NASA SnowEx 2020: Post-campaign update

Organizing Team: HP Marshall, Carrie Vuyovich, Chris Hiemstra, Kelly Elder, Mike Durand, Jerry Newlin, Ludo Brucker, Jeff Deems

Time Series Leads, Aircraft Teams, Field Teams, Partnerships

NASA Terrestrial Hydrology Program (THP)
Updates to SnowEx Community, April 16, 2020
Agenda

- SnowEx2020 Brief Overview – HP Marshall
- SnowEx2020 Time Series – HP Marshall
- SnowEx2020 Grand Mesa IOP – Carrie Vuyovich
- Data submission to NSIDC and timeline – Megan Mason
- Future SnowEx activities and Roadmap – Carrie Vuyovich
- Discussion / Questions - All
The SnowEx 2020 Campaign consisted of coordinated airborne and field-based experiments in the Western U.S. to test instruments under a variety of snow conditions. This effort includes two major components:

1. **A time series experiment with L-band InSAR** *(50% completed; stopped due to pandemic. Remaining flight hours approved for 2020-21 season.)*
   - 13 sites, spanning 5 states
   - 6 total UAVSAR flight periods, Dec-Mar *(COMPLETED)*
   - Weekly in-situ field observations, Airborne LiDAR, TLS, ground-based radar for calibration/validation *(COMPLETED)*

2. **A detailed experiment on Grand Mesa, Colorado**
   - 5-day snow-off campaign November 4-8, 2019 *(COMPLETED)*
   - 10-day snow-on campaign January 27 –February 14, 2020 *(COMPLETED)*
   
   <campaign extended one week to adjust for aircraft delays>
Alignment with THP16 Science Plan

SnowEx 2020: Responds to 6 out of 7 Science Plan Gaps

- Snow climates (Forest, mountain, prairie, maritime)
- Wet snow, accumulation and melt (time series)
- Surface energetics (surface temperature)

SnowEx 2020: Responds to all Science Plan *Mission Critical, Crucial, Important* priorities

- L-band InSAR (UAVSAR)
- X-, K-, Ka-band Passive microwave (SWESARR)
- X-band, dual Ku-band SAR (SWESARR)
- Ka-band InSAR (GLISTIN-A) <scheduled for April, cancelled due to pandemic>
- LiDAR (ASO, Quantum Spatial, CRREL HeliPod)
- Thermal IR (UW)
- Hyperspectral imaging (ASO, Quantum Spatial, SaraniaSat) <SaraniaSat postponed>
- Modeling / Data Assimilation (SEUP, NOHRSC)
- Photogrammetry / Structure from Motion (drone/airborne/satellite)
- FMCW radar (similar to IceBridge SnowRadar; University of Alabama)
SnowEx2020 Time Series – Airborne / Spaceborne

- UAVSAR – testing algorithms for estimating change in depth and SWE between overflights
- LiDAR – used to define snow depth distribution, for calibration and validation of retrievals
- Sentinel C-band radar was tasked for ~6-day repeats over many SnowEx2020 time series sites
- World View tasking, coordinated drone campaigns for surface reconstruction
SnowEx 2020 – UAVSAR

- L-band Interferometric Synthetic Aperture Radar
  - L-Band (1 GHz; 23 cm)
  - Weekly to biweekly flights, Dec-March
  - Relationship between change in SWE/depth vs. change in InSAR phase
- Validation for a range of snow climates, vegetation, and during accumulation & melt
  - L- and S-band (12 cm)
  - 12-day (or shorter) exact repeat orbit
  - Launch date: Dec. 2021
  - 3-10 m resolution

Previous studies have found agreement in accumulation patterns, compared to LiDAR and magnaprobe depth observations.

North Slope Brooks Range, AK [from E. Deeb]
L-band InSAR: Inverting for depth change

\[ \Delta d = -\frac{\Delta \phi \lambda}{4\pi} \frac{1}{\cos \alpha - \sqrt{\varepsilon_s - \sin^2 \alpha}} \]

[e.g., Gunnerison et al., 2001]
QSI and ASO Airborne LiDAR

Riegl VQ1560i Airborne LiDAR Scanner
- Dual channel LiDAR sensor
  - 1 mHz/Laser channel
  - 1064nm Class 3B Laser
  - 58° effective Field of View

Itres CASI 1500H Hyperspectral Sensor
- VNIR Imager
  - 380-1050nm Spectral Range
  - 40° Field of View
  - Pushbroom
  - Up to 288 Spectral Channels
CRREL Helipod LiDAR

- Robinson R66 Helicopter
- Riegl LMS VQ-580 laser scanner
- iXBlue ATLANS-C IMU
- Silverhawk Aviation, Idaho

Contact:
SNOWEX 2020 – Time Series

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<td>Jemez River, NM</td>
<td>Ryan Webb</td>
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Map shows all sites for UAVSAR, 6 flight periods, Dec-March

Sites chosen with existing infrastructure and ongoing research, CZO, LTER, long term well-instrumented watersheds, ground-based remote sensing sites; range of climatology, vegetation, topography

Airborne lidar/TLS: 7 sites
Ground-based radar: 5 sites

~9 weekly in-situ sampling days at each site, Dec 20-Mar 12
SnowEx 2020 – Time Series

Focus on variability of snow and landscape conditions throughout the accumulation and melt season.

Ground observations of:
- Change in snow depth and SWE
- Snow stratigraphy, density, and liquid water content
- Ground-based radar (CSU, UNM, BSU)
- Terrestrial LiDAR (CRREL, BSU)
- Field spectrometer (Univ UT, UNR)

Airborne observations of:
- L-band InSAR (UAVSAR)
- LiDAR (ASO, CRREL Helipod, TLS)
- Ka-band InSAR (GLISTIN A (CA))
L-band InSAR Preliminary Results

- Coherence is promising in many locations, but not in dense forest
- Complex topography will require significant reprocessing with higher-res DEMs

Ongoing Analysis
- Statistical analysis of coherence
- InSAR reprocessing, corrections for atmospheric, topographic and vegetation effects
- Phase unwrapping algorithms, constrained by met data
- Inversion of phase for depth and SWE change
- Comparison to in-situ field data
L-band InSAR Analysis Efforts

- UAVSAR Team [Yunling, Naiara, etc]
- Deeb, Morriss (CRREL, THP16)
- Marshall (BSU, THP16)
- Forster, Lund (U. Utah, THP16, NISAR SDT)
- Jones (JPL, THP16)
- McGrath (CSU, THP17)
- Webb (UNM, THP17)
- SnowEx2020 site leads
- CUAHSI Virtual University – Microwave Radar (Fall 2020)
- SnowEx Hackweek, Sept 2020 (Lundquist, Arendt)

Coordinated analysis effort planned. Contact us if interested.
Time Series Summary:

1. **Time Series**
   - L-band InSAR (6 flight periods, 13 sites)
   - LiDAR, Hyperspectral (subsets of 7 sites)
   - Ground-based radar (4 sites)
   - Online data entry system (NSIDC)
   - ~Weekly field observations at all 13 sites, Dec 20 – March 12
   - LWC observations
   - Some aircraft maintenance and instrument issues, conflicts with other NASA campaigns (ISRO-ASAR, DeltaX)
   - GLISTIN-A planned flights coincident with ASO in CA in April
   - Univ Alabama FMCW flights planned late March / early April
   - WWA SnowSchool K-12 students submitting data; Time Series leads submitted material for NASA blog
   - NSIDC SnowToday Reports (Karl Rittger, Mark Raleigh)
Time Series Data Availability Timeline

- UAVSAR L-band InSAR data: Raw data available, preliminary InSAR products for some sites available, others within the coming weeks. Reprocessed data target: December 2020.
- QSI LiDAR: snow-on data available in ~ 1 month; snow-free flights planned for June/July; depth products fall 2020.
- CRREL Helipod: snow-on data available, snow-free planned for summer 2020
- Field data: Targeting July 1 deadline for instrument PIs; core data (pits, depths) to be released first, target date: end of May

*If you have SnowEx2017 or SnowEx2020 data to contribute, please publish with NSIDC: [https://nsidc.org/data/daac-project/submit](https://nsidc.org/data/daac-project/submit)*
SnowEx 2020 – Collaborations/Coordination

In situ
- Bi-weekly in situ sampling (Colorado, Idaho)
  - Natural Resources Conservation Service (NRCS)
- LiDAR flights (East River, Colorado and San Joaquin/Lakes, California)
- ASO
- Helipod LiDAR/thermal infrared (Boise River Basin, Idaho)
  - U.S. Army Corps of Engineers, CRREL
- UltraWideBand radar (2-18 GHz) (Grand Mesa, Colorado)
  - Uni. of Alabama
- Signal of Opportunity (SoOp) tower experiment (Fraser, Colorado)
  - JPL / U.S. Forest Service
- Gamma flights (Colorado, possibly other states)
  - NOAA National Operational Hydrologic Remote Sensing Center (NOHRSC)

Airborne
- Stereo satellite imagery (e.g., World View, TerraSAR-X)
  - U. of Washington, U.S. Army CRREL
- Sentinel-1/2 C-band SAR
  - FMI, KU Leuven (will also provide 1km snow depth products)

Satellite

Modeling
- Several modeling efforts focused on most sites (e.g., NOHRSC; Snow Ensemble Uncertainty Project – SEUP)
SnowEx 2020

NASA SnowEx 2020 Experiment Plan

Draft (July 2019)

Experiment Plan:

https://tinyurl.com/y4r6oz9d