Project 22
Evaluation of FAA Climate Tools

Motivation and Objectives

- Provide external expert review of the Aviation environmental Portfolio Management Tool - Impacts Climate (APMT-I) research version to facilitate transition to operations.
- APMT is undergoing a new evolution to include representation of climate effects on a regional basis and to consider regional effects.
- 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 effects on climate.
- The long-term 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 Approach

- CAM 3-D chemistry-climate model was used to analyze aviation emissions and resulting chemical impacts for 2006, 2050 scenario 1 (2050S1) and scenario 2 (2050S2).

Table 1. Description of emissions scenarios

	NOx	Sulfate	BC
Unit	TgN/yr	Gg/yr	Gg/yr
2006-Baseline	0.812	6.780	5.960
2050-Baseline	3.950	32.510	29.040
2050-Scenario 1	1.570	18.520	16.560
2050-Scenario 2	1.570	0.000	8.300

- Radiative forcings (RF) of CH_4, O_3-short, O_3-long, stratospheric water vapor (SWV), black carbon (BC) and sulfate (SO_4) are calculated. All species are calculated offline.

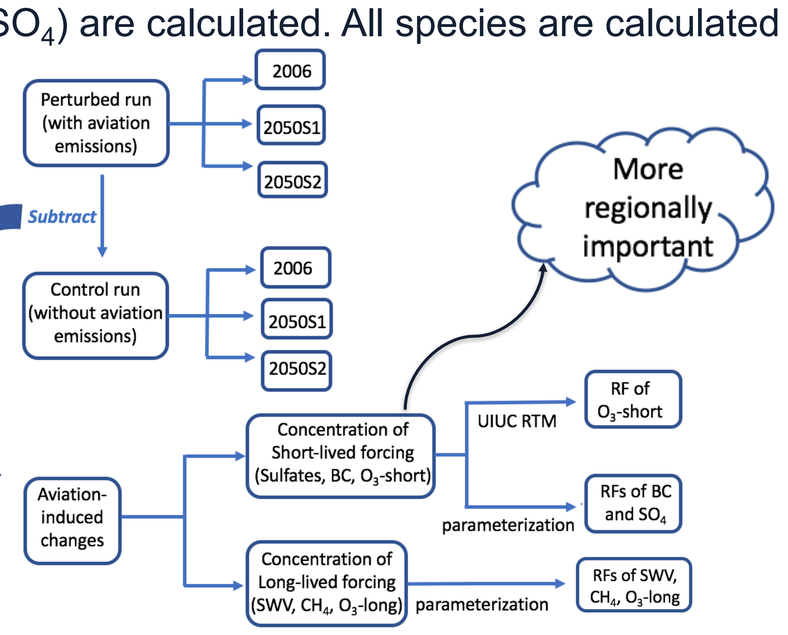


Fig. 1 Brief structure of regional analysis method

- For short-lived O_3, the radiative forcing is calculated in the UIUC RTM (University of Illinois at Urbana-Champaign Radiative Transfer Model).
- RFs of CH_4, O_3-long and SWV are calculated in the following Eqs

$$\Delta[CH_4]_{ss} = [CH_4]_{ref,\,ss} \times \left(-1.4\left(\frac{\Delta\tau}{\tau_{ref}}\right)\right),\quad (\Delta O_3)_{long-term} = \frac{\Delta[CH_4]}{[CH_4]} \times \frac{0.64}{0.1}\,\mathrm{DU}$$

  SWV RF is scaled by the change in CH_4 RF by 21%.
- RFs of BC and Sulfates are calculated by scaling the output concentration from CAM5 simulation based on the global specific RFs reported in ACCRI.

- Regional climate effects are analyzed based on 4 different latitude bands (90°S- 28°S, 28°S-28°N, 28°S-28°N, 60°N-90°N) and regions (US, Europe and East Asia).

Results and Discussion

(a) O_3-short RF

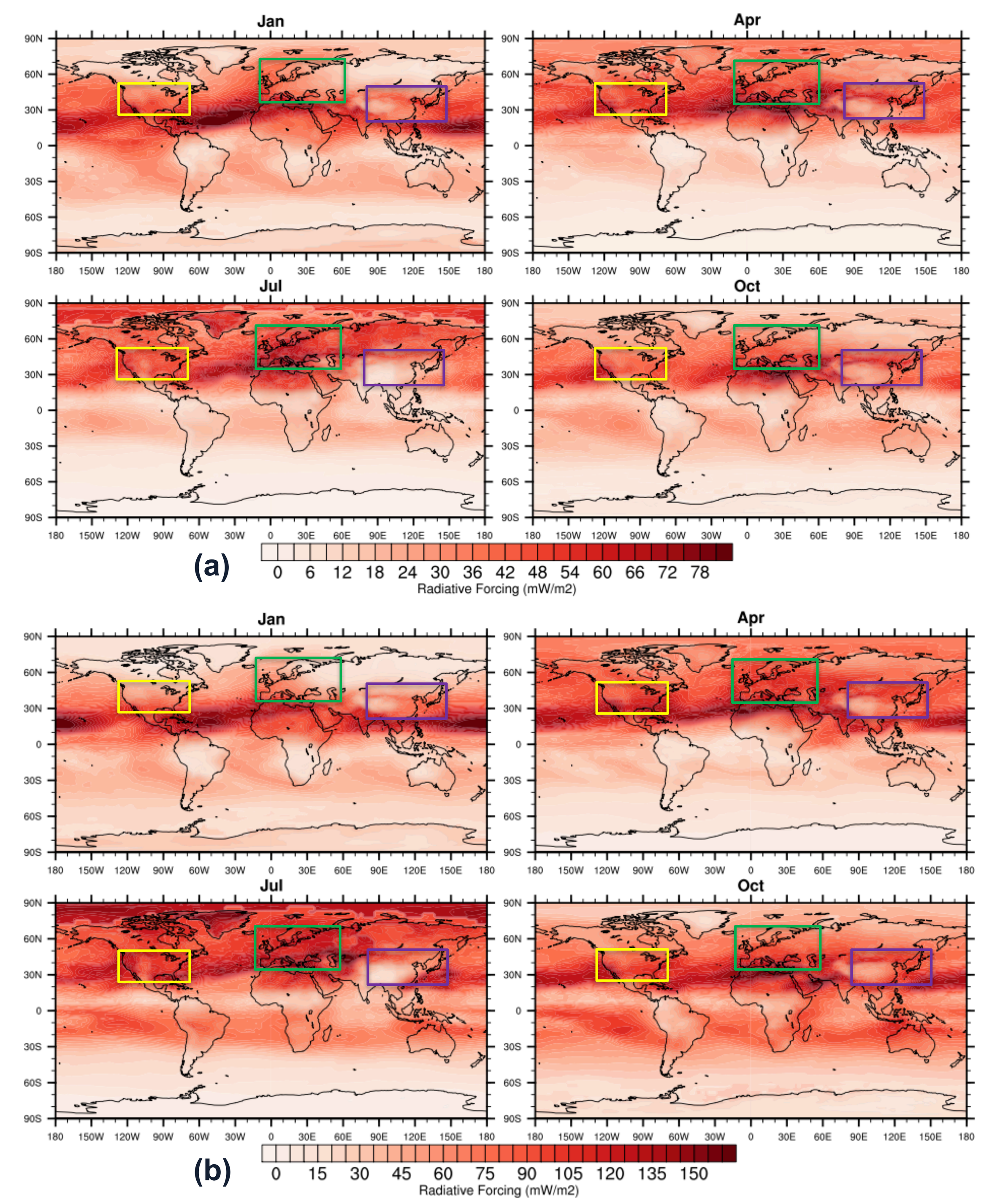


Fig. 2. (a) The global O_3-short RF in 4 seasons for 2006. (b) Same as in (a), but for 2050S1. The RFs for 2050S2 is very similar to 2050S1, so just 2050S1 is shown here. (yellow box covers US, green Europe and purple EA)

- The regional and seasonal variability of O_3 RF is indicated both in 2006 and 2050.

(b) CH_4, O3-long and SWV RF

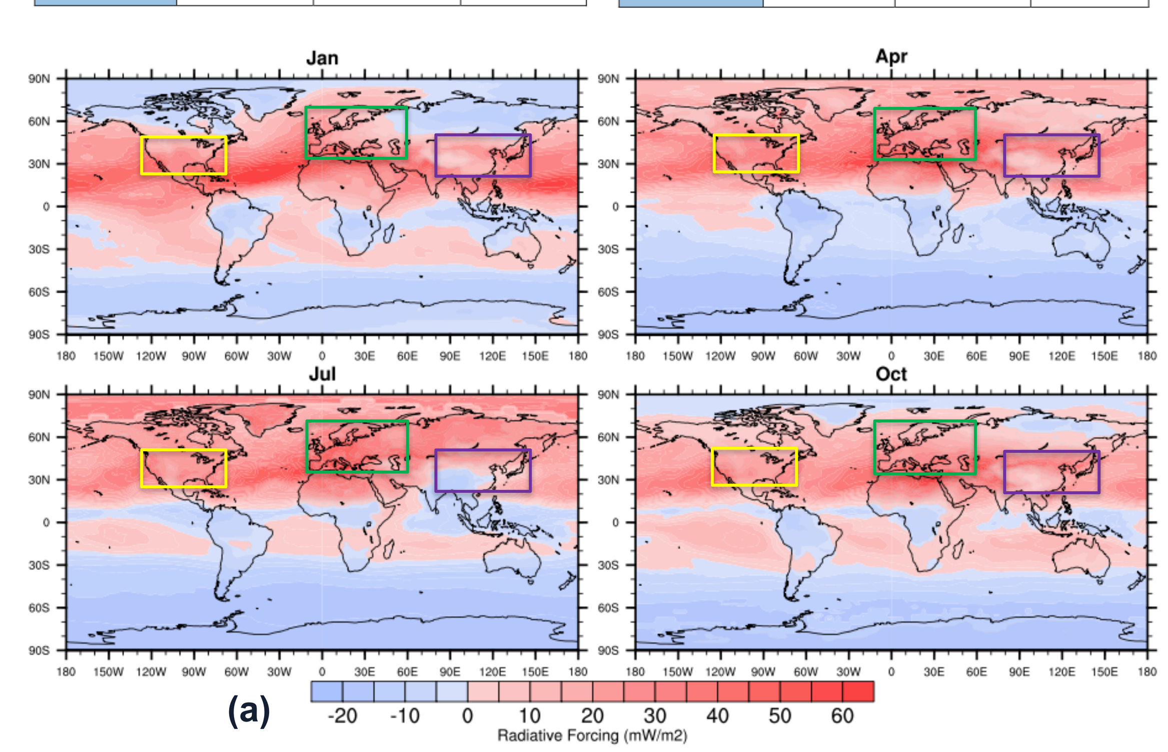
Table 2. (a) CH_4 lifetime from control and perturbed run and its relative change for 2006, 2050S1 and 2050S2. (b) Calculated RFs of long-lived species CH_4, O_3-long and SWV for 2006 and 2050s.

(a)

CH_4 lifetime (year)	Control run	Perturbed run	Relative change (%)
2006	7.85	7.74	1.47
2050S1	8.48	8.26	2.50
2050S2	8.48	8.24	2.73

(b)

Radiative forcing (mW/m2)	CH4	O3-long	SWV
2006	-11.5	-4.7	-2.4
2050S1	-22.3	-8.1	-4.7
2050S2	-24.3	-8.8	-5.1



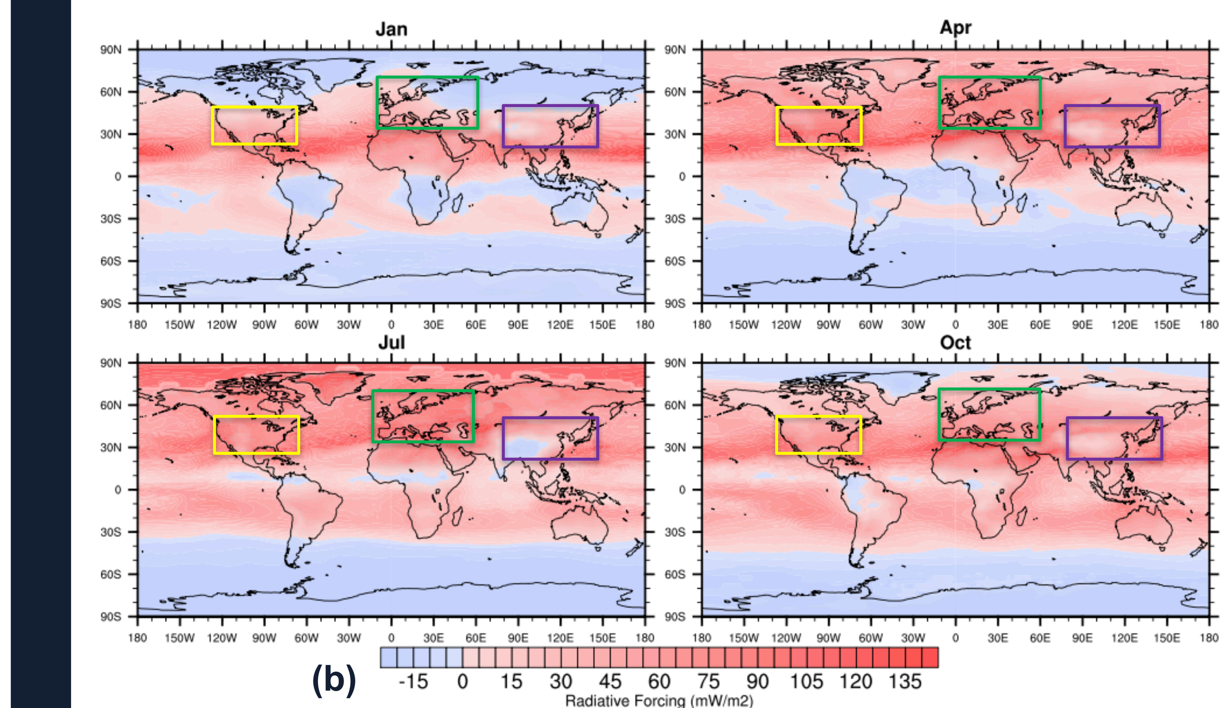


Fig. 3. Same as Fig. (2), but for NOx-induced RF (included O_3-short, CH_4, O_3-long and SWV)

- The short-term O_3 forcing is one of the major contributors to the overall aviation forcing and dominates the net NOx-induced forcing.
- Cooling effects are mainly distributed over the high latitude of Southern Hemisphere (SH), less in tropical regions and some in higher latitude in Jan and Oct.

(c) BC and Sulfate direct RF

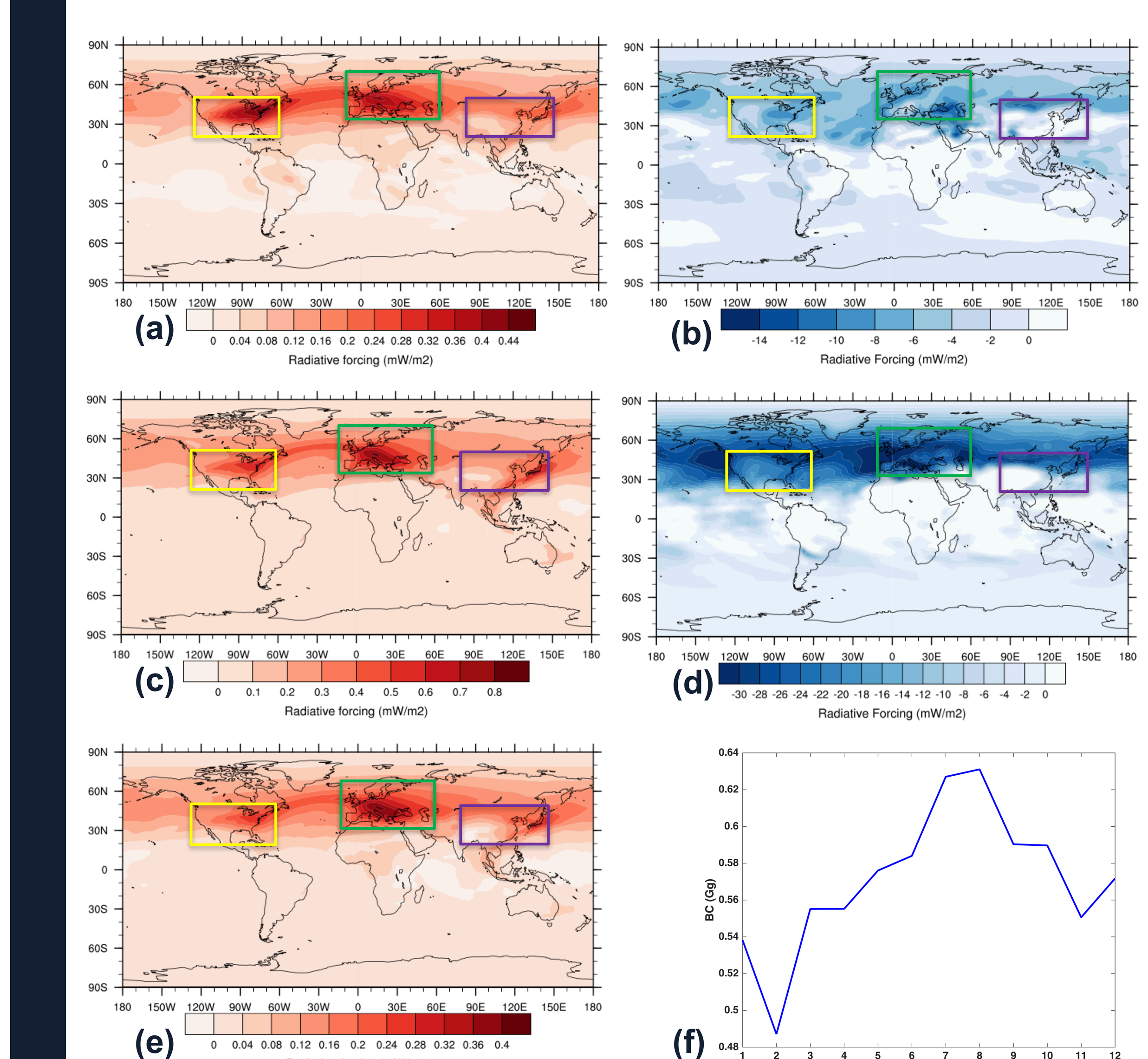


Fig. 4. (a), (c), (e) The global annul averaged BC RFs for 2006, 2050S1 and 2050S2. (b), (d) The global annul averaged sulfate RFs for 2005 and 2050S1 (compared to S1, no sulfur and 50% BC are assumed in S2). (f) Seasonal distribution of global aviation BC emissions for 2006.

- The short-term BC and Sulfate forcings are mainly over Northern Hemisphere (NH). The maximum impact is at the downwind of the aircraft emissions. The BC emission peaks during summer months of NH.

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(d) Regional and latitudinal short-lived RFs

Table 3. (a), (c), (e) RFs of short-lived forcing (O_3-short, BC and Sulfate) over US, Europe and East Asia for 2006, 2050S1 and 2050S2. (b), (d), (f) shows the RFs of short-lived forcing over 4 latitude bands.

(a)

2006 Radiative forcing (mWm^{-2})	US	Europe	East Asia	Global
O_3	69.5	68.5	52.7	37.3
BC	0.8	1.1	0.7	0.3
Sulfate	-12.0	-13.2	-8.5	-4.4

(b)

2006 Radiative forcing (mWm^{-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

(c)

2050S1 Radiative forcing (mWm^{-2})	US	Europe	East Asia	Global
O_3	95	82.7	74.9	56.3
BC	1.6	2.3	1.1	0.6
Sulfate	-31.4	-39.4	-22.1	-13

(d)

2050S1 Radiative forcing (mWm^{-2})	90°S- 28°S	28°S-28°N	28°N-60°N	60°N-90°N	Global
O_3	23.4	63.3	82.6	57.5	56.3
BC	0.15	0.22	1.80	1.37	0.6
Sulfate	-4.86	-6.88	-33.2	-25.51	-13

(e)

2050S2 Radiative forcing (mWm^{-2})	US	Europe	East Asia	Global
O_3	99.5	87.7	78.4	58.5
BC	0.8	1.1	0.6	0.3
Sulfate	-	-	-	-

(f)

2050S2 Radiative forcing (mWm^{-2})	90°S- 28°S	28°S-28°N	28°N-60°N	60°N-90°N	Global
O_3	23.7	65.4	87.2	61.1	58.3
BC	0.07	0.11	0.91	0.67	0.3
Sulfate	-	-	-	-	-

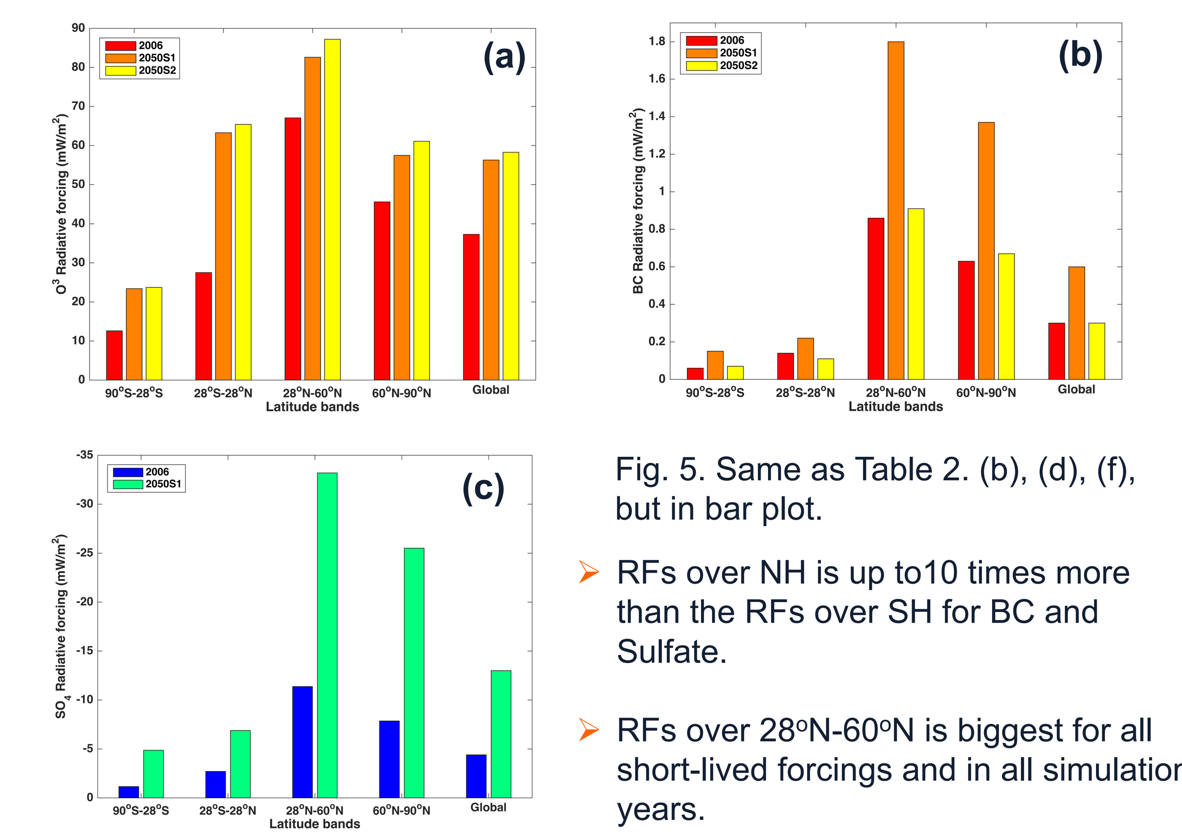

Fig. 5. Same as Table 2. (b), (d), (f), but in bar plot.

- RFs over NH is up to10 times more than the RFs over SH for BC and Sulfate.
- RFs over 28°N-60°N is biggest for all short-lived forcings and in all simulation years.

Conclusions and Next Step

- The short-lived forcings indicate a large hemispheric asymmetry. RF are mainly distributed over the NH, particularly between the latitude band 28°N-60°N, where most of aviation emission occurs.
- The forcing of BC and SO_4, which have larger hemispheric asymmetries than O_3-short, over the NH is up to 10 times more than the forcing over SH. The RFs for short-lived agents over US, Europe and East Asia is around 2~4 times of its corresponding global values.
- It is noticeable the peaks of BC and SO_4 RFs are located over the regions where aviation emission happens, while for O_3-short, the maximum impact shift to the downwind of the source. This could be due to the longer lifetime of O_3-short (around 3 weeks) than BC (4 to 12 days) and SO_4 (5 to 7 days).
- This regional analysis suggests that the globally averaged metrics are not able to capture the significant spatial variability induced by aviation emissions since global averaging will lead to cancellations such that the strength of regional impacts is hidden.

The **Next Steps** include:

- Evaluation of the v24 of APMT-I Climate (which will incorporate the regional effects on a zonal basis)
- Evaluation of Regional Temperature Potential from CICERO