California methane monitoring for climate action and public safety

Riley Duren, Vineet Yadav, Kris Verhulst, Andrew Thorpe, David Thompson, Clare Wong, Stan Sander, Francesca Hopkins, Glynn Hulley, Andrew Aubrey, Bill Johnson, Chip Miller (JPL); Kuldeep Prassad, Kim Mueller (NIST); Elva Kuai (UCLA JIFRESSE); Christian Frankenberg (Caltech)

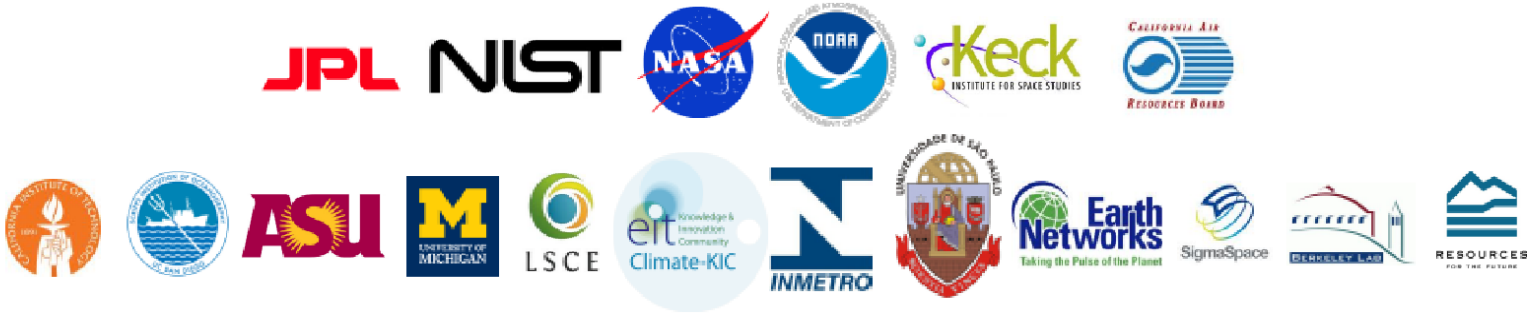
Riley.M.Duren@jpl.nasa.gov

Initiatives & Partners

Understanding User Needs for Carbon Information project

(NASA Carbon Monitoring Program)

Megacities Carbon Project



California Methane Survey (& related pilot efforts)

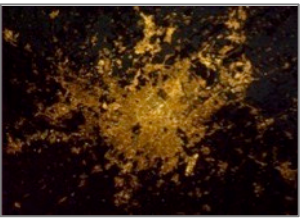
Megacities Carbon Project

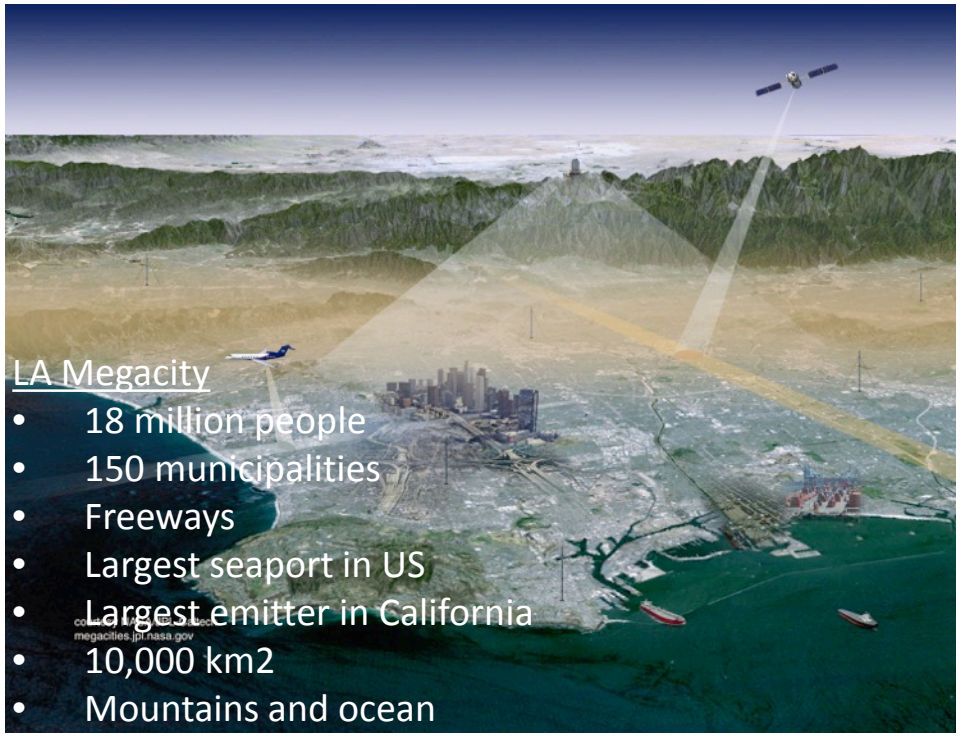
NATURE CLIMATE CHANGE | VOL 2 | AUGUST 2012 | www.nature.com/natureclimatechange

Measuring the carbon emissions of megacities

Riley M. Duren and Charles E. Miller
doi:10.1038/nclimate1629

Carbon emissions from cities represent the single largest human contribution to climate change. Here we present a vision, strategy and roadmap for an international framework to assess directly the carbon emission trends of the world's megacities.





What are the carbon emissions of cities and how are they changing?

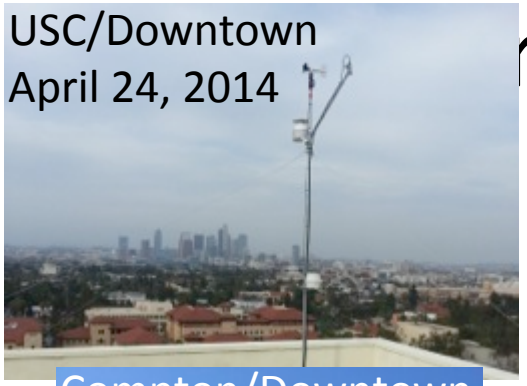
Why are emissions changing (which sectors, policies, and behaviors are responsible)?

Are mitigation efforts having the intended effect?

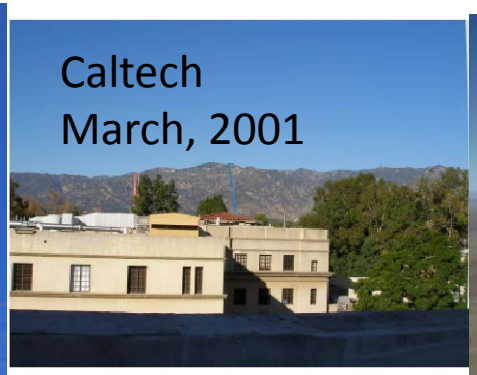
How accurate is urban carbon data (for emission trading)?

Can we share relevant data transparently between cities?

Co-benefits: enhance sustainable planning, air-quality, and public awareness


USC/Downtown
April 24, 2014


Granada Hills
July 9, 2013

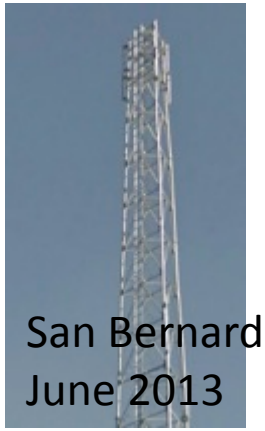

Caltech
March, 2001

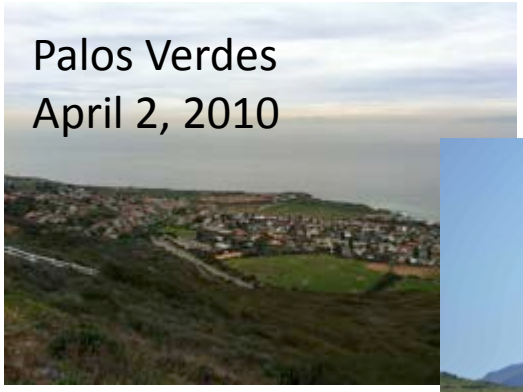

Victorville
April 20, 2012

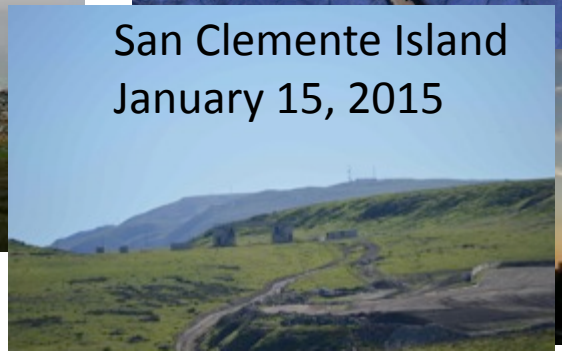

Compton/Downtown
July 17, 2014

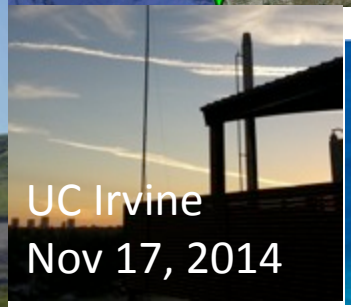

Victorville
Granada Hills
Aliso Cyn
Mt Wilson
Caltech
USC
Ontario
San Bernardino
Compton
CSUF
Palos Verdes
UC Irvine
San Clemente
La Jolla


CSUF: Nov 6, 2014


San Bernardino
June 2013


Palos Verdes
April 2, 2010


San Clemente Island
January 15, 2015

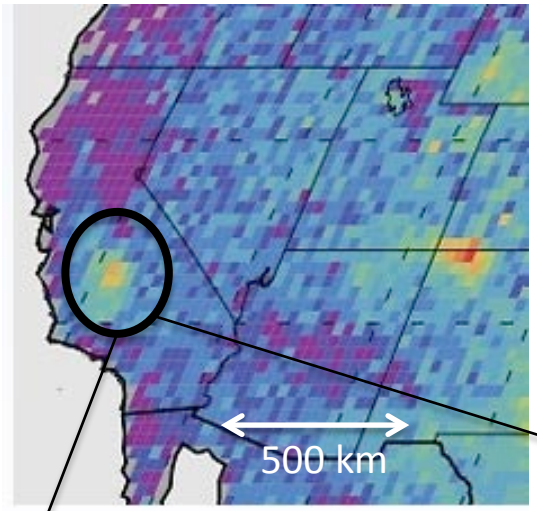

UC Irvine
Nov 17, 2014


La Jolla/Scripps
1979

Methane hotspots seen from space

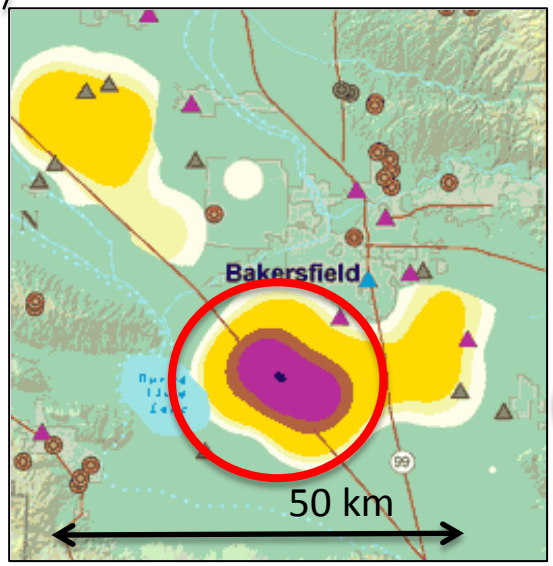
But where and what are the dominant sources?

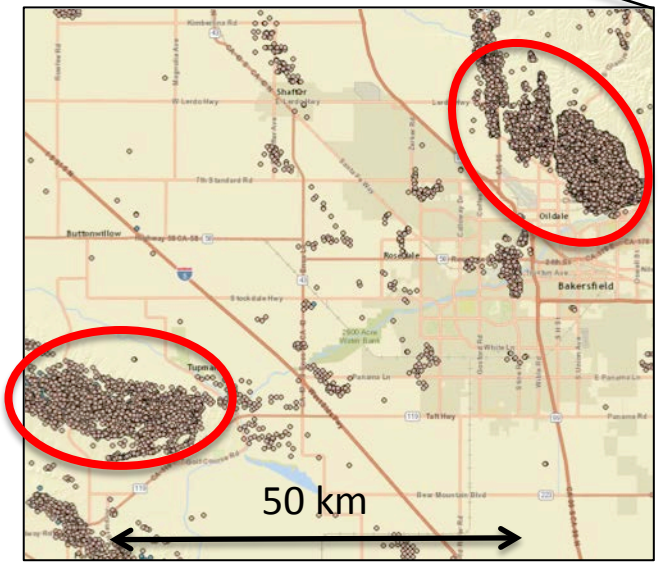
Kort et al 2014
(2003-2009 SCIAMACHY data)



Super-emitters:
60% of emissions come from 5% of facilities in the Barnett shale

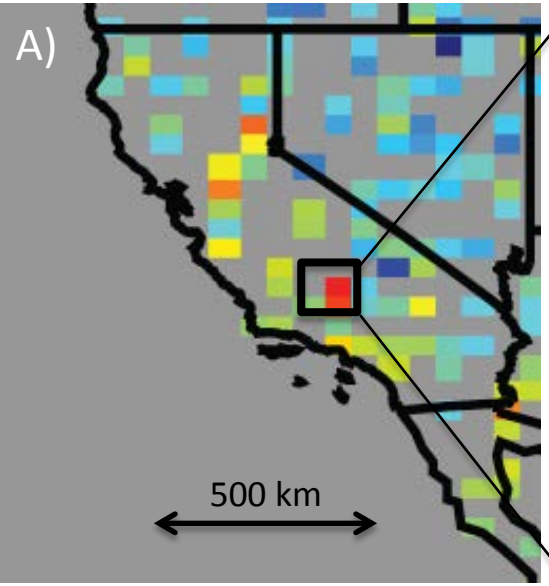
Zavala-Araiza et al et al, Environ. Sci. Technol, 2015

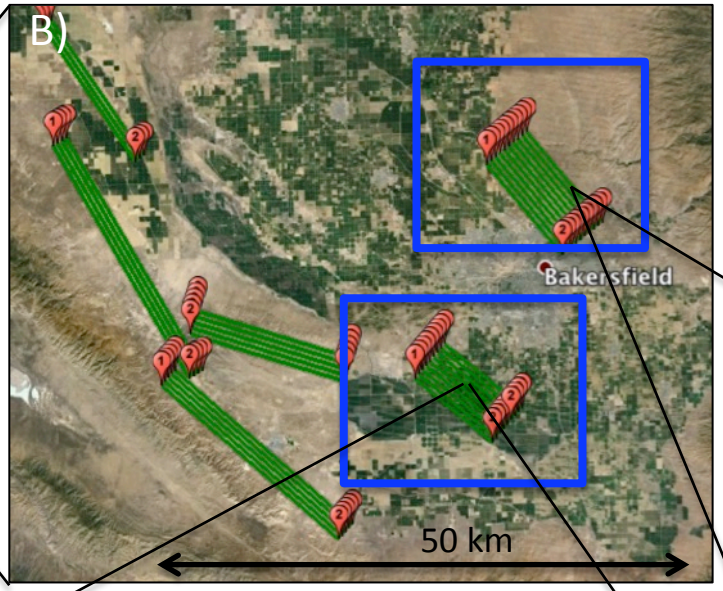


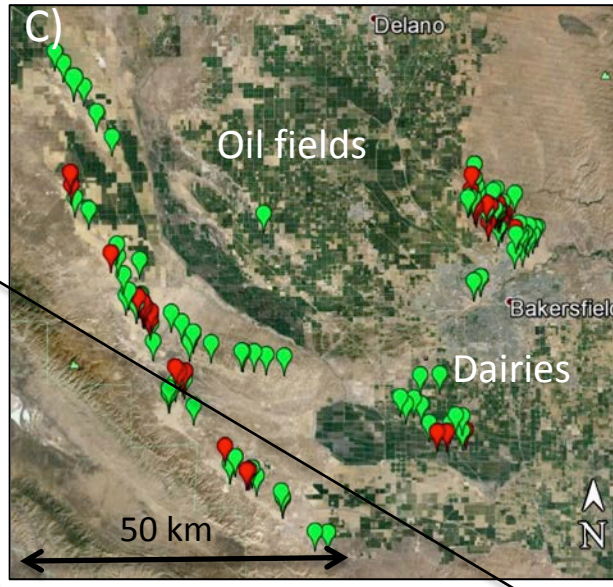


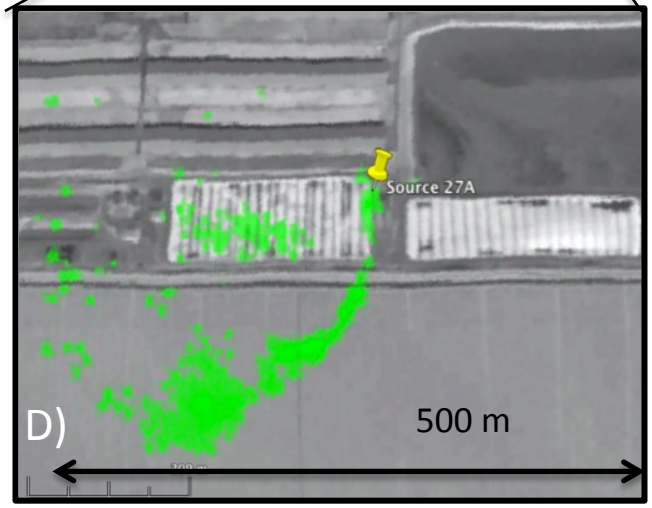
Bakersfield area:
30,000 oil wells
vs
30 mega-dairies
(172,000 cows)

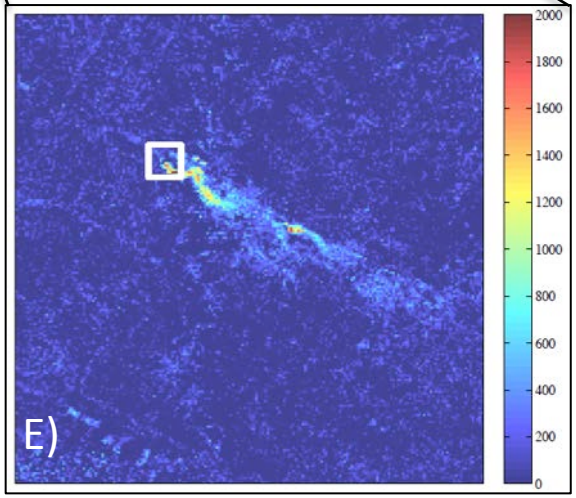
Methane Tiered Observing Strategy: Central Valley example











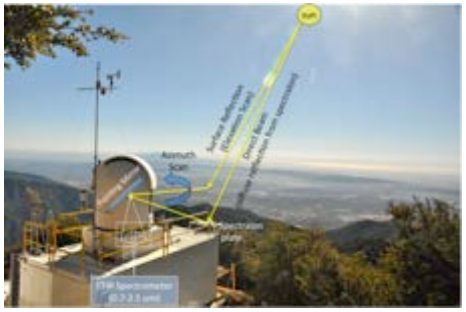
	source	n sampled	n detected	%
Oil field	Wells	14143	9	<0.1
	Tanks	78	10	13
	Facilities	21	7	33
	Waste ponds	3	1	33

Study area	Number of repeated plumes	Minimum CH_4 flux from imaged sources	CALGEM CH_4 inventory emissions	Minimum percent of total CH_4 emissions from imaged sources
Oil field	28	2.4 kton CH_4 y^{-1}	8.3 kton CH_4 y^{-1}	≥ 29%
Dairies	11	1.0 kton CH_4 y^{-1}	4.8 kton CH_4 y^{-1}	≥ 21%

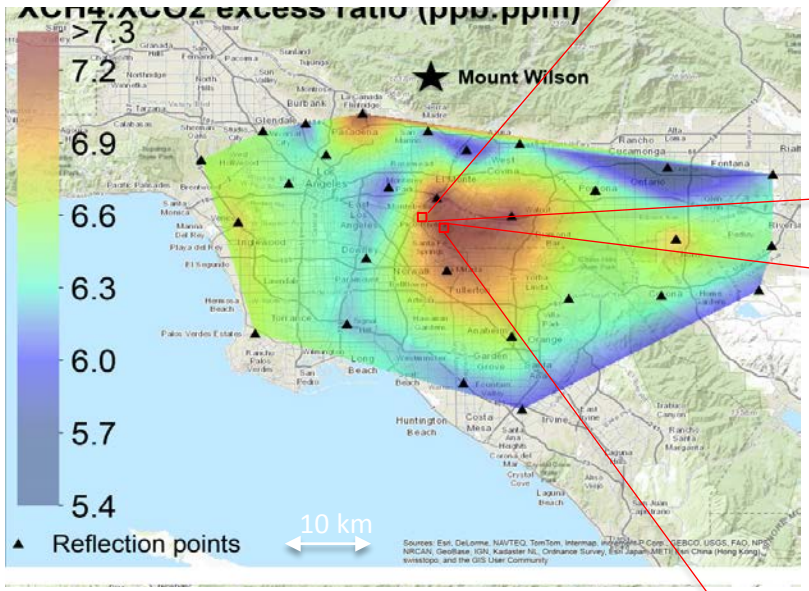
Hopkins, Duren et al, in prep

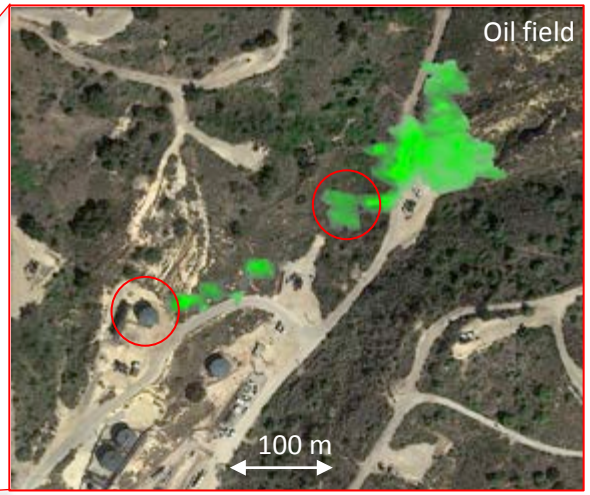
Los Angeles example

Tier 1: prototype "satellite"on Mt Wilson identifies methane hot spot



Tier 2: airborne imaging spectrometer maps point sources





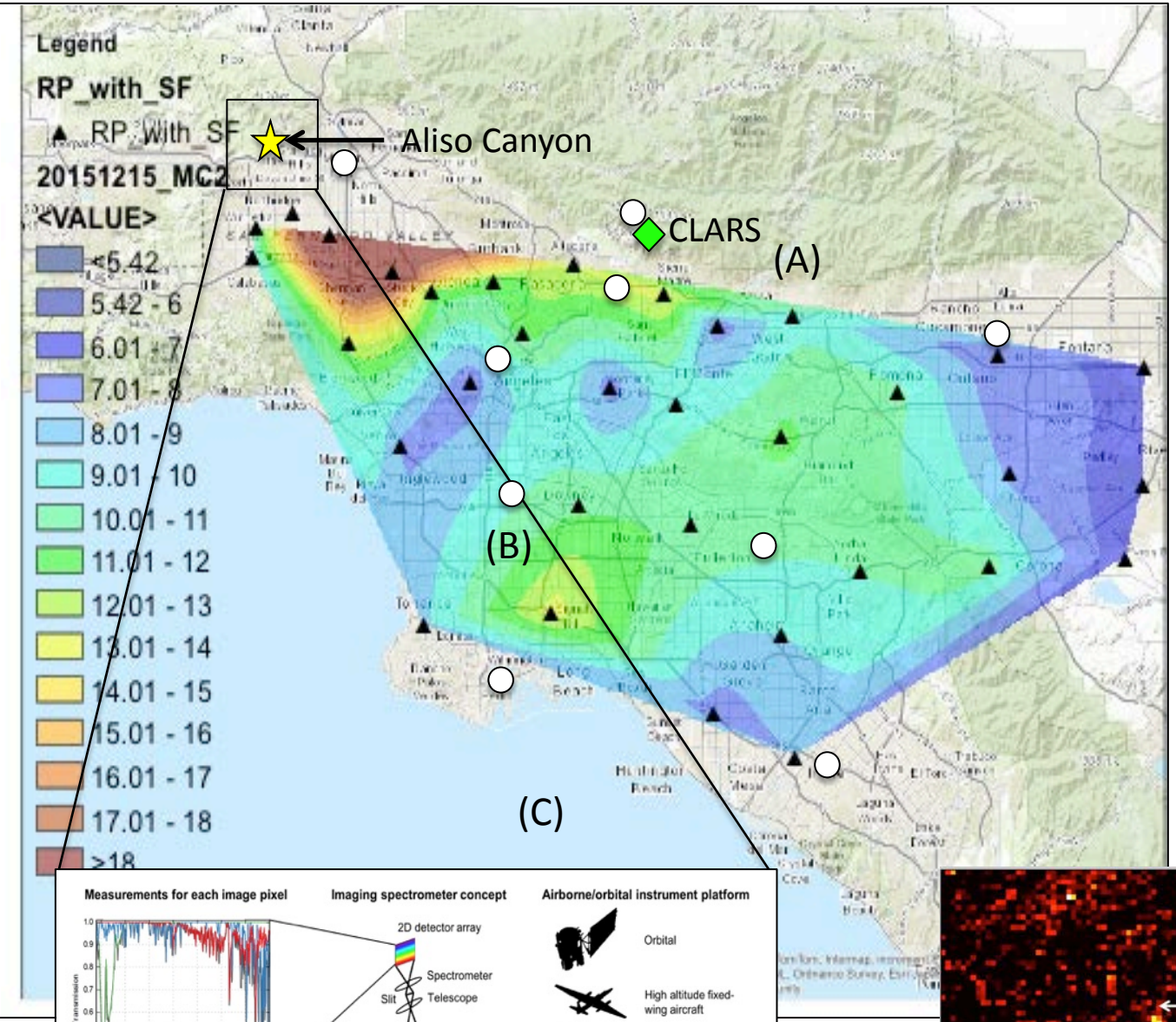
Left: Persistent methane hotspot (central red area) over Los Angeles basin detected by prototype satellite instrument on Mt Wilson (Wong et al, ACP 2015). Right: examples of individual methane leaks (green plumes) from an oil field (upper) and landfill (lower) identified by airborne Hyperspectral Thermal Emission Spectrometer. Courtesy: NASA/JPL-Caltech.

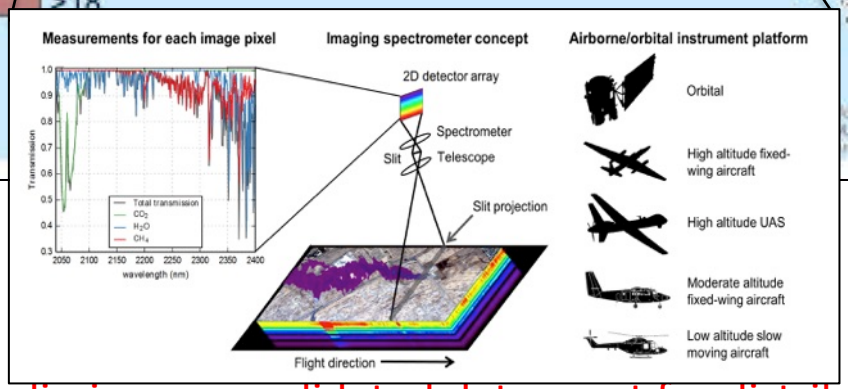
Aliso Canyon gas leak: motivating questions

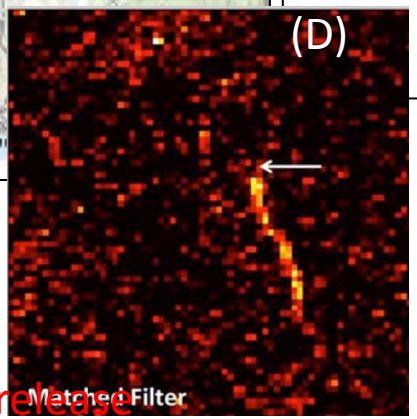
- How much gas was lost during initial, dynamic leak phase?
- What was the spatial extent of the source and how did it evolve over time?
- Was there a systemic leakage issue or precursor event prior to Oct 23?
- Are there systemic issues with other underground gas storage facilities?

Evans, 2008

Aliso Canyon - Five tiers of observations: (A) CLARS basin-wide CH4 mapping (5X/day); (B) continuous tower network measurements (white dots – 9 of 13 shown); (C) 11 airborne imaging spectrometer surveys (AVIRIS & HyTES); (D) Satellite observations (GOSAT & Hyperion); (E) mobile surface surveys (Picarro, Flasks, IR cameras)



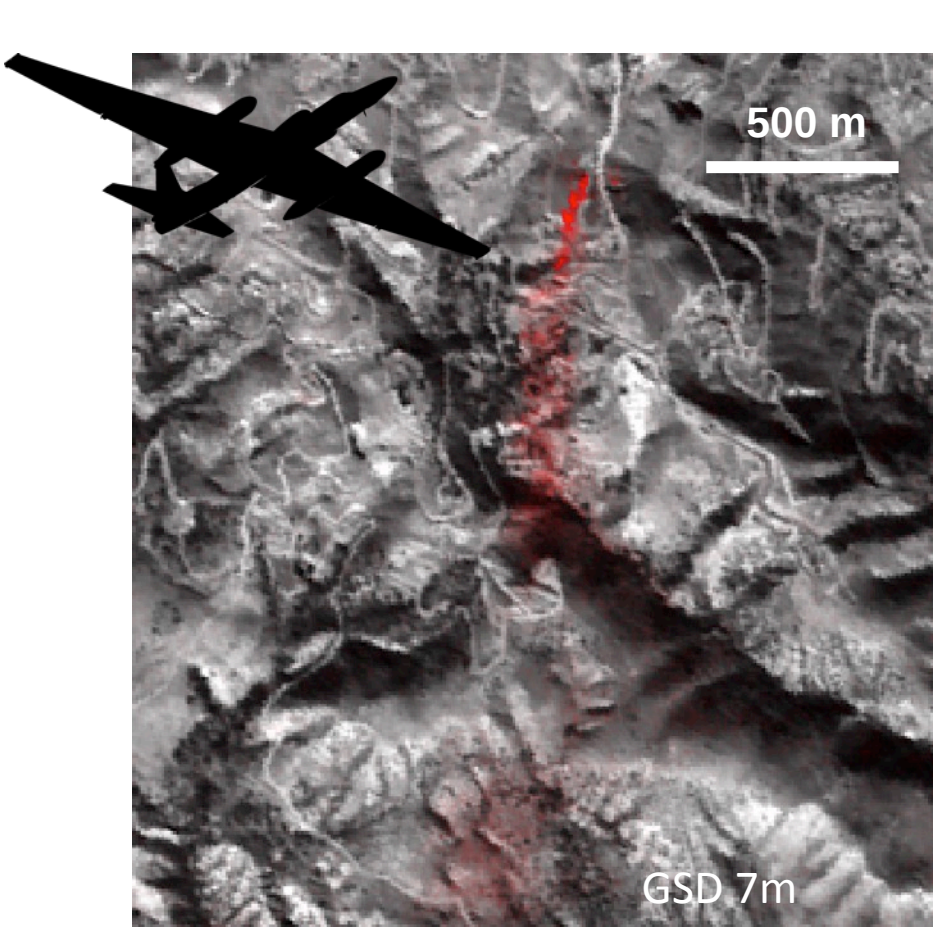


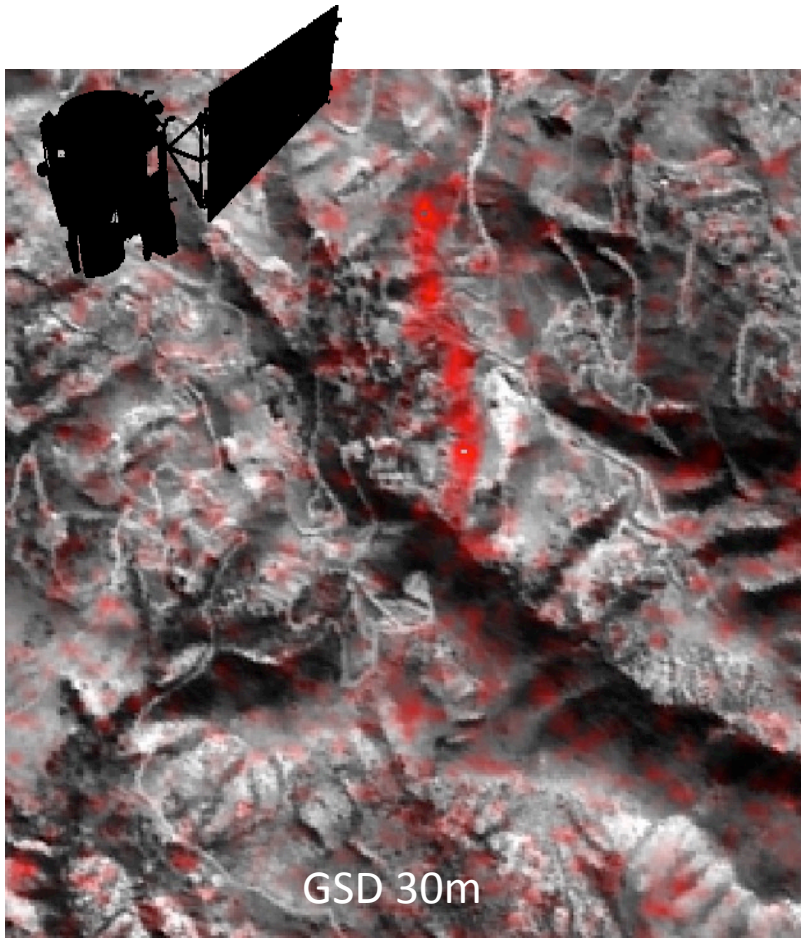


Plume detected (and quantified) from 28,000 ft and low-earth orbit

Comparison of detected plumes from AVIRIS-C on

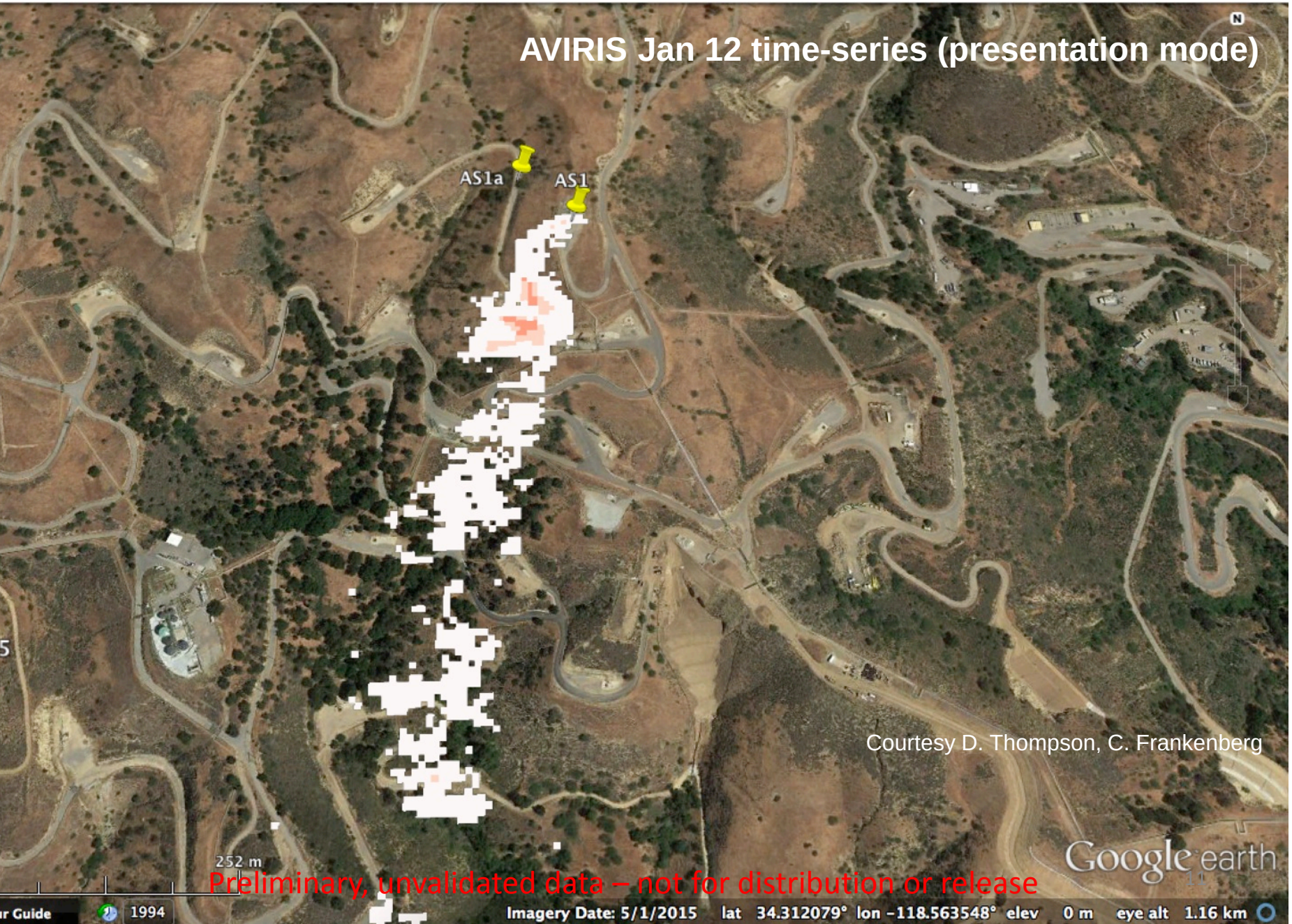
1/12/2016 (Left) and Hyperion on 1/1/2016 (Right)





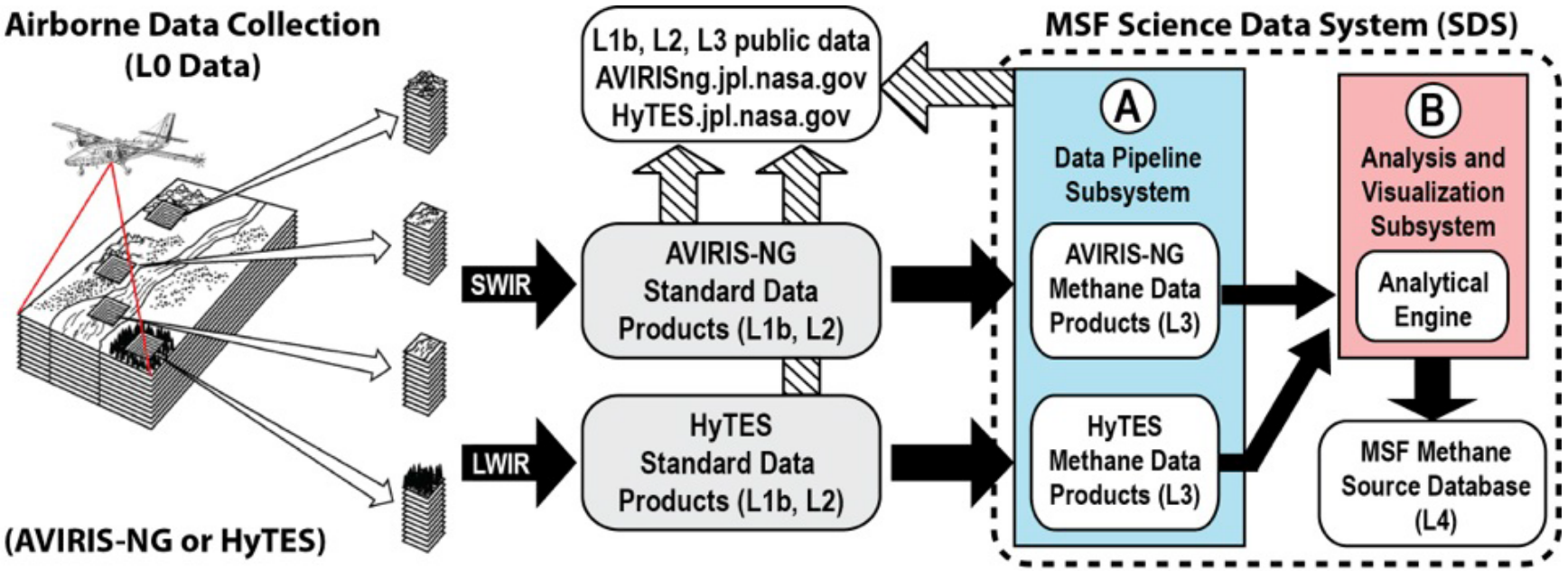
Thompson, D.R., A. Thorpe, C. Frankenberg, R. O. Green, R. Duren, L. Gaunter, A. Hollstein, E. Middleton, L. Ong, S. Ungar, Orbital Spectroscopy of the Aliso Canyon CH4 Super-emitter, GRL, 2016, accepted.

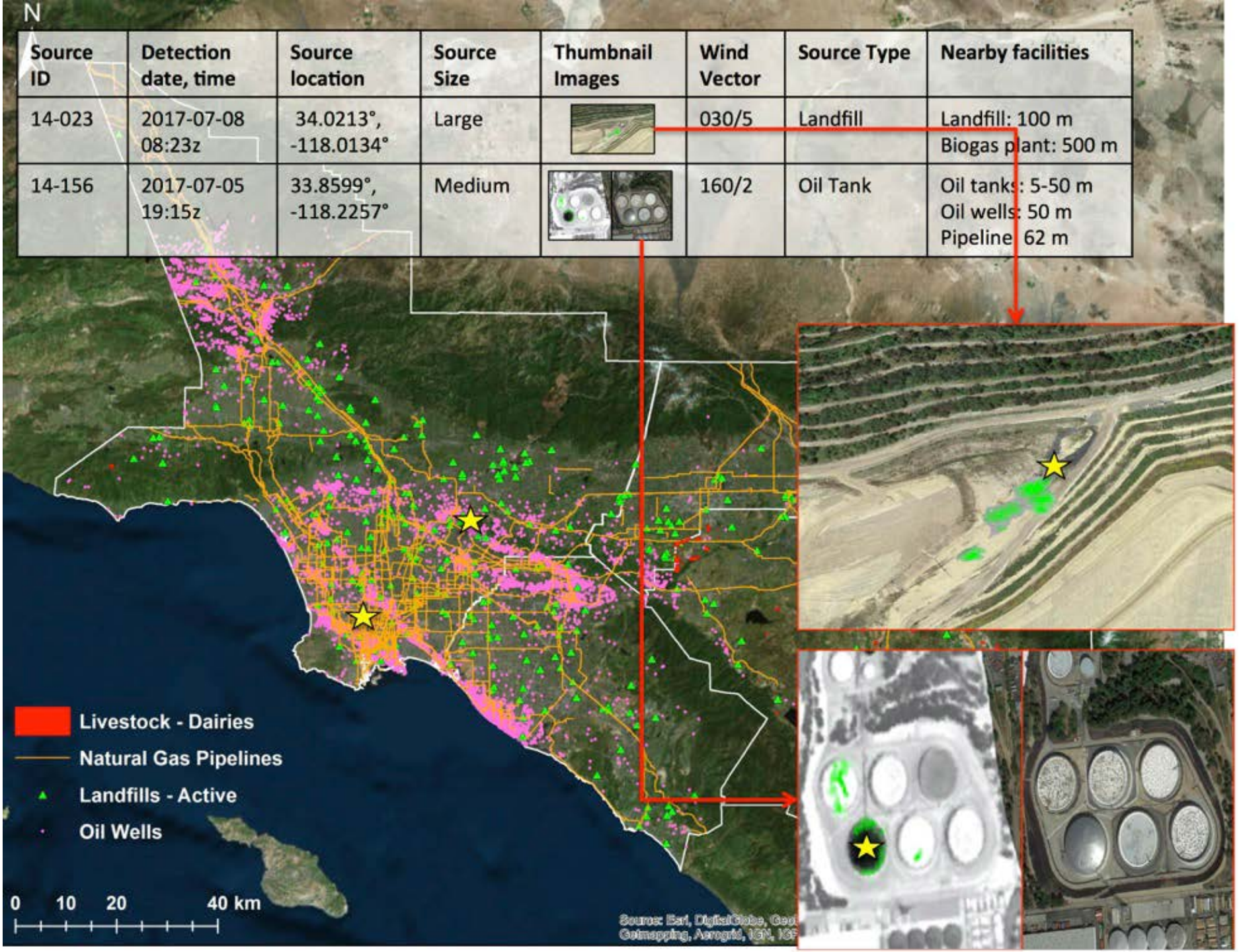
Plume space-time structure



Methane Source Finder (MSF)
Data Processing, Analysis & Visualization

The ability of NASA imaging spectrometers (AVIRIS-NG and HyTES) to rapidly survey large areas, detect and map methane plumes and pinpoint source locations is a transformative advance, but requires fast, efficient data processing, analysis and visualization





Source ID	Detection date, time	Source location	Source Size	Thumbnail Images	Wind Vector	Source Type	Nearby facilities
14-023	2017-07-08 08:23z	34.0213°, -118.0134°	Large		030/5	Landfill	Landfill: 100 m Biogas plant: 500 m
14-156	2017-07-05 19:15z	33.8599°, -118.2257°	Medium		160/2	Oil Tank	Oil tanks: 5-50 m Oil wells: 50 m Pipeline: 62 m

California Baseline Methane Survey summer 2016

Planned* airborne coverage (green outlines) for 2016 California Baseline Methane Survey: South Coast Air Basin (1), key sections of San Joaquin Valley (2-3), key sections of Sacramento Valley (4), and San Francisco Bay Area Air Basin (5). Based on combining information from California stakeholders and gridded greenhouse gas these areas are likely responsible for at least 80% of the state's methane emissions. [*preliminary and subject to change]

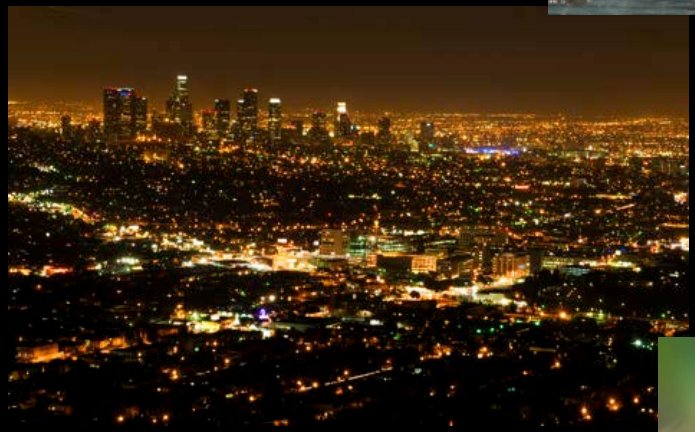
Earthquake response: Real-time gas detection onboard airplane supports rapid response

D. Thompson

Text msg:
GPS coordinates,
plume strength

Summary

- Small number of super-emitters likely dominate overall methane budget for many sectors → major implications for mitigation (agriculture, not just oil & gas)
- Potential source population in California > 100,000 – spread over >30,000 km2
- Remote sensing can identify methane super-emitters for mitigation
- Aircraft offer agility for quickly surveying large areas
- Pilot efforts in Central Valley and LA are demonstrating the Tiered Observing System strategy works for detecting and quantifying fugitive methane emissions
- Approach is scalable for sustained monitoring for California and elsewhere



Thank you

Riley.M.Duren@jpl.nasa.gov

http://megacities.jpl.nasa.gov

https://cmsun.jpl.nasa.gov

http://carbon.nasa.gov