# Optimal estimation of snow and ice surface parameters from imaging spectroscopy measurements

Niklas Bohn[a], David R. Thompson[b], Nimrod Carmon[b], Jouni Susiluoto[b], Michael J. Turmon[b], Mark C. Helmlinger[b], Robert O. Green[b], Joseph M. Cook[c], Luis Guanter[d]

[a] GFZ German Research Centre for Geosciences, Telegrafenberg, 14473 Potsdam, Germany
[b] Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA
[c] Institute of Biological, Environmental and Rural Sciences, Aberystwyth University, Penglais Campus, Aberystwyth, Wales, UK, SY23 3DA
[d] Research Institute of Water and Environmental Engineering (IIAMA), Universitat Politecnica de Valencia (UPV), Valencia, Spain

## Abstract

Snow and ice melt processes are key indicators of climate change, and may be assessed with remote sensing instruments. These processes decrease the surface reflectance with unique spectral patterns due to the accumulation of liquid water and light absorbing particles (LAP), making imaging spectroscopy a powerful tool to measure and map this phenomenon. Here we present a new method to retrieve snow grain size, liquid water fraction, and LAP mass mixing ratio from airborne and space borne imaging spectroscopy acquisitions. This methodology is based on a simultaneous retrieval of atmospheric and surface parameters using optimal estimation (OE), a retrieval technique which leverages prior knowledge and measurement noise in the inversion and also produces uncertainty estimates. We exploit statistical relationships between surface reflectance spectra and snow and ice properties to estimate their most probable quantities given the reflectance. To test this new algorithm, we conducted a sensitivity analysis based on simulated top-of-atmosphere radiance spectra using the upcoming EnMAP orbital imaging spectroscopy mission, demonstrating an accurate estimation performance of snow and ice surface properties. An additional validation experiment using in-situ measurements of glacier algae mass mixing ratio and surface reflectance from the Greenland Ice Sheet yields promising results. Finally, we evaluated the retrieval capacity for all snow and ice properties with an AVIRIS-NG acquisition from the Greenland Ice Sheet demonstrating this approach's potential and suitability for upcoming orbital imaging spectroscopy missions.