Evaluating Environmental Risks and Trade-offs for Aviation Policy Analysis and Technology Development

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Key questions

Aviation environmental effects result from a complex system of interdependent technologies, operations, policies, and market conditions...

- How many resources should we commit to resolving environmental issues related to noise and emissions?
- How should we expend those resources?

Need

Key impediment to resource management is the lack of an integrated framework capable of comparing environmental risks or identifying trade-offs

Objective

Transparently communicate uncertain environmental risks and integrate evaluation of risks to account for trade-offs in decision-making

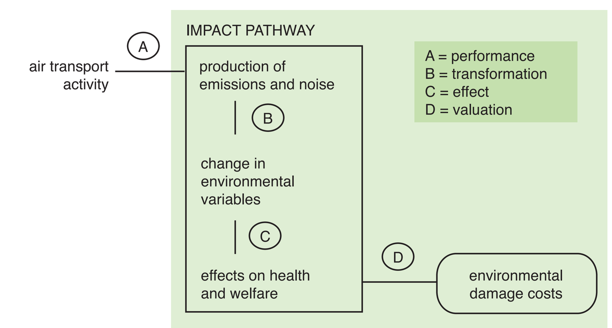
Context

Initial part of a larger effort to develop decision-making tools that can assist in the design of aviation environmental policies

Note: Results herein are based on a small sample of Monte Carlo runs; runs to full convergence are ongoing.

Better metrics

Probabilistic, multi-attribute impact pathway analysis (MAIPA)



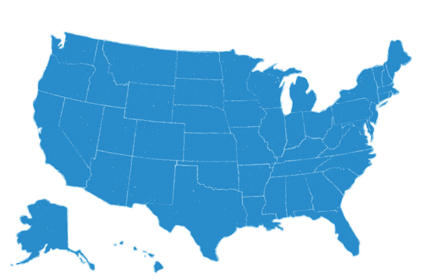
Damage function to estimate change in social welfare

$$\Delta C_{dc}^{k}(p) \approx \Delta C_{dc}^{k}(x,t) = \sum_{j=1}^{J}\left[\sum_{i=1}^{I} c_i(x)\,\Delta q_i^k(x,t) + c_n(x)\,\Delta q_n^k(x,t) + \Delta\varepsilon_{dc}\right]_j$$

j = source index
p = pollution characteristic
c = marginal damage cost of species (i) or noise (n)
q = change in emissions (i) or noise (n)
k = policy option
ε = unquantified or unknown contributions

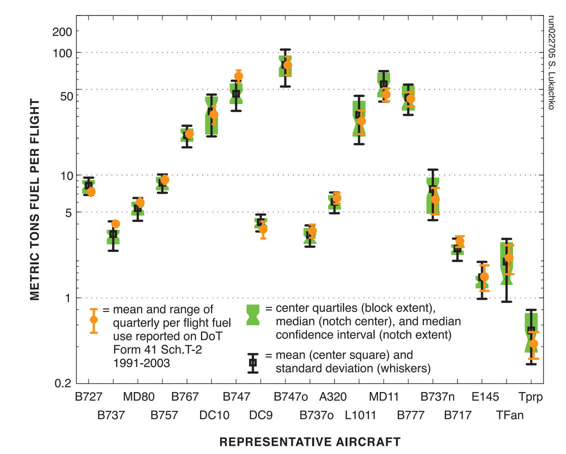
Scope

- United States 1991-2003
- 200+ aircraft performance parameters specify 19 representative aircraft types
- 96 small, medium, and large hub airports



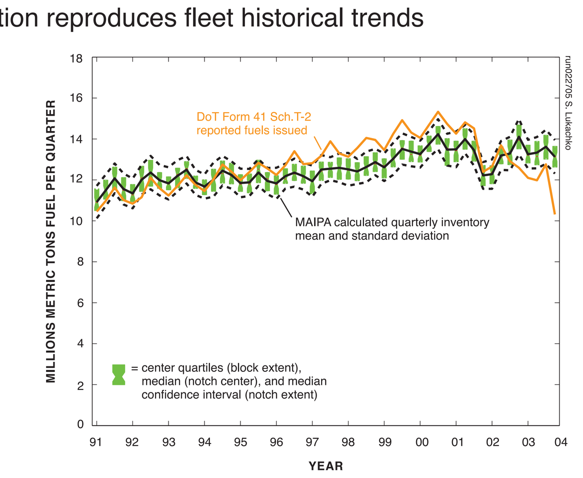
MAIPA per flight fuel use

Typical performance estimate compares well to historical data



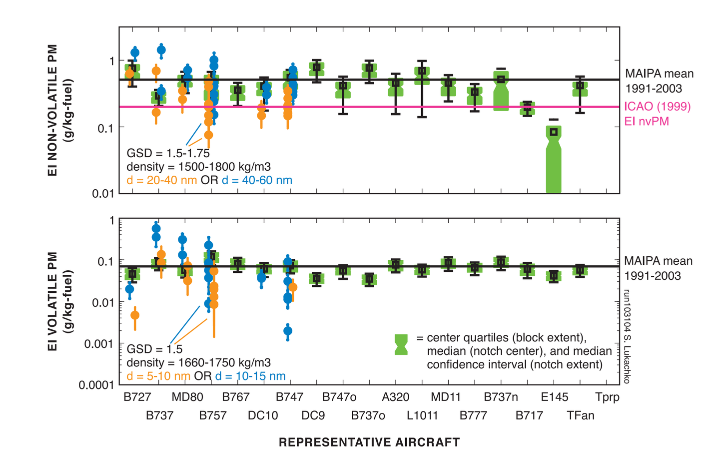
U.S. fuel use inventory

Aggregation reproduces fleet historical trends



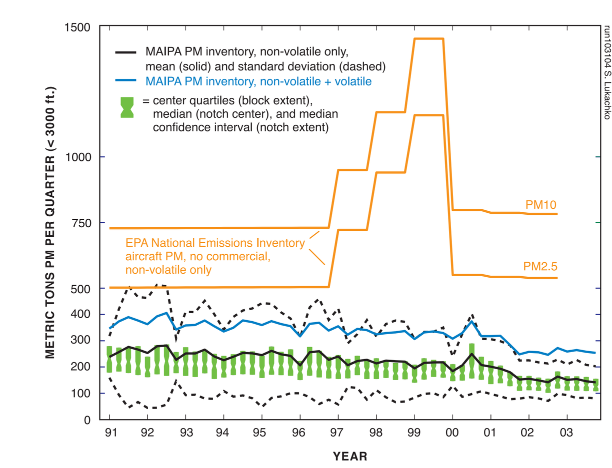
MAIPA volatile and non-volatile PM

Agreement with measured particulate data at cruise



U.S. PM inventory

Contribution small but impact similar to NO_x

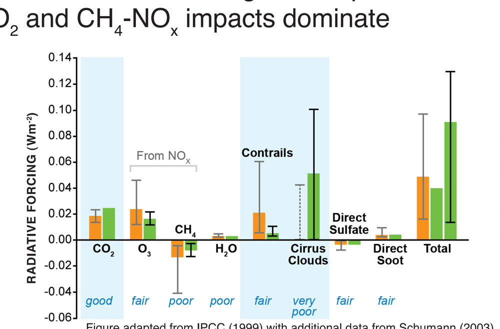


Mean comparison to EPA National Emissions Inventory

NO_x = 0.25%
CO = 0.1%
VOC = 0.1%
SO_x = 0.036%
PM60 = 0.003%
PM2.5 = 0.009%

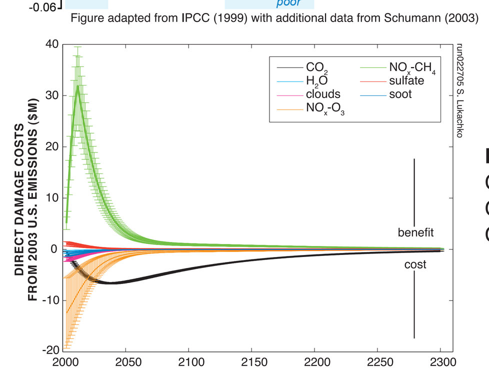
Re-evaluation of climate metrics

Relative radiative forcing overemphasizes short-lived effects, CO_2 and CH_4-NO_x impacts dominate

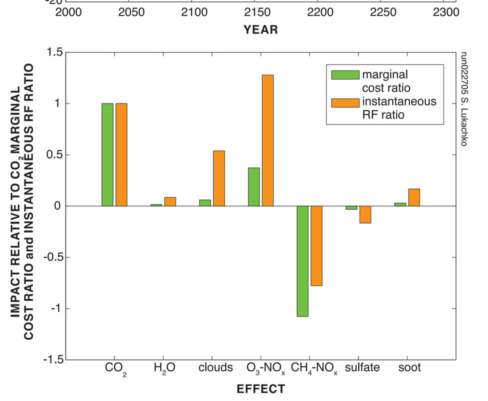


Cumulative fleet CO_2 emissions last over 50 years

Short-lived clouds from emissions last ~1 day



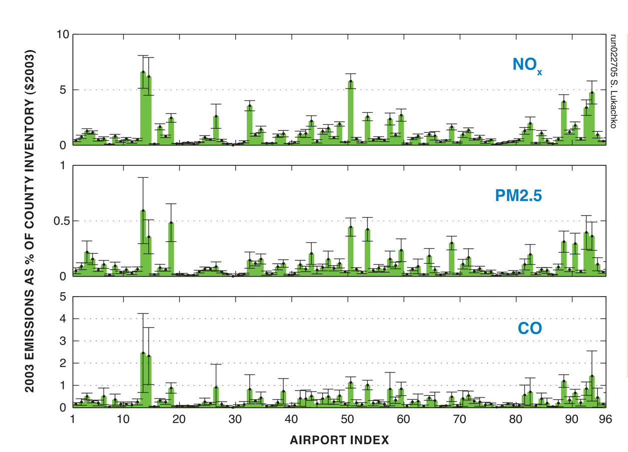
Different lifetimes
CO_2 forcing lasts ~300 years
CH_4 forcing lasts ~10 years
Cloud forcing lasts ~1 day



Marginal cost ratio references integral under curves in plot above

Airport-local inventories

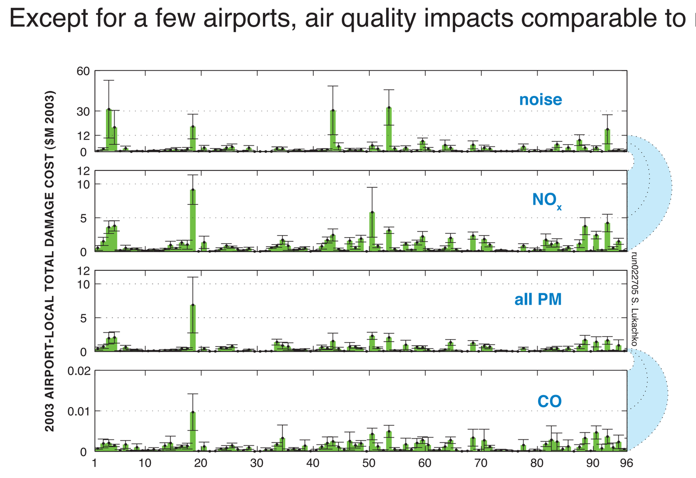
Disaggregation using county-scale demographics



NO_x
1.1% (~0 to 6.6%)
CO
0.36% (~0 to 2.5%)
VOC
0.43% (~0 to 5.3%)
SO_x
0.45% (~0 to 4.9%)
PM2.5
0.10% (~0 to 0.59%)
PM10
0.039% (~0 to 0.25%)

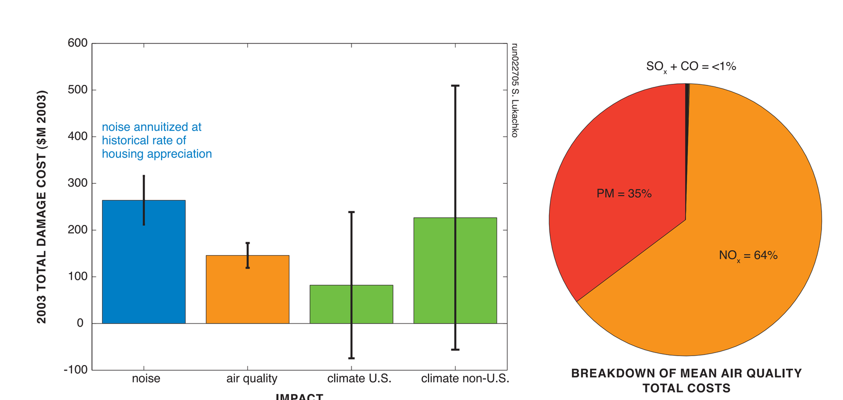
Local impacts

Except for a few airports, air quality impacts comparable to noise



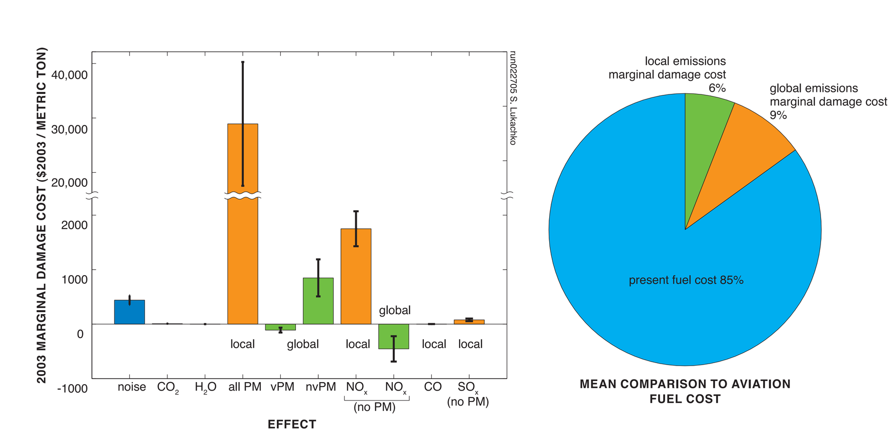
Total environmental costs

Emissions (air quality + climate) account for > 50%



Marginal damage costs

PM highest due to contribution of mortality risk



Central ideas

- Possible to represent uncertain environmental risks in decision-making in a useful, integrated, and rigorous way
- Effect metrics estimated through MAIPA elucidate aviation-environment relationship in ways not previously appreciated

Components

- Understanding and communicating risks in situations with information problems is valuable
- Impact pathway analysis augments knowledge by tracing uncertain statistical risks from source to effect
- Economics is framework for establishing commensurability across different types of risks, enabling prioritization

Key results presented

- PM is an important contributor to air quality impacts
- CO_2 and CH_4-NO_x more significant to marginal future climate effects relative to aviation-induced clouds
- Air quality comparable to noise at local scale
- Mean direct welfare costs amount to > $500M per year

Next step

Establish full cost-benefit capability, including industry costs, macroeconomic feedbacks