Participatory Scientist Measurements of Light-Absorbing Particles (LAPs) on Snow

Ulyana Horodyskyj Peña[1], Carl Schmitt[2], Christi Buffington[2] and many others!

1 - University of Colorado Boulder; Science in the Wild 2 - University of Alaska Fairbanks

The Light-Absorbing Heating Method (LAHM) instrument

The LAHM instrument quantifies the **light absorption capabilities** of particulates present on filters. Rather than measure light transmission through a filter, the LAHM method simply involves shining a well-calibrated light source on the particles. As LAPs absorb the light, excess energy is **reemitted as heat** in an effort to equilibrate with their surroundings. Using an IR thermometer, the temperature of the filter is recorded. The diagram of the LAHM instrument (Figure 1) shows the current form of the instrument. The design provides direct illumination of the filter by the light source while stray light can easily exit the system. The mass of the visibly clear plexiglass plates has significant thermal inertia and the plates do not absorb any radiation from the lamp. The filter edge is the only part of the filter in contact with the instrument, making it nearly thermally independent of the rest of the instrument. The **temperature increase** of the filter can be directly compared with laboratory standards made by NOAA scientists using Fullerene Soot. Figure 2 shows the temperature increase of standard filters with varying amounts of fullerene soot. Note that a blank filter will only increase in temperature by 0.06 °C while one microgram (which is barely detectable visually) will lead to a 1.0 °C temperature increase and a filter with 100 micrograms of Fullerene Soot will increase in temperature almost 14 °C. Currently there are **20 LAHM instruments of this type** with about half being owned by universities and half by individuals.

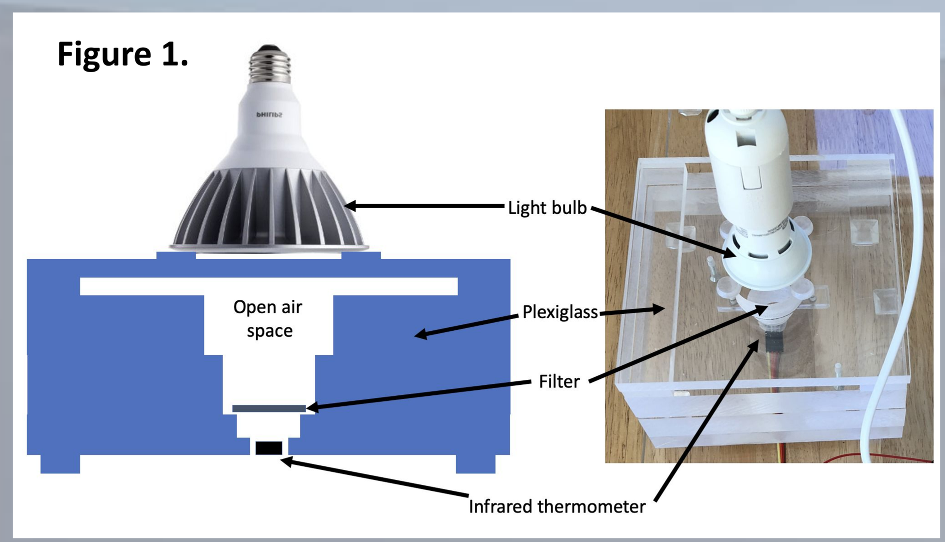


Figure 1.

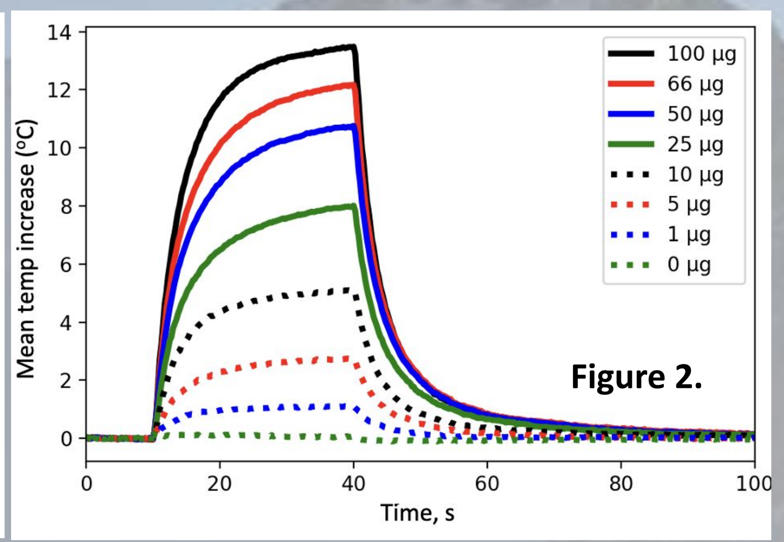


Figure 2.

Figure 3 shows the increase in temperature for a set of 30 calibration filters as well as a fit to the data which is used in analysis of the data. After much experimentation, it has become apparent that the quantity measured by the LAHM instrument is more correctly the mass absorption cross section. Experiments at the AIDA cloud chamber at the Karlsruhe Institute of Technology showed that the temperature increase measured by LAHM was higher for the same mass when comparing soot created with a propane flame than with Fullerene Soot. The difference was found to be the difference that would be expected based on the mass absorption cross section. **Figure 4** shows the same fullerene soot data as Fig. 3 but also shown are data and a fit for propane soot filters.

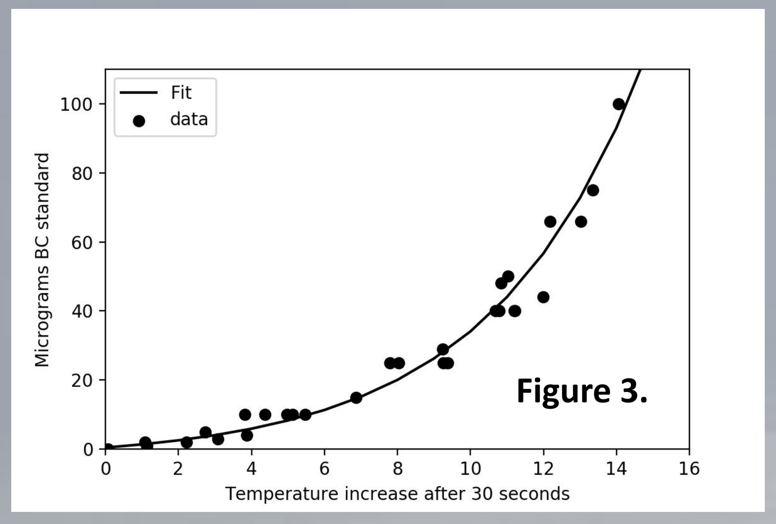


Figure 3.

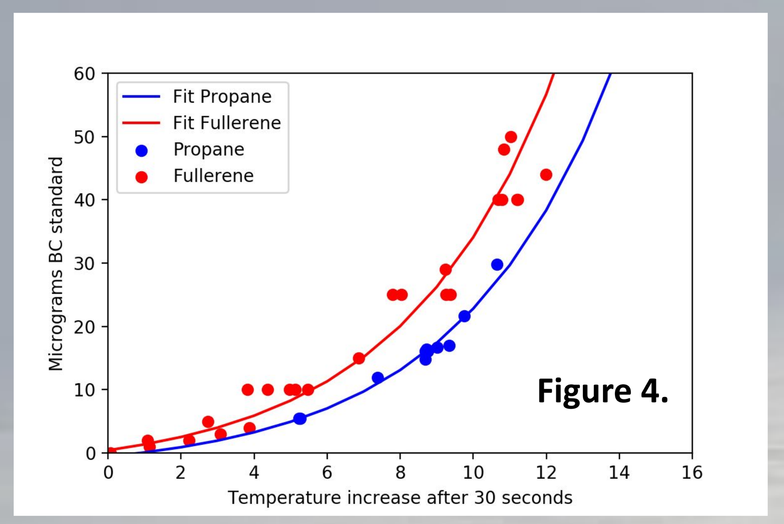
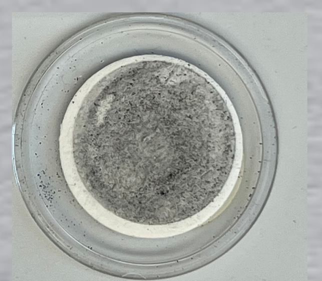
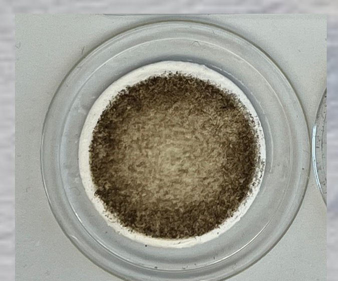


Figure 4.

Initial tests are strongly encouraging that the LAHM instrument can also be used to investigate the black carbon versus brown carbon by estimating the **absorption Angstrom exponent**. Three filters are shown below. The first filter is made up of particles that were in snow collected near an active coal mine. The particles are all likely coal dust particles. The second filter was collected at the Karlsruhe Institute of Technology, where a propane burner was the source of the black carbon on the filter. The third filter is from a glacier collected near Huancayo, Peru which included a lot of colored dust. These three filters were selected for testing based on the visual colors of the particles on the filters. For the tests, the filters were analyzed with LAHM, first using the standard white light LED bulb. The bulb was then replaced by first, a blue light LED, then an IR LED bulb that produces light centered on 850 nm. The table below shows the temperature increase (in degrees Celsius) after 30 seconds for each of the trials.





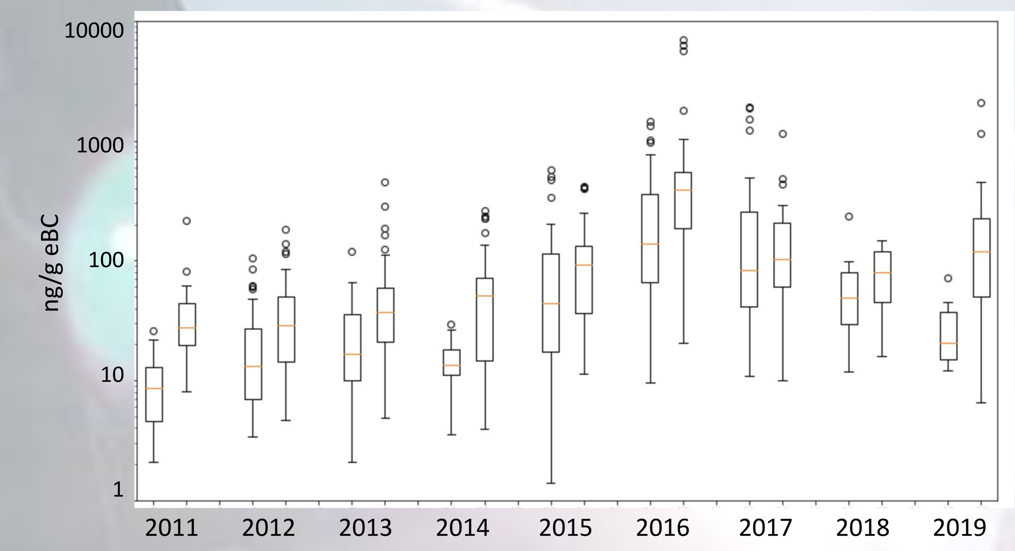
Temperature increase from light bulb normalized to white bulb	Coal dust	Propane soot	Peruvian dust
White	10.0	10.0	10.0
Blue	9.25	9.98	11.53
850nm IR	8.75	7.98	5.06

The motivation behind the development of the LAHM instrument was to encourage **participatory science**. The quantification of Light Absorbing Particles (LAPs) on snow generally requires very complex and expensive instrumentation (e.g. the Single Particle Soot Photometer and associated equipment to nebulize snow samples). The LAHM method provides a **low cost alternative.** While LAHM does not speciate LAPs in samples, it determines the bulk absorption by all particles collected.

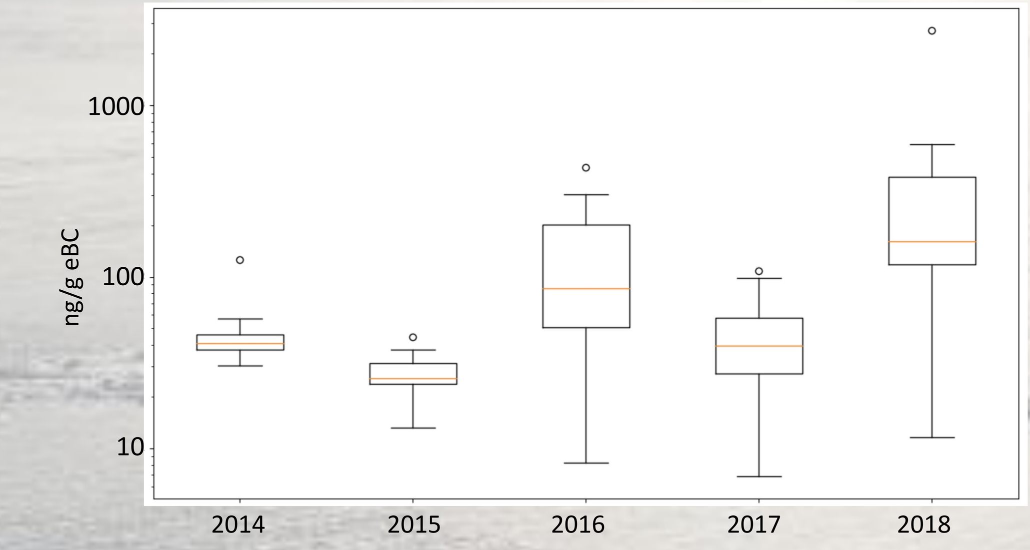
What makes LAHM ideal for participatory science? The LAHM method is straightforward to do and there is near instant feedback. Participatory scientists use a **simple protocol** to collect snow samples. They then melt the snow samples and push the water through filters. The filters are preserved and analyzed using the LAHM instrument. While most people think that snow is clean, typically the buildup of particles on the filters is obvious and often surprising which quickly ignites the curiosity of participatory scientists.

Participatory Science Examples

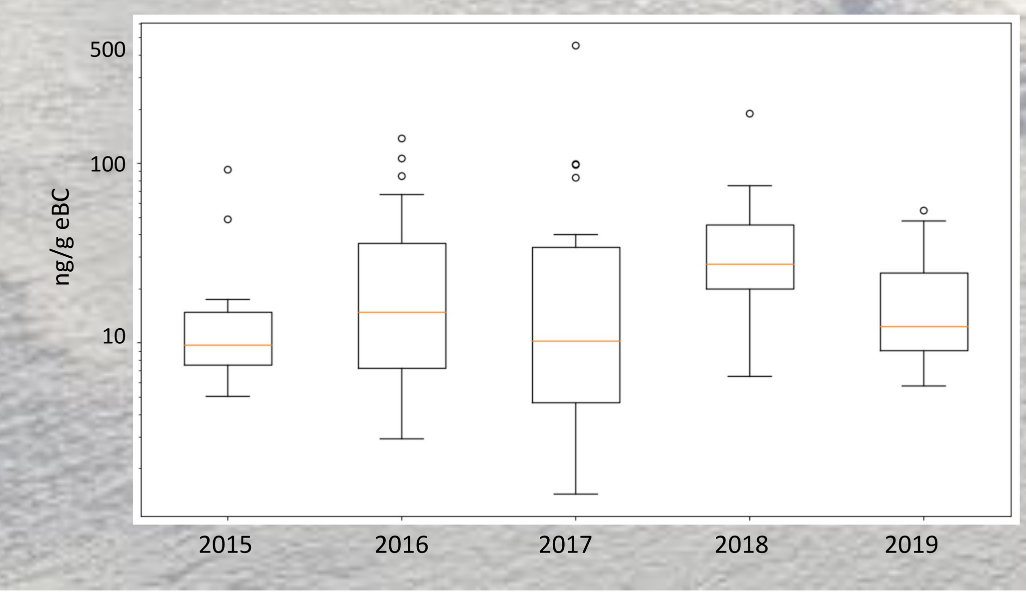
The LAHM instrument originally was developed to analyze samples collected by the American Climber Science Program during research expeditions in the Cordillera Blanca region in Peru, South America. ACSP conducted 9 research expeditions before COVID in the Cordillera Blanca, collecting more than 500 samples in total. The plot below shows two box plots for each of 9 years of measurements. Each box plot represents data collected in the northern half of the range (first box plot) or the southern half of the range. ACSP activities in other regions have led to the collection of several hundred additional samples. More than 150 volunteers and expedition leaders have participated in the data collection. **Leaders: John All, Ellen Lapham, Rebecca Cole, Carl Schmitt.**



Central Wyoming College conducts educational expeditions to Gannett Glacier in the Wind River range in Wyoming as part of their curriculum. During the Interdisciplinary Climate Change Expeditions (ICCE), students have conducted measurements of light absorbing particles on the glacier and in nearby snow fields. The graph below shows box plots of the LAHM eBC values estimated for each of the years from 2014-2018. CWC owns a LAHM instrument and typically 2-3 students focus on the LAHM data analysis. Each year they typically collect 25-50 samples. To date, the total student involvement is >100 with greater than 200 total samples collected and analyzed. **Jacki Klancher, Alex Greenwald, Grace Hartman, Daniel Shade**



LAHM developer, Carl Schmitt, conducted a number of systematic studies in the mountains of Colorado while developing the instrument. During the 2015-2019 period, Schmitt and a core group of volunteers collected samples on the east side of the front range (from Rollinsville to Rocky Mountain National Park) and the west side (in the Winter Park region). Samples were collected weekly to monthly throughout the winter months by approximately 10 different volunteers. A total of about 200 samples were collected. **Ulyana Horodyskyj Peña, Alia Khan, Elizabeth Pike, Carl Schmitt**

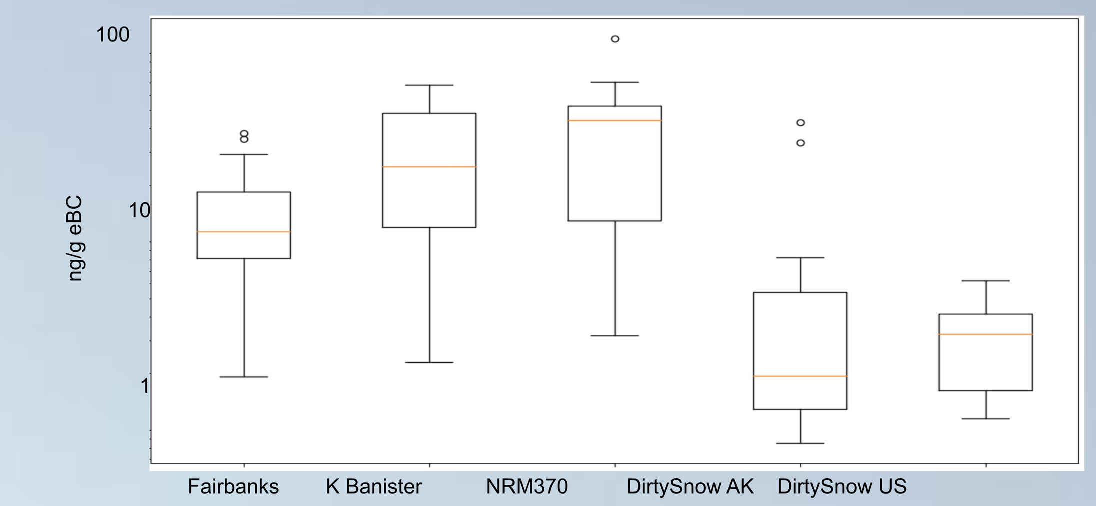


Dirty Snow

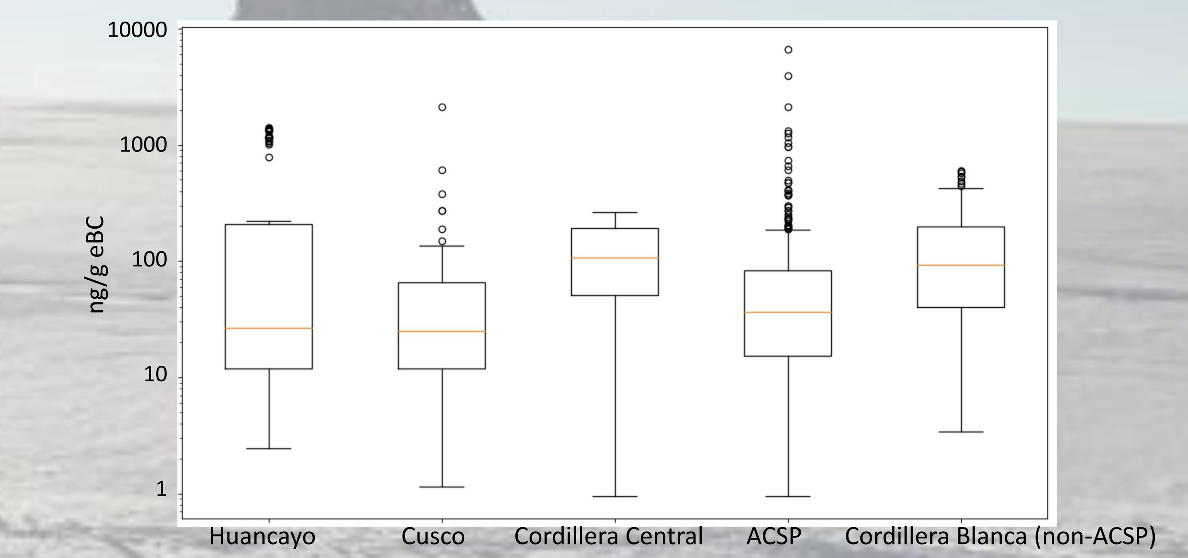
In 2019, Carl Schmitt, the inventor of the LAHM instrument, started a new position at the University of Alaska, Fairbanks. Citizen science activities related to LAPs on snow have followed. In 2021, **Buffington, Schmitt, and Horodyskyj** organized a 5-week STEM engagement program called "DirtySnow" for middle and high school youth. Students from throughout Alaska and across the US joined the program including sampling snow for LAPs in their communities. Students were encouraged to identify questions in their local area of interest.

LAP sampling has also been conducted by university students in a Natural Resource Management (NRM370) Introduction to Watershed Management course. Students identified locations for sampling in the Fairbanks area, collected snow samples and filtered them in class. A LAHM instrument was operated in class to quantify their results on site.

NASA SnowEx Intern Kaila Banister collected snow samples throughout two winter seasons in an effort to monitor the impact of LAPs on snow at locations that were substantially different in regional air pollution. This work was conducted in conjunction with additional measurements in Fairbanks to monitor the evolution of LAPs on snow during the spring melt.



Several university and research organizations in Peru have acquired LAHM instruments and are conducting regular sampling studies. While several of these datasets are unavailable, the data shown below are from groups with whom we continue to collaborate. 1. Students at the University of Huancayo have conducted several years of measurements leading to several peer reviewed publications. 2. The Universidad Andina and Universidad Nacional San Antonio Abad del Cusco both have extensive programs for monitoring nearby mountains in the Cusco region as well as 3. the Cordillera Central. In addition to the ACSP measurements (4), several students have continued to sample throughout the year for over a decade in the Cordillera Blanca (5). **Wilmer Sanchez Rodriguez, Juan Jose Zuñiga Negron, Maxwell Rado, Christian Torres, Luis Suarez, Julio Warthon.**



Peer reviewed publications using LAHM technique and data:

Measurements of light-absorbing particles on the glaciers in the Cordillera Blanca, Peru, CG Schmitt, JD All, JP Schwarz, WP Arnott, RJ Cole, E Lapham,... The Cryosphere 9 (1), 331-340.

Pollution and its impacts on the South American cryosphere, LT Molina, L Gallardo, M Andrade, D Baumgardner, M Borbor-Cordova,...Earth's Future 3(12), 345-369

Impacts of coal dust from an active mine on the spectral reflectance of Arctic surface snow in Svalbard, Norway, AL Khan, H Dierssen, JP Schwarz, C Schmitt, A Chlus, M Hermanson,... JGR: Atmospheres 122(3), 1767-1778.

Measurements of light absorbing particles in the snow of the Huaytapallana glacier in the central Andes of Oeru and their effect on albedo and radiative forcing, C Torres, L Suarez, C Schmitt, R Estevan, D Helmig, Chem. Phys 10, 6603-6615

Particulas Absorbentes de Luz durante El Niño y El Niño Costero en los Glaciares de la Cordillera Blanca, Peru, WS Rodriguez, C Schmitt, Revista de Glaciares y Ecosistemas de Montaña 4, 9-22.

The measurement and impact of light absorbing particles on snow surfaces, CG Schmitt, BL Riggs, UN Horodyskyj, AL Khan, HA Ewing, JD All,...The Cryosphere Discussions 2019, 1-16.

Quantitative estimation of black carbon in the glacier Ampay-Apurimac, C Soto Carrion, CG Schmitt, JJ Zuñiga Negron, W Jimenez Mendoza,...Journal of Sustainable Development of Energy, Water and Environment Systems…

Caracterizacion estacional de los elementos traza y particulas absorbentes de luz (PAL) en la nieve del glaciar Huaytapallana (Peru), C Torres, Y Bendezu, D Alvarez, L Suarez-Salas, AH Cruz, C Schmitt…Revista internacional de contaminacion ambiental 38

Contribution of biomass burning to black carbon deposition on Andean glaciers: consequences for radiative forcing, EX Bonilla, LJ Mickley, EG Beaudon, LG Thompson, WE Rodriguez,...Environmental Research Letters 18(2), 024031

The light absorption heating method for measurement of light absorption by particles collected on filters, CG Schmitt, M Schnaiter, C Linke, WP Arnott, Atmosphere 13(5), 824.