Scaling of Livestock Heat Stress with Global Mean Surface Temperature Change

J.R. Buzan[1], M. Huber[2]

In the summer of 2015, the India heat wave killed 2500 people (Kopp et al., 2015). In May of that heat wave, an estimated 17 million chickens were culled. Trends in global heat stress show distinct regional scale variations. These variations are related to various local factors. But, nonetheless, we show that heat stress is robustly and fundamentally tied to the global mean surface temperature. Heat stress measures accounting for humidity are tied to maximum buoyancy of the atmosphere, and thus, quasi-equilibrium convection theory (Williams et al., 2009). In this study, we conducted Community Land Model version 4.5 simulations to calculate heat stress in future climate projections with Representative Concentration Pathway 8.5 greenhouse gas forcing. We used atmospheric output from CMIP5 to calculate extreme heat stress for two time slices, 2026-2045 and 2081-2100.

To map heat stress globally, high temporal frequency temperature, moisture, and pressure are inputs to calculate wet bulb temperatures (a theoretical perfect evaporator) and the Temperature Humidity Index (a USDA standard for livestock heat stress) using the HumanIndexMod (Buzan et al., 2015). We normalized the wet bulb temperatures and Temperature Humidity Index by global mean surface temperature change for each simulation. Thus our results show direct comparisons of the thermodynamics between different simulations.

Normalized wet bulb temperatures were similar in spatial pattern and magnitude between the CMIP5 simulations. The exception was for the Middle East, and a couple locations in the Central Asia. Additionally, the inter-model spread in wet bulb temperatures is smaller (less than ±2°C) as compared to air temperatures (greater than ±2°C). This is consistent with quasi-equilibrium convection theory. Maximum convection scales with the near ocean surface temperatures (which are at constant ~80% relative humidity), which are tightly linked to maximum wet bulb temperatures. Wet bulb temperatures are an input for the Temperature Humidity Index.

We found that the normalized Temperature Humidity Index values were similar in spatial pattern and magnitude between the CMIP5 simulations in the tropics (30°N to 30°S) except for in the Middle East. Like normalized wet bulb temperatures results, this is consistent with quasi-equilibrium theory. However, outside of the tropics, the spatial patterns and the magnitudes between simulations varied. Europe, China, and the southeastern United States have substantial differences between simulations. For example, the magnitude of the normalized Temperature Humidity Index in the southeastern United States varied between ~1.0-2.0 units. In northeastern China, the magnitudes varied between ~1.5-2.25 units.

However, in all cases, the change in Temperature Humidity Index scales linearly with global mean surface temperature changes, and was always increasing. This implies that countries with large stakes in livestock will have negative impacts to animal size, feed intake and productivity. These countries will need to improve infrastructure to protect livestock. These improvements may require switching to indoor environments, or changing from evaporative

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[1] Jonathon R. Buzan, Ph.D. candidate, Natural Resources and Earth System Science, University of New Hampshire, Durham, New Hampshire, USA; [2] Matthew Huber, Earth Systems Research Center, Institute for the Study of the Earth, Oceans, and Space, University of New Hampshire, Durham, New Hampshire, USA. Corresponding author: J.R. Buzan, email: jonathan.buzan@unh.edu.

cooling mechanisms (Gates et al., 1991) to air-conditioning based cooling.

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