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Modeling of Methane Emission Dynamics in Complex Aerodynamic Conditions

Current Project Overview

Methane (CH_4) emissions from oil and gas (O&G) production facilities are a source of greenhouse gas emissions to the atmosphere, yet the quantification of emissions remains highly uncertain. Many current quantification solutions use data from fenceline CH_4 sensors as input to atmospheric dispersion models to infer emissions rates, however, the aerodynamic complexity of O&G production facilities presents challenges for accurate quantification. Some research suggests that sensor placement could overcome this issue with improvement in accuracy if measurement data is collected farther downwind of the source. So, a series of methane concentration measurements were conducted downwind of controlled releases in different environmental conditions and used as input to two atmospheric dispersion approaches, the Gaussian plume equation (GP), and a backward Lagrangian stochastic (bLS) model. Analysis was then conducted to investigate how model accuracy is affected by distance downwind, obstruction height, and meteorological conditions. The obstruction was the most significant factor that impacted the emission quantification uncertainty with p values of 0.01 and 0.02 for GP and bLS models, respectively. Also, to achieve an uncertainty of 20% using the GP at the experiment site, sensors should be deployed at 49 meters plus 17 times the obstruction's height downwind to the source. Similarly, using the bLS model, it was 54 meters plus 13 times the obstruction's height downwind to the source. Depending upon the source height, emission estimates exhibit decreasing uncertainty with the increment of the distance between the source and sensor.

Research Plan

1. Collect thirty above-ground concentration measurement data.
2. Perform simple atmospheric dispersion modeling: Gaussian Plume and backward Lagrangian Stochastic Models
3. Incorporate complex aerodynamic conditions of the site to observe the uncertainty in emission quantification.

For each experiment, CH_4 concentration was measured at between 5 and 7 points at distances between 13 and 153 m downwind of the emission point.

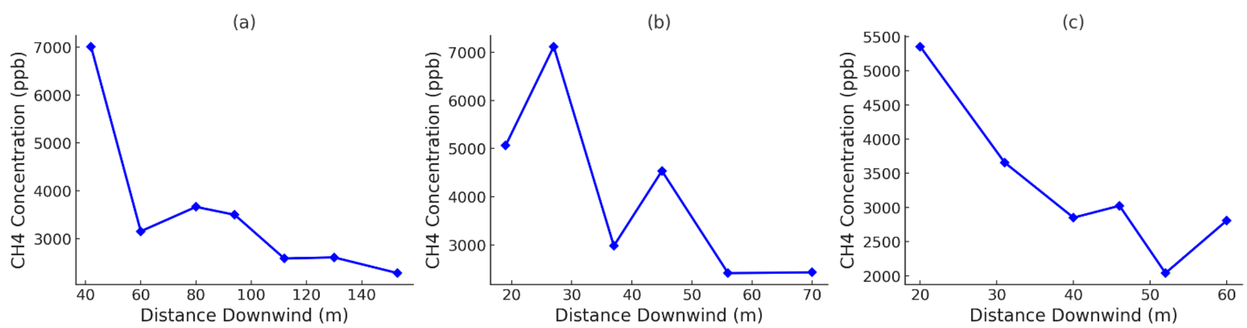

Figure: *Decrement in concentration as the downwind distance increases. The decreasing trend for one of the experiments conducted in the tank (a- experiment 1), separator (b- experiment 2), and wellhead (c- experiment 23)*

Research Progress

The field experiments and data collection were successfully completed at the Methane Emission Technology Evaluation Center (METEC) at Colorado State University. Comprehensive data analysis was conducted using both Gaussian plume (GP) and backward Lagrangian stochastic (bLS) dispersion models, focusing on quantification accuracy under different sensor placements, obstruction heights, and atmospheric conditions.

The findings from this research provide valuable insight into optimizing sensor placement strategies for improved methane emissions quantification. A manuscript summarizing these findings is currently in preparation and will be submitted to a peer-reviewed journal in the near future.

Publications

No publication yet