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# Assessing the effects of severe weather events through remote sensing on Samothrace, Greece: applications for the management of cultural resources

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ABSTRACT

This article demonstrates the utility of high temporal and spatial resolution satellite imagery for the detection and study of the effects of intense surface runoff, particularly in respect to mitigation efforts to protect archaeological sites. We make use of PlanetScope imagery, which has recently become available as a freely available remote sensing data source with a revisit time of less than 24 hours, almost global coverage, and spectral and spatial resolution on par with other commercially available sensors. The high temporal resolution of PlanetScope data allows for better detection of changes in land cover that are the result of severe weather events, whose effects may be cleared up within several days of occurring or are more pronounced in the immediate aftermath of disturbances. Focusing on two severe storms that struck the island of Samothrace, in the northern Aegean, on July 17 and September 25/26 2017 respectively and which caused considerable damage to local infrastructure and archaeological sites, we test the utility of these data for detecting the island-wide distribution of the effects of these weather events. We find that these data are sufficiently sensitive to detect and quantify the extent of surface runoff processes and argue that the detection and monitoring capabilities of these data provide a useful tool for outlining policies to mitigate future damages to cultural heritage sites.

## 1. Introduction

The use of multi-temporal remote sensing data has been cited by recent archaeological studies as critical to enrich and further the analysis of subsurface features and their signatures (Agapiou et al., 2013a; Agapiou et al., 2013b; Hadjimitsis et al., 2009; McCloy, 2010), as well as monitor illegal excavation and other threats to cultural heritage (Agapiou, 2017; Casana and Laugier, 2017; Cuca and Hadjimitsis, 2017; El-Behaedi and Ghoneim, 2018; Lasaponara et al., 2012; Lauricella et al., 2017; Mallinis et al., 2016; Parcak et al., 2016). Optical multispectral satellite sensors are now complemented by a growing number of synthetic aperture radar (SAR) platforms (Chen et al., 2017; Tapete et al., 2016; Tapete and Cigna, 2017), while LiDAR, thermographic, and multispectral equipped UAVs (Casana et al., 2017; McLeester et al., 2018; Thomas, 2018) are becoming increasingly common and affordable. While the use of these remote sensing tools has benefited from their ever-improving spatial resolution, cost, and imaging capabilities, their improving availability and access has also resulted in a greater emphasis on multi-temporal data acquisition and more flexibility in when data is collected (Elfadaly et al., 2018).

For the study and monitoring of cultural heritage, such flexibility and repeated collection of data has been identified as essential for tracking processes of urban sprawl, landscape degradation, and other factors that threaten sites and monuments (Agapiou et al., 2015; Gigli et al., 2012; Goldberg et al., 2018; Vihervaara et al., 2017). The use of legacy remote sensing data, in conjunction with newly collected data, has been particularly useful for tracking long-term changes and evaluating risks threatening cultural heritage sites (Cigna et al., 2014; Hegazy and Kaloop, 2015; Stott et al., 2018). Yet as Opitz and Herrmann (2018: 24) outline, high temporal revisit satellites, such as the Sentinel platforms (Agapiou et al., 2014; Cuca and Hadjimitsis, 2017; Tapete and Cigna, 2018), have also provided "further means to engaging in the study of landscape change at a temporal scale often neglected, the short term, season, or event." High temporal revisit satellites are those that can observe a specific location with high temporal frequency, which compared to available sensors is roughly on the scale of 24 h to about three days (see Cuca and Hadjimitsis, 2017 for review). The risk to cultural heritage within such short-term time scales is as great as from long-term processes, and include such factors as severe weather, geological, or ecological events, vandalism and other forms of deliberate destruction.

Opitz and Herrmann (2018: 24) attribute the "relative neglect" of data from these high temporal revisit satellites in the archaeological literature, however, to the somewhat low spatial resolution of the

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imagery (10 m for Sentinel-2), which prevents detection and study of most archaeological features and limits their application to landscape scale processes. Indeed, Tapete and Cigna (2018) have recently discussed the merits of regularly acquired Sentinel-2 data for assessing damage and risks to heritage sites. They argue that while very high resolution (VHR) satellite imagery, defined as of a resolution of 5 m or greater, has been commonly employed for detection of small features, few publications address the role of regularly acquired high resolution (HR) imagery, of a spatial resolution between 5 and 30 m, That is, the potential of satellite remote sensing with high temporal resolution, even with moderate spatial resolution, is in its ability to systematically monitor the status of cultural heritage sites, and in doing so contribute to the formulation of mitigation strategies, both at the site and landscape level, aimed at their preservation (Cuca and Hadjimitsis, 2017; Elfadaly et al., 2018).

This paper considers the application of a relatively new source of multispectral satellite data, offered by the PlanetScope constellation of satellites (Planet Team, 2018), for cultural heritage monitoring at short temporal scales and at a greater spatial resolution than currently offered by other publicly accessible data sources. PlanetScope satellites have a spatial resolution of approximately 3 m, which classifies them as VHR imagery, and a daily revisit frequency. The combination of high temporal and spatial resolution thus makes this platform well equipped to monitor short-term events at relatively small spatial scales. We test these data in the context of two storm events that took place on the island of Samothrace, in the northeast Aegean Sea, and consider their potential for identifying landscape changes and damages to cultural heritage sites resulting from these events. We argue that the frequent monitoring of landscape processes through such high temporal resolution satellite systems, before and after severe storm events, can contribute to better calibrated soil erosion models, more informed land-use practices, and other erosion prevention strategies that can altogether help mitigate further damages to sites of cultural heritage on Samothrace, and in other contexts as well.

## 2. Case study

Located in the northeast corner of the Aegean Sea, Samothrace is an isolated island with a varied topography and a climate and ecology typical for the region (Fig. 1). Measuring 178 km$^2$ in area, the topography of the island is dominated by the central mountain of Phengari, which rises 1611 m above sea level, and is the third-highest peak in the Aegean. Only a portion of the western edge of the island avoids the foothills of Phengari, where a series of rolling hills and streams serve as the primary agricultural area of the island. In comparison to other islands in the Aegean and the Thracian coast, Samothrace has a good deal of fresh water, which is distributed through a series of waterfalls, perennial rivers, and numerous springs, and results in a much lusher body of vegetation than on other Aegean islands. Samothrace is without any natural harbors or significant bays, and the creation of artificial moles was necessary to facilitate seafaring, fishing, and trade of the agro-pastoral produce, granite, and basalt that have comprised the major Samothracian commodities since antiquity (Matsas, 2010: 44).

The population of the island, numbering some 2859 permanent residents, is currently clustered in three major areas: the port town of Kamariotissa on the island's northwest coast, the main village of Chora which is perched on the slopes of Saós, overlooking the sea, and in Thérma (Loutrá), the major center of tourism, camping, and hiking, and in smaller numbers in villages located throughout the island's north, west, and east coasts and lower foothills. The south of the island, a stark limestone cliff that plunges directly into the sea, and the central mountainous portion of the island have remained largely uninhabited throughout history. That is not to say, however, that these were unexploited areas. Material evidence for current and ancient pastoral activity—wells, dry stone enclosures (*mandria* and *strounga*), and huts—can be found throughout the whole of the island and select terracing on the most rugged parts of the island alludes to periods of intensive cultivation throughout the whole of Samothrace.

Tourism serves as the major driving force of the island's economy.

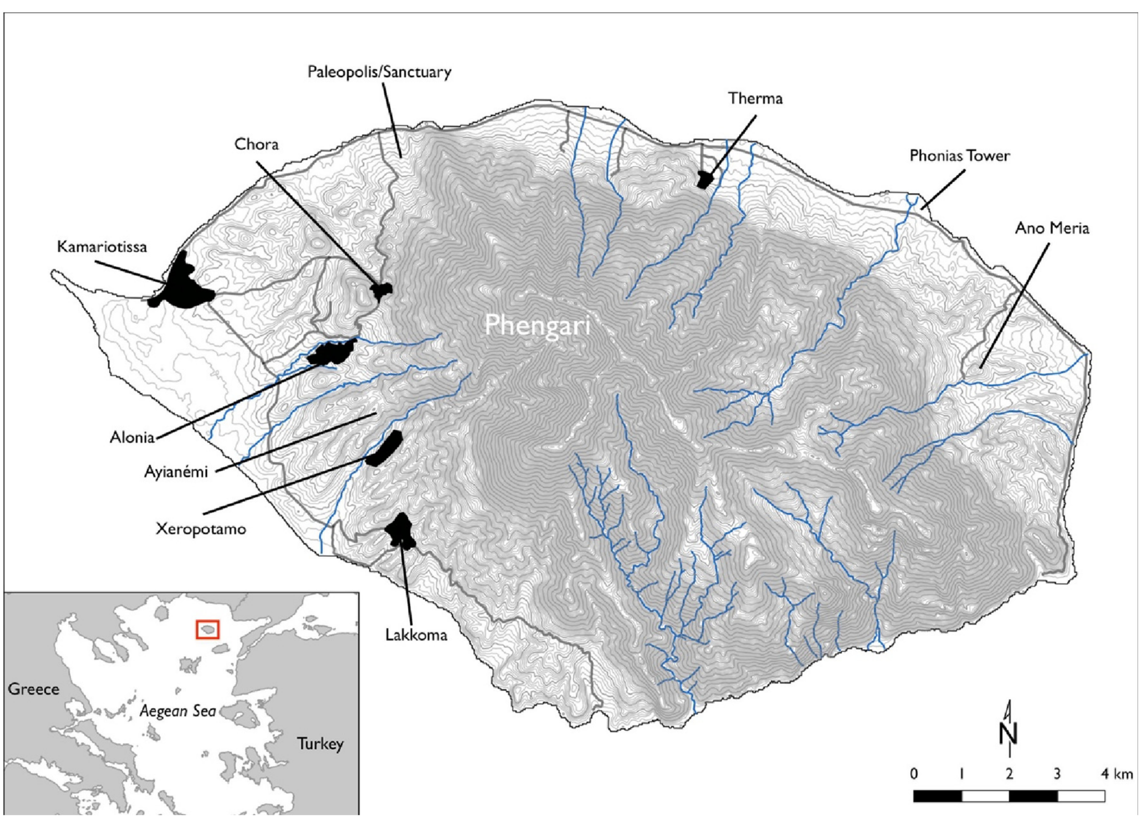


**Fig. 1.** Samothrace with sites mentioned in the text and major perennial rivers.