Coherence in retrievals of snow albedo, grain size, and radiative forcing by light absorbing particles from spaceborne and airborne imaging spectrometers

PETEMcBRIDE

UCLA JIFRESSE

ASO

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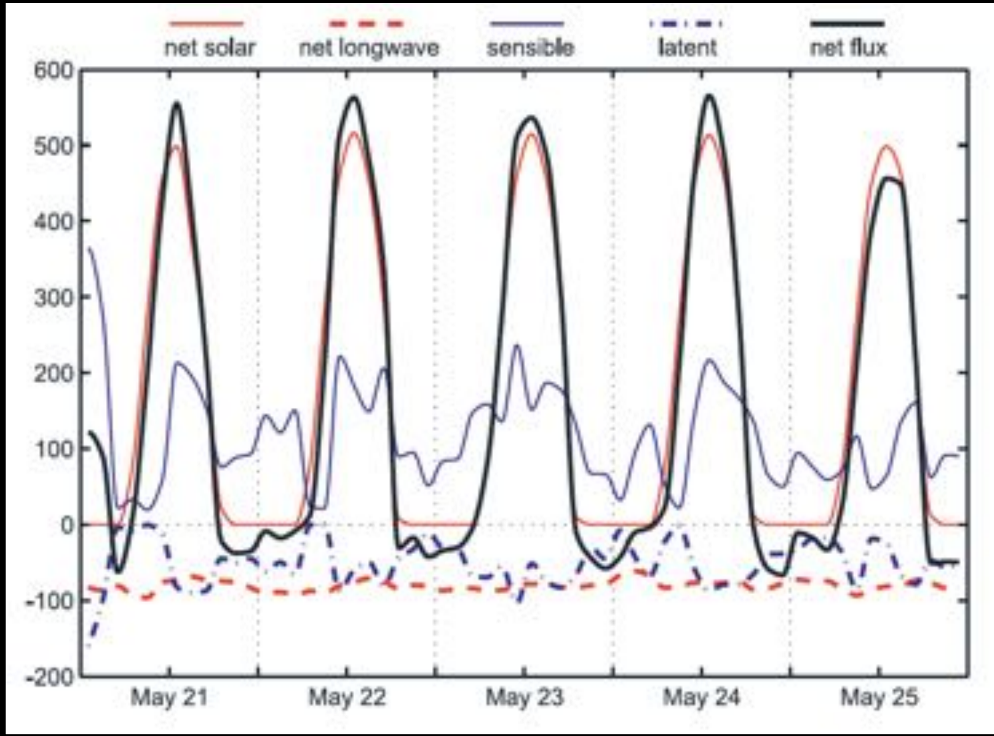
Funding from NASA USPI program, NASA Terrestrial Hydrology, and California DWR/Colorado Water Cons

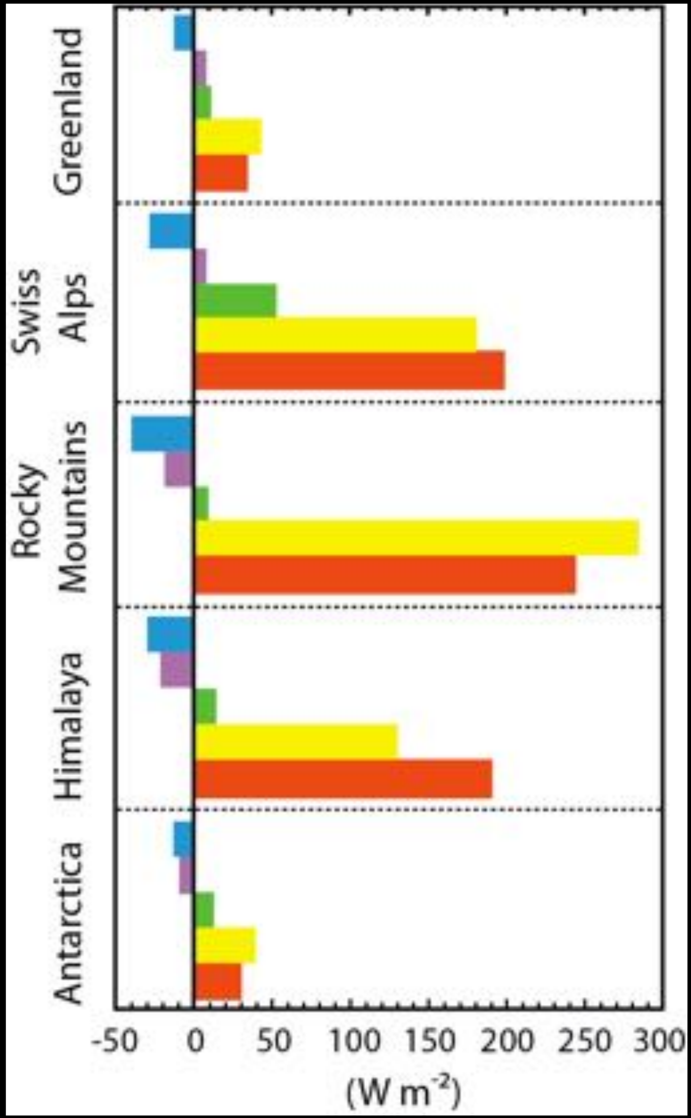
Snow energy balance – net SW dominates

Net Flux | *Net Solar* | *Net Longwave* | *Sensible Heat* | *Latent Heat*

$$\frac{dU}{dt} + Q_m = (1-\alpha)S + L^* + Q_s + Q_v + Q_g$$

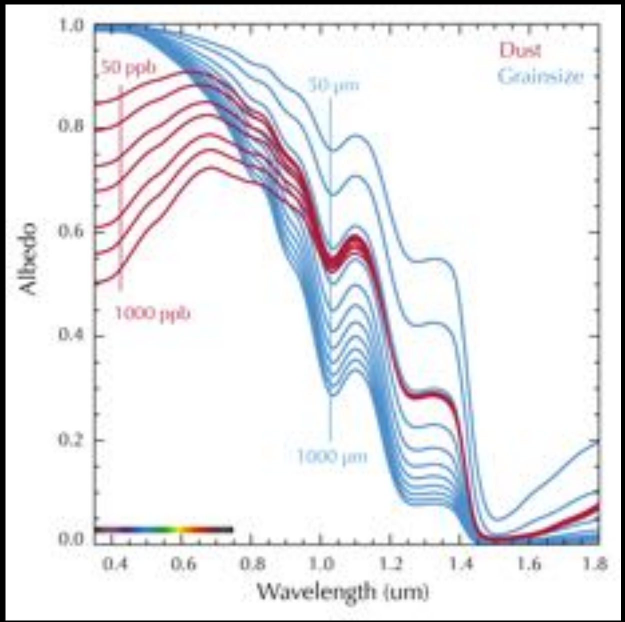


San Juan Mountains, Colorado, 2005

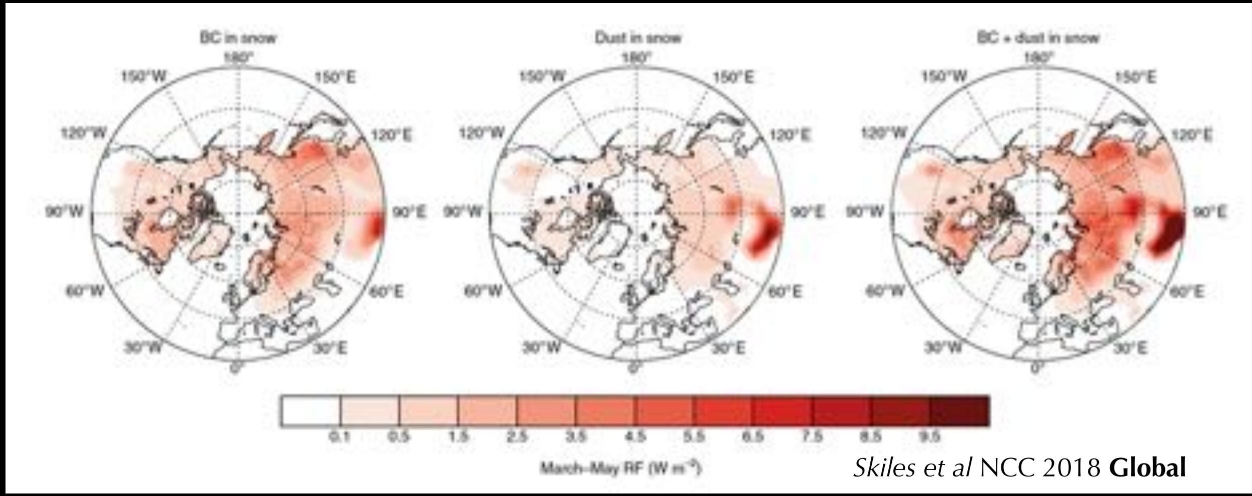


Hence, snow albedo is the dominant snow property in controlling melt. Itself controlled by grain size and LAP

$$\alpha_t = f(GS_t, RF_t, \vartheta_0, E_\lambda)$$



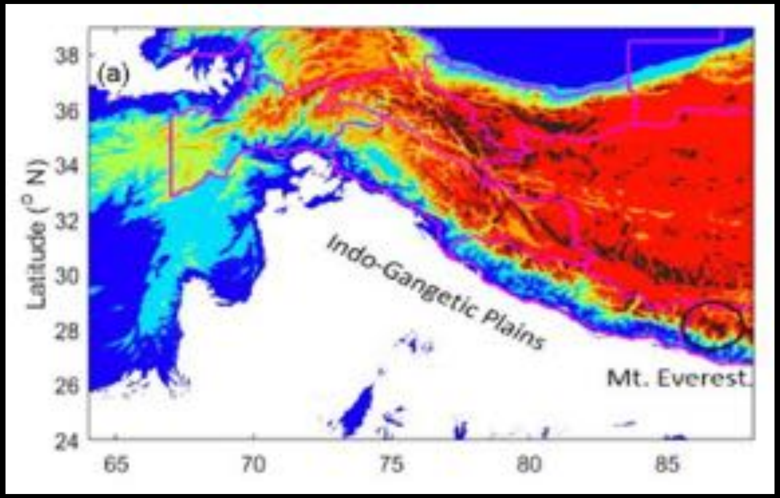
Constraining modeling



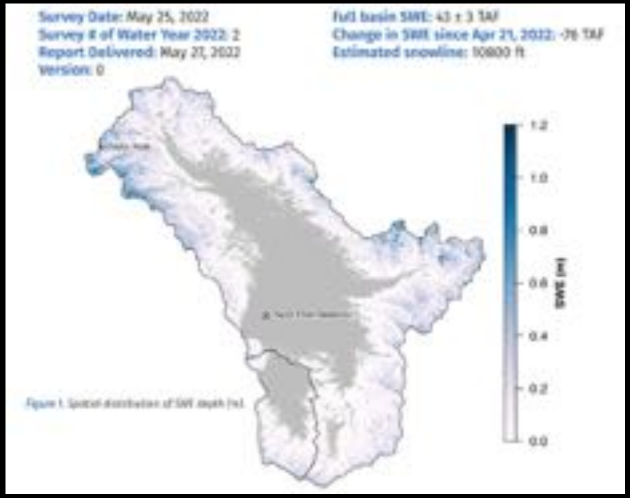
Skiles et al NCC 2018 **Global**

- General circulation modeling and mesoscale modeling
  - Understanding climate sensitivity to GHG and LAP forcings
  - Hydroclimatic change
  - Glacier downwasting
  - Sea level rise
  - *WRF-Chem/SNICAR*

- Basin scale modeling
  - Operational snowmelt runoff forecasting
  - Water resource vulnerability to climate forcing
  - Ecosystem sensitivity
  - Wildfire sensitivity to snowpack perturbation
  - *iSnobal, WRF-Hydro*

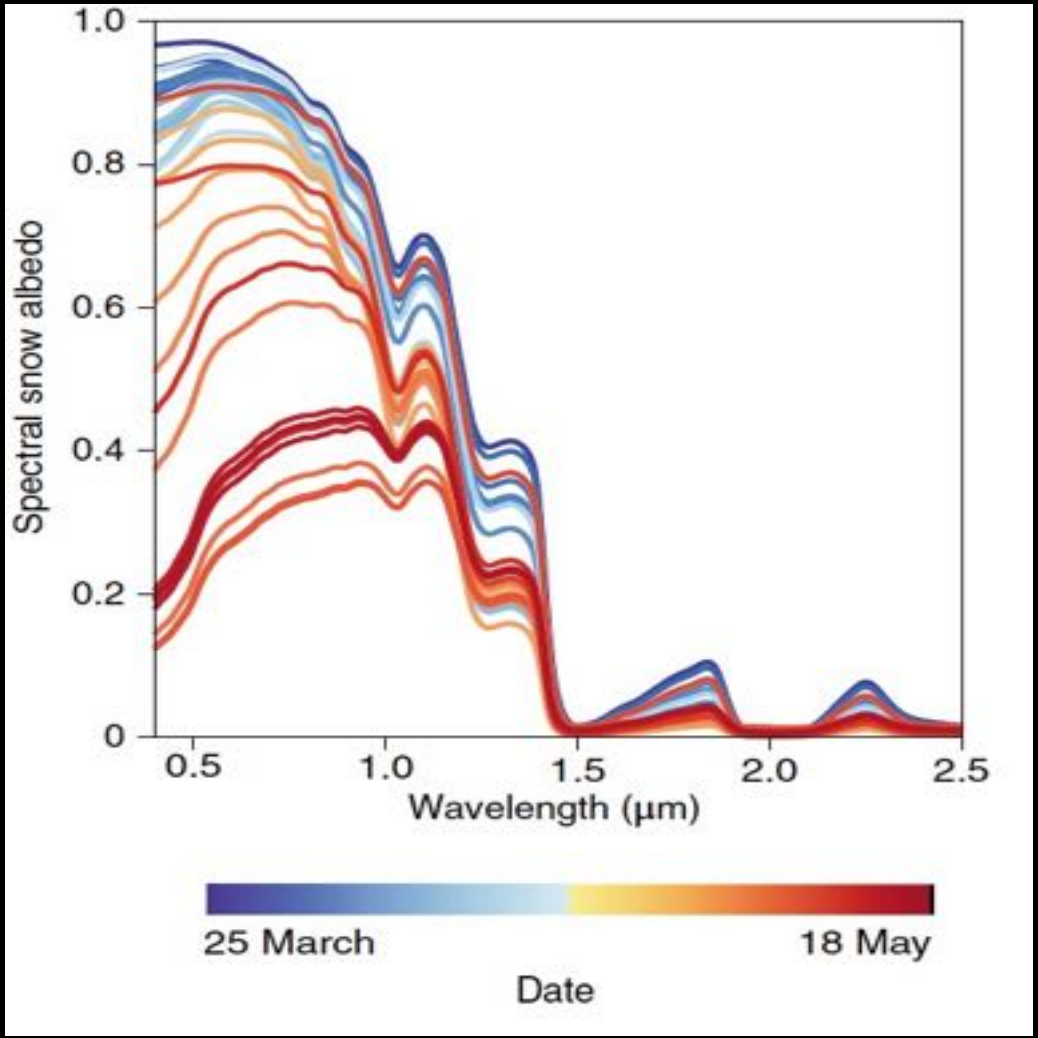


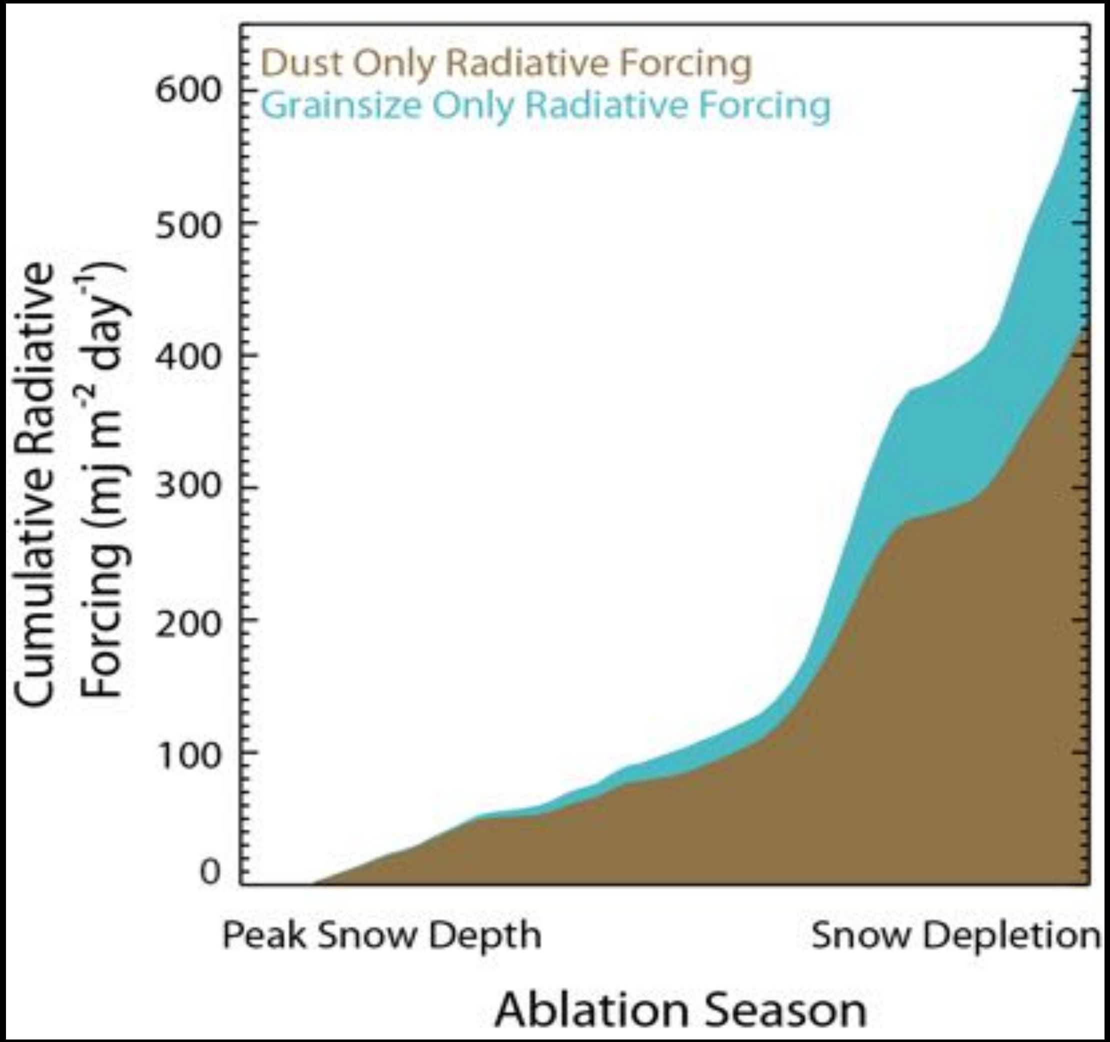
Sarangi et al ACP 2019
Western High Mountain Asia



Airborne Snow Observatories, Inc.
Colorado 2022

Measurement Needs

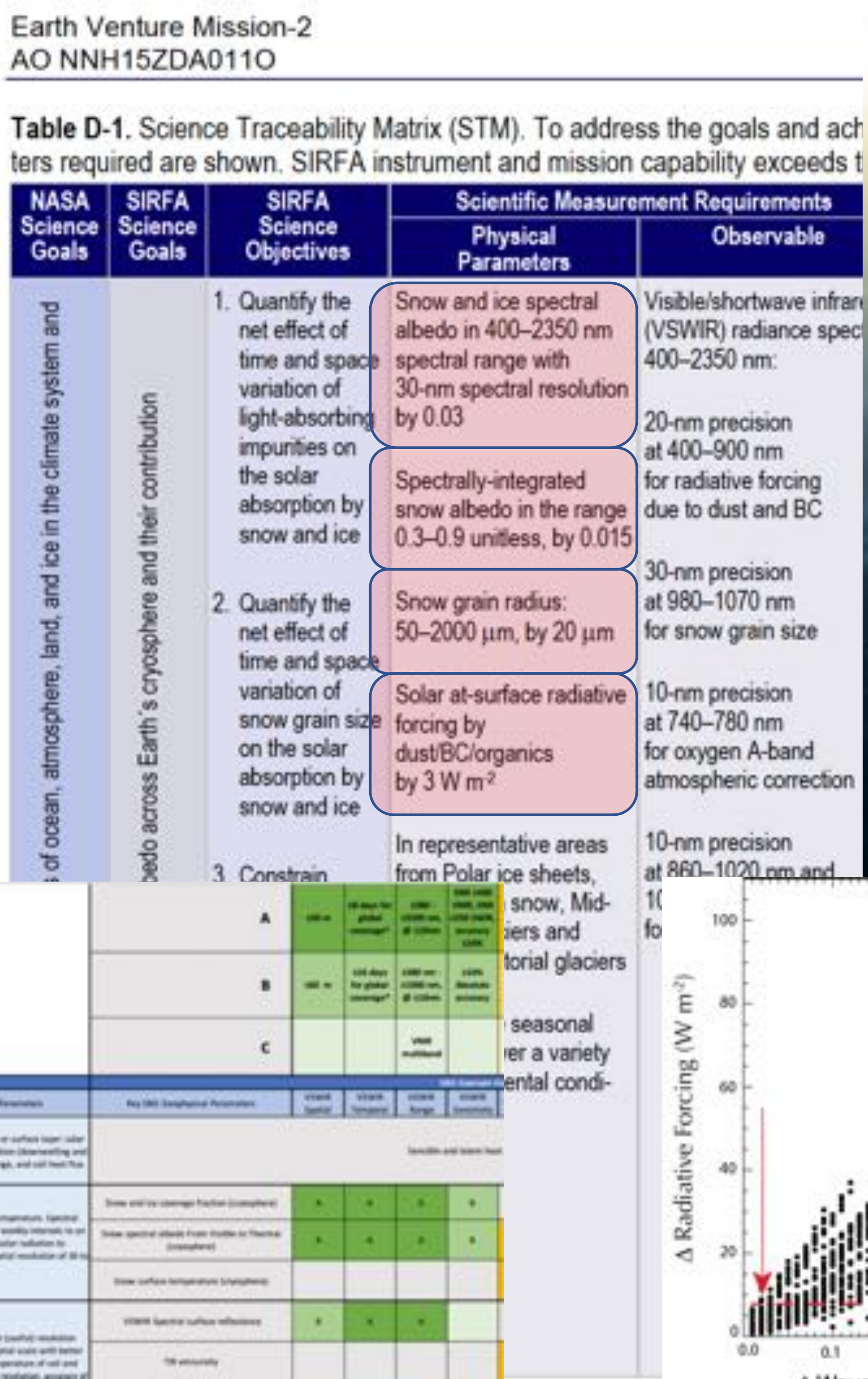




Skiles et al NCC 2018

Science Traceability Matrices

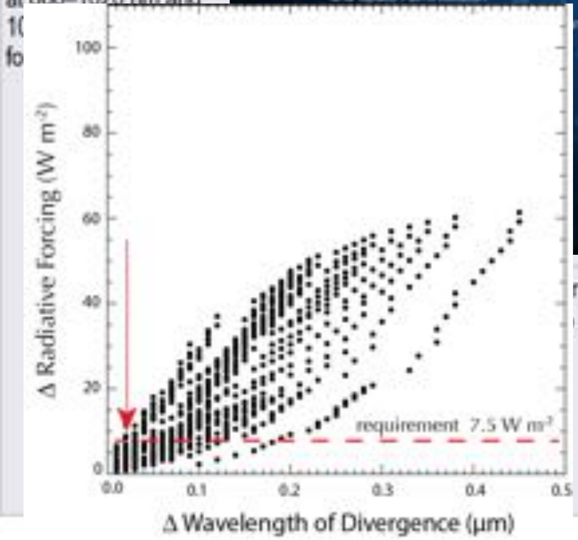
SBG SATM



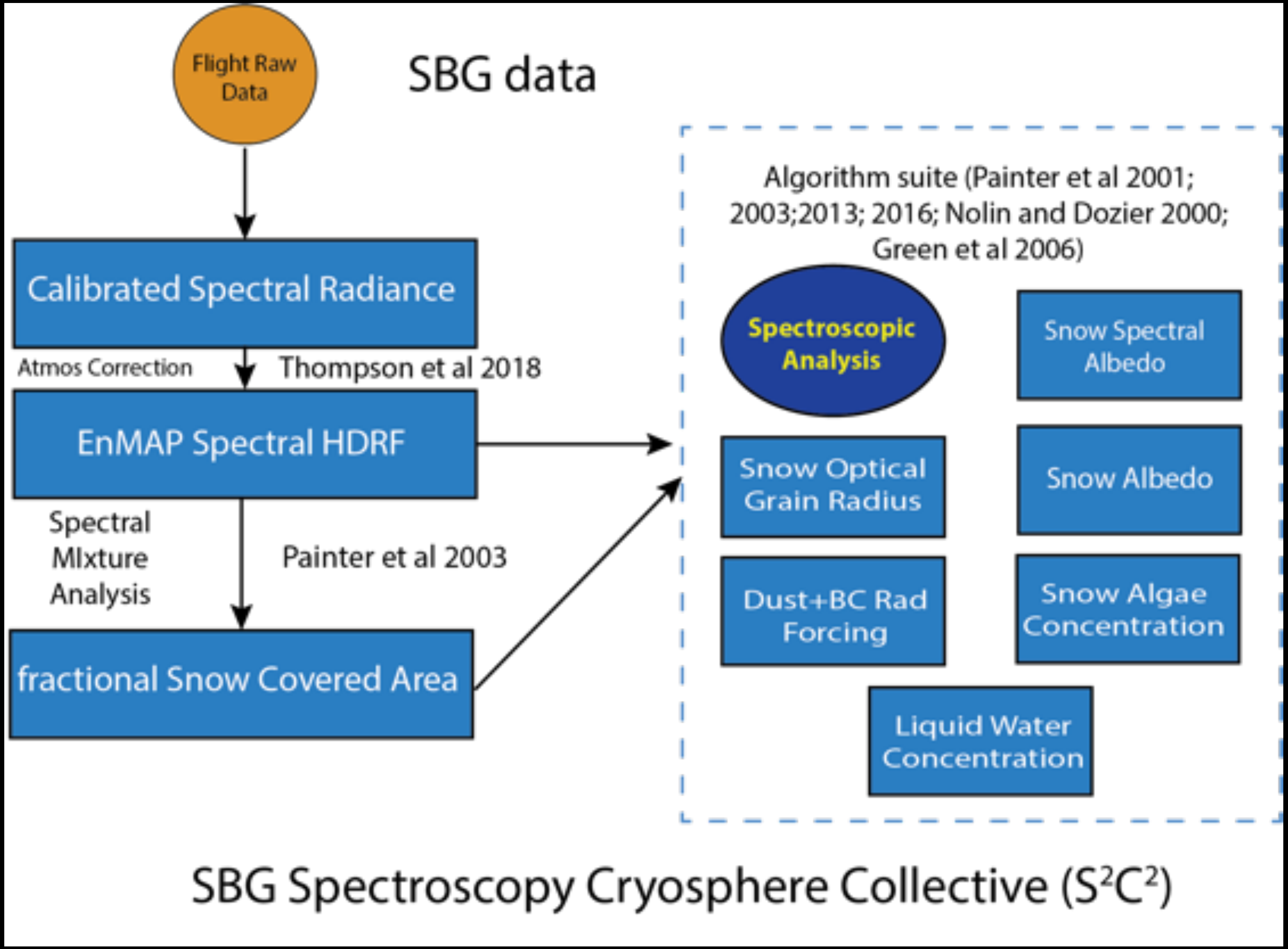
Earth Venture Mission-2
AO NNH15ZDA011O

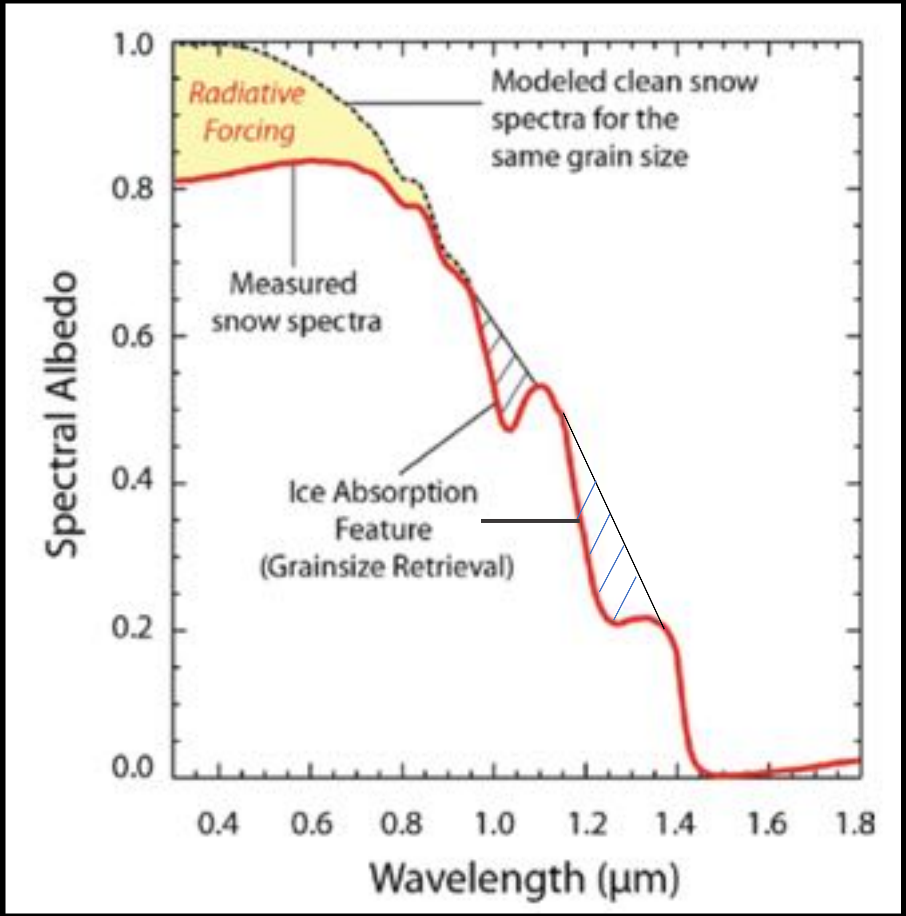
Table D-1. Science Traceability Matrix (STM). To address the goals and ach
ters required are shown. SIRFA instrument and mission capability exceeds t

NASA Science Goals	SIRFA Science Goals	SIRFA Science Objectives	Scientific Measurement Requirements: Physical Parameters	Scientific Measurement Requirements: Observable
…s of ocean, atmosphere, land, and ice in the climate system and	…bedo across Earth's cryosphere and their contribution	1. Quantify the net effect of time and space variation of light-absorbing impurities on the solar absorption by snow and ice	Snow and ice spectral albedo in 400–2350 nm spectral range with 30-nm spectral resolution by 0.03	Visible/shortwave infrar… (VSWIR) radiance spec… 400–2350 nm:
			Spectrally-integrated snow albedo in the range 0.3–0.9 unitless, by 0.015	20-nm precision at 400–900 nm for radiative forcing due to dust and BC
		2. Quantify the net effect of time and space variation of snow grain size on the solar absorption by snow and ice	Snow grain radius: 50–2000 µm, by 20 µm	30-nm precision at 980–1070 nm for snow grain size
			Solar at-surface radiative forcing by dust/BC/organics by 3 W m⁻²	10-nm precision at 740–780 nm for oxygen A-band atmospheric correction
		3. Constrain	In representative areas from Polar ice sheets, … snow, Mid-… …iers and …torial glaciers … seasonal …er a variety …ental condi-	10-nm precision at 860–1020 nm and 1… fo…

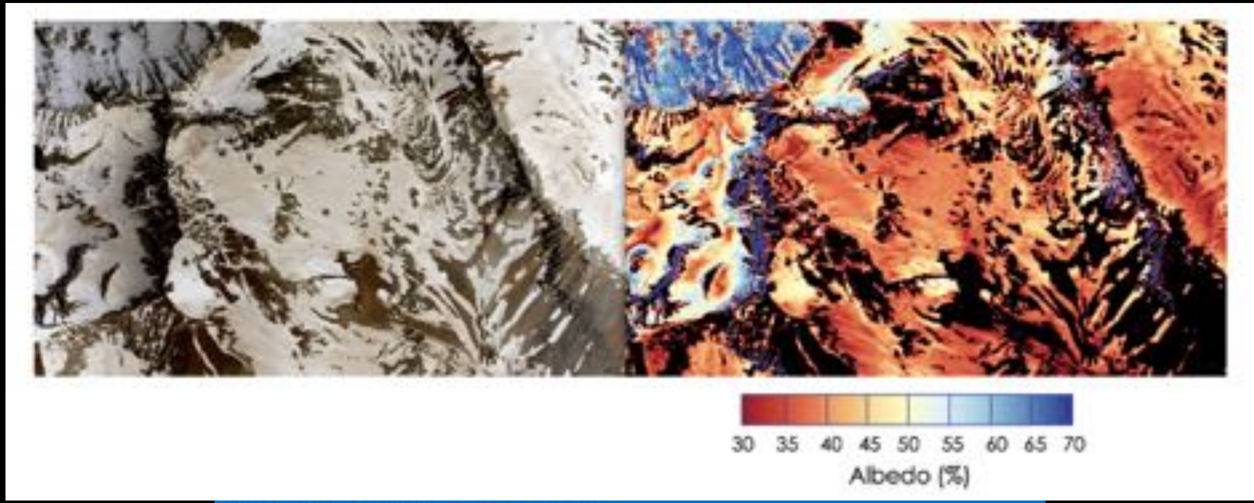


Algorithm Suite for Snow Albedo and Controls





Albedo constraint in physically-based operational runoff models



ASO

Snow Albedo
+ dust conc

EMIT
PRISMA
EnMAP
SBG
CHIME

Snow Albedo
+ dust conc

Gunnison River Basin, Colorado

Survey Date: May 25, 2022
Survey # of Water Year 2022: 2
Report Delivered: May 27, 2022
Version: 0

Full basin SWE: 43 ± 3 TAF
Change in SWE since Apr 21, 2022: -76 TAF
Estimated snowline: 10800 ft

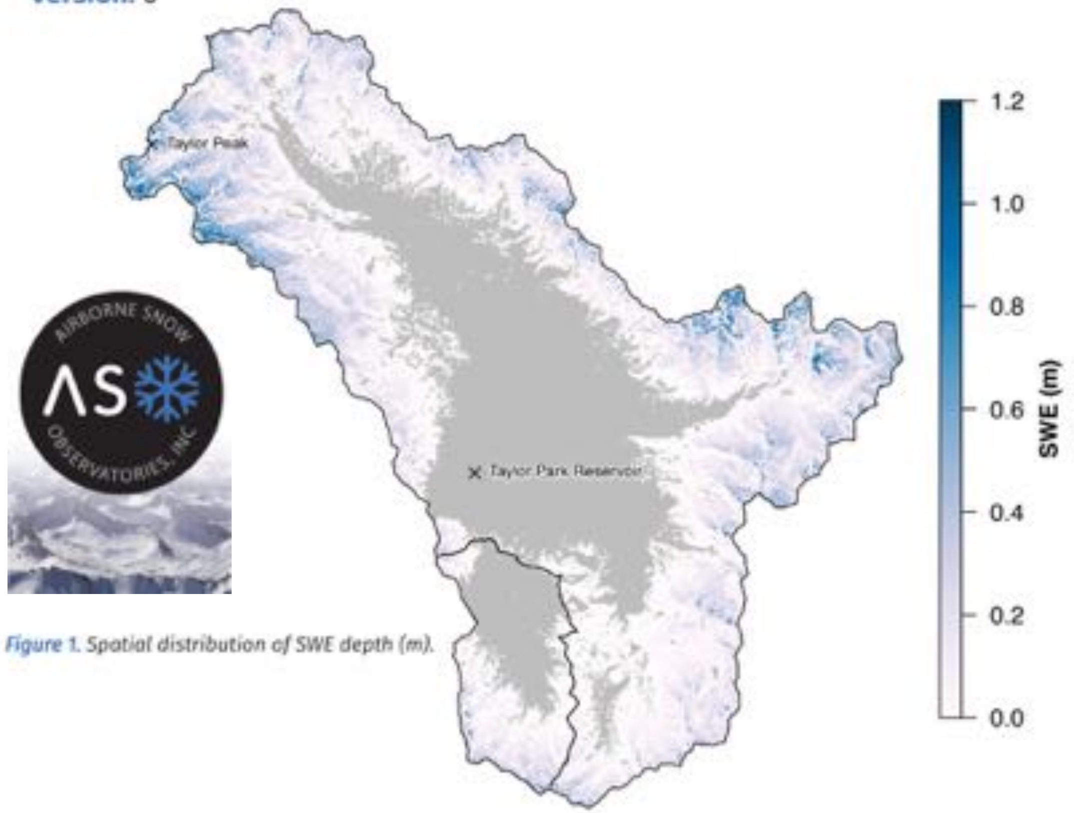


Figure 1. Spatial distribution of SWE depth (m).

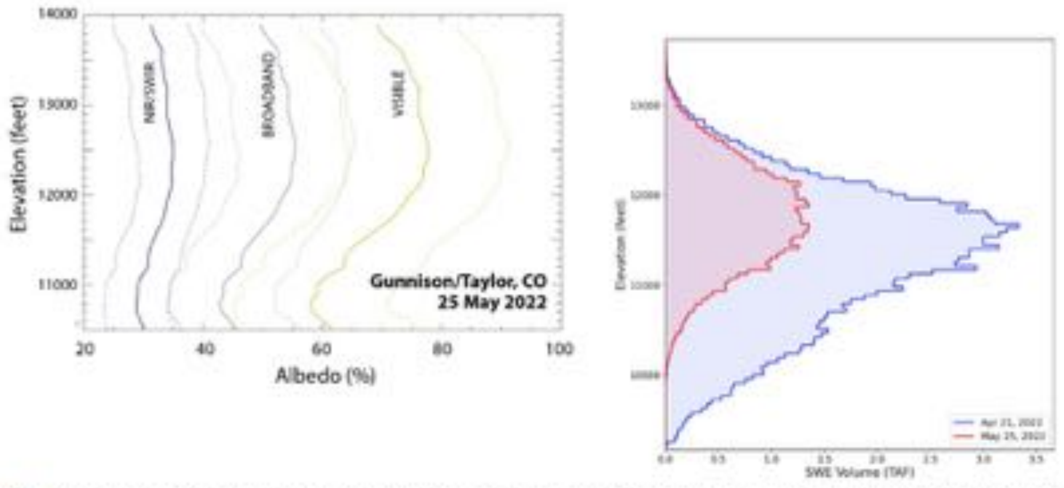


Figure 7.a. Snow albedo (%) by elevation (ft) on May 25 with mean (solid lines) and ± 1 standard deviation (dotted lines) for near and shortwave infrared (dark blue), broadband (gray), and visible (green) wavelengths. 7.b. Distribution of SWE volume (TAF) across elevations; red represents the May 25 survey, blue represents the April 21 survey.

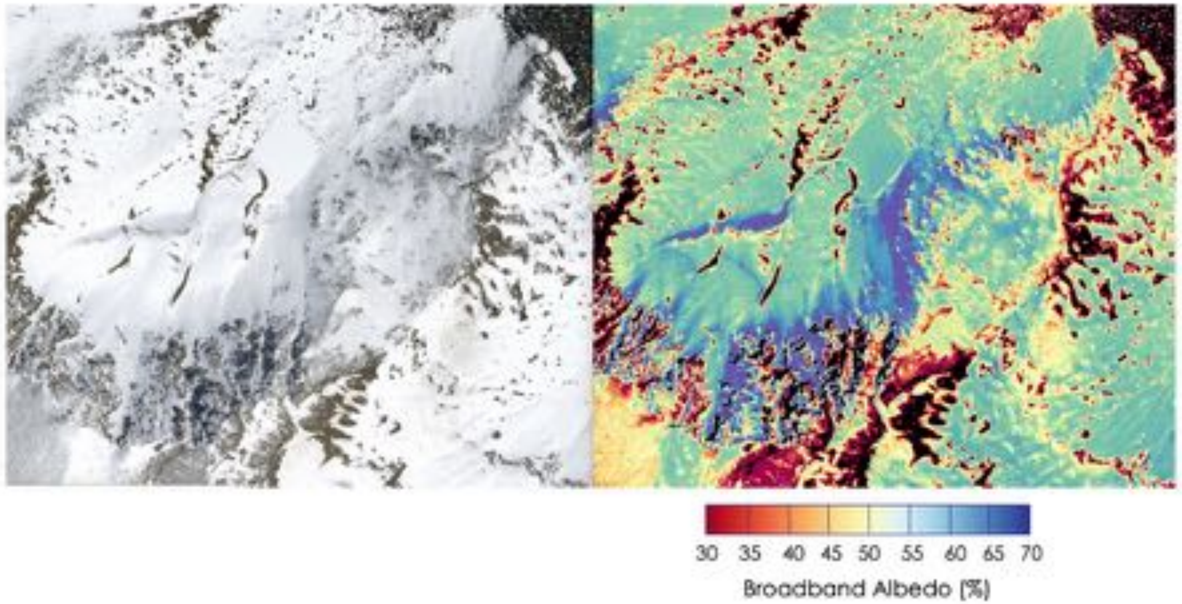
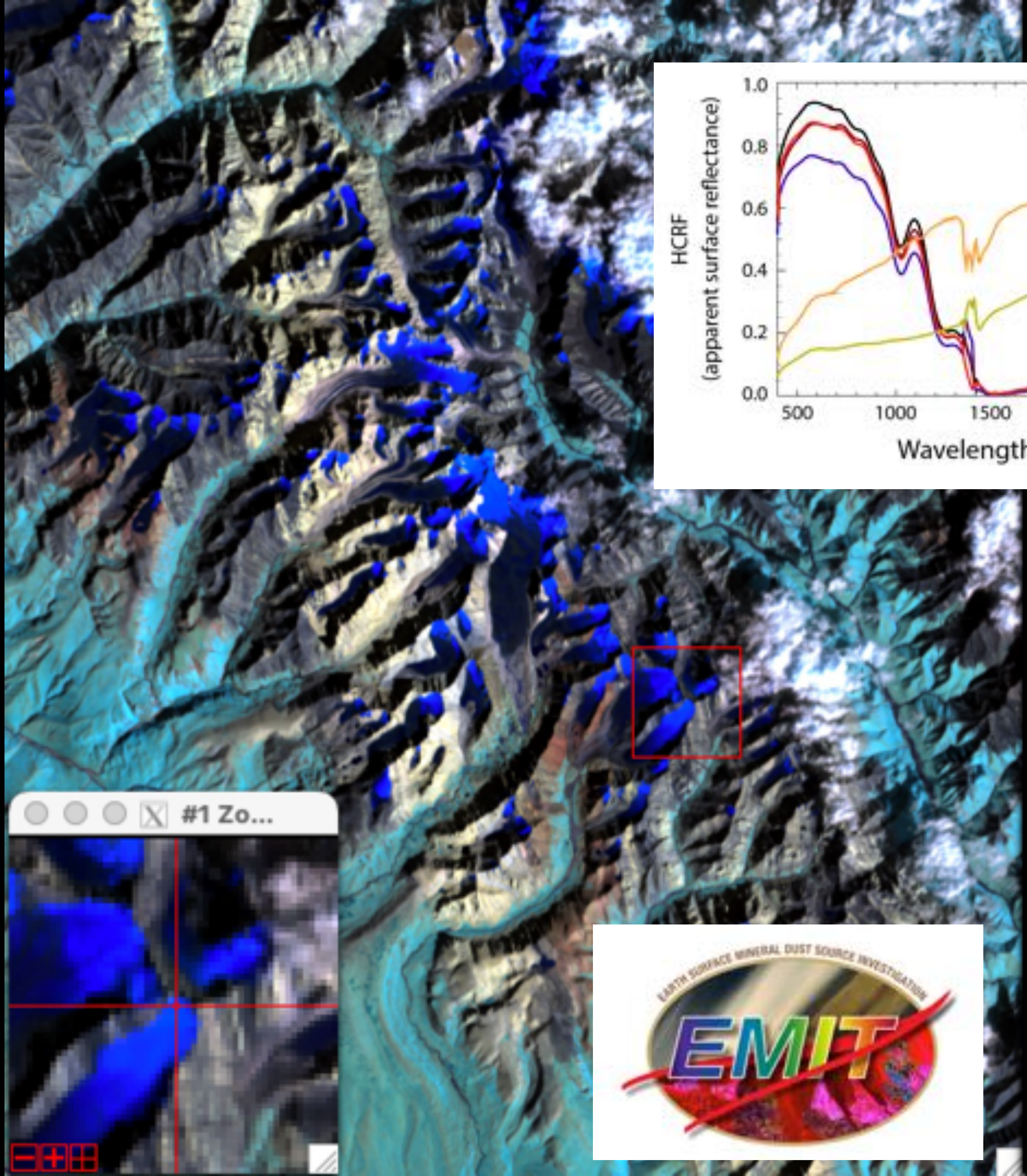
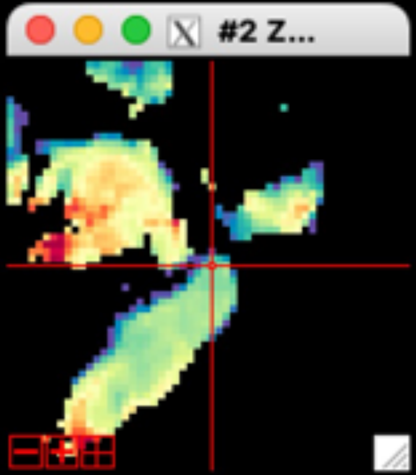
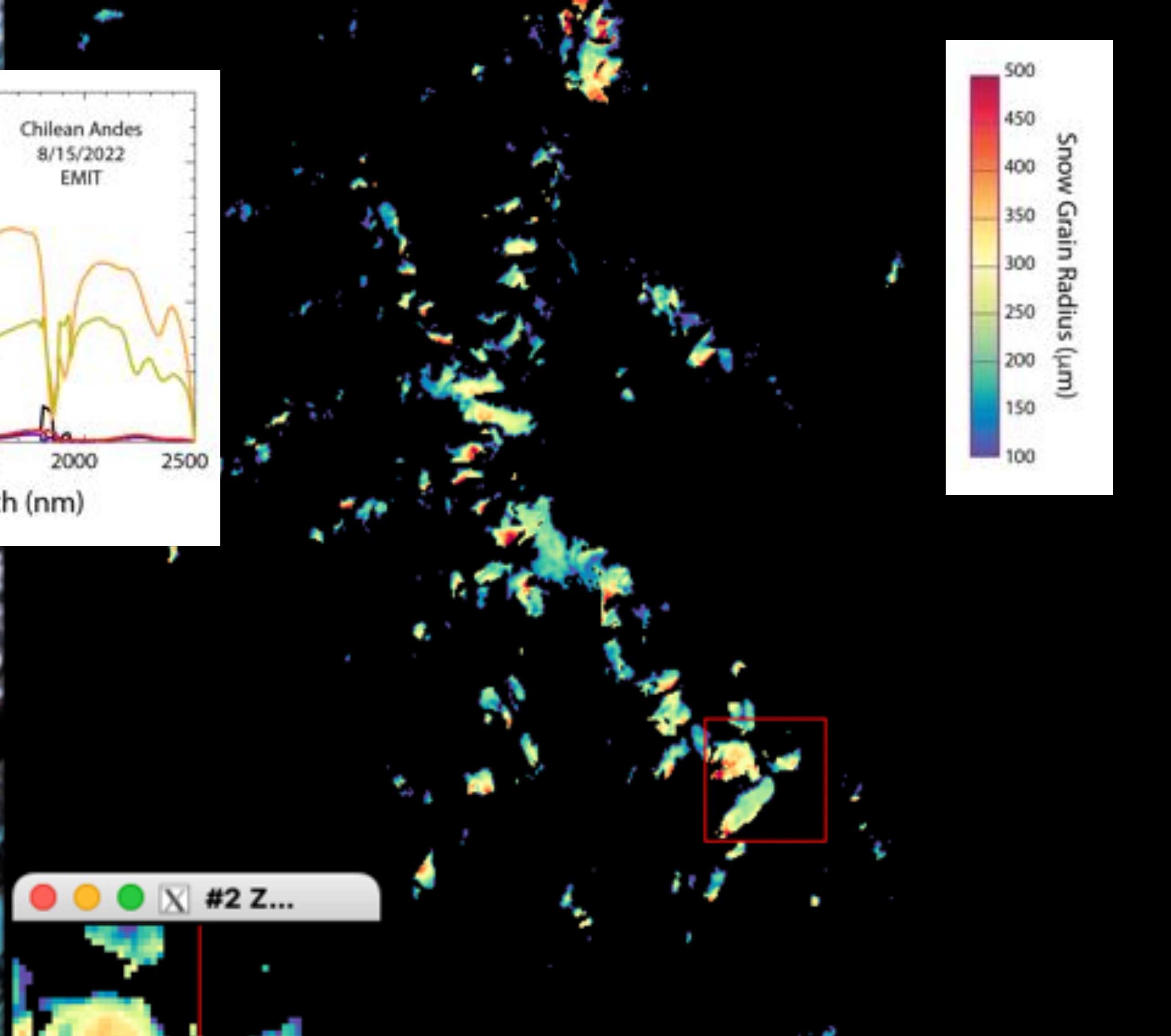


Figure 9. ASO visible images (left panel) from three of the hundreds of ASO spectral bands over the Upper Taylor River near Larson Peak. Corresponding snow albedo maps (right panel) showing the dramatic impact of dust on snow albedo/solar absorption and the snowpack energy balance.







Andes, 15 Aug 2022
First cryosphere retrievals from EMIT

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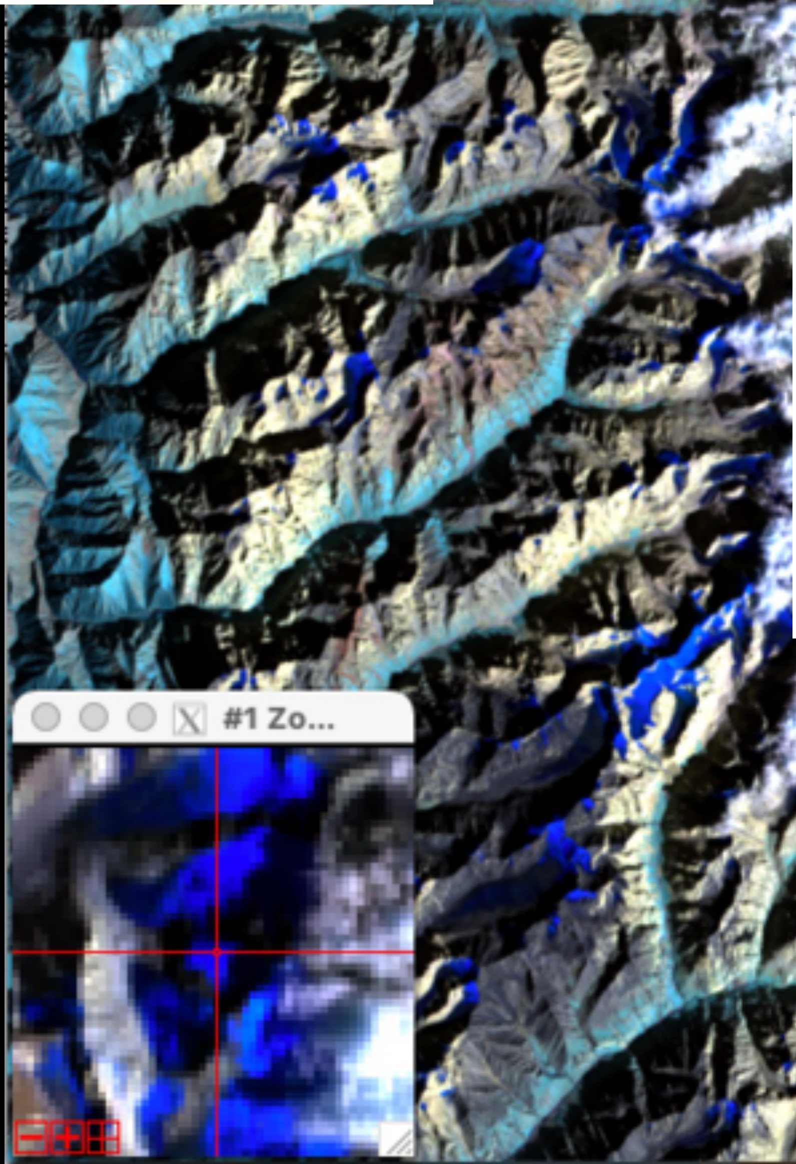
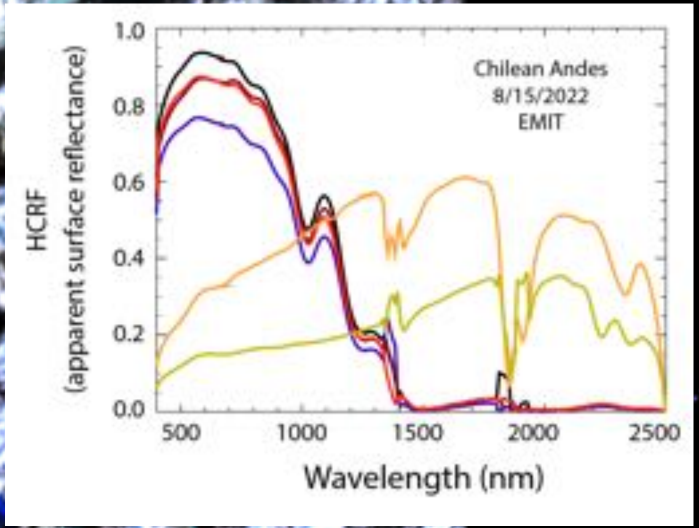
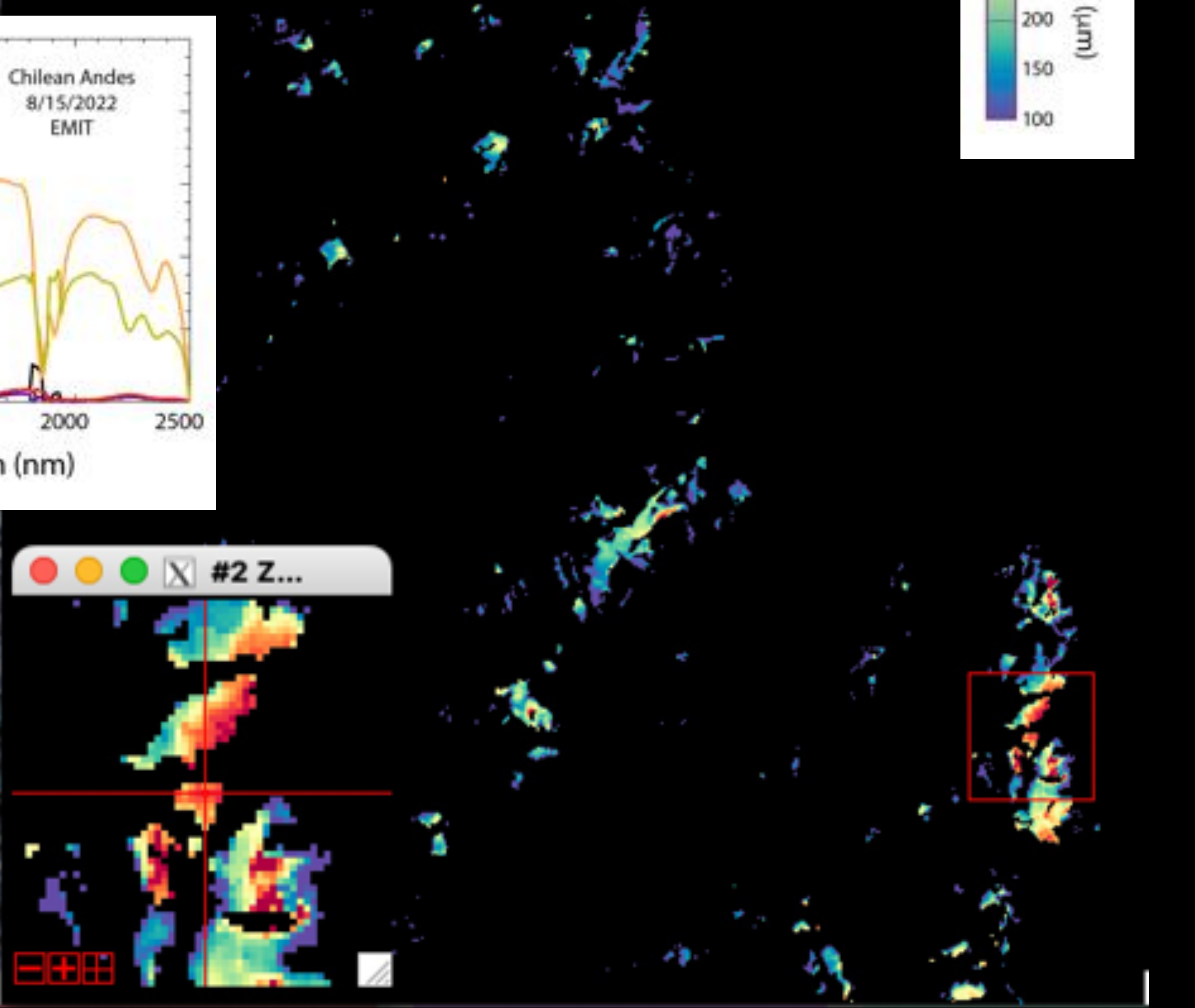
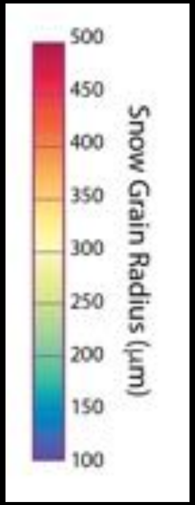
First cryosphere retrievals from EMIT



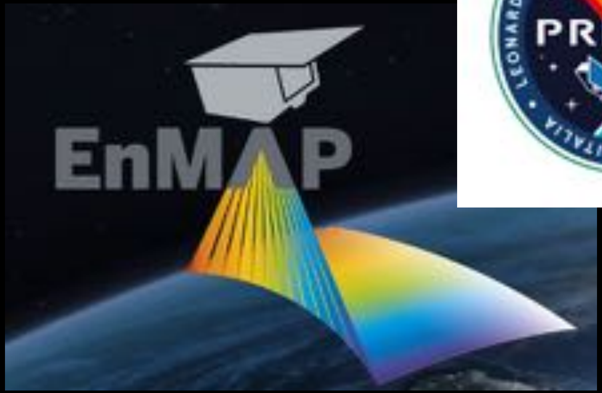






Retrieval consistency

Near-coincident spectra and retrievals from space, air, and field against science and operations STMs



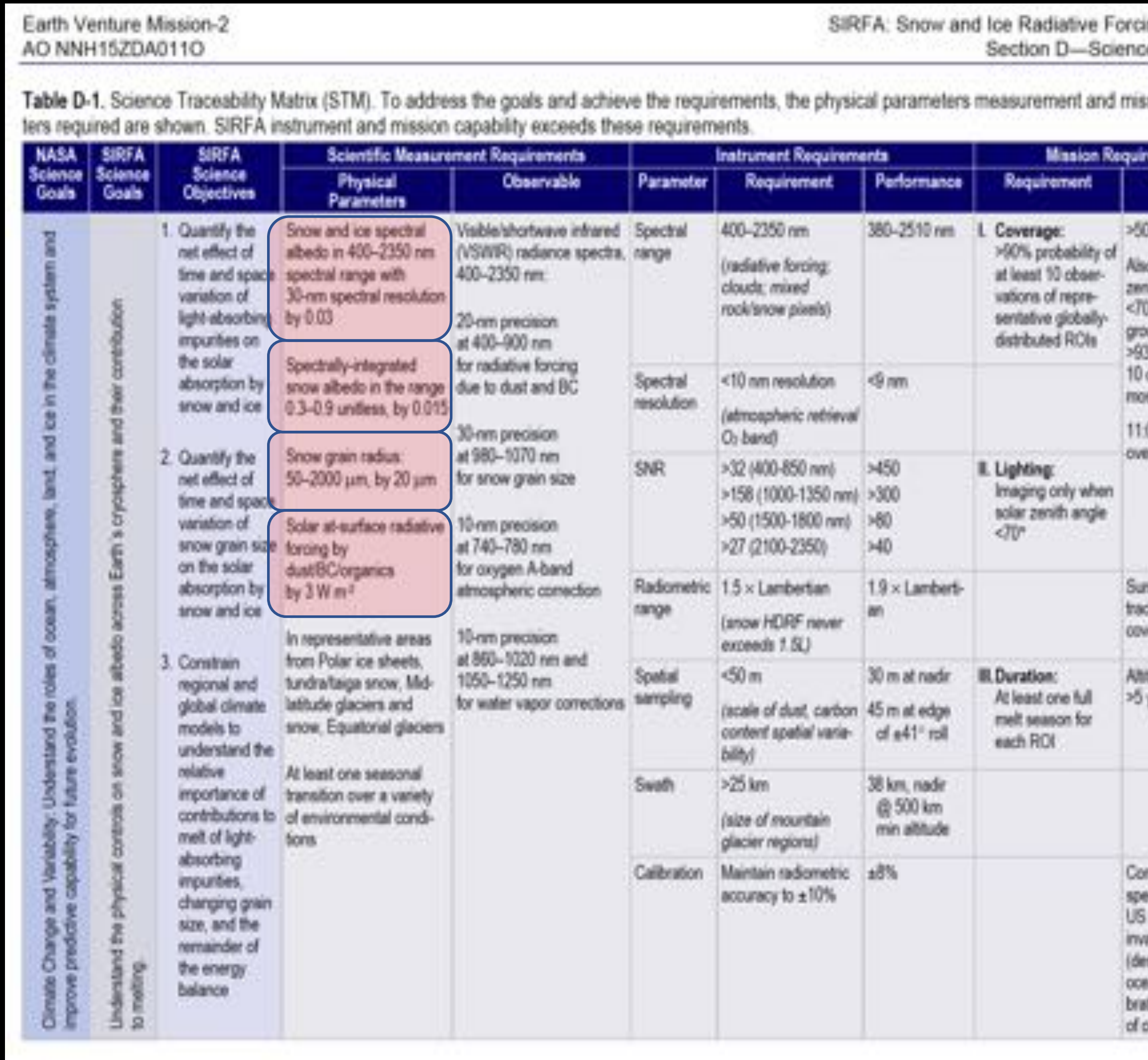


Table D-1. Science Traceability Matrix (STM). To address the goals and achieve the requirements, the physical parameters measurement and mis ters required are shown. SIRFA instrument and mission capability exceeds these requirements.

NASA Science Goals	SIRFA Science Goals	SIRFA Science Objectives	Scientific Measurement Requirements: Physical Parameters	Scientific Measurement Requirements: Observable	Instrument Requirements: Parameter	Instrument Requirements: Requirement	Instrument Requirements: Performance	Mission Requirements: Requirement
Climate Change and Variability: Understand the roles of ocean, atmosphere, land, and ice in the climate system and improve predictive capability for future evolution.	Understand the physical controls on snow and ice albedo across Earth's cryosphere and their contribution to melting.	1. Quantify the net effect of time and space variation of light-absorbing impurities on the solar absorption by snow and ice	Snow and ice spectral albedo in 400–2350 nm spectral range with 30-nm spectral resolution by 0.03	Visible/shortwave infrared (VSWIR) radiance spectra, 400–2350 nm:	Spectral range	400–2350 nm (radiative forcing; clouds; mixed rock/snow pixels)	380–2510 nm	I. **Coverage:** >90% probability of at least 10 observations of representative globally-distributed ROIs
			Spectrally-integrated snow albedo in the range 0.3–0.9 unitless, by 0.015	20-nm precision at 400–900 nm for radiative forcing due to dust and BC	Spectral resolution	<10 nm resolution (atmospheric retrieval O_2 band)	<9 nm	
		2. Quantify the net effect of time and space variation of snow grain size on the solar absorption by snow and ice	Snow grain radius: 50–2000 μm, by 20 μm	30-nm precision at 980–1070 nm for snow grain size	SNR	>32 (400-850 nm) >158 (1000-1350 nm) >50 (1500-1800 nm) >27 (2100-2350)	>450 >300 >80 >40	II. **Lighting:** Imaging only when solar zenith angle <70°
			Solar at-surface radiative forcing by dust/BC/organics by 3 W m^{-2}	10-nm precision at 740–780 nm for oxygen A-band atmospheric correction	Radiometric range	1.5 × Lambertian (snow HDRF never exceeds 1.5L)	1.9 × Lambertian	
		3. Constrain regional and global climate models to understand the relative importance of contributions to melt of light-absorbing impurities, changing grain size, and the remainder of the energy balance	In representative areas from Polar ice sheets, tundra/taiga snow, Mid-latitude glaciers and snow, Equatorial glaciers	10-nm precision at 860–1020 nm and 1050–1250 nm for water vapor corrections	Spatial sampling	<50 m (scale of dust, carbon content spatial variability)	30 m at nadir 45 m at edge of ±41° roll	III. **Duration:** At least one full melt season for each ROI
			At least one seasonal transition over a variety of environmental conditions		Swath	>25 km (size of mountain glacier regions)	38 km, nadir @ 500 km min altitude	
					Calibration	Maintain radiometric accuracy to ±10%	±8%	