Locating changes on an active volcano using ambient seismic noise cross-correlations

Anne Obermann, Thomas Planès, Bérénice Froment, Eric Larose, Michel Campillo

ISTerre, CNRS, Université de Grenoble, France

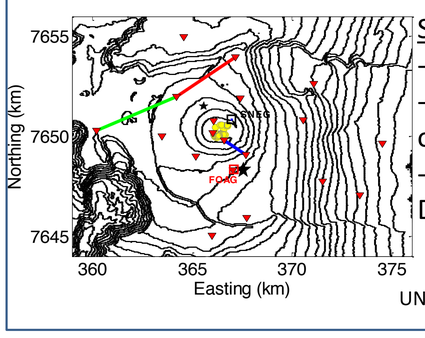
European Research Council
Established by the European Commission

Introduction: We analyze continuous ambient seismic noise records obtained from broad-band sensors over the active volcano Piton de la Fournaise on la Reunion Island from June to December 2010. During this time two volcanic eruptions occurred at two distant places. We calculate the ambient noise cross-correlation functions for this period and develop a linear least square inversion to locate the observed changes in space. We address the following points:

- **Can we locate the eruptions?**
- **Can we forecast the location of a future eruption**?

Piton de la Fournaise

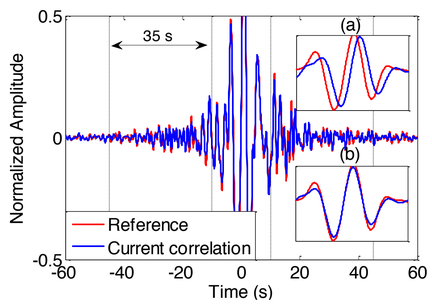
-Intense eruptive but weak tectonic activity
-Ambient seismic noise is constantly monitored



Seismic network
-21 broad-band stations ▼
-7 months (June –Dec. 2010) of continuous seismic record
-2 eruptions: Oct. 14th-31st Dec. 9th -11th ★

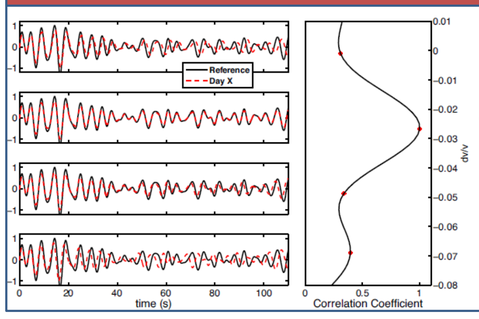
UNDERVOLC

Effect of changes on the coda



(a) time delay (velocity change).
(b) after a correction of the time delay (structural change).

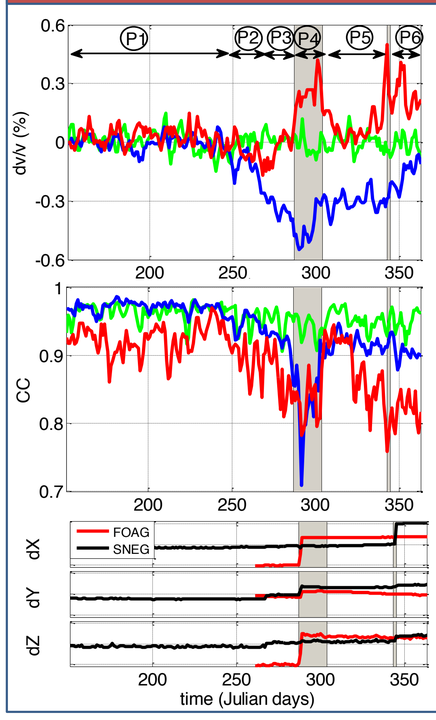
Stretching technique



$$CC(\varepsilon) = \frac{\int_{t_1}^{t_2} \varphi'[t(1-\varepsilon)]\varphi[t]dt}{\sqrt{\int_{t_1}^{t_2} \varphi'^2[t(1-\varepsilon)]dt \int_{t_1}^{t_2} \varphi^2[t]dt}}$$

Hadziiannou et al. 2011

Apparent velocity variations and decoherence in the coda



Seismic data (dv/v and decoherence) are affected differently by the eruptions according to their location.

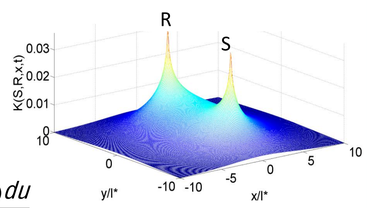
We study the data separately for the periods marked by P1-P6.

GPS data

Inversion procedure

Sensitivity kernel

Pacheco and Snieder (2005),
Larose et al. (2010), Planès et al. (2013)



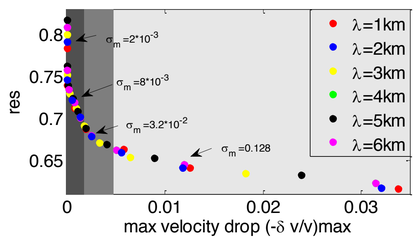
$$K(s, r, x_0, t) = \frac{\int_0^t p(s, x_0, u)\, p(x_0, r, t-u)\, du}{p(s, r, t)}$$

$p(s, r, t)$ Intensity propagator (Diffusion, radiative transfer)

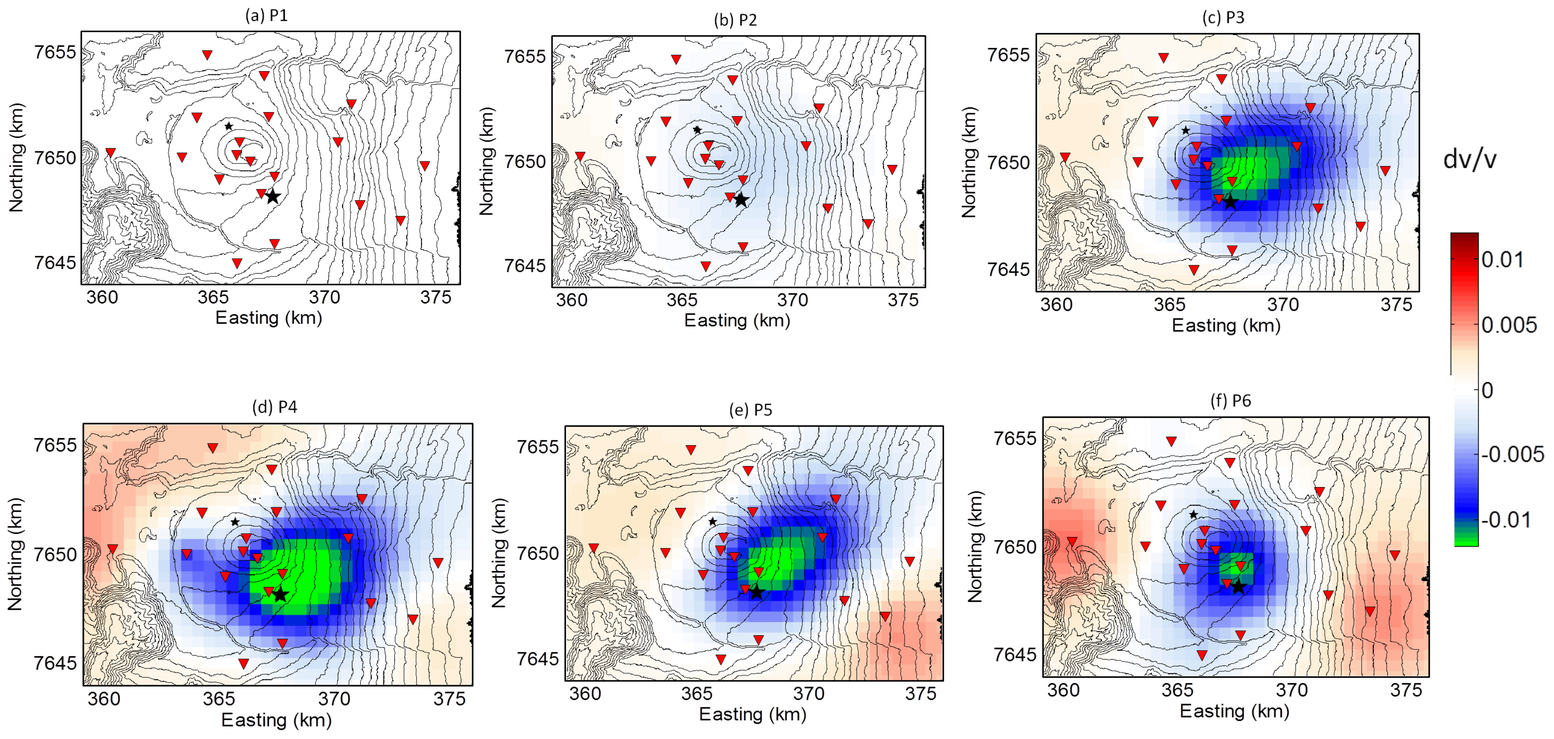
Linear least square inversion

d=Gm

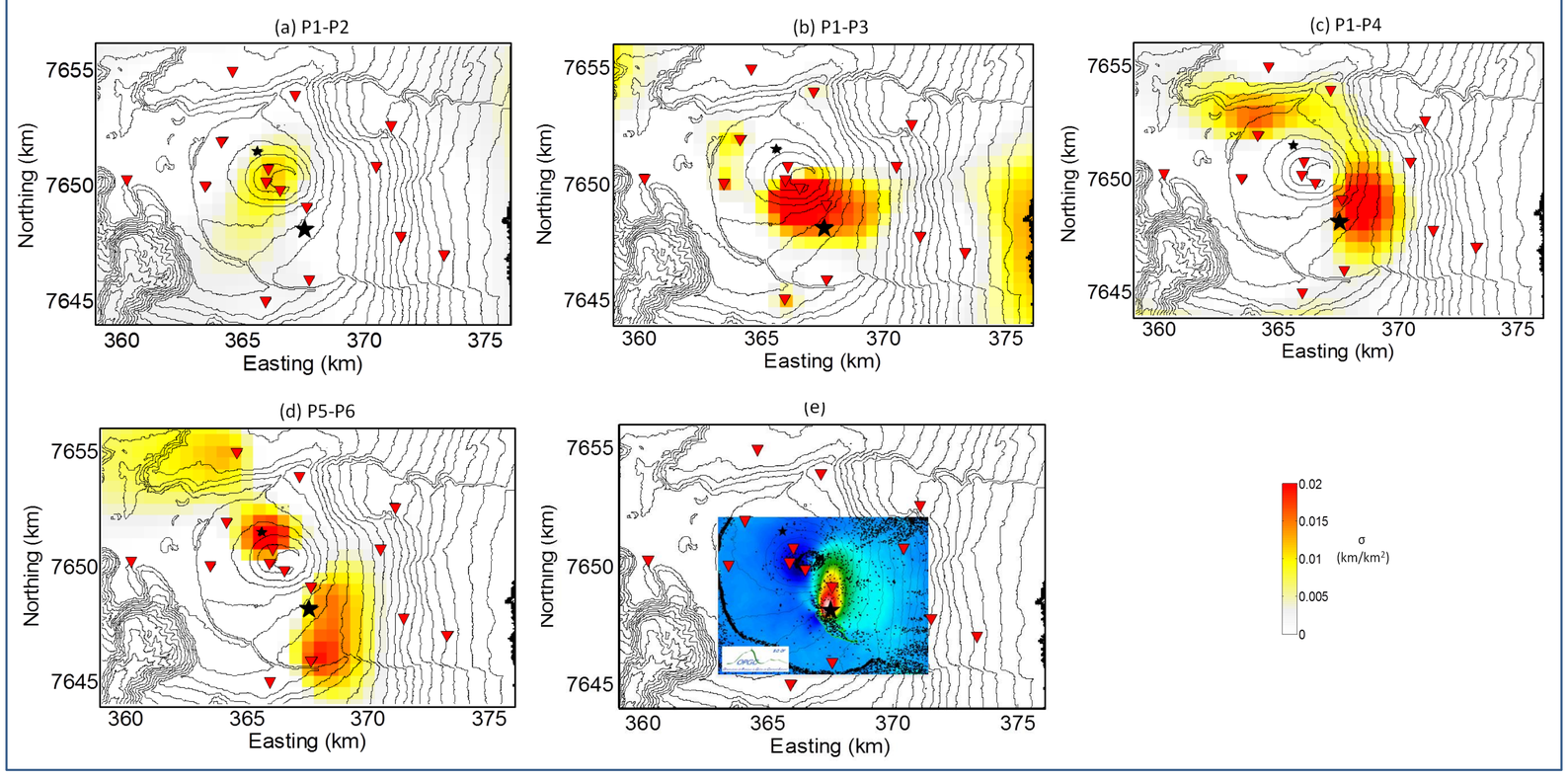
L-curve criterion to cope with under-determination
(Hansen 1992)



Inversion of the apparent relative velocity changes



Inversion of the decoherence values



Conclusions

❖The observed temporal variations parameters are precursors of the two volcanic eruptions.

❖The location of the changes are in good agreement with the actual eruptive activities.

❖ These results demonstrate that the coda of ambient noise correlations contains deterministic information on the position of the eruptive process in an active volcano, and also offer an original and significant constraint on the location of forthcoming volcanic eruptions.

Acknowledgements

ERC Advanced Grant Whisper 227507