Auswirkungen von Hitzestress auf die Milchleistung in Milchkühen

Regionale Analyse mit Wetter-Modelldaten & Beobachtungsdaten

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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
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.

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

\[ THI = (1.8 \cdot T + 32) - (0.55 - 0.0055 \cdot RH) \cdot (1.8 \cdot T - 26) \]
Heat stress is a combination of warm temperatures and high humidity.

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

- **Thermoneutral range**
  - Need to release metabolic heat through the skin
- **Suffer from heat stress**
  - Changing behavior (stand up, lose salvia, chew less)
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

Body temperatures increase by 3-4°C!
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

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Mbutihia et. al. 2022

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

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Submitted to Journal: Frontiers in Animal Science
Specialty Section: Animal Physiology and Management
Negative consequences for milk production traits?

Quantification of thermal stress thresholds for milk production traits at herd level

Development of a better heat load indicator

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

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Specialty Section: Animal Physiology and Management
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.unibonn.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
Is the response of a milk production trait to heat stress immediate or delayed?

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

\[
\text{coolingTHI-days} = \frac{1}{24} \sum_{i=1}^{t} (\text{THI}_{a,i} - \text{THI}_{b})
\]

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

THI\(_{a,i}\) = mean hourly THI
THI\(_{b}\) = THI threshold (here: THI\(_{b} = 60\))
t = number of hours THI > 60

https://blogs.cornell.edu/yourenewa/2017/11/15/newa-at-a-glance-what-are-degree-days/
Complex, but Reproducible Workflow?

- Calculation of THI degree days
  - based on hourly observations

- distance villages to stations
  - maps, incl. altitude differences

- THI calculated from
  - temp and relhum

- missing filled with
  - next closest station

- farms
  - <LKV_Muenchen>
  - several farms per village

- station data
  - <dwd-obs>
  - data_TU_MN009.csv
  - data_TU_MN009.csv
  - data_RELHUM_TU_MN009.csv

- gridded data
  - <dwd-model>
  - only until 31-Aug-2019

- Bavaria open data
  - <ldbu.bayern.de>
  - + altitude

- villages
  - (lat, lon, alt)

- r_script-fill-gaps-closest-station.R
  - <fill-gaps-closest-station.Rmd>

- r_script-fill-gaps-closest-station.R
  - <fill-gaps-closest-station.csv>

- obs-vill-hours.RData
  - <merge-obs-mod-villages.R>
  - <merge-obs-mod-villages.Rmd>

- obs-mod-vill-hours.RData
  - <r_script-mod-vill-days.R>
  - <obs-mod-vill-days.RData>

- r_script-mod-vill-days.R
  - <obs-mod-vill-days.csv>
  - gridded-data-validation.Rnd
  - scatter plots gridded vs. observations
  - Taylor diagrams
  - some statistics, RMSE, etc.
Complex, but Reproducible Workflow?

- **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
Research Institute for Farm Animal Biology (FBN)

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