CO_2 Emissions from C40 Cities: Citywide Emission Inventories, Global Gridded Emission Datasets, and Satellite Data

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1. Introduction

- More than 1,100 global cities have signed onto the Race to Zero campaign (net-zero by 2050)
- The need for accurate greenhouse gas emission tracking methods has become critical
- This study attempts to form bridges between the three emission calculation methods:
  1) the city-scale emission accounting method used by C40 cities (GPC)
  2) the global-scale gridded emission datasets (EDGAR and ODIAC)
  3) Satellite observations-derived CO_2 emission estimates (NASA OCO-3)

2. Citywide Emission Inventories (GPC): Per-capita CO_2 Emissions

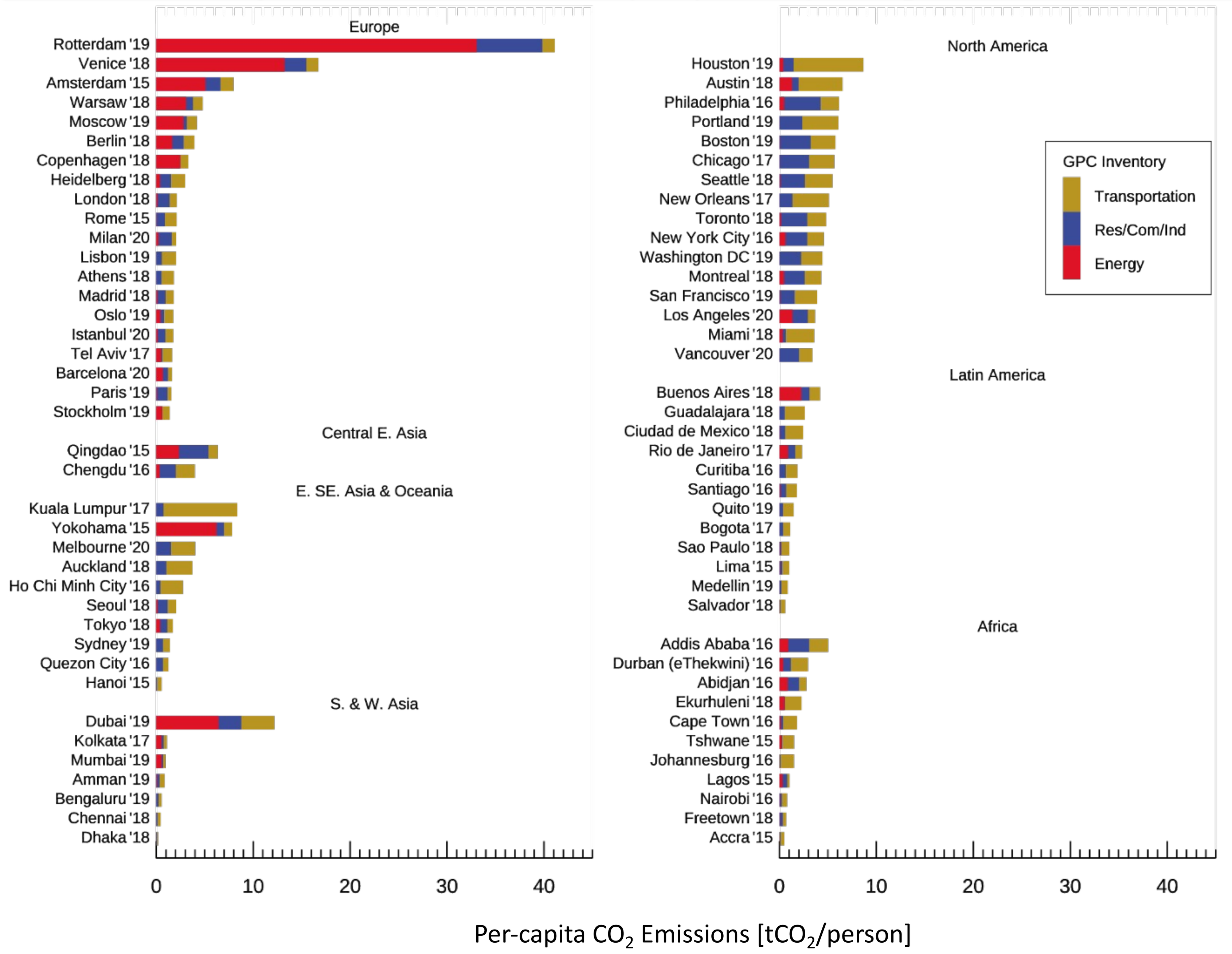

Figure 1. Per-capita CO_2 emissions in the GPC inventories submitted by 78 C40 cities.

❖ Cities with power plants within their geographical boundary tend to have larger CO_2 emissions

3. Citywide Emission Inventories (GPC): Trends in CO_2 Emissions

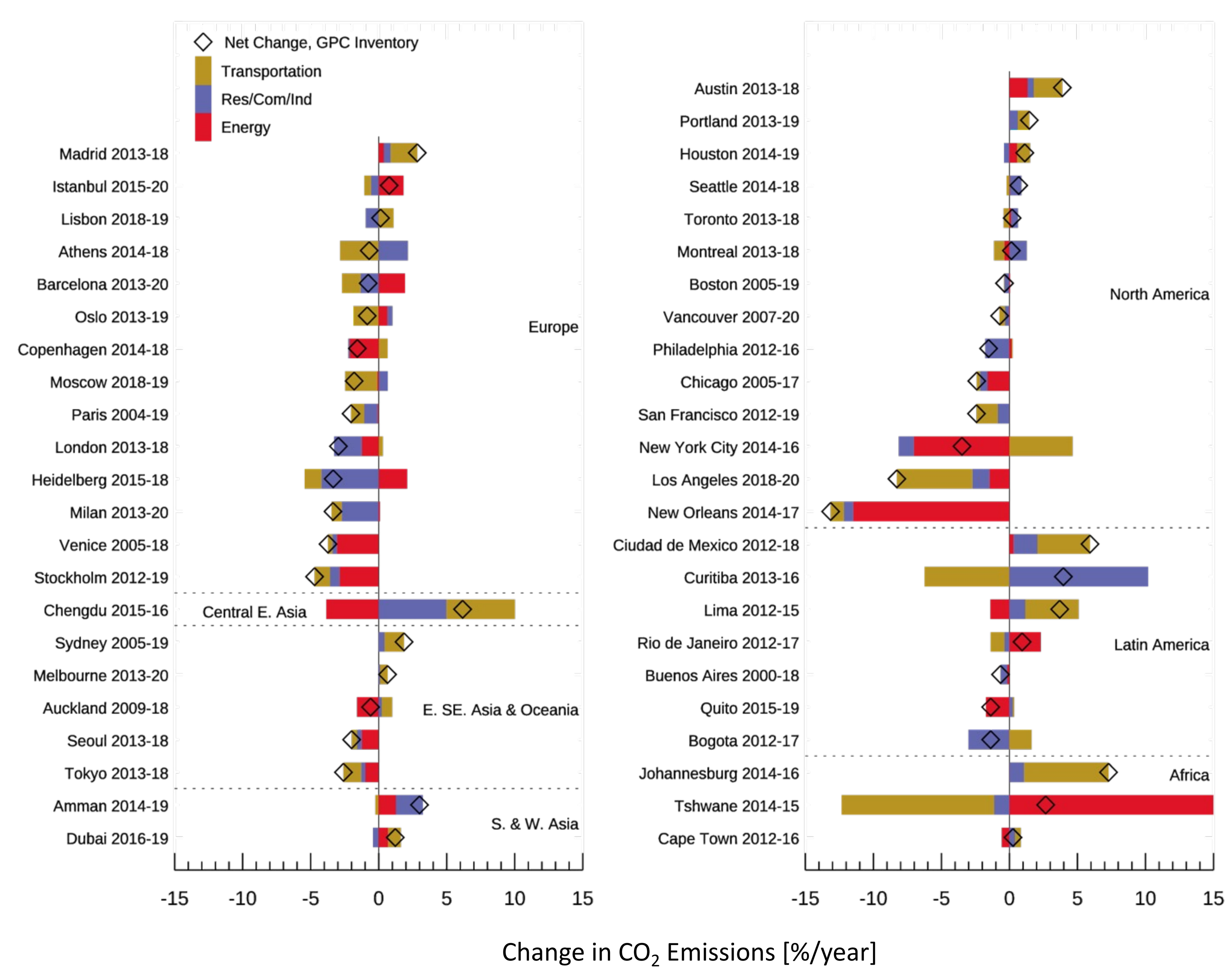

Figure 2. Changes in CO_2 emissions between the earliest and latest GPC inventories for 46 C40 cities

❖ Of the 46 C40 cities, 25 cities show declines in CO_2 emissions over time (median decrease 9%)

4. Global Gridded Emission Datasets: ODIAC and C40 Cities

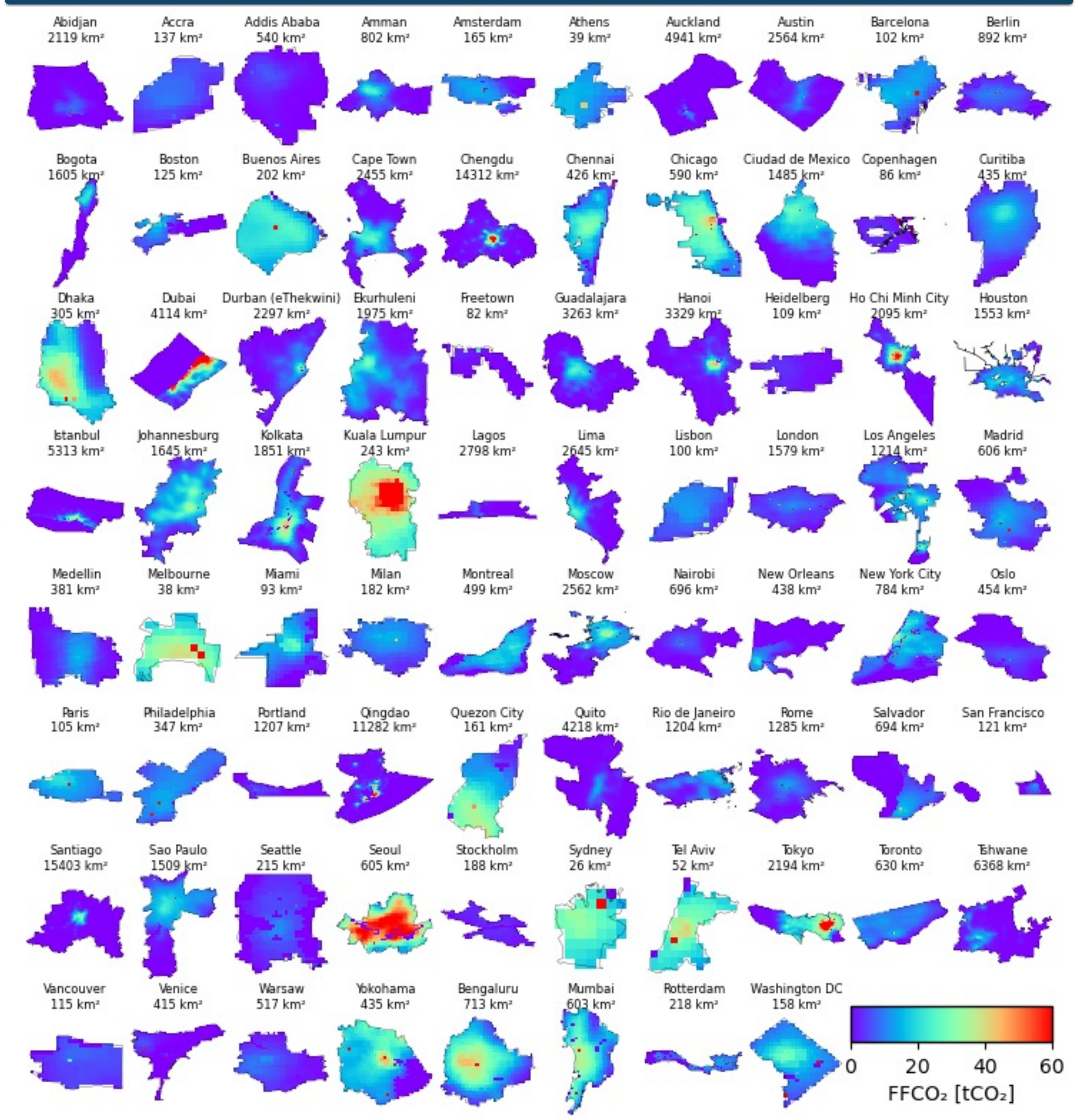

Figure 3. The 78 C40 cities analyzed in this study. Color scales show ODIAC CO_2 emissions

❖ ODIAC resolves spatial gradient of urban CO_2 emissions with C40 city boundaries

5. CO_2 Emission Trends: Citywide Inventories vs Global Gridded Datasets

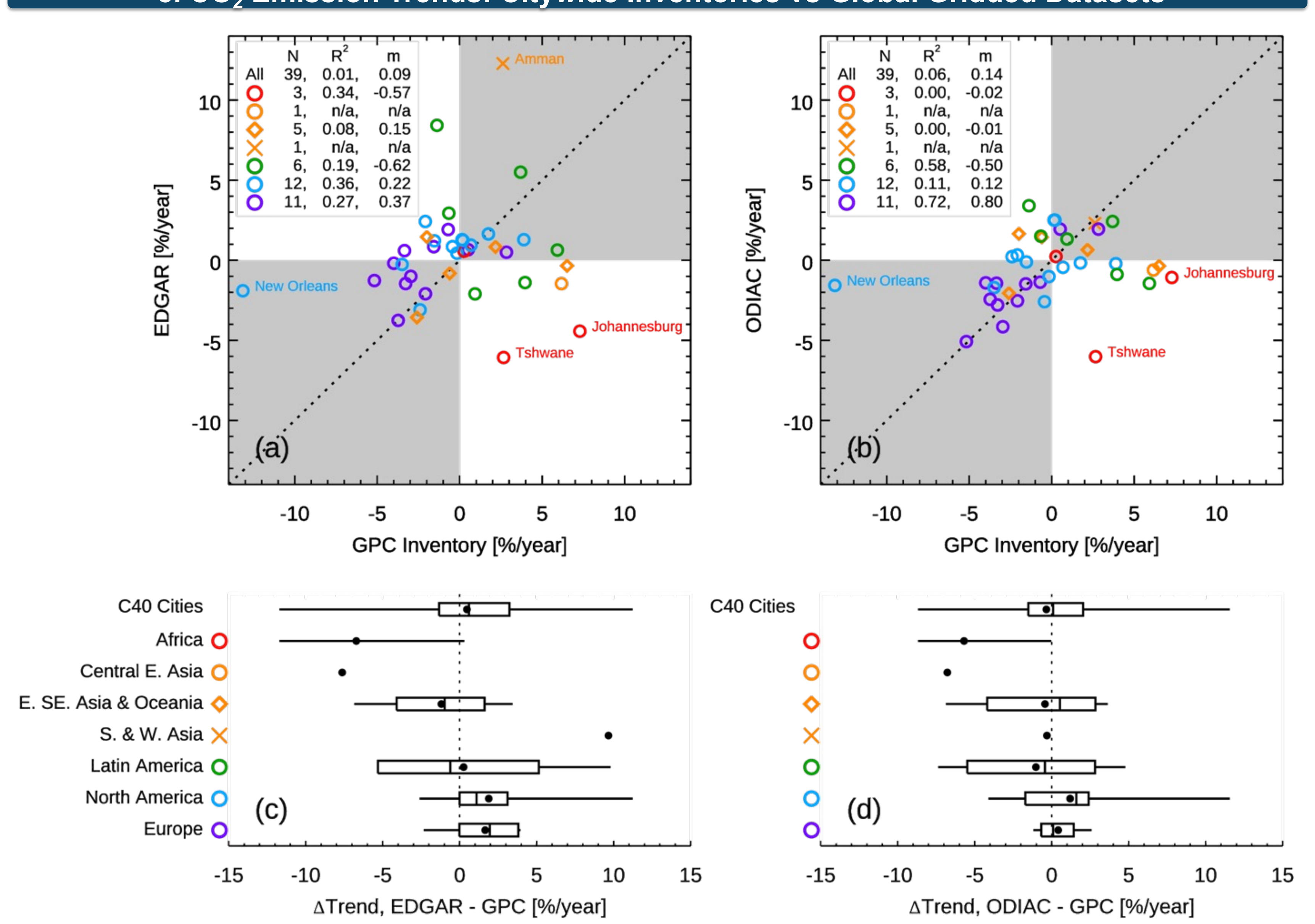

Figure 4. The CO_2 emission trends estimated from the GPC inventory, EDGAR, and ODIAC

❖ EDGAR vs GPC: 0.5 ± 4.7 %/yr and ODIAC vs GPC: −0.3 ± 3.9 %/yr

❖ Such variabilities are a factor of 3-4 greater than −1.3%/yr (net zero by 2050 from 2010)

6. Satellite Observations: OCO-3 and TROPOMI over Los Angeles, USA

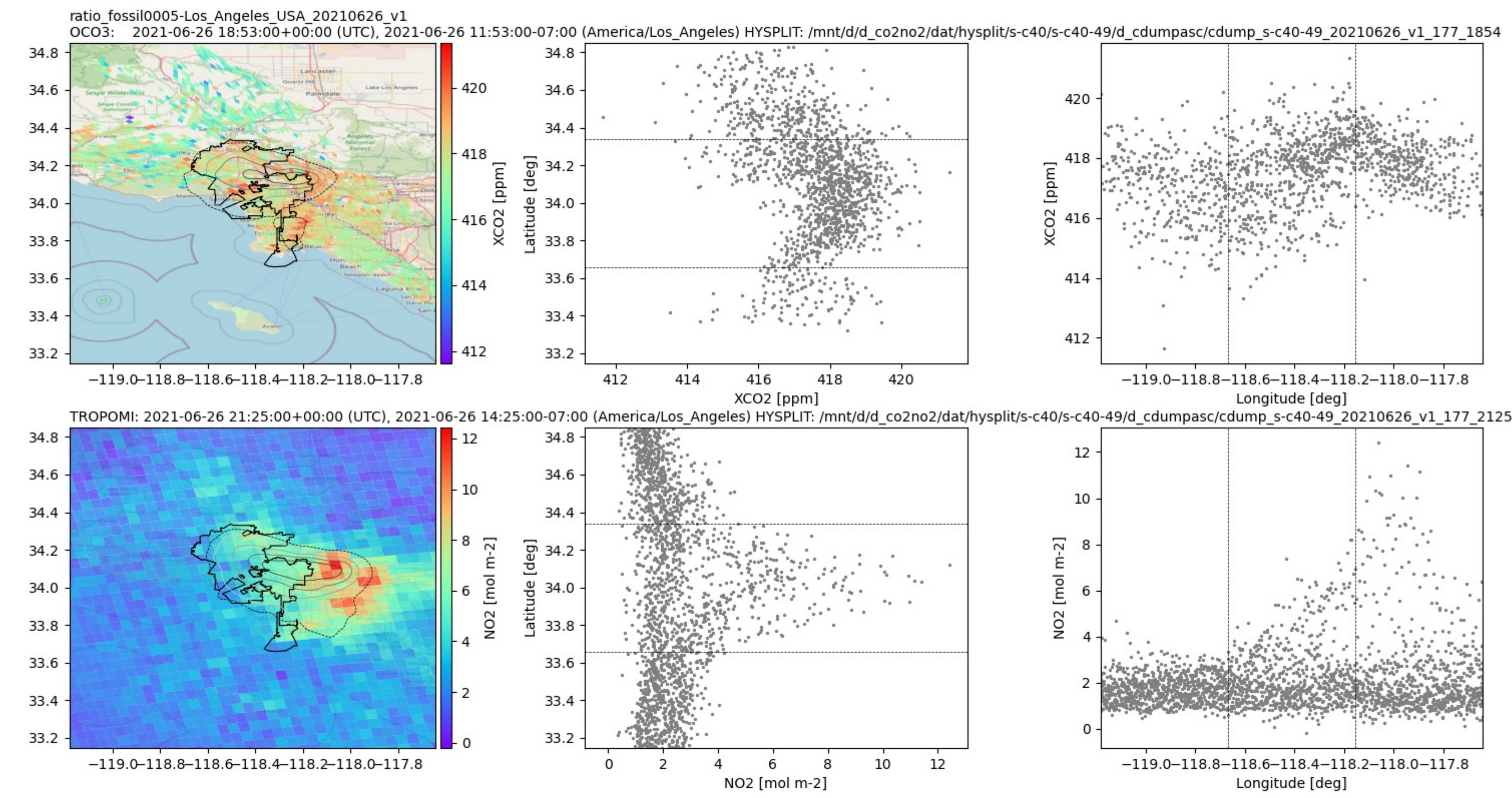

Figure 5. Satellite observations of atmospheric CO_2 and NO_2 over Los Angeles, USA on June 26th 2021. The upper panels show XCO_2 observations from NASA OCO-3 satellite. The lower panels show NO_2 observations from ESA TROPOMI satellite. Black solid line on the map indicates the administrative boundary of Los Angeles, USA. Black dotted lines on the map indicate the shape of polluted air plume from Los Angeles, USA.

❖ Co-located OCO-3 and TROPOMI data found for 46 C40 cities

❖ On average, each city has 19 days of co-located observation (Min: 3, Max:49, 2019-08 ~ 2021-11)

❖ TROPOMI NO_2 data show relatively clear enhancement signal over the city domain than OCO-3

❖ TROPOMI NO_2 data can be utilized to distinguish urban CO_2 plume signals from OCO-3 XCO2 data

❖ Urban plume shapes simulated from HYSPLIT model match to the satellite pixel locations where enhanced atmospheric CO_2 and NO_2 were observed

7. Conclusions

- For the 78 C40 cities, the average sectoral composition were 51% for transportation, 32% for residential/commercial/industrial, and 17% for energy sectors.
- Of the 46 cities that have reported emissions for multiple accounting years, 25 cities have shown declines in emissions since the first reporting year
- We found significant variabilities in the CO_2 emission trend estimates between GPC, EDGAR, and ODIAC
- Satellite-driven emission estimates will bridge gaps between city inventories and gridded datasets
- TROPOMI NO_2 and HYSPLIT model can be used to determine OCO-3 soundings that are influenced by urban plume from relatively clean background air

8. Next Steps

- Develop an algorithm that determines the satellite soundings influenced by urban plume using HYSPLIT plume dispersion and TROPOMI NO_2 data
- Calculate enhanced XCO2 over 46 C40 cities that have OCO-3 overpass data
- Run STILT model to calculate footprint for each OCO-3 satellite sounding
- Compute city-wide CO_2 emissions using enhanced XCO2 estimates and STILT footprint

9. Acknowledgements

The C40 GHG Dashboard data are obtained from the C40 knowledge hub website. Geographical boundary shapefiles are obtained via communication with C40. Annual sector-specific EDGARv6.0 for fossil CO_2 sources are obtained from the JRC EDGAR website. The version of the ODIAC data product (ODIAC2020b) is available from the Global Environ-mental Database website hosted by the Center for Global Environmental Research (CGER), National Institute for Environmental Studies (NIES), Japan. The authors appreciate the helpful comments provided by Tomohiro Oda at the Universities Space Research Association (USRA). NOAA HYSPLIT model was downloaded from the NOAA Air Resources Laboratory website. NASA OCO-3 data were produced by the OCO-3 project at the Jet Propulsion Laboratory, California Institute of Technology, and obtained from the OCO-3 data archive maintained at the NASA Goddard Earth Science Data and Information Services Center. TROPOMI NO_2 data can be downloaded from the European Space Agency Copernicus Open Access Hub. This work was supported by a grant from the Wellcome Trust (Award No. 216075/Z/19/Z).