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Short communication

Tethered balloon-based soundings of ozone, aerosols, and solar radiation near Mexico City during MIRAGE-MEX

J.P. Greenberg*, A.B. Guenther, A. Turnipseed

National Center for Atmospheric Research, Boulder, CO 80307, USA

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ABSTRACT

A tethered balloon sampling system was used to measure vertical profiles of ozone, particles, and solar radiation in the atmospheric boundary layer on the northern edge of Mexico City, in March 2006 as part of the Megacity Impact on Regional and Global Environment-Mexico experiment. Several commercial sensors, designed for surface applications, were deployed on a tethered balloon platform.
Profiles indicate that for these 3 scalars the boundary layer (surface up to 700 m) was well mixed in the period 10:00–16:00 LST. Good agreement was observed for median surface and balloon ozone and particle number concentrations. For most profiles, the surface deposition of ozone was not significant compared to median profile concentrations. Particle number concentration (0.3, 0.5, 1.0 and 5.0 μm) also showed little variation with attitude. Radiatprofiles showed a monotonic increase in diffuse radiation from the maximum altitude of profiles to the surface. Consequently, it was inferred that surface measurements of these likely were representative of lower boundary layer values during this time period.

1. Introduction

The MIRAGE (Megacity Impact on Regional and Global Environment)-MEX field campaign (March 2006) was designed to examine the chemical and physical transformations of gases and aerosols in the polluted outflow from Mexico City. The campaign included observations from ground stations, aircraft, and satellites. (An overview of the experiment is given in Molina et al., 2008). Surface measurements were made at three primary sites: central Mexico City (T0, Instituto Mexicano de Petroleo), the Technical University of Tecamac (T1), approximately 35 km NW of T0, and Rancho de Bisnaga (T2), approximately 70 km from T0. The sites were selected to characterize polluted MC air as it aged in transit from its source (arbitrarily set at T0).

The balloon–platform profiles presented here are from the T1 site (19N42.184, 98W59.917, 2270 m asl) from 13 to 28 March 2006. The primary objective of the tethered balloon study was to determine if surface measurements accurately reflected concentrations in the boundary layer, so that ground based data might be extended to characterize to the atmospheric boundary layer analysis. Vertical profiles of several variables (ozone, particles, and direct and diffuse solar radiation) were made to illustrate mixing from the surface to the maximum balloon height (usually between 400 and 700 m above ground level).

2. Experiment details

2.1. Instrumentation

Extensive details of tethered balloon profiling in the atmospheric boundary layer have been provided previously (Greenberg et al., 1999; Greenberg and Guenther, 2002). Several commercial lightweight sensors were deployed on the balloon platform. Ozone was measured by a UV absorption ozone analyzer (2B Technologies, Boulder, CO, 2.1 kg); a glass fiber filter was placed on the inlet to prevent interference of dust in the optical cell. Ten second average data are reported for each profile. The relative standard deviation of 1 min averaged data was determined experimentally to be approximately 1.3% at approximately 70 ppb. An optical particle counter (Abacus, Particle Measurement Systems, Boulder, CO, 1 kg) was also deployed. Particles numbers were counted for discrete 0.3, 0.5, 1 and 5 μm sizes; 45 s average number concentrations are reported. The reported collection efficiency is approximately 20% for 0.3 μm particles. Total (global), direct (total minus diffuse) and diffuse radiation were measured using Sunshine Sensor, Model BF3 (Delta-T Devices, Ltd., Cambridge, UK, 0.5 kg). This detector has a sensor array which requires no shadow band and need not be

* Corresponding author. National Center for Atmospheric Research, P.O. Box 3000, Boulder, CO 80307, USA. Tel.: +1 303 497 1454; fax: +1 303 497 1400.
E-mail address: greenber@ucar.edu (J.P. Greenberg).

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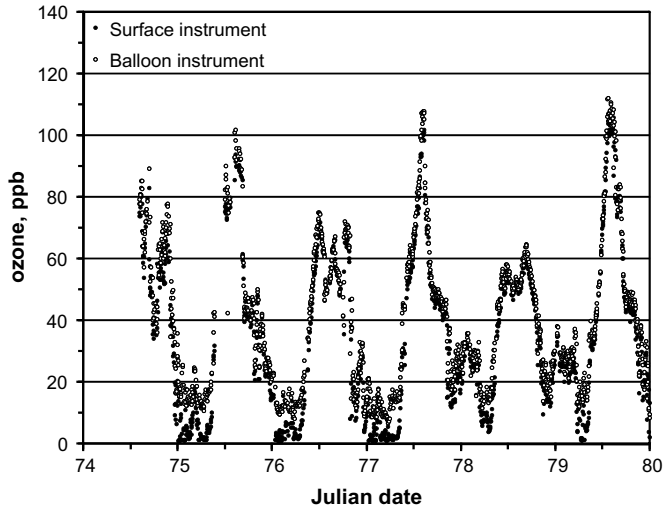

Fig. 1. Ground and balloon instrument inter-comparison of ozone measurements: Both the balloon (2B Technologies, Inc., Boulder, CO, USA) and the surface instruments (Model 14, ThermoEnvironmental Corp., Franklin, MA, USA) operated on the principal of UV absorption by ozone of light (254 nm) from a mercury lamp.

pointed toward the north. While the sensor is normally deployed on level surface, significant errors from a tilted surface only occur at low solar elevation (Wood et al., 2003); small changes in the angle of incidence caused by balloon attitude had generally little effect on the measurement of direct or diffuse radiation. One second data are reported. The overall accuracy for total and diffuse radiation is reported at 12% and 15%, respectively.

Measurements of wind speed and direction and pressure-altitude were made using an NCAR-made instrument (inquiries on specifications may be directed to the authors). Commercial tethered atmospheric sounding systems (Model TS-5A-SP. Atmospheric Instrumentation Research, Boulder, CO, USA and DigiCORAS Tethersonde System, Vaisala, Inc., Helsinki, Finland) have been used in previous studies but are no longer available from the manufacturers.

A 12 m^3 Skydock balloon (Flotograph Technologies, LLC, Silver Springs, MD, USA) and a 9 m^3 blimp (Fire Fly Balloons, Inc., Statesville, NC, USA) were used to lift the tethered measurement systems. Instruments were mounted on a horizontal platform approximately 3 m below the Skydock balloon (ozone, particle and radiation instruments) or, when the blimp was employed, ozone or particle sensors were approximately 1 m below the balloon. The radiation sensor was only deployed on the Skydock platform. The meteorological system was deployed on each flight. Balloons were generally raised and lowered at a constant rate (0.5 m s^{-1}), with approximately the same time (30 min) for ascent and descent. Occasionally, circumstances (usually strong or gusty winds) required differing ascent and descent rates.

Balloon-based measurements were compared with simultaneous measurements made on the surface at the T1 site: ozone by UV absorption (Model 49C, ThermoEnvironmental Co., USA) and particles by an optical particle counter (Lasair Model 1002, Particle Measurement Systems, Boulder, Colorado, USA).

3. Results

3.1. Ozone

Five minute average ozone concentrations measured by co-located balloon and surface ozone instruments were compared (March 12–14, Fig. 1). The 5 min averaging period was arbitrarily for this 3-day comparison (ozone profile measurements used 1 min averaged data to provide more time resolution). The relative standard deviation of balloon instrument ozone concentrations for 5 min averaged data was determined experimentally to be approximately 0.7%. Good agreement was seen for a 14-day comparison (slope = 0.97, intercept 6 ppb, $R^2 = 0.97$). The balloon profiles were collected during the earlier part of this period (Julian days 72–79, or March 13–20, respectively).

The balloon and surface particle sensors (Abacus and Lasair) were both manufactured by Particle Measurement Systems (Boulder, CO); Lasair is the newer model of the Abacus instrument. The balloon particle counter number concentrations at the surface were compared with simultaneous surface counter number density (Fig. 2). For 0.3 and 0.5 μm particles, measurements were highly correlated ($R^2 = 0.87$, and 0.86, respectively), with some differences in slope and intercept of the regression of

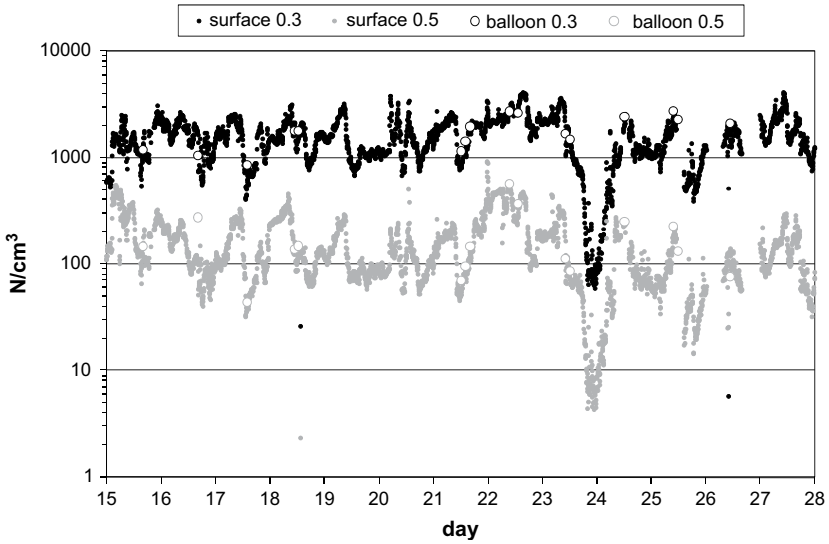

Fig. 2. Comparison of ground (LASAIR, Particle Measurement System, Boulder, Colorado, USA, Iida et al., 2008) and balloon (Abacus, Particle Measurement System, Boulder, Colorado, USA) instruments during the MILAGRO campaign. Very good agreement between 2 optical particle counters was observed for 0.3 and 0.5 μm particles.