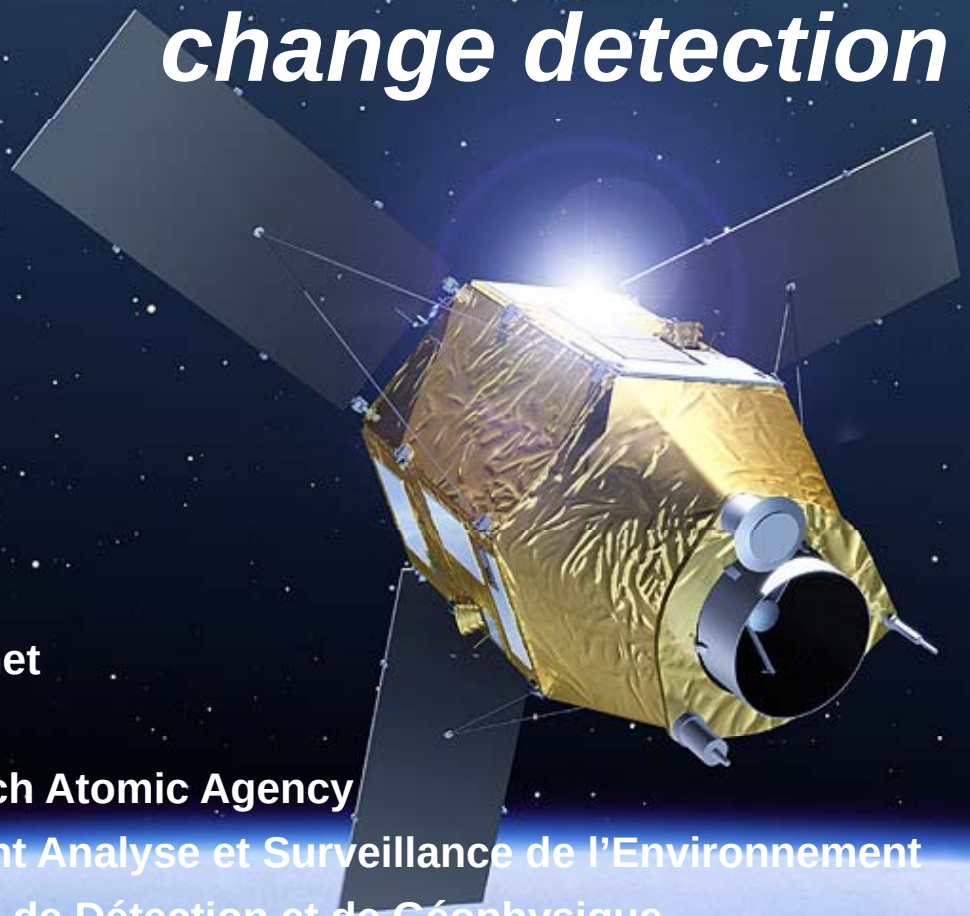
Potential of Very High Resolution Optical Images for geometric change detection



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VHR images characteristics

- Over 10 satellites in the close future
  - Geoeye, Woldview (2), Quickbird, Ikonos, Eros (3), Orbview, Pleiades (2), etc…
- Resolution better than 1m (Pleiades : 0.7m resampled to 0.5m)
- Time revisit : 1-3 days @ +/- 30° incidence angle
- Small swath : ~10 km
  - But possibility to acquire an image mosaic in the same track
- In-track stereo capability
- Tricky acquisition geometry : pushbroom Time Delayed Integration sensor with pitch and yaw satellite driving
- High cost (15-20$/km2)

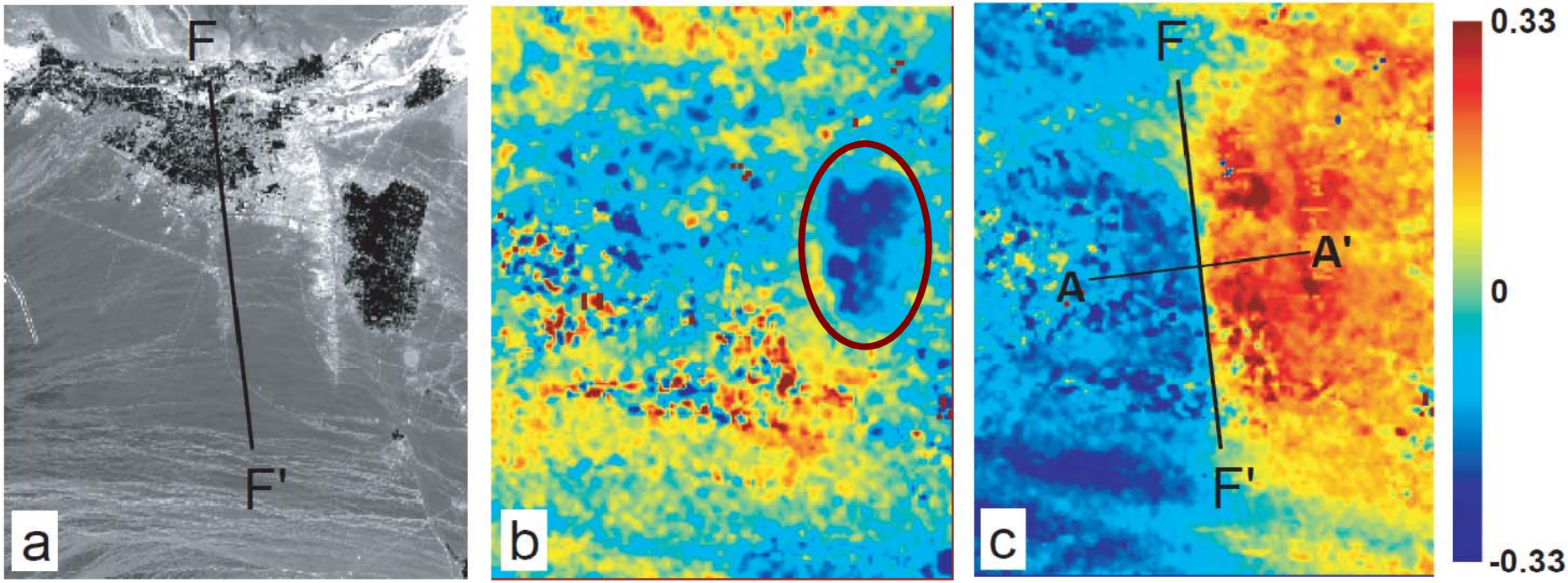
Potential for ground deformation measurements

- Horizontal deformations
  - Enhanced sensitivity : 1/10 pixel = 5cm !
  - Main limitations : no control on incidence angle

- Vertical changes
  - Very high spatial resolution differential DEM
  - No radiometric temporal coherence needed
  - Actual accuracy of DEM (in urban landscape): ~1m. What if sub-pixel measurements are applied to non-urban landscape ?

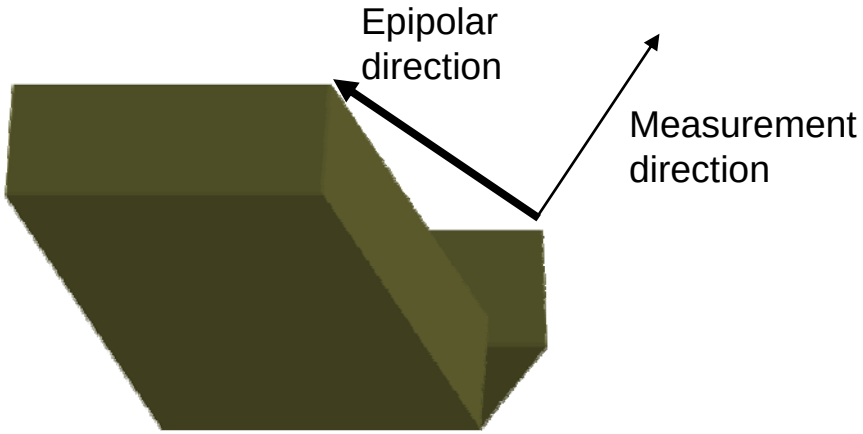
DEM biases issue

- The Bam 2003 earthquake as seen by SPOT-5 (2.5 m)
- EW offset biases due to unknown height of palm trees

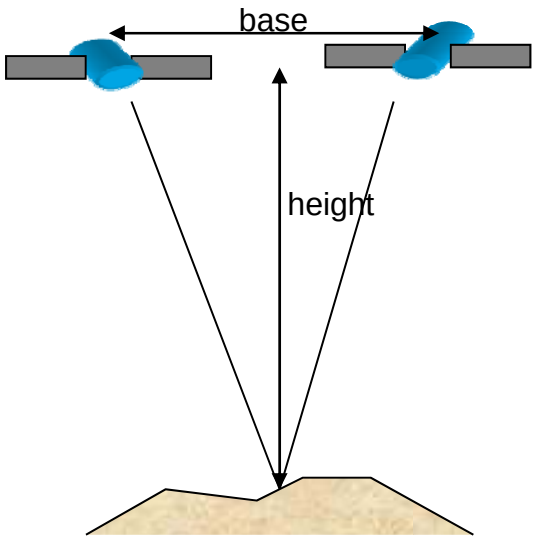


DEM biases characteristics

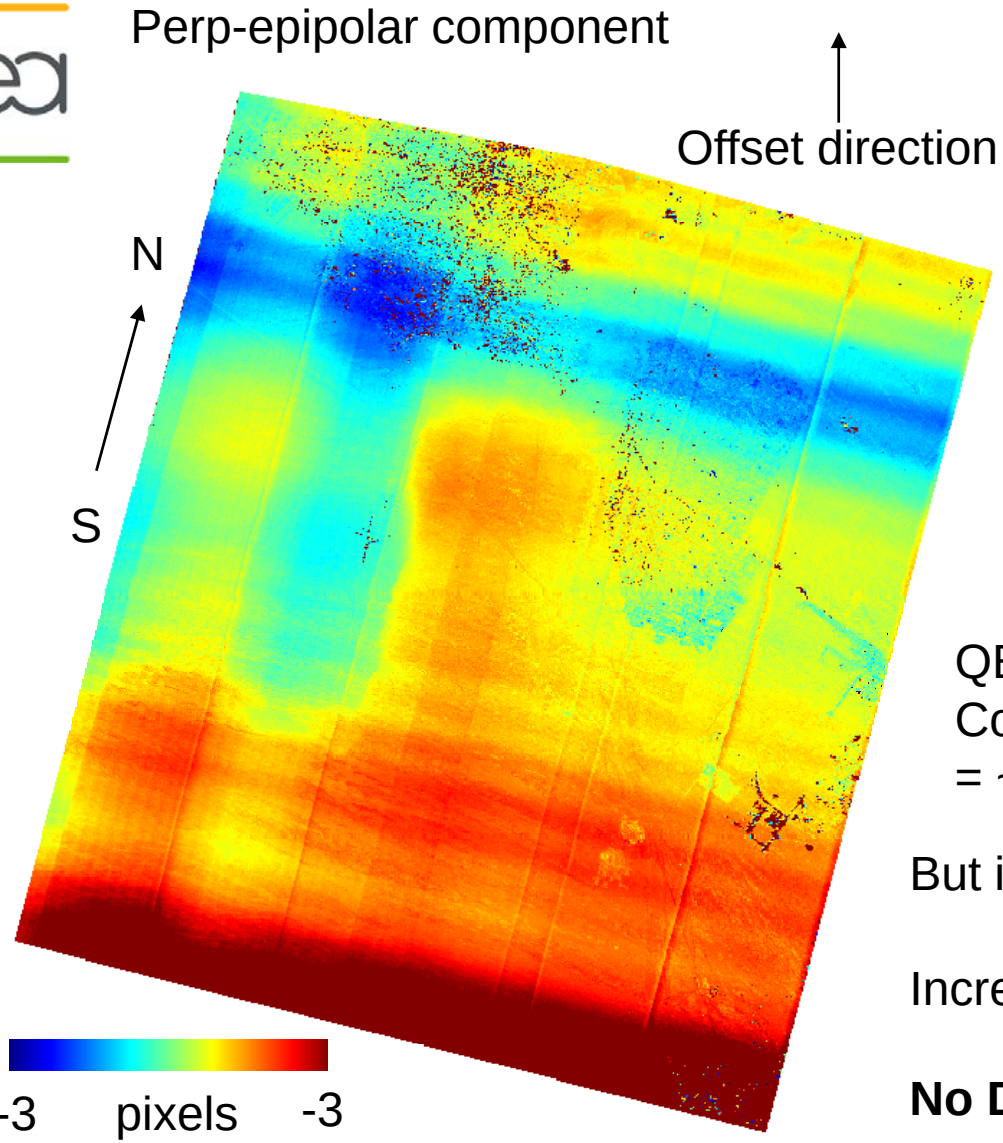
- DEM offset biases
  - Are proportional to Base/Height (B/H) ratio
  - Occur only in the epipolar direction
- Ex: 20m height error + B/H = 0.05 (3°) = 1m offset bias
- Solutions
  - Process only image pairs with very low B/H ratio
  - Compute a precise DEM with high B/H ratio
  - Compute only offsets in the orthogonal epipolar direction
  - ?



Building in image 2



QuickBird Bam offsets



No DEM correlated biases

Satellite jitter : up to 2m

CCD discontinuities

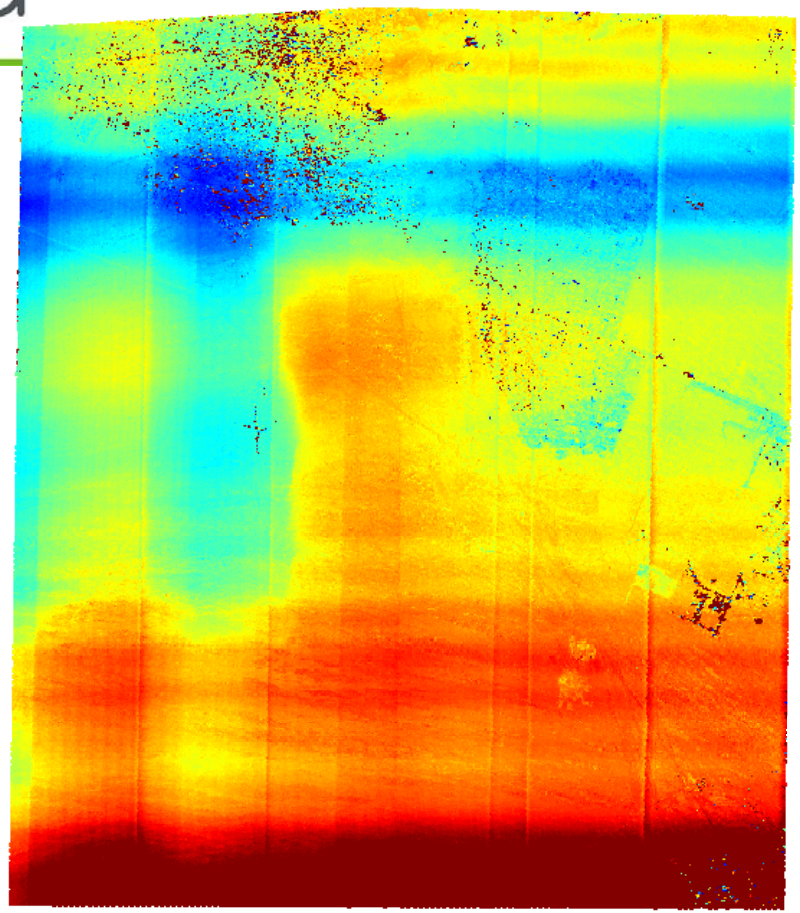
QBird poor image sampling quality:
Correlation accuracy : ~ 1/3 pixel
= ~20cm = SPOT 5 accuracy

But independant measurements X16 !

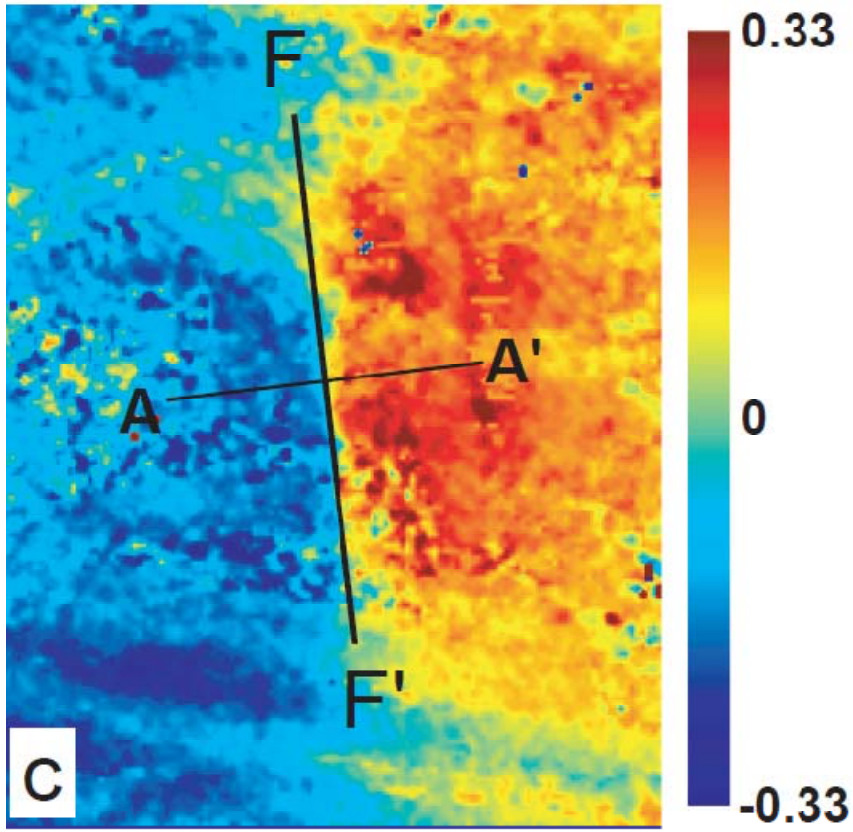
Increased SNR and spatial sampling

No DEM is needed !

QuickBird vs SPOT Bam offsets

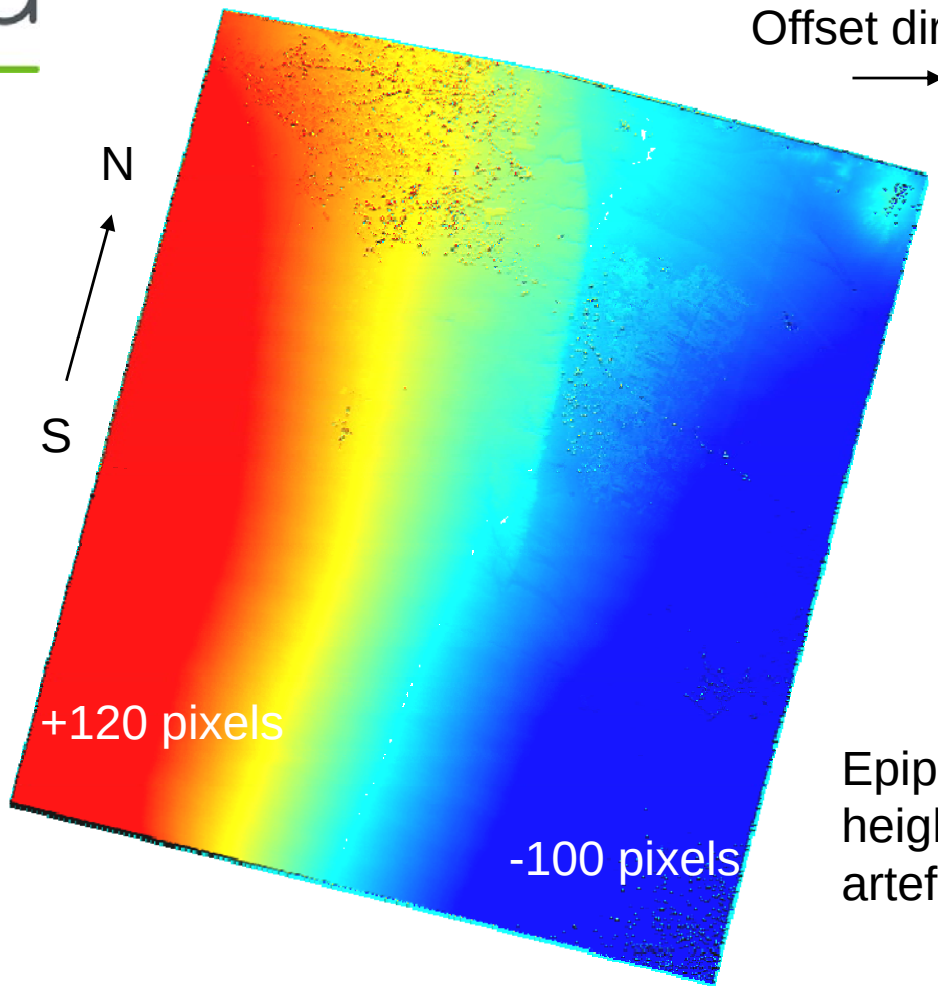


-3 pixels -3



QuickBird Bam offsets

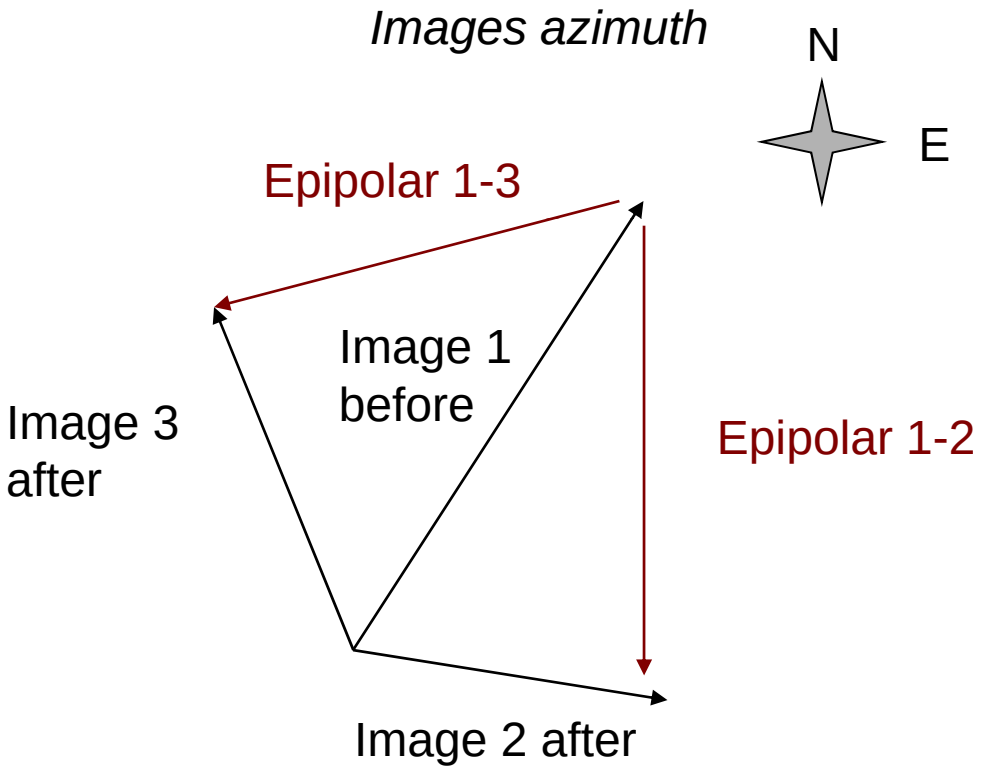
Epipolar offset component



Epipolar offsets are proportional to height (+ deformation + focal plane artefacts)

Possible strategy for 2D deformation measurements

One image before the event
Two images after the event
(or the contrary)



Can be generalized to N scenes

Limiting factors for horizontal ground deformation

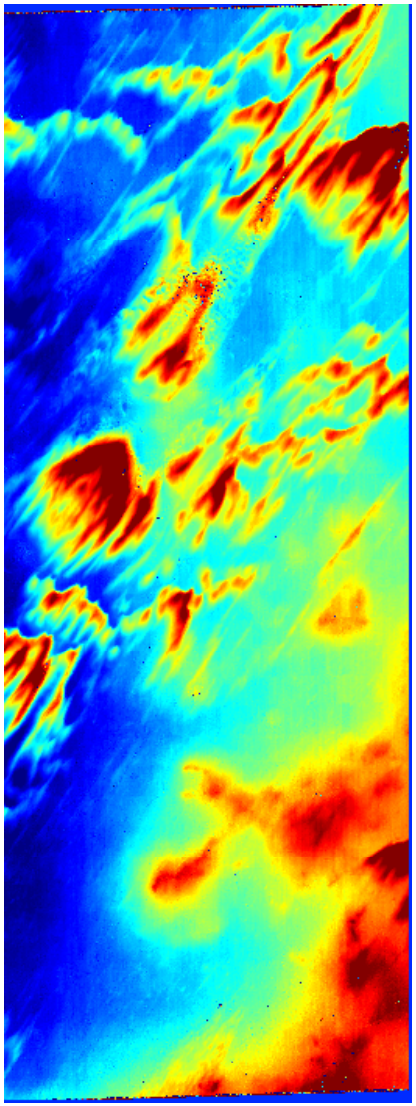
- Quality of geometric model
  - Need high frequency jitter measurements
- Image quality (aliasing, pre-processing)
  - Waiting for Pleiades 50cm oversampled images
- Number of available images
  - Limited archive
    - Correlate images from different VHR satellites ?
  - Different incidence angles : unavailable low B/H couples
    - Take 3 images instead of 2
    - Compute a precise DEM with a stereoscopic couple
  - Small swath
    - Take advantage of satellite agility (image mosaics)
- Price

Vertical Geometric Measurements (stereo)

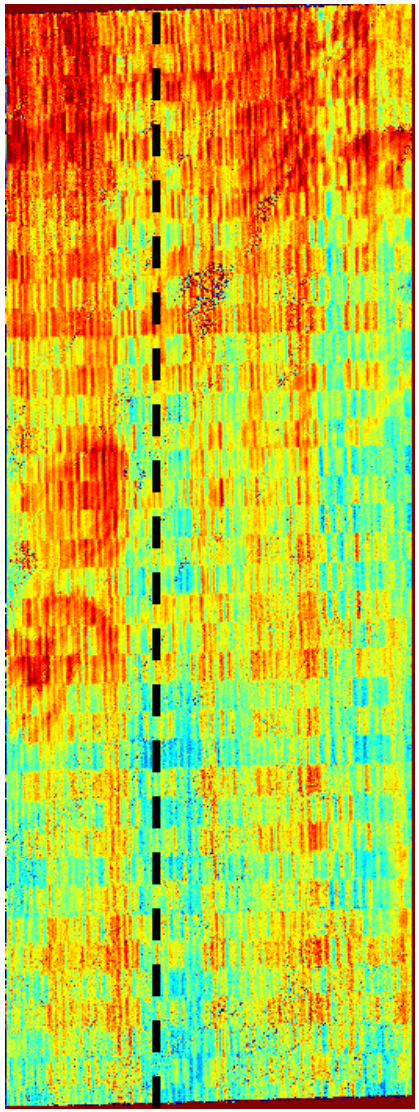
- Input
  - Stereoscopic acquisitions before
  - Stereoscopic acquisitions after
- Output
  - Difference of the 2 DEM
- Advantages
  - No time dependence
    - No radiometric coherence needed between the two dates. Get rid of shadows, seasonal changes, natural changes, etc.
  - Volume change measurements
- Limiting factors
  - Image quality (SNR, Shannon sampling)
  - Correlation precision
  - Quality of geometric models
  - Number of available images

- State of the art : no fine sub-pixel measurements
  - Actual main application : Urban modeling and updating
  - VHR stereo image intrinsic accuracy ?

Geoeye stereo sub-pixel correlation artifacts

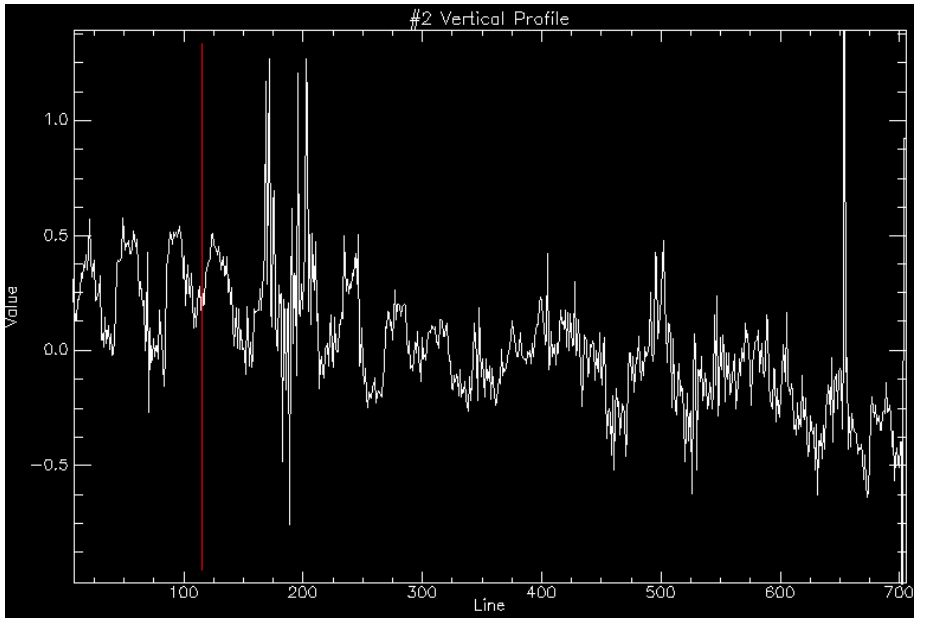


Epipolar direction



Perp.Epi. direction

GEOEYE stereoscopic pair, 50cm resolution



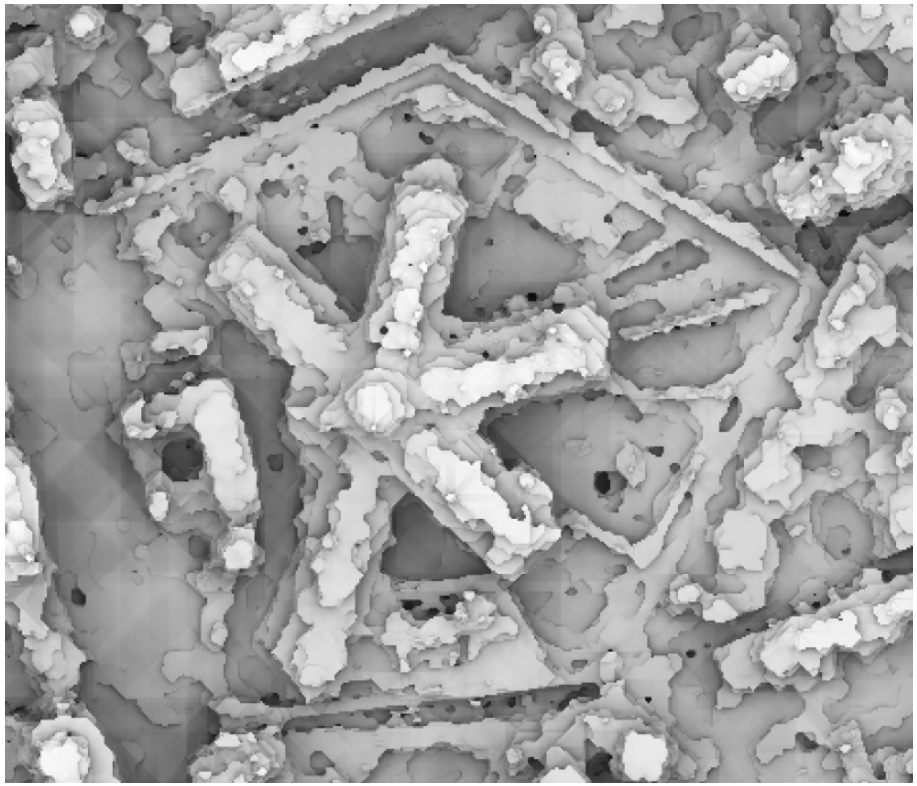
0.5 pixel high frequency pattern
No subpixel measurement allowed with Geoeye !

Pleiades tri-stereo potential

Pleiades simulation, courtesy of CNES

Pleiades tri-stereo potential

Expected height accuracy in urban areas: ~1.5 m



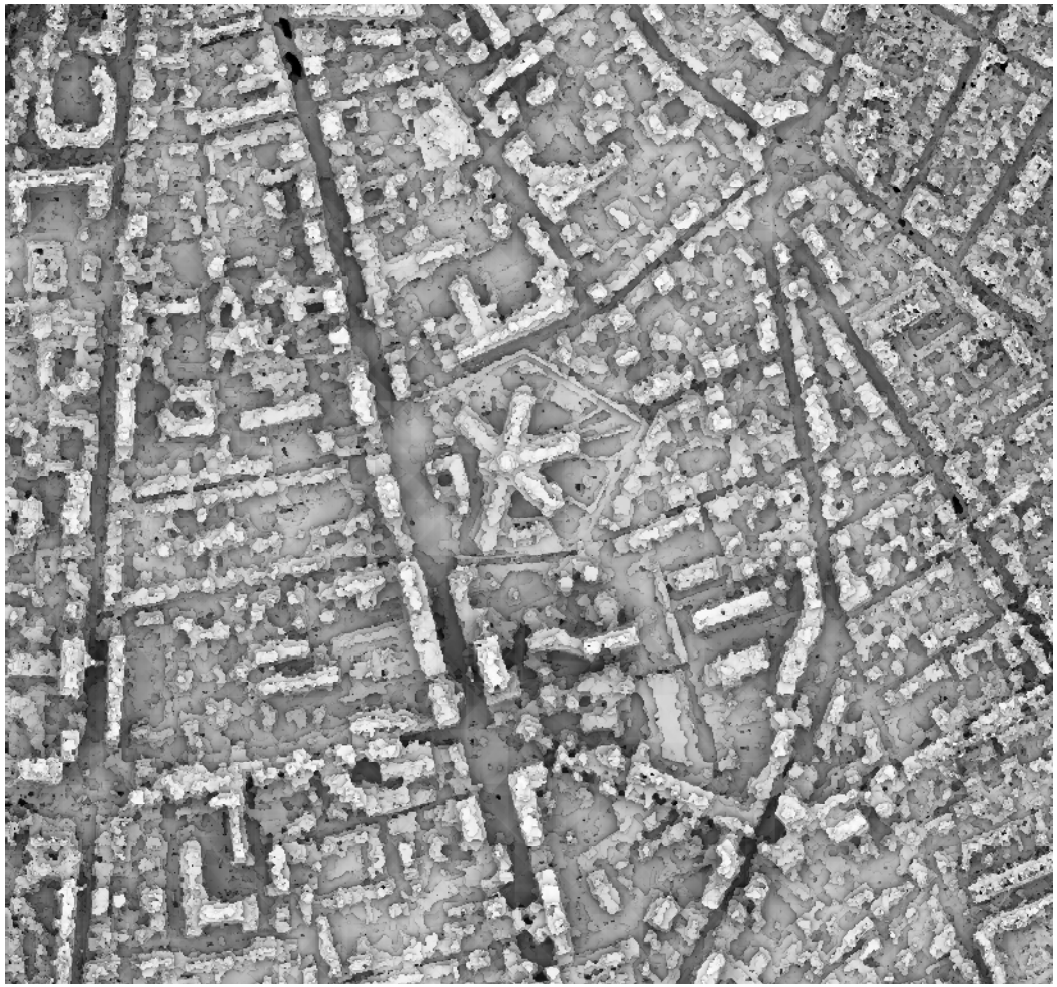
Shaded DEM (MICMAC correlator, courtesy of IGN France)

Correlator is adapted to urban areas

Relief is high frequency

Pleiades tri-stereo potential

Expected height precision in urban areas: ~1.5 m

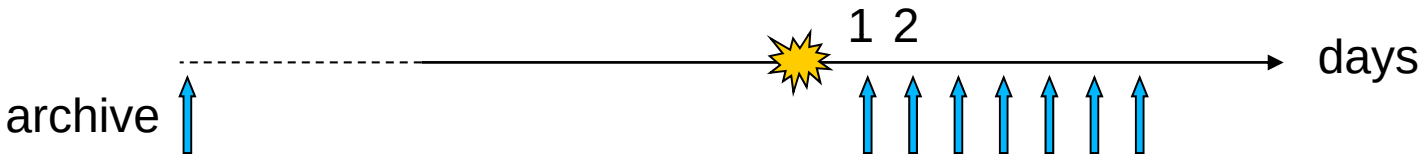


Correlator is adapted to urban areas

Relief is high frequency

Conclusion

- Horizontal ground deformation
  - Could reach 5cm accuracy
  - No DEM needed
  - Pleiades images suitable
  - Application to co-seismic and post-seismic slip measurements:



- Vertical ground deformation
  - No time dependence
  - Sub-pixel correlation could lead to sub-meter height accuracy
  - Accuracy <1m is feasible on non-urban landscape
  - Application to landslides monitoring ?

- Could mix both measurements for 3D displacement