Report on the NASA Snow Remote Sensing Workshop
Boulder, Colorado, 14-16 August 2013

Snow: It quenches our thirst/ it keeps our planet cool.

A three-day community meeting of the NASA Snow Remote Sensing Group (proposed new name: *your suggestion goes here*) took place in Boulder, Colorado at NSIDC. The agenda appears in Appendix 1. About 50 people attended (Fig. 1). Due to size restrictions (limit of about 50), an additional 10 people could not attend but were placed on an email list. The attendee list is in Appendix 2.

Figure 1: Snow remote sensing workshop participants, August 15, 2013.

The ***first*** goal of the meeting was to assess the current state of snow remote sensing (RS), noting recent successes, promising new technologies, and areas where basic research will be needed to make advancements. The ***second*** goal was to begin development on a blueprint detailing (or outlining) steps needed to make progress on key snow-related science questions in which remote sensing plays an important role. This activity included addressing gaps in our understanding of snow properties and processes, promoting technical developments in remote sensing instrumentation, and identifying convergent skills (like modeling, improved techniques for measuring snow on the ground, and data assimilation techniques). The ***third*** goal was to better define the function of the snow RS community and identify strategies to promote a sustainable, vibrant future to attract the next generation of snow researchers as well as research dollars.. Appendix 2 contains the full agenda for the meeting. Karina Mullen, a graphical artist facilitator, collected and captured notes and thoughts on the proceedings. These delightful images are available at http://nasasnowremotesensing.gi.alaska.edu/ and appear below.

The assessment section of the meeting covered the following topics related to snow and snow remote sensing:

History of Snow Remote Sensing	T. Painter
The Physics of Visible & Near-Visible EM radiation and snow	J. Dozier
Visible & Near-Visible RS Systems & Products	D. Hall
Hyper-spectral Basics & Systems Applicable to Snow	A. Nolin
Passive Microwaves and Snow: Physics & Basics	E. Kim
Passive Microwave RS Systems & Products	C. Derksen
Active Microwaves and Snow: Physics & Basics	S. Yueh
Radiometric Modeling of Backscatter in Snow:	L. Tsang
Ultra-broadband FM-CW Radar	C. Leuschen
An Update of the ESA CoReH$_2$O Project	H. Rott
Airborne LiDAR for Snow Depth	J. Deems
LiDAR from Space-IceSAT-II:	M. Jasinski
RS of Falling Snow: Applicability to Snow Cover Studies	R. Bennartz
The Role of Ground Data & Field Campaigns in Snow RS	K. Elder
The Role of Data Assimilation & Modeling in Snow RS	M. Durand
An Integrated System of Modeling, Assimilation, Ground data and RS	H.P. Marshall
Applications of Snow RS – Hydrology	D. Marks
Applications of Snow RS – Climate	D. Robinson

Graphical notes from these talks appear in Figure 2.

Figure 2: Notes from the technical sessions on snow remote sensing.

The presentations associated with these talks can be found at http://nasasnowremotesensing.gi.alaska.edu/content/meeting-presentations. While the following summary does not do justice to the full scope of what was presented, several over-arching points can be highlighted:

- Substantial advances in snow RS have occurred when a) there have been missions of opportunity (the launching of new satellites), b) comprehensive field and airborne programs (like CLPX or CoReH$_2$0) directed at advancing specific technologies, or c) advancements in physically-based modeling of snow.
- A number of emerging new technologies (i.e., LiDAR, hyperspectral RS, better radiative transfer models) have the potential for solving standing problems related to snow RS. The talks also highlight that significant strides have been made in several areas including the monitoring of snow cover area (SCA), a 30-year success story, improving radar backscatter modeling and SWE retrievals, a legacy of the recent CoReH$_2$O campaign, and the development of LiDAR for snow RS. In particularly, it now appears that the rate of decline in SCA globally is as rapid as the loss of Arctic sea ice, the ramifications of which are just starting to be explored.
- Overall, the "toolbox" for addressing snow RS is quite mature, but relatively little attention has been paid toward developing how to optimize using the tools we already have in concert. It was evident that if we focus on doing this, we might be able to provide more widespread, accurate and skillful snow products to meet societal and scientific requirements. While nascent efforts in this direction (e.g., GlobSnow, others) have begun, much remains to be done to optimize multi-sensor approaches blended with modeling, data assimilation and inferences based on time series (Fig. 3). This appears to be perhaps the most promising avenue for the future progress.

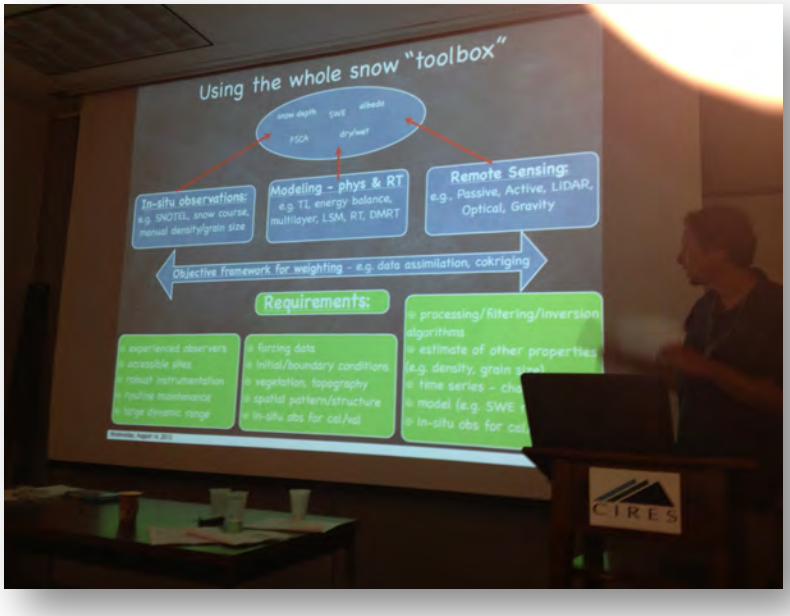

Figure 3: H.P. Marshall presents an idea of how we might use all the snow tools we posess in concert.

Following the assessment, a series of group activities were directed toward identifying our overall goal for snow RS ("envision the future")(Fig. 4), what gaps exist in our knowledge and skills that would be required to achieve that goal (Fig. 5), and the general approaches that we might take to close the knowledge gaps. The last exercise was to design a specific set of activities that might constitute a 10-year research program, replete with Requests for Proposals and outreach, yielding the snow RS capability needed to address societal problems (Fig. 4). The exercise was done among 5 small sub-groups, so the final exercise was to discuss and synthesize the commonalities among approaches (Fig. 6).

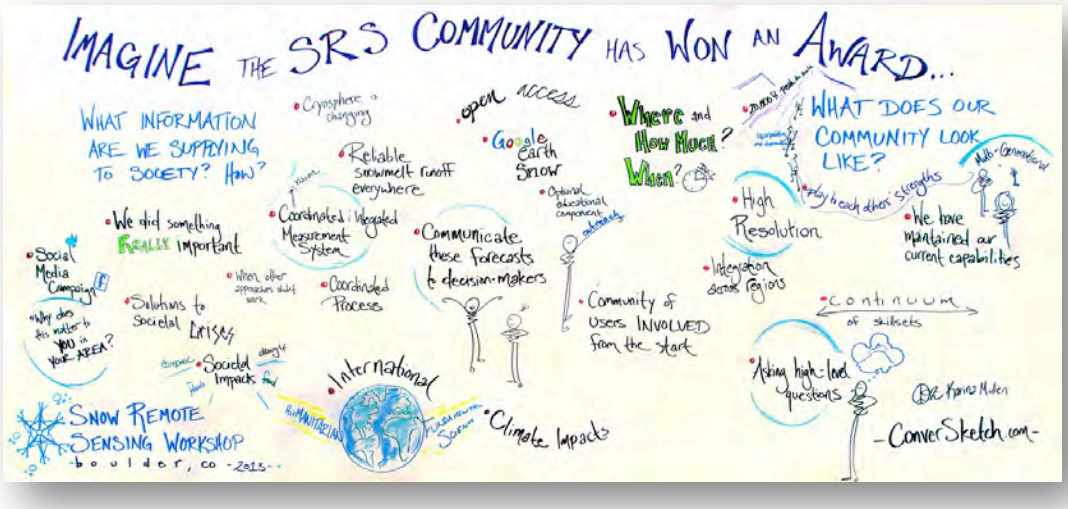

Figure 4: Notes from workshop session called "Envision the Future" wherein the group was asked to imagine the community was doing such a good job at snow remote sensing it had won an award.

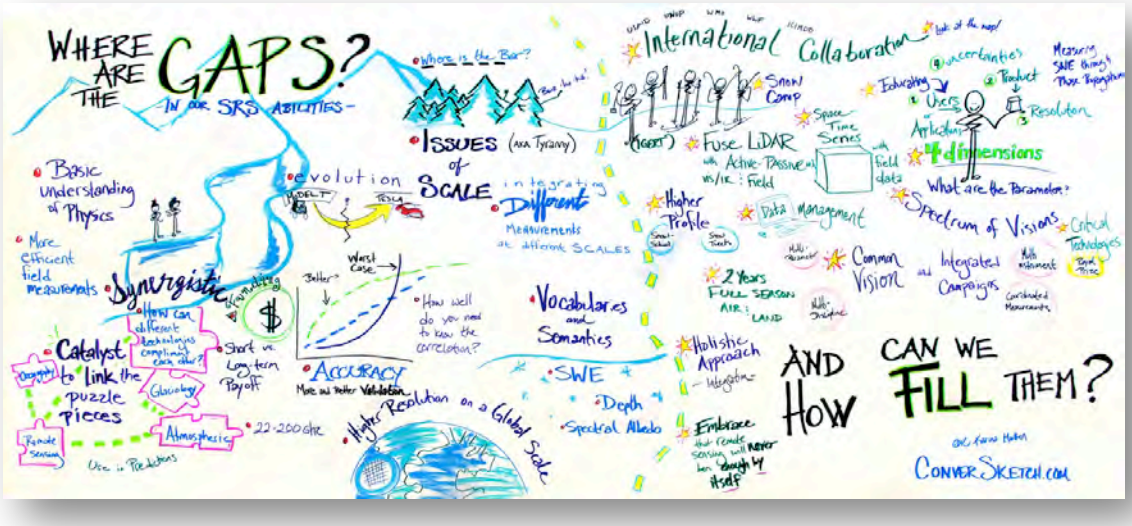

Figure 5: A gap analysis was the second group exercise; the notes from that session appear here.

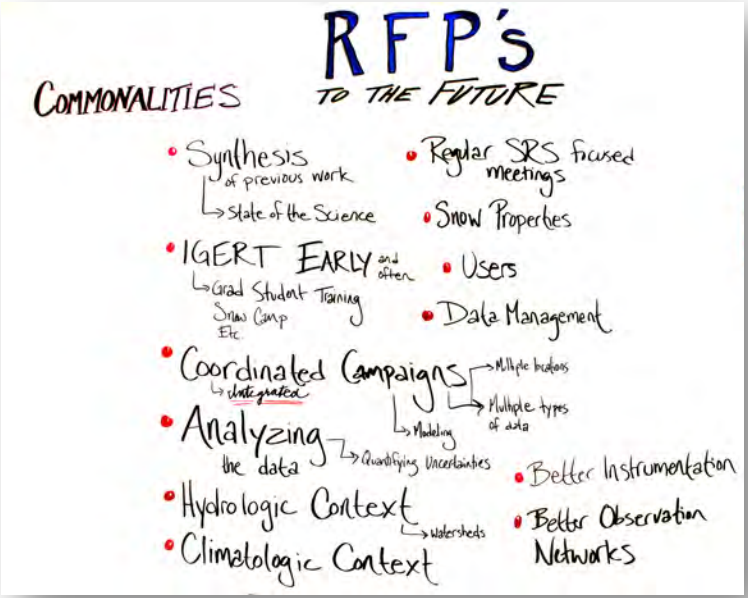

Figure 6: The final exercise was to "design" a 10-year research program on snow remote sensing that would plug the current gaps and deliver a seamless and practical set of snow remote sensing products. This was done independently by five groups, then in plenary the commonalities among the various plans were identified and discussed.

Future Steps

The last day of the meeting (Friday, 16 August) we identified some immediate and longer term steps needed for advance snow and remote sensing science. Immediate steps included:

1. Find a better name for the community (All hands).
2. Create from the current website (http://nasasnowremotesensing.gi.alaska.edu/) a snow community website that would report on the meeting, have interesting content, and serve as a hub for community announcements and communication (Sturm, Weaver).
3. Create a brochure that explains the importance of snow (Robinson, Elder, Molotch) that can be used by community members and others to make the case for snow research.
4. Develop a trial "snow field school" for students that might be done in conjunction with the next community meeting (Marshall, Lundquist)
5. Research ways to better spread the snow community's messages and work via publications and open source journals (Hiemstra and Lundquist)
6. Plan and execute a meeting about 6 months from now to maintain progress (Sturm + Exec. Committee).
7. Develop a "Road Map" Report for snow and remote sensing based on an outline developed at the meeting; iterate with full community (All hands).
8. Seek sustainable funding for the community from funding agencies and other sources (Sturm, Tedesco, Serreze, Jasinski, Gatabe, Others)

APPENDIX 1: SNOW REMOTE SENSING WORKSHOP AGENDA

AUGUST 14-16, 2013
BOULDER, COLORADO

TUESDAY, AUGUST 13

5:00-7:00 PM Icebreaker At Boulder Outlook

WEDNESDAY, AUGUST 14
CIRES AUDITORIUM

MORNING

0830: Opening Remarks M. Serreze/W. Abalati/J. Entin
0835: Organizational Notes C. Brekke
0840: Charge to the Workshop M. Sturm
0900-1000: ***Envisioning Our Future***: Karina. Mullen.
Imagine it is 15 years from now and the snow remote sensing (SRS) community has won an award for supplying society the critical information they need. What does system and community look like? How did the SRS achieve this prestigious award?

- Each person writes down about 3 ideas
- Groups of 3-5, each person shares their ideas with the group
- Each group reports back on the small group's thoughts to the whole group ***(captured graphically by Karina)***

Tying it Together:

We have outlined characteristics of where we want to be in the abstract. These will help guide us for the remainder of the workshop as we assess the steps that need to be taken to get there. Before we delve into designing our future state, we will have a series of presentations outlining the state of the science to ensure future visioning is solid grounded in the reality of remote sensing physics.

1000-1015: BREAK

Remote Sensing Tutorial-Part 1 ***(captured graphically by Karina)***

1015-1030:	History of Remote Sensing	T. Painter
1030-1045:	Visible & Near-Visible Physics & Basics	J. Dozier
1045-1100:	Visible & Near-Visible Systems & Products	D. Hall
1100-1115:	Hyper-spectral Basics & Systems	A. Nolin
1115-1130:	Passive Microwave Physics & Basics	E. Kim
1130-1145:	Passive Microwave Systems & Products	C. Derksen
1145-1200:	Active Microwave Physics & Basics	S. Yueh

LUNCH

Remote Sensing Tutorial-Part 2 ***(captured graphically by Karina)***

1315-1330:	FM-CW Radar	C. Leuschen
1330-1345:	CoReH2O Update	H. Rott
1345-1400:	LiDAR & Altimetry	J. Deems
1400-1415:	LiDAR from Space-IceSAT-II:	M. Jasinski
1415-1430:	Falling Snow	R. Bennartz
1430-1445:	Applications-Hydrology	D. Marks

1445-1515: BREAK

1515-1530:	Applications-Climate	D. Robinson
1530-1545:	Ground Data & Field Campaigns	K. Elder
1545-1600:	Data Assimilation & Modeling	M. Durand
1600-1615:	One Vision of the Way Forward	H.P. Marshall

1615-1630: **Transition to Group Activities/Instructions & Questions**
Sturm & Mullen

1630-1725: World Café #1

This group session builds on the ***Envisioned Future*** and the ***Tutorial*** to address what might be possible. We motivate this session with the following questions:

How do you balance high spatial resolution and high accuracy needs for snow depth or SWE against global coverage of the same or other snow parameters? How frequently do you need these data?
There are fundamental trade-offs in snow remote sensing, but for this exercise we want you to replace the "you" (as in remote sensing scientist) above with an end user. Think of some one from the Dept. of Transportation, perhaps a farmer, or perhaps a climate scientist, then try to answer those questions.
Trade off discussion: ***What snow remote sensing products does society need, where and when, and why?***

1745: Bus to ***Red Lion*** for dinner

THURSDAY, AUGUST 15 -- Drawing the Blueprint for the Future
BOULDER OUTLOOK

MORNING

0830-0900: Review of yesterday's ***Envisioned Future*** exercise (where are we headed), the ***Tutorial*** and the ***Café #1*** findings (what do we need to produce).

Any overnight epiphanies?
What still resonates?
What are the trade-offs on this visual map?
How do responses to the Café and Visioning exercise overlap/integrate/interact?

Goals for the day: 1) Define first in a broad way how we move from the current constellation of tools and community structure to the future world in which we provide the deliverables, then 2) begin to map the more specific steps (general experiments, campaigns, synthesis efforts) needed to actually get there. This should address community structure, funding structure, and technological challenges.

0900-1100: The Path Forward-Big Picture– **World Café #2 (Broad Blueprint)**
Pretend you are a program manager with not many constraints on the amount of funds you can disburse, very limited oversight from above, and not much push from scientists below. You have aircraft, scientists, equipment and vision. Design a 10 year program of initiatives that get us to the Future of SRS. Provide enough information we understand the choices you made. Think about the trade-off between directed from the top vs. bubbling up from the bottom type of science. What is the role of the community in this process?

1100-1115: BREAK
1115-1200: Plenary Discussion about World Café #2 (Broad Blueprint).
Activity: Prune the Future (p. 247) grouping current and future state ideas using a tree as a metaphor to see where the group wants to focus in the future.

LUNCH 1200-1300

AFTERNOON

1300-1315: Radiometric modeling: L. Tsang
1330-1530: **World Café # 3– Down and Dirty**
Big Blueprints are fine, but snow remote sensing is fundamentally technological and practical. What are the big gaps we have to close to execute the Big Blueprint?

- *What are the gaps?*
- *What are the types of work we have to do to fill them?*
- *What is most feasible now (low-hanging fruit?)*
- *What is emerging and is likely to be game-changers?*

1530-1600: BREAK
1600-1700: Plenary Discussion/**activity options:**

Small Groups: $100 Test to determine priorities, report back & discuss
20/20 Vision to prioritize based on benefits of different initiatives, general agreement necessary
NUF Test New, Useful, Feasible matrix – which initiatives are novel and feasible?

FRIDAY, AUGUST 16
CIRES AUDITORIUM

MORNING

0830-0900: Plenary Review of World Café #2 and #3
0900-1100: Small Groups: Graphic Gameplan to create timelines and next steps for projects
1100-11120: BREAK
1120-1245: Summary & Synthesis discussion

- What are the key ideas that have come out of this workshop for you?
- What are the most pressing needs for funding?
    - What are potential sources for funding these projects/needs?
    - Who can follow up on these?
- What is the message to NASA?
-

1245-1300: Critical next steps: assignments and volunteers
LUNCH

AFTERNOON

Writing Workshop by Press Gang and Invitation (CIRES)

APPENDIX 2: ATTENDEES

Arslan, Ali Nadir	Finnish Meteorological Institute
Bennartz, Ralf	Vanderbilt University
Brodzik, Mary Jo	NSIDC
Brucker, Ludovic	NASA GSFC
Cherry, Jessica	IARC/INE/UAF
Crawford, Christopher	NASA Goddard Space Flight Center
Deeb, Elias	US Army Cold Regions Research and Engineering Laboratory
Deems, Jeffrey	NSIDC/University of Colorado
Derksen, Chris	Environment Canada
Dozer, Jeff	University of California
Durand, Michael	Ohio state university
Durham, Timothy	Harris Corporation, GCSD
Elder, Kelly	US Forest Service
Entin, Jared	NASA
Gardner, Alex	Clark University
Gatebe, Charles	NASA GSFC & USRA
Leuchen, Carl	CReSIS, The Univesity of Kansas
Hall, Dorothy	Cryospheric Sciences Laboratory
Hiemstra, Christopher	CRREL Alaska
Hinkelman, Laura	University of Washington
Jafarov, Elchin	University of Boulder Colorado
Khan, Alia	INSTAAR, CU-Boulder
Kim, Ed	NASA
King, Joshua	University of Waterloo
Langlois, Alexandre	Sherbrooke University

Lee, Yong-Keun	CIMSS/SSEC UW-Madison
Lundquist, Jessica	University of Washington
Marks, Danny	USDA-ARS
Marshall, HP	Boise State University
McPhee, James	Universidad de Chile
Molotch, Noah	University of Colorado / JPL Cal Tech
Neumann, Tom	NASA Goddard Space Flight Center
Nolin, Anne	Oregon State University
Painter, Thomas	Jet Propulsion Laboratory/California Institute of Technology
Pulliainen, Jouni	Finnish Meteorological Institute
Qazi, Nuzhat	Forest Research Institute
Racette, Paul	NASA Goddard Space Flight Center
Robinson, Dave	Rutgers University
Rott, Helmut	ENVEO IT
Schneebeli, Martin	WSL Institute for Snow and Avalanche Research SLF
Serreze, Mark	National Snow & Ice Data Center
Singh, Ramesh	Chapman University
Slater, Andrew	NSIDC, University of Colorado
Sturm, Matthew	University of Alaska
Tedesco, Marco	CUNY/NSF
Tsang, Leung	University of Washington
Weaver, Ron	CU Boulder, CIRES, National Snow and Ice Data Center
Yueh, Simon	Jet Propulsion Laboratory