A high-resolution modelling framework for estimating CO_2 emissions of megacities from satellites

N. Kalaitzi [1,2], H. Boesch [1,2], R. J. Parker [1,2], Alex Webb [1,2]

1 Earth Observation Science, Department of Physics and Astronomy, University of Leicester, Leicester, UK

2 National Centre for Earth Observation, Department of Physics and Astronomy, University of Leicester, Leicester, UK

Introduction

- CO_2 is the most important anthropogenic greenhouse gas. The burning of fossil fuels, gas and cement production are its main sources.
- Emissions from urban areas and cities, where human activities are intense, contribute about 70% of global fossil fuel emissions.
- Existing records from bottom-up emission estimates have uncertainties in their values, especially when upscaling to large scales.
- Top-down methods based on atmospheric measurements will help to further verify and validate the city emissions.

Methodology

- We are using NASA's OCO-2 satellite to observe the enhancement of the total column dry air CO_2 mole fraction (XCO_2) from space over megacities such as Los Angeles.
- The OCO-2 satellite, launched in 2014, has a repeat cycle of 16 days with spectral range of 0.758-2.61 μm. OCO-2 can monitor carbon dioxide over individual sources due to the small size of its footprint (~ 4 km^2).
- To link satellite observations to the city emissions, a forward modelling approach needs to be performed to simulate the local enhancement of XCO_2 from the satellite observations using a high resolution transport model as shown by the flowchart in Fig 2.
- We are using a Lagrangian Dispersion Model, NAME, developed by UK Met Office with a horizontal resolution 0.25° x 0.25° and 37 release vertical layers up to 15 km altitude. An example of the model's output is shown in Fig 3.

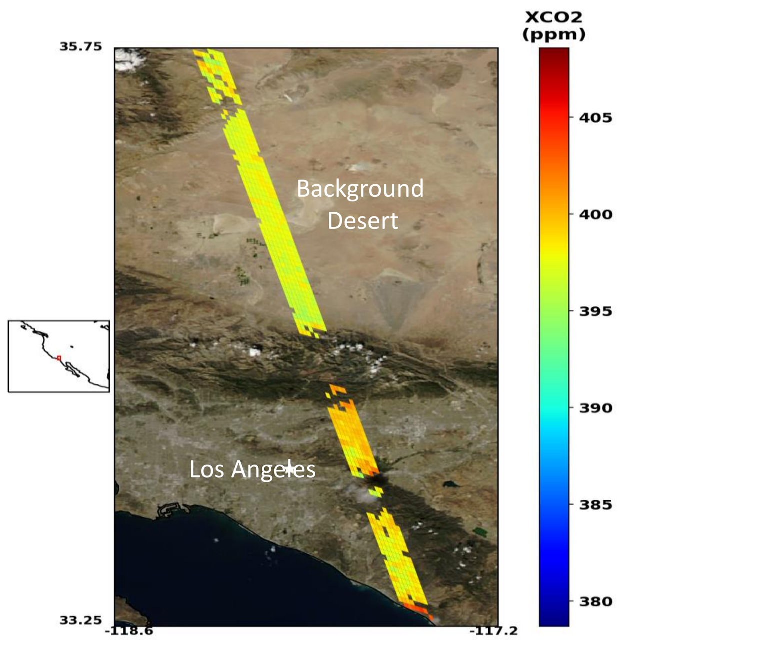

Figure 1: A single overpass of the OCO-2 satellite over Los Angeles.

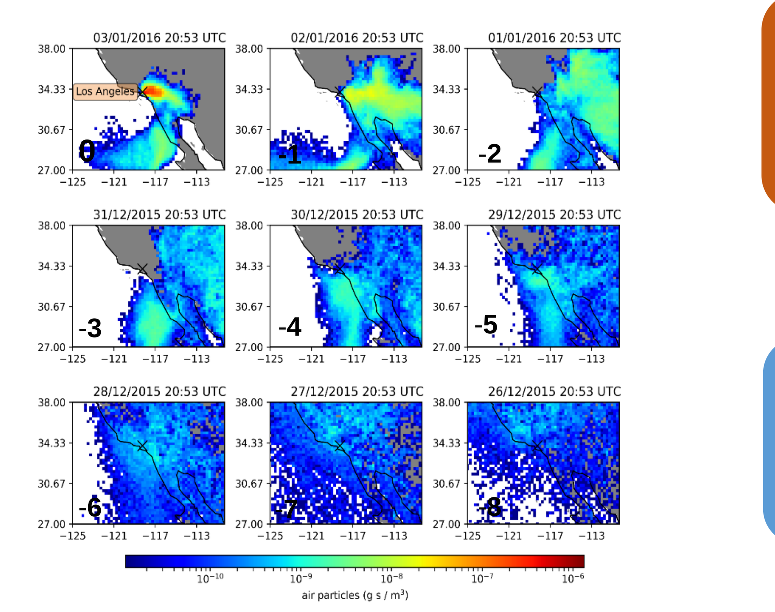

Figure 3: Density of released tracer particles for one OCO-2 sounding location from 8 day back-trajectories on January 3st 2016 at 20:53 UTC with a resolution of 0.25⁰ x 0.25° degree grid at 100 m altitude.

Fundamental Method

$$\text{Obs } (XCO_2 + \Delta XCO_2) = \text{Model } XCO_{2\,\text{Background}} + \text{Model } \Delta XCO_{2\,(\text{Footprint*Emissions})}$$

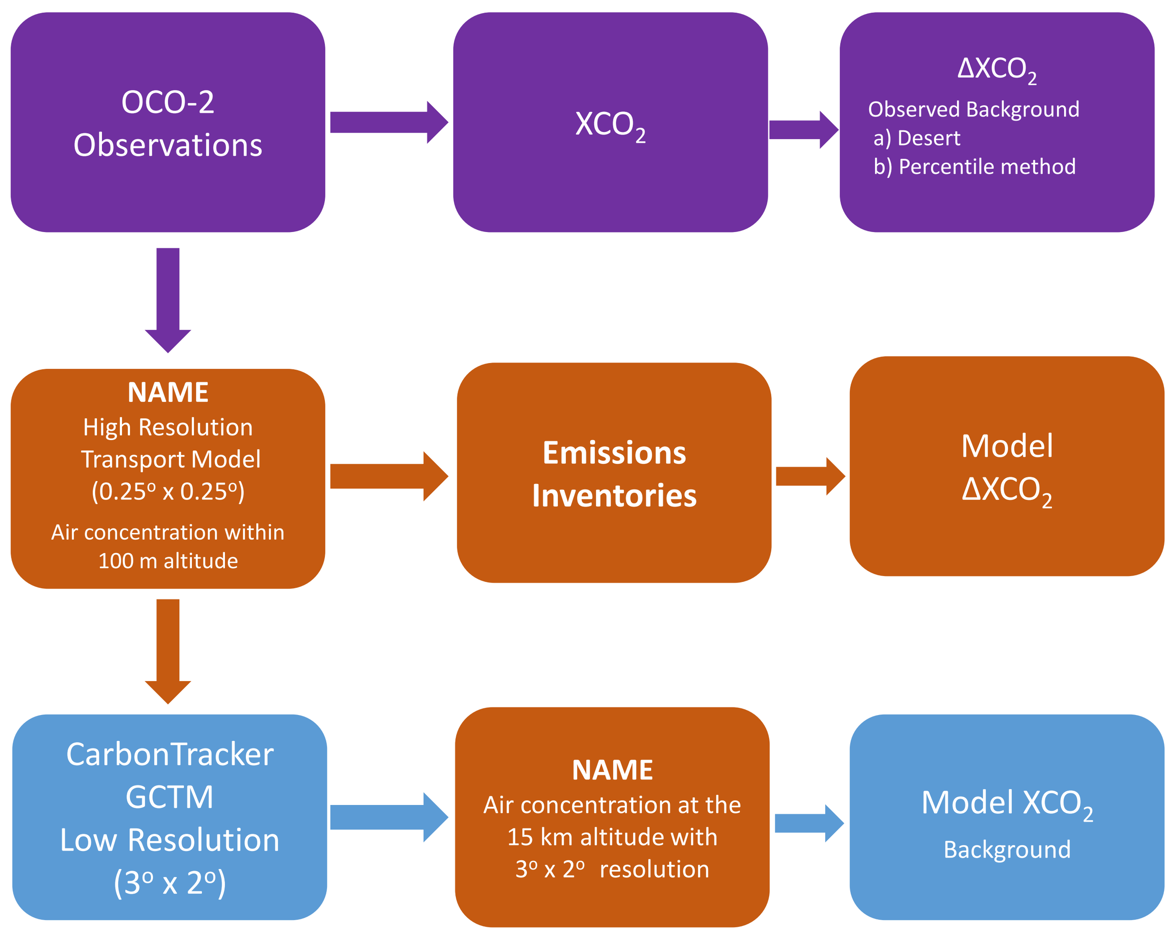

Figure 2: A flowchart of the forward modelling approach.

Case study: Los Angeles

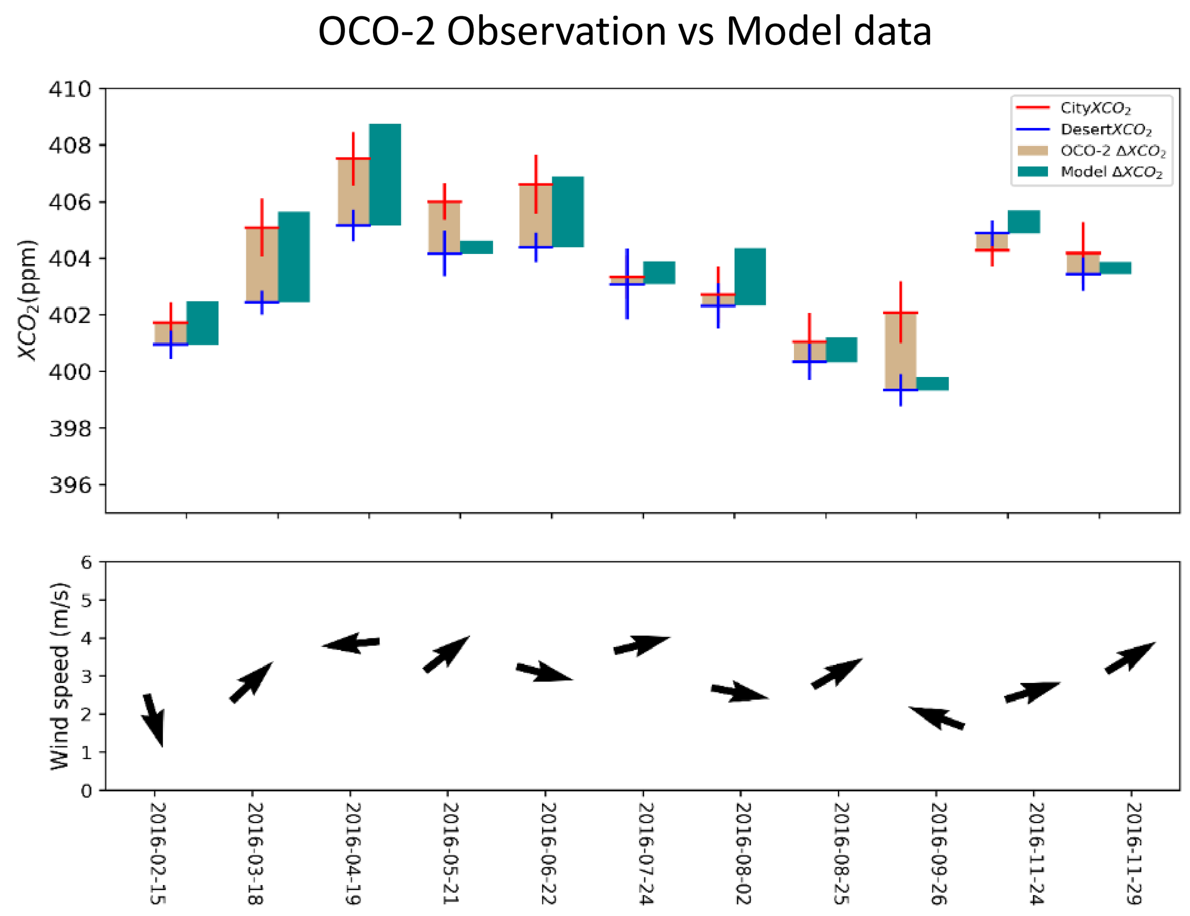

Figure 4: The model enhancement ΔXCO_2 compared the observed enhancement ΔXCO_2 over Los Angels region for the year of 2016.

- The enhancement of ΔXCO_2 observed by OCO-2 using the desert as background is shown by brown bars in Fig 4. The background desert area is shown in Fig 1.
- The modeled enhancement of ΔXCO_2 (green bars) shows similar values to observations with some variability between them.
- This highlights the need to more accurately capture the background concentrations e.g by using a global transport model.
- Wind direction (black arrows) that could influence the enhancement needs to be considered, calculated from the background boundary domain.

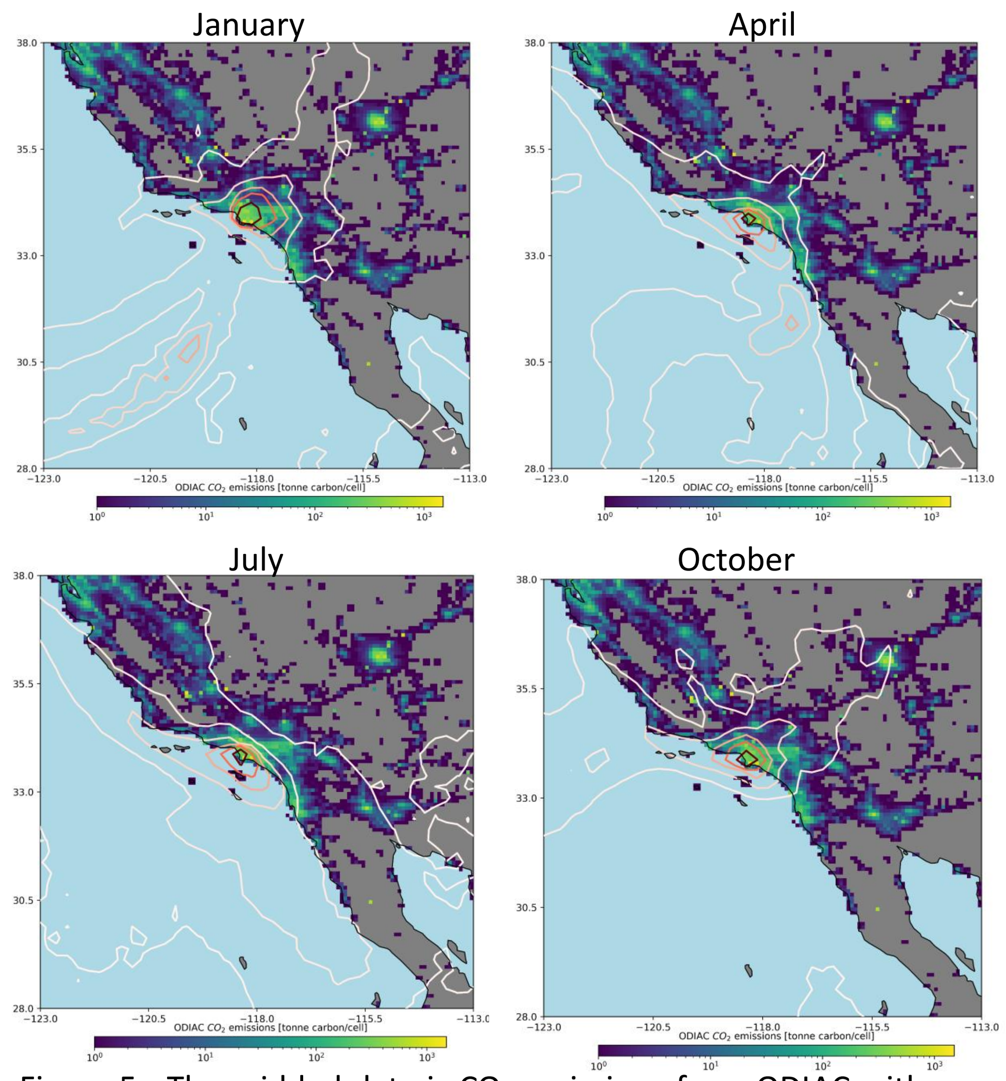

Figure 5: The gridded data is CO_2 emissions from ODIAC with a 1 x 1 km resolution in a monthly scale combined with the monthly column footprints with 0.25° x 0.25° shown by the contour lines.

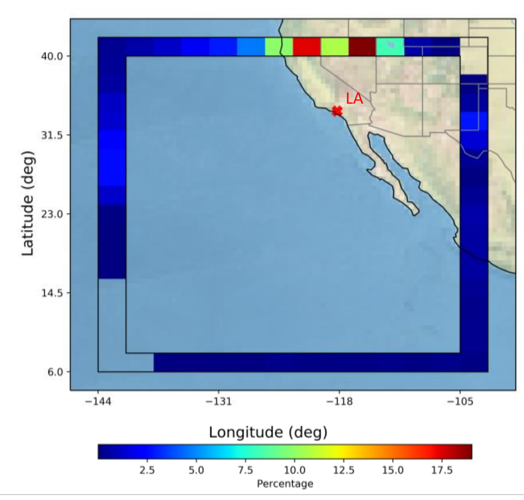

Figure 7: The selected boundary grid boxes represent the background domain produced by running NAME with the same resolution as CarbonTracker with 3° x 2° resolution.

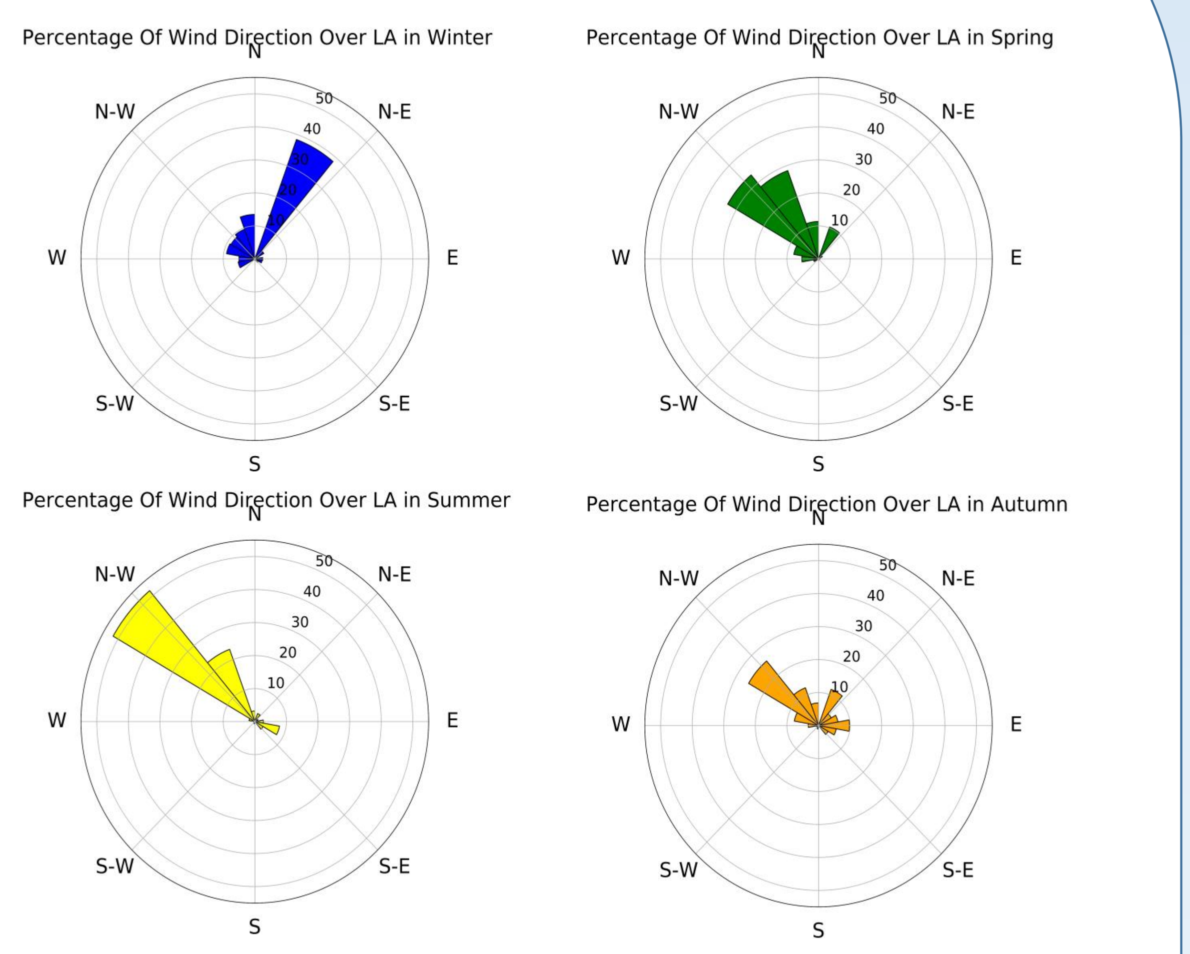

Figure 6: The seasonal polar plots showing wind direction reaching the boundary domain from Los Angeles. Values are given as percentages of the total air particles per season

- The background air particle direction varies depending on the season as shown in Fig 6.
- The N-E wind direction translates to less clear background since air from the mainland could be mixed with emissions from other inland cities.
- 50% of the air is coming from N-W (sea) direction during summer.
- The modelled background domain is shown in Fig 7.

Future work

- A high resolution modelling framework has been developed that is used to interpret column observations from OCO-2 over cities.
- We will now couple it with a global model to better capture the background concentrations of the air that enters the modelling domain.
- We will update the used surface fluxes by using daily emission data and include biogenic fluxes.
- The modelling framework will be combined with an Inverse Method that will allow us to estimate fluxes from satellite observations.

Contact: nk274@Leicester.ac.uk