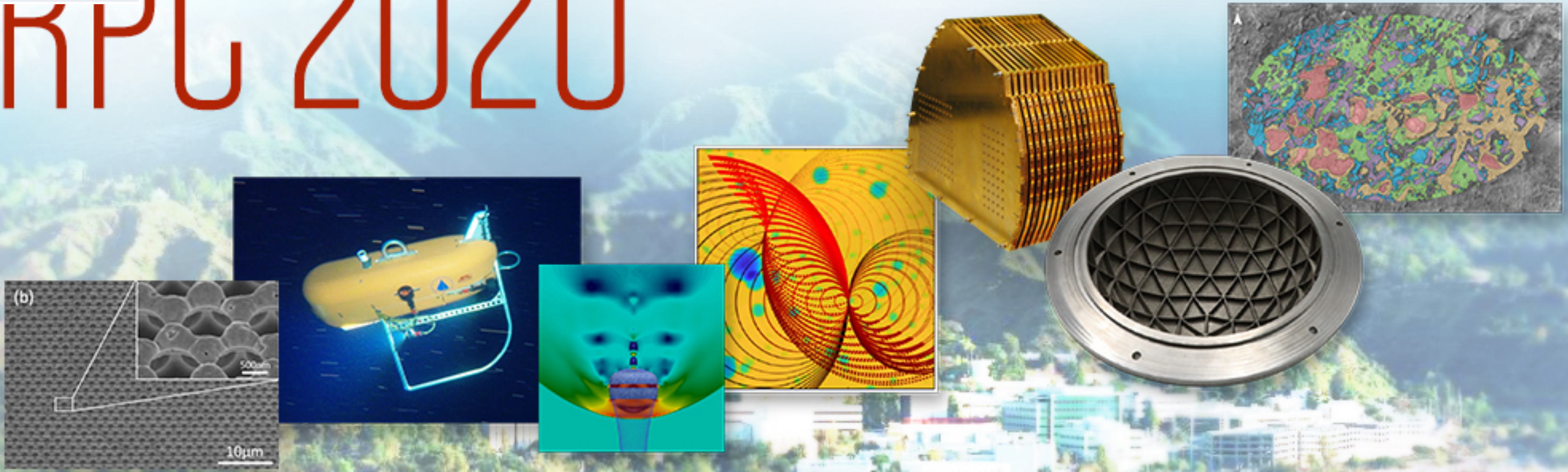
RPC-059

# RPC 2020




# Virtual Research Presentation Conference

## Ice sheet wide comparison of coincident laser and radar observations from ICESat-2 and CryoSat-2 for Greenland and Antarctica

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**Program: Innovative Spontaneous Concepts**

Assigned Presentation #RPC-059

Jet Propulsion Laboratory
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# Tutorial Introduction


**Abstract**

Radar altimetry has since the early 1990s provided the scientific community with key observations about the changes of the Earth's ice sheets and glaciers. This long-term record is of vital importance for understanding current and future trends in ice loss, and the processes governing the ice sheets contribution to global sea-level rise. Though modern radar altimetry allows for detailed mapping of the changes in mass of the ice sheets, this measurement is still affected by changes at the snow-air interface, manifested by penetration of the radar signal into the firn column. These changes can introduce large biases in the retrieved elevation change signal, which to date is one of the major error sources. This error source is difficult to quantify due to lack of an adequate model for correcting changes in the scattering regime and lack of a large-scale validation datasets. With the launch of ICESat-2 in September, 2018, we have the opportunity for the first time to compare unbiased laser measurements with overlapping radar data from CryoSat-2. This will allow us to investigate spatial and temporal changes in the penetration bias and how they are affected by changes in snow properties.

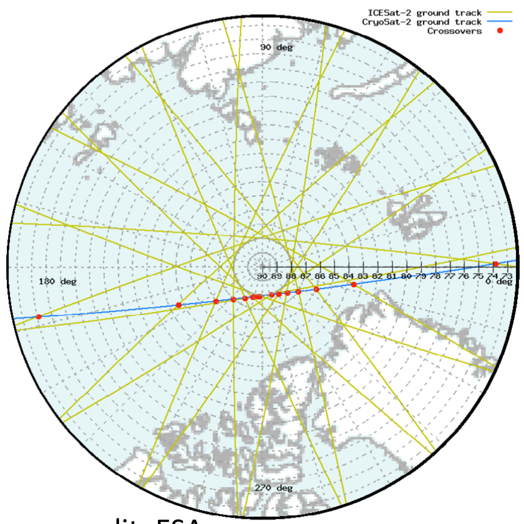



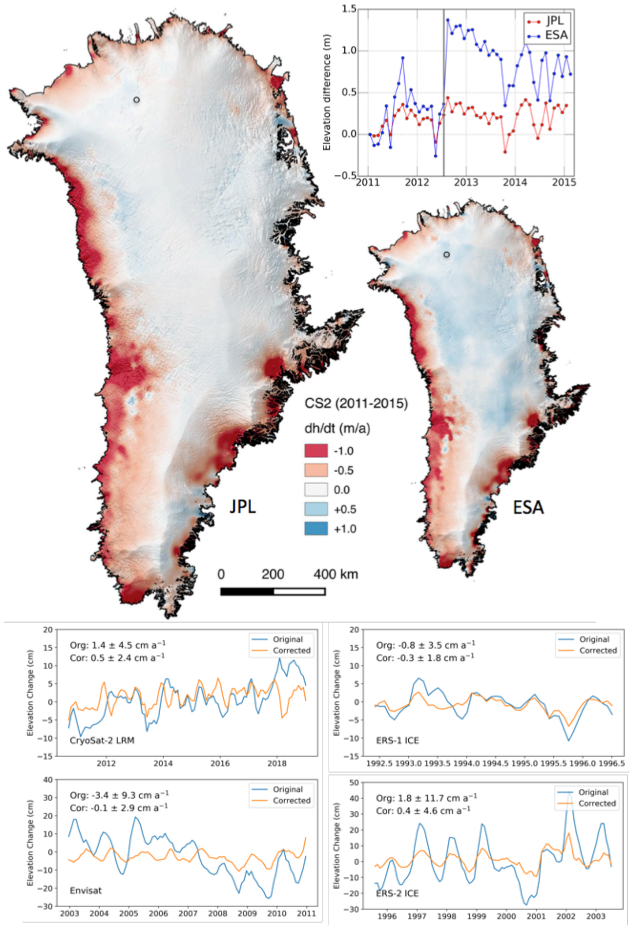

Image credit: ESA

# Problem Description

a) **Context:** Radar altimetry has the longest record of measurements to observe the mass balance of the worlds ice sheets. However, the measurement it affected by the changes in the surface scattering regime creating a spatial and time variable penetration bias. This bias creates both artificial trends and seasonality in the long-term record. Quantifying and removing these effects are essential for the accurate reconstruction of mass balance trends to improve long-term sea-level rise predictions. With the launch of ICESat-2, a laser altimeter, we have for the first time both high fidelity and dense spatial sampling of overlapping radar-laser measurements to investigate the radar penetration bias.

b) **SOA:** Previously, this type of investigation was only possible using Envisat and ICESat (-1). However, this was severally limited as ICESat only delivered data a 1-2 months per year. Hence, this is for the very first time we are able to undertake this type of investigation. It will provide the seed to allow us to obtain invaluable information of how the penetration bias affects long-term trends, as the record grows in length. This developing this type of pipeline is especially important since the synchronization of the Cryosat-2 and ICESat-2 orbits which will increase the satellite overlaps around 100-230%.

c) **Relevance to NASA and JPL:** This work will have a direct impact for several of NASA future radar missions, such as NISAR and SWOT, for both land and sea ice applications. It also directly relevant to the study of ice sheet and glacier long-term mass balance: such as the ITS_LIVE and ISSM projects.



# Methodology

- **Formulation:** We use elevation from both the CryoSat-2 (LRM-mode) and ICESat-2 to generate elevation difference to produce ice sheet wide penetration bias estimates. For CryoSat-2 generate elevations from several different retracking threshold form the radar waveform as these are directly proportional to penetration depth. Further, to quantify or to judge the sensitivity of these different threshold to change in surface properties we extract parameters describing the shape of the waveform (Bs, LeW and TeS). These parameters are directly linked to changes in surface conditions and can be used as a proxy to describe surface properties.
  - Ingestion and preparation of altimetry data and the application of various geophysical corrections.
  - Retracking of the radar data to obtain surface elevations and waveform parameters using our own in-house LRM processing pipeline, by selecting elevation between 10-50% of the maximum amplitude.
  - Correcting for the slope-induced error in the radar altimetry which can reach 100 m for large slopes (1 deg).
  - Generating laser-radar bias by computing elevation difference at each orbital intersection for the two missions for all thresholds.
  - Gridding and filtering of the difference to weekly temporal resolution with a 5 km posting.
  - Generate time series of penetration bias and waveform parameters for both ice sheets.
- **Innovation:** Previously in radar altimetry the volume component has been minimized by removing the correlation between the change in the elevation to change in shape of the waveform. However, approach has limitation as reference surface is lacking. Here, we have for the first time the ability to separate volume from surface scattering using the same approach.

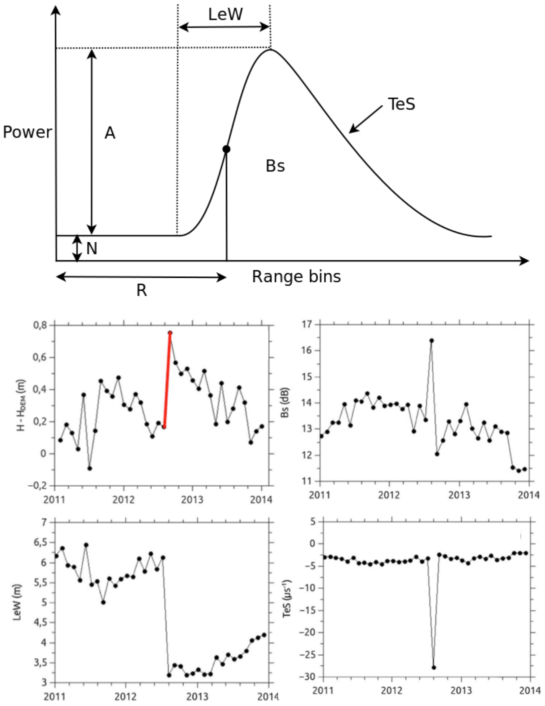
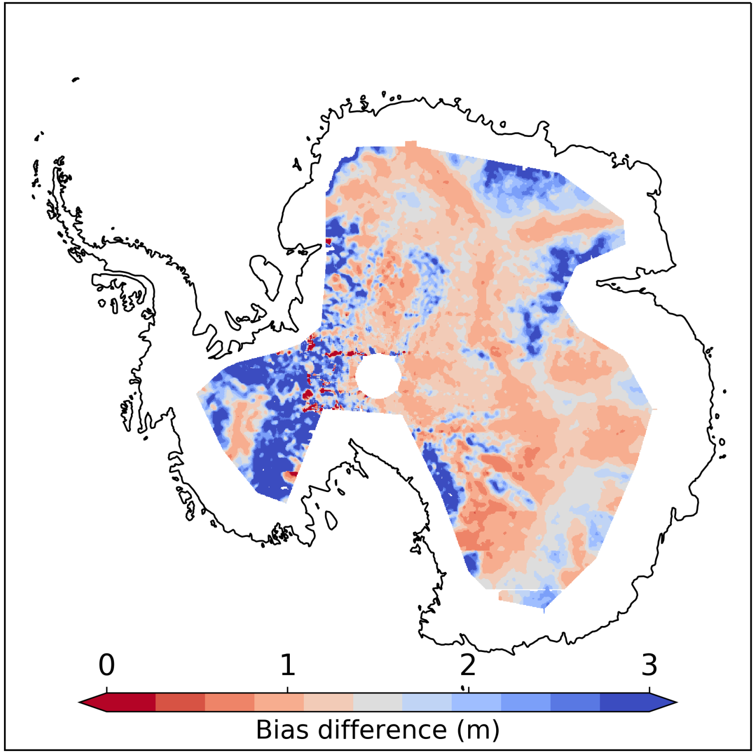
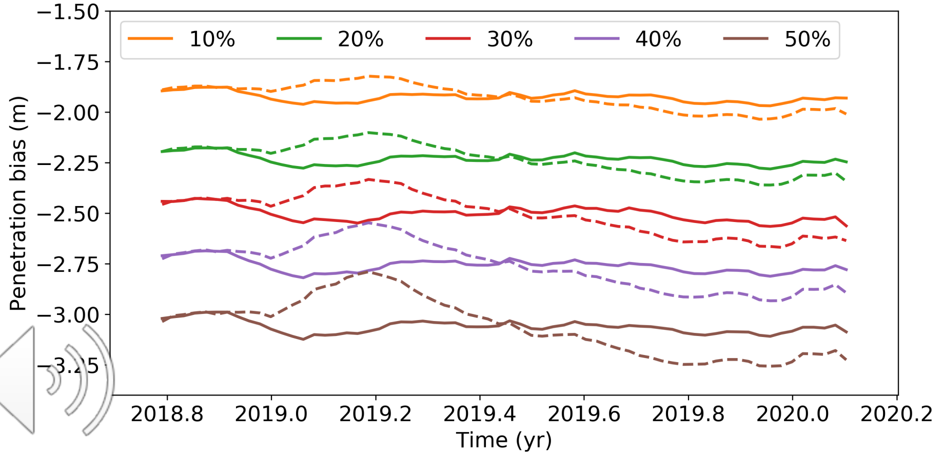
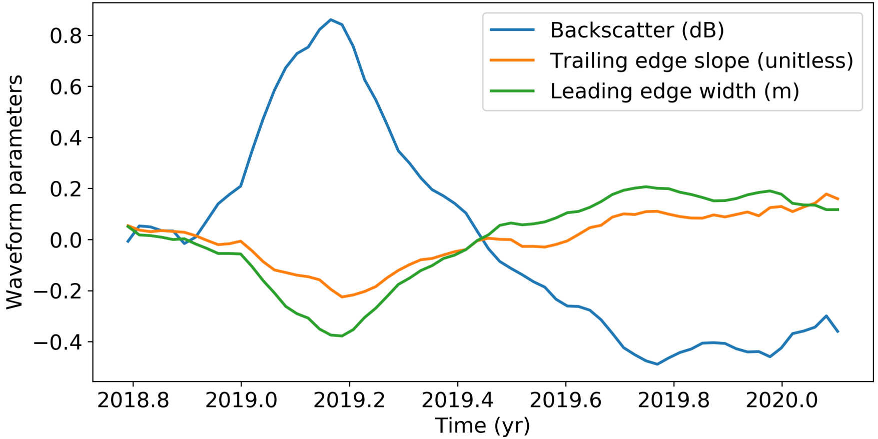



Image credit: Nilsson et al. (2015)

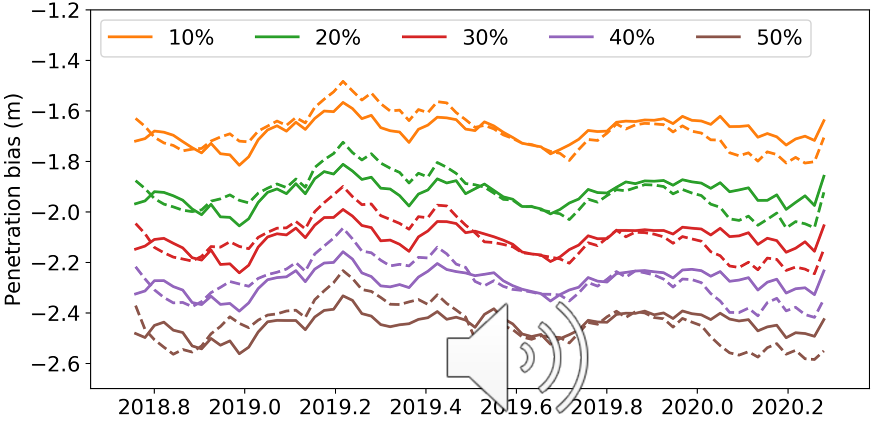
# Results


0
1
2
3
Bias difference (m)

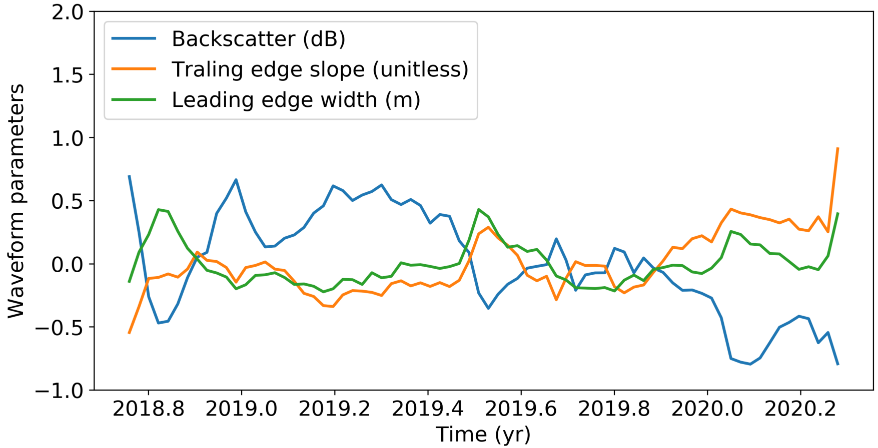

10%
20%
30%
40%
50%
−1.50
−1.75
−2.00
−2.25
−2.50
−2.75
−3.00
Penetration bias (m)
2018.8
2019.0
2019.2
2019.4
2019.6
2019.8
2020.0
2020.2
Time (yr)


Backscatter (dB)
Trailing edge slope (unitless)
Leading edge width (m)
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
Waveform parameters
2018.8
2019.0
2019.2
2019.4
2019.6
2019.8
2020.0
Time (yr)

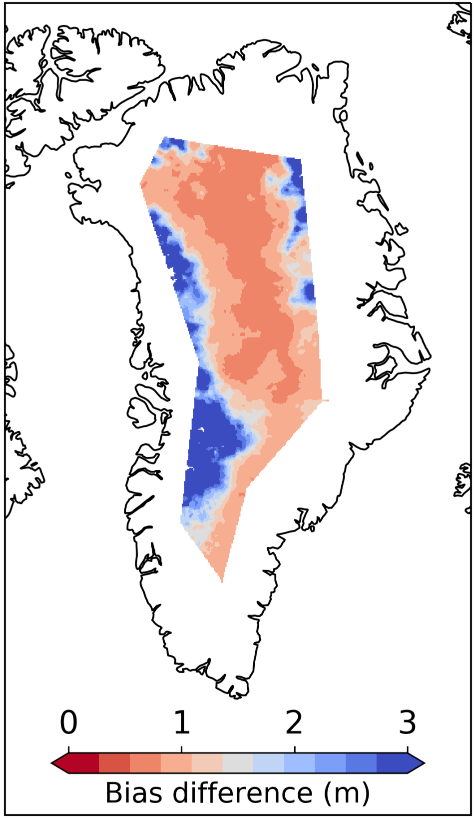
# Results



10%
20%
30%
40%
50%
Penetration bias (m)
−1.2
−1.4
−1.6
−1.8
−2.0
−2.2
−2.4
−2.6
2018.8
2019.0
2019.2
2019.4
2019.6
2019.8
2020.0
2020.2

Backscatter (dB)
Traling edge slope (unitless)
Leading edge width (m)
Waveform parameters
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
2018.8
2019.0
2019.2
2019.4
2019.6
2019.8
2020.0
2020.2
Time (yr)

0
1
2
3
Bias difference (m)

# Results

- **Accomplishments versus goals**: The goal of this project was to create a laser-radar penetration dataset and pipeline to easily produce data that can be used for current and future analysis as more data becomes available. This goal was fully accomplished and we further able to perform initial analysis using the waveform parameters as proxies for real surface conditions.
- **Significance**: This seed will allows us to perform long-term analysis of how the seasonally changing radar horizon responds to and effects mass balance trends from radar altimetry. It will allow us to track the seasonal evolution of snow-depth of the polar ice sheets, and it will allow us to improve our understanding of the interaction between snow/firn/ice on altimetry signals. Further, it will allow us to improve our understanding of ice sheet climatology such as long-term snow accumulation, which can help improve firn-models necessary for converting ice sheet volume to mass. In the end this knowledge can be leveraged to improve our corrections of the historical radar altimetry record and in the end sea-level rise projections.
- **Next steps**: The next steps is to summarize this methodology in a peer-review publication if possible given funding. Further, we hope to extend this record as new data becomes available from the two missions. Given a long-enough record we hope to start to analyzing the seasonal and long-term variations of the penetration bias using external data (temperature, precipitation wind etc.) to hopefully create an empirical model for correction of the long-term record. We plan/hope to continue this work either via internal or external funding.

# Publications and References

Nilsson J, Vallelonga P, Simonsen SB, Sørensen LS, Forsberg R, Dahl-Jensen D, Hirabayashi M, Goto-Azuma K, Hvidberg CS, Kjær HA, Satow K. Greenland 2012 melt event effects on CryoSat-2 radar altimetry. Geophysical Research Letters. 2015 May 28;42(10):3919-26.