The spectral and chemical measurement of light-absorbing impurities on snow near South Pole, Antarctica

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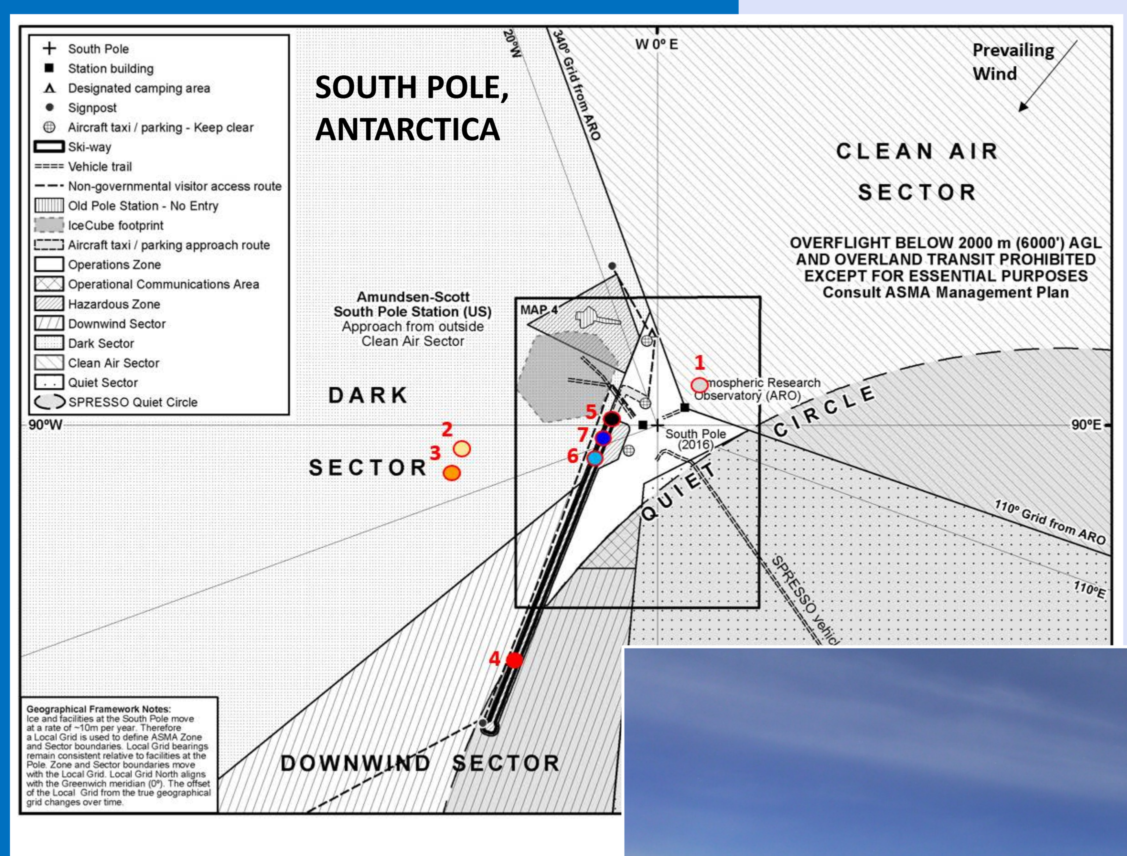
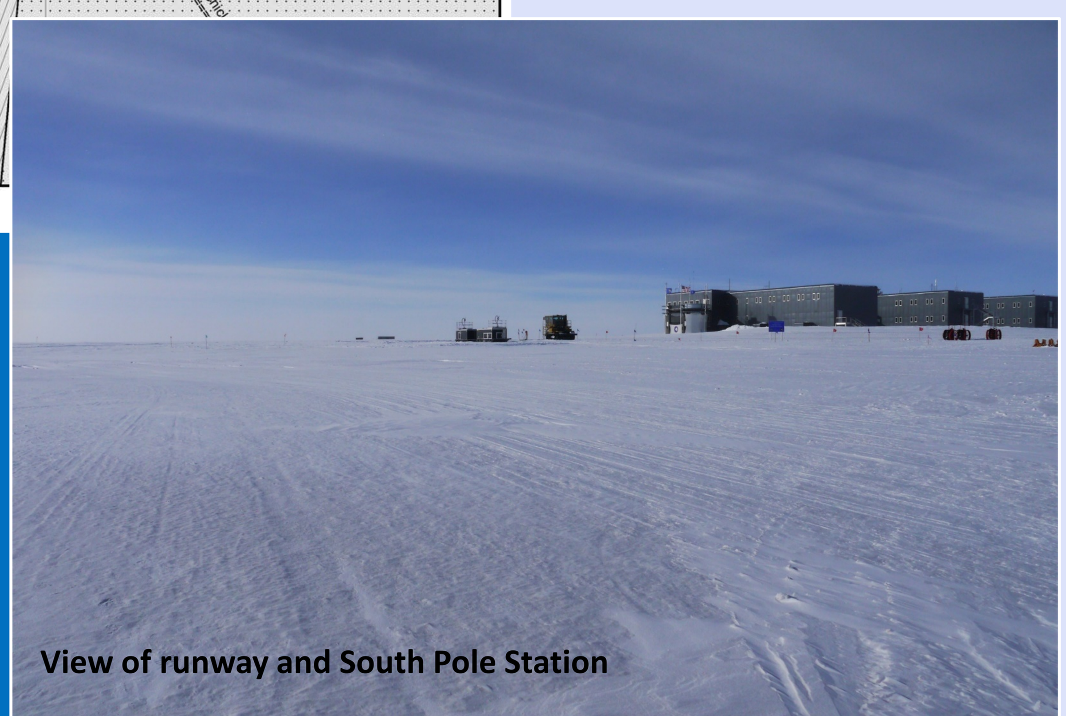
Abstract

Remote sensing of light-absorbing impurities such as black carbon (BC) and dust on snow is a key remaining challenge in cryospheric surface characterization. Snow purity and reflectivity affects local, regional and global radiative energy balance and is an important component of the climate system. We present a quantitative data set of in situ snow reflectance, measured and modeled albedo, and BC and trace element concentrations from clean to heavily fossil fuel emission contaminated snow near South Pole, Antarctica.

Fig 1. Map of study sites



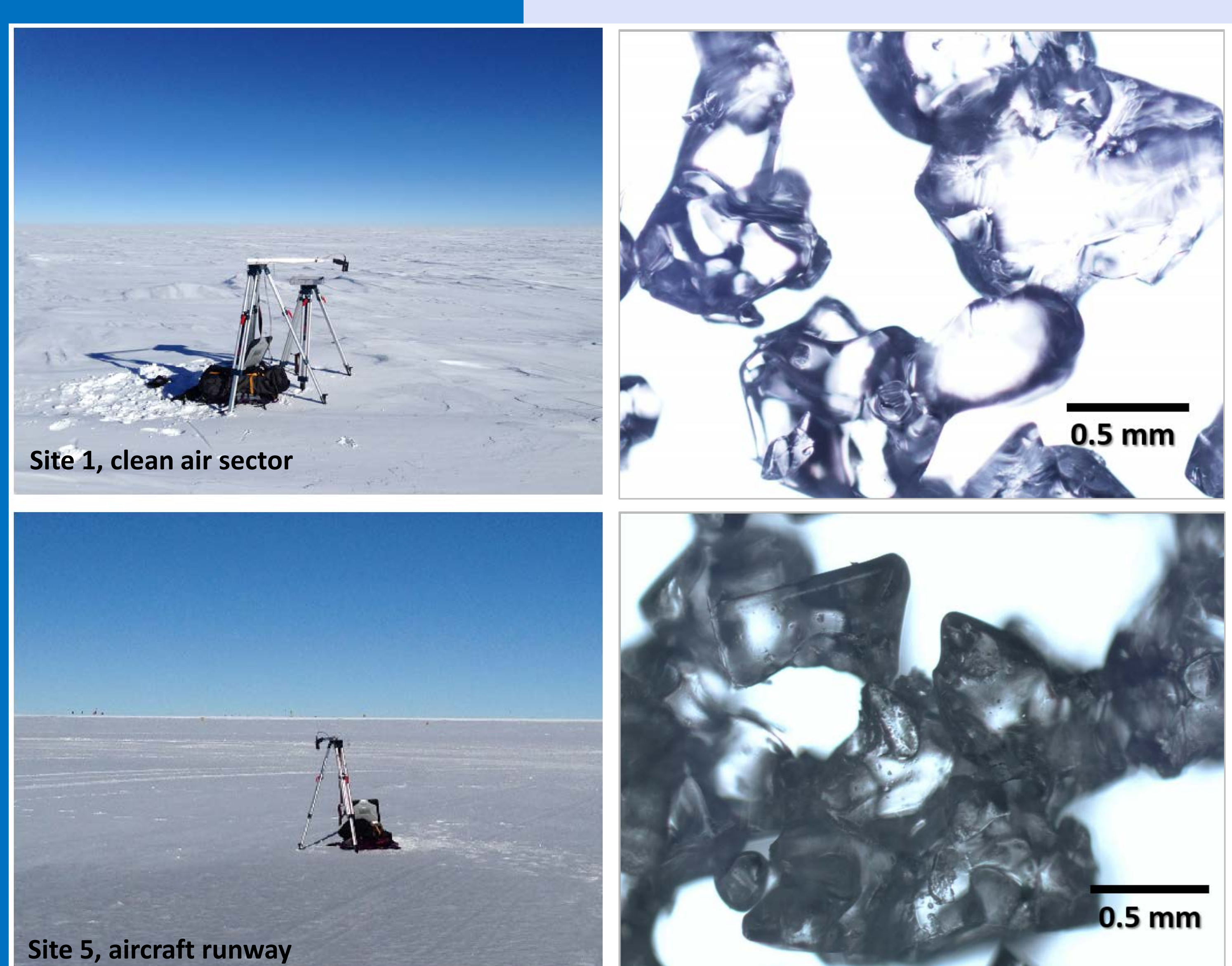


View of runway and South Pole Station

Methods

Over 1130 snow reflectance spectra (350-2500 nm) and 28 surface snow samples were collected at 7 distinct sites in the austral summer season of 2014-2015. Snow samples were analyzed for BC concentration via a single particle soot photometer (SP2), for trace element concentration via an inductively coupled plasma mass spectrometer (ICPMS), and imaged via an optical microscope.

Fig 2. Spectral measurements, snow sampling for ICPMS, SP2 analytical chemistry, imaging



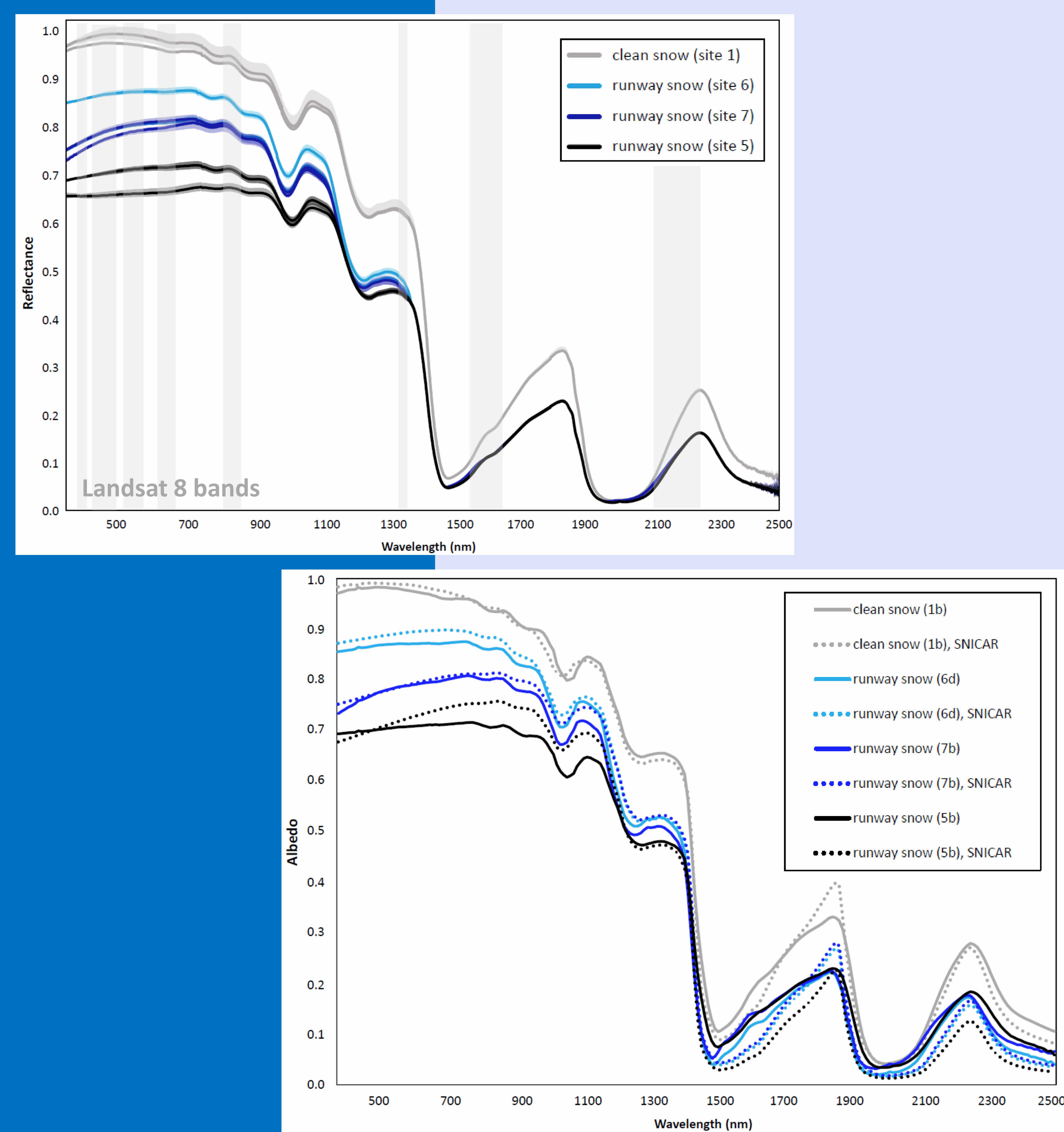
Site 1, clean air sector

Site 5, aircraft runway

Results

Snow impurity concentrations ranged from 0.14 – 7000 ppb BC, 9.5 – 1200 ppb sulfur, 0.19 – 660 ppb iron, 0.043 – 6.2 ppb chromium, 0.13–120 ppb copper, 0.63 – 6.3 ppb zinc, 0.45 – 82 ppt arsenic, 0.0028 – 6.1 ppb cadmium, 0.062–22 ppb barium, and 0.0044 – 6.2 ppb lead. Broadband visible to shortwave infrared albedo ranged from 0.85 in pristine snow to 0.62 in contaminated snow. Light-absorbing impurity radiative forcing, the enhanced surface absorption due to BC and trace elements, spanned from < 1 W m^{-2} for clean snow to ~70 W m^{-2} for snow with high BC and trace element content.

Fig 3. Snow spectral reflectance and modeled snow albedo



Recommendations

Resolving light-absorbing impurities and concentrations on snow and ice remains challenging with most current satellite spectrometers. We recommend next generation sustainable land imaging sensors contain high spectral resolution in order to accurately measure and differentiate cryospheric impurities and snow grain size. Such sensor spectral improvements would also strengthen our ability to assess radiative impacts.

We recommend snow albedo models improve representation of impurities from current broad mineral class estimations to more precise molecular and elemental based spectral absorption features.

Further details including snow trace element chemistry results are presented in:

Casey, K. A., S. D. Kaspari, S. M. Skiles, K. Kreutz, M. J. Handley, 2017, The spectral and chemical measurement of pollutants on snow near South Pole, Antarctica, Journal of Geophysical Research Atmospheres, 122, doi:10.1002/2016JD026418.

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