Air pollution imposes an unseen compound burden on outdoor thermal comfort across India

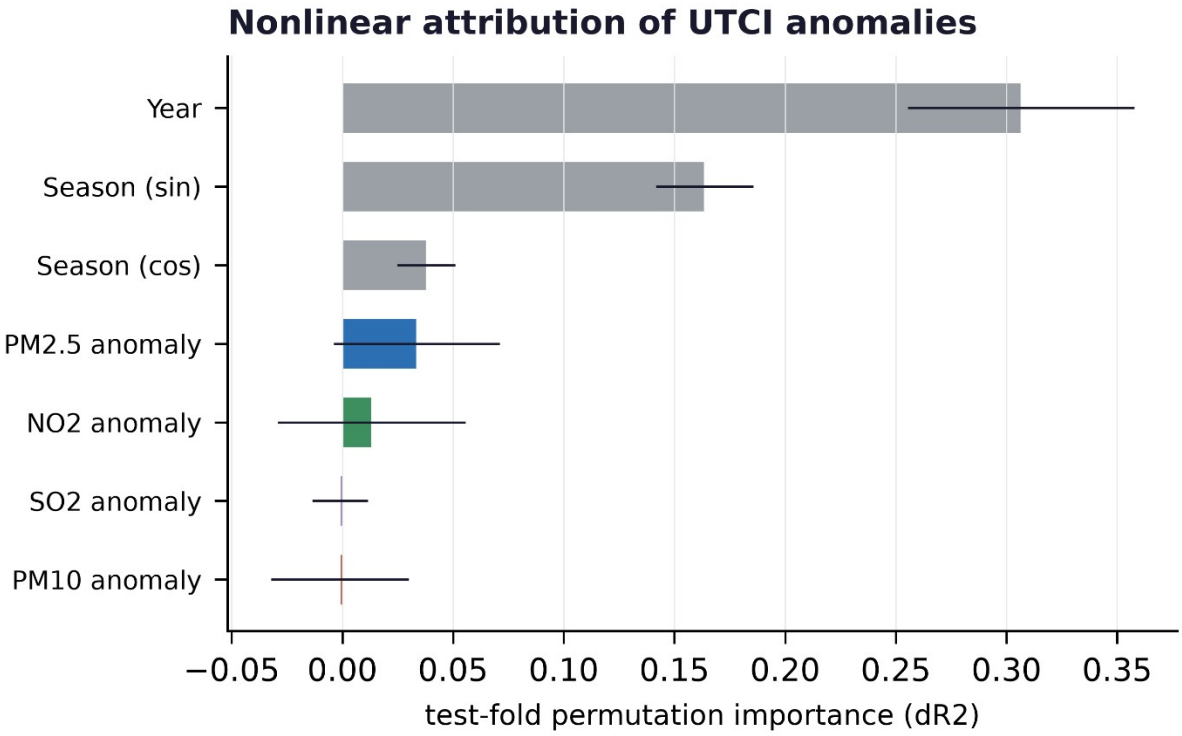
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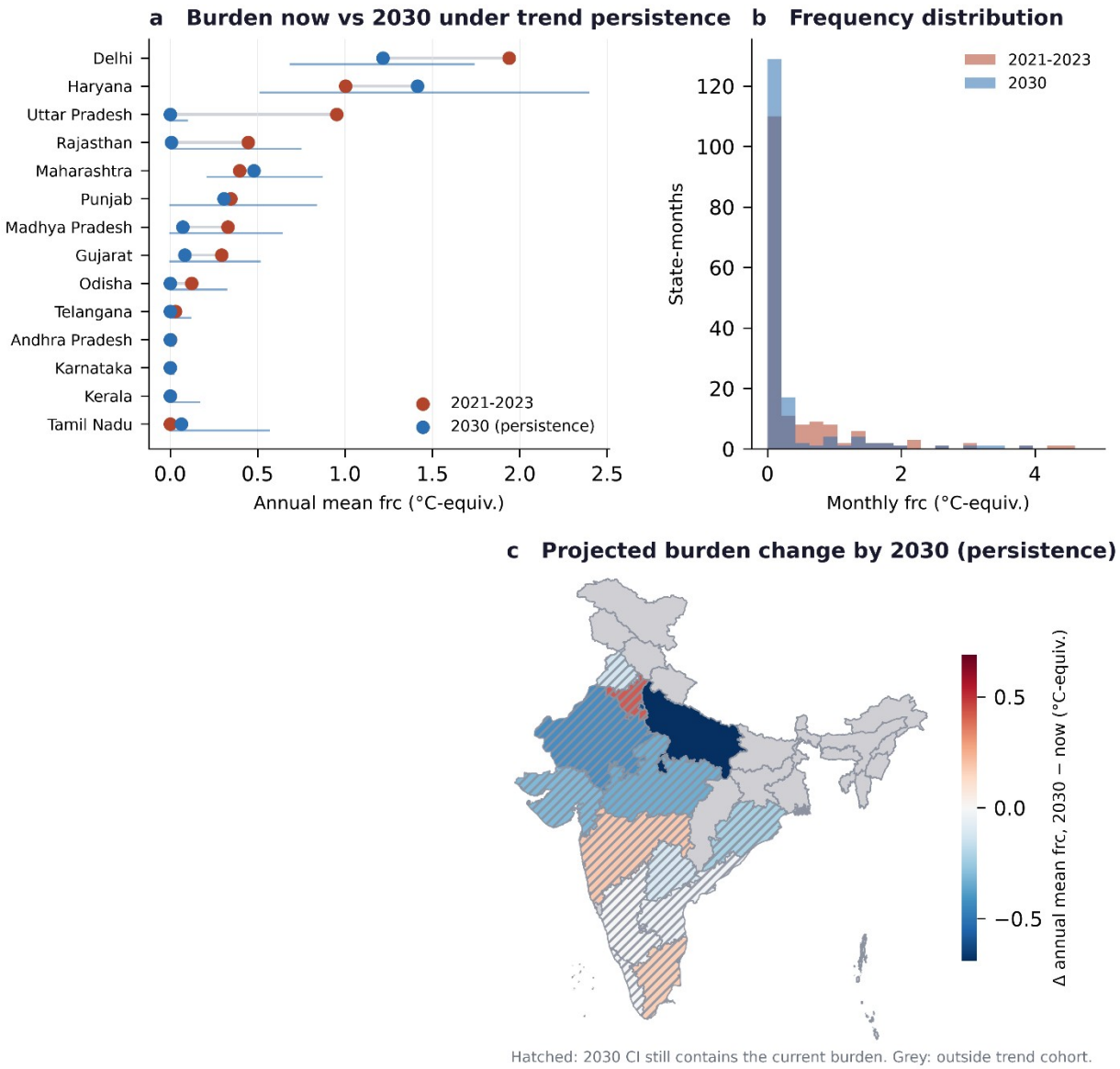
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This file contains: Supplementary Figs. S1–S2 and Supplementary Tables S1–S3.

Supplementary Figures



Supplementary Fig. S1 | Machine-learning robustness of the pollution-blindness null. Test-fold permutation importance (change in R^2; bars, mean ± s.d. across folds) from a gradient-boosting model of deseasonalized UTCI anomalies on pollutant anomalies, seasonal harmonics and year, fitted to the 14-state trend cohort (n = 993 state-months, 2016–2023). Validation is strictly out-of-state (five-fold GroupKFold by state). The model attains a cross-validated R^2 of +0.105 with pollutant features and +0.350 without them (ΔR^2 = −0.245): adding pollution information degrades out-of-state prediction of UTCI anomalies, and no pollutant importance exceeds its fold-to-fold variability. A nonlinear learner therefore confirms the linear fixed-effects null of Fig. 2 — UTCI carries no usable air-pollution signal at the monthly state scale.



Supplementary Fig. S2 | Persistence extrapolation of the pollution relaxation burden to 2030. State-mean annual pollution relaxation (frc, °C) for the trend cohort under the single governing assumption that each state's 2016–2023 seasonal Sen-slope pollutant trends persist linearly to 2030. Baselines are 2021–2023 monthly climatologies; concentrations are projected from the 2022 reference year, floored at 1 μg m^{-3}, and converted to frc with the India-calibrated coefficients of Fig. 4 (Supplementary Table S1). Uncertainty: bootstrap resampling of trend years to recompute Sen slopes, with baselines fixed (B = 500; 95% intervals). This is a quantitative extrapolation of observed trends, not a climate or policy projection: no scenario input is used and the thermal background is held at its trendless (Fig. 1) baseline. The burden geography persists in attenuated form — Delhi declines from 1.94 to 1.22 °C, Uttar Pradesh approaches zero, while Haryana rises from 1.00 to 1.42 °C (Supplementary Table S3).

Supplementary Tables

Supplementary Table S1 | India-calibrated Fechner relaxation coefficients. Coefficients of the relaxation function $rc = k \cdot \log_{10} C + c$ (rc clipped at ≥ 0), anchored to the CPCB National Air Quality Index breakpoints: rc = 0 at the upper bound of the 'Satisfactory' band (the 24-h NAAQS; 8-h for O_3) and rc = 1 at the upper bound of the 'Moderately polluted' band. Concentrations C in μg m^{-3}.

Pollutant	Anchor rc = 0	Anchor rc = 1	k	c
$PM_{2.5}$	60	90	5.679	−10.098
PM_{10}	100	250	2.513	−5.026
NO_2	80	180	2.839	−5.404
SO_2	80	380	1.478	−2.812
O_3	100	168	4.438	−8.877

Supplementary Table S2 | Validation of the AOCT implementation. Annual optimum comfortable temperature (AOCT, °C) computed by our implementation for the five Chinese cities of the source formulation, against the published values. Mean absolute error 0.80 °C; the implementation is used unchanged for the Indian states.

City	Published AOCT (°C)	Computed AOCT (°C)	Error (°C)
Beijing	23.64	24.84	+1.20
Xining	17.23	19.24	+2.01
Nanjing	16.82	17.07	+0.25
Kunming	15.48	15.03	−0.45
Guangzhou	25.08	25.16	+0.08

Supplementary Table S3 | State-level persistence projection of the pollution relaxation burden to 2030. State-mean annual frc (°C) at the 2021–2023 baseline and projected to 2030 (95% bootstrap interval, B = 500), trend cohort only. Change = 2030 − baseline.

State	Baseline frc (°C)	2030 frc (°C)	95% CI	Change (°C)
Delhi	1.94	1.22	0.69–1.74	−0.72
Haryana	1.00	1.42	0.52–2.39	+0.41
Uttar Pradesh	0.95	0.00	0.00–0.10	−0.95
Rajasthan	0.45	0.01	0.00–0.75	−0.44
Maharashtra	0.40	0.48	0.21–0.87	+0.08
Punjab	0.35	0.31	0.00–0.83	−0.04
Madhya Pradesh	0.33	0.07	0.00–0.64	−0.26
Gujarat	0.29	0.08	0.00–0.51	−0.21
Odisha	0.12	0.00	0.00–0.32	−0.12
Telangana	0.03	0.00	0.00–0.12	−0.03
Andhra Pradesh	0.002	0.000	0.00–0.02	−0.002
Karnataka	0.00	0.00	0.00–0.02	0.00
Kerala	0.00	0.00	0.00–0.17	0.00
Tamil Nadu	0.00	0.06	0.00–0.57	+0.06