SigNals Of Opportunity P-band Investigation (SNOOPI): In-Space Validation of Reflectometry from 240-380 MHz

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Specialist Meeting on Reflectometry using GNSS and other Signals of Opportunity (IEEE GNSS+R 2019)
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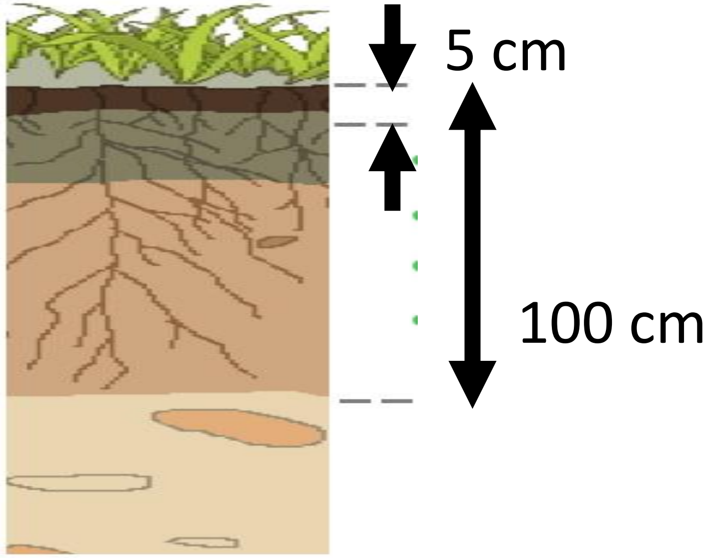
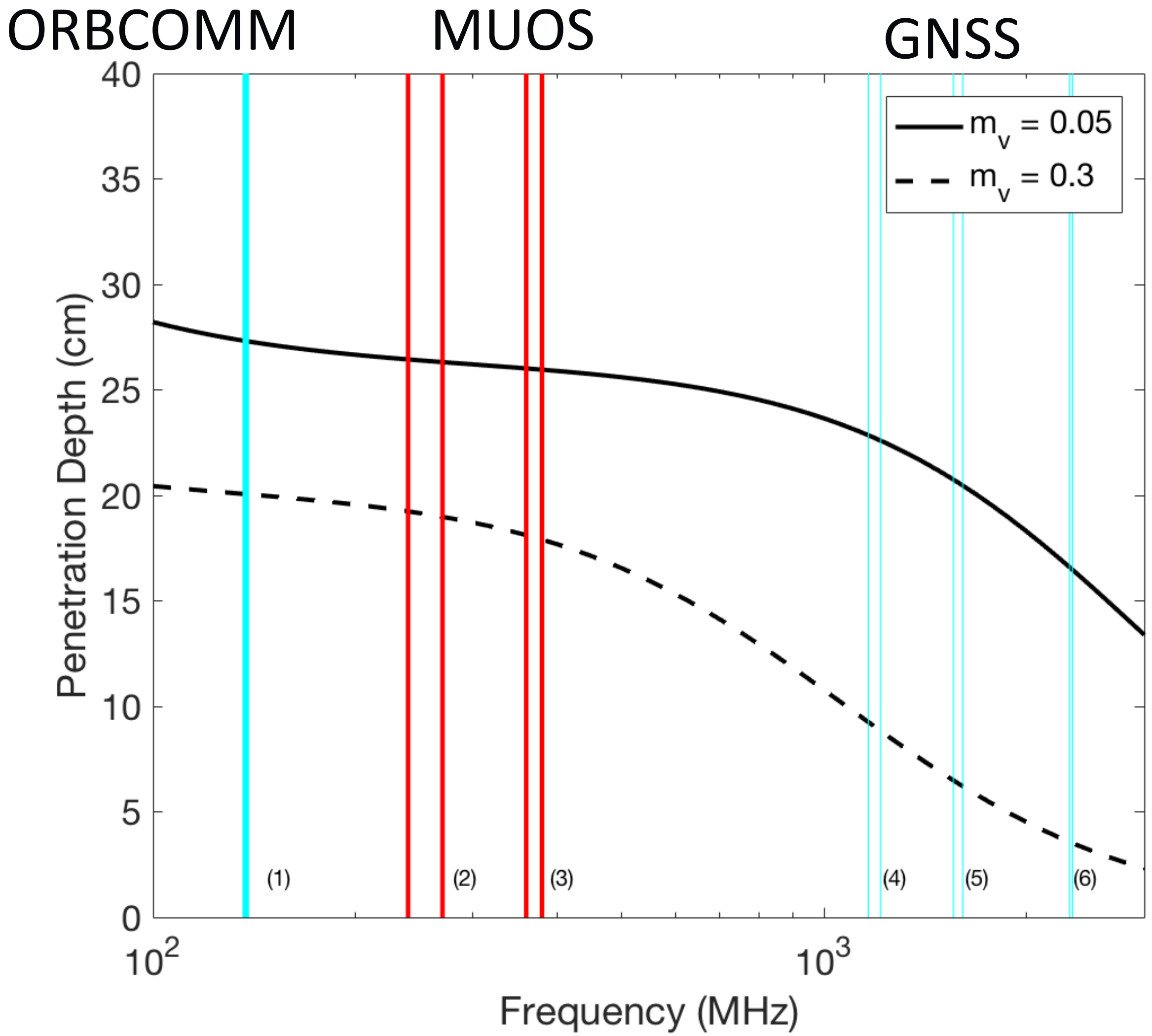
Outline

- Motivation: P-band Signals of Opportunity (SoOp)
- SNOOPI Mission description
- Instrument Heritage
- Mission Design
- Project Organization
- Conclusion

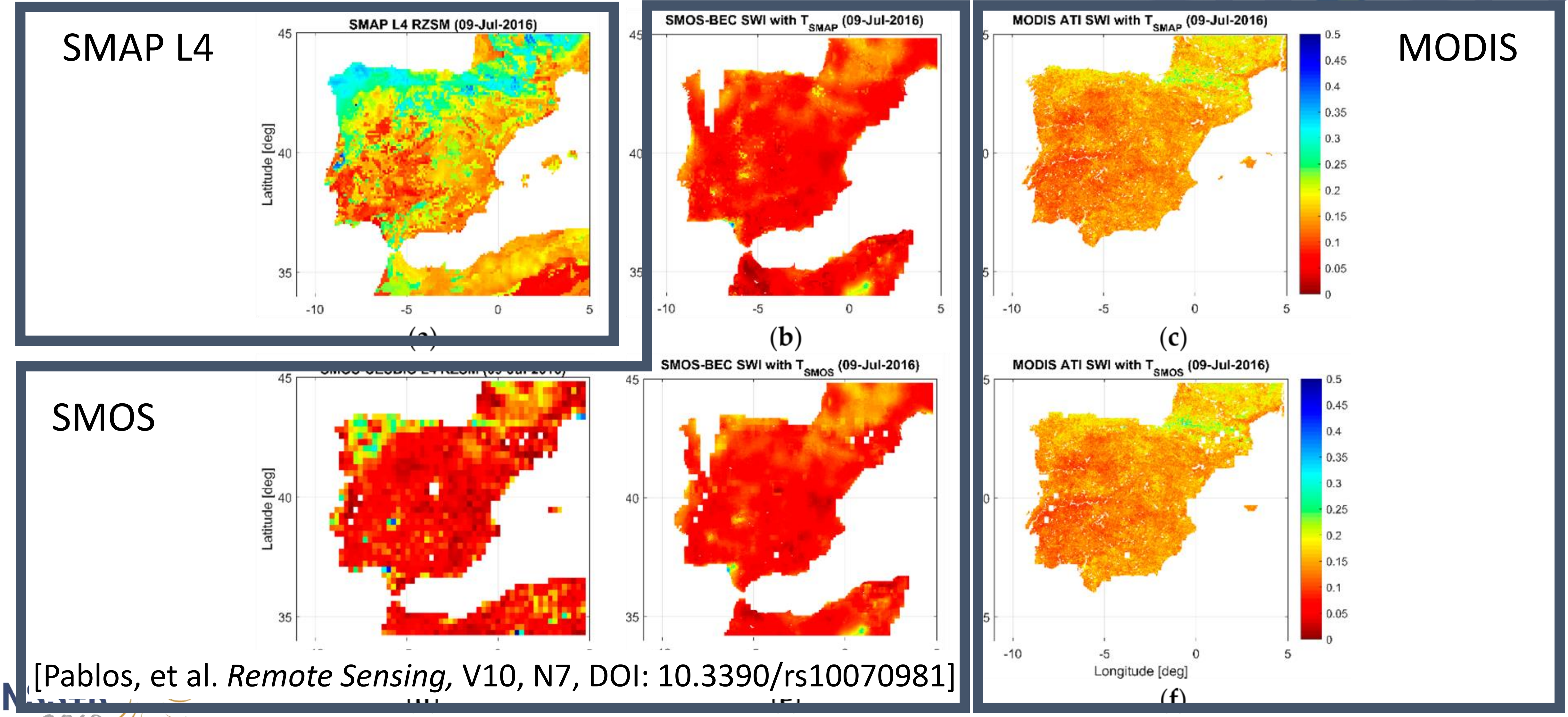
Motivation: Root-Zone Soil Moisture

- Water content in 0-1 m of soil
- Depth of absorption by plants
- L-band penetration ~5 cm
- L4 RZSM data products from assimilation





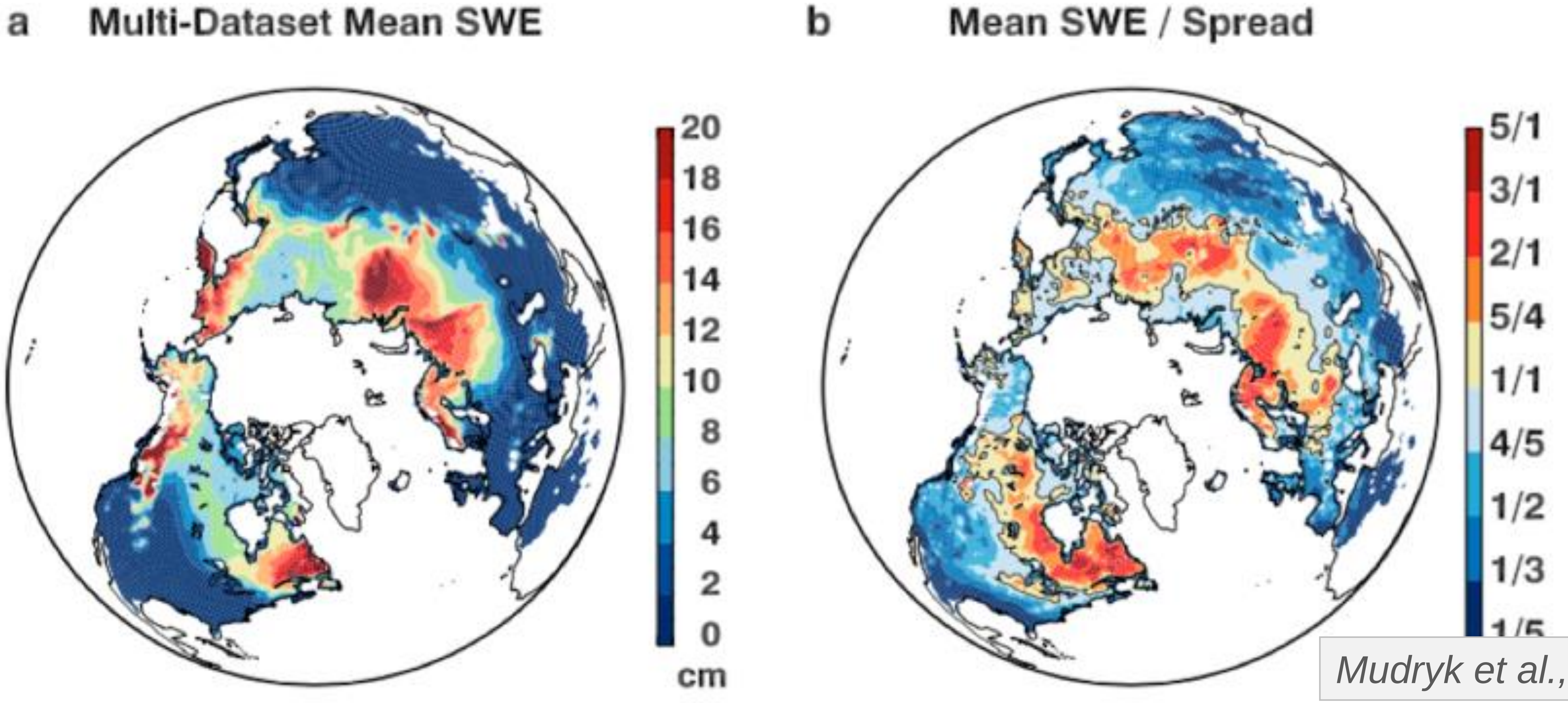
Motivation: Root-Zone Soil Moisture



[Pablos, et al. *Remote Sensing,* V10, N7, DOI: 10.3390/rs10070981]

Motivation: Snow Water Equivalent

- SWE estimates from multi-frequency microwave

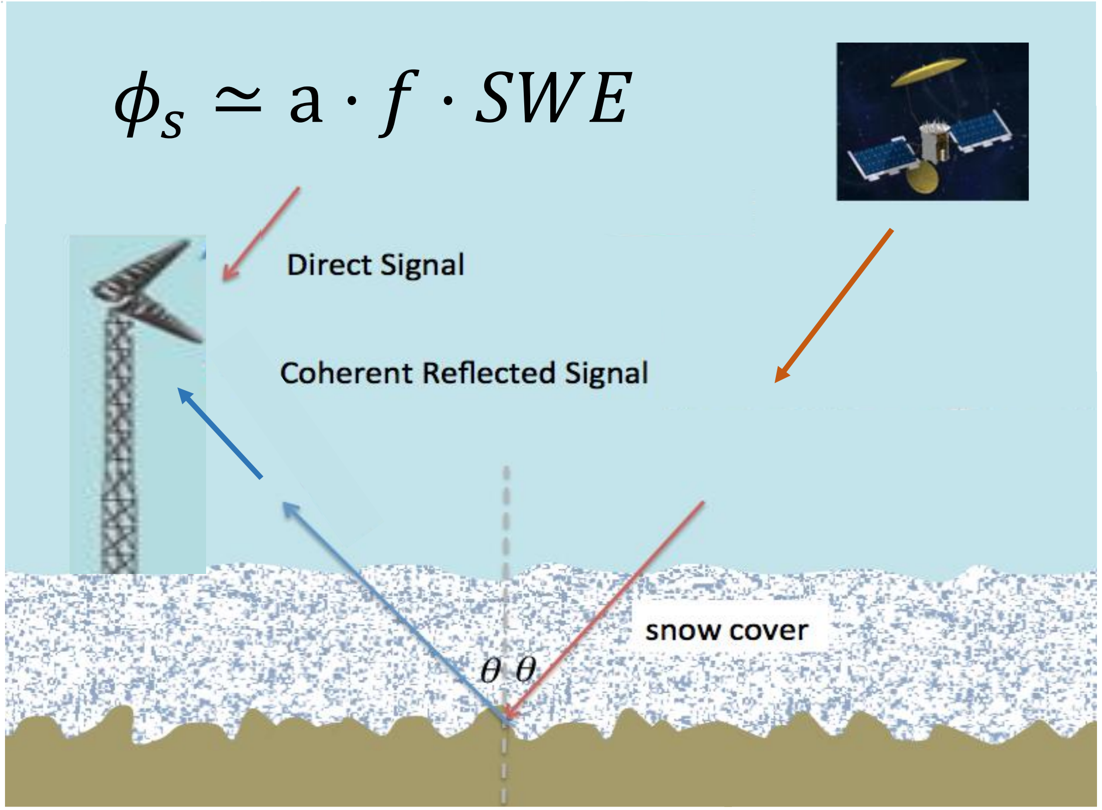


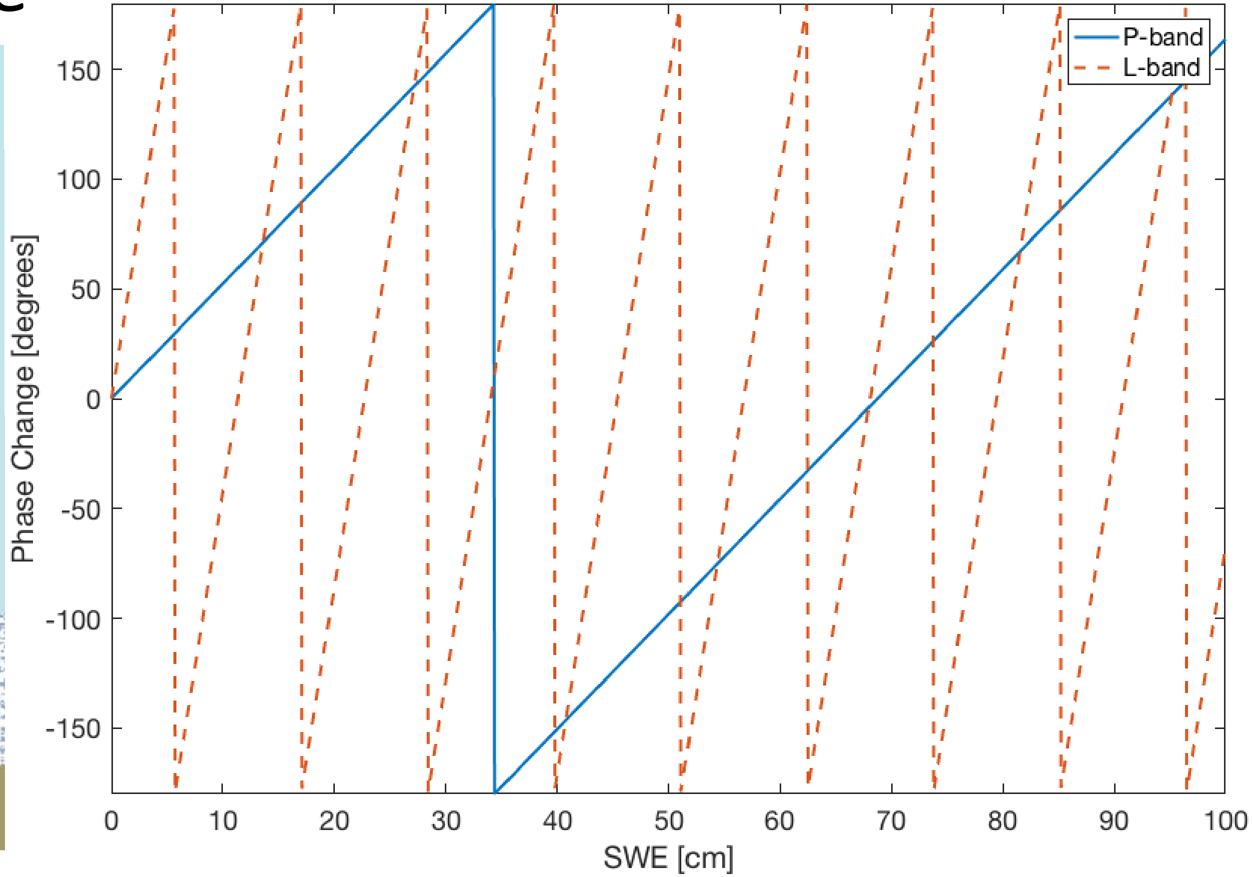
Mudryk et al., 2015

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

Motivation: Snow Water Equivalent

- SWE retrieval from SoOp phase

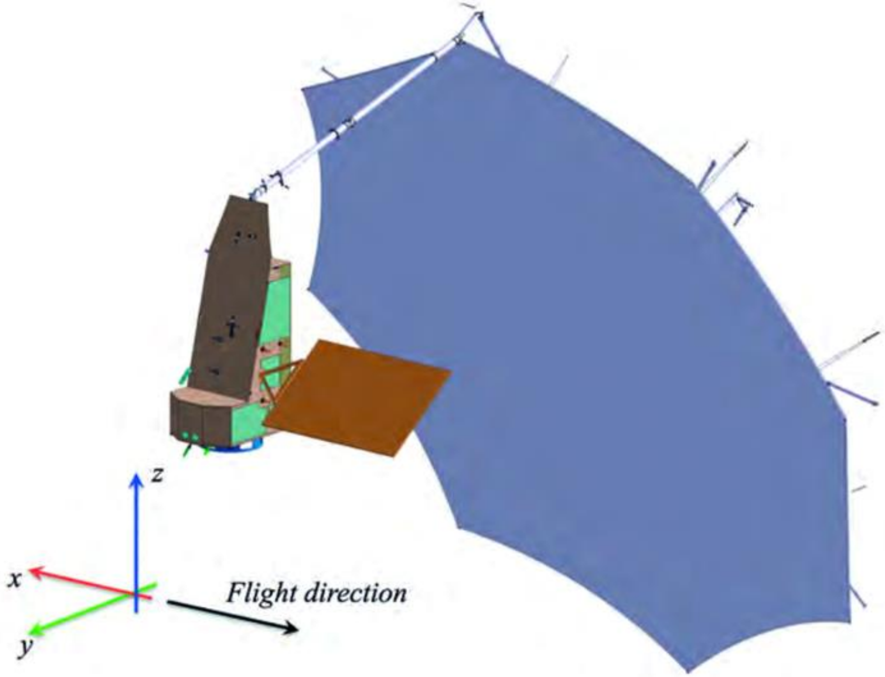




- Long (~1m) P-band wavelength – increase phase wrapping interval

Problems in Sensing <500 MHz

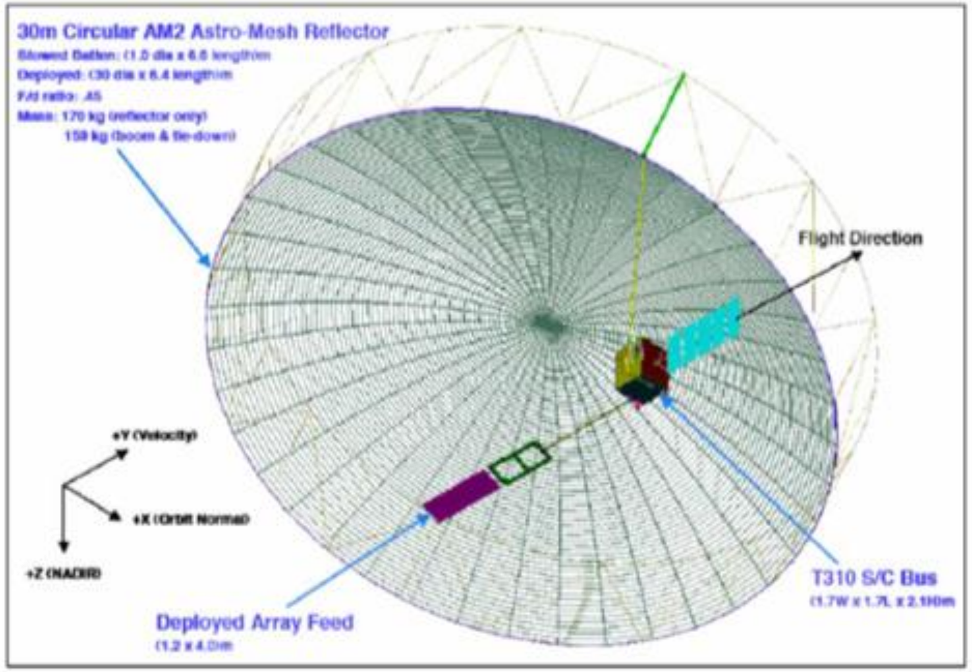
ESA-BIOMASS



12-m Large Deployable Reflector (LDR)

435 MHz Operations prohibited over N. America and Europe due to Space Objects Tracking Radar (SOTR) [ESA SP-132, 2010]

Microwave Observatory of Subcanopy and Subsurface (MOSS)



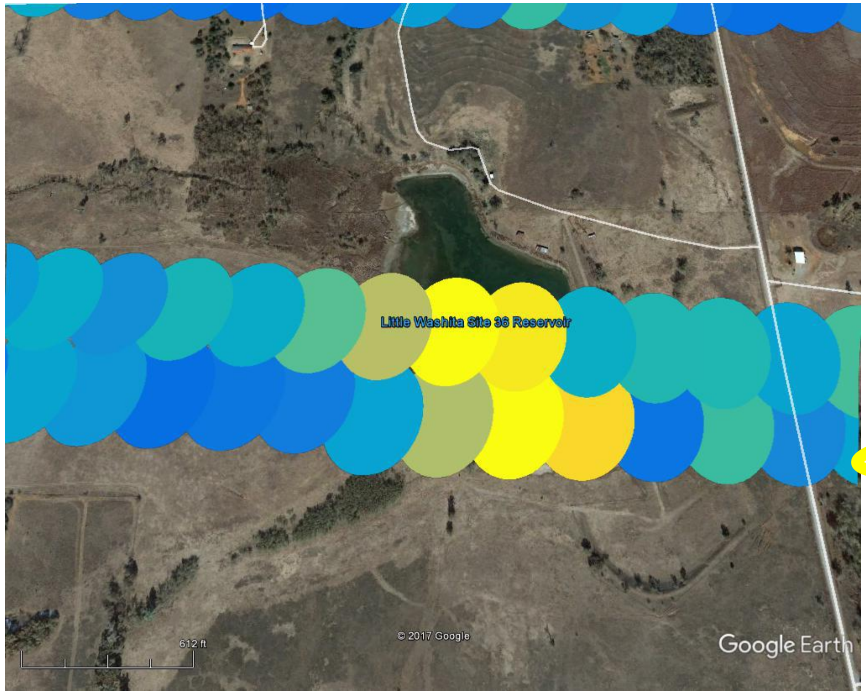
Concept: 30-m deployable antenna (435/137 MHz).

[Moghaddam, et al. TGARS V 45, N 8, 2007, DOI:10.1109/TGRS.2007.898236]

P-band SoOp Demonstrations

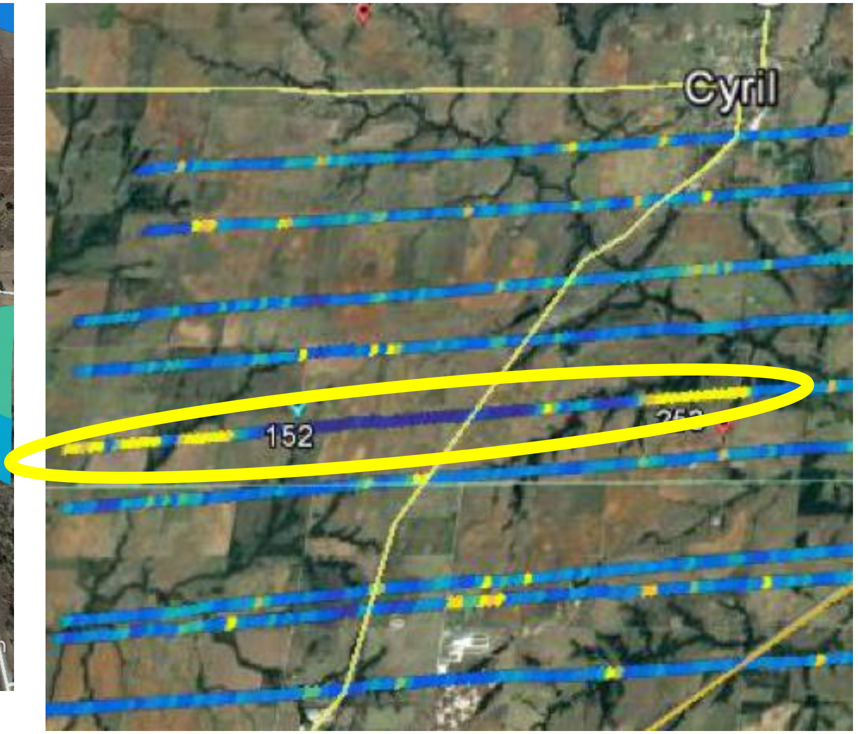
- Signals of Opportunity Airborne Demonstrator (IIP-13)

Strong Response over water



Resolution approximately

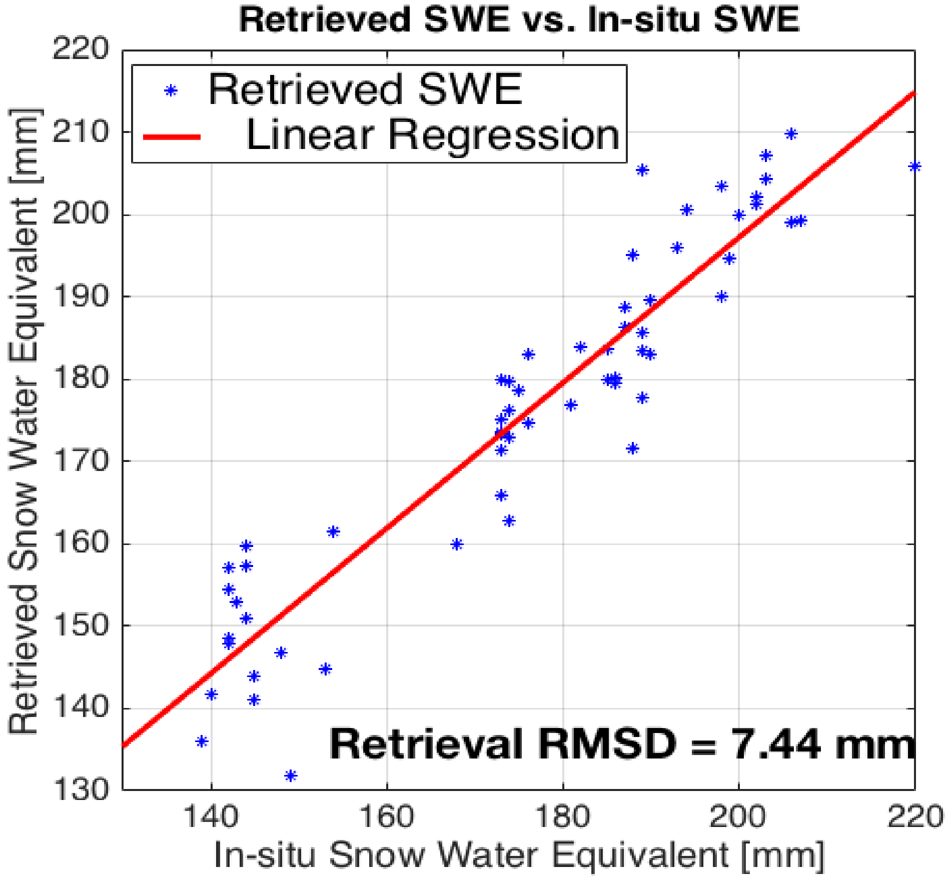
First Fresnel zone

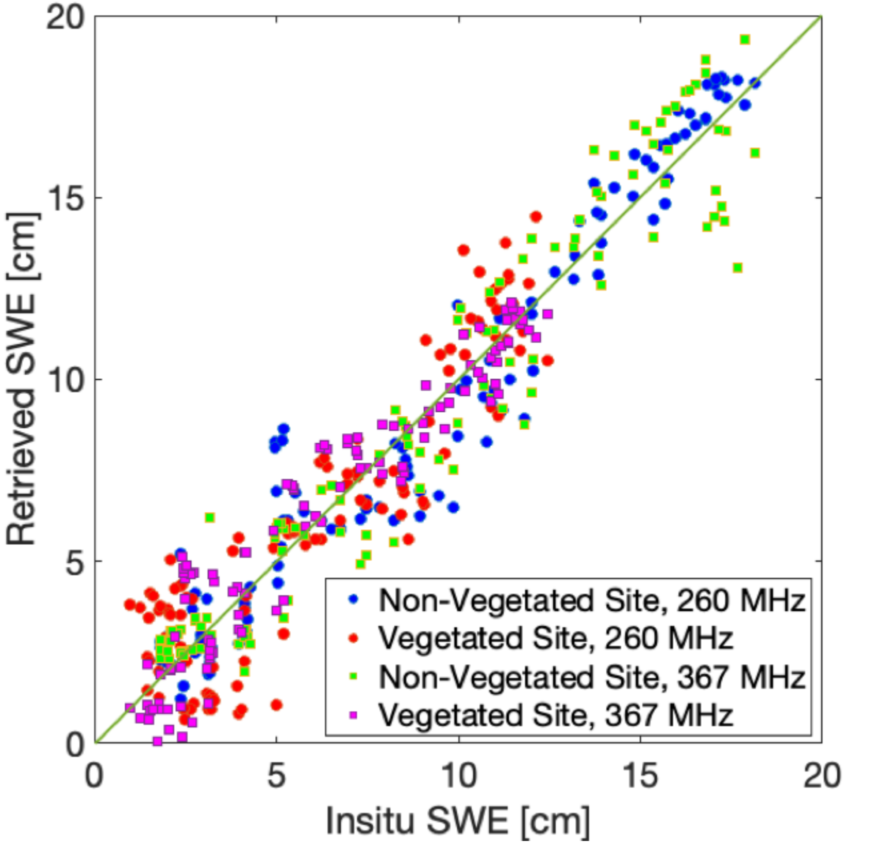


Possible RFI ?

P-band SoOp Demonstrations

- Snow observations (JPL RTD)





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

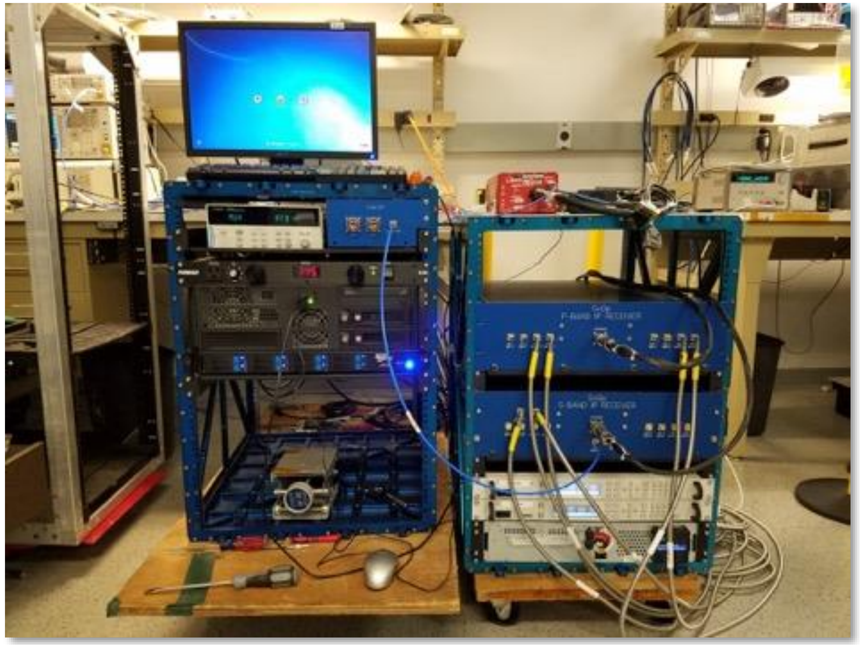
Presentation 12:30 Weds

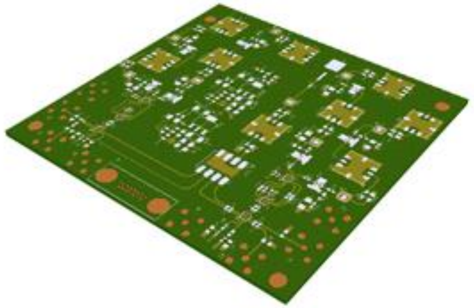
SNOOPI Mission Description

- 2018 InVEST Selection
- 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.

SNOOPI Instrument Heritage

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



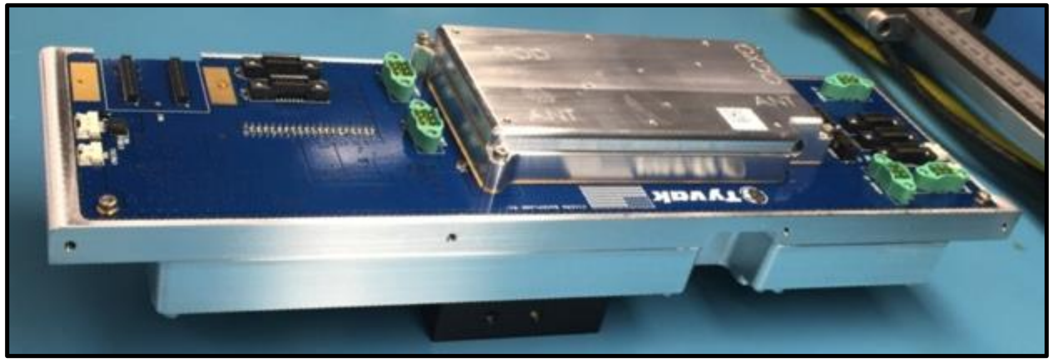


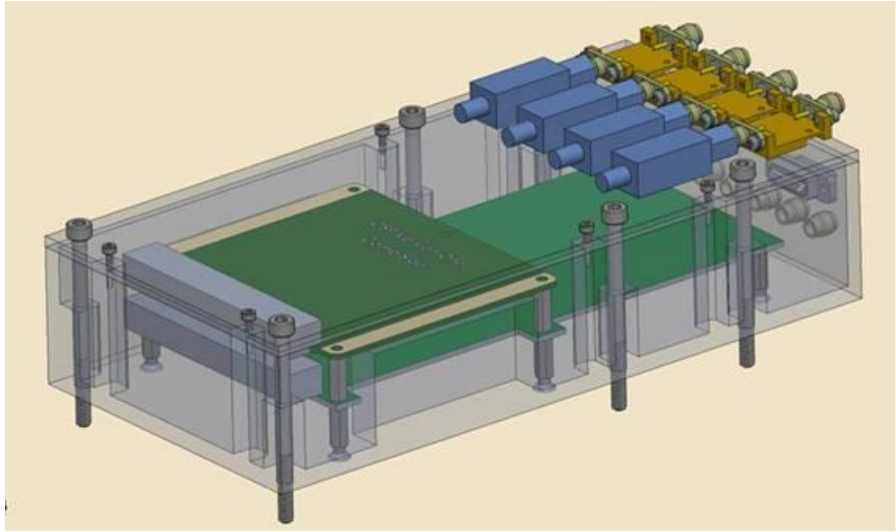
RFE CAD model

Prototype during population

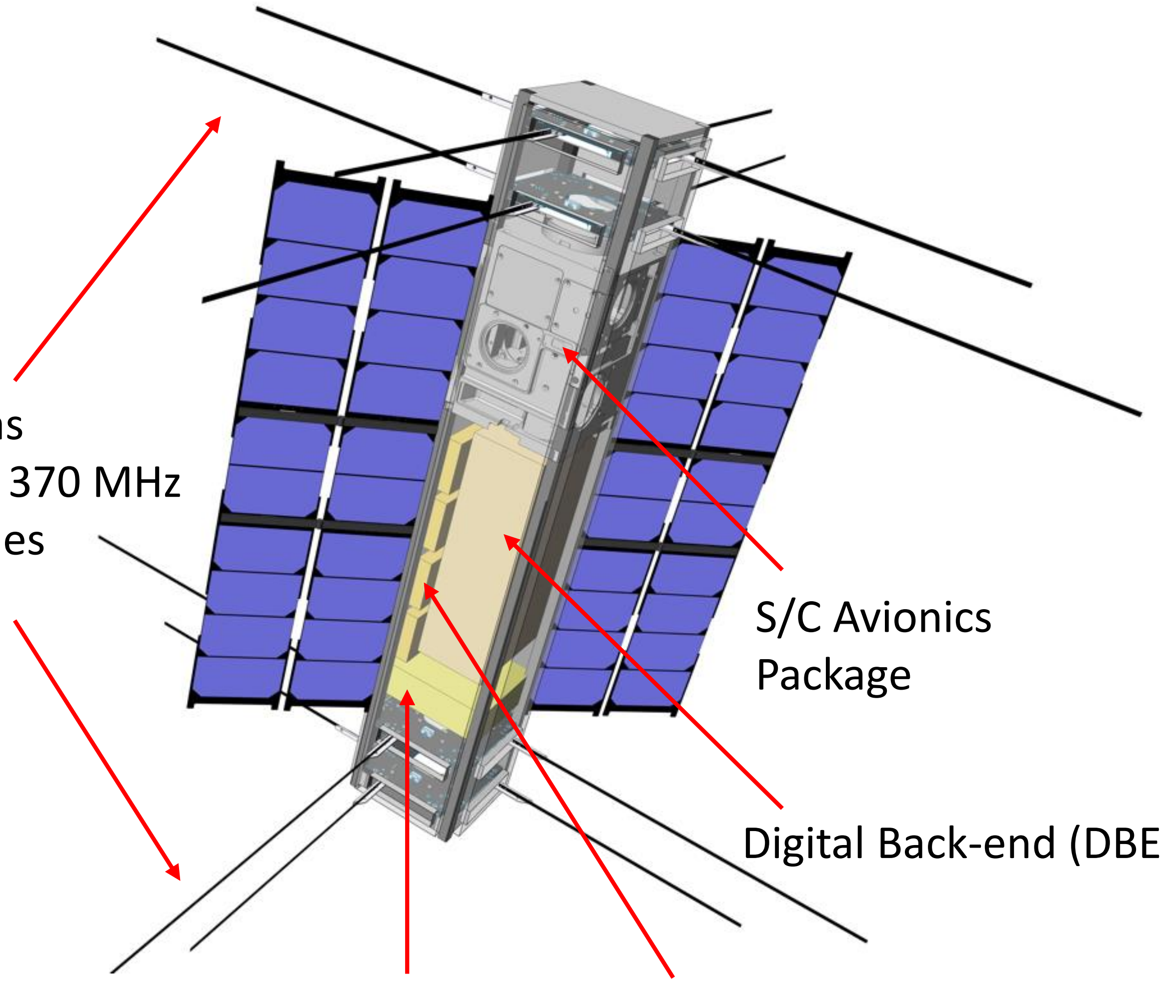
SNOOPI Instrument Heritage

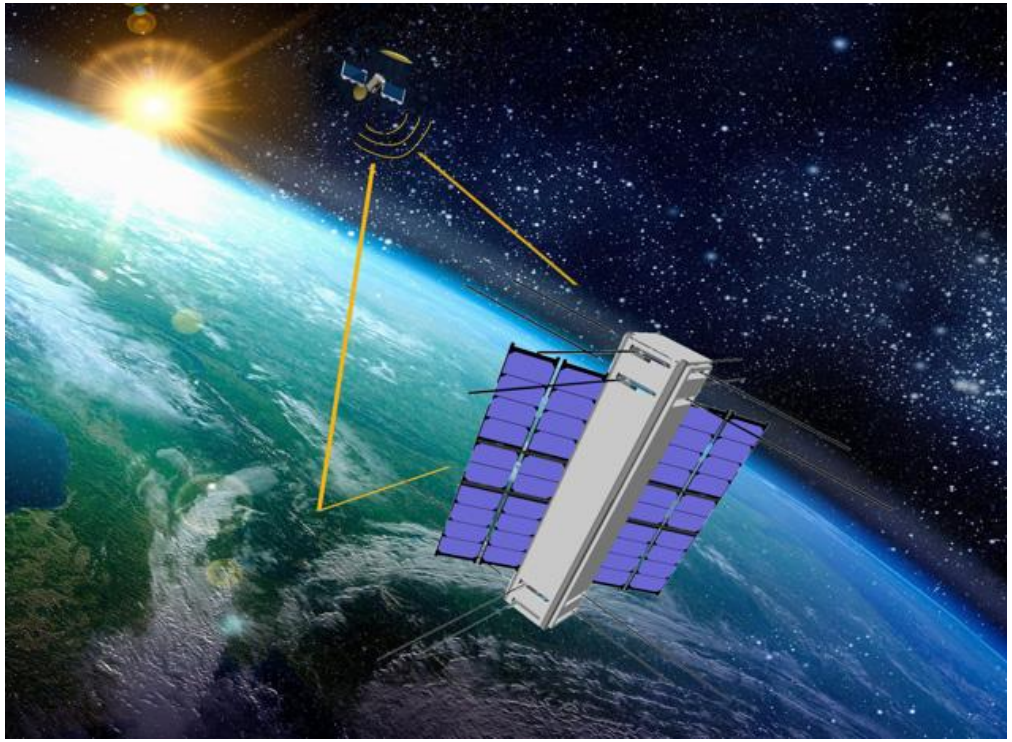
- Digital Back End (DBE): NASA JPL
  - Based on Cion GNSS receiver for Tyvak / CICERO (TRL-8)
  - Changes:
    - Off-the-Shelf Rad-tolerant high-rel CSP computer (TRL 8)
    - P-band capability
  - Leverag existing projects (SunRISE and GNSSPro)





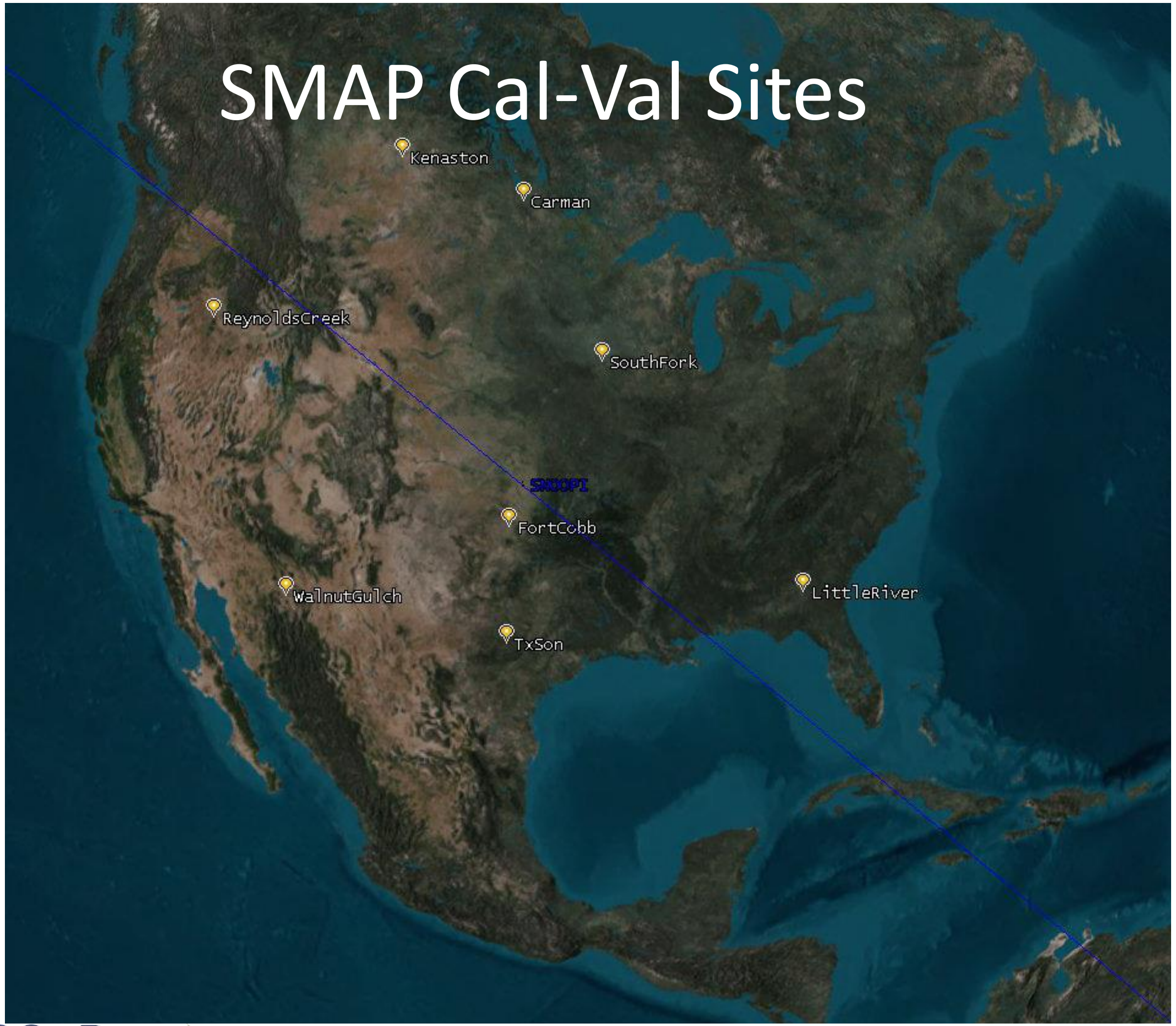
SNOOPI Mission Design

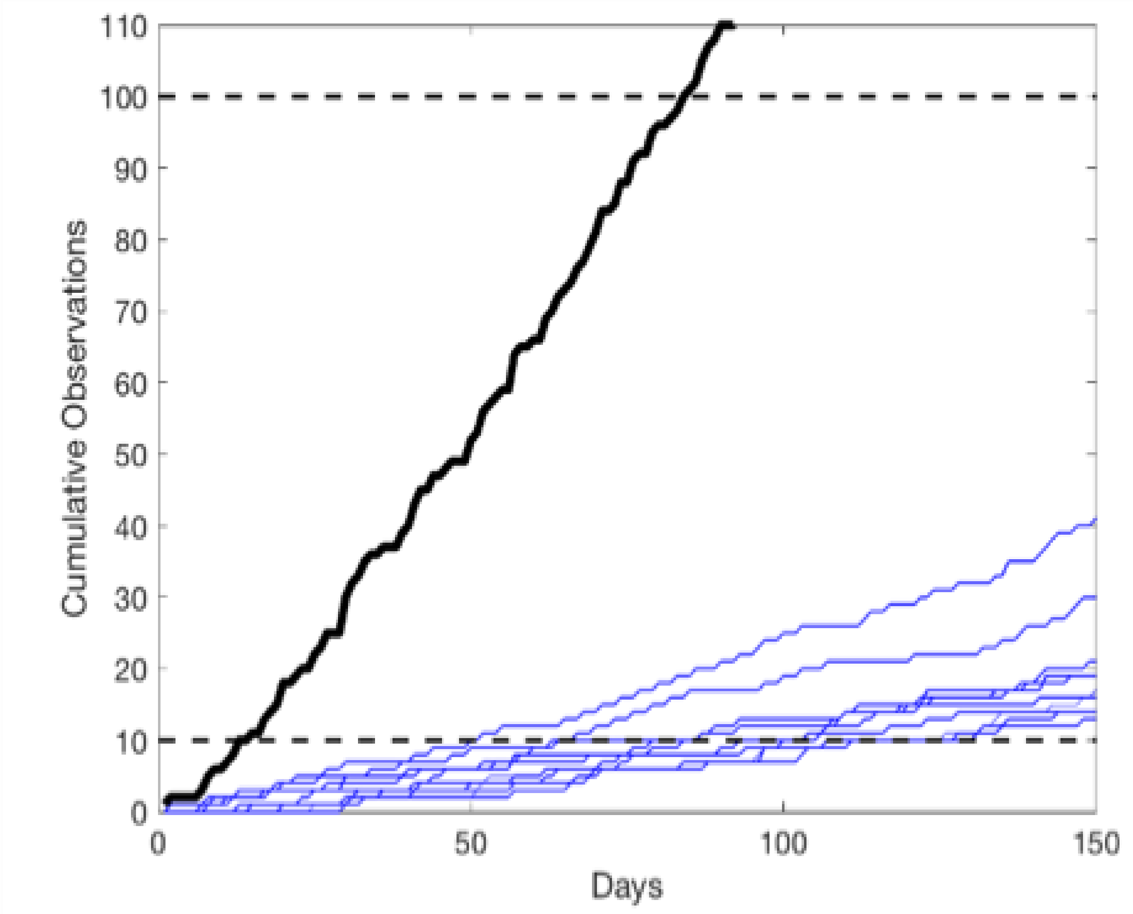




Notional rendition of SNOOPI in orbit.

SNOOPI Mission Design





SNOOPI Mission Design

- Link budget Assumptions:
  - 10 ms integration, 1 sec incoherent avg.
  - Receiver in 410 km orbit.
  - Soil moisture requirement: 0.03 m^3/m^3
  - Receiver noise figure based on SoOp-AD

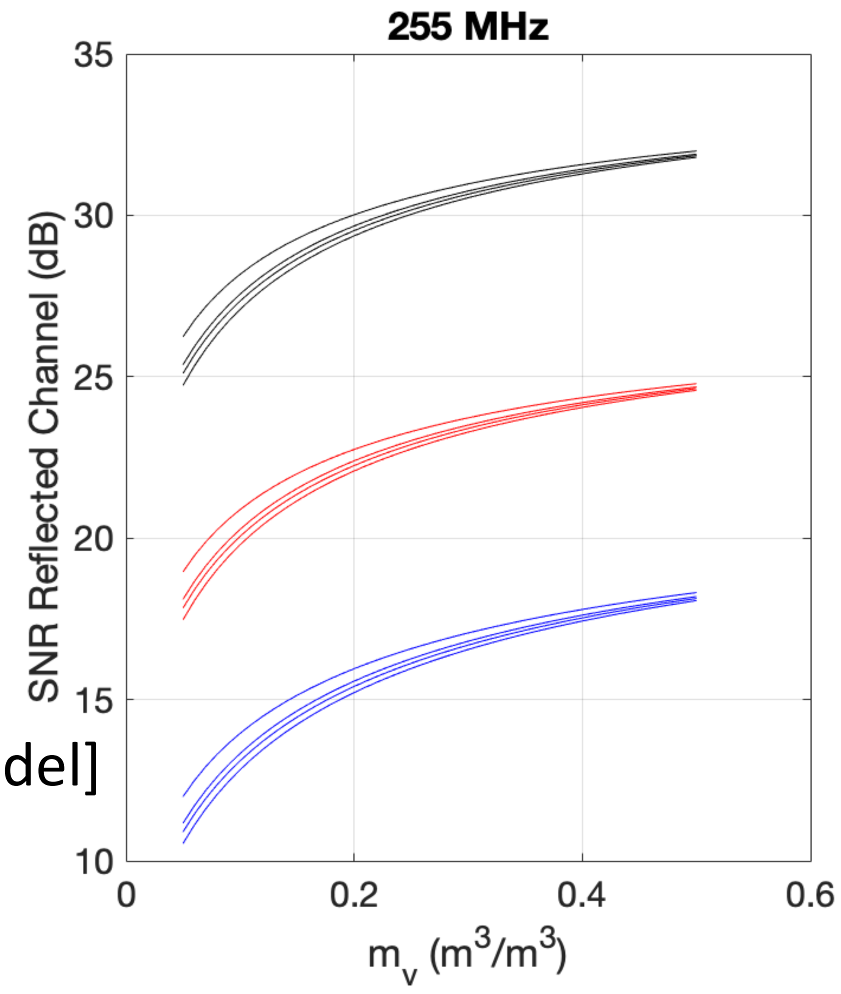
Center Freq.	**240-270 MHz**	**360-380 MHz**
Channel BW	25 kHz	5 MHz
EIRP	27 dBW	37 dBW
Orbit	GEO	GEO
# Channels Available	~10	4

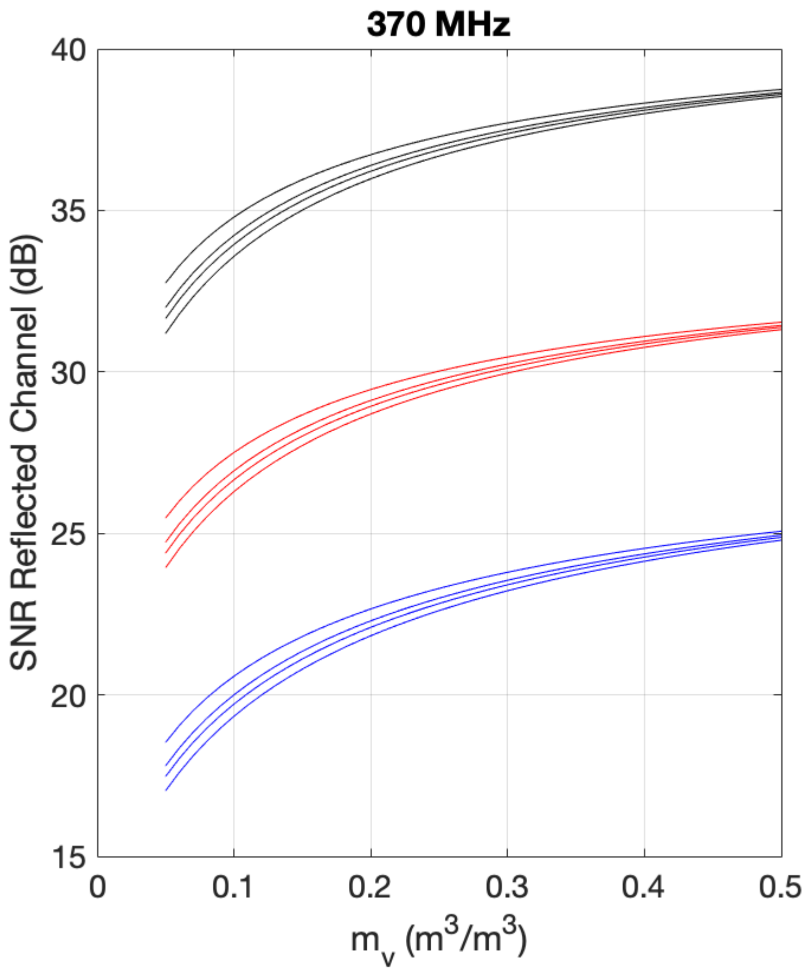
SNOOPI Mission Design

- Post-correlation SNR

0 deg
50 deg
70 deg.

[4 soil types from Peplinski, 1995 model]



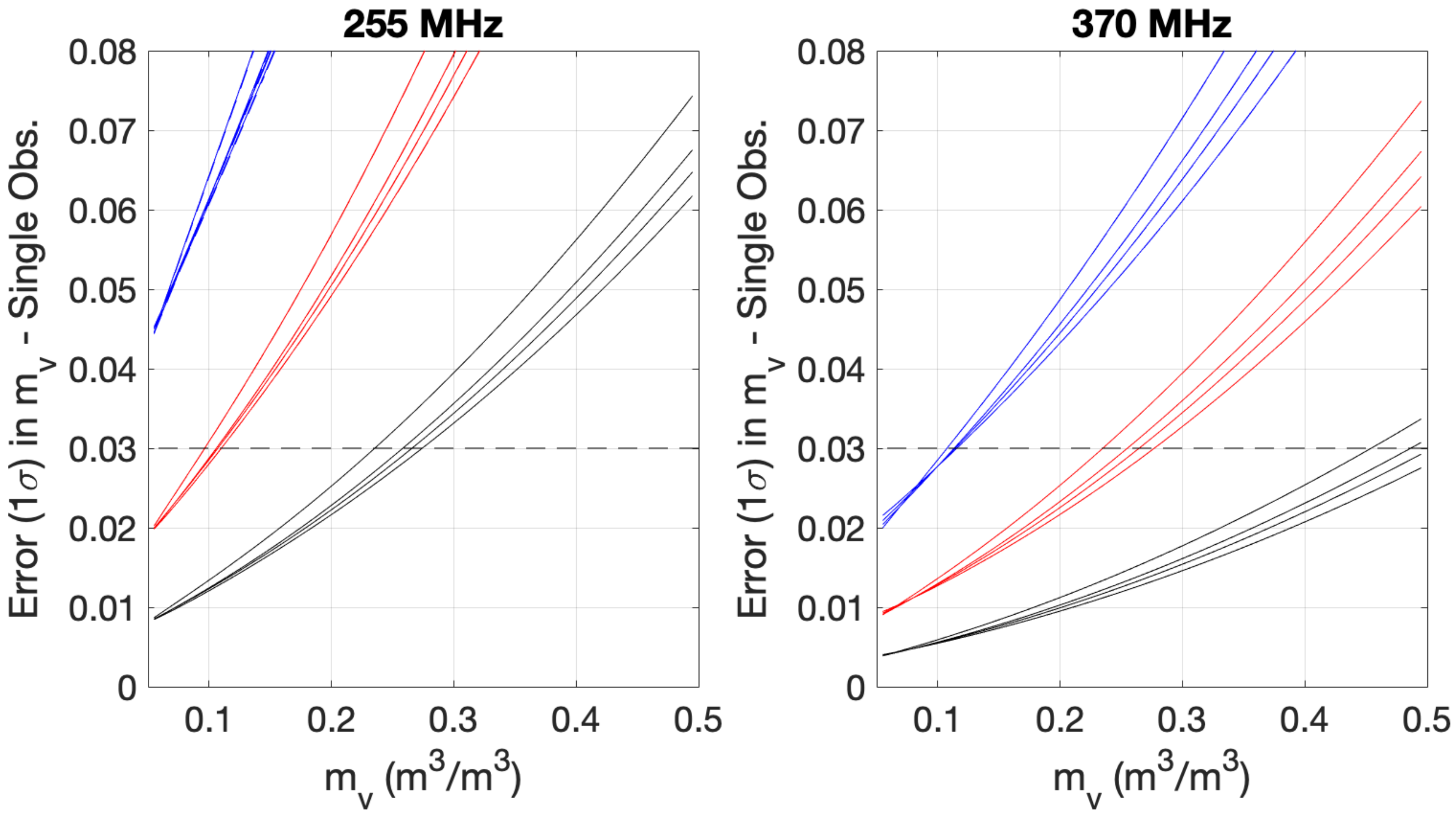


SNOOPI Mission Design

- SMC Error in Single Observation

0 deg
50 deg
70 deg.

[4 soil types from
Peplinski, 1995 model]

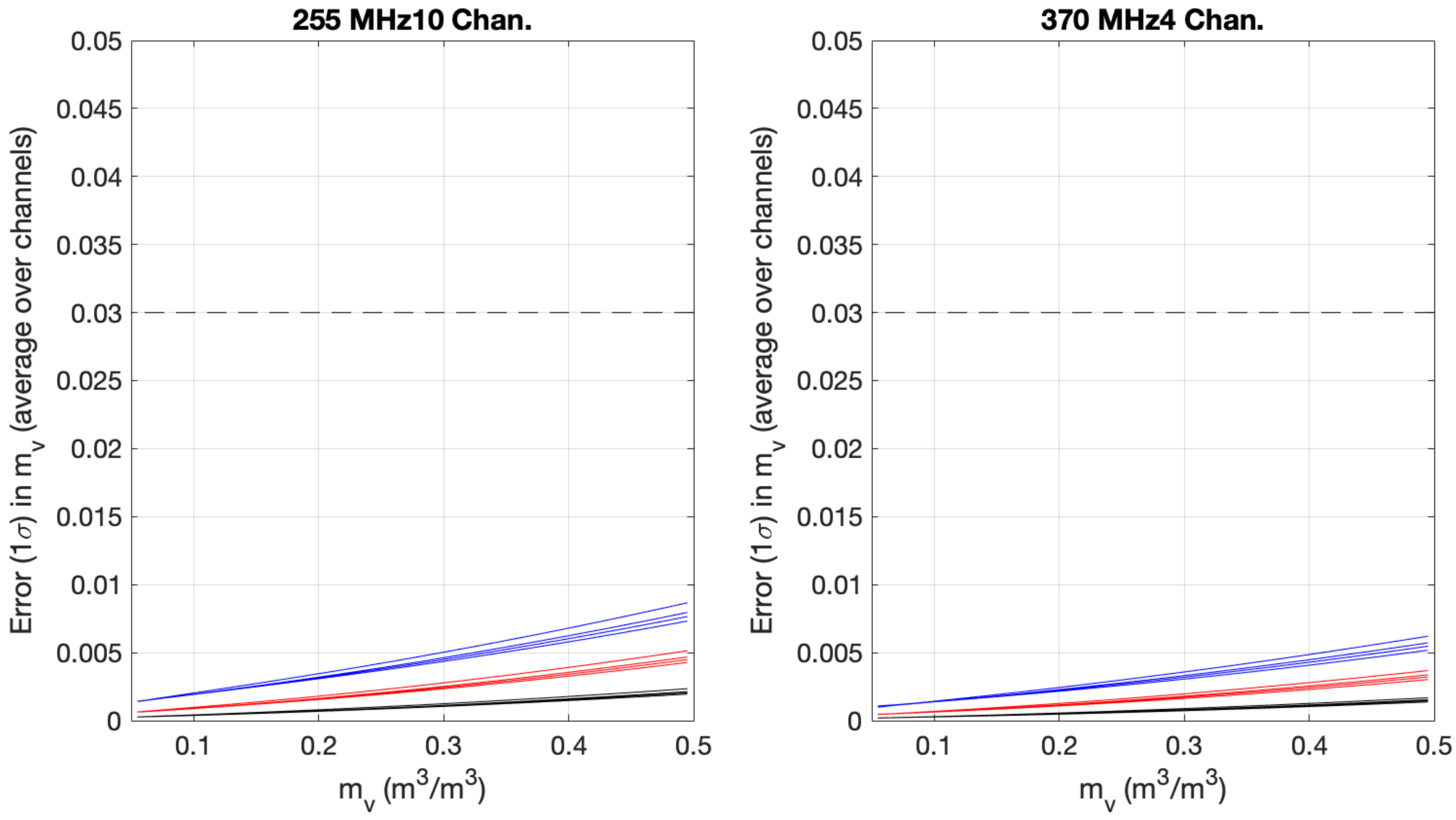


SNOOPI Mission Design

- SMC Error: 1 sec avg. over all Channels

0 deg
50 deg
70 deg.

[4 soil types from
Peplinski, 1995 mo

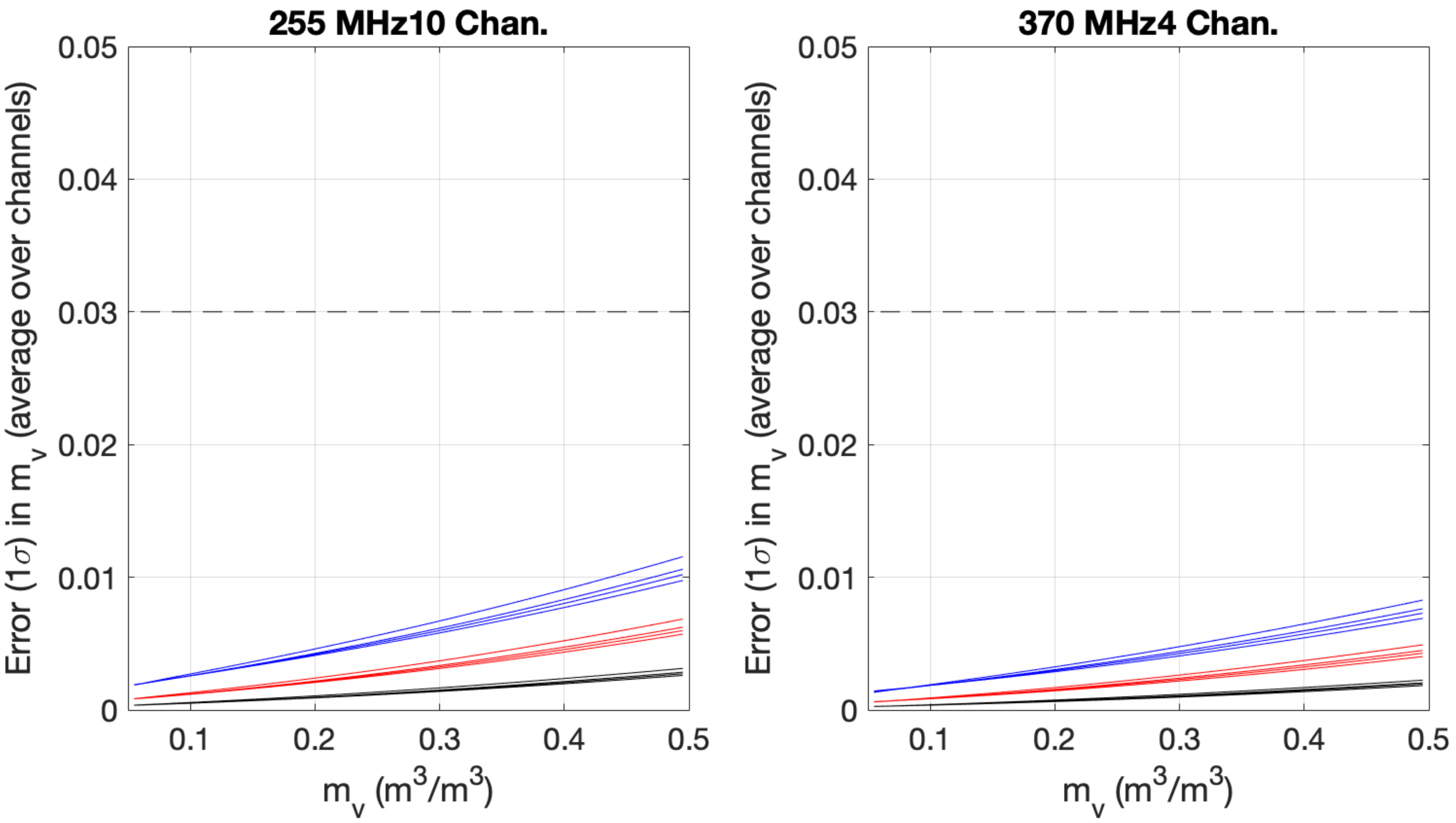


SNOOPI Mission Design

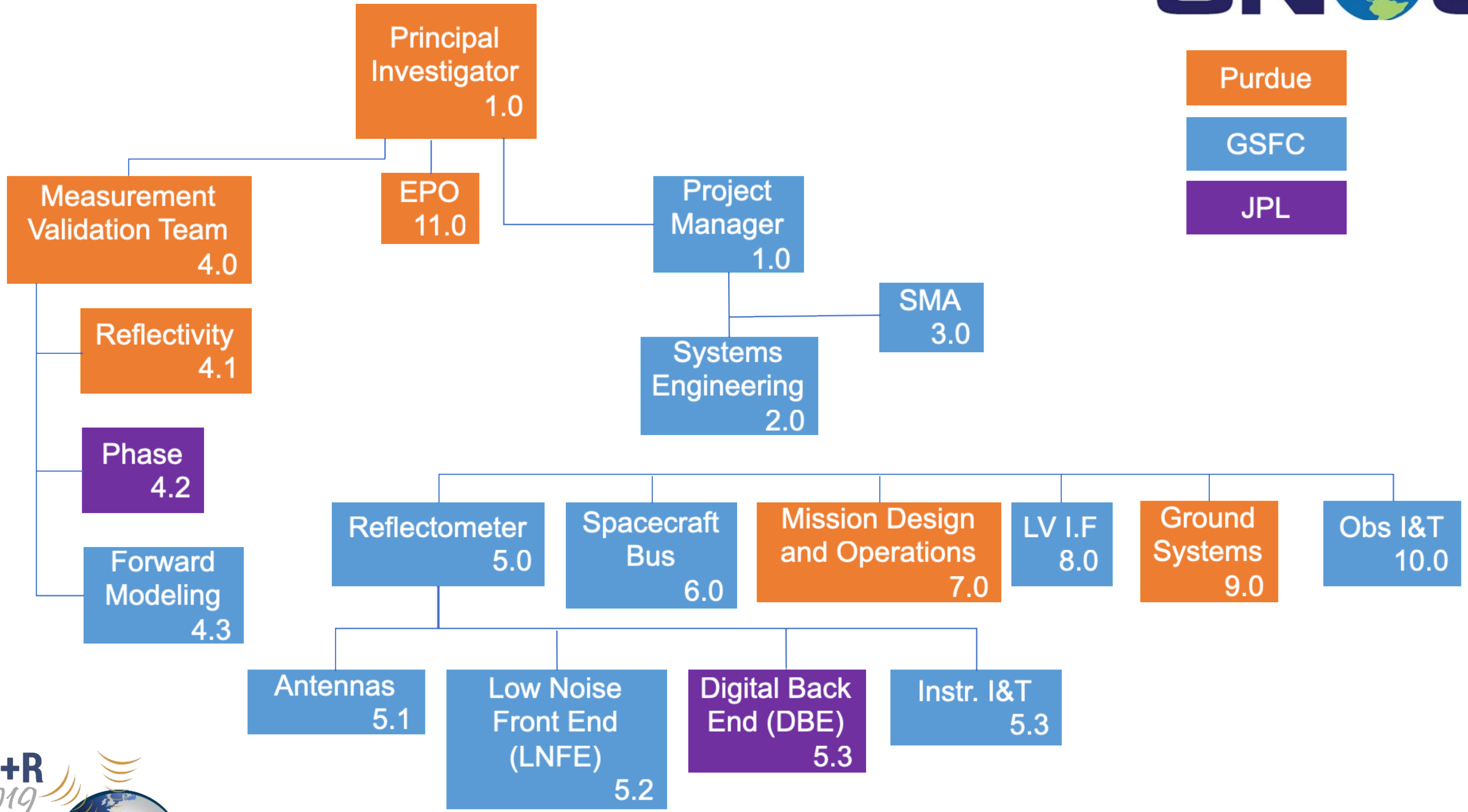
- SMC Error: Avg. over all Channel – 0.25 Chip specular offset

0 deg
50 deg
70 deg.

[4 soil types from Peplinski, 1995 model]



SNOOPI Project Management



SNOOPI Project Management

• Project Initiation	01/19
• SRR	06/19
• Bus development work start	06/19
• PDR	09/19
• CDR	03/20
• SIR	11/20
• FRR	03/21
• Deliver to Launch site	06/21
• Launch	09/21
• Commissioning (2 Mo.)	12/21
• Data Collection & Processing	09/22

Summary

- 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
- System (or “technique”) will be validated in this mission.
- Success criteria are achievable – technology validation based, not science measurements.

Acknowledgement

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

BACKUP

SigNals of Opportunity: P-band Investigation (SNoOPI)

PI: James L. Garrison, Purdue University

Objective

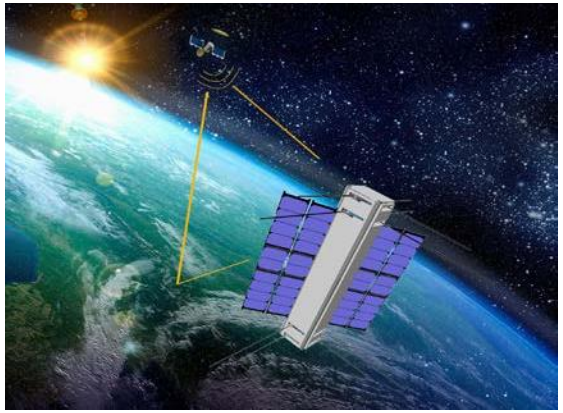
SNoOPI will demonstrate measurement of the reflection coefficient and phase of land surface reflections from P-band (240-380 MHz) communication satellite Signals of Opportunity

P-band Signals of Opportunity measurements will enable the spaceborne remote sensing of Root Zone Soil Moisture (RZSM) and Snow Water Equivalent (SWE) – priority variables in 2017 ESAS

Working requirements:

- Reflection coefficient precision: 0.07 (1-sigma)
- Reflection phase error: 10 deg. (1-sigma)

SNoOPI conceptual design: 1X6U CubeSat bus provides separation between pairs of zenith and nadir antennas, at 255 and 370 MHz.



A digital back end (DBE) cross-correlates direct and reflected signals from geostationary communication satellites

A calibrated Low-Noise Front End (LNFE) uses noise loads for estimation of reflection coefficient magnitude.

Approach:

Pairs of antennas receive signals along two ray paths: direct from the transmitter and reflected from the Earth's surface. Cross-correlating the signals from a pair of antennas can produce the reflection coefficient and reflected signal phase.

Reflection coefficient retrieval will be validated using a forward electromagnetic model and in-situ data at SMAP Cal/Val sites.

Phase retrieval will be validated by comparing variance to a known error model, and measuring differential phase delay due to the ionosphere.

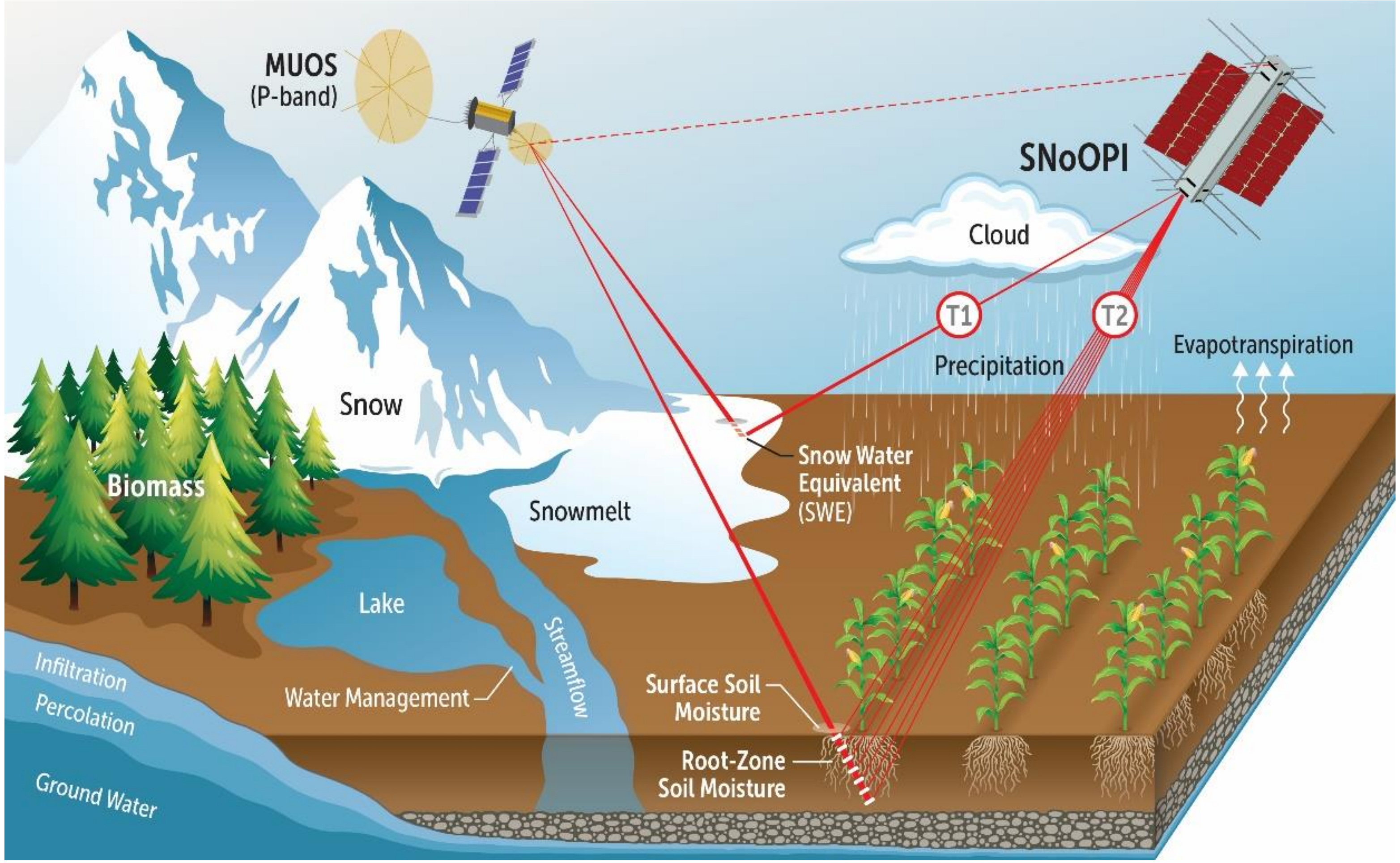
CoIs: Jeffrey Piepmeier, Manuel Vega, GSFC, Rashmi Shah, JPL, David Spencer, Purdue University

Key Milestones

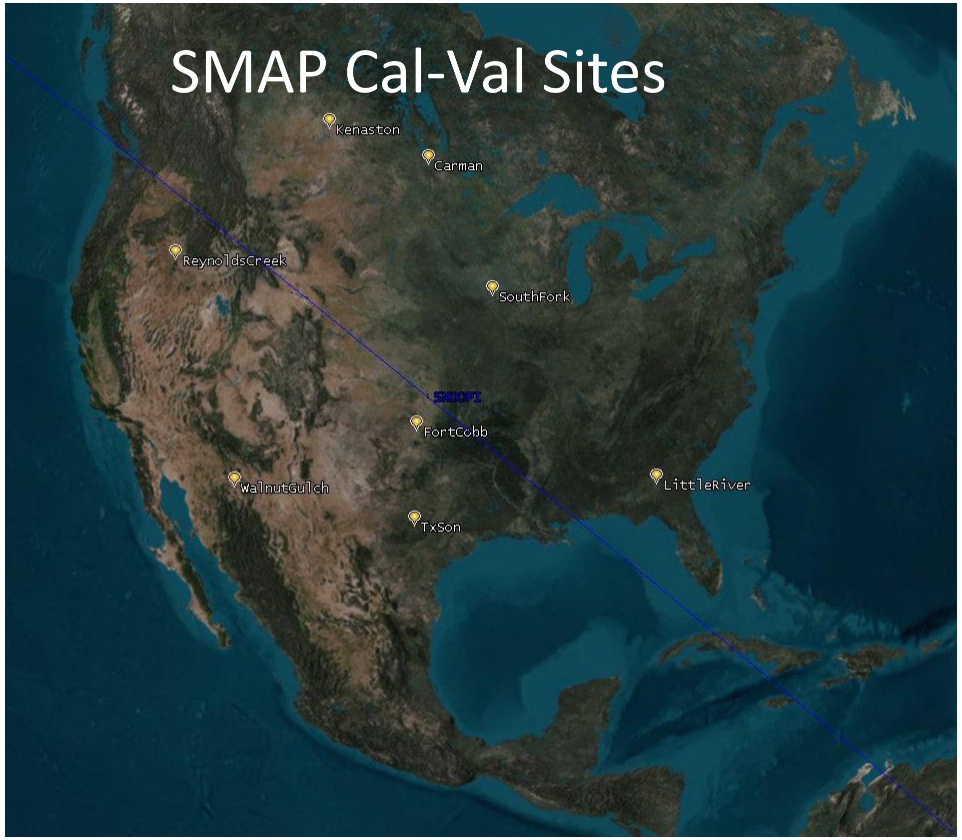
• Project Initiation	10/18
• SRR/PDR: System requirements	02/19
• Spacecraft Bus Contract Award	04/19
• Spacecraft Bus CDR	08/19
• Instrument CDR/EM Fabrication	10/19
• Spacecraft Bus Fabrication	03/20
• Instrument FM	03/20
• Delivery to Observatory	06/20
• FRR	09/20
• Launch (Earliest Opportunity)	10/20
• On-orbit commissioning	12/20
• Data collection and Processing	06/21
• Data reduction	09/21

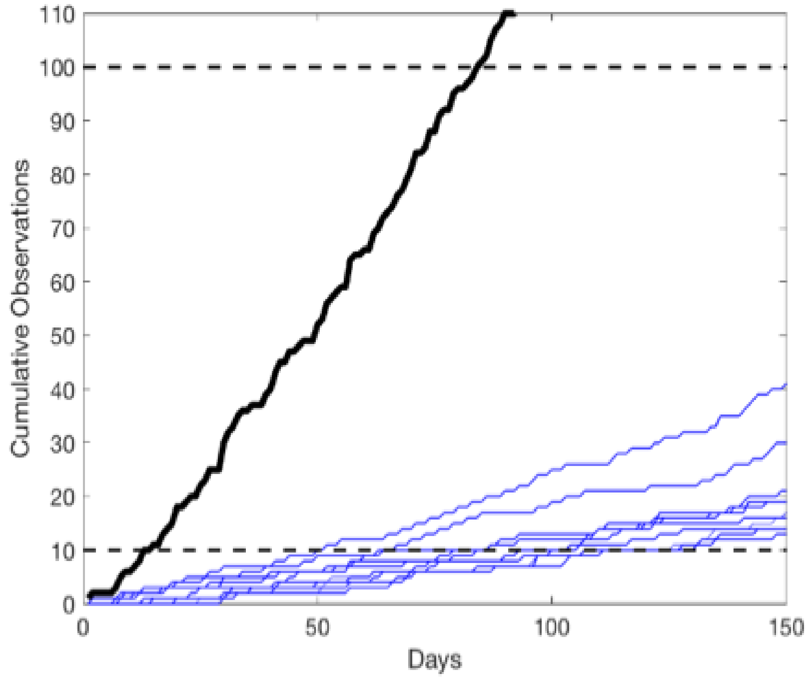
$TRL_{in} = 5$

SNOOPI Mission

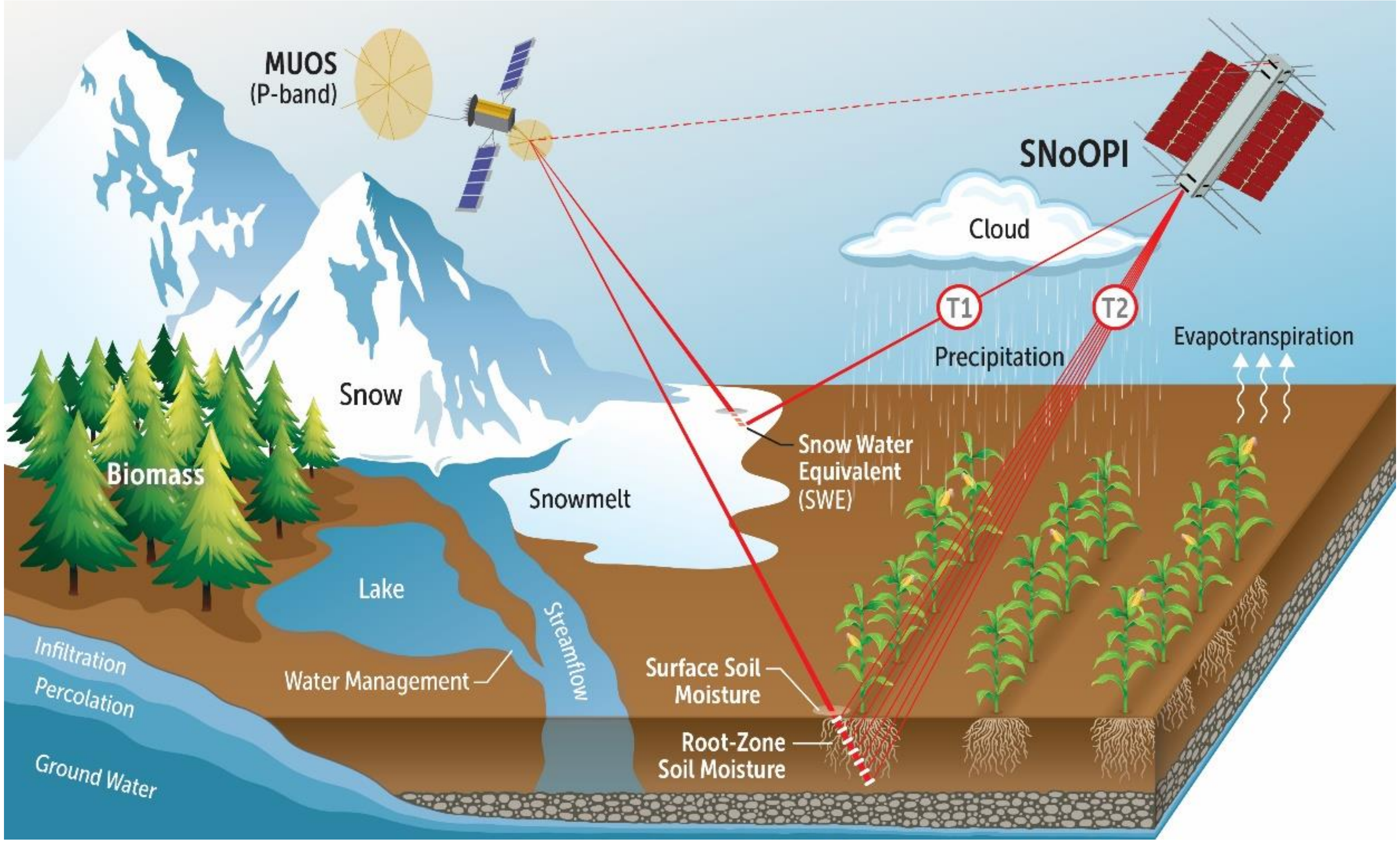


SNOOPI Mission





SNOOPI Mission Description



SNOOPI Mission