Continuous measurement and large-eddy simulation of greenhouse gas emissions at local spatial scales

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Abstract

How can data from sparse sensor networks be used to quantify individual sources of GHGs in the local vicinity of the sensors in the network? Earth Networks' national Greenhouse Gas Network (EN-GHG) provides long-term, continuous measurements of CO2 and CH4 concentration, and standard meteorological variables. Statistical analysis and conditional averaging of CH4 concentration data from EN-GHG sites in Pennsylvania and North Carolina show that the measurements contain information about emissions from "point sources" in the local vicinity (1-10km radius) of the sensors. High spatiotemporal resolution large-eddy simulations (LES) of scalar emissions from surface sources in the atmospheric boundary layer are applied to characterize statistics of concentration fluctuations as a function of atmospheric stability and sensor location in the plume. Results from the LES model may be used to infer the range of a GHG source relative to the sensor location.

Time Series of CH4 Concentration

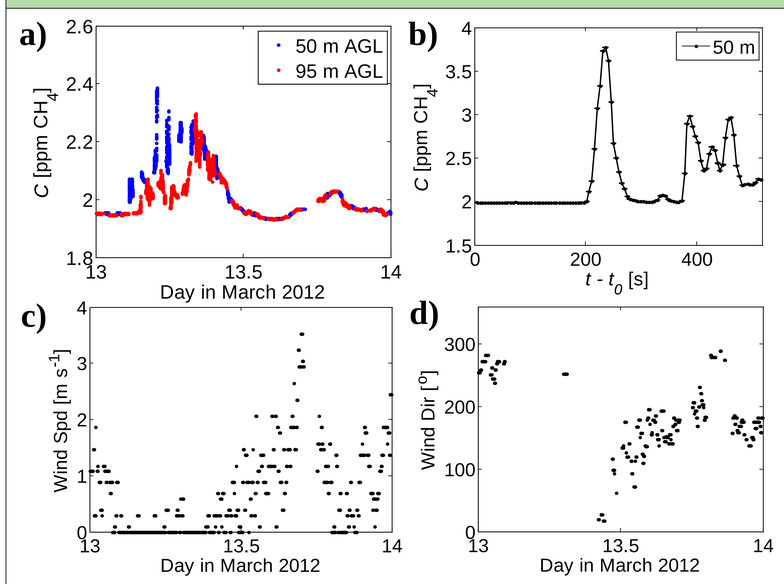


Figure 1 – Time series of measured CH4 concentration in Lewisburg, PA **(a, b)**. Wind speed **(c)** and wind direction **(d)** corresponding to the data in Figure 1a.

Climatology of CH4 Measurements

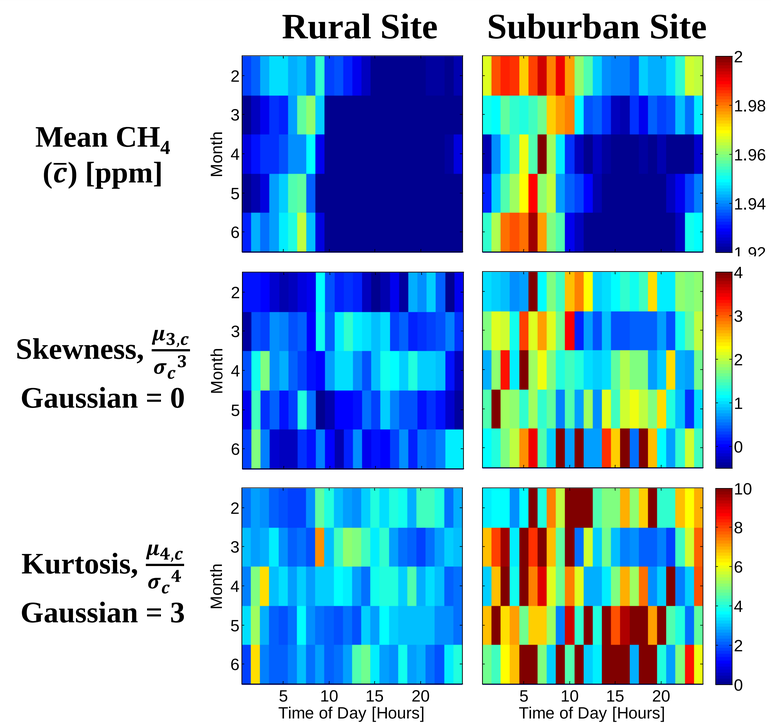


Figure 2 – Climatology of CH4 concentration statistics at two EN-GHG sites. There are no sources of CH4 near the rural site (left column), while the suburban site (right column) is surrounded by multiple CH4 point sources.

Detection of CH4 Emitters

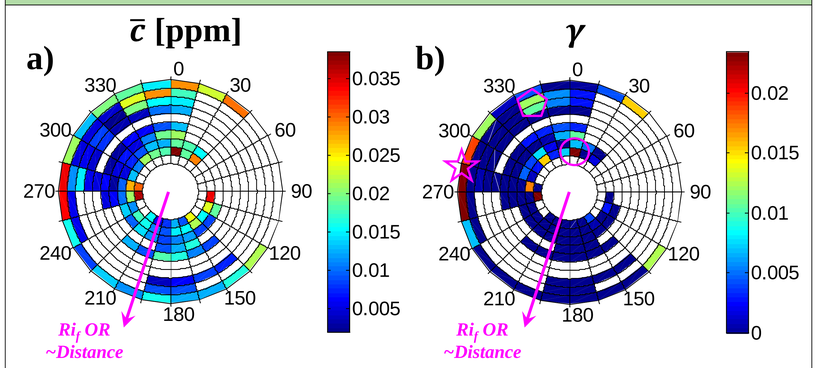
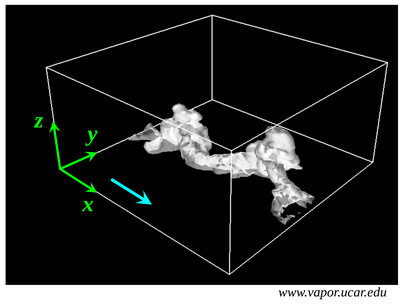


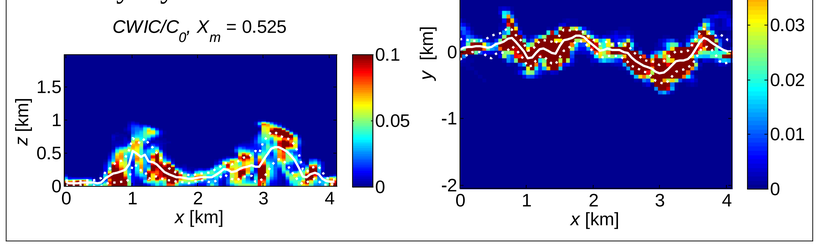
Figure 3 – Conditional averaging was applied estimate average concentration contribution **(a)**, and direction and relative range **(b)** for CH4 sources near the sensor, assuming a fixed sensor location and a constant, continuous source.

Wastewater treatment plant Range: 300m
Industrial area Range: 2000m
Fertilizer processing plant Range: 6000m

Scalar Dispersion with WRF-LES

Figure 4 – High spatio-temporal resolution large-eddy simulations of passive scalar dispersion in the atmospheric boundary layer are used to simulate the concentration fluctuations observed in Figure 1. These concentration fluctuations are associated with small scale turbulent structures in the boundary layer.





Intermittency and Source Range

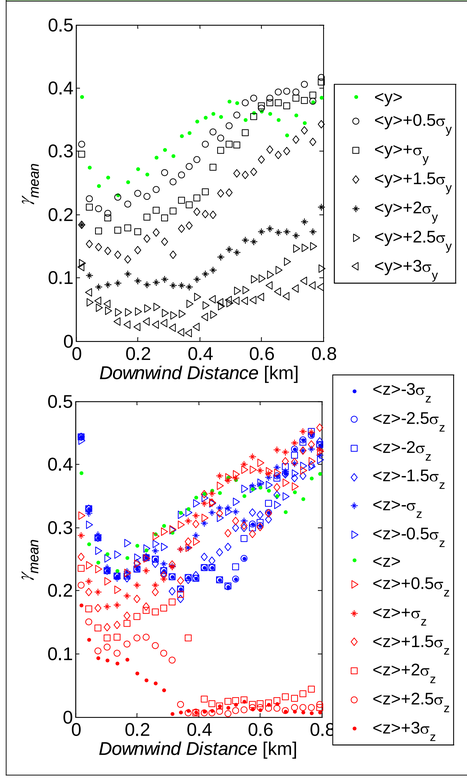


Figure 5 – The intensity, frequency and duration of concentration fluctuations in a scalar plume depend strongly on boundary layer stability, downwind distance from the source and measurement location relative to the plume. The intermittency factor is a useful metric for boundary layer concentration variability and sensor to source range estimation.

$$\gamma \equiv \frac{T_{c>\bar{c}}}{T_{total}}$$

γ is the ratio of time the measured concentration is greater than a threshold level.