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Synthetic Aperture Radar Speckle Reduction for Circular SAR Images

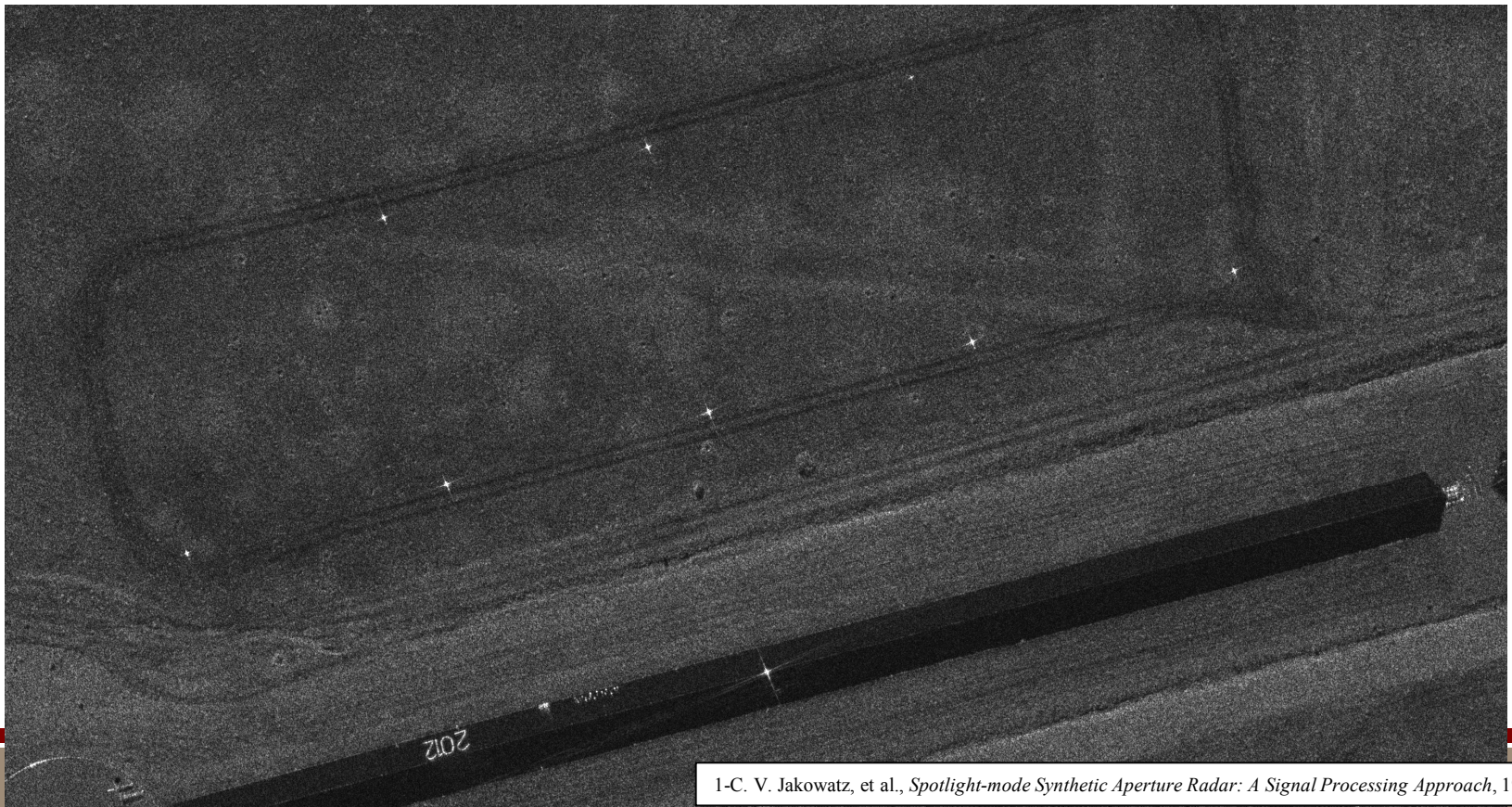
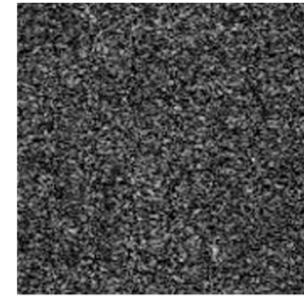
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Sandia National Laboratories

Outline

- Speckle Reduction
- Difficulty for circular SAR images
- Image Registration
 - Coarse – Speeded-Up Robust Features (SURF)
 - Fine – Multi-level pyramidal
- Results

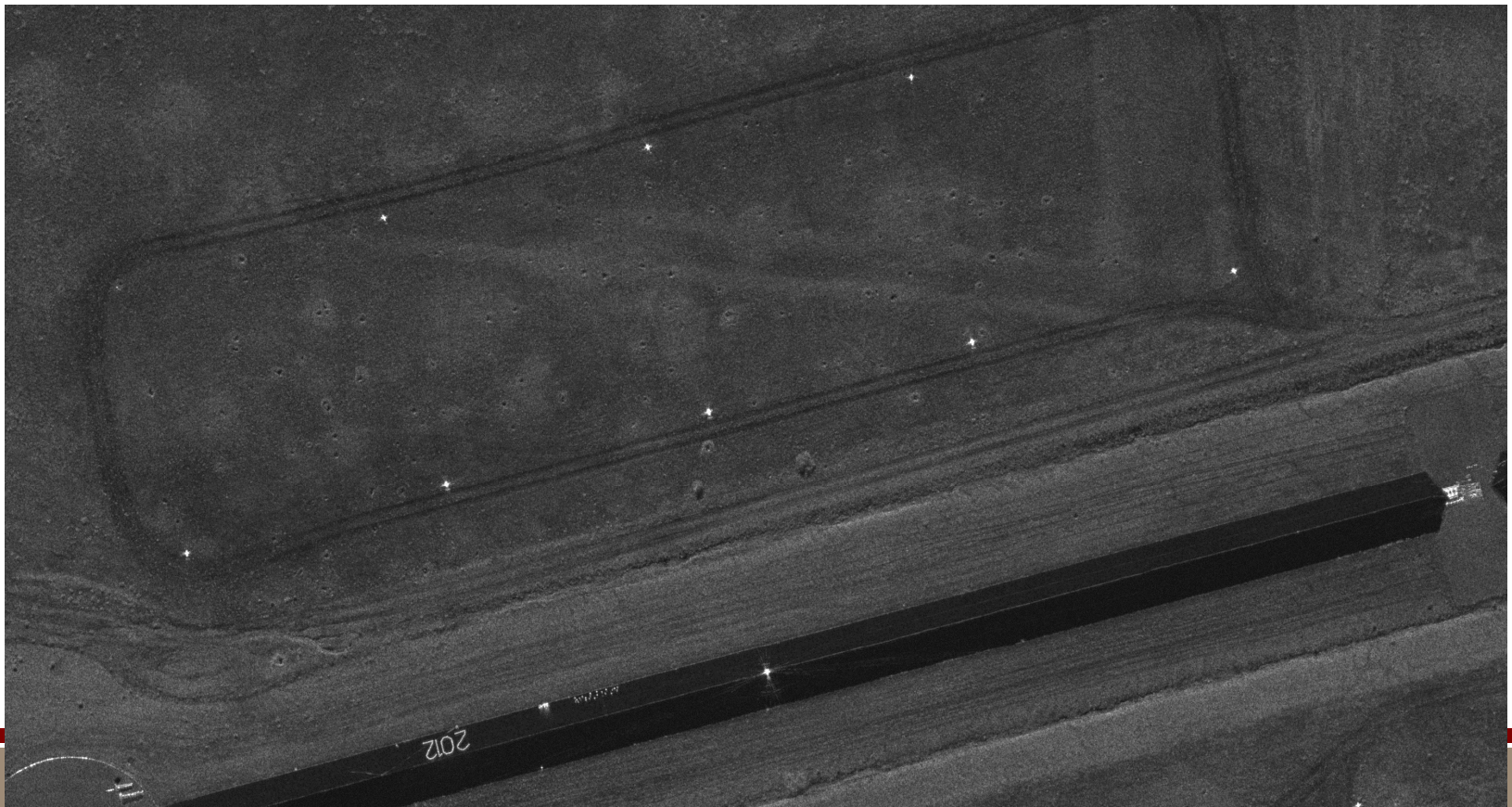
Speckle

- Grainy pattern of bright/dark spots
- “..random phasor sums from many scattering centers within a given resolution cell”¹



Why reduce speckle?

- To better resolve subtle features in terrain.
- Improve visual appeal of imagery
- Apply ‘optical’ image processing techniques



Reduce Speckle by Multilooking

- Multilooking by averaging local area of pixels



Original image

3x3 local average

Reduce Speckle by Multilooking

- Multilooking by averaging local area of pixels



Original image



5x5 local average

Reduce Speckle by Gaussian Blur



Original image



Gaussian blur, $\sigma=1.5$

Reduce Speckle by Subapertures

- Divided phase history into subapertures, then add

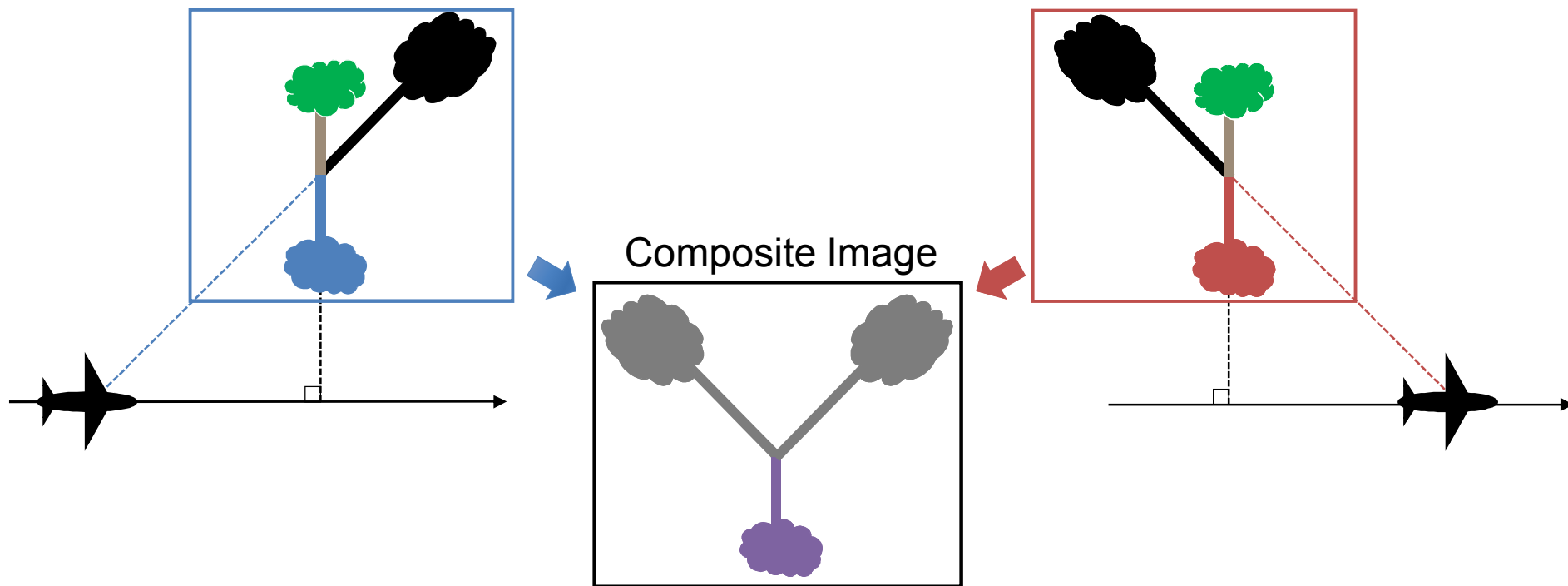


Original image

4 Subaperture images

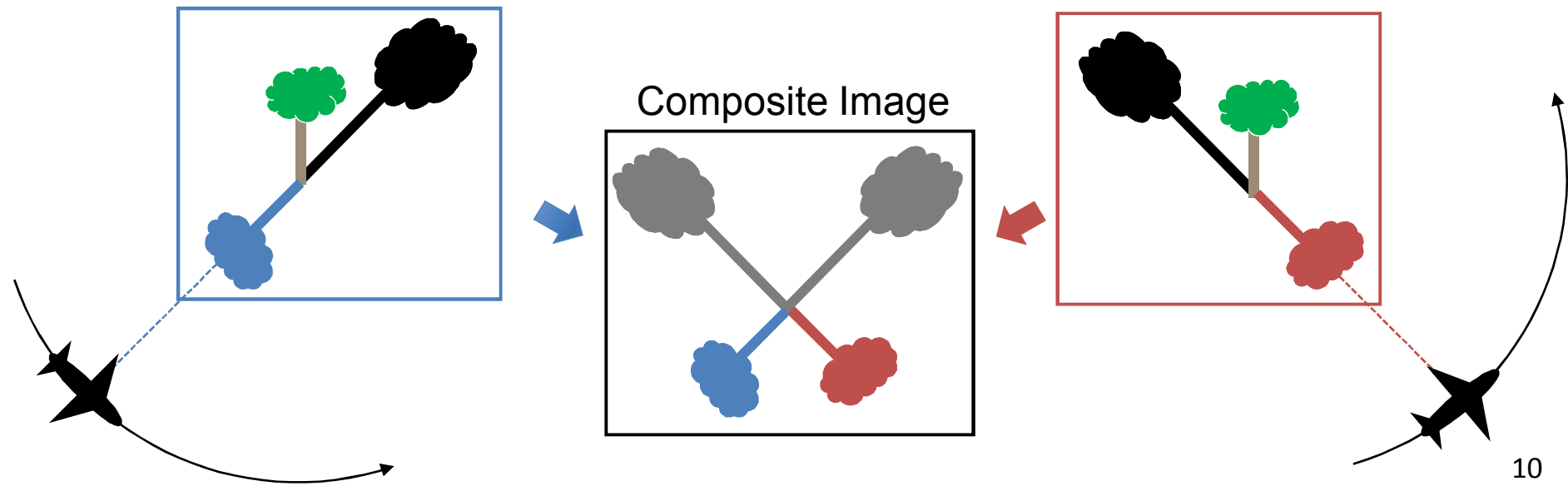
To Reduce Speckle but not resolution

- A spotlight data collection has the same layover direction in each image, to broadside
 - The shadow aligns with each image's mid aperture direction



To Reduce Speckle but not resolution Sandia National Laboratories

- What about a circle SAR data collection?
 - More efficient flight path than spotlight
 - Persistent surveillance applications
- Layover shifts everything towards broadside
 - But now broadside angle changes for each aperture
 - Shadow still aligns with each image's mid aperture direction



Layover Demonstration



- Dome is always down
- Dome defocuses due to motion



By LoneStarMike - Own work, CC BY 3.0,
<https://commons.wikimedia.org/w/index.php?curid=9909150>

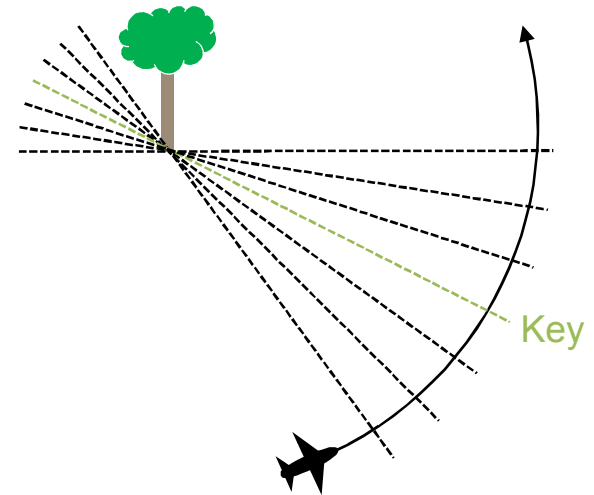
- Also, make the point that SURF is not enough. Theoretically it isn't sufficient. Others have improved the algorithm for SAR, overcoming the speckle difficulties, but they don't address that tree layover case. This work tries to explore what can we do with existing methods and simplifying assumptions. At least it could be a baseline for future improvements.
- Show two snapshots of TX capitol showing the layover is different so people can see this registration is more than a shift and rotate.
- Then a less extreme case in the golf course image
- Later make point I haven't seen SIFT take into account the layover effects of objects.

Circular SAR is Difficult

- Requires distortion
- Limited to cases where topography change is slow
- Limited to small change in aspect angle

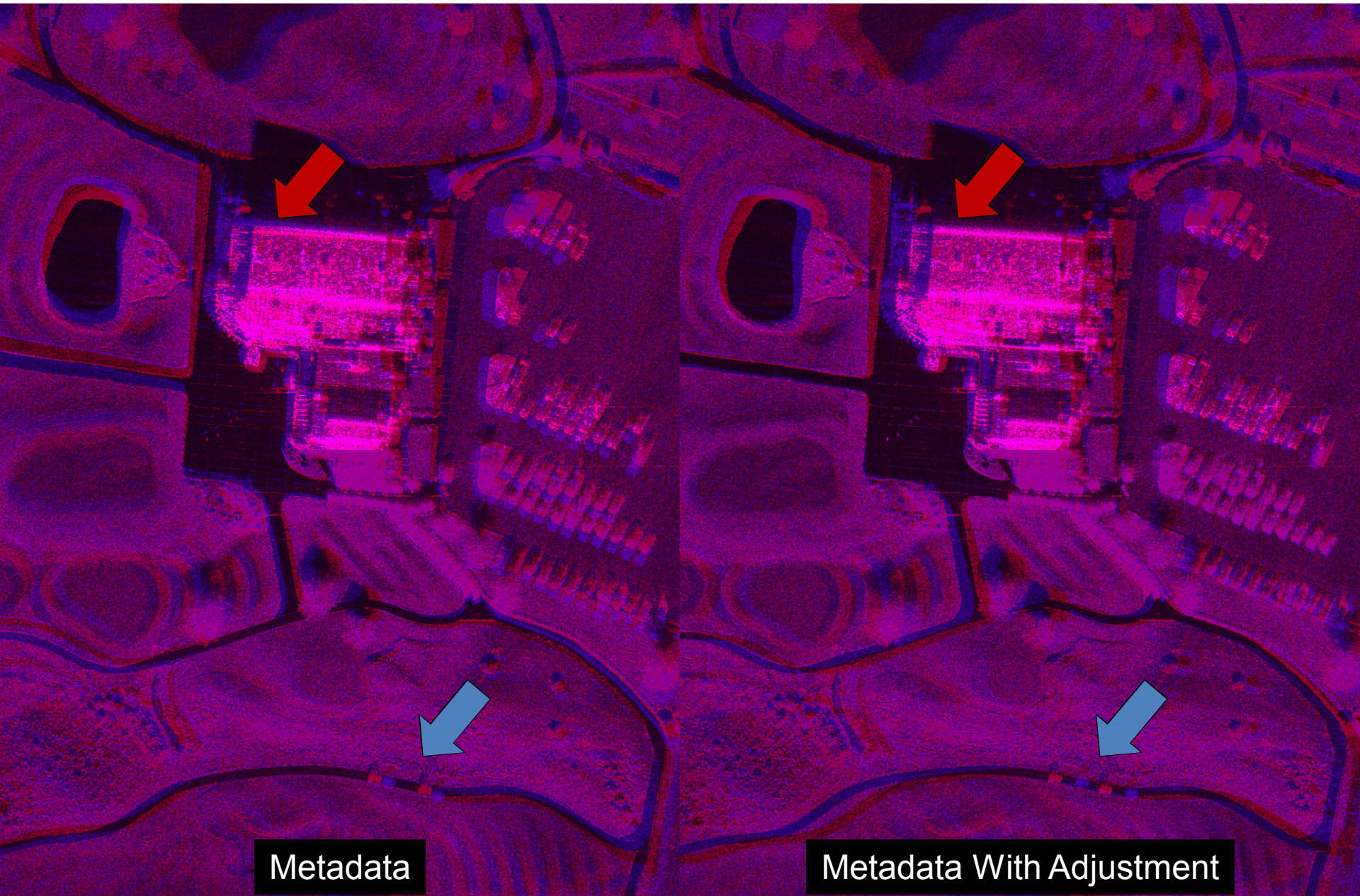
Image Registration Process

- Must allow for local distortion to compensate for layover
- There are many methods to register images
 - SAR images are complex valued
 - SAR images have speckle
- Two steps:
 - Coarse
 - Rotation
 - Global X/Y shift
 - Fine
 - Multi-level warp



Issue with Metadata

Red- Key image
Blue – Registered image
Magenta – Areas that match



Metadata

Metadata With Adjustment

Layover Examples

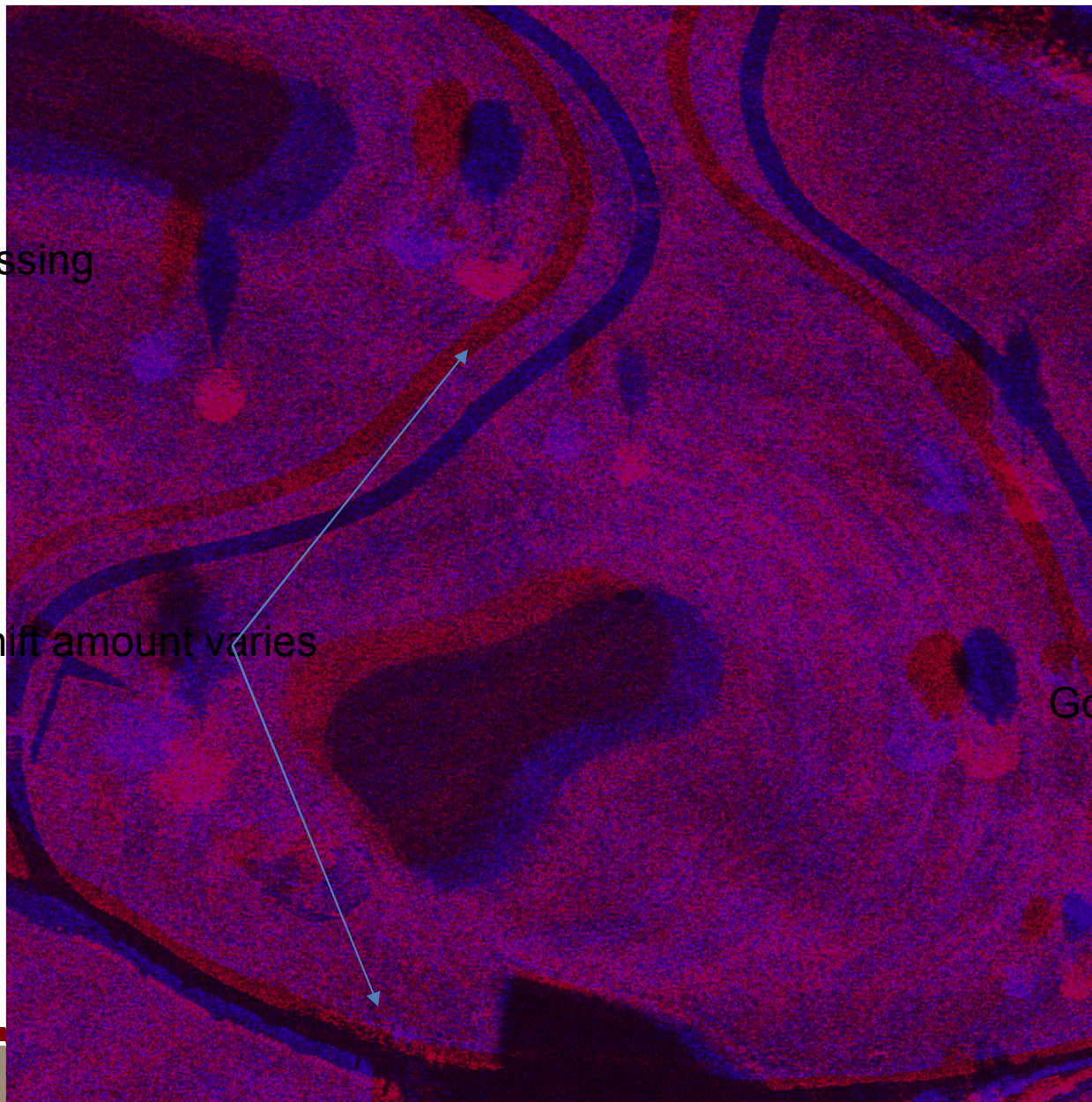
Red- Key image
Blue – Registered image
Magenta – Areas that match



No crossing

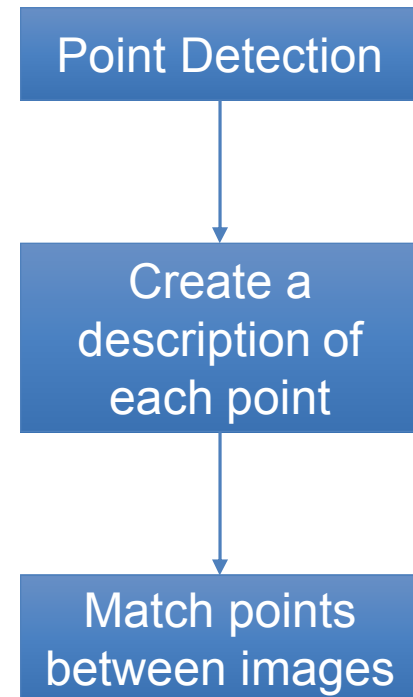
Vertical shift amount varies

Good crossing



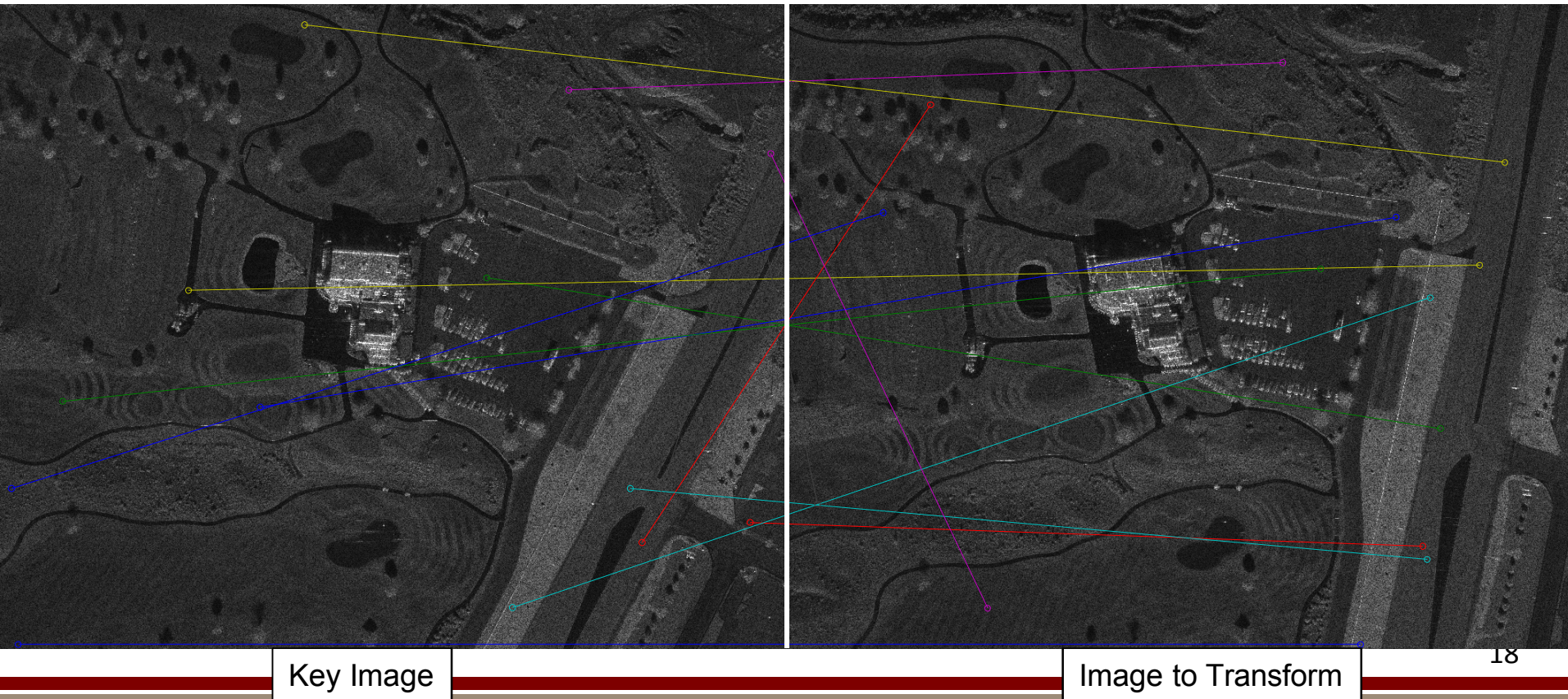
SIFT/SURF

- Scale Invariant Feature Transform (SIFT)
 - Used to create panoramas
 - Also used to create 3D models from series of images
- Speeded-Up Robust Features (SURF)
 - Faster than SIFT
 - Available as openSURF library for openCV and MATLAB code
- Recently, SAR specific modifications have been made
- But since I desire local distortion to overcome layover effects, a simple implementation addresses coarse registration problem



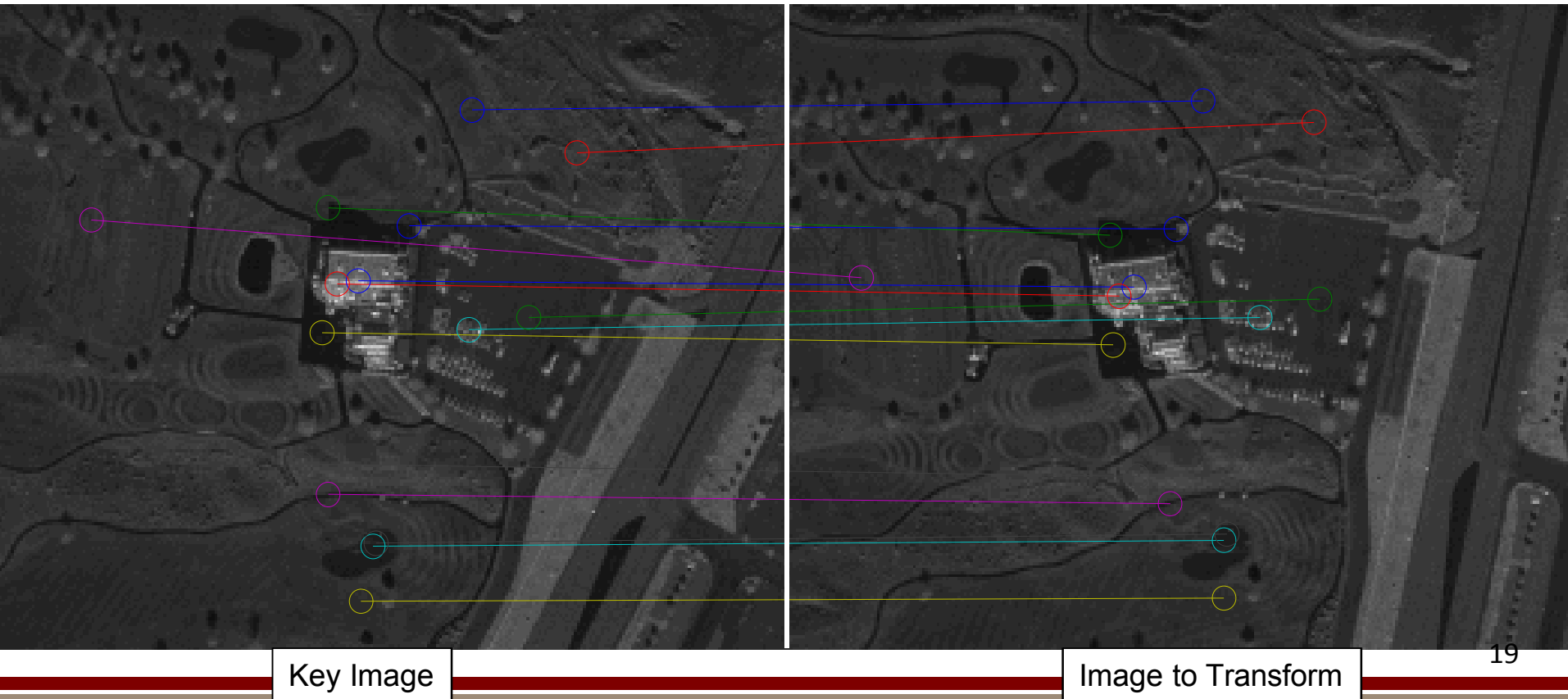
Coarse Registration - SURF

- Images are large, requires lots of operations - long time to process
- Results are bogus



Coarse Registration - SURF

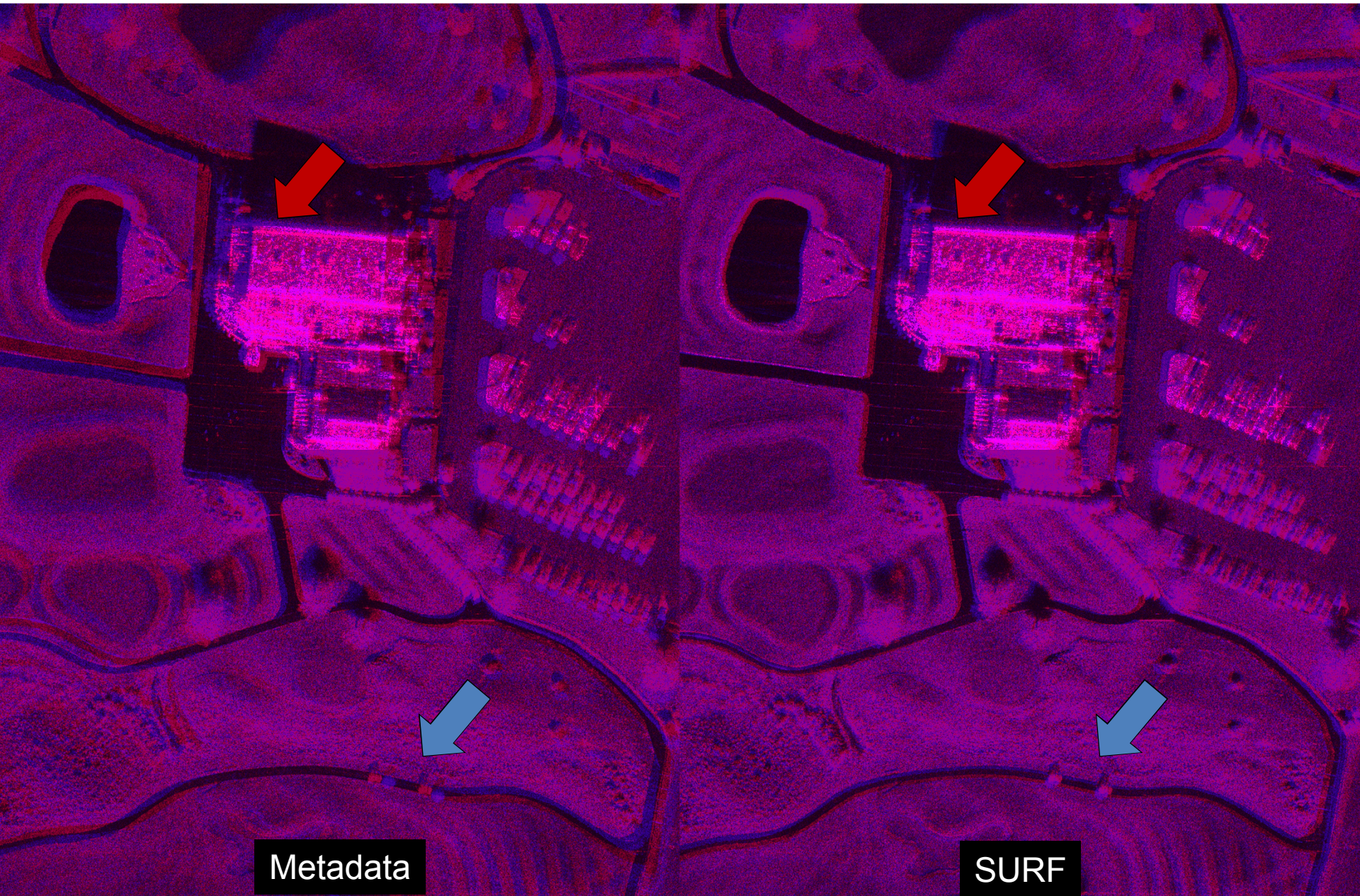
- Multi-looking reduces image size, speeds execution, and removes speckle
- Provides warp in addition to rotate and shift.



Comparing SURF to Metadata

Red- Key image
Blue – Registered image
Magenta – Areas that match

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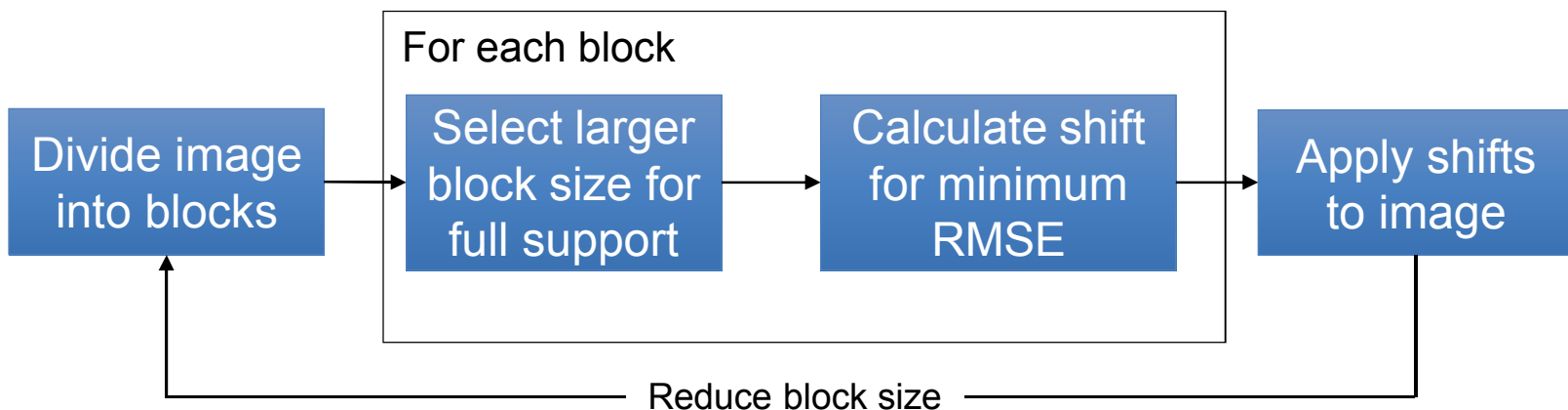
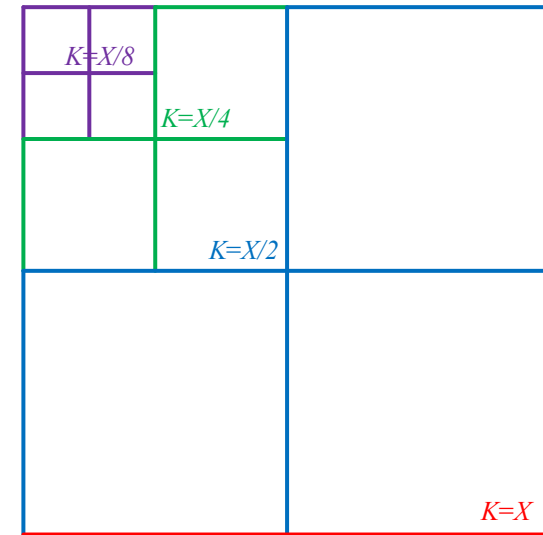


Metadata

SURF

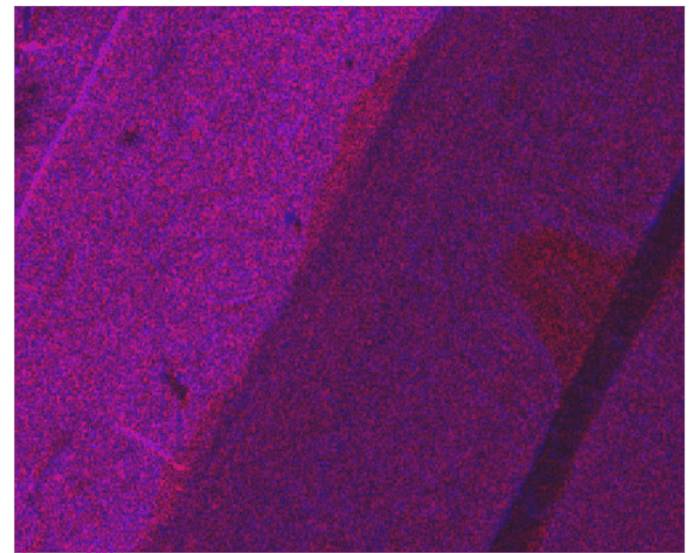
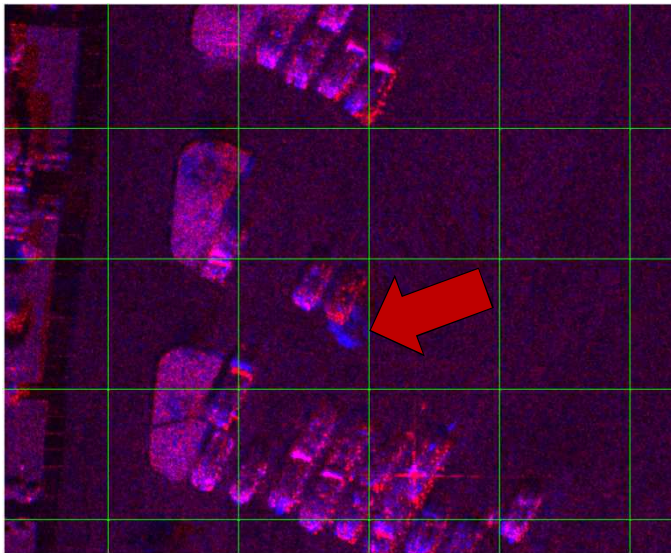
Fine Registration

- Non-coherent registration
- Uses multiple levels of decreasing image block sizes
 - Limits the amount of shift for each level for speed and accuracy
 - Uses a larger image so each shift has full support
- Computes shift that results in lowest root mean squared error (RMSE)
- Subpixel registration only for final, smallest block size



Coherent vs. Non-coherent Registration

- Cross-correlation is a classic registration cost function
 - Computationally efficient versions available¹
- What went wrong for circular SAR data?
 - Data is not coherent - phase doesn't correlate
 - Efficient versions effectively circularly shift the image blocks

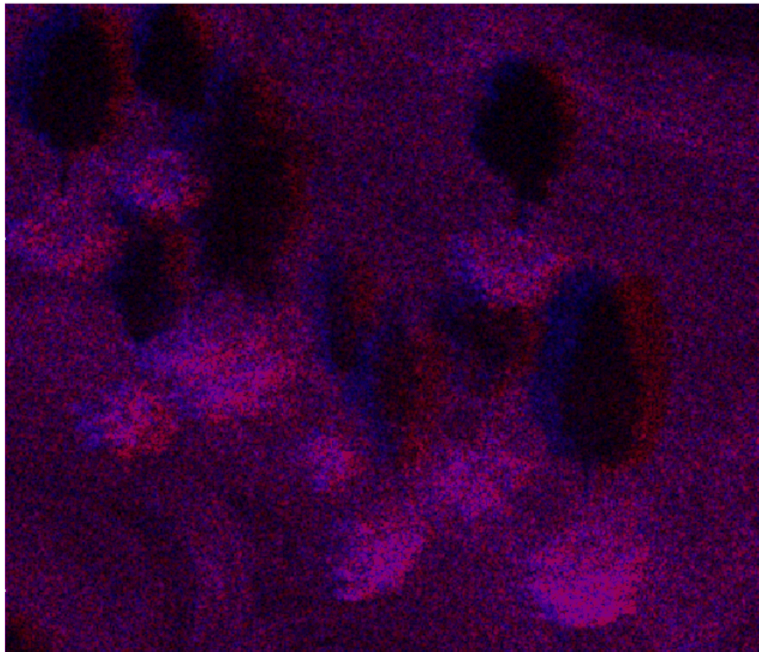


Final Result: 7 Images

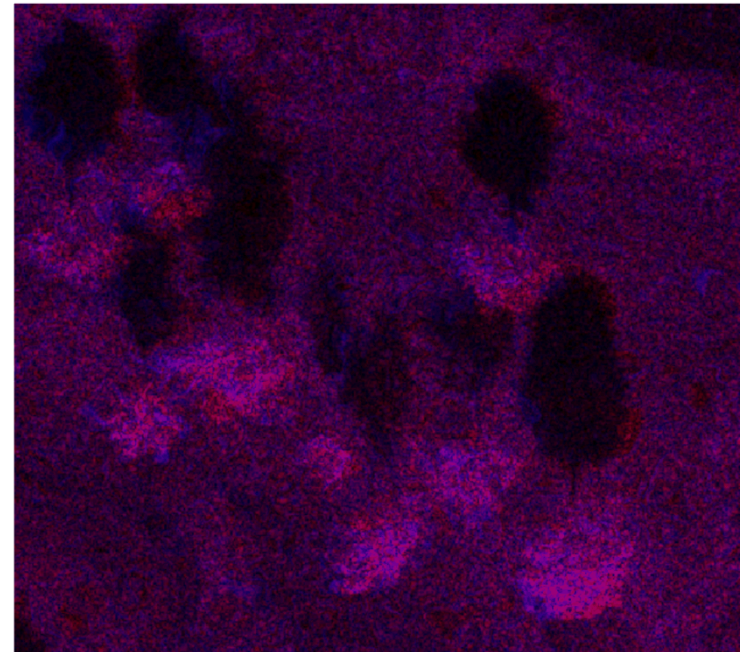


Final Result: Tree Layover

- The multiple level registration is able to distort the tree top and shadow to alignment

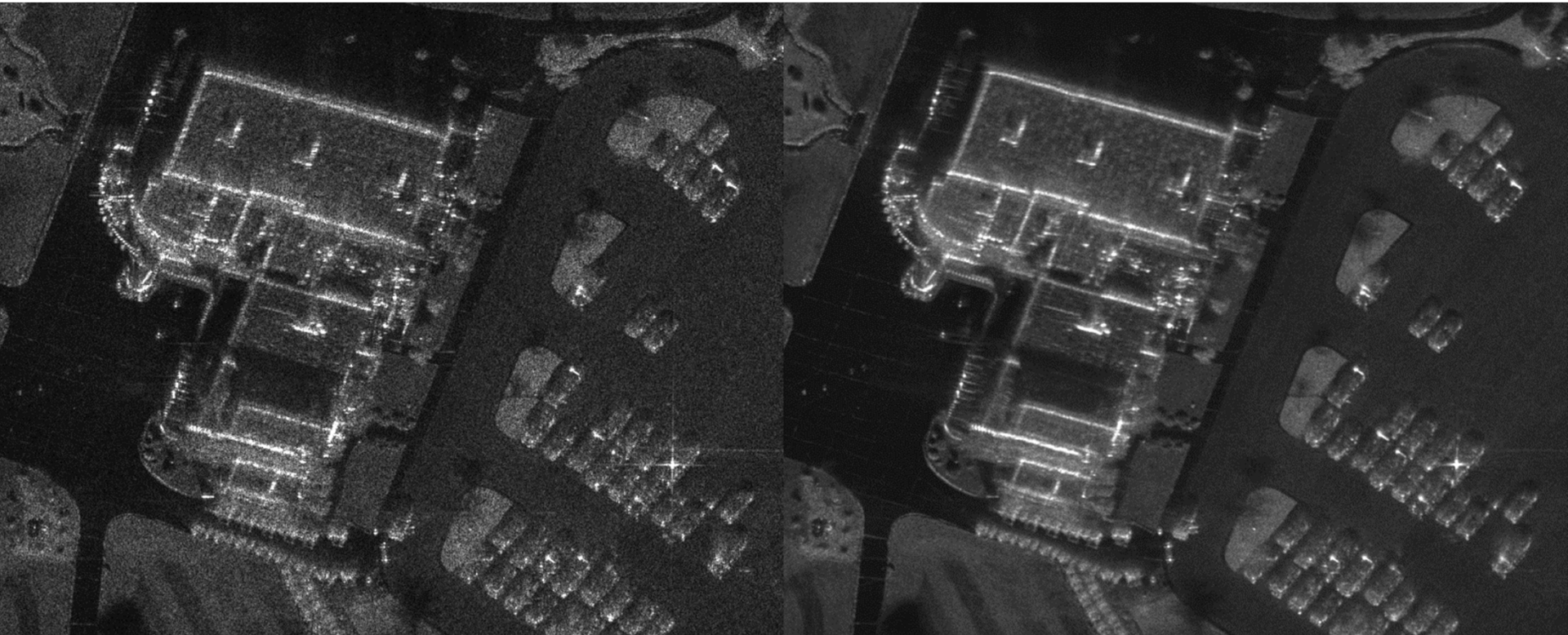


Block Size: 256x256



Block Size: 8x8

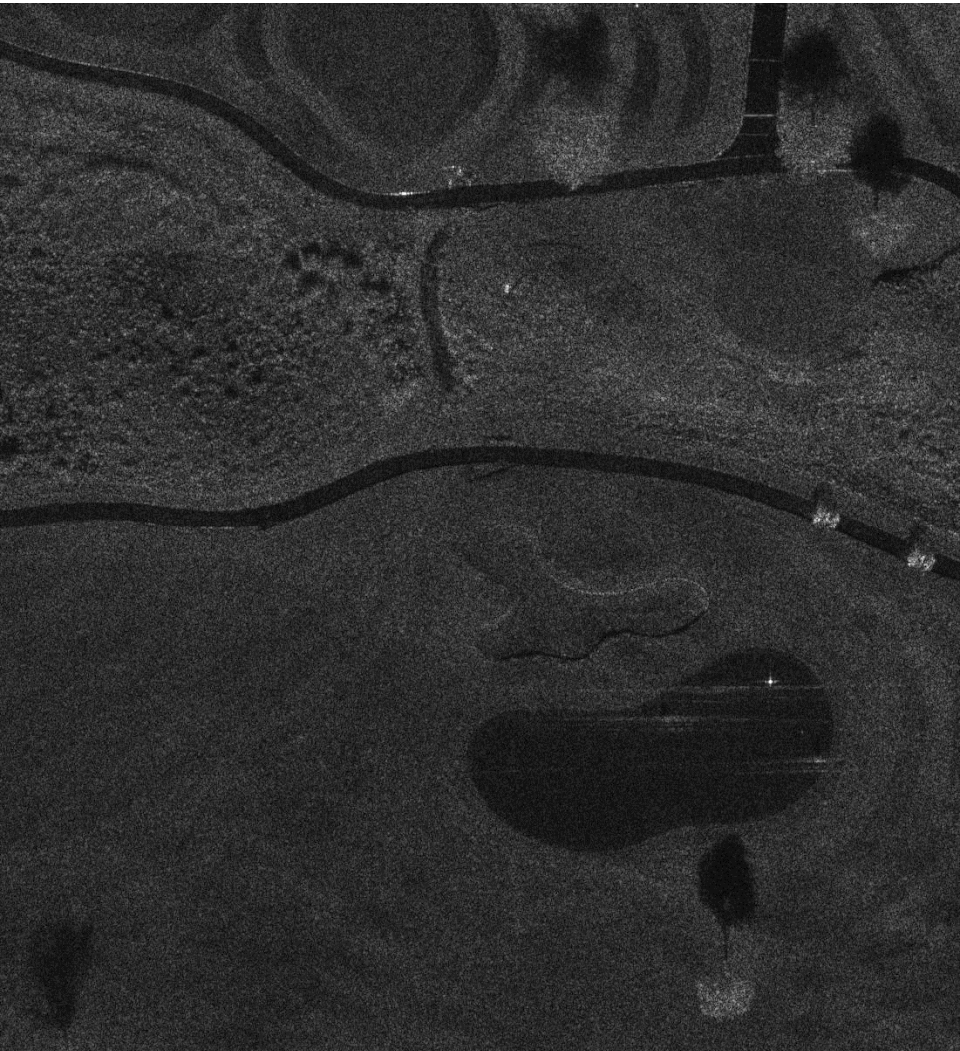
Final Result: Zoomed Comparison



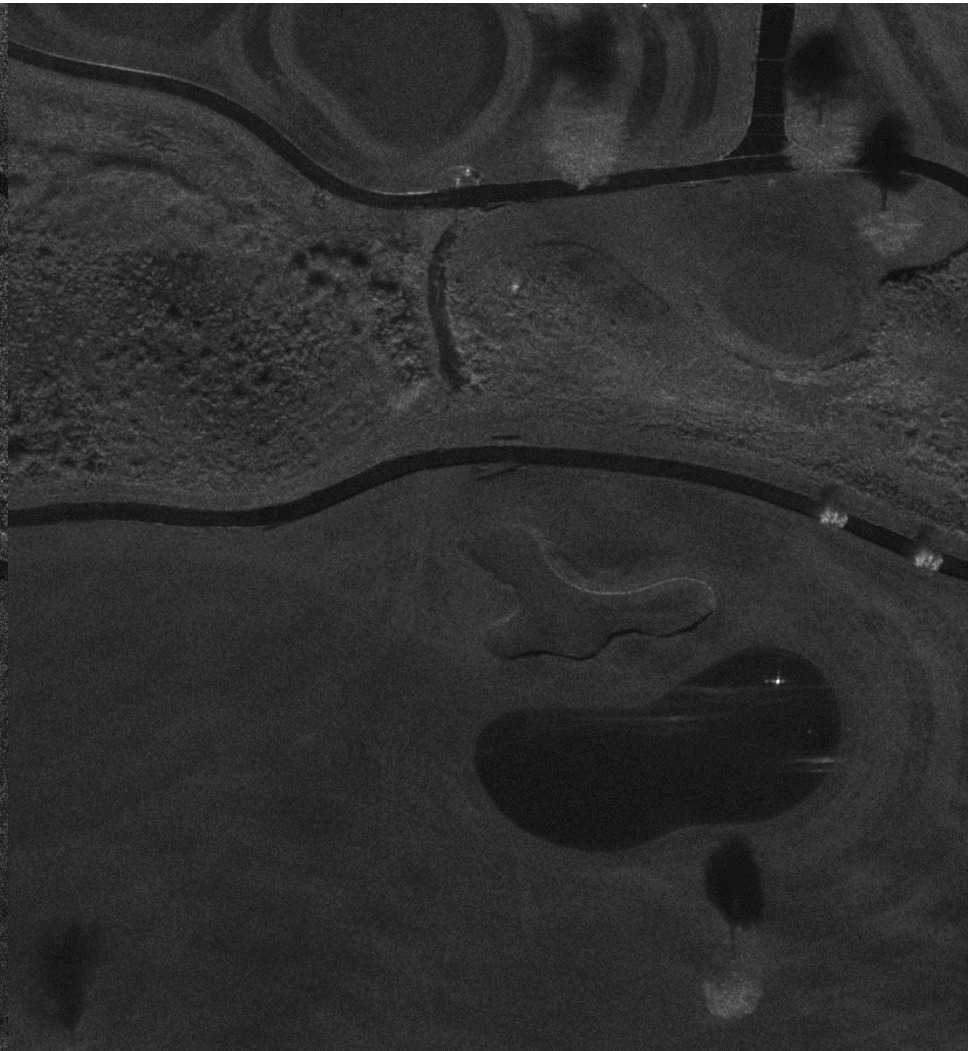
Original, Single Image

Seven Images Combined

Final Result: Zoomed Comparison



Original, Single Image



Seven Images Combined

Conclusions

- SURF relaxes need for using metadata in coarse registration
 - provides a coarse warp in addition to the necessary rotate/shift
- For the non-coherent data registration, SSE seems to be superior to cross-correlation
- Multi-level or pyramidal fine registration is best
- This registration treated SAR images as optical images. Future work should take advantage of information about how the data was collected to reduce spatially-variant defocus

Questions?

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