Dual-polarization radar signatures of the convectively driven Lausanne flash-flood event on June 11, 2018

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During the final part of June 11, 2018 a tropical thunderstorm hit the municipality of Lausanne causing severe damages to the city, which lies on a steep hill just in front of the Lemano lake. Several streets were flooded and acted like artificial creeks; the subway entrances were obviously flooded. According to the local media nothing similar has ever been observed in the last century. Effectively, a rain gage (LSN, 601 m altitude) downtown has observed the Swiss record ever for 10 min of accumulation time (which is the shortest official accumulation time in Switzerland): 40.9 mm, of which 23.7 mm (288 mm/h equivalent) during the 21:00-21:05 UTC interval and 17.2 mm between 21:05 and 21:10 UTC. The gradient in the precipitation field was extreme, even using a longer integration period: from 21 to 22 UTC, the LSN gage has recorded 49.6 mm/h; the closest gage, PUY (2.5 km SE, 456 m altitude) has recorded 17.1 mm/h. The previous 10-min Swiss record was caused by a fast moving super cell in the northeastern part of the Country(36.1 mm on August 2, 2017) while previous records were by summer thunderstorms on the southern side of the Alps: 33.6 mm in 2003 (30.3 mm in 1988). As expected, a national QPE radar product (1 km cartesian pixels), even though accumulated over a 1 hour period, is not adequate for such an event, which was characterized by an extreme spatio-temporal variability of the precipitation field [1]. The radar pixel that contains the LSN gage (~50 mm/h), shows a value of 13 mm/h. Even an intelligent radar-gage merging like Combiprecip [2] cannot significantly mitigate the underestimation in this case. As a matter of fact, the Combiprecip estimate raises "only" to 28 mm/h, despite the clever mechanism called "convection control" introduced in CombiPrecip (see [3] for a detailed description of "convection control"). Take home messages: in such events, one cannot simply take the radar echoes above the gage; rather, the full potential of the radar should be exploited. Indeed, the radar is a unique tool to describe with high spatial and temporal resolution WHEN and WHERE something is happening. For this exceptional event, we could store also radar echoes at the original high range resolution of 83.3 m in additional to the standard operational PPI of 500 m. We think we have been able to back-retrieve in space and time with the best achievable resolution the position of the cell that subsequently hit the gauge and also to identify the corresponding MAX echoes. Taking as an example the specific differential propagation phase delay, we traced high Kdp estimates approaching the gage location from the SW, descending from an altitude of 2440 m (end of PPI at 20:56 UTC), to ~2000 m (end of PPI at 20:58 UTC) and finally to the ground level. Very high Kdp peak values of 13.2°/km (12.9°/km) have been observed at high (standard) range resolution data, suggesting that the number concertation of the drops was extremely high in this cell. The positions of the Kdp MAX values of the cells are consistent and independent of the data range resolution (either 83.3 m or 500 m). As one could expect, high-range resolution data systematically give slightly larger values of Kdp as well as cell MAX reflectivity (typically ~ 2dB). Now we go to the crucial question: what rainfall intensity corresponds to a Kdp estimate of 13 °/km? A R-Kdp relationship optimized for Switzerland [4] would give an instantaneous rain rate of 124 mm/h. However, as pointed out in [4], other polarimetric signatures show that there are some rare cases, even in Switzerland, where the best-fit is inadequate. These are thunderstorms characterized by a maritime tropical air mass; in such rare cases, $R=30Kdp^{0.85}$ should be used [5], which is based on the Beard and Chuang DSD model and leads to a rain rate of 265 mm/h. Adding up, the huge amount of water (24 liters per square meter) measured at the ground between 21:00 and 21:05 UTC has been already detected (at 2.5 km altitude and approximately 3 km distance) by the dual-polarization radar as early as at 20:55:55 UTC. Imagine a futuristic radar signal processing scenario updated after every single sweep (10 or 15 or 20 s in the current operational Swiss scan program): then the real-time monitoring of the extreme event could be updated several times per minute.

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