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Direct space-based observations of anthropogenic CO_2 emission areas from OCO-2

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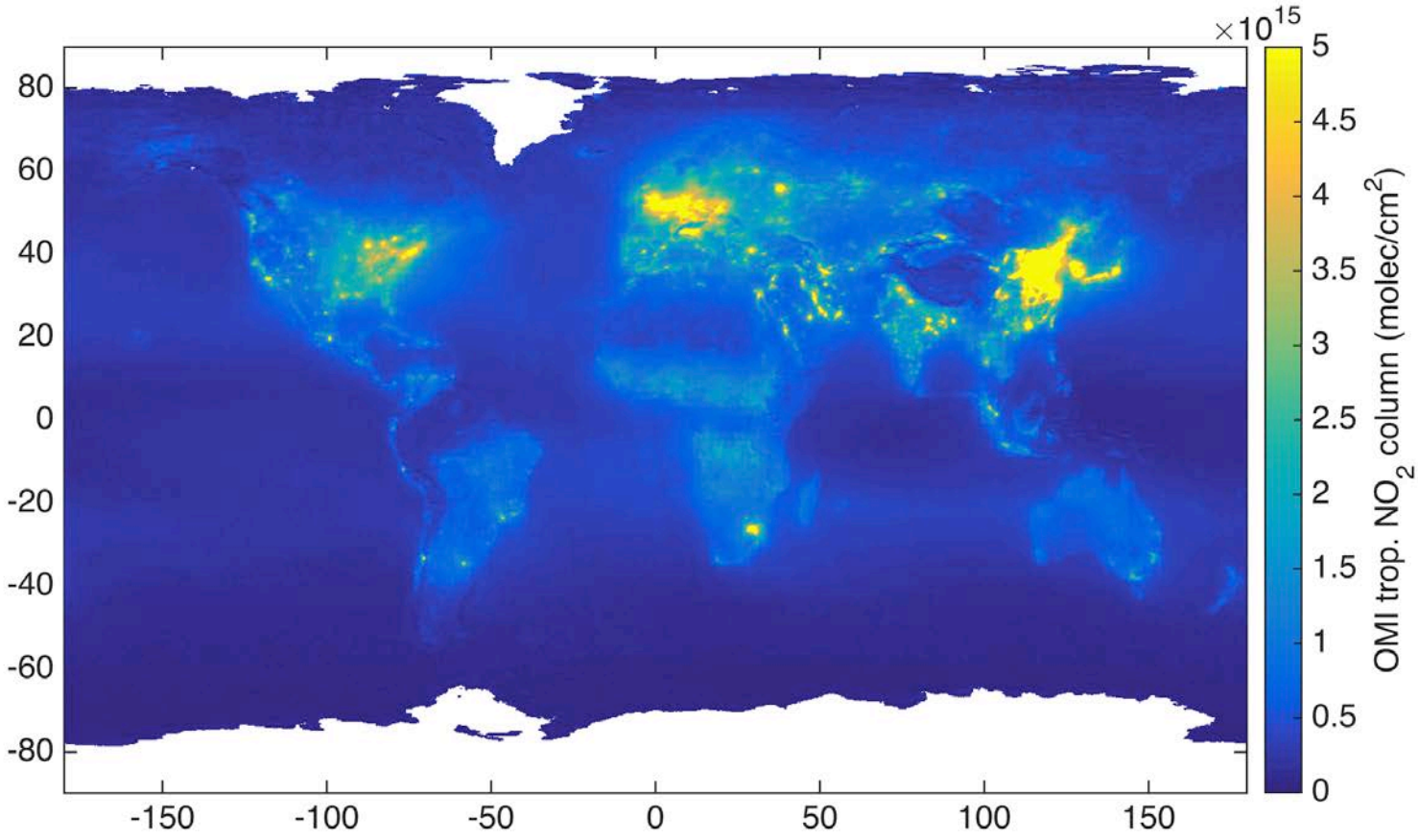
Nitrogen dioxide (NO_2) from space



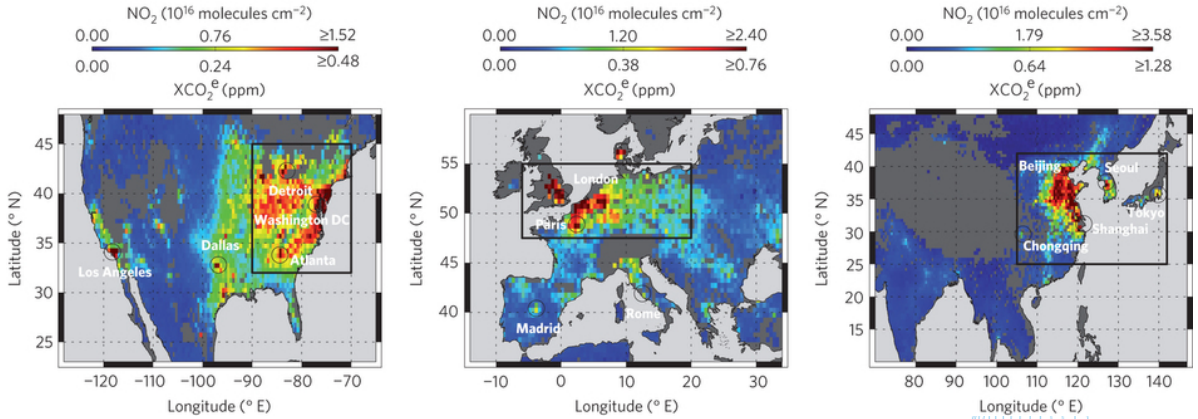
Since the past 20 years spaceborne measurements of air pollutants have revolutionized the way we monitor atmospheric composition, providing more and more accurate information on the pollution levels on global scale.

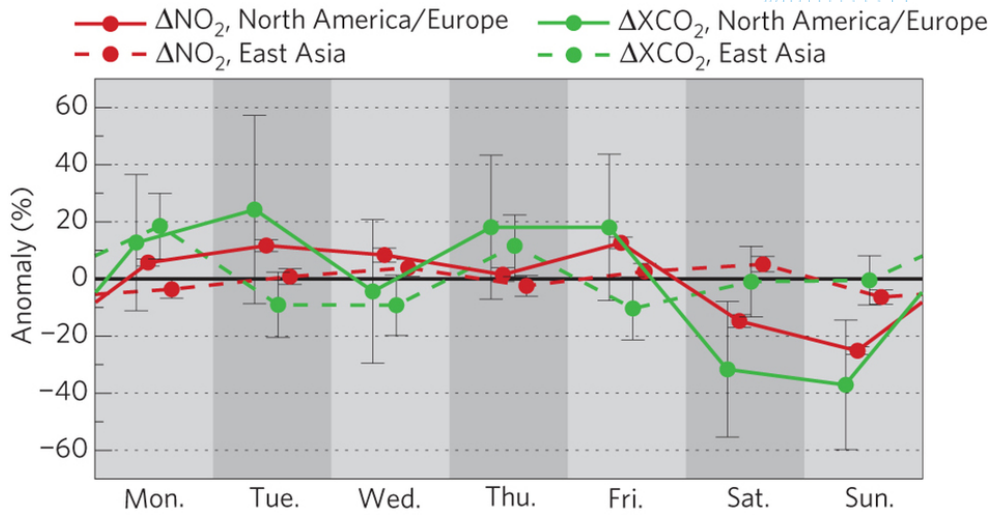
From NO_2 to CO_2

- In comparison to NO_2 and other short-lived air pollutants, trends, seasonality, long life-time and large atmospheric background significantly complicate the analysis of the anthropogenic CO_2 emissions

- NO_2 can be used as proxy for CO_2

- SCIAMACHY and GOSAT CO_2 observations have been used to analyze anthropogenic CO_2

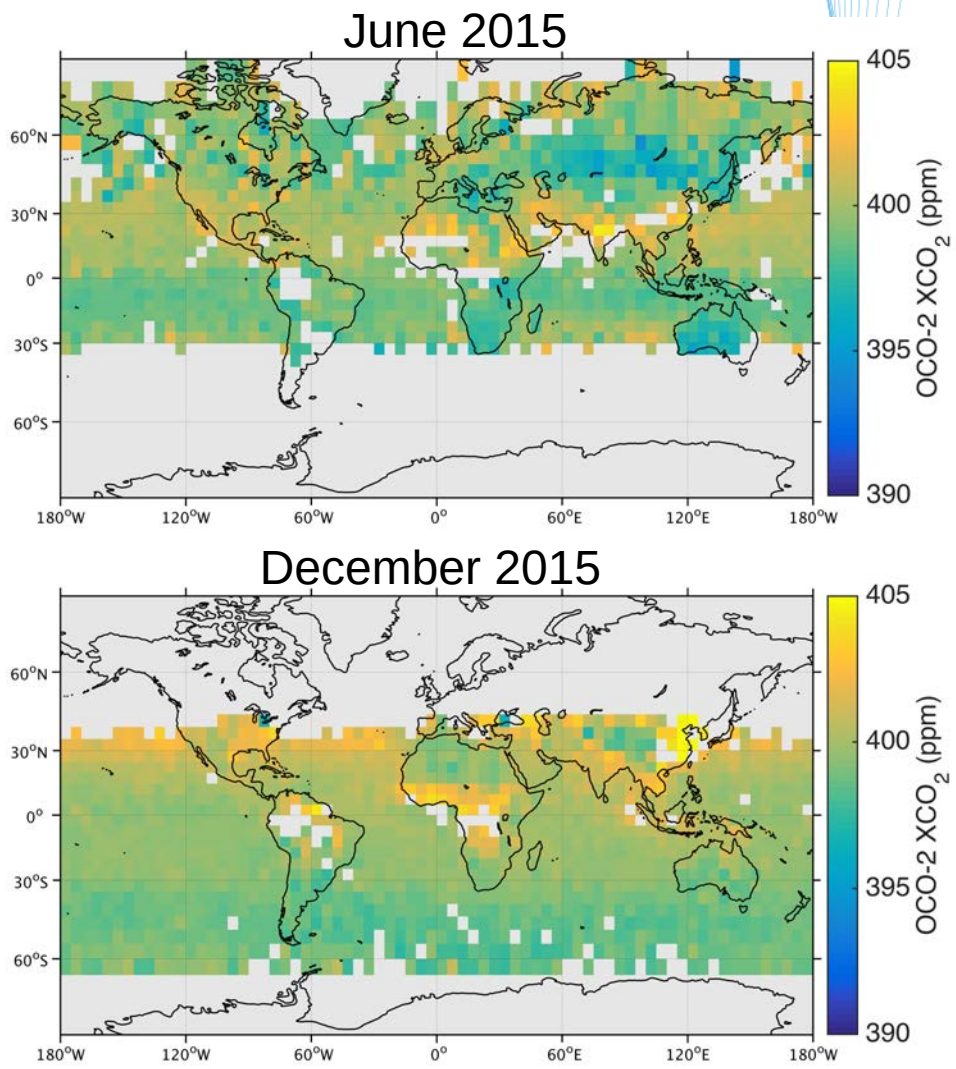




Reuter et al., Nature Geoscience, 2014

Orbiting Carbon Observatory-2

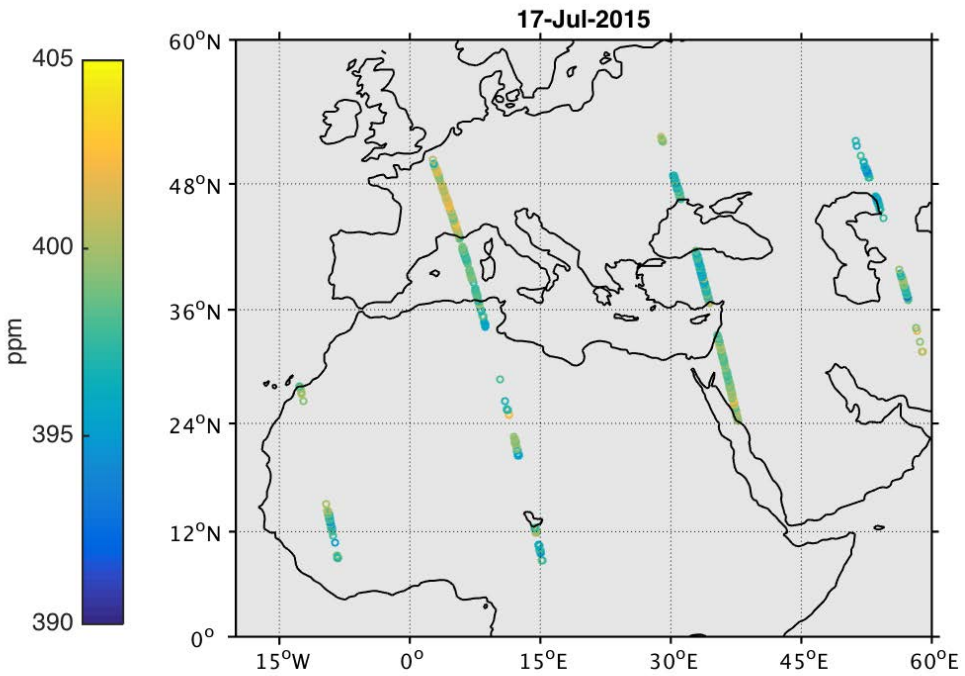
- Launched by NASA on 2 July 2014, science data available from September 2014 to April 2016
- The instrument provides measurements with eight 2.25 km long footprints along a narrow (0.4 to 1.29 km) swath
- The measured spectra cover the three OCO-2 NIR bands: 0.76 µm, 1.6 µm and 2.1 µm
- Column mean dry mole fraction of CO_2 (XCO_2) is retrieved using optimal estimation

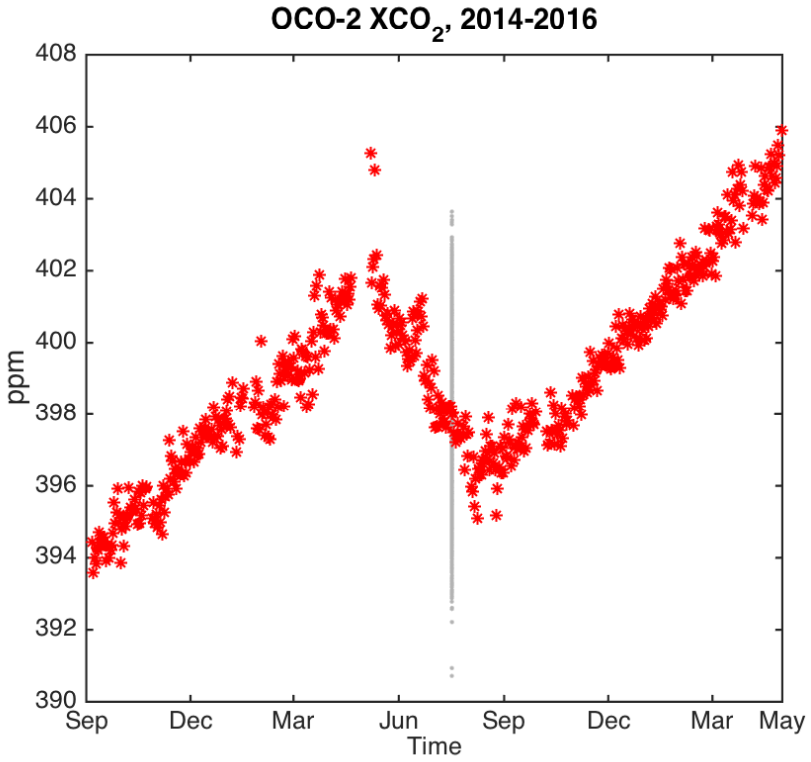


Approach for direct space-based observations of anthropogenic CO_2 emission areas from OCO-2

1. Select investigation regions with large anthropogenic CO_2 emissions (based on existing inventories)
2. Remove the background (daily median) from individual observations, in order to get anomalies
3. Grid the anomalies and calculate the mean

Algorithm for anomalies





XCO_2(anomaly) = XCO_2(individual) − XCO_2(daily median).

This step allows us to simultaneously deseasonalize and detrend the data. It also reduces the effect of the changing spatial distribution of the data points and the impact of potential regional scale biases in the OCO-2 data set.

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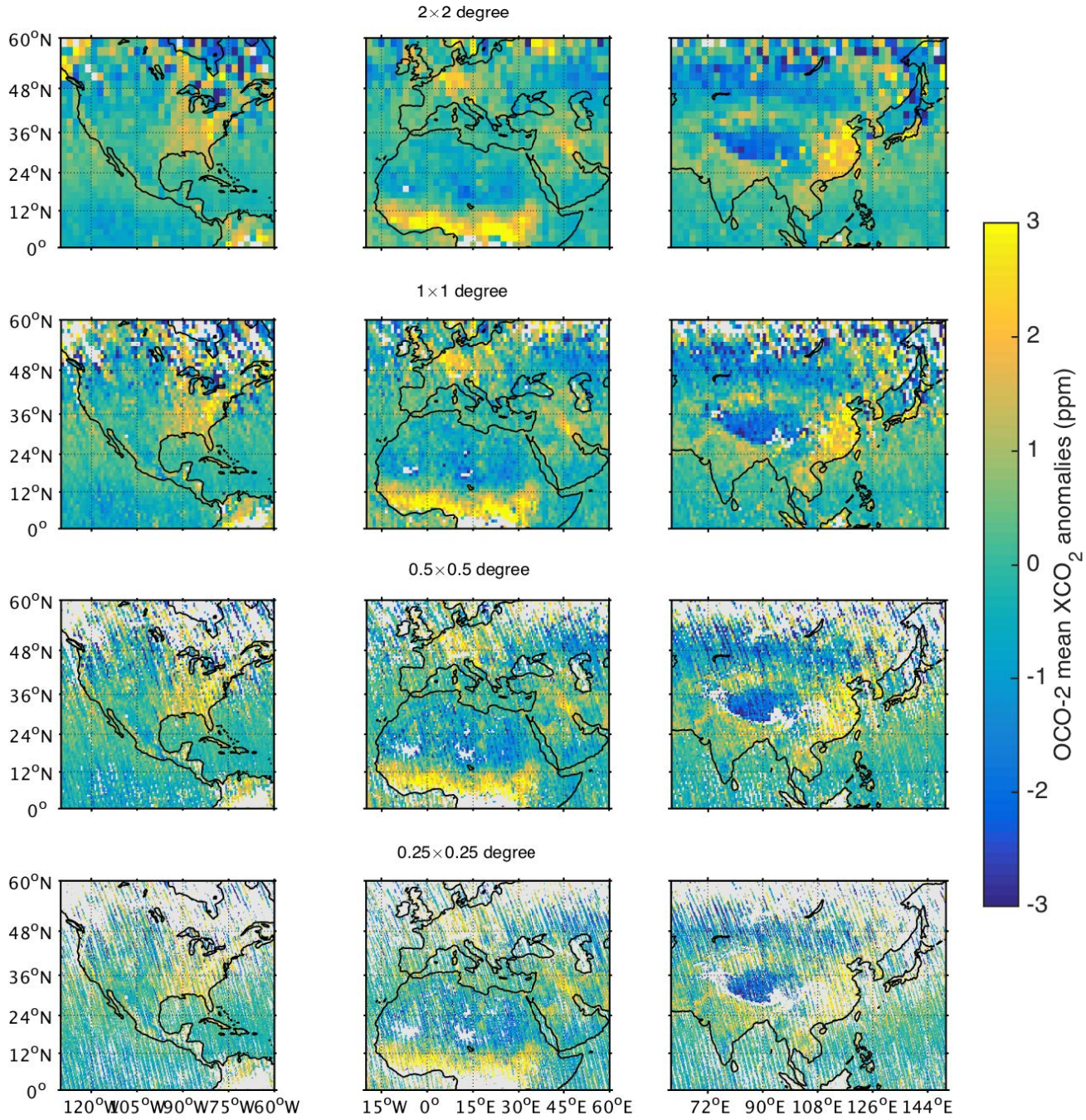
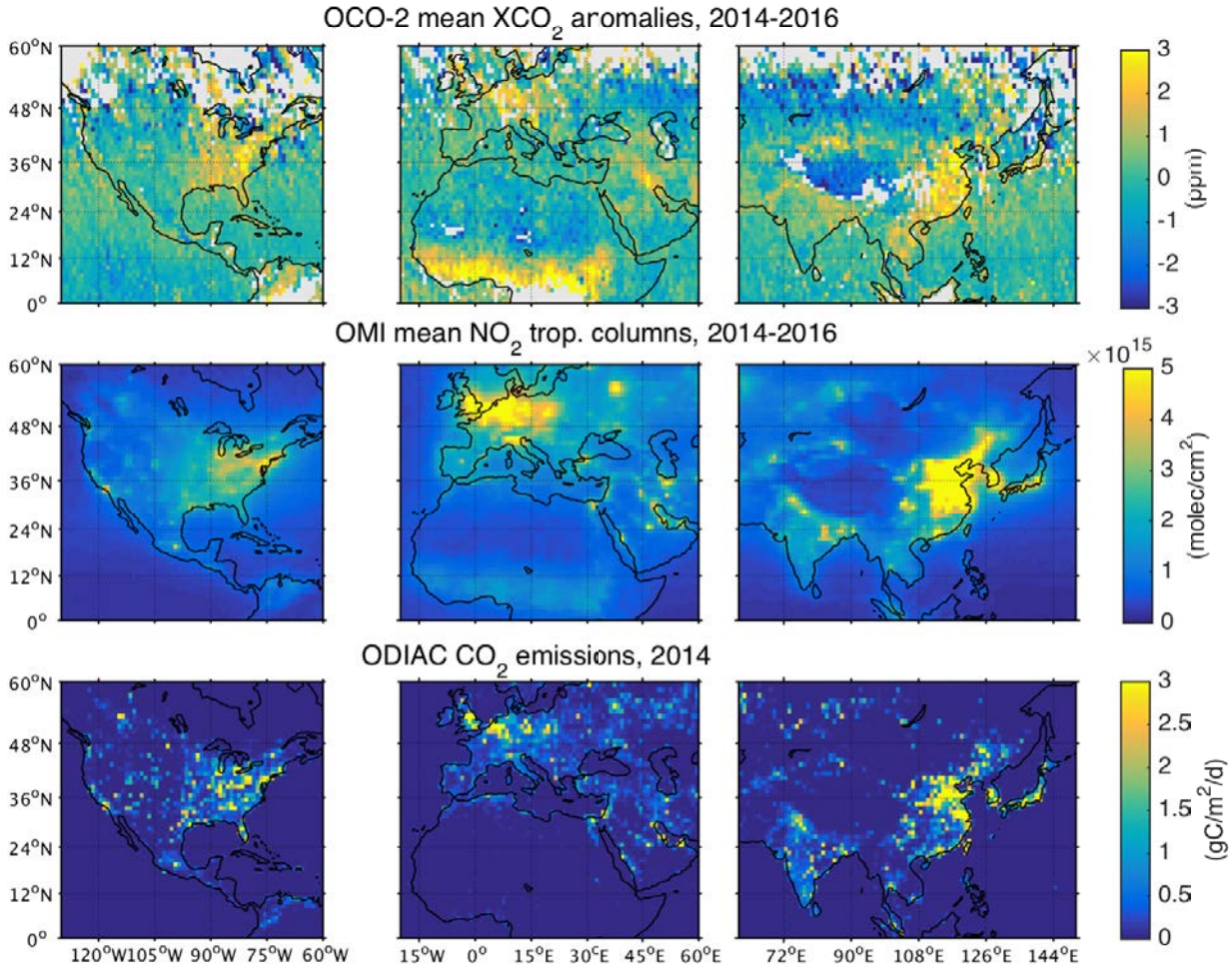
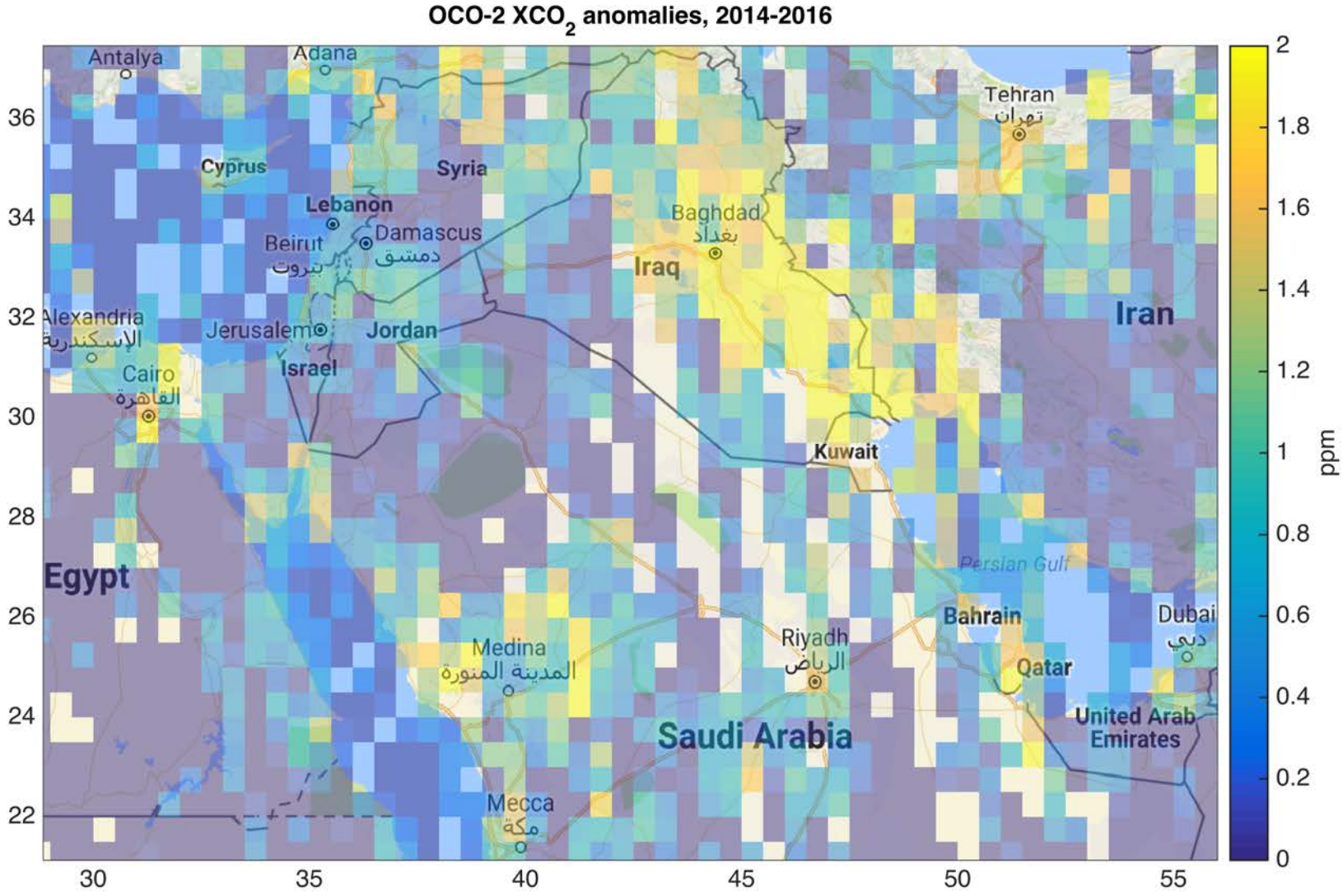
Results

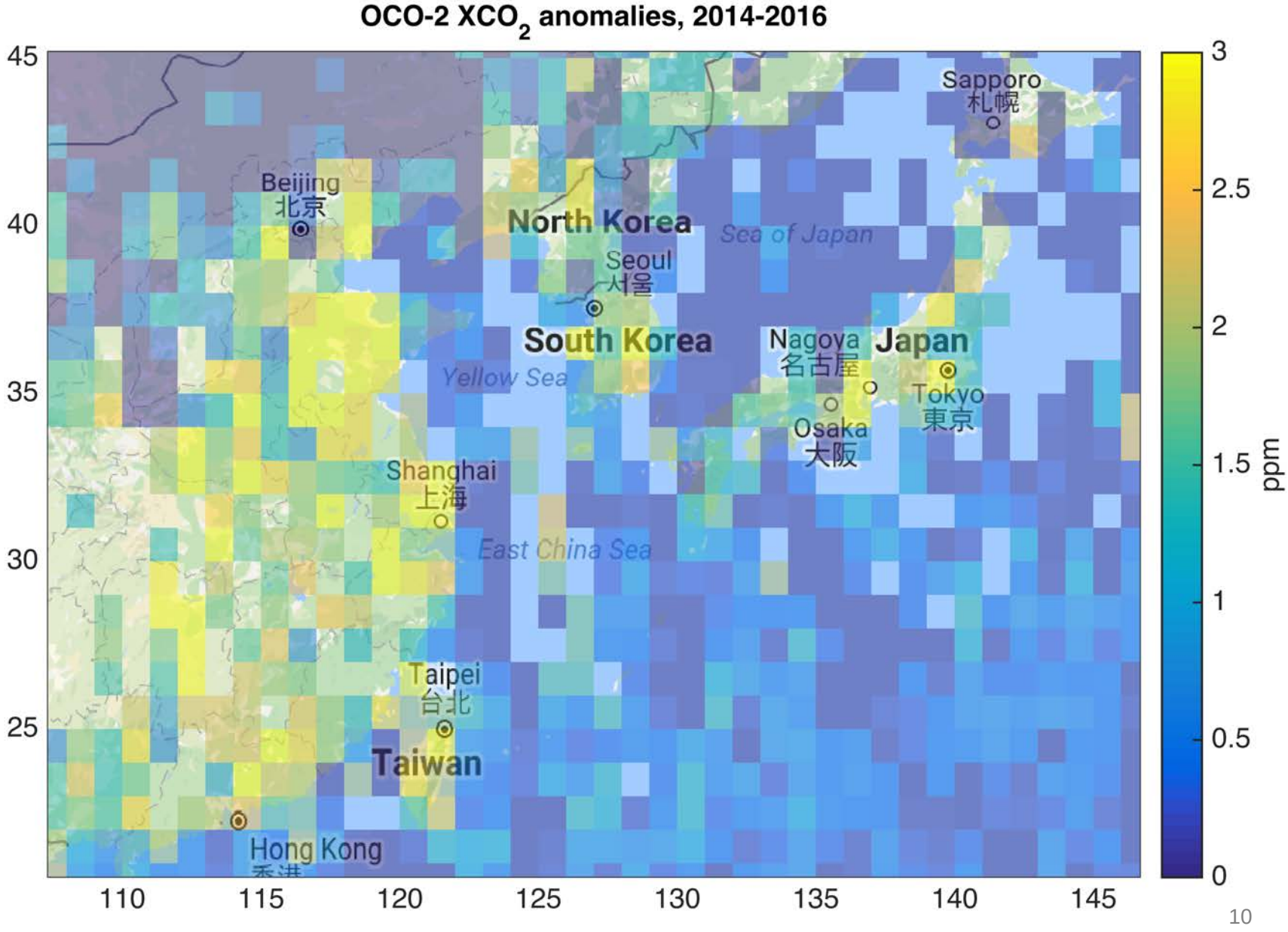


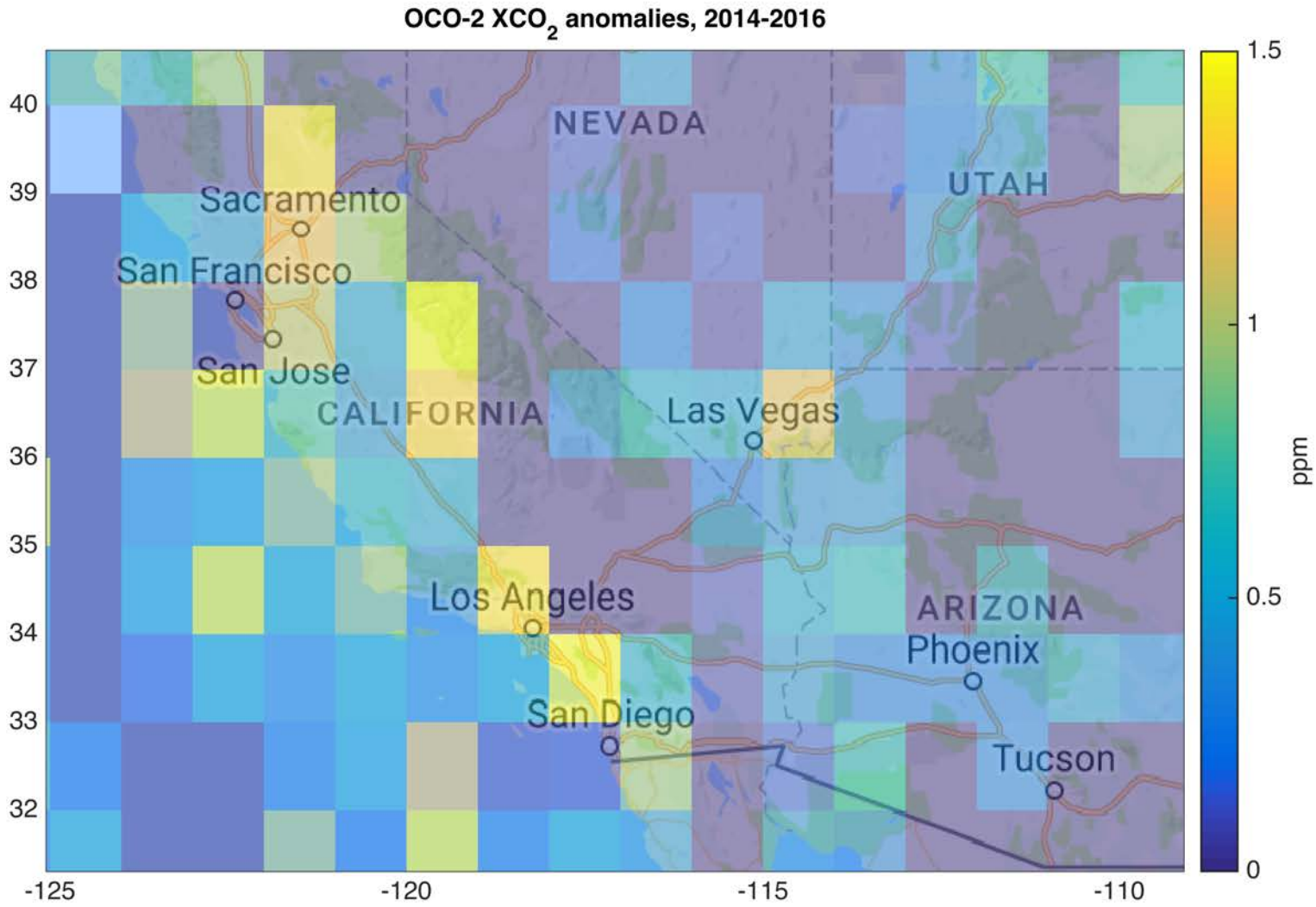
Results


OCO-2 mean XCO2 aromalies, 2014-2016
60°N
48°N
36°N
24°N
12°N
0°
3
2
1
0
-1
-2
-3
(ppm)
OMI mean NO2 trop. columns, 2014-2016
×10^15
5
4
3
2
1
0
(molec/cm^2)
ODIAC CO2 emissions, 2014
3
2.5
2
1.5
1
0.5
0
(gC/m^2/d)
120°W 105°W 90°W 75°W 60°W
15°W 0° 15°E 30°E 45°E 60°E
72°E 90°E 108°E 126°E 144°E

Case studies




OCO-2 XCO2 anomalies, 2014-2016
45
40
35
30
25
110
115
120
125
130
135
140
145
Sapporo
札幌
Beijing
北京
North Korea
Sea of Japan
Seoul
서울
South Korea
Nagoya
名古屋
Japan
Yellow Sea
Tokyo
東京
Osaka
大阪
Shanghai
上海
East China Sea
Taipei
台北
Taiwan
Hong Kong
3
2.5
2
1.5
1
0.5
0
ppm


OCO-2 XCO2 anomalies, 2014-2016
NEVADA
UTAH
Sacramento
San Francisco
San Jose
CALIFORNIA
Las Vegas
Los Angeles
ARIZONA
Phoenix
San Diego
Tucson
40
39
38
37
36
35
34
33
32
-125
-120
-115
-110
1.5
1
0.5
0
ppm

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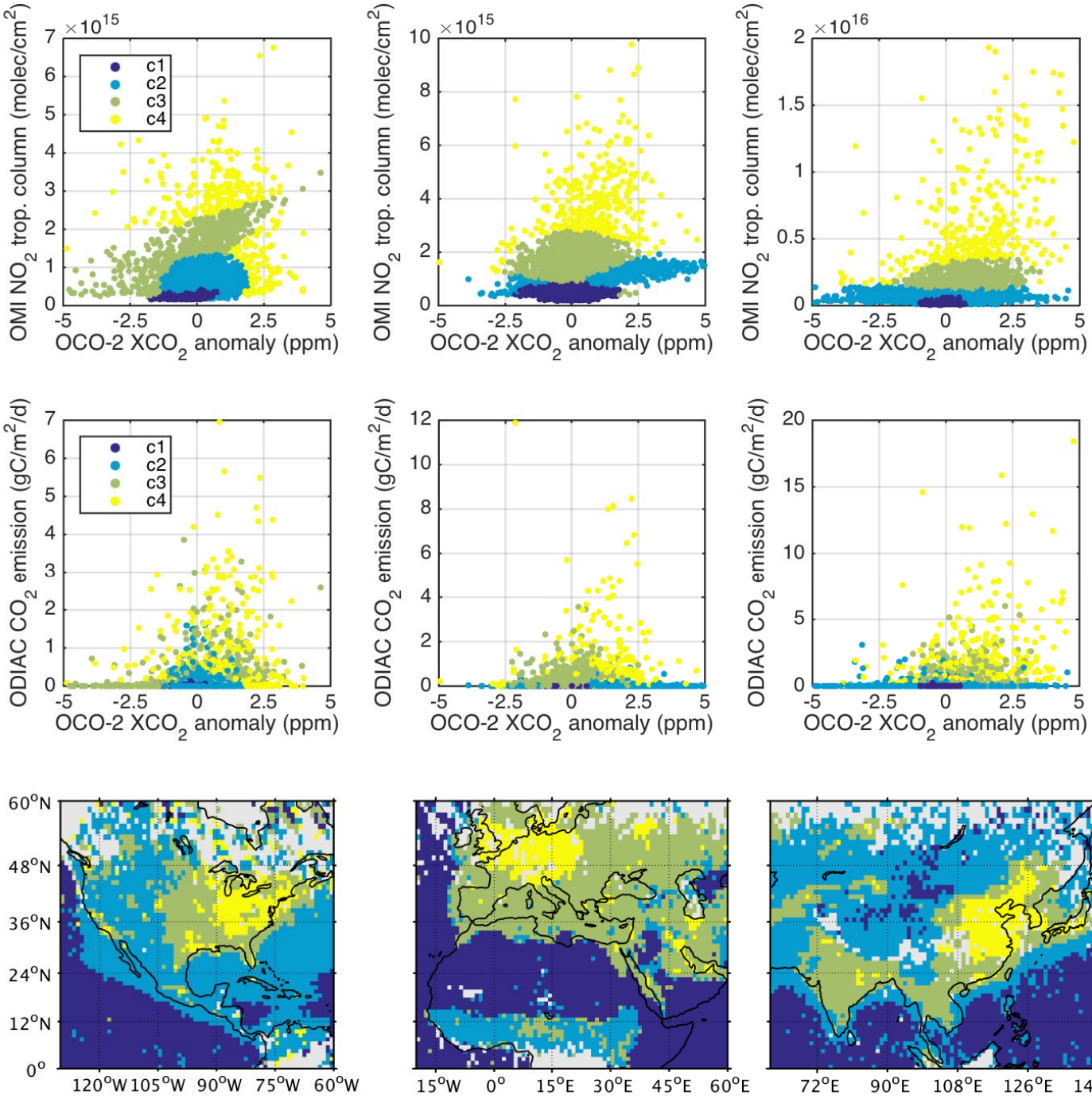
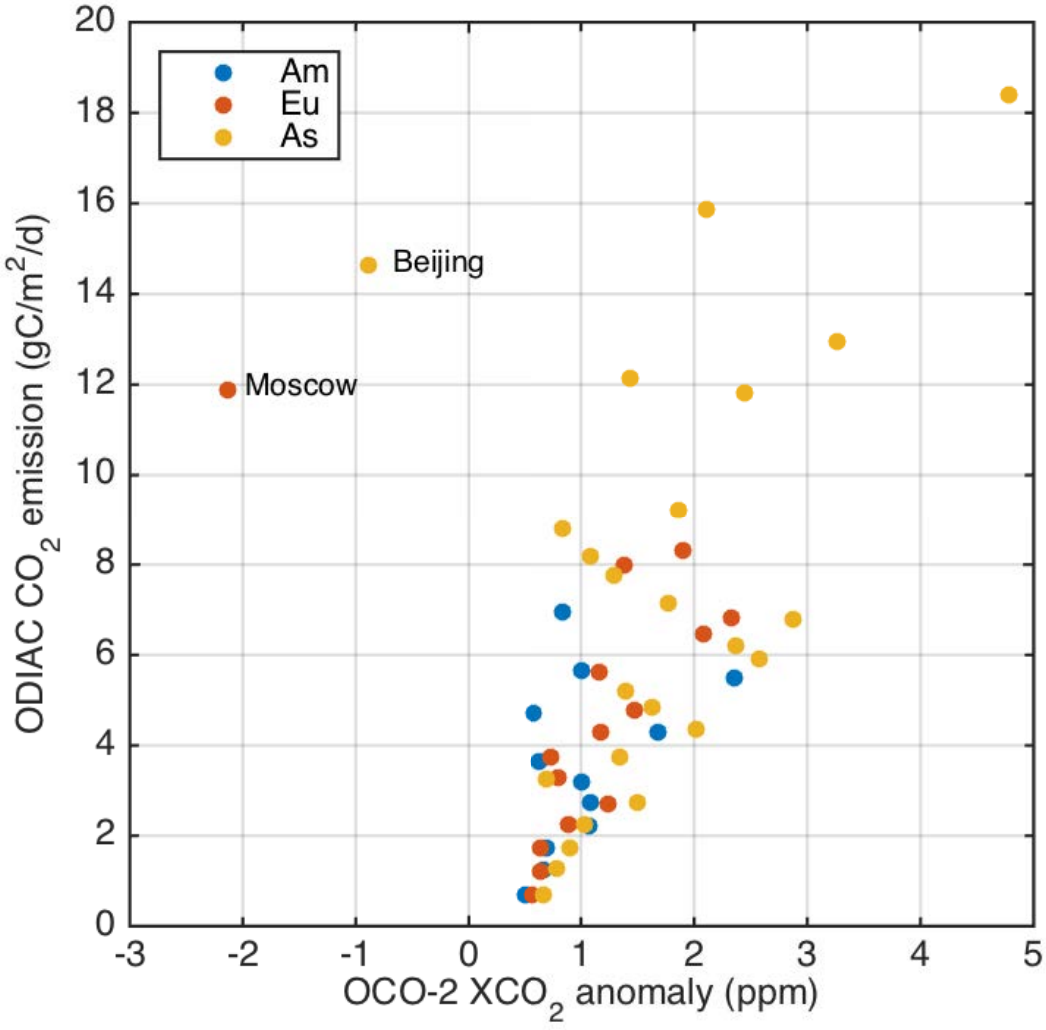
Validation



Validation


Am
Eu
As
Beijing
Moscow
ODIAC CO_2 emission ($gC/m^2/d$)
OCO-2 XCO_2 anomaly (ppm)
20
18
16
14
12
10
8
6
4
2
0
-3
-2
-1
0
1
2
3
4
5

Conclusion

- First **direct** observation of anthropogenic CO_2 emission areas from space.

- Major anthropogenic CO_2 emission areas, such as Europe, USA and China, and several smaller isolated emitting areas, like individual cities, are detectable.

- This was achieved developing a novel methodology to derive the mean XCO_2 anomalies, solely based on spaceborne OCO-2 data with unprecedented spatial coverage and detail.

- The distribution of the pollution areas is in agreement with the existing CO_2 emission maps and the mean XCO_2 anomalies showed positive correlation with the CO_2 emission values.

- This study was based on about a year-and-a-half of OCO-2 data. In the future, as the OCO-2 dataset becomes larger, we aim at studying the CO_2 emissions in more detail and the results are expected to become more robust.