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Field observations of puff meandering in the atmospheric boundary layer

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Knowledge of turbulent dispersion is required for simulating the concentration distribution after deliberate or accidental releases of pollutants. However, high-resolution measurements of turbulent dispersion in the atmospheric boundary layer are sparse and turbulent transport models often rely on parameterization derived from a few such observations. Turbulence causes substances emitted into the atmospheric boundary layer to follow complex motion patterns. In the inertial range of turbulence, an initially spherical puff is statistically described by the meandering of its centre of mass and the relative diffusion around it. Instantaneously, the puff is subject to deformation and rotation and, for non-spherical puffs, this may significantly change the statistical characteristics.

Here, we present high-resolution observations of tracer dispersion from release experiments within the scope of the COMTESSA (Camera Observation and Modelling of 4D Tracer Dispersion in the Atmosphere) project. During two field campaigns in Norway in July 2017 and July 2018, sulfur dioxide (SO_2) was artificially released in continuous plumes and nearly instantaneous puffs from a tower (9 m and 60 m high for 2017 and 2018, respectively). At the release mast and one additional tower, continuous eddy covariance measurements of heat and momentum fluxes were made to characterize the atmospheric stability and flow. Column-integrated SO_2 concentrations were observed with ultraviolet SO_2 cameras with sampling rates of several Hertz and a spatial resolution of a few centimetres. We employed up to six cameras simultaneously to observe the motion of the puffs from multiple directions. The single puffs can be detected and tracked in the videos using a computer vision algorithm. The tomographic camera setup enabled us to reconstruct the three-dimensional centre of mass trajectories of the puffs.

We present observations of the general puff movement with focus on the meandering. Puff release experiments were carried out on seven days at different times of the day. The wind was blowing mostly southerly with phases of slow and fast directional changes. The wind speeds were generally increasing from 1-2 m/s in the early morning to up to 7 m/s later during the day. SO_2 cameras are based on absorption of back-scattered sunlight and thus generally operate best during clear sky and high sunlight intensities. Therefore, all observations reported here, were made during periods with no or sparse cloud cover. Consequently, the atmospheric boundary layer was mostly unstable or near neutral. Individual puffs can be observed up to 500 m downwind of the source while the crosswind and vertical meandering is statistically characterised for 200 m downwind. Ensembles of puff releases (ca. 30 realizations per hour) are used to study the statistical behaviour of turbulent dispersion in dependency of the state of the atmospheric boundary layer.