First DairyCare conference: **Health and Welfare of Dairy Animals**,
Copenhagen August 22nd and 23rd 2014

Improving ventilation efficiency in dairy cattle buildings using computational fluid dynamic tools

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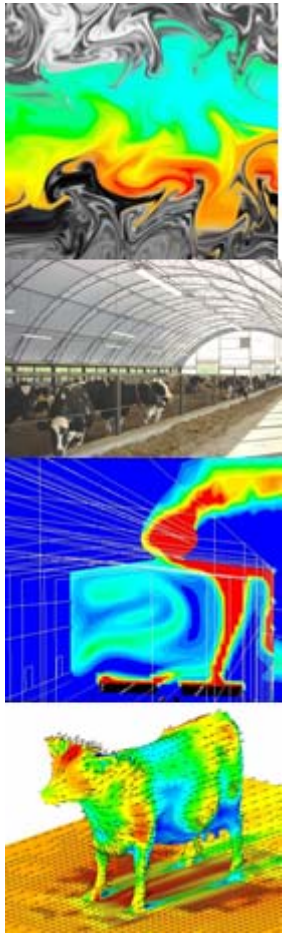
Efficient ventilated dairy cattle buildings

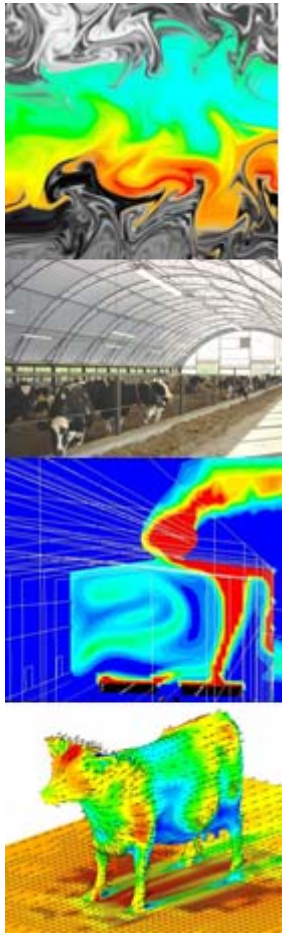


An efficient ventilation systems is crucial for:

- ✓ Remove excess heat
- ✓ Remove excess water vapour
- ✓ Remove microorganisms, dust and GHG
- ✓ Provide a uniform distribution of air
- ✓ Provide correct air speed for stock
- ✓ Improve welfare of animals

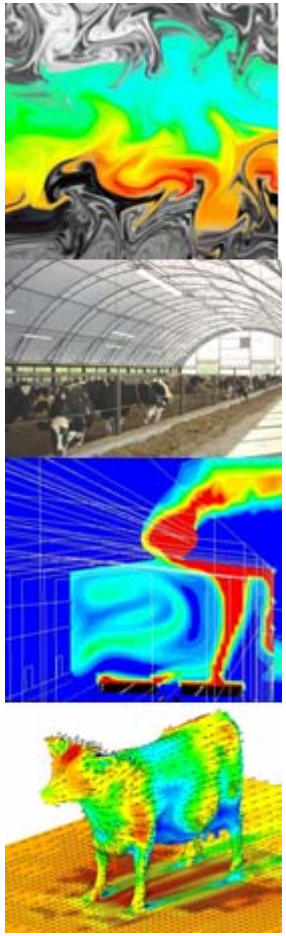
Natural ventilation is the least troublesome, most efficient and least expensive system for providing an optimum environment within a building

Efficient ventilated dairy cattle buildings



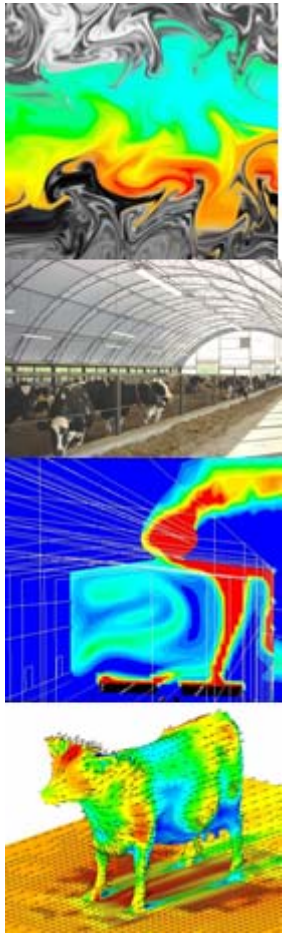
- ✓ In naturally ventilated buildings, the indoor environment is directly influenced by the outdoor wind speed and direction, as well as its turbulent nature
- ✓ Experimentally it is very difficult to analyse airflow and associated microclimate patters and GHG emissions (expensive equipment, time consuming, unstable ambient conditions, improper air mixing) in large ventilated buildings.
- ✓ However, it can be assessed using modelling techniques such computational fluid dynamics (CFD).

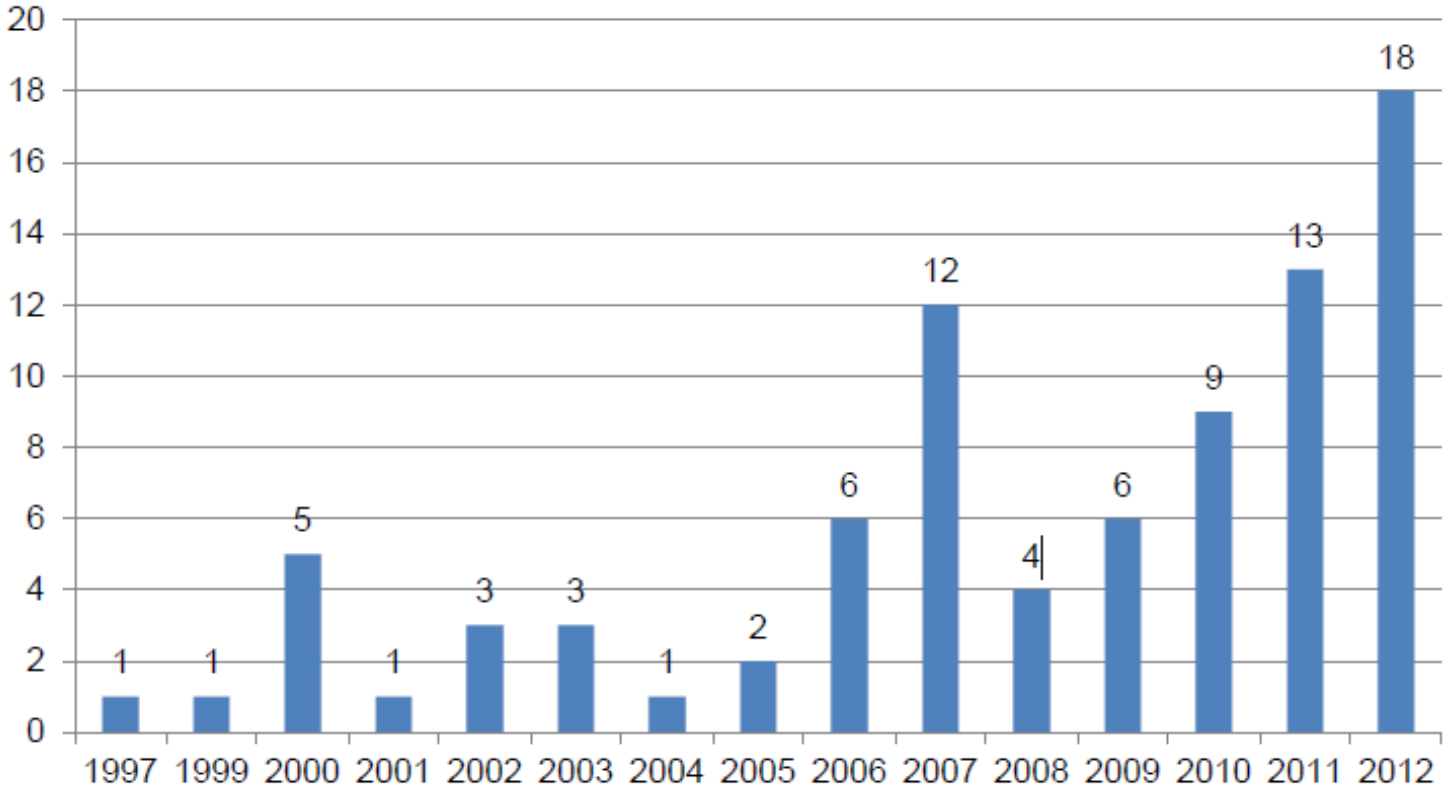
Computational Fluid Dynamics - CFD



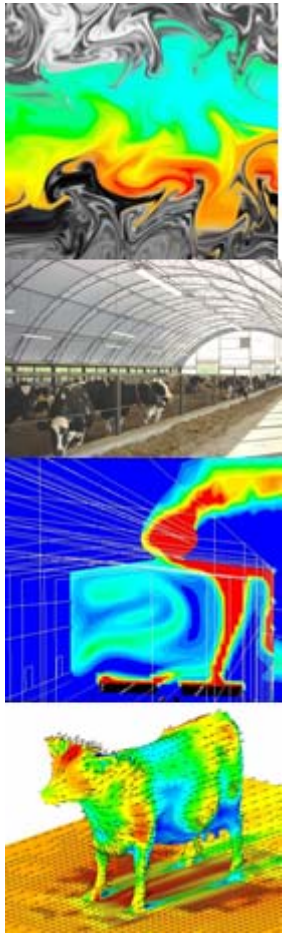
- ✓ Computational Fluid Dynamics is a simulation technique that can efficiently develop both spatial and temporal field solutions of fluid pressure, temperature and velocity, and has proven its effectiveness in system design and optimization within the chemical, aerospace, and hydrodynamic industries.
- ✓ In the CFD model actual weather conditions and structural specifications can be simulated and changed easily while maintaining stable and identical boundary conditions
- ✓ In the ventilation of buildings, engineers have turned to CFD to model airflow processes and accomplish comprehensive system evaluation and design

Published papers



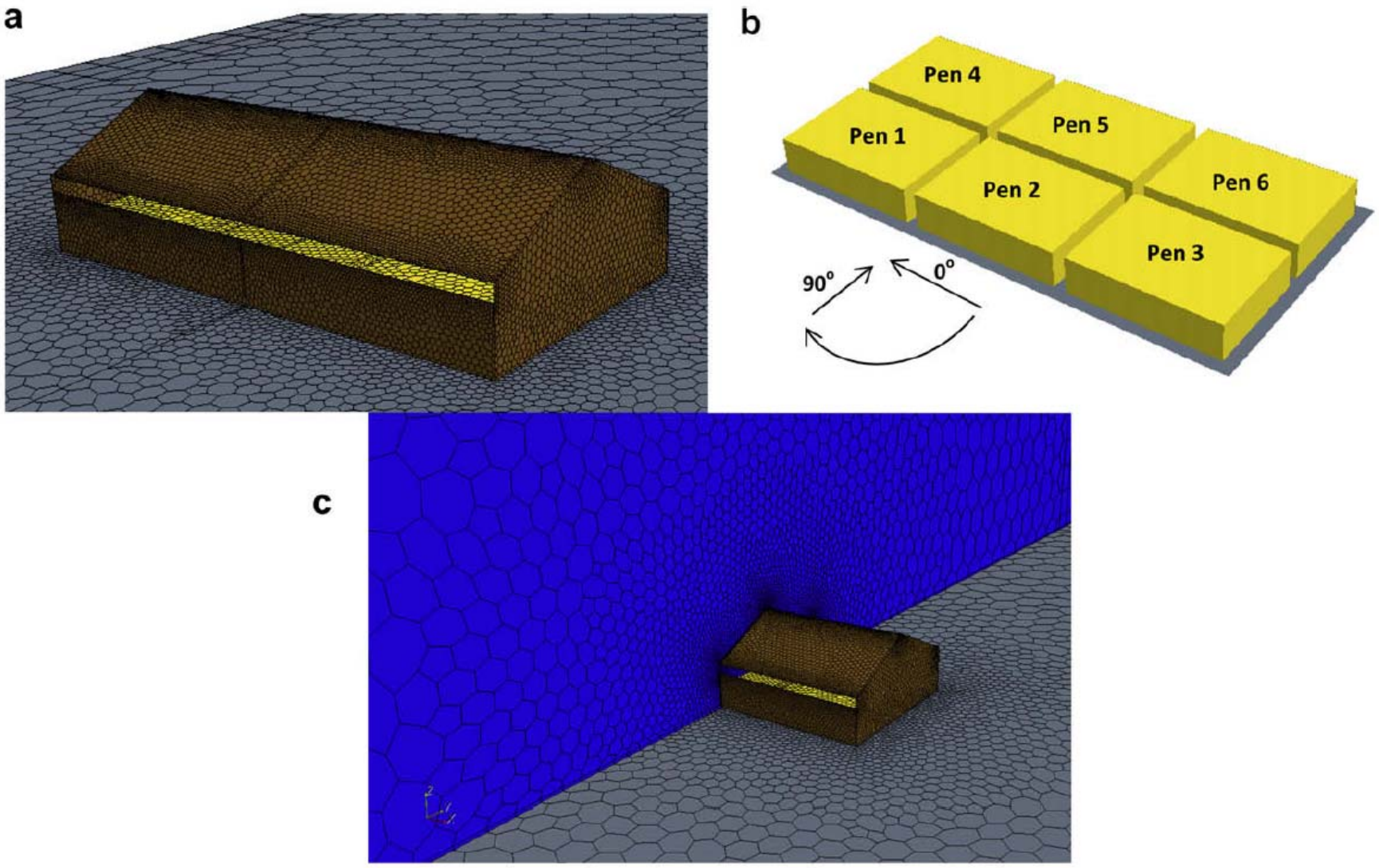


Number of publications related to CFD and natural ventilation in livestock buildings

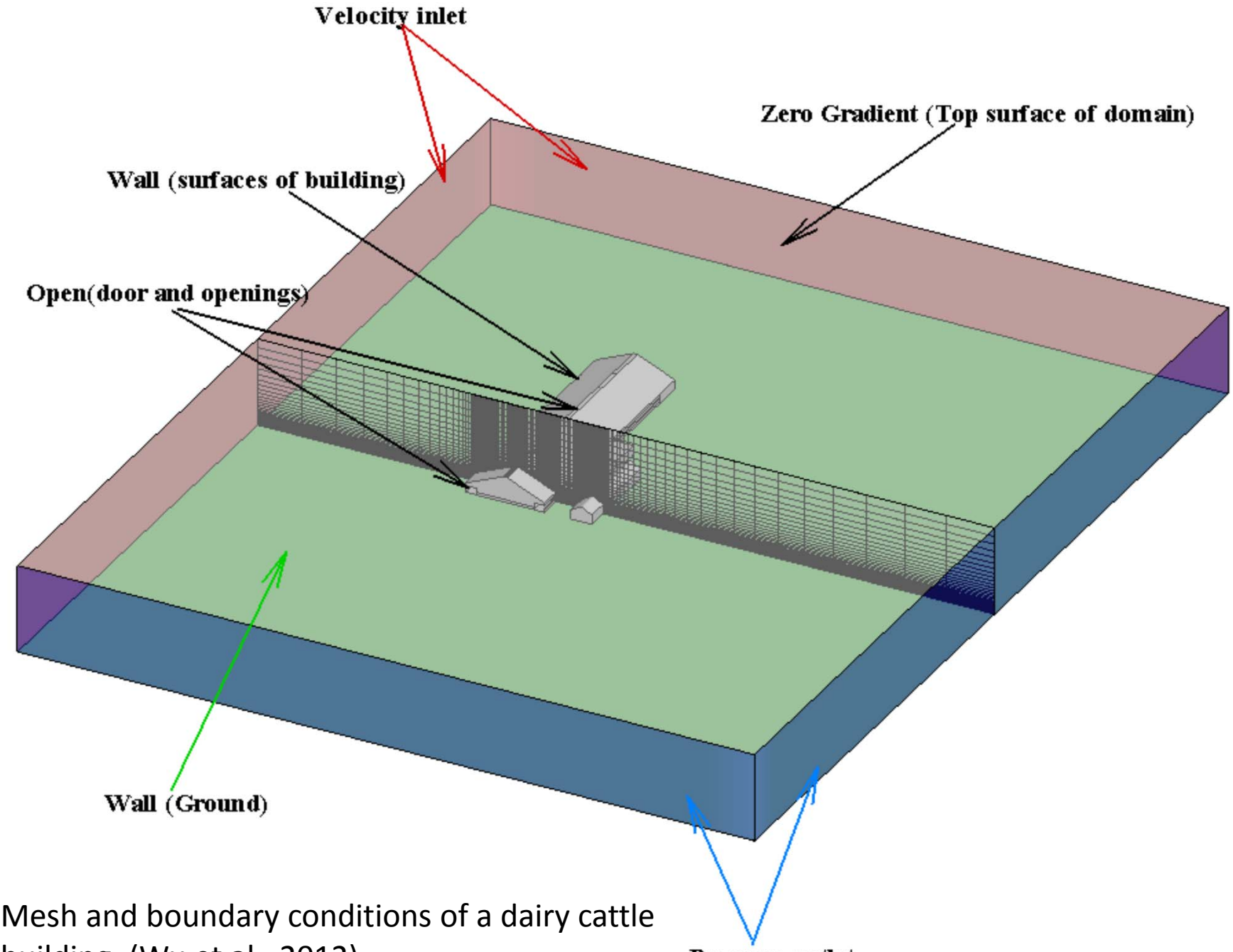


Modelling the computational domain

Computational Domain

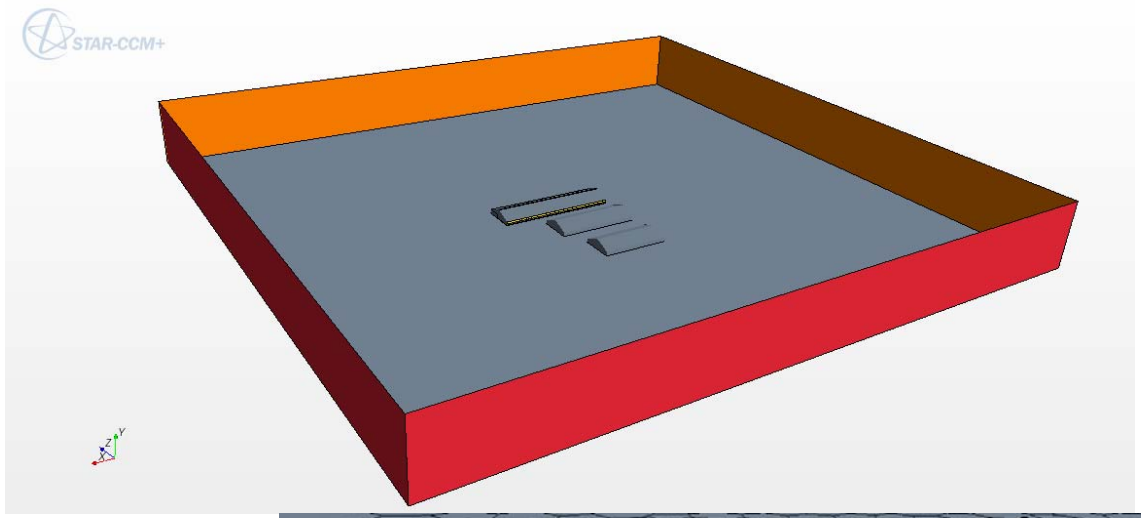


The surface mesh (a); the internal pen/AOZ regions of the building (b); the volume mesh in a typical CFD simulation of a naturally ventilated livestock building, Norton et al. 2012

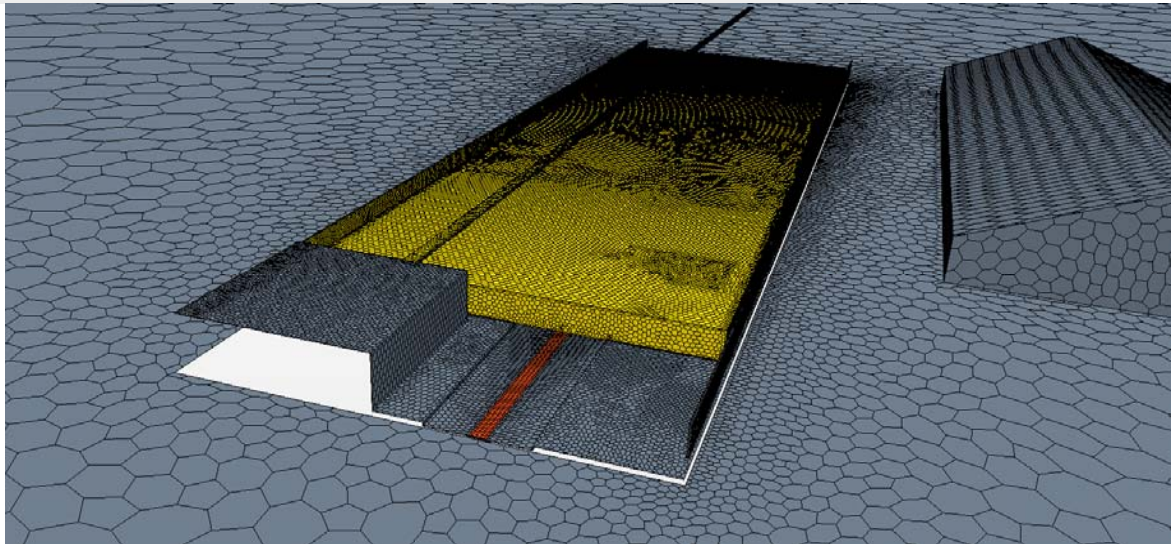


Mesh and boundary conditions of a dairy cattle building, (Wu et al., 2012)

Physical domain

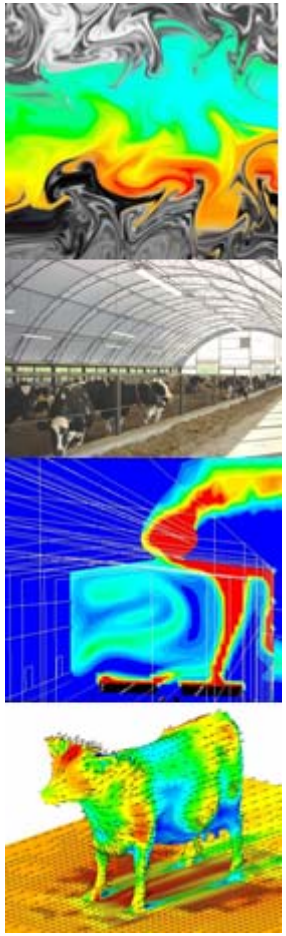


Computation domain

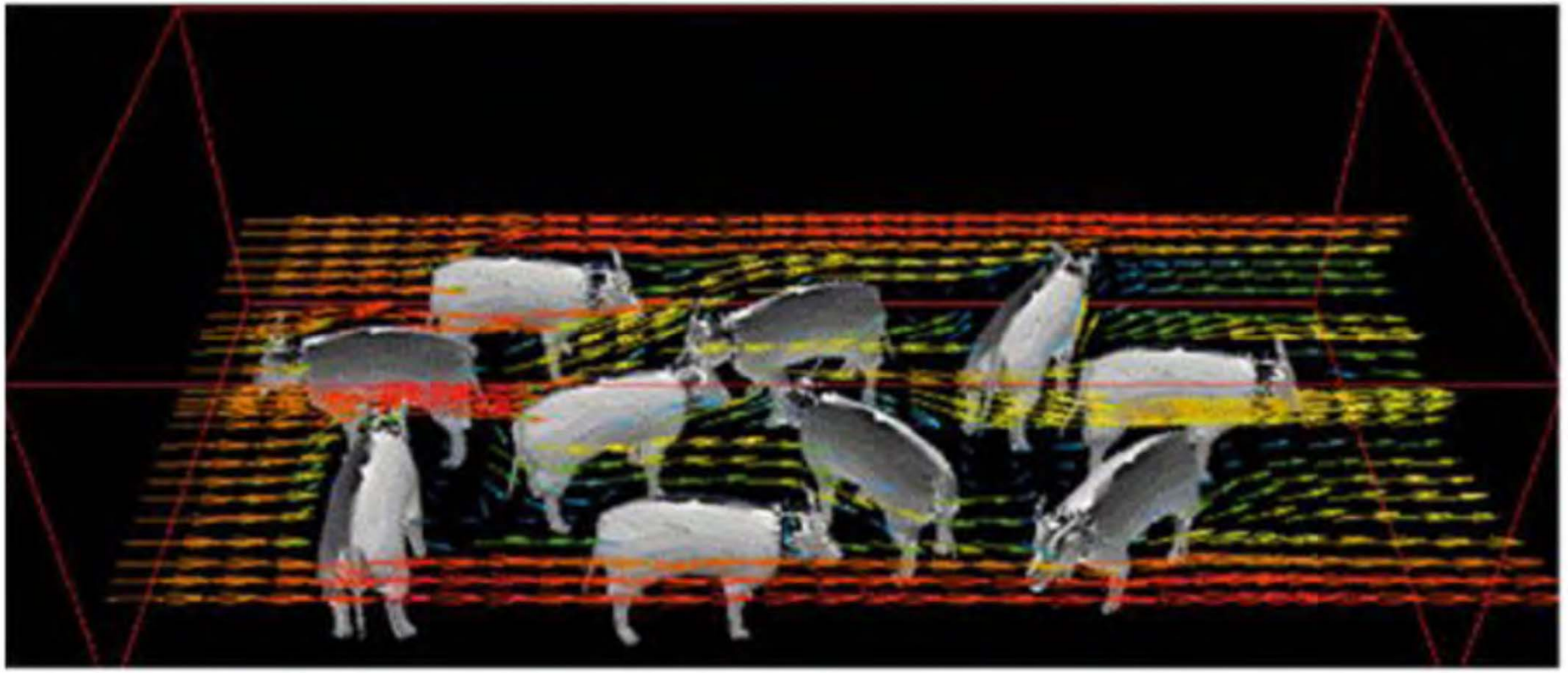


Grid details

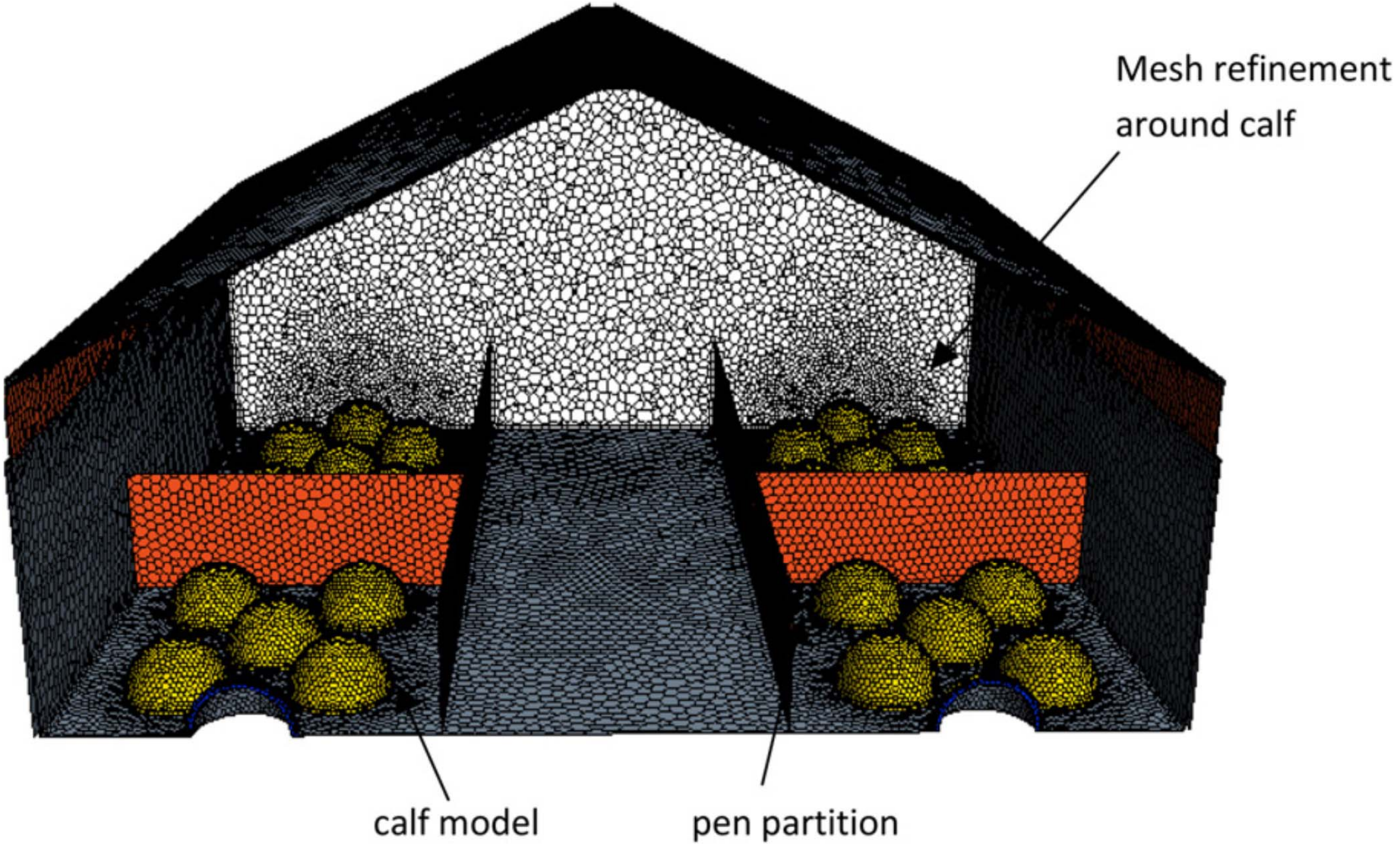
Bartzanas et al.2013



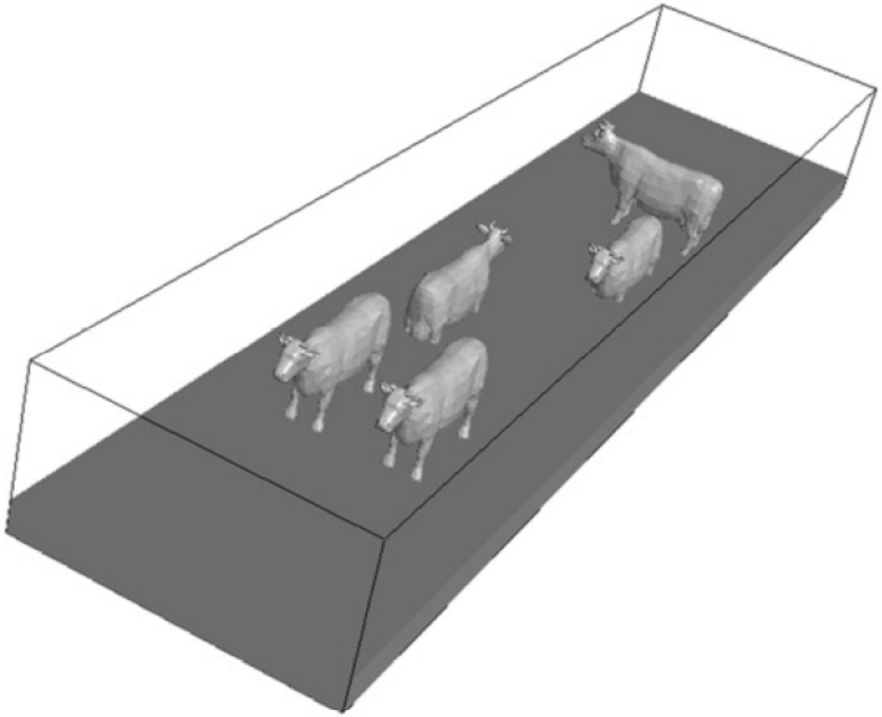
Including animals in the simulations



Flow field around a ventilated room of cows, (Gebremedhin and Wu, 2003)

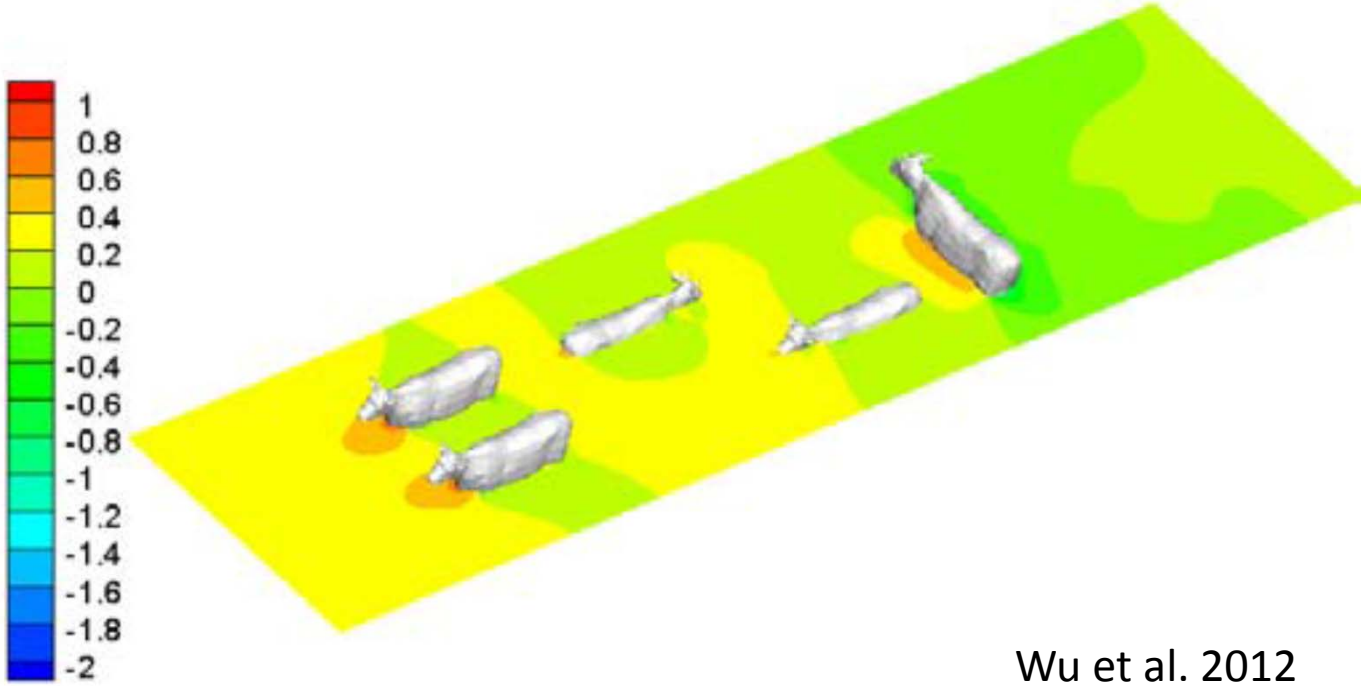


Surface and volume meshing used during the CFD simulations of the commercial calf house, Norton et al. 2010



CAD model

Pressure field



Wu et al. 2012

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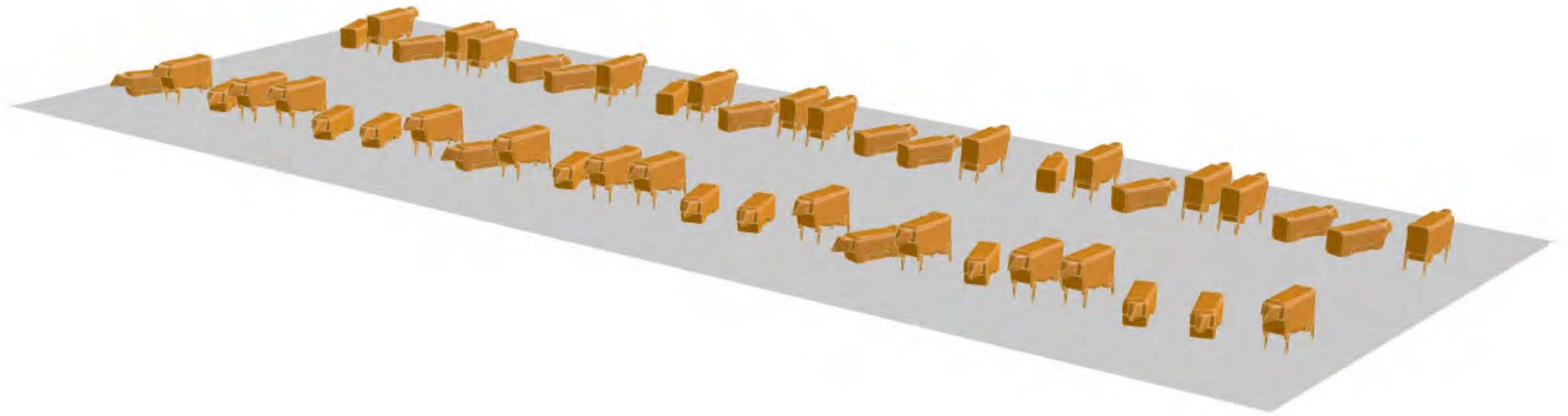
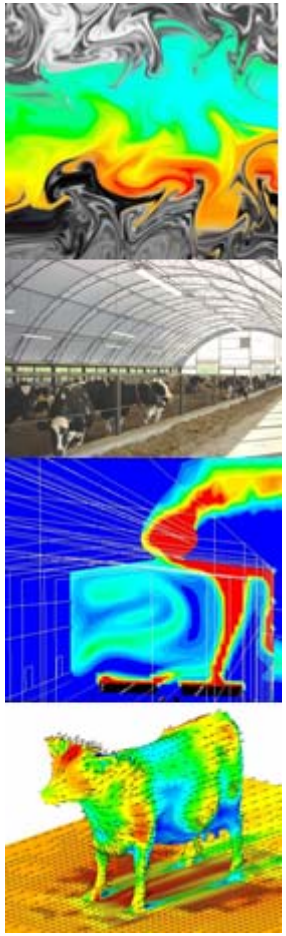
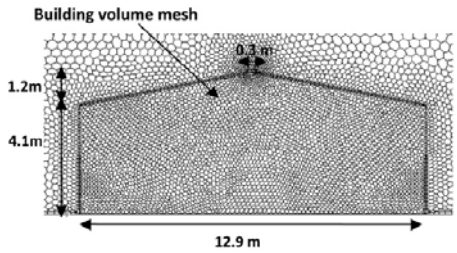
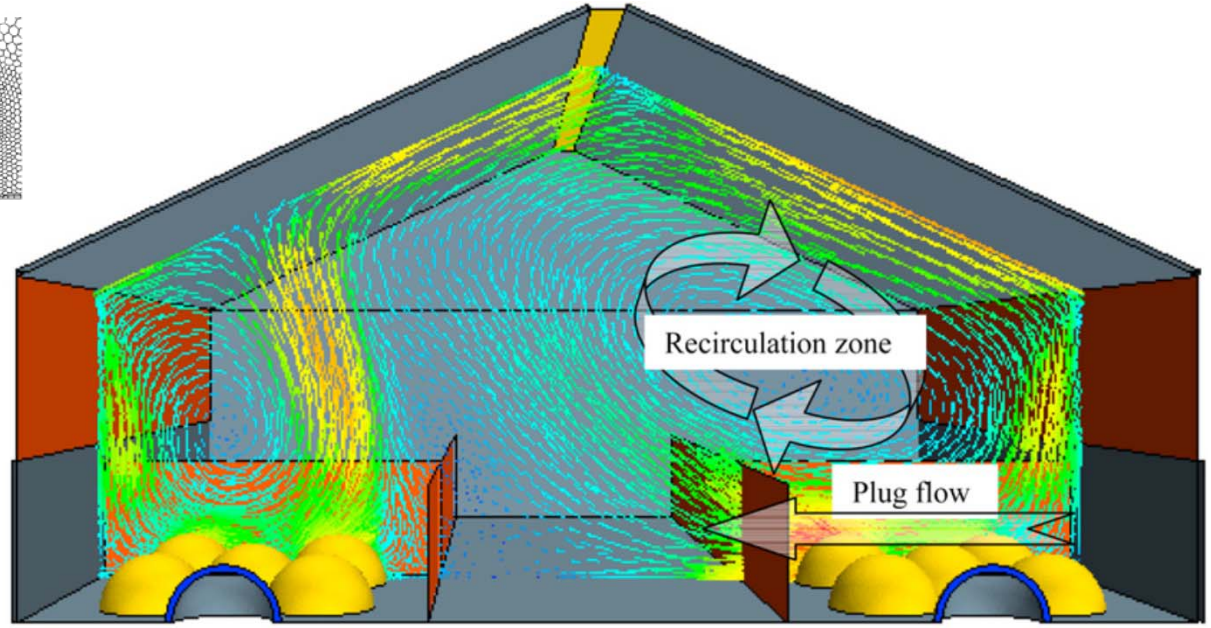


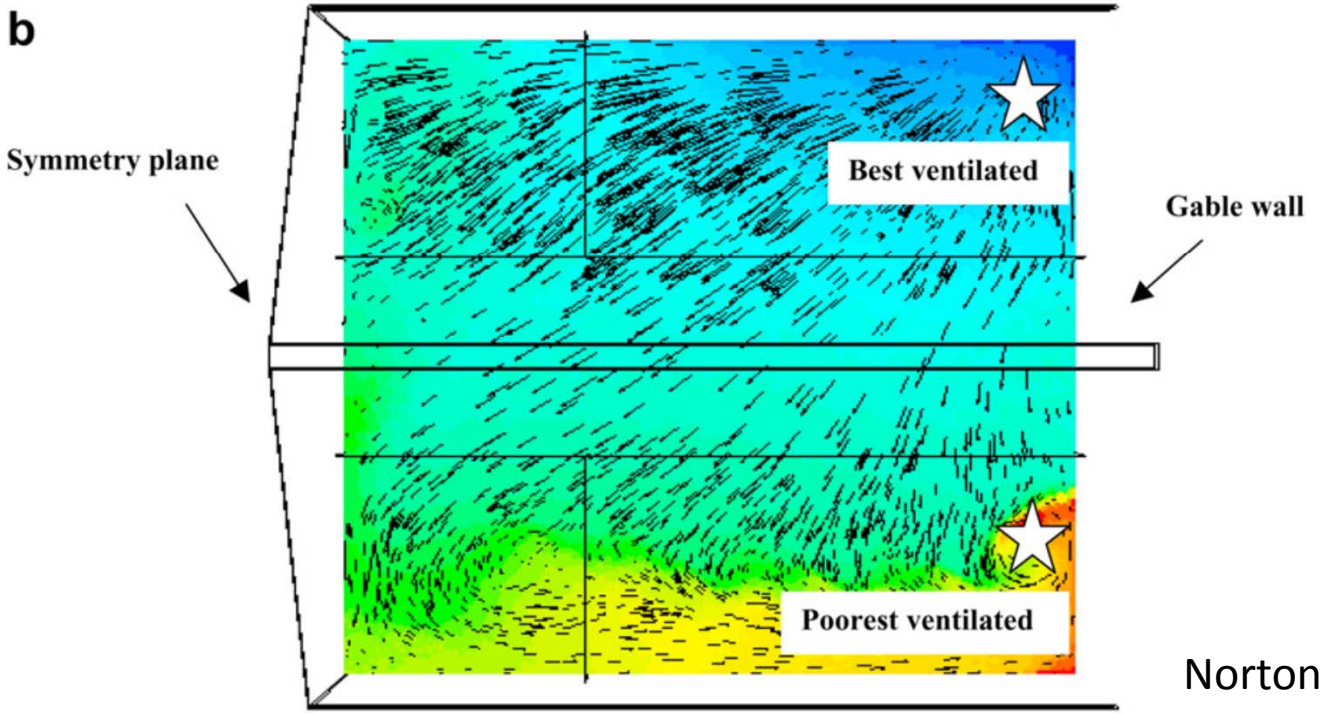
3D model of a virtual dairy cow house with 48 cows (Sapounas et al., 2012)



Airflow and ventilation efficiency

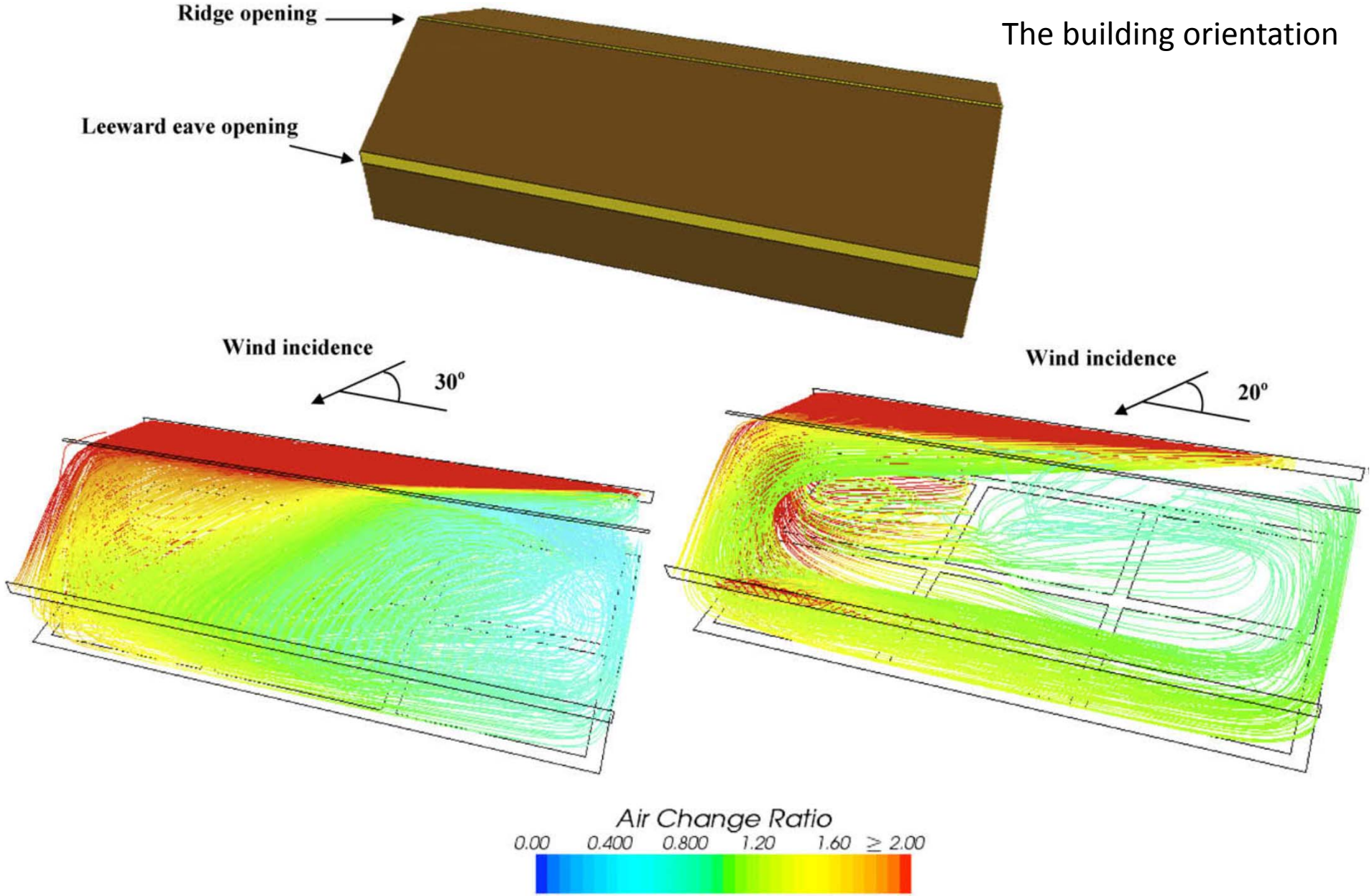




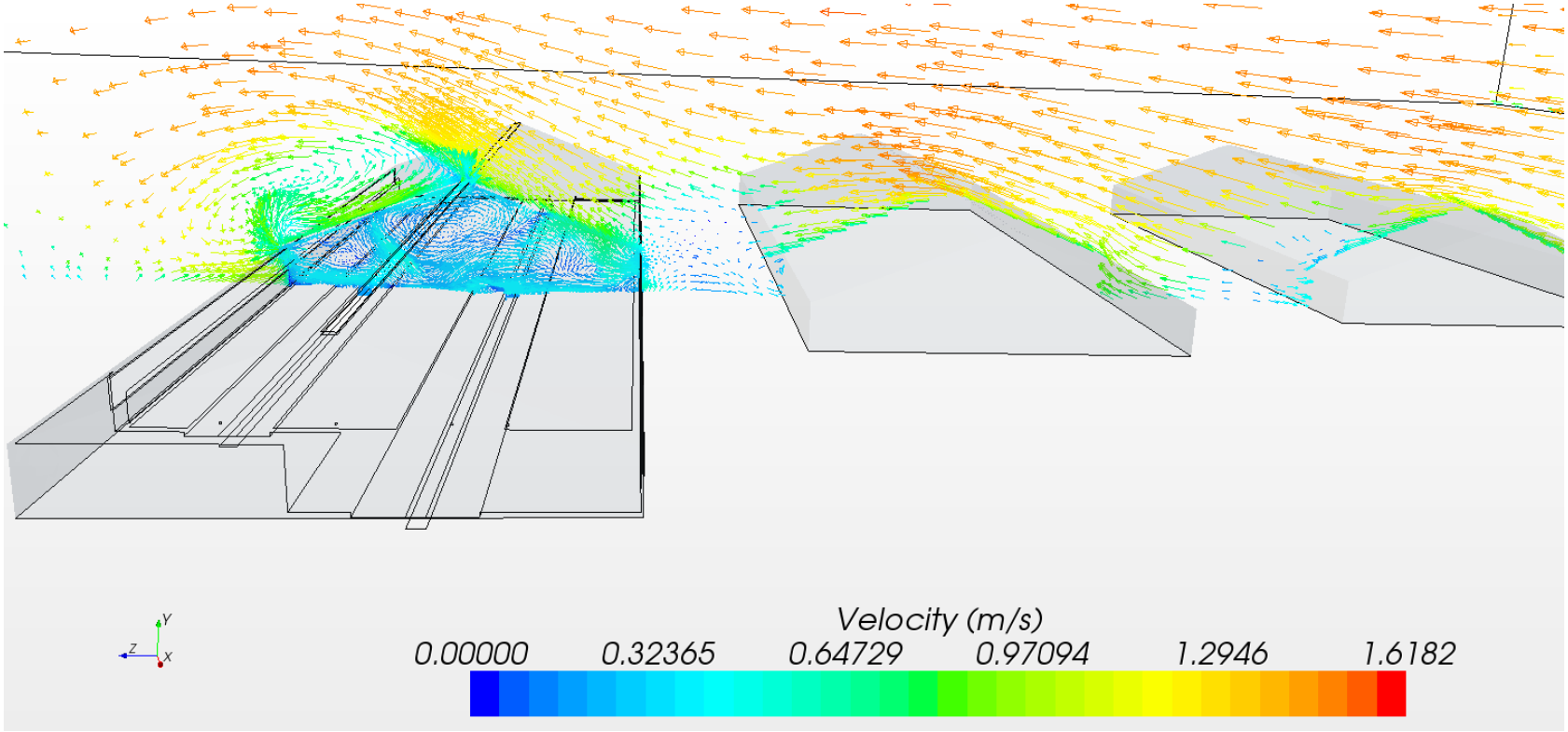


Norton et al. 2010

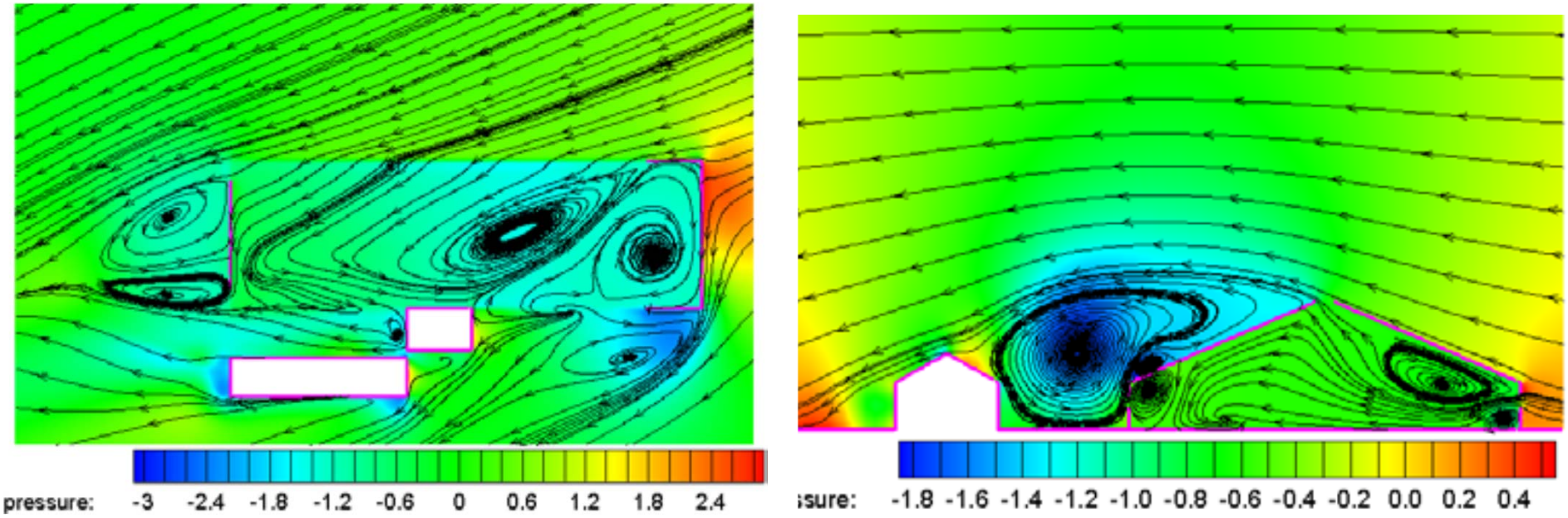
The building orientation



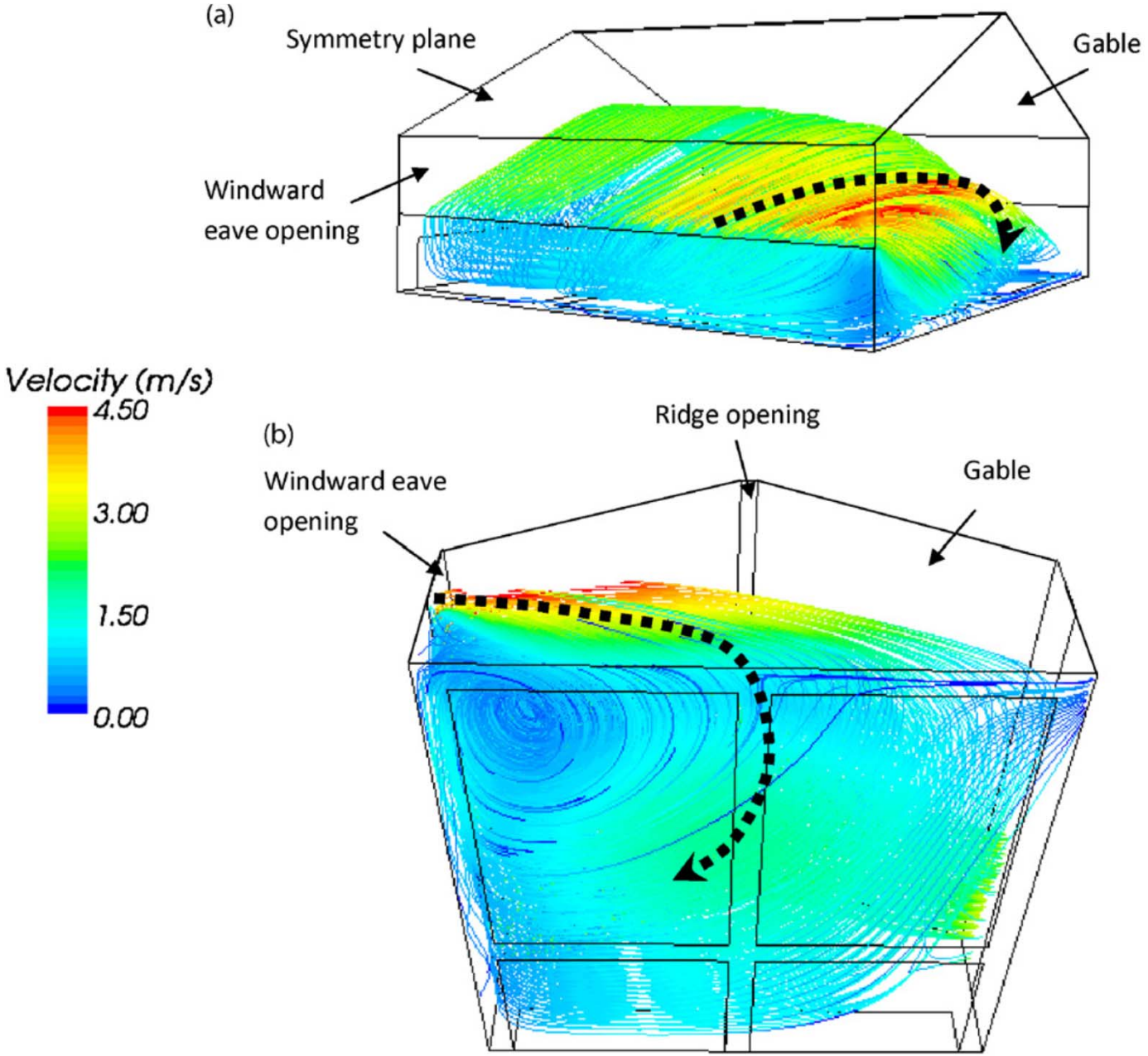
Streamlines illustrating the airflow patterns coloured by LMA distribution (Norton et al. 2009)



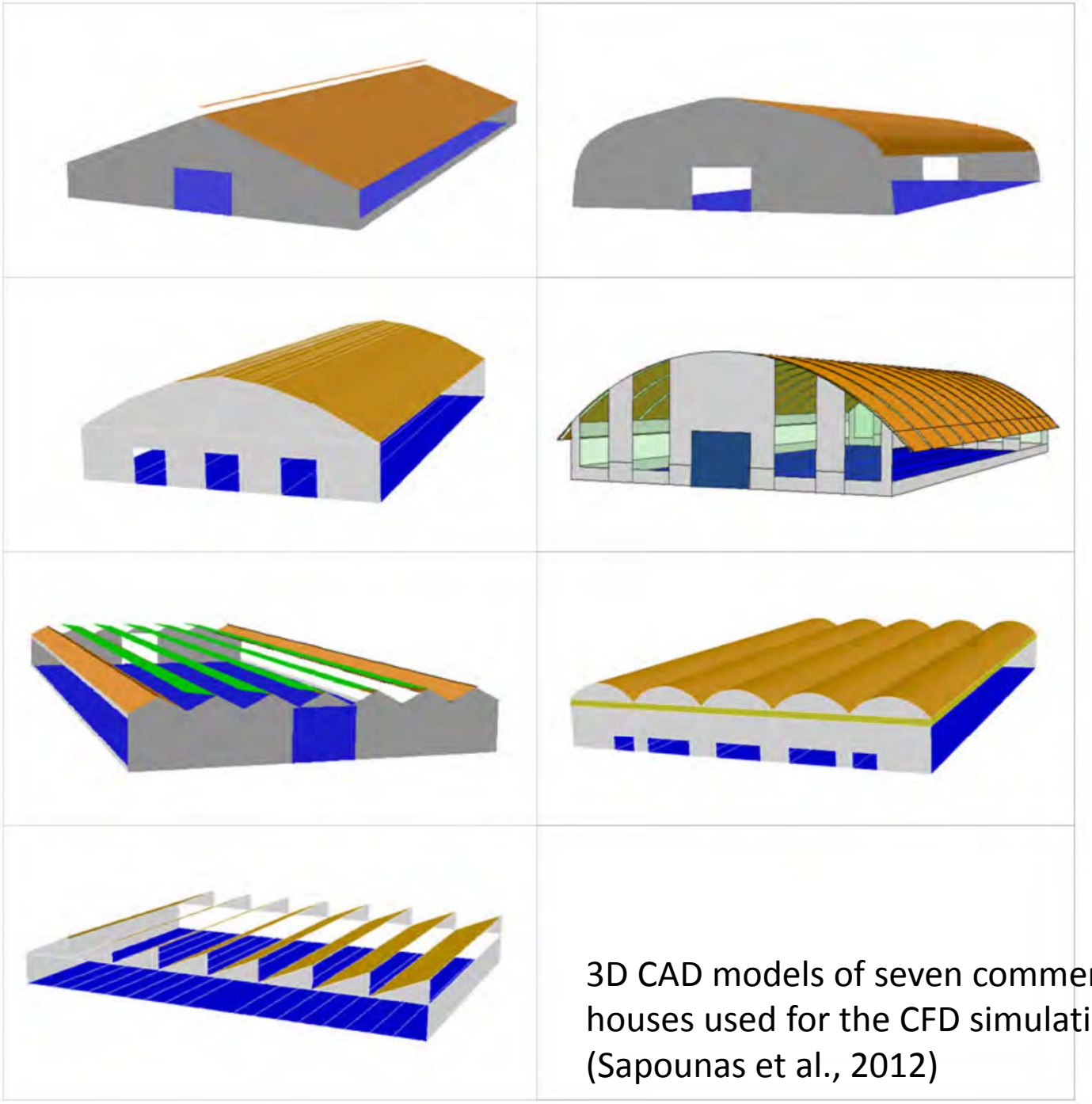
Velocity vectors in the computational domain, (Bartzanas et al., 2013)


pressure: -3 -2.4 -1.8 -1.2 -0.6 0 0.6 1.2 1.8 2.4
sure: -1.8 -1.6 -1.4 -1.2 -1.0 -0.8 -0.6 -0.4 -0.2 0.0 0.2 0.4
279 279.4 279.8 280.2 280.6 281 281.4 281.8 282.2 282.6
279.0 279.6 280.2 280.9 281.5 282.1 282.7 283.3 284.0 284.6

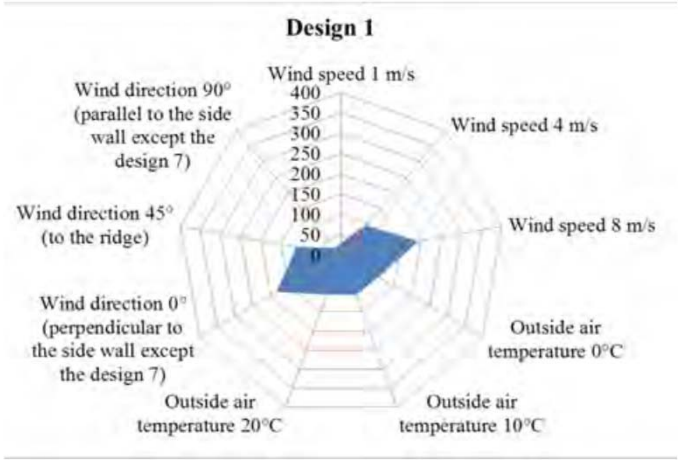
Wu et al., 2012

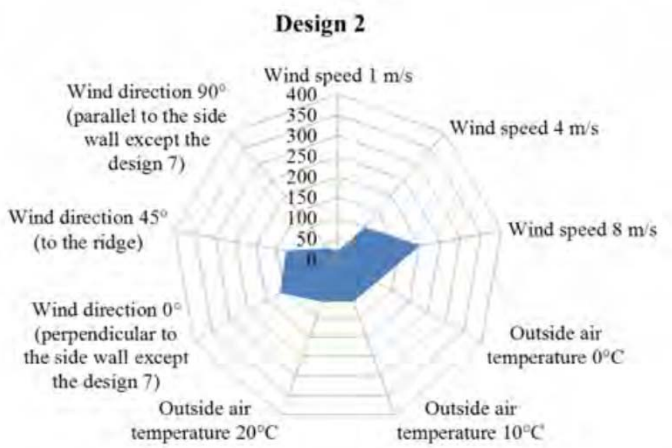


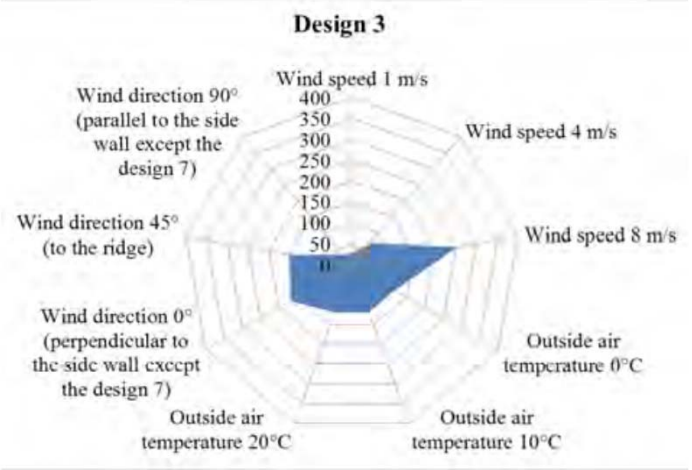
Streamline visualisation of the flow regime in a building. The black dashed line highlights the main flow pattern: (a) side-view and (b) bottom-view (Norton et al. 2010)

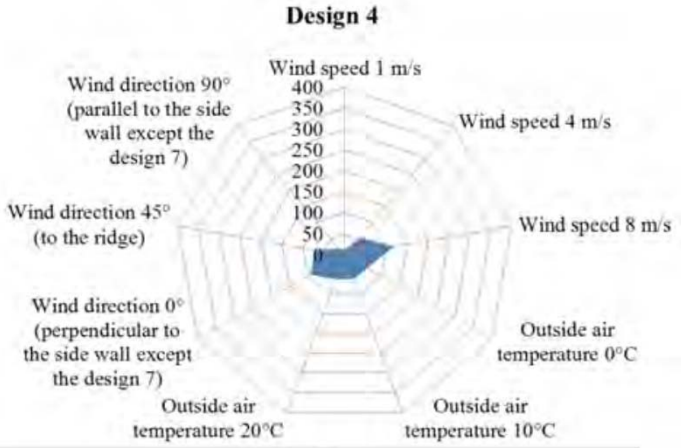


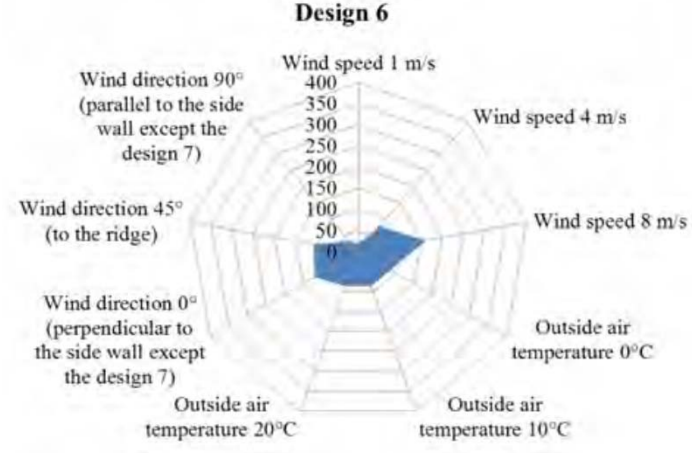
3D CAD models of seven commercial dairy cow houses used for the CFD simulation models, (Sapounas et al., 2012)

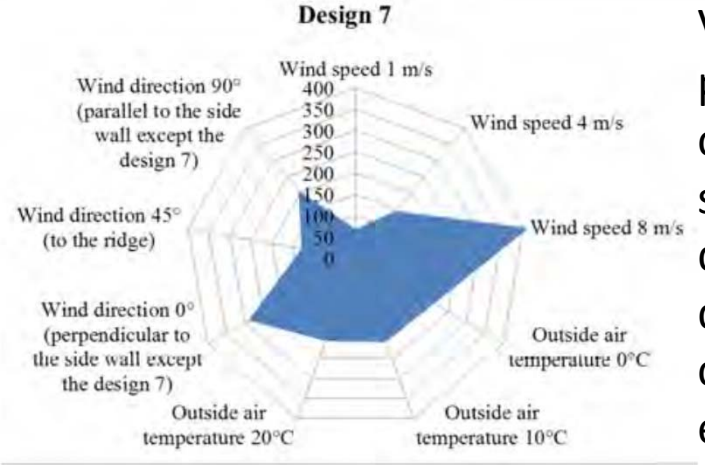












Ventilation performance (air changes per hour) of seven commercial dairy cow houses for different climatic conditions, (Sapounas et al., 2012)

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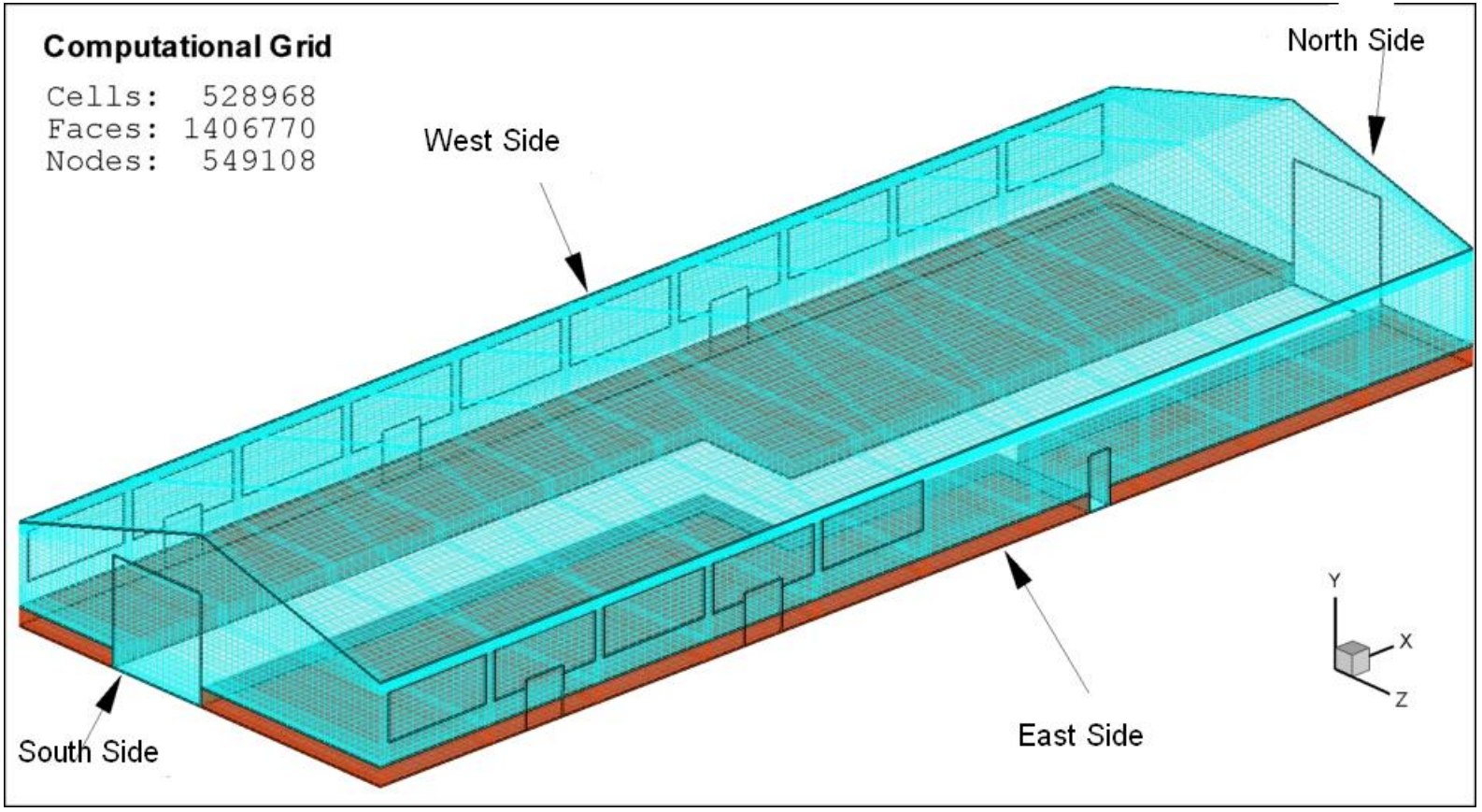

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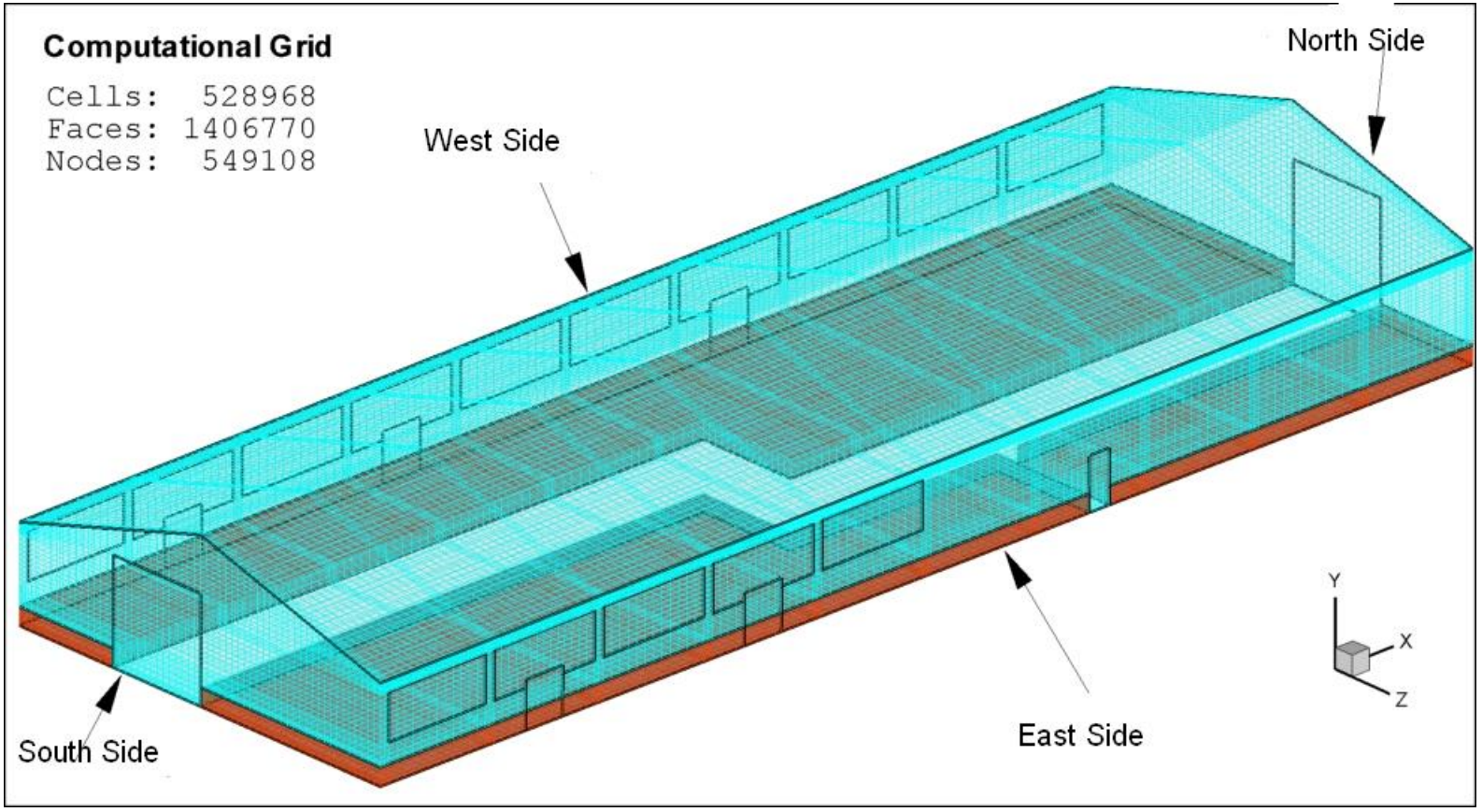

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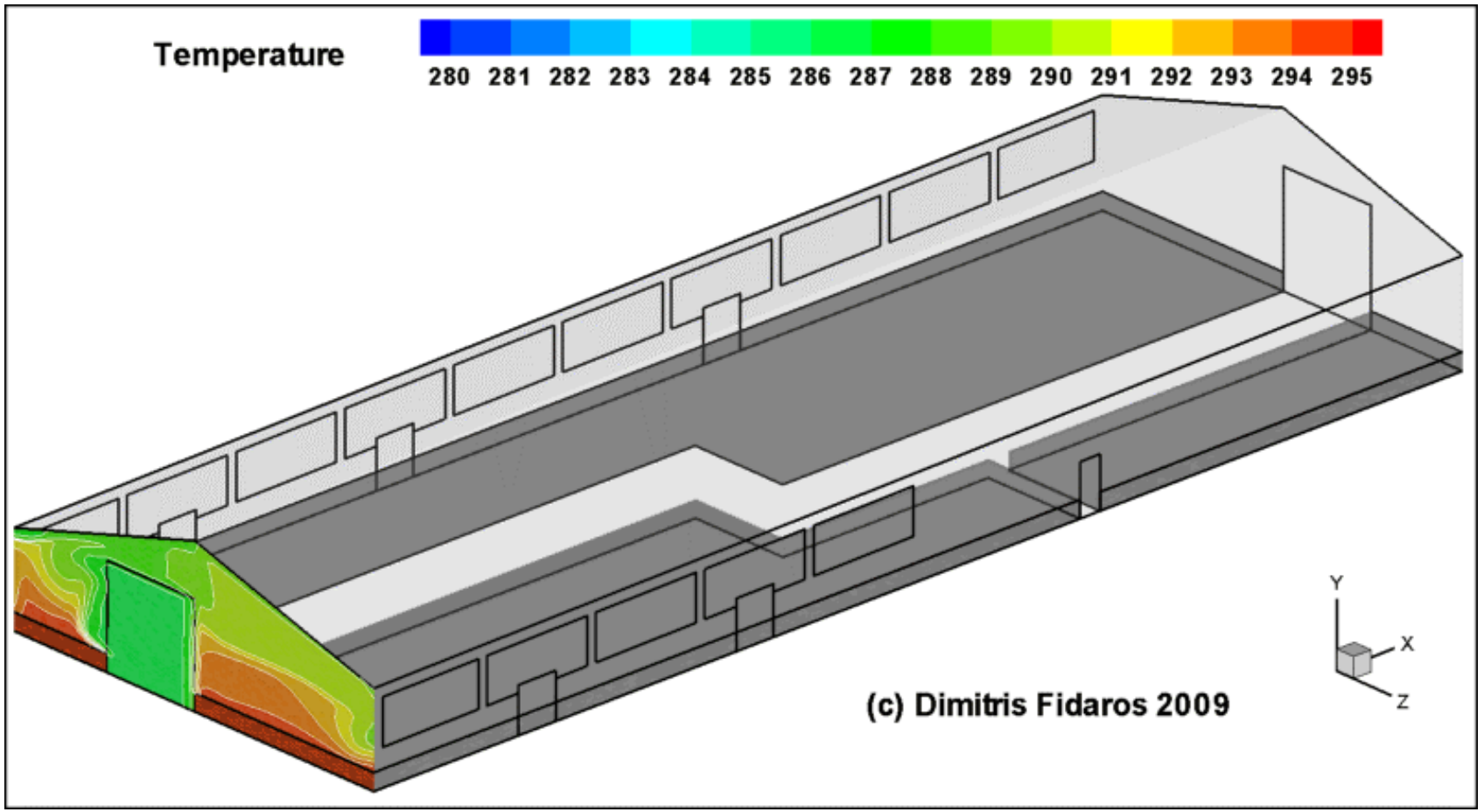

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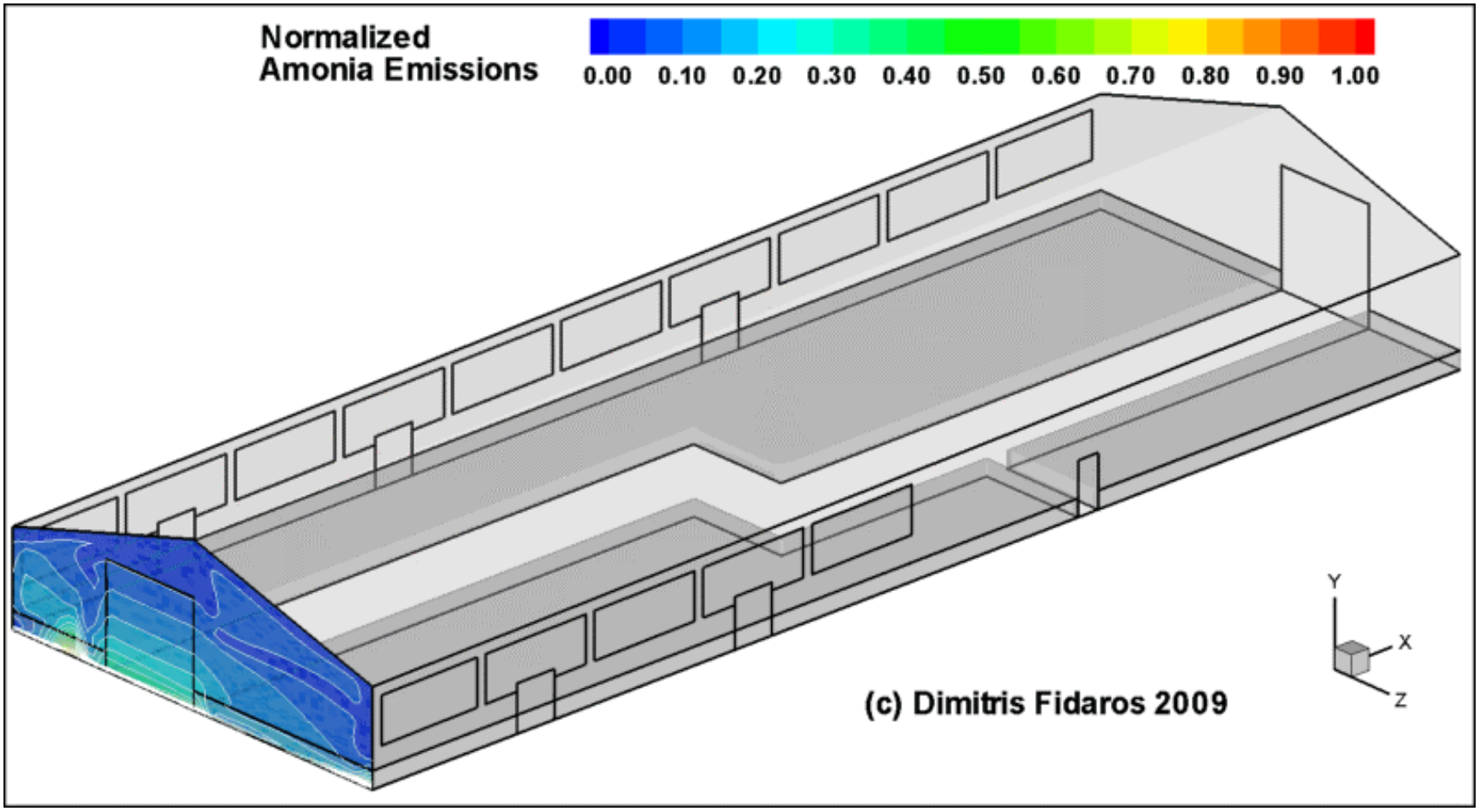

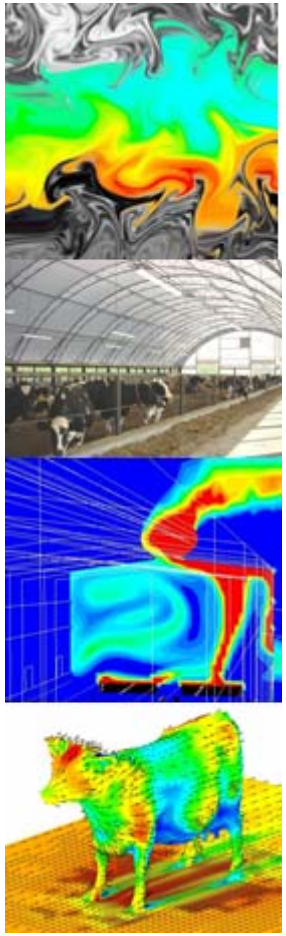

Concluding remarks

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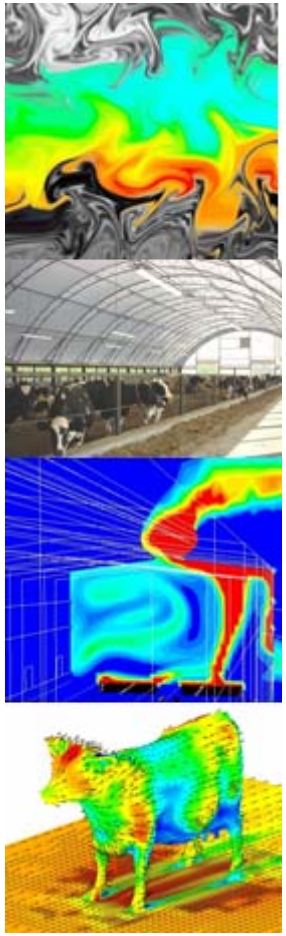
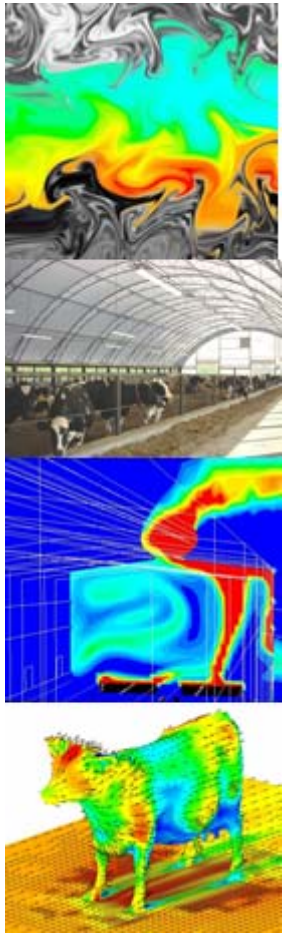


- ✓ CFD comprehensively simulates the natural ventilation, and has demonstrated its usefulness as an analysis, design and system optimization tool over recent years.
- ✓ However, due to the enormous complexity involved in these simulations, CFD techniques are not yet amenable to the on-line control of ventilation systems
- ✓ Validation of numerical results has been successful in many cases and even in cases where discrepancies exist, deficiencies in the model or measurement technique were readily identifiable.



Future challenges

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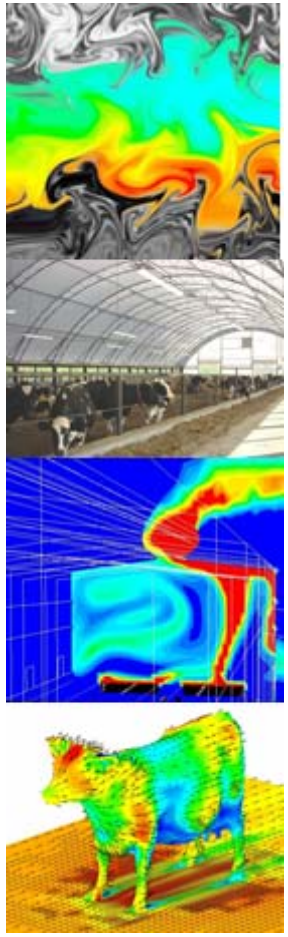

- **Animals movement**
- **Dispersion modelling**

- **Turbulence modelling**
- **Transient solutions**

Application issues

Modelling issues

Validation issues

Control and design issues

- **Need for more experimental data**
- **In-expensive experimental methods**

Application of CFD results in ventilation control

- **Design new structures / vent systems**