Introduction: Remote Sensing Techniques for Landslide Mapping and Monitoring

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Abstract

Remote sensing is an effective tool for landslide mapping and monitoring. This chapter provides a general overview of the recent applications of optical and radar images for landslide detection, mapping and monitoring with special attention to SAR interferometry that has proved as a promising technique in landslide studies.

Keywords

Landslide • Remote sensing • SAR interferometry • Optical imagery

Remote sensing techniques represent effective tools for landslide detection, mapping, monitoring and hazard analysis. Applications are originating from nearly all types of sensors available today. Rapid developments in this field are fostered by the very high spatial resolution obtained by optical systems (currently in the order of tens of centimeters) and by the launching of SAR (Synthetic Aperture Radar) sensors, purposely built for interferometric applications with revisiting times of few days such as TerraSAR X and COSMO-SkyMed (Tofani et al. 2013a). Also, in the last years satellites have provided accurate measurements of precipitation such as the Tropical Rainfall Measuring Mission (TRMM), which was launched in 1997. Remote rainfall measurements can be used to predict rainfall-induced landslides in the framework of landslide hazard analysis (Adler et al. 2000; Hong et al. 2006; Baum and Godt 2010).

Landslide detection and mapping benefit from both optical and radar imagery. Recently, a new generation of high resolution satellites as World-View, Geo-eye and the Pleiades constellation provides resolutions ranging from 0.5 to 2 m and offers a very powerful tool for a quick reproduction of regional inventory maps (up to a scale of 1:2,000). In particular the increasingly higher spatial and temporal resolution of optical satellite observations enables (i) more detailed and reliable identification of affected areas, (ii) an immediate response minimizing the risk of omission (due to landslide traces fading away with time), and (iii) repeated observations potentially leading to multi-temporal inventories, which can be easier related to specific events.

There is a large number of studies which proposed, applied and compared automated (both pixel and object-based) techniques for landslide mapping with optical data (Hervás et al. 2003; Cheng et al. 2004; Nichol and Wong 2005; Marcelino et al. 2009; Martha et al. 2010; Lu et al. 2011).

Airborne LiDAR techniques show particular strength for the mapping of old landslides under forest (e.g. Van Den Eeckhaut et al. 2007) but can also be used to support the mapping of newly triggered shallow landslides (Ardizzone et al. 2007; Lu et al. 2011). There seems to be a general agreement that LiDAR based mapping yields more accurate

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K. Sassa et al. (eds.), *Landslide Science for a Safer Geoenvironment*, Vol. 2,
DOI 10.1007/978-3-319-05050-8_47, © Springer International Publishing Switzerland 2014

and complete inventories than field surveys alone (Ardizzone et al. 2007; Schulz 2007; Van Den Eeckhaut et al. 2007). Resulting inventories have been employed for efficient susceptibility models whereby the LiDAR derived terrain model provides also valuable input to extract influential topographic variables (Van Den Eeckhaut et al. 2006, 2009).

The application of the interferometric techniques to radar images is a powerful tool for landslide detection and mapping at large scale. In particular the A-DinSAR technique can contribute to the creation of landslide inventory maps which can be used for susceptibility mapping over large scale. There are a few of examples in literature of the use of landslide inventory maps derived from radar images for landslide hazard assessment (Singhroy et al. 1998; Catani et al. 2005). It's worth noticing that the realization of landslide inventory maps with InSAR technology benefits from the integration with optical imagery, geological and topographic information (Singhroy 2002).

Both Differential SAR interferometry (DInSAR) and multi interferograms SAR Interferometry (A-DInSAR) can be used for landslide monitoring. Though it represents a promising technique for landslide monitoring, the characteristics of the existing satellites put strong constraints on the use of DInSAR as a monitoring instrument. In particular, the spatial resolution of SAR images, the time-interval between two consecutive passages of the satellites and the wavelength of the radiation are unsuitable for a systematic monitoring of landslides that are characterized by relatively rapid movements or that are located on steep slopes or narrow valleys (Rott et al. 2000; Refice et al. 2001). Quantitative information on landslide activity can be acquired in case of extremely slow movements (velocity <16 mm/year according to Cruden and Varnes 1996), affecting large areas with sparse vegetation (Kimura and Yamaguchi 2000; Rizzo and Tesauro 2000). However the availability of deformations time series provided for long period by the radar satellites as ERS and ENVISAT can be used for the definition of the recurrence of landslides. At the same time the comparison of the time series with triggering factors data can define the causes and the deformation thresholds.

An extensive bibliography contains works on the use of DInSAR and A-DinSAR for landslide monitoring (Singhroy and Molch 2004; Strozzi et al. 2005; Meisina et al. 2007; Fornaro et al. 2009; Prati et al. 2010). In many cases the A-DInSAR data have been integrated with in-situ monitoring instrumentation (Strozzi et al. 2010; Tofani et al. 2013b). The joint use of satellite and ground-based data facilitates the geological interpretation of a landslide and allows a better understanding of landslide geometry and kinematics.

Optical imagery can give a great a contribution in the landslide susceptibility assessment especially in the definition of the preparatory factors. In particular the use of optical images is quite common when the analysis is carried out over large areas since these data can be easily collected. As reported in Metternicht et al. (2005) optical imagery, as well as aerial photographs, have provided the main contribution for the mapping of landslide related factors.

Optical imagery can be used for defining the land cover (Cheng et al. 2004; Catani et al. 2005; Kirschbaum et al. 2009), geology and lithology (Sarkar and Kanungo 2004; Grebby et al. 2011), tectonics lineaments (Ramli et al. 2010) and for the set up of a Digital Elevation Model (DEM) which can be the inputs data for the heuristic and statistical susceptibility approach.

One of the most intriguing applications currently being investigated regarding the use of remote sensing is the temporal prediction of shallow landslides. Drawing on recent advances of satellite remote sensing technology, experimental landslide prediction models are developed to identify the timing for landslides induced by heavy rainfall (Hong et al. 2007; Adler et al. 2000).

Satellites have provided global estimates of precipitation over various temporal and spatial scales since the 1970s. A long history of development in the estimation of precipitation from space has culminated in sophisticated satellite instruments and techniques to combine information from multiple satellites to produce long-term products useful for climate monitoring. In November 1997, the Tropical Rainfall Measuring Mission (TRMM) was launched with the primary objective of making accurate measurements of rainfall and latent heating from space. In particular the Tropical Rainfall Measuring Mission (TRMM) Multi-satellite Precipitation Analysis (TMPA, Huffman et al. 2007) has been used for landslide prediction at global scale (Hong et al. 2006, 2007).

This chapter provides an overview of the application of remote sensing for landslide mapping, monitoring and hazard analysis.

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