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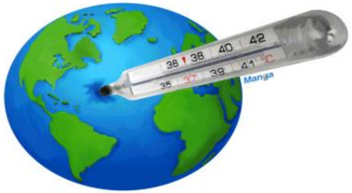
Leibniz-Institut für Agrartechnik und Bioökonomie

Future heat stress risk in European dairy cattle husbandry

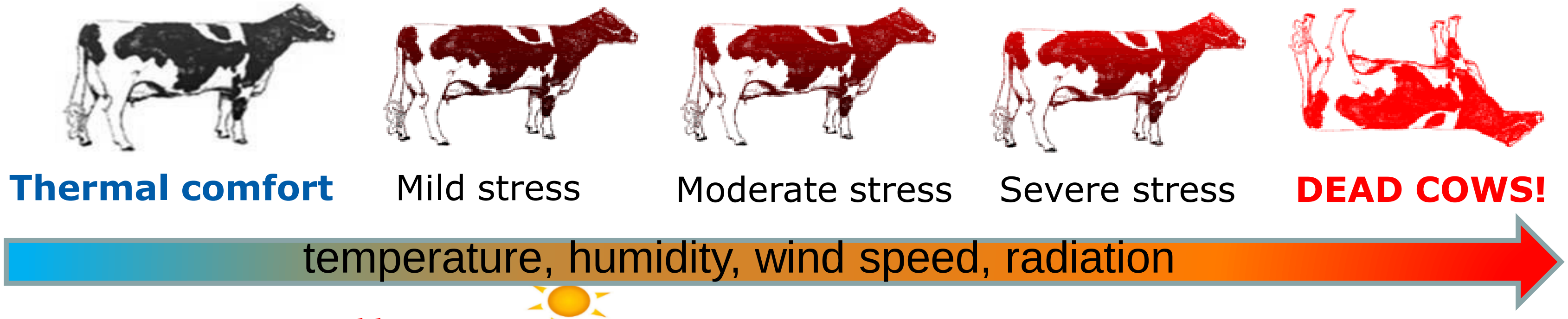
Sabrina Hempel, Christoph Menz, Thomas Amon

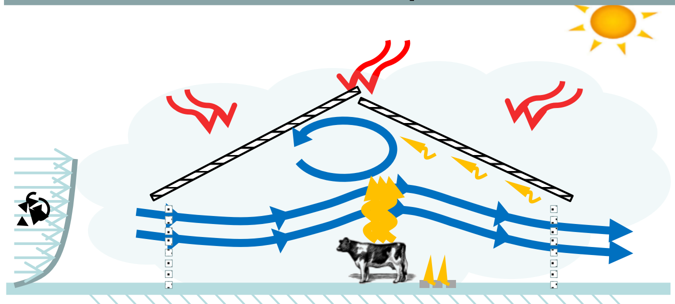
Leibniz Association

Motivation



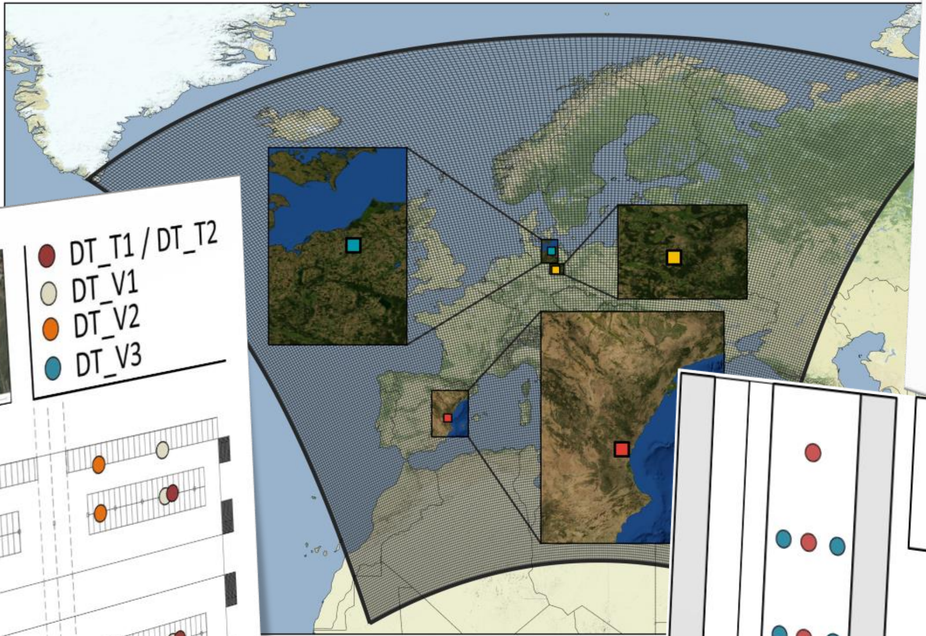
- Exceptional global warming trend
- Modifications in humidity and wind regime

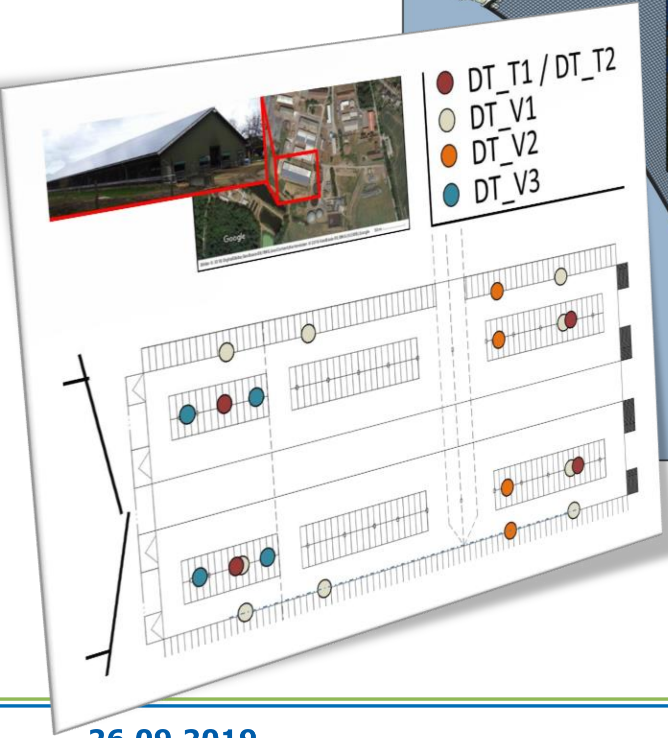


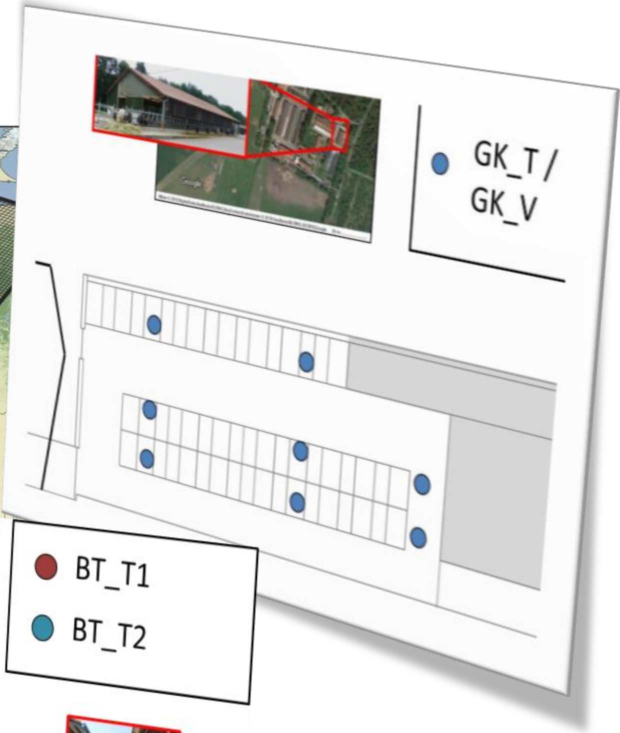


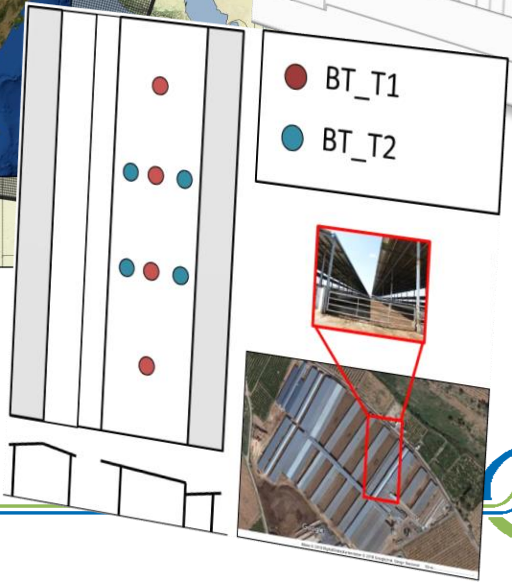
- Adaptation option via breeding and housing management, but balance welfare, environmental and economic issues barely investigated

Focus Regions & Reference Barns









Meteorological Indoor Data

Fokus region	Begin	End	Device
Central European maritime	27-05-15	01-11-16	4 COMARK
Central European maritime	01-11-16	28-08-17	4 EasyLog
Central European maritime	23-03-15	28-08-17	9 Wind Master
Central European maritime	23-03-15	12-10-16	4 Wind Master
Central European maritime	26-10-16	28-08-17	4 Wind Master
Central European continental	02-06-15	19-05-17	8 EasyLog
Central European continental	02-06-15	19-05-17	8 Wind Master
Western Mediterranean	30-06-16	06-07-16	4 EasyLog
Western Mediterrranean	18-07-17	08-09-17	4 EasyLog

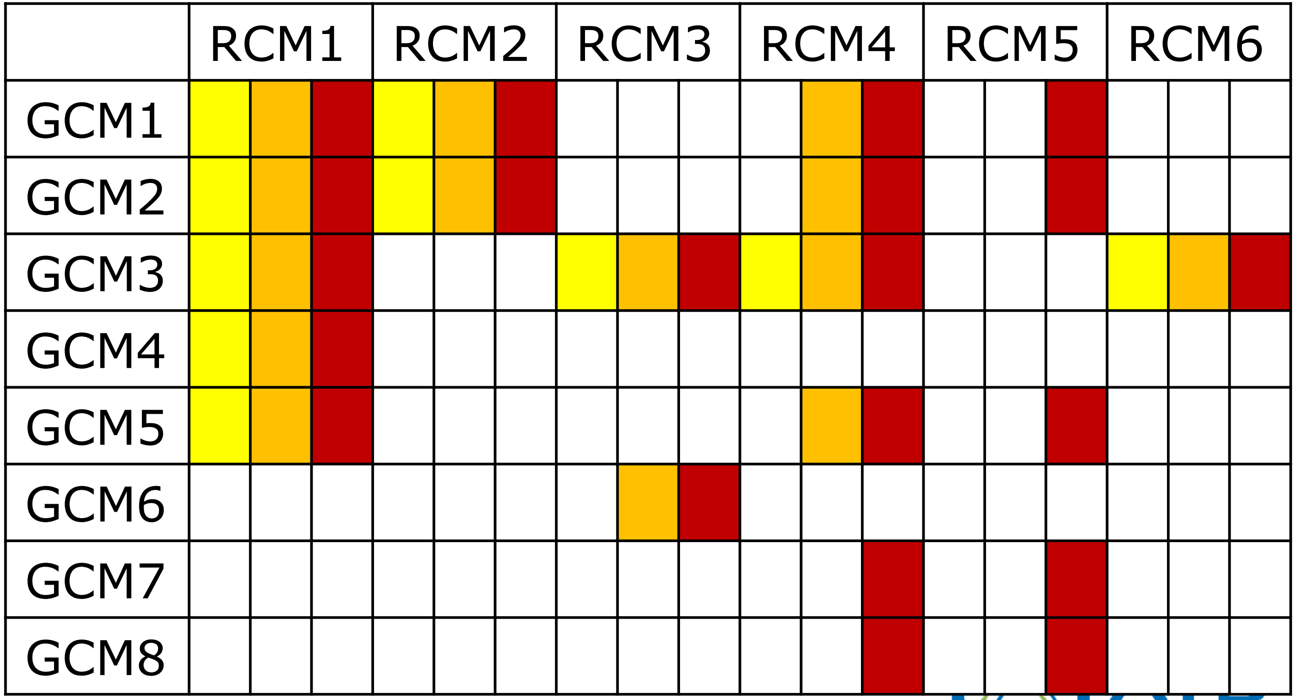
Meteorological Outdoor Data

- Station data (approx. 20 km distance to the reference barn) from DWD and NOAA/NCEI for model deduction

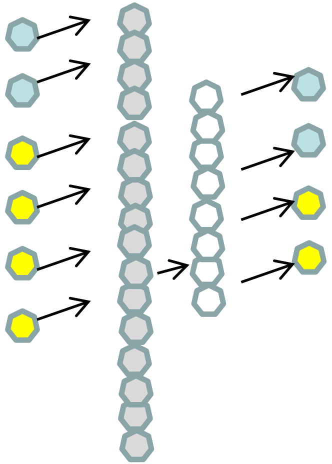
- Greenhouse gas concentration scenario (RCP) simulations

→heat stress projections

RCP2.6
RCP4.5
RCP8.5



Artificial Neuronal Network Models

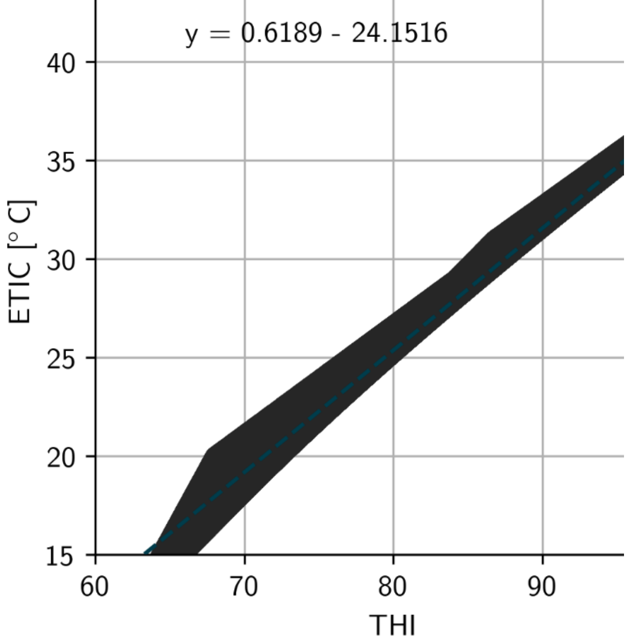


Backpropagation algorithm

- 4 Predictands and 6 Predictors
- 2 Hidden Layers
- Rectified linear unit activation function

Reference barn	Layout	Activation	Predictor	Predictand	Total R^2
Dummerstorf	(78, 54)	ReLU	T, H, W, P, R	T, H, W	0.74
Groß Kreutz	(90, 74)	ReLU	T, H, W, P, R	T, H, W	0.56
Bétera	(50)	ReLU	T, H	T, H	0.85

Empirical Heat Stress Models



1. Temperature Humidity Index (**THI**)

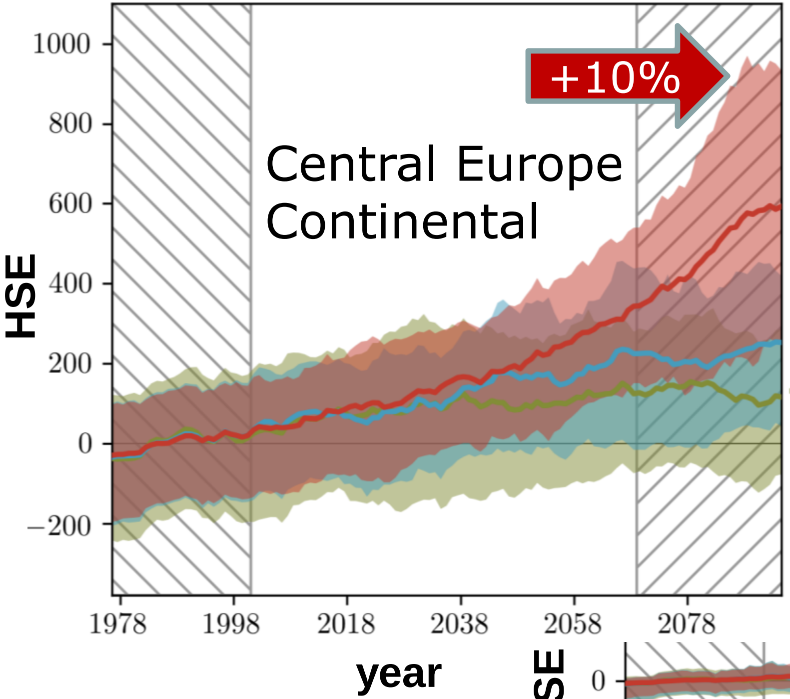
$$THI = (1.8 \cdot T + 32) - ((0.55 - 0.0055 \cdot H) \cdot (1.8 \cdot T - 26))$$

2. Equivalent Temperature Index of Cattle (**ETIC**)

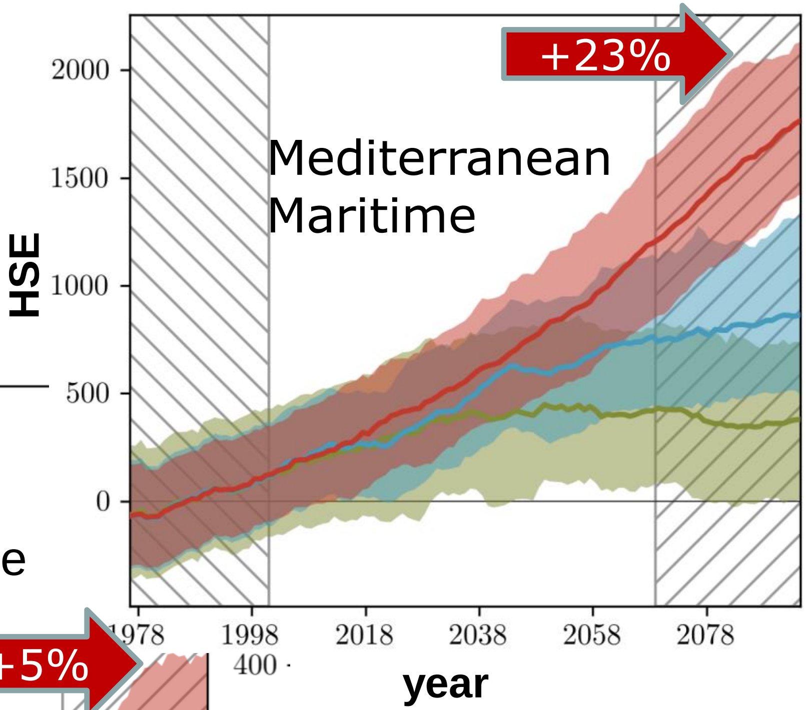
$$ETIC = T - 0.0038 \cdot T \cdot (100 - H) - 0.1173 \cdot |v|^{0.707} \cdot (39.20 - T) + 1.86 \cdot 10^{-4} \cdot T \cdot Q$$

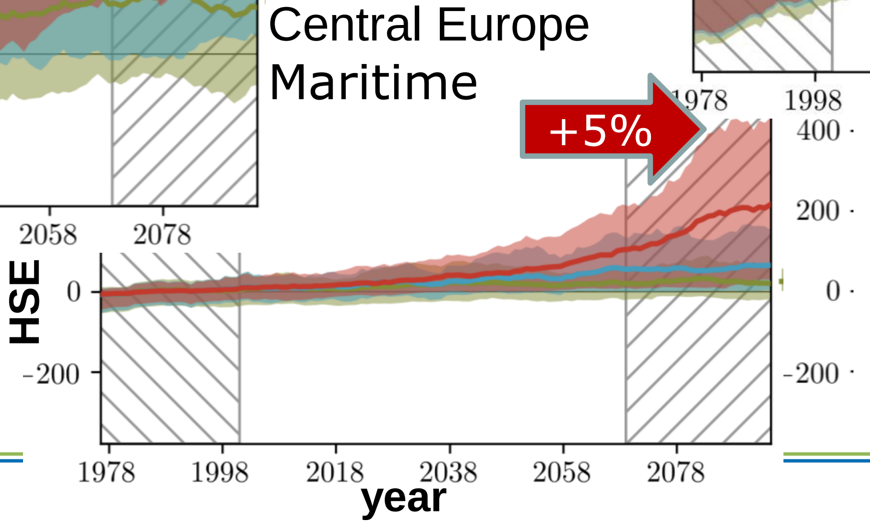
- Number of heat stress events (**HSE**) & heat stress event duration (**HSED**) with at least moderate stress (**THI >= 72 / ETIC >= 20**)

Risk of Heat Stress Events



<u>Reference:</u>
total hours per year (8760)

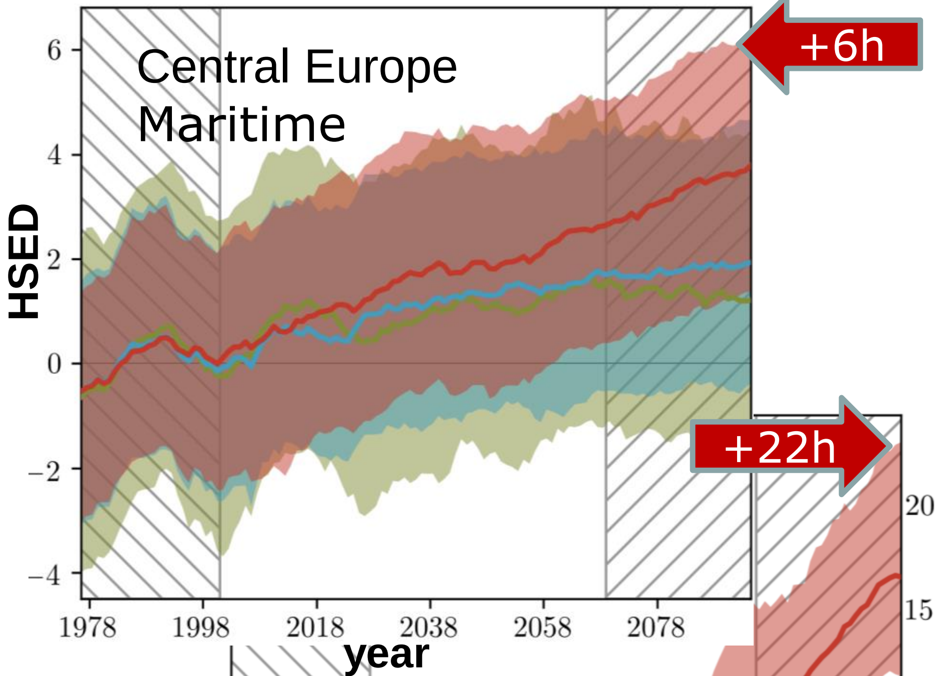


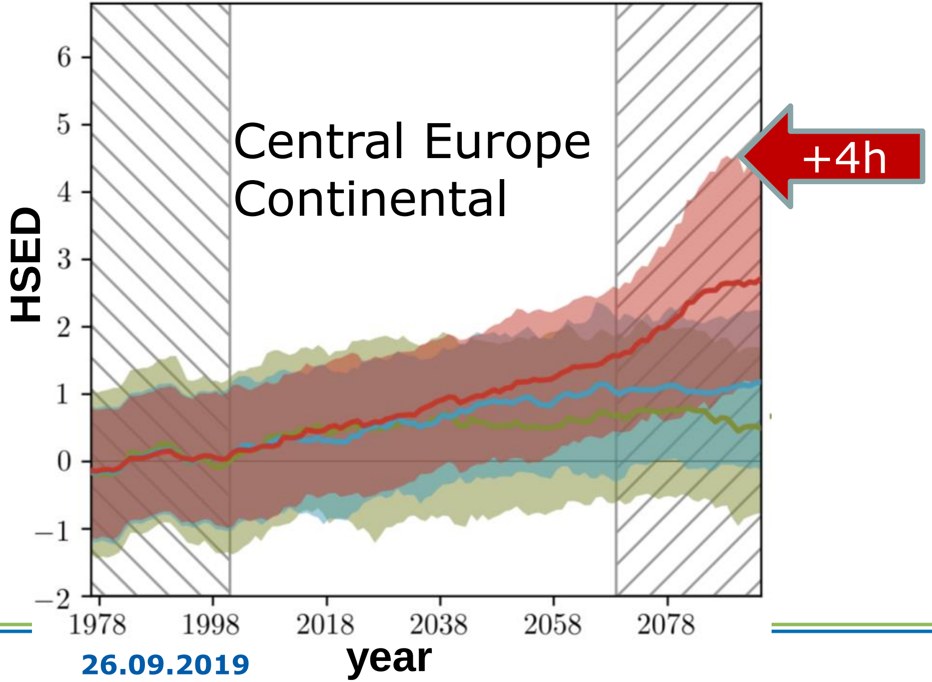


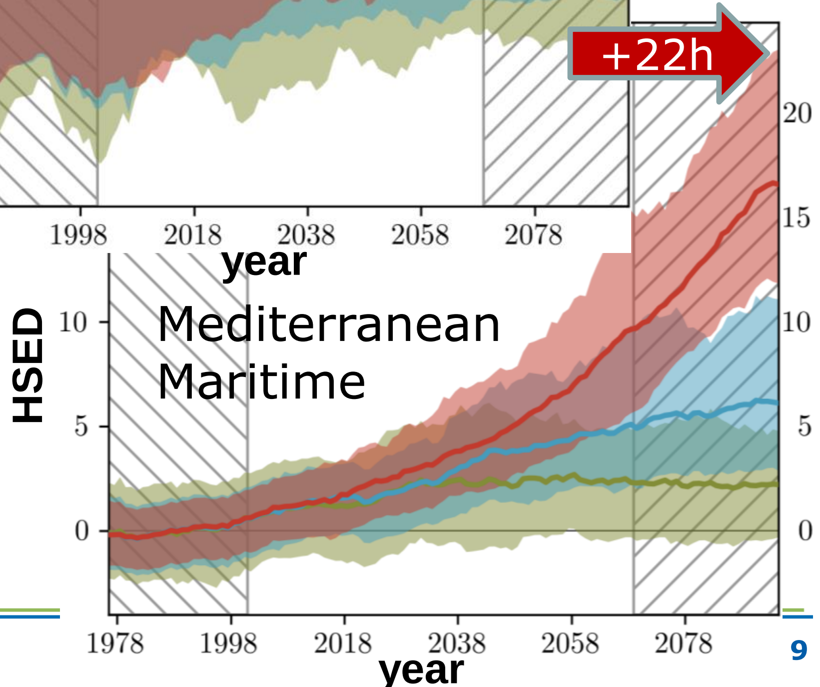
HSE = number of hours with at least moderate heat stress

Change of Heat Stress Event Duration (HSED)

HSED = number of consecutive hours with at least moderate heat stress

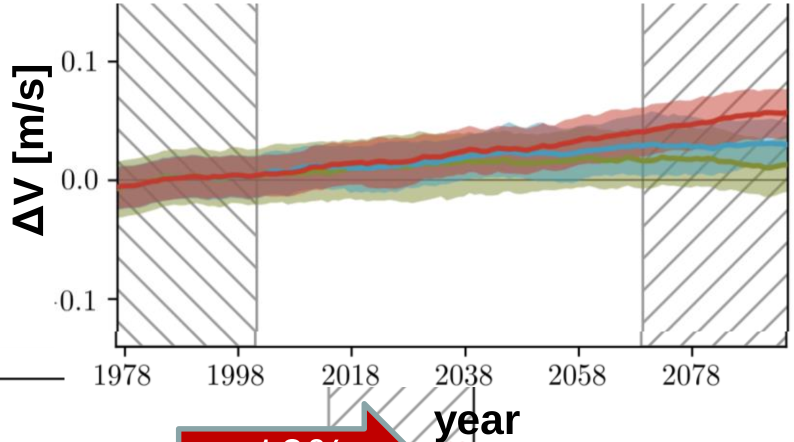


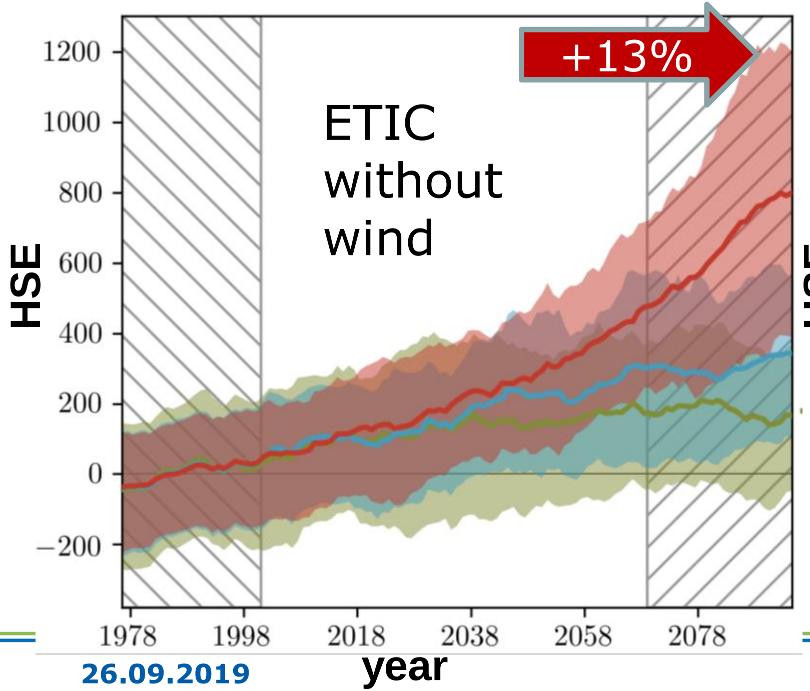


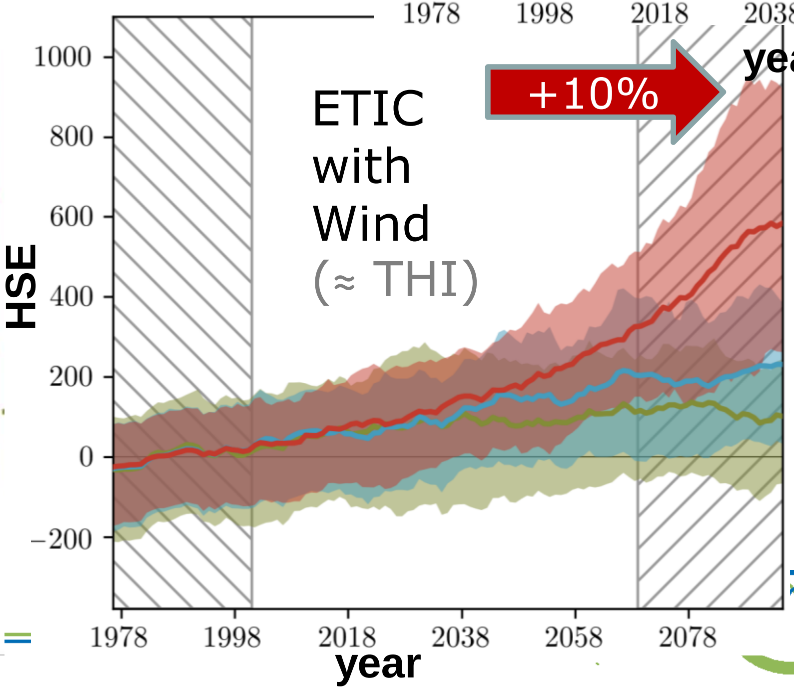


The Effect of Air Movement

- Less than 0.1m/s increase of average wind speed → 200 HSE deviation
- Deviation ETIC vs. THI 200 HSE







EXAMPLE
Centerpiece
European
Contin

Extrapolated Impacts without Adaptation

- Approx. 2.4 kg less milk per heat stress day and cow
  → **milk yield -3.5%** of present European milk yield
  → monthly **farm income in summer -6.6%**

- Increasing demand for emission reduction measures
  → **+16 Gg ammonia per year** (approx. 0.4% of NEC target)
  → **+0.1 Gg methane per year**

- health issues and increased probability of medical treatments
  → **+60% respiration rate** during 1/4 of summer hours
  → **standing time +1h** during 1/3 of the days of the year

Summary and Conclusions

cf. Hempel et al. 2019, ESDD
https://doi.org/10.5194/esd-2019-15

- Average **indoor microclimate** can be statistically modeled barn individual with **ANN approach**

- By the end of the century (relative to 1971-2000):
  → number of **annual stress events up to +2000h**
  → average **duration of events +22h**

- Clear **trend, but large uncertainty**
  (climate model, ANN, heat stress model, threshold, …)

- Strong **impacts** on animal welfare, milk yield and emissions → mid-term **adaptation strategies**

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Acknowledgement

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Abstract

- In the last decades, an exceptional global warming trend was observed. Along with the temperature increase, modifications in the humidity and wind regime may amplify the regional and local impacts. Modifications in housing management are the main measures taken to improve the ability of livestock to cope with the resulting climatic stress conditions. Measures and systems that balance welfare, environmental and economic issues are, however, barely investigated in the context of climate change and are thus almost not available for commercial farms.
- In Europe cows are economically highly relevant and are mainly kept in naturally ventilated buildings that are most susceptible to climate change. We used a modeling chain to estimate future heat stress risk in dairy cattle husbandry. Meteorological data was collected inside three reference barns in Central Europe and the Mediterranean region. An artificial neuronal network (ANN) was trained to relate the outdoor weather conditions to the indoor microclimate. Subsequently, this ANN model was driven by regional climate model projections. For the evaluation of the heat stress risk, we considered the amount and duration of heat stress events, which we defined as hours of at least moderate heat stress.
- We found that by the end of the century the number of annual stress events can be expected to increase by up to 2000 hours while the average duration of the events increases by up to 22h relative to a reference period 1971 to 2000. Although the degree of severity of the projected increase of heat stress risk varies depending on the region, the climate model and the anticipated greenhouse gas concentration, there was an overall increasing trend. This implies strong impacts on animal welfare, milk yield and emissions and an urgent need for mid-term adaptation strategies.