Mini-RF:
LRO Data Users Workshop

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Overview

- About Mini-RF
- Where to Find Data
- What data is available
- How to process in ISIS
- Mosaics that are available
- Bistatic -> Angela
Mini-RF: Lunar SAR Instruments

Build 1: Forerunner
Chandrayaan-1
Indian Space Research Organization (ISRO)
Launched 21 October 2008

Build 2: LRO
Lunar Reconnaissance Orbiter

Mission Ended

In Operations
Lunar Reconnaissance Orbiter
As Mounted on the Spacecraft

- Chandrayaan-1
- Magellan
- LRO
Instrument Description

- Two-band, two-resolution imaging radar
  - S-band ($\lambda=12.6$ cm)
  - X-band ($\lambda=4.2$ cm)
  - SAR Baseline 150 m
  - Zoom 15x30 m

- Hybrid-architecture polarimetric SAR
  - Transmit LCP; Receive H- and V- linear coherently
  - Four Stokes parameters derived

- Mini-RF can measure topography
  - Interferometry: 15 m/pix spatial, sub-meter vertical resolution
  - SAR-stereo: 30 m/pix spatial, ~10 m vertical

- Low mass and power requirements
  - 13 kg, 150 W
A Hybrid Dual-Polarized **Synthetic Aperture** Radar?

- A form of radar that uses the relative motion between an antenna and its target to obtain higher resolution information.
A Hybrid Dual-Polarized Synthetic Aperture Radar

And, to top it off

- Polarization is a property of waves that can oscillate with more than one orientation.
Examples of Mini-RF Data

Typical strip is 1920 x 10 km

Mini-RF SAR data co-registered with Clementine UVVIS context mosaics.
Basic Data Products Often Used and We Provide

Polarization Info: H, V, Re, Im

Stokes Products \((S_1, S_2, S_3, S_4)\)

\[
\text{SC} = (S_1-S_4) \\
\text{OC} = (S_1+S_4) \\
\text{CPR} = (S_1-S_4)/(S_1+S_4) = \text{SC}/\text{OC}
\]

- Indicator of the roughness of a surface, as determined by the distribution of wavelength-scale and larger radar scatterers (e.g., boulders).

- Young, fresh craters are distinctive in radar images obtained with the Mini-RF instrument because of the surface roughness associated with their ejecta deposits.
Surfaces ‘smooth’ at the scale of the wavelength will have a low Circular Polarization Ratio.

\[ \text{CPR} = \frac{\text{SC}}{\text{OC}} < 1 \]
If there is a corner reflector the polarization will change twice returning as it was transmitted in the particular case. High SC signal

\[ CPR = \frac{SC}{OC} \geq 1 \]
Mini-RF maps the roughness of the lunar surface. In doing so it can map the ejecta blankets that surround impact craters.

Mini-RF can see ejecta that are not visible in optical images.

This could be because the extended ejecta cause subtle variations in surface roughness or that Mini-RF is detecting subsurface effects.

Mapping the continuous and discontinuous ejecta blankets that surround impact craters will help us to better understand the physics of impact cratering.

Oblique impact crater in mare Nubium. Both the continuous and extended ejecta blankets are detected.
Melt Flow Roughness
IMAGING SHADOWED AND SUBSURFACE DEPOSITS

- Imaging subsurface deposits
- Imaging at night
- Key towards Mini-RF’s total data collection
- LROC didn’t usually image at night
IMAGING IN PERMANENT SHADOW

- It leads to permanent shadow
SEARCHING FOR ICE

CPR
Where To Find Data: Planetary Data Explorer

- LRO Mini-RF Data can be accessed through planetary data explorer
- Mini-SAR too!
Tessera: Data Access Tool
Where To Find Data

- Planetary Data System – Wash. U. Node (pds-geosciences.wustl.edu)
- http://pds-geosciences.wustl.edu/missions/lro/mrf.htm
Monostatic data was collected until Dec. 25th, 2010 (Merry Christmas!)

<table>
<thead>
<tr>
<th>Volume</th>
<th>Data acquisition dates</th>
<th>Orbit range</th>
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<tbody>
<tr>
<td>LROMRF_0001</td>
<td>2007-07-13 to 2010-01-19</td>
<td>200-2599</td>
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<tr>
<td>LROMRF_0002</td>
<td>2010-01-19 to 2010-06-17</td>
<td>2600-4499</td>
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<tr>
<td>LROMRF_0003</td>
<td>2010-06-17 to 2010-07-23</td>
<td>4500-4999</td>
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<tr>
<td>LROMRF_0004</td>
<td>2010-07-23 to 2010-12-05</td>
<td>5000-6699</td>
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<tr>
<td>LROMRF_0005</td>
<td>2010-12-05 to 2011-01-23</td>
<td>6700-7302</td>
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Data Available

- **PDRs**: While available need a specialized processor (VEXCEL)
- **CDRs**: ('LEVEL 1' unprojected .img and .lbl files)
- **CDR-INSAR** (small number) coming soon
- **CDR-MAPs**: ('LEVEL 2' projected .img and .lbl files – again can be brought into ISIS)
- **CDR-MOSAICs**

The Mini-RF archive includes these data sets:

<table>
<thead>
<tr>
<th>Raw Data Products</th>
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<tbody>
<tr>
<td>PDR - Packetized Data Records (Directories DATA/SAR/.../RAW and DATA/SAR/.../HOUSEKEEPING)</td>
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<tr>
<th>Calibrated Data Products</th>
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<tr>
<td>CDR - Calibrated Data Records (Directory DATA/SAR/.../LEVEL1)</td>
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<tr>
<td>CDR-INSAR - Interferometric Calibrated Data Records — to be released later</td>
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<tr>
<th>Derived Data Products</th>
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<tbody>
<tr>
<td>CDR-MAP - Map-Projected Calibrated Data Records (Directory DATA/SAR/.../LEVEL2)</td>
</tr>
<tr>
<td>CDR-MOSAIC - Polar Mosaic Calibrated Data Records (Directory DATA/SAR/MOSAICS)</td>
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</tbody>
</table>
Level 1 Data

- CDRs: ‘LEVEL 1’
- Non-Orthorectified
- Unprojected
- .img, .lbl, .txt files
- Products Include
  - ‘cd’ -> H, V, Re, Im (4 Bands)
- ISIS Compatible
  - mrf2isis
Level 2 Data

- CDRs: ‘LEVEL 2’
- Non-Orthorectified
- Equirectangular projections
- .img, .lbl, .txt files
- Products Include
  - ‘cd’ -> H, V, Re, Im (4 Bands)
  - Stokes denoted ‘s1, s2, s3, s4’
  - ‘cp’ -> CPR
  - ‘oc’ -> opposite sense
  - ‘sc’ -> same sense
- ISIS Compatible
  - mrf2isis
Quikview JPEG Data

- CDRs: jpegs are not in the same place
- Look in ‘Extras’ > ‘Quikview’
- JPEG Products Include
  - ‘cd’ -> H, V, Re, Im (4 Bands)
  - Stokes denoted ‘s1, s2, s3, s4’
  - ‘cp’ -> CPR
  - ‘oc’ -> opposite sense
  - ‘sc’ -> same sense
Data Processing Level 1 and 2: ISIS

- ‘mrf2isis’ will process both Level 1 and 2 files in for all data product arrays (S₁, CPR, OC, SC, etc.)

- To orthorectify image use ‘spiceinit’ to LOLA altimetry in ISIS3 base data
Level 3: Near Complete Polar Coverage

- Polar Mosaics are available in S-Band if you dig into LROMRF_0005 directory
- Resolutions: 32 & 256 ppd
- S1 and CPR products
- Both look directions combined
Data Processing Level 3
Mosaics: ISIS

- ‘mrf2isis’ WILL NOT process the mosaics
- Need to use ‘pds2isis’
Near Complete Global Coverage

- Global S-band is coming to the PDS
- Data set was not in the SIS for submittal to PDS
- Is being reviewed as a separate delivery to the PDS
- 128 ppd
- Stokes products, CPR, OC, SC, m-chi, etc.
- **Controlled Data Sets** coming available soon (regional)

- **Isolated collects** of roll-derived high resolution stereo topography

- **Several rolled collects** of lunar poles
Monostatic Mini-RF Data Set

• Mini-RF is a highly capable instrument, obtaining data about lunar surface properties,

• Tech-demo Mini-RF was only supposed to make a very small number of mono-static collects.

• Mini-RF is a unanticipated and first Global S-band data set of the Moon which the LRO Project and Mini-RF team is giving the Planetary community.
  • 67% of lunar surface mapped
  • >95% polar regions covered
  • >17 TB of (>45 TB with products) Mini-RF delivered to NASA public data archive (PDS)

• The best has not yet been pulled from this data set!

Please see Lynn Carter’s Poster # 2152 on Tuesday
MINI-RF/GROUND COMPARISON

PLEASE SEE LYNN CARTER’S POSTER # 2152 ON TUESDAY
Mini-RF Reborn!!!: A Hybrid Dual-Polarized Synthetic Aperture Bistatic Radar in Orbit around the Moon