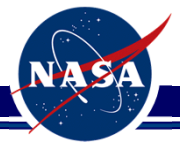


High Fidelity 3D Reconstruction

Adnan Ansar
Jet Propulsion Laboratory, California Institute of Technology

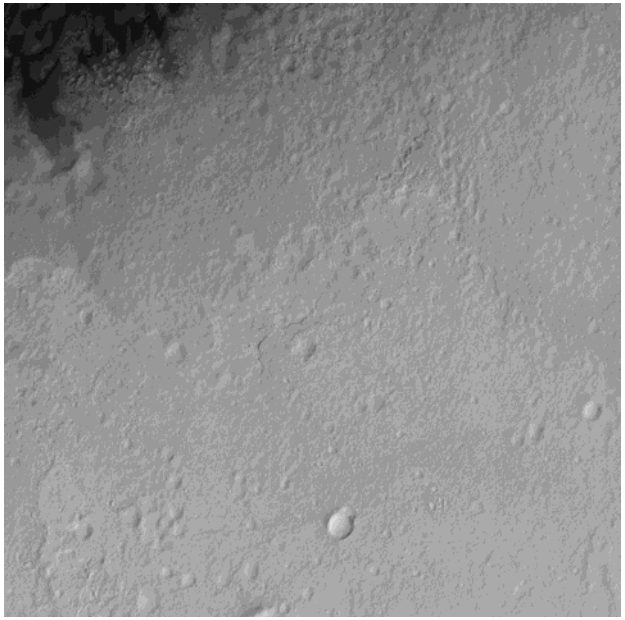
KISS Workshop: Gazing at the Solar System
June 17, 2014

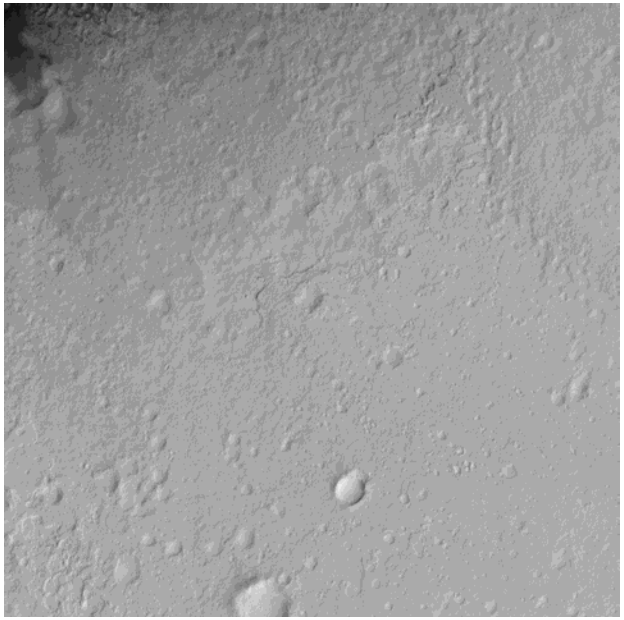
Overview

- Approaches to higher fidelity structure recover
  - Imagery with higher native resolution
    - Super resolution as an option
  - Enhancements to binocular stereo
    - Image enhancement via pre-filtering
    - More sophisticated sub-pixel interpolation
  - Multi-view / Multi-instrument reconstruction
    - Handling cross-modality
  - Improvement of state information
  - Direct adjustment of DEM with image consistency constraint

High resolution processing

- Recovery of fine structure surface features
- Test case: HiRISE images PSP_010573_1755 & PSP_010639_1755

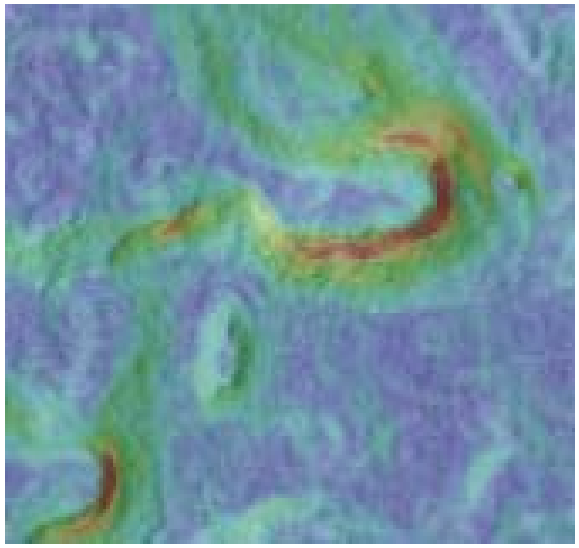




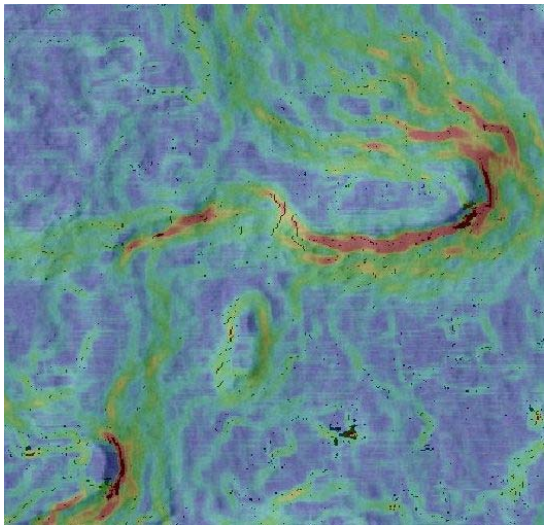
High resolution processing

- Slopes computed from USGS DEM (1m posts) vs. in-house DEM (0.3m posts)

Ortho-photo



1m DEM



0.3 m DEM

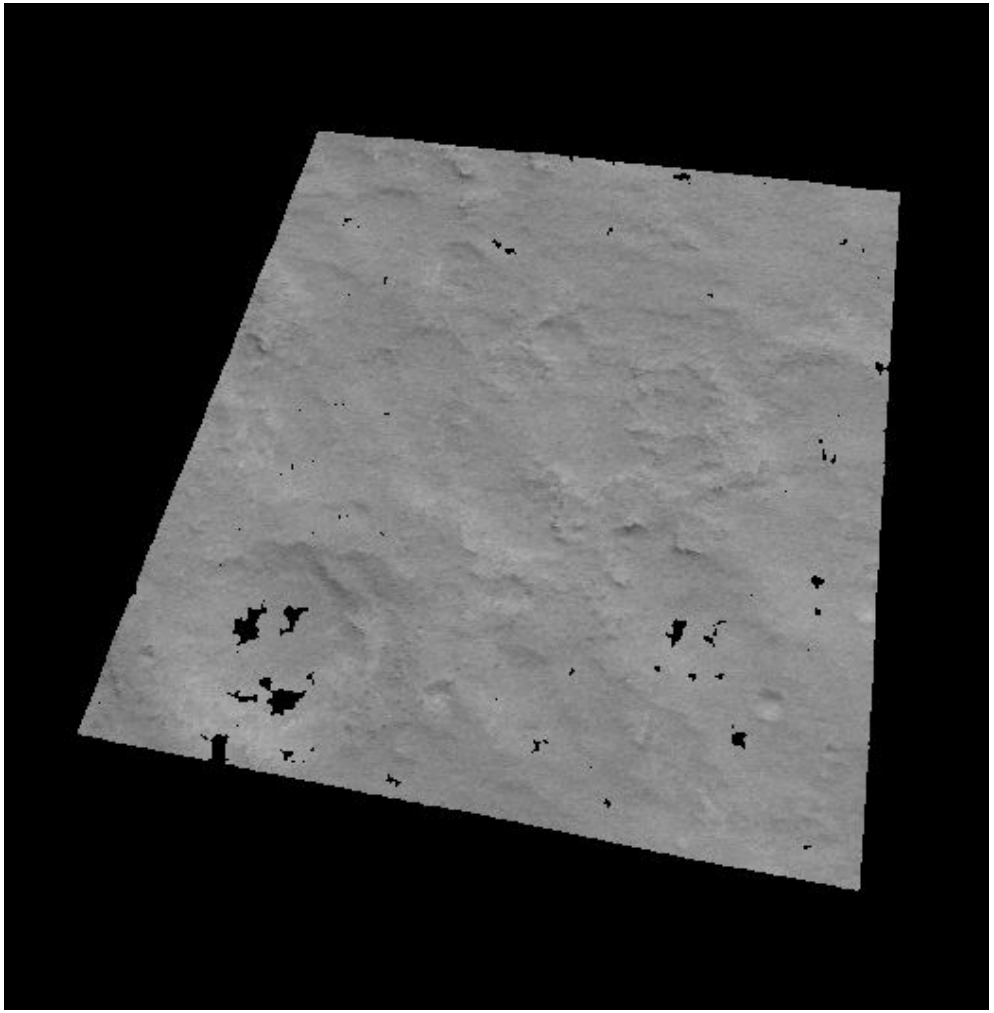
High Resolution Processing

- Comparison of slopes derived from 1m DEM and from 0.3 m DEM to rover telemetry at end for SOL for 8 randomly chosen SOLs.

SOL	1m DEM Derived Slope	0.3m DEM Derived Slope	Slope from Rover Telemetry
15	8.79	4.13	4.19
41	3.04	2.70	2.08
42	3.89	3.94	4.24
43	2.12	3.88	3.69
52	5.59	2.69	2.63
55	3.55	4.94	5.66
102	8.01	9.64	9.41
508	4.71	3.77	3.49

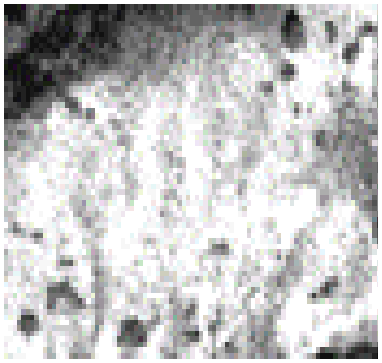
High Resolution Processing

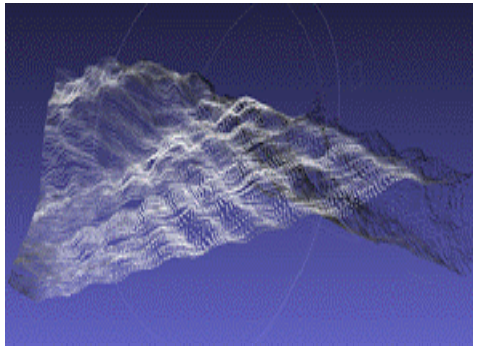
- Mars surface patch (300 m x 300 m at ~1/3 m/pxl resolution)



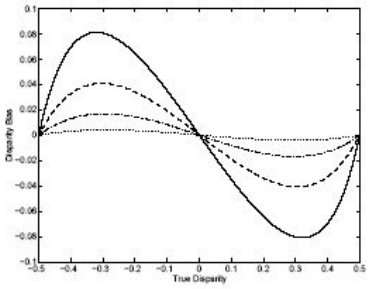
Subpixel refinement

- Correlators find integer-level matches between images
- Subpixel refinement typically depends on quadratic fit to correlation scores.
  - Still biased towards integer values: pixel locking

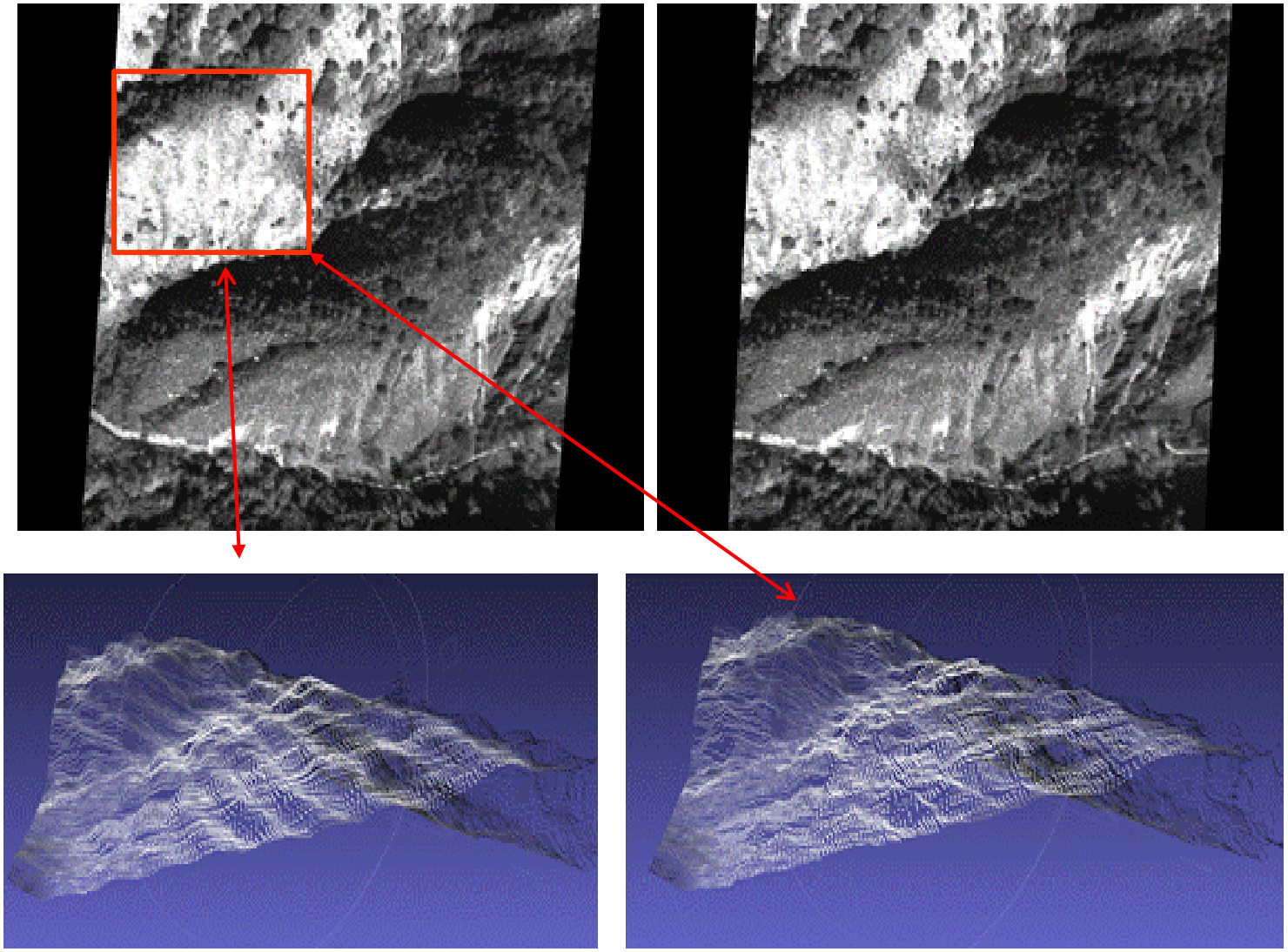




- Incorporate autocorrelation to determine disparity bias model and correct

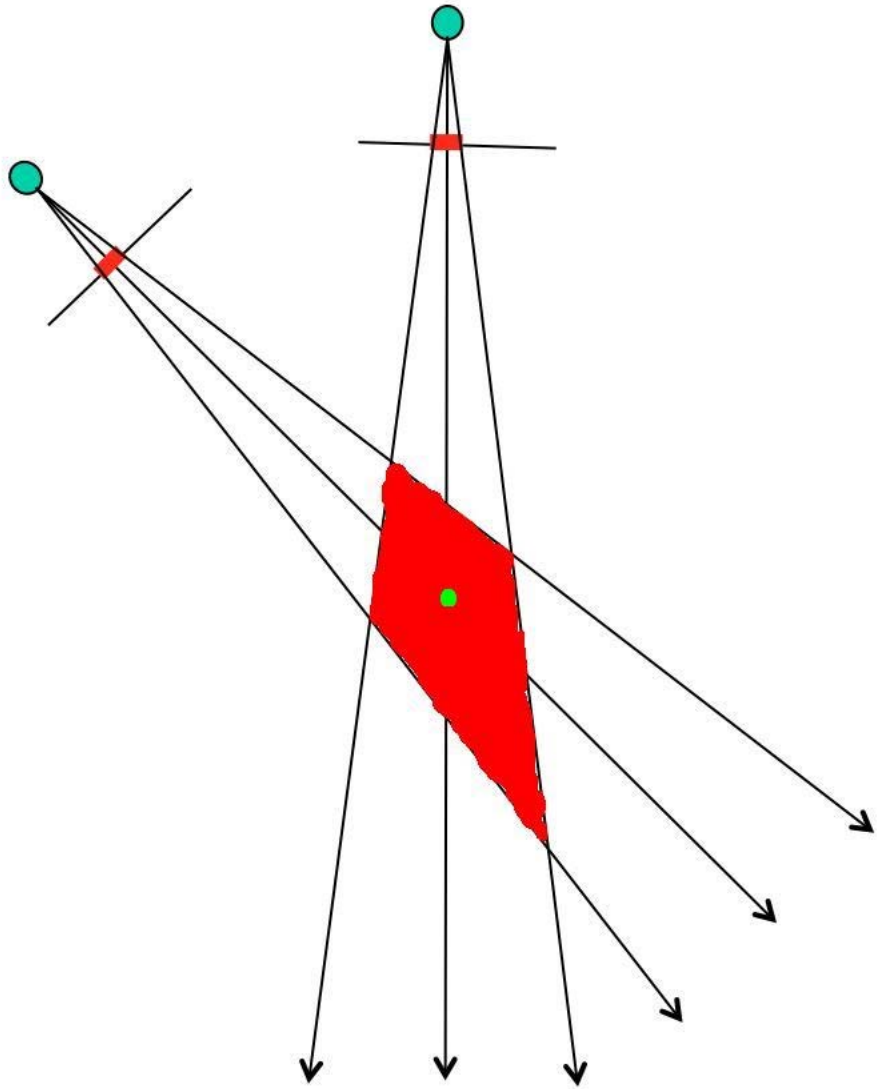


SSD vs SBRA on Real Images over Natural Terrain



Gain from multi-view stereo

- Uncertainty in pointing / position knowledge
- Each pixel subtends an angle
- Uncertainty in localization during match (image processing)



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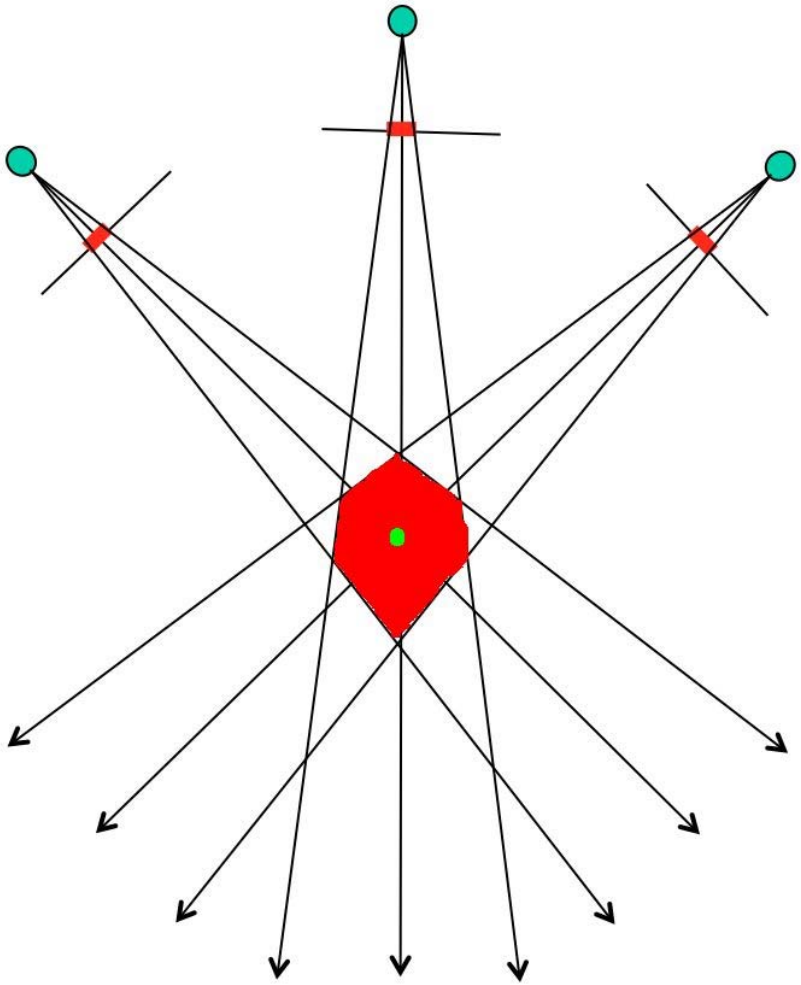
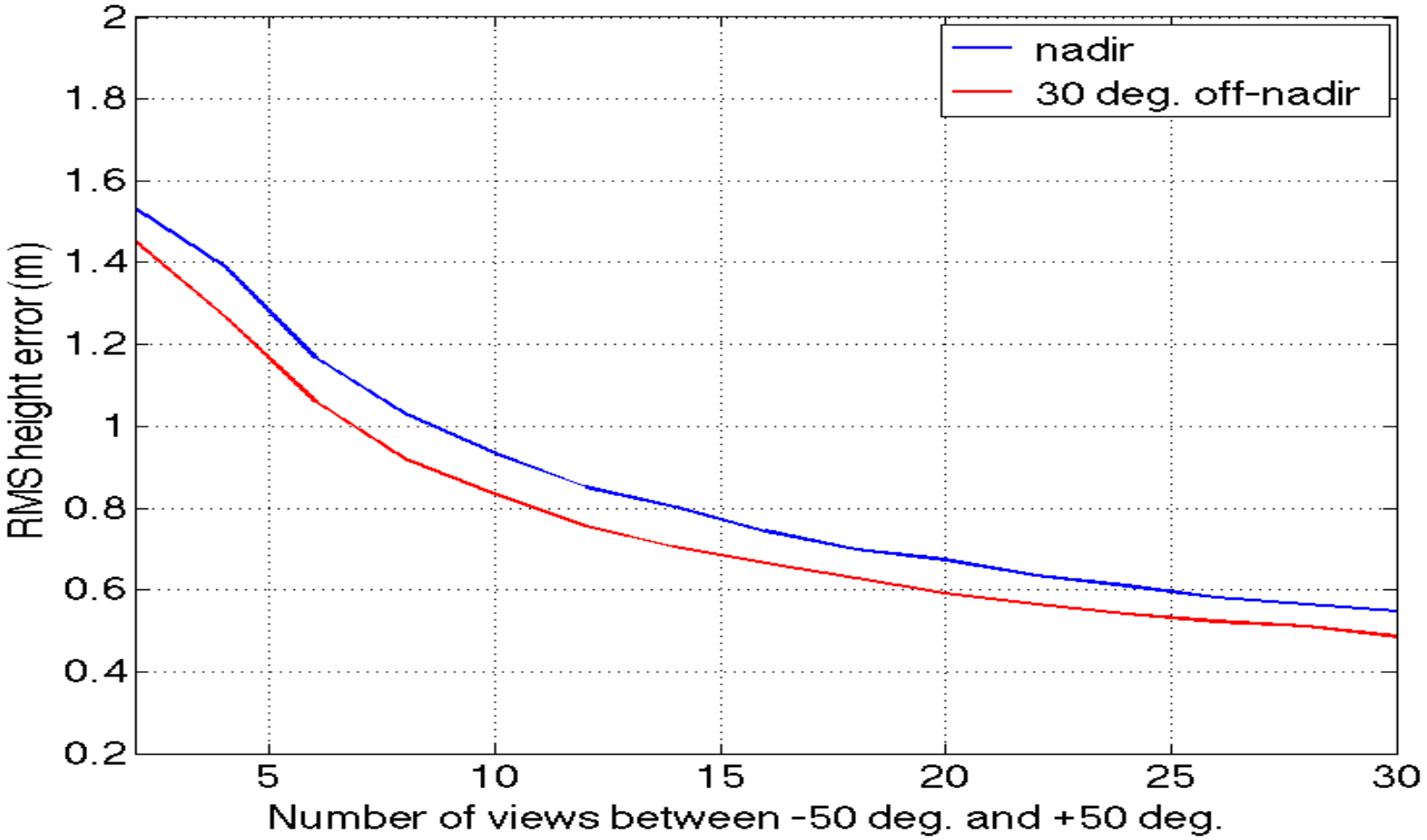


Gain from multi-view stereo

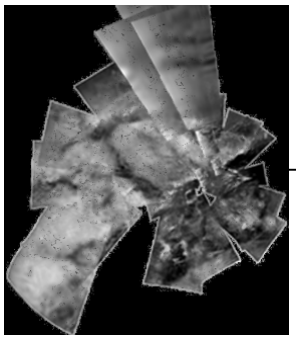
- Monte-Carlo simulation for 12MP sensor at 0.3 deg FOV, at 400km orbit



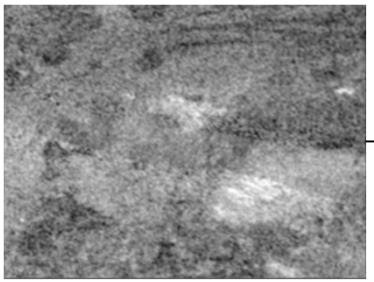
Feasibility of cross-modal matching

Titan example:

DISR (660 – 1000 nm, visible – near IR) + SAR (2.18 cm Ku-band)

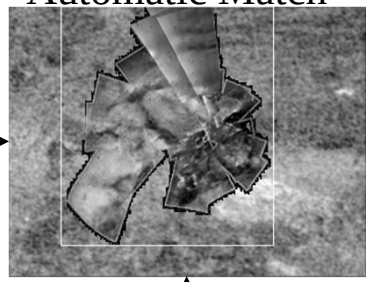


DISR Mosaic

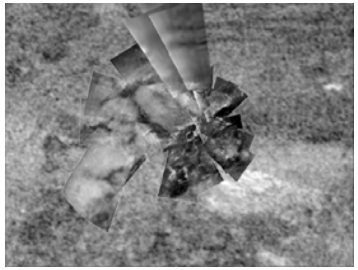


Orbital SAR

Automatic Match

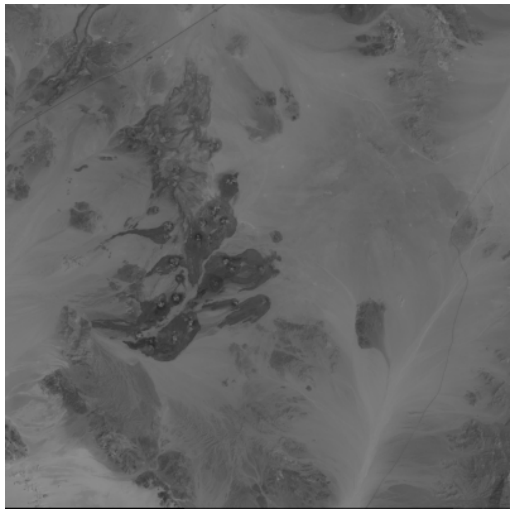


Hand Match



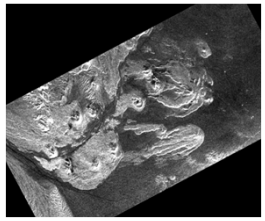
Automatic registration is qualitatively indistinguishable from hand registration

Matching in cross-modal case



ASTER (SWIR, 1600-1700 nm)

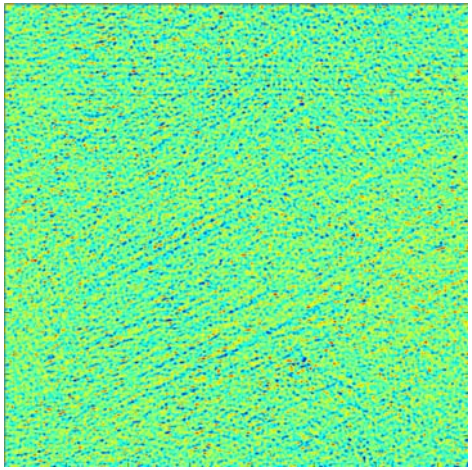
+



C-band Airborne SAR (5.8 cm, TP)

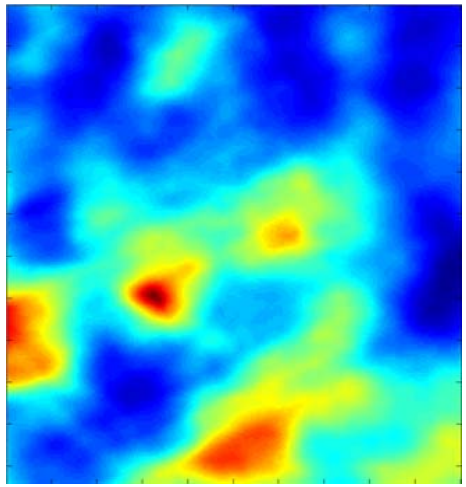
→ Correlation:

Prefilter = Local intensity normalization



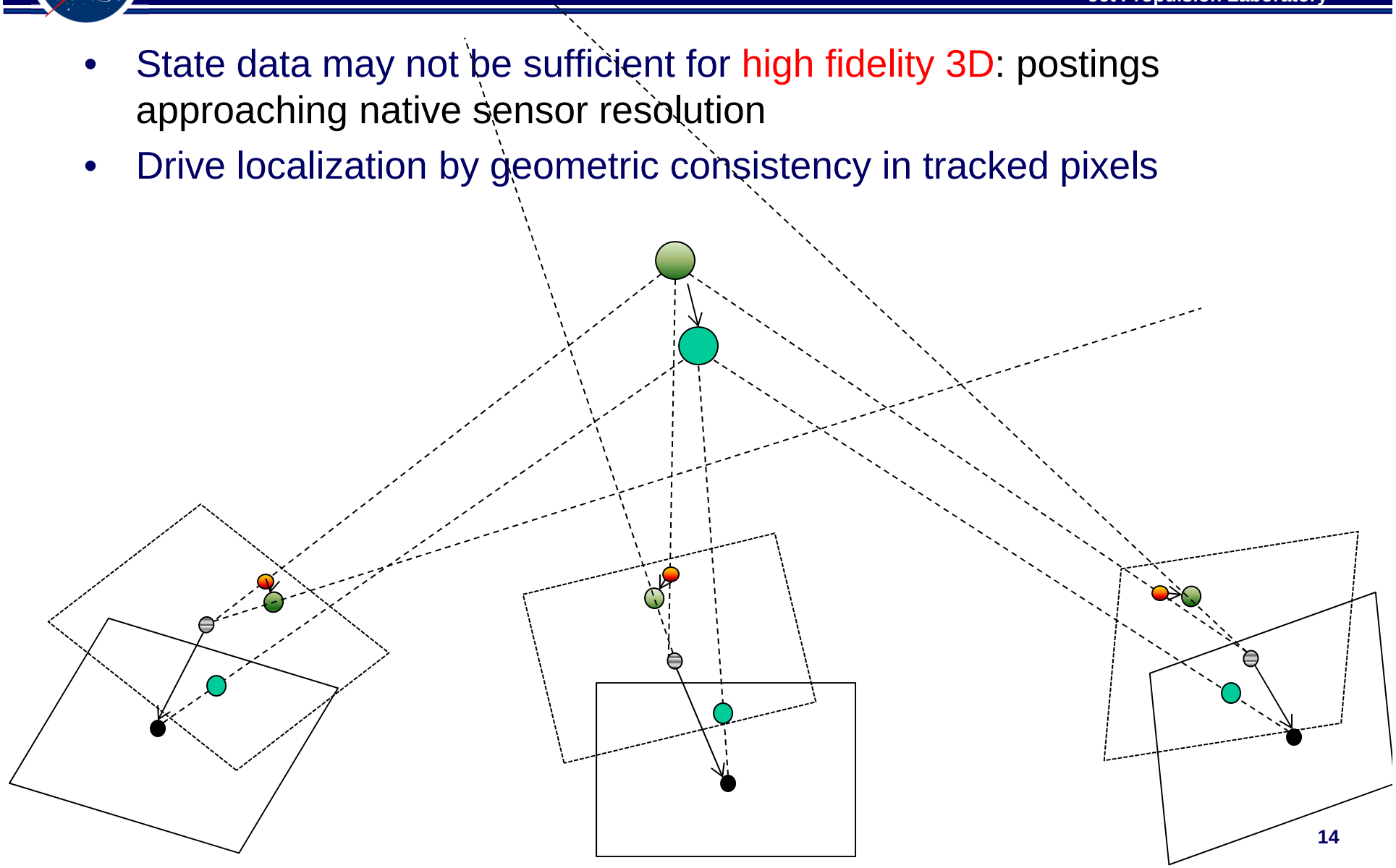
→ Mutual information:

No image prefilter

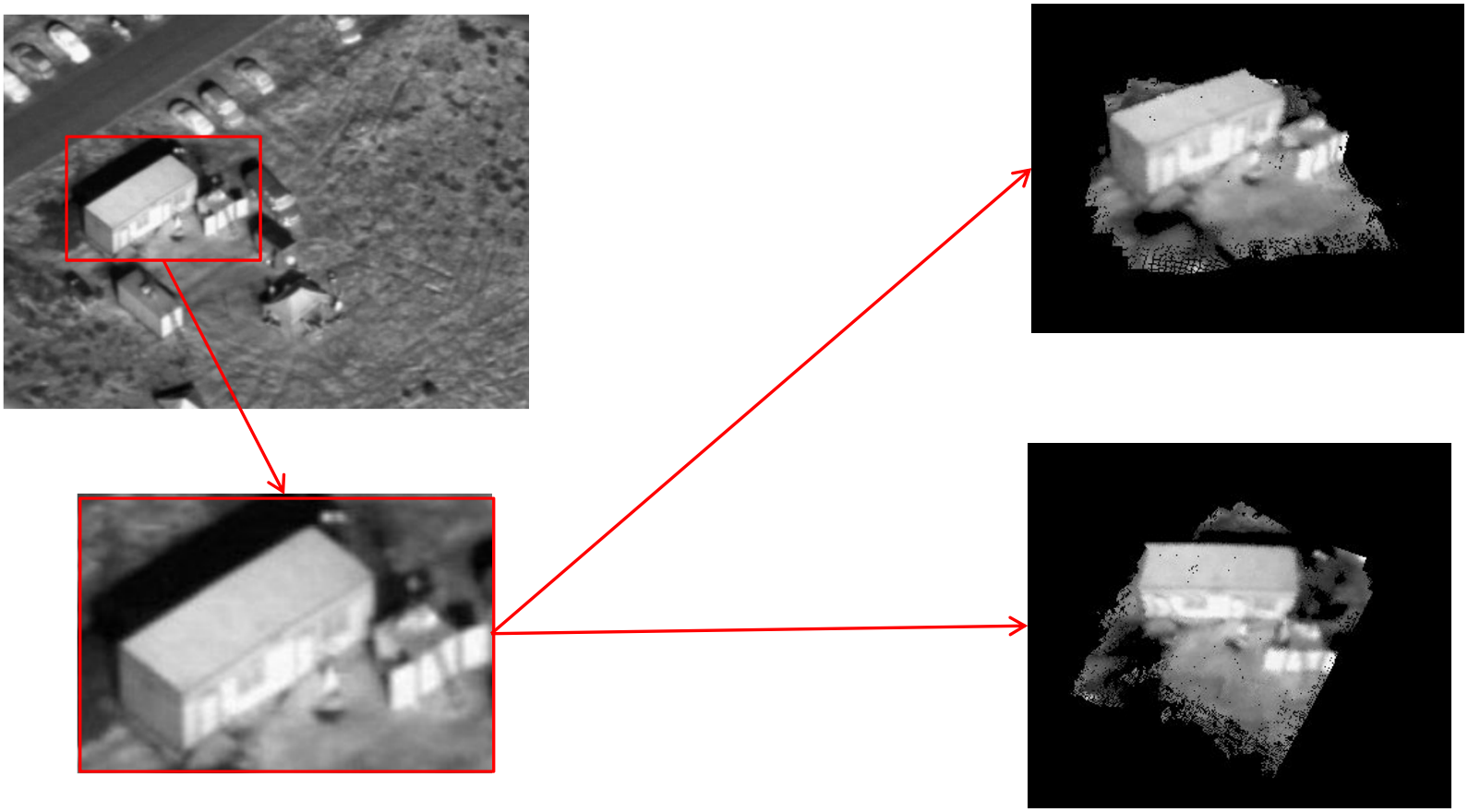


Camera Localization / Bundle Adjustment

- State data may not be sufficient for high fidelity 3D: postings approaching native sensor resolution
- Drive localization by geometric consistency in tracked pixels

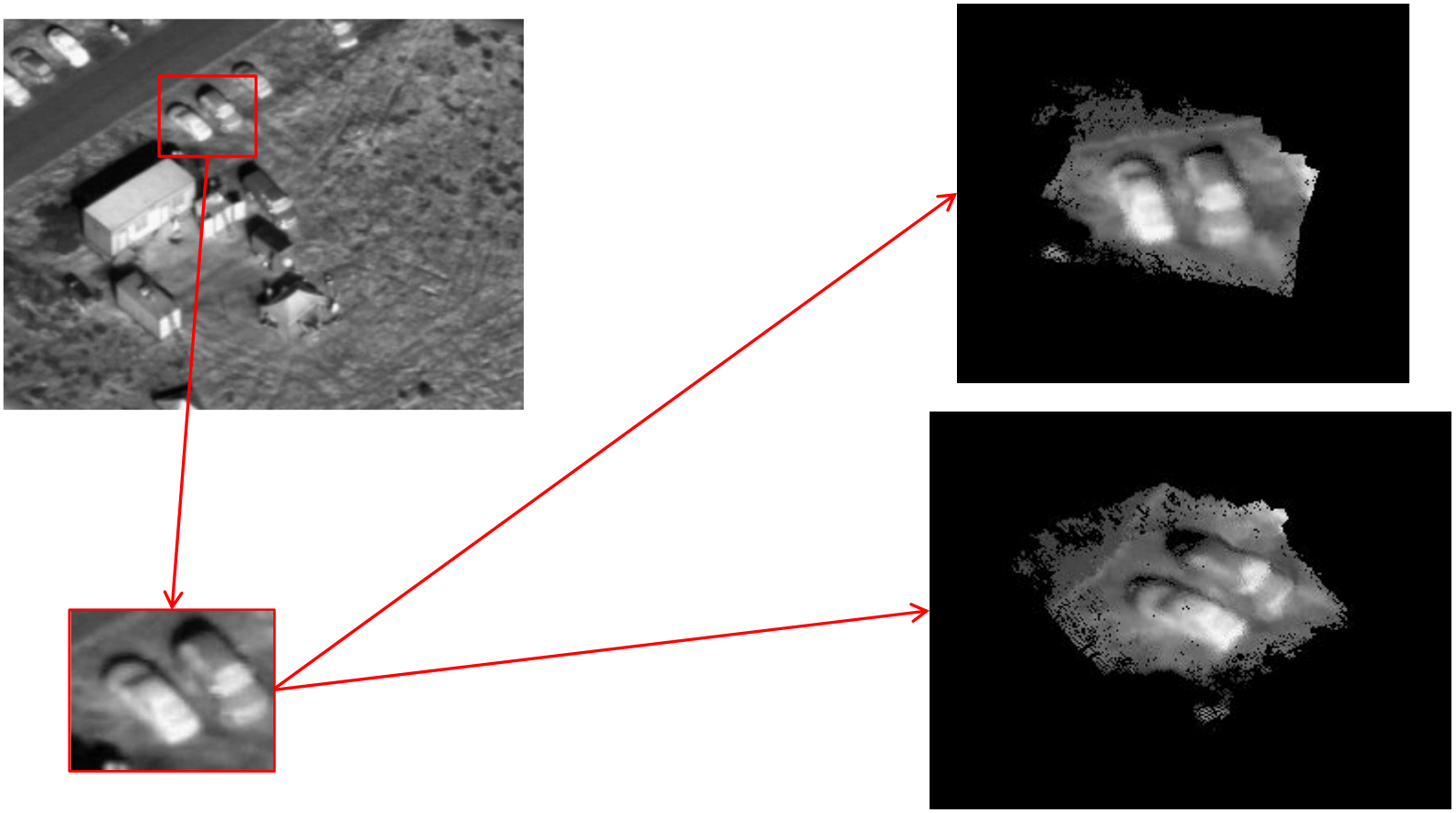


Reconstruction from UAV (low alt.)



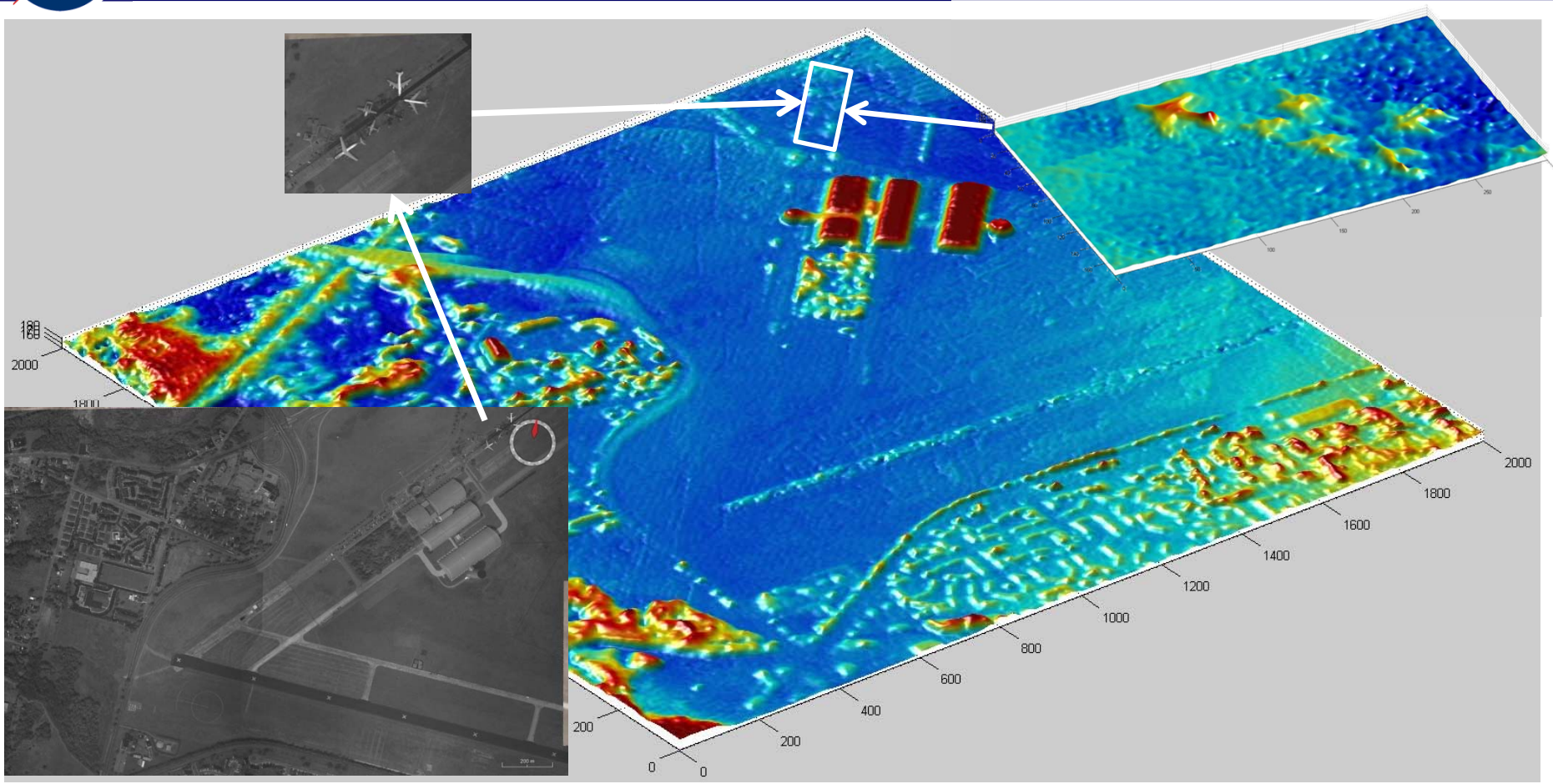
JPEG compressed VGA images with no prior state information

Reconstruction from UAV (low alt.)



JPEG compressed VGA images with no prior state information

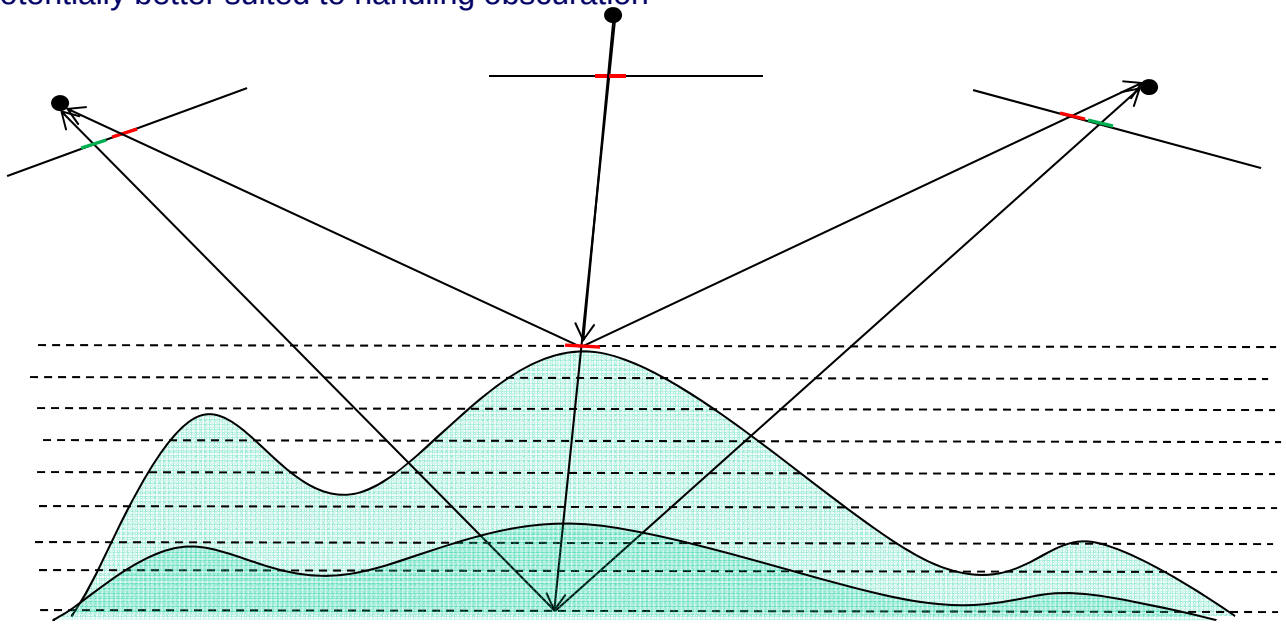
Reconstruction from AngelFire (high alt.)



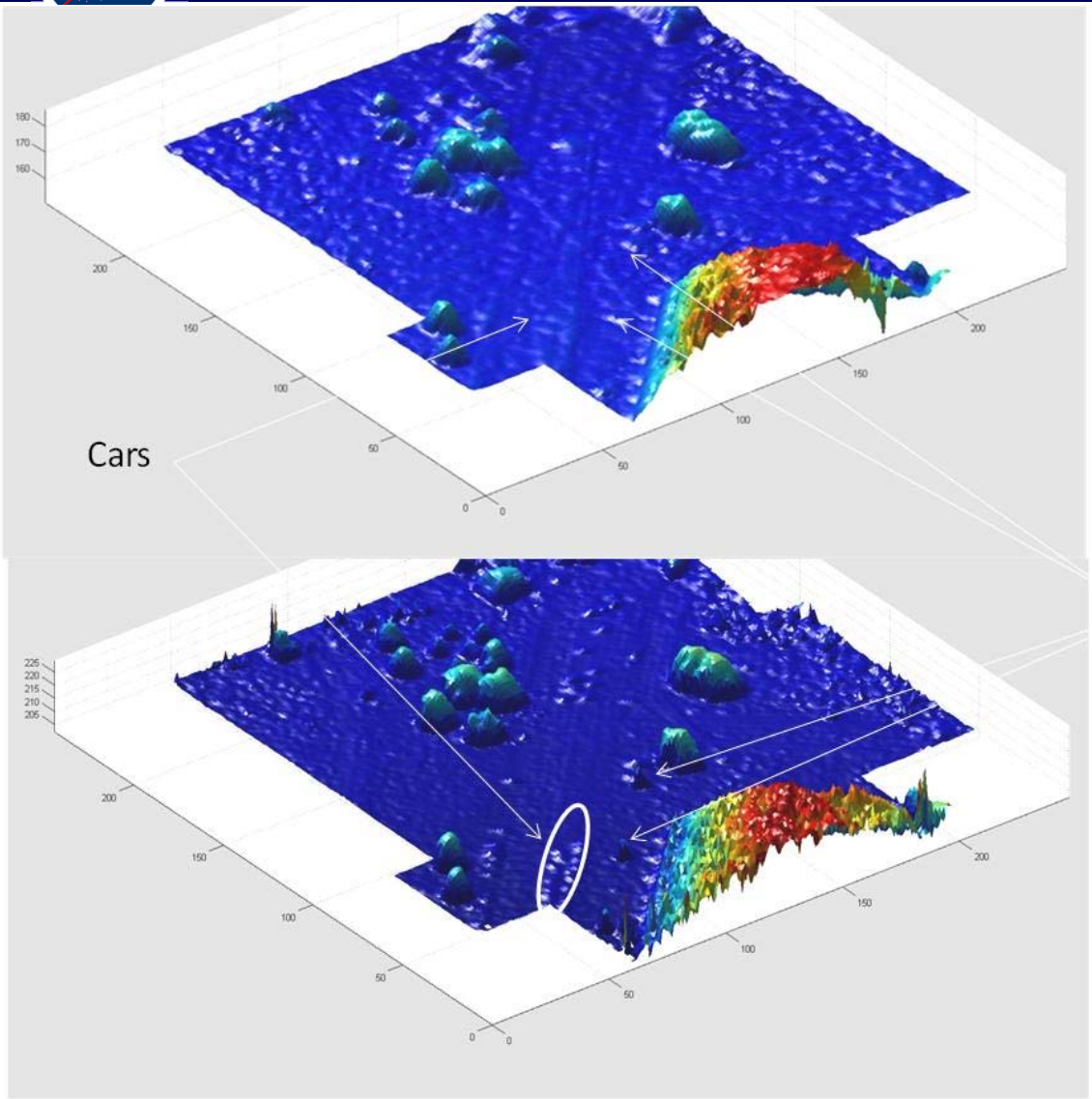
Publically Released Imagery of Wright-Patterson AFB taken from AngelFire platform.
Reconstruction based on subsampled orbit

DEM Refinement

- Basic principle: Dense reconstruction by triangulation of corresponding points across multiple images
- Each pixel in a reference image is assigned to a particular 3D plane (or distorted DEM) according to consistency across images.
- Benefits:
  - Simultaneous (not pairwise) use of all data: No merging of pairwise results
  - No need for pairwise rectification for near real-time performance
  - Intrinsically better suited to wide viewpoint diversity
  - Potentially better suited to handling obscuration



Reconstruction from AngelFire (high alt.)

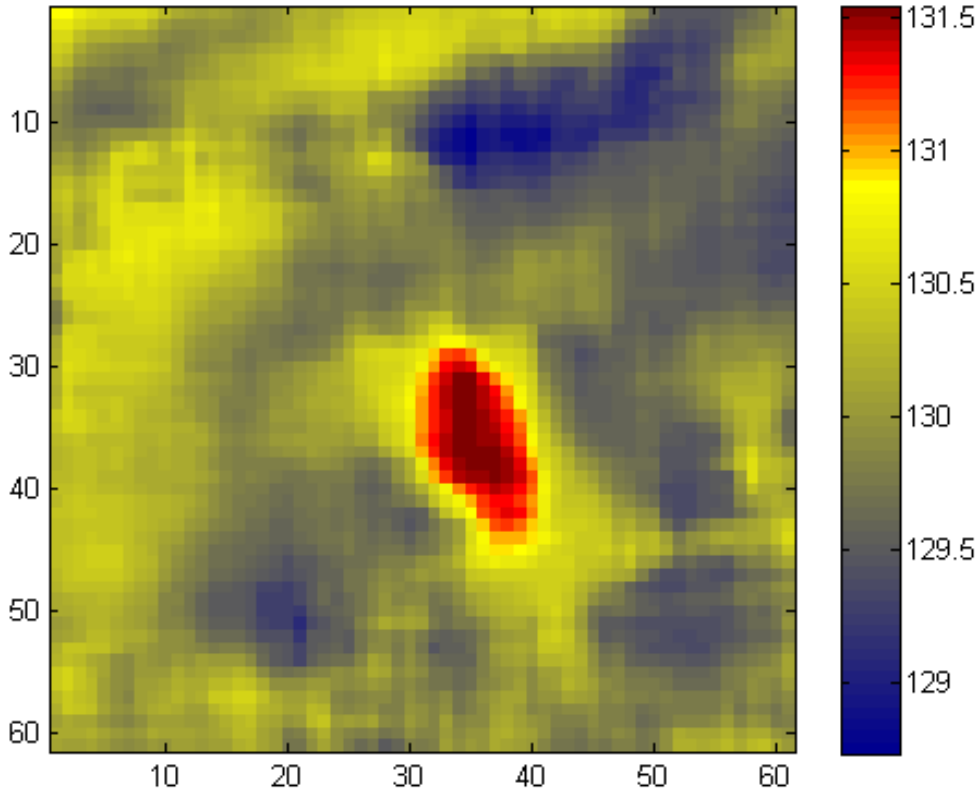


Improved Image-Based, automated, 3D generation
– top picture, stereo based
structure from motion
– bottom picture, multi-base
line structure from motion (more discrimination closer to the ground)

The multi-baseline technique
provides better height estimation (over a specified range) and spatial resolution. Lamp posts and cars can be picked out in the bottom image but not in the top

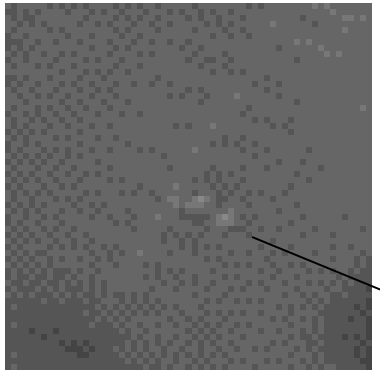
Reconstruction from AngelFire (high alt.)

Multi-baseline stereo algorithm rectifies arbitrarily many images to plane slices parallel to ground and picks best slice for each pixel

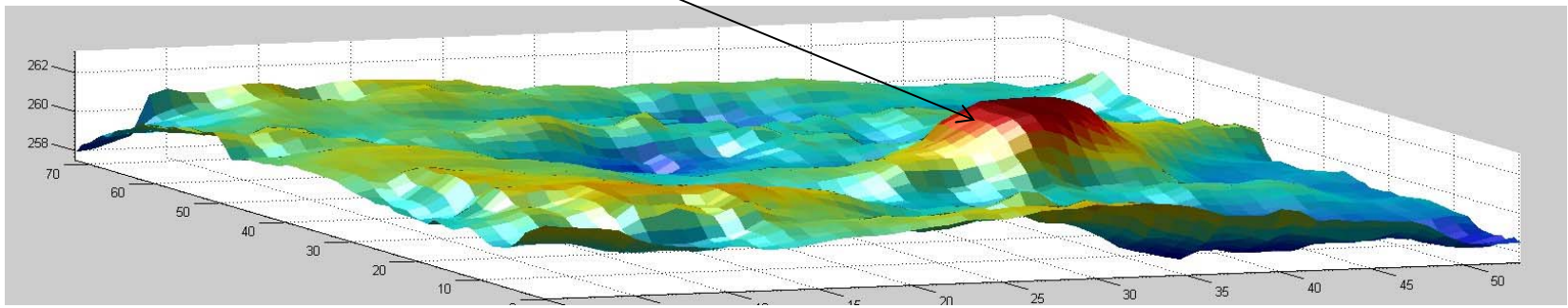


Elevation map for cropped region around car. Area around car ~1.5 m higher than neighboring ground plane. Higher image resolution might address some remaining noise issues.

Reconstruction from AngelFire (high alt.)

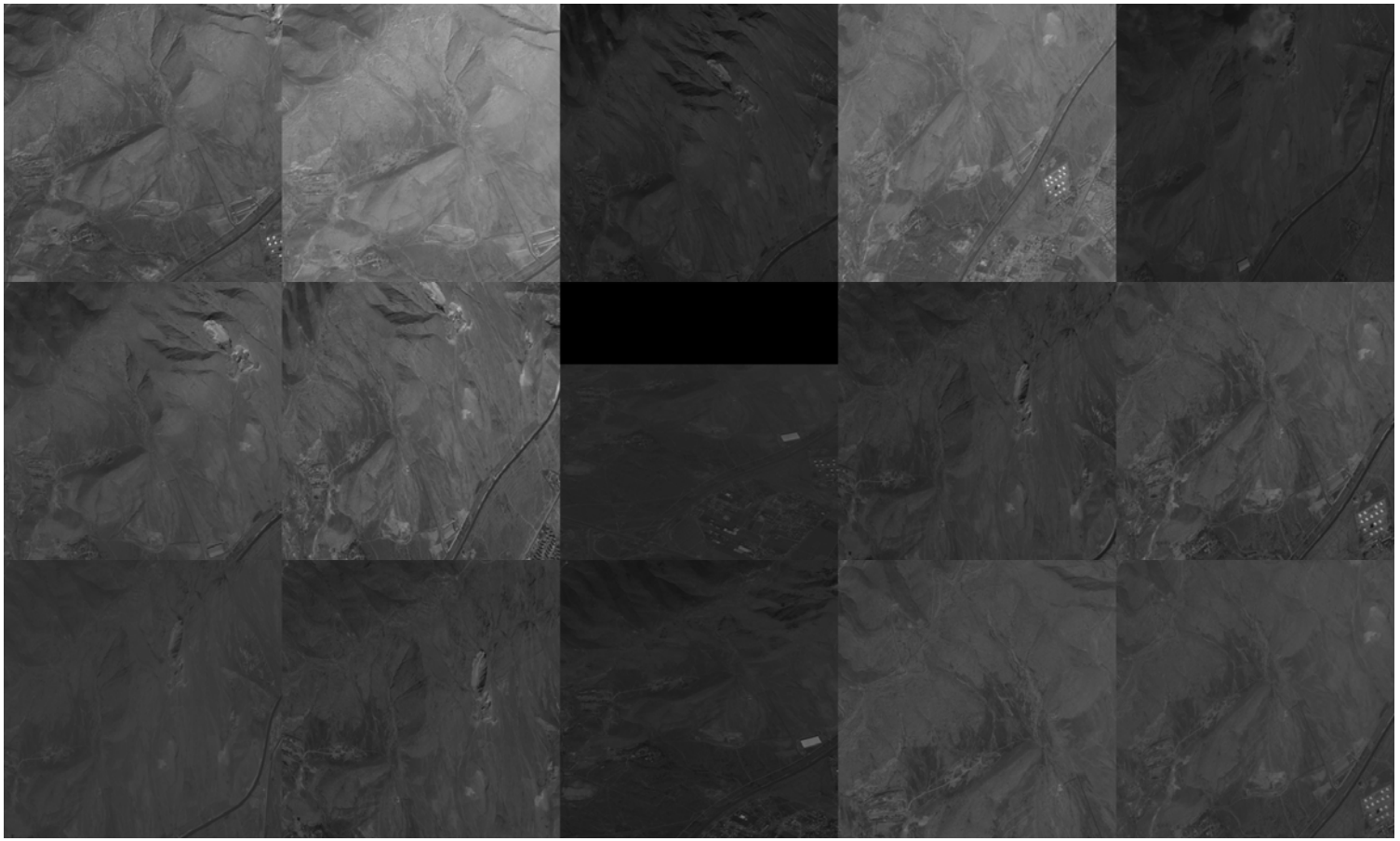


Full resolution image on right, but data actually processed at 1m GSD.



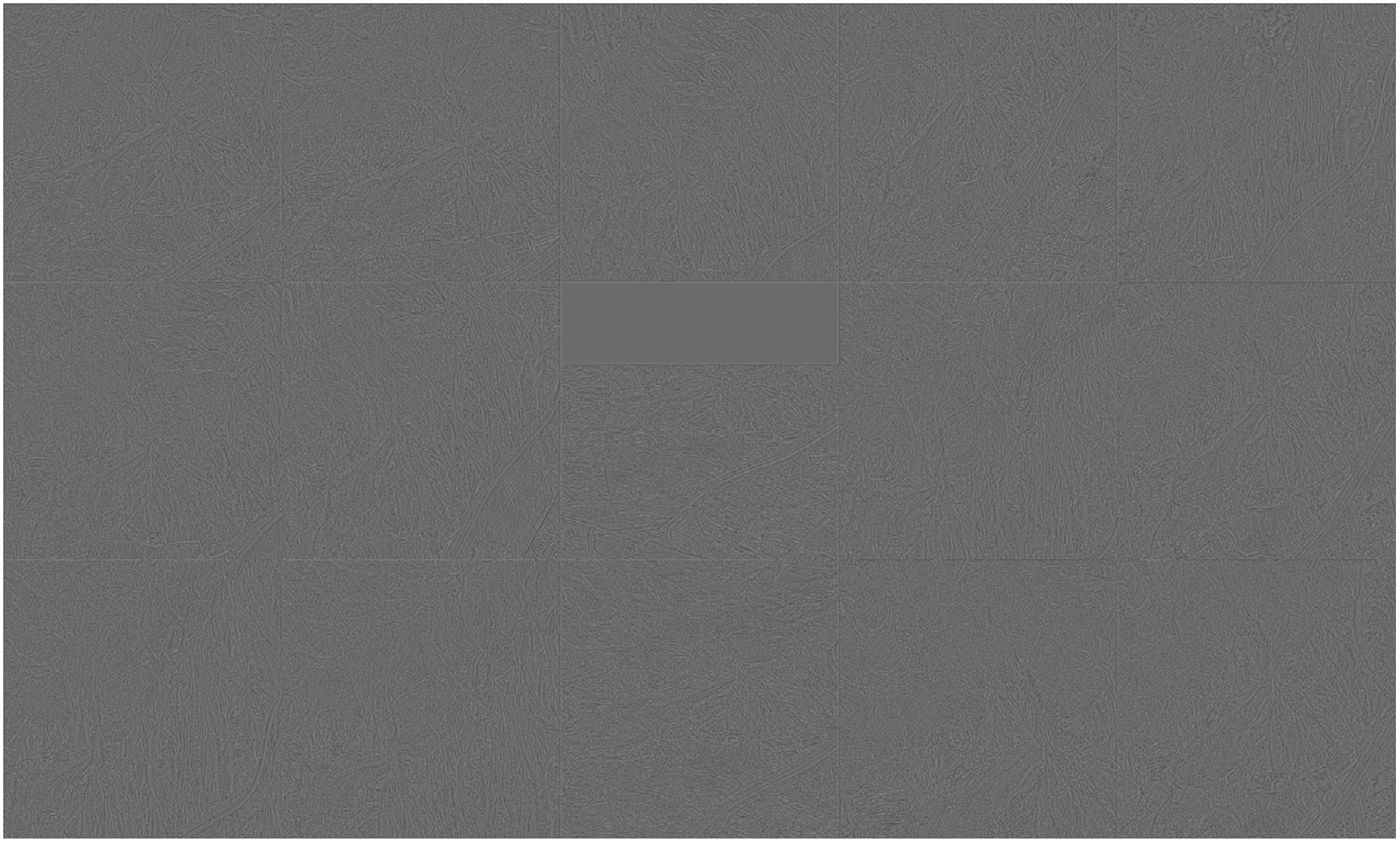
Reconstruction from World View 2 (orbital)

- 15 WV2 images with large angle diversity.



Reconstruction from World View 2 (orbital)

- 15 WV2 images after pre-filtering.



Reconstruction from World View 2 (orbital)

- Reconstruction from 15 WV2 images.
- Initialized using Bundle Adjustment and binocular stereo for coarse DEM