Monitoring Oceanographic Parameters and Submesoscale Structures of the El Hierro Volcano with Satellite Remote Sensing Imagery

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Abstract

Satellite study of volcanoes can provide data for large areas of the Earth's surface with a range of modalities ranging from visible to infrared, radar and beyond. Satellite sensing can also access remote locations and hazardous regions without difficulty. Accordingly, this work is not intended as a comprehensive treatment of the application of remote sensing to the selected natural hazards but rather as recognition of the contributions of satellite remote sensing to understanding underlying phenomena and providing critical information for decision support by emergency managers and the disaster response community. In this context, satellite remote sensing systems have proven useful for a range of applications including the capabilities to improve the understanding of submarine volcanic processes by means of remote sensing images.

A regular multidisciplinary monitoring of the El Hierro underwater volcano has been carried out in order to quantify the environmental impact by analyzing low resolution remote sensing images providing more frequent observations and scientific information at a wide variety of wavelengths. Multisensor and multitemporal satellite data obtained from MODIS (MODerate resolution Imaging Spectroradiometer) and MERIS (MEdium-spectral Resolution Imaging Spectrometer) sensors have been the main source of information to improve the understanding of El Hierro submarine volcanic processes. MODIS instruments, flying on both the TERRA and AQUA satellites, provide excellent temporal coverage with 2 daylight and 2 night overflights per 24 hours. On the other hand, MERIS, aboard the ENVISAT satellite, is a programmable, medium-spectral resolution, imaging spectrometer operating in the solar reflective spectral range. One important capability of MERIS is the provision of full resolution data at 300 m resolution. These remote sensing data have played, as well, a fundamental role during field campaigns guiding the Spanish government oceanographic vessel to the appropriate sampling areas.

A milky green plume water in the El Hierro volcano area stretched 25-30 kilometers at its widest and, approximately, 100 kilometers long, from a large mass near the coast to thin tendrils as it spreads to the southwest. This plume has provided a unique and outstanding source of tracer. In our work, low and high-resolution satellite images obtained from MODIS, MERIS and WORLDVIEW 2 sensors have been processed to provide information on the concentration of a number of oceanographic parameters, specifically, chlorophyll-a (Chl-a) and diffuse attenuation coefficient (Kd).

Chl-a concentration can be properly estimated from remotely sensed data in open ocean waters. Unfortunately, the accurate monitoring of chlorophyll concentration by remote sensing is not possible during a submarine eruption due to the specific conditions and the alterations provoked in the water composition. By comparing MODIS and MERIS algorithms with in situ measurement, we can conclude that MODIS and MERIS open ocean models completely fail while the MERIS ALGAS-2 coastal algorithm performs slightly better, but only in areas with moderate turbidity.

Respect to the diffuse attenuation coefficient (Kd) parameter, we examined two existing Kd (490) models (MODIS and MERIS) for waters surrounding the El Hierro submarine volcano area. Results, using the in situ measurements obtained from four cruises around the island of El Hierro, were not satisfactory and the Kd(490) values achieved were clearly underestimated. Thus, improved algorithms were developed for turbid waters and applied to MODIS and MERIS bands showing a good correlation between real Kd

(490) values and estimations from low-resolution satellites. Concerning Very High Resolution imagery, a novel algorithm to extract the diffuse attenuation from the original bands was proposed and validated with previous data. This new Kd (490) operational algorithm, developed for high resolution WorldView-2 data, has demonstrated a good performance in this particular situations.

In addition, satellite image sequences obtained from MODIS and MERIS sensors have been processed to analyze the volcanic submesoscale front-like and filament-like structures and also to monitor their evolution. First, accurate geometric correction, land masking, and filtering, to remove noise without edge deterioration, are applied. Next, thresholding methods are implemented to properly segment the structures. Finally, morphological image processing operators and other post-processing techniques are included in the methodology to properly define the submesoscale structures. This detection approach has been validated over a database of MERIS and MODIS oceanographic products and it has demonstrated an excellent performance and robustness.

References

1. Eugenio, F., Martin, J., Marcello, J. and Fraile-Nuez, E. (2014). Environmental monitoring of El Hierro Island submarine volcano, by combining low and high resolution satellite imagery. International Journal of Applied Earth Observation and Geoinformation. 29, 53–66.

2. Eugenio, F., Martin, J., Marcello, J. and Bermejo, J.A. (2012). Atmospheric correction models for high resolution WorldView-2 multispectral imagery: A case study in Canary Islands, Spain. Proceedings SPIE Remote Sensing. Edimburgh, September 2012.

3. Fraile-Nuez, E., González-Dávila, M., Santana-Casiano, J. M., Arístegui, J., Alonso-González, I. J., Hernández-León, S., Blanco, M. J., Rodríguez-Santana, A., Hernández-Guerra, A., Gelado-Caballero, M. D., Eugenio, F., Marcello, J., de Armas, D., Domínguez-Yanes, J. F., Montero, M. F., Laetsch, D. R., Vélez-Belchí, P., Ramos, A., Ariza, A. V., Comas-Rodríguez, I. and Benítez-Barrios, V. M. (2012). The submarine volcano eruption at the Island of El Hierro: physical-chemical perturbation and biological response. Scientific Reports, 2.

4. Joyce, K., Belliss, S., Samsonov, S., McNeill, S and Glassey, P. (2009). A review of the status of satellite remote sensing and image processing techniques for mapping natural hazards and disasters. Progress in Physical Geography. 33, 2, 183–207.

5. Tralli D. M., Blom, R. G., Zlotnicki, V., Donnellan, A. and Evans, D. L. (2005). Satellite remote sensing of earthquake, volcano, flood, landslide and coastal inundation hazards. ISPRS Journal of Photogrammetry and Remote Sensing, 59 (4), 185-198.