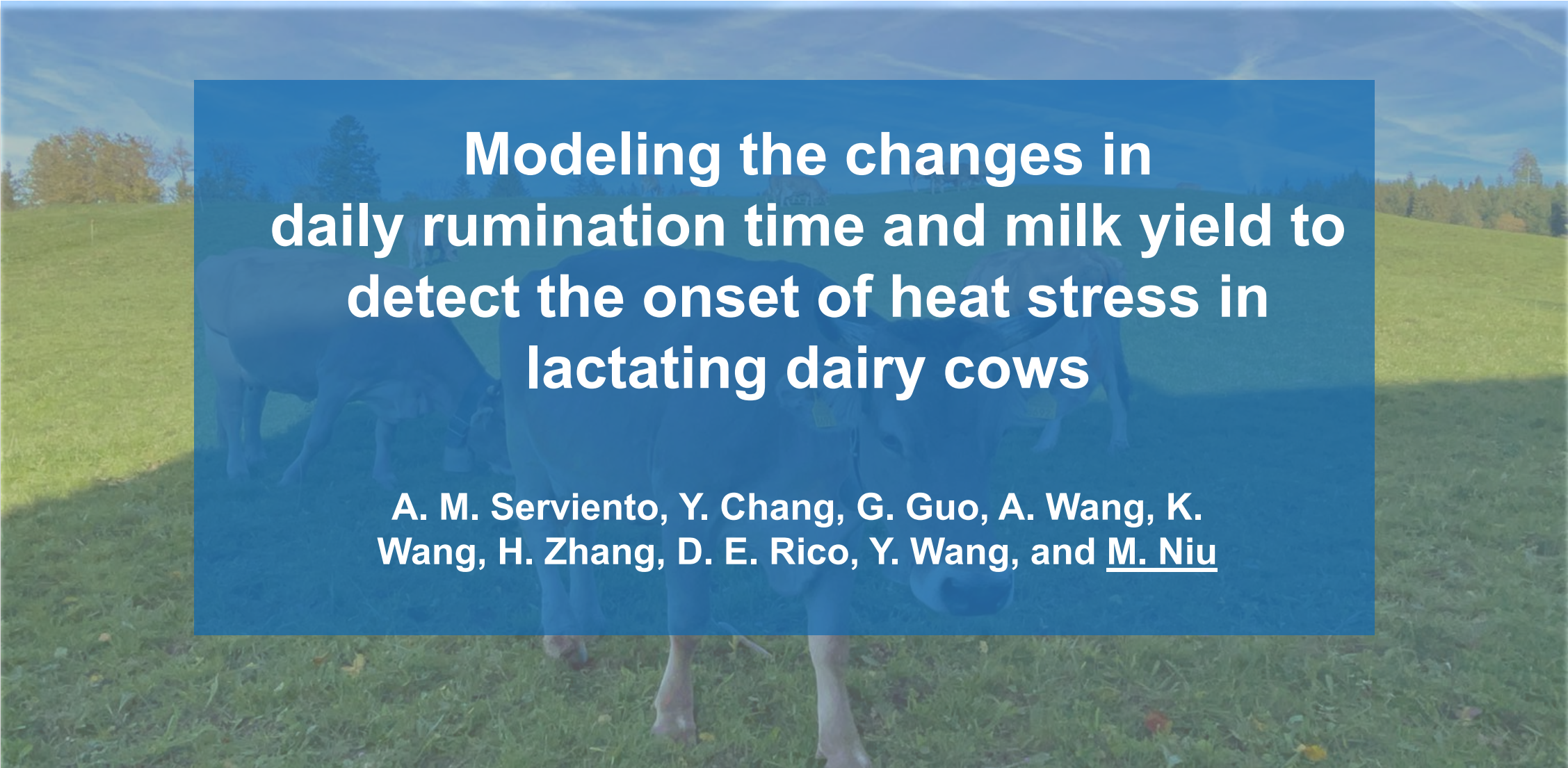
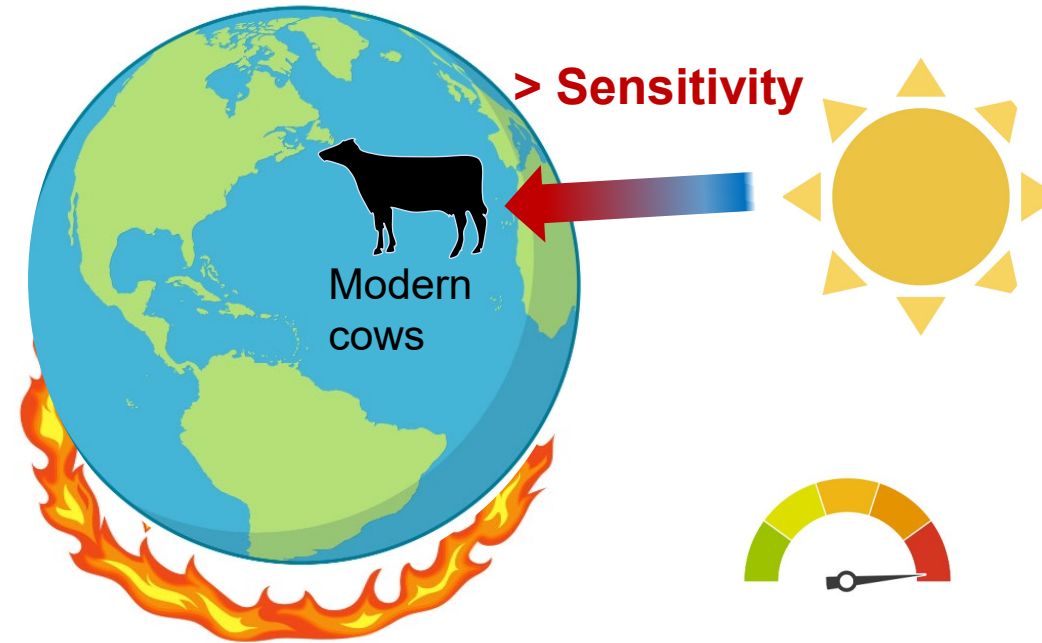
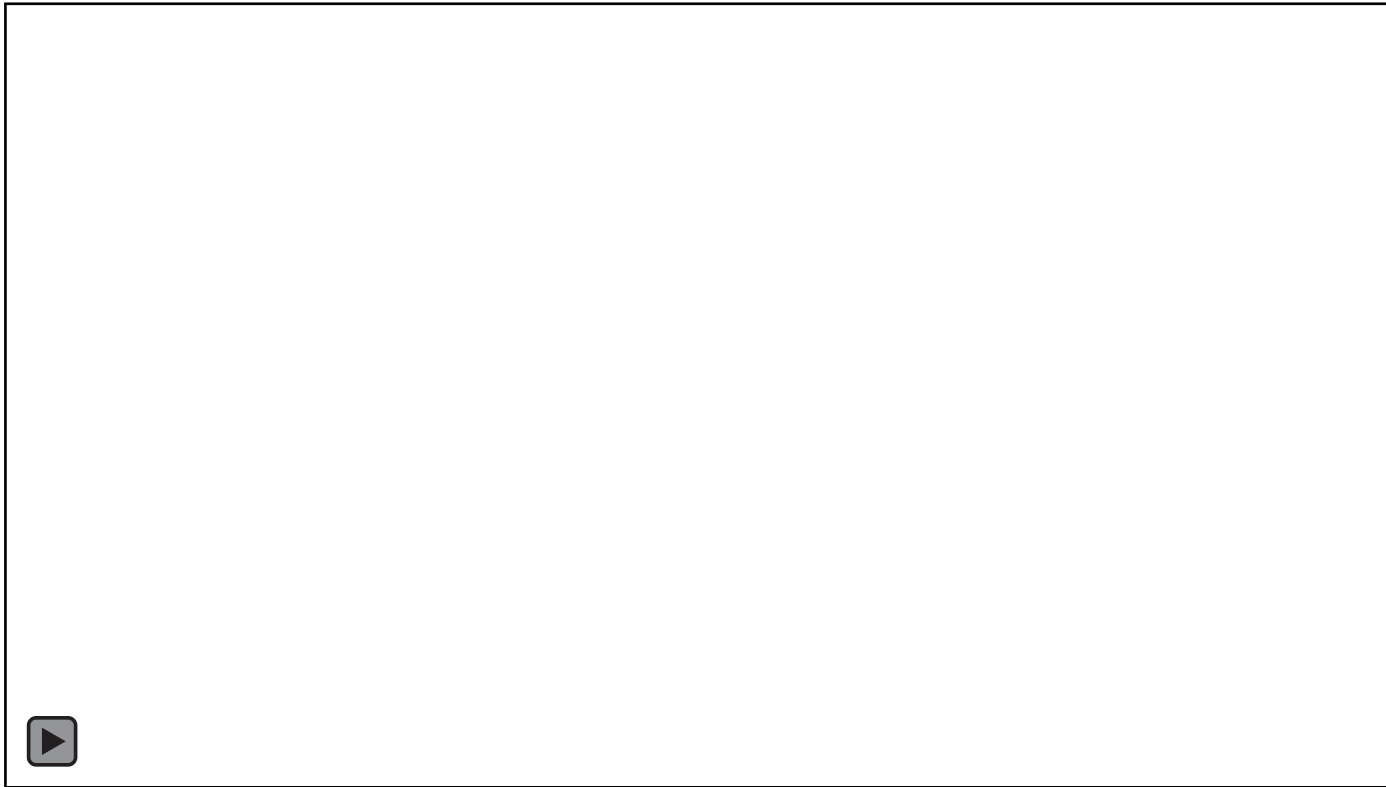




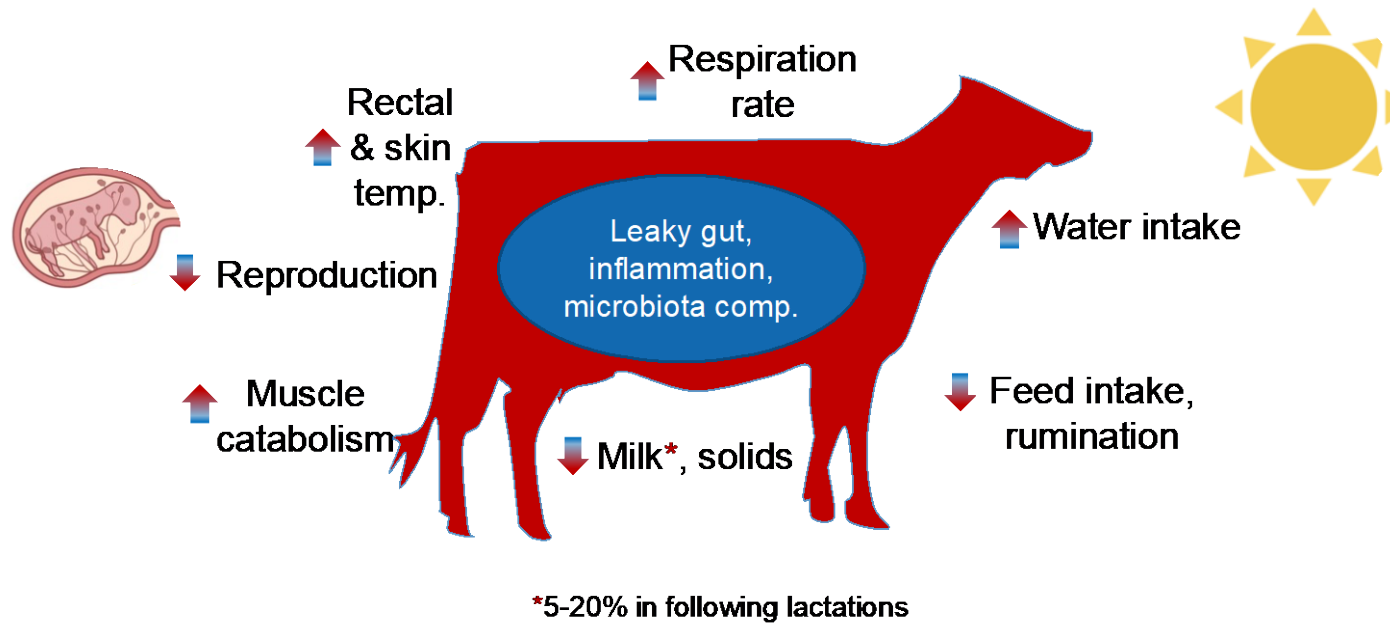
Modeling the changes in daily rumination time and milk yield to detect the onset of heat stress in lactating dairy cows

A. M. Serviento, Y. Chang, G. Guo, A. Wang, K.
Wang, H. Zhang, D. E. Rico, Y. Wang, and M. Niu

The planet is heating up...



Impact of climate change in dairy cows

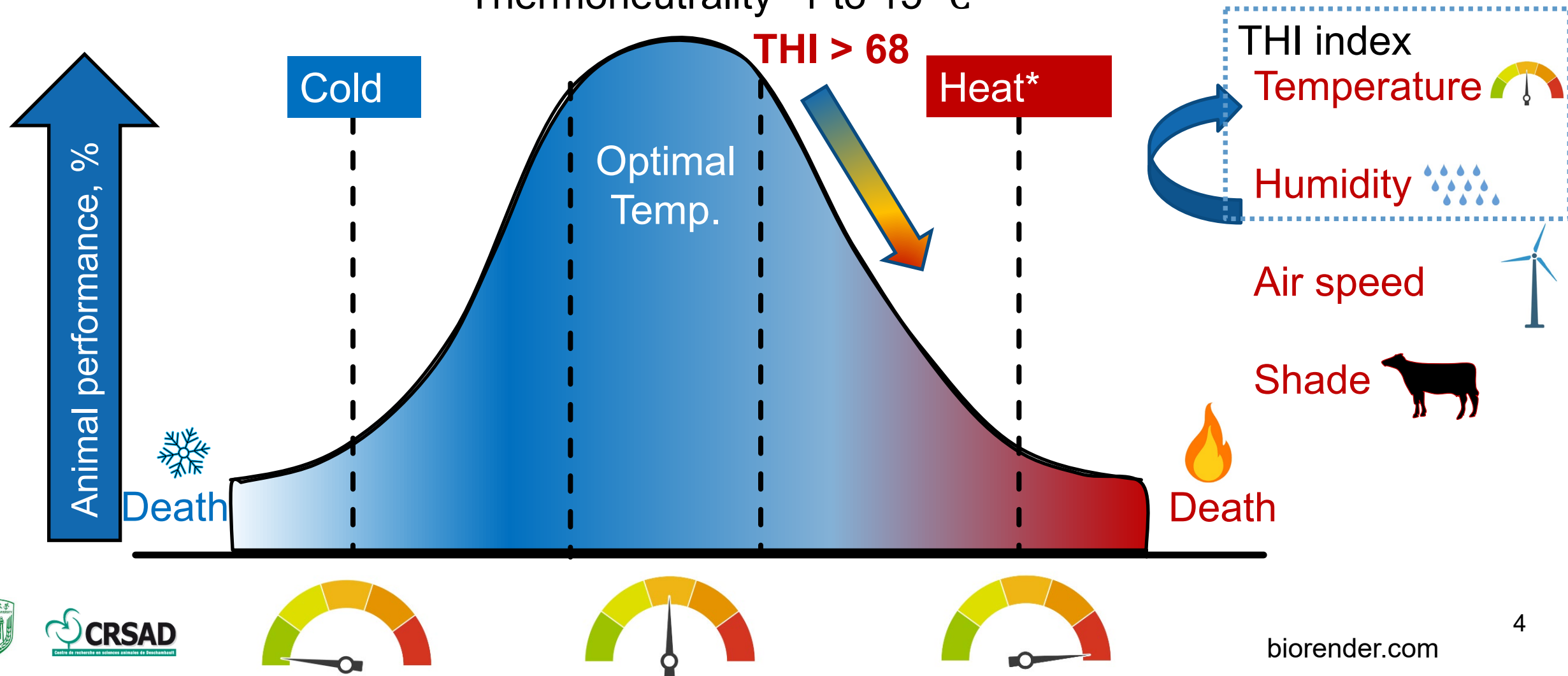


biorender.com

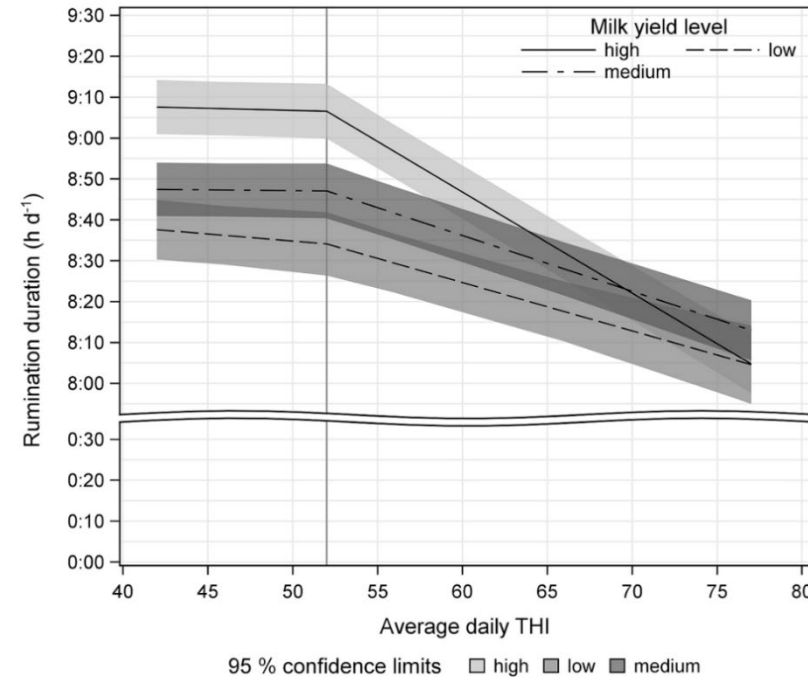
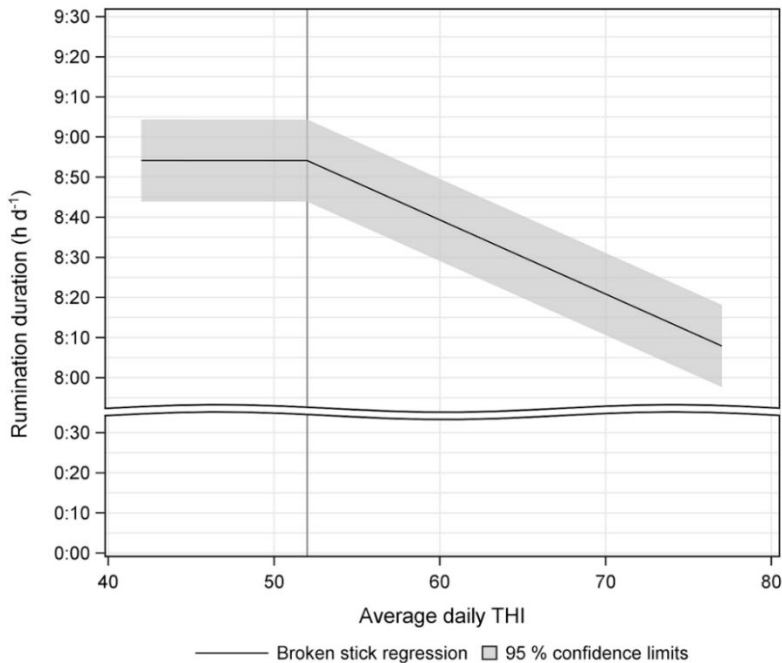
- Heat stress (HS) negatively affects production and health of dairy cows.
- In the U.S., HS costs \$1.5B/year
- In Europe, -5.4% the monthly income in the summer season

Threshold of heat stress: temperature humidity index (THI) > 68

Thermoneutrality -1 to 15 °C



Rumination can serve as an early indicator of heat stress



- A HS threshold of THI 52 was identified based on rumination time using broken-stick regression, but lacking flexibility.

Explore the effect of THI on rumination in comparison to milk production using a more flexible modeling framework

■ Hypothesis:

- the HS threshold of rumination time is lower than that of milk production,
- the HS threshold can vary depending on
 - Parity
 - Production level of animals
 - Lactation stage

Item	Parity		Production level	
	Primiparous	Multiparous	Low	High
Number of cows, n				
Rumination time	498	546	99	117
Milk yield	474	495	99	117
Milk quality measures ²	696	605	66	88
Mean (±SD)				
Parity	1.0 (±0.00)	2.2 (±0.42)	2.33 (±0.47)	2.24 (±0.42)
Rumination time, min/d	542 (±69.8)	524 (±78.4)	512 (±76.9)	547 (±72.3)
Milk yield, kg/d	35.4 (±6.34)	40.3 (±10.32)	35.8 (±7.30)	51.2 (±6.20)

Data collection

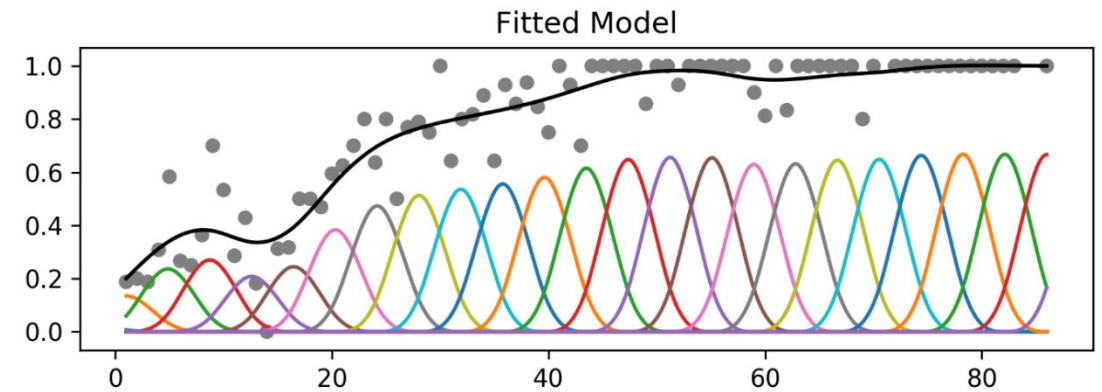
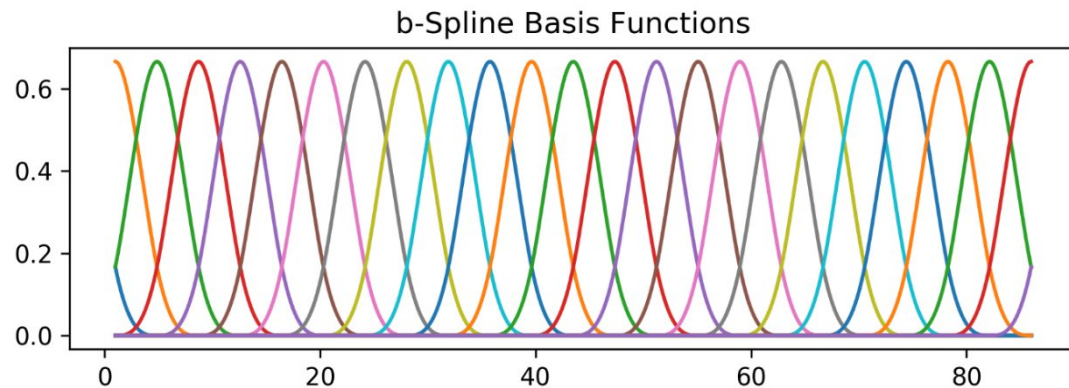
- Data were collected from 920 lactating dairy cows (Holsteins) for 1,108 days between May 2015 to June 2018 in Beijing, China.
 - SCR HR sensors were used
- **Exploration of different climate metrics**
 - Daily mean THI
 - Number of hour per day when THI > 68
 - Daily max or min THI



Climate metrics	Observations, n	Mean	Median	Min	Max	SD
THI	1,108	56.4	59.2	25.6	84.8	15.46
THI above 68, h/d	1,108	7.18	0.00	0.00	24.0	8.996

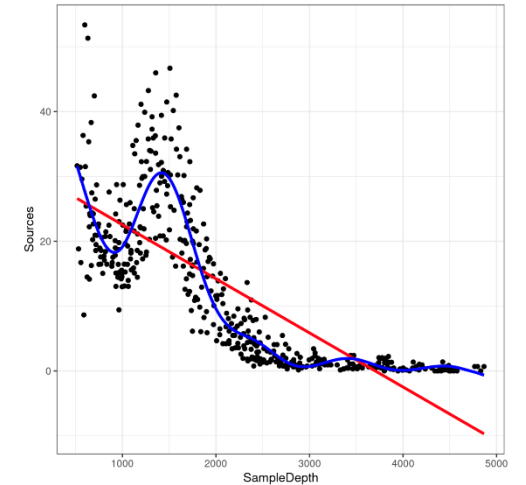
Generalized additive models (GAMs) – a semi-parametric approach

- GAMs are smooth semi-parametric models of the form:
$$g(\mathbb{E}[y|X]) = \beta_0 + f_1(X_1) + f_2(X_2, X_3) + \dots + f_M(X_N)$$
- GAMs extend generalized linear models by allowing non-linear functions of features
- Since the model is additive, it is easy to examine the marginal effect of each variable

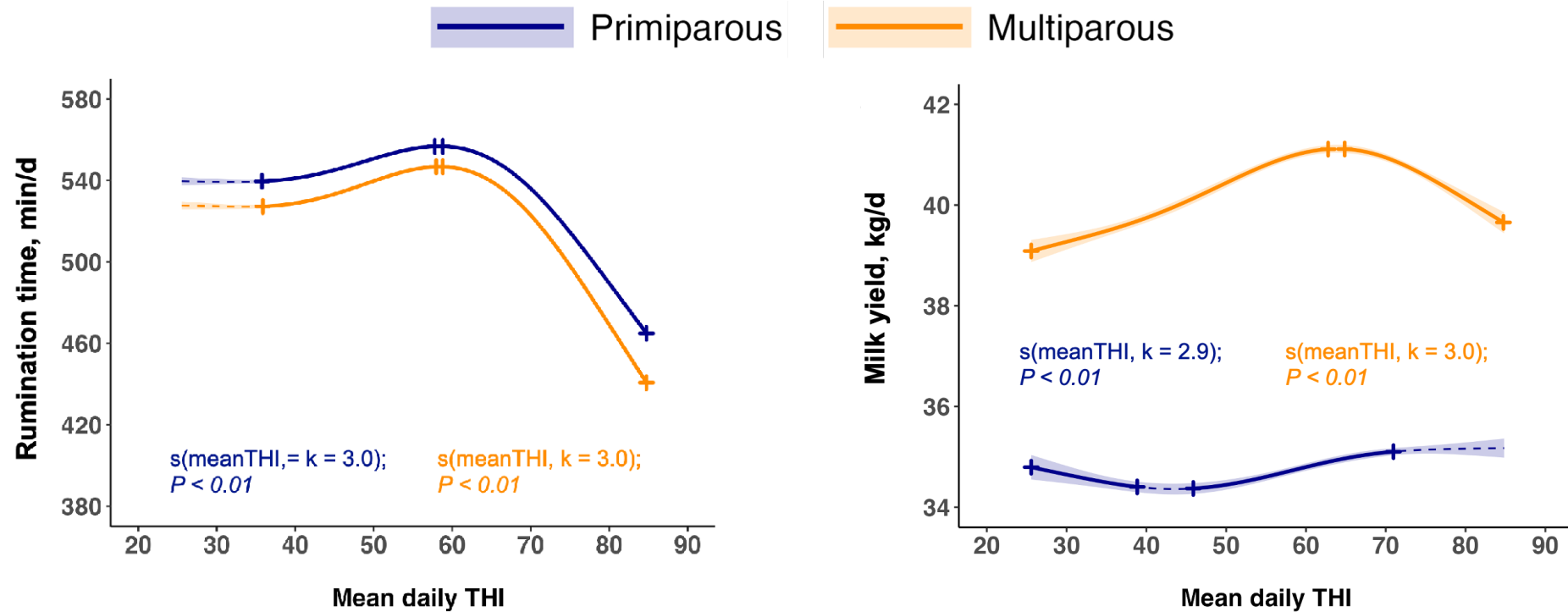


Model structure and determination of inflection point

- Generalized additive mixed model including:
 - Random effect of cows
 - Fixed effect of days in milk (interacting with parity or production level)
 - Fixed effect of THI (interacting with parity or production level)
 - Fixed effect of time of year/Julian day (but dropped due to lack of effect)
- Pointwise derivatives (i.e., the slopes) of the fitted means determined based on the partial effects of THI.
- Inflection points will then be determined from the slopes and will be used for interpreting the HS threshold for different parameters.

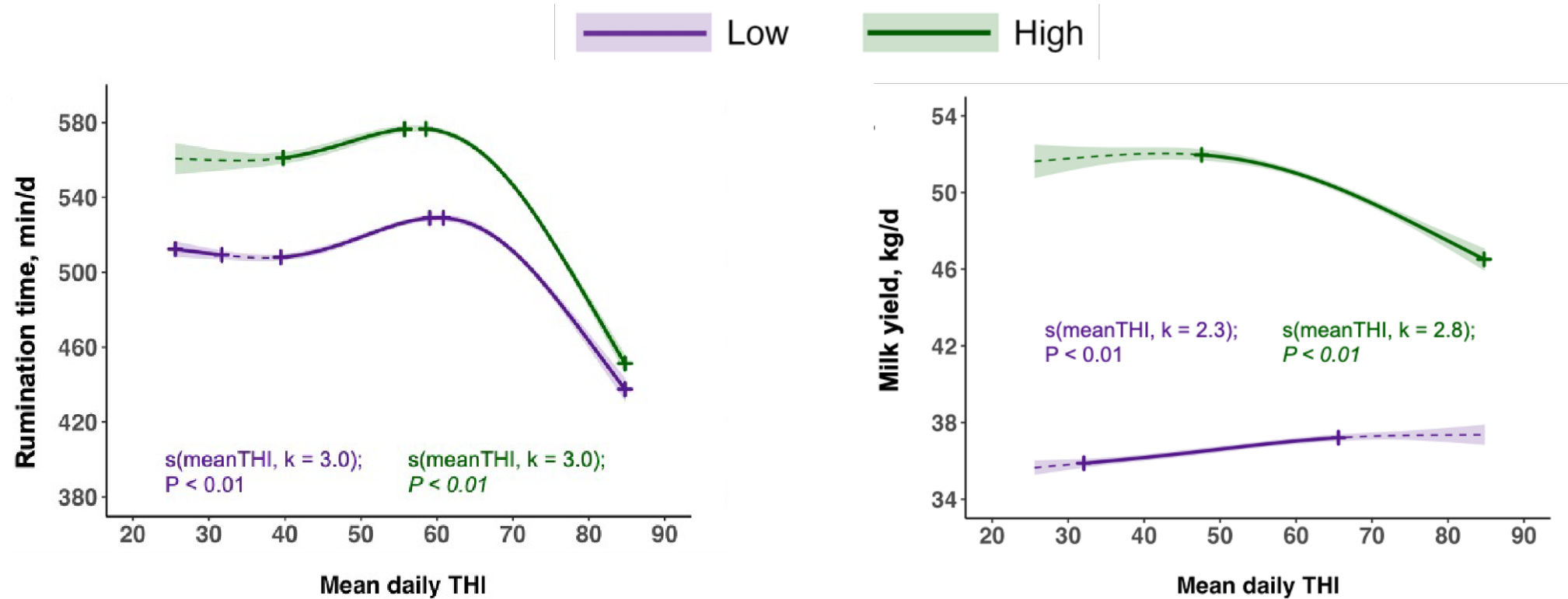


Variable heat stress thresholds for primi- vs. multiparous cows



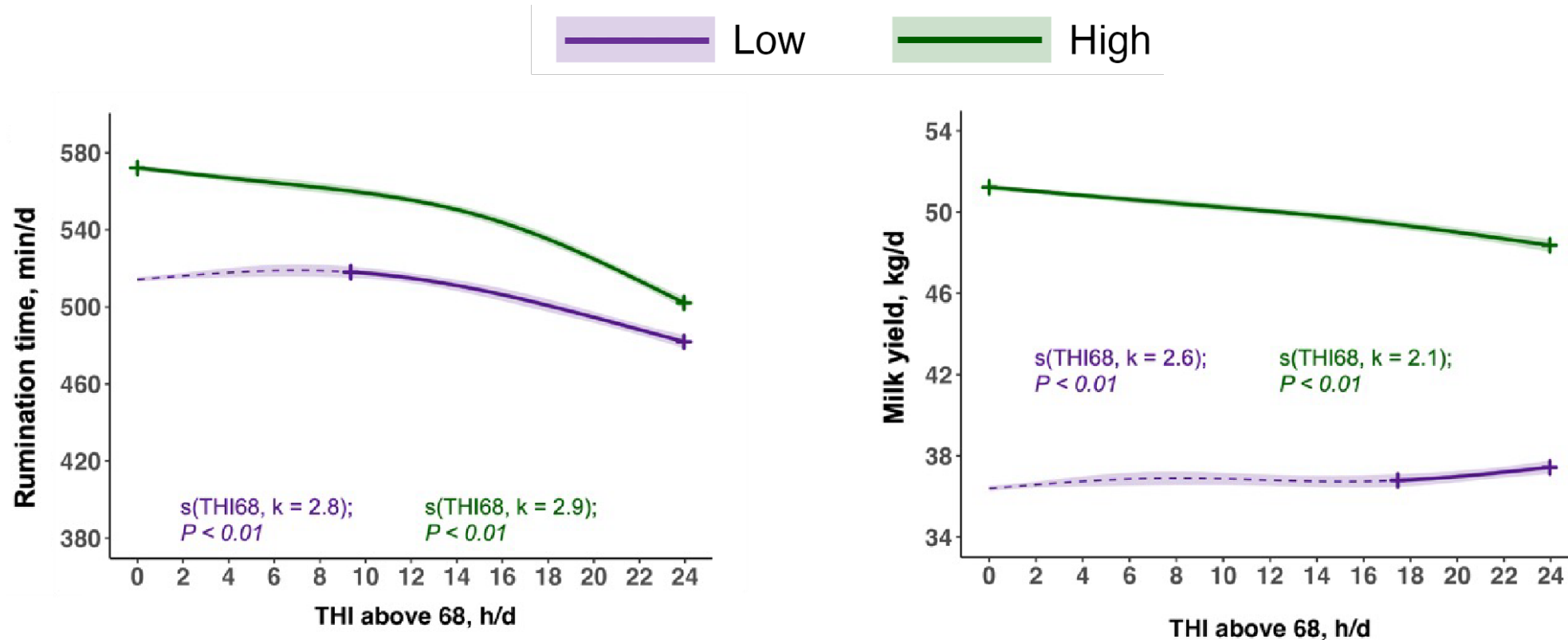
Item	Rumination time, min/d	Milk yield, kg/d
Parity		
Primiparous	58.8 (-3.76)	-
Multiparous	58.8 (-4.35)	65.0 (-0.0782)

Variable heat stress thresholds for high- vs. low-producing cows



Item	Rumination time, min/d	Milk yield, kg/d
Production level		
Low	60.9 (-4.08)	-
High	58.6 (-5.07)	47.6 (-0.154)

Would a different climate metrics tell us more?



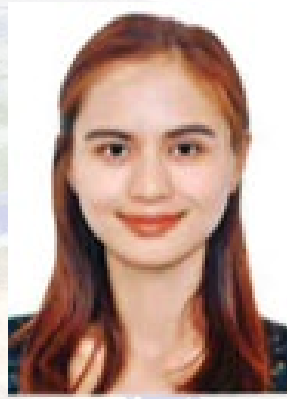
Item	Rumination time, min/d	Milk yield, kg/d
Production level		
Low	9.39 (-2.58)	-
High	0.00 (-2.71)	0.00 (-0.115)

Take home message

- Rumination can be considered as an early indicator of heat stress.
- Heat stress threshold based on rumination time showed $THI = 58.8$ regardless of parity of cows, but limited to up to ~2 lactations; compared to $THI = 65$ for multiparous cows.
- Heat stress threshold based on rumination time showed that high-producing cows are more sensitive than low-producing cows ($THI = 60.9$ vs. 58.6 , respectively).
- Further investigation and tuning to improve model robustness.



Yachun Wang



Aira Serviento



Daniel Rico

Livestock

Environment

Thank you!