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Supplement of

LESSONS report: Fine-scale representation of consecutive dry days

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S1 Additional years and an independent convection-permitting simulation

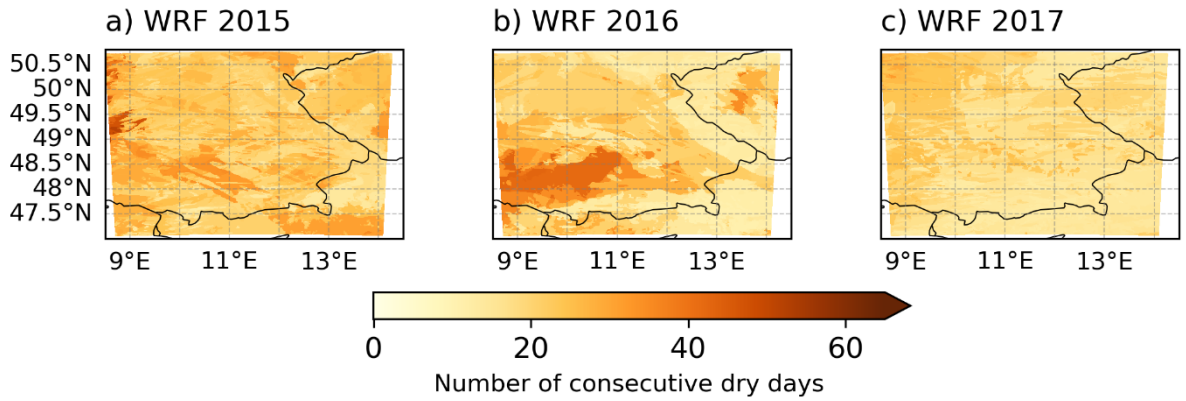


Figure S1: Number of consecutive dry days in 2015 (a), 2016 (b), and 2017 (c) based on the convection-permitting 1.5 km resolution WRF simulation by Collier & Mölg (2020).

S2 Alternative dry-day thresholds

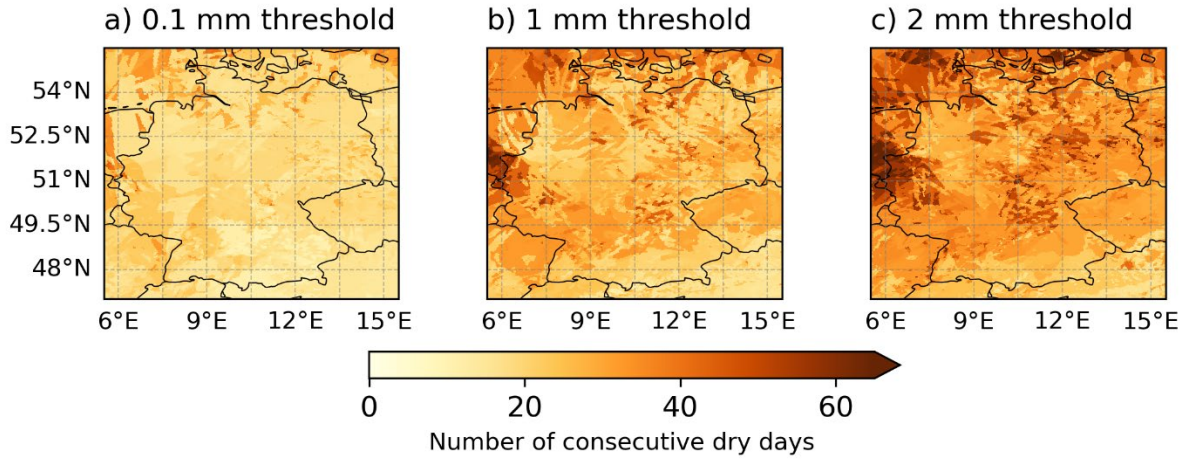


Figure S2: Number of consecutive dry days in 2018 for convection-permitting simulations of COSMO-CLM using a dryness threshold of 0.1 mm (a), 1 mm (b), and 2 mm (c).

S3 Resolution dependence of CDD

To test how CDD depends on the grid spacing, we averaged the daily COSMO-CLM precipitation of 2018 conservatively over blocks of 2 × 2 to 33 × 33 grid cells, corresponding to grid spacings of 6, 12, 24, 30, 51 and 99 km, and recomputed CDD on each grid (Fig. S3). With coarser grid spacing, the mean number of wet days (≥ 1 mm) over Germany increases from 94 at 3 km to 101 at 30 km and 111 at 99 km, because spatial averaging spreads local precipitation over the whole grid cell. Accordingly, the mean CDD over Germany decreases from 26.8 days at 3 km to 24.5 days at 30 km and 23.0 days at 99 km (Fig. S3e). About 40 % of the difference between COSMO-CLM (26.8 days) and ERA5 (21.0 days) is therefore explained by the grid spacing alone, consistent with the decrease of dry-day frequency and dry-spell length after conservative remapping of kilometre-scale models reported by Wille et al. (2025). In contrast, averaging the 3 km CDD field instead of the precipitation leaves the mean almost unchanged (26.8 to 27.0 days): a coarse-grid CDD is not the average of the local CDD.

At a fixed radius of about 100 km, Moran's I increases from 0.17 at 3 km to 0.28 at 30 km and 0.32 at 51 km (Fig. S3f; at 99 km, Germany contains only 36 grid cells and the estimate of 0.23 is uncertain), i.e. coarser CDD fields are spatially more coherent. The coefficient of variation of the CDD field, however, changes little (0.27 at 3 km, 0.24 at 30 km, 0.23 at 99 km), and the 12 and 30 km fields still show abrupt jumps between adjacent grid cells (Fig. S3b, c). The threshold sensitivity thus persists at every resolution, at the scale of the grid cell.

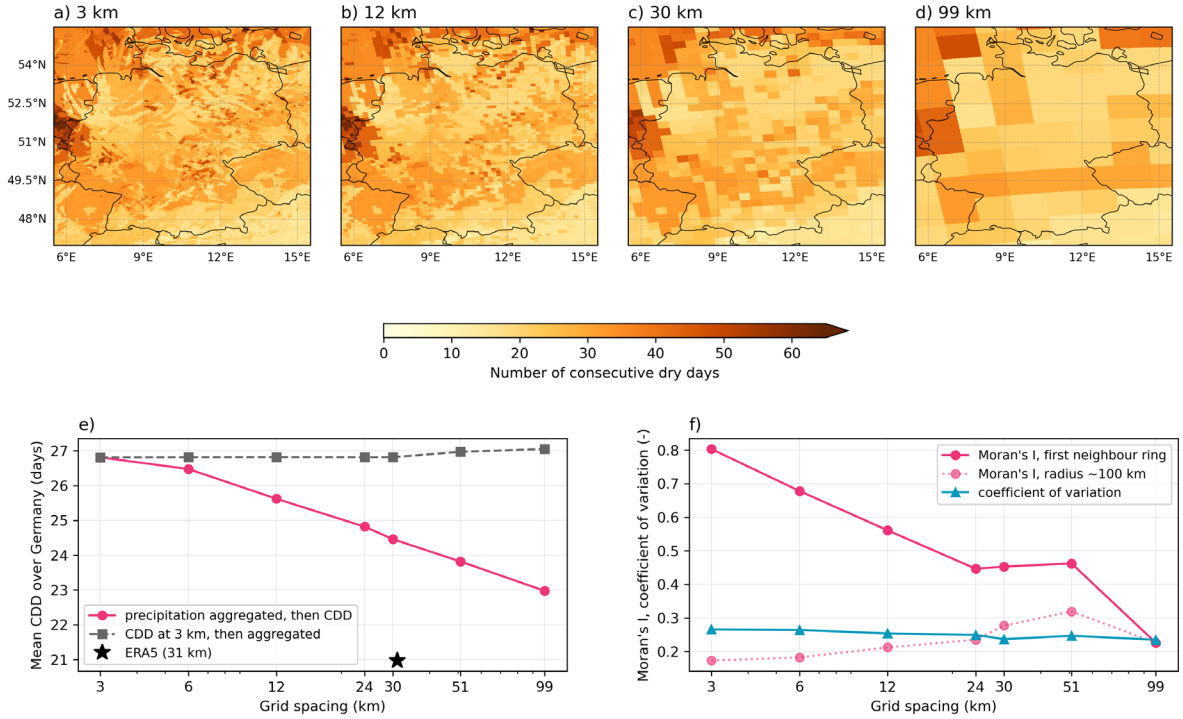


Figure S3: CDD in 2018 from COSMO-CLM after averaging the daily precipitation to (a) 3 km (native), (b) 12 km, (c) 30 km and (d) 99 km. (e) Mean CDD over Germany as a function of grid spacing when the precipitation is aggregated before computing CDD (pink) and when the 3 km CDD is aggregated (grey); the star marks ERA5. (f) Moran's I for the first neighbour ring (8 directly adjacent grid cells) and for a radius of about 100 km, and coefficient of variation of the CDD field over Germany.

S4 CDD compared with other indices of the same simulation

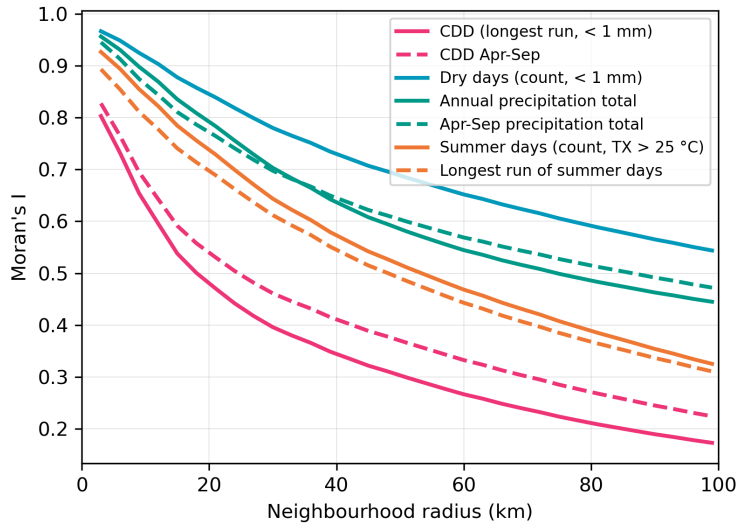


Figure S4: Moran's I as a function of neighbourhood radius for indices computed from the COSMO-CLM simulation of 2018 over Germany: the number of dry days (< 1 mm), the annual and April to September precipitation totals, CDD restricted to April to September, the number of summer days (daily maximum temperature above 25 °C) and the longest run of summer days.

S5 Abrupt CDD transitions in RADKLIM

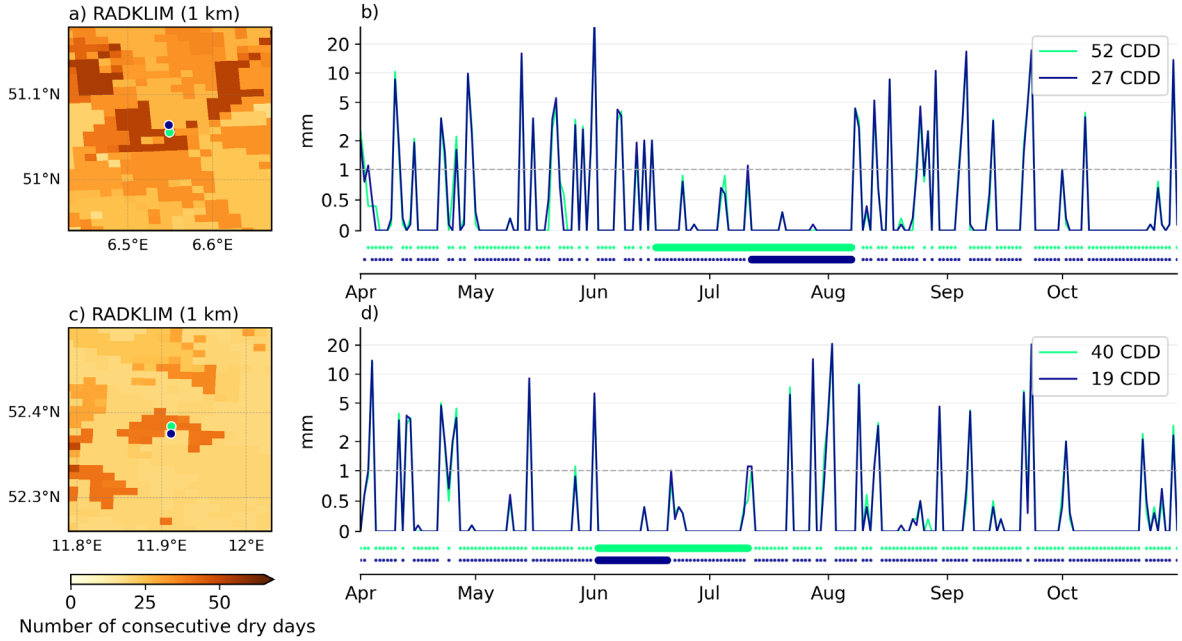


Figure S5: As Fig. 2, but for RADKLIM (1 km): CDD in 2018 in two regions (a, c) and time series of daily precipitation (b, d) at the two adjacent pixels marked in (a) and (c). The dots in (b) and (d) mark dry days below the threshold of 1 mm, where the thick line highlights the longest spell of consecutive dry days. The y-axis is linear below 1 mm and logarithmic above 1 mm.

S6 Comparison with rain gauges

We used the daily precipitation records of the DWD station network (open data of the DWD Climate Data Center, daily precipitation, historical archive). Of the 2134 records in Germany covering 2018, 2084 contain data for 2018, i.e. one gauge per 172 km² (equivalent spacing of 13 km; median distance to the nearest gauge 8.6 km). Nearly all values carry the DWD quality level 9 (routine quality control), and no negative values occur. Complete records for 2018 are available at 1757 gauges (82 %) and complete records for April to October at 1810 gauges (85 %). To avoid discarding gauges because of a few missing days, we retained all gauges whose CDD is uniquely determined, 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 used the 1862 of these gauges that lie in the largest common domain of all data sets (3 km cells where COSMO-CLM, HYRAS and RADKLIM are valid, as for Figs. 1 and 3 and Table S1), and all statistics of the gridded data sets refer to pairs of grid cells within this domain.

Figure S6a shows the semivariance of CDD, $\frac{1}{2}\,E[(CDD_i - CDD_j)^2]$, for distances up to 30 km, normalised by the spatial variance of each data set over the common domain. The normalisation separates the spatial structure from the overall variability, which is considerably larger in COSMO-CLM. For gauges 5 to 10 km apart (946 pairs), the semivariance amounts to 41 % of the spatial variance, similar to RADKLIM (42 %) and COSMO-CLM (38 %) and clearly more than HYRAS (26 %). In absolute terms (Fig. S6b), these gauges differ by 3.2 days on average, compared with 3.0 days for RADKLIM, 3.4 days for COSMO-CLM and 1.9 days for HYRAS at the same distances; beyond 10 km, the absolute differences of COSMO-CLM exceed those of the gauges because of its larger overall variability. The rain gauges therefore confirm a substantial CDD variability over distances of a few kilometres.

At the gauge locations (nearest grid cell; Fig. S6c to f), HYRAS reproduces the station CDD ($r = 1.00$, mean absolute difference below 0.1 days), as expected for an interpolation of these gauges. RADKLIM agrees moderately ($r = 0.47$, bias −0.5 days, mean absolute difference 3.7 days). ERA5 and COSMO-CLM are not expected to reproduce the CDD of individual gauges as they do not assimilate precipitation. ERA5 represents area means of about 30 km and underestimates CDD by 3.9 days on average ($r = 0.30$), consistent with its drizzle bias, and the free-running COSMO-CLM does not place individual precipitation events at the observed locations ($r = 0.20$, bias +1.6 days, mean absolute difference 5.9 days).

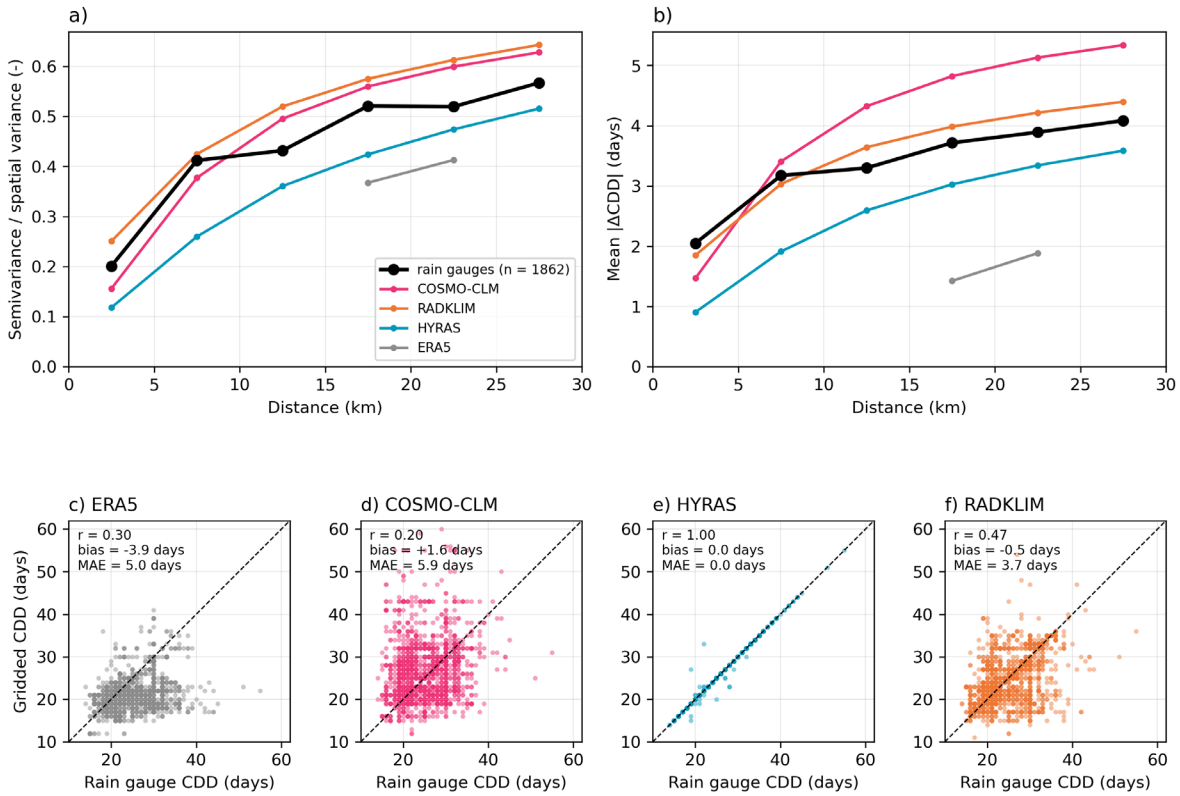


Figure S6: Comparison of CDD in 2018 with 1862 DWD rain gauges in the largest common domain of all data sets. (a) Semivariance of CDD normalised by the spatial variance of each data set and (b) mean absolute CDD difference as a function of distance, for pairs of rain gauges (black) and for all pairs 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.

S7 Events separating neighbouring grid cells

For all pairs of horizontally or vertically adjacent grid cells whose CDD differ by at least 10 days, we determined the largest daily precipitation at the cell with the shorter CDD during the longest dry spell of its neighbour (Fig. S7a). The analysis covers the common domain of COSMO-CLM and RADKLIM, i.e. the 34,857 cells of the 3 km grid where the daily RADKLIM precipitation, remapped to the COSMO-CLM grid, is available on all days of 2018. In COSMO-CLM, 5.9 % of the 68,759 adjacent pairs differ by at least 10 days in 2018. For these 4050 pairs, the separating event has a median of 1.4 mm; it is below 2 mm in 70 % and below 5 mm in 94 % of the pairs, typically on a single wet day, and the median additional precipitation over the whole spell is 1.0 mm. In RADKLIM, 5.4 % of the same adjacent pairs differ by at least 10 days; the separating event has a median of 1.3 mm and is below 2 mm in 84 % and below 5 mm in 97 % of the pairs (on the native 1 km grid: 2.8 % of the pairs, of which 96 % are separated by events below 2 mm).

Such abrupt transitions are most frequent in dry years (Fig. S7b). Among the 30 years 1989 to 2018 of COSMO-CLM, 2018 has the highest share of adjacent pairs with CDD differences of at least 10 days in the same domain (5.9 %; median of all years 1.4 %), and the share increases with the mean CDD of the year (Spearman $\rho = 0.60$).

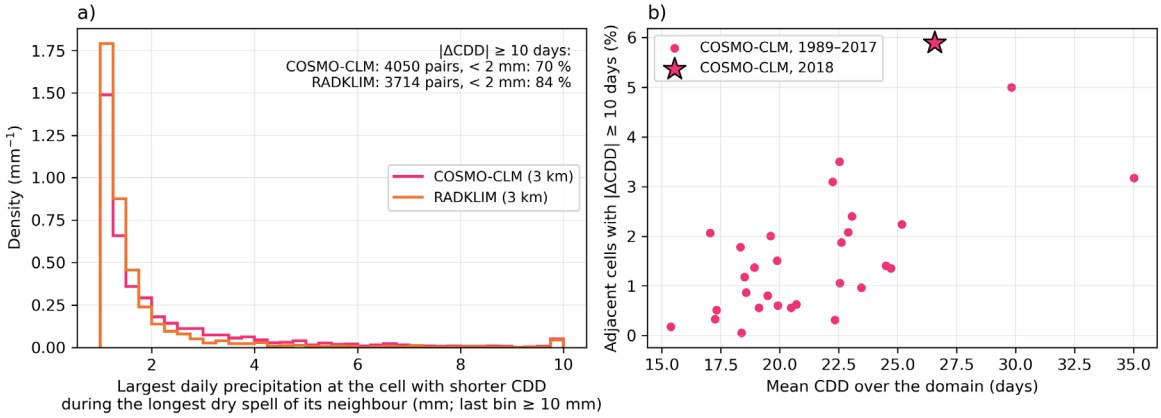


Figure S7: (a) Largest daily precipitation at the cell with the shorter CDD during the longest dry spell of its neighbour, for all adjacent pairs of 3 km grid cells in the common domain of COSMO-CLM and RADKLIM with CDD differences of at least 10 days in 2018. (b) Share of adjacent COSMO-CLM cell pairs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

Table S1: Statistics of CDD in 2018 for the four data sets, sampled at the centres of the 36,634 cells (3 km) of the largest common domain of all data sets, i.e. where COSMO-CLM, HYRAS and RADKLIM are valid (as for Figs. 1 and 3): number of sample points, mean, median, standard deviation, percentiles, minimum and maximum (days).

Data set and native resolution	Grid cells	Mean	Median	SD	P1	P5	P95	P99	Min	Max
ERA5 (31 km)	36634	21.0	20	3.7	15	16	30	33	12	41
COSMO-CLM (3 km)	36634	26.8	26	7.1	16	19	41	50	12	68
HYRAS (1 km)	36634	24.5	23	5.4	16	17	33	36	13	55
RADKLIM (1 km)	36634	24.5	23	5.5	15	17	34	39	11	56