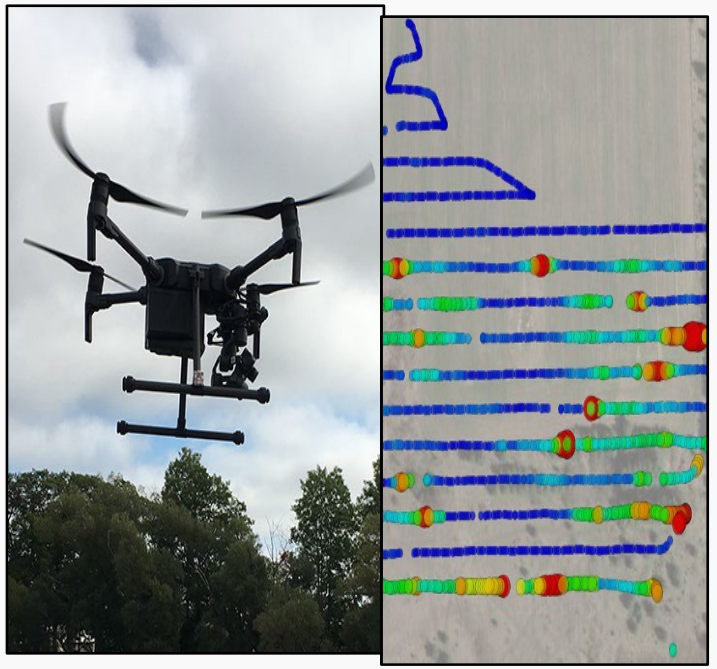
Using Drones, Aircraft, Sensors, Satellite, and Other Next Generation Emissions Measurement Technology at a Landfill

Presentation for FRTR Spring 2022
Web Meeting - Application of
Robotics, Machine Learning and
Artificial Intelligence Technologies to
Site Remediation
June 6, 2022



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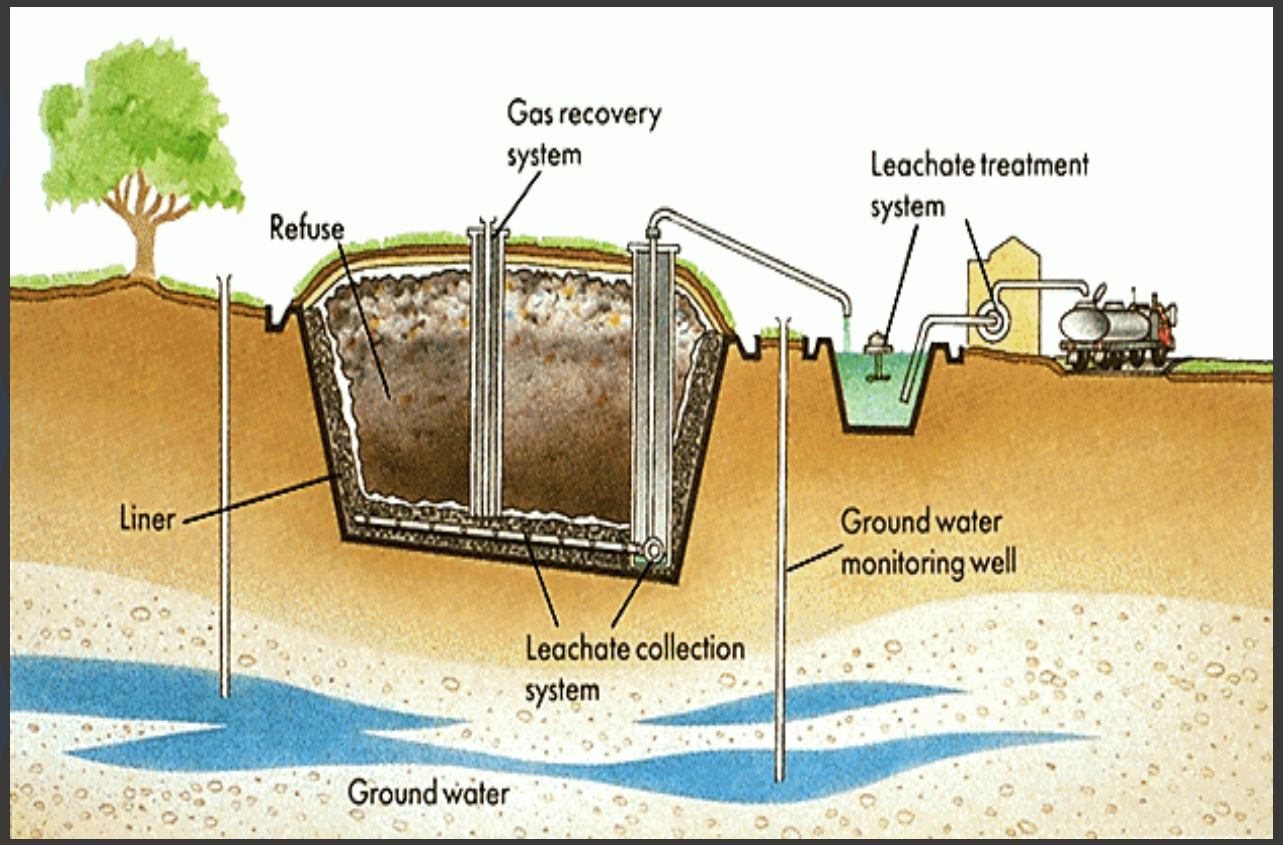
“Sanitary” Landfills

- Typical footprint is hundreds of acres
- Waste can be buried for decades before the site is closed – “Landfill life”
- After the landfill “closes”, for decades you must monitor cover material failures, air emissions, and leachate leakage to ground or surface water bodies.



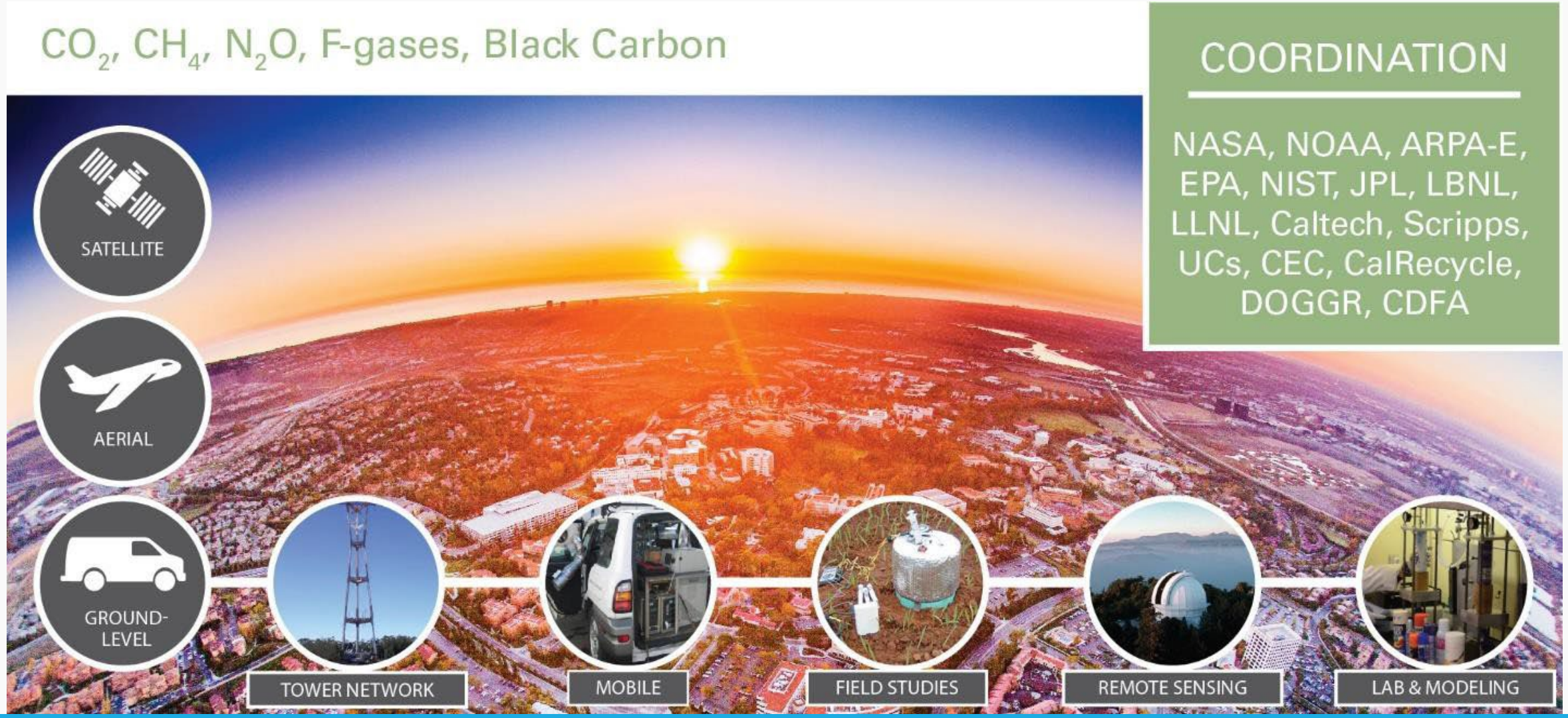
Landfill Workface

- The “workface” is where waste is added every day with use of daily cover at the end of the day
- Workface is currently not included in surface emission measurements
- From ground-based optical remote sensing measurements we found that the work face serves as a chimney for major plumes of methane and other air pollutants
- From waste burial, the landfill has 5 years to install gas extraction wells

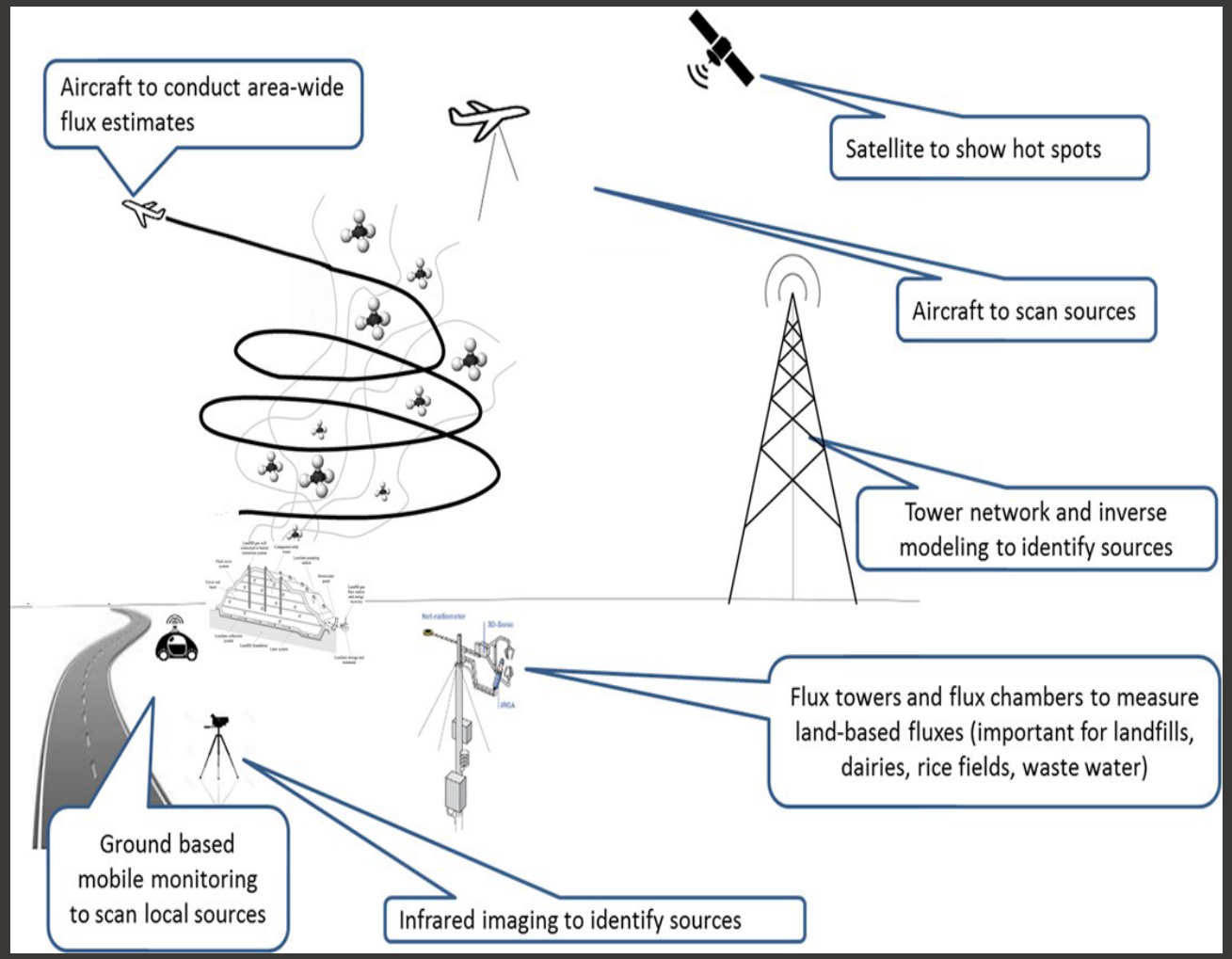
Ground Based Optical Remote Sensing

- ORD research helped drive some of the technology changes that we are now seeing
- In the past, site access was required – that is no longer needed thanks to use of satellites, aircraft, and drones
- We can hit the ground running due to our collaboration with those with active research programs including CARB, ECCC, NASA, Carbon Mapper, and others

California GHG Research Program



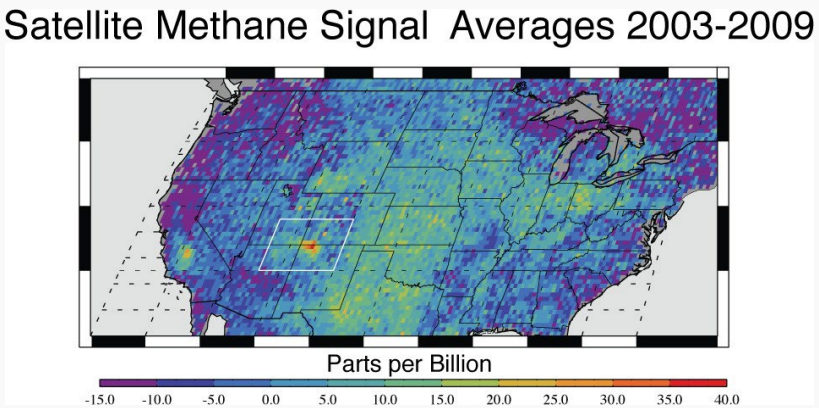
CARB Landfill Methane Research Systems

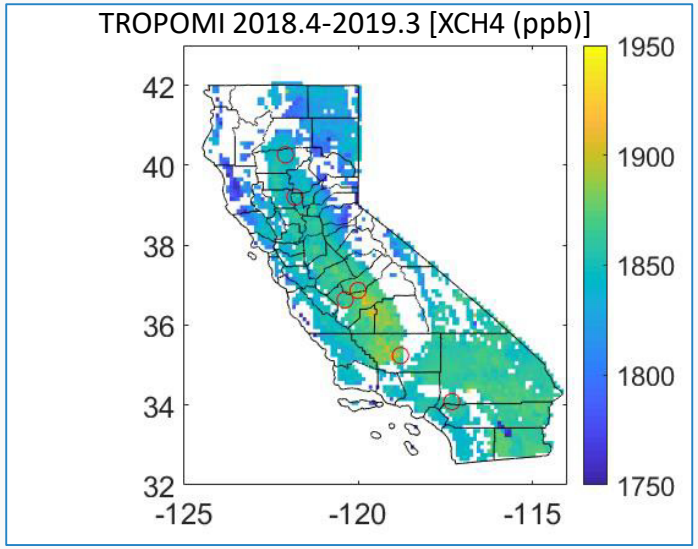


- Regional Emissions:
  - Statewide Monitoring Network and Inverse Modeling
  - Satellite Data
- Point Source/Large Leak Detection:
  - NASA/JPL AVIRIS flights
  - Carbon Mapper Satellite (2023)
- Total Facility Emissions:
  - Mass balance flights (Scientific Aviation)
  - CARB Mobile Platforms
- Facility Zonal Emissions:
  - EC flux tower
- Leak Detection / Enforcement Support:
  - Method 21
  - Infrared imagers
  - Drones

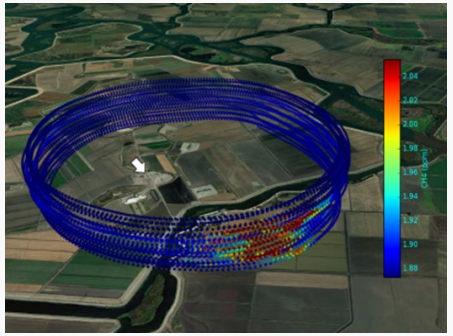
Hotspot Identification using Satellite Data

- Applications:
  - Identify regional hotspots
  - Statistical analysis and modeling to understand spatial distribution of emission sources
- Advantages:
  - Statewide coverage
  - Provides daily monitoring
- Limitations:
  - Spatial resolution is limited due to large grid sizes (11 km)
  - Single pass per day; limited temporal information
  - Computationally intensive to analyze and model data





Facility Level Emission Measurement with Aircraft (Scientific Aviation)



Objective:

- Compare real-world emissions with inventory estimates
- Understand regional and seasonal variation of landfill emissions
- Investigate the relationship between landfills emission and point source detection

Project status: Completed

- Reports available: https://ww2.arb.ca.gov/our-work/programs/methane/ab1496-research
- 46 landfills in multiple regions (33 open landfills + 13 closed landfills, 19 with detected plumes)

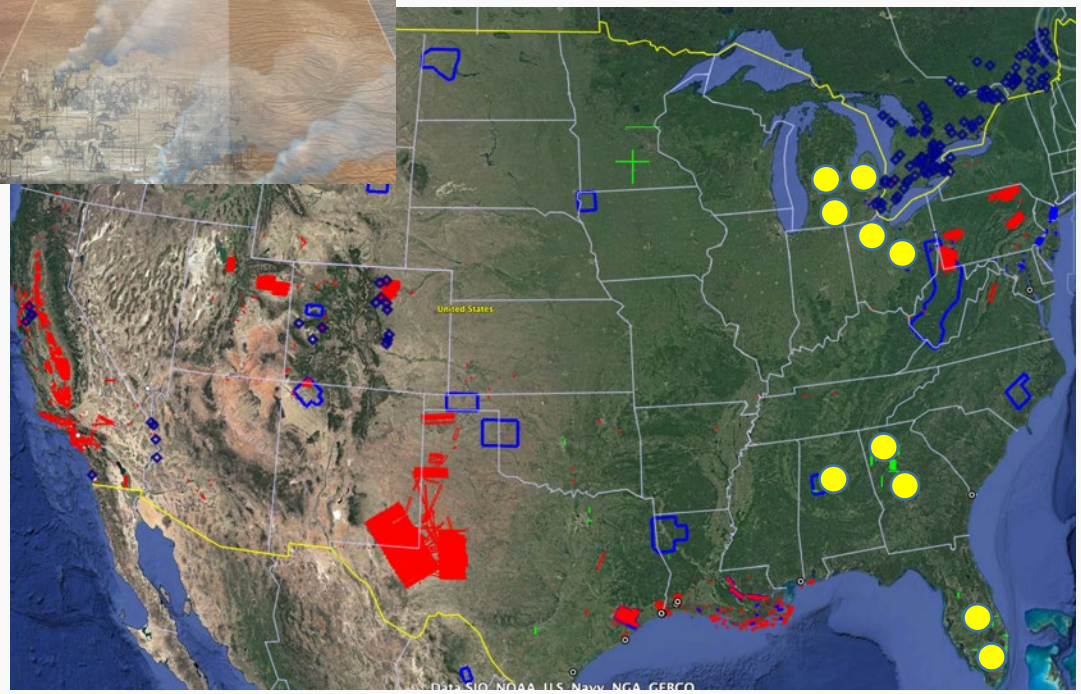
Highlights

- **Open landfills**: More than 60% show higher measurement than inventory estimates, 60% of which have point source plumes detected (not all of them were covered).
- **Closed landfills**: Measured emissions were much lower than estimated in the inventory, and these differences are especially noticeable for landfills with large amounts of waste-in-place

Observing strategy for quantifying landfill methane emissions

Slide from Riley Duren, 5/22

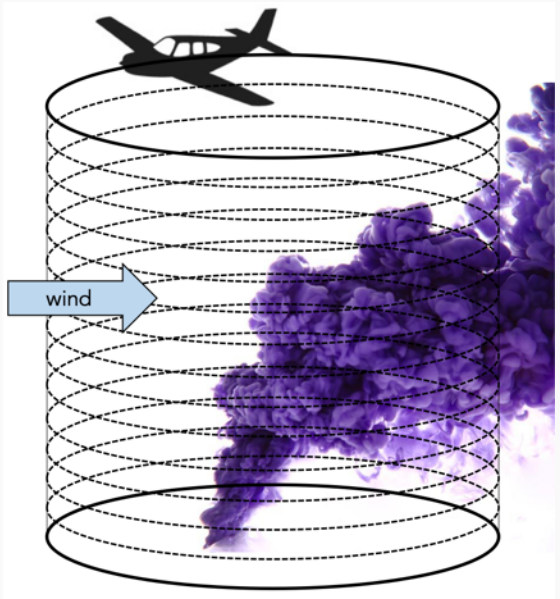
(1) Carbon Mapper uses high altitude remote sensing (aircraft and satellite) – found to efficiently measure high-emission point sources at hundreds of landfills over large regions



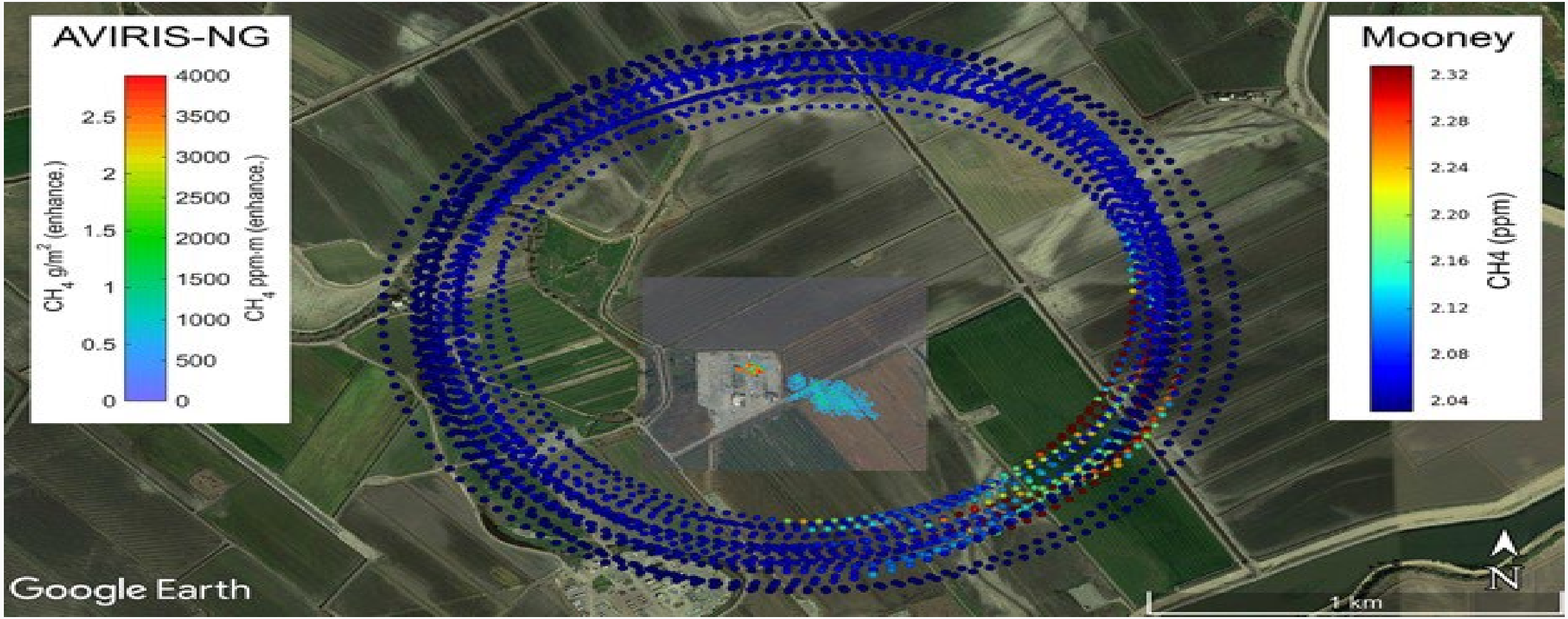
Yellow dots: coordinated Validation surveys with both aircraft

Red/blue/green lines: broader regional remote sensing surveys

(2) Low altitude in-situ sensing aircraft (Scientific Aviation) can provide independent measurements of total landfill emissions for a representative subset of facilities – offering independent validation of the remote-sensing methods



Gold Standard for Cross-validation approach used in California – Working with Carbon Mapper (AVIRIS-NG) and Scientific Aviation (Mooney) of natural gas storage facility

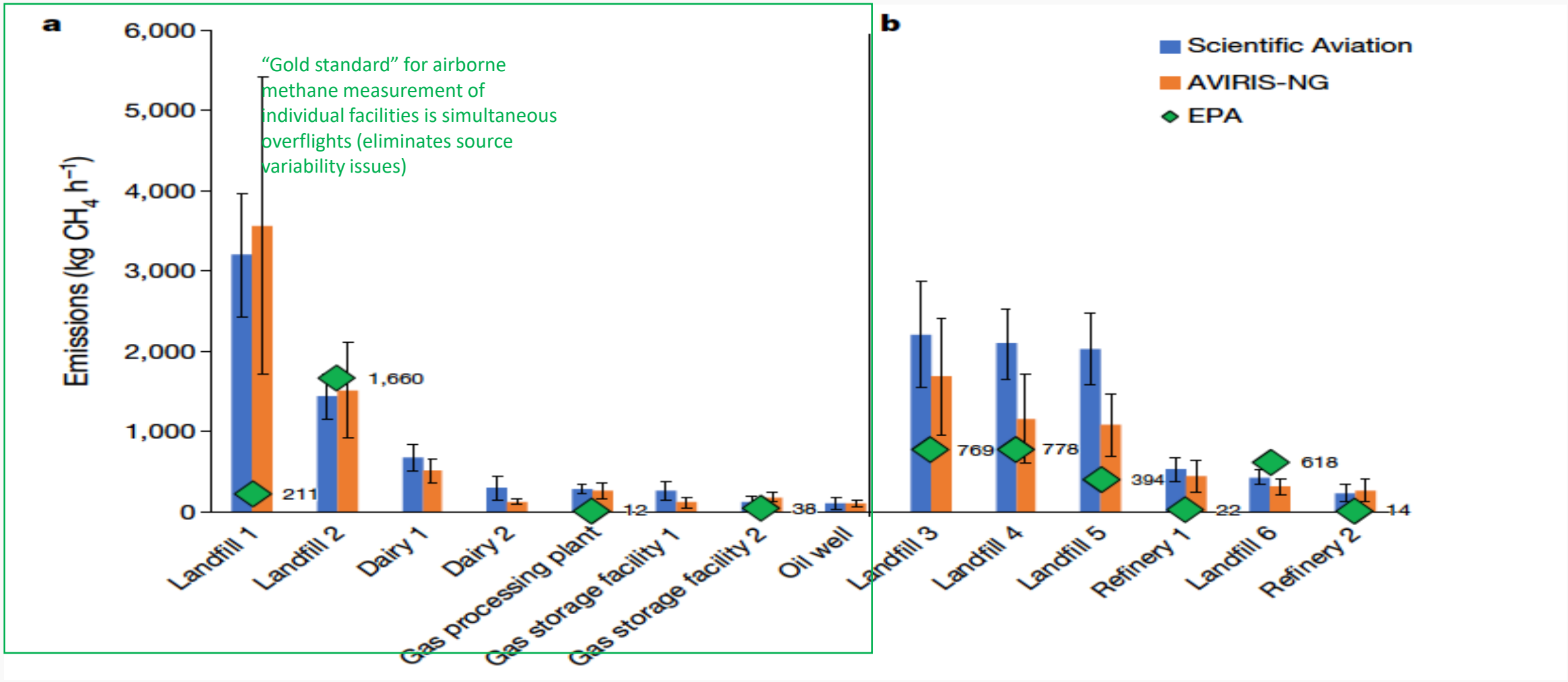


Duren *et al.,* Nature 2019

Slide from Riley Duren, 5/22

Consistent estimates from independent methods

Slide from Riley Duren, 5/22

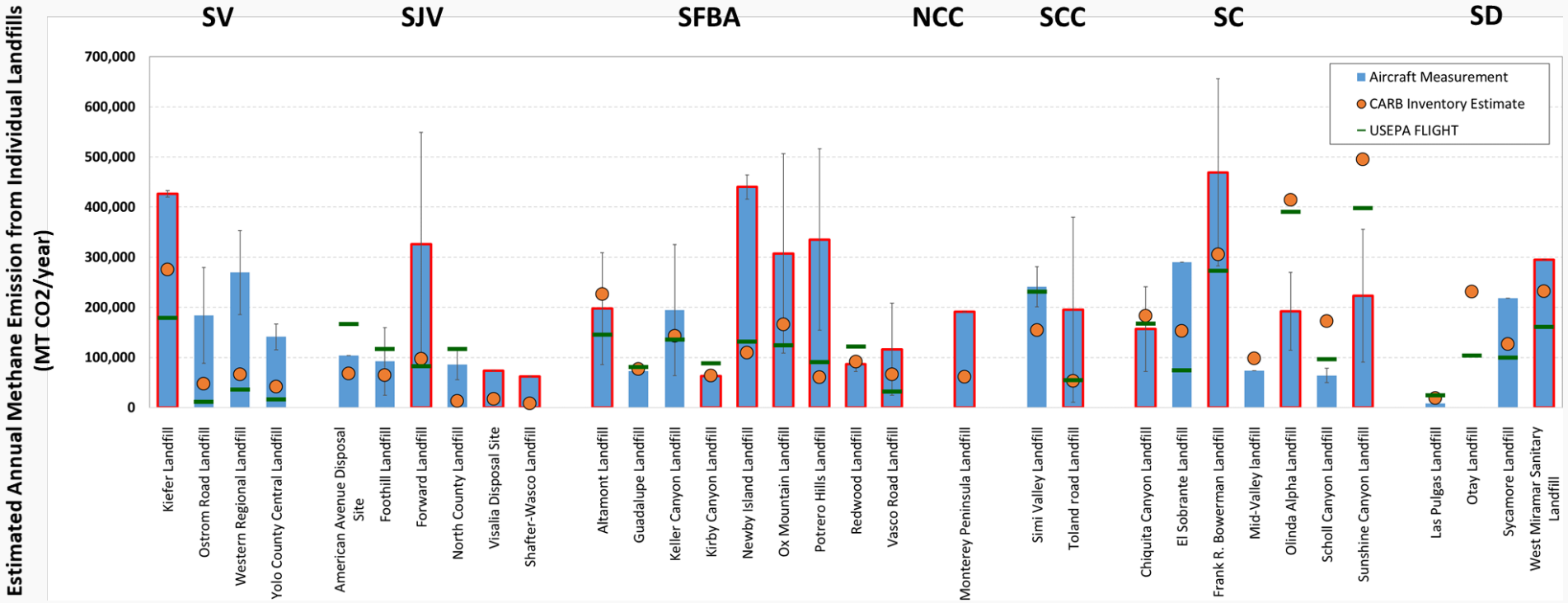


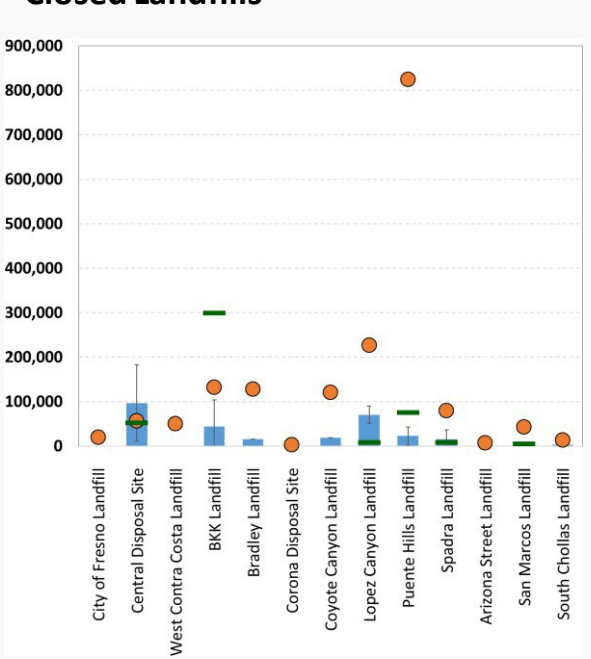
Duren *et al.,* Nature 2019

a, Simultaneous flights; **b**, average emissions from multiple non-simultaneous flights over several months.

Findings from CARB Measurements

- **Open landfills:** More than 60% (20 out of 33) of them show *higher* measurements than inventory estimates. 12 of them with point source plumes detected
- In more than 60% of the cases (12 out of 19), a NASA detection is indicative that the real-world facility-wide emissions are higher than inventoried emission estimate.
- **Closed landfills:** Measured emissions were *much lower* than estimated in the inventory, and these differences are especially noticeable for landfills with large amounts of waste-in-place

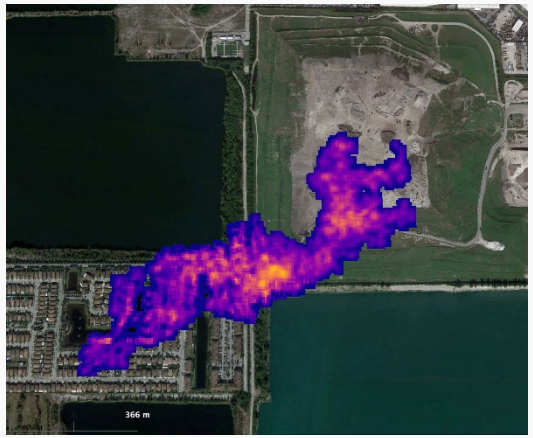




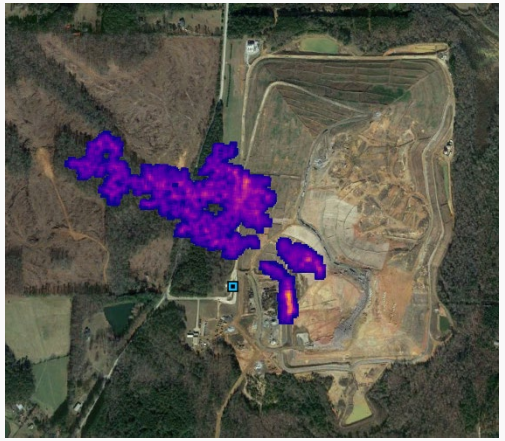
** Box with red outlines indicate landfills with NASA detections*

High emission methane point sources observed in many regions outside California

Florida



Georgia

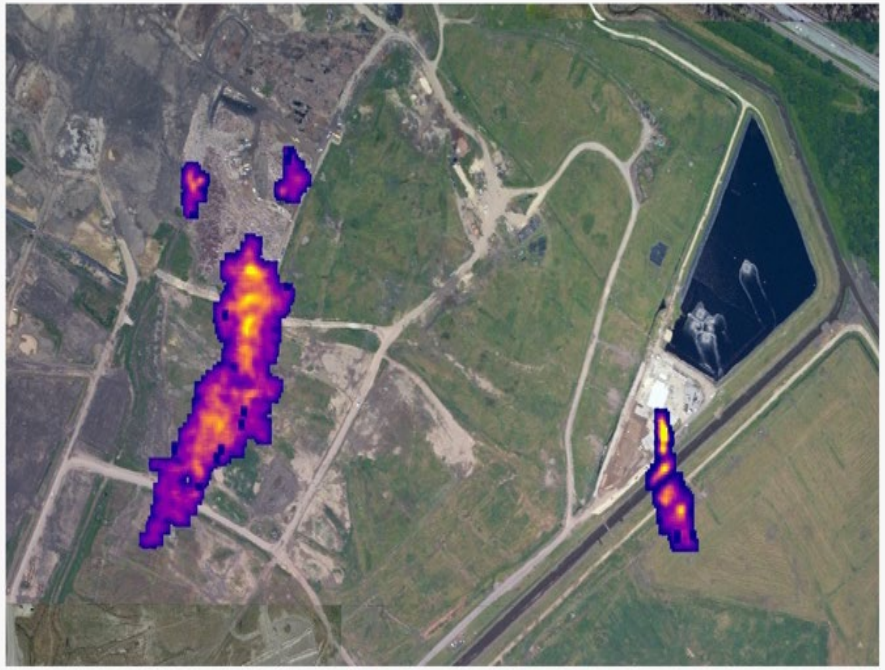


Alabama

Louisiana

Amid reports of "super emitters," experts say getting the emissions numbers right is essential to curbing a potent climate pollutant.

By James Bruggers and Phil McKenna (Inside Climate News), Amy Green (WMFE) and Robert Benincasa (NPR)
July 13, 2021

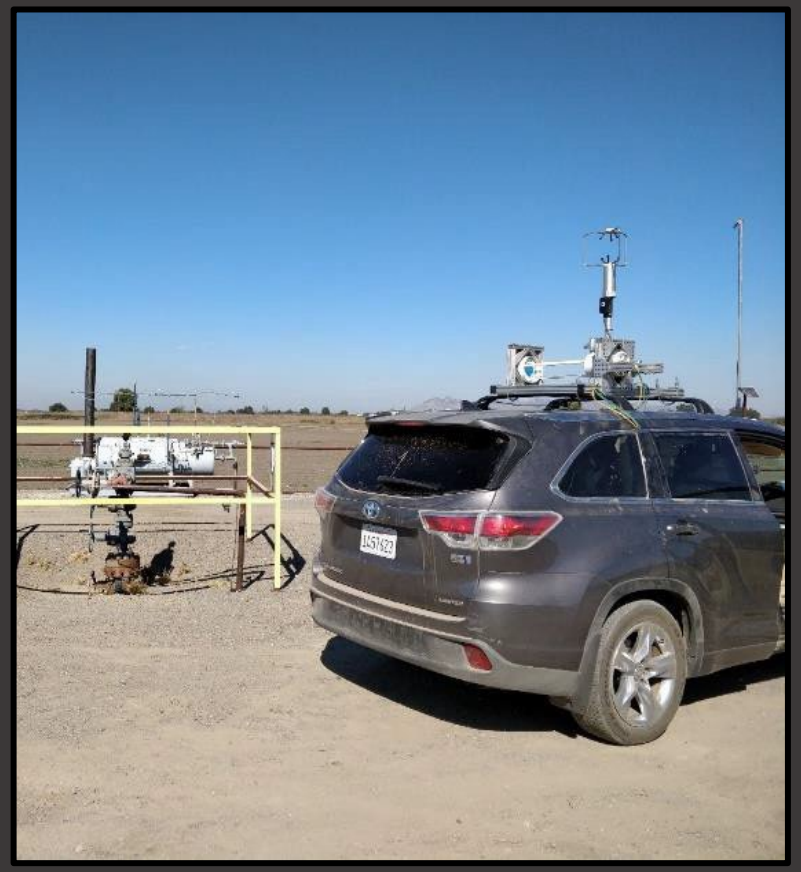


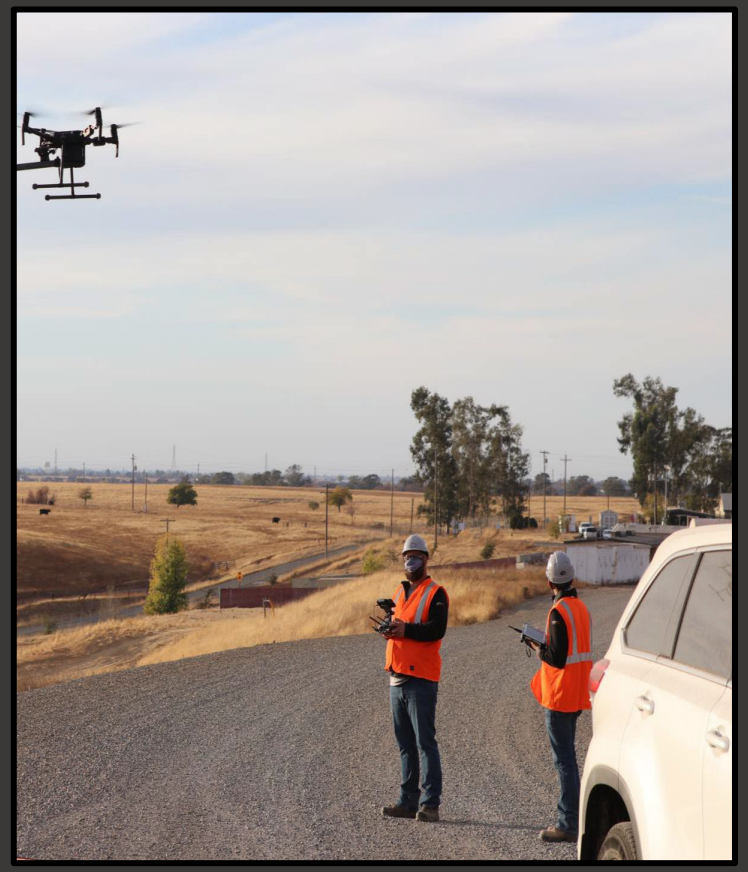
Remote sensing of methane from high altitude aircraft reveals plumes of the gas coming from the open face, on the left, and from a vent, on the right, at the River Birch landfill outside New Orleans in April 2021. Researchers from the University of Arizona, Arizona State University, NASA's Jet Propulsion Laboratory, and Carbon Mapper calculate the rate of methane venting at approximately 2,000 kilograms per hour, which would be 48 metric tons per day. Credit: University of Arizona, Arizona State University, NASA JPL and Carbon Mapper.

Many similar examples in CA, CO, NV, LA, MI, OH, PA

Slide from Riley Duren, 5/22

Ground based Mobile Platform (GMAP) and Drones



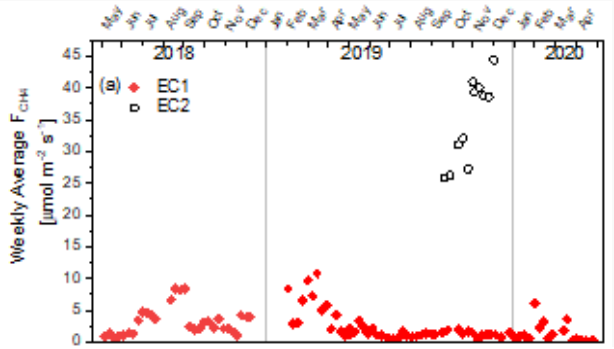


- CARB and others think we will use satellites for routine data collection within the next decade
- Currently have to deploy people for surface emissions monitoring (SEMs) required quarterly – however some sites are now using drones versus people
- Current technology measurements are only a snapshot and reliant on good weather
- GMAP used to respond to a complaint - not continuous
- Drone integrations can get z-axis to GMAP

Eddy Covariance Project Kiefer/Yolo Landfills

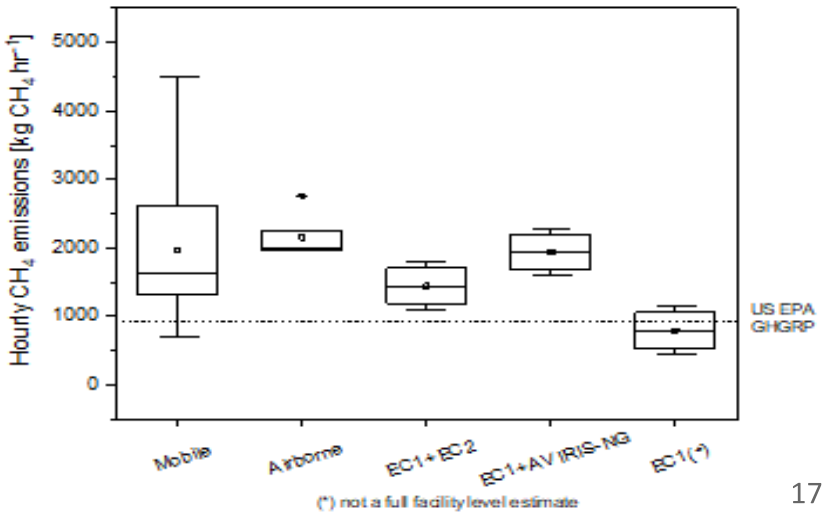
Objective:

- Comprehensive, long-term study of landfill methane emissions at Kiefer LF
- Emissions assessment using a variety of tools and methods alongside EC
- Observe climatic and operational impacts (different cover types) on methane emissions
- Expanding to different landfill (Yolo LF) with different cover type (membrane)



Project status: Completed (Kiefer, Phase 1) / Ongoing (Phase Yolo,2)

- Kiefer study completed, Yolo deployment in summer 2021
- Kiefer Landfill Study Manuscript ready to be submitted to journal
- Periods of heavy rainfall, high temperatures, and falling pressure corresponded to the highest methane emissions behavior from area sources
- Active landfill zones were associated with the largest emissions (20-40 times higher and sometimes up to 250 times) than the methane emissions in inactive areas



Technology to tune a field of gas wells due to changes in atmospheric pressure expected to be exacerbated due to Climate Change

- Landfill gas wellhead tuning is performed manually
- Landfill gas emissions change due to atmospheric pressure and precipitation
  - Very dynamic system
- Newly available tech from Loci could improve gas capture and decrease fugitive emissions
- Has a system for both gas and water management

Next Steps

- Plan to team with Carbon Mapper and Scientific Aviation to conduct measurements using high- and low-altitude remote sensing like what CARB did for landfills in California
- Initial set of measurements will be in EPA Region 5 (Region includes Illinois, Indiana, Michigan, Minnesota, Ohio, Wisconsin and 35 Tribes)
- Plan to conduct additional measurements in other EPA Regions to help inspectors prioritize sites to inspect
- Plan to conduct ground-based measurements in conjunction with aircraft and satellite measurements

*The views expressed in this presentation are those of the authors and do not necessarily represent the views or policies of the U.S. Environmental Protection Agency

Thank you for your Attention!

For further information, contact members of our research team

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