MOBILE OPTICAL REMOTE SENSING FOR AIR QUALITY AND EMISSION MONITORING

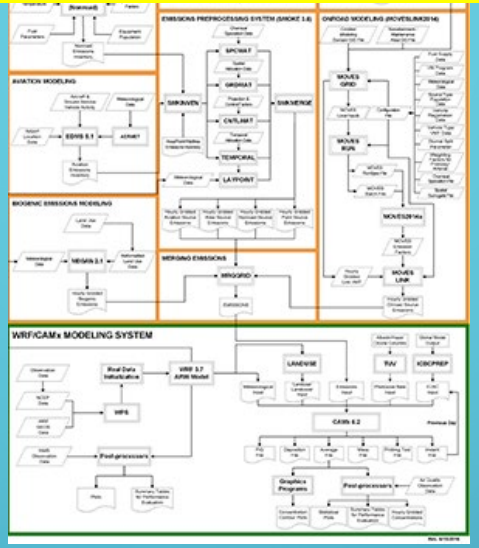
OLGA PIKELNAYA

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT, DIAMOND BAR, CALIFORNIA,

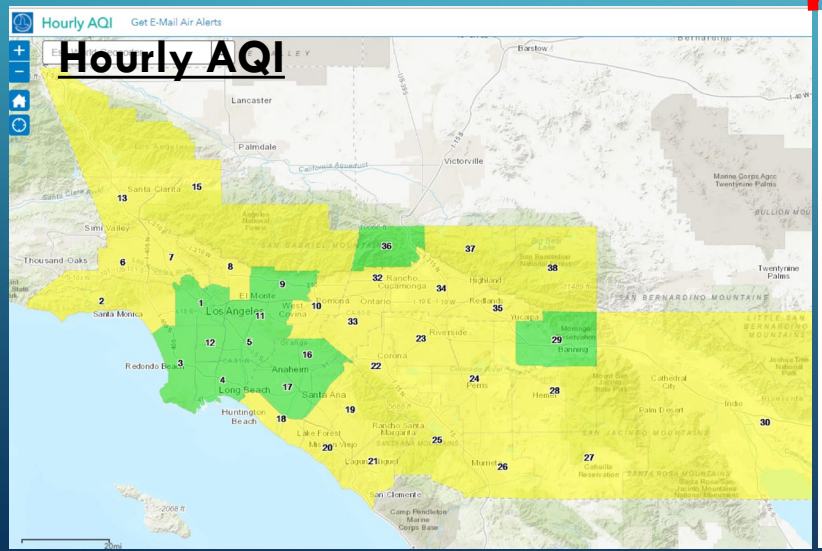
TRADITIONAL APPROACH TO ACCESS AIR QUALITY

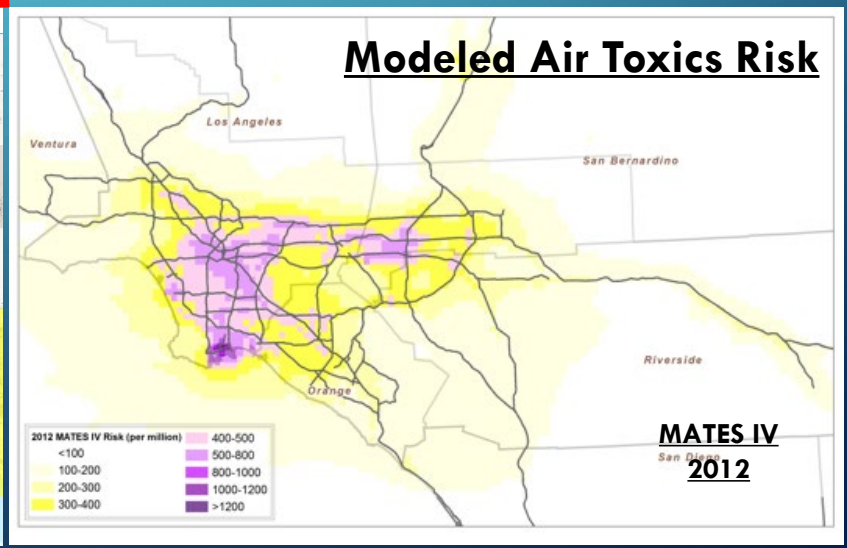
Air Monitoring Stations

Air Quality Modeling



Emissions Inventories





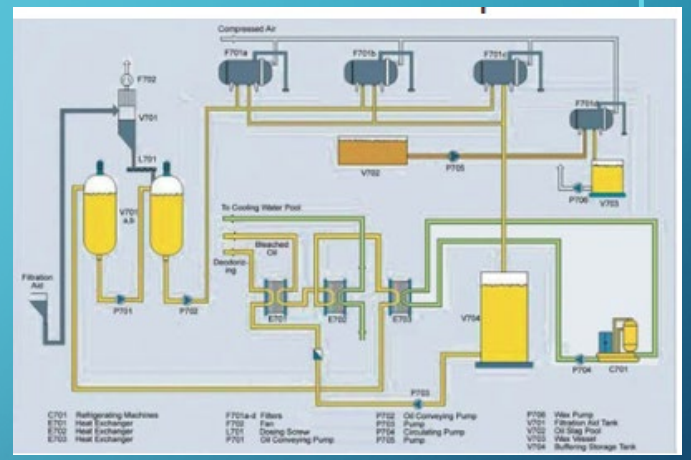
TRADITIONAL APPROACH TO QUANTIFY EMISSIONS

AP-42 Emission Factors

Emission Estimation Protocol

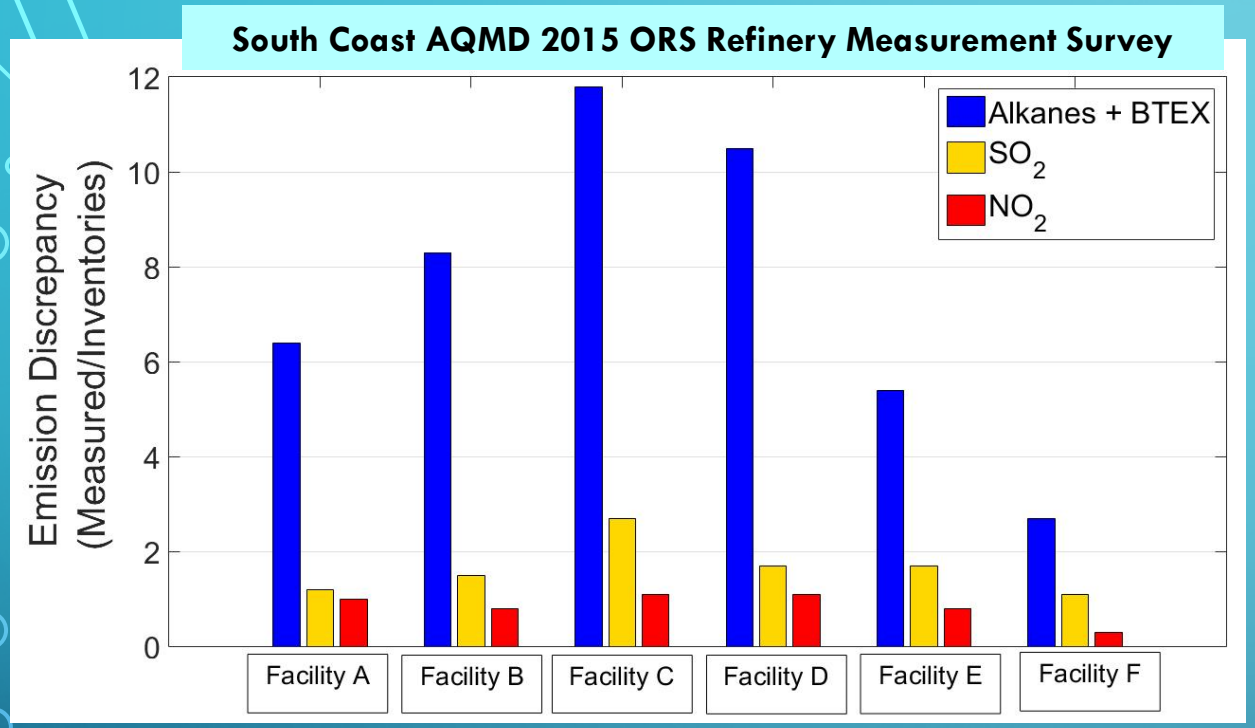
https://www3.epa.gov/ttn/chief/efpac/protocol/Protocol%20Report%202015.pdf

Refinery Equipment

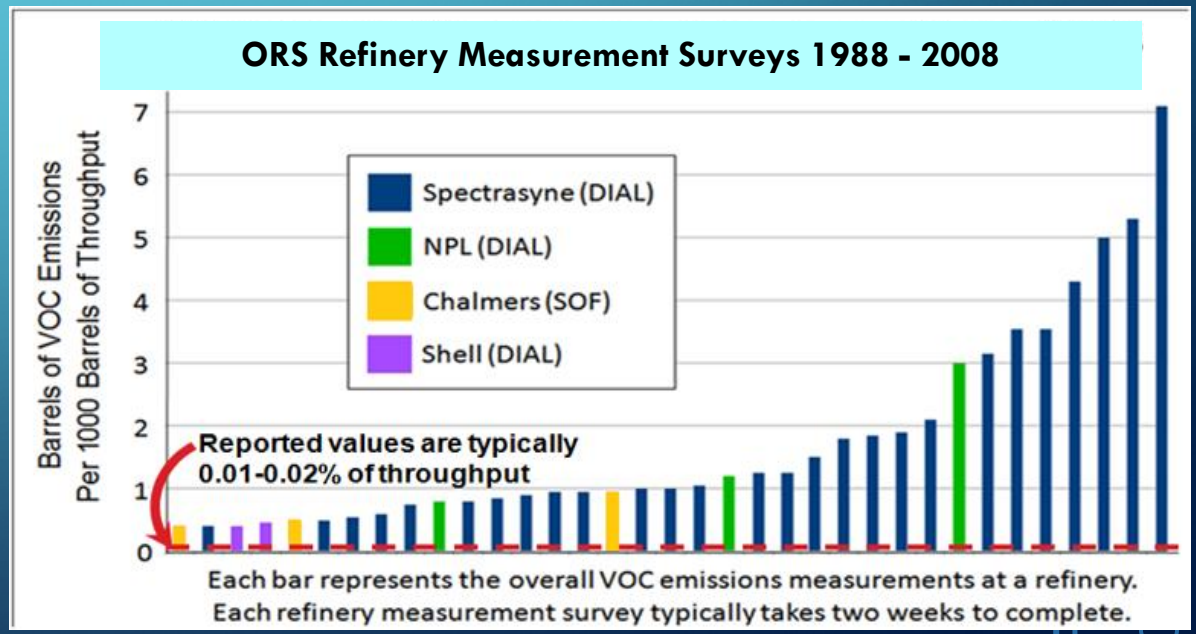


Emission Inventory

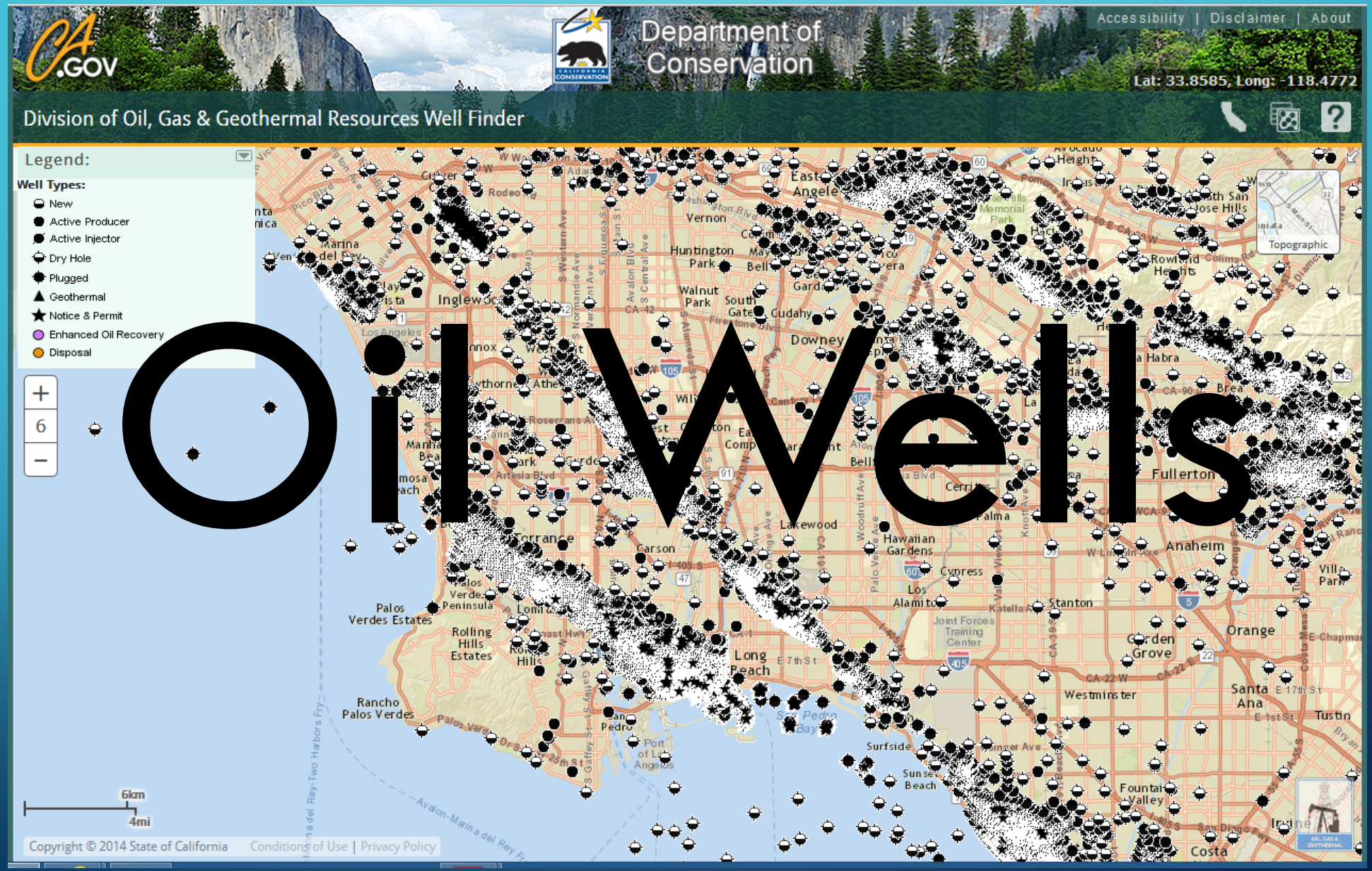
INVENTORIES MAY UNDERESTIMATE FUGITIVE VOC EMISSIONS



http://www.aqmd.gov/fenceline-monitoring



Adapted from Cuclis, 2012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Division of Oil, Gas & Geothermal Resources Well Finder
Legend:
Well Types:
New
Active Producer
Active Injector
Dry Hole
Plugged
Geothermal
Notice & Permit
Enhanced Oil Recovery
Disposal
Oil Wells
Topographic
6km
4mi
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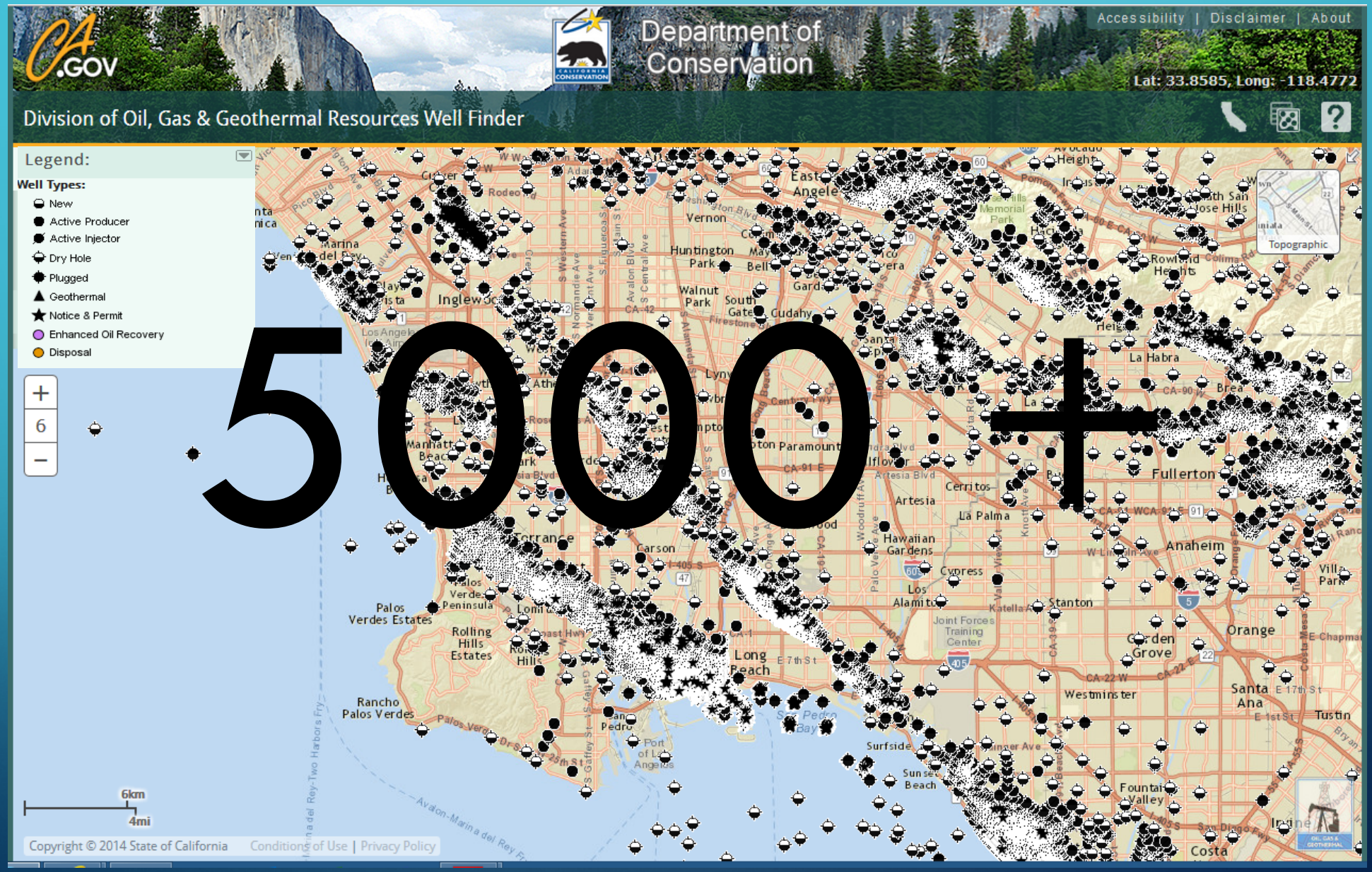
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Division of Oil, Gas & Geothermal Resources Well Finder
Legend:
Well Types:
New
Active Producer
Active Injector
Dry Hole
Plugged
Geothermal
Notice & Permit
Enhanced Oil Recovery
Disposal
5000+
Topographic
6km
4mi
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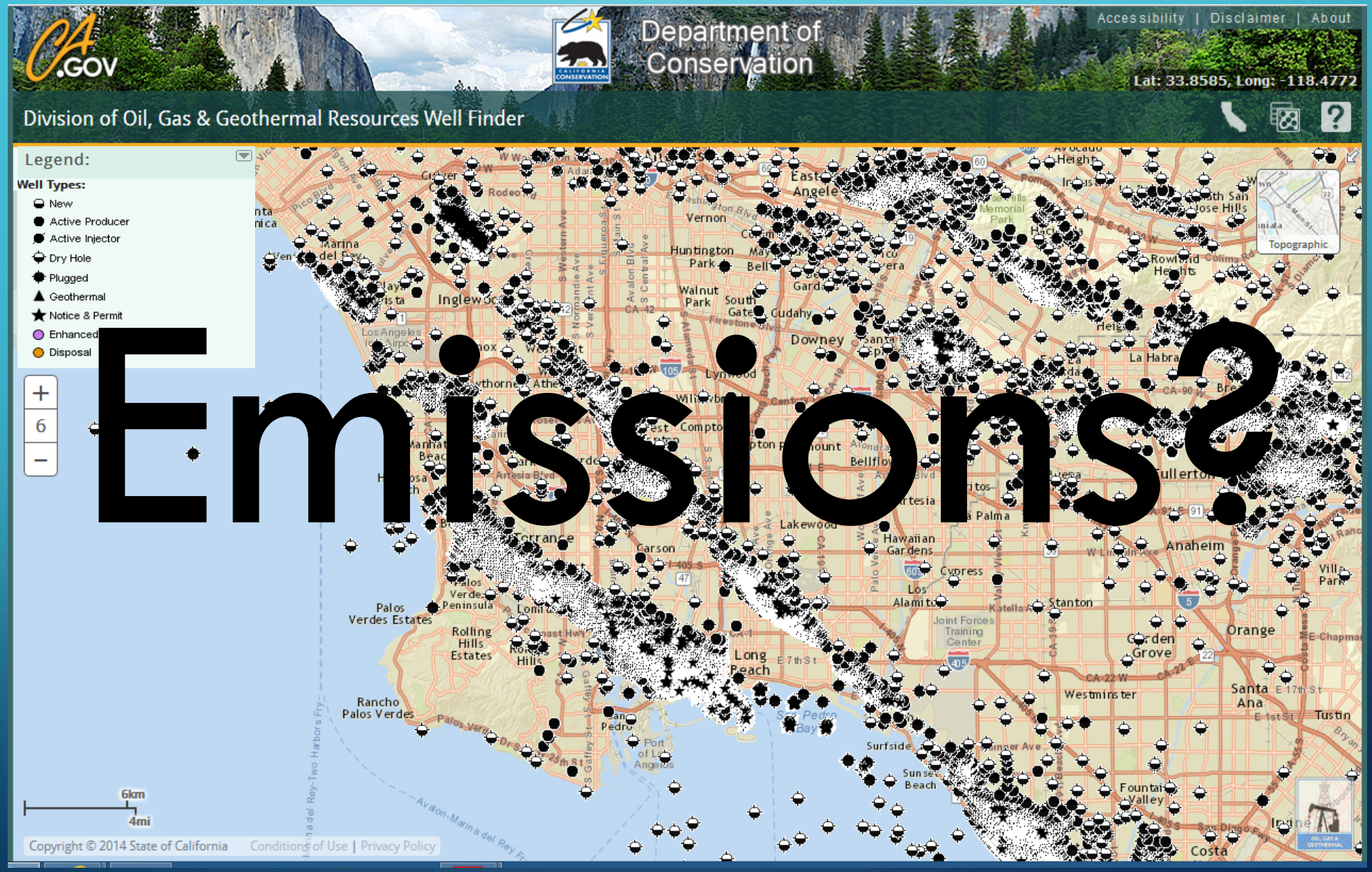
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Division of Oil, Gas & Geothermal Resources Well Finder
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Enhanced
Disposal
Topographic
Emissions?
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4mi
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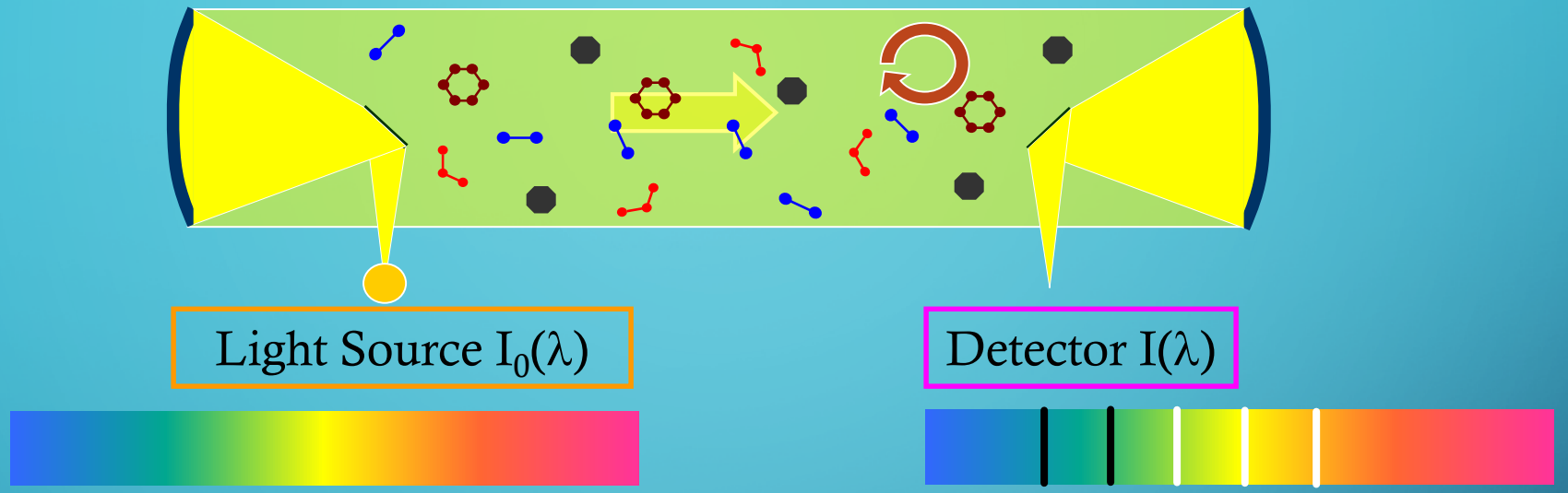
COMMUNITY AIR QUALITY CONCERNS

- Communities
  - are concerned with exposure to industrial emissions and
  - desire real-time information on air quality at the fenceline and in the community
- State and local rules and regulations mandate
  - community air monitoring
  - fenceline monitoring at refineries

OPTICAL REMOTE SENSING METHODS

- Optical Remote Sensing (ORS) Technologies
  - Matured over the past decade
  - Fully automated / continuous / no calibration required
  - Ideally suited for long-term fenceline monitoring, allow to characterize and quantify emissions
  - Can be deployed from various mobile platforms for rapid leak detection, emission flux measurements, and community monitoring

PRINCIPLE OF OPTICAL REMOTE SENSING



Initial light spectrum

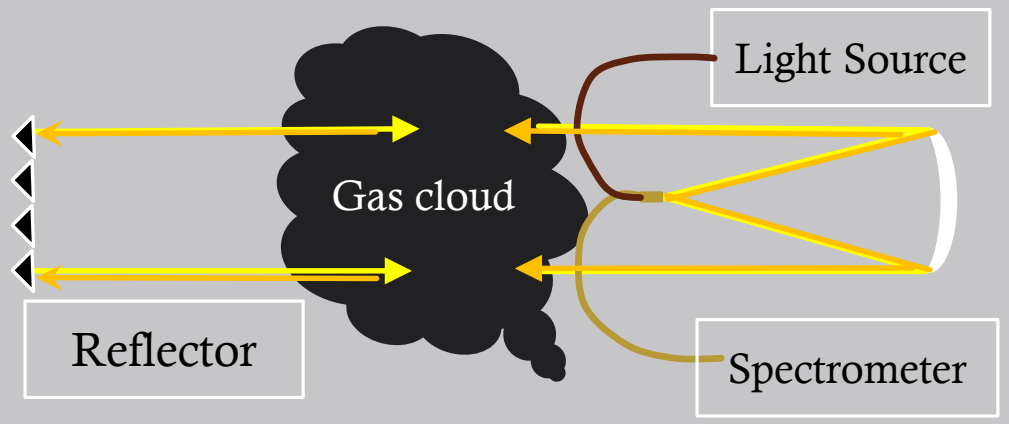
Light spectrum after passing through gas cloud

- Beer-Lambert Law
- Trace gases in the atmosphere absorb light
- Each molecule has its own unique fingerprint
- Multiple gases can be observed simultaneously
- Works with natural (e.g. direct or scattered sunlight) or artificial light

MOBILE ORS MEASUREMENT STRATEGY

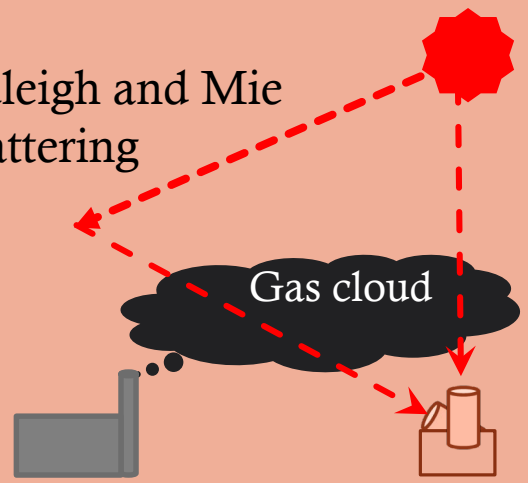
REMOTE SENSING TECHNIQUES

Active: Artificial Light Source



- UV-vis: O_3, SO_2, NO_2, HCHO, BTEX, aerosol
- IR: O_3, CO_2, CO, CH_4, VOCs
- Measurements during day and night
- Permanente installation

Passive: Direct or Scattered Sunlight



- HCHO, NO_2, SO_2, HONO, aerosol, total alkanes
- Plume vertical and horizontal extend
- Measurements during the day
- Permanent installation or on mobile or aerial platforms

FLUXSENSE MOBILE LABORATORY

INSTRUMENTS ABOARD MOBILE LABORATORY

Method	Solar Occultation Flux	Mobile Zenith sky DOAS	Mobile Extractive FTIR	Mobile White Cell DOAS
Compounds	Alkane, C2H4, C3H6, C4H8, NH3, CO	NO2 SO2 HCHO	Alkane, CH4, C2H4, C3H6, C4H8, NH3, CO,CO2, N2O	BTEX SO2
Principle	Remote sensing	Remote sensing	Extractive	Extractive
Measured unit	Vertical Column	Vertical Column	Concentration	Concentration
Sensitivity	0.1 mg/m2	0.1 mg/m2	1-10 ppb	0.2 ppb
Flux limit	0.2 kg/hr	1kg/hr	0.2-2 kg/hr	1-2 kg/hr
Wind Speed	2-12m/s	2-12m/s	2-12m/s	2-12m/s
Time response	1-5 sec	1-5 sec	5-15 sec	1-3 sec

Direct emission flux measurements

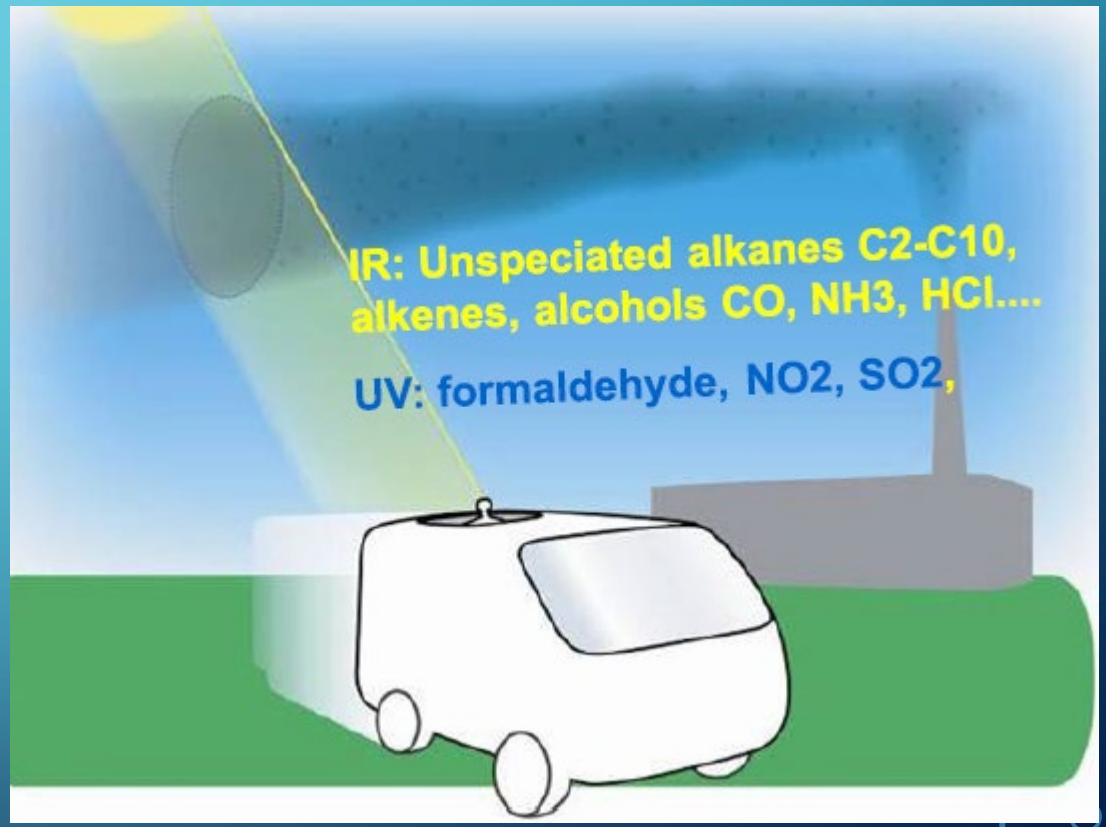
Direct emission flux measurements

Concentration mapping and flux measurements

Concentration mapping and flux measurements

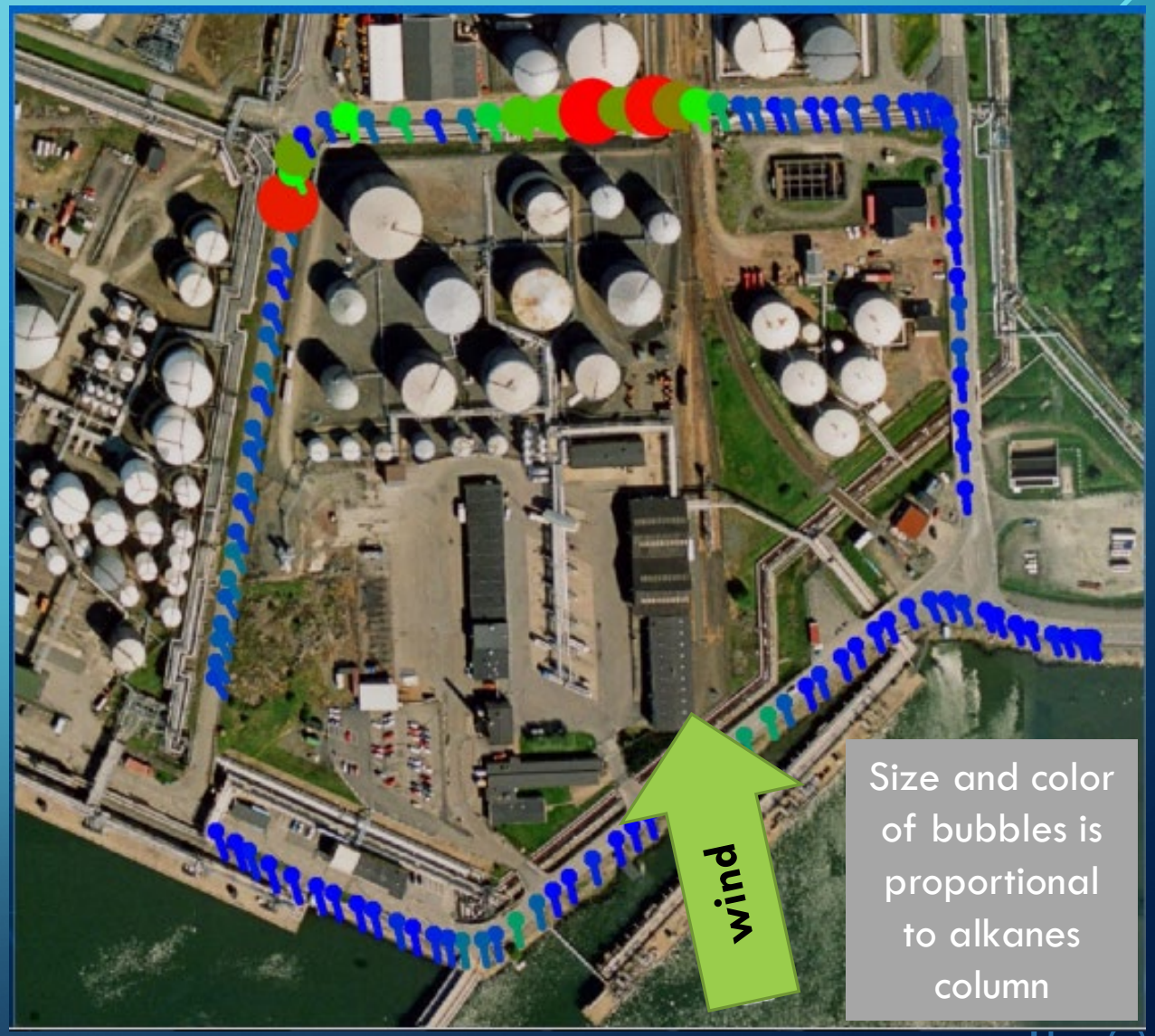
MEASUREMENT STRATEGY

- Spectroscopic analysis of direct solar IR light and zenith scattered UV light to determine the number of molecules for the key species above the mobile laboratory (column)
- The measurements are conducted while driving therefore measuring the total mass of molecules along the traveled path
- The total mass is multiplied by the wind which yields the flux (kg/hr)

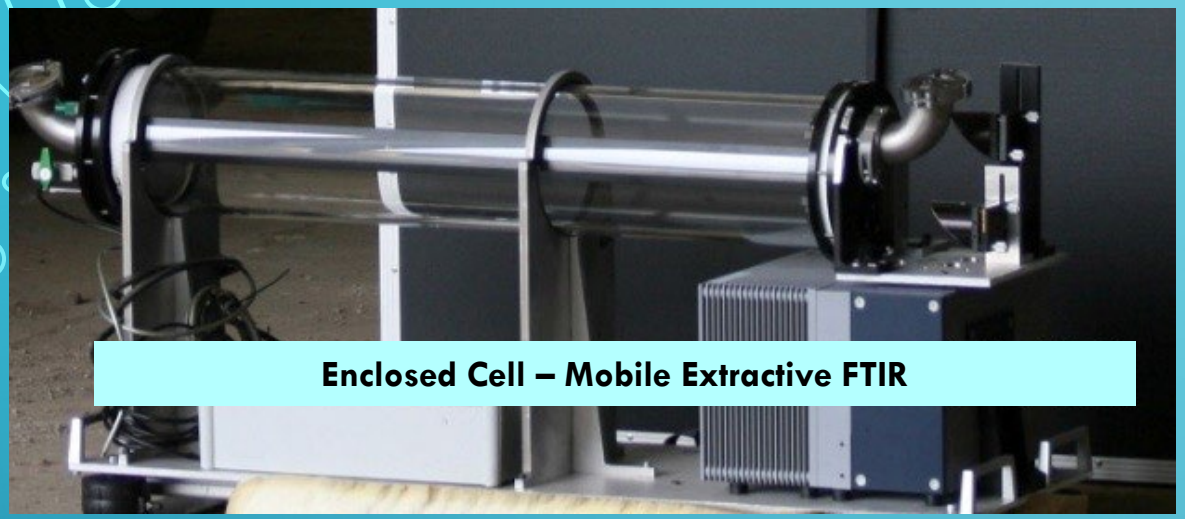


MEASUREMENT STRATEGY

- Circumvent facility multiple times
- The upwind ("background") measurements are subtracted from the downwind measurements in to remove contribution from other sources
- Emission flux is determined by combining column measurements with wind speed and direction



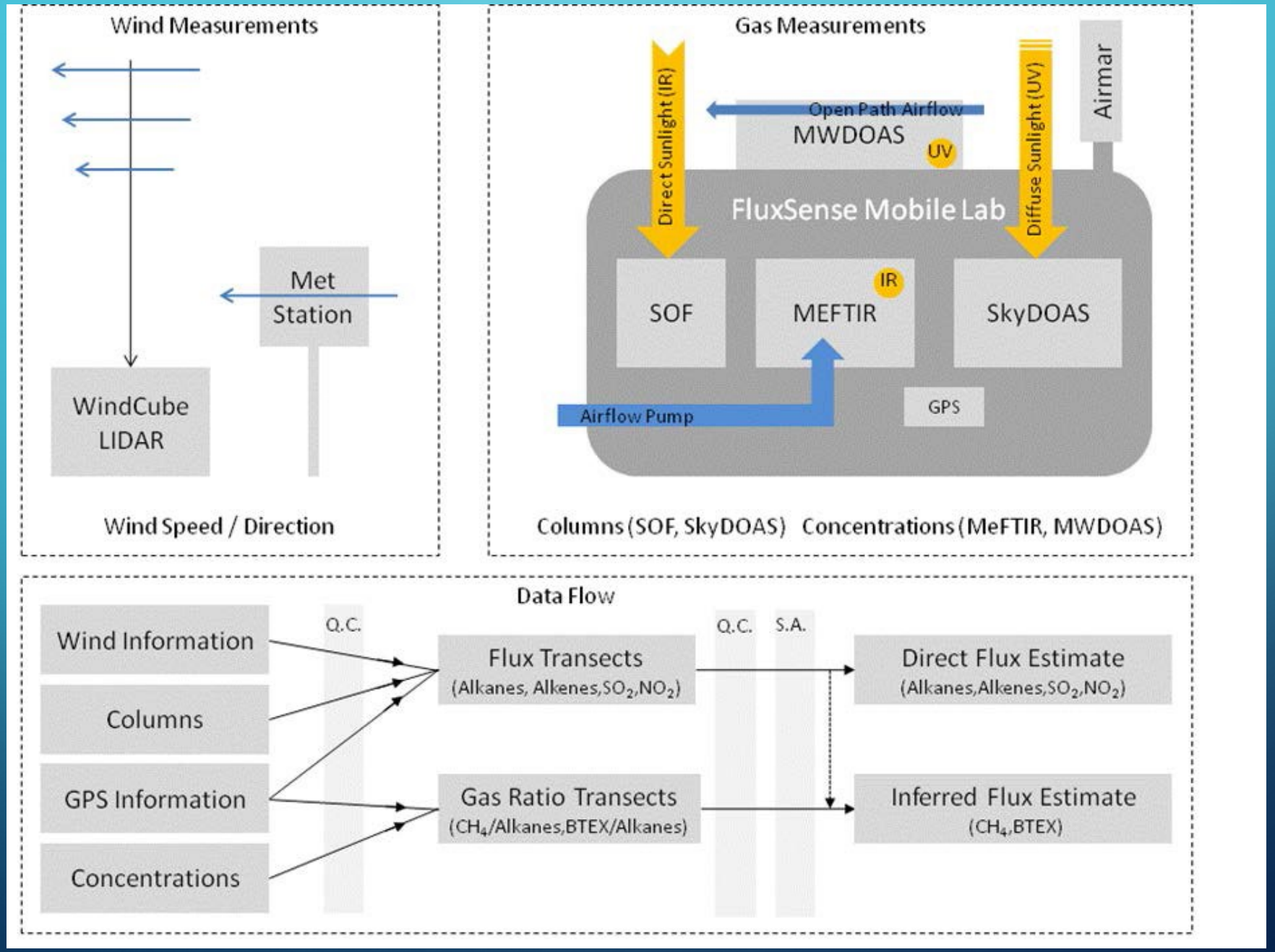
MOBILE UV AND FTIR CELLS



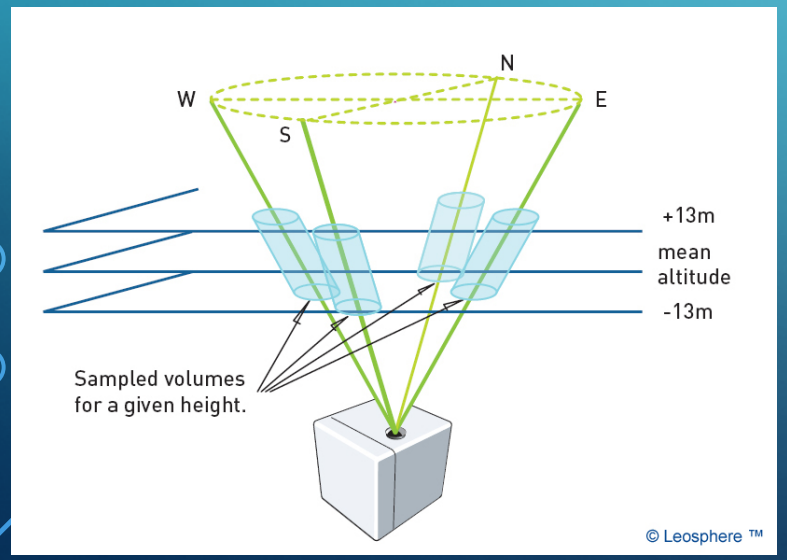
Enclosed Cell – Mobile Extractive FTIR

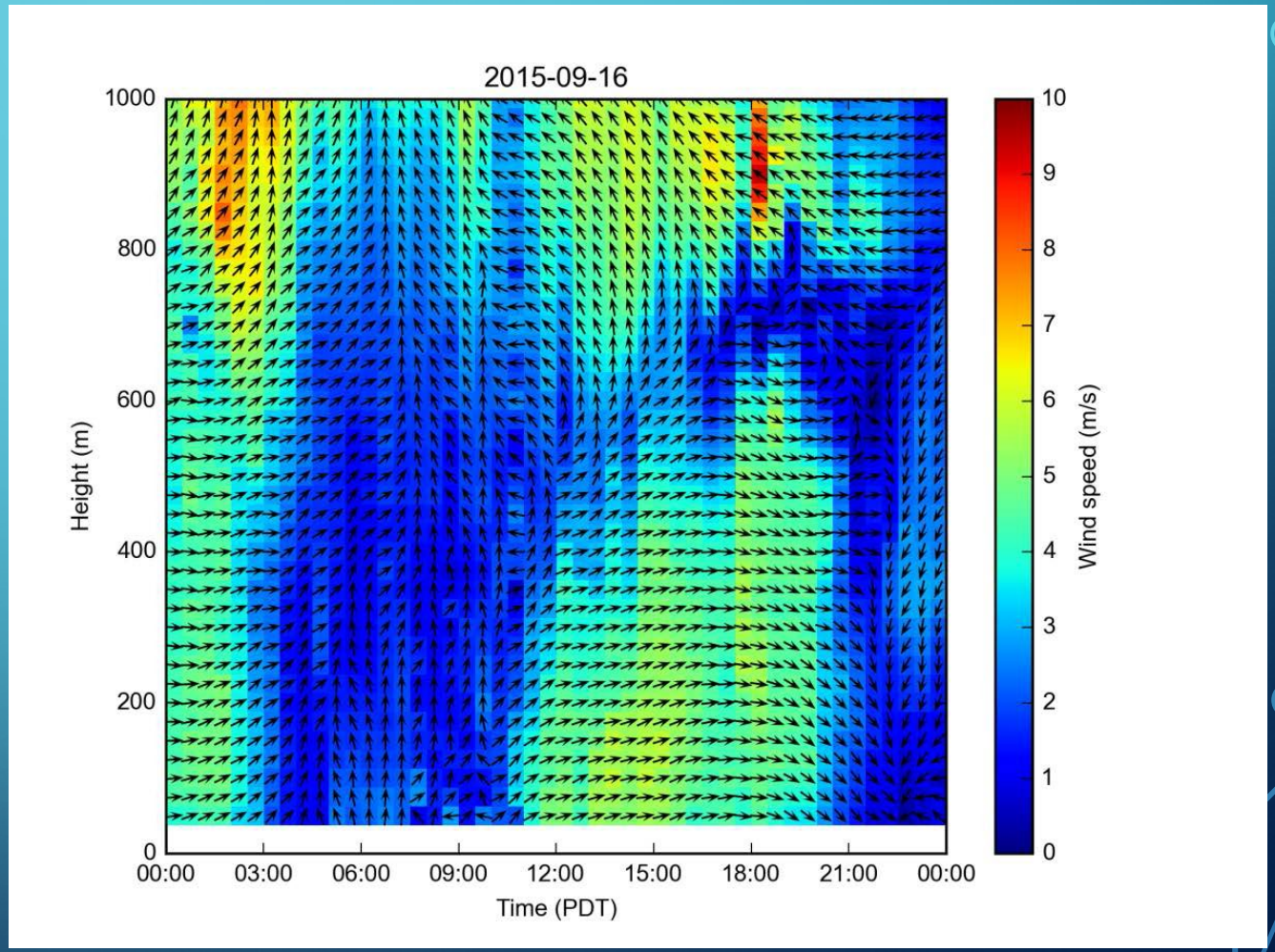
Open Cell – Mobile White Cell DOAS

- Multi-reflection cells with effective pathlength of ~100 – 200 m
- UV: Real time concentration measurements of BTEX and SO2 with 1-30 s time response and 0.2 -3 ppb detection limits
- IR: Real time concentration measurements of alkanes, alkenes, methane, CO, CO_2 and NH_3 with 1-15 s response time and 1-10 ppb detection limit


Wind Measurements
Met Station
WindCube LIDAR
Wind Speed / Direction
Gas Measurements
Direct Sunlight (IR)
Open Path Airflow
MWDOAS
UV
Diffuse Sunlight (UV)
Airmar
FluxSense Mobile Lab
SOF
MEFTIR
IR
SkyDOAS
Airflow Pump
GPS
Columns (SOF, SkyDOAS) Concentrations (MeFTIR, MWDOAS)
Data Flow
Wind Information
Columns
GPS Information
Concentrations
Q.C.
Flux Transects
(Alkanes, Alkenes,SO2,NO2)
Gas Ratio Transects
(CH4/Alkanes,BTEX/Alkanes)
Q.C.
S.A.
Direct Flux Estimate
(Alkanes,Alkenes,SO2,NO2)
Inferred Flux Estimate
(CH4,BTEX)

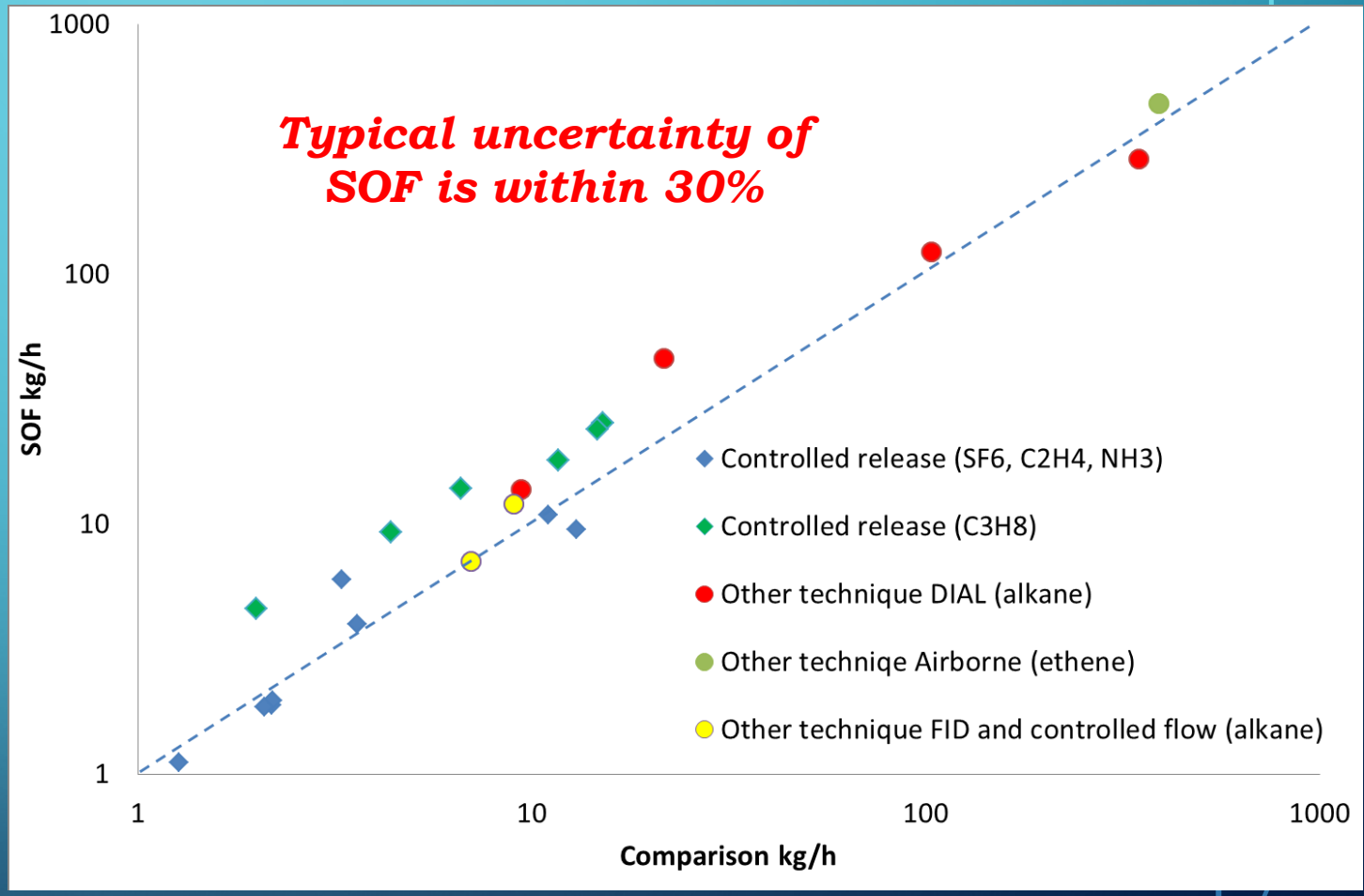
VERTICAL WIND PROFILES – WIND LIDAR



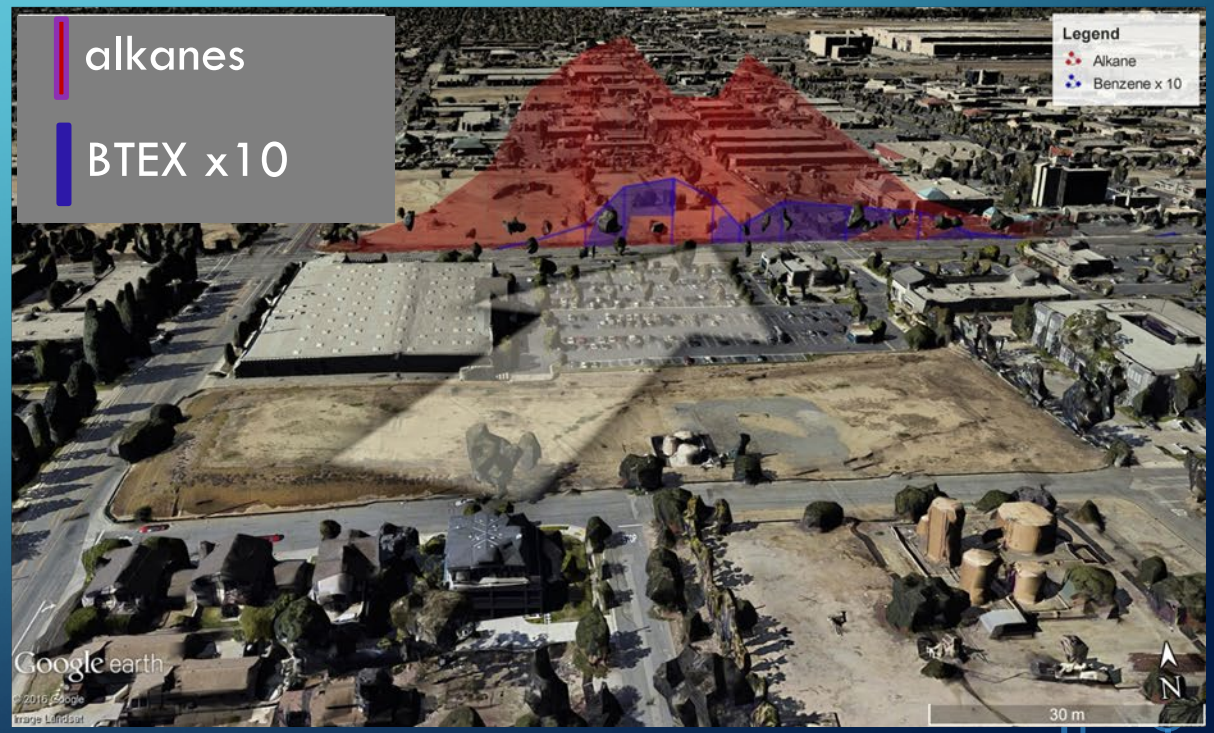


CONTROLLED-RELEASE EXPERIMENTS

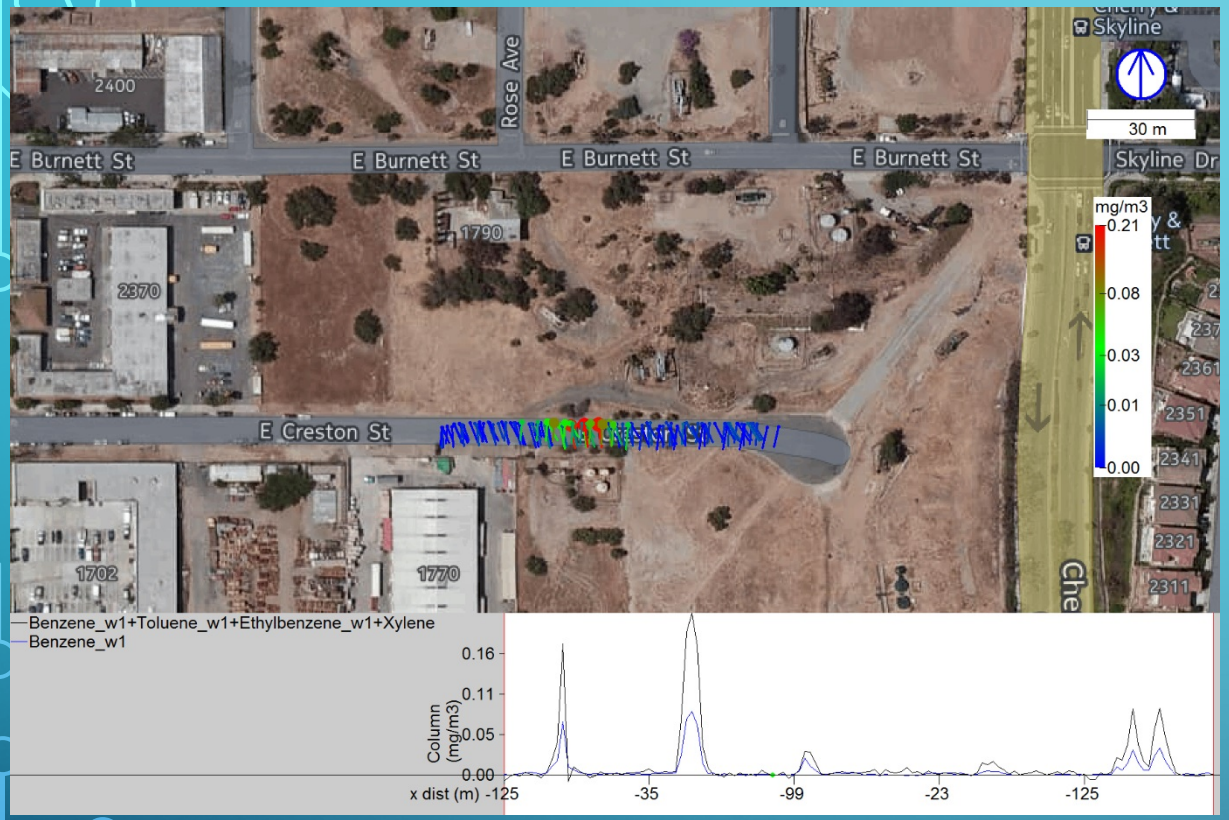
- Designed to test the capability of ORS method (e.g. SOF) to detect and quantify certain pollutants
- "Blind" release operated by independent observer
- Coordinated measurements with other techniques

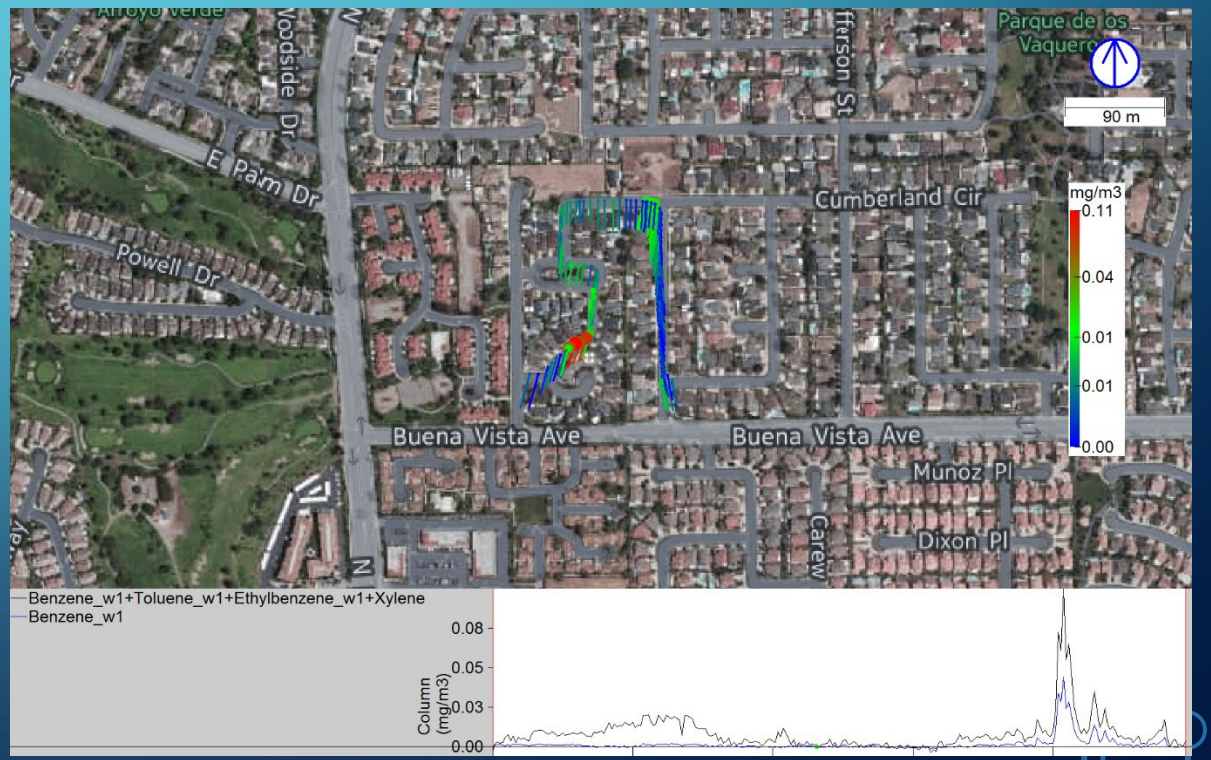


DETECTION OF AIR TOXICS PLUMES



CONCENTRATION MAPPING





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FluxSense

Marianne Ericsson Jerker Samuelsson, Johan Mellqvist, and the entire FluxSense team

RESOURCES AND CONTACT INFO.

South Coast AQMD Fenceline Air Monitoring:

http://www.aqmd.gov/fenceline-monitoring

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