EGU General Assembly 2021

EGU21-13010, updated on 14 Jun 2021
https://doi.org/10.5194/egusphere-egu21-13010
EGU General Assembly 2021

Evaluation of the performance of different short-range atmospheric dispersion models for the monitoring of CH_4 emissions from industrial facilities

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Methane (CH_4) is a powerful greenhouse gas which plays a major role in climate change. The accurate monitoring of emissions from industrial facilities is needed to ensure efficient emission mitigation strategies. Local-scale atmospheric inversions are increasingly being used to provide estimates of the rates and/or locations of CH_4 sources from industrial sites. They rely on local-scale atmospheric dispersion models, CH_4 measurements and inversion approaches. Gaussian plume models have often been used for local-scale atmospheric dispersion modelling and inversions of emissions, because of their simplicity and good performance when used in a flat terrain and relatively constant mean wind conditions. However, even in such conditions, failure to account for wind and mole fraction variability can limit the ability to exploit the full potential of these measurements at high frequency.

We study whether the accuracy of inversions can be increased by the use of more complex dispersion models. Our assessments are based on the analysis of 25 to 75-min CH_4 controlled releases during a one-week campaign in October 2019 at the TOTAL's TADI operative platform in Lacq, France (in a flat area). During this campaign, for each controlled release, we conducted near-surface in situ measurements of CH_4 mole fraction from both a mobile vehicle and a circle of fixed points around the emission area. Our inversions based on a Gaussian model and either the mobile or fixed-point measurements both provided estimates of the release rates with 20-30% precision.

Here we focus on comparisons between modeling and inversion results when using this Gaussian plume model, a Lagrangian model "GRAL" and a Gaussian puff model. The parameters for the three models are based on high-frequency meteorological values from a single stationary 3D sonic

anemometer. GRAL should have relatively good skills under low-wind speed conditions. The Gaussian puff is a light implementation of time-dependent modeling and can be driven by high-frequency meteorological data. The performance of these dispersion models is evaluated with various metrics from the observation field that are relevant for the inversion. These analyses lead to the exploration of new types of definitions of the observational constraint for the inversions with the Gaussian puff model, when using the timeseries from fixed measurement points. The definitions explore a range of metrics in the time domain as well as in the frequency domain.

Eventually, the Lagrangian model does not outperform the Gaussian plume model in these experiments, its application being notably limited by the short scales of the transport characteristics. On the other hand, the Gaussian puff model provides promising results for the inversion, in particular, in terms of comparison between the simulated and observed timeseries for fixed stations. Its performance when driven by a spatially uniform wind field is an incentive to explore the use of meteorological data from several sonic stations to parameterize its configuration. The fixed-point measurements are shown to allow for more robust inversions of the source location than the mobile measurements, with an average source localization error of the order of 10 m.

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