Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Ambient temperature and acute intestinal infection morbidity in Uzbekistan: a national surveillance-based statistical analysis, 2020–2025

Nodira Yodgorova
Tashkent State Medical University
Zamira Fayzullayeva
Tashkent State Medical University
Zukhra Nuruzova
Tashkent State Medical University
Bakhodir Rakhimov
b.b.raximov@tashmeduni.uz
Tashkent State Medical University
Aminjon Nematov
Center for Development of Professional Qualification of Medical Workers

Research Article

Keywords: Acute intestinal infections, Diarrhoeal disease, Ambient temperature, Climate and health, Seasonality, Surveillance, Central Asia, Uzbekistan

Posted Date: September 28th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-10718549/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

Abstract

Background.

Ambient temperature is one of the most consistently reported drivers of diarrhoeal disease, but the relationship has not been quantified for Central Asia. Using national surveillance data and validated reanalysis climate data, we examined whether acute intestinal infection (AII) morbidity in Uzbekistan is statistically associated with ambient air temperature.

Methods.

We analysed routine national surveillance records for AIIs: monthly counts by territory for 2021, multi-year monthly counts for the capital (2021 and 2023–2025), annual counts and etiologic structure for all 14 territories, and the national age distribution. Monthly mean air temperature for 2015–2025 was obtained from NASA POWER reanalysis and validated against in-country measurements. The temperature–AII association was quantified with Spearman correlation at the national and regional level and with negative-binomial regression across regions; a multi-year, season-adjusted model for the capital served as a sensitivity analysis.

Results.

AII morbidity was strongly seasonal, peaking in summer alongside temperature. Reanalysis temperature agreed closely with measurements (Pearson r = 0.99). Ambient temperature was positively and significantly associated with AII incidence: nationally (Spearman r = 0.73, p = 0.007) and in 6 of 10 territories (r from 0.59 to 0.94). In the cross-regional model, each 1°C higher monthly temperature corresponded to a 3.4% higher case count (incidence rate ratio 1.034, 95% confidence interval 1.017–1.051; p < 0.001), close to the global meta-analytic estimate. In a multi-year sensitivity analysis in the capital, the association attenuated after adjustment for the annual cycle, indicating that it is substantially seasonal. The burden fell mainly on children under five (67.4% of cases).

Conclusions.

Ambient temperature is positively and significantly associated with acute intestinal infection morbidity in Uzbekistan, consistent with global evidence. The association is closely tied to the summer season, and separating a direct thermal effect from seasonal co-variation will require multi-year monthly analysis. These findings establish a climate–health signal for enteric disease in Central Asia and a baseline for temperature-attributable assessment and seasonally timed prevention.

Background

Diarrhoeal diseases remain among the leading causes of illness and death in young children, responsible for more than a million deaths worldwide in 2021 despite decades of decline in age-standardised rates [1]. Ambient temperature is one of their most frequently reported environmental determinants [2]. A widely cited meta-analysis of 26 studies found that all-cause and bacterial diarrhoea rise by about 7% for every 1°C increase in temperature (incidence rate ratio [IRR] 1.07, 95% confidence interval [CI] 1.03–1.10), with no comparable signal for viral diarrhoea [3]. Because temperature influences the survival and replication of enteric bacteria and the human behaviours that shape food and water contamination [4], a warming climate is widely expected to alter the enteric-infection burden, and temperature-attributable projections now feature in global climate-and-health assessments [5].

For Central Asia, however, this relationship has not been quantified. The region is warming faster than the global average, yet the temperature dependence of enteric infection remains unstudied, and burden figures are available chiefly as modelled estimates rather than from direct surveillance [6]. Uzbekistan, the most populous Central Asian state, maintains a long-standing reporting system for acute intestinal infections (AIIs), but its output has not, to our knowledge, been analysed against climate. Whether AII morbidity in Uzbekistan is statistically associated with ambient temperature — and how any such association compares with global estimates — is therefore unknown.

Using the national surveillance record together with validated reanalysis climate data, this study quantifies the association between ambient air temperature and AII morbidity in Uzbekistan. We describe the seasonality of the burden, estimate the temperature–AII association at the national and regional level, compare it with the global benchmark, and test its robustness to the shared annual cycle of temperature and enteric disease.

Methods

Setting and surveillance data

Uzbekistan comprises 14 administrative territories (12 provinces, the Republic of Karakalpakstan and Tashkent city) with a population of about 37 million. AII data were drawn from the routine reporting system of the national sanitary-epidemiological service. A national month-by-territory table provided monthly counts for all territories in 2021; city-level analytic reports provided monthly counts for Tashkent city for 2021 and 2023–2025; annual structural returns provided counts, the etiologic breakdown and the age distribution for 2020–2022. Territories whose monthly counts could not be reconciled with their annual totals were excluded from the correlation analysis, leaving 10 territories with complete, internally consistent monthly series for 2021.

Temperature data and validation

Monthly mean air temperature for 2015–2025 was obtained for all 14 territories from the NASA POWER project (MERRA-2 reanalysis), extracted at each territory’s administrative-centre coordinates [7]. Because

reanalysis is a modelled product, we validated it against in-country measured temperature available for four climatically distinct territories (Tashkent city, Namangan, Karakalpakstan/Nukus and Surxondaryo/Termiz) for 2021, using the Pearson correlation coefficient and the mean absolute difference.

Statistical analysis

This was an observational analysis of routine surveillance data. Seasonality was summarised by the monthly seasonal index (each month as a percentage of the annual monthly mean), the June–August share of cases and the peak-to-trough ratio. The temperature–AII association was quantified with the Spearman rank correlation coefficient between monthly temperature and monthly case counts, nationally (against the mean temperature of the four sentinel territories) and within each of the 10 territories. To obtain a pooled effect estimate we fitted a negative-binomial regression of monthly counts on temperature across all 10 territories with territory as a fixed effect, reporting the IRR per 1°C with 95% CI. Because temperature and the enteric season coincide within a calendar year, we performed a sensitivity analysis in the capital — the only territory with a multi-year monthly series — in which a negative-binomial model included temperature together with harmonic seasonal terms and a linear trend, so that the temperature coefficient reflected departures from the seasonal cycle. Two-sided $p < 0.05$ was considered significant. Analyses used Python 3.11 (SciPy, statsmodels) and are reproducible in IBM SPSS; figures were produced in R 4.3 with ggplot2.

Ethics

The study used aggregated, de-identified routine surveillance data with no individual-level information and did not constitute research on human participants; the requirement for ethics approval and consent was waived. This study was performed in line with the principles of the Declaration of Helsinki. Approval for the present secondary analysis of the de-identified dataset was granted by the Ethics Committee of Tashkent state medical university (protocol no. 07b-2026 from 10 March 2026y.).

Results

Seasonality and burden

AII morbidity was strongly seasonal and rose in parallel with temperature (Fig. 1). Nationally in 2021, monthly counts increased from 1812 in January to a June peak of 4258 — a seasonal index of 175% of the annual monthly mean — before falling to 1797 in December; the peak-to-trough ratio was 2.4 and June–August accounted for 33.8% of the year’s cases. The burden was concentrated in young children (67.4% of cases in children under five) and, in 2022, 59031 cases were registered nationally. Key characteristics are summarised in Table 1.

Table 1
Key characteristics of acute intestinal infection morbidity, Uzbekistan

Indicator	Value
Registered cases, 2021 (national)	28951
Registered cases, 2022 (national)	59031
Peak month	June
Seasonal index at peak (% of annual mean)	175%
June–August share of annual cases	33.8%
Peak-to-trough ratio (national)	2.4
Children under 5 years, share of cases	67.4%
Etiologically confirmed cases (2022)	14.5%

Values are registered surveillance figures. Counts from different reporting strands are not pooled; absolute totals are approximate.

Reanalysis temperature agrees with measurements

Before use, NASA POWER reanalysis temperature was validated against in-country measured records for the four sentinel territories in 2021. Agreement was close: the two series were highly correlated (Pearson r = 0.99) with a mean absolute difference of 1.7°C, the small residual reflecting the expected difference between a grid cell and a point station (Fig. 2). This supported the use of reanalysis temperature for all territories.

Ambient temperature is associated with AII morbidity

At the national level, monthly temperature was positively and significantly associated with AII counts (Spearman r = 0.73, p = 0.007; Fig. 3a). The association was present in most territories: it was statistically significant in 6 of 10, ranging from r = 0.59 in Karakalpakstan to r = 0.94 in Namangan, and was strongest in agrarian and hot-climate territories (Fig. 3b; Table 2). In the pooled cross-regional model, each 1°C higher monthly temperature corresponded to a 3.4% higher case count (IRR 1.034, 95% CI 1.017–1.051; p < 0.001) — an estimate close to, and slightly more conservative than, the global meta-analytic value of 1.07 per °C [2] (Table 3). The capital was the main exception, showing no monotonic within-year association (r = − 0.01) and an autumn rather than mid-summer peak.

Table 2
Association between monthly temperature and AII counts by territory, 2021

Territory	Annual cases	Spearman r	p-value	Peak month
Namangan	674	**0.94**	< 0.001	Jul
Surxondaryo	3053	**0.79**	0.002	Jun
Andijon	750	**0.70**	0.011	Jul
Samarqand	4171	**0.68**	0.015	Jul
Sirdaryo	567	**0.67**	0.017	Jun
Karakalpakstan	2925	**0.59**	0.042	Jun
Buxoro	738	0.57	0.051	Jun
Jizzax	689	0.33	0.295	Feb
Navoiy	335	0.28	0.379	Jul
Tashkent city	9888	−0.01	0.983	Jun

Spearman rank correlation between monthly mean temperature (NASA POWER) and monthly registered cases. Significant coefficients ($p < 0.05$) are in bold.

The association is closely tied to the season

Because temperature and the enteric season rise together within a year, we tested the association in the capital across four years, where the seasonal cycle can be modelled explicitly. The crude multi-year correlation was again positive (Spearman r = 0.62, p < 0.001), but after adjustment for the annual cycle and trend the independent temperature term was negligible (IRR 1.00 per °C, 95% CI 0.96–1.05; p = 0.87), indicating that the within-year association is substantially seasonal rather than a distinct thermal effect (Table 3). The main and sensitivity estimates are shown together in Table 3.

Table 3
Temperature–AII association: main and sensitivity estimates

Analysis	Data	Estimate (per 1°C)
National monthly correlation	2021, 12 months	r = 0.73 (p = 0.007)
Cross-regional pooled model	2021, 10 territories	IRR 1.034 (1.017–1.051)
Capital, season-adjusted (sensitivity)	2021, 2023–2025	IRR 1.00 (0.96–1.05)

IRR incidence rate ratio per 1°C. The cross-regional model adjusts for territory; the sensitivity model adjusts for the annual seasonal cycle and trend, isolating temperature from season.

Discussion

Using national surveillance and validated reanalysis climate data, this study provides the first quantification of the temperature–enteric infection relationship for Central Asia. Ambient temperature was positively and significantly associated with acute intestinal infection morbidity in Uzbekistan: the association held nationally and in most territories, and its magnitude — about 3–4% more cases per additional degree — was close to the pooled global estimate of 7% per °C for all-cause and bacterial diarrhoea [3]. That an independent surveillance system in a previously unstudied region reproduces the direction and approximate size of the global signal is itself informative, and places Uzbekistan within the broader climate–health picture for enteric disease.

The association was, however, closely bound to the summer season. When we exploited four years of monthly data in the capital to separate temperature from the annual cycle, the independent temperature term fell to essentially nothing. This does not overturn the association — warmth and enteric infection genuinely rise and fall together in Uzbekistan — but it cautions that the within-year relationship is substantially seasonal, and that a simple thermal coefficient should not yet be read as a causal, temperature-attributable effect. The capital's divergent behaviour, with no within-year temperature association and an autumn peak, is consistent with its centralised treated-water supply and a larger contribution of viral pathogens, for which temperature associations are typically absent [2].

For practice, the strong and regular summer seasonality is the most immediately useful result: whatever its ultimate driver, it identifies June–August as the natural window for intensified prevention, and children under five — who bear two-thirds of the burden — as the priority group [1]. For research, the findings define a concrete agenda: establishing whether temperature exerts a distinct effect beyond season, and estimating any temperature-attributable burden, will require multi-year monthly case series for several climatically distinct territories and distributed-lag non-linear modelling [8, 9].

Strengths and limitations

The strengths of this study are its national scope, the validation of the exposure data against in-country measurements, and the analysis of the association at multiple levels rather than from a single correlation. Its limitations follow from surveillance data. Case ascertainment is incomplete and definitions differed across reporting strands, so absolute counts should be read as approximate; we therefore emphasised internally consistent relationships over absolute numbers. Most importantly, the principal estimates are cross-sectional within a single year, in which temperature and season are collinear; the multi-year sensitivity analysis rests on one city. As an aggregate analysis it cannot address individual-level mechanisms, and reanalysis temperature at administrative-centre points does not capture within-territory climate gradients.

Conclusions

Ambient temperature is positively and significantly associated with acute intestinal infection morbidity in Uzbekistan, at a magnitude close to global estimates — the first such quantification for Central Asia. The association is strongly seasonal, and distinguishing a direct thermal effect from seasonal co-variation will require multi-year, multi-region monthly analysis. In a warming region, these findings establish a climate–health signal for enteric disease, support seasonally timed and paediatric-focused prevention, and provide the baseline for future temperature-attributable assessment.

Abbreviations

AII
acute intestinal infection
CI
confidence interval
IRR
incidence rate ratio
MERRA-2
Modern-Era Retrospective analysis for Research and Applications, version 2
NASA POWER
National Aeronautics and Space Administration, Prediction of Worldwide Energy Resources.

Declarations

Ethics approval and consent to participate

The study analysed aggregated, de-identified routine surveillance data with no individual-level information and did not constitute research on human participants; the requirement for ethics approval and informed consent was waived.

Consent for publication

Not applicable; the manuscript contains no data from any individual person.

Competing interests

The authors declare that they have no competing interests.

Funding

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

Author Contribution

NY conceived and designed the study, curated the surveillance and climate data, BR performed the analysis and drafted the manuscript. ZF and ZN contributed to data acquisition and interpretation. AN supervised the work and critically revised the manuscript. All authors read and approved the final manuscript.

Acknowledgement

The authors thank the staff of the regional sanitary-epidemiological services of the Republic of Uzbekistan for maintaining the surveillance records analysed in this study.

Availability of data and materials

The climate data are openly available from NASA POWER [7]. The underlying surveillance returns are held by the sanitary-epidemiological service of the Republic of Uzbekistan and are available from the corresponding author on reasonable request and with the permission of that authority.

References

1. Kyu HH, Vongpradith A, Dominguez R-MV, Ma J, Albertson SB, Novotney A, Global Burden of Disease Study 2021. Global, regional, and national age-sex-specific burden of diarrhoeal diseases, their risk factors, and aetiologies, 1990–2021, for 204 countries and territories: a systematic analysis for the. The Lancet Infectious Diseases. 2025;25:519–36. https://doi.org/10.1016/s1473-3099(24)00691-1. GBD 2021 Diarrhoeal Diseases Collaborators. Global, regional, and national age-sex-specific burden of diarrhoeal diseases, their risk factors, and aetiologies, 1990–2021: a systematic analysis for the Global Burden of Disease Study 2021. Lancet Infect Dis. 2025;25(5):519–36.
2. Levy K, Woster AP, Goldstein RS, Carlton EJ. Untangling the Impacts of Climate Change on Waterborne Diseases: a Systematic Review of Relationships between Diarrheal Diseases and Temperature, Rainfall, Flooding, and Drought. Environ Sci Technol. 2016;50:4905–22. https://doi.org/10.1021/acs.est.5b06186.
3. Carlton EJ, Woster AP, DeWitt P, Goldstein RS, Levy K. A systematic review and meta-analysis of ambient temperature and diarrhoeal diseases. Int J Epidemiol. 2015;45:117–30. https://doi.org/10.1093/ije/dyv296.
4. Kraay ANM, Hayashi MAL, Hernandez-Ceron N, Spicknall IH, Eisenberg MC, Meza R, et al. Fomite-mediated transmission as a sufficient pathway: a comparative analysis across three viral pathogens. BMC Infect Dis. 2018;18. https://doi.org/10.1186/s12879-018-3425-x.
5. Romanello M, di Napoli C, Green C, Kennard H, Lampard P, Scamman D, et al. The 2023 report of the Lancet Countdown on health and climate change: the imperative for a health-centred response in a

world facing irreversible harms. Lancet. 2023;402:2346–94. https://doi.org/10.1016/s0140-6736(23)01859-7.

6. Reyer CPO, Otto IM, Adams S, Albrecht T, Baarsch F, Cartsburg M, et al. Climate change impacts in Central Asia and their implications for development. Reg Envriron Chang. 2015;17:1639–50. https://doi.org/10.1007/s10113-015-0893-z.
7. NASA Langley Research Center. POWER: Prediction Of Worldwide Energy Resources. National Aeronautics and Space Administration. https://power.larc.nasa.gov. Accessed 15 Aug 2026.
8. Gasparrini A, Guo Y, Sera F, Vicedo-Cabrera AM, Huber V, Tong S, et al. Projections of temperature-related excess mortality under climate change scenarios. Lancet Planet Health. 2017;1:e360–7. https://doi.org/10.1016/s2542-5196(17)30156-0.
9. Gasparrini A, Armstrong B, Kenward MG. Distributed lag non-linear models. Stat Med. 2010;29:2224–34. https://doi.org/10.1002/sim.3940.

Figures

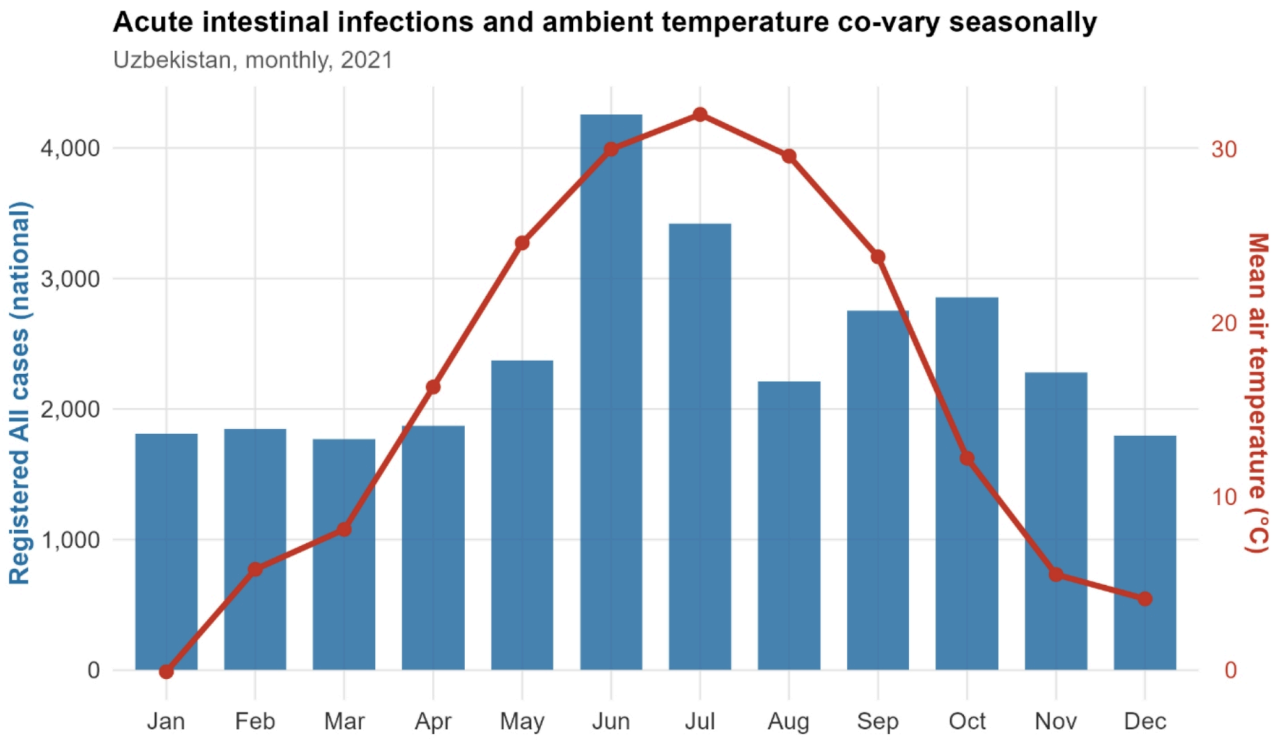


Figure 1

Acute intestinal infections and ambient temperature, Uzbekistan, 2021. Monthly national registered cases (bars) and mean ambient temperature (line). Morbidity and temperature rise and fall together

across the year.

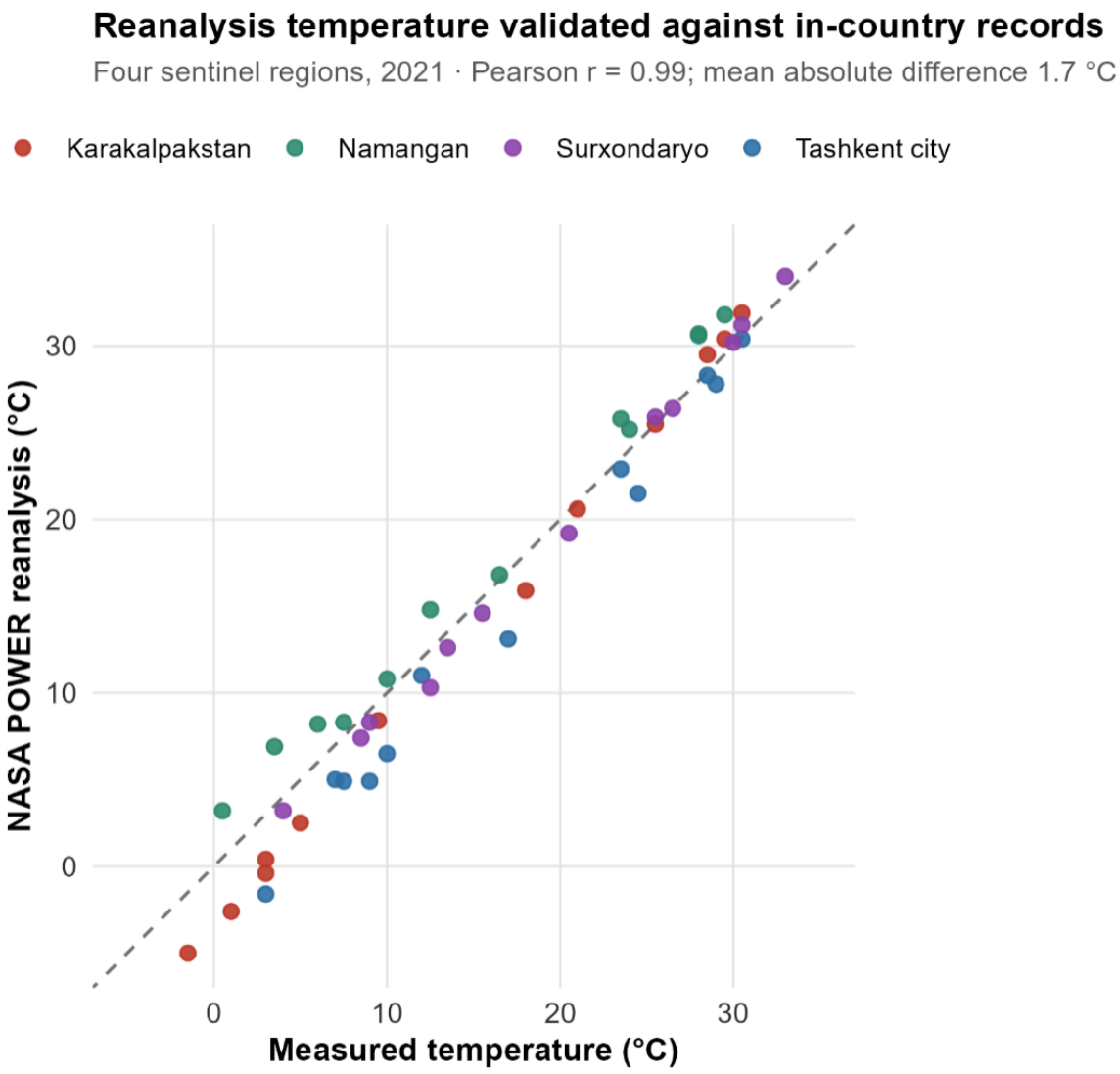


Figure 2

Validation of reanalysis temperature against in-country measurements. NASA POWER monthly temperature versus measured temperature, four sentinel territories, 2021 (Pearson r = 0.99; mean absolute difference 1.7 °C). The dashed line is the 1:1 line.

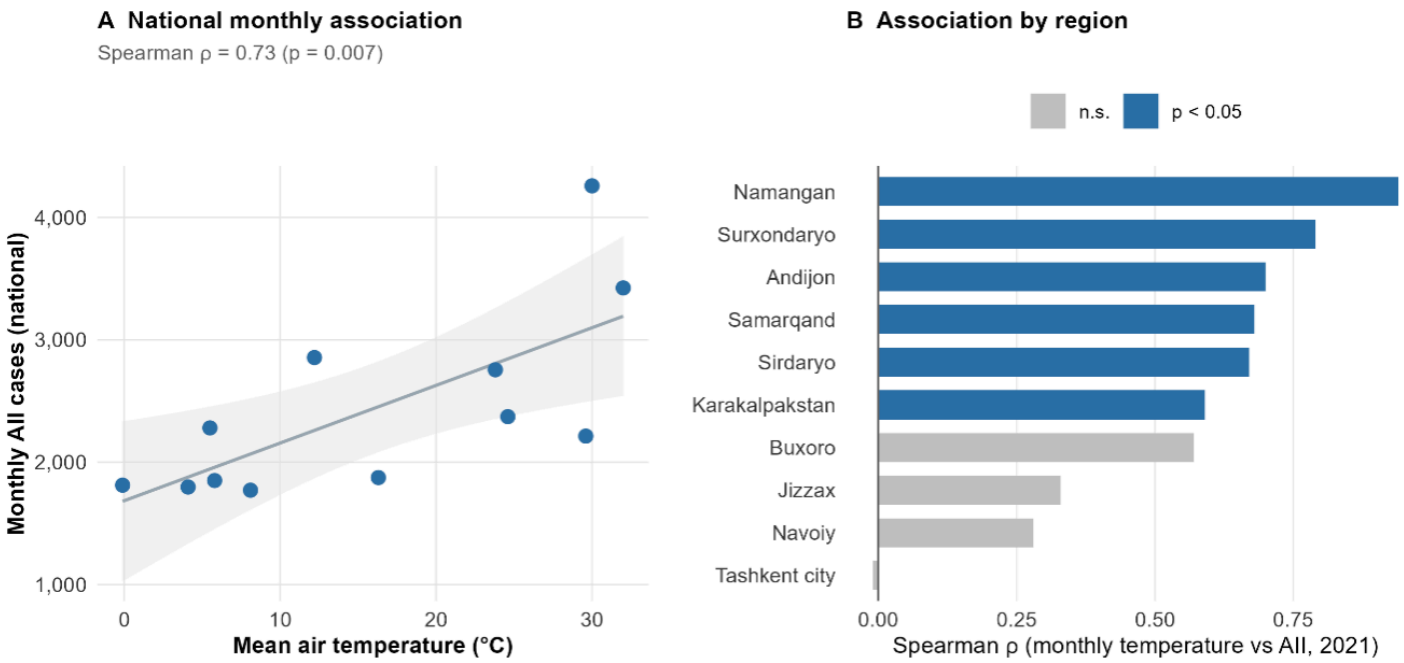


Figure 3

Association between ambient temperature and AII morbidity, 2021. (a) National monthly cases against mean temperature, with fitted line (Spearman r = 0.73). (b) Spearman correlation between monthly temperature and cases by territory; darker bars indicate p < 0.05.