Genomics of adaptability in beef cattle

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Climatic stress and beef cattle

- Major limiting factor of production efficiency
  - In beef cattle in tropical and subtropics environm.
  - In dairy cattle throughout most of the world
- > **50%** cattle in the world – maintained in hot and humid environments
  - including ~ 40% of beef cows in US
- Substantial differences in thermal tolerance
  - Among breeds
  - Among animals within breeds
- Indication of opportunities for selective improvement

Heat stress effects

- High ambient temperature (threshold depends on features of the environment and the animal)
  - Temperature & humidity index **THI**
- Productive functions (growth, reproduction, meat quality) are compromised
- Main reasons:
  - physiological adaptations to regulate body temperature - negative effects on production
    - decreased feed intake
    - redistribution of blood flow to the skin
  - negative effects of elevated body temperature on physiological functions of specific organ systems

Future climate prediction

- Detrimental effects on livestock productivity associated with heat stress will intensify and expand into currently temperate zones (IPCC).
- Most animal-producing areas in US - predicted to experience extreme summer conditions
- By **2100** avg temp. in US projected to increase **2°- 6°C**
- No. days with temp. above **32°C** (90°F) expected to increase
  - SE & SW US: from **60** days/year currently to **150** days/year by the end of the century

Ability to cope with heat stress

- Strategies to improve ability to cope with heat stress
  - enhance productivity of US livestock industry
  - secure global food supplies
- Swine, poultry and dairy cattle - more severely affected by heat stress than beef cattle
  - climate control via housing design and management interventions is feasible (due to confinement and intensive production systems)
- Beef cattle (cow-calf) - limited opportunities for controlling environmental stress (extensive systems)
- **Genetic improvement** - one of few feasible strategies for adequate and sustainable production of beef protein in an increasingly hot world.

Heat stress adaptation mechanisms

- **Thermoregulation** - neural process
  - Environmental information elicits an appropriate response to maintain body temperature
  - Narrow range necessary for optimal cellular and molecular function
  - Joint regulation of heat production and heat loss

Normal Rectal Temperature Ranges		
Species	**°C**	**°F**
Beef cow	**36.7 – 39.1**	**98.0 – 102.4**
Dairy cow	**38.0 – 39.3**	**100.4 – 102.8**

Adapted from Robertshaw D. Temperature Regulation and Thermal Environment, in *Dukes' Physiology of Domestic Animals*

Heat stress:

heat produced and absorbed **>** heat dissipated

In response to heat stress:

- Regulate internal **heat production**
  - Modulating basal metabolic rate
  - Changing: feed intake, growth, lactation, activity
- Regulate **heat exchange**
  - increasing blood flow to the skin
  - increasing evaporative heat loss through sweating & panting

Hyperthermia: body temp increases despite these adjustments

Improvements in production - more susceptible animals to hyperthermia during heat stress

Genetics of thermotolerance

- Heritability of rectal temperature
  - 0.19, Brahman x Angus crossbred pop. (Riley et al. 2012)
  - 0.17, dairy cattle in FL (Dikmen et al. 2012)
- Selection for improved thermal tolerance is possible
  - If we can identify animals with genetically superior core body temperature regulation when exposed to environmental thermal stress.
  - Need phenotypes and tools to make selection decisions

Reveal the **genetic architecture** of traits defining **thermal tolerance** in *Bos Indicus* influenced cattle.

UF - Multibreed AngusxBrahman Herd

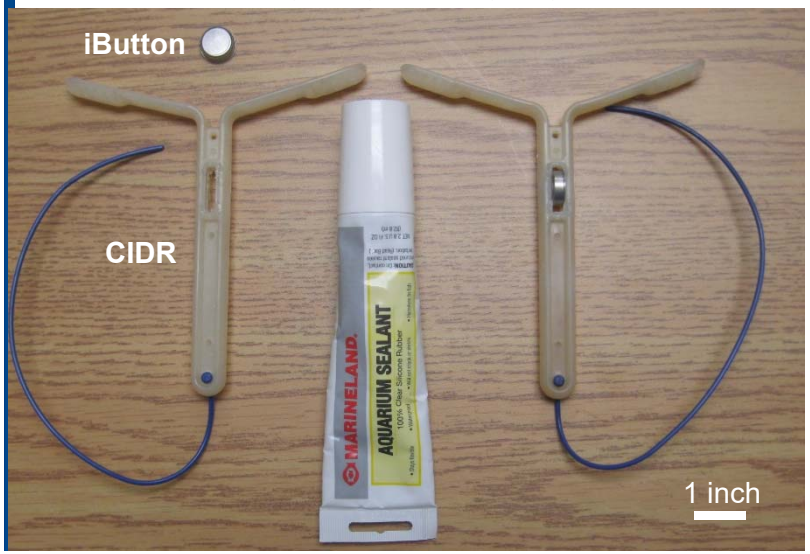
- Summer 2015
  - 191 cows: from 100% Brahman to 100% Angus

Breed Group	Angus %	Brahman %	Angus %	Brahman %
1	100	0	100-80	0-20
2	75	25	79-60	21-40
3	62.5	37.5	62.5	37.5
4	50	50	59-40	41-60
5	25	75	39-20	61-80
6	0	100	19-0	81-100

UF - Multibreed AngusxBrahman Herd

- Summer 2015
  - 191 cows: from 100% Brahman to 100% Angus
  - Vaginal temperature at 5-min intervals for 5 days
  - Air temperature and relative humidity - recorded continuously in the pastures

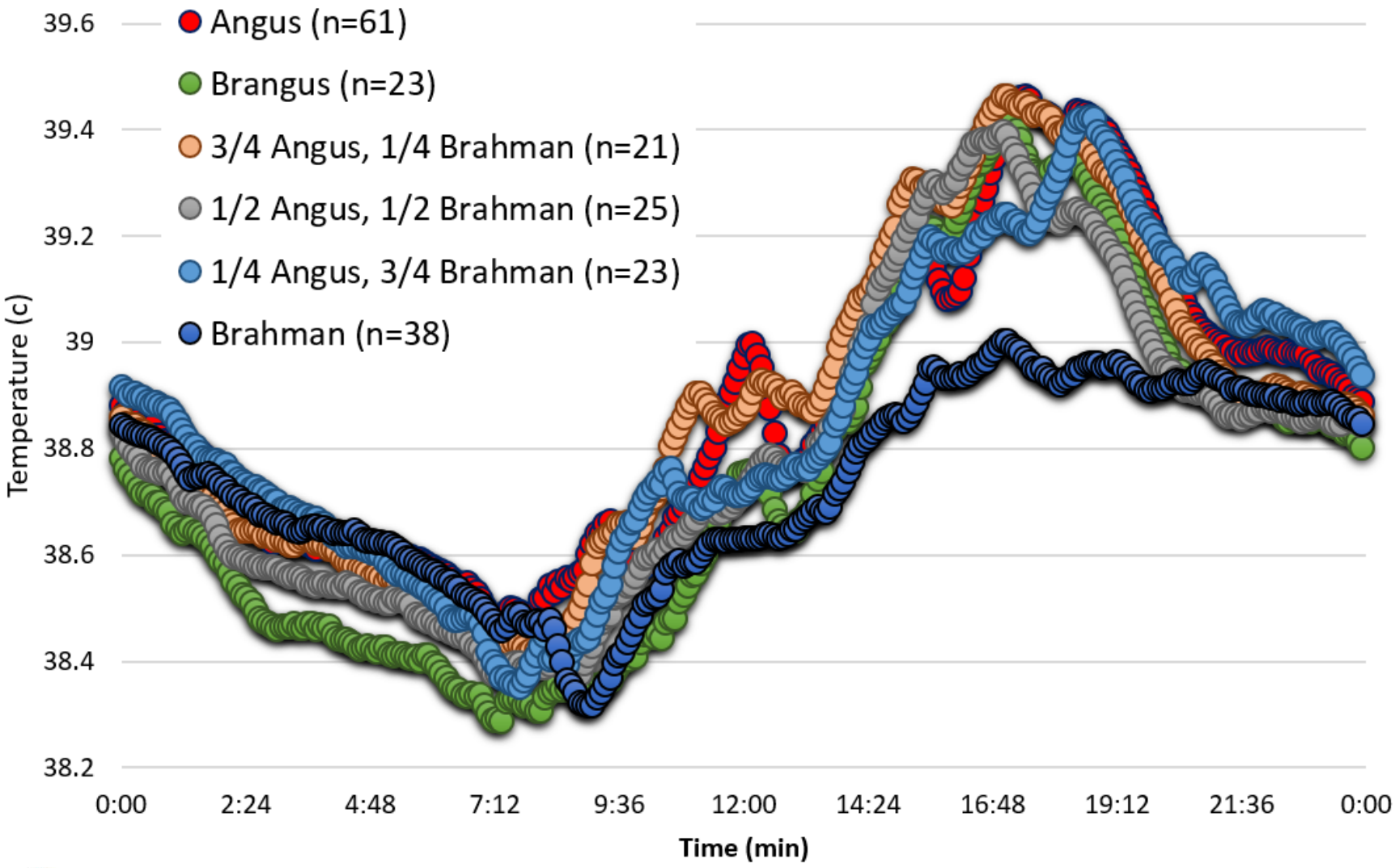
DS1922L iButton Temperature Logger - Maxim Integrated Products,
120 San Gabriel Drive, Sunnyvale, CA
Range: -40°C to +85°C
Resolution: 0.0625°C (11 bit) or 0.5°C (8 bit)



UF - Multibreed Herd, Summer 2015

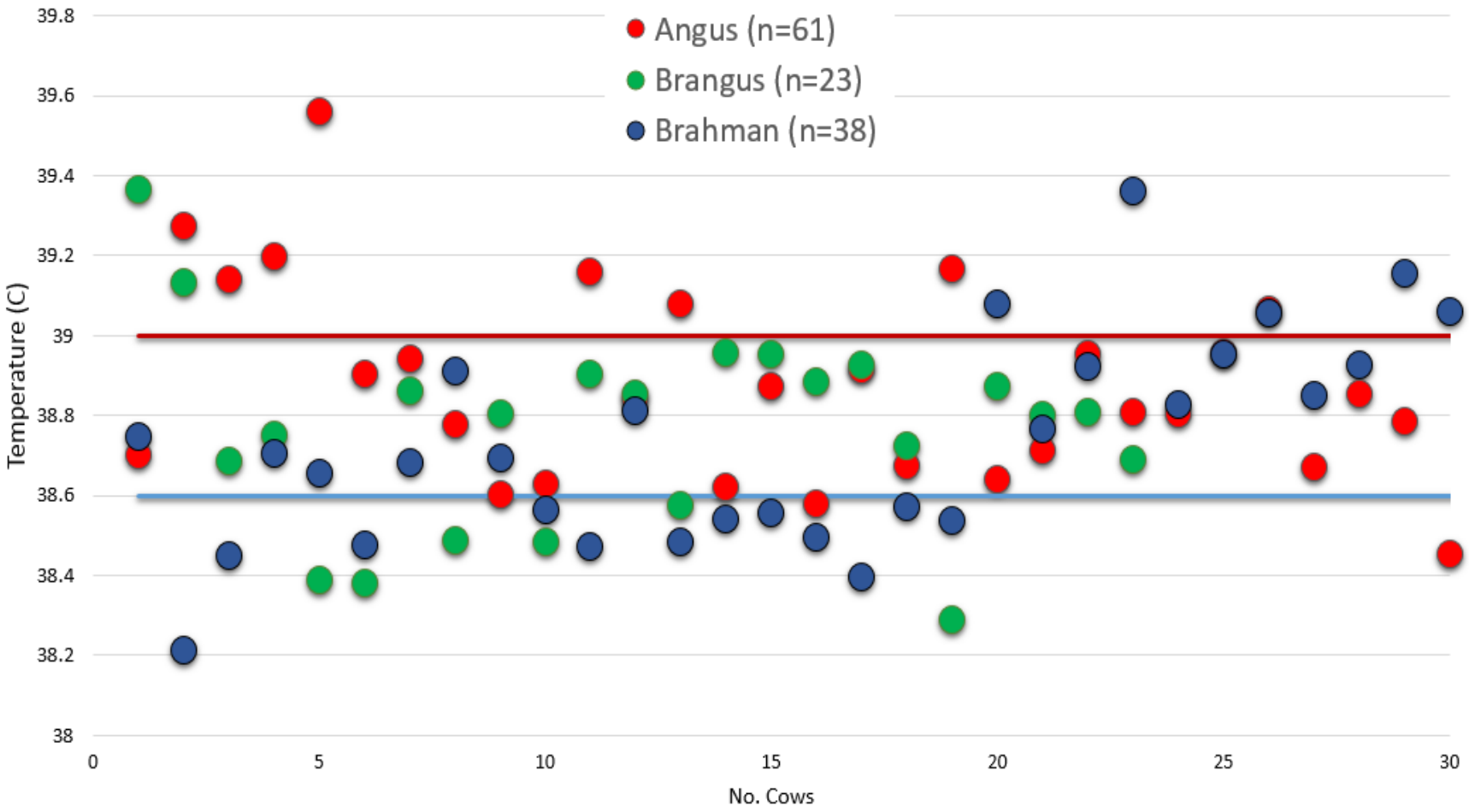
- 191 cows, in 4 replicates, 3-4 days of continuous vaginal temp. per replicate
  - Replicate 1: 50 cows, all breed groups
  - Replicate 2: 49 cows, all breed groups
  - Replicate 3: 46 cows, all breed groups
  - Replicate 4: 45 cows, all breed groups
- For each cow: average temperature for each time point (average over 3 or 4 days)

UF - Multibreed Herd, Summer 2015



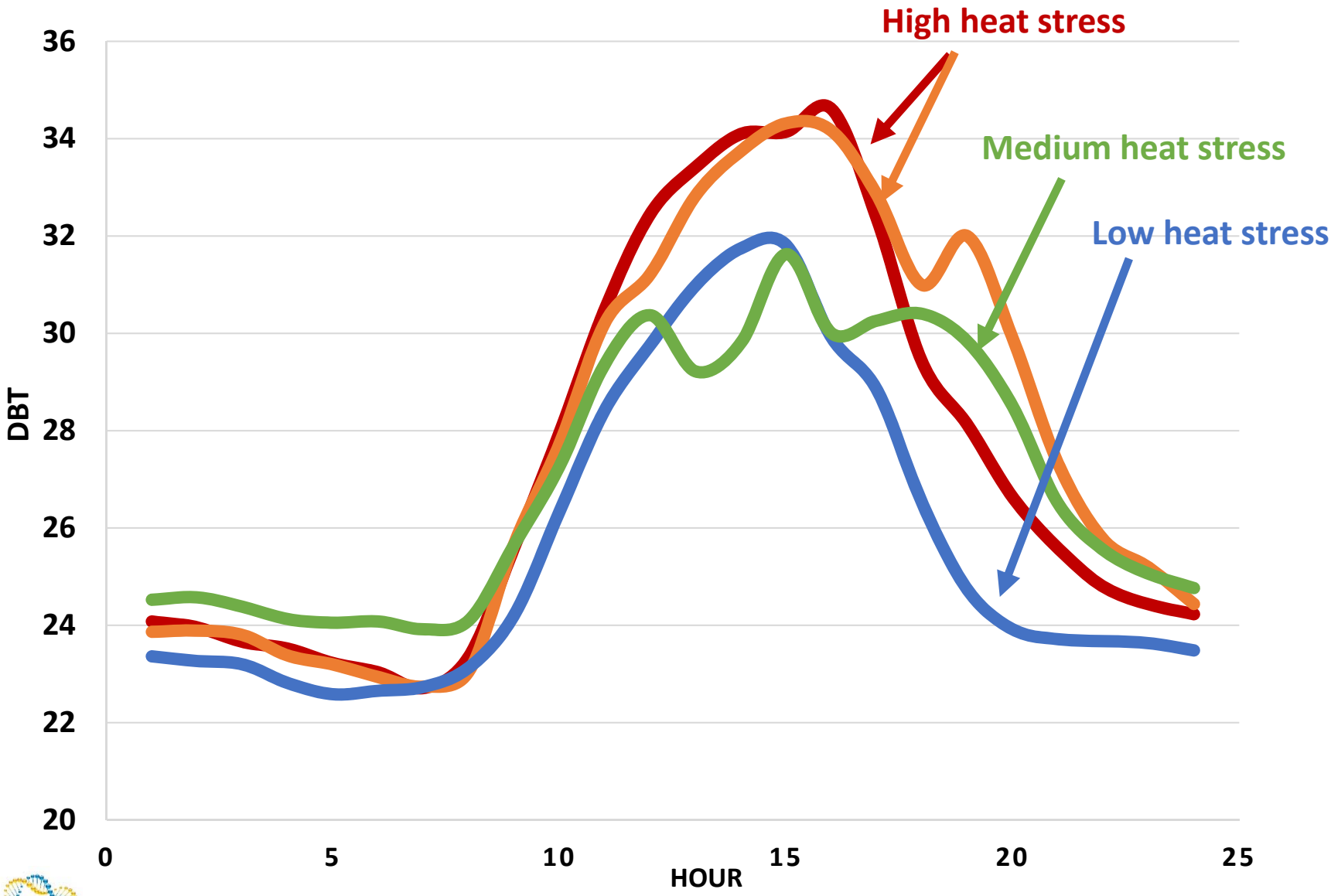
Daily variation in vaginal temperature in UF cows of different breed composition presented as average temperature over a 5-day period for each breed group.

UF - Multibreed Herd, Summer 2015

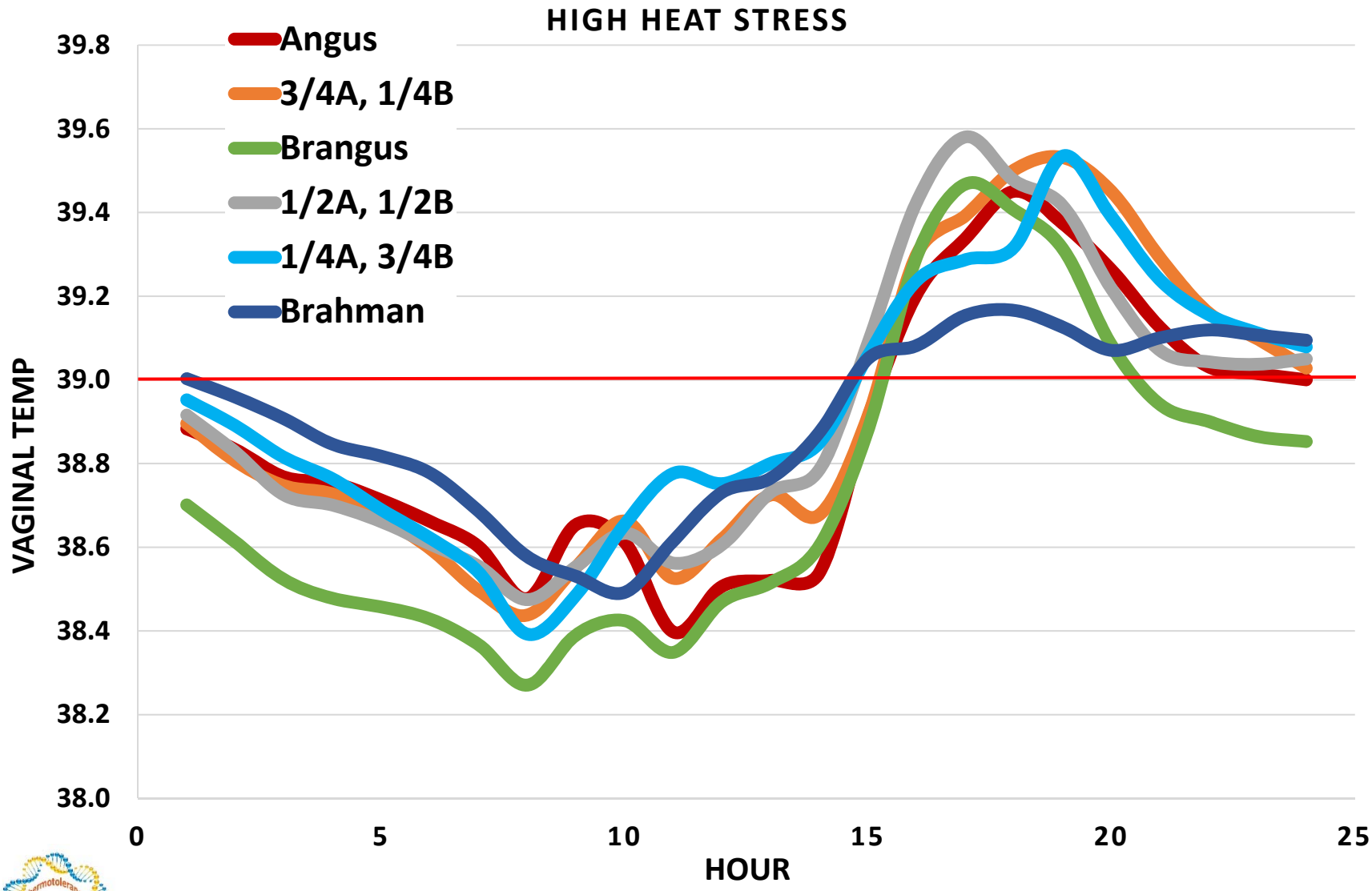


Phenotypic variation in 5-day average vaginal temperature in Angus, Brangus and Brahman cows. The blue horizontal line is "normal" body temperature and the red line represents a rough estimate of the body temperature at which fertility declines.

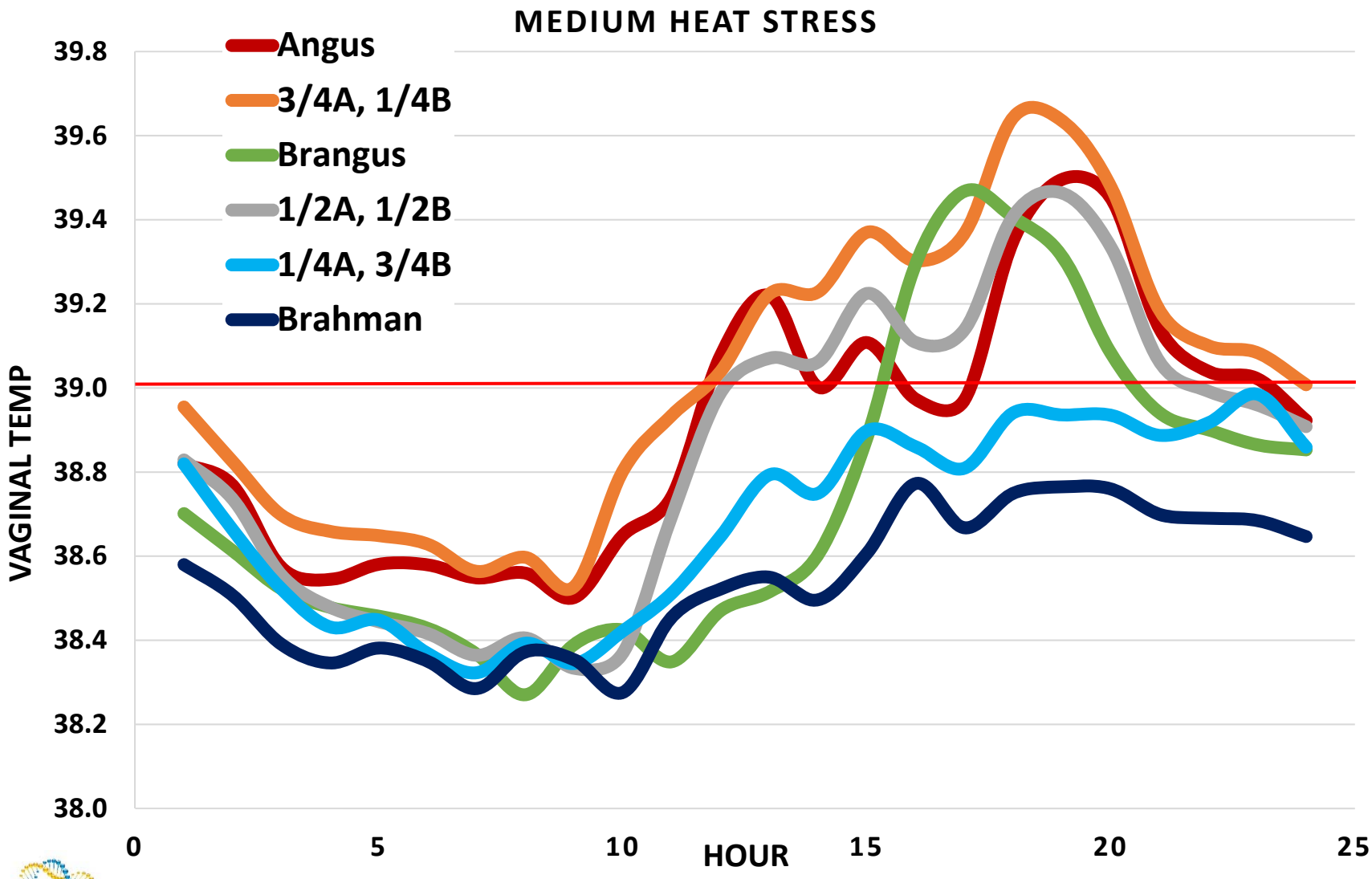
Outside temperature – by replicate



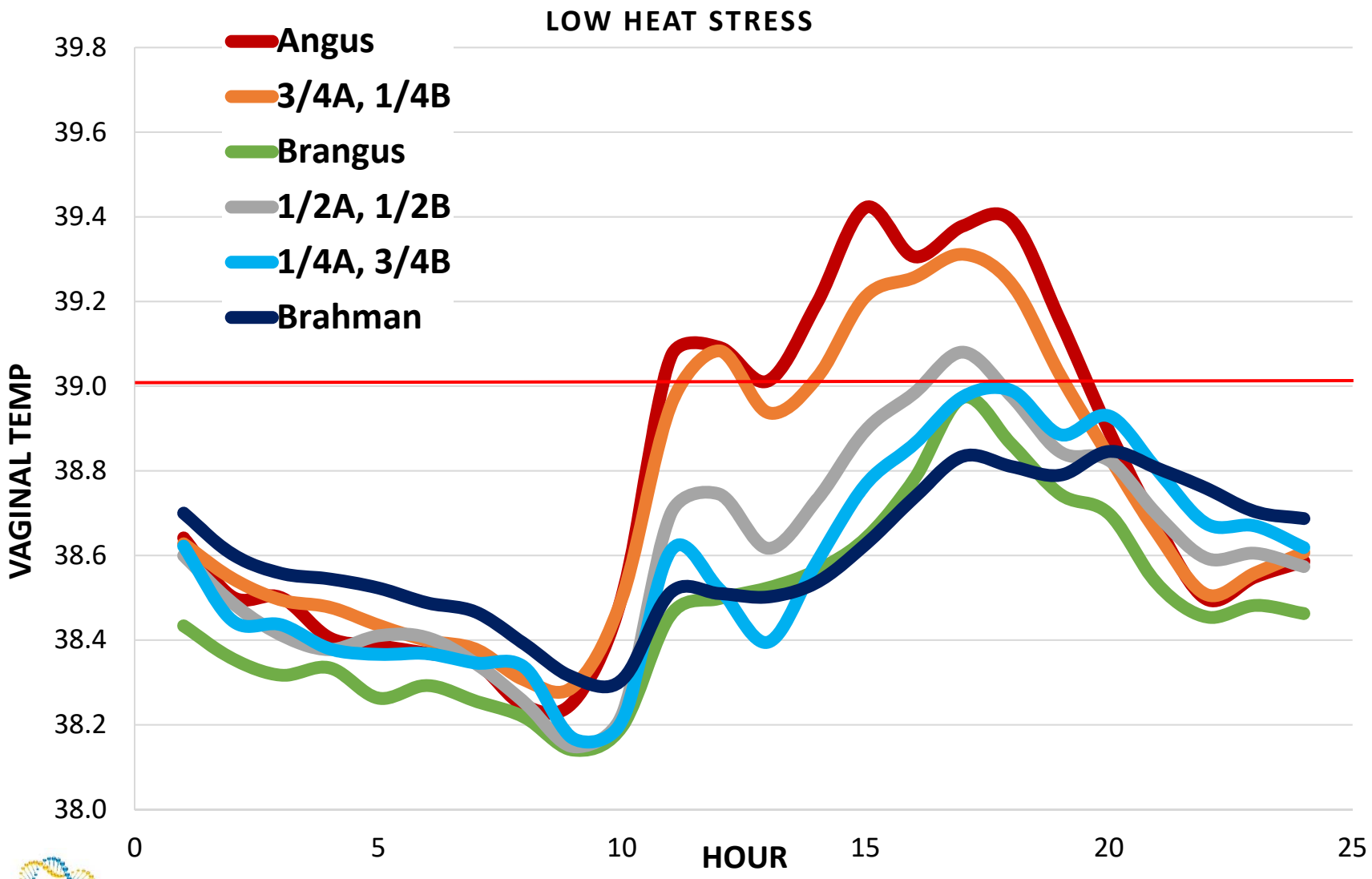
Vaginal Temp. under high heat stress



Vaginal Temp. under med. heat stress



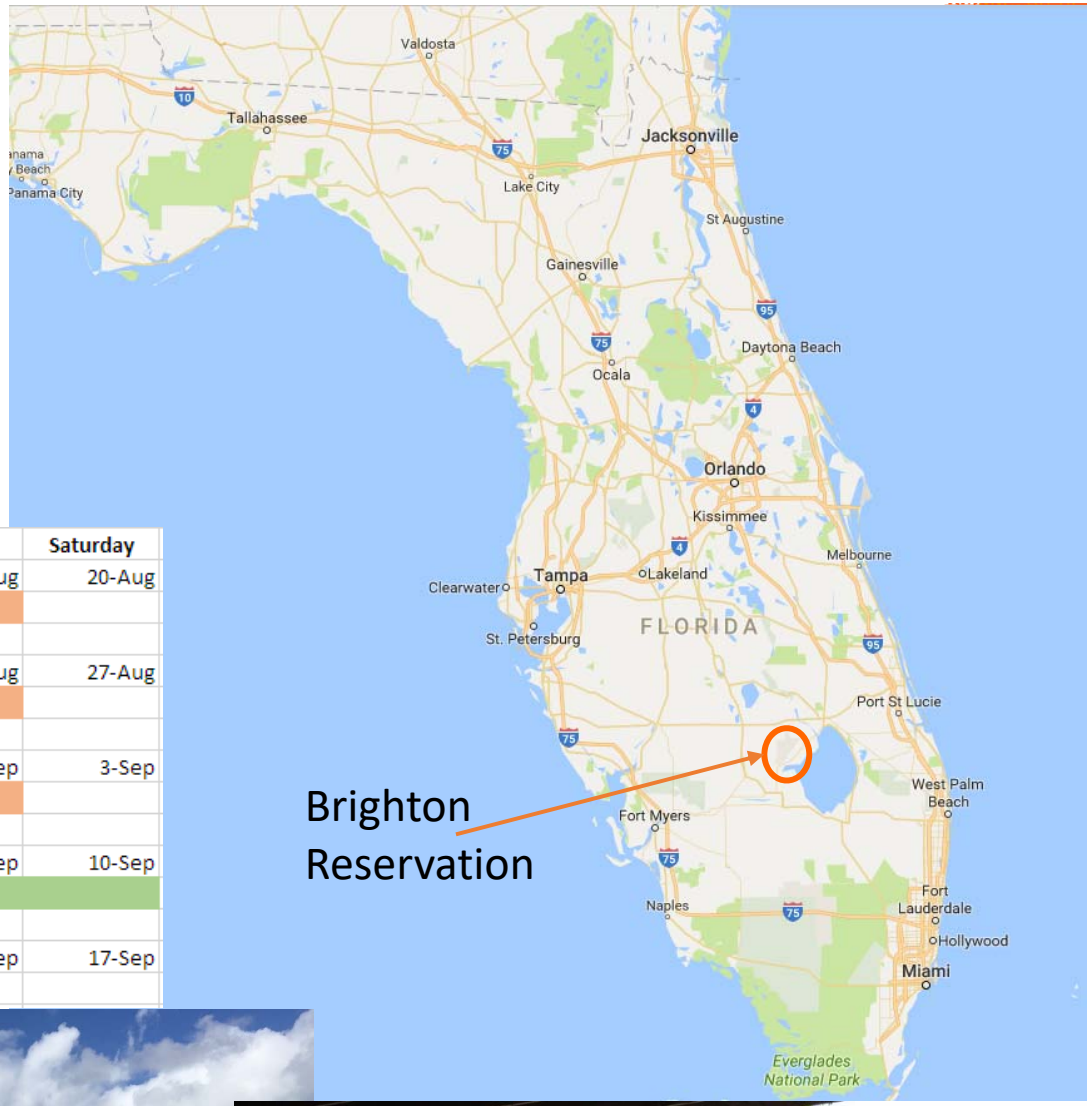
Vaginal Temp. under low heat stress

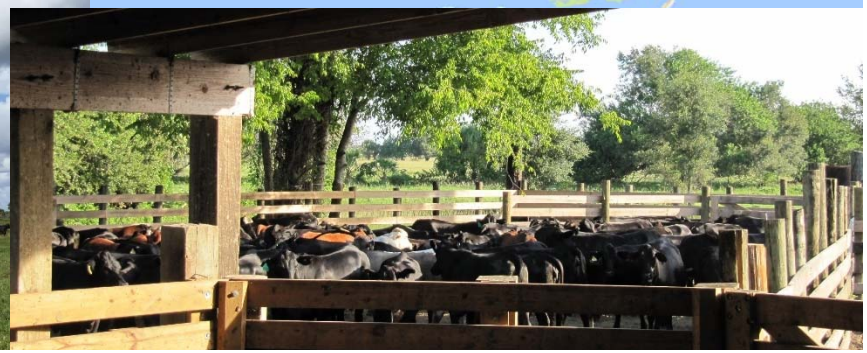


Summer 2016

- Seminole Tribe of Florida, Summer 2016
  - 725 two-year old Brangus heifers
  - 4 groups of ~ 200 - vaginal temperature at 5-min intervals for 5 days, sweating rate, hair coat color and score, and temperament

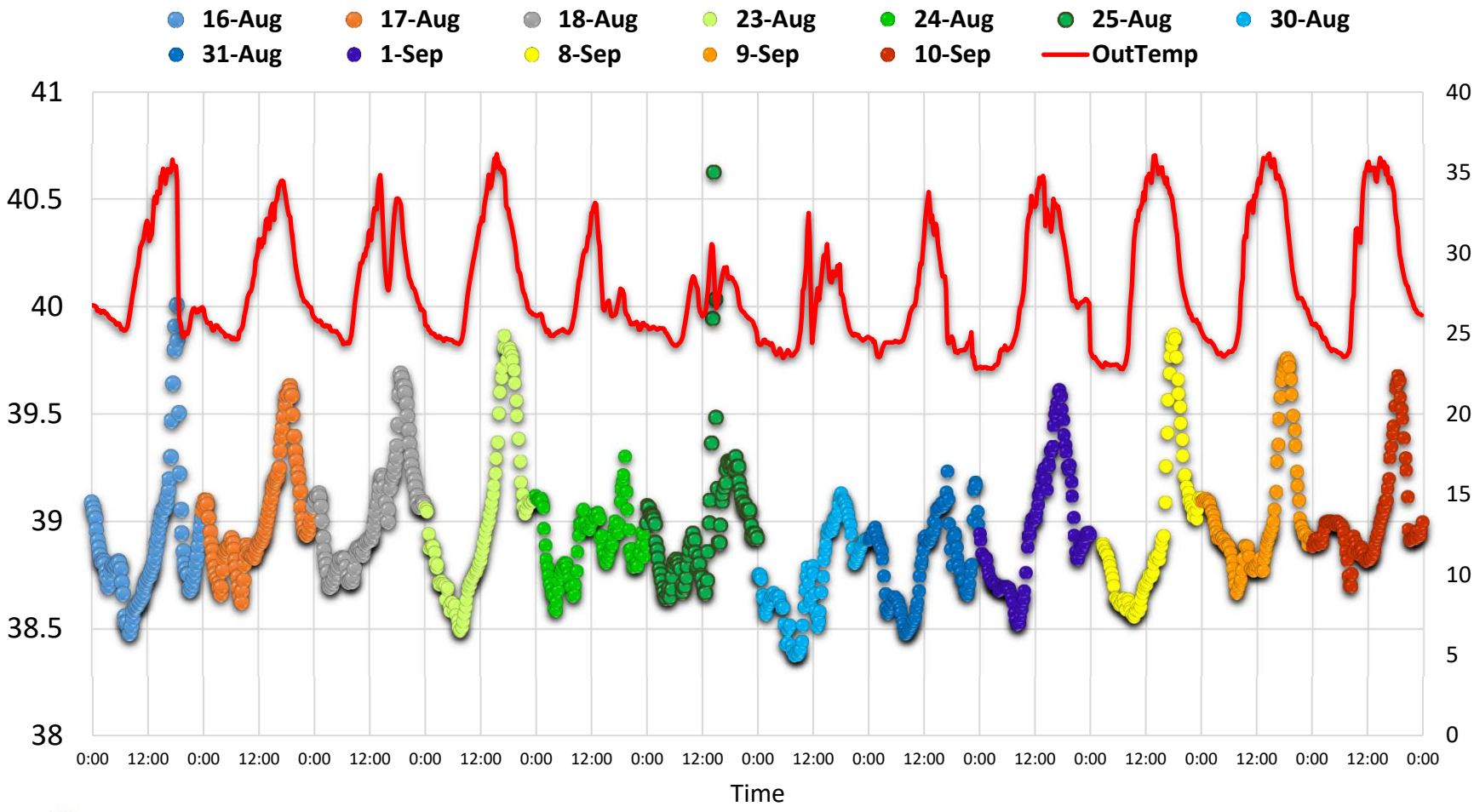
Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug
Driving	Insert				Pull out	
21-Aug	22-Aug	23-Aug	24-Aug	25-Aug	26-Aug	27-Aug
Driving	Insert				Pull out	
28-Aug	29-Aug	30-Aug	31-Aug	1-Sep	2-Sep	3-Sep
Driving	Insert				Pull out	
4-Sep	5-Sep	6-Sep	7-Sep	8-Sep	9-Sep	10-Sep
		Driving	Insert			
11-Sep	12-Sep	13-Sep	14-Sep	15-Sep	16-Sep	17-Sep
	Pull out					





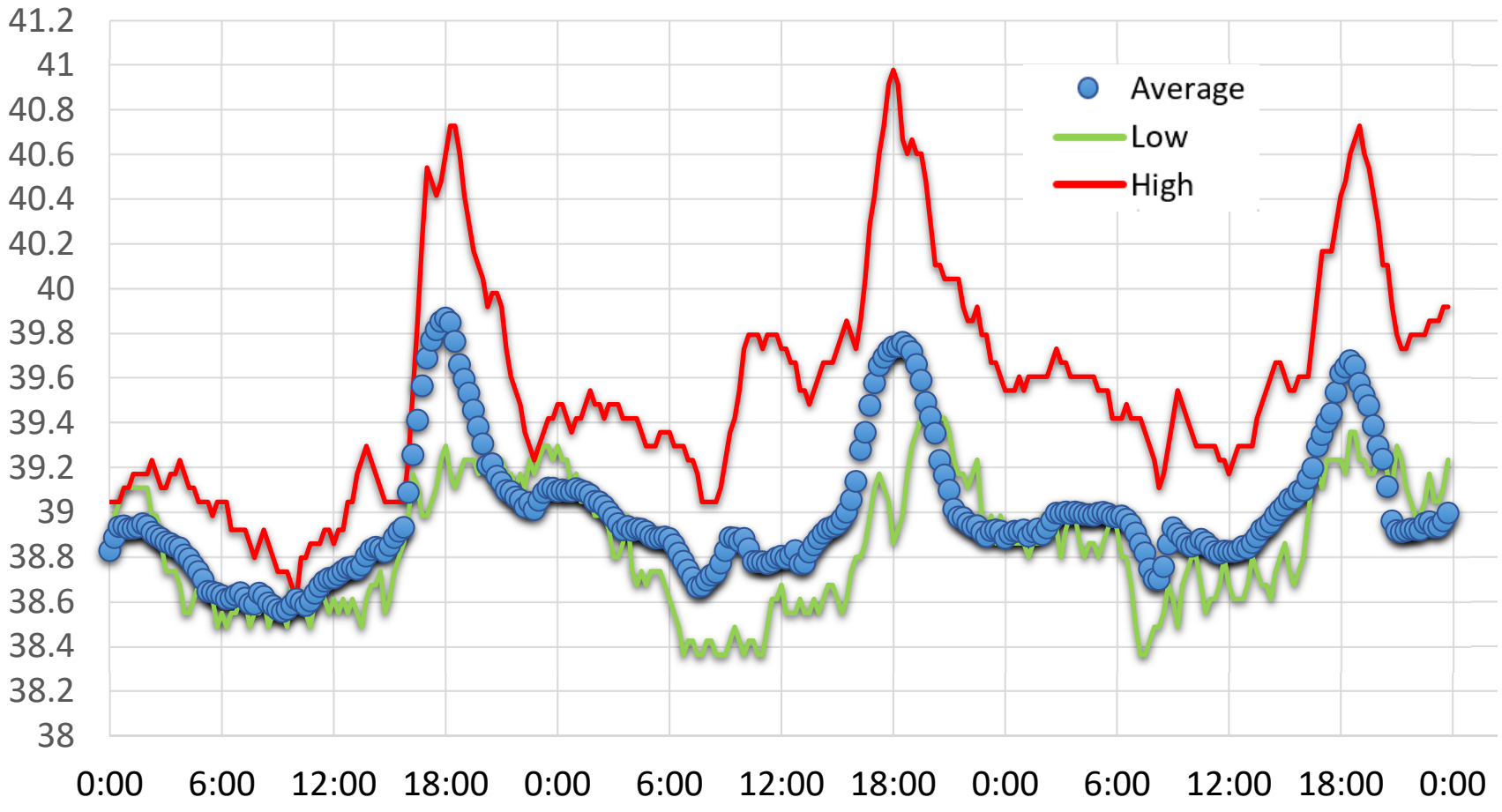
Vaginal Temperature – Daily Average

- Repeated Obs. model



vagtmp every 15 min by day - REPEATED with cov structure type = ARH(1) autoregressive order one AR(1)

Vaginal Temperature – variation



Sept 8 - 10, Vaginal Temperatures

Hair measurements

- Coat color
- Coat score
- Hair: length, diameter

Coat score
1. excessively smooth
2. fairly smooth
3. long coat
4. woolly
5. excessively woolly coat

Coat Color	No
1. Black	684
2. Brindle	11
3. white	6
4. red	14
5. orange	2
6. tan	2
7. smoky	1
8. brown	2
9. grey	1
10. red/white	2

Coat Score

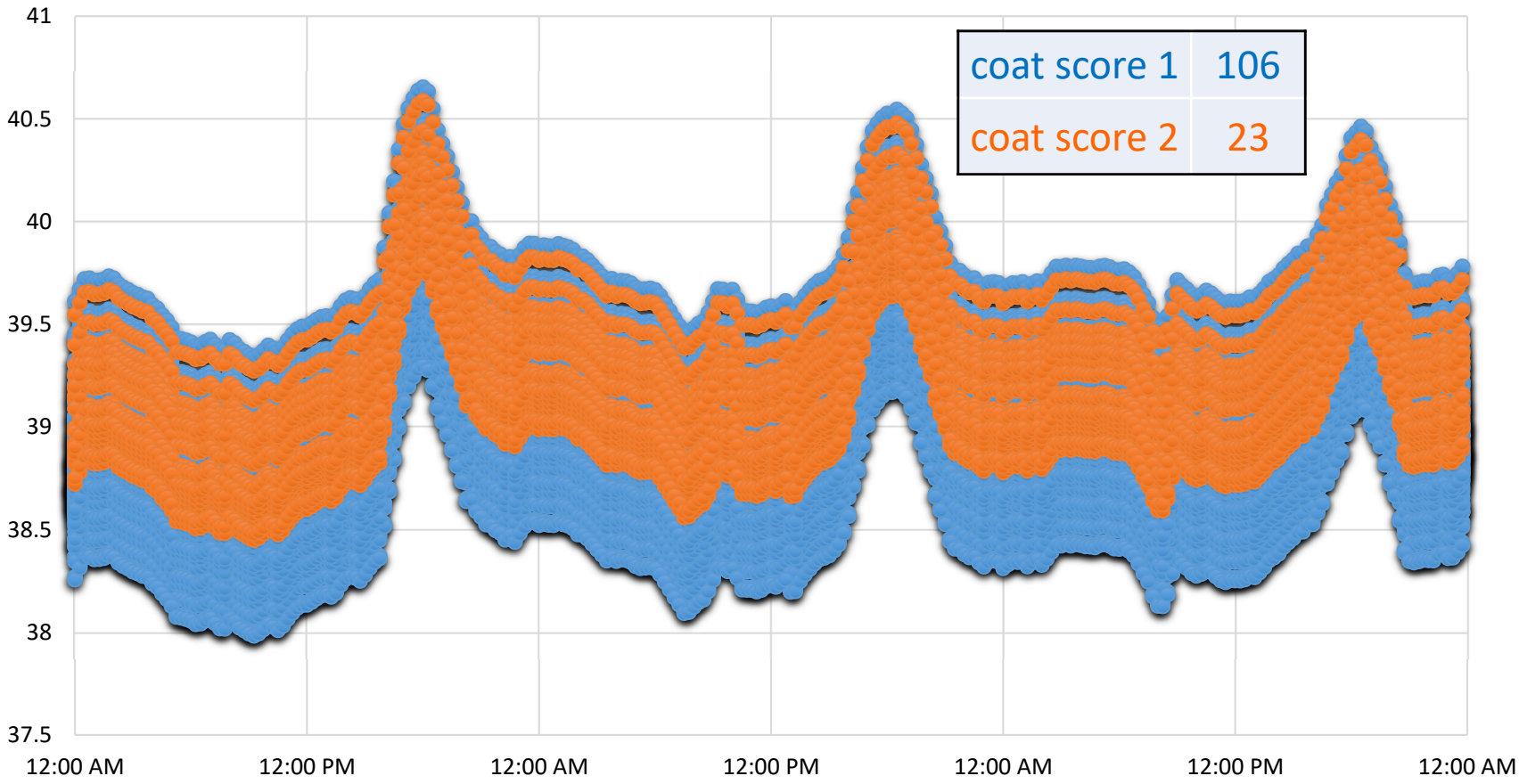
Score 1
Excessively Smooth
N = 526

Score 2
Fairly Smooth
N = 189

Score 3
Long Coat
N = 7

Score 4
Wooly
N = 1

Vaginal temp., 3 days, rep 4 by coat score

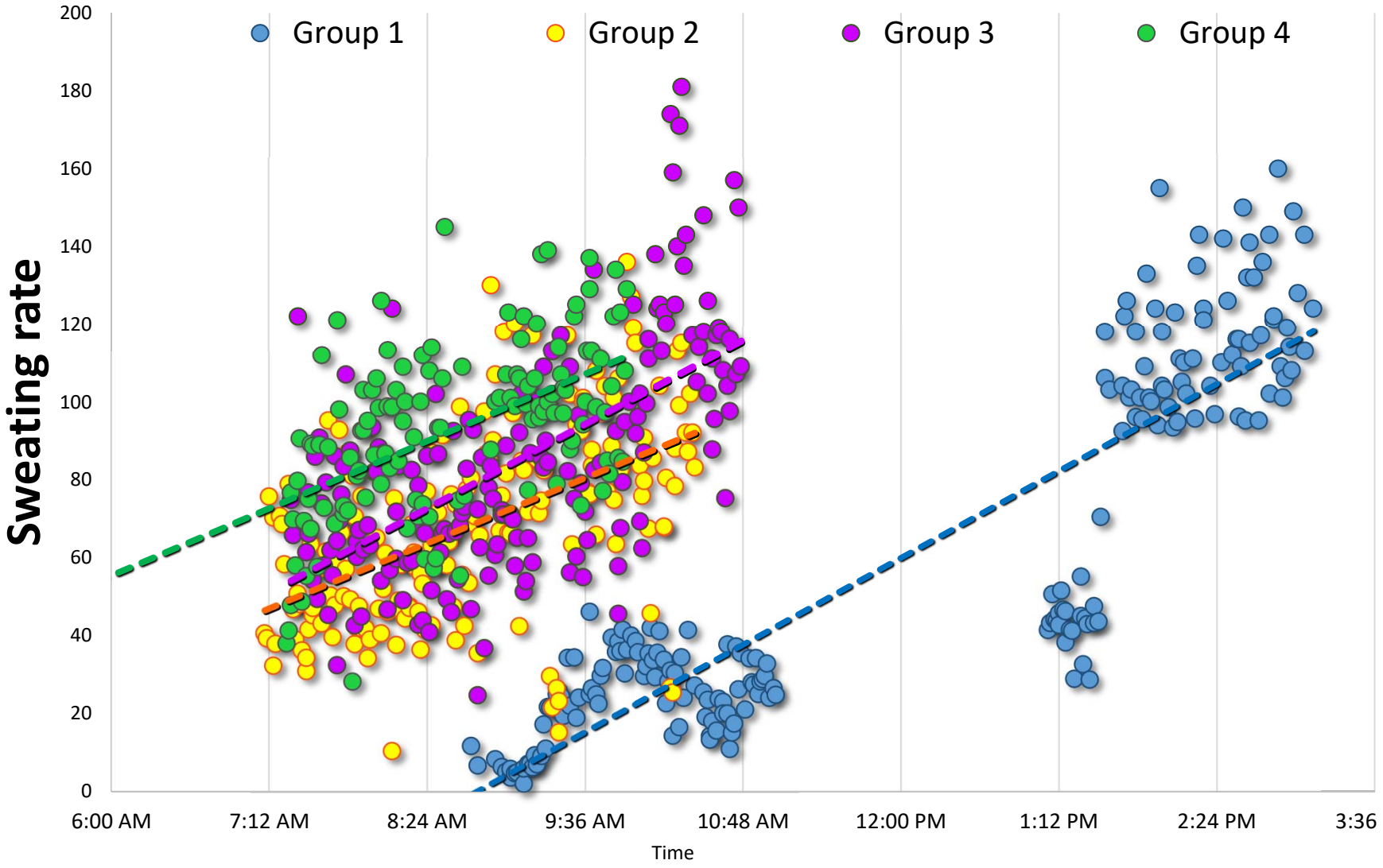


vagtmp every 15 min by day for rep 4 by coat type autoregressive order one AR(1)

Perspiration rate

- VapoMeter: measures transepidermal water loss values and evaporation rates.
- Sensor monitors the increase of relative humidity (RH) inside the chamber during the measurement.
- The evaporation rate value (g/m^2h) is automatically calculated from the RH increase.

Sweating rate vs Chute time by group (day)



Ongoing

- 725 heifers: synchronized AI and fertility data at first calving.
- Genotypes: 250K functional SNP chip.
- USDA-NIFA grant "**Breeding climate-smart beef cattle**" - reveal the genetic architecture of traits defining thermal tolerance using *Bos indicus* influenced cattle.
  - 2,000 Brangus heifers with thermotolerance phenotypes over the next 2 years.
  - Genotypes: 250K functional SNP chip.
  - Integrate phenomics for thermal tolerance and genomic data to identify chromosomal regions associated with regulation of body temperature.
  - Develop functionally-enriched gene networks to identify major drivers and pathways controlling thermal tolerance.

Acknowledgments

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- Phillip Clark
- Sheri Holmes

PhD position available
Genetics of thermotolerance/
Breeding climate-smart beef cattle
USDA-NIFA funded

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