Dense networks and next generation satellites: Data for new approaches to understanding the atmosphere

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EPA Air Sensors 2018

Connecting Science to Policy

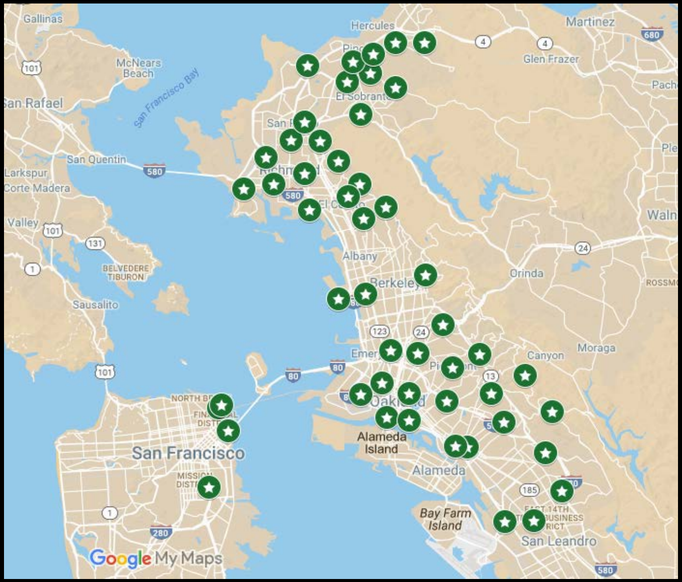
Can observations provide better tools for epidemiology? And individual health?

How can observations directly evaluate the efficacy of emissions policies? On relevant timescales?

New dense observing systems coupled to similarly high resolution inverse and assimilation models are changing how we approach these questions.

Instead of extrapolating from points we are building maps and making movies.

Remote sensing
NO_2, CO, CO_2, ...

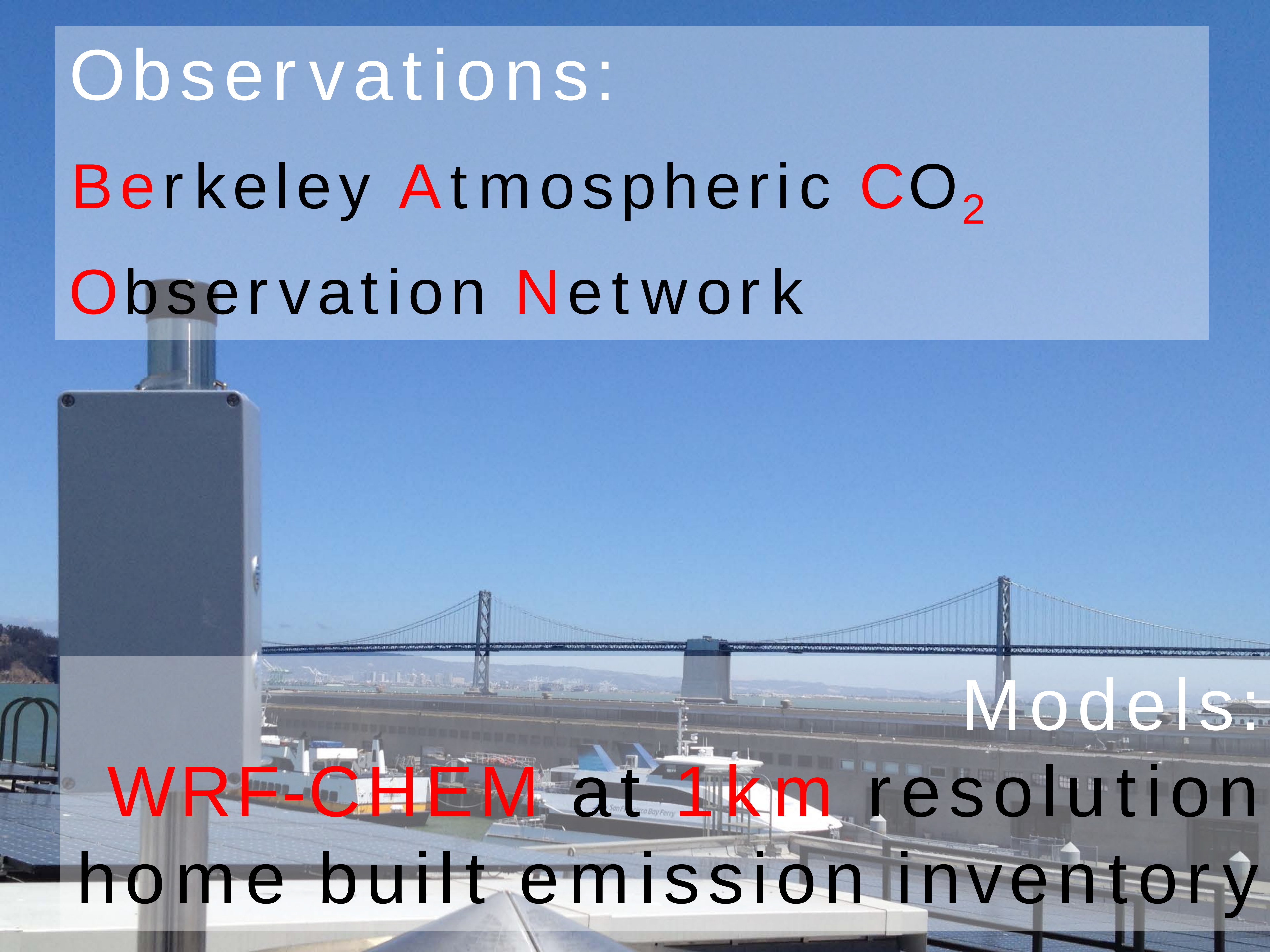


Ubiquitous sensing
CO_2, NO_2, O_3, ...

New questions that are hard (impossible?) to answer with the current suite of instruments—but would be possible with dense networks.

Is cold start the dominant source of NO_x; if so what changes in spatial pattern have occurred are occurring?

Are emissions of household organics competitive with emissions from vehicles as source of urban reactive carbon? (Mcdonald et al. Science 2018)



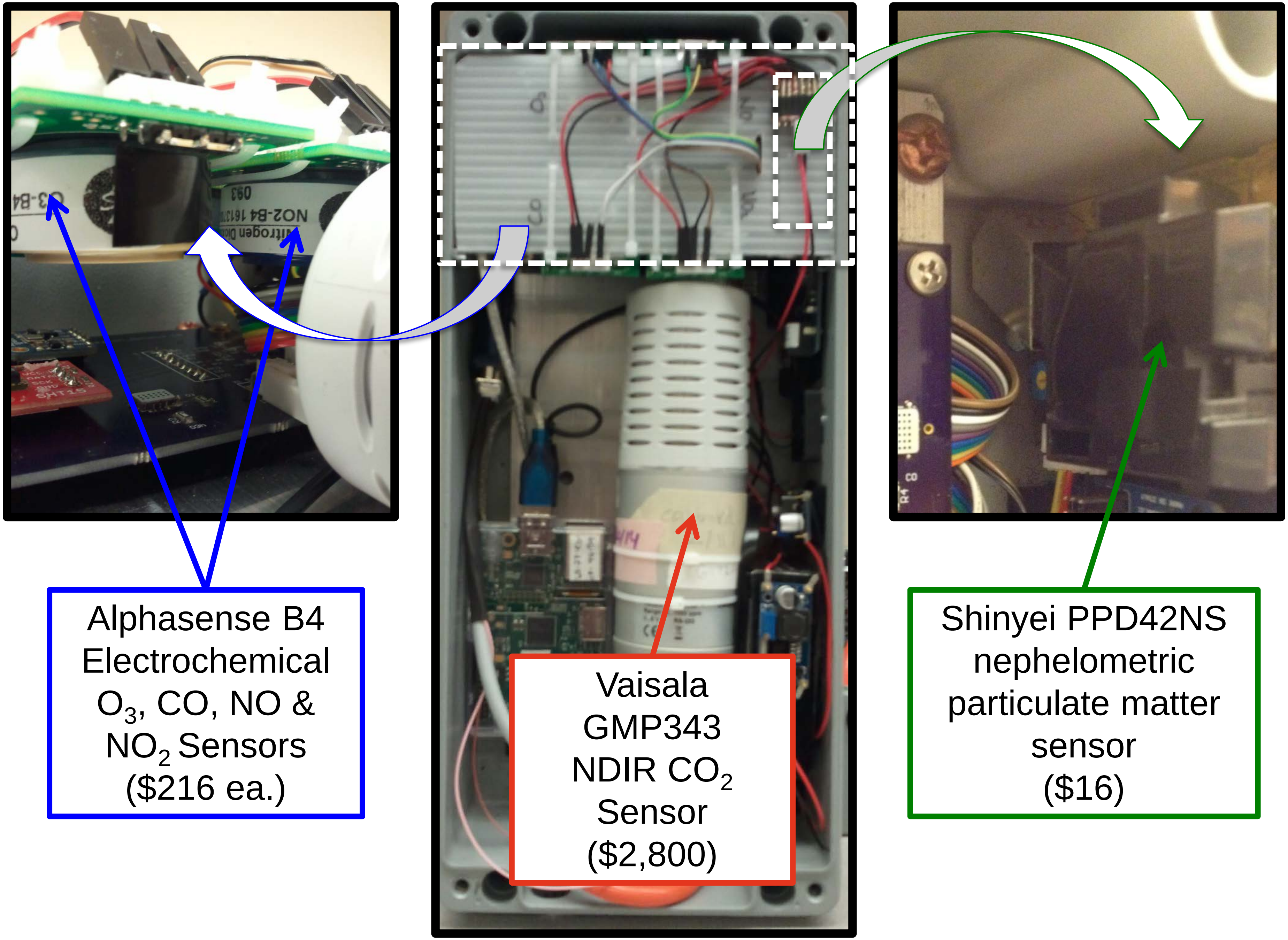
Observations:

Berkeley Atmospheric CO_2 Observation Network

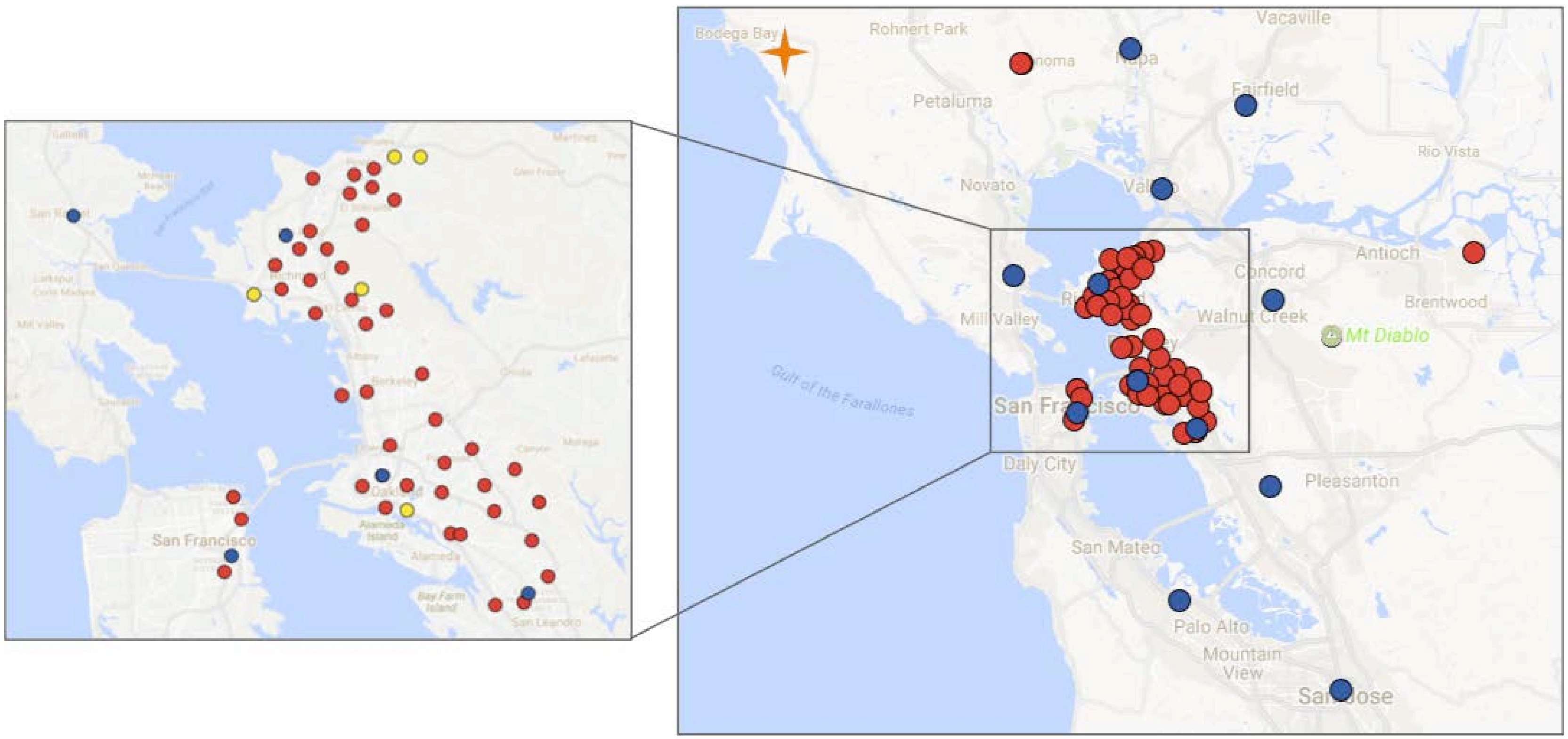
Models:

WRF-CHEM at 1km resolution

home built emission inventory

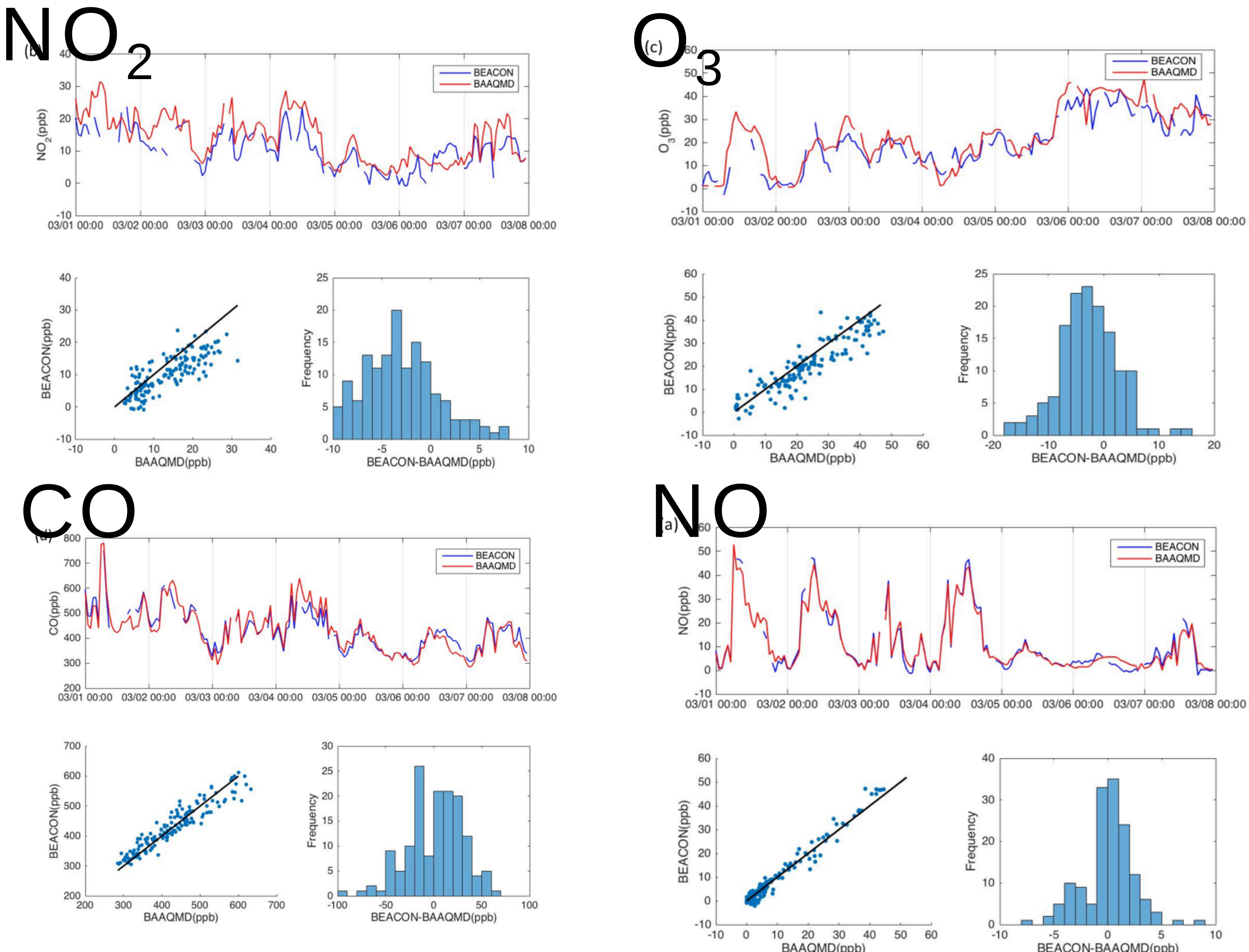

Alphasense B4 Electrochemical O_3, CO, NO & NO_2 Sensors ($216 ea.)
Vaisala GMP343 NDIR CO_2 Sensor ($2,800)
Shinyei PPD42NS nephelometric particulate matter sensor ($16)

Red and Yellow BEACO$_2$N. Blue BAAQMD

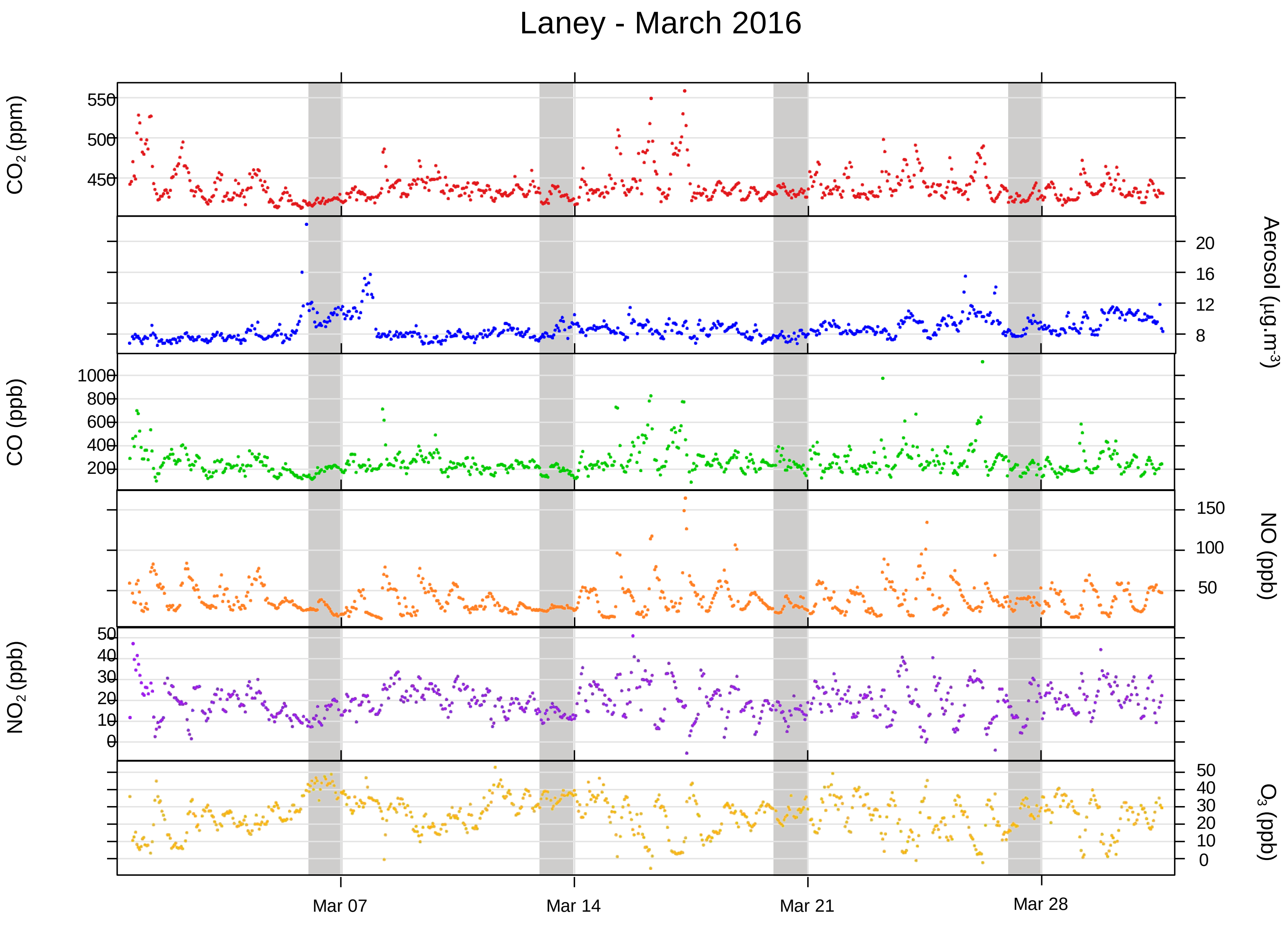


BEACO$_2$N

65 nodes in SF Bay Area
18 nodes Houston, TX
8 nodes NYC

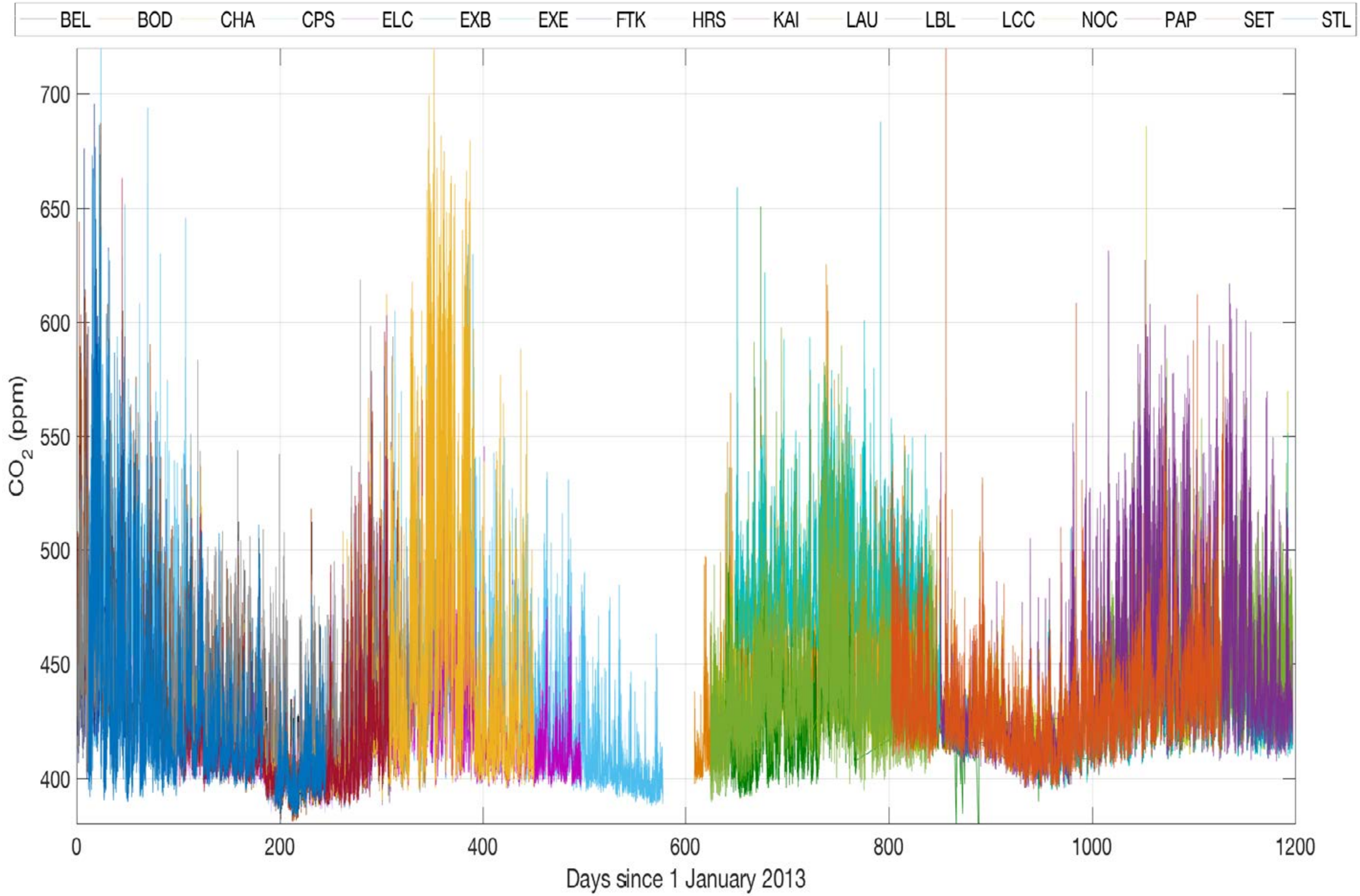


Blue $BEACO_2N$ Red Independent



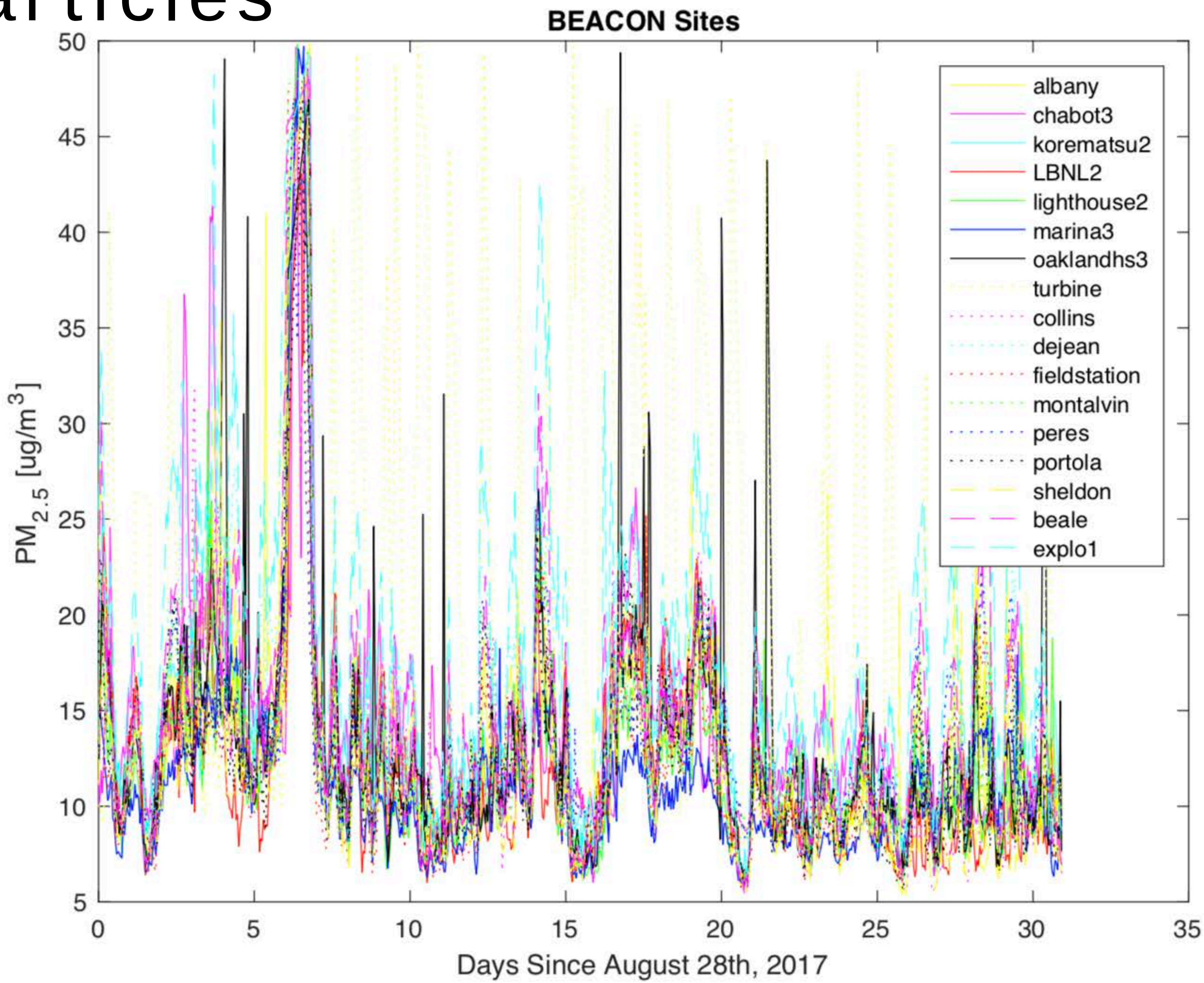
Laney - March 2016
CO2 (ppm)
550
500
450
Aerosol (µg.m-3)
20
16
12
8
CO (ppb)
1000
800
600
400
200
NO (ppb)
150
100
50
NO2 (ppb)
50
40
30
20
10
0
O3 (ppb)
50
40
30
20
10
0
Mar 07
Mar 14
Mar 21
Mar 28

CO_2



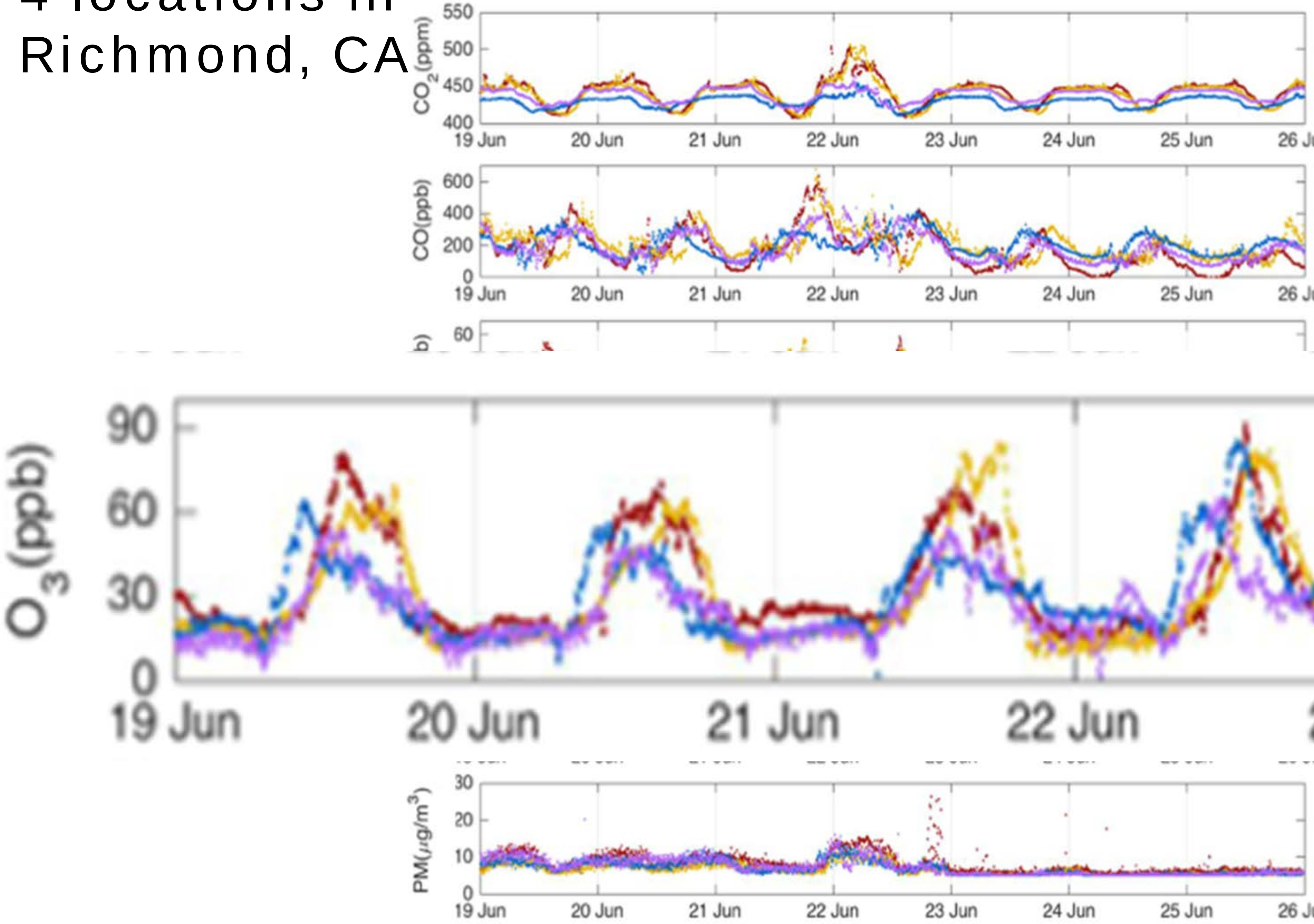
BEL
BOD
CHA
CPS
ELC
EXB
EXE
FTK
HRS
KAI
LAU
LBL
LCC
NOC
PAP
SET
STL
700
650
600
550
500
450
400
CO2 (ppm)
0
200
400
600
800
1000
1200
Days since 1 January 2013

Particles



BEACON Sites
PM2.5 [ug/m3]
Days Since August 28th, 2017
50
45
40
35
30
25
20
15
10
5
0
5
10
15
20
25
30
35
albany
chabot3
korematsu2
LBNL2
lighthouse2
marina3
oaklandhs3
turbine
collins
dejean
fieldstation
montalvin
peres
portola
sheldon
beale
explo1

4 locations in Richmond, CA



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., 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., 2016.

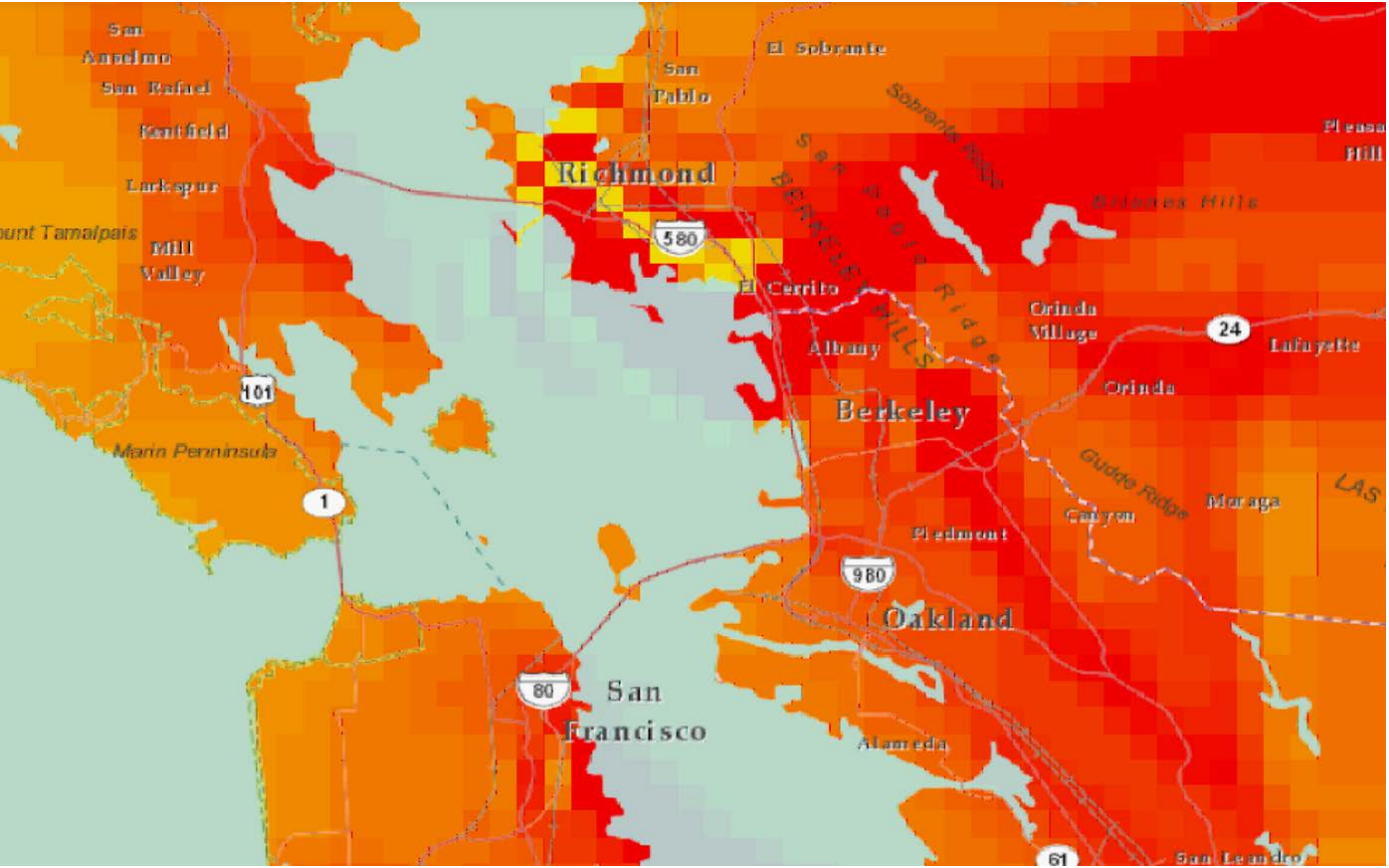
A.A. Shusterman, J. Kim, K.J. Lieschke, C. Newman, P.J. Wooldridge, R.C. Cohen, *Observing local CO_2 sources using low-cost, near-surface urban monitors*, Atmos. Chem. Phys. Disc. 2018.

AQ gases

J. Kim, A.A. Shusterman, K.J. Lieschke, C. Newman, and R.C. Cohen, The BErkeley Atmospheric CO_2 Observation Network: field calibration and evaluation of low-cost air quality sensors, Atmos. Meas. Tech., 2018.

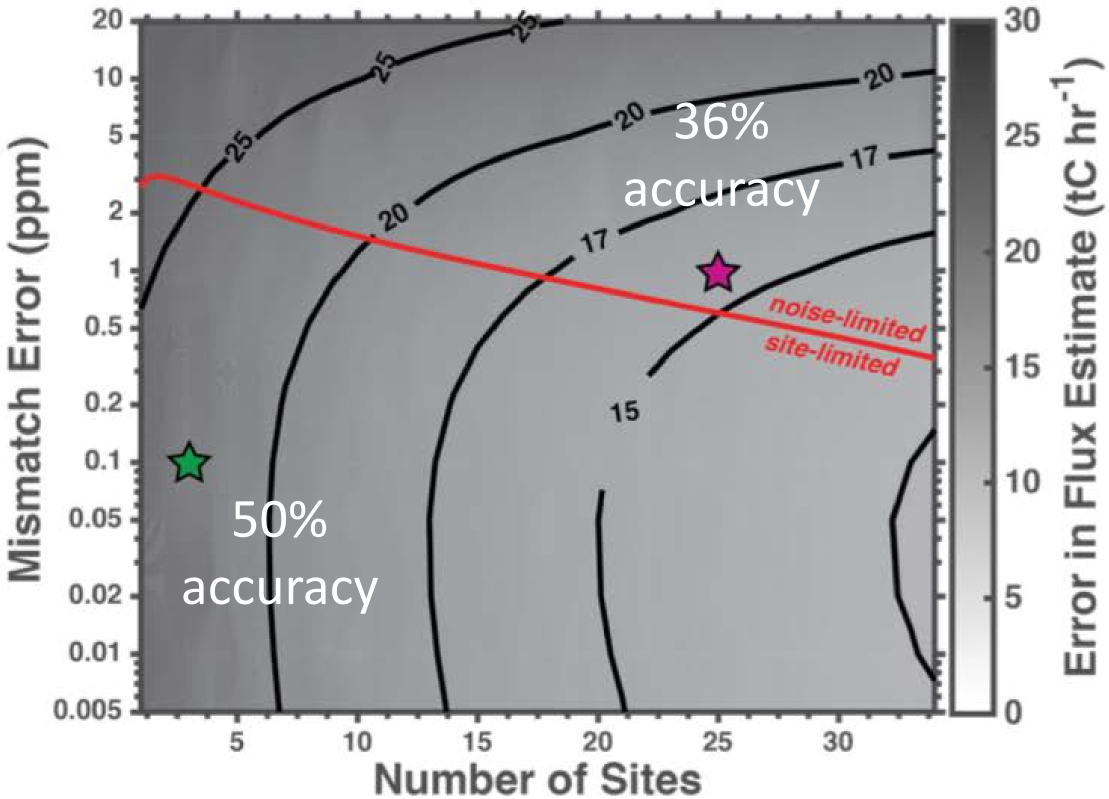
Aerosol

1 frame from a 1km CO_2 movie



Observations aim to test this or other model

Networks are better



Large numbers of low cost instruments (★) will out perform a few state-of-the-art high cost ones (★) for quantifying emissions within a city.

Turner et al. ACP 2016.

Issues we need to think about:

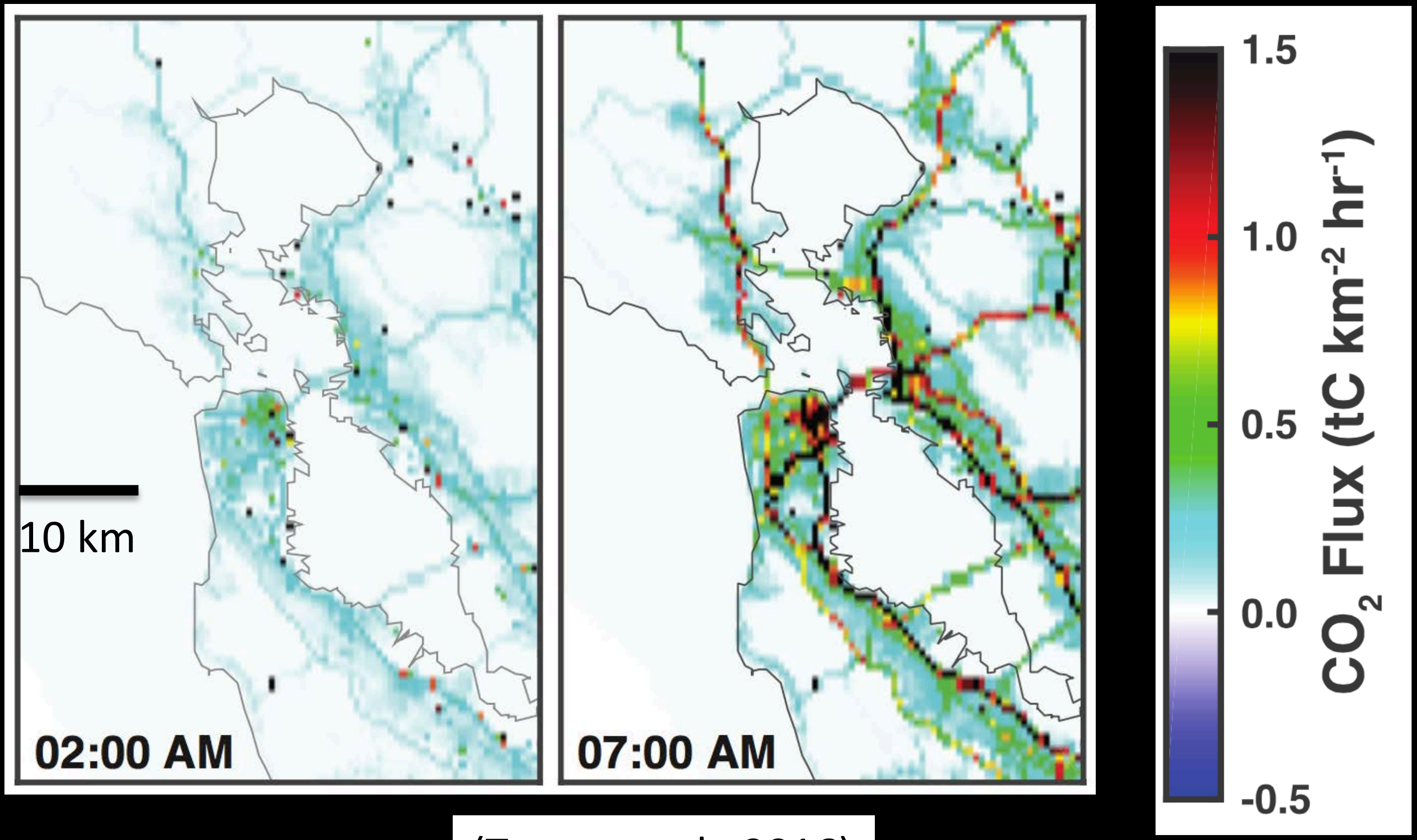
1-Calibrate and performance of a network, not single devices

2-Calibration and performance of a networked system of multispecies and multi-instrument (including surface and satellite) measurements not just one chemical at a time

3-Inverse and assimilation models coupled to observations

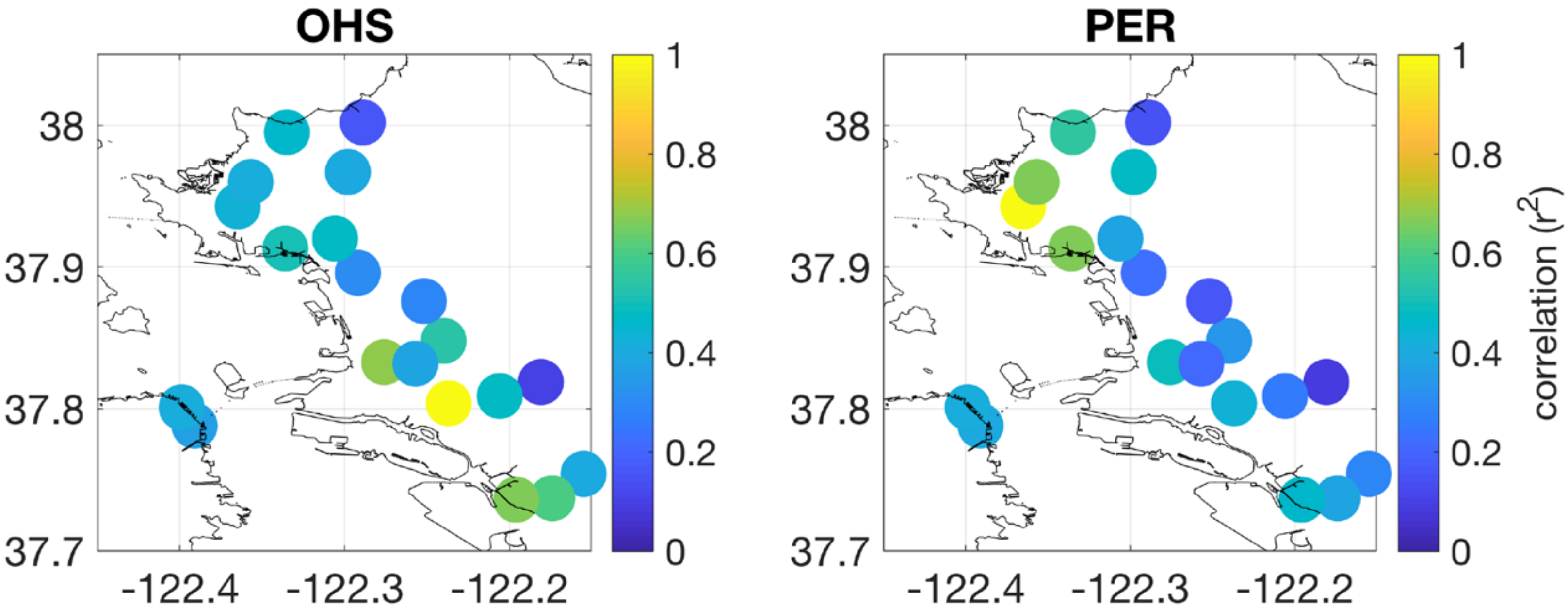
What is the accuracy/precision of a map? Does it go as √n of the number of measurements?

Emission Inventory

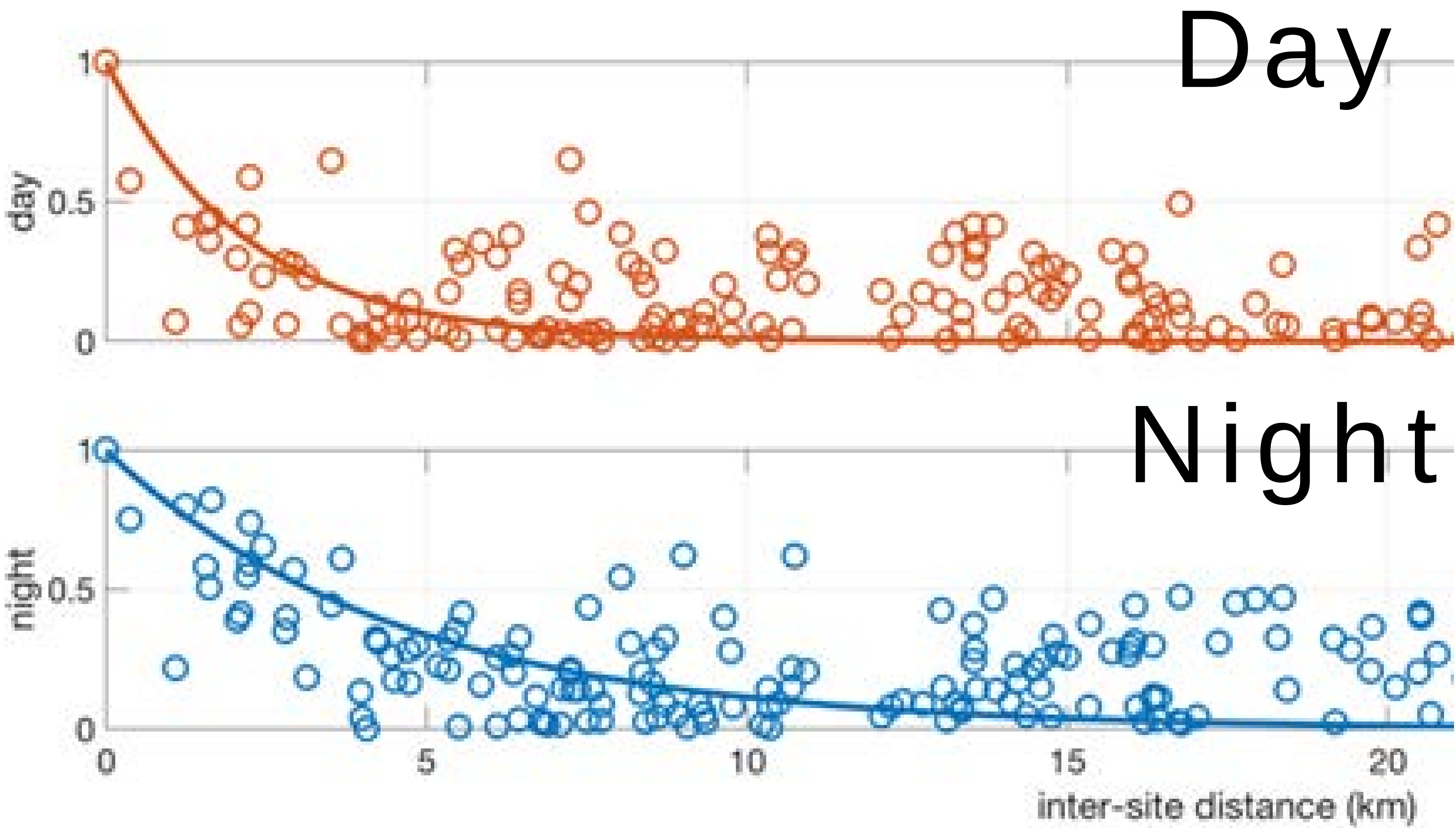


(Turner et al., 2016)

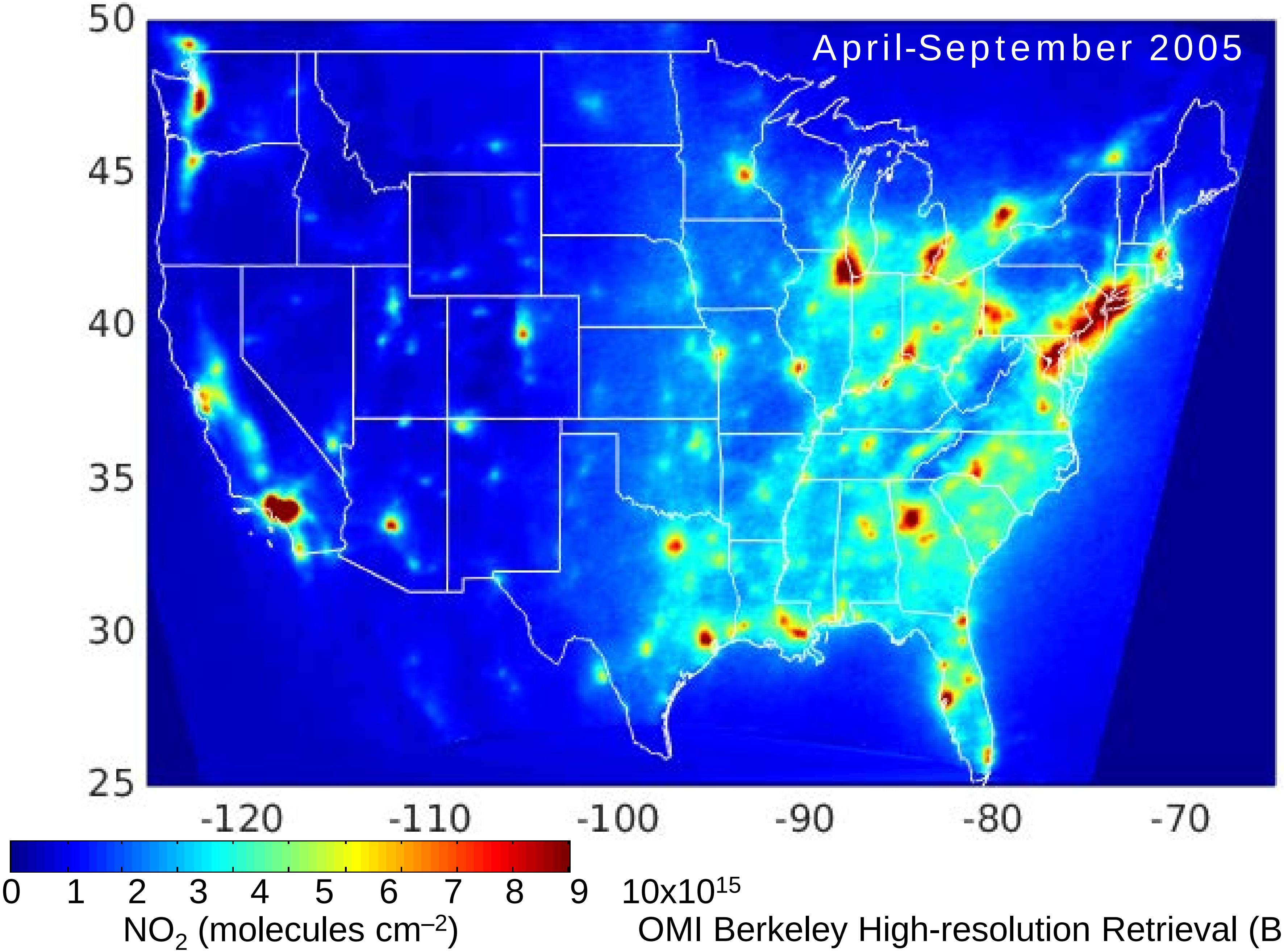
CO_2 correlation length scale



CO_2 correlation length scale

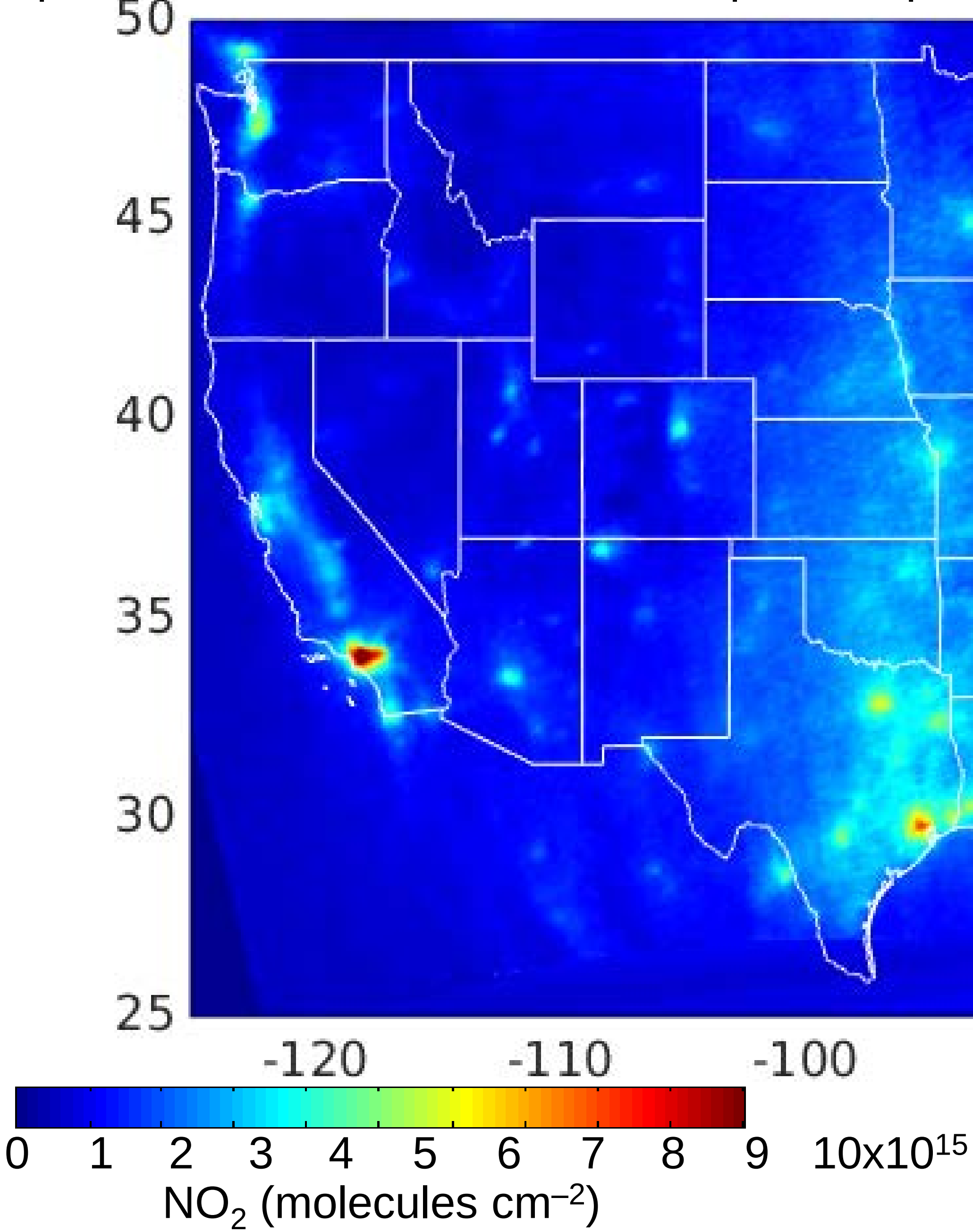


A multicomponent observing system



OMI Berkeley High-resolution Retrieval (BEHR)

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



http://behr.cchem.berkeley.edu/

Performance Standards

Precision and accuracy of individual instruments:

Independent of T and RH of sample and of the sensor location

Precision and accuracy should have Gaussian noise and improve with averaging over time and multiple sensors

Precision and accuracy of systems:

Information need not be at the individual sensor level—think weather; typically we care about a forecast that is a synthesis of billions of measurements

Cross sensitivities removed at system level

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.

Challenges:

- learning to interpret dense networks as more than the sum of individual instruments.
- integrating multiple different measurement approaches
- learning to think about daily variability in ways that teach us about processes and personal exposure.

Thank you!