FY24 Strategic Initiatives Research and Technology Development (SRTD)

Earth System Explorer - Snow Depth and Snow Water Equivalent (3 of 5)

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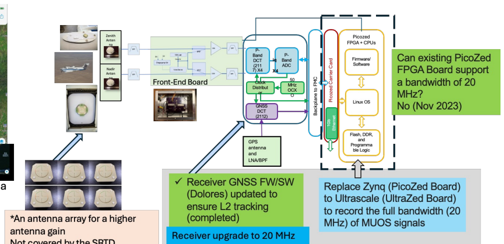
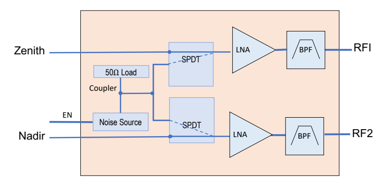
Strategic Focus Area: Earth System Explorer – Science Definition and Technology Maturation | **Strategic Initiative Leader:** Sabrina M Feldman

Objectives: Our overarching objective is to develop a scientifically compelling terrestrial snow mission concept that JPL can propose to NASA Earth System Explorer (ESE) calls over the next decade.

Background: Snow is both the fastest changing component of the water cycle and the least known and monitored. Terrestrial snow plays an important role in weather and climate forecasts through its influence on the heat exchange between land and atmosphere. Models that predict how snow evolves seasonally and into a warmer future are largely unconstrained by measurements or have poor parameterization of snow processes, leading to large uncertainties. The hydrology of snow-dominated watersheds is also changing as the climate warms. Spring snow accumulation has substantially declined over the last half-century in the Western U.S., and similar patterns are apparent globally. The most important snow water towers in the Alps, Andes, High-Mountain Asia, and Western North America are also the most vulnerable to these climate change drivers and other socioeconomic pressures. Yet despite snow's importance to basic human and ecosystem needs, we are not currently able to measure how much fresh water is stored in global mountains. In-situ snow observations are challenging and often impractical, so spaceborne investigations are essential for frequent and global monitoring of terrestrial snowpack. The 2017 Earth Decadal Survey (DS) established the Explorer mission line, which calls for PI-led concepts in seven investigation categories. This task focuses on concept and technology maturation for Snow Depth and Snow Water Equivalent (SD/SWE).

Approach and Results:

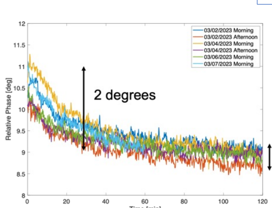




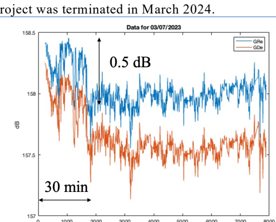
The design of SoOpSAR internal calibration design in the Radio Frequency Front-End box uses a common source for injection into both receivers to compute cross-correlation for phase and gain calibration.

JPL P-band Signals of Opportunity Synthetic Aperture Radar (SoOpSAR) on the NASA AFRC Super King Air with flights in February and March 2023 over Grand Mesa, Colorado and Sagehen Creek, California to collect data to mature the P-band SoOpSAR technology for remote sensing of snow. Nominally 11 racetracks with an average spacing of about 10 meters between tracks.

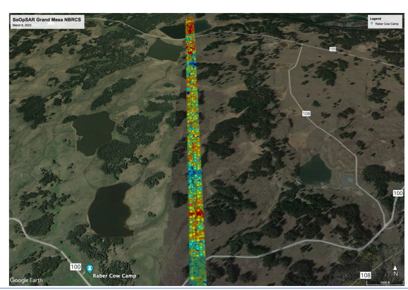
- SoOpSAR block design ported from Zynq (PicoZed Board) to Ultrascale (UltraZed Board) and tested in simulation environment.
- Capability added to ensuring alignment of incoming data and achieving parallel data widths up to 14 bits needed for the ADC. The design's constraints file was remapping from the Zynq pin layout to the Ultrascale layout.
- Receiver GNSS FW/SW updated to ensure L2 tracking, which means we don't need external GNSS receiver anymore.
- However, FPGA board changed from PicoZed Board to UltraZed Board and the FPGA UltraZed board testing could not be completed because the funding for this R&TD project was terminated in March 2024.



The relative phase of two receivers was extremely consistent (~0.5 deg) over different days during airborne campaign. The initial ramp-down trend is from system warming up – still better than the less than 4-deg requirement.



The Direct and Reflected Receiver gains had about 0.5 dB drift during initial warm up for the data acquired on 7 March 2023. The gains became stable to within about 0.2 dB after 30 min (meeting requirement).



Calibrated SoOpSAR image of the normalized bistatic radar cross-section (NBRCS) of reflection on March 7, 2023 (pseudo color) at a spatial resolution of 10 m have been produced. The data showed strong reflections (color coded in red) over the Anderson reservoir as expected. The edge of high reflection essentially lines up with the border of the reservoir, revealed by the underlying Google map. The spatial pattern of the reflected signal essentially corresponds to the land cover and soil conditions under the snowpack.

Significance/Benefits to JPL and NASA:

- Our airborne P-band SoOp campaign data have confirmed the P-band SoOpSAR instrument receiver design by showing that the necessary phase and radiometric calibration stability of SoOp receivers can be obtained with a well-defined internal calibration scheme.
- We have also shown that the multistatic SAR processing can be performed to achieve high spatial resolution by using data from multiple airborne or satellite tracks.
- The results were incorporated into the SnoWatch mission proposal submitted by the University of California at Los Angeles (UCLA) and JPL to the first NASA ESE program announcement of opportunity.

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Publications:

Simon Yueh, Rashmi Shah, Mario J. Chaubell, Javier Bosch-Lluis, and Justin Nguyen, "Radiometric Calibration of P-band Signals of Opportunity Synthetic Aperture Radar for Remote Sensing of Land Surface," 17th Specialist Meeting on Microwave Radiometry & Remote Sensing of the Environment, Alexandria, VA, 2024

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