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Hail detection and probability using fuzzy logic and X-band single-polarization weather radar data

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This work proposes a new method for hailstorm detection, based on single-polarization X-band radar measurements, in order to support operational monitoring of hailstorms. X-band radars performances are typically limited by the impact of two-way path attenuation, but their compact size, relatively low-cost technology and easy installation make them adequate for small-area surveillance, especially in urban environment. The innovative criterion relies on the fuzzy-oriented optimal combination of two hail detection techniques, based on single-polarization radar observations: the first one exploits the reflectivity vertical gradient (RVG), whereas the second one is based on vertically-integrated liquid density (VLD) product. Using a large and well-documented data set, consisting in radar volumes, ground truth observations and atmospheric sounding data, a Probability Of Hail (POH) index has been trained and adapted within a pilot study area (the Naples metropolitan environment). POH index has been retrieved from RVG, VLD and a combination (CMB) of these techniques through a multiple regression analysis method, as well as from the proposed technique, named hail fuzzy-oriented detection (HFOD), using weighted-ramp membership functions. The performances of all four trained POH indexes have been evaluated through a test dataset, which includes 22 thunderstorm events. The results show that the HFOD performs better than RVG, VLD and CMB methods both in terms of critical success index and false alarm ratio, thus it is very promising for the prevention of the hail-induced risks, especially for agrometeorological monitoring and urban hydrology. An example of application of the radar-based POH products developed in this work is presented and discussed in detail for two relevant hailstorms, occurred in the study area on 26 May 2012 and on 21 July 2014.