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Severity of storms associated to lightning from dual polarization radar measurements

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Severe thunderstorms are typically associated to intense precipitation also with hail at ground, wind gust and lightning. Intense precipitations that occur in short time and limited areas can cause flash floods, erosions, landslides, and interruption of road and railway networks. Moreover, lightning can cause fires, problems to air traffic protocols and unexpected power interruption.

Several networks exist worldwide to detect the lightning events. These networks are essential to track in space and time the core of severe thunderstorm as well as to explain the microphysical processes related to graupel and hail formation. However, from the standpoint of the operational aspects there are few analysis aimed at defining the favourable conditions for lightning occurrences. Among other instruments, polarimetric Doppler weather radar allows observations of storms with the proper spatial and temporal resolution for the definition of proxy indexes indicating the severity of storms and the conditions fostering the lightning formation. Through a proper hydrometeor classification method trained by electromagnetic model to simulate radar measurements is possible to identify the presence of particles associated to severe storms, such as hail, hail mix and graupel particles as well as provide estimations of Ice Water Content (IWC). Indeed, several studies show that ice mass, in particular that mass fraction associated to graupel, is directly related to lightning production.

In this work, the storm impact associated to lightning activity is investigated in terms of severity of storms. The severity of storms concept has been already used in previous studies but its connection with the lightning activity has not been fully assessed from an experimental point of view. Thus, the severity of storms will be put into relation with the IWC associated to graupel (hereinafter IWC_g) and density of flashes. The first objective of this work is predicting the lightning occurrences associated to the ice mass estimated by polarimetric radar measurements exploiting the IWC-flashes relation, whereas a second goal is the definition of different levels of severity of storms based on the quantity and typology of flashes predicted.

Our investigation is based on the observations of the Polar 55C Doppler C-band dual polarization research radar, installed on the roof of the Institute of Atmospheric Sciences and Climate (ISAC) in Rome and on the lightning strokes detected by the Lightning data from the European LIghtning detection NETwork (LINET) made available in real time at ISAC. A set of T-matrix simulations specific for graupel were set up to (i) tune a fuzzy logic hydrometeor classification algorithm for the detection of graupel from Polar 55C measurements and (ii) to retrieve IWC_g from radar reflectivity through an exponential relation. Estimation of columnar IWC_g by vertically integrating the IWC_g for each radar sampled volume classified as graupel in the region that typically consists of negative charging zone (vertical extension between -40° C and 0° C). Using a linear relation between columnar IWC_g (kg m^{-2}) and the number of flashes per km^{-2}, the possible flashes produced by given amounts of graupel mass can be inferred. Then the severity of storms can be defined in relation to the quantity of flashes predicted. A couple of significant case studies (the 15 October 2012 and the 14 October 2015) in which convective precipitation and intense lightning activities occurred, are presented. The dataset is partitioned to independently assess both the relation IWC-flashes and to test the prediction of flashes. One practical expected outcome of our analysis is a radar product that reveals the level of severity of the observed storms associated to the predicted lightning activity.