Questions & Answers Part 1

Please type your questions in the Question Box. We will try our best to get to all your questions. If we don't, feel free to email Amita Mehta (amita.v.mehta@nasa.gov) or Sean McCartney (sean.mccartney@nasa.gov).

Question 1: What is the basin here? (Slide 5)
Answer 1: The three basins are in Western Washington state, USA. The low elevation basin is Day Creek, the mountain basin is the South Fork of the Nooksack River, and the glacierized basin is Thunder Creek. The reference is: https://doi.org/10.1002/j.1551-8833.1969.tb03696.x.

Question 2: Can you please provide the source from where this percentage number is coming about contribution of snow and ice? (Slide 7)
Answer 2: Please see: https://www.usgs.gov/special-topics/water-science-school/science/where-earths-water.

Question 3: For lidar, how do we measure snow depth over a glacier? Is there any penetration of lidar in snow or ice?
Answer 3: In general, lidar will measure the surface of the snow, but radar frequencies can give the surface of the ice (penetrating the snow). The combination of these two datasets can return snow depth. I should add that having a digital elevation model (DEM) of the region can give you the snow depth from the lidar data in the absence of ice.

Question 4: What is the unit of snow water equivalent (SWE) measurement, m equivalent of water or kg/square meter?
Answer 4: In water resources and hydrology, SWE is usually given meters. However, for output from reanalysis products, snow may be given in kg/m^2. 1 m of SWE is equivalent to 1,000 kg/m^2.

Question 5: What is the maximum depth of snow that can be measured using passive microwave remote sensing? Please highlight the saturation problem of passive microwave remote sensing.
Answer 5: This depends on the frequency of the signal and moisture content of the snow pack, and, to a lesser extent, other characteristics of the snow pack, such as grain size. Water in the snow pack increases absorption of electromagnetic radiation in microwave frequencies. For dry snow, there are both minimum and maximum limits for passive microwave snow retrievals. The lower limit is 3 cm. These shallow snow packs have very little impact on emission at frequencies used for snow retrieval. The upper limit, where the signal becomes saturated, is between 1 m and 1.25 m.
See: https://www.sciencedirect.com/science/article/pii/S0034425723000275#s0075.

Question 6: Are there any planned updates or upcoming missions that aim to overcome current limitations in snow retrievals using visible/infrared sensors, particularly regarding cloud cover and forest canopy challenges?
Answer 6: There have been a number of field campaigns (CLPX, SnowEx) to study and evaluate snow retrievals. Clouds and forest canopy have, generally, been addressed algorithmically. There is a potential Canadian mission. I'm not sure of the status, but it is a dual-frequency SAR sensor. More info can be found here:
https://www.ouranos.ca/en/news/2025-01-17/satellite-mission-%20snow-cover

Question 7: Do you have any research on measuring greenhouse gas emission such as methane gas leakage due to melting down of snow in the permafrost?
Answer 7: NASA Arctic-Boreal Vulnerability Experiment has data at certain locations in Alaska.

Question 8: Could you recommend some of the decent NDSI applied research or unique research on them?
Answer 8: Rosenthal, W. and J. Dozier, 1996: Automated mapping of montane snow cover at subpixel resolution from the Landsat Thematic Mapper, Water Resources Research, 32, pp 115-130.
Also the ATBD for the MOD10A1 product, which can be found from the dataset landing page for the product https://nsidc.org/data/mod10a1/versions/61.

Question 9: What is the coverage of ASO data? Globally?

Answer 9: The ASO data archived at NSIDC are all in North America. A list of basins can be found at: https://nsidc.org/data/documentation/aso-basins-and-geographical-extents.

Question 10: How is the validation results of snow depth in Ryan's presentation? What are the typical error margins or uncertainty ranges in SWE/Snow albedo?
Answer 10: GLDAS is a combination of models estimating depth over a large area. Spatial resolution is very coarse, so we are not able to report on uncertainty at this point.

Question 11: Is there any way to downscale the resolution of MODIS snow cover data?
Answer 11: There are papers out there with various methods. For example: Downscaling MODIS NDSI to Sentinel-2 fractional snow cover by random forest regression.

Here is another example:
Rittger, K., Krock, M., Kleiber, W., Bair, E. H., Brodzik, M. J., Stephenson, T. R., Rajagopalan, B., Bormann, K. J., & Painter, T. H. (2021). Multi-sensor fusion using random forests for daily fractional snow cover at 30 m. Remote Sensing of Environment, 264, 112608. https://doi.org/https://doi.org/10.1016/j.rse.2021.112608

Look within the literature for Random Forest Regression and downscaling to Sentinel-2 (20 m) resolution or Landsat (30 m). Algorithms are available to combine those datasets.

Question 12: Could you please recommend the methods or modeling tools to analyze snow cover pattern change over a long period of time?
Answer 12: This will be addressed more in the next sessions.

Question 13: What is the latency of data observed either by MODIS or VIIRS and when it is available on public websites for use by practitioners like flood forecaster?

Answer 13: MOD10A1f and VNP10A1f science processing has a 3 day lag. MOD10A1f and VNP10A1f near real time products have a 3 hour lag from NASA's LANCE system). SPIReS has a < 24 hour lag at NSIDC's Snow Today.

Question 14: Which of the products are most suitable for analysing the snow cover and estimating SWE for Southeast Asia?
Answer 14: The global products from MODIS and VIIRS are the most suitable snow cover extent products for Southeast Asia. LandSat is another option. Passive microwave products could be used to estimate SWE but this comes with caveats noted in the webinar. Combined products such as GlobSnow are also available.

Question 15: Are there any near-real time snow products from NASA?
Answer 15: Yes, I know the NASA LANCE system processes MOD10A1f. Snow Today at NSIDC processes SPIReS currently.

Question 16: How have Alaska's glaciers changed in mass and surface movement over the past two decades, based on NASA's GRACE, ICESat-2, and Landsat datasets?
Answer 16: The most recent assessment is from the GlaMBIE project: https://www.nature.com/articles/s41586-024-08545-z.

Question 17: How can one design snow monitoring networks? What methods can be used for snow monitoring network densities?
Answer 17: For water resources, you are generally trying to site monitoring stations in representative locations. This requires field studies. Modelling can also be used. Approaches to estimating density usually involve measuring mass of snow and snow depth. The US SNOTEL network is an example. SNOTEL stations measure mass using snow pillows, which are flexible bladders containing a fluid with a low freezing point. The mass of snow is estimated by measuring changes in pressure in the fluid. Snow depth is measured using sonic rangers.

Question 18: Can isostatic rebound be detected to observe the density of ice fields?
Answer 18: Glacial isostatic adjustment is an important contribution to changes in mass measured by gravimetry missions like GRACE and GRACE-FO, and is required to

retrieve changes in ice mass. Isostatic adjustment depends on the underlying geology and glacier history. Generally, it is estimated using modelling. It is also a major source of uncertainty and calculations of ice mass change.

Question 19: What about the Normalized Difference Snow Index (NDSI) in rock glaciers?
Answer 19: NDSI is used to detect snow using visible wavelengths. It cannot be used to determine what is under the snow. It only takes a few centimeters of snow to obscure the underlying surface. Because rock glaciers are mostly rock, the interstitial ice is below the surface, they cannot be detected using NDSI.

Question 20: How is the snow grain size calculated?
Answer 20: In the field, grain size is estimated using a hand lens and putting snow grains on a graduated snow grain size card. Grain size can also be measured using scanning electron microscopy and by X-ray tomography, which creates a 3D image of snow microstructure. Using remote sensing, grain size retrievals are done by spectral unmixing. The reflectivity of snow is dependent on grain size with more solar radiation absorbed by larger grains especially in the near-infrared wavelengths. The normalized difference grain size index can be used or for perhaps more accurate grain sizes, a spectral unmixing model finds the snow spectra with best fit to the spectral reflectance curves measured by the satellite sensor from a library of spectra for snow with different grain sizes.

Question 21: How can we download the data as opposed to viewing it in the ARSET viewer?
Answer 21: Part 2 of this series will show different methods of retrieving data. If you want to explore ahead of time, go to nsidc.org and click on Explore Data and enter a search term like "SWE" to find related data sets and links to download tools.

Question 22: Will you cover the estimation of snow depth using RADAR during this meeting?
Answer 22: Walt Meier talked a little bit about some of the ground penetrating radar measurements collected during the SnowEx campaign. From a remote sensing perspective, we have focused on visible and passive microwave sensors.