High resolution modeling of the upper troposphere and lower stratosphere region over the Arctic

GEM-AC simulations for the future climate with and without aviation emissions

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Upper troposphere and lower stratosphere (UTLS) region is a layer around the tropopause. Perturbation of the chemical composition in the UTLS region can impact physical and dynamical processes that can lead to changes in cloudiness, precipitation, radiative forcing, stratosphere-troposphere exchange and zonal flow. The objective of this study is to investigate the potential impacts of aviation emissions on the upper troposphere and lower stratosphere. In order to assess the impact of the aviation emissions we will focus on changes in atmospheric dynamic due to changes in chemical composition in the UTLS over the Arctic. Specifically, we will assess perturbations in the distribution of wind, temperature and pressure fields in the UTLS region. Our study will be based on simulations using a high resolution chemical weather model for two scenario of future (2050) climate: with and without aviation emissions.

The GEM-AC model

GEM-AC is an on-line and interactive tropospheric and stratospheric chemistry model with a unique capability to run in a global variable resolution where the uniform portion of the computational grid can be placed over the region of interest. In this study, a global variable grid with horizontal resolution 0.5 x 0.5 deg over Arctic was used. The model was integrated on 70 hybrid levels with the top at 0.1 hPa. The vertical resolution in the UTLS region is equal about 500 m. Time step simulation: 30min. Chemistry: 75 gas phase species, 194 chemical reactions, 45 photochemical reactions, aerosol microphysics (MT), climate physics. SST from the Canadian Earth System Model - CanESM2.

The model was run for two emissions scenario: with (A1) and without (A0) aviation emission for future climate, based on RCP8.5 emission scenarios for 2050 year. Simulation included anthropogenic emission according to RCP 8.5 for 2050 and for scenario A1 aviation emission of NOx, SO2, CO, BC from FAA (AIRDIT, Volpe) 2050 FAA and Euro Control flight data (distance traveled, aircraft and engine type) base scenario – where aviation fleet is developed by retiring and replacing older aircraft.

RESULTS

- The biggest changes were observed in the stratosphere and the mesosphere rather than in the UTLS region.
- Seasonal fluctuations in atmospheric parameters with no constants time or space trend were observed.
- Changes in the humidity (HU) in the future climate indicate a significant increase in humidity in high latitude, especially for the Eastern Hemisphere and the Arctic.
- The biggest increase of HU was in the troposphere.
- The spatial fluctuation of changes in the humidity may be connected with a global air mass transport.
- The seasonal variability of the temperature (TT) shows that the biggest changes occurred during winter and spring seasons.
- An increase of the temperature in the UTLS region in high latitudes was noticed in spring (2K), summer (5K) and autumn (3K) seasons. A decrease of 2K in the temperature occurred during the winter season.
- The strongest changes of TT was located over the Western Hemisphere. Noticeable changes over Eastern Hemisphere occurred only during the autumn season.
- We found significant seasonal changes in geopotential height (GZ). In the UTLS region over the high latitudes, the strongest changes between scenarios occurred during the winter and autumn seasons.
- During the winter we can see -15dam decrease of GZ over the Western Hemisphere and during the autumn there was +15dam increase of GZ over Eastern Hemisphere. In the summer season, the changes in the UTLS were negligible.
- Changes in the zonal wind vector (UU) and meridional wind vector (VV) indicates significant changes in the jet streams.
- The seasonal changes in UU and VV in the UTLS over the high latitudes show that the most significant differences, especially in the meridional wind vector, between two emission scenarios occurred during the winter and spring seasons, with the maximum increase +25kt (0.6Ht) and the maximum decrease -10kt (1.2W).
- The smallest changes were noticed in the summer.

SUMMARY

- Changes in dynamics and physics fields due to aviation emission are significant.
- The most pronounced changes were noticed in the stratosphere rather than in the UTLS region.
- The mean trend of changes in the atmospheric parameters in current and future climate due to aviation emission looks similar.
- More noticeable changes occurred in future climate simulations.
- Although the annual mean does not show any significant differences between scenarios with and without aviation emissions, the seasonal changes show a more pronounced impact of aviation emission on the atmospheric parameters. The largest changes occurred in autumn and winter seasons.
- Aviation emissions have a significant impact on atmospheric parameters in high latitudes. The increase of temperature in the UTLS may have a significant influence on the boundary between the polluted troposphere and rich in ozone stratosphere.

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