

Response to Reviewer #3 (RC3)

Manuscript egusphere-2026-4014: "LESSONS report: Fine-scale representation of consecutive dry days"

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We thank Dr Marc Lemus-Canovas for a constructive and openly signed review. The two aspects raised by you go to the core of the lesson, and both lead to new analyses: an observational benchmark based on rain gauges, and a quantitative example of what kilometre-scale CDD differences mean in terms of water input. As the main text is close to the length limit of LESSONS Reports, the analyses are documented in the Supplement and summarised in the main text.

Reviewer comments are reproduced in dark red italics. New or revised manuscript text is quoted in blue; line numbers refer to the initial preprint. LESSONS Reports are limited to about 2000 words in the main text.

General assessment

This manuscript investigates the fine-scale spatial representation of CDD using four precipitation datasets over Germany. The authors show that CDD exhibits pronounced fine-scale spatial variability in the convection-permitting simulation and radar product, with sharp spatial gradients that arise from small differences in precipitation around the 1 mm/day threshold. The comparison using spatial autocorrelation and spectral analysis provides an interesting perspective on the scale dependence of CDD. In my opinion, the topic is relevant and the results potentially interesting for the interpretation of high-resolution precipitation datasets and dry-spell metrics. However, I think that two aspects of the manuscript require further consideration before the work can be considered for acceptance.

Response: We thank the reviewer for the positive assessment of the topic and address the two aspects below.

Specific comment #1

SC#1: Observational benchmark

The manuscript shows that COSMO-CLM and RADKLIM exhibit similar fine-scale spatial structures, whereas HYRAS and particularly ERA5 produce smoother CDD fields. The similarity between COSMO-CLM and RADKLIM is an interesting result. However, a benchmark dataset is still missing. To me, this is particularly relevant as the authors themselves highlighted that RADKLIM has uncertainties in the representation of low-intensity precipitation, including an underestimation of low-intensity precipitation events. Since CDD is defined using a threshold of 1 mm/day, these uncertainties are directly relevant to the metric investigated here.

I would suggest the authors compare CDD calculated directly from neighbouring in-situ precipitation stations with the corresponding CDD from COSMO-CLM, RADKLIM, HYRAS and ERA5 at the station locations. This would provide an independent observational benchmark and would

allow the authors to assess whether the fine-scale variability identified in the CPM and radar product is actually supported by observations. This could be included as a supplementary analysis/figure to strengthen the main message of the work.

Response: We agree that a benchmark is needed, in particular because the uncertainties of RADKLIM for light precipitation touch the 1 mm threshold. Before describing the new analysis, we note what Kreklow et al. (2020) report: the underestimation refers to hourly intensities below 1 mm h^{-1} , which they attribute to the filtering of low reflectivities during clutter correction and to shading. Such hourly underestimation can lower daily totals near 1 mm and thereby lengthen dry spells. In the domain mean, however, RADKLIM and HYRAS differ by less than 0.1 days (24.5 and 24.5 days over Germany, will be given in revised caption of Fig. 1). Since gridded gauge data tend to overestimate the wet-day frequency (Rauthe et al., 2013), this agreement could partly result from compensating effects, which is why we follow your suggestion.

We will add a station benchmark as new Supplement Figure. It uses the daily precipitation records of the DWD station network: 2084 gauges in Germany have data for 2018, i.e. one gauge per 172 km^2 (median distance to the nearest gauge 8.6 km). Requiring complete records would have excluded 18 % of the gauges. We therefore retained all gauges whose CDD is uniquely determined despite missing days, i.e. identical when missing days are treated as wet or as dry (1941 gauges, 91 %). For the comparison with the gridded data sets, we use the 1862 of these gauges that lie in the largest common domain of the three gridded data sets, and restrict the gridded statistics to pairs of grid cells within this domain. Nearly all values carry the DWD quality level 9 (routine quality control). The benchmark consists of two parts:

(a) Short-distance variability: For all pairs of stations up to 60 km apart, we compute the semivariance of their CDD, $0.5 E[(CDD_i - CDD_j)^2]$, in distance classes (0–5, 5–10, 10–15, 15–20, 20–30, 30–40, 40–60 km), and compare it with the semivariance of COSMO-CLM, RADKLIM, HYRAS and ERA5 over all pairs of grid cells at the same distances. This is the independent test of whether the fine-scale variability of the CPM and the radar product is supported by observations, as asked by the reviewer: if neighbouring gauges within 5 to 10 km differ as much as neighbouring COSMO-CLM and RADKLIM cells, the brushstrokes are real; if they differ as little as HYRAS, they are not.

(b) Point-wise agreement: At each station, we compare the station CDD with the CDD of the nearest grid cell of each data set (bias, mean absolute difference, correlation). We note two limitations. HYRAS interpolates these stations and RADKLIM is adjusted with gauge data, so the point-wise comparison is not independent for these two data sets. COSMO-CLM is free-running and is not expected to match individual stations (l. 74–76); for the CPM, only the statistics of part (a) are meaningful.

Results (draft of Fig. S6), for distances up to 30 km:

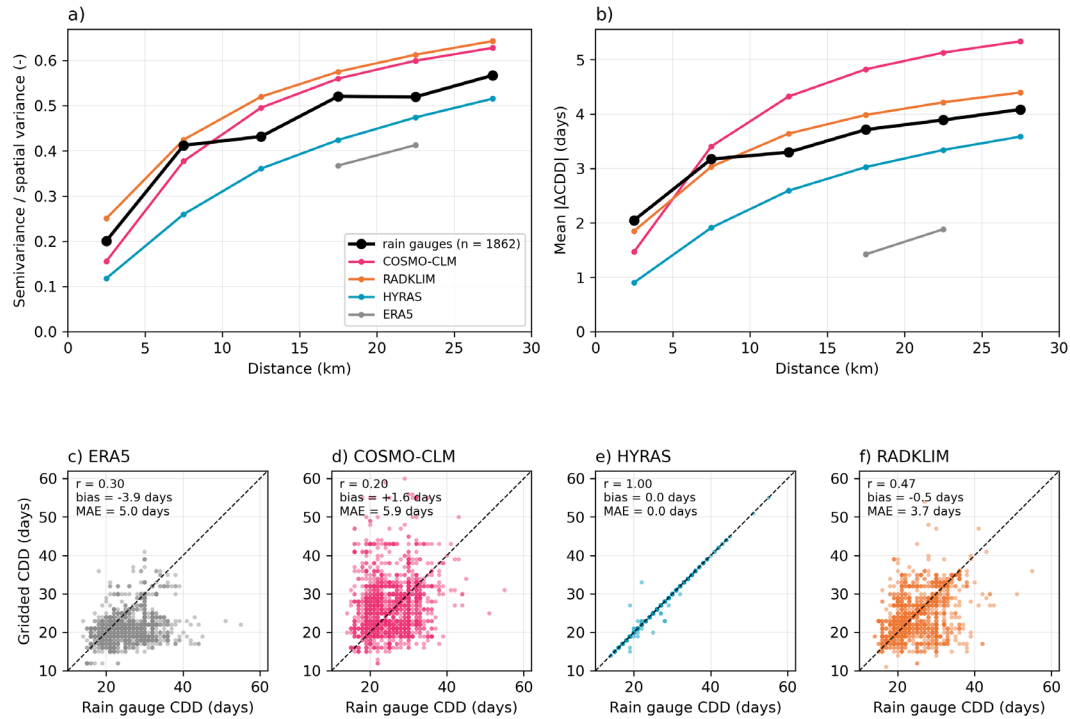
(a) The gauges confirm a substantial CDD variability over distances of a few kilometres. Gauges 5 to 10 km apart (946 pairs) differ by 3.2 days on average, and 6.4 % of these pairs differ by at least 10 days. RADKLIM shows very similar values (3.0 days; 8.4 %), COSMO-CLM somewhat larger ones (3.4 days; 11.7 %), and HYRAS considerably smaller ones (1.9 days; 5.0 %), i.e. HYRAS smooths between the gauges. COSMO-CLM has a larger overall spatial variability of CDD (variance of 50.3 days^2 compared with 30.1 days^2 for the gauges), so that its absolute differences exceed those of the gauges beyond 10 km. Relative to the spatial variance of each data set, however, the semivariance at

5 to 10 km is 0.41 for the gauges, 0.42 for RADKLIM, 0.38 for COSMO-CLM and 0.26 for HYRAS: the spatial structure of the CPM and the radar product is supported by the observations.

(b) Point-wise, HYRAS reproduces the gauge CDD ($r = 1.00$), as expected. RADKLIM agrees moderately ($r = 0.47$, bias -0.5 days, mean absolute difference 3.7 days), which also shows that its underestimation of light precipitation does not cause a noticeable CDD bias. ERA5 and COSMO-CLM are not expected to reproduce individual gauges: ERA5 underestimates CDD by 3.9 days on average ($r = 0.30$), consistent with its drizzle bias (l. 113–116), and the free-running COSMO-CLM does not place precipitation events at the observed locations ($r = 0.20$, bias $+1.6$ days, mean absolute difference 5.9 days). We summarise the result in the main text within the revised sentence at l. 133 (see also our response to Reviewer #2, comment 4):

New text (tracked change, Sect. 4, l. 133):

"We therefore assume that CPMs are capable of reproducing the fine-scale spatial statistics of CDD: the free-running CPM agrees with the independent radar product (Fig. 3; Supplement Sect. S5), and rain gauges 5 to 10 km apart differ by 3.2 days on average, comparable to COSMO-CLM (3.4 days) and RADKLIM (3.0 days) and more than in HYRAS (1.9 days) at the same distances (Supplement Sect. S6)."



Draft of new Fig. S6. Comparison of CDD in 2018 with 1862 DWD rain gauges in the largest common domain of all data sets. (a) Semivariance of CDD normalised by the spatial variance of each data set and (b) mean absolute CDD difference as a function of distance, for pairs of rain gauges (black) and for all pairs of grid cells of the gridded data sets in the common domain. (c to f) CDD of the nearest grid cell versus rain gauge CDD; ERA5 and COSMO-CLM are not expected to reproduce the CDD of individual gauges.

Specific comment #2

SC#2: Implications for drought conditions and impacts

The authors state that the observed spatial variability in CDD for short distances has implications for drought monitoring, impact assessment, drought propagation and low-flow analyses, etc, but none of these implications is explicitly discussed. In particular, it remains unclear to me whether large differences in CDD at kilometre scales translate into meaningful differences in drought conditions or impacts. I encourage the authors to discuss this scale dependence more explicitly and, if possible, provide at least one example illustrating whether the fine-scale CDD variability has consequences for a relevant application.

Response: We agree that the paper stated these implications without discussing them, and we thank you for pushing us to be explicit. We will now provide the requested example and a general quantification (newly revised Supplement Sects. S5 and S7), and the answer to the reviewer's question is, for our data: large CDD differences at kilometre scales mostly do not reflect meaningful differences in the water input.

- **Example (Fig. 2):** The two neighbouring cells in Fig. 2b (4.3 km apart) have CDD of 55 and 21 days, but they received 143 and 149 mm from April to October, with a correlation of 0.99 between their daily series. During the 55-day spell, the two cells received 2.3 and 5.0 mm; the difference is two events of 1.39 and 1.75 mm. In the second pair (Fig. 2d), the cell with the longer CDD (49 versus 26 days) even received more precipitation from April to October (307 versus 273 mm). The radar product shows the same behaviour: two adjacent RADKLIM pixels in western Germany received 228 and 235 mm from April to October but have CDD of 52 and 27 days, separated by a single day with 1.1 mm (Fig. S5).
- **Generalisation:** In the common domain of COSMO-CLM and RADKLIM, 5.9 % of all 68,759 pairs of adjacent COSMO-CLM cells differ by at least 10 days in 2018. For these pairs, the largest daily precipitation at the cell with the shorter CDD during the longest spell of its neighbour is below 2 mm in 70 % and below 5 mm in 94 % of the cases, and the median additional precipitation over the whole spell is 1.0 mm. In RADKLIM, 84 % of the corresponding pairs are separated by events below 2 mm. Across all 3 km cells, CDD is almost uncorrelated with the April to September precipitation total (Spearman $\rho = -0.13$).
- **Dependence on dry years:** Among the 30 years 1989–2018, 2018 has the highest share of adjacent pairs with CDD differences of at least 10 days (5.9 %; median of all years 1.4 %), and the share increases with the mean CDD of the year (Spearman $\rho = 0.60$). The noise is thus largest in drought years, when CDD is consulted most.

What this means for applications: water-balance-driven impacts such as soil moisture deficits, crop water stress or low flows respond to precipitation amounts and evaporative demand accumulated over weeks, not to whether a shower of 1.5 mm crossed a threshold on a single day. A CDD map at kilometre resolution would therefore show local drought 'hotspots' and 'coldspots' a few kilometres apart that have no counterpart in the water supply; used as a predictor in impact models, or in the evaluation of a CPM against stations, kilometre-scale CDD adds noise rather than information. We did not run an impact model, so we cannot show directly that the impacts are similar; we will therefore phrase the lesson in terms of water input. In the main text, the example and the

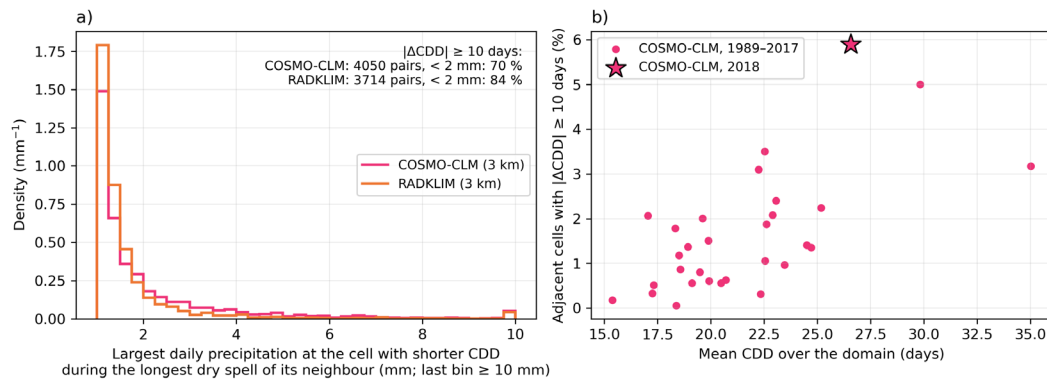
generalisation are added after l. 141 (two sentences, shared with the response to Reviewer #1), and the final paragraph now formulates the lesson for the applications listed by the reviewer:

New text (tracked insertion, Sect. 4, after l. 141):

"For instance, the two neighbouring cells in Fig. 2b differ by 34 days in CDD, although they received 143 and 149 mm from April to October. In COSMO-CLM and RADKLIM, 70 % and 84 % of the adjacent cells whose CDD differ by at least 10 days are separated by events below 2 mm, and such jumps are most frequent in dry years (Supplement Sect. S7)."

New text (tracked change, Sect. 4, replacing l. 145–147):

"Hence, as our lesson learnt, CDD is not a resolution-independent property of the local climate: coarse grids yield the shorter dry spells of area-mean precipitation, whereas kilometre-scale CDD at a single location is often decided by one event close to the threshold (Supplement Sects. S3 and S7). CDD should therefore only be compared between data sets of similar resolution and be interpreted with caution at individual locations in dry spell monitoring, drought impact and low-flow analyses, and climate model evaluation (e.g. ESMValTool; Weigel et al., 2021), whereas its spatial variability may serve as a diagnostic of precipitation intermittency."



Draft of new Fig. S7. (a) Largest daily precipitation at the cell with the shorter CDD during the longest dry spell of its neighbour, for all adjacent pairs of 3 km grid cells in the common domain of COSMO-CLM and RADKLIM with CDD differences of at least 10 days in 2018. (b) Share of adjacent COSMO-CLM cell pairs with CDD differences of at least 10 days versus the mean CDD over Germany for each year 1989–2018.