Atmospheric Composition and Air Quality Group



Karn Gongda Connor Eloise Bex Eleanor Nana Find out more about the group: <u>https://maraisresearchgroup.co.uk/</u> Find out more about me: <u>https://www.ucl.ac.uk/geography/eloise-marais</u>



Air pollution from fossil fuel extraction, production and use and the impact on public health

Karn Vohra, Research Fellow

Quantifying the size of air pollution sources in very polluted cities in South and Southeast Asia

Gongda Lu, Research Fellow





Climate change and ozone depletion from megaconstellation mission launches and waste

Connor Barker, Research Fellow



Addressing knowledge gaps of the under-appreciated upper troposphere with NASA aircraft observations

Nana Wei, PhD

Making innovative use of satellite observations to address data gaps in tropospheric atmospheric composition

Bex Horner, PhD





Measuring atmospheric composition and air quality in Central London

Eleanor Gershenson-Smith, PhD







Other Group Activities

- Organize and host international meetings at UCL
- □ Past research into UK agriculture and the impact on public health
- Training to share research with the media (Sky, BBC, Channel 4, The Guardian, Time, and so on)
- □ Training to present research to other scientists at conferences
- □ Routine, structured research group meetings
- Weekly / fortnightly structured supervisory meetings
- Research-relevant information on frequently updated internal wiki
- □ Training in open science (code, data, talks, papers)
- □ Training in lead author and co-author of high-impact papers (write → implement feedback → submit → respond to reviewers)

Any questions about my group?

What to do to make an informed decision about your PhD?

Environmental Effects of the Space Sector: Rockets and waste



More diverse space sector than the first space race

Number of rocket launches per country in each year



Even the UK has joined the race



Dramatic increase in objects in space



Image from ESA's Annual Space Environment Report, 2023

Air pollutant emissions from rocket launches



 NO_{x} HCI+CI $AI_{2}O_{3}$ $H_{2}O$ BC

Hypergolic





 H_2O

BC

Cryogenic





Air pollutant emissions from rocket launches



NO_{x} HCI+CI $AI_{2}O_{3}$ $H_{2}O$ BC

Hypergolic



Kerosene



Cryogenic





Climate concern

Black carbon or soot particles here on Earth



Air pollutant emissions from rocket launches



Solid



Hypergolic



Kerosene NO_x H₂O BC

Cryogenic



Direct ozone depletion

Air pollutant emissions from re-entry



Natural:

2-40 Gg NO_x per year

Artificial:



Current "sustainable" way of cleaning up space is re-entry vaporization of waste

The Protective Ozone Layer



100 200 300 400 500 600 700

Total Ozone (Dobson units)

0



https://ozonewatch.gsfc.nasa.gov/

Calculate and map a single year of emissions



~100 successful launches in 2019

Reaches 135 in 2021. 186 in 2022. Already 159 in 2023

Incorporate these in a Chemical Transport Model



Stratospheric ozone depletion due to rockets and re-entry



Oscillatory pattern takes 2-3 years to establish

Seasonality tracks sunlight chemistry

50:50 contribution from re-entry NO_x and rocket launch chlorine

Peak decline in spring is 0.15% in the NH and 0.04% in the SH

Springtime Arctic upper stratospheric ozone depletion reaches ~0.15% after a decade of launches This is ~10% of upper stratospheric ozone recovery attributed to Montreal Protocol ban on ODS

Couple the model to a radiative transfer model

Values are % or arbitrary



https://www.noaa.gov/

Radiative forcing due to black carbon (soot) emissions



Rockets ~3% of BC radiative forcing from all anthropogenic sources, but only 0.01% of emissions.

BC from rockets 400-500 times greater radiative effect than BC from Earth-bound sources

SpaceX Starship mission plan is 3 launches per day, so 10-fold increase in annual launches

Are rocket pollution emissions cause for concern?

Number of rockets launched likely to surpass 200 this year, but this is still far less than the millions of passenger flights each year. **So, should we care?**

How do rocket emissions of NO_x from a SpaceX Falcon 9 kerosene-fuelled rocket stack up against NO_x emissions from the most polluted city (Dhaka) and the highest-capacity power plant in the UK.

Step 1: Find the data.

Google search "UCL Eloise Marais", click on my UCL profile, scroll down to "Lab/Research Group Website" in the right panel below my picture, click on the Education then Teaching tab and select the PDF slides below the "NERC DTP Induction 2023-2024 heading" to download this presentation.

UK Point source emissions in 2021: <u>https://naei.beis.gov.uk/data/map-uk-das?pollutant_id=6</u>

Dhaka, Bangladesh: <u>https://maraisresearchgroup.co.uk/Presentations/GLu-GCE2-talk.pdf</u>

Rocket kerosene emission factors: Table 1 of Ryan et al. (2022) (<u>https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2021EF002612</u>)

SpaceX Falcon 9 rocket propellant mass: https://doi.org/10.5522/04/17032349

Step 2: Put the data on the same scale (same units).

Step 3: Compare.