TH13F: NASA SnowEx - Enhancing new sensing technologies to retrieve snow water equivalent in forested and other lands

Monday, December 12, 2016
12:30 – 1:30 PM

Moscone West - 2002
<table>
<thead>
<tr>
<th>Time</th>
<th>Session Title</th>
<th>Speaker(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12:30-12:31</td>
<td>Welcome</td>
<td>Jared Entin</td>
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<tr>
<td>12:31-12:40</td>
<td>Overview of SnowEx current status</td>
<td>Ed Kim</td>
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<tr>
<td>12:40-12:50</td>
<td>Report on fall campaign in Grand Mesa and Senator Beck</td>
<td>Kelly Elder</td>
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<td>12:50-1:05</td>
<td>iSWGR</td>
<td>Alex Langlois &amp; Jessica Lundquist</td>
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<td>1:05-1:15</td>
<td>2017 winter campaign information</td>
<td>Amy Misakonis</td>
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<td>1:15-1:20</td>
<td>ASO - SnowEX</td>
<td>Tom Painter</td>
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<td>1:20-1:25</td>
<td>SnowEx update</td>
<td>Jared Entin</td>
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<td>1:25-1:30</td>
<td>Q/A</td>
<td>C. Gatebe</td>
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SnowEx: a NASA airborne campaign leading to a snow satellite mission

SnowEx update @ AGU townhall
Dec 12, 2016

SnowEx Team/contributors to this report: Edward Kim, Charles Gatebe, Amy Misakonis, Dorothy Hall, HP Marshall, Ludovic Brucker, Kelly Elder, Chris Hiemstra, Matt Beckley, Alex Coccia, Amanda Leon, Jeff Deems, Tom Painter

Sponsored by NASA Headquarters/Terrestrial Hydrology Program Manager: Jared Entin
<table>
<thead>
<tr>
<th>What/When/Where/Why</th>
<th>What is SnowEx?</th>
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<td>• Multi-year airborne snow campaign</td>
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<td></td>
<td>• Address key issues for a global snow satellite mission</td>
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<td>• Collect multi-sensor obs + ground truth</td>
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<td>• Year 1 will challenge sensing techniques with forested conditions</td>
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<thead>
<tr>
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<th>Where?</th>
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<tbody>
<tr>
<td></td>
<td>• Western Colorado</td>
</tr>
<tr>
<td></td>
<td>• Primary: Grand Mesa</td>
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<td>• Secondary: Senator Beck basin</td>
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<tr>
<td></td>
<td>• Year 1 = 2016-17</td>
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<tr>
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<td>• Year 2: no campaign</td>
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<td>• Years 3,4,5: campaigns</td>
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Who

• Lead: NASA Goddard Space Flight Center
• Partners
  – US Forest Service
  – Cold Regions Research Engineering Lab
  – Naval Research Lab
  – Jet Propulsion Lab
  – European Space Agency
  – Center for Snow & Avalanche Studies
  – National Snow & Ice Data Center
  – National Weather Service
  – NOAA
  – Universities, research centers
Confirmed and potential sensors

CONFIRMED CORE SENSORS
• SnowSAR: X & Ku-band radar (ESA)
• CAR (BRDF from GSFC)
• AESMIR (passive mw, from GSFC) 18 & 36 GHz
• Thermal IR/video suite
  • Imager (GSFC)
  • High-accuracy non-imaging (KT.15, from U.Washington)
  • Video camera (GSFC)
• ASO suite (JPL)
  • Lidar
  • Hyperspectral imager

CONFIRMED EXPERIMENTAL SENSORS
• UAVSAR: L-band radar (JPL)
• GLISTIN-A: Ka-band radar (JPL)

POTENTIAL SENSORS
• WISM: X, Ku, & Ku-band radar (GSFC)
• UAV w/lidar (CRREL)
• NRL ice suite
Confirmed and potential aircraft

List as of Dec 12

**Confirmed**
- NRL P-3 (VXS-1)
- King Air with ASO (same as fall)
- NASA G-III with GLISTIN-A (same as fall)
- NASA G-III with UAVSAR

**Potential**
- Twin Otter with WISM
- Another Twin Otter with NRL ice suite
- UAS (drone) with lidar

Flight coordination for safety & science quality will be essential
Overview of Current status – Dec 2016

• 13 yrs ago... the last big community campaign – CLPX-1
• 2yrs ago...SnowEx was announced at AGU
• 1.5 yrs ago...1st workshop (May 2015, Columbia MD)
• Only 1 yr ago...serious prep started
• Only 9 months ago (March 2016)...Seattle meeting
  – No site selected
  – Primary aircraft not known
• Only 7 months ago (May) ...sites selected
• Only 5 months ago (July) ...major aircraft decided; LSOS identified
• Only 2 months ago (Sep/Oct) ...first airborne & ground truth obs, met stations, GBRS begun
• Only 1 month ago (Nov) ...winter participant selection was still in process

TODAY:
• 8 airborne instruments confirmed
• 4 aircraft confirmed
• 2 sites confirmed
• ~100 participants from dozens of institutions notified
• Nearly 100 transects marked
• 14 TLS sites identified
• 22 GBRS instruments planned
• 4 new met stations installed
• 2 existing met stations augmented
• Data center identified/prep started
• SnowEx year 1 is on target
• AMAZING what the snow community can do when it pulls together!!!
SnowEx Ground Measurements

🌟 Safety for all, high-quality measurements 🌟

Kelly Elder (US Forest Service - RMRS)

Physical measurements of the snowpack

Christopher Hiemstra (US Army - CRREL)

Snow-Vegetation interactions – Land cover classification

Ludovic Brucker (NASA - Goddard)

Ground based remote sensing (GBRS)

Local scale observation site (LSOS)

Hans-Peter Marshall (Boise State University)

Senator Beck Basin
Physical Snowpack Measurements

Snow depth – transects
manual probes & MagnaProbes

Snow pits
depth
density
water equivalent
stratigraphy
  grain type
  grain size
snow temperature
surface roughness
snow wetness
soil temperature
soil moisture

Meteorology
5 stations - Grand Mesa
2 stations – Senator Beck
Overview

NSIDC DAAC will archive and distribute data products from the NASA SnowEx campaigns focusing on collecting snow data in forested regions with airborne multi-sensor and in situ validation observations.

Campaign Resources

Year 1: Colorado

Shapefiles of the campaign study areas including transects, Terrestrial Laser Scan (TLS) areas, met towers, and raster data imagery with some tree classification/density layers. Also including flight-line boxes.

Photographs taken with SnowEx cameras during the Fall 2016 campaign. Photos depict terrain and environment for the upcoming February 2017 campaign.
Continuous monitoring by

- 12 instruments
- weather station
- Microwave radiometers
- Radars
- Sun photometer
- GPS
- Tree accelerometers
- Precipitation instruments
- Snow depth sensors
- Time lapse camera

[Uni Michigan]
[Boise State Uni]
[NASA GSFC]
[Uni Colorado]
[Uni Colorado]
[NASA WFF]
[Uni Colorado]
[Uni Washington]
Local Scale Observation Site & Ground Based Remote Sensing

Truck-mounted microwave radiometers [Uni Michigan]

Terrestrial Lidar Systems [CREEL, Uni Colorado, Boise State Uni]

>12 sites with snow free data from Sept.

Tree sway [Uni Colorado]
## Local Scale Observation Site & Ground Based Remote Sensing

<table>
<thead>
<tr>
<th>Ground-Based</th>
<th>Airborne</th>
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<tr>
<td>Lidars</td>
<td>Airborne Snow Observatory</td>
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<tr>
<td>Radars &amp; Scatterometers</td>
<td>SnowSAR, UAVSAR, GLISTIN-A</td>
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<tr>
<td>Microwave radiometers</td>
<td>AESMIR</td>
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<tr>
<td>Spectroradiometers</td>
<td>Imaging spectrometer</td>
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<tr>
<td>Goniometer</td>
<td>Cloud Absorption Radiometer</td>
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### . . . VISION . . .

#### Experiment Plan

[Defined by the community (GBRS = 30+ people)]

#### Field Campaign

[Executed by the community (80+ people)]

#### Data Delivery to NSIDC

[Controlled by the community (>35+ instruments)]

#### Science

[Carried out with collaborations]
Senator Beck Basin

**Instrumentation, Spatial surveys**

- Two energy-balance met stations [*Center for Snow and Avalanche Studies*]
- Time lapse cameras and tree accelerometers [*CU*]
- NetR9/NetRS GPS [*CU, NSIDC, UNAVCO*]
- Sun photometer [*Aeronet*]
- 1-6 GHz impulse, 24-26 GHz FMCW tower-based microwave radars [*BSU*]
- Stream gauge [*Center for Snow and Avalanche Studies*]
- TLS surveys [*NSIDC, CRREL*]
- GB radar surveys [*BSU*]
- Historical ASO overflights [*NASA JPL*]
Senator Beck Basin

- Alpine
- Treeline
- Subalpine
DRAFT sampling plan

- Sampling in safe areas 1st priority
- Focus on high snow variability, complex terrain
- 100 m N/S, E/W depth transects, central snowpits
- TLS surveys
- Radar surveys
- Spectrometer
- NIR photography
- SnowMicroPen
- Snow casting
SnowEx Ground Contacts

Kelly Elder (US Forest Service - RMRS)
  kelly4snowex@gmail.com

Christopher Hiemstra (US Army - CRREL)
  Christopher.A.Hiemstra@usace.army.mil

Ludovic Brucker (NASA - Goddard)
  ludovic.brucker@nasa.gov

Hans-Peter Marshall (Boise State University)
  hpmarshall@boisestate.edu
iSWGR 2013-2016 Snow schools

Fraser, Colorado 2014: Snow measurements
27 students

AGU TownHall meeting, December 2016
iSWGR 2013-2016 Snow schools

Boulder, Colorado: Snow modelling
32 students

AGU TownHall meeting, December 2016
iSWGR 2013-2016 Snow schools

Sherbrooke, Québec 2015: Snow remote sensing
30 students

AGU TownHall meeting, December 2016
iSWGR 2013-2016 Snow schools

Fraser, Colorado 2016: Snow measurements
35 students

AGU TownHall meeting, December 2016
iSWGR 2013-2016 Snow schools

- Clear growing interest;
- Unfortunately no school in 2017, but received >130 applications;
- Working on plans and location for the next snow school 2018.

AGU TownHall meeting, December 2016
iSWGR 2013-2016 Workshops

Next meeting, past workshops (reports available at iswgr.org).

Workshop #1: 14-16 August 2013 (Boulder, Colorado)
Workshop #2: 13-16 January 2014 (Granby, Colorado)
Workshop #3: 26-27 June 2014 (Boulder, Colorado)
Workshop #4: 29-31 March 2016 (Seattle, Washington)

Next meeting:
- Joint SnowEx-iSWGR meeting
- Boulder, Colorado, Week of August 7th 2017
iSWGR Charter

Opportunity to be the first to sign the Charter here. Elections for new steering committee will take place at the next meeting:

- Joint SnowEx-iSWGR meeting
- Boulder, Colorado, Week of August 7th 2017
NASA’s Airborne Snow Observatory - SnowEx

- Wall to wall mapping of SWE and albedo
- Weekly flights in winter and spring
- < 24 hour turnaround of distributed products and modeling/management distillations

Snow depth
- Riegl Q1560 dual laser scanning lidar
- 1064 nm
- Full-waveform
- 60° field of view

Snow albedo
- CASI-1500 Imaging Spectrometer
- 72 bands between 0.35 and 1.05 μm
- 40° field of view

GNSS/IMU – Applanix AP60
RTX GNSS correction
ASO for SnowEx

- Snow depth measurements
- SWE retrievals
- Snow albedo measurements
- Vegetation structure measurements for baseline for all other RS

Products

- DSM+DTM+topographic metrics
- Snow depth + SWE
- Vegetation height + density + cover
- Snow grain size + albedo

Grand Mesa, Colorado
Digital surface model
9/26/2016

Grand Mesa, Colorado
Digital surface model
9/26/2016

Grand Mesa, Colorado
Digital surface model
9/26/2016

Grand Mesa, Colorado
Digital terrain model
9/26/2016

Grand Mesa, Colorado