Improved representation of street canyons with the CityChem extension of urban-scale air quality model EPISODE

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EPISODE-CityChem model

The new urban chemistry transport model EPISODE-CityChem (based on the Eulerian urban dispersion model EPISODE by NILU) simulates the photochemical transformation of multiple pollutants along with atmospheric diffusion to produce pollutant concentration fields for the entire city on a horizontal resolution of 100 m or even finer and a vertical resolution of 24 layers up to 4000 m height [1]. CityChem contains representations of street canyons and local photochemistry for the sub-grid scale modelling near line sources. A simplified street canyon model (SSCM) is implemented to account for pollutant transfer along streets, including a parameterization of a simplified building geometry at street level. A fundamental assumption is that an hourly averaged recirculation vortex is always formed (see fig. 1), when the wind blows over a rooftop in a street canyon [2].

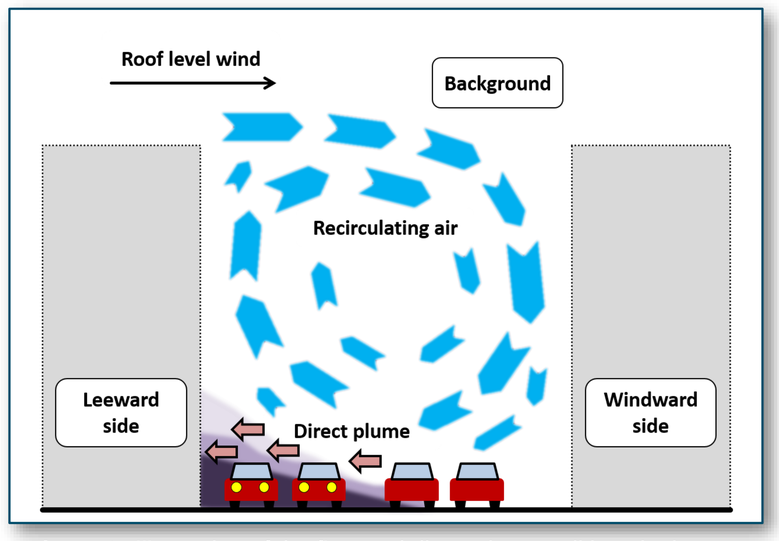

Figure 1: Illustration of the flow and dispersion conditions in the street canyon.

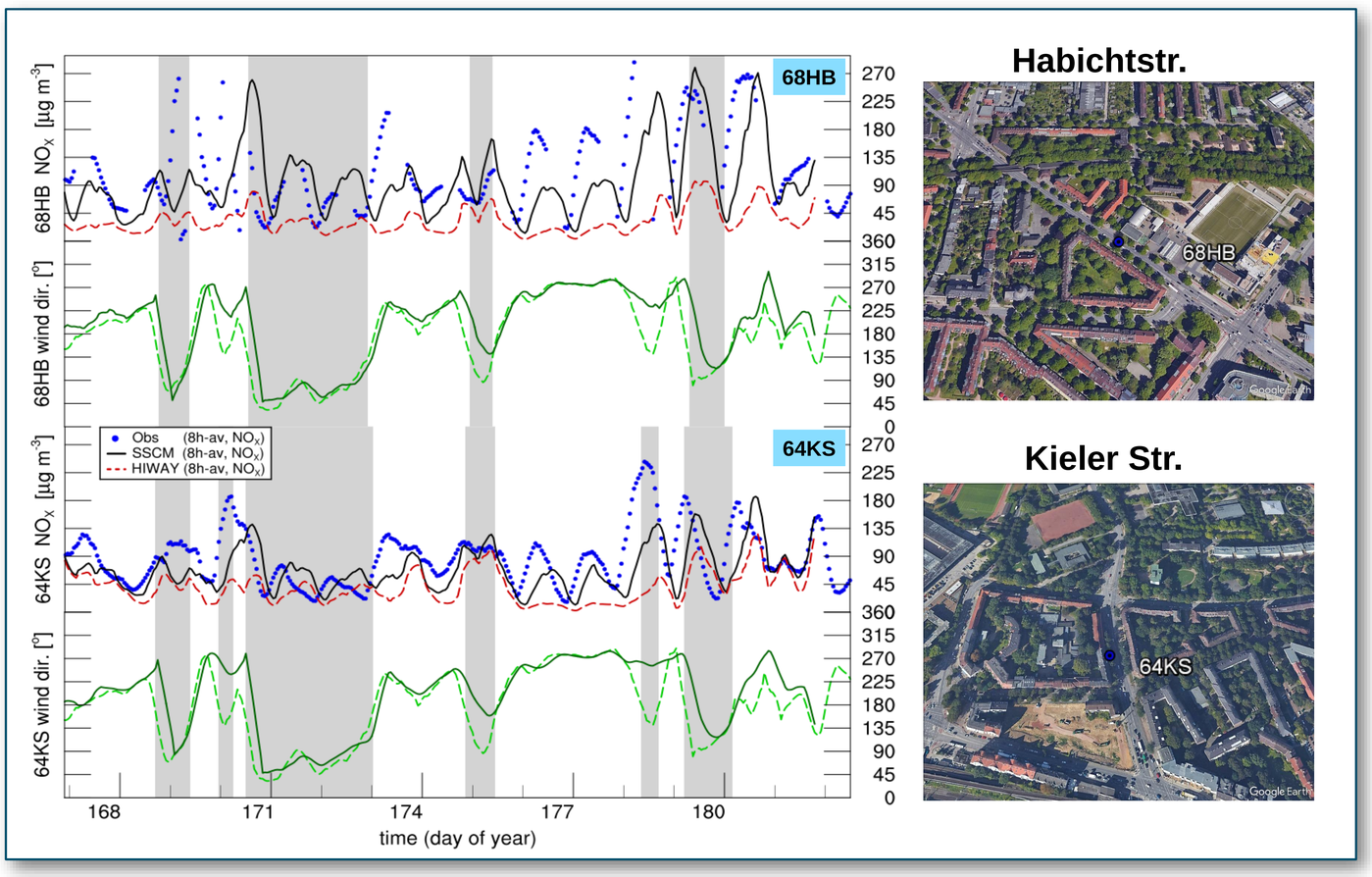

Figure 3: Measured (blue) and modelled NO_X concentrations and wind direction (green lines) at two street canyons. Windward side is grey shaded. Upper part: station 68 HB, Habichtstr., lower part: station 64 KS, Kieler Str..

Street canyons in Hamburg

The street canyon model in CityChem follows in most aspects the Operational Street Pollution Model (OSPM) [3]. The complex and divers geometry of street canyons is approximated by three generic types. Each line source for which the geometric mid-point is located in a grid cell with urban land use is identified as street canyon. Results from SSCM are compared to the open road dispersion model HIWAY for examples in fig. 2, 3, and 4. Table 1 summarizes the configuration of the tested street canyons.

	Habichtstr.	Kieler Str.	Wind test
Street orientation wrt North	135°	173°	135°
Canyon width	24 m	24 m	18 m
Building height	18 m	18 m	18 m
Wind flow field	Prognostic meteorological fields from TAPM [4]		0°-360°, steps of 10° 0.5, 1, 2, 4, 6 m s^{-1}
Emissions	0.732 g s^{-1} (NO_X)	0.343 g s^{-1} (NO_X)	2.0 g s^{-1} (PM_{10})

Table 1: Street canyon geometry in the presented examples.

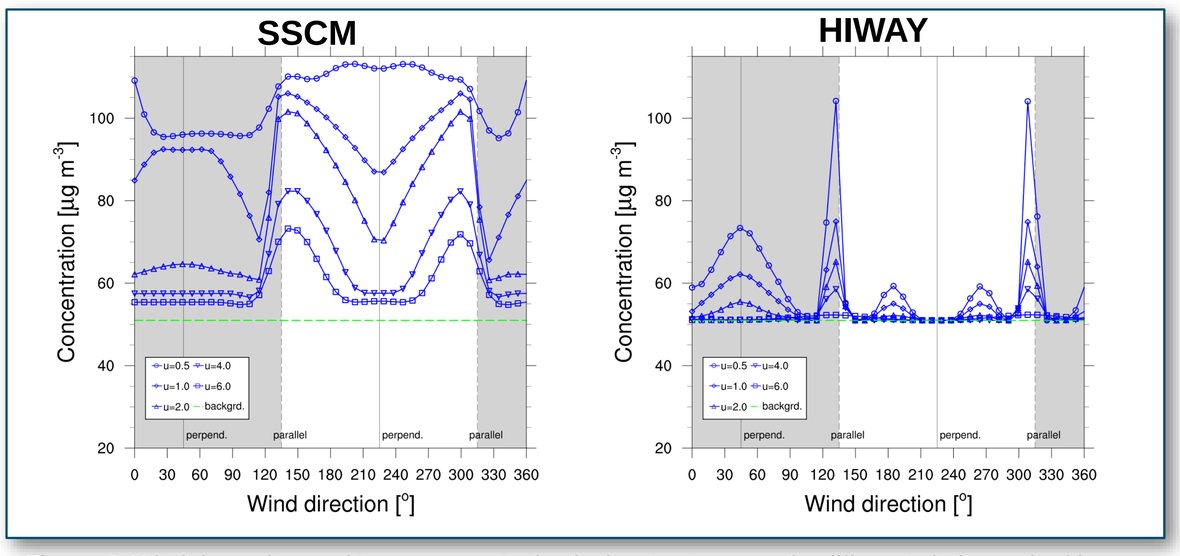

Figure 4: Wind dependence of tracer concentration in the street canyon for different wind speed; with SSCM (left) and HIWAY (right). Receptor is southwest of street. Wind speed (m s^{-1}) in legend.

Wind dependence

- The dependency of concentrations of an inert tracer in a canyon with street axis in SE-NW direction was examined at different wind speeds.
- SSCM gave higher concentrations because it considers the reduced ventilation inside the canyon and the recirculation of the traffic plume. HIWAY is designed for free dispersion from an open road or highway.
- Both models result maximum concentration contributions when wind is near parallel to the street.
- At very low wind speed, the traffic generated turbulence dominates. In SSCM, leeward concentrations are higher than windward (grey shaded) concentrations. The opposite is the case in HIWAY.

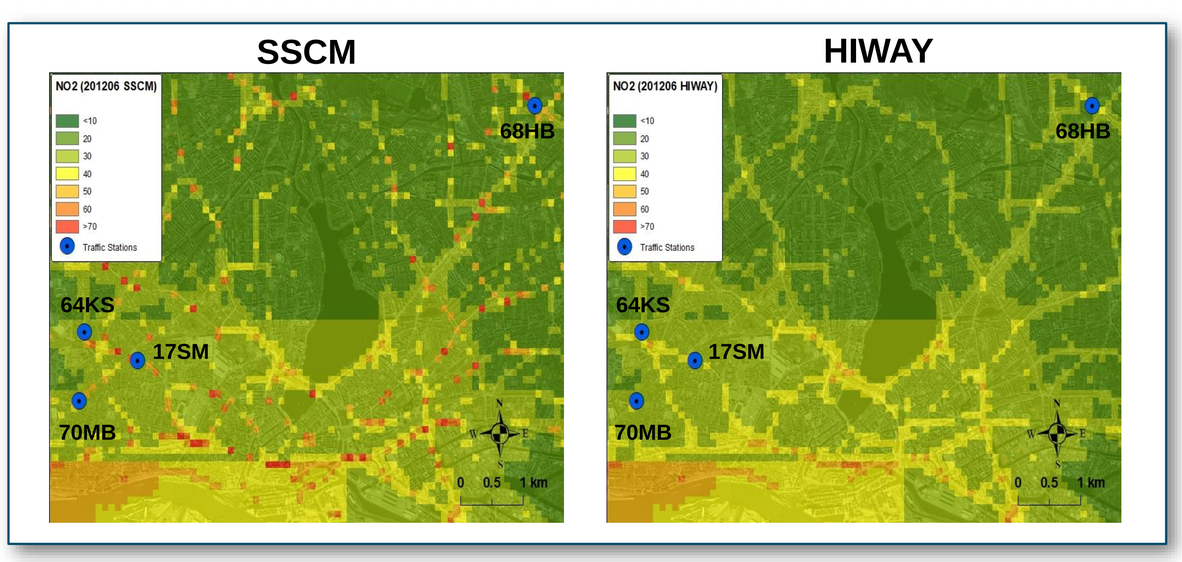

Figure 5: Monthly mean concentration of NO_2 (µg m^{-3}) in Hamburg in June 2012 with SSCM (left) and with HIWAY open road dispersion (right).

Outlook

- The simplified street canyon model allows for a better treatment of NO_X at traffic stations.
- The wind dependence of concentrations at a receptor located in a street canyon is as expected from the literature [2].
- SSCM needs to be refined in particular with respect to a better representation of the street canyon geometry; for instance, by using spatially resolved data on building height and street canyon width, for example by extracting this information from the 3-D city building model LoD1-DE Hamburg.

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Literature:
[1] Karl, M. 2018. Development of the city-scale chemistry transport model CityChem-EPISODE and its application to the city of Hamburg. Geosci. Model Dev. Discuss., https://doi.org/10.5194/gmd-2018-8.
[2] Hertel, O. and Berkowicz, R., 1989. Modelling Pollution from Traffic in a Street Canyon, Evaluation of Data and Model Development, National Environmental Research Institute, Roskilde, Denmark.
[3] Berkowicz, R., Hertel, O., Larsen, S. E., Sørensen, N. N., and Nielsen, M., 1997. Modelling traffic pollution in streets, Ministry of Environment and Energy, National Environmental Research Institute, Roskilde, Denmark.
[4] Hurley 2009 - Hurley, Peter/Edwards, Mary/Luhar, Ashok (2009): Evaluation of TAPM V4 for Several Meteorological and Air Pollution Datasets. In: Air Quality and Climate Change, 43 (3), pp. 19–24.