Are Switzerlands Dogs Threatened by Future Unabated Global Warming?

Report in Climate Risk Assessment

Me carrying my overheating dog Tuuli (Finnish for *wind*)
down a small mountain in southern Spain (04.2023)

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Bern, 3rd June 2024

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1 Introduction

Dogs are integral to Swiss society. They serve society through their work as military-, police-, search and rescue-, and assistance dogs [15], and as a pet dog they improve their owner's physical, psychological and social well-being [13]. In Switzerland, 544.000 dogs were registered in 2022, averaging 6 dogs per 100 inhabitants [19]. This ratio is constant with small fluctuations since the 1950s [16]. Consequently, dogs play a vital role in many parts of Swiss society.

Dogs as well as humans face an increased risk through heat stress due to anthropogenic climate change and global warming [4, 2], especially in urban environments [10]. Heat stress is expected to increase in Switzerland in moderate to high emission scenarios [3] with urban areas facing amplified warming compared to rural areas [20, 21] notably at night [6]. In the past, increased heat stress has led to a rising human mortality rate in Switzerland [17].

With rising ambient temperatures, dogs switch their thermoregulation from radiative cooling to evaporation through increasingly excessive breathing (panting) [7, 9]. With increasing relative humidity above 35%, cooling through panting decreases in efficiency and above 80% panting looses all effectiveness [11]. Consequently, high humidity in high ambient temperature condition increase the heat stress experienced by dogs as they lose their ability to cool themselves [1]. According to Hall et al. (2022), heat-related injuries and illnesses appear on average already at 16.9°C mean ambient temperature.

This report investigates the increase in heat stress for dogs in a potential climate scenario with unchanged greenhouse gas emissions (RCP8.5). An adapted version of the Humidex index will be used to identify the potential increase in heat stress relevant days with relative humidity being taken into account. The increase of the number of tropical nights will represent the absence of nocturnal cooling, which leads to prolonged heat stress. I hypothesize that (i) heat stress for dogs will increase in the RCP8.5 emission scenario especially north of the Alps and (ii) in densely populated areas.

2 Data

For this evaluation of future heat stress on dogs, two time periods were compared. The time period 1971-2000 was used as a historical reference for the RCP8.5 scenario from 2071-2100. For these two time periods, 4 model chains from the Coordinated Regional Climate Downscaling Experiment (CORDEX) were used (see Table 1) to investigate the influence of a specific general circulation model (GCM) and a specific regional climate model (RCM) on the model output. The implementation of a regional model into a global model improves the spatial resolution while keeping the computational cost low. This enables a better representation of the topography, physical processes and extreme events among others.

Table 1: Model Chains

Chain ID	GCM	RCM
ICHEC-EC-EARTH_CLMcom-CCLM4-8-17_v1	EC-EARTH	CLIM
ICHEC-EC-EARTH_SMHI-RCA4_v1	EC-EARTH	SMHI
MPI-M-MPI-ESM-LR_MPI-CSC-REMO2009_v1	MPI	REMO
MPI-M-MPI-ESM-LR_SMHI-RCA4_v1a	MPI	SMHI

The data from these model chains was cropped to the spacial dimensions of Switzerland: latitude 45.5°N-48°N, longitude 5°E-11°E and had a resolution of 0.11°x 0.11° with daily observations. The variables that were used from these datasets are listed in table 2. Additionally, gridded population density estimates from 2080 were used. They were cropped to the same spatial extent and had a spatial resolution of 0.11°x 0.11°, consisting of one population value per grid cell. I assumed, that the dog population is on average similarly distributed as the human population.

Table 2: Variables

ID	Name	Unit	Index
tas	daily mean 2 m air temperature	K	Humidex index
tasmin	daily minimum 2 m air temperature	K	Tropical nights
rh	relative humidity	%	Humidex index

3 Methods

3.1 Humidex Index

The Humidex index was used to evaluate the combined development of daily mean temperature (tas) and relative humidity (rh) from a historic to a RCP8.5 scenario. The Humidex index was calculated according to the xclim documentation (see [22]).

For this report, the daily Humidex index temperatures were filtered for temperatures above 16.9°C, as this was the average temperature at which heat-related injuries and illnesses were recorded in Hall et al. (2022). Then the remaining days with temperatures above 16.9°C were counted per time period and then divided by the number of years per time period: 30. As a last step, the temporal averages of the historical scenario were subtracted from the temporal averages of the RCP8.5 scenario originating from the same model chain.

3.2 Tropical Nights

The number of tropical nights per year indicates heat stress, which endures over the night. Tropical nights are defined as days with minimum temperatures greater than 20°C. The yearly number of tropical nights was calculated according to the xclim documentation (see [22]). These yearly numbers were temporally averaged for every time period. Afterward, the historical scenario was subtracted from the RCP8.5 scenario from the corresponding model chain.

4 Results

4.1 Summer Heat Stress

All model chain differences showed relatively similar patterns regarding the number of days with Humidex temperatures above 16.9°C (dHt16.9) (Figure 1). The Alps experienced a minor increase of 0-10 dHt16.9 with small areas up to 35 days in the MPI GCM. All model chains also shared a relatively severe difference in dHt16.9 in Ticino, which amplified towards Italy and had the highest difference in Switzerland with up to 100 days in MPI REMO. The Jura had an increase in dHt16.9 of 0-65, with specific ranges depending on the model chain, and both EC-EARTH models predicting smaller differences to the historic scenario than MPI. The most complex patterns could be observed in the densely populated Swiss plateau, which received additional 20-50 dHt16.9, in some model chains even 50-60 days in large areas. In summary, all model chains showed the smallest increase in dHt16.9 in the Alps, followed by the Jura region, with the greatest increase in Ticino and complex patterns of medium increases in the Swiss plateau.

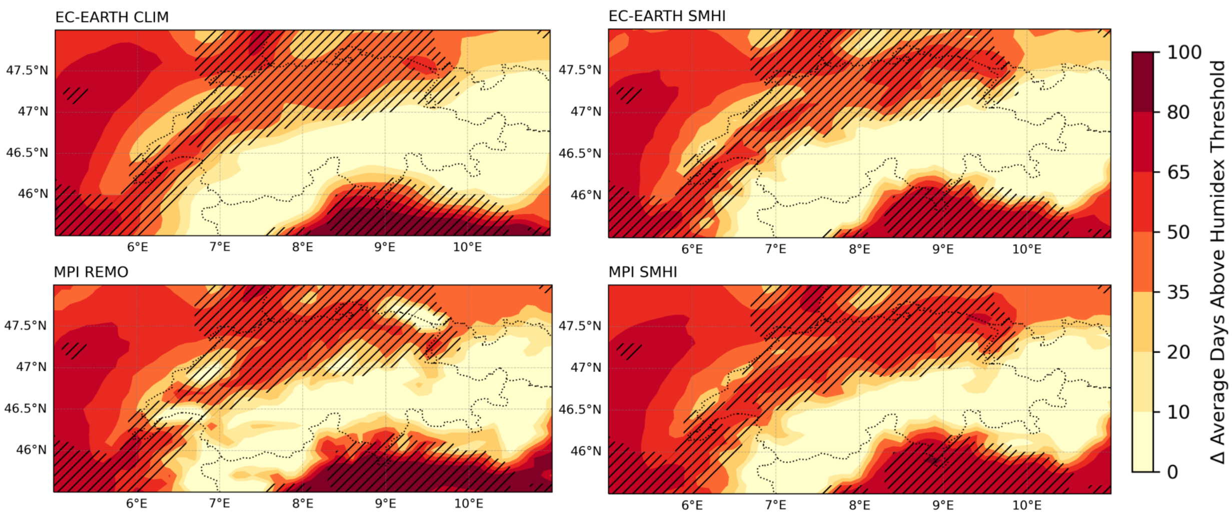

Figure 1: Difference between RCP8.5 and historical scenarios of average number of days per year above the Humidex index temperature of 16.9°C. Hashed areas have a population density > 300.000 in 2080. GCM and RCM are indicated in the top left of every difference plot.

Investigating the differences between model chains, EC-EARTH CLIM and EC-EARTH SMHI were the most similar. Both MPI model chains differed more, especially close to the Lake Constance, Lake Geneva and in the Jura. In general, MPI model chains, especially REMO, showed more complex patterns in the Jura and Ticino, compared to EC-EARTH model chains. Both SMHI RCM model chains had similar features in Ticino and the northern end of the Alps, but in general, projections of the same GCM were more similar than of the same RCM.

4.2 Night Heat Stress

In all model chains, the Alps experienced little increase in the number of tropical nights (nTN) with 0-2 days, as well as the Jura with 0-8 days, with subranges depending on the model chain (Figure 2). Similarly to the Humidex results, the Ticino showed severe increases up to 46 days in the nTN which are intensifying towards Italy. The Swiss plateau had diverse patterns depending on the model chain of rising nTN with ranges between 0-16 days. The prediction for the increase in nTN of the 5 biggest Swiss cities differed across model chains. The prediction ranges for Lausanne and Zürich were spread between 0-2 to 16-26 and from 0-2 to 8-16 nTN respectively, while predictions for BE, BS and GE were more consistent across model chains.

Compared to Section 4.1, EC-EARTH SMHI and MPI SMHI were the most similar, sharing most patterns and differing only slightly in magnitude. Both EC-EARTH model chains differed in their overall magnitude and in their patterns in the Swiss plateau and the Jura. Both MPI model chains represented the Ticino and the Alps relatively similar, but also showed different patterns in the Swiss plateau, the Jura and around Lake Geneva and Lake Constance. In summary, the same RCM in different model chains produced a higher degree of similarity than the same GCM in different model chains.

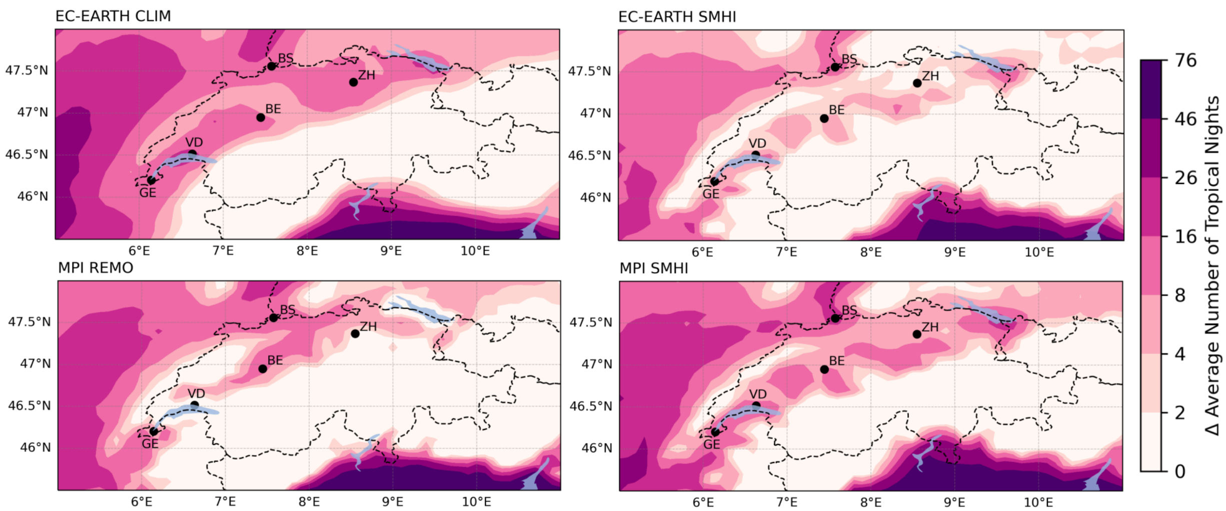

Figure 2: Difference between RCP8.5 and historical scenarios of average number of tropical nights per year. Major lakes are given in blue and the five biggest Swiss cities population wise (12.2023) [8] are marked: Geneva GE, Lausanne VD, Bern BE, Basel BS, Zürich ZH. GCM and RCM are indicated in the top left of every difference.

5 Discussion and Conclusion

This report aimed to estimate the increase of future heat stress for dogs in Switzerland using two indices. They assessed the increase in days with potential heat stress for dogs and the danger of prolonged heat stress indicated by the absence of nocturnal cooling. I hypothesized that heat stress will increase north of the Alps, especially in densely populated areas.

My results show that dogs will be most affected by the increase of dHt16.9 in the densely populated Swiss plateau. The number of dHt16.9 will increase up to 100 in Ticino, but due to its low population only few dogs will be under threat. This also applies for the Alps, where dHt16.9 potentially won't increase at all, but only a smaller part of the dog population will benefit from this. The increase of dHt16.9 largely depends on elevation, as all high elevation areas expect the lowest rise in dHt16.9. The comparison of different model chains indicates that this rise depended on the GCM as there were only minor differences between model chains that differed only in their RCM. This could be explained by the large influence daily weather has on mean temperature, leading to a dependency on atmospheric circulation.

The increase in the nTN potentially won't affect high elevation areas like the Alps and the Jura, but the Swiss plateau and especially Ticino will see a rise of up to 26 and 46 nTN respectively. How much and where the Swiss plateau will be affected by this development differed between model chains, as well as the impact on the 5 biggest Swiss cities. Especially predictions for the areas around Lake Geneva and Lake Constance were contradicting each other. These contradictions represent uncertainties of how minimum temperature will react to the RCP8.5 emission scenario locally. Better agreement between model chains regarding the impact on cities could be achieved by improving the spatial resolution. The differences between model chains were largely driven by the RCM, which also could result from different parameters concerning nocturnal cooling like vegetation, urbanization and the influence of large water bodies.

These results show that heat stress for dogs will increase in a scenario of unchanged greenhouse gas emission, especially in densely populated areas. This is consistent with other model simulations, that document future warming [18, 4, 6]. Specific preparations have to be made to reduce this threat for canine health, for example increased implementation of artificial cooling in buildings and the distribution of cooling mats [5, 12]. These measures are even more pressing as the Humidex index often underestimates the heat risk for dogs [14]. Future studies should investigate whether the Humidex index appropriately represents perceived temperature by dogs.

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