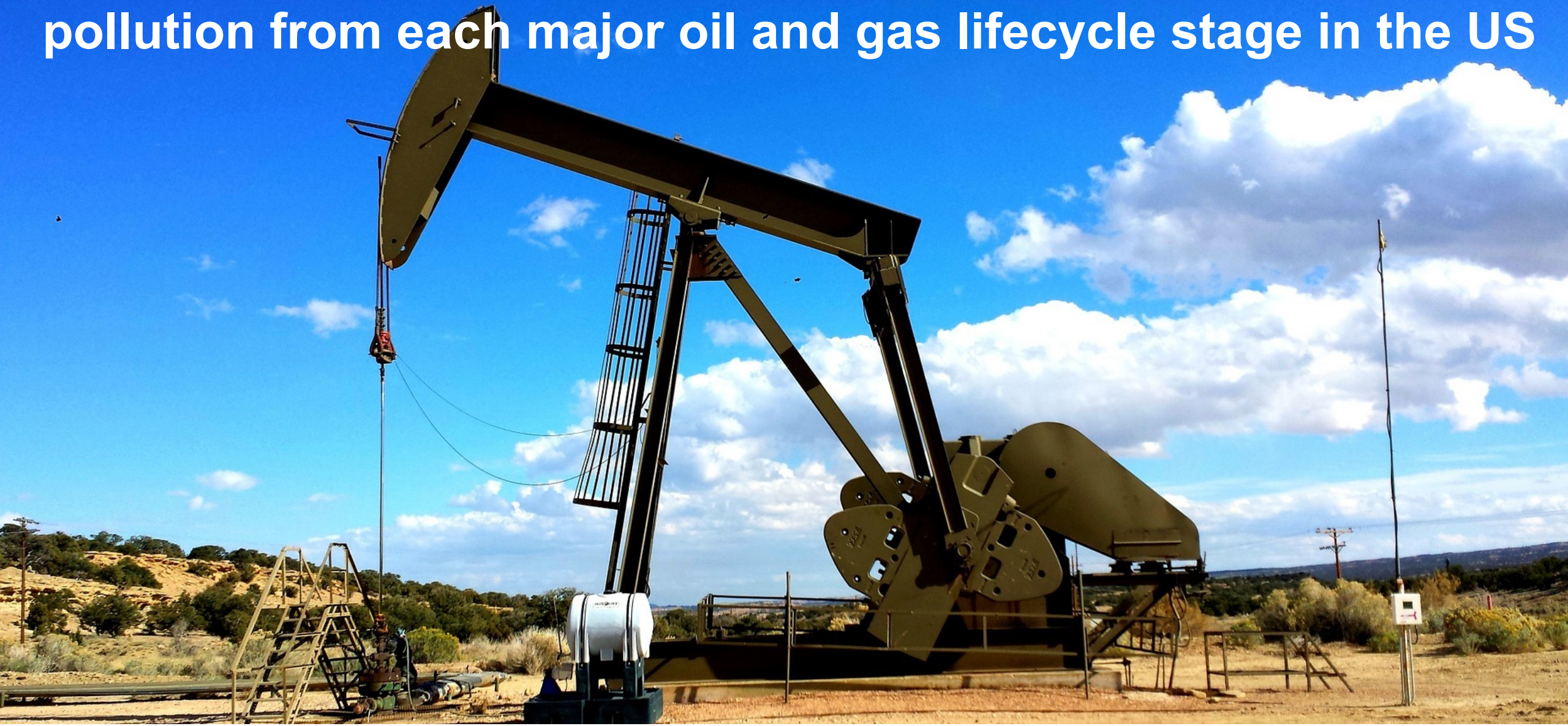
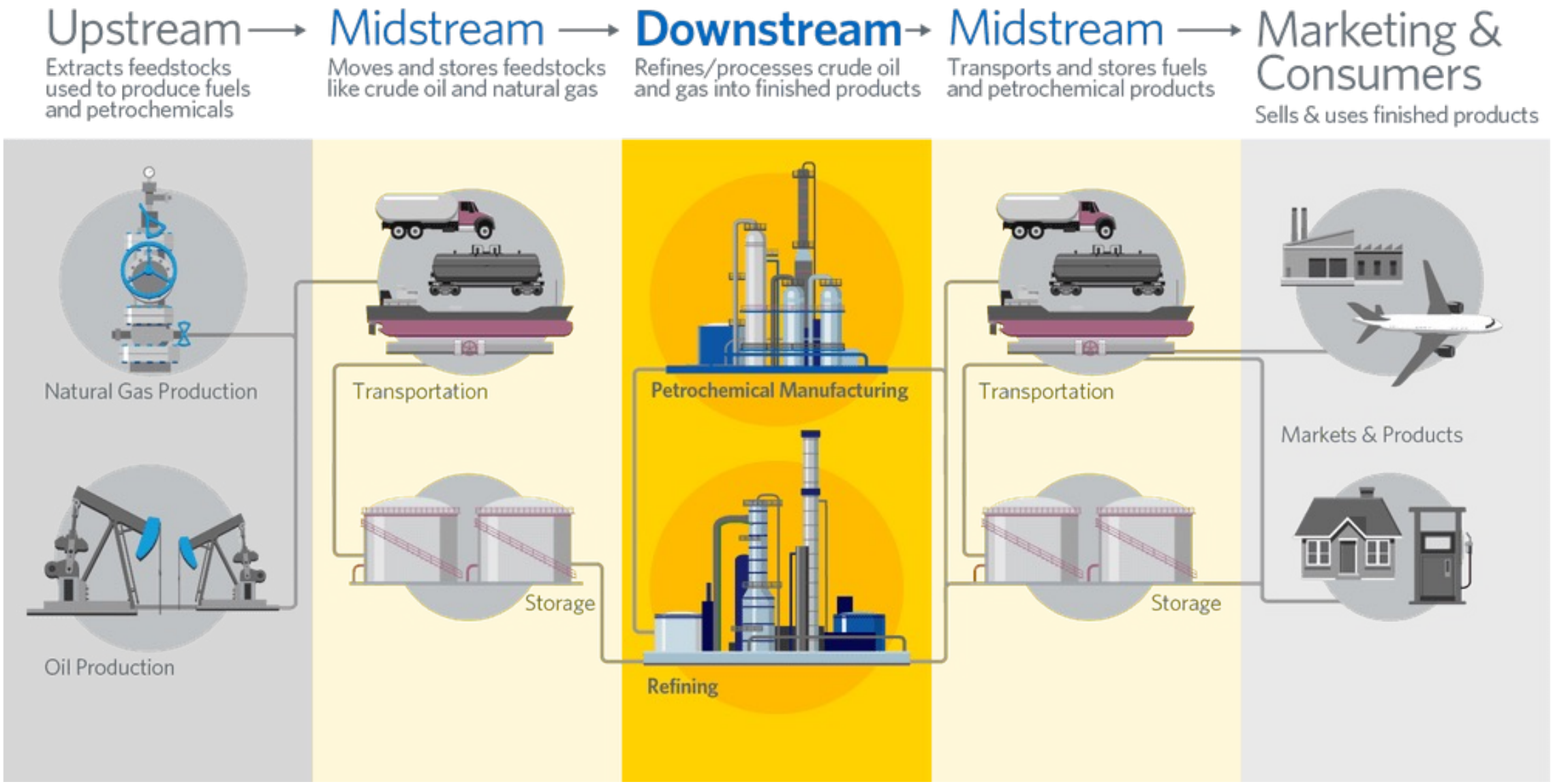
Early deaths, asthma incidences and cancer risks linked to air pollution from each major oil and gas lifecycle stage in the US



Karn Vohra (k.vohra@ucl.ac.uk), Ploy Achakulwisut, Eloise A. Marais, Gongda Lu, Jamie Kelly, Colby Francoeur, Colin Harkins, Brian McDonald, Susan Anenberg, Tia Scarpelli

15 August 2023

Major stages of the oil and gas lifecycle



Source *AFPM.org*

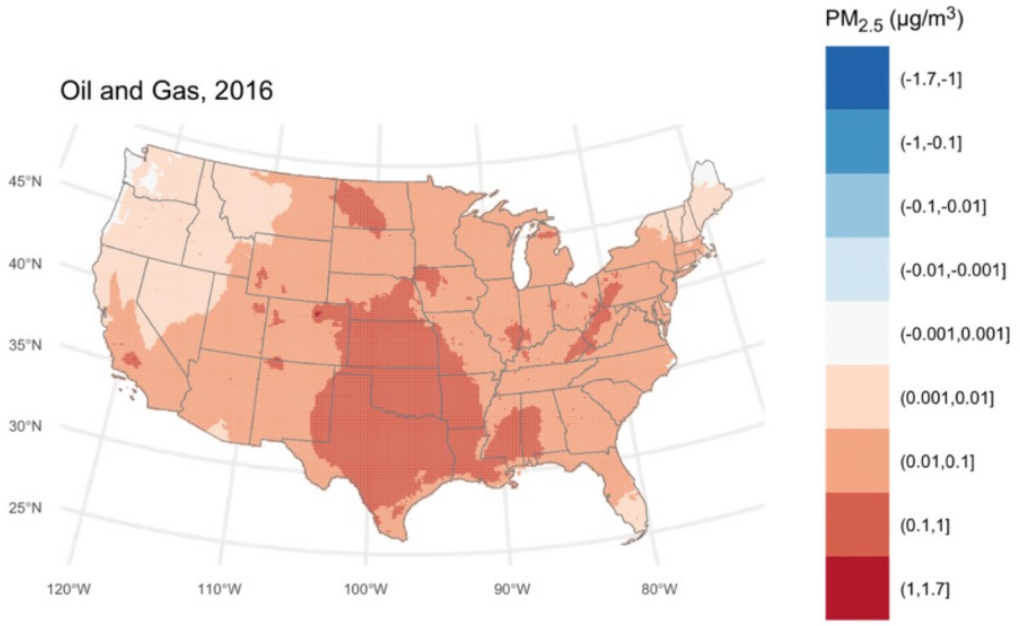
Air pollution linked to the oil and gas lifecycle

Can be from drilling and operating oil and gas wells, equipment, fugitive emissions, construction activity or vehicles

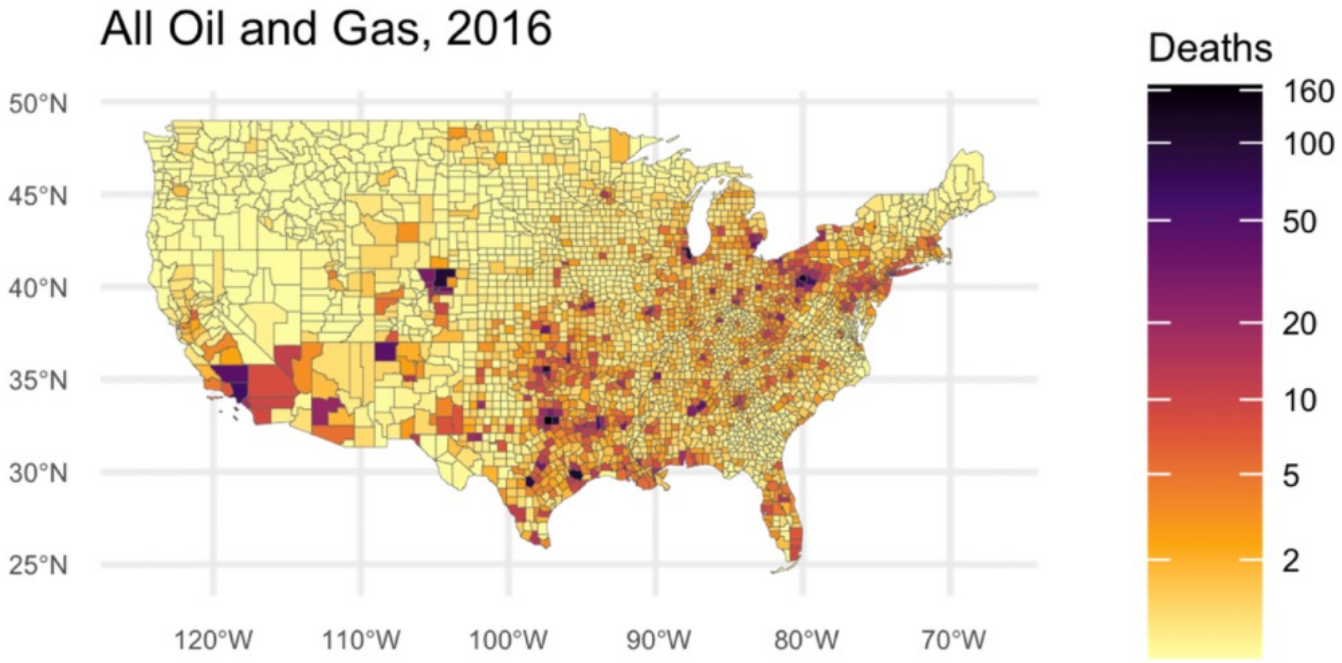
Release a suite of air pollutants (nitrogen oxides, VOCs, CO, and particulate matter or PM)

Recent study investigates health burden linked to the oil and gas production

$PM_{2.5}$ linked to oil and gas production



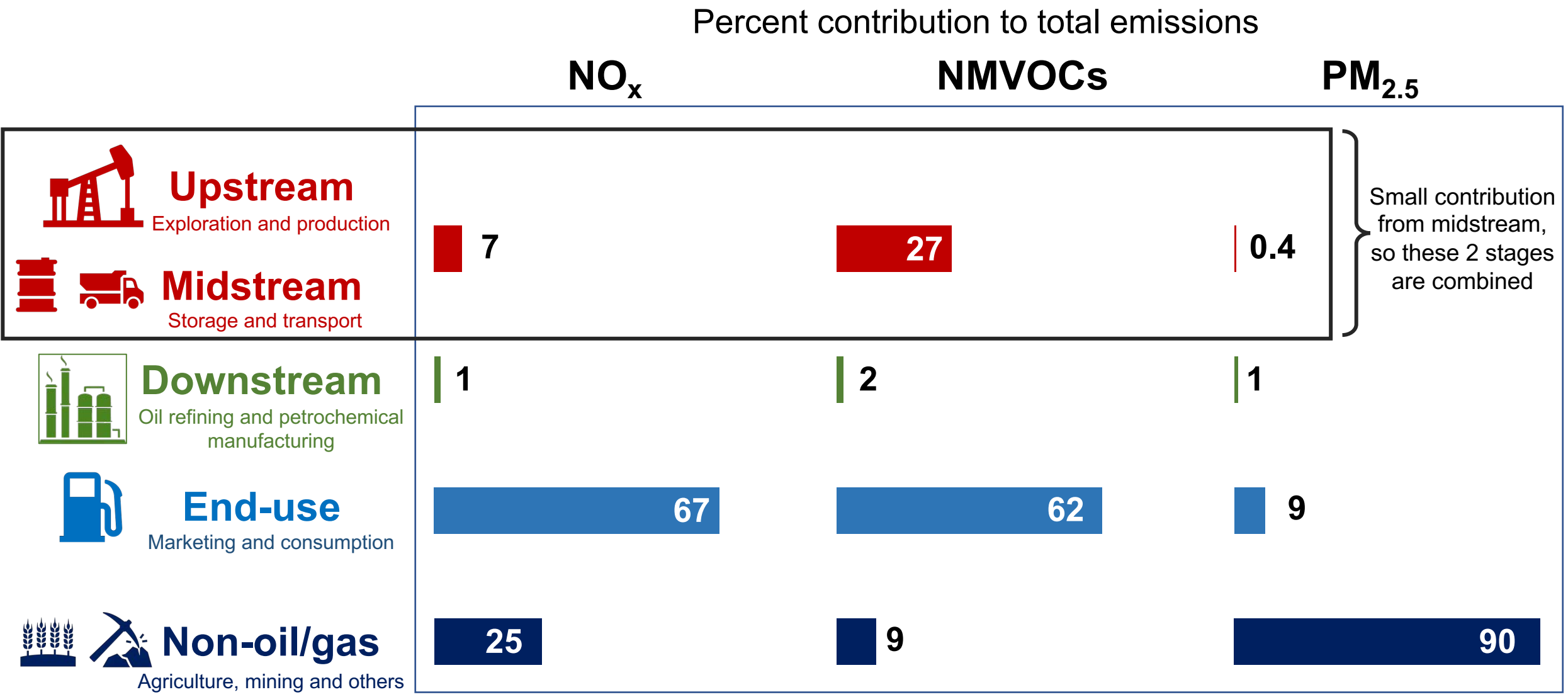
Mortality linked to $PM_{2.5}$, ozone and NO_2



[Buonocore et al., 2023]

What about the different stages? End-use?
Any other pollutants of concern?

Air pollutant emissions from the US oil and gas lifecycle



Oil and gas activities in the US are 75% of NO_x, 91% of NMVOCs and 10% of primary $PM_{2.5}$ emissions

[Emissions from US NOAA collaborators]

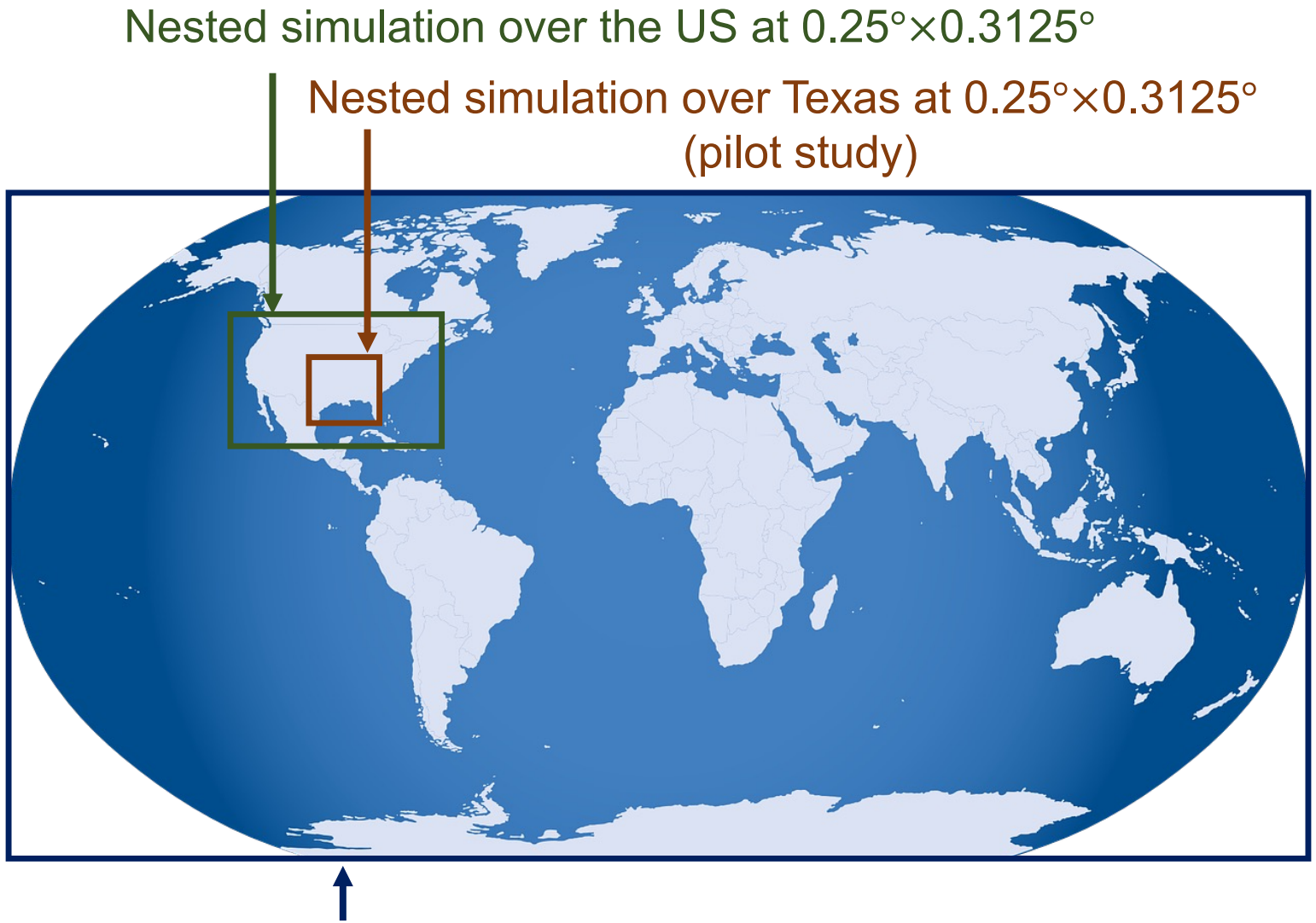
We use state-of-the-art 3D chemical transport model to simulate surface concentrations of pollutants hazardous to human health

Emissions

GEOS Chem

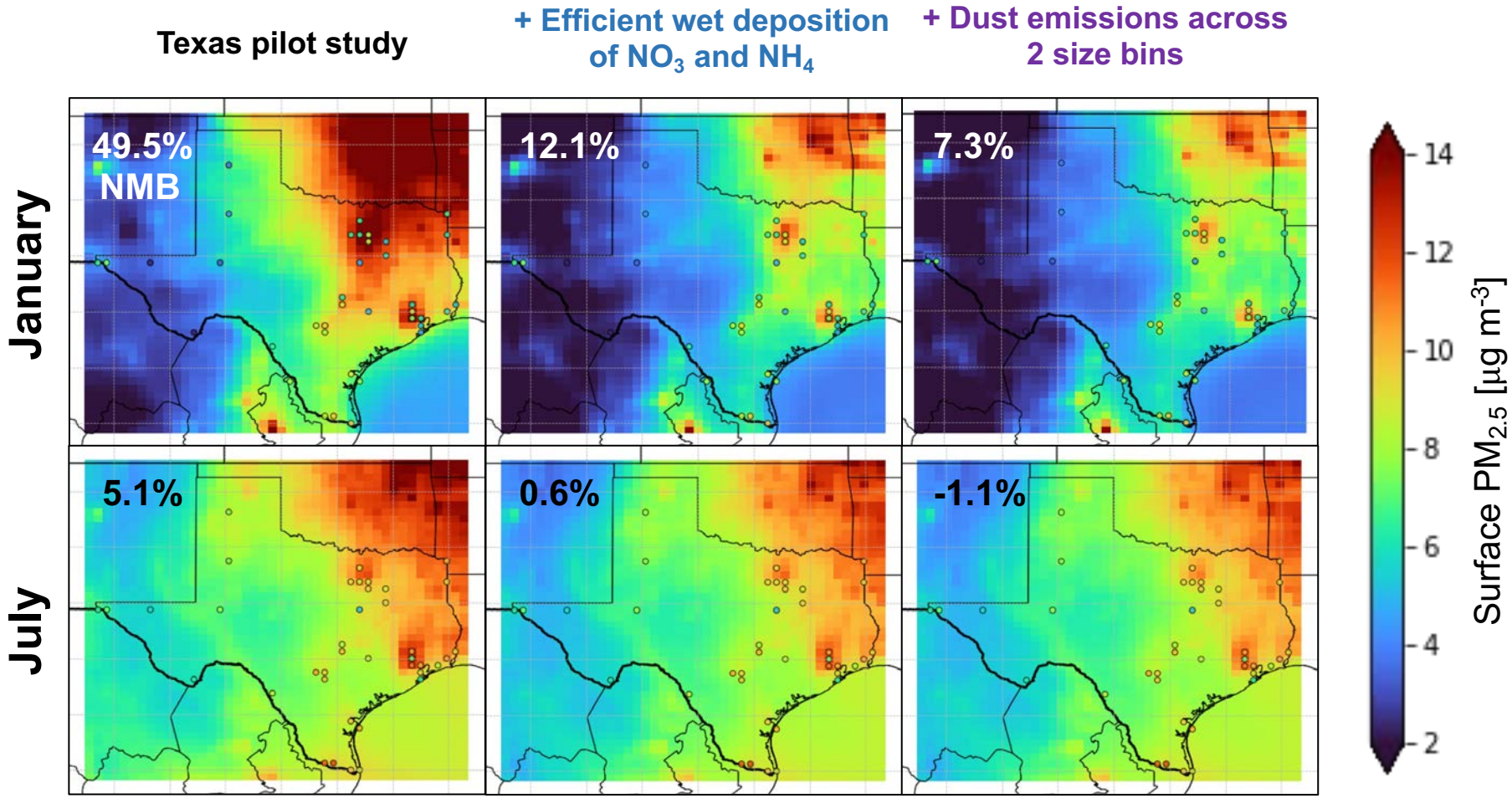
v13.0.0

Meteorology



GEOS-Chem updates and validation

We incorporate 2 updates in GEOS-Chem based on our findings from Texas pilot study

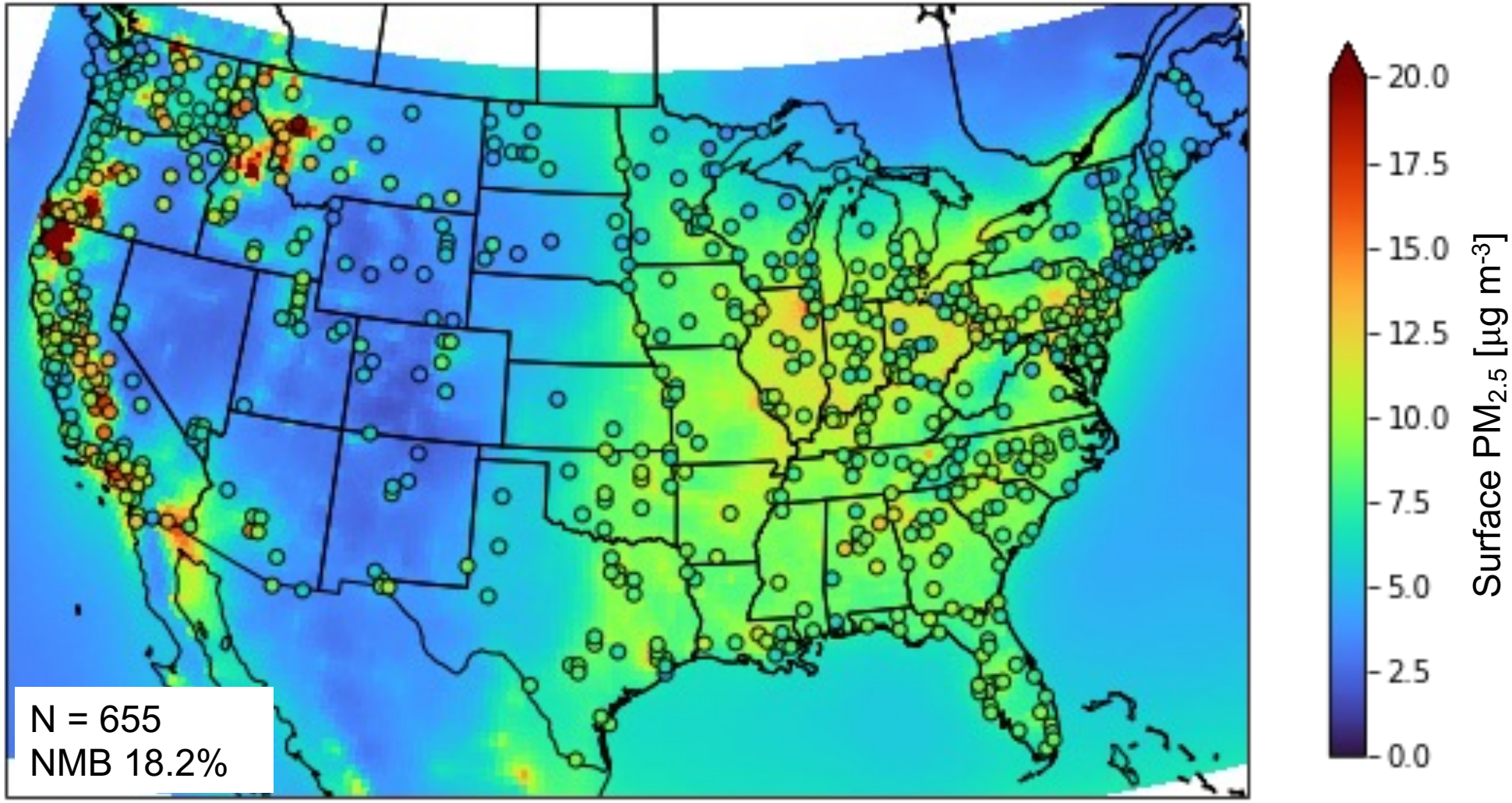


Updated treatment of wet processes as in Luo et al. (2019)

We emit dust $PM_{2.5}$ as DST1 (0.2-2 µm) and DST2 (2-3.6 µm) in the ratio 3:1 from experimental campaigns

We also use an updated timezone file which is at a finer resolution ($0.1° \times 0.1°$) and has daylight savings time

Assessment of GEOS-Chem surface $PM_{2.5}$

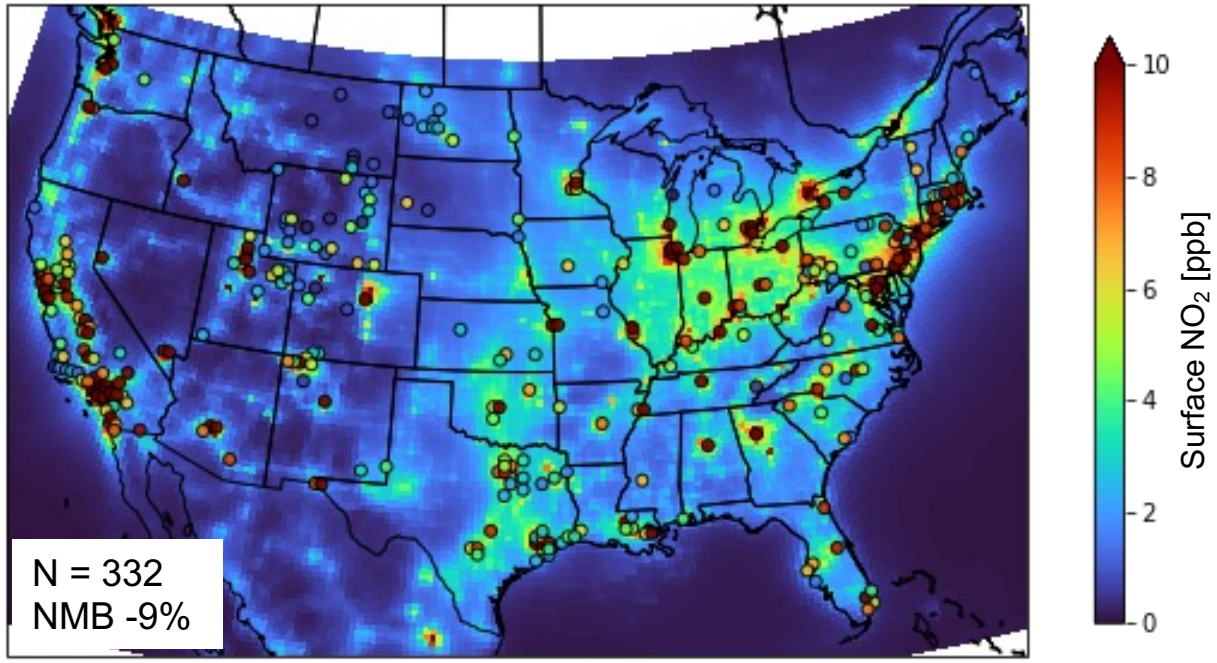


Model overestimates annual US-wide $PM_{2.5}$ by 18%

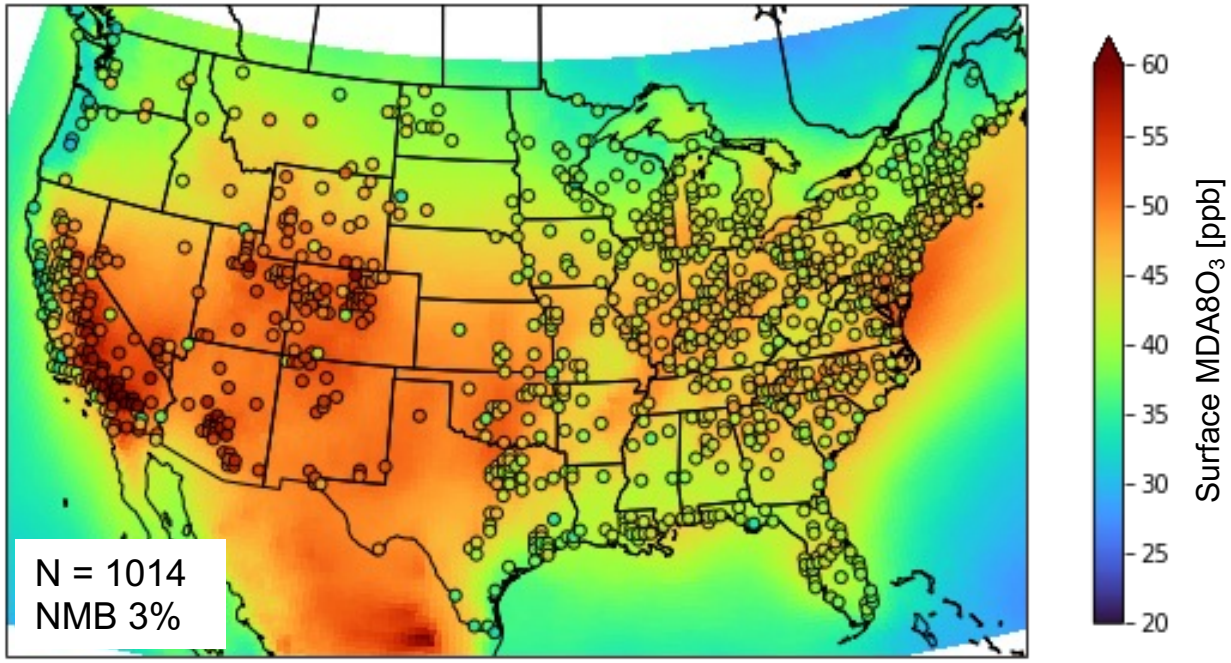
Assessment of GEOS-Chem surface NO_2 and $MDA8O_3$

We conduct similar assessment for annual NO_2 and peak-season maximum daily 8-h mean ozone $MDA8O_3$ against ground-based observations from US EPA

NO_2



$MDA8O_3$

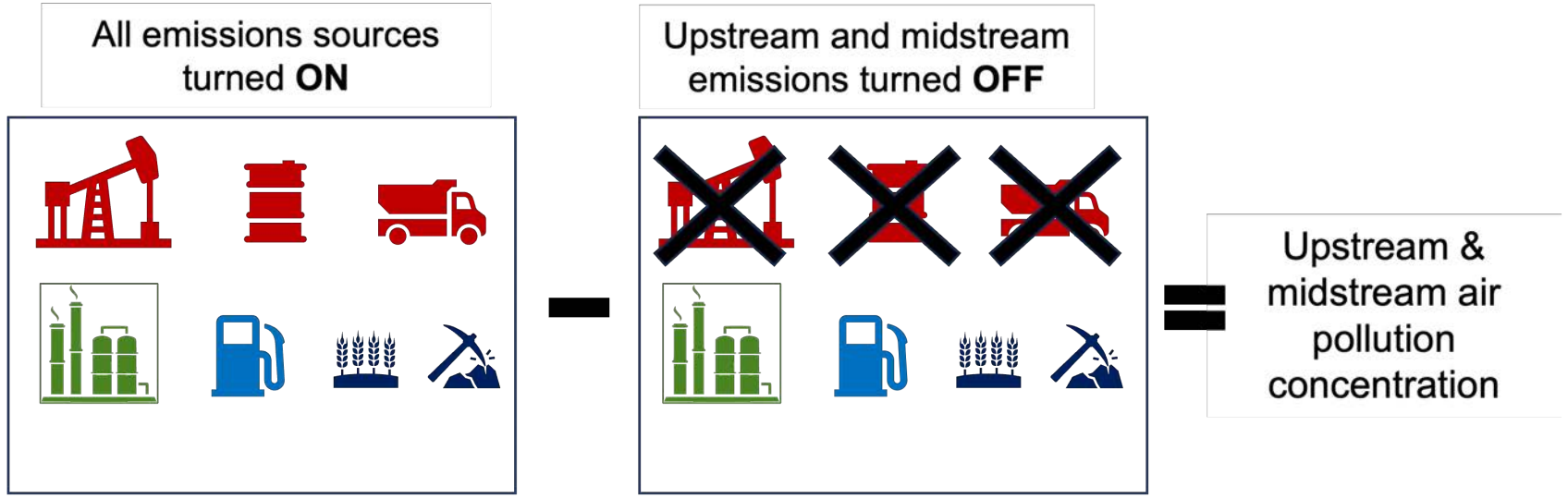


Model underestimates annual NO_2 by 9% and overestimates spring summertime US-wide surface $MDA8O_3$ by 3%

Simulated concentrations of air pollutants

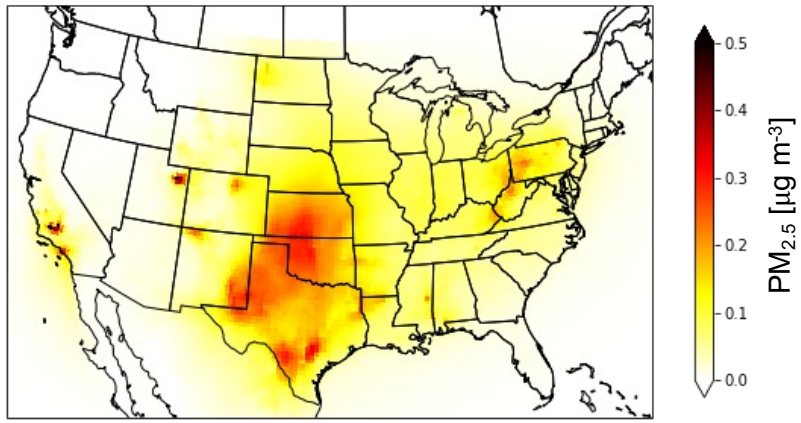
Health-hazardous pollutants linked to oil and gas activities in 2017

We conduct 4 model simulations:
1 with all sources and 3 with emissions from individual lifecycle stages set to zero.

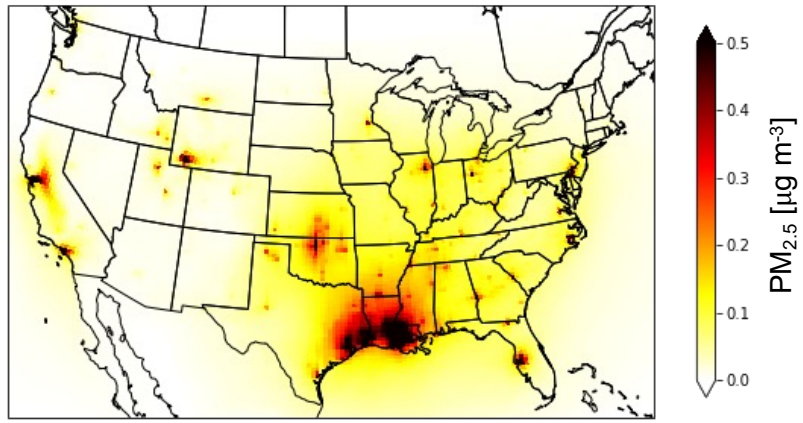


Annual-mean $PM_{2.5}$ of individual stages obtained with GEOS-Chem:

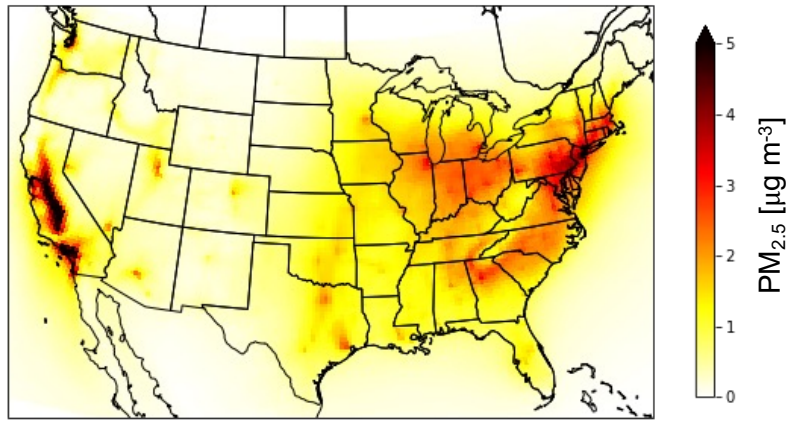
Upstream + Midstream



Downstream



End-use

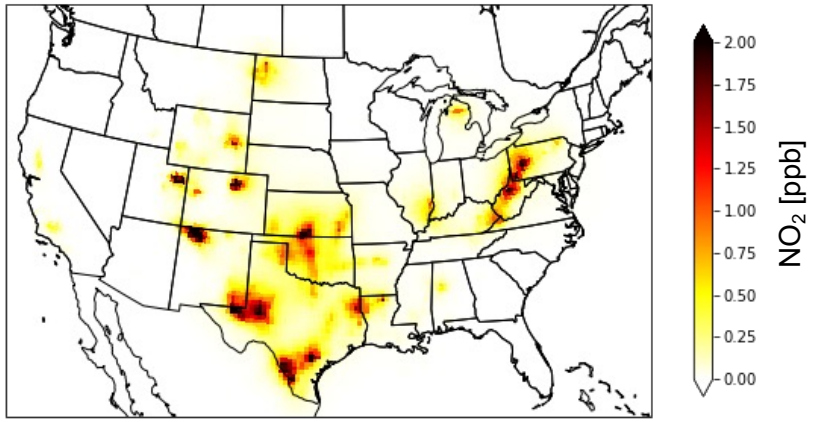


23% of $PM_{2.5}$ exposure linked to oil and gas activities in the US (92% from end-use)

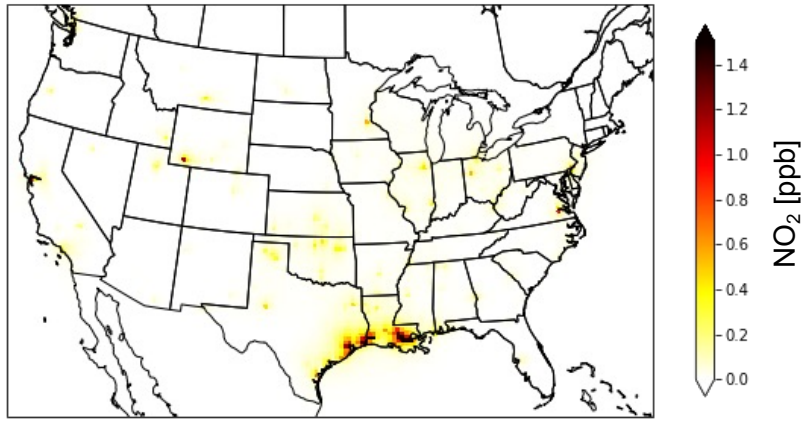
Health-hazardous pollutants linked to oil and gas activities in 2017

Annual-mean NO_2

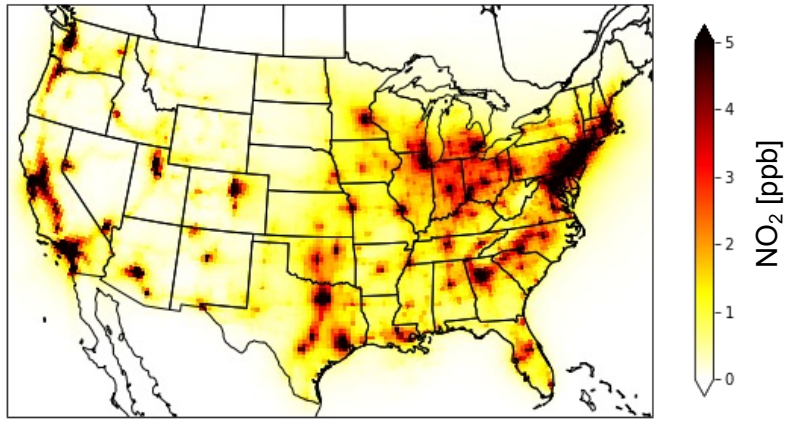
Upstream + Midstream



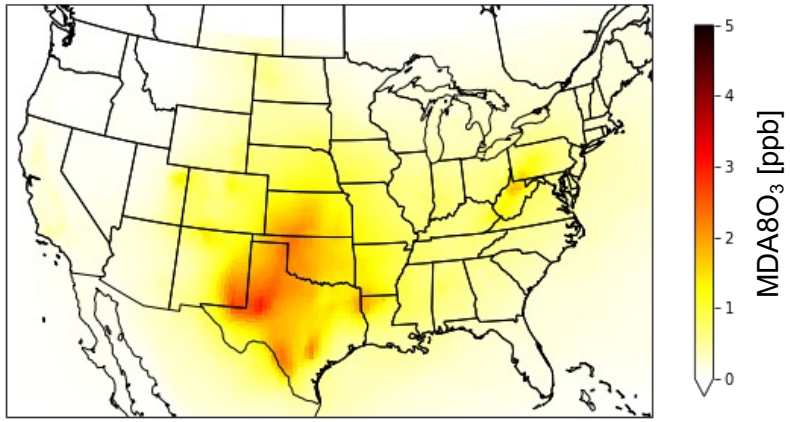
Downstream

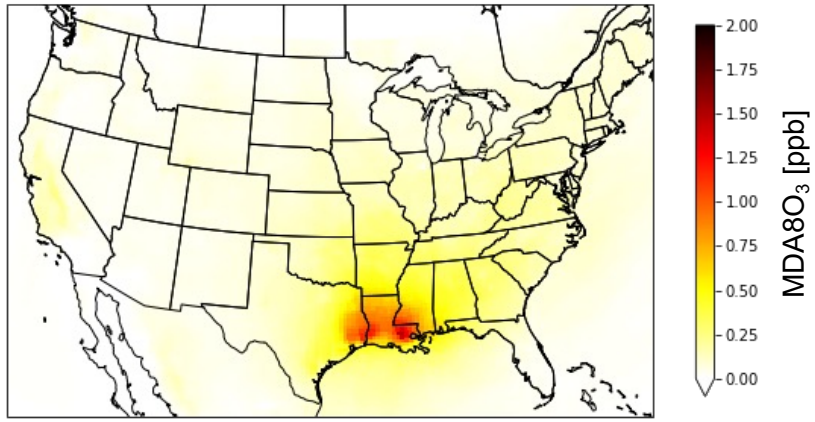


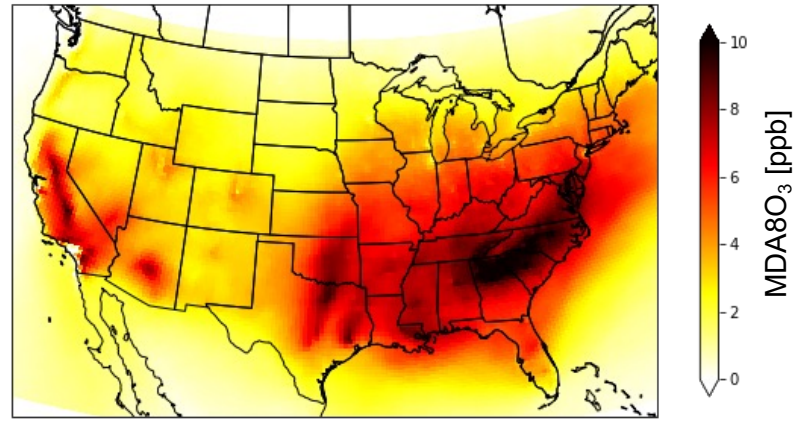
End-use



Peak-season (Spring-Summer) $MDA8O_3$





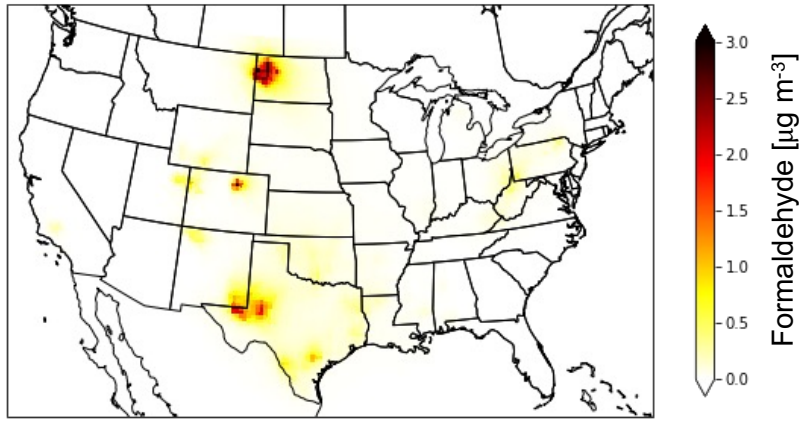


76% NO_2 exposure and 12% $MDA8O_3$ exposure linked to the oil and gas activities (mostly end-use)

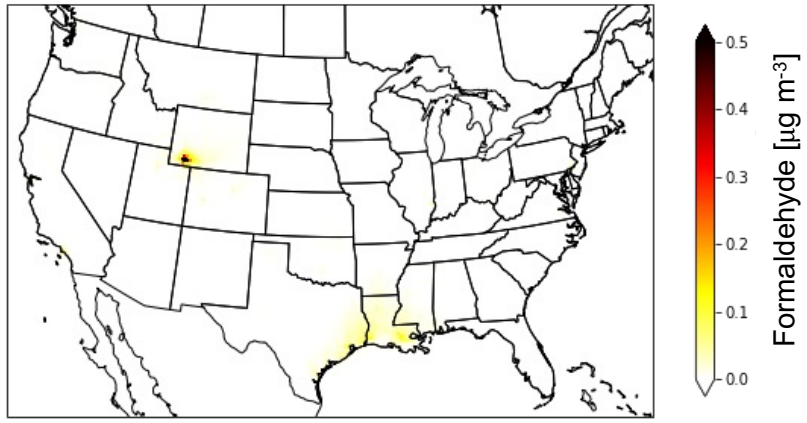
Annual mean VOCs (HAPs) concentrations linked to oil and gas activities

Annual mean formaldehyde

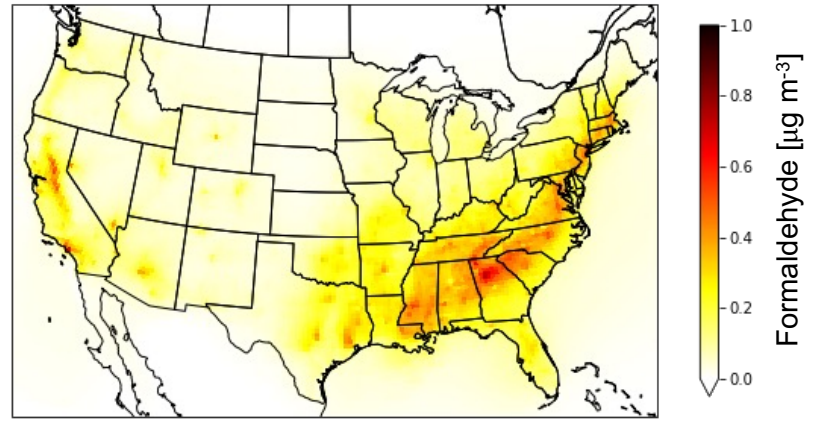
Upstream + Midstream



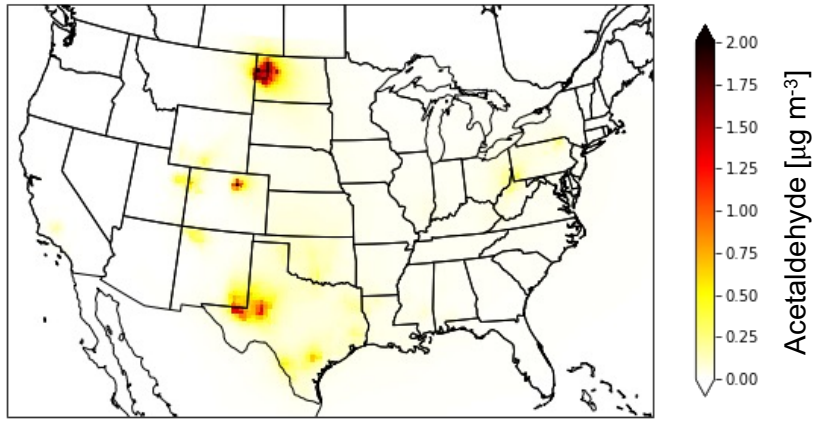
Downstream

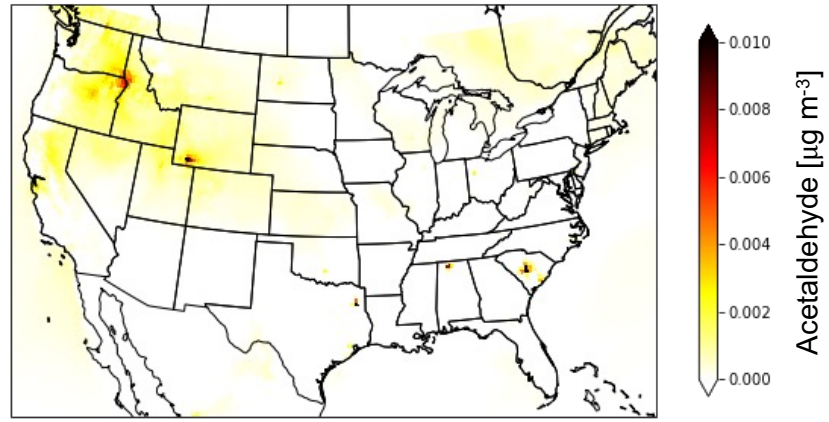


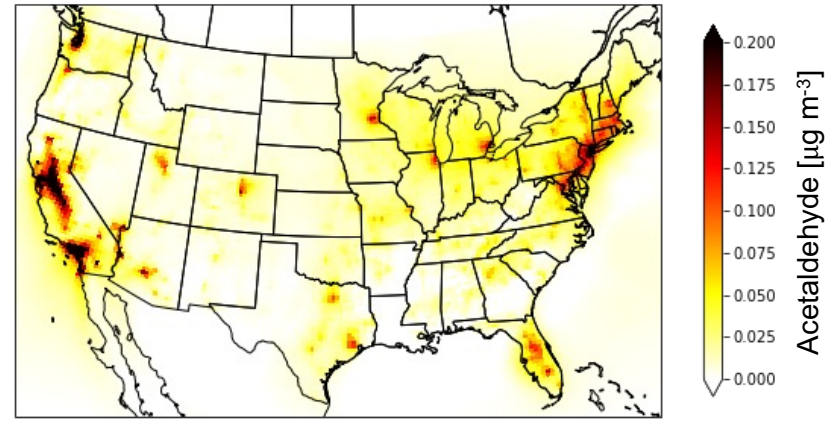
End-use



Annual mean acetaldehyde





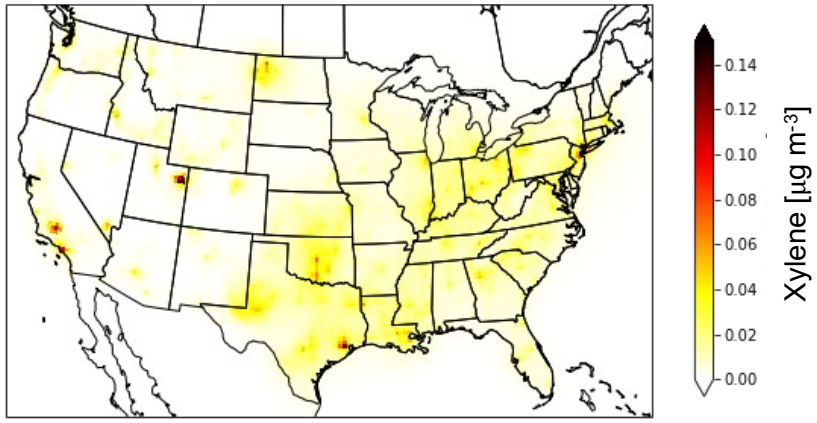


Large concentrations of formaldehyde and acetaldehyde in regions of upstream activities.
End use includes large secondary source from oxidation of VOC precursors

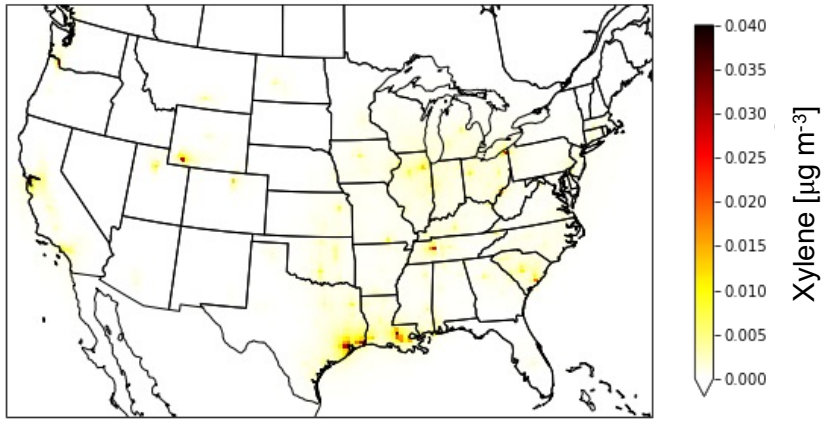
Annual mean VOCs concentrations linked to oil and gas activities

Annual mean xylene

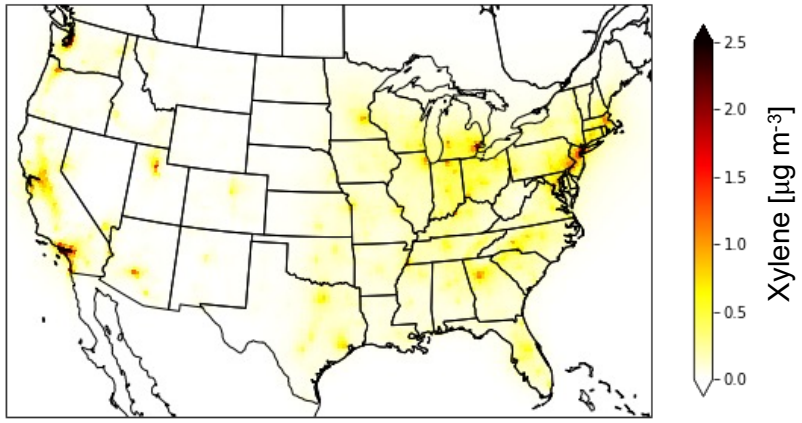
Upstream + Midstream



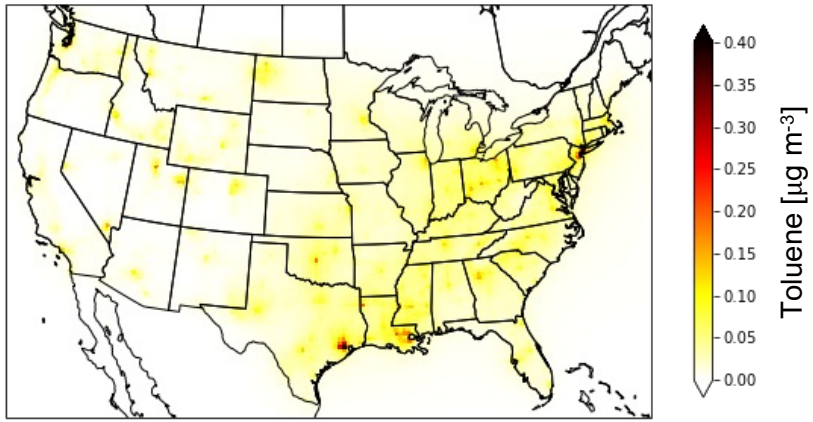
Downstream

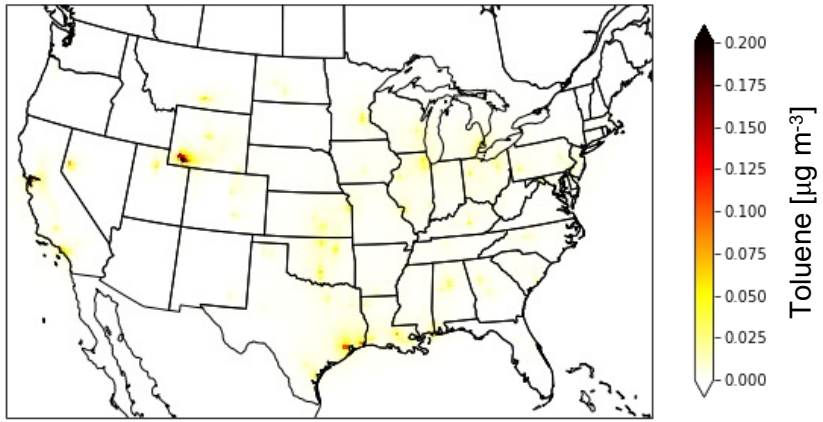


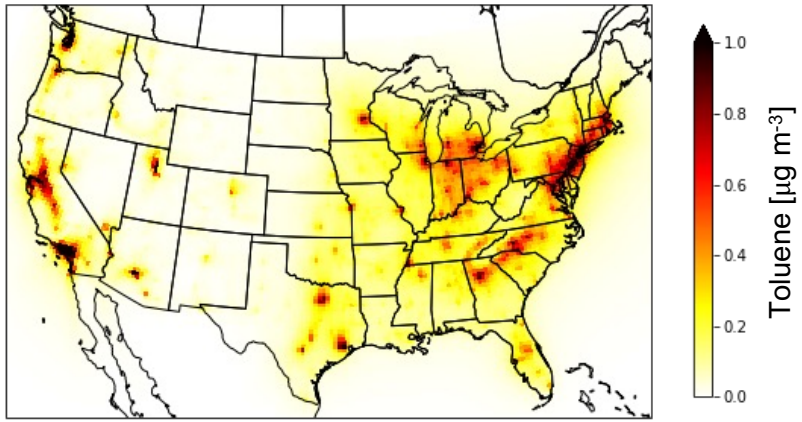
End-use



Annual mean toluene



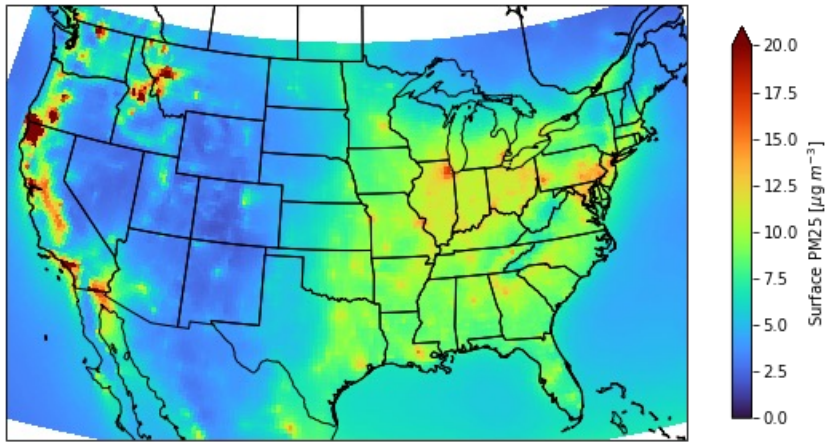




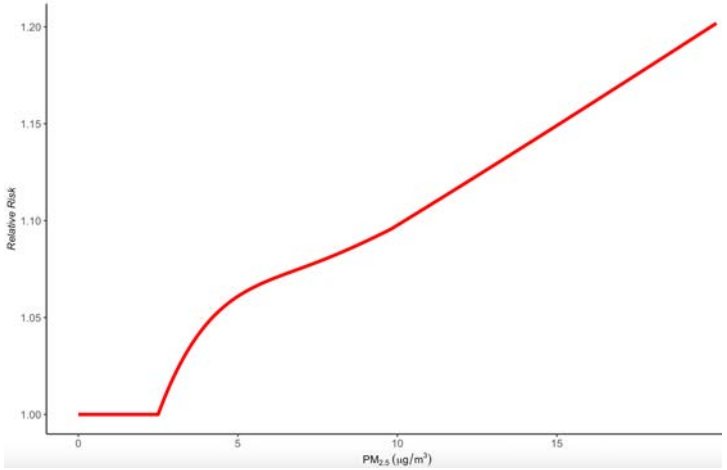
Concentrations of xylene and toluene are orders of magnitude less than levels known to be a non-cancer health risk, so are not considered further in health burden calculations

Health Impact Assessment

Methodology for health burden assessment

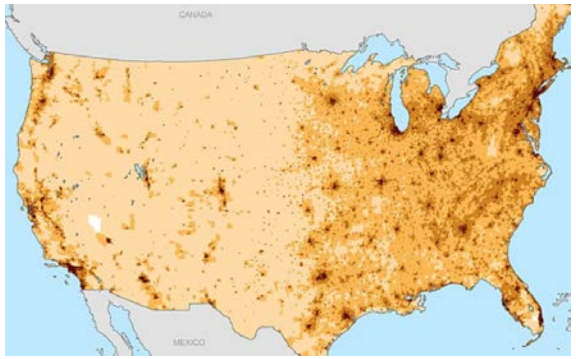


Pollutant concentration with and without the lifecycle stage

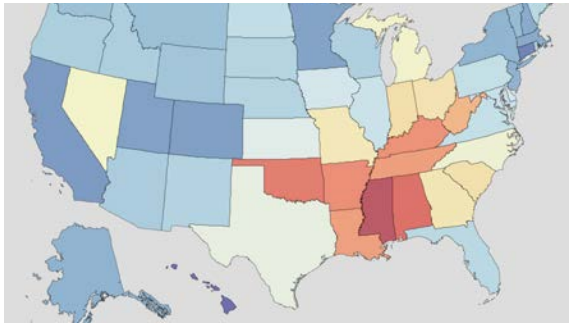


Relative risks for health end point

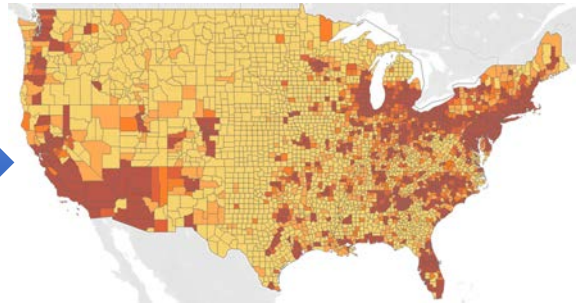
Population Attributable Fraction



Population data from WorldPop



Baseline mortality/incidence data from Global Burden of Disease



Adverse health outcome estimates

Adult (25+ years) premature mortality linked to $PM_{2.5}$ from oil and gas activities

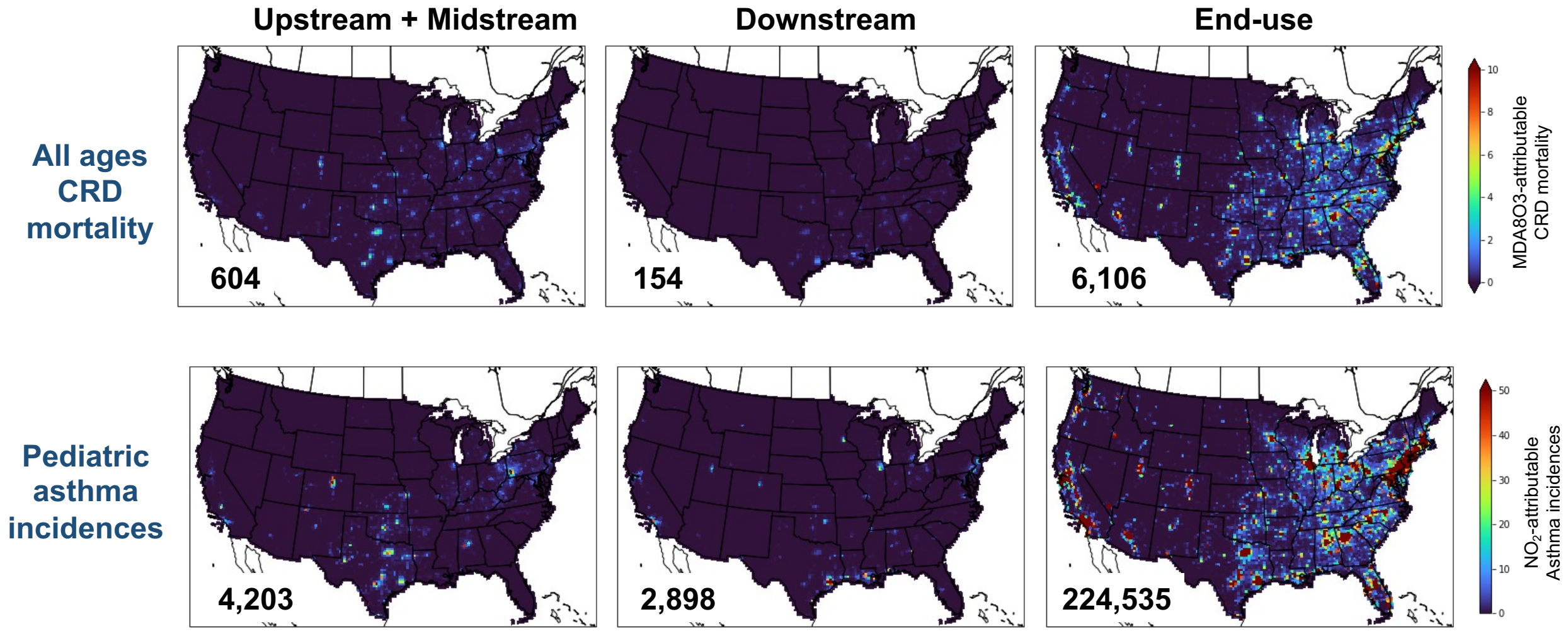
Maps are premature deaths attributable to $PM_{2.5}$ from 2 health risk models

	Upstream + Midstream	Downstream	End-use
Premature deaths (Vohra CRF) [Marais et al., *in review*, 2023]	1,425	2,442	43,122
Premature deaths (GEMM CRF) [Burnett et al., 2018]	1,400	2,333	44,203

Lifecycle total adult premature deaths from $PM_{2.5}$-exposure of 46,990 (95% confidence interval: 42,250-52,758) using Vohra CRF and 47,936 (95% CI: 35,339-59,781) using GEMM CRF. 92% from end use

Chronic respiratory diseases (CRD) mortality and asthma incidences

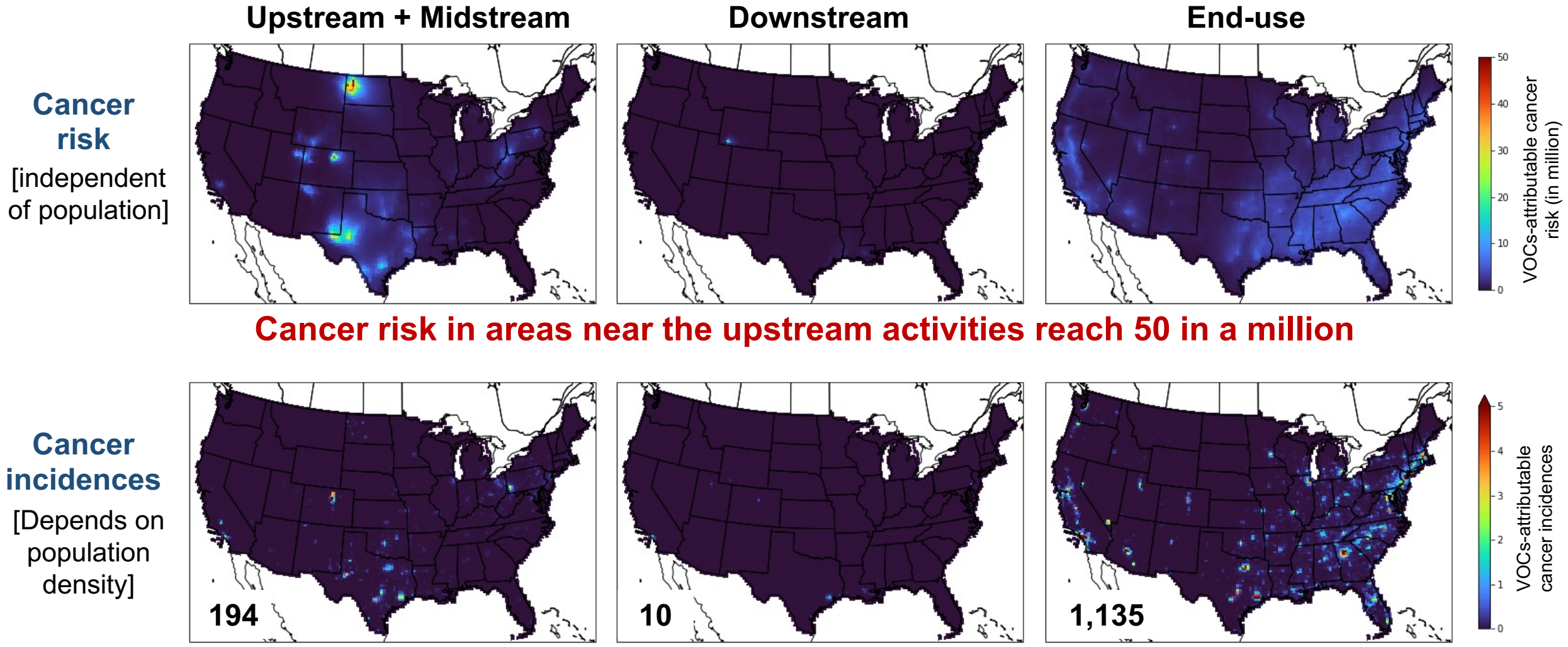
Maps are $MDA8O_3$-attributable CRD mortality (top) and NO_2-attributable pediatric asthma incidences (bottom)



6,865 CRD premature deaths from peak-season $MDA8O_3$ exposure and 231,636 pediatric asthma incidences from annual NO_2 exposure in 2017

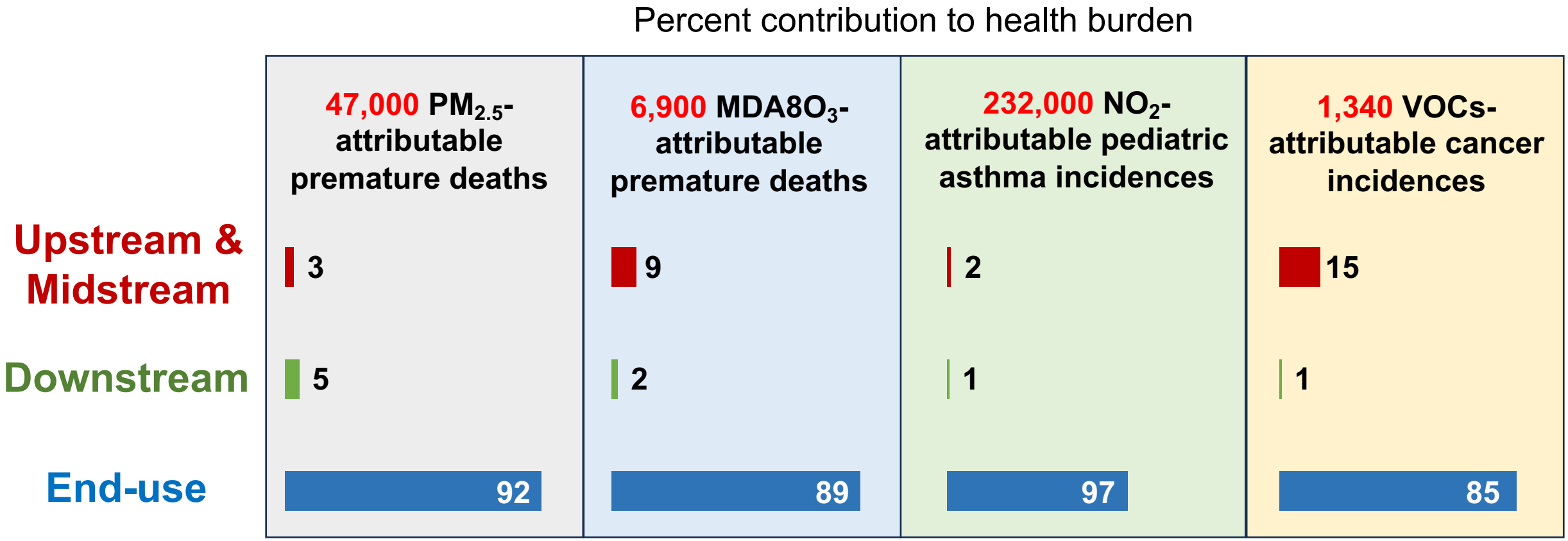
Cancer associated with hazardous air pollutants (HAPs) from

Maps are cancer risk per million (top) and cancer incidences (bottom) from cumulative exposure to formaldehyde and acetaldehyde



Conclusion

End-use activities in the US make the largest contribution to $PM_{2.5}$, NO_2 and $MDA8O_3$, but there are large VOCs emissions **(~30%)** from oil and gas production.



Any Questions? Email k.vohra@ucl.ac.uk