Project 022 Evaluation of FAA Climate Tools: APMT

University of Illinois at Urbana-Champaign

Project Lead Investigator

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University Participants

University of Illinois at Urbana-Champaign
P.I.(s): Dr. Donald Wuebbles

- Period of Performance: October 16, 2017 to October 15, 2018
- Task(s):
    1. Evaluate version 24 of APMT
    2. Using the CESM global chemistry-climate model, update our earlier analyses of regional effects from aviation based on latitude bands and regions

Project Funding Level

Support from the FAA over this time period was $75,000 with an additional $75,000 in matching support, including about $10,000 from the University of Illinois, but also as in-kind support from Reading University.

Investigation Team

Dr. Donald Wuebbles: project oversight
Jun Zhang (graduate student): analyses of APMT and 3-D atmospheric climate-chemistry modeling analyses

Project Overview

The primary objective of this project was to evaluate the capabilities of the APMT-I model, particularly the Climate module, to ensure this FAA policy analysis tool uses the current state of climate science. Regional climate impacts of aviation were also evaluated using the 3D atmospheric climate-chemistry model. Findings from these studies were reported at several meetings and in special reports to the FAA.

Task 1- APMT-I Climate Evaluation and Review of Requirements Document

University of Illinois at Urbana-Champaign

Objective(s)

In this project, we act as a resource to FAA for analyses relating to metrics and to model development and evaluation of FAA modeling tools and datasets, with special emphasis on testing the Aviation Environmental Portfolio Tool (APMT) model and the further development and evaluation of its climate component to ensure that the underlying physics of the model is addressed properly. A specific focus of this project is on analyses of zonal and regional effects of aviation on climate and testing the resulting incorporation of such effects within APMT. As such, we want to make sure the APMT linking of aviation emissions with climate impacts and the representation of the various components of the cause–effect chain (i.e., from emissions to climate effect) properly represents the state-of-the-science.

Research Approach

We have evaluated APMT version 24 and provided the FAA with feedback and improvement for the future development. We have assessed the APMT v24 by looking into the entire emissions-to-impact pathways to ensure APMT represents each module correctly and then focused on the modules where the improvements can be made to enhance the whole model performance of APMT. The carbon module and temperature module are tested by looking at the response of aviation effect on the CO2 concentration, the radiative forcing on climate, and the change in temperature to an emission pulse and sustained emissions under low, mid and high future scenarios. The short-lived gas emissions effects module and the NOx-related effects have also been analyzed to ensure all aviation emissions are represented correctly based on the most recent findings, e.g., such as those from the FAA ACCRI program. We also are evaluating the APMT model following the cause-effect chain from aviation emissions to the resulting effects on climate. The project evaluates the APMT components relative to state-of-the-art modeling that fully considers the physics and chemistry important to the various processes. Our aim is to ensure that the physics and chemistry underlying the treatments in APMT are addressed properly based on our and others published modeling studies.

Milestone(s)

Evaluated the newly developed APMT v24 and sent report to FAA.

Major Accomplishments

Most relevant to this project is the evaluation we provided on APMT v24. We found some additional changes need to be made to improve the performance of this simplified climate model. We recommend that the water vapor be revised to separate the indirect from the direct effects to consider the longer lifetime of the indirect water vapor emission. Furthermore, the radiative forcing of NOx-related effects (O3-short, O3-long and CH4) in APMT should be updated to represent the most recent literature. As a result of making these changes, APMT should be better able to link the various components of aviation emissions with climate impacts relative to the findings from ACCRI. All in all, APMT v24 made significant progress compared to v23.

Publications

Zhang and Wuebbles, Evaluation of FAA Climate Tools: APMT. Report for the FAA, March 2018

Outreach Efforts

American Geophysical Union Fall Meeting – December 11-15, 2017 (Presentation)
ASCENT Advisory Committee Meeting – April 3-4, 2018 (Presentation)
ASCENT Advisory Committee Meeting – October 9-10, 2018 (Presentation)
Bi-weekly meeting with project manager Daniel Jacob

Awards

None

Student Involvement

Graduate Student: Jun Zhang
Ms. Zhang is responsible for the analyses and modeling studies within the project and leading the initial preparation of the project reports.

Task 2- Three-dimensional Atmospheric Climate-Chemistry Modeling Studies for Aviation Regional Effects on Climate

University of Illinois at Urbana-Champaign

Objective(s)

The aim in this work was to have a better understanding of the climate impacts from aviation emissions on a zonal and regional basis. Since the aviation emissions have significant spatial variability in the sign and magnitude of response, the strength of regional effects is highly likely hidden due to the global averaging of climate change. Thus, it can be important to look at the impact of aviation emission on climate on a regional scale as well as on the global scale. We continue to use a state-of-the-art three-dimensional chemistry-climate model to further our understanding of the chemistry and climate effects from aviation emissions and to do our regional analysis and compare our results with the earlier findings. As part of this effort, we used CAM5-Chem and will now be using the new CAM6-Chem model, the atmospheric component of the Community Earth System Model (CESM). We plan to conduct a series of studies to evaluate aviation impact on climate both in 2006 and 2050. The ultimate goal of this project is to estimate the temperature change over specific regions of interest (e.g., the United States, Europe, and East Asia) resulting from aircraft emissions in 2006 and 2050.

Research Approach

In this study, the newest version of the NCAR chemistry-climate model Community Atmosphere Model (CAM-chem6) is being used to examine the regional climate effects based on 4 different latitude bands (90°S- 28°S, 28°S-28°N, 28°S-28°N, 60°N-90°N) and regions (contiguous United States, Europe and East Asia). We have also used existing CESM model results to derive the relationship between surface temperature change and radiative forcing change both on global and regional scale. Then this relationship will be applied to aviation emissions to calculate the regional temperature change using the regional radiative forcing simulated from CESM model. We are undergoing the development of the temperature and radiative forcing relationship.

Milestone(s)

We recently made the transition from CAM-chem5 to the new CAM-chem6 model (NCAR considers this model to be a major upgrade over previous versions of the global atmospheric model) to conduct high resolution one degree in latitude and longitude experiments. We will then derive temperature and radiative forcing change relationships based on the modeling studies. We already are laying out the exact plans for these analyses so that we go from emissions to regional temperature effects for aviation. A presentation of findings and discussion of progress is held with representatives from the FAA every two weeks.

Major Accomplishments

This project is currently on going. We have started to set up simulations on the newly released CAM-chem6 (the state-of-the-art climate-chemistry model) and at the same time we are develping the realtionships between the temperature change and radiative forcing using the exsiting CESM model results. Interim results (Figure 1) shows the annual surface temperature anomaly for both observation and model data in a 40 year period from 1975 to 2015. The dashed lines are the linear fit for observation and model data. Figure 1 indicates that the linear fit for observation and model data are very close both in global scale and regional scale, especially when you account for model noise and nature variability. The model has a good performance on simulating surface temperature change – we can now continue to develop the relationship between the surface temperature and radiative forcing change both globally and regionally.

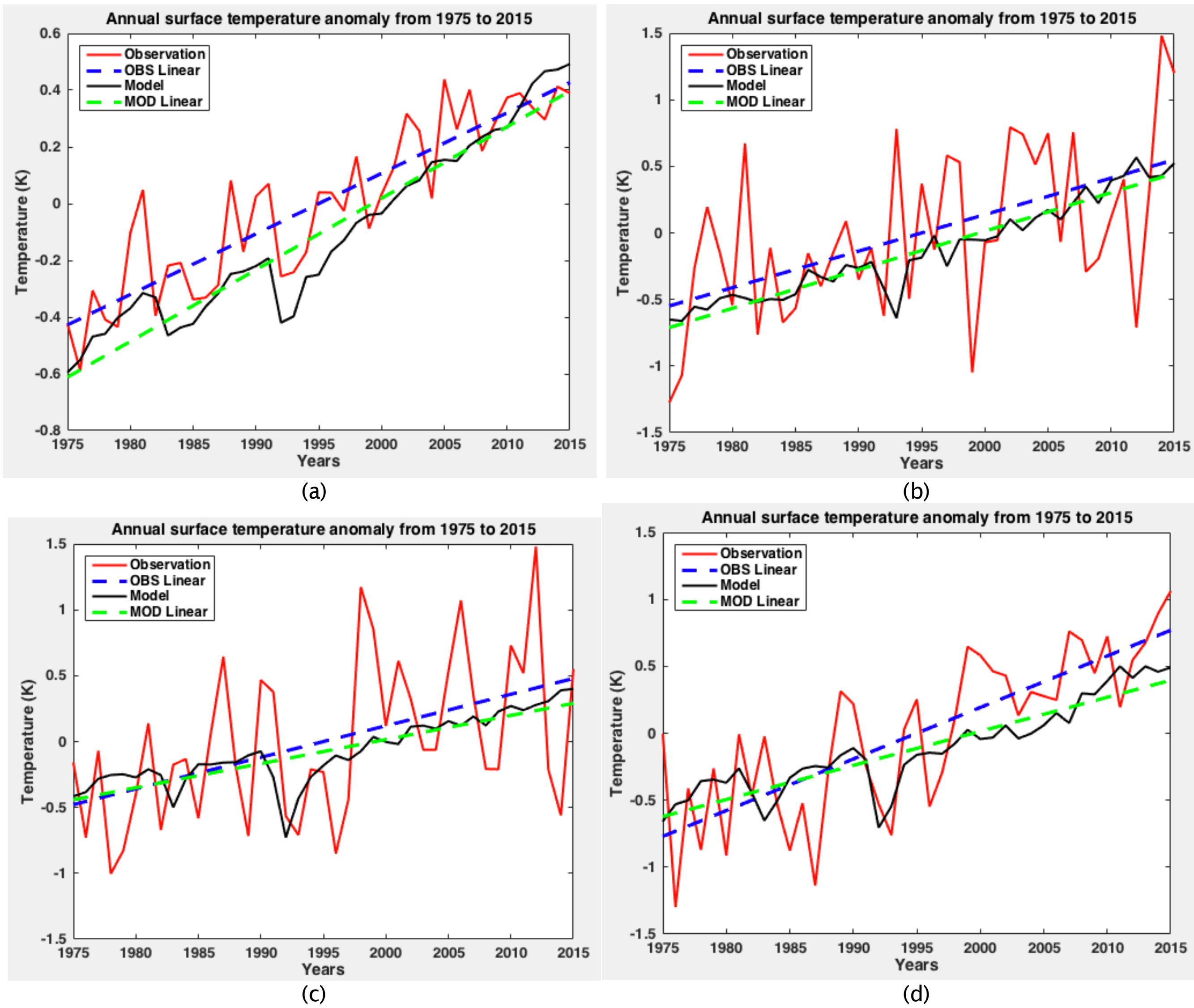
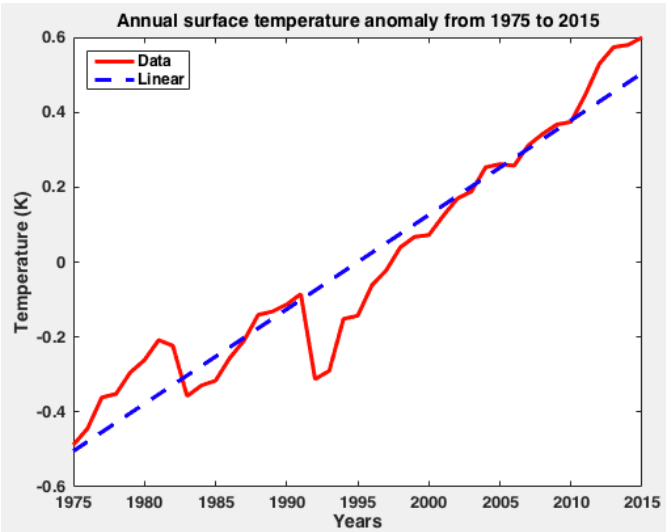
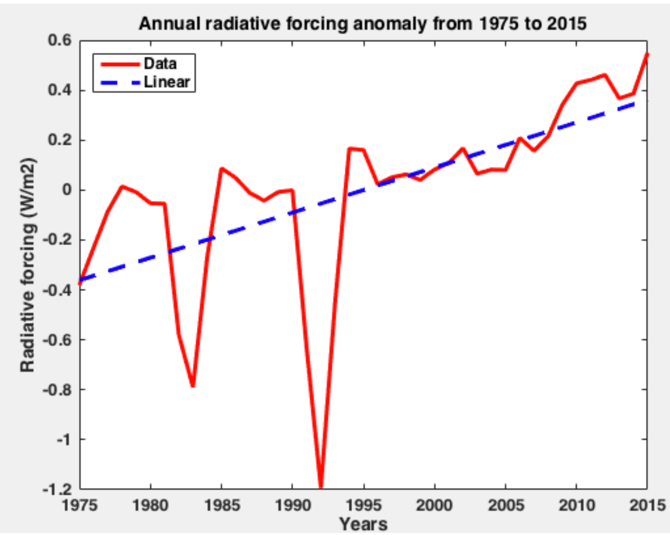


Figure 1. Annual surface temperature anomaly (degrees K) from 1975 to 2015 for (a) the global average; (b) Europe; (c) East Asia; (d) United States, respectively. The red and black lines are the observation data and model data, respectively; and the blue and green dash lines are the corresponding linear trend for observation and model data.

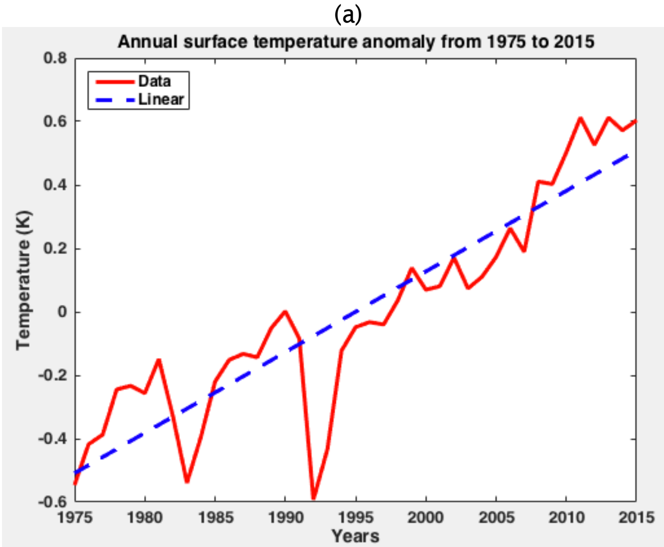
The annual surface temperature and radiative forcing anomaly from 1975 to 2015 is presented in Figure 2. The linear trend for surface temperature and radiative forcing anomaly for globe, United States and Europe (Figure (a), (b); (c), (d), (g). (h)) is both monotonic increase but at a different rate, which indicates that the surface temperature and radiative forcing change has positive relationship. As radiative forcing increase in time, the surface temperature will also increase. However, for East Asia (Figure 2 (e), (f)), as the radiative forcing decrease, the surface temperature increase, which shows an inverse relationship. This is due the large amount of aerosol emissions in East Asia region during 1975 to 2015 time period – the particles (not all but most) reflect solar radiation to cause cooling effect. However, reflection of sunlight by particles only happens during the day time, during the night time the greenhouse gases warming effects is dominant which results in the increase of the surface temperature. This will be accounted for in our analyses.


Annual surface temperature anomaly from 1975 to 2015
Data
Linear
Temperature (K)
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
1975 1980 1985 1990 1995 2000 2005 2010 2015
Years

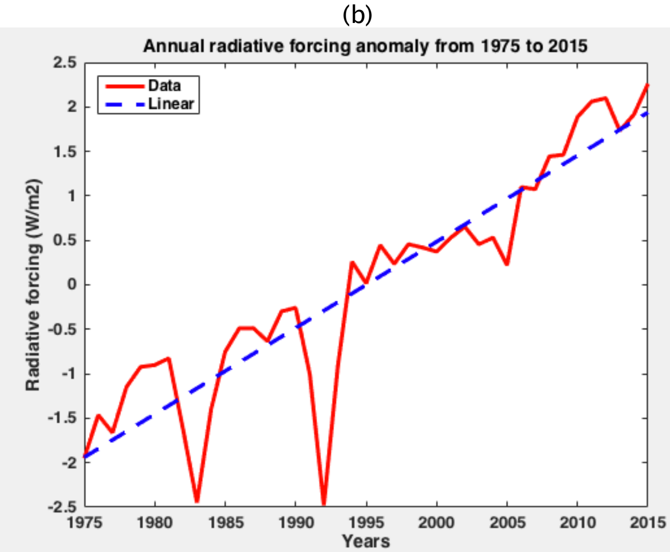
(a)


Annual radiative forcing anomaly from 1975 to 2015
Data
Linear
Radiative forcing (W/m2)
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
1975 1980 1985 1990 1995 2000 2005 2010 2015
Years

(b)


Annual surface temperature anomaly from 1975 to 2015
Data
Linear
Temperature (K)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
1975 1980 1985 1990 1995 2000 2005 2010 2015
Years

(c)


Annual radiative forcing anomaly from 1975 to 2015
Data
Linear
Radiative forcing (W/m2)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
1975 1980 1985 1990 1995 2000 2005 2010 2015
Years

(d)

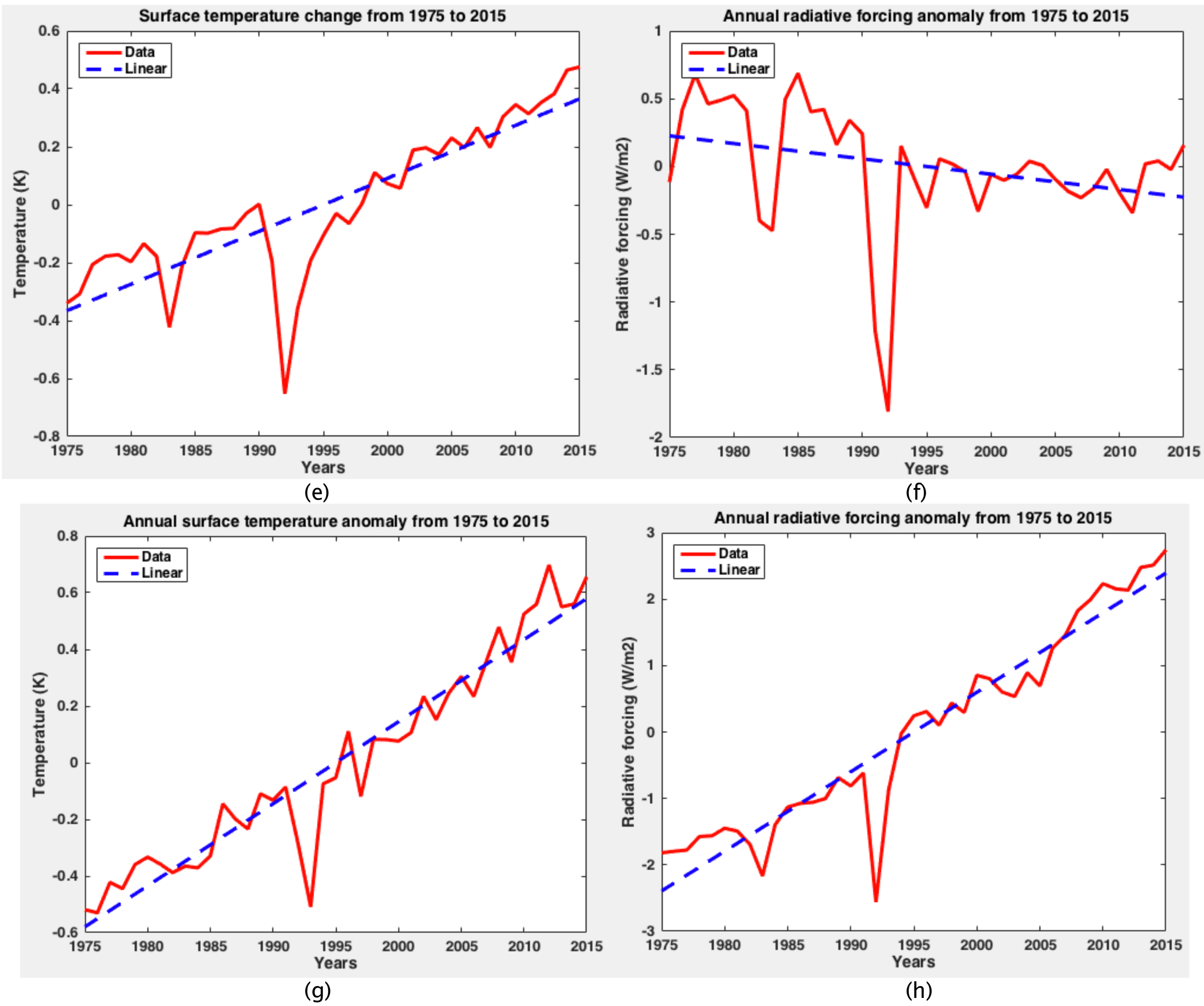


Figure 2. Annual surface temperature anomaly (degrees K) from 1975 to 2015 for (a) global average; (c) United States; (e) East Asia; (g) Europe. Annual radiative forcing anomaly from 1975 to 2015 for (b) global average; (d) United States; (f) East Asia; (h) Europe respectively. Red solid line is the model data; blue dash line is a linear fit.

Publications

Zhang, J., and D. Wuebbles, Report to the FAA on analyses of APMT v24. University of Illinois, 2018

Outreach Efforts

Results presented at several ASCENT meetings. Journal paper to expected from the regional aviation analyses.
Dr. Wuebbles made a special invited presentation on the history of the understanding of environmental effects from supersonic aircraft at a FAA sponsored meeting in spring 2018.

Awards

None

Student Involvement

Graduate student Jun Zhang is responsible for the analyses and modeling studies within the project and leading the initial preparation of the project reports.

Plans for Next Period

Continue doing regional analysis. The following aspects will be focused on in the next period:

1) Continue developing the relationship between surface temperature and radiative forcing change using the existing CESM model data – determine the appropriate approach to represent the radiative forcing change over East Asia;
2) Conducting model simulations to calculate the induced radiative forcing for aviation gases and particle emissions using the CAM-chem6 model;
3) Apply the developed relationship to aircraft emissions to obtain the aviation induced surface temperature change for both global and regional scales. The calculated aviation induced temperature change over four latitude bands will be compared with the temperature change calculated from CICERO approach, to evaluate the findings as a test of their and our methodologies;
4) Using the evaluated relationships, determine the change in temperature from aviation emissions (current and future projections) over various regions.
5) Prepare and submit report to the FAA and a corresponding journal paper.