Real-time rainfall maps from satellite telecommunication signals

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Modern ways to measure rainfall provide a variety of different solutions, direct and indirect, with respect to the standard approach that is the raingauge method. Retrieving the actual rain fallen on a target domain is not in fact as easy task due to its temporal and spatial variability, but its importance is paramount for meteorology and for the effects on human lives and the environment. Rainfall regimes are changing almost at every latitude with dramatic effects, with a complex connection to climate change in large part to be still understood.

Among the emerging new methods for rainfall estimation, a specific interest is in the so-called ‘opportunistic’ measurements, because they provide a chance to augment information without adding new infrastructures, also with clear cost advantages. These data are of course less precise than those from dedicated instruments. Therefore some smart efforts in devising proper processing are needed to extract all the geophysical information that they can provide. Use of microwave links in cellular phone networks is among these methods, bringing information on rainfall rates along their path through signal attenuation caused by raindrops. Following a similar principle also broadcast telecommunication satellite signals can be used, with additional problems related to the definition of the intercepted precipitation volumes and the effects of the melting layer, but additional advantages related to the worldwide availability of the signal and the easiness of data acquisition, that can be natively centralised when using two ways communication receivers. NEFOCAST, a research project funded by the regional administration of Tuscany (Italy), exploited this feature through new two-way (transmit-receive) devices named SmartLNB (Smart Low-Noise Block converter), that are going to constitute networks of sensors of opportunity, densely distributed especially in urbanised areas. Two-way receivers allow both to estimate and relying attenuation data that can be centralized to be processed for real-time rainfall estimation, every minute.

An experimental network of SmartLNBS has been deployed in Italy (namely Florence, Pisa and Rome), including co-located raingauges and radar measurements for cal/val objectives. SmartLNBS
provide average measurements along quasi-parallel non-nadir paths, so that information on the structure of the intercepted rainfall system is needed in order to retrieve ground precipitation. The high rate of measurements provided by the SmartLNBs suggested to approach the rainfall retrieval problem similarly to a trajectory assessment in a phase space, using an ensemble Kalman filter to produce the rainfall field over a given domain. MSG satellite precipitation products can be used for the purpose and also as initial and boundary conditions, while atmospheric motion vectors from the same data source are used in the propagation model of the Kalman filter.

In this work, we present the measurement concept, the signal processing algorithm and the method to retrieve the rainfall fields, through some significant synthetic and real case studies, for events with different intensity, dynamics and morphology and for various sensor distributions.