ASSESSING THE INFLUENCE OF FLIGHT PARAMETERS AND INTERFEROMETRIC PROCESSING ON THE ACCURACY OF X-BAND IFSAR-DERIVED FOREST CANOPY HEIGHT MODELS

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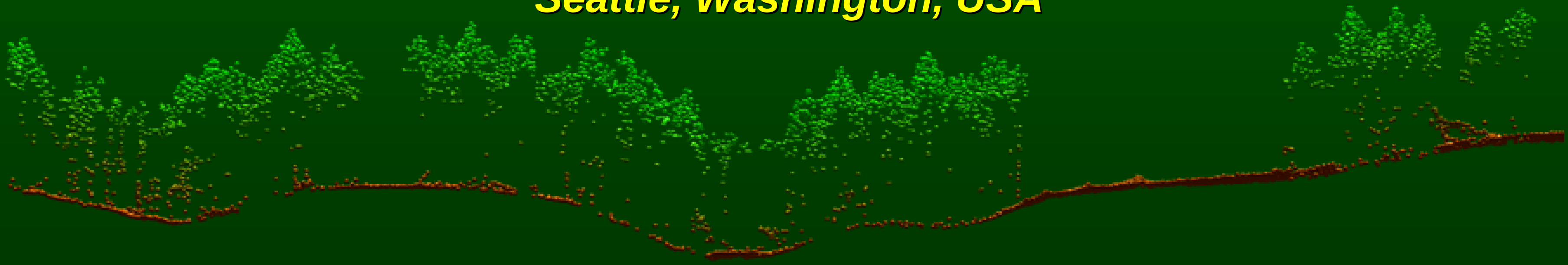


Lidar & IFSAR for Forestry Applications

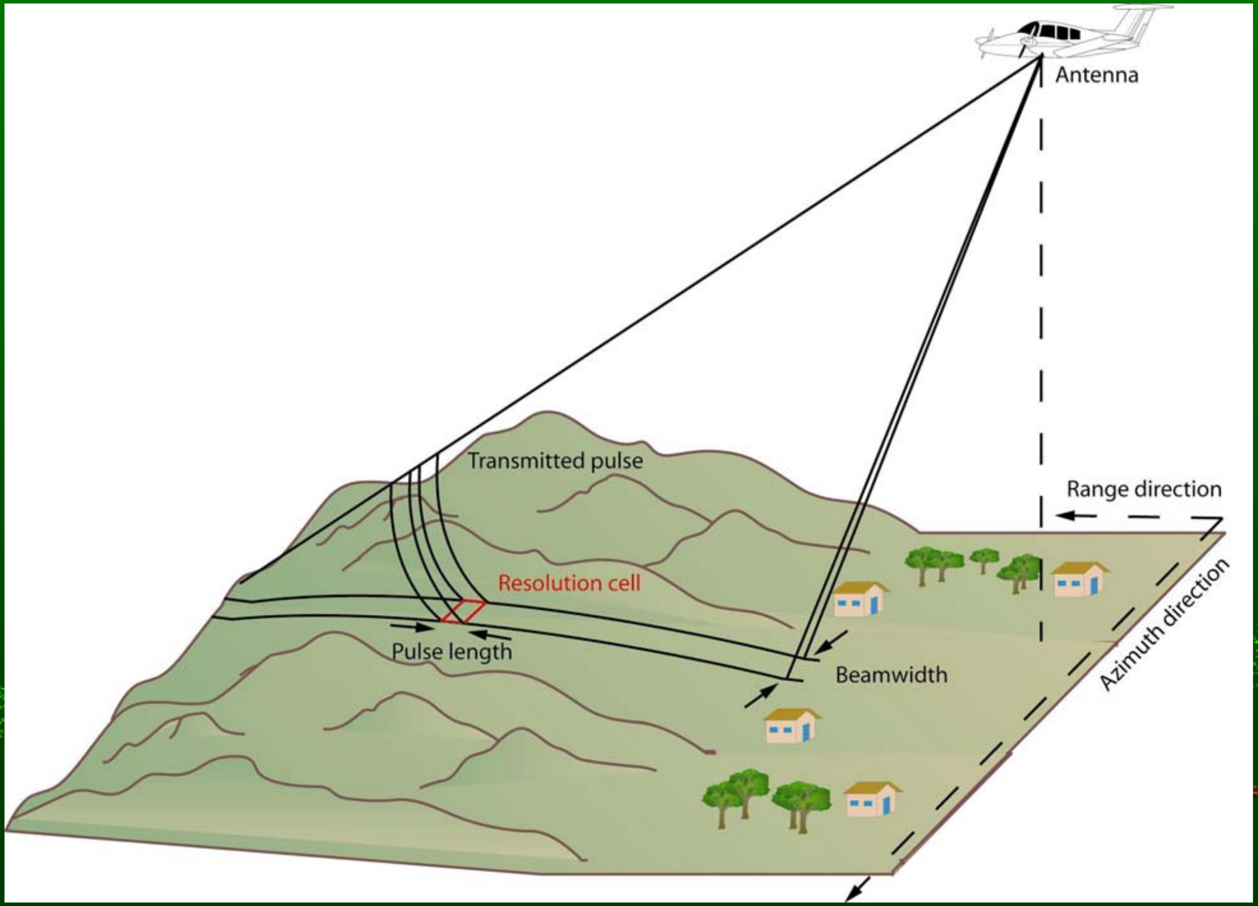
- ***3-D forest structure information needed for variety of forestry applications***
  - ***Timber management***
  - ***Wildlife habitat***
  - ***Fire management***
- ***Canopy height and canopy cover are most important parameters describing 3-D forest canopy structure***
- ***Lidar provides high-resolution measurements of canopy and underlying terrain***
- ***X-band IFSAR provides high-resolution measurements of forest canopy surface***

IFSAR Technology Overview

- *Up to 10,000 km² per hour data collection rate*
  - *Lower resolution than lidar (1.25 m vs 0.25 m)*
- *Costs for IFSAR much lower than lidar*
  - *$10-50/km² for IFSAR vs. $250/km² for lidar*
- *IFSAR could provide economical means of monitoring large areas at frequent intervals*
- *IFSAR mission parameters are not optimized for forestry application*

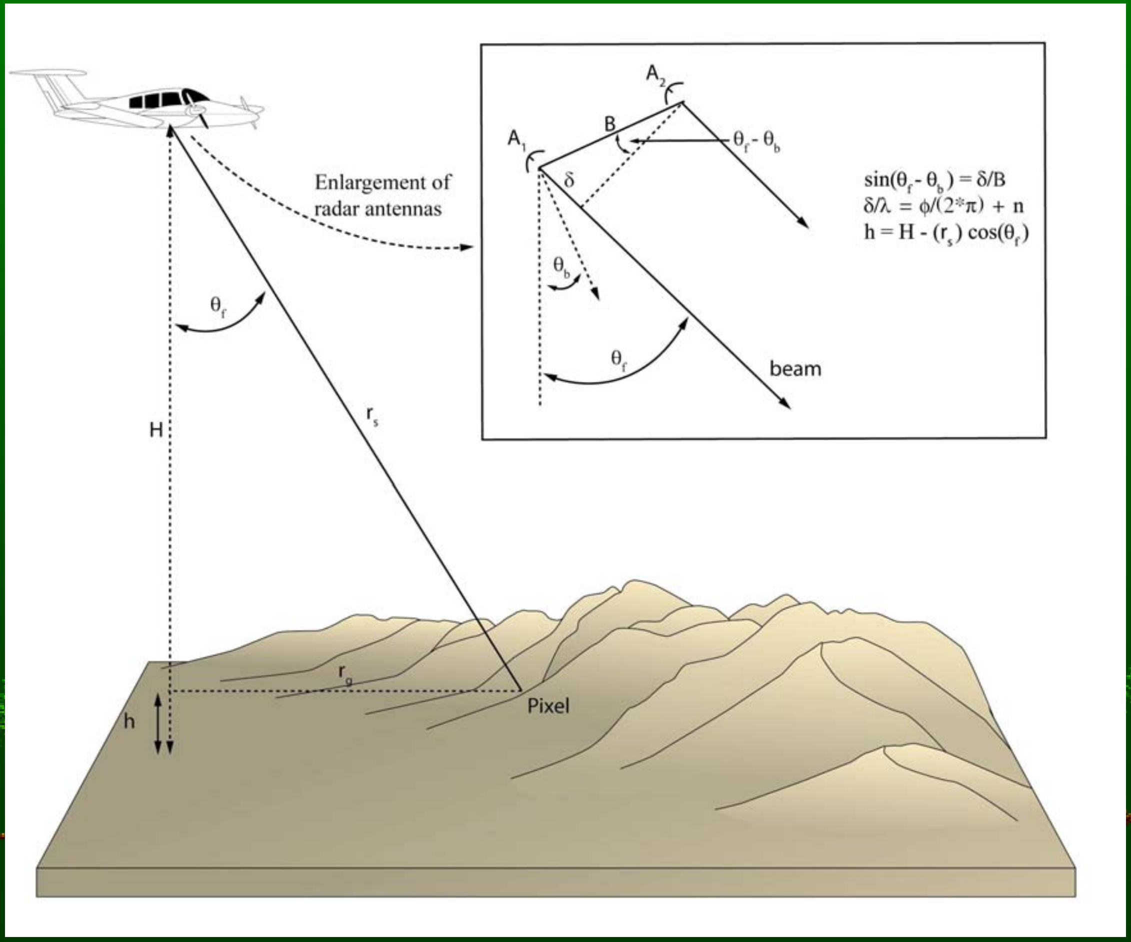
IFSAR Technology Overview

- Side-looking airborne radar system



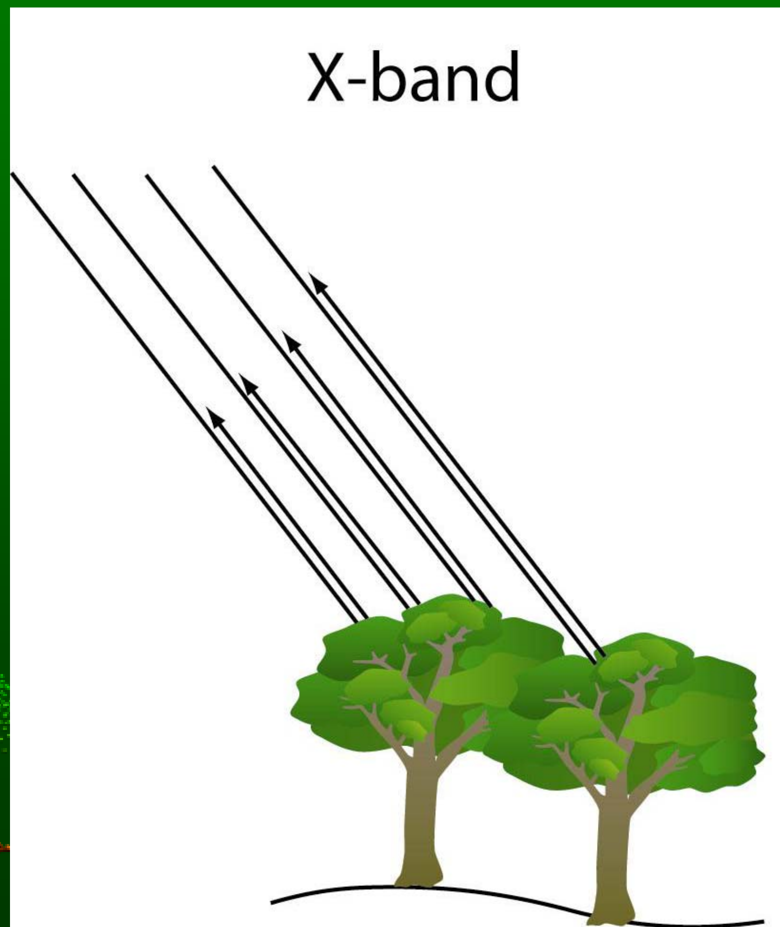
IFSAR Technology Overview

- *Interferometry provides 3-D elevations*



IFSAR Technology Overview

- *X-band energy reflects from canopy surface*



IFSAR Technology Overview

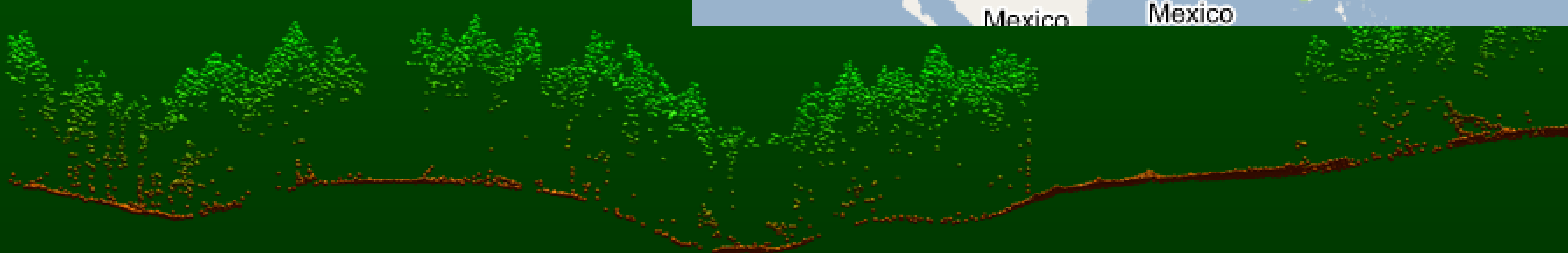
- “Phase noise” is dominant source of error in X-band IFSAR elevation measurement
  - Height error is function of signal-to-noise ratio (SNR)
- SNR can be increased by:
  - Lowering flying height (increasing signal power)
  - Filtering interferogram (decreasing noise power)
- IFSAR is acquired at shallow look angles
  - Accuracy of IFSAR measurements in forest areas also strongly influenced by sensing geometry and shadowing

Study objectives

- ***IFSAR acquired at 2 different flying hts:***
  - ***4500 m***
  - ***6000 m***
- ***Interferograms filtered to 4 different levels:***
  - ***Oversampling factors (OSF) of 1, 2, 4, 8***
- ***IFSAR acquired from 3 different look directions:***
  - ***Side, opposite, orthogonal***
- ***Evaluate IFSAR for:***
  - ***Canopy height***
  - ***Maximum height***
  - ***Canopy cover***
- ***Comparison to high-density lidar***

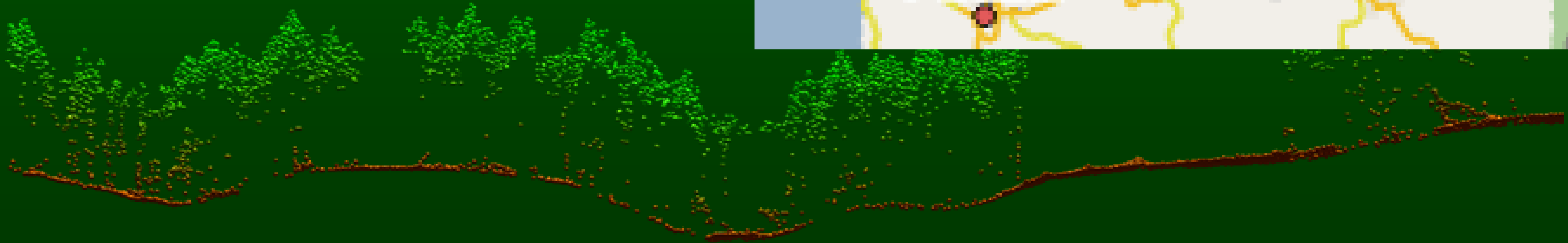
Mission Creek Study Area

- ***5 sq. km. area within Wenatchee National Forest, Washington State, USA***



Mission Creek Study Area

- ***5 sq. km. area within Wenatchee National Forest, Washington State, USA***



Mission Creek Study Area

- *5 sq. km. area within Wenatchee National Forest, Washington State, USA*
- *Mixed-conifer forest (Douglas-fir, Ponderosa Pine)*
- *Mountainous, dry site, highly fire-prone*

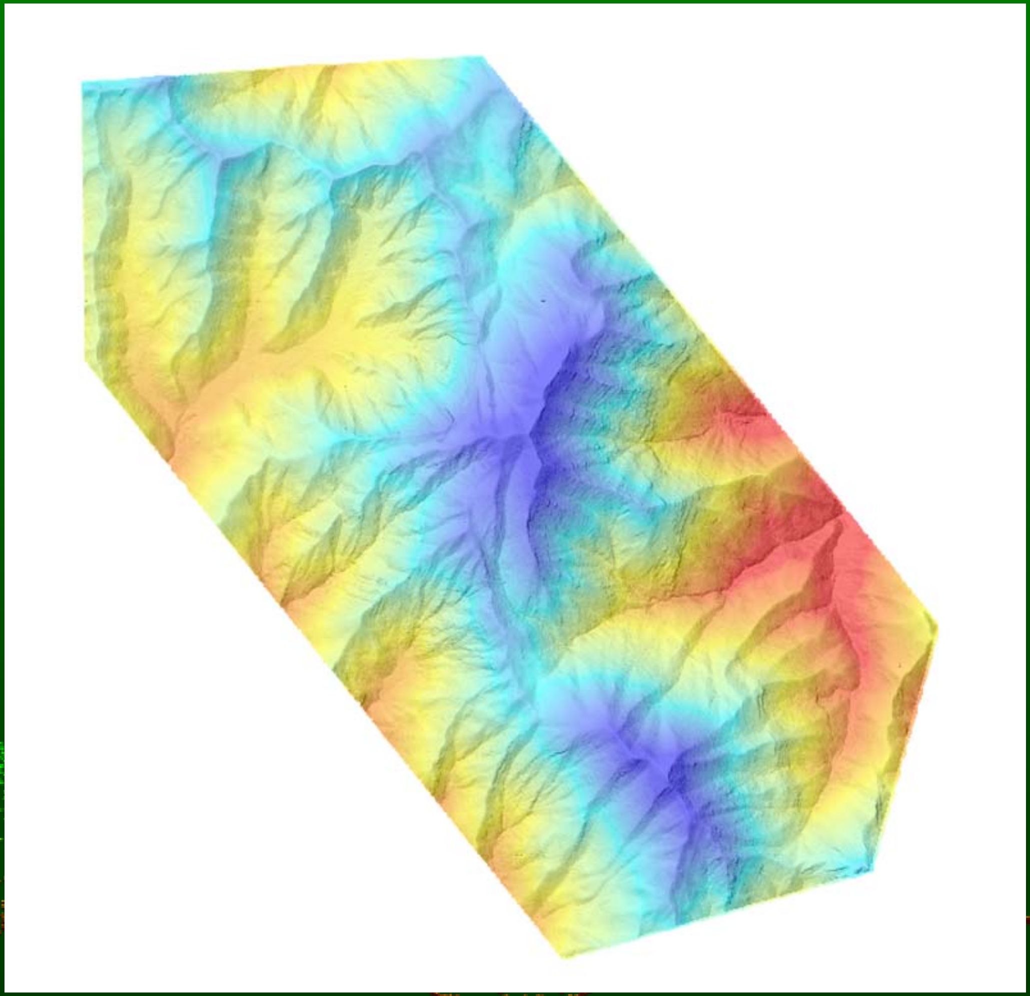
Orthophoto of study area

2004 LIDAR Flight Parameters And System Settings

- *Optech ALTM 3070*
- *Platform: fixed-wing*
- *Flying height: 1200 m*
- *Flying speed: 250 km/h*
- *Scanning swath: 600 m*
- *Laser pulse density: 4 pulses/m^2*
- *Laser pulse rate: 70,000 pulses/second*

Lidar digital terrain model

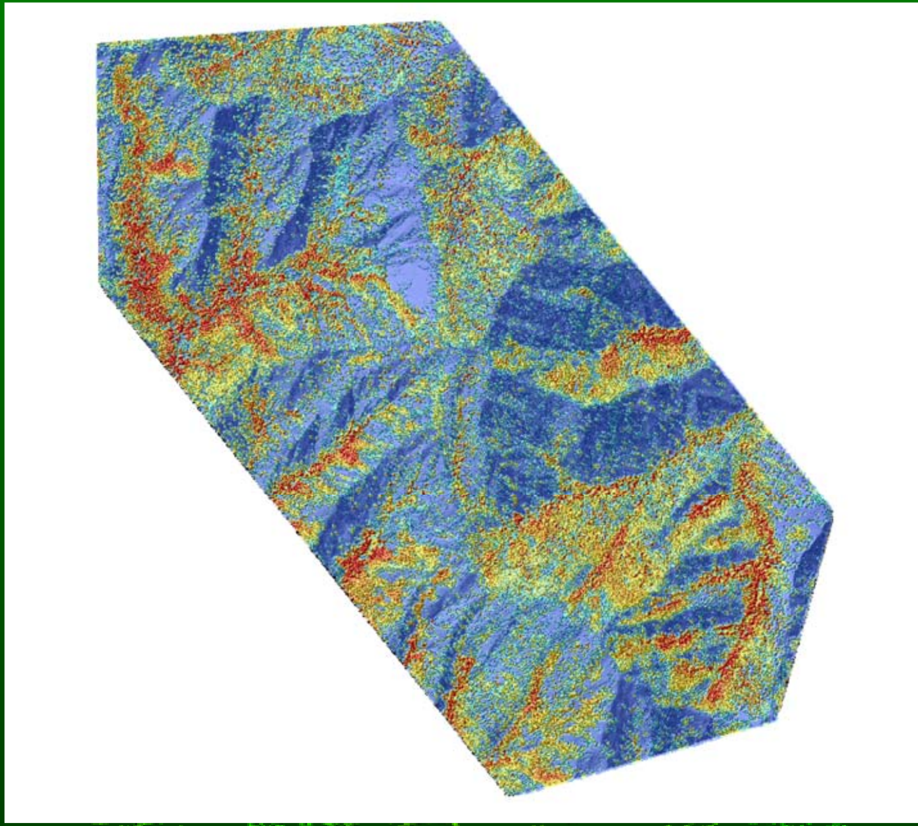
Lidar digital terrain model

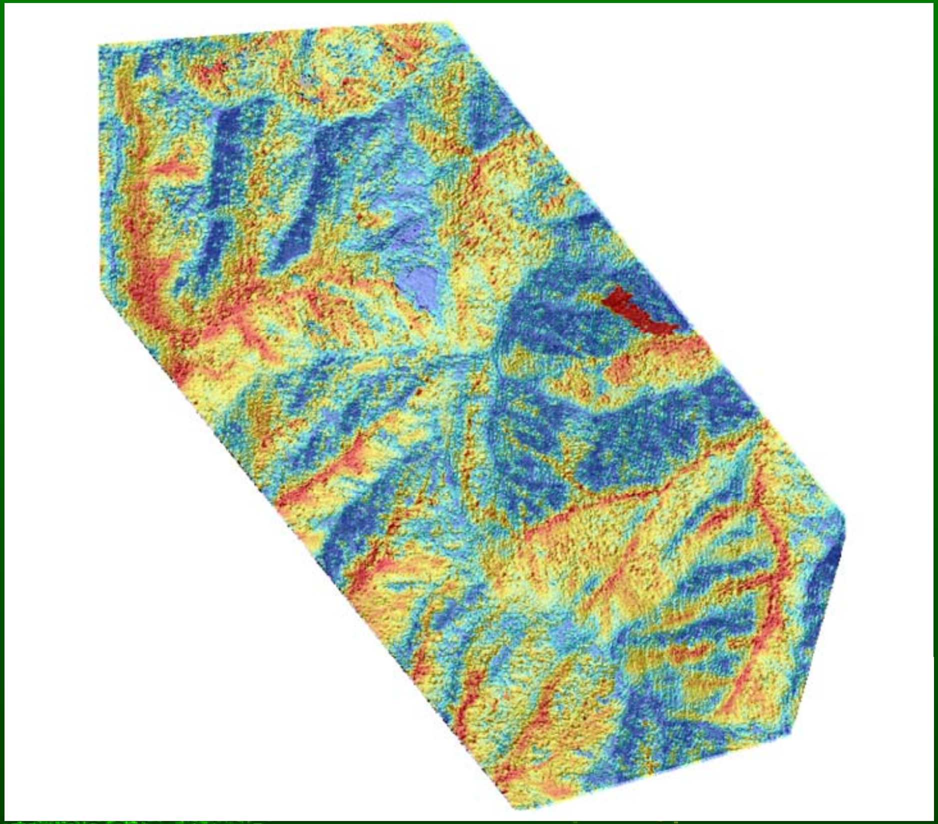


2005 IFSAR Flight Parameters And System Settings

- Intermap Star-3i system
- Wavelength: 3.1 cm (X-band)
- Platform: Learjet 36A
- Flying speed: 720 km/h
- Flying height: 4500 m, 6000 m
- Scanning swath: 7000 m @ 6000 m AGL, 5200 m @ 4500 AGL
- Spatial resolution: 1.25 m

Lidar & IFSAR canopy height models





Lidar canopy height *IFSAR canopy height*

(Blue is low canopy, red is high canopy)

Methods

- ***Estimates of canopy ht., maximum ht., and canopy cover generated at each 30-m grid cell***
- ***Canopy ht. estimated by 90th percentile surface ht. within cell***
  - ***Represents generalized (smoothed) description of canopy ht.***
- ***Maximum ht. estimated by highest surface point within cell***
  - ***Represents direct measurement of emergent canopy features***
- ***Canopy cover estimated as fraction of surface hts. within cell greater than 5 meters***
- ***Void areas excluded from analysis***

Results: Influence of flying height

SUMMARY STATISTICS FOR DIFFERENCE BETWEEN IFSAR- AND LIDAR-DERIVED FOREST HEIGHT MEASUREMENTS

	Canopy Height Diff. (m)				Maximum Height Diff. (m)			
	Mean	SD	Median	QD	Mean	SD	Median	QD
6000 m	-7.5	4.9	-7.2	2.9	-10.7	6.9	-10.3	2.9
4500 m	-7.0	4.9	-6.7	2.8	-10.2	6.3	-9.9	3.6

- *Flying height has little effect on measurement of canopy height or maximum height in forested areas*

Results: Influence of interferometric processing

	Canopy Height Diff. (m)				Maximum Height Diff. (m)			
	Mean	SD	Median	QD	Mean	SD	Median	QD
OSF 1	-6.5	4.4	-6.1	2.2	-1.6	9.6	-2.5	4.4
OSF 2	-6.5	4.5	-6.0	2.3	-2.7	9.5	-3.3	4.3
OSF 4	-6.5	4.6	-6.1	2.5	-4.1	8.6	-4.6	4.3
OSF 8	-7.0	4.9	-6.7	2.8	-10.2	6.3	-9.9	3.6

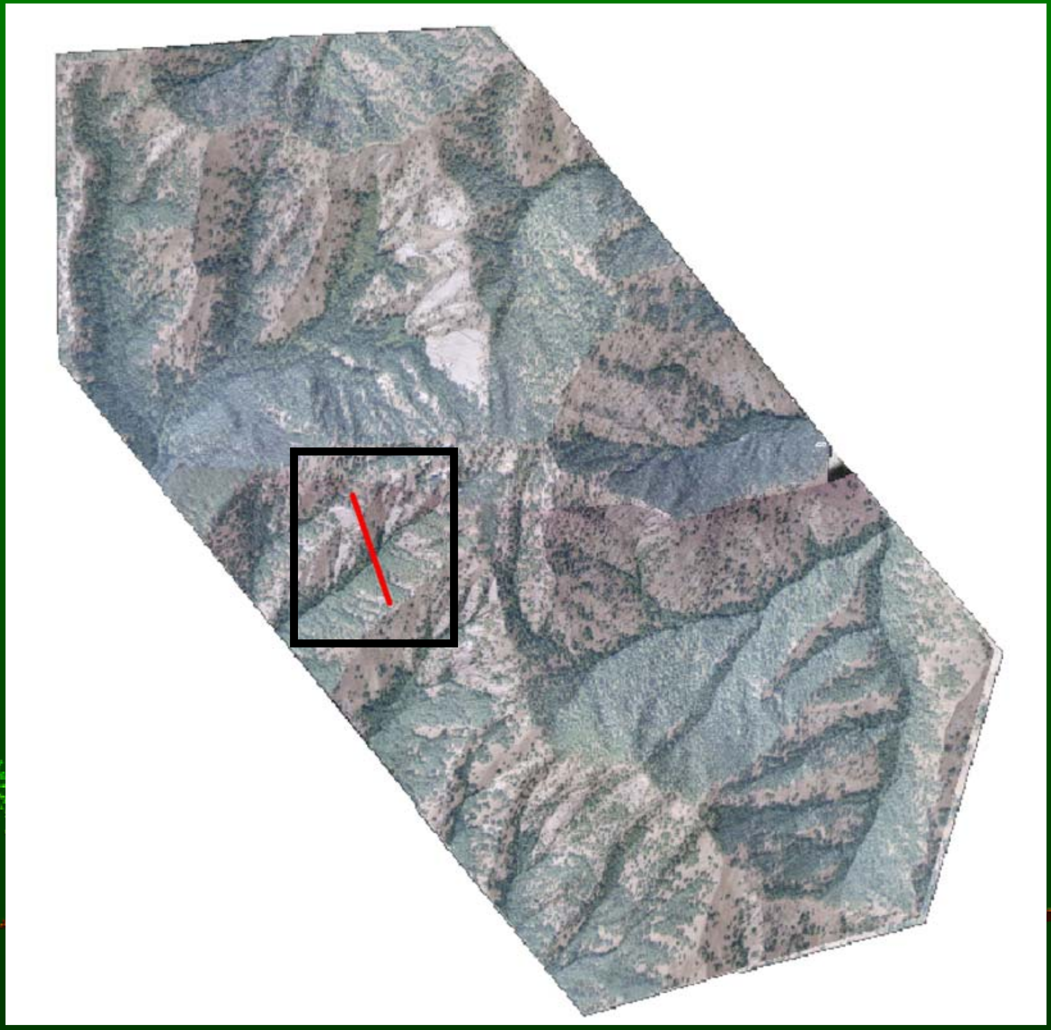
- Level of filtering has little effect on measurement of canopy height
- Filtering has significant effect on measurement of maximum height

Results: Influence of sensing geometry

	Canopy Height Diff. (m)				Maximum Height Diff. (m)			
	Mean	SD	Median	QD	Mean	SD	Median	QD
Side looks	-3.2	4.9	-3.2	2.9	-5.4	7.5	-5.8	3.6
Opposite	-2.2	3.5	-2.5	2.0	-4.4	5.5	-5.0	2.6
Orthogonal	-1.6	4.1	-1.6	2.1	-3.4	7.1	-4.2	2,8
All looks	-0.6	3.9	-0.8	2.0	-2.1	7.1	-3.2	2.9

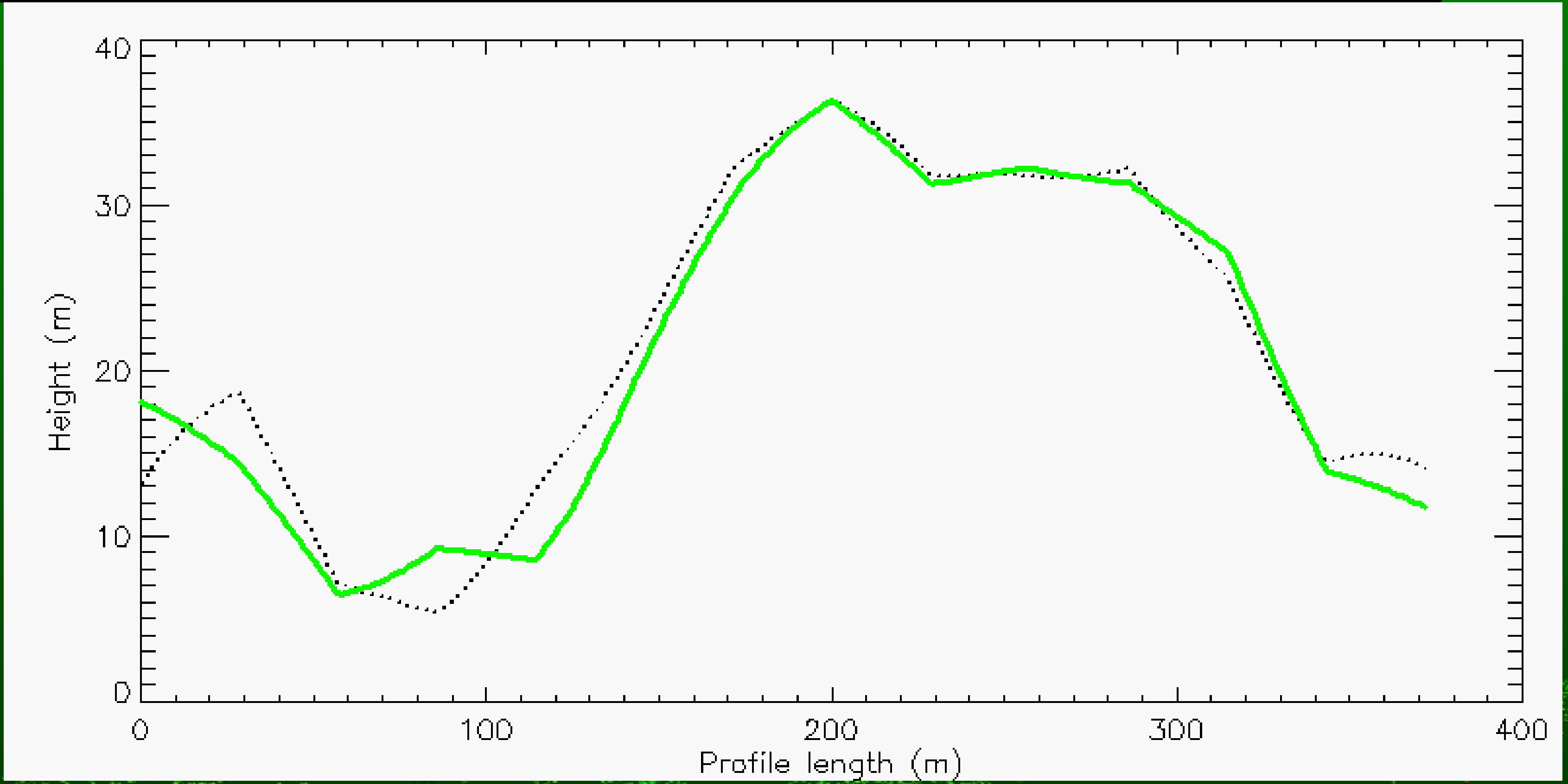
- Use of multiple looks can significantly improve accuracy
- Highest accuracy results from merging all looks

Canopy profiles



Canopy profiles

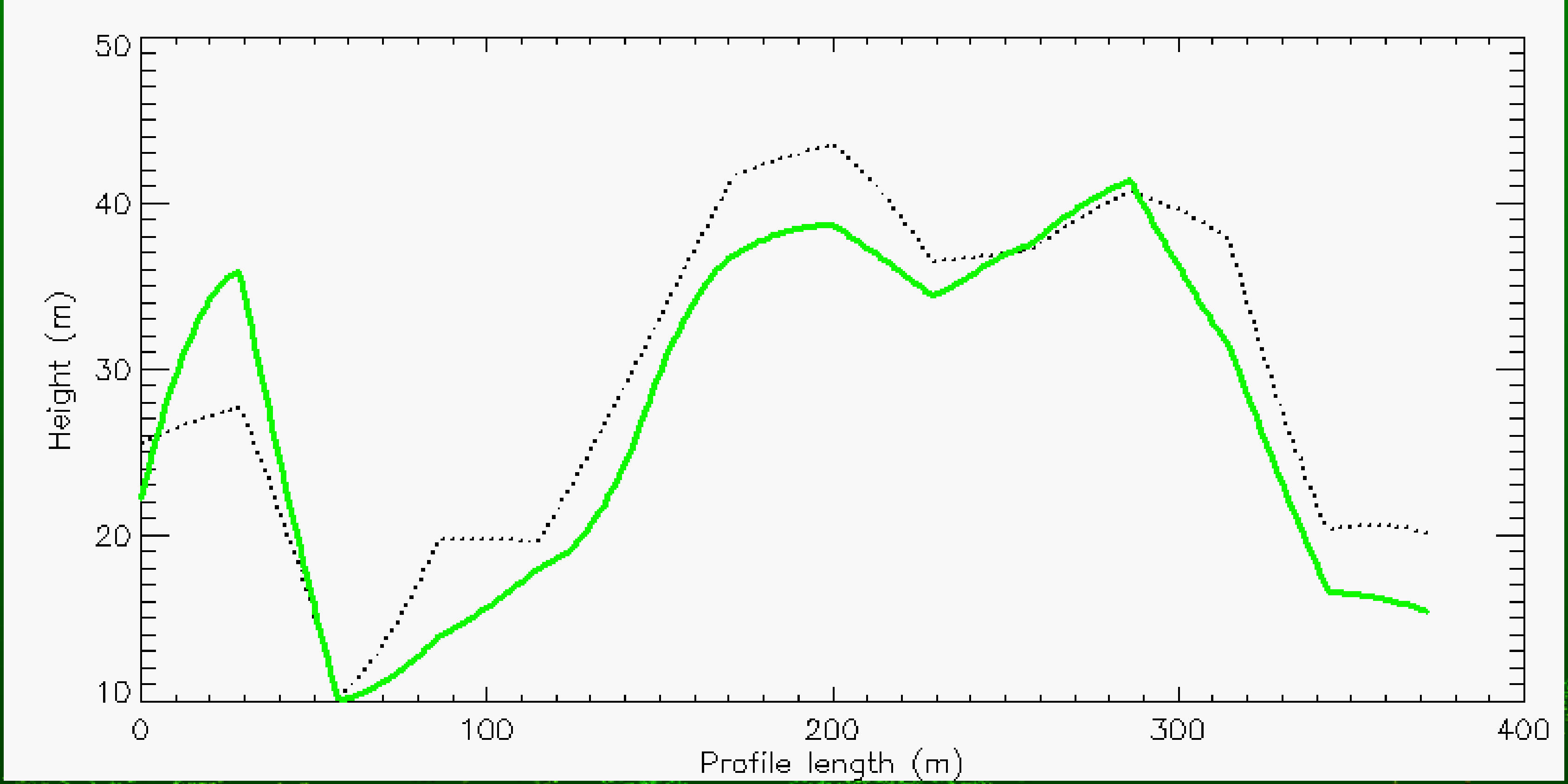
Canopy height profile (30-m resolution)



Green: IFSAR 90th percentile ht.

Black: Lidar 90th percentile ht.

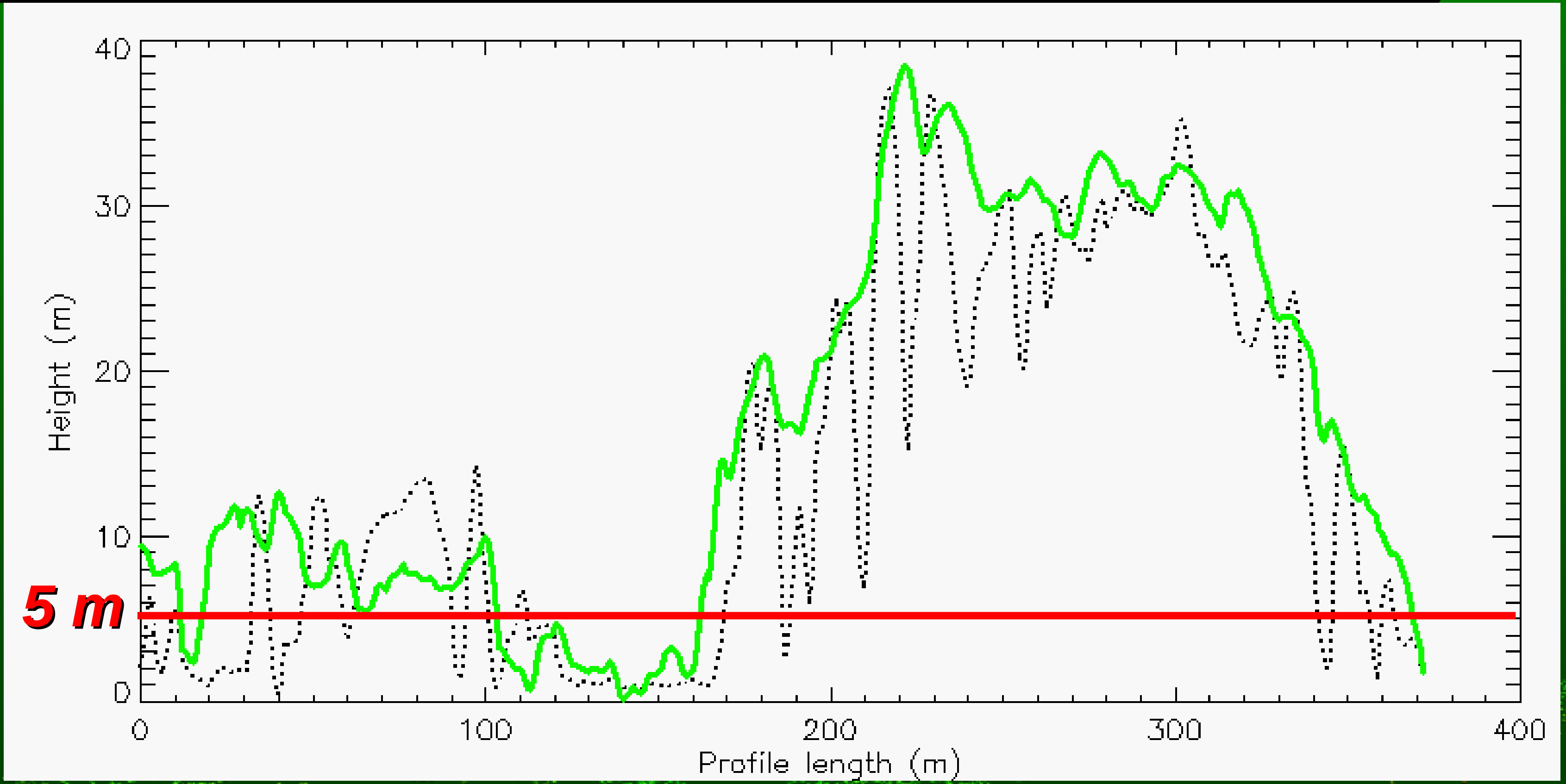
Maximum height profile (30-m resolution)



Green: IFSAR Maximum ht.

Black: Lidar Maximum ht.

Canopy height profile (1.25-m resolution)

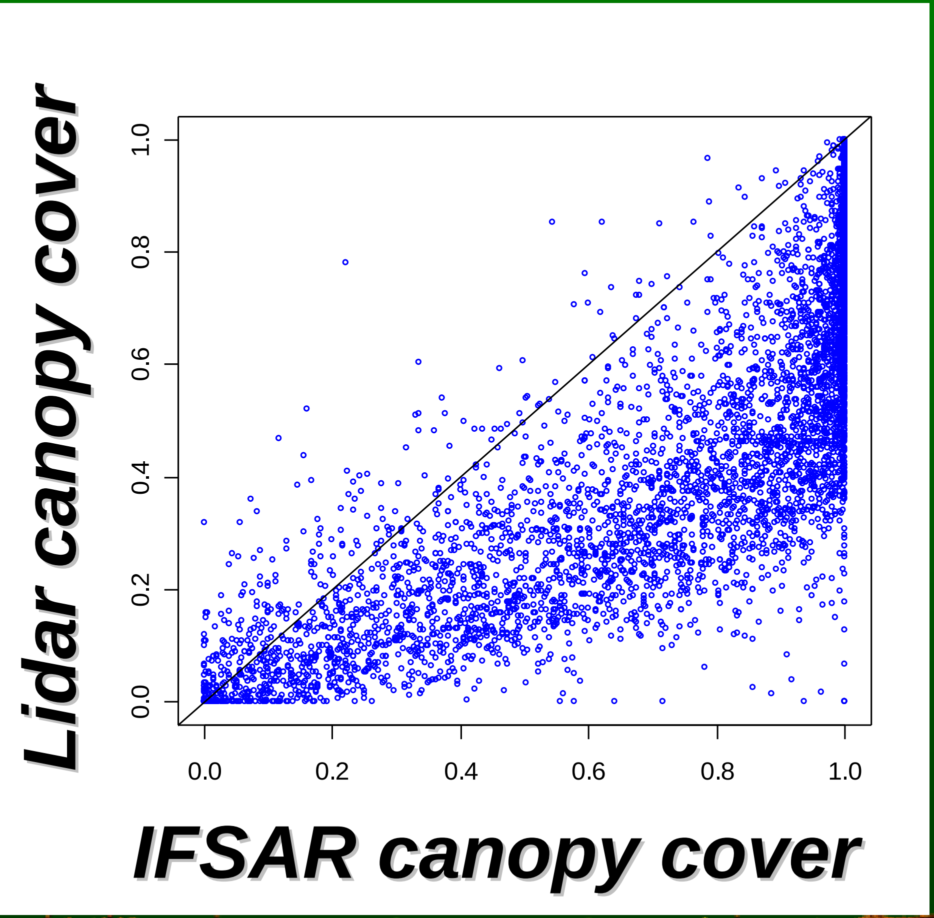


Green: IFSAR surface ht.

Canopy cover estimated as fraction of surface hts. > 5 m

Black: Lidar surface ht.

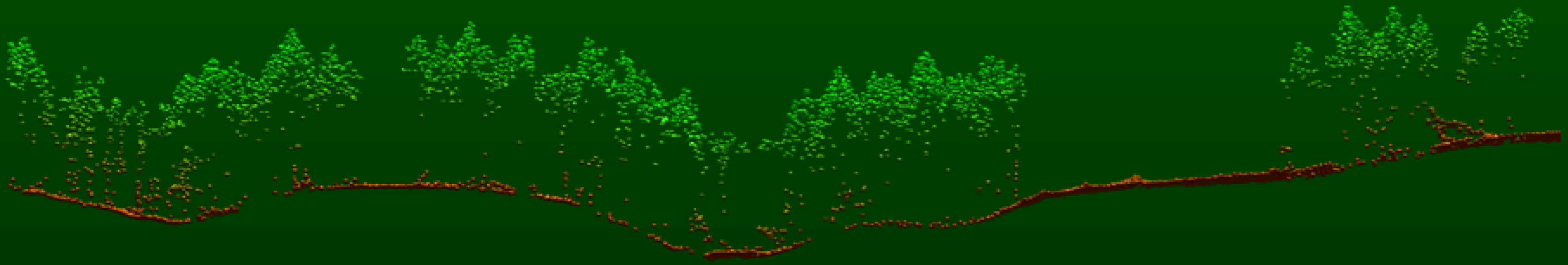
Results: Estimation of Canopy Cover



- IFSAR consistently overestimates canopy cover

Summary

- ***Difference in flying heights studied here (4500 m vs. 6000 m) has little effect on accuracy of canopy height measurement***
- ***Level of interferogram filtering has little effect on accuracy of general canopy height***
  - ***Filtering does have significant effect on maximum ht. measurement***



Summary (cont.)

- ***Using a combination of several overlapping looks can significantly improve accuracy, esp. in mountainous areas***
  - ***Even two looks offers significant improvement over a single look***
  - ***Combining orthogonal, side, and opposite looks provides most accurate canopy height measurements***
- ***Canopy cover estimation using only IFSAR elevation data is difficult***
  - ***Scanning geometry of IFSAR does not allow for accurate measurement of high frequency details in canopy surface, including individual trees and gaps***

Conclusions

- Study indicates that X-band IFSAR can be an economical source of data for monitoring forest canopy height over large areas
- Typical system parameters for high accuracy IFSAR topographic survey (e.g. Intermap Type II standards) also adequate for forest survey applications
  - More looks may be needed for high accuracy forest measurements
- IFSAR elevation data alone not adequate to accurately characterize canopy cover

Future Directions

- *Evaluate influence of terrain characteristics (slope, aspect) on accuracy of IFSAR forest measurements*
- *Incorporate high-resolution IFSAR backscatter information (texture, etc.) into canopy cover estimate*
- *Compare IFSAR estimates to field data at plot-level*