Livestock-environment-interaction in naturally ventilated housing on the example of ammonia

Sabrina Hempel, Huyen Vu, Moustapha Doumbia, Qianying Yi, David Janke, Thomas Amon

Goal: We use fluid dynamics and reaction-kinetics modelling to better understand the complex interaction between outdoor climate, indoor microclimate and the emission source strength and gas dilution of naturally ventilated livestock housing. This basic understanding will be further used to improve the prediction of emission values, to optimize monitoring systems and to identify and evaluate emission mitigation potentials.

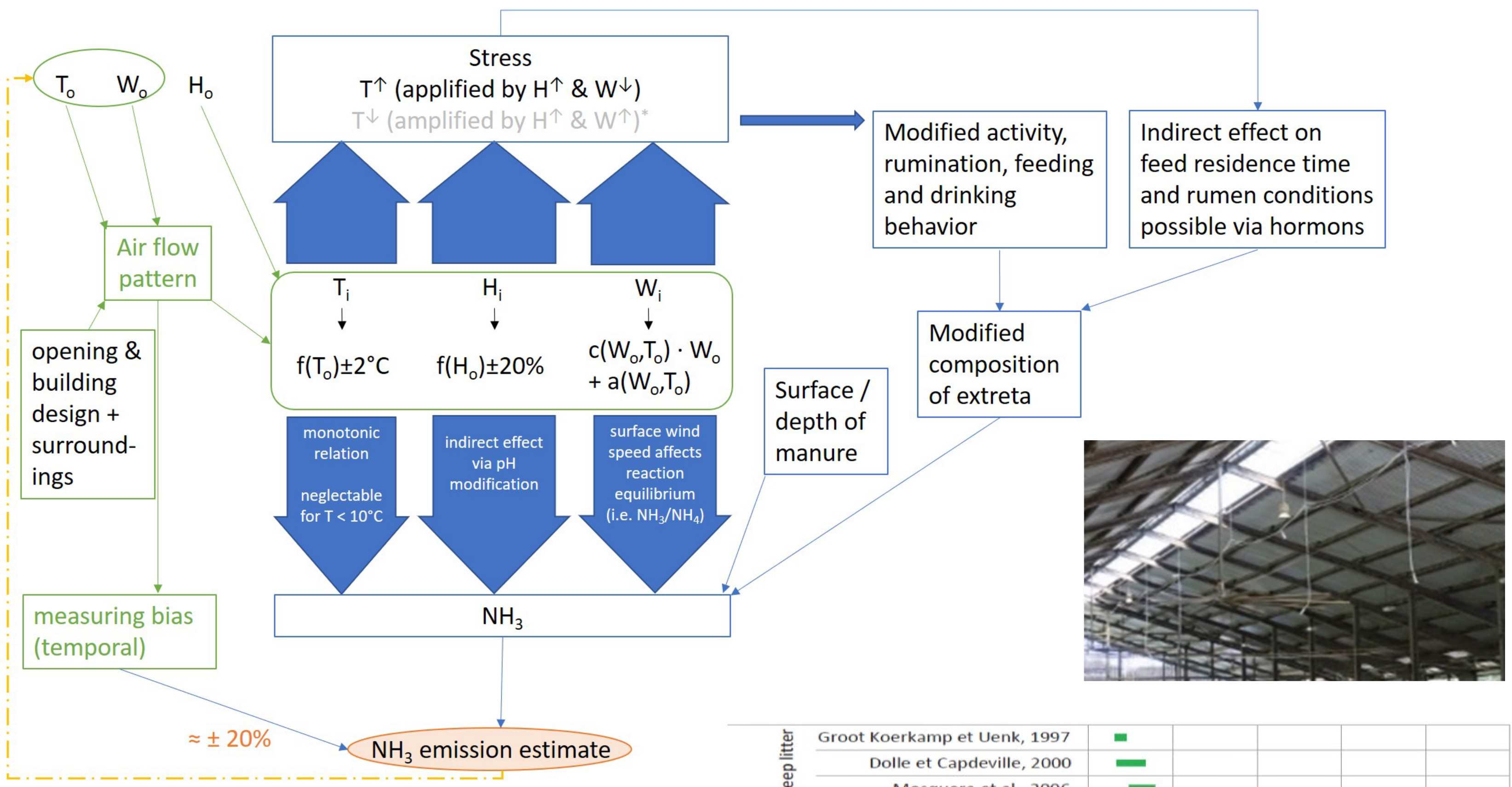
Relevance

More than 90% of emitted ammonia is associated with agriculture (about half of related to livestock husbandry, particularly cattle & pig housing). Without adapting the husbandry system several thousand tons of ammonia are expected to be additionally released from livestock husbandry as a consequence of climate change at the end of the century.

Ammonia emission causes large nitrogen entries into soils, water and vegetation leading to eutrophication and acidification.

The potential chemical reaction products of the short living ammonia affect the climate system and are a threat to the health of animals and humans. For example, ammonia is a significant source of indirect emissions of nitrous oxide and a source of the secondary inorganic aerosols (SIA) ammonium sulfate and ammonium nitrate which occur as particulate matter in the atmosphere.

Uncertainty



There are large differences in the emission rate between individual farms, which are not well understood so far. One of the reasons is the complex interaction between outdoor climate, indoor microclimate and the emission source strength and gas dilution.

Sampling strategy, preprocessing and data aggregation and calculation aproach considerably effect the estimated emission value. Currently available standards are insufficient to avoid this.

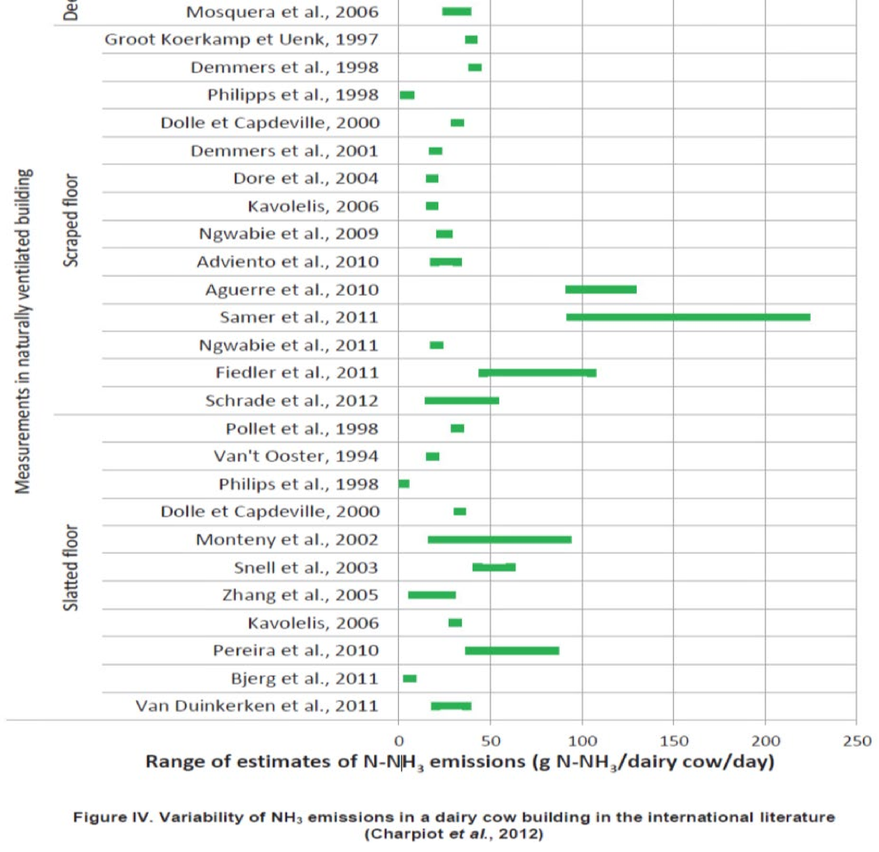
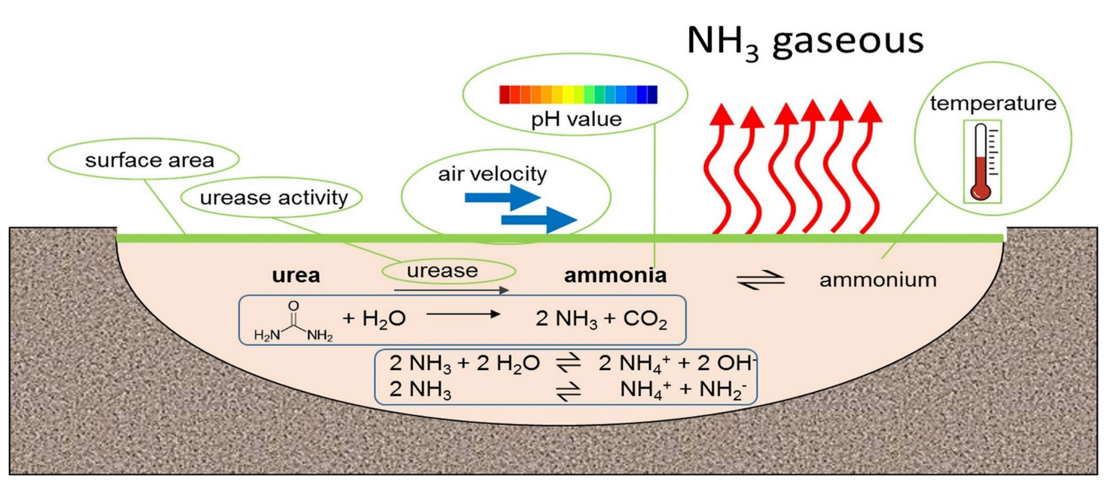
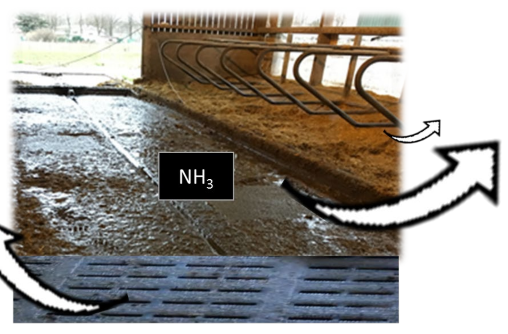


Figure IV. Variability of NH_3 emissions in a dairy cow building in the international literature (Charpiot et al., 2012)

Reaction-kinetics modeling

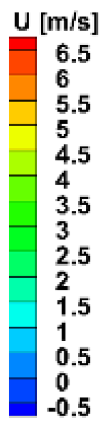


$$E = \frac{k * A * [C] * f}{H}$$

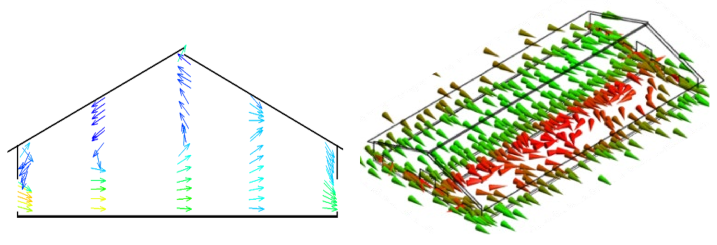


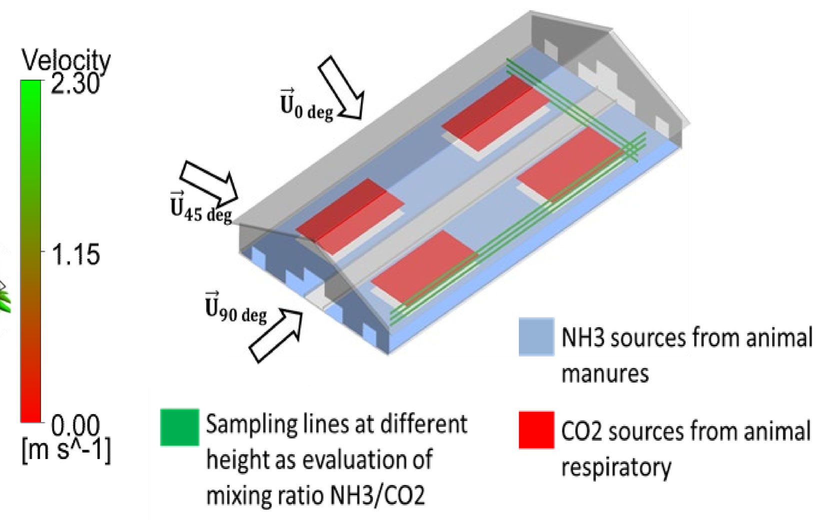
Emission source strength depends on TAN concentration ([C]), surface area (A) and three „constrants“ that depend on fluid temperature and pH as well as on surface wind speed. Change of TAN concentration over time system of two differential equations.

Fluid dynamics modeling (CFD & wind tunnel)

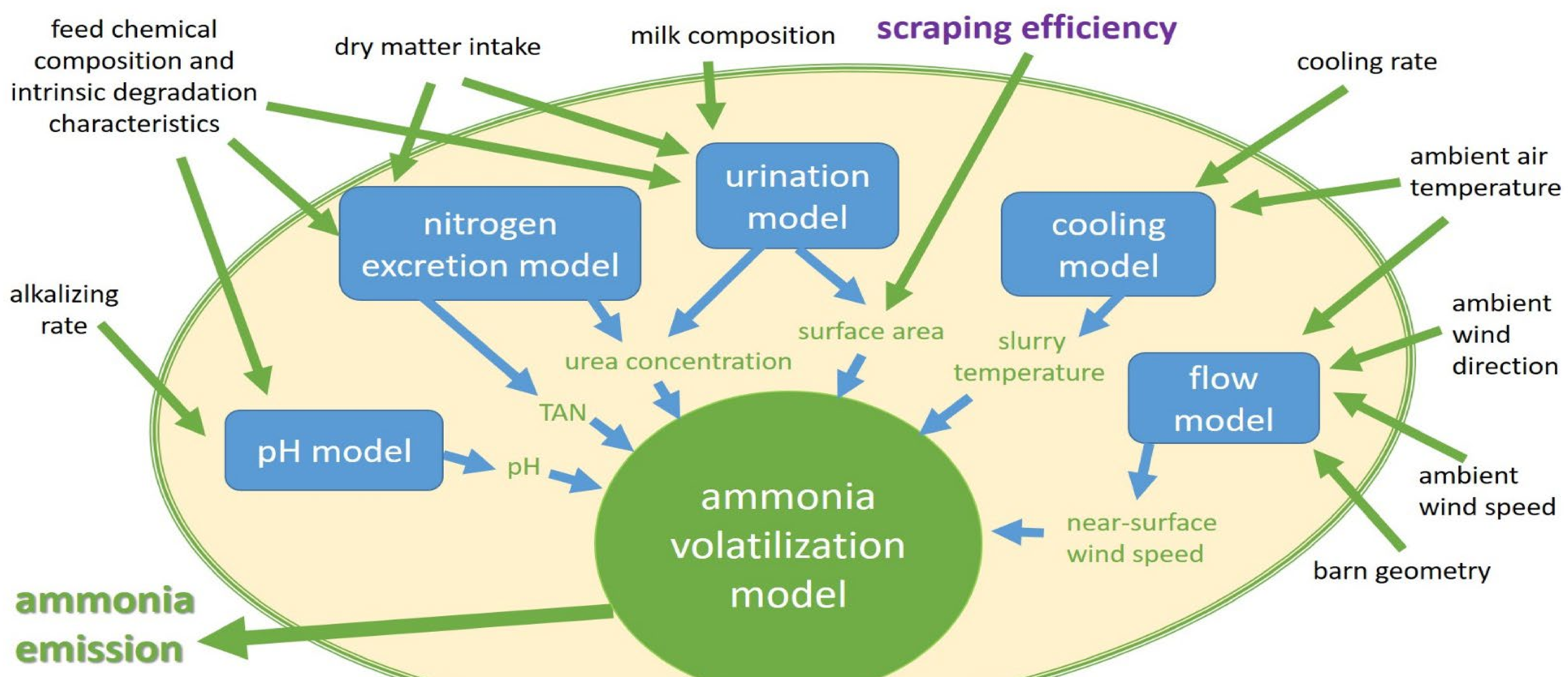


Raynolds-averaged Navier-Stokes (RANS) simulations validated with boundary layer wind tunnel

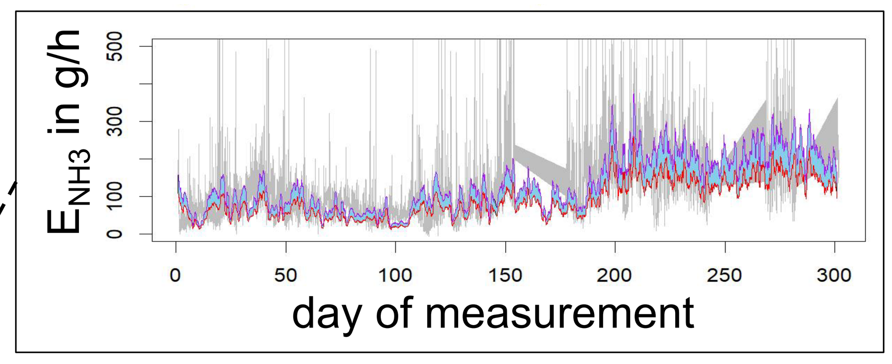


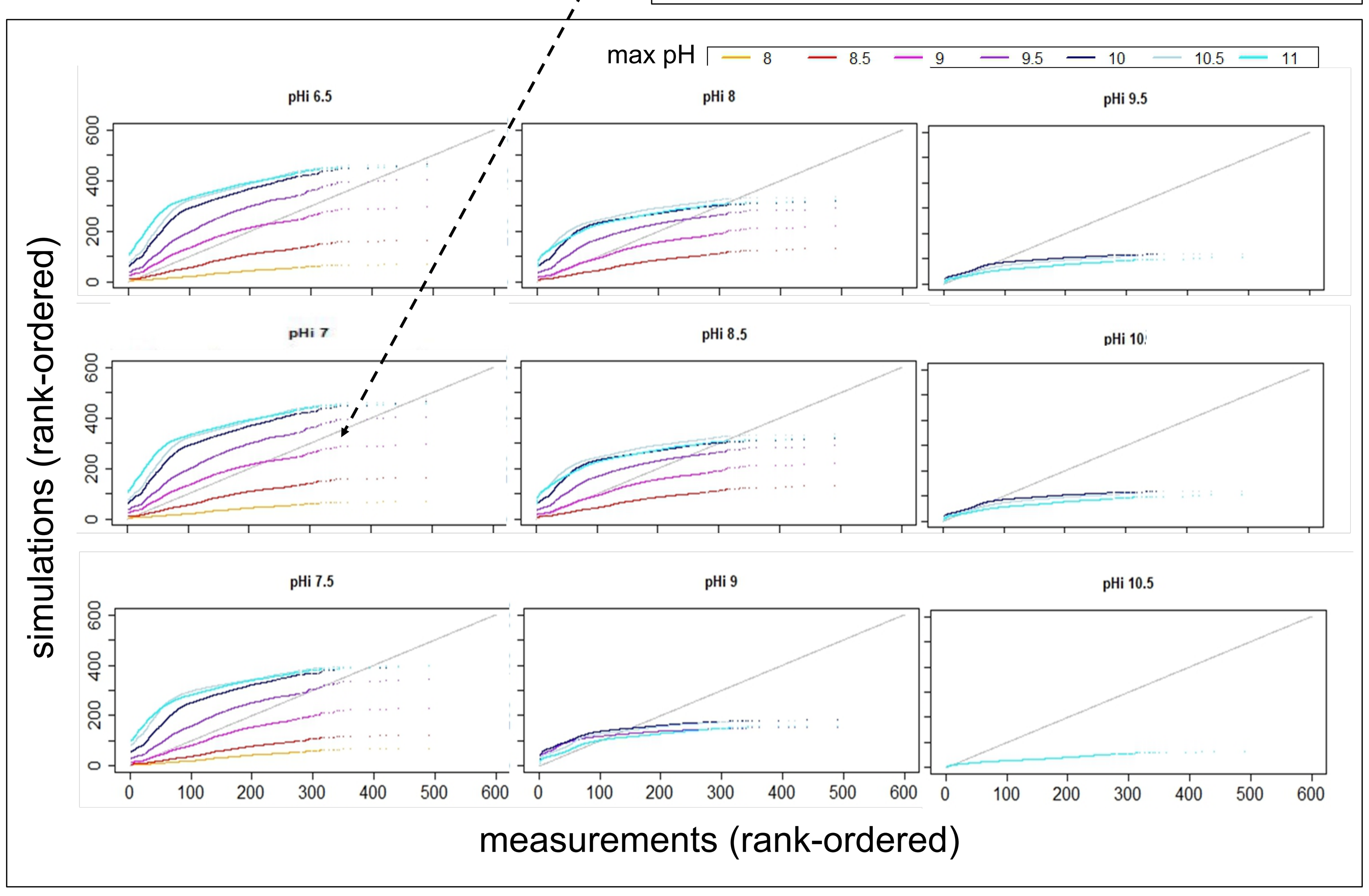


Model coupling



Compartment specific downscaling of wind speed using CFD improved the correlation between model and measurements from 0.5 to 0.6





The dynamics of the pH (interacting with ambient temperature) have a non-linear impact on the emission dynamics, which is not well understood & hard to measure.

Conclusion: There is a great potential of coupling (semi-)mechanistic modelling approaches to project ammonia emission dynamics of livestock housing using easy accessible input data. The deviations between our modelled and the measured long-term average emission value were in the same order of magnitude as the deviation between the emission values obtained by the different approaches of gas concentration balancing. The uncertainty of model predictions was comparable to the uncertainty of projections obtained from regressions based on intermittent measurements. Further model refinement, more dynamic coupling between the modules and adding specific modules that mimic the spatial and temporal variability of the input data are expected to further improve the overall model performance on the shorter time scales.

Leibniz Institute for Agricultural Engineering and Bioeconomy
Max-Eyth-Allee 100 | 14469 Potsdam | Germany | atb@atb-potsdam.de | www.atb-potsdam.de

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