Impacts of aircraft emissions on the air quality near the ground

Arezoo Khodayari , Donald J. Wuebbles
Daniel B. Phoenix

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UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Outline

- Introduction
  - Objective
- Model and Data
- Changes in gases (NO_y and O_3)
- Changes in aerosols (PM 2.5)
  - PM 2.5 = sulfate + ammonium nitrate + black carbon + organic carbon
- Summary

Introduction

- Many previous studies have shown the relationship between emissions during the landing and takeoff (LTO) cycle and air quality near major airports

- *Barrett et al.*, 2010 suggest that current non-LTO aviation emissions (climb/descent + cruise altitude emissions) impact local air quality by increasing PM 2.5.

- Jacobson et al., 2013 suggest that current aviation emissions impact local air quality by increasing PM 2.5 and O3.

- *Lee et al.*, 2013 suggest that the impact of current non-LTO aviation emissions (climb/descent + cruise altitude emissions) on local air quality is not statistically significant

Objective

- We focused on the impacts of non-LTO aircraft emissions on ozone, NO_y and PM 2.5
- How well we scientifically understand these perturbations to put numbers on them?

Model

- CAM4 (Community Atmosphere Model)-chem
  - 56 vertical levels covering up to 2 hPa, with the horizontal resolution of approximately a 2.5° (longitude) × 2.0° (latitude)
  - Full chemistry of troposphere and stratosphere
  - Prognostic aerosol processes
  - Meteorological fields MERRA representing 2006
  - Background emissions from RCP4.5

Data

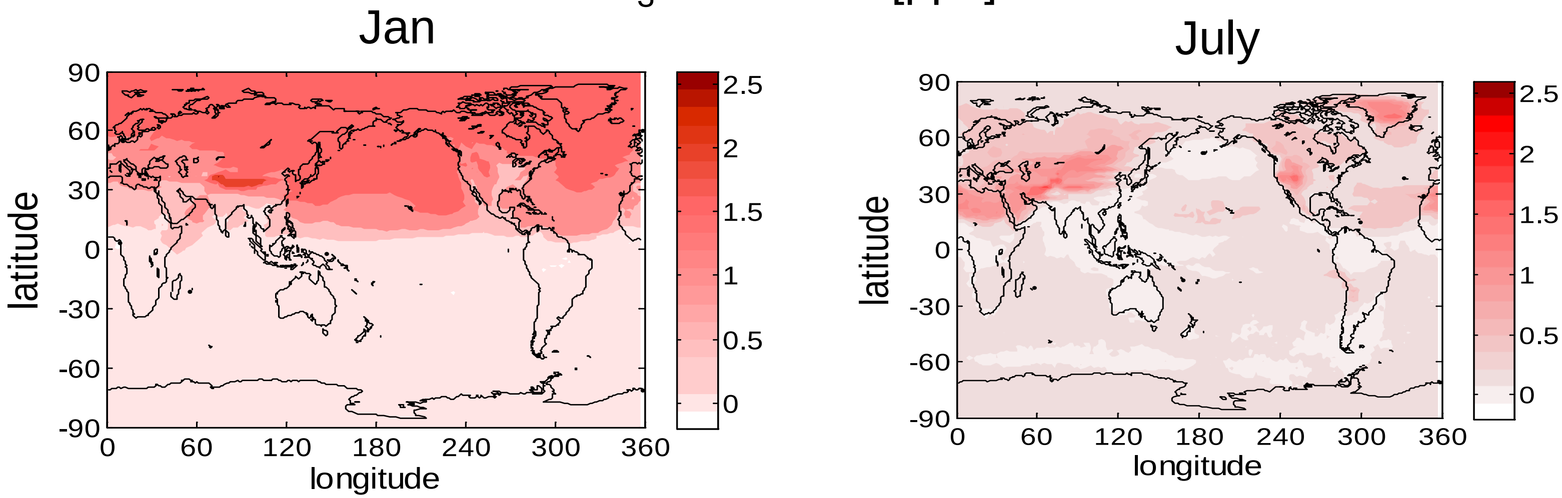
- Aviation emission data from ADET for 2006

	NOx (Tg N)	BC (Gg)	OC (Gg)	CO (Tg)	H2O (Tg)	SO2 (Tg)	SO4 (Gg)
All	0.82	5.9	6.3	0.68	232.0	0.221	6.77
Non-LTO	0.73	5.0	5.0	0.41	205.3	0.196	6.0

Case	LTO emissions (0-1 km)	Non-LTO emissions (1 km-8 km)
control	No	No
aircraft	Yes	Yes
aircraft_non_LTO	No	Yes

Overall surface O_3 increase by aviation emissions

O_3 difference [ppb]



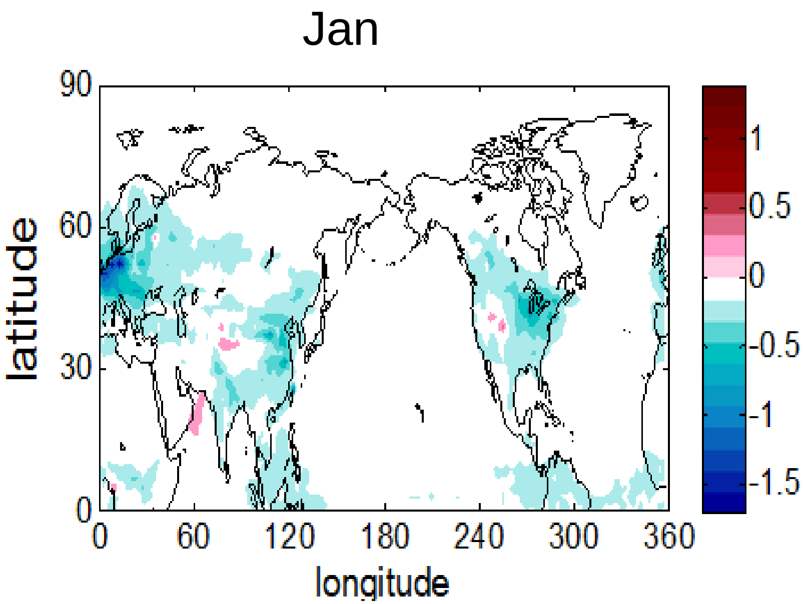
Mostly due to non-LTO emissions, higher in Jan than in July

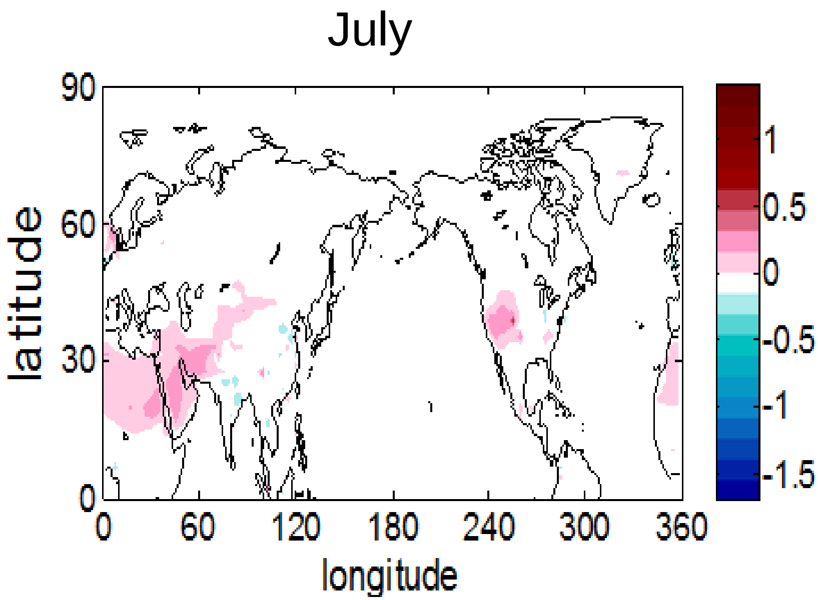
Annual mean surface increase in NH: 0.8 ppb
Mean surface increase in Jan in NH : 1.2
Mean surface increase in July in NH : 0.4

EPA guideline (75 ppbv as daily 8 hours maximum average concentration)
low background concentration in winter relative to EPA guideline

Decrease in the boundary layer NO_y by non-LTO emissions during wintertime

NOy mixing ratio 1e-10 mol/mol





Non-LTO emissions decrease NO_y near the ground and limit O_3 titration (increase ozone) in the winter.

What causes the seasonal differences in NOy and O_3 between January and July?

- Heterogeneous reactions on aerosols

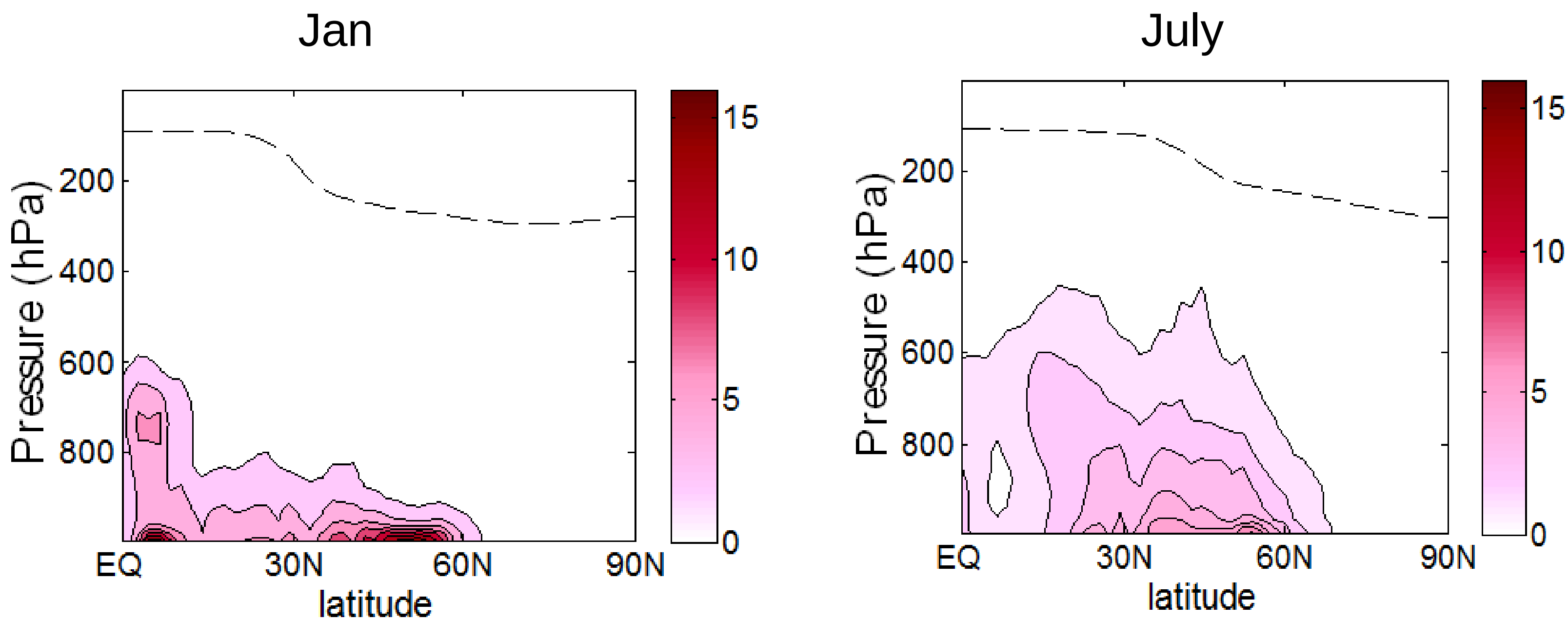
$N_2O_5 \rightarrow 2\ HNO_3$

$NO_3 \rightarrow HNO_3$

$NO_2 \rightarrow 0.5 * (OH + NO + HNO_3)$

- NO_x to HNO_3 reactions: diminish perturbations
- These reactions could explain higher ground NO_x and O_3 perturbations in January than July.

Background PM 2.5 distributions (zonally averaged between 0 and 90E)



Heterogeneous reaction might become more important in in winter near the surface.

Cause of the seasonal differences in NOy and O_3 between January and July

NO_x and O_3 increase by non-LTO emissions

↓

NO_3 regime

$$NO_2 + O_3 \rightarrow NO_3$$
$$NO_3 + NO_2 \rightarrow N_2O_5$$
$$N_2O_5 + H_2O \rightarrow HNO_3$$

↓

attenuated O_3 perturbation
almost zero NO_x perturbation

NO_3 regime

High aerosol

↓

$$NO_2 + O_3 \rightarrow NO_3$$
$$NO_3 + NO_2 \rightarrow N_2O_5$$
$$N_2O_5 + H_2O \rightarrow HNO_3$$
$$N_2O_5 \rightarrow 2\ HNO_3$$
$$NO_3 \rightarrow HNO_3$$
$$NO_2 \rightarrow 0.5^*(OH + NO + HNO_3)$$

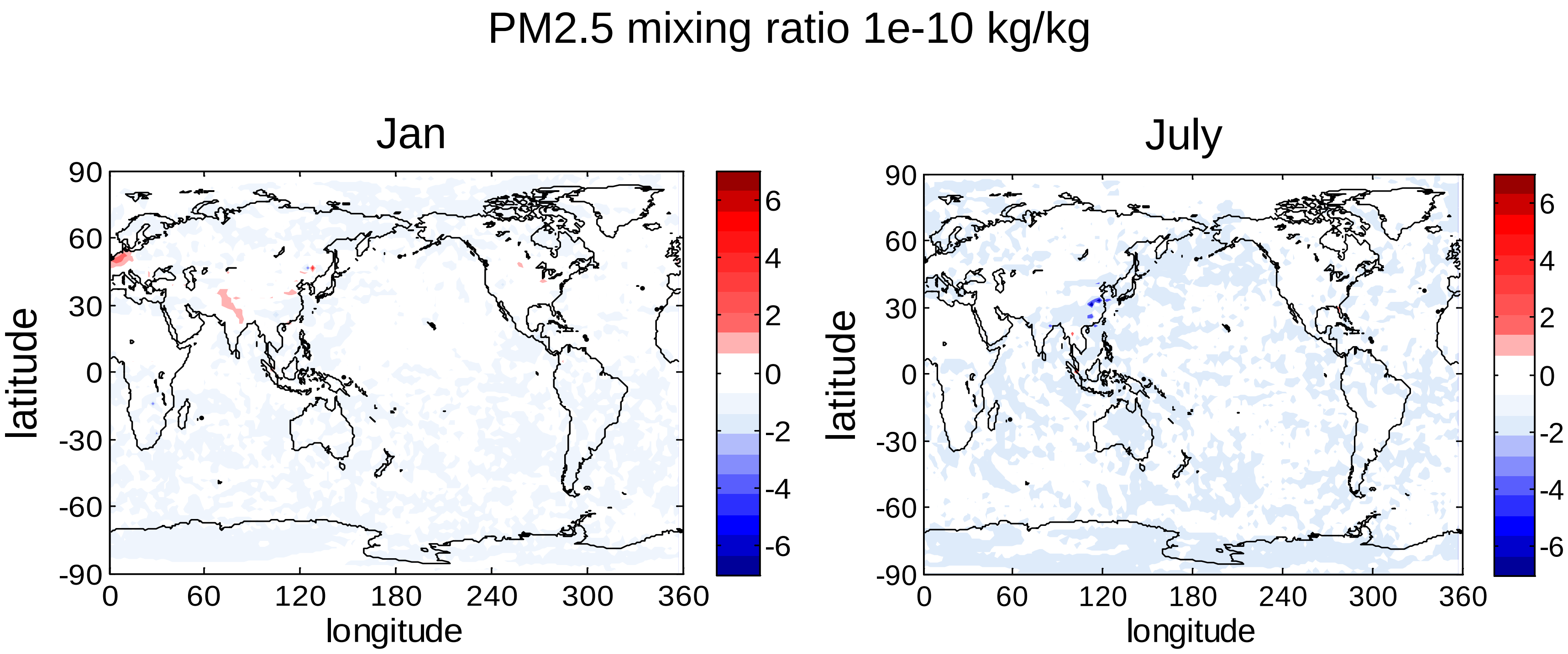
↓

O_3 perturbation is limited
pre-existing NO_x is decreased

- **Net reaction**

$2NO_2 + O_3 + H_2O\ (s) \rightarrow 2\ HNO_3$

PM 2.5 differences due to non-LTO emissions



Mostly due to non-LTO emissions, higher in Jan than in July

Annual mean surface increase in NH: 0.40 $\mu g/m^3$ (0.20%)
Mean surface increase in Jan in NH : 0.64 (0.18%)
Mean surface increase in July in NH : 0.076 (0.14%)

In the wintertime boundary layer the increased HNO_3 determines the effects of non-LTO emissions on the boundary layer PM2.5 rather than directly emitted aerosols from aircraft

- The increase of PM 2.5 in the wintertime boundary layer is mostly due to the NH_4NO_3 increase related to the HNO_3 perturbation
- In July, sulfate perturbation dominates the PM2.5 perturbation

Summary

- Non-LTO emissions decrease NOy near the surface and increase O_3 near the surface
- Overall, wintertime (January) perturbation due to aviation emissions is larger than summer (July), decreased background NO_x can diminish O_3 perturbation.
- Non-LTO emissions is a big contributor to the perturbations in the surface O_3, NO_y and PM 2.5 compared to LTO emissions.
- Several ppbv of wintertime O_3, much smaller O_3 perturbations in summer, and less than 1% increase of PM 2.5 in NH, air quality implications?

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Propagation of O_3 perturbation