Project 22
Evaluation of FAA Climate Tools

ASCENT AVIATION SUSTAINABILITY CENTER

ILLINOIS UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Motivation and Objectives

- Aviation emissions have significant spatial variability in the sign and magnitude of response and impacts, so it is necessary to study the regional and zonal effects of aviation emissions effects on climate (that is on smaller scales).
- Previous research has shown the distribution of regional radiative forcings (RF) in four latitudinal bands. Here we move into the next step of the cause-effect chain - to calculate the regional temperature change.
- The ultimate **objective** of this project is to enhance the overall understanding of aviation impacts on climate and the evaluation of the capabilities and limitations of the simple models (e.g., APMT).

Methods and Materials

- The sub-global climate metric Absolute Regional Temperature Potential (ARTP) is calculated to investigate the regional climate effects from aviation emissions.
- ARTP is obtained by using the following equation from Lund et al, 2017.

$$ARTP_{i,m}(H) = \sum_l \frac{RF_{i,l}}{E_i} * RCS_{i,l,m} * IRF(H)$$

- $RF_{i,l}$ is the RF in latitude band l caused by 1 year of emissions E_i of species i. The E values are obtained from AEDT inventory and RF values are calculated from the Community Atmosphere Model version 5, which are listed below in Table 1 and 2 respectively.
- The regional climate sensitivity $RCS_{i,l,m}$ is the unitless regional response in latitude band m due to a radiative forcing in latitude band l caused by a change in species i, relative to global sensitivity.
  - RCSs are developed from a complex atmosphere–ocean climate model NASA GISS (Shindell and Faluvegi, 2009).
- The impulse response function IRF(H) is a temporal temperature response to an instantaneous unit pulse of RF.

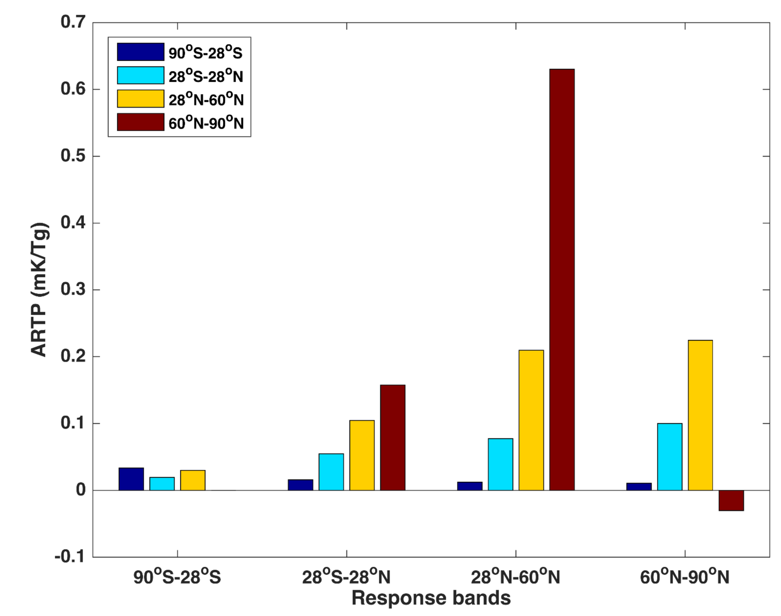
Table 1. Regional aviation emissions in 2006

emissions (kg)	90°S-28°S	28°S-28°N	28°N-60°N	60°N-90°N	Global
NOx	1.95E+08	2.42E+08	3.32E+08	4.65E+07	8.12E+08
BC	1.40E+06	1.79E+06	2.44E+06	3.30E+05	5.96E+06
Sulfate	1.59E+06	2.04E+06	2.77E+06	3.76E+05	6.78E+06

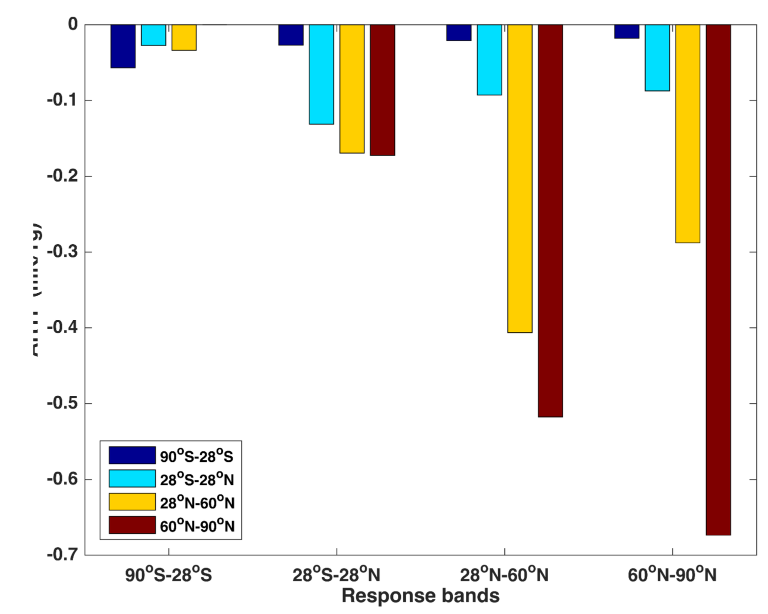
Table 2. Regional radiative forcings in 2006

Radiative forcing (mW/m^2)	90°S-28°S	28°S-28°N	28°N-60°N	60°N-90°N	Global
O_3	12.6	27.5	67.1	45.6	37.3
BC	0.06	0.14	0.86	0.63	0.3
Sulfate	-1.15	-2.7	-11.37	-7.86	-4.4

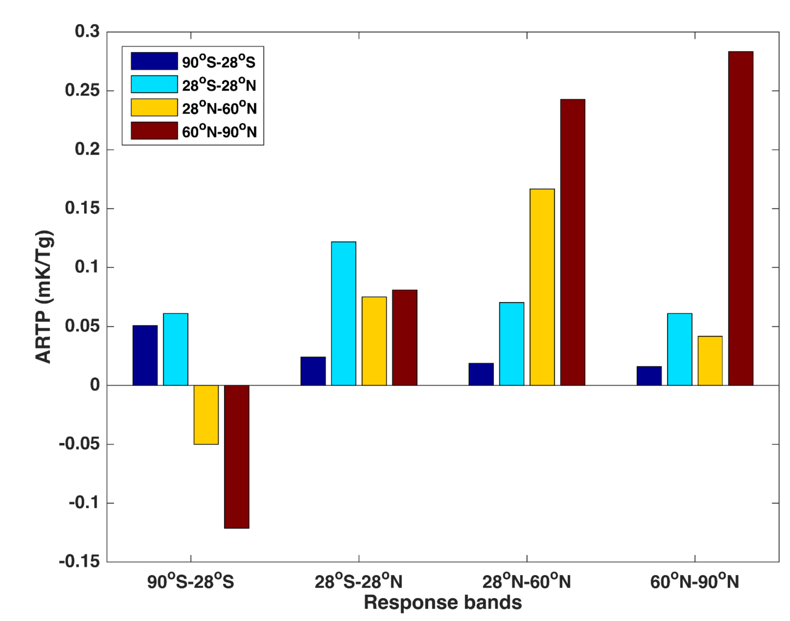
Results and Discussion



(a) BC

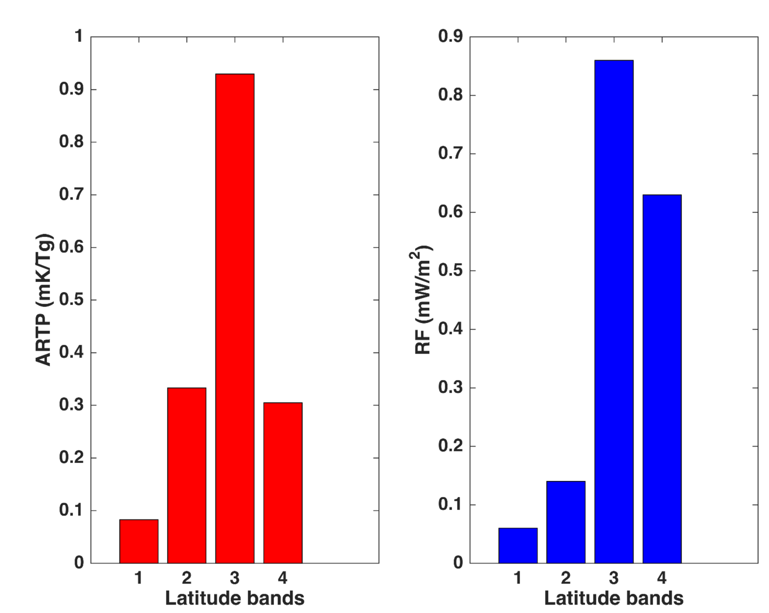


(b) Sulfate

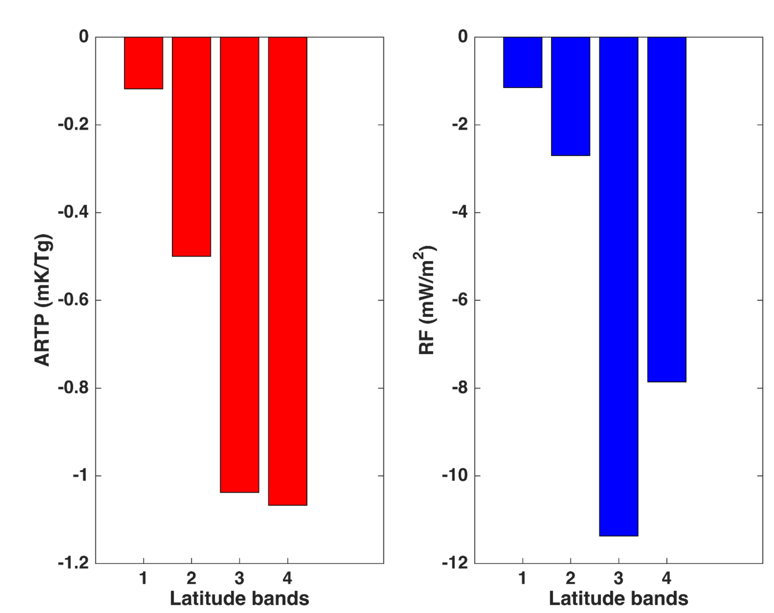


(c) O_3

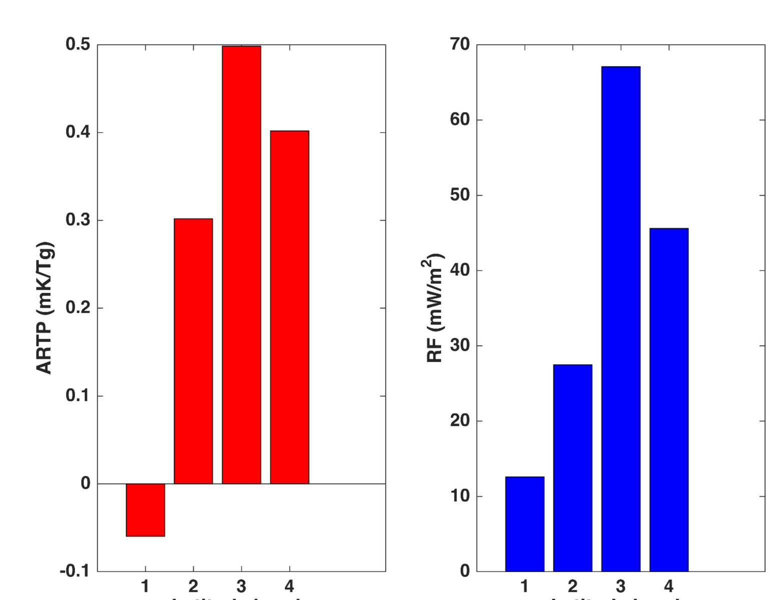
Figure 1. ARTPs of aviation (a) BC, (b) Sulfate, (c) O_3 (NOx-induced short-term O_3 production). It gives the temperature impact per unit emission (mK/Tg). The ARTPs in each response bands are showing from the RFs in 4 different latitude bands, with the different color bars indicate different forcing bands.



(a) BC



(b) Sulfate



(c) O_3

Figure 2. ARTPs and RFs of aviation (a) BC, (b) Sulfate, (c) O_3 (NOx-induced short-term O_3 production). ARTP is on the left of each figure, while the RF is on the right. The numbers of the x-axis mean different latitude bands with the 1 denotes 90°S-28°S; 2 denotes 28°S-28°N; 3 denotes 28°N-60°N and 4 denotes 60°N-90°N. The ARTPs here for each latitude bands sum up the response from 4 different forcing bands.

- The magnitude of ARTP in a given latitude band is determined both by the local forcing and the forcing exerted remotely, which are related to the RCS values in that band.
- The negative ARTPs in Figure 1. (a), (c) for BC and O_3 over band 60°N-90°N and 90°S-28°S are due to the negative RCS values over that bands. For ARTP of BC over 60°N-90°N, the temperature response to local forcing is negative.
- Forcings over latitude band 60°N-90°N result in zero or negative temperature response on latitude band 90°S-28°S. The highest ARTP values over response band 28°N-60°N for all BC, Sulfate and O_3 are attributed to the forcing over band 60°N-90°N.
- By comparing the latitudinal distribution of the RF values with that of the ARTPs (Fig. 2), it is shown that the ARTPs can be considerably larger or smaller than the RFs indicated by the corresponding bands (eg. The RF of sulfate over latitude band 60°N-90°N is much lower than the RF over band 28°N-60°N, while the ARTP dependence is opposite). This is because the ARTPs depend both on RF and RCS.

Conclusions and Next Steps

- Using ARTPs shows that the temperature response in given latitude bands is not necessarily proportional to the RF in that band. The response can be considerably stronger than the corresponding RF and can be attributed to forcings in the opposite hemisphere.
- The regional temperature change are determined not only on the forcing over the local region, but also on the forcing exerted remotely by large-scale circulation impacts and feedbacks in the climate system.

The **Next Steps** include:

- Evaluation of the v24 of APMT-I Climate when it becomes available.
- Examine how remote emissions and forcings affect local responses. More CAM-chem5 runs might be needed to fully understand the forcing mechanicsm.

Lead investigator: D. J. Wuebbles, University of Illinois
Group members: J. Zhang, A. Khodayari
Project manager: D. Jacob and R. Halthore, FAA

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