Reconciling risk-based and storyline attribution with Bayes theorem

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CLIMXTREME Climate Change and Extreme Events

Risk-based attribution

Model **probability** of an event in two scenarios:

1. Factual scenario S_1 with climate change
2. Counterfactual S_0 without

Report probability ratio:

> *"Heatwaves of this magnitude have become twice as likely due to anthropogenic climate change."*

Unconditional attribution of an event class.

Storyline attribution

Simulate **specific event** twice:

1. realistic, observed boundary conditions
2. modified boundary conditions
   → warmer or cooler world

Report difference in event properties:

> *"The 2010 heat wave would have ended two weeks earlier in a 1°C degree cooler climate."*

Attribution of an event, **conditional on the weather situation** that generated it.

Conditional and unconditional probability ratio are linked by Bayes theorem

Usual probability ratio:

$$\mathrm{PR}(E) = \frac{Prob(E|S_1)}{Prob(E|S_0)}$$

Joint probability ratio:

$$\mathrm{PR}(E,C) = \frac{Prob(E,C|S_1)}{Prob(E,C|S_0)}$$

Conditional probability ratio:

$$\mathrm{PR}(E|C) = \frac{Prob(E|C,S_1)}{Prob(E|C,S_0)} = \frac{\mathrm{PR}(E,C)}{\mathrm{PR}(C)}$$

E : *Event*

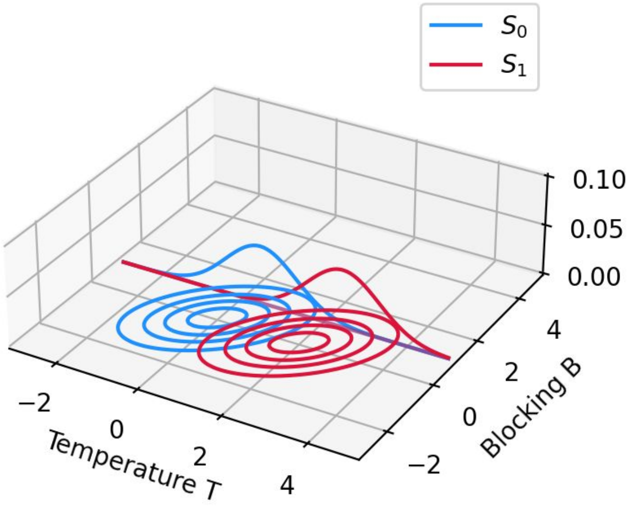
C : *Conditions*

S_1 : *Factual scenario*

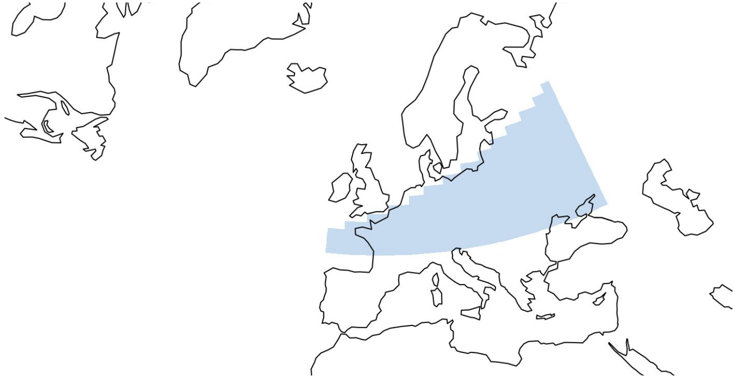
S_0 : *Counterfactual scenario*

Conditional attribution = ratio of two "classic" attributions

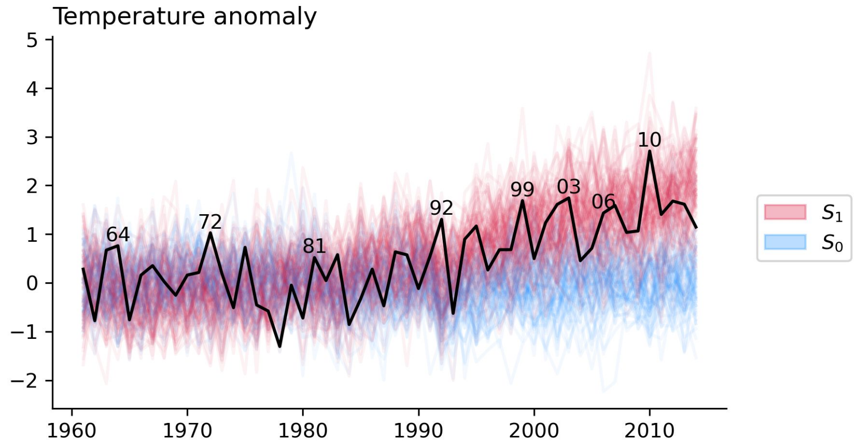
1. **joint PR of event and conditions**
2. **PR of the conditions alone**

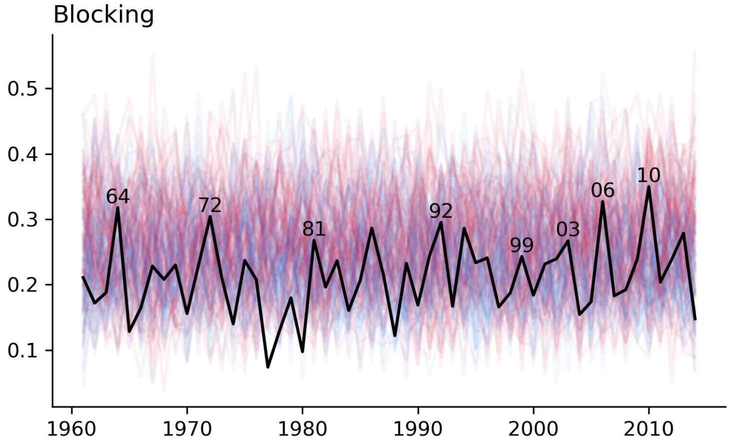


Attribution of Summer Temperature conditional on Blocking

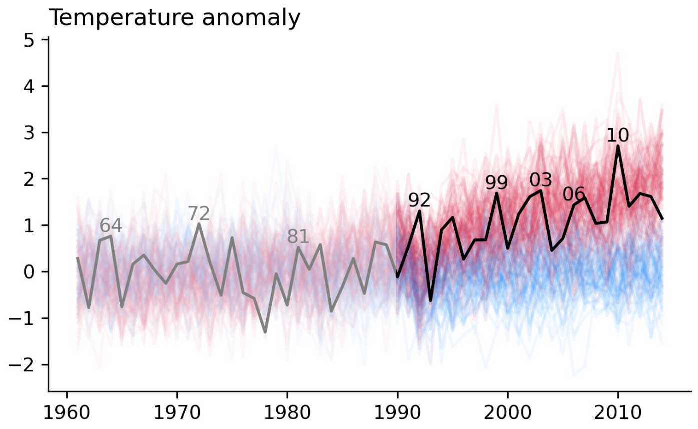


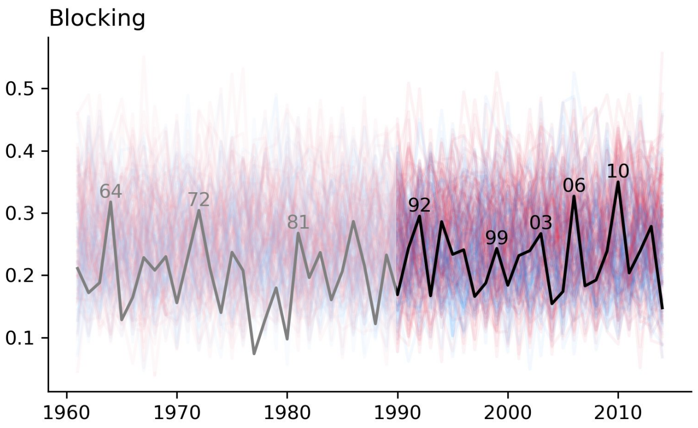
- Central Europe summer (JJA) means of **T2m**, **blocking index** (Sousa et al. 2021)
- 8 CMIP6 ensembles (S_1 : *historical* S_0 : *hist-nat*), ERA5 1961-2014
- Bayesian Gaussian mixture model for the probabilities

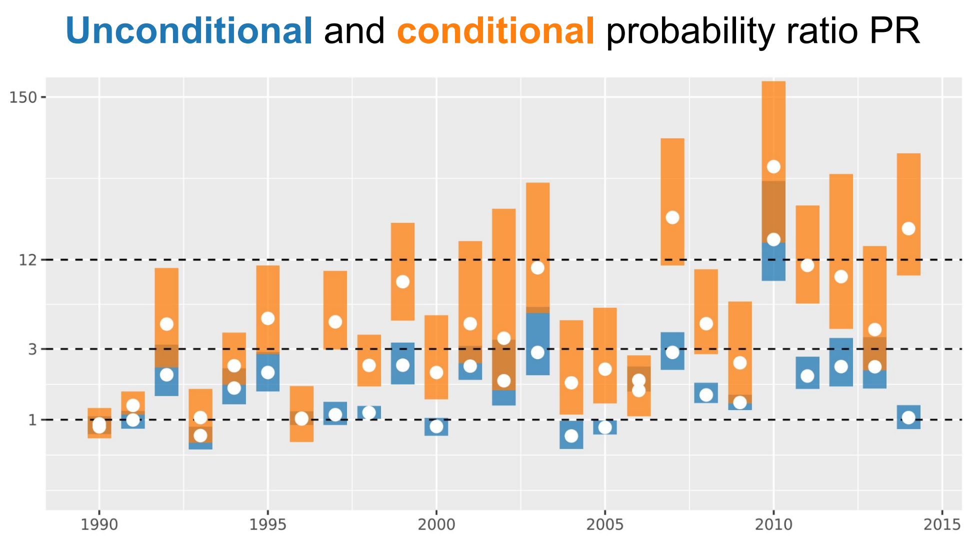




Attribution of Summer Temperature conditional on Blocking







Bars represent 95% confidence interval based on uncertain choice of climate models and obs. covariance, white dots mark the medians.

Summary

- Risk-based vs Storyline → unconditional vs conditional attribution
- General link via Bayes theorem:

$$\mathrm{PR}(E|C) = \frac{\mathrm{PR}(E, C)}{\mathrm{PR}(C)}$$

- Example PR(Temperature | Blocking) → PR overall enhanced, especially for weakly blocked years like 2007, 2014.

References

Sousa, P. M., Barriopedro, D., García-Herrera, R., Woollings, T., & Trigo, R. M. (2021). A New Combined Detection Algorithm for Blocking and Subtropical Ridges. Journal of Climate, 34(18), 7735-7758. https://doi.org/10.1175/JCLI-D-20-0658.1

Min, S. K., Hense, A., Paeth, H., & Kwon, W. T. (2004). A Bayesian decision method for climate change signal analysis. Meteorologische Zeitschrift, 13(5), 421-436.

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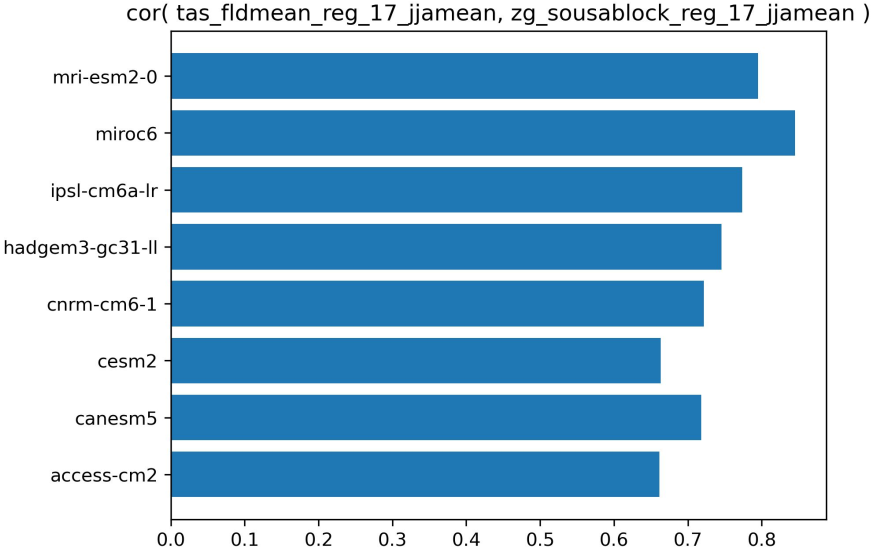
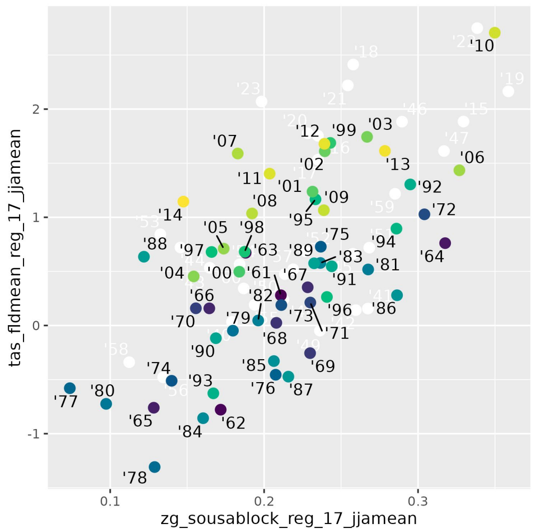
Additional information

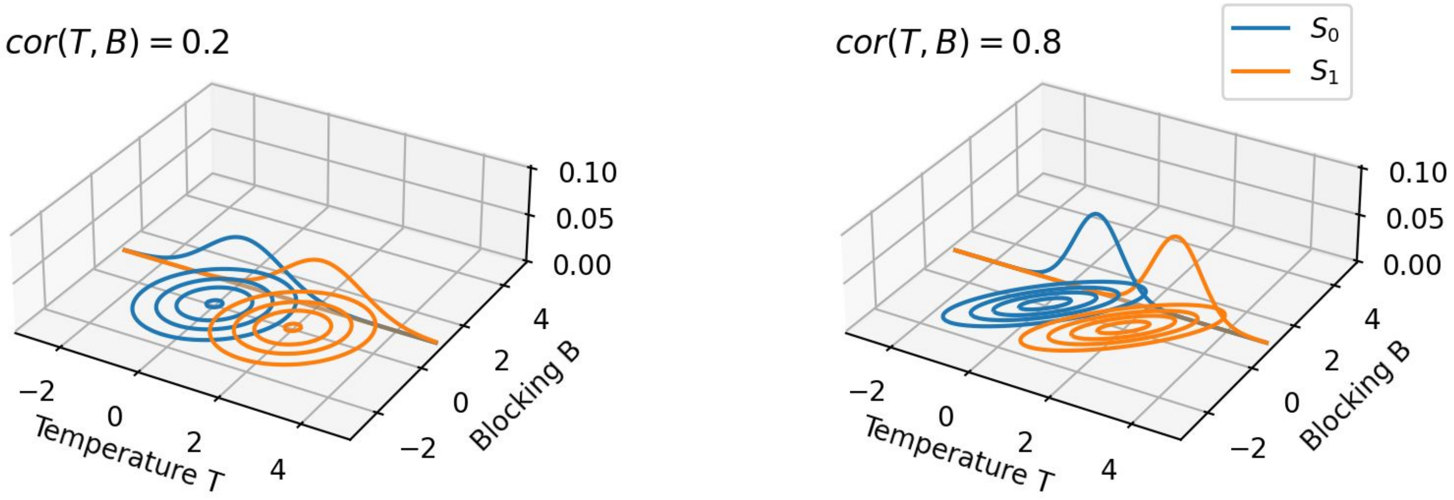




	model	hist	hist_nat	piControl
0	access-cm2	3	3	30
1	canesm5	35	45	1051
2	cesm2	10	1	1200
3	cnrm-cm6-1	24	3	316
4	hadgem3-gc31-ll	4	10	500
5	ipsl-cm6a-lr	23	6	115
6	miroc6	10	3	500
7	mri-esm2-0	5	5	200
9	total	114	76	3912

Attribution of Summer Temperature T conditional on Blocking B

Idealized example: (T,B) is bivariate Gaussian with unit variances, *B is independent of the scenario*



$$\log PR(T|B) = (\ T - \ mean(\mu) - \rho\times B\ ) \times (\ \mu(S1) - \mu(S0)\ ) \ \times (\ 1 - \rho^2\ )^{-1}$$