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83 On August 31 and September 2, 1996, backscattersondes were launched from Cuiaba, Brazil (16 degree S, 56 degree W) during an intense agricultural burning period. The instrumentation employed senses the aerosol backscatter at two wavelengths (490 and 940 nm) as well as the ozone concentration, relative humidity, air temperature and pressure with a vertical resolution of about 25 m. The primary objective was to evaluate the potential of the instrument for biomass burning studies, both as a supplement to more comprehensive measurements from aircraft, and as a stand alone technique in the absence of any extensive field campaign. It was also anticipated that the results may illuminate proposed processes in which the lower altitude air penetrates the top of the planetary boundary layer (PBL) and is transported into the free troposphere. on both soundings an abrupt, two order of magnitude drop in the aerosol backscatter was observed at the precise altitude of the PBL top (about 5 km). The ozone mixing ratio also shows a drop from 90 ppbv at the top of the PBL to 40 ppbv a few kilometers higher, with the decrease being more gradual than in the case of the aerosol. Also in both soundings small layers of enhanced ozone, water vapor and aerosol backscatter were observed above the PBL in air significantly dryer than that found in the PBL, but not as dry as that found at higher altitudes. Values of the aerosol to ozone ratio and relative humidity in these layers are not consistent with simple conservative transport from the PBL to the free troposphere and .
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BALLOONBORNE AEROSOL AND OZONE MEASUREMENTS OVER CENTRAL BRAZIL DURING A PERIOD OF INTENSE BIOMASS BURNING

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Abstract. On August 31 and September 2, 1996, backscattersondes were launched from Cuiaba, Brazil (16°S, 56°W) during an intense agricultural burning period. The instrumentation employed senses the aerosol backscatter at two wavelengths (490 and 940 nm) as well as the ozone concentration, relative humidity, air temperature and pressure with a vertical resolution of about 25 m. The primary objective was to evaluate the potential of the instrument for biomass burning studies, both as a supplement to more comprehensive measurements from aircraft and as a stand alone technique in the absence of any extensive field campaign. It was also anticipated that the results may illuminate proposed processes in which the lower altitude air penetrates the top of the planetary boundary layer (PBL) and is transported into the free troposphere. On both soundings an abrupt, two order of magnitude drop in the aerosol backscatter was observed at the precise altitude of the PBL top (about 5 km). The ozone mixing ratio also shows a drop from 90 ppbv at the top of the PBL to 40 ppbv a few kilometers higher, with the decrease being more gradual than in the case of the aerosol. Also in both soundings small layers of enhanced ozone, water vapor and aerosol backscatter were observed above the PBL in air significantly dryer than that found in the PBL, but not as dry as that found at higher altitudes. Values of the aerosol to ozone ratio and relative humidity in these layers are not consistent with simple conservative transport from the PBL to the free troposphere and indicate that aerosol was preferentially removed if they originated in the PBL.

Introduction

It is well known that biomass burning is potentially capable of greatly altering the character of tropospheric trace constituents on a global scale, especially in the southern hemisphere, where there is less industrial pollution and more agricultural burning. Since the products of biomass burning would be more quickly transported in the free troposphere to distant regions, it is important to understand the mechanics of how the polluted air penetrates the top of the planetary boundary layer (PBL) into the free troposphere where it can travel to distant locations. Possible injection mechanisms that might be considered are cumulus activity, dry convection driven by sufficiently intense fires, and lifting by convection associated with the sub-tropical jet stream. Since the trace constituents may continue to evolve after reaching the free troposphere, it is important to identify the "initial conditions" in the local region of biomass burning. The goal of the research described here was to assess the possible contribution that relatively simple balloonborne instrumentation, which simultaneously measures ozone and aerosols, can make in addressing such biomass burning issues.

Experimental Setting

Two backscattersonde soundings (August 31, September 2, 1996) were conducted from Cuiaba, Brazil (16°S, 56°W) during the peak period of the Brazilian biomass burning season. From previous studies it is known that the launch site is located well within the major burning area [Kirchhoff et al., 1988]. Additional ozone, relative humidity, and temperature soundings are available on the days of the backscattersonde soundings.

Instrumentation

The backscattersonde is a relatively simple balloon borne instrument that senses the backward scattered light from a well defined beam produced by an intense xenon flash lamp. Two color channels are employed with effective wavelengths of 490 and 940 nm. The sample volume is on the order of a cubic meter and one measurement is obtained every 7 seconds, giving an altitude resolution of about 30 m, assuming a normal ascent rate. The onboard ozone sensor is a standard ECC and the pressure, temperature, and relative humidity are determined with an integrated Vaisala sonde. It should be noted that the relative humidity measurements are suspect below air temperatures of -55 to -60°C. A more complete description of the backscattersonde is given by Rosen and Kjome [1991].

Results and Discussion

Figure 1 presents the results of the backscattersonde sounding made on August 31 at 2100 local time. The profiles show a remarkably well defined PBL top, especially in the temperature, water vapor and aerosol. The drop in the ozone mixing ratio is notably less dramatic, occurring over a larger distance. This effect cannot be attributed to the time response of the ozone sensor and suggests differential transport of aerosol and ozone from the PBL into the free troposphere near the PBL top.

It can also be seen that the surface ozone value associated with a pronounced surface temperature inversion is very low compared to values throughout the PBL. This result is strongly suggestive of an effective surface ozone sink. The high ozone values in the PBL are undoubtedly a result of ozone production associated with the biomass burning. The backscatter in the PBL is an order of magnitude larger than normal in the red channel. To the eye, the sky appeared notably gray and hazy.

The PBL appears relatively well mixed in the water vapor and ozone profiles except for the shallow layer immediately above the surface. The aerosol backscatter profile shows a slight enhancement near the top of the PBL, most likely due to enhanced particle size resulting from the higher relative humidity in this region. Intuitively, a much larger enhancement may have been expected from possible hygroscopic particle effects.

The water vapor drops markedly at the PBL top as previously noted, but then decreases noticeably again at about 8 km. This structure suggests the existence of a perturbed layer or region that is immediately above the PBL.

Near the top of the perturbed region above the PBL is a layer centered at 400 mb containing enhanced ozone, aerosol, and to a smaller extent, water vapor. The relatively high ozone mixing ratio in the layer suggests that ozone production rather than horizontal transport is responsible for the enhancement. The ozone mixing ratio in this layer is consistent with simple transport from the PBL with about 50% entrainment of the surrounding air. However, the same cannot be said of the aerosol in the layer because the backscatter is only about 1% of that found in the PBL. In addition, there has also been a disproportionate loss of water vapor compared to ozone. Thus, the layer could not be explained by simple transport across the PBL top, since aerosols and water vapor are far from being conserved. The loss of aerosol and water vapor is suggestive of wet removal as may be associated with cumulus activity.

An alternative explanation of the relative ozone, aerosol and water vapor concentrations in the 400 mb layer might be considered in which the trace constituents are quasi-conserved in the transport process across the PBL top and then diluted by mixing with air of the free troposphere. The ozone concentration would then be further enhanced by continued chemical production. However, the large dilution factor would probably prevent significant ozone production. Thus, this scenario does not seem very probable.

Figure 1 shows that the ozone mixing ratio begins increasing toward stratospheric values at about 300 mb, well below the level of the tropopause. This relatively high ozone content is probably not related to the local biomass burning activity, since the temperature profile (lapse rate) indicates that there is not vigorous vertical mixing above about 230 mb. Transport from the stratosphere is a more likely explanation for the upper tropospheric ozone, although other possibilities cannot be strictly eliminated. Such considerations question the source of the ozone layer at 400 mb: is it really associated with biomass burning, or is it a result of transport from the stratosphere? The fact that the water vapor shows a positive correlation with the ozone would imply that the layer is of lower tropospheric origin. This issue could be settled more decisively if trace gases characteristic of biommass burning were measured and found in the layer.

Figure 2 illustrates the results of the second backscattersonde sounding which has features very similar to that of the first sounding. In this case, however, there appears to be two layers of enhanced ozone, aerosol and water vapor (250 and 450 mb) in the perturbed region above the PBL top. In the ozone sounding made earlier in the day (not shown) the notch in the ozone profile is much more pronounced, thus clearly distinguishing and separating the air above and below the PBL. Again the ozone mixing ratio in the layers is consistent with a PBL source and the aerosol backscatter is only a small percentage of that found in the PBL. The water vapor profile shows decisive enhancement that is highly suggestive of a lower altitude source, but not without significant water vapor removal.

As in the first sounding, there is a modest enhancement in the aerosol backscatter at the top of the PBL where the relative humidity reaches about 93%. Again the enhancement is less than expected if the aerosols were significantly hygroscopic.

Conclusion

The results as interpreted above would seem to present a scenario in which the process of air penetrating the PBL top and irreversibly entering the free troposphere involves aerosol and water vapor removal, but probably not significant ozone removal. It would appear that wet removal of aerosol particles as expected in cumulus activity might account for the observations, but the required transport of the resulting droplets to lower altitudes during the dry season needs further illumination. Perhaps there is adequate rain originating in the perturbed region above the PBL followed by complete evaporation in the dry lower PBL.

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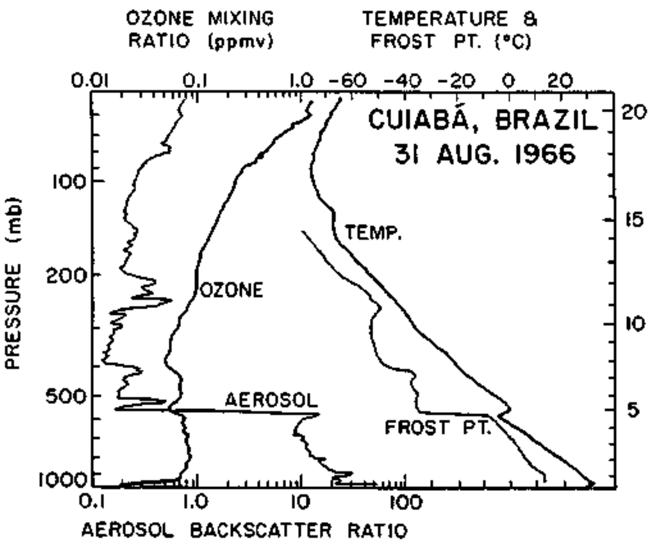

Figure 1. Results of first backscattersonde sounding.

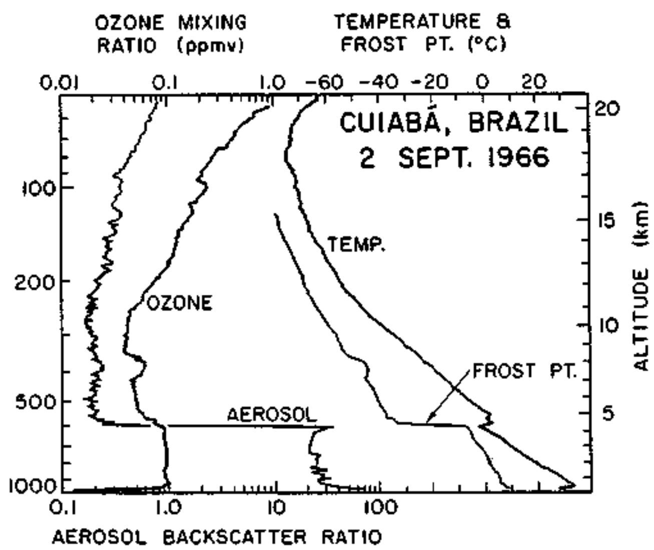

Figure 2. Results of the second backscattersonde sounding.