Signals of Opportunity Airborne Demonstrator (SoOp-AD): Results of First Field Experiment

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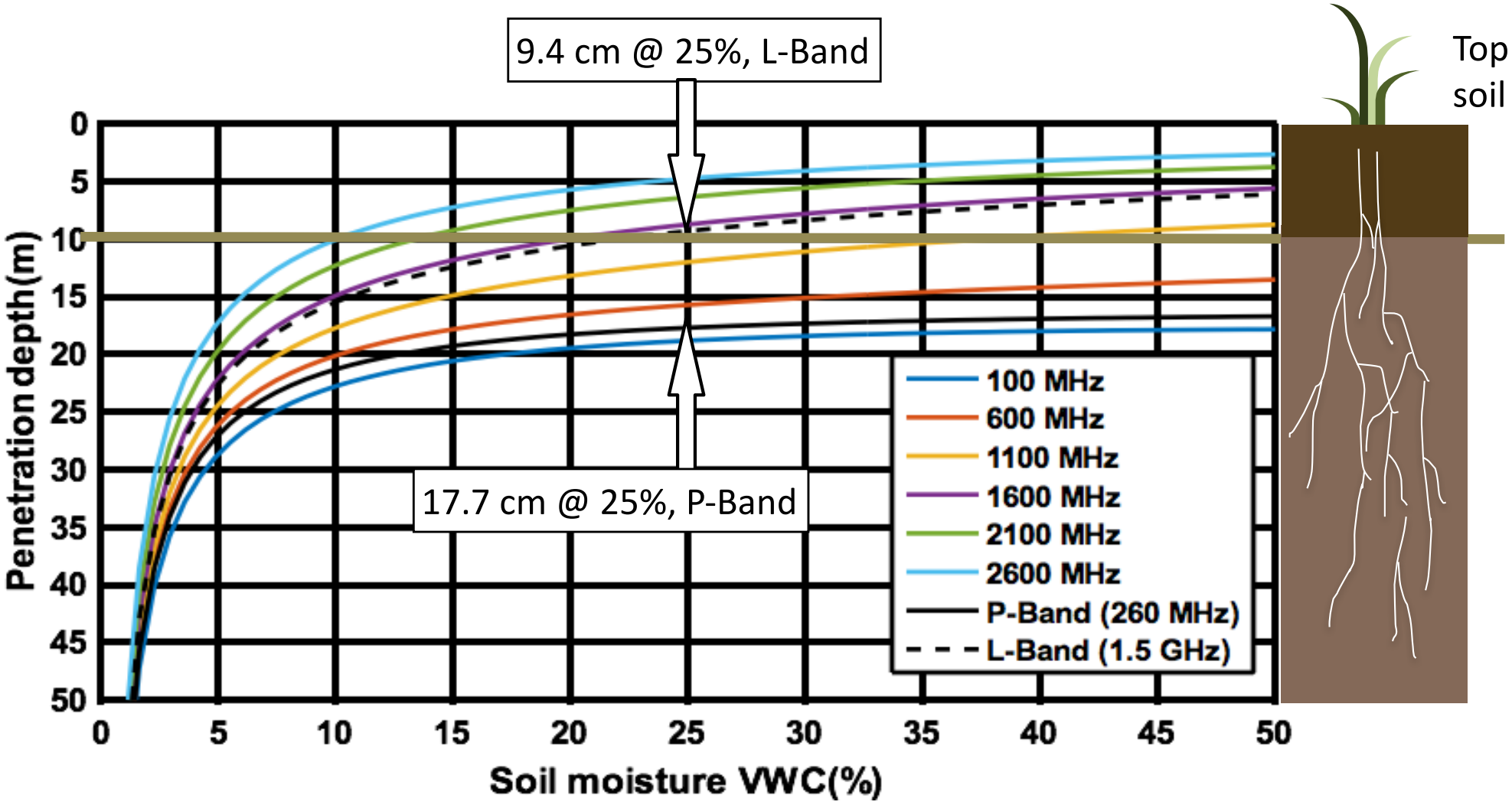
Outline

- Root Zone Soil Moisture (RZSM)
- Potential advantage of P-band SoOp
- Overview of SoOp-AD Airborne instrument
- Little Washita, OK campaign: Oct 2016
- Data Processing and First Results
- Future Work
- Conclusions

Root Zone Soil Moisture (RZSM)

- Water in top ~1 meter of soil
- Critical link between surface hydrology and deeper process
- Drainage and absorption by plant roots
- Connection between near-term precipitation and long-term availability of fresh water
- Presently available globally – only through model assimilation of surface soil moisture (e.g. SMAP L4)

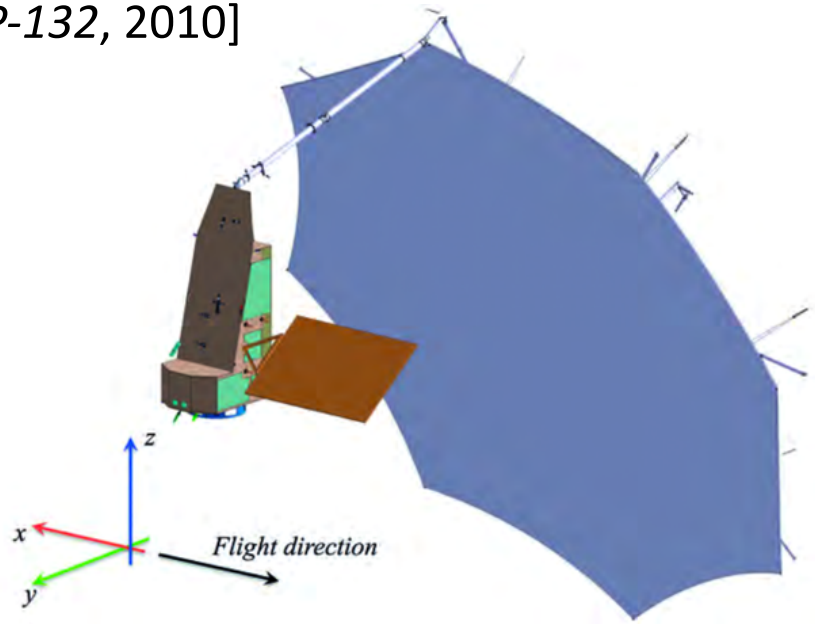
Importance of Sensing < 500 MHz

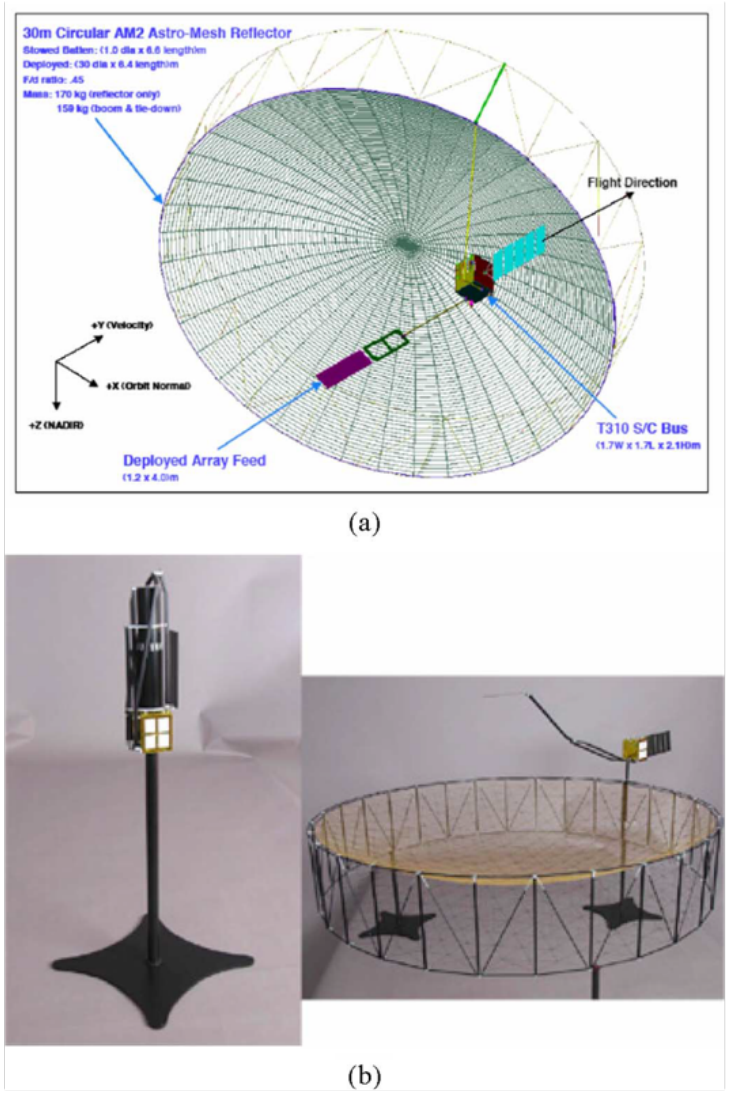


Sand: 40%, Clay: 20%, Temperature: 20 °C

Difficulty of 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]

Difficulty of Sensing < 500 MHz

- Large antenna size to meet resolution requirements
- No protected bands
- High RFI from terrestrial sources

Consequence: L-band (1-2 GHz) may be the current practical lower frequency limit for spaceborne radar or radiometer

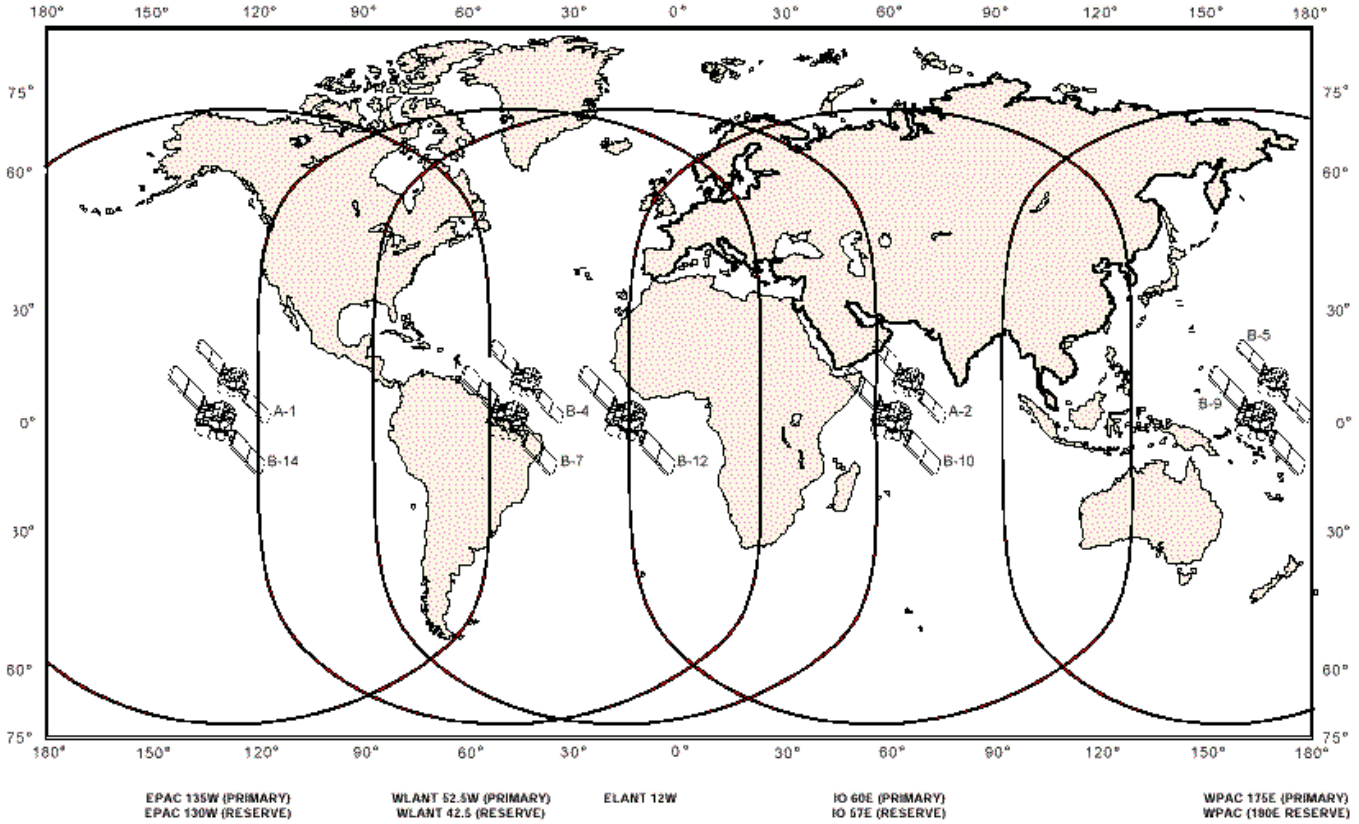
P-band Signals of Opportunity (SoOp)

- Re-utilization of existing transmissions (e.g. potential RFI ***sources***)
- Bands allocated for Space-Earth communications
- High power, forward scatter -> High SNR/smaller antenna
- Resolution set by signal bandwidth – not antenna diameter

P-band SoOp may offer first possibility of direct remote sensing of Root-Zone Soil Moisture (RZSM) from space

P-band Signals of Opportunity (SoOp)

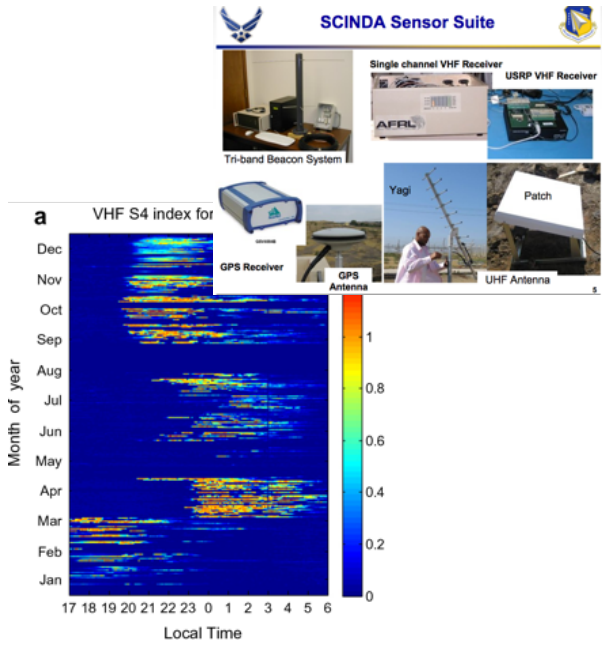
- **225–420 MHz** allocation for defense/government use
- Continuous use by US & Others since 1978 (FLTSATCOM)
- Planned utilization through 2024



P-band Signals of Opportunity (SoOp)

- Multiple Low bandwidth (5, 25 KHz) digital channels.
- Well documented and (supposedly) easy to receive by:

Ionospheric Researchers



[Olwendo, et al. *Adv. Space Research* 51 (2013), DOI: . 10.1016/j.asr.2012.12.017]

Hobbyists

[www.uhf-satcom.com, www.crypto.com]

Pirates

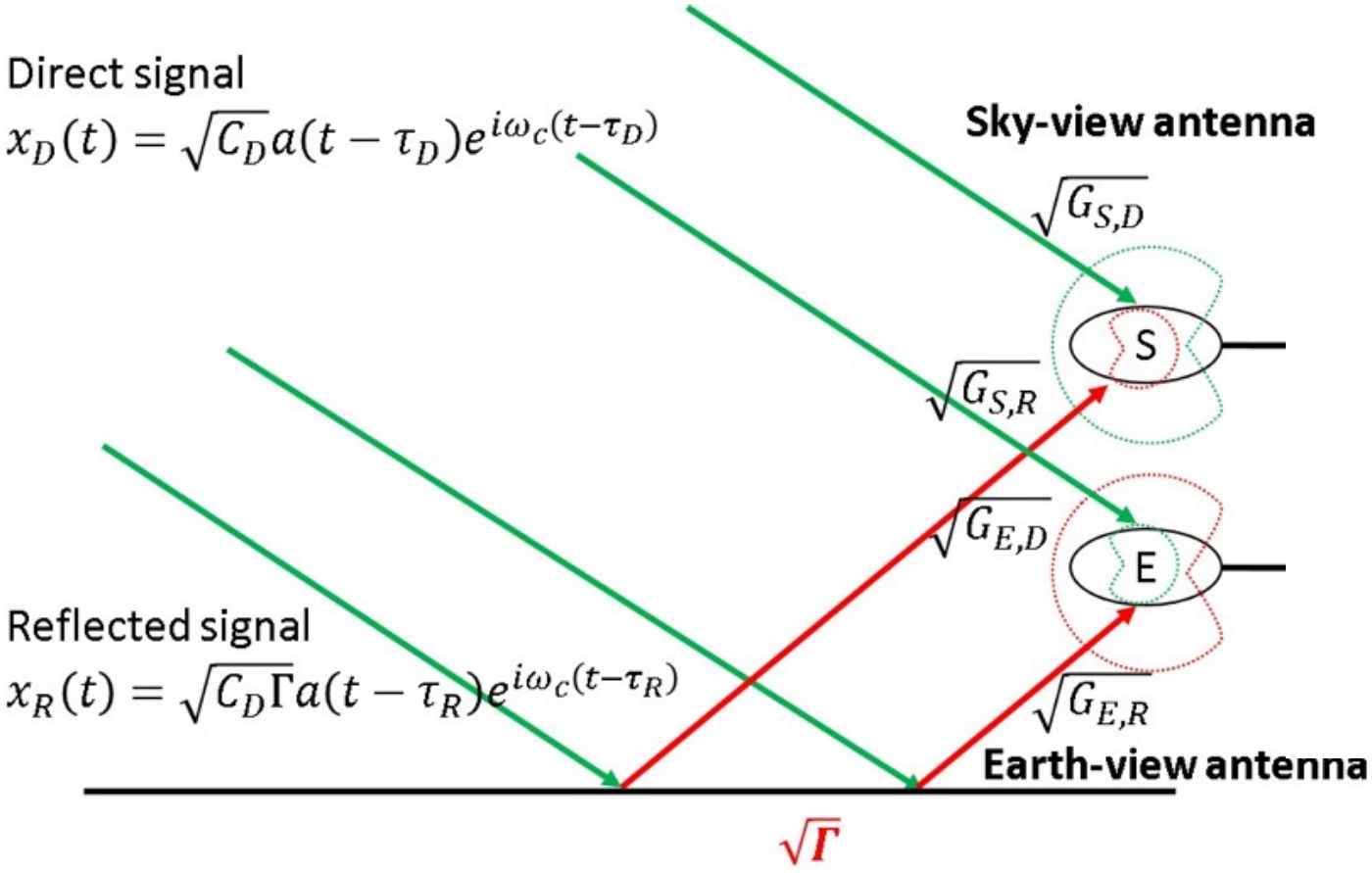
"Nearly illiterate men rigged a radio in less than one minute" [*Wired*, April 20, 2009]

Signals of Opportunity Airborne Demonstrator (SoOp-AD)

- 2013 Instrument Incubator Program (IIP) Selection
- Objectives:
  - Airborne instrument to demonstrate SoOp concepts at P- and S-band
  - Breadboard digital receiver with “path to space” tested in relevant environment (TRL-5)
  - Airborne science instrument for future algorithm development
- Working requirements:
  - Resolution: 100 m (airborne), 1km (satellite)
  - Sensing depth: 0-30 cm
  - RZSM accuracy of 0.04 (volumetric)

Signals of Opportunity Airborne Demonstrator (SoOp-AD)

- Measurement Model

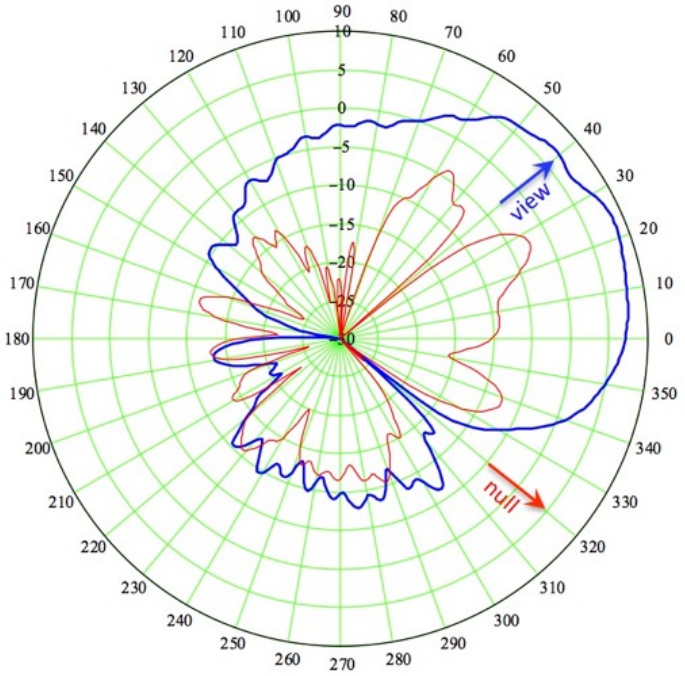


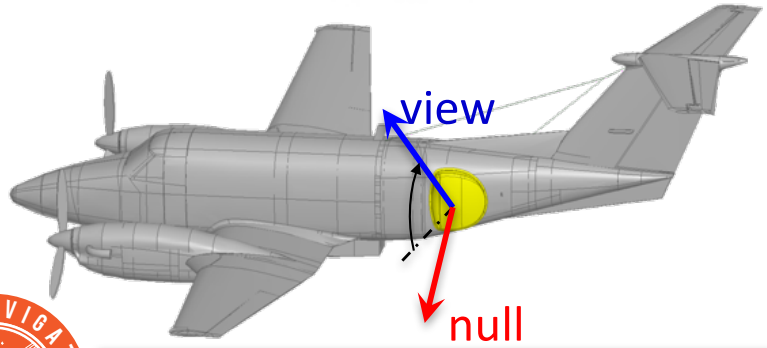
Accounting for Direct-Reflected Interference:

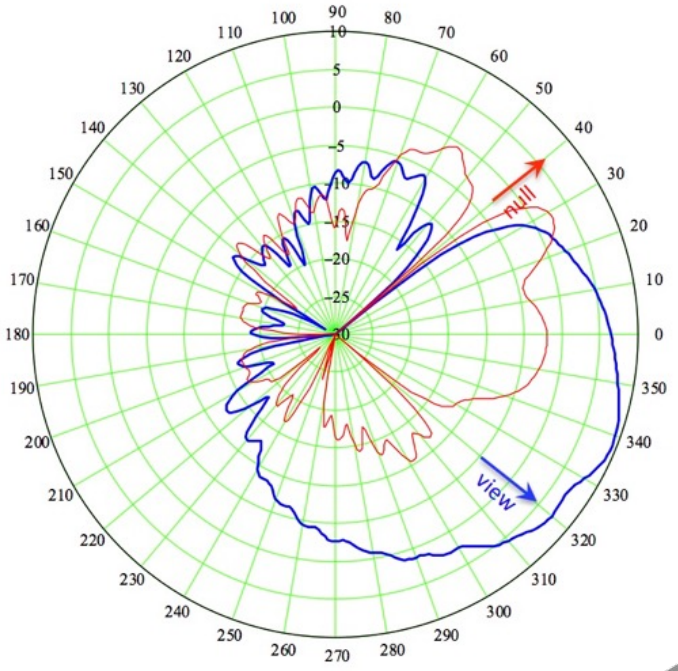
- Null-Steering (post-process)
- Retrieval Forward model
- Vicarious calibration over water

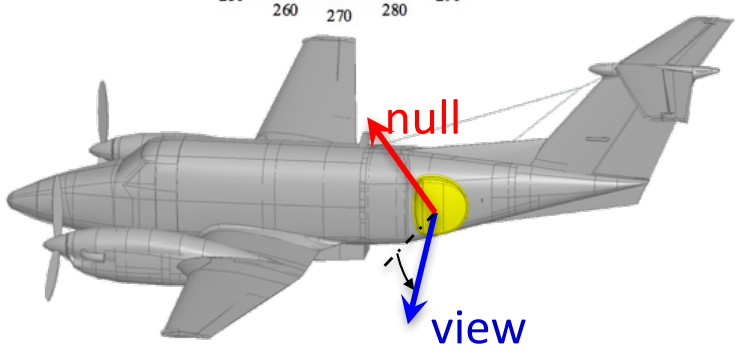
Signals of Opportunity Airborne Demonstrator (SoOp-AD)

- Antenna Null-Steering (post-process)



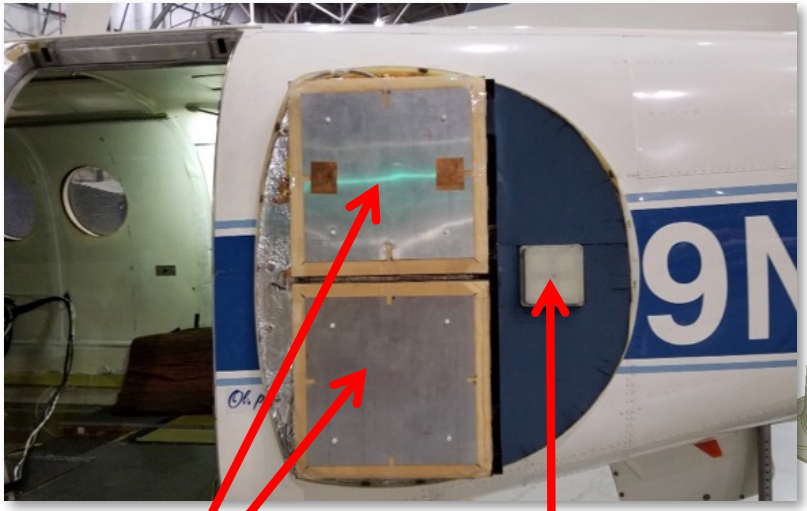






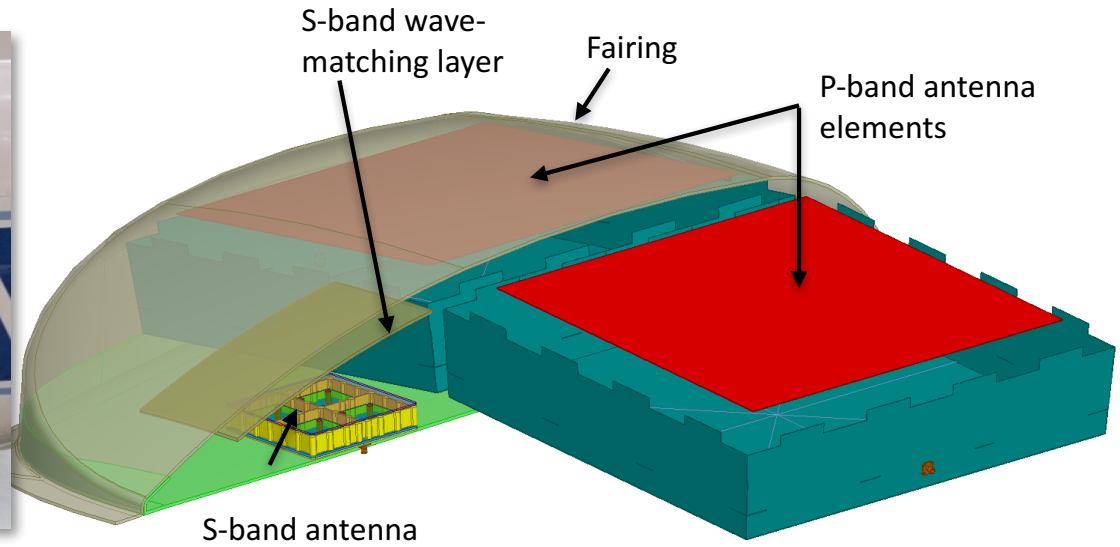
Signals of Opportunity Airborne Demonstrator (SoOp-AD)

- Antenna Installation on NASA Langley B-200 Aircraft



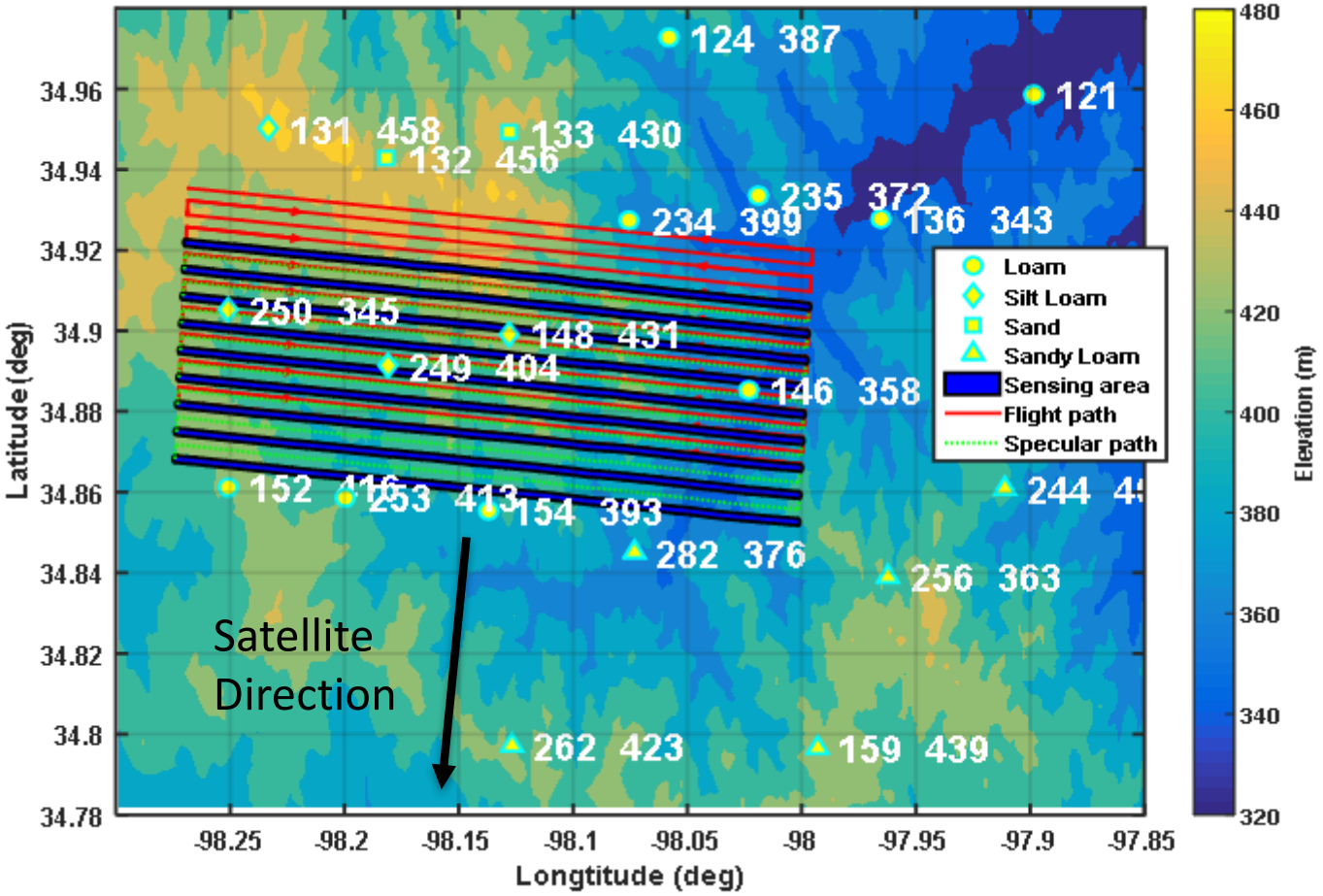
P-band elements

2x2 element S-band array
(integrated assembly shown
with radome cover on aircraft)



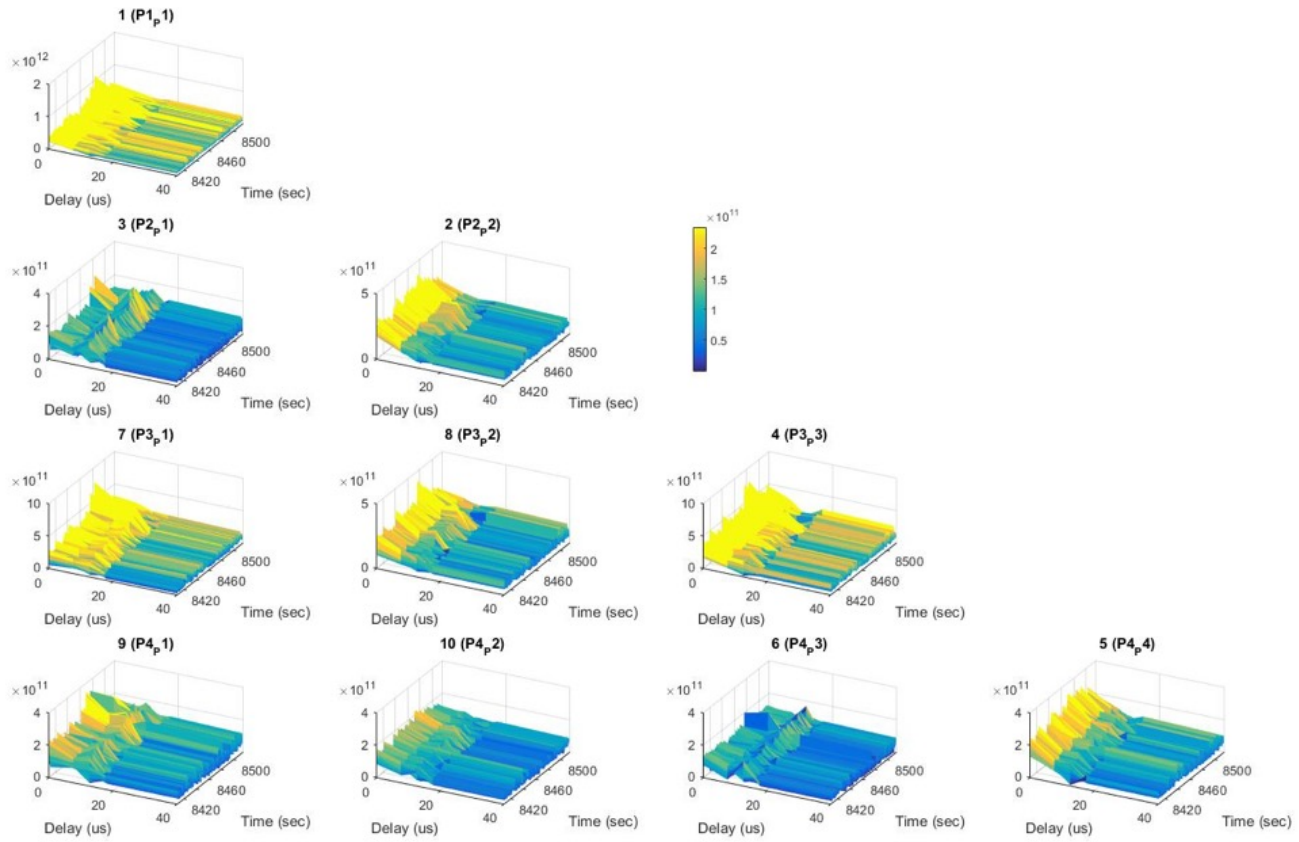
Flight Campaign: Little Washita, OK

- Flight planning software: Showing ARS Micronet sites.



First Look at Data

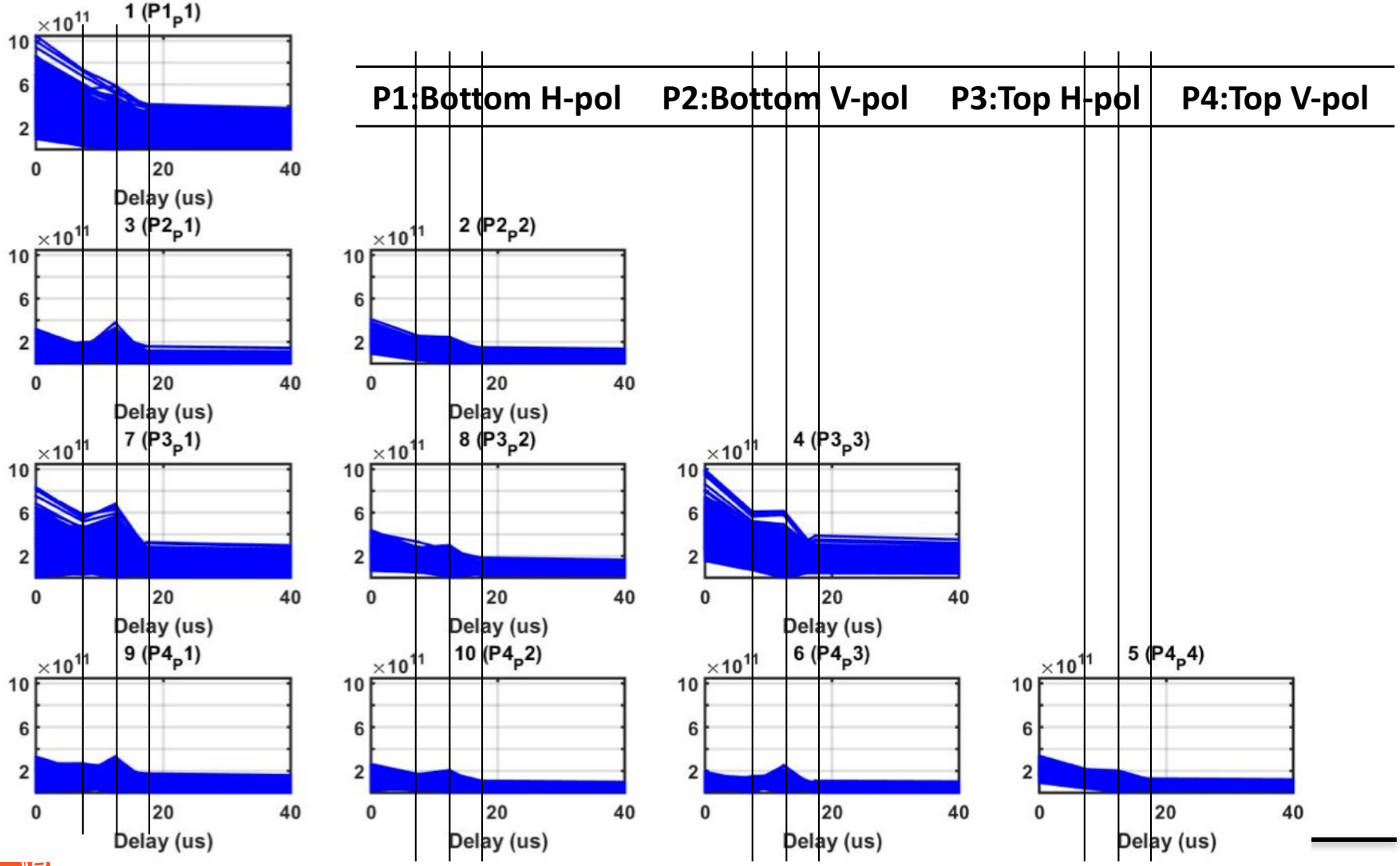
- Functioning of correlator array:



P1:Bottom H-pol **P2:Bottom V-pol** **P3:Top H-pol** **P4:Top V-pol**

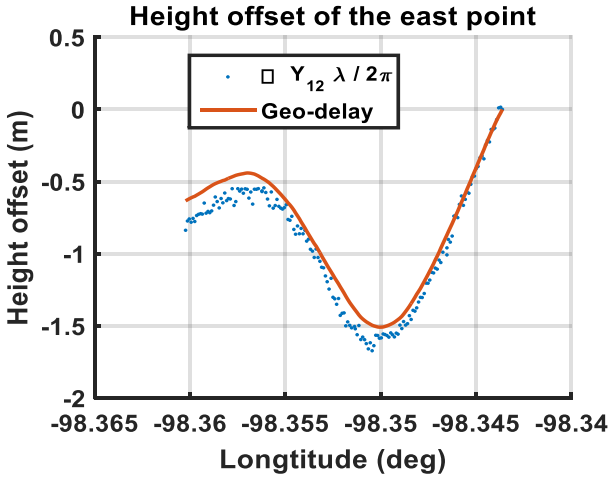
First Look at Data

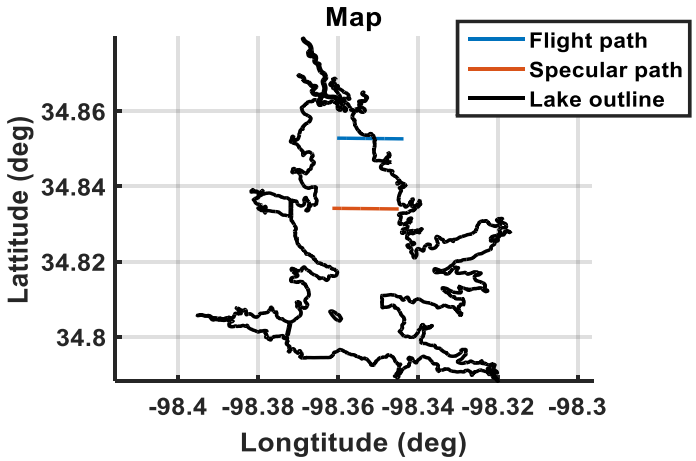
- Functioning of correlator array:

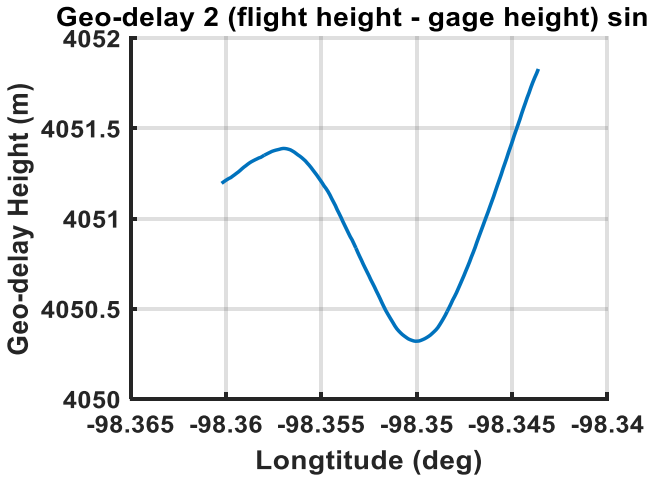


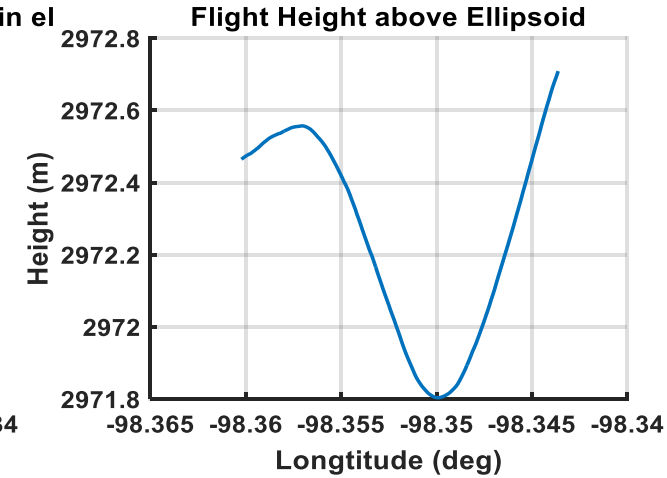
First Look at Data

- Flight Date: 10/22/2016

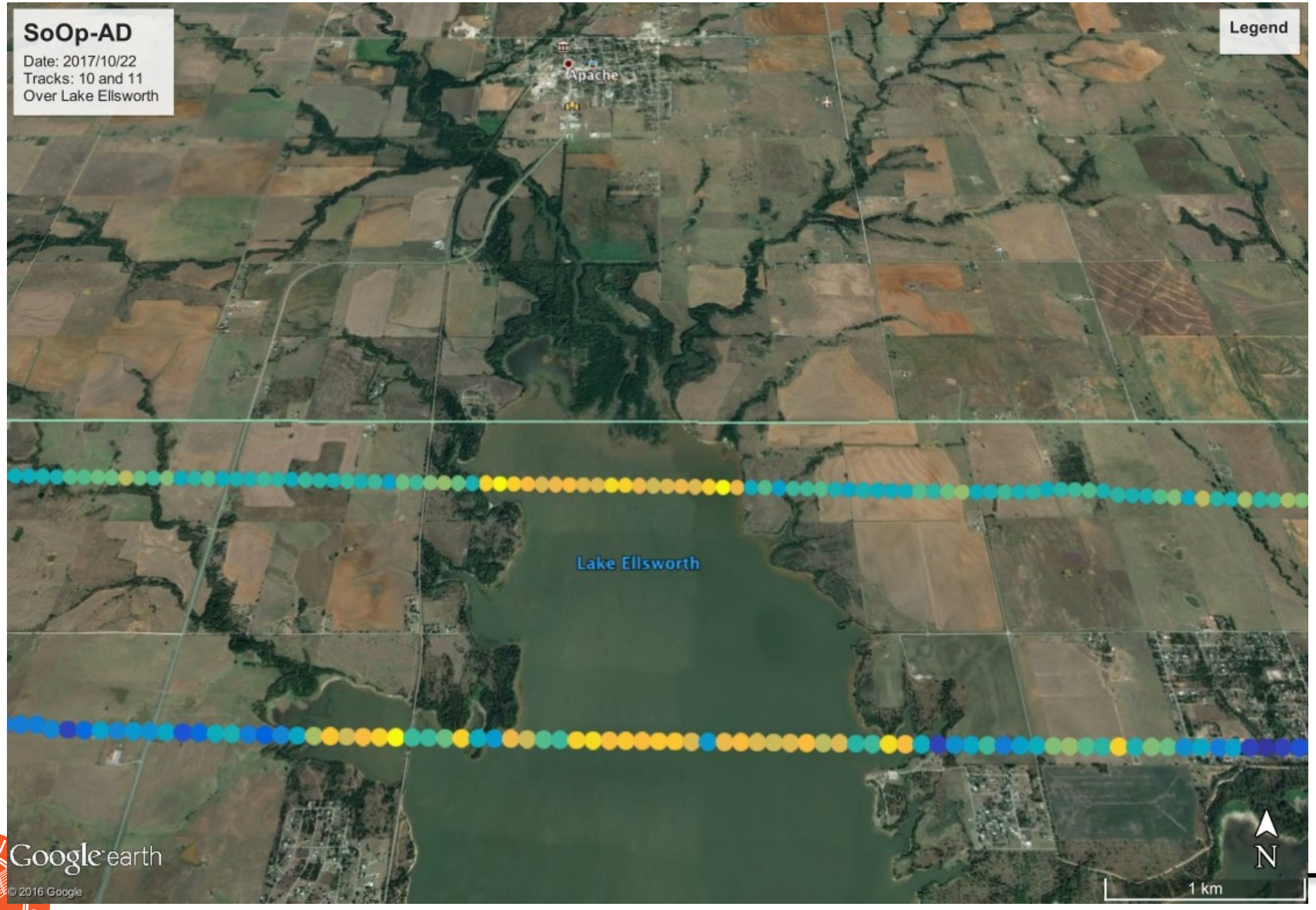






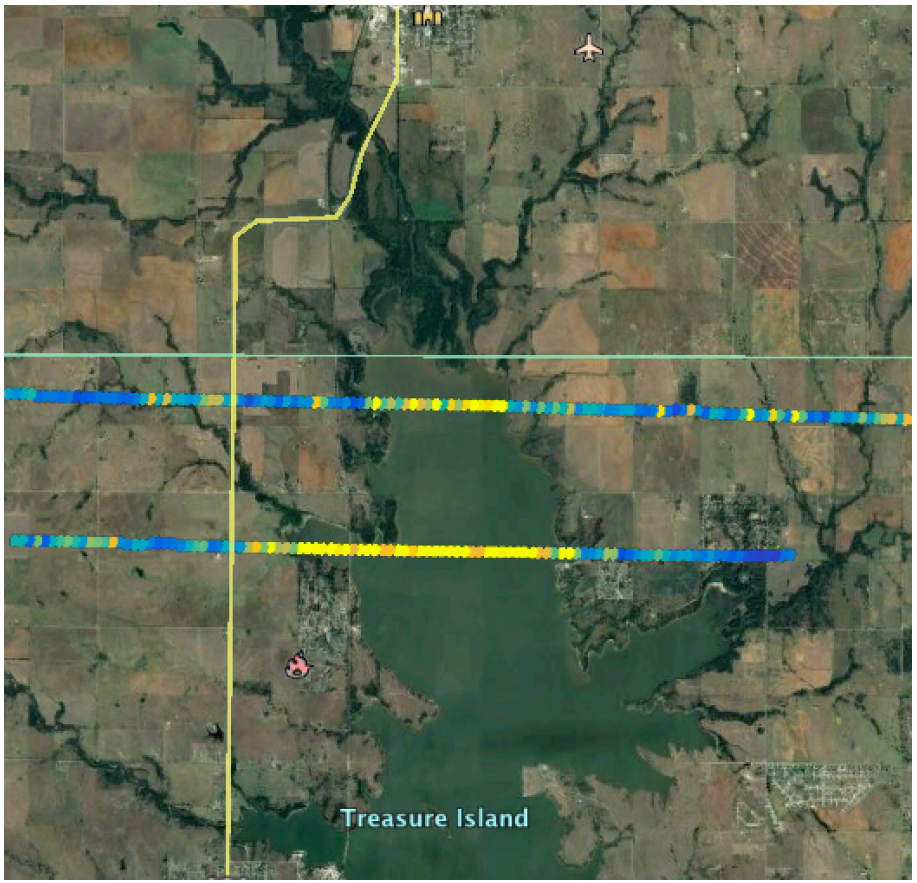


First Look at Data: ”Quick Look” Processing

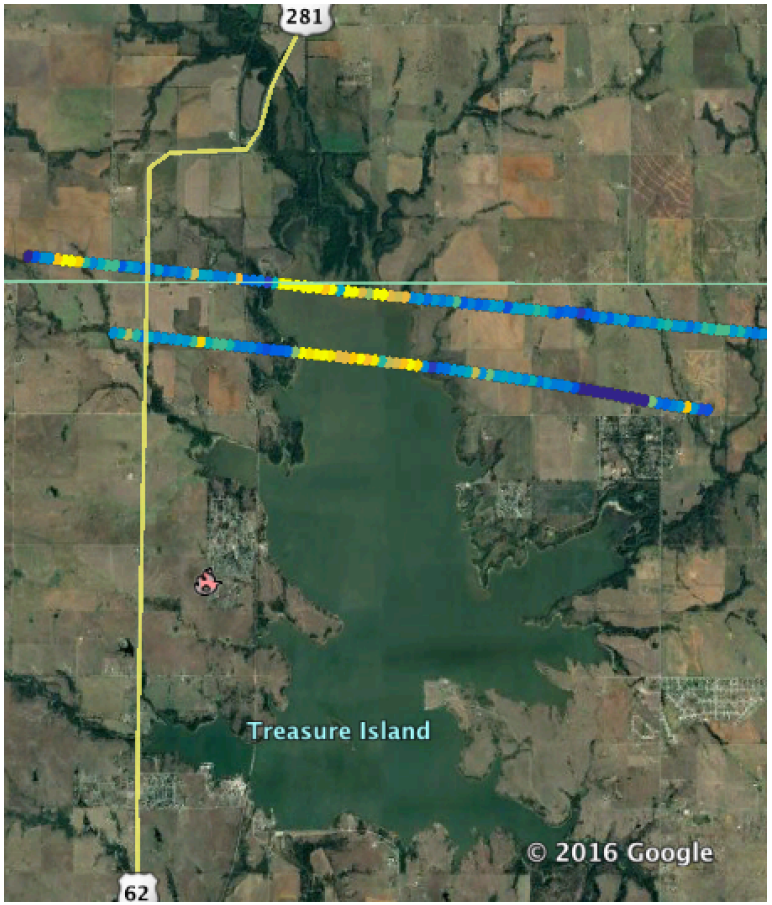


First Look at Data: Antenna Null-Steering and Adjustment

- Lake Ellsworth Overflights



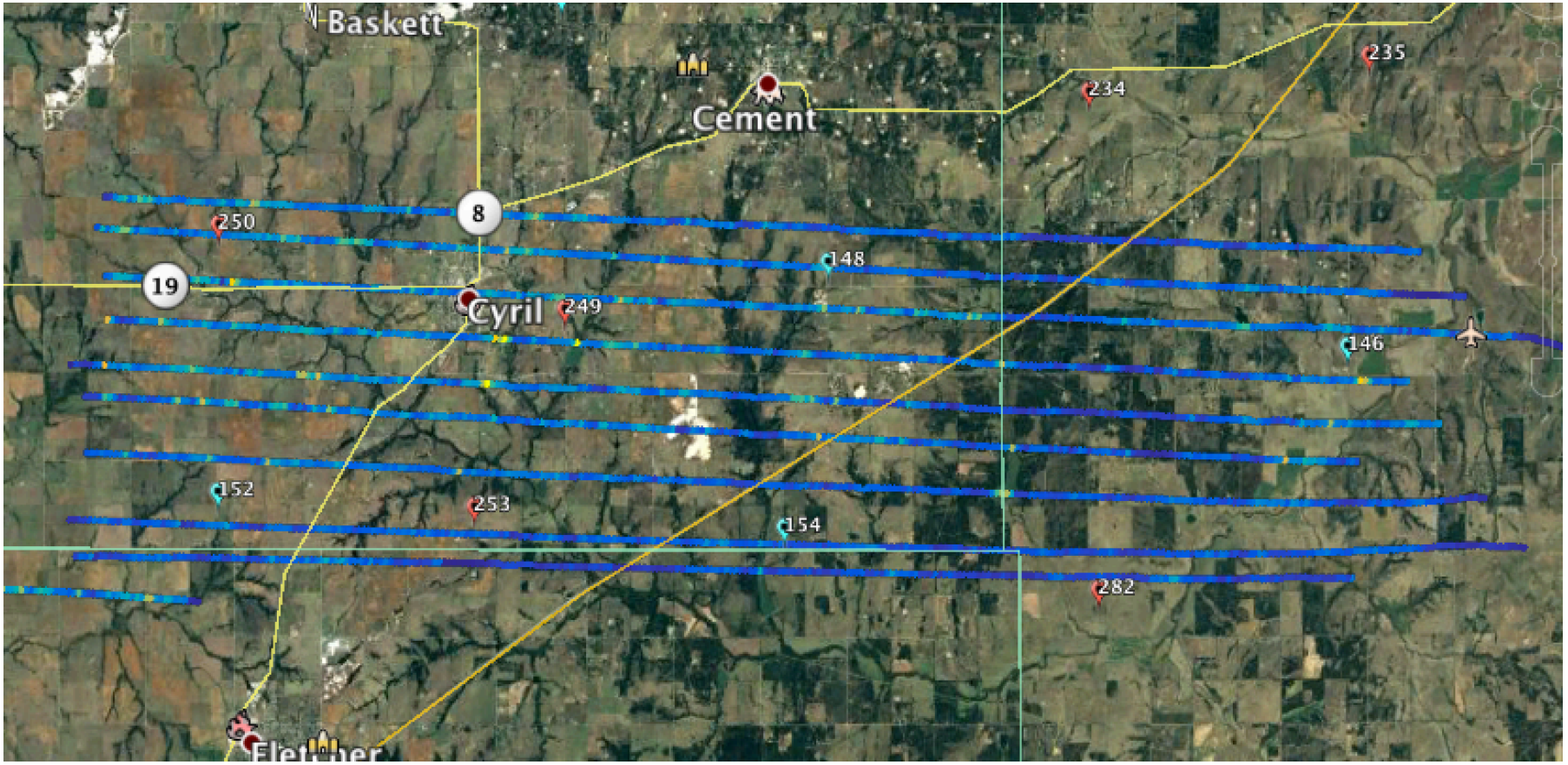
Science Flight 3 (10/22)



Science Flight 5 (10/25)

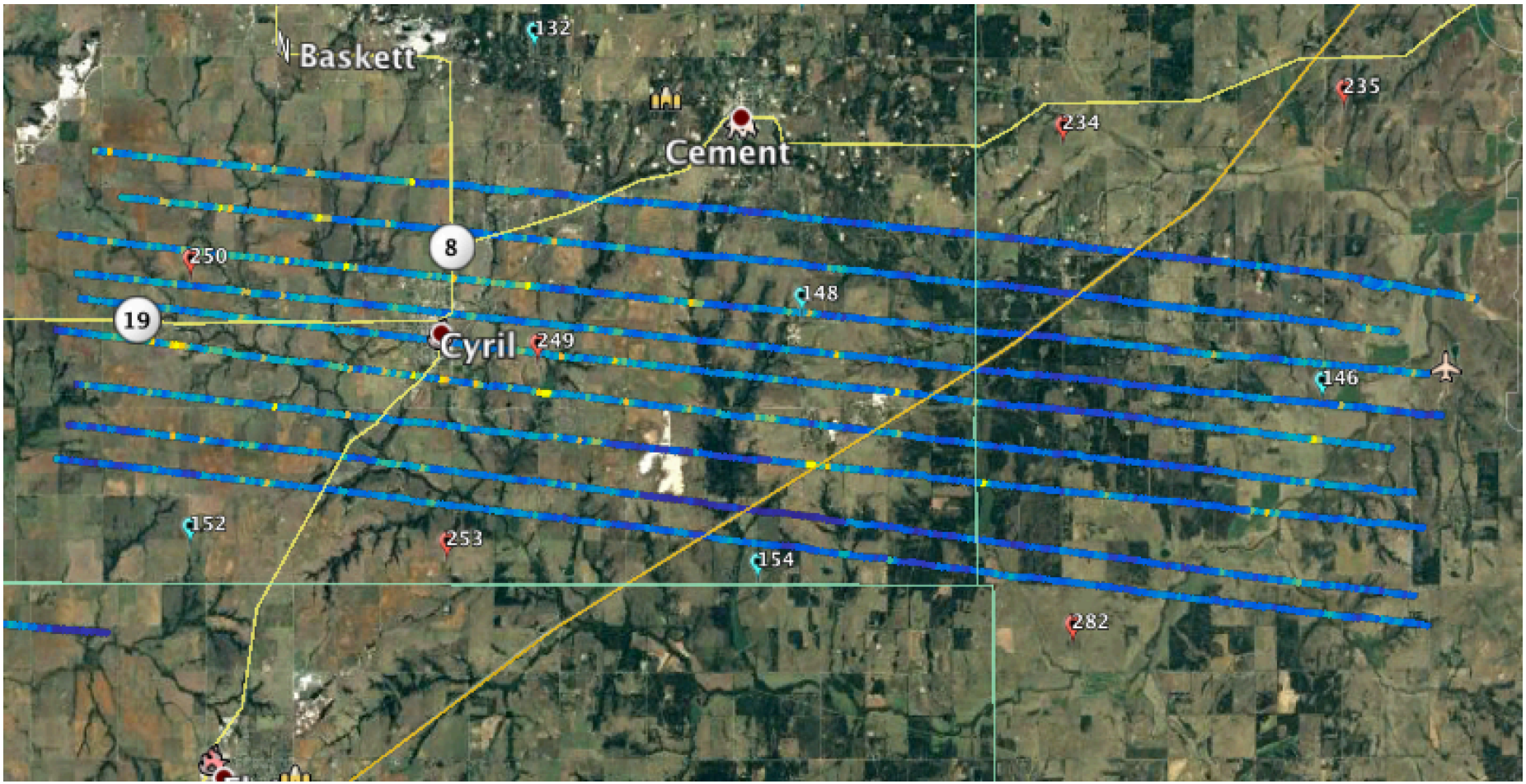
First Look at Data: Antenna Null-Steering and Adjustment

- Science Flight 3 (10/22/2016)



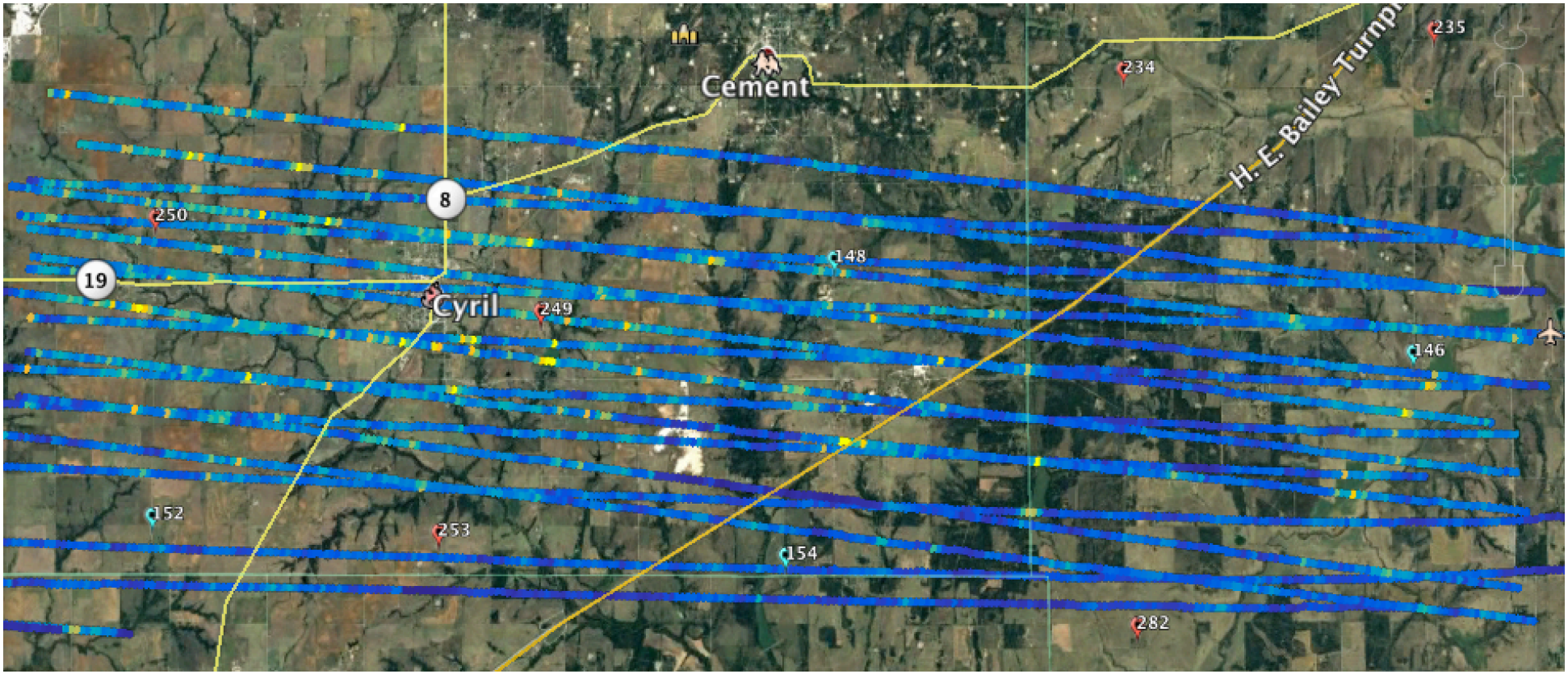
First Look at Data: Antenna Null-Steering and Adjustment

- Science Flight 5 (10/25/2016)



First Look at Data: Antenna Null-Steering and Adjustment

- Science Flights 3 and 5 overlay



Summary

- Completed engineering testing of ”breadboard” FPGA correlator in “relevant environment” (TRL5)
- Completed first attempt at reflectivity retrieval using null-steering and vicarious antenna calibration
- Work in Progress (under IIP-13):
  - Comparison of reflectivity retrieval vs. in-situ observations
  - Comparison vs. SLAP data
  - Processing of S-band data
  - Processing of full-spectrum P-band data
  - Definition of satellite mission requirements
- Future Work:
  - Soil moisture profile retrieval algorithms

Acknowledgements

- This work was funded under NASA Grant NNX14AE80G (2013 Instrument Incubator Program).
- USDA (Michael Cosh) provided valuable assistance with utilizing the Little Washita ARS Micronet data.