Health burden of air pollution from the oil and gas lifecycle in Texas

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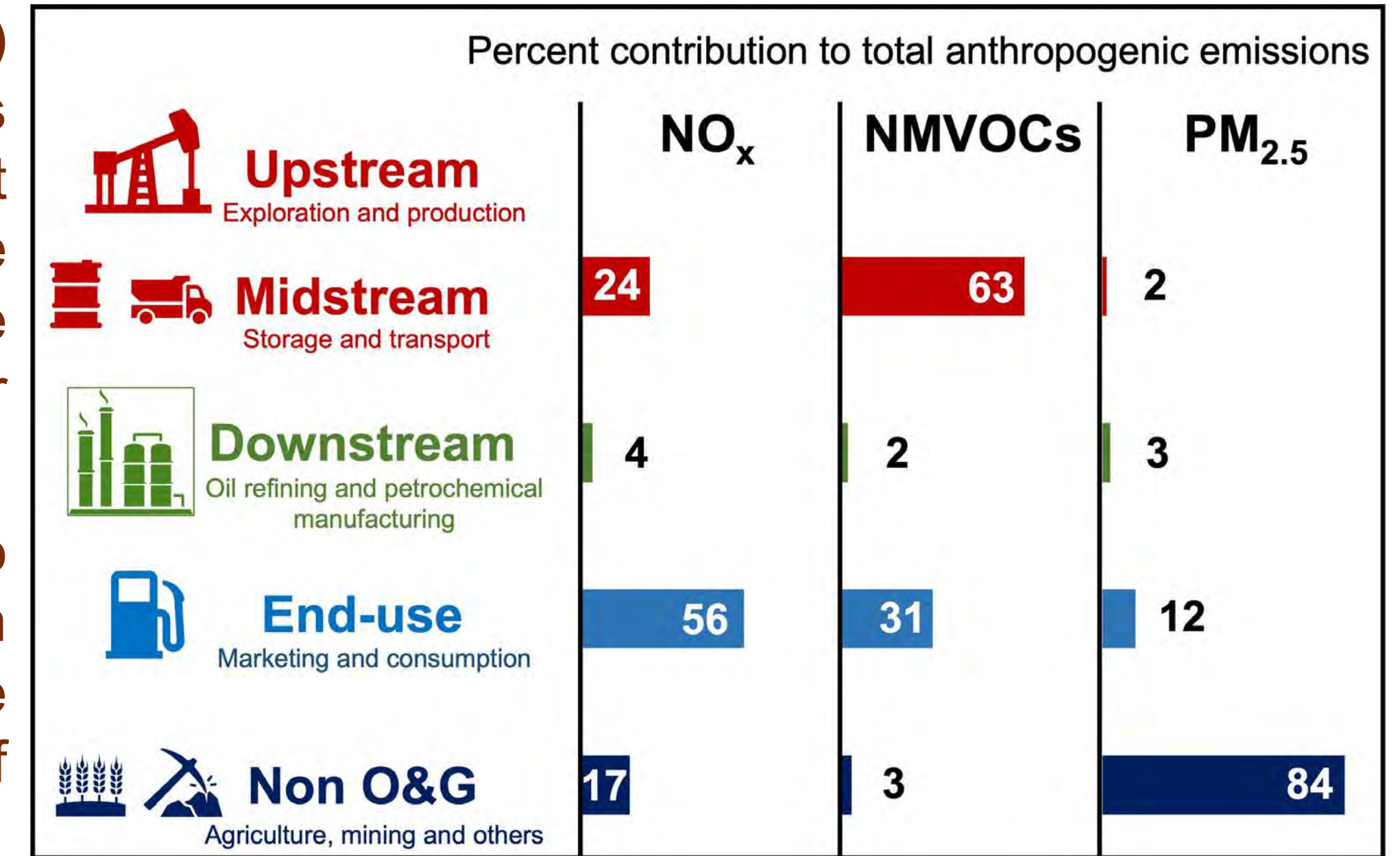UCL · SEI Stockholm Environment Institute · University of Colorado Boulder · NOAA

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.

Percent contribution to total anthropogenic emissions

	NO_x	NMVOCs	$PM_{2.5}$
Upstream Exploration and production	24	63	2
Midstream Storage and transport			
Downstream Oil refining and petrochemical manufacturing	4	2	3
End-use Marketing and consumption	56	31	12
Non O&G Agriculture, mining and others	17	3	84

3. GEOS-CHEM MODEL: SIMULATIONS AND PERFORMANCE

- We use the 3D chemical transport model GEOS-Chem (v13.0.0) nested over Texas at $0.25° \times 0.3125°$ to simulate surface concentrations of pollutants hazardous to human health.
- The model overestimates air pollutant concentrations by 12-15% for NO_2 and ozone and more (34%) for $PM_{2.5}$ due to a known bias in nitrate aerosol in winter (*Shah et al., 2018*).
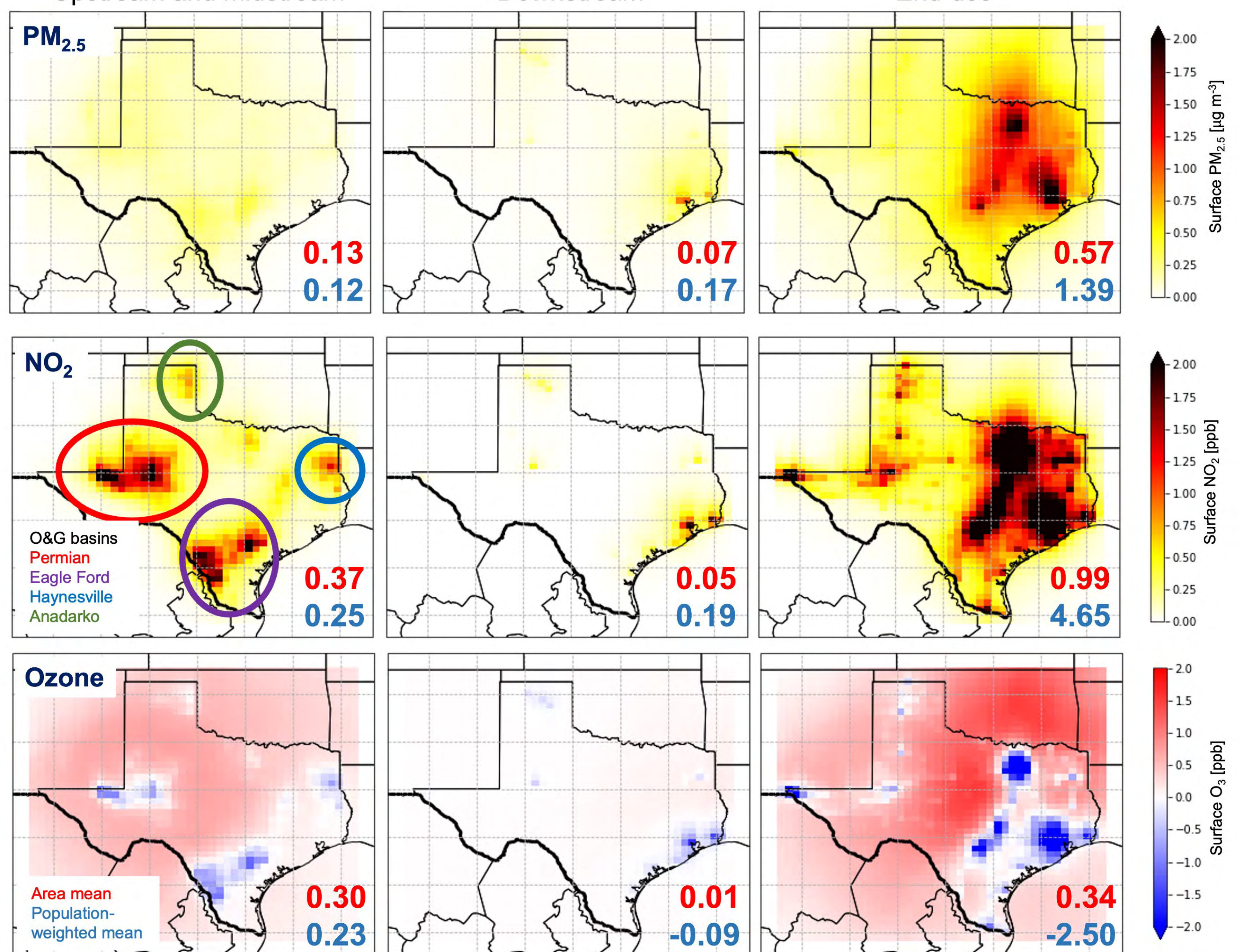
Simulated surface concentrations for the base simulation over Texas in 2017. Circles are US EPA monitoring sites.

PM2.5 — 34.0% — 9.37 — 12.4
NO2 — 15.4% — 2.26 — 6.49
Ozone — 11.6% — 34.7 — 30.2
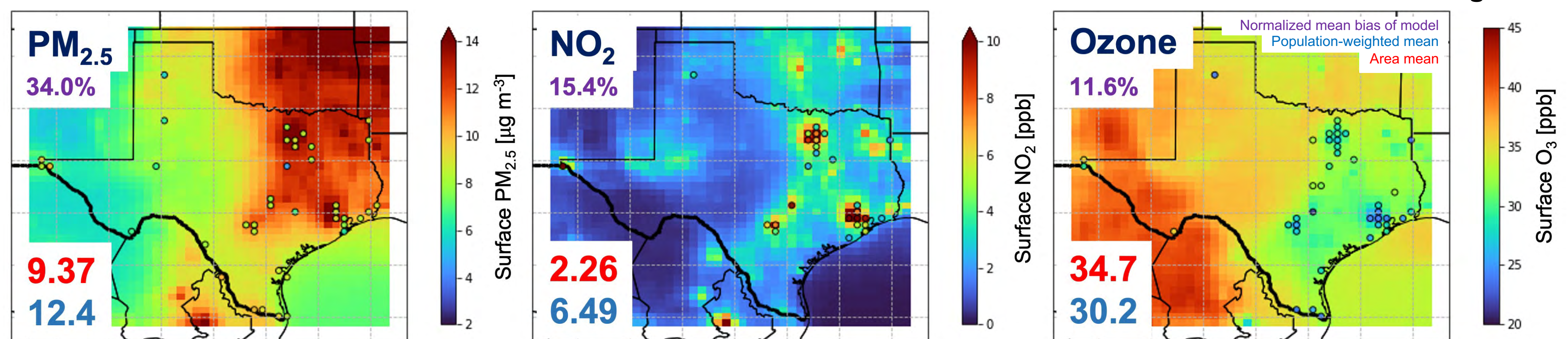
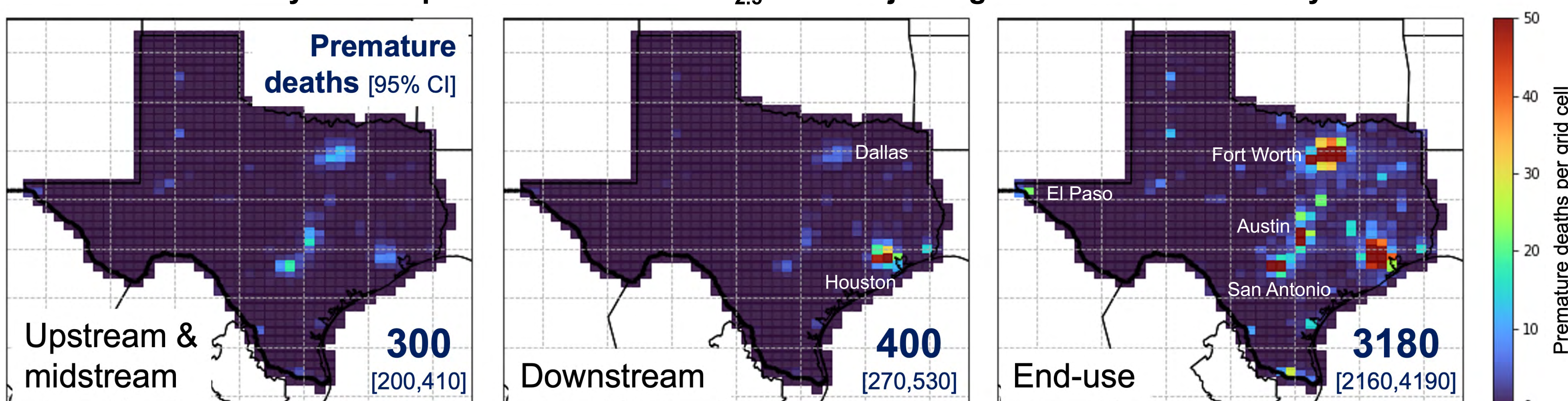## 4. AIR POLLUTION IN TEXAS FROM MAJOR OIL AND GAS SEGMENTS

- 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 NO_2 (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 NO_2 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 NO_2 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

Upstream and midstream | Downstream | End-use

PM2.5: 0.13 / 0.12 — 0.07 / 0.17 — 0.57 / 1.39

NO2: 0.37 / 0.25 — 0.05 / 0.19 — 0.99 / 4.65
O&G basins: Permian, Eagle Ford, Haynesville, Anadarko

Ozone (Area mean / Population-weighted mean): 0.30 / 0.23 — 0.01 / -0.09 — 0.34 / -2.50

5. HEALTH IMPACT ASSESSMENT

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

Premature deaths [95% CI]
Upstream & midstream: 300 [200,410]
Downstream: 400 [270,530] (Dallas, Houston)
End-use: 3180 [2160,4190] (El Paso, Fort Worth, Austin, San Antonio)

- 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 (*Vodonos 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 NO_2 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.

REFERENCES
Burnett et al., doi:10.1289/ehp.1307049, 2014
Burnett et al., doi:10.1073/pnas.1803222115, 2018
Cushing et al., doi:10.1088/1748-9326/abd3d4, 2021
Dix et al., doi:10.1029/2019GL085866, 2019
Fann et al., doi:10.1021/acs.est.8b02050, 2018
Harkins et al., doi:10.1088/1748-9326/ac0660, 2021
Shah et al., doi:10.1073/pnas.1803295115, 2018
Vodonos et al., doi:10.1016/j.envres.2018.06.021, 2018
Vohra et al., doi:10.1016/j.envres.2021.110754, 2021

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