**# README\_Gamma\_demo\_BM3D\_filter**

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**# CM, UW 20190219**

**# README file and input data used are in ./inputs**

**# visualizations of some results are in ./results**

**#**

**# data include:**

**# - airborne high resolution backscatter (mli)**

**# - TerraSAR-X high resolution backscatter (mli)**

**# - Sentinel-1 backscatter (mli)**

**# - rasterfile gray scale image (bmp)**

**# - rasterfile color image (bmp)**

**# - complex valued S1 differential interferogram (fcomplex)**

Youtube: [What is Block Matching & 3D filtering for denoising?](https://www.youtube.com/watch?v=aJrG8IH81SY)

**Demo examples on the use of the new bm3d filtering program (in LAT module).**

**Besides backscatter images complex valued images as interferograms or rasterfiles can be filtered.**

bm3d - Block-Matching and 3D filtering for reducing noise in images.

EXAMPLE

bm3d 20110216.mli 3395 20110216\_bm3d.mli 0 0 25

Reduces noise in 20110216.mli using the SAR-BM3D method.

DESCRIPTION

Block-Matching and 3D filtering [1] is an advanced non-local algorithm for reducing noise in images. The implemented algorithm works using the following framework:

1. Analysis of the data for estimating the noise variance.
2. First step

* Block-matching
* Coarse filtering on block stacks
* Results aggregation

1. Second step

* Block-matching using the noisy data as well as the results of first step
* Wiener filtering using the noisy data as well as the results of first step on block stacks
* Results aggregation

The data analysis computes an estimate for the noise parameter sigma **(~standard deviation of the noise)** as well as a dissimilarity threshold (this threshold is used only when **[d\_max]** is set to 0 (default)). The estimated sigma value will be used for the denoising when no [sigma] value is entered by the user. It is a good starting point, from which the denoising can be carried out a second time with a more appropriate value.

The block-matching procedure compares reference blocks (**[block\_size]** is typically 8x8 pixels) with all blocks available in a neighborhood (with maximum distance **[s\_dist]**), and sorts the blocks using a similarity estimator from the most similar to the least similar block. The n (e.g. n = 16 or 32) most similar blocks are kept in a group. Reference blocks are defined every **[step]** pixels.

The filtering is performed on 3D-transformed groups. All blocks within the group are first 2D-transformed, and a 1D transform is then carried out along the "stack" direction. The 2D transforms in the implemented bm3d software are performed using the **discrete cosine transform (DCT)**, while the 1D transform is performed either using a **Haar wavelet transform** or a DCT (option [t1d]). **The filtering is typically a hard-thresholding in the first step**, and a **Wiener filter in the second step** (see [1-5]). The filtered coefficients are then inverse-transformed.

Each pixel will typically have been filtered several times in slightly different ways. The aggregation is a weighted average; weights are calculated during the filtering and are inversely proportional to the group variance.

The bm3d program offers several methods for denoising images:

The BM3D method corresponds to the algorithm described in [1] and [2]. The filtering can be performed directly on the data, on the square root of the data, or on the log of the data:

**Filtering on the log of the data is relatively well adapted to SAR multilooked intensity images**, however it may "eat" some isolated, strongly scattering elements.

**Direct filtering on the data values of SAR multilooked intensity images results in non-homogeneous denoising, with darker areas much more strongly denoised than brighter areas.** This method works well for linearly-scaled images or optical images. This method also supports data with negative values or complex data.

The square root method provides intermediate results for SAR multilooked intensity images.

The SAR-BM3D method is based on [3] and [4]. It is adapted from [1] to deal with the characteristics of speckle noise in multilooked intensity images. **The actual implementation is close to that described in [4].** The denoising results are similar to those obtained when filtering on the log of the data, however with much improved preservation of isolated, strongly scattering elements. Two profiles are available, a "fast" profile (although slightly slower than the BM3D profiles) and a "fine" profile with larger search distance and a larger maximum number of blocks per group.

The C-BM3D filters color images. It transforms the RGB input image into a YCbCr color space. In both the first and second steps, the block-matching procedure is performed only on the luminance channel, while the filtering is performed separately on each channel. The final result in YCbCr color space is transformed back into RGB values.

**The InSAR-BM3D method is based on [5] and aims at denoising wrapped interferograms.** It is adapted from [1] to handle the characteristics of SAR interferometric images. Note that in that case, the [sigma] parameter is a factor multiplying the standard deviation estimated from the data. Entering the accurate number of looks (option [looks]) is crucial for obtaining high quality results with this method. As an approximation to the equivalent number of looks, the multilook factor can be used (e.g.: if 8 looks in azimuth and 2 looks in range were used to generate the interferogram, entering 16 as the equivalent number of looks should not be too far from the actual value).

bm3d is a computationally demanding algorithm, in case of large images, first tries can be performed on a subset of the image, with the full image being processed when the appropriate method and [sigma] parameter has been found. Another possibility is decreasing the maximum search distance [s\_dist]. The Haar transform in the third dimension is also slightly faster than the DCT.

BM3D（Block Matching and 3D Collaborative Filtering）：

フィンランドのタンペレ工科大学のDabovらが開発。BM3Dでは、ノイズ除去空間として、ブロックを重ねた3次元配列に対する**離散コサイン変換基底**や**離散ウェーブレット変換基底**により張られる空間を用いる。ノイズの縮退は、固定の縮退しきい値を用いたしきい値処理である。BM3Dは現在、世界最高水準の性能を持つノイズ除去方式の一つとして知られているが、縮退しきい値が画像全体について固定値であるため、画像信号の複雑なテクスチャを十分に保持できないという欠点も持っている。

シュリンケージ方式のノイズ除去処理の概要：

シュリンケージ方式は、画像中に複数画像をまとめたベクトルを、正規直交基底により張られる空間へ射影する。縮退しきい値よりも小さい射影係数をノイズとみなして縮退させる。縮退後の射影係数を用いてブロックを再構成し、もともとのブロックを置き換えることで画像からノイズを除去する。

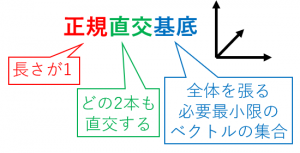
※正規直交基底とは？：<https://oguemon.com/study/linear-algebra/orthonormal-basis/>もしくは<https://mathwords.net/seikityokkoukitei>

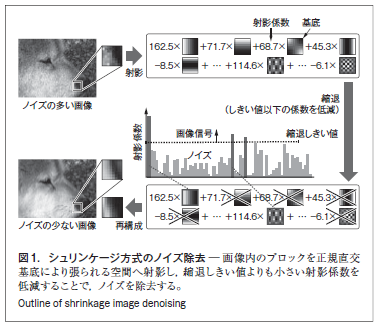
正規直交基底とは、

・それぞれの長さが 1（正規化されている）で

・互いに直交している（内積が 0）

のような基底（線形結合で全てを表せるような必要最小限のベクトルの集合）です。





シュリンケージ方式には、２つの重要な課題：

①ノイズと信号を分離しやすいノイズ除去空間を張る基底をいかに用意するか

②画像信号を損なうことなく、いかにノイズだけを縮退させるか

である。

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# - TerraSAR-X high resolution backscatter (mli)

# TerraSAR-X Venezia; image width is 1024 pixel, 5 range x 5 azimuth looks

cp inputs/TX\_Venezia.mli .

cp inputs/TX\_Venezia.mli.par .

bm3d TX\_Venezia.mli 1024 TX\_Venezia\_bm3d.mli 0 0 25

dis2pwr TX\_Venezia.mli TX\_Venezia\_bm3d.mli 1024 1024

|  |  |
| --- | --- |
| TX\_Venezia.mli.bmp | TX\_Venezia\_bm3d.mli.bmp |
|  |  |

# indicate a reduced number of looks (looks may be correlated)

bm3d TX\_Venezia.mli 1024 TX\_Venezia\_bm3d12.mli 0 0 12

dis2pwr TX\_Venezia\_bm3d.mli TX\_Venezia\_bm3d12.mli 1024 1024

**# --> almost identical result**

# indicate step 1 (slower by possibly slightly better)

bm3d TX\_Venezia.mli 1024 TX\_Venezia\_bm3d\_step1.mli 0 0 25 - 8 16 1

dis2pwr TX\_Venezia\_bm3d.mli TX\_Venezia\_bm3d\_step1.mli 1024 1024

**# --> almost identical result**

# display using logarithmic (dB) scale

ras\_dB TX\_Venezia.mli 1024 1 0 1 1 -22. 3.5 25 1 TX\_Venezia.mli.bmp

ras\_dB TX\_Venezia\_bm3d.mli 1024 1 0 1 1 -22. 3.5 25 1 TX\_Venezia\_bm3d.mli.bmp

dis2ras TX\_Venezia.mli.bmp TX\_Venezia\_bm3d.mli.bmp &

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# - Sentinel-1 backscatter (mli)

# Sentinel-1 Greenland, image width is 1024 pixel, 10 range x 2 azimuth looks

cp inputs/S1\_Greenland.mli .

cp inputs/S1\_Greenland.mli.par .

bm3d S1\_Greenland.mli 1024 S1\_Greenland\_bm3d.mli 0 0 20

dis2pwr S1\_Greenland.mli S1\_Greenland\_bm3d.mli 1024 1024 - - - - 0.95 0.3

# display using logarithmic (dB) scale

ras\_dB S1\_Greenland.mli 1024 1 0 1 1 -22. 3.5 60 1 S1\_Greenland.mli.bmp

ras\_dB S1\_Greenland\_bm3d.mli 1024 1 0 1 1 -22. 3.5 60 1 S1\_Greenland\_bm3d.mli.bmp

dis2ras S1\_Greenland.mli.bmp S1\_Greenland\_bm3d.mli.bmp &

|  |  |
| --- | --- |
| S1\_Greenland.mli.bmp | S1\_Greenland\_bm3d.mli.bmp |
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**# - complex valued S1 differential interferogram (fcomplex)**

# S1A-S1B Interferogram Italy earthquake, image width is 1024 pixel, 10 range x 2 azimuth looks

cp inputs/S1AS1B\_Italy\_Interfero.diff .

cp inputs/S1AS1B\_Italy\_Interfero.diff.par .

bm3d S1AS1B\_Italy\_Interfero.diff 1024 S1AS1B\_Italy\_Interfero\_bm3d.diff 1 6 20

dis2mph S1AS1B\_Italy\_Interfero.diff S1AS1B\_Italy\_Interfero\_bm3d.diff 1024 1024 &

rasmph S1AS1B\_Italy\_Interfero.diff 1024 1 0 1 1 1. 0.35 1 S1AS1B\_Italy\_Interfero.diff.bmp

rasmph S1AS1B\_Italy\_Interfero\_bm3d.diff 1024 1 0 1 1 1. 0.35 1 S1AS1B\_Italy\_Interfero\_bm3d.diff.bmp

dis2ras S1AS1B\_Italy\_Interfero.diff.bmp S1AS1B\_Italy\_Interfero\_bm3d.diff.bmp

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# check effect on unwrapping:

cc\_wave S1AS1B\_Italy\_Interfero.diff - - S1AS1B\_Italy\_Interfero.diff.cc 1024 5 5

mcf S1AS1B\_Italy\_Interfero.diff S1AS1B\_Italy\_Interfero.diff.cc - S1AS1B\_Italy\_Interfero.diff.unw 1024 0 0 0 - - 1 1 512 350 400 0

cc\_wave S1AS1B\_Italy\_Interfero\_bm3d.diff - - S1AS1B\_Italy\_Interfero\_bm3d.diff.cc 1024 5 5

mcf S1AS1B\_Italy\_Interfero\_bm3d.diff S1AS1B\_Italy\_Interfero\_bm3d.diff.cc - S1AS1B\_Italy\_Interfero\_bm3d.diff.unw 1024 0 0 0 - - 1 1 512 350 400 0

dis2rmg S1AS1B\_Italy\_Interfero.diff.unw S1AS1B\_Italy\_Interfero\_bm3d.diff.unw 1024 1024 1 0 0 0 0.333

**# --> in this case the unwrapping seems to work better with the filtered differential interferogram**

# compare also with an unwrapping using a multi-looking

create\_offset S1AS1B\_Italy\_Interfero.diff.par S1AS1B\_Italy\_Interfero.diff.par S1AS1B\_Italy\_Interfero.off1 1 1 1 0

multi\_cpx S1AS1B\_Italy\_Interfero.diff S1AS1B\_Italy\_Interfero.off1 S1AS1B\_Italy\_Interfero.diff2 S1AS1B\_Italy\_Interfero.off2 2 2

cc\_wave S1AS1B\_Italy\_Interfero.diff2 - - S1AS1B\_Italy\_Interfero.diff2.cc 512 3 3

mcf S1AS1B\_Italy\_Interfero.diff2 S1AS1B\_Italy\_Interfero.diff2.cc - S1AS1B\_Italy\_Interfero.diff2.unw 512 0 0 0 - - 1 1 512 175 200 0

multi\_real S1AS1B\_Italy\_Interfero.diff2.unw S1AS1B\_Italy\_Interfero.off2 S1AS1B\_Italy\_Interfero.diff2.unw1 S1AS1B\_Italy\_Interfero.off1 -2 -2

dis2rmg S1AS1B\_Italy\_Interfero.diff2.unw1 S1AS1B\_Italy\_Interfero\_bm3d.diff.unw 1024 1024 1 0 0 0 0.333

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# Color image : Jupiter\_1, width: 600, noise: 13

cp inputs/Jupiter\_1.bmp .

bm3d Jupiter\_1.bmp 600 Jupiter\_1\_bm3d.bmp 2 5 - 13

dis2ras Jupiter\_1.bmp Jupiter\_1\_bm3d.bmp &

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| --- | --- |
| Jupiter\_1.bmp | Jupiter\_1\_bm3d.bmp |
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# Grayscale image : Jupiter\_2\_grayscale, width: 600, noise: 21

cp inputs/Jupiter\_2\_grayscale.bmp .

bm3d Jupiter\_2\_grayscale.bmp 600 Jupiter\_2\_grayscale\_bm3d.bmp 2 2 - 21

dis2ras Jupiter\_2\_grayscale.bmp Jupiter\_2\_grayscale\_bm3d.bmp &

|  |  |
| --- | --- |
| Jupiter\_2\_grayscale.bmp | Jupiter\_2\_grayscale\_bm3d.bmp |
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**# Change detection using a backscatter pair (avalanche mapping in Aletsch region)**

**# TSX HH-pol, range width 1024, 4 range x 4 azimuth looks**

cp inputs/Aletsch.201212??.TSX\_HH.rmli .

cp inputs/Aletsch.201212??.TSX\_HH.rmli.par .

**# Spatial filtering using bm3d**

bm3d Aletsch.20121206.TSX\_HH.rmli 1024 Aletsch.20121206.TSX\_HH\_bm3d.rmli 0 0 16

bm3d Aletsch.20121217.TSX\_HH.rmli 1024 Aletsch.20121217.TSX\_HH\_bm3d.rmli 0 0 16

bm3d Aletsch.20121228.TSX\_HH.rmli 1024 Aletsch.20121228.TSX\_HH\_bm3d.rmli 0 0 16

**# generate RGB of the 3 scenes using raspwr (for unfiltered and filtered MLIs)**

raspwr Aletsch.20121206.TSX\_HH.rmli 1024 - - - - - - - Aletsch.20121206.TSX\_HH.rmli.bmp

raspwr Aletsch.20121217.TSX\_HH.rmli 1024 - - - - - - - Aletsch.20121217.TSX\_HH.rmli.bmp

raspwr Aletsch.20121228.TSX\_HH.rmli 1024 - - - - - - - Aletsch.20121228.TSX\_HH.rmli.bmp

ras\_to\_rgb Aletsch.20121206.TSX\_HH.rmli.bmp Aletsch.20121217.TSX\_HH.rmli.bmp Aletsch.20121228.TSX\_HH.rmli.bmp Aletsch.20121206\_20121217\_20121228.TSX\_HH.rmli.bmp

raspwr Aletsch.20121206.TSX\_HH\_bm3d.rmli 1024 - - - - - - - Aletsch.20121206.TSX\_HH\_bm3d.rmli.bmp

raspwr Aletsch.20121217.TSX\_HH\_bm3d.rmli 1024 - - - - - - - Aletsch.20121217.TSX\_HH\_bm3d.rmli.bmp

raspwr Aletsch.20121228.TSX\_HH\_bm3d.rmli 1024 - - - - - - - Aletsch.20121228.TSX\_HH\_bm3d.rmli.bmp

ras\_to\_rgb Aletsch.20121206.TSX\_HH\_bm3d.rmli.bmp Aletsch.20121217.TSX\_HH\_bm3d.rmli.bmp Aletsch.20121228.TSX\_HH\_bm3d.rmli.bmp Aletsch.20121206\_20121217\_20121228.TSX\_HH\_bm3d.rmli.bmp

ras\_to\_rgb - Combines 3 8-bit raster images into a single red/green/blue (RGB) 24-bit composite raster image

ras\_to\_rgb <red\_channel> <green\_channel> <blue\_channel> <output> [LR] [null\_flag]

dis2ras Aletsch.20121206\_20121217\_20121228.TSX\_HH.rmli.bmp Aletsch.20121206\_20121217\_20121228.TSX\_HH\_bm3d.rmli.bmp &

|  |  |
| --- | --- |
| Aletsch.20121206\_20121217\_20121228.TSX\_HH.rmli.bmp | Aletsch.20121206\_20121217\_20121228.TSX\_HH\_bm3d.rmli.bmp |
|  |  |

**In this case,**

**Red\_channel: Aletsch.20121206.TSX\_HH\_bm3d.rmli.bmp**

**Green\_channel: Aletsch.20121217.TSX\_HH\_bm3d.rmli.bmp**

**Blue\_channel: Aletsch.20121228.TSX\_HH\_bm3d.rmli.bmp**

**So, the center part shows the blue color which means “avalanche” was happened between 2012/12/17 and 2012/12/28.**

**# change detection method 0: ratio with 5x5 box filter (in ratio program)**

**# change detection method 1: apply bm3d filtering to ratio of unfiltered data**

**# change detection method 2: ratio of bm3d filtered MLIs without filtering in ratio program**

**# change detection method 3: ratio of bm3d filtered MLIs with 5x5 box filter in ratio program**

**# for 20121228, 20121217**

**# calculate ratios**

ratio Aletsch.20121217.TSX\_HH.rmli Aletsch.20121228.TSX\_HH.rmli Aletsch.20121217\_20121228.TSX\_HH.ratio0 1024 5 5

ratio Aletsch.20121217.TSX\_HH.rmli Aletsch.20121228.TSX\_HH.rmli Aletsch.20121217\_20121228.TSX\_HH.ratio1tmp 1024 1 1

ratio - Estimate ratio of image data values: d1/d2 (float data).

ratio <d1> <d2> <ratio> <width> [bx] [by] [wgt\_flag]

**# filter ratio with bm3d profile 4 (log): BM3D, filtering on log(data)**

bm3d Aletsch.20121217\_20121228.TSX\_HH.ratio1tmp 1024 Aletsch.20121217\_20121228.TSX\_HH.ratio1 0 4

ratio Aletsch.20121217.TSX\_HH\_bm3d.rmli Aletsch.20121228.TSX\_HH\_bm3d.rmli Aletsch.20121217\_20121228.TSX\_HH.ratio2 1024 1 1

ratio Aletsch.20121217.TSX\_HH\_bm3d.rmli Aletsch.20121228.TSX\_HH\_bm3d.rmli Aletsch.20121217\_20121228.TSX\_HH.ratio3 1024 5 5

**# for the visualization we want to display the ratios in color using log scale**

**# convert to dB scale**

linear\_to\_dB Aletsch.20121217\_20121228.TSX\_HH.ratio0 Aletsch.20121217\_20121228.TSX\_HH.ratio0\_dB 1024

linear\_to\_dB Aletsch.20121217\_20121228.TSX\_HH.ratio1 Aletsch.20121217\_20121228.TSX\_HH.ratio1\_dB 1024

linear\_to\_dB Aletsch.20121217\_20121228.TSX\_HH.ratio2 Aletsch.20121217\_20121228.TSX\_HH.ratio2\_dB 1024

linear\_to\_dB Aletsch.20121217\_20121228.TSX\_HH.ratio3 Aletsch.20121217\_20121228.TSX\_HH.ratio3\_dB 1024

linear\_to\_dB - Convert image from linear scale to dB scale and also the inverse

# visualization 1: colorscale for ratio -3 dB to +3 dB (green: no change, red: increase of backscatter, blue: decrease of backscatter (**better suited to assess noise level**)

# visualization 2: colorscale for ratio -6 dB to +6 dB **with bm3d filtered backscatter as brightness** (green: no change, red: increase of backscatter, blue: decrease of backscatter **(better suited as visualization of the change)**

vispwr.py Aletsch.20121217\_20121228.TSX\_HH.ratio0\_dB 1024 0 -3 3 -m hls.cm -u Aletsch.20121217\_20121228.TSX\_HH.ratio0\_dB.bmp

visdt\_pwr.py Aletsch.20121217\_20121228.TSX\_HH.ratio0\_dB Aletsch.20121228.TSX\_HH\_bm3d.rmli 1024 -6 6 -m hls.cm -u Aletsch.20121217\_20121228.TSX\_HH.ratio0\_dB\_mli.bmp

vispwr.py Aletsch.20121217\_20121228.TSX\_HH.ratio1\_dB 1024 0 -3 3 -m hls.cm -u Aletsch.20121217\_20121228.TSX\_HH.ratio1\_dB.bmp

visdt\_pwr.py Aletsch.20121217\_20121228.TSX\_HH.ratio1\_dB Aletsch.20121228.TSX\_HH\_bm3d.rmli 1024 -6 6 -m hls.cm -u Aletsch.20121217\_20121228.TSX\_HH.ratio1\_dB\_mli.bmp

vispwr.py Aletsch.20121217\_20121228.TSX\_HH.ratio2\_dB 1024 0 -3 3 -m hls.cm -u Aletsch.20121217\_20121228.TSX\_HH.ratio2\_dB.bmp

visdt\_pwr.py Aletsch.20121217\_20121228.TSX\_HH.ratio2\_dB Aletsch.20121228.TSX\_HH\_bm3d.rmli 1024 -6 6 -m hls.cm -u Aletsch.20121217\_20121228.TSX\_HH.ratio2\_dB\_mli.bmp

vispwr.py Aletsch.20121217\_20121228.TSX\_HH.ratio3\_dB 1024 0 -3 3 -m hls.cm -u Aletsch.20121217\_20121228.TSX\_HH.ratio3\_dB.bmp

visdt\_pwr.py Aletsch.20121217\_20121228.TSX\_HH.ratio3\_dB Aletsch.20121228.TSX\_HH\_bm3d.rmli 1024 -6 6 -m hls.cm -u Aletsch.20121217\_20121228.TSX\_HH.ratio3\_dB\_mli.bmp

dis2ras Aletsch.20121217\_20121228.TSX\_HH.ratio0\_dB.bmp Aletsch.20121217\_20121228.TSX\_HH.ratio1\_dB.bmp

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| --- | --- |
| Aletsch.20121217\_20121228.TSX\_HH.ratio0\_dB.bmp   * **ratio with 5x5 box filter** | Aletsch.20121217\_20121228.TSX\_HH.ratio1\_dB.bmp   * **apply bm3d filtering to ratio of unfiltered data** |
|  |  |

dis2ras Aletsch.20121217\_20121228.TSX\_HH.ratio0\_dB\_mli.bmp Aletsch.20121217\_20121228.TSX\_HH.ratio1\_dB\_mli.bmp

|  |  |
| --- | --- |
| Aletsch.20121217\_20121228.TSX\_HH.ratio0\_dB\_mli.bmp | Aletsch.20121217\_20121228.TSX\_HH.ratio1\_dB\_mli.bmp |
|  |  |

# conventional result (ratio0) is more noise and for the change areas less "focussed" than the ratio1 result confirming that **the bm3d filtering (using log profile) of the unfiltered ratio worked well !**

dis2ras Aletsch.20121217\_20121228.TSX\_HH.ratio1\_dB.bmp Aletsch.20121217\_20121228.TSX\_HH.ratio2\_dB.bmp

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| --- | --- |
| Aletsch.20121217\_20121228.TSX\_HH.ratio1\_dB.bmp   * **apply bm3d filtering to ratio of unfiltered data** | Aletsch.20121217\_20121228.TSX\_HH.ratio2\_dB.bmp   * **ratio of bm3d filtered MLIs without filtering in ratio program** |
|  |  |

dis2ras Aletsch.20121217\_20121228.TSX\_HH.ratio1\_dB\_mli.bmp Aletsch.20121217\_20121228.TSX\_HH.ratio2\_dB\_mli.bmp

|  |  |
| --- | --- |
| Aletsch.20121217\_20121228.TSX\_HH.ratio1\_dB\_mli.bmp | Aletsch.20121217\_20121228.TSX\_HH.ratio2\_dB\_mli.bmp |
|  |  |

# In "noisy areas" the filtering done by bm3d is minimal and so **the unfiltered ratio is very noisy there.**

# For areas with a more smooth backscatter ratio2 is also slightly more noisy than ratio1

dis2ras Aletsch.20121217\_20121228.TSX\_HH.ratio1\_dB.bmp Aletsch.20121217\_20121228.TSX\_HH.ratio3\_dB.bmp

|  |  |
| --- | --- |
| Aletsch.20121217\_20121228.TSX\_HH.ratio1\_dB.bmp   * **apply bm3d filtering to ratio of unfiltered data** | Aletsch.20121217\_20121228.TSX\_HH.ratio3\_dB.bmp   * **ratio of bm3d filtered MLIs with 5x5 box filter in ratio program** |
|  |  |

dis2ras Aletsch.20121217\_20121228.TSX\_HH.ratio1\_dB\_mli.bmp Aletsch.20121217\_20121228.TSX\_HH.ratio3\_dB\_mli.bmp

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| --- | --- |
| Aletsch.20121217\_20121228.TSX\_HH.ratio1\_dB\_mli.bmp | Aletsch.20121217\_20121228.TSX\_HH.ratio3\_dB\_mli.bmp |
|  |  |

# Applying the aditional box filter in the ratio3 calculation **increases the spatial scale of the noise in "noisy areas".** It also results in a somewhat less "focussed" result for the change areas.

# So, at least in this example, it seems **calculating the ratio from the unfiltered MLIs and then applying the bm3d filtering (using log profile) provides the best result for the detection of change** (avalanches present in 20121228 but not in 20121217).

# display result with color scale

visdt\_pwr.py Aletsch.20121217\_20121228.TSX\_HH.ratio1\_dB Aletsch.20121228.TSX\_HH\_bm3d.rmli 1024 -6 6 -m hls.cm -b

# the same can be done for the pair 20121206\_20121217 that does not show the same level of change (new avalanches)

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# flood mapping (Houston, Aug. 2017)

# using S1 data (vv and vh pol.) on 20170812 (S1A, pre-flood) and 20170830 (S1B, flooded, Hurricane Harvey)

# image width is 2900 pixel (calibrated, geocoded, using 5x5 looks of GRD product)

cp inputs/Houston.S1.201708??.v?.sigma0 .

**# characteristics of flooded areas (and water surfaces):**

**# - low vv backscatter (single scene criteria)**

**# - low vh backscatter (single scene criteria)**

**# - high vv/vh ratio (single scene criteria)**

**# - high vv-unflooded/vv\_flooded (multi scene criteria)**

**# - high vh-unflooded/vh\_flooded (multi scene criteria)**

**# - high (vh/vv-unflooded)/(vh/vv\_flooded) (multi scene criteria)**

# calculate unfiltered ratios

ratio Houston.S1.20170812.vv.sigma0 Houston.S1.20170812.vh.sigma0 Houston.S1.20170812.vv\_vh\_ratio 2900 1 1 0

ratio Houston.S1.20170830.vv.sigma0 Houston.S1.20170830.vh.sigma0 Houston.S1.20170830.vv\_vh\_ratio 2900 1 1 0

ratio Houston.S1.20170812.vv.sigma0 Houston.S1.20170830.vv.sigma0 Houston.S1.20170812\_20170830.vv\_ratio 2900 1 1 0

ratio Houston.S1.20170812.vh.sigma0 Houston.S1.20170830.vh.sigma0 Houston.S1.20170812\_20170830.vh\_ratio 2900 1 1 0

ratio Houston.S1.20170812.vv\_vh\_ratio Houston.S1.20170830.vv\_vh\_ratio Houston.S1.20170812\_20170830.vv\_vh\_ratio 2900 1 1 0

# bm3d filtering of backscatter images

bm3d Houston.S1.20170812.vh.sigma0 2900 Houston.S1.20170812.vh.sigma0.bm3d 0 0 16

bm3d Houston.S1.20170812.vv.sigma0 2900 Houston.S1.20170812.vv.sigma0.bm3d 0 0 16

bm3d Houston.S1.20170830.vh.sigma0 2900 Houston.S1.20170830.vh.sigma0.bm3d 0 0 16

bm3d Houston.S1.20170830.vv.sigma0 2900 Houston.S1.20170830.vv.sigma0.bm3d 0 0 16

# filter ratios with bm3d profile 4 (log)

bm3d Houston.S1.20170812.vv\_vh\_ratio 2900 Houston.S1.20170812.vv\_vh\_ratio.bm3d 0 4

bm3d Houston.S1.20170830.vv\_vh\_ratio 2900 Houston.S1.20170830.vv\_vh\_ratio.bm3d 0 4

bm3d Houston.S1.20170812\_20170830.vv\_ratio 2900 Houston.S1.20170812\_20170830.vv\_ratio.bm3d 0 4

bm3d Houston.S1.20170812\_20170830.vh\_ratio 2900 Houston.S1.20170812\_20170830.vh\_ratio.bm3d 0 4

bm3d Houston.S1.20170812\_20170830.vv\_vh\_ratio 2900 Houston.S1.20170812\_20170830.vv\_vh\_ratio.bm3d 0 4

# convert filtered ratios to dB scale

linear\_to\_dB Houston.S1.20170812.vv\_vh\_ratio.bm3d Houston.S1.20170812.vv\_vh\_ratio.bm3d\_dB 2900

linear\_to\_dB Houston.S1.20170830.vv\_vh\_ratio.bm3d Houston.S1.20170830.vv\_vh\_ratio.bm3d\_dB 2900

linear\_to\_dB Houston.S1.20170812\_20170830.vv\_ratio.bm3d Houston.S1.20170812\_20170830.vv\_ratio.bm3d\_dB 2900

linear\_to\_dB Houston.S1.20170812\_20170830.vh\_ratio.bm3d Houston.S1.20170812\_20170830.vh\_ratio.bm3d\_dB 2900

linear\_to\_dB Houston.S1.20170812\_20170830.vv\_vh\_ratio.bm3d Houston.S1.20170812\_20170830.vv\_vh\_ratio.bm3d\_dB 2900

linear\_to\_dB Houston.S1.20170830.vv.sigma0.bm3d Houston.S1.20170830.vv.sigma0.bm3d\_dB 2900

linear\_to\_dB Houston.S1.20170830.vh.sigma0.bm3d Houston.S1.20170830.vh.sigma0.bm3d\_dB 2900

linear\_to\_dB Houston.S1.20170812.vv.sigma0.bm3d Houston.S1.20170812.vv.sigma0.bm3d\_dB 2900

linear\_to\_dB Houston.S1.20170812.vh.sigma0.bm3d Houston.S1.20170812.vh.sigma0.bm3d\_dB 2900

# visualize individual criteria using only "flooded" acquisition

vispwr.py Houston.S1.20170830.vv.sigma0.bm3d\_dB 2900 0 -22 3.5 -m hls.cm -u Houston.S1.20170830.vv.sigma0.bm3d\_dB.bmp

vispwr.py Houston.S1.20170830.vh.sigma0.bm3d\_dB 2900 0 -30 -4.5 -m hls.cm -u Houston.S1.20170830.vh.sigma0.bm3d\_dB.bmp

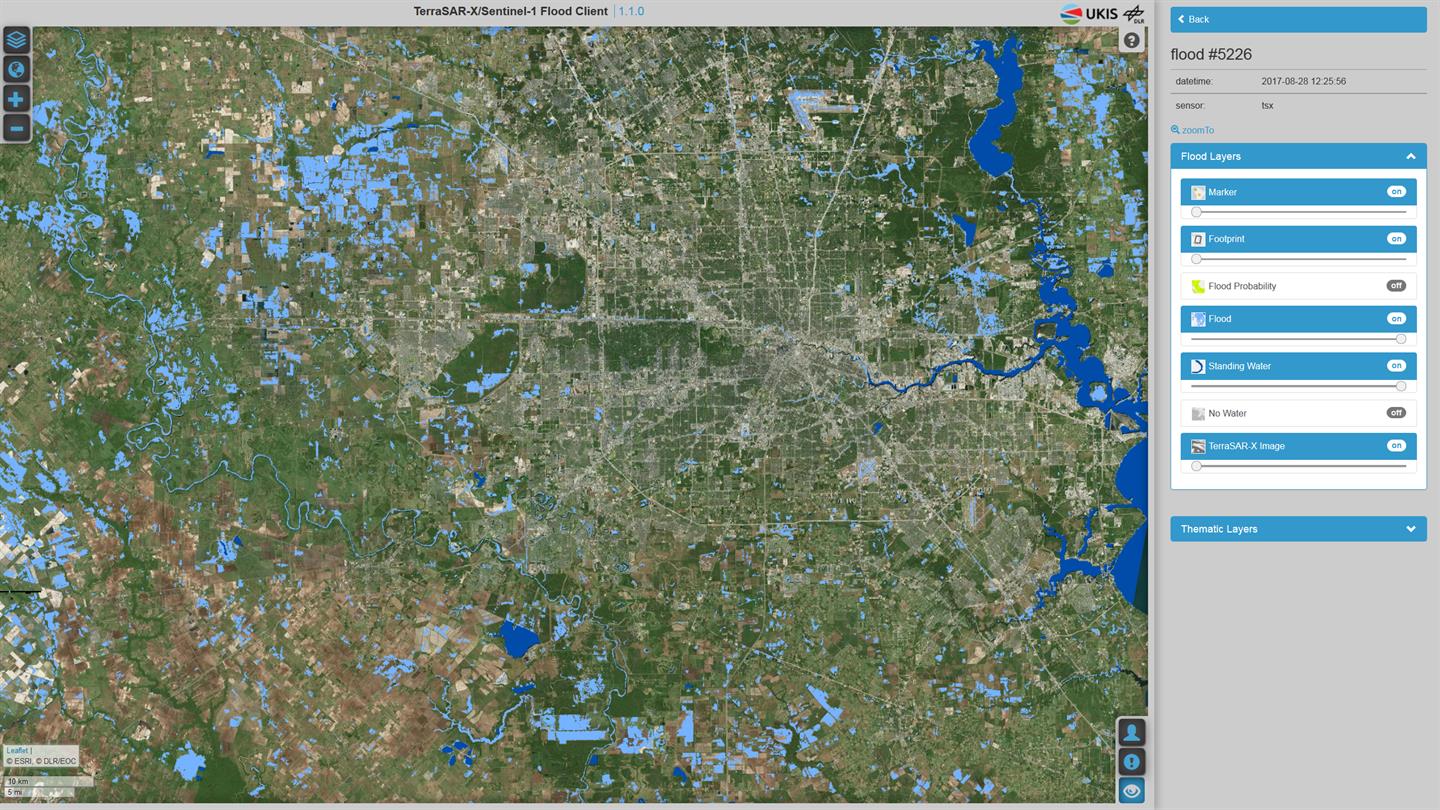
vispwr.py Houston.S1.20170830.vv\_vh\_ratio.bm3d\_dB 2900 0 -2 14 -m hls.cm -u Houston.S1.20170830.vv\_vh\_ratio.bm3d\_dB.bmp

visdt\_pwr.py Houston.S1.20170830.vv.sigma0.bm3d\_dB Houston.S1.20170830.vv.sigma0.bm3d 2900 -22 3.5 -m hls.cm -u Houston.S1.20170830.vv.sigma0.bm3d\_dB\_mli.bmp

visdt\_pwr.py Houston.S1.20170830.vh.sigma0.bm3d\_dB Houston.S1.20170830.vv.sigma0.bm3d 2900 -30 -4.5 -m hls.cm -u Houston.S1.20170830.vh.sigma0.bm3d\_dB\_mli.bmp

visdt\_pwr.py Houston.S1.20170830.vv\_vh\_ratio.bm3d\_dB Houston.S1.20170830.vv.sigma0.bm3d 2900 -2 14 -m hls.cm -u Houston.S1.20170830.vv\_vh\_ratio.bm3d\_dB\_mli.bmp

eog results/Harvey\_Hurricane\_TSX\_Charter\_6\_xl.png.jpg &



**# visualize individual criteria using "pre-flooding" and "flooded" acquisitions**

vispwr.py Houston.S1.20170812\_20170830.vv\_ratio.bm3d\_dB 2900 0 -6 6 -m hls.cm -u Houston.S1.20170812\_20170830.vv\_ratio.bm3d\_dB.bmp

vispwr.py Houston.S1.20170812\_20170830.vh\_ratio.bm3d\_dB 2900 0 -6 6 -m hls.cm -u Houston.S1.20170812\_20170830.vh\_ratio.bm3d\_dB.bmp

vispwr.py Houston.S1.20170812\_20170830.vv\_vh\_ratio.bm3d\_dB 2900 0 -6 6 -m hls.cm -u Houston.S1.20170812\_20170830.vv\_vh\_ratio.bm3d\_dB.bmp

visdt\_pwr.py Houston.S1.20170812\_20170830.vv\_ratio.bm3d\_dB Houston.S1.20170830.vv.sigma0.bm3d 2900 -6 6 -m hls.cm -u Houston.S1.20170812\_20170830.vv\_ratio.bm3d\_dB\_mli.bmp

visdt\_pwr.py Houston.S1.20170812\_20170830.vh\_ratio.bm3d\_dB Houston.S1.20170830.vv.sigma0.bm3d 2900 -6 6 -m hls.cm -u Houston.S1.20170812\_20170830.vh\_ratio.bm3d\_dB\_mli.bmp

visdt\_pwr.py Houston.S1.20170812\_20170830.vv\_vh\_ratio.bm3d\_dB Houston.S1.20170830.vv.sigma0.bm3d 2900 -6 6 -m hls.cm -u Houston.S1.20170812\_20170830.vv\_vh\_ratio.bm3d\_dB\_mli.bmp

**# visualize multiple criteria using only "flooded" acquisition**

# RGB of flooded vv, vh, vv\_vh\_ratio

ras\_linear Houston.S1.20170830.vv.sigma0.bm3d\_dB 2900 1 0 1 1 -22 3.5 1 Houston.S1.20170830.vv.sigma0.bm3d\_dB\_gray.bmp

ras\_linear Houston.S1.20170830.vh.sigma0.bm3d\_dB 2900 1 0 1 1 -30 -4.5 1 Houston.S1.20170830.vh.sigma0.bm3d\_dB\_gray.bmp

ras\_linear Houston.S1.20170830.vv\_vh\_ratio.bm3d\_dB 2900 1 0 1 1 -2 14 1 Houston.S1.20170830.vv\_vh\_ratio.bm3d\_dB\_gray.bmp

ras\_to\_rgb Houston.S1.20170830.vh.sigma0.bm3d\_dB\_gray.bmp Houston.S1.20170830.vv.sigma0.bm3d\_dB\_gray.bmp Houston.S1.20170830.vv\_vh\_ratio.bm3d\_dB\_gray.bmp Houston.S1.20170830.vh.vv.vv\_vh\_ratio.bm3d\_dB.bmp

**# visualize multiple criteria using only "un-flooded" acquisition (for comparison)**

# RGB of flooded vv, vh, vv\_vh\_ratio

ras\_linear Houston.S1.20170812.vv.sigma0.bm3d\_dB 2900 1 0 1 1 -22 3.5 1 Houston.S1.20170812.vv.sigma0.bm3d\_dB\_gray.bmp

ras\_linear Houston.S1.20170812.vh.sigma0.bm3d\_dB 2900 1 0 1 1 -30 -4.5 1 Houston.S1.20170812.vh.sigma0.bm3d\_dB\_gray.bmp

ras\_linear Houston.S1.20170812.vv\_vh\_ratio.bm3d\_dB 2900 1 0 1 1 -2 14 1 Houston.S1.20170812.vv\_vh\_ratio.bm3d\_dB\_gray.bmp

ras\_to\_rgb Houston.S1.20170812.vh.sigma0.bm3d\_dB\_gray.bmp Houston.S1.20170812.vv.sigma0.bm3d\_dB\_gray.bmp Houston.S1.20170812.vv\_vh\_ratio.bm3d\_dB\_gray.bmp Houston.S1.20170812.vh.vv.vv\_vh\_ratio.bm3d\_dB.bmp

dis2ras Houston.S1.20170830.vh.vv.vv\_vh\_ratio.bm3d\_dB.bmp Houston.S1.20170812.vh.vv.vv\_vh\_ratio.bm3d\_dB.bmp &

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| Houston.S1.20170830.vh.vv.vv\_vh\_ratio.bm3d\_dB.bmp | Houston.S1.20170812.vh.vv.vv\_vh\_ratio.bm3d\_dB.bmp |
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**# visualize multiple criteria using "pre-flooding" and "flooded" acquisitions**

ras\_linear Houston.S1.20170812\_20170830.vv\_ratio.bm3d\_dB 2900 1 0 1 1 -6 6 1 Houston.S1.20170812\_20170830.vv\_ratio.bm3d\_dB\_gray.bmp

ras\_linear Houston.S1.20170812\_20170830.vh\_ratio.bm3d\_dB 2900 1 0 1 1 -6 6 1 Houston.S1.20170812\_20170830.vh\_ratio.bm3d\_dB\_gray.bmp

ras\_linear Houston.S1.20170812\_20170830.vv\_vh\_ratio.bm3d\_dB 2900 1 0 1 1 -6 6 1 Houston.S1.20170812\_20170830.vv\_vh\_ratio.bm3d\_dB\_gray.bmp

# RGB of flooded vv, vh, pre-flood\_flood vv ratio

ras\_to\_rgb Houston.S1.20170830.vh.sigma0.bm3d\_dB\_gray.bmp Houston.S1.20170830.vv.sigma0.bm3d\_dB\_gray.bmp Houston.S1.20170812\_20170830.vv\_ratio.bm3d\_dB\_gray.bmp Houston.S1.20170830\_vh.20170830\_vv.20170812\_20170830\_vv\_ratio.bm3d\_dB.bmp

dis2ras Houston.S1.20170830\_vh.20170830\_vv.20170812\_20170830\_vv\_ratio.bm3d\_dB.bmp Houston.S1.20170830.vh.vv.vv\_vh\_ratio.bm3d\_dB.bmp &

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| Houston.S1.20170830\_vh.20170830\_vv.20170812\_20170830\_vv\_ratio.bm3d\_dB.bmp | Houston.S1.20170830.vh.vv.vv\_vh\_ratio.bm3d\_dB.bmp |
|  |  |

# RGB of flooded vv, vh, pre-flood\_flood vh ratio

ras\_to\_rgb Houston.S1.20170830.vh.sigma0.bm3d\_dB\_gray.bmp Houston.S1.20170830.vv.sigma0.bm3d\_dB\_gray.bmp Houston.S1.20170812\_20170830.vh\_ratio.bm3d\_dB\_gray.bmp Houston.S1.20170830\_vh.20170830\_vv.20170812\_20170830\_vh\_ratio.bm3d\_dB.bmp

dis2ras Houston.S1.20170830\_vh.20170830\_vv.20170812\_20170830\_vh\_ratio.bm3d\_dB.bmp Houston.S1.20170830.vh.vv.vv\_vh\_ratio.bm3d\_dB.bmp &

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| --- | --- |
| Houston.S1.20170830\_vh.20170830\_vv.20170812\_20170830\_vh\_ratio.bm3d\_dB.bmp | Houston.S1.20170830.vh.vv.vv\_vh\_ratio.bm3d\_dB.bmp |
|  |  |

# RGB of flooded vv, vh, pre-flood\_flood vv\_vh ratio

ras\_to\_rgb Houston.S1.20170830.vh.sigma0.bm3d\_dB\_gray.bmp Houston.S1.20170830.vv.sigma0.bm3d\_dB\_gray.bmp Houston.S1.20170812\_20170830.vv\_vh\_ratio.bm3d\_dB\_gray.bmp Houston.S1.20170830\_vh.20170830\_vv.20170812\_20170830\_vv\_vh\_ratio.bm3d\_dB.bmp

dis2ras Houston.S1.20170830\_vh.20170830\_vv.20170812\_20170830\_vv\_vh\_ratio.bm3d\_dB.bmp Houston.S1.20170830.vh.vv.vv\_vh\_ratio.bm3d\_dB.bmp &

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| Houston.S1.20170830\_vh.20170830\_vv.20170812\_20170830\_vv\_vh\_ratio.bm3d\_dB.bmp | Houston.S1.20170830.vh.vv.vv\_vh\_ratio.bm3d\_dB.bmp |
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