# Agricultural Terrain Analysis Using Remote Sensing Derived Elevations

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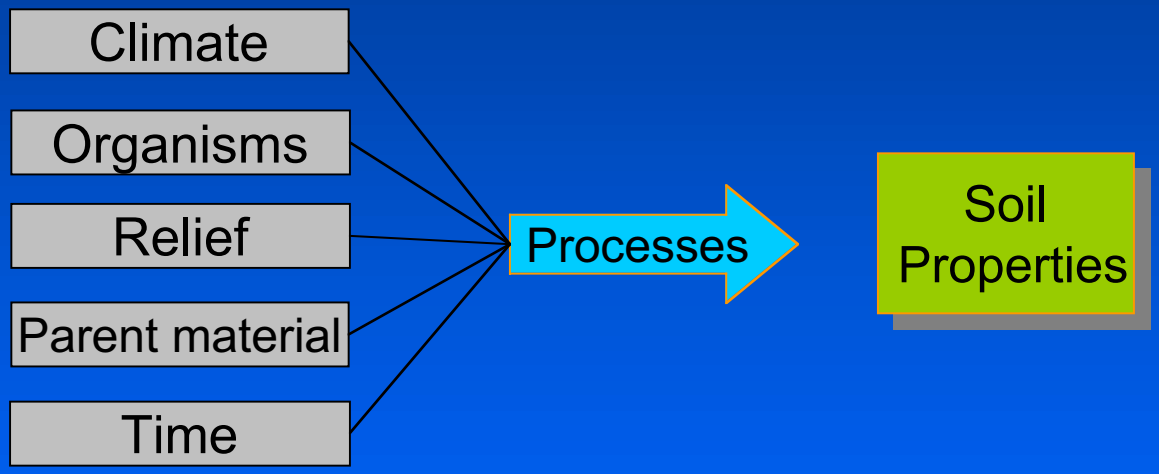
# The Role of Topography

- Links many agricultural and environmental variables
- Influence of topography in the variability
  e.g. yield variability, areas sensitive to weather conditions
- Spatial data to identify and quantify the variability
  e.g. support of soil delineations, determination of crop management zones
- Land Characterization for Hydrologic Modeling

# Soils and Topography

***Jenny (1941) 'Factors of Soil Formation'***

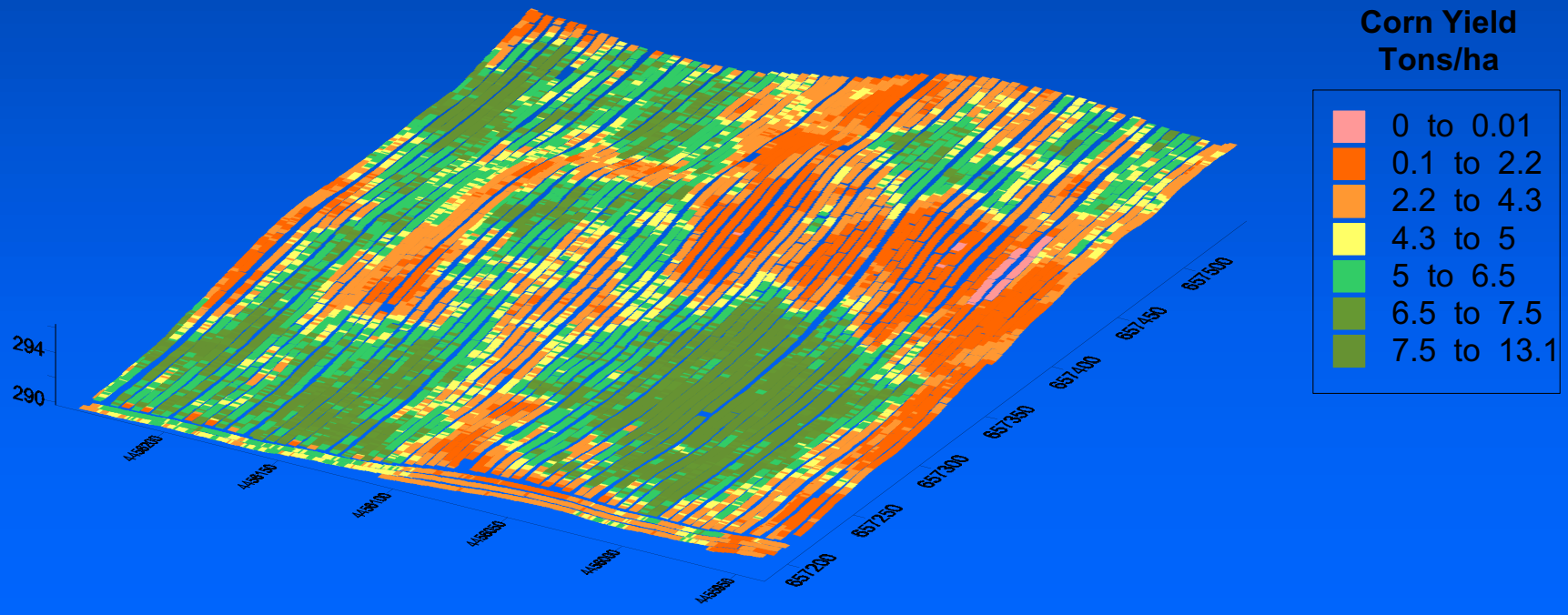
$s = f(cl, o, r, p, t, .....)$




- Linkage of soil attributes and landscape position

# Topography for Site-Specific-Farming

- Need of superior spatial resolution and accuracy
- Topography is a one-time acquisition



# Improvement of Remote Sensing Resolutions

- New technologies
- Direct observations of surface topography

1. Spatial Resolution

   meter / few meters

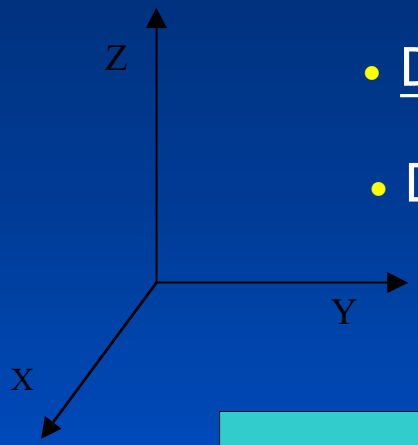
2. Vertical Accuracy

   centimeters

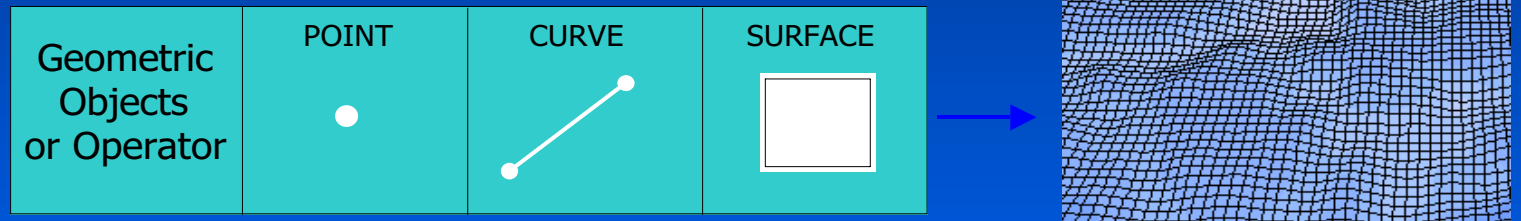
3. Radiometric Resolution

   8 bit system: 256 shades of gray
   32 bit system: millions shades of gray

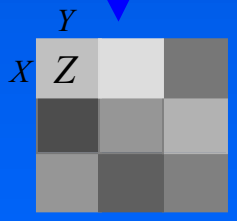
# What is a DEM?



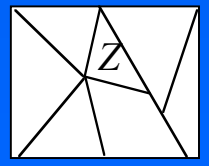

- Digital Elevation Model = DEM / DEMs
- Digital elevation: 3-D location (X,Y,Z)








Grid

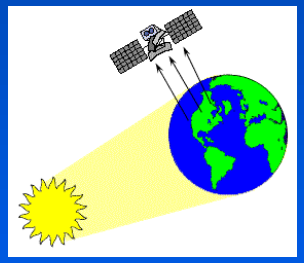



Triangulated Irregular Network

# Sources of Digital Elevation Data

- Building up a classification

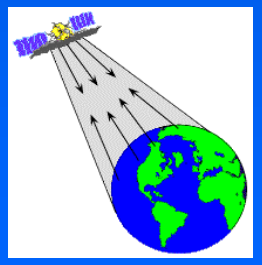
| Data Collection | Sensor | Vertical Accuracy |
|---|---|---|
| **Ground Surveying:** | *Geodesic GPS / Laser Beacon* | 2 cm / 15 cm |
| **Photogrammetric methods:** | *USGS DEMs* | 7 – 15 m |
| **Remote Sensing derived DEMs:** | | |



**Passive Optical Systems**

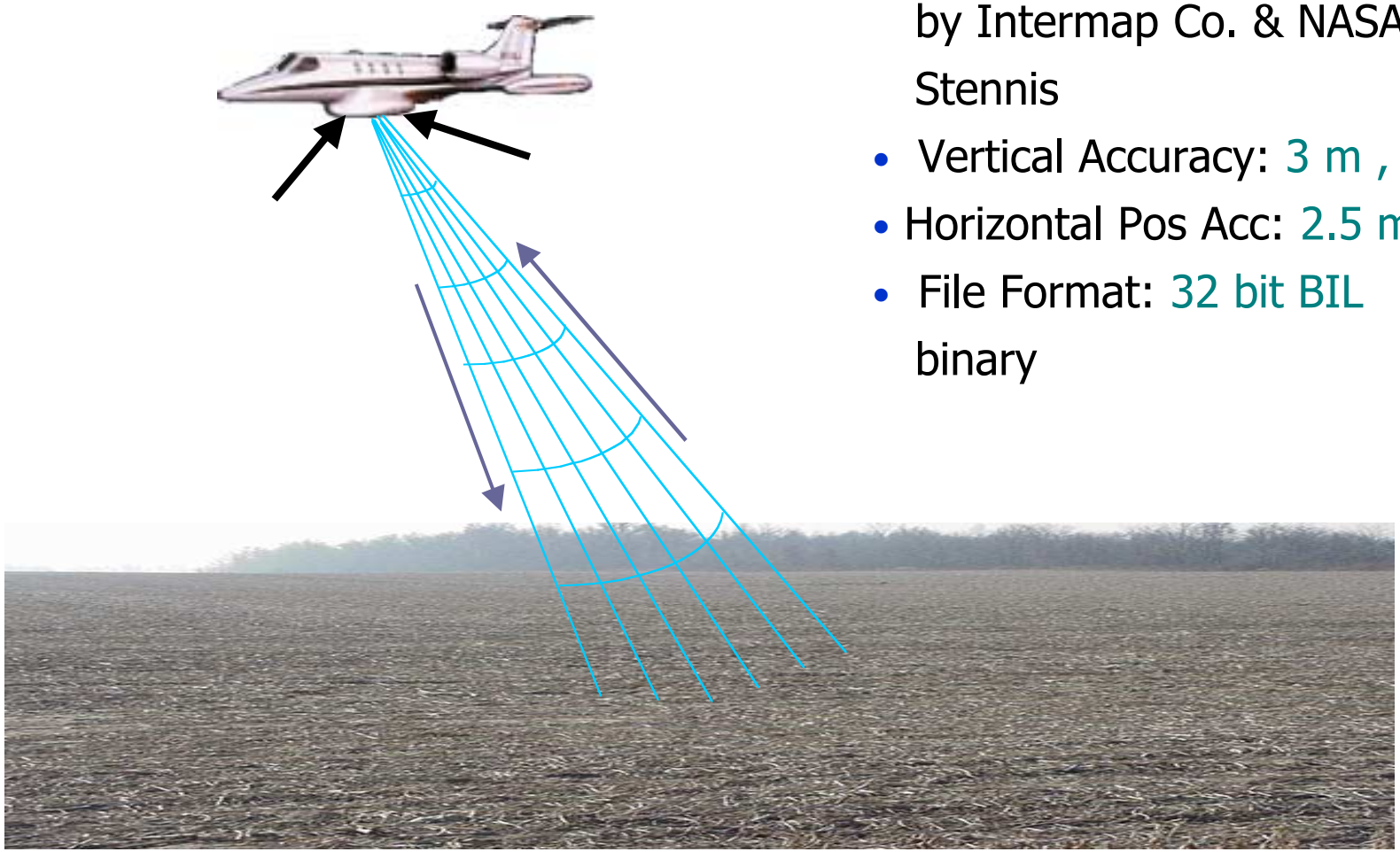
| | | |
|---|---|---|
| • Stereo Aerial photography | *Orhtophotography* | 0.5 – 2.5 m |
| • Satellite stereoscopy | *Spot, ASTER,etc* | 20 – 50 m |

**Active Microwave Systems**



| | | |
|---|---|---|
| • Radar Systems | | |
| 1. Radar Stereo | *Radarsat* | 5 – 50 m |
| 2. Interferometry | | |
| Two-passes interferometry | *ERS-1* | |
| Single-pass IFSAR | *TOPSAR, STAR3i* | 0.5, 1, 3, 5 m |
| • Airborne Laser: LIDAR | *Lasescanners* | 0.3 – 1 m |

# IFSAR: Interferometric Synthetic Aperture Radar



- November 13, 1999 (night) by Intermap Co. & NASA Stennis
- Vertical Accuracy: 3 m , 1 m
- Horizontal Pos Acc: 2.5 m
- File Format: 32 bit BIL binary

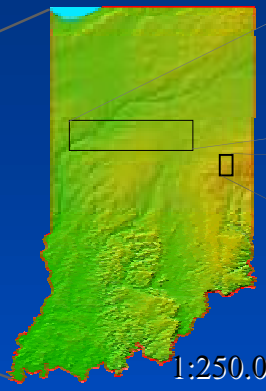
## Main Objective

Provide a comprehensive evaluation of Digital Elevation Models with emphasis on IFSAR technology for terrain analysis at field level and land characterization for hydrologic modeling.

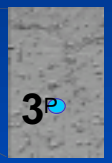
## Particular Objectives

- Analysis of main properties
- Establish a framework of required pre-processing
- Generation of primary topographic attributes, hydrologic analysis and spatial representations
- Landforms and soils characterization

# Location

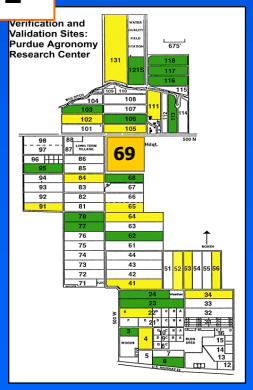

GT3 acquisition: 3000 km²


GT1 acq.: 70 km²

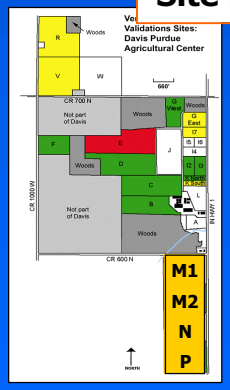
**Verification and Validation Site**
**NASA & Purdue V&V**

**Site 1**




Agronomy Research Center (ARC)

**Site 2**

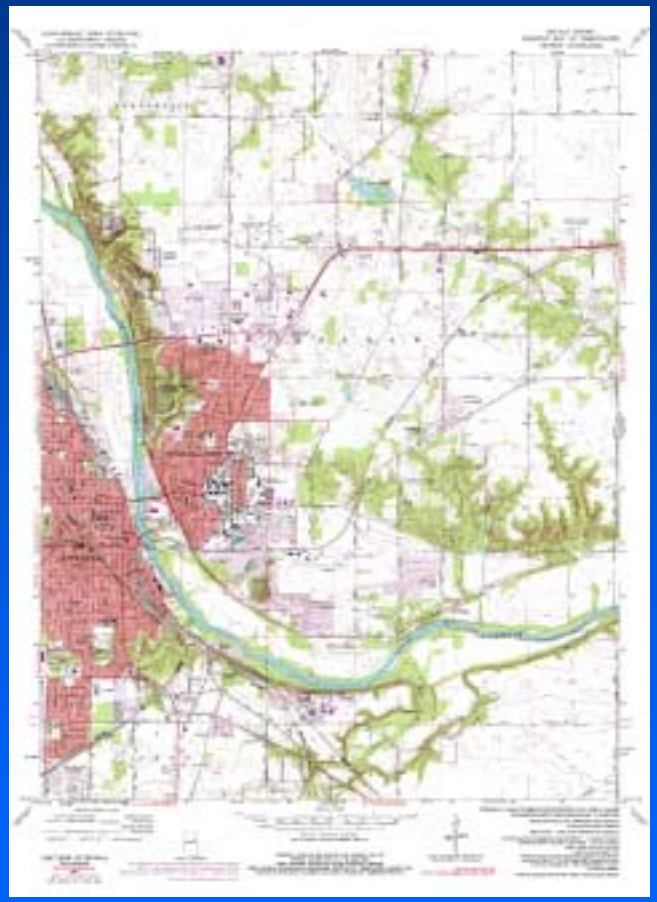



Davis-Purdue Ag Center (DPAC)

**Site 3**

# Analysis of the IFSAR DEM

**Lafayette West - 7.5 Minute Quadrangle**

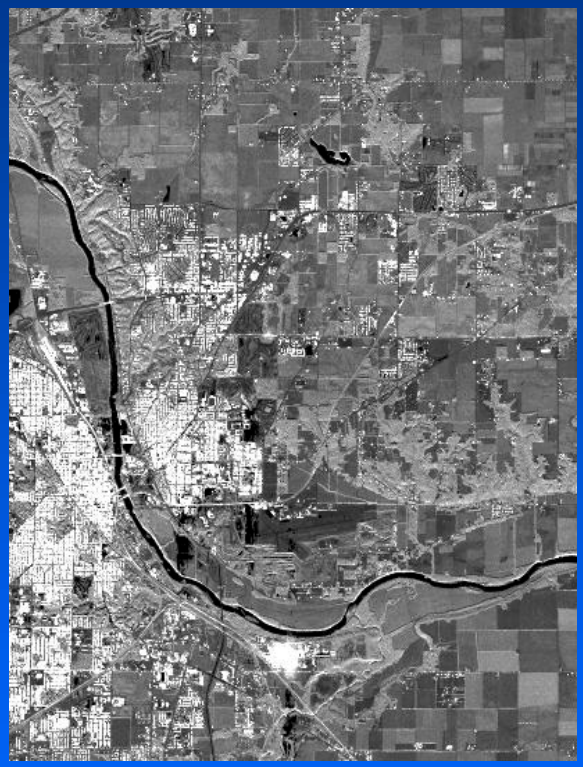


**Digital Elevation Model DEM**

higher elevation value

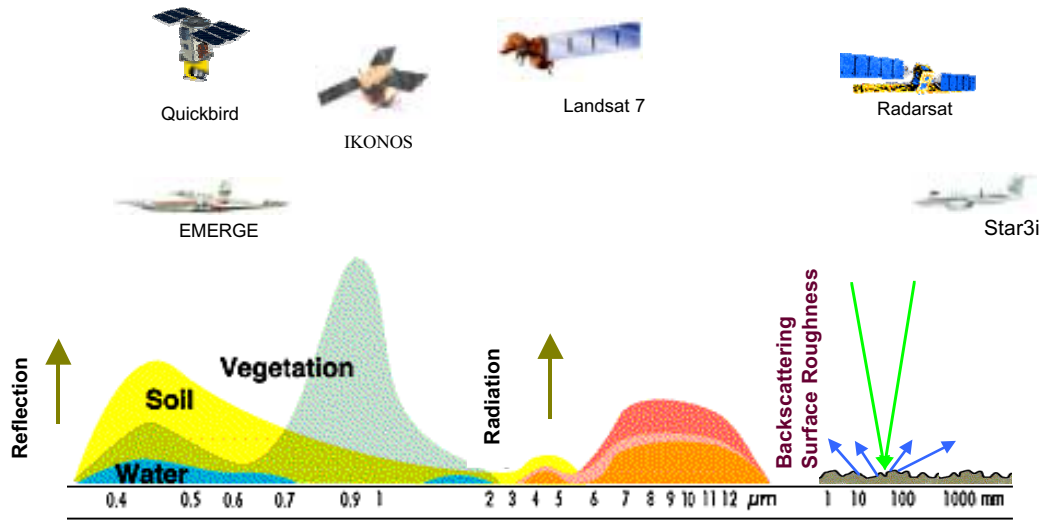
lower elevation value

**Orthorectified Radar Image - ORI**



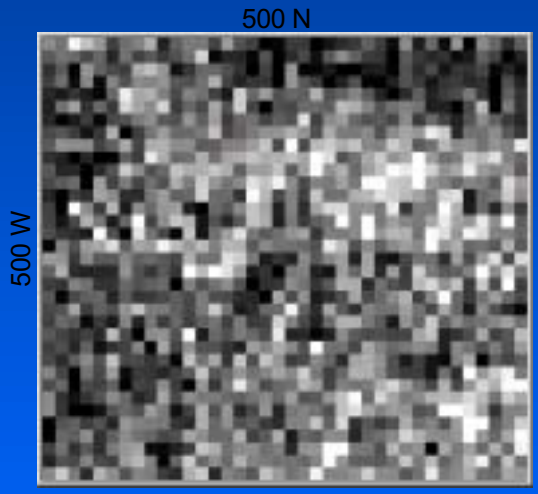
# Main Properties of IFSAR

## Where in the Electromagnetic Spectrum?




- Band X : 2.5 – 3.7 cm

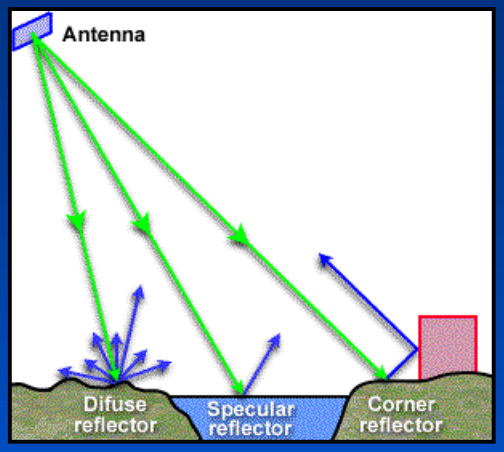
## Which Radar Artifacts?



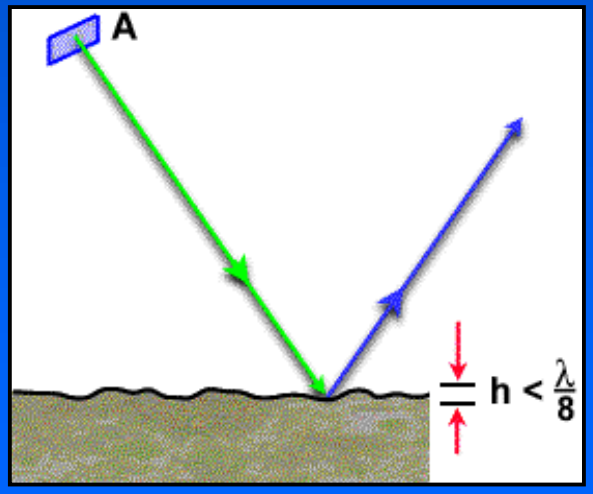

Zoom at ARC Field 69

- Speckle noise

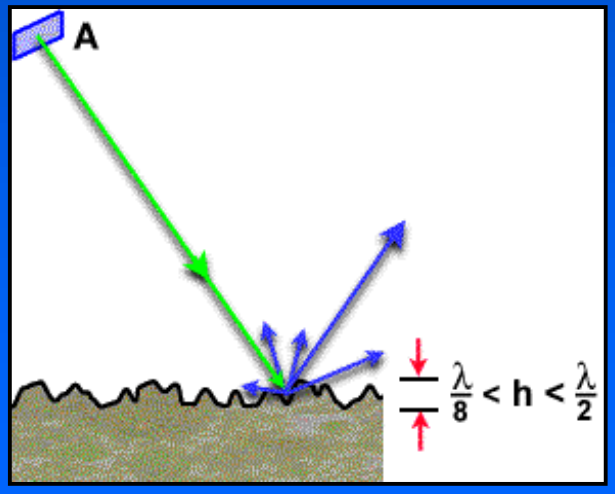
# Understanding Properties of SAR Data



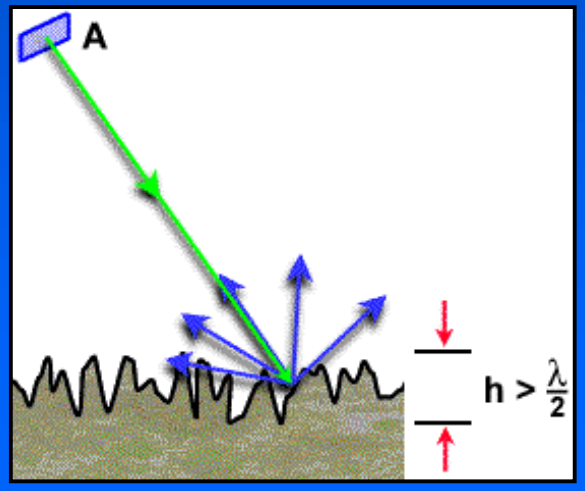

Smooth surface; specular reflection; no return.




Intermediate roughness; mixed scatter; moderate return



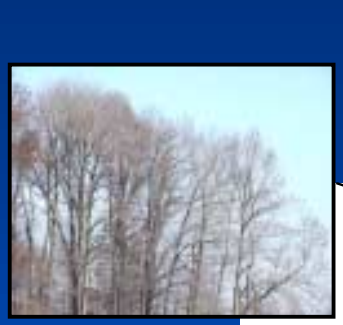

Rough surface; diffuse scatter; strong return




*where A = antenna; h = height variations of surface; λ radar wavelength.*

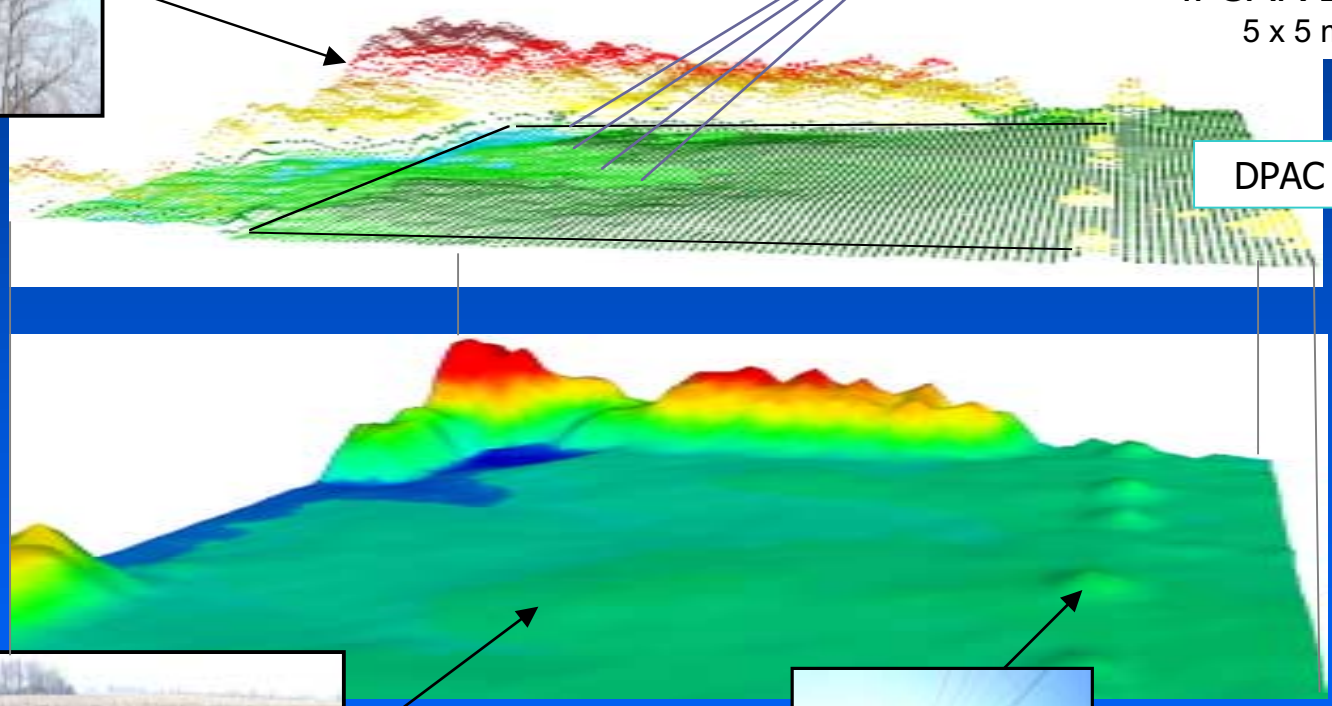
- CCRS: radar

# Elevation / Vegetation Relationship



IFSAR DEM (GT1)
5 x 5 m postings

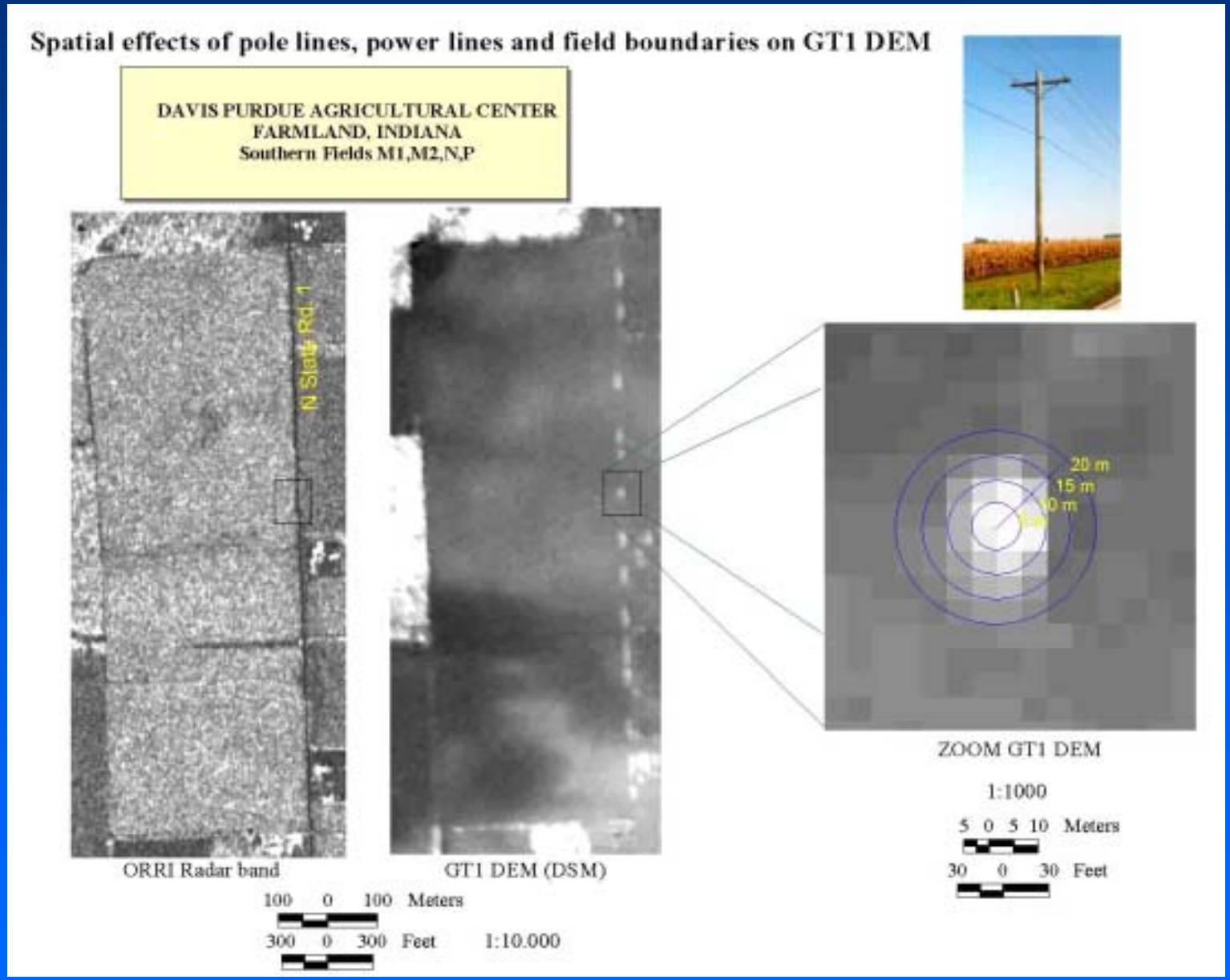
DPAC Field M1



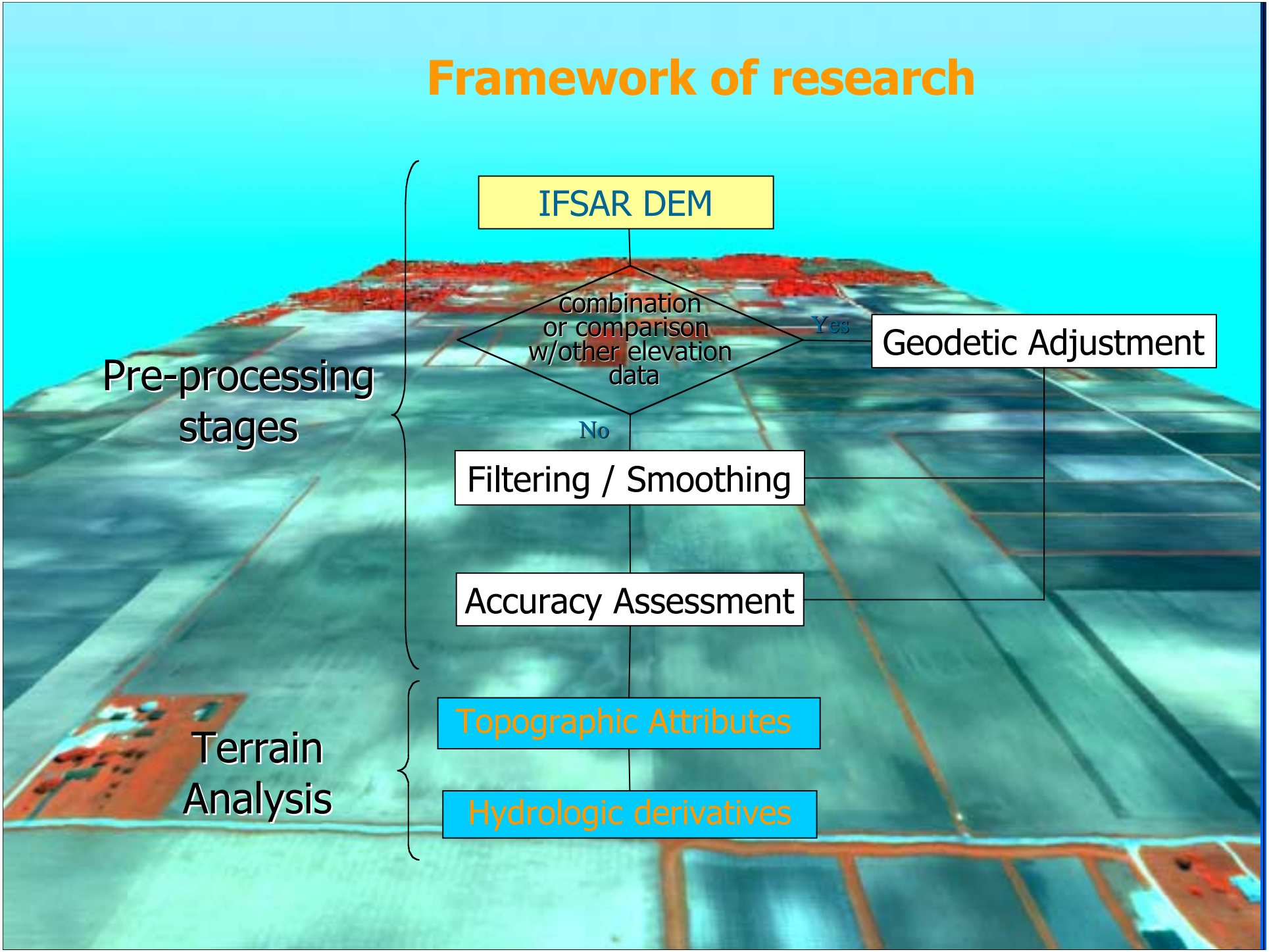
High

Low

# Elevation / Manmade Features Relationship



# Framework of research

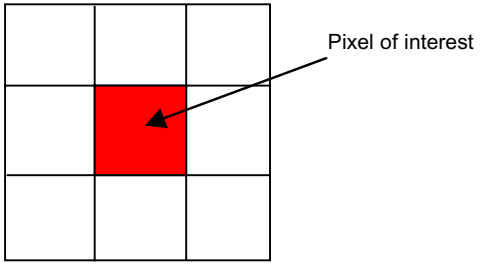


# Filtering & Smoothing

Pre-processing Stages
Geodetic Adjustments
Filtering and Smoothing

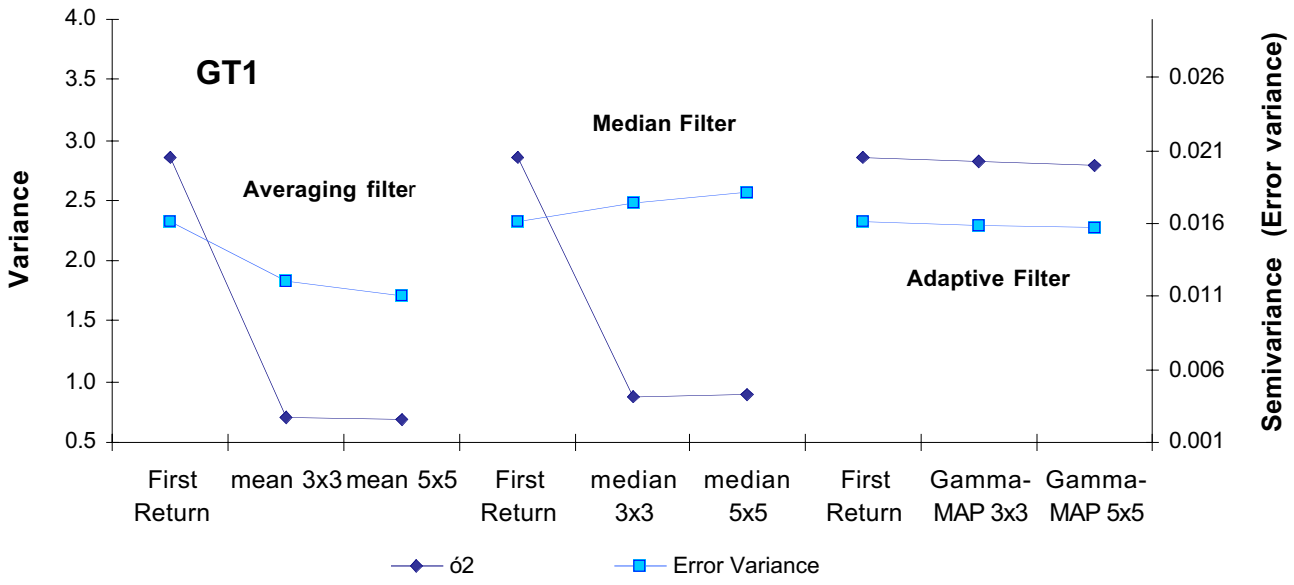
1. What type of filter?

- spatial domain methods




- Averaging Filters (mean, low pass)
- Ranking Filters (median)
- Adaptive Filters: (e.g. Gamma MAP)

$C.of\,V. \Rightarrow \frac{\sqrt{\text{var}\,iance}}{mean}$



# Filtering & Smoothing

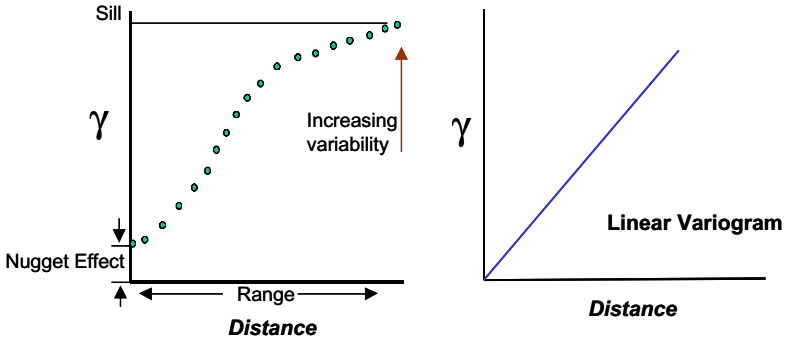
Pre-processing Stages

Geodetic Adjustments

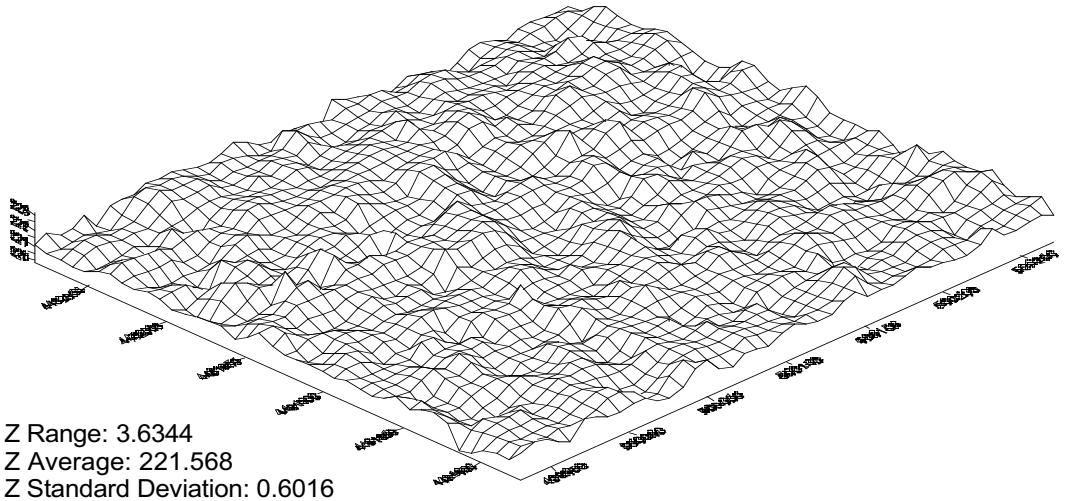
Filtering and Smoothing

## 2. Amount of noise and smoothness

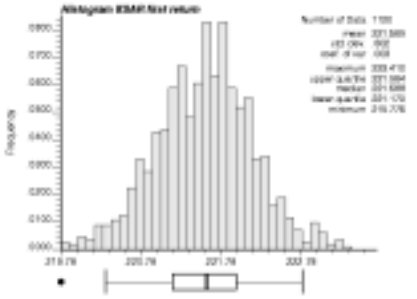
- Visual analysis of surfaces
- Descriptive statistics
- Spatial structure

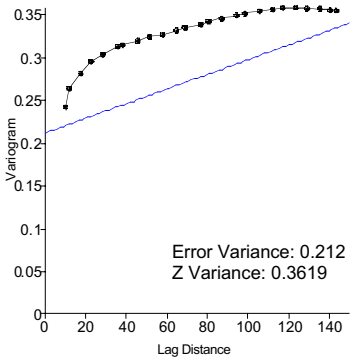



### Raw (First Return)



Z Range: 3.6344
Z Average: 221.568
Z Standard Deviation: 0.6016





# Filtering & Smoothing

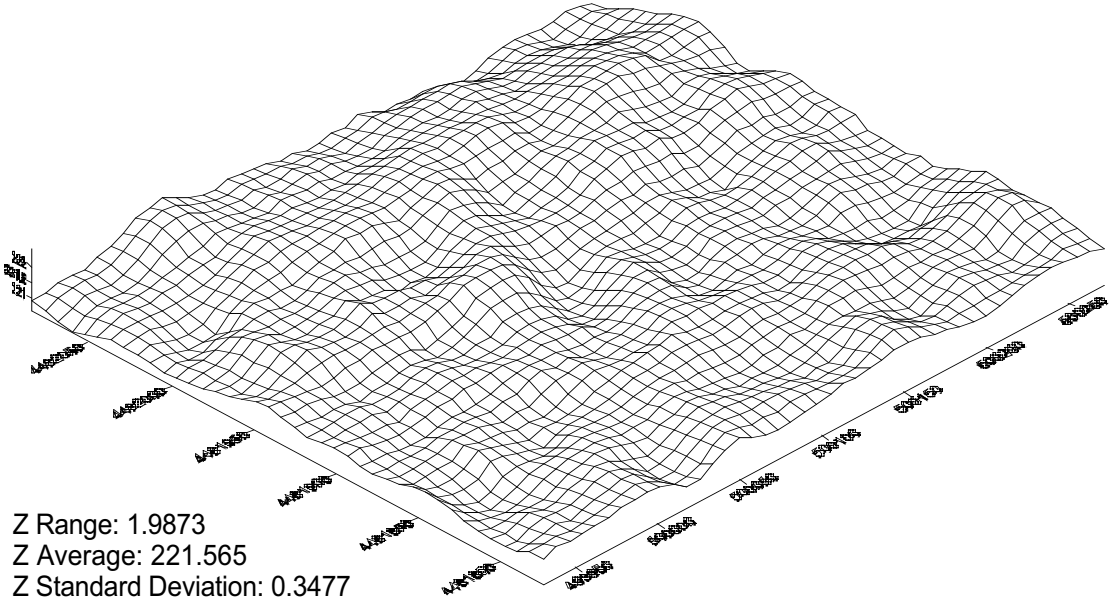
Pre-processing Stages

Geodetic Adjustments

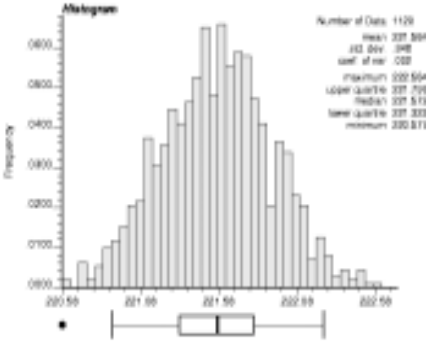
▼

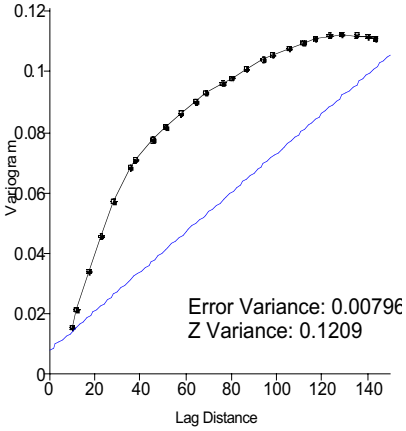
Filtering and Smoothing

Gamma MAP: 3 x 3



Z Range: 1.9873
Z Average: 221.565
Z Standard Deviation: 0.3477





Pre-processing Stages

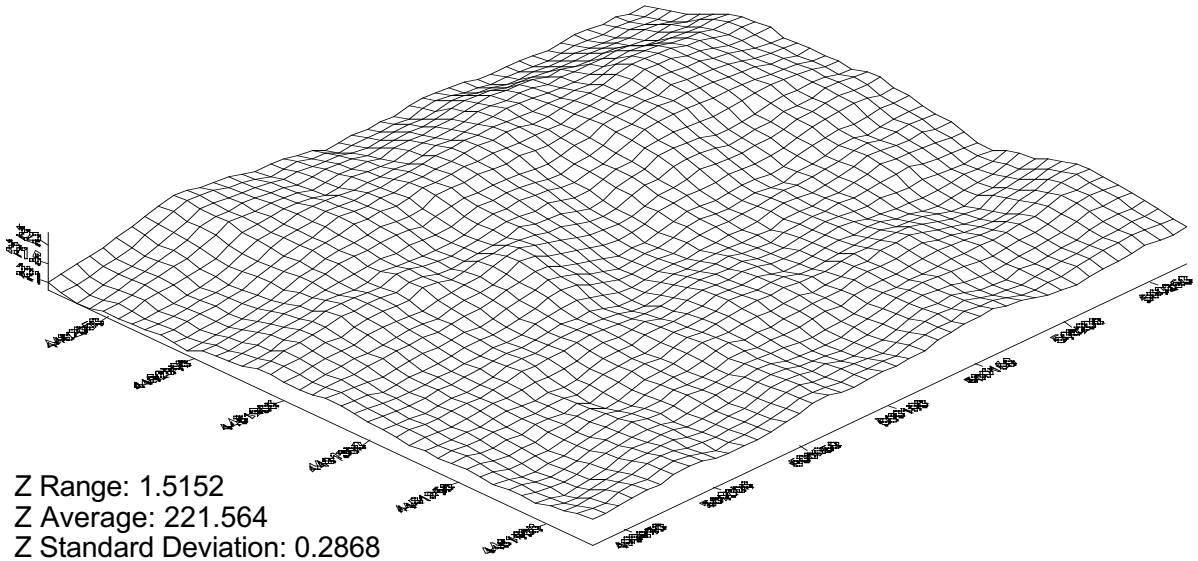
Geodetic Adjustments

▼

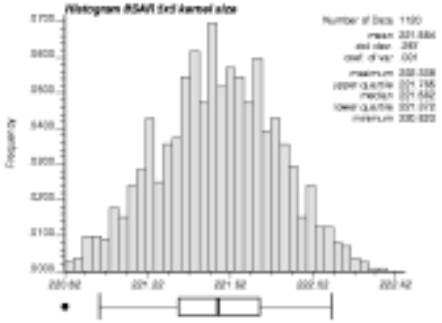
Filtering and Smoothing

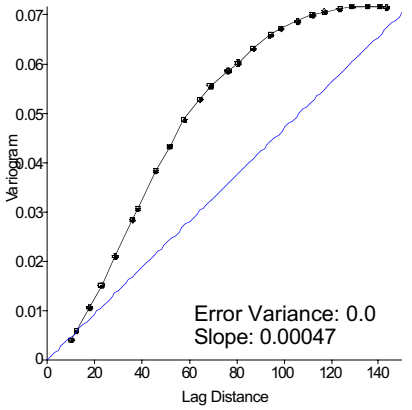
# Filtering & Smoothing

## Gamma MAP: 5 x 5



Z Range: 1.5152
Z Average: 221.564
Z Standard Deviation: 0.2868





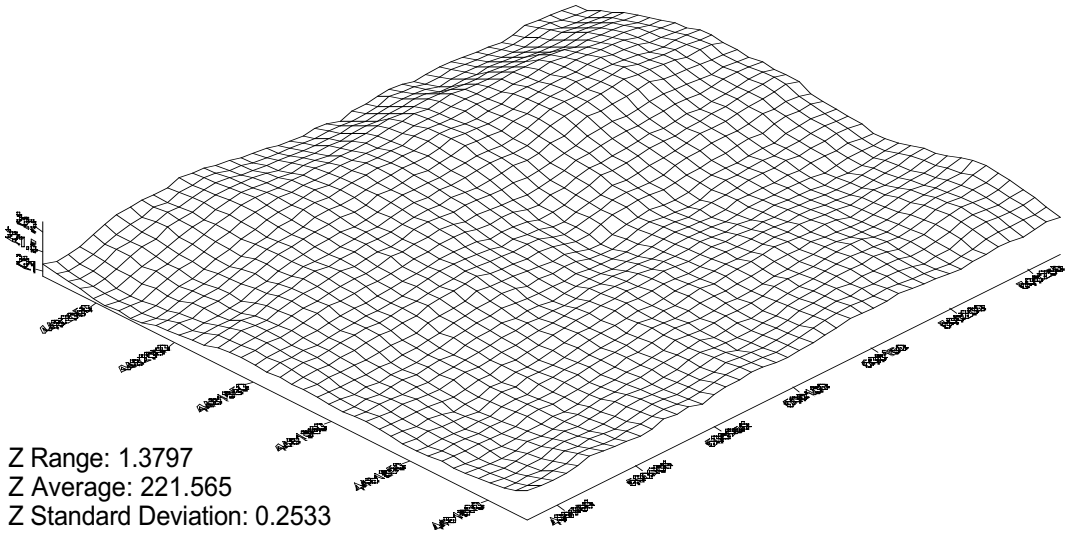
# Filtering & Smoothing

Pre-processing Stages

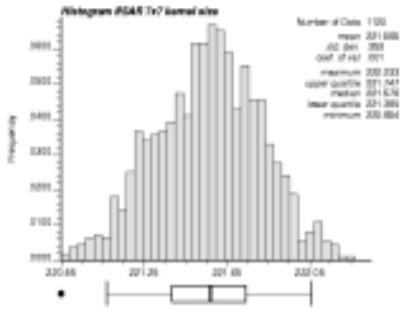
Geodetic Adjustments

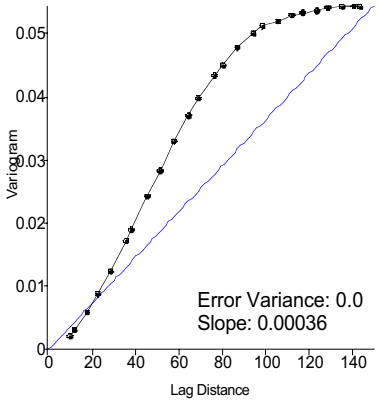
Filtering and Smoothing

## Gamma MAP 7x7



Z Range: 1.3797
Z Average: 221.565
Z Standard Deviation: 0.2533





Pre-processing Stages

Geodetic Adjustments

Accuracy Assessment

# Accuracy Assessment

- Testing vertical accuracy - **bald-Earth**
- Small errors in height lead to large errors in derivatives
- Assessment of Quality: **Accuracy**, Precision, Consistency and Completeness

Root-mean-square criteria

$$RMSE = \sqrt{\frac{\sum (z_{data\ i} - z_{check\ j})^2}{n}}$$

- Two independent, reliable and higher accurate sources of elevation:

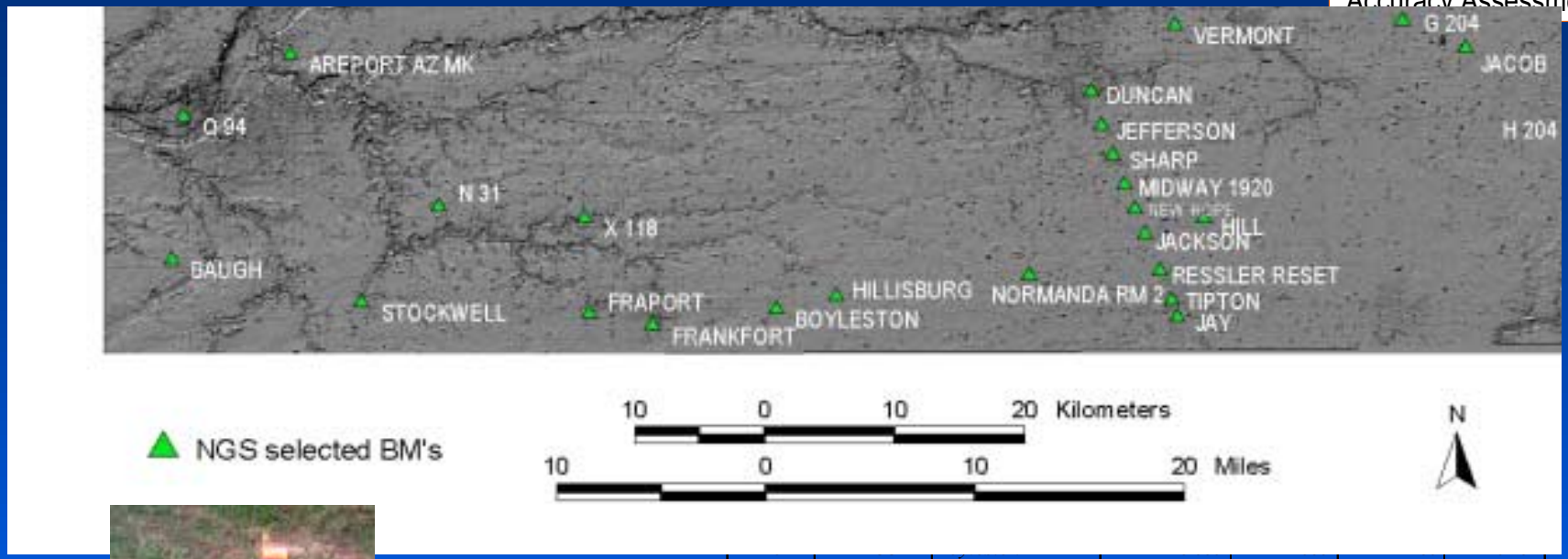
1. National Geodetic Survey – NGS NOAA ( 2 cm )
2. Ground laser Leveling – DGPS ( 15 cm )

# NGS vs. GT3

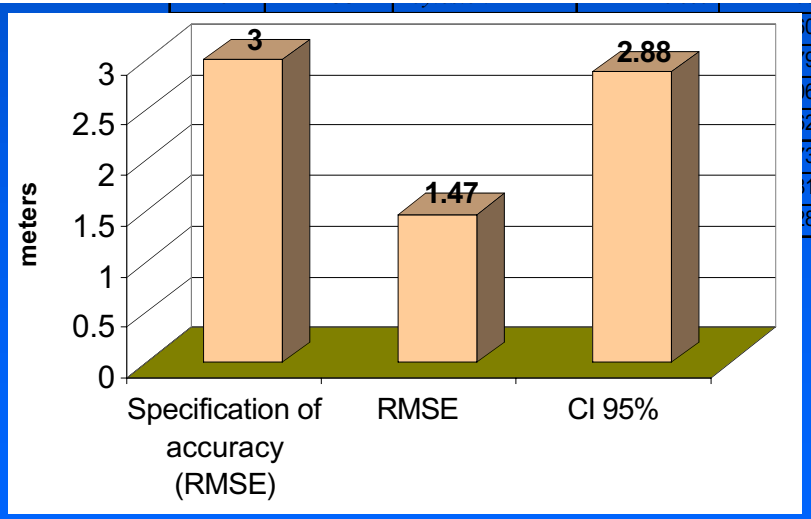
Pre-processing Stages

Geodetic Adjustments

Accuracy Assessment




NGS HARN Q94



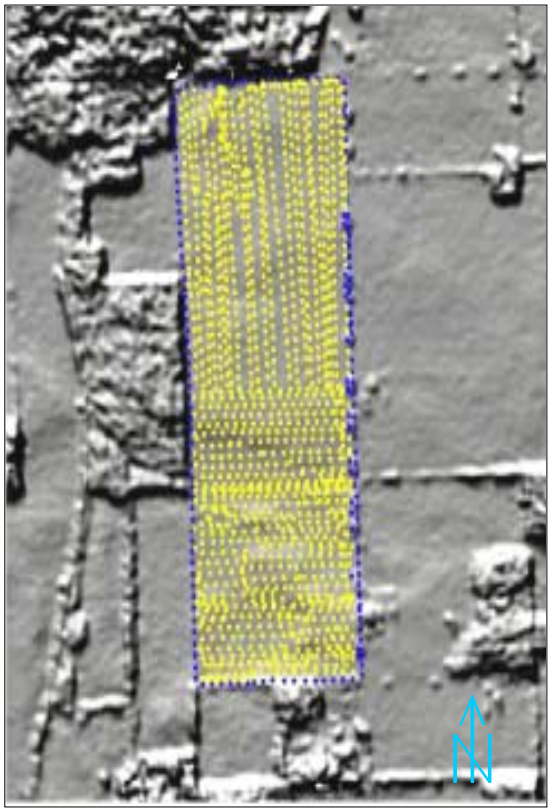

| | | |
|---|---|---|
| | 1.299 | 1.688 |
| | 0.855 | 0.730 |
| | -0.482 | 0.232 |
| | -0.277 | 0.077 |
| | -0.110 | 0.012 |
| | -0.192 | 0.037 |
| | 1.336 | 1.784 |
| | SUM | 49.806 |
| | AVE | 2.165 |
| | **RMSE** | **1.472** |
| | **95% CI** | **2.884** |

Vertical Accuracy

# DEM GT1 vs Laser leveling

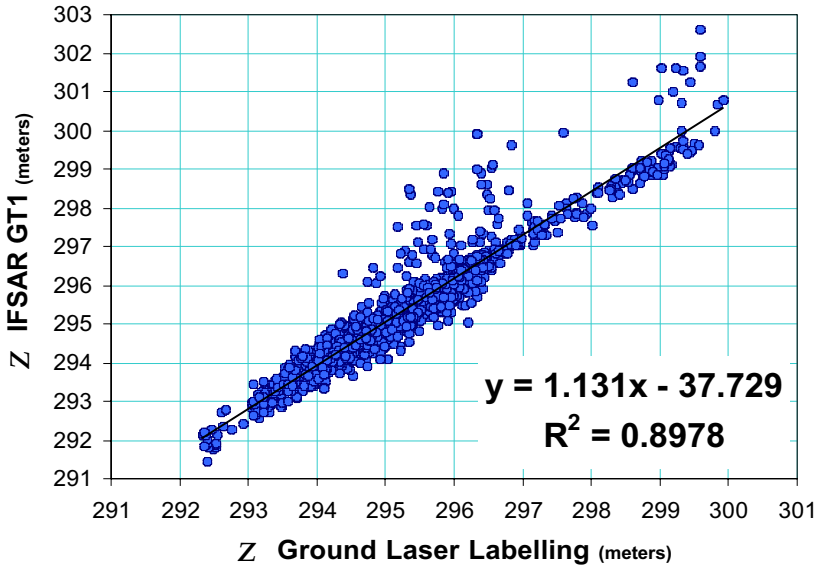
Pre-processing Stages
Geodetic Adjustments
Accuracy Assessment

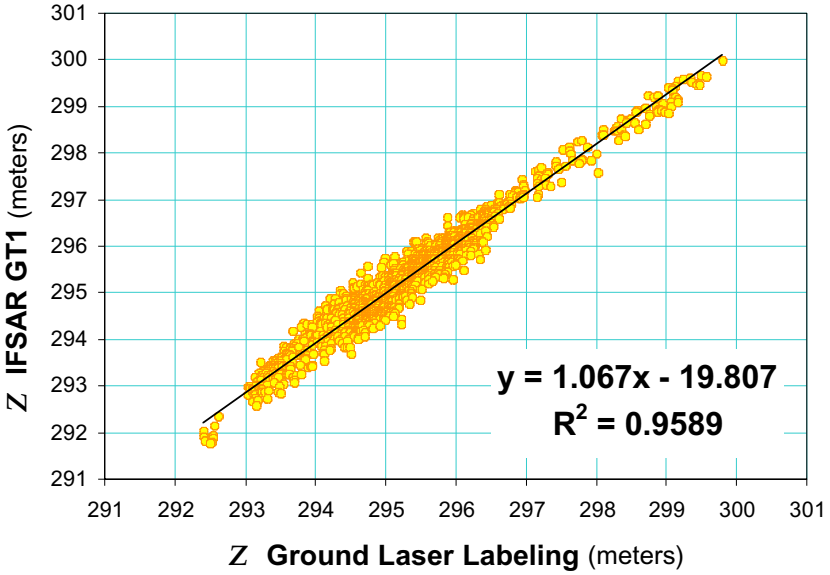
**Shaded Relief GT1**
Southern Fields Davis Farm
with laser data point overlay



● and ● 1531 data points, include field borders, electric line ( 48 ha ~ 116 acres)

● 1335 data points included in analysis
(44.5 ha ~ 109 acres)



# DEM GT1 vs Laser Leveling

Pre-processing Stages

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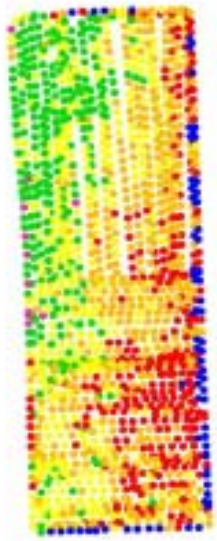
Accuracy Assessment

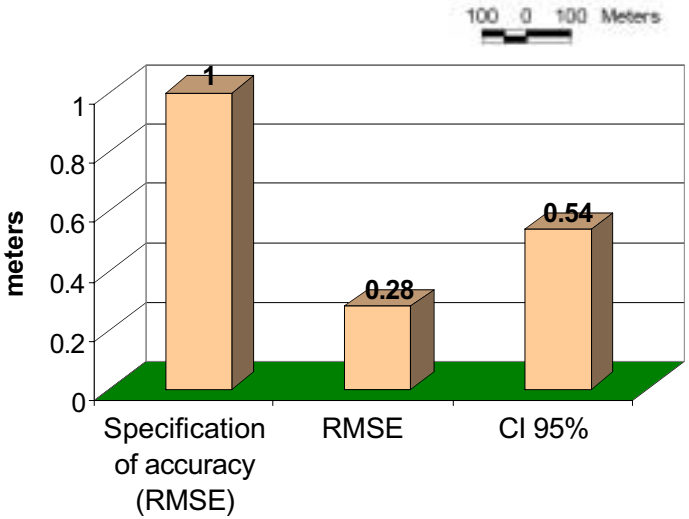
IfSAR GT1 Digital Surface Model



Height diference (m)

-0.41 - 0
0 - 0.5
0.5 - 0.75
0.75 - 1
1 - 1.5
1.5 - 4.35

Survey postings "set up"


**Vertical Accuracy**

- Surface residue of different crop: No significant differences in mean
- The high $r^2$ value indicates a good confidence in the assessment

# GT3 DEM Extremely Flat Topography

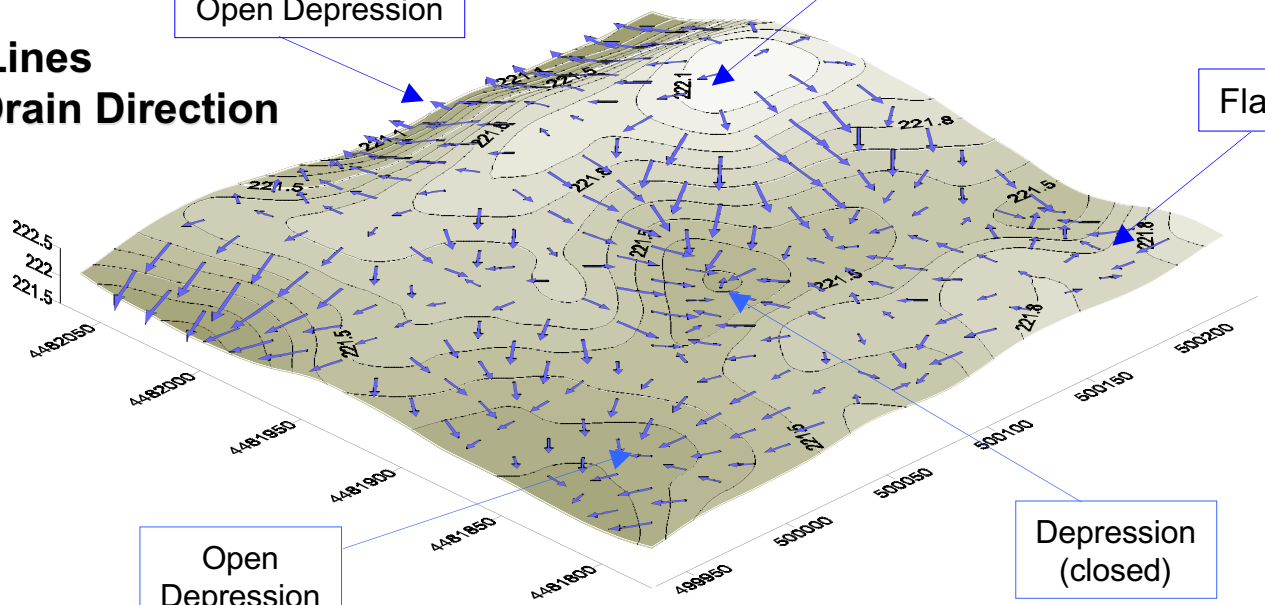
## ARC: Field 69 : 16 Ha (39 acres)

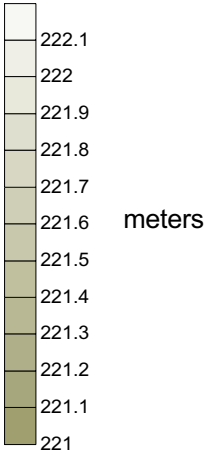
Pre-processing Stages

Terrain Analysis

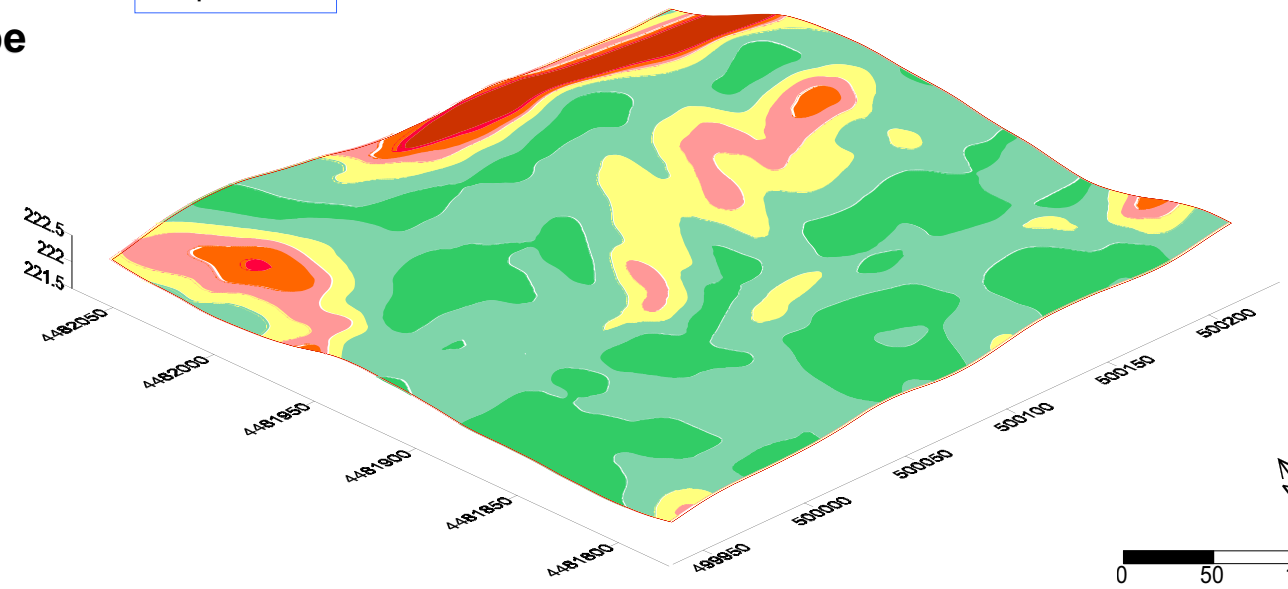
Generation of Topographic Attributes

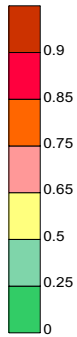
**Contour Lines**
**Primary Drain Direction**

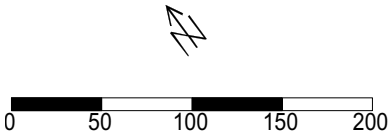


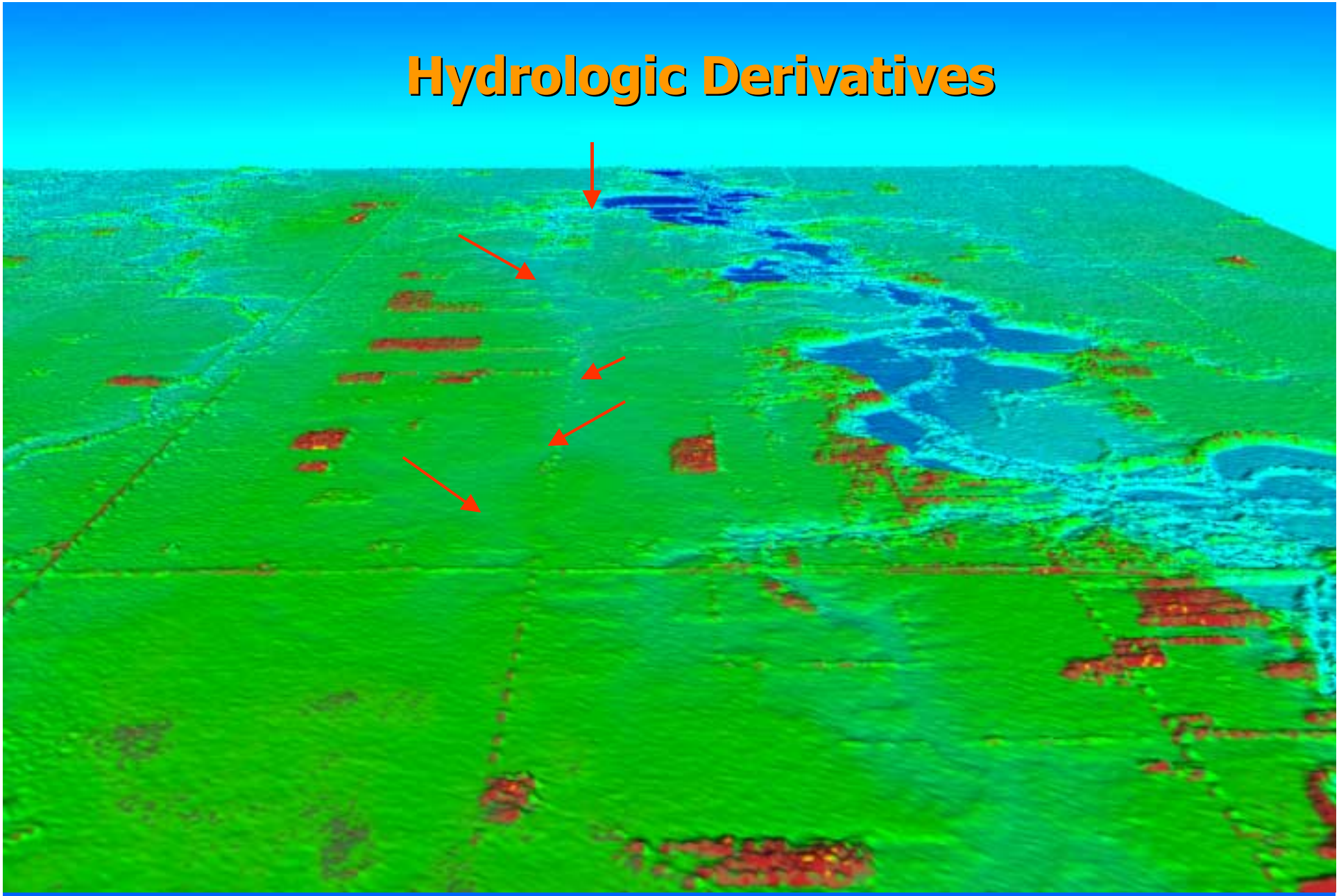

**Slope**



# Hydrologic Derivatives



IFSAR perspective view of Rossville area, from E to W

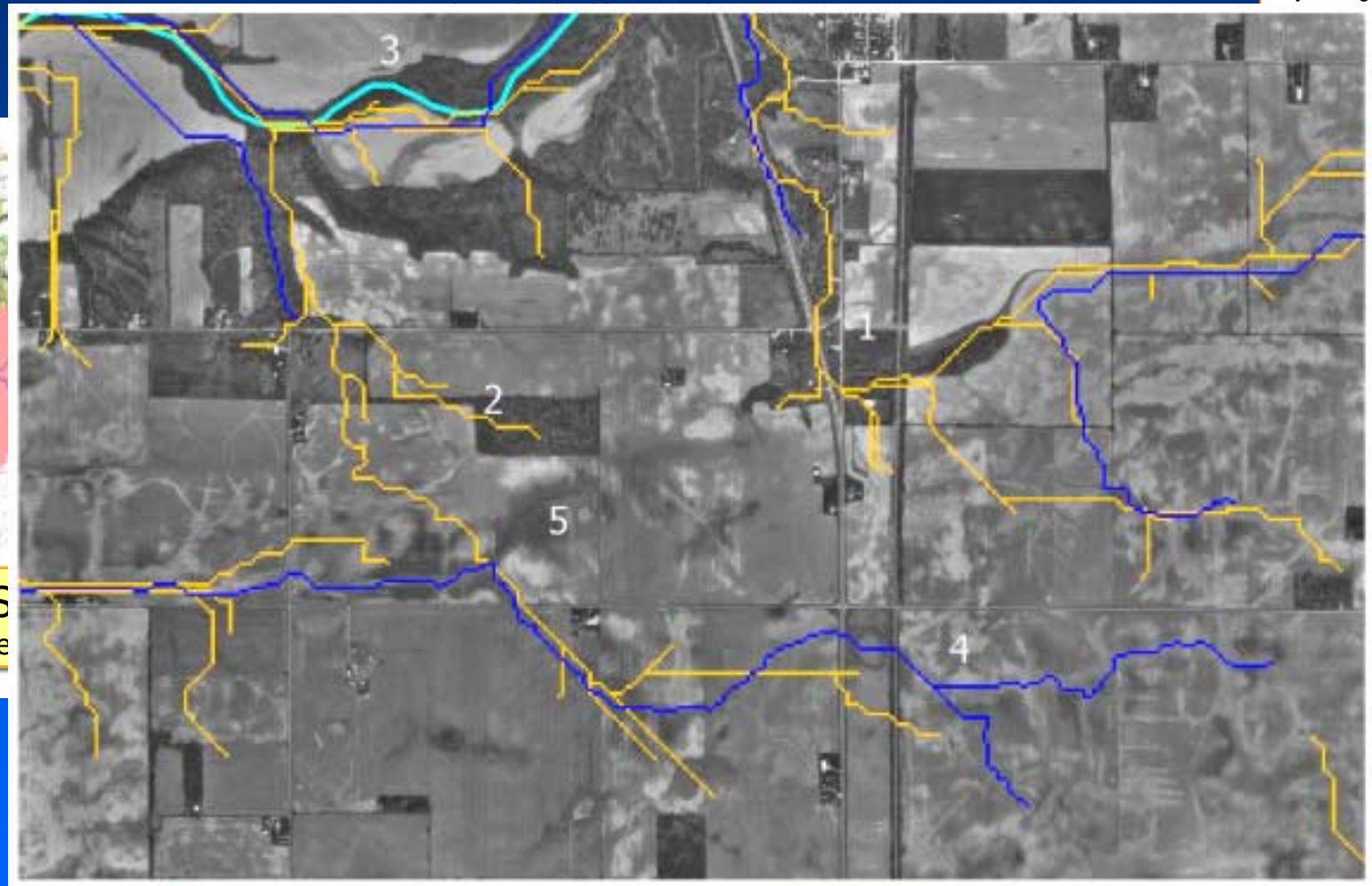
Intensity / Hue/ Saturation (IHS) color slice over DEM

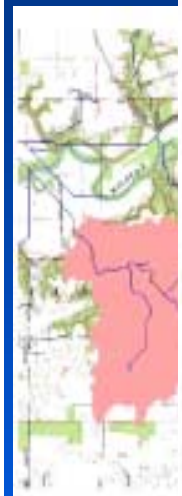
# Hydrologic Derivatives

Pre-processing Stages

Terrain Analysis

Hydrologic Derivatives



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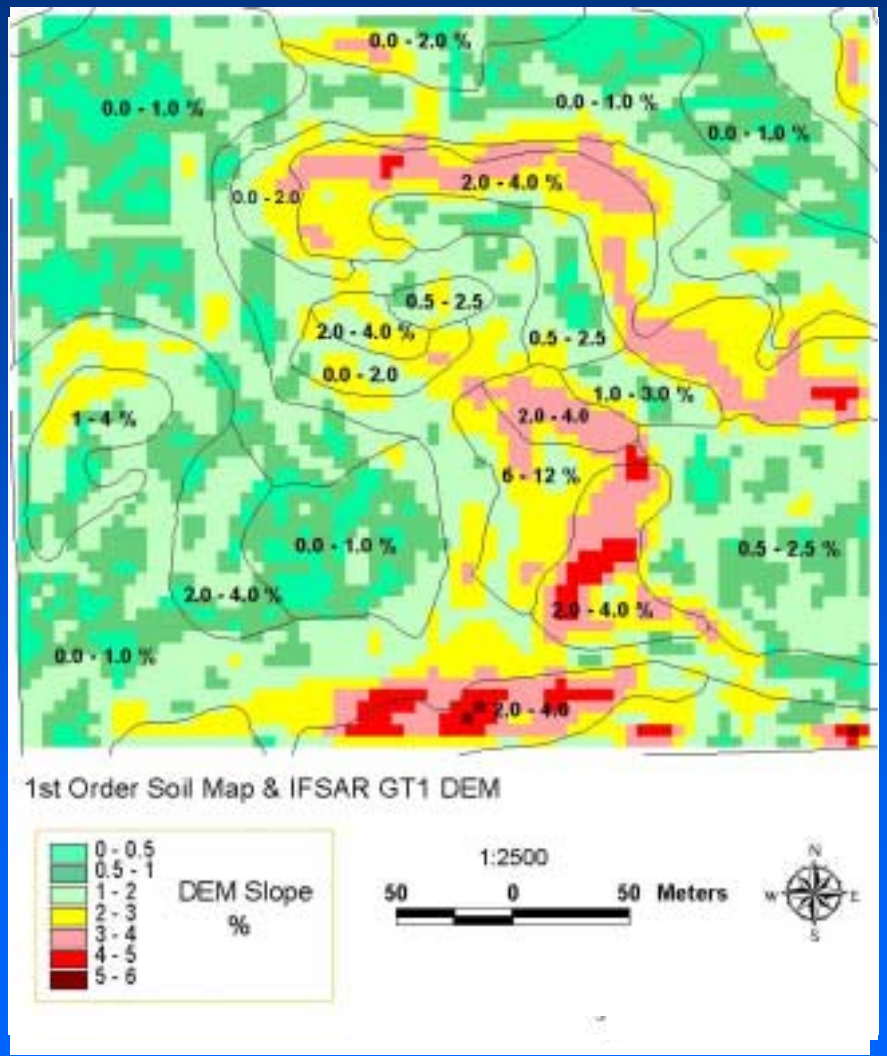
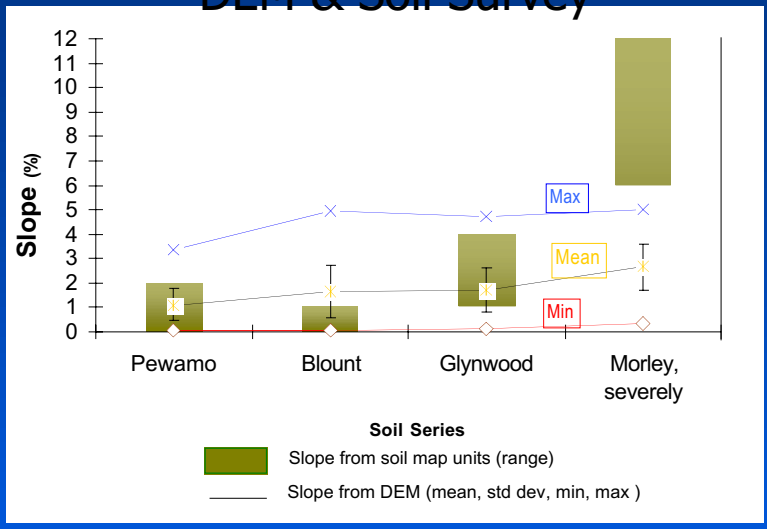
# Soils and Terrain Analysis

Pre-processing Stages
↓
Terrain Analysis
↓
Primary Topographic Attributes
↓
Slope

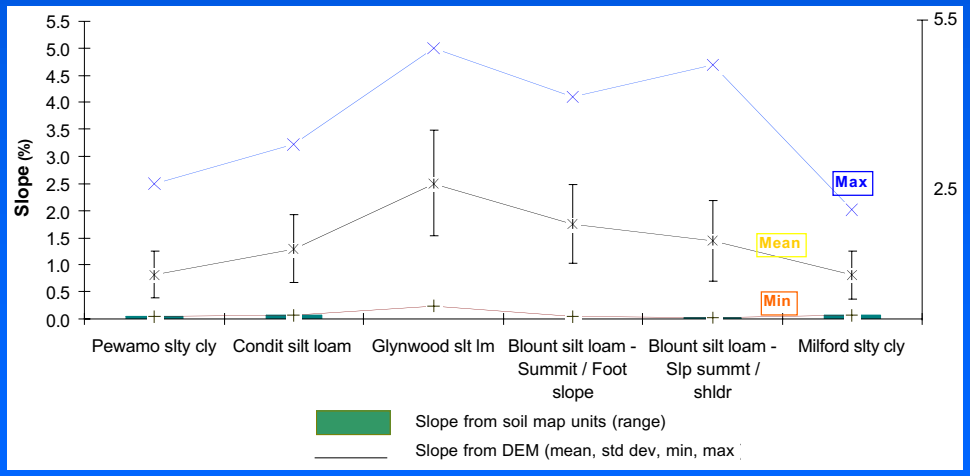



1st Order Soil Map & IFSAR GT1 DEM

## DEM & Soil Survey




## DEM & Order 1



# SRTM 02/2000

Mission Objective:

- To use C-band and X-band (IFSARs)
- 80% of Earth's land mass

Resolution

30 x 30

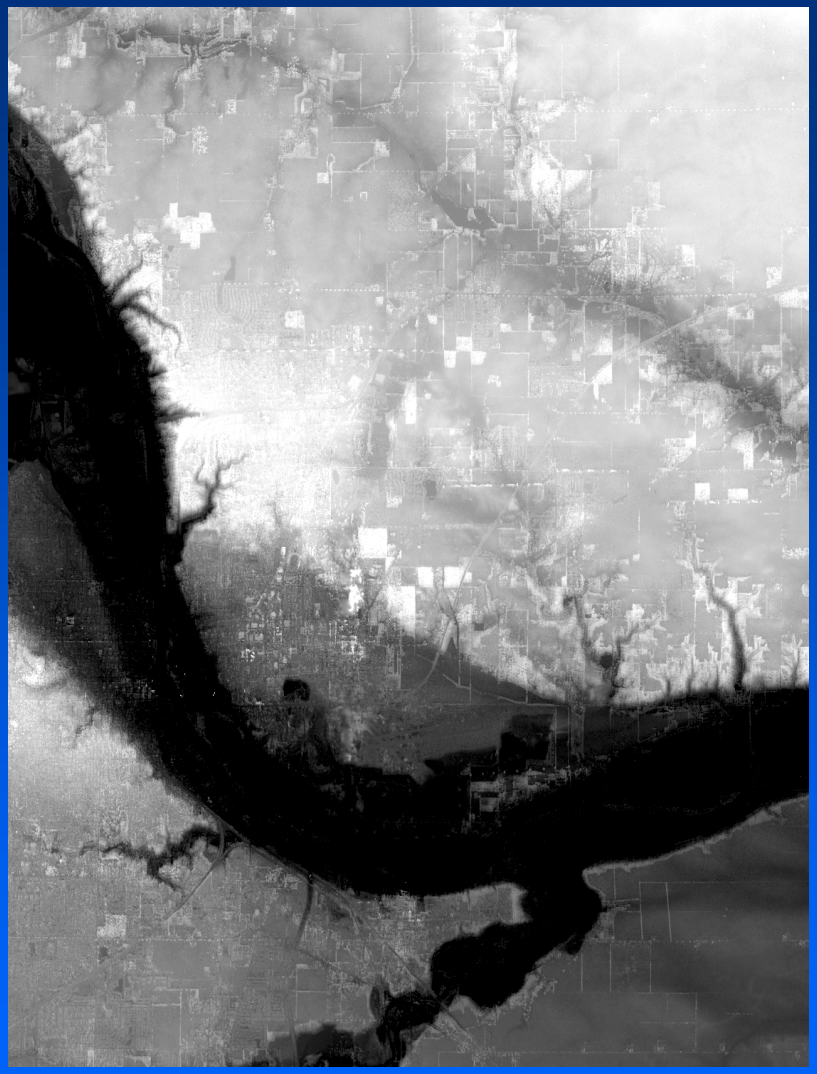
16 Absolute vertical acc

10 Relative vertical acc

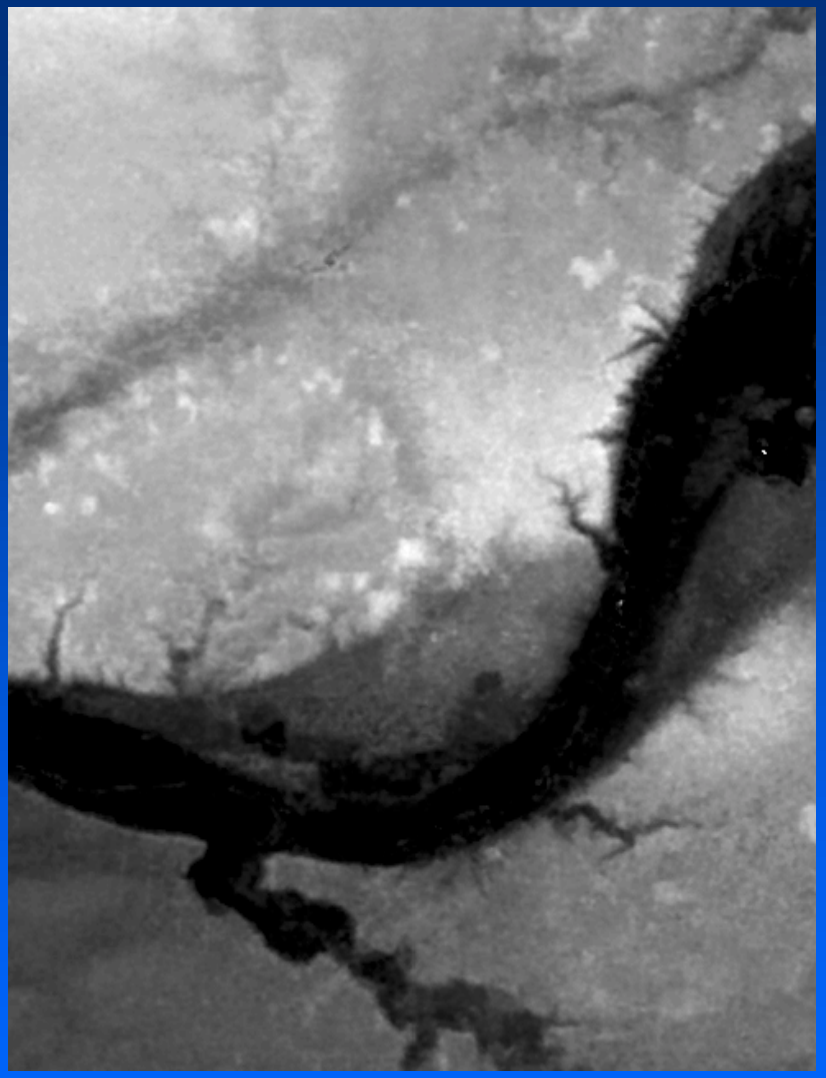
Data Distribution

- NIMA Level 2 (DTED-2)
- USGS
- JPL (c)
- DLR (x)

# COMPARISON of 'IFSARs' Data

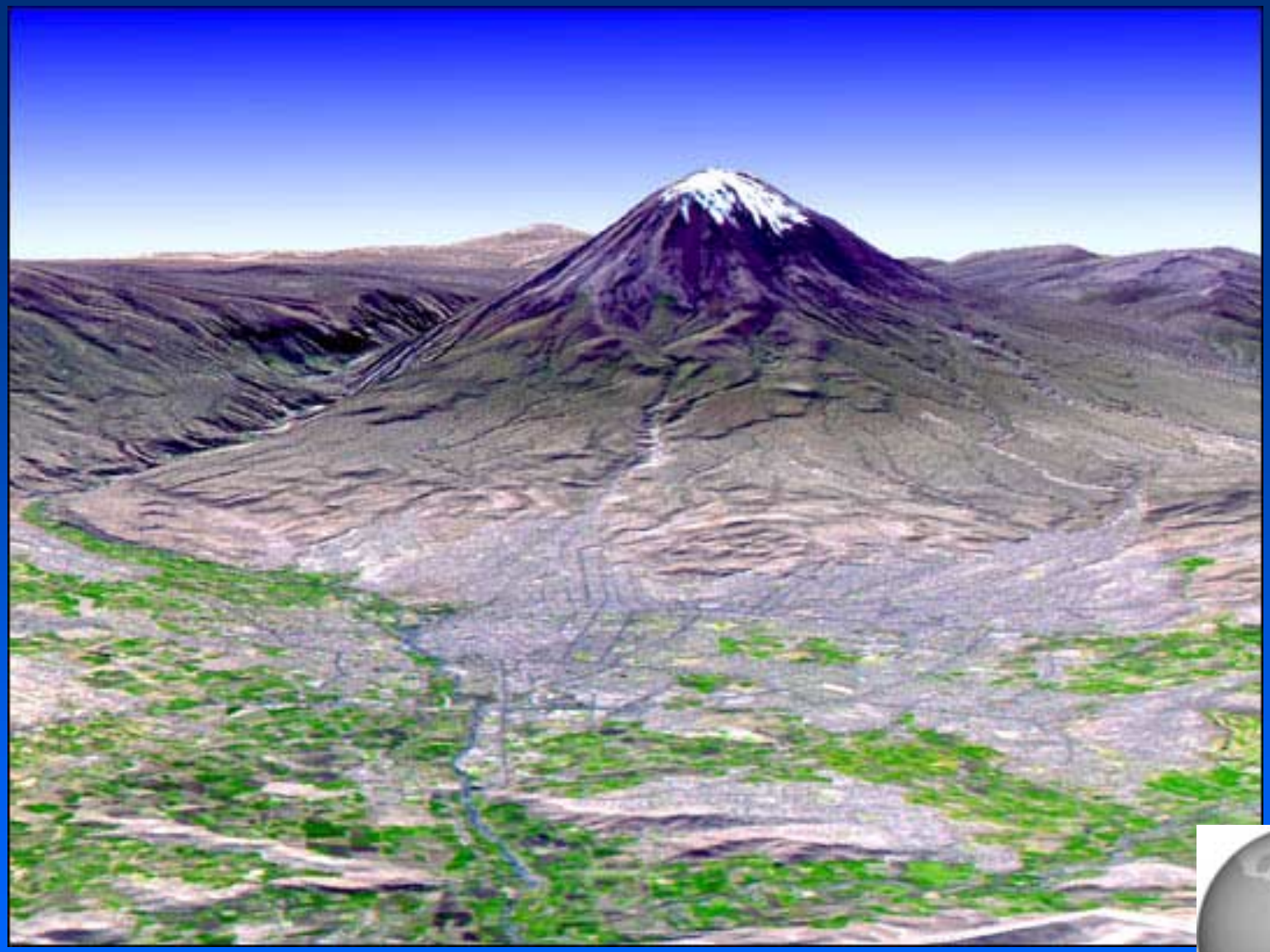


**STAR3i at 3000m – 10 m**



**SRTM at 233 km: 30 m**

Lafayette West Quad – Purdue University

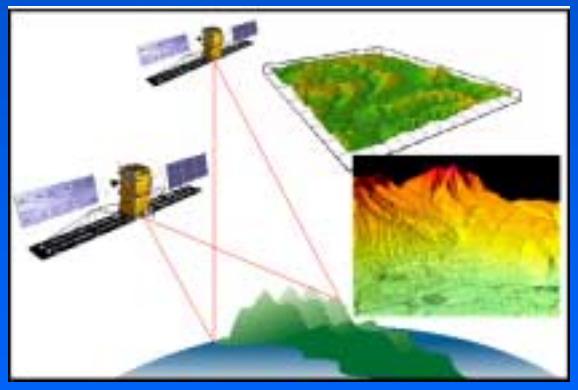


- El Misti Volcano and the City of Arequipa, Peru

Credits: Aster Science Team: NASA/GSFC/MITI/ERSDAC/JAROS, and U.S./Japan

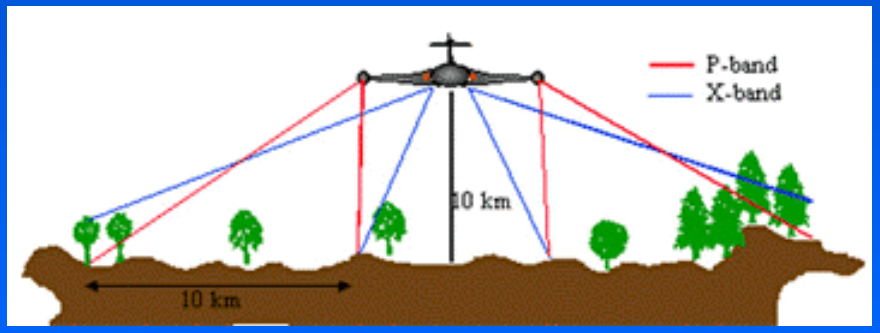
# OTHER IFSARs Systems

**RADARSAT 2 & 3**

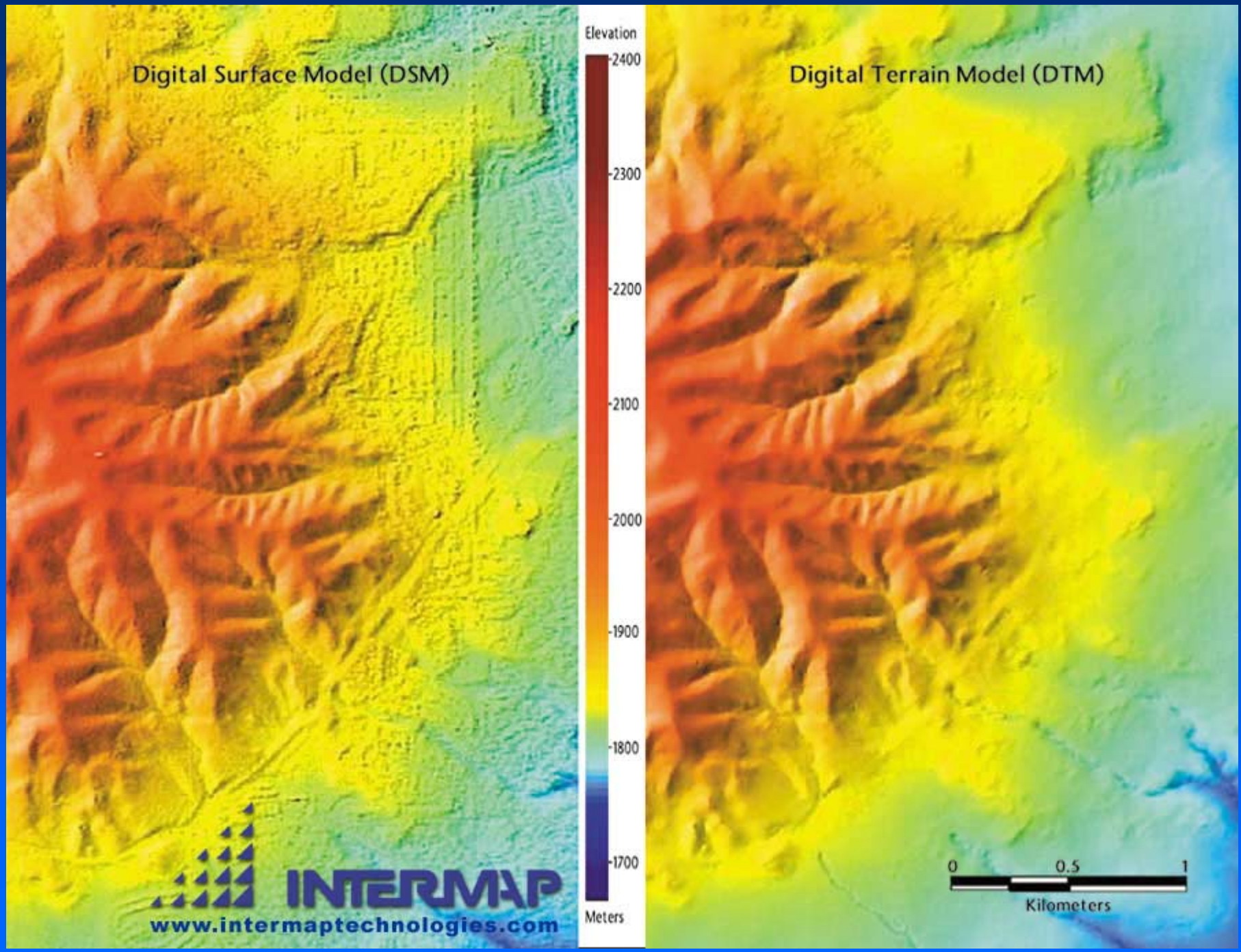


- CSA

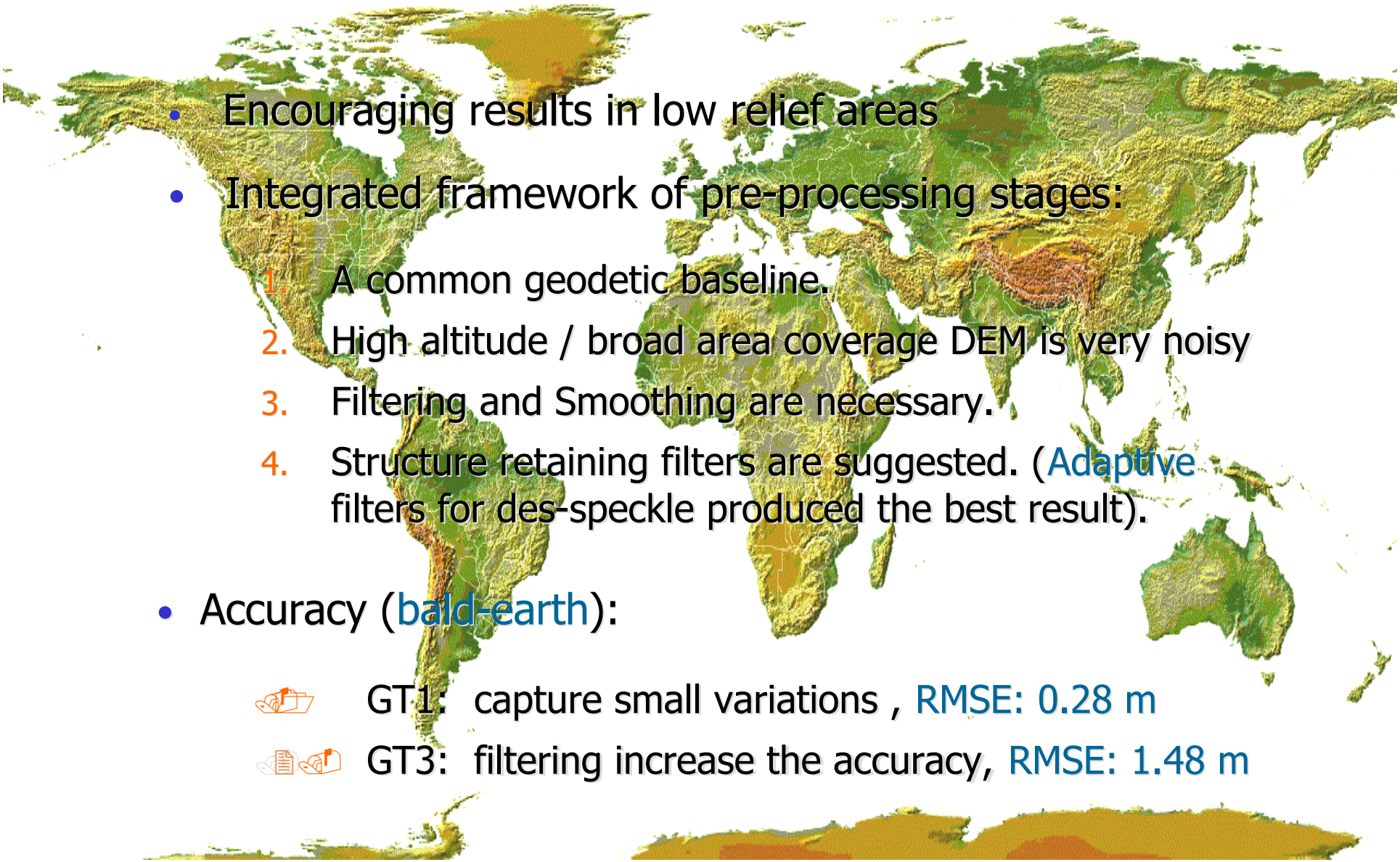
**GeoSAR and FOPEN**




- NASA JPL

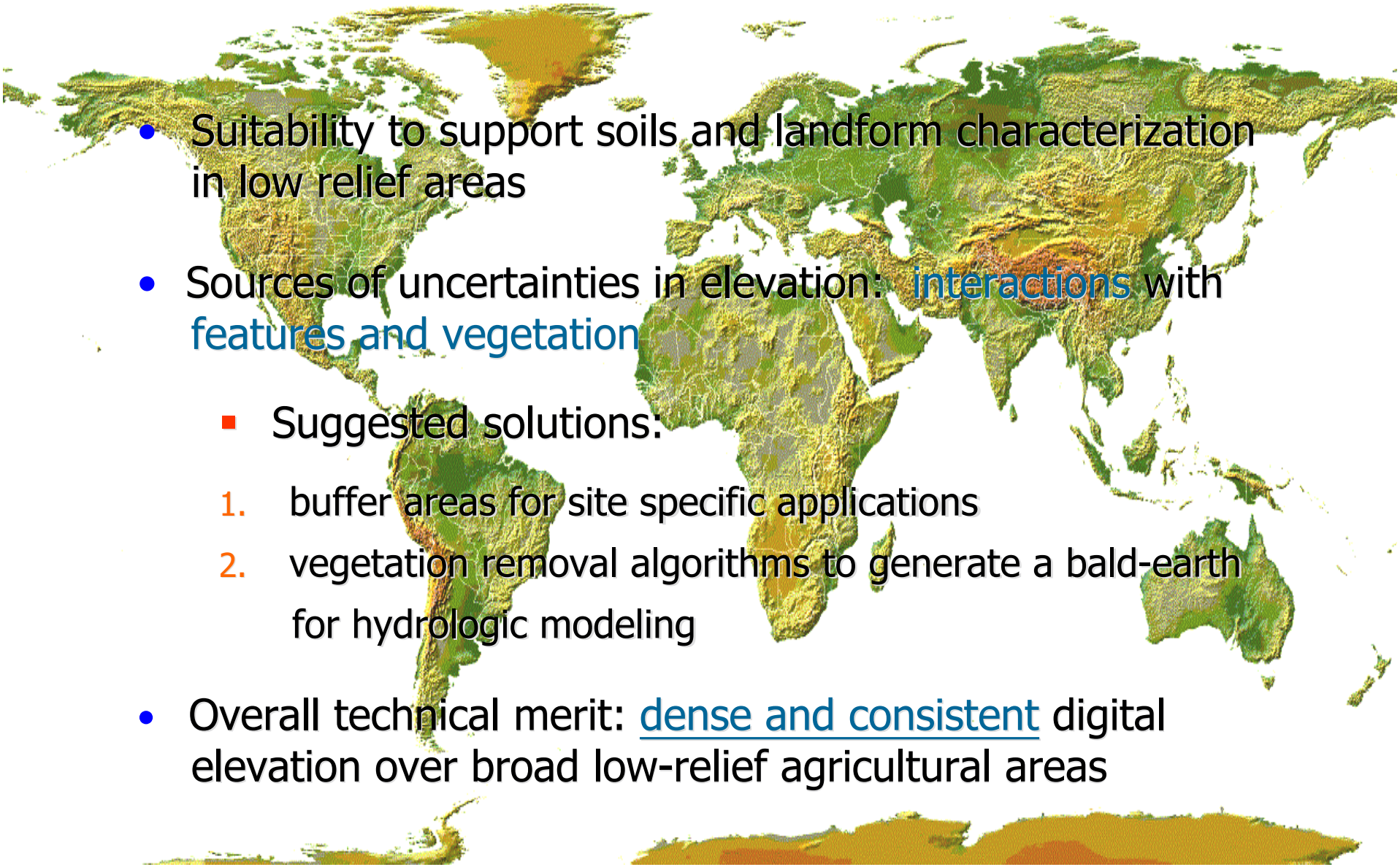

Digital Surface Model (DSM)
Digital Terrain Model (DTM)
Elevation
2400
2300
2200
2100
2000
1900
1800
1700
Meters
0
0.5
1
Kilometers
INTERMAP
www.intermaptechnologies.com

# Conclusions



- Encouraging results in low relief areas
- Integrated framework of pre-processing stages:
  1. A common geodetic baseline.
  2. High altitude / broad area coverage DEM is very noisy
  3. Filtering and Smoothing are necessary.
  4. Structure retaining filters are suggested. (Adaptive filters for des-speckle produced the best result).
- Accuracy (bald-earth):
  - GT1: capture small variations , RMSE: 0.28 m
  - GT3: filtering increase the accuracy, RMSE: 1.48 m

# Conclusions



- Suitability to support soils and landform characterization in low relief areas
- Sources of uncertainties in elevation: interactions with features and vegetation
  - Suggested solutions:
    1. buffer areas for site specific applications
    2. vegetation removal algorithms to generate a bald-earth for hydrologic modeling
- Overall technical merit: dense and consistent digital elevation over broad low-relief agricultural areas

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& GT1 was provided under AULA by **Intermap Technologies Corp.**

IKONOS was provided by **NASA CRSP** Program

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