Radar Image Filters

TNTmips provides several sets of image filters that can be applied to grayscale or color images temporarily as a Display option (using the Filter tabbed panel on the Raster Layer Display Controls window) or permanently using the Spatial Filter process (Image / Filter / Spatial Filter). For ease of selection these spatial filters are organized into groups based on their purpose. To select a filter, choose the filter group from the Type menu and the specific filter from the Filter menu (see the Technical Guide entitled *Spatial Filter Process*).

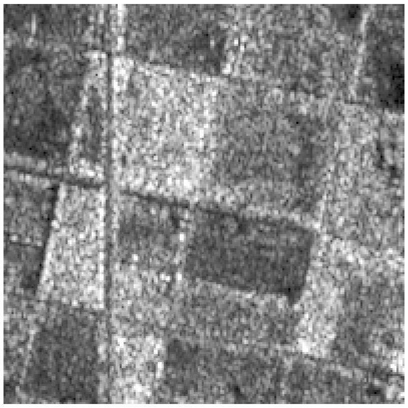
Radar images have a distinctly grainy appearance that results from a characteristic image noise known as *speckle*. Speckle arises from random variations in the strength of the backscattered radar signal that are inherent in the radar imaging process (see box to the right for details). Speckle makes it difficult to assess the characteristics of the target materials from the measured radar response. In non-uniform areas, the presence of speckle also reduces the human interpreter's ability to resolve details in the image.

Origin of Radar Image Speckle

The radar signal received from a single ground-resolution cell is actually the sum of many signals generated by individual objects and surfaces within the cell. The strength of the aggregate return signal varies with direction and angle of view, in part due to varying degrees of constructive and destructive interference occurring among the individual signals. A minor change in direction of view can result in a great difference in the strength of the aggregate signal received by the sensor. As a result, image cells in areas with uniform ground materials and slope exhibit random variations in image brightness, producing a speckled appearance.

It is useful to consider the total return signal strength in a radar image as a function of a true signal (dependent on the properties of the objects in the individual cell) and a random, superimposed speckle noise. Unlike the additive image noise in many optical images, speckle is approximately multiplicative in nature. The brightness of a cell in the image is the product of the true signal and the random noise, so as target brightness increases, so does the amplitude of the noise. The radar filters included in this group are designed to account for this property of speckle noise. They are adaptive filters, varying the filter parameters spatially on the basis of the local statistical properties of the image.

Using the multiplicative model for speckle noise, it can be shown that the standard deviation of the speckle noise equals the ratio of the standard deviation of image brightness to the mean image brightness. Typically this ratio is nearly constant for areas of varying average brightness in a radar image. Some of the radar filters calculate the noise standard deviation for each filter window using local values, whereas others assume the constancy property and calculate a single noise standard deviation value for the entire image. The resulting value is then used along with the local statistics in each filter window to estimate the value of the true signal for the center cell of the filter window. The adaptive nature of these filters allows them to reduce speckle noise while minimizing loss of spatial resolution and preserving edge detail. With user-adjustable parameters (set by a slider control) chosen to produce optimum results for each filter, the output images from the different filters may show only subtle visual differences.



Sample Radar Image

As in all filters, increasing the filter window size extends the filter effects to larger image features and results in more smoothing. The filters in the Radar group are not static linear convolution filters, so the Kernel tabbed panel in the Spatial Filter process is inactive when you select this filter group.

Sigma Filter

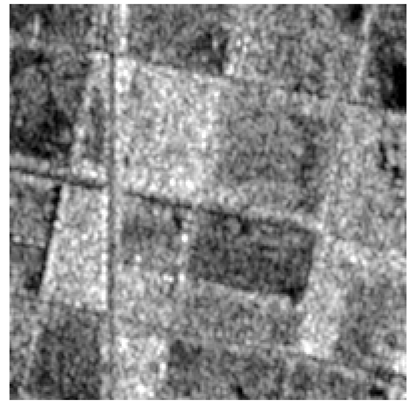
The Sigma filter assumes that the variation in brightness due to speckle noise for a particular average image brightness has a Gaussian (normal) distribution and that the noise standard deviation is constant for the entire image. For each filter window, the filter output is the average of the cells whose values fall within a prescribed range above and below that of the center cell value. The limits of this range are set as a user-adjustable multiple of the estimated noise standard deviation. Variation within these limits is assumed to be the result of speckle noise in a uniform area, whereas cells with values outside these limits probably represent different surface materials, and thus should not contribute to the averaging process. The Sigma filter therefore can suppress speckle with minimal blurring of edges and fine detail.

Sigma 3 x 3, Smoothing = 2
Central Range Threshold = 2

(over)

The Speckle Smoothing slider adjusts the value of the standard deviation multiplier that defines the averaging limits. Its value can range between 0.1 and 3.0 standard deviations on either side of the mean. Increasing the Speckle Smoothing value increases the amount of smoothing but may result in blurring of edges.

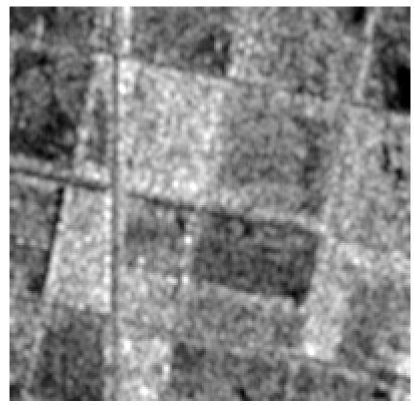
When the filter window is centered on an isolated cell with an extreme value (noise), the selective averaging procedure described above is not an appropriate result. Only a few cells (or perhaps only the center cell) may lie within the specified standard deviation limits around this extreme value. If the number of such cells is less than the Central Range Threshold parameter value, the Sigma filter replaces the extreme center cell value with the simple average of the surrounding cell values, removing the noise value. Small values for the Central Range Threshold parameter remove isolated noise values without degrading inherent fine features of the image. Repeat application of the Sigma filter may be required in order to eliminate all isolated outlier values.



Frost 3 x 3

Frost Filter

The Frost filter estimates the standard deviation of the speckle noise for each filter window, assuming it has a negative exponential distribution. The filter performs a weighted average of the cell values in the filter window, with the weights for each cell being determined from the local statistics to minimize the mean square error of the signal estimate. The filter weight for a cell is a negative exponential function of the noise standard deviation; the weights also decrease with distance from the center cell. The center cells are weighted more heavily as the variance in the filter window increases. The filter therefore smoothes more in homogeneous areas, but provides a signal estimate closer to the observed value of the center cell in heterogeneous areas. The Damping factor is an exponential value that modifies the filter weights. Larger damping values preserve edges better with less smoothing of homogeneous areas, while smaller values smooth more. A damping value of 0 results in the same output as a low pass filter. A damping value of 1 (the default) is recommended for most radar images.



Lee 3 x 3

Lee Filter

The Lee filter uses a least-squares approach to estimate the true signal strength of the center cell in the filter window from the measured value in that cell, the local mean brightness of all cells in the window, and a gain factor calculated from the local variance and the estimated noise standard deviation. The filter assumes a Gaussian (normal) distribution for the noise values and calculates the local noise standard deviation for each filter window. The Lee filter calculation produces an output value close to the local mean for uniform areas and a value close to the original input value in higher contrast regions. Most smoothing occurs in the more uniform areas, while edges and other fine details are maintained. The Lee filter has no user-adjustable parameters except for the filter window size.

Kuan Adaptive Noise Smoothing 3 x 3, Smoothing = 1.0

Kuan (Adaptive Noise Smoothing)

The Kuan Adaptive Noise Smoothing filter uses a minimum mean square error calculation to estimate the value of the true signal for the center cell in the filter window from the local statistics. It is similar in approach to the Lee filter, but makes fewer simplifying assumptions in the calculations. The Adaptive Noise Filter calculates the signal estimate from the local mean and variance and the noise standard deviation (assumed to be constant for the entire image); it assumes a Gaussian (normal) distribution for the speckle noise. The adjustable Speckle Smoothing parameter value is a multiplier applied to the noise standard deviation to vary the amount of smoothing. This value can vary from 1.0 to 5.0.