Auswirkungen von Hitzestress auf die Milchleistung in Milchkühen

Regionale Analyse mit Wetter-Modelldaten & Beobachtungsdaten

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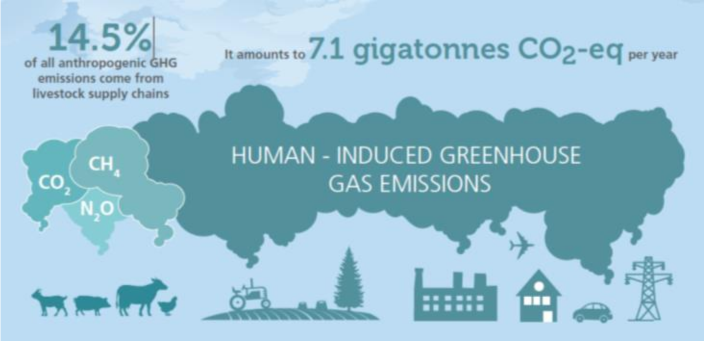
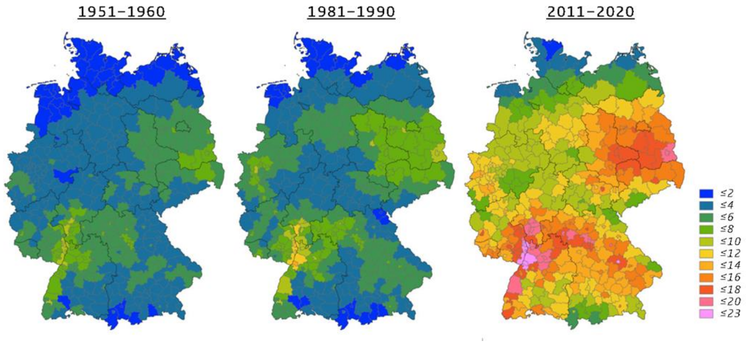
Forschungsinstitut für Nutztierbiologie

Sommertagung der AG Landwirtschaftliches Versuchswesen
22. Juni 2022, Landwirtschaftszentrum Eichhof / Bad Hersfeld

Livestock and Climate Change





Livestock farming contributes to climate change

- Reducing GHG emissions through, *e.g.*:
  - Decrease number of animals
  - Feed quality
  - Manure management
  - Breeding

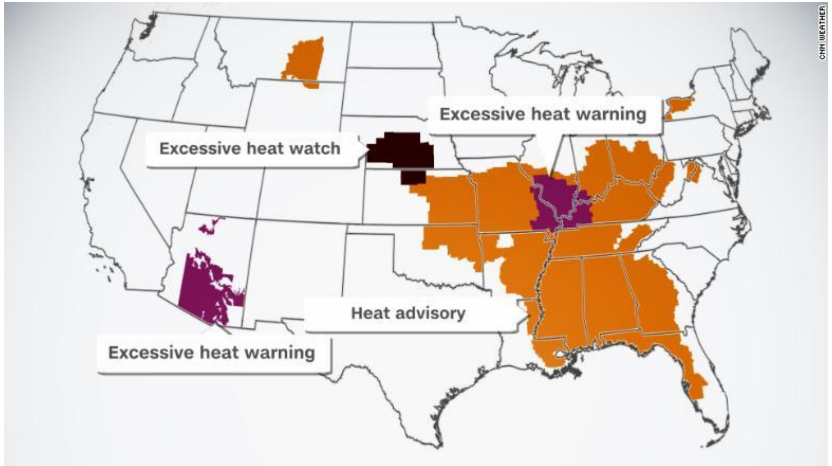
Summer heatwaves impact livestock

- Number of extremely hot days (>30°C) is rising
- Heat stress causes, *e.g.*:
  - Increased risk of health problems
  - Increase in mortality
  - Change in quality and availability of feed

FAO (2016): Livestock and Climate Change
https://www.gdv.de/de/medien/aktuell/klimawandel-zahl-der-hitzetage-seit-den-1950er-jahren-verdreifacht--70978

Extreme heat and humidity killed thousands of cattle in Kansas

- >2,000 cattle are known to have died during the heat wave (Kansas Department of Health and Environment)
- Heat, humidity and lack of wind created the "perfect storm" for heatstroke in cattle
- Nighttime temperatures remained high, i.e. animals could not shed the body heat during nights



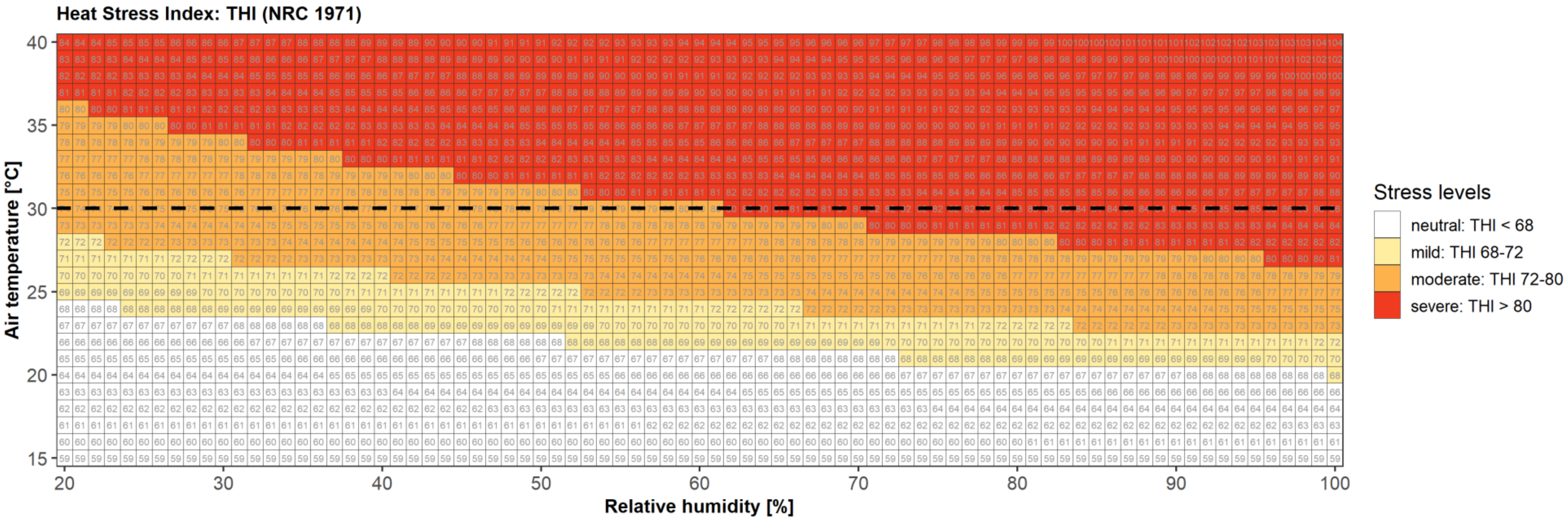
Heat alerts for Thursday, June 16th, 2022.

https://www.theguardian.com/us-news/2022/jun/16/cattle-deaths-kansas-heat-wave-climate

Temperature Humidity Index (THI)

- Heat stress is a **combination** of warm temperatures and high relative humidity

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



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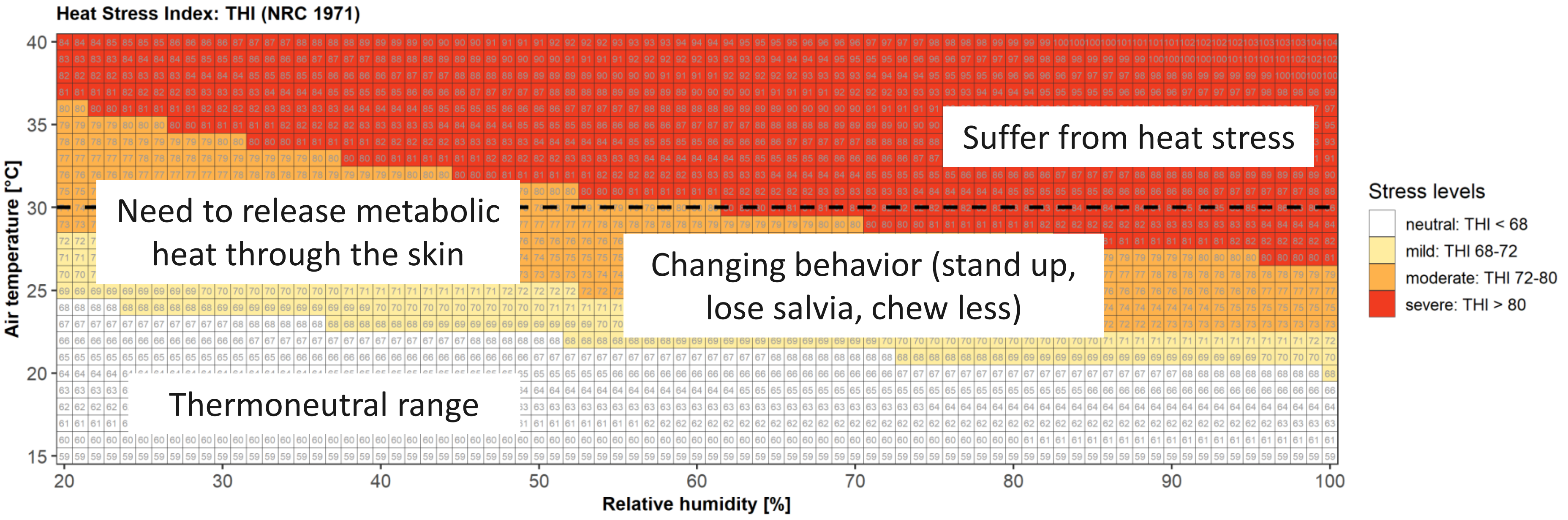


Counteract Heat Stress in Dairy Cattle

Negative effects on cow's health & economic effects on milk production traits

- **Measures** taken to counteract heat stress:
  - Modern outdoor climate stables with a large air volume
  - Fans for better air movement and pollutant gas removal
  - Counteract heat-induced reduced feed intake with a higher energy diet
  - ...

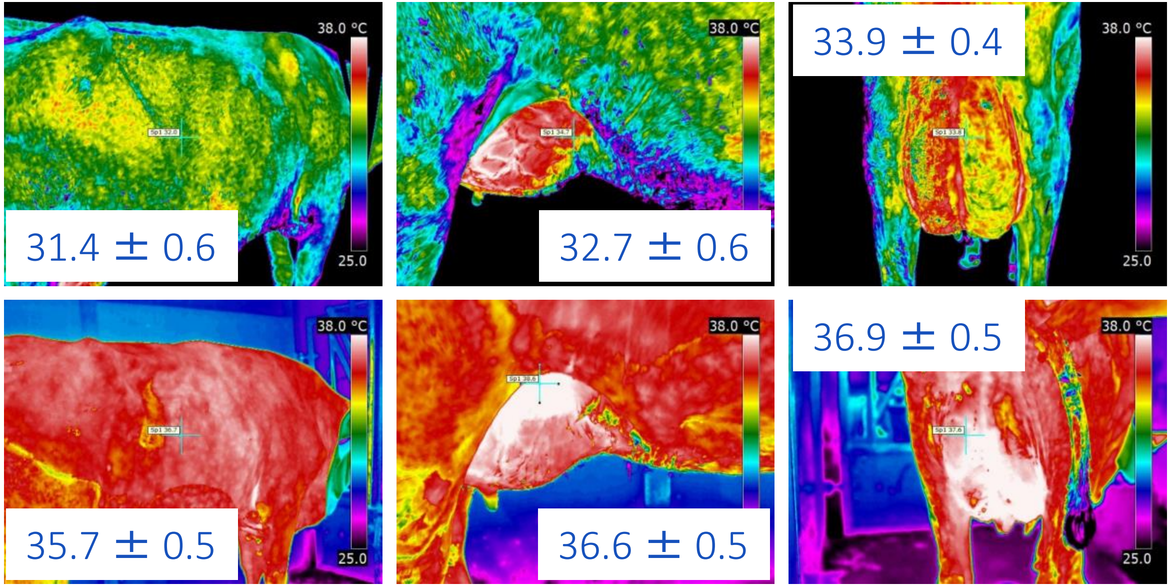
https://www.praxis-agrar.de/tier/rinder/hitzestress-bei-kuehen

Heat Stress Studies @FBN

Side area | Lateral udder | Posterior udder

Thermoneutrality THI = 60

Heat stress THI = 76



Body temperatures increase by 3-4°C !

Franziska Koch @FBN

Climate room @FBN

PhD thesis of Jackson Mbuthia

Agricultural and Forest Meteorology 322 (2022) 108923

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Agricultural and Forest Meteorology

journal homepage: www.elsevier.com/locate/agrformet

Check for updates

Comparison of high resolution observational and grid-interpolated weather data and application to thermal stress on herd average milk production traits in a temperate environment

Jackson M. Mbuthia, Anja Eggert, Norbert Reinsch *

Research Institute for Farm Animal Biology (FBN), Institute of Genetics and Biometry, Wilhelm-Stahl-Allee 2, Dummerstorf 18196, Germany

Mbuthia et. al. 2022

Jackson Mbuthia in Kenya

frontiers

Cooling THI-days as heat load indicator for milk production traits

Jackson M. Mbuthia[1], Anja Eggert[1], Norbert Reinsch[1*]

[1]Institute of Genetics and Biometry, Research Institute for Farm Animal Biology (FBN), Germany

Submitted to Journal:
Frontiers in Animal Science

Specialty Section:
Animal Physiology and Management

FBN

Negative consequences for milk production traits?

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Mbuthia et. al. 2022

- Quantification of thermal stress thresholds for milk production traits at herd level
- Development of a better heat load indicator

frontiers

Cooling THI-days as heat load indicator for milk production traits

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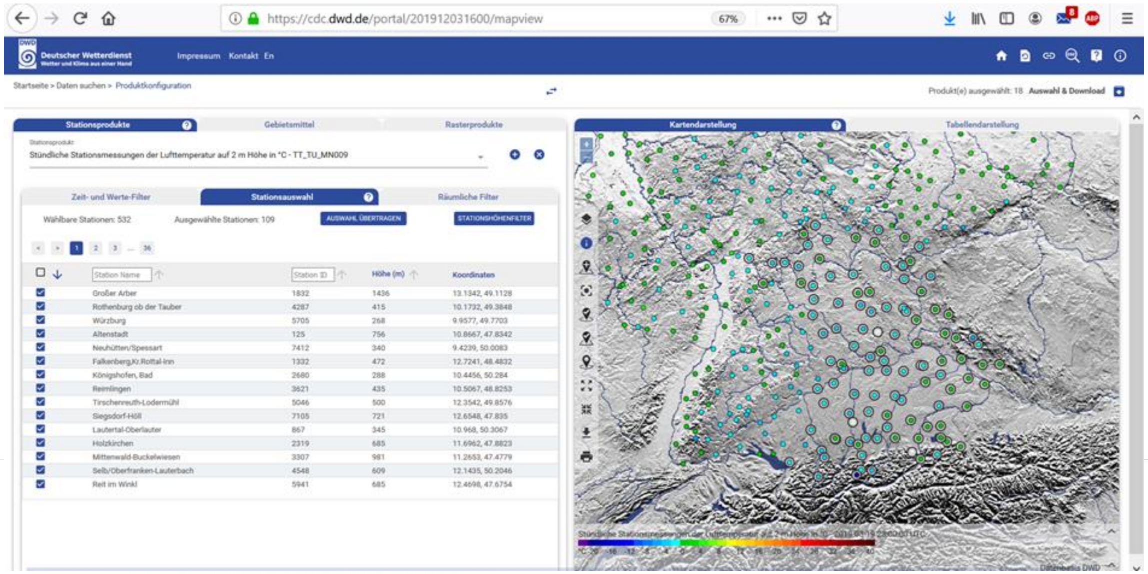
Milk Performance Records

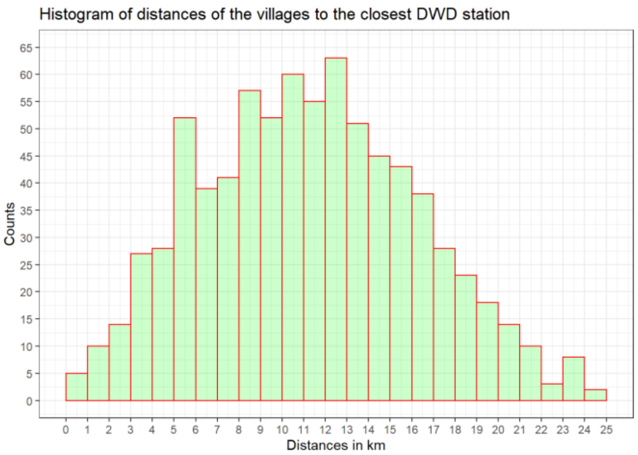
- Test-day records provided by LKV Bayern
- 746,705 cows in 12,606 farms from the year 2010 to 2019 (>16 million test-day records)
- Farms located in 786 villages (Swabia & Upper Bavaria)
- Breed: mainly Fleckvieh (77%)
- Traits:
  - Milk yield
  - Protein content & yield
  - Fat content & yield
  - Milk urea
  - Somatic Cell Score (SCS)

https://www.lkv.bayern.de/

Weather Station Data @DWD

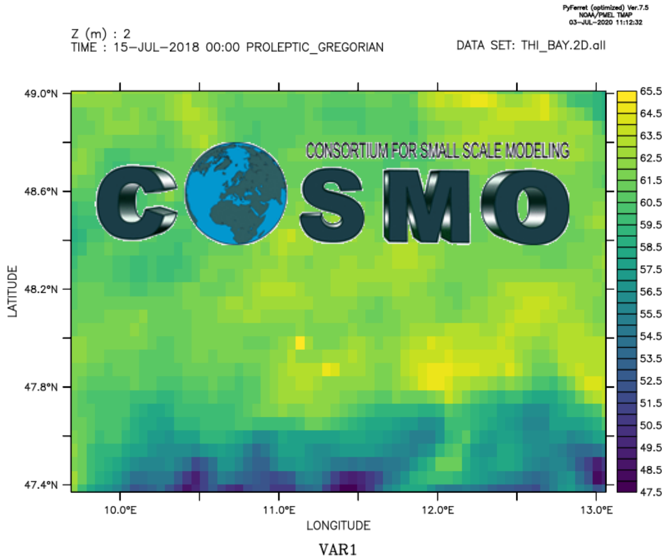
- Hourly data obtained from **Climate Data Centre Portal** (https://cdc.dwd.de/portal/)
- **53 stations** distributed in the study area, average distance is **12 km**
- Parameters used: air temperature and relative humidity to calculate THI

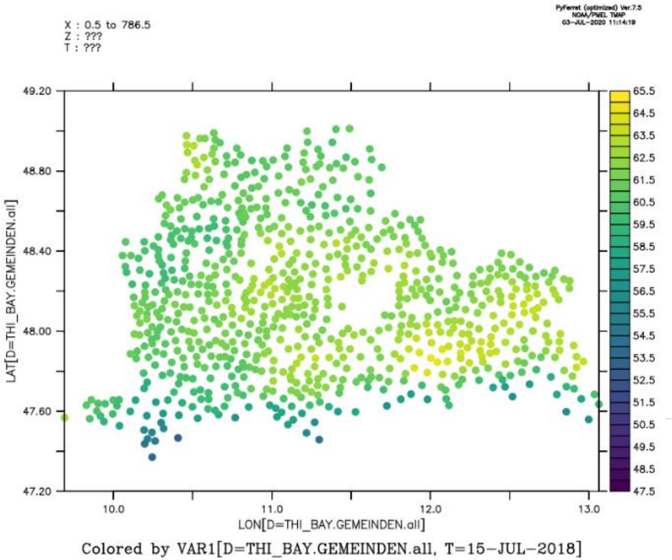




Numerical Weather Prediction model @DWD

- Consortium for Small-Scale Modelling (COSMO-REA6, https://reanalysis.meteo.uni-bonn.de/?COSMO-REA6)
- Grid-interpolated data fields with **~6 km** horizontal and **1 hour** temporal resolution
- Parameters: air temperature and relative humidity to calculate THI





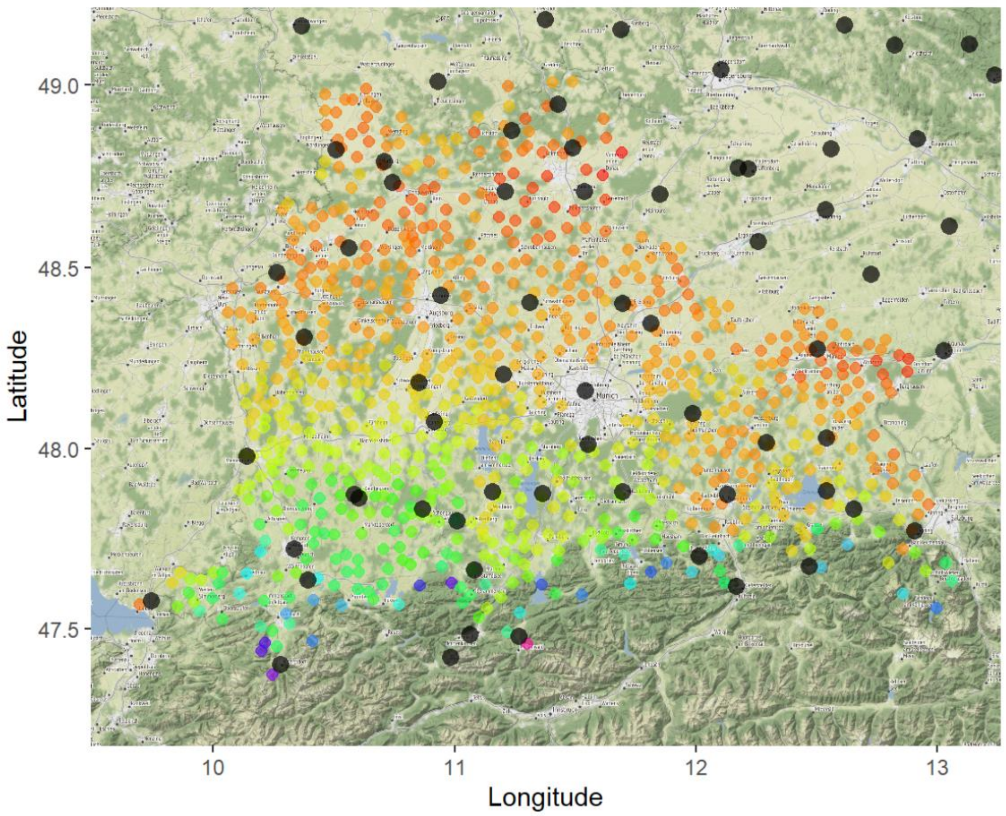
Study Region: Swabia & Upper Bavaria

- 10 years (2010 - 2019)
- Response at herd level and herd test-day

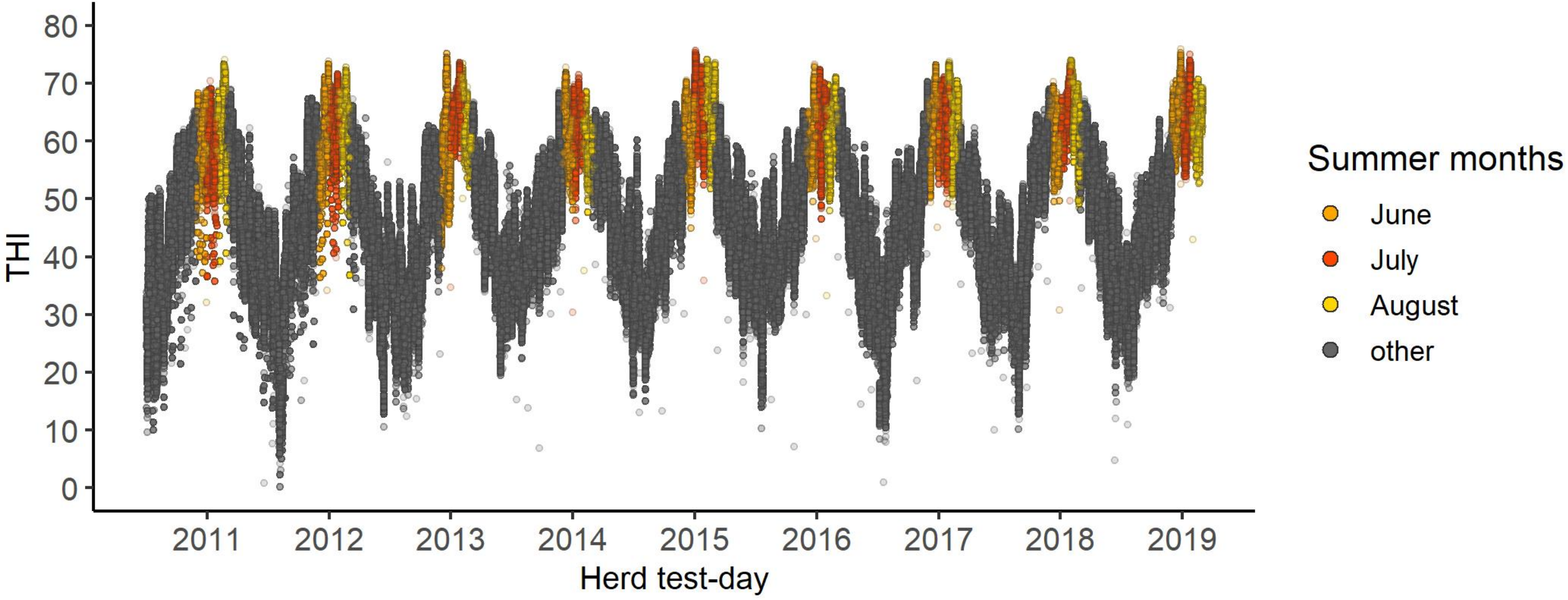
Is the response of a milk production trait to heat stress immediate or delayed?

- Consider: lag 1, 2, 3 days & 3-day moving average

Coloured altitude of villages, stations in black



THI Seasonality in Bavaria
- Station Data -



Fitting Reaction Norms

Mixed regression model with quartic Legendre polynomial functions

$$Y_{ijklmnopqrsu} = H_i + P_j + PLS_{jk} + CT_l + CE_m + mon_n + yr_o + yrs_{op} + \sum_{q=0}^{4} \alpha_q Z_q(t) + htd_{is} + e_{ijklmnopqrs}$$

$H_i =$	herd effect
$P_j =$	multiple regression of % cows in different parities (parity 1, 2 and 3) at each herd and test day
$PLS_{jk} =$	lactation stage by parity effect; which is a multiple regression on % of cows in different lactation stages (LS1 – LS10) by parity interaction at each herd and test day
$CT_l =$	multiple regression of % cows in a given calving type (single or twins) at each herd and test day
$CE_m =$	multiple regression of % cows in a given calving ease category (6 calving ease classes; 0 – easy without assistant to 5 – surgical delivery/fetotomy)
$mon_n =$	month effect
$yr_o =$	year effect
$yrs_{op} =$	year by season interaction effect with following seasons : winter (DJF), spring (MAM), summer (JJA), autumn (SON)
$\alpha_q =$	regression coefficients for THI
$Z_q =$	covariates of the q^{th} Legendre polynomial evaluated at THI point (t)
$htd_{is} =$	random short-term test-day effect auto-correlated (AR1) within herd

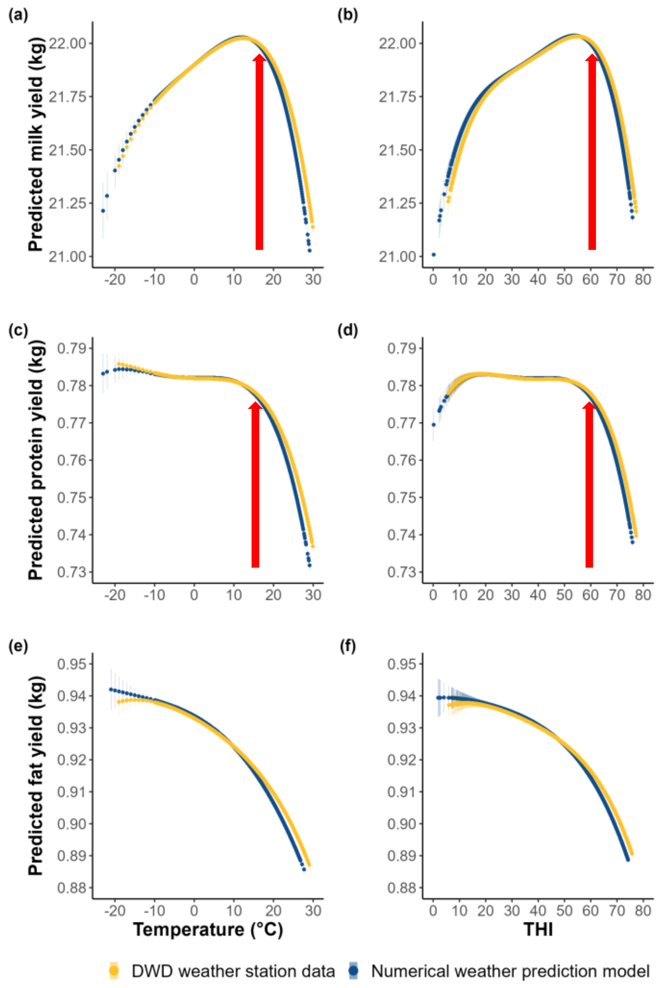
ASReml®

Heat Stress Thresholds

- Good agreement between station data and numerical model
- Heat stress threshold for milk and protein yield: **16°C and 60 THI**

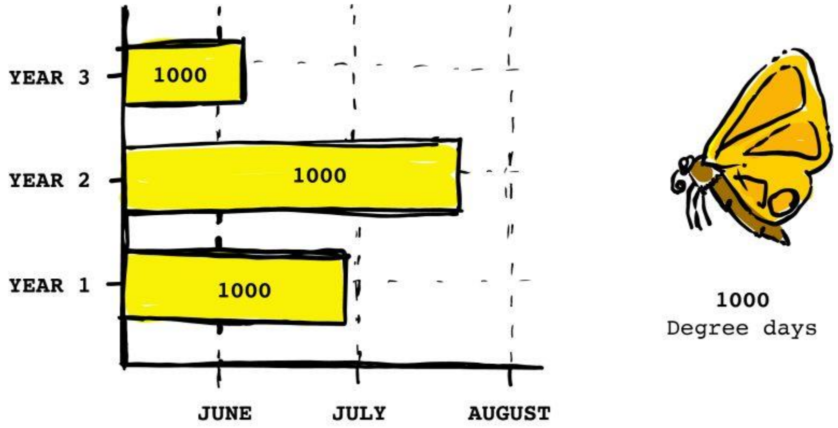
Is the response of a milk production trait to heat stress immediate or delayed?

- Smallest residual variance
- Often: 3 days lag, sometimes 3-day moving average



Aus: Mbuthia et al. (2022)

Exploring a new indicator based on degree-day model: Cooling THI-days



Degree day requirements for an insect does not change. But the time needed to gather those degree days is variable.

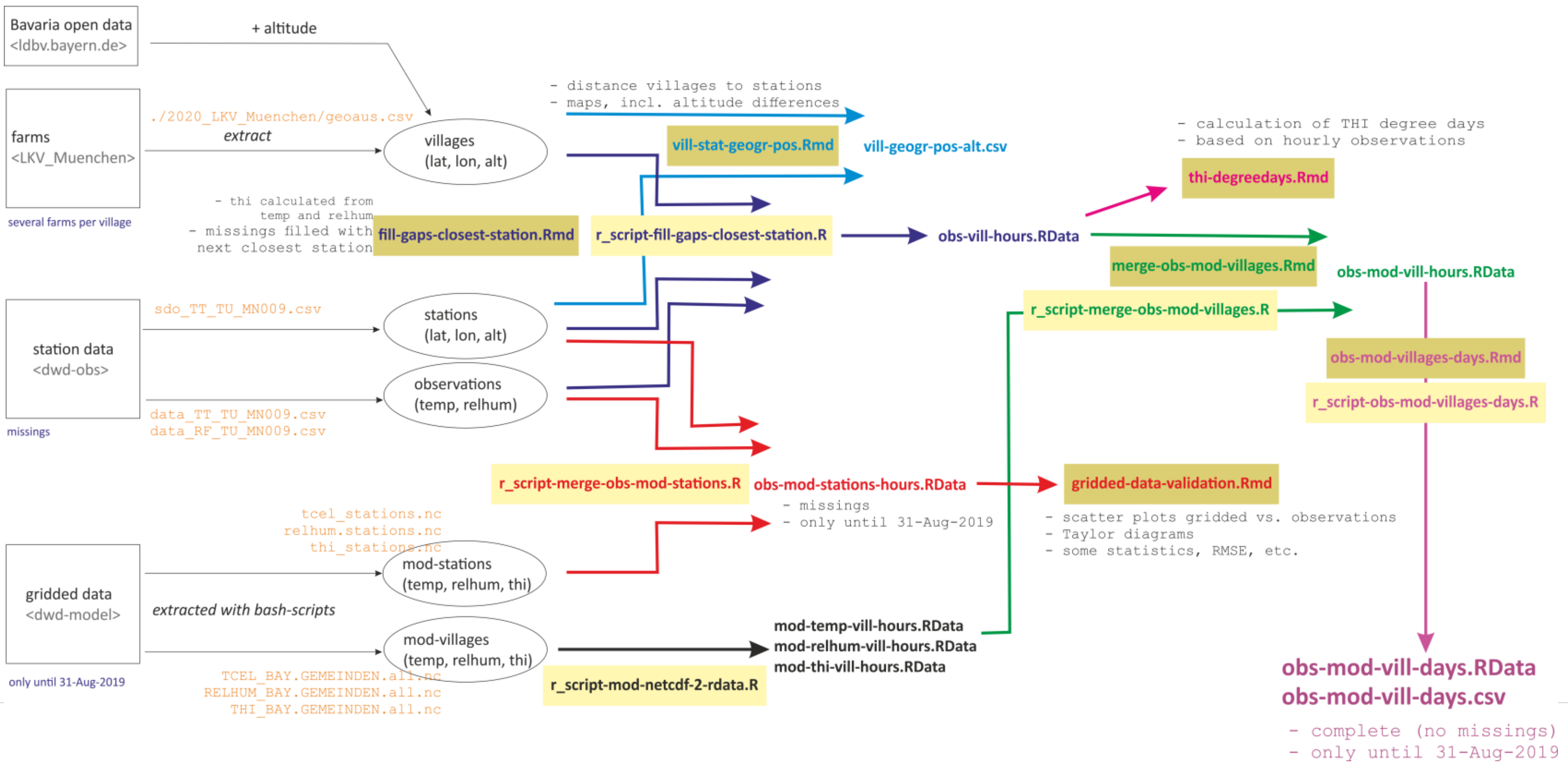
$$\text{coolingTHI-days} = \frac{1}{24}\sum_{i=1}^{t}\left(THI_{a,i} - THI_{b}\right)$$

$THI_{a,i}$ = mean hourly THI

THI_{b} = THI threshold (here: $THI_{b} = 60$)

t = number of hours THI > 60

Complex, but Reproducible Workflow?



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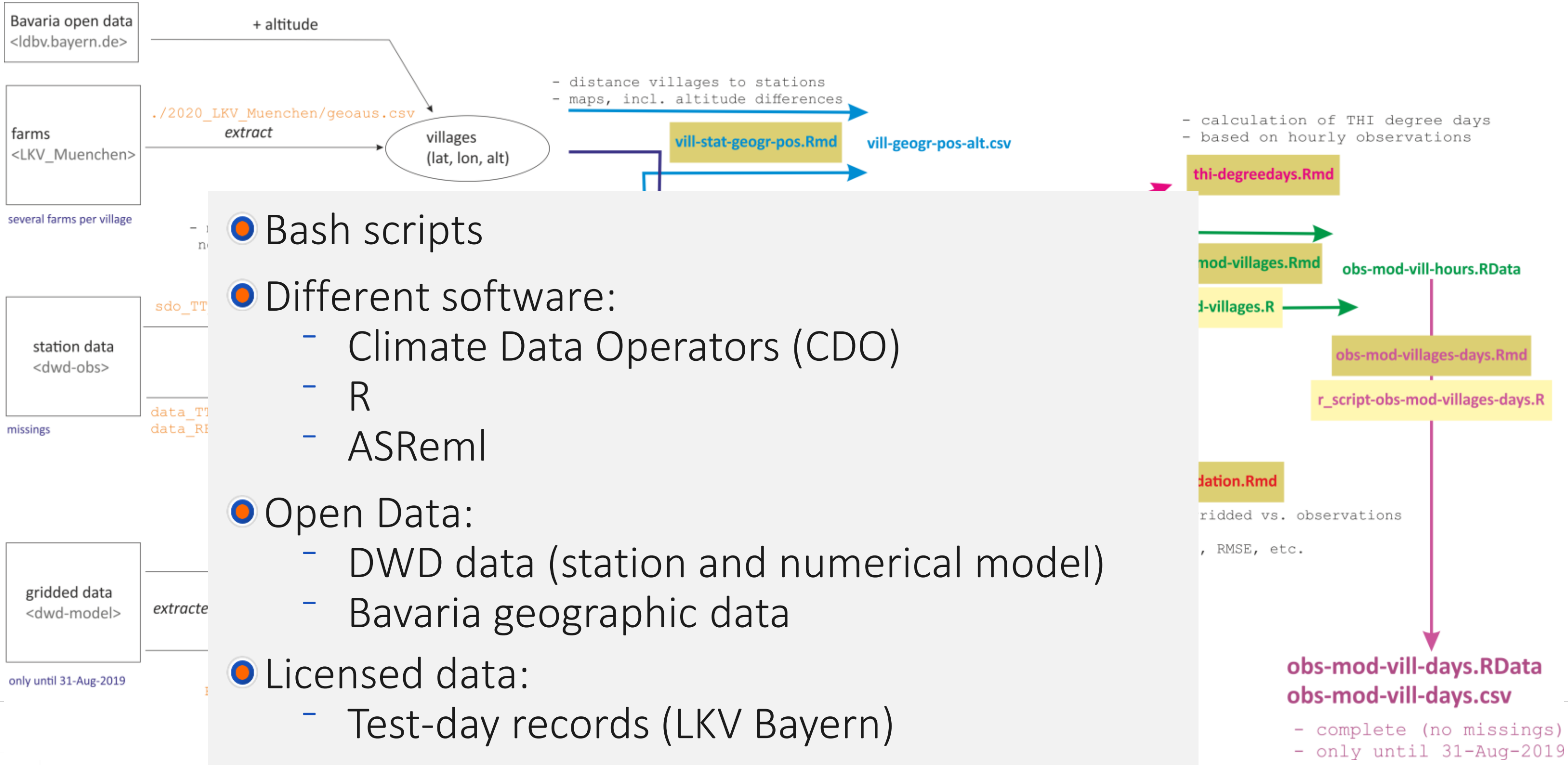
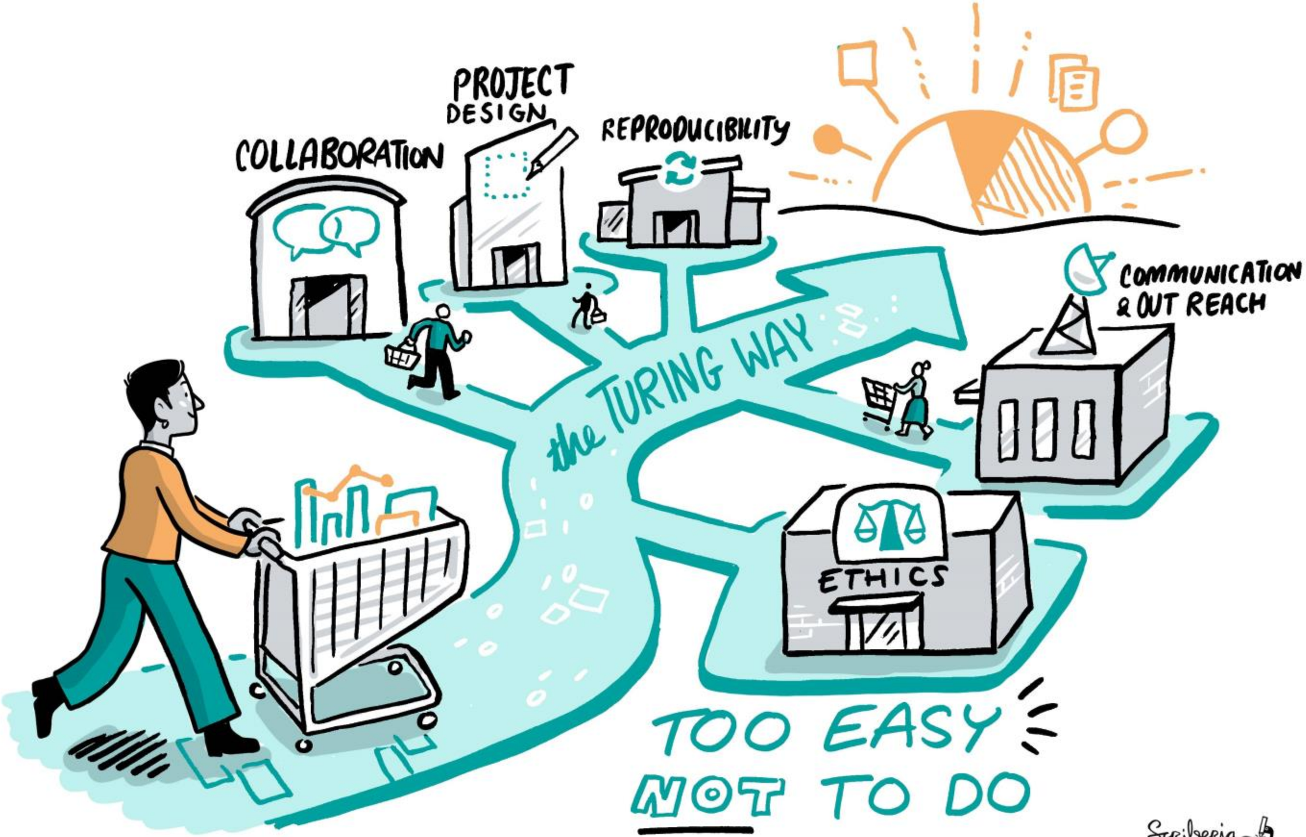


- Bash scripts
- Different software:
  - Climate Data Operators (CDO)
  - R
  - ASReml
- Open Data:
  - DWD data (station and numerical model)
  - Bavaria geographic data
- Licensed data:
  - Test-day records (LKV Bayern)
- Metadata & Provenance

The Turing Way
handbook to reproducible, ethical and collaborative data science



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