FROM RESEARCH TO INDUSTRY

DSM GENERATION FROM VERY HIGH RESOLUTION STEREOSCOPIC IMAGERY

Cyrielle GUERIN (CEA, France)

KISS Workshop :
Gazing at the Solar System

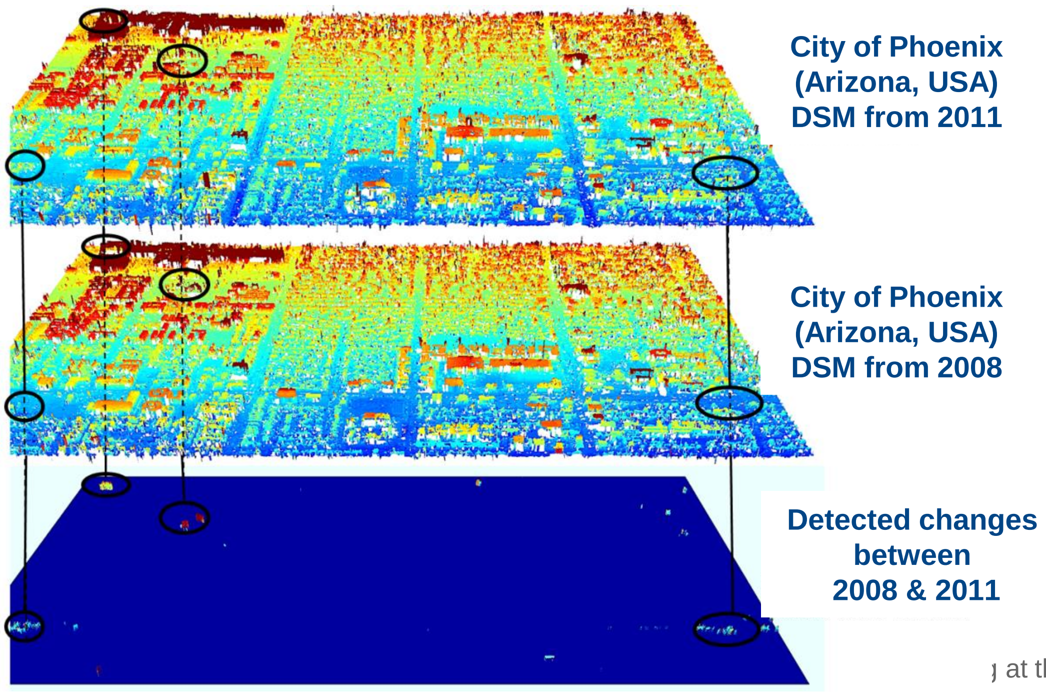
JUNE, 2014

www.cea.fr

CONTEXT

Digital Surface Model (DSM)

- Used for various applications :
  - Image ortho-rectification,
  - 3D ground measurements,
  - Elevation changes detection between two DSMs acquired at different dates ➔ Urban changes.



CONTEXT

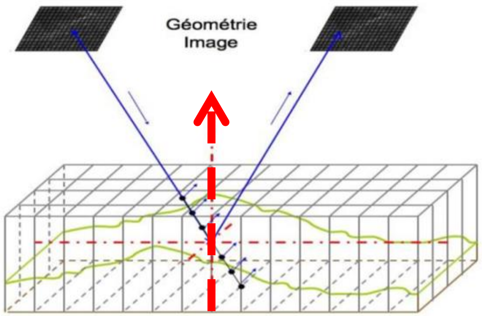
Various applications that require increasing accuracy

- Especially for :
  - Buildings edges,
  - Transitions areas (occlusion),
  - Homogeneous or complex featured areas,
  - Mobiles targets, etc.

And accurate image co-registration

- Intra couple: for the DSM generation,
- Inter couple : for DSM comparison,

Optimization function



- Micmac tool* from IGN :
  - Free open source tool,
  - 3 different matching geometry available :
  - Epipolar – ground space – image space
  - Multi-scale

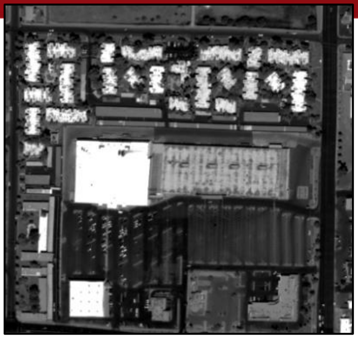
- Better accuracy with the image space matching when dealing with stereoscopic couples
  → no errors on the master images occlusions.

- Homologous pixels selected according to :
  - Normalized Cross Correlation Coefficient (NCC),
  - Spatial regularization.

- General equation : $E(z) = \sum_{x \in X} NCC\big(z(x)\big) + \sum_{y \in V(x)} f(|z(x) - z(y)|)$

* Download at http://logiciels.ign.fr/?-Micmac,3-

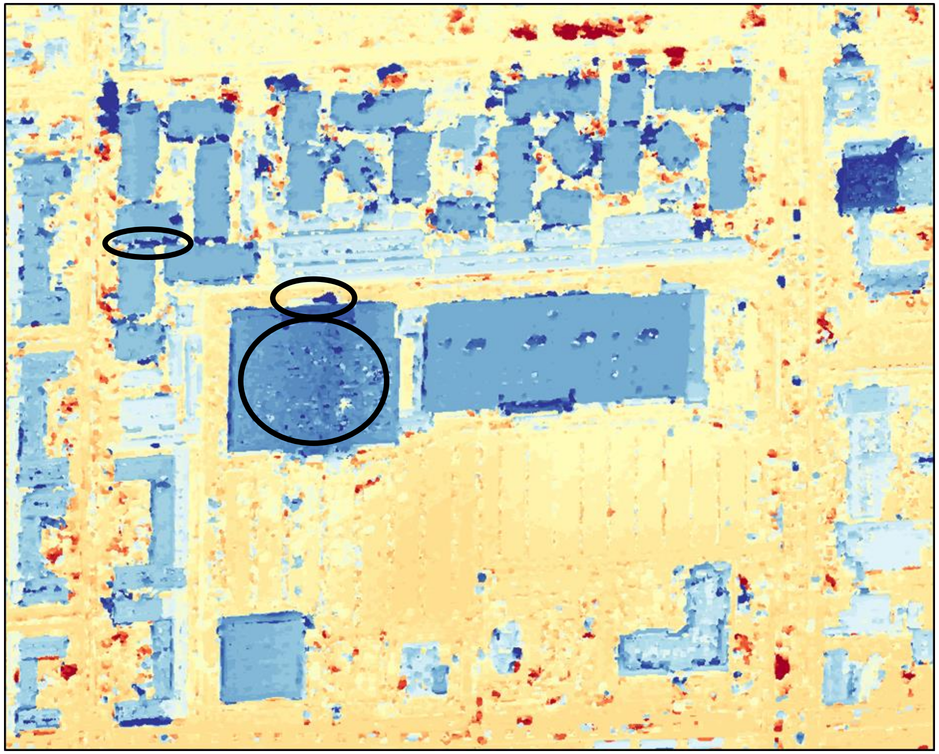
RESULT : ELEVATION IMAGE



- Elevation image in the master image geometry

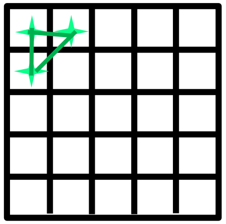
- Numerous errors:
  - Occlusions,
  - Homogeneous areas,
  - heavy slopes.

➔ Errors on the elevation images often have an impact on the final result :
  - Change detection,
  - Volume estimation,
  - Ortho-rectification.



Elevation image from WorldView -1 stereoscopic images

ELEVATION RESAMPLING ONTO A REGULAR GEOGRAPHIC GRID : OCCLUSION HANDLING

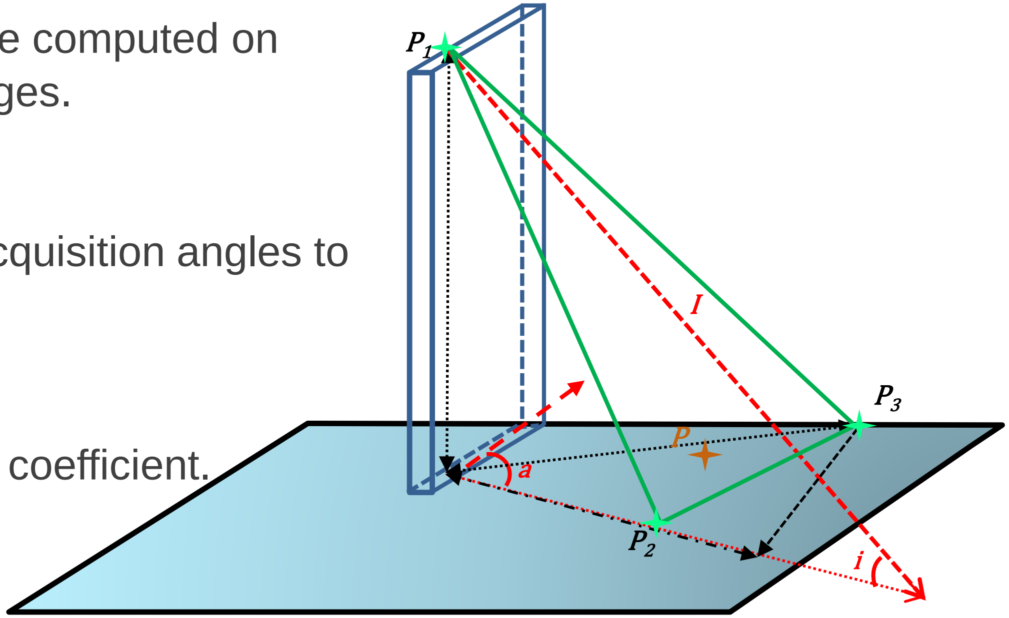


Additional constraints to the image resampling

- Z-buffer condition :
  ➔ selection of the higher value computed on each pixel to avoid building frontages.

- Geometric constraints :
  ➔ use of the master image acquisition angles to mask the occlusion areas.

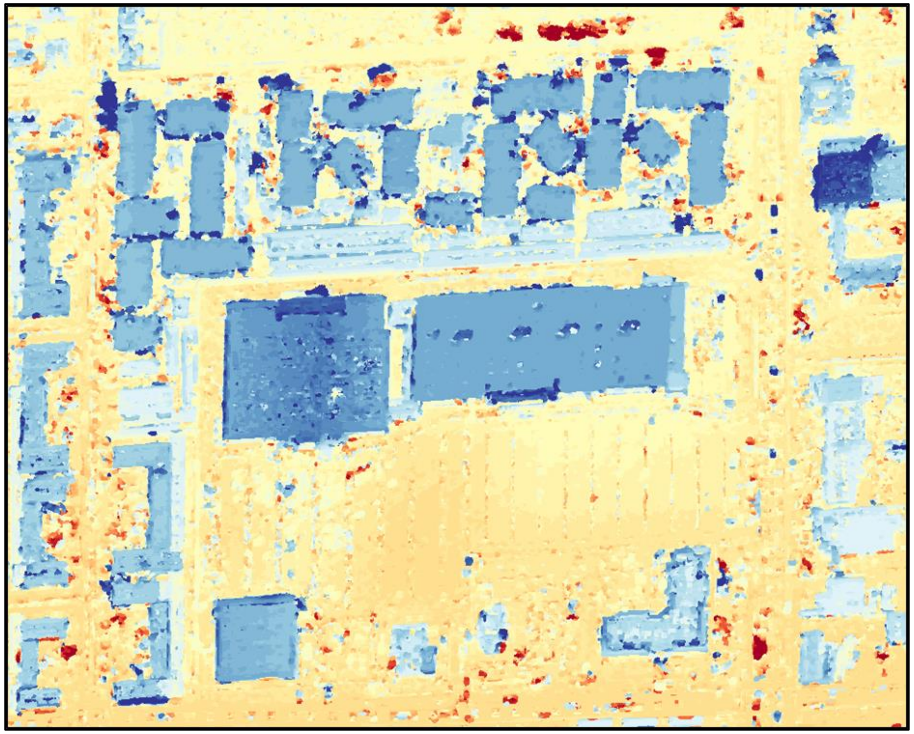
- Qualitative constraints :
  ➔ threshold on the correlation coefficient.



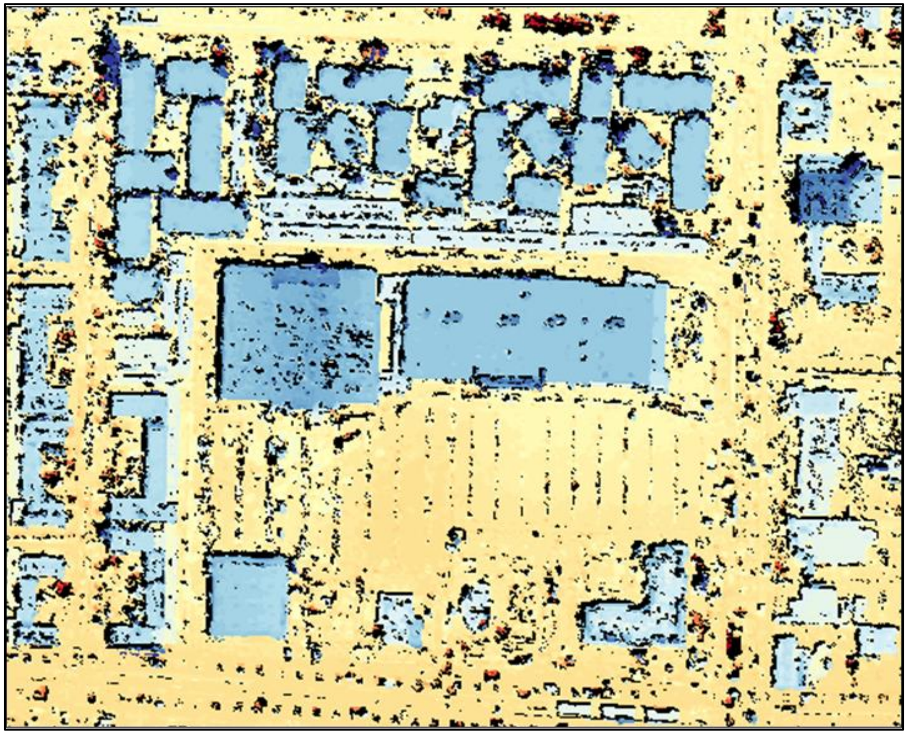
RESULT : MASTER IMAGE OCCLUSION HANDLING

Master image space elevation & resampled elevation

Image orientation

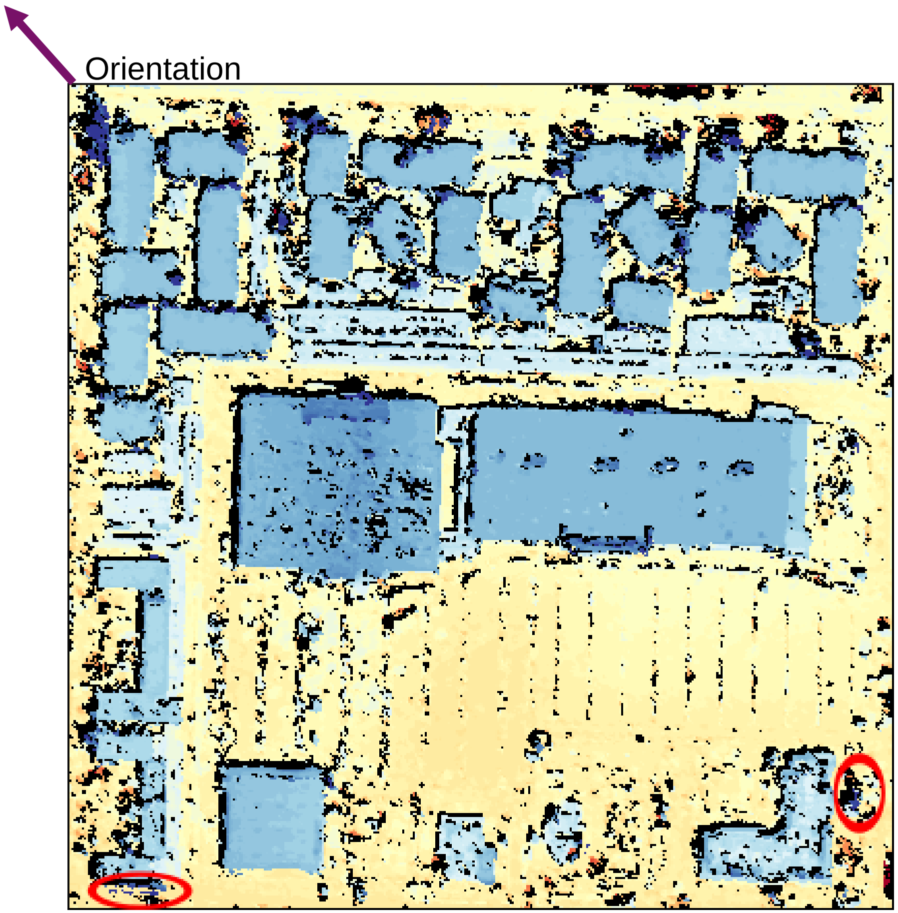


Elevation in the master image space

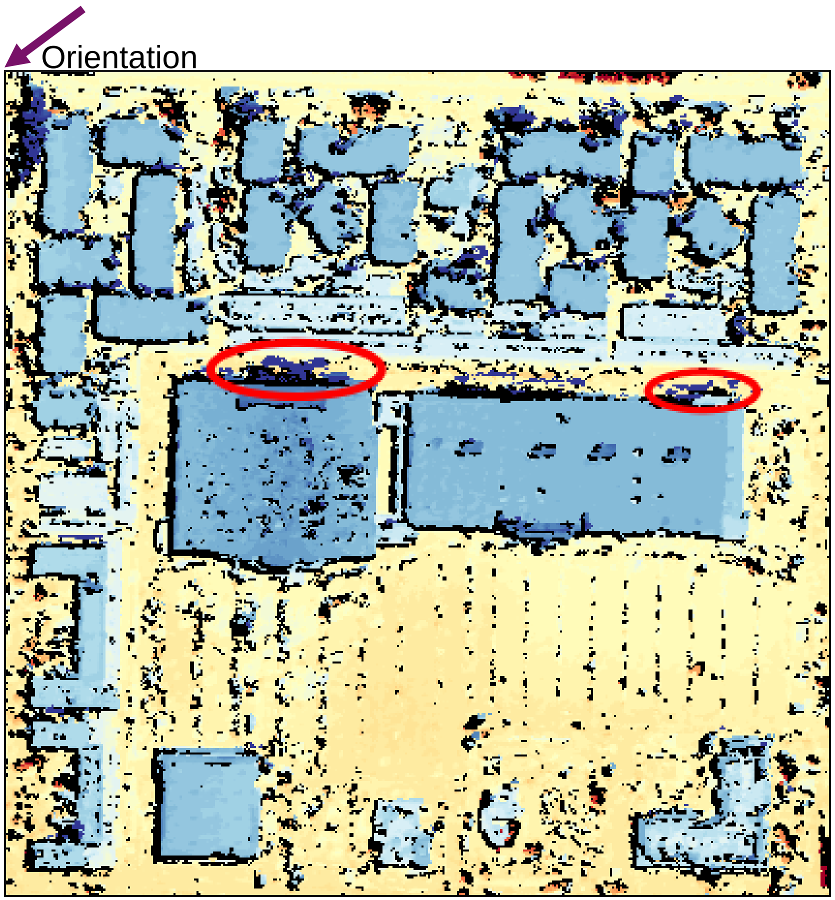


Resampled elevation

RESULT : RESIDUAL ERRORS ON THE OCCLUSION AREAS FROM THE SLAVE IMAGE



Elevation image from the image 1 resampled onto a geographic grid



Elevation image from the image 2 resampled onto a geographic grid

SOLUTION : DSM FUSION

Two computed DSM from the same image couple :

- Accurate co-localization,
- Each contains its own miss-correlation,
- Each associated with its own occlusion mask,
- Each associated with a correlation image, containing the correlation scores obtained on each pixel.

➔ Fusion of these DSM in order to get a result that is :

- Spatially coherent ➔ need a regularization constraint,
- Accurate on building edges ➔ require the use of the occlusion masks.

MEAN FUSION : EXEMPLE

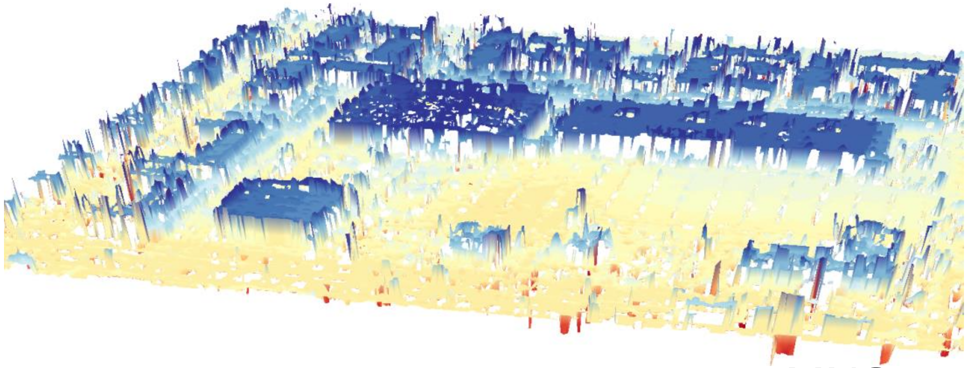
- Mean calculation between the value obtained at each pixel :
  - 0 if one of them is masked,
  - mean($I_1(i,j)$,$I_2(I,j)$) if both are determined.

SEMI-GLOBAL LABELLING FUSION

Labels :

- Label 1 :
  - $n^1 = MNS_1$

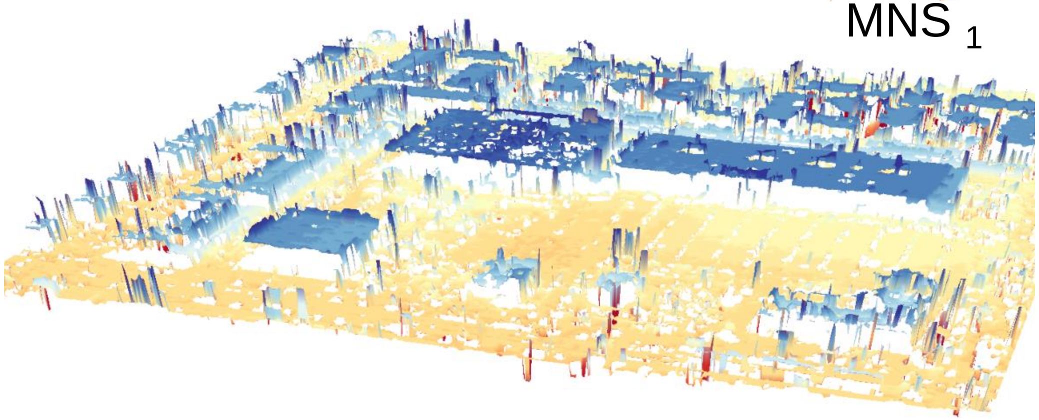
$$C_{data}\left(x, n^1(x)\right) = 1 - NCC(x, MNS_1)$$



MNS $_1$

- Label 2 :
  - $n^2 = MNS_2$

$$C_{data}\left(x, n^2(x)\right) = 1 - NCC(x, MNS_2)$$



MNS $_2$

- Label 3 :
  - $n^2 = Occlusion$

$$C_{data}\left(x, n^3(x)\right) = max[NCC(x, MNS_1), NCC(x, MNS_2)] + \frac{1}{1 + e^{-L(|Z(x,MNS_1) - Z(x,MNS_2)| - t_1)}}$$

SEMI-GLOBAL LABELLING FUSION : GENERAL ALGORITHM

- DSM Labels :
  - The Agreement data depends on the obtained correlation score :

$$C_{data}\left(x, n^1(x)\right) = 1 - NCC(x, MNS_1)$$

  - ➢ The higher it is, the more relevant the elevation value is

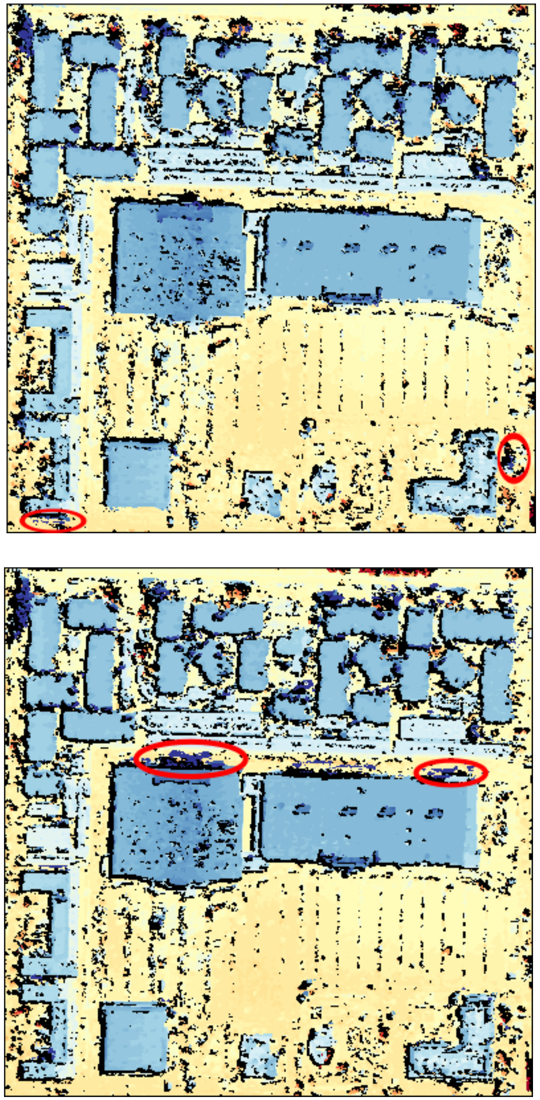
- Occlusion Label :
  - the agreement data term linked to :
    - Strongly different values on the same pixel in both DSM
    - Masked pixels in one or both DSM.

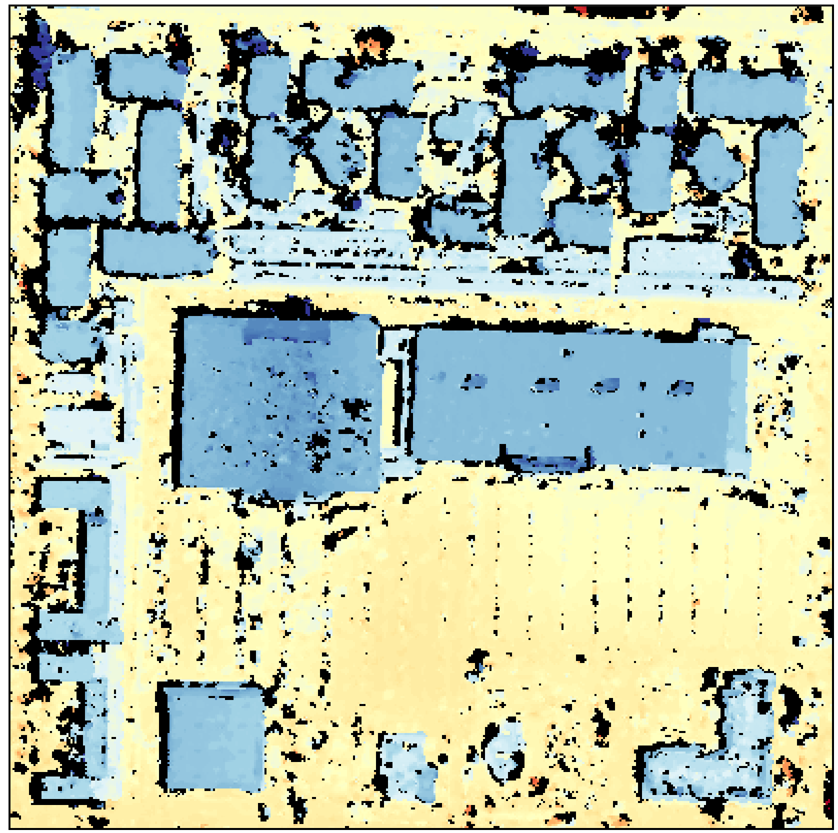
$$C_{data}\left(x, n^3(x)\right) = max[NCC(x, MNS_1), NCC(x, MNS_2)] + \frac{1}{1 + e^{-L(|Z(x,MNS_1) - Z(x,MNS_2)| - t_1)}}$$

- Regularization term :

$$C_{reg}\left(\left(x, n^k(x)\right), \left(y, n^j(y)\right)\right) = \frac{1}{1 + e^{-L\left(\left|Z(x, n^k(x)) - Z(y, n^j(y))\right| - t_2\right)}}$$

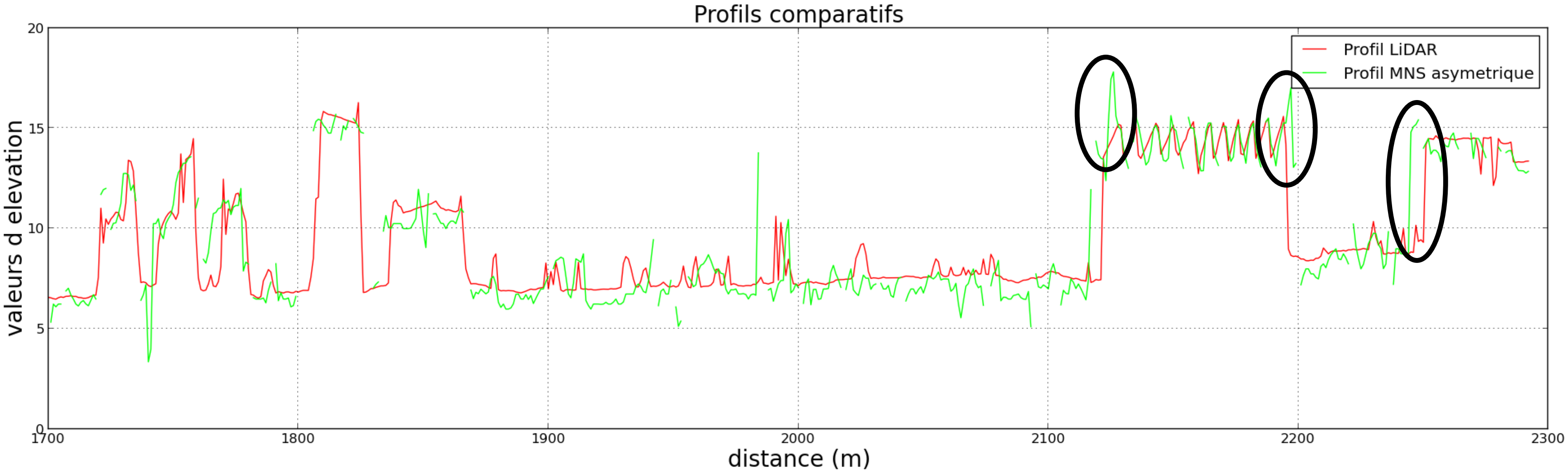
FUSION RESULTS

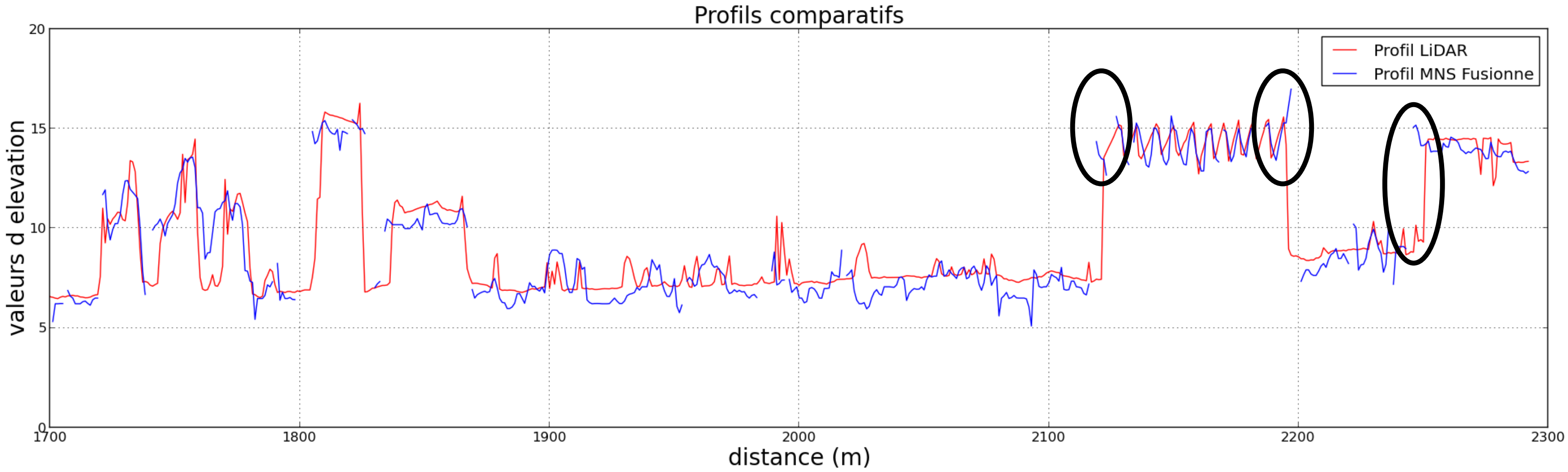




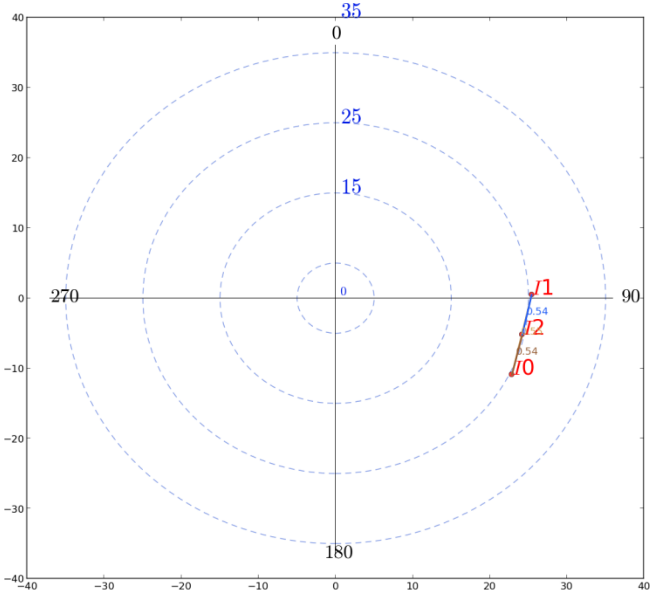
Fusion result

DSM PROFILS

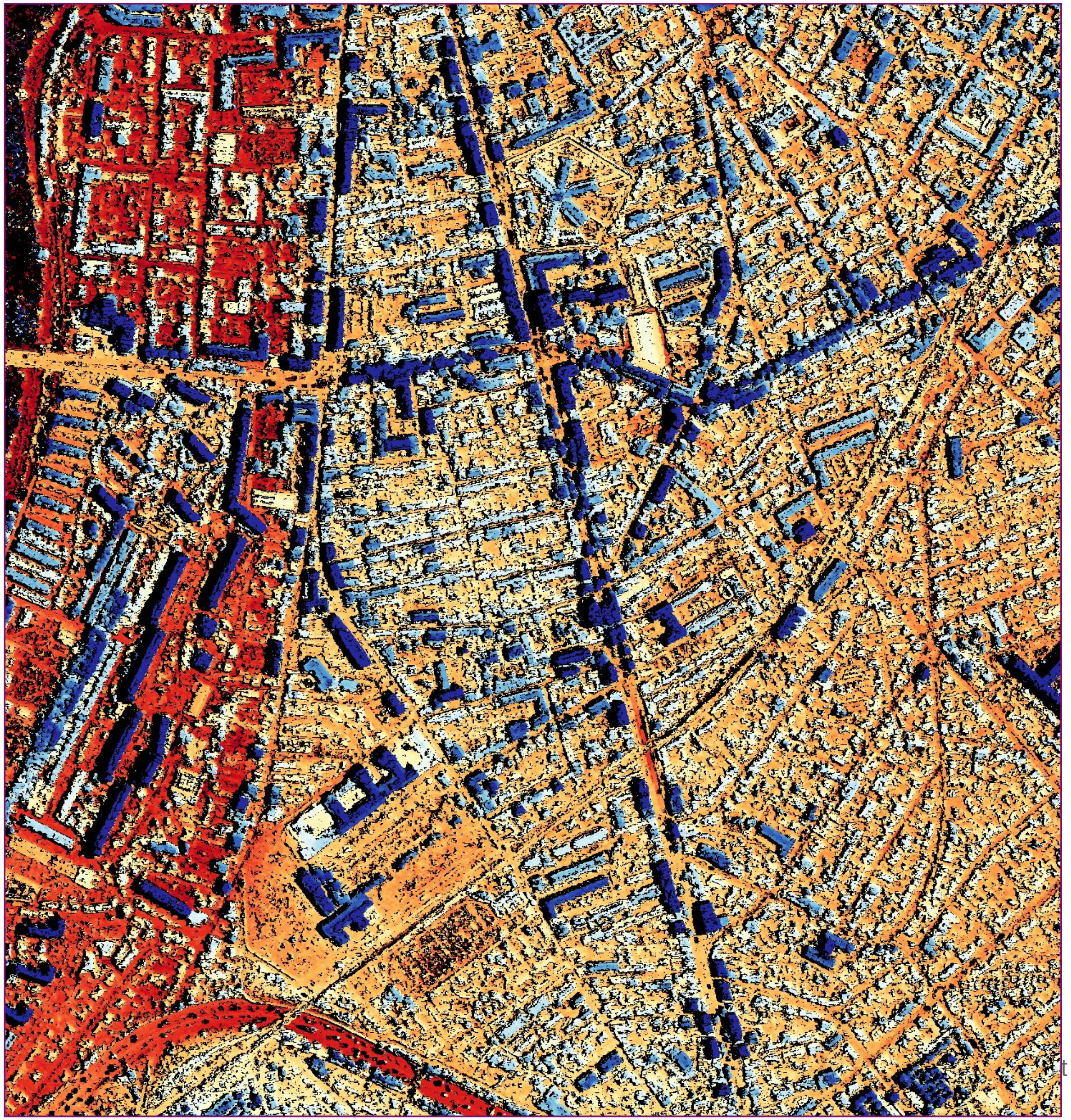

Profils comparatifs
Profil LiDAR
Profil MNS asymetrique
valeurs d elevation
distance (m)
0
5
10
15
20
1700
1800
1900
2000
2100
2200
2300


Profils comparatifs
Profil LiDAR
Profil MNS Fusionne
valeurs d elevation
distance (m)
0
5
10
15
20
1700
1800
1900
2000
2100
2200
2300

APPLICATION TO MULTI-STEREOSCOPIC IMAGES

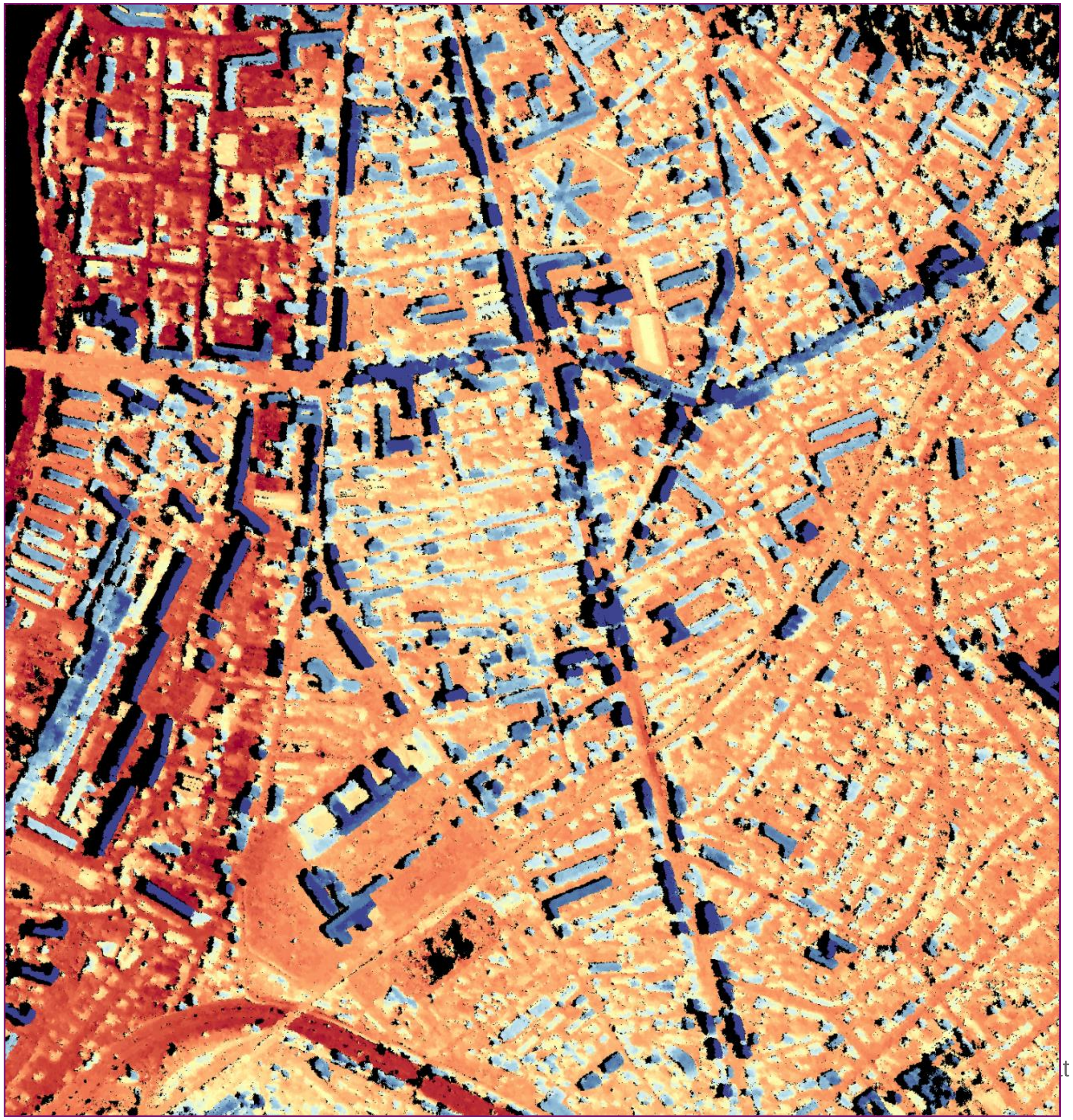


APPLICATION TO MULTI-STEREOSCOPIC IMAGES



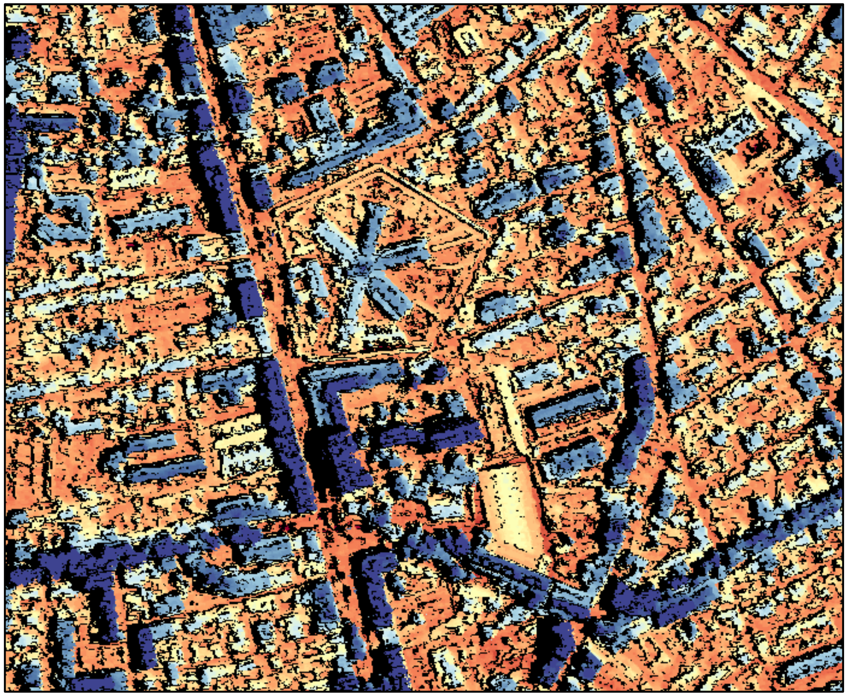
DSM generated with a stereoscopic couple. Toulouse 2012

APPLICATION TO MULTI-STEREOSCOPIC IMAGES

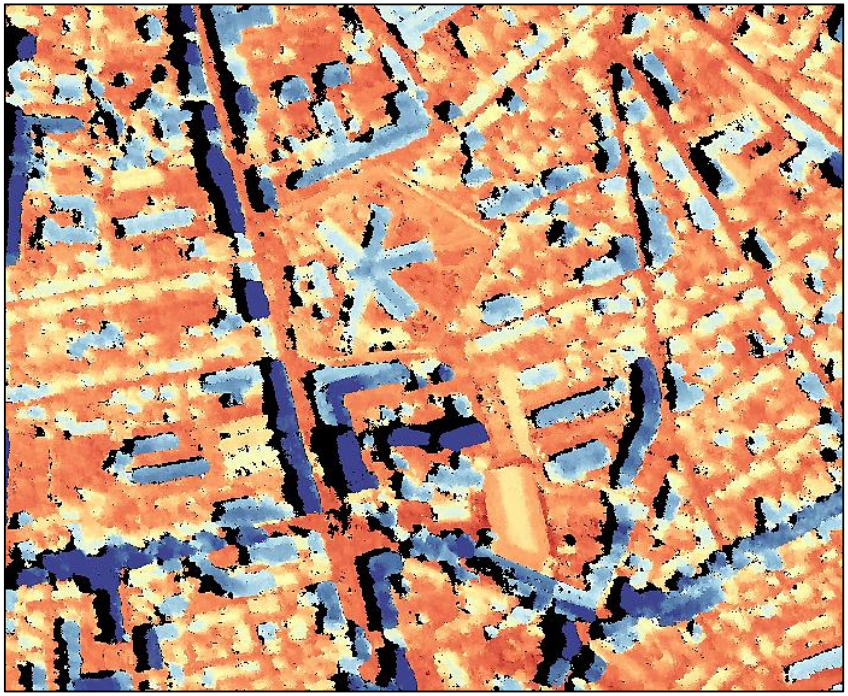


DSM generated with a tri- stereoscopic couple.
Toulouse 2012

APPLICATION TO MULTI-STEREOSCOPIC IMAGES



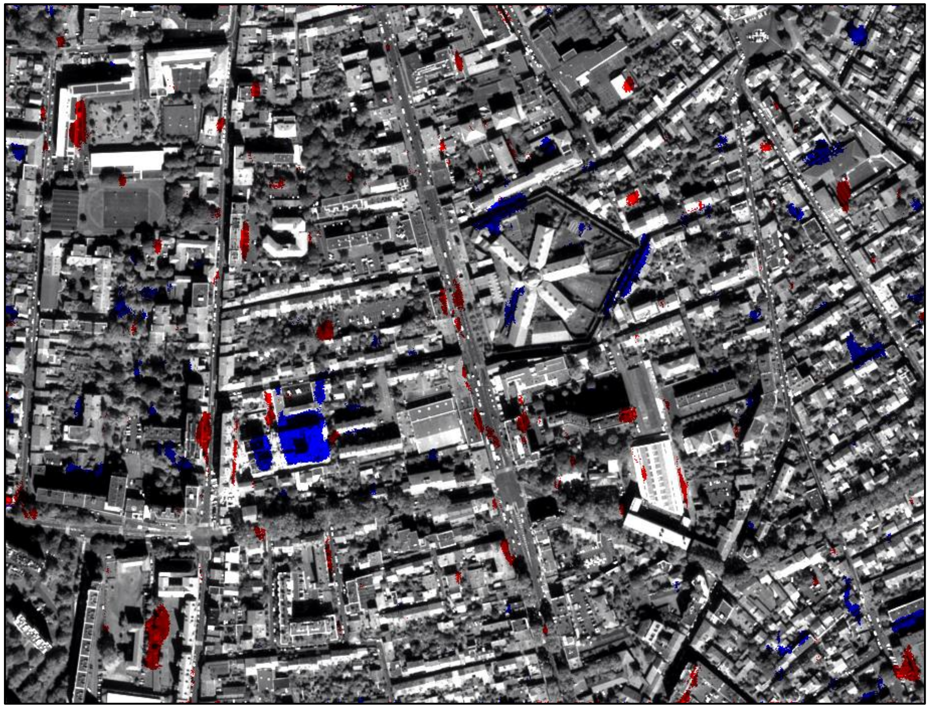
DSM generated with a
stereoscopic couple.
Toulouse 2012



DSM generated with a
tri- stereoscopic
couple.
Toulouse 2012

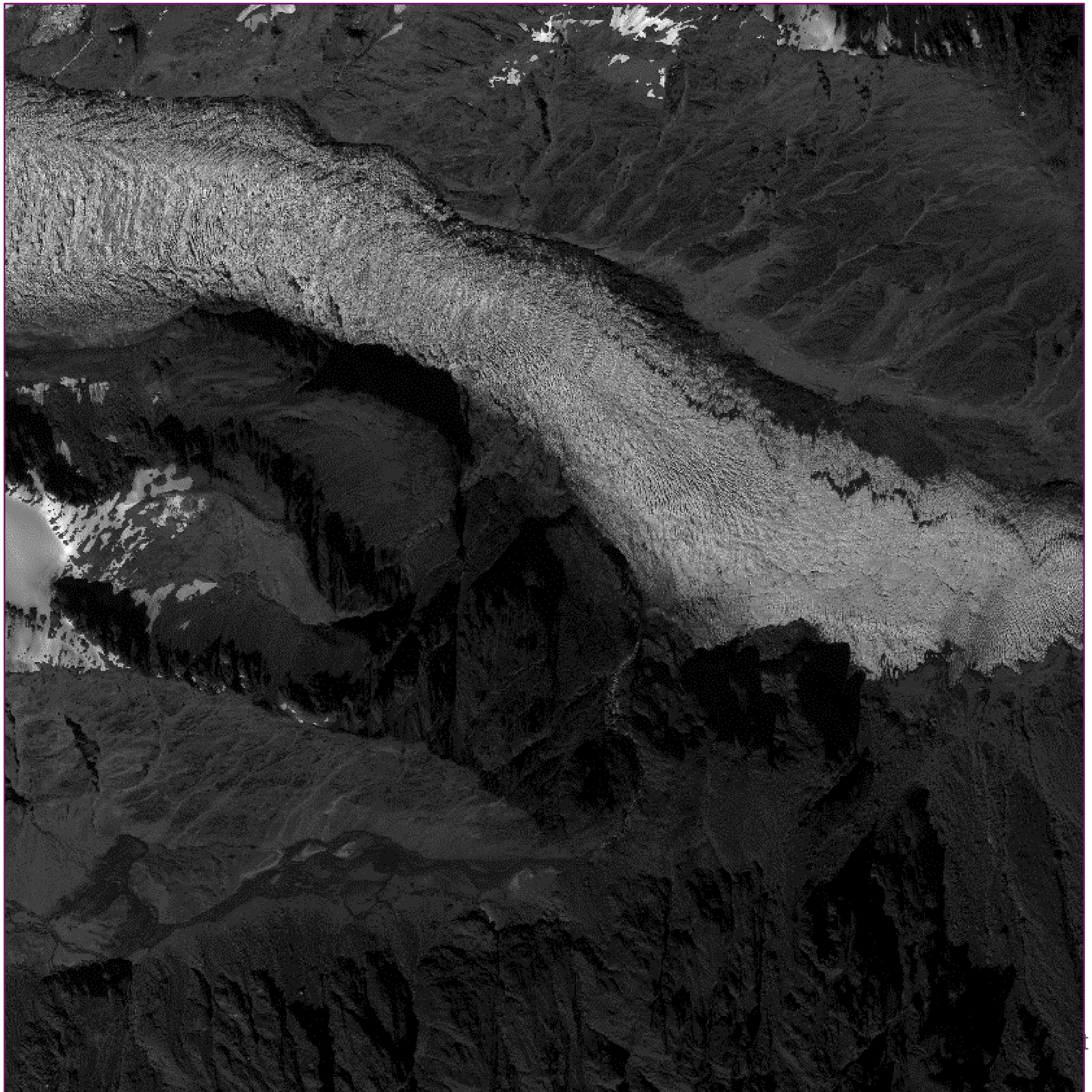
APPLICATION : CHANGE DETECTION OF ELEVATION

Pléiades Image
Toulouse 2012



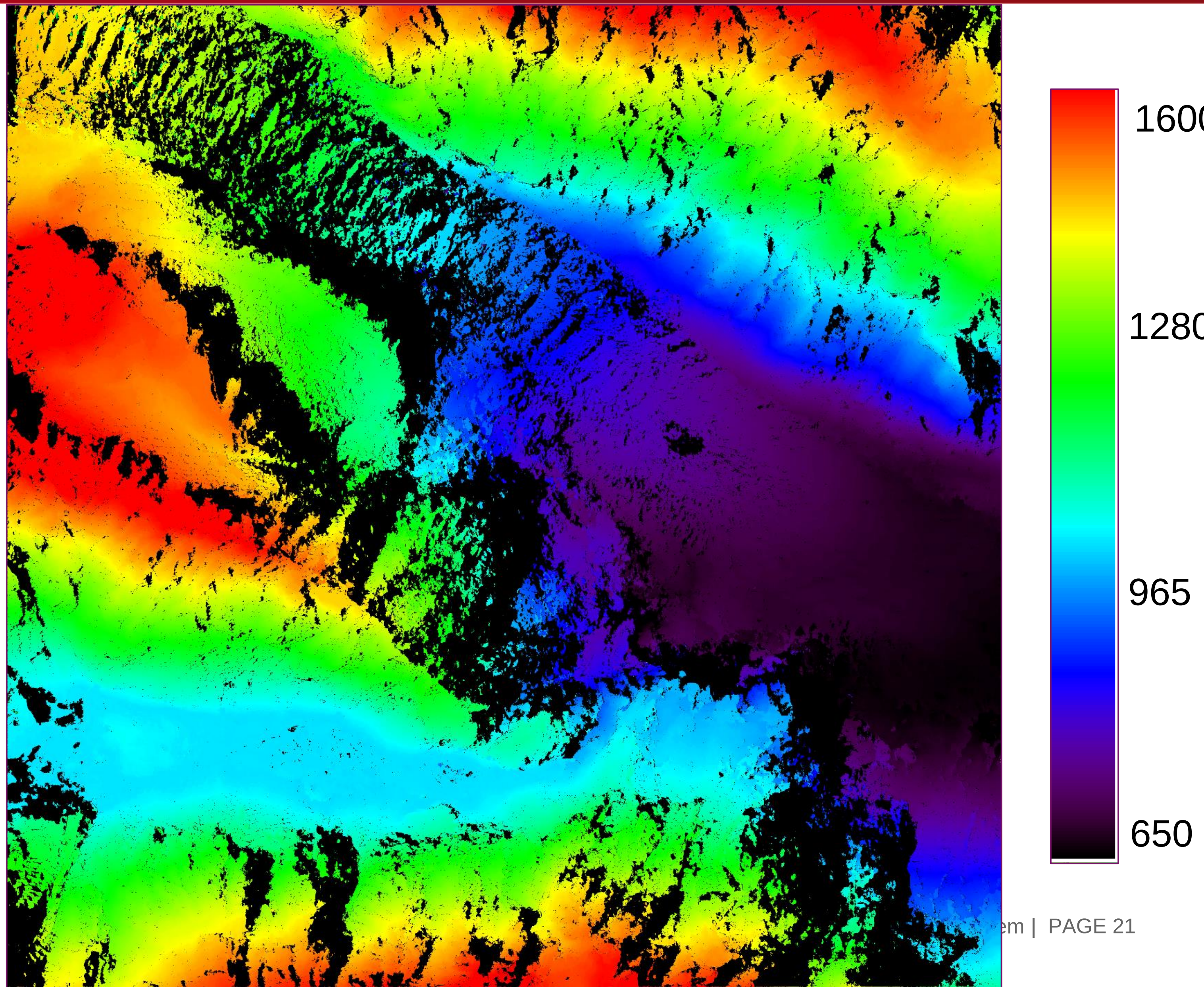
Pléiades Image
Toulouse 2013 and
detected changes

FIRST RESULT ON A GLACIER

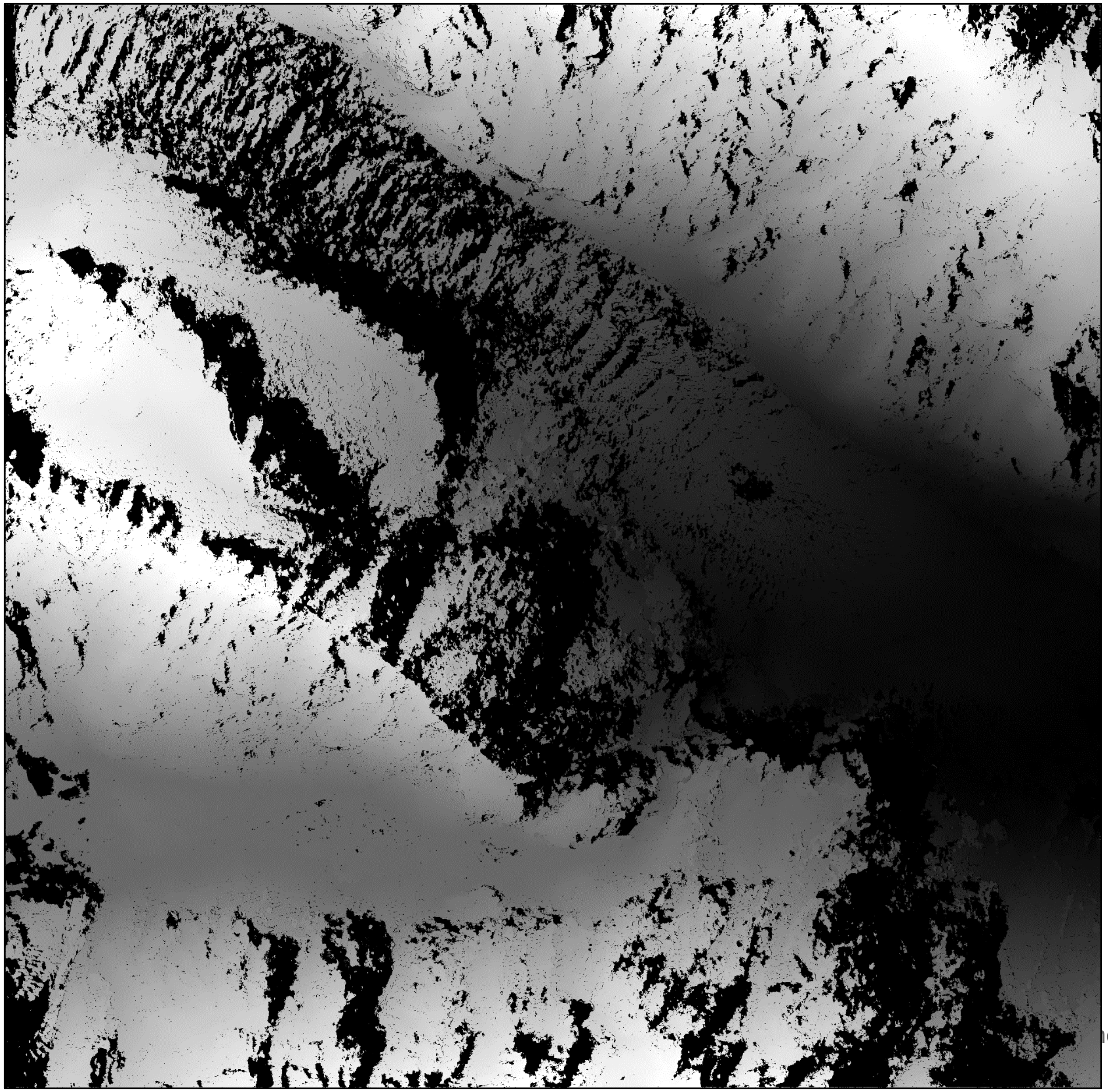


Franz Josef Glacier
New- Zealand

FIRST RESULT ON A GLACIER



FIRST RESULT ON A GLACIER



Thank you for your attention