# Section 1: Health Hazards, Exposure, and Impact

## 1.1 Health and heat

### Indicator 1.1.1: exposure of vulnerable populations to heatwaves

Indicator Authors

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Methods

Heatwave Indicator Definition and Methodology

The heatwave indicator defines a heatwave as a period of two or more consecutive days in which both the minimum and maximum temperatures exceed the 95th percentile of the local climatology, based on the 1986–2005 reference period. The indicator is designed to capture both direct heat stress from high maximum temperatures and the health risks associated with insufficient nighttime cooling due to elevated minimum temperatures.

To determine heatwaves, the 95th percentile of daily minimum and maximum temperatures was computed using the European Centre for Medium-Range Weather Forecasts (ECMWF) ERA5 dataset, gridded at a 0.25° × 0.25° global resolution for the 1986–2005 baseline period. Based on this definition, the number of heatwave events and the total number of heatwave days per year were calculated for each year from 1980 to 2023.

Vulnerable Populations and Exposure Calculation

Vulnerable populations are defined as individuals over 65 years of age and infants under one year old, as these groups are particularly susceptible to heat-related health impacts.

Exposure is calculated using the person-days metric, which quantifies heatwave exposure by multiplying the number of heatwave days by the total vulnerable population. This approach ensures the indicator reflects changes in both heatwave frequency and duration, as well as demographic shifts that may increase the number of at-risk individuals.

Global gridded demographic data from the WorldPop project, available at a 1 km × 1 km resolution for the period 2000–2020, was used to identify vulnerable populations, based on the “top-down unconstrained approach”. For infants under one year old, separate datasets for males and females were aggregated at each grid point. For the elderly population (65+), age groups were merged by summing values from datasets for ages 65–70, 70–75, 75–80, and 80+. These aggregated datasets were then downscaled to match the ERA5 grid resolution (0.25° × 0.25°) by identifying the nearest neighbour for each ERA5 grid point and summing corresponding values.

For historical demographic data prior to 2000, the Lancet Countdown 2023 dataset was used. This dataset was generated from the ISIMIP Histsoc dataset and resampled to a 0.25° × 0.25° resolution using a 2D linear interpolation method that incorporates population densities and NASA GPWv4 land area data. Post-2020 population projections were estimated using linear interpolation at each grid point. Given the discontinuity in population datasets across time periods (pre and post 2000), direct comparisons of population changes were avoided. Instead, the analysis focuses on changes in exposure to heatwaves, mitigating inconsistencies in demographic data across different sources.

The WorldPop methodology combines census data, surveys, and remote sensing, though data quality and timelines vary by region. In areas with limited data or political instability, the approach relies more heavily on modelling.

Code and resources to reproduce the results

The results were generated using Python, a copy of the code is available in this public repository XXX. Users who want to reproduce the data will need to download the datasets listed below and can use our code to reproduce the results, please refer to the README file with detailed instructions on how to run the Python code.

Data

* **Climate Data**: ECMWF ERA5 reanalysis dataset
* **Demographic Data (1980–2000)**: Hybrid gridded demographic dataset from the Lancet Countdown 2023 (0.25° resolution)
* **Demographic Data (2000–2020):** WorldPop Age and Sex Structure Unconstrained Global Mosaic

Caveats

To ensure consistency over time, data from multiple sources were integrated to capture both spatial and temporal demographic trends. However, validation of this integrated dataset is limited. In regions with sparse demographic data or shifting political boundaries, inconsistencies may arise in the spatial distribution of populations. For example, the division of Sudan is reflected in the dataset as missing or incomplete information for infant populations, illustrating the challenges of maintaining demographic continuity in dynamically changing regions.

WorldPop’s "top-down unconstrained" approach was used for population mapping. This method estimates population distribution without restricting allocation to residential areas, unlike the "constrained" approach, which relies on satellite imagery to identify inhabited locations. While this method ensures continuous coverage across all land areas, it may overestimate populations in low-density regions and underestimate them in high-density areas.

Future form of the indicator

Discuss with Ollie

Additional analysis

Figure 1 illustrates the change in the number of heatwave days in 2023 compared to the baseline period, highlighting intense events across the Americas, Africa, Central and Eastern Europe, the Middle East, East and Southeast Asia, and Central Asia.

A map of the world

AI-generated content may be incorrect.

Figure 1. Map depicting the change in the number of heatwave days over land in 2023 compared to the 1986–2005 baseline.

The total number of heatwave days experienced annually by individuals in vulnerable age groups rose by 52% in 2024. Older adults (65+) endured a record 17.6 billion person-days of heatwaves, while infants under one year experienced 2.9 billion person-days, as illustrated in Figure 2.



Figure 2. Total number of heatwaves days experienced per year by older adults and infants.

Figure 3 shows that on average across the world heatwave exposure is higher among individuals over 65 (20.8 heatwave days per person), while infants experienced 20.4 days.



Figure 3. Average number of heatwave days experienced by individuals over 65 and infants under one year old.

When analyzed by country, as shown in Figure 3 and Figure 4, China and India have the highest number of affected individuals in both age categories, primarily due to their large populations. In 2024, a significant number of people over 65 were also impacted in Japan, the United States of America, and Italy, while heatwave exposure among infants was particularly high in Indonesia, Nigeria, and the Democratic Republic of the Congo.



Figure 4. Total heatwave person-days experienced by infants under one year old, presented by year and by the most affected countries.

Figure 5. Total heatwave person-days experienced by individuals over 65, presented by year and by the most affected countries.

Before 2024, countries classified as ‘Low’ HDI, on average, exhibited lower heatwave exposure for both age groups, as shown in Figure 5. However, these countries experienced the fastest growth in 2024 and both groups experienced at more than 20 heatwaves days per year on average.



Figure 6. Average number of heatwave days experienced aggregated by HDI level.

Figure 6 presents data aggregated by WHO regions. The Wester Pacific region was the most affected for the infants (under 1) and the over-65 population.



Figure 7. Average number of heatwave days experienced aggregated by WHO region.

Additional analysis

While climate change drives the increase in heatwave days, population growth also contributes to the rising number of heatwave person-days. This section compares the periods 1986–2005 and 2004–2024 to estimate how many heatwave days vulnerable populations would have experienced if climate change had not occurred, considering only demographic shifts.

For each geographic coordinate, the average annual heatwave days affecting both elderly and infant populations were calculated for 2004–2024. The same calculation was repeated while holding heatwave incidence constant at 1986–2005 levels, isolating the impact of climate change. Comparing these scenarios reveals how many heatwave days vulnerable populations would have been exposed to purely due to demographic changes.

Under a constant heatwave incidence at baseline levels, vulnerable populations would have experienced an average of XX heatwave days per person per year in 2004–2024—YY% fewer than observed. Infants faced an average increase of ZZ heatwave days per year, while individuals over 65, a rapidly growing group, experienced an additional YY heatwave days annually. Notably, a slight decrease in per-person heatwave exposure would have been expected if heatwave incidence remained at 1986–2005 levels, reflecting shifts in the geographic distribution of vulnerable populations.