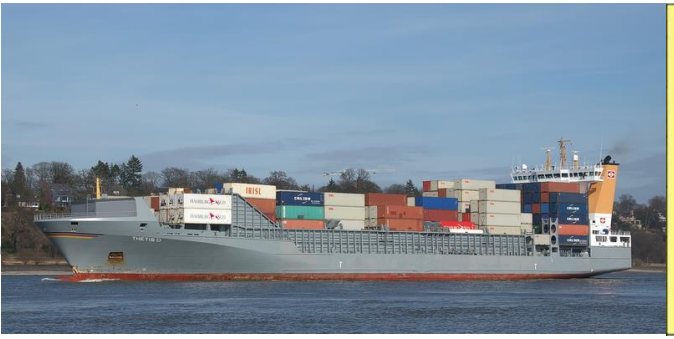
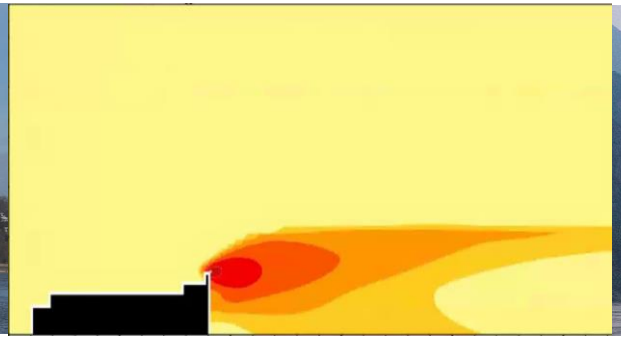
Microscale Ship Plume Dispersion Modeling for Harbor Areas

R. Badeke, V. Matthias, D. Grawe and H. Schlünzen





Institute of Coastal Research

In cooperation with Fudan University Shanghai

Project **ShipChem**

5th of September 2019

Helmholtz-Zentrum Geesthacht

Centre for Materials and Coastal Research

INTRODUCTION

Key Challenges of Ship Emission Modeling

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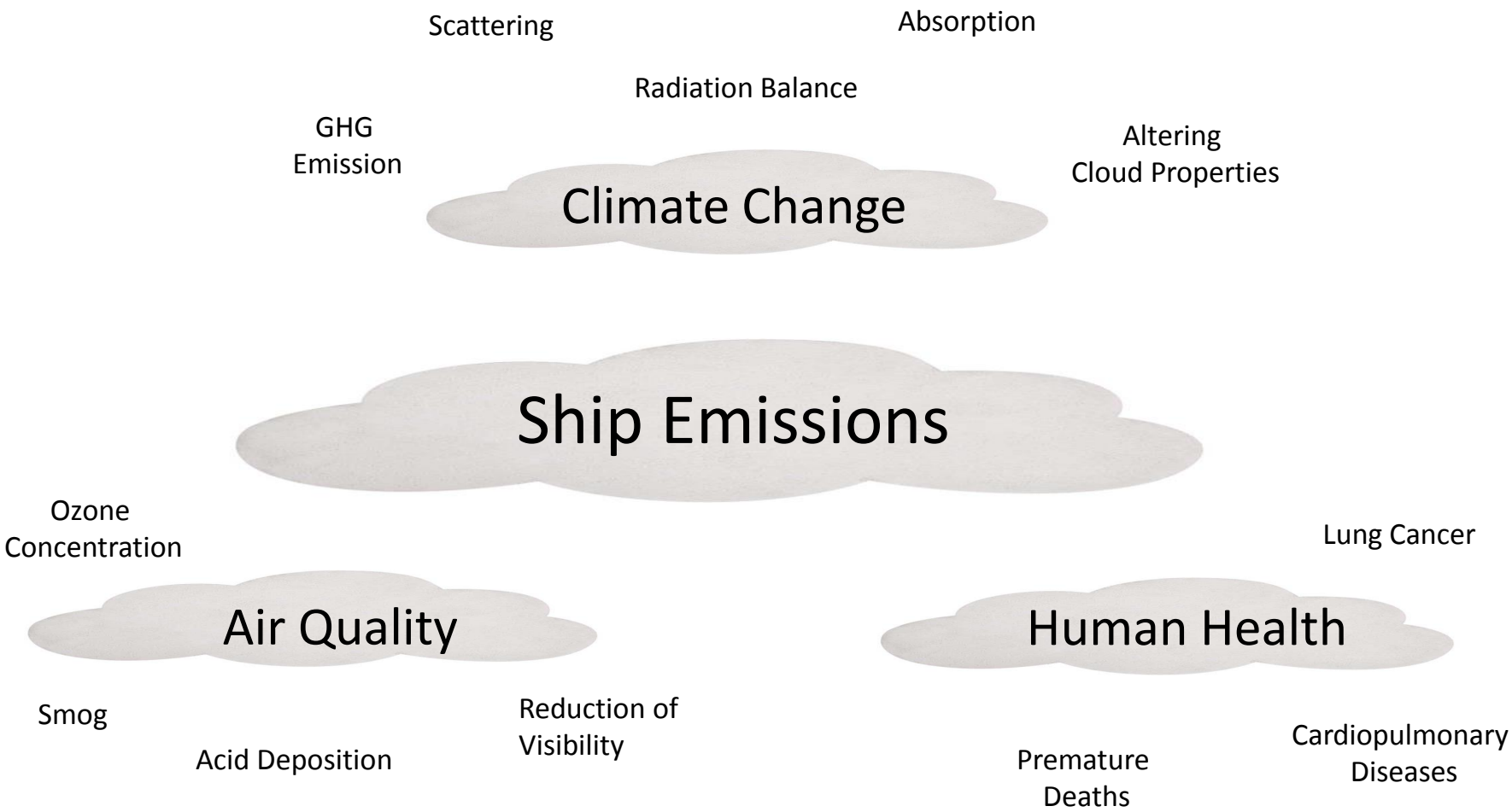

INTRODUCTION

Population Density of Hamburg

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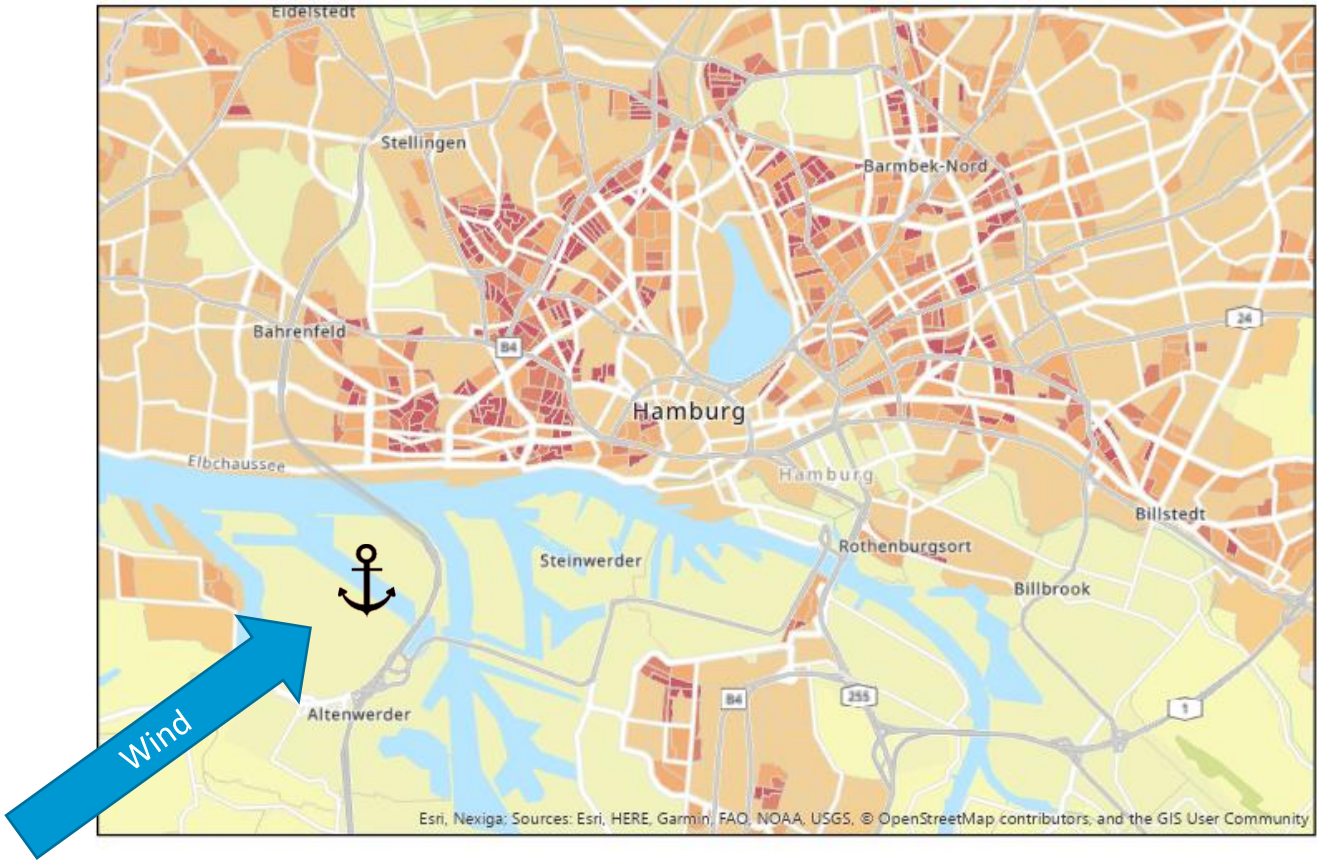


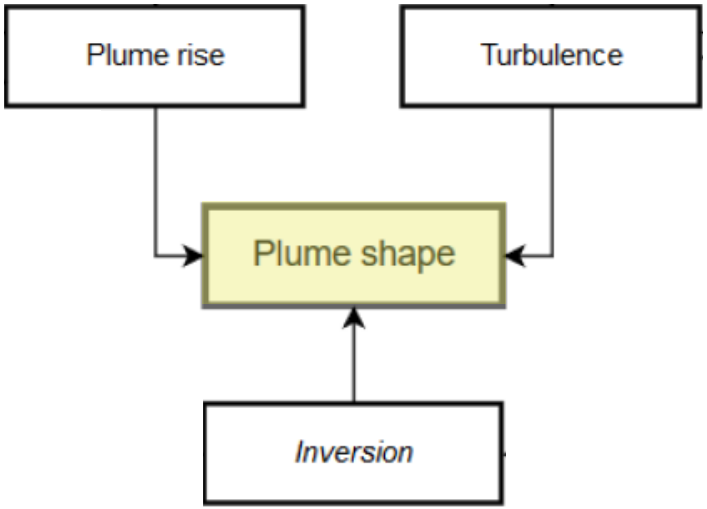
0 2 4 8 Kilometers

Population Density

- 0 - 570 people per sq km
- 570 - 6,800 people per sq km
- 6,800 - 13,100 people per sq km
- 13,100 - 19,400 people per sq km
- 19,400 - 600,000 people per sq km

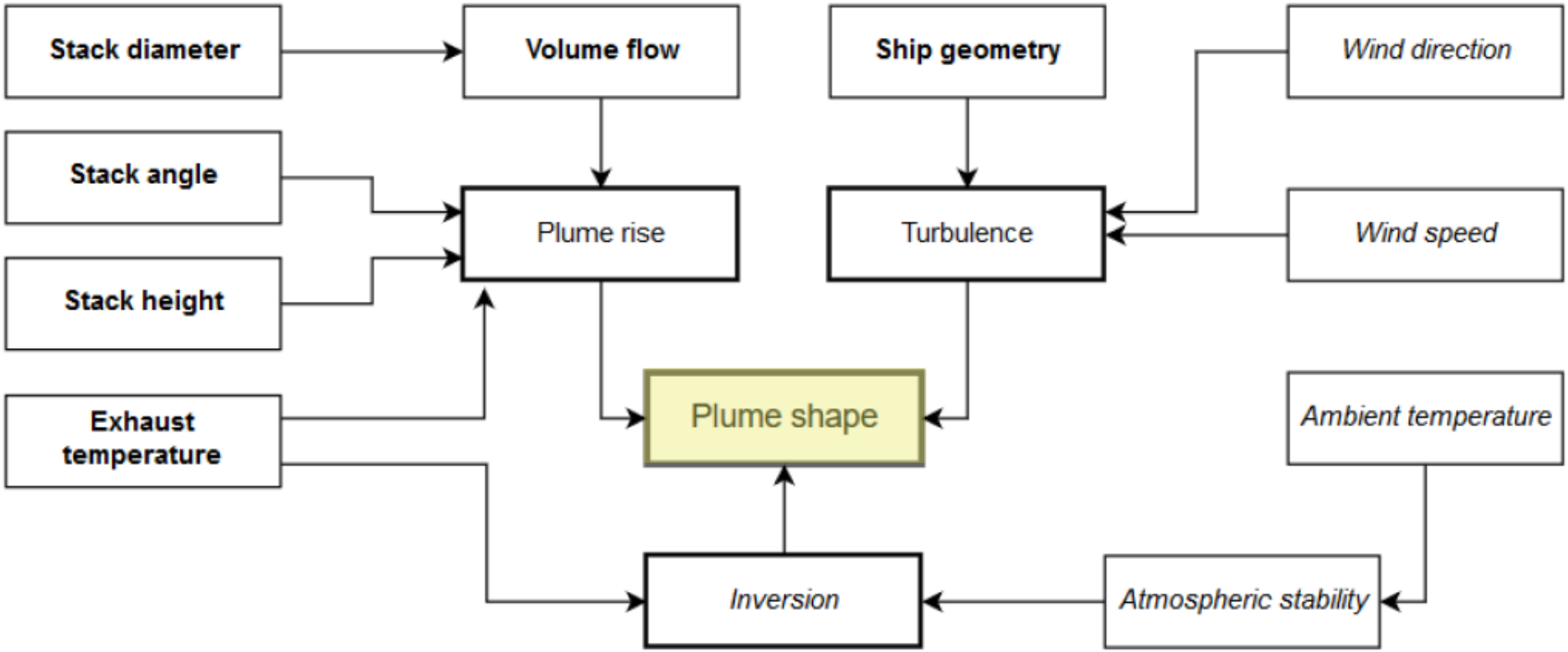
INTRODUCTION

Conceptual Model



INTRODUCTION

Conceptual Model



INTRODUCTION

Aims of the research

- Improve the ship plume emission and transport modeling in city-scale models

➔**Plume rise**

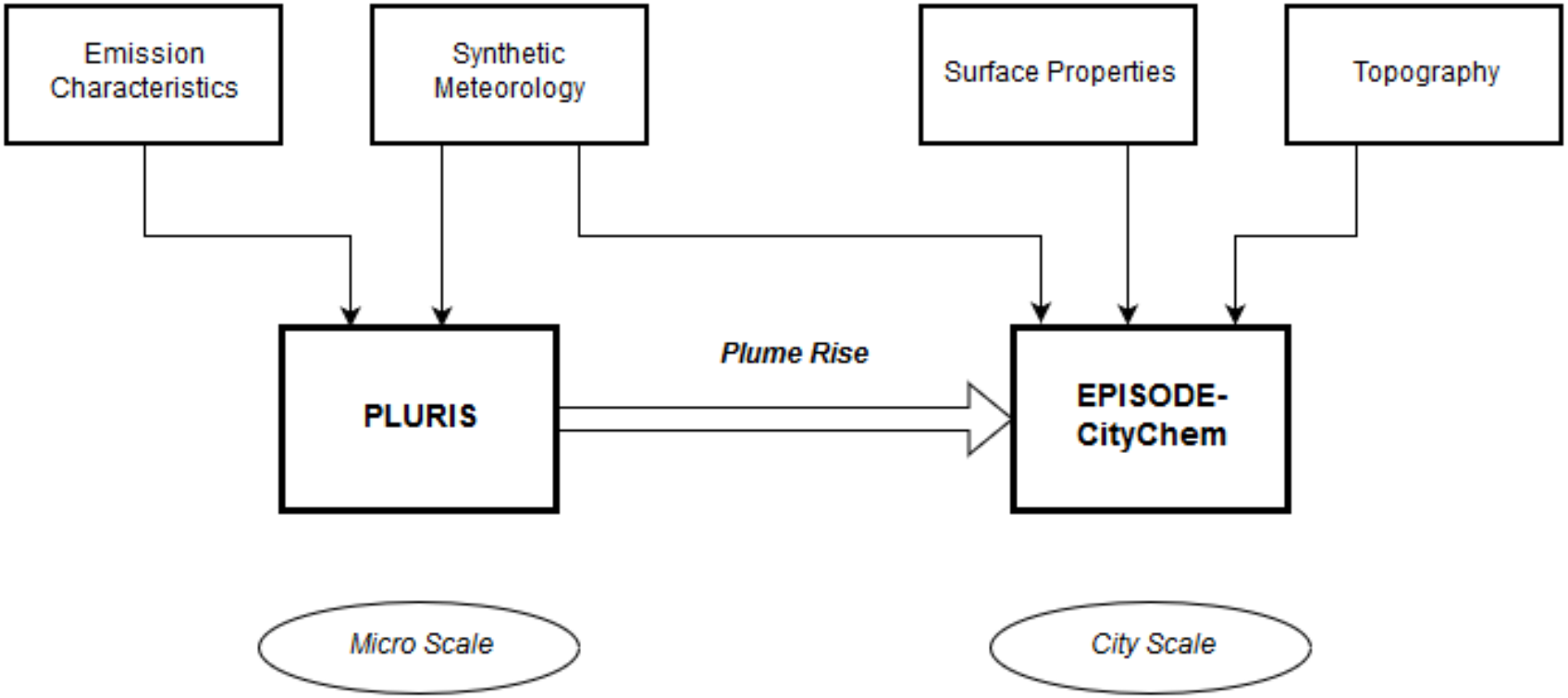
➔**Turbulence**

- Connecting Microscale and City-scale models

➔**Handover values for vertical concentration profiles**

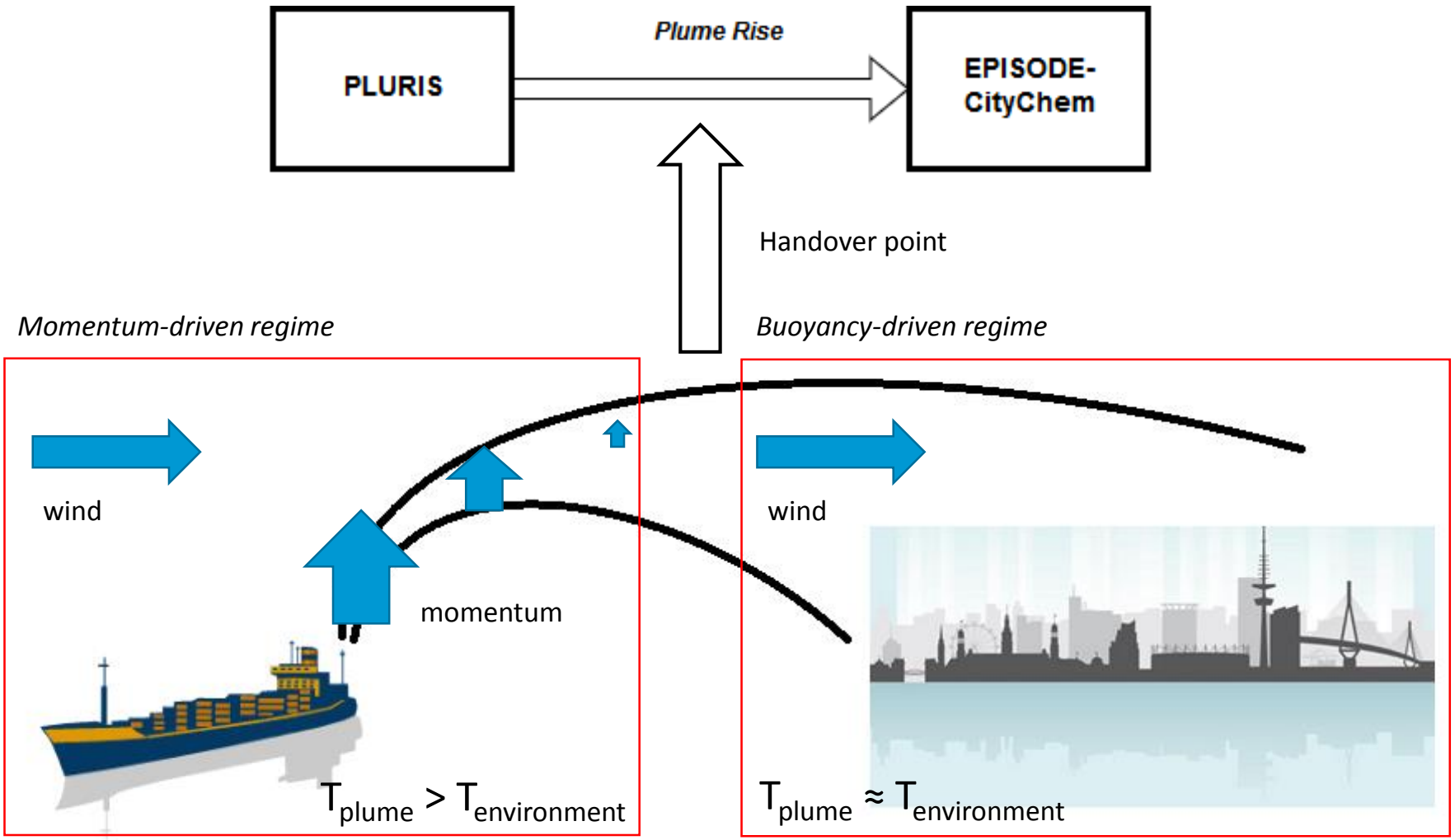
METHODS

Model Chain



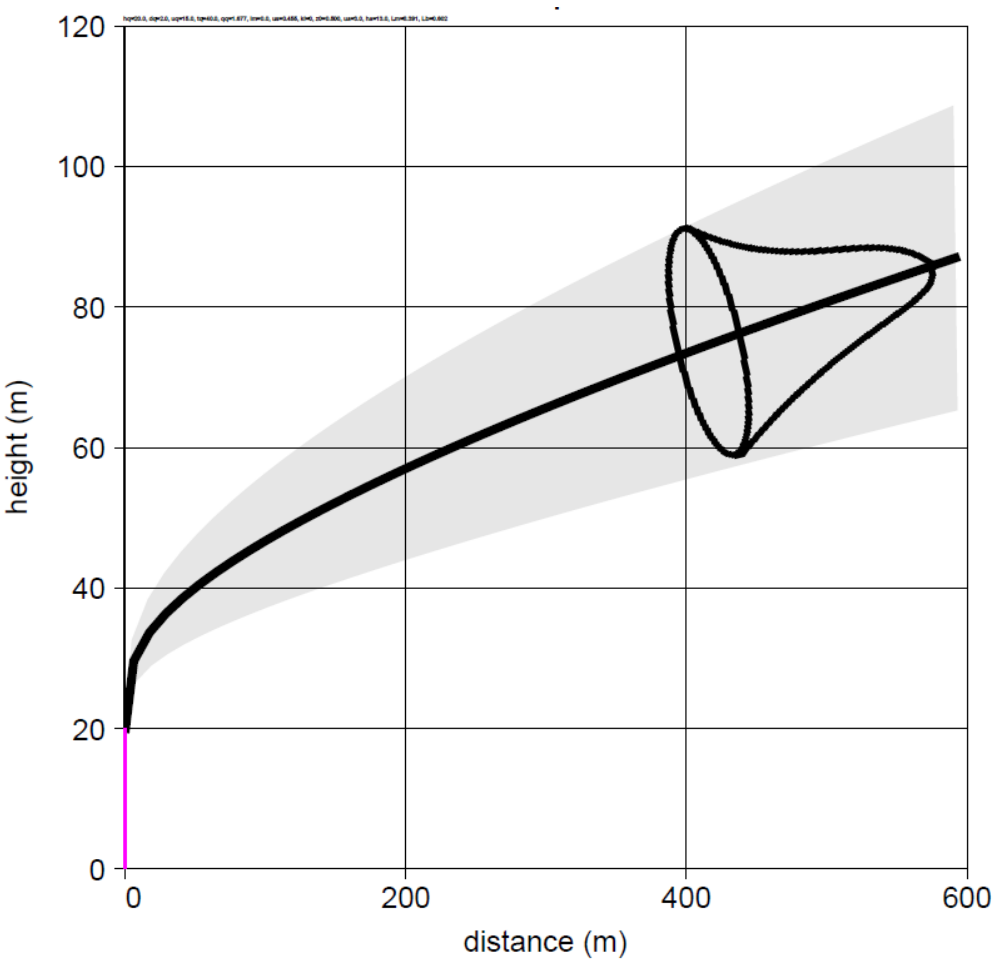
METHODS

Model Chain



METHODS

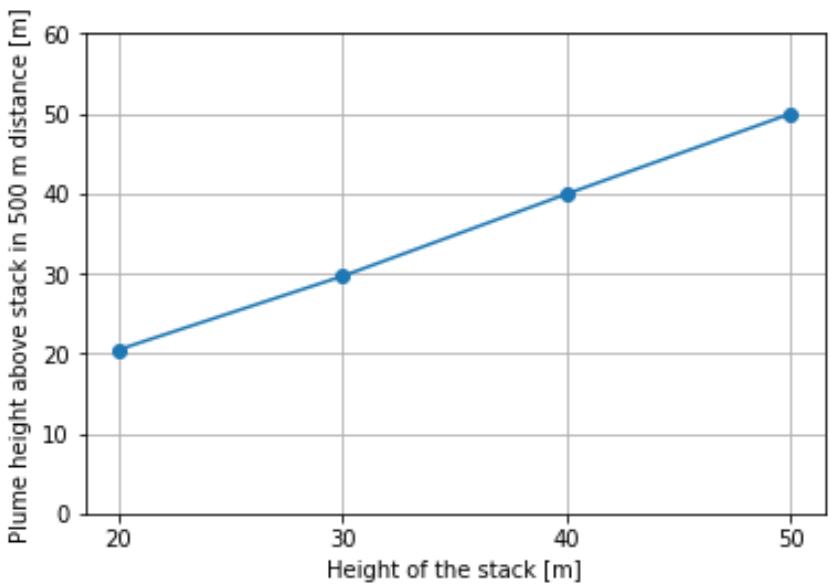
PLURIS

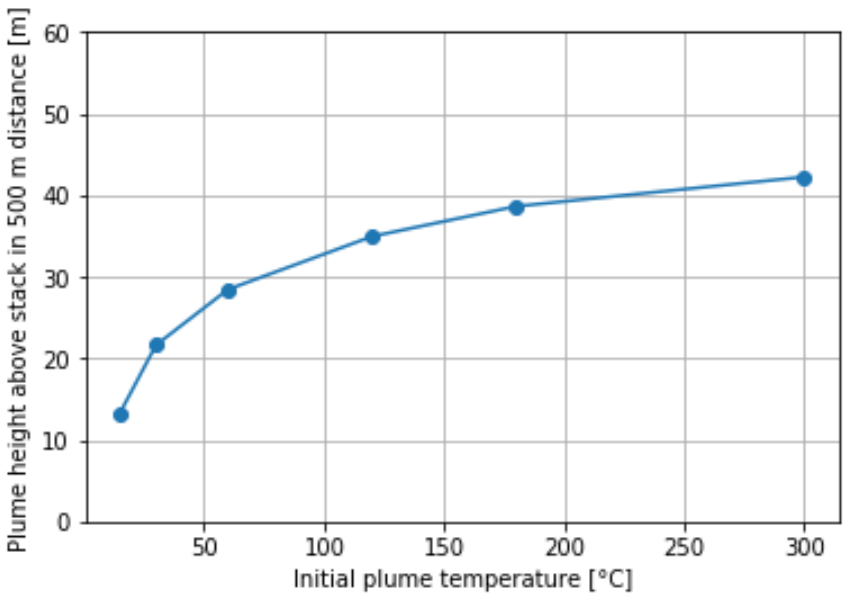


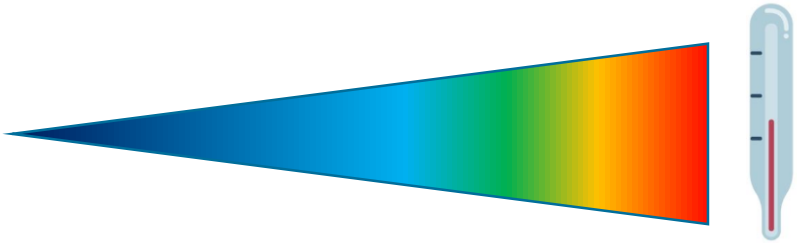
- Analytical solution of bent-over plumes by integral modeling
- Conservation of:
  - mass
  - momentum
  - energy
  - scalar quantities (e.g. T, c)
- Parametrization of entrainment function

RESULTS

PLURIS







RESULTS

Calculation of Handover Values

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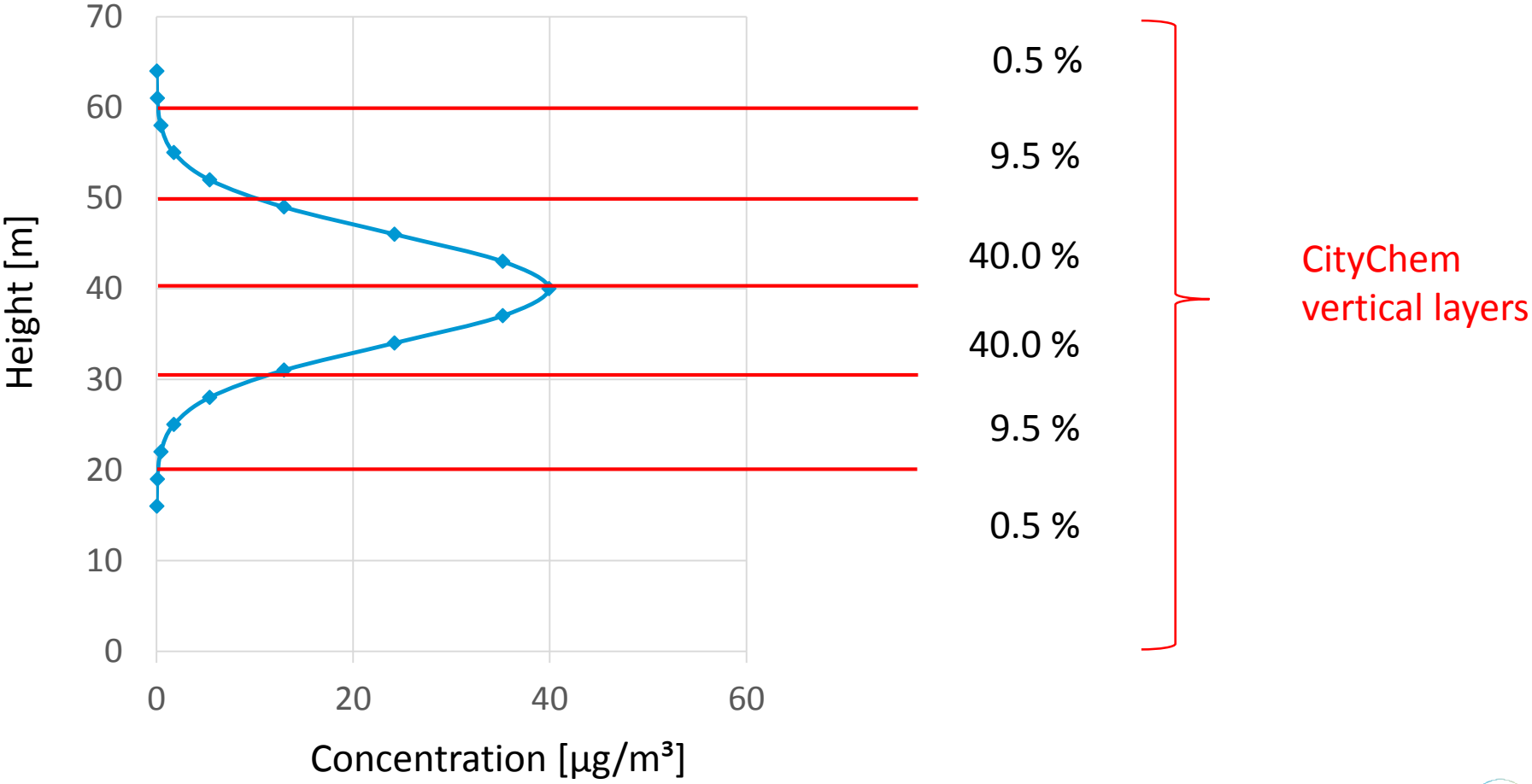
Handover Criteria:

- Plume dispersion is dominated by buoyancy
- Plume temperature equals surrounding temperature



RESULTS

CityChem

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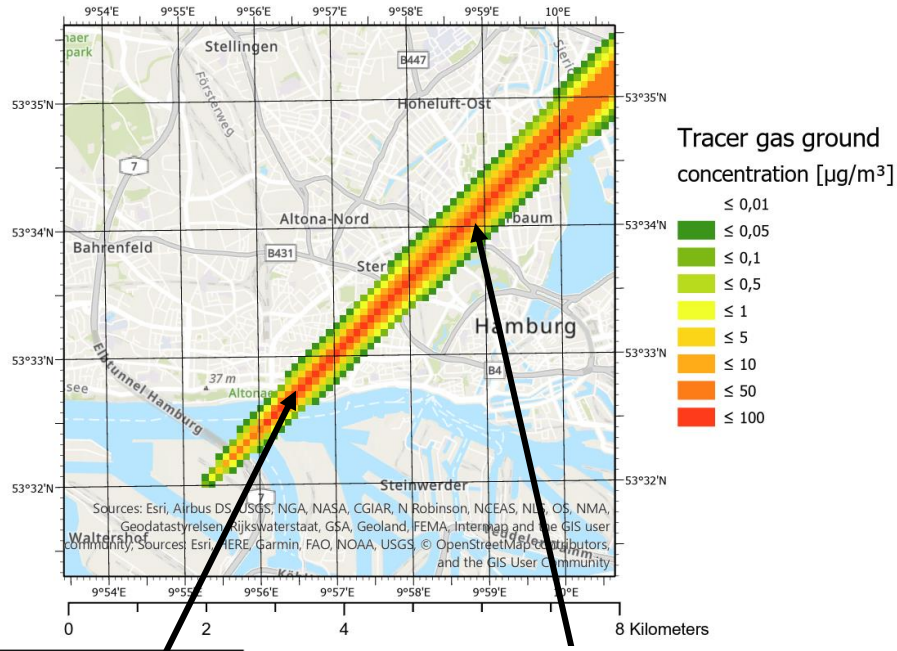
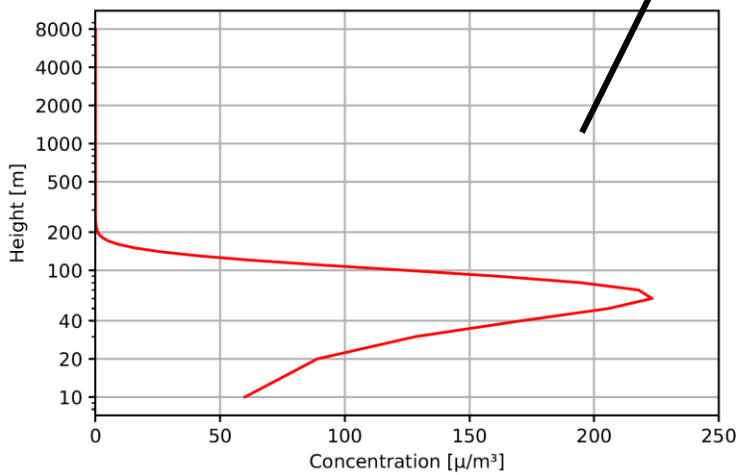
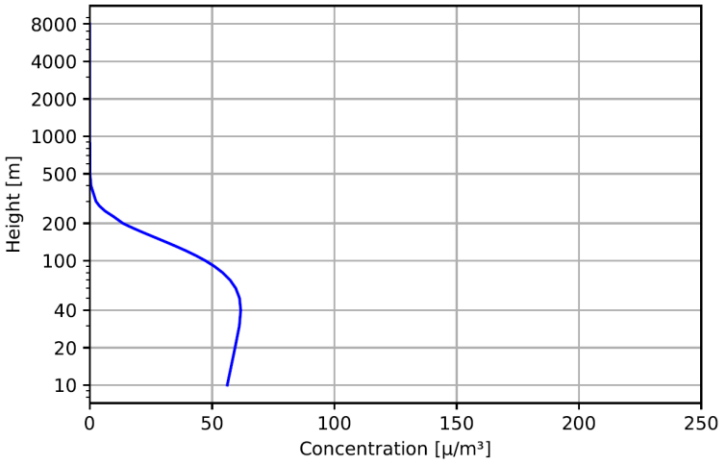
v_{wind} = 5 m/s
v_{plume} = 10 m/s
T_{air} = 15 °C
T_{plume} = 200 °C
Emission: 25 kg/h







RESULTS

Dependency on Stack Height

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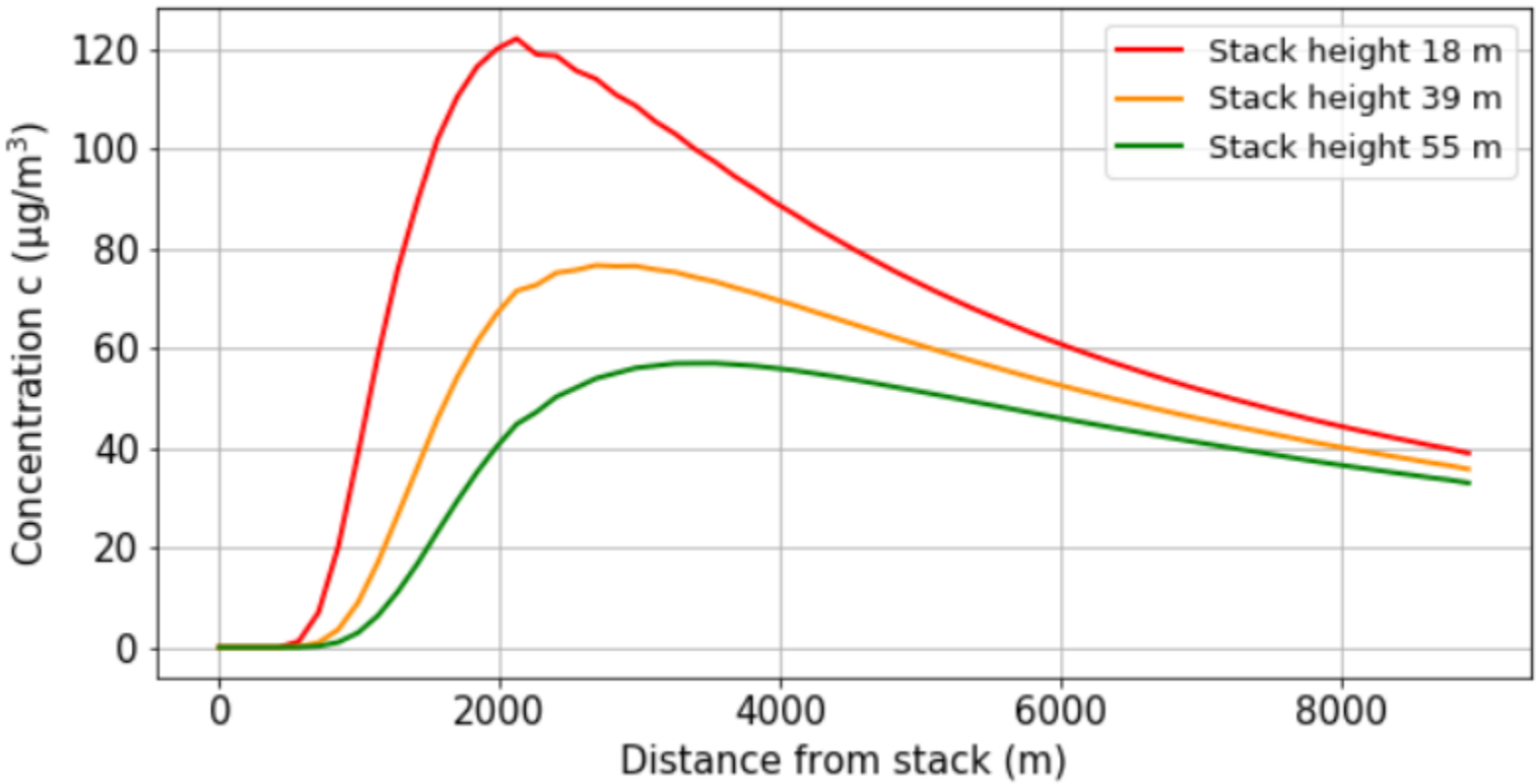
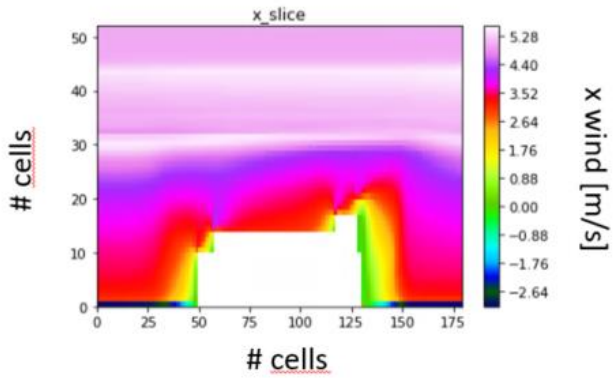


K. Reinck

OUTLOOK

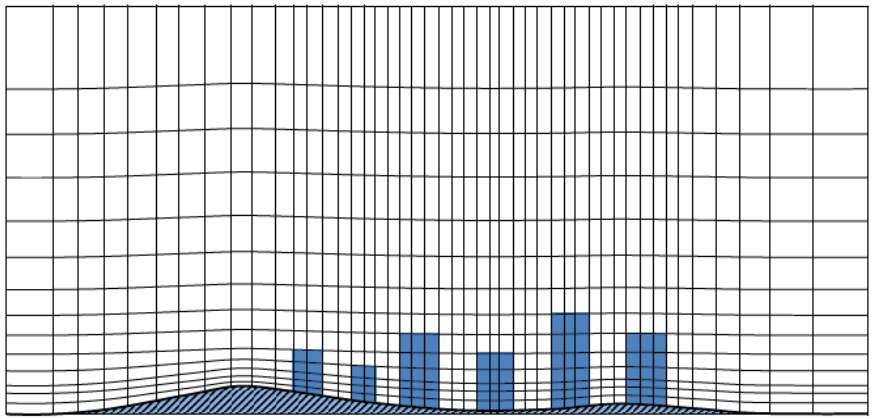
Mitras

- Numerical 3D modeling of meteorological parameters, concentration, etc.
- High resolution of 1 m * 1 m * 1 m possible
- Obstacle resolving ➔ considers object-induced turbulence



Equations:

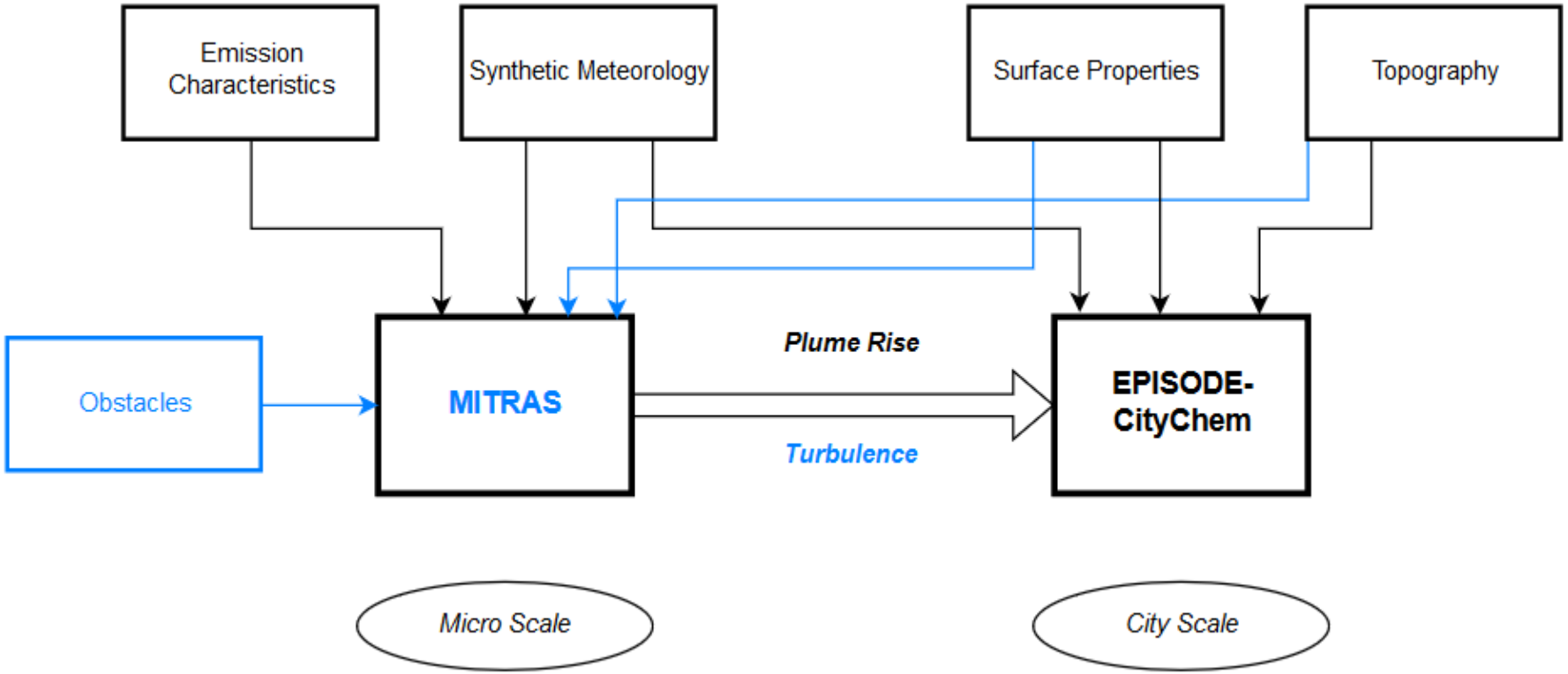
- Navier-Stokes Equation
- Continuity Equation
- Conservation Equation for scalar quantities



Salim et al. (2018)

OUTLOOK

Model Chain

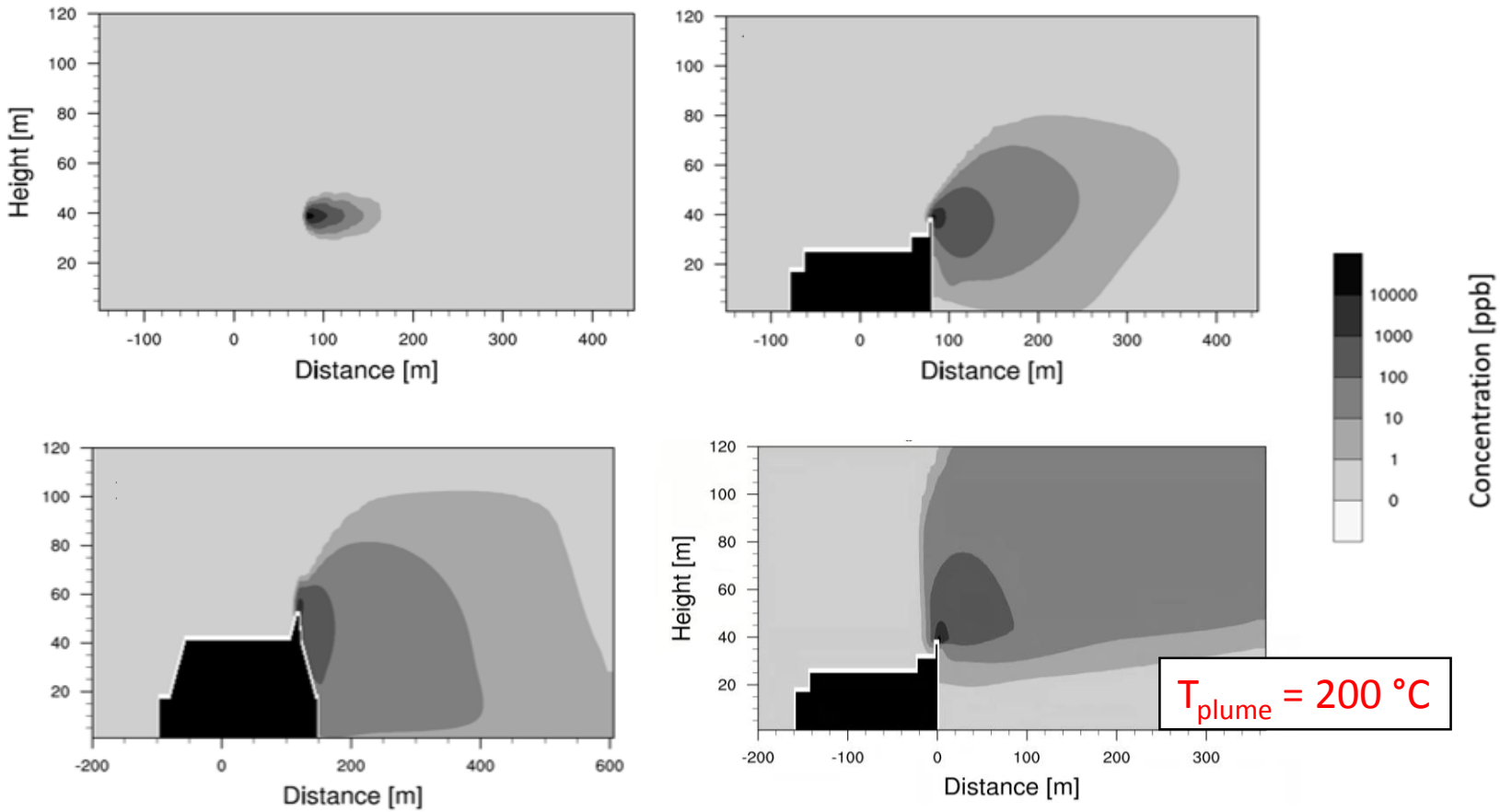


OUTLOOK

Mitras

v_{wind} = 5 m/s
v_{plume} = 10 m/s

T_{air} = 15 °C
Emission: 20 kg/h



OUTLOOK

What we want to do:

- Include (photo-)chemical transformation
  - $NO_x + O_3$
  - SO_2
  - PM2.5
- Simulate real situations and compare model results with measurements

What we need:

- Ship-specific data
  - Number of stacks, engine type, engine power use
  - Emission data (chemical composition, emission rate)
- Close collaboration between measurement groups and (other) modelers (CFD, LES)

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