Title: Linking digital twins to individual-based models to predict heat stress effects on dairy cattle

Team: UOS: Karin Frank, Frank Hilker
ATB: Thomas Amon, David Janke

Abstract:
Dairy production is crucial for food security but also under pressure from the ongoing climate change. Of particular severity is the projected increase of heat waves. Evidently, heat waves cause stress effects on cattle by altering its metabolism with implications for its milk production, fecundity, and emissions. Thus, it is crucial to predict future developments under scenarios of climate change, to causally understand the heat stress effects on the cattle, and to clarify what factors are determining its strength. A subsequent task is to identify critical extents of heat waves where the cattle's functions collapse, but also to find options of barf management which can reduce the heat stress on the cattle. There are excellent data available at the ATB on the relationship between various environmental factors and various cow-attributes. For predictions of future developments, however, the mechanisms underlying these relationships have to be fully understood.

Aim of the project is to develop innovative methods for linking an ATB Digital Twin (DigiMuh) on the cattle-environment-relationship with so-called individual-based models (IBM) of the next generation and important concepts from disturbance / resilience theory. 'Next-generation IBMs' (expertise of UOS) relate all individual-level processes to 'first physiological principles' (esp. thermodynamics, dynamic energy budget theory; expertise of ATB and UOS). This will enable simulating the cattle's stress response to heat waves in a mechanistically sound way, improving causal understanding of the cattle-environment-relationships from the DT, and predicting implications of scenarios of future climate change and barf management. The project can also be seen as case study for linking process-based models with digital twins in a way that the workflows are rooted in system theories, help understanding causalities and tackling pressing needs from a changing world.

Desired skills of the applicant:

- Background: applied systems sciences, computational ecology, mathematics, or similar
- Experience with process-based models (ideally ecological models) and complex data analysis
- Excellent programming skills
- Interest in model-data-integration, workflows for linking simulation models to digital twins
- Interest in predicting and tackling challenges to bioeconomy under climate change.

References:

Chimienti, M, Desforges JP, Beumer, LT, Nabe-Nielsen, J, van Beest, FM, Schmidt, NM (2020). Energetics as common currency for integrating high resolution activity patterns into dynamic energy budget-individual based models*, Ecological Modelling* 434: 109250.

Bogdanowski A, Banitz T, Muhsal LK, Kost C, Frank K (2022) McComedy: A user-friendly tool for next-generation individual-based modeling of microbial consumer-resource systems. PLoS Comput Biol 18(1): e1009777.

Foroushani, S, Amon, T (2022) Thermodynamic assessment of heat stress in dairy cattle: lessons from human biometeorology. *Int J Biometeorol* 66: 1811–1827.

Grimm V, Berger U (2016). Structural realism, emergence, and predictions in next-generation ecological modelling: synthesis from a special issue. *Ecological Modelling* 326: 177–87.

Schlüter, M, Müller, B, Frank, K (2019). The potential of models and modeling for social-ecological systems research: the reference frame ModSES. *Ecology and Society* 24(1):31.