Present and projected humid heat exposure and precipitation extremes in Turkey

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BACKGROUND

- Humid heat extremes will become more frequent and intense in areas already affected and will expand from tropical locations to higher latitudes, making mid-latitudes hotspots for intensified heat stress[1,2,3,4,5,6].
- A 3.0°C global temperature increase could regularly affect 5 billion people with wet-bulb temperatures above 27.5°C, while 100 million could experience deadly wet-bulb temperatures of 35°C[3].
- Climate simulations reveal that extreme precipitation incidents will become more intense with shorter return periods in the following decades. Several studies show the GEV method can be a good choice to model the return period/level of extreme precipitation indexes[7,8,9,10,11,12].
- Turkey is located in the Eastern Mediterranean close to the Middle East, currently highly susceptible to humid heat and hydrological extremes.

DATA AND METHODS

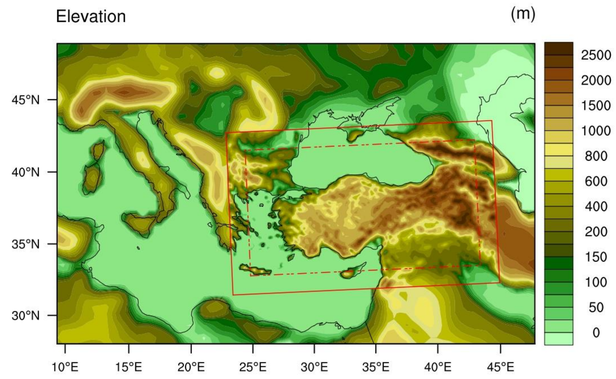

Fig 1. We run long-term historical and future climate simulations under the RCP8.5 scenario using COSMO-CLM. The outer (inner) domain has a resolution of 0.44° (0.11°). The utilized boundary data is MPI-ESM-LR. The model precipitation output and the calculated wet-bulb temperature (Tw) is verified and bias-corrected against the ERA5-Land reanalysis.

Humid Heat Exposure

- We employed the (Stull, 2011)[13] version of the wet-bulb temperature (Tw) formula as the heat stress metric
- We quantified the population exposure to the summertime WBT extremes using the widely exploited person-days approach[14]
- For the base and projection periods, we used the population estimates from the GPWv4 and SSP5 data, respectively

Precipitation Extremes

- First, we calculated hourly extreme precipitation indexes: Intensity Index (InI), Frequency Indexes (FrI), and Persistence Indexes (PeI)
- Then, we explored the projected changes in the return level of these indexes utilizing stationary GEV theory
- Lastly, we revealed the non-stationary impact based on the stationary and non-stationary model difference

HUMID HEAT EXPOSURE

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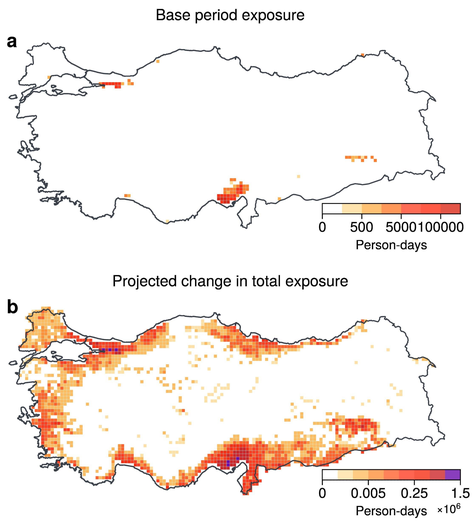

Fig 2. The population exposure in the base period, along with projected changes in total exposure. In our case, the population exposure refers to the average number of people that will encounter severe humid heat stress (with a daily maximum of 27°C) for a certain number of days per year. This exposure is measured in person-days.

Please scan the QR code to see the supplementary material

- The exposure to 27°C is geographically limited in the base period mainly located in the southeastern city of Adana and east of the Marmara Sea with the exposure rarely exceeding 100,000 person-days (Fig 2)
- In contrast, in the projection period, the total population exposure increases by at least 5,000 person-days along most of the coastal locations, with a spatially intermittent surge in exposure by as much as 1.5 million person-days
- Exposure to these extremes across the inner continental parts of the country is sporadic, with projections showing less pronounced increase
- Cities accommodating millions of people experience the greatest increase in exposure in spite of the finding that the majority of these cities will lose some of their population to their surroundings (Fig S1)

- While, on average, 20.4% of the total population is exposed to 27°C and above for at least one hour, only 4.15% of the total population is projected to experience this severe heat stress for five consecutive hours (Fig 3)
- 31°C might be experienced by only 0.13% of the total population for at most one consecutive hour
- Note that 0.13% of the total population corresponds to more than 80 thousand people.

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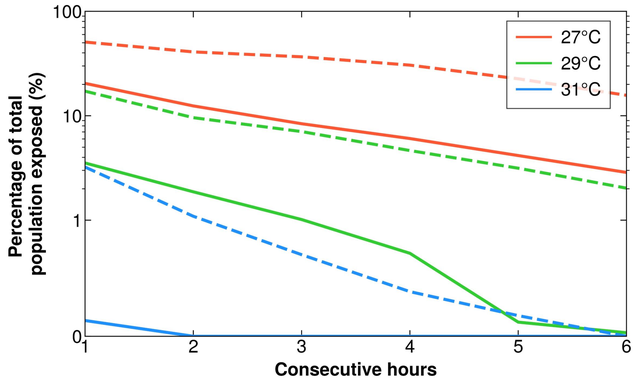
Fig 3. The proportion of Turkey's population that will be exposed to three distinct humid heat stress thresholds (27°C, 29°C, and 31°C) for different consecutive hours. The solid and dashed lines represent the temporal average and the temporal maximum of the yearly persistence index, defined as the maximum number of consecutive hours above the utilized WBT thresholds at every grid in our domain.



PRECIPITATION EXTREMES

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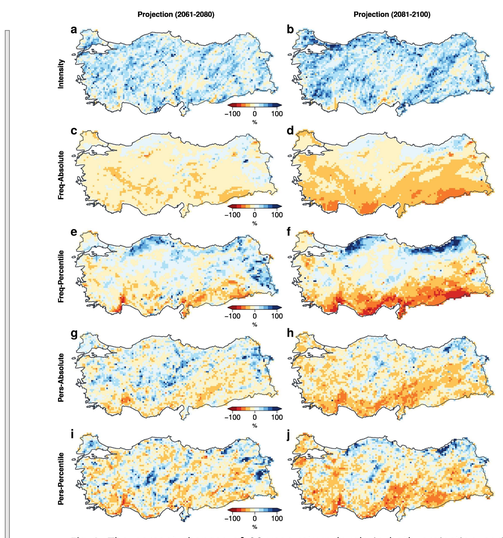

Fig 4. The percent changes of 20-year return levels in both projection periods (2061-2080 and 2080-2100) relative to the reference period (1985-2005) for each extreme precipitation index (see the supplementary file for definitions) based on stationary GEV analysis.

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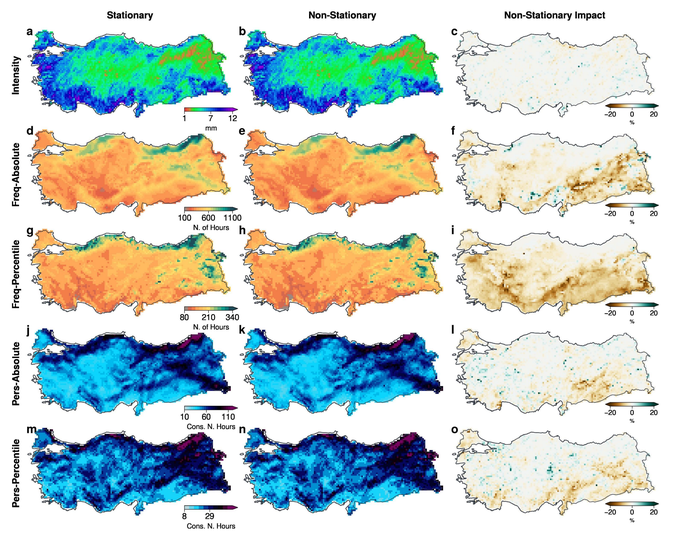

Fig 5. The stationary and non-stationary 20-year return level (RL) values as well as the non-stationary impact for each extreme precipitation index for the combination of future periods (40 years: 2061-2100). Negative (positive) values in the non-stationary impact correspond to a higher RL value in the stationary (non-stationary) configuration.

Intensity: While in *2061-2080*, the increase in InI hovers around %40, the change becomes more evident in *2081-2100* (almost %80).

Frequency: Latitudinal (north-south) gradient is apparent in both frequency indexes. Frequency increases (decreases) in *Black Sea* (*Mediterennean*)

Persistence: Persistence indexes reveal not as *systematic* latitudinal gradient as in frequency-based metrics. Yet, similar findings still apply.

Intensity: InI has the most homogeneous non-stationary impact. It has the lowest magnitudes of influence - no more than %5 in both directions - while the majority of the country shows no impact.

Frequency: *Negative* non-stationary impact is evident across much of Turkey for both frequency-based indexes. *FrI-percentile* index exhibit negative non-stationary impacts that are more pronounced (%10-%20).

Persistence: Both *persistence* indexes display parallel impact patterns. In that, Southeast Anatolia and Mediterranean-Aegean coasts show negative non-stationary impact values (~%10). Conversely, northern and interior parts exhibit positive impact.

Conclusion

- There is a dramatic increase in population exposure to heat stress especially along the coastal areas. While the intensity of precipitation increases in the country, the frequency metric shows a decline in the south but an increase in the north, and our results show the important impact of non-stationarity on the analysis of precipitation patterns.
- Our results have implications for the society and different sectors, including tourism, given that the biggest changes occur near coastal cities.
- Further studies can incorporate urban aspects using urban canopy models since urbanization can promote urban heat islands and further exacerbate humid heat extremes and modify precipitation extremes.
- We can not quantify uncertainty in our results, since we used only one initial-boundary condition data. Also, our conclusions are based on the RCP8.5 emission scenario. These limitations can be addressed by employing an ensemble of simulations.

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