Signals of Opportunity P-band Investigation (SNOOPI): A Technology Validation Mission

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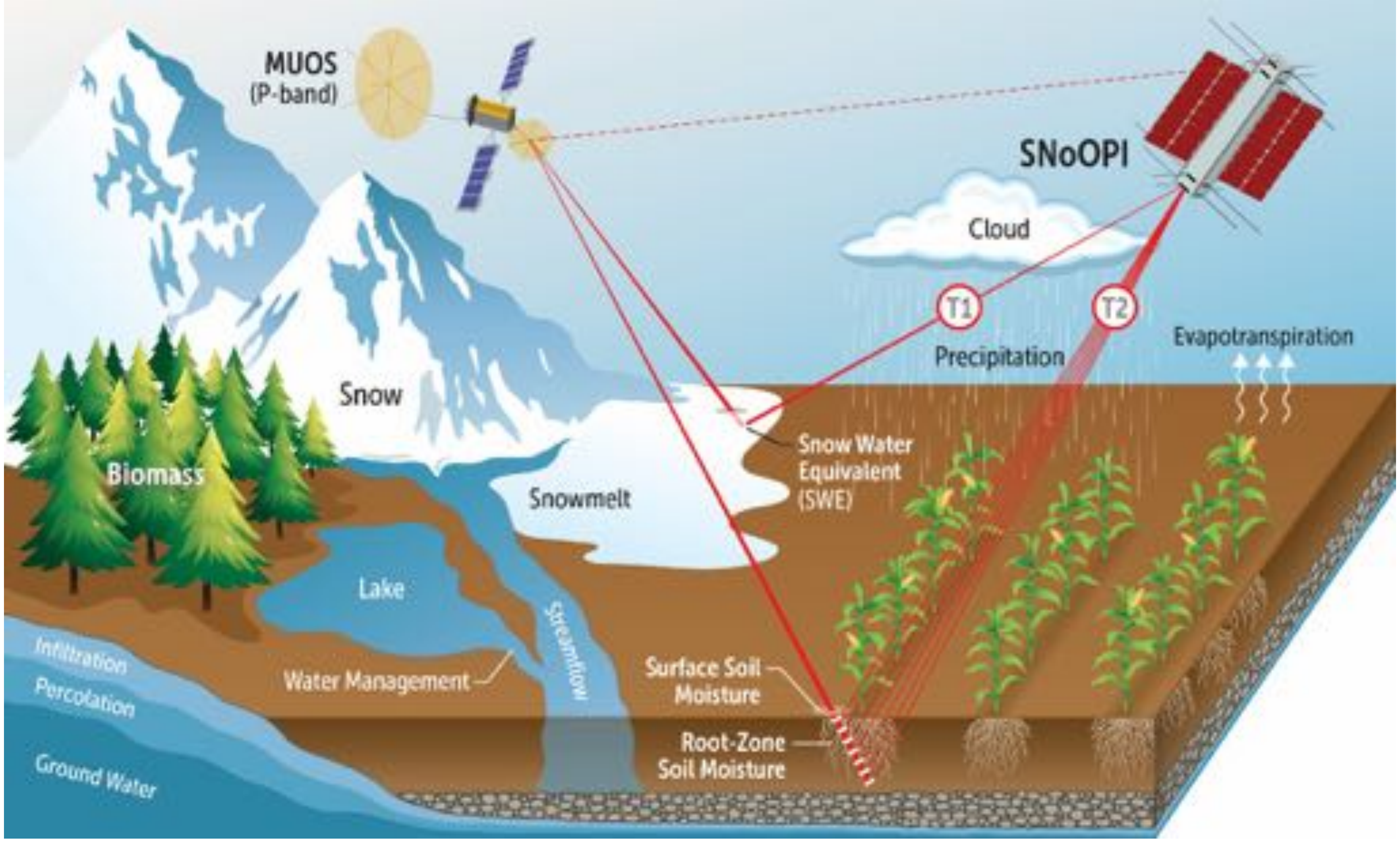
Outline

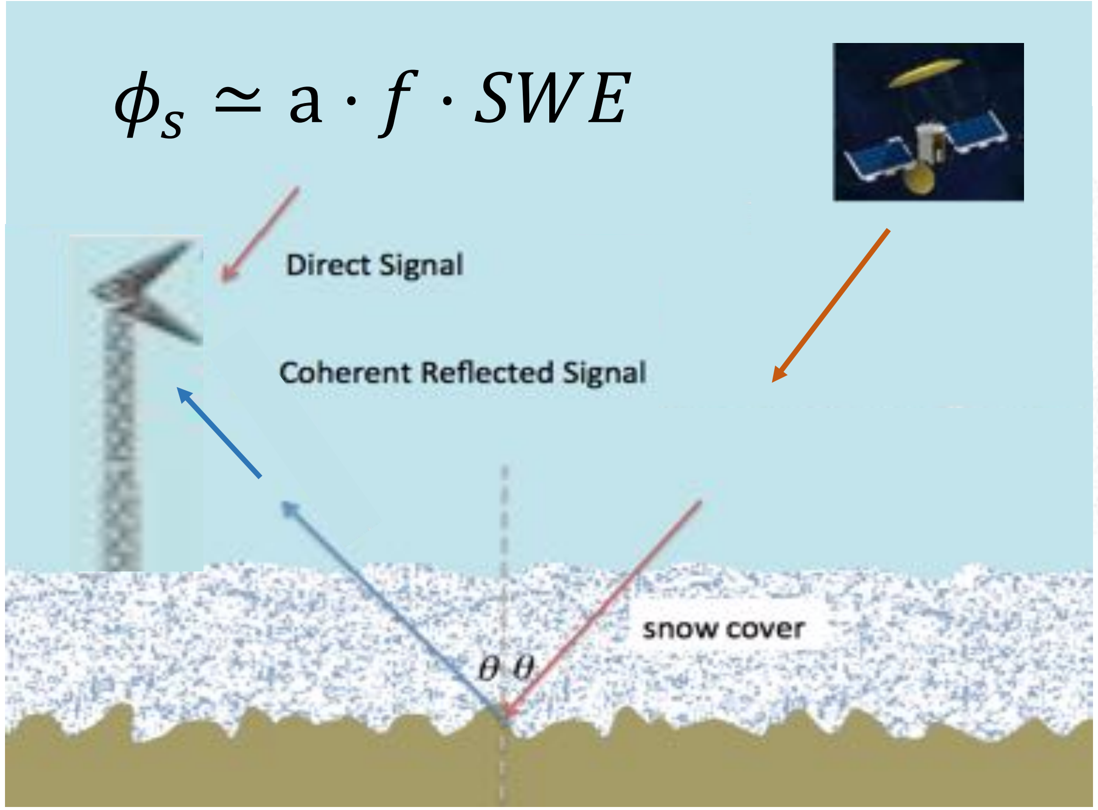
- SNOOPI Mission Description
- Motivation: P-band Signals of Opportunity (SoOp)
- Instrument Heritage
- Mission Design

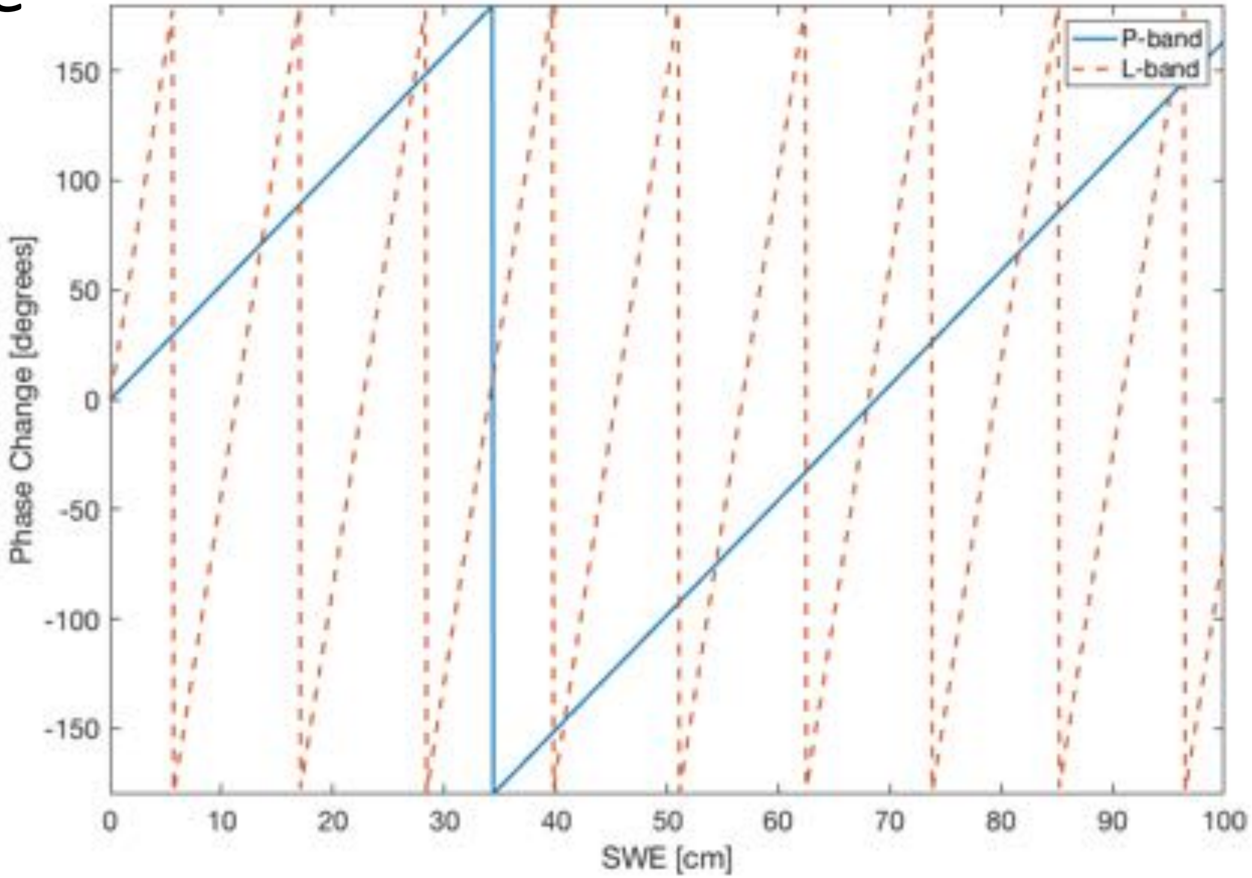
SNOOPI Mission Description



Snow Water Equivalent

- SWE retrieval from SoOp phase



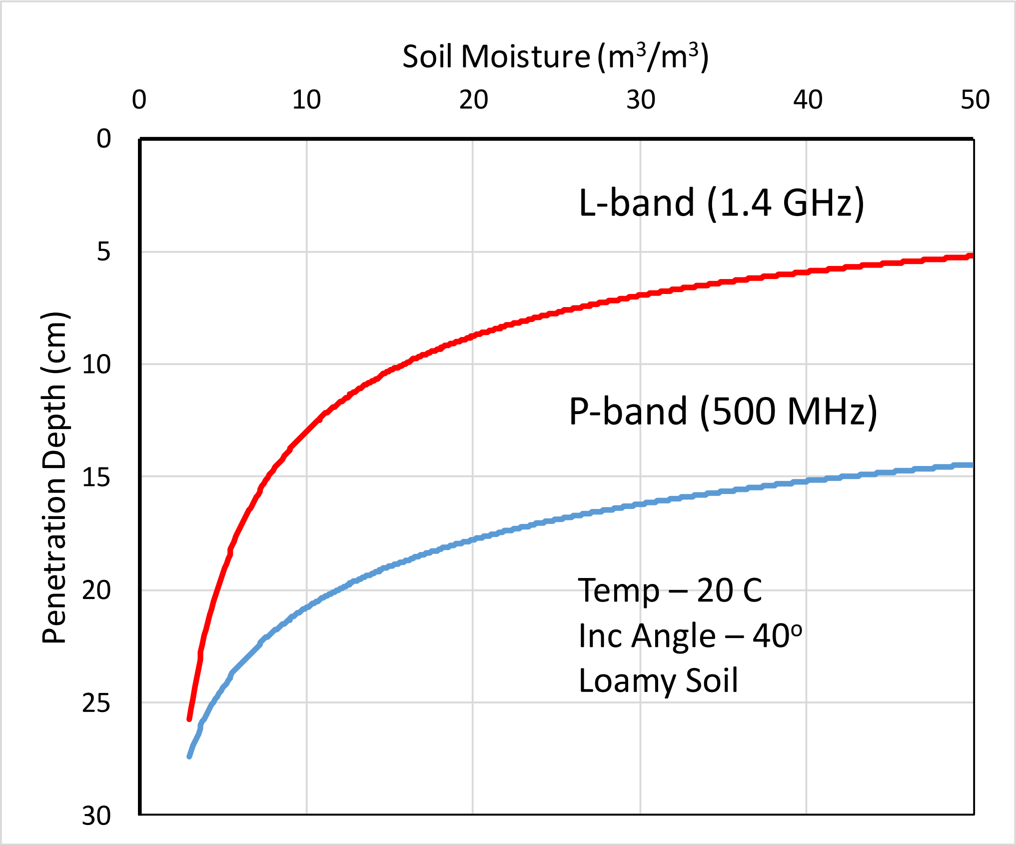


- Long (~1m) P-band wavelength – increase phase wrapping interval

Root-zone Soil Moisture

- Root-zone soil moisture provides the critical link between surface hydrology and deeper processes (hydrologic linkage to the GRACE mission)
- Provides the root uptake for plant growth
- Accurate soil moisture data in the root zone are critical to agriculture (especially food production) and are of global importance.
- Account for rainfall estimate uncertainty in models
- Soil moisture profile information will allow accurate estimates of soil hydraulic properties

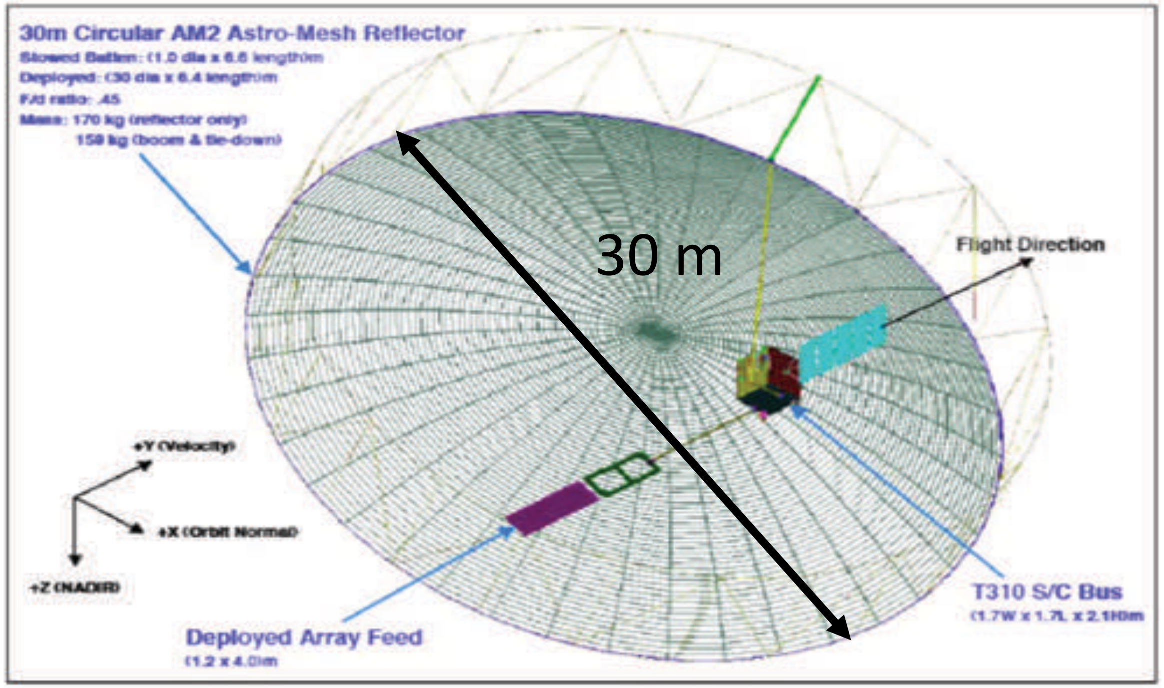
Penetration Depth in Bare Soil



Difficulty of Sensing < 500 MHz

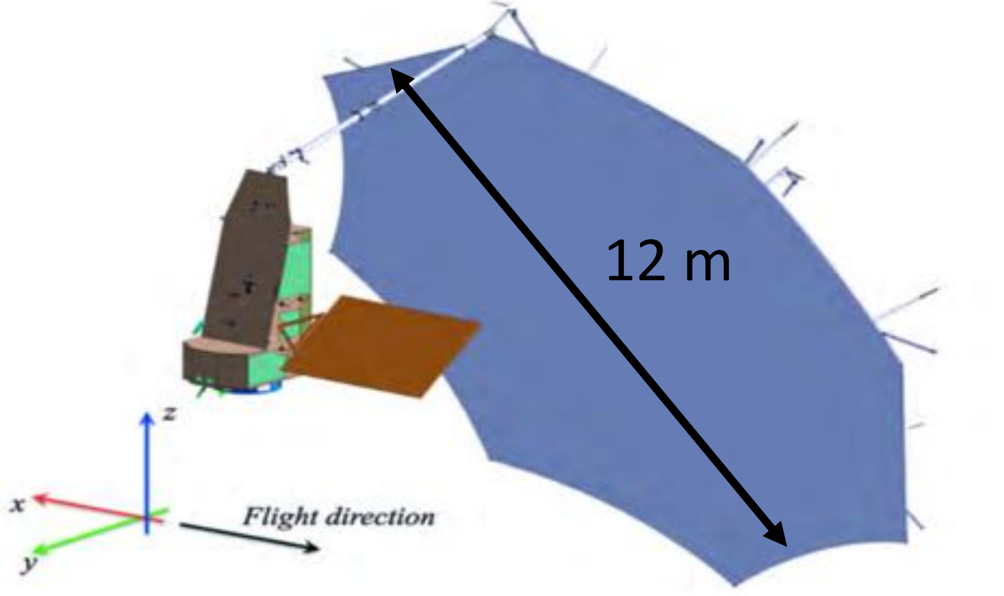
- Large antenna size to meet resolution requirements
- Few protected bands
- High RFI from terrestrial sources

MOSS: 435 & 137 MHz



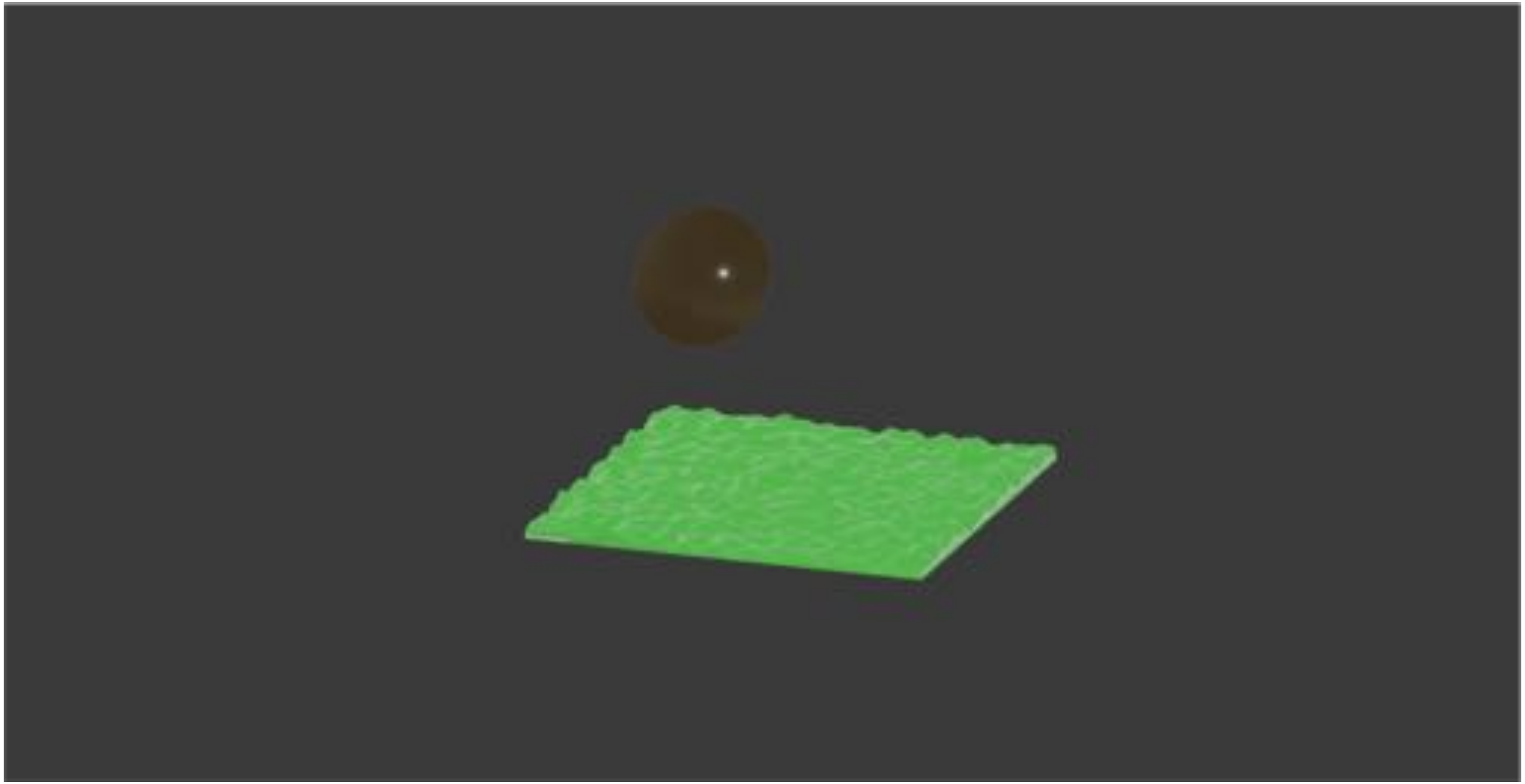
[DOI:10.1109/TGRS.2007.898236]

ESA-BIOMASS
435 MHz (limited Ops.)



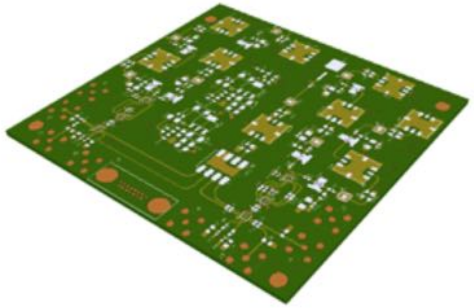
[*ESA SP-132*, 2010]

Signals of Opportunity

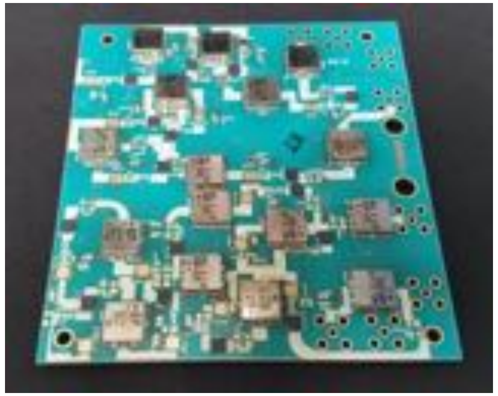


SNOOPI Instrument Heritage

- Low Noise Front End (LNFE): NASA GSFC
  - CubeSat form factor (90 x 96 mm) derived from IIP13 experience
  - 4 channels, 80 dB available gain, internal calibration paths



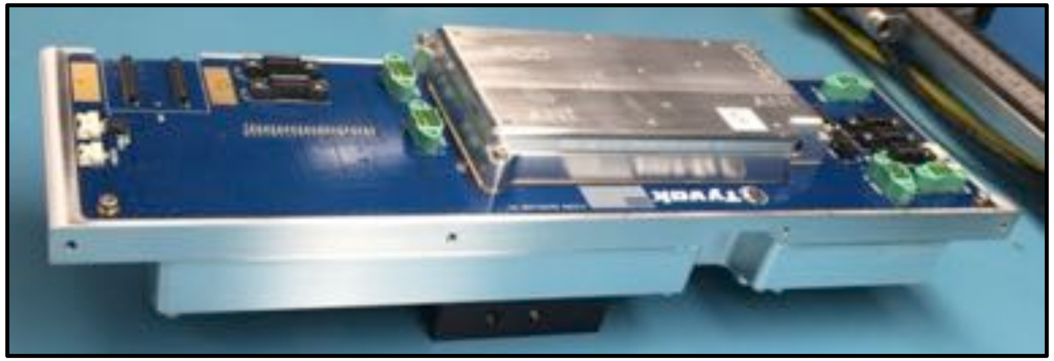
RFE CAD model

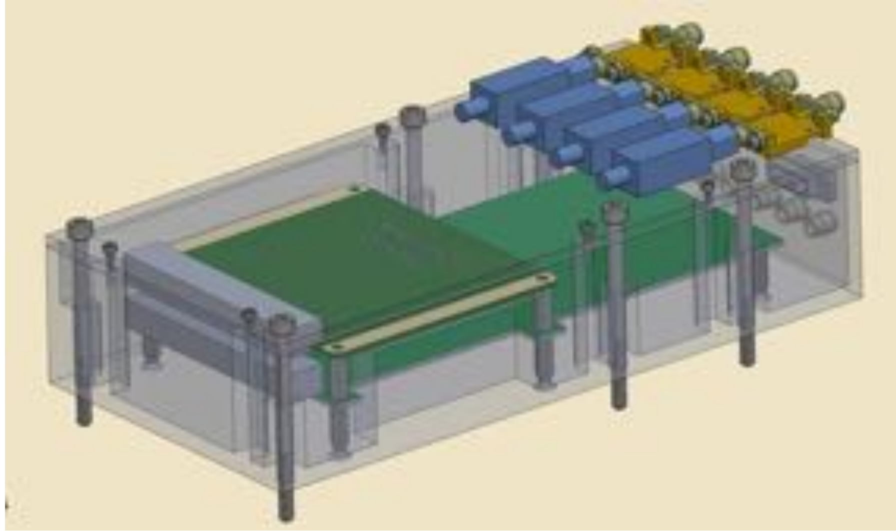


Prototype during population

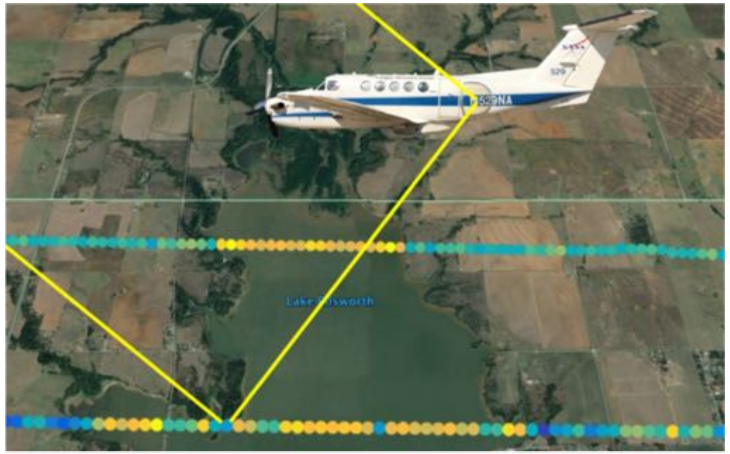
SNOOPI Instrument Heritage

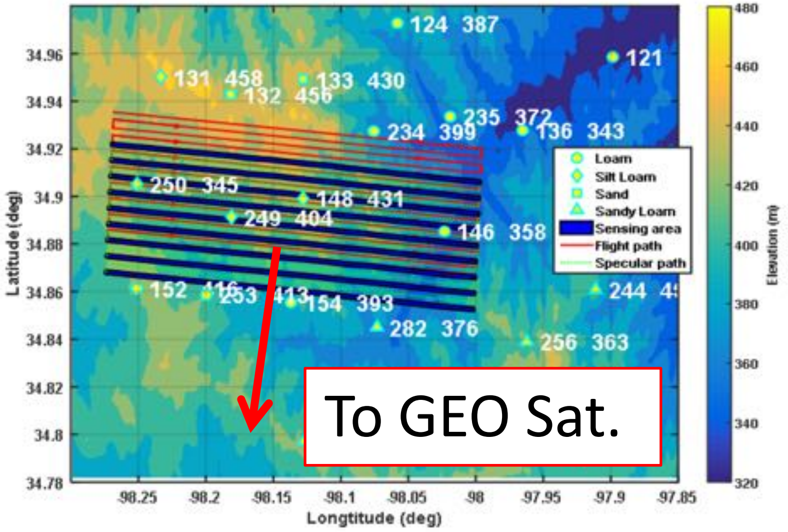
- Digital Back End (DBE): NASA JPL
  - Based on Cion GNSS receiver for Tyvak / CICERO (TRL-8)
  - Changes:
    - Off-the-Shelf Rad-tolerant high-rel CSP computer (TRL 8)
    - P-band capability

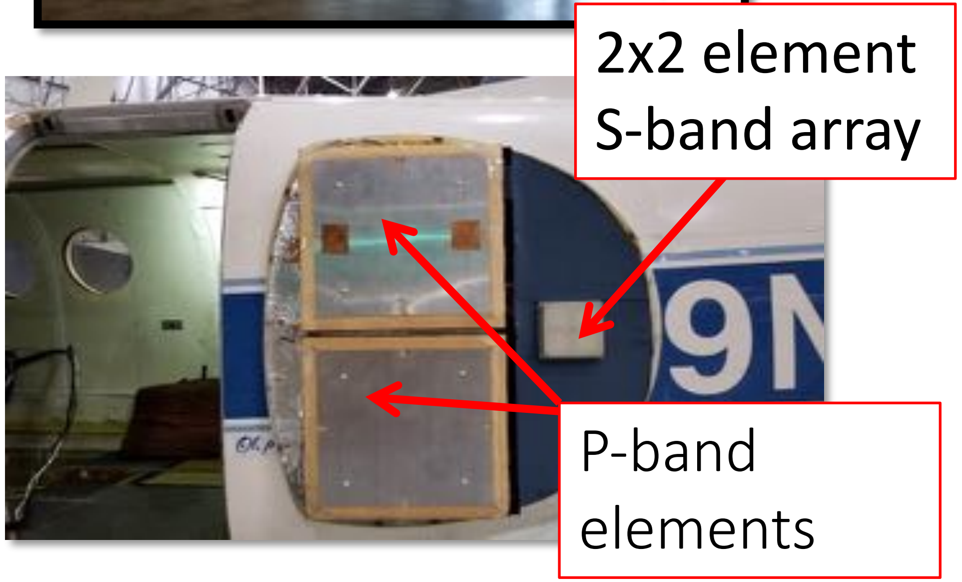




P-Band Signals of Opportunity Airborne Demonstrator (SoOp-AD)

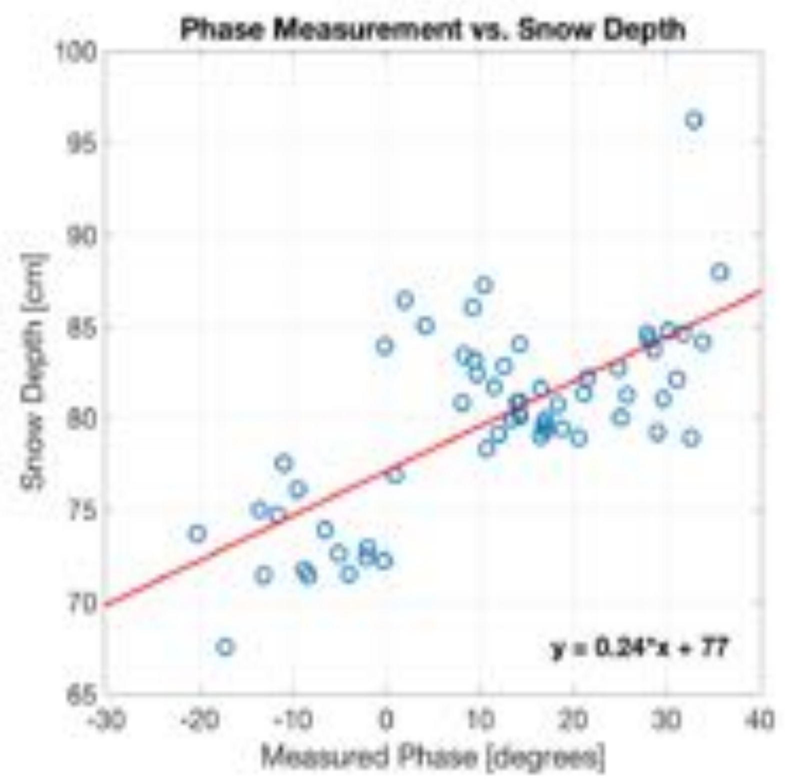


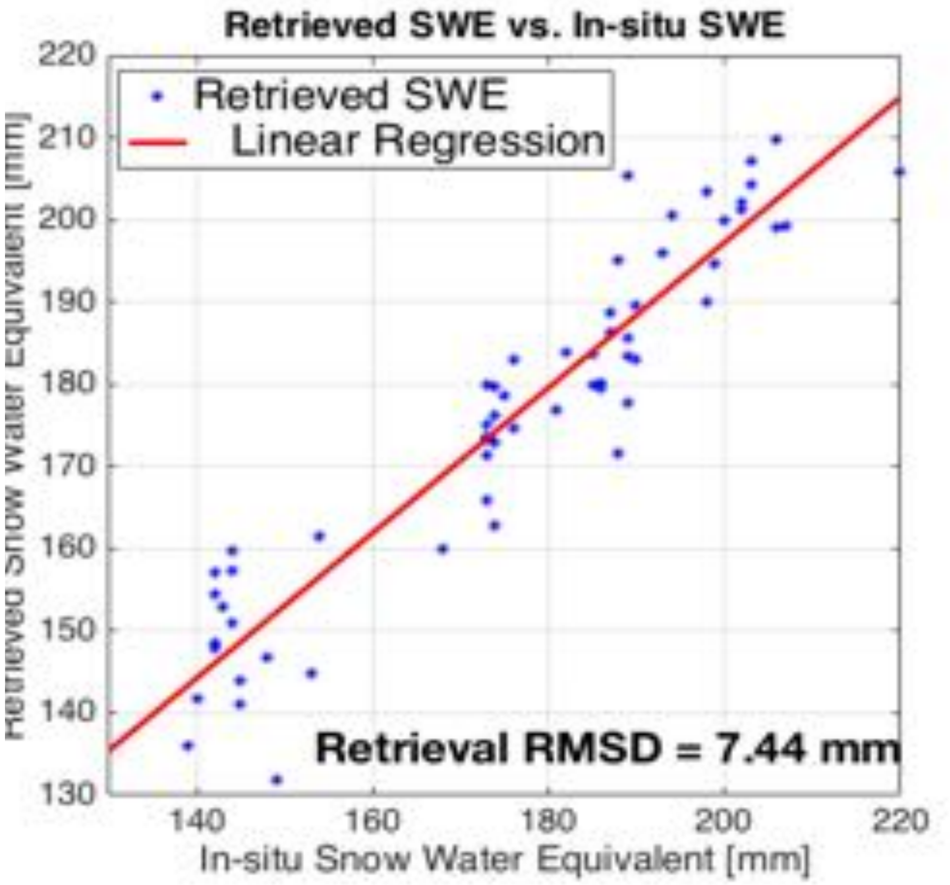




P-band SoOp Demonstrations

- Snow observations



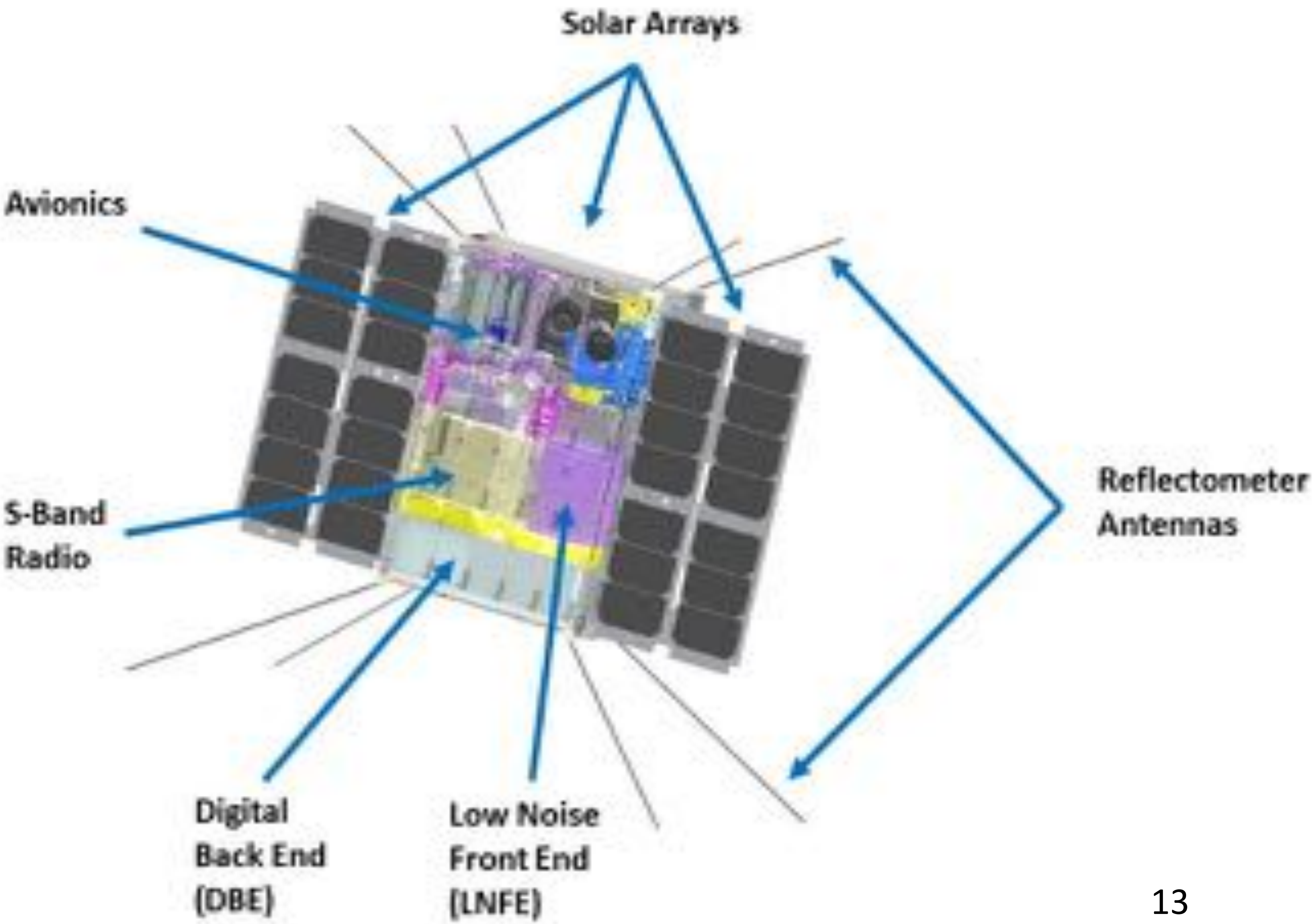


[Shah, et al., 10.1109/LGRS.2016.2636664]

SNOOPI Mission Description

- Objective – In Space Validation of the SoOp ***technique*** in P-band
- Necessity of Space validation:
  1. Demonstrate sufficient ***signal coherence*** at orbital altitudes and speeds to make phase measurement
  2. Quantify ***RFI from space*** (broad field of view, global distribution of measurements)
  3. Model prediction and instrument tracking validated for orbital delay and Doppler.

Spacecraft Overview



SNOOPI Mission Design

- Link Budget Assumptions:
  - 10 ms integration, 1 sec incoherent avg.
  - Receiver in 410 km orbit.
  - Receiver noise based on SoOp-AD

Center Freq.	240-270 MHz	360-380 MHz
Channel BW	25 kHz	5 MHz
EIRP	27 dBW	37 dBW
Orbit	GEO	GEO
# Channels Available	~10	4

SNOOPI Milestones

Project Initiation	01/19
System Requirement Review	06/19
Critical Design Review	03/20
System Integration Review	11/20
Flight Readiness Review	03/21
Deliver to Launch site	06/21
Launch	09/21
1 year mission operation	09/22

Summary

- P-Band SoOp Technique will be validated in this mission.
  - Coherence time
  - Quantify RFI measurements
  - Robustness to DDM uncertainty
- All hardware is high-TRL components
  - Digital Back End (DBE) – Cion heritage
  - Low Noise Front End (LNFE) – Miniaturized SoOp-AD. (IIP-13) instrument
  - Antennas – COTS
- SNOOPI data will be publically available
- SNOOPI mission is excited to partner with others on validation of SWE estimates from SoOp observations

Acknowledgement

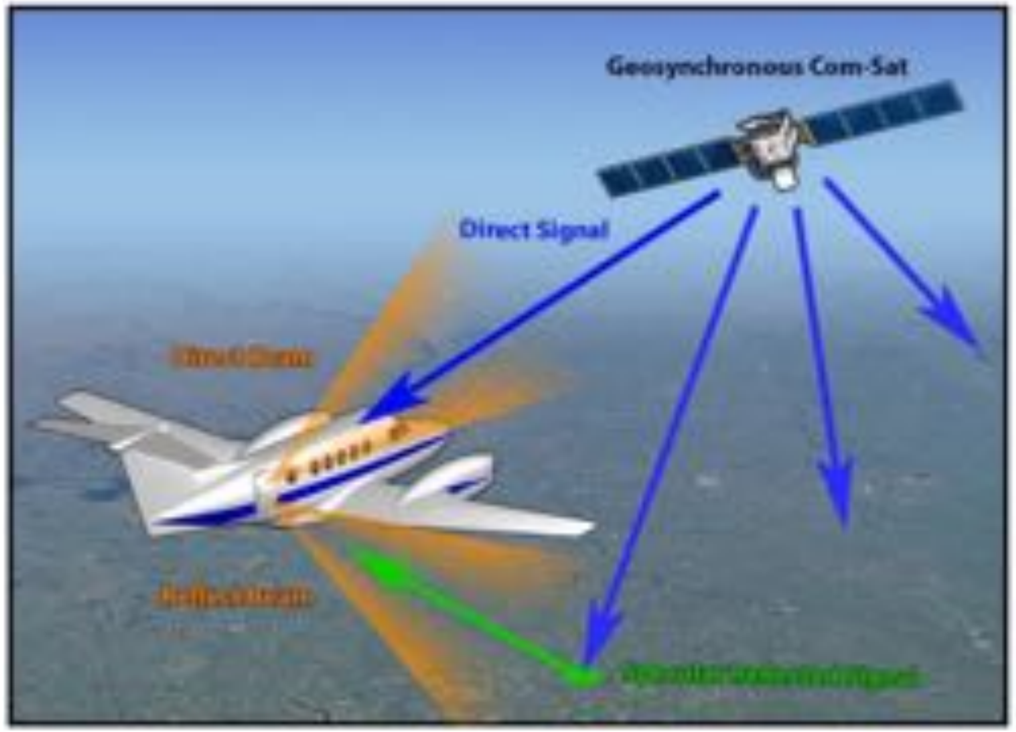
This work was supported by NASA InVEST program Grant 80NSSC18K1524, “Signals of Opportunity P-band Investigation (SNOOPI)”

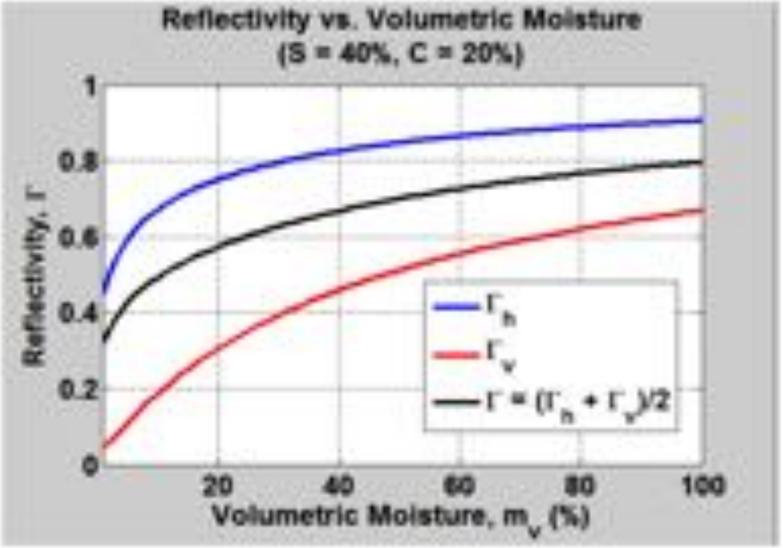
BACKUP

P-band SoOp Demonstrations

Signals of Opportunity Airborne Demonstrator (SoOp-AD)

NASA IIP-13 Selection





Parameter	SoOp Airborne	SoOp Spaceborne
Resolution*	100m	870m
Antenna Size	75 x 75 cm	75 x 75 cm
Sensing Depth	0-30cm	0-30cm
Sensing Precision**	0.04m³/m³	0.04m³/m³

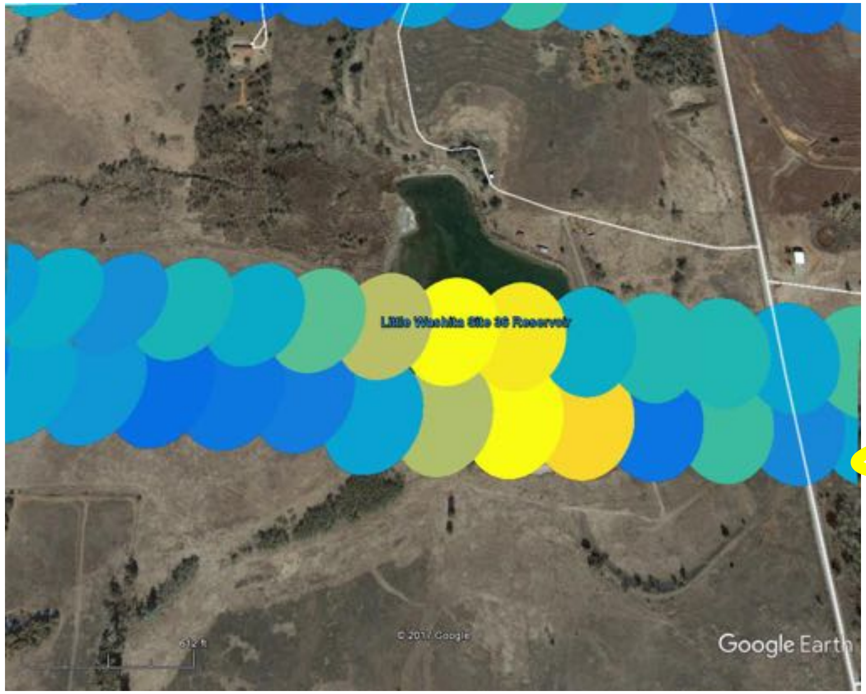
*Specular Reflection Assumed

**SMAP Requirement

P-band SoOp Demonstrations

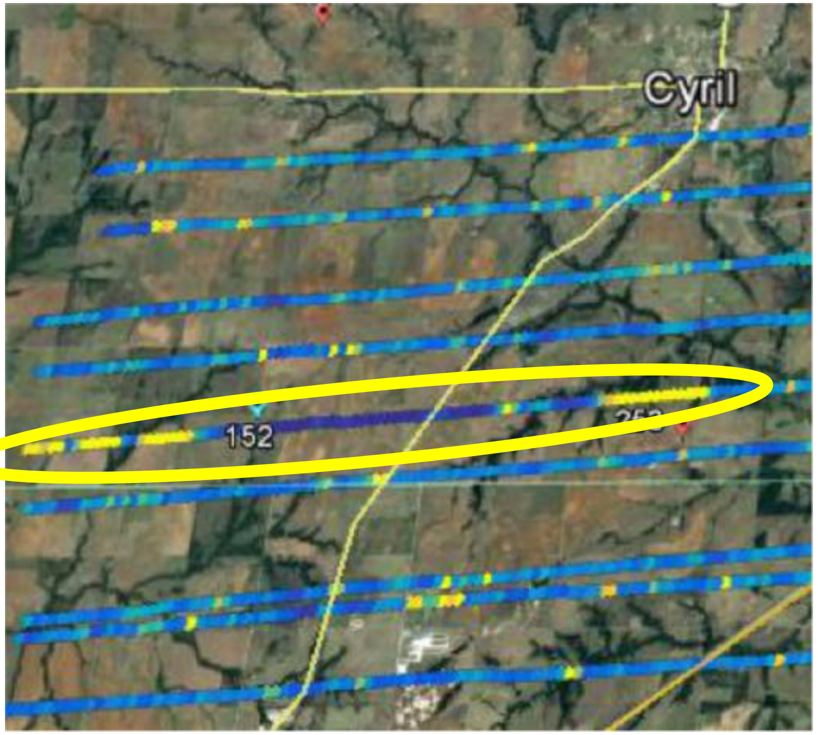
- Signals of Opportunity Airborne Demonstrator (IIP-13)

Strong Response over water



Resolution approximately

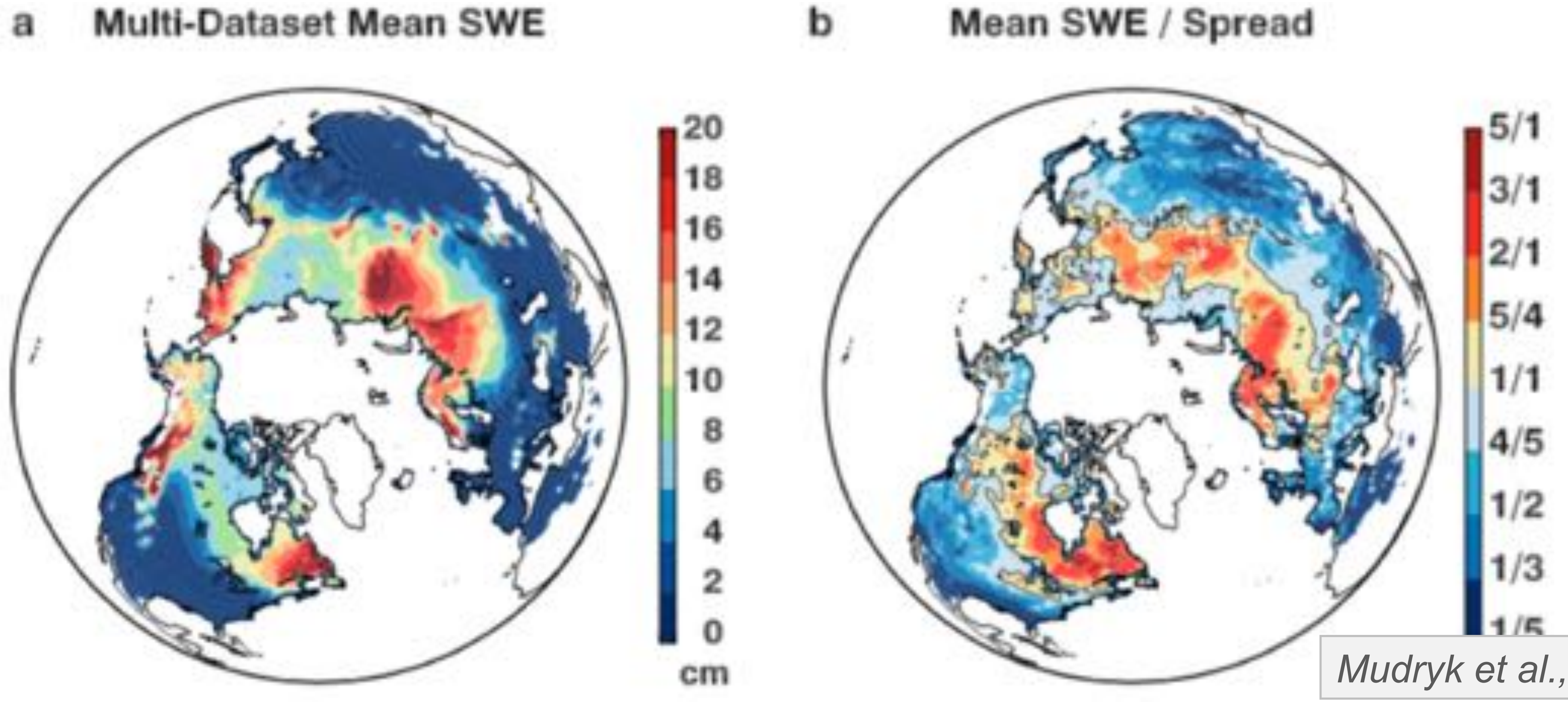
First Fresnel zone



Possible RFI ?

Motivation: Snow Water Equivalent

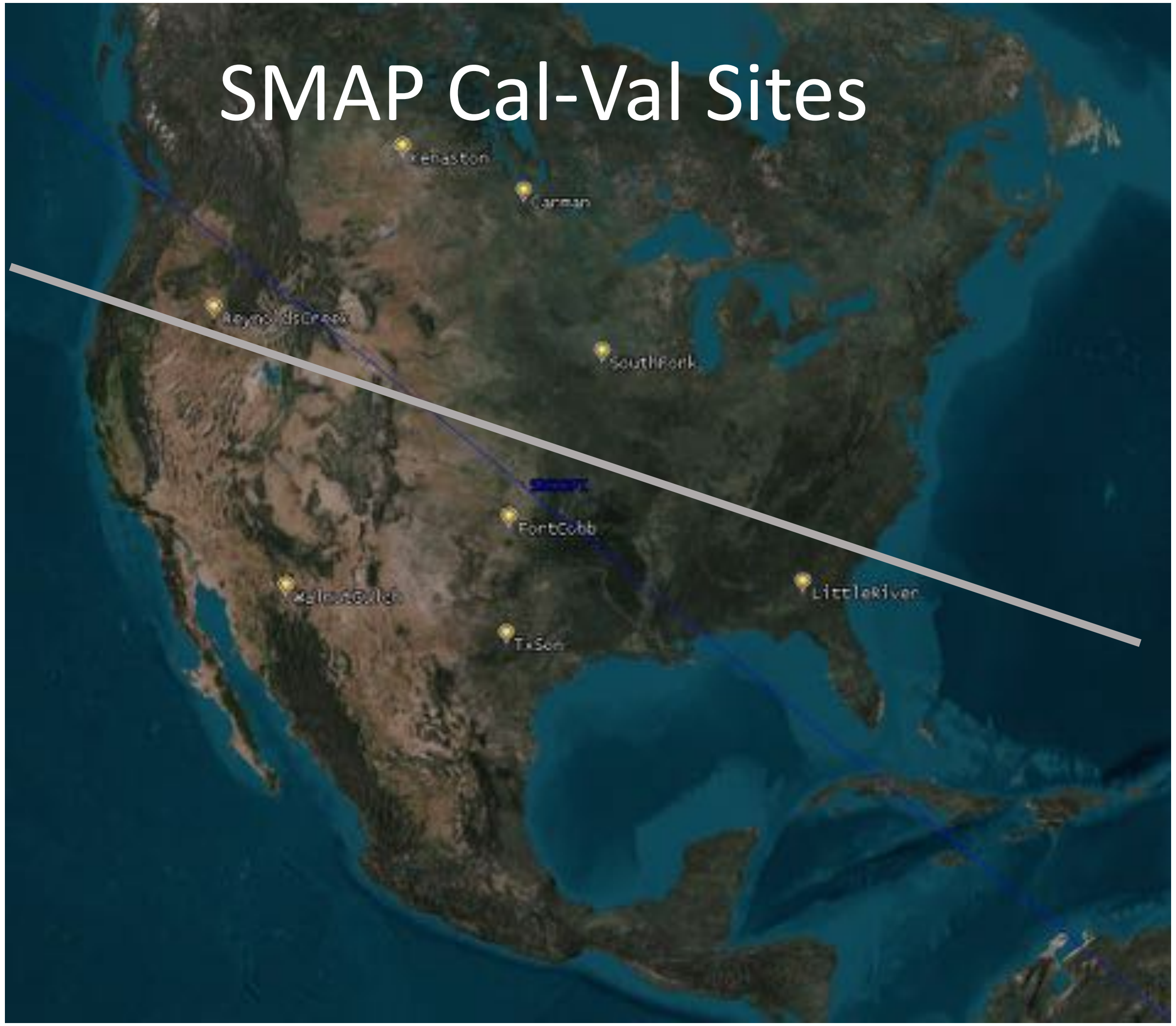
- SWE estimates from multi-frequency microwave

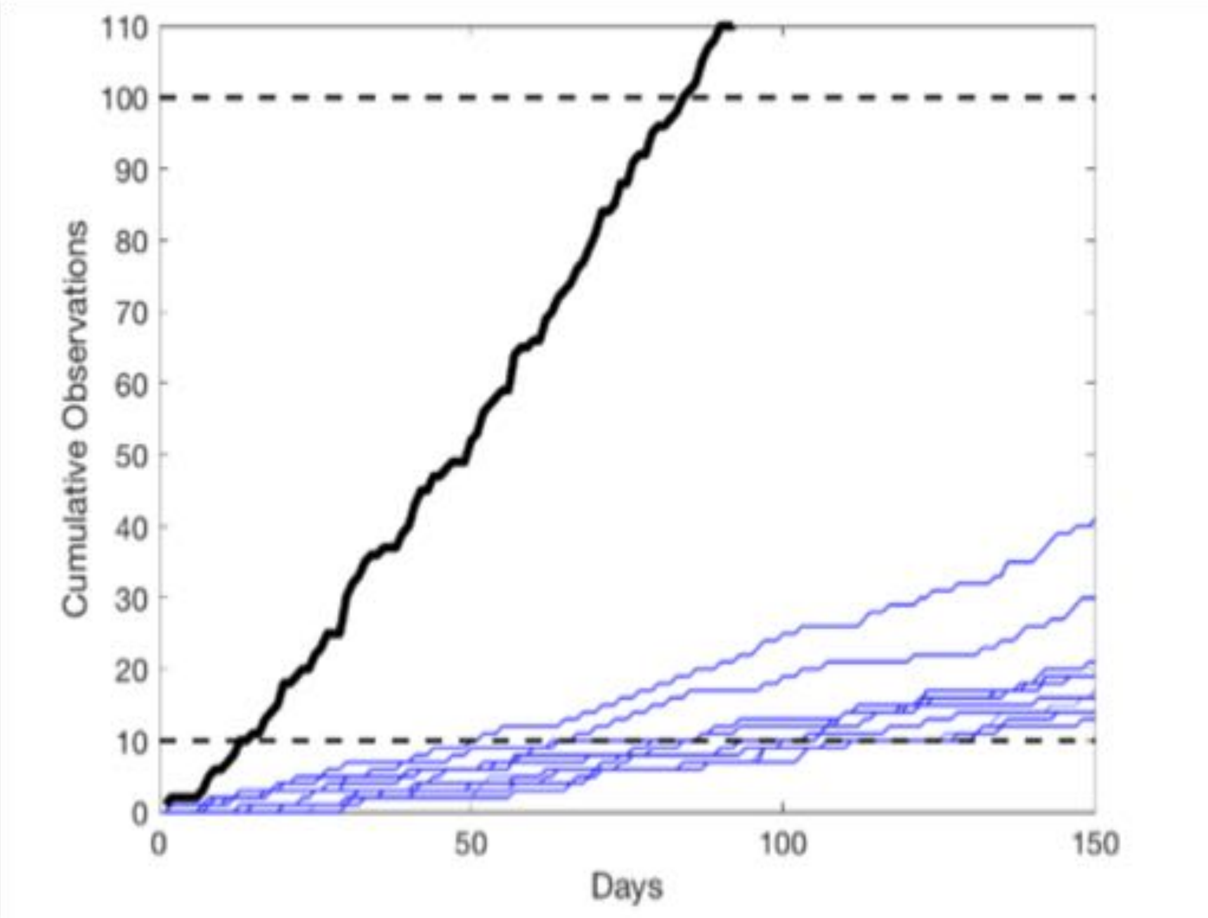


Mudryk et al., 2015

- Model spreads of -50% to 250%, - common in mid-latitude regions

SNOOPI Mission Design



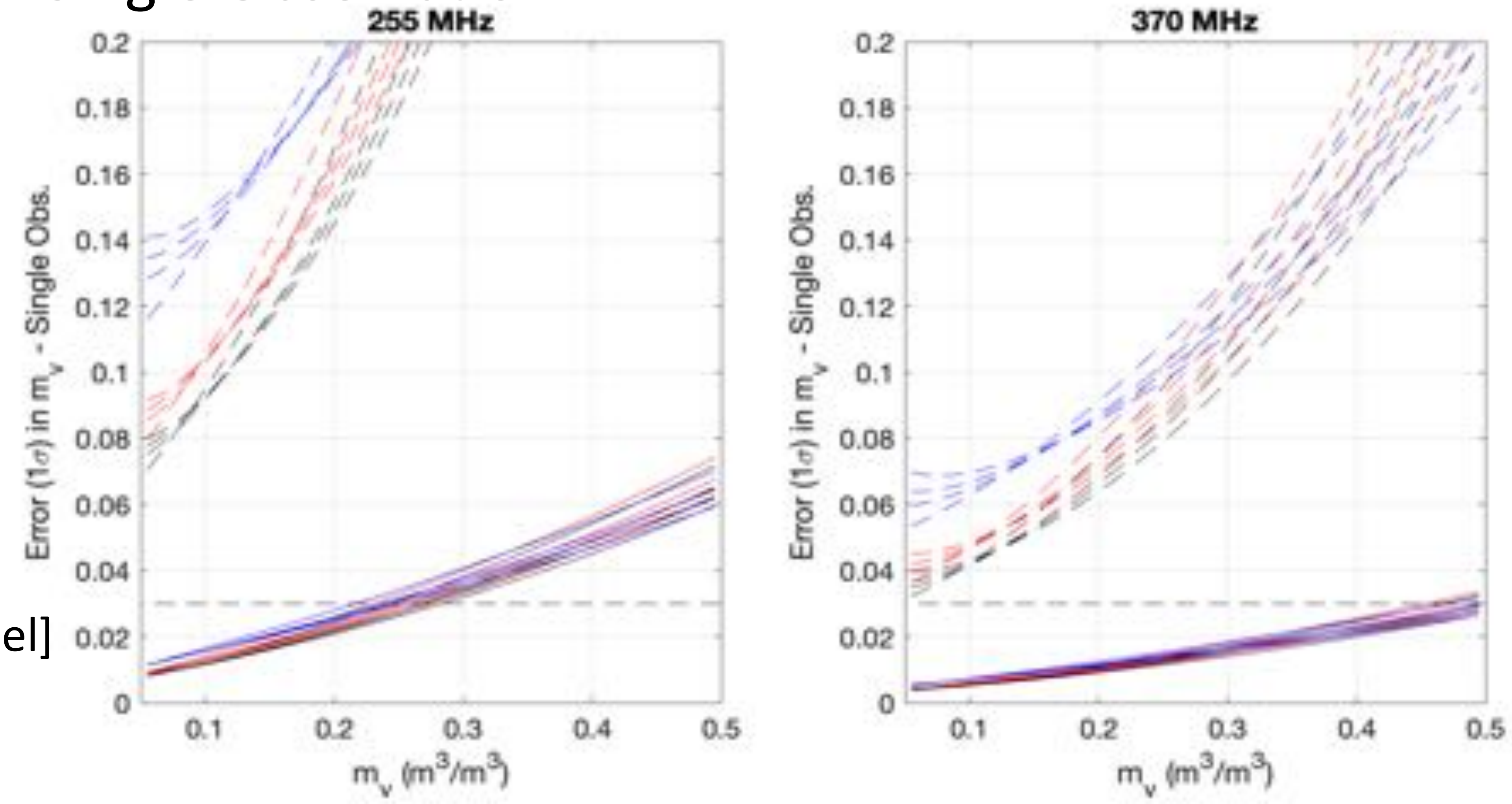


SNOOPI Mission Design

- SMC Error in Single Observation

0 deg
50 deg
70 deg.

[4 soil types from Peplinski, 1995 model]



SNOOPI Mission Design

- SMC Error: 1 sec avg. over SNOOPI Channels

0 deg
50 deg
70 deg.

[4 soil types from Peplinski, 1995 model]