ZERO Institute

Citizen science for multi-scale climate assessment:

integrating distributed modelling and crowdsourced observations to inform urban heat adaptation.

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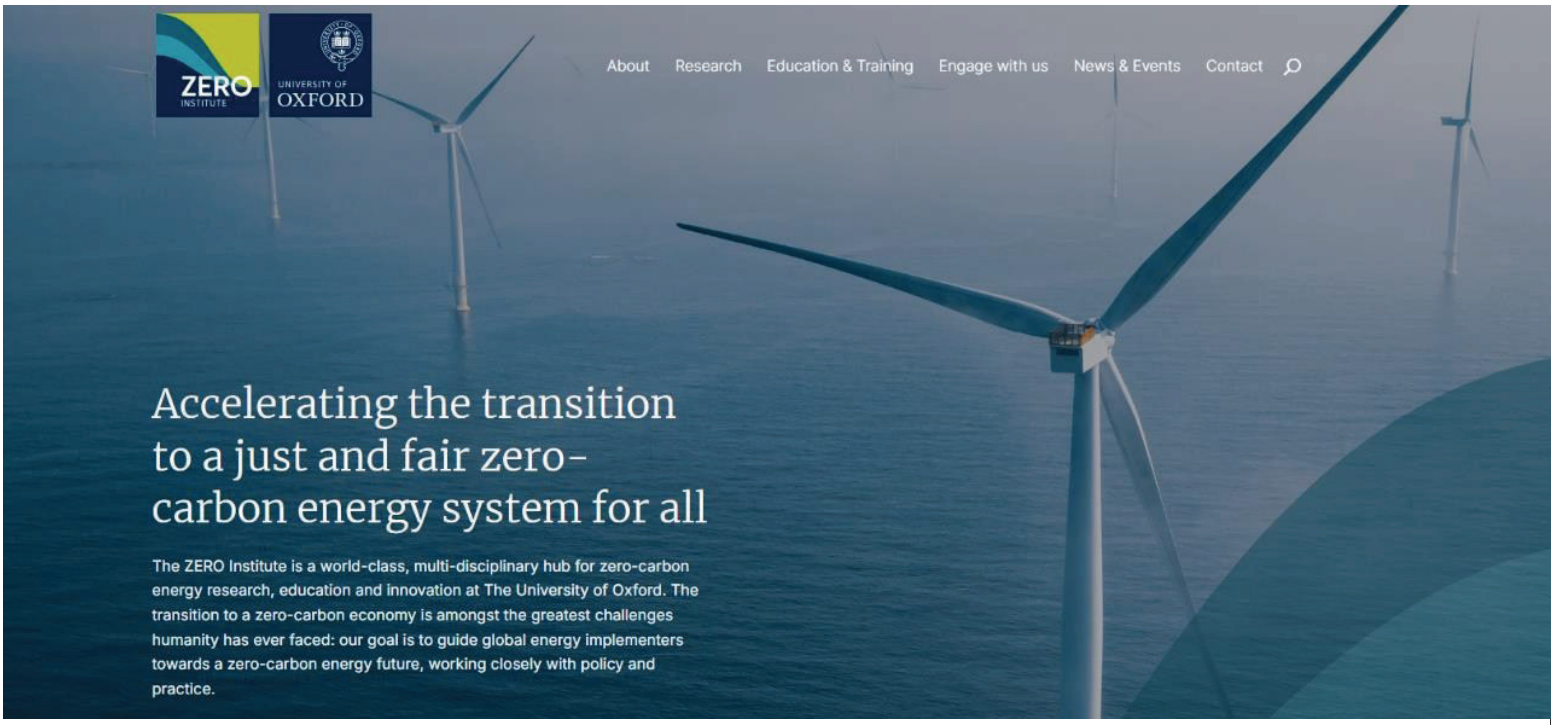

The ZERO INSTITUTE at the University of Oxford
https://zero.ox.ac.uk/

www.zero.ox.ac.uk | @ZERO_Oxford

Zero-Carbon Heating and Cooling

Leading research – Enabling collaborations in Oxford and abroad - With global impact

in heating and cooling — standing on the shoulders of giants — in science, policy, and practice

HEATING ⟵ ⟶ **COOLING**

climate change **MITIGATION**	climate **RISK**	climate **ADAPTATION**
Heating decarbonisation - net-zero targets	Climate-related hazards – exposure - vulnerability	Mitigation of rising cooling needs - Resilience

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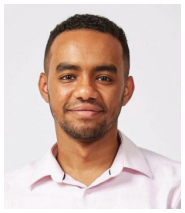

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How is climate change reshaping existing exposure to cooling and heating needs globally?

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Citizen science for accurate climate information

a, Global climate modelling

Citizen-driven distributed computing

Climate scale: global (macro and meso)

Spatio-temporal resolution: **6h at 60km²**

Platform: Climateprediction.net (CPDN)

Model: HadAM4

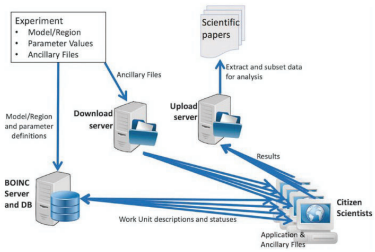

Fig. 1. Workflow of publically volunteered computers for climate modelling

b, Local climate observations

Citizen weather data

Climate scale: city (local and micro)

Spatio-temporal resolution: **1h at 1km²**

Platforms: Netatmo, Wunderground

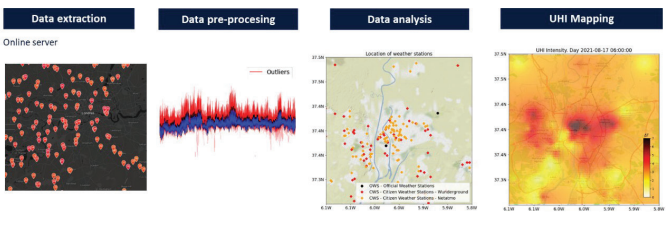

Fig. 2. Workflow of citizen weather data for high-resolution urban climate mapping

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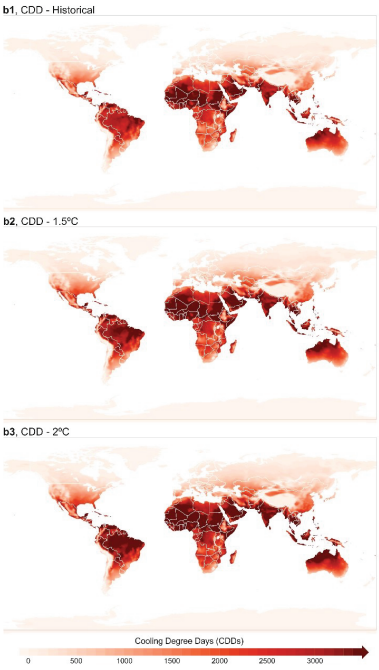

Global climate modelling

Citizen-driven distributed computing

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Approach: Climate change modelling

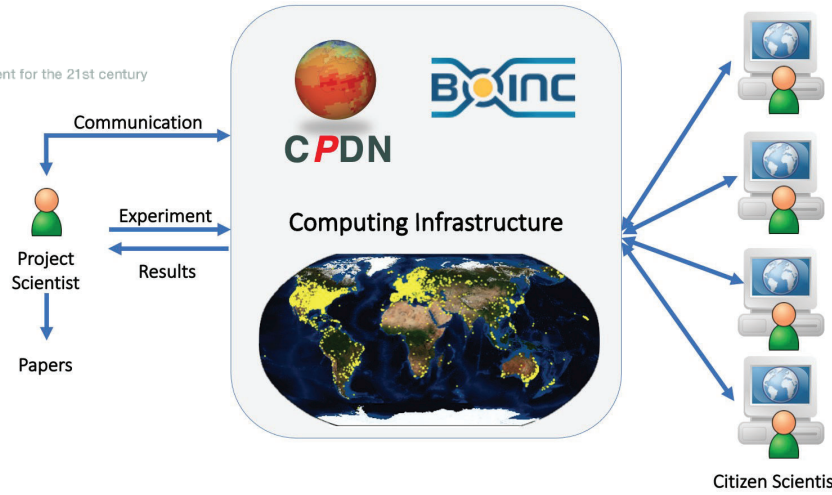
Climate modelling for 1.0°C, 1.5°C and 2.0°C scenarios

The highest combined (temporal/geographical) resolution of temperatures for global 1.5°C and 2.0°C scenarios

climateprediction.net
the world's largest climate forecasting experiment for the 21st century

Public Volunteers from around the world donate idle time on their computers to run climate model simulations

Able to generate very large ensembles of simulations



Workflow of publicly volunteered computers for climate modelling

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Contribution:

- **Scenario-agnostic and policy-oriented design**

Provides projections for **1.0°C, 1.5°C, and 2.0°C warming levels, independent of when they occur and regardless of the pathways leading to them**.

- **Large, high-resolution climate model/ensemble**

Built on a **70-member ensemble with 6-hourly temperature data**, offering much higher temporal resolution and ensemble size than typical CMIP datasets (daily with 20-30 members).

- **Bias-corrected global dataset**

Integrates **quantile-mapping bias correction**, improving reliability and comparability versus earlier global datasets that lacked bias correction

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Methods: Climate modelling

Volunteered distributed computing

1) Modelling approach:

Climate model	Spatio-temporal resolution:	Simulation environment:	Scenarios above pre-industrial:	Simulation size:
• HadAM4 Atmosphere-only General Circulation Model (AGCM) from the UK Met Office Hadley Centre	• Temporal: 6 hourly • Spatial: ≈60km^2 (0.883° × 0.556°)	• Climateprediction.net (CPDN) distributed computing platform	HAPPI protocol: • 1.0°C • 1.5°C • 2.0°C	• Ensemble: 70 members • Period: 10 years per scenario

2) Global Heating and cooling needs:

$$HDD = \frac{\sum_{t=0}^{t=m} (T_{base} - T_t)}{n}, T_t < T_{threshold}$$

$$CDD = \frac{\sum_{t=0}^{t=m} (T_t - T_{base})}{n}, T_t > T_{threshold}$$

Where:
t = time step
m = last time step of the year
n = number of time steps in one day (n = 4 for 6-hourly data)
T_t = mean outdoor temperature at time t
T_{base} = reference temperature used to calculate the temperature difference
$T_{threshold}$ = outdoor temperature above which temperature differences are calculated.

3) Five statistical descriptors:

- Mean
- Median
- 10th percentile
- 90th percentile
- standard deviation

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Results:

NEW RESOURCE:

New global dataset of heating and cooling degree days (HDD & CDD), capturing climate variability under climate change scenarios.

DATASET CHARACTERISTICS:

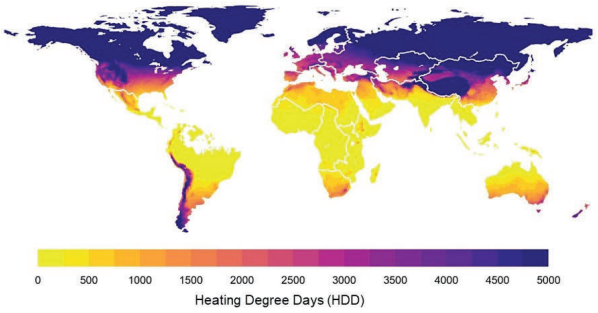
- A total of 30 global maps
- Global Land Surface
- 10-year representative period
- Resolution: 0.883° × 0.556°
- Variables: HDD | CDD
- Global warming levels: 1.0°C | 1.5°C | 2.0°C
- Statistics: mean, median, P10, P90, SD

TWO EXAMPLES:

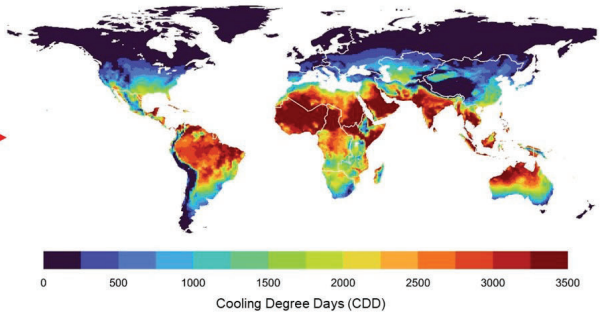
a, Global mean HDD for a global mean temperature rise of 1.0ºC (2006-2016) above the pre-industrial levels.

b, Global mean CDD for a global mean temperature rise of 1.0ºC (2006-2016) above the pre-industrial levels.

a, Mean Heating Degree Days (HDD, 2006-2016)



b, Mean Cooling Degree Days (CDD, 2006-2016)



Available in:

J. Lizana, et al. (2026), Nature Sustainability.
https://doi.org/10.1038/s41893-025-01754-y

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Key findings 1/2:

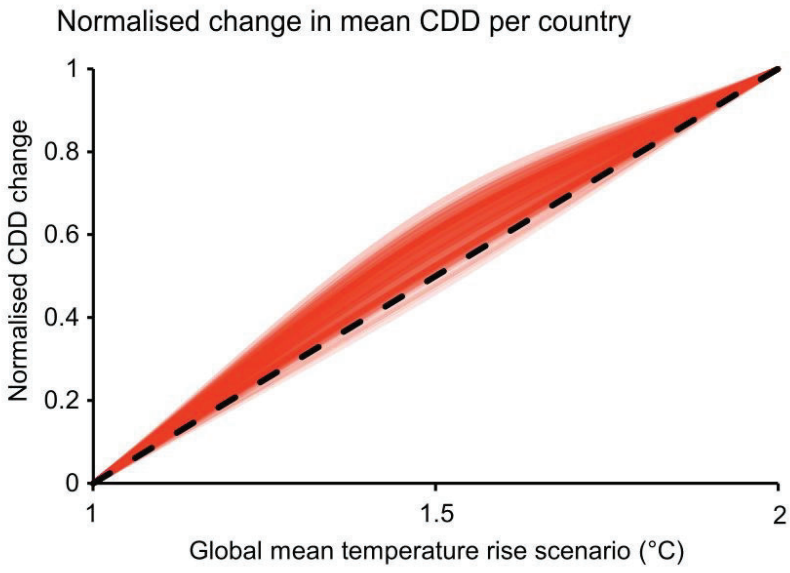

Figure: Normalised changes in area-weighted mean CDD for all countries between 1.0°C and 2.0°C of global mean temperature rise above pre-industrial levels.

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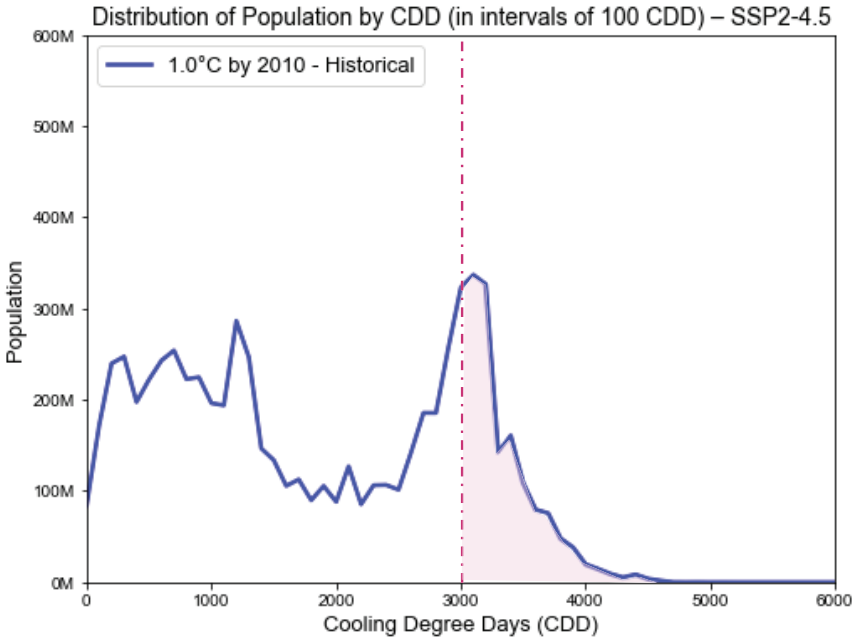
Key findings 2/2:



Population exposed to > 3000 CDD:

- **2010 – 23% (≈1.54 billion)**

Figure: Population distribution across CDD in the SSP2-4.5 shared socioeconomic pathway, aggregated into 100 CDD intervals.

Lizana et al. (2025)

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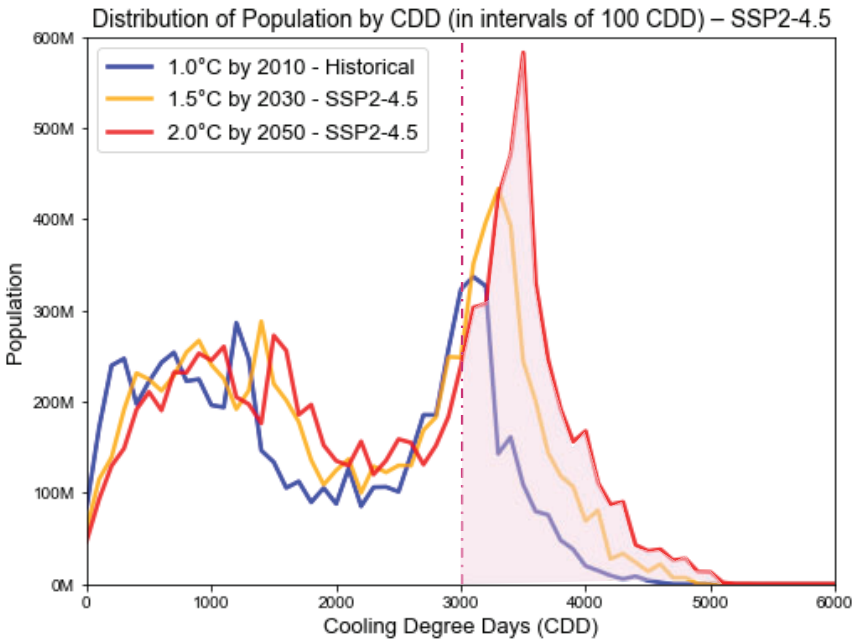
Key findings 2/2:



Population exposed to > 3000 CDD:

- **2010 – 23% (≈1.54 billion)**
- **2030 - 34% (2.80 billion)**
- **2050 - 41% (3.79 billion)**

Figure: Population distribution across CDD in the SSP2-4.5 shared socioeconomic pathway, aggregated into 100 CDD intervals.

Lizana et al. (2025)

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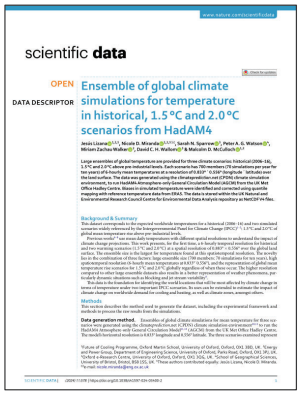
Data availability:

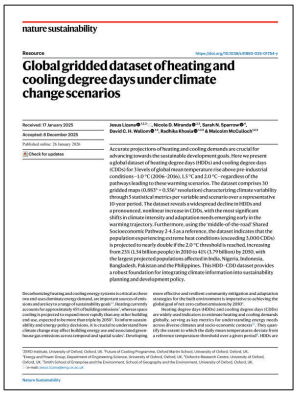
Temperature dataset



J. Lizana, et al. (2024), Ensemble of global climate simulations for temperature in historical, 1.5 °C and 2.0 °C scenarios from HadAM4, Scientific Data. 11, 578. https://doi.org/10.1038/s41597-024-03400-2

Data repository:
https://catalogue.ceda.ac.uk/uuid/9c41e3aa67024bbdad796290a861e968

CDD-HDD dataset



+ GitHub repository with ready-to-use code for data analysis.

J. Lizana, et al. (2026), Global gridded dataset of heating and cooling degree days under climate change scenarios, Nature Sustainability. 9. 470–480. https://doi.org/10.1038/s41893-025-01754-y

Data repository:
https://doi.org/10.5287/ora-w4qpqy522.

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Urban climate observations

Citizen weather stations

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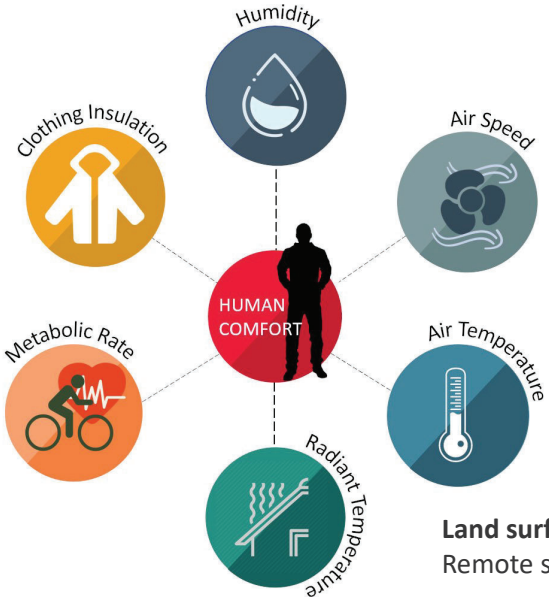
Introduction



Atmospheric air temperature
meteorological networks – lack of urban climate data

Land surface temperature
Remote sensing (satellite data) – low temporal resolution

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Citizen weather data

Citizen data refers to data from people generated via Internet-connected devices and shared through open access platforms

netatmo.com

wunderground.com

R. Agrawal, et al. (2026), The evolution of citizen weather stations in urban climate research: A bibliometric analysis, Urban Climate. 65 (2026) 102808 Contents. https://doi.org/10.1016/j.uclim.2026.102808

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Methods: framework

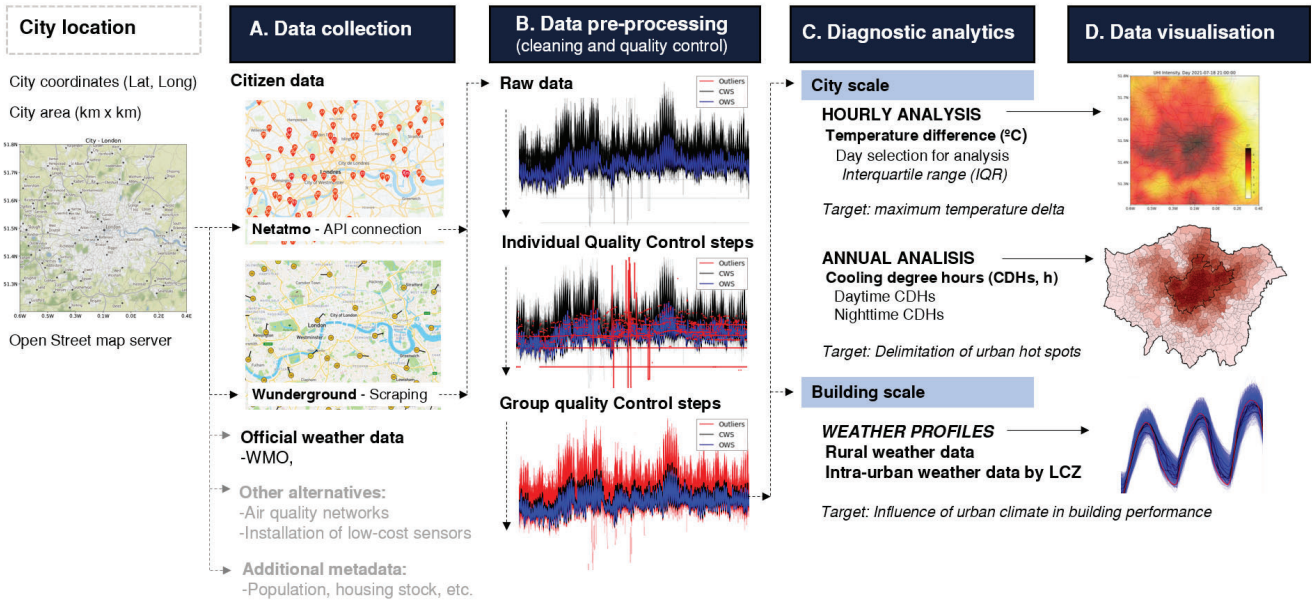

Figure: The approach defined to work with CWS

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Methods: ML-driven urban climate observations

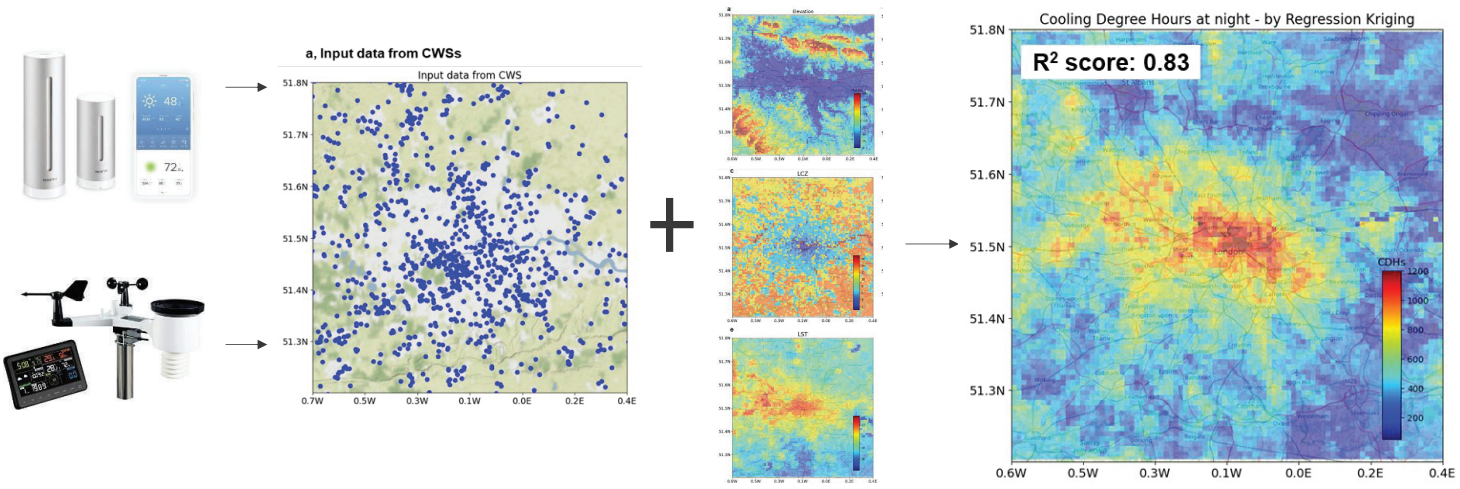

Figure: ML-driven observations - Proof of concept

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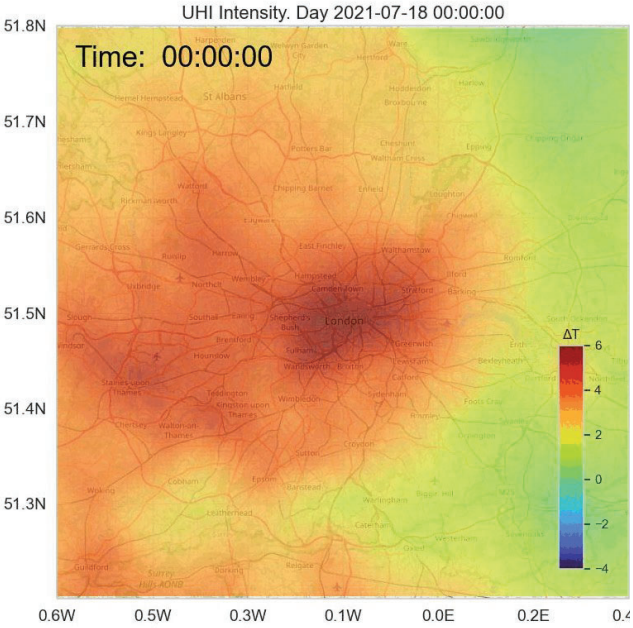
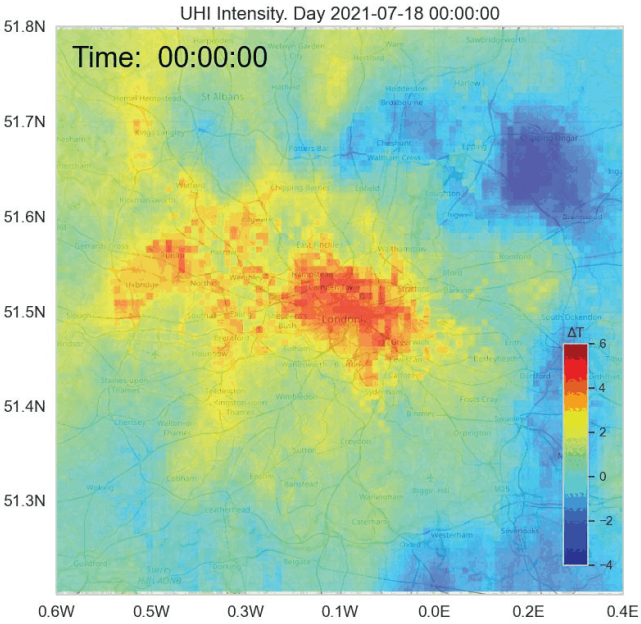
Initial key findings 1/2

Urban air temperature observations





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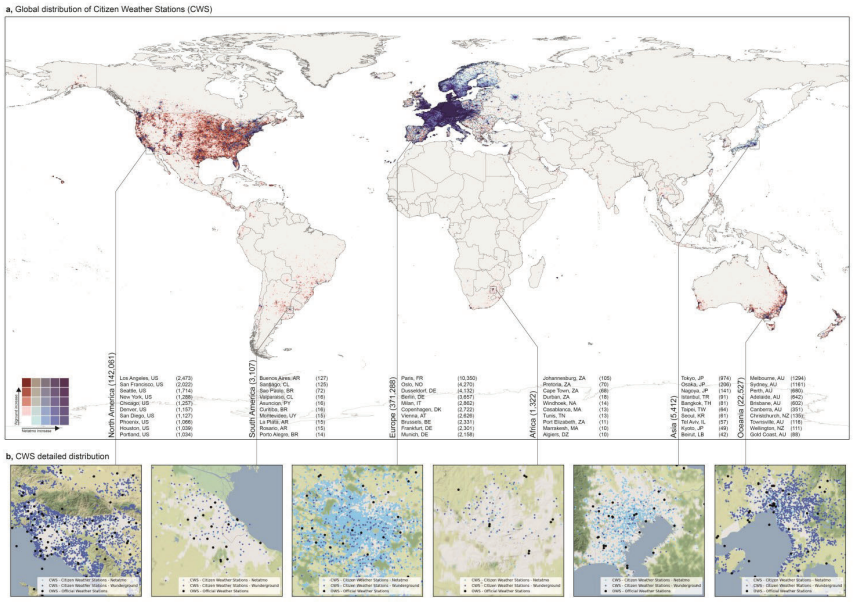
Initial key findings 2/2

Applicability of 550,000 citizen weather stations globally



- >550,000 citizen weather stations are found globally
- No homogeneous distribution
- More citizen data found in United States, Europe, Australia, Japan and Russia

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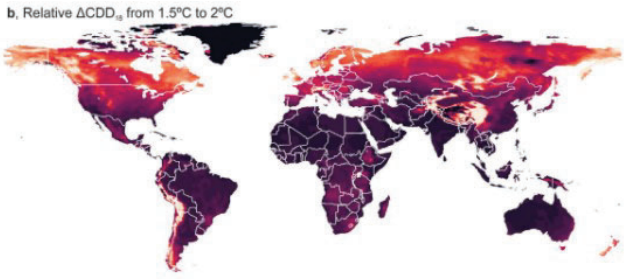
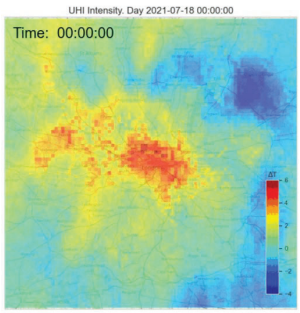
Final remarks

a, Global climate modelling
Resolution: 6 hours at 60km²



b, Urban climate observations
Resolution: 1 hour at 1km²



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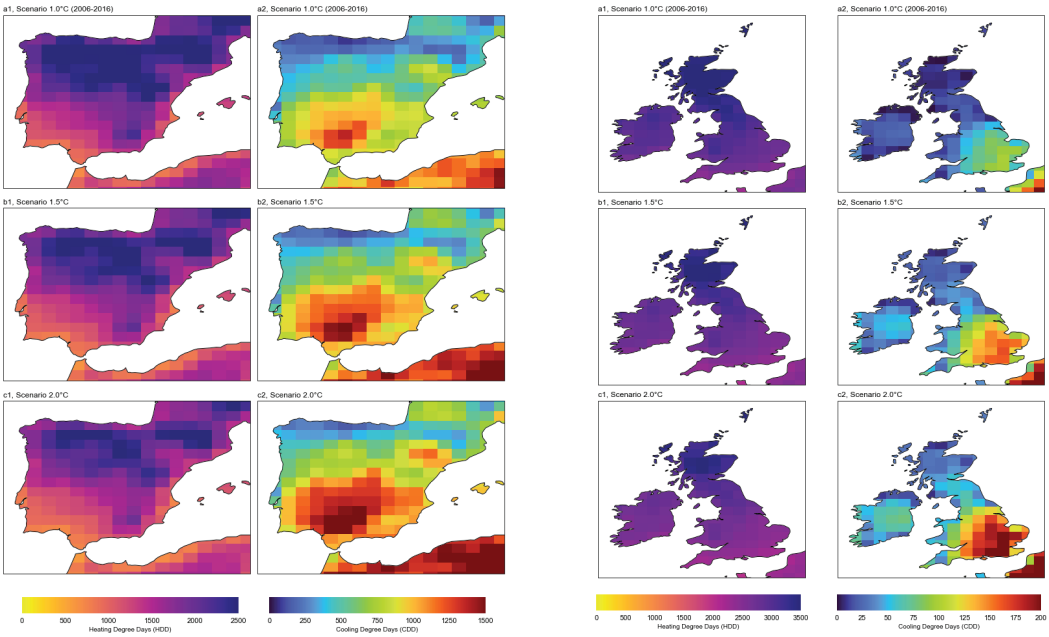
Annex A



Global mean HDD and CDD in the UK for three scenarios: 1.0ºC (2006-2016), 1.5ºC and 2.0ºC. Administrative boundaries were used from Natural Earth.

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