AirMOSS P-band SAR Calibration

Alexandra Chau¹, Elaine Chapin¹, Angelica Ceniceros¹,², Brandon Heavey¹, Scott Hensley¹, Yunling Lou¹, Rich Machuzak¹, Mahta Moghaddam³, Ronald Muellerschoen¹, Ryan van Schilfgaarde¹, K. Charles Wang¹

¹Jet Propulsion Laboratory, California Institute of Technology
²Massachusetts Institute of Technology
³University of Michigan

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Outline

• Introduction to AirMOSS
• AirMOSS P-band SAR
• Calibration strategy
• Hardware calibration paths
• 4.8 m corner reflector
• Future plans
Introduction to AirMOSS

- Airborne Microwave Observatory of Subcanopy and Subsurface
- NASA Earth Venture (EV-1) program
- AirMOSS will provide a new net ecosystem exchange (NEE) estimate for North America with a reduced uncertainty by:
  - Providing high-resolution observations of root zone soil moisture (RZSM) over regions representative of the major North American biomes
  - Quantifying the impact of RZSM on the estimation of regional carbon fluxes
  - Upscaling the reduced-uncertainty estimates of regional carbon fluxes to the continental scale of North America
Scientific Approach (1)

Uncertainty in Annual and Seasonal Net Ecosystem Exchange Estimates over North America

Based on spatial resolution of ~ 0.5 degree
Uncertainty in Annual and Seasonal Net Ecosystem Exchange Estimates over North America

Based on spatial resolution of ~ 0.5 degree

Bottom-up scaling

North America water and carbon fluxes
Reduce uncertainty of continental scale fluxes

AirMOSS model integration over North American biomes
Extrapolate between biomes using stats derived at 50km scale

AirMOSS data over modeling sub-grid: 2500 km²
Spatial and temporal distribution of RZSM @ 50m; capture seasonal & interannual variability (ED NEE & hydrology model runs).

Tower site footprint
1km x 1km
Currently used to calculate NEE by routine scaling up; RZSM assumed homogeneous

Plot Level (0-50m)
North American Biomes to Cover

Biome 1

Biome 2

Biome 3

Biome 4

Biome 5

Biome 6

Biome 7

Biome 8

Biome 9
AirMOSS P-band SAR

- Fully polarimetric P-band (aka UHF) synthetic aperture radar
- Hardware is capable of 80 MHz maximum contiguous bandwidth within 280-440 MHz band – frequency permission is a limiting factor
- First engineering flights to begin in Spring 2012
- Science flight campaigns to begin in Summer 2012

### AirMOSS Mission Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
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<tbody>
<tr>
<td>Platform altitude</td>
<td>12 km above terrain</td>
</tr>
<tr>
<td>Platform velocity</td>
<td>215 m/s</td>
</tr>
<tr>
<td>Pulse width</td>
<td>40 microseconds</td>
</tr>
<tr>
<td>PRF (fast)</td>
<td>1200 Hz</td>
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<tr>
<td>Center frequency</td>
<td>420 MHz</td>
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<tr>
<td>Bandwidth</td>
<td>20 MHz</td>
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<tr>
<td>Transmit Power</td>
<td>1995W</td>
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AirMOSS hardware is primarily based on UAVSAR heritage. In fact, UAVSAR was originally designed with accommodations for future P-band capability

- Antenna frame was sized to fit the GeoSAR P-band antenna
- Space in the nose cone was reserved for P-band transmitter
UAVSAR Instrument Pods

Operational L-band pod

Pod in experimental Ka-band configuration (includes a new passive Ka-band antenna)
Passive GeoSAR antenna (reduced in size by 3%)
AirMOSS Electronics Block Diagram

Aircraft System Interfaces
- Battery
- Power Distribution Unit

Flight System Radar Electronics
- L-band UPC
- RF Switch
- L-band Rx

Digital Subsystem
- Power Subsystem
- Differential (GeoSAR heritage)

Differential GPS Subsystem
- Power Distribution Unit
- Battery

Power Subsystem
- Processor Subsystem
- Data Transfer Subsystem
- Disk Storage
- Data Acquisition

Ground Data System
- Flight Planning Subsystem

Flight System Radar Electronics
- HPA
- Front-end
- Up-Conv.
- DDS
- TRAC

Antenna Subsystem
- P-band Passive Antenna (GeoSAR heritage)

Flight System Radar Electronics
- Radar Operator Workstation
- Automatic Radar Controller (ARC)
- Command and Timing Unit (CTU)
- Telemetry Acquisition

Antenna Subsystem
- Radome

New Units
- Legacy UAVSAR
- Flight System
- New Units
- Other

Legacy Units
- VME
- 1553
- Coax
- Fiber
- Ethernet

* Requires S/W, F/W or H/W Changes
AirMOSS P-band SAR reuses the L-band front end.

Direct Digital Synthesizer (DDS) generates signal to mix L-band chirp down to P-band:

- Commandable to generate any center frequency between 280 and 440 MHz.
- Commandable to any bandwidth between 6 and 80 MHz.
- Can be changed on a pulse-to-pulse basis.

For example:

- 290 ± 10 MHz
- 430 ± 10 MHz
P-band for Soil Moisture Retrieval

- P-band is suitable for RZSM because it can penetrate tens of centimeters into the ground
- However, backscatter curves saturate with respect to soil moisture
  - Need well calibrated sigma0s for inversion algorithms!
    - I.e., 0.5 dB calibration error to achieve desired 0.05 m$^3$/m$^3$ RZSM error

![Graphs showing VV and HH sigma0 vs. soil moisture content](image)

Mixed Forest data cube
roughness = 0.0237 m, VWC = 11.9412 kg/m$^2$
Calibration Strategy

- Monitor and correct for hardware variations
  - Temperature sensors (characterize temperature dependence during integration and test)
  - Calibration paths
- Corner reflectors for radiometric, geographic, range delay calibration
Calibration Paths

Antenna Transmit Calibration Test
- Route (attenuated) transmitted pulse to receiver
- Interleave every ~256\textsuperscript{th} pulse

Caltone
- Inject caltone into receive window for every pulse
- Use measured magnitude and phase to characterize receive path

Resistive Load/Noise Diode Test
- Send stable (better than 0.05 dB) signal into receive chain
- Group of pulses at the beginning and end of each data take
- Noise source is a combined resistive load/noise diode
  - With high attenuation, use strong signal from noise diode
  - With low attenuation, use weak signal from resistive load

Micronetics SMN3018
“The world’s smallest packaged noise source”
- Frequency: 200 MHz to 6.0 GHz
- ENR: 26 dB min
- Flatness: 3 dB max
2.4 m Corner Reflector Array

- JPL maintains an array of 23 corner reflectors at Rosamond Dry Lake, CA for UAVSAR calibration
- Each corner reflector is 2.4 m (short leg) and weighs ~ 50 lbs.

L-band UAVSAR image of CR array at Rosamond
4.8 m Corner Reflector

• Corner Reflector (CR) comprised of 12 identical modular triangles

• Size:
  – CR Leg: 4.80 m (15.8’)
  – CR Hypotenuse: 6.79 m (22.3’)
  – Modular triangle leg: 2.40 m (7.9’)
  – Modular triangle hyp: 3.39 m (11.1’)

• Weight:
  – CR: 238 kg (525 lbs CBE)
  – Modular triangle: 17 kg (37 lbs CBE)

• Stands:
  – 1 Vertex Balance Stand (VBS)
  – 3 Leading Edge Stands (LES)

• Retention:
  – Cinder blocks on LES
  – Stakes through stand bases
  – Guy ropes running to stakes
Boresight of CR co-aligned with center of AirMOSS radar look angle range (25° to 45°)
Profile Dimensions

Note: CR shown with leading edge perpendicular to page

4.5 m (14.8 ft)

1.2 m (3.8 ft)

4.8 m (15.8 ft)

20°
**Materials**

**Structure:** Aluminum Alloy 6061 T6

- Aluminum L-Channel chosen for light weight and uniformity
- Al Alloy 6061 T6 chosen for strength
  - Yield strength: 40 ksi
  - Cost: ~$6/ft

**Mesh:** Aluminum Alloy 3003 H14, ½” round holes, 48% open area

- Hole diameter of 1.3 cm chosen to allow CRs to be compatible with L-Band radar
  - P-Band: \( \lambda = 0.68 \) m (AirMOSS)
  - L-Band: \( \lambda = 0.24 \) m (UAVSAR)
  - RE-08: The active surface of the CR shall not contain gaps larger than \( \lambda/10 \)
- Percent open area chosen to minimize drag coefficient and weight while maintaining structural integrity

[11/7/11]

http://www.mcmaster.com

The modular design of the CR panels allow different size and shape reflectors to be constructed:

- **Dihedral Corner Reflectors**
  - 2.4 m x 2.4 m 4 modular triangles
  - 2.4 m x 4.8 m 8 modular triangles
  - 4.8 m x 4.8 m 16 modular triangles

- **Trihedral Corner Reflectors**
  - 4.8 m 12 modular triangles (AirMOSS)
  - 3.4 m 6 modular triangles
  - 2.4 m 3 modular triangles (UAVSAR)

New mounting schemes are required for CR permutations
Modular Design – Trihedral CR Sizes

4.8 m
12 modular triangles
(AirMOSS)

3.4 m
6 modular triangles

2.4 m
3 modular triangles
(UAVSAR)

Resized mounting schemes and corner brackets are required for trihedral CR permutations
Stress Analysis: Surface Deflection

- Max displacement: 12.1mm (0.48in)
  - P-Band Requirement: <68mm (2.7in)
  - L-Band Requirement: <24mm (0.9in)
- Max angular deflection: 0.005deg
  - Requirement: <0.5deg

0.25g Lat + 2g Vert

- Max displacement: 71.6mm (2.8in)
  - Wind loads (parallel to ground) of 50mph assumed for this analysis (scales by v^2)
- Max angular deflection: 0.015deg

Wind Load LC4
First Corner Assembly at JPL

• Assembled a prototype corner reflector at JPL on Oct 26, 2011
• We predicted it would take 7 people up to 8 hours to assemble
Assembly Procedure (1)

- Orient and assemble lower face on ground
  - Place face panels mesh down
  - Orient one flip about hypotenuse away from desired final position
  - Bolt panels together
- Bolt 2 corner L-channels and center strap to lower face
- Flip face about hypotenuse into desired position (mesh facing up)
- Verify azimuth of lower face is correct, adjust as necessary
Assembly: Individual Side Panels
Assembly Procedure (2)

- Panel weighs 150 lbs
- Vertex weighs 50 lbs

Flip about hypotenuse
Assembly Procedure (3)

Note: Creating handle by tying rope around support structure will ease holding panel in vertical position.
Assembly: Raising the Sides
Assembly Procedure (4)

- Install remaining bolts
- Install cross braces
Assembly Procedure (5)

• Raise leading edge (LE) of CR using Hi-Lift jacks and bumper hooks
• Place step ladders near 4th bolt hole from ends
• Lower LE onto step ladders and secure with spring pins
Assembly Procedure (6)

- Raise vertex of CR from jack points located 42” from vertex using Hi-Lift jacks and bumper hooks
- Position Vertex Balance Stand (VBS) under vertex
  - Verify azimuth of VBS is correct, adjust as necessary
- Lower vertex onto VBS
Assembly: Vertex Balance Stand
Assembly Procedure (7)

- Support LE with jacks and remove spring pins
Assembly: Jack the Leading Edge
Assembly Procedure (8)

- Raise LE and slide leading edge supports (LESs) into position
- Lower LE onto LESs and install bolts
Assembly: Leading Edge Supports
After CR is oriented, load cinder blocks on LESs, drive in stakes and install guy ropes
Assembly: Secure with Guy Ropes
The corner reflector was assembled by 9 people in about 4 hours.

We predict that the second time, it can be assembled by 4 or 5 people in the same amount of time.
Side View

Five feet tall
Cross Bars
UAVSAR Image of 4.8 m Corner

4.8 m corner reflector located here
UAVSAR Corner Reflector Response

<table>
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<tr>
<th></th>
<th>RCS [dBsm]</th>
<th>Δ [dBsm]</th>
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<tbody>
<tr>
<td>Predicted</td>
<td>42.837</td>
<td>-</td>
</tr>
<tr>
<td>HH</td>
<td>42.148</td>
<td>-0.689</td>
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<tr>
<td>VV</td>
<td>43.668</td>
<td>0.839</td>
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</tbody>
</table>

Azimuth response (oversampled)

Range response (oversampled)

4.8m CR, JPL
2.4m CR, Rosamond

11/7/11
Future Plans

- Characterize P-band SAR hardware and calibration paths (ongoing)
- Fabricate remaining corner reflectors for array (~5 at Rosamond Dry Lake)
- Deploy corner reflectors at Rosamond (spring 2012)
- Fly AirMOSS!
A time lapse video of the corner reflector assembly is at
http://airmoss.jpl.nasa.gov/science/calval/