Shade Treatment Effects on Cattle Heat Stress

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1. Background

Project Details

Supervisors

- Dr. Garth Tarr (Statistics)
- Dr. Angela Lees (Animal science)

Experiment details

- 1st January – 7th April, 2021
- 90 animals divided equally across 9 pens
- 9 pens each allocated one of three shade treatments — un-shaded, shade cloth, waterproof shelter
- Interested in whether the benefits of these shade structures are significant

Aims & Impacts

General aim

- To see how different shade treatments affect the rumen temperature and drinking patterns of cattle

Key concepts

- Rumen temperature
- Heat stress in cattle
- Weather-based indices for estimating heat stress

Impacts

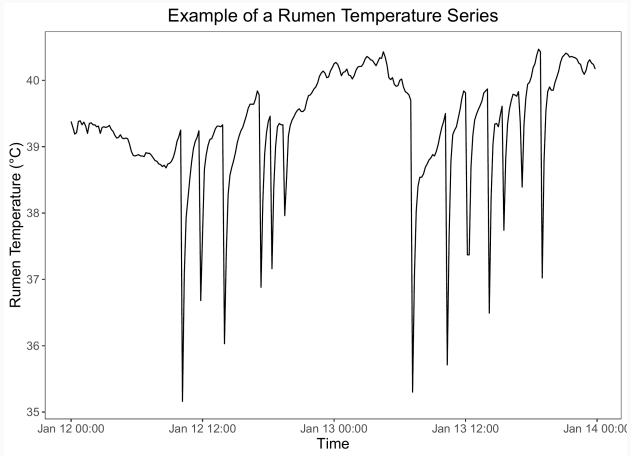
- Economic, ethical & welfare

2. Data

Data Sources

Weather station

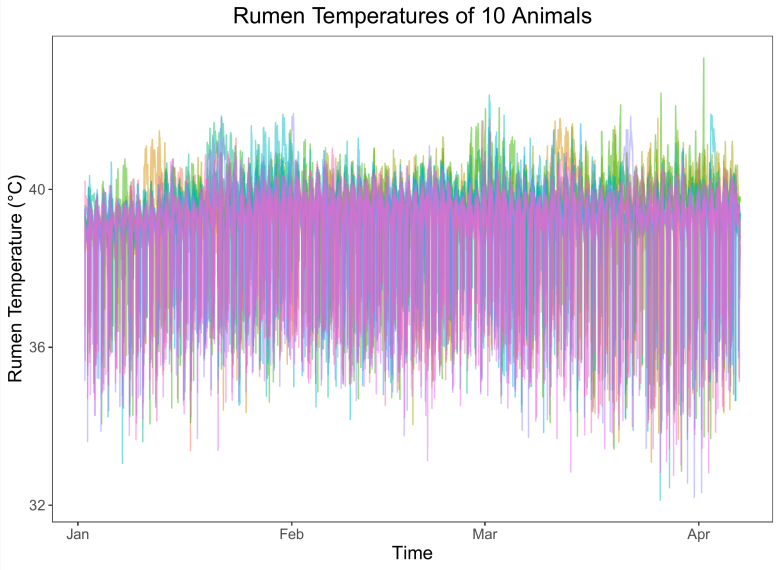
Rumen temperature boluses



Data Cleaning and Processing

Packages used

How much data?



Missing Values

Missing records

- Timestamp did not even exist
- Occurred at midnight every day for the weather data
- Fixed by introducing blank rows at the missing timestamps

timestamp	solar_0_w_m_2	precipitation_0_mm	strikes_0
2021-01-01 23:40:00	0	0.000	0
2021-01-01 23:50:00	0	0.000	0
2021-01-02 00:10:00	0	0.000	0
2021-01-02 00:20:00	0	0.000	0

timestamp	solar_0_w_m_2	precipitation_0_mm	strikes_0
2021-01-01 23:40:00	0	0.000	0
2021-01-01 23:50:00	0	0.000	0
2021-01-02 00:00:00	*NA*	*NA*	*NA*
2021-01-02 00:10:00	0	0.000	0
2021-01-02 00:20:00	0	0.000	0

Other sources of missing values

- Extreme values such as wind speeds of -9990 km/h
- Missing values randomly scattered throughout the data sets

Imputing Missing Values

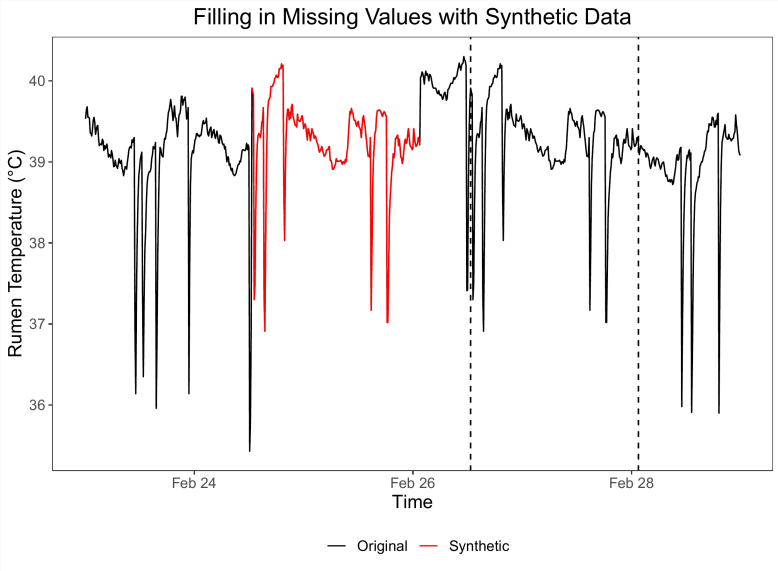
Linear interpolation

- Good for small, continuous chunks of missing values
- Applied to weather and rumen temperature data

before	after
10.11	10.11
10.13	10.13
10.14	10.14
10.21	10.21
NA	10.18
NA	10.15
NA	10.12
10.09	10.09
10.02	10.02

Synthetic data

- Preserves drinking event drops and time-of-day effects
- Only applied to rumen temperature data



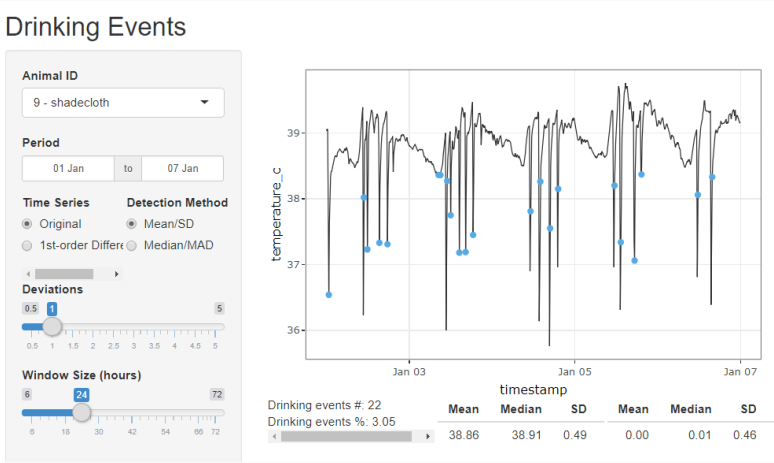
3. Methodology

Detecting Drinking Events

Web app

- Created an interactive web app to investigate new methods
- Incorporated tune-able parameters based on
  - Measures of centre and spread (classical vs. robust)
  - Number of deviations from centre required to classify as a drinking event
  - Raw temperature series vs. differenced temperature series
  - Window sizes

Link



rajan-shankar.shinyapps.io/drinking_events

Modelling

Data curation

- Calculated the Accumulated Heat Load (AHL) using a formula
- Aggregated 10-minutely data into day summaries (10am – 4pm) and night summaries (12am – 6am)
    - Allowed us to disentangle cooler night-time patterns and heat-of-day effects

Modelling considerations

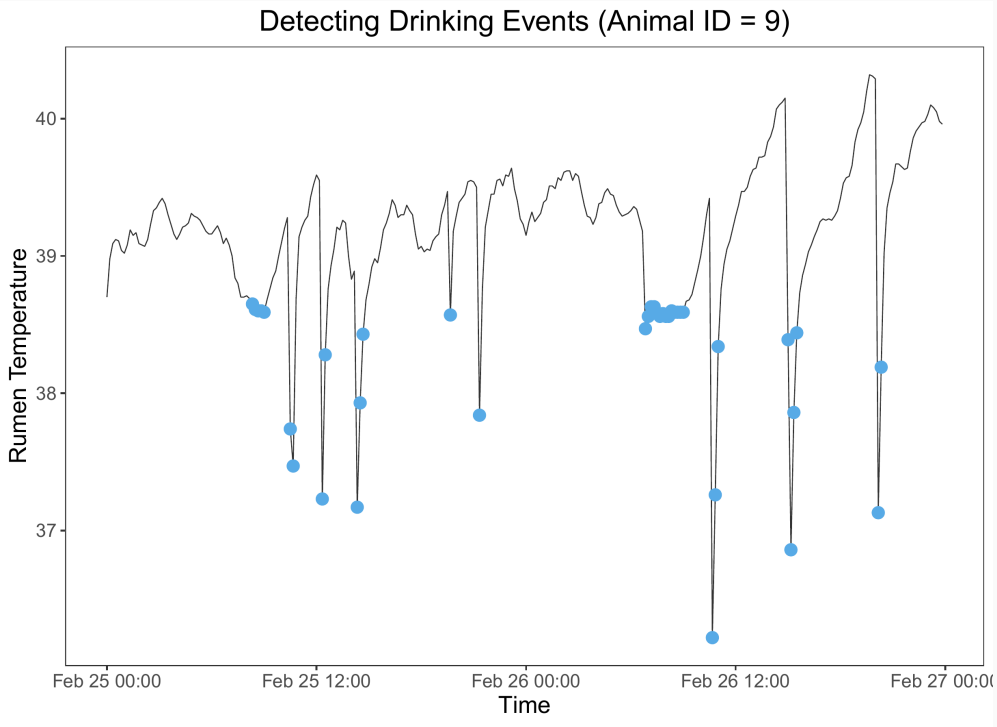
- Used a **smoothed** version of the rumen temperature series
- Accounted for animal-specific random effects by building **linear mixed-effects models**

4.1 Discussion of Results: Drinking Events

Drinking Events Detection Method

Vázquez-Diosdado et al. (2019) [1]

- Too many false positives
- Highlights multiple nearby time-points that represent the same drinking event



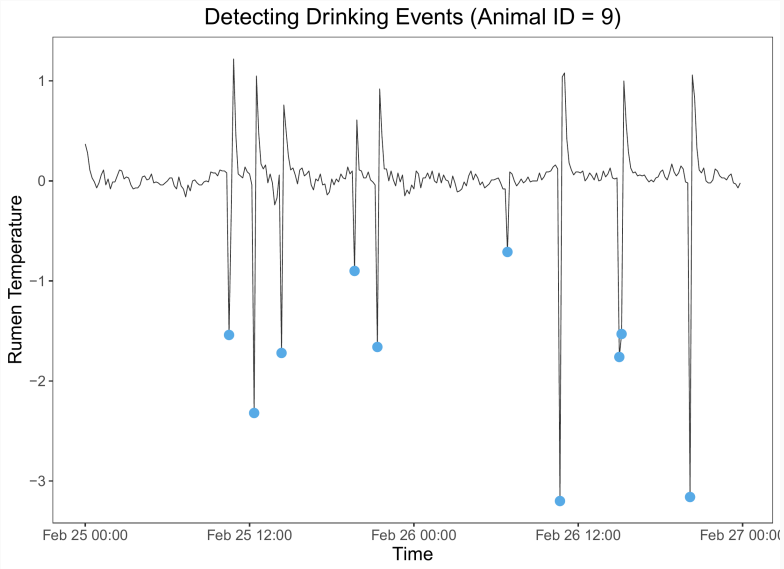
[1] Vázquez-Diosdado et al. (2019) "Developing and evaluating threshold-based algorithms to detect drinking behavior in dairy cows using reticulorumen temperature." *Journal of Dairy Science*, 102(11), 10471–10482.

Drinking Events Detection Method

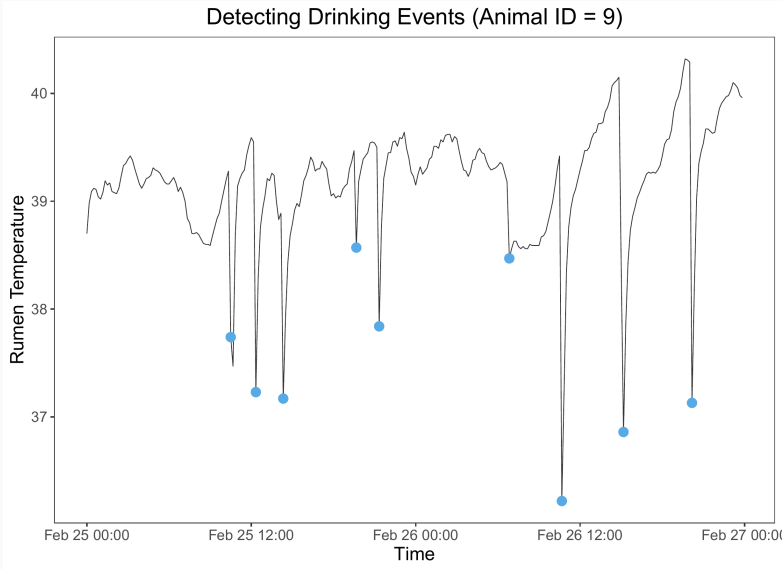
New method

- Uses the median and median absolute deviation (MAD)
- Uses the differenced temperature series
- A time-point is classified as a drinking event if its difference is 5 MADs below 0

Differenced

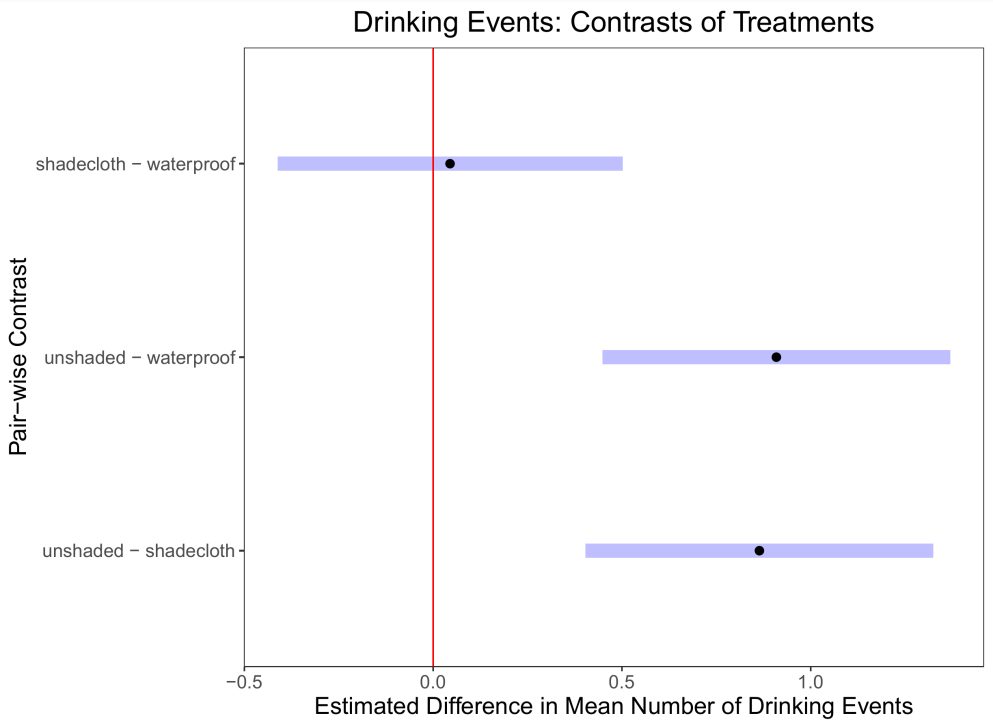


Original



Drinking Events by Shade Treatment

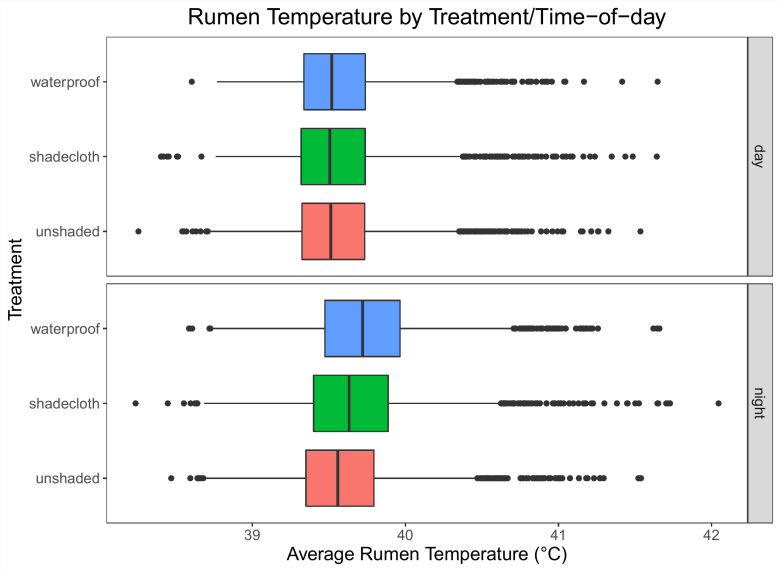
- Application of our new drinking event detection method
- ANOVA results show that the means of daily drinking events are significantly different at the 5% level
- Pair-wise contrasts reveal that un-shaded animals drink significantly more often than animals under shade cloth/waterproof shelters

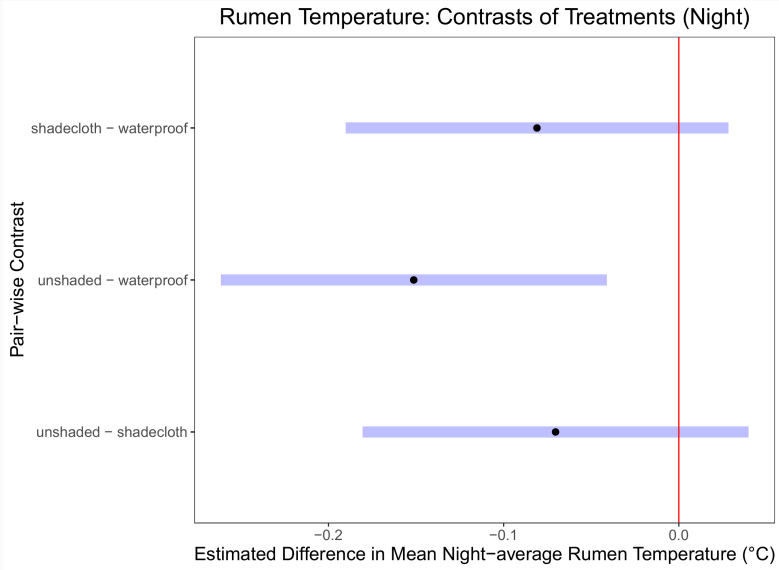


4.2 Discussion of Results: Rumen Temperature

Rumen Temperature by Shade Treatment

- Day and night average tested separately
- ANOVA results show that only the means of the night-average rumen temperature is significantly different at the 5% level
- Pair-wise contrasts reveal that animals under the waterproof shelter are kept significantly warmer than un-shaded animals at night



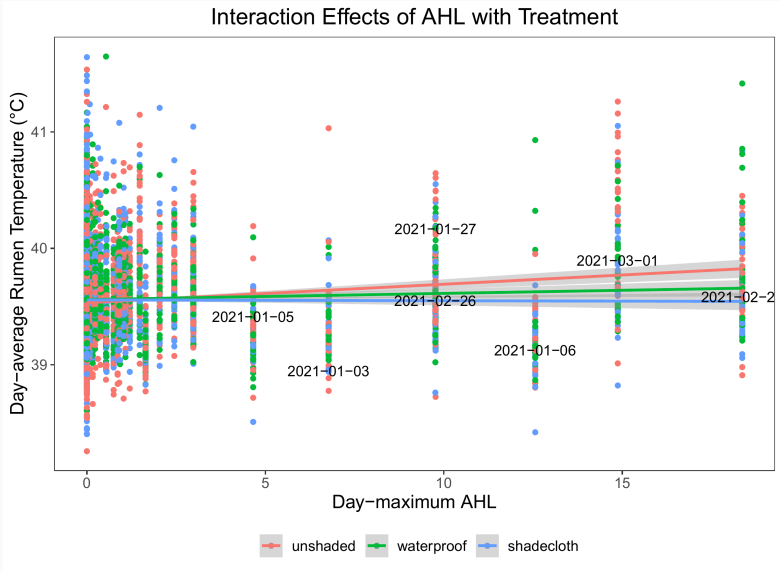


Interaction Effects of Shade Treatment and AHL

- Used day-maximum AHL and day-average rumen temperature
- Slope differs depending on shade treatment
- ANOVA results show strong evidence for an interaction effect
- Why do some dates not follow the increasing trend?

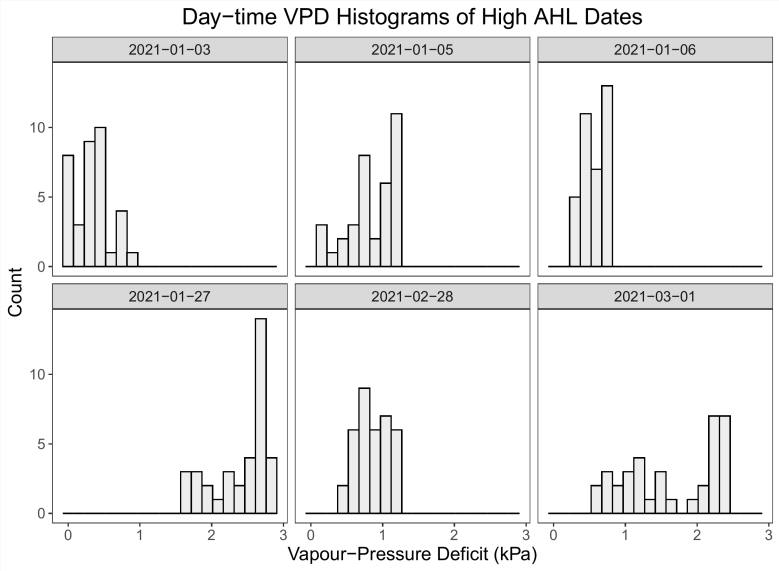
ANOVA Table

term	p.value
treatment	0.944
max_ahl	< 0.001
treatment:max_ahl	< 0.001



Investigating High AHL Dates

- Goal: to be able to explain why some dates follow the increasing trend in the previous slide and why others do not
- Histograms of 10-minutely vapour-pressure deficit (VPD) are distinctly different between dates that follow the trend and dates that do not



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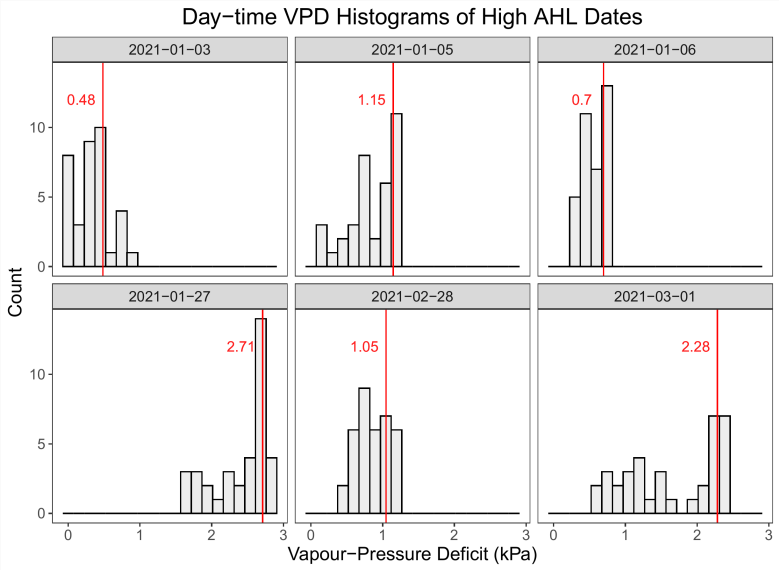
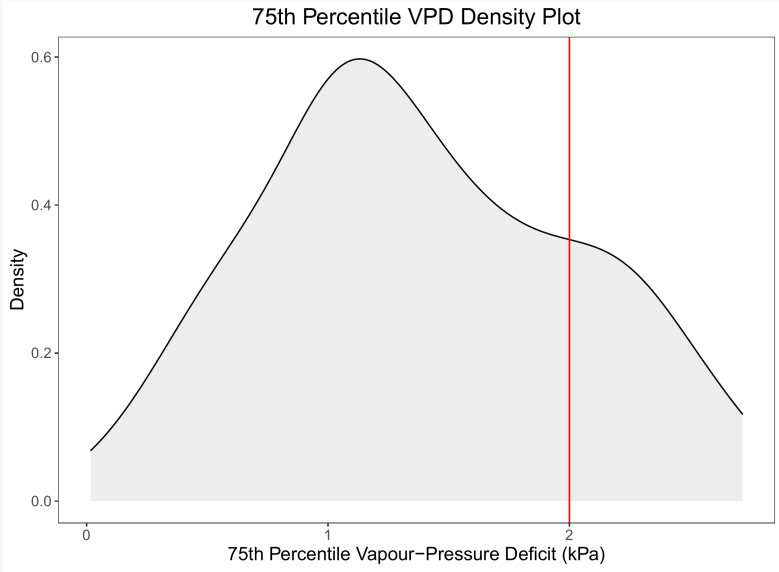


- Day-time third-quartile VPD of 2 is an appropriate separation threshold

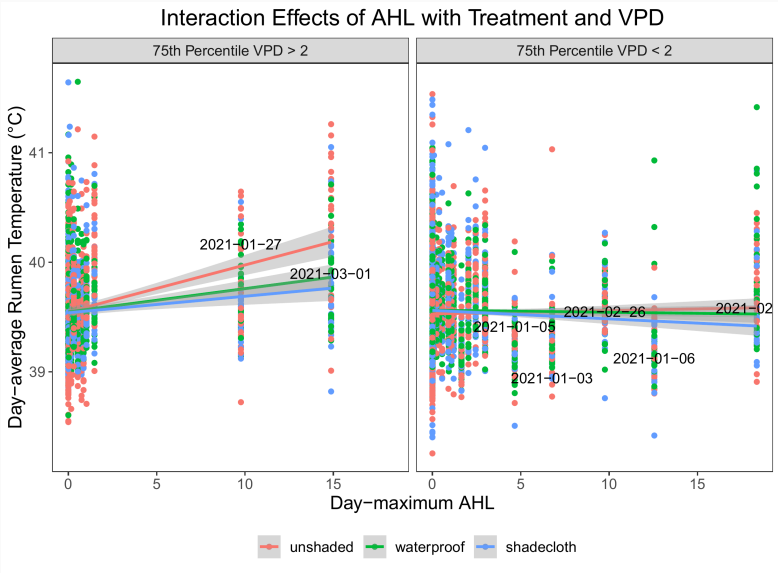


New Interaction Model

- Previously looked at a two-way interaction model consisting of shade treatment and AHL
- Now include a binary factor based on VPD to produce a three-way interaction model
- Slope differs depending on both shade treatment and VPD binary factor
- ANOVA results show that all interaction terms are significant

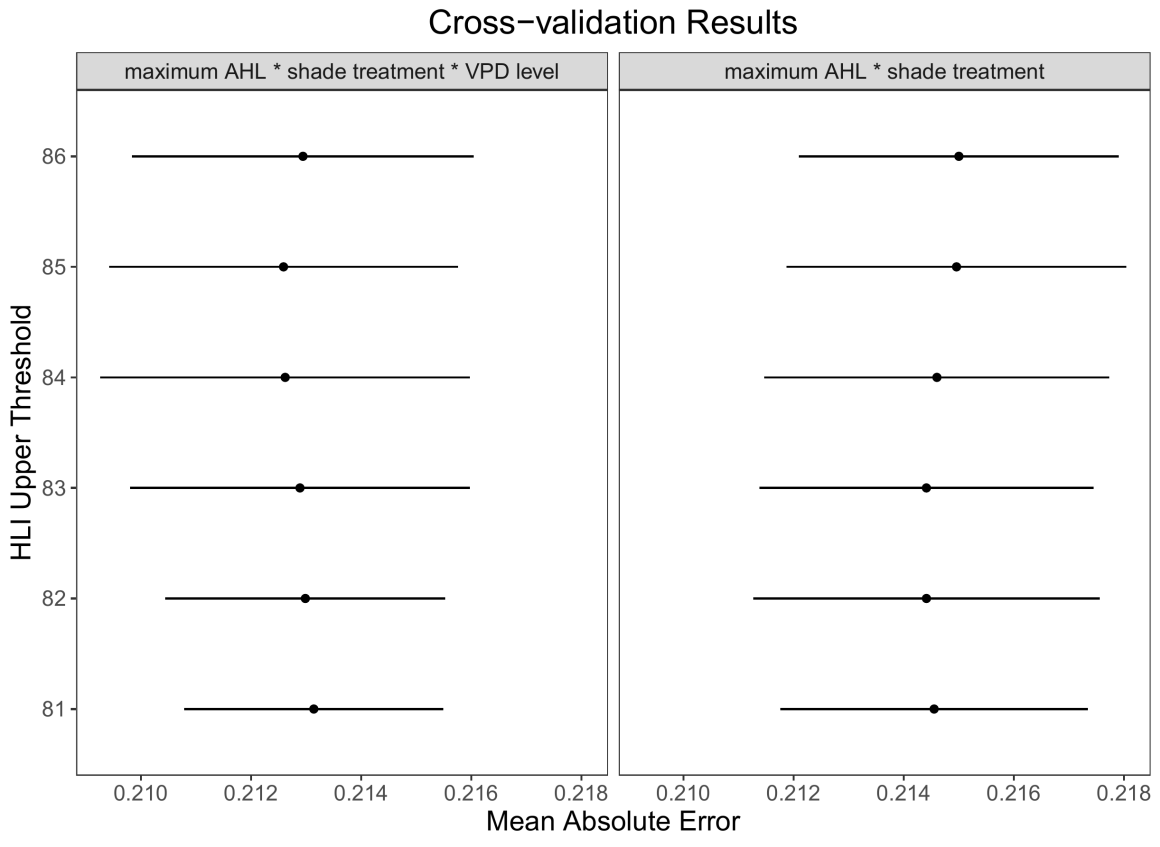
ANOVA Table

term	p.value
treatment	0.944
max_ahl	< 0.001
vpd_threshold	< 0.001
treatment:max_ahl	< 0.001
treatment:vpd_threshold	0.003
max_ahl:vpd_threshold	< 0.001
treatment:max_ahl:vpd_threshold	0.004



Tuning the HLI Upper Threshold

- The HLI upper threshold is a pre-specified parameter involved in the calculation of the AHL
- Want to see if lowering this threshold results in better model performance
- Use cross-validation to assess performance



5. Conclusion

Conclusion

Outcomes for industry

- Better detection method to monitor drinking patterns in cattle
- Un-shaded cattle require significantly more drinks
- Waterproof shelter keeps cattle warm during the night (especially important for winter)
- Significant interaction effects between AHL and shade treatment on the day-average rumen temperature
- Decreasing HLI upper threshold does not increase predictive performance
- AHL calculation may need to be tweaked to include VPD

Limitations

- Unable to test our drinking event detection method in a supervised context
- Not much data to support the importance of using VPD in combination with AHL

Further research

- Explore different modelling techniques such as generalised additive models
- Link shade treatment effects to eating quality of beef

End