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Thermal infrared observation of pre-seismic vertical permeability changes. The Boumerdes-Zemmouri (M = 6.8) case

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Since nearly 20 years, huge transient thermal warm anomalies have been observed in different regions worldwide. The main peculiarity of these thermal anomalies is their close relationship with the occurrence of earthquakes of magnitude > 5. Most of the thermal anomalies appear tens of days before the earthquake and reach a maximum positive value of ∼10 K few hours before the main shock. They are located at hundreds kilometres from the epicentres and can cover areas of ∼10,000 km^2. Some hypotheses have already been proposed to explain these thermal anomalies, e.g., variation of the groundwater level, release of greenhouse gases creating a localised greenhouse effect or air ionisation.

This study focuses on the Boumerdes-Zemmouri earthquake (M = 6.8) that hit Algeria in 2003. This earthquake was preceded by a thermal anomaly observed by AVHRR (Advanced Very High Resolution Radiometer; 1 km/pixel) thermal sensor on the NOAA-15 satellite. This region is very adapted to a preliminary study as 1) the tectonic is less complex than in other regions, 2) the semi-arid environment allows high temporal coverage as cloud cover is not significant, and 3) vegetation is excessively sparse. The objective of this study is to interpret this excess temperature and to improve our understanding of the processes behind their development. The thermal anomaly was located in a sedimentary basin ∼400 km south from the epicentre and covered a maximal surface of 41,000 km^2. It appeared ten days before the earthquake and reached a maximum temperature anomaly of +7 °C a few hours before the main shock. The results obtained from a combination of MODIS thermal infrared data with climate reanalyses from ECMWF (European Center for Medium Range Weather Forecasts) demonstrated first that this thermal anomaly cannot be explained by meteorological variations, neither by changes in the physico-chemical properties of the surface. We suggest that this earthquake-related thermal anomaly in Algeria can be explained by subsurface alterations induced by the pre-seismic stresses (Lopez et al, in preparation). Publications have shown that pre-seismic stresses may change the groundwater circulation and/or its physico-chemical properties. Development of thermal anomalies prior to an earthquake suggests that pre-seismic stresses change the vertical permeability of the system and thus have an influence on the groundwater circulation. This leads to a short-term increase of the aquifers and the atmosphere connexion. Indeed, the southern limit of the thermal anomaly seems to be controlled by the extension of aquifer artesianism (Lopez et al, submitted). Moreover, the transfer of elastic stresses might explained the distance observed between the thermal anomaly and the epicentre.

The original combination of thermal infrared images with other EO dataset and geophysical data may lead to a new vision of a subject so far very little studied. In that context, the thermal infrared sensor might play a future key role in understanding the development and transfer of pre-seismic loading or unloading stresses in (semi)-arid regions.