



¹NASA Goddard Space Flight Center; ²Boise State University; ³NASA Ames Research Center; ⁴University of Alaska Fairbanks; ⁵U.S. Forest Service; ⁶Portland State University; ⁷Ohio State University; ⁸Science Systems and Applications Inc.; ⁹University of Washington; ¹⁰University of Maryland; ¹¹NASA HQ



NASA SnowEx, 2016 – 2023

NASA SnowEx is a multi-year field campaign, sponsored by NASA's Terrestrial Hydrology Program (THP), to assess the ability of different remote sensing techniques across a range of snow climates and topographic and vegetation gradients. Research and validation have aimed to address unique environmental challenges needed for global snow satellite observations to be successful.

- Over 250 Participants
- 49 Institutions
- 20 Sites
- 8 Aircraft
- 18 Airborne Instruments
- 184 Datasets



Community-wide field campaign efforts













- 2017: Grand Mesa and Senator Beck, Colorado. Test wide range of instruments in different vegetation and topographic conditions
- **2019-2020**: Grand Mesa, CO. Seven different airborne instruments on 5 different aircraft over a week in November & 3 weeks in February
- 2020-2021: Western U.S. Time Series. L-band InSAR time series over 14 sites across Western U.S., range of snow climates, local field teams deploy on each of 16 sorties
- 2022-2023: Fairbanks and North Slope, Alaska. Lidar/SfM and X/Ku-band SAR in boreal and tundra snow climates; Multispectral imagery during the snowmelt period in boreal forest

SWE/Snow Depth Airborne Sensors

Instrument	Measurement	Campaigns	Organization	Aircraft
Lidar	Snow depth	2017	ASO	King Air
Lidar	Snow depth	2020, 2021	Quantum Spatial	King Air 90
Lidar	Snow depth	2023	U. of Alaska Fairbanks	Cessna 206
Stereo Imagery	Snow depth	2023	U. of Alaska Fairbanks	Cessna 206
UAVSAR, L-band SAR Interferometry	Change in SWE	2017, 2020, 2021	JPL	NASA G-III
GLISTIN-A, Ka-band Radar	Snow depth	2017	JPL	NASA G-III
SnowSAR, X & Ku-band radar	SWE	2017	ESA	NRL P-3
SWESARR, X/Ku Radar; X/K/Ka Radiometer	SWE	2020, 2023	GSFC	Twin Otter
WISM, X/Ku Radar; X/K/Ka Radiometer	SWE	2017	GSFC	Twin Otter
FMCW Radar	SWE/ Stratigraphy	2020	U. of Alabama	Twin Otter
Gamma	SWE	2020	NOAA NOHRSC	Twin Commander

Albedo, Temperature & Optical Airborne Sensors

Instrument	Measurement	Campaigns	Organization	Aircraft
CAR	Bidirectional Reflectance Distribution Function (BRDF)	2017	GSFC	NRL P-3
CASI	Hyperspectral/Albedo	2017	ASO	King Air
CASI	Hyperspectral/Albedo	2020, 2021	Quantum Spatial	King Air 90
AVIRIS-NG	Reflectance/Albedo	2021, 2023	JPL	King Air B-200
Thermal IR	Surface temperature	2017, 2020	University of Washington	NRL P-3
Imager	Optical imagery	2017	GSFC	NRL P-3
Video Camera	Optical video	2017	GSFC	NRL P-3

Ground Measurements

Manual:

•Snow pits: (Density; Liquid water content; Temperature; Stratigraphy; Snow depth; Weather, Vegetation and Substrate characteristics)

- •Snow Depth
- •Gravimetric Water content (substrate)
- Interval Boards
- •Snow depth
- •SWE Tube

Ground-based remote sensing: •Microstructure

- •Terrestrial Laser Scanner (TLS)
- •Ground penetrating radar (0.5-1.5 GHz)
- •Radiometer (multiple frequencies)
- •Radar (C-, X-, and Ku-band)
- •Time lapse cameras
- Field spectrometer

snow.nasa.gov

Acknowledgements

Advancing global snow observations through the NASA SnowEx campaign Carrie Vuyovich¹, H.P. Marshall², Edward Kim¹, Charles Gatebe³, Svetlana Stuefer⁴, Kelly Elder⁵, Kelly Gleason⁶, Michael Durand⁷, Megan Mason^{1,8}, Matthew Sturm⁴, Jessica Lundquist⁹, Dorothy Hall^{1,10}, Jared Entin¹¹

(Specific Surface Area; Snow Micropenetrometer; Casting)

•UAV: hyperspectral, lidar, thermal IR, optical/stereo



SGS 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 formation Unit; and NOAA National Centers for Environmental Information, U.S. Coastal Relief Model. Data refreshed April, 2023.

Figure 1: Map showing the location of SnowEx field sites (red dot). Base map shows snow classes defined in Sturm & Liston (2021).

SnowEx Data

Data collected during the SnowEx campaigns is archived and available at the National Snow and Ice Data Center (NSIDC, https://nsidc.org/data/snowex).



SnowEx Findings to Date

The NASA SnowEx campaign has helped improve process-level understanding advance snow remote sensing and algorithm development and explore data integration and merging techniques.



Figure 4: Publications addressing SnowEx Science objectives can be split into 3 groups: Data Science (5), Measurement Science (17), and Snow Process Science (12).





Figure 3: Total number of unique SnowEx data download and users per year since 2017



Figure 5: To date, 34 publications have explicitly used SnowEx data in their analysis. Over 20 additional publications have directly addressed SnowEx objectives or cited SnowEx protocols while using other datasets

SnowEx Hackweek

Hackweek is a participant-driven workshop designed and implemented through a partnership with the University of Washington's eScience Institute, Boise State University, and the SnowEx community to foster collaboration, provide education in the tools and methods of open science, and align community members around shared software and SnowEx datasets.

- virtual seminar series.

- modeling, and group projects
- Upcoming Hackweek, Summer 2024



Outreach & Snow Schools



 NASA/CUAHSI Snow School: 4-day hands-on field school; prepare researchers at all career levels to make quality field observations using standard techniques NASA MAIANSE: Undergraduate interns from American Indian and Alaska Native serving institutions exploring SnowEx data SnowEx-Ed, NASA STEAM Education with Snow: Snow science kits were designed, built and distributed to schools across the US to highlight



Community Building & Next Steps

community through:

- meetings.
- opportunities in mind.
- System Explorer solicitation.





• Three Hackweeks: 2 week-long workshops (1 in-person, 1 virtual) + 1

• Team of tutorial developers and organizers

• Event @UW eScience, tutorials on SnowEx data, tools, access,

• Tutorials and database access available to community





https://snowex.hackweek.io/

Multiple snow-focused outreach efforts have promoted snow science and measurement in conjunction with SnowEx:

• Winter Wildlands Alliance Snow School: K-12 program that takes over 35,000 students into the snow environment to teach science

snow science, along with fun outdoor snow activities to give students snow measurement experience

Over the past 7 years, SnowEx has helped bring together the snow

• Multiple field campaigns, working groups and community-wide

• A 10-year roadmap was developed to steer snow research and goals into the future with upcoming satellite missions and snow mission

• Two snow mission proposals were submitted to the recent NASA Earth

• Stay Tuned! Plans for an in-person science meeting are underway to discuss remaining science gaps and next steps

Contact

Carrie Vuyovich Carrie.M.Vuyovich@nasa.gov