

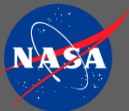
Advancing global snow observations through the NASA SnowEx campaign (2017-present and beyond)



Presented by: Carrie Vuyovich, NASA GSFC

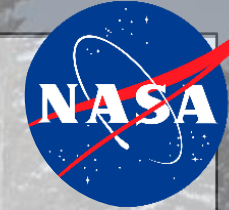
HP Marshall, Sveta Stuefer, Ed Kim, Charles Gatebe, Jack Tarricone, Kelly Elder, Mike Durand, Rosemary Carroll, Paul Siqueira, Megan Mason, McKenzie Skiles, Kelly Gleason, Matthew Sturm, Jessica Lundquist, Dorothy Hall, and many, many more

Photo credit: Sveta Stuefer



NASA Hydrosphere Investigator Meeting
1-3 September 2026, Washington DC





What is SnowEx?

SnowEx is a multi-year field & airborne experiment to evaluate how well different remote sensing technologies observe snow throughout the season in various landscapes

Sponsored by
NASA Terrestrial Hydrology, Earth Science Division



National Aeronautics and Space Administration

NASA SnowEx Science Plan:
Assessing Approaches for Measuring
Water in Earth's Seasonal Snow

NASA Hydrosphere Investigator Meeting
1-3 September 2026, Washington DC



Why is seasonal snow important?

- Approximately 2 billion people depend on seasonal snow for water supply
 - 70% of water resources in Western U.S.
- Massive impact on surface albedo and global energy balance
 - Over 1/3 of the Earth's land surface covered by snow annually
- Supports global agriculture and ecosystems
- Contributes to disasters (floods, droughts, avalanches, wildfires)
- Patterns are changing - earlier melt, more frequent rain-on-snow, changing snowlines
- But challenging to measure and model:
 - Length scale of variability in depth 20-200m
 - Dynamic changes on time scales of hours-days
 - Models show widespread both temporally and spatially, largely due to uncertainties in forcing data



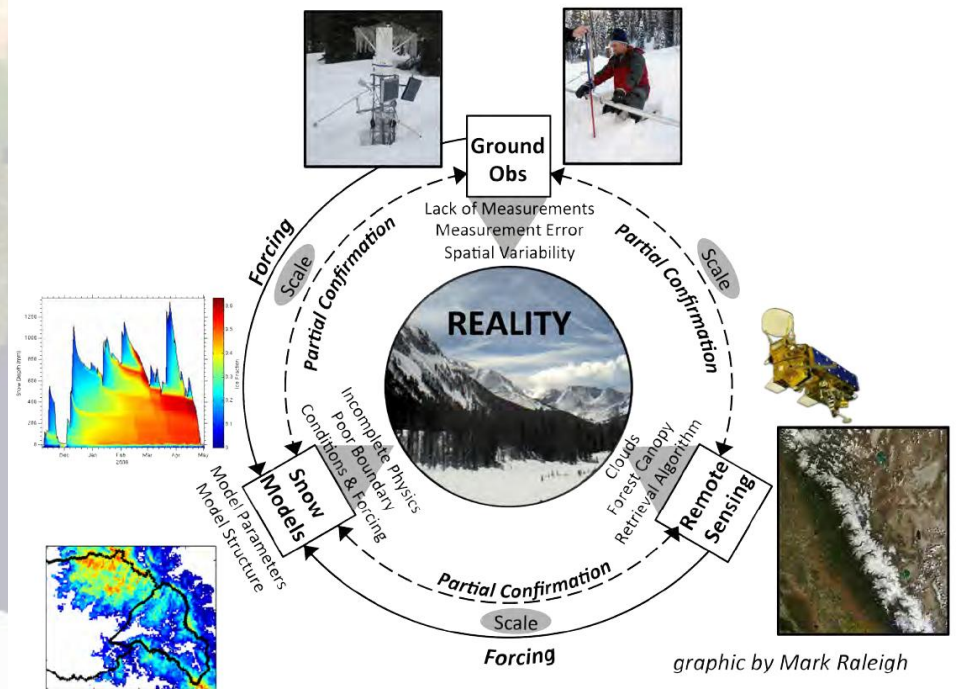
Snow Data Needs

- Accurate, global snow information to understand the altering climate and water availability and predict future snow water resources.
- Satellite remote sensing is the only way to provide spatially distributed, near real-time observations of global snow

Critical Snow Observations:

- **Albedo**
 - **Snow Covered Area**
 - **SWE/Snow Depth** ← **Biggest gap in snow remote sensing**
- Progress made in recent decades
 - Mature algorithms and satellite observations available

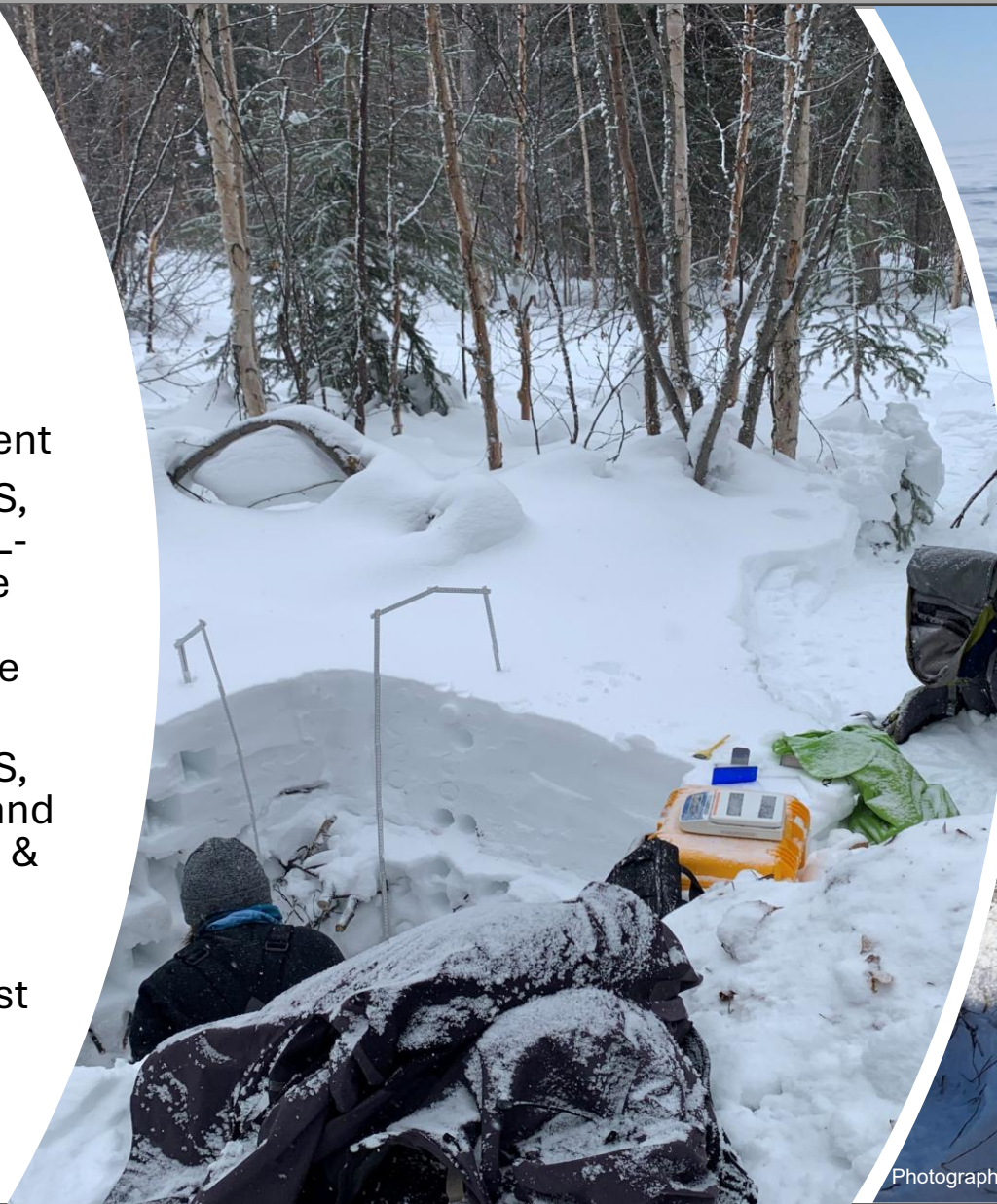
Solution to global snow monitoring: fusion of remote sensing, models, ground obs.



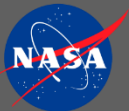


NASA SnowEx

- **SnowEx 2017** – Colorado, focused on multiple instruments in forest gradient
- **SnowEx 2020** – Western US, focused on Time Series of L-band InSAR, Active/passive microwave for SWE and Thermal IR for snow surface temp
- **SnowEx 2021** – Western US, Continue Time Series, L-band InSAR, also address Prairie & Albedo questions
- **SnowEx 2023** – Northern Alaska, Tundra/Boreal forest focus; plans developed to address SWE/snow depth and albedo objectives



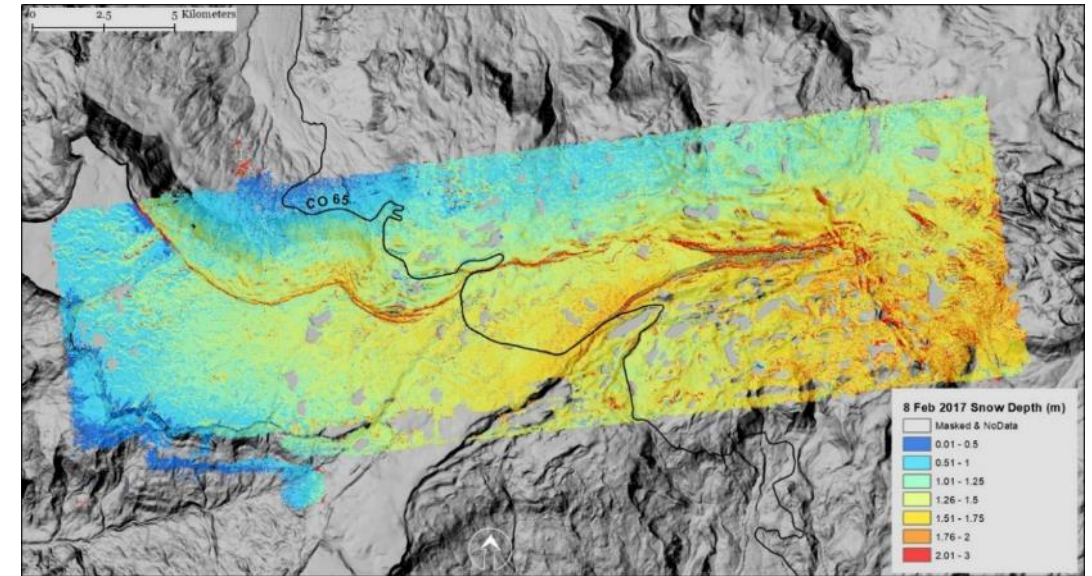
Photographs taken on March, 2022 by Sveta Stuefer



NASA Hydrosphere Investigator Meeting
1-3 September 2026, Washington DC

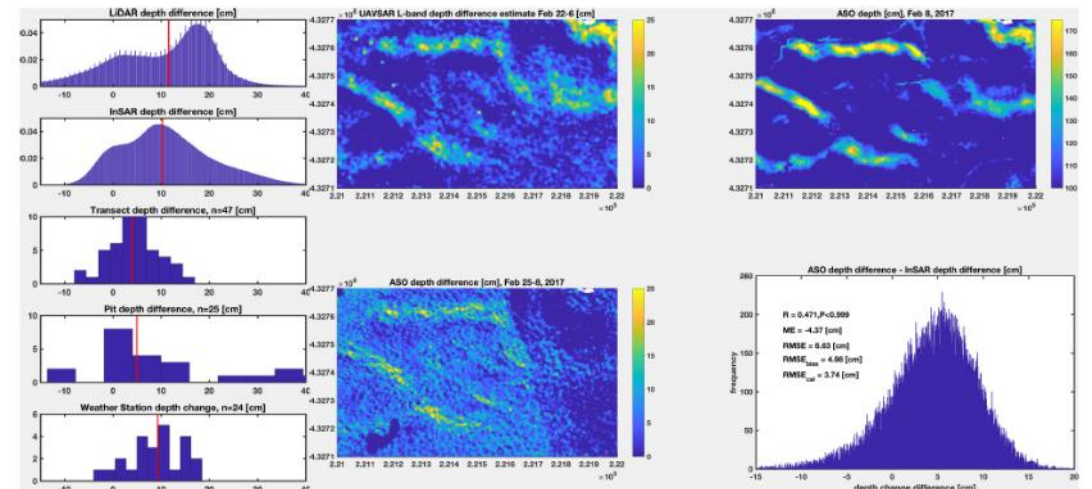


NASA SnowEx 2017



Highlights:

- 100 participants (scientists, students, international)
- 24 institutions
- 5 of 5 aircraft & 9 of 10 sensors flown
- 154 snow pits; 165 transects
- 30 ground remote sensors
- Extensive community-building activities
- Snow.nasa.gov website stood up
- 1st SnowEx workshop Aug 2017; 92 attendees



L-band InSAR results showing agreement with lidar and depth obs

NASA SnowEx 2020

Campaign design:

- Time Series of weekly to biweekly UAVSAR flights, Dec-March
- Intensive observing period (IOP) in Grand Mesa, CO, Nov/Jan/Feb
- Over 100 students, researchers from 20+ organizations

Naval Postgraduate School Twin Otter

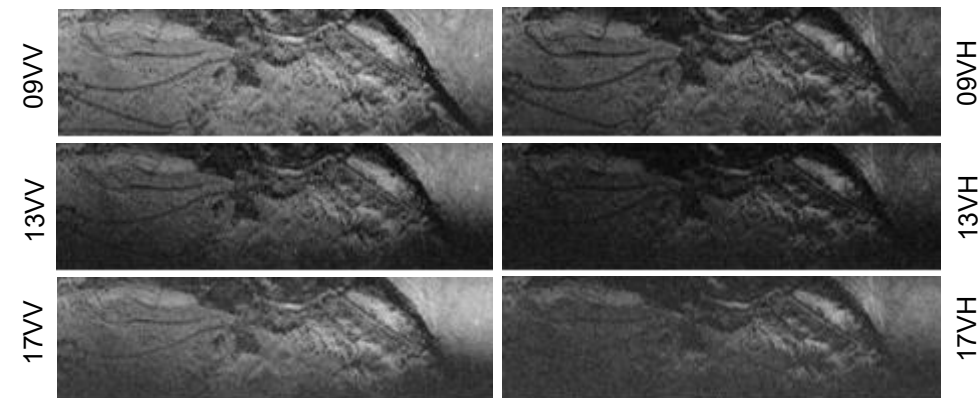


NASA Airborne observations:

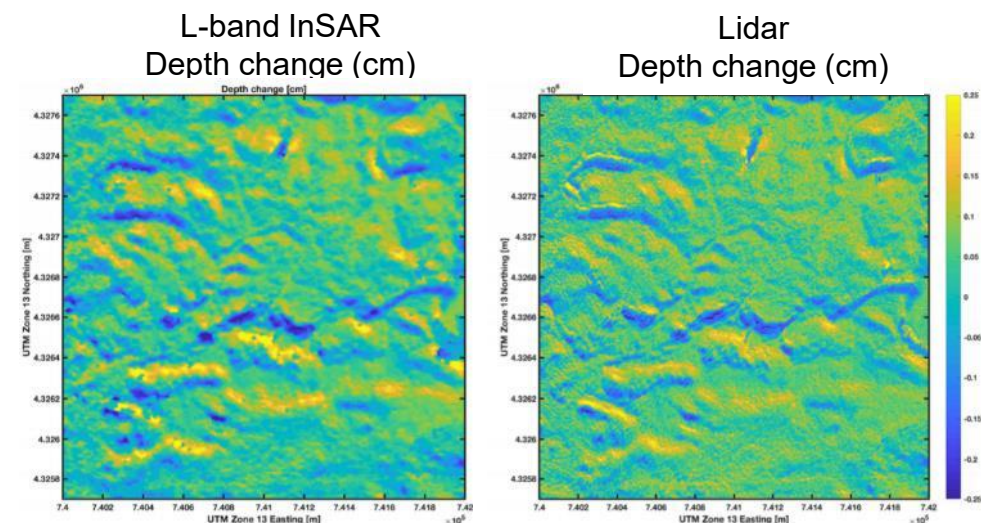
- L-band InSAR, UAVSAR (JPL) on JSC GIII
- Active/Passive microwave, SWESARR (GSFC) on NPS/CIRPAS Twin Otter
- Thermal IR (U. of Washington) on NPS/CIRPAS Twin Otter
- Reigl 1560i Lidar and CASI hyperspectral (Quantum Spatial) on Dynamic Aviation A90

Partner Airborne observations:

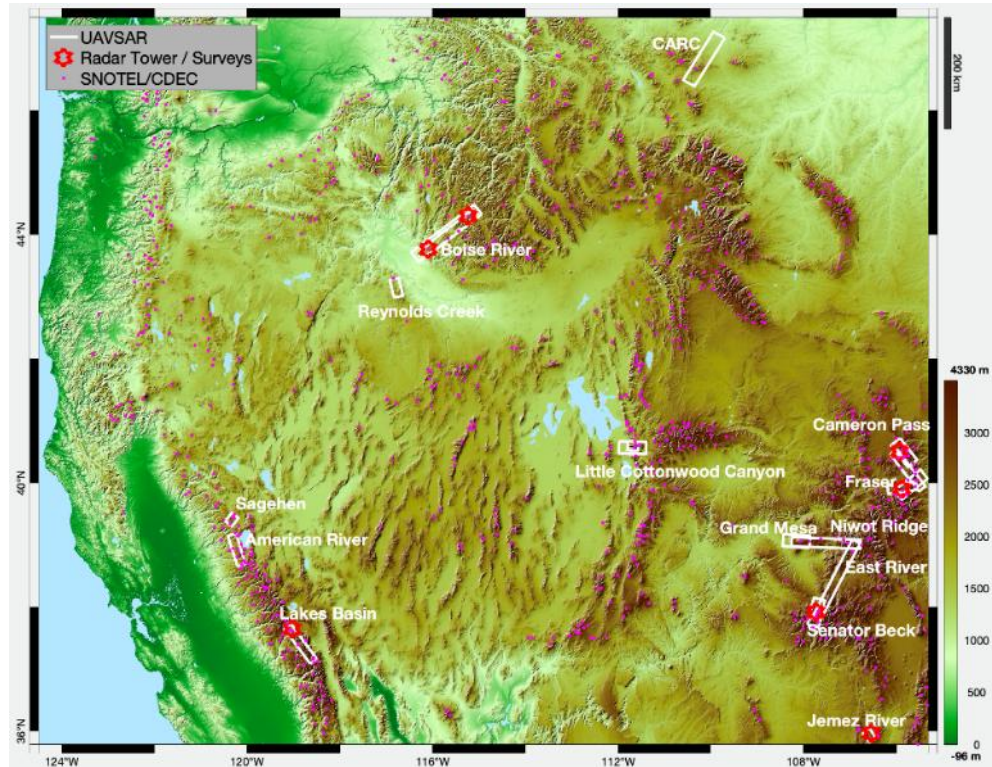
- FMCW Radar led by University of Alabama TOI Twin Otter
- Gamma Airborne Survey led by NOAA NOHRSC on Twin Commander



SWESARR Radar data collected over Grand Mesa, CO during the Feb 2020 IOP. The data were processed with a Time Domain Back Projection algorithm and used for snow water equivalent (SWE) retrieval.



Preliminary results from SnowEx 2020 show good snow depth change agreement between L-band InSAR and lidar data: R-value = 0.76, RMSD=4.7cm depth, 0.9cm SWE.



NASA SnowEx 2021

Time series experiment

- L-band Interferometric Synthetic Aperture Radar (UAVSAR)
- Test in range of snow climates and during accumulation & melt
- Weekly to bi-weekly aircraft overflights and field campaigns

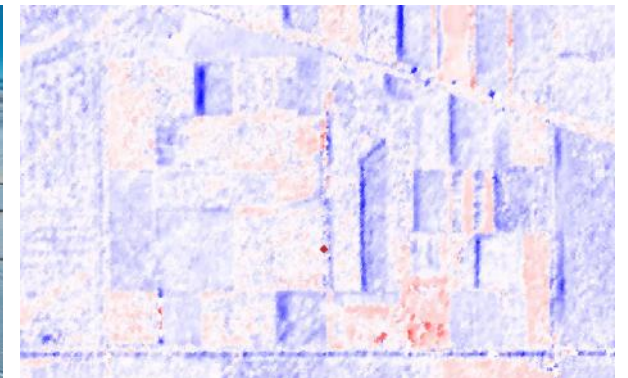
Snow albedo

- Multispectral (AVIRIS-NG) over Senator Beck Basin, CO
- Spatiotemporal variability in complex terrain

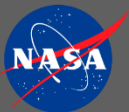


NASA Airborne observations

Observation	Sensor	Aircraft
L-band InSAR	UAVSAR (JPL)	JSC GIII
Lidar and Hyperspectral	Reigl 1560i and CASI (QSI)	Dynamic Aviation A90
VIS-IR Imaging Spectrometer	AVIRIS-NG (JPL)	B-200 King Air



Prairie site at Central Agricultural Research Center, MT (left) showing shallow snow redistributed by wind into ditches and fields. UAVSAR image of CARC (right).

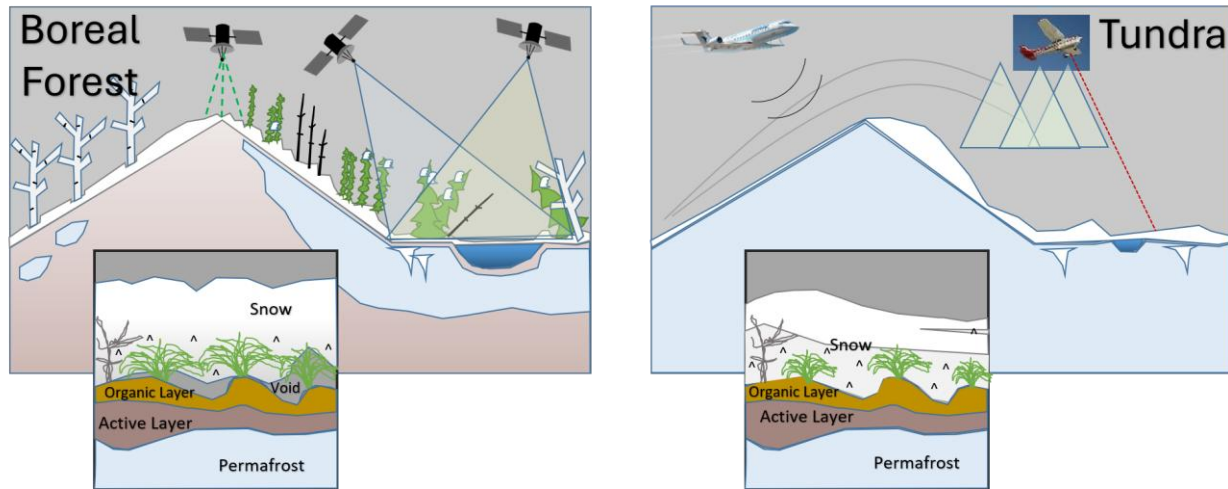


NASA Hydrosphere Investigator Meeting
1-3 September 2026, Washington DC



NASA SnowEx 2023 - Alaska

Understanding unique snow remote sensing challenges in the tundra and boreal forest



Highlights:

- Over 100 people
- More than 30 different institutions, 4 different countries
- 3 aircraft, 4 different sensors
- 170 Snow pits
- Over 30,000 snow depth measurements
- Ground-based remote sensing sensors

Objectives

- Test depth/SWE retrievals from lidar and SfM in tundra and Boreal snow environments (UAF lidar)
- Test SWE retrievals from X/Ku-band SAR (SWESARR)
- What factors control variability in accumulation and ablation in arctic (AVIRIS-NG)





Community Training & Outreach

Hackweeks

Hackweeks are participant-driven workshops designed to foster collaboration, provide education in the tools and methods of open science, and align community members around shared software and NASA datasets.

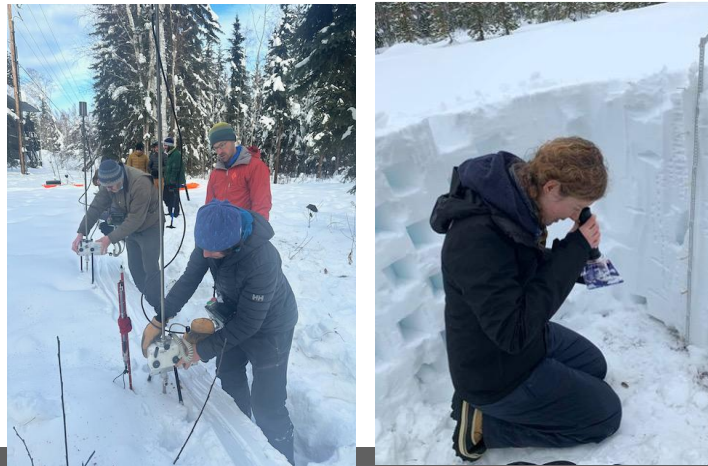
<https://snowex.hackweek.io/>



CUAHSI Field

Measurement Schools

4-day hands-on field school; prepare researchers at all career levels to make quality field observations using standard techniques (depth, density, temperature, grain size/type, SWE, etc), in addition to some exposure to new technologies

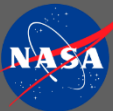


NASA Hydrosphere Investigator Meeting
1-3 September 2026, Washington DC

Winter Wildlands

Alliance Snow School

- K-12 program that takes over 35,000 students into the snow environment to teach science. 80+ local programs across the U.S.
- Students learn the importance of snow, how to measure SWE, depth, stratigraphy, in addition to winter ecology, shelter building, etc
- Pre/Post classroom visits, demonstrated increases in learning
- Students made measurements for SnowEx, improved SnowSchool curriculum





Community Training & Outreach

SnowEX-ED: NASA STEAM Education With Snow

To bring the excitement and science of SnowEx to the public:

- 1) Designed and built snow science kits (~800)
- 2) Distributed these across the US through outdoor schools & nature centers
- 3) Facilitated press releases highlighting snow science and society's reliance on snow for water
- 4) Delivered fun in-person outdoor snow experiences to thousands of adults and youths across Alaska.



University of Alaska student measuring SWE at Fairbanks campus during SnowEx 2023

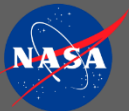


SnowEx-MAIANSE Internships, 2000-present

- 10+ Interns to date from American Indian and Alaska Native serving institutions
- Projects developed based on SnowEx data needs & student interest and ongoing local activities
- Student paired with mentor to work on the project



Fond Du Lac Tribal and Community College students measuring SWE at Minnesota campus location



NASA Hydrosphere Investigator Meeting
1-3 September 2026, Washington DC





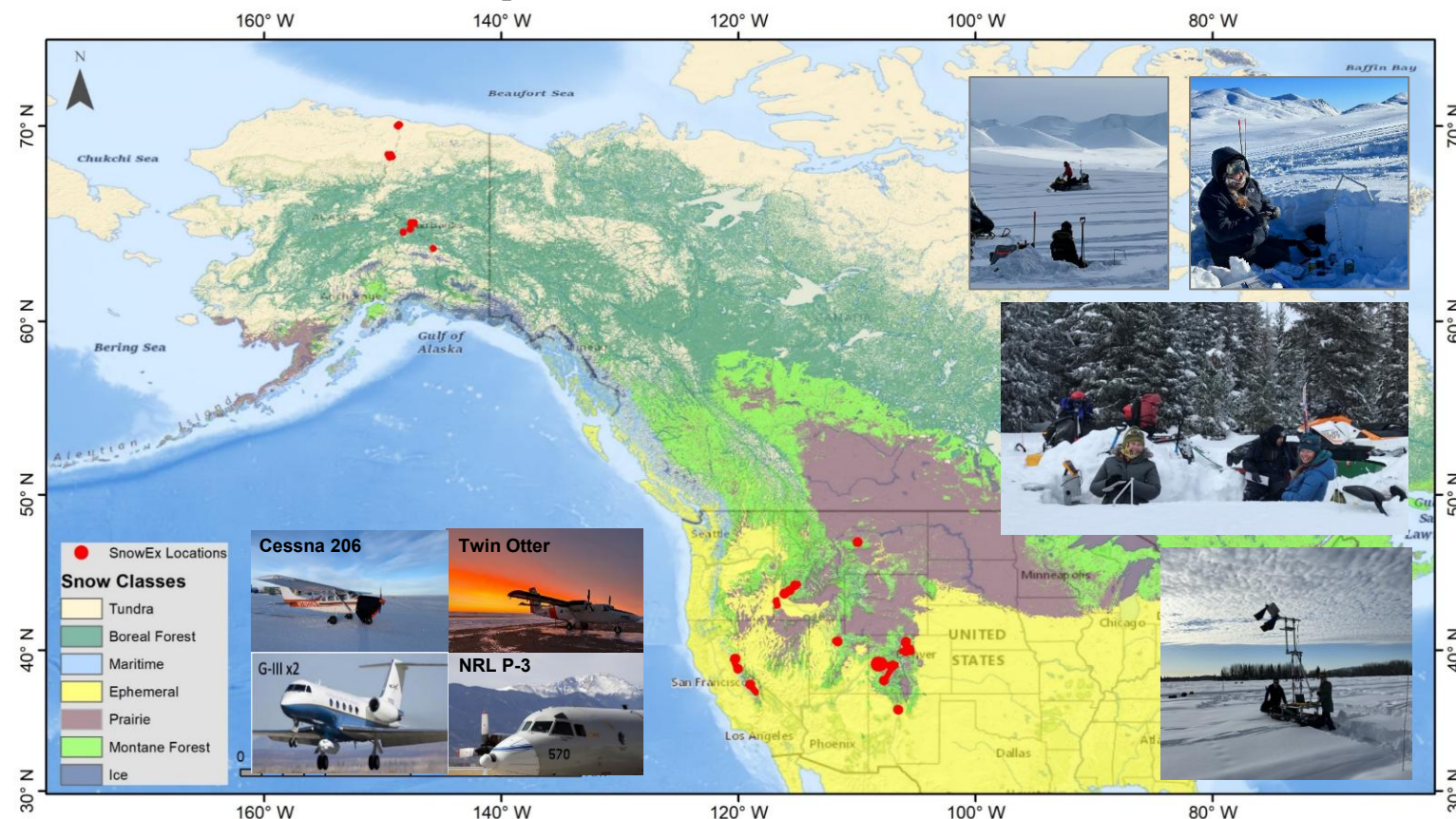
NASA SnowEx, Accomplishments to Date

NASA Terrestrial Hydrology SnowEx Summary to date:

- Over 250 Participants
- From 49 Institutions
- 8 Aircraft
- 14 Airborne Instruments
- 184 Individual Datasets
- 68 Publications using SnowEx data
- >40 PhD Dissertations and 6 Masters Theses complete or in progress
- 2 satellite mission proposals to the Earth System Explorer solicitation



[SnowEx References](#)



Service Layer Credits: USGS The National Map: National Boundaries Dataset, 3DEP Elevation Program, Geographic Names Information System, National Hydrography Dataset, National Land Cover Database, National Structures Dataset, and National Transportation Dataset; USGS Global Ecosystems; U.S. Census Bureau TIGER/Line data; USFS Road Data; Natural Earth Data; U.S. Department of State Humanitarian Information Unit; and NOAA National Centers for Environmental Information, U.S. Coastal Relief Model. Data refreshed April, 2023.

Four SnowEx campaigns were conducted at 20 different locations in the Western US and Alaska (red dots). Base map shows snow classes defined in Sturm & Liston (2021). Map credit: Svetlana Stuefer, UAF



NASA Hydrosphere Investigator Meeting
1-3 September 2026, Washington DC



Status of global snow satellite observations

Upcoming opportunities, new developments and ongoing research efforts

In this decade several potential opportunities for spaceborne snow observations are possible:

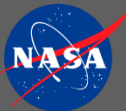
- Earth System Explorer (ESE) – no snow mission selected in 2024 solicitation; Next potential ESE solicitation in 2028?
- Terrestrial Snow Mass Mission (TSMM) – Canadian mission, Dual Ku-band SAR
- Radar Observing System for Europe in L-band (ROSE-L) – ESA mission planned launch in 2031
- EAGLE – Directed mission to collect hyperspectral and thermal, planned launch in 2028

In addition, new techniques and advances are being demonstrated with existing satellites:

- C-band SAR - Sentinel-1
- Stereo-photogrammetry – Worldview, Planet, Pleiades
- Spaceborne lidar – ICESat-2, GEDI
- L-band InSAR – NISAR

Ongoing research using SnowEx data:

- Advance scientific understanding of snow processes
- Quantify uncertainty of remote sensing techniques in different conditions
- Model integration and data merging techniques in development to tie pieces together



CryoSAR Ku and L-band observations of Quebec forested landscapes: 2026-2029



Overview: University of Waterloo (PI: Richard Kelly) is conducting season-long airborne and ground campaign to test Ku- and L-band measurements in forested landscapes of Quebec, Canada over 2 winter seasons: 2026-27 and 2027-28

- Terrestrial Snow Mass Mission (TSMM) science development
- Opportunity for collaborative survey flights to test multi-frequency SAR observations
 - CryoSAR: University of Waterloo, Ku- and L-band airborne cryosphere-observing synthetic aperture radar
 - SNOWWI: University of Massachusetts, dual-Ku- and C-band airborne SAR with interferometric capabilities
- Ground teams from Canada and US

CryoSAR



UW Cryosphere Synthetic Aperture Radar (CryoSAR)

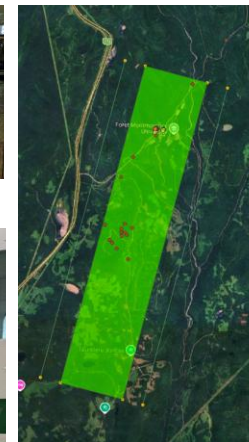
	Band	Freq (GHz)	Pol
Active	L	1.30	VV, HH, HV, VH
Active	Ku-Lo	13.50	VV, HH, HV, VH



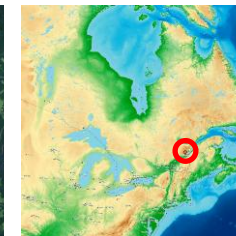
STC: Cessna 208B, DC-3



Basler



Foret Montmorency is a research forest with more snow than anywhere else in Quebec

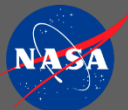


University of Massachusetts Amherst



UMASS Snow Water-equivalent Wide Swath Interferometer and Scatterometer (SNOWWI)

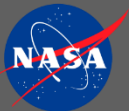
	Band	Freq (GHz)	Pol
Active	C	5.35	VV,VH
Active	Ku-Lo	13.60	VV,VH
Active	Ku-Hi	17.25	VV,VH

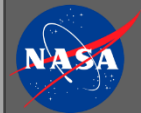


SnowEx Collaborations & Partnerships



NASA Hydrosphere Investigator Meeting
1-3 September 2026, Washington DC





NASA Hydrosphere Investigator Meeting
1-3 September 2026, Washington DC

