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Volcanic submarine hydrothermal activity from satellites : regional mapping and temporal evolution in shallow water systems

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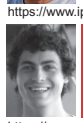
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Risk assessment at active volcanic islands is particularly critical near populated area. We evaluate the potential of satellite imagery to map and monitor the activity of shallow-water hydrothermal systems, which are often found at volcanic islands.

For this study we used publicly available data and proprietary WorldView-2 satellites images, with spectral bands that can penetrate up to water depths of 30 m. Shallow water hydrothermal sites are visible on satellite imagery, primarily with publicly available data, that occur preferentially along volcanic islands, showing intense near-shore, shallow-water hydrothermal activity, and distinct styles of hydrothermal venting. Satellite imagery thus can constrain regional outflow geometry and the temporal variability or stability of these systems, demonstrating their potential as a monitoring tool of this activity, and as a proxy for volcanic activity.

Milos Island (Fig. 3) shows hydrothermal outflow associated with reflective mineral precipitates and/or bacterial mats, which are stable over time (2010-2014). These outflows locally define polygonal patterns likely associated with hydrothermal convection in porous media. In Kueishantao Island (Fig. 2) individual hydrothermal plumes charged with particles are visible at the sea surface, and display great variability in intensity and distribution of plume sources (2002-2019). Worldwide we have identified ~15 shallow water hydrothermal sites with satellite imagery (Fig. 1), that are similar to either the Milos system (e.g., Vulcano and Panarea, Italy), or the Kueishantao system (numerous sites along Pacific volcanic islands).

We thus demonstrate that satellite imagery can be used to map and monitor different types of shallow-water hydrothermal systems, at regional scale, and monitor their evolution over periods of time ranging from <1 yr to decades. Satellite data provides not only regional and temporal information on these systems, unavailable to date, but also the regional context for follow-up in situ field data and observations (e.g., instrumental monitoring, sampling, observations and mapping with divers or AUVs) to understand both the nature and dynamics of these systems and ultimately the associated fluxes.

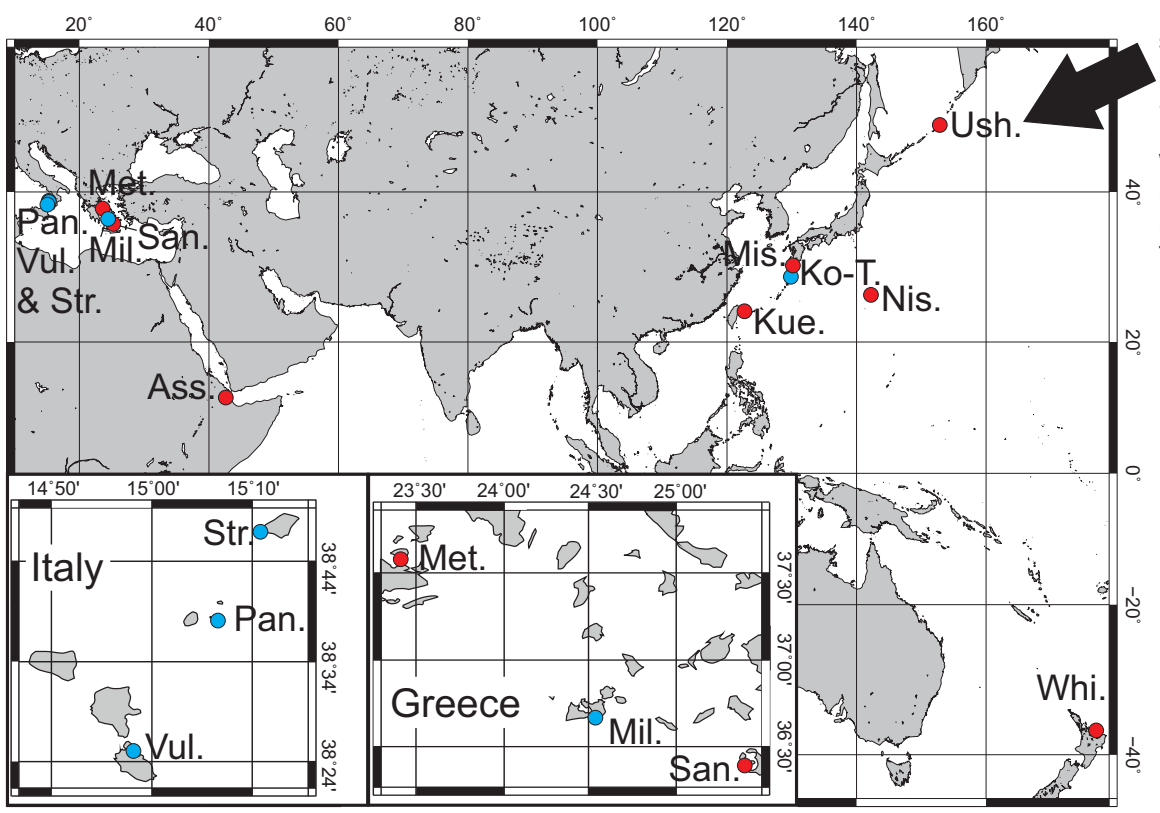

Fig. 1. Active submarine hydrothermal sites visible on satellite images, either as seafloor structures linked to hydrothermal outflow (blue dots) or hydrothermal plumes visible at the sea surface (red). Pan. Panarea, Vul. Vulcano, Str. Stromboli, Mil. Milos, Met. Methana, San. Santorini, Ass. Assal, Kue. Kueishantao, Ko-T. Ko-Takara-Jima, Mis. Mishima Island, Nis. Nishinoshima, Ush. Ushishir, Whi. White Island. A synthesis of identified sites in the literature is available in review papers (e.g., Tarasov et al., 2005; Price and Giovanelli, 2017), and references therein

Tarasov, V. G., et al., 2005. Chem. Geol. 224, 5-39. https://doi: 10.1016/j.chemgeo.2005.07.021
Price, R. E., Giovannelli, D., 2017. Reference Module in Earth Systems and Environmental Sciences. https://doi.org/10.1016/b978-0-12-409548-9.09523-3

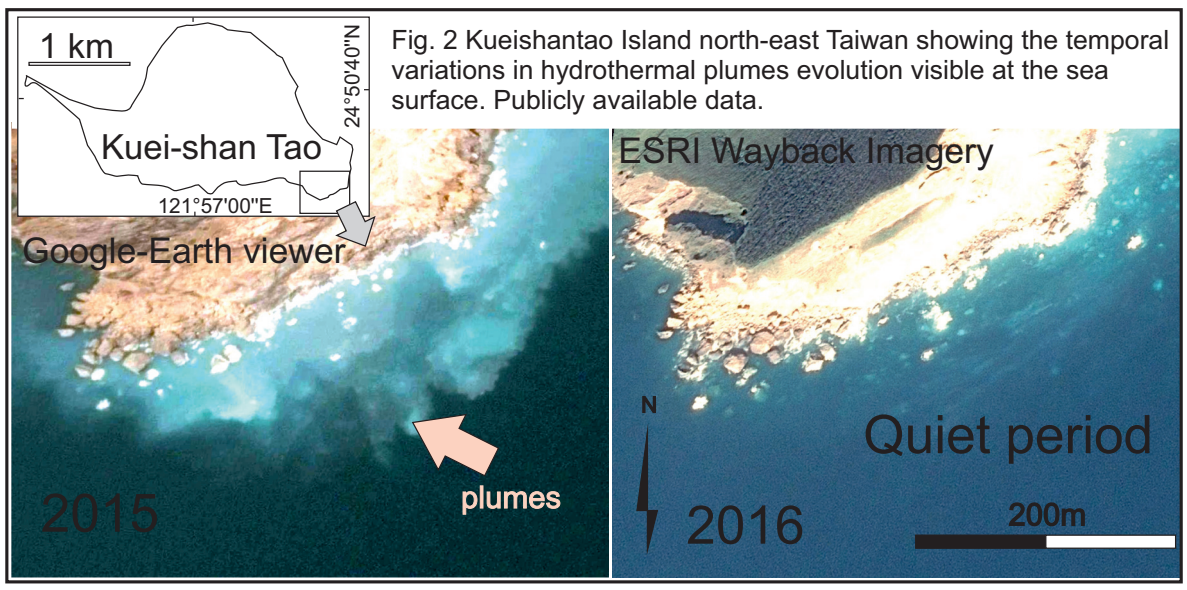

Fig. 2 Kueishantao Island north-east Taiwan showing the temporal variations in hydrothermal plumes evolution visible at the sea surface. Publicly available data.

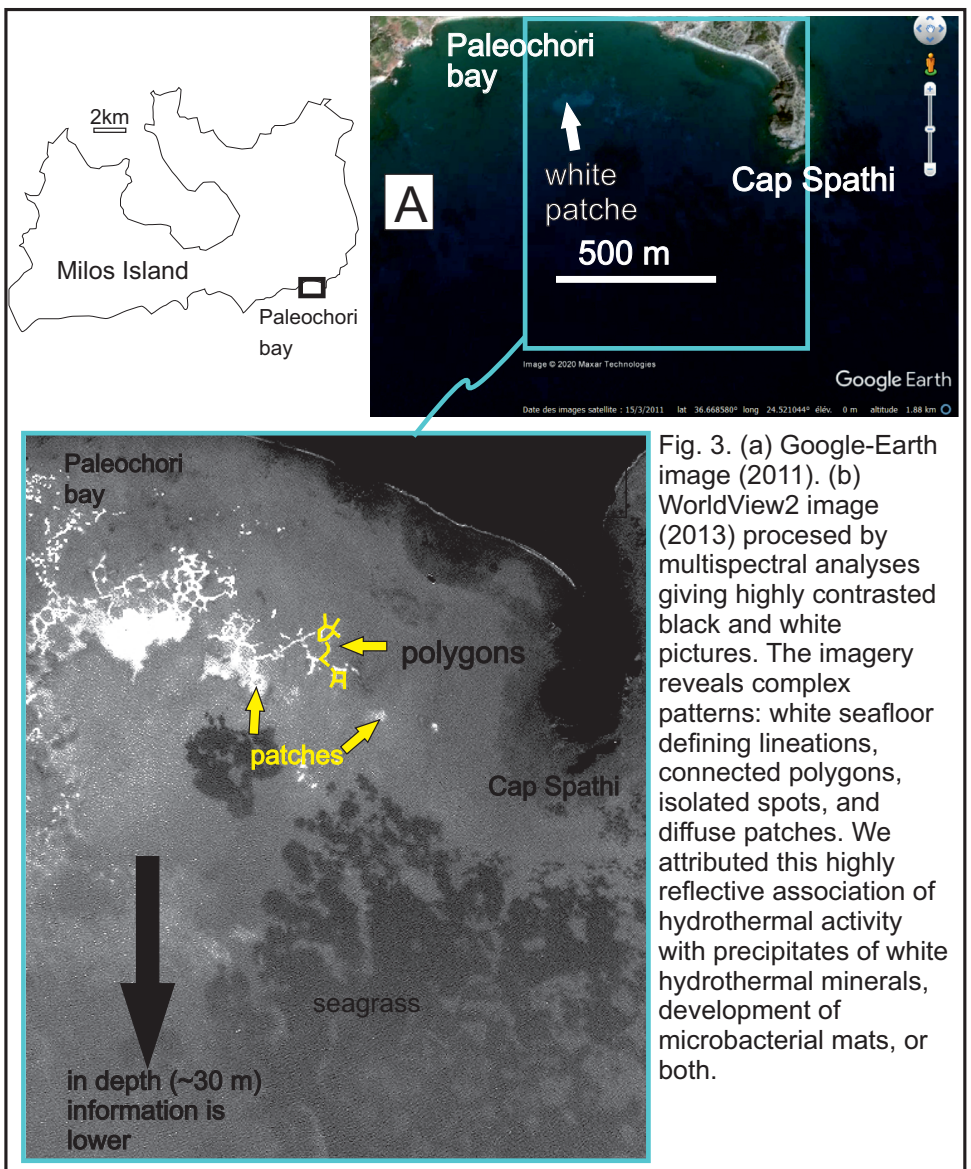

Fig. 3. (a) Google-Earth image (2011). (b) WorldView2 image (2013) procesed by multispectral analyses giving highly contrasted black and white pictures. The imagery reveals complex patterns: white seafloor defining lineations, connected polygons, isolated spots, and diffuse patches. We attributed this highly reflective association of hydrothermal activity with precipitates of white hydrothermal minerals, development of microbacterial mats, or both.

More data are available at Martelat, J.-E., Escartin, and J., Barreyre, T. 2020. Terrestrial shallow water hydrothermal outflow characterized from out of space. Marine Geology Volume 422, April 2020, 106119 https://doi.org/10.1016/j.margeo.2020.106119