Impact of Aviation Emissions on Atmospheric Composition and Climate

Jacek W. Kaminski
Centre for Research in Earth and Space Science
York University, Canada

Joanna Struzewska
Warsaw University of Technology, Poland

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Outline

• Motivation
• GEM-AC model description and configuration
• Emissions → current and future climate
• Analysis methodology
• Impact on climate in the interactive model
• Impact on atmospheric composition (up to 1mb)
• Impact on air quality (ozone)
• Summary
Motivation

• Study of aviation emissions deposition in the atmosphere and resulting interactions with the environment

• Apply an integrated modelling framework to conduct research on:
  – Impacts of aviation emissions that focuses on the chemistry and transport aspects in current and future climate states in the Arctic
    • In the UT/LS (upper troposphere/lower stratosphere)
    • At the surface (ozone and PMs)
  – Climate impacts of future emission scenarios in the Arctic

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GEM-AC model description

- On-line implementation of stratospheric, tropospheric chemistry and aerosols in the Canadian weather forecast model the Global Environmental Multiscale (GEM) model
  - 70 hybrid levels with model top at 60 km (0.1 hPa)
  - Chemistry: 75 gas phase species, 194 chemical reactions, 45 photochemical reactions
  - Aerosol microphysics (M7)
  - Climate physics
  - Ozone and water from chemistry used in radiation calculation
Model Configuration

• For climate runs 3x3 deg grid is used

• High resolution (0.5 deg) model simulations over the Arctic (with a wide margin)

• Initial conditions for current climate (i.e. year 2006) from Canadian Meteorological Centre objective analysis

• Initial conditions (meteorology and chemistry) for future climate in 2025 and 2050 taken from the GEM-Clim model
GEM-AC model configuration

• Climate runs at 3x3 degree resolution

• Emissions
  – Anthropogenic:
    • ACCMIP historical emissions – current climate
    • RCP 8.5 for 2050
  – Aviation (NOx, SO2, CO, BC) from FAA (AEDT, Volpe)
    • 2006 year hourly emissions calculated from FAA and Euro Control flight data (distance traveled, aircraft and engine type)
    • 2050 FAA base scenario – aviation fleet is developed by retiring and replacing older aircraft.

• SST from Canadian Earth System Model - CanESM2
Aviation emissions

Vertical (ft.) distribution of NOx emissions (g) for January 2006

2006 reference year
based on FAA and Euro Control radar data – lat/long 1 deg. 500 ft. altitude grid

2050 Baseline
do nothing with regard to technology and operational improvements.
The 2050 fleet is developed by retiring and replacing older aircraft.
Analysis methodology

• Two time slices selected (10 years): 2000, 2050
• DELTA – difference between scenario with aviation emissions (A1) and without (A0)
• Temporal averaging – monthly
• Spatial averaging:
  – Focus on the Northern Hemisphere
  – Hemispheric zonal average – western and eastern centred over the North Pole
  – Longitudinal average in bands: 0-30N, 30-60N, 60-90N
Hemispheric zonal average (western and eastern hemisphere centered over North Pole)

Longitudinal average in bands:
0-30N, 30-60N, 60-90N
Impact on meteorology/climate – Temperature 2000 (delta A1 – A0)

- DJF
- MAM
- JJA
- SON
Impact on meteorology/climate – Geopotential 2000 (delta A1 – A0)

DJF

W & E hemispheric average for A1-A0_3x3_2006_DJF

Annual average

MAM

W & E hemispheric average for A1-A0_3x3_2006_MAM

JJA

W & E hemispheric average for A1-A0_3x3_2006_JJA

SON

W & E hemispheric average for A1-A0_3x3_2006 Sonata
Impact on meteorology/climate – Wind delta A1-A0 (March 2000)

Zonal wind – U [knots]

Meridional wind – V [knots]
Impact on ozone (delta A1- A0)

W & E hemispheric average for A1-A0_3x3_200607

July 2000

W & E hemispheric average for A1-A0_3x3_205207

July 2050
Impact on ozone (delta A1-A0)

Average latitude bands for A1-A0_3x3_200607

Average latitude bands for A1-A0_3x3_205207

July 2000

July 2050
Impact on NOx (delta A1 – A0)

July 2000

July 2050
Impact on NOx (delta A1 – A0)

Average latitude bands for A1-A0_3x3_200607

Average latitude bands for A1-A0_3x3_205207

July 2000

July 2050
GEM-AC model results: 5-year climate run

Current

2050

Scenario with minus without aviation emissions
Summary 1/2

• Significant impact of aviation emissions on meteorological parameters. Modification of thermal structure and circulation
  – Lack of aviation emissions may result in model inaccuracy
  – Further work – comparison with reanalysis

• Impact on near surface air quality (ozone)
Summary 2/2

• Significant impact of aviation emissions on atmospheric composition
  – Maximum impact in the stratosphere
  – High signal in the Arctic (>60°N)
  – Similar pattern on DELTAs in current and future climates, but:
    • Higher contribution of aviation emissions to tropospheric ozone budget in 2050
    • Smaller increase (or decrease) of NOx in the troposphere in 2050 (change of chemical regime ?)

• Further work – analysis for other species