Using ArcGIS for Radar Analysis and Map Production for USDA NAIP Test Program

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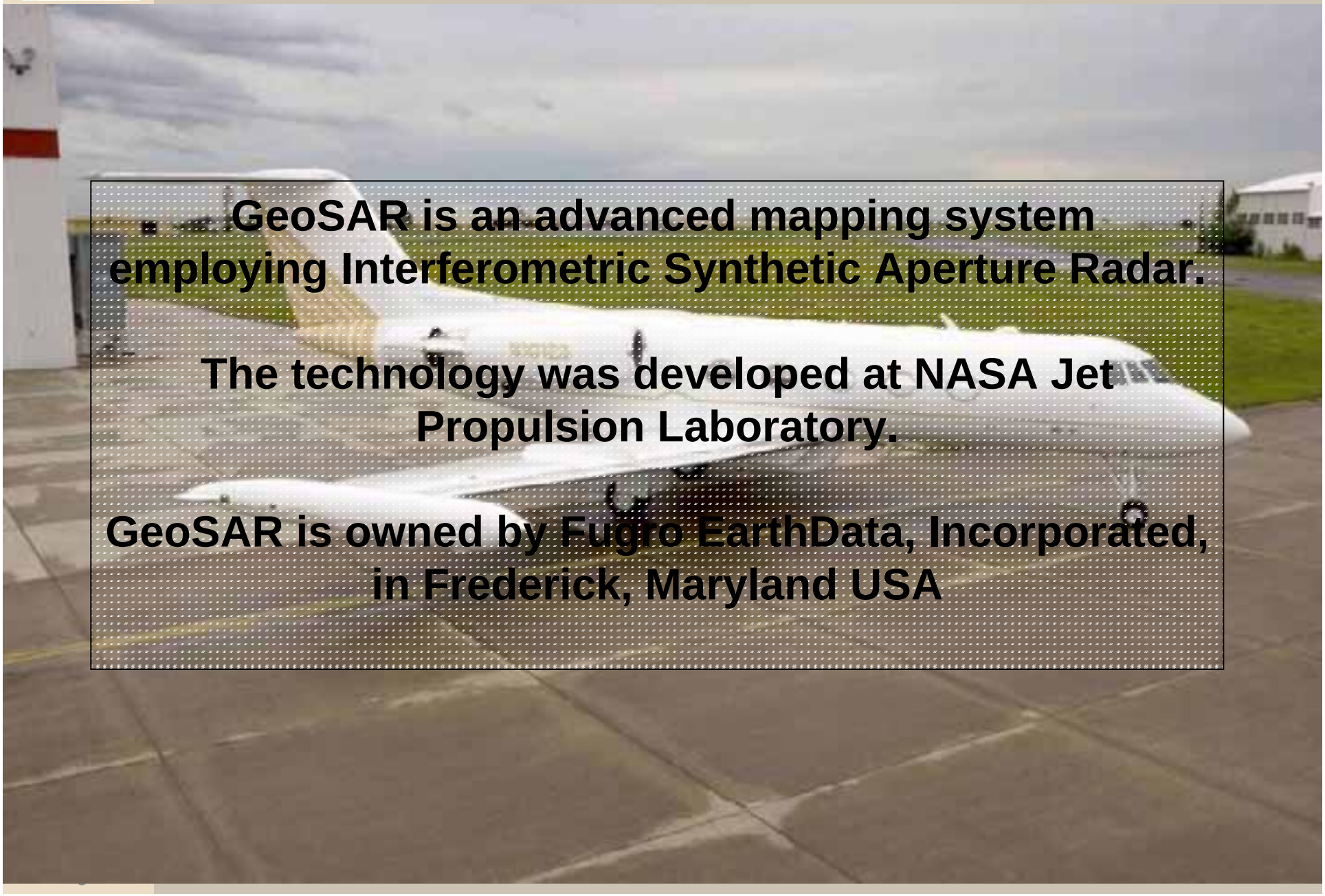
Agenda

1. Description of Interferometric Synthetic Aperture Radar (IFSAR) Technology and the Fugro EarthData GeoSAR System.
2. Characteristics of X and P Band SAR
3. Applications of Synthetic Aperture Radar to the US Department of Agriculture National Agriculture Imagery Program (NAIP).

The GeoSAR Aircraft



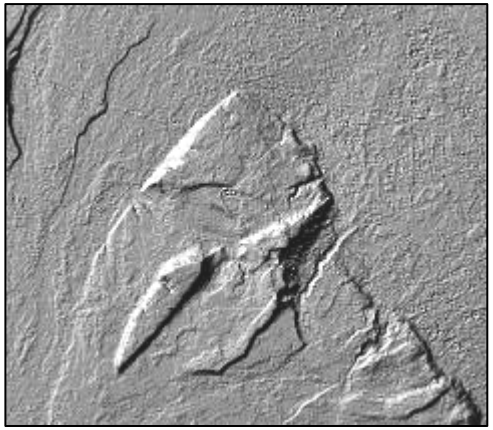
GeoSAR is an advanced mapping system employing Interferometric Synthetic Aperture Radar.

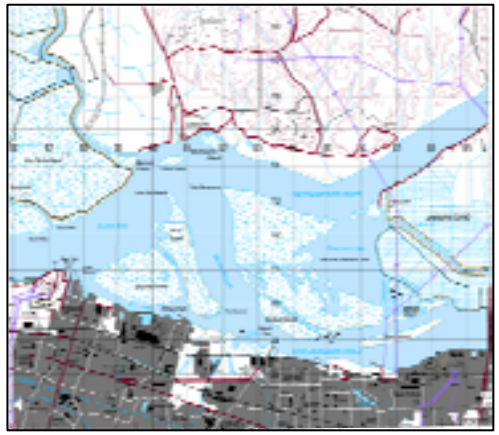
The technology was developed at NASA Jet Propulsion Laboratory.

GeoSAR is owned by Fugro EarthData, Incorporated, in Frederick, Maryland USA

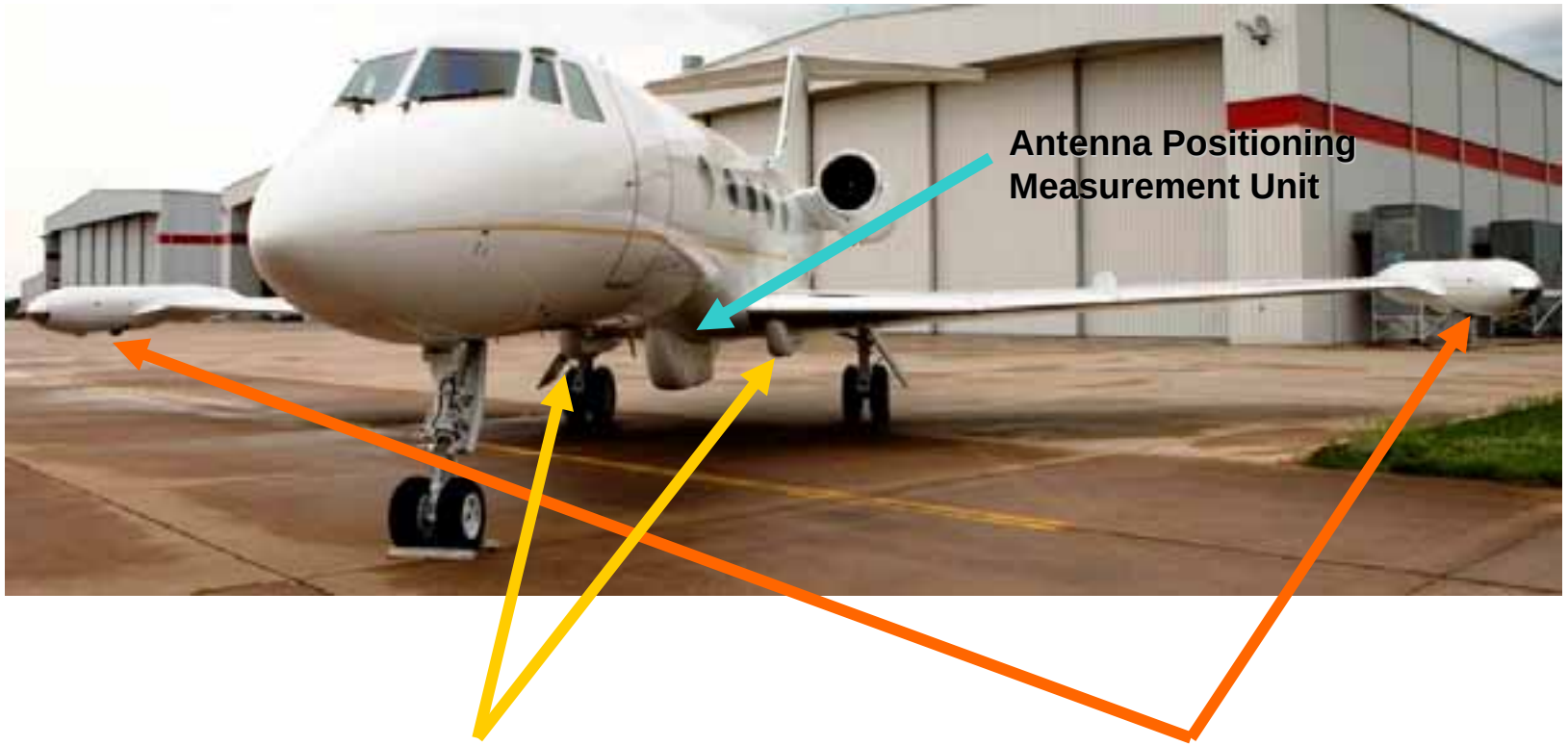
What is GeoSAR?

- Single-pass, dual frequency, interferometric radar mapping system
  - X-band (3 cm) shows first surface
  - P-band (85 cm) reveals detail beneath canopy
- Rapid, large area mapping through cloud cover, day and night
- Products include:
  - Ortho-rectified radar reflectance maps (1.5 Meter Resolution)
  - Digital elevation models (DEMs) (5 Meter Resolution)
  - Large Scale Maps





Major GeoSAR Components

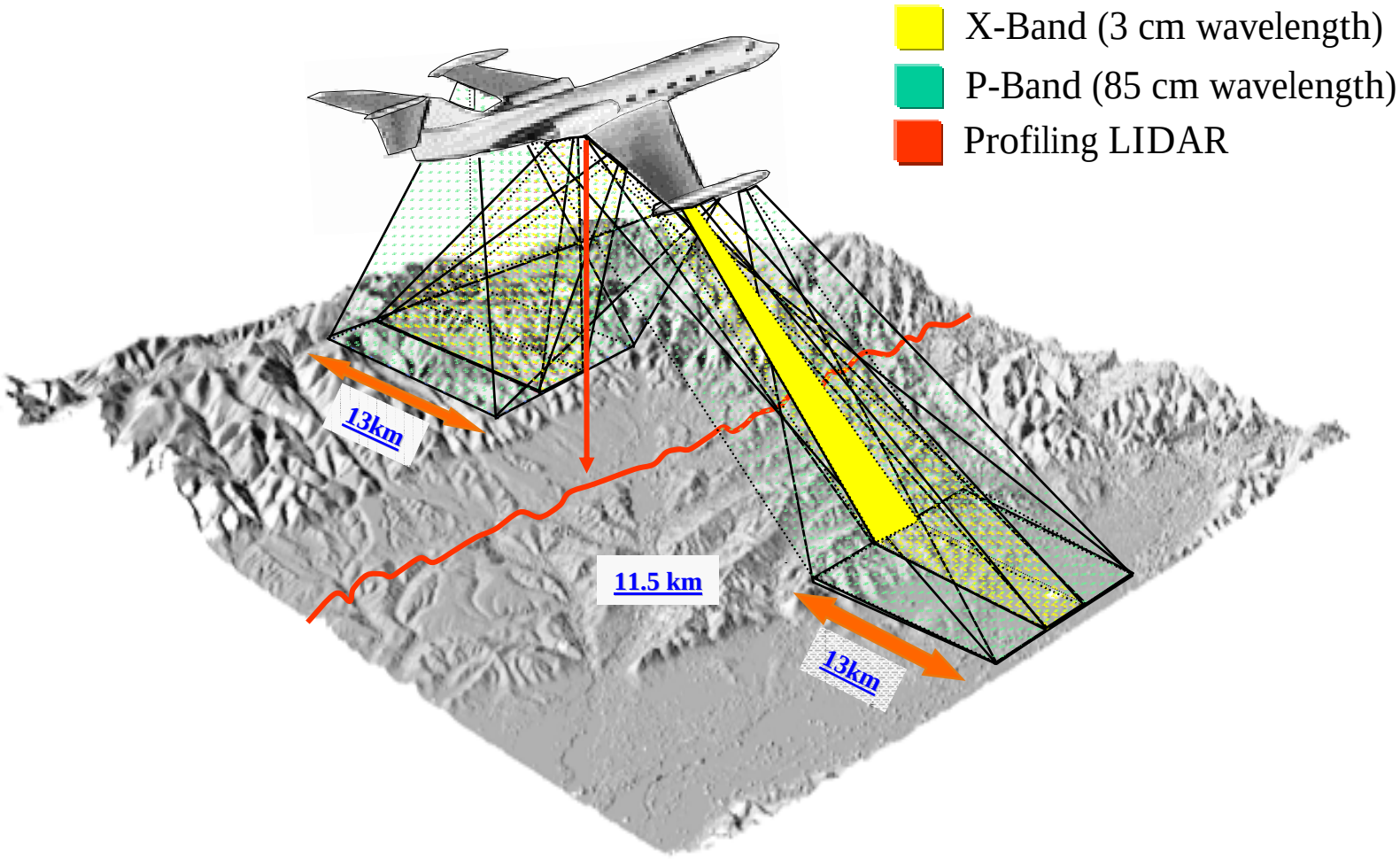


Two X-band Antennas Are Mounted Under Each Wing Close to the Fuselage and Use Frequency From 9630–9790 MHz

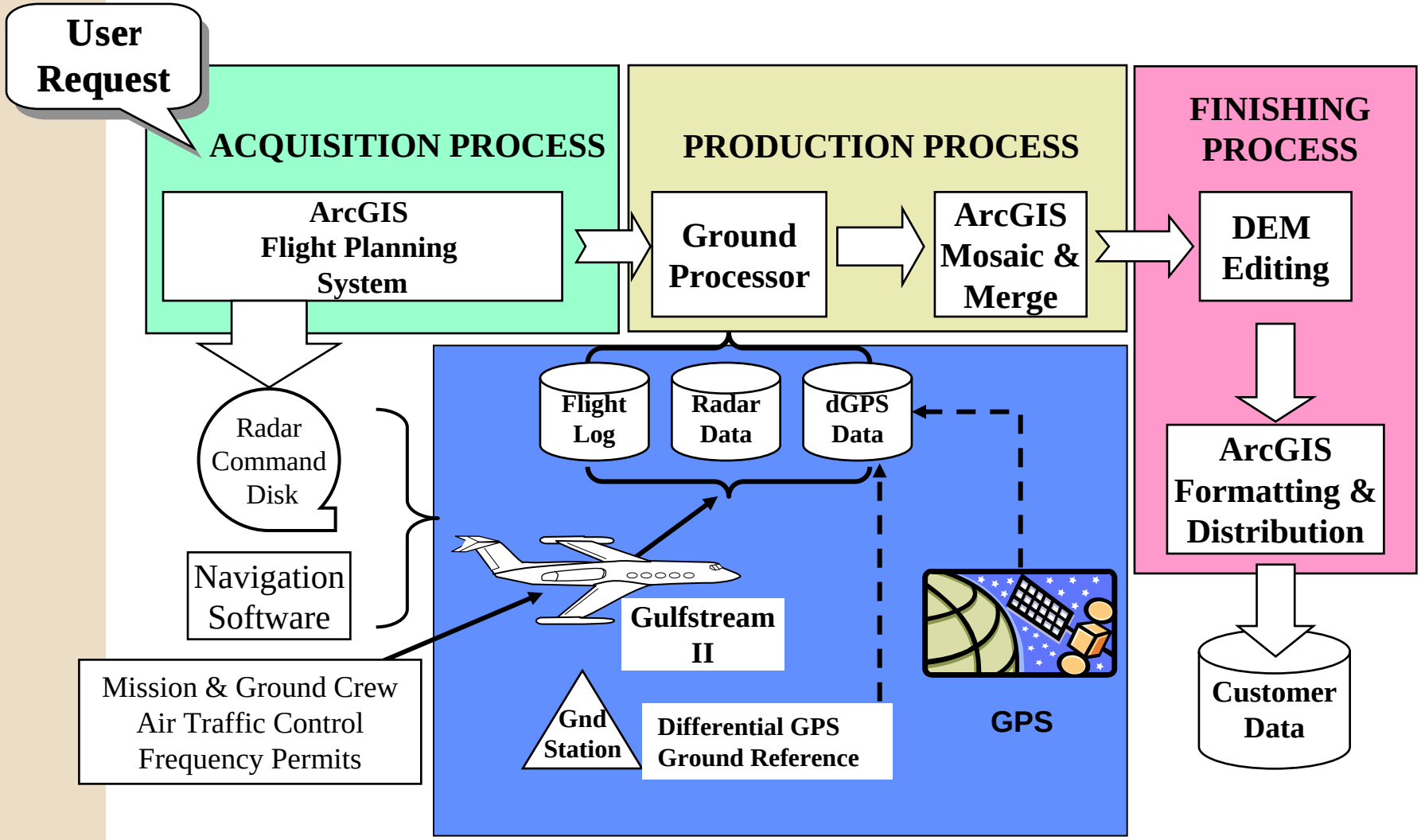
Two P-band Antennas Are Mounted on Each Wingtip and Use Frequency From 270–430 MHz

GeoSAR Data Collection Configuration

Collection Height:
9.5 km to 12 km



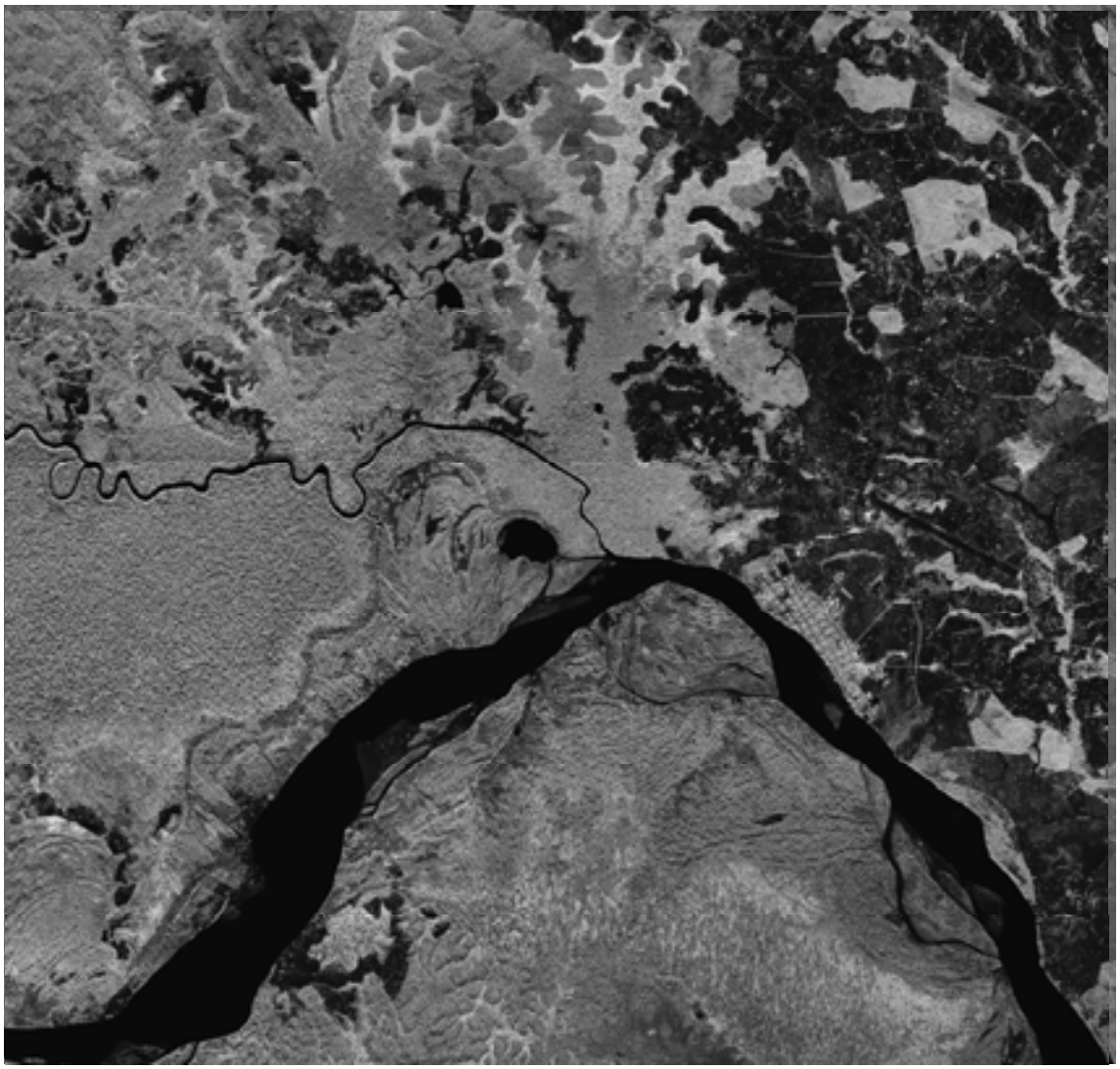
ArcGIS in the GeoSAR Process



Radar waves will propagate until they encounter an object with a radar cross-section as large as the wavelength.

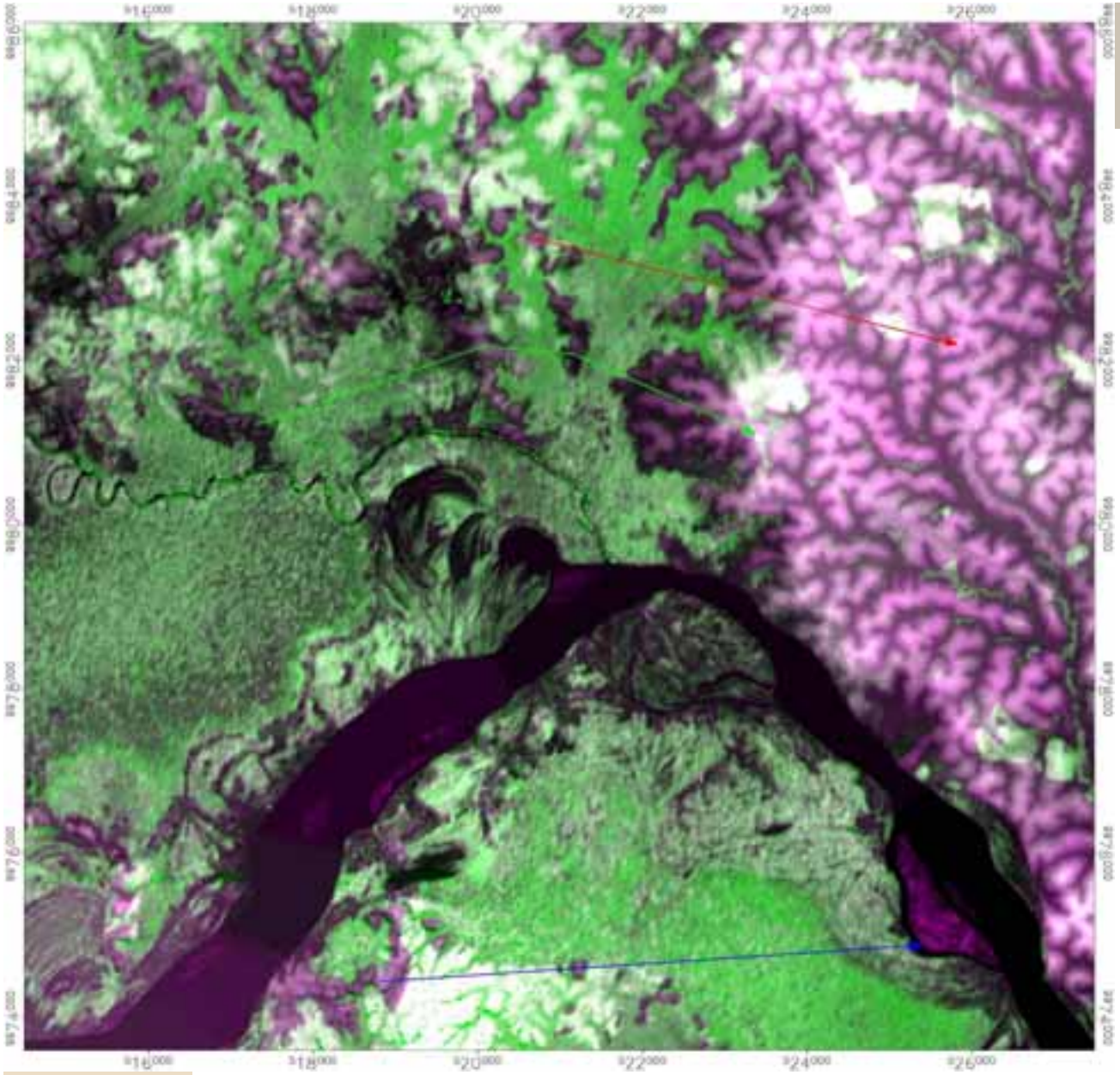
- For this reason, X-Band SAR, with a 3 cm wavelength, will tend to scatter off tree tops, or have relatively shallow penetration.
- The longer wavelength (85 cm) of the P-Band SAR gives it foliage penetration or FOPEN capabilities.
- P-Band will penetrate much deeper into the canopy, often all the way to the ground.

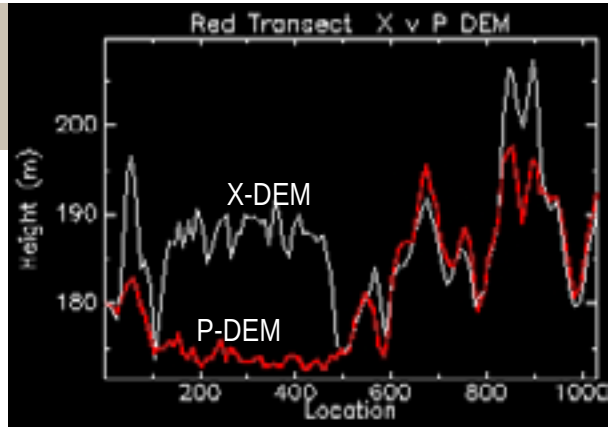
Foliage Penetration

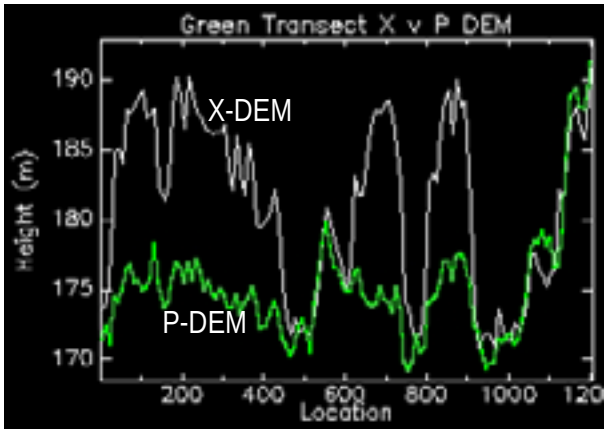


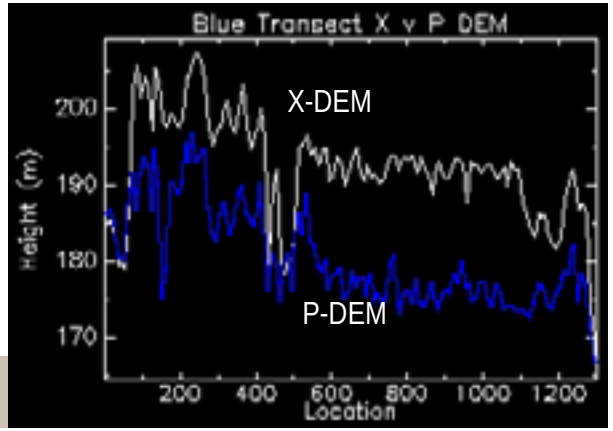
Colombia, 2006

P-Band Image

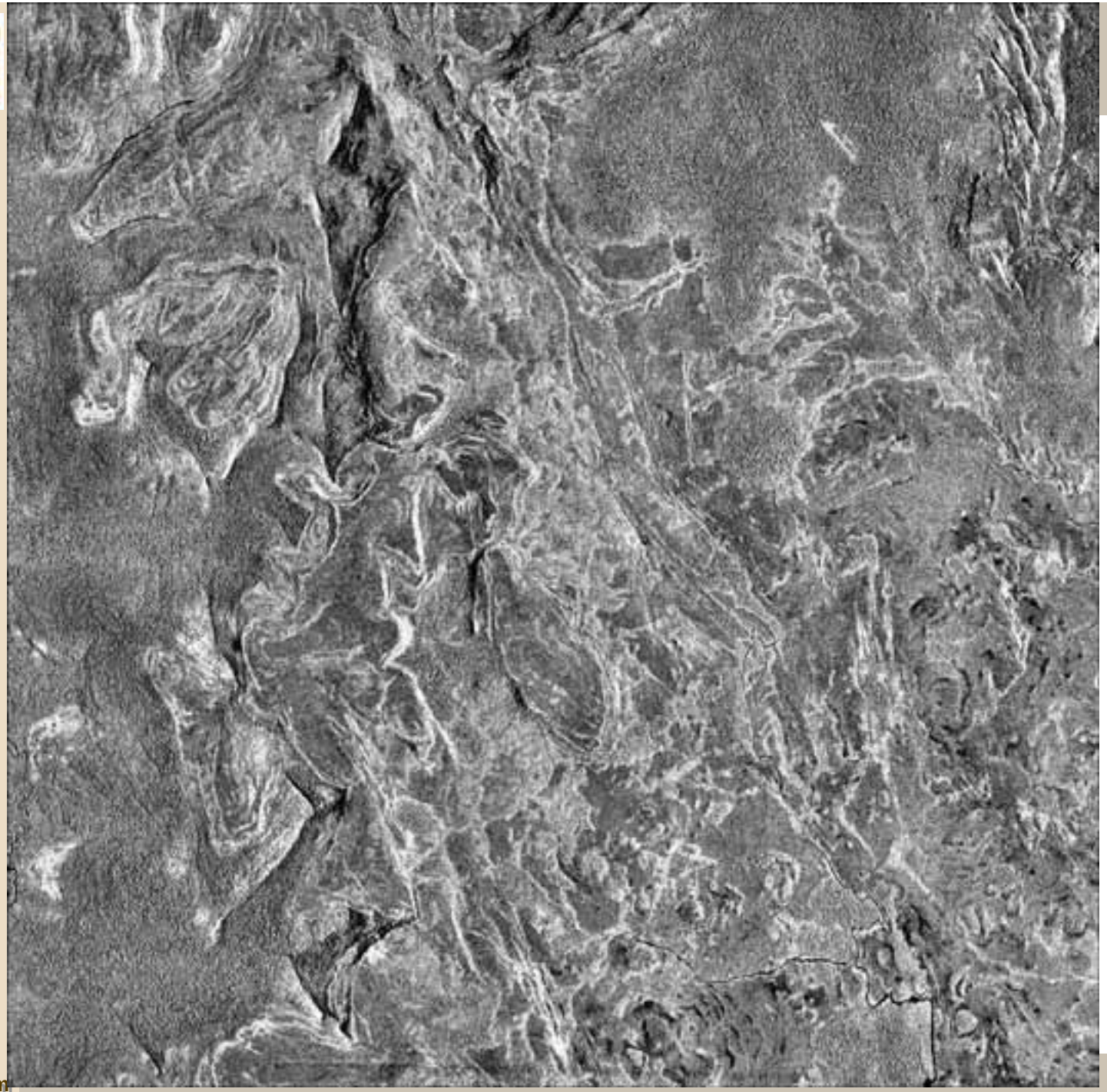






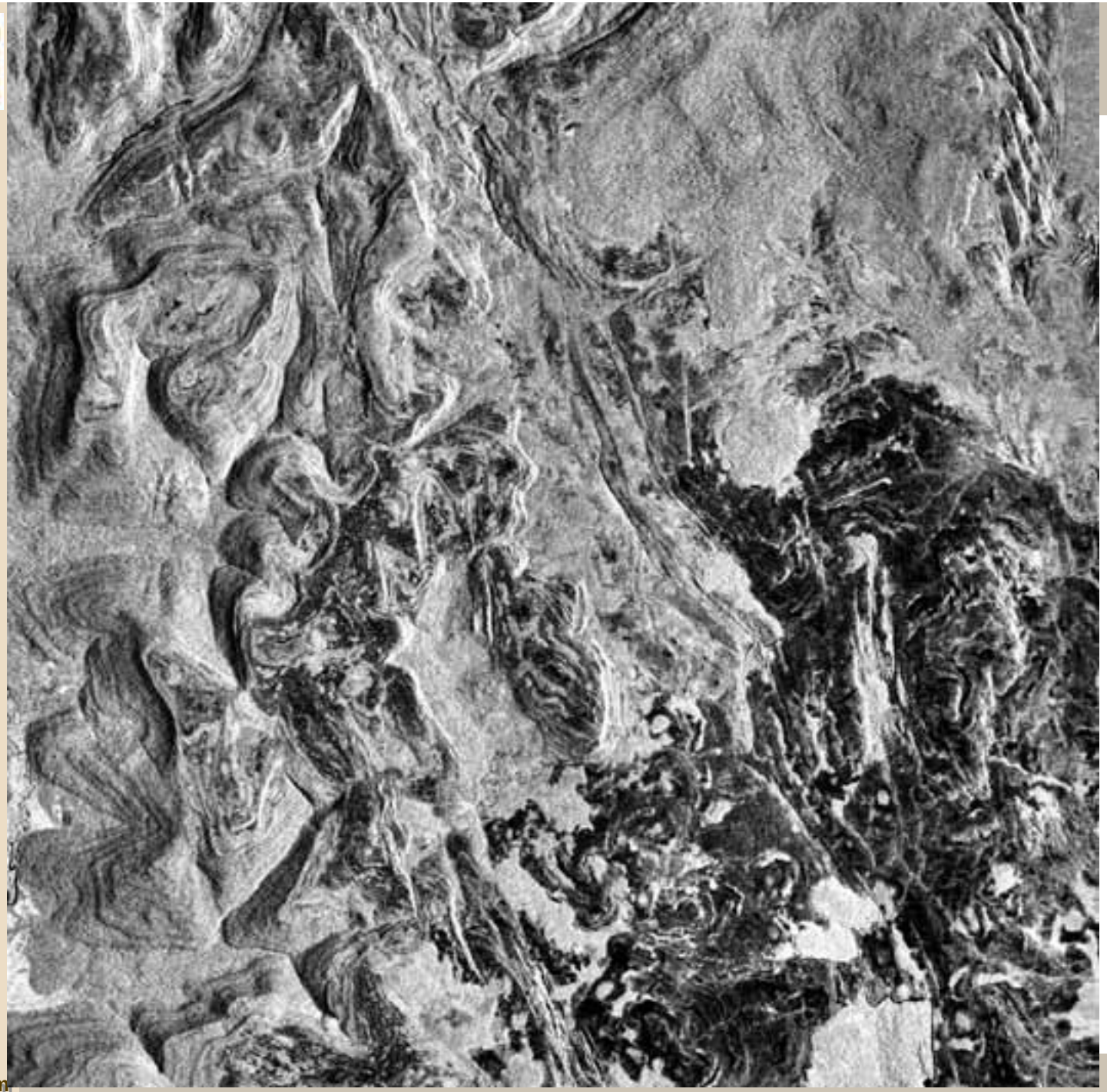


RGB composite IFSAR data



Xvv

12 x 12 km



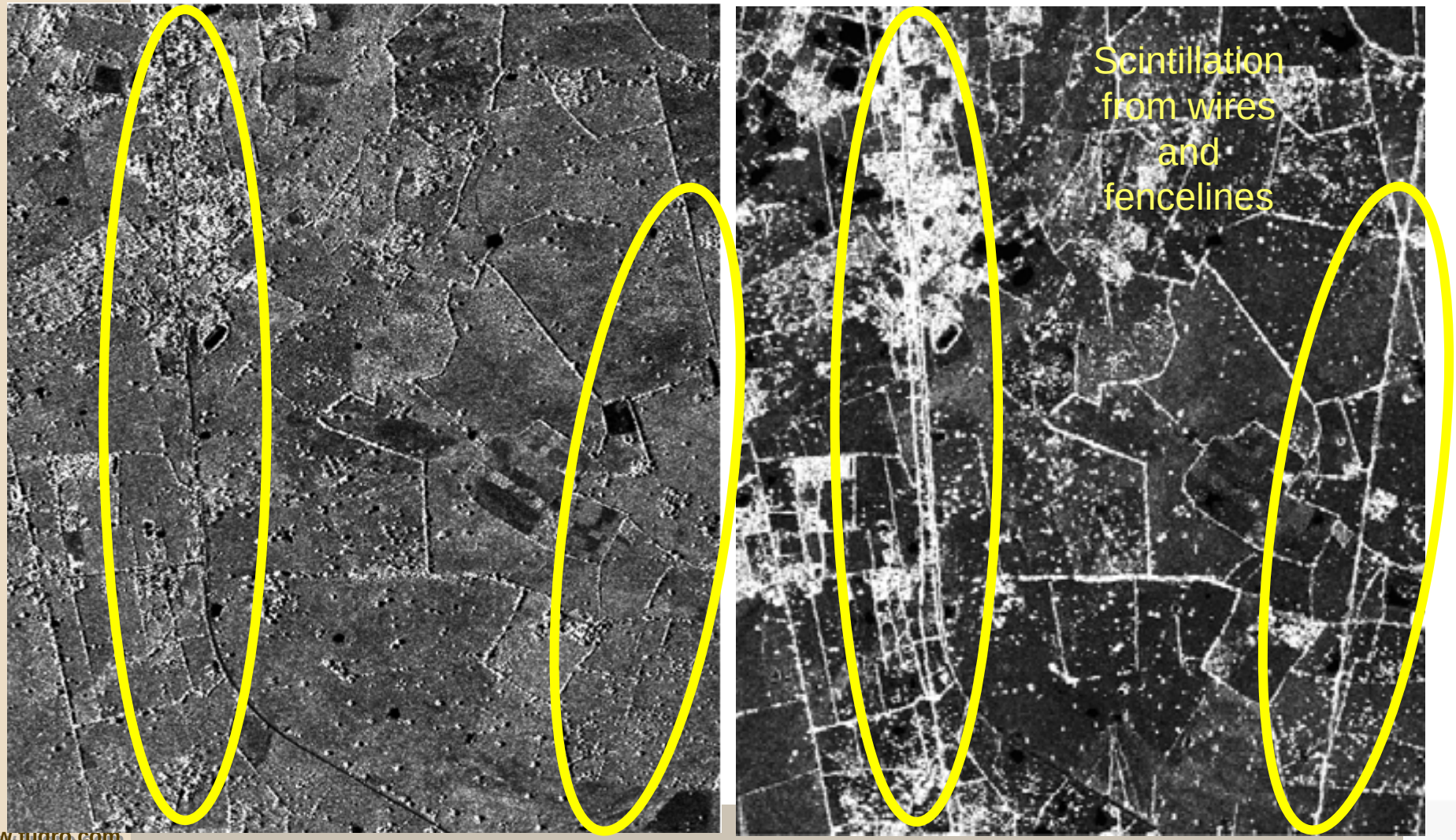
Phh

12 x 12 km

P-Band SAR Interaction with Linear Metallic Objects

- Long wire objects, such as phone and electrical lines, as well as fences, tend to show up very bright in a P-Band SAR image.
- The wire objects act as antennas to the long-wavelength SAR, re-radiating a great deal of energy back to the emitter.
- This allows LOC to be traced quite clearly in the SAR images, even when canopy closes over the objects.

Unique Information Content



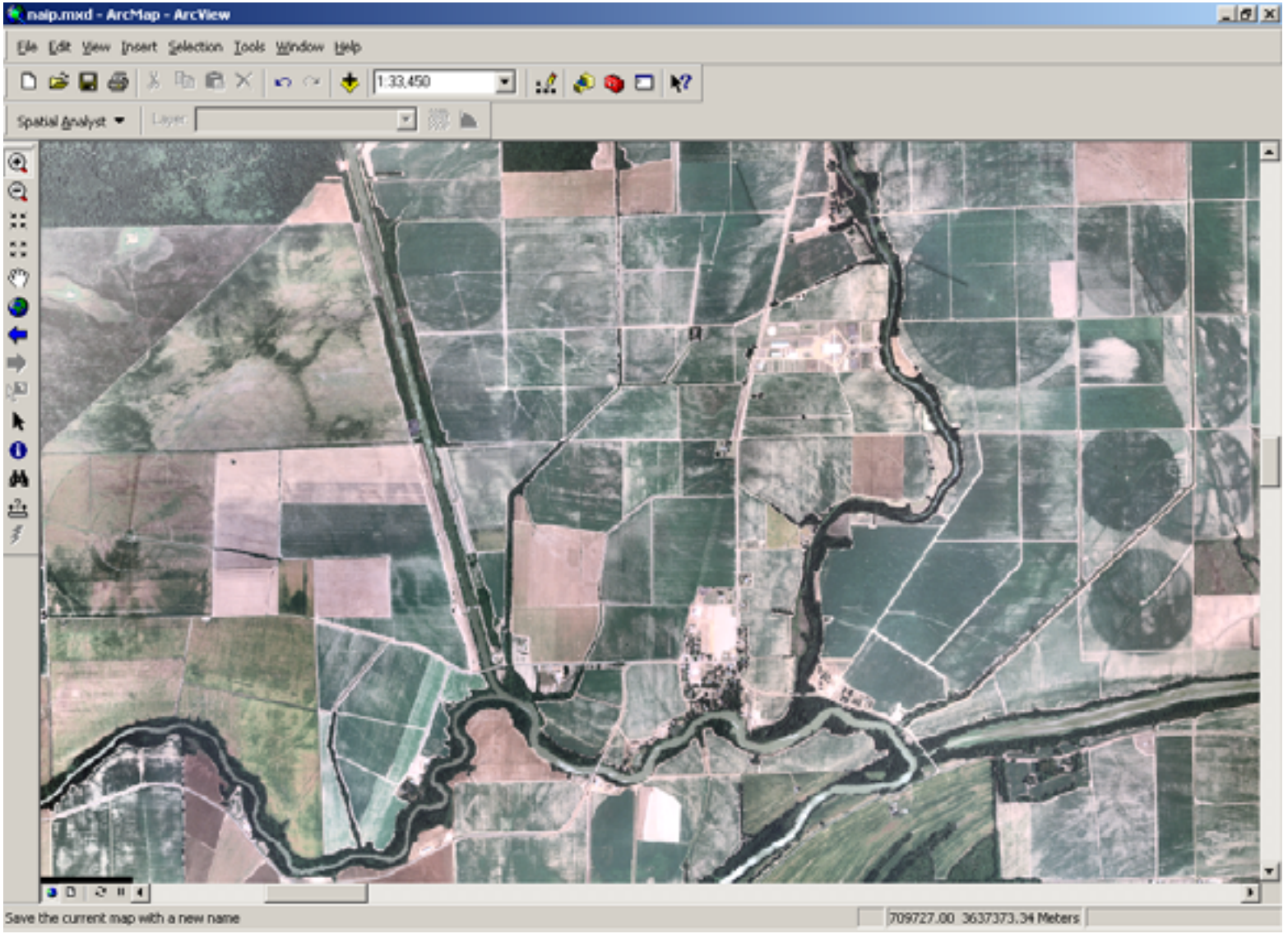
Determine the applicability of IFSAR data to the NAIP Program

1. Collect a county in Mississippi during NAIP collection window.
2. Produce image data.
3. Demonstrate geodetic accuracy compared to NAIP imagery and Common Land Unit Data.
4. Demonstrate ability to separate between crop types in the SAR data.

National Agriculture Imagery Program (NAIP)

- The National Agriculture Imagery Program (NAIP) of the United States Department of Agriculture (USDA) annually acquires 1 and 2 meter resolution digital orthorectified imagery for agricultural regions in the United States during the summer crop growing season.
  - About twenty percent of the annual coverage is 1 meter resolution, and eighty percent is 2 meter resolution.
- One limitation with the NAIP program is the need for continuous cloud-free days in the height of the growing season in order to complete the state-wide imagery collection projects.
- This is often a problem, particularly in the southeastern United States. One way to relieve this issue is to collect NAIP quality imagery with radar sensors, which can image day or night and through cloud cover.

NAIP Imagery Example



Overview of Project

- Fugro EarthData, Inc. is conducting a pilot project to demonstrate the capabilities of the GeoSAR airborne Interferometric Synthetic Aperture Radar (IFSAR) to augment the USDA National Agriculture Imagery Program (NAIP).
- The EarthData GeoSAR system collected sufficient X-band and P-band interferometric SAR data using its standard imaging modes to fully map the county of Yazoo, Mississippi.
- GeoSAR collected a total of 16 lines of data between August 29, 2007, and August 31, 2007.
- EarthData is processing this data in its Frederick, Maryland, facility to produce standard products, including 3-meter resolution X-band elevation models and orthorectified mosaics and 5-meter resolution P-band elevation models and orthorectified mosaics.
- Additionally, a subset of the X-band data is being processed into a 1.25 meter resolution orthophoto mosaic to demonstrate a resolution product similar to NAIP imagery.

Overview of Project

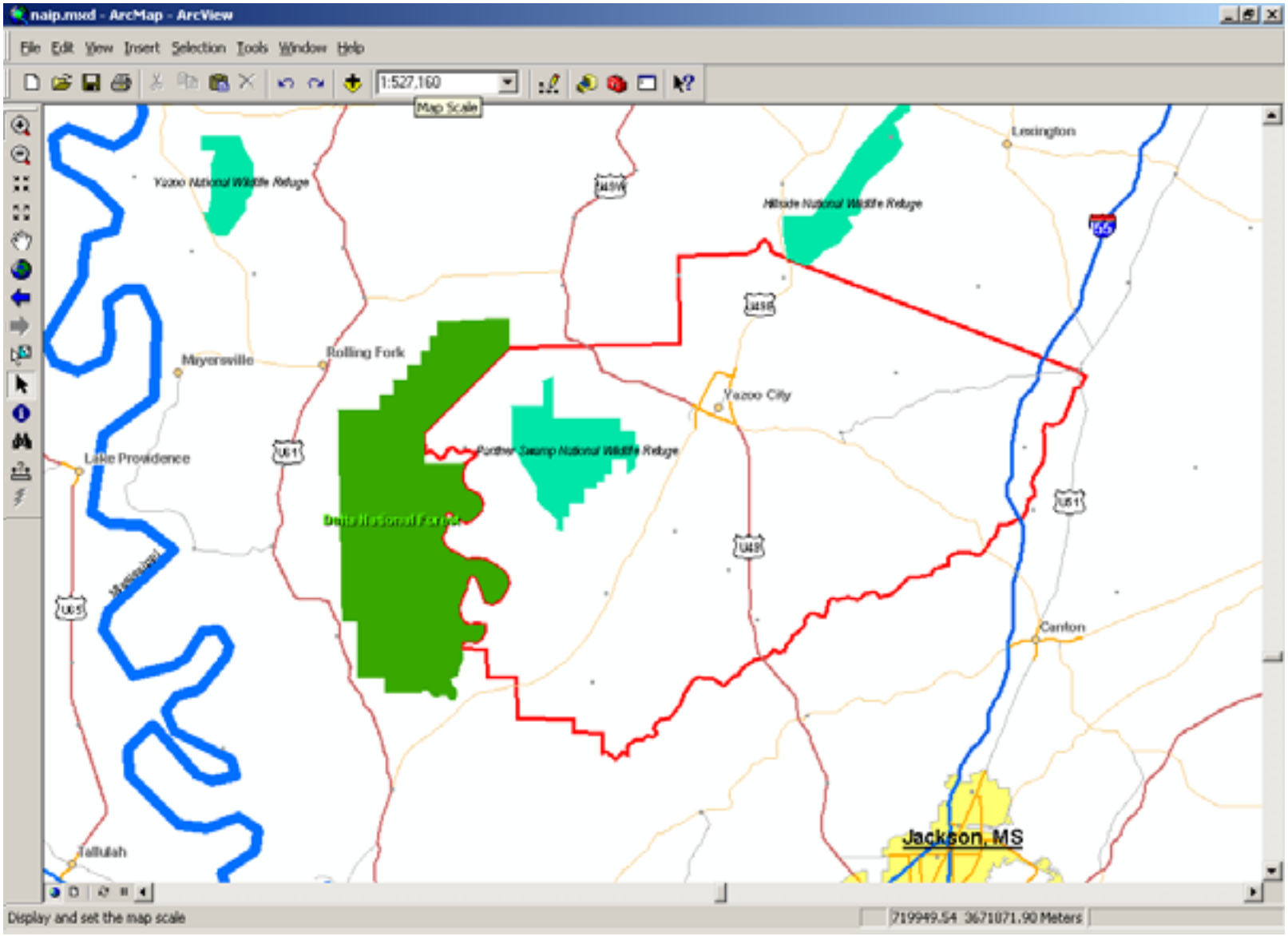
Besides producing usable imagery from the GeoSAR radar, the project goals are to demonstrate:

1. That the GeoSAR system will be able to collect data under conditions that would be impossible for digital cameras (at night and through clouds).
2. That the geodetic accuracy of the radar data products are equivalent to the USDA Common Land Unit data.
3. That the GeoSAR data will support semi-automated classification for common crop types found in the study area.

Yazoo County, Mississippi

- Yazoo County, Mississippi, is a predominantly rural county in west central Mississippi, with an area of 2,419 km2 (934 mi2).
- The major crops in the county, in terms of economic value, are corn, cotton, rice, wheat, hay, soybeans and sweet potatoes. The major livestock commodities are cattle and catfish.
- The physiography of the county can be divided into two regions:
  1. Yazoo-Mississippi Basin or delta. This terrain is level to very gently undulating near the Yazoo River and around abandoned and extinct river channels. The land cover in the delta consists of swampy forests, agricultural fields, and occasional catfish ponds.
  2. Eastern low, wooded Loess Bluffs or Brown Loam Hills. Among the hills nearest the bluff, valleys are often deep and steep-walled.

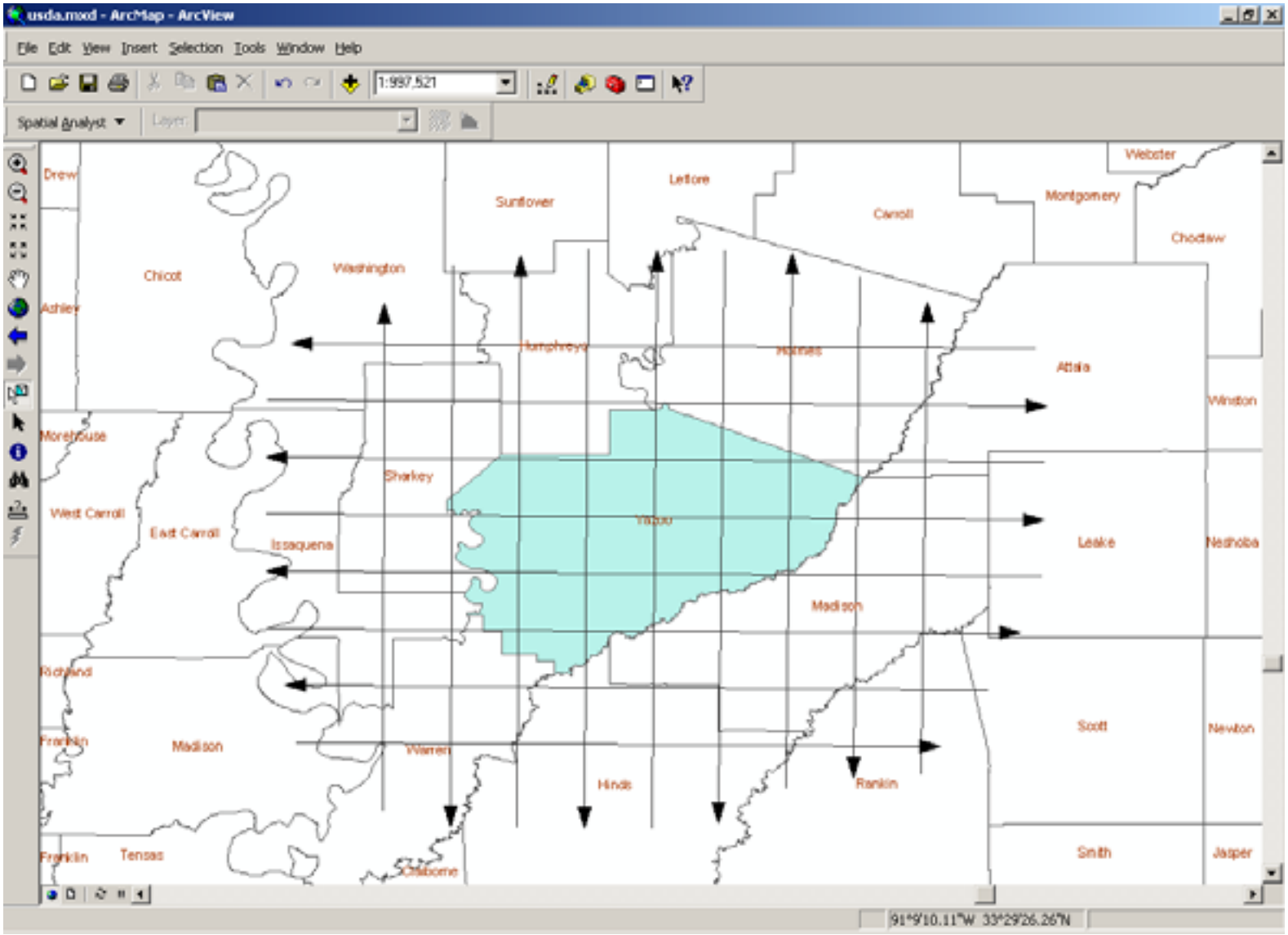
Yazoo County Overview



Typical Yazoo-Mississippi Delta Agriculture

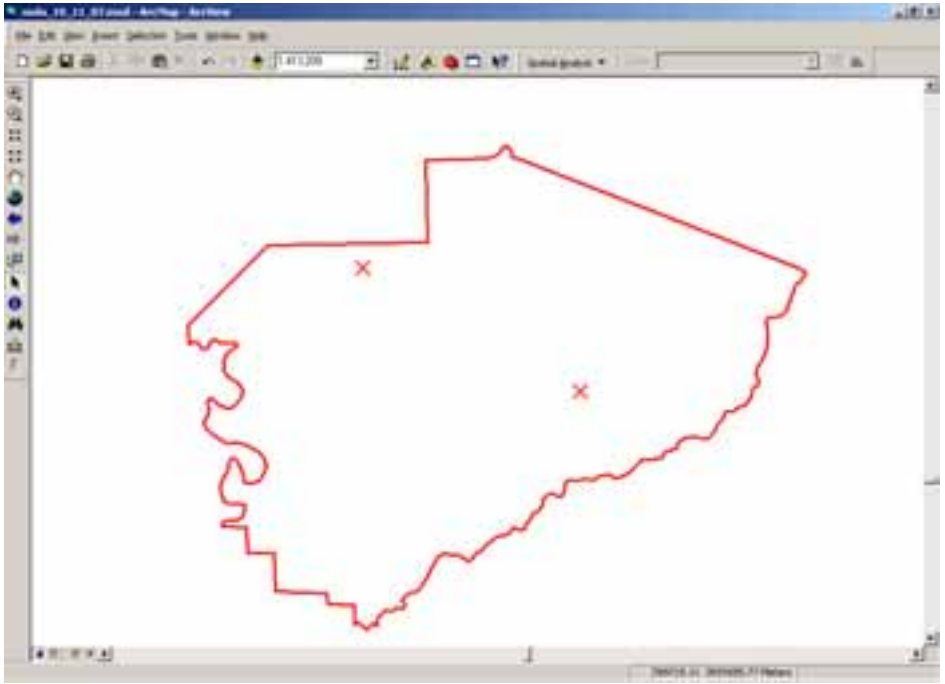
Image shows typical agriculture of region, with catfish ponds, cotton and corn fields.

ArcGIS Software Based Flight Planning



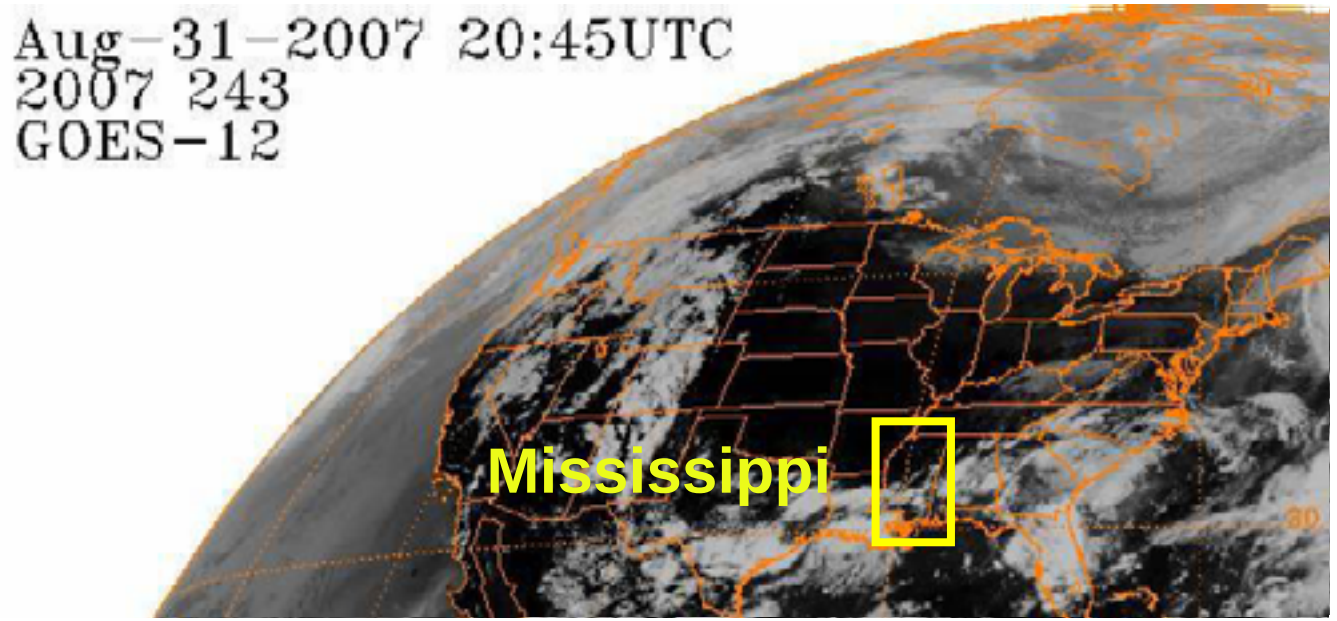
Corner Reflectors

Two trihedral X-band corner reflectors were placed in the study area, with their locations precisely measured through GPS and imported in ArcGIS.



The corner reflectors are used for absolute geometric and radiometric control of the radar data.

All Weather Collection

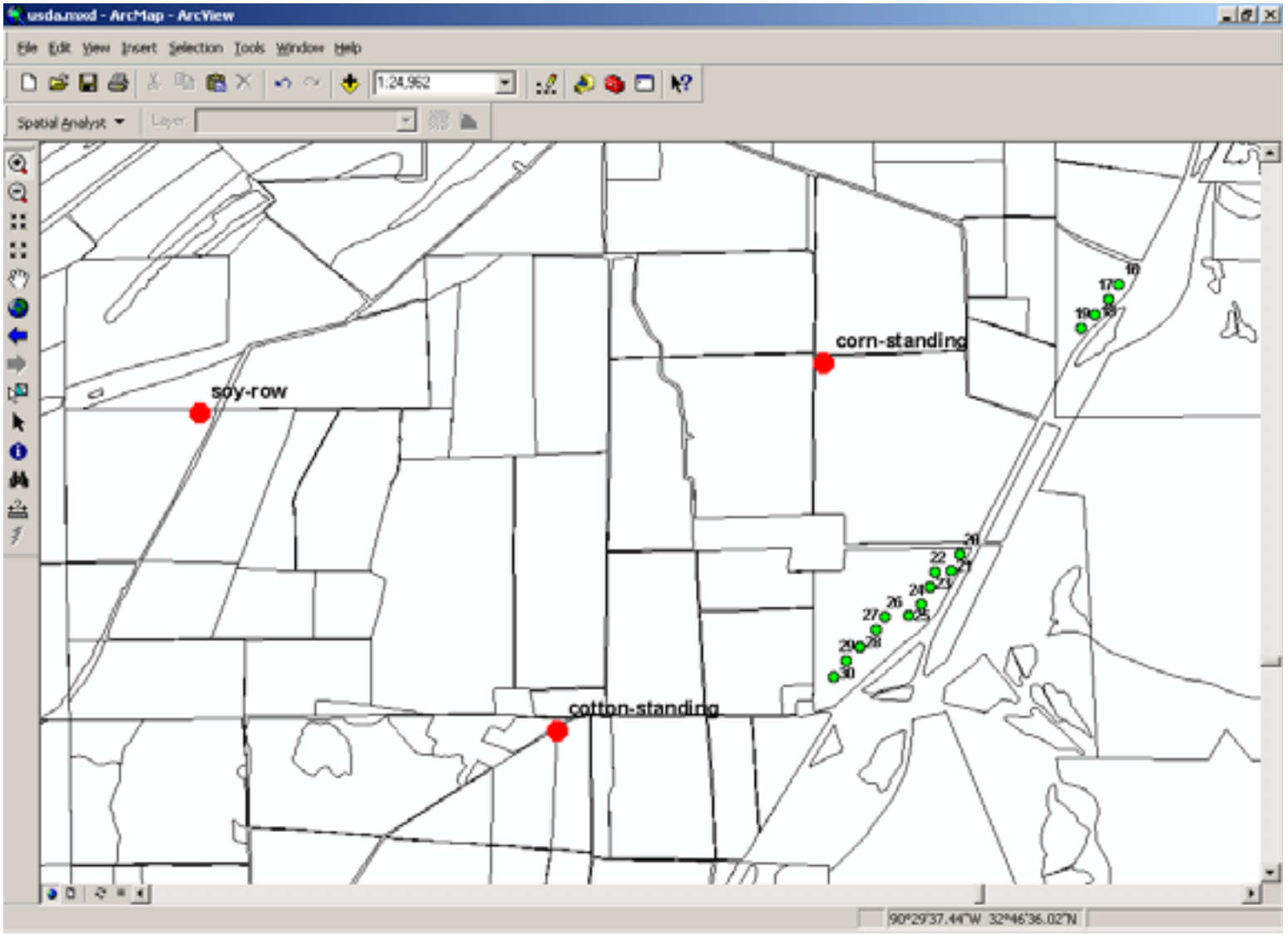


- GOES-12 IR Images of Eastern US from Aug 29-31 2007, about 09:00 AM to 03:00 PM (Typical Imaging window for optical images).
- Demonstrates ability to collect during cloudy weather.

Ground Data Collection

- A ground campaign was conducted in conjunction with the radar collection by a team of three EarthData scientists, accompanied by the local USDA extension officer.
- We visited approximately 25 sites where data was collected on individual fields regarding the crop type, local soil roughness, row spacing, plant height, width, spacing, and predominant compass direction of rows.
- Approximately 220 ground-based photographs were to assist in the evaluation of field and crop conditions.
- Soil cores were collected in 5 major soil types for later laboratory analysis for bulk density, soil moisture and electrical conductivity.
- The team conducted an airborne reconnaissance for 2.5 hours of flight time in a light aircraft and acquired approximately 550 oblique, natural color images from an altitude of 150-200 meters.

Ground Data Illustration



Comparison of GeoSAR and NAIP Imagery

NAIP imagery from 2006 (left, courtesy of the USDA Farm Service Agency Aerial Photography Field Office) with the same area of GeoSAR composite (right, courtesy Fugro EarthData Inc.) from Yazoo Mississippi. The GeoSAR imagery combines the backscatter and elevation information to produce a colorized image.

Sweet Potato Crop

Crop Height: .5 m

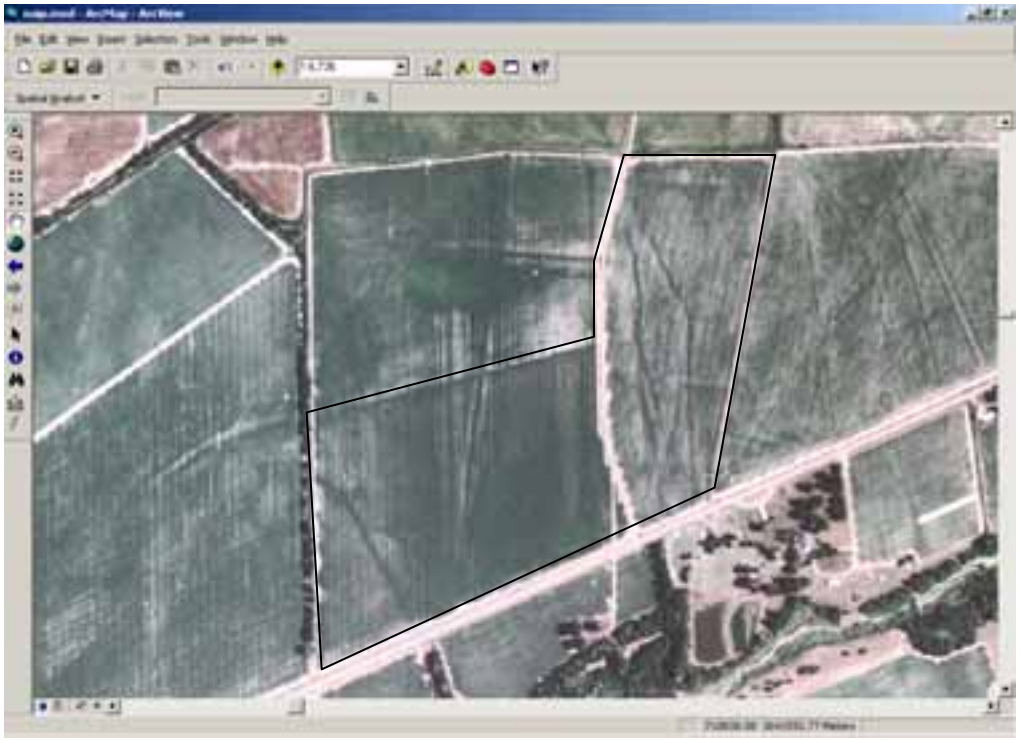
Row Spacing: ~1 m

Stem Spacing: 7.5 cm

Sweet Potato Crop

NAIP 2006 Image

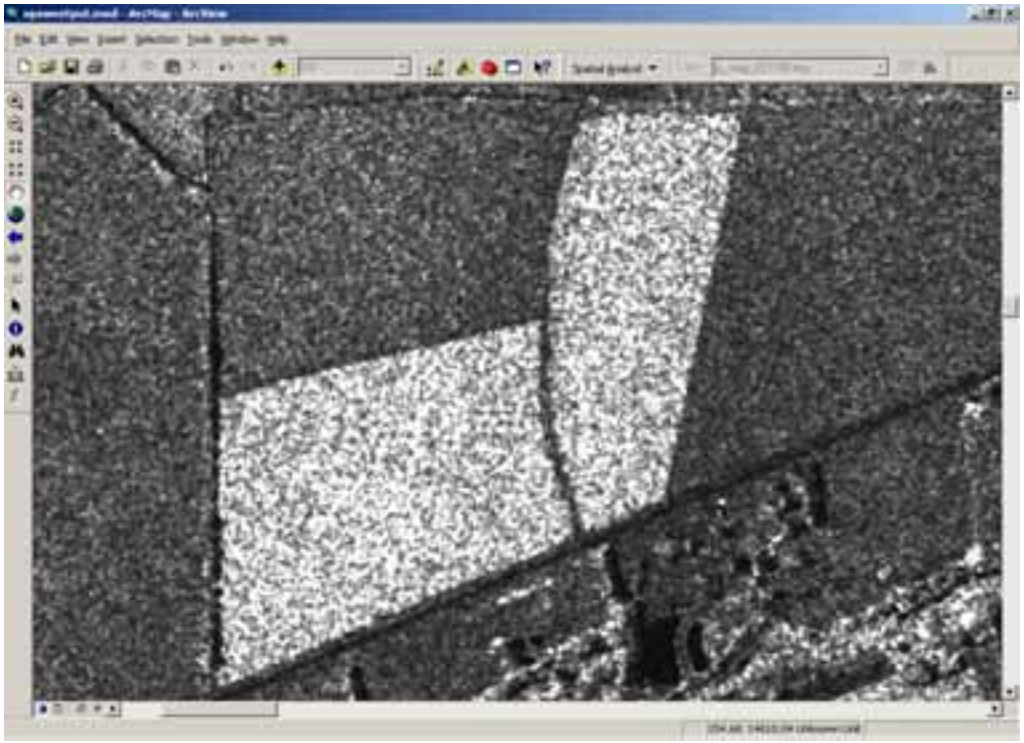
- 2006 Image was collected after the sweet potato harvest.
- The image shows bare soil and furrow structure.

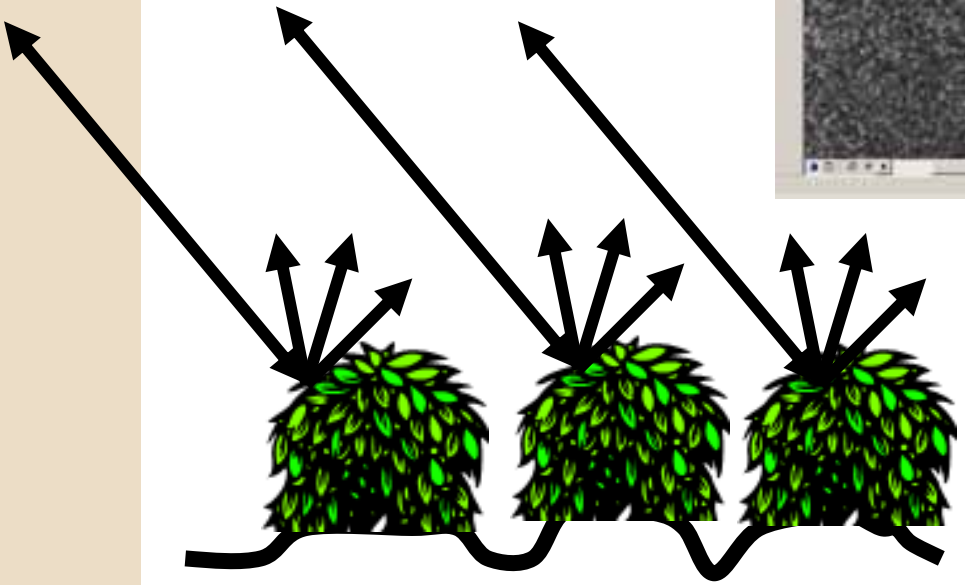


Sweet Potato Crop

X Band SAR Image

- Very bright return
- High contrast with surrounding fields
- Broad leaf, dense bushy habit of sweet potatoes
  - > Predominant scattering is from the vegetation

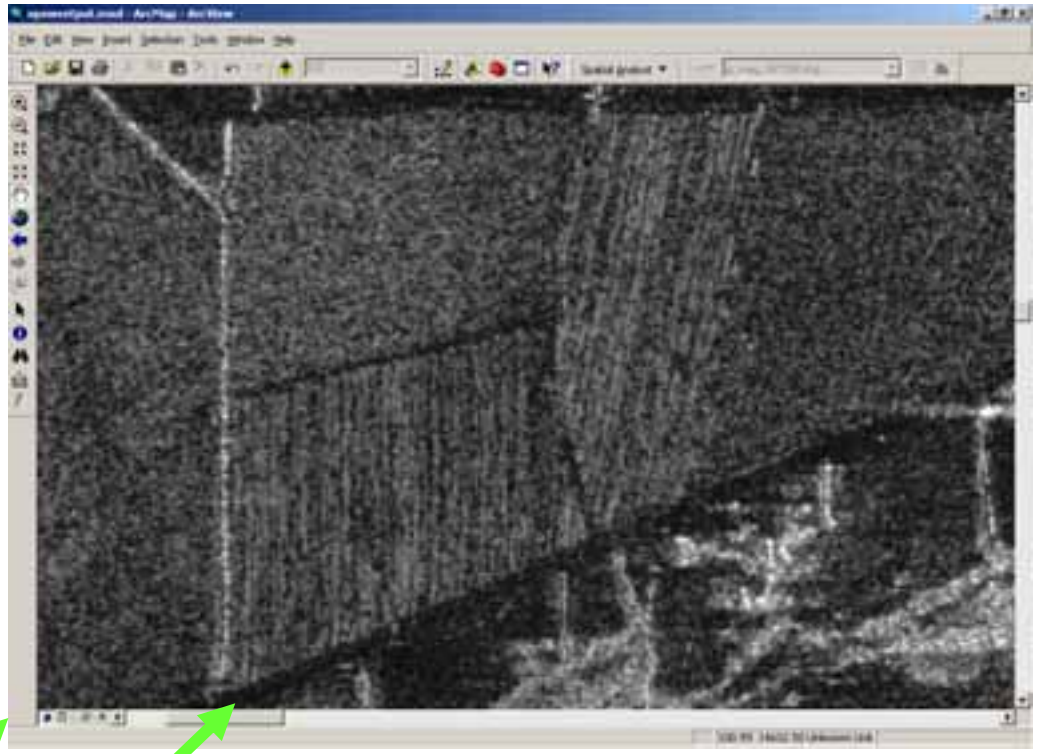


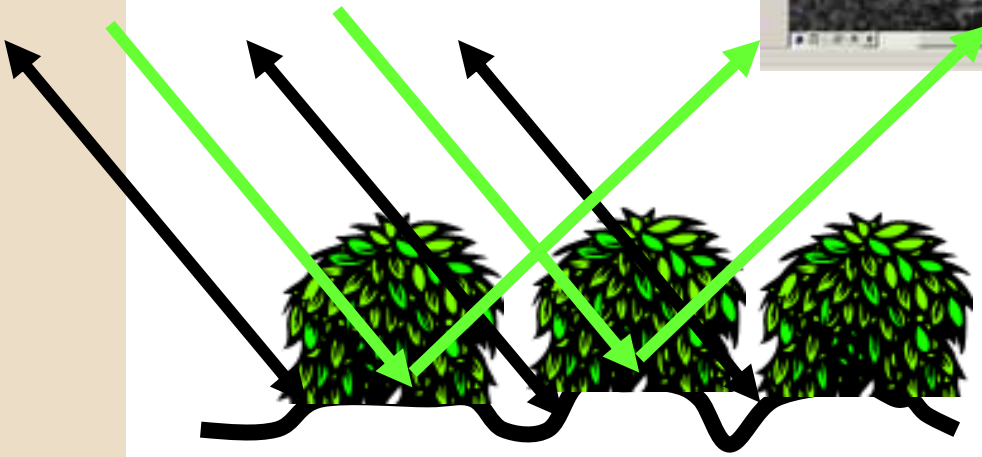


Sweet Potato Crop

P Band SAR Image

- Much darker return
- Long wavelength penetrates vegetation
  - > Predominant scattering surface seems to be the ground (note visible row structure)





Center Pivot Irrigation

Ground Image

- Typical Center Pivot Irrigation structure

Center Pivot Irrigation

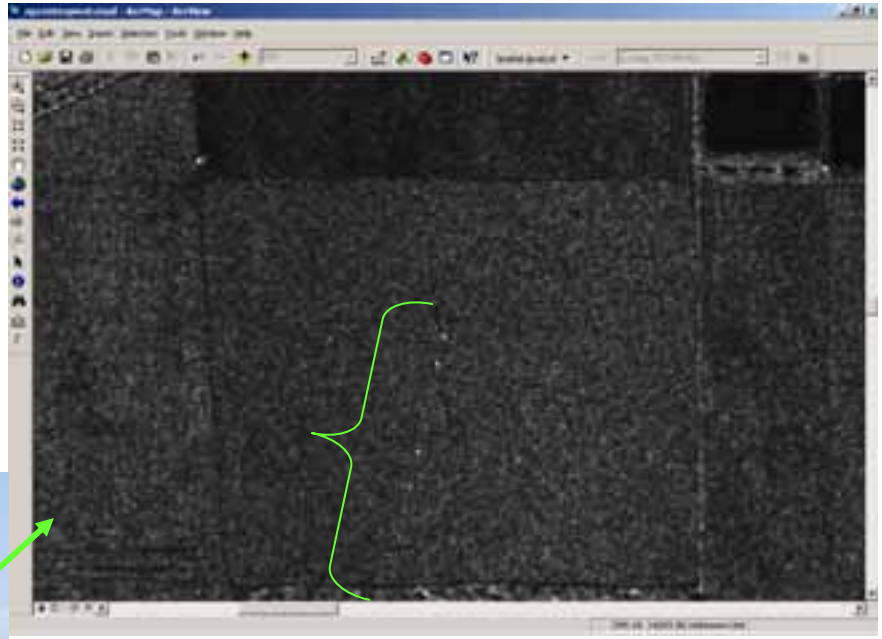
NAIP Image

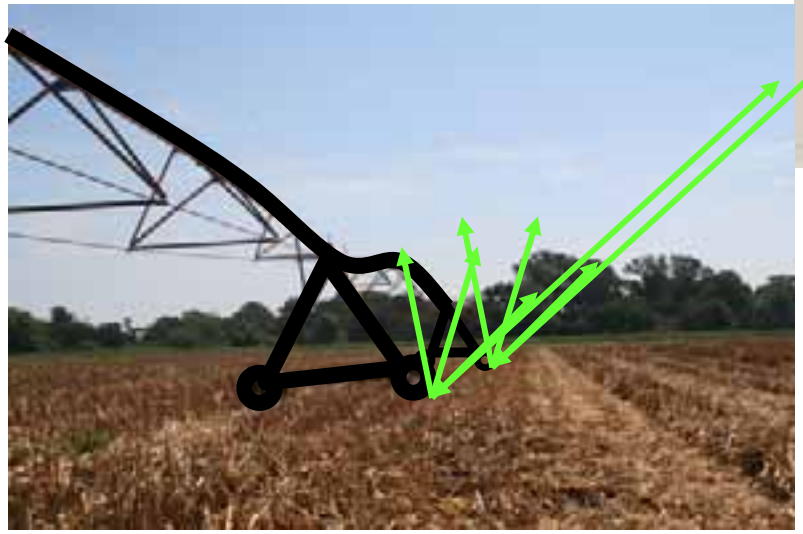
- Typical circular pattern from center pivot irrigation
- Note “bulls-eye” pattern from wheels.

Center Pivot Irrigation

X Band SAR Image

- Predominant scattering of the X Band signal is off the wheel structure of the irrigation system.
- This leads to isolated bright scatterers.

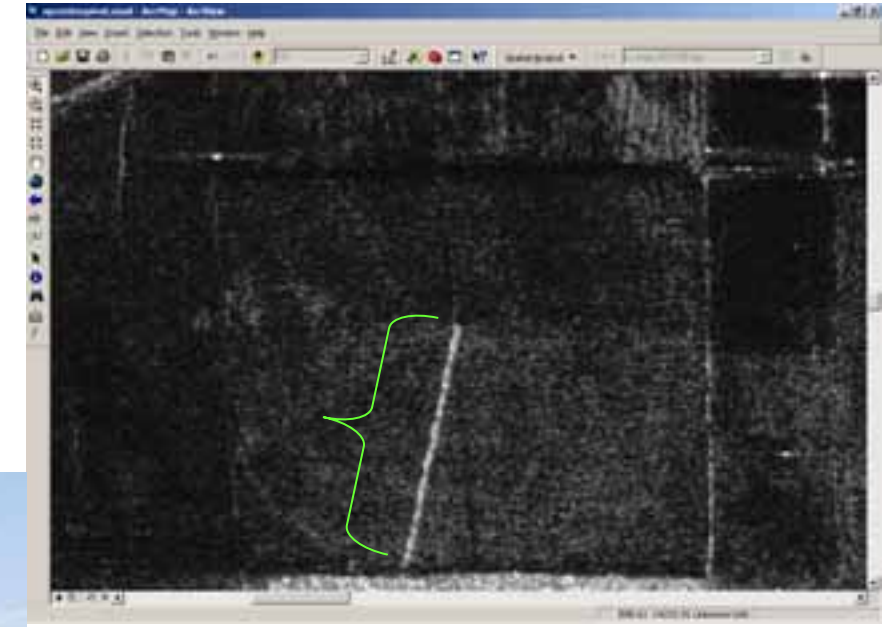




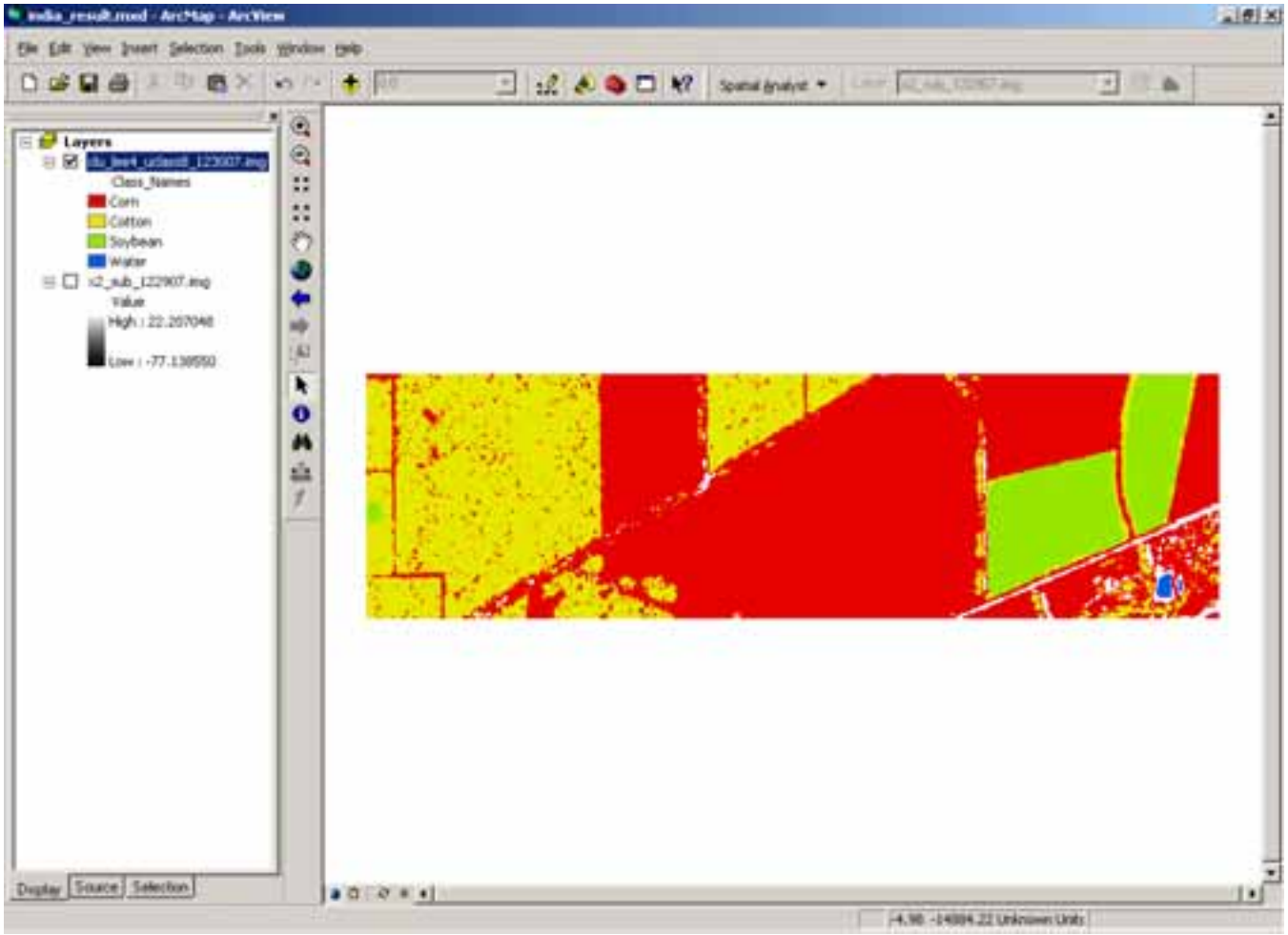
Center Pivot Irrigation

P Band SAR Image

- The horizontal linear structure of the irrigation system acts as an antenna, re-radiating the signal back to the SAR.
- This leads to strong linear scatterers from the structure.



Crop Classification Result



ISODATA Maximum Likelihood Classification Based on X Band Backscatter Images.

Conclusions

- GeoSAR has demonstrated the ability to collect and process wide area SAR imagery and digital elevation models for mapping.
- Fugro EarthData, Incorporated, is conducting research to extend the capabilities into land use/land cover classifications for agriculture, forestry and other uses.
- ArcGIS software-based tools are integral for planning, managing and presenting GeoSAR radar data.