



## **Monitoring unstable urbanized slopes in Granada coast through InSAR analysis of Sentinel-1 images**

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The coast of Granada (southern Spain) has already been the subject of several studies about landslides in urban areas. This is the case of (1) Cármenes del Mar, (2) Marina del Este, (3) Alfamar and (4) Monte de los Almendros resorts. Previous studies evidence that Cármenes del Mar and Marina del Este resorts were built in hillsides affected by quiescent landslides that were reactivated after their construction. By means of DInSAR, both areas were monitored from May 2003 to December 2009, showing displacements between 4 and 10 mm/year. Related to Alfamar and Monte de los Almendros sorts, other study documented the existence of ground instability in both locations by applying the on-line SBAS InSAR service of the Geohazard Exploitation Platform (European Space Agency). In this study, images from March 2003 to December 2009 were used and the derived displacement map showed values higher than 8 mm/year. In all the four sorts, moderate and severe damages in buildings were found and evaluated, what shows the relevance of these phenomena in these areas. On the point of this, we continued analyzing these areas to obtain more recent displacement rates and thus, to check the activity of these landslides. We produced a surface velocity map and displacement time series of all the measured points by processing 139 radar images of the Sentinel-1 (A and B) satellite on ascending orbits from 10 March 2015 to 20 September 2018. A procedure designed in the CTTC (Centre Tecnològic de Telecomunicacions de Catalunya) was applied to process the images and measure the surface displacements.

High displacement rates were found in all the four sorts: (1) Cármenes del Mar shows deformation velocities between 4 and 8 mm/year, reaching around 15-20 mm/year in the lower part of the landslide. (2) Marina del Este shows velocities between 3 and 6 mm/year, being the highest values in the upper part of the landslide. (3) Alfamar velocities range between 3 and 8 mm/year, being the deformation homogeneously distributed along the slope (4) Monte de los Almendros shows values between 3 and 9.5 mm/year, reaching around 11 mm/year in the lower part of the sort and even 14 mm/year in the upper part.

Our analysis not only improves the resolution and level of detail in comparison with the previous studies, as we have been able to obtain a higher number of measurement points with the Sentinel-1 images, but also confirm the instability in all the urbanized slopes, 9 years after the last monitoring. These results offer another example of how InSAR techniques represent an effective tool to identify, delimit and control slope movements that may generate damages in buildings. The gathered measurements also provide new information about the ground conditions in the stable and unstable areas. As the urban development continues growing in the analysed coast, this information may help in the future land management in the region.