Imaging Radar For The Study Of Land Cover And Land Use Change A Brief Review

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OUTLINES

• Introduction
• Scattering Mechanisms and Radar Image Characteristics
• Data Availability
• Example of Applications
• Potential and Limitations
• Future Radar Missions
INTRODUCTION

• Provide a brief overview of the utility, availability, and limitation of imaging radar data for the study of land cover and land use change
• Not intend to review all important works
• Try to balance between potential and limitation
Scattering Mechanisms

-Surface scattering
-Double-bounce scattering
-Volumetric scattering

Factors that effect radar backscattering include:

*Radar parameters:*
Incidence angle
Wavelength and polarization

*Targets:*
Surface roughness
Moisture contents
Scatterer’s geometry

Major backscattering components from a forest canopy:
-Volumetric scattering from tree crowns
-Ground surface scattering
-Trunk-ground double-bounce scattering
-Crown-ground multiple scattering
Penetration capability of multifrequency radar

The penetration depth of radar beam depends on

1) radar wavelength Longer wavelength has deeper penetration

2) radar polarization e.g. vertical thin dielectric cylinders have less penetration at V than at H polarization

3) target properties e.g. dense vegetation, wet soil have less penetration
Geometric Distortion of Radar Images

Geometric Distortion

Foreshortening

Layover

Shadowing

(ASF)
Complementarity Between Optical and Microwave Sensors

Bright areas on TM5 image are young healthy vegetation (grass, shrub, young aspen, etc).
Bright areas on JERS-1 L HH image are mature forests with high woody biomass, and bright areas on RADARSAT C HH image are rough surfaces, flooded low vegetation along river, at fen sites, etc.
Safsaf Oasis, Egypt

TM bands 7,4,1 false color

SIR-C/XSAR Lhh, Chh, Xvv

(JPL)
Potential of Imaging Radar
(Temporal, Polarimetric, Interferometric)

- Timely data (all weather, day and night)
- Penetration into canopies, desert, ice
- Sensitive to 3D structure of targets (tree geometry, building type, etc.)
- Direct information about biomass
- Vertical canopy structure from InSAR
Imaging Radar Applications in Land Cover and Land Use Change Studies

Forest characterization
  - Forest mapping, biomass estimation, monitoring disturbances
Agriculture
  - Crop classification, monitoring and yield estimation
Urban Development
  - Land use analysis, Population estimation
Others
Old Jack Pine
Reddish areas are wetter, with alders
Clear cut, very young jack pine
Young Jack Pine ~ 15 years old
New burns in 1993 trees dead, but only leaves and small branches burned
Forest Classification and Biomass Estimation
From SIR-C Radar Images, in Canada

CLASSIFICATION AND BIOMASS MAPS
BOREAL SSA

(NASA GSFC)
Trunk Height, Basal Area, Biomass of Crown, Trunk, and Total From SIR-C Data (Dobson et al)
Non-burned Forests and Forests at Different Stages of Fire Succession

Yellowstone National Park, Wyoming, The image at the left is L band HV image obtained on Oct 2, 1994 by SIR-C/XSAR Mission. The image on the right is derived biomass image, showing the non-burned forests and recovery of forests after a fire. Colors of brown, light brown, yellow, light green, green represent biomass levels of <4, 4-12, 12-20, 20-35, and > 35 tons per hectare.

(NASA JPL)
SIR-C/X-SAR
MANAUS, BRAZIL SUPERSITE
INUNDATION MAP
APRIL 12, 1994

(NASA JPL)
This is a three-frequency, false color, SIR-C/X SAR image (L band total power - red, C band total power - green, and X band vv - blue) of Flevoland, The Netherlands, taken on April 14 1994. At the top of the image, across the canal from Flevoland, is an older forest shown in red. At this time of the year, the agricultural fields are bare soil, and they show up in this image in blue. The changes in the brightness of the blue areas are equal to the changes in roughness.

(NASA JPL)
Rice field identification and classification from temporal ERS-1 data
San Fernando Valley, California

SIR-C Lhh, Lhv, Chv False Color Image

(NASA JPL)
SIR-C Image of Changzhou (31.6N, 119.6E), China. April 18, 1994. Lhh, Lhv, Chv
Thaw/frozen condition

from ERS-1 data
Acquired across Alaska in 1991
Each transect is 100 km by 1400 km
Areas which show a decrease in backscatter larger than 3 dB are coded blue

(Rignot and Way, 1994)
INTEGRATED AIRSAR PROCESSOR

LIVERPOOL PLAINS 344-1 (C)

Radar illumination

Velocity

P-kilometers

Pixel Size = 10 m

Date Acquired: 6 Sept 1993
Date Processed: 5 June 1995
CCT ID: TS0049

P-Band Total Power  L-Band Total Power  C-Band VV

North

Approximate Image Center:
Latitude: -31.52
Longitude: 150.54
Lines in image: 1062
Samples per line: 1180

Brightness: C-Band VV Radar Cross-Section

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Interferometric Land-use Image - Red:
Interferometric coherence, Green: Average intensity, Blue: Intensity change

Interferometric Phase Image - a cycle of colors represents phase change of 2 PI

Vince, Italy
Green area - Heavy vegetation
Blue area - Water
Red area - Bare surface
Yellow area - Urban center

(From European Space Agency - ESA)
Interferometric Land-Use Image (Virginia Beach, USA)
(From European Space Agency - ESA)
Disadvantages and Limitations of Imaging radar

- **Speckle** degrades image (reduce by multi-look and filtering) and poses difficulties for machine interpretation
- **Terrain effect** complicates image processing
- **Composite signal** requires more effort to extract information from it
- Data is not widely available (will be better soon)
Forest clearcut on Mountains of Western Sayani, Russia. SIR-C image, April 16, 1994
Red - L band HH, Green - L band HV, Blue - C band HV, Brown areas are clearings
Mapping Forests in Sayani Mountains, Siberia Using SIR-C SAR Data
- Using DEM data for orthorectification and terrain effect correction,
or using image ration to reduce terrain effects

Lhh SIR-C radar image | Ratio Images | PC of ratio images
Existing SAR Data

- **SIR-C/XSAR** data: April and October, 1994, order from EROS, USGS, [http://edcwww.cr.usgs.gov/landdaac/sir-c/survey.html](http://edcwww.cr.usgs.gov/landdaac/sir-c/survey.html) $15 per scene (both L and C bands)
- **ERS-1/2** data: Global cover since 1991, ~$1500 per scene
- **JERS-1** data: 1992-1998, ~$1500 per scene
- **RADARSAT** data: $3500 per scene, NASA has a share
- Data received and processed by ASF (Alaska SAR Facility) - $15 per scene
FUTURE SAR MISSIONS

- **SRTM** (Shuttle Radar Topography Mission) C and X bands InSAR - Sept. 1999, NIMA, NASA, DLR, ASI
- **ASAR** (Advanced SAR) on ENVISAT-1, C band multi-pol, 2000, ESA
- **RADARSAT-2**, C band multi-pol, 2001, CCRS, Canada
- **ALOS-PALSAR**, L band multi-pol, 2002, NASDA, Japan
- **LightSAR**, L band full-pol, C band hi-res, 2003, NASA
SRTM  
(*NIMA, NASA, DLR, ASI*)

September 16-27, 1999  
C and X band InSAR  
Coverage: from 60° N to 56° S  
Data Products:  
1. Terrain height data - Pixel spacing 1″ (15-30 m), 5° x 5°  
   Absolute accuracy:  
   - horizontal 20 m  
   - vertical 16 m  
2. Random height error data sets  
3. Strip orthorectified image data  
   Pixel spacing 15 m
ENVISAT-1 ASAR

(Advanced Synthetic Aperture Radar)

Launch: 2000
Wavelength: C band
Polarization: HH & VV,
               HH & HV, VV & VH

Image Products:
- Single-look complex - Resolution ~6 m
  Image size 100 km x 100 km
- Multilook precision - Resolution < 30 m
  Image size 100 km x 100 km
- Median resolution image: Resolution < 150 m
  Image size: Normal 100 km x 100 km,
  Wide swath: 400 km x 400 km
Global monitoring: Pixel size 1 km

A Coherent Active Phased Array C band SAR
ASAR’s five mutually exclusive modes of operation:
- Global monitoring, Wave mode
- Image mode (HH or VV)
- Alternating polarization mode (Two polarization),
- Wide swath mode (HH or VV)

European Space Agency - ESA
### RADARSAT-2 Imaging Modes

**Beam Modes** | **Nominal Swath** | **Incidence Angles** | **Number of Looks** | **Approx. Resolution**
--- | --- | --- | --- | ---
Standard | 100km | 20-50 | 1x4 | 25m x 28m
Wide | 150km | 20-45 | 1x4 | 25m x 28m
Low Incidence | 170km | 10-20 | 1x4 | 40m x 28m
High Incidence | 70km | 50-60 | 1x4 | 20m x 28m
Fine | 50km | 37-48 | 1x1 | 10m x 9m
ScanSAR Wide | 500km | 20-50 | 4x2 | 100m x 100m
ScanSAR Narrow | 300km | 20-46 | 2x2 | 50m x 50m
Standard Quad | 25km | 20-41 | 1x4 | 25m x 28m
Polarization | | | | |
Fine Quad | 25km | 30-41 | 1 | 11m x 9m
Ultra-fine Wide | 20km | 30-40 | 1 | 3m x 3m
Ultra-fine Narrow | 10km | 30-40 | 1 | 3m x 3m
Phased Array type L-band Synthetic Aperture Radar (PALSAR)
NASDA, JAPAN
Launch 2002
on ALOS
(Advanced Land Observing Satellite)

Altitude: 700 km
Inclination: 98°
Recurrent: 45 days

L band, Multiple polarization

<table>
<thead>
<tr>
<th>Mode</th>
<th>Resolution</th>
<th>Swath</th>
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<tbody>
<tr>
<td>Fine resolution</td>
<td>10-20 m</td>
<td>70 km</td>
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<tr>
<td>ScanSAR</td>
<td>100 m</td>
<td>250 - 360 km</td>
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LIGHTSAR

New earth-imaging Radar Satellite
NASA
Launch Date 2003

L band multiple polarization, resolution 25 m
Swath 100 km
C (X) band high resolution (1-3 m) with narrow swath in the middle of L band swath
Multiple operation modes: Spotlight, High resolution strip, Dual or Quad polarization, Repeat pass interferometric, and ScanSAR
SUMMARIES

- Imaging Radar contributes to LCLUC studies by providing timely, unique and complementary data
- Complexity in Radar image processing and interpretation requires more efforts
- Imaging radar has bright past and future - From Seasat (1978) to LightSAR (2003)