CONTROLLED-RELEASE EXPERIMENT TO VALIDATE FIELD MEASUREMENTS FROM DIFFERENT OPTICAL REMOTE SENSING TECHNIQUES

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BACKGROUND

- Optical Remote Sensing (ORS) technologies evolved significantly over the last decade
- Fully automated / continuous / no calibration or regular maintenance needed
- Can characterize and quantify emissions
- Ideal for long-term fenceline monitoring
- Mounting number of field studies shows that measured VOC emissions can be substantially higher than those reported by emission inventory
- Pressing need to quantify and characterize actual emissions from refineries, oil wells, gas stations and other sources in the SCAB
- Need to access accuracy of ORS emission measurements

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 PROJECTS

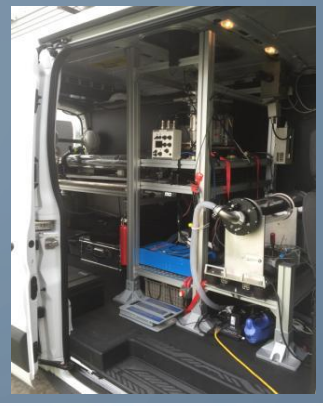
- Project 1: Quantify fugitive emissions from large refineries

- Project 2: Quantify gaseous emissions from small point sources

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

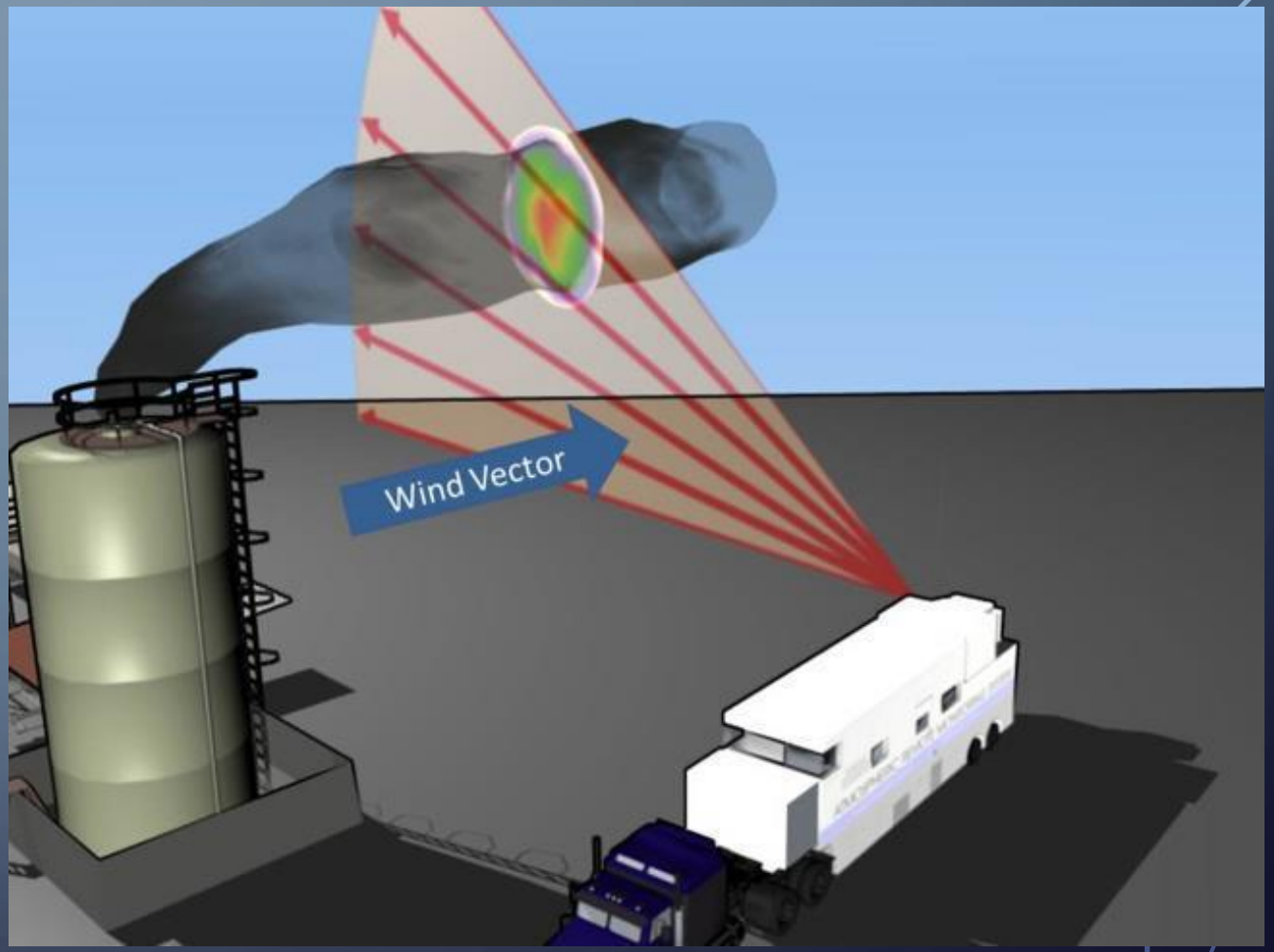
METHODS: SOLAR OCCULTATION FLUX (SOF)

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



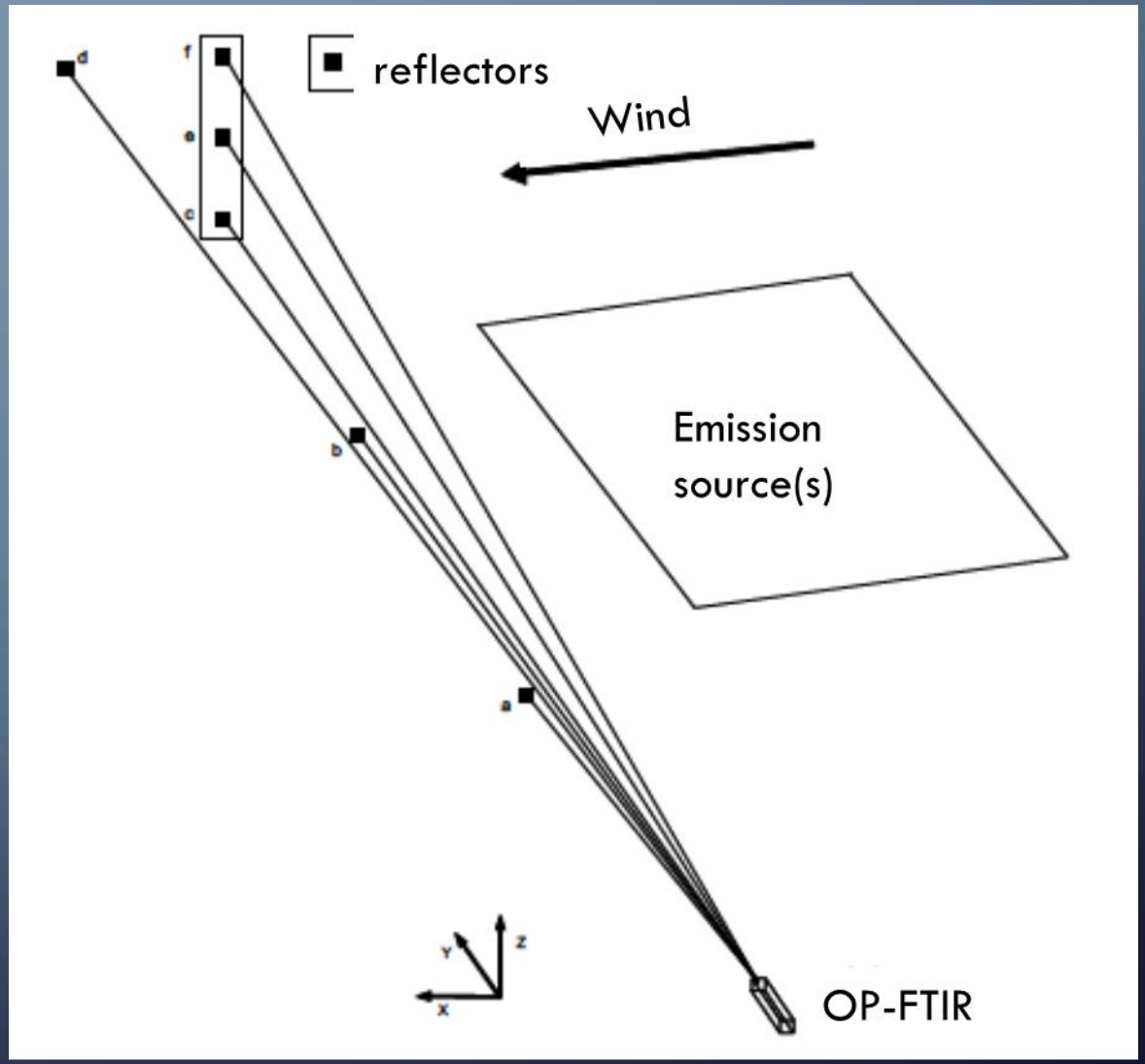
METHODS: DIFFERENTIAL ABSORPTION LIDAR (DIAL)

- 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



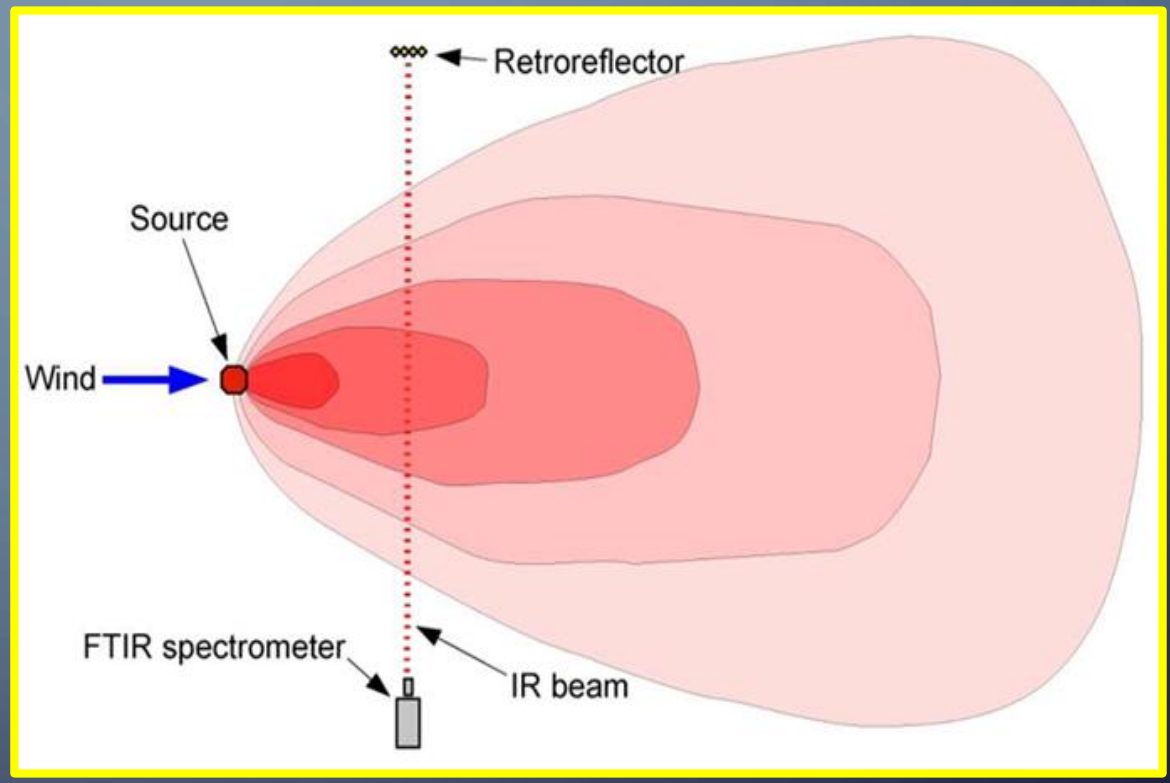
METHODS: VERTICAL RADIAL PLUME MAPPING (VRPM)

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



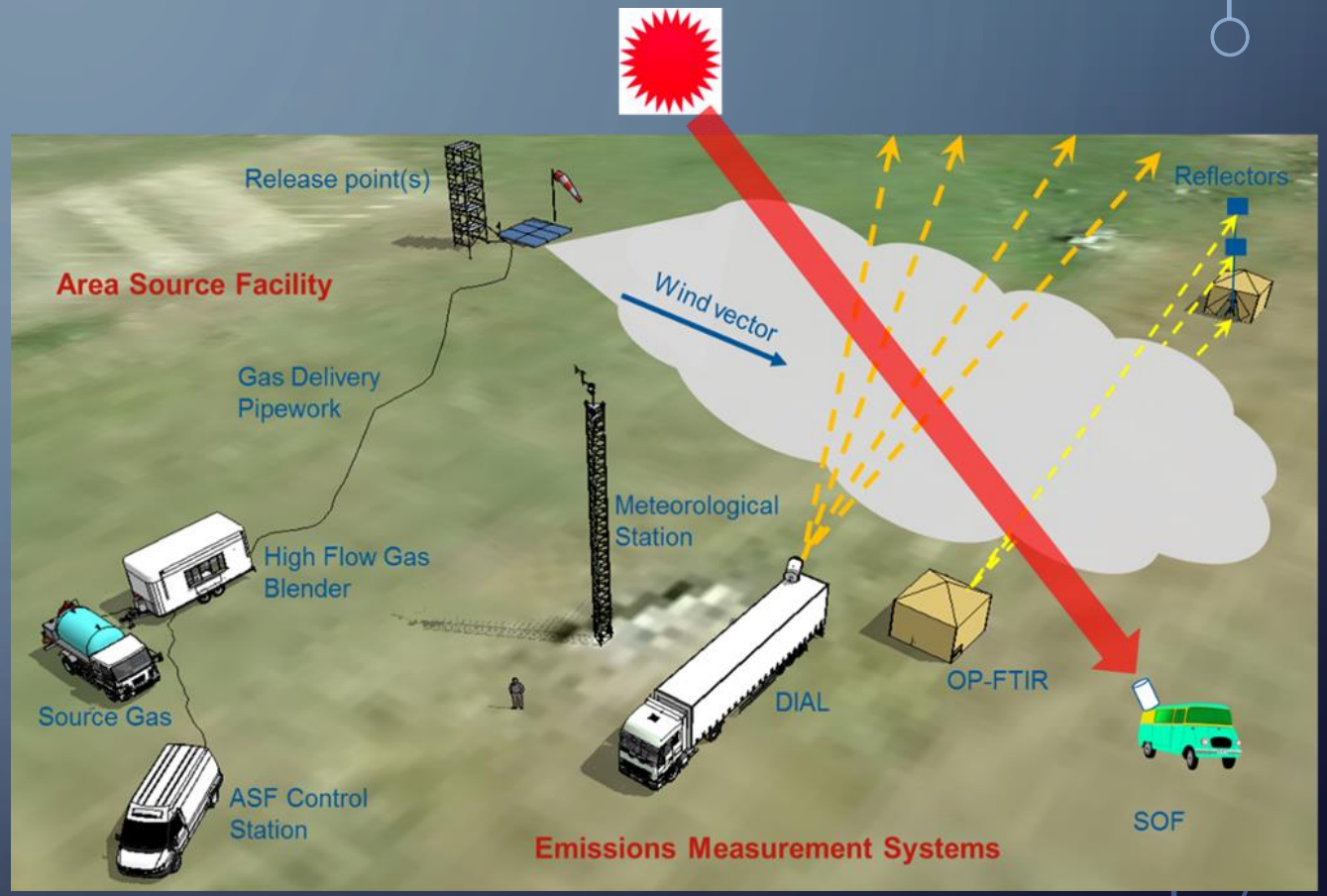
METHODS: AREA SOURCE TECHNIQUE

- Single light path OP-FITR system is positioned downwind from the source
- Retroreflector is placed so emission plume crosses the light path
- Path-averaged concentrations from OP-FITR measurements, wind speed and direction used to model emission fluxes

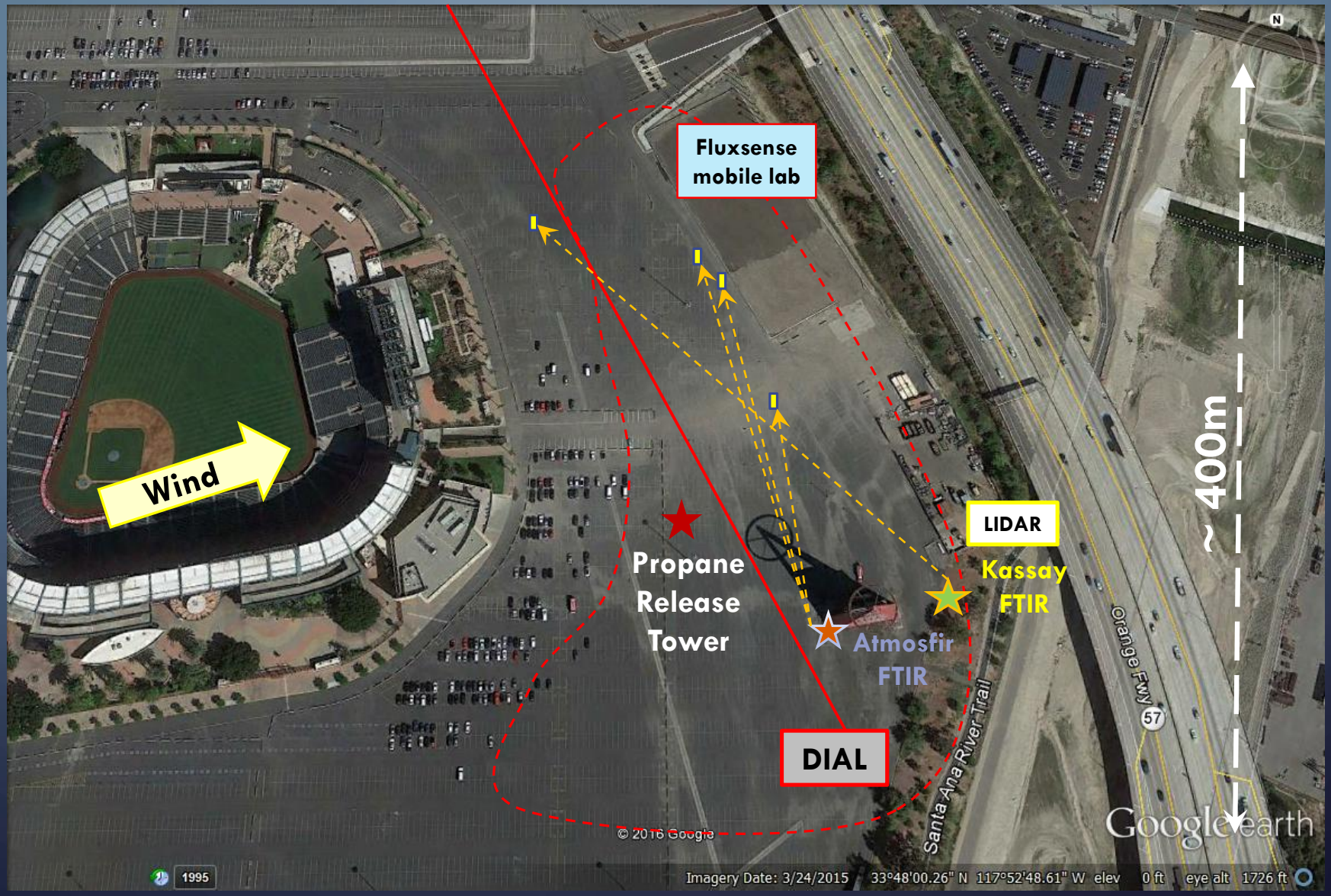


CONTROLLED-RELEASE STUDY: OVERVIEW

- Method inter-comparison 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



CONTROLLED-RELEASE STUDY: EXPERIMENTAL SETUP



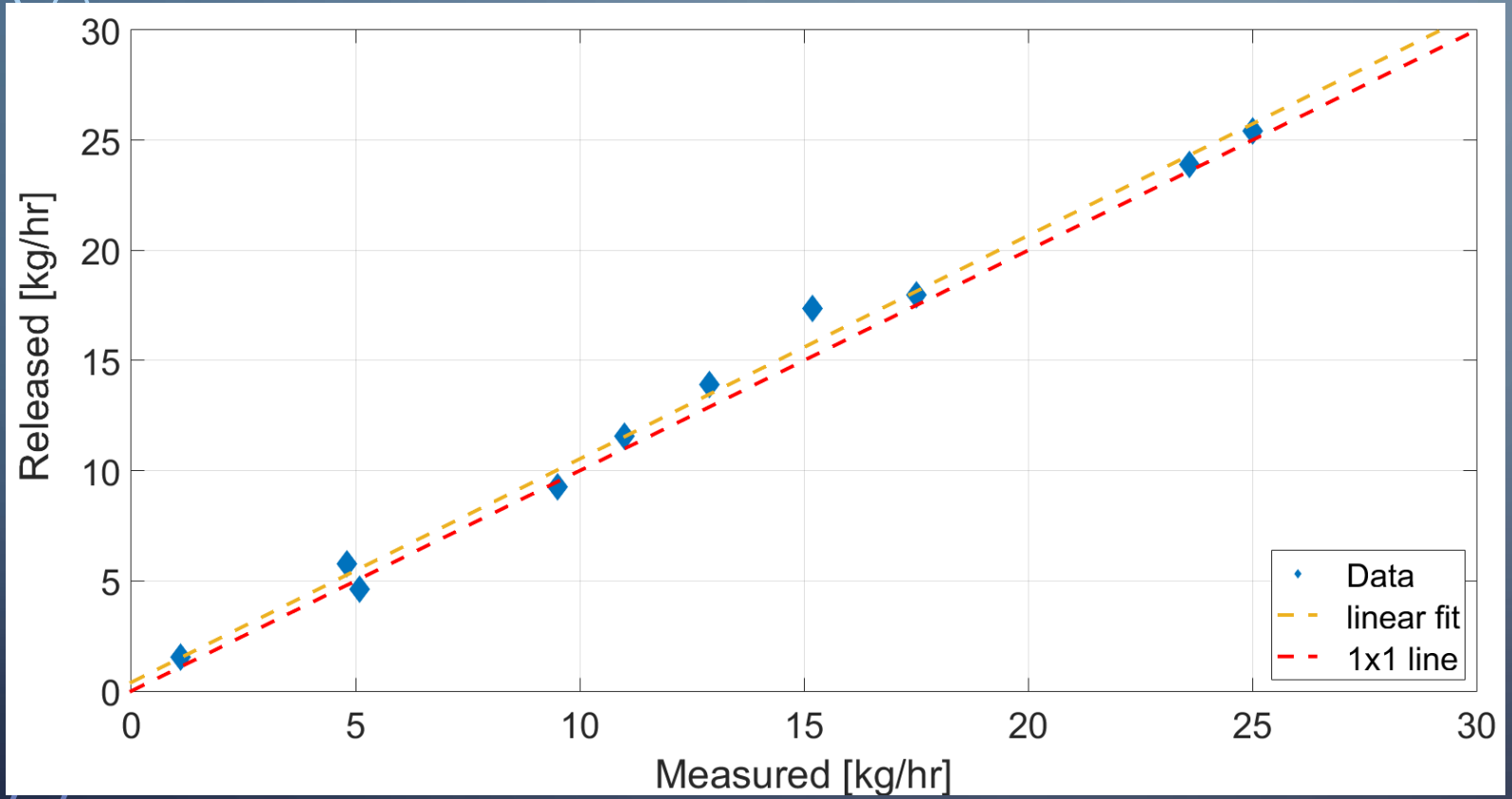
CONTROLLED-RELEASE STUDY: PLUME VISUALIZATION

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

CONTROLLED-RELEASE STUDY: DATA OVERVIEW

Date	Alt. (m)	Release rate [kg/hr]	Fluxsense	NPL	Atmosfir	Kassay	Weather Conditions
10/12/15	3	5.8	No data due to unfavorable weather	4.8	3	5.3	Cloudy, variable winds (1.5 - 3.5 m/s)
10/12/15	3	11.6	Same as above	11	6.1	14	
10/12/15	3	17.4	Same as above	15.2	10.8	12.3	
10/13/15	3	13.9	6.6	12.9	11.7	19.6	
10/13/15	6.4	4.6	2.0	5.1	No data - VRPM not applicable	No data - method not applicable	Clear sky, steady wind (2.5 - 7 m/s)
10/13/15	6.4	18.0	11.7	17.5	Same as above	Same as above	
10/13/15	6.4	1.6	0.6	1.1	Same as above	Same as above	
10/13/15	6.4	9.3	4.4	9.5	Same as above	Same as above	
10/13/15	7.9	25.4	15.2	25	Same as above	Same as above	
10/13/15	3	23.9	14.7	23.6	18.8	52.5	

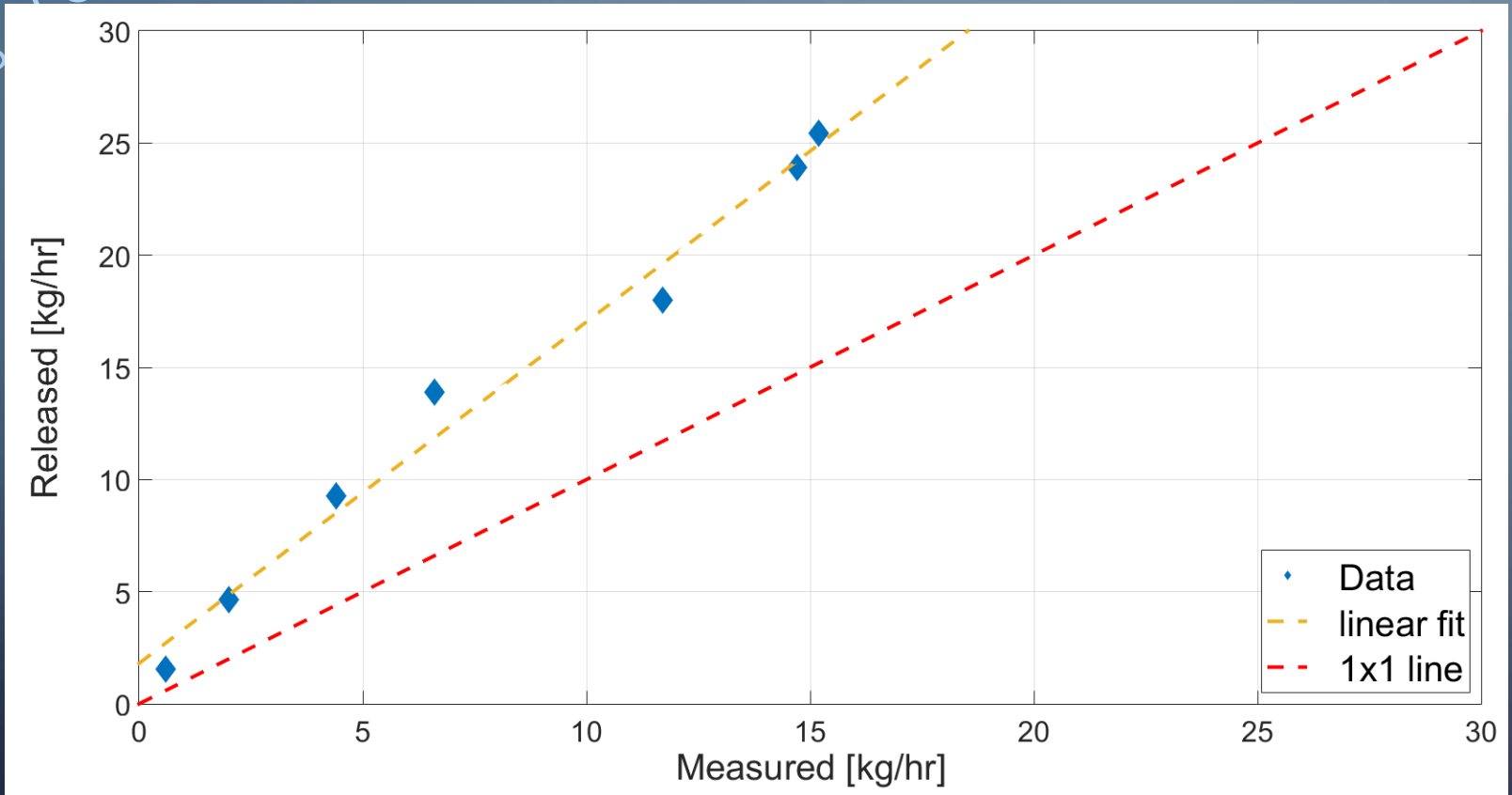
CONTROLLED-RELEASE STUDY: RESULTS OF DIAL MEASUREMENTS



- DIAL method accurately quantified and visualized propane emission plume
- DIAL measurements not affected by meteorological conditions
- $y = 1.01x + 0.4$

  $R^2 = 0.99$

CONTROLLED-RELEASE STUDY: RESULTS OF SOF MEASUREMENTS



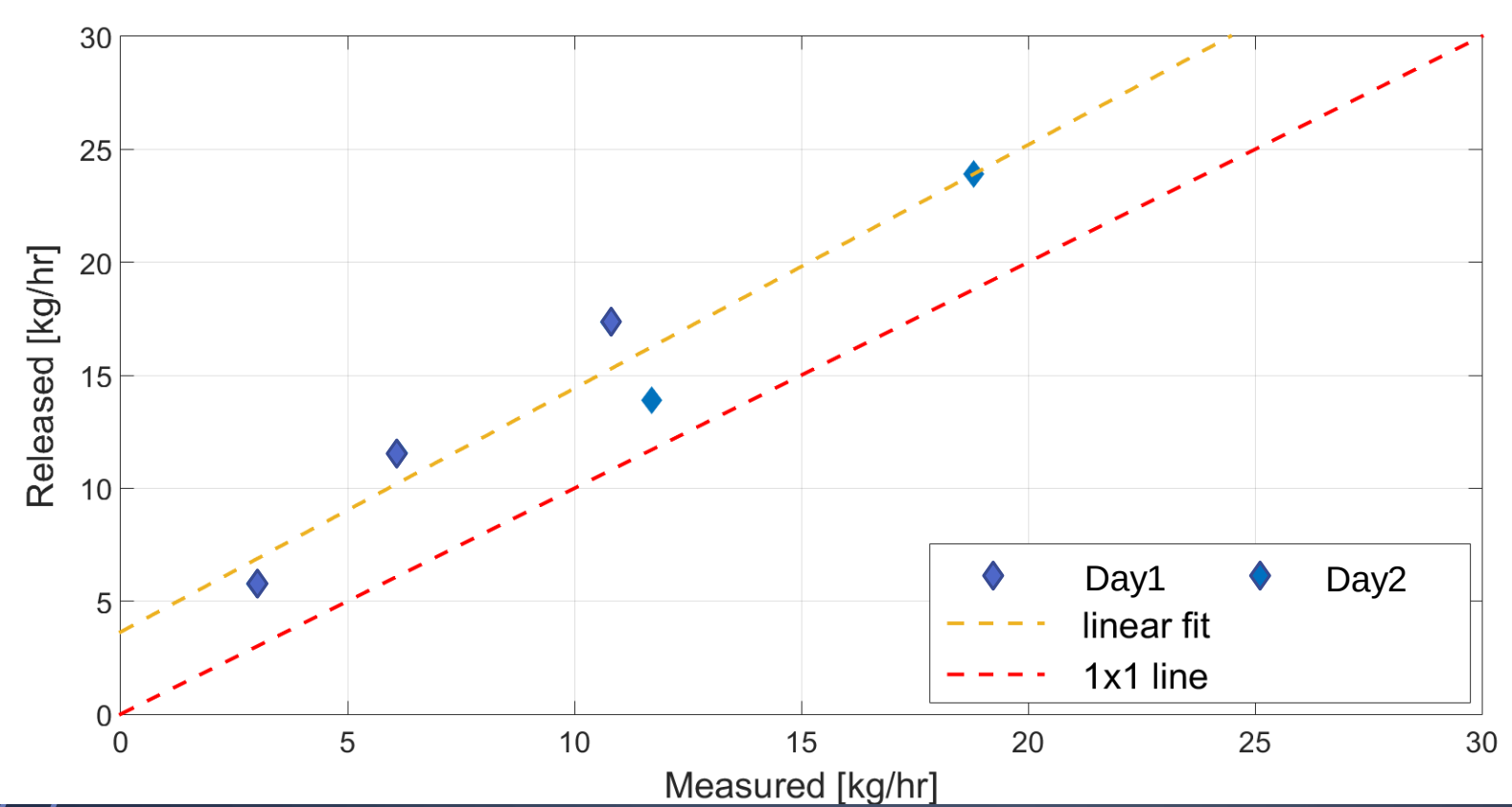
- Excellent linearity and correlation coefficient

$$y = 1.52x + 1.81$$

$$R^2 = 0.98$$

- SOF method consistently underestimated emissions by ~40%
- Close proximity to release source caused underestimation

CONTROLLED-RELEASE STUDY: RESULTS OF VRPM MEASUREMENTS



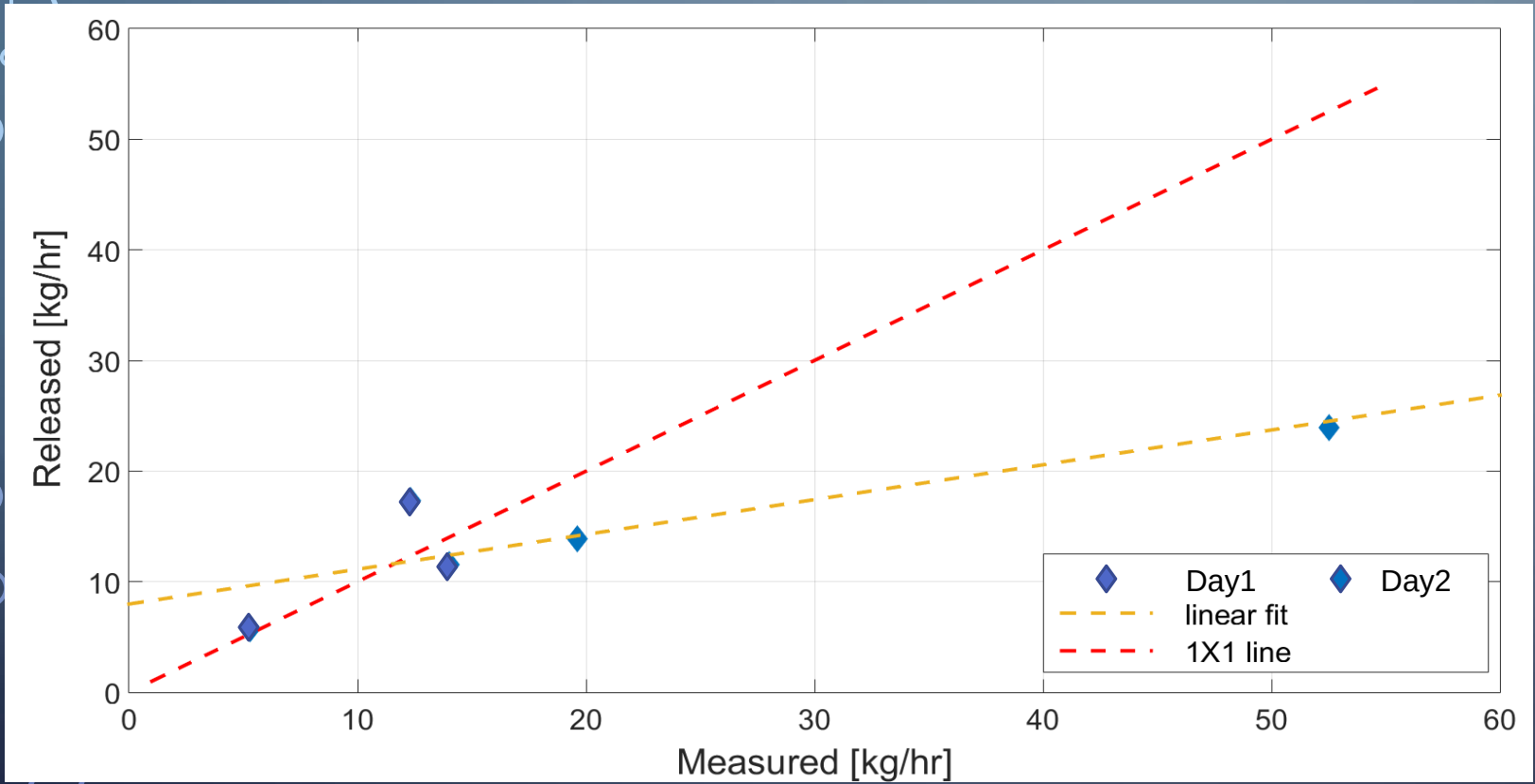
- Quantified releases from 3m altitude only
- Good linearity and correlation coefficient

$$y = 1.08x + 3.64$$

$$R^2 = 0.92$$

- Measured fluxes were slightly underestimated
- Better correlation during day 2 due to more favorable meteorological conditions

CONTROLLED-RELEASE STUDY: INITIAL RESULTS FOR AREA SOURCE TECHNIQUE



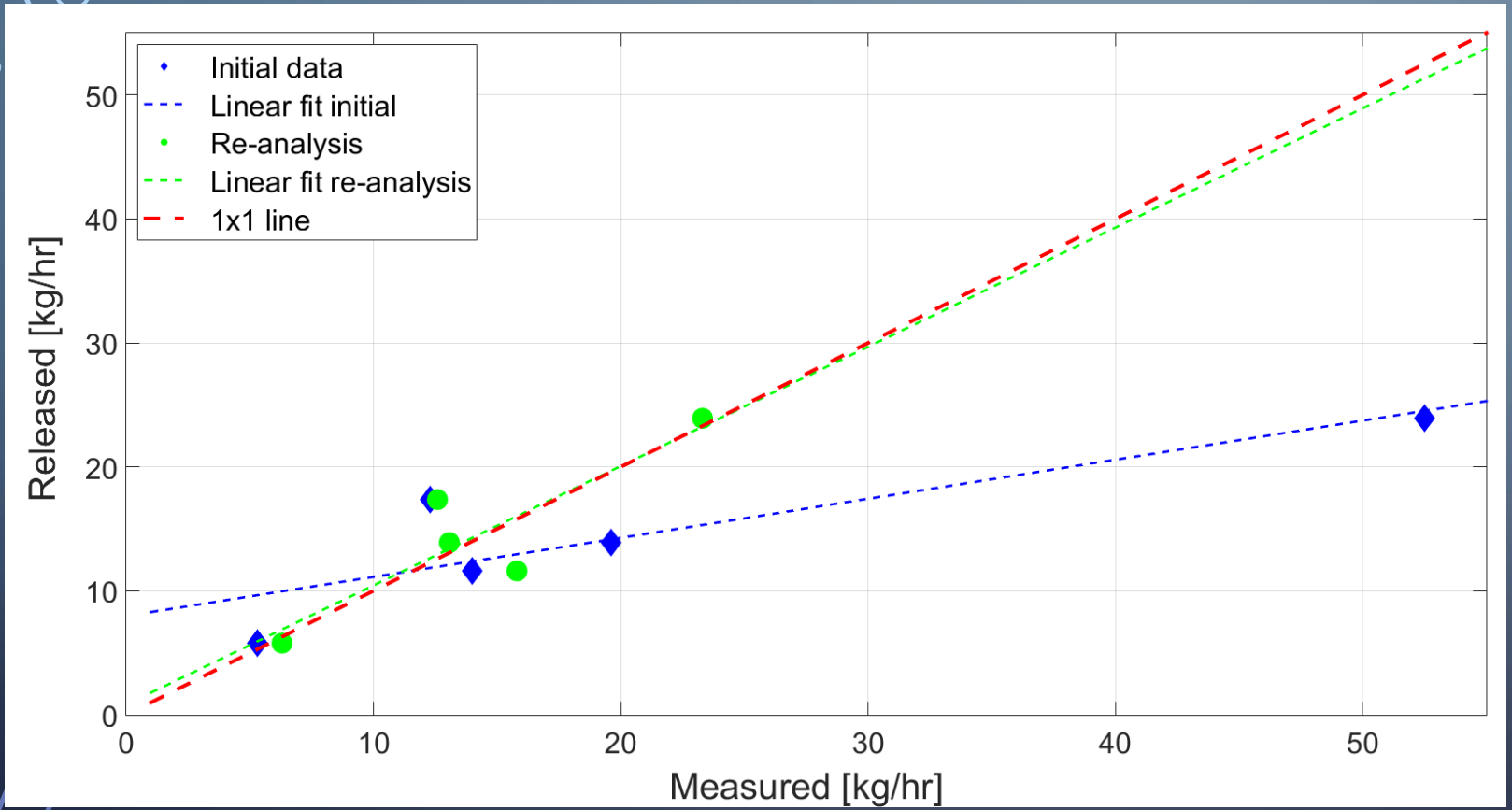
- Quantified releases from 3m altitude only

$$y = 0.315x + 7.98$$

$$R^2 = 0.74$$

- First day fluxes ranged between -29.2% and 20.9% of actual release rates
- Day two fluxes were overestimated by factor of two

CONTROLLED-RELEASE STUDY: REANALYSIS FOR AREA SOURCE TECHNIQUE



- Reanalysis of the data by
  - adjusting surface roughness parameter
  - Accounting for stable atmospheric conditions on day two
- Significant improvements in calculated fluxes

$$y = 0.962x + 0.824$$

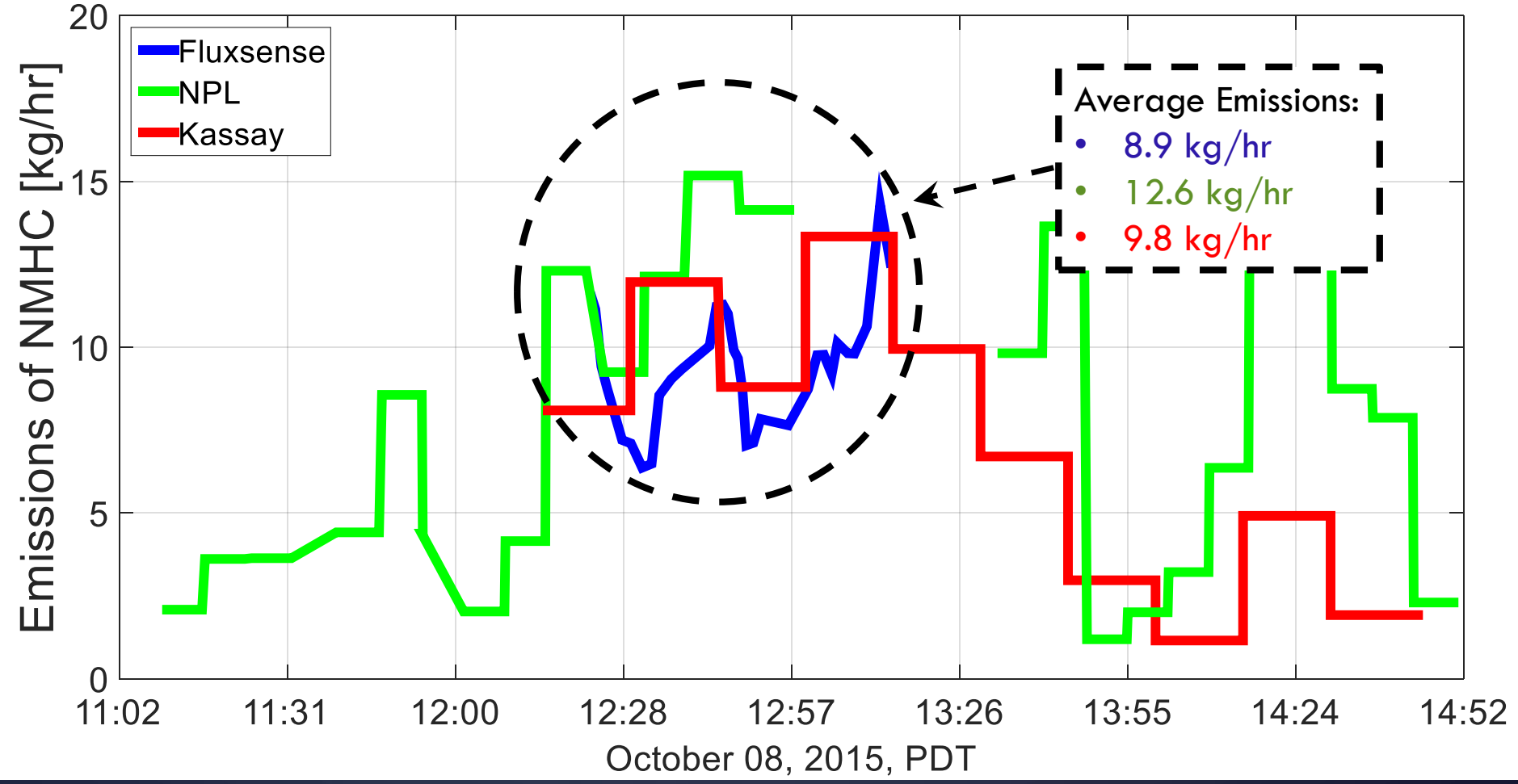
$$R^2 = 0.77$$

- Care should be taken in selecting model input parameters

INTERCOMPARISON MEASUREMENTS OF EMISSION FROM A SMALL OIL FIELD

Note: SOF position and track are approximate (for illustration only)

INTERCOMPARISON MEASUREMENTS OF EMISSION FROM A SMALL OIL FIELD



CONCLUSIONS

- First side-by-side field comparison between different ORS techniques
- Strong correlations (R^2) between released and measured emissions for all methods
- Emission fluxes during co-located monitoring of "real-life" sources were in good agreement for all instruments
- Strengths and weaknesses of each ORS technology:
  - DIAL
    - Very accurate and precise
    - Ideal for validation measurements but not suited for long-term studies
  - SOF
    - Close proximity to the source of release may lead to flux underestimation
    - Good agreement between SOF and DIAL during actual "real-life" measurements
    - Mobile capabilities of SOF make it an attractive method for routine surveys of facility (inside and outside)
  - OP-FTIR
    - Permanent OP-FTIR installations at refinery fenceline can provide useful information on long-term variability of emissions
    - Cannot account for elevated source contributions
    - Care must be taken when choosing input parameters for reverse modeling of emission sources

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