Assimilation experiments of GNSS-derived ZTD and Sentinel-derived products into WRF to improve forecasts of severe rain events in Italy

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The Italian peninsula is frequently struck by severe floods and flash floods causing losses of lives and significant damages every year. Improving the accuracy of rain forecasts is a fundamental goal to limit social and economic damages. Forecasts based on numerical weather prediction (NWP) models are challenged by the uncertainty related to the initial state of the atmosphere at small spatial-temporal scales. The inevitable model spin-up often results in an inaccurate simulation of the timing, the location and the severity of convective events. This challenge becomes even more relevant when the model grid spacing is approaching the kilometer scale, mainly because of the lack of high spatiotemporal resolution observations. In this scenario the STEAM (SaTellite Earth observation for Atmospheric Modelling) project, funded by the European Space Agency (ESA), has the aim of investigating to what extent GNSS-derived and Sentinel SAR-derived tropospheric delay data, as well as other Sentinel-derived products (i.e. soil moisture, soil and sea temperature, wind over sea) can be used to better understand and predict, with high spatial-temporal resolution, the atmospheric phenomena resulting in severe rain events and intense atmospheric turbulence. About 400 GNSS stations distributed throughout Italy were processed by the precise point positioning (PPP) technique, by means of the free and open source software goGPS, to estimate zenith total delay (ZTD) time series. Atmospheric phase screens (APS) were generated from Sentinel-1 observations, calibrated and converted to absolute tropospheric delays by using data from the Generic Atmospheric Correction Online Service for InSAR (GACOS). Surface soil moisture maps were retrieved from Sentinel-1 observations, by means of a multi-temporal algorithm that uses time series of Sentinel-1 data and ancillary data, such as a plant water content map, as inputs. Soil and sea temperature are directly available from ESA as level-2 products based on Sentinel-3, as well as the wind field over sea, based on Sentinel-1.
The experimental results concern two intense rainfall events and subsequent floods that occurred in Italy in Autumn 2017. The best results were obtained by assimilating the wind field (in the first test case) and the GNSS-derived ZTD (in the second test case). Promising results were achieved also by performing a combined assimilation of wind field and ZTD, and direct insertion of soil moisture. The outcomes of this study seem to confirm the synergy between high-resolution numerical weather models and a set of GNSS-derived and Sentinel-derived Earth Observation products, at least for the forecast of severe rain events.

Keywords: GNSS, SAR, Sentinel, NWP, Assimilation

