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Opportunistic Use of Microwave Satellite Signals for Early Flooding Detection and Real-Time Rainfall Field Reconstruction

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Accurate weather forecasting, with updated information on a very short-term scale in time and space domains (the so-called *nowcasting*), is playing a dramatic role in many important aspects of everyday's life. Nowcasting is particularly relevant for public safety, business-oriented services, and personal services, just to mention a few. For instance, the availability of reliable real-time forecast for hazardous and extreme weather conditions, such as cloudburts and thunderstorms, may effectively reduce the threat to life and property, thanks to timely emergency rescue operations. This branch of meteorology has been made possible by a combination of factors, including the availability of low-cost and low-consumption sensors, and the proliferation of new information and communication technologies, which made the distribution and the application of real-time weather information possible at nearly any location. Quantitative precipitation estimation can in fact be obtained by several observing systems using different measurement principles that have different time and space resolutions, and accuracies [1]. For instance, rain gauges (RGs) and disdrometers are point devices which can measure the accumulated rainfall (in mm) during a given amount of time and at a given location. Remote sensing devices, such as satellite sensors, though available on a global scale, suffer from scarce time and space resolution, whereas weather radars have a higher temporal (from 5 to 10 minutes) and spatial resolution (less than 1 km, although not uniform). Note also that there are regions of the globe where networks of sensing devices (in some cases, including RGs) are not available.

In the last few decades, the opportunistic use of pre-existing microwave (μW) communication links has been investigated to retrieve precipitation estimates. The basic idea is to estimate rainfall intensity relying on the attenuation due to the presence of precipitation along the propagation path, which affects either terrestrial links (e.g., backhaul connections in cellular networks), or the downlink of direct-to-home (DTH) satellite broadcasting, at Ku-band 10-13 GHz). In particular, satellite-based opportunistic systems for rain monitoring [2], powered by dedicated algorithms [3], turn out to be very appealing due to: *i*) the wide diffusion over the territory of already-installed DTH satellite receivers which could, in principle, act as rain sensing devices, prospectively allowing for a considerable geographical capillarity, at least in densely populated areas; *ii*) the ease of installation of new terminals to obtain higher spatial density; and *iii*) the low cost of commercial-grade satellite receive equipment. In this contribution, we aim at presenting the application of a cost-effective opportunistic technique for the estimation of rainfall intensity and accumulated precipitation, yielding high accuracy and small-scale spatial resolution. These features enable timely detection of cloudbursts and other life-threatening phenomena, and thus trigger evacuations and emergency rescue operations. Some case studies, including the heavy rain event that devastated western Germany in July 2021, are reported to evaluate the accuracy and demonstrate the potentials of the proposed methodology.

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