

# LES of Tracer Gas Dispersion Events with Focus on Peak Concentration in the MUST (Mock Urban Setting Test) Experiment

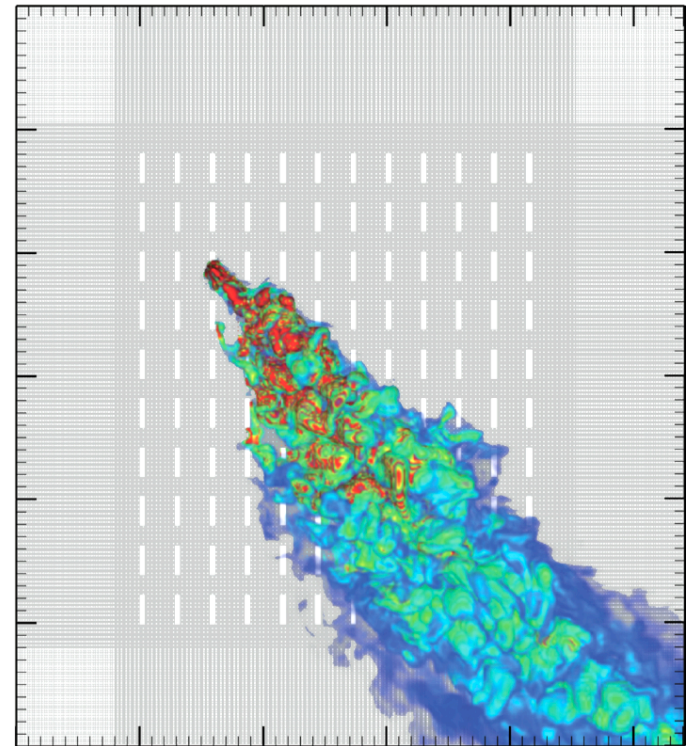
Marcel König<sup>1</sup> & Oswald Knoth<sup>1</sup>

<sup>1</sup>*Leibniz Institute for Tropospheric Research*

21st Symposium on Boundary Layers and Turbulence  
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9-13 June 2014

Member of the  
  
Leibniz Association



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Leibniz Institute for  
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## **Gas emissions from industrial stacks – large interest in environmental point of view**

- Large research background for mean concentration plumes
- Advected with mean wind

## **Objective**

- Gas emissions from traffic in urban areas
- Turbulent wind structure gets more important
- Extreme amounts of concentration
- Model validation

# Mock Urban Setting Test experiment MUST

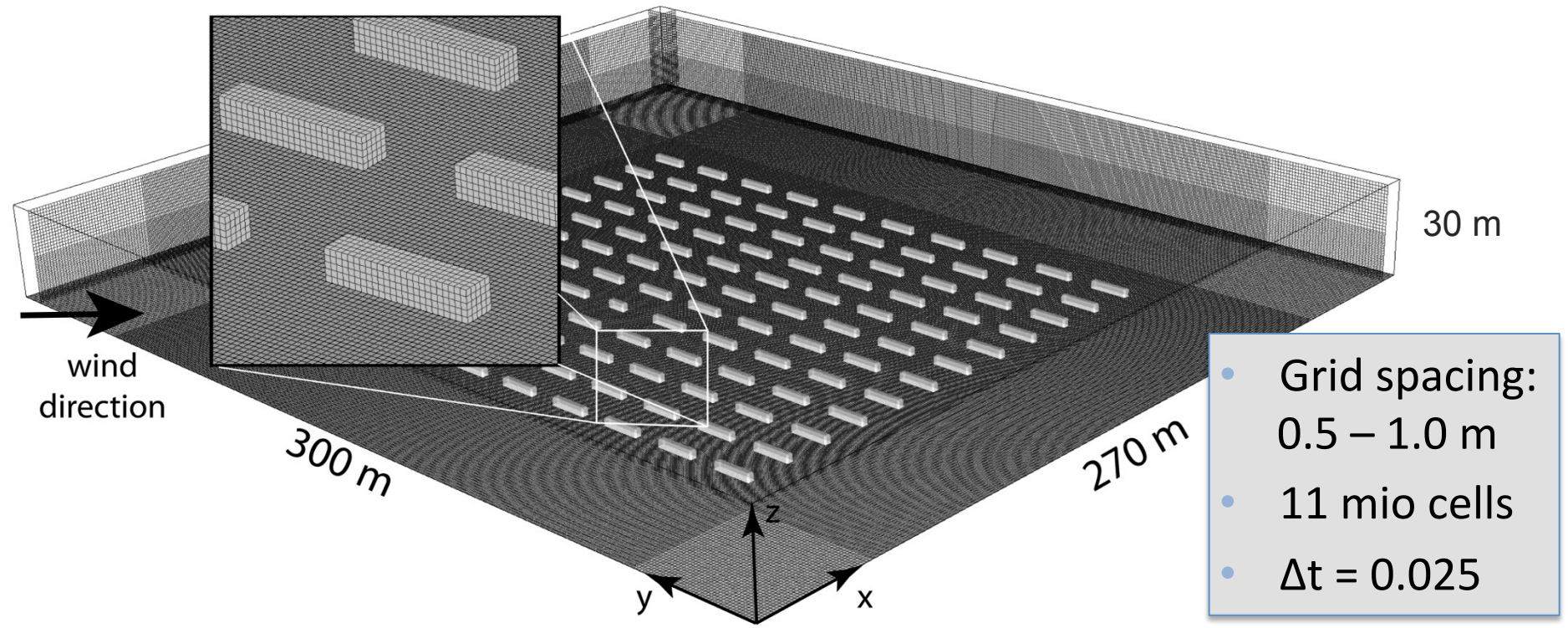
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- Near full scale urban test experiment - *Biltoft et al. (2001)*
- Took place in 2001 at the dessert of Utah/USA
- Shipping container as roughness elements
- Well documented meteorological data set and dispersion

# All Scale Atmospheric Model - ASAM

- Fully compressible Large-Eddy Simulation Model
- Fully parallelized code with MPI
- Cartesian grid
- Dynamic Smagorinsky sub-grid scale parameterization



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# Turbulent inflow condition

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- Goal: estimate extreme values of wind gusts and concentration
- Time independent laminar inflow inadequate  
→ Need turbulent inflow conditions

- Add synthetic generated turbulence to a mean wind

$$u(\mathbf{x}, t) = \overline{u(\mathbf{x}, t)} + \sum_{n=1}^N E_{1,n} \cdot \sin[k_{1,n}x_2 + \omega_{1,n}t + \Delta\phi_{1,n}]$$

Use basics of  
*Lee et al. (1992)*

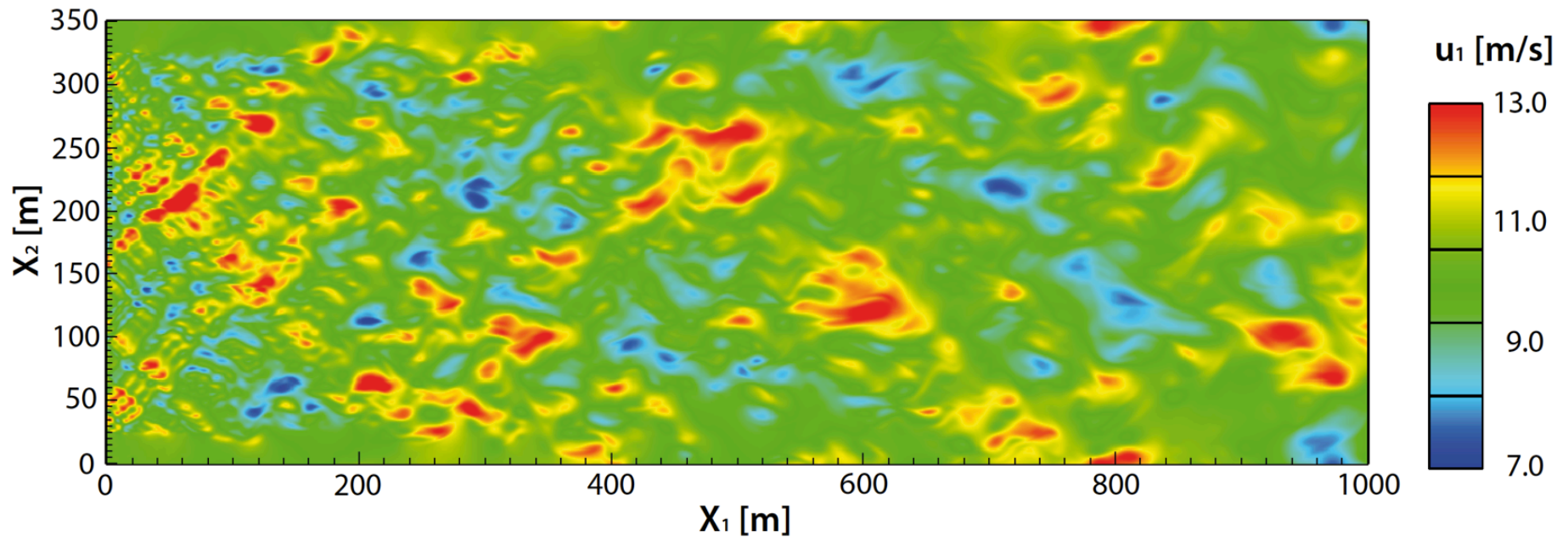
- Fluctuations consist of a described lengths scale and a pre-defined energy spectrum (intensity)
- For isotropic turbulence  $k$  and  $\omega$  have to be connected

# Turbulent inflow condition

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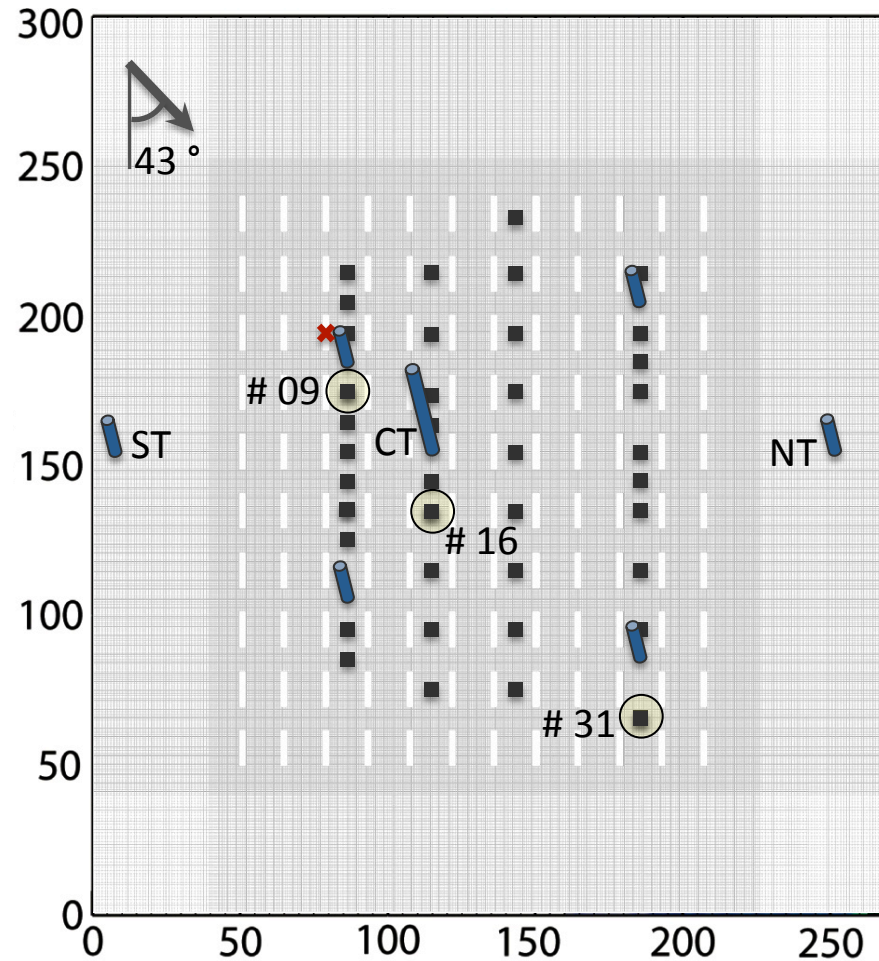
## Fluctuations...

- are generated at every inflow cell
- are adapted to horizontal neighbor cells



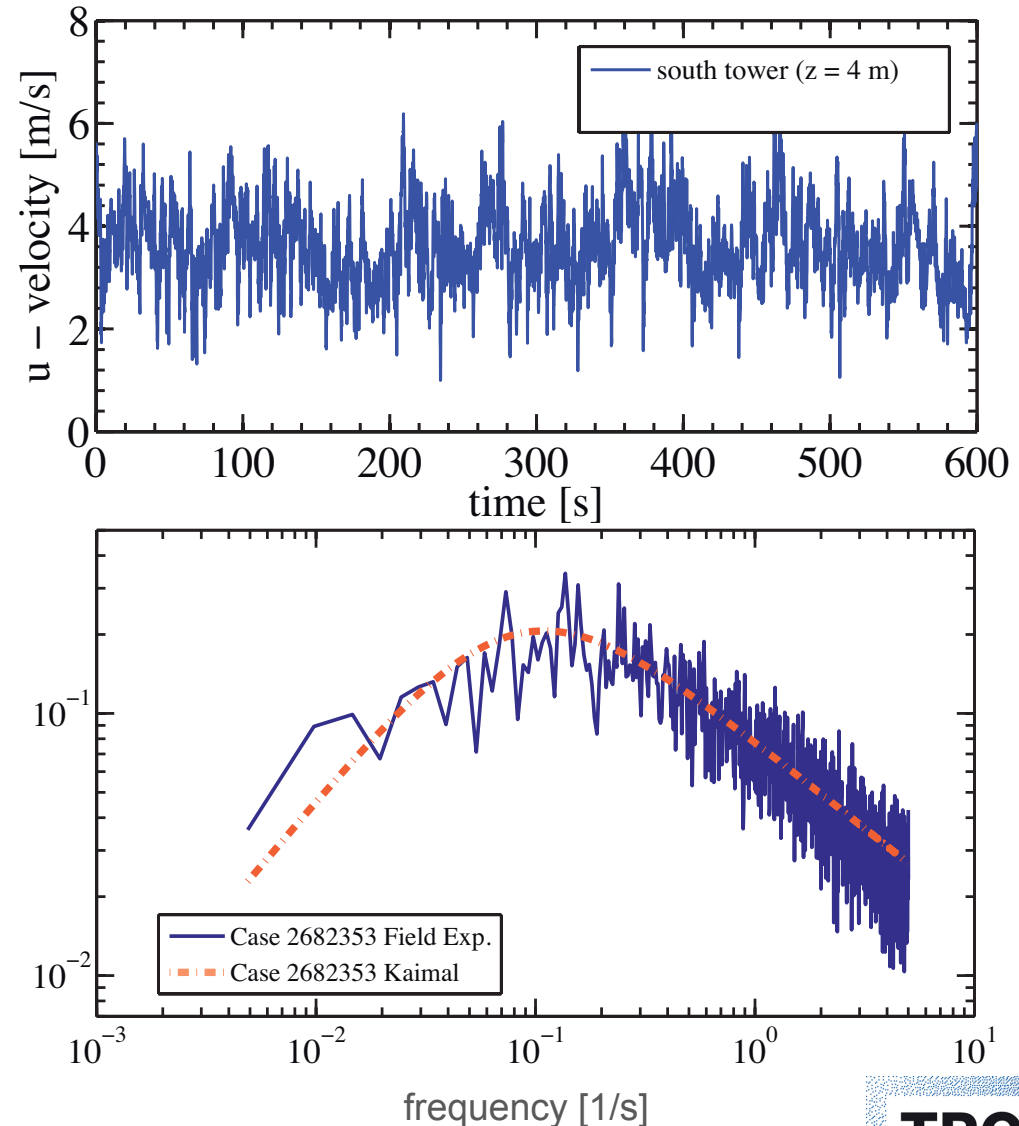
# Model-setup for a MUST-simulation case

- Mean wind direction  $43^\circ$
- Time series from south tower measurement



# Model-setup for a MUST-simulation case

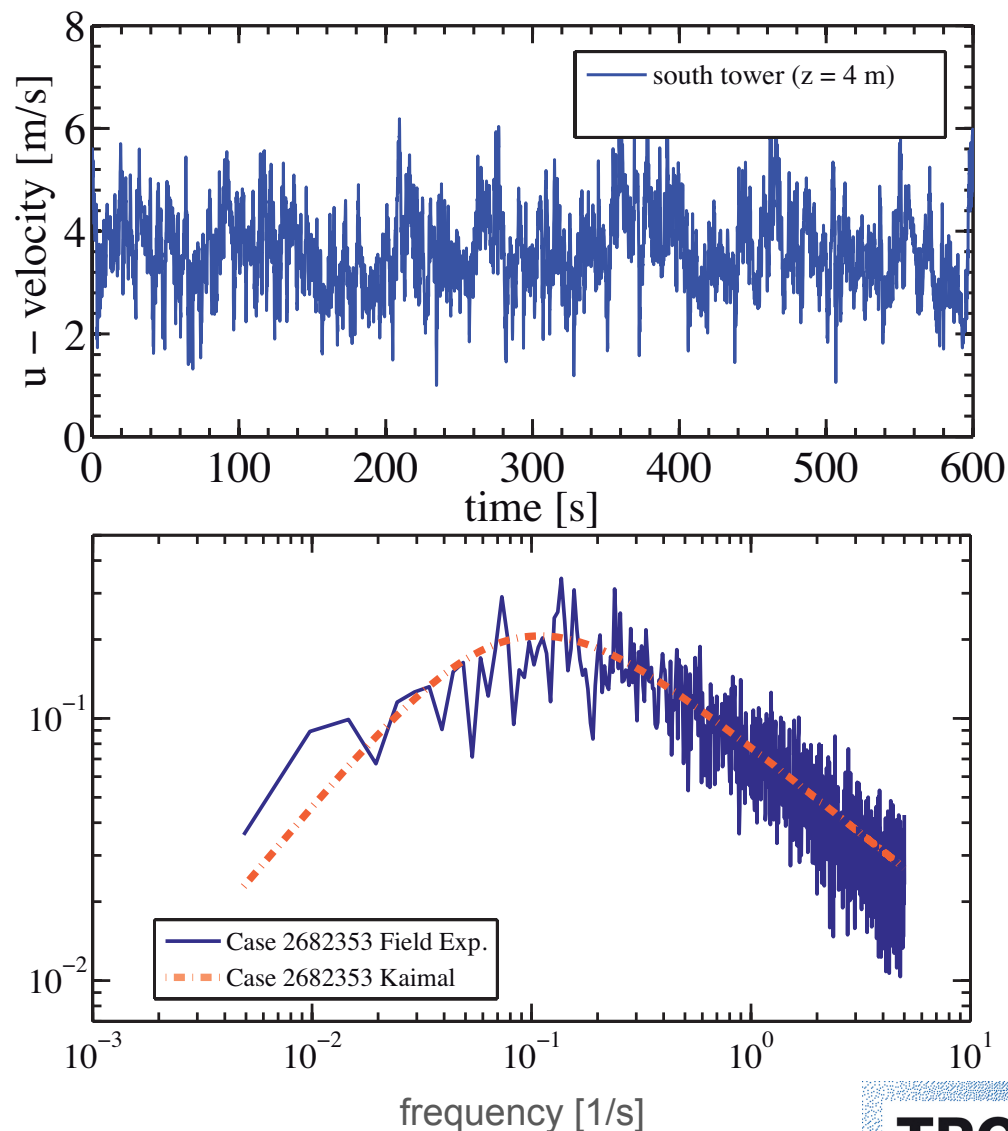
- Mean wind direction  $43^\circ$
- Time series from south tower measurement
  
- FFT transformation
- Mean behavior with standardized Kaimal spectrum





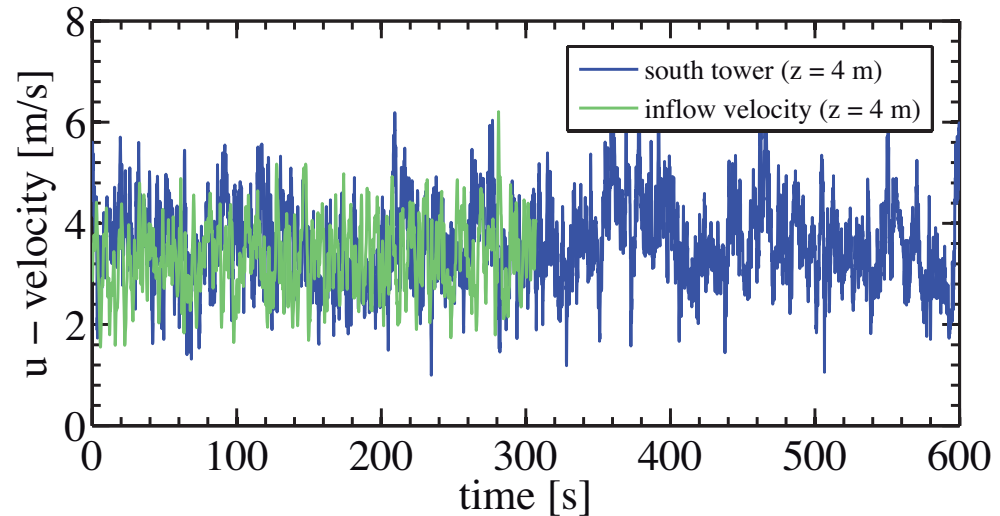
# Model-setup for a MUST-simulation case

- Mean wind direction  $43^\circ$
  - Time series from south tower measurement
  - FFT transformation
  - Mean behavior with standardized Kaimal spectrum
- **Inflow-parameter**
- 100 random modes between 0.01 and 2 Hz (400 - 3m)
  - Amplitude from spectra for every mode

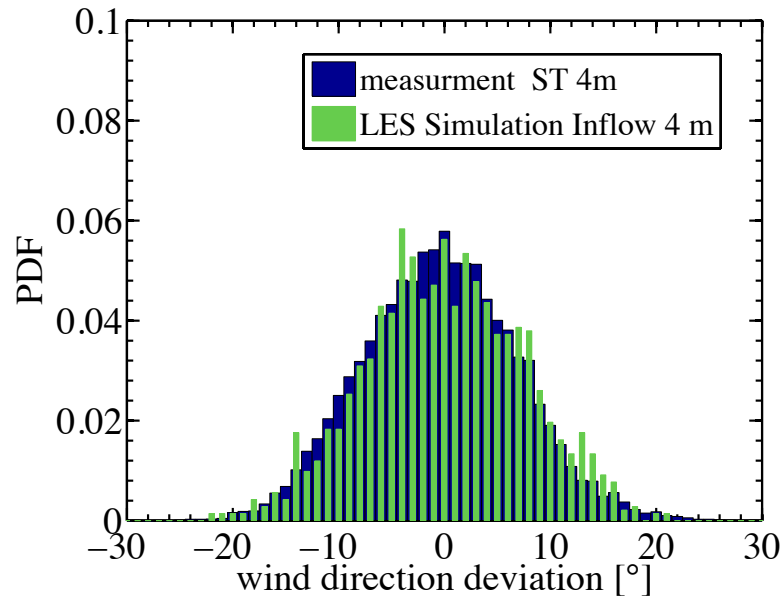


# Model-setup for a MUST-simulation case

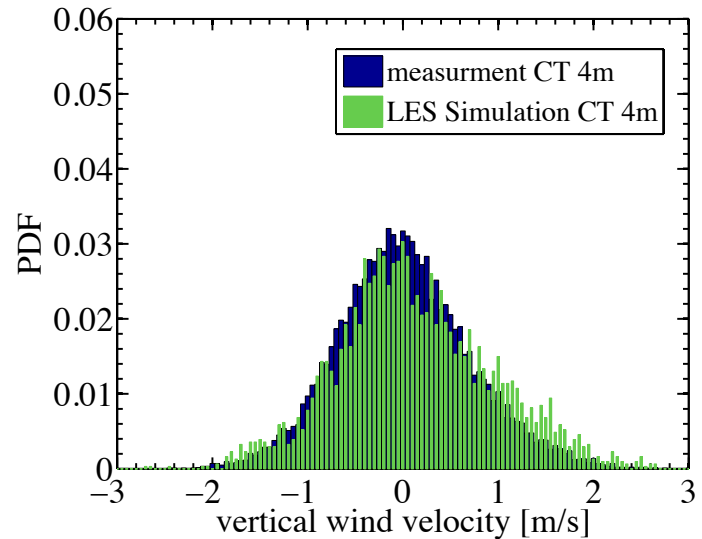
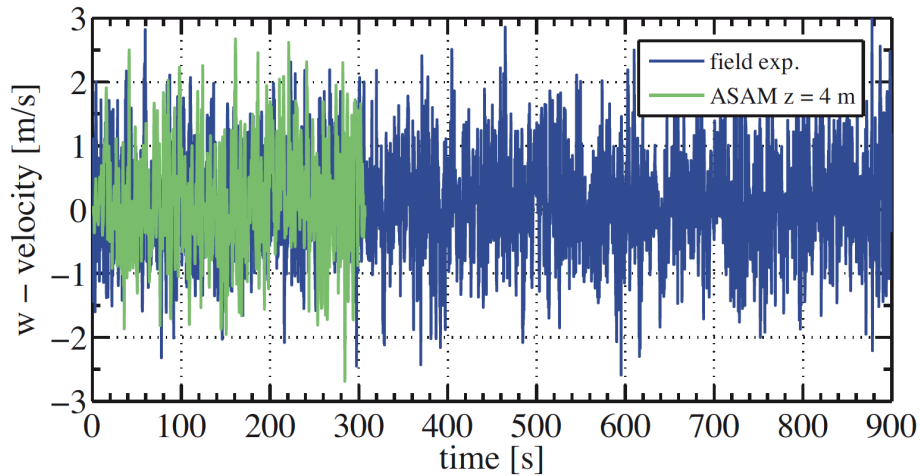
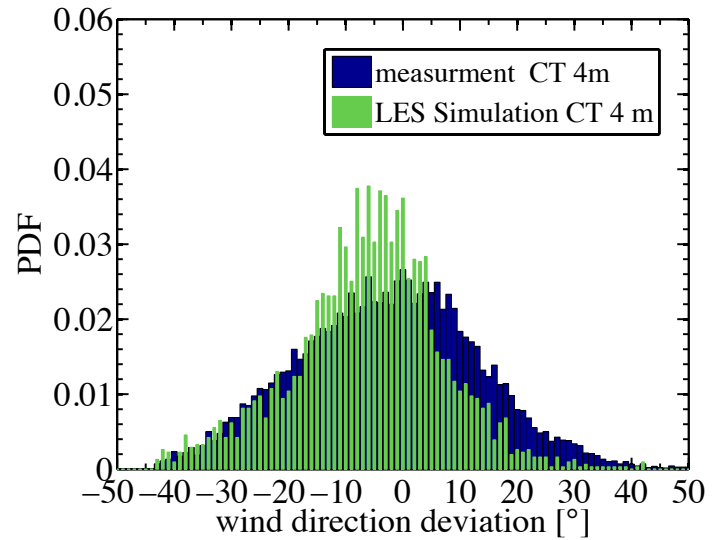
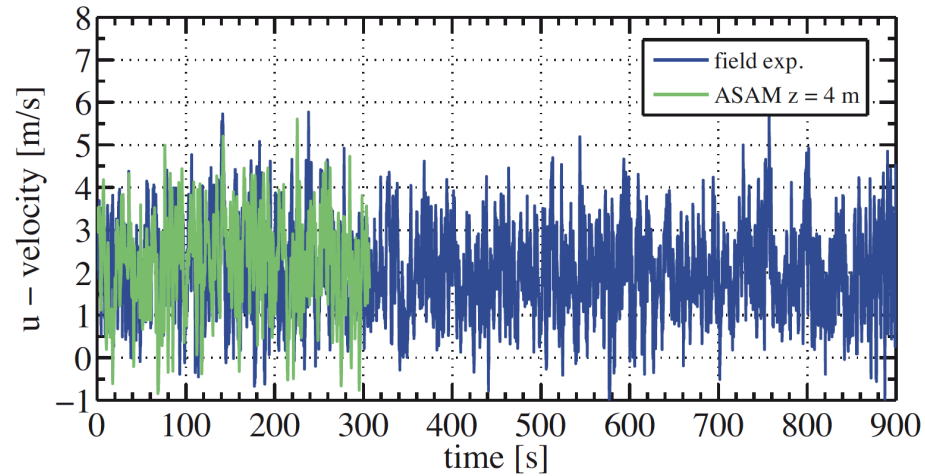
- Generated inflow time series against measured one at south tower
- Good comparison



- PDF of wind direction deviation



# Comparison at center tower



# Tracer gas dispersion event

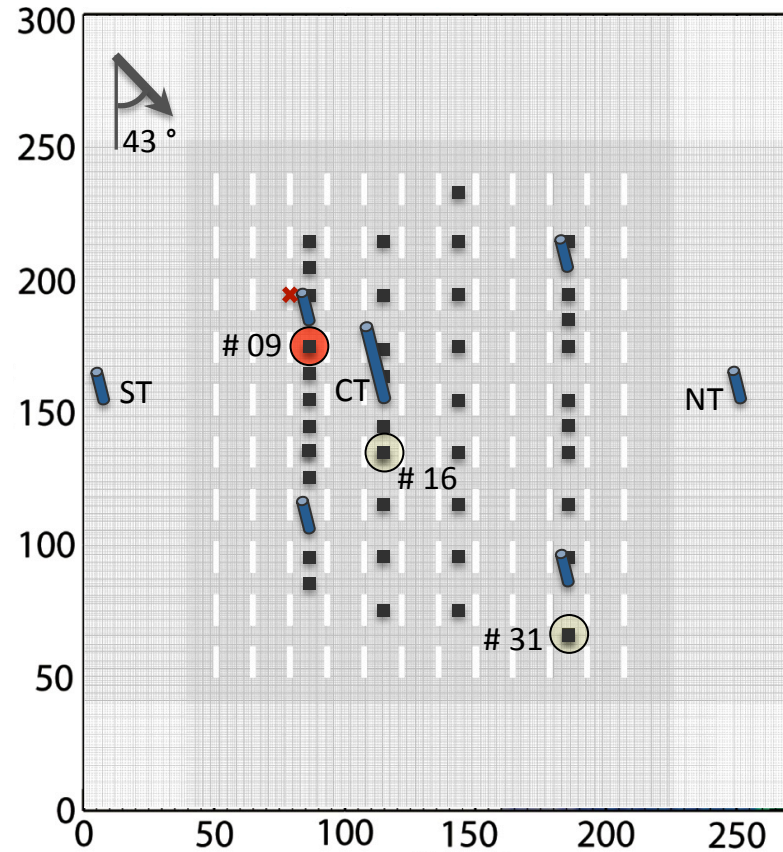
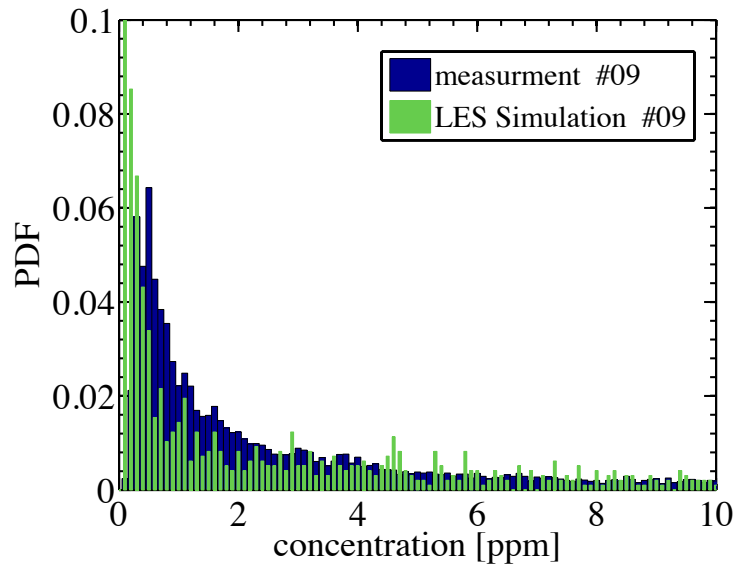
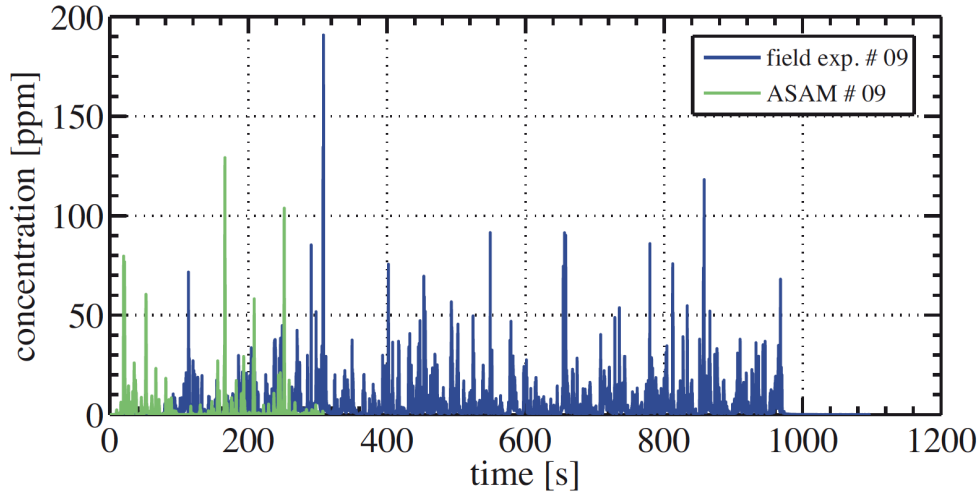
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The logo for TROPOS, consisting of the word "TROPOS" in a bold, black, sans-serif font, centered within a white rectangular box. This box is surrounded by a thick, blue, textured border that has a grainy, stippled appearance.

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# Comparison with experimental measurement

## Station # 09

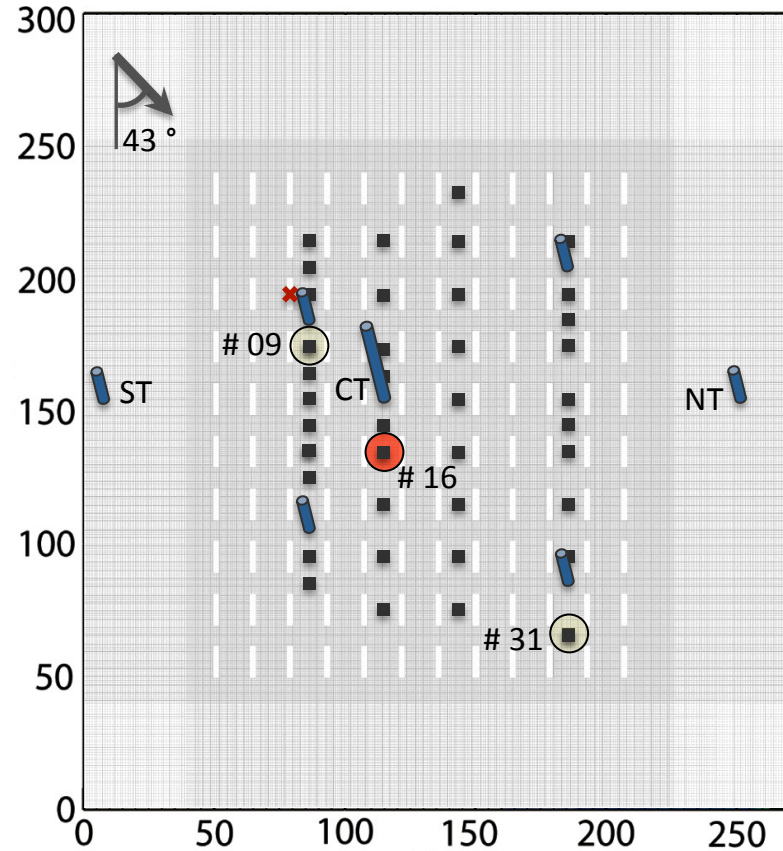
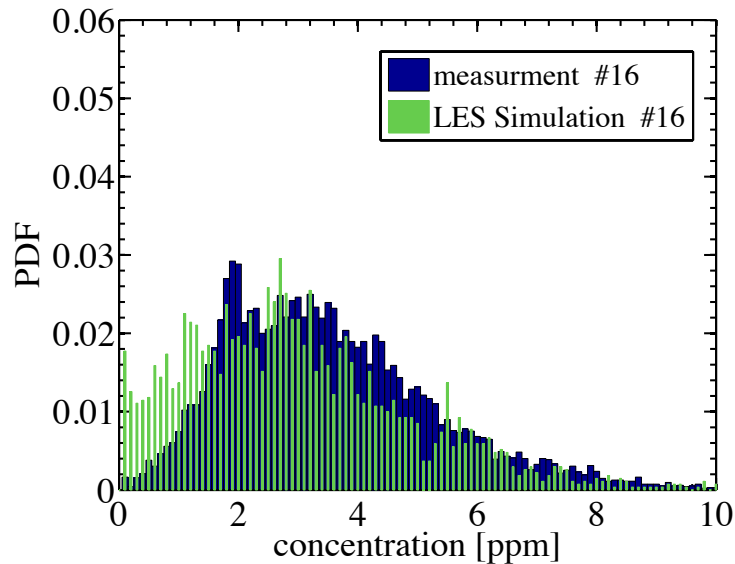
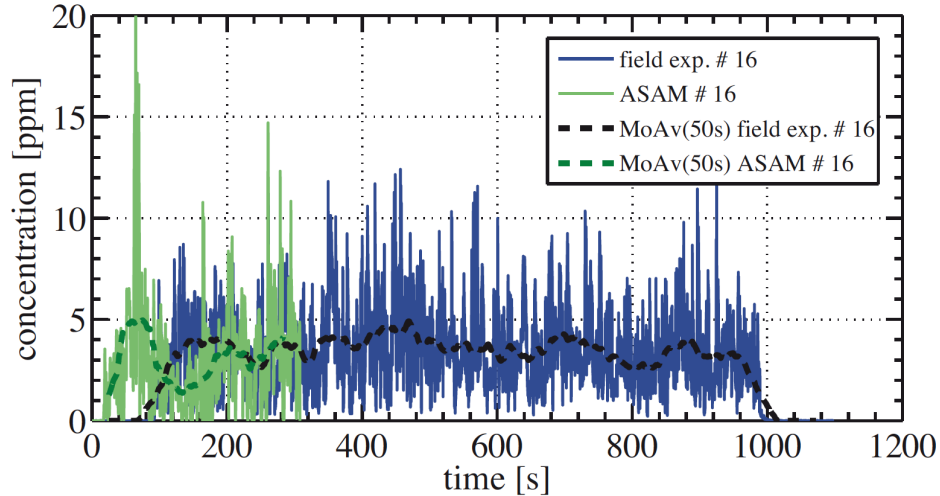


- Largest peaks about 50 ppm
- High probability above 0 ppm
- Also comparable values for larger peaks

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# Comparison with experimental measurement

## Station # 16

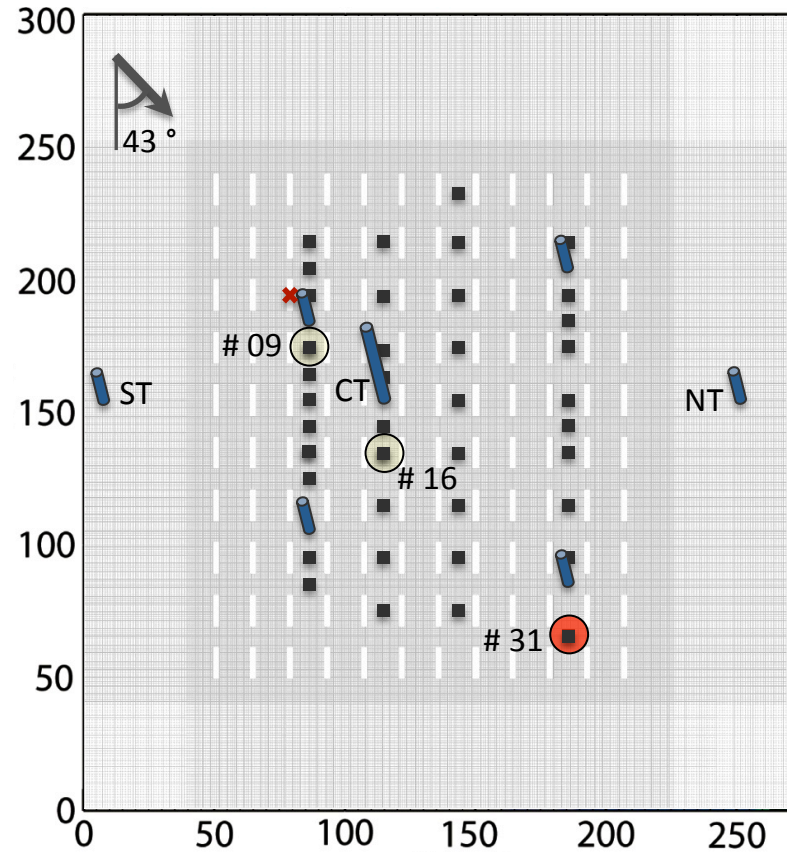
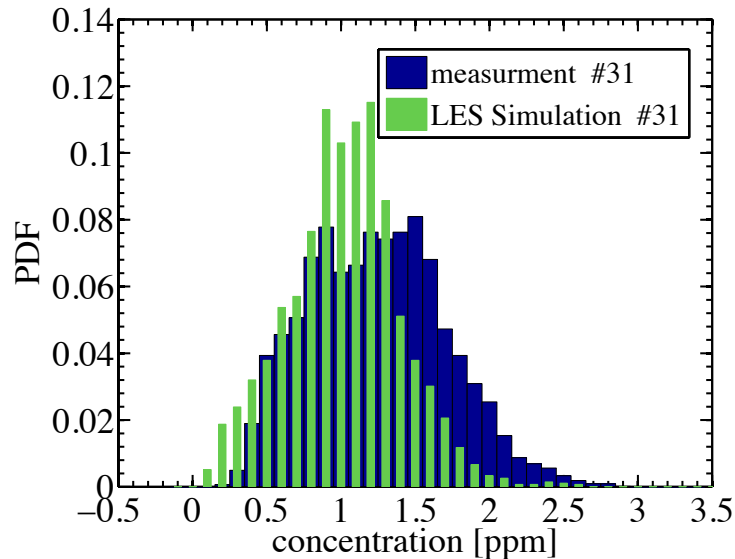
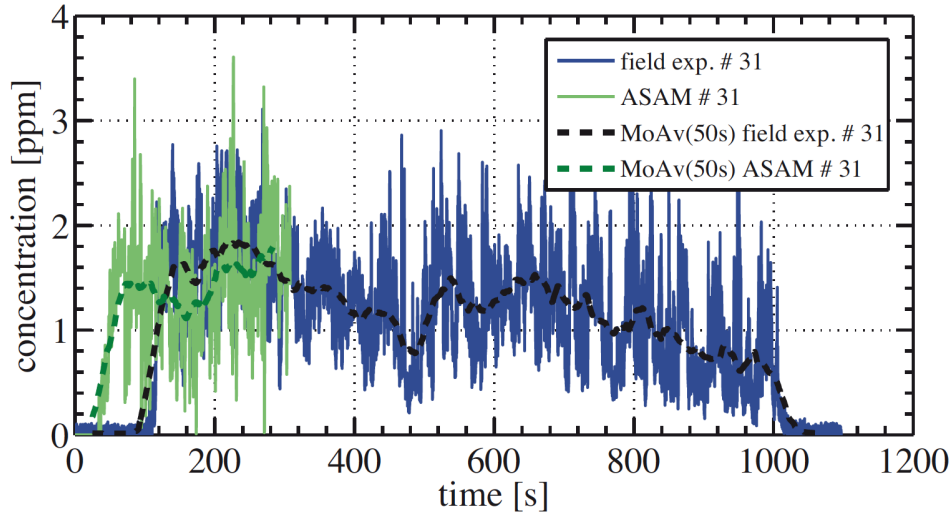


- Real large peaks vanished
- Pdf different to station # 09
- More Gaussian like behavior

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# Comparison with experimental measurement

## Station # 31



- Rarely 0 ppm concentration
- Large peaks are removed
- Still fluctuating with values of 1 ppm
- Sub-grid model

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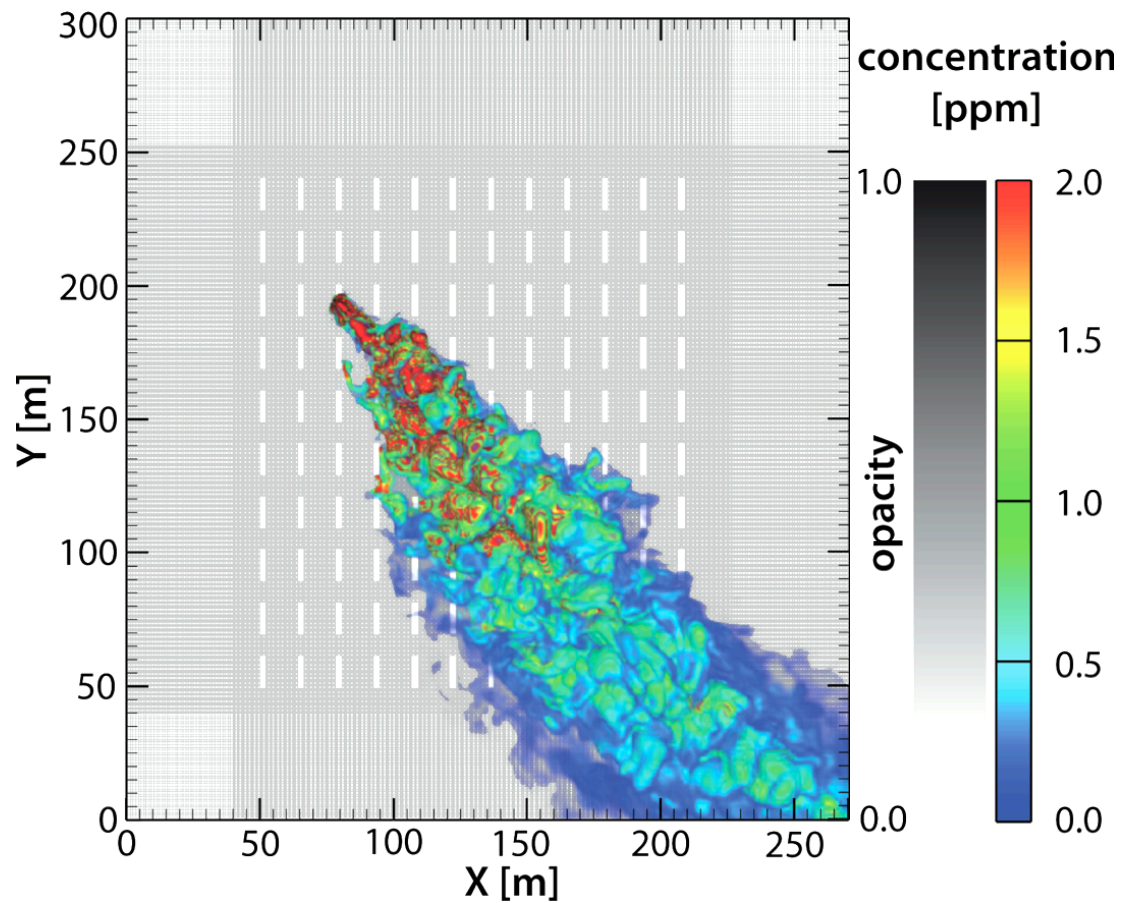
# Summary

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- Able to set up predefined turbulent structure for inflow condition (scales and intensity)
- Simulate near full scale urban area
- Spatial resolution is sufficient to resolve the significant flow structures
- Peaks in wind speeds and concentrations are comparable with the measurement data with respect to peak values and frequency
- → do simulation with real urban geometry and simulate traffic emissions as line sources in the street canyons

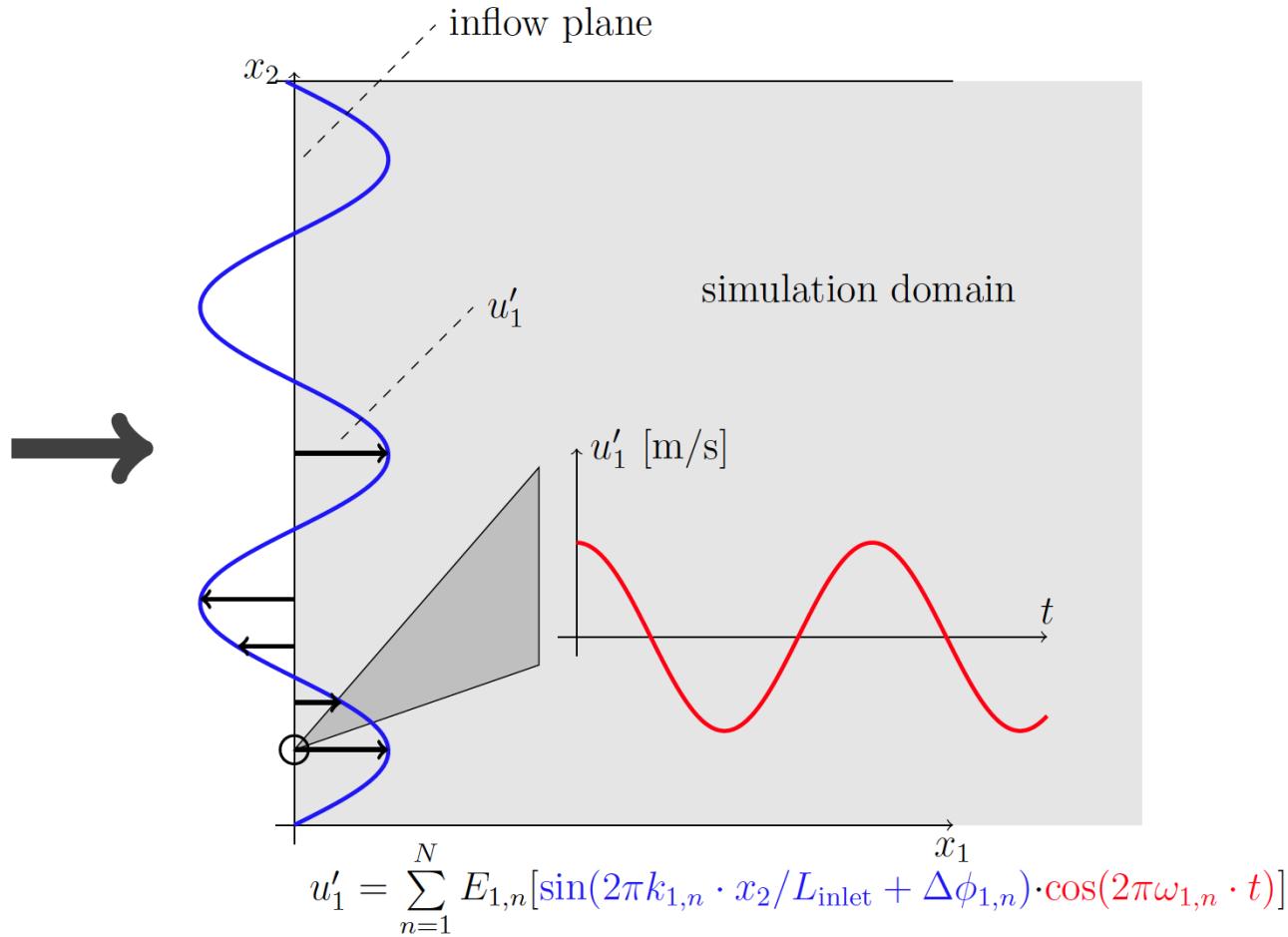


# Thank you for listening! Questions?

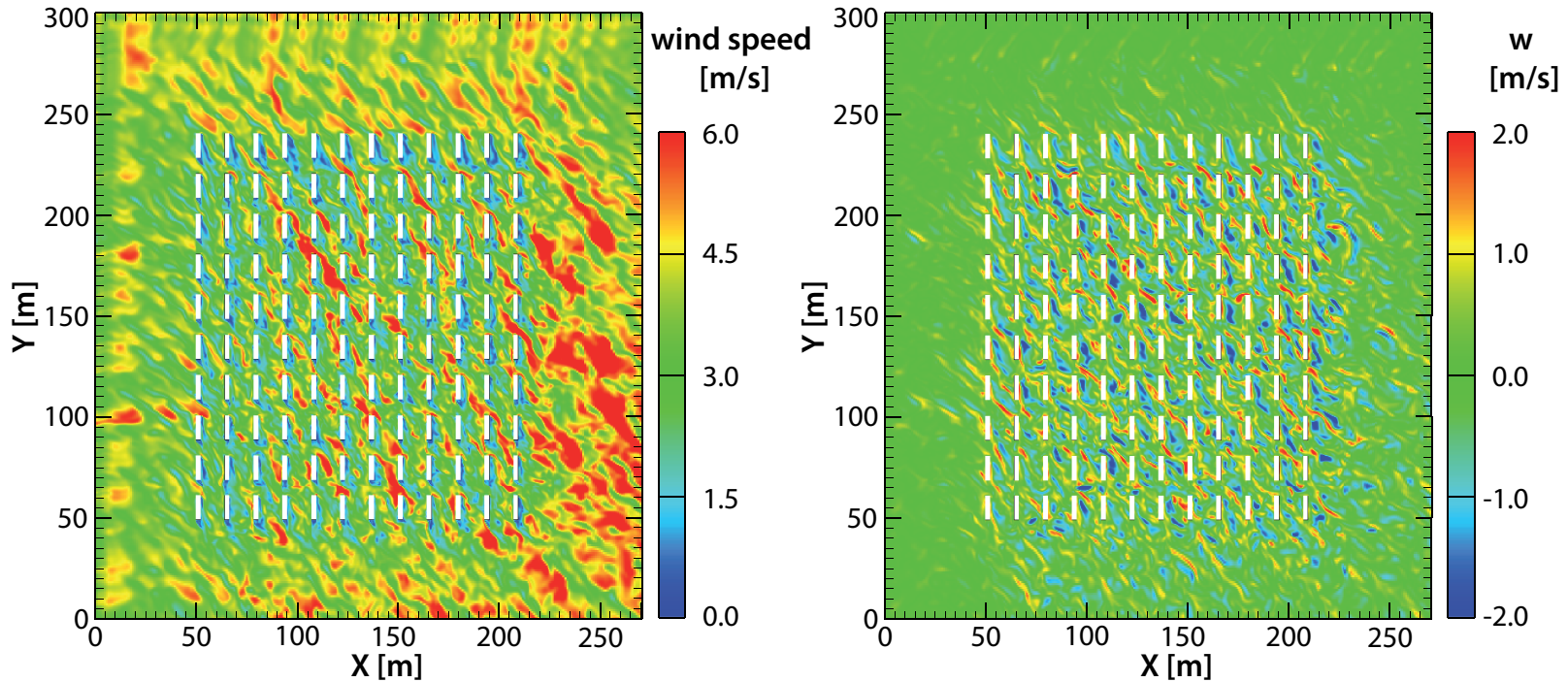


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# Modell-Setup für MUST-Simulation

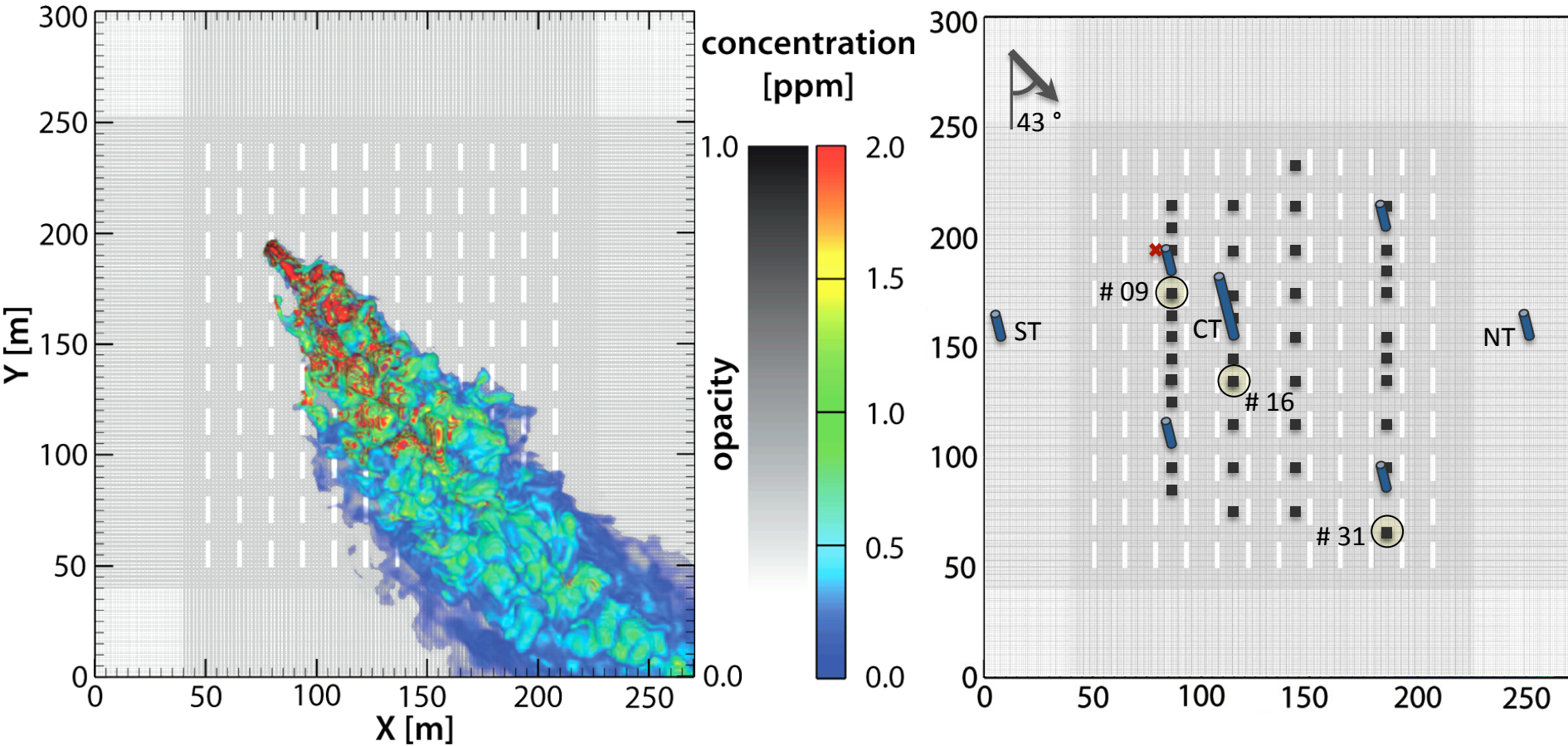


# Modell-Setup für MUST-Simulation



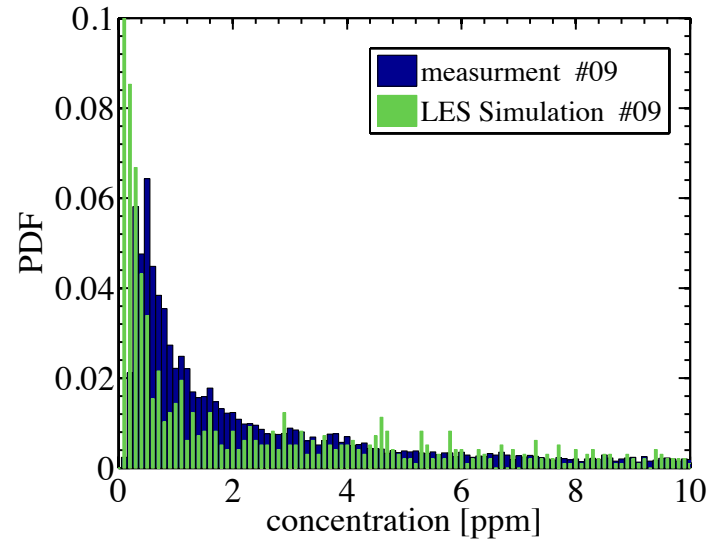
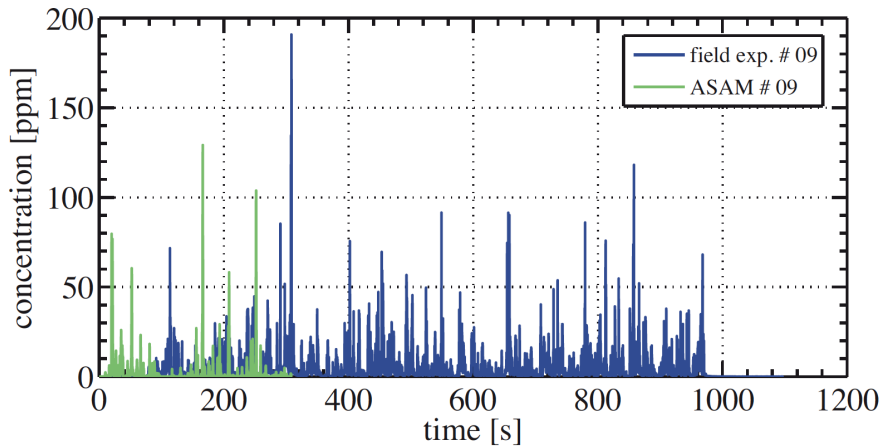
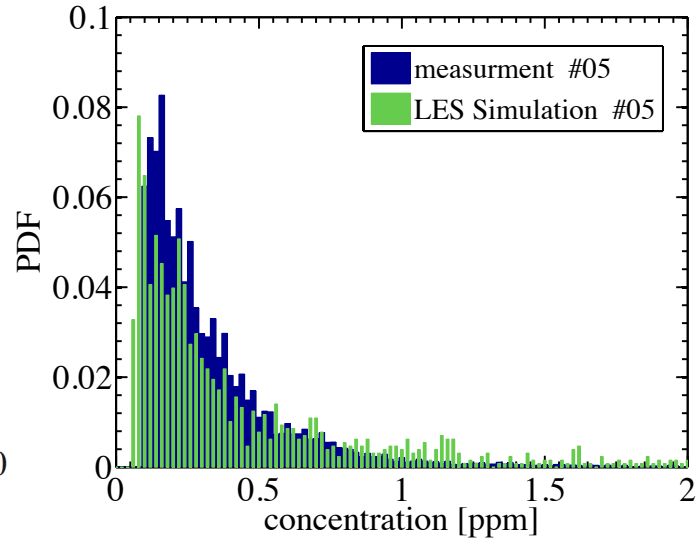
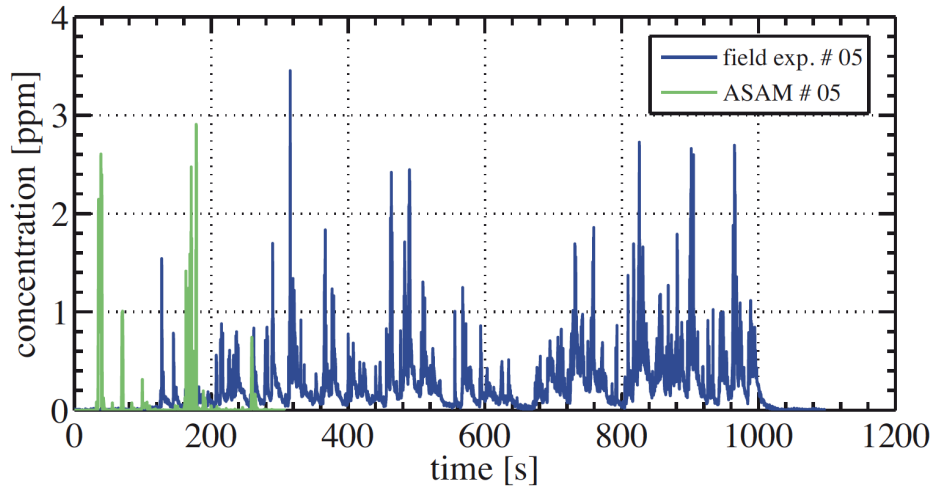
- Dynamic flow structures in street canyons
- Container trigger vertical motion inside the container domain

# Tracer gas dispersion event

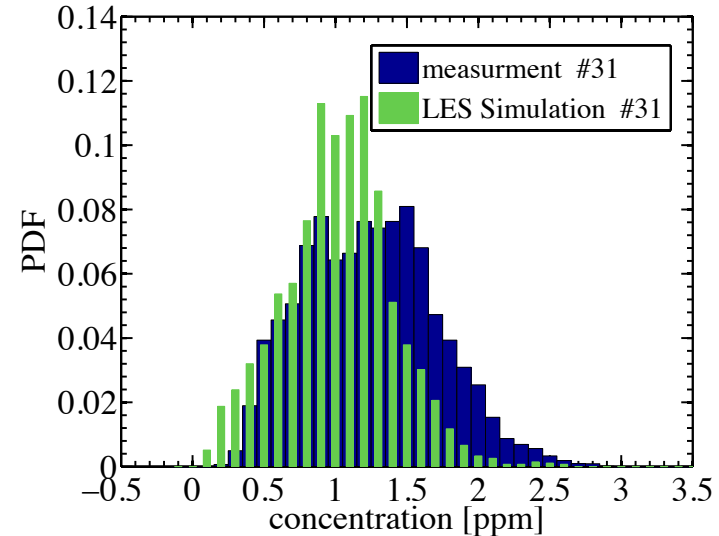
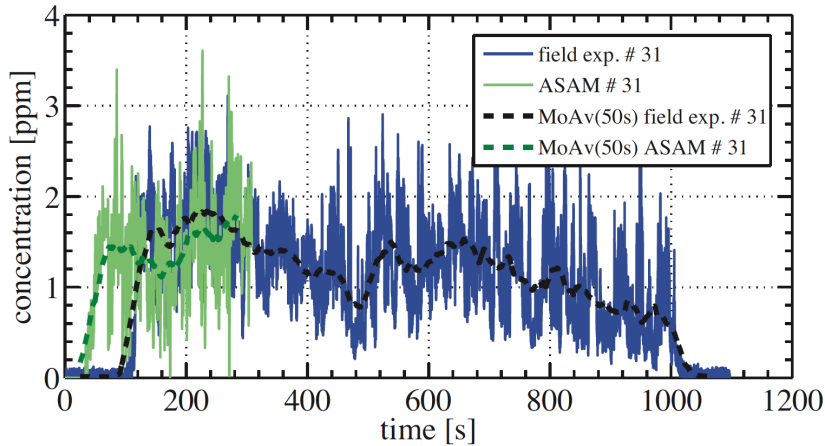
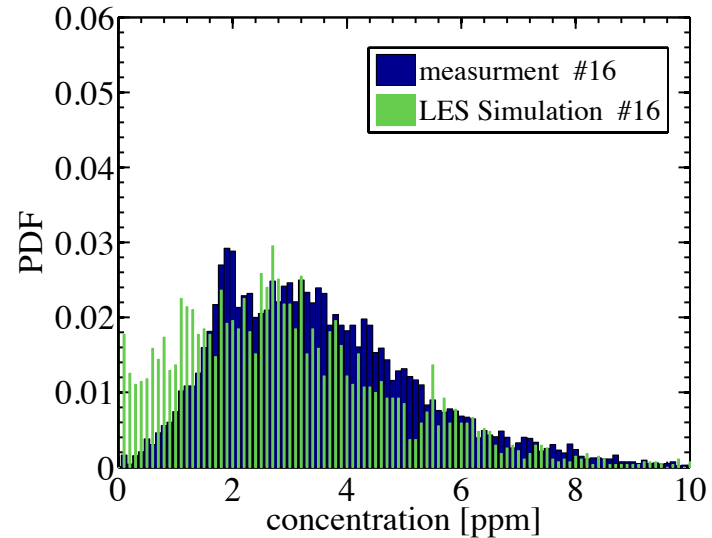
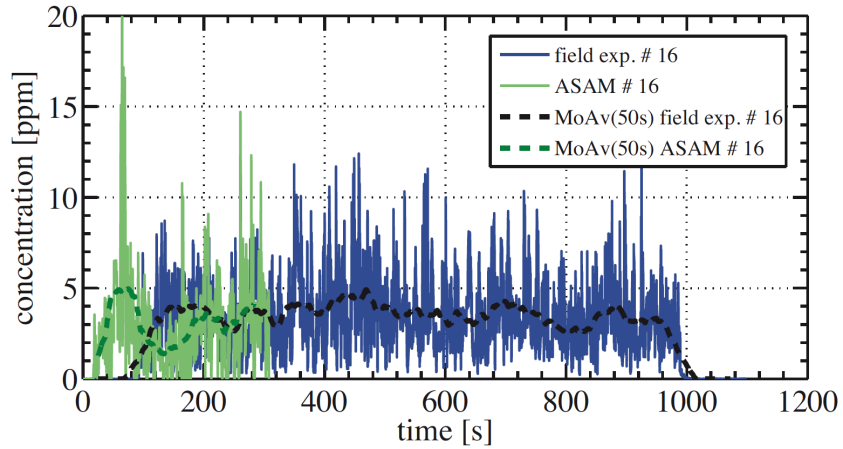


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# Modell-Setup für MUST-Simulation



# Modell-Setup für MUST-Simulation



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