SAR Image Simulation Study

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Objectives

•Develop a tool to simulate a SAR image, given sensor parameters, sensor trajectory, and a DEM (digital elevation model)

•Primary consideration is image geometry, secondary consideration is image radiometry

•Visualize and understand layover / relief displacement

•Primary purpose is to simulate systems such as ERS-1,2. We are not trying to simulate higher resolution airborne systems where urban features and manmade infrastructure become important, and difficult to model, considerations

•Examine applications of such simulated imagery

•Compare (geometry of) actual images to simulated images to evaluate understanding of sensor models

Review of prior work

•Kaupp, V., et al, 1983, “Simulation of Spaceborne Stereo Radar Imagery: Experimental Results”, IEEE Transactions on Geoscience and Remote Sensing, vol 21, no 3, July, 1983

•Pairman, D., Belliss, S., McNeill, S., 1997, “Terrain Influences on SAR Backscatter around Mt. Taranaki, New Zealand”, IEEE Tranasctions on Geoscience and Remote Sensing, vol 35, no 4, July 1997

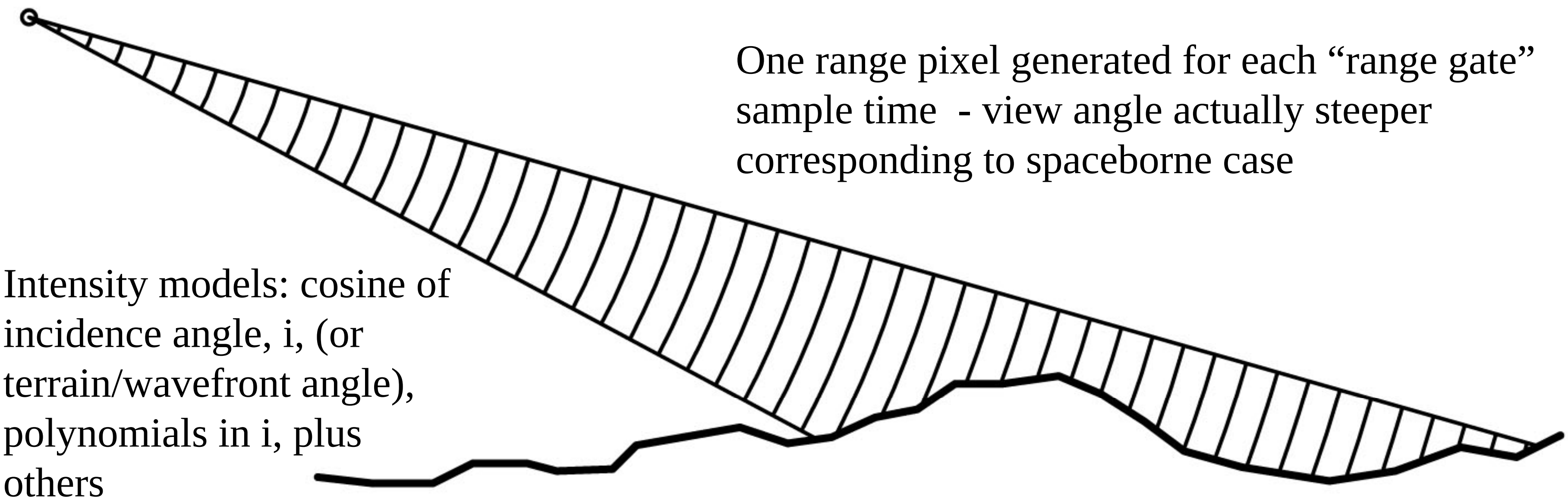
•Small D., Meier, E., Nuesch, D., 2004, “Robust Radiometric Terrain Correction for SAR Image Comparison”, IEEE 0-7803-8742-2/04

•Bayer, T., Winter, R., Schreier, G., 1991, Terrain Influence in SAR Backscatter and Attempts to their Correction”, IEEE Transactions on Geoscience and Remote Sensing, vol 29, no 3, May 1991

•Soergel, U., Thoennessen, U., Stilla, U., 2004 (?), ISPRS Proceedings, Commission III, WG III

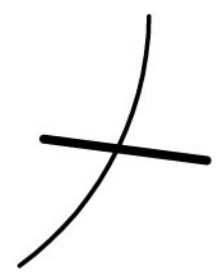
Series of figures to Illustrate the Projection Geometry

One range pixel generated for each “range gate” sample time - view angle actually steeper corresponding to spaceborne case



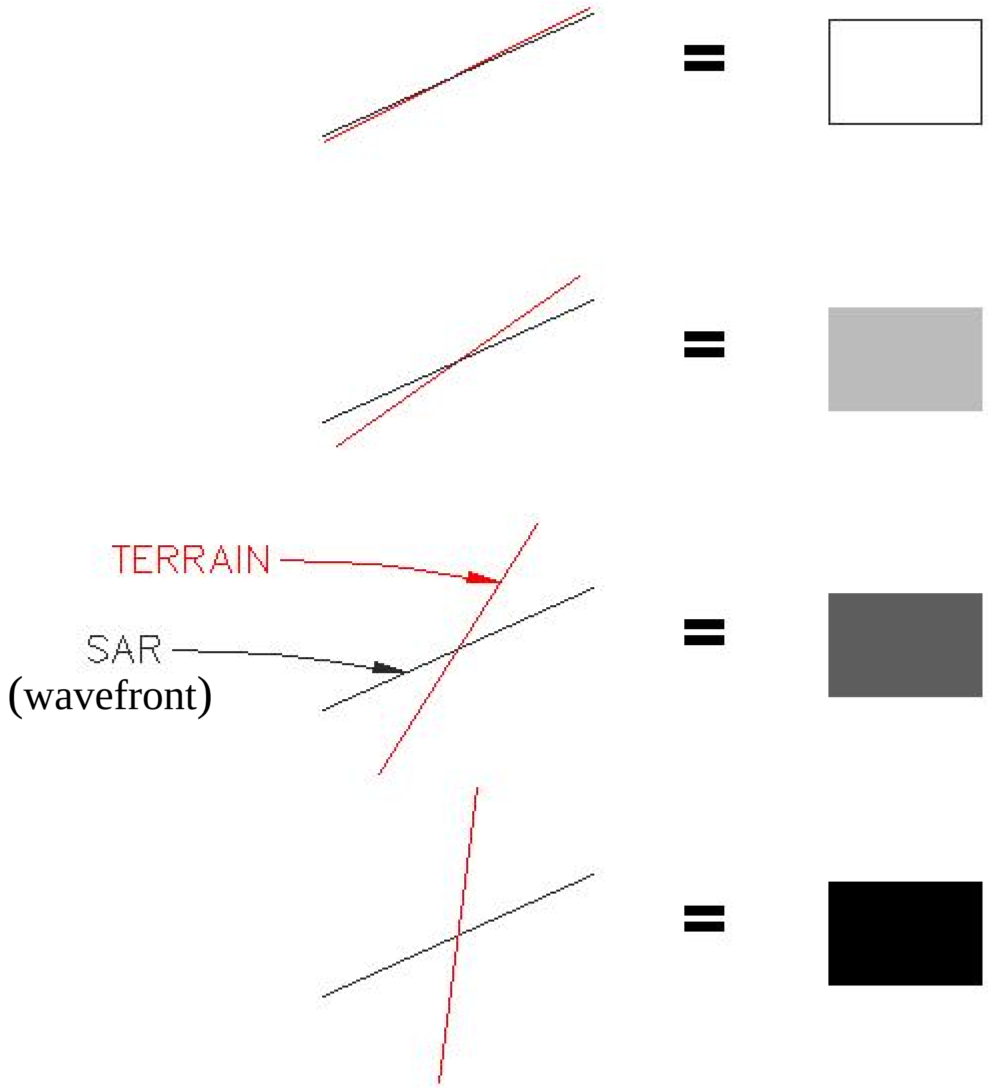
Intensity models: cosine of incidence angle, i, (or terrain/wavefront angle), polynomials in i, plus others

Small angle yields bright intensity

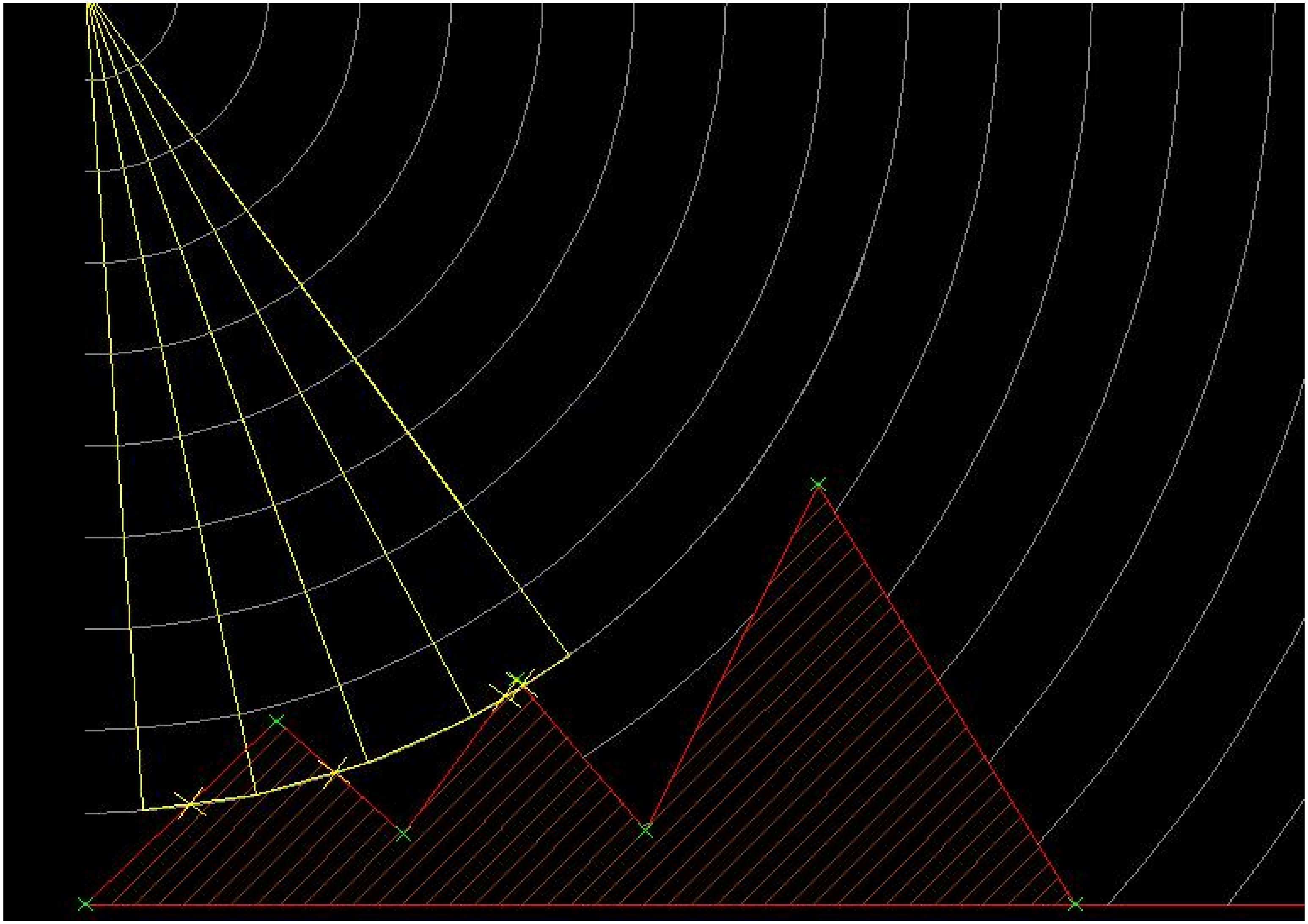


Large angle yields darker intensity

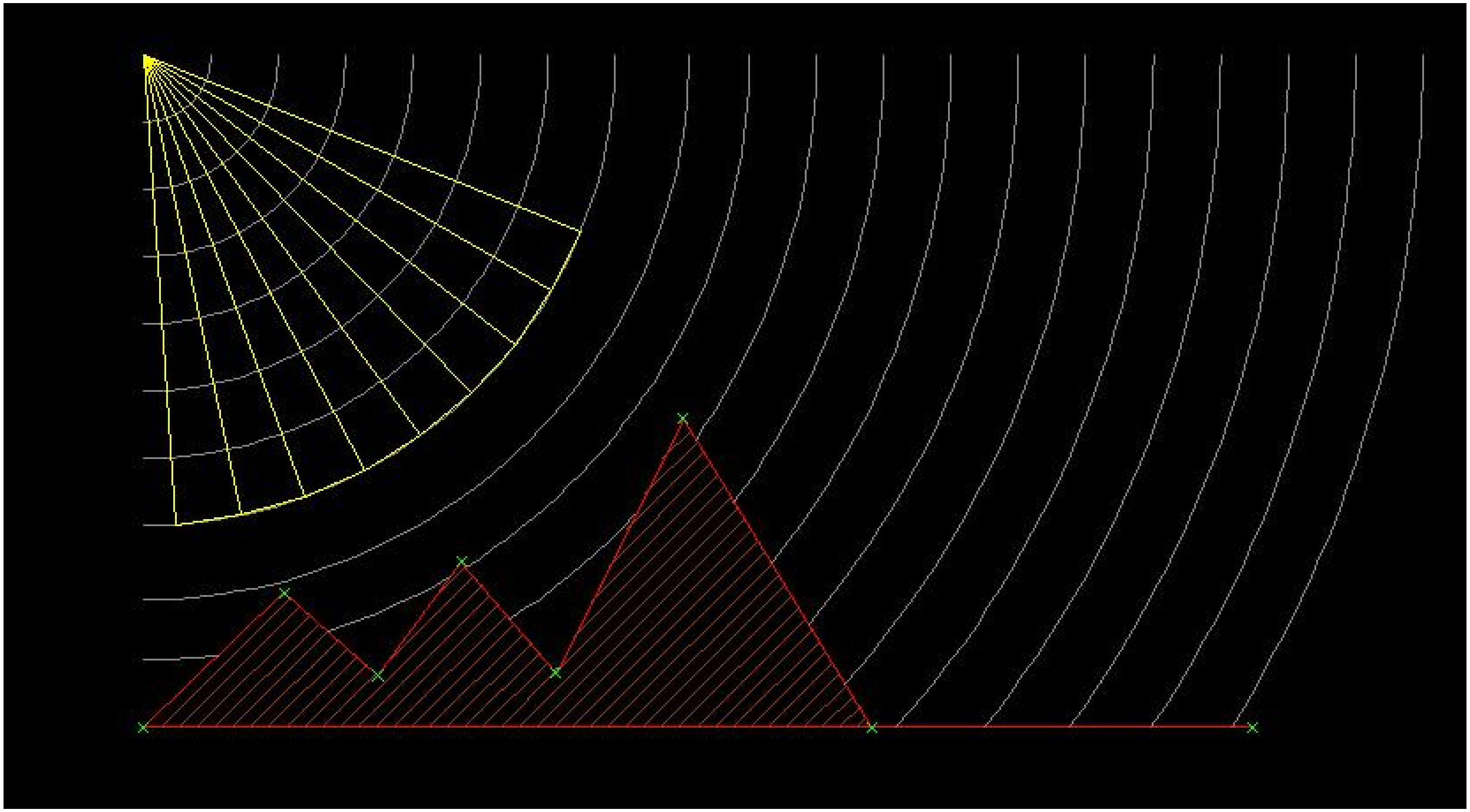
Illustration of intensity model



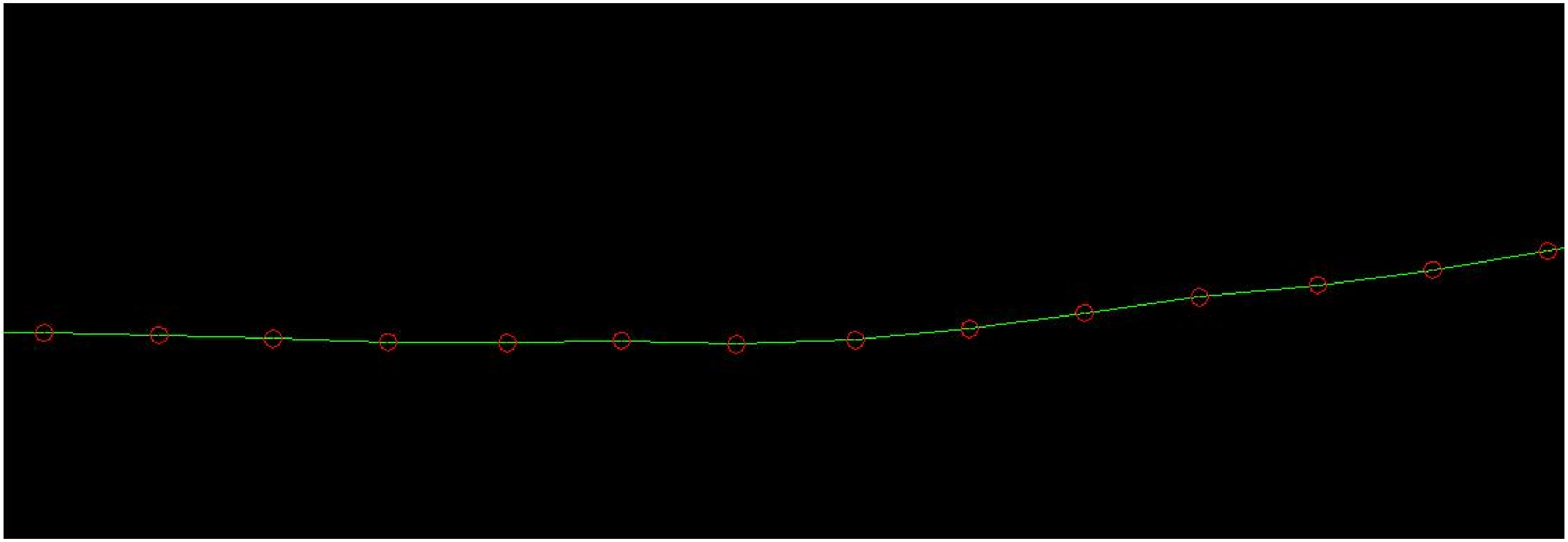
Wavefront – terrain intersection – multiple intersections would contribute to same pixel - we select just one - sketch has exaggerated terrain relief



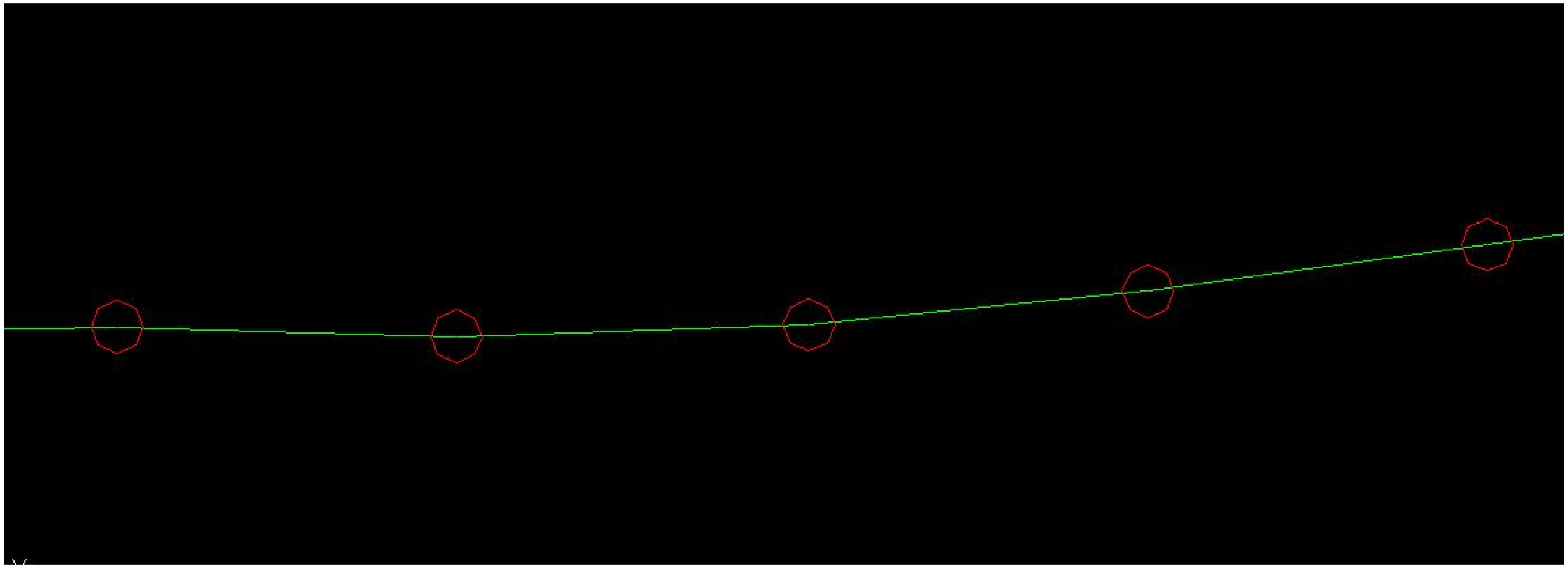
Algorithm: first used discrete steps in range and look angle, later approximate with line



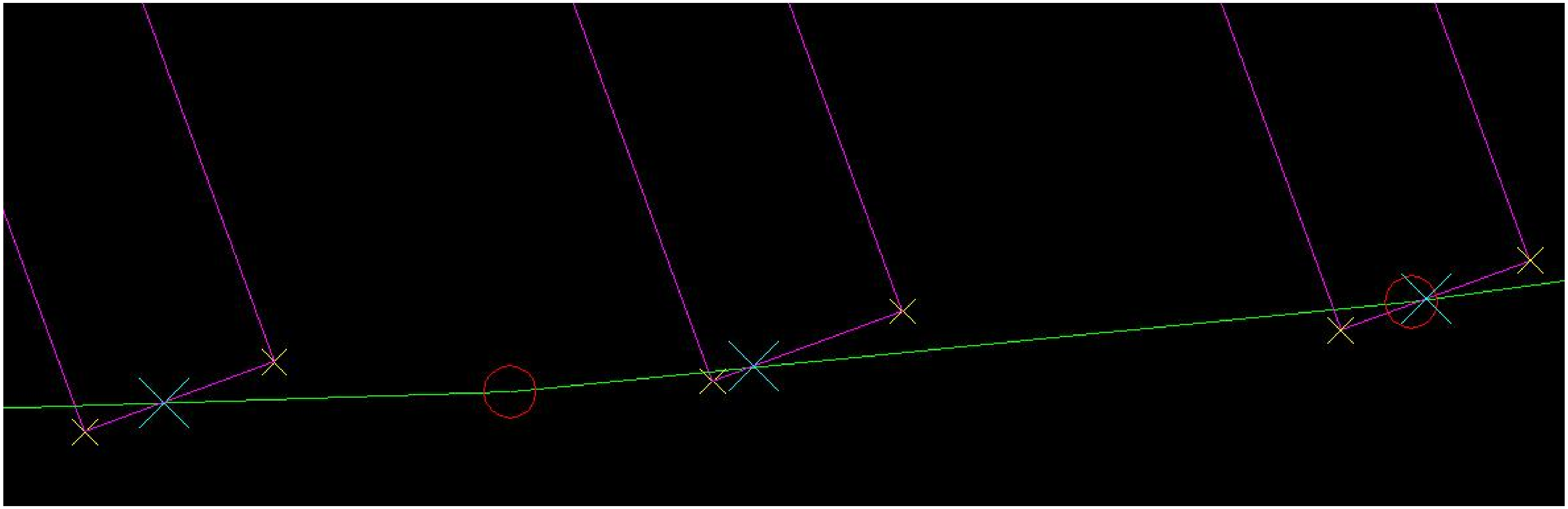
Input DEM profile



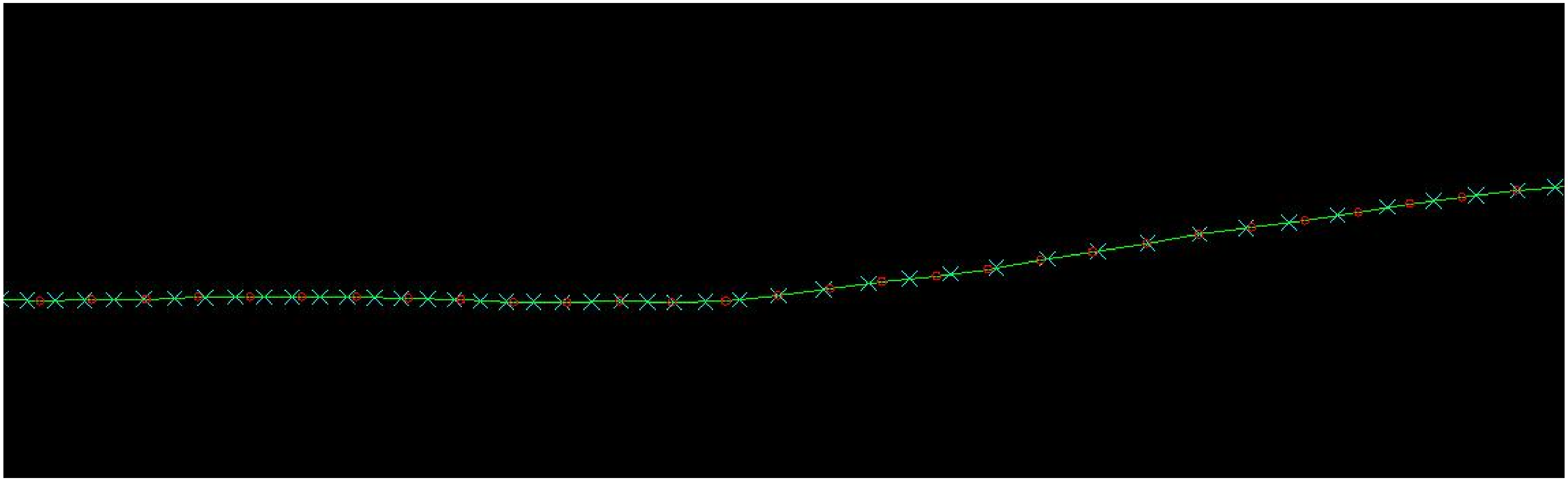
Zoom 2x



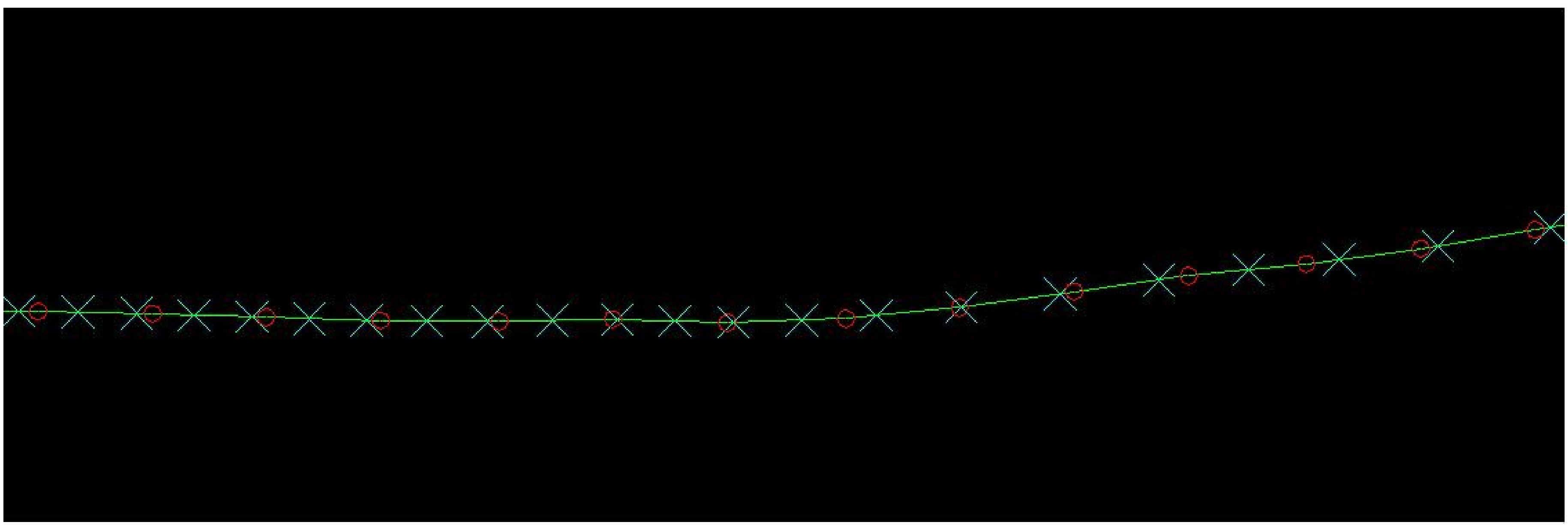
Detail of the arc-segment / terrain-segment intersection



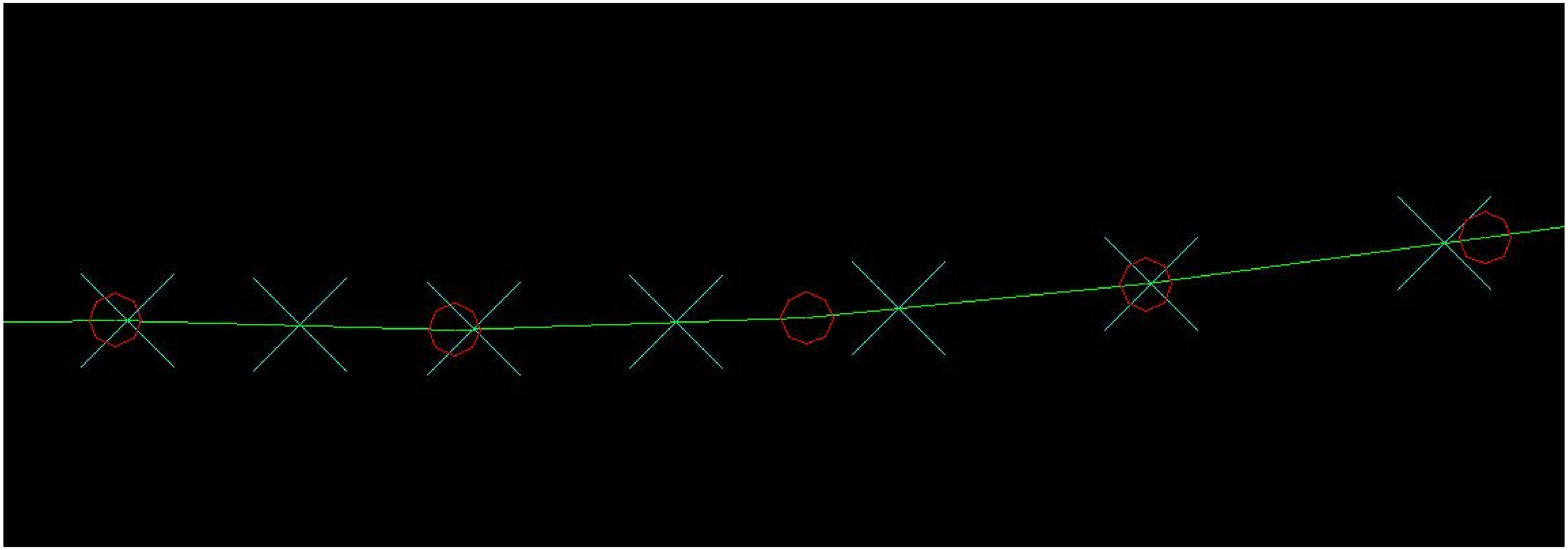
Terrain segments / range samples – note slope effect on sample distance



Zoom in 2x



Zoom in 4x

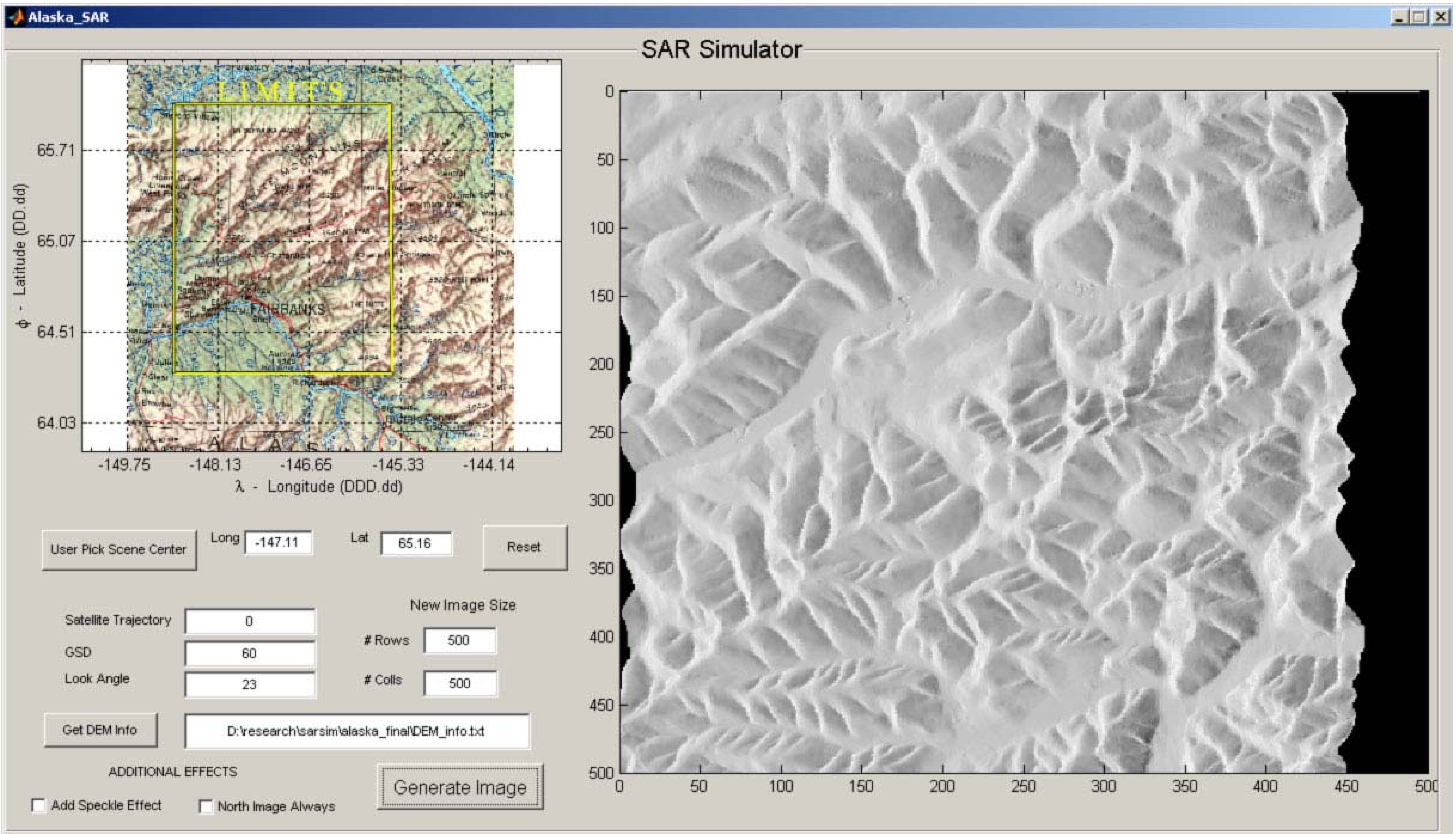


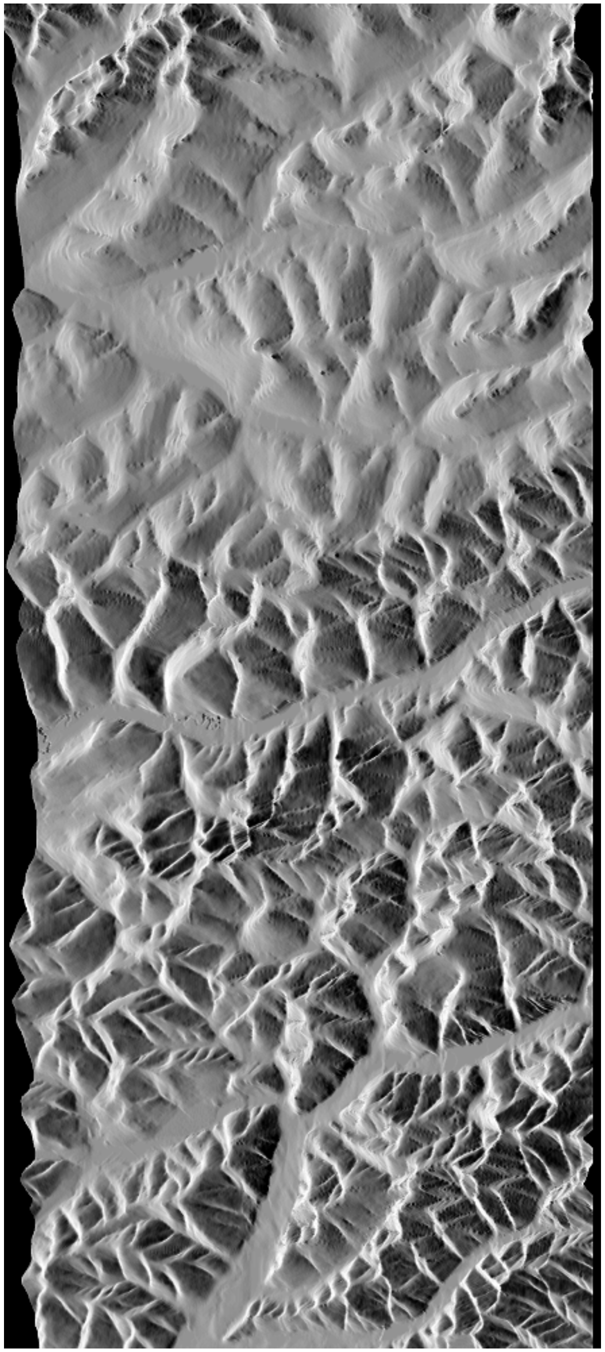
Circles = terrain segments

Crosses = range samples

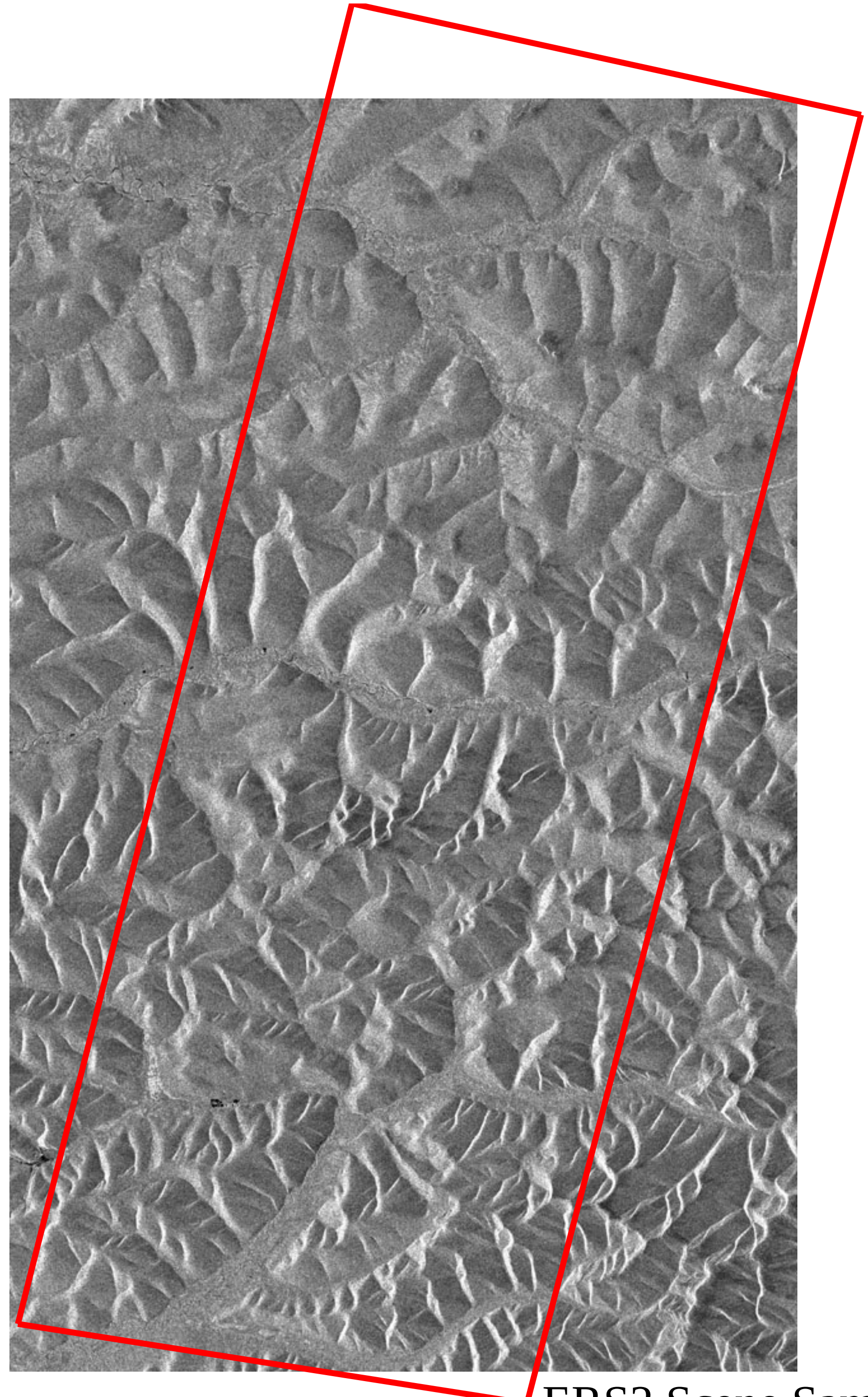
USGS Terrain in Alaska

Screenshot of Matlab GUI to Specify and Display SAR Scene

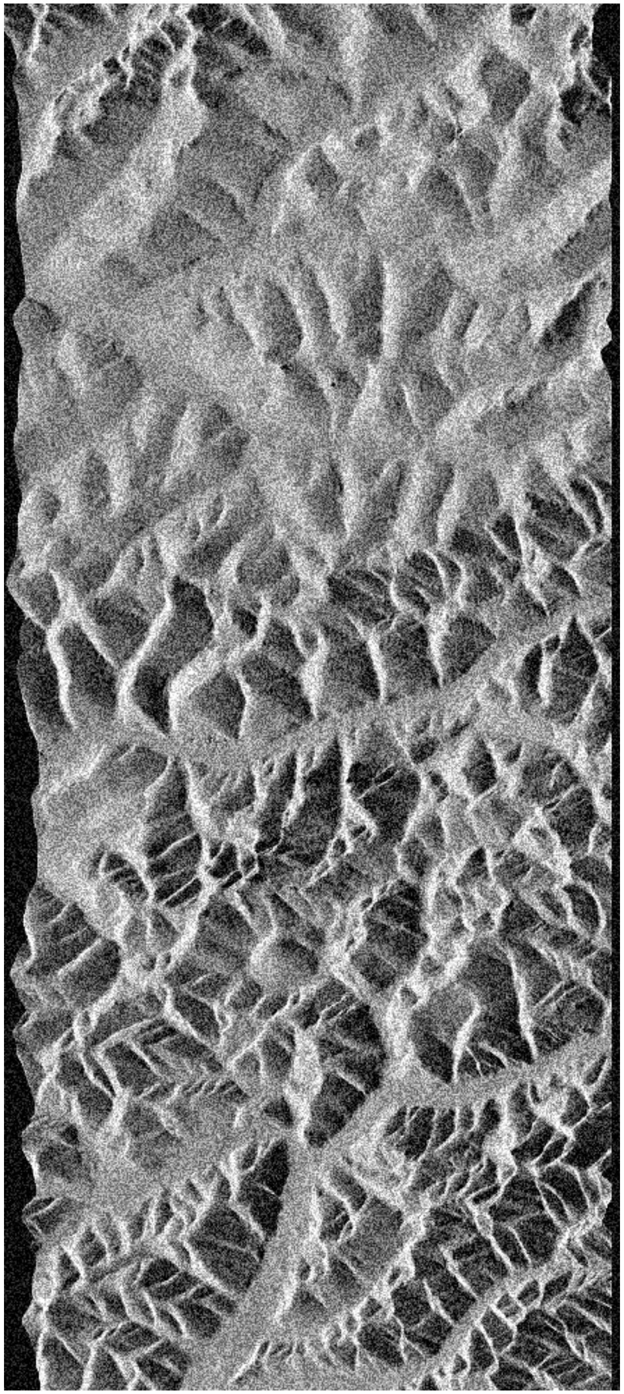




Simulated Image / North Traj.



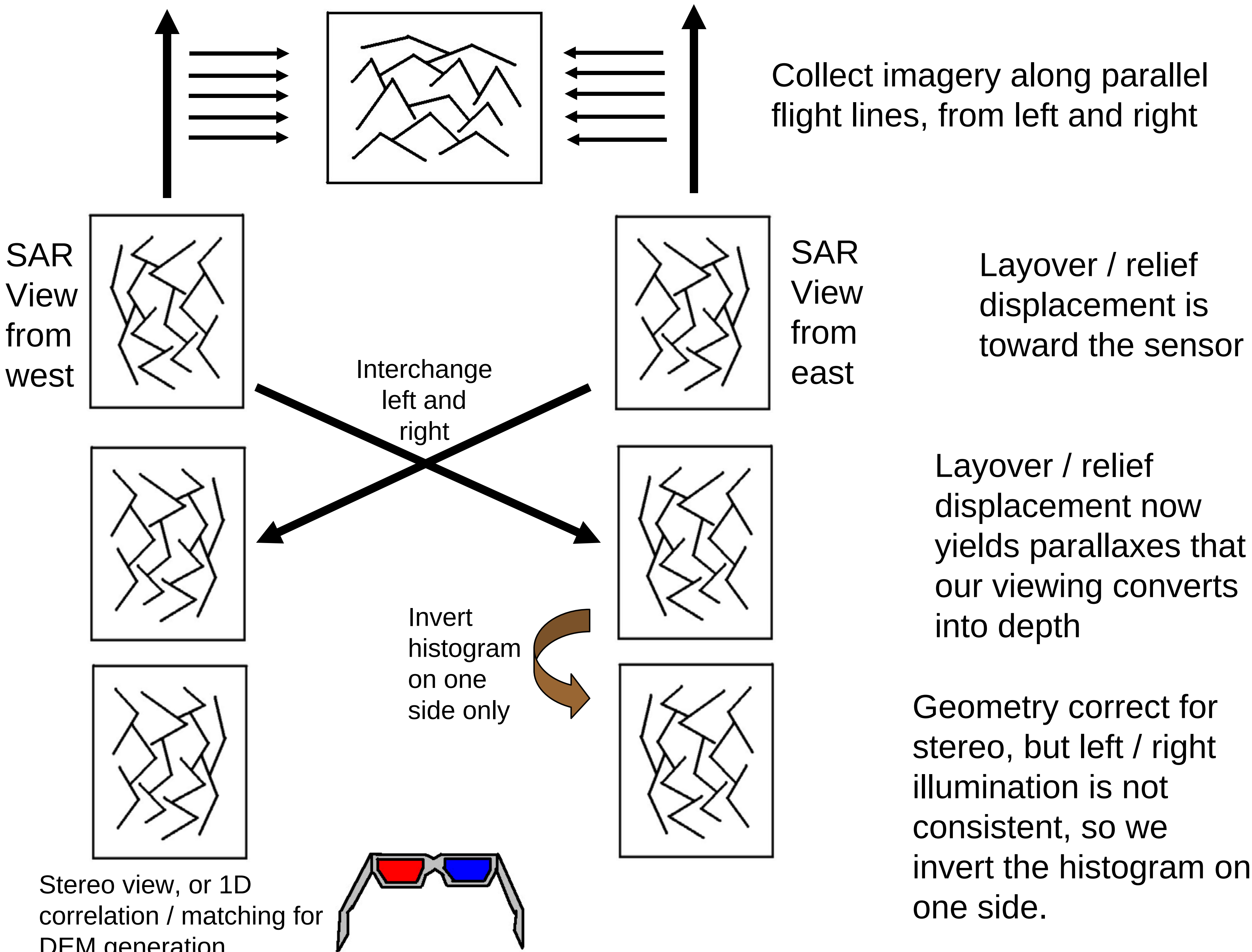
ERS2 Scene Same Area



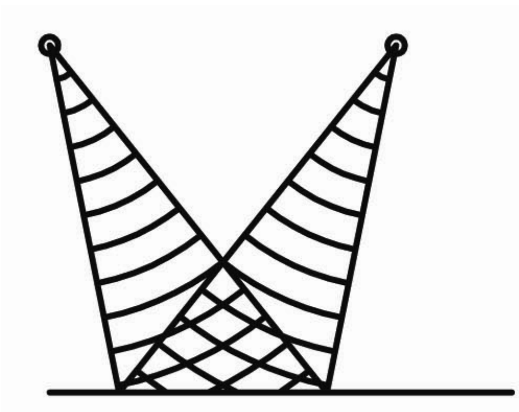
Generated image with addition of uniformly distributed noise to simulate speckle which is characteristic of SAR imagery. At least from first visual inspection, the terrain layover effects and radiometry appear to be depicted consistent with range / cross-range geometry.

Sequences of simulated scenes collected into animations to show the effects of different view directions

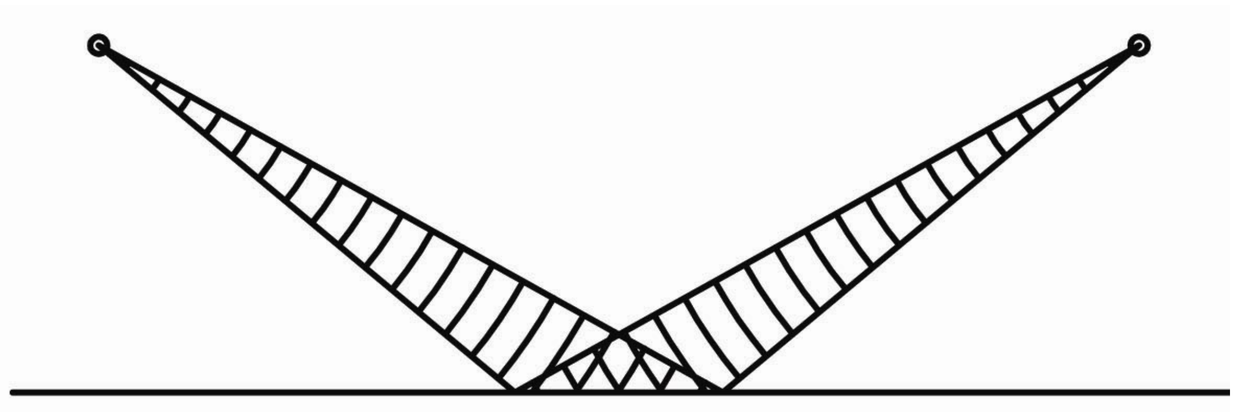
Moving red arrow indicates the view direction, note that illumination and layover track the view direction


Collect imagery along parallel flight lines, from left and right
SAR View from west
SAR View from east
Layover / relief displacement is toward the sensor
Interchange left and right
Layover / relief displacement now yields parallaxes that our viewing converts into depth
Invert histogram on one side only
Geometry correct for stereo, but left / right illumination is not consistent, so we invert the histogram on one side.
Stereo view, or 1D correlation / matching for DEM generation

Controlling the layover or vertical exaggeration in the stereo model is done by modifying the “look angle” or “off-nadir angle”. Small look angle (narrow base) yields large layover. Large look angle (wide base) yields small layover. In the limit, horizontal viewing produces zero layover, though lots of occlusions.



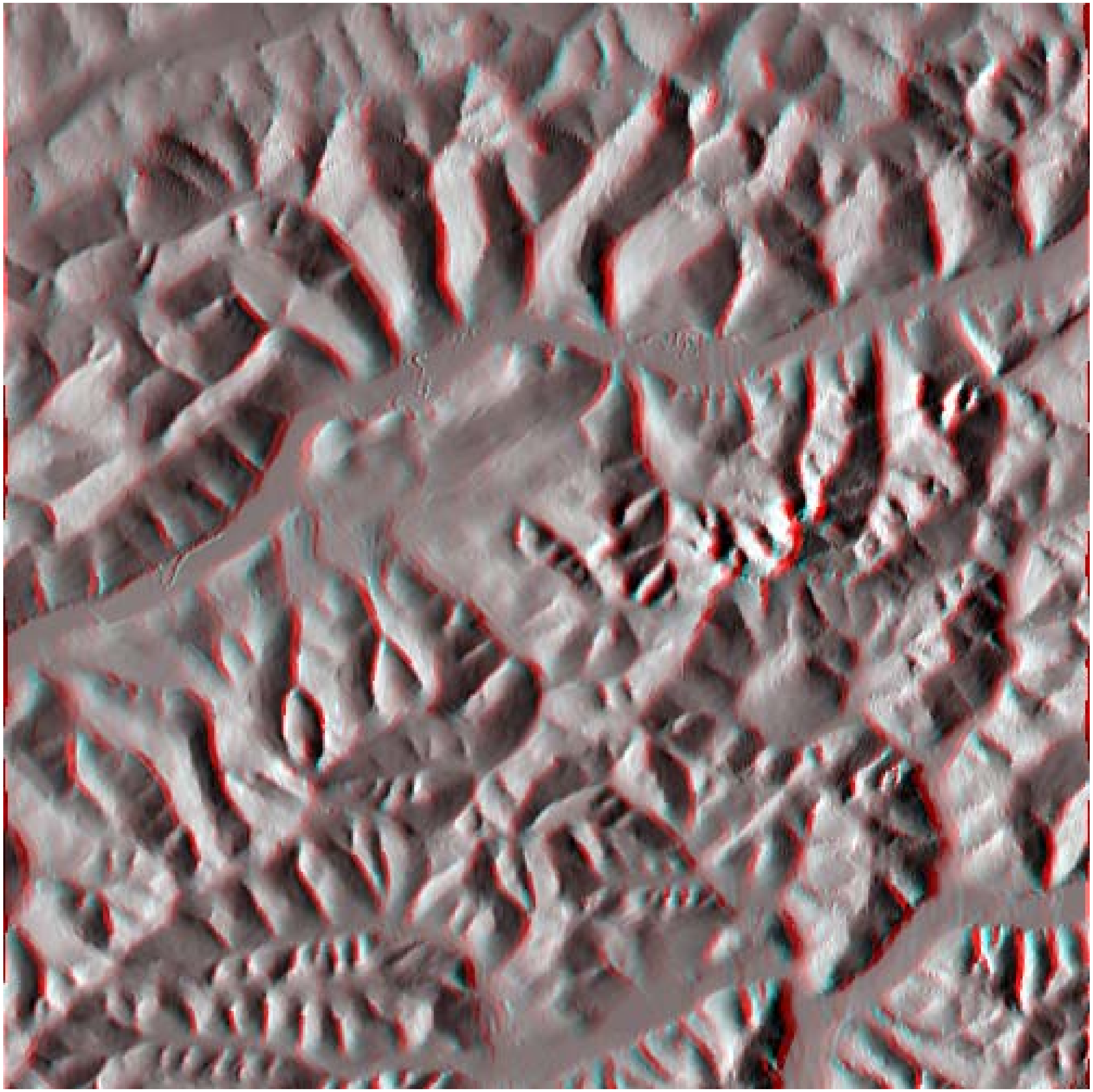
Narrow base = large layover



Wide base = small layover

(opposite of optical imagery!)

For the following example we increased nominal 23 deg look angle to 65 deg



Conclusions

•Visual inspection of results of the SAR simulation tool suggest that the fundamental SAR geometric characteristics are achieved.

•Detailed geometric comparison has not been done.

•Departures from consistency could indicate flaws in simulator or flawed interpretation of metadata of the image being simulated.

Future Work

•Evaluate quantitatively geometric quality of simulations

•Consider adding texture/reflectivity map to terrain, to model different backscatter characteristics

•Model occlusions/shadows

•Model urban features for airborne imagery simulation