Connecting space-based observations with dense networks of surface measurements

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$ BAAQMD, NASA, UC Berkeley, HEI, Koret Foundation

My Questions

What can we do to understand the processes affecting air quality at the neighborhood scale?

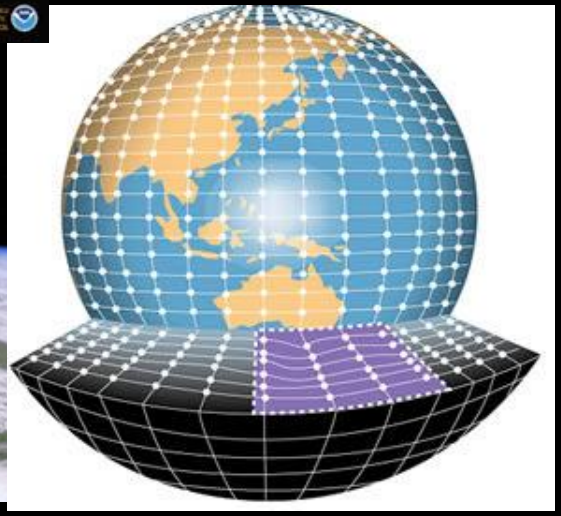
How are those processes changing over time?

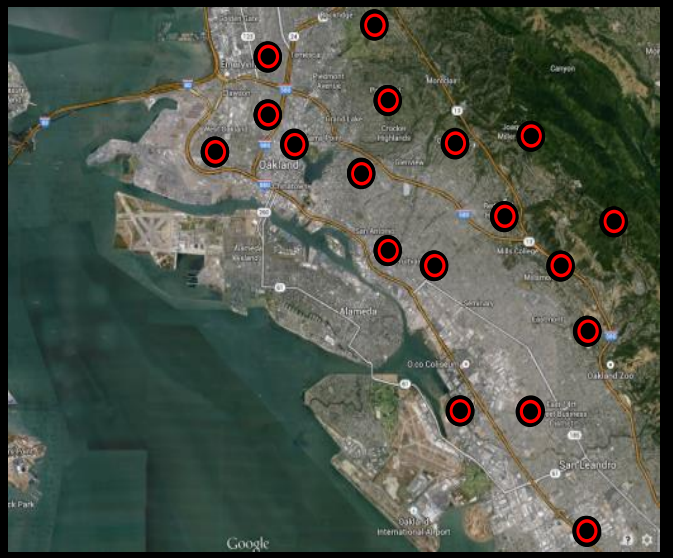
1972 **2001**

New York City

Surface

Aircraft





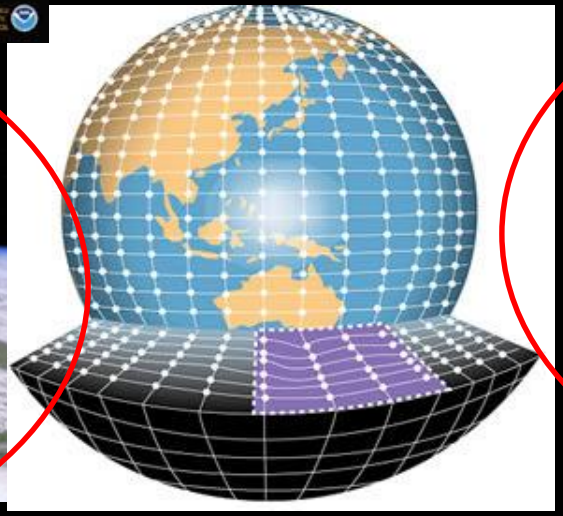
Remote sensing
NO_2

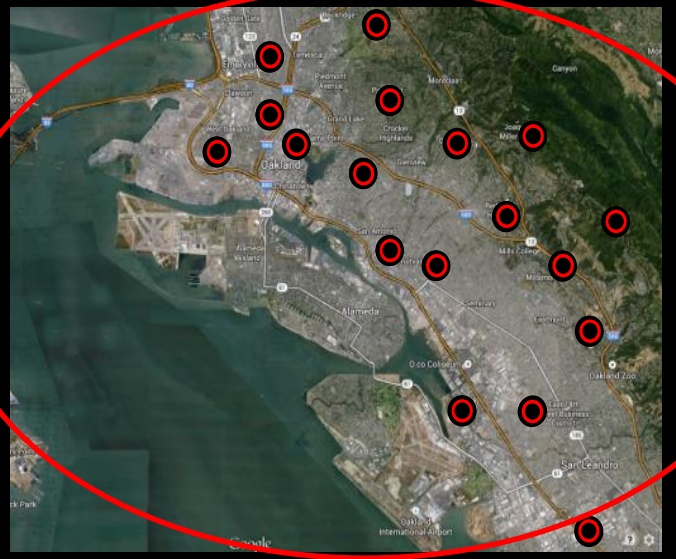
Data–Model Syntheses

Ubiquitous sensing
CO_2, NO_2, …

Surface

Aircraft



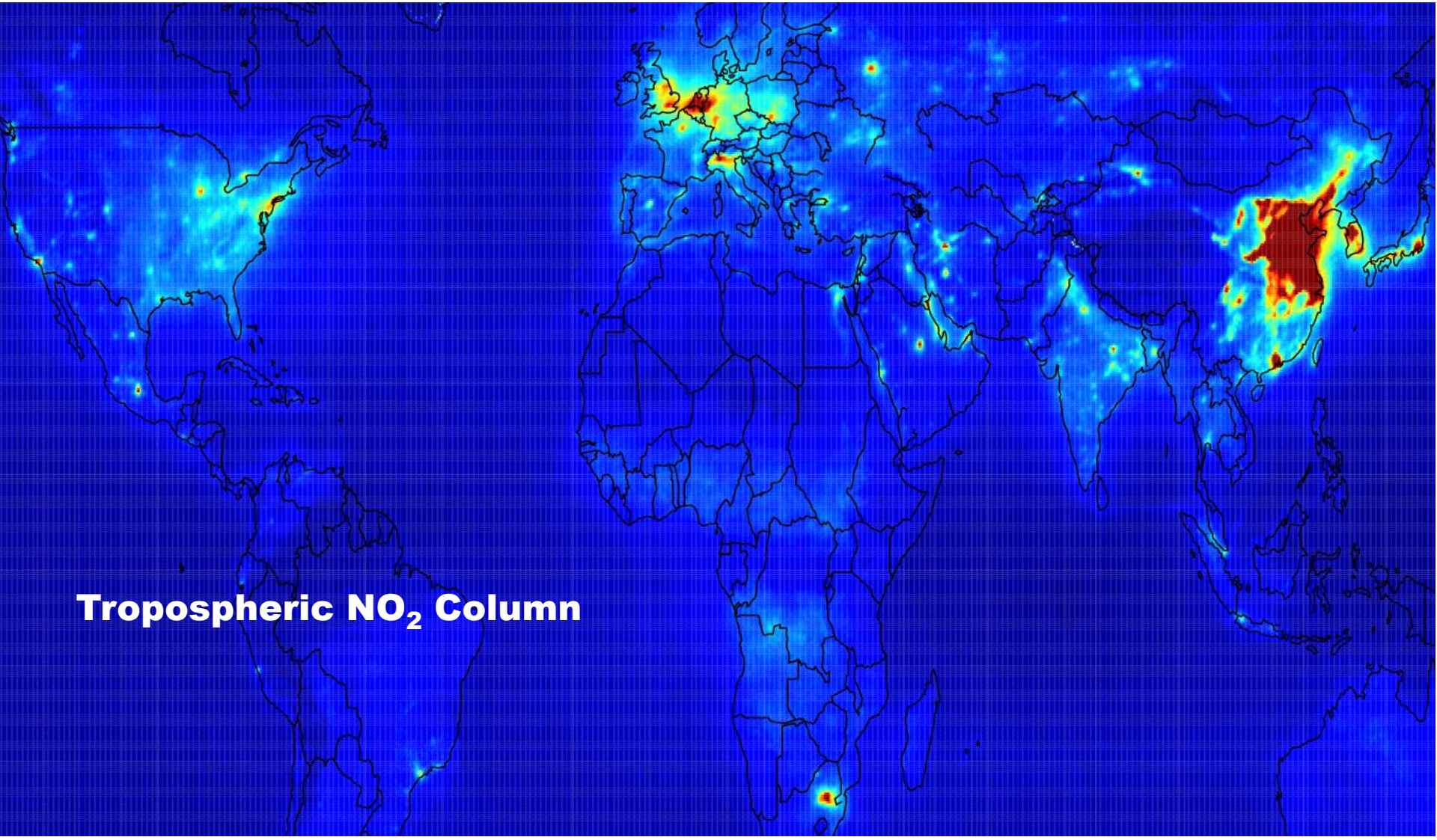


~~Remote sensing~~
NO_2

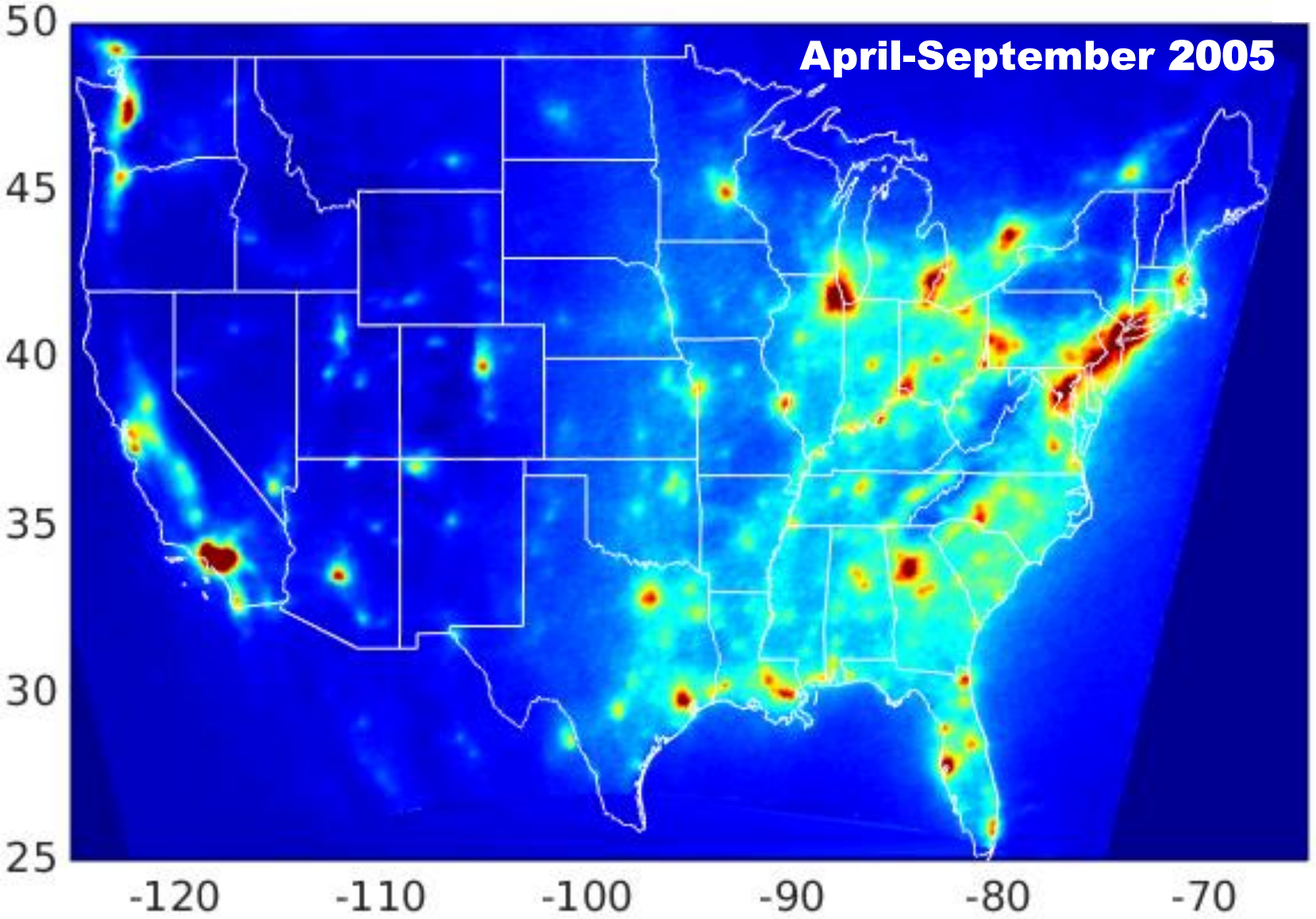
Data–Model Syntheses

Ubiquitous sensing
CO_2, NO_2, ...

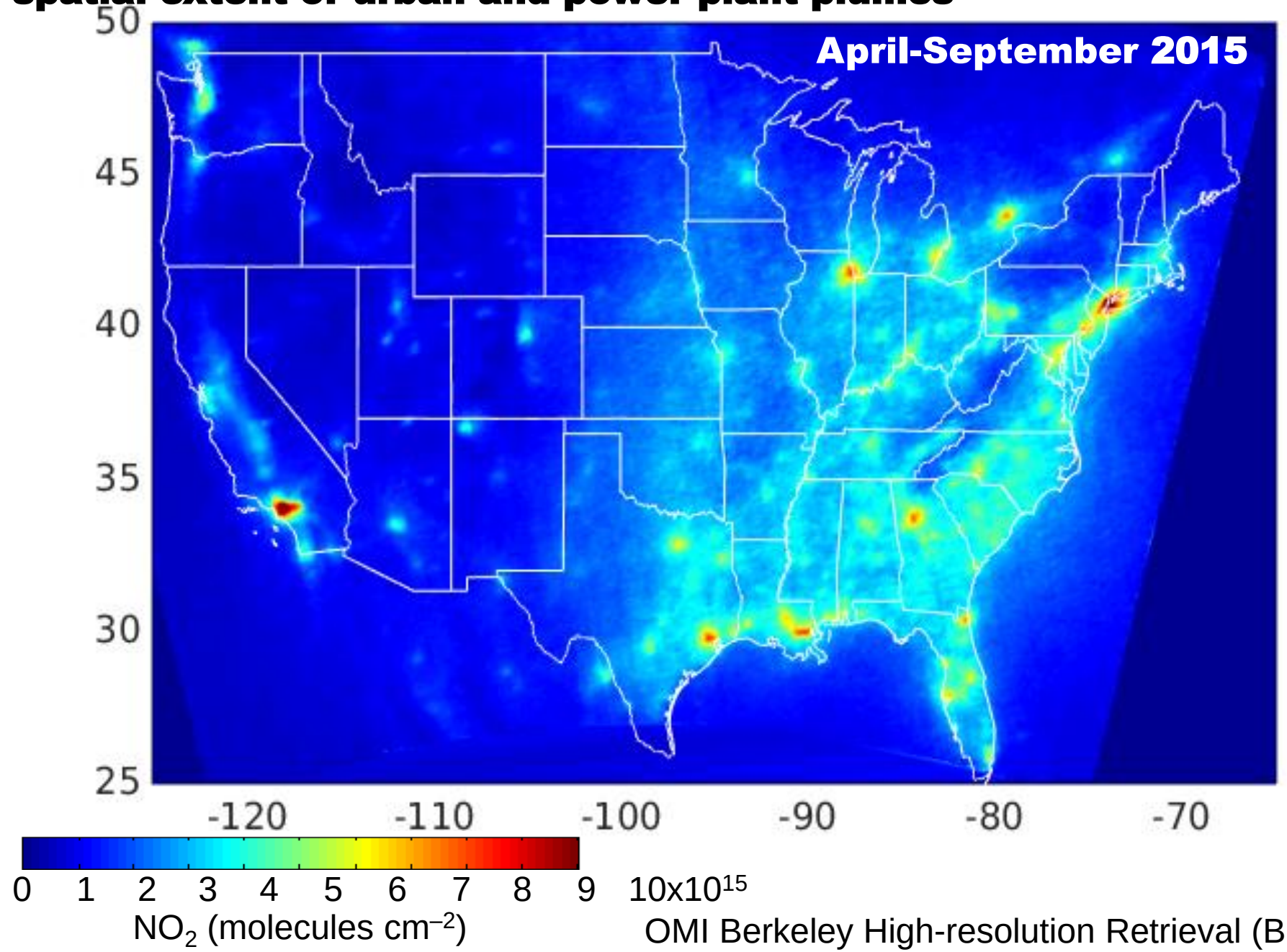
Satellite remote sensing of chemicals:
global and once per day



Continental and urban scale averages

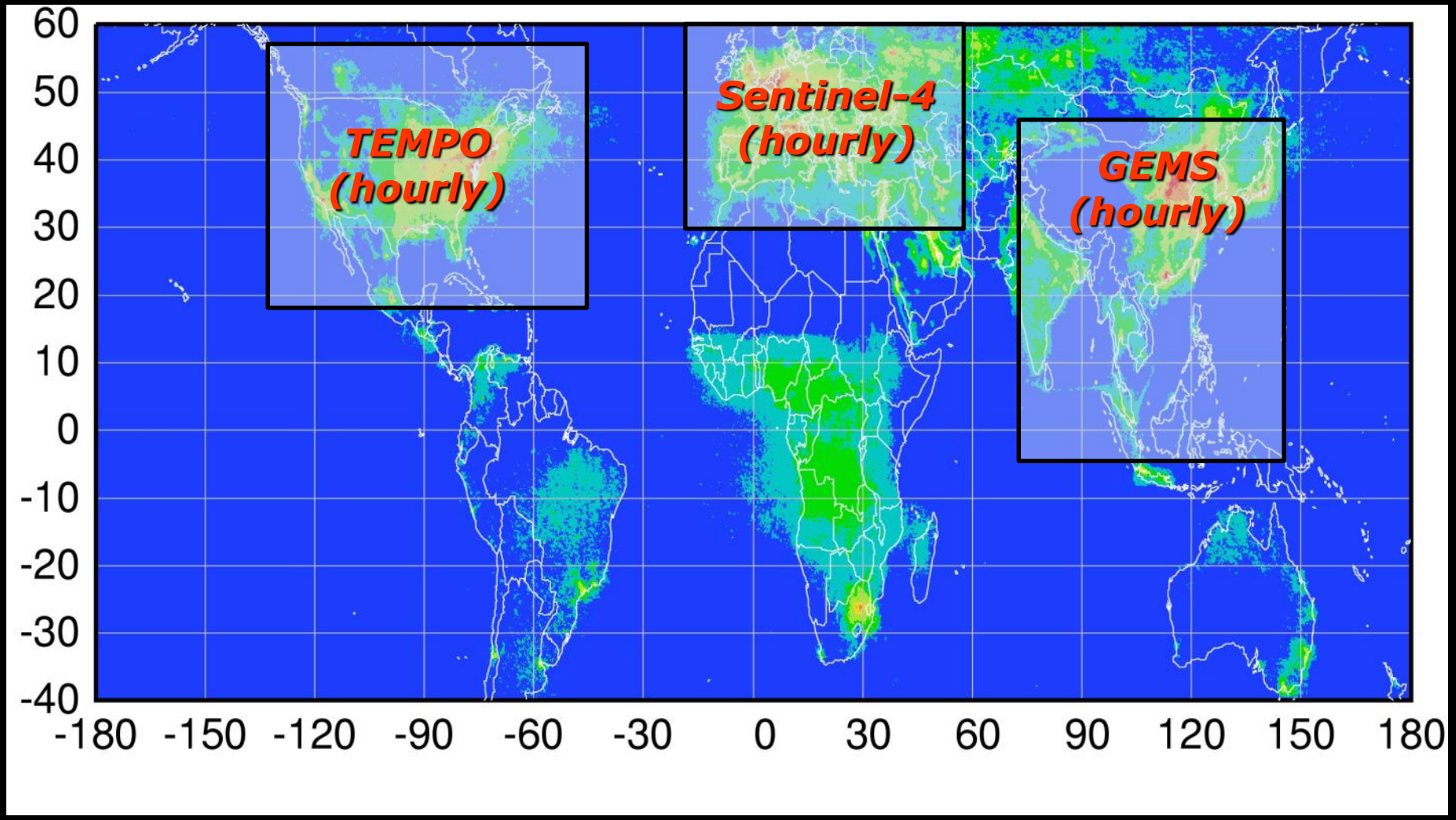


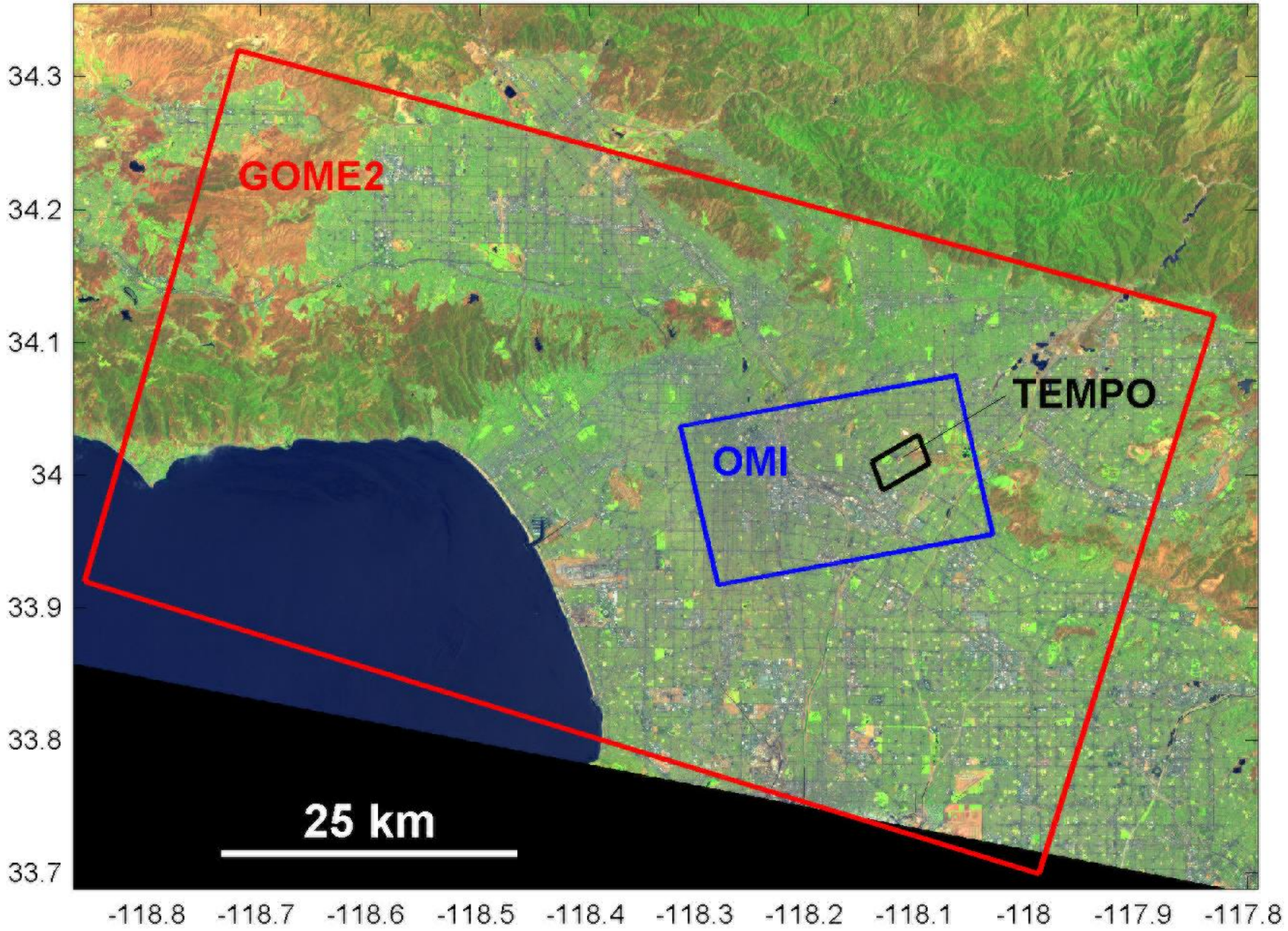
Large decreases over the last decade in U.S. result in smaller spatial extent of urban and power plant plumes



- Measurements (voltage, current …)
- ……..
- Understanding about how the world works

Geostationary instruments to be launched soon will be local and ~12 times per day

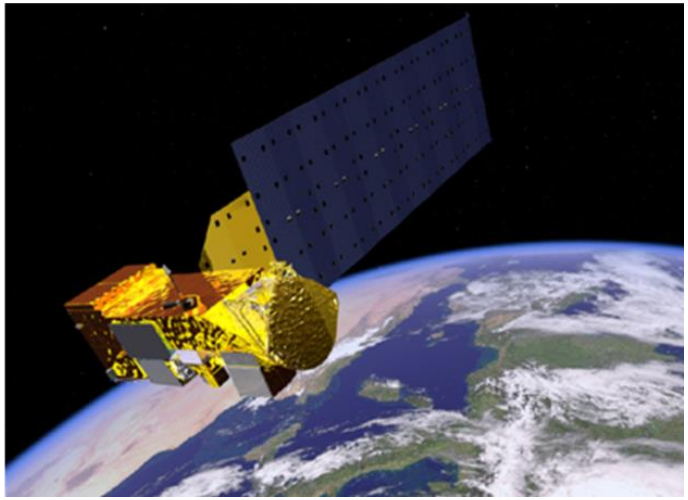


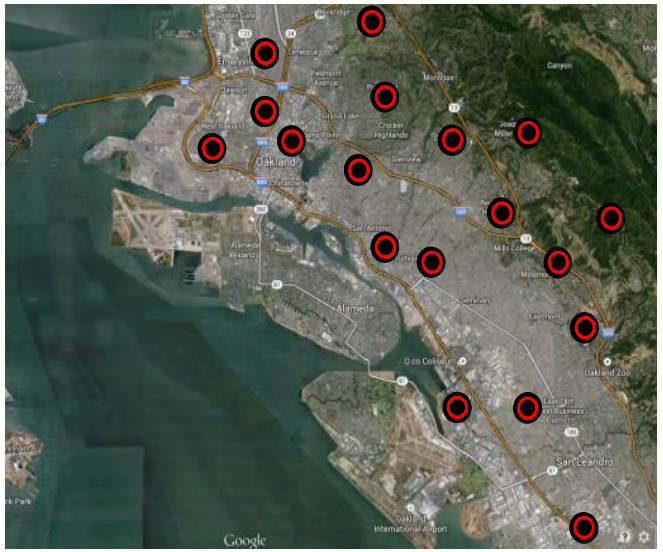

Instrument Footprint over Northwest Los Angeles
GOME2
OMI
TEMPO
25 km
34.3
34.2
34.1
34
33.9
33.8
33.7
-118.8
-118.7
-118.6
-118.5
-118.4
-118.3
-118.2
-118.1
-118
-117.9
-117.8


On a neighborhood scale new satellites and
inexpensive sensing will change how we think
about emissions and air quality


On a neighborhood scale inexpensive sensing is one way we will provide ground truth for new satellites

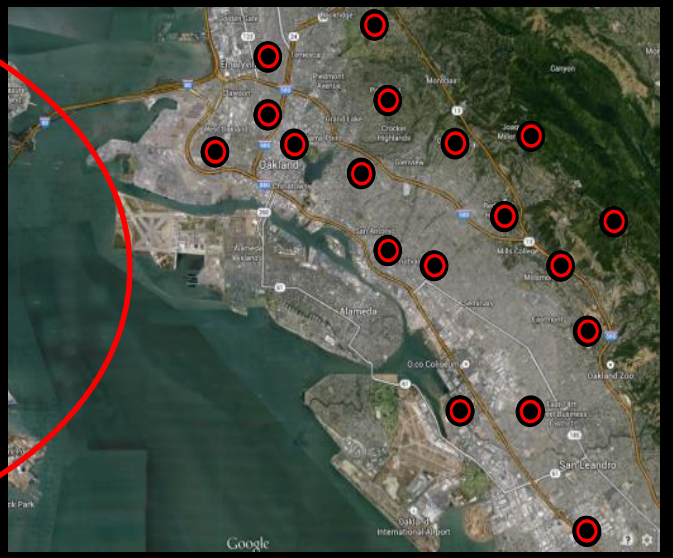
To understand what low cost sensors and satellites can teach us that is genuinely new, we have some hard work to do to express current understanding in accessible forms.





Surface

Aircraft

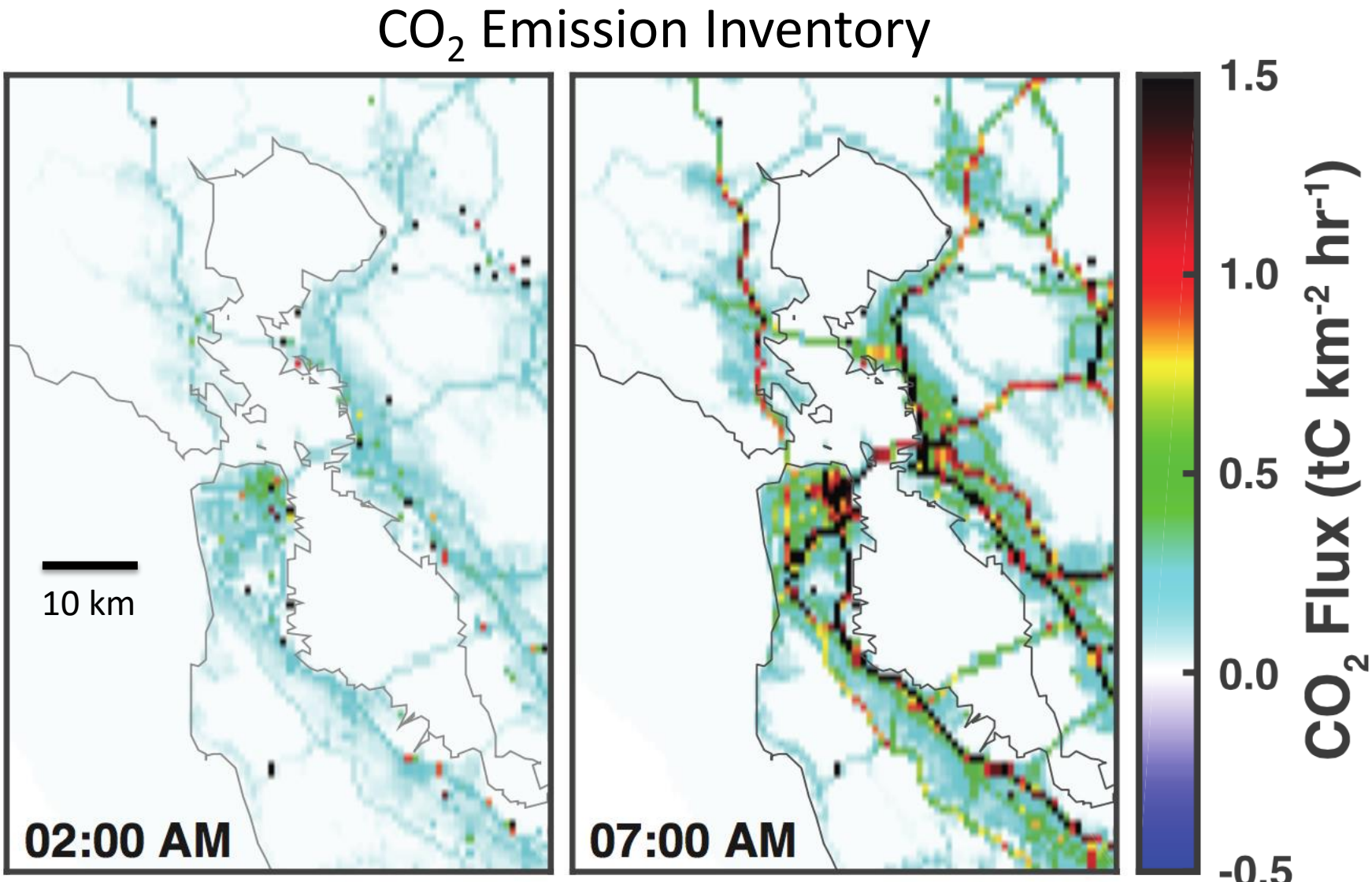


Remote sensing
NO_2

Data–Model Syntheses

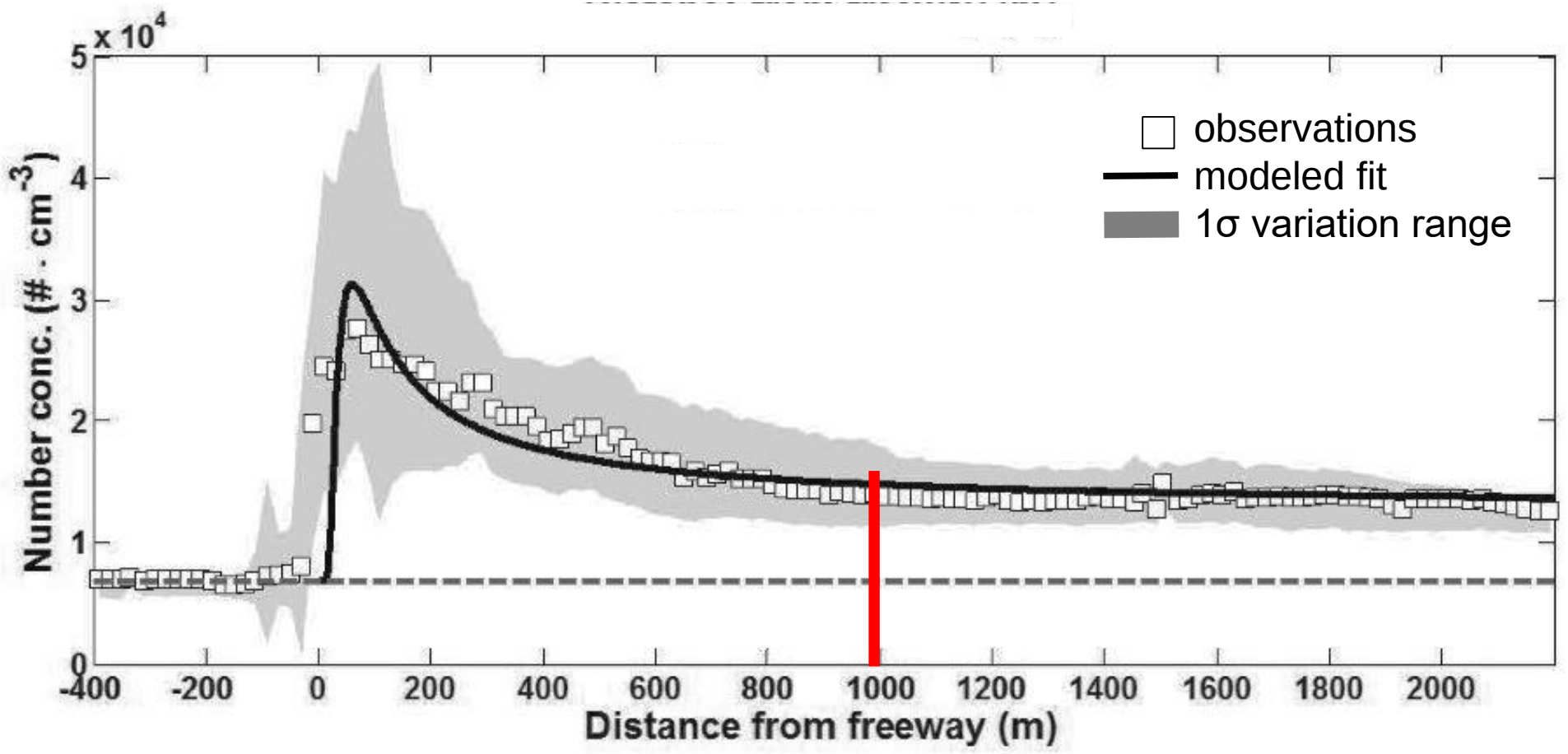
Ubiquitous sensing
CO_2, NO_2, ...

Current models of emissions have few parts that respond to day-to-day variations in human behavior or weather.



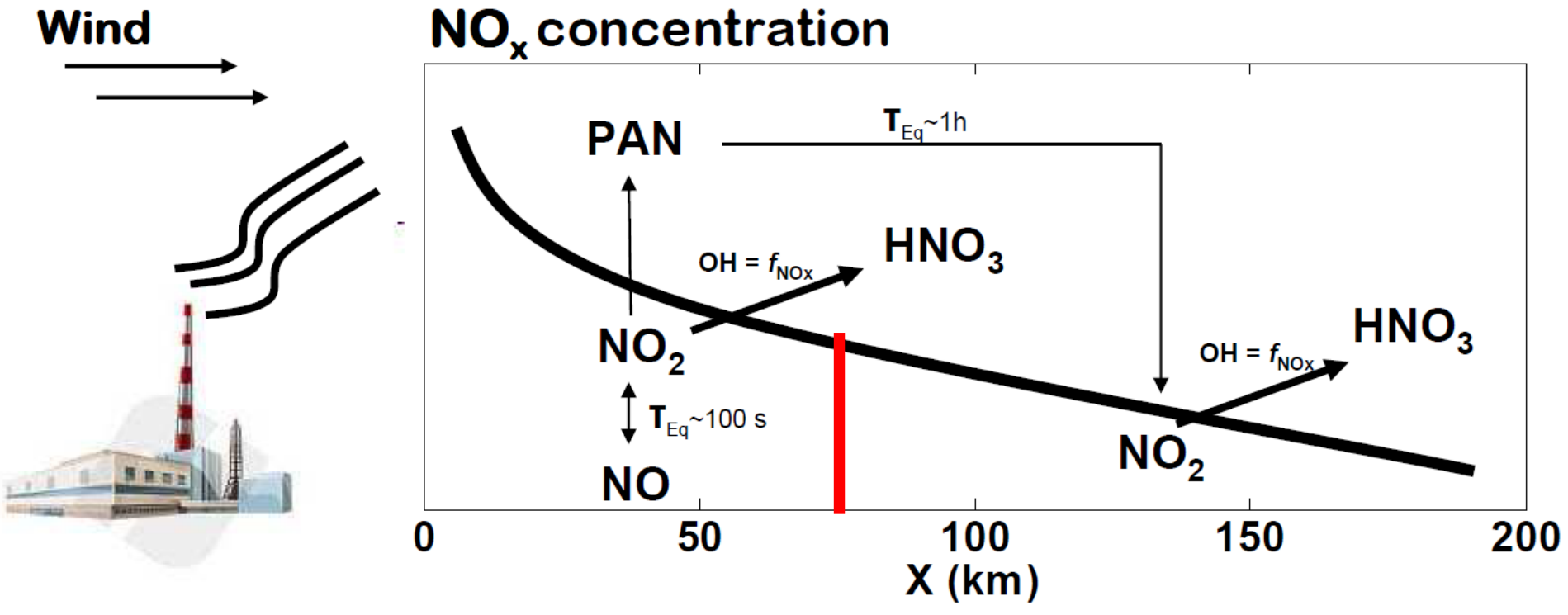
(Turner et al., 2016)

Atmospheric mixing and dilution occurs on many space and time scales

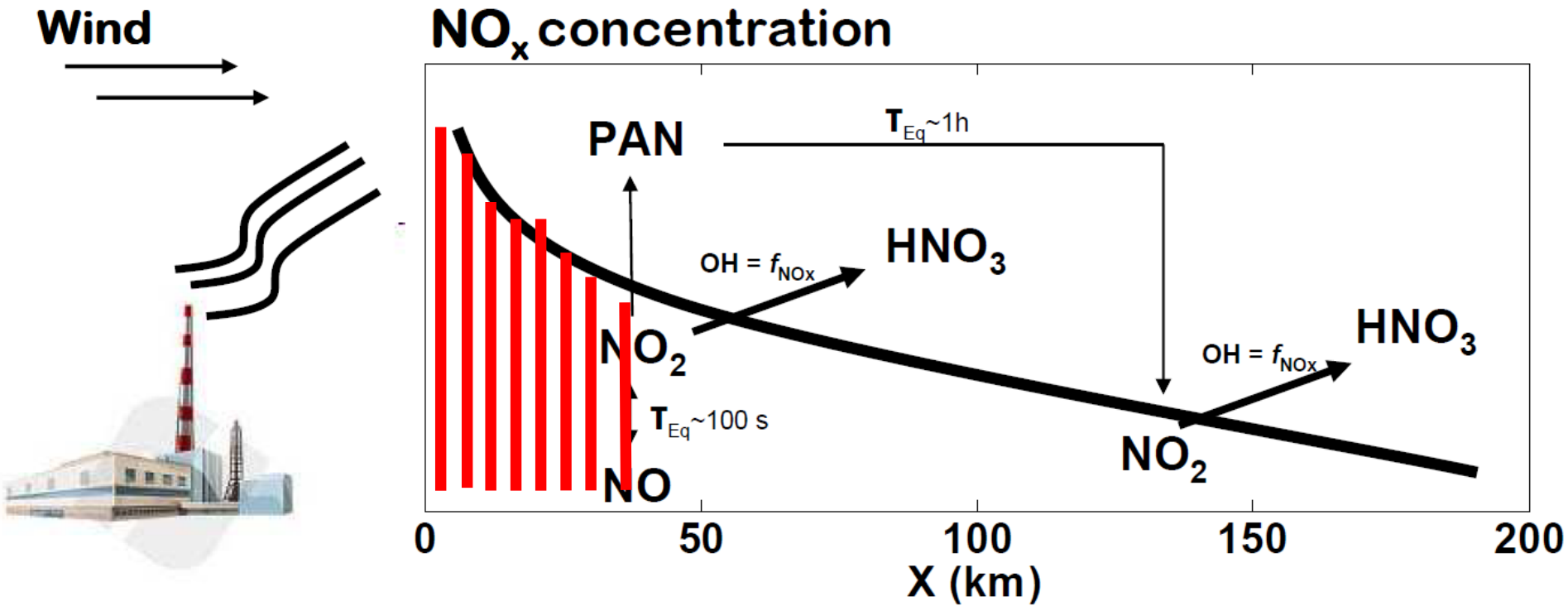


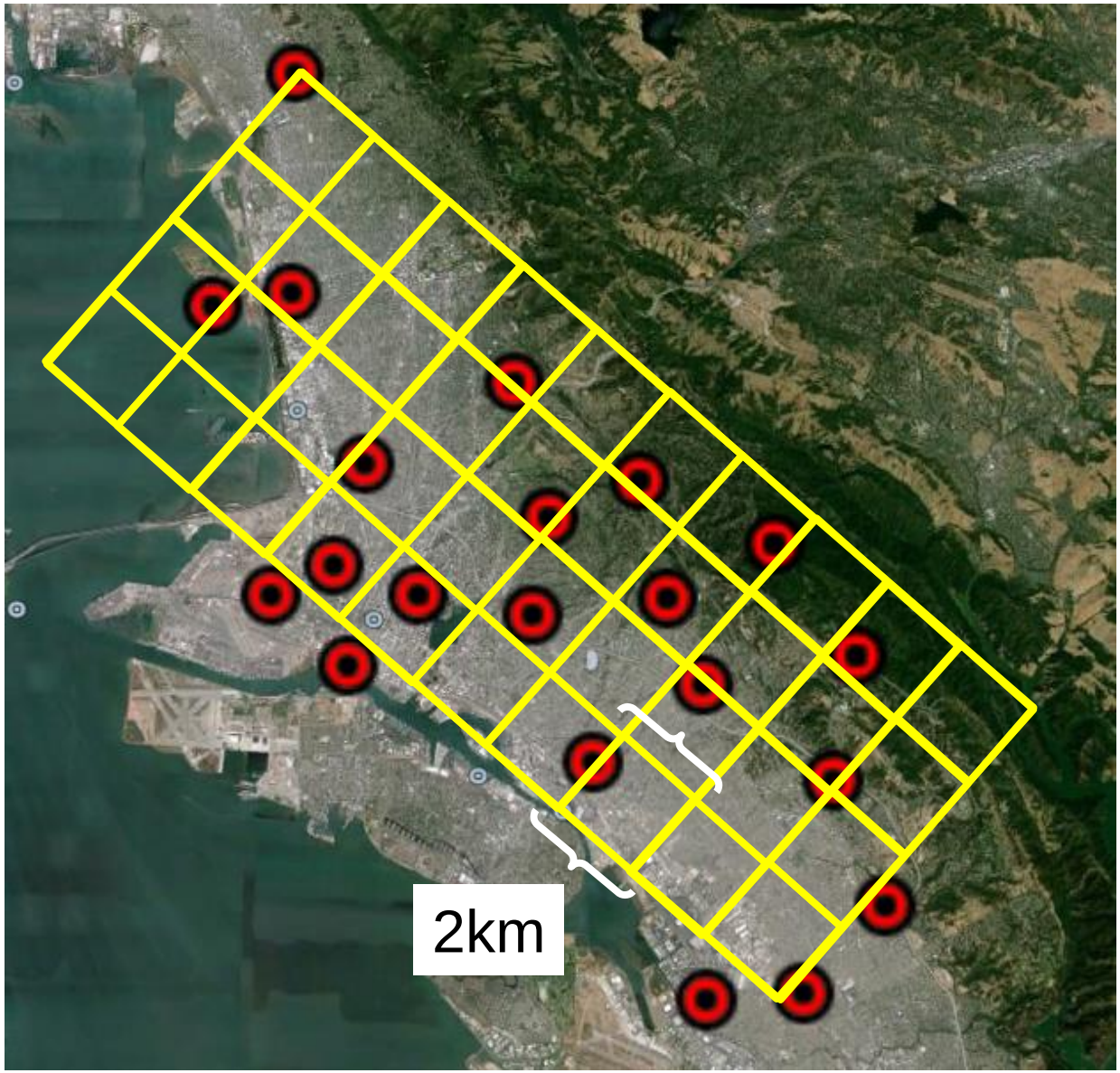
from Choi et al. 2014

Atmospheric chemistry also has characteristic space and time scales



$BEACO_2N$— pointwise surface network at ~2km resolution





BErkeley

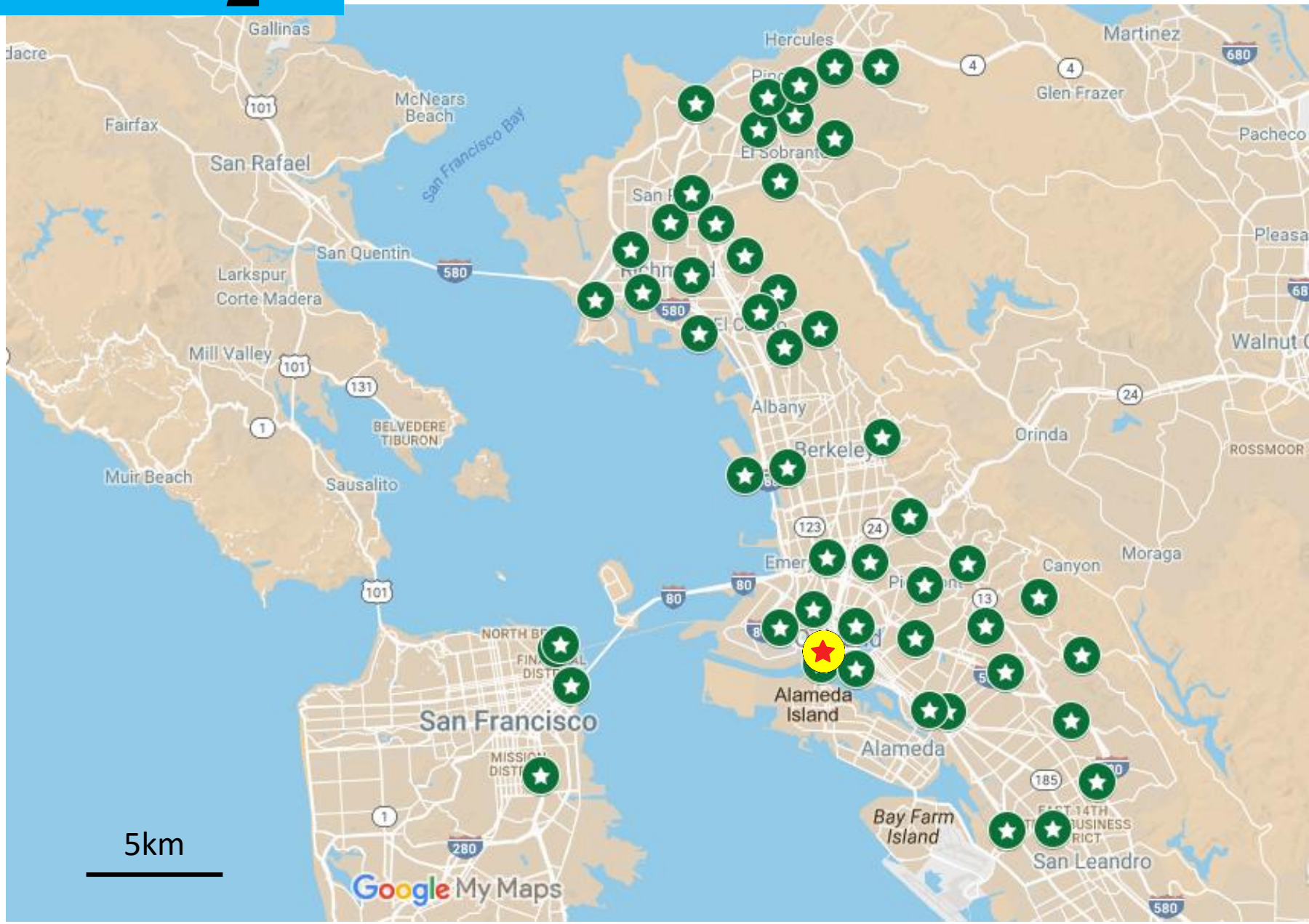
Atmospheric

CO_2

Observation

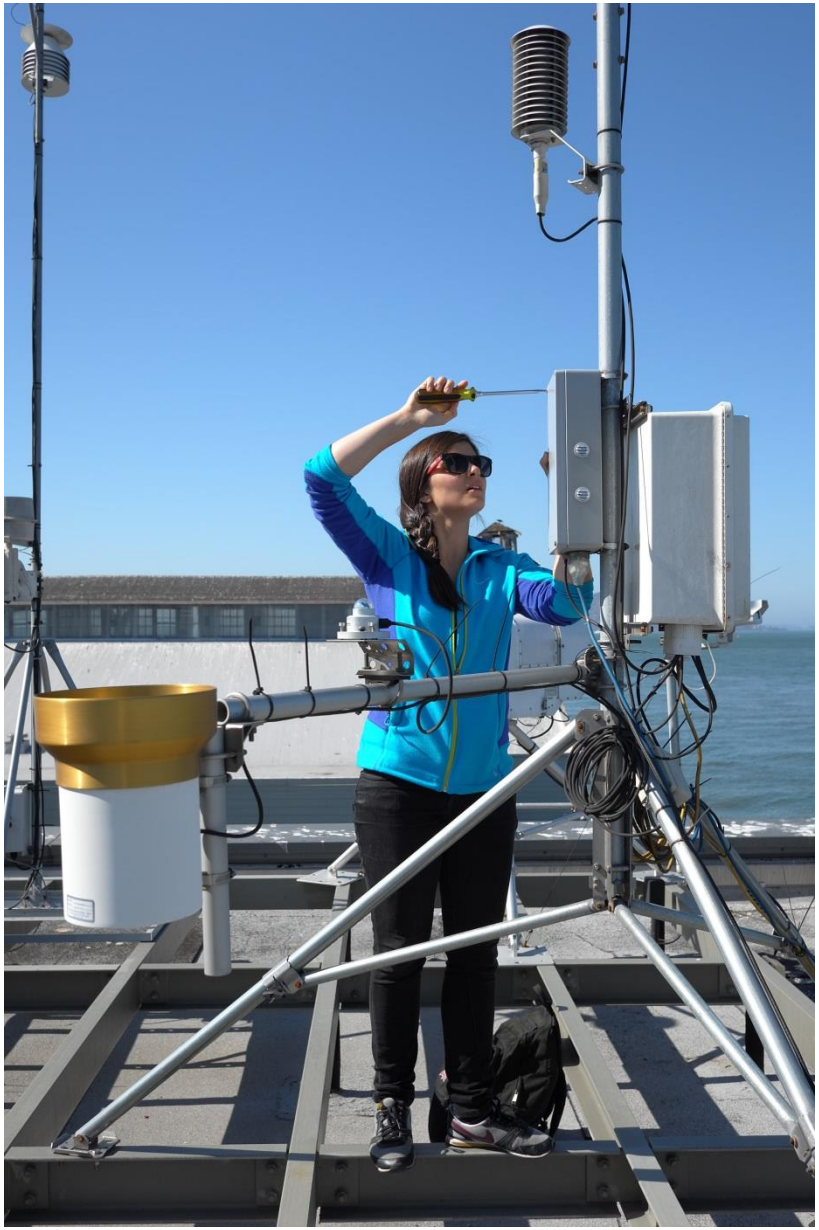
Network

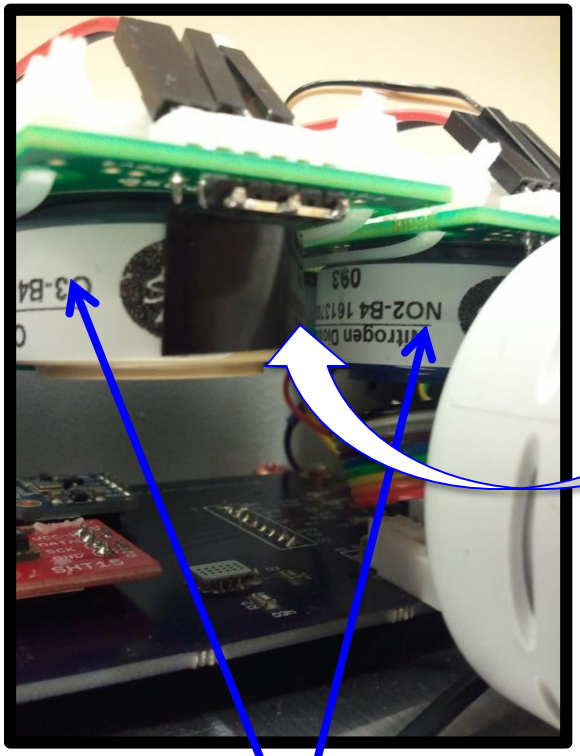
BEACO$_2$N

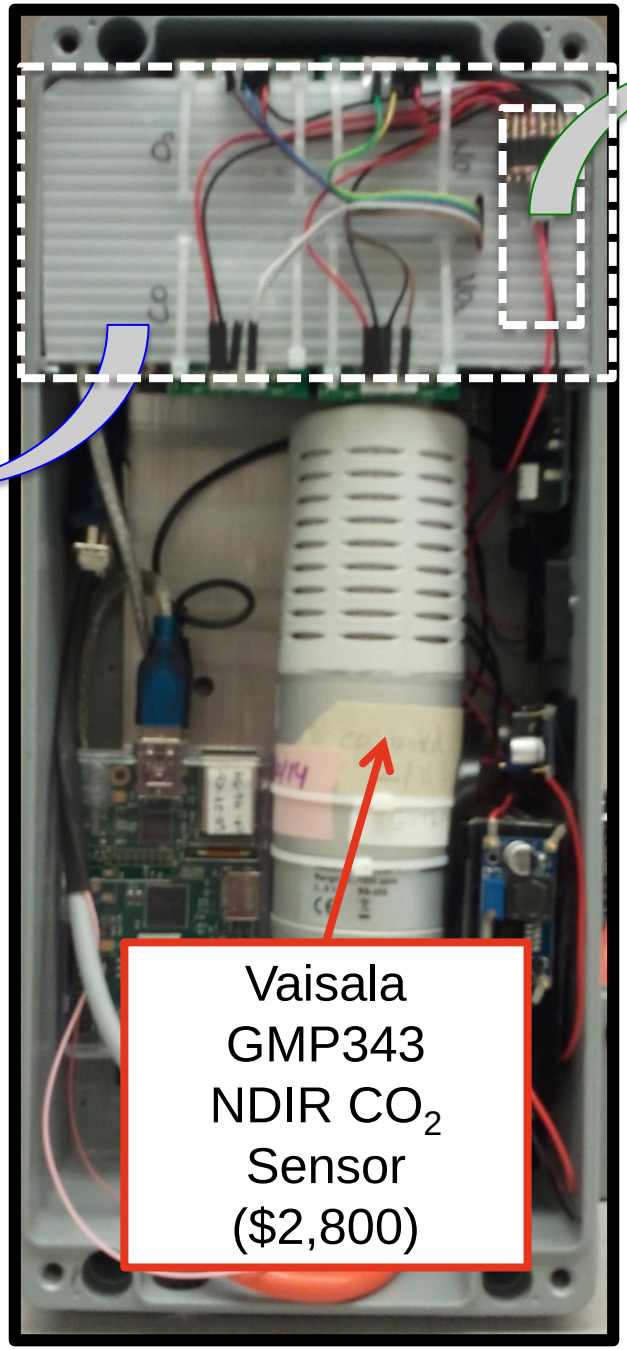

Gallinas
Fairfax
San Rafael
McNears Beach
San Francisco Bay
San Quentin
Larkspur
Corte Madera
Mill Valley
BELVEDERE
TIBURON
Muir Beach
Sausalito
Hercules
Martinez
Glen Frazer
Pacheco
El Sobrante
Pleasa
Walnut
Albany
Berkeley
Orinda
ROSSMOOR
Moraga
Canyon
Alameda Island
Alameda
Bay Farm Island
San Leandro
San Francisco
NORTH
MISSION
5km
Google My Maps

Posters by
Jinsol Kim and Kaitlyn Lieschke

BEACO$_2$N: 2.5m – 130m AGL







Alphasense B4 Electrochemical O_3, CO, NO & NO_2 Sensors ($216 ea.)

Vaisala GMP343 NDIR CO_2 Sensor ($2,800)

Shinyei PPD42NS nephelometric particulate matter sensor ($16)

Calibration using approach that is largely different than any of the others you heard about thus far --- Jinsol Kim

Atmos. Meas. Tech. Discuss., https://doi.org/10.5194/amt-2017-339
Manuscript under review for journal Atmos. Meas. Tech.
Discussion started: 28 September 2017

Atmospheric Measurement Techniques Discussions

The BErkeley Atmospheric CO_2 Observation Network: Field Calibration and Evaluation of Low-cost Air Quality Sensors

Jinsol Kim[1], Alexis A. Shusterman[2], Kaitlyn J. Lieschke[2], Catherine Newman[2], and Ronald C. Cohen[1,2]

[1]Department of Earth and Planetary Science, University of California Berkeley, Berkeley, CA 94720, USA
[2]Department of Chemistry, University of California Berkeley, Berkeley, CA 94720, USA

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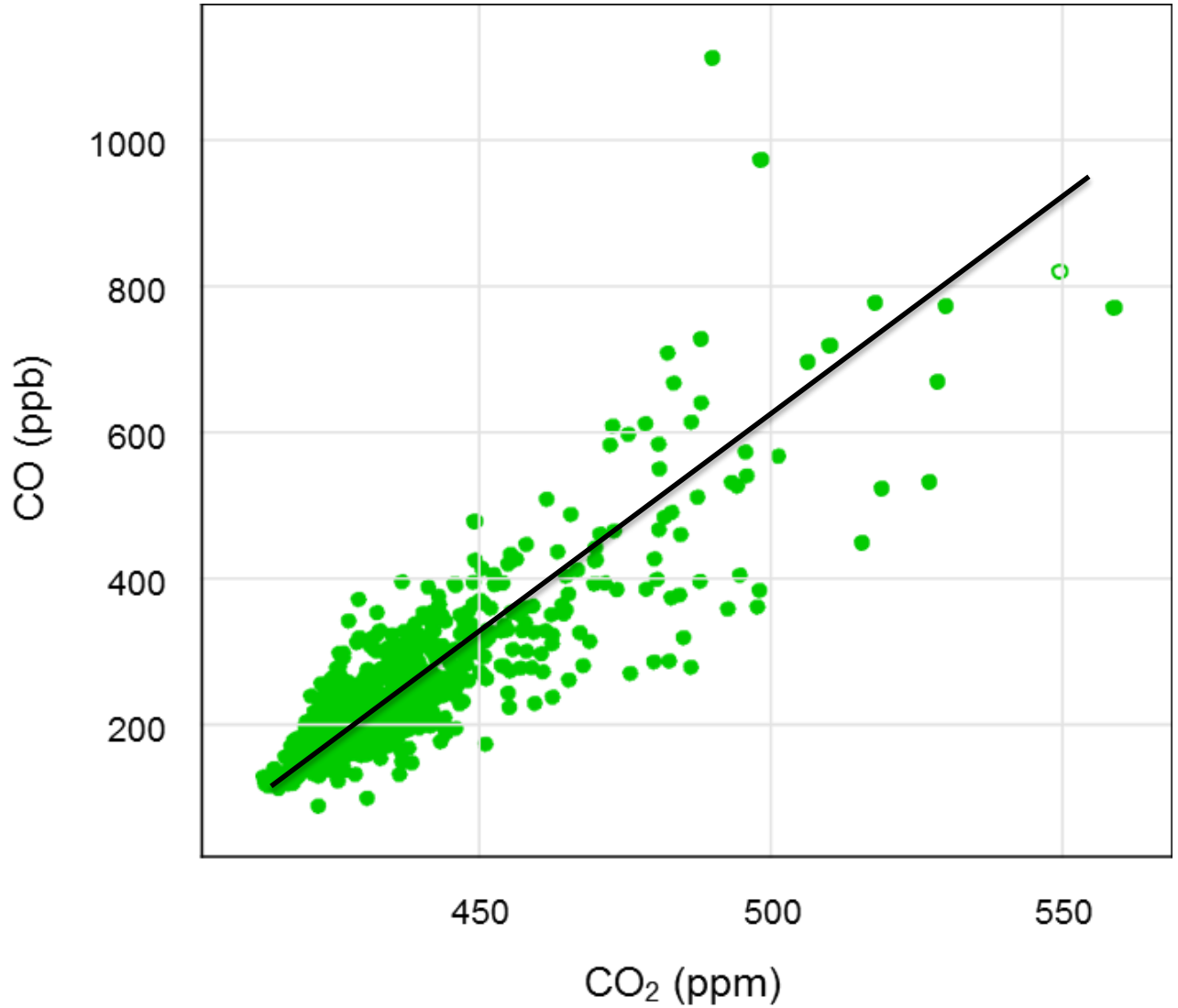
Abstract. The newest generation of air quality sensors is small, low cost, and easy to deploy. These sensors are an attractive option for developing dense observation networks in support of regulatory activities and scientific research. They are also of interest for use by individuals to characterize their home environment and for citizen science. However, these sensors are difficult to interpret. Although some have an approximately linear response to the target analyte, that response may vary with time, temperature, and/or humidity, and the cross-sensitivity to non-target analytes can be large enough to be confounding. Standard approaches to calibration that are sufficient to account for these variations require a quantity of equipment and labor that negates the attractiveness of the sensors' low cost. Here we describe a novel calibration strategy for a set of sensors including CO, NO, NO_2, and O_3 that makes use of multiple co-located sensors, a priori knowledge about the chemistry of NO, NO_2, and O_3, as well as an estimate of mean emission factors for CO and the global background of CO. The strategy requires one or more well calibrated anchor points within the network domain, but it does not require direct

Sources emit multiple compounds and aerosol



0.6% CO/CO_2

Sources emit multiple compounds and aerosol

- **Cookstoves and charcoal burning**

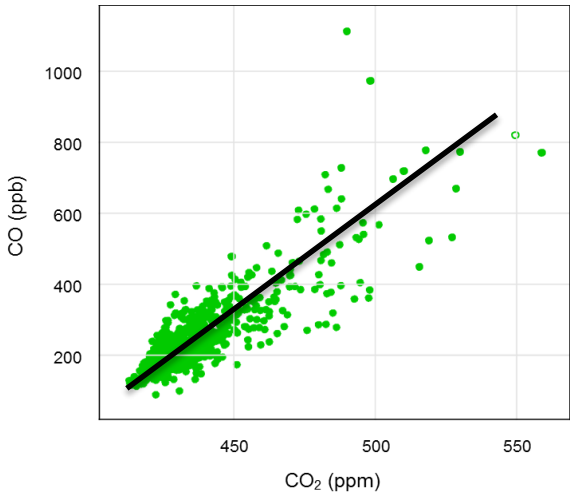
  ~6% CO/CO_2; low NO_x, high aerosol
- **Gasoline cars with catalysts (U.S.)**

  0.75% CO; 0.01% NO_x per CO_2; low aerosol
- **Coal fired power plants**

  low $CO:CO_2$, high NO_x and SO_2 unless controlled
- **Heavy duty diesel trucks**

  0.4% CO, .12 NO_x per CO_2, high aerosol

0.6% CO/CO_2



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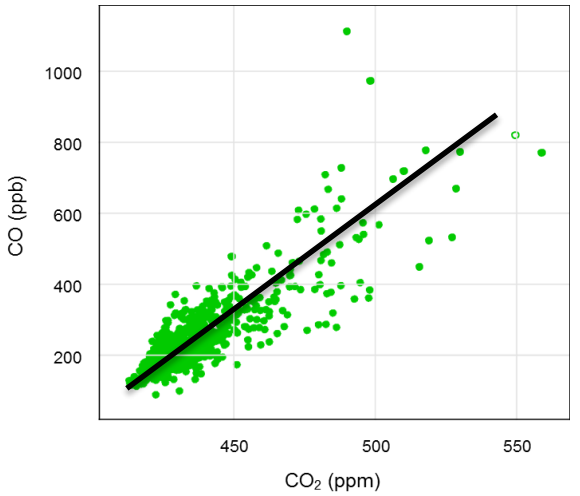
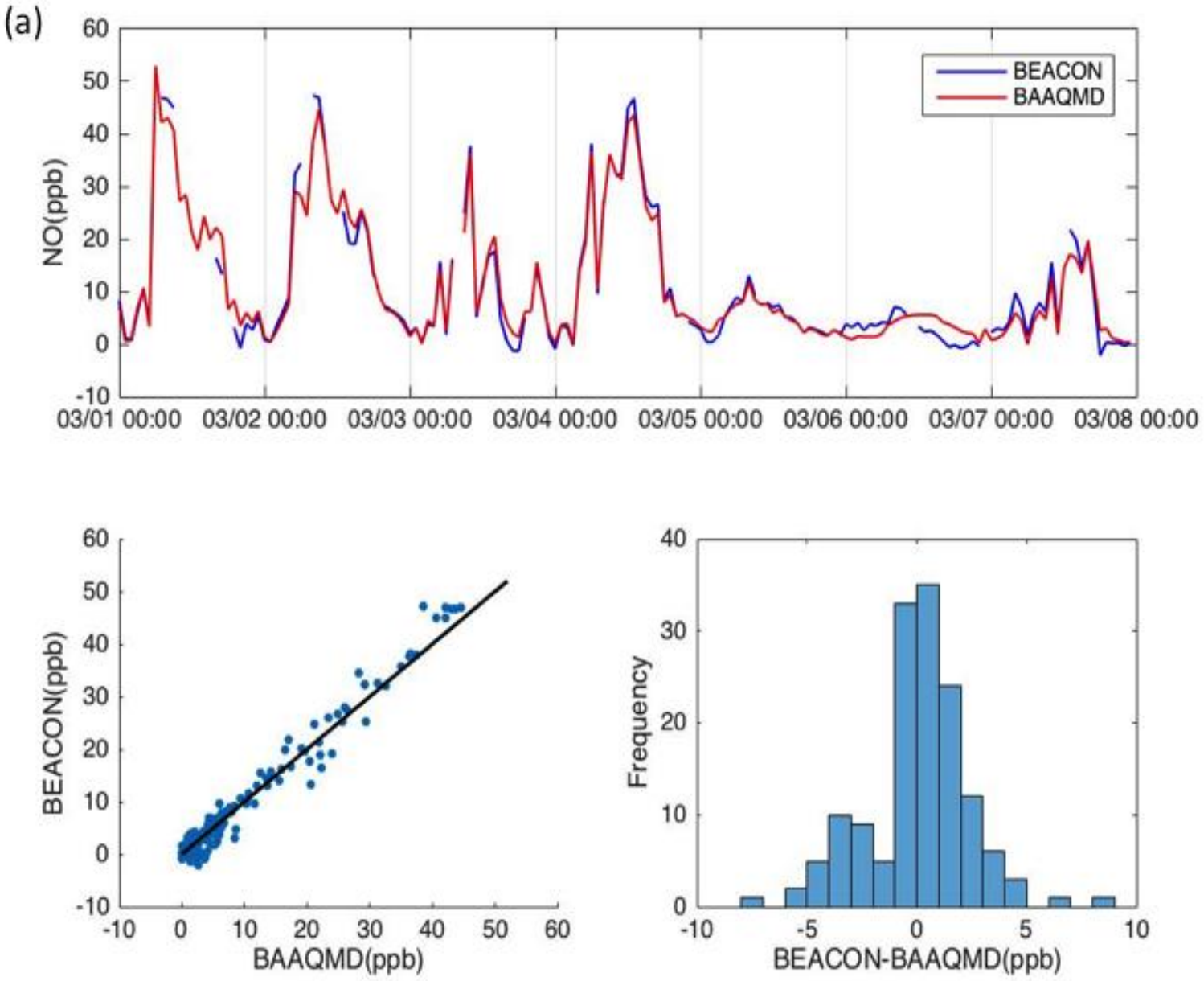
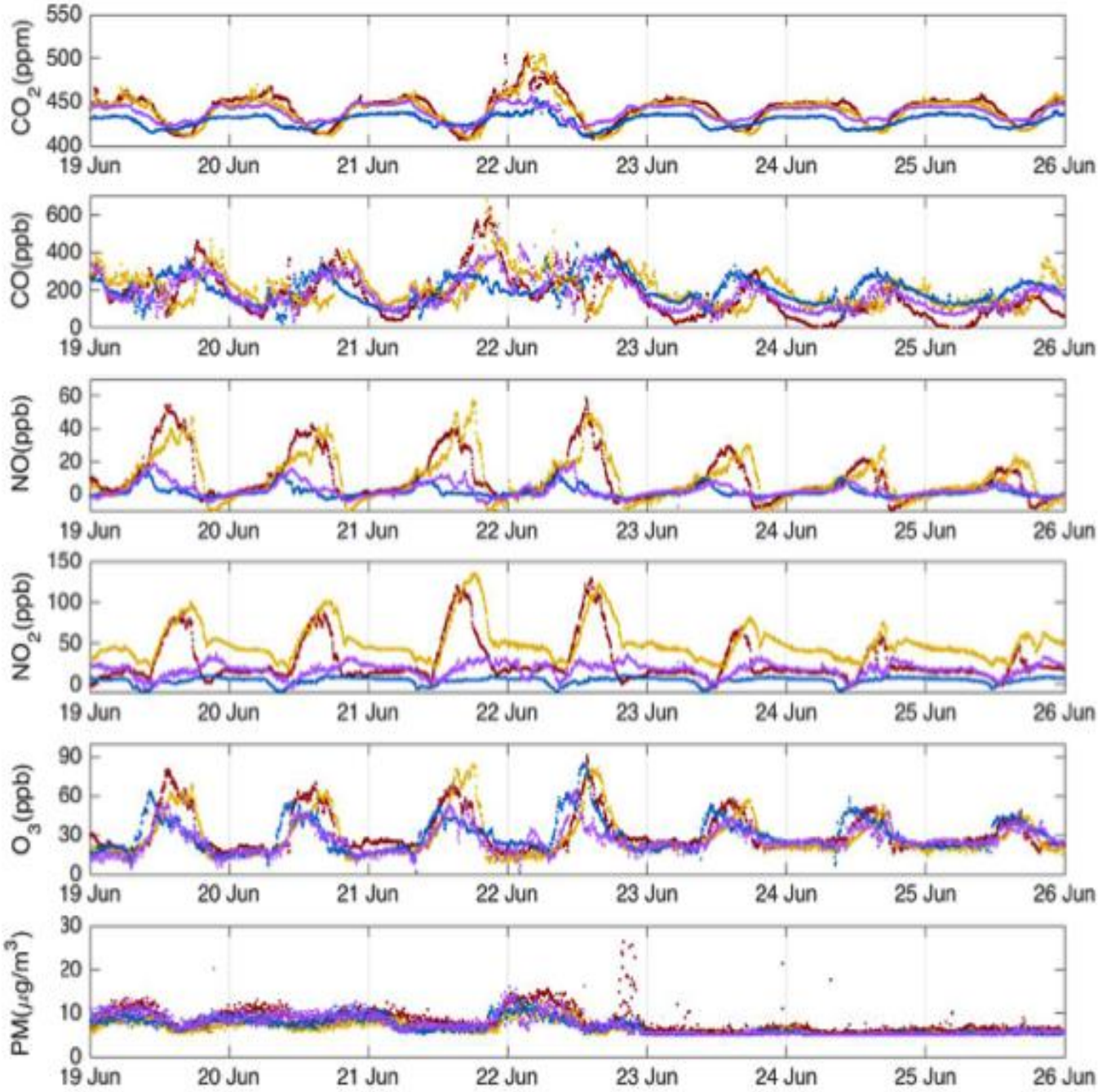
0.6% CO/CO_2

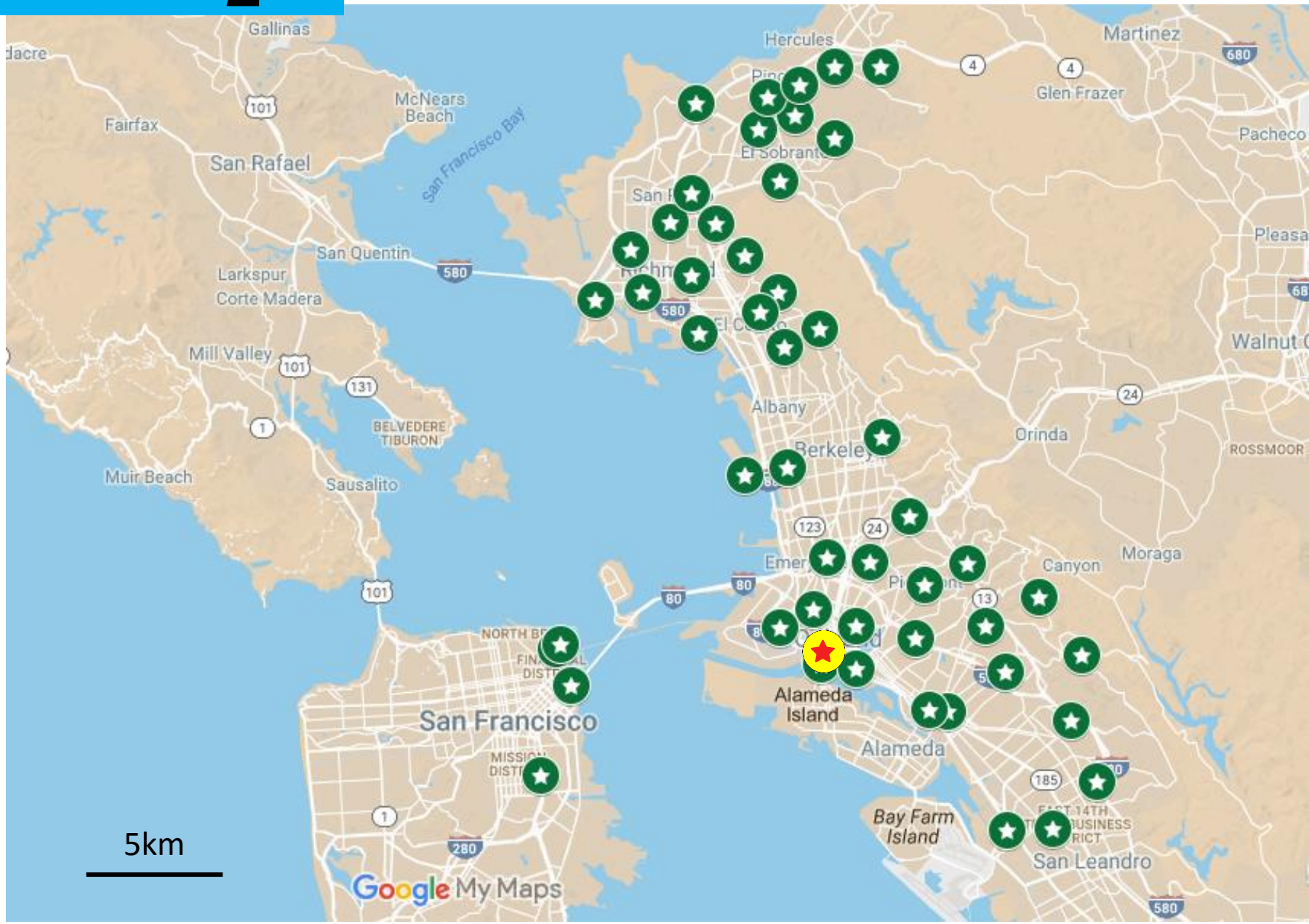


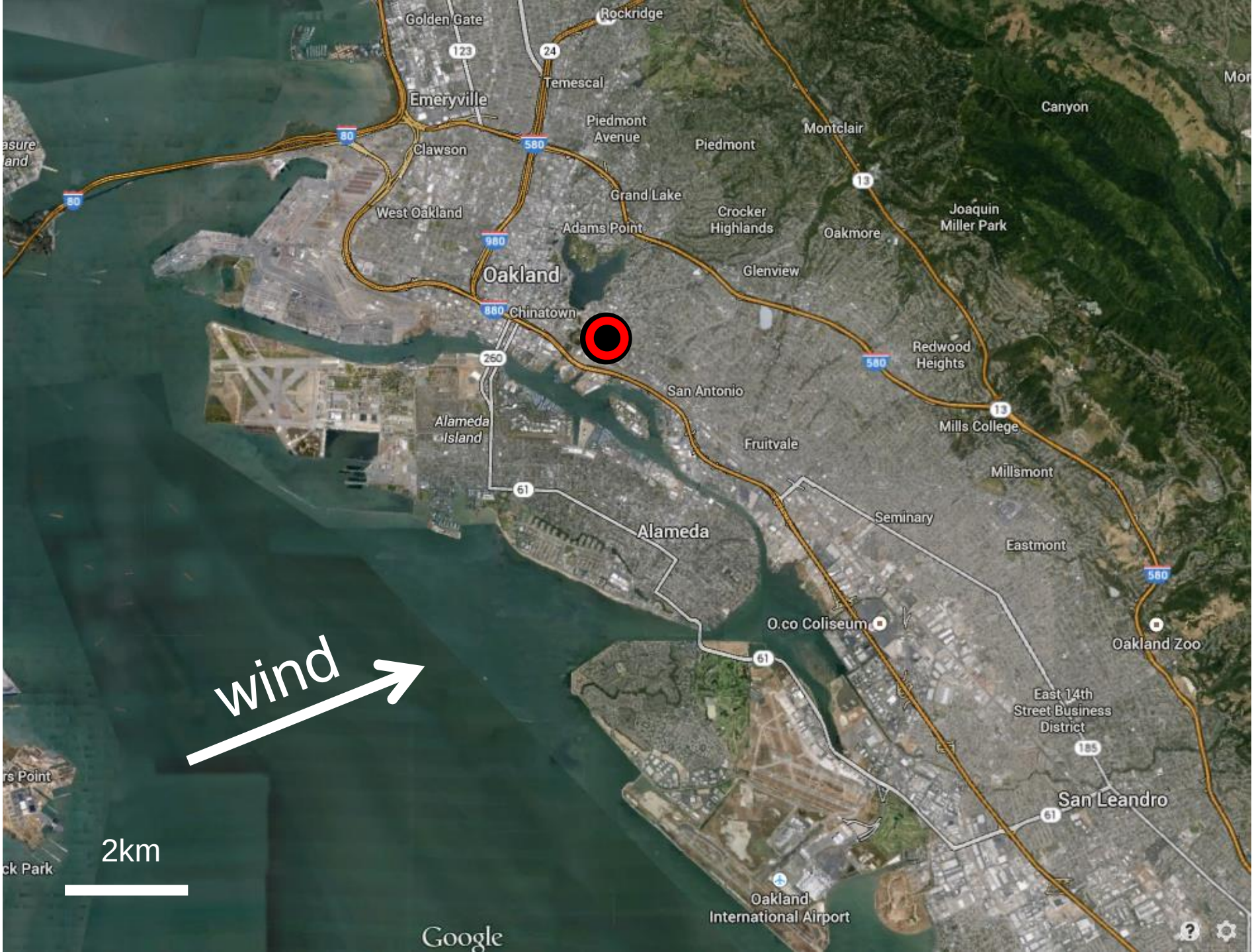

(a)
NO(ppb)
BEACON
BAAQMD
03/01 00:00
03/02 00:00
03/03 00:00
03/04 00:00
03/05 00:00
03/06 00:00
03/07 00:00
03/08 00:00
BEACON(ppb)
BAAQMD(ppb)
Frequency
BEACON-BAAQMD(ppb)



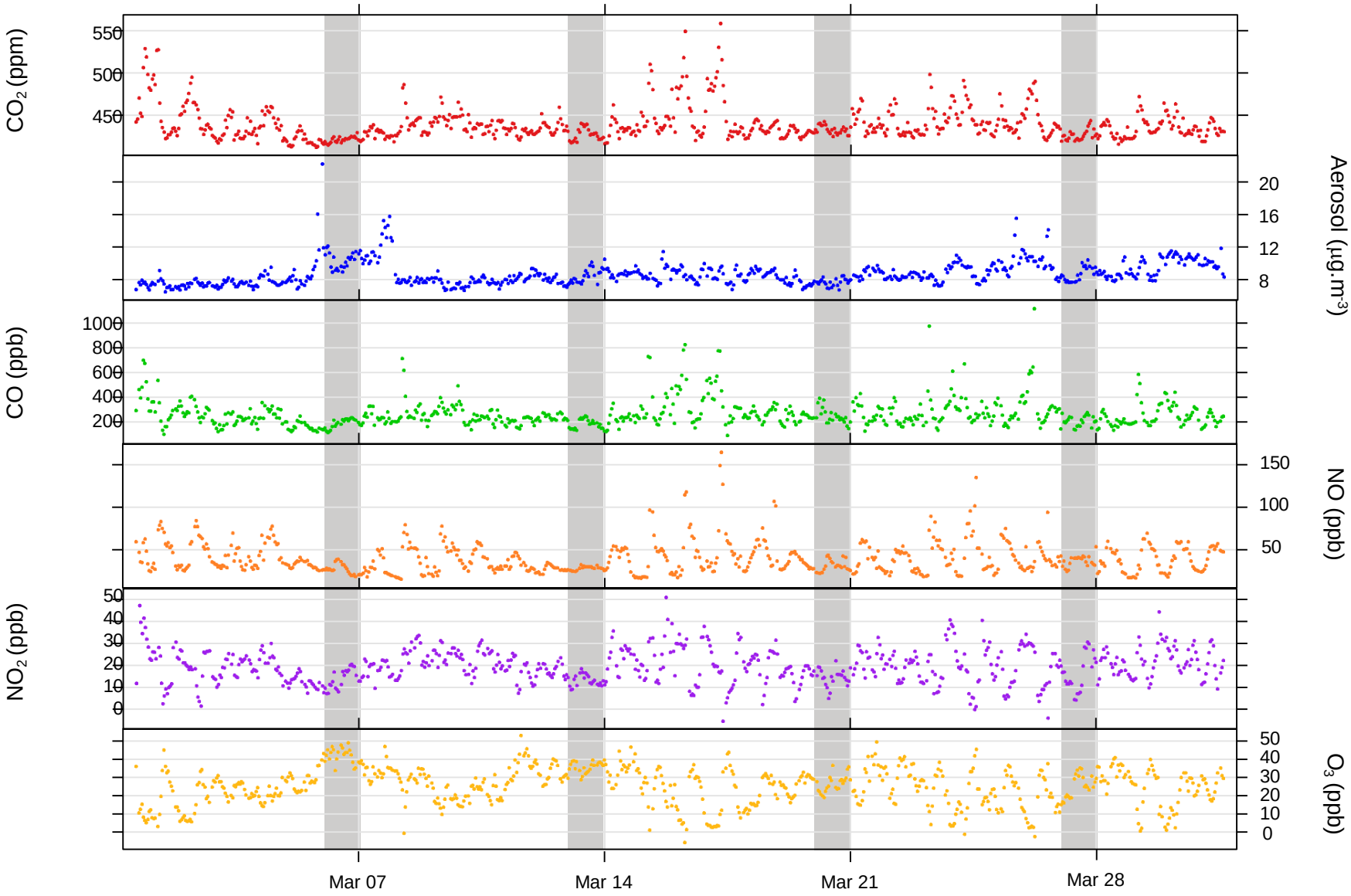
4 sites in Richmond and nearby cities

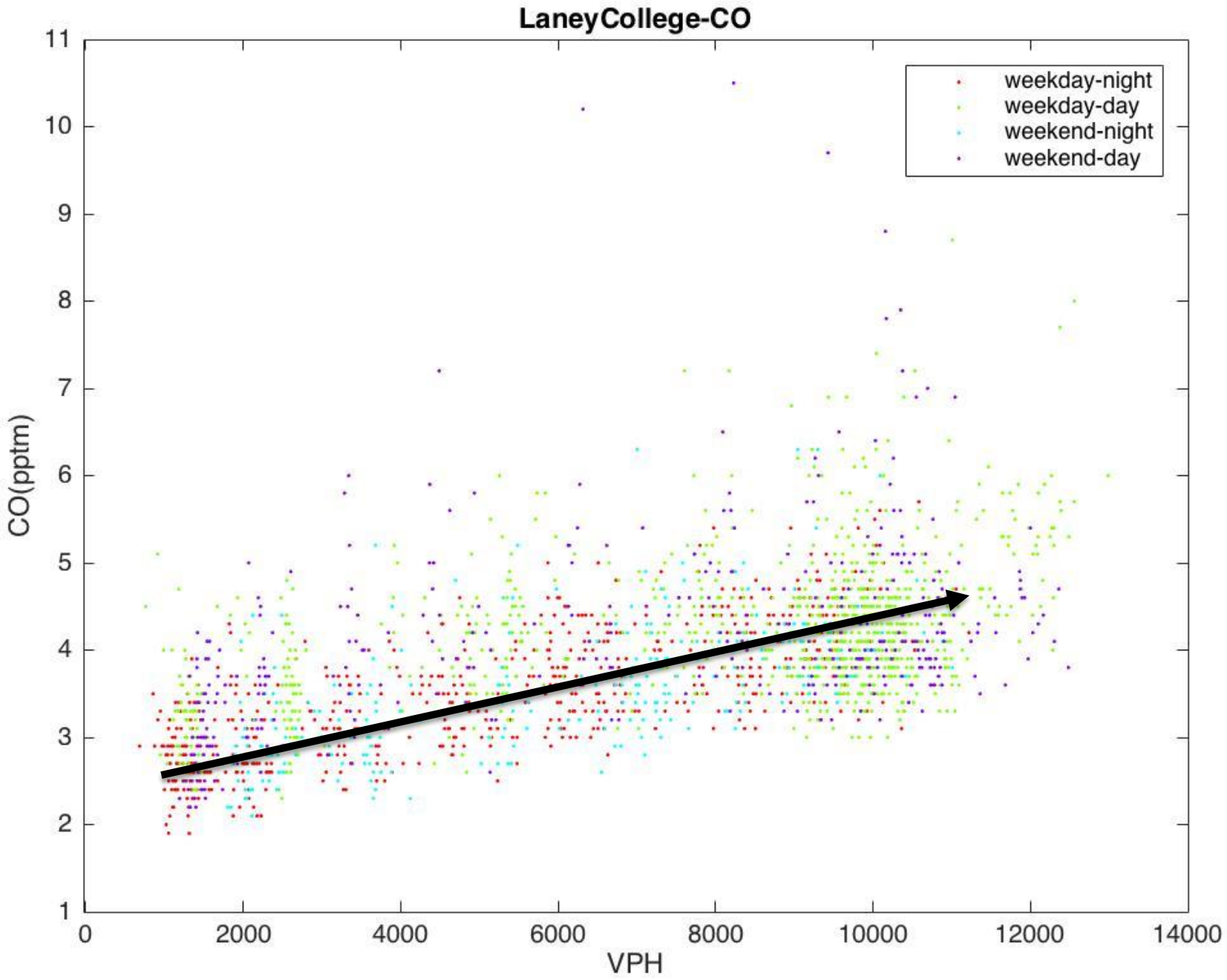
BEACO$_2$N


Gallinas
Fairfax
San Rafael
McNears Beach
San Francisco Bay
San Quentin
Larkspur
Corte Madera
Mill Valley
BELVEDERE
TIBURON
Muir Beach
Sausalito
Hercules
Martinez
Glen Frazer
Pacheco
El Sobrante
Pleasa
Walnut
Albany
Berkeley
Orinda
ROSSMOOR
Moraga
Canyon
Alameda Island
Alameda
Bay Farm Island
San Leandro
San Francisco
NORTH
MISSION
5km
Google My Maps

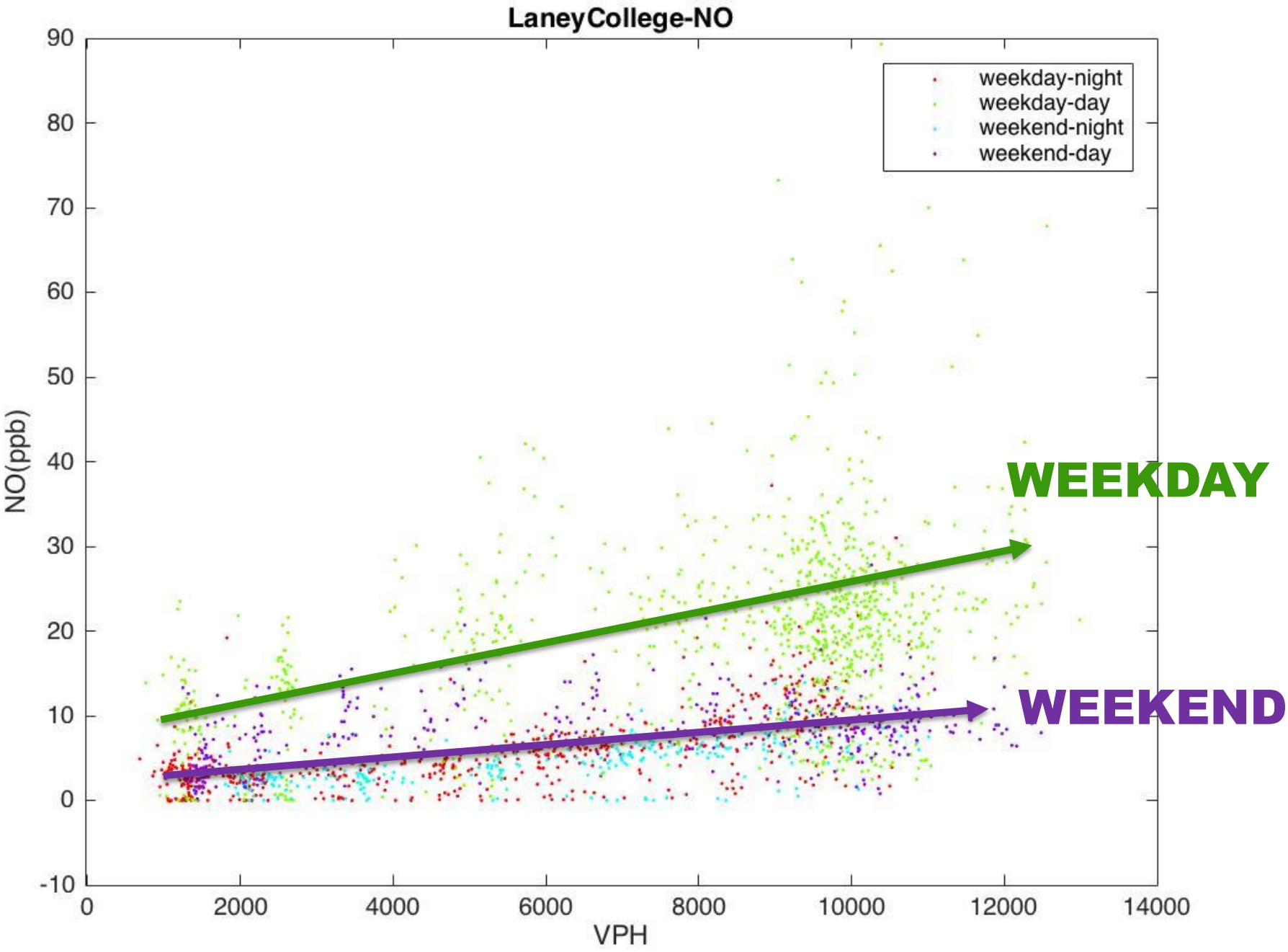

Golden Gate
Rockridge
Temescal
Emeryville
Piedmont Avenue
Piedmont
Montclair
Canyon
Clawson
Grand Lake
West Oakland
Adams Point
Crocker Highlands
Oakmore
Joaquin Miller Park
Oakland
Glenview
Chinatown
Redwood Heights
San Antonio
Alameda Island
Mills College
Fruitvale
Millsmont
Seminary
Alameda
Eastmont
O.co Coliseum
Oakland Zoo
East 14th Street Business District
San Leandro
Oakland International Airport
wind
2km
Google

One site, not far from highway - March 2016

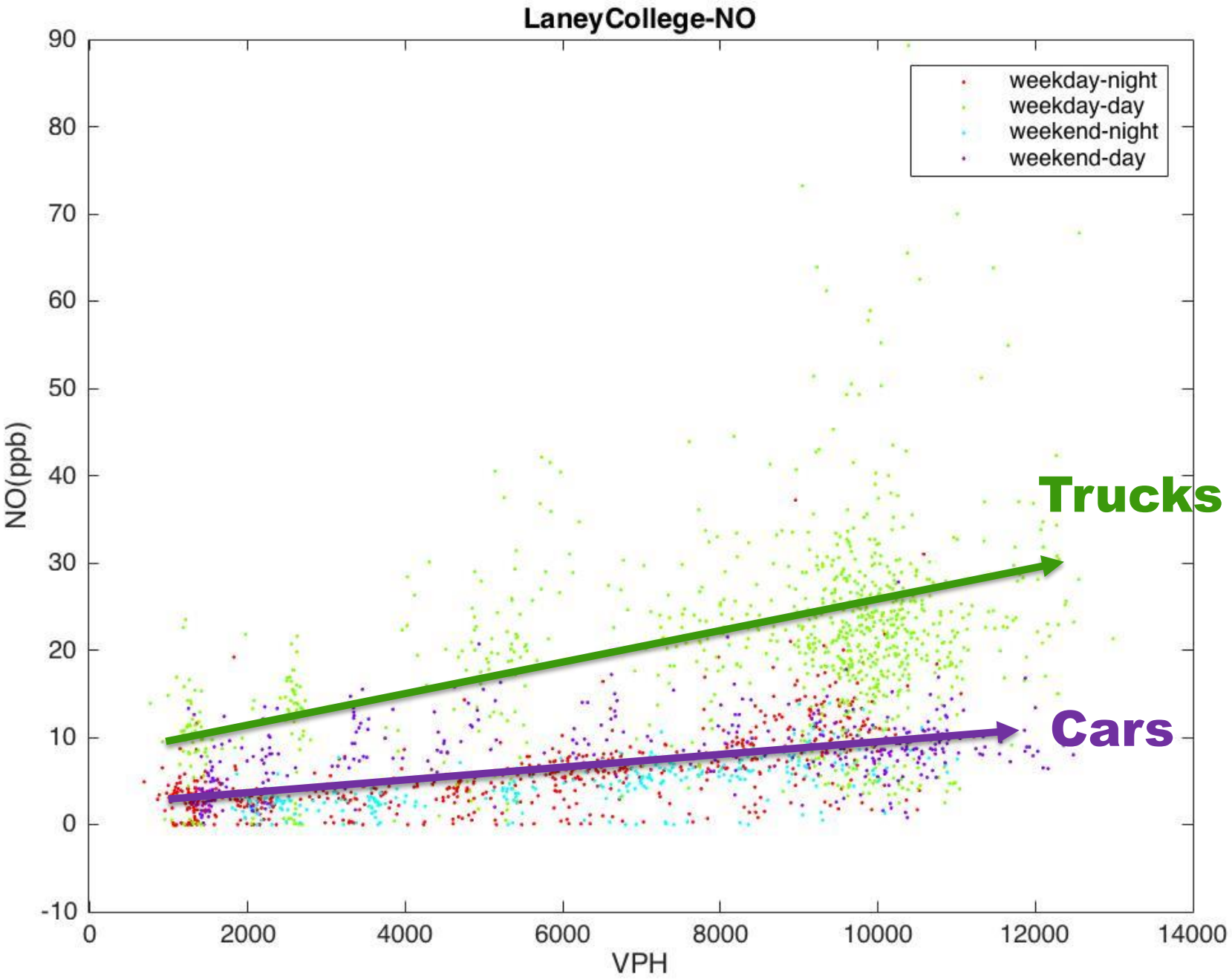




Vehicle # per hour

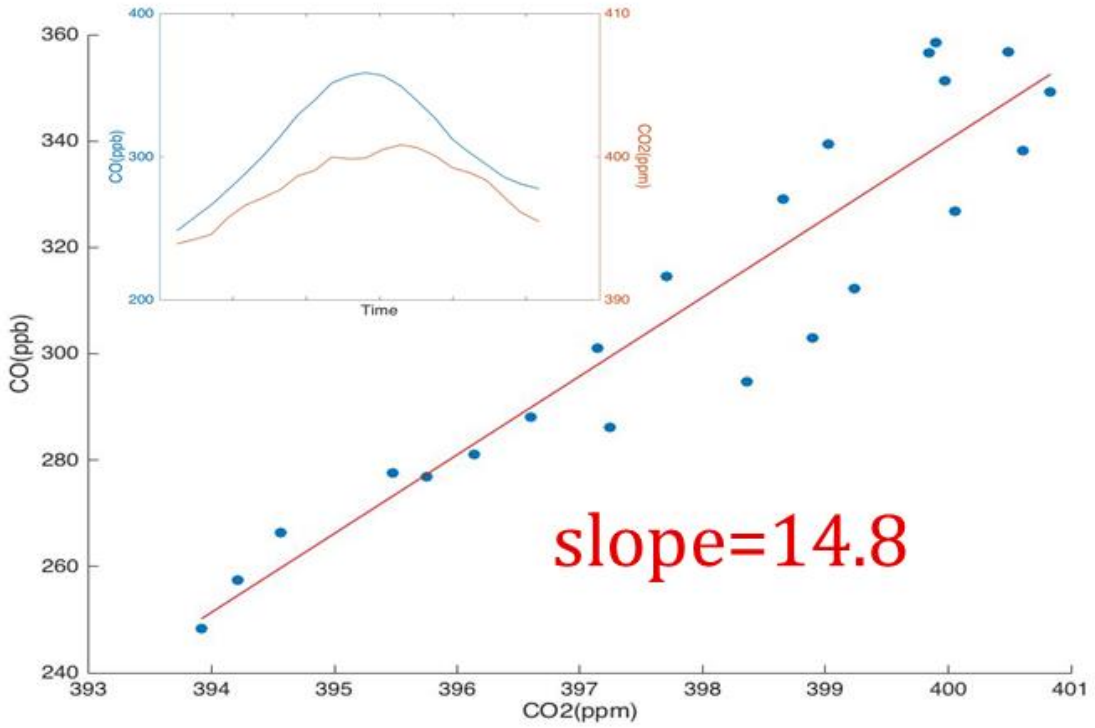


Vehicle # per hour

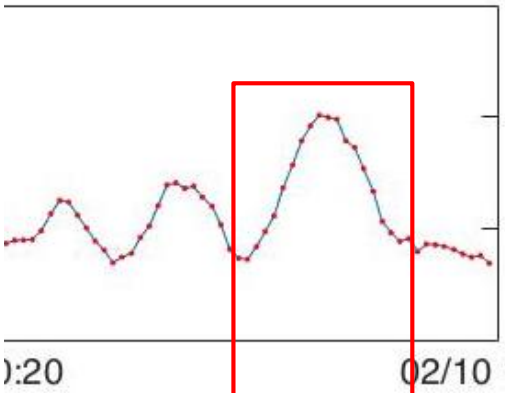


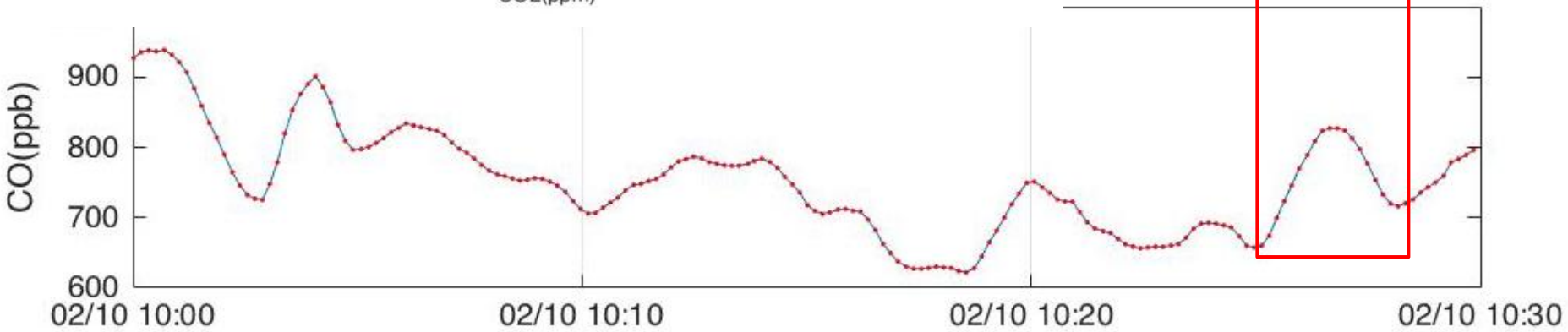
Vehicle # per hour

Analyze every plume

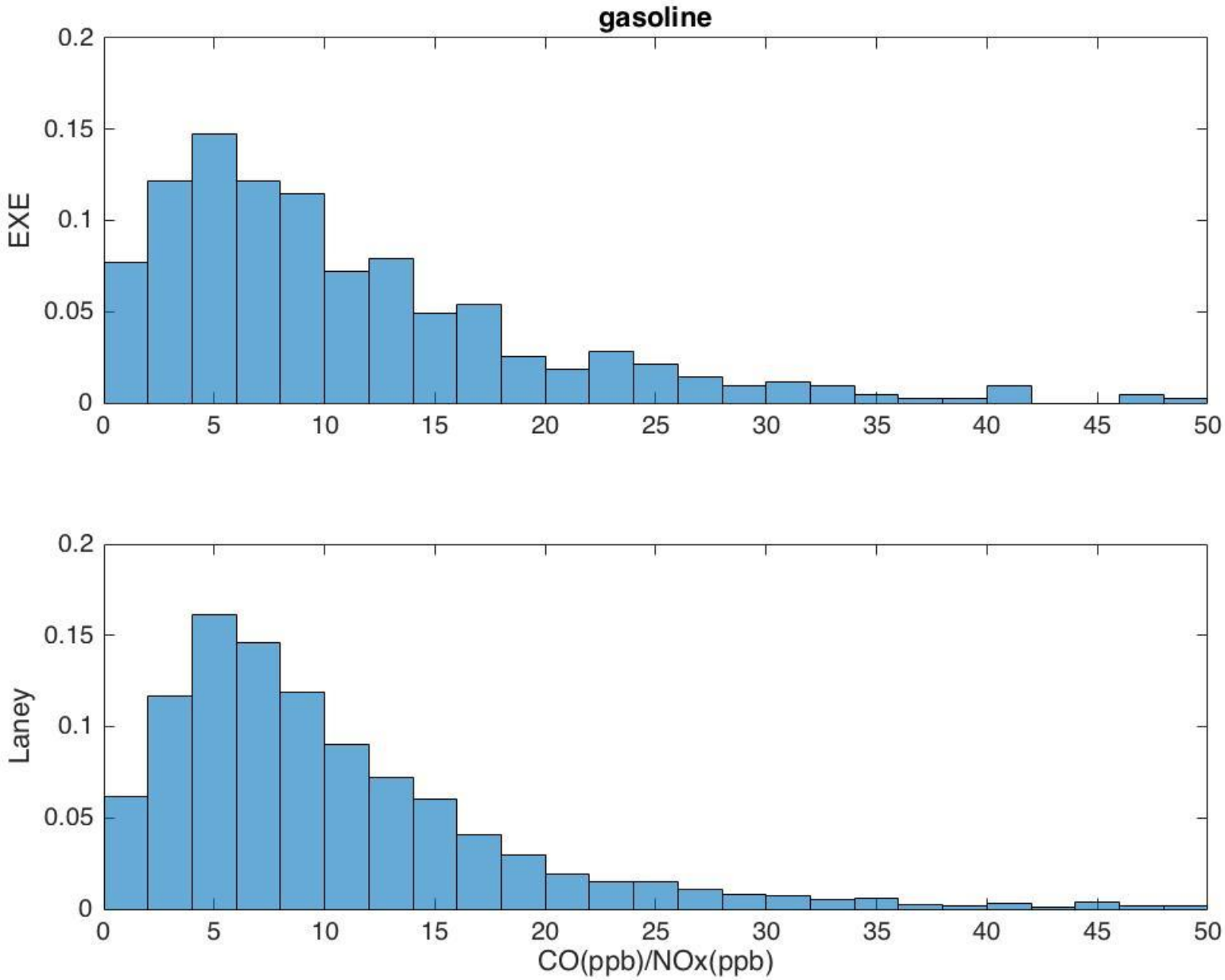


near highway

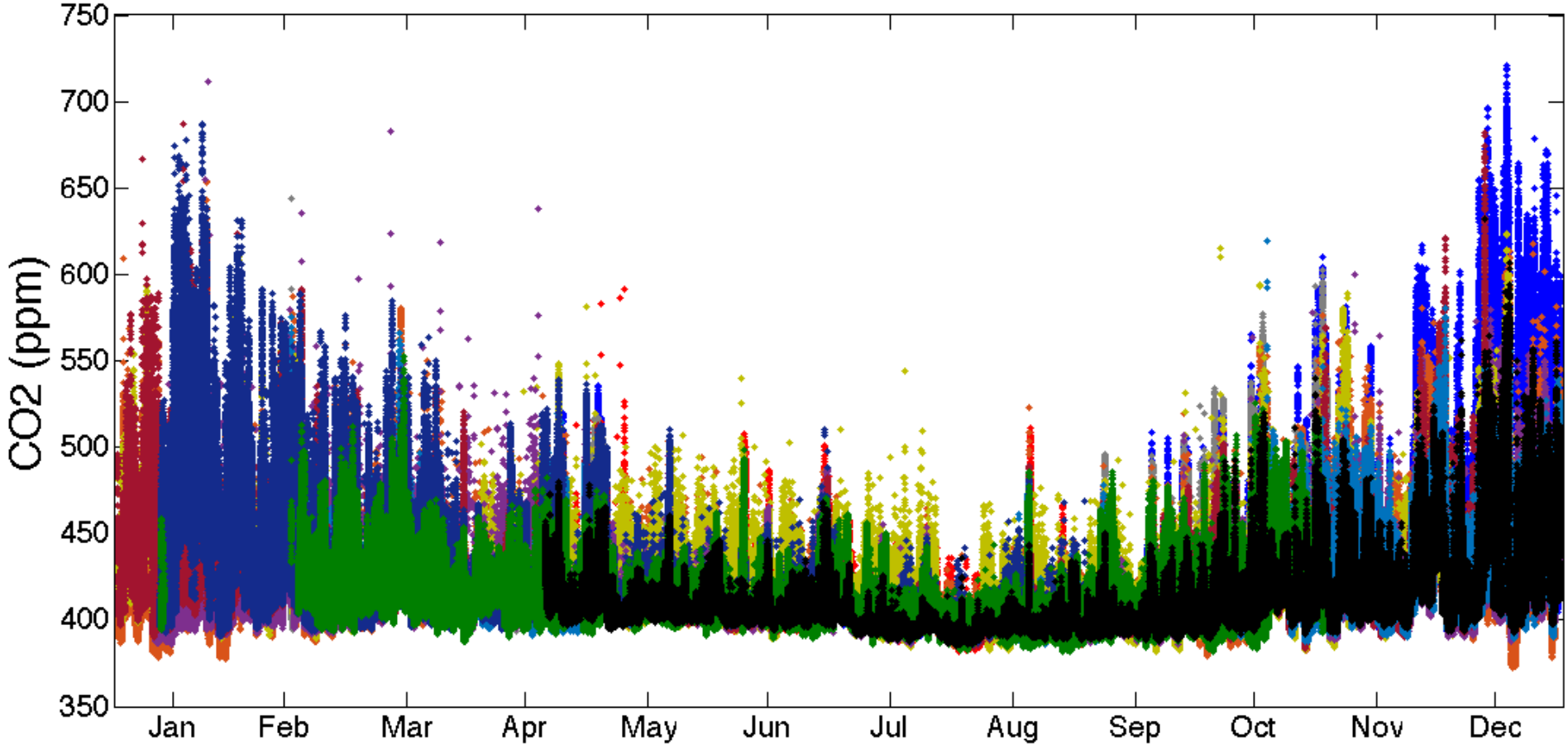




Emission Factors are similar in different locations



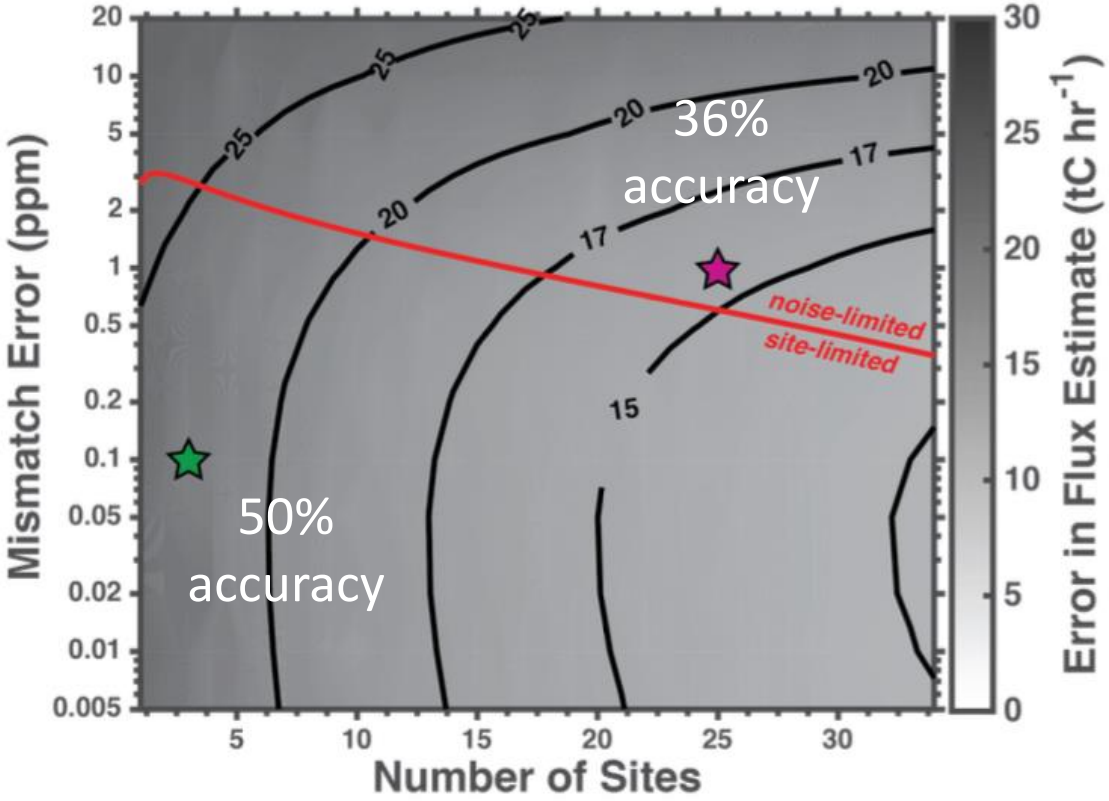
BEACO$_2$N CO$_2$ 2013



Sites:

Burckhalter
Prescott
Laurel
Kaiser
CollegePrep
Korematsu
ODowd
StLiz
HeadRoyce
ElCerrito
NOakland

Quality vs. Quantity



★ Network of roughly BEACO$_2$N's size (25) & precision (1ppm)

★ Network of three much more precise instruments (0.1ppm)

Turner et al. ACP 2016

BEACO$_2$N: A high spatial resolution observing system for GHGs (CO_2) and air quality (CO, O_3, NO, NO_2, particles)

CO_2

A.A. Shusterman, V. Teige, A.J. Turner, C. Newman, J. Kim, and R.C. Cohen: T*he BErkeley Atmospheric CO_2 Observation Network: initial evaluation*, Atmos. Chem. Phys., doi:10.5194/acp-2016-530, 2016.

A.J. Turner, A.A. Shusterman, B.C. McDonald, V. Teige, R.A. Harley and R.C. Cohen, *Network design for quantifying urban CO_2 emissions: Assessing tradeoffs between precision and network density* Atmos. Chem. Phys. Disc., 2016.

AQ gases

J. Kim, and above team, In field calibration of CO, NO, NO_2, O_3, submitted manuscript

Aerosol

Kaitlyn Lieschke and above team

Conclusions and Outlook

High space and time resolution observations using networks with multiple chemicals and aerosol offer a new window into mechanisms affecting emissions and chemistry in cities.

Satellites will offer the same kinds of information with much more complete coverage.

Such networks are one way we will evaluate new space based geostationary sensors that have very small footprints