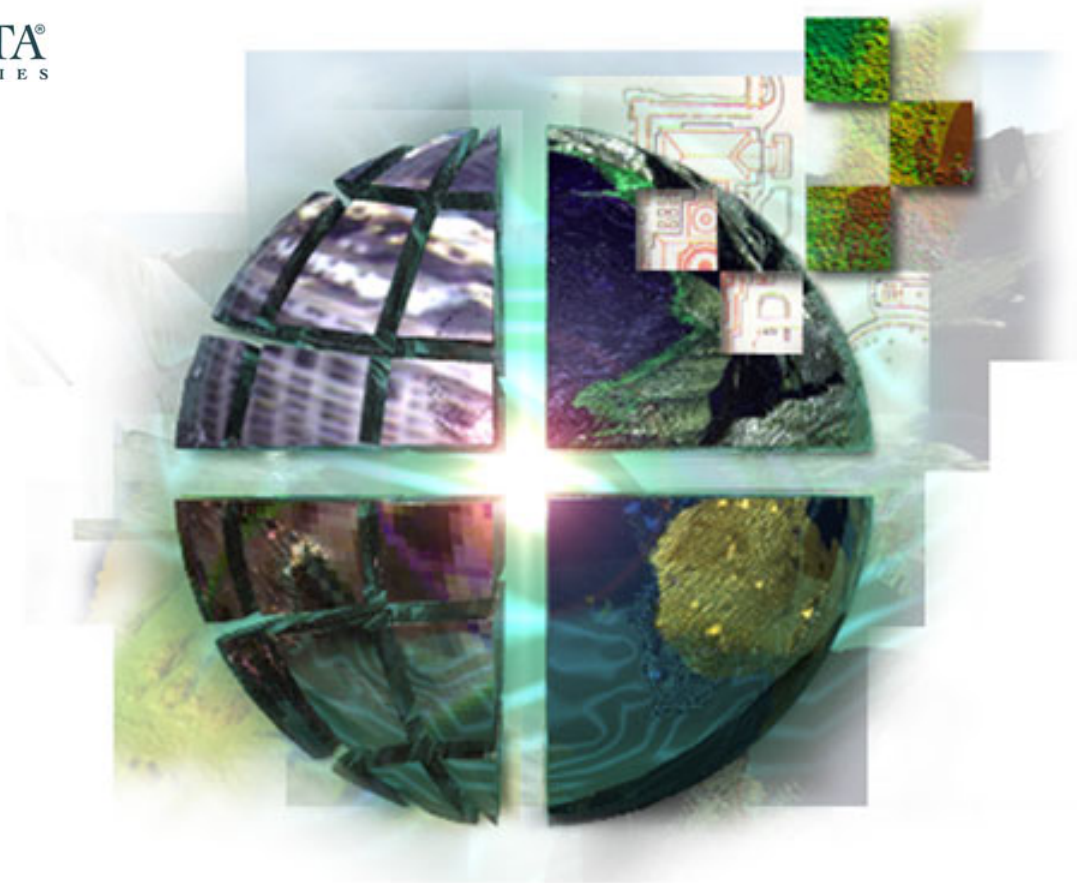
EARTHDATA TECHNOLOGIES



GeoSAR P-band and X-band Performance In Southern California and Colombia, South America

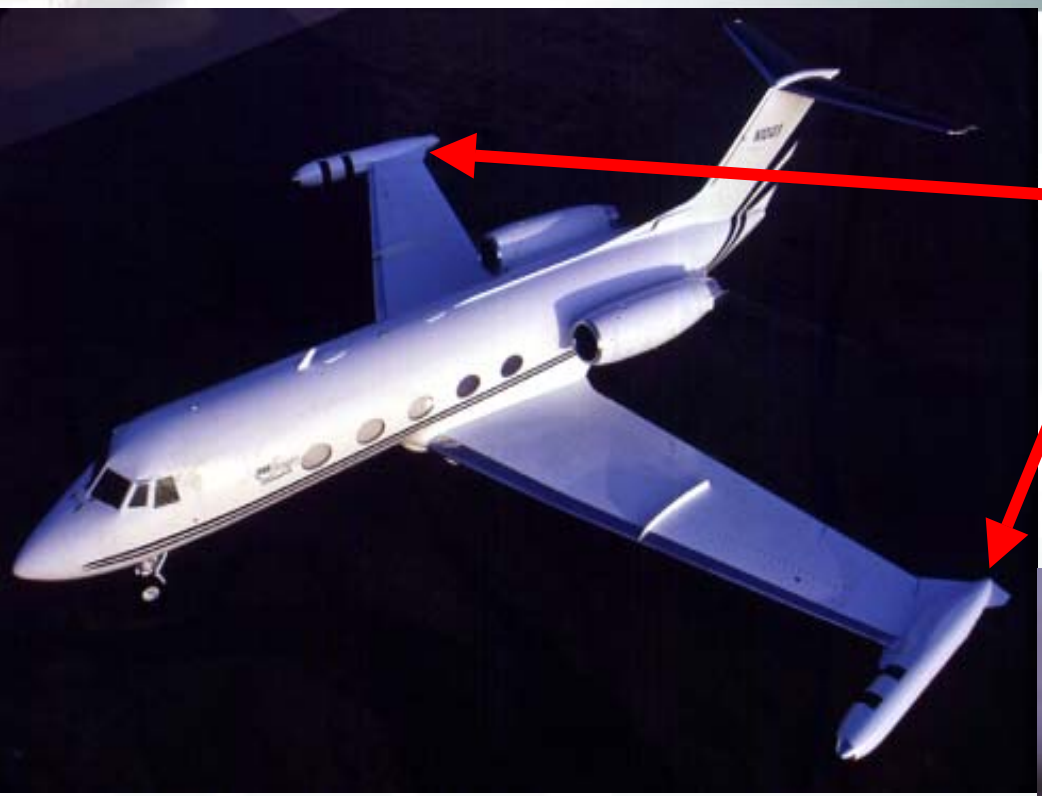
ISPRS International WG 1/2 Workshop 2005

James J Reis, EarthData Technologies
Dr. Scott Hensley, Jet Propulsion Laboratory

Outline

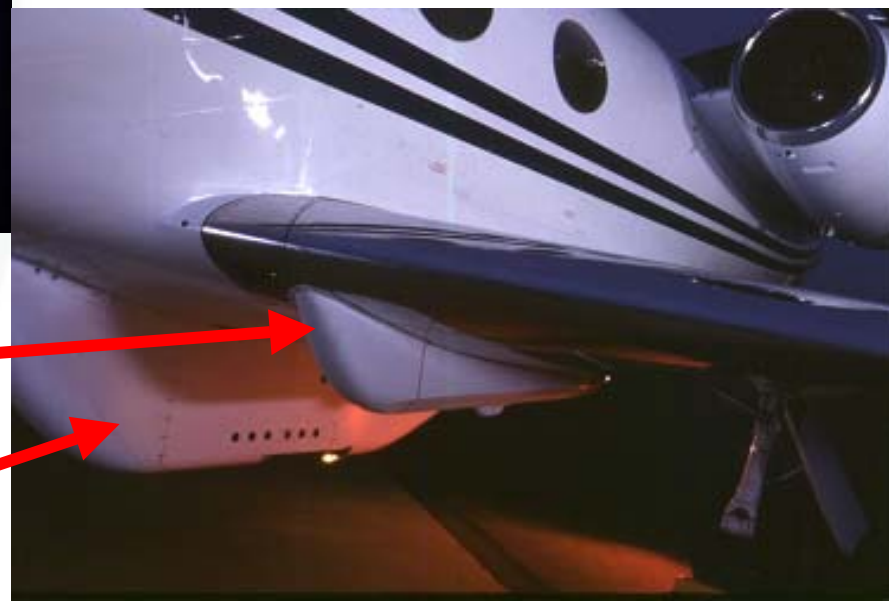
- GeoSAR Overview, Including Latest Upgrades
- NOAA Watershed Project Overview
  - Planarmetric Accuracy (X-band)
  - Effects of Notching P-band Transmit Waveform
  - Anecdotal P-band Ground Penetration of Arid Soil
- GeoSAR Results in Colombia South America
  - X-band vs. P-band Reflectance Differences
  - Foliage Penetration (Early Results)
- GeoSAR Collection and Processing Methodology
  - Inherent Collection Redundancy
  - Mosaic of Multiple Looks
  - Issues Associated with Differential Penetration

GeoSAR Overview, Including Latest Upgrades



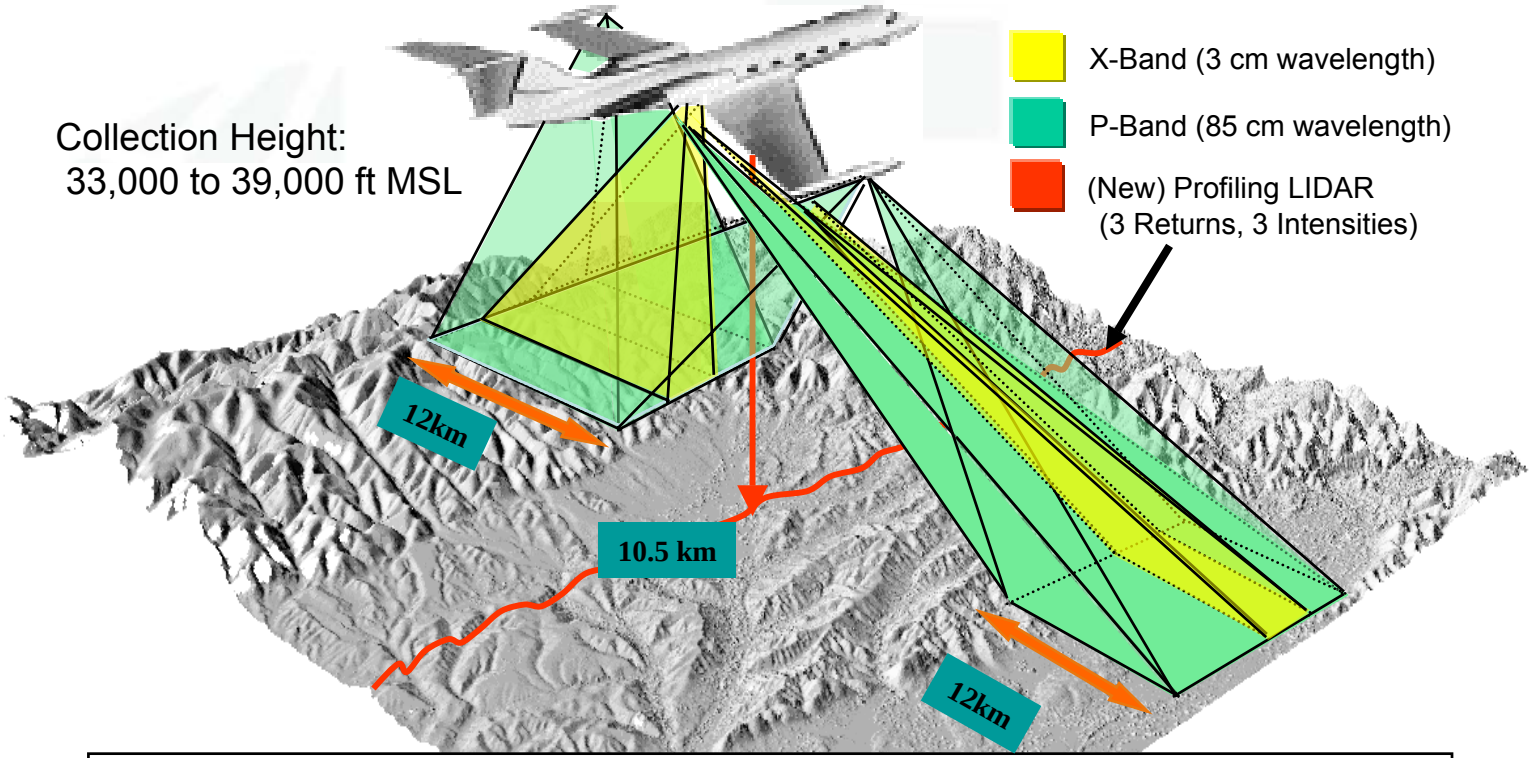
Aircraft Exterior

- Two P-band Antennas Are Mounted On Each Wingtip And Operate Over 270–430 Mhz
- 20m40m Dual Baseline



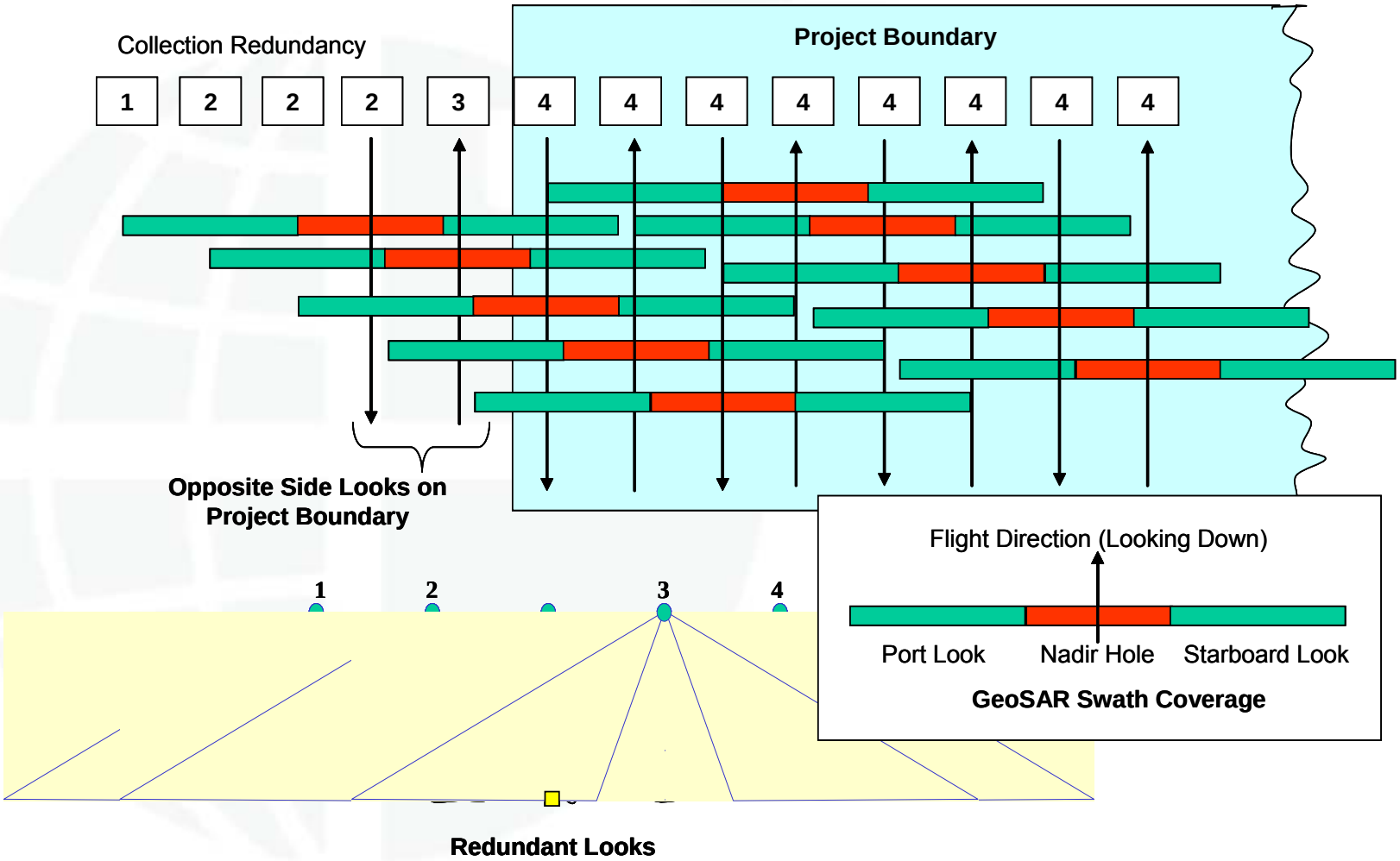
- Two X-band Antenna Are Mounted Under Each Wing Close To The Fuselage And Operate Over 9630–9790 Mhz
- New 2nd Generation Antenna Position Measurement Unit

GeoSAR Data Collection

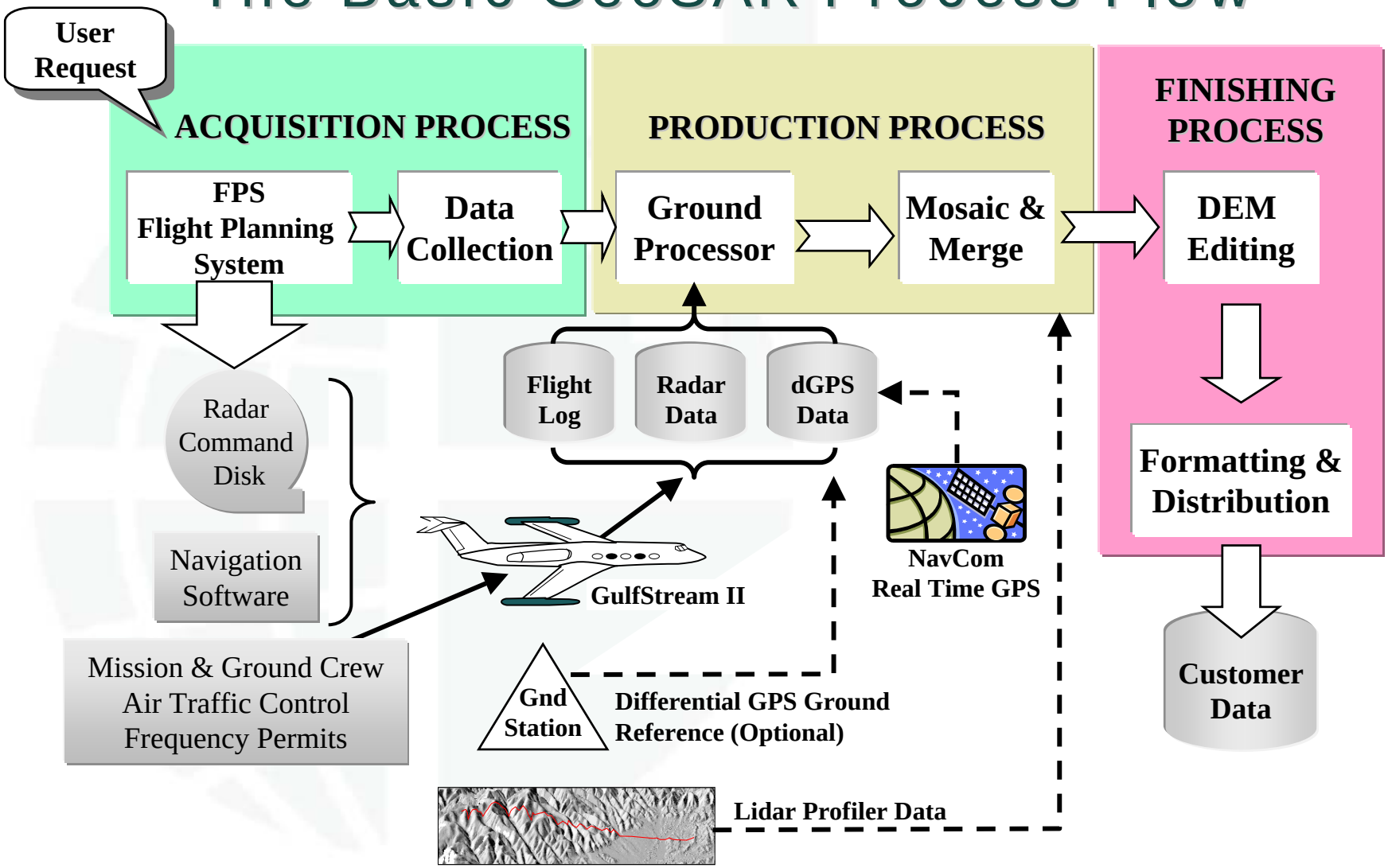


- Simultaneous X-band and P-band Interferometric Radar Data Collection on Left and Right Sides of Aircraft
- Flight Lines up to 1200 Km in Length, 380MBs Data Rate
- Flight Duration Approximately 5 Hours

GeoSAR Redundant Collection Methodology

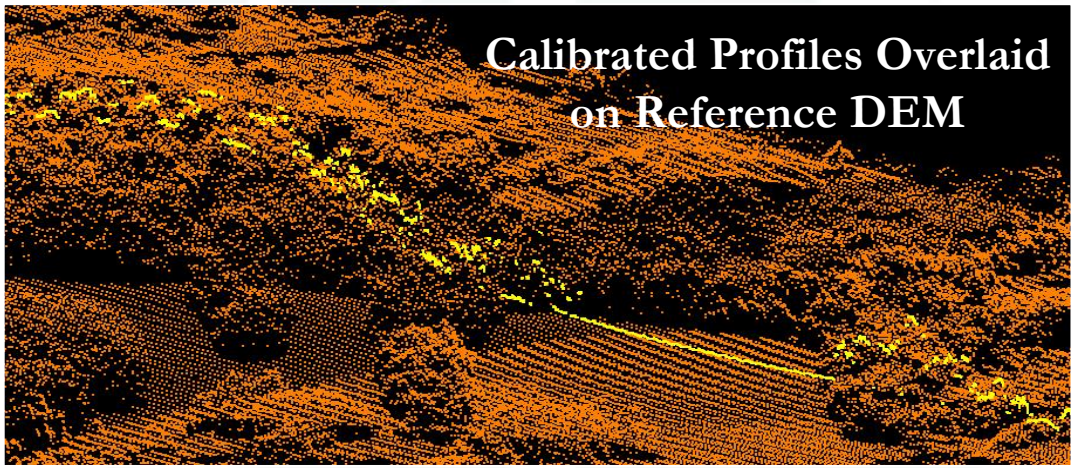


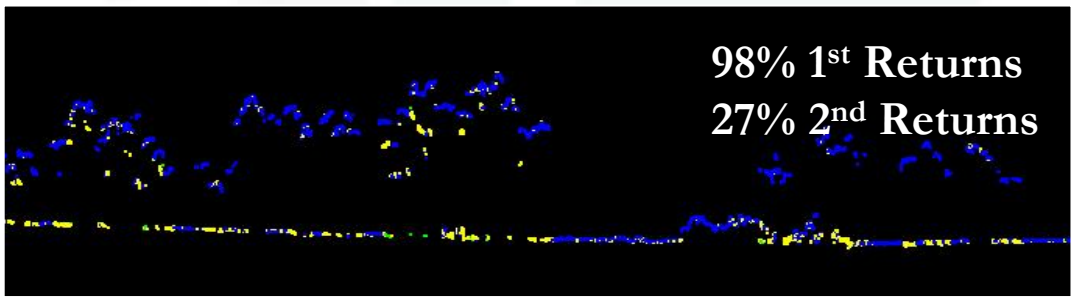
The Basic GeoSAR Process Flow



LIDAR Profiler 3 Returns, 3 Intensities

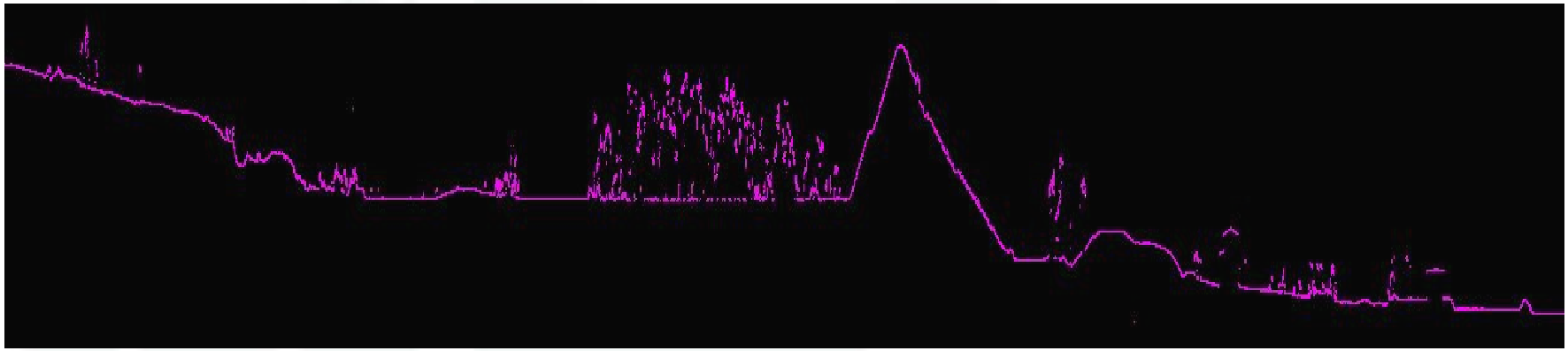
- **LIDAR Profiler**
  - Add a lidar profiler to operate at high altitude
  - ***Reduces/eliminates need for ground control in remote, inaccessible or inhospitable areas. Improves accuracy of mosaicked products and DEM.***





Leica ALS40 Lidar Modified for High Altitude Profiling

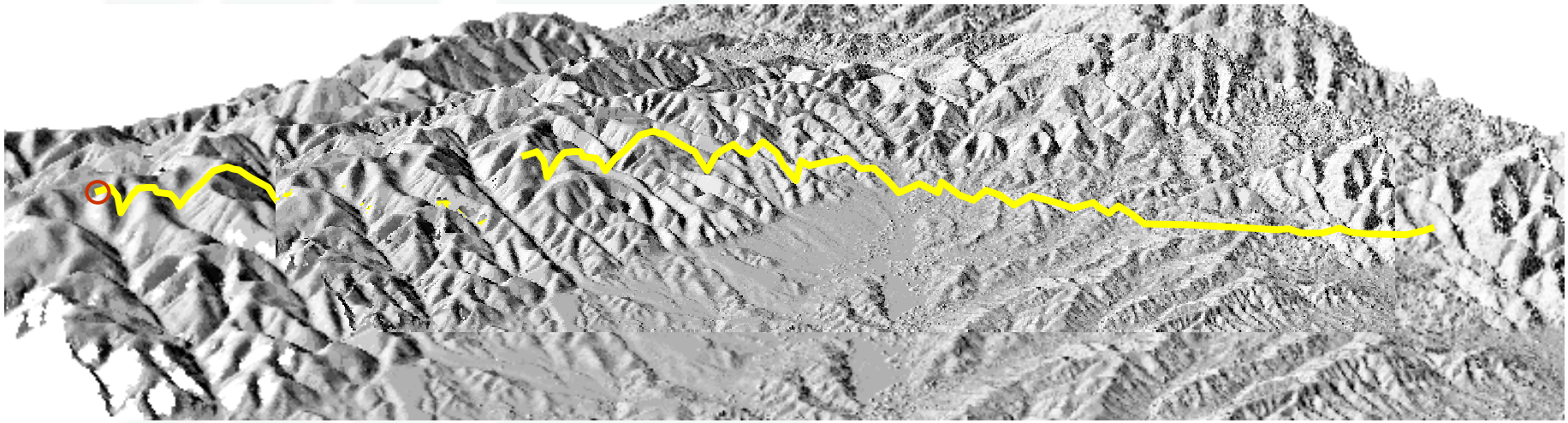
Profile of Hansen Dam



- 2-3m Spot size
- 3-5cm Spot Posting
- 3 Returns
- 3 Intensities

Application Of Lidar Profile To Corrective Image/DEM/Mosaic Formation

Swath Is Flow With SAR
Lidar Cross Swath Is Flown



Lidar Profile Correlated With The Swath—
Used in Mosaic Level Affine Adjustments

Synopsis of GeoSAR Features

- Dual-band X & P, Dual Sided, Single Pass Interferometric
  - 4Q05 Upgrade: 10-bit Data Samples (no compression)
  - Dual Baseline X-band
  - 370MBS collection Rate
- Two Sided Systems (GeoSAR) Collects Twice As Much Data Per Flight Distance Flown
- The Only Commercial IFSAR With A Co-mounted Lidar Profiler
- GeoSAR Flightline Spacing Yields An Additional Factor Of 2 Increase In Collection Data Redundancy
- LMS Mosaic Error Propagation Improves DEM Quality Without Effecting Spatial Resolution (MTF)

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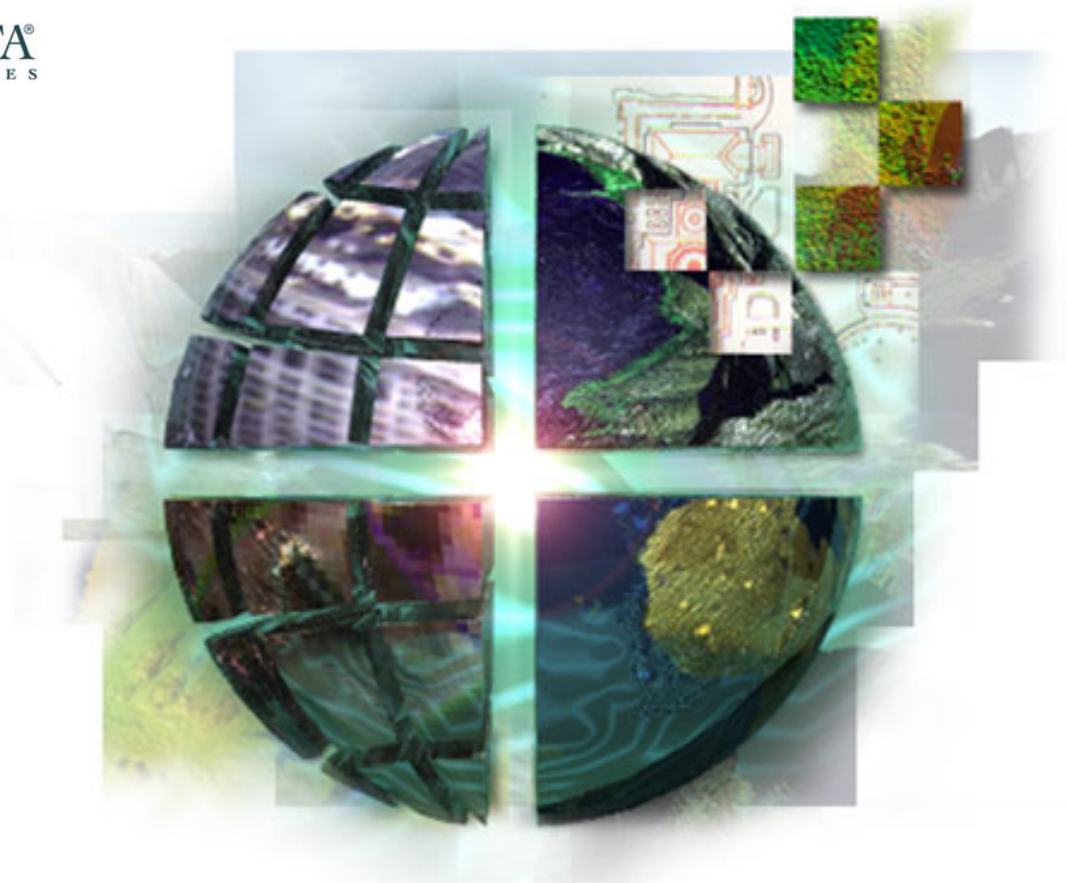

NOAA Watershed Project Overview

Emphasis on P-band

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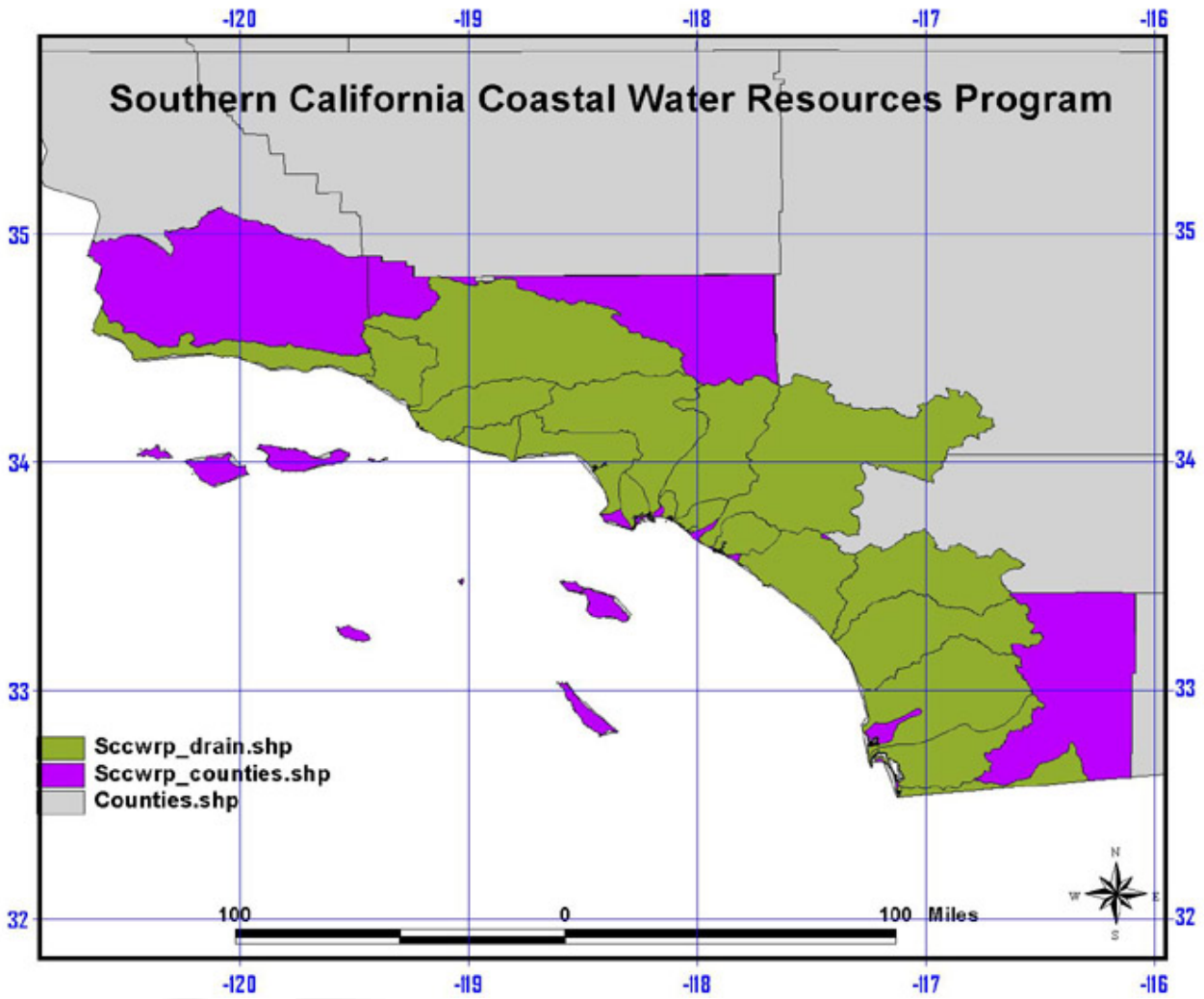
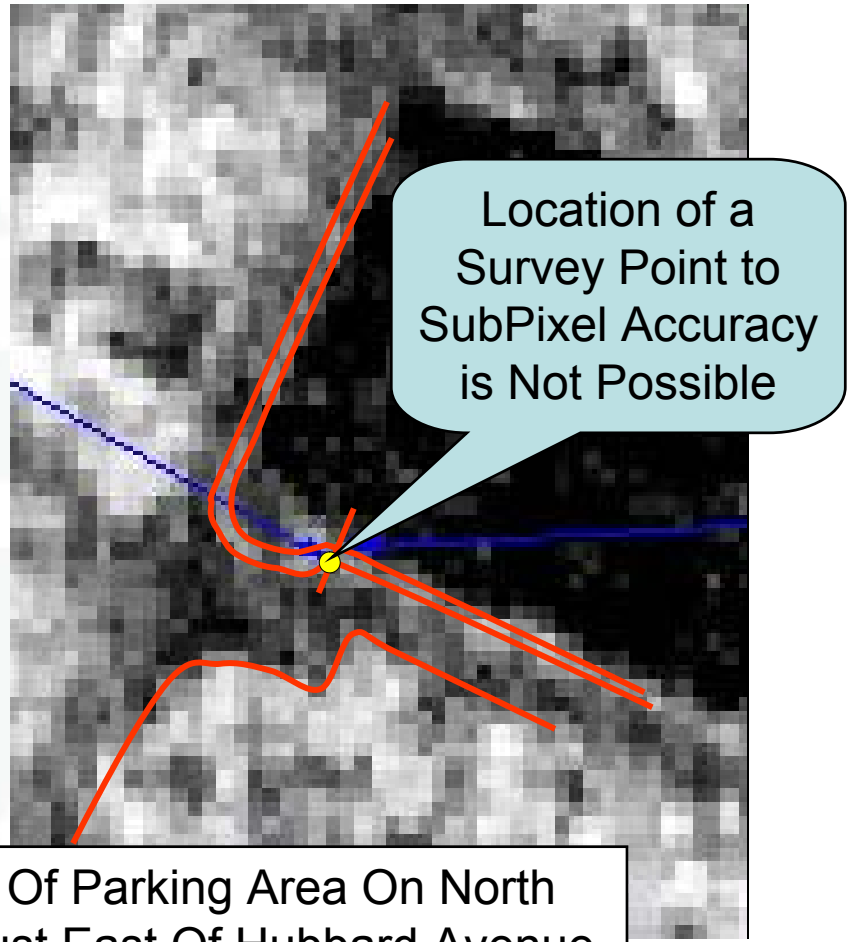
NOAA Project, All Phases 315 Quads Delivered, 3m Post, 1m Vertical RMSE

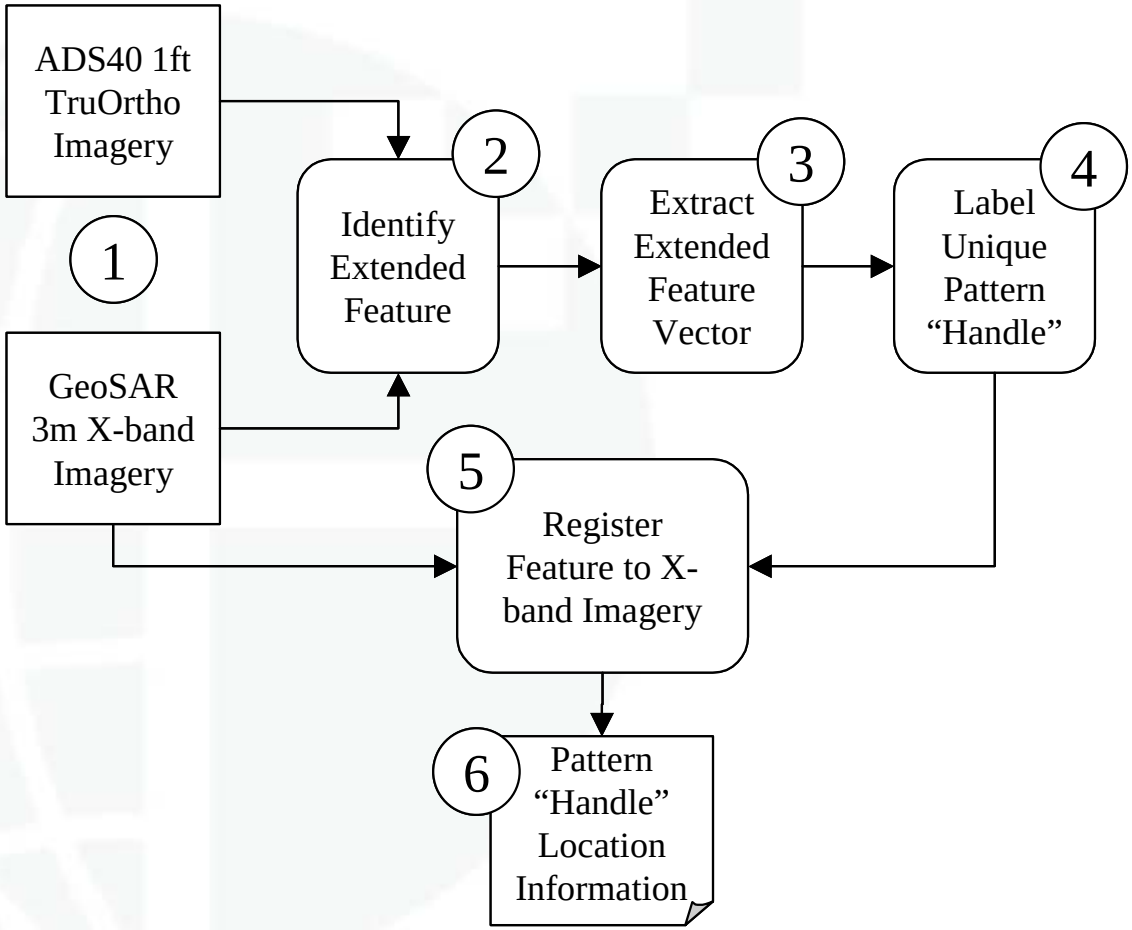


Problematic Measurement of Planarmetric Accuracy from Surveyed Point



Description: NW Corner Of Parking Area On North Side Of Morales Street, Just East Of Hubbard Avenue

Extended Control Feature Extraction Process

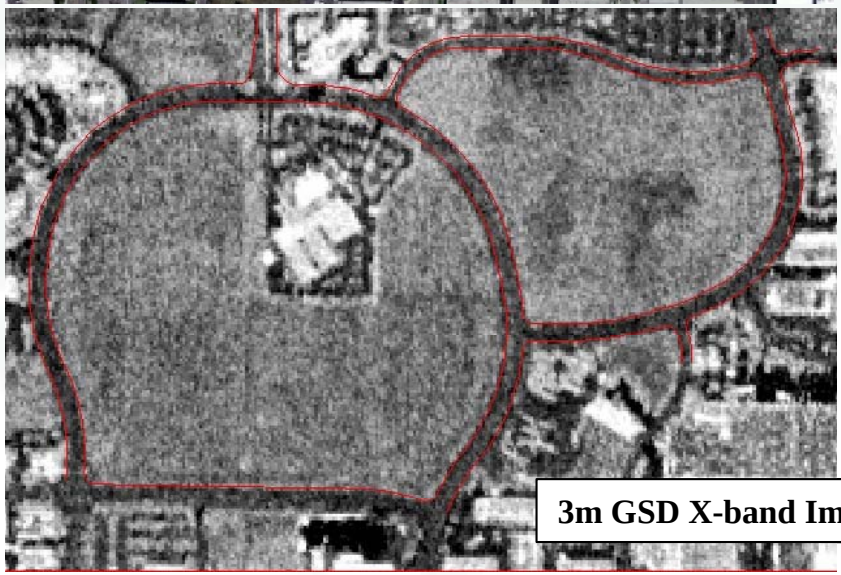


Ortho Control (Pattern-2)

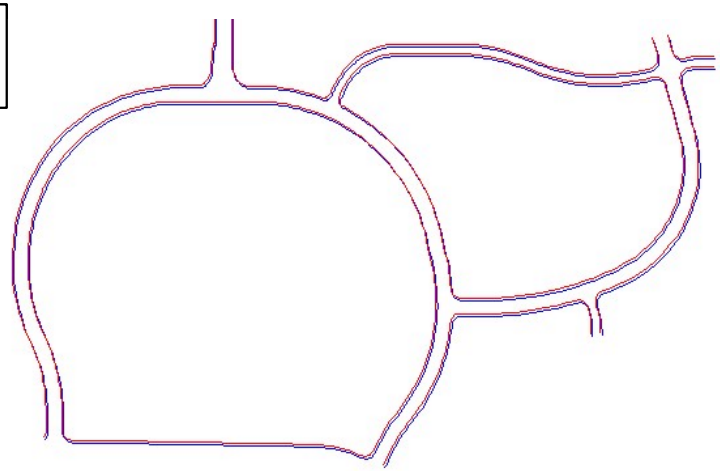
The closed loop patterns have high radar contrast that create many simultaneous spatial constraints.

Vector Pattern "Best" Match

ADS40 1ft GSD Natural Color TruOrtho



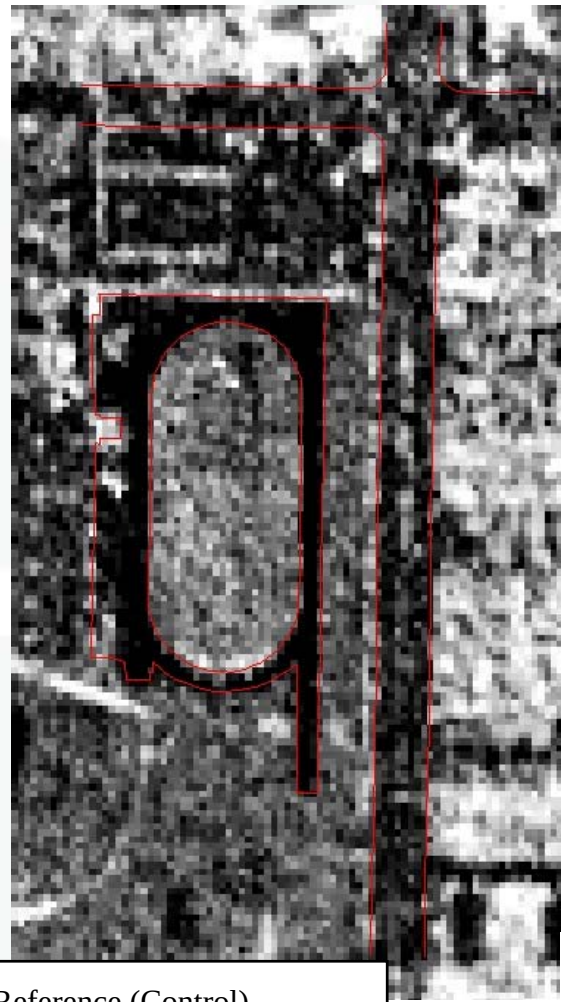
3m GSD X-band Imagery



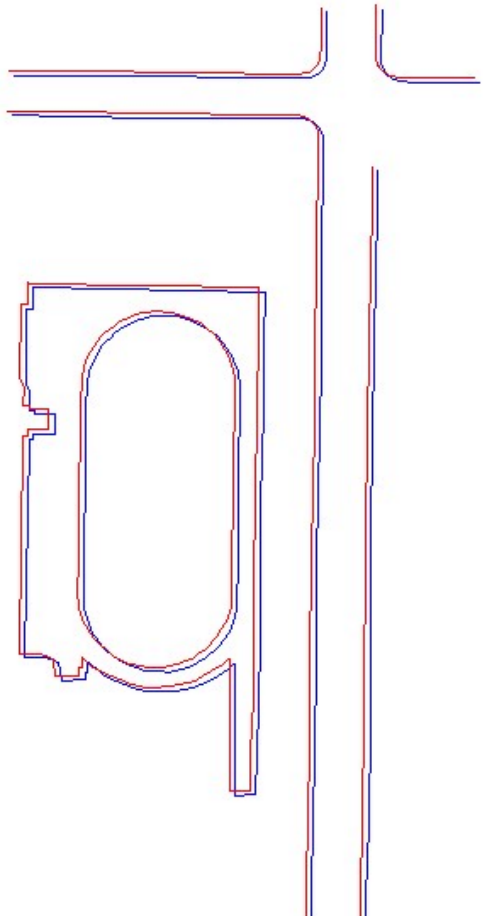
Blue Lines = Ortho Reference (Control)
Red Lines = "Best" Translational Match (Radar)

ADS40 1ft GSD Natural Color TruOrtho

3m GSD X-Band imagery



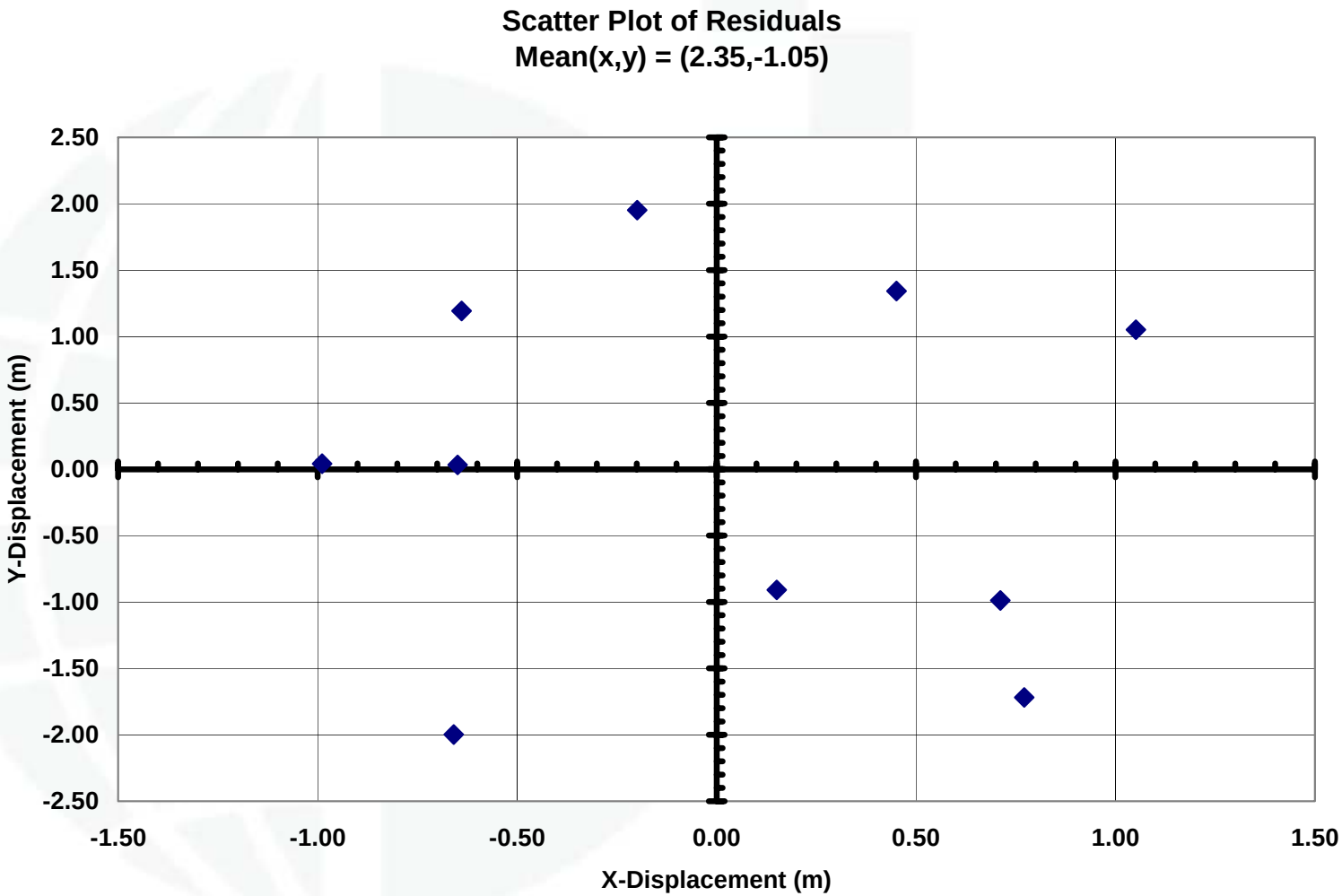
Vector Pattern "Best" Match



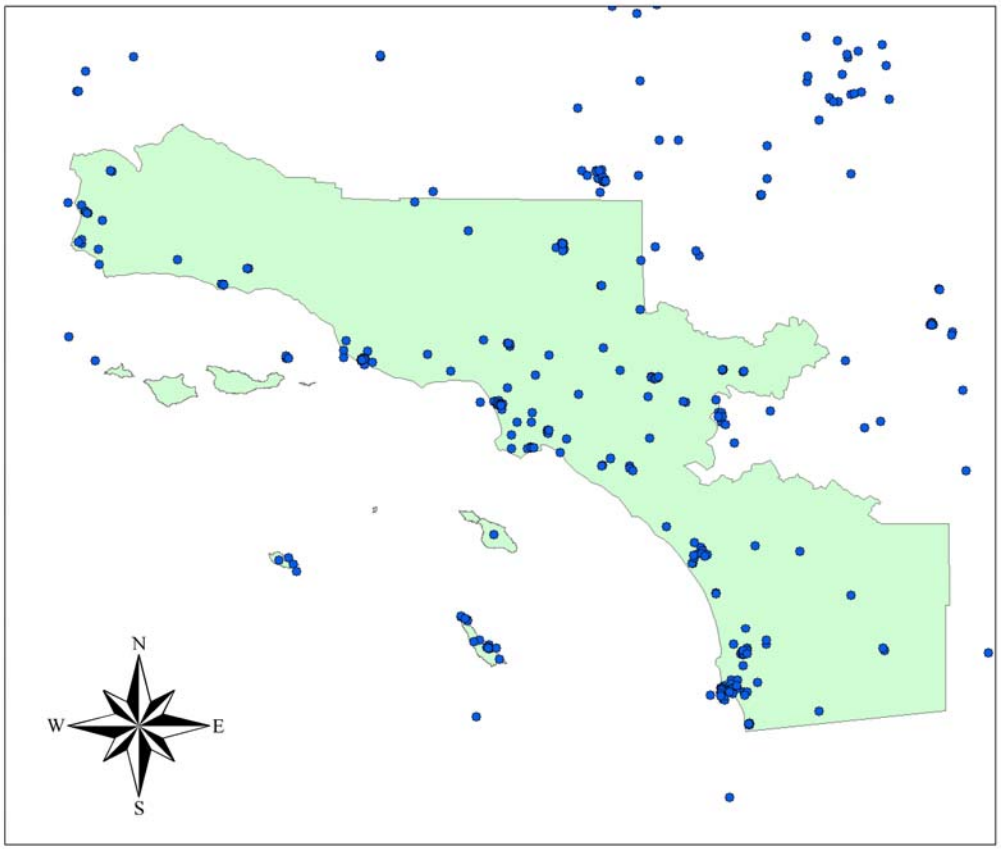
Blue Lines = Ortho Reference (Control)
Red Lines = "Best" Translational Match (Radar)

Ortho Control (Pattern-7)

Scatter Plot of Residual Errors (Bias Removed)

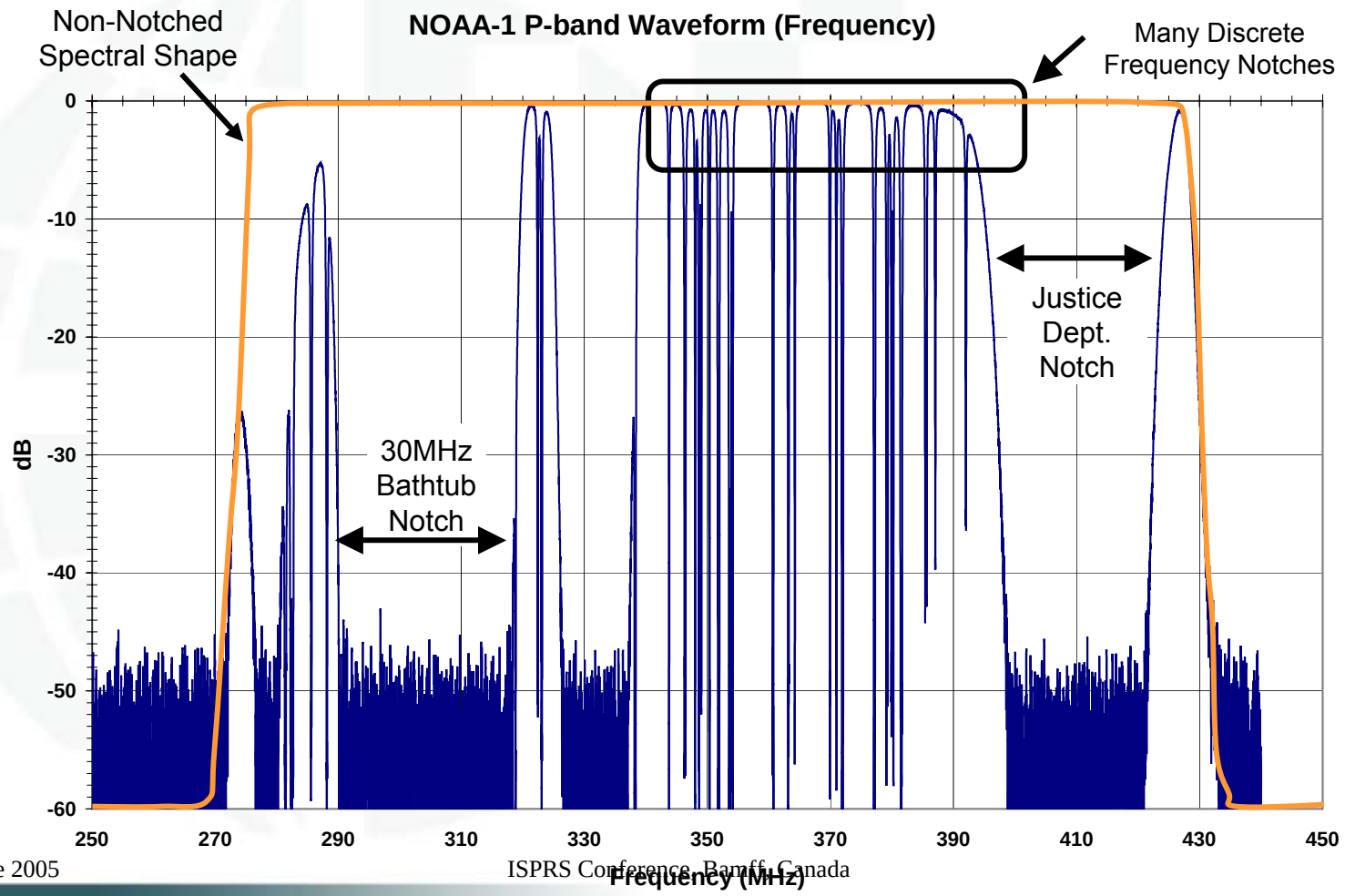


P-Band Frequency Management
315 Quads of Collection Area



- Preprogrammed waveform is notched to assure compatibility with other users of 270-430 MHz frequency band.
- The greater the notching in an area, the lower the resolution of the P-band image; some degradation of P-band DEM.
- Optimal location for P-band processing is in an area where frequency usage is lowest.

NOAA-1 P-band Transmit Waveform (Frequency Domain)

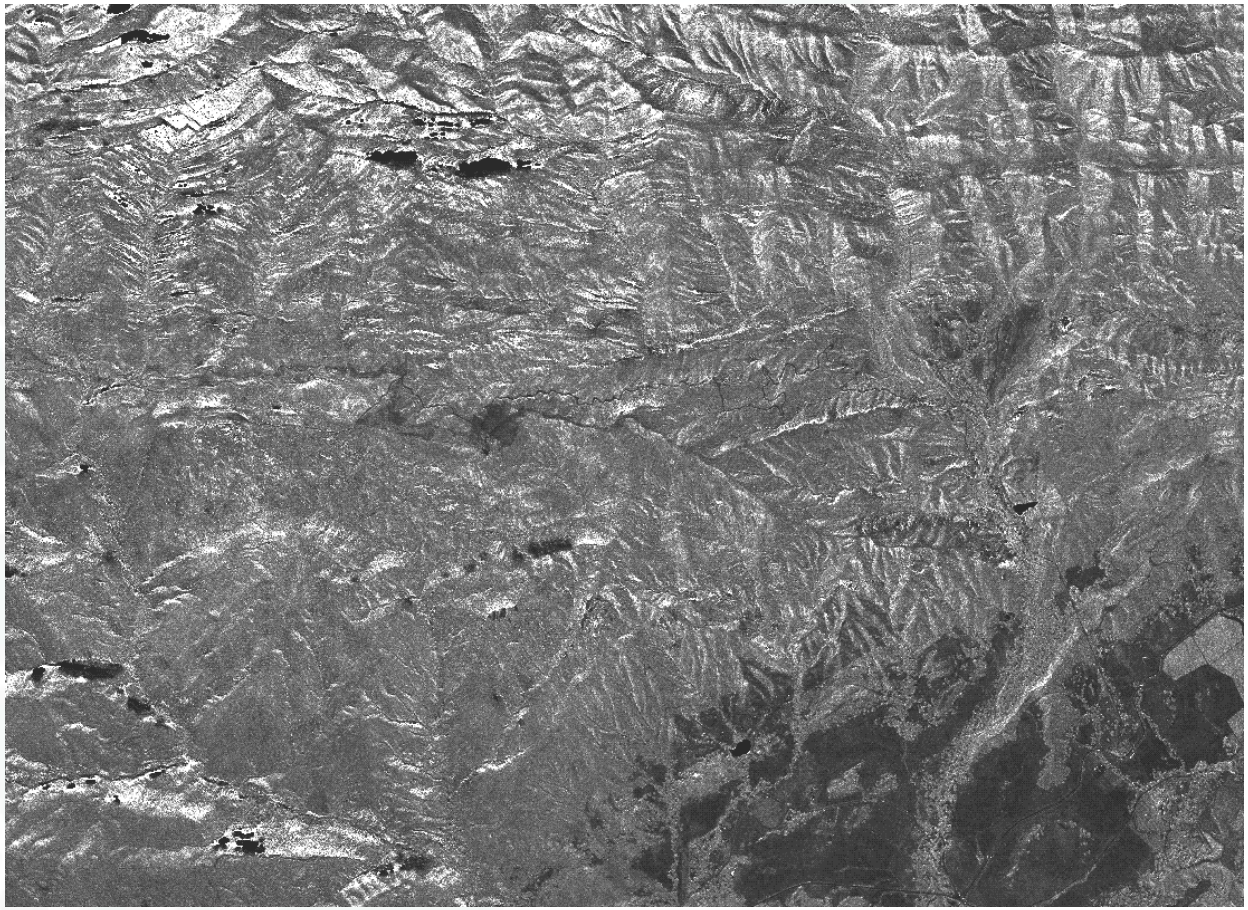


GeoSAR P-band Image, 5m Posting (Zoomed)

Note: Imagery Is Blurred In The Range Direction Due To High Sidelobe Structure In The Transmit Waveform

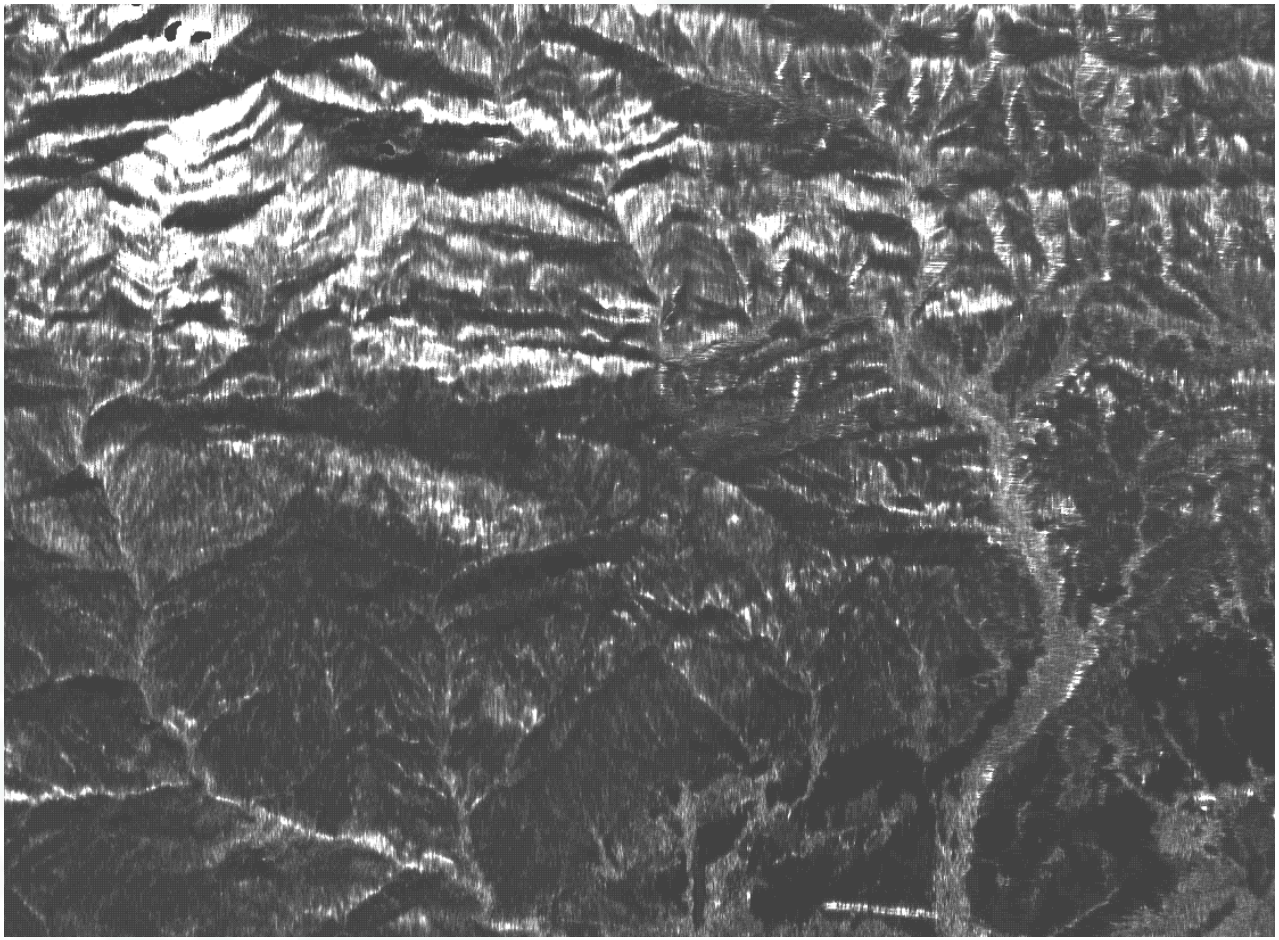
Increasing Range

X-band Drainage (3m Posting)



X_BAND_DRAIN.TIF

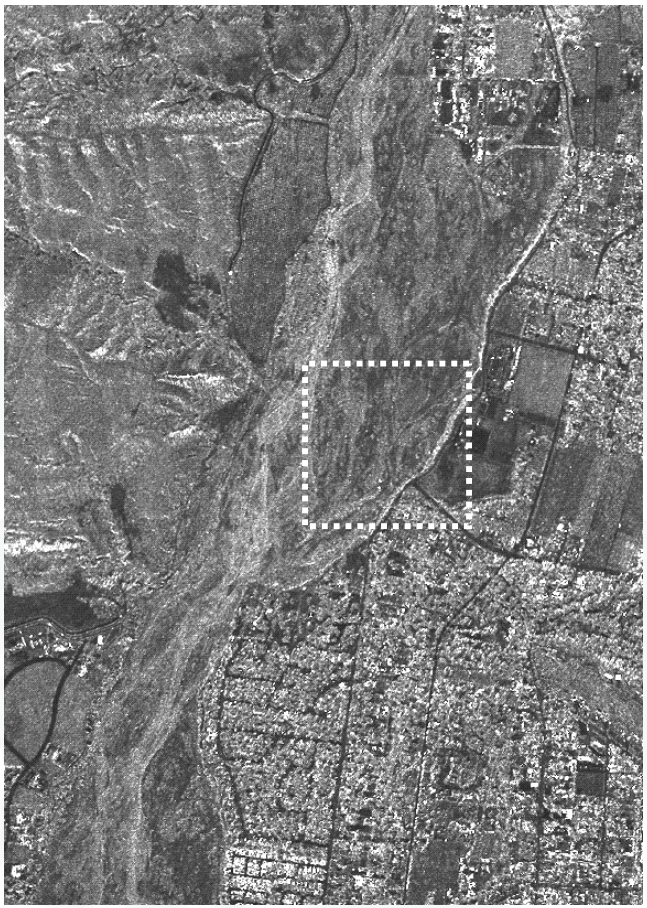
P-band Drainage (5m Posting)



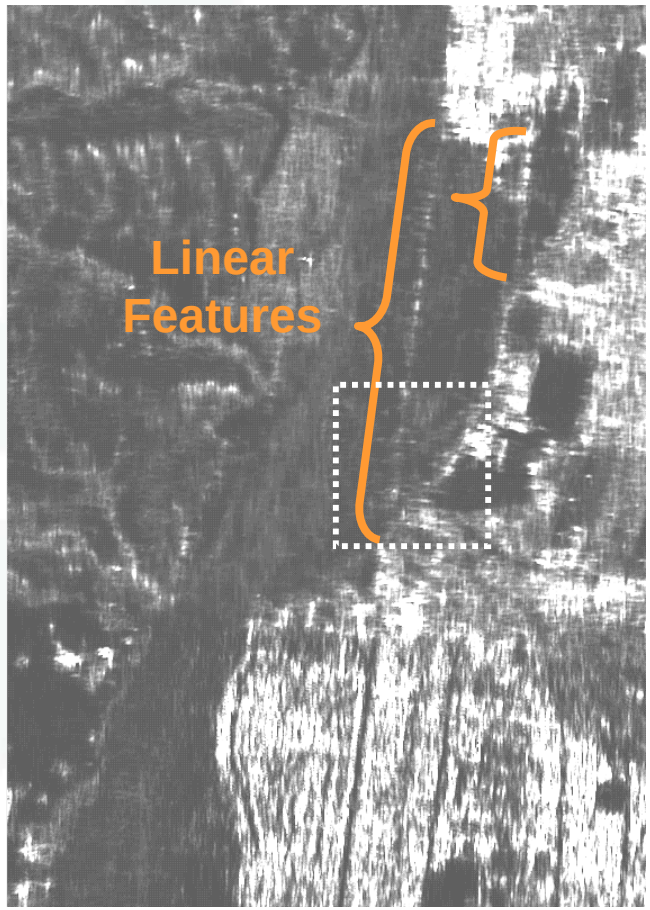
P_BAND_DRAIN.TIF

Linear Feature Orthophoto

Linear Feature X-band vs. P-band



X_BAND_LINEAR_FEATURE_MAG.TIF



P_BAND_LINEAR_FEATURE_MAG.TIF

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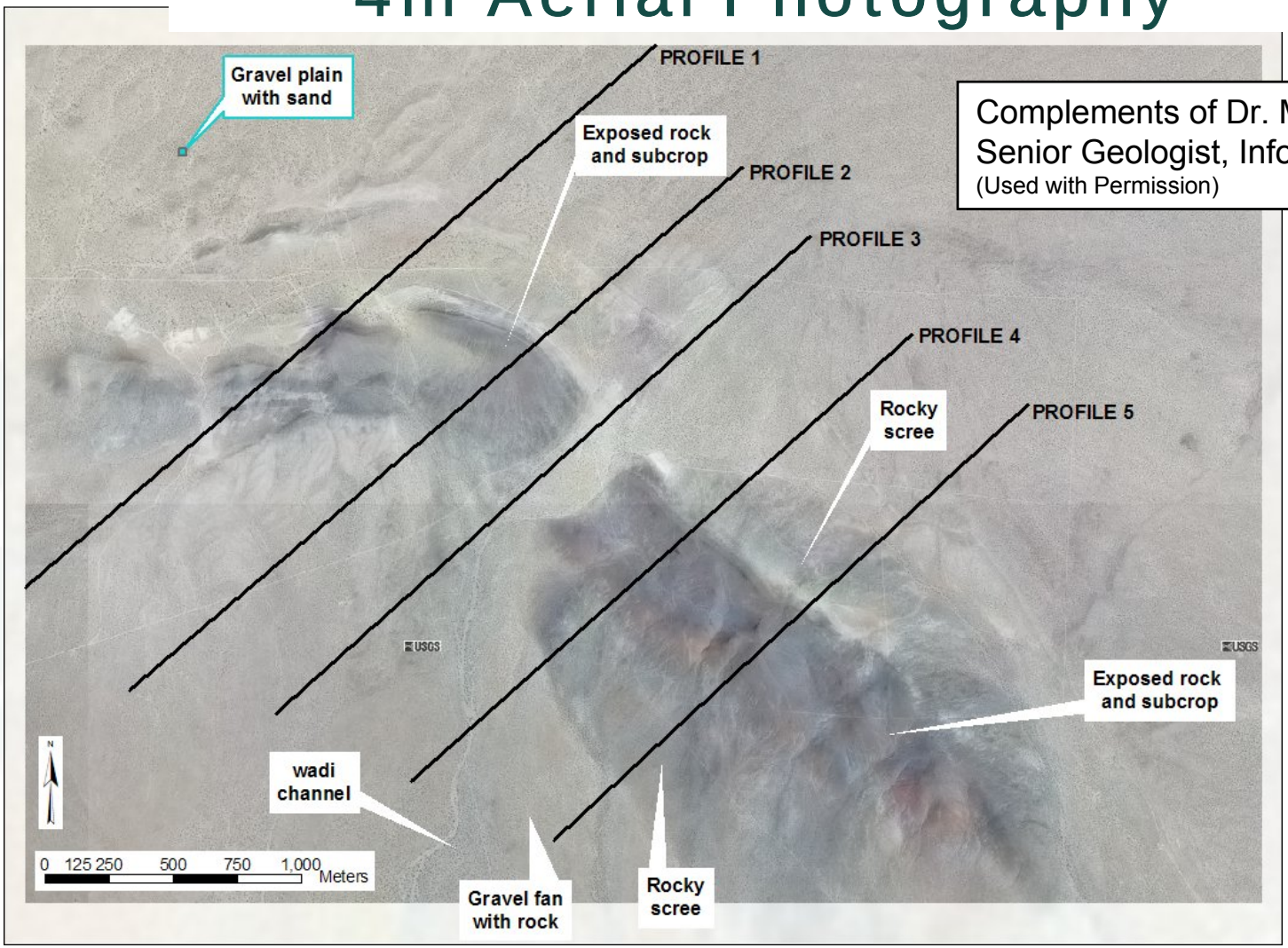
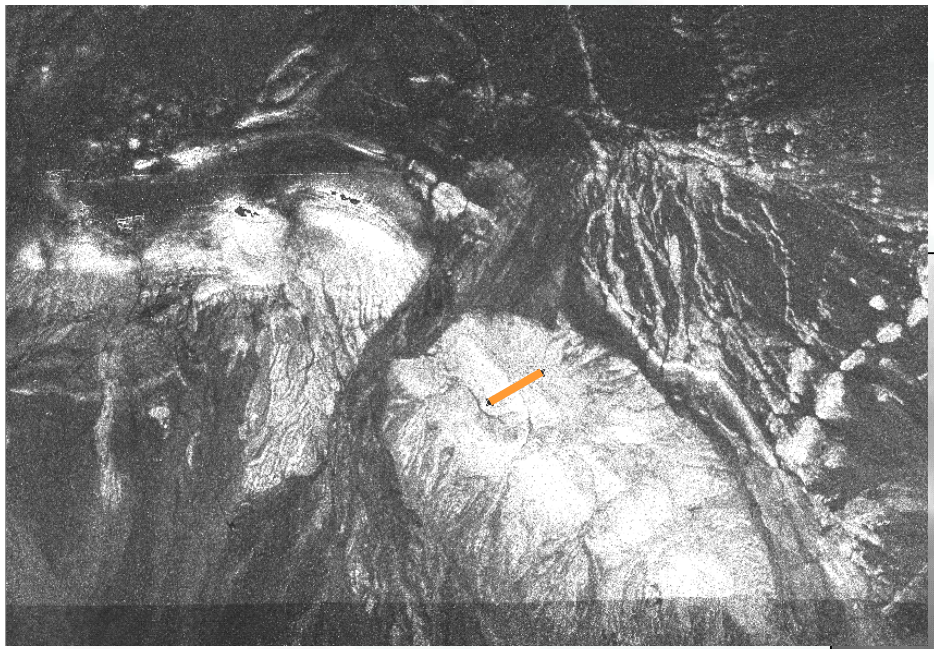
Band 742 Landsat Merged with 4m Aerial Photography



Complements of Dr. Martin Insley, Senior Geologist, Infoterra Ltd.
(Used with Permission)

Geological Formation – X-band

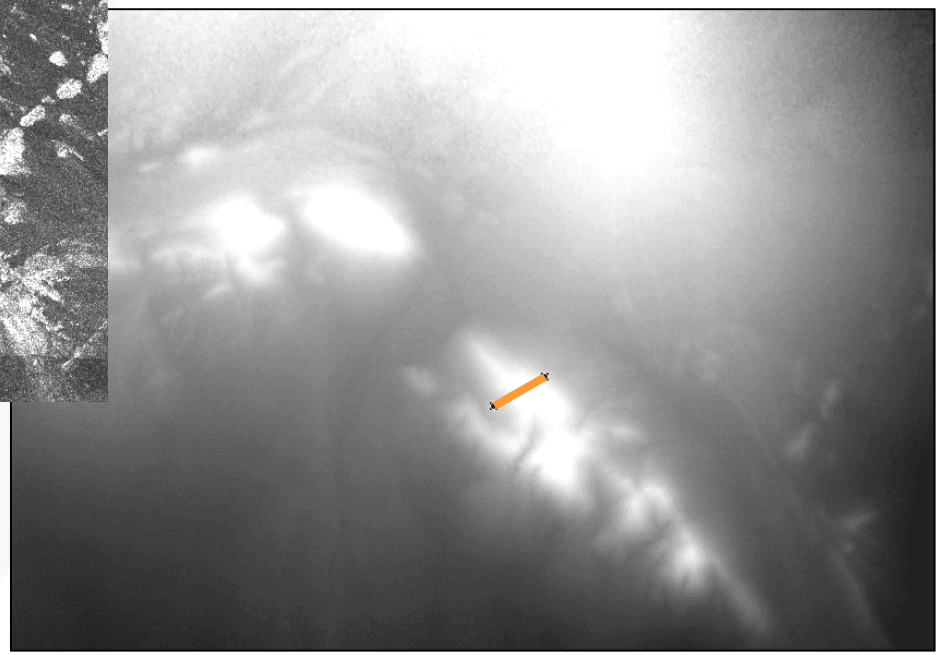


Edwards_X_mag2.tif

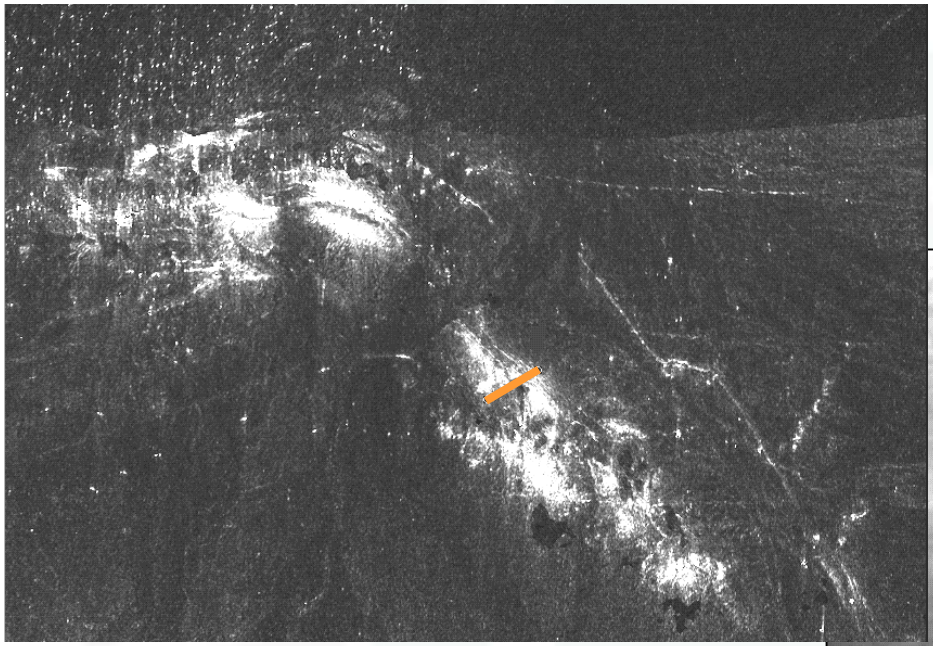
Direction of Illumination

3m Posting

Edwards_X_dem2.tif



Geological Formation P-band

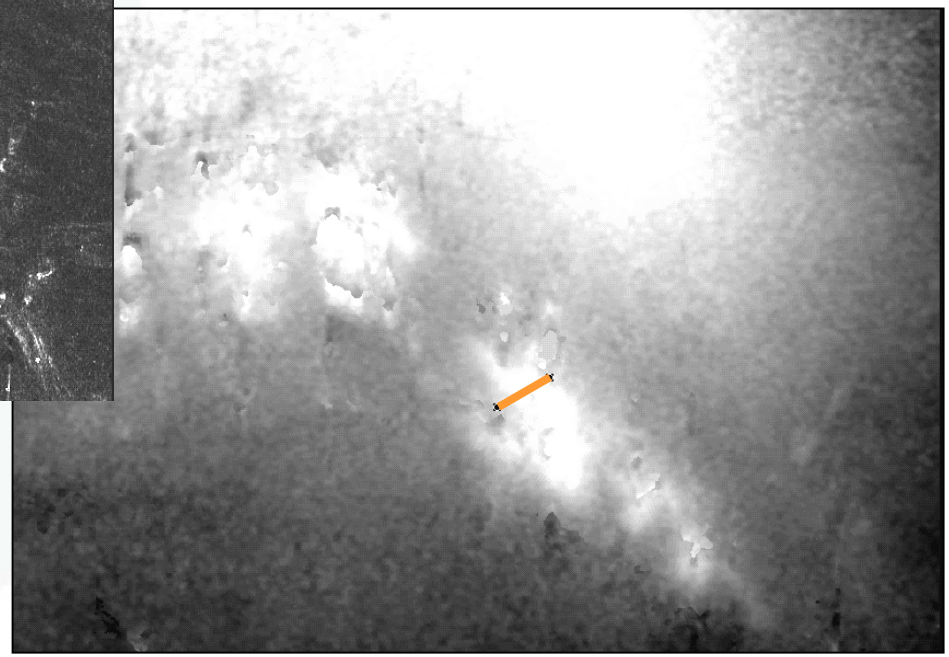


Edwards_P_mag2.tif

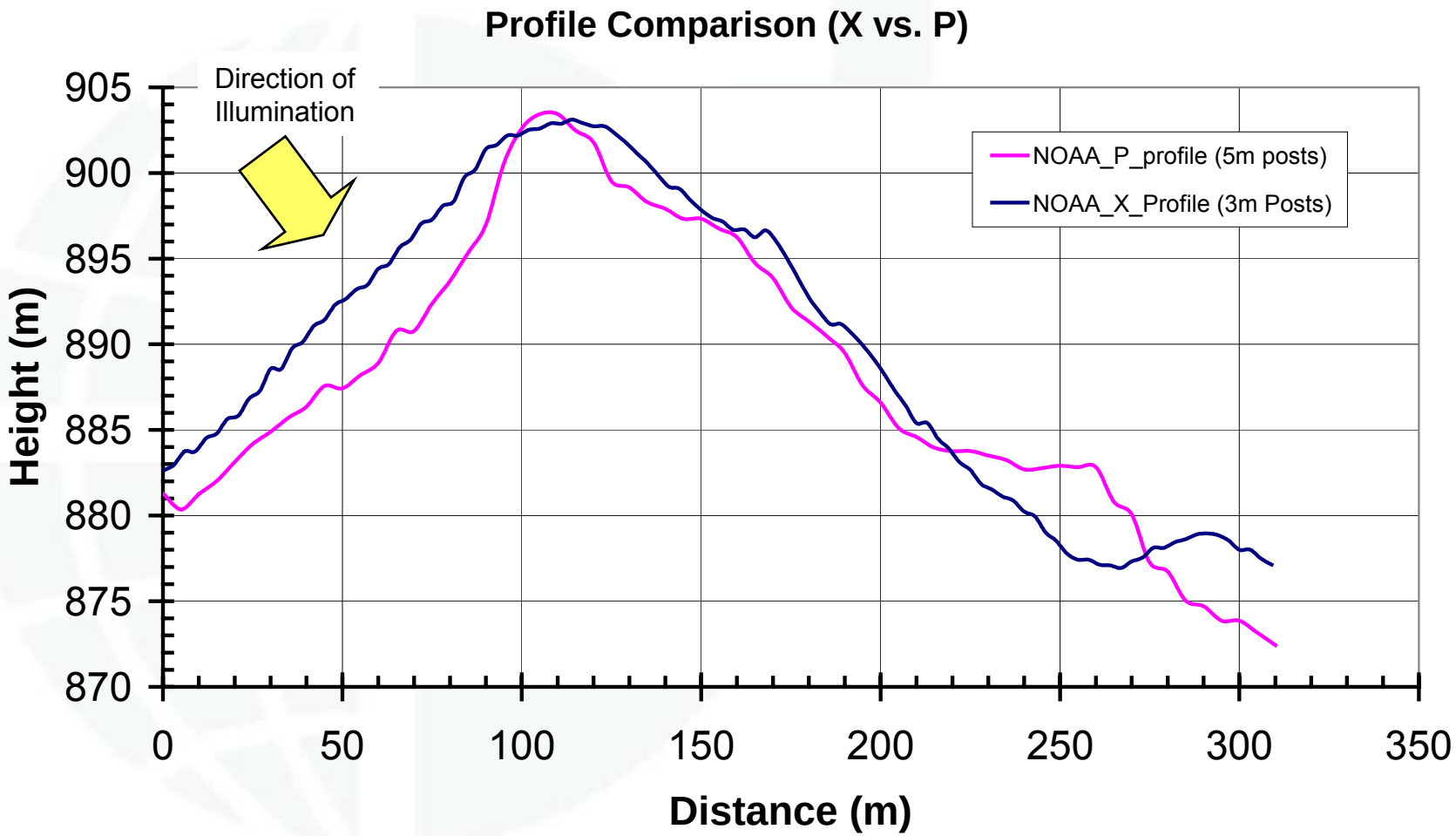
Direction of Illumination

5m Posting

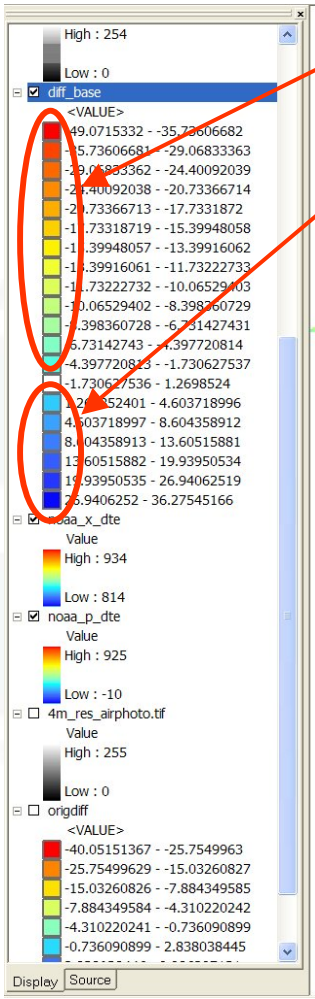
Edwards_P_dem2.tif



Profile of Geological Formation

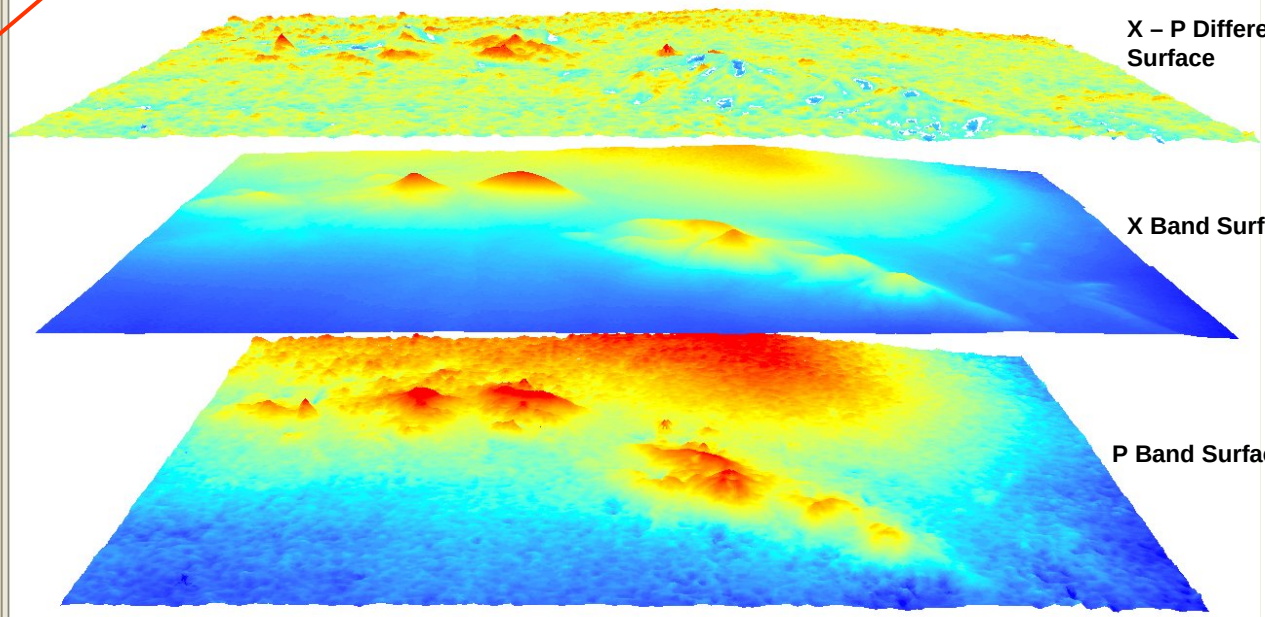


Comparison Between P, X and X-P Band Surfaces



Negative values indicate areas where P band is higher than the X band elevation

Positive values indicate areas where P band is lower than the X band elevation I.e. areas with ground penetration



X – P Difference Surface

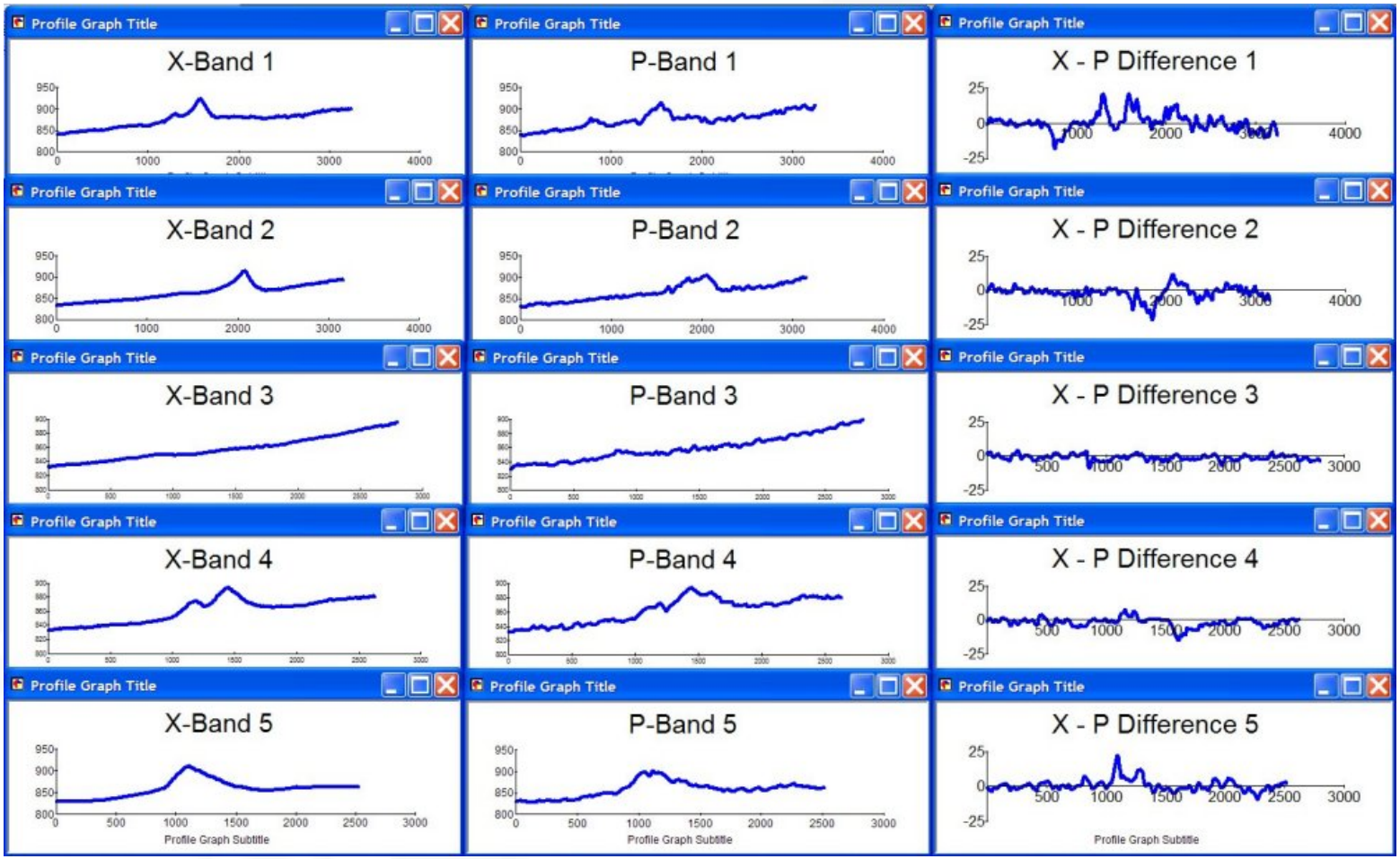
X Band Surface

P Band Surface

Complements of Dr. Martin Insley, Senior Geologist, Infoterra Ltd.
(Used with Permission)

Comparison Between X, P and X - P Vertical Profiles

Complements of Dr. Martin Insley, Senior Geologist, Infoterra Ltd.
(Used with Permission)



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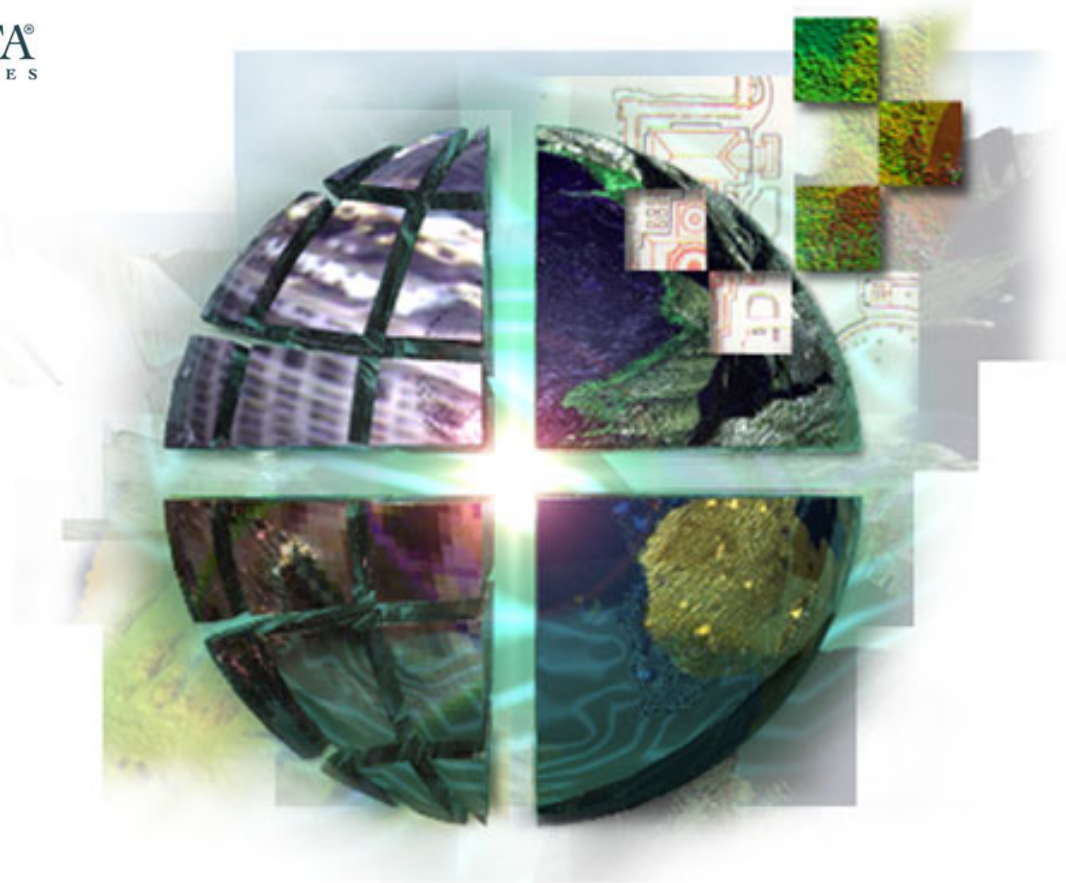

GeoSAR Results in Colombia South America

Alpha Collection Pipeline Terminus X-band, 3m Post

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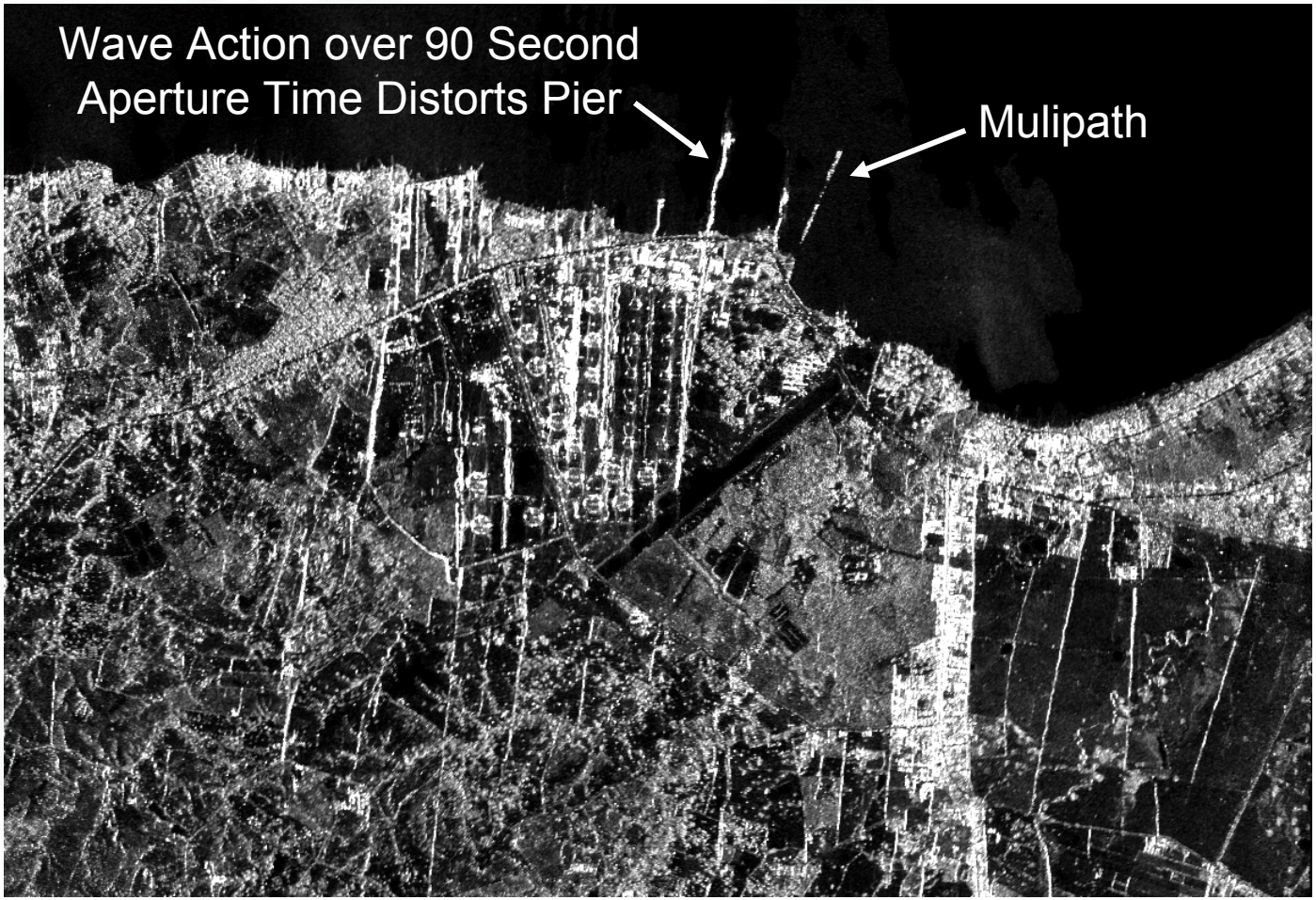
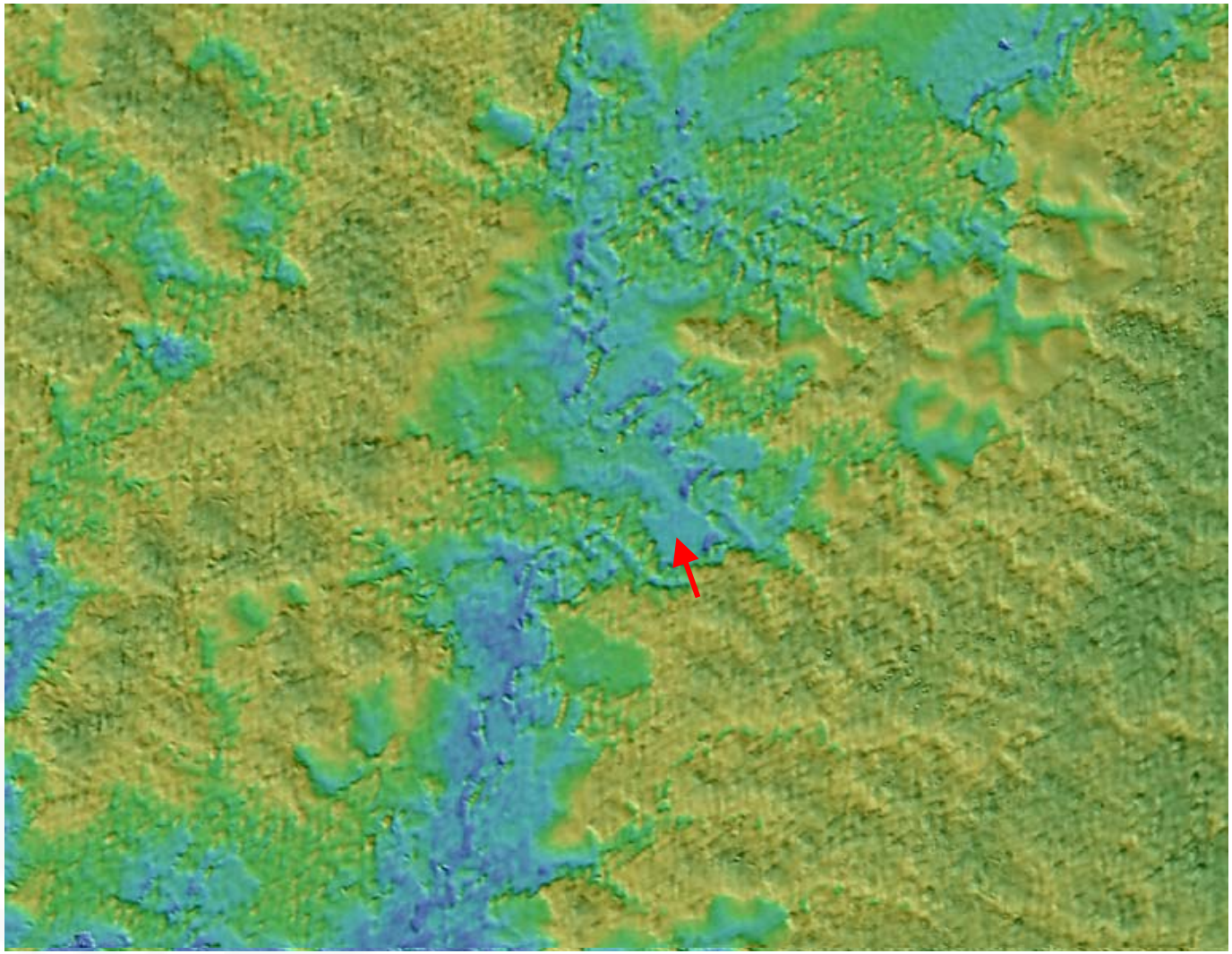
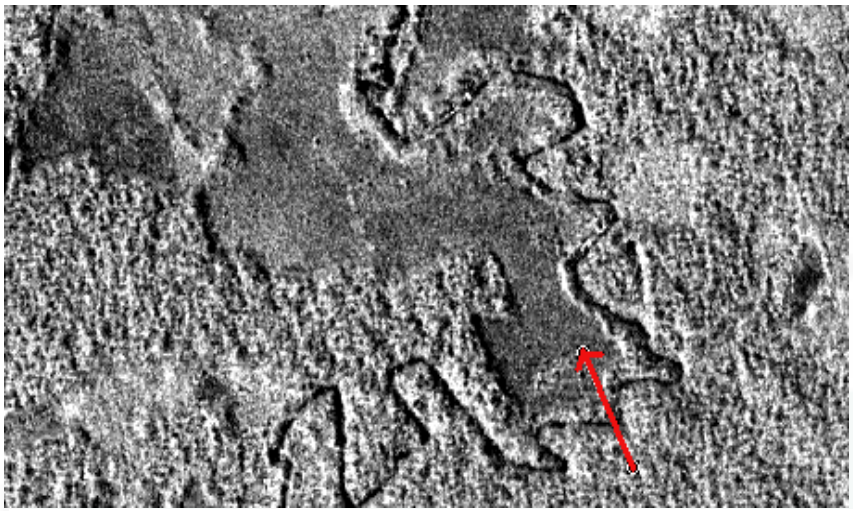
Alpha Collection Pipeline Terminus P-band, 5m Post

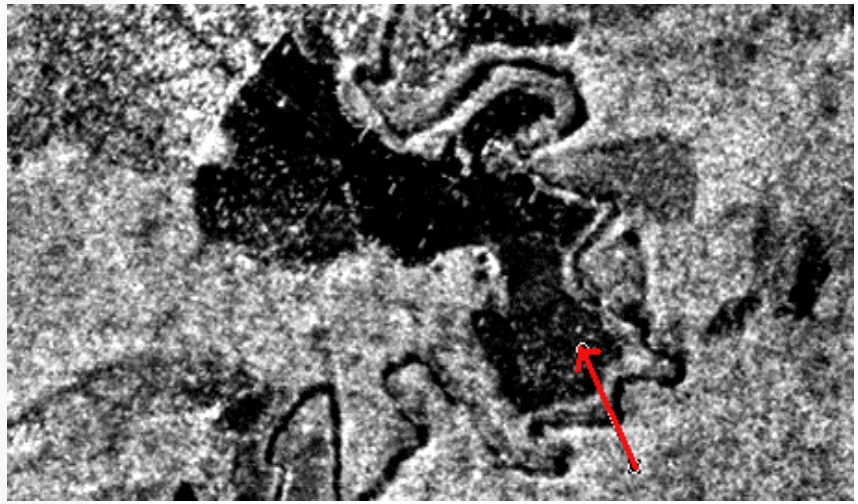


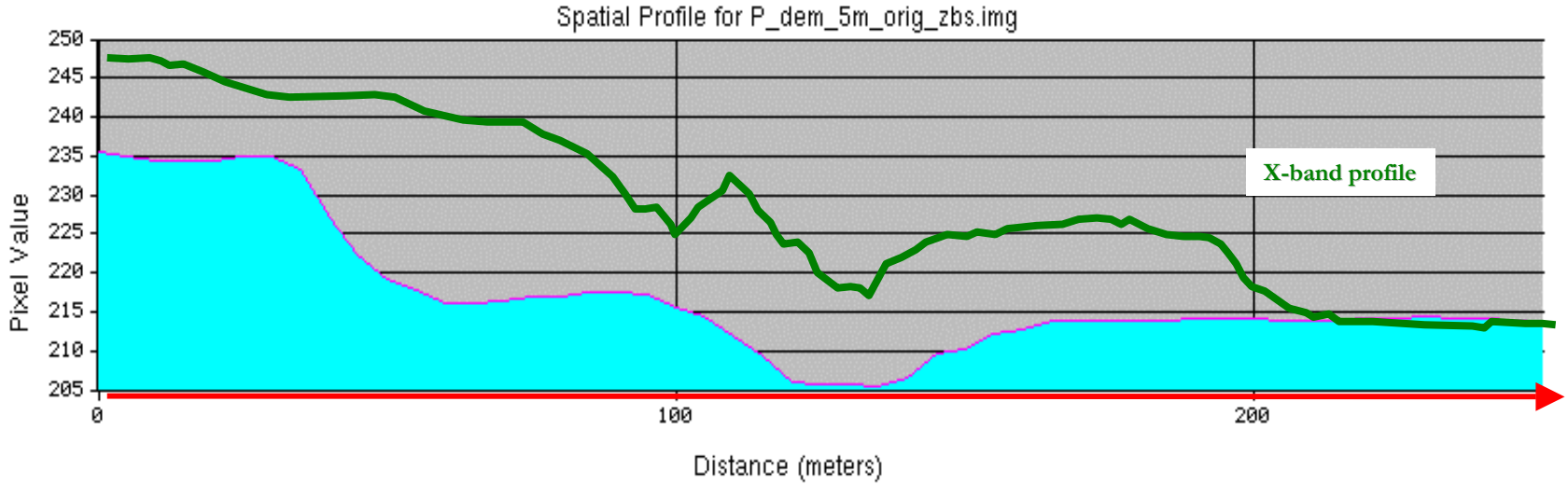


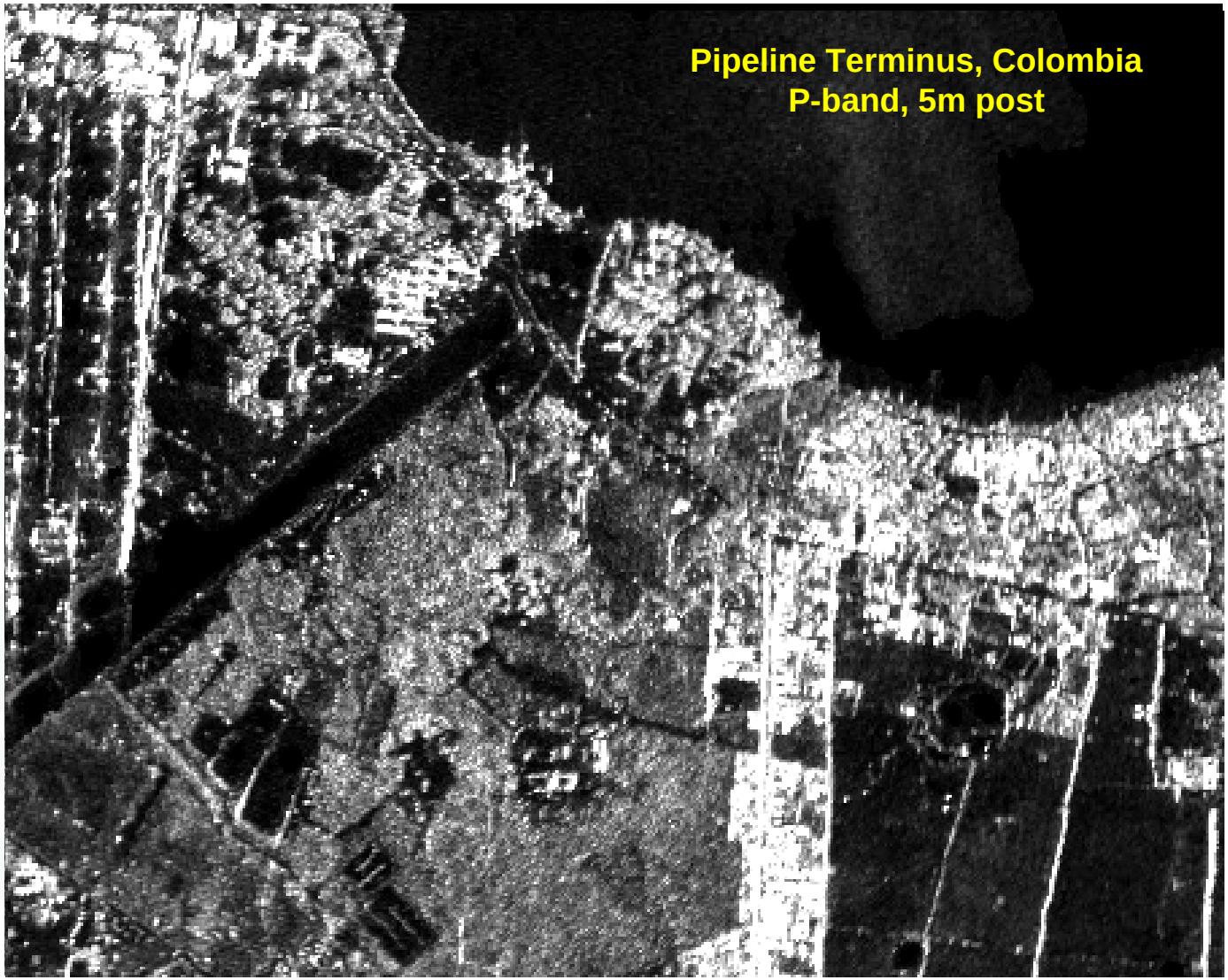
P-band 5M DEM

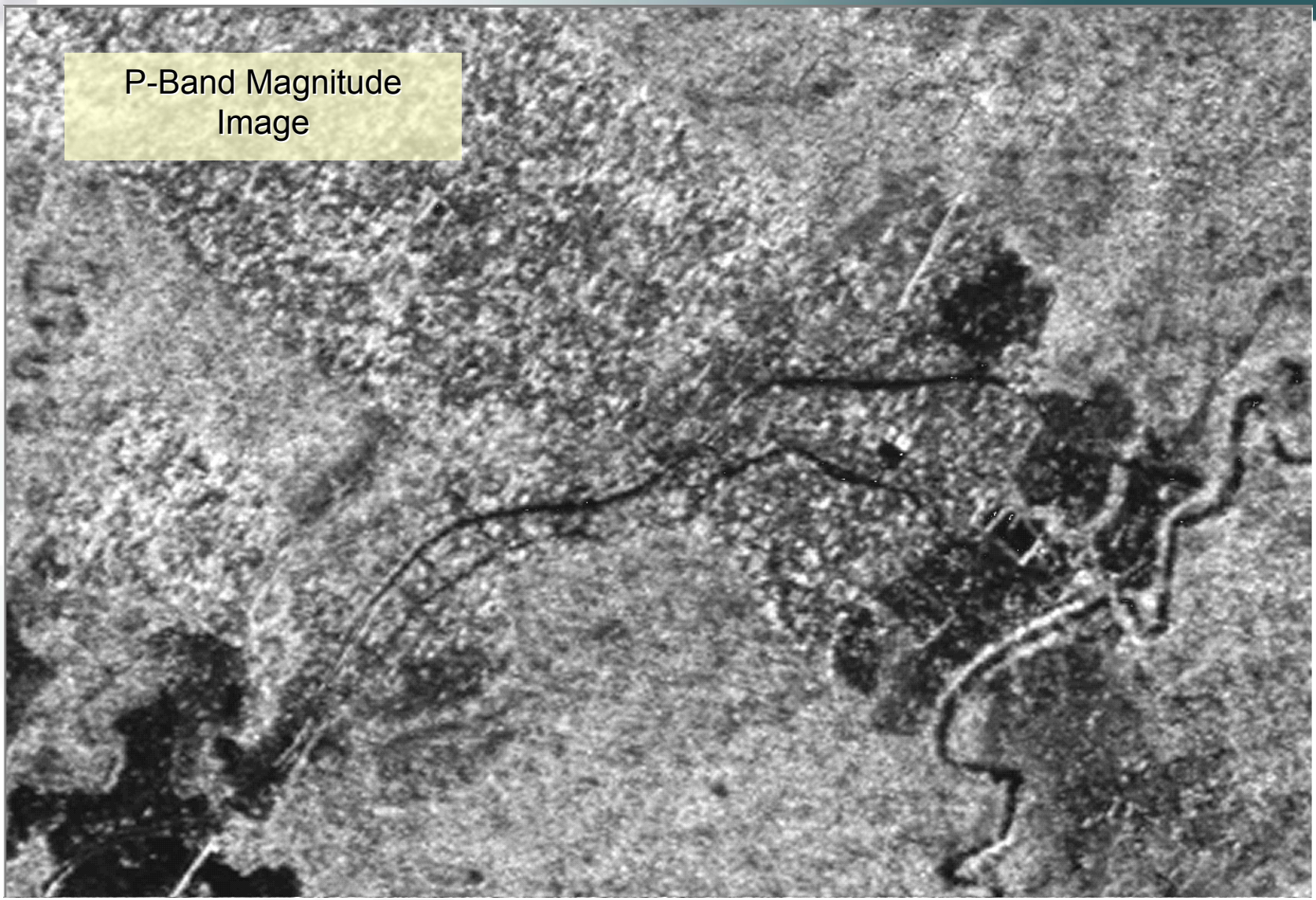
X-band vs. P-band DEM Comparison







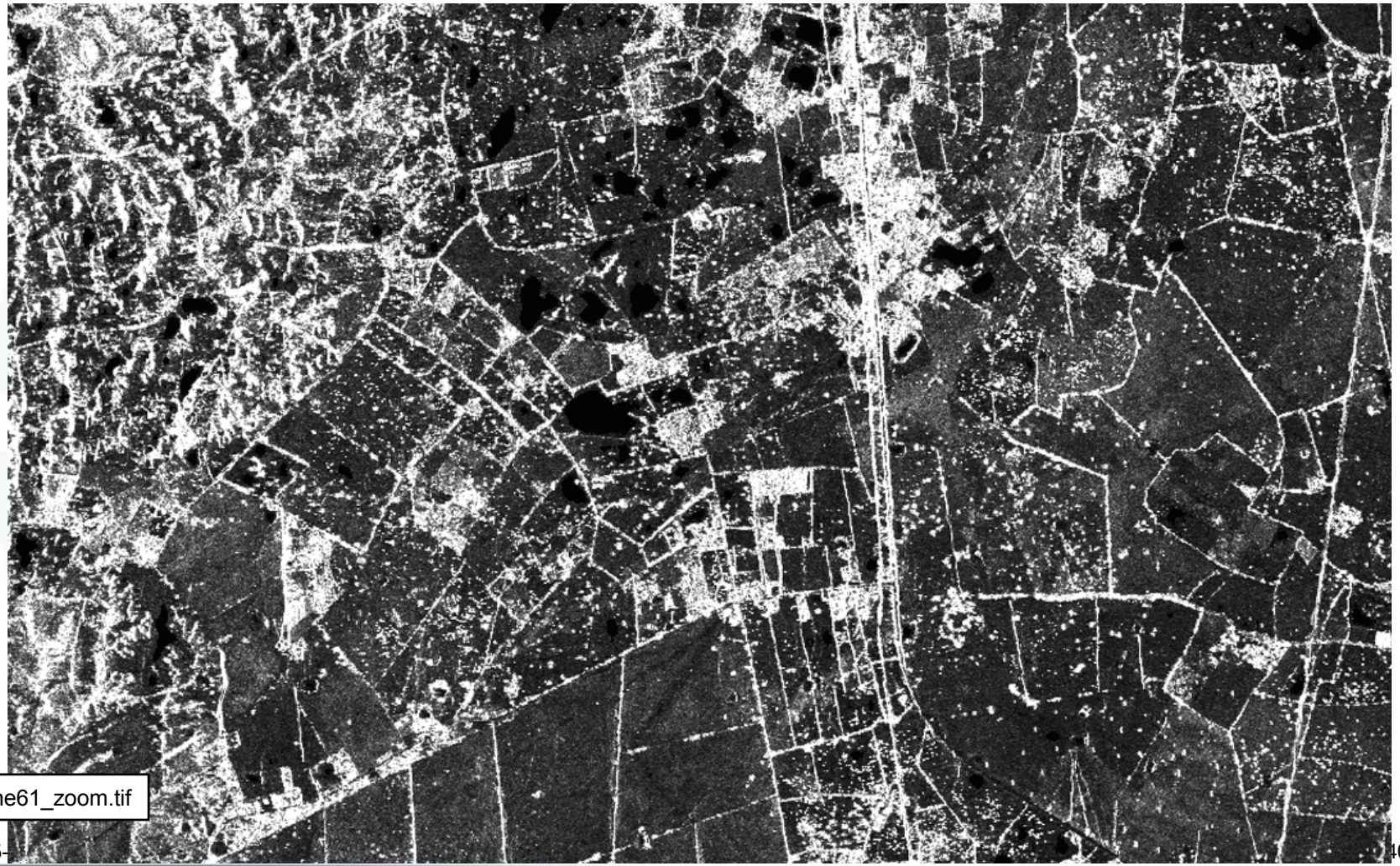

Pipeline Terminus, Colombia
P-band, 5m post


P-Band Magnitude
Image

X-band 3m Posts

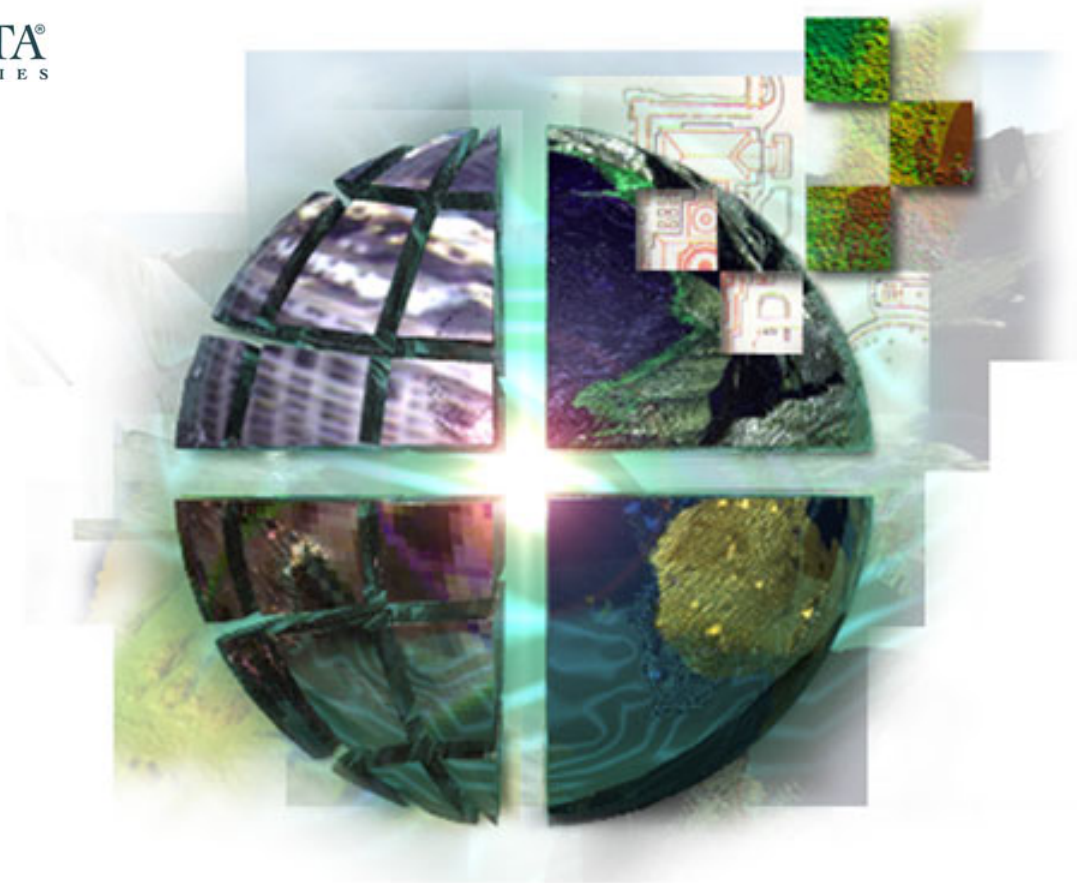
XR_Line61_zoom.tif

P-band 5m Posts



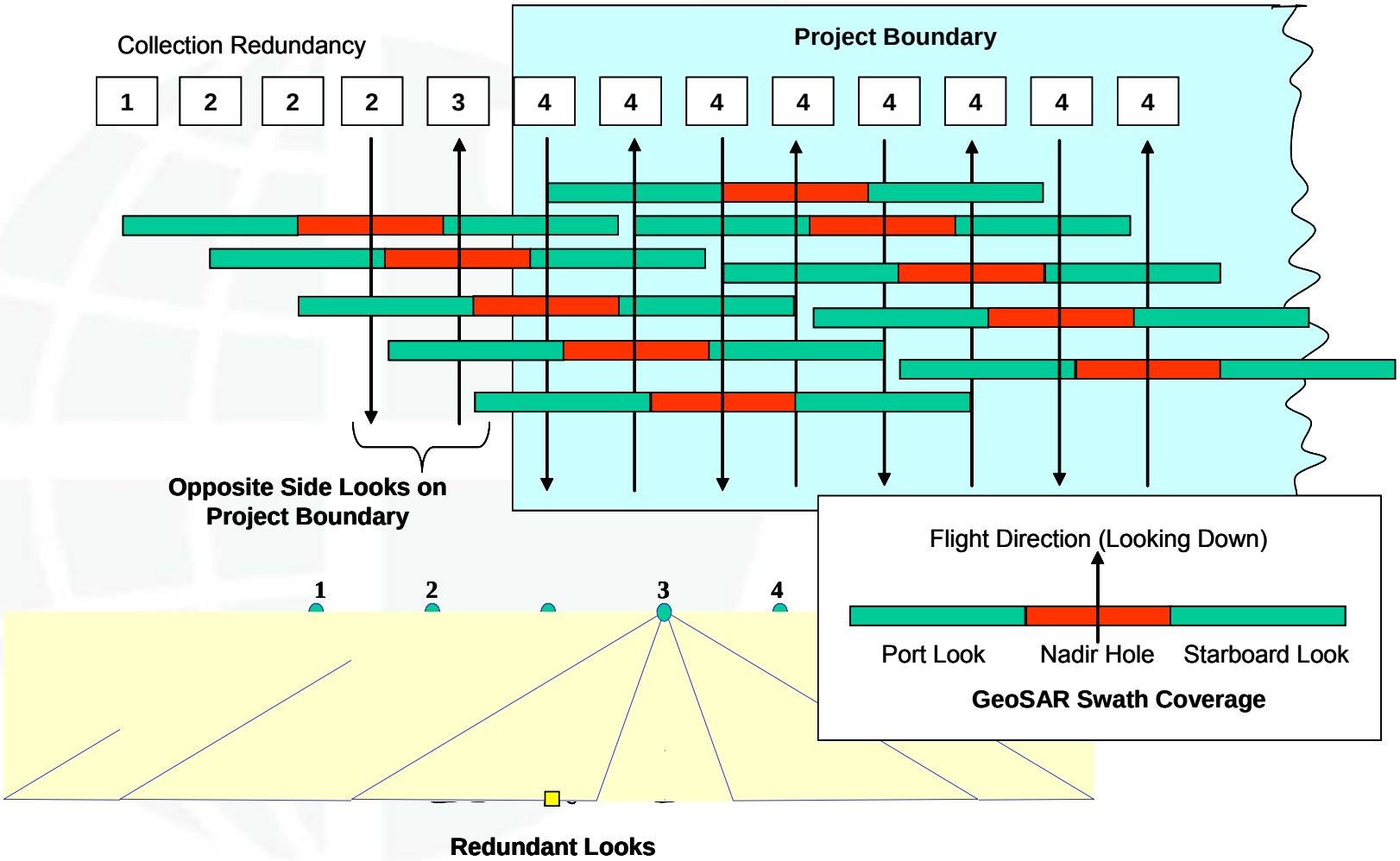
UR_Line61_zoom.tif

EARTHDATA TECHNOLOGIES



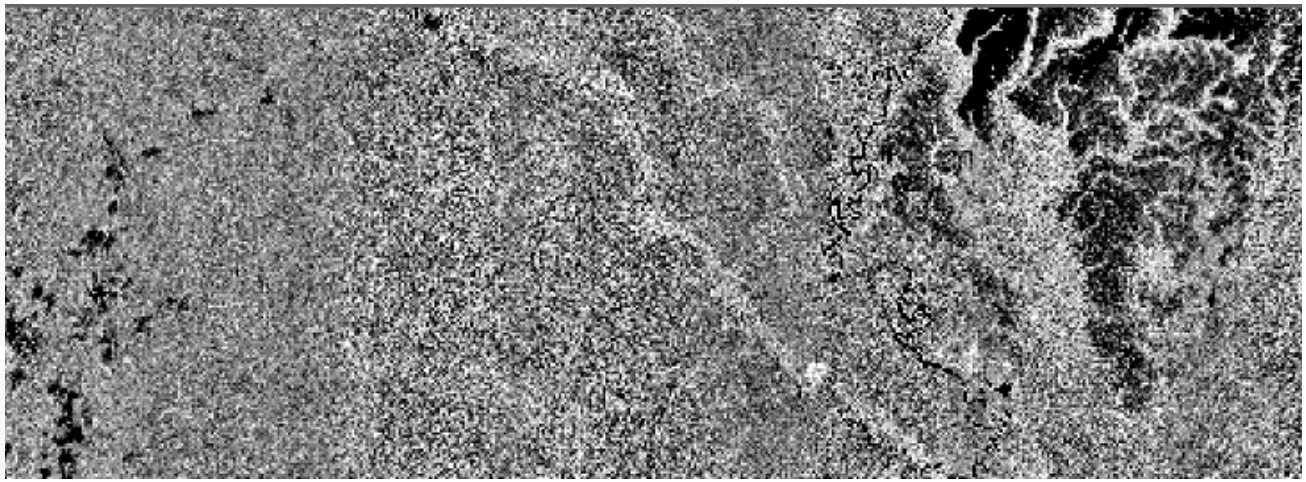
GeoSAR Collection and Processing Methodology

GeoSAR Redundant Collection Methodology



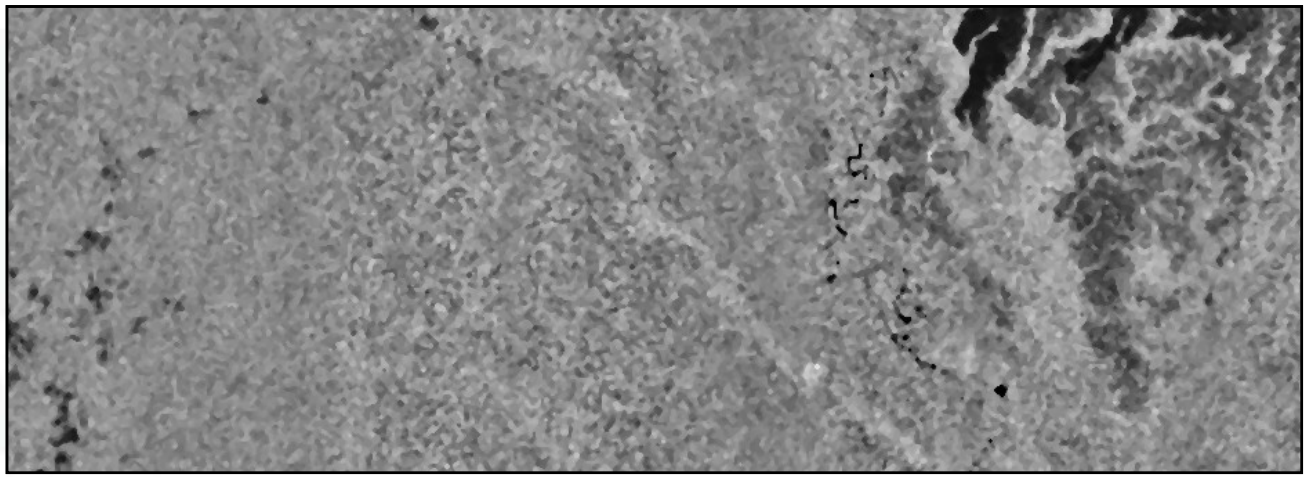
Example of Textural Banding in Nexus Data

Unfiltered



Spatial Filter

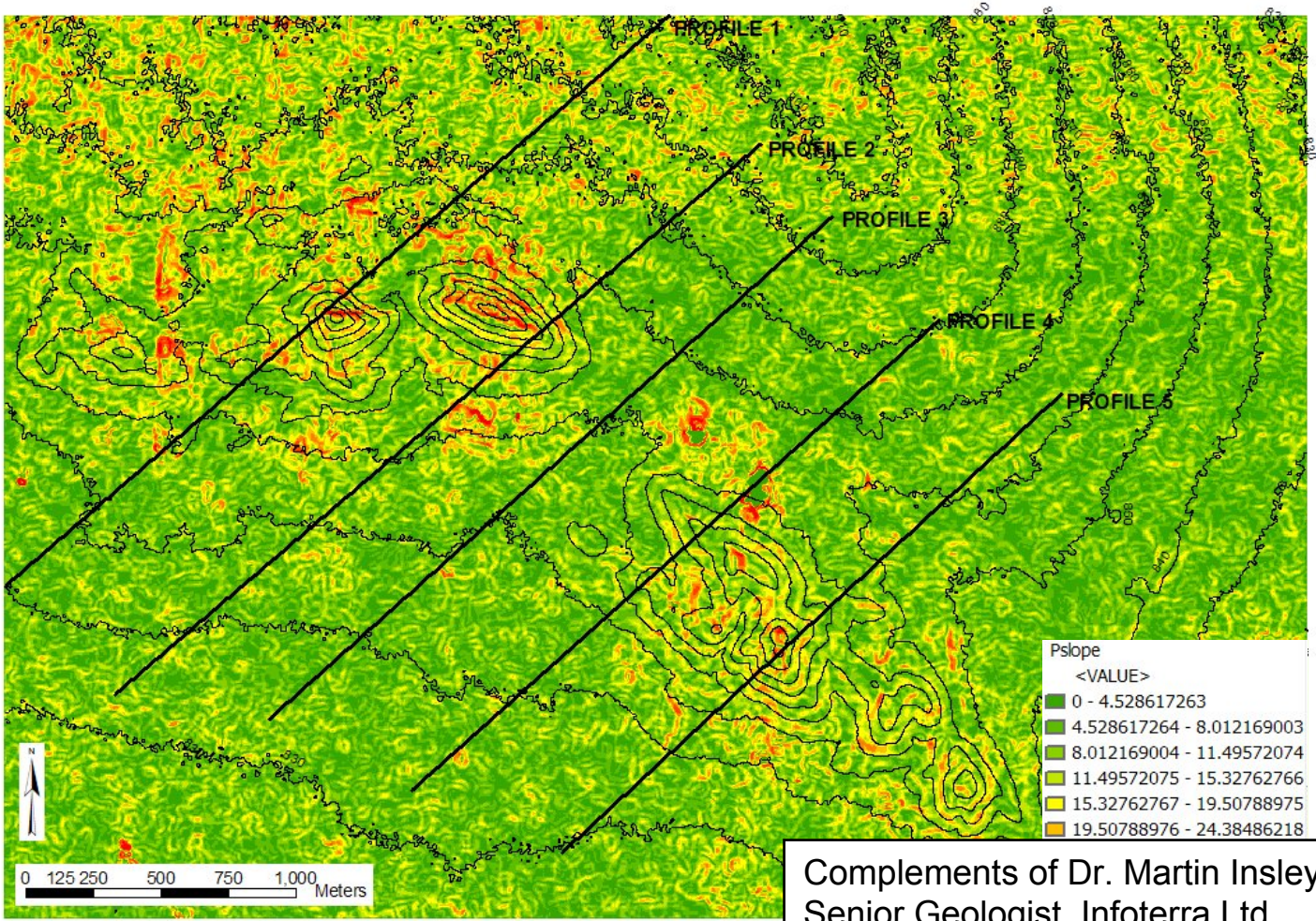
Filtered



P Band Slope Map

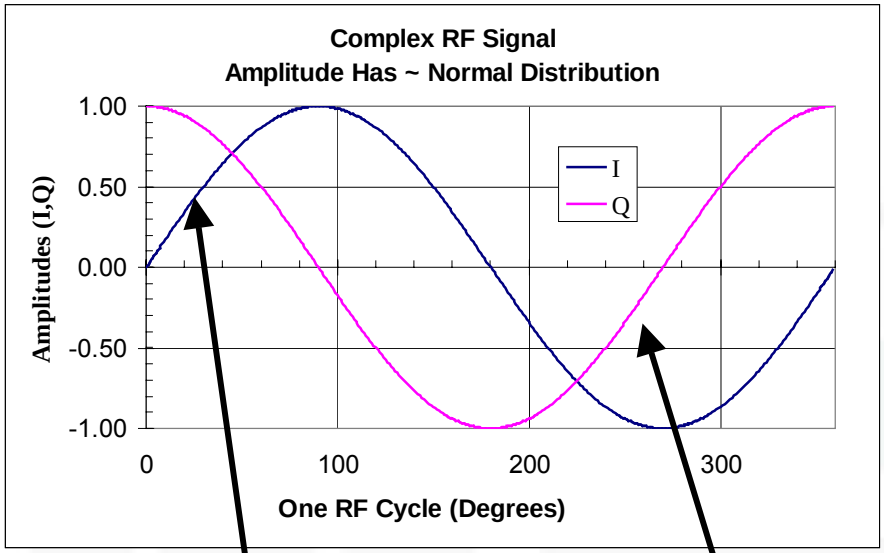
Single-Look DEM

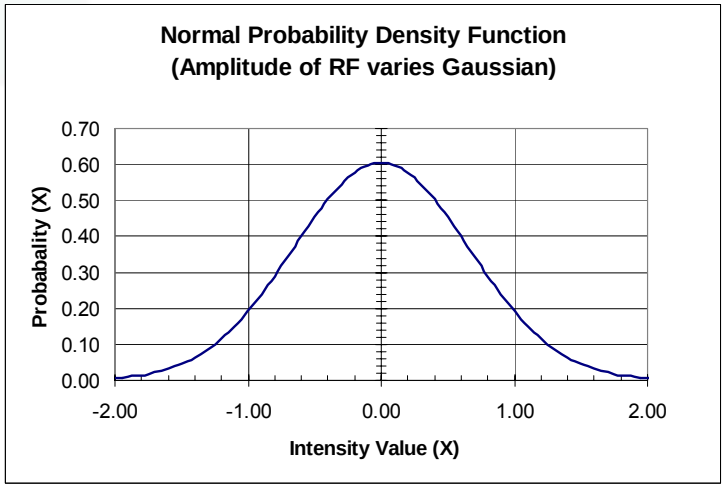
Two-Look DEM



Complements of Dr. Martin Insley, Senior Geologist, Infoterra Ltd.
(Used with Permission)

Radar Intensity Data





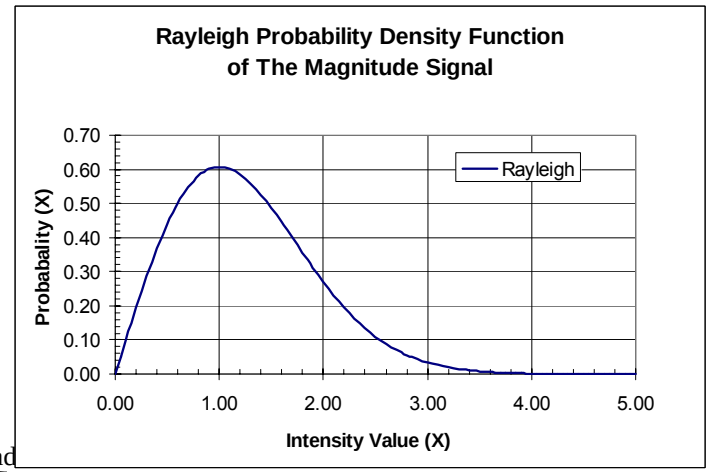
Real Channel "I"

Quadrature Channel ("Q")

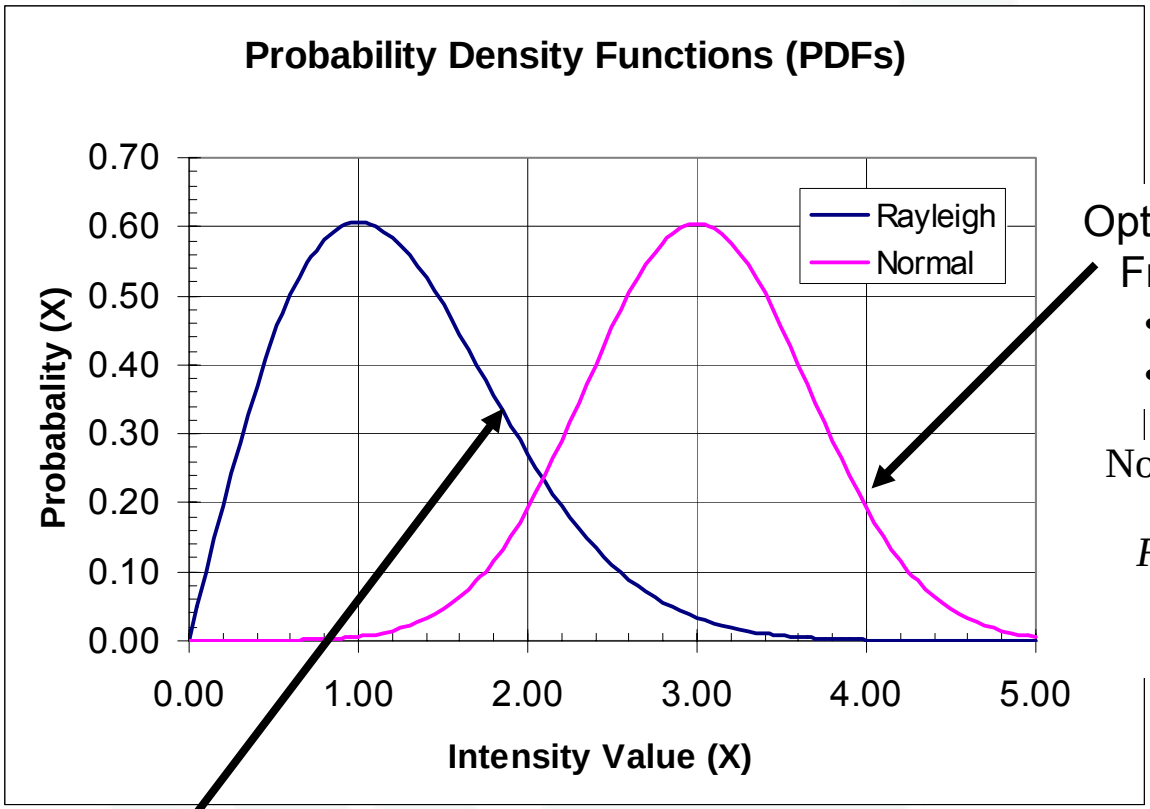
$|\Sigma|$

Magnitude

$$\sqrt{I^2 + Q^2}$$



Comparison of Intensity Distributions



Optical Imagery has 2 Degrees of Freedom:

- Gain (Standard Deviation, σ)
- Brightness (Mean, μ)

Normal Distribution (Optical):

$$F(x) = \frac{1}{\sigma\sqrt{2\pi}} \exp\left\{-\left(x-\mu\right)^2 / 2\sigma^2\right\},$$

μ=3.0 and σ=0.66

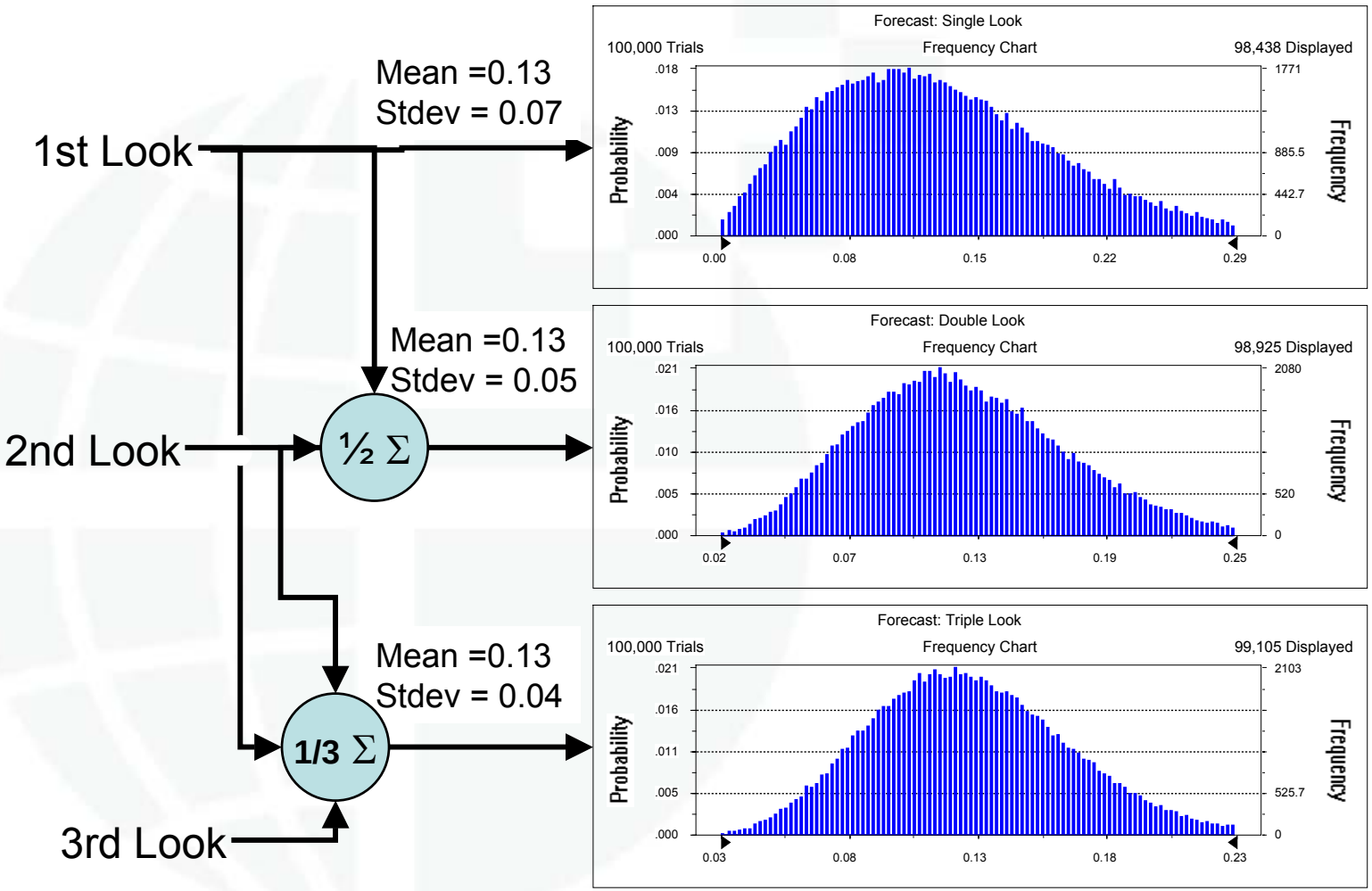
Radar Imagery has 1 Degree of Freedom:

- Scaling Parameter, β

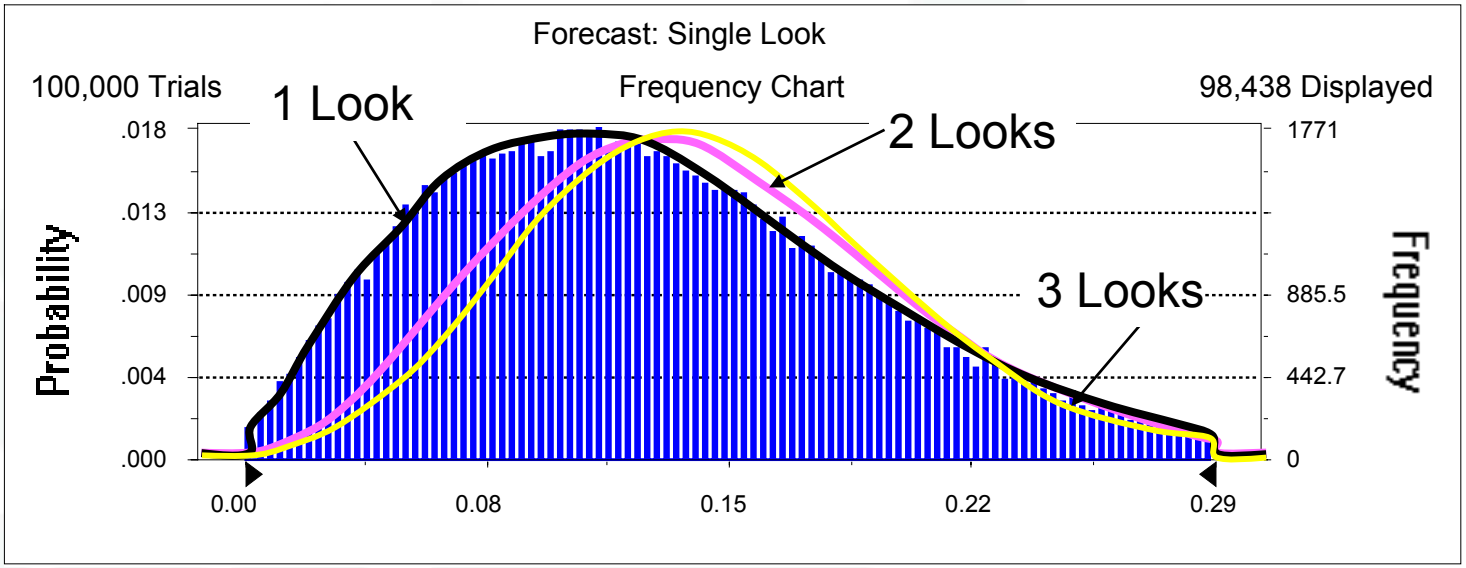
Rayleigh Distribution (Radar):

$$F(x) = \frac{x}{\beta^2} \exp\left(-x^2 / 2\beta^2\right), \ \beta=1.0$$

Affects of Additional Looks



Histogram Comparisons



- As The Number Of Looks Increase, The Histogram Takes On A Decidedly More Gaussian Shape
- The Greatest Change Occurs from 1 to 2 Looks
- 3 Or More Looks Have Minimal Affect On Output Texture

Signal Processing Issues

- In general for radar imagery, removal of textural banding in the mosaic process by gain adjustments also leads to a contrast differential (and vice versa), which in turn causes brightness banding
- One solution is to filter the data spatially *prior* to mosaicking so the amplitude statistics for adjacent regions are (more or less) identical. This, however, will show up as a loss of spatial detail in the filtered areas
- EarthData *does not* spatially filter its radar products, preferring instead to deliver to the client products with *full spatial resolution* over products with cosmetic improvements in viewing quality

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Questions?