Regional sensitivities of air quality to aviation emissions

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Background

- Full-flight emissions → health impacts

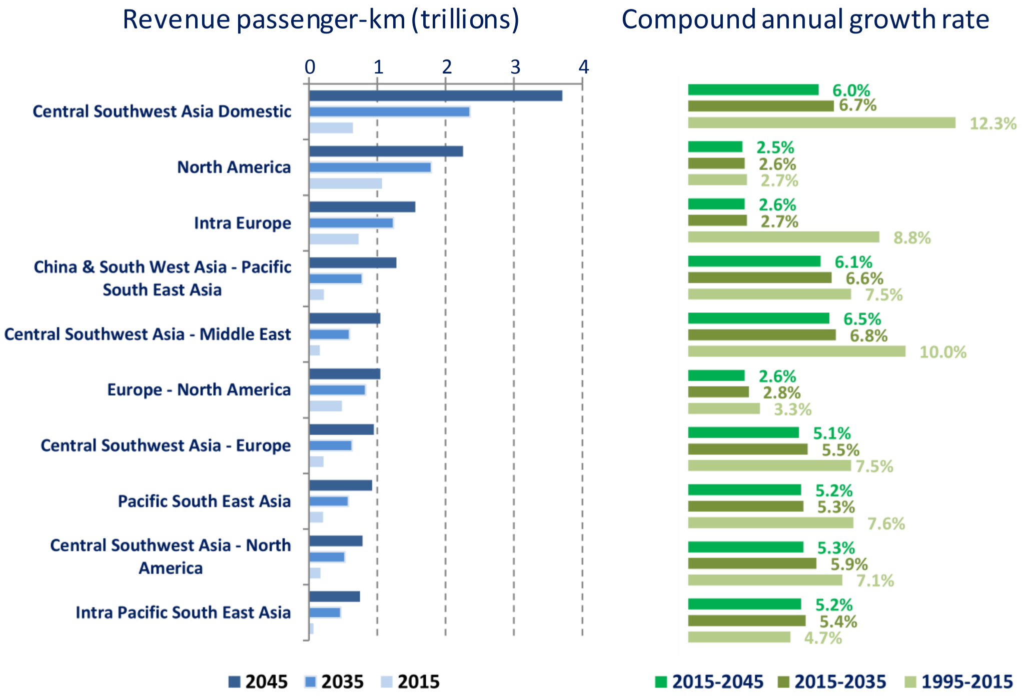
Additional ground level $PM_{2.5}$ and ozone:
- Estimated 16,000 annual premature deaths globally*
- 90% of emissions are above 3 kft, being responsible for an estimated 75% of these impacts*

* Yim *et al* 2015 Global, regional and local health impacts of civil aviation emissions *Environ. Res. Lett.* **10** 034001

- Regional differences

- Population density
- Non-aviation emissions → background atmospheric composition

- Aviation growth



International Civil Aviation Organization 2018
ICAO Long-Term Traffic Forecasts

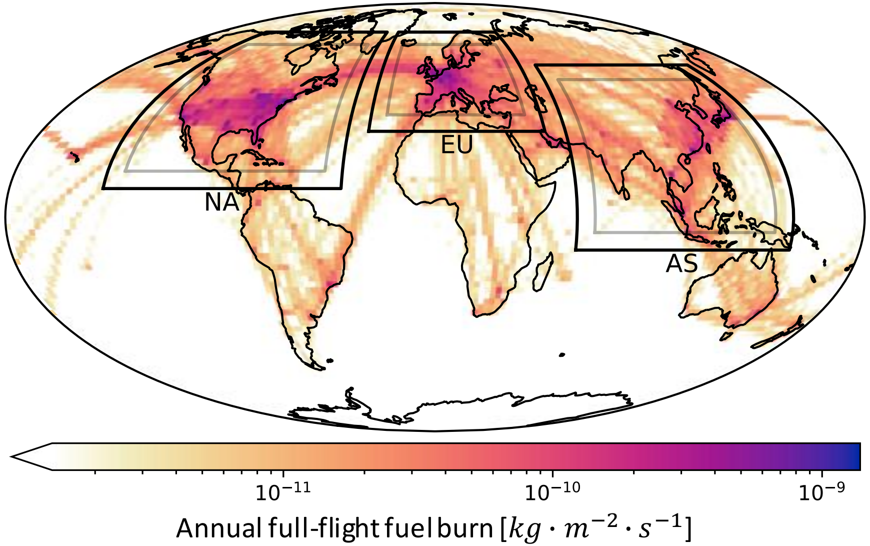
Methodology

Burnett **et al** 2018 Global estimates of mortality associated with long-term exposure to outdoor fine particulate matter *Proc. Natl. Acad. Sci.* **115** 9592–7
Simone **et al** 2013 Rapid estimation of global civil aviation emissions with uncertainty quantification *Transp. Res. Part Transp. Environ.* **25** 33–41
Turner **et al** 2016 Long-Term Ozone Exposure and Mortality in a Large Prospective Study *Am. J. Respir. Crit. Care Med.* **193** 1134–42

- Scenarios

2005 emissions
Test cases:
- Baseline
- EU +10%
- NA +14%
- AS +27%

- Global aviation emissions
  - Based on Simone *et al* (2013)



- Atmospheric chemistry-transport model

GEOS-Chem

- Prescribed meteorology, emissions
- Tropospheric + stratospheric chemistry

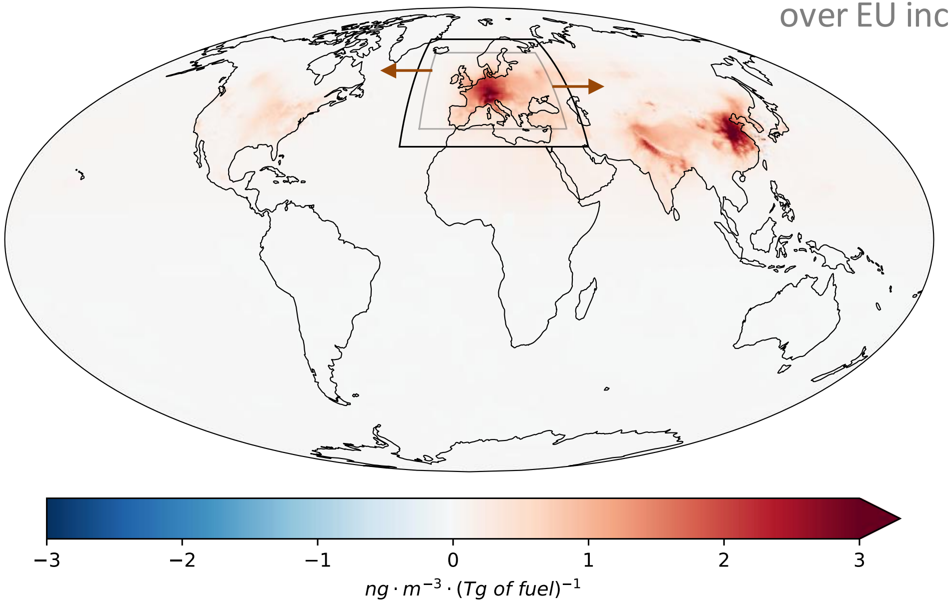
- Air quality impacts
  - $PM_{2.5}$ and ozone ground level increases

- Health impacts

Attributable premature mortality estimated with concentration response functions (CRFs):
- $PM_{2.5}$: CRF from Burnett *et al* (2018)
- Ozone: CRF from Turner *et al* (2016)

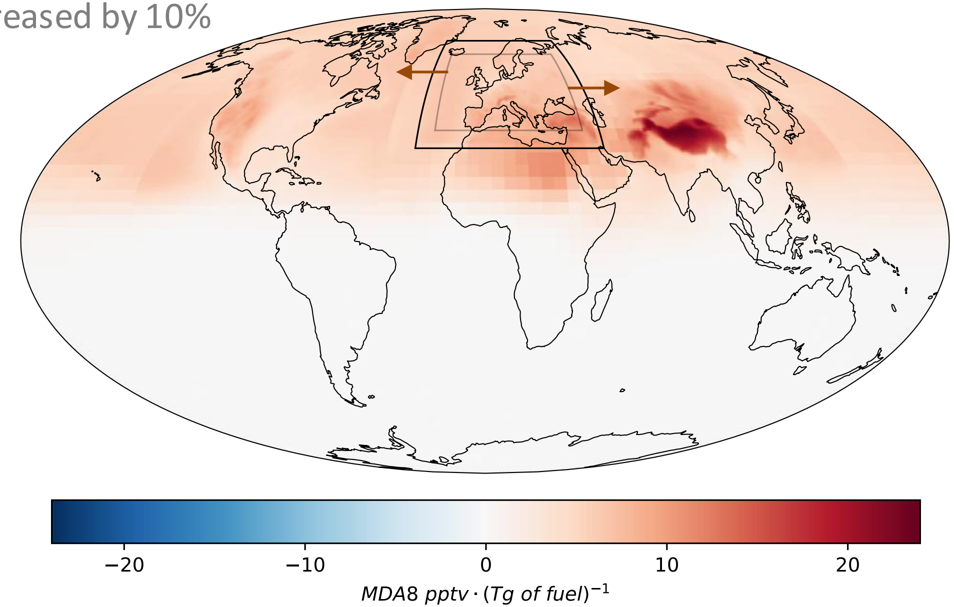
Spatial distribution of air quality impacts

- Increase in annual average of surface concentrations
  - Full-flight aviation emissions over EU increased by 10%



$PM_{2.5}$

Associated with availability of free ammonia



Ozone

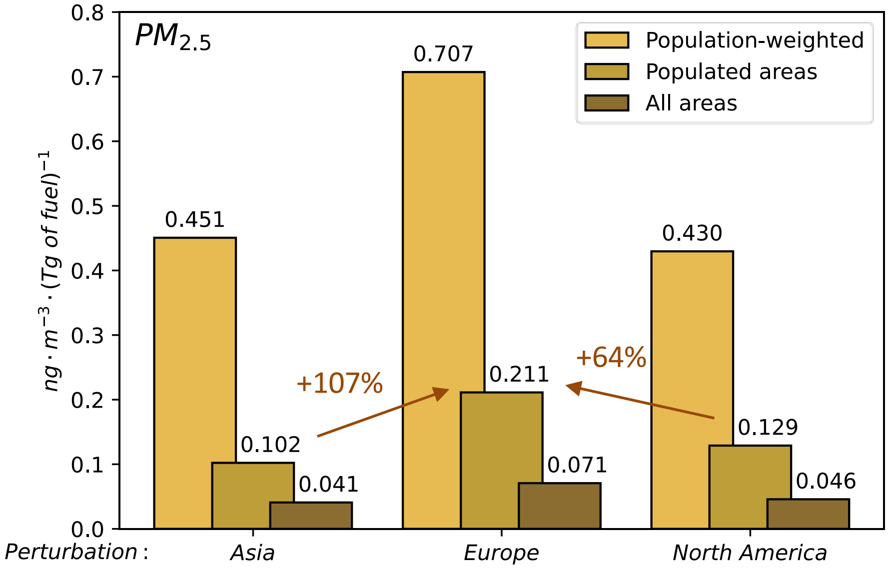
Associated with availability of volatile organic compounds

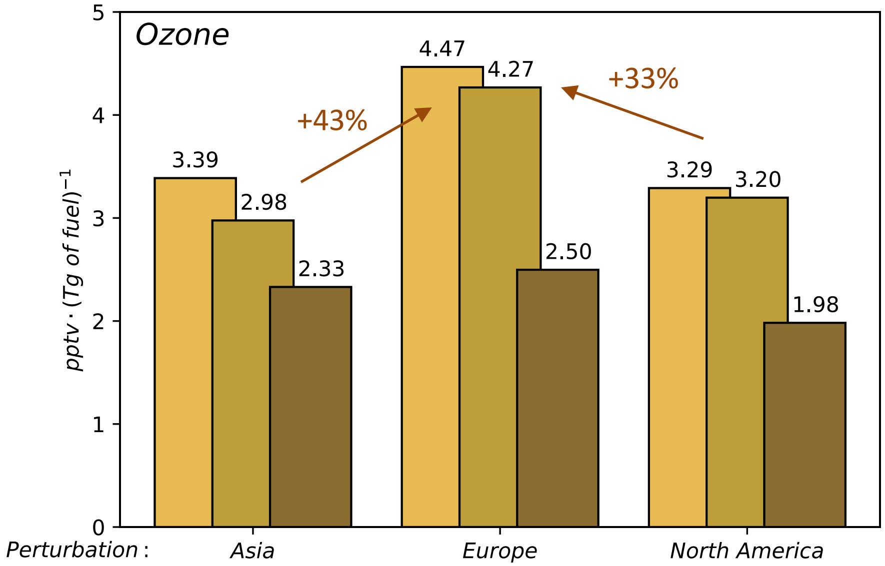
Sensitivities driven by atmospheric processes and non-linear chemistry

Global air quality impacts

- Sensitivity of global air quality to full-flight aviation emissions

Global annual increase in ground level concentration per additional mass of (full-flight) fuel burned over a specific region



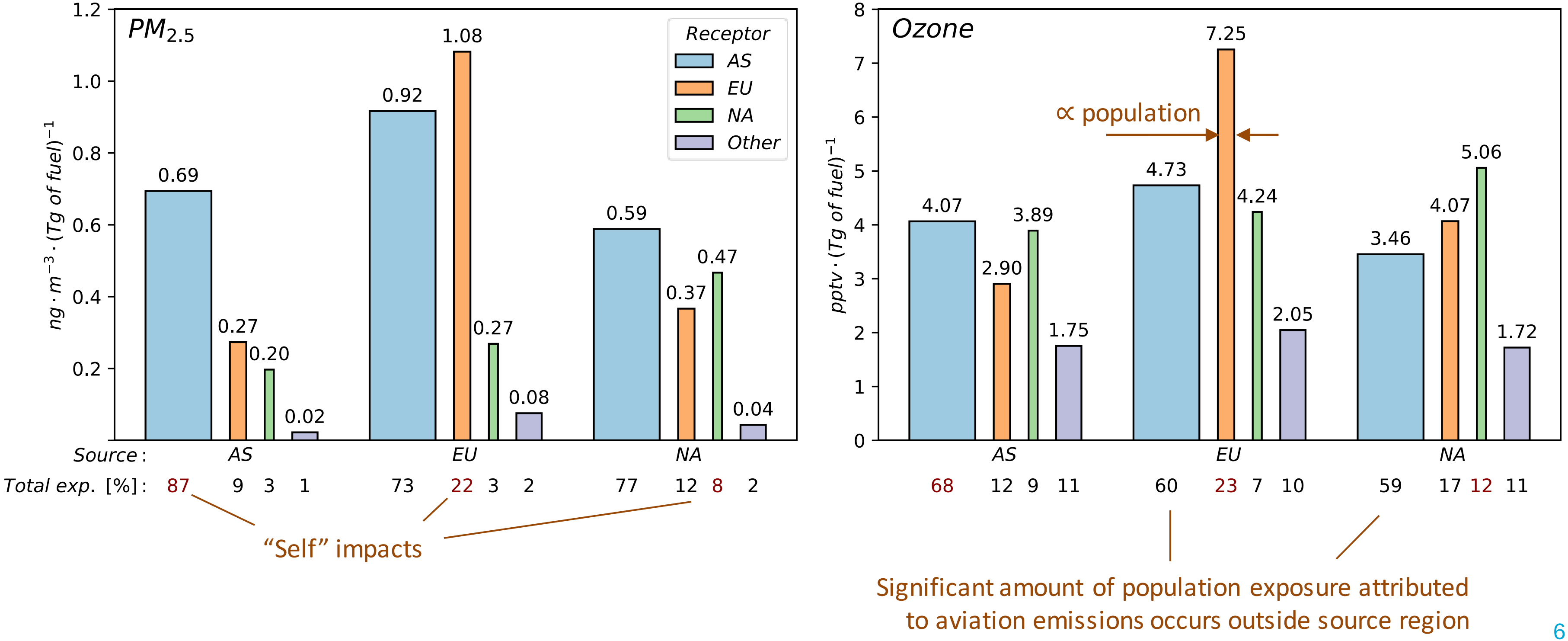


Global air quality shows higher sensitivity to aviation emissions over Europe

Population exposure

- Source-receptor sensitivity pairs

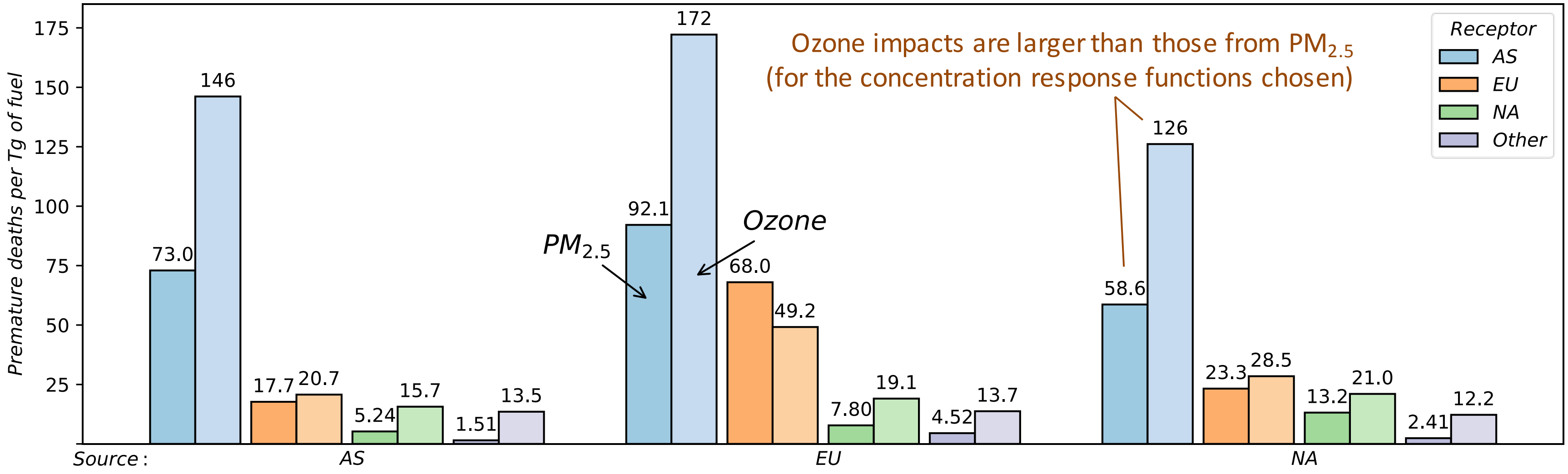
Population-weighted increases, per additional mass of (full-flight) fuel burned over a specific region



Health impacts

- Premature mortality from additional $PM_{2.5}$ and ozone

Premature mortality from additional $PM_{2.5}$ and ozone per (full-flight) fuel burn mass for each source-receptor regional pair



$PM_{2.5} + O_3$:	219	38.5	20.9	15.1	264	117	26.9	18.3	185	51.7	34.2	14.6
Receptor % of world $PM_{2.5}$:	75	18	5.4	1.6	53	39	4.5	2.6	60	24	14	2.5
O_3 :	75	11	8.0	6.9	68	19	7.5	5.4	67	15	11	6.5
Tot. :	75	13	7.1	5.1	62	27	6.3	4.3	65	18	12	5.1

Majority of health impacts occur in Asia in all cases

Conclusions

- Global air quality more sensitive to aviation (full-flight) emissions over Europe
  - 45% and 50% more premature mortality caused by a given amount of aviation emissions over Europe than over Asia and North America, respectively
  - Strong dependence on background atmospheric composition and, therefore, non-aviation emissions
- Significant intercontinental effects
  - 73% and 88% of premature mortality caused by aviation full-flight emissions over Europe and North America, respectively, occurs outside those regions

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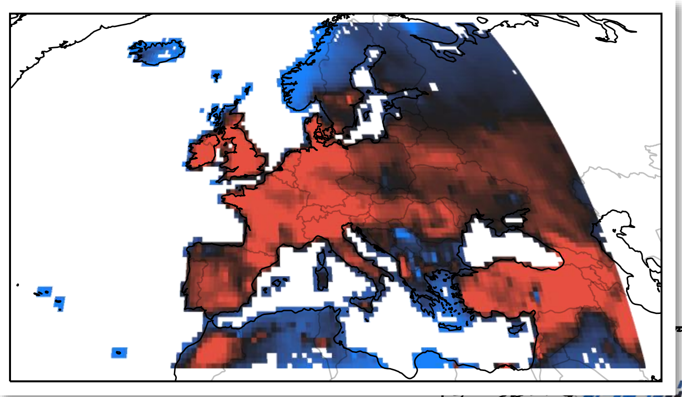
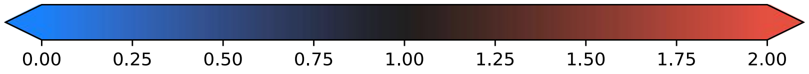
Backup slide – Ammonia availability

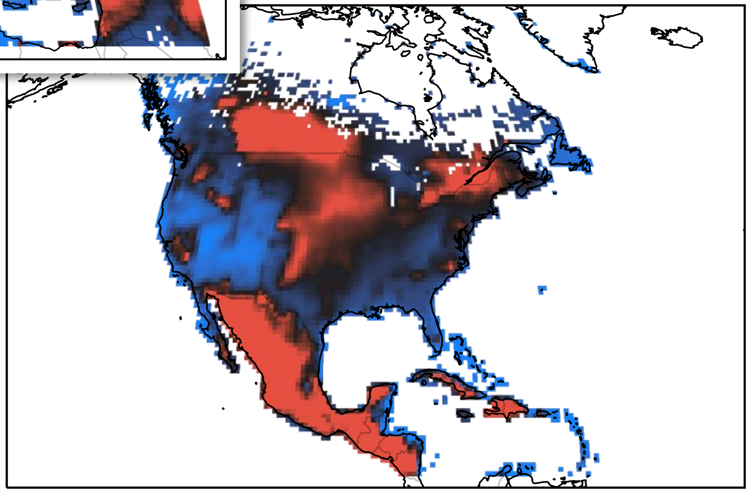
Average ground level gas ratio (GR = free ammonia to total nitrates) during January

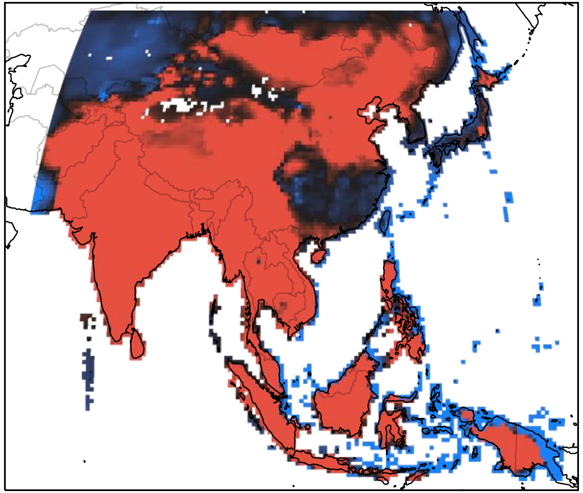


$$GR = \frac{[NH_3] + [NH_4^+] - 2[SO_4^{2-}]}{[HNO_3] + [NO_3^-]}$$



Enough NH_3 to neutralize additional nitrates (formed from aviation NO_x)

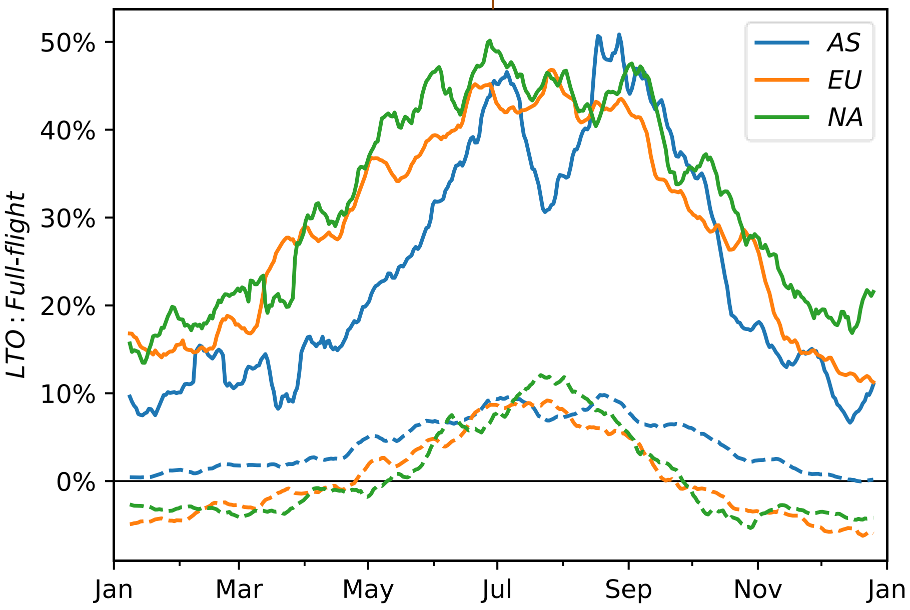




Backup slide – LTO air quality impacts

Population-weighted regional $PM_{2.5}$ and ozone increases with LTO and full-flight perturbations in the same region

– Ratio between LTO and full-flight (14-day averages)



– Annual averages per mass of fuel burn for each case

– Summer (Apr-Sep) and winter (Oct-Mar) averages