

Response to Reviewer #2 (RC2)

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

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We thank Dr Eleonora Dallan for a constructive and openly signed review. Her four comments led us to generalise the mechanism of Fig. 2 to all neighbouring grid cells and to the radar product, to report the domain-mean CDD of all data sets, to quantify the station density behind HYRAS, and to state more carefully what serves as the reference for the fine-scale patterns. As the main text is close to the length limit of LESSONS Reports, the new 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

The paper presents an analysis of the spatial structure of a threshold-based drought metric, the number of consecutive dry days (CDD), for four different precipitation products. While the 31-km resolution ERA5 shows limited spatial variability, the three km-scale products show substantially higher variability at short distances. In particular, the authors show how the surprising “brush-stroke” pattern emerging from the CPM and radar product is related to the threshold-based definition of CDD rather than to artifacts in these products. As a main lesson, they suggest caution when using this type of metric for drought assessment.

Based on my reading, the paper is clearly written and presents useful insights into the use of CDD (and similar threshold-based climate indices). I find it suitable for publication as LESSONS report after addressing the following minor comments.

Response: We are grateful for the positive assessment and have addressed all four comments as detailed below.

Minor comments

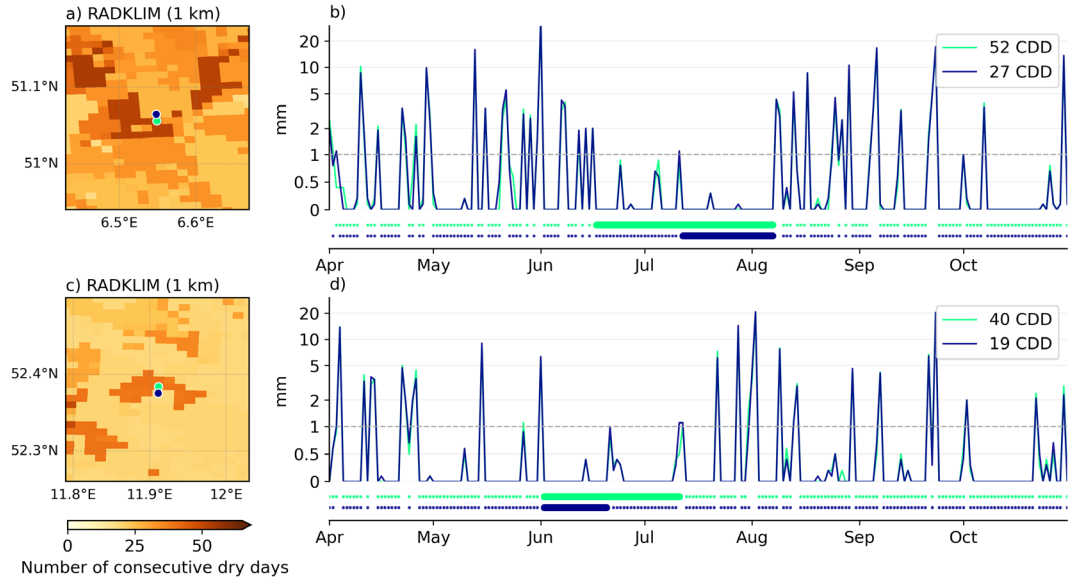
Figure 2: The radar product also shows “brush-stroke” patterns. Is this due to the same mechanism illustrated for the CPM in Figure 2? Adding a similar example based on two radar grid points could help clarify this point.

Response: Yes, the same mechanism is at work, and we will show it in two new Supplement Figures. We will add an example analogous to Fig. 2 for two pairs of adjacent RADKLIM cells (new Fig. S5 and Supplement Sect. S5): in western Germany, two pixels with 228 and 235 mm from April to October and almost identical daily series have CDD of 52 and 27 days, because a single day with 1.1 mm crossed the threshold at one of them; in eastern Germany, two days with 1.0 and 1.1 mm separate

CDD of 40 and 19 days at pixels with 164 and 165 mm. Because of the length limit, the main text only states the result, and the numbers are given in the Supplement:

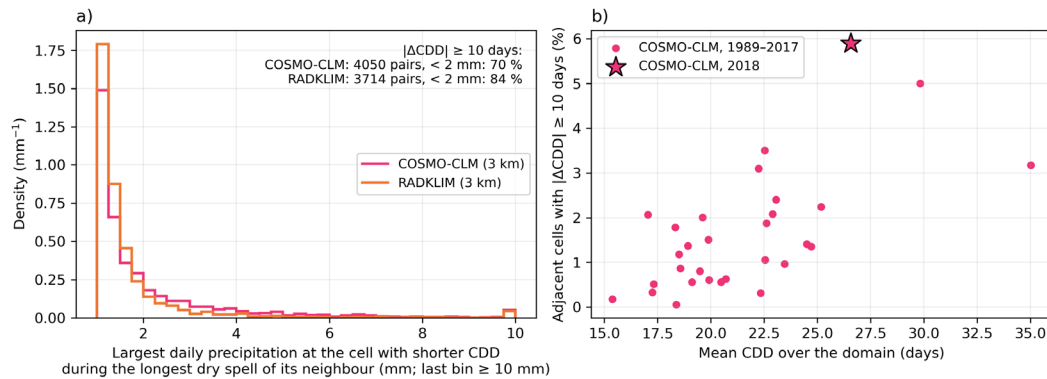
New text (tracked insertion, Sect. 3, after I. 88):

"The same mechanism produces the brushstrokes in RADKLIM (Fig. S5)."



Draft of new Fig. S5. As Fig. 2, but for RADKLIM (1 km): CDD in 2018 in two regions (a, c) and time series of daily precipitation (b, d) at the two adjacent pixels marked in (a) and (c).

Further, on the common 3 km grid, 5.1 % of all adjacent RADKLIM cell pairs differ by at least 10 days, similar to COSMO-CLM (6.0 %) and twice as often as in HYRAS (2.4 %). Generalizing the exercise of Fig. 2 to the full 68,759 cells of COSMO & RADKLIM in their common domain, we assess each pair with a CDD difference of at least 10 days. We determine the precipitation that fell at the cell with the shorter CDD during the longest dry spell of its neighbour. For COSMO-CLM (4050 pairs in the common domain of COSMO-CLM and RADKLIM), the largest daily amount in this window has a median of 1.4 mm, is below 2 mm in 70 % and below 5 mm in 94 % of the pairs. For RADKLIM on the same 3 km grid (3714 of the same 68,759 adjacent pairs), the median is 1.3 mm, and the event is below 2 mm in 84 % and below 5 mm in 97 % of the pairs; on the native 1 km grid, 96 % of the pairs with CDD differences of at least 10 days are separated by events below 2 mm.



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.

Lines 114–116: You mention here the possible underestimation of CDD by ERA5. Since “evaluation of the CDD magnitudes is not the focus of the study” (line 74), perhaps the lesson learned could focus more specifically on the spatial structure and the implications of the threshold-based definition. The same applies to lines 128–130. Alternatively, if the magnitude of CDD is relevant to the discussion, you could add some consideration of the average CDD over the domain when presenting Figure 1.

Response: We will follow the second option, because the magnitudes are needed for two arguments of the paper: the lower CDD of ERA5, and the possible effect of the underestimation of light precipitation in RADKLIM. We will add the mean CDD over the largest common domain of all four data sets to the caption of Fig. 1 (ERA5: 21.0 days, COSMO-CLM: 26.8 days, HYRAS: 24.5 days, RADKLIM: 24.5 days) and the full statistics (median, percentiles, range) in a new Table S1. With these numbers, the statements at l. 113–116 and 126–130 become verifiable, and we will sharpen both:

ERA5 (l. 113–116). ERA5 has the lowest mean CDD of all data sets. Following a suggestion of Reviewer #1, we aggregated the COSMO-CLM precipitation to coarser grids before computing CDD, which shows that about 40 % of the difference between COSMO-CLM and ERA5 is explained by the grid spacing alone: "Part of this difference stems from the grid spacing: averaging the COSMO-CLM precipitation to 30 km before computing CDD reduces its mean over Germany from 26.8 to 24.5 days, compared with 21.0 days in ERA5 (Supplement Sect. S3)."

RADKLIM (l. 126–130). The mean CDD of RADKLIM is within 0.1 days of that of HYRAS. We now state this, and we specify that the underestimation found by Kreklow et al. (2020) refers to hourly intensities below 1 mm h⁻¹: "In a comparison with rain gauges, Kreklow et al. (2020) found that RADKLIM underestimates the frequency of low-intensity precipitation events (hourly intensities below 1 mm h⁻¹), ... Nevertheless, spatial patterns are generally well reproduced, and the mean CDD of RADKLIM over the common domain differs from that of HYRAS by less than 0.1 days (Fig. 1)." We note in the Supplement that this agreement does not prove the absence of biases, since gridded gauge data tend to overestimate the wet-day frequency (Rauthe et al., 2013) and the two effects may partly compensate; the station benchmark requested by Reviewer #3 addresses this point (Supplement Sect. S6). The station benchmark confirms that the agreement of the domain means does not hide a large bias: at the gauge locations, the RADKLIM CDD is on average only 0.5 days shorter than the gauge CDD.

l. 73–77. We kept the statement but specified it: "We note that a direct evaluation of CDD magnitudes at individual grid cells is not the focus of this study, ..."

Lines 117–119: Could you mention the typical inter-station distance? The steep gradients also depend on how close the stations are to each other when their CDD values “differ substantially”.

Response: Thank you, this is an important detail. HYRAS interpolates daily station values with the REGNIE method, that is, daily ratios to a regression-based background field are distributed with inverse distance weights from the four closest stations, and the observed values are retained at grid points with stations (Rauthe et al., 2013). In 2018, 2084 daily rain gauges with data were operated in Germany (DWD open data), i.e. one gauge per 172 km², corresponding to an equivalent spacing of 13 km; the median distance from a gauge to its nearest neighbour is 8.6 km. The bull’s-eye structures in Fig. 1c appear to have diameters of the same order of magnitude, which is consistent with your point that the gradients depend on the station distance. Rauthe et al. (2013) also document both effects

that matter here: bull's-eye patterns around single stations and a blurred distinction between dry days and days with small amounts, because small station values are spread into the surrounding grid cells. We revised the sentence at l. 117–119:

New text (tracked change, Sect. 4, l. 117–119):

"Although HYRAS is derived from about 2100 rain gauges in Germany (one gauge per 172 km² in 2018, with a median distance of 8.6 km to the nearest gauge), the bull's-eye anomalies in CDD are attributed here to the interpolation, which preserves daily precipitation at gauge locations but produces bull's-eye patterns around single gauges and spreads small amounts into the surrounding grid cells (Rauthe et al., 2013), a known property of inverse distance weighting (Cressie, 2010)."

We also now describe the interpolation method of HYRAS precisely in the data section:

New text (Sect. 2, l. 48):

"3) gridded observations of quality-checked rain gauge measurements (HYRAS) at 1 km, obtained by interpolating the ratio between daily gauge precipitation and a background field from multiple linear regression with inverse distance weights of the four nearest gauges (Rauthe et al., 2013), ..."

Line 133: On what basis do you conclude that the CPM reproduces the fine-scale spatial patterns of CDD? Similarly, at line 143, on what basis do you conclude that the station-based product misses them? In other words, what is considered the reference or "truth" for these fine-scale patterns?

Response: This is a fair question, and we have rephrased both statements. There is no gridded *truth* for CDD at scales of a few kilometres. Our conclusion at l. 133 rests on the agreement of the spatial statistics, not of the patterns themselves, between two sources that are independent in how they obtain fine-scale structure: a radar product that observes the precipitation field with full spatial coverage and a free-running CPM that does not assimilate precipitation observations. Both agree in Moran's I, in the spectra (Fig. 3), and in the frequency of sharp jumps between adjacent cells (6.0 % and 5.1 % of pairs differ by at least 10 days). Neither is the truth: the CPM has model errors, and RADKLIM has known measurement uncertainties (Kreklow et al., 2020). As an independent observational reference for the existence of short-distance CDD variability, we will add the station benchmark requested by Reviewer #3, which compares the CDD differences between neighbouring rain gauges with those in the gridded data sets. The gauges confirm a substantial CDD variability over a few kilometres (see our response to Reviewer #3): gauges 5 to 10 km apart differ by 3.2 days on average, similar to RADKLIM (3.0 days) and COSMO-CLM (3.4 days) at the same distances, and clearly more than HYRAS (1.9 days), which smooths between the gauges. Relative to the spatial variance of each data set, the semivariance at these distances is 0.41 for the gauges, 0.42 for RADKLIM, 0.38 for COSMO-CLM and 0.26 for HYRAS. All gauge-based statistics refer to the largest common domain of the three gridded data sets.

At l. 143, our point was that a station network samples the CDD at points: each gauge records the local CDD, but with one gauge per 172 km² (median distance to the nearest gauge 8.6 km), the network *samples* these structures rather than *mapping* them, and gridded station data such as HYRAS smooth between the gauges (see C3). We revised both passages:

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)."

New text (tracked change, Sect. 4, l. 142–144):

"... which is what the ETCCDI were originally designed for: a gauge records the local CDD, but with one gauge per 172 km², a station network samples rather than maps the fine-scale variability documented here (Supplement Sect. S6), and the apparent (dis-)agreement between station records and gridded CDD may be coincidental rather than physically meaningful."