Universität Rostock Traditio et Innovatio

Gas dispersion in atmospheric boundary layers

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Motivation

- Simulation of gas dispersion in urban enviroment with OpenFOAM
- Prediction e.g. for toxic and flamable gases
- Very complex underground
- Area upstream of dispersion should be resolved
- Reduce inlet length (synthetic turbulence at inlet)
- No precurser or recycling needed (less computational costs)


*

Description of solver

- Using rhoReactingBuoyantFoam solver
- Conservation equations

$$\frac{\partial \bar{\rho}}{\partial t} + \nabla \cdot \left(\bar{\rho} \tilde{U} \right) = 0 \quad (1)$$

$$\frac{\partial \bar{\rho} \tilde{U}}{\partial t} + \nabla \cdot \left(\bar{\rho} \tilde{U} \tilde{U} \right) = -\nabla \bar{p} + \nabla \cdot \left(\tilde{\tau}_{eff} \right) + \bar{\rho} g \quad (2)$$

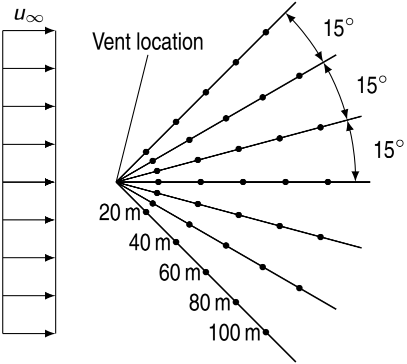
$$\frac{\partial \bar{\rho} \tilde{Y}_i}{\partial t} + \nabla \cdot \left(\bar{\rho} \tilde{U} \tilde{Y}_i \right) = +\nabla \cdot \left(\mu_{eff} \nabla \tilde{Y}_i \right) + \bar{S}_y \quad (3)$$

$$\frac{\partial \bar{\rho} \tilde{h}}{\partial t} + \nabla \cdot \left(\bar{\rho} \tilde{U} \tilde{h} \right) + \frac{\partial \bar{\rho} K}{\partial t} + \nabla \cdot \left(\bar{\rho} \tilde{U} K \right) = -\nabla \cdot \left(\alpha_{eff} \nabla \tilde{h} \right) + \bar{S}_h \quad (4)$$

- With additional initialization of p_rgh field
- Little changes in pressure correction for stability reasons

Description of first test case

†



† Jennifer Wen u. a. "Dispersion of carbon dioxide from vertical vent and horizontal releases—a numerical study". In: *Proceedings of the Institution of Mechanical Engineers, Part E: Journal of Process Mechanical Engineering* 227.2 (2013), S. 125–139.

Description of first test case

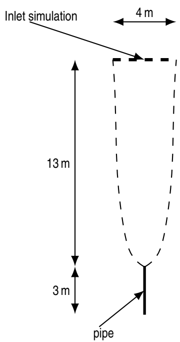
†

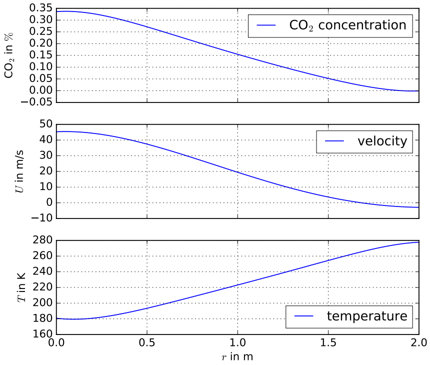
- Dispersion of CO_2 from jet (20 s inflow)
- Pure CO_2 at the outlet
- Vent with D = 50 mm at 3 m height
- Pressure in CO_2 vessel 151 bar
- Wind velocity at 2 m height ≈ 1,8 m/s
- Measurements of CO_2 concentration downstream at 1m height

* Wen u. a., “Dispersion of carbon dioxide from vertical vent and horizontal releases—a numerical study”.

Description of simulation

- Profiles for T, U, CO2-fraction in 13 m above pipe (from †)

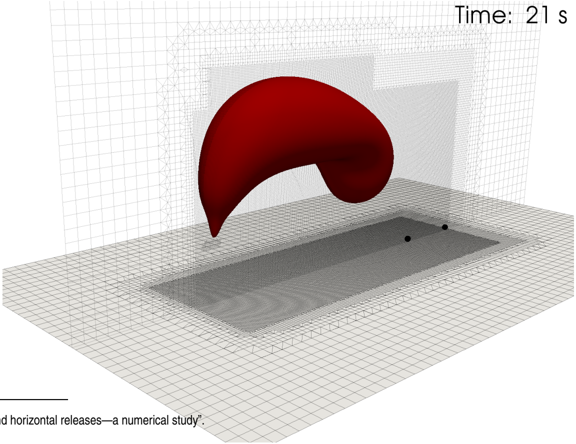




* Wen u. a., "Dispersion of carbon dioxide from vertical vent and horizontal releases—a numerical study".

Description of simulation

- RANS with constant atmospheric boundary layer profile ($z_0 = 0.01$, suggested in †)
- Domain 190 m x 120 m x 150 m
- Mesh size 1M to 10M cells



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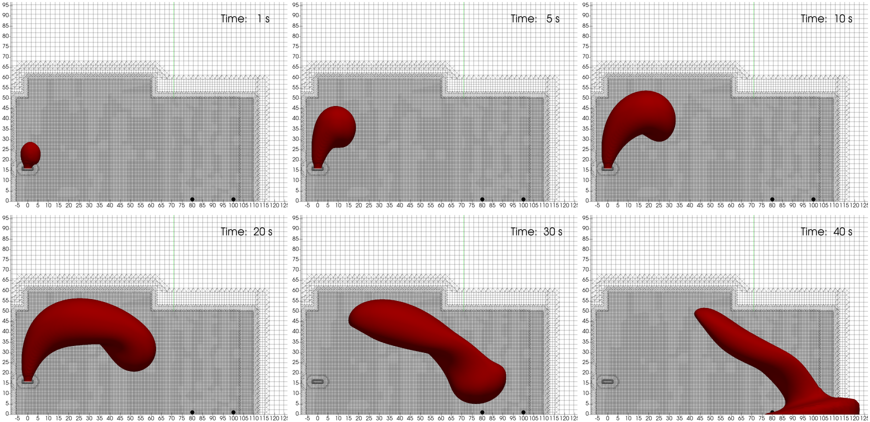
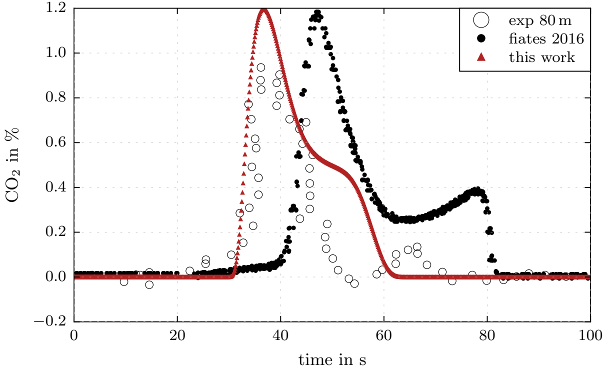
Contour of CO_2 concentration=1%



CO_2 concentration at 80 m



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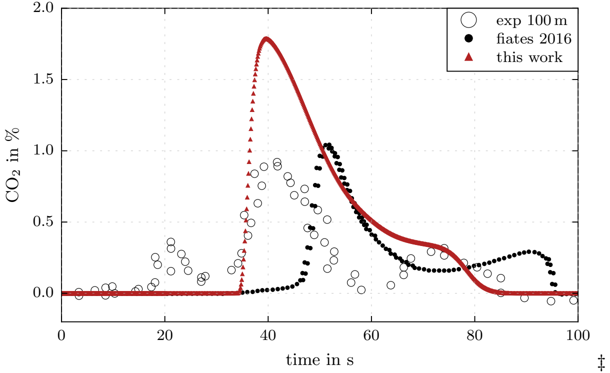
- Good agreement with measurements
- Maximum is slightly overpredicted, second peak not occurs

‡ Juliane Fiates u. a. "An alternative CFD tool for gas dispersion modelling of heavy gas". In: *Journal of Loss Prevention in the Process Industries* 44 (2016), S. 583–593.

CO_2 concentration at 100 m



- Good agreement with increasing time of CO_2
- Overpredicted maximum, second peak is only indicated

‡ Fiates u. a., "An alternative CFD tool for gas dispersion modelling of heavy gas".

Difficulties

In this comparison

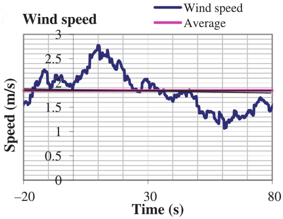
- Fluctuation in wind speed and direction

In general:

- Measurements in the field are not repeatable
- RANS fluctuactions are completely modelled
- Modelling of highly rough walls is still subject of research

⇒ Using high quality wind tunnel measurements for different urban enviroments

⇒ Long time intervals for statistical analysis of turbulence and gas occurrence



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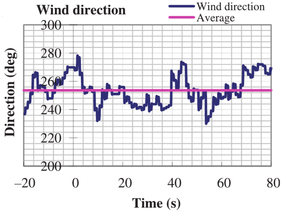

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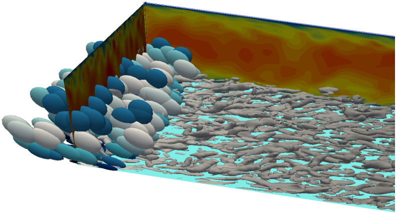
† Wen u. a., "Dispersion of carbon dioxide from vertical vent and horizontal releases—a numerical study".

Outlook

- Verify the LeMoS-Inflow-Generator for urban athmospheric boundary layer (currently working on this, using measurements of Michelstadt experiment)
  - ⇒ Reproduce urban atmospheric boundary layer with LES simulation in free terrain (wall function or porous media at the bottom, periodic BC)
  - ⇒ Verify turbulence properties
  - ⇒ Extract U-profiles, length scales L and reynolds stresses R
  - ⇒ Inflow-Generator in same domain
  - ⇒ Validate turbulent boundary layer
- Dispersion simulation with Inflow-Generator in urban enviroment



Thank you for your attention!