ATB
Leibniz-Institut für Agrartechnik
Potsdam-Bornim e.V.

OptiBarn

Air flow patterns and gas concentration distribution in naturally ventilated barns – results from field measurements and CFD simulations

Marcel Koenig, David Janke, Sabrina Hempel, Chayan Saha,
Merike Fiedler, Werner Berg, Thomas Amon

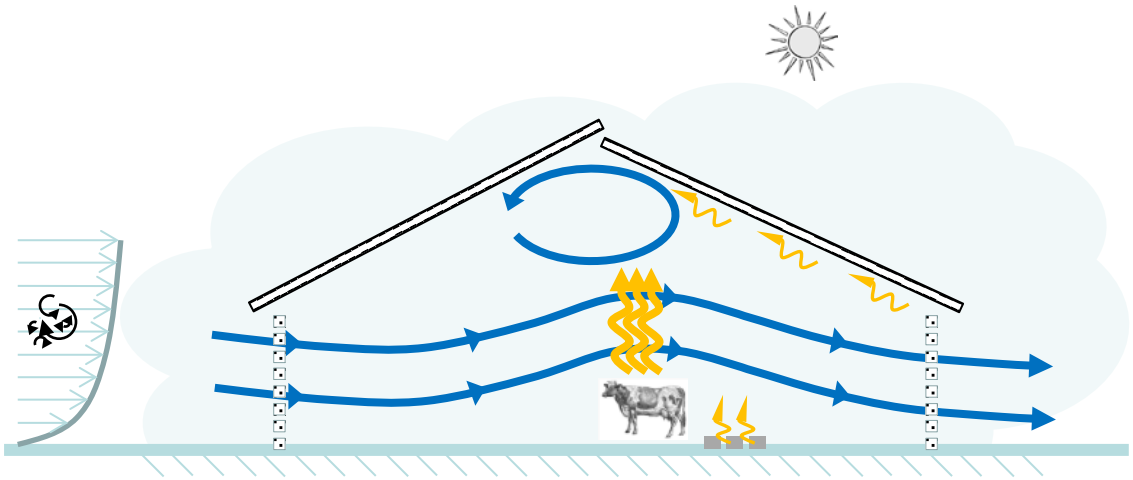
Leibniz
Leibniz-Gemeinschaft

Outline

- Motivation
- Air flow measurements
- Air exchange simulation
- CO_2-balance

Motivation

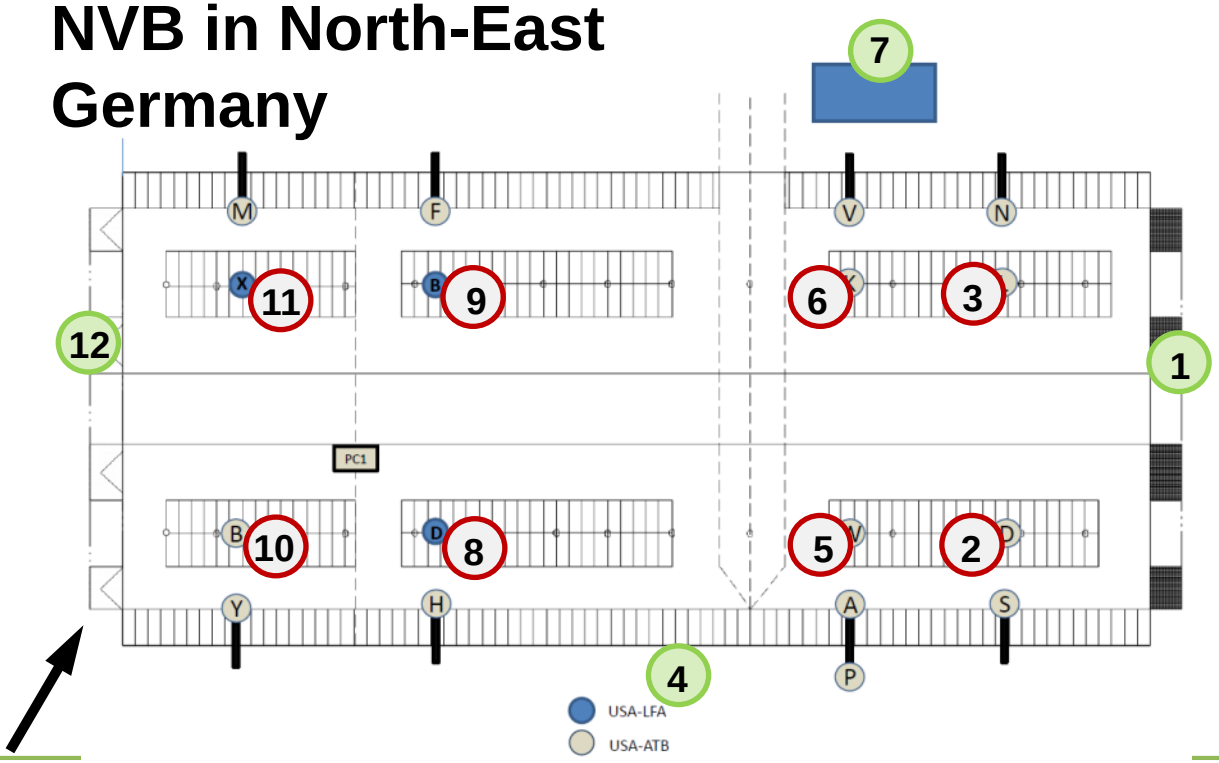
- Air flow through naturally ventilated barns (NVB) links outdoor environment and buildings microclimate
- Varying climate conditions affect transport of excess heat, moisture and pollutant gases



- <u>Challenge:</u> Quantification of air exchange and prediction of indoor climate parameter distribution
- <u>Problem:</u> Large spatial and temporal variability

Methods: On-farm measurements

NVB in North-East Germany



High-resolution data

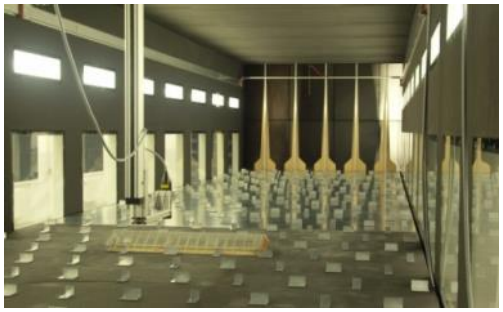
- 14 (+3) USA
- 12 FTIR

suction points

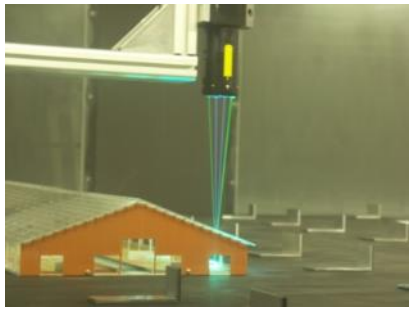
(8 inside, 4 outside)

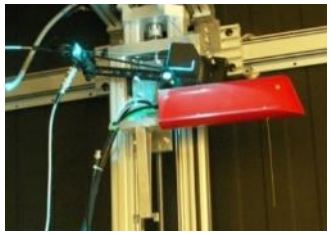
Methods: Boundary layer wind tunnel

- Wind tunnel 20m x 3m x 2.3 m
- Scale model of the barn and surroundings 1:100

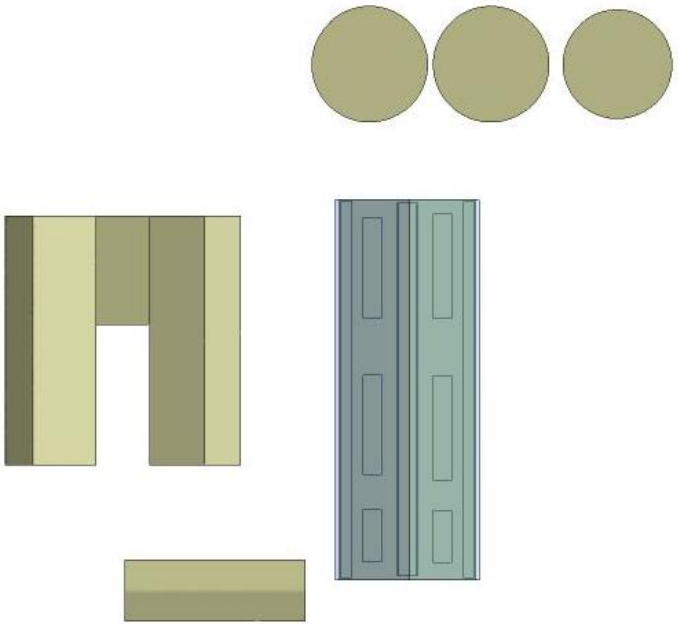


- LASER-light-section (flow visualisation)
- 2D LDA and fast-FID (quantitative measurements)





Methods: Computational Fluid Dynamics (CFD)



- Boundary conditions: velocity inlet, presure outlet and walls

ANSYS 14.5

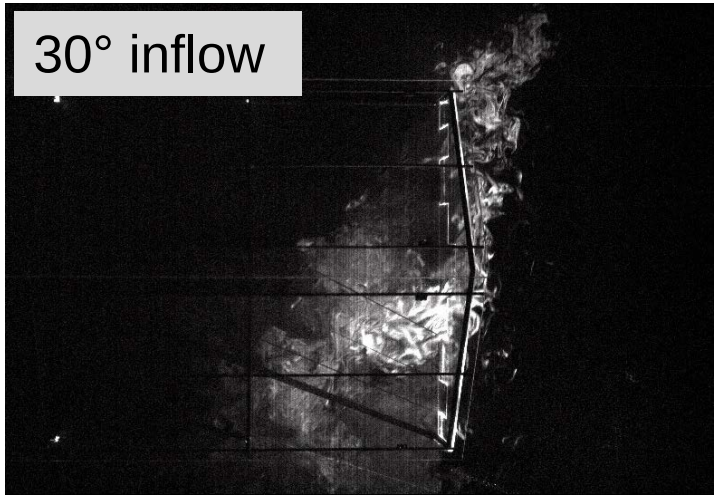
- Raynolds-averaged Navier-Stokes [RANS] approach with standard kinetic energy (k) dissipation (μ) model for turbulence parametrisation

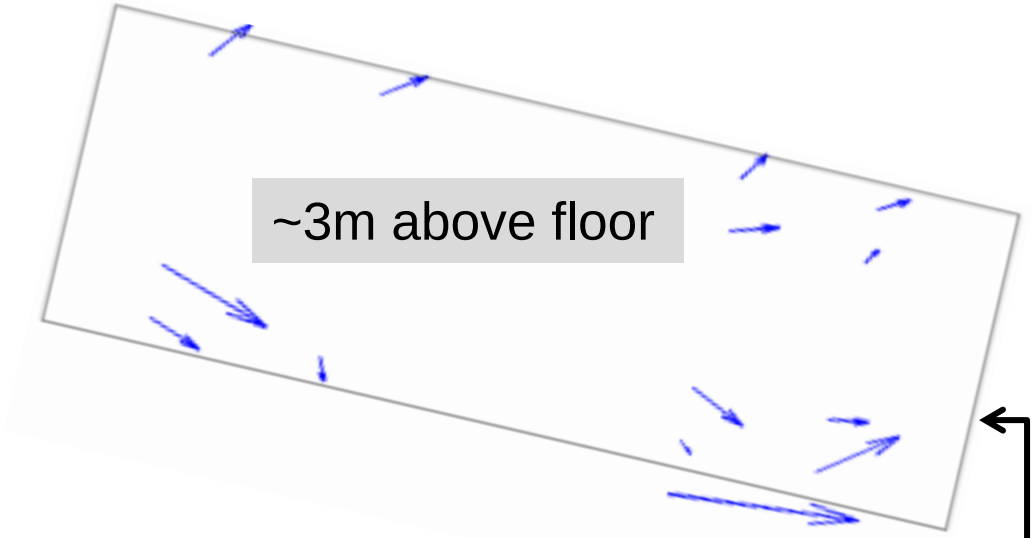
OpenFoam 2.3.0

- Large Eddy Simulation [LES] with eddy viscosity model for the subgrid-scales

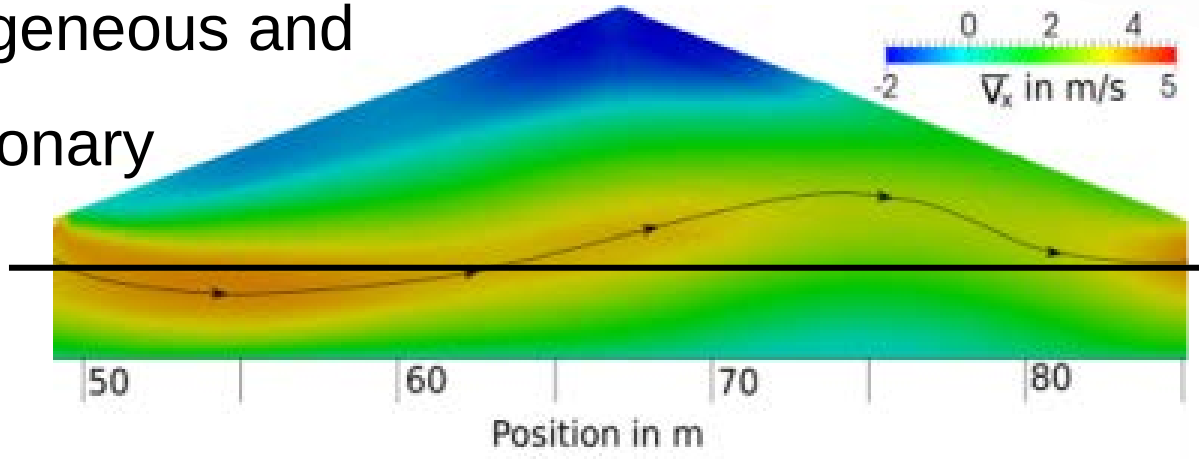
Preliminary results: Air flow pattern

- typical patterns for selected meteorological boundary conditions



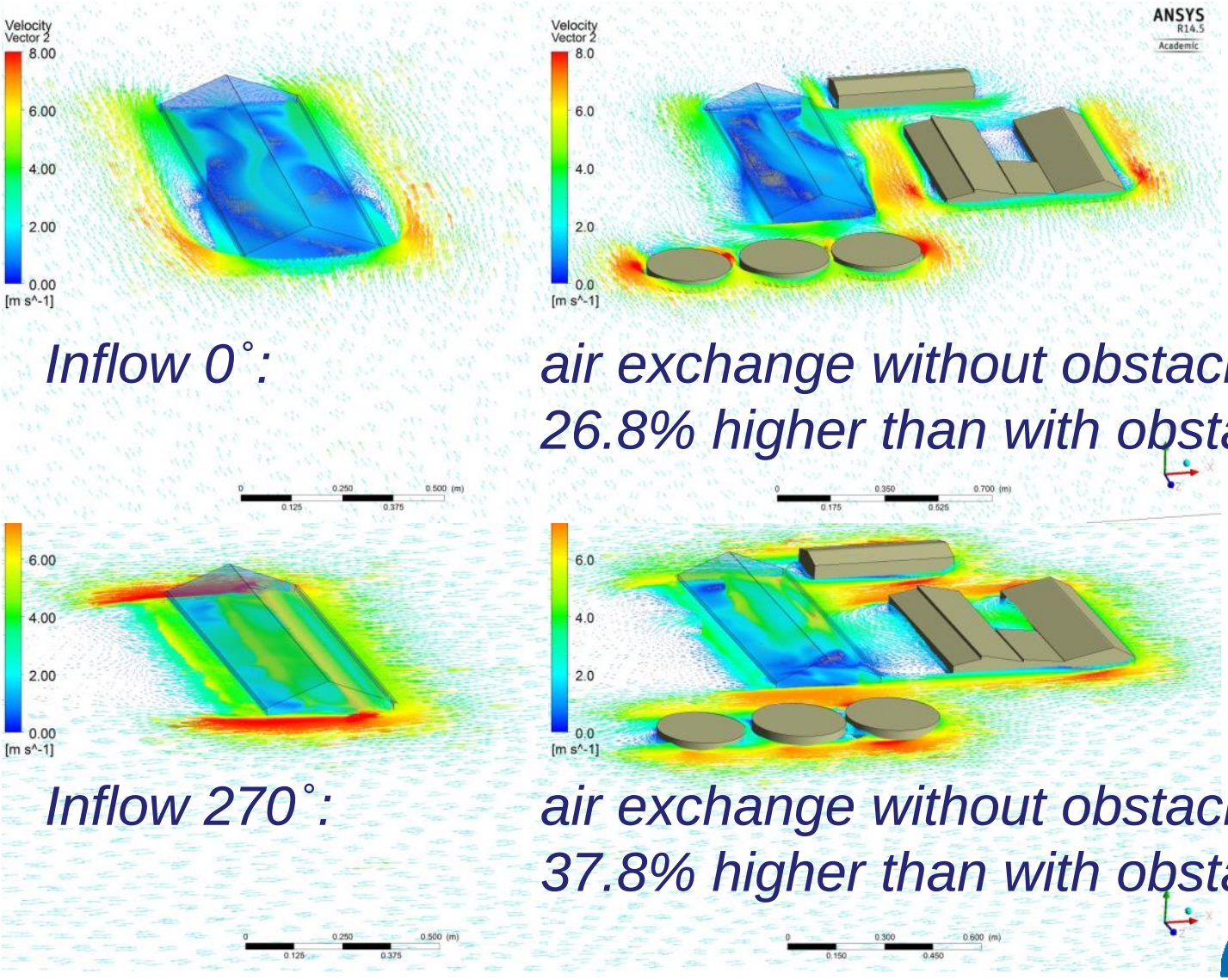


- Inhomogeneous and nonstationary flow



Preliminary results: Air exchange (CFD)

” AER d77% depending on inflow angle



Inflow 0˚:

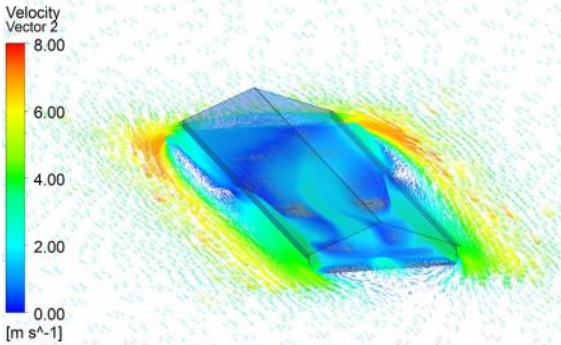
air exchange without obstacles
26.8% higher than with obstacles

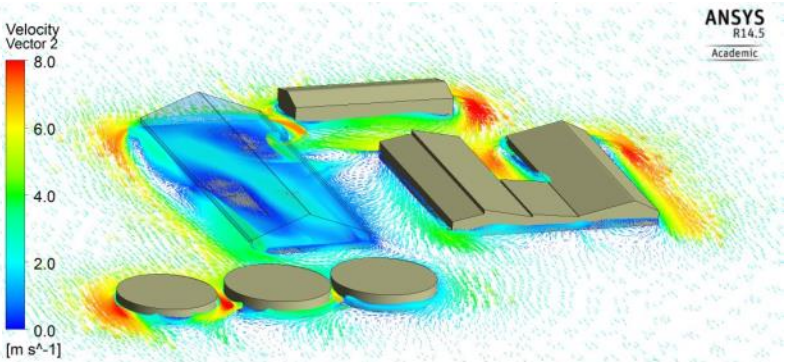
Inflow 270˚:

air exchange without obstacles
37.8% higher than with obstacles

Preliminary results: Air exchange (CFD)

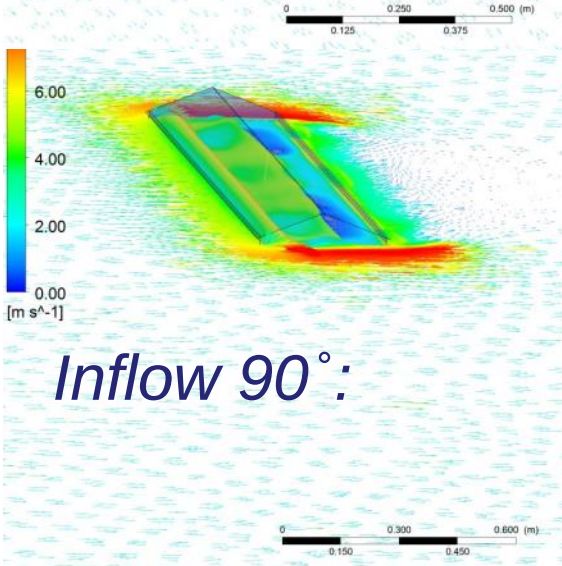
” AER d77% depending on inflow angle

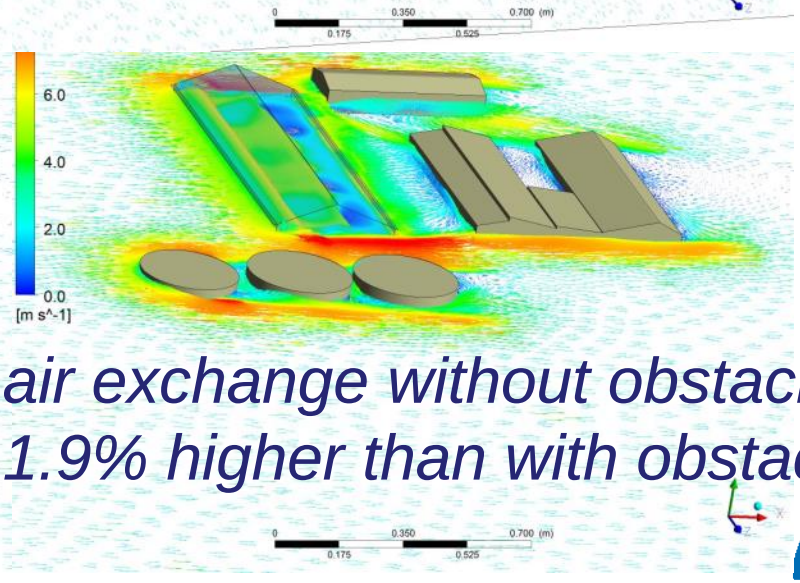




Inflow 180˚:

air exchange without obstacles
14.9% higher than with obstacles

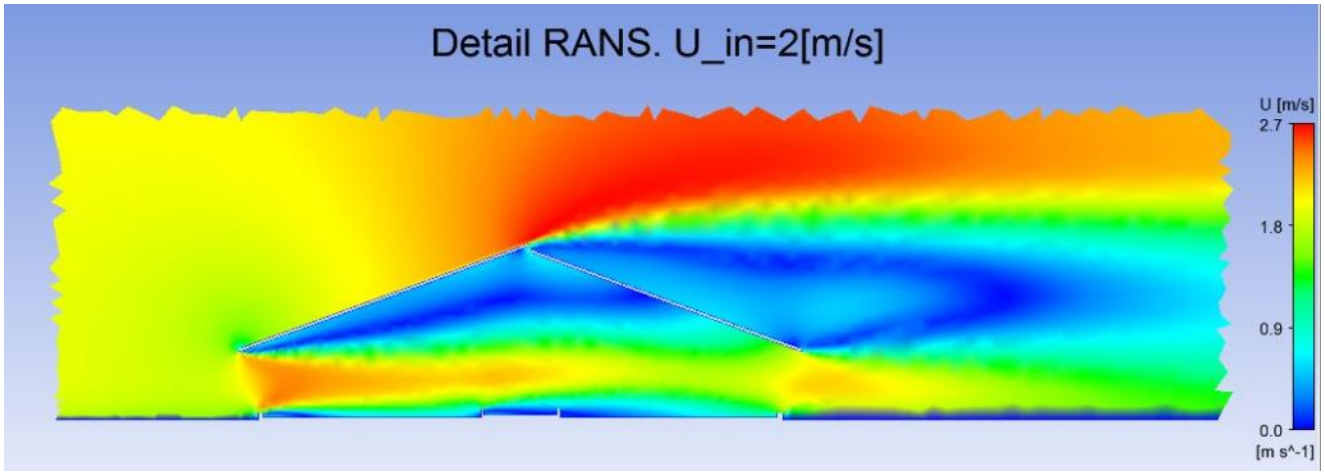




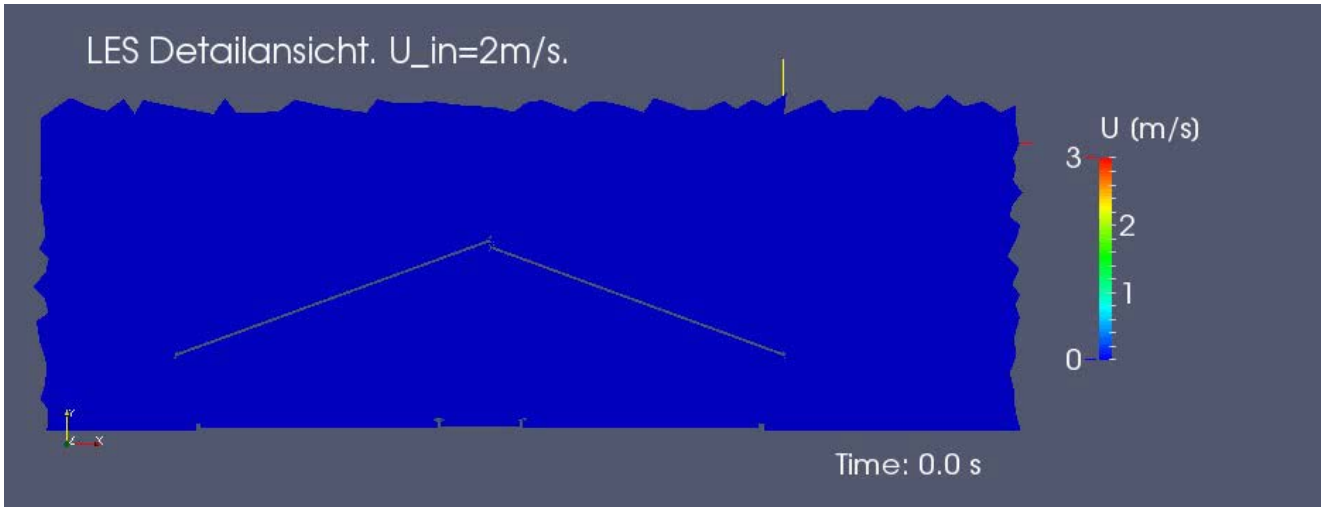
Inflow 90˚:

air exchange without obstacles
1.9% higher than with obstacles

Preliminary results: Time dependence



Steady-state Reynolds-average Navier-Stokes (RANS)

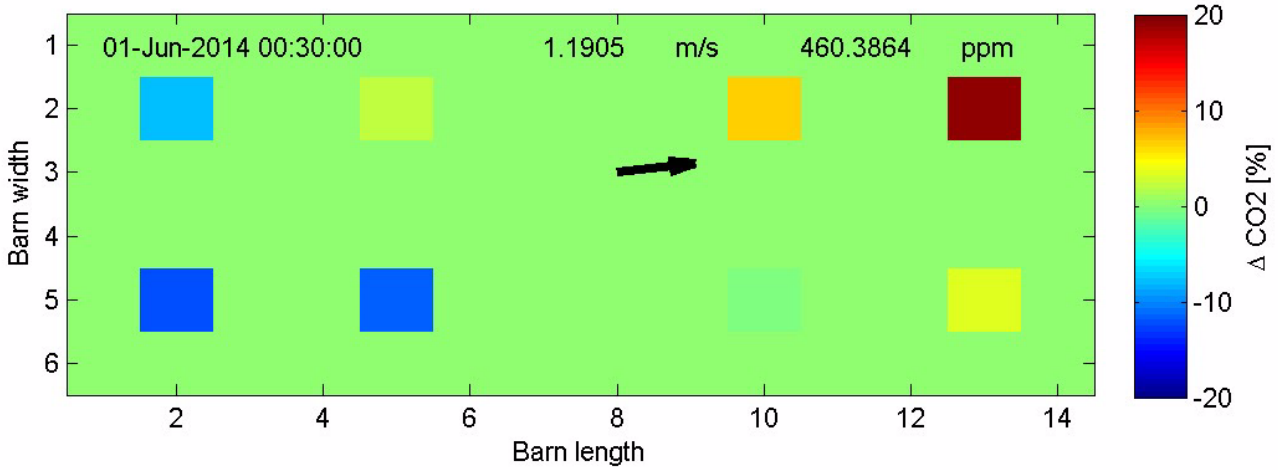


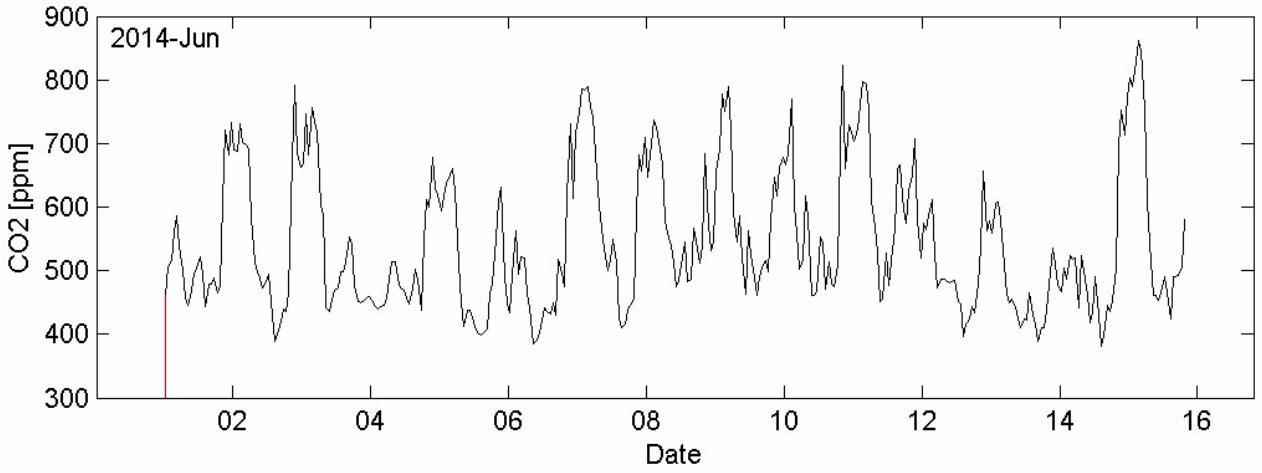
VERSUS

Unsteady Large Eddy Simulation (LES)

→unsteady behaviour affects estimated air exchange

Preliminary results: CO_2 indoor distribution





Large spatial deviations in wind speed lead to high fluctuating gas concentrations

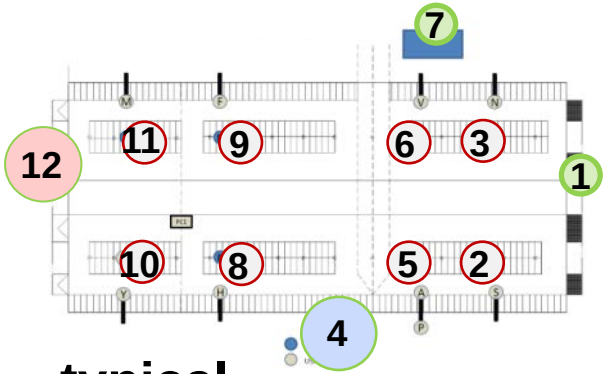
Preliminary results: CO_2 background for balance

Outdoor concentration	Available daily values	Average air exchange [h^{-1}]	Mean total error [h^{-1}]
„Gold“ – Min.	148	25.8	
MP 4	141	26.2	0.9
MP 12	96	30.2	6.1

„Gold Standard“ (outdoor minimum)

best choice: MP 4

worst choice: MP 12



typical inflow direction

Conclusion

- 3-columns to significantly improve knowledge of the emission source „dairy barn“
  - Field measurements: long-term on-farm data for model validation, assessment of emission rates
  - Modelling: study influence of boundary conditions, high-resolution data

    → physical modelling (boundary layer wind tunnel) and numerical simulations (focus on LES)