L-BAND INSAR DECORRELATION ANALYSIS IN VOLCANIC TERRAINS USING AIRBORNE LIDAR DATA AND *IN SITU* MEASUREMENTS: THE CASE OF THE PITON DE LA FOURNAISE VOLCANO, FRANCE

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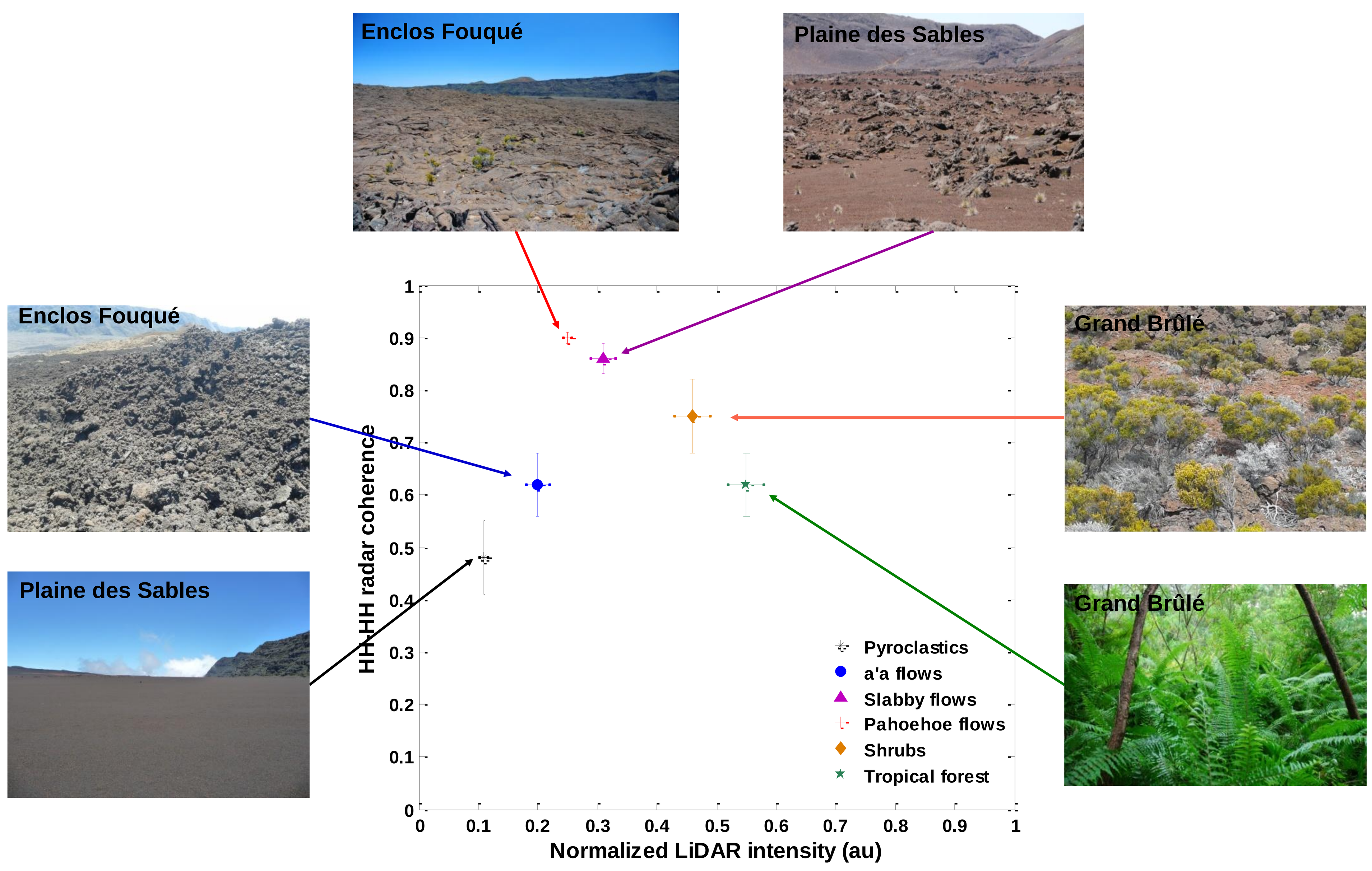
Introduction:

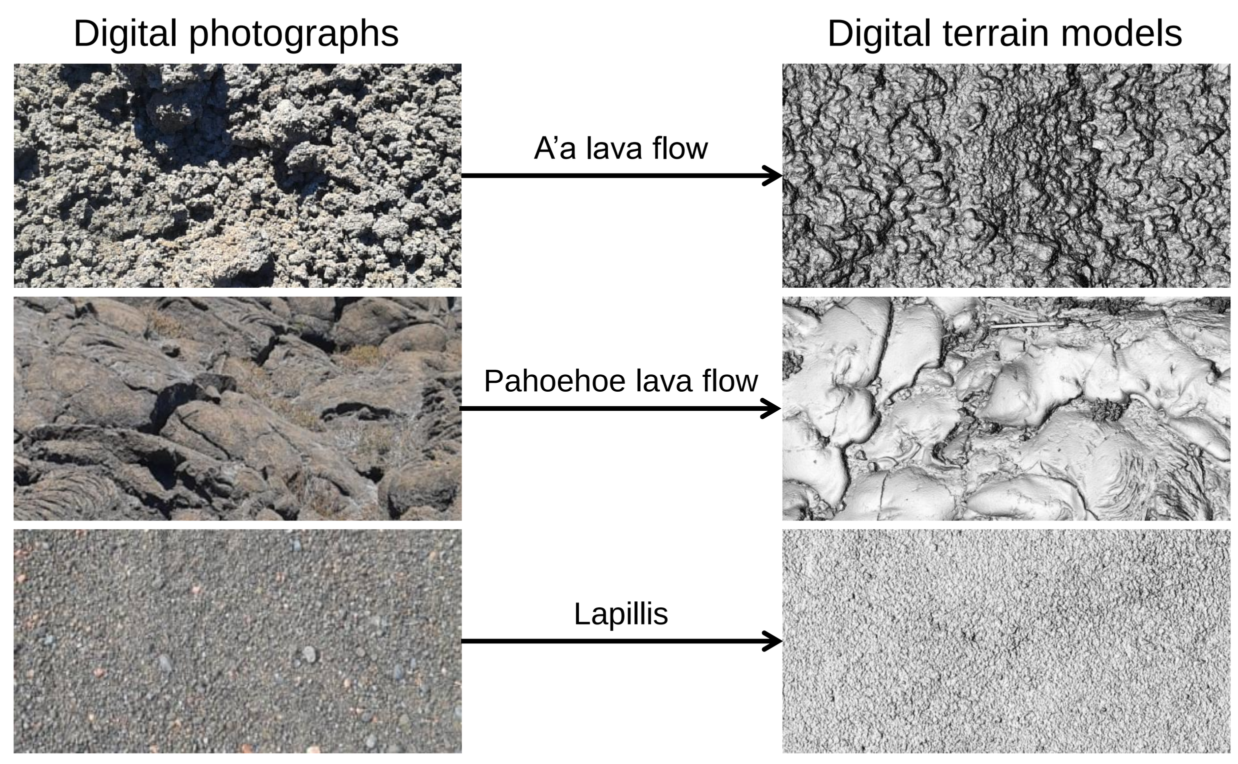
- ALOS-PALSAR coherence images are combined with airborne LiDAR data, both acquired over the Piton de la Fournaise volcano (Reunion Island, France), to investigate the main causes of errors that affect repeat-pass InSAR measurements.
- Our study is focused on several sites characterized by different levels of vegetation density (LAI) and on bare volcanic surfaces displaying different geophysical properties: pahoehoe and a'a lava flows, slabby pahoehoe flows, and pyroclastic deposits (lapillis).
- A field experiment has been carried out in 2011 in the central and western part of the volcano to better understand InSAR and LiDAR data.

InSAR-LiDAR synergy



Correlation between HH-HH radar coherence (06 Sept – 22 Oct 2008) and normalized LiDAR intensity (Oct 2008) over several surfaces.

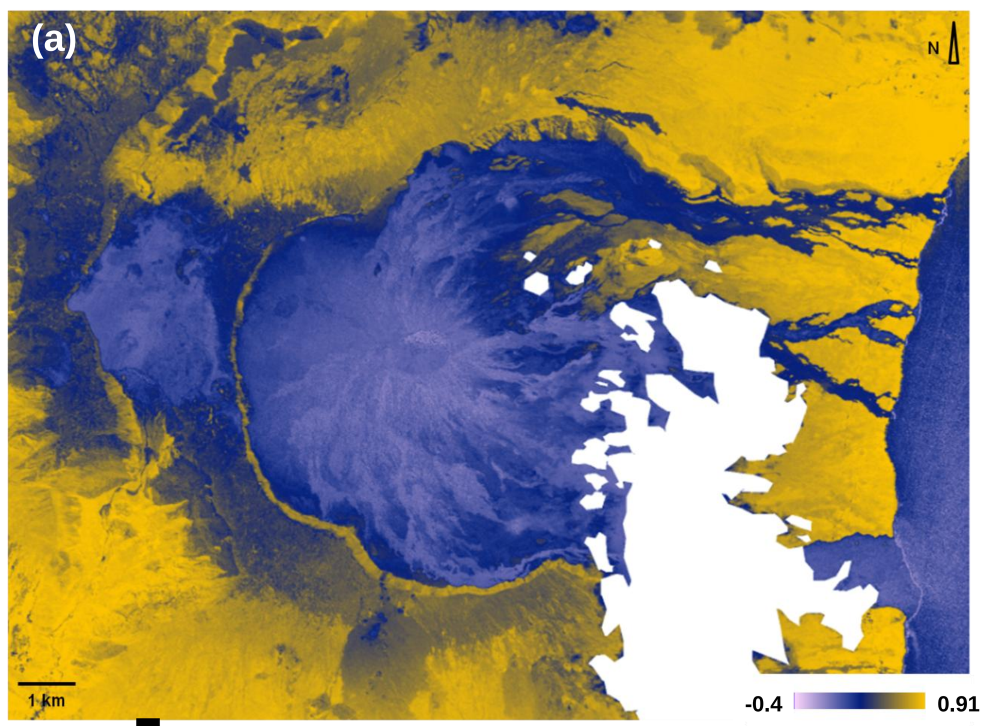
Surface roughness measurement



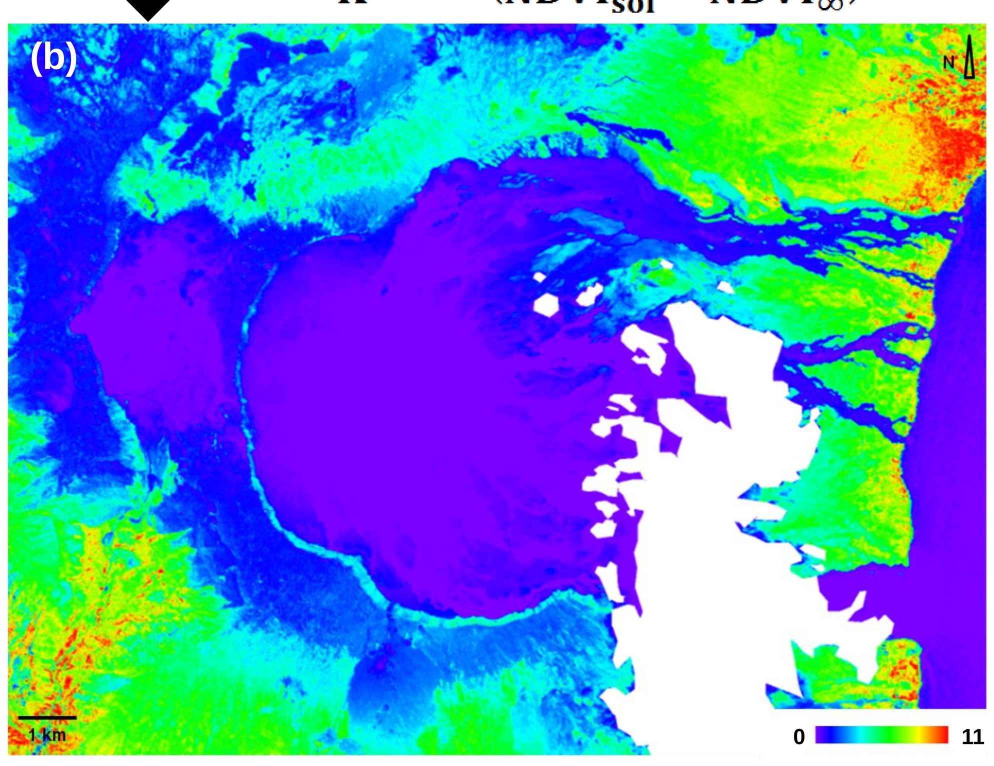
Surface type	Standard deviation of height σ (cm)	Correlation length L_c (cm)	$Z_s = \sigma^2/L_c$ (cm)
A'a lava flow	7.5 1.1	20.1 9.2	3.7 1.5
Pahoehoe lava flow	4.6 0.4	30.6 1.1	0.8 0.2
Slabby pahoehoe lava flow	3.7 1.4	26.4 5.3	0.7 0.4
Lapillis	0.7 0.2	43.3 8.2	0.01 0.01

Surface roughness parameters for different volcanic terrains.

Vegetation structure analysis



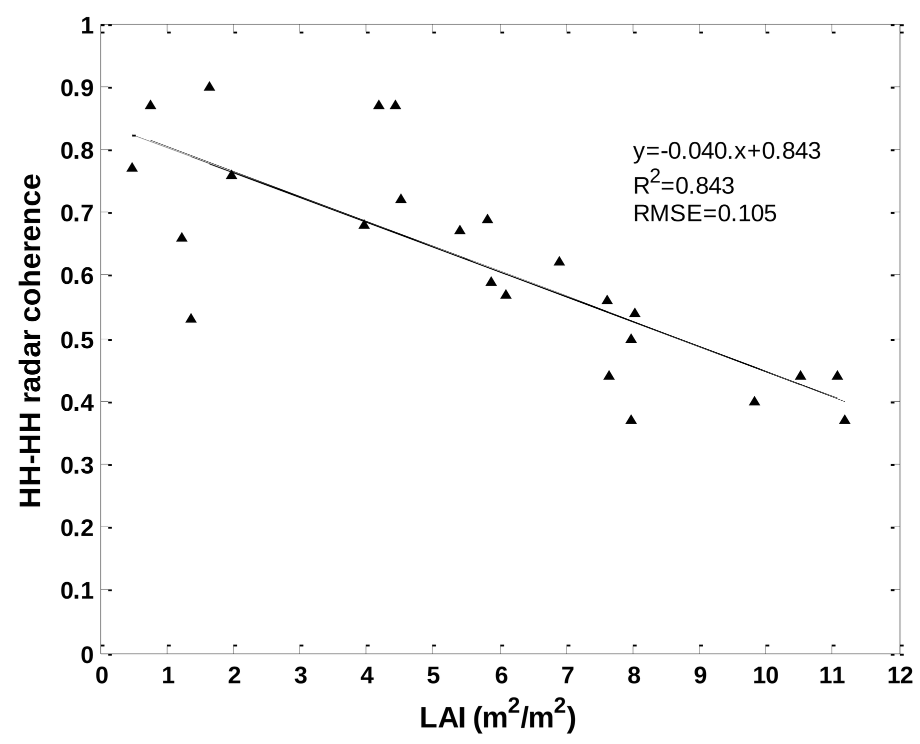
$$\mathrm{LAI} = \frac{-1}{\mathrm{K}} \times \ln\left(\frac{\mathrm{NDVI} - \mathrm{NDVI}_\infty}{\mathrm{NDVI_{sol}} - \mathrm{NDVI}_\infty}\right)$$



(a) NDVI and (b) Leaf Area Index (LAI, [m².m⁻²]) maps over the Piton de la Fournaise calculated from a SPOT-5 image (May 2011, http://kalideos.cnes.fr/). Spatial resolution = 10 m.

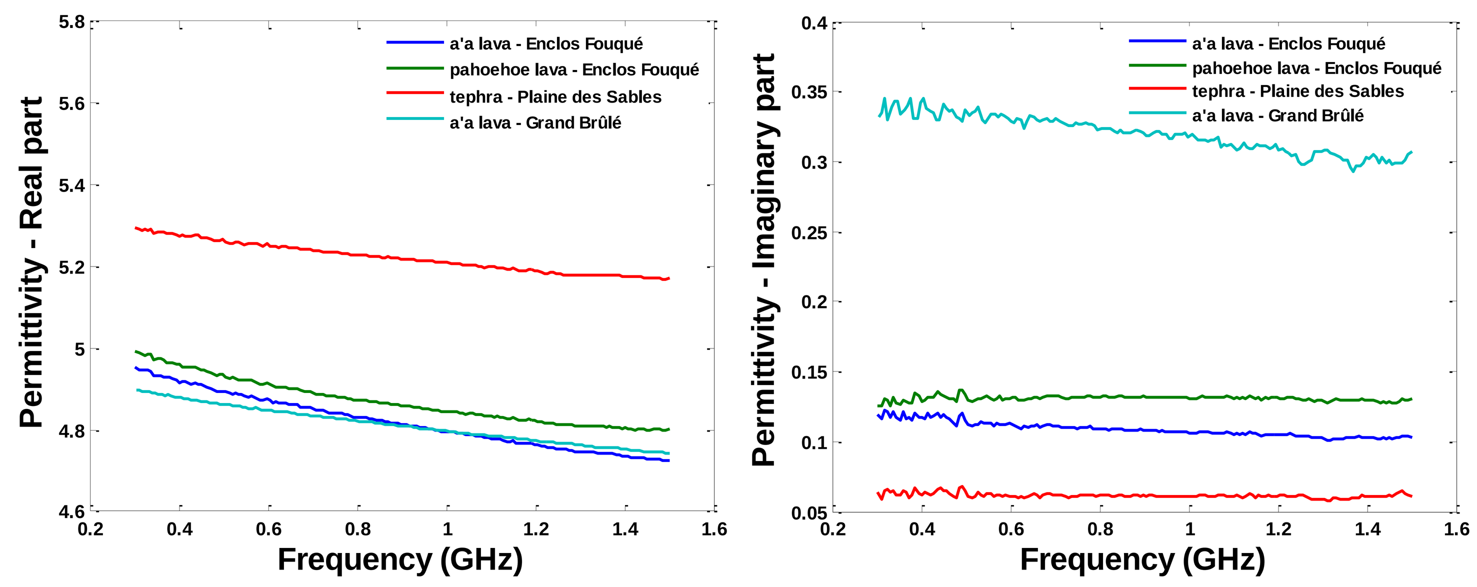
Vegetation characteristic	Mean of LAI ($m^2.m^{-2}$)	Mean of NDVI
Shrubby plants	1.7 0.3	0.51 0.2
Sparse forest	2.6 0.5	0.57 0.1
Intermediate forest	7.0 0.2	0.81 0.06
Dense forest	9.5 0.6	0.78 0.1

LAI and NDVI values for different levels of vegetation density.



Correlation between HH-HH radar coherence and LAI [m².m⁻²].

Penetration depth estimation



Real and imaginary parts of the dielectric constant of several volcanic materials with residual moisture content measured between 0.2 and 1.6 GHz.

Loss tangent of dielectric medium:

$$\tan\delta = \frac{\varepsilon''}{\varepsilon'} \qquad \begin{cases} \varepsilon' = \text{real part of the permittivity} \\ \varepsilon'' = \text{imaginary part of the permittivity} \end{cases}$$

Penetration depth in the case of slightly dispersive media:

$$\delta_p \approx \frac{\lambda}{2\pi}\frac{\sqrt{\varepsilon'}}{\varepsilon''}$$

Surface type	ε'	ε''	tan δ	δ_p (cm)
Lapillis	5.18	5.96×10^{-2}	1.15×10^{-2}	143
Pahoehoe lava flow	4.81	1.30×10^{-1}	2.71×10^{-2}	63
A'a lava flow	4.75	1.04×10^{-1}	2.18×10^{-2}	79

Electromagnetic properties of several volcanic surfaces measured at 1.27 GHz (L-band).

Conclusion

This study allowed us to discriminate between **scattering** and **volumetric** effects: we observe high coherence loss over rough a'a lava flow (Enclos Fouqué) due to multiple scattering of the radar waves and over pyroclastic deposits (Plaine des Sables) caused by radar wave penetration into the medium.
When vegetation is present, the radar coherence is directly related to plant density: the higher the Leaf Area Index (LAI), the lower the coherence. The accuracy of InSAR measurements strongly decreases for LAI higher than 7.