Experimental assessment of different mineral dust on snow properties and melt dynamics under cold laboratory conditions

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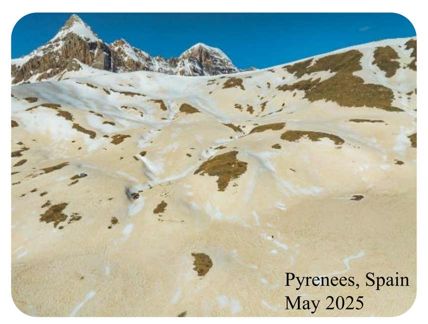
Introduction

Mineral dust deposition on snow is a first-order control on snowpack energy balance and melt dynamics. Current models and simulations of **light-absorbing impurities (LAIs)** often assume uniform mineralogical composition, neglecting the strong geochemical variability of dust sources at the global scale. This simplification introduces significant uncertainty in predicting snowmelt timing and magnitude.


Pyrenees, Spain May 2025


Sierra Nevada, Spain Feb 2017


Colorado, USA May 2014

Photo: Center for Snow and Avalanche Studies, CO, USA

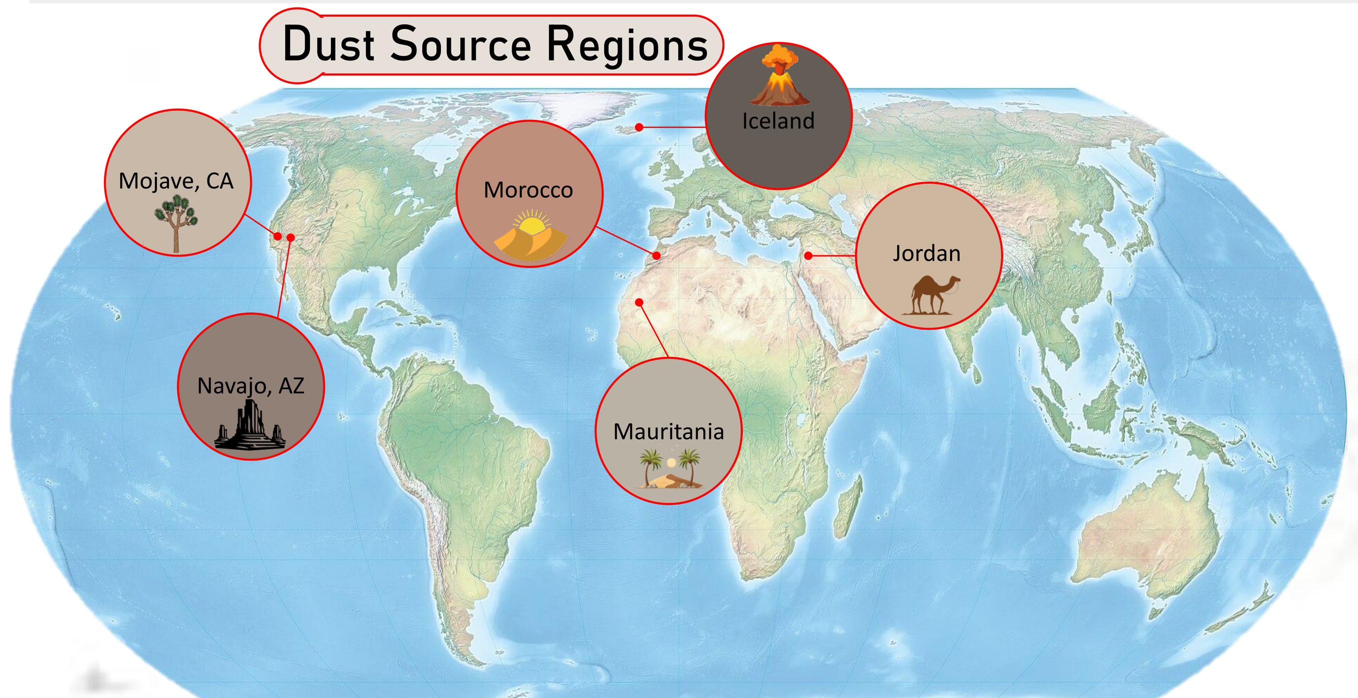
Driving Question

How does **mineral dust** from different source regions modify snow **albedo** and **melt**?

Approach

We present controlled experiments conducted in the **SubZero Laboratory** at Montana State University, using mini-lysimeters to quantify snowmelt under varying and realistic concentrations of mineral dust from six distinct source regions (**Morocco**, **Mauritania**, **Arizona**, **California**, **Iceland**, and **Jordan**), evaluating how different dust types modify snow properties and drive differences in melt rates.

Dust Source Regions



- Mauritania
- Morocco
- Arizona
- California
- Jordan
- Iceland

Methodology

A controlled cold-laboratory setup **(SubZero Laboratory)** was used to simulate snow-dust interactions under defined environmental forcing (radiation, air and snow temperature, density and %RH). Snow (natural and artificial) was collected into custom mini-lysimeters, weighed, and artificially doped with the mineral dust samples.

Concentrations

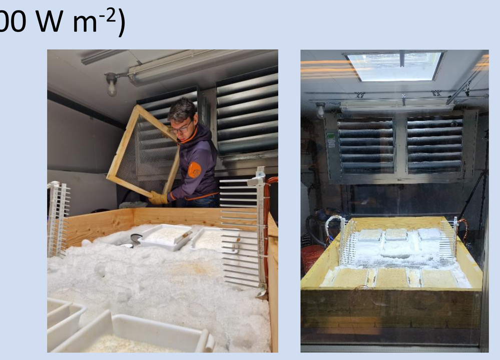
- 6 pairs of trays
- 2 g m^{-2} (x2)
- 5 g m^{-2}
- 10 g m^{-2} (x2)
- BLK

Snow

- Powder snow (0-4 days) or from Snow Maker
- Old snow (+4 days)

Conditions

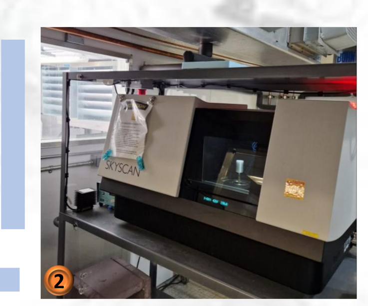
- COLD (Air temp 6-7ºC, Solar radiation 300-500 W m^{-2})
- WARM (Air temp 9-10ºC, Solar radiation 800-1000 W m^{-2})
- 4 hours



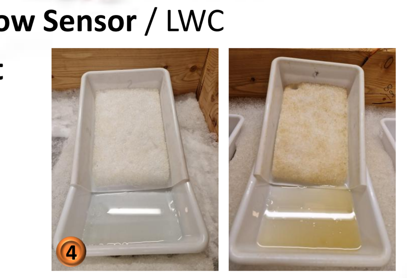
Preparation & Measurements

- Dust characterization
  Fe content (weight %)

U.S. → ~**3.0** wt%
Morocco → ~**3.6** wt%
Mixed Mauritania → ~**5.5** wt%
Iceland → ~**9.5** wt%

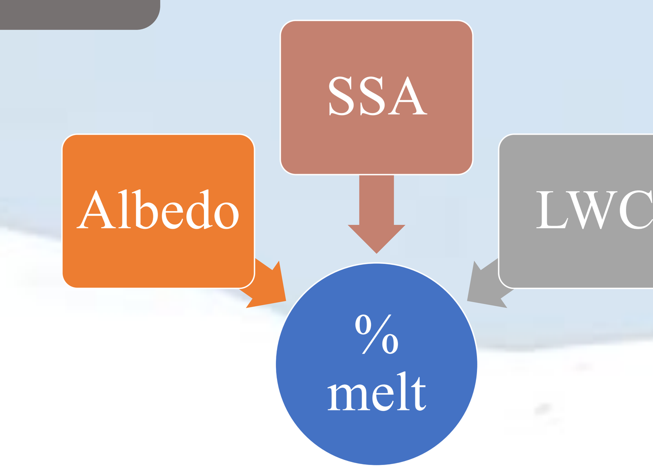


1. **ASD Spectrometer** / albedo
2. **SKYSCAN** / SSA
3. **SLF Snow Sensor** / LWC
4. **% Melt**

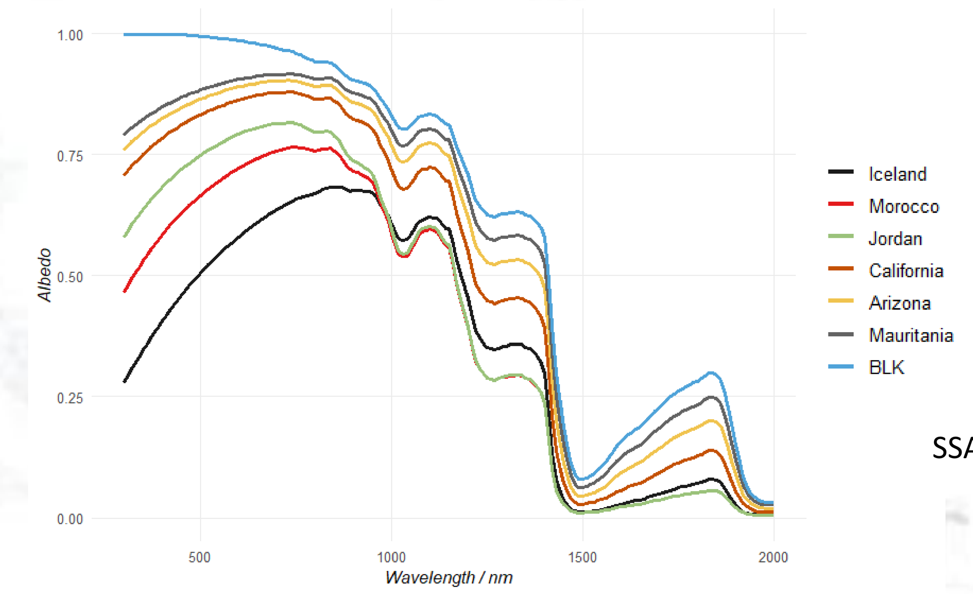


Preliminary Results

Snowmelt, spectral albedo, specific surface area (SSA), and liquid water content (LWC) were analyzed to assess the impact of dust vs BLK.

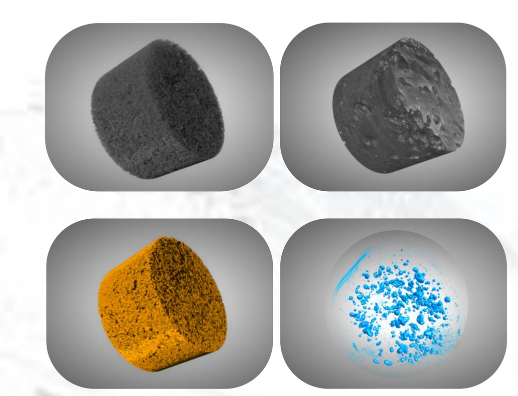


1 **ASD Spectrometer** / albedo



2 **SKYSCAN** / SSA

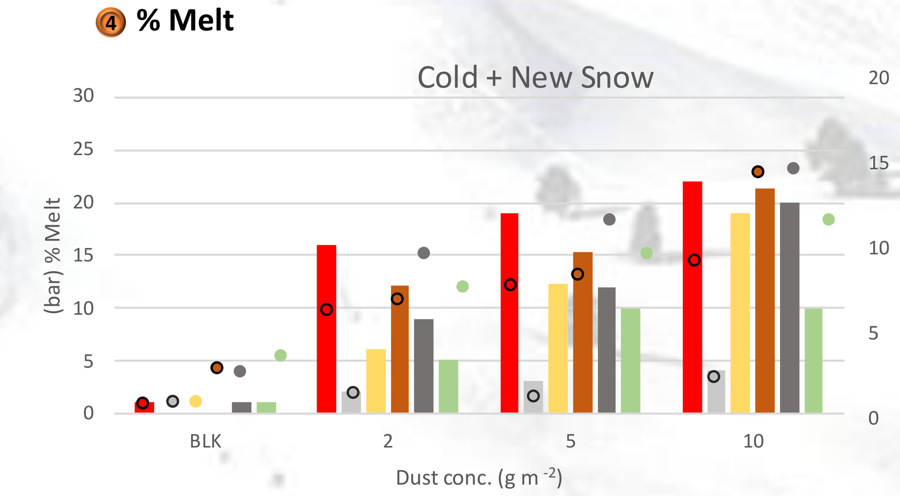
	BLK	DUST $_{10g}$
SSA (m² kg⁻¹)	~45	~5

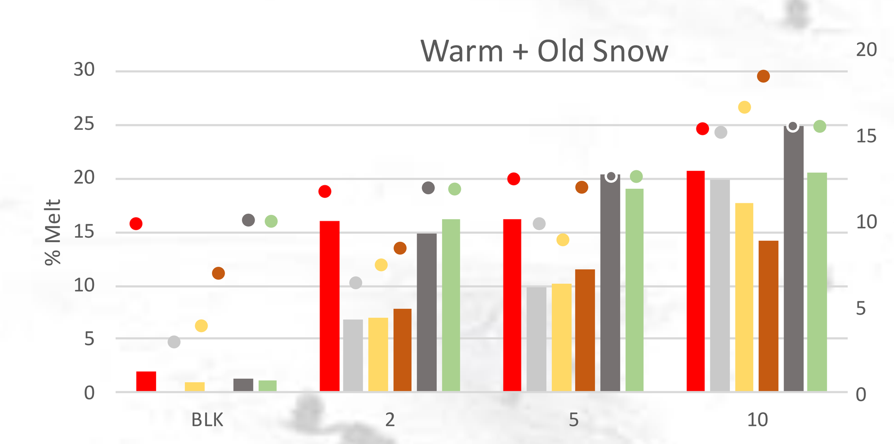


The **BLK** sample shows a porous structure with defined geometric crystals.

The **DUST** $_{10g}$ sample displays a denser matrix of transformed and bonded ice crystals, reflecting snow metamorphism.

3 **SLF Snow Sensor** / LWC
4 **% Melt**





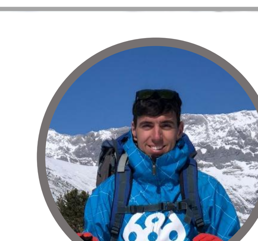
Under cold conditions, melt remains low (BLK ~1%) but increases up to ~29% (Iceland), with Morocco and Jordan also showing high responses.

Under warm conditions, melt is strongly amplified (up to ~38%), maintaining similar source-dependent ranking.

Icelandic dust produces the strongest effect, followed by Morocco and Jordan.

References

- **Bandrés, J., López-Moreno, J. I., Salvador, P., & Pey, J. (2025).** *Atmospheric Research,* 331, 108686.
- **Pey, J., Revuelto, J., Moreno, N., Alonso-González, E., Bartolomé, M., Reyes, J., Gascoin, S., & López-Moreno, J. I. (2020).** *Atmosphere,* 11, 937.
- **Skiles, S.M., Flanner, M., Cook, J.M., Dumont, M. & Painter, T. H. (2018).** *Nature Climate Change,* 8, 964–971.
- **McKittrick, L. (2015)** *Subzero Science and Engineering Research Facility.*
- **Colorado Dust-on-Snow Program (CODOS), Center for Snow and Avalanche Studies (CSAS), 2004.**



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