Online Resource 1

Supplementary material to: Observational source choice outweighs the emission scenario in projected dependable precipitation: evidence from 44 rain gauges in southern Brazil.

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S1 Exclusion of rain gauge 2854016

Section 2.3 states that exclusion of a gauge required concurrent failure in independent criteria. Gauge 2854016 was the only one to meet that condition. Its monthly totals disagree with every neighbour within 50 km, its annual series carries a change point in 2011 and a steep negative trend, and none of the gridded products reproduces either at the same location.

Table S1 Monthly correlation of gauge 2854016 with each rain gauge within 50 km, 2002 to 2025

Gauge	Name	Distance (km)	Months	r
2854018	JÓIA	32.2	212	0.664
2853003	CONCEIÇÃO	32.7	212	0.675
2854006	PASSO VIOLA	37.0	213	0.622
2854003	GIRUÁ	40.2	215	0.536
2854012	COIMBRA	44.3	224	0.641
2854001	BOA VISTA	45.2	212	0.575
2854005	PASSO MAJOR ZEFERINO	49.1	214	0.632

Distances are great-circle. Months is the number of calendar months in which both series have at least 26 valid days.

Table S2 The same correlation set against the coherence of the retained network

Comparison	Median r	5th percentile	Maximum
Gauge 2854016 against its 7 neighbours	0.632	0.536	0.675
All retained pairs < 50 km (n = 109)	0.876	0.806	—
Weakest retained gauge (2855008)	0.760	—	—

Pairs of retained gauges less than 50 km apart agree at a median r of 0.876 and none falls below 0.76. Gauge 2854016, at 0.632, lies below the 5th percentile of that distribution.

The annual series of the gauge gives a Sen slope of −52.3 mm per year over the 20 usable years and a Pettitt change point in 2011 at p = 0.005. At the same location CHIRPS and NASA POWER give slopes of +1.6 and −12.0 mm per year and neither test is significant, which is the asymmetry reported in Section 3.1.

S2 Month assignment under the 360-day calendar

Section 2.5 reports that the inverted annual cycle of KACE-1-0-G is not an artefact of the month reconstruction. KACE-1-0-G is the only model of the set with a 360-day calendar, in which mapping model dates onto the Gregorian calendar produces 53 collisions over 30 years. The month was therefore reconstructed from the position of each record within the year. Three independent criteria of

month assignment were compared: the month of the converted date, the position within the year divided by 30, and the position rescaled to twelve equal months. The monthly climatologies returned by the three agreed to the third decimal place, and the optimal circular shift of the simulated cycle against the observed one was zero under all three, whereas a calendar artefact would have produced a shift of about six months.

Table S3 Phase of the simulated annual cycle against the observed one, under three criteria of month assignment, 2002 to 2014

Criterion	Model	r at zero shift	Optimal shift	r at optimal shift	Peak	Trough	Amplitude (mm)
Position / 30	ACCESS-ESM1-5	0.931	0	0.931	Oct	Aug	107.2
Position / 30	IPSL-CM6A-LR	0.575	0	0.575	Dec	Jul	83.2
Position / 30	INM-CM4-8	0.733	0	0.733	Dec	Aug	80.8
Position / 30	INM-CM5-0	0.577	0	0.577	Dec	Aug	86.0
Position / 30	ACCESS-CM2	0.494	1	0.572	Oct	Mar	51.2
Position / 30	KACE-1-0-G	−0.185	7	0.593	May	Aug	156.7
Converted date	ACCESS-ESM1-5	0.973	0	0.973	Oct	Aug	113.8
Converted date	IPSL-CM6A-LR	0.621	0	0.621	Oct	Jul	86.7
Converted date	INM-CM4-8	0.798	0	0.798	Oct	Aug	74.8
Converted date	INM-CM5-0	0.527	0	0.527	Oct	Aug	86.1
Converted date	ACCESS-CM2	0.526	0	0.526	Oct	Jul	51.9
Converted date	KACE-1-0-G	−0.184	7	0.605	May	Aug	156.7
Position rescaled	ACCESS-ESM1-5	0.969	0	0.969	Oct	Aug	113.8
Position rescaled	IPSL-CM6A-LR	0.608	0	0.608	Oct	Jul	91.1
Position rescaled	INM-CM4-8	0.784	0	0.784	Oct	Aug	74.8
Position rescaled	INM-CM5-0	0.559	0	0.559	Oct	Aug	86.1
Position rescaled	ACCESS-CM2	0.485	0	0.485	Oct	Jul	61.5
Position rescaled	KACE-1-0-G	−0.185	7	0.593	May	Aug	156.7

The optimal shift is the circular displacement of the simulated cycle, in months, that maximises its correlation with the observed cycle. The first criterion is the one the pipeline applies to a 360-day calendar. The observed cycle of the network peaks in October and troughs in August.

KACE-1-0-G is negatively correlated with the observed cycle under all three criteria, and all three place its optimum at a shift of seven months, where the correlation still reaches only 0.59 to 0.61. The five retained models require no shift, the single exception being ACCESS-CM2 at one month under the second criterion. A reconstruction error would have been removed by at least one of the criteria, or the shift would have recovered a high correlation. Neither happens, so the inverted peak is a property of the model and not of the calendar handling. The trough of KACE-1-0-G falls in August under every criterion, which is also the observed trough, so it is the position of the maximum alone that is misplaced.

S3 Change factors for the 2027 to 2040 window

Figure 5 shows the change factors for 2041 to 2070. The tables below give the same quantities for the near window. Values are medians across the 44 network sites, expressed relative to the historical window of 1985 to 2014, so that values above 1 denote an increase. Over both windows and all three scenarios the factors span 0.65 to 1.30 for occurrence and 0.69 to 1.36 for intensity.

Table S4 Occurrence change factors, 2027 to 2040

Scenario and model	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
SSP1-2.6 ACCESS-ESM1-5	0.93	0.85	1.06	1.00	1.13	0.97	1.07	1.06	1.11	1.10	0.98	0.91
SSP1-2.6 INM-CM4-8	1.03	1.03	0.97	1.15	0.99	1.02	1.11	1.19	1.02	1.02	0.89	1.03
SSP1-2.6 IPSL-CM6A-LR	1.02	1.09	1.04	1.00	0.96	1.08	0.90	0.74	0.96	0.99	1.00	0.90
SSP1-2.6 ACCESS-CM2	0.93	1.01	1.00	0.97	0.88	1.04	1.04	1.08	1.20	1.13	1.21	1.02
SSP1-2.6 INM-CM5-0	1.05	1.00	1.00	1.03	1.02	1.02	1.12	1.06	0.99	0.97	1.11	0.91
SSP2-4.5 ACCESS-ESM1-5	0.99	1.20	1.21	1.07	1.07	1.04	0.98	0.90	1.06	1.00	1.10	0.81
SSP2-4.5 INM-CM4-8	0.99	1.01	1.07	1.02	0.79	0.89	1.03	1.09	0.98	0.96	0.86	1.03
SSP2-4.5 IPSL-CM6A-LR	0.94	1.05	0.81	1.07	0.83	0.93	0.83	0.82	0.75	1.01	0.97	1.06
SSP2-4.5 ACCESS-CM2	0.89	1.02	0.96	1.09	0.84	1.00	1.01	1.18	1.13	1.08	1.17	1.07
SSP2-4.5 INM-CM5-0	1.12	1.03	1.03	1.22	0.89	1.05	1.10	1.18	1.06	1.07	0.99	0.89
SSP5-8.5 ACCESS-ESM1-5	0.97	1.13	1.07	1.05	1.07	0.86	0.93	1.00	0.95	1.03	1.07	0.90
SSP5-8.5 INM-CM4-8	1.06	1.05	0.93	1.15	0.91	0.86	0.97	1.20	0.99	0.96	1.07	1.01
SSP5-8.5 IPSL-CM6A-LR	0.97	0.96	0.93	0.99	0.91	0.85	0.90	0.74	0.88	0.90	1.03	1.03
SSP5-8.5 ACCESS-CM2	0.99	1.01	0.96	1.05	1.01	0.99	1.08	1.22	1.13	1.05	1.11	1.09
SSP5-8.5 INM-CM5-0	1.12	1.06	1.03	0.95	0.91	1.14	1.09	1.04	1.02	0.98	1.02	1.02

Medians across the 44 sites.

Table S5 Intensity change factors, 2027 to 2040

Scenario and model	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
SSP1-2.6 ACCESS-ESM1-5	1.09	0.95	1.03	1.19	1.02	1.19	0.93	0.94	1.04	0.99	1.06	0.95
SSP1-2.6 INM-CM4-8	0.98	0.93	0.99	1.01	1.09	1.18	1.00	1.19	0.98	1.10	0.98	0.99
SSP1-2.6 IPSL-CM6A-LR	0.99	1.02	1.06	0.97	0.99	0.83	1.03	1.06	1.02	0.97	1.04	0.94
SSP1-2.6 ACCESS-CM2	1.01	1.00	0.93	1.00	0.94	1.11	1.18	1.15	0.99	1.10	1.17	1.03
SSP1-2.6 INM-CM5-0	0.99	0.98	0.98	1.12	1.02	1.00	0.99	0.78	0.94	1.03	0.97	1.03
SSP2-4.5 ACCESS-ESM1-5	1.01	0.93	1.08	1.06	1.15	1.17	0.94	0.87	1.01	1.06	1.12	0.98
SSP2-4.5 INM-CM4-8	0.96	0.92	1.12	1.09	0.96	0.83	1.08	1.21	1.13	0.99	1.05	1.01
SSP2-4.5 IPSL-CM6A-LR	1.01	0.98	1.12	0.91	0.85	1.06	1.16	0.90	0.96	0.98	1.10	0.99
SSP2-4.5 ACCESS-CM2	0.90	1.03	0.88	1.05	1.05	1.14	0.97	0.90	0.98	1.07	1.19	1.04
SSP2-4.5 INM-CM5-0	0.97	1.05	1.06	1.22	1.00	1.06	0.95	0.88	1.15	1.09	1.14	0.99
SSP5-8.5 ACCESS-ESM1-5	1.07	1.06	1.11	1.01	1.03	0.98	1.07	0.97	0.87	1.09	1.10	0.98
SSP5-8.5 INM-CM4-8	0.99	0.99	1.22	1.11	0.86	0.90	1.05	1.28	0.87	1.03	1.02	0.99
SSP5-8.5 IPSL-CM6A-LR	1.03	1.00	0.98	0.91	0.99	1.02	1.13	0.97	1.00	0.92	1.12	1.00
SSP5-8.5 ACCESS-CM2	1.01	0.92	1.05	1.00	0.95	1.08	1.13	0.95	1.05	0.99	1.06	1.10
SSP5-8.5 INM-CM5-0	0.98	0.99	0.99	1.06	1.02	0.97	0.88	0.87	1.04	1.07	1.10	0.92

Medians across the 44 sites. The near window shows no systematic ordering by scenario, as reported in Section 3.4 for the distant window.

S4 Choice of the wet-day intensity distribution

Section 2.6 reports that the gamma was retained after comparison with the lognormal, Weibull and exponential alternatives over the 1584 combinations of site, source and calendar month. A wet day is defined by a threshold of 1.0 mm, so the sample of intensities is truncated on the left, and the likelihood used here discounts the truncated mass, $\log L = \Sigma \log f(x) - n \log[1 - F(1.0)]$. The uncorrected comparison is kept as a control because the difference between the two is itself informative.

Table S6 Best-fitting family by AIC, with the left truncation accounted for

Source	n	gamma	lnorm	weibull	exp	Gamma best (%)	Gamma ΔAIC < 2 (%)	Median ΔAIC	P90 ΔAIC
ANA rain gauges	528	237	12	81	198	44.9	97.7	0.24	1.92
CHIRPS	528	209	282	25	12	39.6	56.1	0.78	13.36
NASA POWER	528	475	0	53	0	90.0	100.0	0.00	0.01
All three	1584	921	294	159	210	58.1	84.6	0.00	5.96

Columns gamma to exp give the number of combinations in which each family attains the lowest AIC. ΔAIC is the AIC of the gamma minus the lowest of the four, so that zero means the gamma is the best-fitting family. Combinations with fewer than 30 wet days were excluded, as in Section 2.6.

Table S7 The same comparison without the truncation correction, as a control

Source	n	gamma	lnorm	weibull	exp	Gamma best (%)	Gamma ΔAIC < 2 (%)	Median ΔAIC	P90 ΔAIC
ANA rain gauges	528	108	257	21	142	20.5	55.1	1.94	11.76
CHIRPS	528	140	388	0	0	26.5	35.6	5.07	16.58
NASA POWER	528	3	515	0	10	0.6	3.2	28.53	45.42
All three	1584	251	1160	21	152	15.8	31.3	7.51	35.41

Estimated by the same numerical optimiser with the truncation term removed. The counts reproduce the closed-form maximum likelihood estimates exactly, which verifies the optimiser. The ranking reverses in favour of the lognormal, and the reversal is attributable to the treatment of the threshold alone.

Table S8 Competitiveness of the gamma by calendar month, with the truncation correction

Month	n	Gamma best (%)	Gamma ΔAIC < 2 (%)	Median ΔAIC
Jan	132	26.5	63.6	1.01
Feb	132	57.6	78.0	0.00
Mar	132	43.2	73.5	0.33
Apr	132	78.0	95.5	0.00
May	132	78.0	94.7	0.00
Jun	132	80.3	100.0	0.00
Jul	132	36.4	73.5	0.36
Aug	132	63.6	86.4	0.00
Sep	132	68.2	99.2	0.00
Oct	132	53.0	80.3	0.00
Nov	132	61.4	97.0	0.00
Dec	132	51.5	73.5	0.00

The gamma is least competitive in January, March, July and December. Across the twelve months competitiveness correlates with mean wet-day intensity (r = 0.57), being lowest where wet-day amounts are smallest relative to the 1.0 mm threshold.

Table S9 Effect of the choice of intensity distribution on 75% dependable precipitation

Source	Median |Δ| (mm)	P90 |Δ| (mm)	Max |Δ| (mm)	Median ΔP0.9 (mm)	Median ratio	Max ratio
ANA rain gauges	3.58	8.93	16.17	45.0	0.084	0.331

CHIRPS	2.62	5.05	8.38	38.5	0.071	0.242
NASA POWER	5.35	8.72	12.74	35.2	0.161	0.431
All three	3.79	7.93	16.17	39.8	0.104	0.431

Δ is the monthly value obtained with the family favoured by AIC minus the value obtained with the gamma, computed from the same occurrence chain and the same simulated vector of wet days, so that the intensity distribution is the only difference. The fits used are the uncorrected ones of Table S7, which maximise the disagreement and therefore give an upper bound. ΔP0.9 is the natural variability band of Eq. (10) and the ratio columns give |Δ| divided by it.

Table S10 The same effect aggregated to the year

Source	Gamma (mm)	AIC-favoured (mm)	Median difference (%)	Largest absolute difference (%)
ANA rain gauges	1190	1139	−3.61	7.43
CHIRPS	1284	1254	−2.32	3.21
NASA POWER	1169	1102	−5.64	7.21

Medians across the 44 sites. For comparison, the spread among observational sources in the same annual quantity has a median of 11.9% and the median projected change is 3.7% of the baseline.

Once the truncation is accounted for the gamma attains the lowest AIC in 58.1% of the combinations and lies within 2 AIC of the best in 84.6%. The exception is CHIRPS, where the lognormal is favoured in 282 of 528 combinations, consistent with the compression of both tails reported for that product in Section 4.1. Replacing the gamma by the family favoured by AIC shifts monthly dependable precipitation by a median of 3.8 mm against a band of 39.8 mm. The shift acts on the level and not on the projected change, because the change factor is applied identically, so no detectability result depends on it.

The gamma is retained because it is competitive by AIC under the correct likelihood, because a sum of independent gamma variates of equal rate is itself gamma, which is what makes the single-step Monte Carlo of Eq. (8) exact, and because it is the conventional formulation in the dependable precipitation literature.

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