Heat and Cold Wave Index (HCWI)

This Factsheet provides a detailed technical description of the indicator Heat and Cold Wave Index (HCWI), which is implemented in the Copernicus Global Drought Observatory (GDO), and which is used for detecting and characterizing periods of extreme-temperature anomalies (i.e. heat and cold waves). The meteorological variables, upon which the HCWI indicator produced by GDO is based, as well as the indicator's temporal and spatial scales and geographic coverage, are summarized below. An example of the HCWI indicator in GDO, is shown in Figure 1.

Variables	Temporal scale	Spatial scale	Coverage
Daily minimum and maximum temperatures	Daily	0.25 degrees (~ 25 km)	Europe

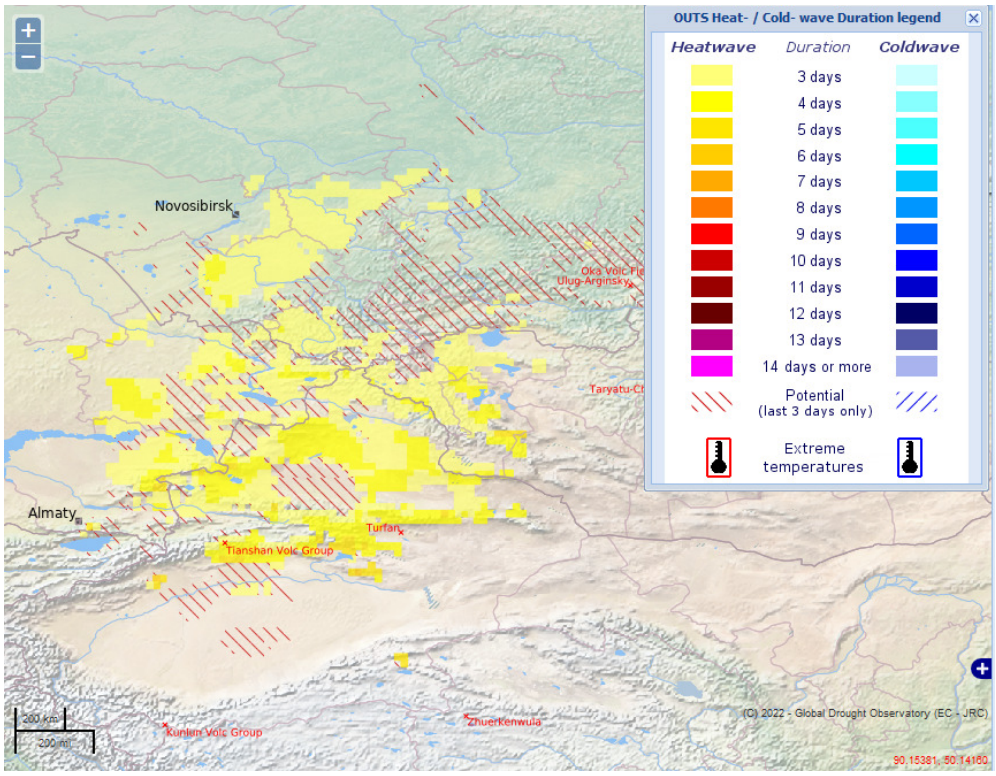

***Figure 1**: Example of the continuously updated HCWI indicator, produced by the Copernicus Global Drought Observatory (GDO), showing a major heat wave of the summer of 2022 at the border of Russia, Mongolia, China and Kazakhstan.*

1. Brief overview of the indicator

The Heat and Cold Wave Index (HCWI) that is implemented in the Copernicus Global Drought Observatory (GDO) is used to detect and monitor periods of extreme-temperature anomalies (i.e. heat and cold waves) that can have strong impacts on human activities, health and ecosystem services such as sprouting of crops. The HCWI indicator is computed for each location (grid-cell), using the methodology developed by Lavaysse et al. (2018), based on the persistence for at least three consecutive days of events with both daily minimum and maximum temperatures (Tmin and Tmax) above the 90th percentile daily threshold (for heat waves) or below the 10th percentile daily threshold (for cold waves). For each location, the daily threshold values for Tmin and Tmax are derived from a 30-year climatological baseline period (1991-2020), using the GloFAS/ERA5 derived temperature data.

2. What the indicator shows

The HCWI indicator that is implemented in GDO shows the duration in days of detected heat waves - defined as events of at least three consecutive "hot" days - and detected cold waves - defined as events of at least three consecutive "cold" days. In this context, a "hot day" is a day with both daily minimum and maximum temperatures (Tmin and Tmax) above their daily threshold values, calculated as the 90th percentile values of Tmin and Tmax for that calendar day during the climatological baseline period (1981-2010). Similarly, a "cold day" is a day with both Tmin and Tmax below their daily threshold values, calculated as the 10th percentile values of Tmin and Tmax for that calendar day during 1981-2010.

The following heat and cold wave-related data layers are also available via the EDO interface:

- Daily minimum and maximum temperatures (Tmin and Tmax) during a selected day.
- Daily amplitude of the diurnal temperature cycle, defined as the difference in between Tmax and Tmin, which provides information on nighttime cooling, and is a proxy for cloud-cover.
- Daily maximum temperature anomaly, not necessarily related to extreme events.
- The daily calendar thresholds used in the HCWI indicator to detect heat and cold waves, showing the spatial variability of these thresholds.

3. How the indicator is calculated

The HCWI indicator is computed from daily minimum and maximum temperature values, which are obtained from the GloFAS/ERA5 database containing daily meteorological satellite born observations, calibrated with real observation, from 1990 to the present day, interpolated onto a 0.25 decimal degree grid for all of inhabited world, in two main steps, as is described below and illustrated in Figure 2.

1. Definition of the daily threshold values for heat and cold waves:

The threshold values of daily minimum and maximum temperature (Tmin and Tmax) that characterize a heat or cold wave are computed from the observed Tmin and Tmax for that calendar day during a 30-year baseline period (1981-2010). For heat waves, the daily threshold values for Tmin and Tmax are defined as the 90th percentile ("Q90") of the 330 respective temperature values in an 11-day window centred on that day, for all years in the baseline period. For cold waves, the daily threshold values for Tmin and Tmax are defined as the 10th percentile ("Q10") of the 330 temperature values in an 11-day window centred on that day, for all years in the baseline period.

2. Calculation of the duration of detected heat or cold waves:

A heat or cold wave is detected when there are at least three consecutive days with both Tmin and Tmax above (for heatwaves) or below (for cold waves) their daily threshold values (defined as described previously). When two successive heat or cold waves are separated in time by one day, these are considered mutually dependent events, and so are merged ("pooled") as a single event. The duration (in days, not counting "pool" days) of the detected waves, is then computed.

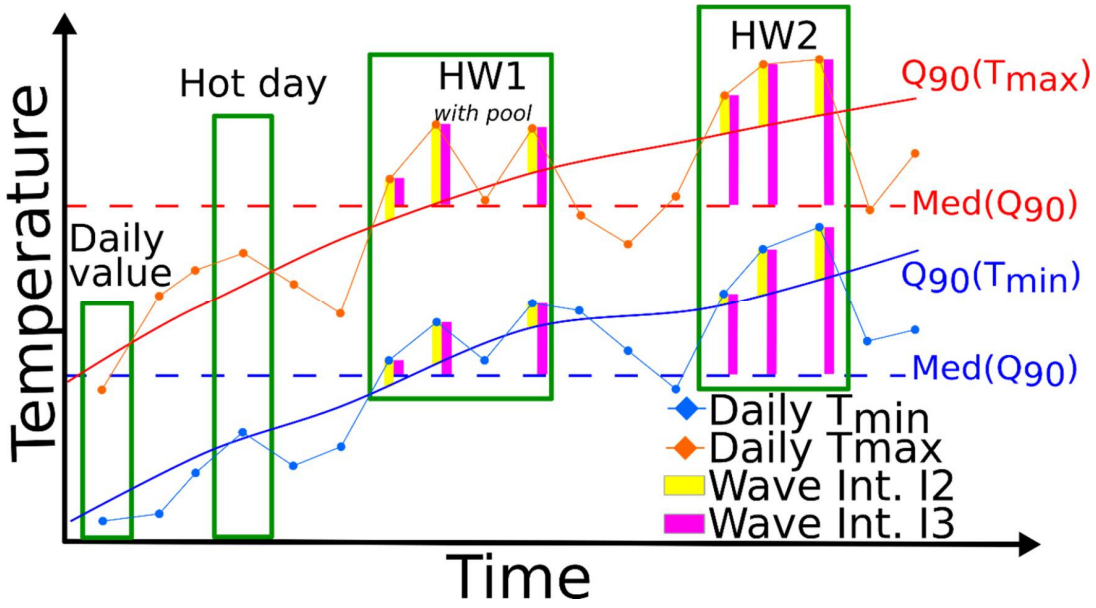

*Figure 2. Illustration of the calculation of the HCWI indicator, for two heatwaves (HW1 and HW2). Note that while only the **duration** of heat (and cold) waves is displayed in GDO, as can be seen their **intensity** ("I2" or "I3") can also be quantified, based on anomalies of Tmin and Tmax from calendar day ("Q90") or constant yearly ("Med(Q90)") threshold values. From: Lavaysse et al. (2018).*

4. How to use the indicator

The HCWI indicator that is implemented in GDO, indicates directly where and when a heat or cold wave has occurred, while the long term climatology that is also available can be used for monitoring and validating past events. As can be seen in Figure 1 above, the HCWI indicator displays the duration of a heat or cold wave in order of increasing magnitude, with colour scales ranging from yellow to red (for heat waves) and blue to black (for cold waves). By definition, the minimum duration of a wave is three days, increasing to fourteen days and longer. For durations under three days, the affected grid-cells are indicated with red stripes (for heat waves) and blue stripes (for cold waves), in order to flag areas where waves may potentially be starting. Finally, waves that include daily temperatures above 40°C (for heat waves) or below minus 20°C (for cold waves), are higlighted by thermometer icons coloured red or blue, respectively, in order to highlight the potential increased risks for human health.

5. Strengths and weaknesses of the indicator

Strengths:

- The HCWI indicator that is implemented in GDO is updated on a daily basis (with a two-day delay), and provides a conceptually simple and easy-to-use method for assessing the duration and geographical distribution of sustained temperature anomalies (i.e. heat and cold waves) over Europe, for any given day from 1990 onwards.
- The use of calendar day percentile-based threshold values to determine hot and cold days means that the temperature anomalies that are detected are specific for the time of year, and for the geographic location.
- Furthermore, because it uses both daily minimum and maximum temperatures (Tmin and Tmax), the HCWI indicator takes account of the strong human impacts of nighttime temperatures (i.e. Tmin) during a heatwave, as recommended by WMO (2015). This contrasts with commonly used methods for measuring heat waves, which only use Tmax.

Weaknesses:

- The HCWI indicator shows the duration of the heat or cold wave on a selected day. However, in order to determine if this is towards the beginning, middle or end of the wave, the user may have to navigate to other days.
- Due to the different methods that are used, for example, in different countries to measure daily minimum and maximum temperatures, the HCWI indicator might not be exactly comparable with similar indicators that are available at national or regional levels.

References

- Lavaysse, C., C. Cammalleri, A. Dosio, G. van der Schrier, A. Toreti, and J. Vogt. 2018. Towards a monitoring system of temperature extremes in Europe. Natural Hazards and Earth System Sciences, 18, 91-104. https://doi.org/10.5194/nhess-18-91-2018

- Russo, S., A. Dosio, R. G. Graversen, J.Sillmann, H. Carrao, M. B. Dunbar, A. Singleton, P. Montagna, P. Barbola, and J. Vogt. 2014. Magnitude of extreme heat waves in present climate and their projection in a warming world, J. Geo-phys. Res. Atmos., 119, 12,500–12,512. Doi: 10.1002/2014JD022098

- World Meteorological Organization and World Health Organization. 2015. Heatwaves and Health: Guidance on Warning-System Development. McGregor, G.R., P.Bessemoulin, K. Ebi and B. Menne (eds.). WMO-No. 1142. WMO, Geneva. 96 pp. ISBN 978-92-63-11142-5.