MEASURING CH_4 FROM CARS, SHIPS, AIRPLANES, HELICOPTERS & DRONES USING HIGH-SPEED OPEN-PATH TECHNOLOGY

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INTRODUCTION

Major sources of CH_4 include oil and gas networks, landfills and lagoons, agricultural and natural production

The majority of emissions happen via variable-rate point sources or diffused spots in topographically challenging terrains

Locating and quantifying distributed and point sources of CH_4 emissions in these areas is challenging when using traditional techniques

Novel approaches are being developed to address these challenges, including high space- and time-resolution measurements of CH_4 from moving platforms

INSTRUMENTATION

Open-path CH_4 analyzer, LI-7700, takes 8 Watts of nominal power, operates at ambient pressure

Resolves 5 ppb of CH_4 at 10 Hz, can sample up to 40 Hz

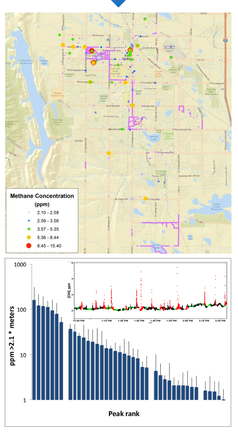
Originally developed for stationary eddy covariance measurements

Increasingly used in mobile measurements due to low power consumption, high resolution, and very rapid time response

EXAMPLES OF METHANE MEASUREMENTS WITH FAST OPEN-PATH TECHNOLOGY: MOVING CARS, MANNED AIRCRAFTS & DRONES

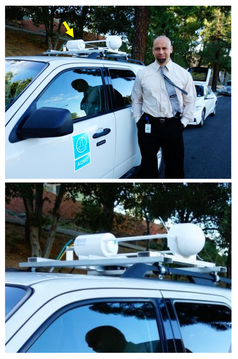
CSU, EDF, GOOGLE — fugitive emissions

- Colorado State University, EDF, and Google
- Methane mapping
- Leak detection algorithms
- Research & monitoring
- Multiple cities
- Vehicle-mounted
- Wind: not needed/Gill-WM
- CH_4 data: LI-7700
- GPS: Hemispheres A100

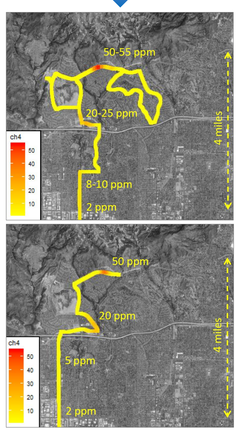


- Fort Collins, Denver, etc.
- Hi-res CH_4 maps may be sufficient to locate leaks
- Wind may not be needed
- Leak detection method is being developed
- Leaks found correctly in most cases, verified by company

SCAQMD — fugitive emissions

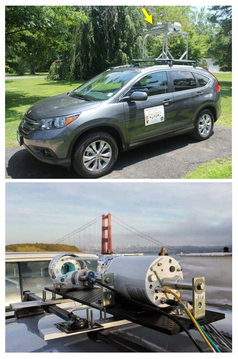


- South Coast Air Quality Management District
- Methane mapping
- Regulatory compliance
- Regulatory monitoring
- Large leak from SoCal Gas Co.
- Vehicle-mounted
- Wind data: not needed
- CH_4 data: LI-7700
- GPS: Atlas Link

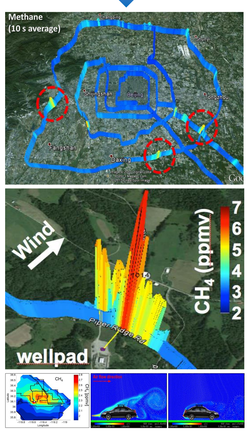


- Porter Ranch, California, USA
- Hi-res CH_4 maps may be sufficient to locate gas leaks
- Survey detected clear and significant increases in CH_4
- After leak was plugged, some emissions remained due to CH_4 stored in bedrock and soil

Princeton — fugitive emissions



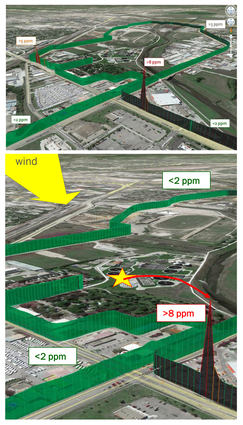
- Princeton University Atmospheric Chemistry Group
- Methane mapping
- Leaks and vehicle emissions
- Research & development
- Agricultural & urban areas
- Vehicle-mounted
- Wind data: Vaisala WXT-520
- CH_4 data: LI-7700
- GPS: GlobalSat EM-406a



- Agro: San Joaquin Valley, NE Colorado; North China Plain
- Urban: Beijing, Houston, Denver, San Francisco, Los Angeles, Philadelphia
- Petrochemical: Marcellus Shale, Denver-Julesberg basin
- Difficult to measure wind well

LI-COR — fugitive emissions

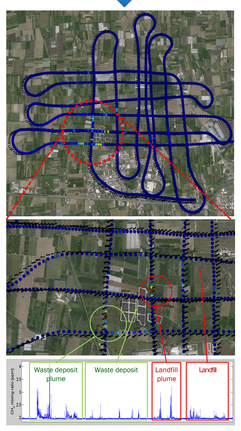
- LI-COR Biosciences - Environmental
- Test mapping of methane
- Test geolocation
- Instrument development
- City
- Vehicle-mounted
- Wind data: not needed
- CH_4 data: LI-7700
- GPS: Garmin 18x



- Lincoln, Nebraska, USA
- Hi-res mapping is easy
- Features are seen in real time
- Need wind to locate source: local AWS data is sufficient
- Need map to locate source
- Just mapping concentrations is not fully conclusive

CNR — landfills

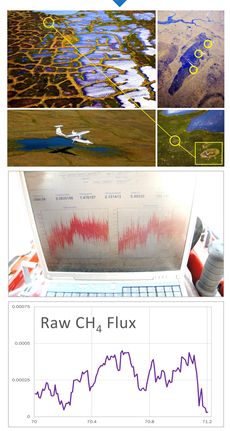
- Italian National Research Council
- Methane profiles & mapping
- Methane flux measurements
- Research & monitoring
- Landfills, waste deposit areas
- Enclosed, aircraft-mounted
- Wind: BAT Pressure Sphere
- CH_4 data: LI-7700
- GPS: Novatel



- Terra dei Fuochi, Italy
- Flight grids repeated at 4 altitudes
- Wind vector measured
- Lagrangian Dispersion Model coupled to observations
- Mass balance method used to calculate emissions
- Individual landfills resolved

SDSU — permafrost

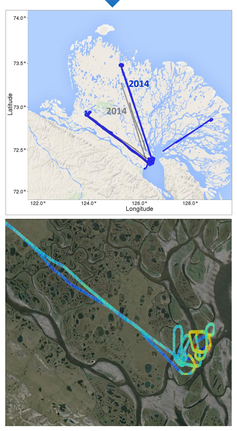
- GCRG - San Diego State University
- Methane profiles & mapping
- Methane flux measurements
- Ecological research
- Arctic coastal wetlands
- Aircraft-mounted
- Wind: BAT Pressure Sphere
- CH_4 data: Prototype-7700
- On-board GPS



- North slope, Alaska, USA
- Concentrations are easy
- Computing fluxes is possible
- Can compare to towers
- Can run flux transects
- Flux processing is complex
- Need agreement on flux methodology

GFZ-Potsdam — permafrost

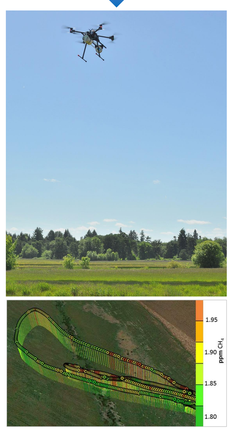
- GFZ German Research Centre for Geosciences
- Methane mapping
- Methane flux measurements
- Ecological research
- Permafrost areas
- Helipod-mounted
- Wind data: 5-hole probe
- CH_4 data: LI-7700
- GPS: 3D, GNATTI, Geo++ GmbH



- Lena River Delta, Siberia
- 100 km transects and vertical profiles
- High-res CH_4 flux maps
- 3 seasons: winter, break-up, and summer
- Fluxes of CH_4, CO_2, H_2O, and sensible heat

AmeriFlux-Atlatl Sensing — wetland

- AmeriFlux-LBNL
- Atlatl Sensing LLC
- Methane profiles & mapping
- Methane flux measurements
- Ecological research
- Seasonal wetland
- Drone-mounted
- Wind: ground based CSAT3
- CH_4 data: LI-7700
- GPS: U-Blox M8 3 const.GNSS



- Willamette Valley, USA
- Concentration mapping
- Can compare to towers
- Can run transects
- Transport modeled fluxes
- Flux tower footprint verification
- Processing of the transport model fluxes is complex

OPEN-PATH vs. CLOSED-PATH APPROACHES

Mobile measurements using open-path technology have excellent time and space resolution, but need more care:

+ excellent time response
+ high-resolution mapping in time and space
+ good detection of narrow peaks, sharp plume edges, *etc.*

- vibration, have to install on a single rigid mount
- need to clean often on rainy days, or design a splashguard

Mobile measurements using closed-path technology have reduced time and space resolution, but need less care:

- relatively slow time response
- lower-resolution mapping in time and space
- poor detection of narrow peaks, sharp plume edges, *etc.*

+ no vibration issues since installed inside the car
+ no need to clean often on rainy days; still need to clean filter

SUMMARY

Many methodological challenges for mobile CH_4 measurements are similar for open- and closed-path devices:

- plumes are not Gaussian when moving through
- movement distorts plume shape & averages concentration signature
- mapping concentrations is easy but often inconclusive, quantifying emission rates is conclusive but not easy

However, open-path technology offers new possibilities particularly attractive for mobile mapping:

- precision mapping due to low signal attenuation and high resolution in space and time
- multiple flexible deployment opportunities due to low weight and very low power demand

When driving at variable speed with traffic up to 50 mph, maps can be generated with:

- 0.55 m or better spatial resolution
- 0.025 s or better temporal resolution
- 0.01 ppm resolution of CH_4 concentration

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