Primal sketch of image series with edge preserving filtering
Application to change detection

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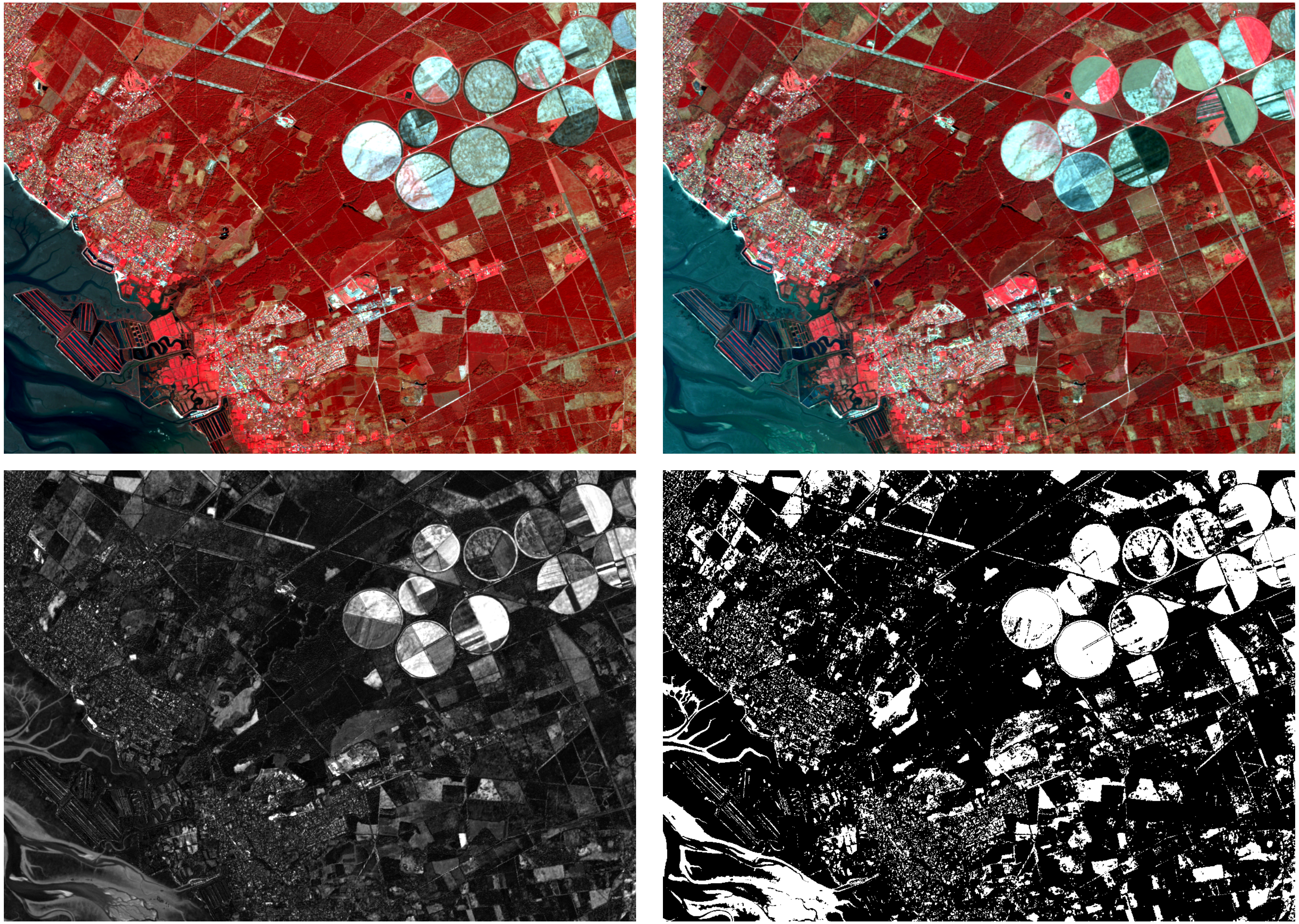
Aim of the study

Spot 5 multispectral images (Arcachon - 16/03/2009 and 08/03/2011)

Change detection problem: euclidean distance + hard threshold ($\delta = 50$)



In some cases, almost everything can be considered as change

- Evolution of vegetation during the year
- Varying acquisition angle and sun illumination

Is it possible to propose a method focusing on

- New / disappeared buildings
- Crop split / crop merge
- Coastal evolution
- *etc.*

Proposed solution: extract stable elements into images

- Points
- **Edges: sketch of the image**
- Regions

Contents

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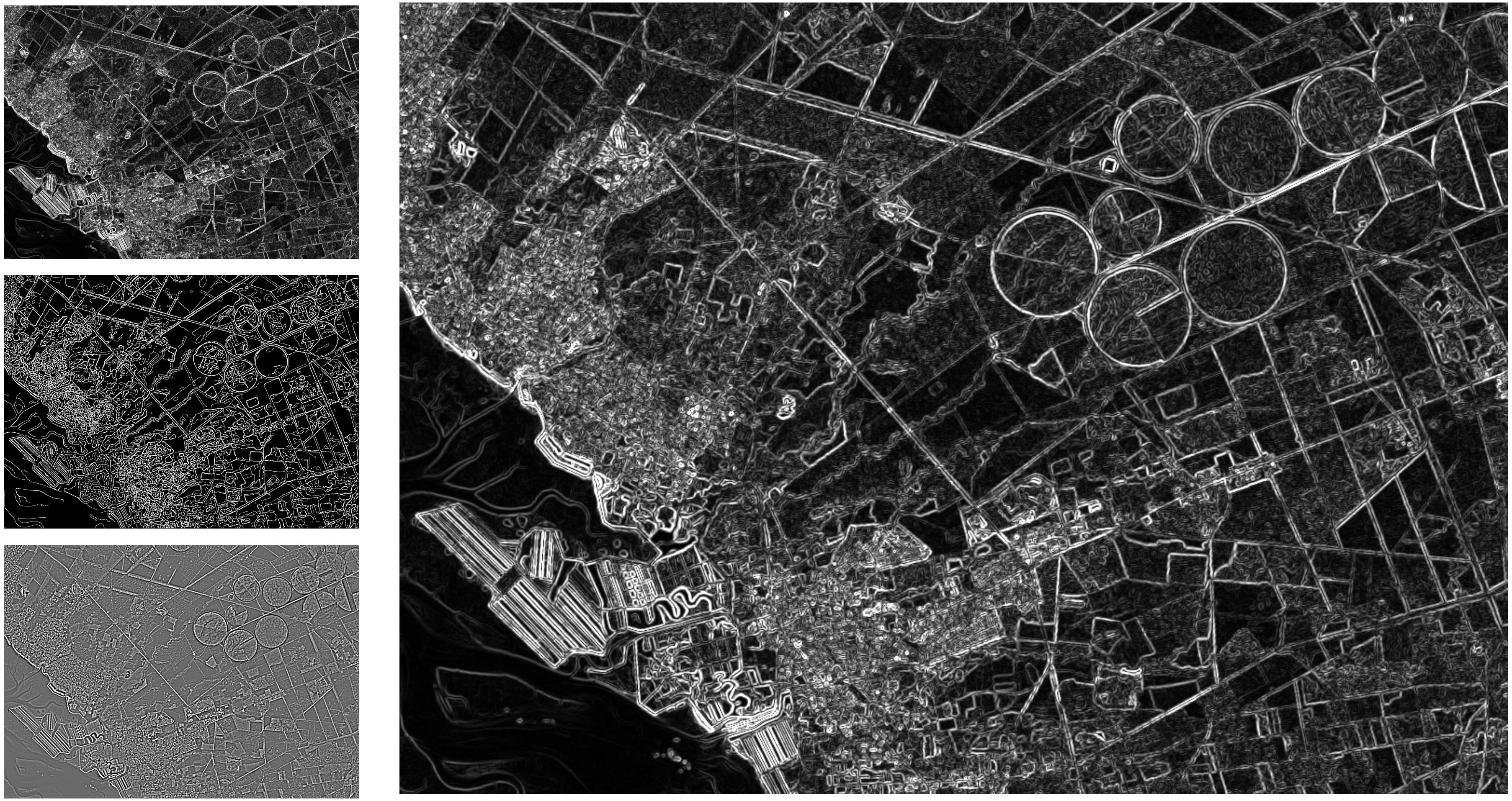
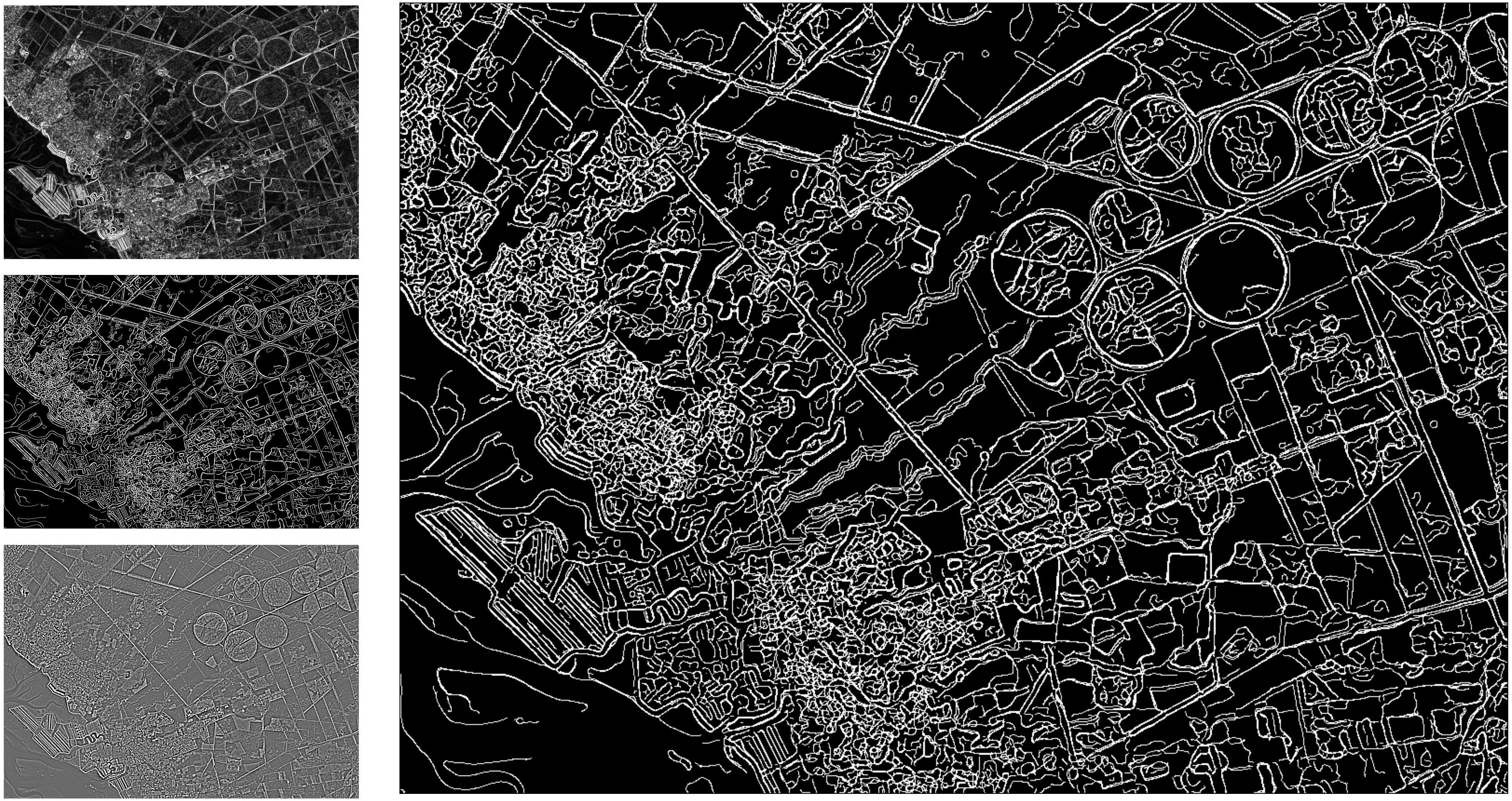
Common edge detection algorithms outputs

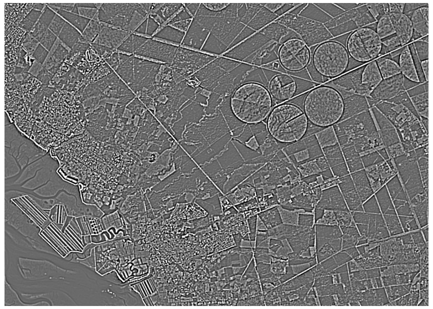
Sobel, Canny, Laplacian of Gaussian (LOG)

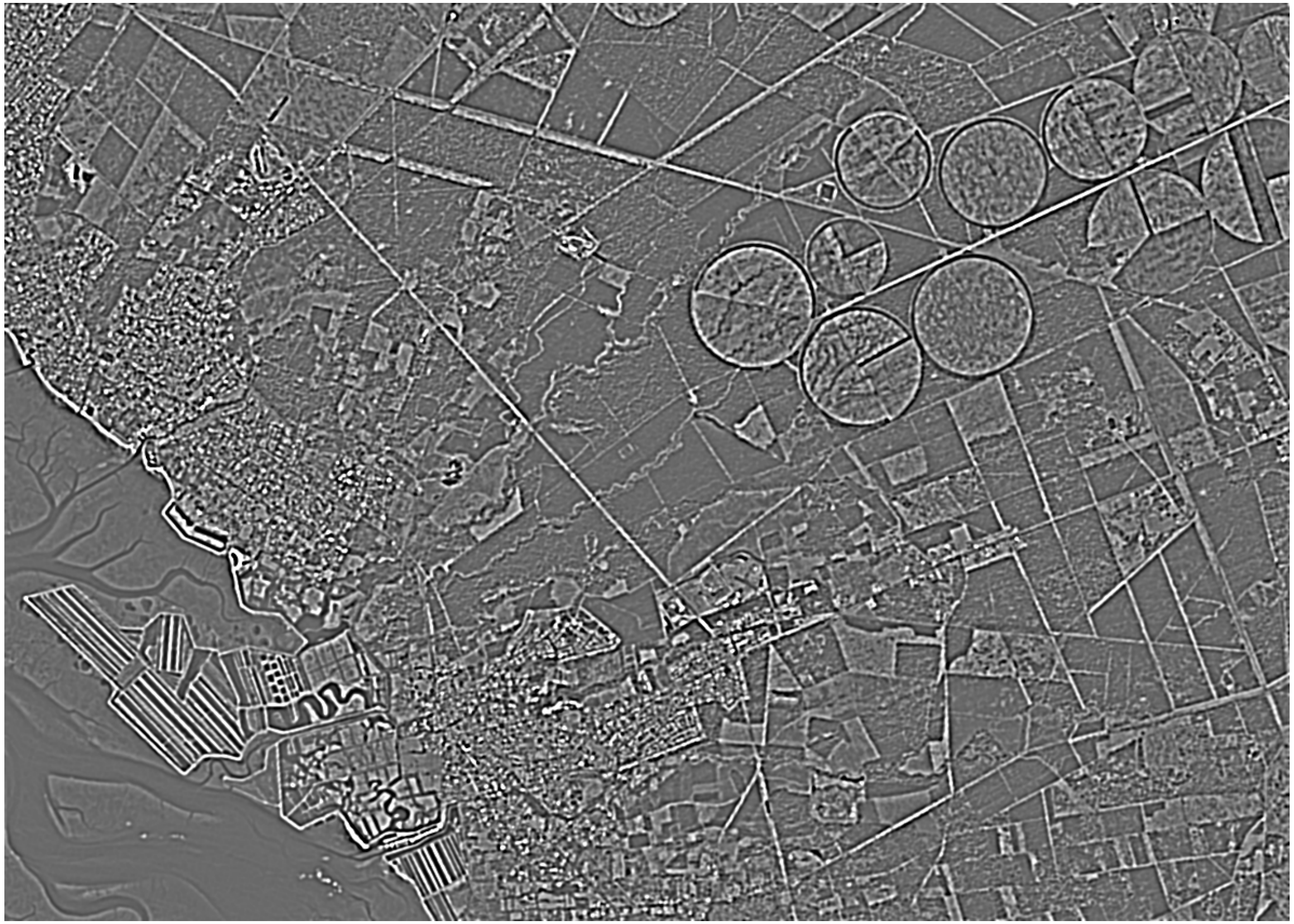


Sobel, *Canny* ($\sigma = 2.5, \delta = 40$), Laplacian of Gaussian (LOG)



Sobel, Canny, *Laplacian of Gaussian* (LOG, $\sigma = 1.4$)





Families of methods

- Bilateral filter [Tomasi, Manduchi 1998]
- Anisotropic diffusion [Perona, Malik 1987]
- Mean-shift filtering [Comaniciu, Meer 2002]
- Adaptive smoothing [Saint-Marc *et al.* 1989]

⇒ Some of them are affected by the staircase effect: new edges appear
⇒ Choice of **anisotropic diffusion**

Description of the Perona-Malik algorithm

- Algorithm based on discretization of the anisotropic diffusion equation:

$$I_t = div(c(i,j,t)\nabla I)$$

- $I_0(i,j)$ original image
- $c(i,j,t)$ is the diffusion coefficient
- ∇ gradient operator
- *div* divergence operator (divergence of gradient = Laplacian)
- I_t are derived images at time t

Pietro Perona and Robert Jitendra Malik, "Scale-space and edge detection using anisotropic diffusion," IEEE Transactions On Pattern Analysis and Machine Intelligence, July 1990.

Perona-Malik filtering algorithm steps

$X_{i,j,k}$ pixel value of the image located at position (i,j) in the k-th band

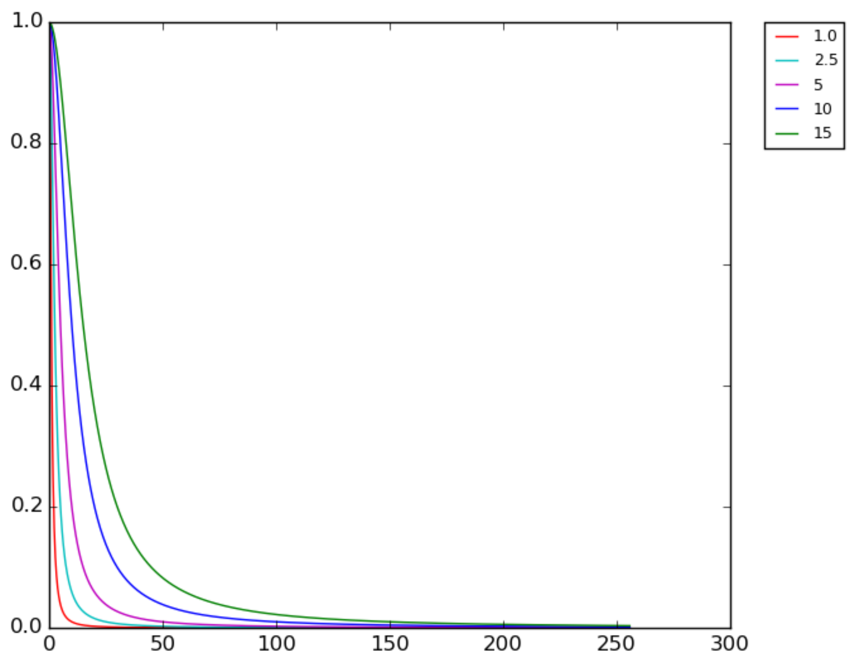
1. Loop on t from 1 to number of iterations *nb_iter* for steps 2 and 3:
2. Compute height signed differences $D_{u,v}$ with eight spatial nearest neigbors of a pixel: $D_{u,v} = X_{u,v,k} - X_{i,j,k}$
3. Compute the new pixel value

$$X_{i,j,k}(t+1) = X_{i,j,k}(t) +$$
$$\delta_t \cdot [D_{-1,0} \cdot g(|D_{-1,0}|,\lambda) + D_{0,-1} \cdot g(|D_{0,-1}|,\lambda) + D_{1,0} \cdot g(|D_{1,0}|,\lambda) + D_{0,1} \cdot g(|D_{0,1}|,\lambda)] +$$
$$0.5 \cdot \delta_t \cdot [D_{-1,-1} \cdot g(|D_{-1,-1}|,\lambda) + D_{1,-1} \cdot g(|D_{1,-1}|,\lambda) + D_{-1,1} \cdot g(|D_{-1,1}|,\lambda) + D_{1,1} \cdot g(|D_{1,1}|,\lambda)]$$

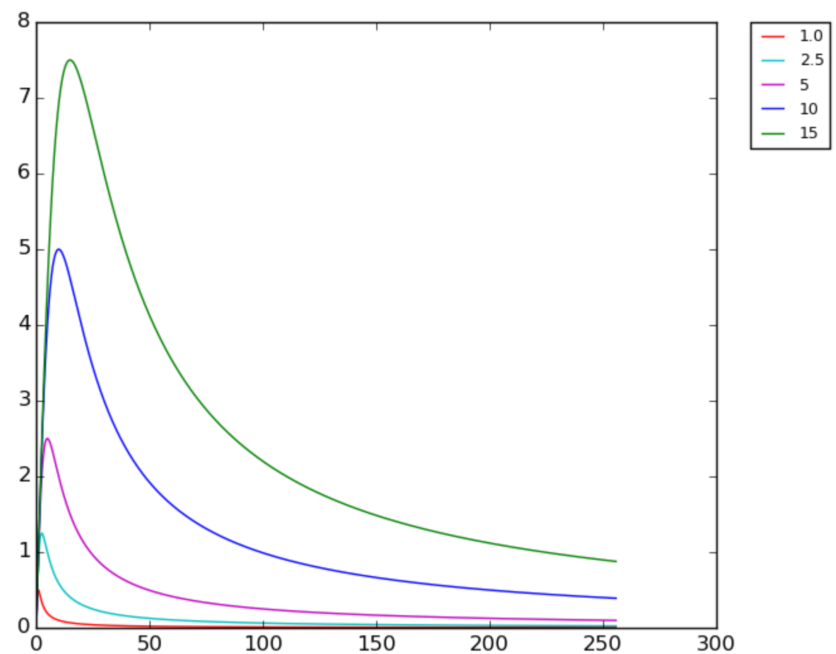
- g diffusion function $g(x,\lambda) = \frac{1}{(1+(x/\lambda)^2)}$
- 3 parameters: δ_t sensitivity parameter, λ diffusion value, and *nb_iter* number of iterations
  - Typical values: $\lambda = 5$, $\delta_t = 0.5$, $nb\_iter = 10$

Diffusion function

- g diffusion function $g(x,\lambda) = \frac{1}{(1+(x/\lambda)^2)}$
- λ diffusion value

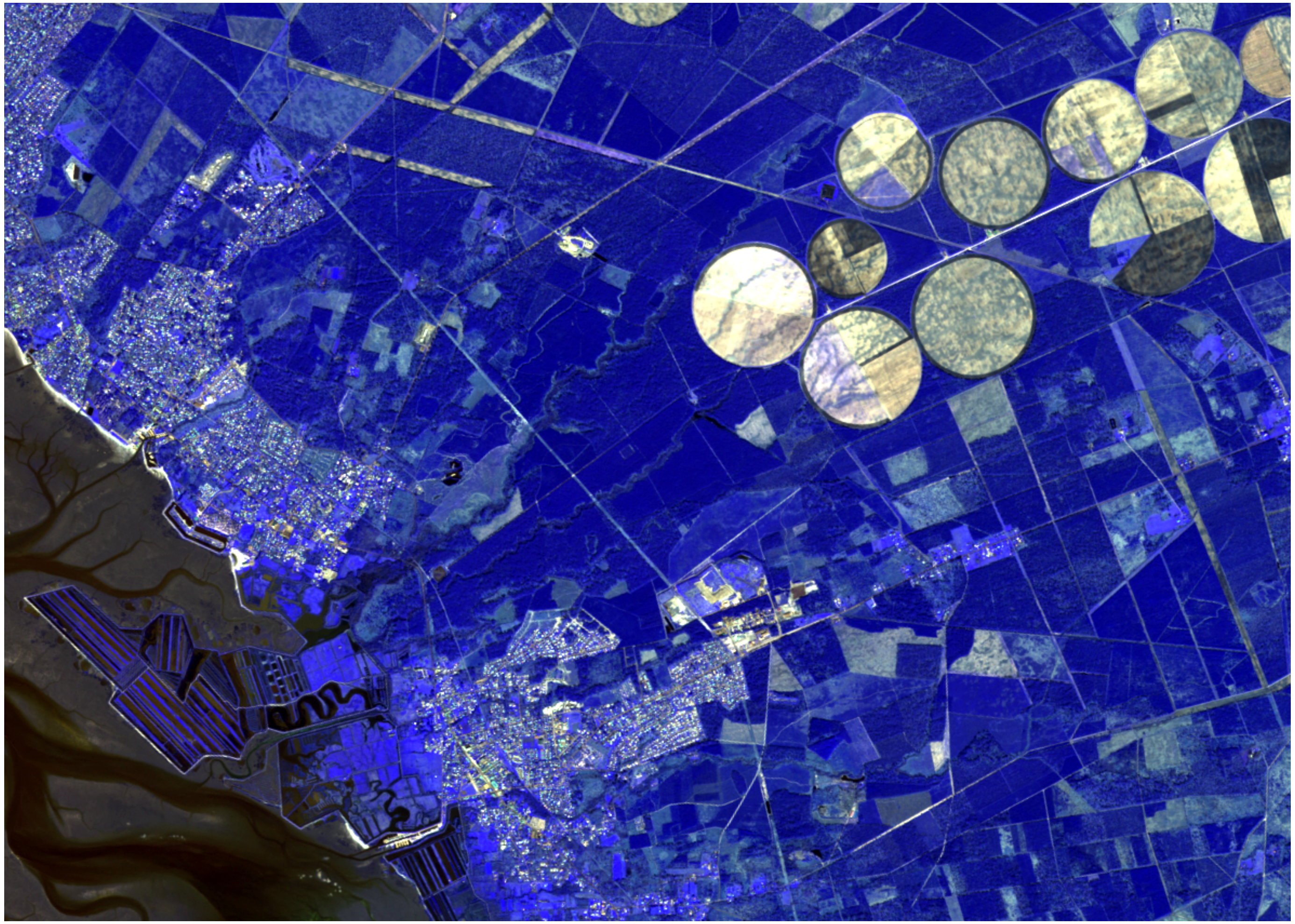


$$g(x,\lambda) = \frac{1}{(1+(x/\lambda)^2)}$$

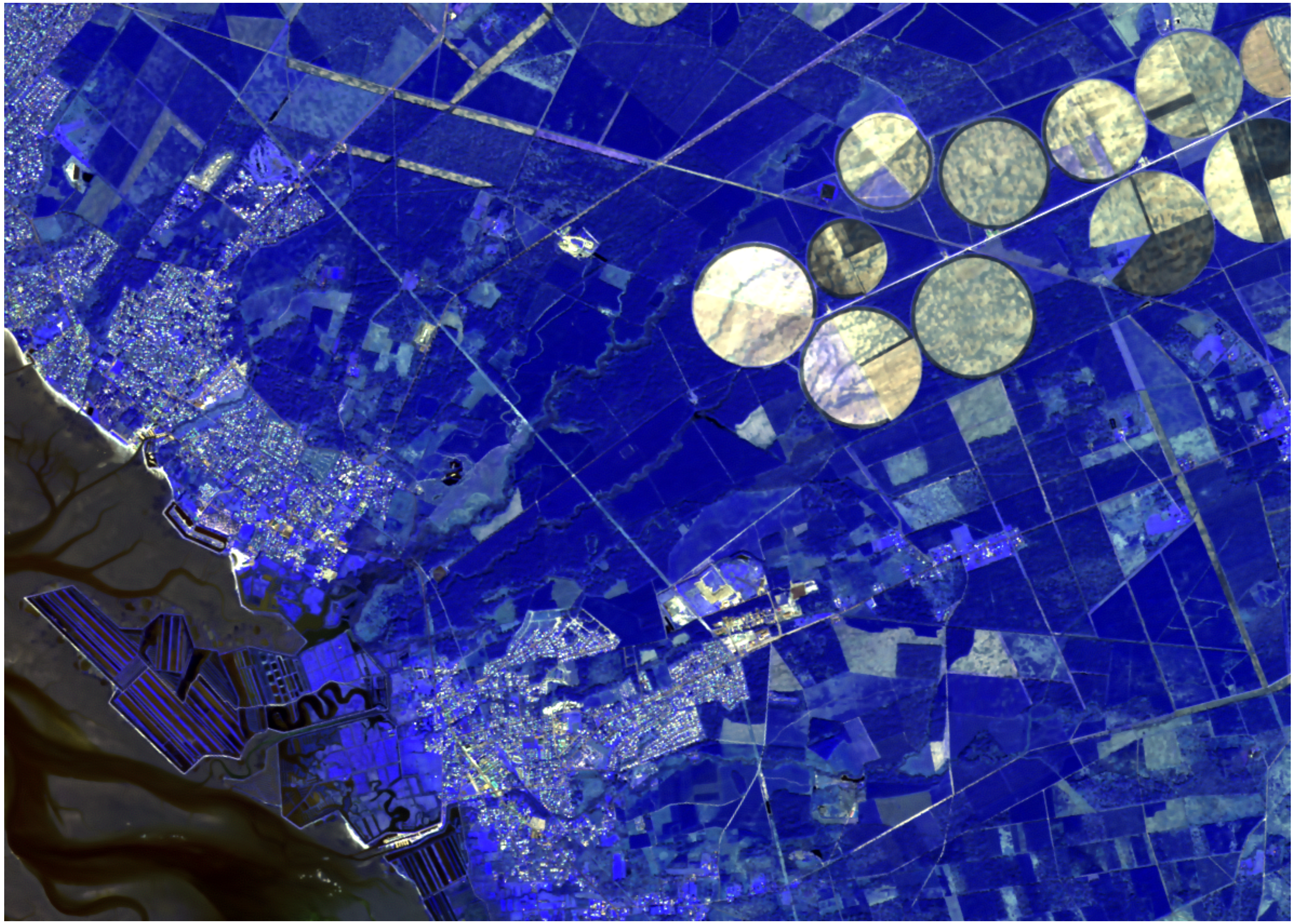


$$h(x,\lambda) = x.\frac{1}{(1+(x/\lambda)^2)} = x.g(x,\lambda)$$

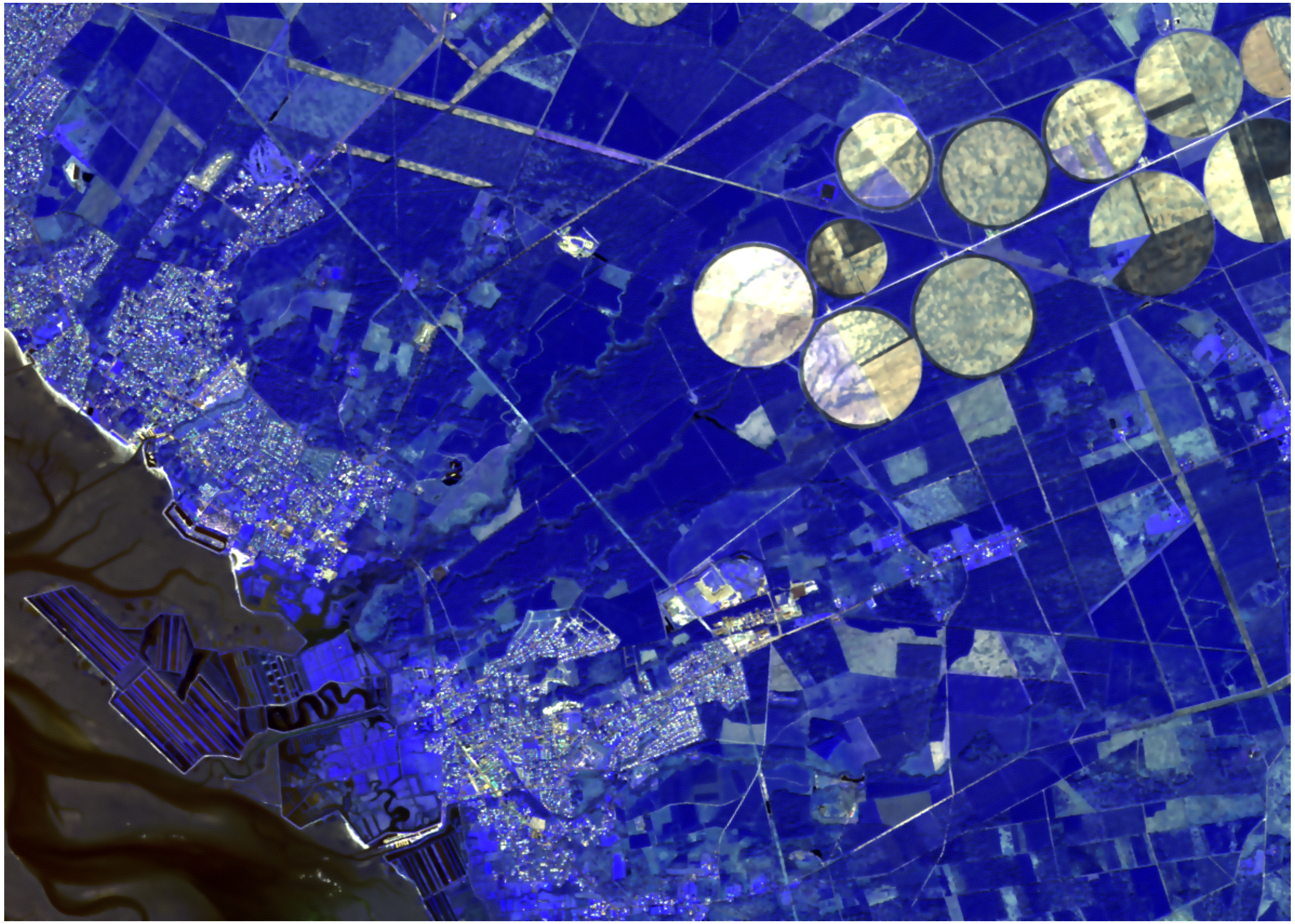
Filtered image - Iteration 0 - original image



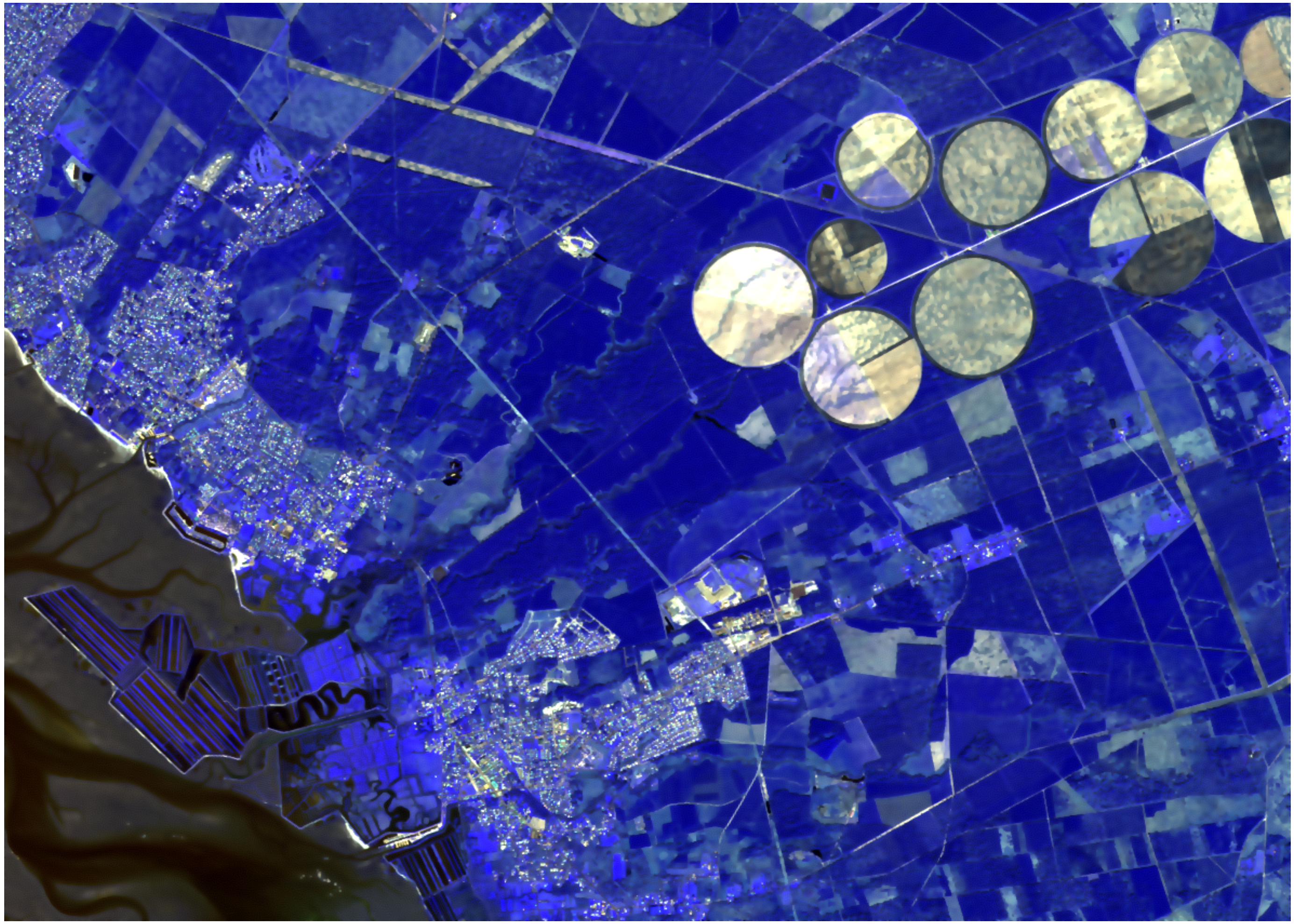
Filtered image - Iteration 1 - noise is filtered



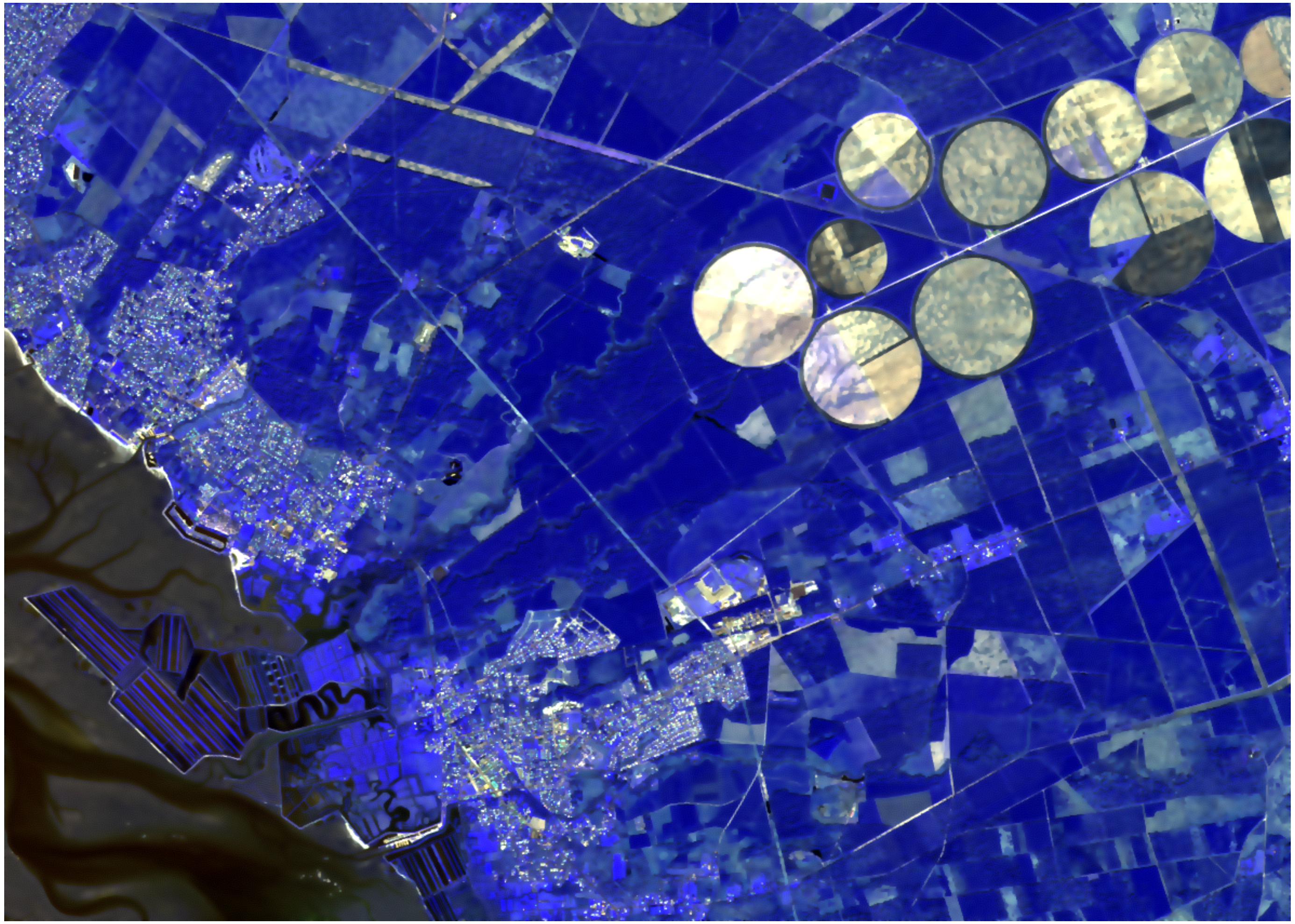
Filtered image - Iteration 2 - noise is filtered



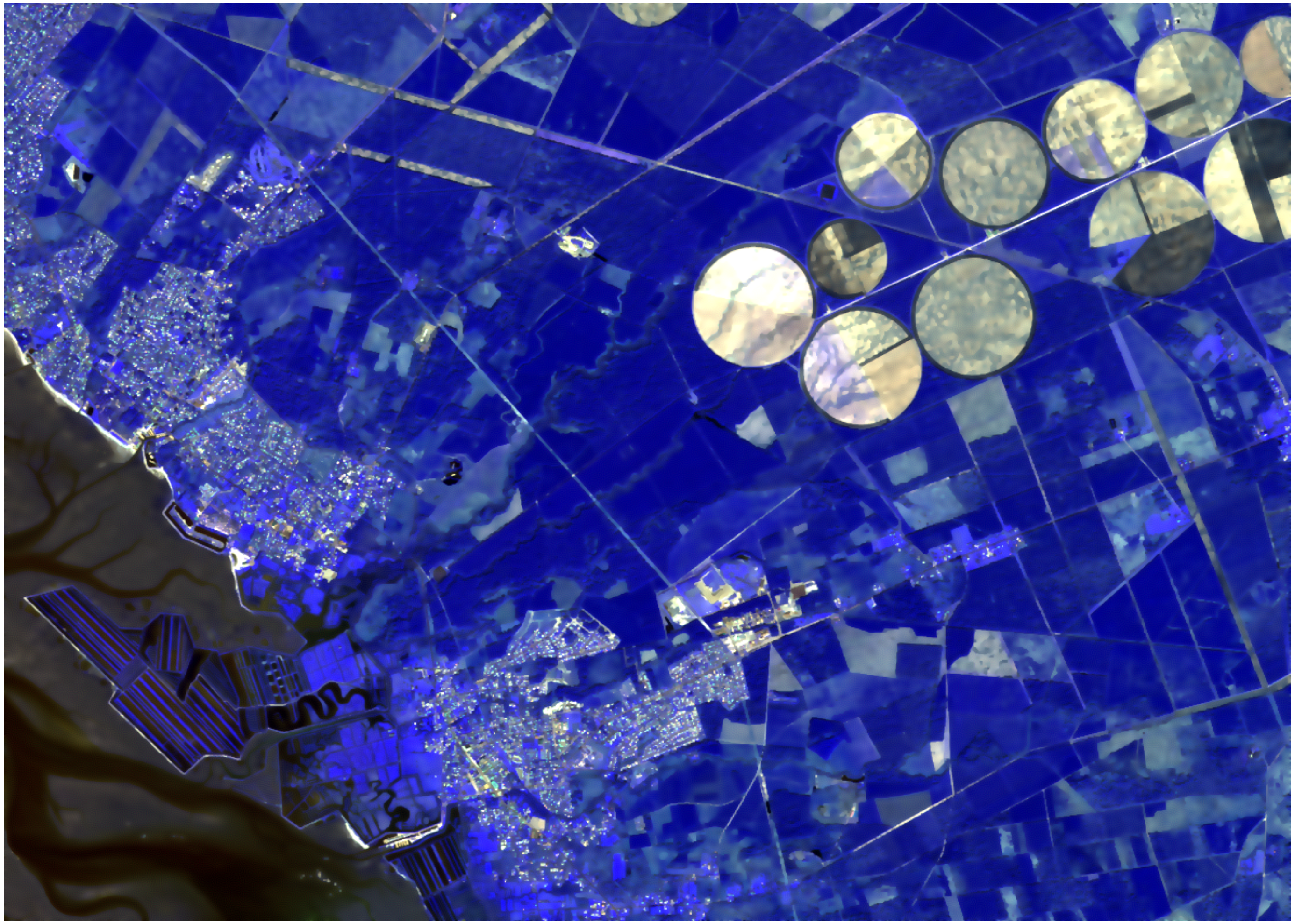
Filtered image - Iteration 3



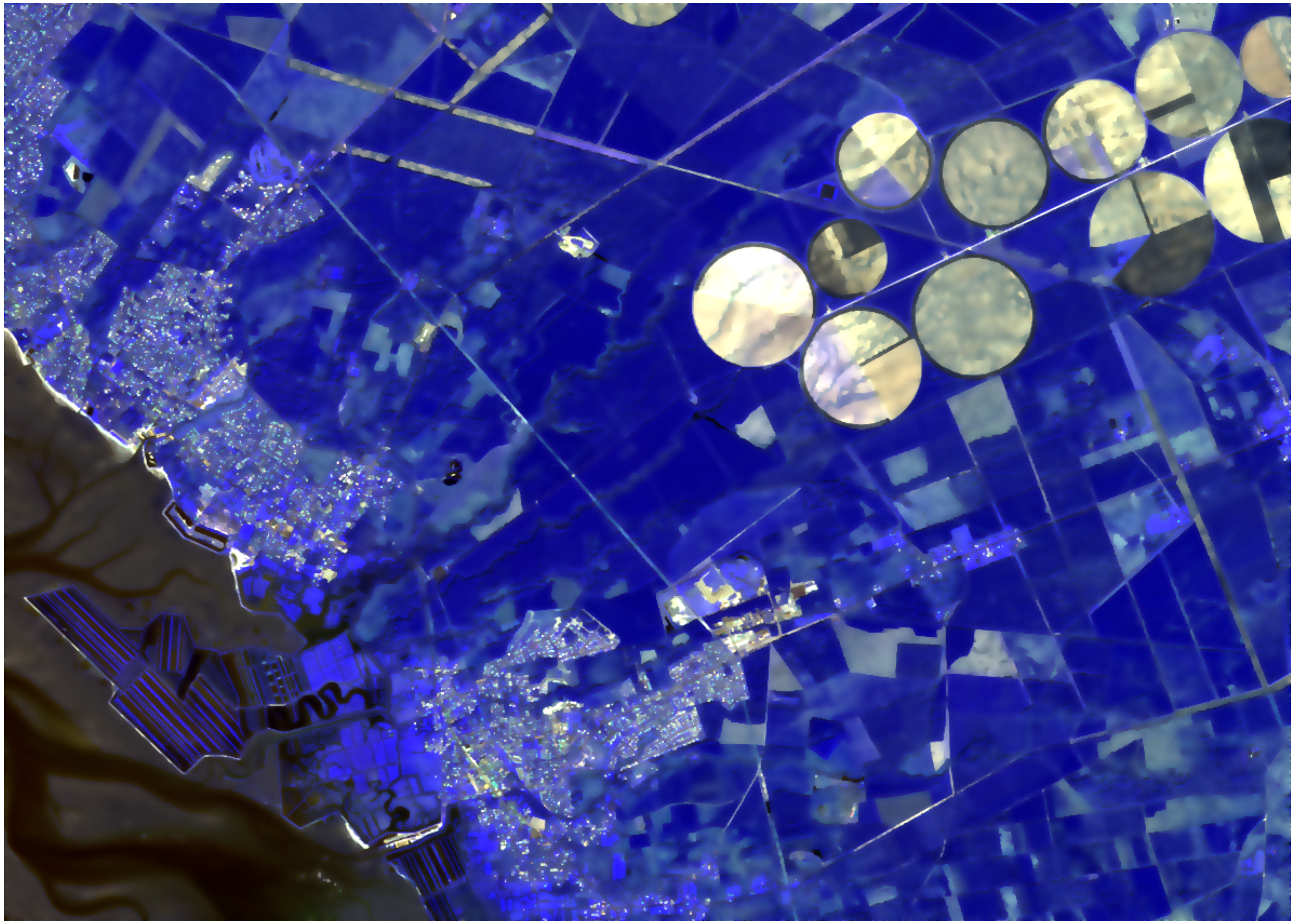
Filtered image - Iteration 4



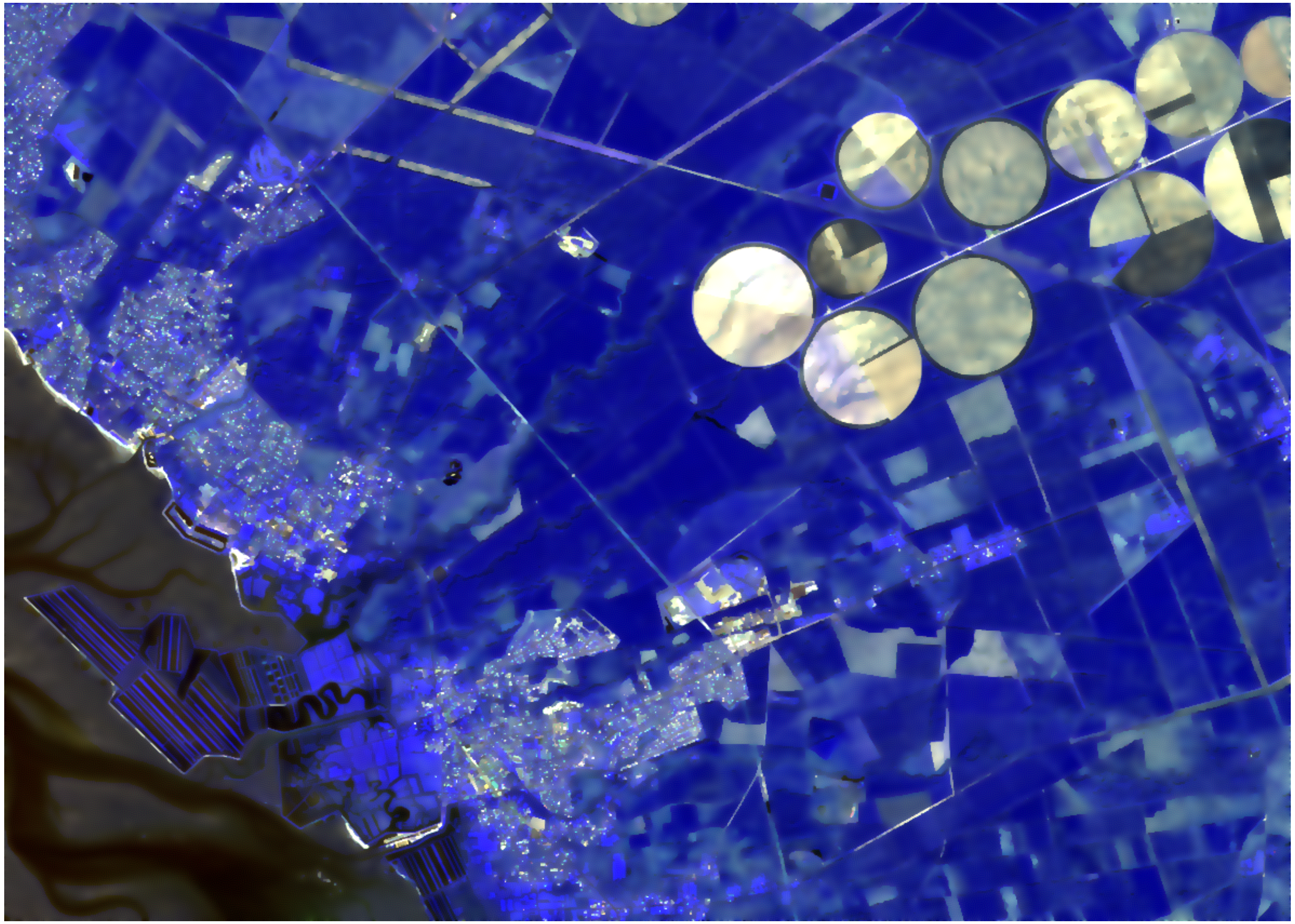
Filtered image - Iteration 5



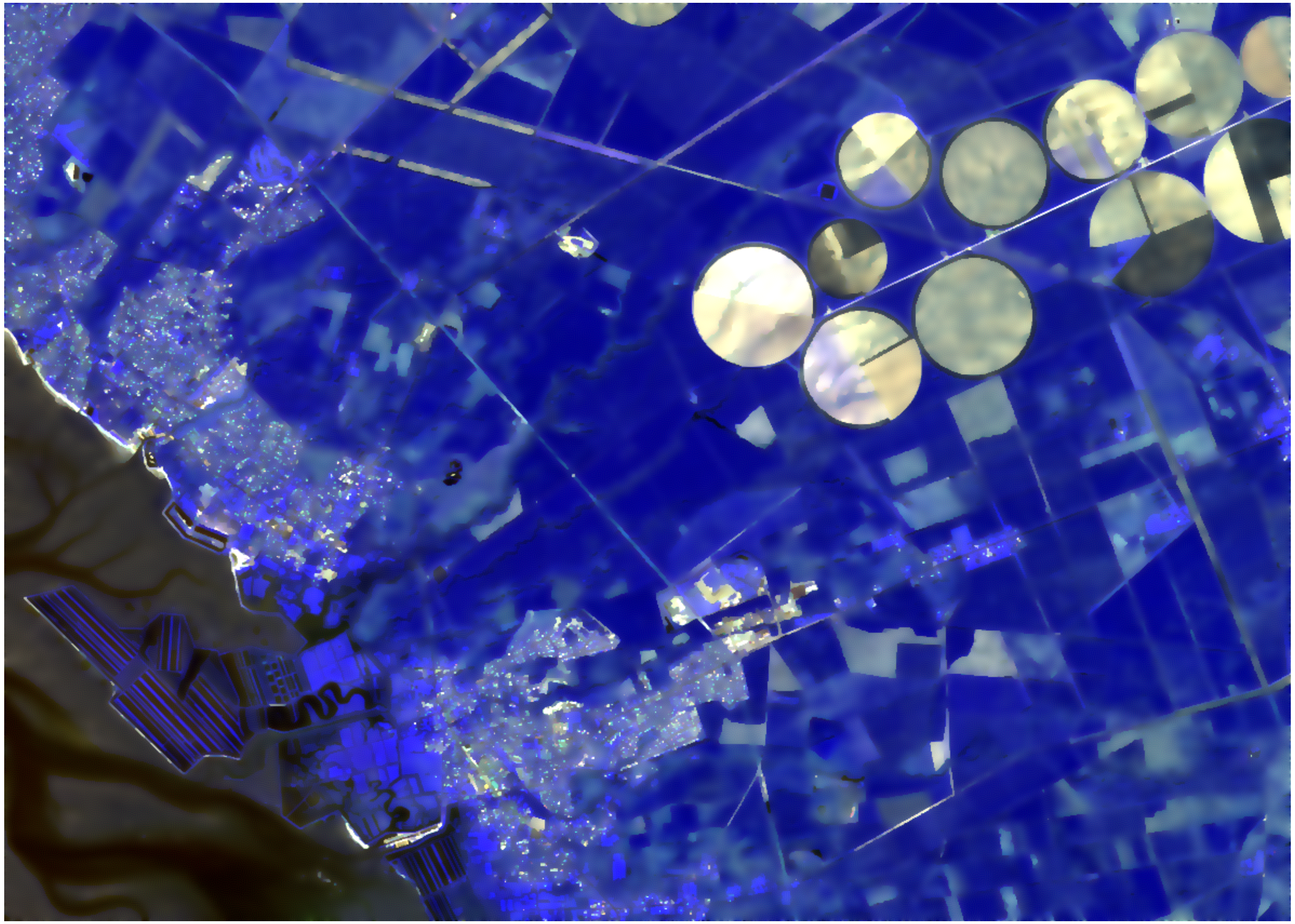
Filtered image - Iteration 10



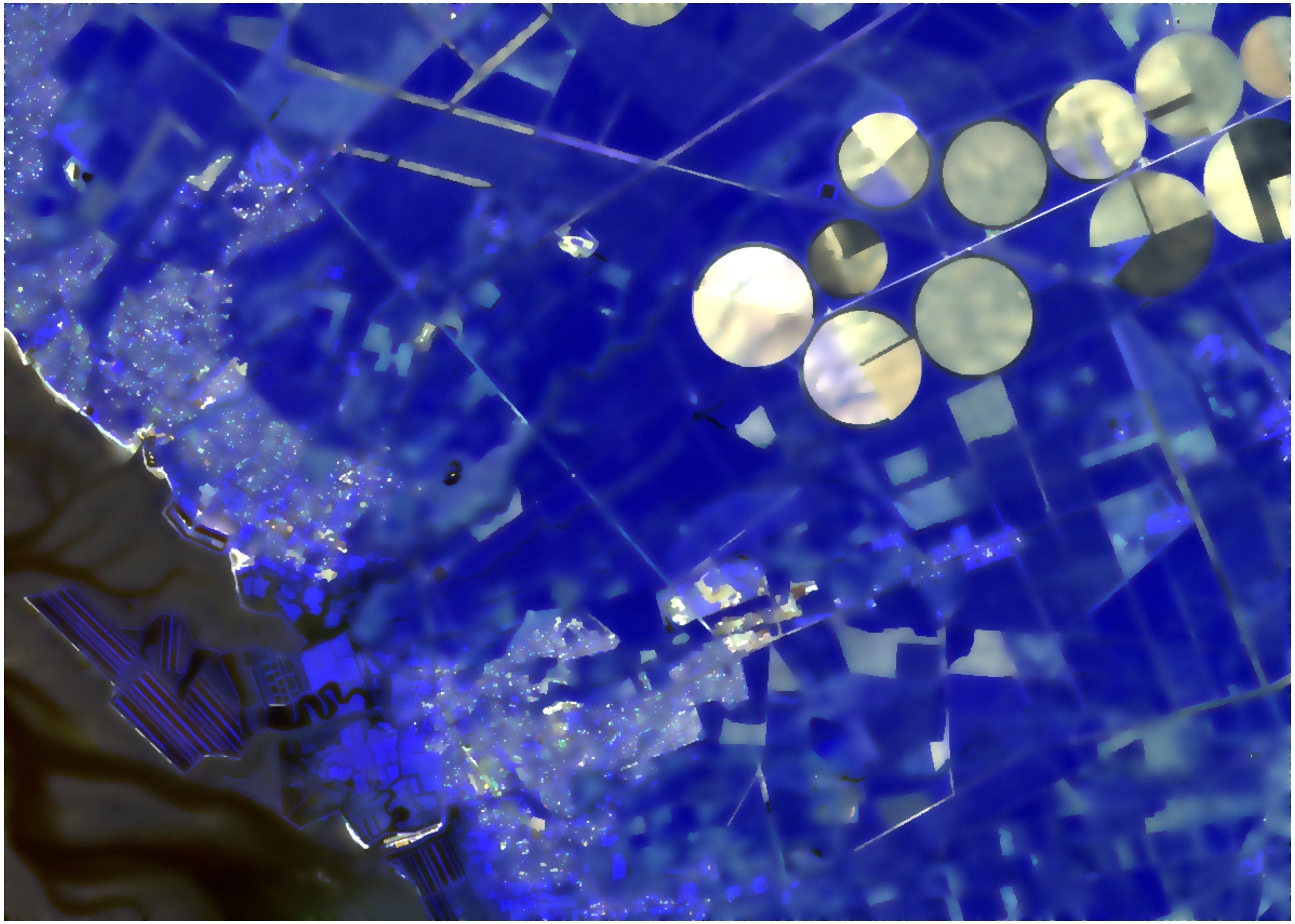
Filtered image - Iteration 15 - texture is filtered



Filtered image - Iteration 20 - texture is filtered



Filtered image - Iteration 30 - interested elements have disappeared



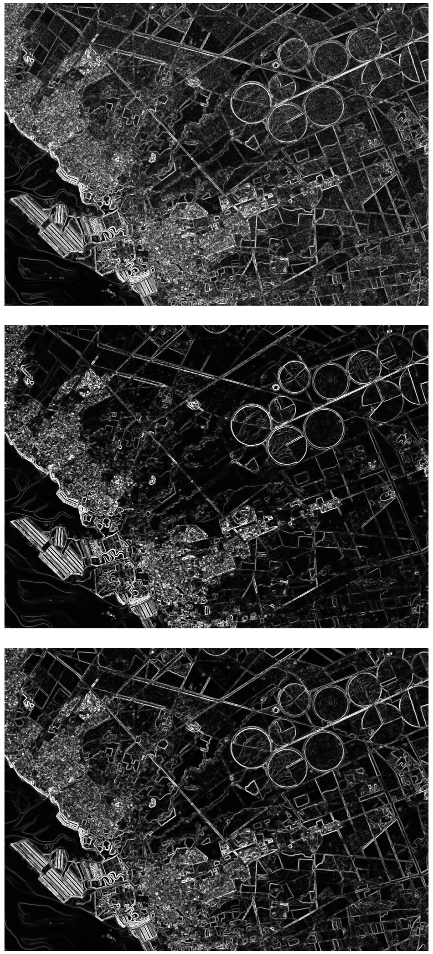
Contents

Proposed algorithm

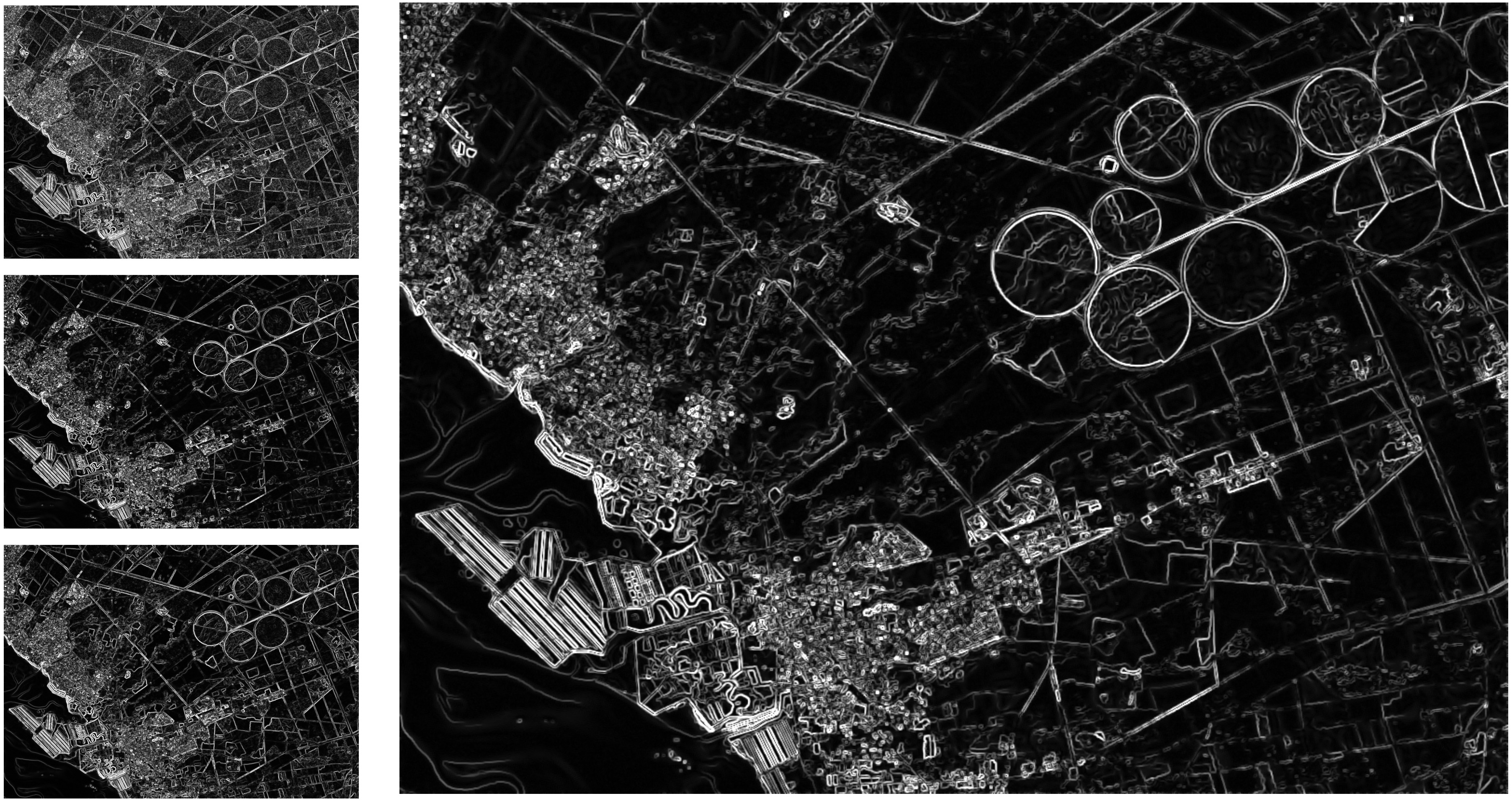
1. Loop on t from 1 to number of iterations nb_iter for steps 2, 3, 4, 5:
2. Considering one band k, compute height signed differences $D_{u,v}$
3. Compute the new pixel value $X_{i,j,k}(t+1)$
4. Compute the gradient $\nabla X_{i,j,k}(t+1)$
5. Compute for each pixel the maximum value among all bands:
   $M_{i,j}(t+1) = \max_{1 \leq k \leq nb\_bands}(\nabla X_{i,j,k}(t+1))$, with nb_bands the number of bands
6. Final sum of the gradient images: $G_{i,j} = \sum_{t=iter_0}^{nb\_iter} M_{i,j}(t)$

- One new parameter: first iteration for the sum $iter_0$

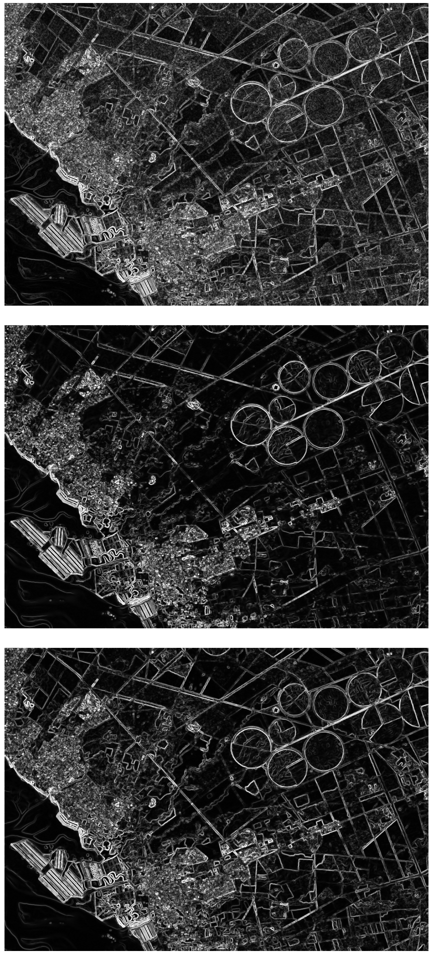
Sobel, Perona-Malik (10 iterations) + Sobel, Our method



Sobel, *Perona-Malik (10 iterations) + Sobel*, Our method



Sobel, Perona-Malik (10 iterations) + Sobel, *Our method* (iterations 2-10)



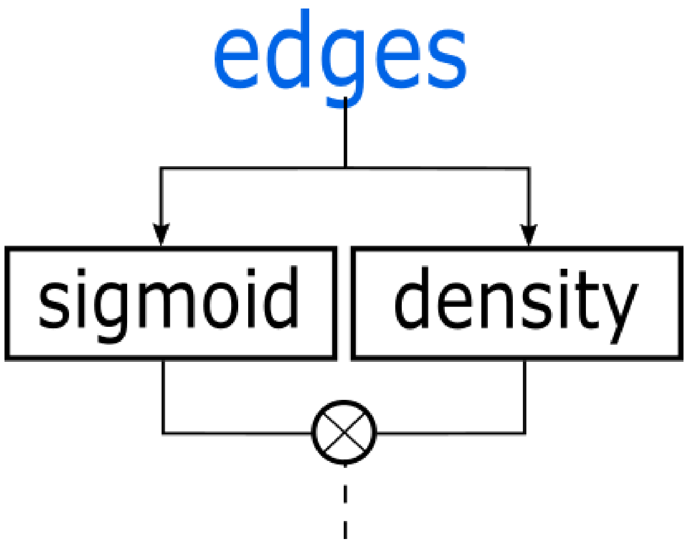
Characteristics

- Method that preserves location of edges
- Be able to extract elements at different scales according to our natural perception

Advantages

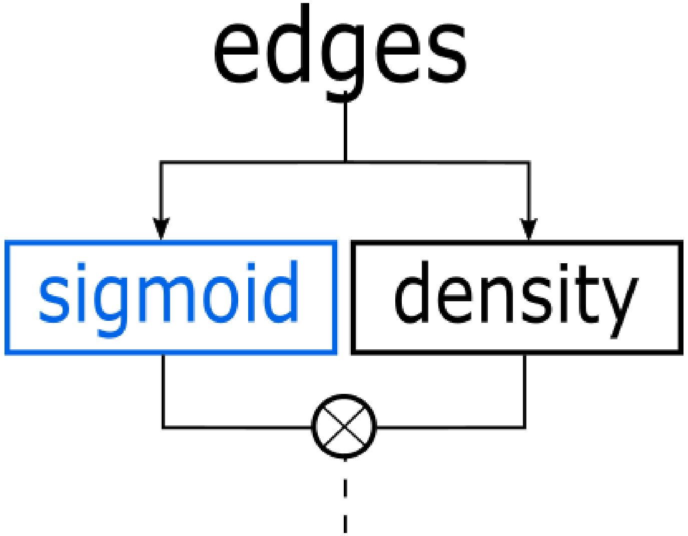
- Less sensitive as possible to noise effects ($iter_0$)
- Be able to consider (or not) some slight linear elements ($iter_0$)
- Reduce the sensitivity on the choice of the iterations number parameter (nb_iter)
- Reduce the sensitivity on the choice of the diffusion law parameters (λ, δ_t)

Ouput of the edge detection



Enhancing the contrast of edges: adjust highest edge values

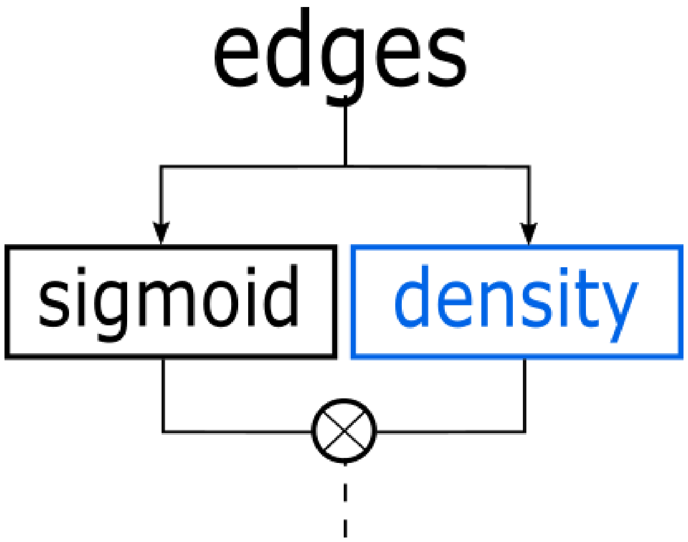
- Soft thresholding with a sigmoid function: $f(x) = \frac{1}{1+e^{-\frac{x-\alpha}{K}}}$
- Parameters:
  - α gives the position of symmetry point and inflection point
  - $\frac{1}{4K}$ gives the slope of tangent at inflection point
  - Typical values: $\alpha = 80$, $K = 20$

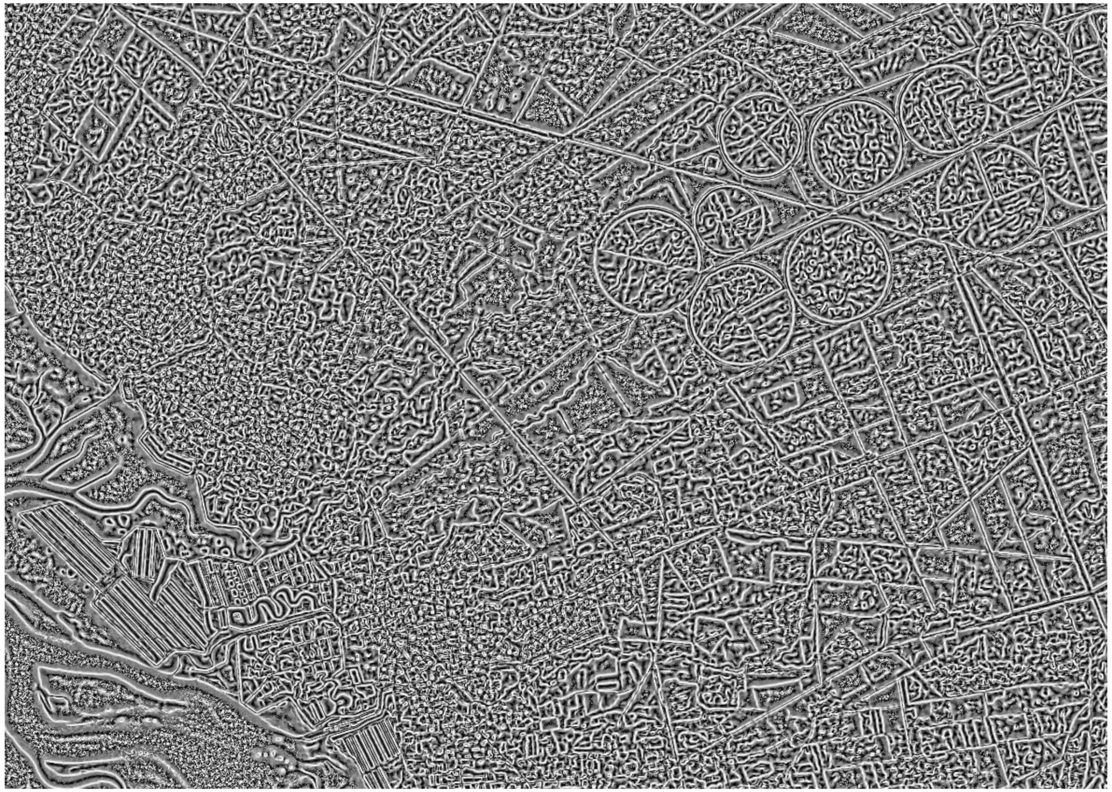


Reinforce slight linear elements

- Compute density / percentage of pixels with higher value than the central pixel
- Parameters: size and shape of the neighborhood (typical shape: 9×9)

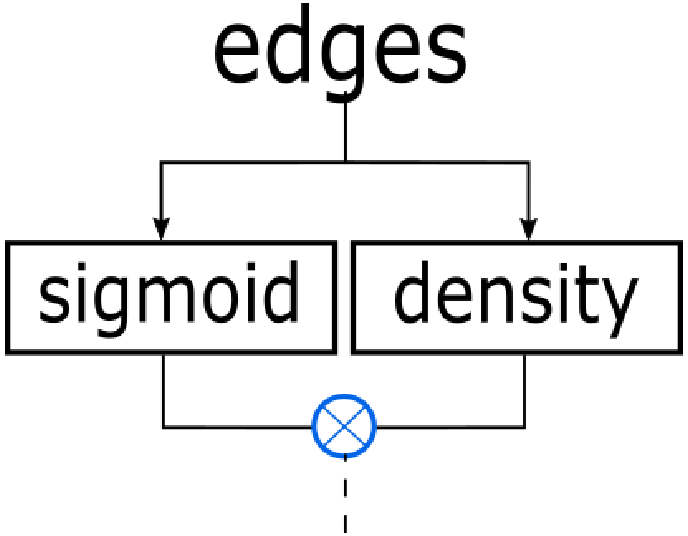
$\Rightarrow$ Local edges detected even with low value edges





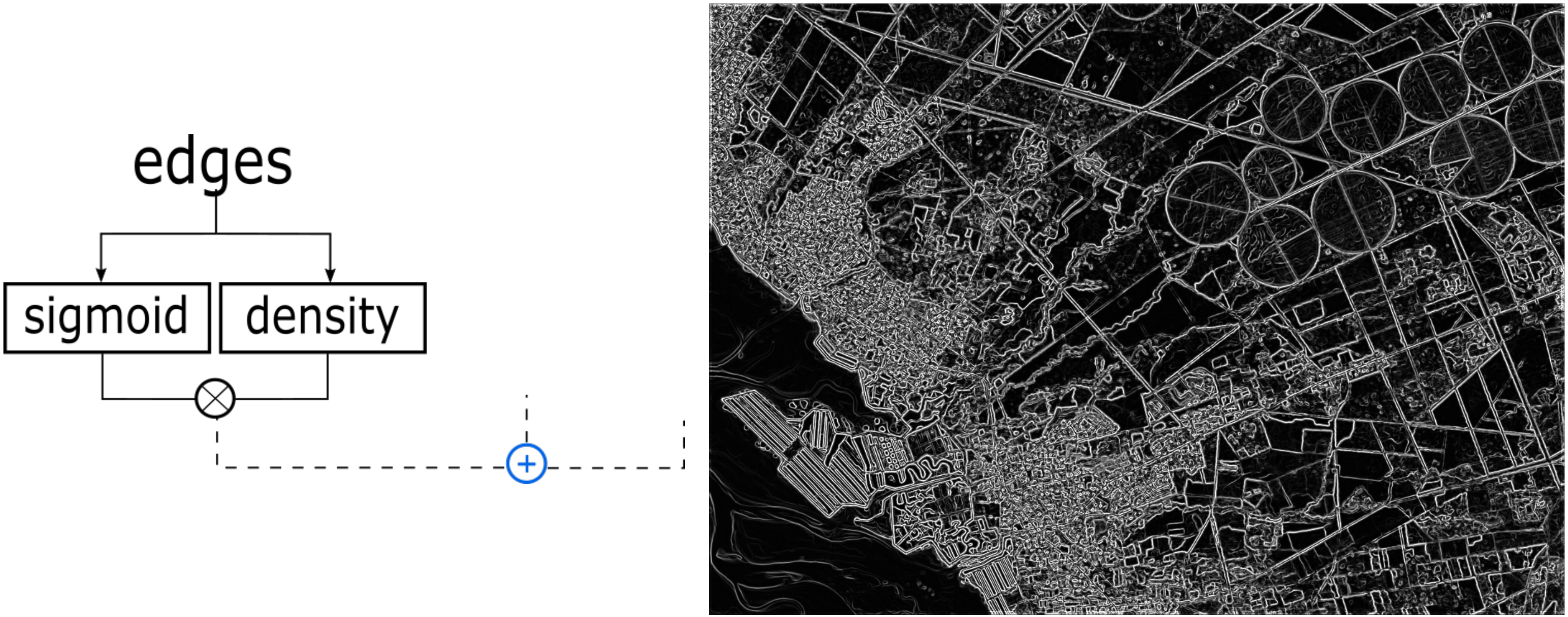
Multiply both

- Take into account slight edges
- Reduce influence of local maximum
- Reduce the density of edges to keep only main edges into high density areas



Global sketch for a Satellite Image Time Series

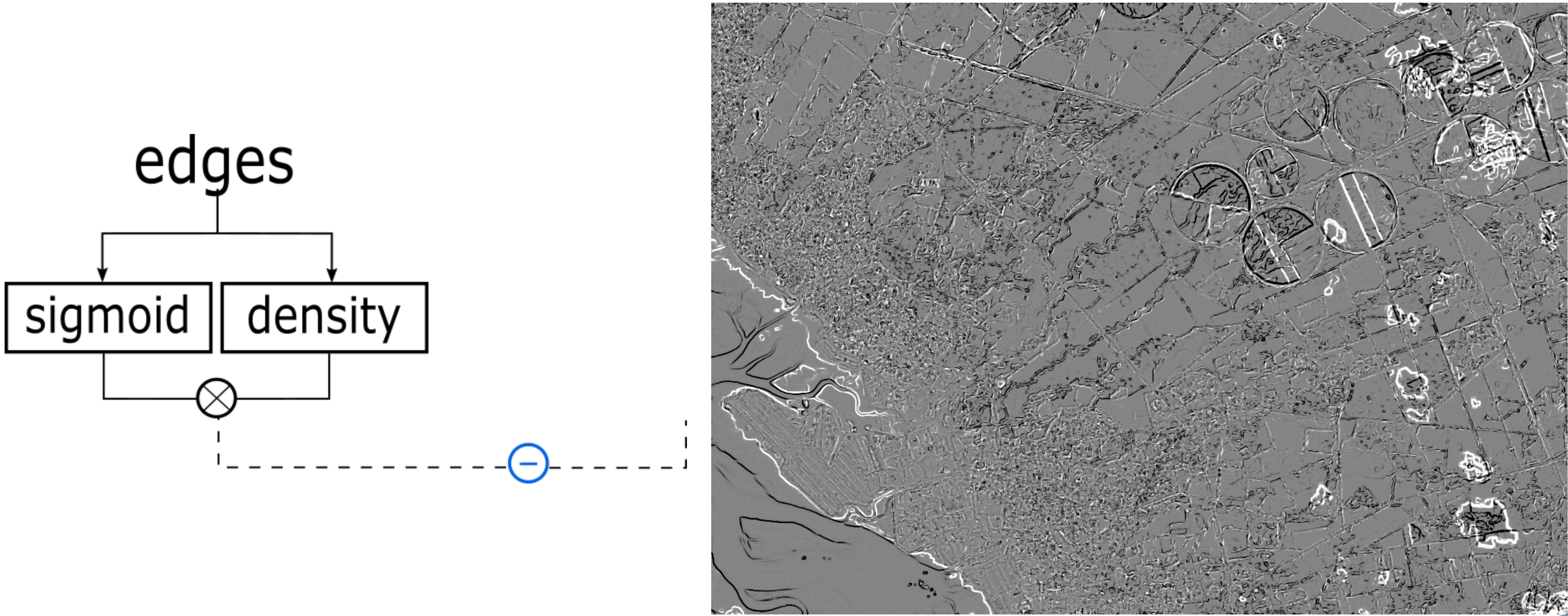
- Simply sum all of them...



To the change detection...

- Simple difference between sketch outputs
  - Sea
  - Circle crop split into the second image
  - Small clouds over the second image

(white = what appears into the second image)



To the change detection...

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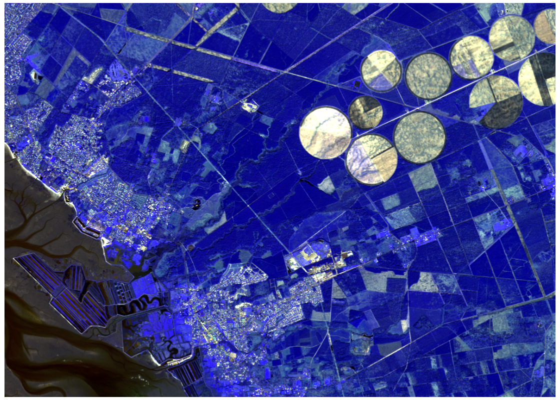

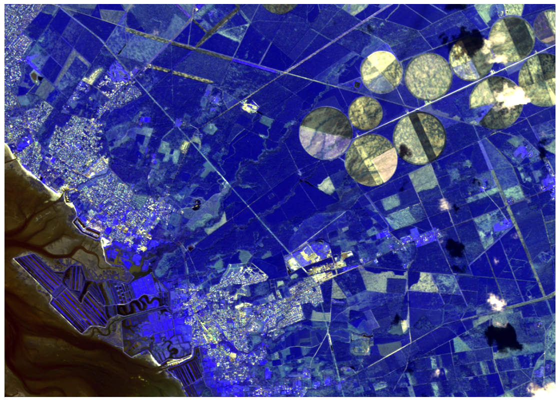

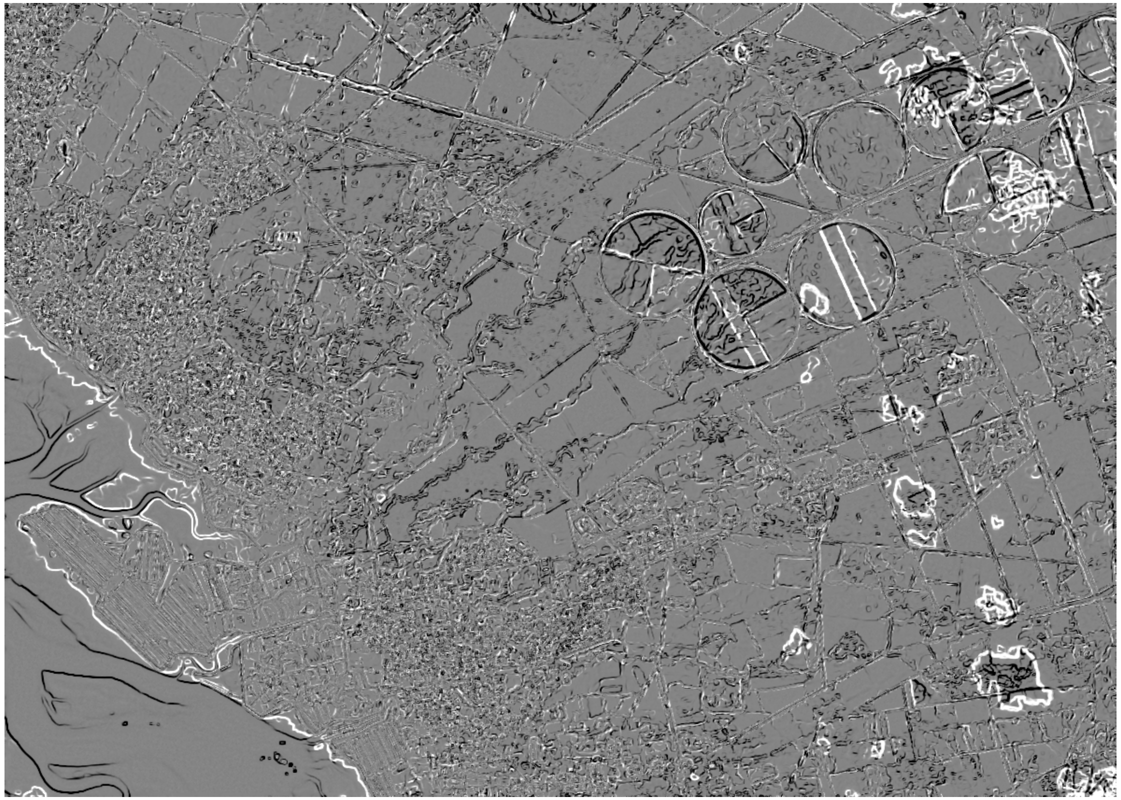

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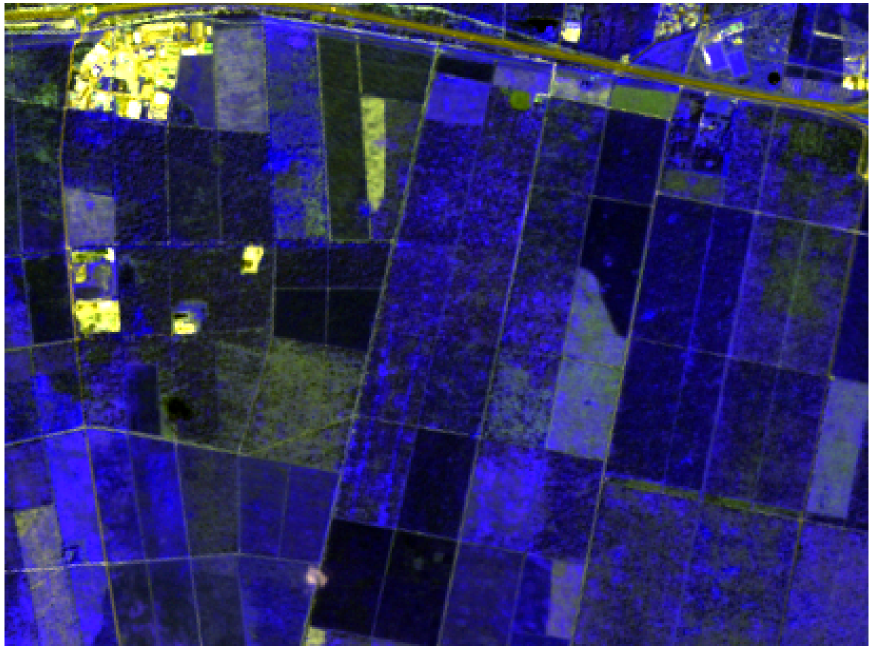
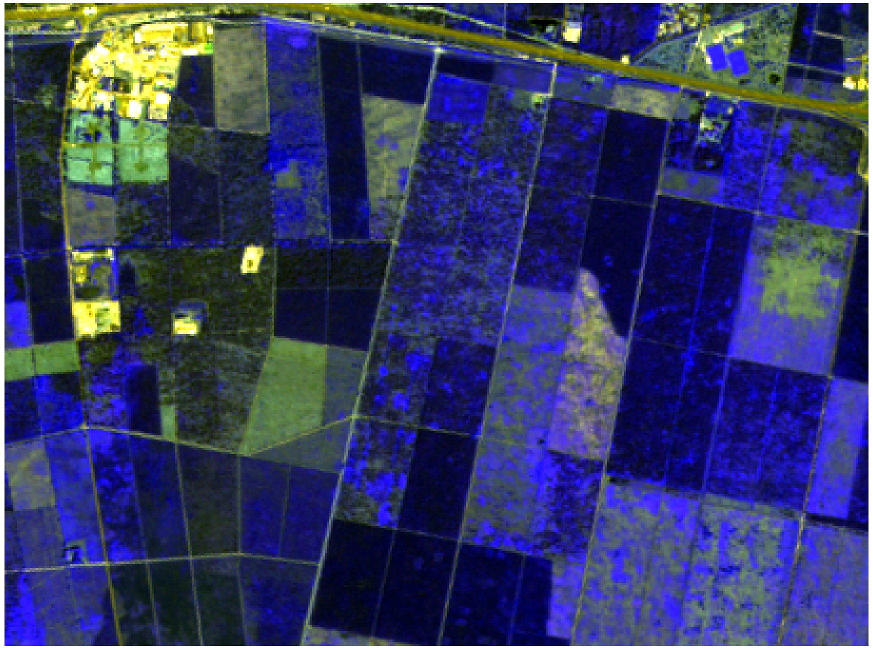
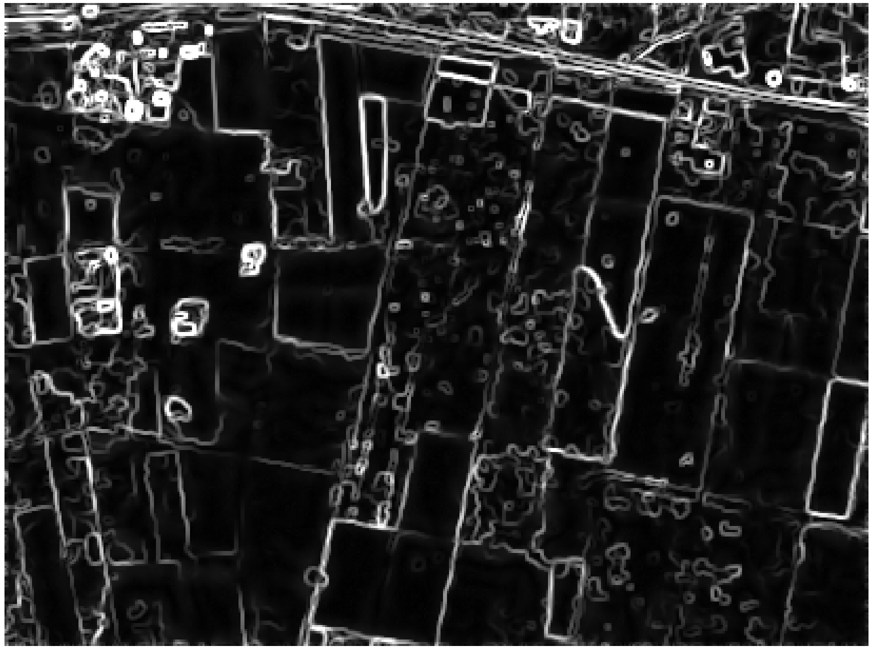
Series with 20 Spot 5 XS images (10m.). Source: http://kalideos.cnes.fr

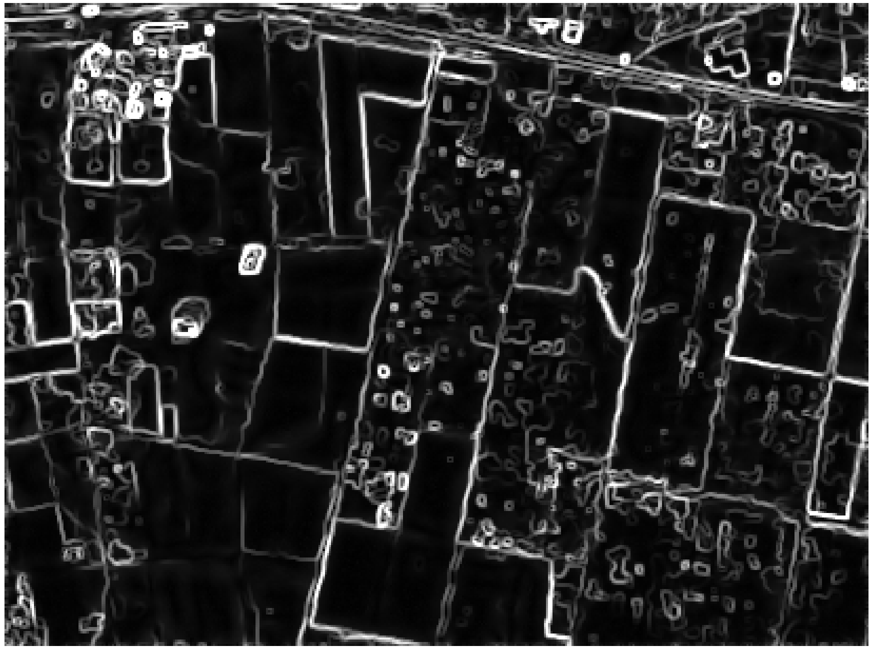
- Source: Kalideos (http://kalideos.cnes.fr)
- Change detection with 2 dates: 02/06/2009 and 01/07/2011



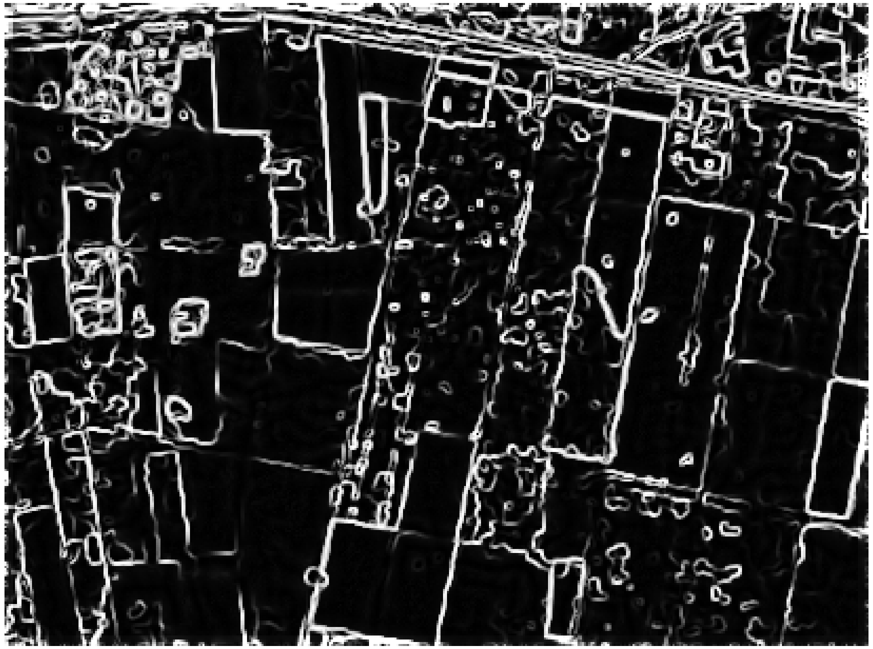


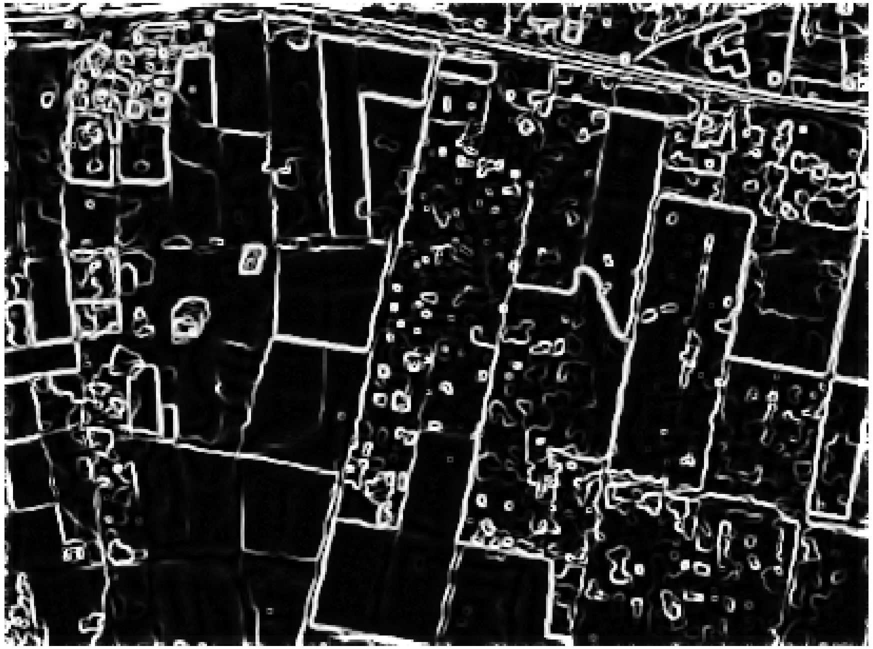
- Edge detection



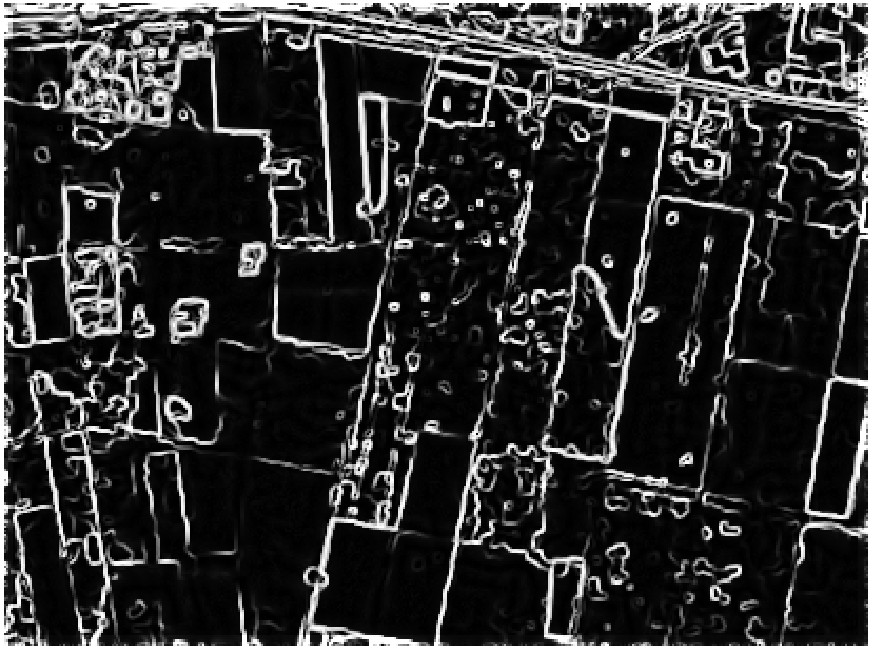


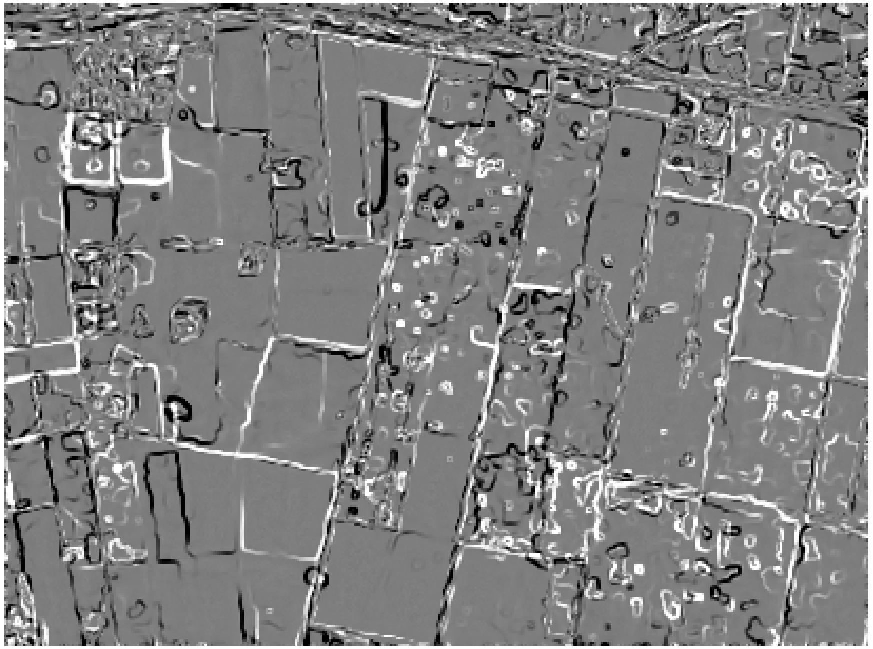
- Sketch images



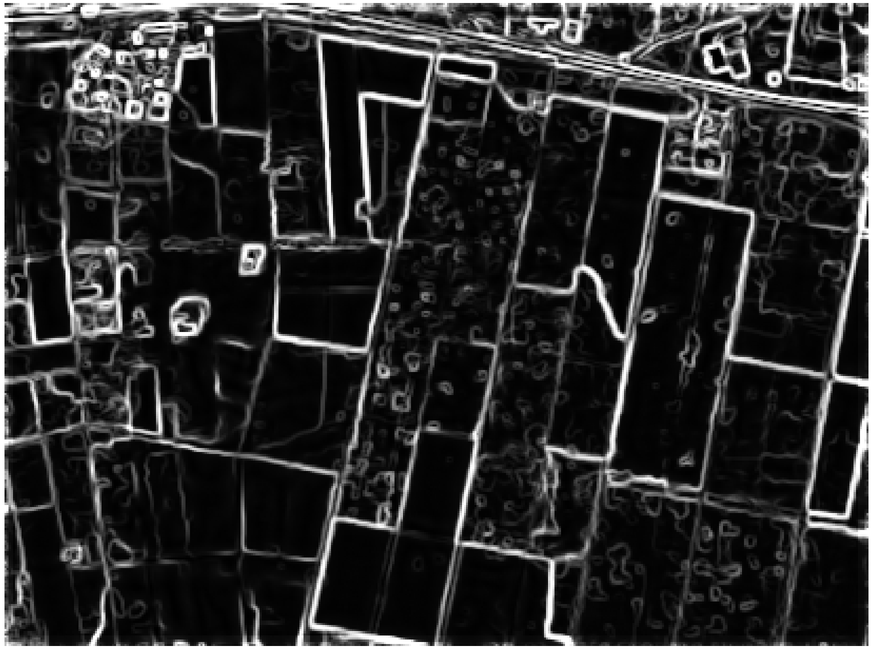


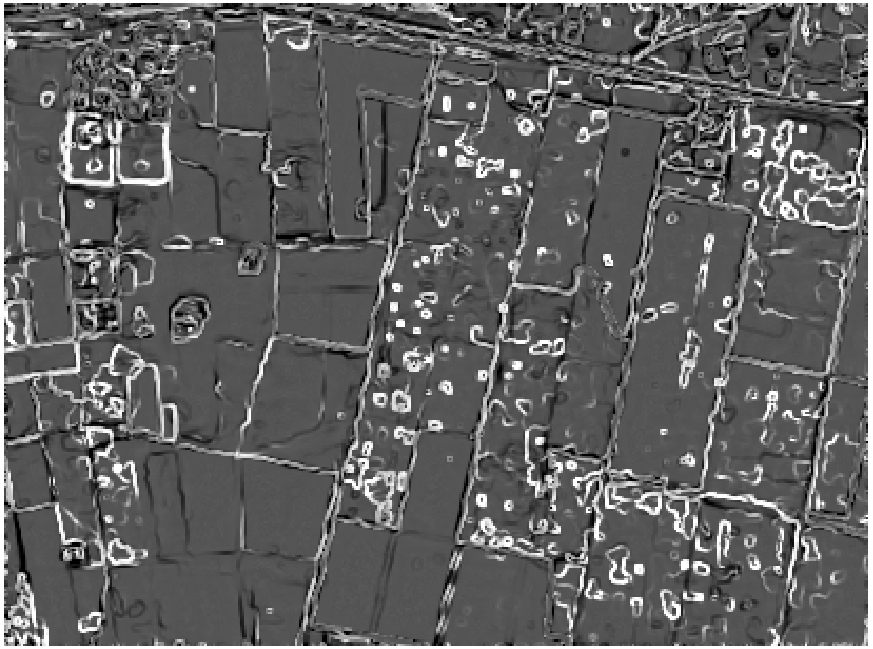
- Reference sketch image (02/06/2009) and change detection map





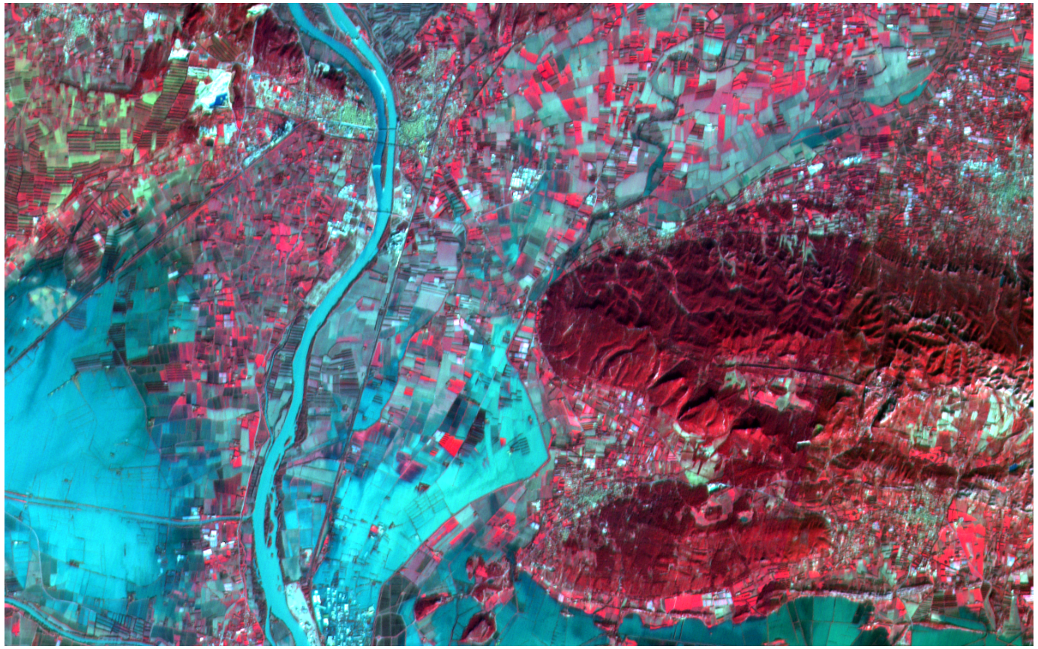
- Global sketch (20 images) and change detection map





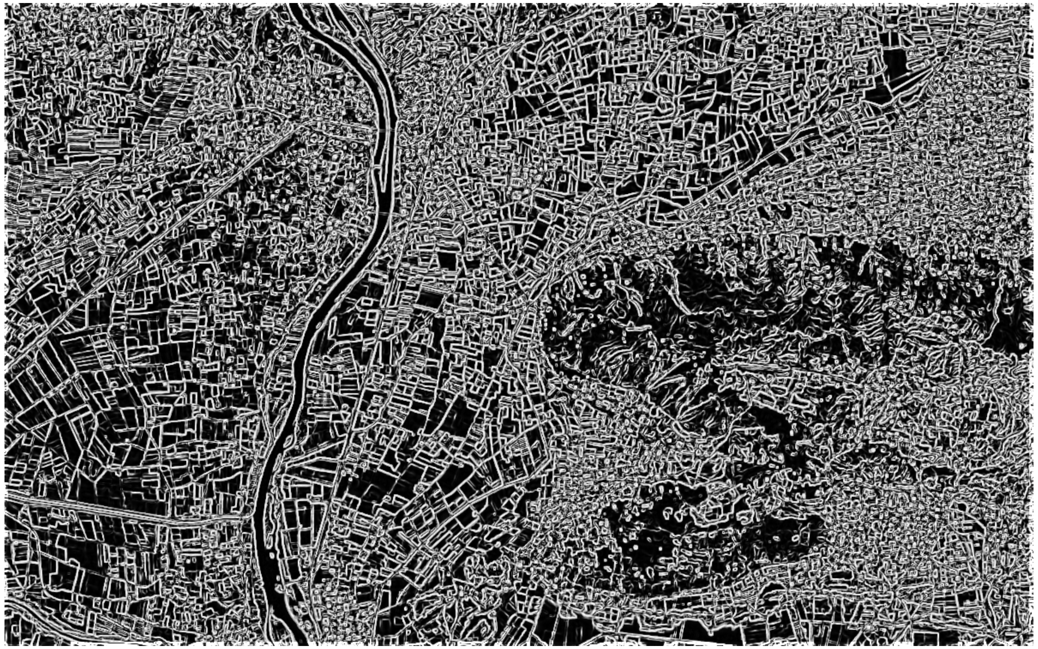
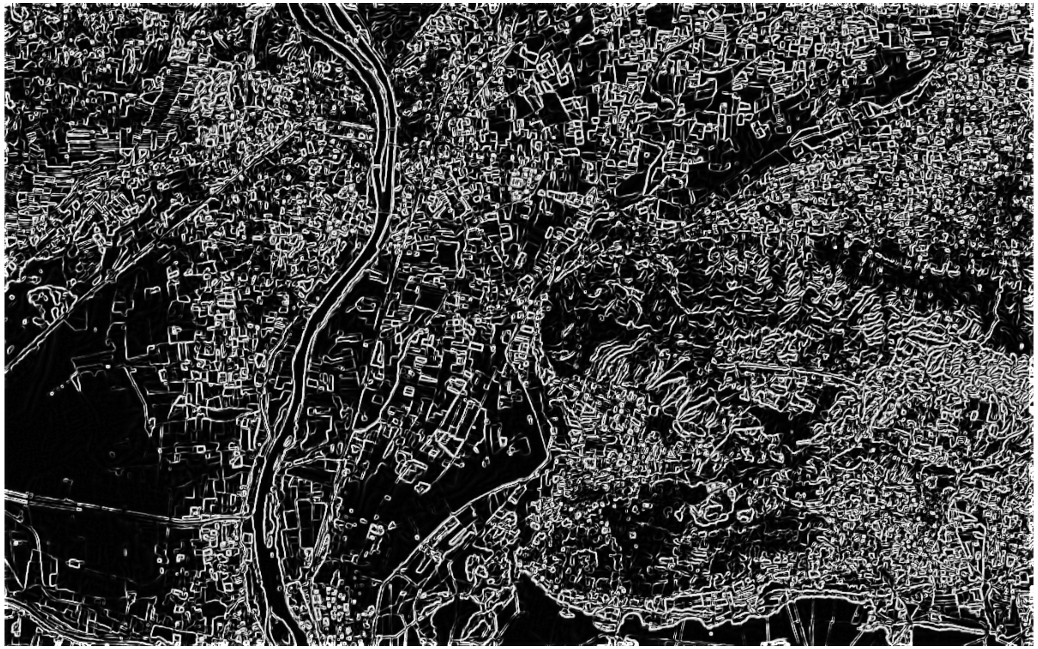
Series with 167 Spot 4 XS images (20m.)

- Source: Theia + Spot World Heritage
- Change detection with 2 dates: 10/10/2003 and 08/12/2003

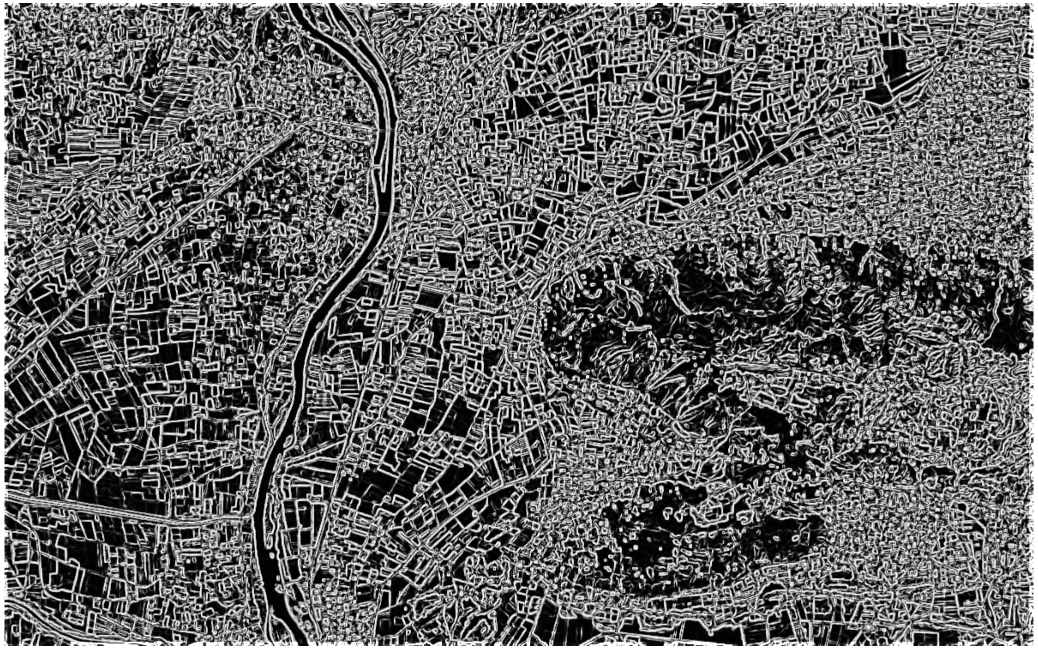


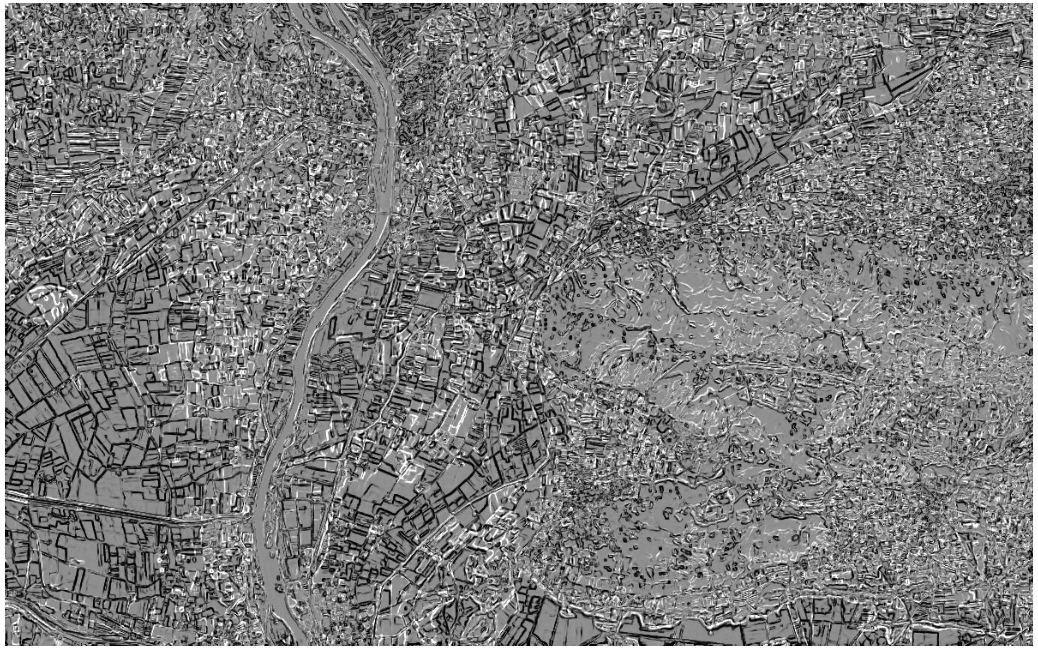
- Edge detection

- Sketch images

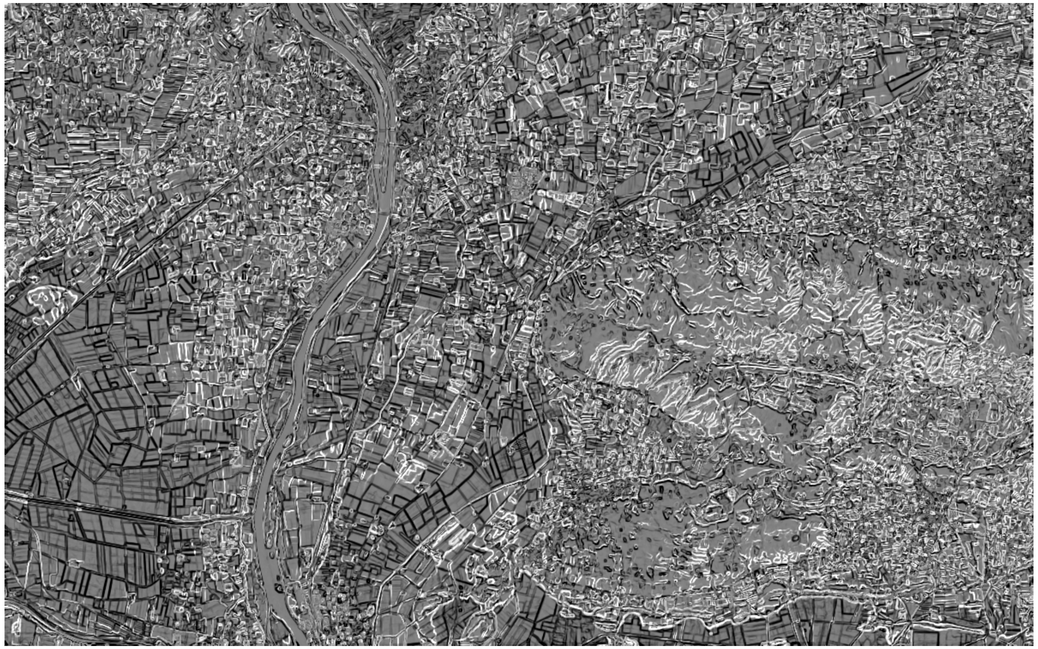



- Reference sketch image (10/10/2003) and change detection map





- Global sketch (167 images) and change detection map



Series with 3 Quickbird P+XS images (60cm.)

- Source: International Charter 'Space and major disasters'
- Change detection with 3 dates: 22/04/2002, 23/05/2003 and 13/06/2003

- Edge detection

- Sketch images

- Image and change detection map between 23/05/2003 and reference 22/04/2002

- Image and change detection map between 13/06/2003 and reference 22/04/2002

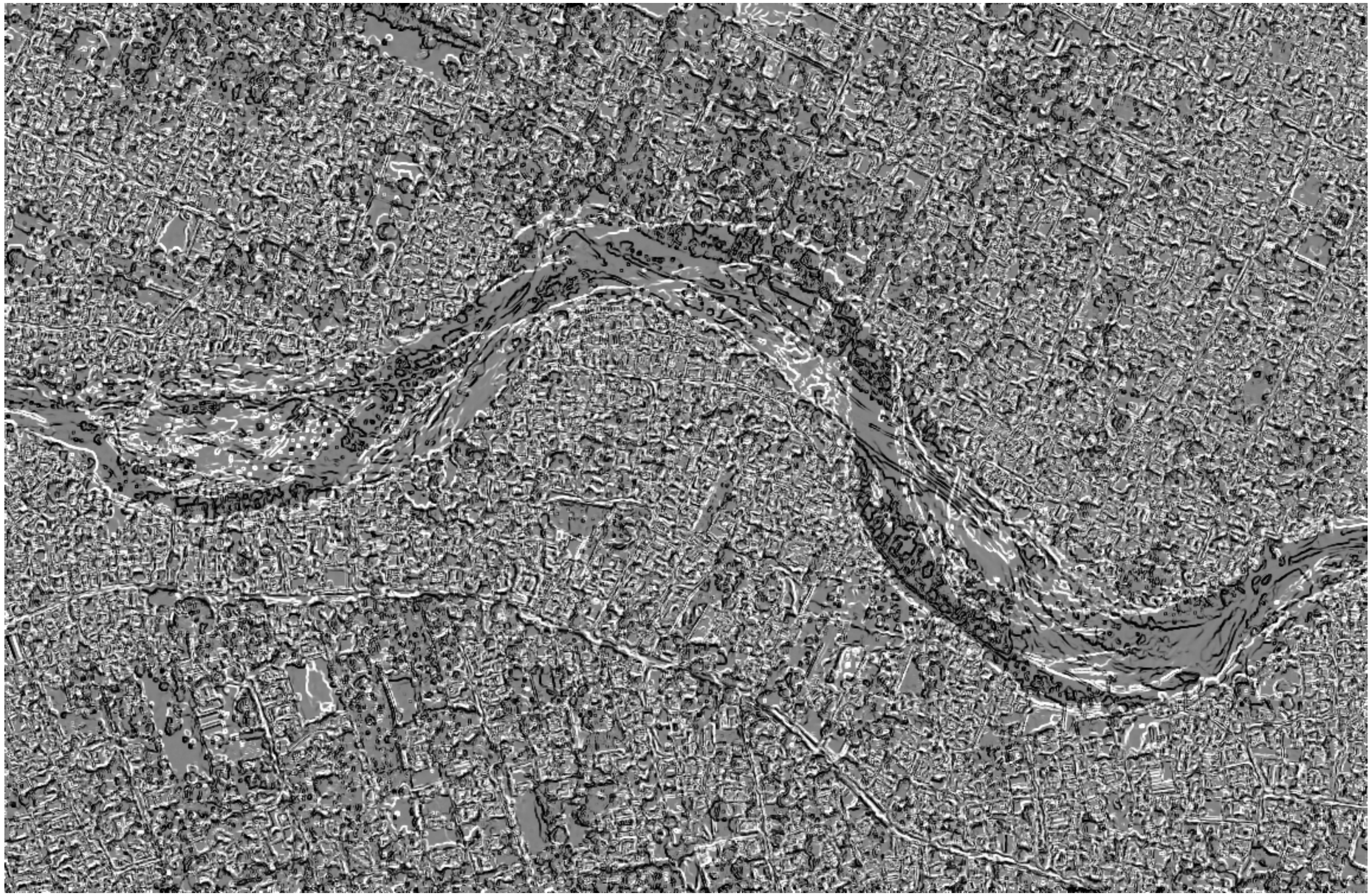
Series with 2 Pleiades XS images (2.80m.)

- Source: International Charter 'Space and major disasters'
- Change detection with 2 dates: 19/07/2012 and 02/11/2012

Series with 2 Pleiades XS images (2.80m.)

- Source: International Charter 'Space and major disasters'
- Change detection with 2 dates: 19/07/2012 and 02/11/2012

Sketches difference map



Contents

Synthesis

- New edge detection method derived from Perona-Malik algorithm
- New sketch algorithm
- Sketch is a powerful tool that can be used for different actions: global registration of images, change detection, pattern recognition
- Seems to be a fast and robust tool for risk management

Perspectives

- Enhance comparison between sketch images to detect impacted areas
- Limitations remain on Very High Resolution satellite images (different view angles)
- Further evaluation of radar application
- Require photointerpreters experience return to assess interest of the method