Université de Rennes 1

Sapienza Università di Roma

Institut Mines-Telecom

Building profile reconstruction using TerraSAR-X data time-series and tomographic techniques

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8th International Workshop on the Analysis of Multitemporal Remote Sensing Images
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Aim of the work

Why?

- ↗ Necessity to monitor and characterize **Earth's surface dynamics**
- ↗ Interest on **multitemporal data** analysis and processing
- ↗ Number of satellites with **high** spatial and temporal **resolution**

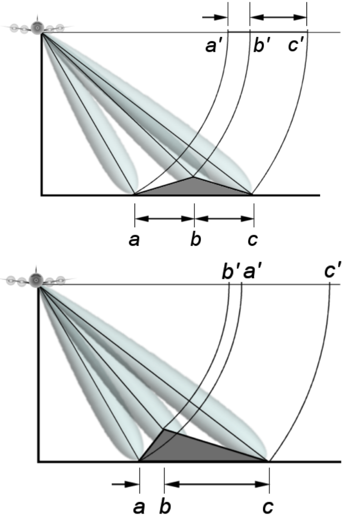
What?

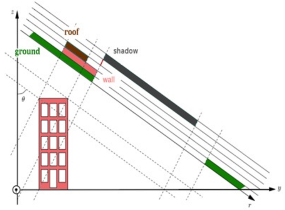
3-D characterization (height, reflectivity, time stability) of **built-up areas**

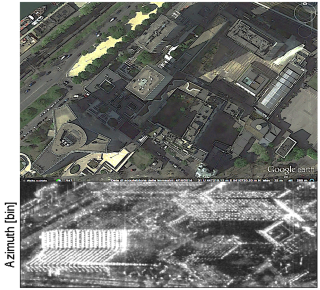
How?

- ▷ **SAR Tomography** classical estimators *vs.* **Compressive Sensing**: temporal analysis and focusing with smaller number of images
- ▷ **TerraSAR-X** data: multibaseline and multitemporal single-pol high resolution Spotlight stack

Layover elevation displacement





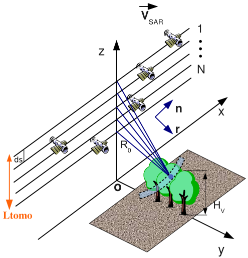


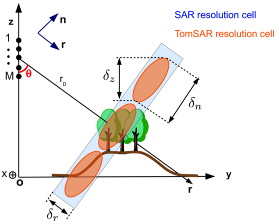
Tomographic approach

Tomography SAR principles

- SAR principle in elevation direction (**syntethic vertical aperture**: L_{tomo})
- **Multiple passes** of the radar and **resolving ambiguities in elevation**
- **Phase+amplitude** signal information
- **Spectral analysis**: backscattered energy distribution at different heights
- **Good geometric resolution** : high details in the elevation direction

$$\delta_z = \delta_n sin\theta \text{ with } \delta_n = \frac{\lambda}{R_0} 2L_{tomo}$$

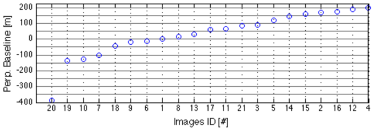


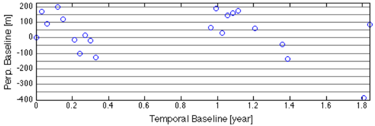


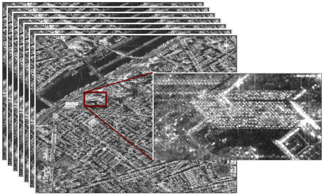
Test site

- 21 TerraSAR-X* High Resolution Spotlight (HS) single-pol (HH) images acquired on Paris urban area

*Acknowledgement to DLR in the frame of the project ID LAN1746







Area Of Interest: multitemporal averaged amplitude (top) and Google Map (bottom) images

Stack main characteristics

AOI	Acquisition date		Mean look angle (deg)	Orbit	Polarisation	Normal Baseline (m)		Temporal Baseline (days)	
Paris	from	24/01/2009	34.7	Asc	HH	Max abs	386.70	Max	506
						Min abs	13.38	Min	11
	to	26/11/2010				Mean abs	116.57	Mean	241.39

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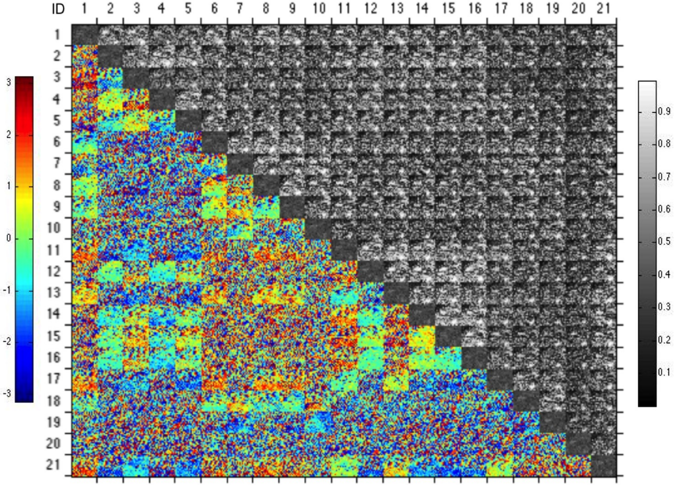
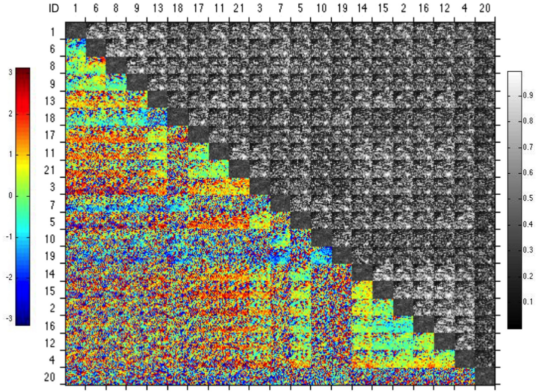
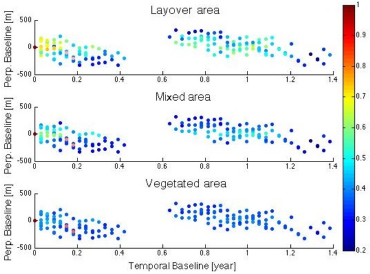
Interferogram-coherence matrix: increasing temporal baseline



Interferogram-coherence matrix: increasing (abs) spatial baseline





Spatial-temporal trend of coherence mean values

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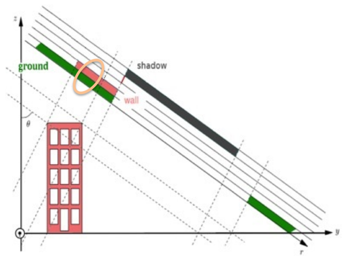
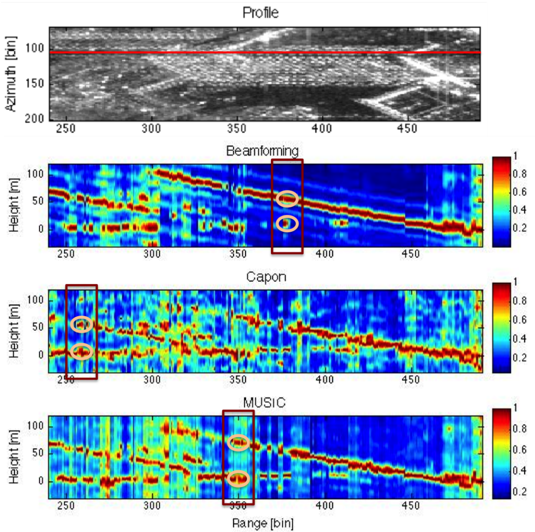
Slant range tomograms

- Layovered profile over AOI





Slant range tomograms

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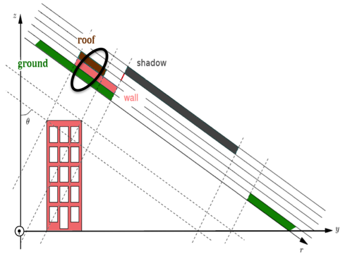
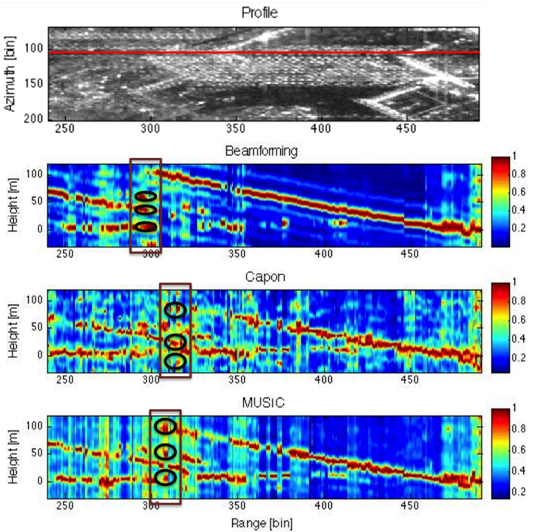
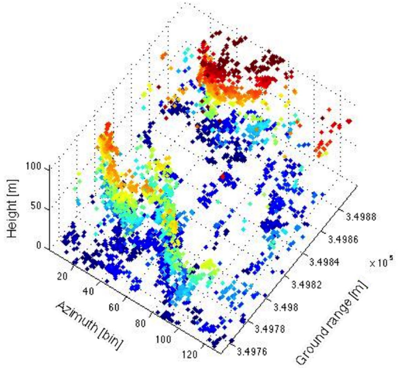
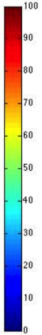
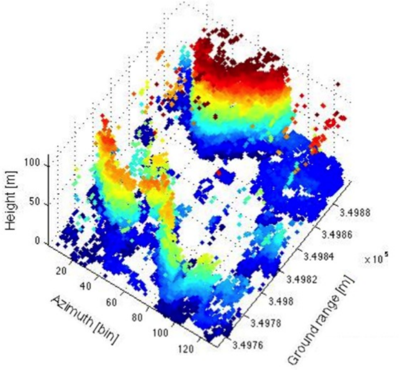




3-D elevation map





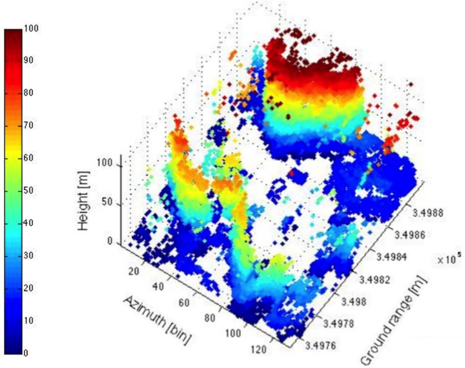


MUSIC: second detected scatterers

MUSIC: dominant, second and third detected scatterers

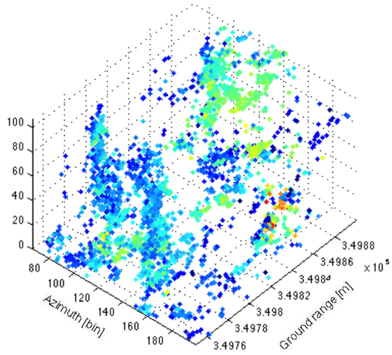
3-D elevation map

AOI: Google Earth 3-D view

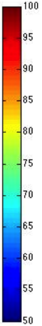


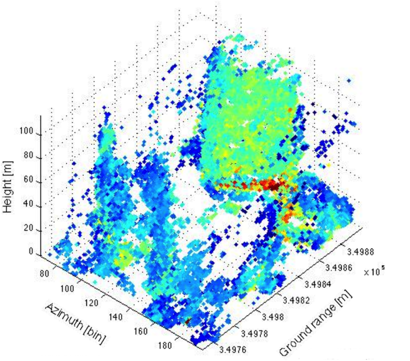
MUSIC: dominant, second and third detected scatterers

3-D intensity map



MUSIC: second detected scatterers





MUSIC: dominant, second and third detected scatterers

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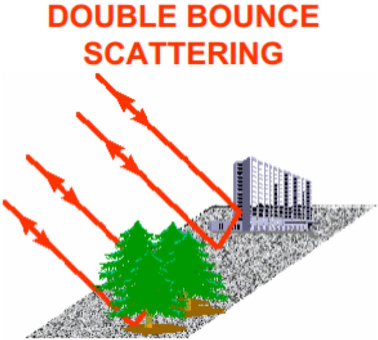

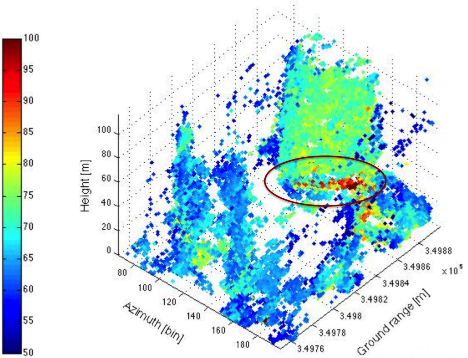

MUSIC: dominant, second and third detected scatterers

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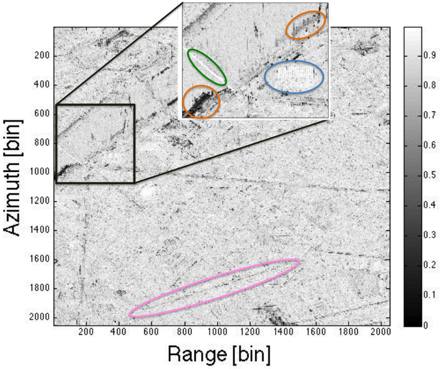
Stationarity parameter Λ

- 2-D temporal (incoherent) stability of

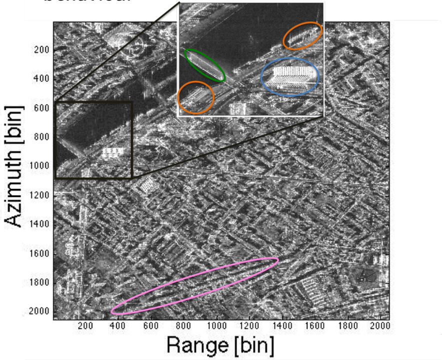
$$\{I_i(x,y)\}_{j=1,j\neq i}^{19}$$

- Maximum Likelihood statistical test



Stationarity parameter $\Lambda^{(1)}$ on the test site

- Buildings, bridges: high stationary behaviour
- Boats, main streets: very low stationary behaviour



Multitemporal averaged amplitude image

(1) L. Ferro-Famil and E. Pottier, "Urban area remote sensing from L-band PolSAR data using time-frequency techniques," Urban Remote Sensing Joint Event, URS, 2007

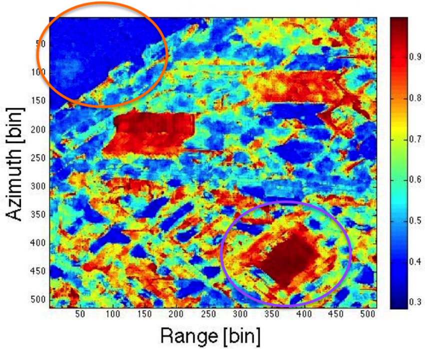
Coherence indicator ρ

- 2-D temporal (coherent) stability of

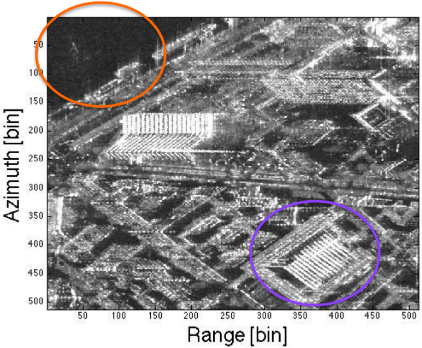
$$\{s_j\}_{j=1, j\neq i}^{19}$$

- Maximum Likelihood statistic test

- Man-made targets, buildings: very high cross-correlation
- Natural environments: very low cross-correlation



Coherence indicator $\rho^{(2)}$ over a subset



Multitemporal averaged amplitude image

(2) C. Hu, L. Ferro-Famil, and G. Kuang, "Ship discrimination using polarimetric SAR data and coherent time-frequency analysis," Remote Sensing, vol. 5, no. 12, pp. 6899–6920, 2013

Temporal stability analysis I

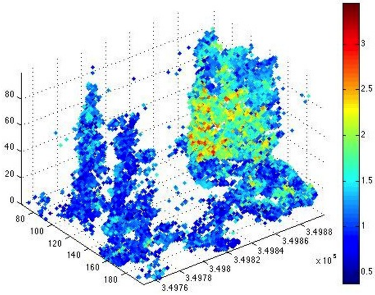
$\{s_j\}_{j=1, j \neq i}^{19}$ **TomoSAR** 2-D

$\Downarrow$ $\Downarrow$

$\{I_i(x,y,z)\}_{j=1, j \neq i}^{19}$ 3-D

3-D temporal stability in term of a modified **CV** from **incomplete tomograms**

$$\{I_i(x,y,z)\}_{i=1}^{19}$$



3-D reconstruction of the estimated ***CV***

Temporal stability analysis I

$\{s_j\}_{j=1, j \neq i}^{19}$

$\Downarrow$

$\{I_{\mathbf{i}}(x,y,z)\}_{j=1, j \neq i}^{19}$

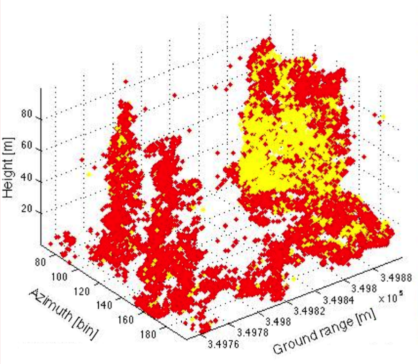
TomoSAR

2-D $\Downarrow$ 3-D

3-D temporal stability in term of a modified **CV** from **incomplete tomograms**

$$\{I_i(x,y,z)\}_{i=1}^{19}$$

Unstable (yellow) pixels



Temporal stability analysis I

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TomoSAR

2-D $\Downarrow$ 3-D

3-D temporal stability in term of a modified **CV** from **incomplete tomograms**

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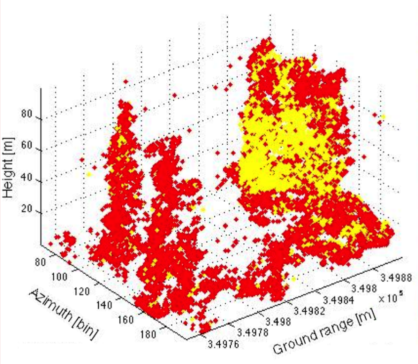
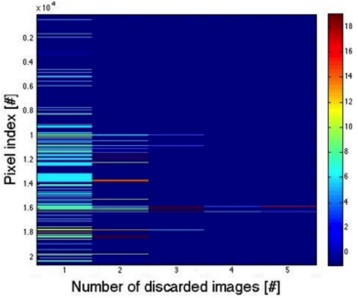
Similar resolution properties and **importance of the missing image**

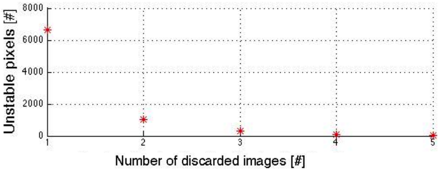
Unstable (yellow) pixels



Temporal stability analysis II

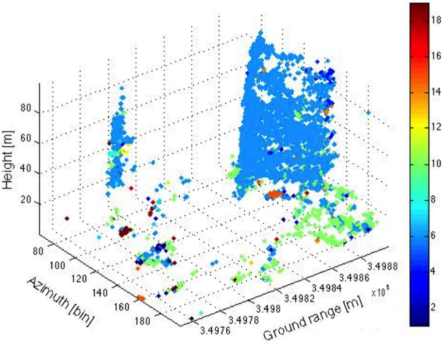


Extraction of the most perturbing contributions



Number of the unstable pixels at different steps

Extraction of the **most perturbing contributions**



3-D reconstruction of the relative indices at the first step

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Conclusions

- Improvement in 3-D imaging capabilities processing **high resolution TerraSAR-X multitemporal data**
- Strong **geometric distortions** derived from **layover** in **urban areas** analysis
- Global characterization of **build-up areas**
- **3-D reconstructions** regarding buildings **heights**, vertical **reflectivity** and time **stability** analysis
- **TomoSAR** technique **potentialities**:
  - layover distortions correction
  - separating different scatterers and detecting the corresponding reflectivity within one resolution cell
  - using classical mono-dimensional estimators (not Compressive Sensing)

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... thank you for your attention!