FINNISH METEOROLOGICAL INSTITUTE

LEScape

Vaarallisen päästölähteen nopea paikantaminen ja vaikutusalueen määrittäminen kaupunkiympäristössä

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Perustiedot

- **Hanke:** Vaarallisen päästölähteen nopea paikantaminen ja vaikutusalueen määrittäminen kaupunkiympäristössä (LEScape)
- **Projektinumero:** 2500M-0078
- **Toteuttaja:** Ilmatieteen laitos
- **Vastaava tutkija:** Antti Hellsten
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  - Helsingin kaupungin pelastuslaitos
  - Neste Jacobs Oy
  - Neste Oyj

Outline

- Motivation
- The idea of LEScape
- Restrictions and limitations
- Status of the work

Motivation

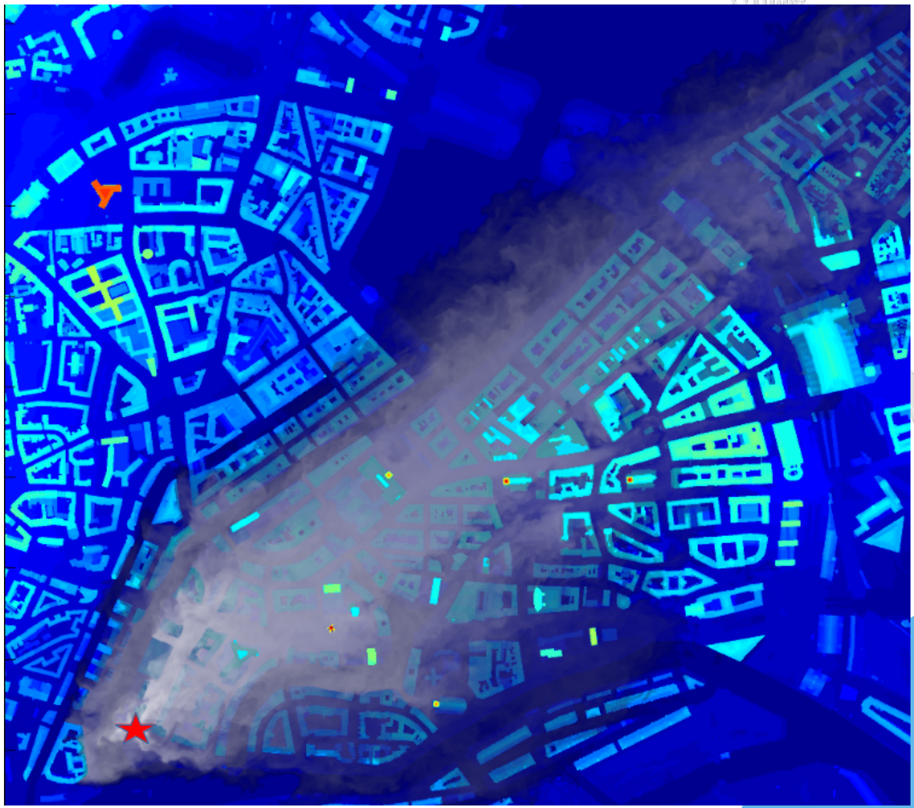
- Releases of airborne hazardous materials (hazmat):
  - Urban areas (quite small probability but possibly high number of influenced people):
    - Chemical transport accidents
    - Toxic fires
    - Terrorist attacks
    - ...
  - Industrial areas (higher probability but possibly lower number of influenced people):
    - Leaks
    - Fires
    - Explosions
    - ...
- However, in this project we focus only on one particular area: central Helsinki.

Motivation

- **Goal**: the LEScape system now under development will eventually become a quick and easy-to-use tool for the **first responders.**
- There exist “traditional” models for this purpose such as the Escape model also developed at FMI.
- However, such traditional models cannot predict dispersion in built areas realistically as they cannot take the effects of buildings, terrain shape and e.g. trees into account.
- This is why we think that a new approach is needed.

Motivation

- Dispersion in built environment is different and much more complicated than dispersion over approximately flat and open terrain.
- Computational Fluid Dynamics (CFD), especially Large Eddy Simulation (LES) can take the effects of built environment into account.
- **Animation.**



Motivation

- However, even the most simplified CFD is way too time consuming to be used in real hazmat-release situations.
- Therefore pre-computing is the only way to utilize CFD in the first-response model development.
- When performing pre-computations, the source is obviously unknown!
- So, how to account for arbitrary sources?

Motivation

- We cannot afford running CFD separately for all imaginable sources even in a limited area in numerous meteorological conditions. So how to pre-compute dispersion for any arbitrary release?
- US Naval research Laboratory (NRL) answered this question by introducing so called dispersion nomographs → CT-Analyst.
- CT-Analyst is the only first-response model tool of its kind (non-traditional so to say) in the world.
- It is used in USA and in Germany.
- We are now aiming at this goal in an even more advanced way.

The idea of LEScape

- Our answer to this question is to use a Lagrangian-stochastic (LS) particle model with distributed sources combined with **a specific on-line analysis algorithm.**
- The analysis algorithm is coupled with the LES-LS model.
- It keeps track of plumes (=affected areas and concentrations) formed by particles from all possible sources in the simulation domain.
- It also keeps track of the footprints (=source area functions) of all possible observation points in the simulation domain.
- In the end of a LES-LS run it writes all the necessary data in a large data set in the NetCDF 4 format.
- LES-LS has to be run for a sufficient number of different meteorological conditions (for instance 18 mean wind directions, etc.).

The idea of LEScape

- Computational particles represent any airborne hazmat concentration.
- Particles are released on all locations within the domain considered as possible release locations including also building roofs.
- In the LS-model each particle knows its origin.
- Therefore plumes from individual sources (and footprints of individual observations) can be constructed by examining the particle data during the LES-LS run using the analysis algorithm.
- This may sound simple, but it is a complicated task within LES-LS simulations based on parallel computing.

The idea of LEScape

- Storing all the plumes (footprints) as 2-D distributions would require way too much memory and storage space as there will be approximately 500 000 plumes and footprints in each simulation.
- Therefore the plumes (footprints) are stored in a simplified 1-D form.
- Only certain 1-dimensional parameters are stored in each LES-LS run:
  - Plume (footprint) envelope left edge
  - Plume (footprint) envelope right edge
  - Cross-plume (footprint) averaged concentration (footprint function)
  - Cross-plume (footprint) location of the maximum concentration (footprint function)
  - Hazmat arrival time since the beginning of release [only for plumes]
  - Hazmat removal time since the end of release [only for plumes]
- The data set will include these data for all plumes and footprints in the target area in all considered meteorological conditions.

The idea of LEScape

- The precomputing phase for the focus area (production runs) takes a lot of time (several months).
- When LEScape is used, the LEScape server software will first find out the prevailing meteorological conditions on the site, select and read the relevant part of the data stored in the LEScape data set, and reconstruct the plume(s) (or footprint(s)) as requested by the user through the user-interface (client).
- **The user-interface displays the desired results on a map.**
- **The user should get the answer practically instantly.**
- The server-part will run on an FMI server and the user runs the client on his/her computer.

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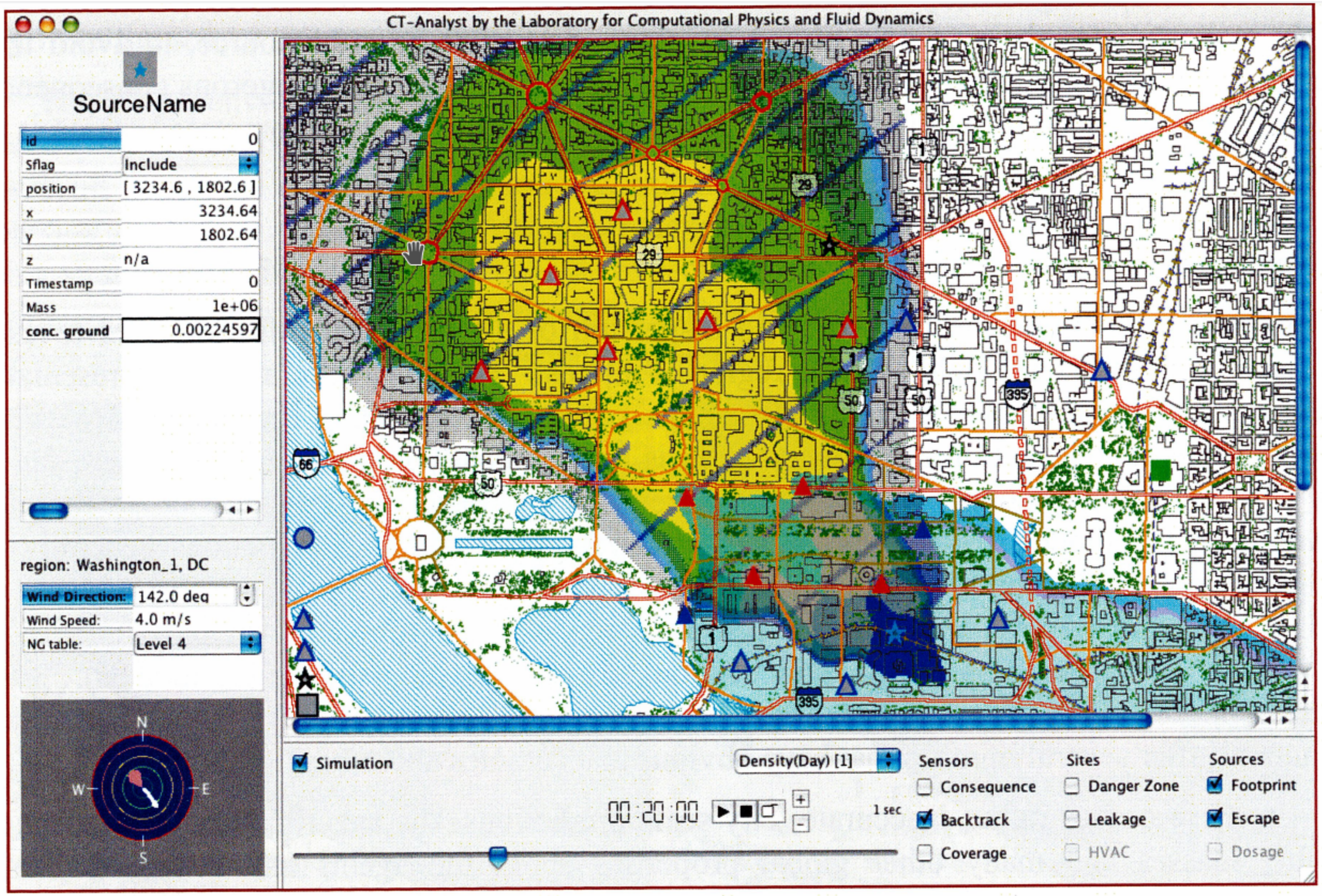
The idea of LEScape



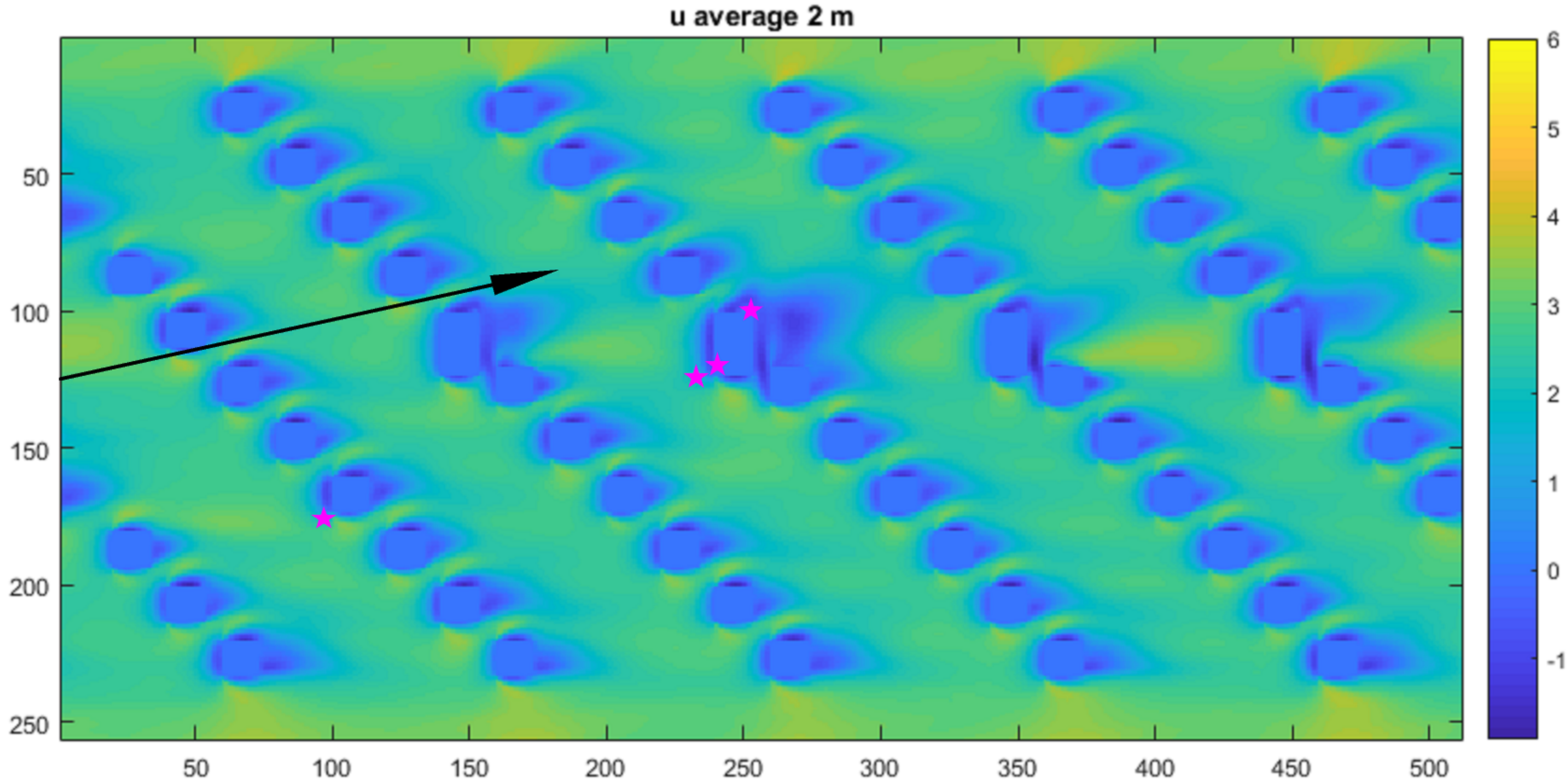
Example view on the CT-Analyst display

The idea of LEScape

Dispersion nomographs versus the LEScape algorithm:

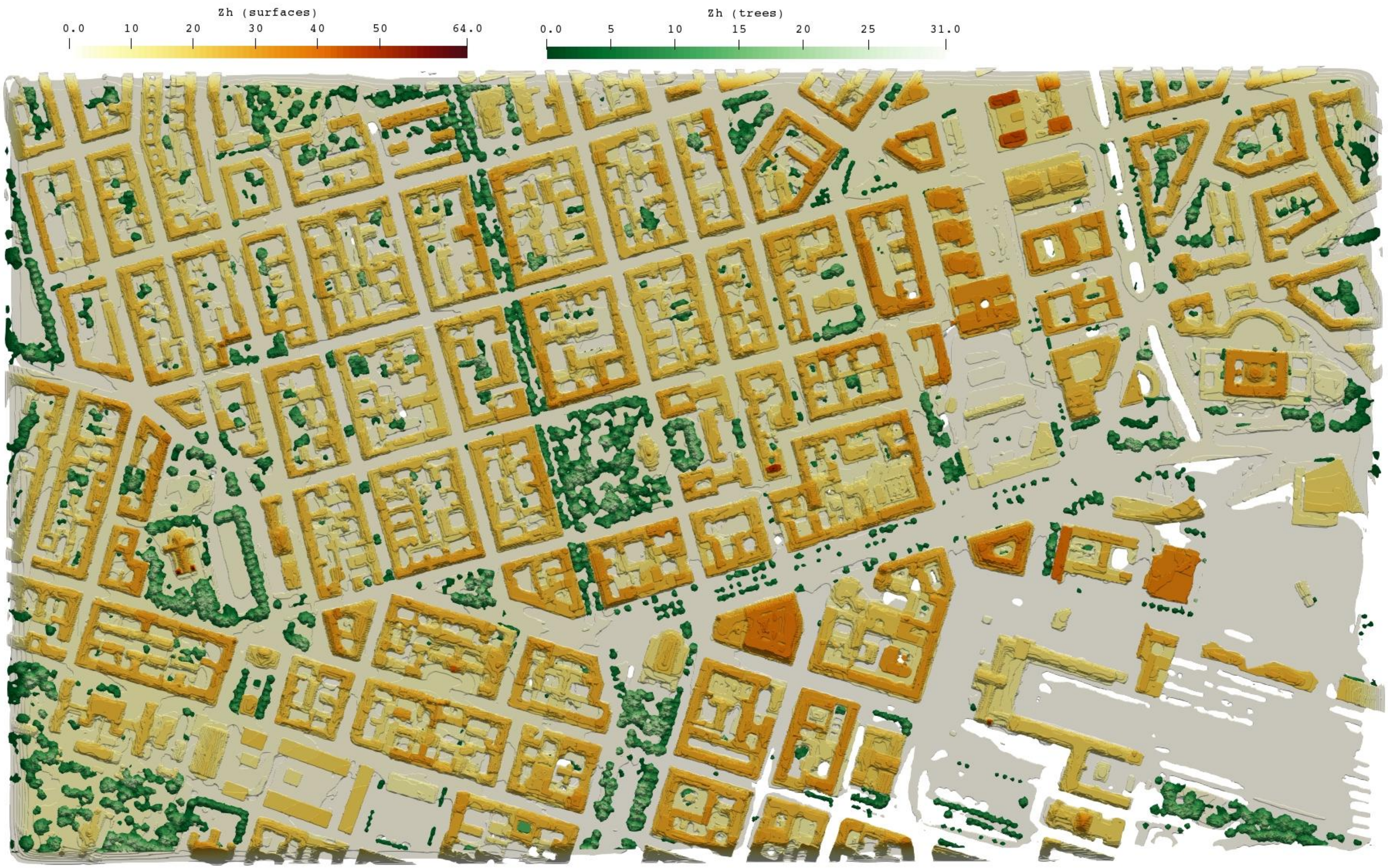
- Nomographs are based only on the LES-predicted wind field, no dispersion at all is modelled within the LES.
- Nomographs are a compact way to describe mainly the outer envelope of the plumes from any point source (or the footprints for any point observation).
- For example the vertical dispersion must be entirely parameterized in the nomograph approach.
- The LEScape approach directly models the dispersion by means of the coupled LS model.
- The data is stored in totally different way in the LEScape approach.
- In addition, we aim at higher resolution and accuracy than the CT-Analyst team (although more limited coverage at this phase).

The idea of LEScape

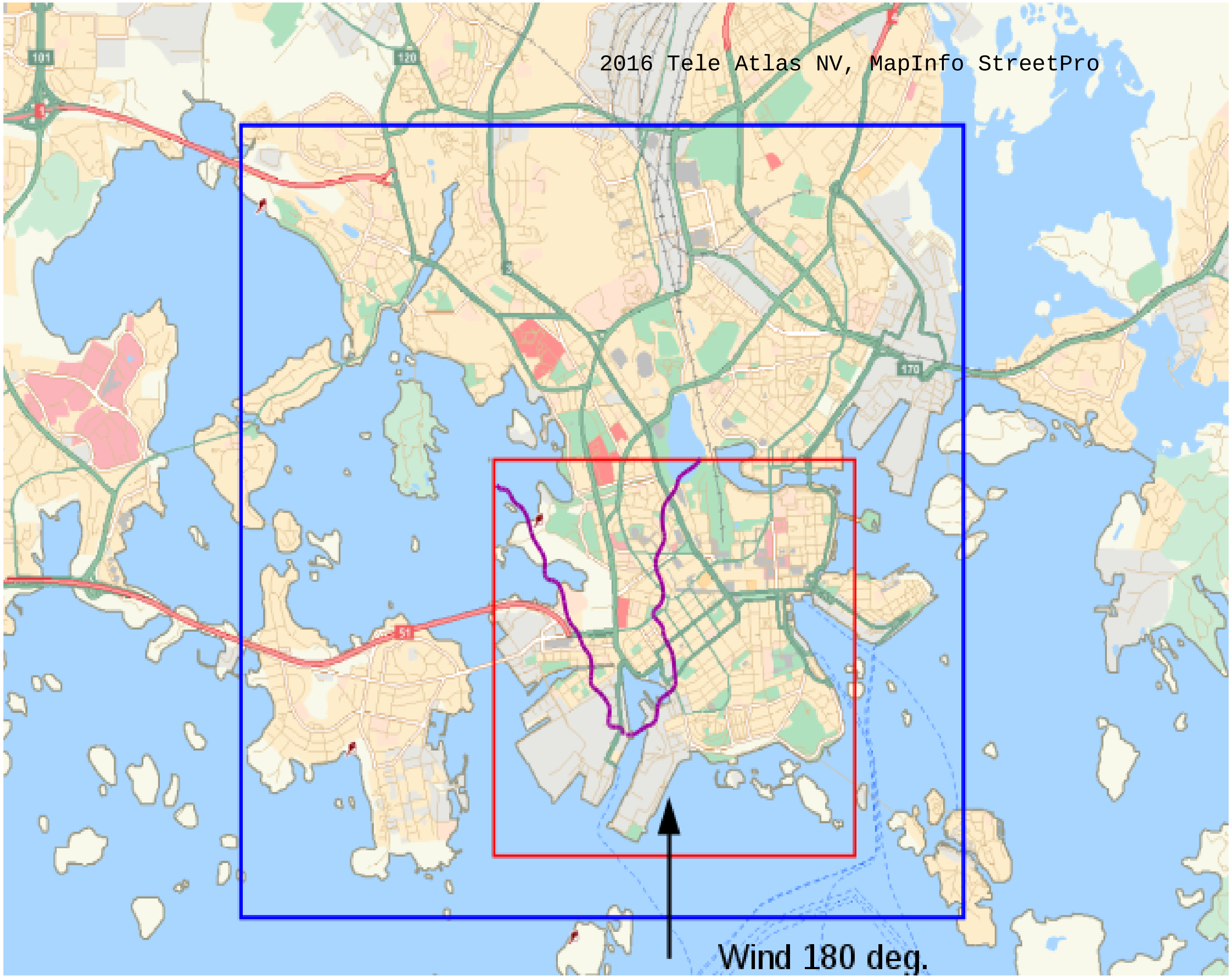


Our current test- and development case: a set of rectangular obstacles on flat terrain. It is a highly simplified model for dispersion in built areas. This view is from above showing averaged wind velocity at 2 m height. In this case the domain contains “only” 32 768 source and sensor points. Pink stars show the four source points selected for inspection. Black arrow indicates the mean-wind direction.

The idea of LEScape



The idea of LEScape



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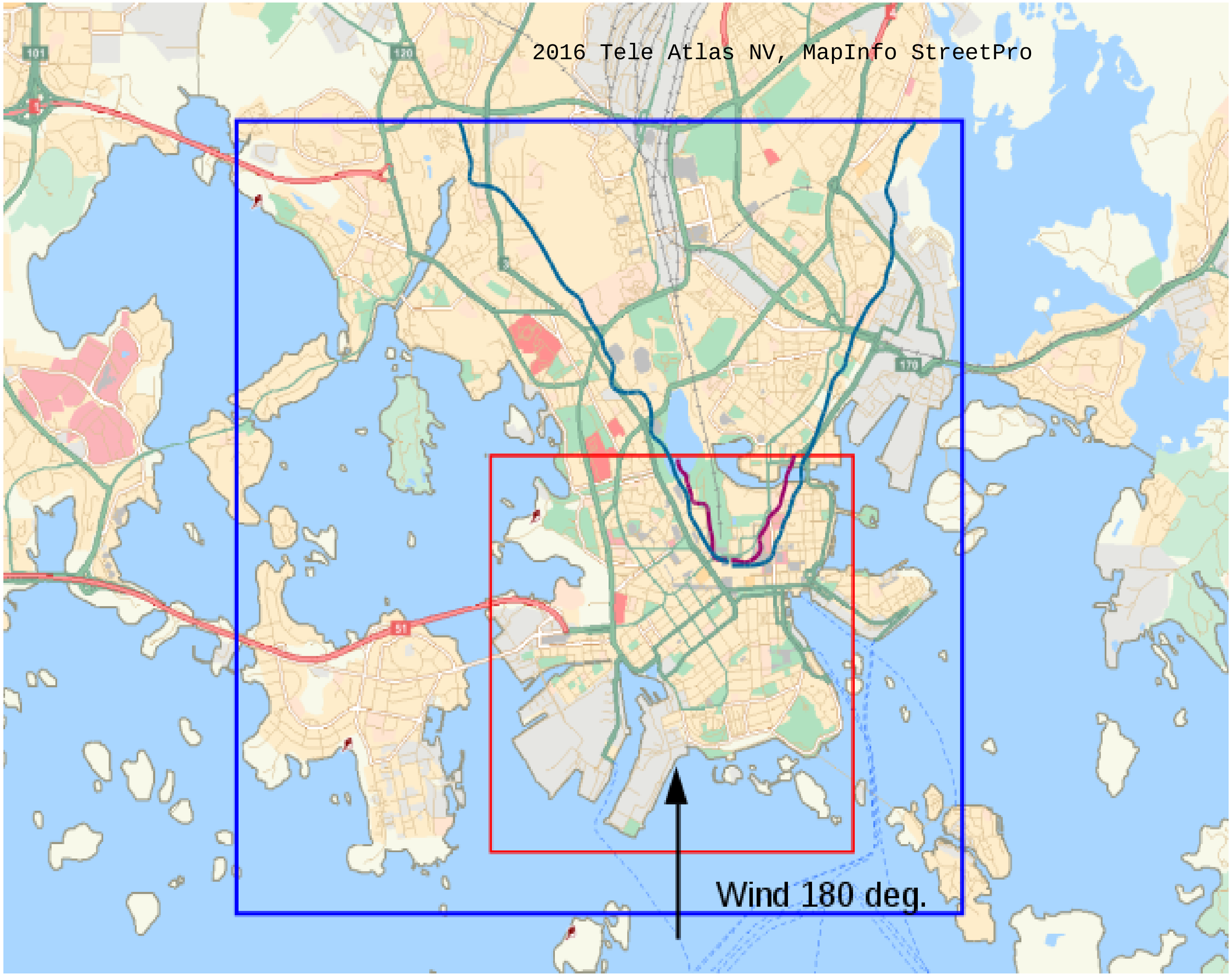

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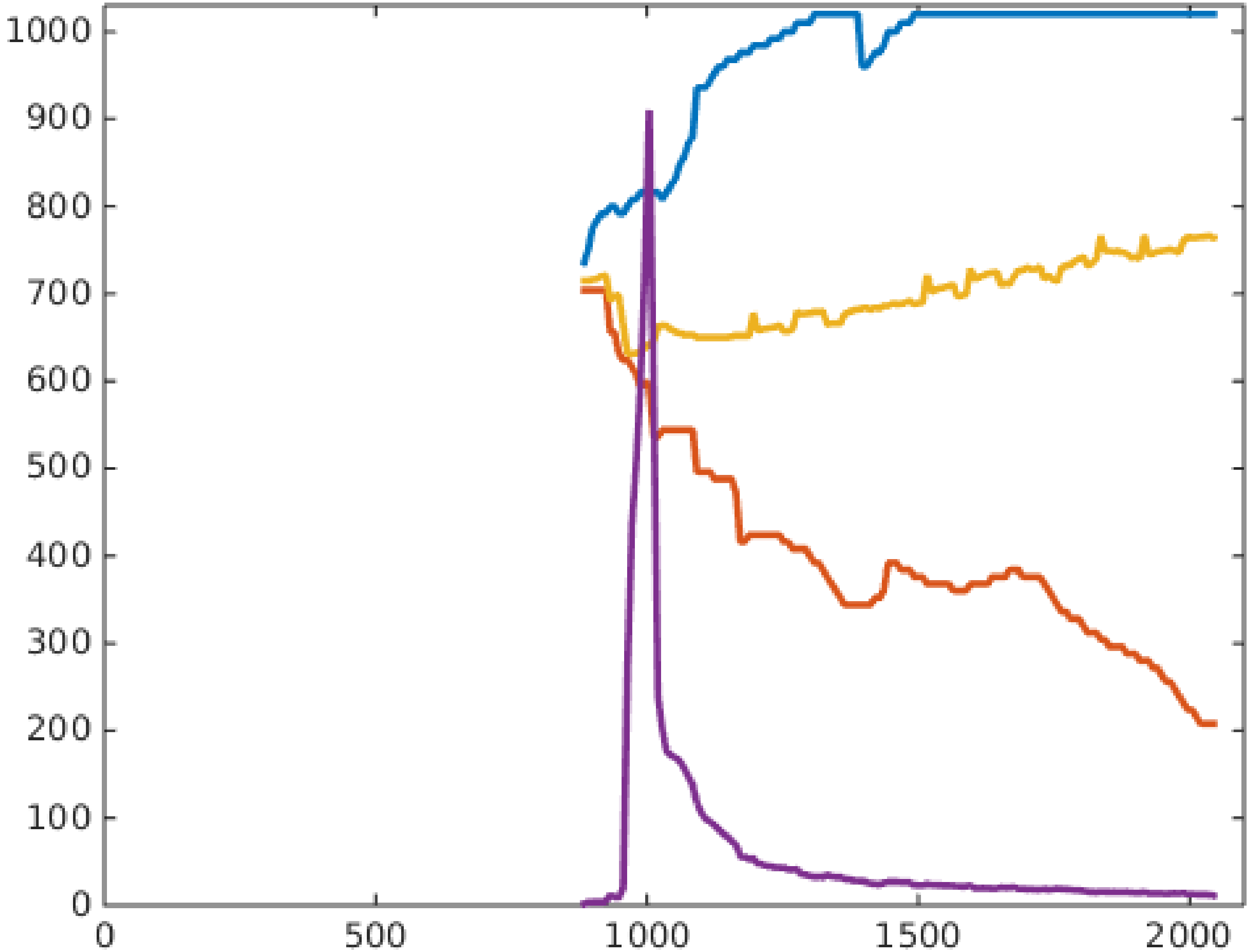

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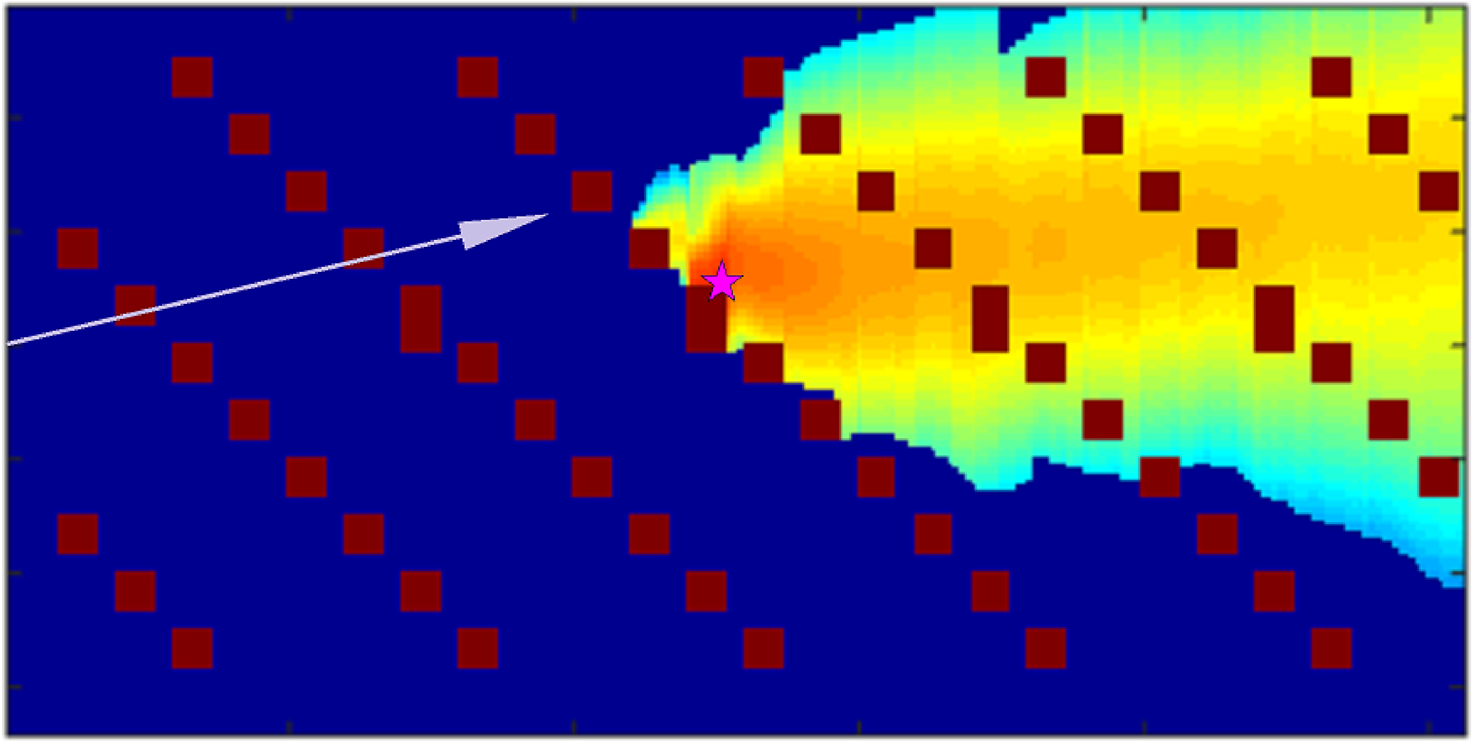
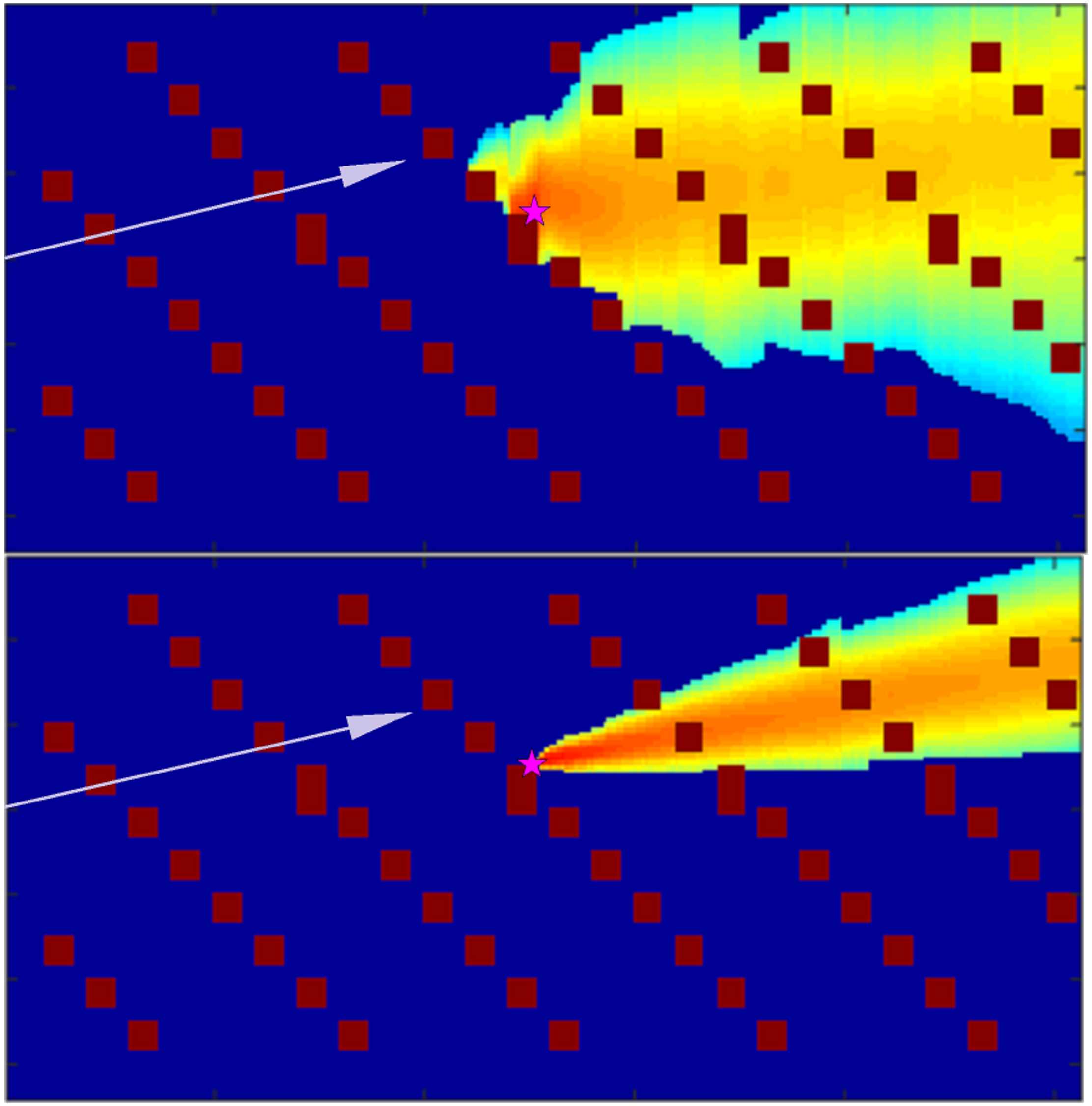
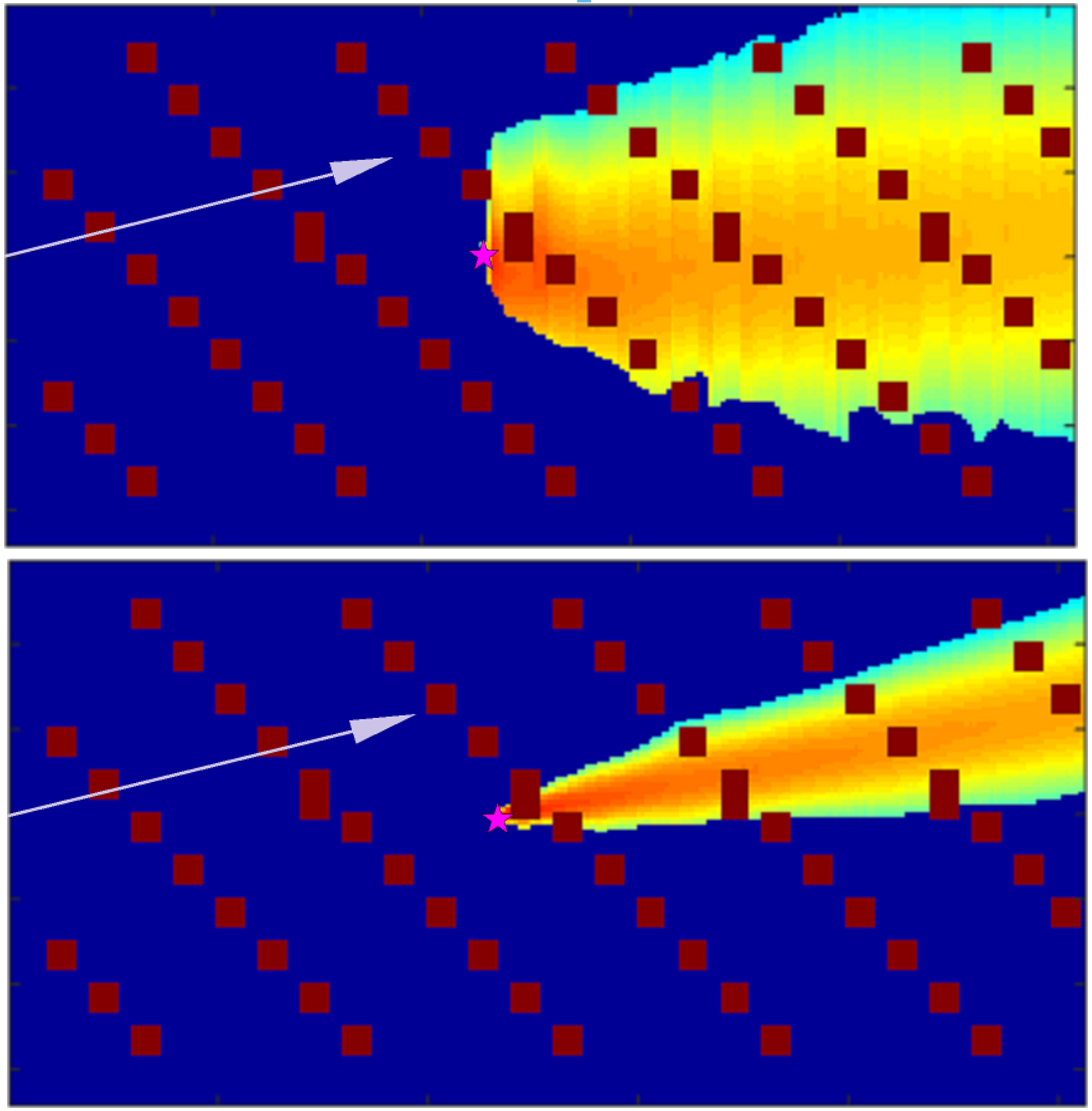


The same plume reconstructed using our generalized asymmetric Gaussian parametrization.

The idea of LEScape



The idea of LEScape



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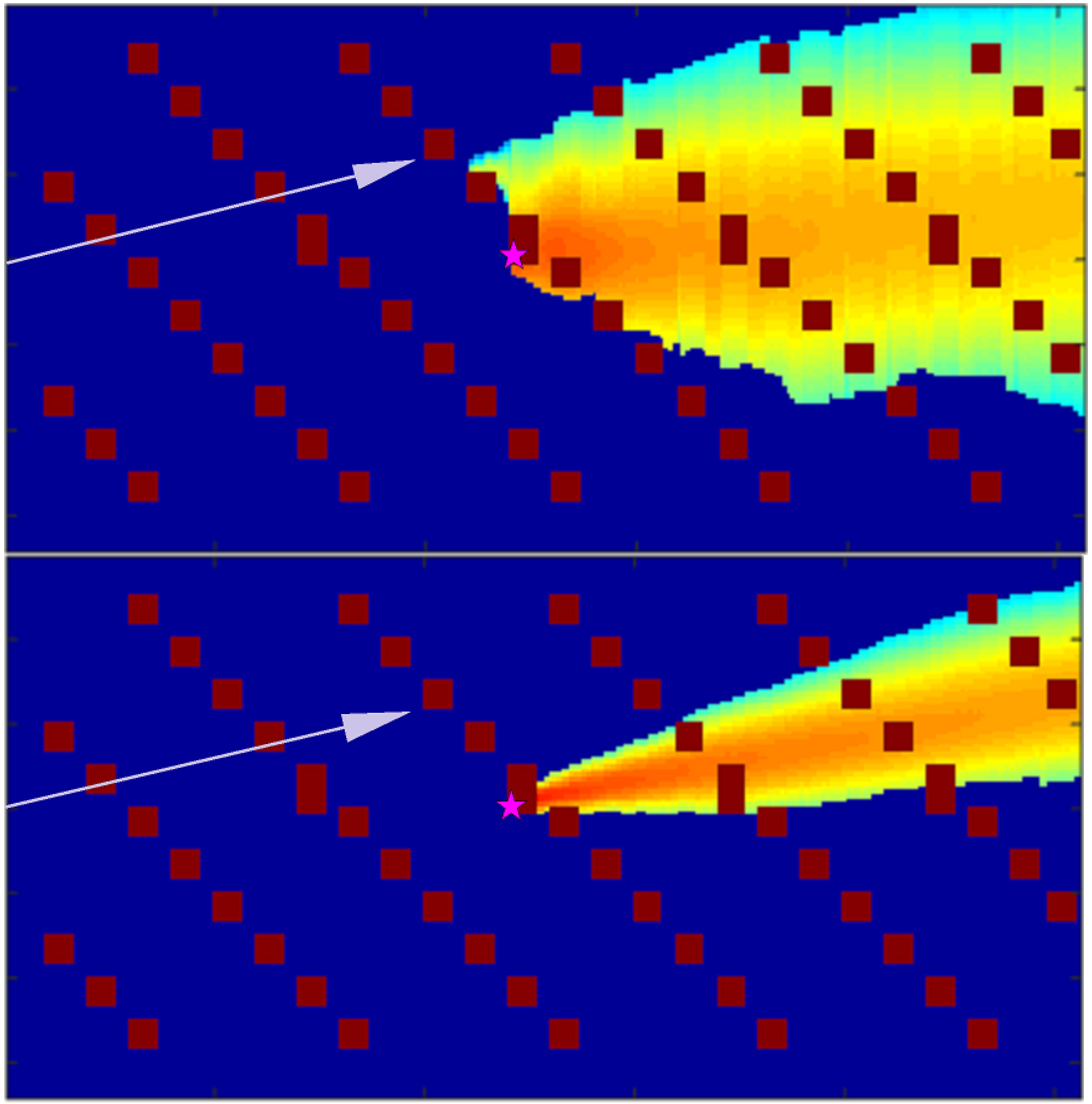
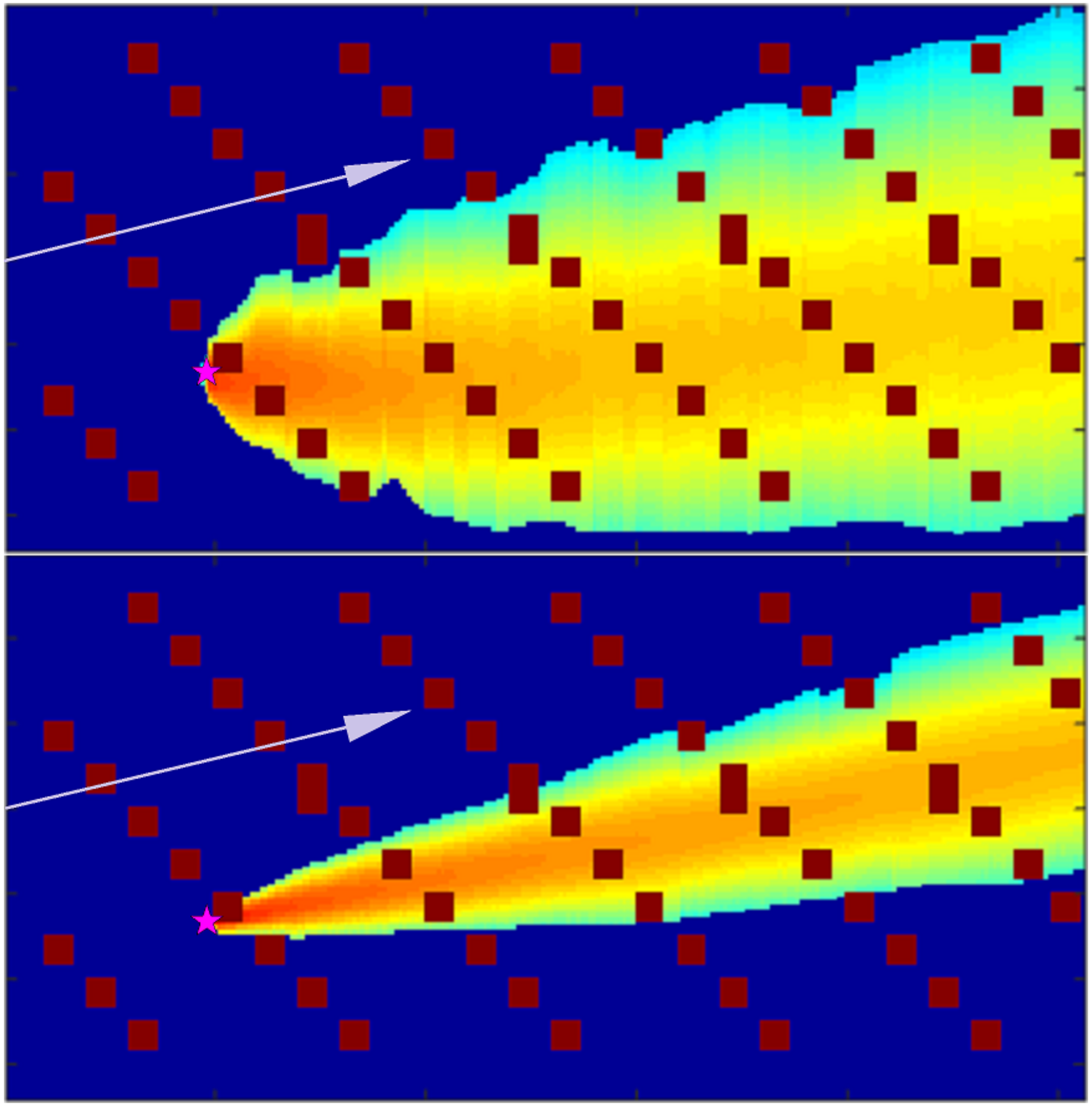


The idea of LEScape



Restrictions and limitations

- The focus areas are relatively limited at this phase (tens of square kilometres).
- The production LES-LS runs have to be performed separately for each focus area → a lot of computation and also human work.
- Modelling of different source characteristics is more limited than in traditional models like Escape, e.g.:
  - buoyant sources not considered: fires, explosions, dense-gas releases,...
  - source momentum not considered: e.g. high-pressure-high-volume leaks, explosions,...
- Possible lack of sensors hinder locating an unknown source:
  - Industrial sites are usually instrumented with sensors, but other areas maybe not
  - Strategic targets: “Puolustusvoimien siirrettävä suojeluvalvontajärjestelmä”?
  - Normal urban areas: reported human symptoms? Coordination of relevant emergency calls?
  - What else?
- These questions will be discussed with the stakeholders.

Status of the work

- The **LEScape analysis algorithm** has been coded.
- First it was tested using an ad-hoc tester program.
- It was coupled with the PALM LES-LS model in the early spring.
- Since then it has been intensively tested and debugged using simple flat-terrain test cases with no buildings and using the generic test case with rectangular obstacles as shown earlier.
- **It is now demonstrated that the basic idea works.**
- **The analysis algorithm can be considered as completed now.**
- The server part of the LEScape user tool is now under development.
- The generalized asymmetric Gaussian reconstruction algorithm is ready.
- The production-run LES models are currently being set up.

Status of the work

- The FMI supercomputing environment is currently being updated (about one month break)
- As soon as the new supercomputer is operative, we will start experimenting with the production-run models for the central Helsinki.
- The production-run model is based on the new Helsinki 3-D model which includes also trees (12 km x 7 km area in 1 m resolution).
- After sufficient initial experimenting and adjustments, we will finally start the production runs to create the data sets.
- The development of the LEScape user tool (client and server parts) will be completed.

Status of the work

- Testing and debugging of the analysis algorithm has taken quite much more time than planned.
- The supercomputer update break was not known during the project planning.
- For these reasons we are now approximately four months behind the originally planned schedule.
- On the other hand, the new computer will obviously speed up the production runs as soon as it becomes operational and all the systems are successfully converted to the new environment.

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