Identification of landslides in La Reunion Island with JERS-1 and RADARSAT-1 radar interferometry

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ABSTRACT

La Réunion Island is affected by constant slope movement and huge landslides due to the rough topography, a wet climate and favourable geological context. Radar interferometry can provide a mean for identifying landslides on a large scale. Because of the vegetation cover, C-band interferograms are generally hampered. Using JERS-1 images, we show that the L-Band can be used to overcome the loss of coherence observed in the C-band. The technique has been applied to the cases of the Grand Ilet and Hellbourg landslides located in Salazie Circle.

INTRODUCTION

Due to its geological and climatic conditions, La Réunion Island is deeply concerned by landslide hazard. Huge landslides (up to several kilometers) severely affect infrastructures (especially roads) and habitations [1]. In order to mitigate this landslide risk, there is a need for new solutions to be added to the traditional in situ monitoring methods. In this study, we used satellite radar interferometry for detecting landslides on the Island from both RADARSAT-1 (C-band, λ=5.6cm) and JERS (L-band, λ=23.5cm) data. 15 RADARSAT-1 images (1999-2001) and 6 JERS-1 (1997) images has been acquired. A comparison between the performances of C-band and L-band interferometry in the tropical context of the Island characterized by a dense vegetal cover has been carried out.

DATA PROCESSING

For interferometric applications and in particular landslide characterization, ERS data are the mainly used ([2],[3]). However, no ERS image has been acquired on La Réunion Island because of the lack of onboard data recorder and neighboring reception station. We have therefore processed 16 Radarsat images (C-band) acquired between 26/01/1999 and 10/01/2002. In addition, 6 JERS-1 images (L band) covering the period January 1997 - August 1997 for this study. The contribution of the topography has been removed using a Digital Elevation Model (DEM provided by the French National Geographic Institute, IGN, with a planimetric resolution of 25x25 m and a vertical accuracy of 2.5 m). An adaptive filter [4] has been finally applied to improve the signal to noise ratio of the interferograms.

RESULTS

Eleven interferometric combinations have been produced from the Radarsat data. Figure 1 left shows a representative interferogram covering the whole Island.
If a good coherence level is observed on bare soils, vegetated areas appear most of the time noisy due to the high temporal decorrelation. In addition the deformations rates have to be compatible with the time sampling provided by the InSAR technique: rates larger than decimeters/months for L-band (several centimeters/months for C-band) are generally too fast for InSAR.
According to ground based studies, two major landslides of La Reunion Salazie Circle sector (Grand Ilet and Hellbourg) show characteristics suitable for the technique, with deformation rates ranging between few centimeters to decimeter per month and low slopes (less than 15° for Hellbourg landslide).

Thought the L-band is less sensitive to deformation (1 fringe = 11.5 cm instead of 2.8 cm for C-band), it penetrates deeper into the vegetation cover [5]. It is therefore much less sensitive to the temporal decorrelation induced by vegetation changes (figure 1 right). It should be noted that high coherence level have also been obtained with images acquired during the unfavorable wet season.

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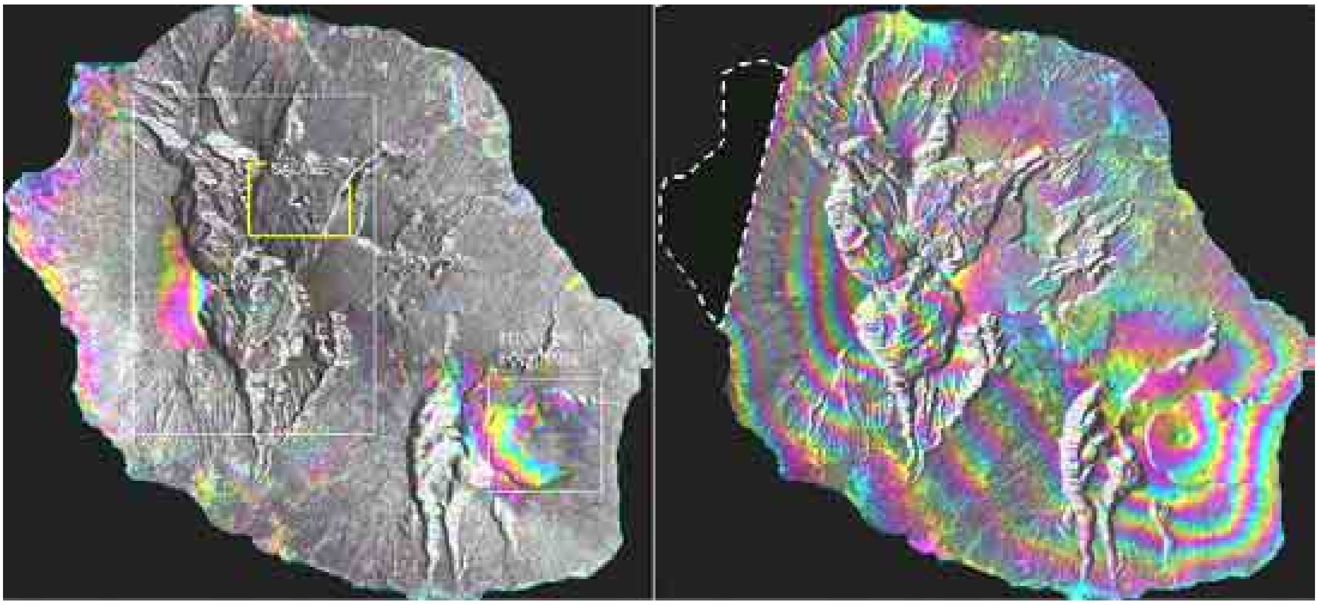

Figure 1: Left: Radarsat interferogram (orbits 28885 and 31599: 2001/05/15 – 2001/11/23, perpendicular baseline=68m). The white frames indicate the Circles sector and the Piton de la Fournaise volcano. The yellow frame shows the limits of figure 2. Right: JERS-1 (02/01/1997-14/05/1997, perpendicular baseline=187m) interferogram. No major coherence loss is observed in the L-band. The interferograms are superimposed on intensity images.

Grand Ilet and Hellbourg Landslides

The Landslides of Grand Ilet and Hellbourg in the Salazie Circle (located on figure 2) represent a serious hazard for buildings, infrastructure and even lifes. They are continuously monitored by GPS and leveling.

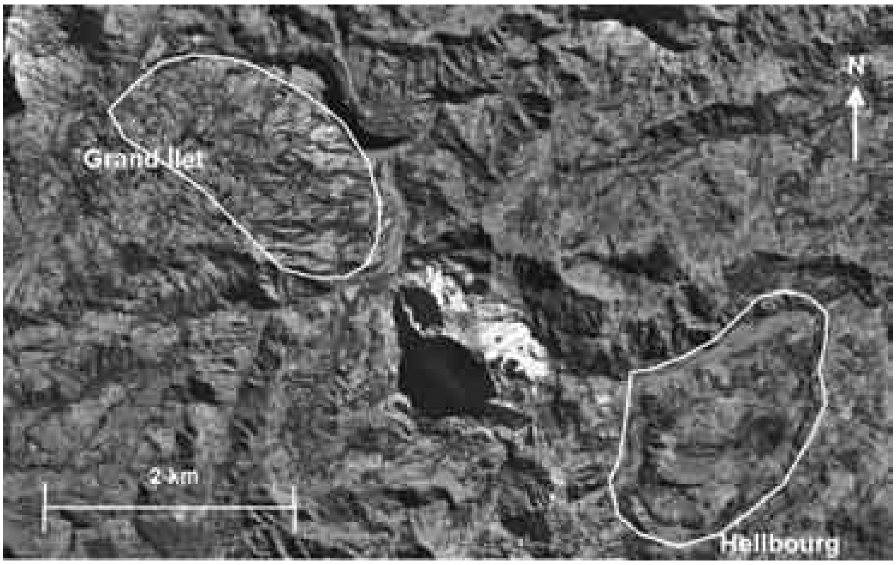

Figure 2: Aerial photograph of the area of Grand Ilet / Hellbourg (source IGN). The known unstable areas are shown.

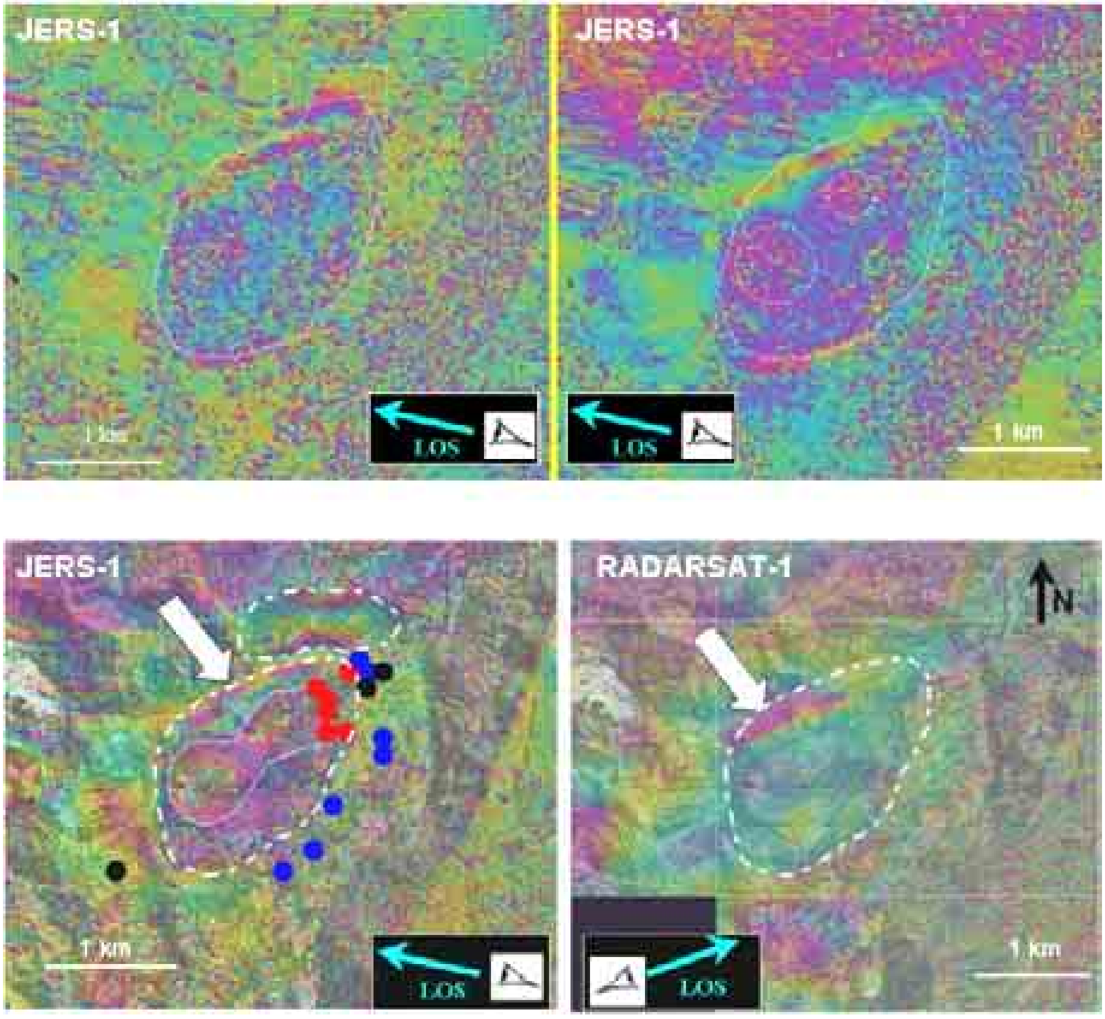

Figure 3:
a): JERS-1 interferogram 02/01/1997-31/03/1997.
b): JERS-1 interferogram 15/02/1997-14/05/1997.
1 fringe= 12 cm displacement in Line Of Sight.
The displacement signature appears on the 2 independent interferograms excluding the possibility that it could be an atmospheric effect.
The circles show areas which seems slightly faster (in LOS) than the rest of the landslide. The white frame in the North East of the landslide points a fringe pattern which is not confirmed on the right image. It could be a displacement occurred during the period 02/01/1997-15/02/1997.
c): sum of the two previous 3 months JERS-1 interferograms (1 fringe = 6cm in Line Of Sight). The boundaries of the landslide are clearly delimited by the fringe pattern. Dots correspond to GPS points (black: value unavailable for the studied period, blue less than 6 cm displacement (modulus of all components), red: more than 12 cm displacement)
d): 2001/06/08-2001/07/26 RADARSAT-1 interferogram (1 fringe=2.8 cm in line of sight): the landslide is partially detected but severely hampered by atmospheric effects and loss of coherence. Background: aerial photograph (source IGN).

The two independent JERS-1 interferograms 1997/01/02-1997/03/31 and 1997/02/15-1997/05/14 (figure 3) show the signature of the landslide The redundancy of the signature on two independent pairs confirms the detection by rejecting the assumption of atmospheric artifact which is not supposed to be spatialy staionnary.
A good consistency is obtained with the available GPS measurements (colored circles). However, the InSAR study provides a better delimitation of the landsliding area by giving a synoptic view of the phenomenon. The upper part of the landslide, which is the most active, shows up to 1.5 fringe, which corresponds to a deformation of 9 cm in 3 months. This deformation fringe pattern also appears in the 48 days Radarsat interferogram (one fringe, corresponding to a mean deformation rate of ~3 cm /month, which is consistent with the L-band measurement) but hampered by atmospheric noise.

Figure 4 shows the sum of the two JERS-1 interferogram and the Radarsat pair on the Grand Ilet area. Colored circles correspond to the GPS points affected by motion during the 1997 period. As this landslide is slower than the previous, it is more difficult to detect with the short time spans used. However a possible signature of about 5 cm is shown, which is consistent with the available GPS data which unfortunately do not cover the maximum of deformation.

Conversely, the Radarsat which is more hampered by noise and layover/shadowing phenomena shows no relevant deformation signature.

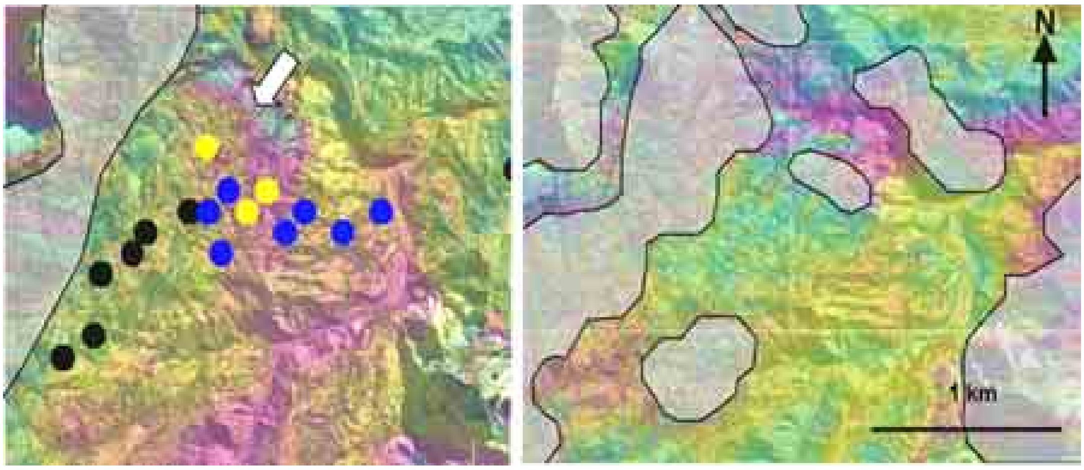

Figure 5 : Grand Ilet Landslide. Left : sum of two 3 months JERS-1 interferograms (1 fringe = 6 cm of deformation in the line of sight). The white arrow shows a deformation signature. Colored circles correspond to GPS points (black: value unavailable for the studied period, blue less than 6 cm displacement (modulus of all components), yellow: 6-12 cm displacement). Right: 29198 (2001-06-08) / 29884 (2001-07-26) Radarsat interferogram (1 fringe=2.8cm): no relevant signature is identified in this 24 days period. The masked area corresponds to phase layover/shadowing or noisy areas. Background: aerial photograph (source IGN).

CONCLUSION

This study has shown the potential of radar interferometry for monitoring landslides in the sector of the Circles in La Reunion Island. This area is affected by major risk issues. Because of the vegetal cover and meteorological specificities, the L-band InSAR seems much more efficient than the C-band.
The reduced JERS archive (only 6 images in 1997) precludes a comprehensive analysis of the landslides dynamic evolution (but allows the detection of the described events). However our results show that the forthcoming L-Band missions such as Alos, Terrasar L, and Saocom could play a significant role in the near future for the monitoring of landslides in vegetated areas. Provided that an homogeneous archive is progressively built, such a remote sensing technique could provide an operational tool which is complementary with ground based techniques for the mitigation of landslide risks.

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