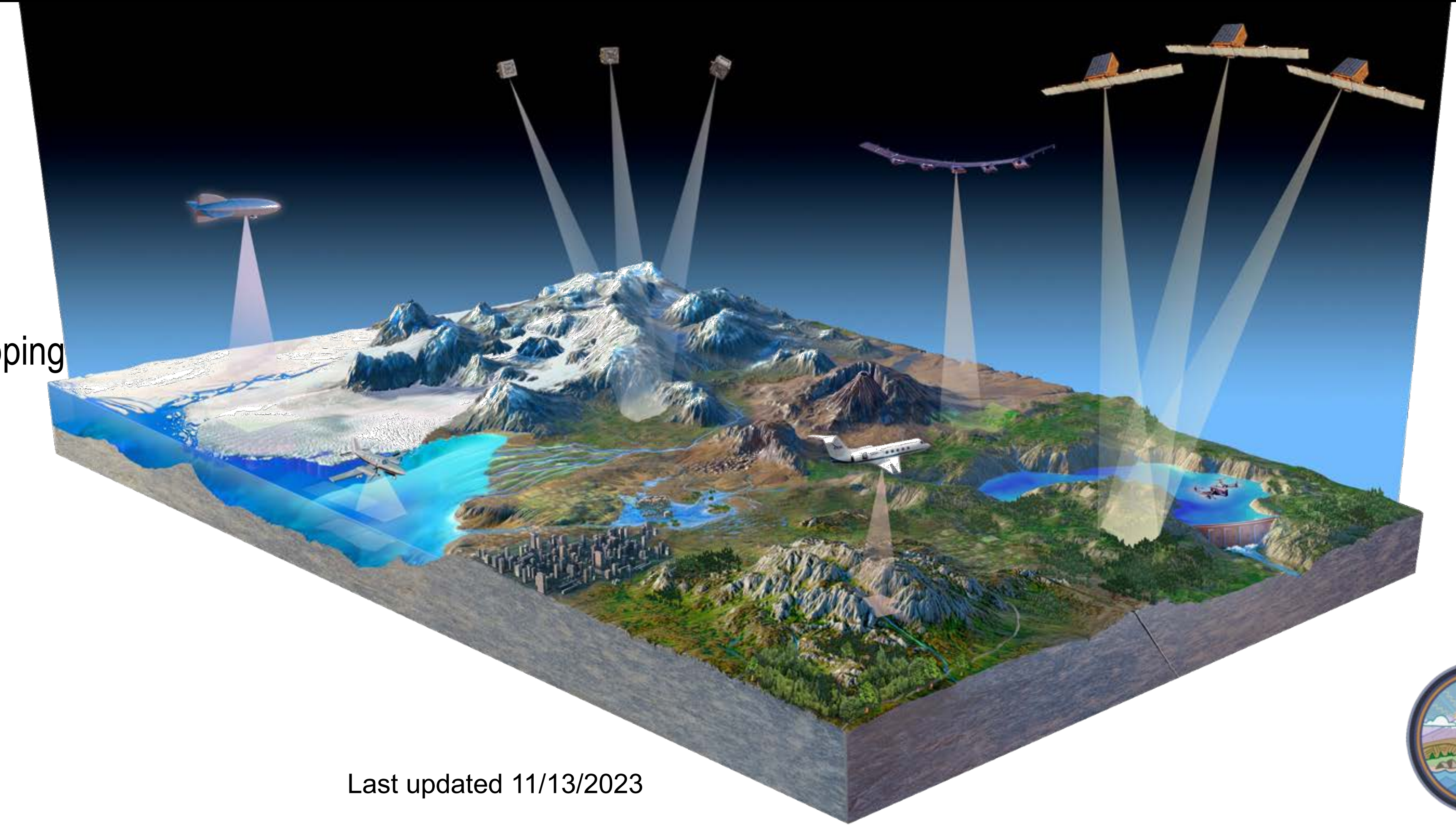
# NASA's Surface Topography and Vegetation Study

*Mapping Earth's changing surface and overlying vegetation structure*

# Measurement Needs



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# Science to Measurement Traceability

← NASA →

← Science Leads →

← Technology Leads →

← Architecture Leads →

| Science Goal | Science Objectives | Scientific measurement requirements: Observables | Scientific measurement requirements: Physical parameters | Instrument requirements | | Projected performance | Mission requirements (Top Level) |
|---|---|---|---|---|---|---|---|
| Understand how Earth's changing surface structure inform us about climate change, natural hazards, ecosystem habitats, and water availability | Understand how Earth's surface structure respond to tectonic and climate forces and what are the implications for geologic hazards | Digital surface model | Canopy height | Coverage | Global | 90% global coverage | Seasonal measurements |
| | Understand how Earth's vegetation is responding to climate change and what the feedbacks to the carbon cycle, hydrologic cycle, and ecosystems are. | Digital terrain model | Bare Earth topography | Vertical Resolution | 1 m | .5 m | 5 year duration to measure change |

Notional

etc.

# Guidance from 2017 Decadal Survey

| | |
|---|---|
| Surface Topography and Vegetation | • Improve understanding of measurement needs, through modeling and mission concept studies, to define which can be addressed with state-of-the-art technology and which require further development.<br>• Identify which measurement needs can be obtained through suborbital means and which require a space-based component. Identify those ready to compete in Venture-class opportunities.<br>• Identify any proposed components that could be ready for Earth System Explorer opportunity, for consideration by Midterm Assessment.<br>• Consider appropriate split between global observations from space and potentially less expensive and higher resolution airborne measurements.<br>• Look into obtaining commercial data to meet needs; define a pathway to ensure any identified spaceborne component matures toward flight in the following decade. |

# Guidance from 2017 Decadal Survey

**Science and Applications Value**. Characterizing surface topography with contiguous measurements at 5 m spatial resolution and 0.1 m vertical resolution will allow for detailed understanding of geologic structure and geomorphological processes, which in turn can provide new insights into surface water flow, the implications of sea-level rise and storm surge in coastal areas, the depth of off-shore water in near coastal areas, and more. In addition, assuming a lidar-based system, the implications for understanding ecosystem structure, and the associated cycling of carbon will be significant, as described earlier under the Terrestrial Ecosystem Structure Targeted Observable.

**Observational Approach, Technology Readiness, and Risk.** Space-based lidar offers the possibility of simultaneously mapping at high spatial resolution the vegetation structure and underlying "bare earth" topography across the globe. Such data would revolutionize our capability to understand how Earth's surface works, and greatly enhance our ability to predict hazards and anticipate the effects of surface change. Although increased topographic resolution from 30 m (SRTM) to 12 m (TanDEM-X) using synthetic aperture radar has been accomplished, much higher resolution is needed. Deriving vegetation height from radar involves much analysis. Optical methods, such as that provided by DigitalGlobe, have increased the resolution to 2-5 m, but such methods track canopy heights, not the ground surface in vegetated environments.

(page 155)

# STV Incubation Study (Table 3.2)

| PARAMETER | | ASPIRATIONAL | | | THRESHOLD | | |
|---|---|---|---|---|---|---|---|
| | | Median Need (rounded) | Most Stringent Need | Most Stringent Discipline | Median Need (rounded) | Most Stringent Need | Most Stringent Discipline |
| Coverage Area of Interest | % | 90 | 95 | C, H | 55 | 90 | C |
| Latency | Days | 5 | 0.5 | SE | 60 | 1 | SE |
| Duration | Years | 9 | 10 | SE, C, A | 3 | 3 | SE, V, C, CP |
| Repeat Frequency | Months | 0.1 | 0.03 | SE, A | 3 | 0.2 | SE |
| Horizontal Resolution | m | 1 | 1 | SE, C, H, A | 20 | 3 | SE |
| Vertical Accuracy | m | 0.2 | 0.03 | SE, C, H | 0.5 | 0.1 | C |
| Vegetation Vertical Resolution | m | 1 | 0.5 | H, A | 2 | 0.2 | CP |
| Bathymetry Max Depth | m | 25 | 30 | C, CP | 10 | 10 | SE, C, CP |
| Geolocation Accuracy | m | 1 | 1.0 | SE, V, H, A | 5 | 3 | SE, V |
| Rate of Change Accuracy | cm/y | 5 | 1 | SE, C, A | 35 | 1 | SE |

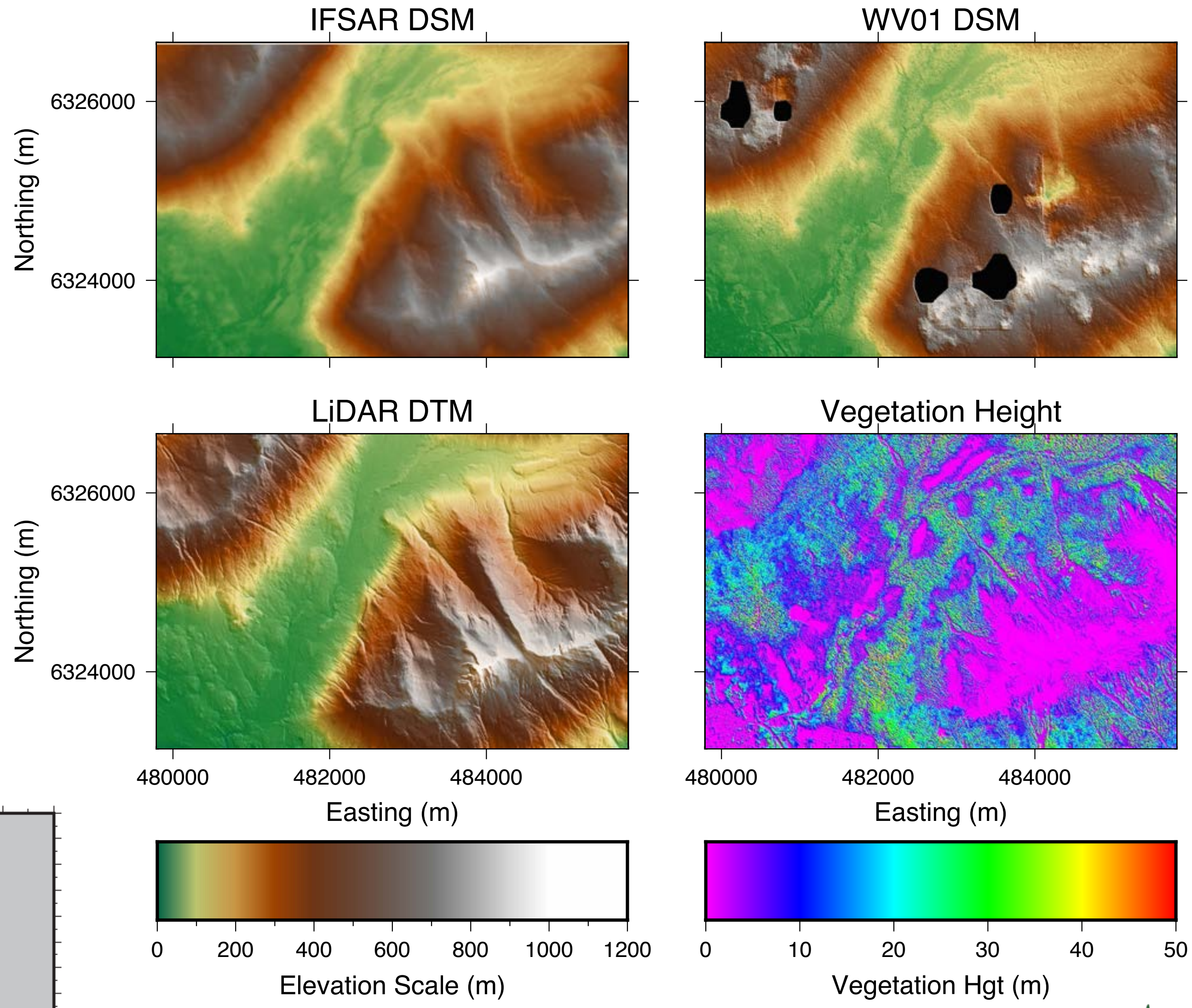
# Example: Sitka Alaska

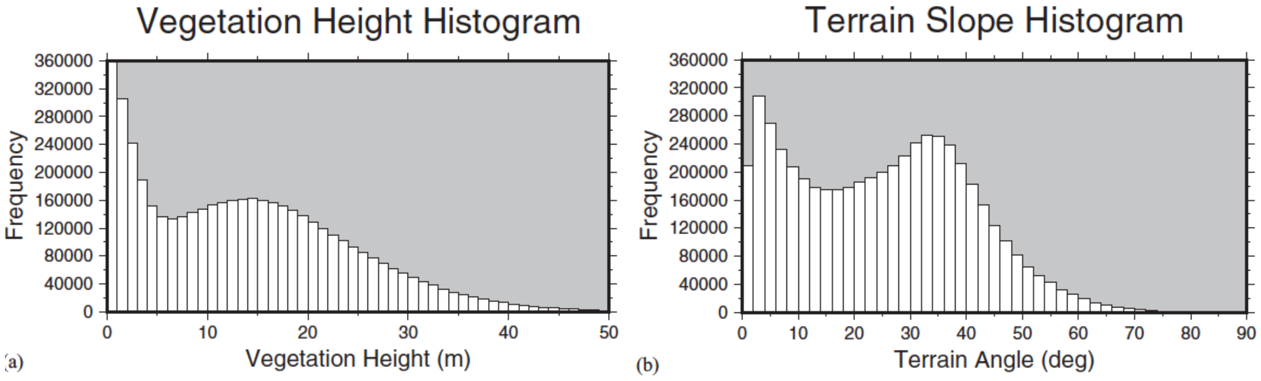
**Airborne Lidar**
- May 2, 2016
- Helicopter-based. Nominal 25 pts/$m^2$

**IFSAR DEM**
- 2014 Airborne IFSAR (Fugro)
- Dual-band (X and P) GeoSAR Platform
- 5 m grid postings (DSM and DTM)

**ArcticDEM**
- Worldview – August 19, 2015
- SETSM 2 m grid postings
- Vertical registration with 72 ICESat GCPs

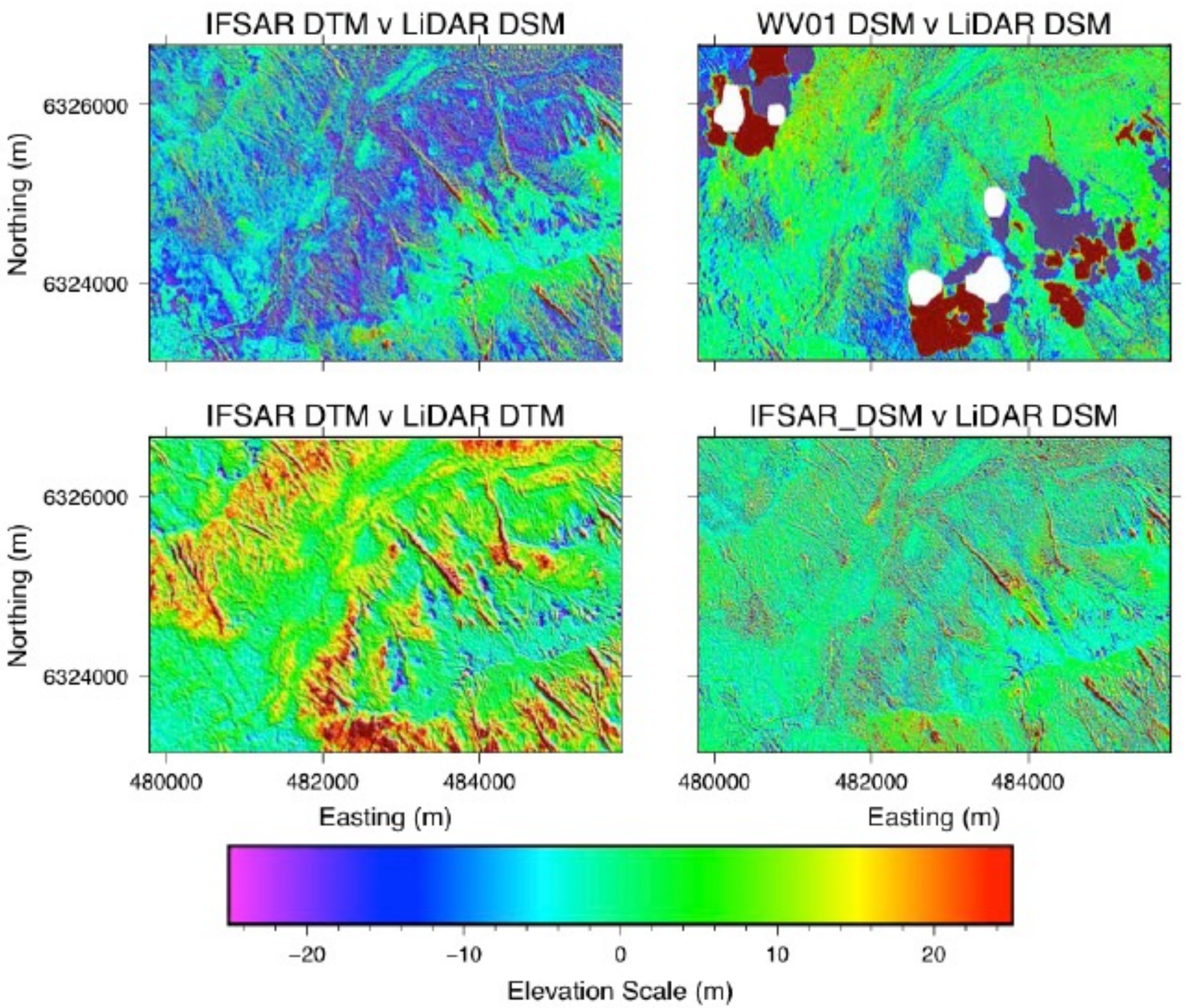
**Study Area**
- Approximately 25 $km^2$

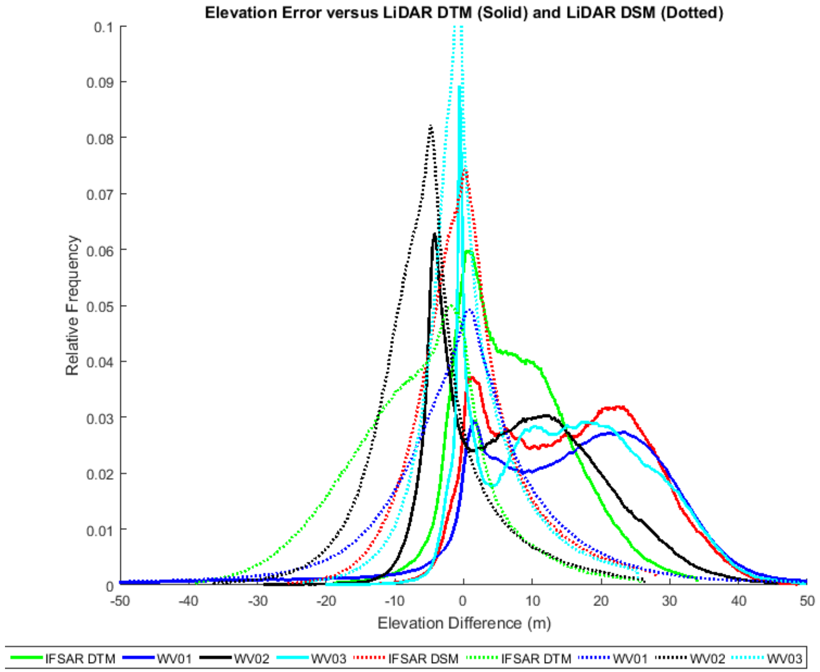


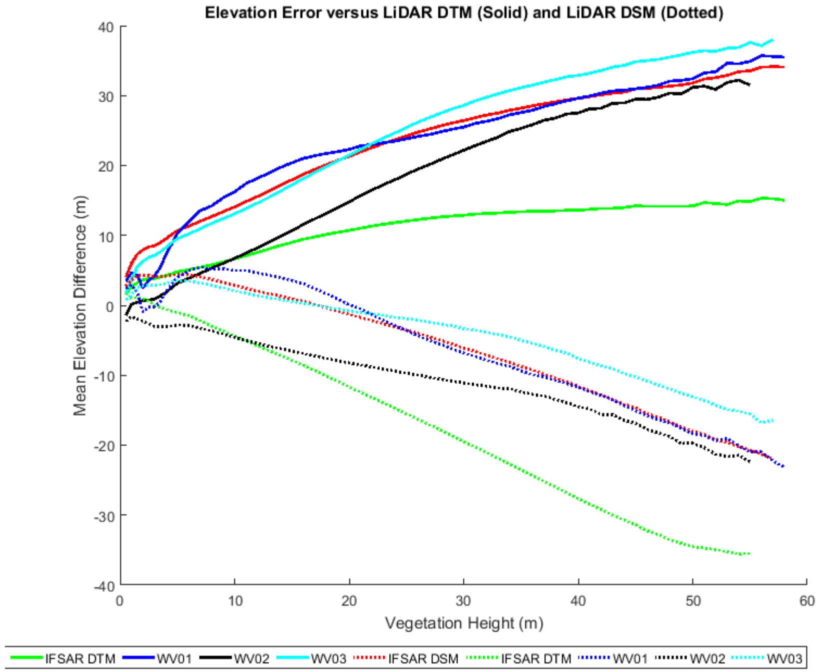




Glennie, C. (2018). Arctic high-resolution elevation models: Accuracy in sloped and vegetated terrain. *Journal of Surveying Engineering*, *144*(1), 06017003.

# Results


IFSAR DTM v LiDAR DSM
WV01 DSM v LiDAR DSM
IFSAR DTM v LiDAR DTM
IFSAR_DSM v LiDAR DSM
Northing (m)
6326000
6324000
480000
482000
484000
Easting (m)
−20
−10
0
10
20
Elevation Scale (m)


Elevation Error versus LiDAR DTM (Solid) and LiDAR DSM (Dotted)
Relative Frequency
Elevation Difference (m)
IFSAR DTM
WV01
WV02
WV03
IFSAR DSM
IFSAR DTM
WV01
WV02
WV03


Elevation Error versus LiDAR DTM (Solid) and LiDAR DSM (Dotted)
Mean Elevation Difference (m)
Vegetation Height (m)
IFSAR DTM
WV01
WV02
WV03
IFSAR DSM
IFSAR DTM
WV01
WV02
WV03

# Results Continued…

**Table 3: Statistics of DEM Errors versus LiDAR DSM and DTM reference surfaces. Outliers were considered to be $> 3\sigma$ (three standard deviations) from the mean, and have been excluded from the calculation of statistics.**

| | | Mean | Sigma | Max | Min | Outliers | Total |
|---|---|---|---|---|---|---|---|
| **LIDAR DTM** | IFSAR_DSM | 15.26 | 11.02 | 48.58 | -18.00 | 6009 | 5236387 |
| | IFSAR_DTM | 7.34 | 8.22 | 33.89 | -18.82 | 52347 | 5190049 |
| | WV01 | 15.75 | 30.47 | 192.05 | -164.46 | 183094 | 4912844 |
| | WV02 | 8.07 | 11.19 | 45.41 | -29.29 | 18569 | 3766238 |
| | WV03 | 14.71 | 11.60 | 49.67 | -20.26 | 3223 | 3281751 |
| **LIDAR DSM** | IFSAR_DSM | 0.65 | 7.95 | 27.95 | -25.75 | 80446 | 5161954 |
| | IFSAR_DTM | -6.91 | 10.10 | 25.72 | -39.03 | 50216 | 5192184 |
| | WV01 | 1.02 | 29.39 | 174.43 | -175.57 | 185314 | 4910675 |
| | WV02 | -5.35 | 8.26 | 26.22 | -36.47 | 50378 | 3734441 |
| | WV03 | 0.48 | 7.02 | 25.26 | -23.49 | 62354 | 3222639 |

# What Are We Missing?

## Stereo Imaging

- Top Surface Model Only
- Very Little Penetration in Vegetated Areas
- Correlation Process Rounds Edges

## IFSAR

- DSM Shows Some Penetration
- DTM Above Actual Ground Level
- Are Offsets Consistent or Able to Be Modeled?

## Lidar

- Good Vegetation Penetration and Ground Definition
- Automated Classification Still Challenging
- Global Acquisition Possible?

# What Are the Needs?

**Type of Observing System?**

- Likely Requires Combination of Technologies
- Which Ones?

**Fusion Algorithms**

- Take Advantage of Each Systems Strengths
- Automated Separation of Ground and Vegetation

**Airborne Campaigns**

- Collection Using all Possible Technologies
- Areas of Interest?
- Leveraging Existing Data Sources?

# USGS 3DEP Lidar Coverage