Imprint of Urban CO_2 Emissions Detected by OCO-2 Observations of Total Column CO_2

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INTRODUCTION

❑ Global economic development has given rise to steady increase of atmospheric CO_2 during the past 200 year, which has significant contributions to climate change.

❑ Cities are responsible for about 70% of the global energy-related CO_2 emissions. Accurate estimations of CO_2 emissions over urban area is a crucial need for independent verification of urban emissions from fossil-fuel energy consumption.

❑ Space-based observations of the total column averaged CO_2 concentration (XCO_2) are expected to have an important role in constraining the surface CO_2 fluxes using atmospheric inversion methods.

❑ Although the potential of satellite XCO_2 for global or regional scale flux inversions has been examined, only few studies demonstrated their potential applicability at urban scale.

OBJECTIVES

❑ Evaluate the availability of OCO-2 retrievals for detecting urban emission signals.

❑ Taking transport model error and boundary inflow into consideration, we discuss the implications of the detected signals on constraining urban fossil-fuel CO_2 emissions.

❑ Investigate the potential of XCO_2 measurements retrieved from the NASA Orbiting Carbon Observatory-2 (OCO-2) in the context of urban inversions of CO_2.

Figure courtesy of http://oco.jpl.nasa.gov/observatory/

DATA & METHODS

❑ Enhancements in XCO_2 induced by urban fossil-fuel CO_2 emissions and atmospheric transport are examined using OCO-2 L2 Lite products for Sept 2014 to Aug 2015.

❑ Forward transport model simulations
   – Weather Research and Forecasting model with chemistry (WRF-Chem)
   – Urban emission: Open-source Data Inventory for Anthropogenic CO_2 (ODIAC).

Model Settings			
Model version	WRF-Chem V3.5.1	LW radiation	RRTMG
Grid Resolution	27, 9, 3, 1 km	SW radiation	RRTMG
Vertical levels	51 eta-levels	PBL physics	MYNN2.5
Microphysics	Thompson	Land Surface	Noah LSM
Cumulus	Kain-Fritsch	Surface layer	MYNN

RESULTS

Imprint of Urban CO_2 Emissions observed by OCO-2

• OCO-2 tracks overpassing Riyadh, Saudi Arabia are shown. The overpassing time is about 10:00 UTC. 7 dates among our study period are chosen to show the general XCO_2 distribution along tracks, with some enhancements of XCO_2 possibly due to urban emissions. Maps demonstrate the average urban CO_2 emissions in corresponding months according to the Open-source Data Inventory for Anthropogenic CO_2 (ODIAC). Vectors represent surface wind field using the NCEP FNL (Final) Operational Global Analysis data.

FF Emission from ODIAC [10^5 mol km^{-2}h^{-1}]

0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1

XCO_2 [ppm]

396.00 396.75 397.50 398.25 399.00 399.75 400.50 401.25 402.00

Terrain Height

50 300 550 800 1050 1300 1550
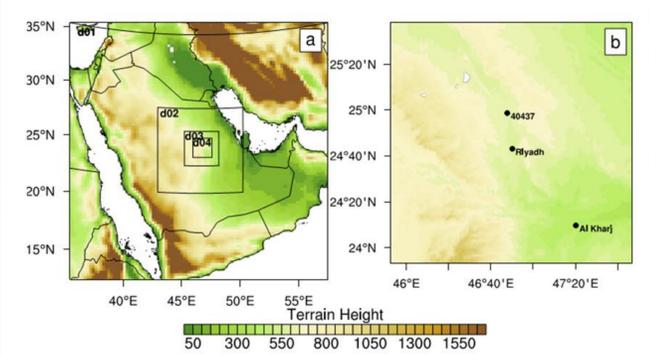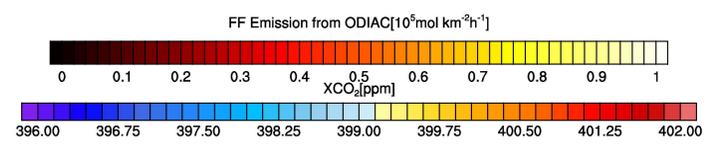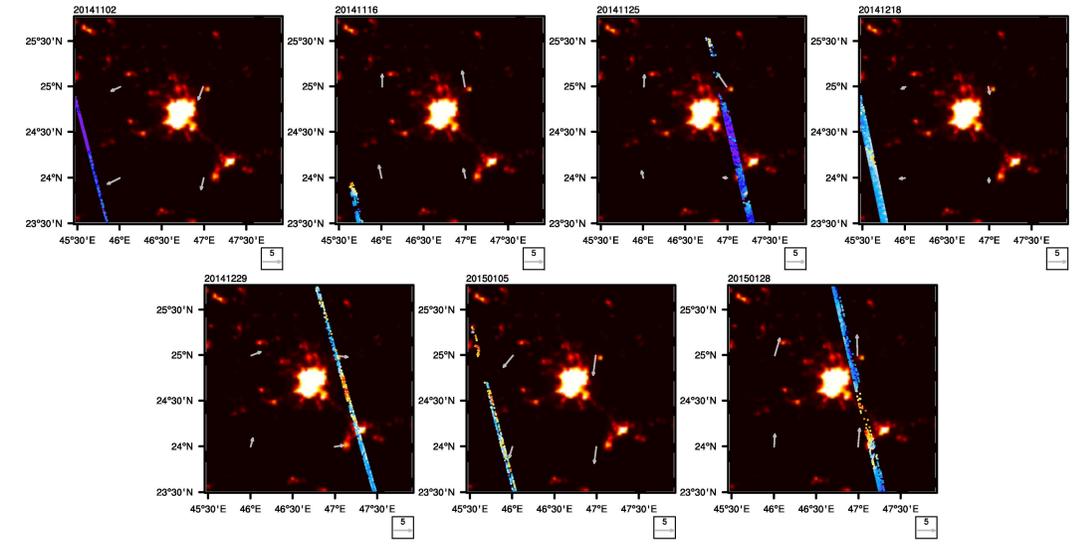
Model resolution and emission structure

• Four one-way nested domains are used in the forward simulation with 27-, 9-, 3-, and 1-km horizontal resolution.

• The structure of urban emission field interpolated onto the model grid is related to the grid resolution as well as the emission center location (marked by '+'). This will result in differences in the CO_2 plumes reproduced by simulation, along with the transport differences due to grid resolution.

Resolution=1 km   Resolution=3 km   Resolution=9 km

Gridded FF Emission from ODIAC [10^6 mol km^{-2}h^{-1}]

0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2 2.2 2.4 2.6 2.8 3 3.2 3.4 3.6 3.8 4
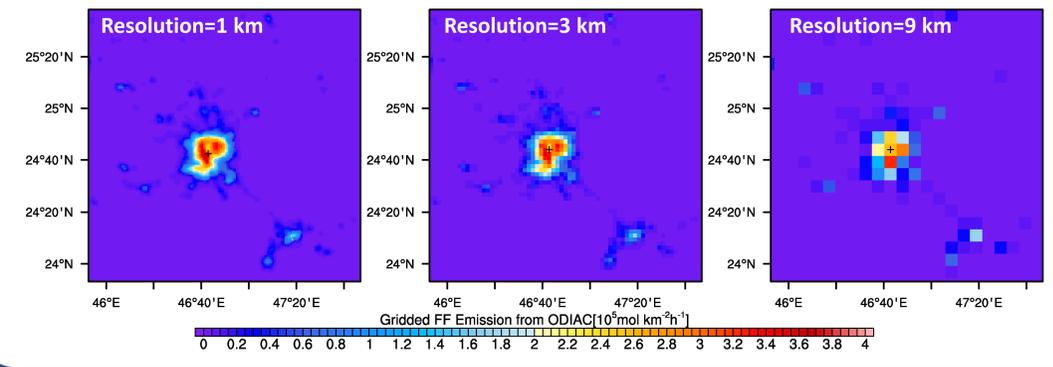
Simulated XCO_2 by WRF-Chem and implications to inverse modeling

10:00 UTC Dec 29, 2014   10:00 UTC Jan 28, 2015

OCO-2: QF=0, WL<=8; QF=0, WL>8; QF=1   Model: res=1 km, res=3 km, res=9 km   Dec 29, 2014 10:00 UTC

OCO-2: QF=0, WL<=8; QF=0, WL>8; QF=1   Model: res=1 km, res=3 km, res=9 km   Jan 28, 2015 10:00 UTC
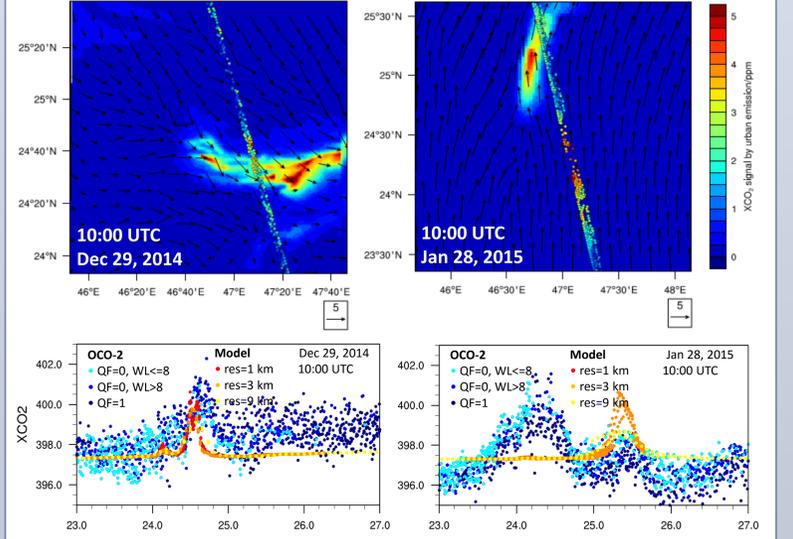
• Two cases are chosen to show the typical scenarios of the reproduction of CO_2 plumes by the forward simulation. In the case on Dec 29 2014, the observed CO_2 enhancement is generally consistent with the simulated values, which will lead to an effective constraint of emissions by inversion method. In the other case on Jan 28 2015, the observed enhancement will yield into unrealistic enhanced emissions in its footprint area.

• For the case on Dec 29 2014, a scaling factor is used to optimize the emissions in Riyadh. The 9-km resolution results give us the best possible optimization, which shows the dependence of inversion on model resolution. Note that this result is also method dependent.

Model: res=1 km, res=3 km, res=9 km   OCO-2: QF=1   Dec 29, 2014 10:00 UTC

res=1 km, res=3 km, res=9 km
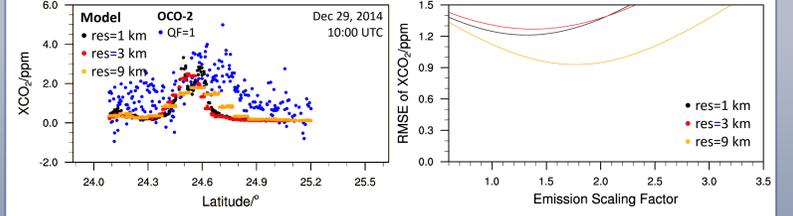
SUMMARY AND FUTURE WORK

❑ OCO-2 XCO_2 provide a promising dataset to improve estimation of emissions, although for urban-scale the spatial and temporal availability is limited due to the narrow swath width and the contamination of aerosols and clouds.

❑ The potential for emission optimization has relation to model resolution, which can differ the gridded emission structure and meteorological condition.

❑ We are currently developing a framework to estimate the potential for emission optimization in urban area statistically.

ACKNOWLEGEMENTS

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