Urban fossil fuel CO_2 emissions from space: lessons learned from the OCO missions

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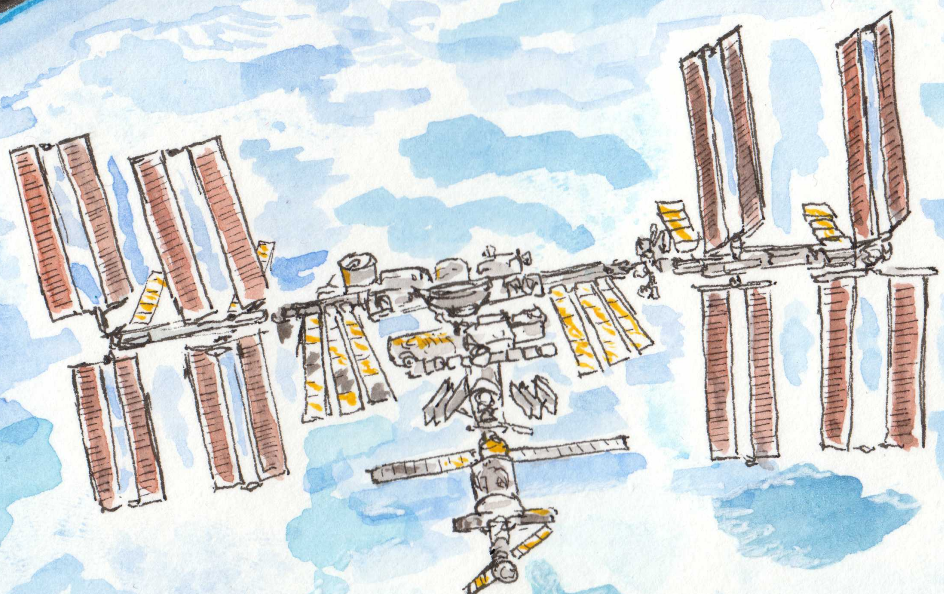

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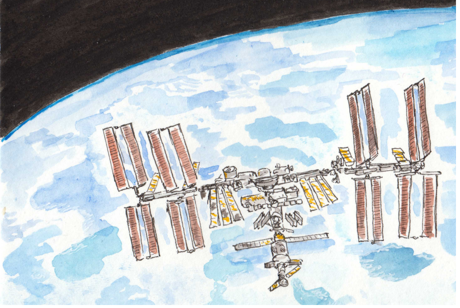


Urban CO_2 emissions from space

Major challenges related to urban emission quantification using XCO_2 measurements

- Atmospheric model errors (varying with terrain complexity)

- Impact of the local vegetation (urban to rural gradients)

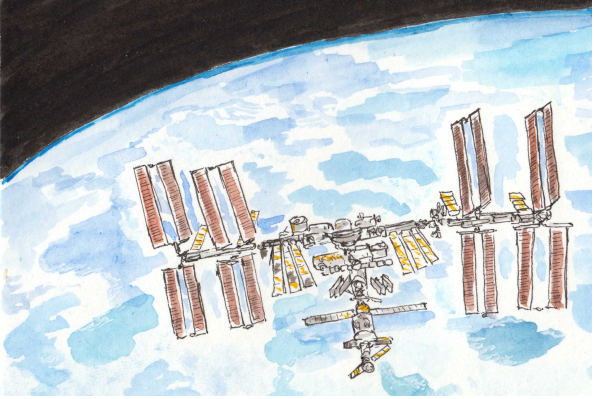
- Definition of spatial gradients from distant sources and sinks (background XCO_2)

- Measurement errors (esp. urban aerosols)

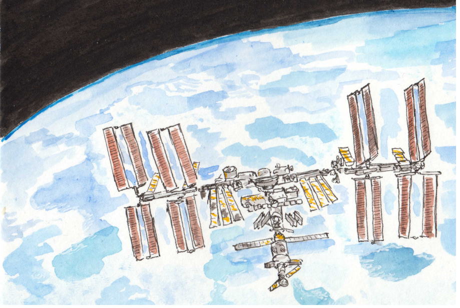
- Sampling density for long-term carbon budgets

Study presented today

Based on a selection of OCO-2 tracks near large metropolitan areas, we examined **large metropolitan areas** in **flat and complex terrain**, over **arid and vegetated zones**, **inland and near the shore**, with a state-of-the-art modeling system (WRF-Chem)



Transport model errors in flat and complex terrain



Urban CO_2 emissions from space: analysis of OCO-2 tracks

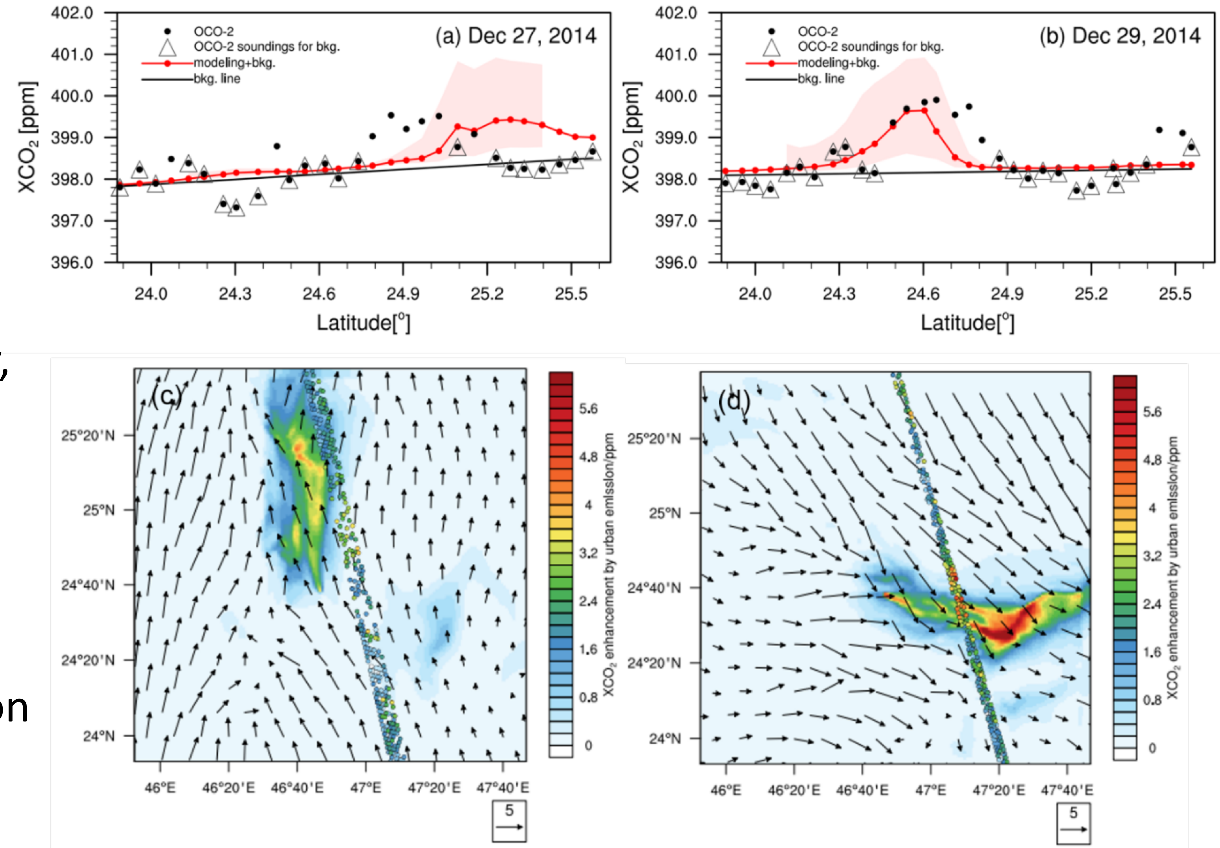
Flat terrain in arid climate: Riyadh, Saudi Arabia

A first look at urban XCO_2 plumes

- Selection of OCO-2 tracks near large metropolitan areas
- First selected cases: simple topography, low vegetation, clear sky

Analysis of local XCO_2 enhancements

- WRF-Chem simulation at high resolution (1km) coupled to ODIAC emissions
- Smoothing (1-s averages) and filtering (QF=0)

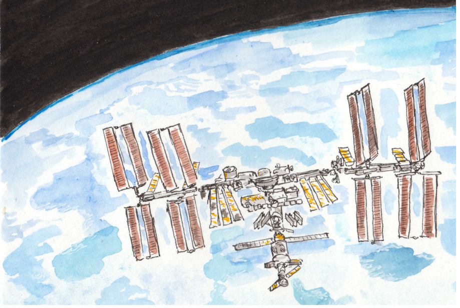


Comparisons of modeled and observed ffX_{CO2} enhancements by the OCO-2 data on 27 and 29 December 2014 at 10 UTC over Riyadh, Saudi Arabia

First conclusions (city: Riyadh, Saudi Arabia)

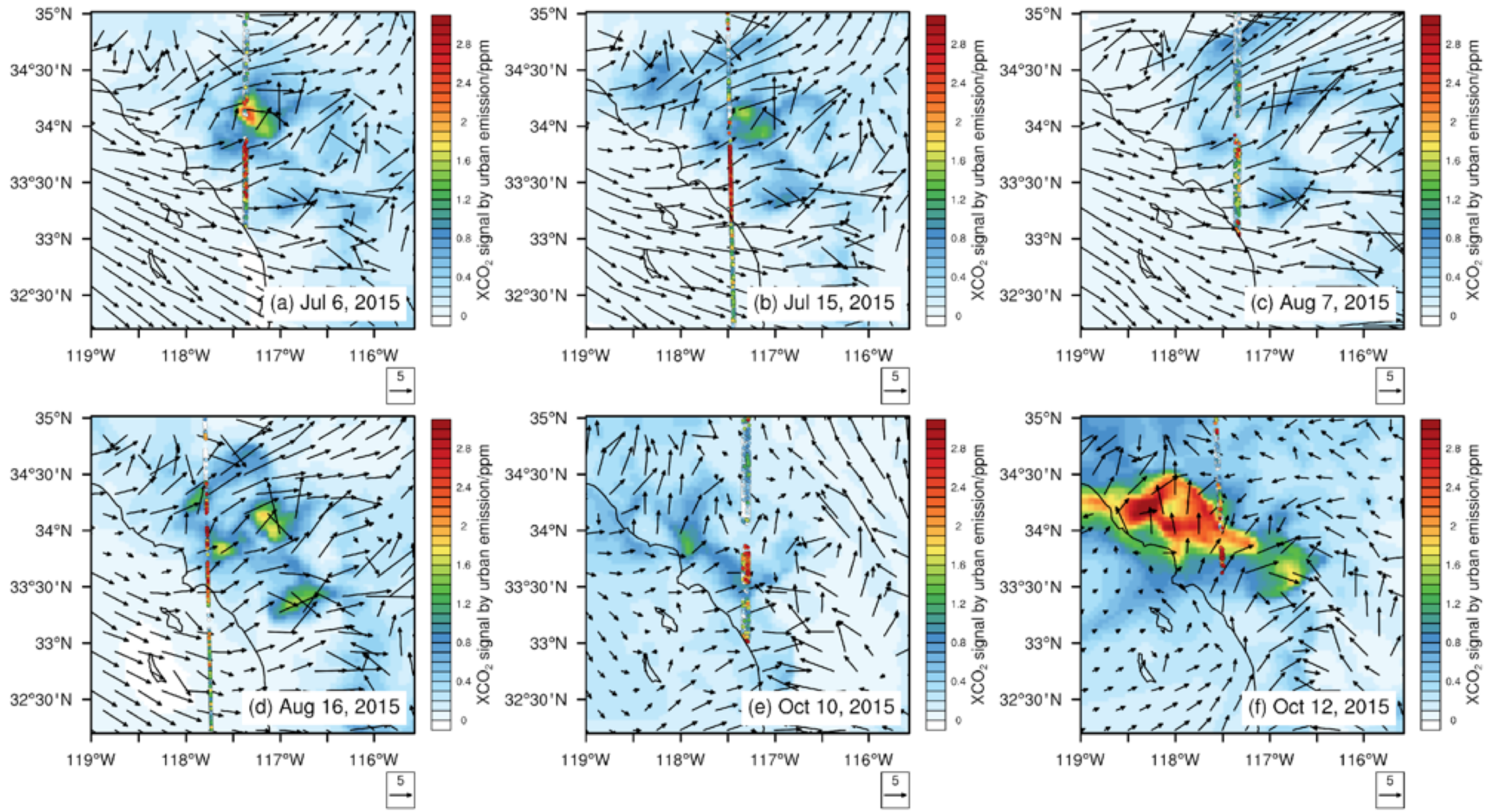
Overall agreement between simulated and observed XCO_2 enhancements, with displacement of the plume structures (wind speed/direction errors)

Ye et al., 2020; JGR-Atmos.



Urban CO_2 emissions from space: analysis of OCO-2 tracks

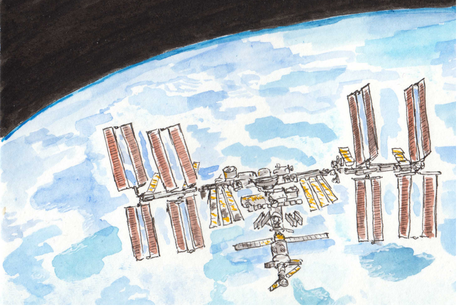
Complex topography near the shore: Los Angeles, CA



Comparisons of modeled and observed ffX_{CO2} enhancements by the OCO-2 data over Los Angeles, CA

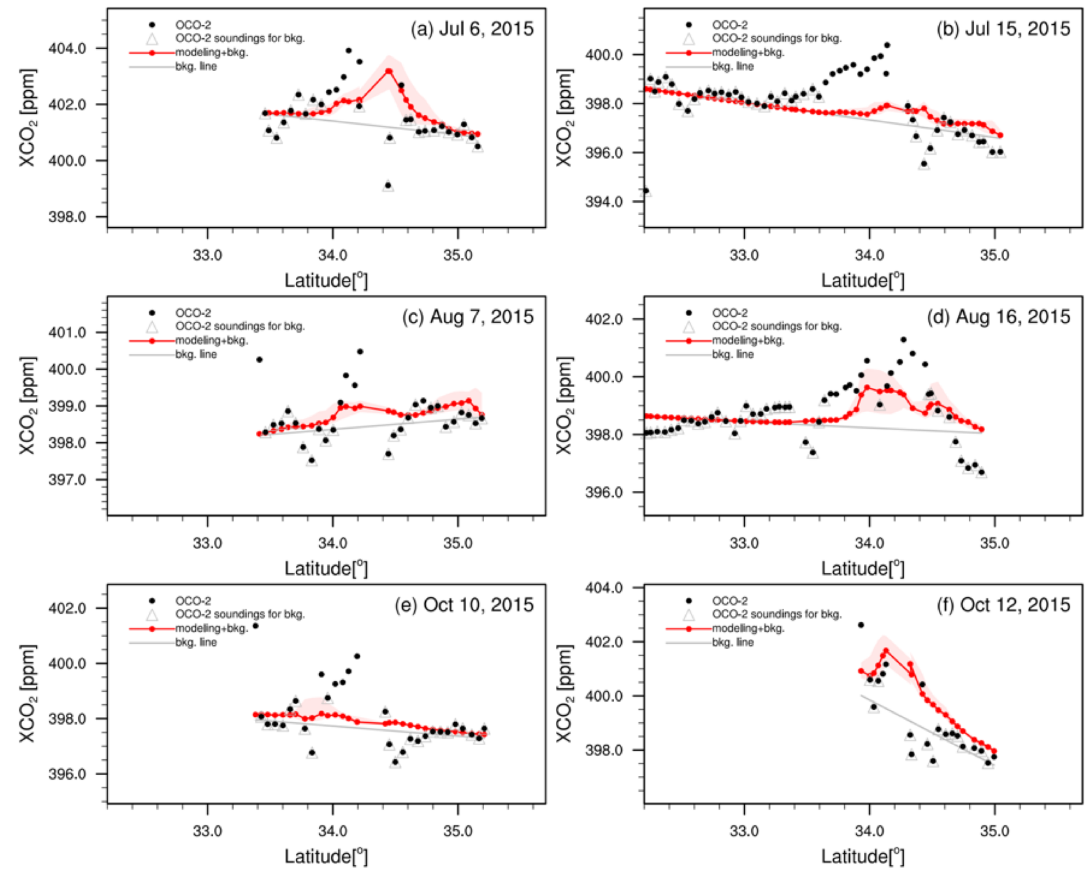
Ye et al., 2020; JGR-Atmos.

Complexity of the mesoscale circulation over the LA basin responsible for large differences in the observed XCO_2 enhancements



Urban CO_2 emissions from space: analysis of OCO-2 tracks

Complex topography near the shore: Los Angeles, CA



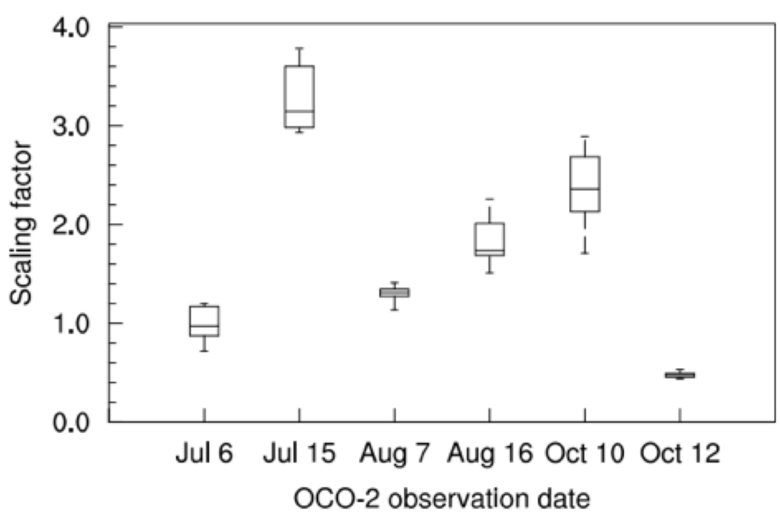
Impact of complex topography

- Large disagreement on individual tracks
- Definition of the background more uncertain (linear regression)

Conclusions

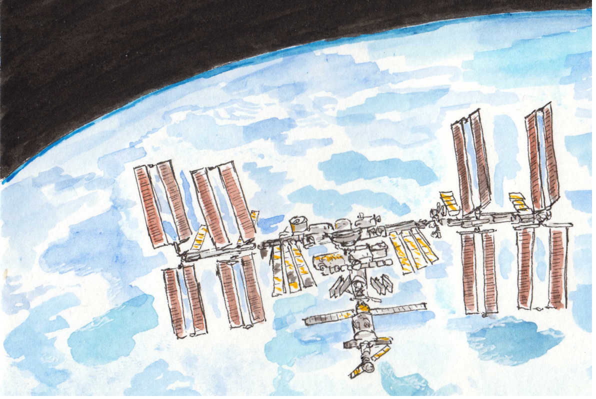
Uncertainties from mesoscale model simulations increase with significant gradients in the background

Comparisons of modeled and observed ffX_{CO2} enhancements by the OCO-2 data over Los Angeles, CA

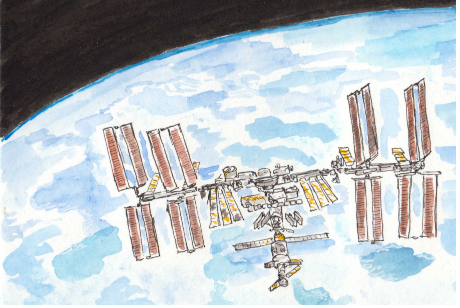


Scaling factors applied to ODIAC emissions for the different OCO-2 tracks

Ye et al., 2020; JGR-Atmos.

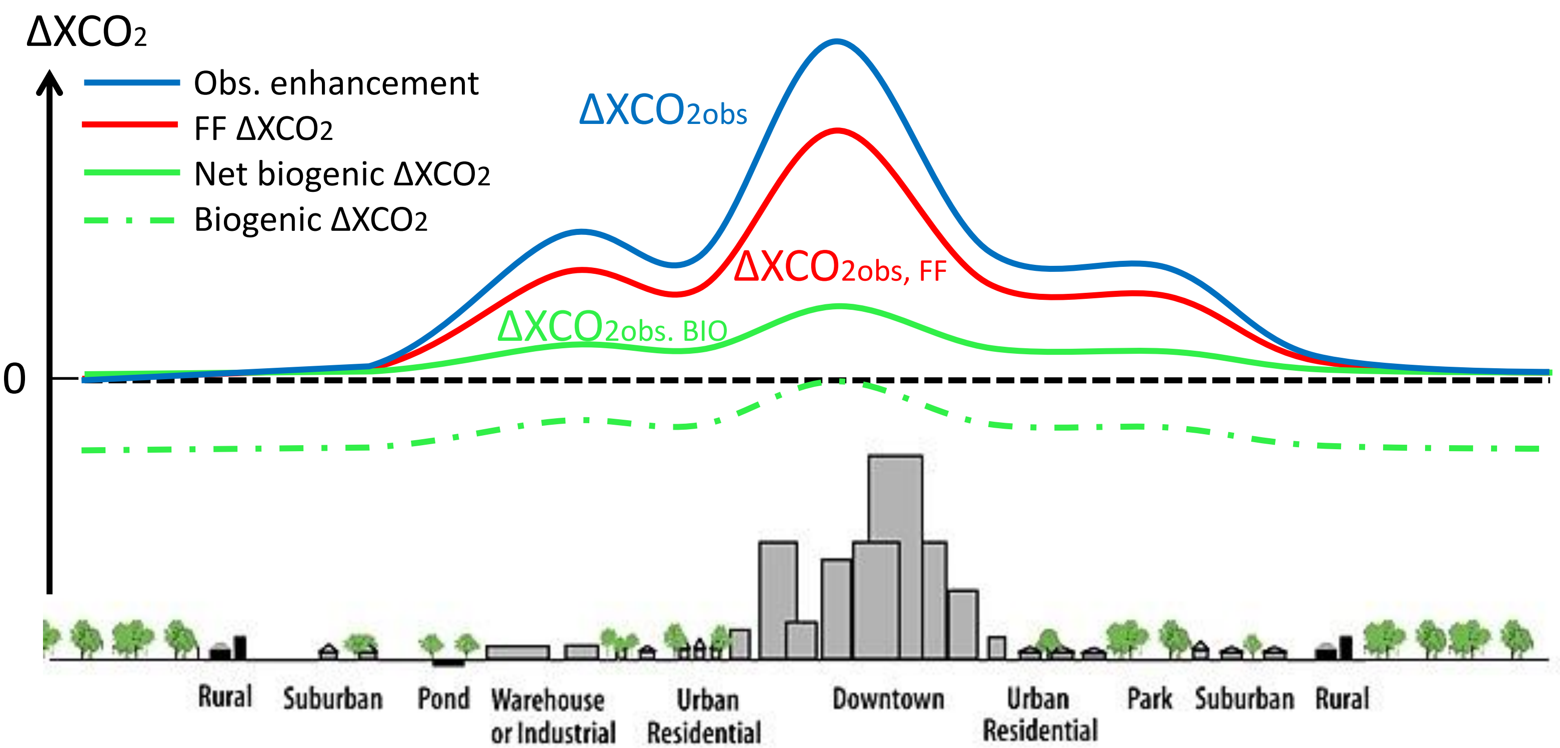


Biogenic flux uncertainties

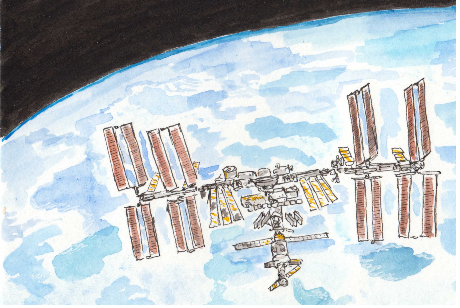


Urban CO_2 emissions from space: analysis of OCO-2 tracks

Coastal city in densely-vegetated area: Yangtze River Delta, China



Representation of the biogenic and fossil fuel contribution to the observed XCO_2 enhancements across the urban-to-rural spatial gradient



Urban CO_2 emissions from space: analysis of OCO-2 tracks

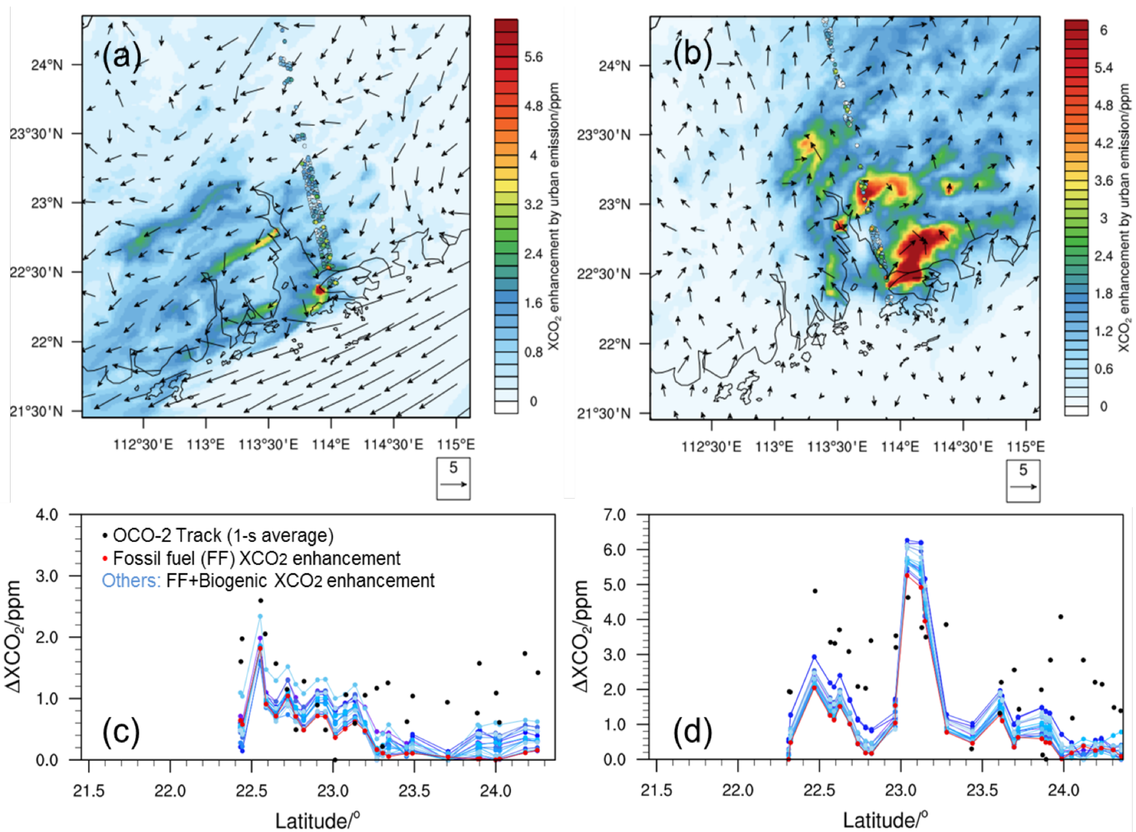
Coastal city in densely-vegetated area: Pearl River Delta, China

Biogenic CO2 fluxes

- Ensemble of 15 biogeochemical models (MsTMIP)
- Upscaled using Green Vegetation Fraction from MODIS
- Urban and rural vegetation assumed similar

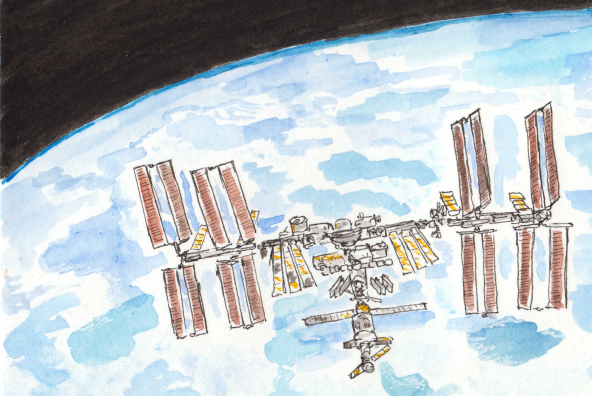
Impact of vegetated surroundings

- Large uncertainties in fossil fuel CO_2 emissions due to biogenic flux uncertainty (32% and 24%)

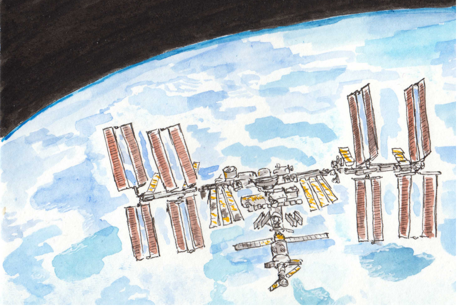


Simulated ffX_{CO2} over the PRD region and the 10-m wind vectors in the 1.333-km resolution domain at (a) 05:00 UTC January 15, 2015, and (b) 05:00 UTC August 4, 2015

Ye et al., 2020; JGR-Atmos.



Measurement quality assessment of XCO_2 retrievals



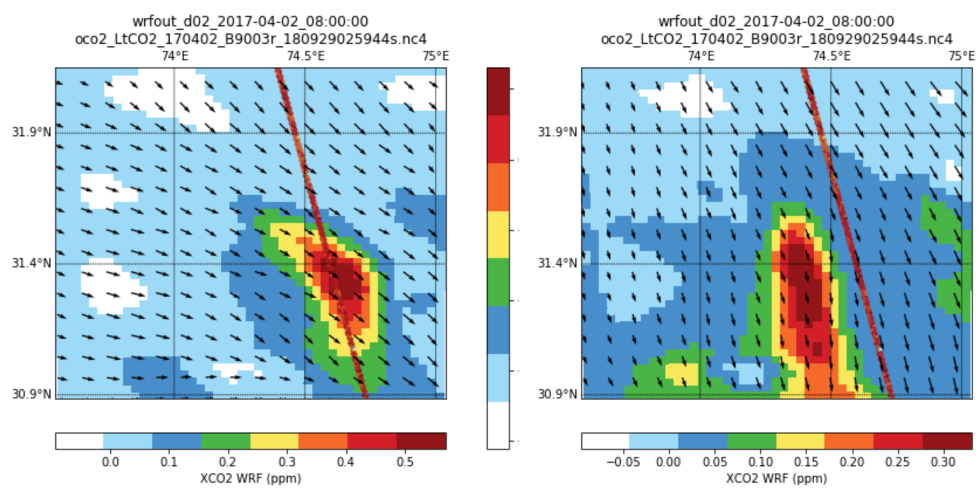
Urban CO_2 emissions from space: analysis of OCO-2 tracks

Fast-growing city in flat terrain: Lahore, Pakistan

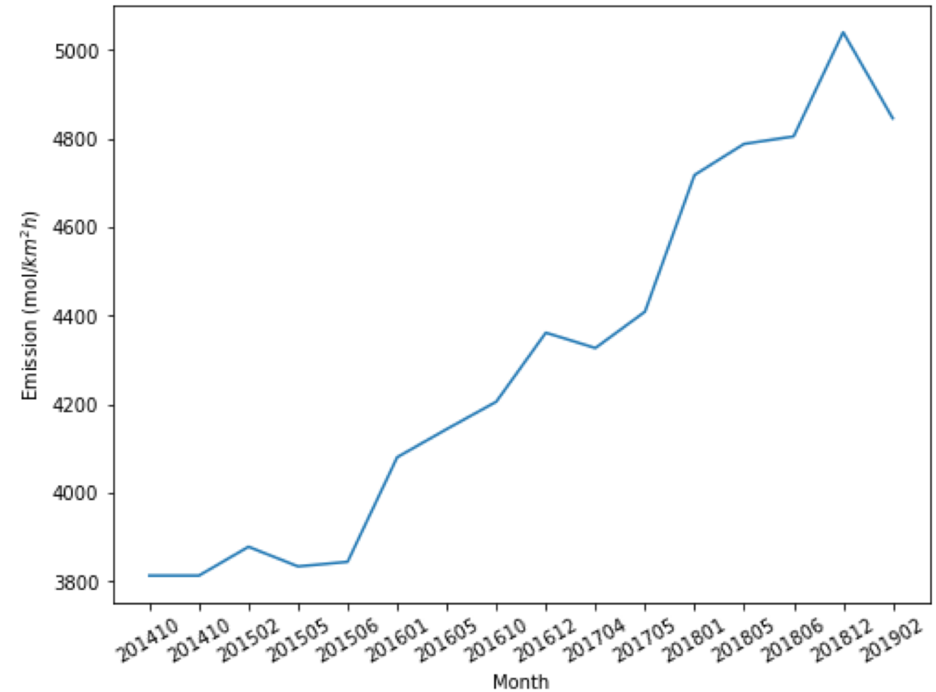
XCO-2 retrievals over Lahore

- Fast-growing urban area with potentially high aerosol content

- Meteo data assimilation identified as critical to represent the local enhancements

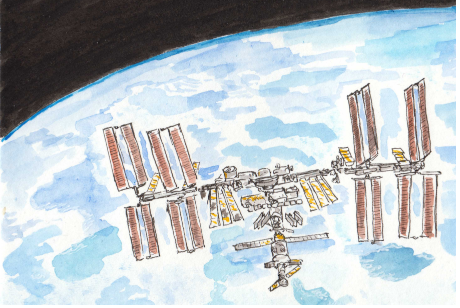


Simulations of XCO_2 mixing ratios with meteorological data assimilation (left) and without (right) over Lahore



Evolution of fossil fuel CO_2 emissions over Lahore, Pakistan based on national fuel consumption statistics (ODIAC) from 2014 to 2019

Lei et al., in prep.; Remote Sensing



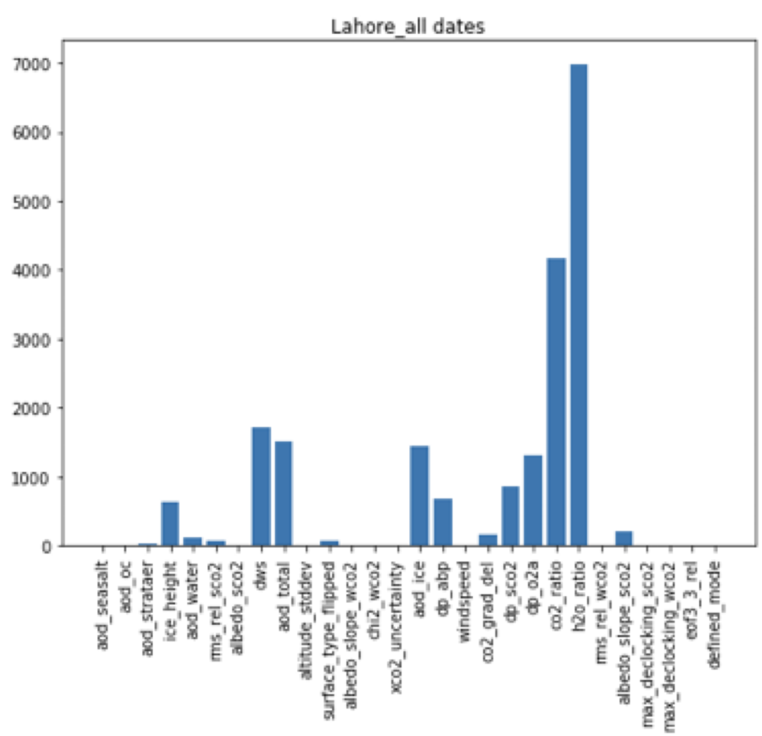
Urban CO_2 emissions from space: analysis of OCO-2 tracks

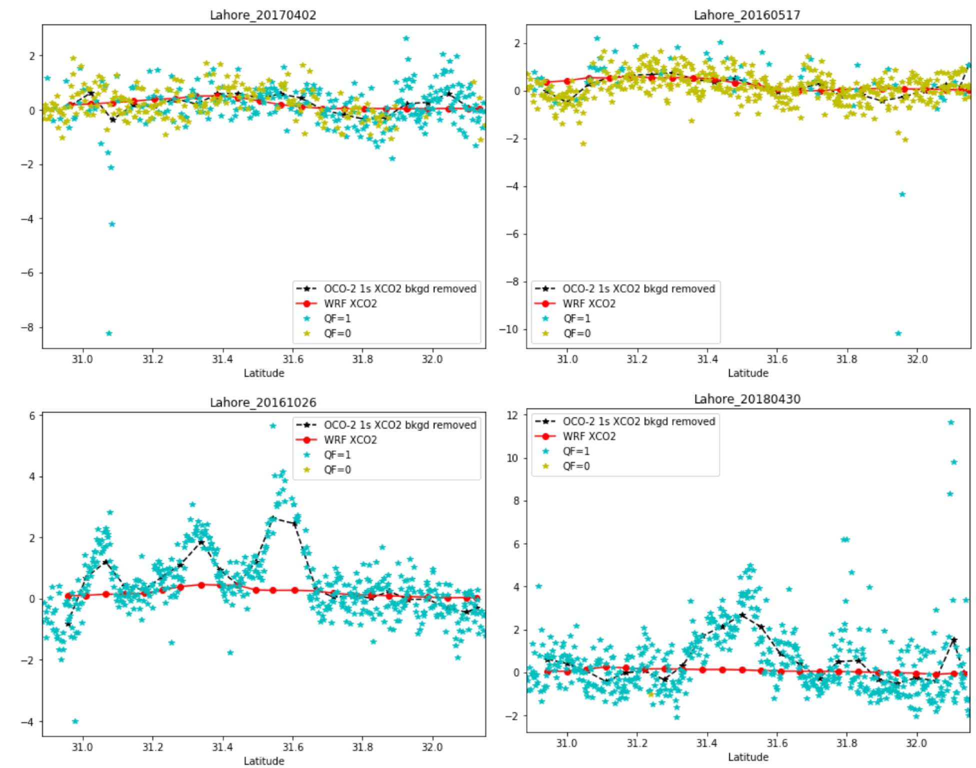
Fast-growing city in flat terrain: Lahore, Pakistan

Quality flags in OCO-2 retrievals

- Large plumes detected in both high-quality and low-quality data

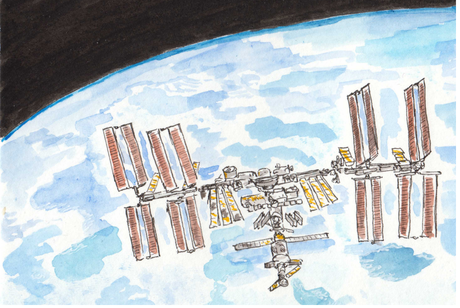
- Unclear if qualitfy flags are relevant at local scales





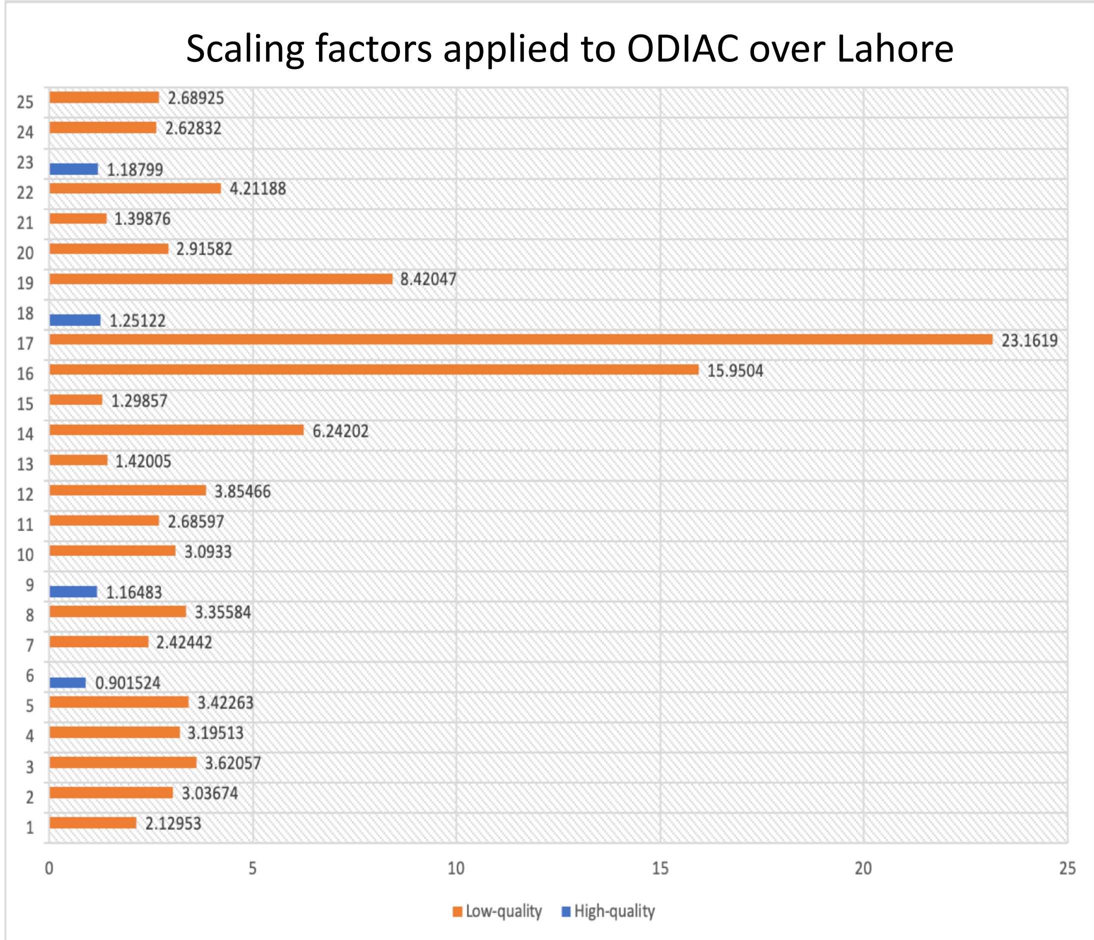
Examples of low-quality (in blue) and high-quality (in green) XCO2 data for four tracks over Lahore, Pakistan

Lei et al., in prep.; Remote Sensing



Urban CO_2 emissions from space: analysis of OCO-2 tracks

Fast-growing city in flat terrain: Lahore, Pakistan



Quality flags for OCO-2 emissions

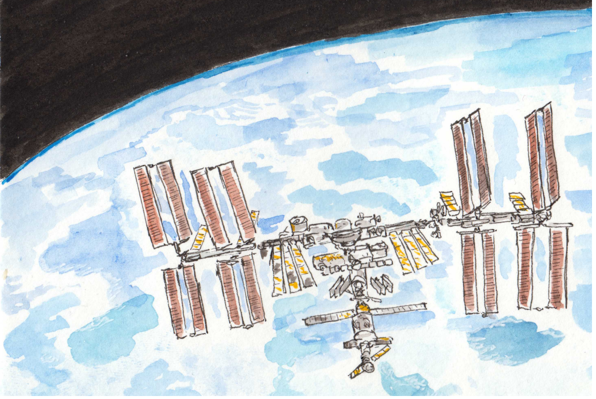
- High-quality tracks produce consistent CO_2 emission estimates (in blue)

- Low-quality flags show inconsistent scaling factors (in orange)

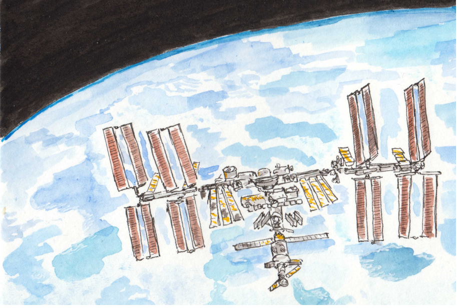
Conclusions on OCO-2 quality flags

- Plumes detected in low-quality tracks caused by aerosol/cloud contamination
- Quality flags are highly-relevant to local source estimation

Lei et al., in prep.; Remote Sensing



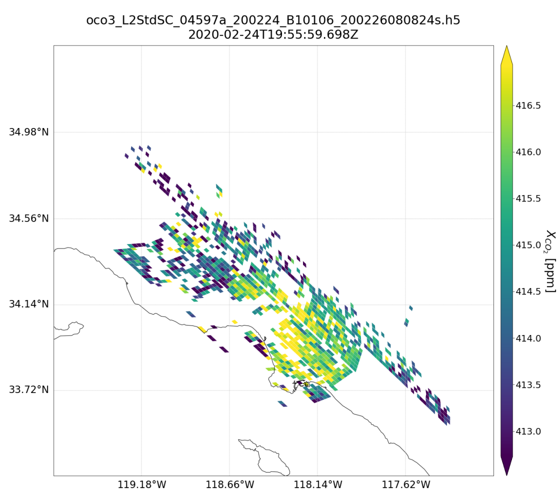
First look at OCO-3 Scanning Area Mode



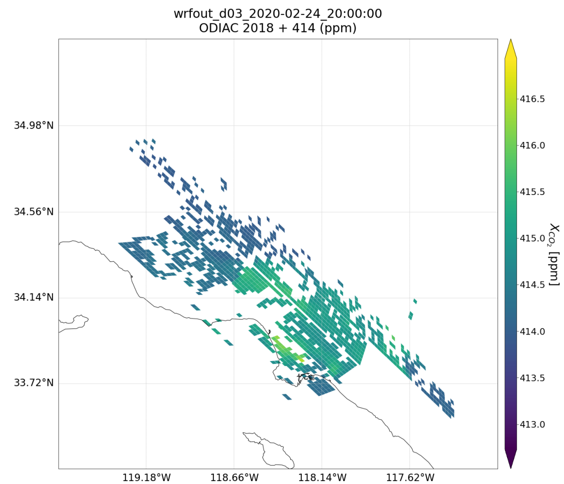
Urban CO_2 emissions from space: analysis of OCO-3 SAMs

Los Angeles, CA

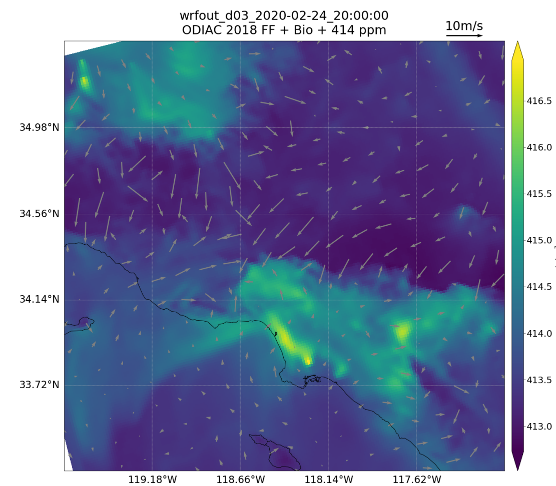
OCO-3



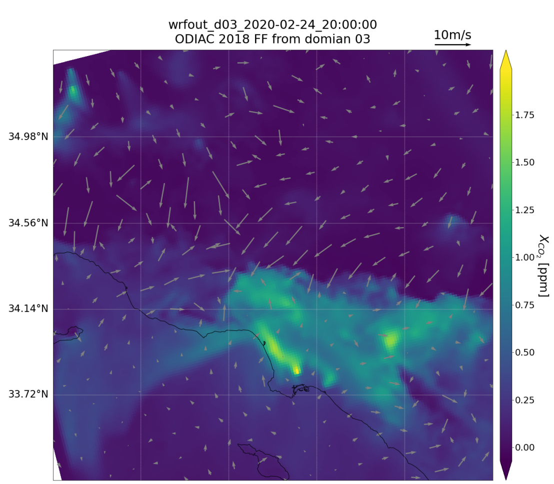
WRF ODIAC 2018 XCO2 (OCO-3 sampled)



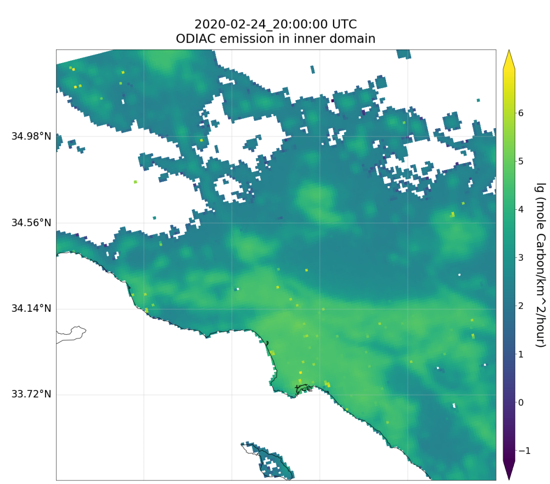
WRF ODIAC 2018 XCO2



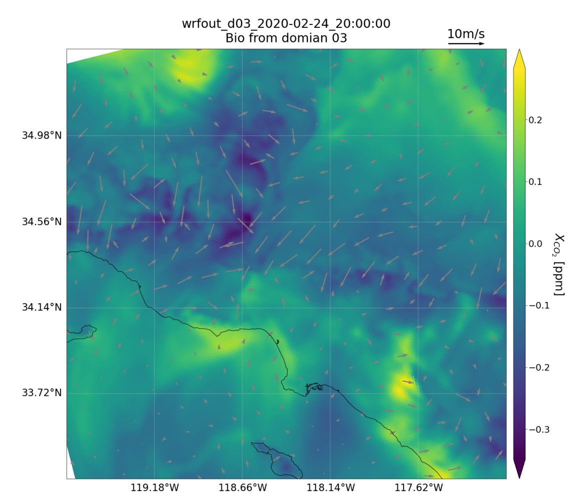
WRF Fossil Fuel XCO2



ODIAC emission



Biogenic XCO2 (GVF+MsTMIP)



Kiehl et al., in prep.

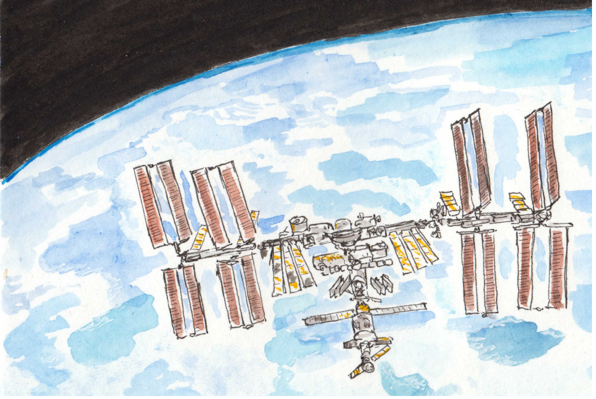


Illustration by Orlanda Marin Lopez

Conclusions

High-resolution modeling systems agree within 25% compared to ODIAC (for high-quality tracks)

Meteorologcial data assimilation is required to obtain such an agreement

Quality flags defined for global-scale inversions are relevant for local source determination

Large fraction of the tracks are lost due to aerosol/cloud contamination (21 out of 25 tracks)

First SAM's over Los Angeles and simulated XCO2 mixing ratios are consistent