THE NEXT FRONTIER IN ADVANCED MONITORING TECHNOLOGIES

CAPCOA ENGINEERING & ENFORCEMENT SYMPOSIUM

FOLSOM, CALIFORNIA

NOVEMBER 8, 2017

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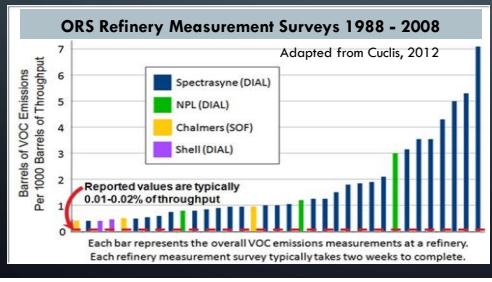
OPTICAL REMOTE SENSING

MOTIVATION

- Optical Remote Sensing (ORS) technologies evolved significantly in the past decade
- Fully automated / continuous / no calibration required
- Ideally suited for long term fenceline monitoring. Can characterize and quantify emissions
- Can be deployed from various mobile platforms for rapid leak detection, concentrations mapping and emission flux measurements
- Measured VOC emissions can be higher (up to an order of magnitude) than those from emission inventories



Technical Memorandum

TO: EPA Docket No. EPA-HQ-OAR-2003-0146

FROM: Brenda Shine, EPA/SPPD

DATE: July 27, 2007

SUBJECT: Potential Low Bias of Reported VOC Emissions from the Petroleum Refining Industry

SCAQMD OPTICAL REMOTE SENSING MONITORING PROGRAM

- Demonstrate feasibility and effectiveness of fenceline monitoring using optical remote sensing
- Improve LDAR program and reduce emissions
- Provide real time alerts to downwind communities
- Measure actual facility wide emissions
- Improve existing emission inventory estimates

South Coast AQMD

2016 2018
Combined ORS and low cost sensors deployments to study impacts of HAPs on communities

2015
ORS measurements campaign to study emissions from refineries, small stationary sources and ships

AQS
UCLA Atmospheric & Oceanic Sciences
FluxSense

2012 2014
Two successful technology demonstration projects for refineries

2008
LP DOAS for fenceline monitoring. Contractor failed to fulfill obligations

2015 SCAQMD OPTICAL REMOTE SENSING STUDY

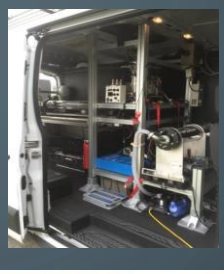
- Project 1: Quantify fugitive emissions from large refineries

- Project 2: Quantify gaseous emissions from small point sources

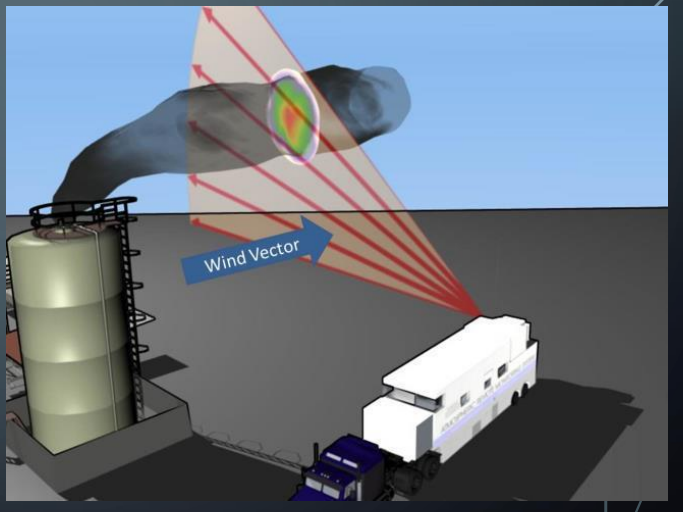
- Project 3: Quantify stack emissions from marine vessels/ports

METHODS: SOLAR OCCULTATION FLUX (SOF)

- Mobile measurements to record total mass of molecules along path traveled
- Total mass and wind data used to calculate flux emissions (kg/s)
- Also can be used identify "hot spot" areas inside the facility
- Light source direct sunlight
- Daylight measurements only
- Accurate wind data obtained using SCAQMD's LIDAR



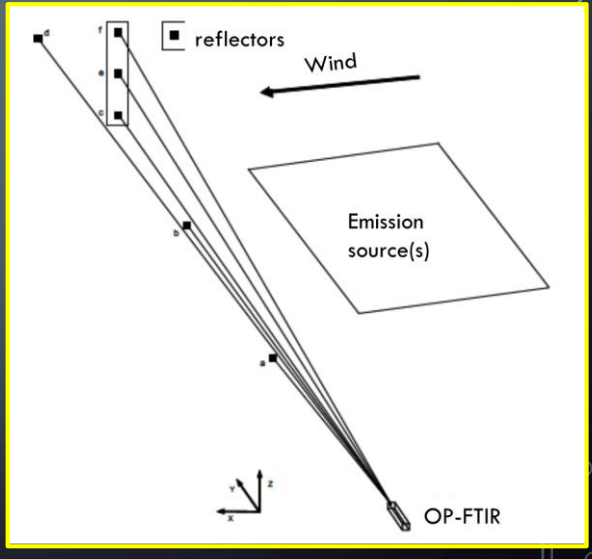
METHODS: DIFFERENTIAL ABSORPTION LIDAR (DIAL)



- Vertical scans enable plume mapping and flux calculation
- Combine integrated concentration with simple wind field to obtain flux
- Can measure away from source
- Light source IR or UV laser
- Daytime and nighttime measurements

METHODS: VERTICAL RADIAL PLUME MAPPING (VRPM)

- OP FTIR system is positioned downwind from the source
- Multiple retroreflectors strategically placed to cover outflow from the source
- VRPM combines path averaged concentrations from OP FTIR measurements with wind speed and direction to calculate emission fluxes
- Permanent installation



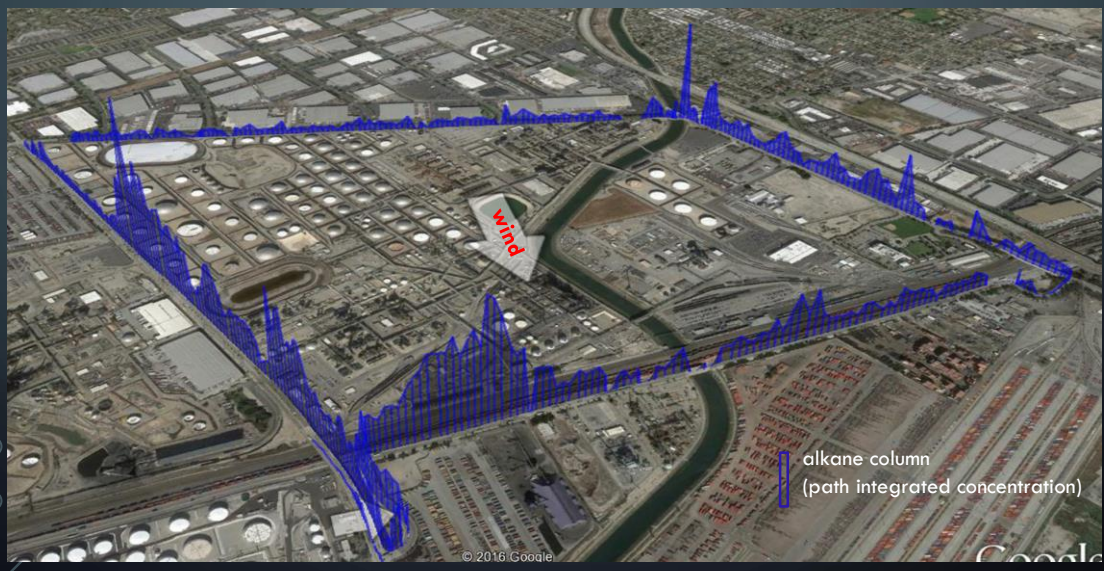
PROJECT 1: QUANTIFY FUGITIVE EMISSIONS FROM LARGE REFINERIES

- *FluxSense*
  - **SOF + FTIR + DOAS**
  - Mobile measurements (daytime only)
  - 5 week study at 6 refineries in the SCAB
  - Facility wide emissions of methane, non methane VOCs, NO_2, SO_2, BTEX

- *National Physical Laboratory (NPL)*
  - **DIAL**
  - Stationary daytime and nighttime measurements
  - 1 week study at 1 refinery
  - Facility wide emissions of non methane VOCs, BTEX
  - **Ideal for field validation**

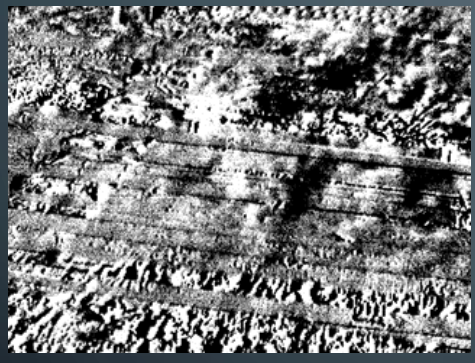
- *Atmosfir Optics*
  - **VRPM Using Open-path FTIR**
  - Large installation, continuous (24/7) measurements
  - 5 week study at 1 refinery
  - Emissions of methane, non methane VOCs
  - EPA OTM 10 method
  - **Complements mobile and other short term observations**

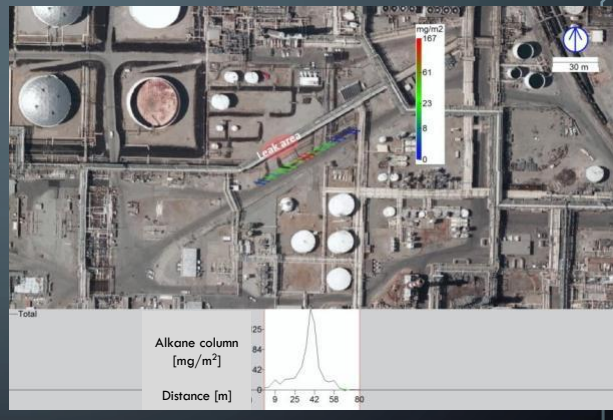
SOF MEASUREMENTS ALONG REFINERY FENCELINE



ALKANES AND BTEX DOWNWIND OF A REFINERY

DISCOVERY OF UNDERGROUND LEAK FROM A CORRODED PIPE

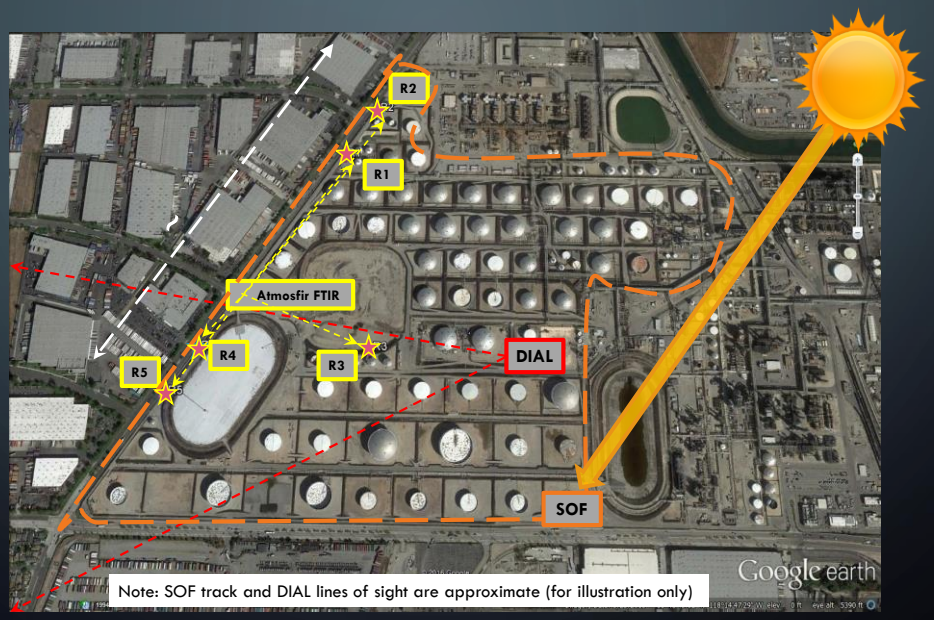




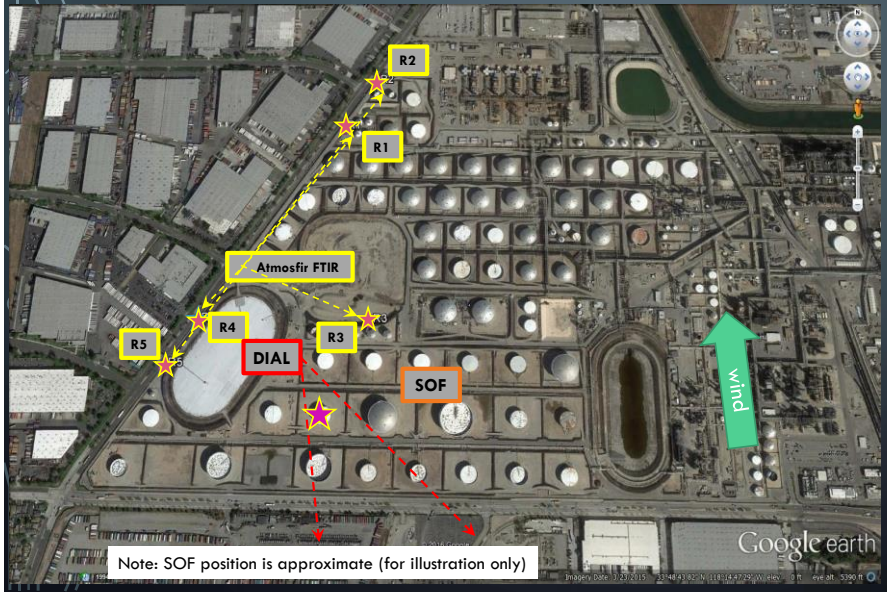
- September 30, 2015, at ~4:00pm
- Fluxsense discovered a leak from a corroded underground pipe
- Discovery was made while driving inside the facility
- FLIR images/videos confirmed emissions from the ground

- Measured alkanes concentrations: ~70,000 ppb
- Average VOC emissions: 31 kg/h

CO LOCATED MEASUREMENTS AT REFINERY TANK FARM

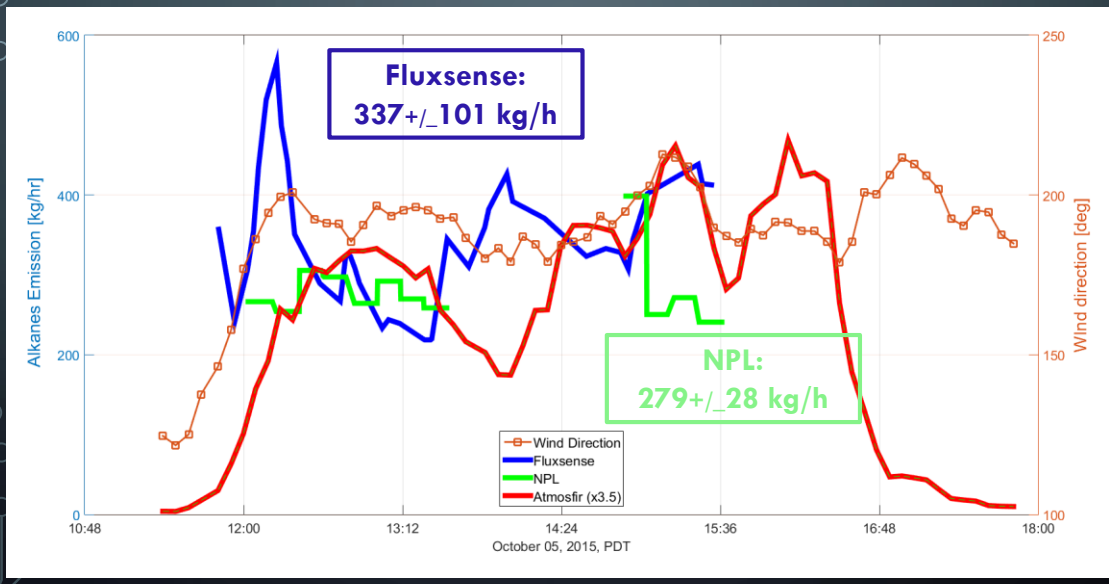


MONITORING OF A TANK LEAK EVENT

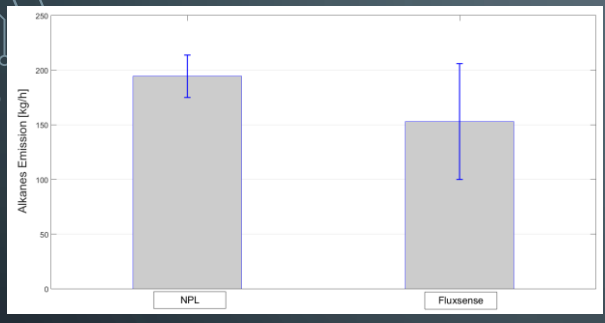


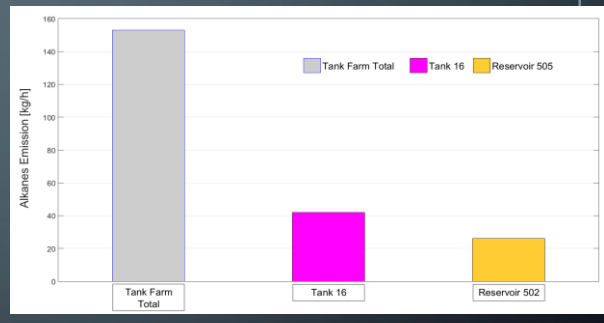
- October 5, 2015 11:30am 4:30pm
- Emissions from a tank were observed by all three ORS technologies
- Fenceline concentrations of alkanes decreased dramatically after emissions stopped

EMISSIONS OF ALKANES FROM A LEAKING TANK



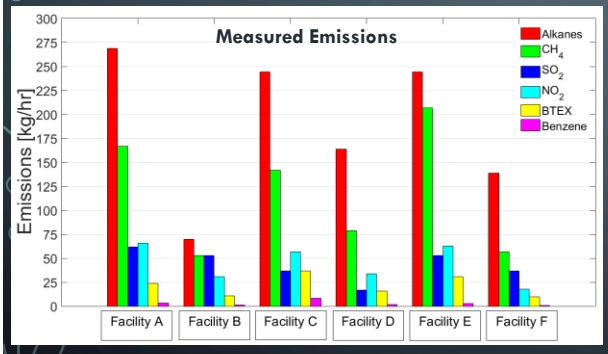
MEASURED EMISSIONS OF ALKANES FROM A TANK FARM

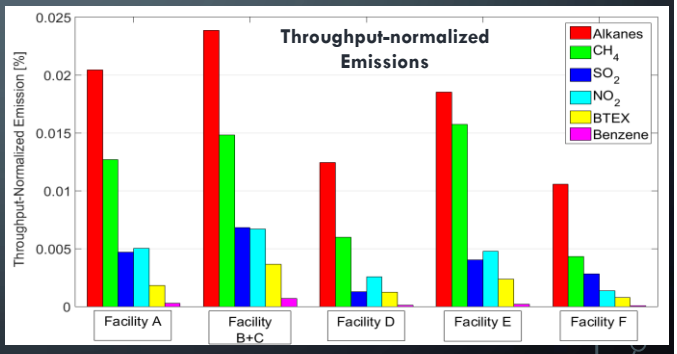




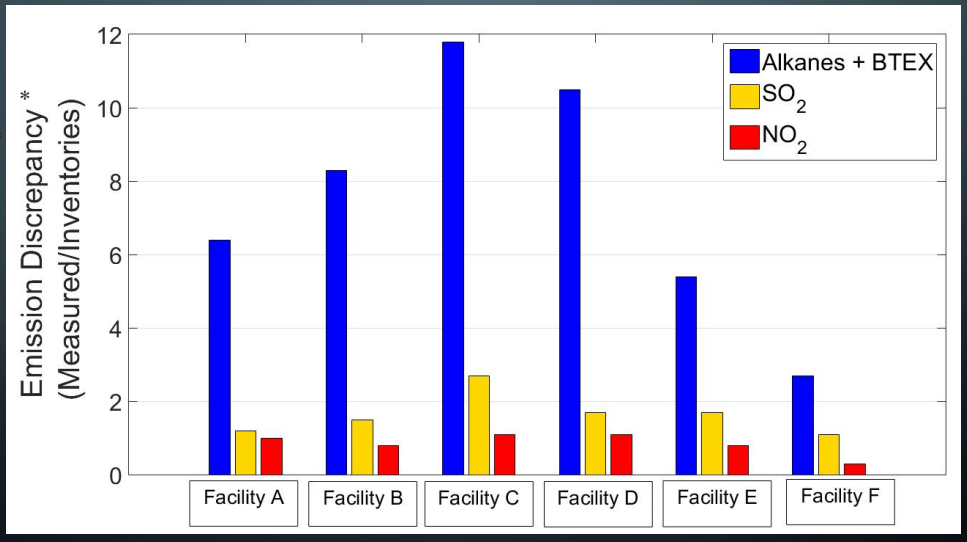
- Fluxsense and NPL measurements are in very good agreement
- Tank 16 and Reservoir 502 contribute to more than 50% of total alkanes emissions from the tank farm

PROJECT 1 RESULTS: REFINERY EMISSIONS (FLUXSENSE)





PROJECT 1 RESULTS: REFINERY EMISSIONS (FLUXSENSE)



*Median measured emissions (September 2015) / Reported annual emissions divided by 12

PROJECT 2: QUANTIFY GASEOUS EMISSIONS FROM SMALL POINT SOURCES

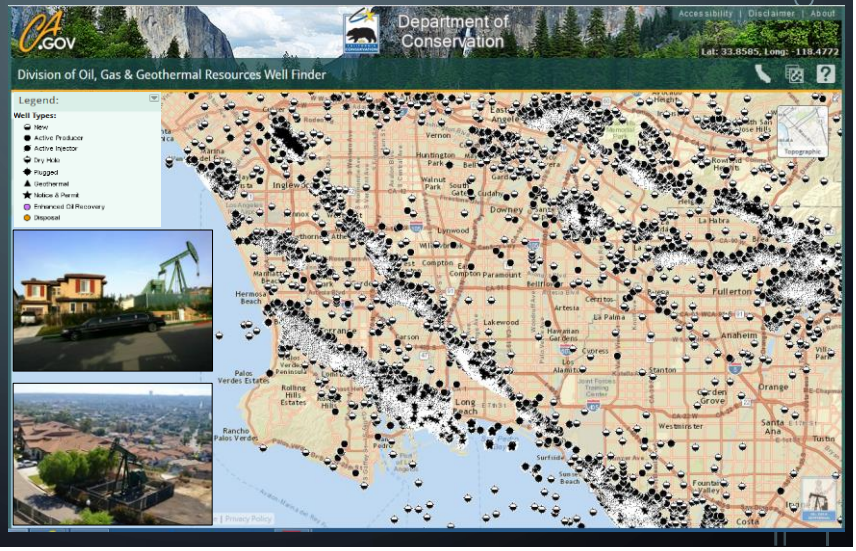
- *FluxSense*
  - **SOF + Extractive FTIR + DOAS**
  - Mobile measurements (daytime only)
  - 5 week study of 100 small sources:
    - Oil wells
    - Intermediate oil treatment facilities
    - Gas stations
    - Other small sources
  - Methane and non methane VOCs, BTEX

- *National Physical Laboratory (NPL)*
  - **Differential Absorption Lidar (DIAL)**
  - Stationary daytime and nighttime measurements
  - 1 week study at selected sources
  - Methane and non methane VOCs
  - **Ideal for field validation**

- *Kassay Field Services*
  - **Open-path FTIR + reverse plume modeling**
  - Stationary daytime and nighttime measurements
  - 5 week study at 50 small sources
  - Methane and non methane VOCs, BTEX
  - OP FTIR using EPA TO 16 method

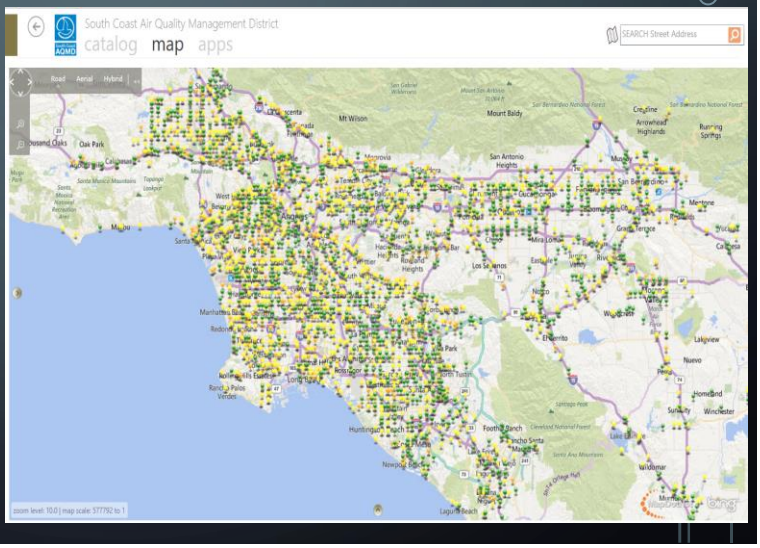
BACKGROUND: VOC EMISSIONS - OIL WELLS

- Thousands of oil wells in the SCAB, many in residential neighborhoods
- SCAQMD rules:
  - Rule 222: well registration
  - Rule 1148.1: housekeeping practices for emission reduction
  - Rule 1148.2: chemical reporting
- Actual emissions from oil wells and other small

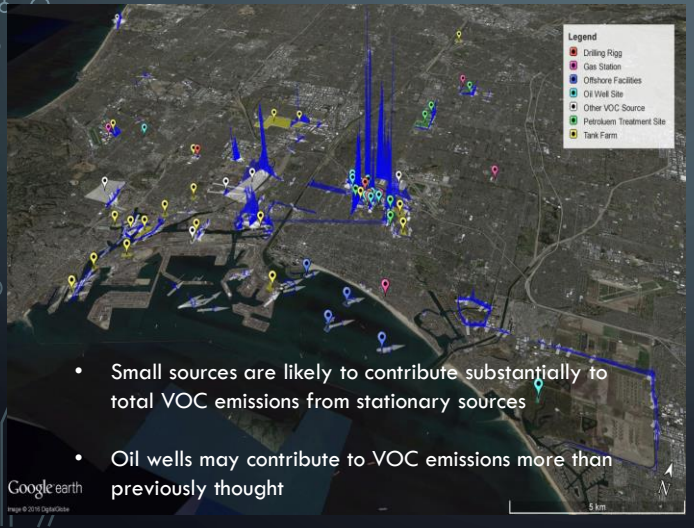


BACKGROUND: VOC EMISSIONS - GAS STATIONS

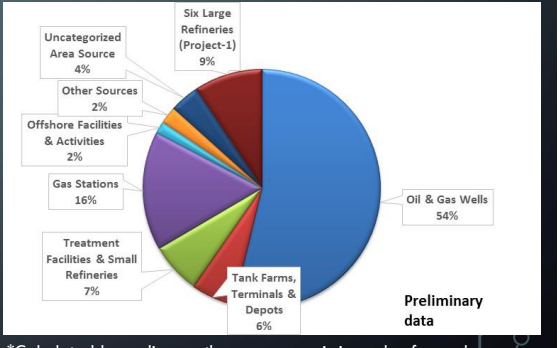
- 3100+ gas stations, many adjacent to residential buildings
- Enhanced vapor recovery (EVR) and In Station Diagnostic (IDS) systems required
- SCAQMD rules:
  - Rule 461:
    - Daily inspections of vapor recovery system by owner/operator
    - Inspections by SCAQMD compliance staff
    - Periodic Source Testing



Project 2 Results: VOC Emissions From Small Sources in the SCAB

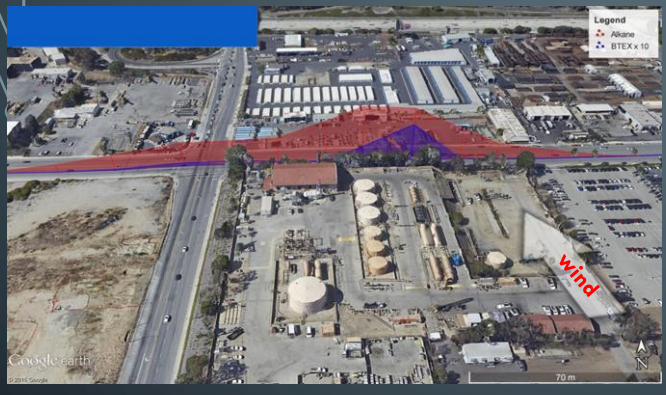


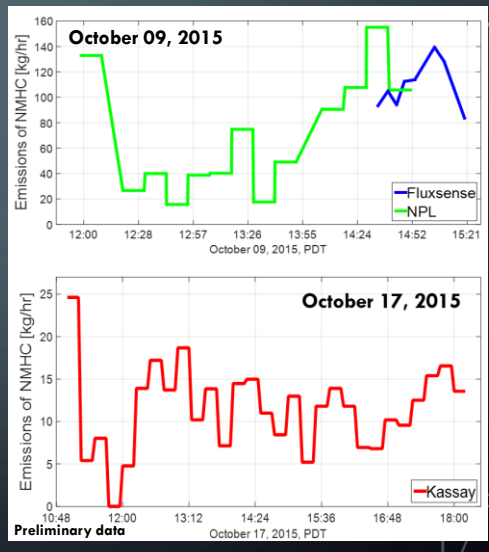
- Small sources are likely to contribute substantially to total VOC emissions from stationary sources
- Oil wells may contribute to VOC emissions more than previously thought



*Calculated by scaling up the average emission value for each category by the total number number of units/sources in the SCAB

EMISSIONS FROM A SMALL OIL TREATMENT FACILITY

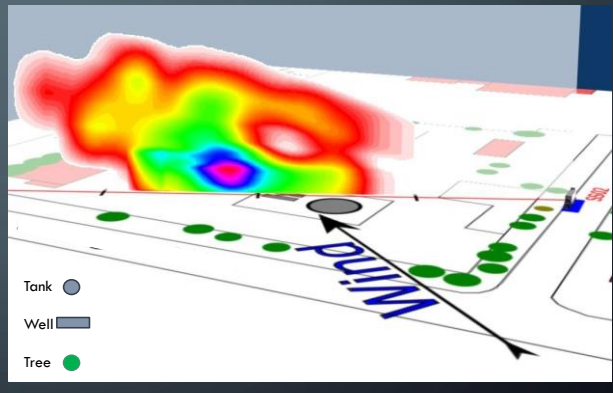




- 24 mobile SOF surveys over 5 weeks
- Elevated NMHC emissions detected during all monitoring days
- Good agreement between SOF and DIAL during co located measurements
- FTIR not able to capture the entire plume, but useful for long term trends

VISUALIZATION OF EMISSIONS FROM A SMALL OIL TREATMENT FACILITY

FLIR video

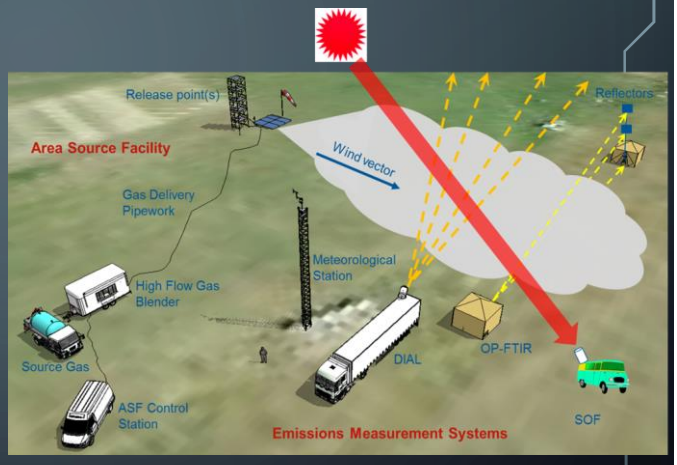


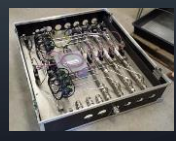
DIAL visualization of VOC emissions

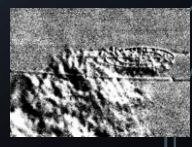
Storage tank is most likely the main source of emissions from the facility

CONTROLLED RELEASE METHOD INTERCOMPARISON STUDY

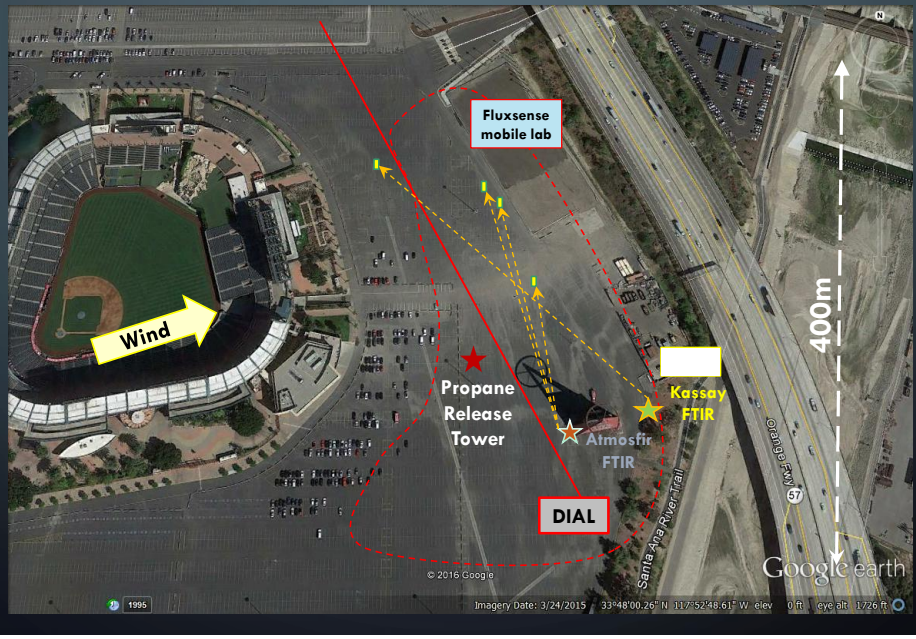
- Conducted on October 12 13, 2015 inside the Angels' Stadium in Anaheim, CA
  - Complex urban environment
  - Near a major freeway
- NPL Area Source Facility (ASF) operated by SCAQMD staff
- Non odorized propane released at various emission rates; each release lasted 1 hour
- Release point heights: 3m, 6.4m, 7.9m
- Blind measurements performed by all ORS contractors
- Meteorological data collected by and shared with all vendors
  - SCAQMD operated LIDAR to provide accurate wind profile data







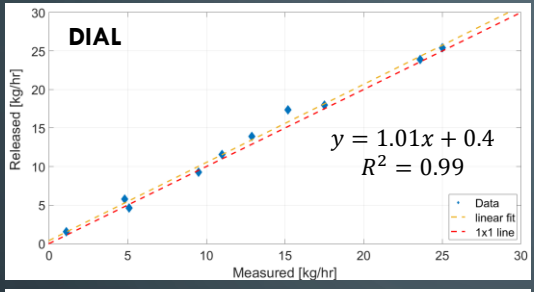
EXPERIMENTAL SETUP

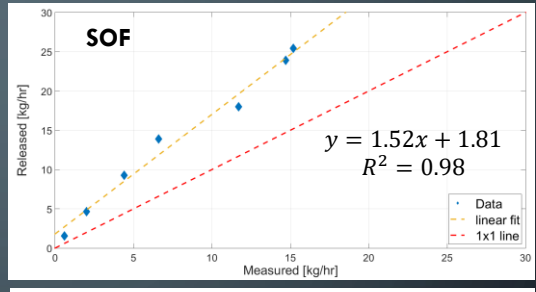


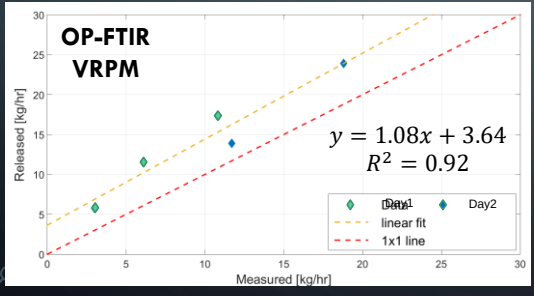
PROPANE PLUME VISUALIZATION

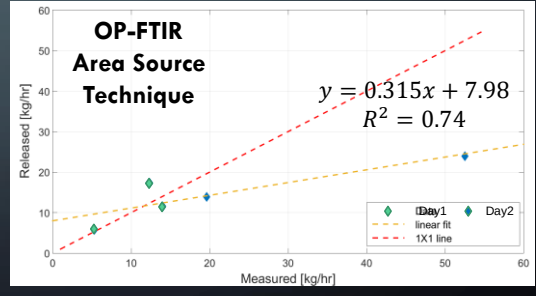
- FLIR video (October 13, 2015 3:41pm)

CONTROLLED RELEASE STUDY: RESULTS









SUMMARY OPTICAL REMOTE SENSING

- ORS techniques can provide:
  - Quick identification of potential leaks, offering substantial improvement of LDAR program or ISD systems
  - Detailed characterization of areas that contribute the most to measured emissions
  - Real or near real time emission measurements
  - Improved emission inventories
- ORS methods are suitable for monitoring of emissions from large facilities as well as small sources
- Mobile ORS methods are effective way to screen large number of small sources quickly
- Good agreement between different ORS techniques during co located measurements of "real life sources
- Strong correlations (R^2) between released and measured emissions for all methods during controlled release study
- Strengths and weaknesses of each technology:
  - SOF: mobile measurements are ideal for routine surveys inside and outside facilities
  - DIAL: very precise and accurate, but not suited for long term monitoring
  - OP FTIR: can provide useful information on long term variability of emissions and record fenceline concentrations of pollutants

ACKNOWLEDGEMENTS

- ORS contractors:
  - Johan Mellqvist, Jerker Samuelsson, Marianne Ericsson
    FluxSense Inc., San Diego, CA/Göteborg, Sweden
  - Rod Robinson, Fabrizio Innocenti, Andrew Finlayson
    National Physical Laboratory, Hampton Rd, Eddington, United Kingdom
  - Steve Perry
    Kassay Field Services, Mohrsville, PA
  - Ram Hashmonay
    Atmosfir Optics Ltd., Ein Iron, Israel
- Tesoro Carson refinery environmental staff