Remote Sensing of the water cycle using Signals of Opportunity: challenges and opportunities

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Abstract

Recent proof-of-concept experiments have demonstrated the potential utility of Signals of Opportunity (SoOp) in remote sensing. SoOp methods involve the re-use of existing satellite transmissions as sources in bistatic radar, applying fundamental physical principles to estimate surface and scattered medium properties from reflectivity and phase observables in the reflected signal. Through utilizing signals intended for communications, SoOp methods can make these observables using frequencies that are not allocated or protected for scientific use. Two promising applications in hydrology have been studied: Sub-canopy root-zone soil moisture (RZSM) using satellite communications signals below 500 MHz and snow water equivalent (SWE) retrieval from the observed phase different through propagation through the snow layer. Signals of Opportunity P-band Investigation (SNOOPI) is a NASA Cubesat technology demonstration mission to test forward scattering models and validate a prototype instrument for SoOp reflectometry in 250-380 MHz range. Contribution to the panel discussion will focus on the expected contributions of the SoOp techniques validated in the SNOOPI mission and the existing challenges in the full utilization of SoOp methods for both RZSM and SWE remote sensing. Multiple frequencies are required in order to solve the inverse problem and estimating a sub-surface profile. In the case of SoOp, this may require combining observations with diverse geometry due to the different orbits of the potential sources. This presents new challenges in the development of retrieval algorithms and may possibly require the integration of additional data sources. Another important challenge for SWE retrieval is the need for repetitive coverage to extract phase differences between subsequent passes, coupled with orbit determination for the non-cooperative sources. In contrast to GNSS reflectometry (in which high-precision orbits are publicly available for use in positioning), communication satellite orbits are not known to the required meter-level accuracy. Even geostationary sources frequently have a small inclination which results in motion relative to the surface of the Earth. Finally, antenna calibration is a substantial contribution to the error budget.

Remote Sensing of the Water Cycle using Signals of Opportunity: Challenges and Opportunities

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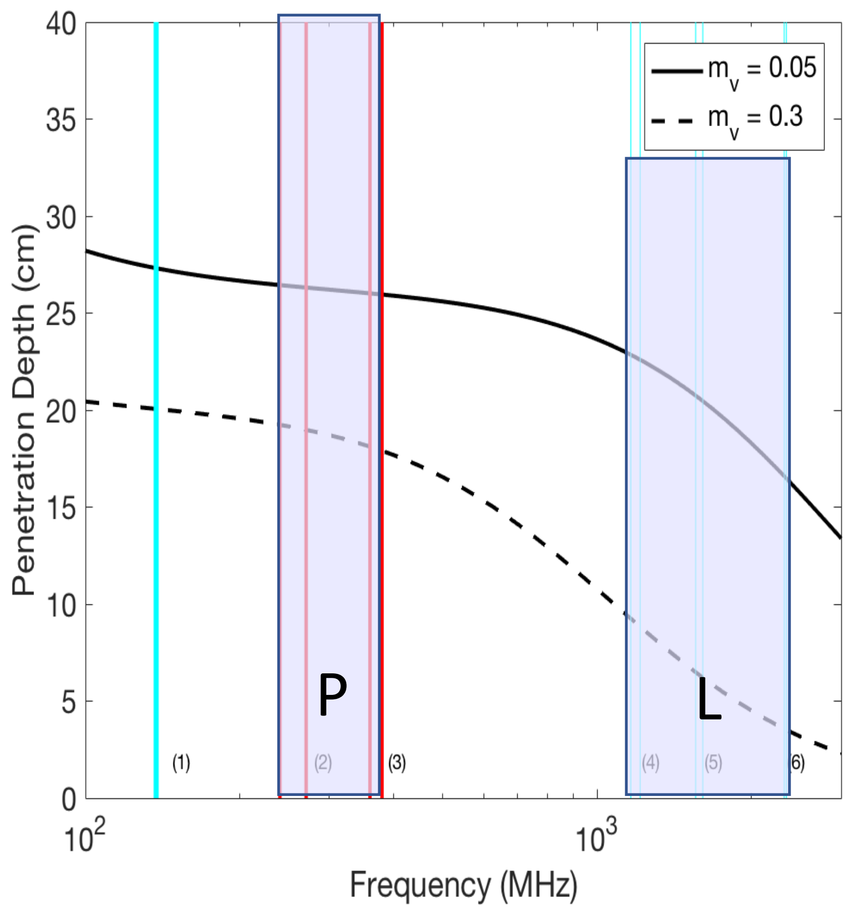
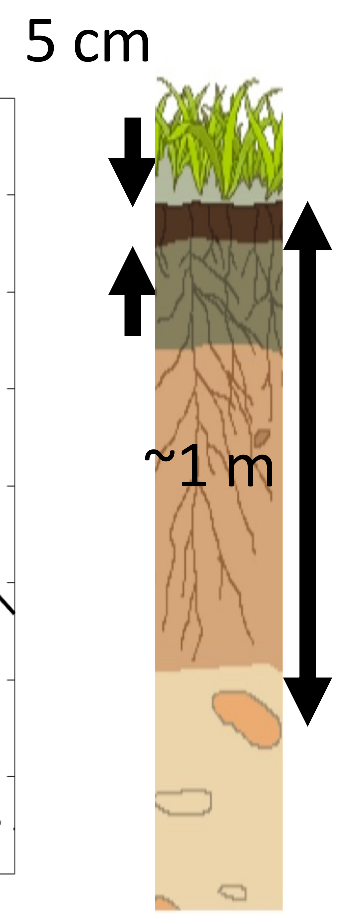
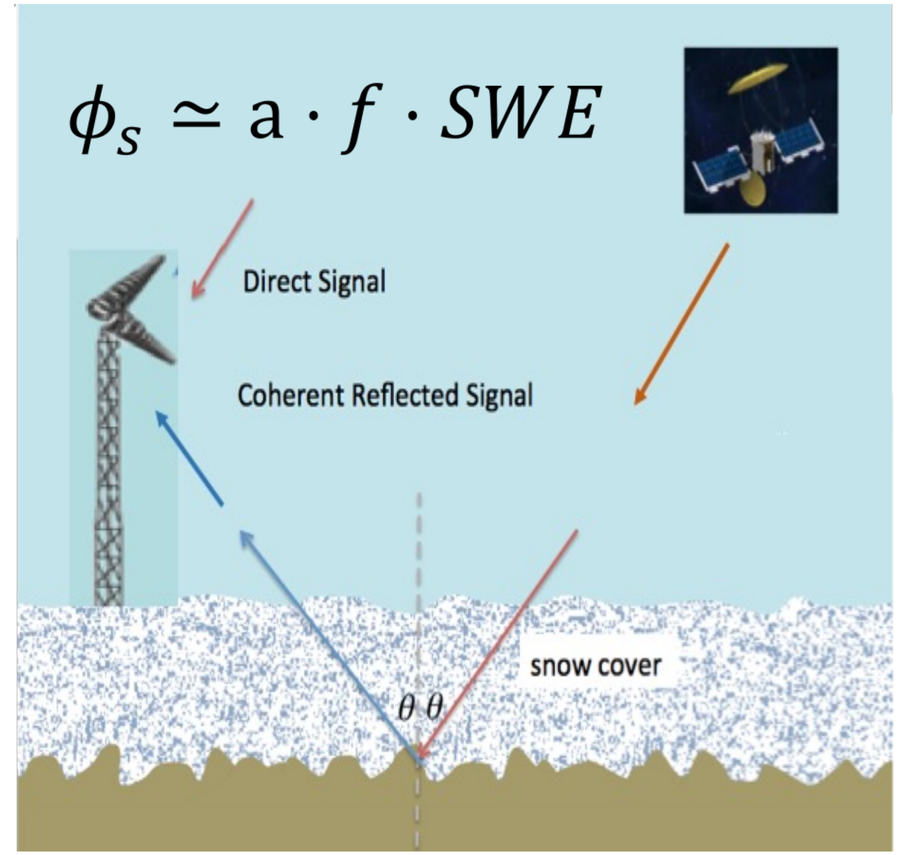
First: The OPPORTUNITY!



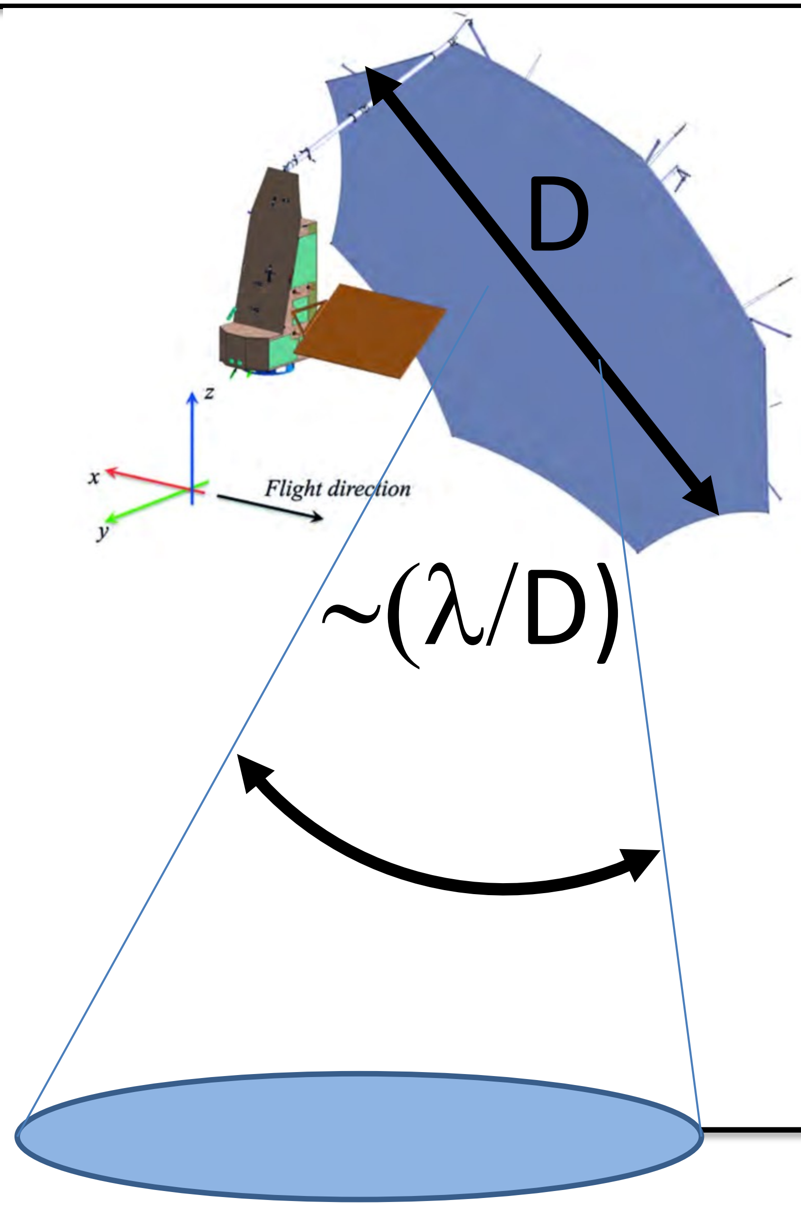


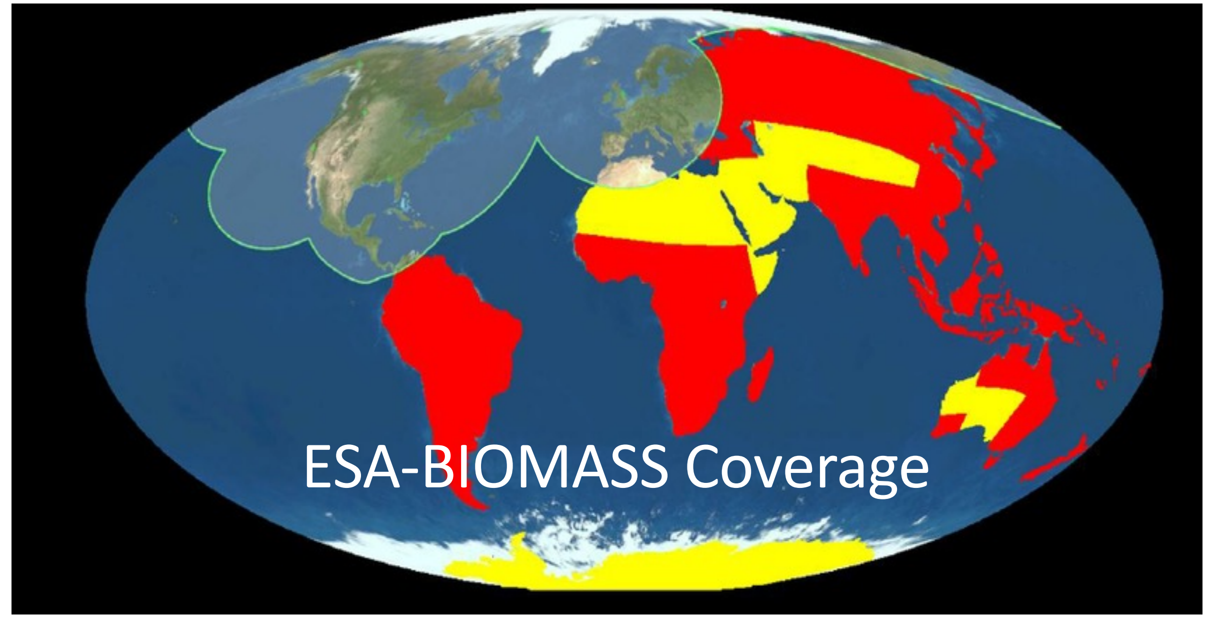
Root Zone Soil Moisture (RZSM)



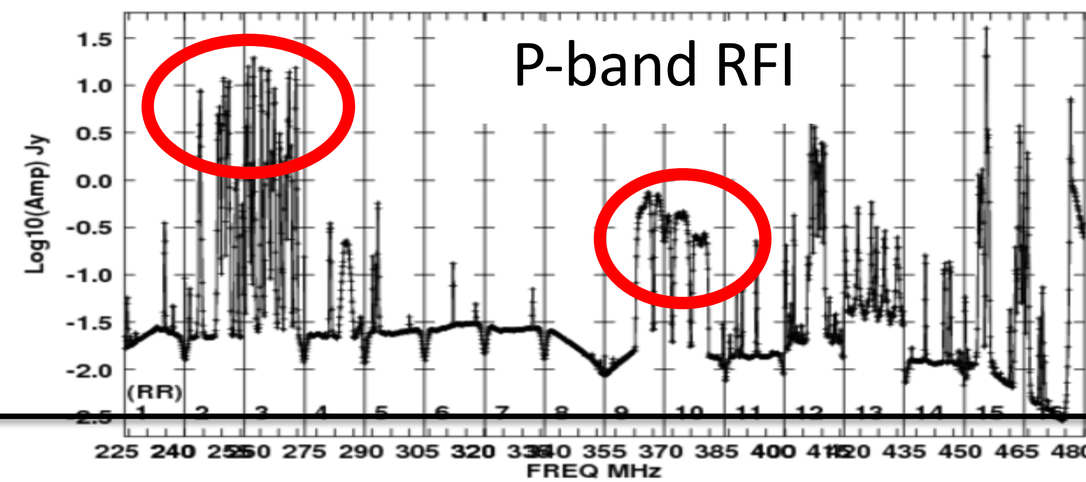
Snow Water Equiv. (SWE)

Why is P-band Difficult ?



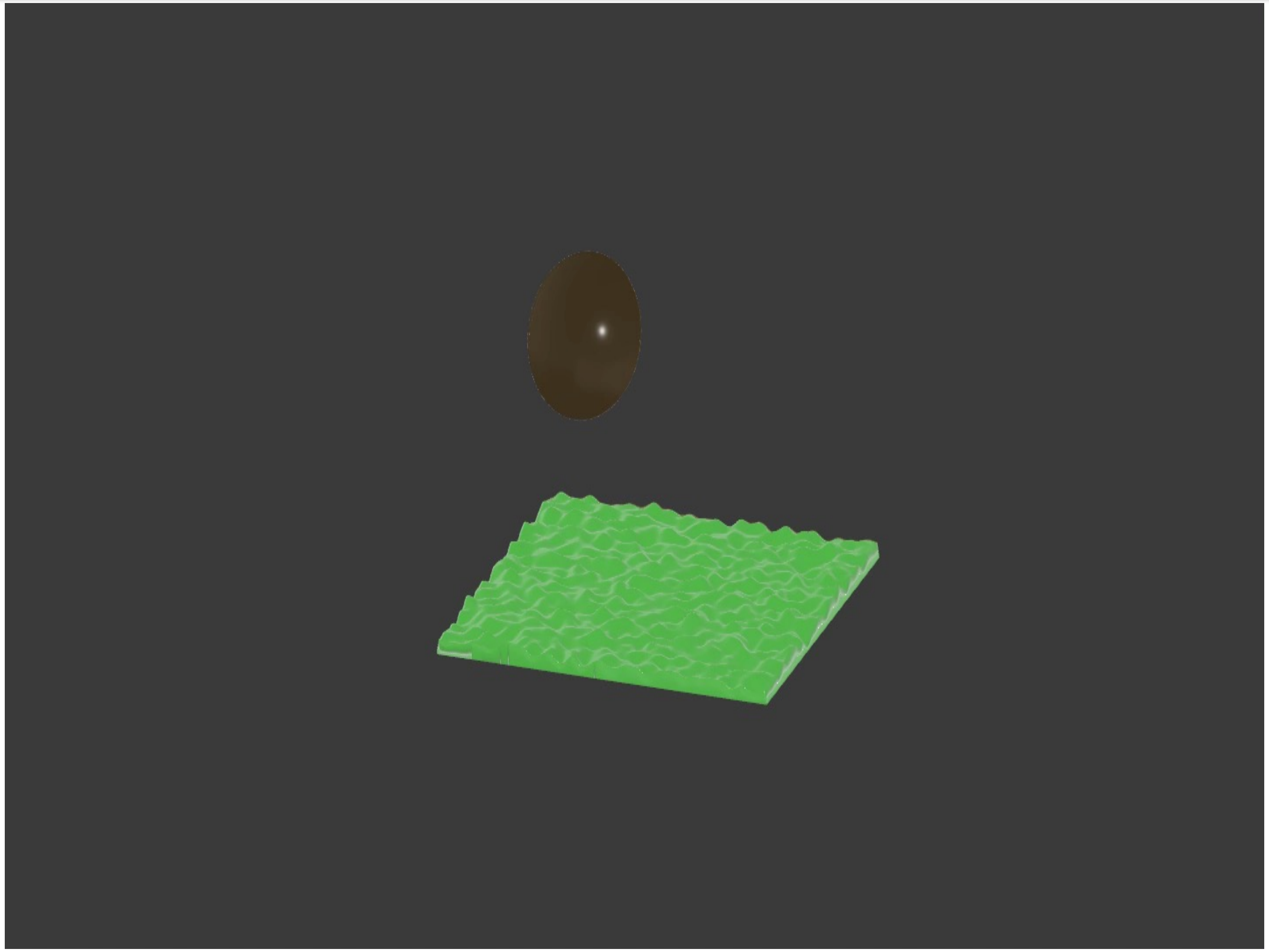


[Hélière, et al, EARSeL, 2013]



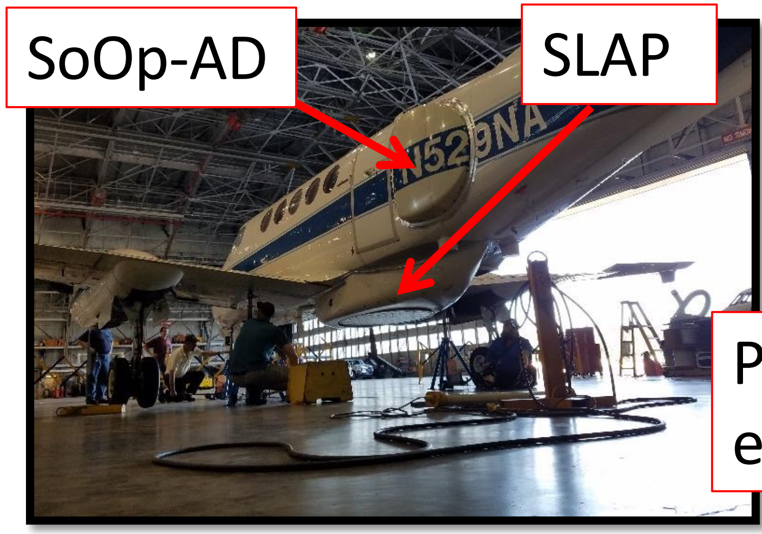
[NRAO]

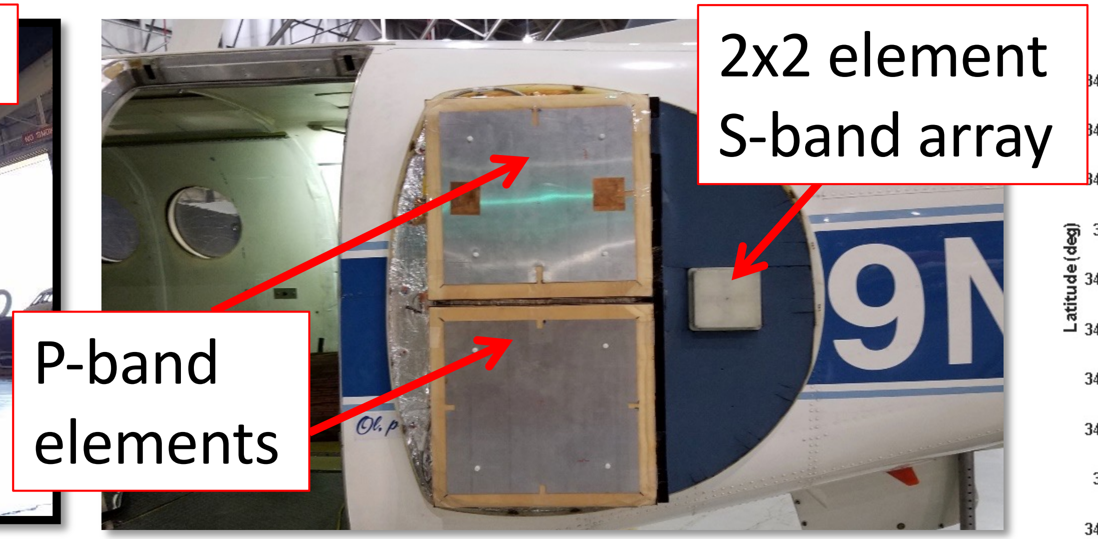
Signals of Opportunity

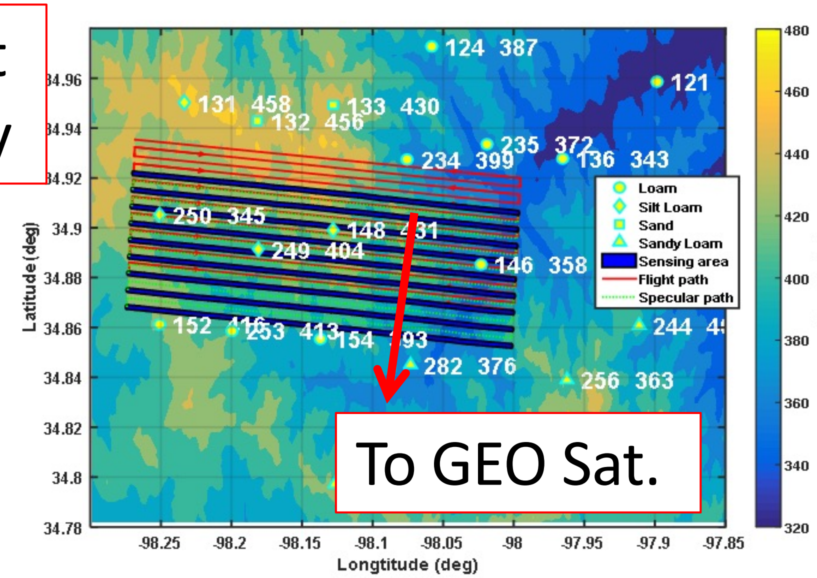


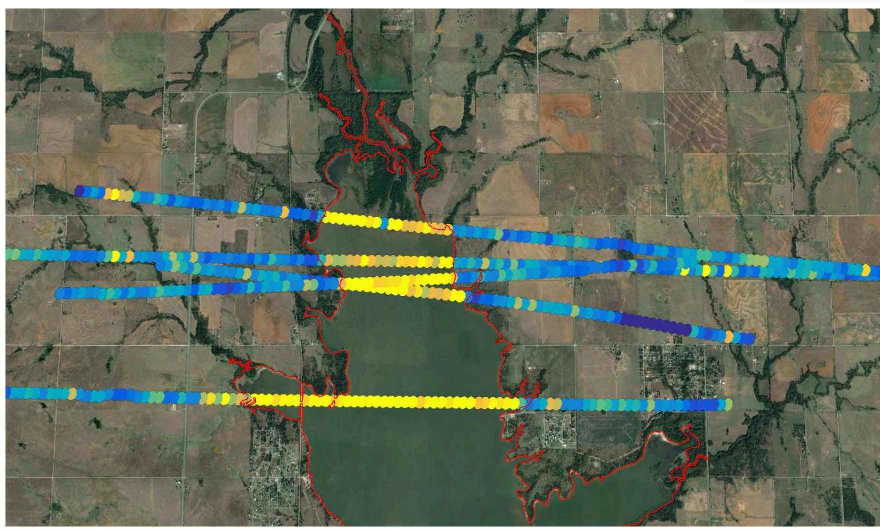
P-Band SoOp Heritage

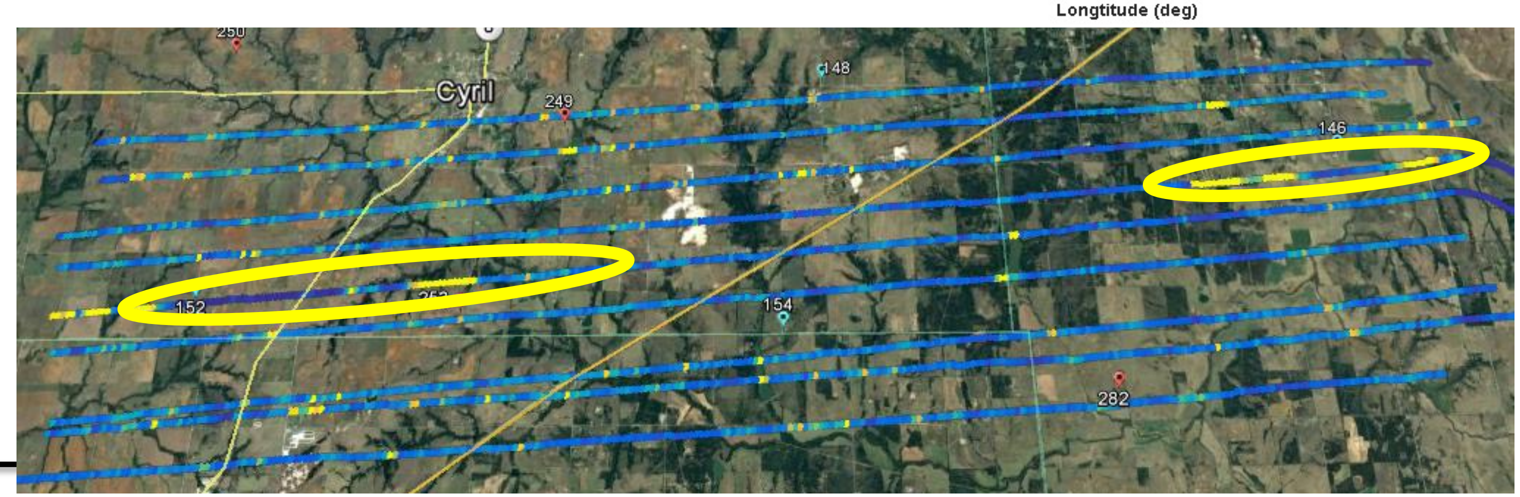
IIP-13 Award: Signals of Opportunity Airborne Demonstrator (SoOp-AD)



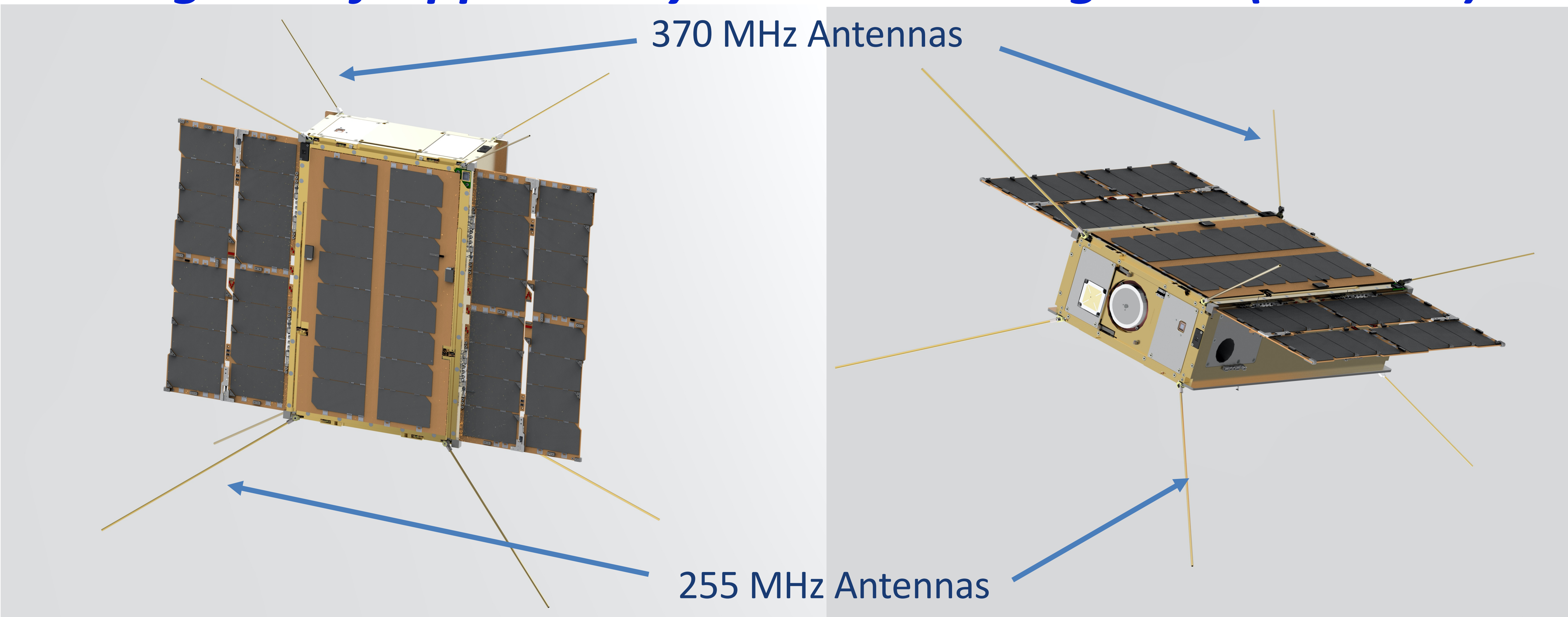








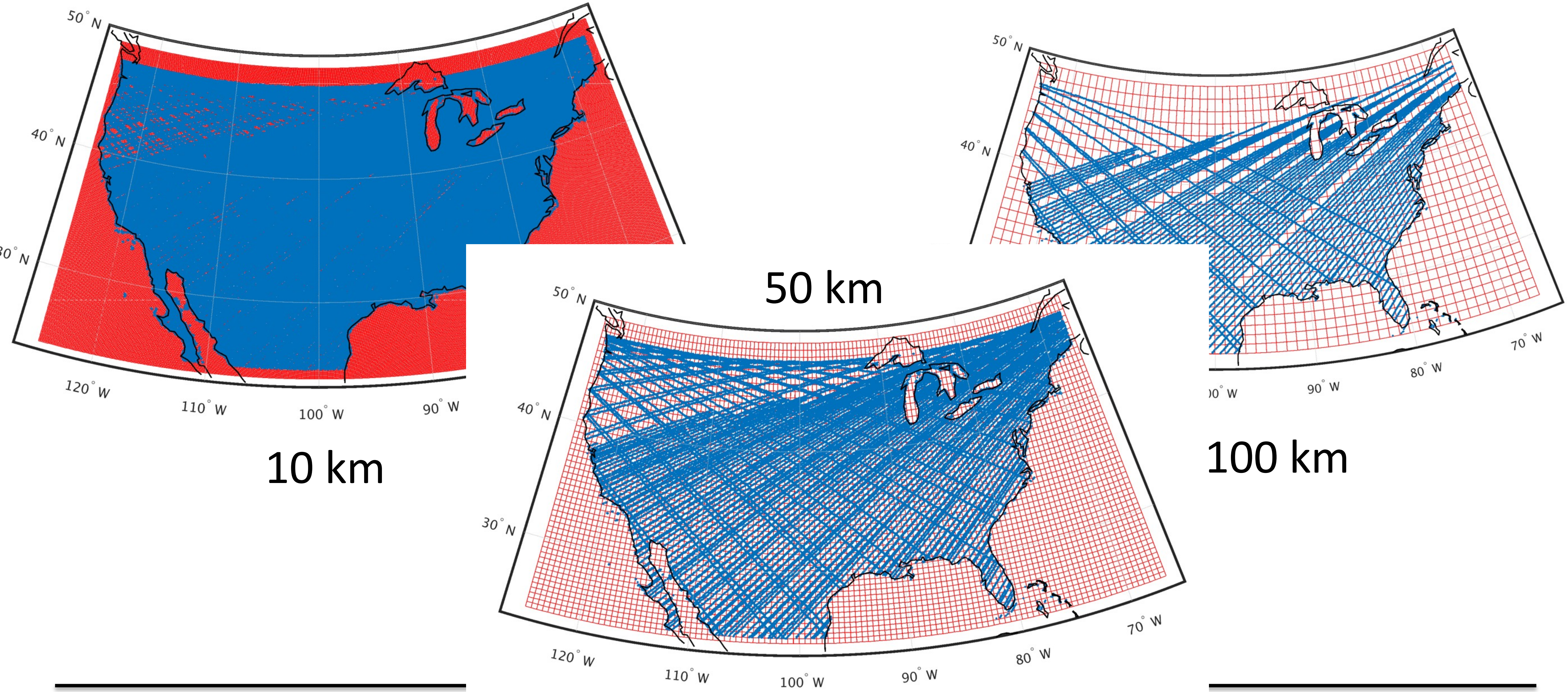
Signals of Opportunity P-band Investigation (SNOOPI)



In-Space Validation

1. Validate **link budget** from orbital altitudes and speeds to quantify uncertainty in reflectivity and phase
2. Quantify **RFI effect** from space (broad field of view, global distribution of measurements)
3. Demonstrate model prediction and instrument tracking for orbital delay and Doppler with non-cooperative transmitter

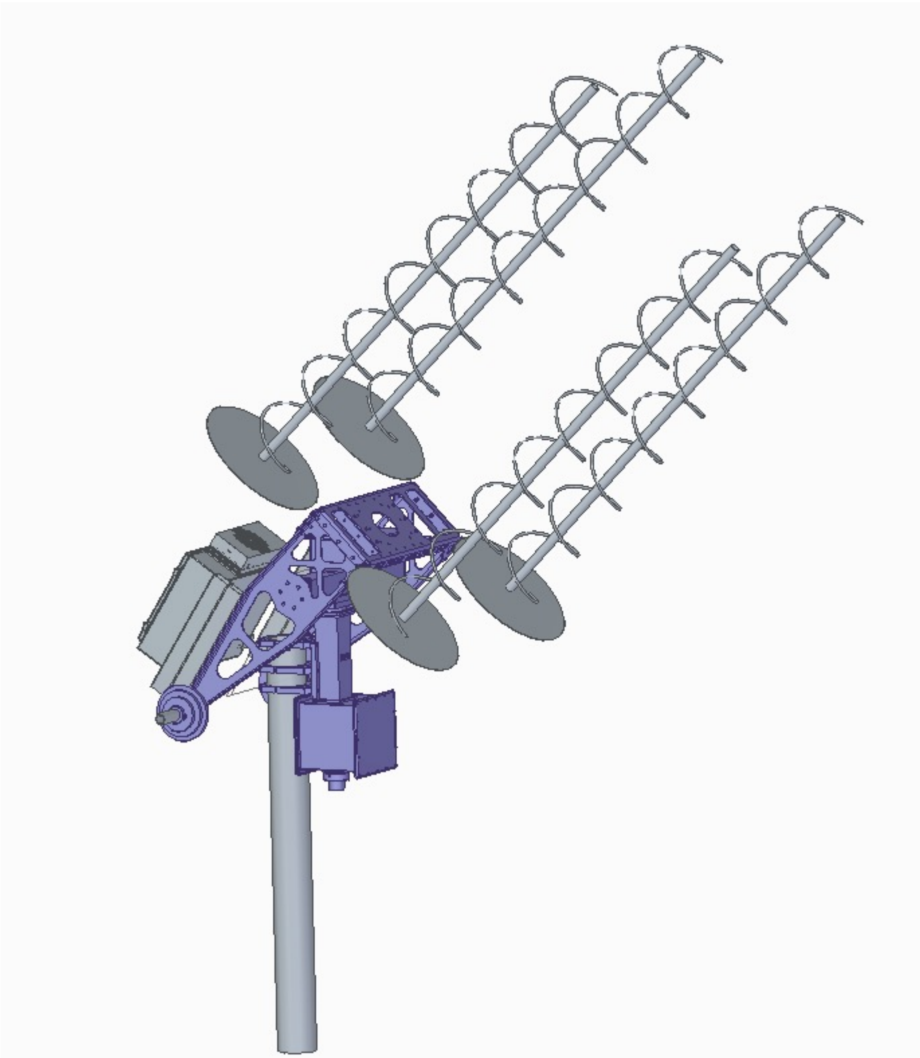
Mission Design: CONUS Mapping

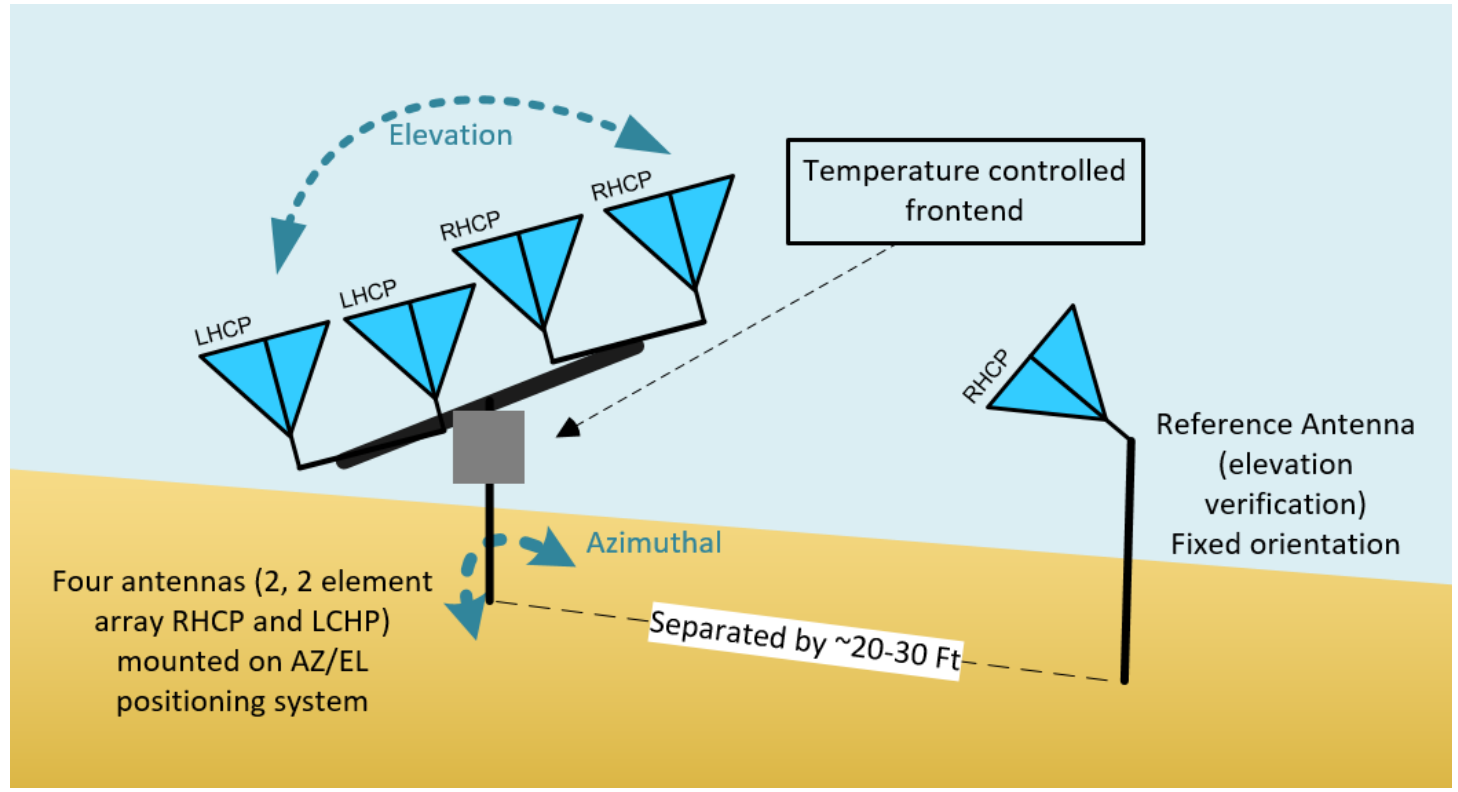


SoOp Challenge

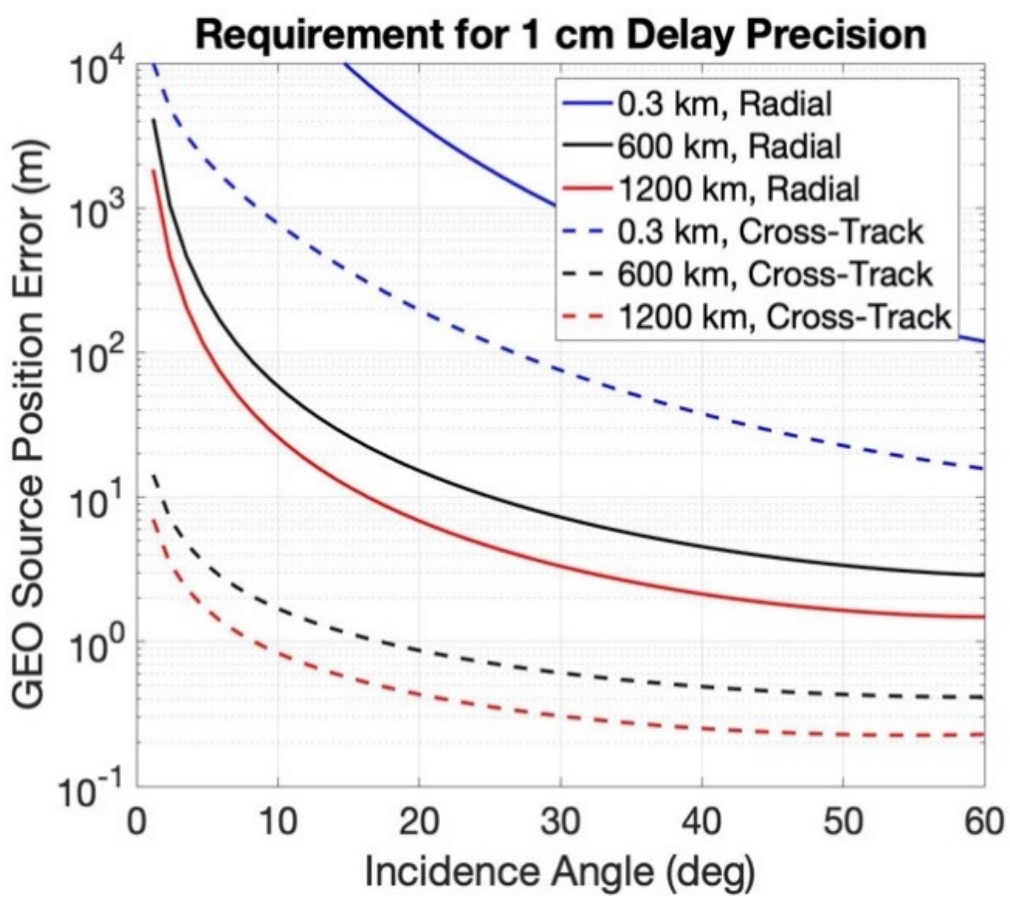
- Use of ***Non-cooperative*** source – many unknowns beyond our control.
- GNSS-R Methods developed for CYGNSS not always applicable to non-navigational sources.
- Examples:
  - Orbit knowledge – high-precision orbits do not exist except for GNSS
  - Variation in transmitter power, modulation, channel occupancy
  - Receiver antenna pattern
  - Spot beams

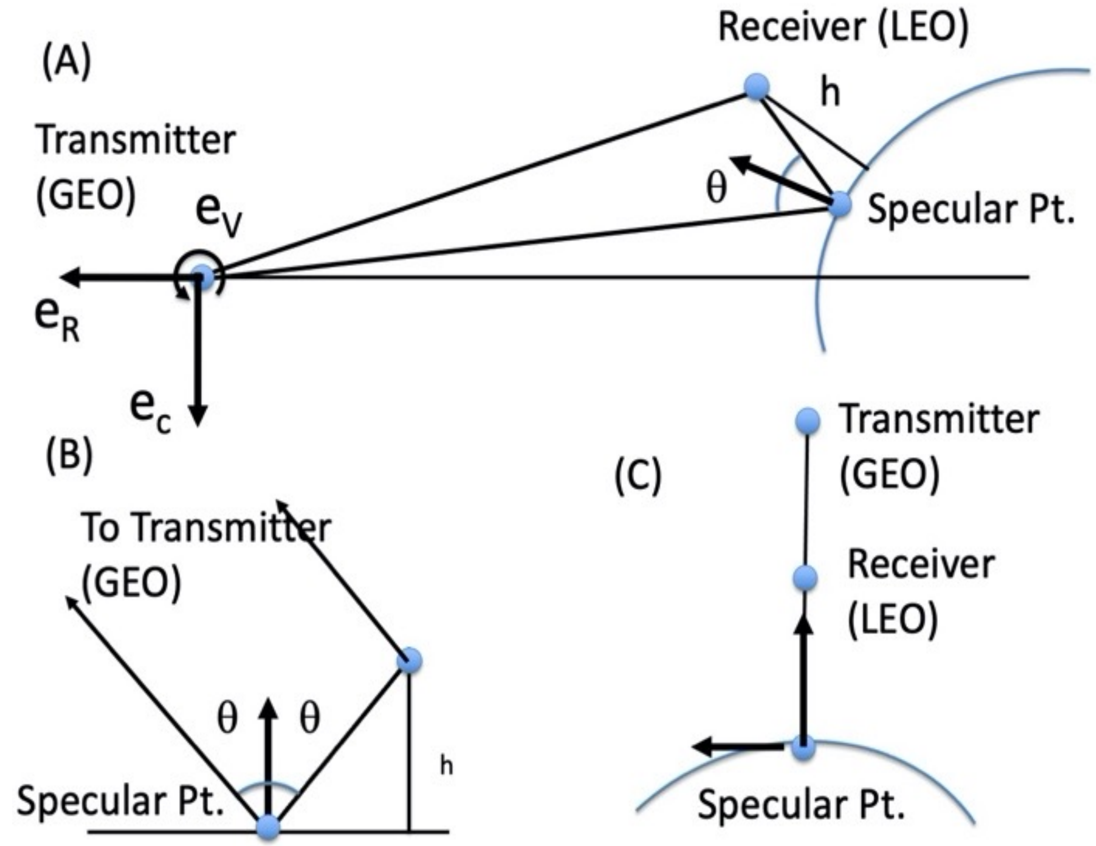
SoOp Challenge: Signal Properties





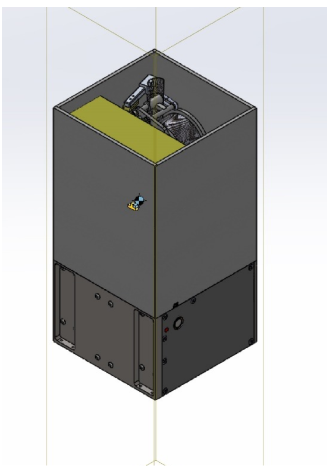
SoOp Challenge: Orbit Knowledge



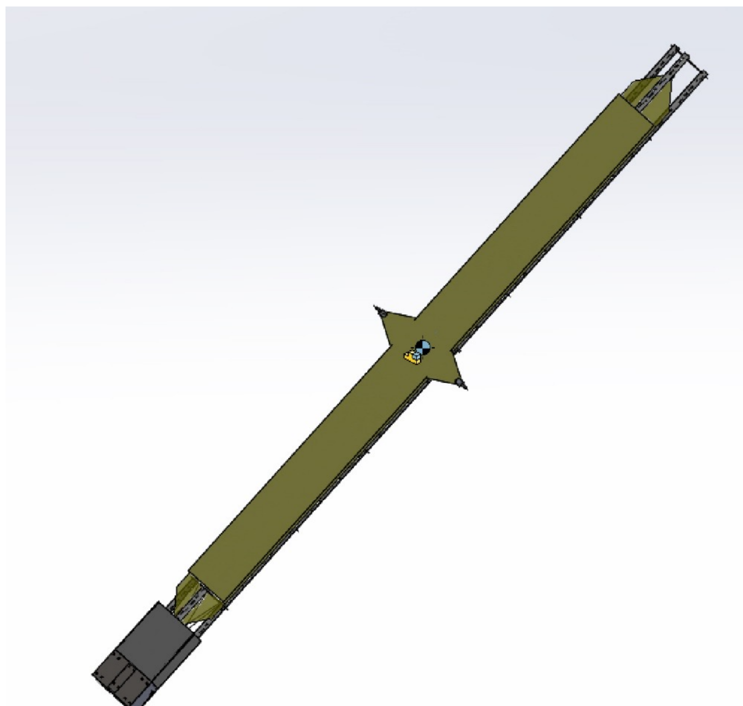


SoOp Challenge: Antenna Gain Knowledge

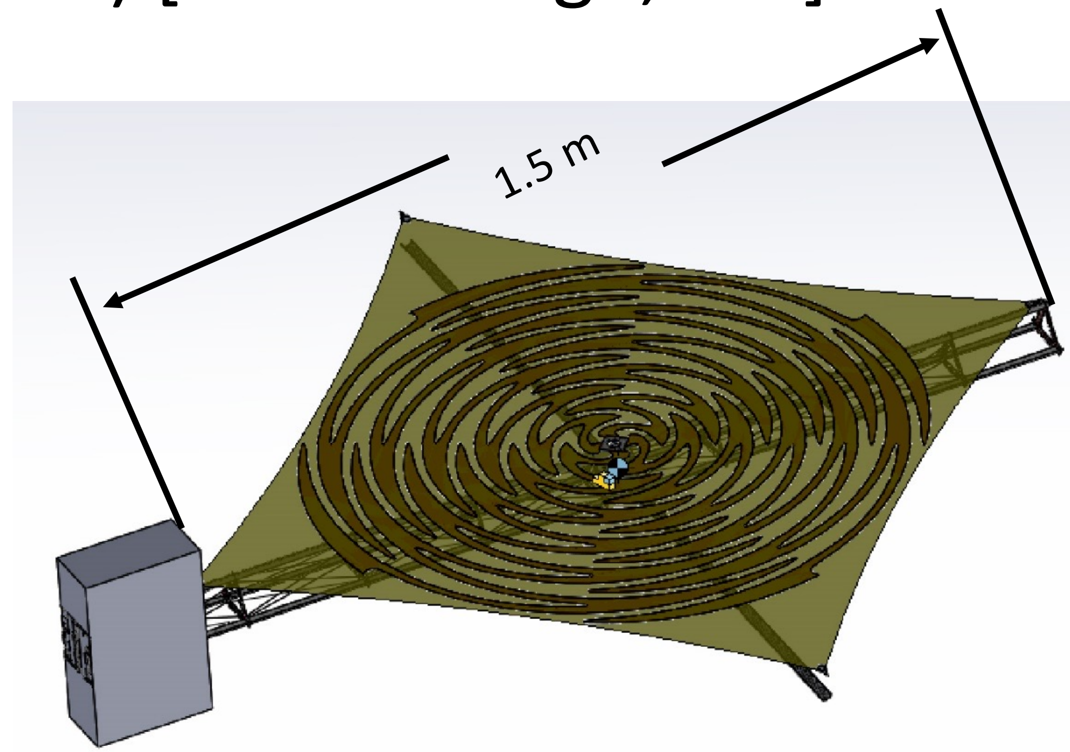
- NASA ESTO (ACT-2017) supported project: Deployable membrane antenna (137-380 MHz) [MMA Design, LLC]



Stowed



Truss boom deployed



Full antenna deployed

Acknowledgement

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