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Institut für Tier- und Umwelthygiene

Through-flow patterns in naturally ventilated dairy barns

3 methods - 1 complex approach

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EAAP Annual Meeting 2015 - session 30
Warsaw, 2nd September 2015

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Outline

- Motivation
- 3-column-approach
- Validation results
- Conclusion

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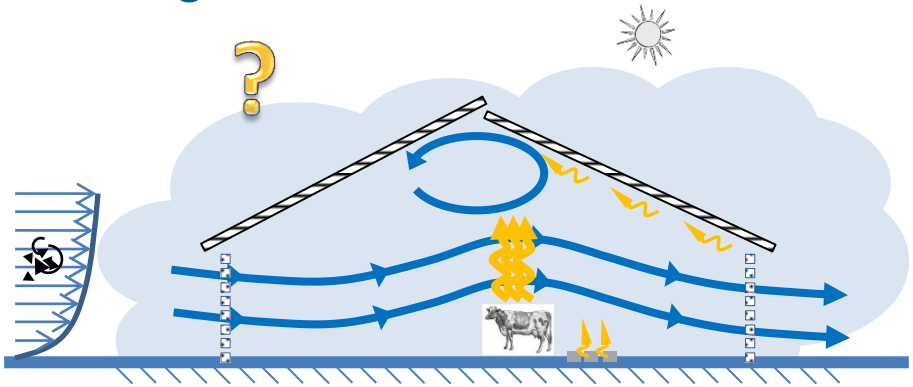
Motivation

- Sustainable, eco- and animal-friendly and resource-efficient livestock farming
  - Predict air flow pattern
  - Quantify transport of pollutants, humidity and heat
  - Determine air exchange and emission rates



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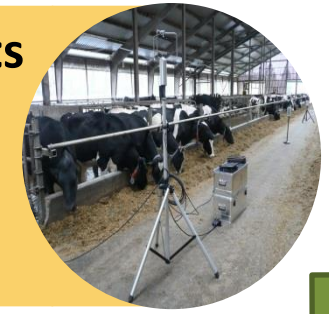
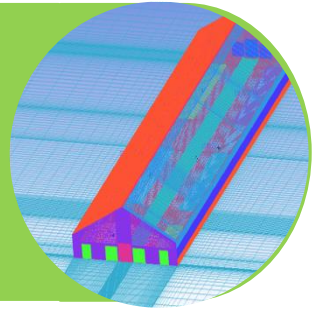
The 3 column approach

Field measurements
Complex on-farm data; limited temporal and spatial resolution



Wind tunnel
controlled boundary conditions; full 3D resolution; many repetitions possible

Numeric simulation
controlled boundary conditions; high level of abstraction; high resolution possible



→ **Mutual validation of methods needed!!!**

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Field measurements

→ adjustable curtains in the sidewalls and space boards and doors in the gable walls

- Long-term air velocity, temperature, humidity and gas measurements (sensors in ~2.7m)

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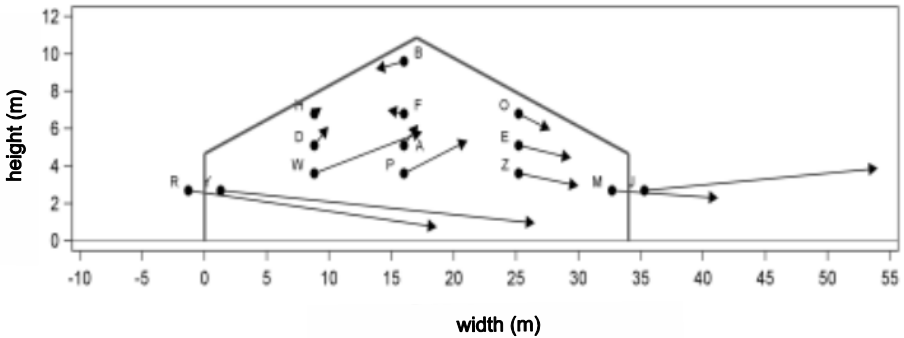
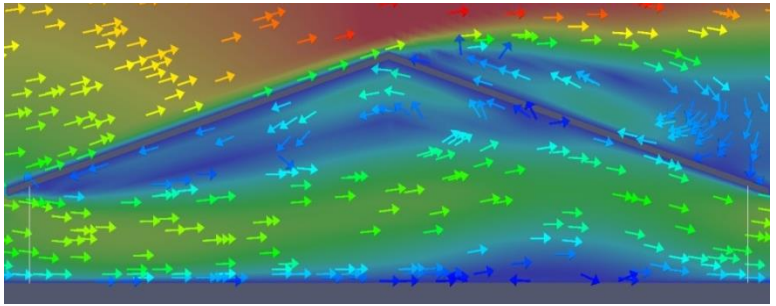
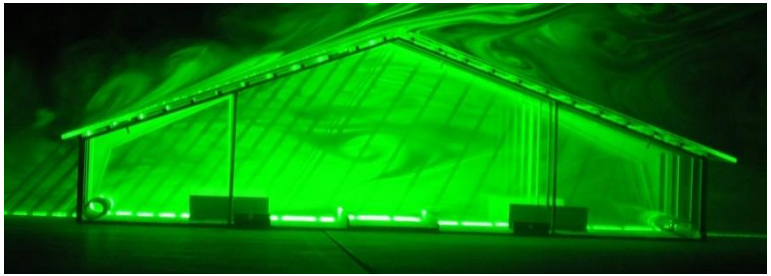
Air flow pattern





- meandering flow
  (low air flow in the back half)
- vortex under the roof
  (recirculation in the upper half)
- Almost no interaction between upper and lower air volume



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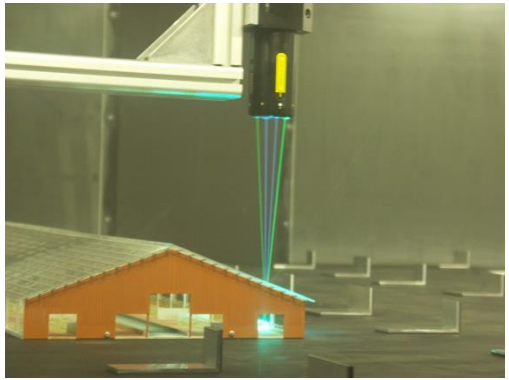
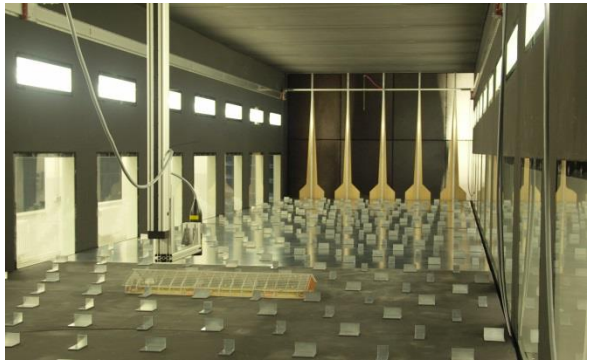
Wind tunnel

2D Laser Doppler anemoneter (LDA)





laser light section

- Boundary layer wind tunnel (20m x 3m x 2.3m)
  - **model turbulent inflow with roughness elements**
  - **measure flow through the scale model (1:100)**

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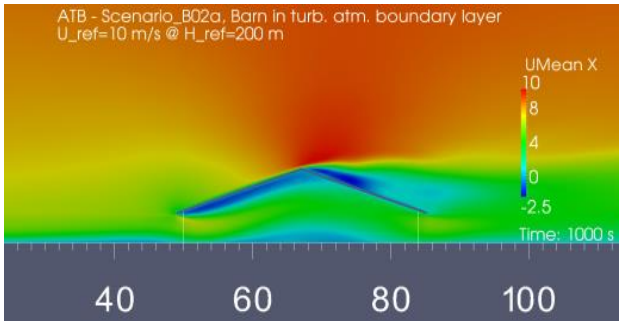
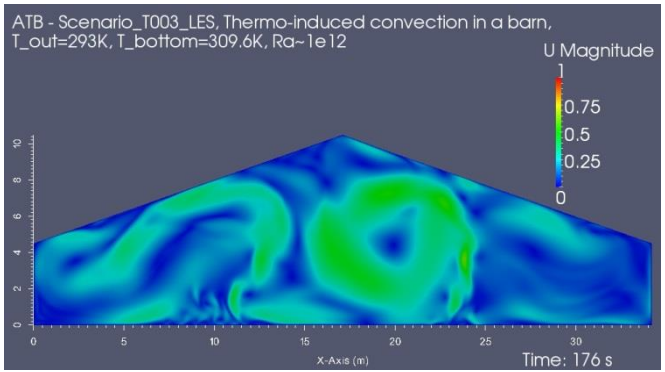
Numeric Simulation

Tools

- Open Source - Open FOAM
- Commercial - ANSYS

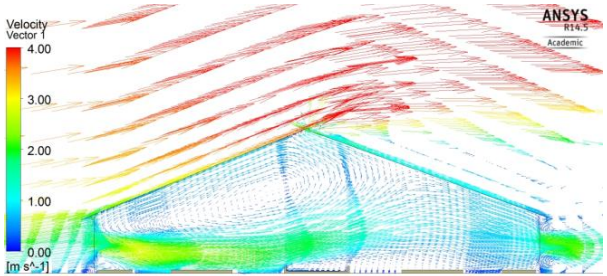


LES vs RANS



Modeling includes

- Barn geometries
- Turbulent inflow
- Heat sources



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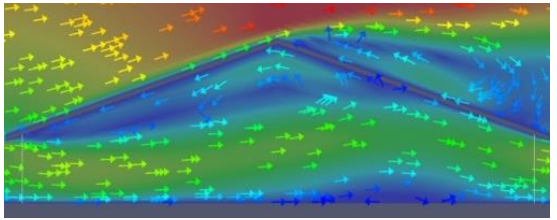
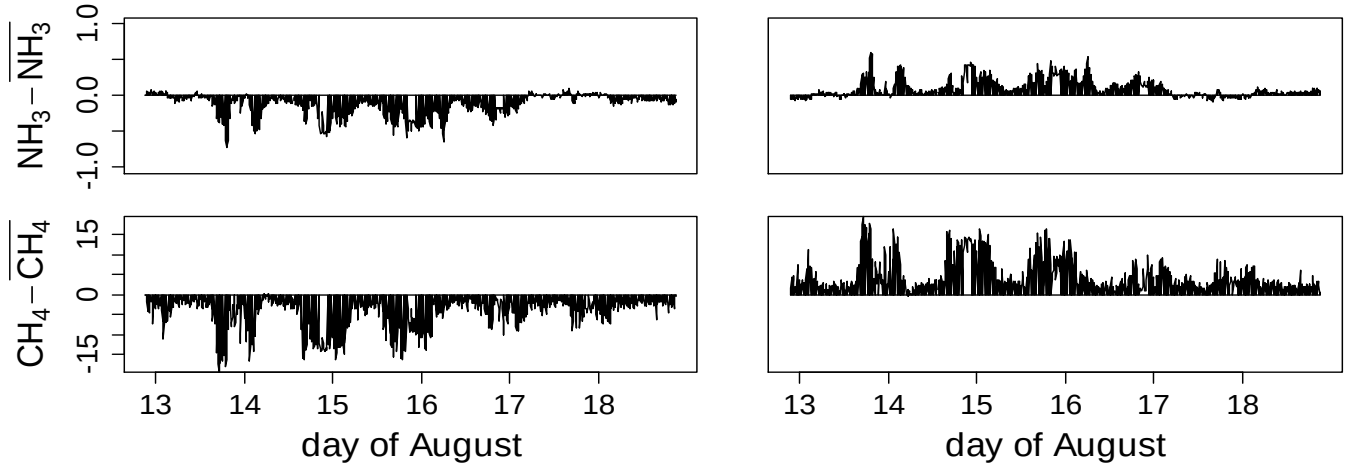
Gas distribution

- Gas emission in the lower back part persist (concentration typically higher than the overall spatial average)





- Air exchange rate is determined by lower front air volume

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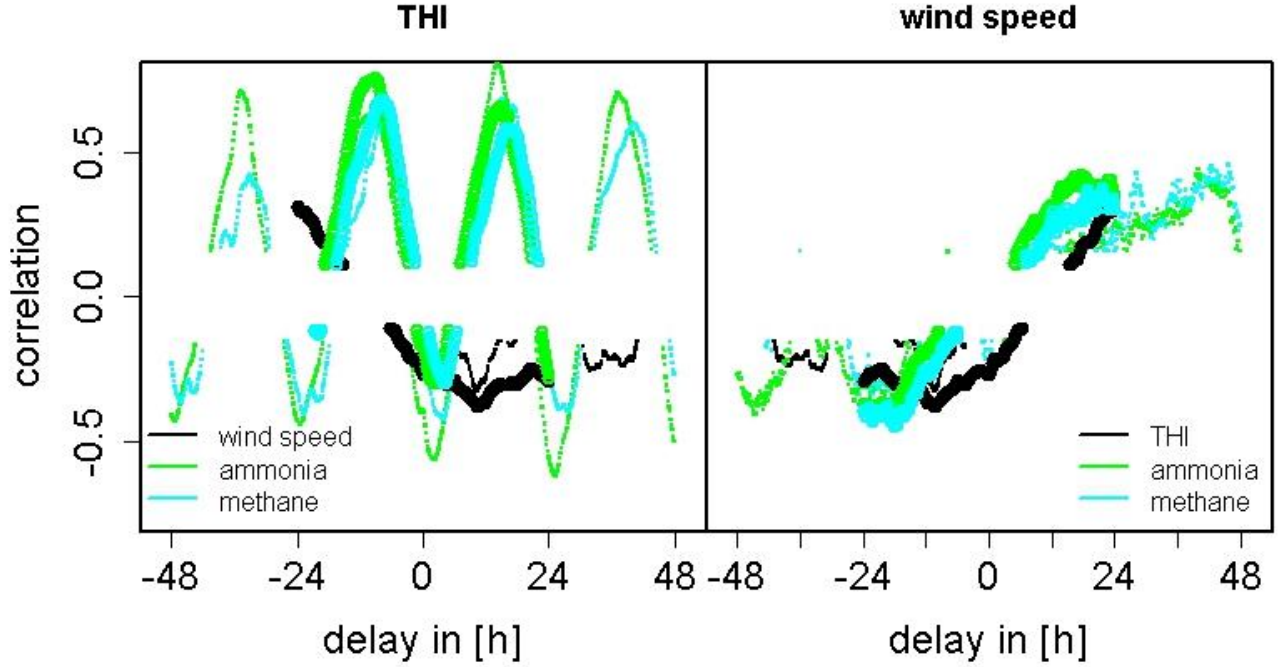
Correlation

- Correlation between outdoor and indoor variables maximal for about 12 h delay



- Related to inherent frequencies in THI and gas concentrations ?
- Not yet implemented in the models

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Conclusion

- Developing region-specific, optimal solutions for livestock farming requires deep understanding of trough-flow patterns

- Combining multiple approaches yields maximal information output
  - Modeling → high resolved data and defined boundary conditions
  - Field measurements → complex interactions → Validation of models

- "Measurement - Model /Simulation - Validation" can support advandements
  → improved animal welfare
  → adaptation to climate change
  → emission reduction

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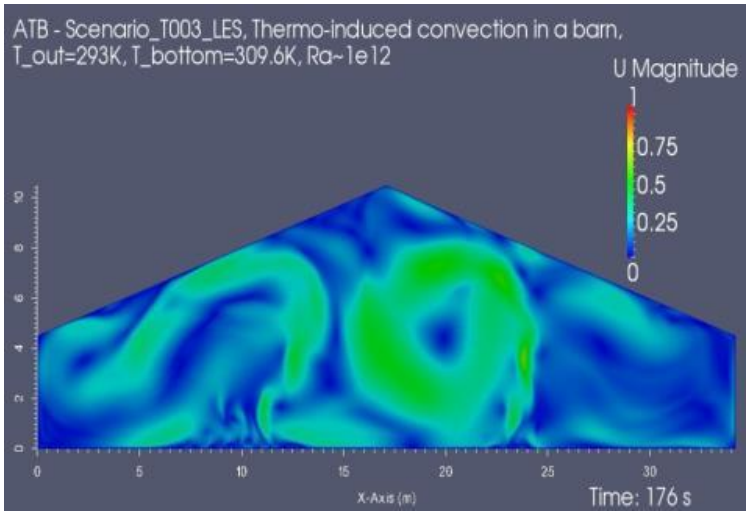

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