VERTICALLY RESOLVED CONCENTRATIONS AND MIXING STATE OF ABSORBING AEROSOLS IN THE ATMOSPHERE

TW Kirchstetter[1,2], DL Wilson[1,2], OL Hadley[1], S Dasey[1], CE Corrigan[3], J Blair[4]
[1]LBNL; [2]UC Berkeley; [3]UC San Diego; [4]AethLabs

Problem

A recent assessment (Bond et al., JGR 2013) affirms that black carbon warms the atmosphere, alters regional clouds and precipitation, and is the second most important anthropogenic climate forcing agent in the present-day atmosphere (only CO_2 ranks higher). The vertical distribution of black carbon is a strong controlling factor, determining its absorption forcing efficiency, effects on clouds, semi-direct effects, removal rates, lifetime, and deposition to the cryosphere. Since climate model prescriptions and satellite retrievals of the vertical distribution of aerosols carry high uncertainty, both would benefit from in-situ measurements of vertically resolved black carbon concentrations, which are at best available during intensive operating periods of only a few major field campaigns.

Research Approach

We are filling this critical data gap using balloon-borne packages that deliver vertically resolved aerosol measurements in the troposphere. The near, mid, and long term objectives of the project are to a) develop, test, modify, and improve a lightweight, technology-integrated payload that is lifted through the troposphere by a balloon, b) collect data that benefit climate and air quality prediction, and c) make vertically resolved measurements of climate-relevant pollutants in the atmosphere routine. The latter objective could be readily enabled through integration with current programs of routine deployment of radiosondes and ozone sondes worldwide, which have provided foundational knowledge for understanding extreme weather events and stratospheric ozone dynamics.

Recent Supporting Accomplishments

We have assembled an instrumented payload that includes a) radio communication, data logging, telemetry, and tracking capabilities for payload retrieval, b) a micro-aethalometer modified for increased black carbon measurement stability and sensitivity, and c) relative humidity, temperature, and altitude sensors. At a predetermined altitude, the payload's onboard computer releases the balloon, a parachute deploys, and the payload descends back to the Earth's surface. Transmitters incorporated into the instrument payload relay its location to a ground operator's smartphone throughout the flight, allowing the payload to be recovered after each mission.

Instrumented payloads are being deployed with increasing regularity in California to begin to quantify temporal variation in the vertical structure of black carbon. To date, we have succeeded in conducting eight missions demonstrating the ability to predict the rise rate, flight path (using NOAA wind fields), and recovery location of the instrumented payload.

On two missions, black carbon was detected at high altitudes and above clouds, where radiative forcing is amplified. These observations support prior evidence of long-range transport of pollutants over the Pacific Ocean and support the notion that air pollution layers above the planetary boundary layer, in addition to locally emitted air pollution, may contribute to climate change.

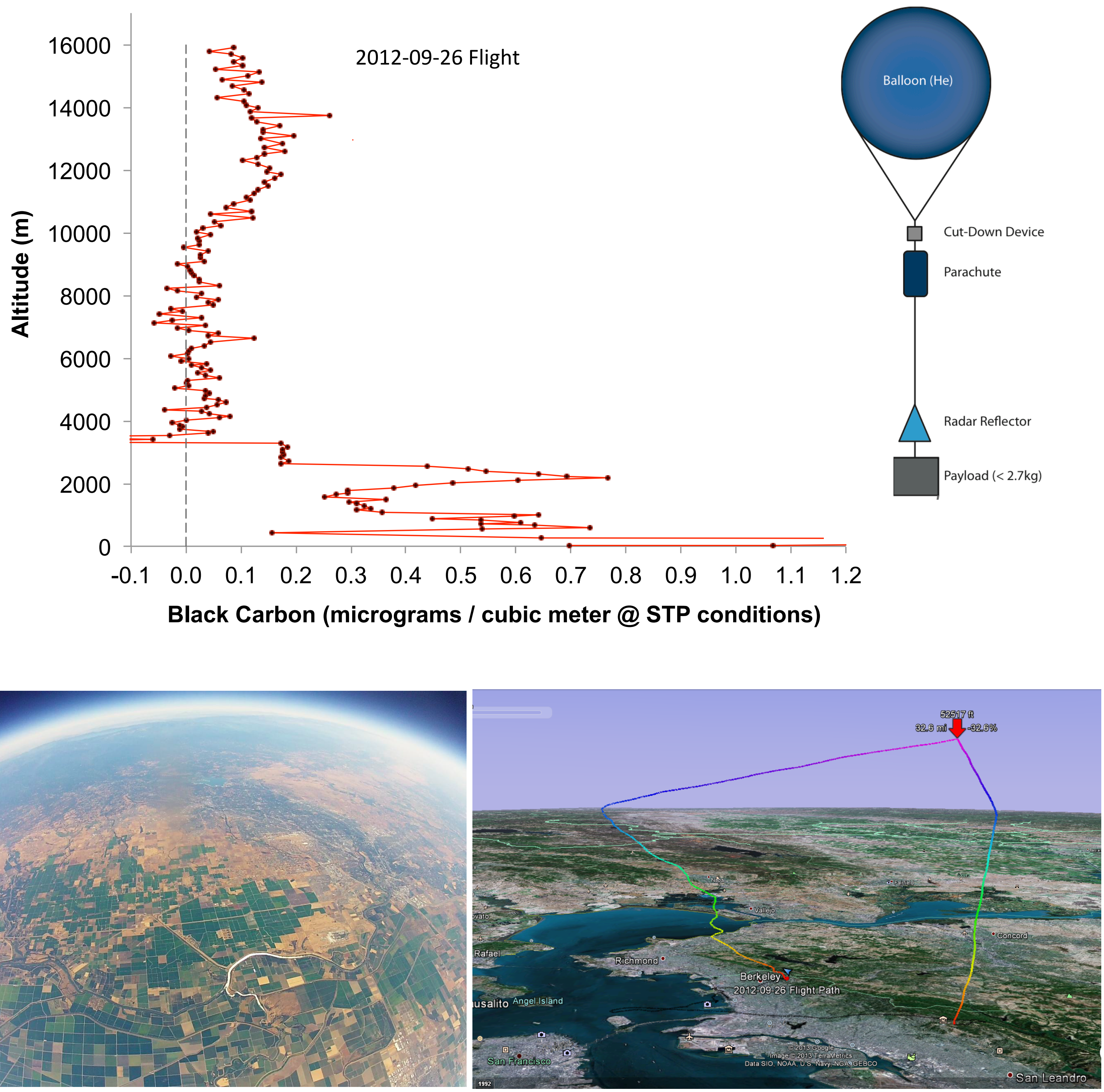

Figure 1: Summary of flight mission on 26-September-2012. (Top) Measured vertical distribution of black carbon showing layers below 3 km and above 10 km. (Bottom Left): Payload cameras provide visual record of flight, including cloud layers. (Bottom Right) Flight path of the instrumented balloon-borne payload launched and recovered in the San Francisco Bay Area, superimposed on a Google earth map.

Next Steps

We are continuing to assess and increase the quality of the retrieved black carbon data, which will involve integrating a second black carbon sensor and minimizing relative humidity effects on measured aerosol properties. Additional advances sought include the following.

Instrumentation and methods:

- Integration of an aerosol collector programmed to collect samples present in selected layers of the atmosphere from the ground to the tropopause, enabling subsequent analysis of aerosol chemical composition, including radionuclides, and aerosol mixing state.

- Integration of an optical particle counter to measure particle size distribution in addition to black carbon.

- In collaboration with its manufacturer, redesigning the micro-aethalometer to deliver the same or better measurement sensitivity as the instrument we are presently using but at a much lower cost, which would enable routine black carbon monitoring at various locations, including in regions where payload recovery may not be certain, such as the Arctic or the Himalayas.

Science and applications:

- Routine aerosol sampling in California to evaluate the 1) extent to which transpacific transport events advect Asian aerosols to the United States, aiming to improve global transport of pollution and transport models, and 2) vertical distribution of aerosols, aiming to improve our understanding of aerosol radiative forcing efficiency and provide boundary conditions for regional models.

- Collaboration with other investigators to include additional instrumentation and to include balloon-borne vertical profiling of aerosols in other regions, including in campaigns where ground, aircraft, and satellite measurements are made to better understand atmospheric processes related to climate change.

- Integration with ongoing and related activities, such as greenhouse gas profiling at the ARM site in Oklahoma (a BER-TES programmatic effort), ASR activities in India, and ARB-supported radionuclide measurements at Mt. Tamaulipas in California.

Contact

Thomas Kirchstetter
Staff Scientist, Environmental Energy Technologies Division
Lawrence Berkeley National Laboratory
twkirchstetter@lbl.gov
510-486-5319

Associate Adjunct Professor, Civil and Environmental Engineering Department
University of California, Berkeley
twkirchstetter@berkeley.edu
510-908-1237