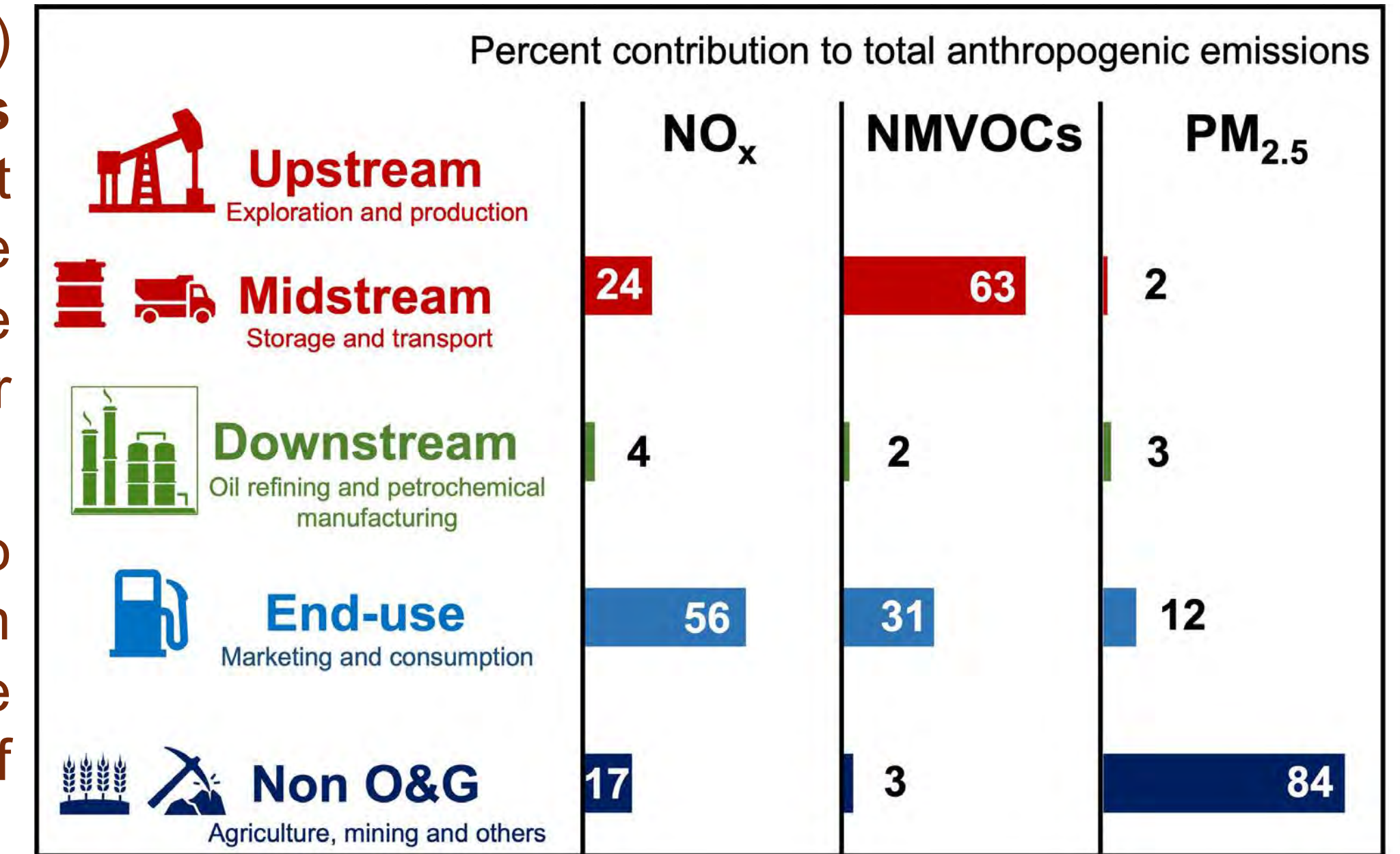


1. INTRODUCTION

- Texas is the largest oil and gas (O&G) producing state in the US. Recent (mid-2010s) increases in production and lack of enforcement of regulations targeting activities such as flaring is leading to a rapid increase in air pollution (*Cushing et al., 2021, Dix et al., 2019*).
- Previous studies have focused on end use (*Vohra et al., 2021*) or the collective sector (*Fann et al., 2018*).
- Here we use updated emissions estimates for 2017 and GEOS-Chem at high spatial resolution (25-31 km) to quantify the impact of major segments in the O&G lifecycle on air quality and health in Texas.

2. UPDATED EMISSIONS INVENTORY

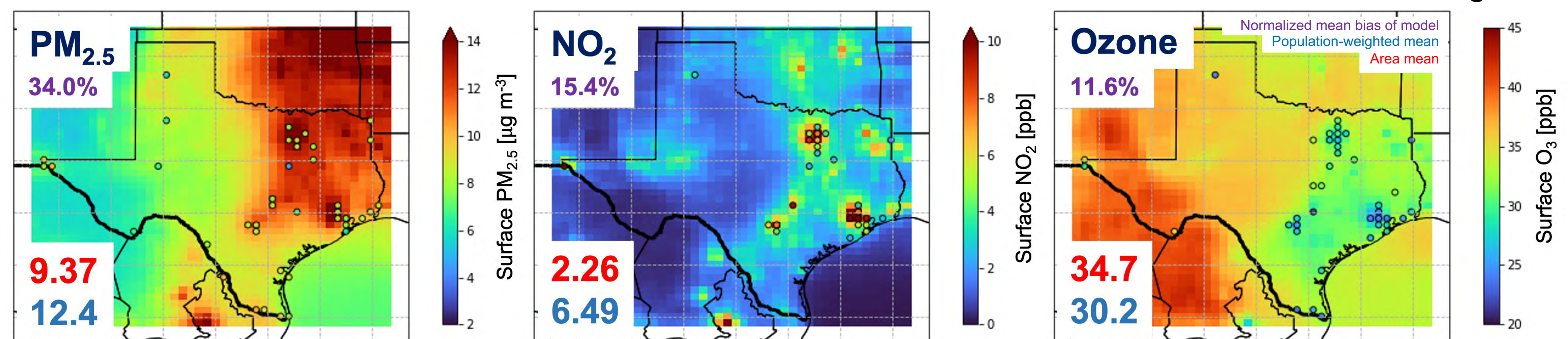
- US EPA National Emissions Inventory (NEI) reports emissions data for **oil and gas production**. Here, we use NEI 2017 for point and area sources from each O&G lifecycle segment and mobile sources for end-use emissions from the Fuel-based Inventory for Vehicular Emissions (*Harkins et al., 2021*).
- Texas O&G lifecycle contribution to anthropogenic emissions is 84% of nitrogen oxides (NO_x), 97% of non-methane volatile organic compounds (NMVOCs) and 16% of primary fine particles (PM_{2.5}) emissions.



3. GEOS-CHEM MODEL: SIMULATIONS AND PERFORMANCE

- We use the 3D chemical transport model GEOS-Chem (v13.0.0) nested over Texas at 0.25° × 0.3125° to simulate surface concentrations of pollutants hazardous to human health.
- The model overestimates air pollutant concentrations by 12-15% for NO₂ and ozone and more (34%) for PM_{2.5} due to a known bias in nitrate aerosol in winter (*Shah et al., 2018*).

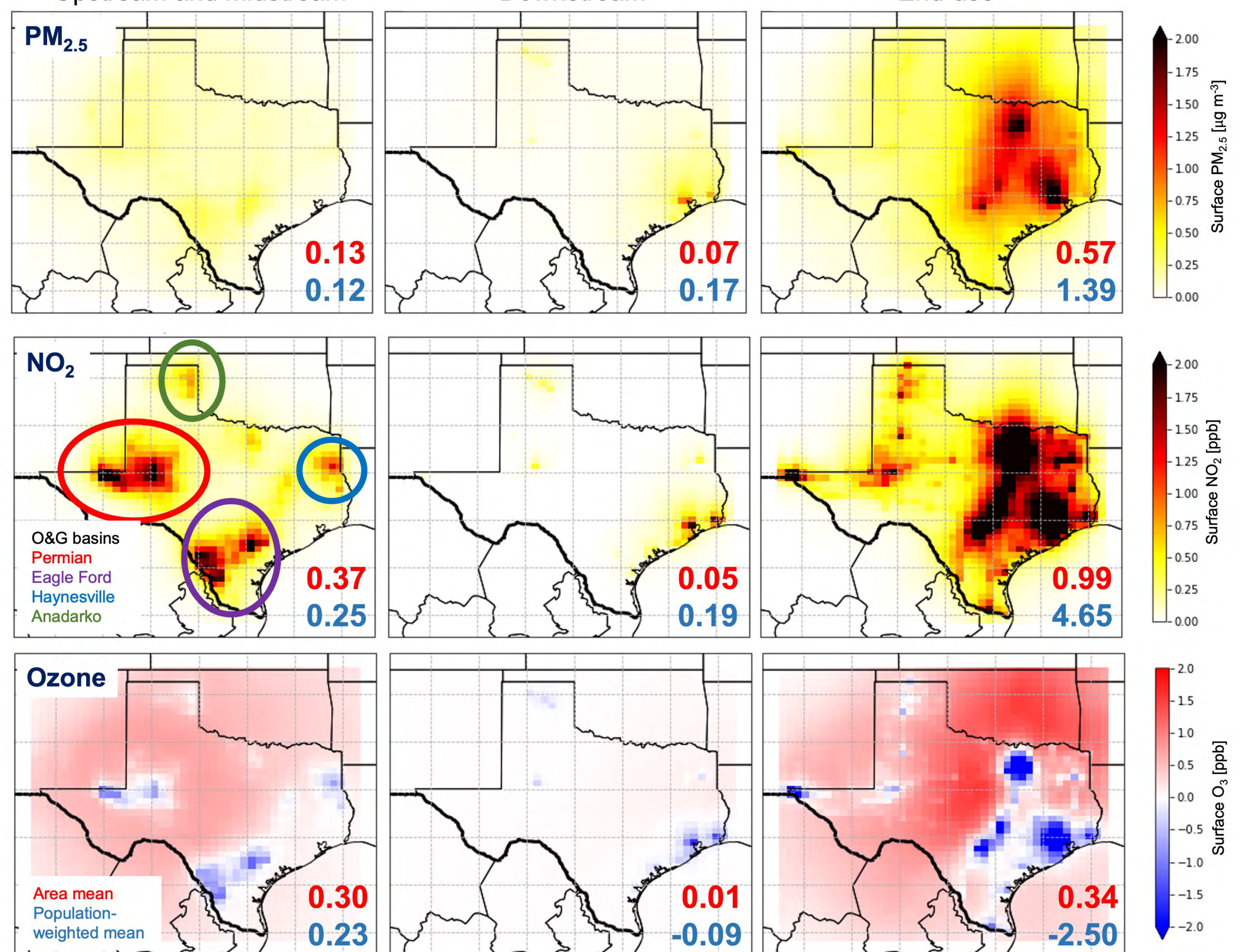
Simulated surface concentrations for the base simulation over Texas in 2017. Circles are US EPA monitoring sites.



4. AIR POLLUTION IN TEXAS FROM MAJOR OIL AND GAS SEGMENTS

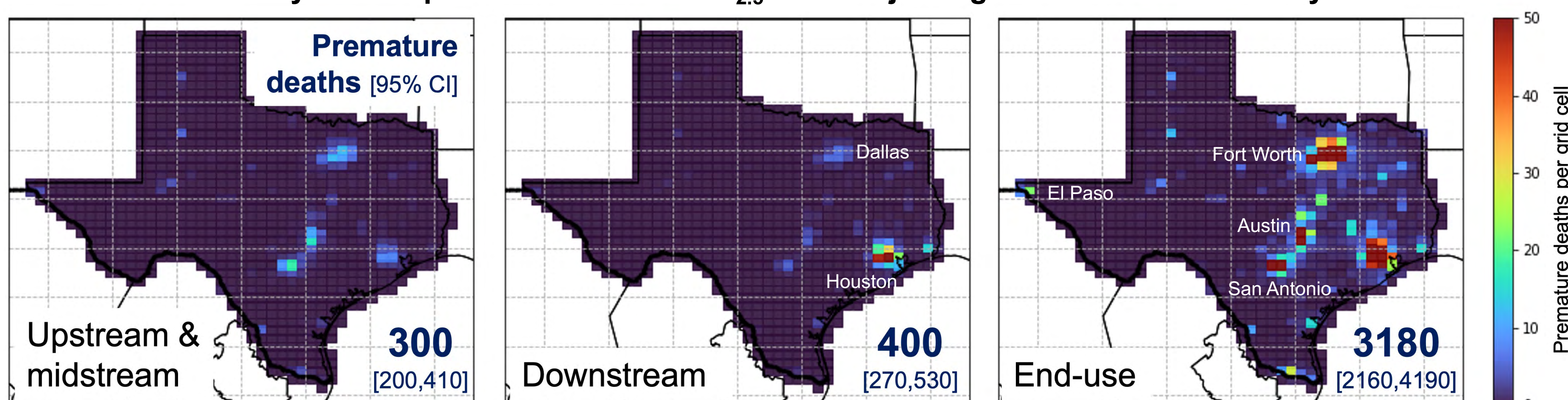
- We run sensitivity simulations by turning off emissions from major segments in the O&G lifecycle in Texas. The difference between the base simulation and sensitivity simulations is used to determine the contribution of the O&G lifecycle segment to pollutant concentration.
- O&G activities in Texas contribute to 0.77 µg m⁻³ (8.2%) of PM_{2.5}. Most of it is from end-use (0.57 µg m⁻³) dominated by on-road mobile sources.
- 62% of NO₂ (1.41 ppb) in Texas from O&G activities. 0.99 ppb from end-use and 0.37 ppb from upstream and midstream activities such as flaring and use of compressor engines in **Permian**, **Eagle Ford**, **Haynesville** and **Anadarko** basins.
- Texas O&G lifecycle also contributes to PM_{2.5} in neighbouring regions in the nested domain (**0.59 µg m⁻³ in Oklahoma, 0.48 µg m⁻³ in Louisiana, 0.18 µg m⁻³ in New Mexico, and 0.19 µg m⁻³ in Mexico**)
- Most PM_{2.5} and NO₂ from end-use activities is in regions surrounding major cities in Texas and so the population-weighted mean is higher than the area mean.
- Decline in ozone occurs at NO₂ hotspots in Texas. Urban population exposure to ozone decreases due to NO_x titration.

Simulated surface concentrations from the major segments in the O&G lifecycle over Texas in 2017



5. HEALTH IMPACT ASSESSMENT

Premature mortality from exposure to ambient PM_{2.5} from major segments in the O&G lifecycle in Texas



- We estimate adult (>14 years old) premature deaths from long-term PM_{2.5} exposure using population data at 100 m resolution, county-level baseline mortality rates and an updated health risk assessment model (*Vodanis et al., 2018*) which includes more cohort studies at low PM_{2.5} concentrations (<10 µg m⁻³) and estimates higher relative risk at such low concentrations than previous health risk assessment models (*Burnett et al., 2014; 2018*).
- 3,880** premature deaths in 2017 from PM_{2.5} exposure linked to Texas O&G activities (**82%** from end-use, **10%** from downstream and **8%** from upstream activities).

6. CONCLUSIONS

- End-use activities make the largest contribution (70-75%) to PM_{2.5} and NO₂ from Texas O&G lifecycle, followed by combined upstream and midstream (17-26%) and downstream (4-9%) activities. End-use and downstream activities are in populated areas and so PM_{2.5}-attributable premature deaths from these is higher (82% and 10% respectively) than from upstream activities (8%).
- O&G production has grown by over 30% since 2017, so the current impact on health may be more severe than we estimate.