

Assessment of methods for mapping snow albedo from MODIS

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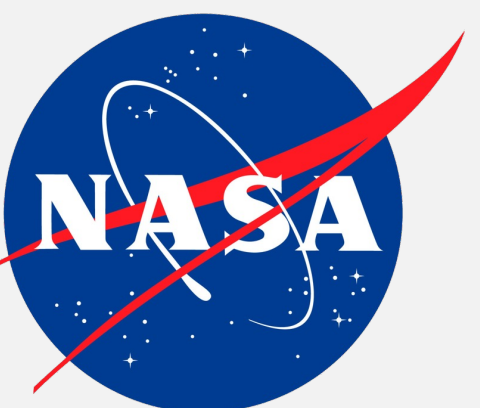
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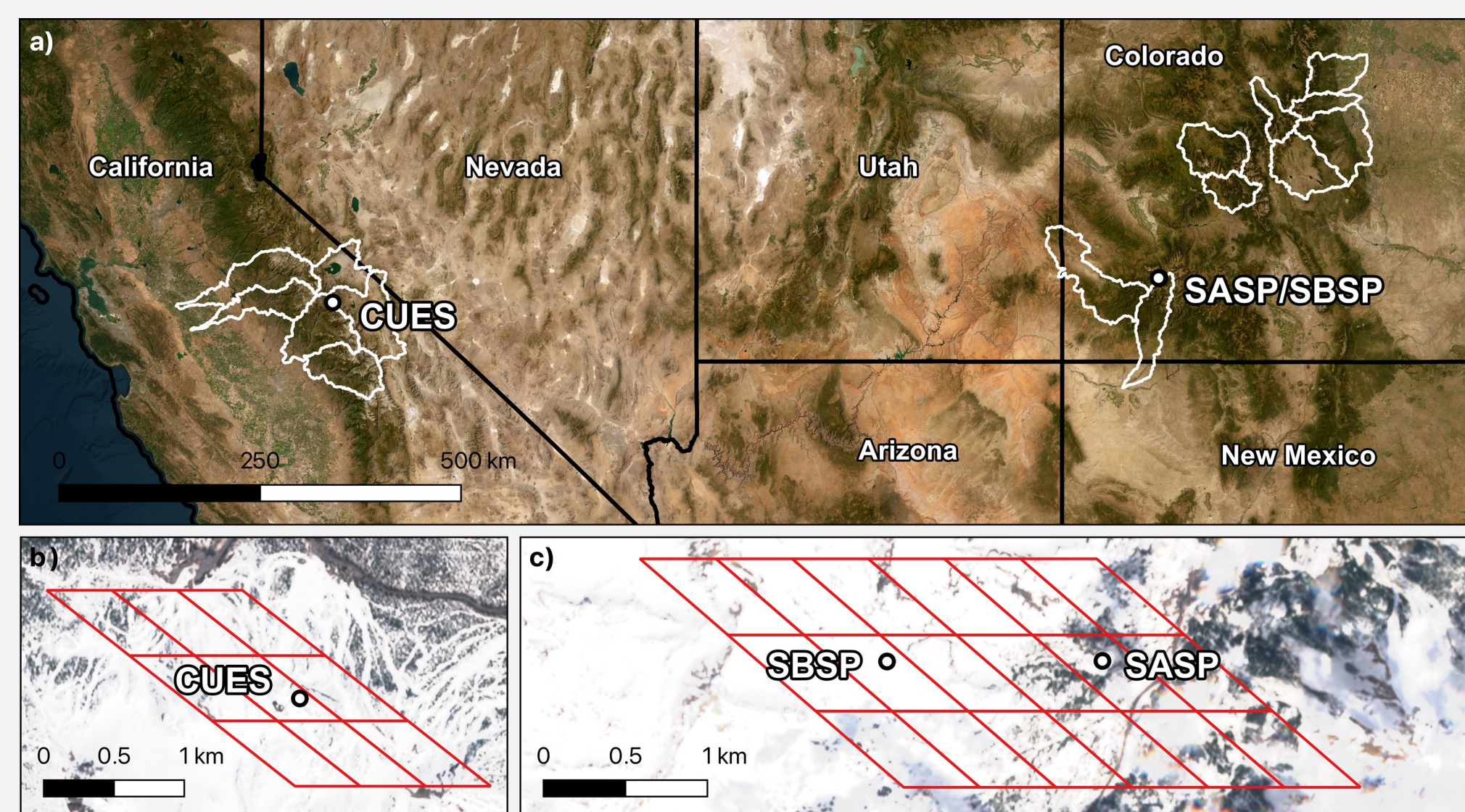
University of Colorado Boulder

Introduction

Remotely sensed snow albedo measurements provide important spatially-distributed input data for snow modeling and hydrological forecasting. We compare **five MODIS-derived snow albedo products** using data from three in situ stations and 31 airborne spectrometer surveys across 15 basins in California and Colorado, USA.

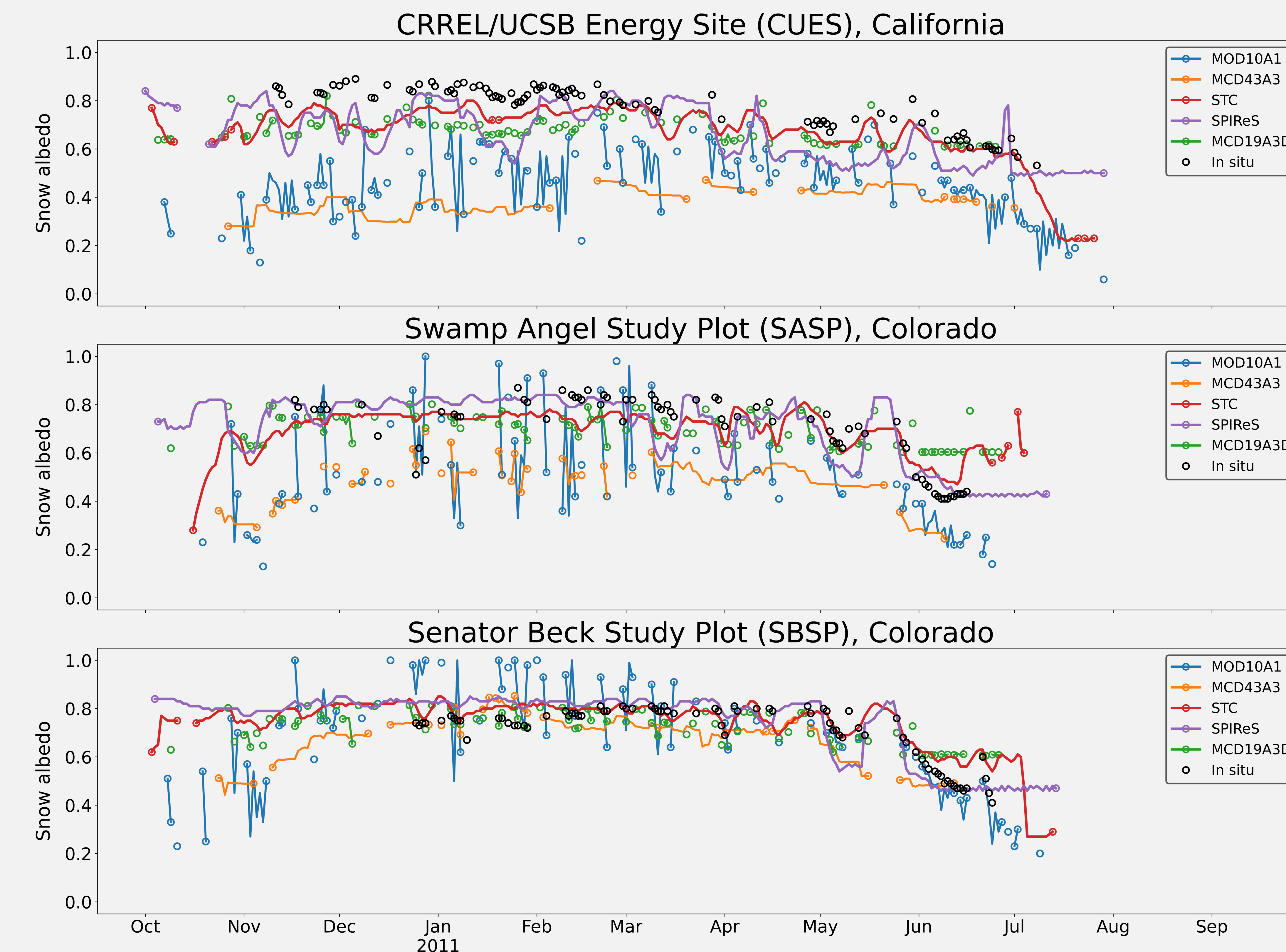
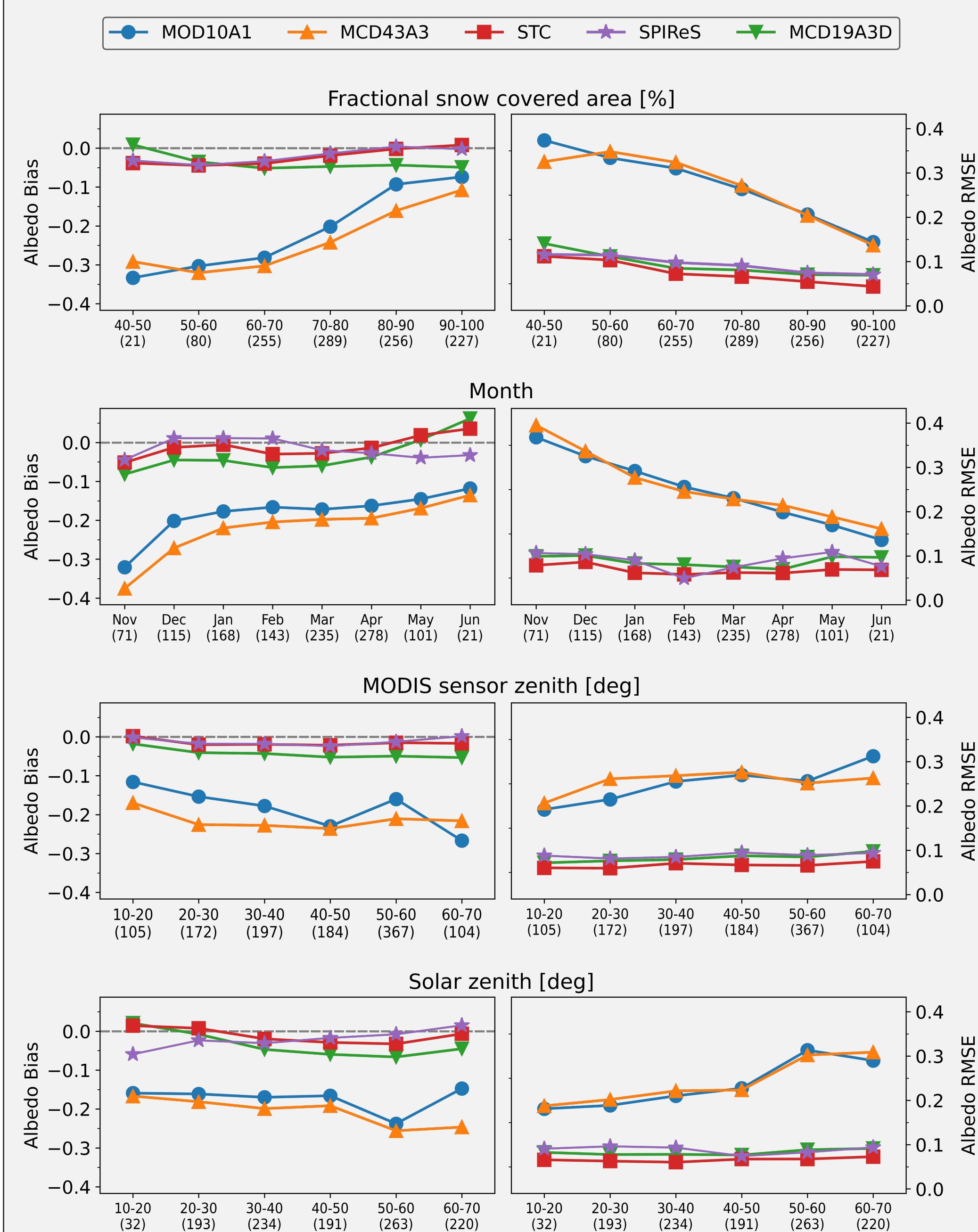
Name	NASA standard product?	Variable	Spatial/temporal resolution	Spatial/temporal interpolation	Whole-pixel or spectrally-based	Input data
MOD10A1	Yes	Snow albedo	Daily/463 m	No/No	Whole-pixel	MOD09GA surf. refl.
MCD43A3	Yes	Snow albedo	Daily/463 m	No/Yes	Whole-pixel	MOD09GA surf. refl.
STC-MODSCAG	No	Snow albedo	Daily/463 m	Yes/Yes	Spectrally-based	MOD09GA surf. refl.
SPIReS	No	Snow albedo	Daily/463 m	Yes/Yes	Spectrally-based	MOD09GA surf. refl.
MCD19A3D	Yes	Snow grain size*	Daily/926 m	Yes/Yes	Spectrally-based	MODIS L1B radiance

* requires additional end-user processing to convert to snow albedo



Top: In situ station locations in California and Colorado, USA. White outlines depict basins where the airborne surveys were collected. Bottom: High resolution winter true color images at the in situ stations with 463 m MODIS pixels superimposed.

A more detailed analysis over the entire timeseries record shows **spectrally-based products have lower errors, smaller biases, and more consistency** across various environmental and sensor characteristics. Even in pixels that are mostly or fully snow covered (90-100%), all spectrally-based datasets (STC, SPIReS, MCD19A3D) perform better than both whole-pixel datasets (MOD10A1, MCD43A3).



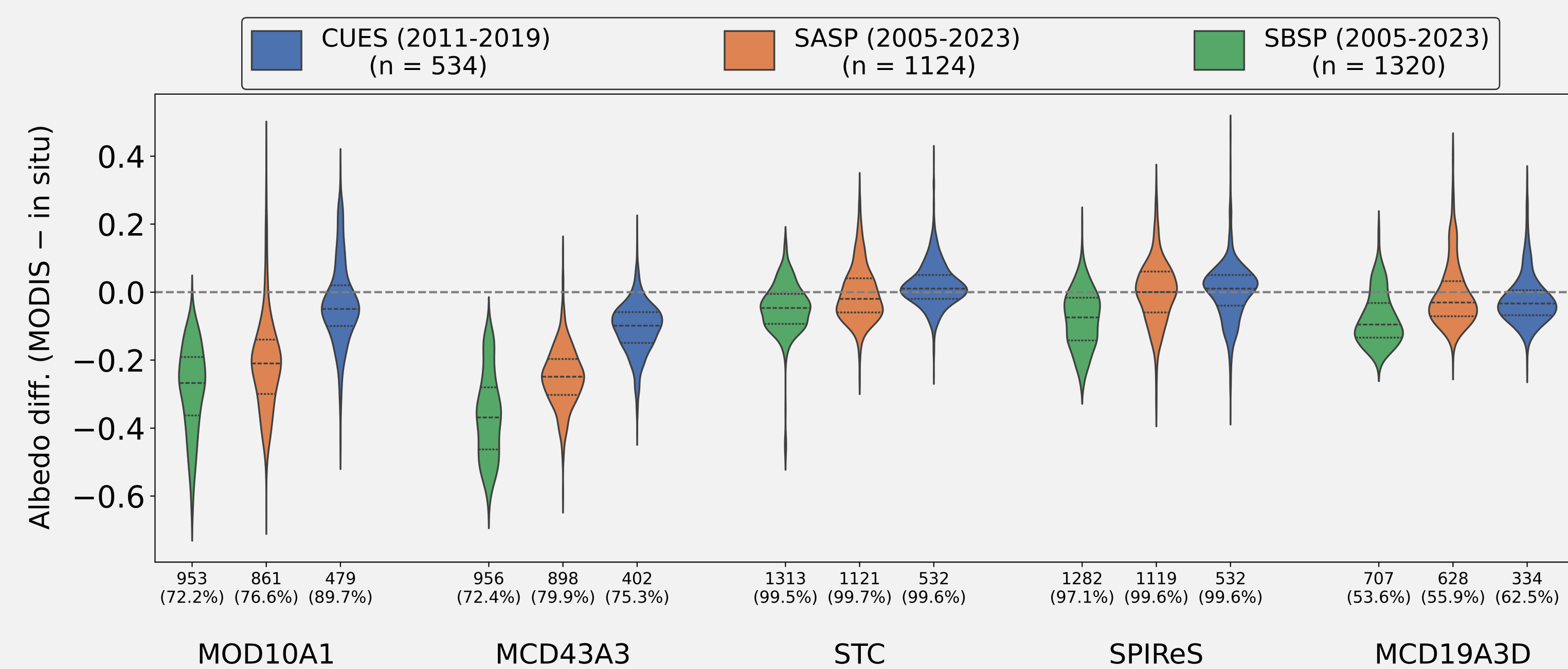
Whole-pixel products MOD10A1 and MCD43A3:

- Consistently underestimate snow albedo because they incorporate non-snow land surfaces into their calculations.
- Generally have less complete data records due to less accurate snow detection in fractionally-covered pixels.
- MOD10A1 data fluctuate considerably at a daily timescale. This is likely an artifact related to the sensor view angle in the MOD09GA surface reflectance dataset.
- Temporal averaging in MCD43A3 smooths over real snow albedo changes from early snow and dust deposition events.

Spectrally-based products STC, SPIReS, and MCD19A3D:

- Produce snow albedo data that more closely matches in situ records across all three in situ sites.
- STC and SPIReS have more complete data records due to more accurate snow detection in fractionally-covered pixels and advanced interpolation and cloud-gap-filling routines.
- MCD19A3D has the least complete data record due to the strictest threshold for snow detection across the five MODIS products and data loss issues from regional processing (see spatially distributed albedo maps in right column).

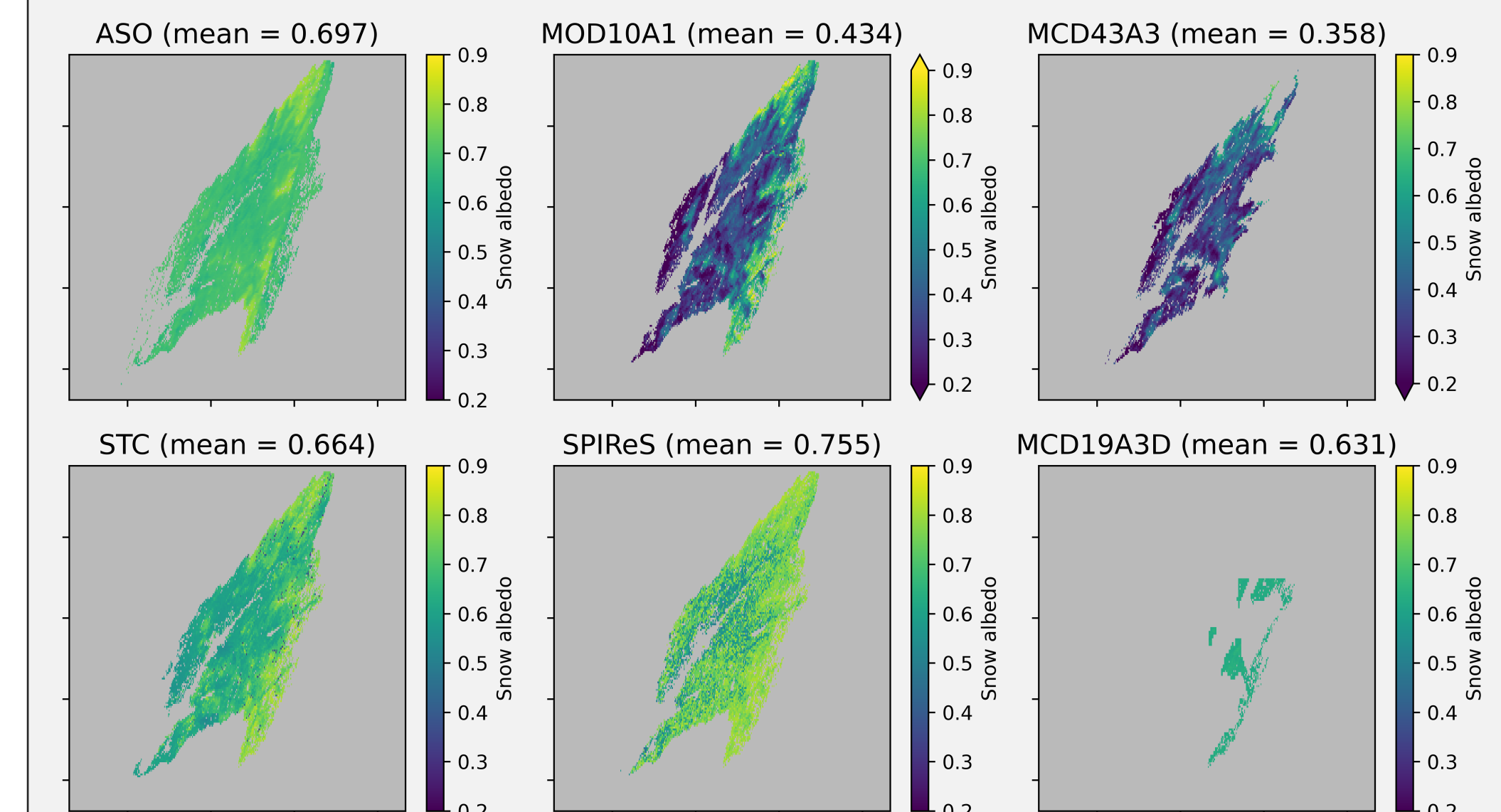
Analysis over the entire timeseries (below) shows that similar trends hold across the three in situ sites for the full data record.



Dataset	Bias	RMSE	Valid data
MOD10A1	-0.153	0.225	77.0%
MCD43A3	-0.210	0.248	75.8%
STC	-0.002	0.077	99.6%
SPIReS	-0.013	0.093	98.5%
MCD19A3D	-0.029	0.090	56.0%

Spatial snow albedo comparison

During the 2022-23 winter ASO collected 31 snow albedo surveys using optical imaging spectrometers (VNIR: 186 channels from 400-1000 nm; SWIR: 360 channels from 960-2500 nm). Although these surveys have not yet been independently validated they offer an excellent opportunity to compare MODIS products across space. An example from April 2023 in the San Joaquin basin (CA) is shown below along with the corresponding MODIS data.



Similar analysis over all 31 airborne surveys shows results similar to those found in the timeseries comparison: Spectrally-based STC and SPIReS products were closest to airborne snow albedo data and had the most complete data records.

Dataset	Mean difference	Valid data
MOD10A1	-0.225	58.7%
MCD43A3	-0.246	57.6%
STC	-0.040	96.3%
SPIReS	-0.014	92.6%
MCD19A3D	-0.005	26.8%

The spatially-distributed data allows for a comparison across other environmental variables that is not possible using point-based timeseries. The figure below shows the parameter space of elevation and canopy cover across all ASO surveys, and the difference in snow albedo in the five MODIS datasets across the same parameter space.

