PWGS Contract T8497-120001/001/TOR

Assessing the Climate Impact of Aviation in the Arctic

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and do not necessarily reflect the views Transport Canada

Boeing 737 landing at Eureka, NU, Canada. Photo by Pierre Fogal.

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

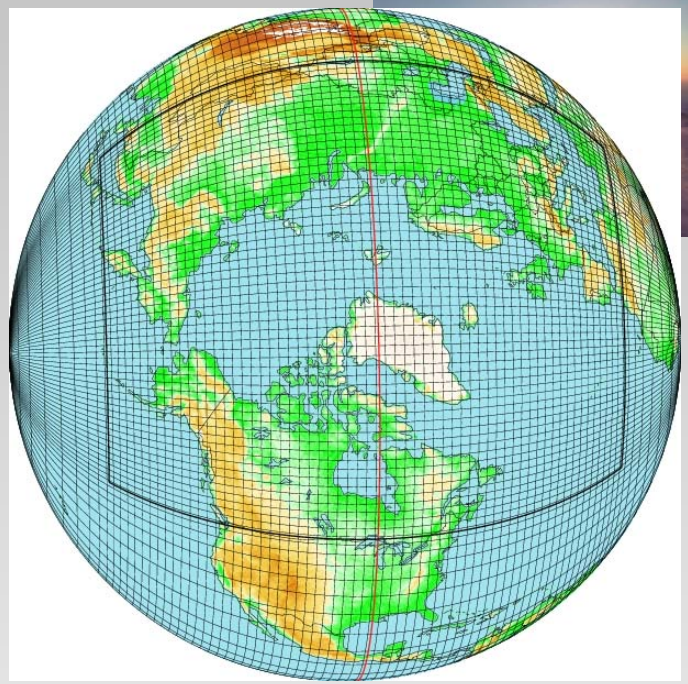
- Study of aviation emissions deposition in the atmosphere and resulting interactions with the environment
- Apply an integrated modelling framework to conduct research on:
  - Impacts of aviation emissions that focuses on the chemistry and transport aspects in current and future climate states in the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

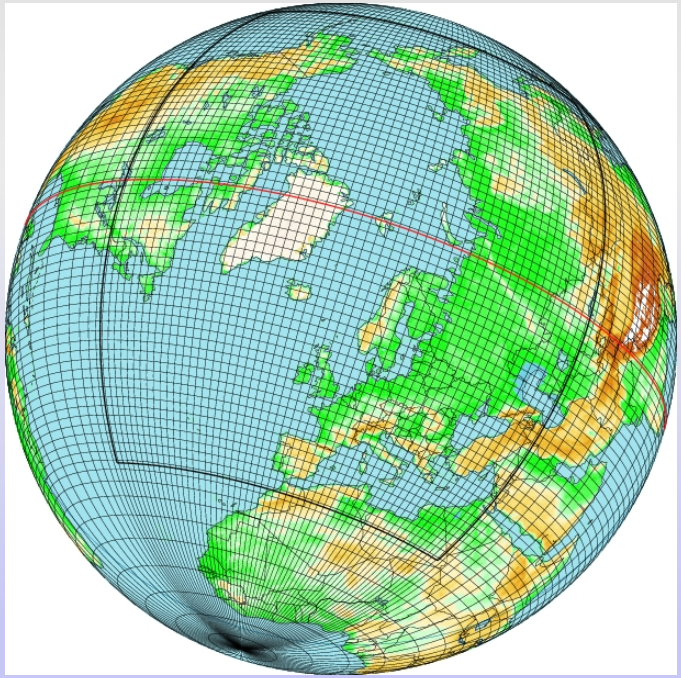
GEM-AC model description

- 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 the Canadian Meteorological Centre objective analysis
- Initial conditions (meteorology and chemistry) for future climate in 2025 and 2050 taken from the GEM-Clim model



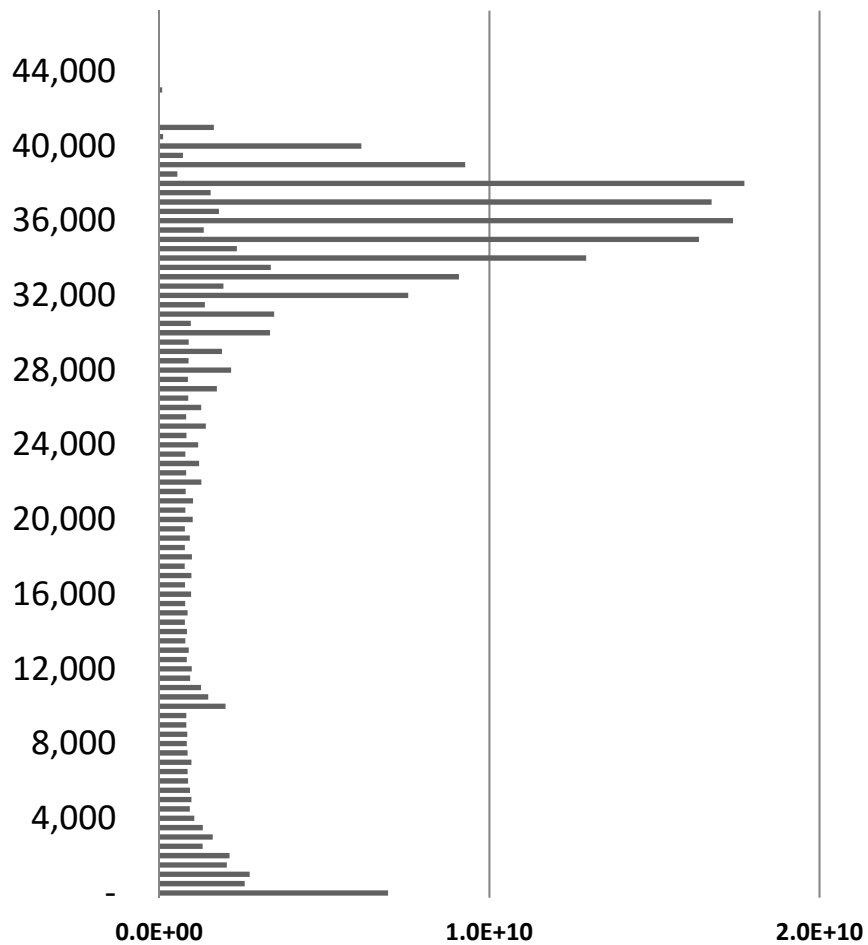


GEM-AC model configuration

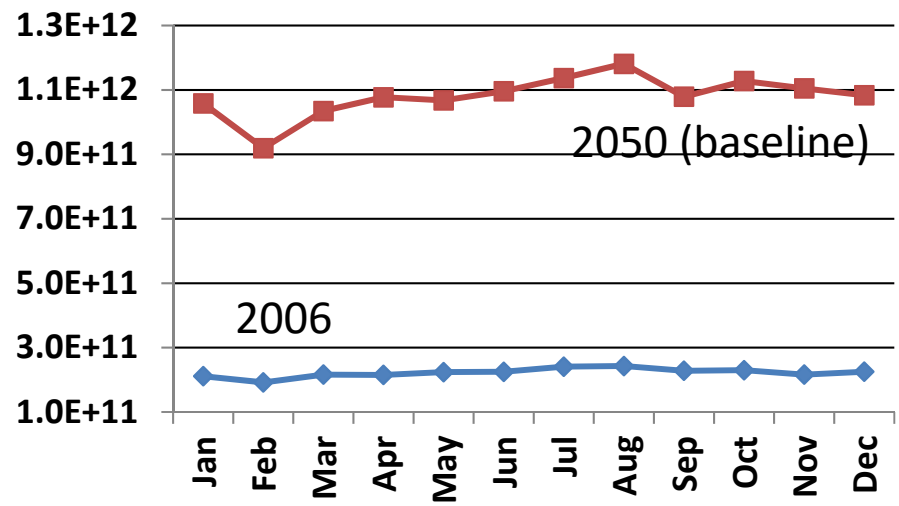
- Climate runs at 3x3 degree resolution
- Emissions
  - Anthropogenic:
    - ACCMIP historical emissions – current climate
    - RCP 8.5 for 2050
  - Aviation (NOx, SO2, CO, BC) from FAA (AEDT, Volpe)
    - 2006 year hourly emissions calculated from FAA and Euro Control flight data (distance traveled, 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



NOx emissions (g)



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

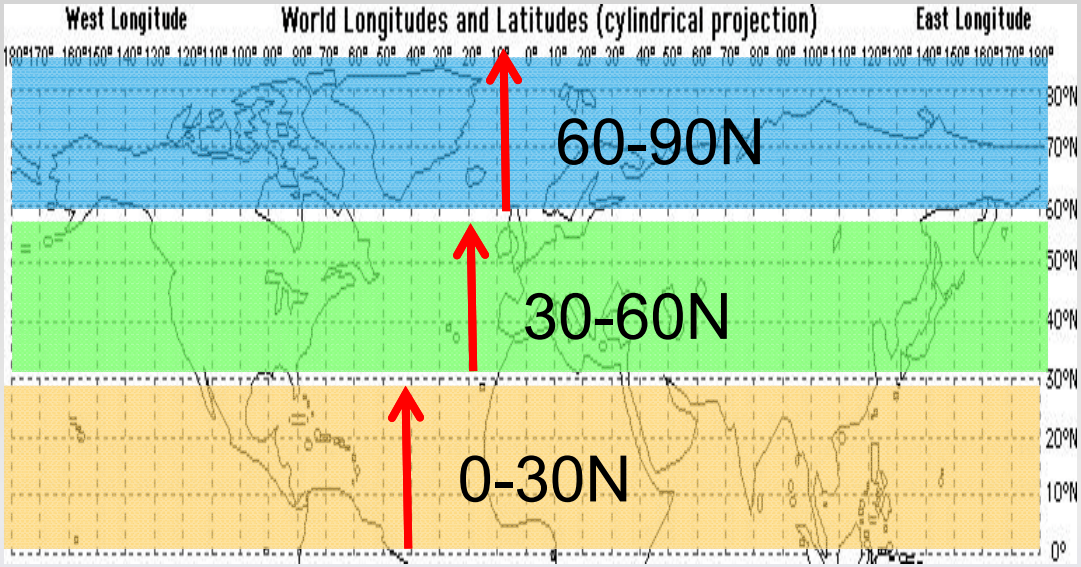
2050 Baseline
do nothing with regard to technology and operational improvements.
The 2050 fleet is developed by retiring and replacing older aircraft.

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

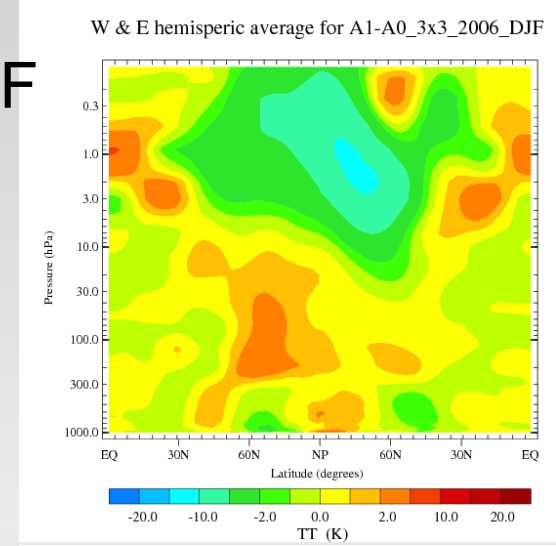
WH EH



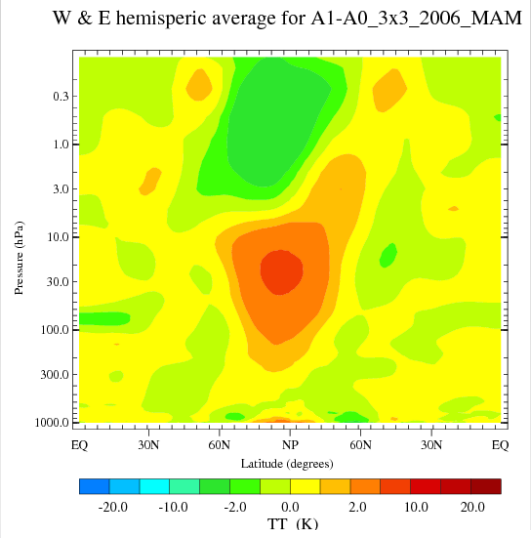
Longitudinal average in bands:
0-30N, 30-60N, 60-90N

Impact on meteorology/climate – Temperature 2000 (delta A1 – A0)

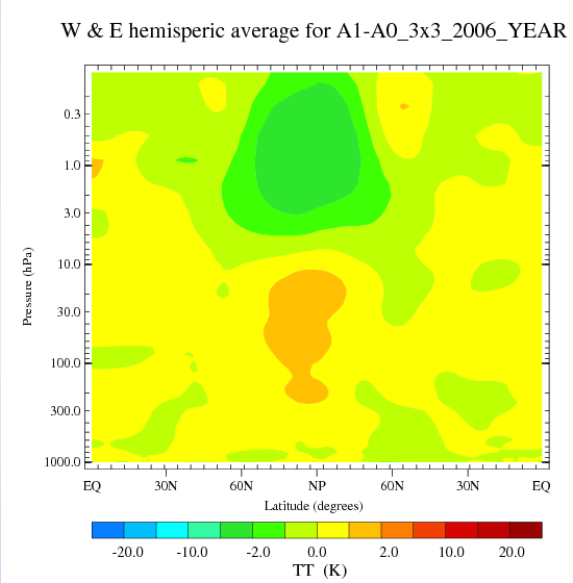
DJF



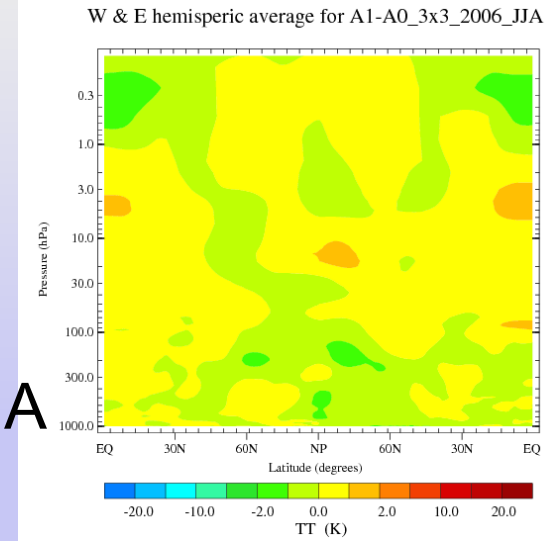
MAM



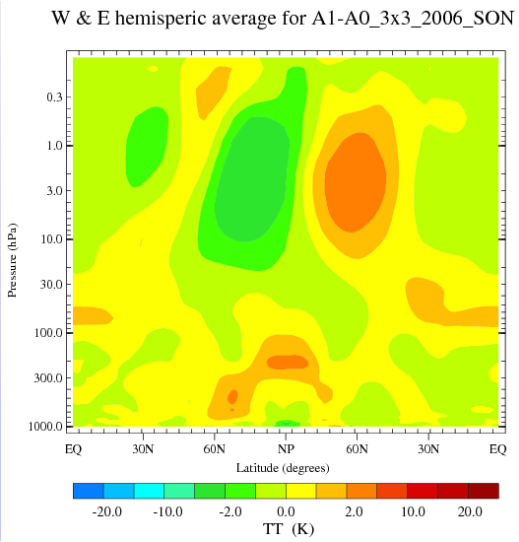
Annual average



JJA

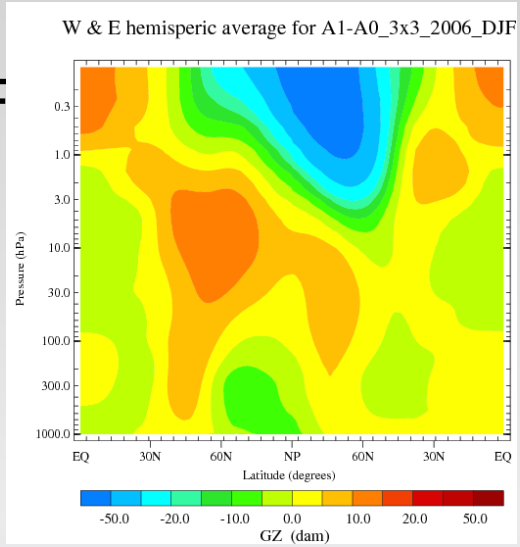


SON



Impact on meteorology/climate – Geopotential 2000 (delta A1 – A0)

DJF



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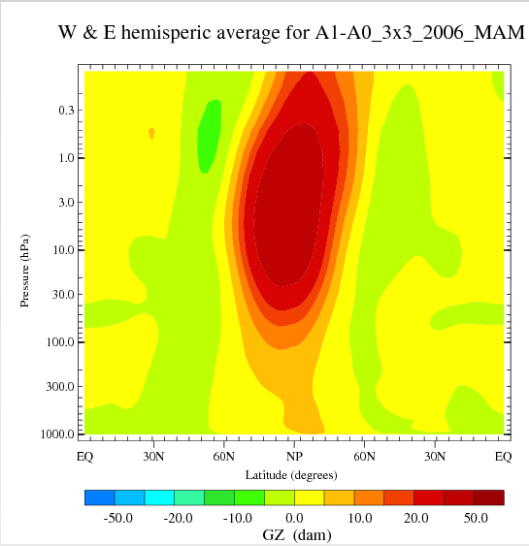
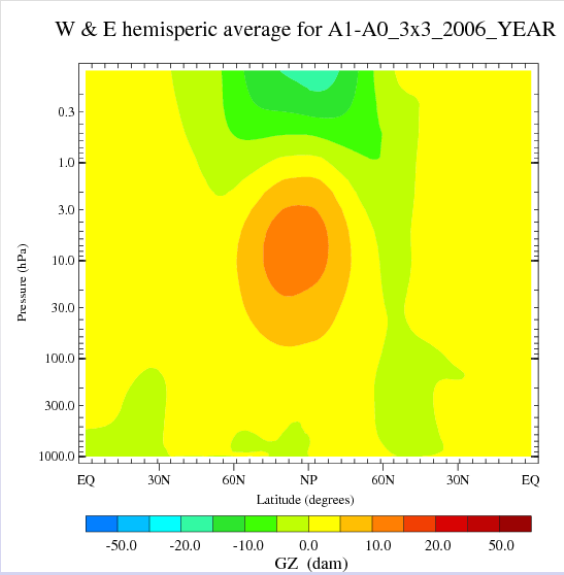
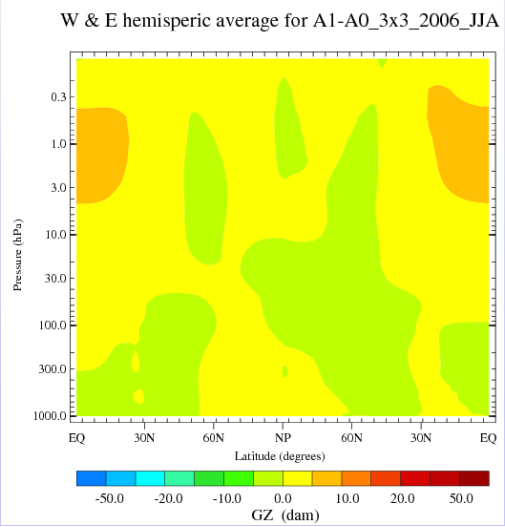
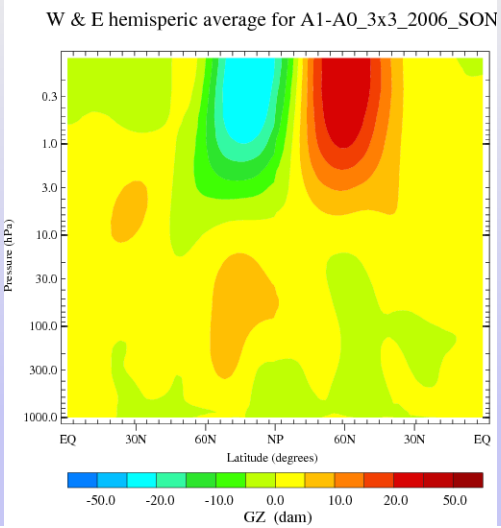


Annual average



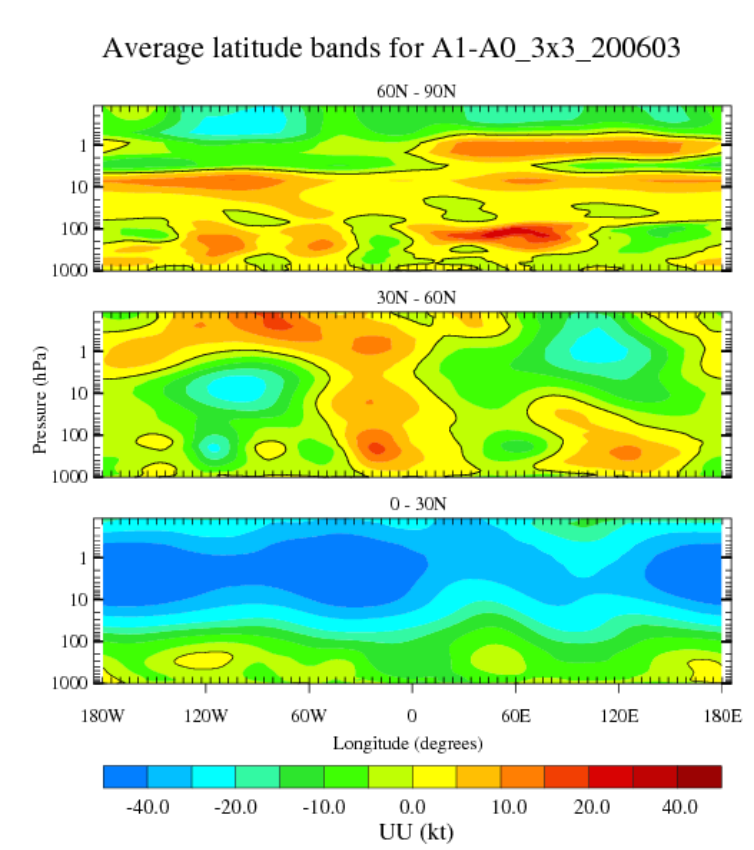
JJA

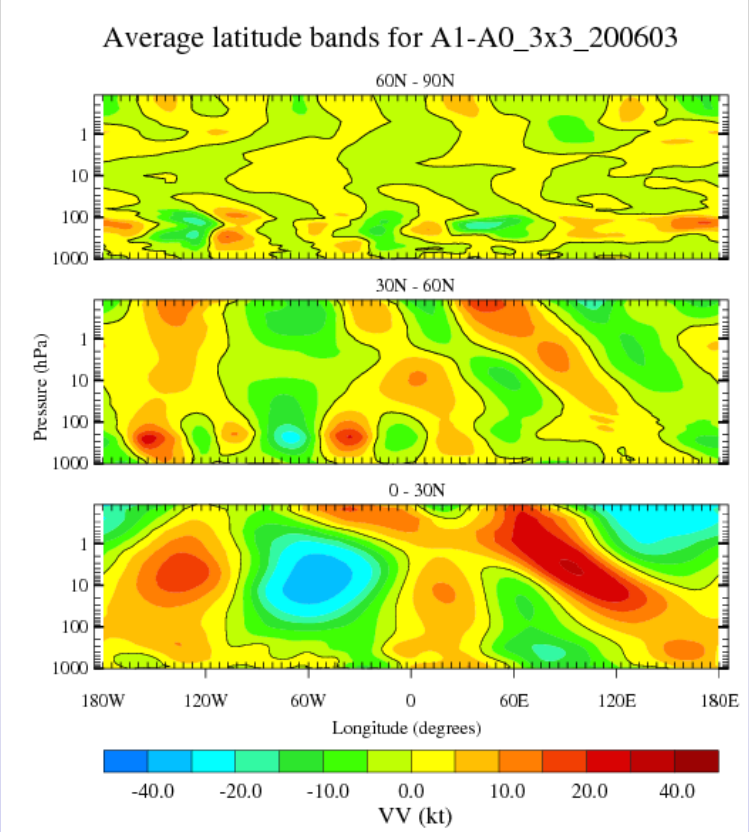




SON

Impact on meteorology/climate – Wind delta A1-A0 (March 2000)

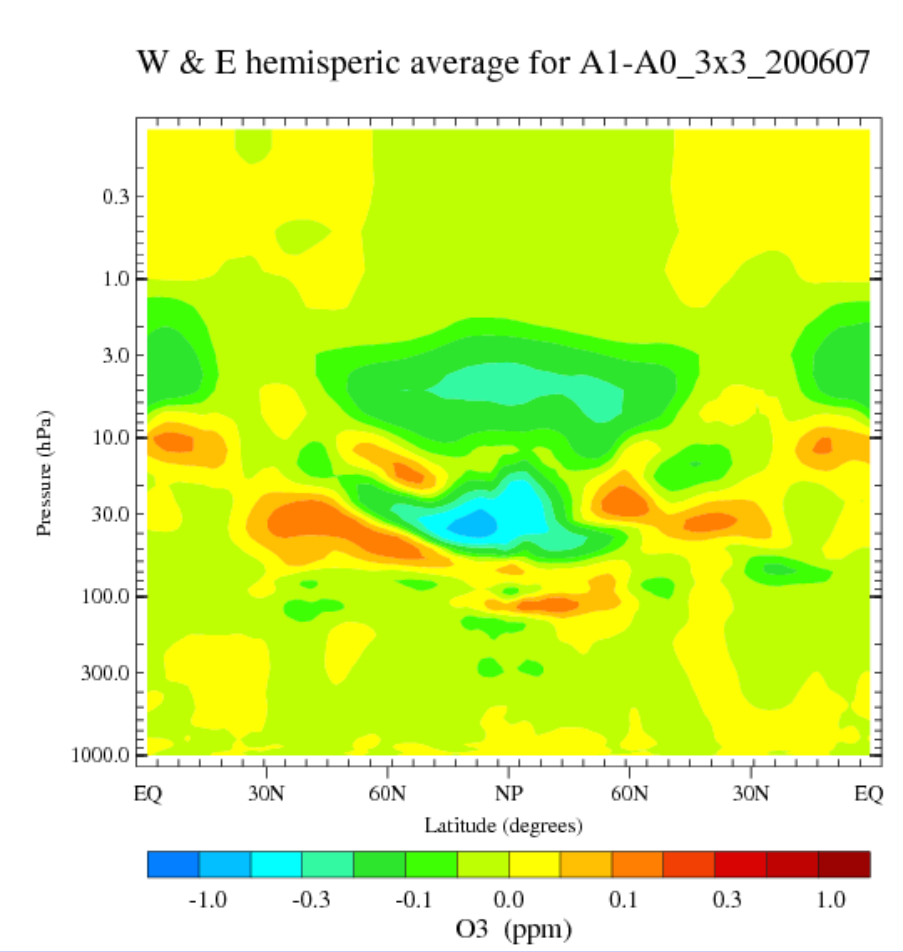




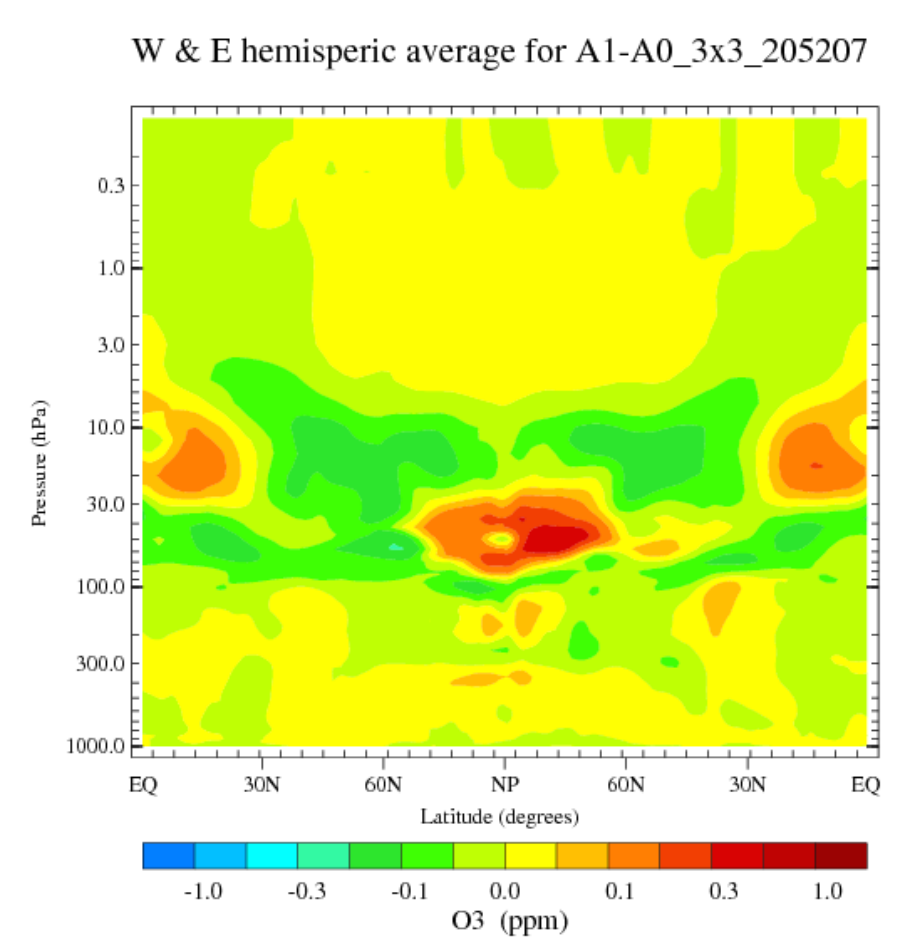
Zonal wind – U [knots]

Meridional wind – V [knots]

Impact on ozone (delta A1- A0)

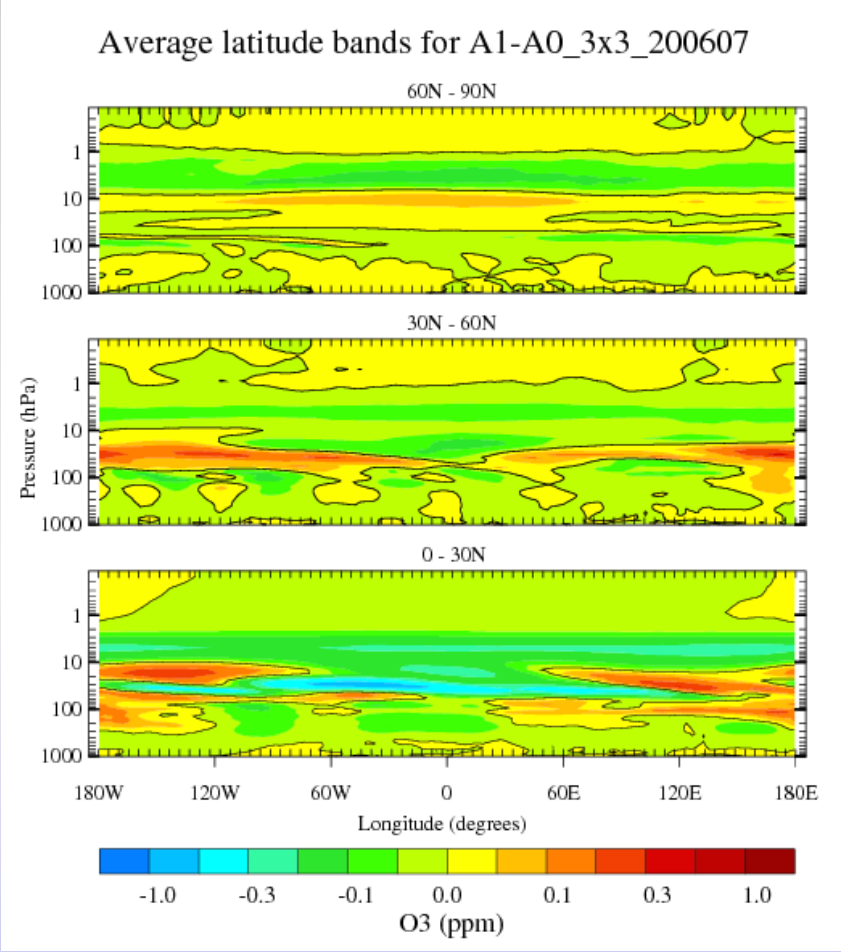


July 2000

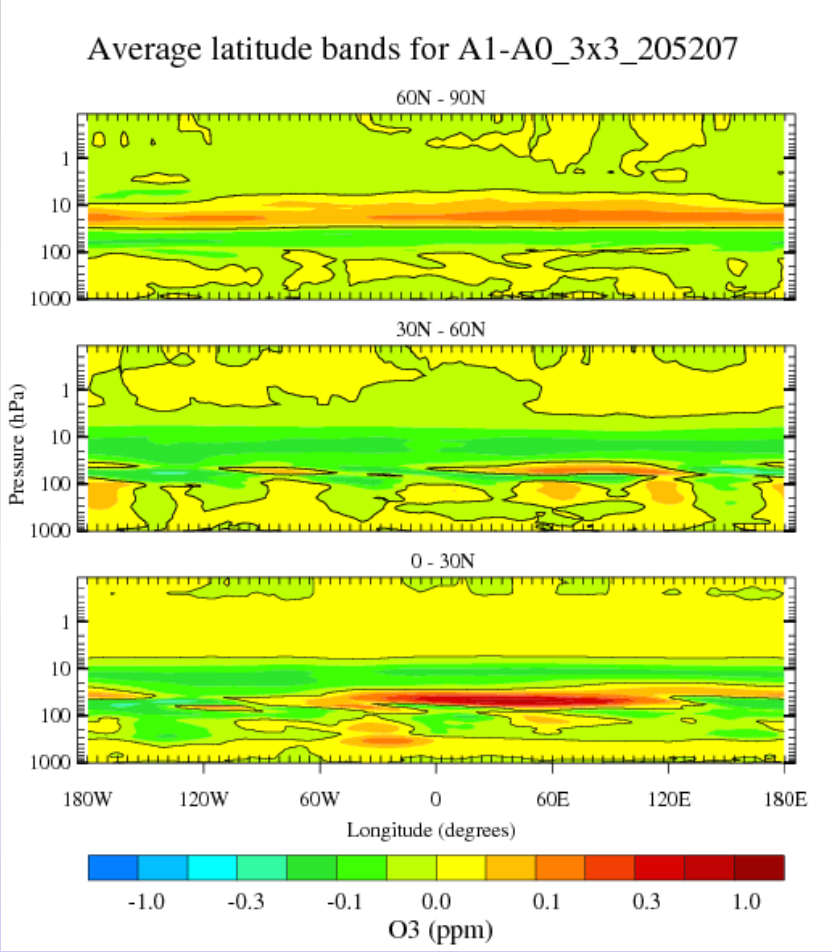


July 2050

Impact on ozone (delta A1-A0)



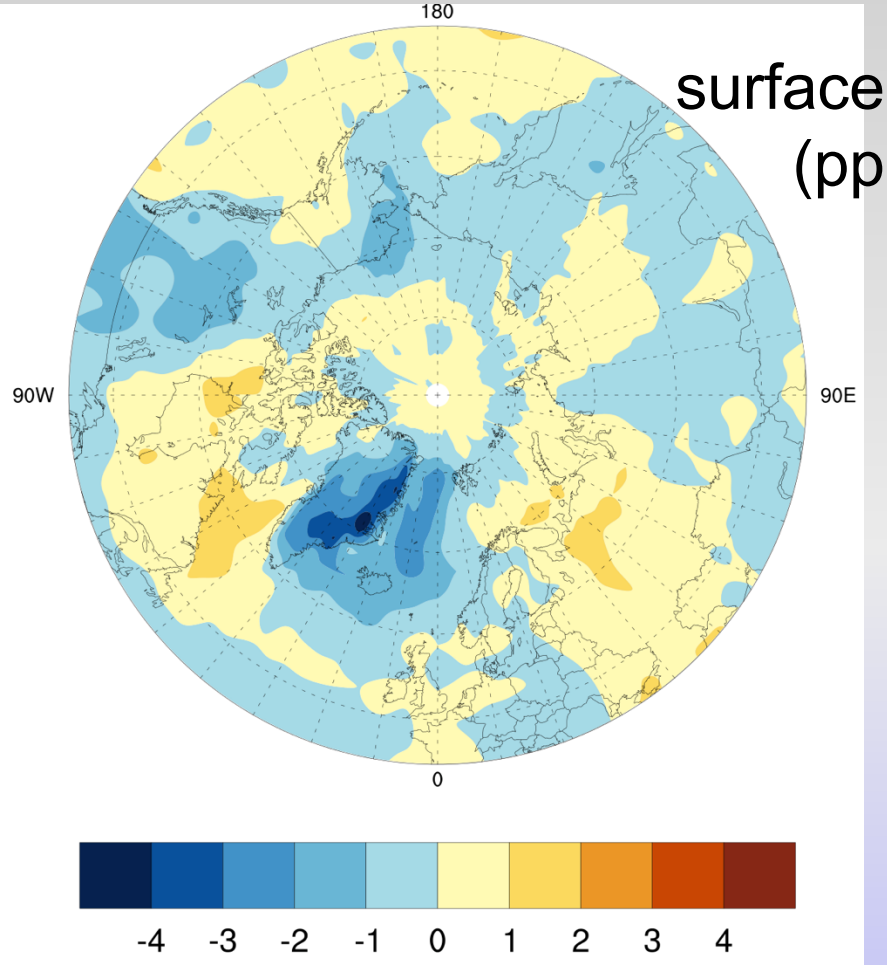
July 2000



July 2050

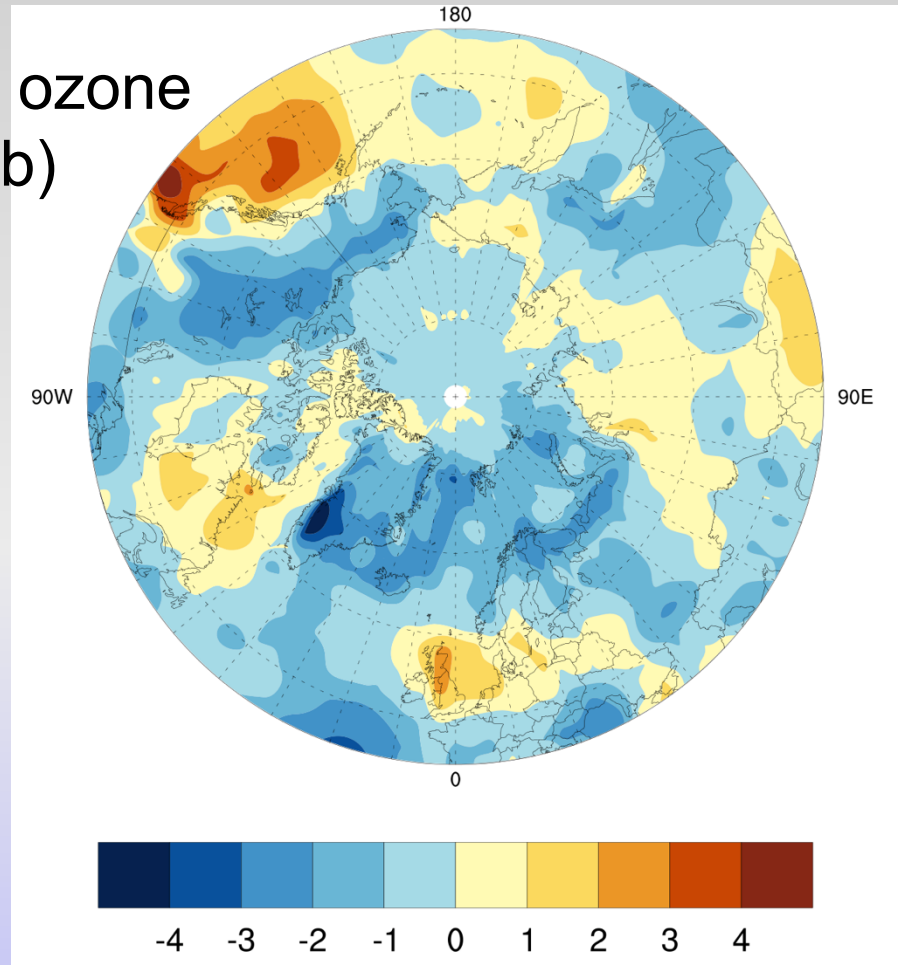
GEM-AC model results: 5-year climate run

Current



surface ozone (ppb)

2050



Scenario with *minus* without aviation emissions

Summary

- Significant impact of aviation emissions on
  - meteorological parameters
  - modification of thermal structure and circulation
  - changes in atmospheric composition
- Maximum impact in the stratosphere
- High signal in the Arctic (>60°N)
- Similar pattern for DELTAs in current and future climate
- Further work
  - analysis for other species
  - impact on near surface air quality (ozone)

Contributors

Jennifer Beale, PhD student at York University, expected to graduate June 6, 2016. Thesis title: Implementing Aerosol Radiative Effects in the GEM-AC model.

Magdalena Porebska, PhD student at Warsaw University of Technology, expected to graduate in 2017. Thesis title: High resolution dynamical modeling of the upper troposphere and lower stratosphere region over Europe.

Karol Szymankiewicz, PhD student at Warsaw University of Technology, expected to graduate in September 2016. Thesis title: Interannual variability of tropospheric NO_2 column over Central Europe - observations from SCIAMACHY and GEM-AQ model simulations.

Maciej Jefimow, PhD student at Warsaw University of Technology, expected to graduate in 2017. Impact of aerosol direct effect on meteorological forecasts.

iAREA consortium (Impact of Absorbing Aerosols on Radiative Forcing in the European Arctic) – Modelling and field observations on Spitsbergen.

Publications

In preparation:

- Impact of Aviation emissions on the Arctic atmosphere – model simulations for current and future climate
- Biomass burning and Lightning sources of emissions from ACE-FTS, OSIRIS, and MOPITT satellite data using GEM-AQ in high resolution mode
- Exploration of UTLS processes using OSIRIS and ACE data with extended GEM-AC

Submitted:

- Lisok, et al., 2015, A study of aerosol physical and chemical properties during the iAREA2014 campaign on Spitsbergen, submitted to Atmospheric Environment
- Struzewska, et al., 2015, Impact of climate change on air quality in Central Europe – GEM-AQ model simulations, submitted to ACPD

Published:

- Struzewska, J., Zdunek, M., Kaminski J.W., Lobocki, L., Porebska, M., Jefimow, M., and Gawuc, L.: Evaluation of the GEM-AQ model in the context of the AQMEII Phase 1 project, Atmos. Chem. Phys., 2015
- Szymankiewicz, K., Kaminski, J.W. and Struzewska, J.: Interannual variability of tropospheric NO_2 column over Central Europe - observations from SCIAMACHY and GEM-AQ model simulations, Acta Geophysica, vol. 62, 915-929 DOI: 10.2478/s11600-014-0211-z, 2014

Future Work

- Model runs for additional 2050 emission scenarios
- Model analysis for additional species
- Impact on near surface air quality (ozone and PMs)
- On-going model evaluation with
  - Satellite observations
  - In-situ observations
  - Model inter-comparison
- On-going model development
- Model application in future assessments
  - Aviation – 'improved' emission estimates
  - IPCC AR6 – new approach to future emission estimates

Thank you