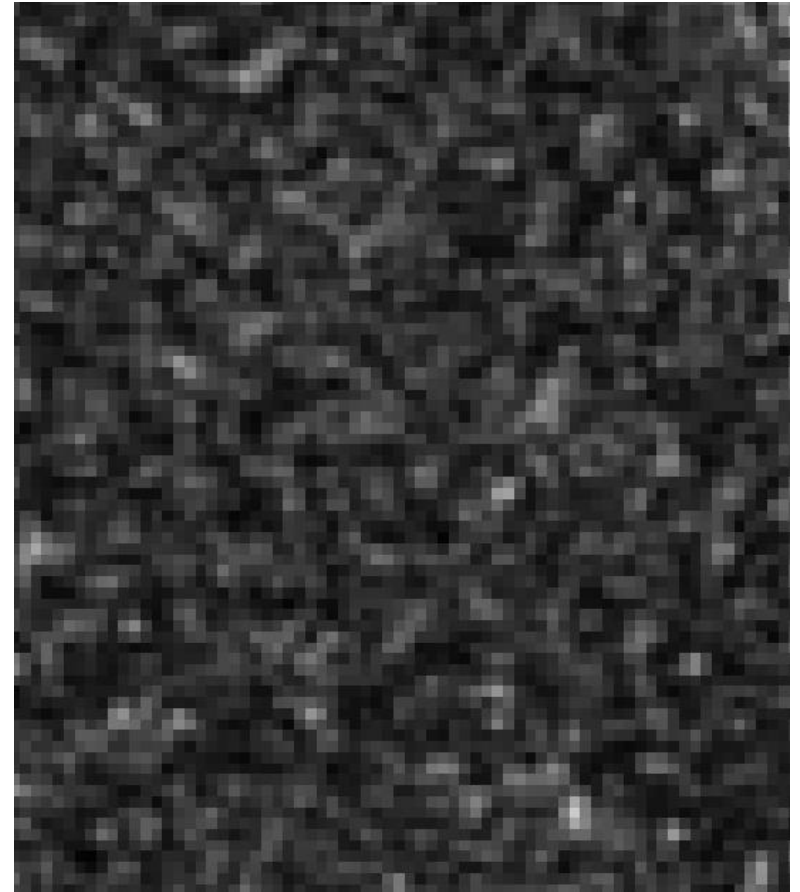


What is Speckle?

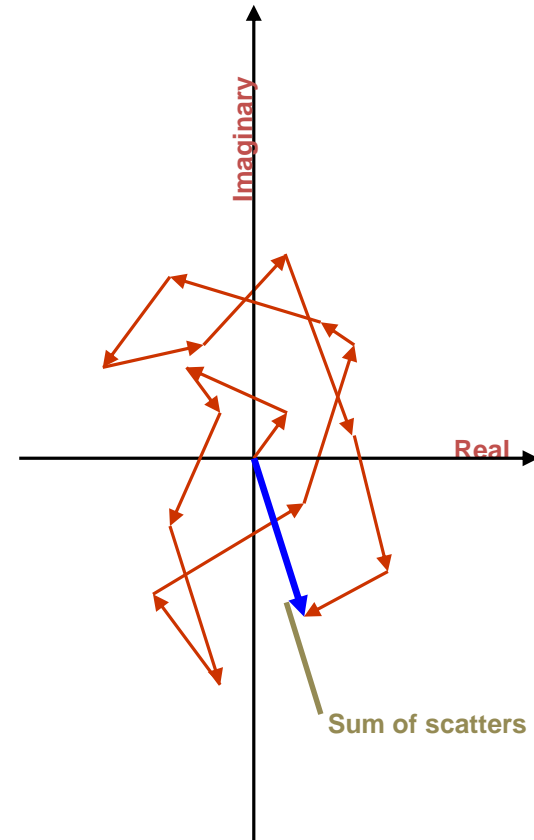
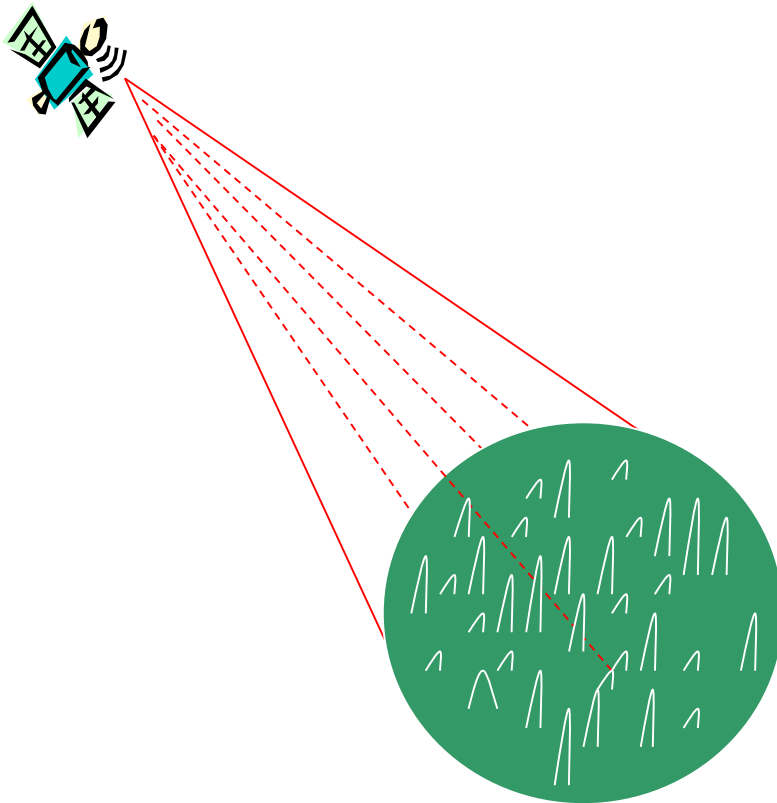
- Consider waves incident on a target of identical but randomly placed scatterers (for example, blades of grass)
- Each individual scatterer (blade of grass) within a resolution cell (“pixel”) will return a vector of constant amplitude BUT arbitrary phase



Speckle Phenomenon

Speckle Phenomenon

- The radar adds these responses coherently (amplitude and phase) to a single vector (vector sum)
- Constructive or destructive interference among the backscatter waves of individual blades of grass within one resolution cell creates speckle



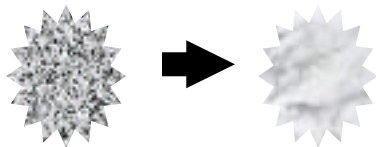
Speckle Filtering



Speckle Filtering

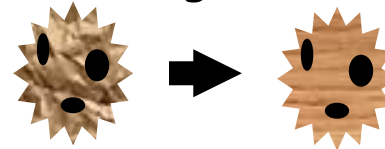


Homogeneous Area



Speckle Reduction
(Radiometric Resolution)

Heterogeneous Area



Details Preservation
(Spatial Resolution)

Speckle Filtering

Speckle filtering is not an exact science subjective → image dependent

Therefore, an ideal speckle filter must satisfy to the following specifications:

- Speckle Reduction
- Edge Sharpness Preservation
- Line and Point Target Contrast Preservation
- Retention of Mean Values in Homogeneous Regions
- Retention of Texture Information

Information source: Quantitative Criteria (J.S. Lee - IGARSS 98)

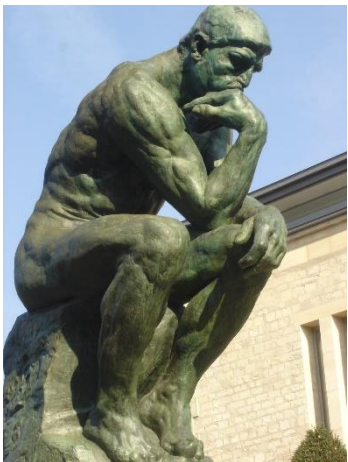


Image source:
https://commons.wikimedia.org/wiki/File:ThinkingMan_Rodin.jpg



What to do?

- Multi-look processing
- Image Filtering



Image source:

https://commons.wikimedia.org/wiki/File:Neutral_density_filter_demonstration.jpg

Multi-looking

- Multi-looking is usually applied for ground range images by the Instrument Processing Facility before releasing the products

Sentinel-1 Level-1 GRD products are multi-looking images

1 look in Azimuth and 5 looks in Range

- Users have the choice to apply multi-looking processing again in order to further reduce the speckle.

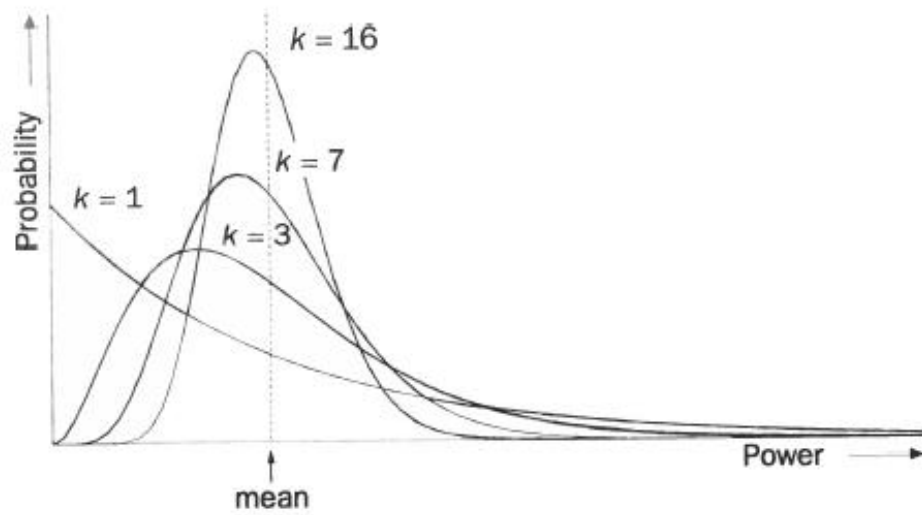
Multi-looking

Multi-looking processing for intensity images

- Averaging intensity (Not complex images) of neighboring pixels
- Good noise smoothing
- Spatial resolution loss - blurring edges - erasing thin lines
- Loss of linear or point features

Multi-looking

Impact of Multi-looking



Distribution of averaged power for 1, 3, 7 and 16 look radar images.

Image source: Van der Sanden, 1997

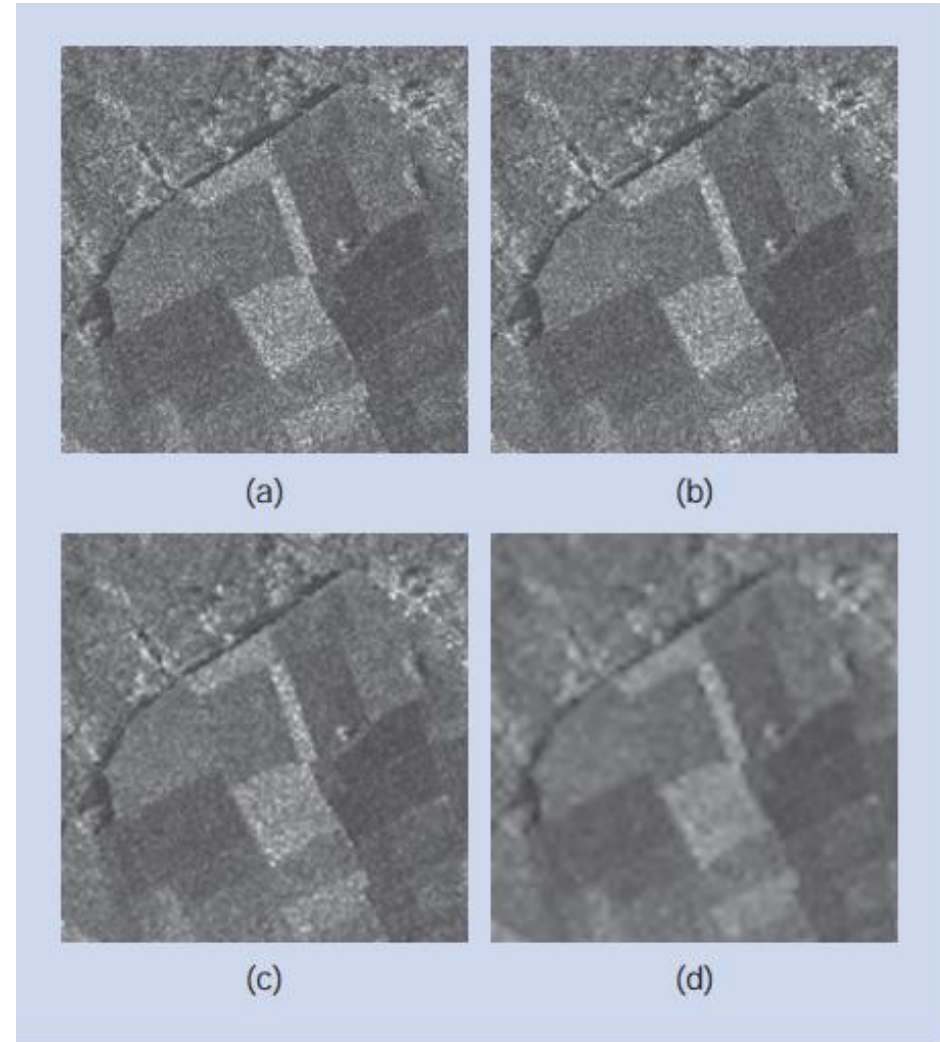


FIGURE 5. The effect of speckle can be reduced through multi-look in azimuth and range which also worsens the resolution as seen in the multi-looked SAR images above. (a) Without multi-look. (b) 2×2 multi-look. (c) 4×4 multi-look. (d) 8×8 multi-look.

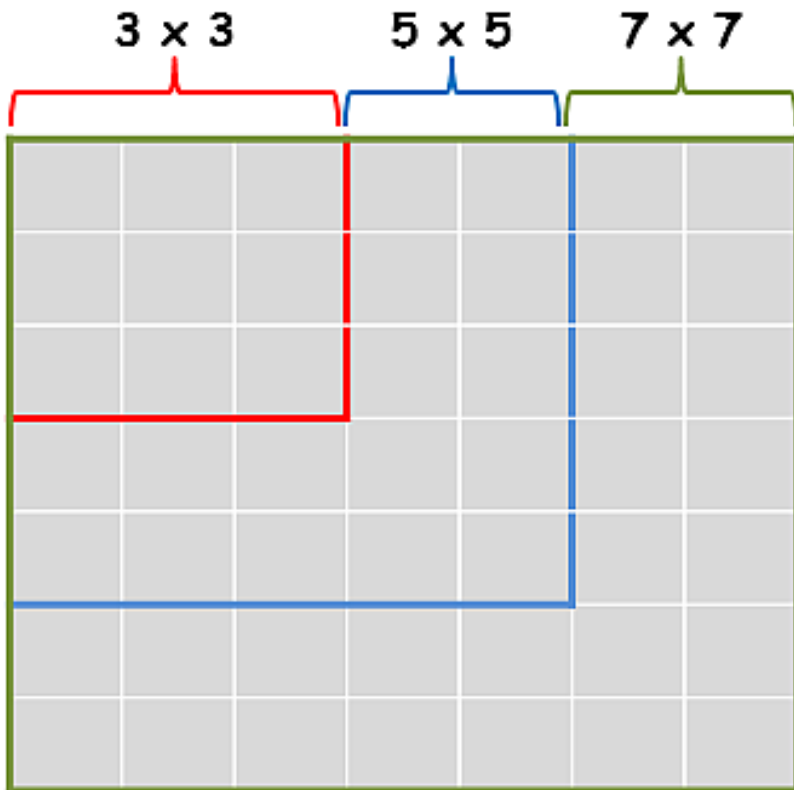
Image source: Moreira et al., 2013

Speckle Filtering

- Speckle filtering is therefore a compromise between speckle removal (radiometric resolution) and details preservation (spatial resolution)
- Good speckle removal requires the use of large processing windows
- On the contrary, good preservation of the image details like texture is needed

Age Old Question: What Filter Size?

- There is **no** simple answer
- Choice depends on the targets (point target, distributed target) and the target size (for example field sizes)

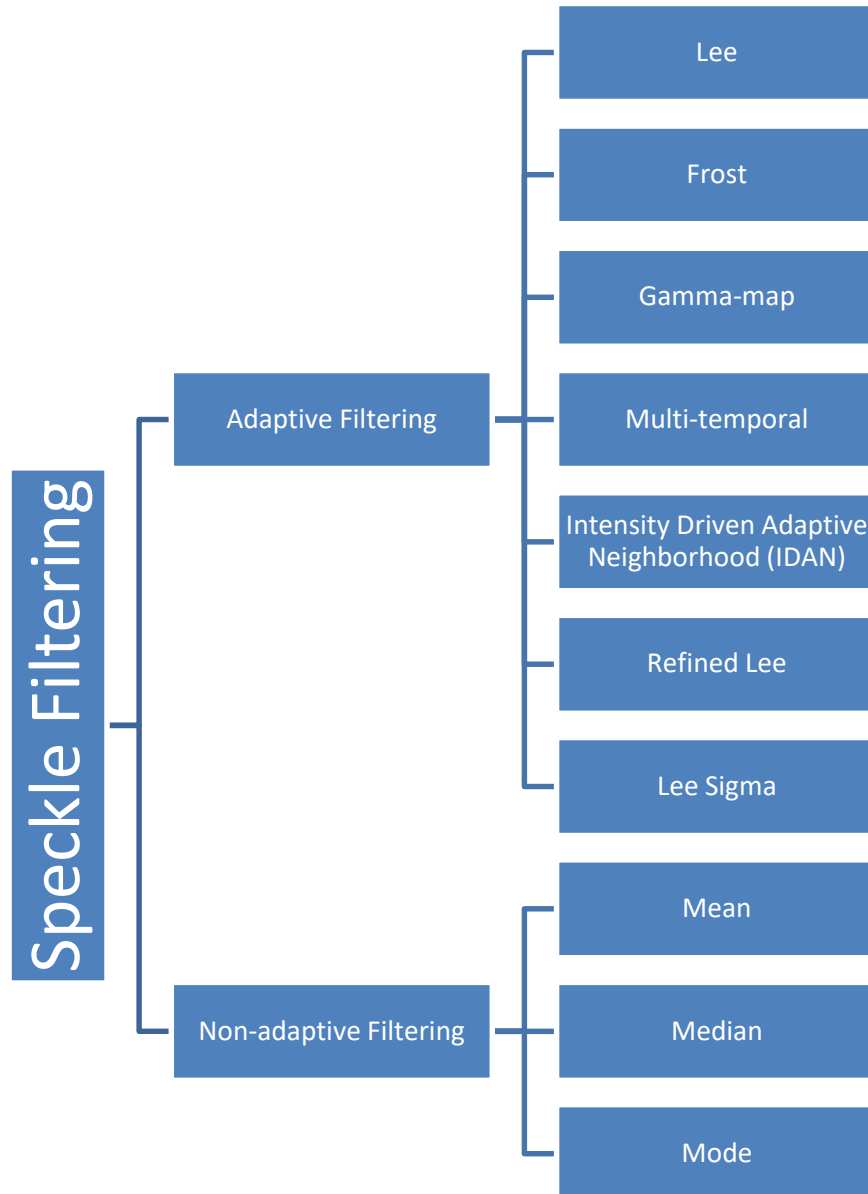


What is the target?



Let the target dictate the filter size

Speckle Filtering



New methods are developing constantly

Non-Adaptive Filters

- Commonly used in remote sensing . . . **but** not for SAR processing
- Intensity of each sample in the image is replace by the mean/median/mode of pixel values in a moving window surrounding the sample

Mean

5	7	4
9	8	6
5	5	8

Median

5	7	4
9	8	6
5	5	8

Mode

5	7	4
9	8	6
5	5	8

$$5+7+4+9+8+6+5+5+8 = 57$$
$$57/9 = 6.33$$

Mean = 6

4,5,5,5,6,7,8,8,9

Median = 6

4
555
6
7
88
9

Mode = 5

Non-Adaptive Filters

Mean filter

Mean filter: Not an optimal filter for SAR because dark and bright pixels within the filter window can cancel each other out. However, it produces image blur, loss of details and, eventually, loss of spatial resolution.



HV polarization multi-looked unfiltered image



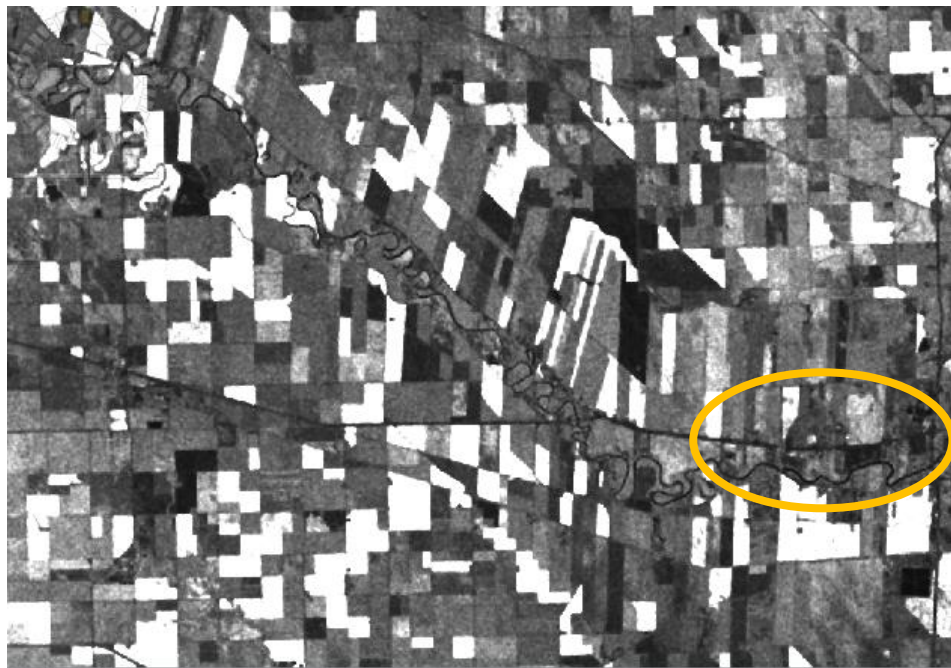
Mean filter (7 by 7 window size)

Non-Adaptive Filters

Median filter: This filter is useful for removing speckle when the noise is less than a half of the filter window. The median filter is edge preserving, although it may lead to the removing of small objects from the image.



Mean filtered image

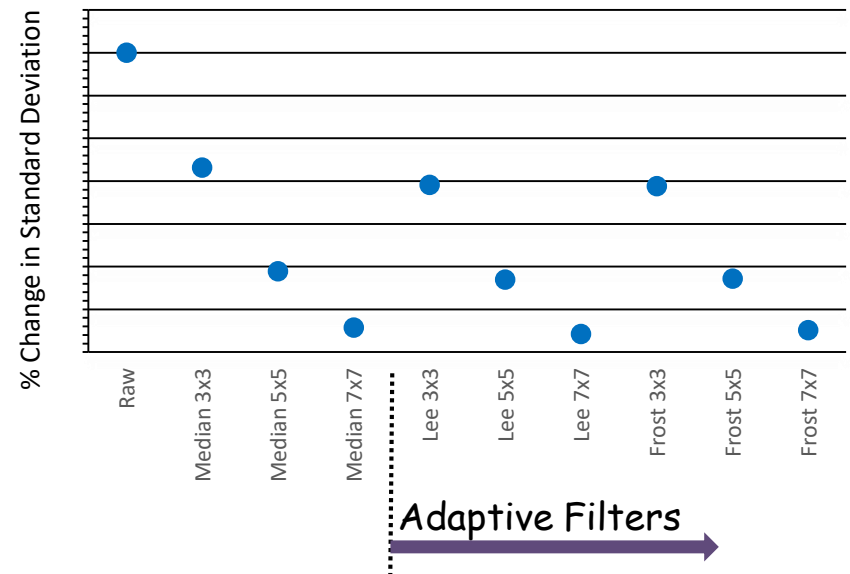
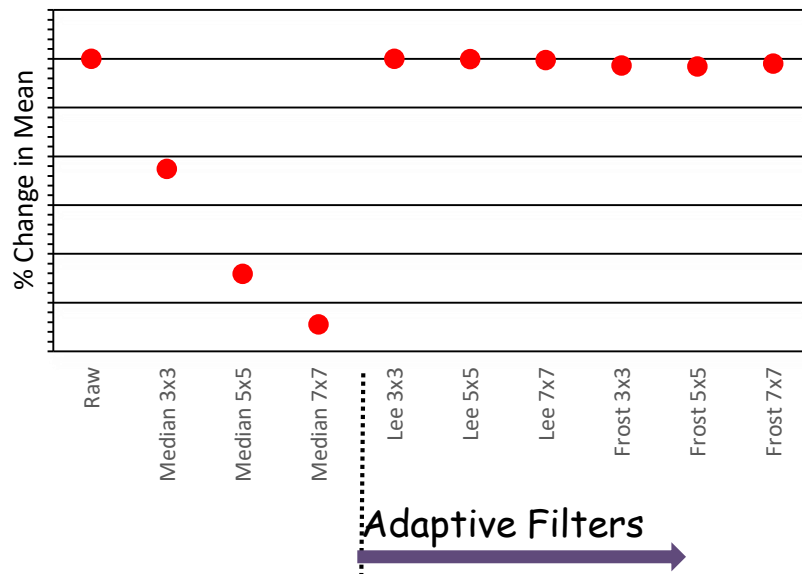


Median filter (7 by 7 window size)

Radar Adaptive Filters

- Adaptive filters are all adaptive as a function of the local coefficient of variation.
- The filters modify the image based on appropriate scene and speckle models extracted from the local environment of each pixel

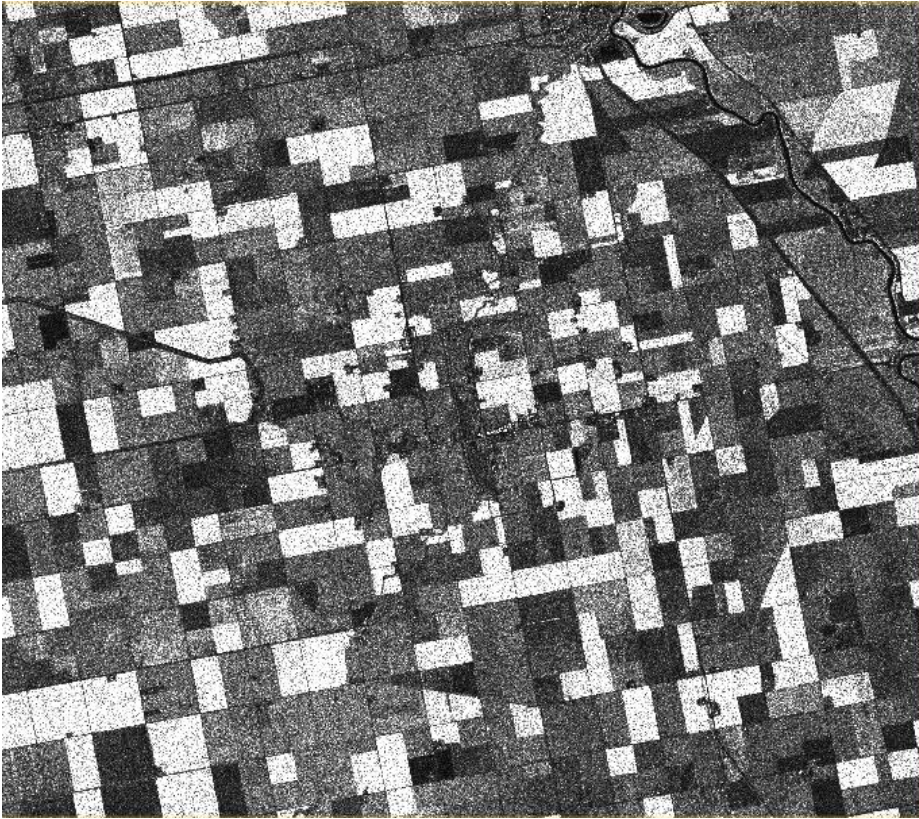
Filter Size and Type



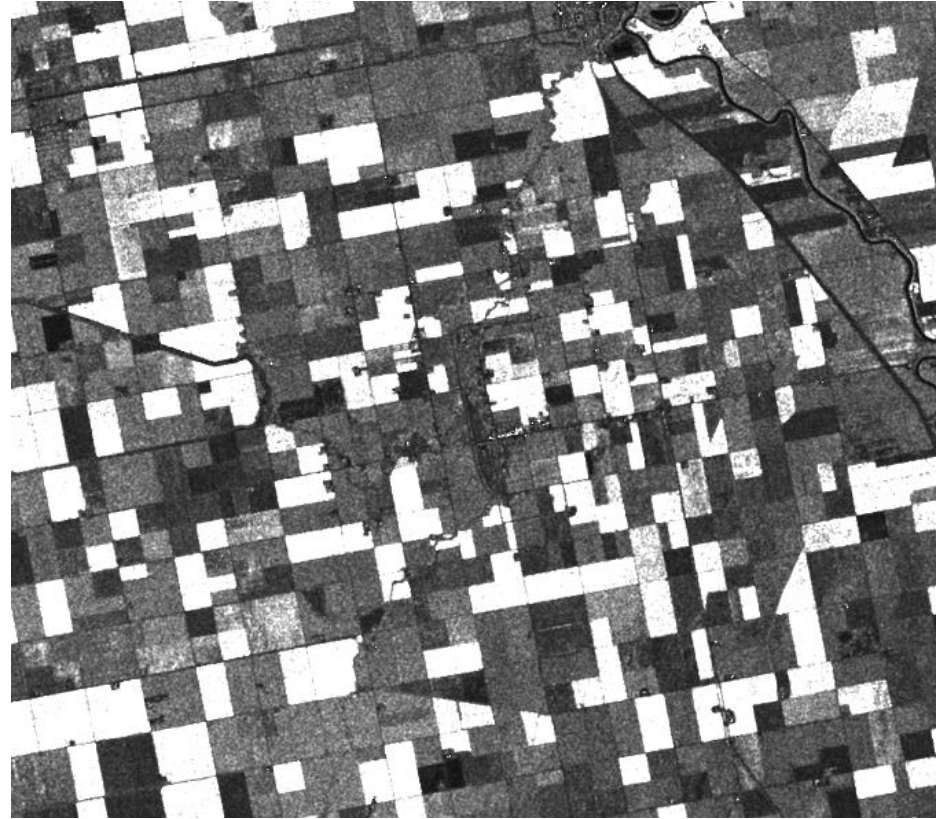
Gamma MAP Filter

- Based on the assumption that the (unspeckled) intensity of the underlying scene is Gamma distributed
- The filter minimizes the loss of texture information better than Frost or Lee filters within gamma distributed scenes
- Suitable for a wide range of gamma distributed scenes such as forested areas, agriculture areas and oceans
- The filter preserves pixel value for non-Gamma distributed scenes

Gamma Map Filter



HV polarization multi-looked unfiltered image



Gamma map filter (7 by 7 window size)