NASA Community Snow Meeting
Day 1 Breakout Session I Final Merged Summary

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Note Taker: Mimi Abel

This is a designated space for compiled notes from the summary slide presentations. *Only the listed note taker will update this document.* The purpose of this document is to compile unique takeaways presented across all breakout session groups.

Questions:

1. What do you feel are the biggest innovations and applications of this technique in the past decade?
    a. What has enabled this to occur?
    b.
2. What are the biggest remaining challenges and development opportunities for this approach?
3. How do you think this approach fits into a global snow observing system or strategy?
    a. How well does this approach perform in measuring snow depth, SWE, snowmelt, albedo?
    b. How well does this approach work under different snow/environmental conditions
        i. In forests versus open areas?
        ii. In shallow snow?
        iii. In complex terrain?
        iv. Dry versus wet
        v. Under clouds
    c. Has the uncertainty been defined? If so, at what scale (basin, mountain range, hemispherical, global)?
        i. How big is the impact?
4. Does this technique support a path to space?
    a. If so, how mature is it?
    b. If not, does it complement spaceborne observations and how?
5. What does this technique rely on or need to pair with to work? What other techniques are highly complementary to this approach? (synergies)

Microwave Scattering

- Struggled a bit to summarize it all – feels like a diffuse breakthrough. See the slides for some of these ‘diffuse breakthrough’ – each bullet is a paper. Multiple different algorithms each of which have paper/validation/etc.

- Field campaigns/hackweeks/etc led to this
- Continuing to have datasets that fully represent the different kinds of snow. Finding new ways to make progress on things that previously were intractable.
- Able to estimate snow depth and SWE well in many contexts – don't measure snowmelt directly; cutoff with trees is higher than we thought; some issues in complex terrain; issues with wet snow
- Path is there
- Multiple algorithms each of which has pros/cons

Signals of Opportunity

- Based on the collection of people at the table – skewed toward P-band; GNSS or L-band also possible but not really represented in this discussion
- Relatively new – has benefits and drawbacks. Hasn't been entrained in the SnowEx context – has a long way to go
- SNOOPI – tech demo – remains to be seen how much it improves
- Need a SnowEx-level campaign. Towers, drones, larger airborne platforms - really needs to be proven
- Pole-to-pole – doesn't work. But does provide a pathway for 'global' mountains and deeper snow
- Using C-, L-, and P-band together has a lot of complementarity advantages
- What is the pathway to these kinds of missions? Is airborne sufficient? Time-series? snapshots?

UAV applications

- Increased payload/range have been major recent innovations
- Wide range of sensing techniques that can be used on these platforms
- Opportunities for sensor integration and connection to ground-based; spanning spatial/temporal scales
- Limitations – often legal - varied and restrictive airspace; Logistics; rapid growth of UAV has meant equipment becomes obsolete very quickly
- No path to space for this tech but it's essential for validation – key stepping stone for demonstrating space-borne technologies
- Need more standards that facilitate and encourage integration/use of UAV obs

Modeling

- Broke up into three groups (machine learning, data assimilation, and physically motivated models) – each question has three responses reflecting this (on the slides)

- Rapid growth of ML in past decade – figuring out how to integrate/when to trust is a challenge
- Modeling is the 'glue' that can integrate advances from other areas/more obs
- Too much uncertainty in obs is a big problem for models – makes things unusable
- Models – especially ML models – are very flexible and can use loads – challenge is in interpretation
- R2O challenges – when satellites are decommissioned it can cause big problems

Observations

- Worked hard to bring together the 'three-legged stool' (more people in the field)
- Adding drones has helped integrate
- Geolocation has also helped immensely
- Scale mismatches are a problem here as well – local->regional->global
- Essential for ground validation; variable uncertainty depending on surface heterogeneity (e.g. forests/complex terrain/shallow snow)
- More drone work would be helpful

Albedo

- Have obs ability pretty well-worked-out; biggest innovation has been working toward consensus in the community
- Has been designated under SBG – boon
- Lack of consensus around obs datasets – particularly ground-based – no consensus obs dataset. No snow albedo products – not being generated into the future.
- Good obs in open areas, less well-observed in forest/shallow snow/shadow+roughness over scales

InSAR

- C- and L-band was main focus
- Major innovations as part of SnowEx – works well with high frequency repeat – really good coverage even in places where they didn't expect
- Various uncertainties associated with the technique are the biggest remaining challenges
- Will not work during the melt season. Not for wet snow.
- Robust pathway to space – NISAR++
- Need atmospheric models to coordinate the phase space

Spaceborne lidar/stereo

- Operational potential for lidar was discussed the most
- Relatively new concept – can get pretty good resolution and accuracy from ICESat2 –

- Have several upcoming missions
- Cost – missions are pretty expensive; also coverage can have big gaps; also issues wit cloud cover and steep topography
- Accurate snow-off DEM are needed
- Snow-depth is a key observable – there have been some concepts to use backscatter to get other snow properties (e.g., density)
- ICESat2 revisits the same location every ~3 months – this is an issue, along with data latency issues; these challenge using these data on the operational side

Questions

- There's a lot of common threads between each of these groups – having a forum to work together incorporating different perspectives – important that we find the commonalities across these 8 groups. Let's implement 'bridging the gaps'
- Two-way communication between ground obs, airborne, etc – critical and room for improvement in this area
- Suggestion: It's the modeling group that's going to find the synergies between the different groups, etc
- Desire to make tools (developed from SnowEx) available to the community – would be great for us to think of ways to collect those tools.
- Efforts toward partnerships with industry?
    - Different types of industry (may not cover all of them); future missions happen at the center-level (not really with the program managers); this is a growing area that might be worth exploring; community should reach out and build some of these partnerships and then could work with program managers to coordinate; 'feel it out as we go'
    - Quickly developing area; working on ways to increase the opportunities for 'onramps'; can work to making sure there is representation of the different areas of the community on the eval panels
- Documents are living documents – continue to edit those as there's time for it