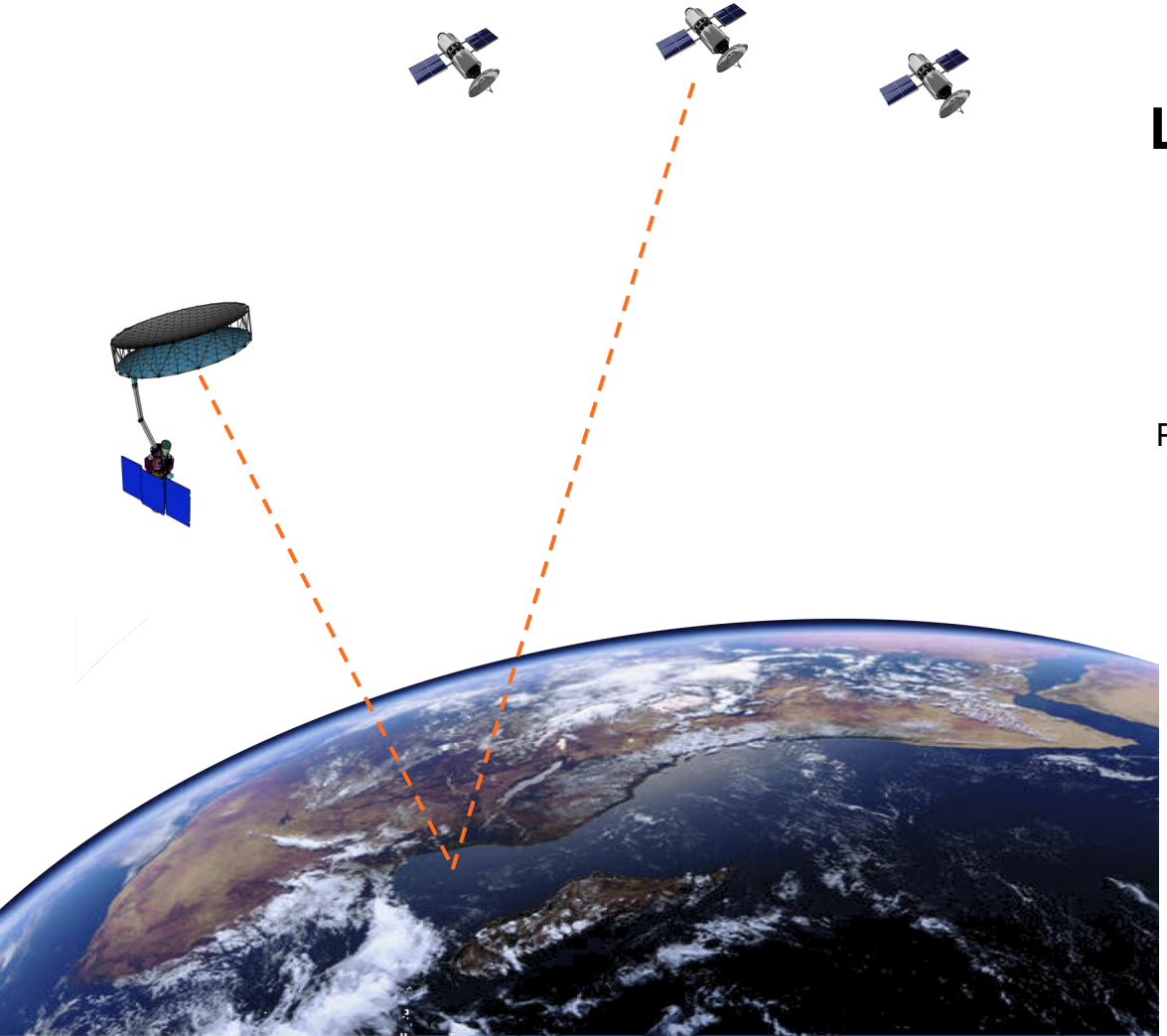


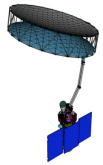
Characterization of the Land Surface Freeze/Thaw State with SMAP-Reflectometry (SMAP-R)

Nereida Rodriguez-Alvarez
Planetary Radar and Radio Sciences Group (332K)
Communications, Tracking and Radar Division

Erika Podest
Carbon Cycle and Ecosystems (329G)
Earth Science Division

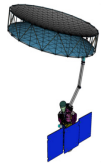
Jet Propulsion Laboratory
California Institute of Technology

IGARSS 2019
FR4.R2: Freeze-Thaw Status and Lake Ice
August 2, 2019

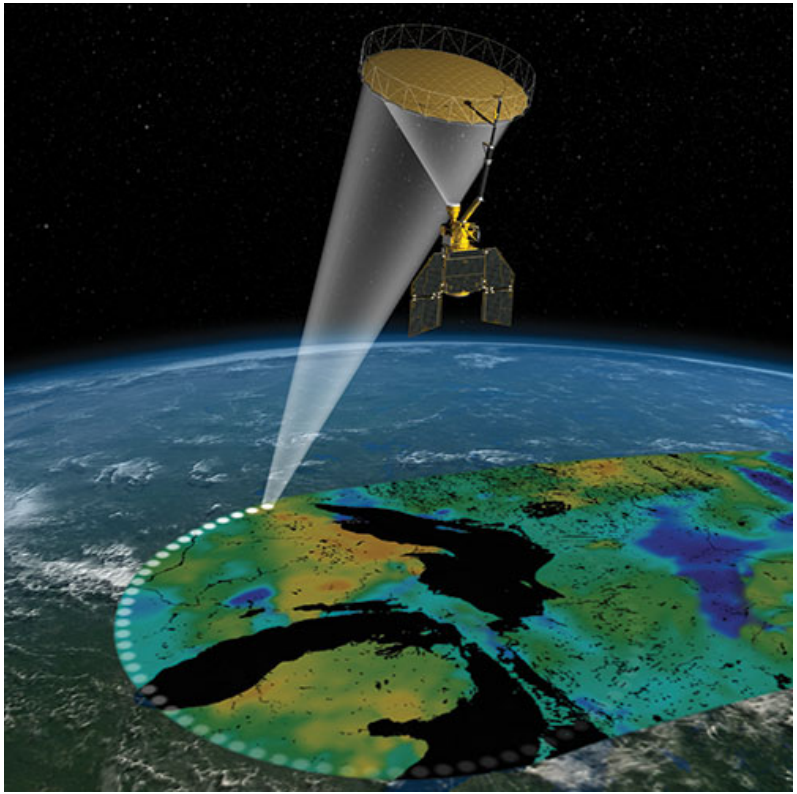


Index

- SMAP mission
- SMAP-Reflectometry
- Calibration
- Freeze/Thaw Studies
- Conclusions
- Future work



SMAP mission



SMAP observations of soil moisture and freeze/thaw state from space allow significantly improved estimates of water, energy, and carbon transfers between the land and atmosphere.

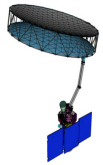
Conical scan, fixed incidence angle at 40°

Contiguous 1000 km swath

Sun-synchronous 6am/6pm orbit (680 km)

Global, ~3 day (or better) revisit

Boreal, ~2 day (or better) revisit



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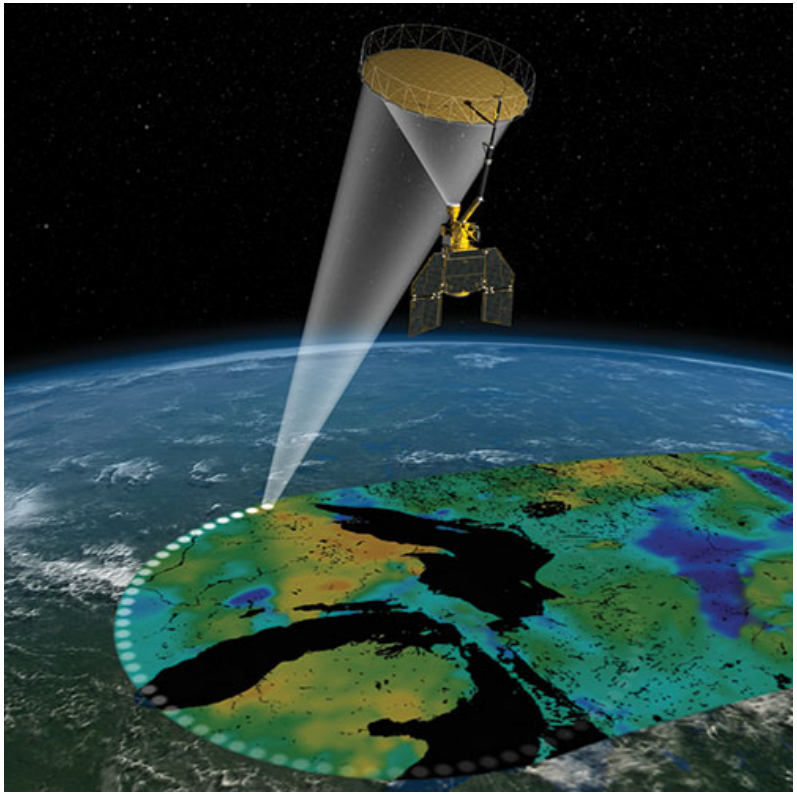


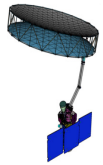
Scientific Measurement Requirements

Soil Moisture:
~±0.04 cm3cm–3 volumetric accuracy in the top 5 cm
for vegetation water content ≤ 5 kg m–2
Hydrometeorology at ~10 km resolution
Hydroclimatology at ~40 km resolution

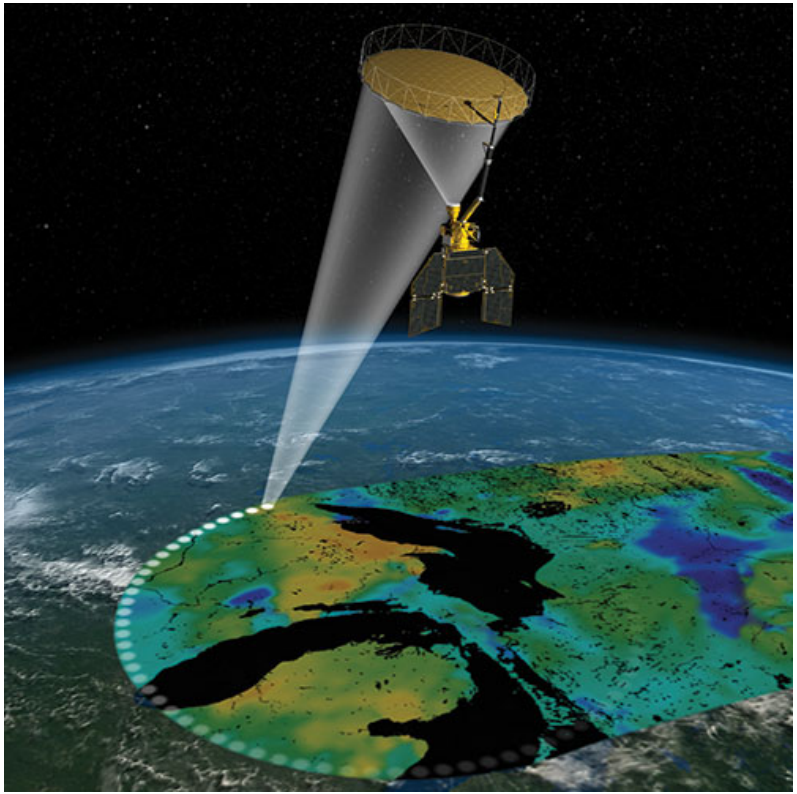
Instrument Functional Requirements

L-Band Radiometer (1.41 GHz):
- Polarization: V, H, 3rd and 4th Stokes Parameters
- Resolution: 40 km
- Radiometric Uncertainty*: 1.3 K

L-Band Radar (Tunable from 1.22–1.3 GHz):
- Polarization: VV, HH, HV (or VH)
- Resolution: 10 km
- Relative accuracy*: 0.5 dB (VV and HH)
- Constant incidence angle** between 35° and 50°



SMAP mission



Scientific Measurement Requirements

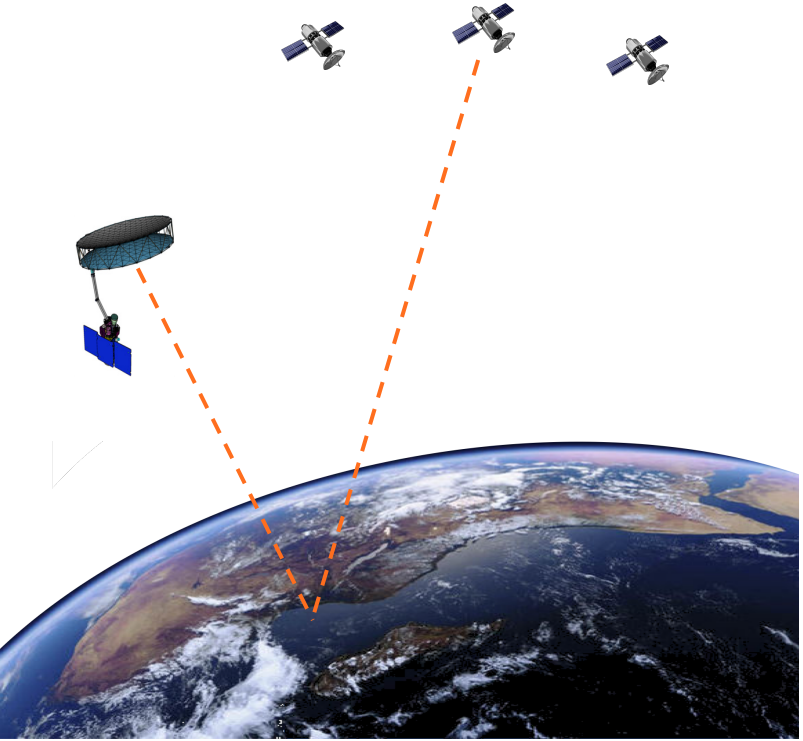
Freeze/Thaw State:
Capture freeze/thaw state transitions in integrated vegetation-soil continuum with two-day precision, at the spatial scale of landscape variability (~3 km).

Instrument Functional Requirements

L-Band Radar (Tunable from 1.22–1.3 GHz):

- Polarization: HH
- Resolution: 3 km
- Relative accuracy*: 0.7 dB (1 dB per channel if 2 channels are used)
- Constant incidence angle** between 35° and 50°

SMAP-Reflectometry

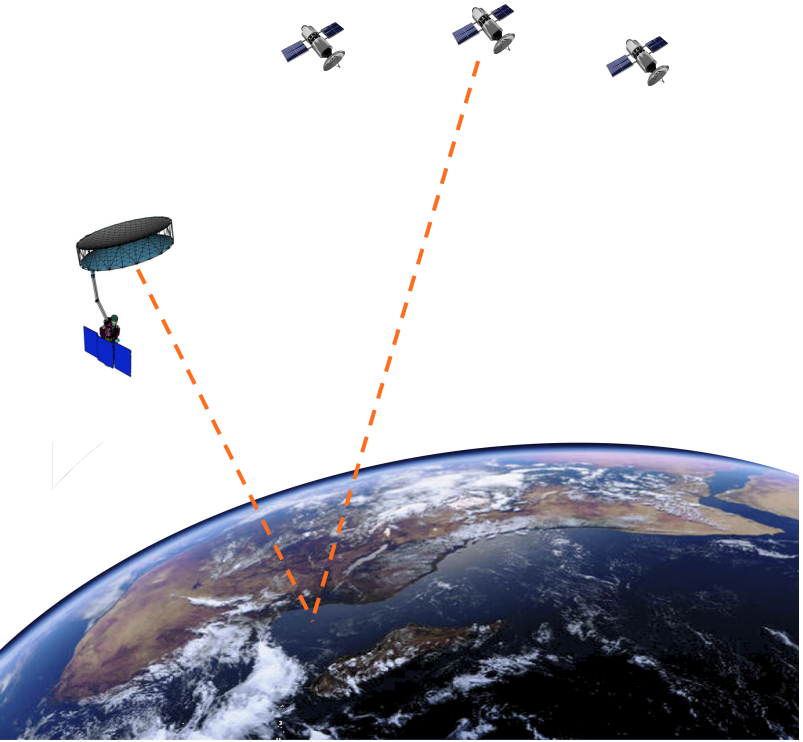


SMAP radar transmitter suffered an anomaly. The radar receiver bandpass center frequency was switched to 1227.45 MHz enabling GNSS-R capabilities.

Specifics

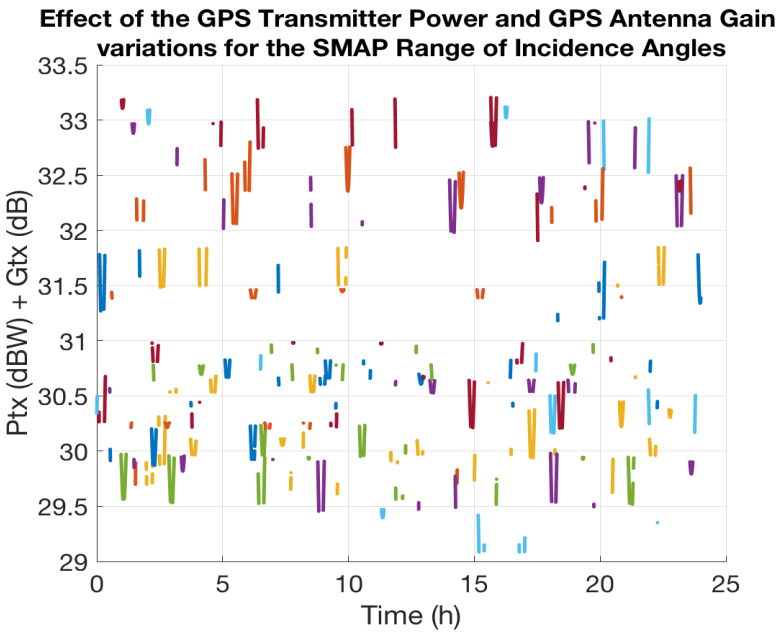
- Measuring GPS L2C from Aug. 20, 2015.
- Sun-Synchronous orbit altitude: 685 km, inclination: 98.12º.
- Near-global revisit coverage in 2–3 days
- SMAP-R Goal: To investigate the benefits of having L-band polarimetric measurements with polar coverage.

SMAP-Reflectometry

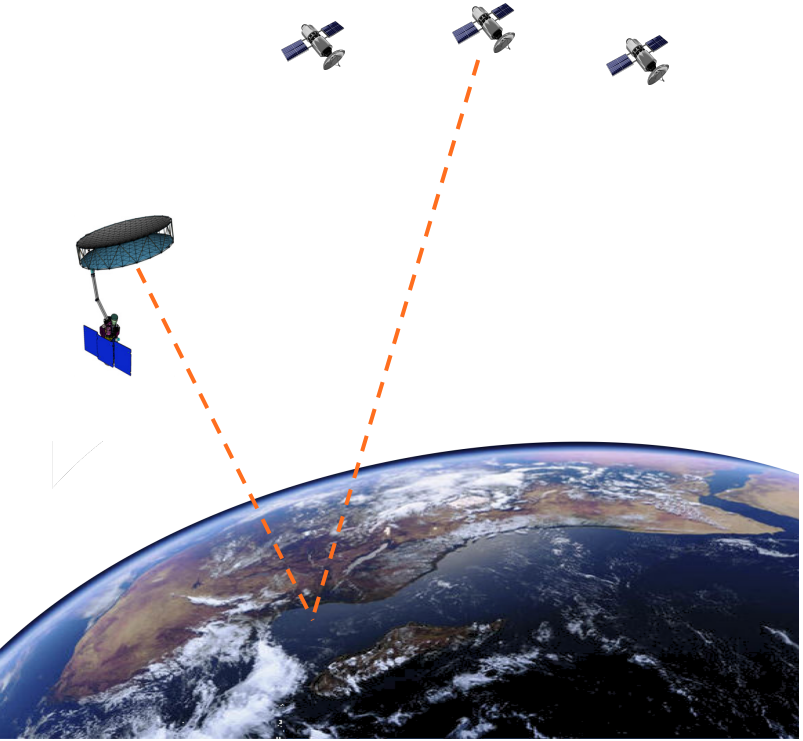


Limitations

Lack of direct signal information



SMAP-Reflectometry

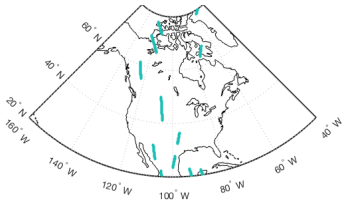


Limitations

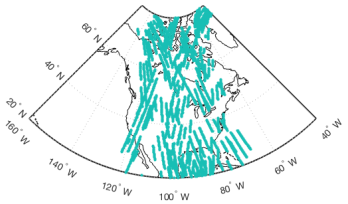
Reduced sampling ➔ rotating narrow antenna beam antenna

- Fewer reflections as compared to other GNSS-R missions.
- Due to rotation each continuous observation is ~25km apart. The number of consecutive samples within each continuous observation depends on the integration time selected.

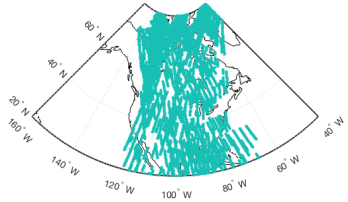
1 day of measurements



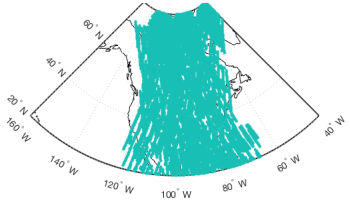
15 day of measurements



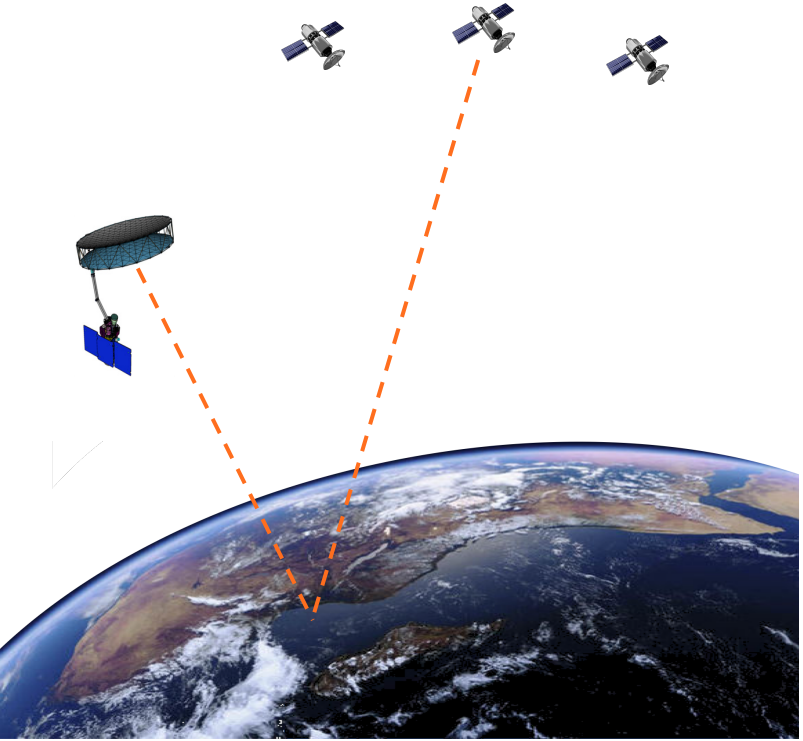
1 month of measurements



2 months of measurements



SMAP-Reflectometry



Benefits

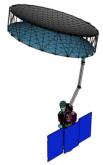
High gain antenna: Better SNR for shorter integration times resulting in better spatial resolutions.

Integrations of 25 ms as compared to 1000 ms produce elongations on the along-track direction of 180 m as compared to 6 km.

Dual-polarization: H- pol and V-pol allowing polarimetric studies.

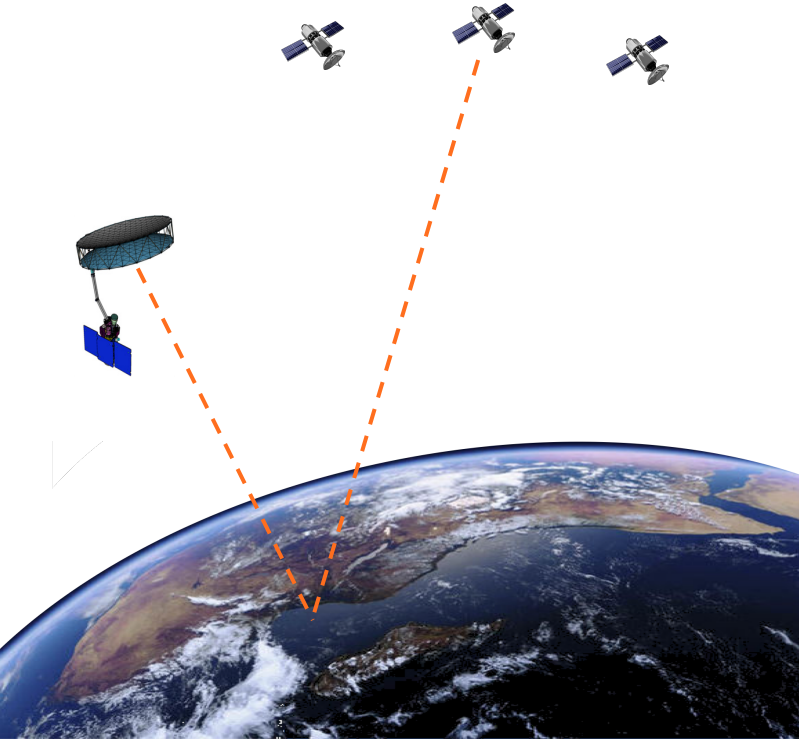
Fixed geometry: Easing the calibration.

Availability of raw data: Versatility on processing data at shorter integration times optimizing the spatial resolution and benefiting science applications.



Calibration

This work has been developed also in collaboration with Mary Morris and Sidharth Misra from JPL



The methodology

We have performed a calibration based on the standard equation:

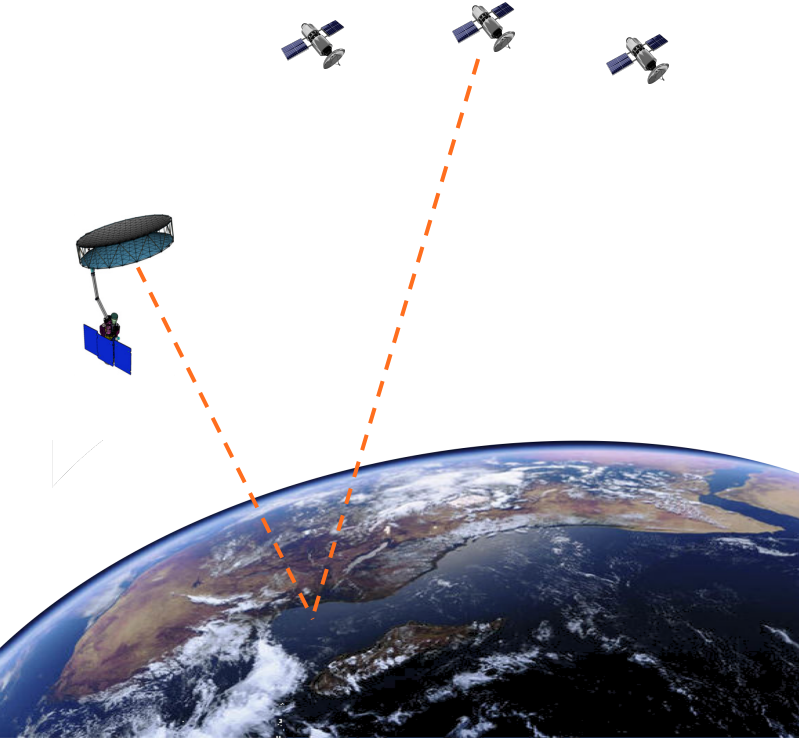
$$\langle \sigma_0 \rangle = \frac{(4\pi)^3 P_{incoh}(\tau, f_d)\, R_{rx_{sp}}^2 R_{tx_{sp}}^2}{T_i^2 P_{tx} G_{tx} \lambda^2 G_{rx_{sp}} \bar{B}(\tau, f_d)}$$

but having into consideration SMAP unique characteristics.

- Lack of direct signal information
- Narrow beam antenna effect

Calibration

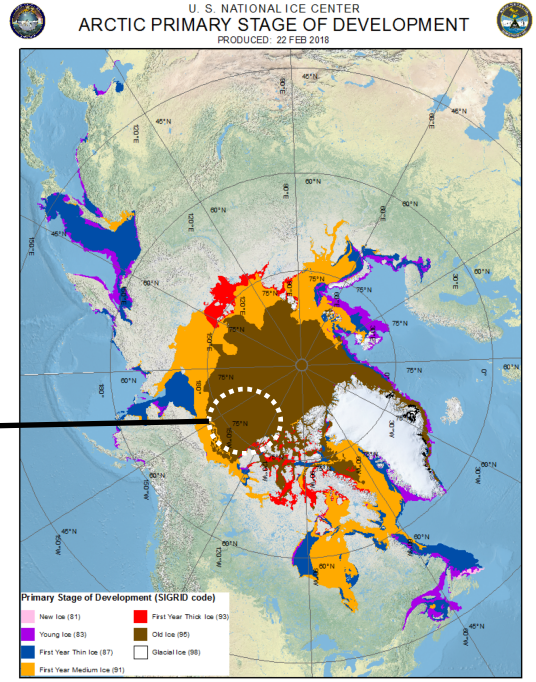
This work has been developed also in collaboration with Mary Morris and Sidharth Misra from JPL



The calibration target

We have selected an area of constant old sea ice during winter 2017 – 2018.

Area of constant coherent scattering (old sea ice), low variability due to relatively small changes in the ice and nearby first year ice – much more reflective.



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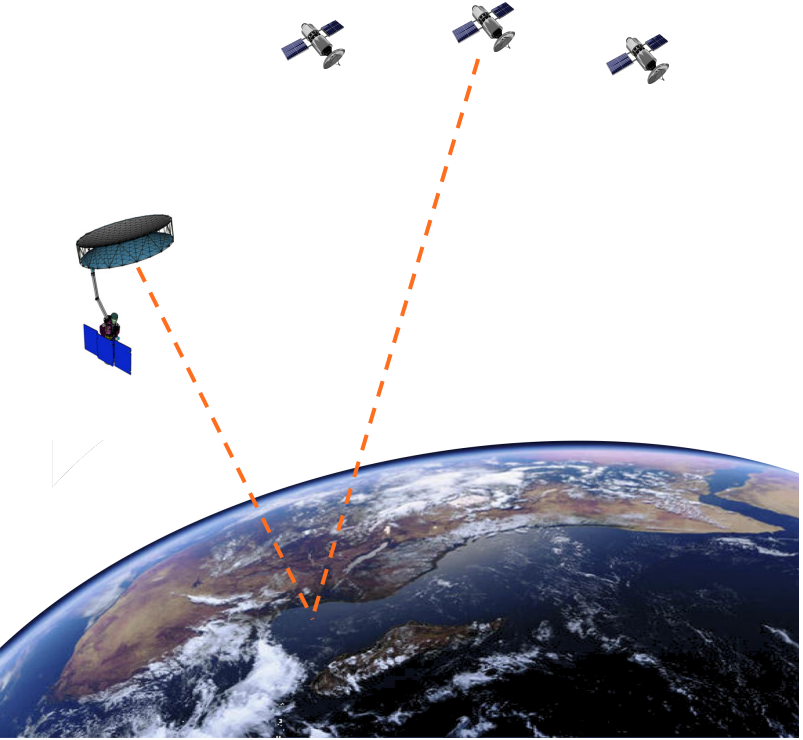
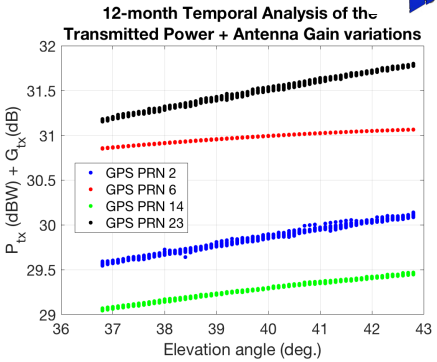


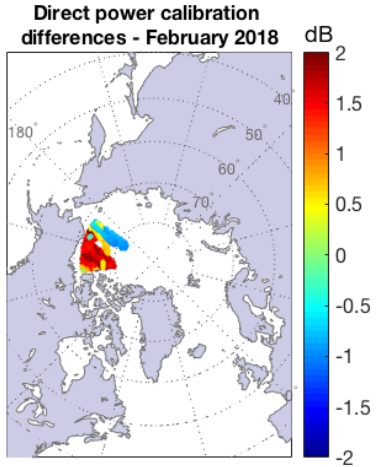
Direct Power Information

- We have looked into a 1 year of direct power information in CYGNSS metadata as a function of the elevation angle within the range of SMAP geometries:

$$P_{tx_dB} + G_{tx_dB}$$

- We have collocated CYGNSS information with SMAP-R measurements, when available and built a Look-Up-Table when no coincident times are available. Mean transmitted power seem to be fairly constant and antenna gain is going to be valid for the same incidence angle. The azimuthal differences are in the order of 0.1 – 0.2 dB.





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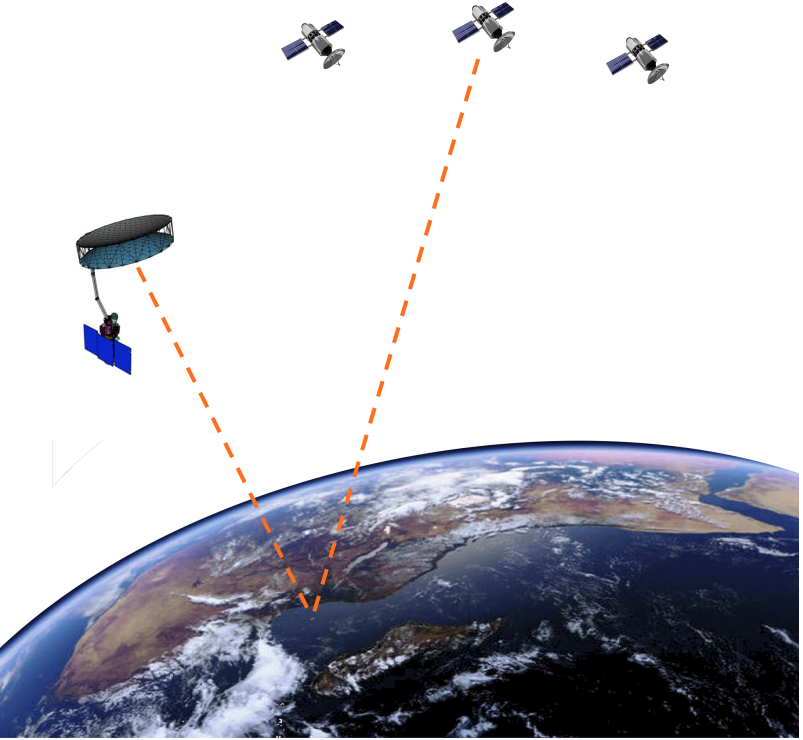
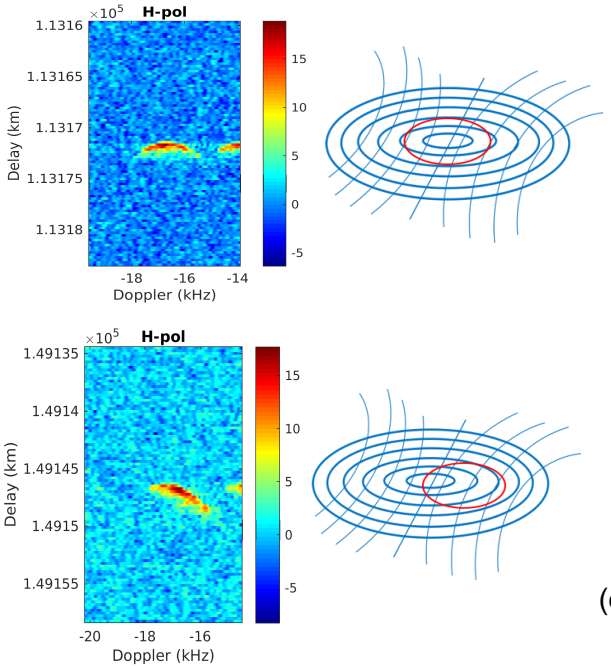
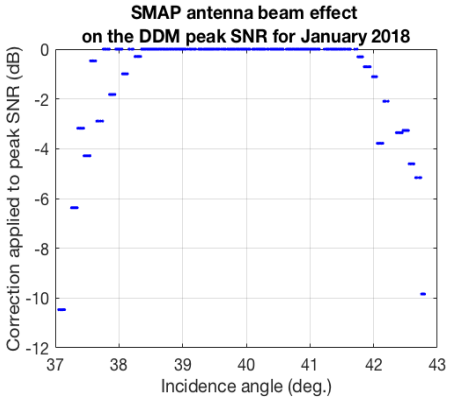


Narrow Beam Antenna

- Effect of the DDM shape



- Effect of on the SNR of the DDMs



(plot shows the effect on the peak)
(each DDM bin needs to be corrected)

Calibration

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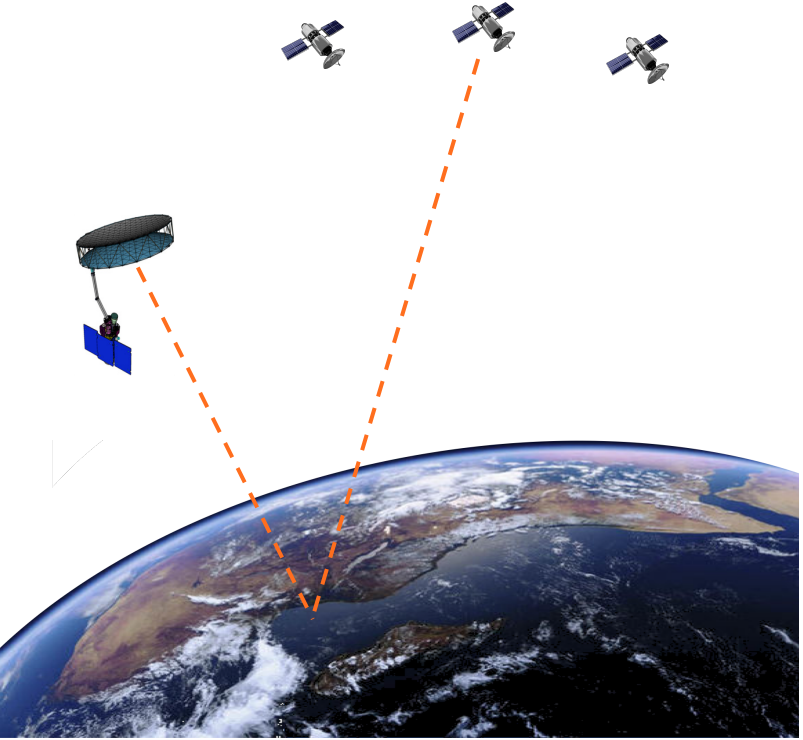

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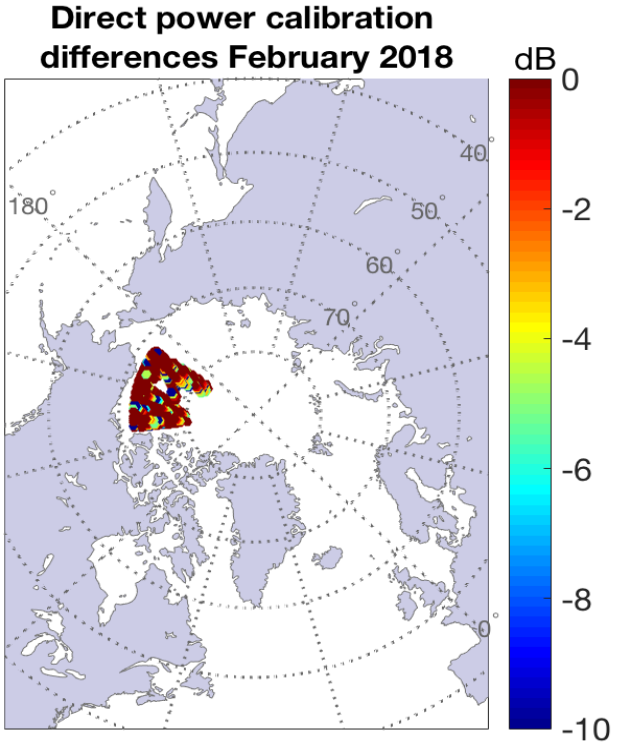

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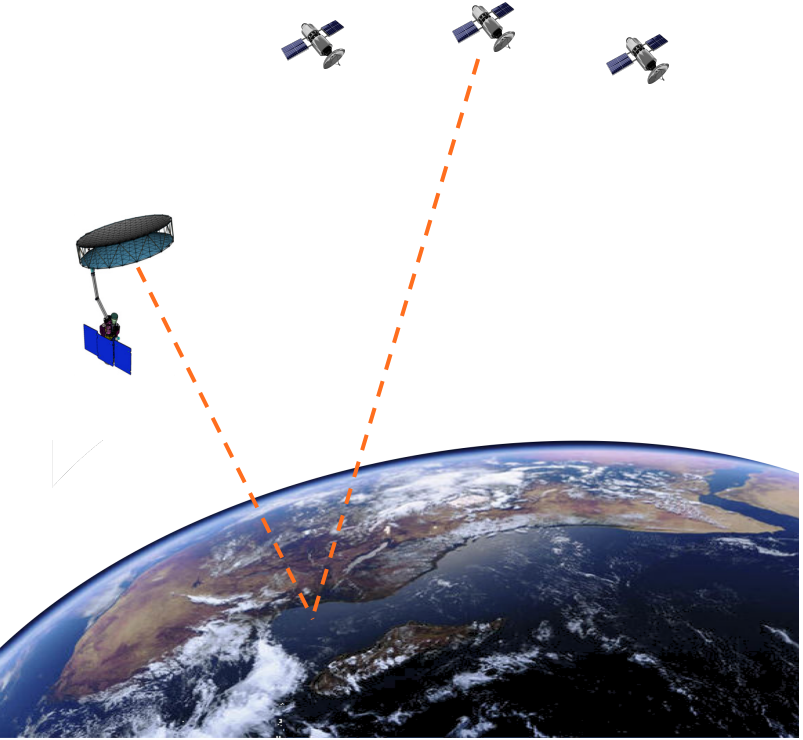
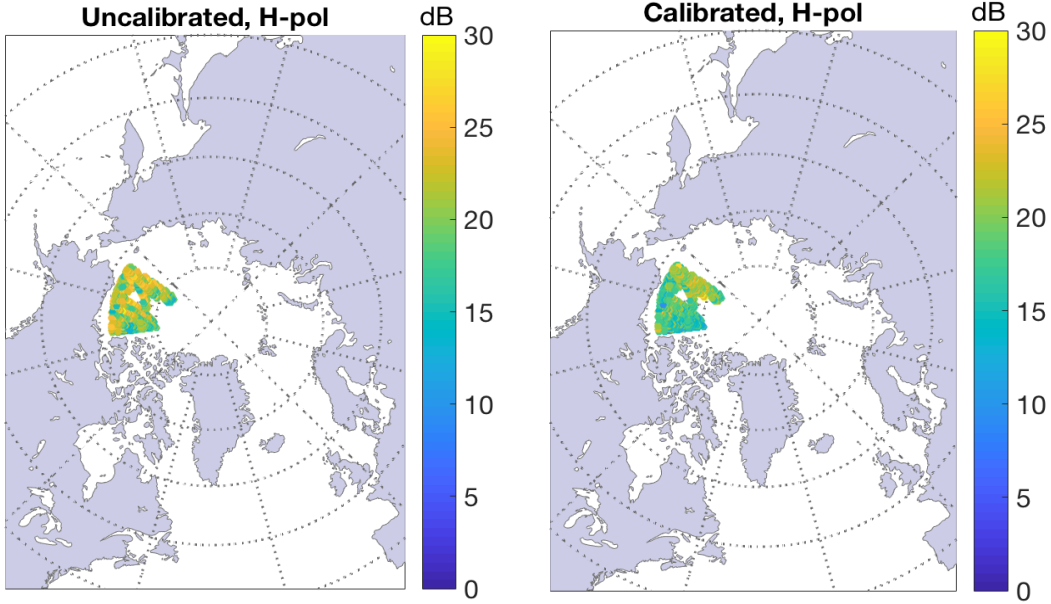
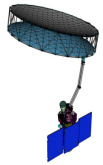


Calibration Results

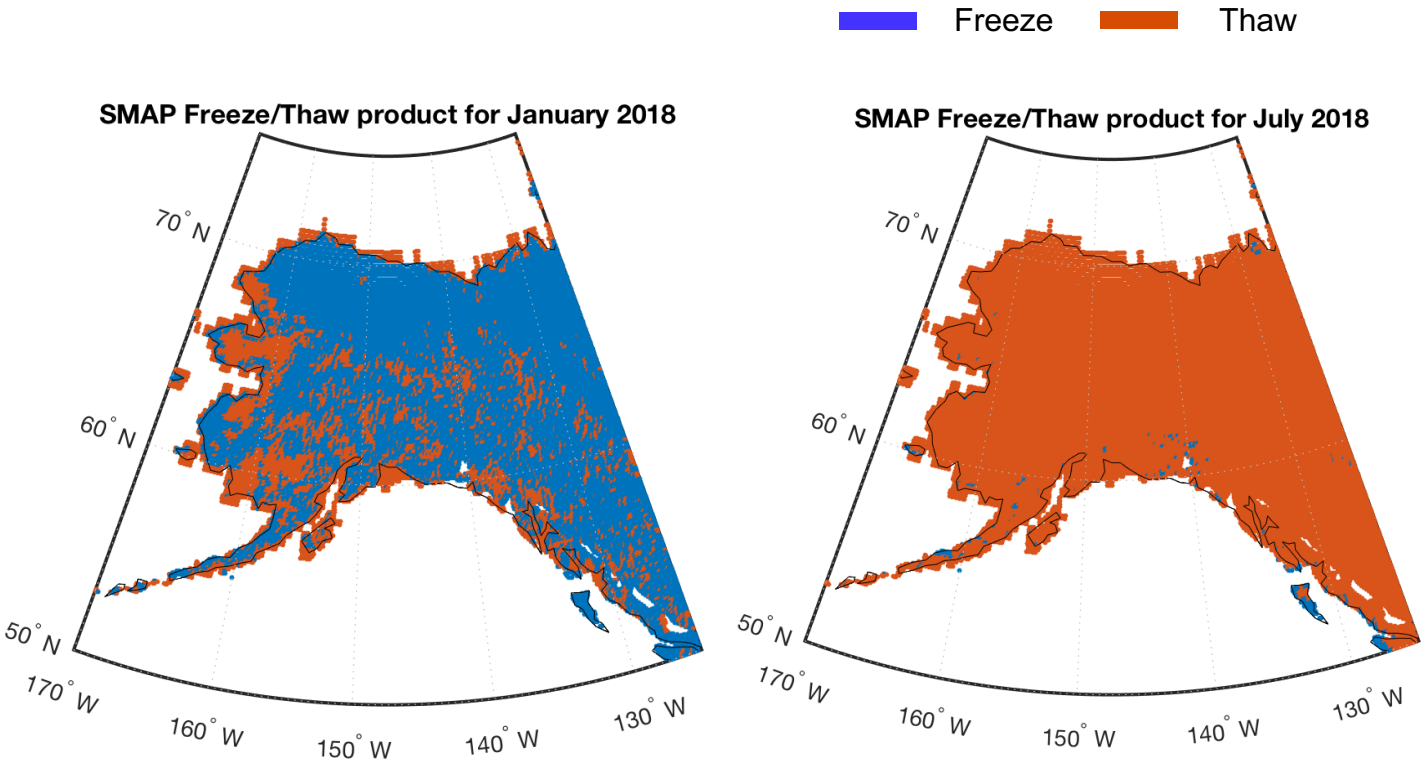




Freeze/Thaw Studies

Reference Dataset

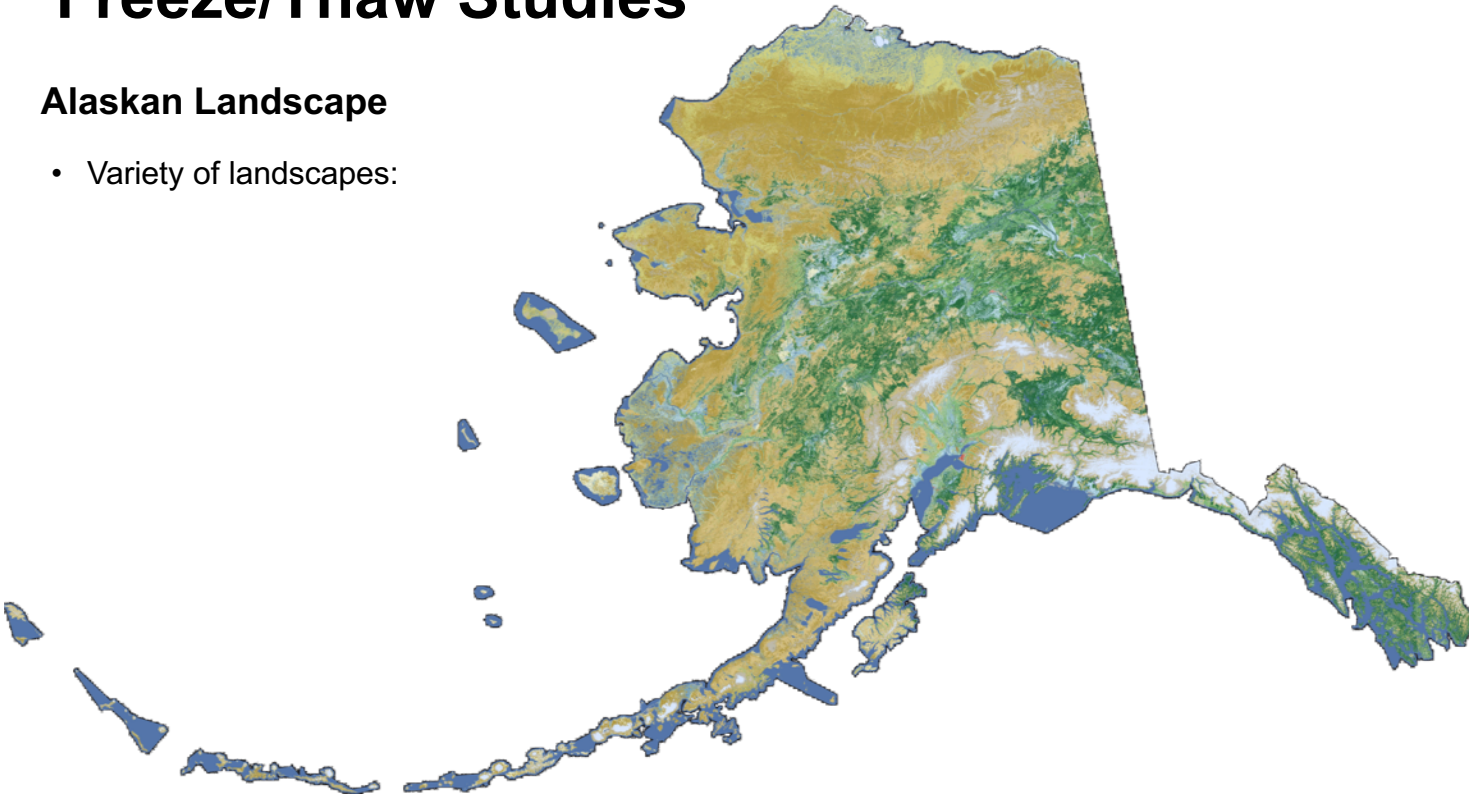
- Daily classification of freeze/thaw state for land areas north of 45°N
- Derived from the SMAP radiometer
- Winter months (Frozen/ Thawed areas)
- Summer months (Thawed areas)



Freeze/Thaw Studies

Alaskan Landscape

- Variety of landscapes:

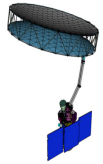


NLCD Land Cover Classification Legend

- 11 Open Water
- 12 Perennial Ice/ Snow
- 21 Developed, Open Space
- 22 Developed, Low Intensity
- 23 Developed, Medium Intensity
- 24 Developed, High Intensity
- 31 Barren Land (Rock/Sand/Clay)
- 41 Deciduous Forest
- 42 Evergreen Forest
- 43 Mixed Forest
- 51 Dwarf Scrub*
- 52 Shrub/Scrub
- 71 Grassland/Herbaceous
- 72 Sedge/Herbaceous*
- 73 Lichens*
- 74 Moss*
- 81 Pasture/Hay
- 82 Cultivated Crops
- 90 Woody Wetlands
- 95 Emergent Herbaceous Wetlands

* Alaska only

Freeze/Thaw Studies



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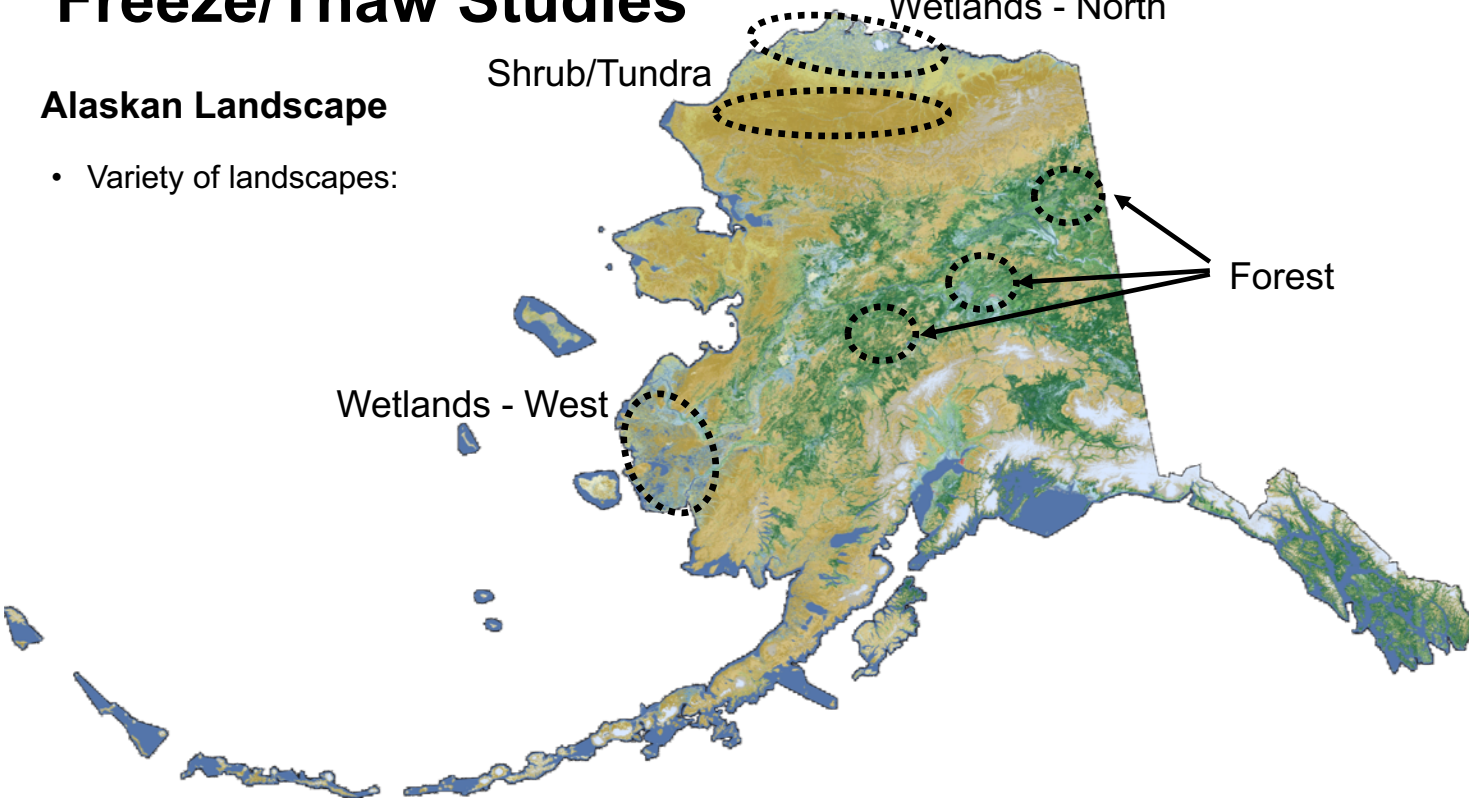

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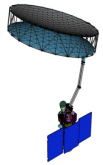
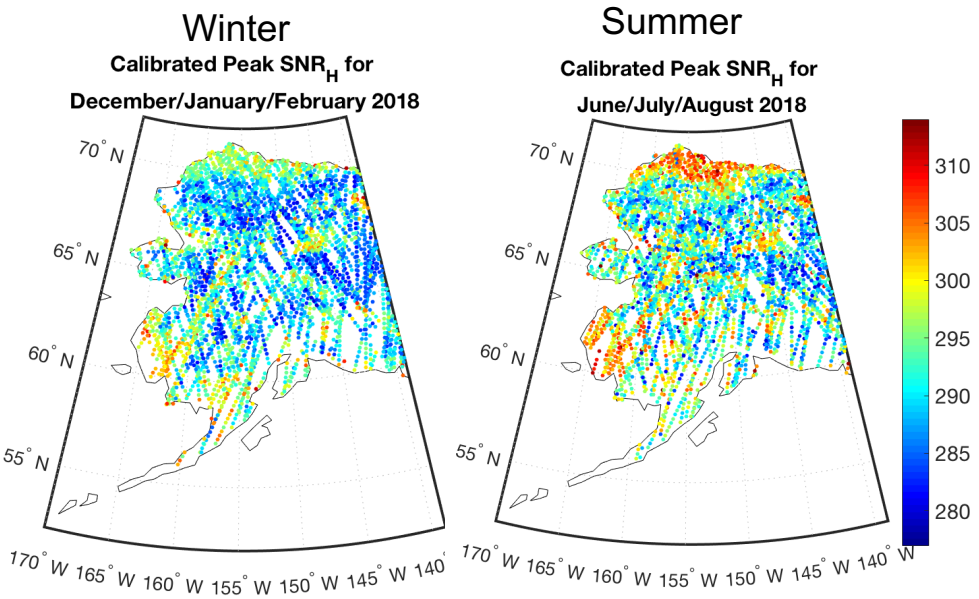
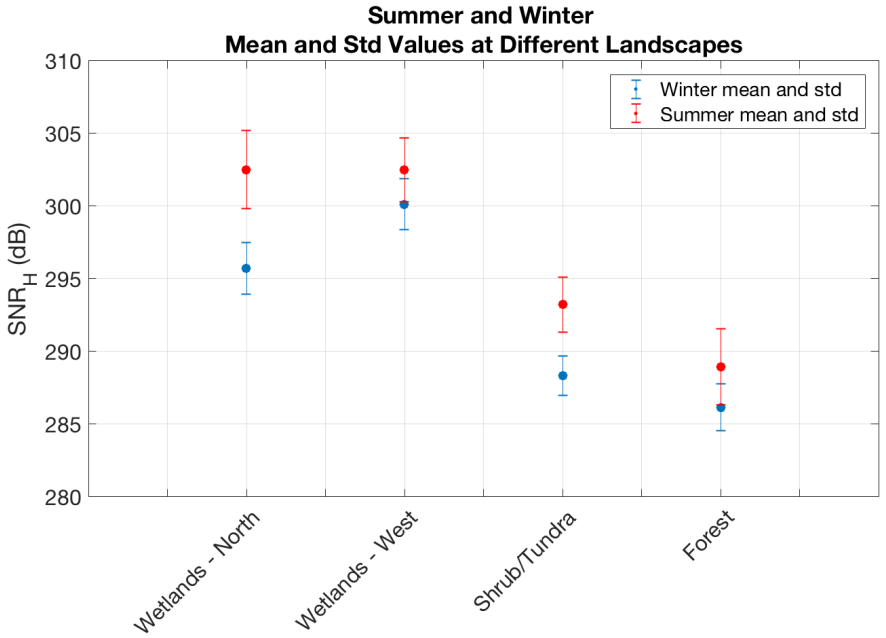


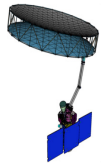
Freeze/Thaw Studies

SMAP-R Measurements

- SMAP-R Measurements over Alaska at H-pol



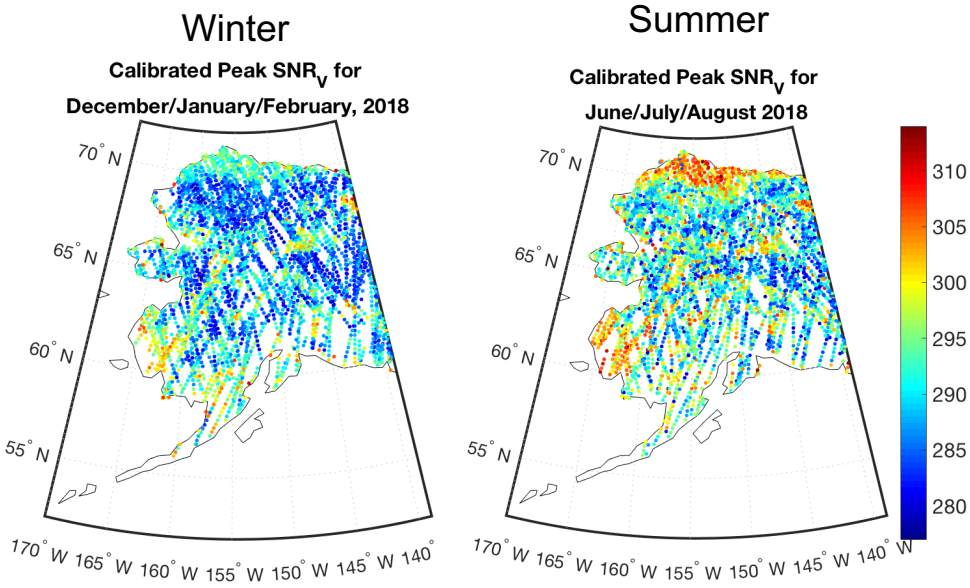


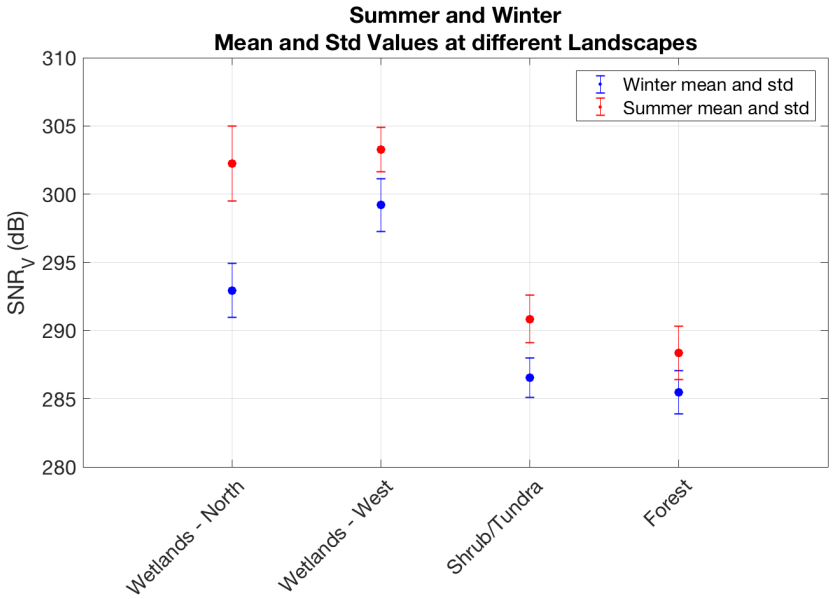


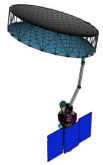
Freeze/Thaw Studies

SMAP-R Measurements

- SMAP-R Measurements over Alaska at V-pol





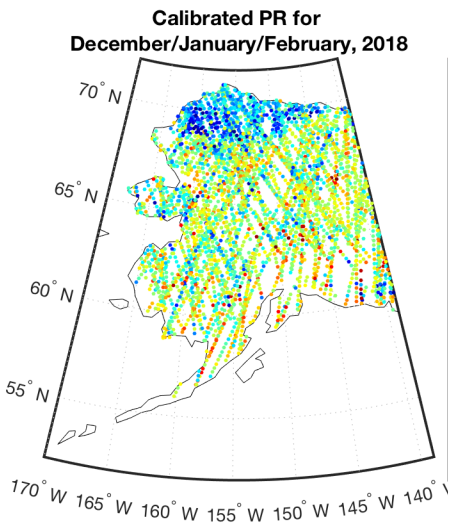


Freeze/Thaw Studies

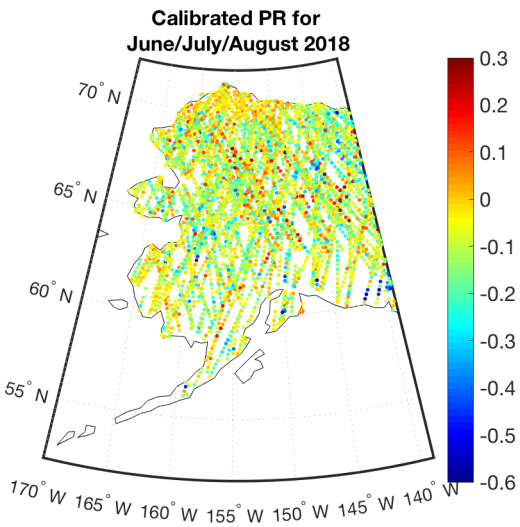
SMAP-R Measurements

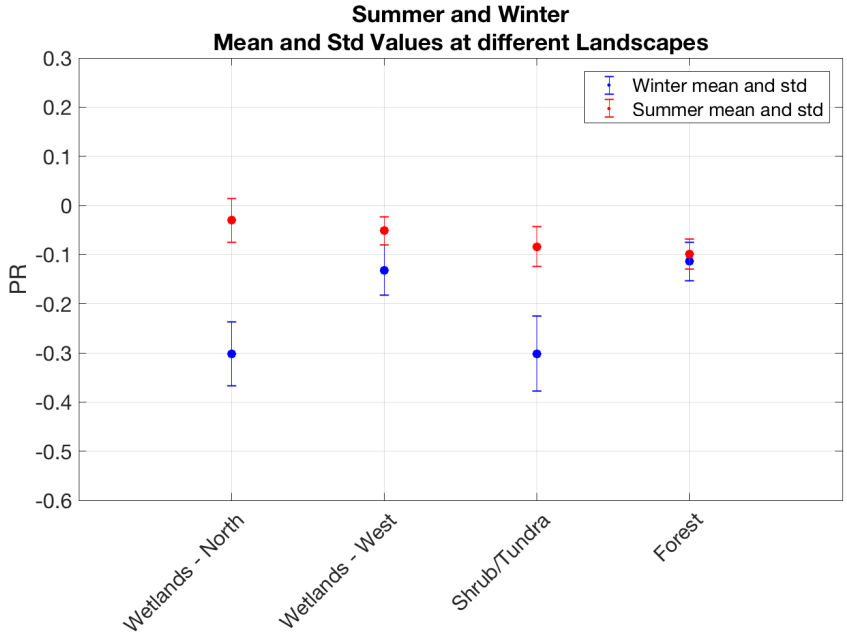
- SMAP-R Measurements over Alaska Polarimetric Ratio (PR)

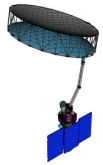
Winter



Summer



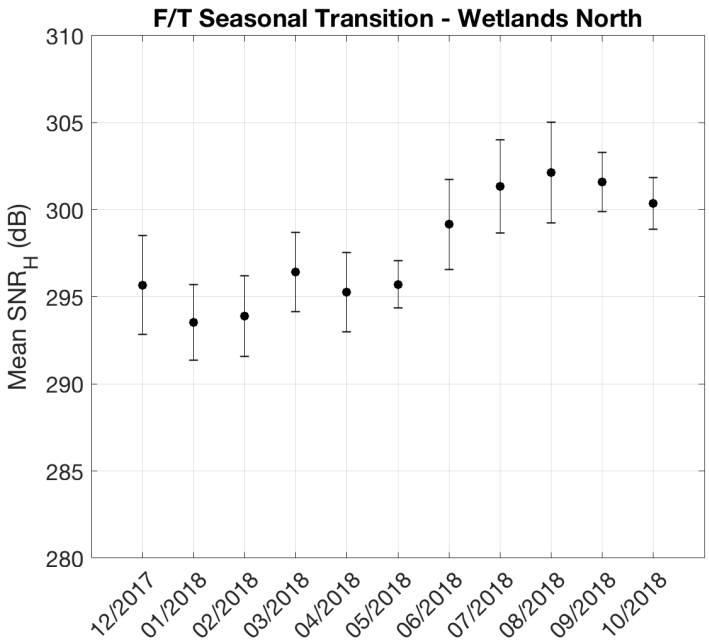




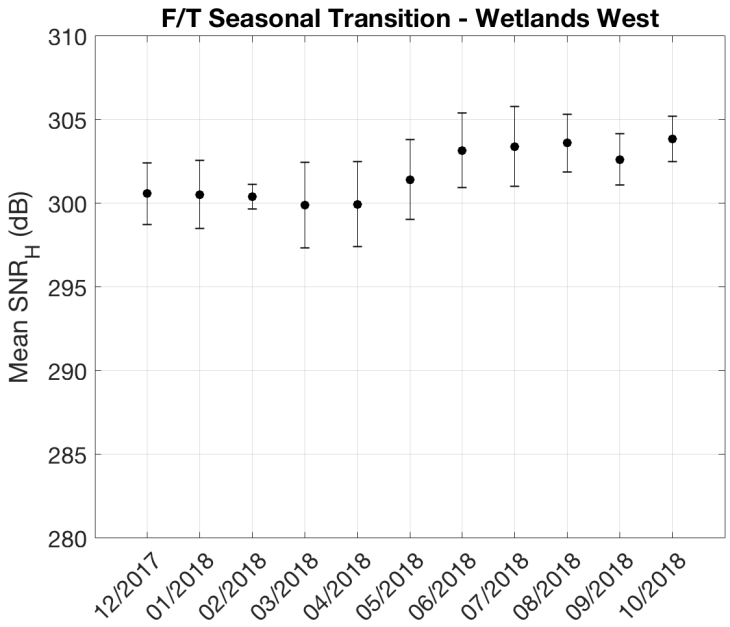
Freeze/Thaw Studies

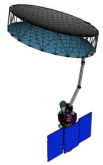
Freeze to Thaw Transitions

Wetlands - North



Wetlands - West

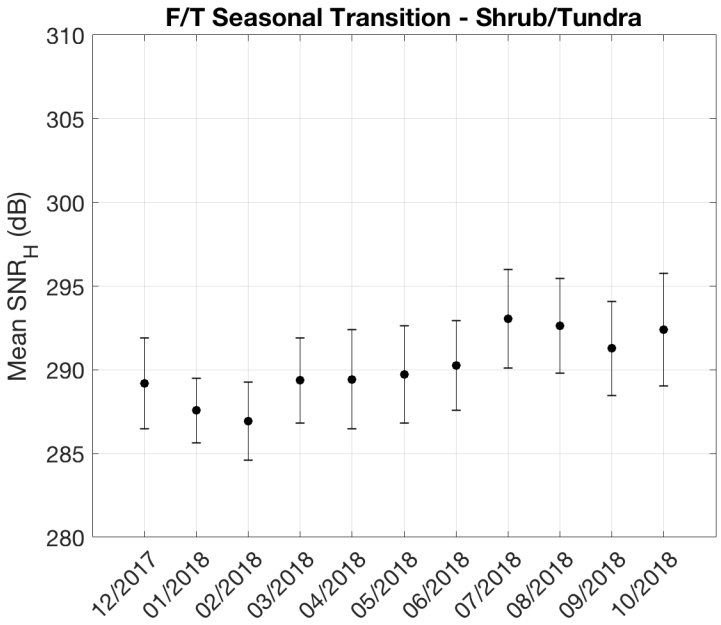




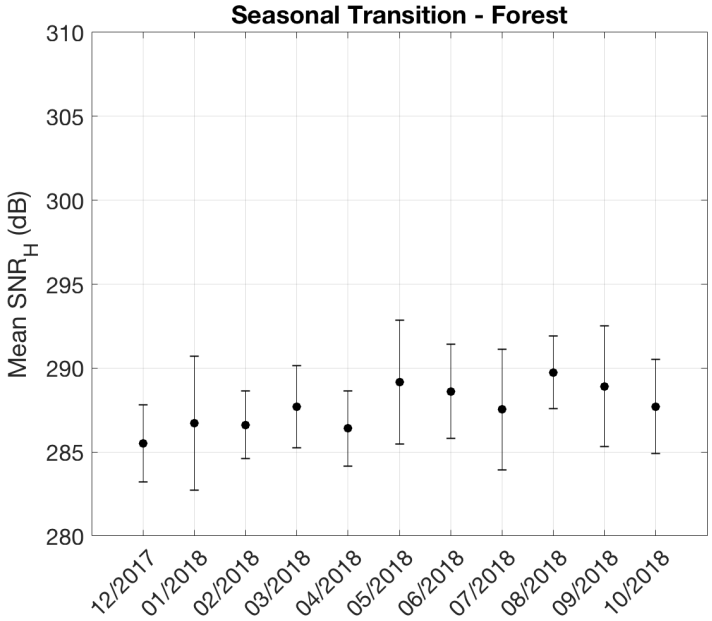
Freeze/Thaw Studies

Freeze to Thaw Transitions

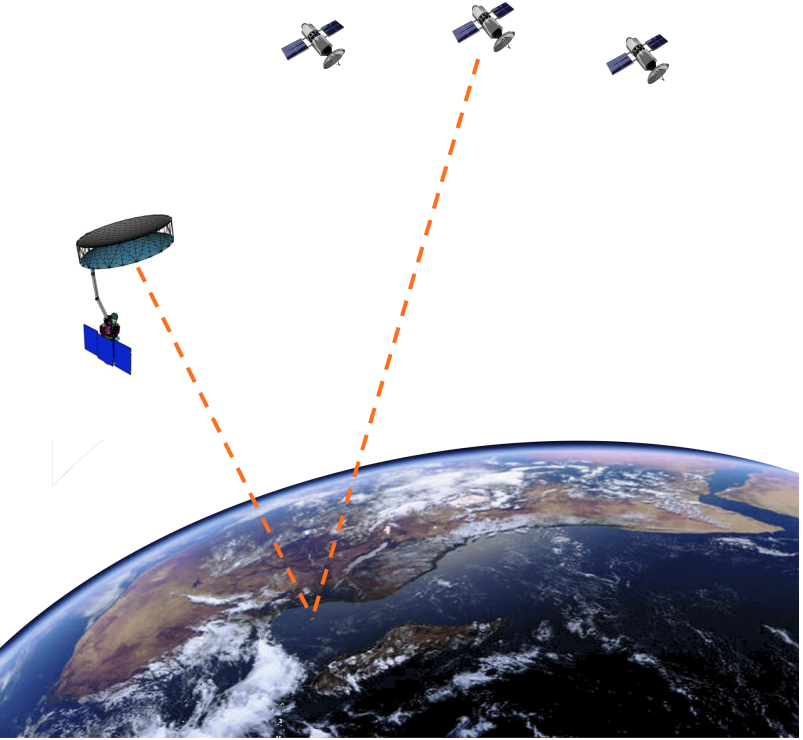
Shrub/Tundra



Forest

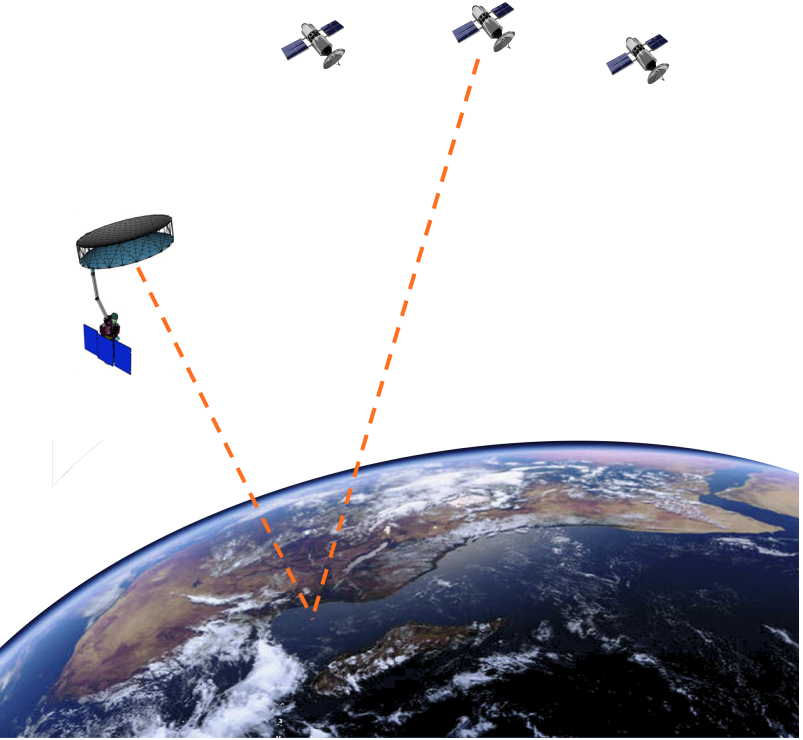


Conclusions



- Calibration of SMAP-R signals is challenging but can be done
  Key step to producing science from the SMAP-R dataset.
- Low coverage limits applications needing high temporal repeat.
  Different strategies can be implemented based on a two state transition observational strategy.
- Polarimetric information has potential to help better understand the role of vegetation on the freeze/thaw processes.
  H-pol and V-pol measurements brings extra capabilities to reduce the error on the f/t state estimations.
- Results on F/T state prove the sensitivity of L-band polarimetric measurements and the benefit of SMAP-R spatial resolutions.
- SMAP-R is sensitive to F/T state transitions.
- We are working on implementing an algorithm to ingest SMAP-R measurements and obtain F/T state of the observed surfaces.

Other Related Works in IGARSS 2019



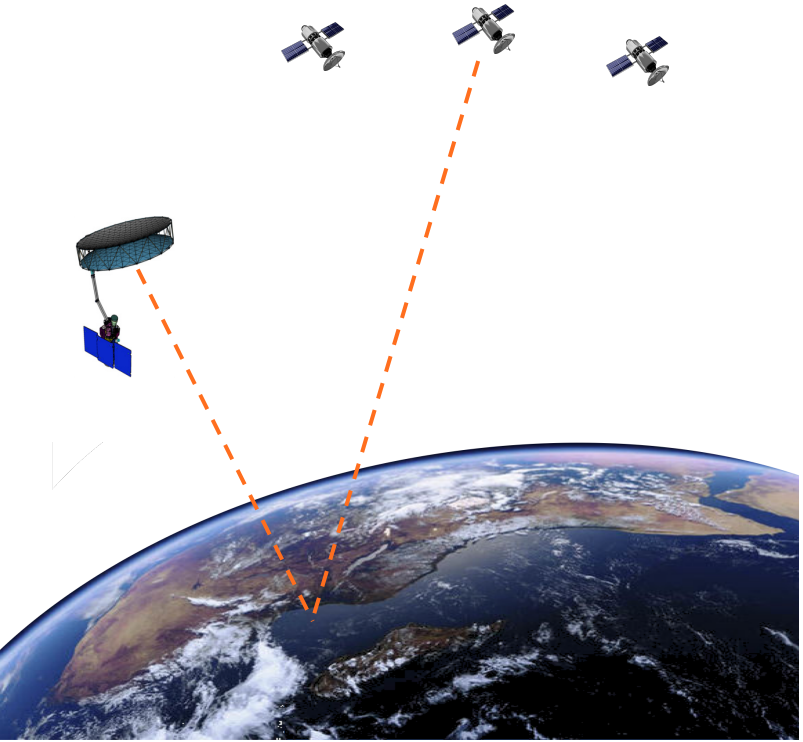
- Poster Presentation

  Nereida Rodriguez-Alvarez, et al., JPL
  Thursday, August 1, 15:20 - 16:20
  THP2.PT: Forest Parametrization with SAR and Optics
  Poster Area T

- Oral Presentation

  Mary Morris, et al., JPL
  Wednesday, July 31, 13:40 - 15:20
  WE3.R12: Ocean Surface Winds and Currents V
  Room 421

Acknowledgements



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