ASCENT 20
Development of NAS wide and Global Rapid Aviation Air Quality Tools

Motivation and Objectives

- Aviation emissions contribute to particulate matter ($PM_{2.5}$) and ozone (O_3) in the atmosphere
- Long term exposure to $PM_{2.5}$ and O_3 can lead to cardiopulmonary diseases and lung cancer. Health impacts have been shown to exist on local, regional and global scale

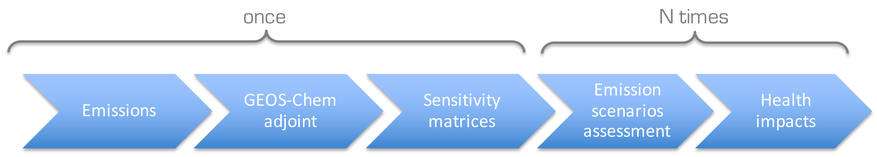
- Impact assessments usually rely on computationally-expensive **chemical transport models**
- In a policy context however, many scenarios need to be evaluated in a short period of time

- The adjoint approach is designed to alleviate the burden of computation and render chemical transport models compatible with policy applications

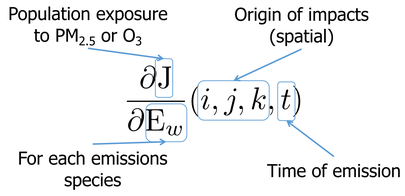
- **Current capabilities:**
  - Coarse global estimates of $PM_{2.5}$ and O_3 impacts
  - Fine-resolution estimates for US and Southeast Asia domains.

- **Objectives:**
  - Short-term: extend capabilities to include the **EU nested domain**
  - Medium-term: quantify the impact of uncertainties and changes in background emissions on aviation impacts, including uncertainty in **background ammonia**
  - Long-term: provide a validated tool for multiple domains, that enables the **rapid air quality assessment** ($PM_{2.5}$ and O_3) of aviation emissions scenarios

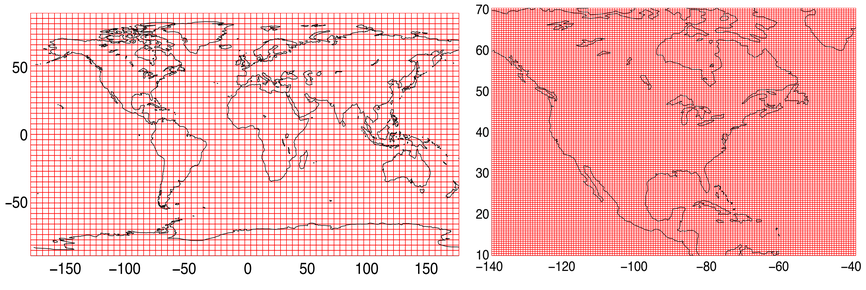
Methods and Materials



Sensitivity matrices give us the gradient of the objective function (e.g. population exposure) with respect to multiple inputs. It allows detailed analysis of spatial, temporal and speciated variations.



The adjoint tool allows us to rapidly assess the effects of **perturbations** including changes in technology or policy.



Available domains: global (4°×5°, left), nested NA domain (0.5°×0.667°, right), and nested Southeast Asia domain (0.5×0.667°, see upper right corner).

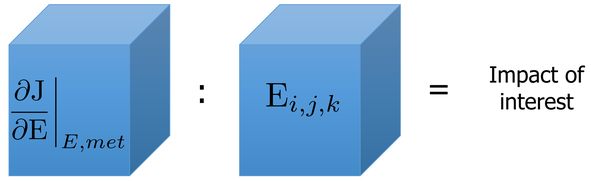
Summary

- Present and future air quality and health impacts of aviation emissions need to be understood and controlled
- In a policy context, the number of scenarios to be assessed does not allow traditional modeling, due to the computational cost of those models

- This project aims to develop a **rapid air quality assessment tool**, computationally fast without compromising the underlying chemistry and transport calculations

- Sensitivity matrices allow detailed analysis of the spatial and temporal origin of emissions impacting the quantity of interest (e.g. population exposure in a given area)

- Use of sensitivity matrices only requires the definition of the quantity of interest, for instance US population exposure to $PM_{2.5}$
- The total impact is obtained by multiplying the sensitivity matrix element-wise by the emissions matrix. The summation of the obtained matrix corresponds to the impact of the scenario under scrutiny



Sensitivity matrix Scenario emissions

- Recent developments:
  - Extension of the tool capabilities to include ozone exposure,
  - Finer resolution spatial representation of Southeast Asia

Results so far include the production of sensitivity matrices for:
- Global exposure to $PM_{2.5}$ and ozone
- Regional exposure of same in North America and South East Asia

The adjoint tool was also applied to support the ICAO CAEP nvPM standard air quality analysis.

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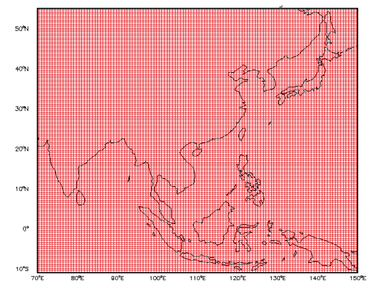
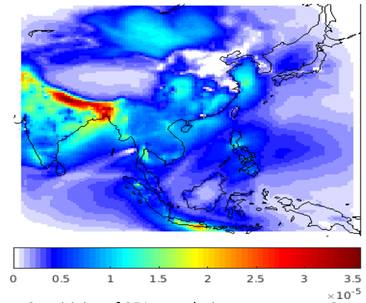
Results and Discussion

Most recent developments include the implementation of the fine-resolution Southeast Asia domain represented below. Fine-resolution sensitivity matrices will allow a better understanding of aviation impacts in the region.

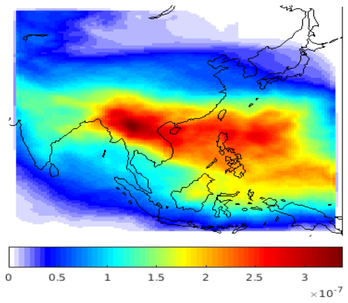


SEA fine-resolution (0.5°×0.667°) grid

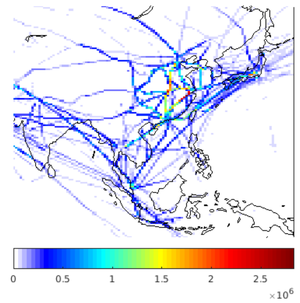


Sensitivity of SEA population exposure to O_3 to LTO NO_x emissions (people.ppbv per kg(NO_x))

This updated version of the tool will be useful to estimate the relative impacts of LTO and cruise emissions on population exposure to ozone in Southeast Asia.



Sensitivity of SEA population exposure to O_3 to cruise level NO_x emissions (people.ppbv per kg(NO_x))



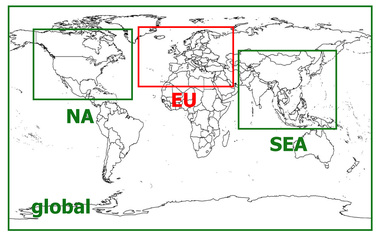
Cruise-level NO_x emissions on a particular day of 2015 (kg)

The adjoint tool was recently applied in the ICAO CAEP nvPM standard analysis.

Conclusions and Next Steps

The adjoint air quality tool is a powerful rapid assessment model that allows the analysis of a large number of scenarios in a computationally practical manner, as required to inform policymaking. It has recently been used to inform the US FAA on the AQ effects of different proposed stringencies for the **nvPM standard** under development at the International Civil Aviation Organization.

Next steps include:
- Support the analysis of the air quality impacts of **supersonic aviation**
- Second order sensitivities analysis (in progress)
- Extended spatial capability (Europe)



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References

1. Dedoussi, I. C., & Barrett, S.R.H. (2014). Air pollution and early deaths in the United States. Part II: Attribution of $PM_{2.5}$ exposure to emissions species, time, location and sector. Atmospheric Environment, 99, 610–617.
2. Dedoussi, I. C., & Barrett, S.R.H. (2015). US aviation air quality impacts and comparison with other sectors. Presentation given that Aiircraft Noise and Emissions Reduction Symposium, September 22-25 2015, La Rochelle, France..