INSAR TROPOSPHERIC ARTIFACTS FOR AFRICAN VOLCANOES CLOSE TO THE INTER TROPICAL CONVERGENCE ZONE (ITCZ)

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1. INTRODUCTION

Monitoring active volcanoes located close to populated areas is a necessity in order to provide early warnings. However a ground-based monitoring network must be dense to obtain a spatial coverage precise enough to follow the deformation evolution. Differential interferometry synthetic aperture radar (DinSAR) is an alternative way and has demonstrated its capability to monitor volcanic activity over broad areas and over time [5]. However a dominant source of errors is the phase delay produced by variation in the water vapor content of the lower part of the troposphere [7]. These artifacts can result in significant delays impeding identification and interpretation of surface deformation [2].

This study presents the case of two African volcanoes, Pico do Fogo (2829 m a.s.l) and Mount Cameroon (4095 m a.s.l). Pico do Fogo on Fogo island is located about 800 km off the Western African coast. Mount Cameroon is located on the Western African coast. Both areas are under the influence of the Atlantic and African oscillation of the Inter tropical convergence zone (ITCZ), a permanent low-pressure belt surrounding the Earth near the Equator, and characterized by increased moisture and precipitation [8].

The objective of this study is to identify and quantify the magnitude of phase delay induced by troposphere so that it can be distinguished from ground deformation signals. We applied a network adjustment procedure to determine relative tropospheric delays [1, 6] and compared results with precipitable water vapor (PWV) content in the troposphere using MODIS and GPS data .

2. DATA

86 single look complex images (SLC) of ENVISAT ASAR were used to investigate Fogo island and Mount Cameroon. From these images, two-pass InSAR interferograms were computed using DORIS software. Orbital errors were corrected with DEOS and ESA precise orbits. The digital elevation models were obtained from the Shuttle Radar Topography Mission (SRTM) data and used to remove topographic component. All produced interferograms have a perpendicular baseline below 360 m. The temporal coverage is from June 2005 to December 2007 for Fogo island and July 2004 to January 2008 for Mount Cameroon.

A network adjustment based on an over-determined set of equations is applied on each interferogram to relate the number of fringes with the phase delay on the days of acquisition of the master and slave images used to obtain it. Finally, PWV retrieved from MODIS monthly global product and GPS data are used to discuss the results.

3. RESULTS

Observed fringe pattern on both volcanoes are different. On Fogo island, phase delay fringes are circular and centered on the volcano and visible almost on the entire island due to a coherence well preserved over time. On the opposite, fringes on Mount Cameroon can exhibit an ellipsoid pattern oriented along the main axis of the volcano and are only preserved around the summit where recent lava flows are exposed, other parts being covered by dense vegetation reducing coherency.

Fringe pattern is directly related to the shape of the volcano and in both cases phase delay fringes are strongly correlated with topography. Moreover the pattern is time-dependant. Indeed, fringe number depends on the period of the year of SAR images acquisition. On Fogo island, number of fringes can reach up to 6 over 2500 m and up to 4 over 2000m on Mount Cameroon, which represents between 11 to 17 cm of pseudo ground deformation. Number of fringes is closely related to the seasonal oscillation of the ITCZ which influences the water vapor content in the troposphere as demonstrated by the comparison of relative phase delay obtained for each individual SAR images using a network adjustment procedure with MODIS PWV and GPS data.

4. CONCLUSION

This study emphasizes the importance of characterizing tropospheric effects over volcanic active areas temporally and spatially. Indeed the network adjustment of 86 SLC Envisat ASAR images for Fogo volcano and Mount Cameroon shows an annual cyclic behavior which corresponds with the variation of precipitable water vapor content in the troposphere. This variability is linked with the Atlantic and Africa ITCZ seasonal migration. The magnitude of phase delays induced by tropospheric effects is more important on these two African volcanoes than on other studied ones [4 , 6]. These results can also be used to identify preferable months for ENVISAT ASAR data acquisition, if the objective is to achieve ground deformation analysis on those specific African volcanoes.

5. REFERENCES

[1] F. Beauducel F. and P. Briole, “Volcano-wide fringes in ERS synthetic aperture radar interferograms of Etna (1992-1998) : Deformation or tropospheric effect ?”, *Journal of Geophysical Research*, 105, B7, American Geophysical Union, pp. 16391-16402, 2000

[2] J. Foster, B. Brooks, T. Cherubini, C. Shacat, S. Businger, and C. L. Werner, “Mitigating atmospheric noise for InSAR using a high resolution weather model”, *Geophysical Research Letters*, vol. 33, L16304, doi:10.1029/2006GL026781, American Geophysical Union, 2006

[3] B-C. Gao, Y.J. Kaufman, “Water vapor retrievals using Moderate Resolution Imaging Spectroradiometer (MODIS) near-infrared channels”, *Journal of Geophysical Research* 108 (D13), 4389, 10 doi:10.1029/2002JD003023, American Geophysical Union, 2003

[4] Pavez, D. Remy, S. Bonvalot, M. diament, G. Gabalda, J-L. Froger, P. Julien, D. Legrand, D. Moisset,” Insight into ground deformations at Lascar volcano (Chile) from SAR interferometry, photogrammetry and GPS data: Implications on volcano dynamics and future space monitoring”, *Remote Sensing of Environment,* Elsevier, pp. 307-320, 2005

[5] M.E. Pritchard, M. Simons, “A satellite geodetic survey of largescale deformation of volcanic centres in the central Andes”, *Nature* 418, Nature publishing group, pp. 167-171, 2002

[6] D. Remy, S. Bonvalot, P. Briole, M. Murakami, “Accurate measurements of tropospheric effects in volcanic areas from SAR interferometry data: application to Sakurajima volcano (Japan)”, *Earth and Planetary Science Letters* 6730, Elsevier, pp. 1-12, 2003.

[7] N.F. Stevens, G. Wadge, “Towards operational repeat-pass SAR interferometry at active volcanoes”, *Natural Hazards* 33, Springer Netherlands, pp. 47-76, 2004

[8] D.E. Waliser, C. Gautier, « A satellite-derived climatology of the ITCZ”, *Journal of Climate* 6, American Meteorological Society, pp. 2162-2174, 1993