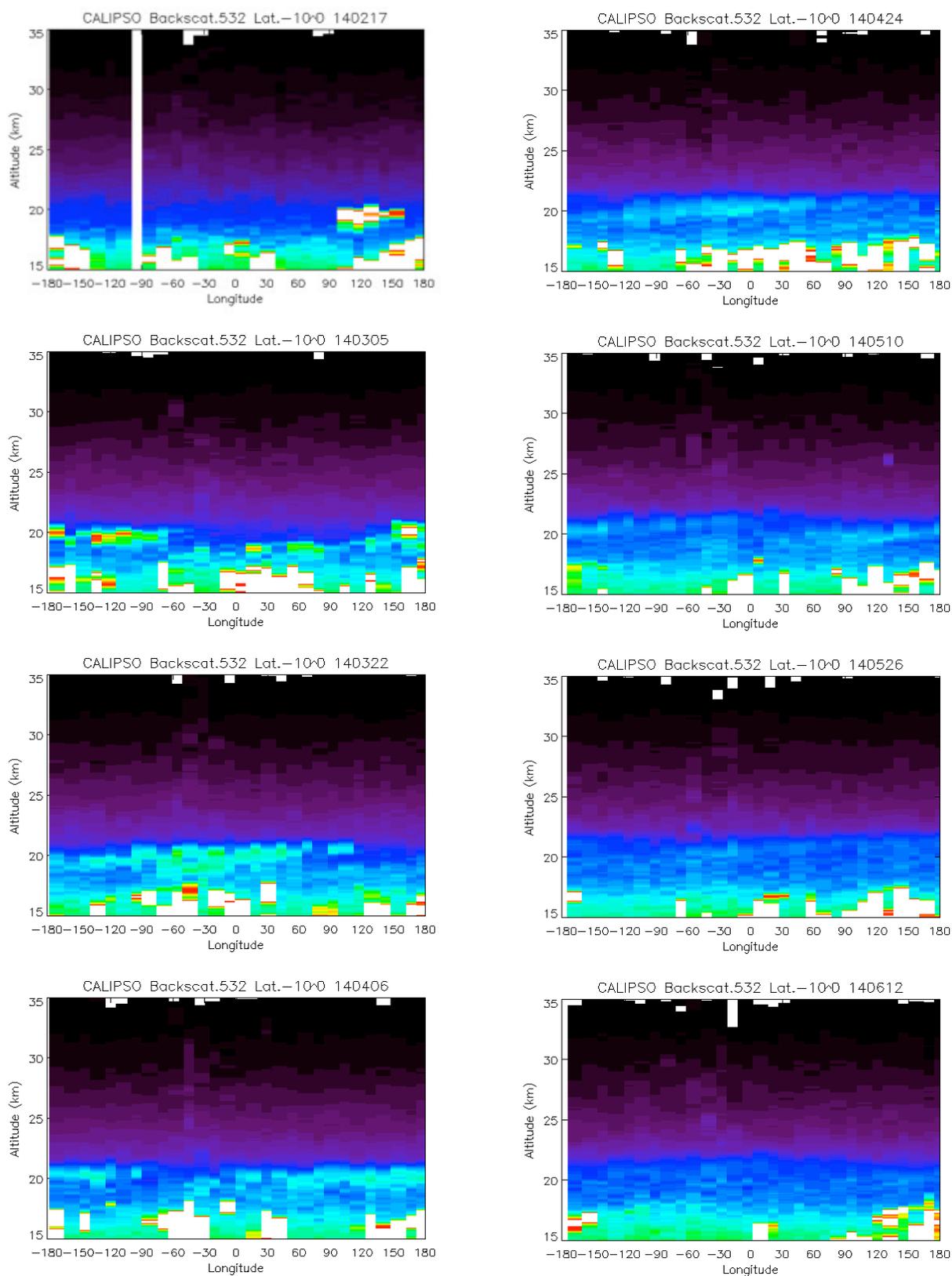


Figure 2 Two days composited of the CALIOP meridional mean [0-10S] of 532nm total attenuated Backscattering ratio every 16 days from 17 February 2014.

Figure 2 shows two days composit of the CALIOP meridional mean [0-10S] of 532nm total attenuated Backscattering ratio every 16 days from 17 February 2014. Stratospheric aerosol cloud around 20km exist over 100-120E longitude on 17-18 February 2014. It begun to move eastward and did one lap of earth in approximately one month. Aerosol layer was spread in the longitude direction with the lapse of time. Aerosol should be carried by a equatorial Kelvin wave. The spread in the latitude direction was slower than in the longitude direction

4. CONCLUSIONS

We have observed 2014 Kelut volcanic stratospheric aerosol from 28 February 2014 at equatorial lidar site located in the Sumatra island of Indonesia (0.2S, 100.3E). We observed the depolarization maximum to be up to 2km below the backscatter maximum in April 2014. We also observed the vertical transportation process of stratospheric aerosol to troposphere by equatorial Kelvin wave instability.

From CALIOP data, Kelut aerosol cloud movement of eastward by equatorial Kelvin wave was clearly seen. Aerosol layer was spread in the longitude direction with the lapse of time but the spread in the latitude direction is slower.

As the SO₂ mass injected into the stratosphere by Kelut eruption is moderate, these observations are good example of transportation of materials from the equatorial stratosphere to the troposphere.

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