Health and Welfare Impacts of Aviation Emissions

– Evaluating Choices –

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Presenting the work of the FAA Aviation Environmental Portfolio Management (APMT) development team including many researchers and students

Vital Link
Policy Analysis

mvaconsultancy BB&C

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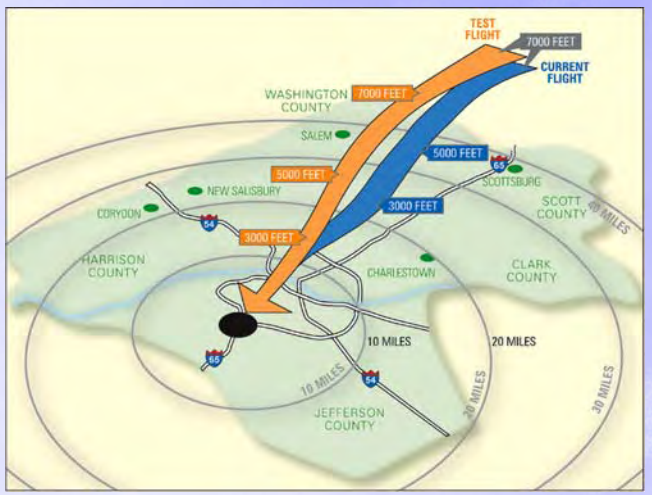
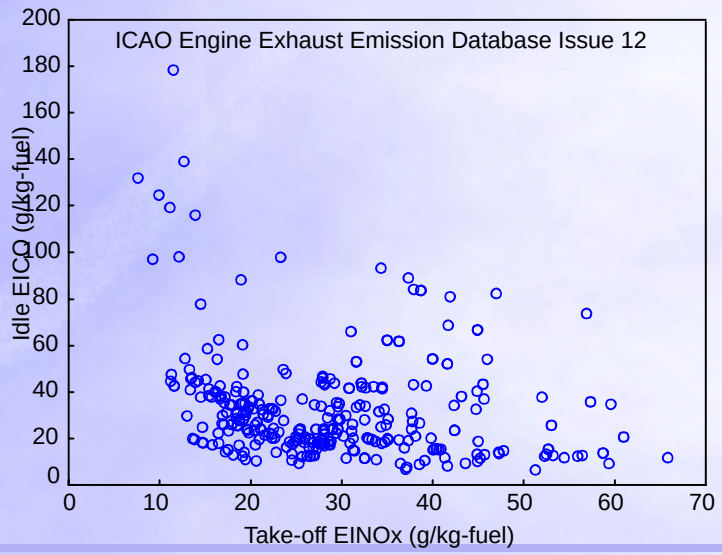
The work we present here is preliminary and should not be used for guiding policy. We expect the results will change as we continue to develop and improve our methods.

Choices exist

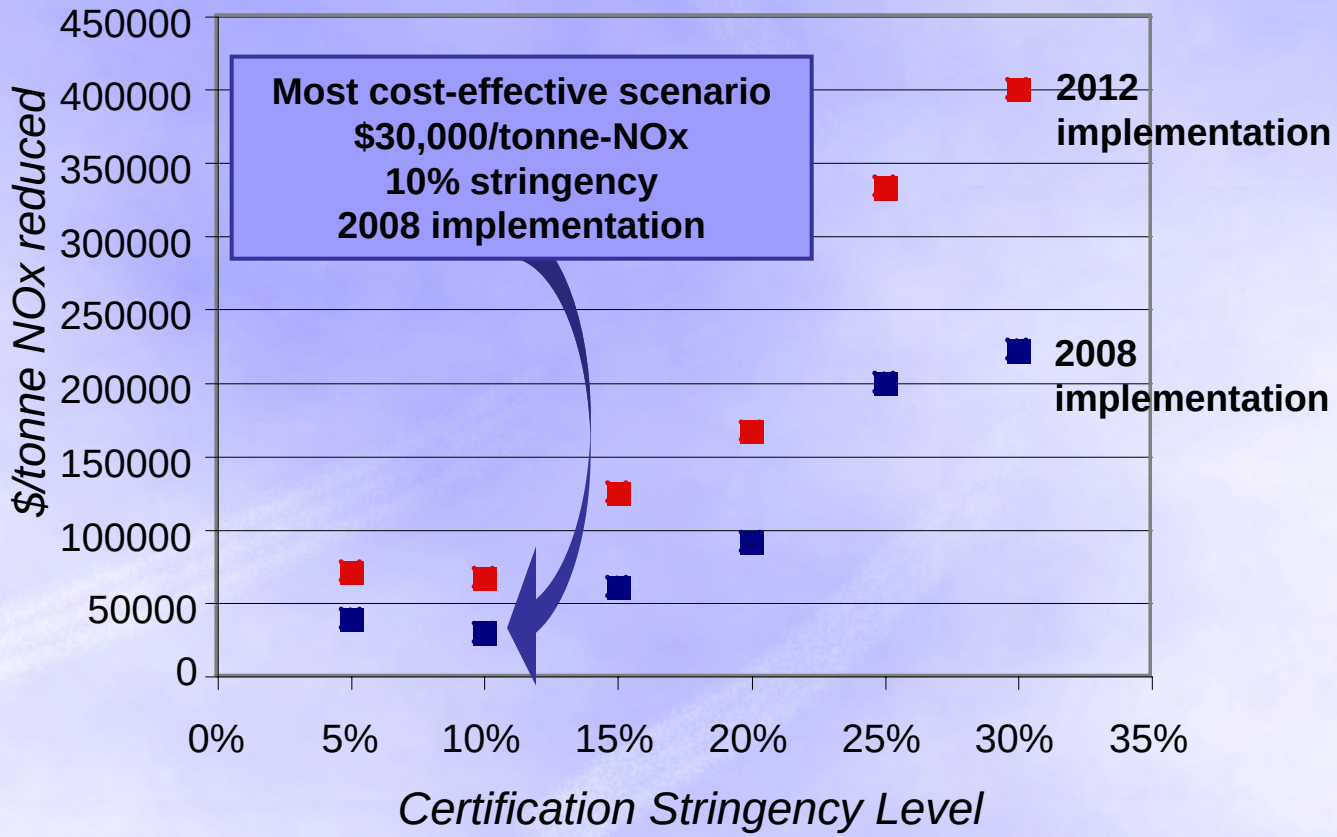
- Every airplane design represents a different balance of noise, performance, emissions
- Every operational procedure represents a different balance of noise, performance, emissions
- Capital costs are high (e.g. $10B for a new airplane program)
- Time-scales are long (20-30 years)





How do we make choices today?
ICAO CAEP/6 NOx stringency

Cost-effectiveness estimates
2002-2020



Source: FESG CAEP/6-IP/13; estimates shown assume high level of manufacturers' NRC and lost fleet value, discount rate 3%

An incomplete balance sheet

- CAEP/6 NOx stringency example
  - Of several options for NOx reduction, the least expensive is $30,000/tonne-NOx; does this produce a net benefit to society?
  - What is the impact of the additional fuel burn and noise estimated to be associated with the NOx reduction?
- Must fill in the balance sheet to assess trade-offs
  - Local air quality, noise, climate change, consumer and industry costs
- The stakes are high (serious impacts, billions of $)
  - We, as a community, need to improve our methods and tools and do this better than we do it today

New FAA tools to guide decision-making

inputs

Policy scenarios
- Certification stringency
- Market-based measures
- Land-use controls
- Sound insulation

Market scenarios
- Demand
- Fuel prices
- Fleet

Environmental scenarios
- CO_2 growth

Technology and operational advances
- CNS/ATM, NGATS
- Long term technology forecasts

FAA Tool Suite

outputs

Cost-effectiveness
- $/kg NOx reduced
- $/# people removed from 65dB DNL
- $/kg PM reduced
- $/kg CO_2 reduced

Focus of presentation

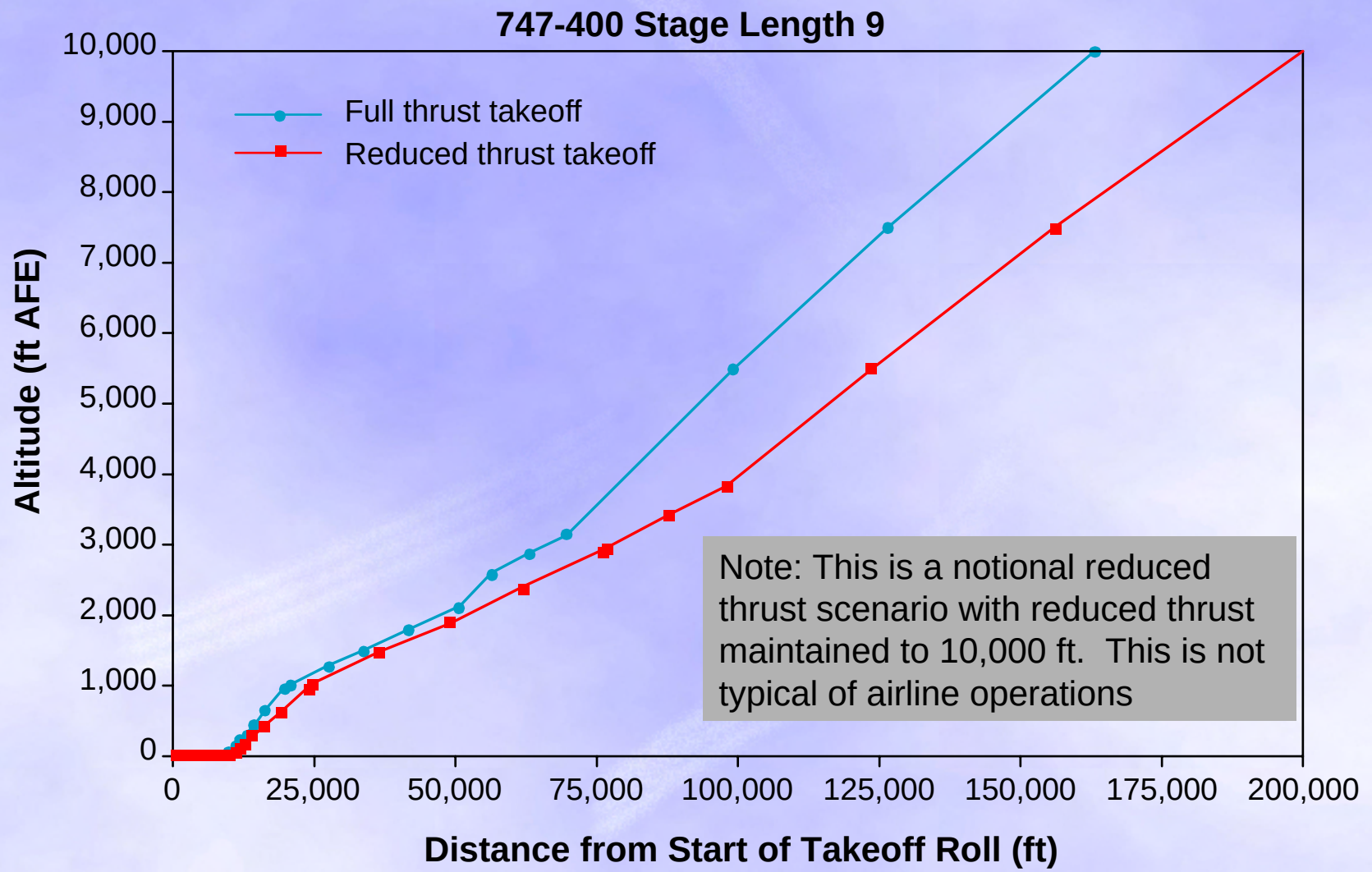
Benefit-cost
- Health and welfare impacts
- Change in societal welfare ($)

Distributional analyses
- Who benefits, who pays
- Consumers
- Airports
- Airlines
- Manufacturers
- People impacted by noise and pollution
- Special groups
- Geographical regions

Global, Regional, Airport-local

Notional example application

Described in CAEP/7-SG/20063-WP/30



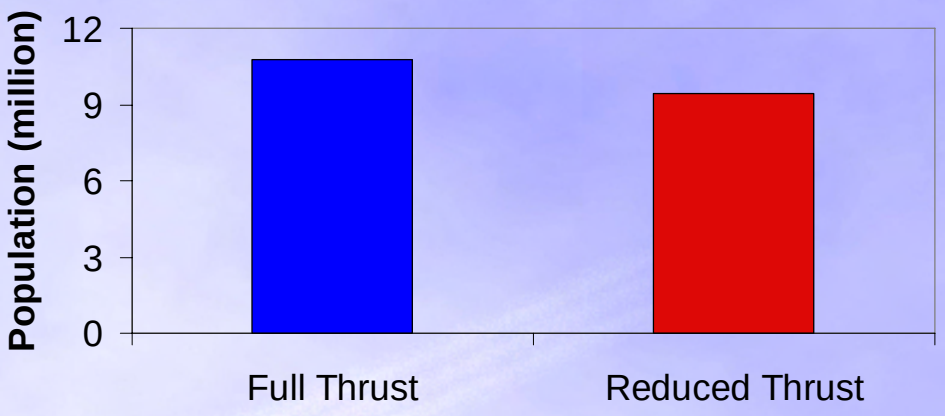
Notional example application

Even simple changes may lead to complex trade-offs, for example…

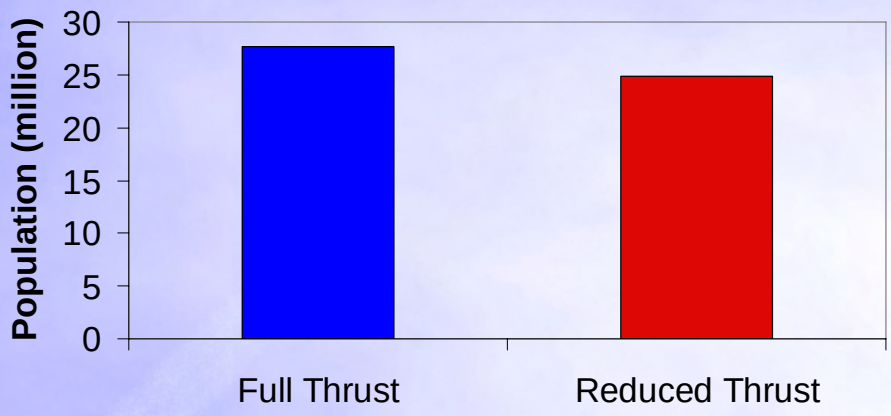
- One aspect of airplane operations changed
  - Throttle setting reduced during take-off
- Emissions and noise change
  - **CO_2 increases**
  - **NO_x decreases**
  - **SO_x increases**
  - **PM decreases**
  - **Noise decreases**
- Affects aviation economics

Noise impact (number of people impacted)

Population in 55 dB Contours in North America



Population in 55 dB Contours Worldwide

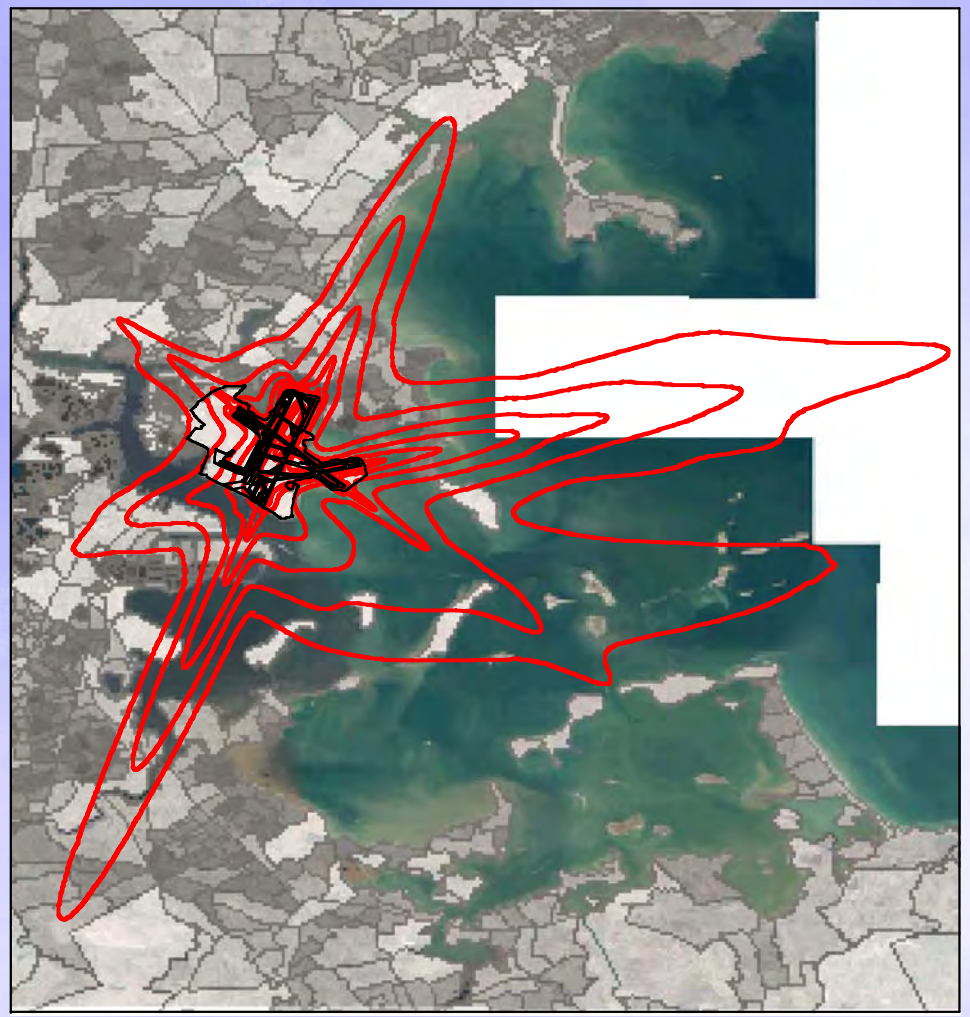


Noise impact

Noise Depreciation Index (NDI) used to correlate noise levels with housing capital depreciation

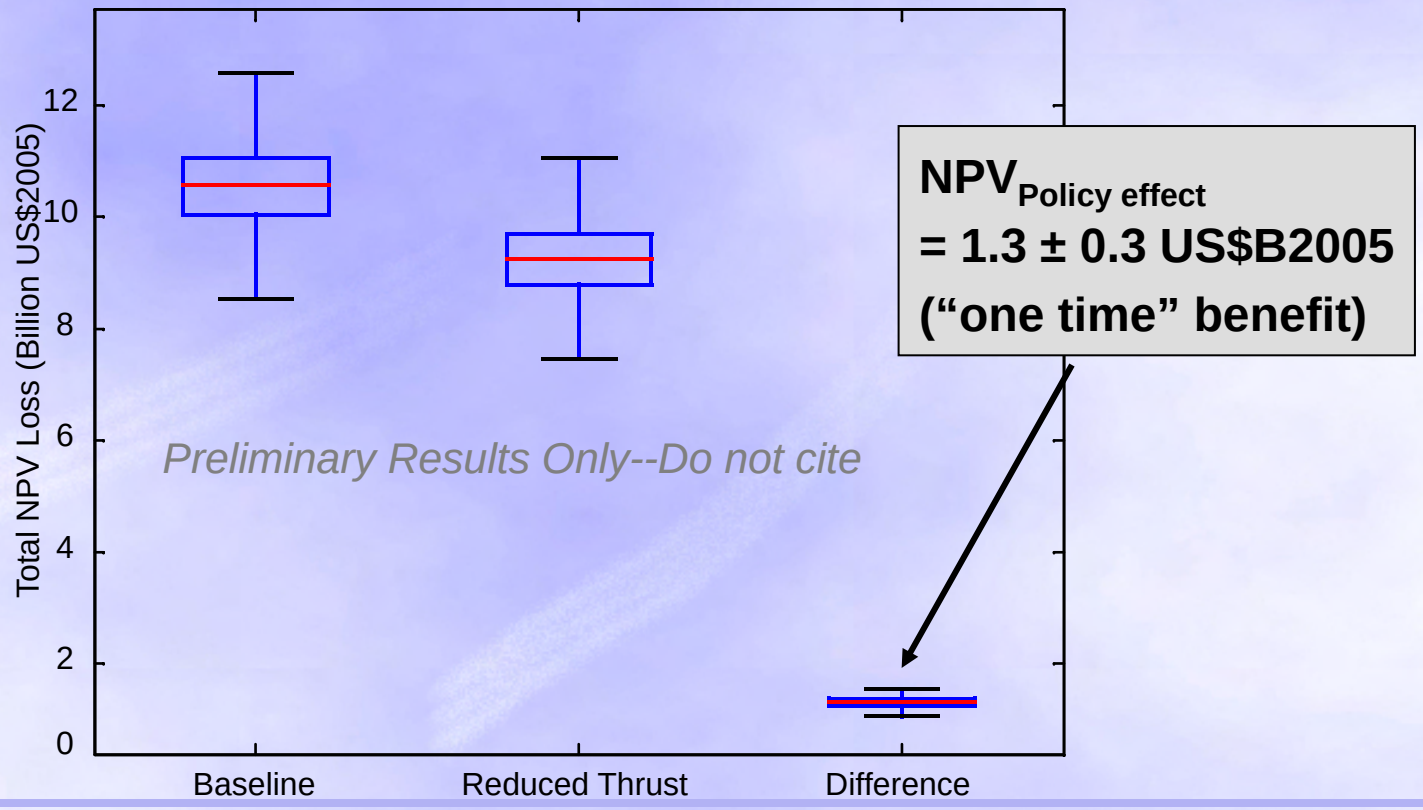
Adding additional noise metrics:

- sleep awakenings
- % highly annoyed
- location of schools



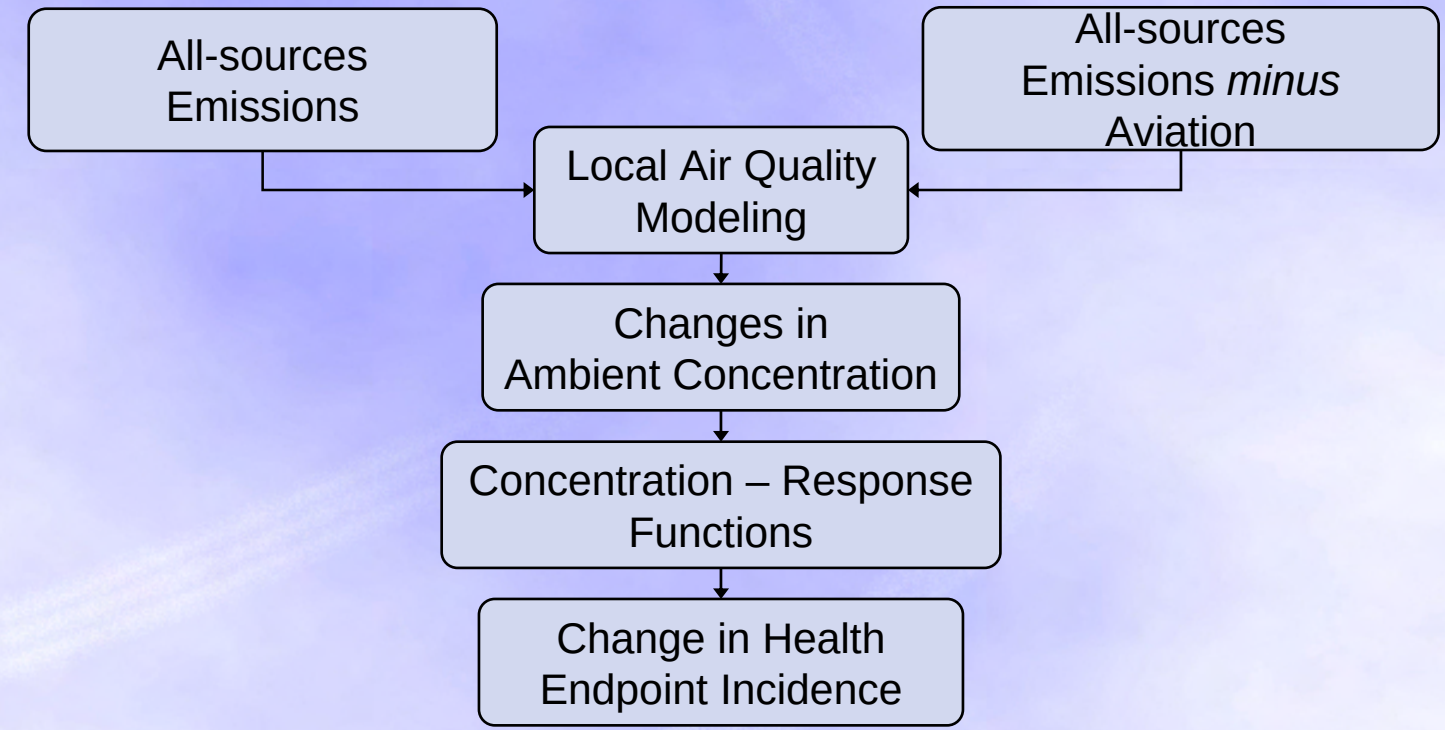
U.S. Noise impact

- Aggregated monetary metric: Net Present Value of housing capital depreciation (89 MAGENTA Shell-1 U.S.airports)
- Monte-Carlo simulations provide measure of uncertainty



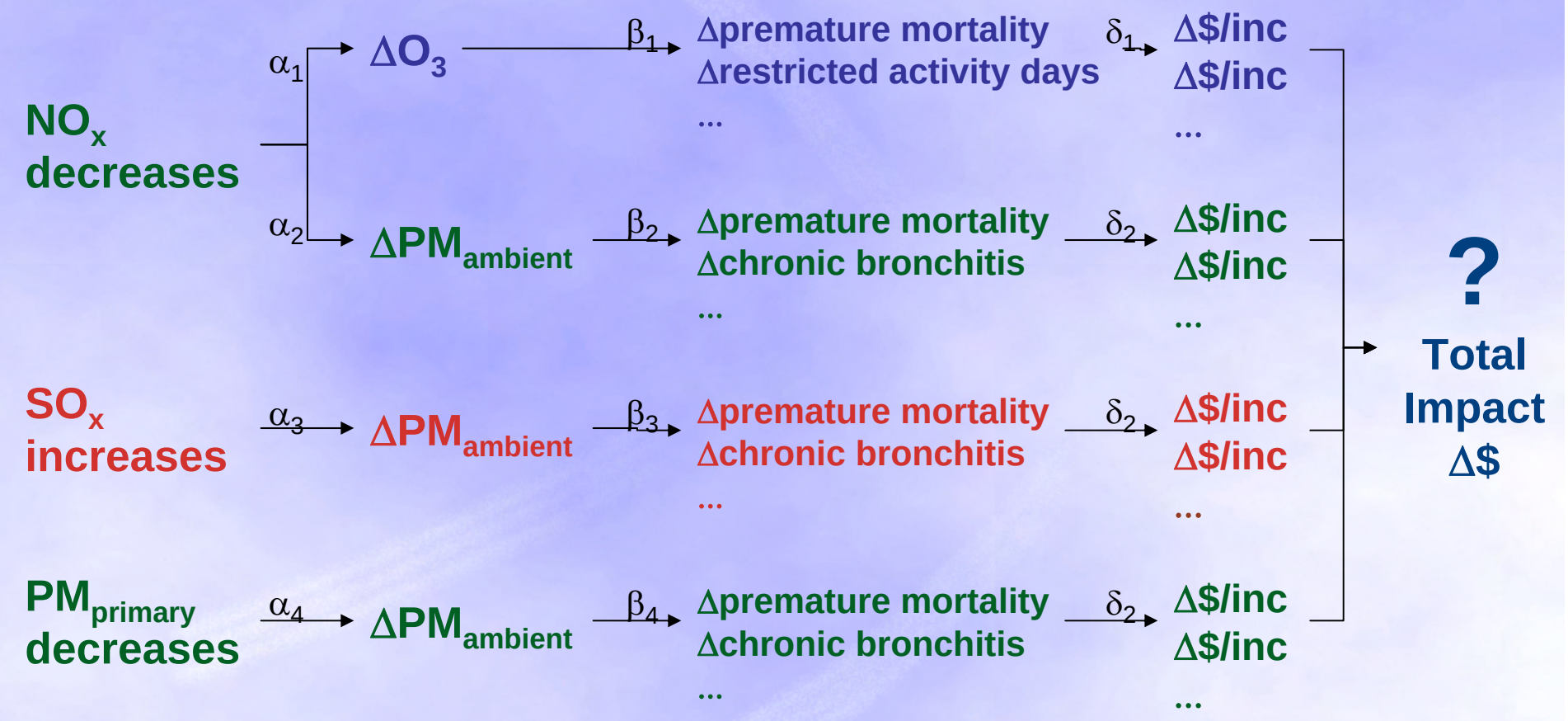
Health impacts assessment

Consistent with US EPA and EU practice, considering effects of ozone and particulate matter (PM)



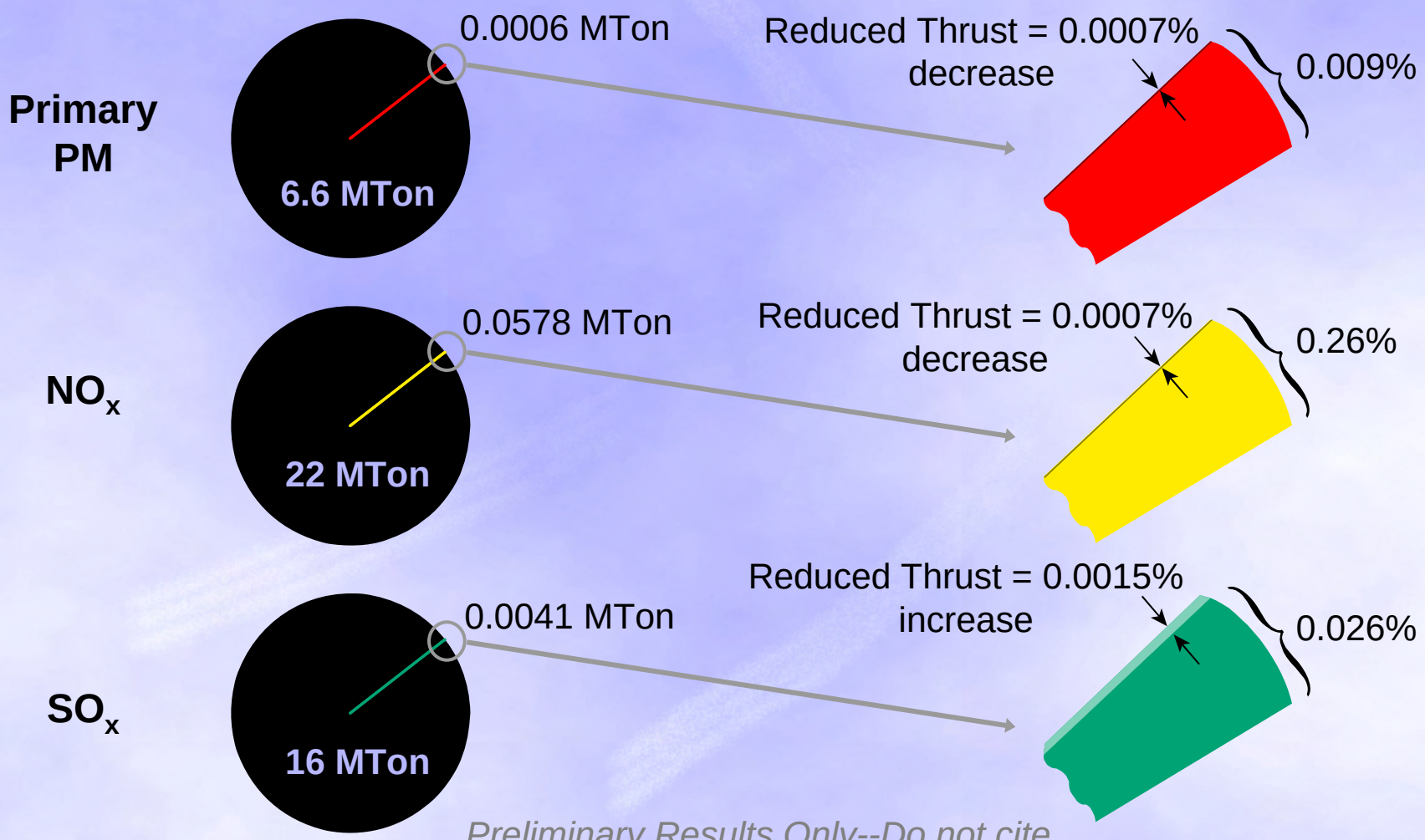
$$\Delta \text{ health costs} = \Delta \text{ emissions} \times \frac{\Delta \text{ambient concentration}}{\Delta \text{emission}} \times \frac{\text{health incidence}}{\Delta \text{ambient concentration}} \times \frac{\text{cost}}{\text{health incidence}}$$

Impact pathway



Local air quality and climate response cannot be determined directly from observing changes in inventories

What is the implication of small change in overall emissions?



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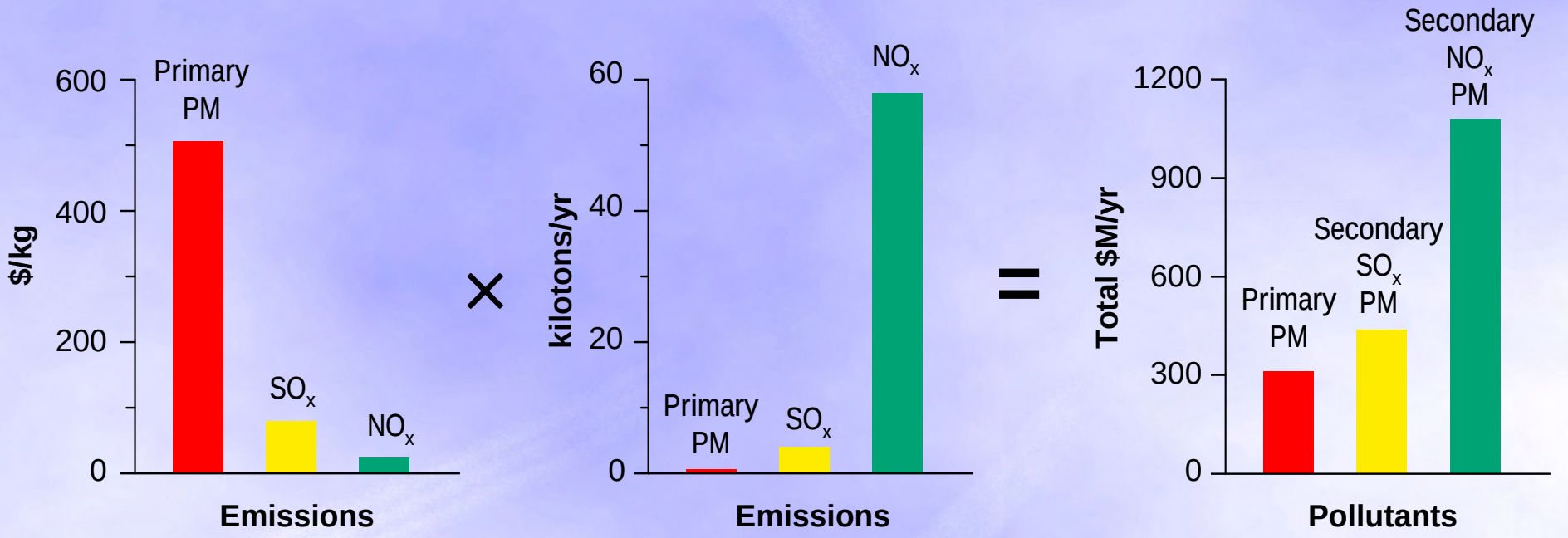
US Aviation PM Health Costs



- APMT analysis for U.S. aviation health impacts, AEDT 2005 inventory estimate, FOA3 PM method, Greco et al. [2007] Mobile Source Intake Fraction method
- This graphical equation is a simplification of the more complicated analysis that we perform

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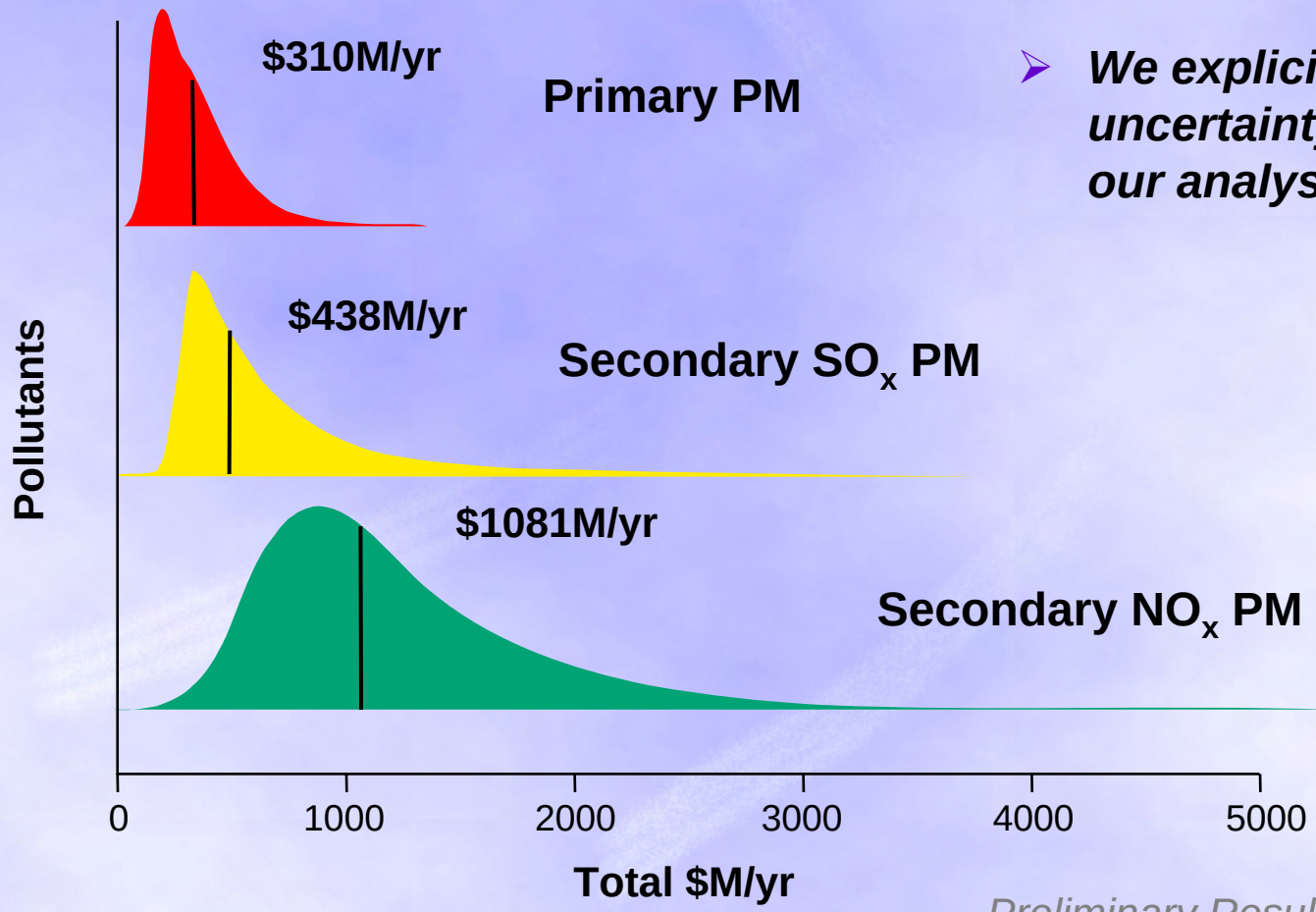
Propagated uncertainties in U.S. Aviation PM Costs



- ***We explicitly calculate uncertainty in all of our analyses***

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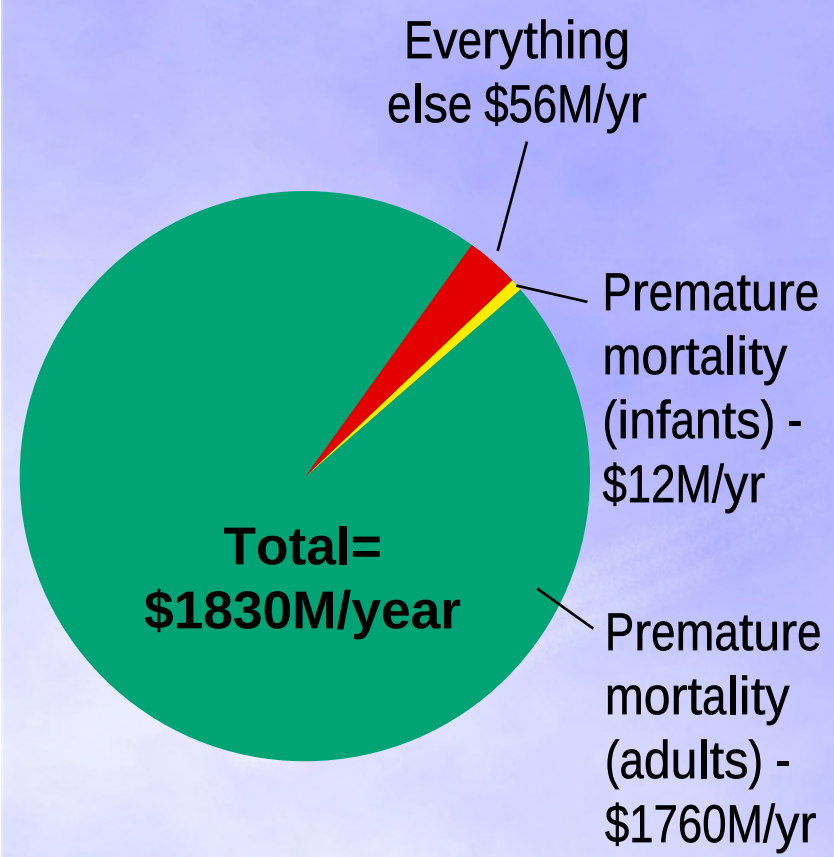
Health and welfare impacts of US Aviation PM



PM-related Endpoints (mean estimates shown, 95% confidence intervals typically ± 50% of mean)	Cases per year
Premature mortality:	
Long-term exposure (adults age 30+)	319
Long-term exposure (infants age <1yr)	2
Chronic bronchitis	129
Hospital admissions-respiratory	93
Hospital admission-cardiovascular	93
Emergency room visits for asthma	219
Minor restricted activity days	124505

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US Aviation PM premature mortality in context

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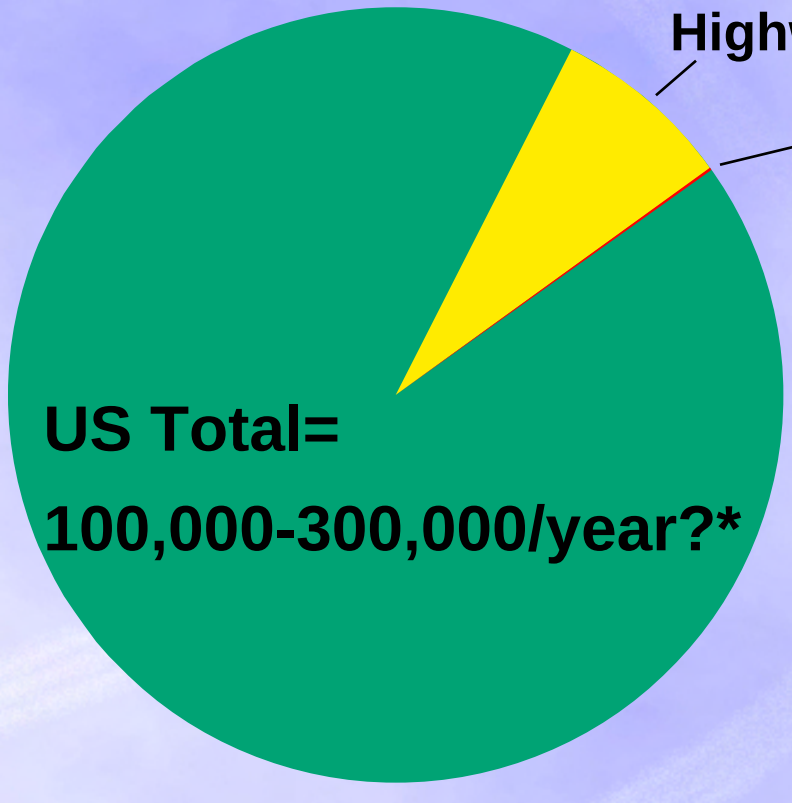
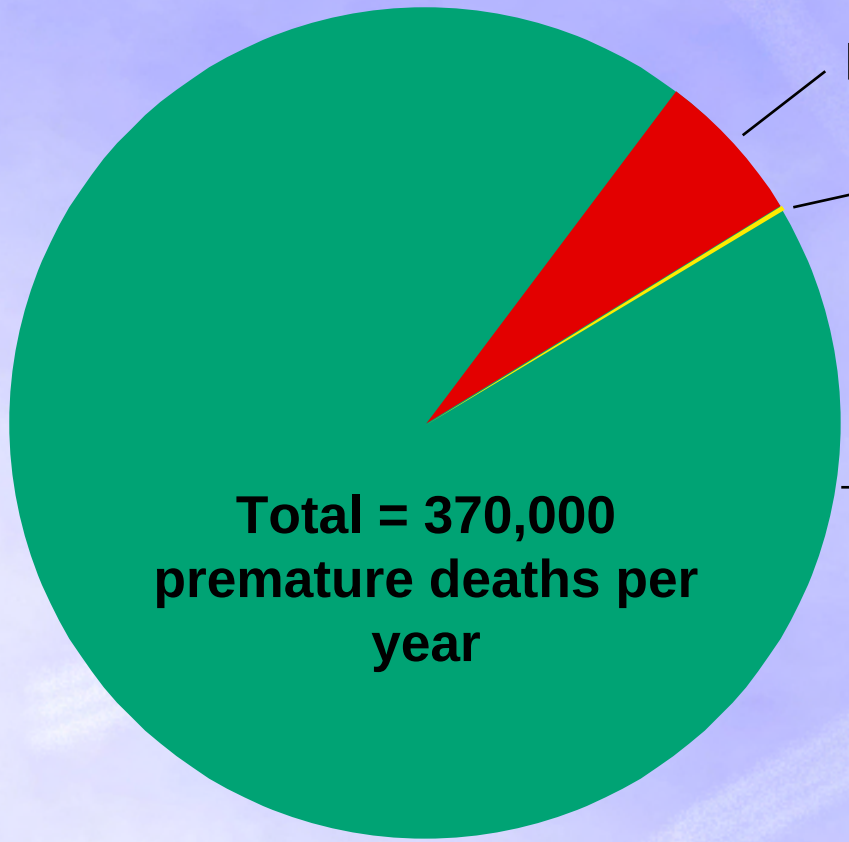


22/year
Average U.S. Airline passenger fatalities 2002-2006 (Part 121)

http://www.ntsb.gov/aviation/Table5.htm

***We do not have a good estimate for the total premature deaths per year in the United States due to local air quality. Scaling the per capita numbers derived from EU analyses would suggest something on the order of 240,000 premature deaths/year; using the mobile source intake fraction methods that we have applied for aviation and highway vehicles would suggest something on the order of 350,000 premature deaths per year.

EU 25 Air Quality, All sources, Yearly Premature Deaths*

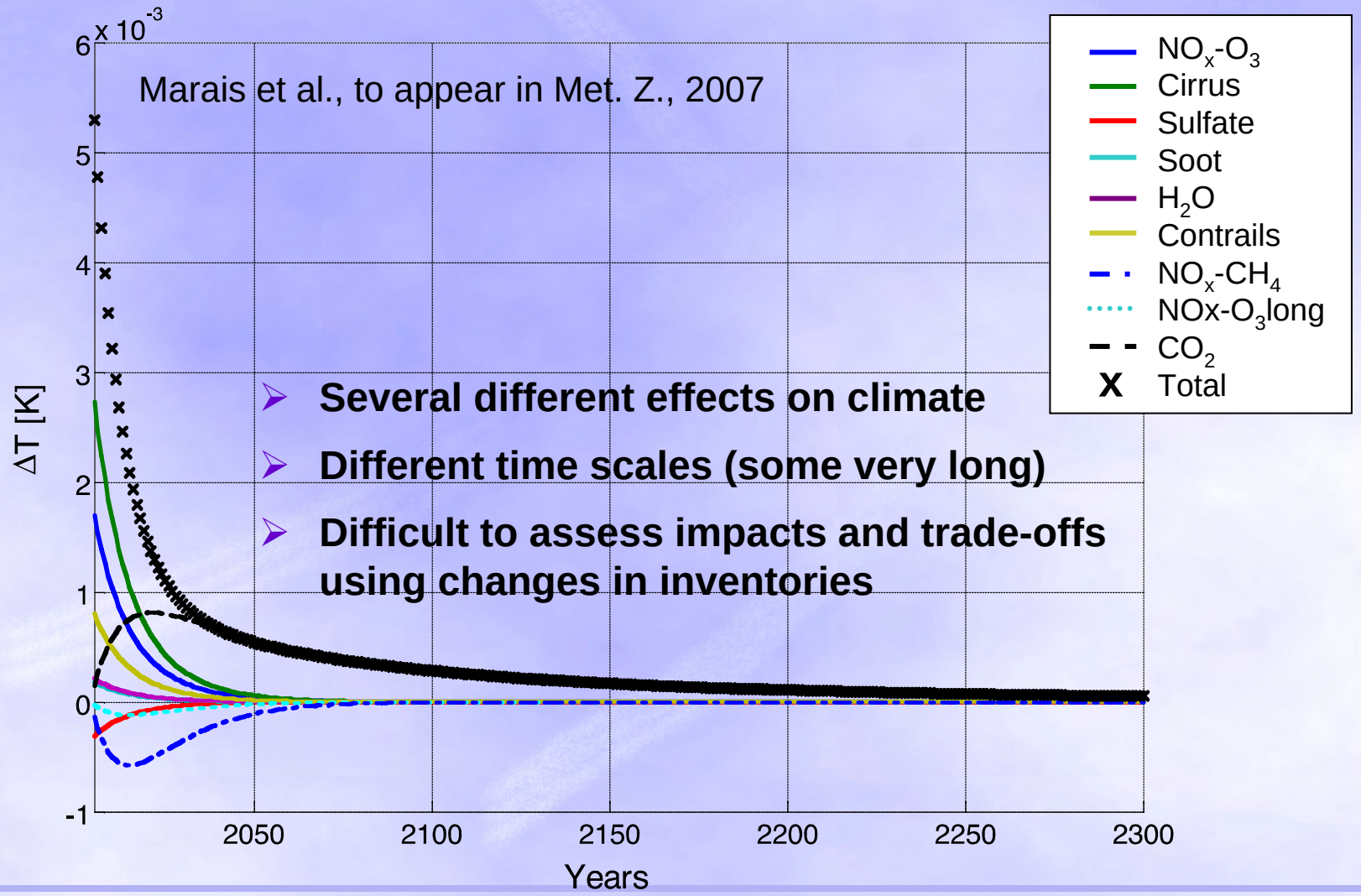


EU25 Population ~ 460,000,000

*Data from EU CAFE Program: http://ec.europa.eu/environment/air/cafe/general/keydocs.htm

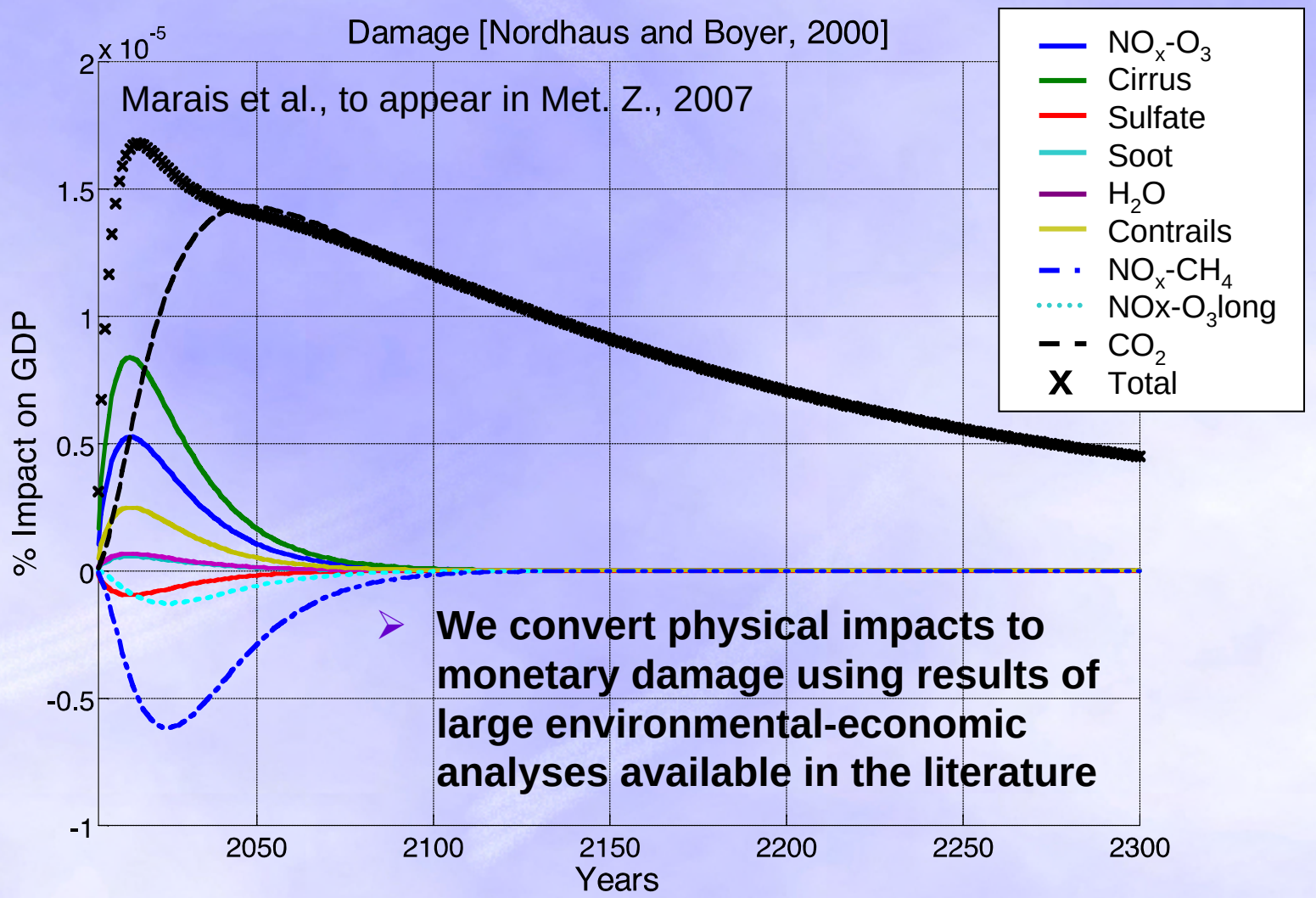
Climate impacts equally complex

Average global surface ΔT for one year of aviation emissions



- **Several different effects on climate**
- **Different time scales (some very long)**
- **Difficult to assess impacts and trade-offs using changes in inventories**

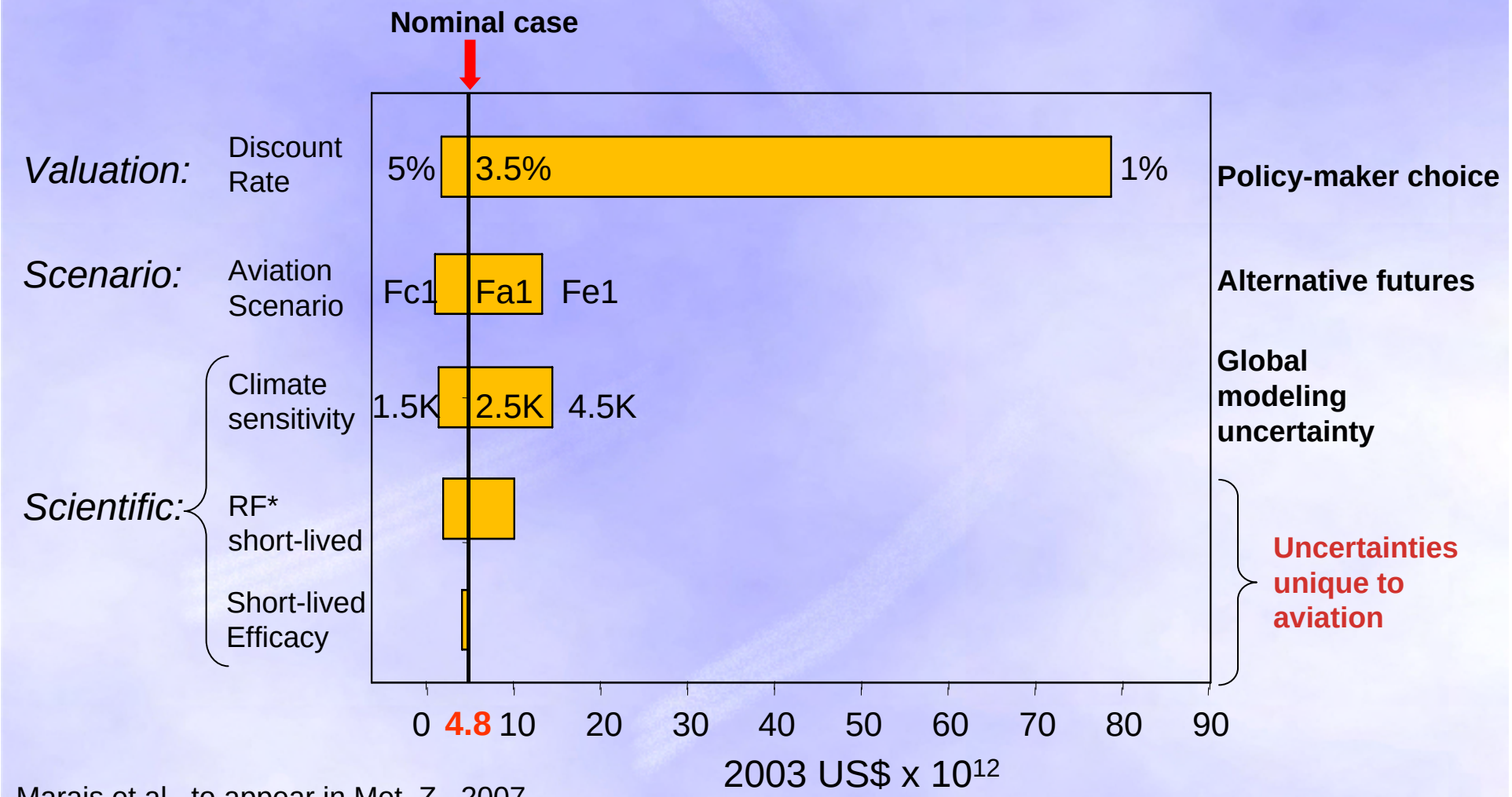
Damage [% GDP]
for one year of aviation emissions



- **We convert physical impacts to monetary damage using results of large environmental-economic analyses available in the literature**

Climate cost sensitivity

100 year aviation scenarios (impacts to 800 years)



Marais et al., to appear in Met. Z., 2007

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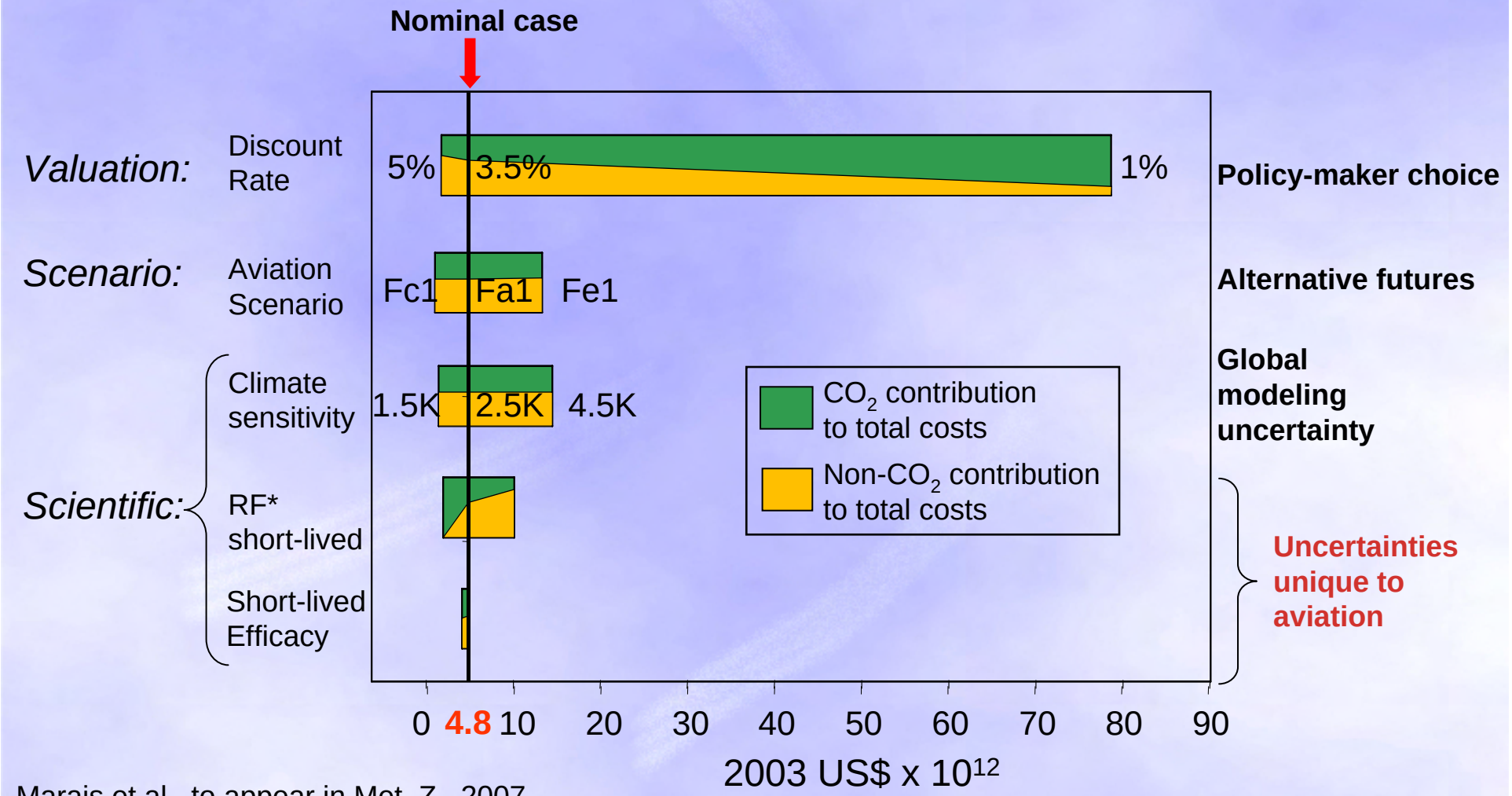

Marais et al., to appear in Met. Z., 2007

Interdependencies

(for *one* particular set of scenarios and assumptions)

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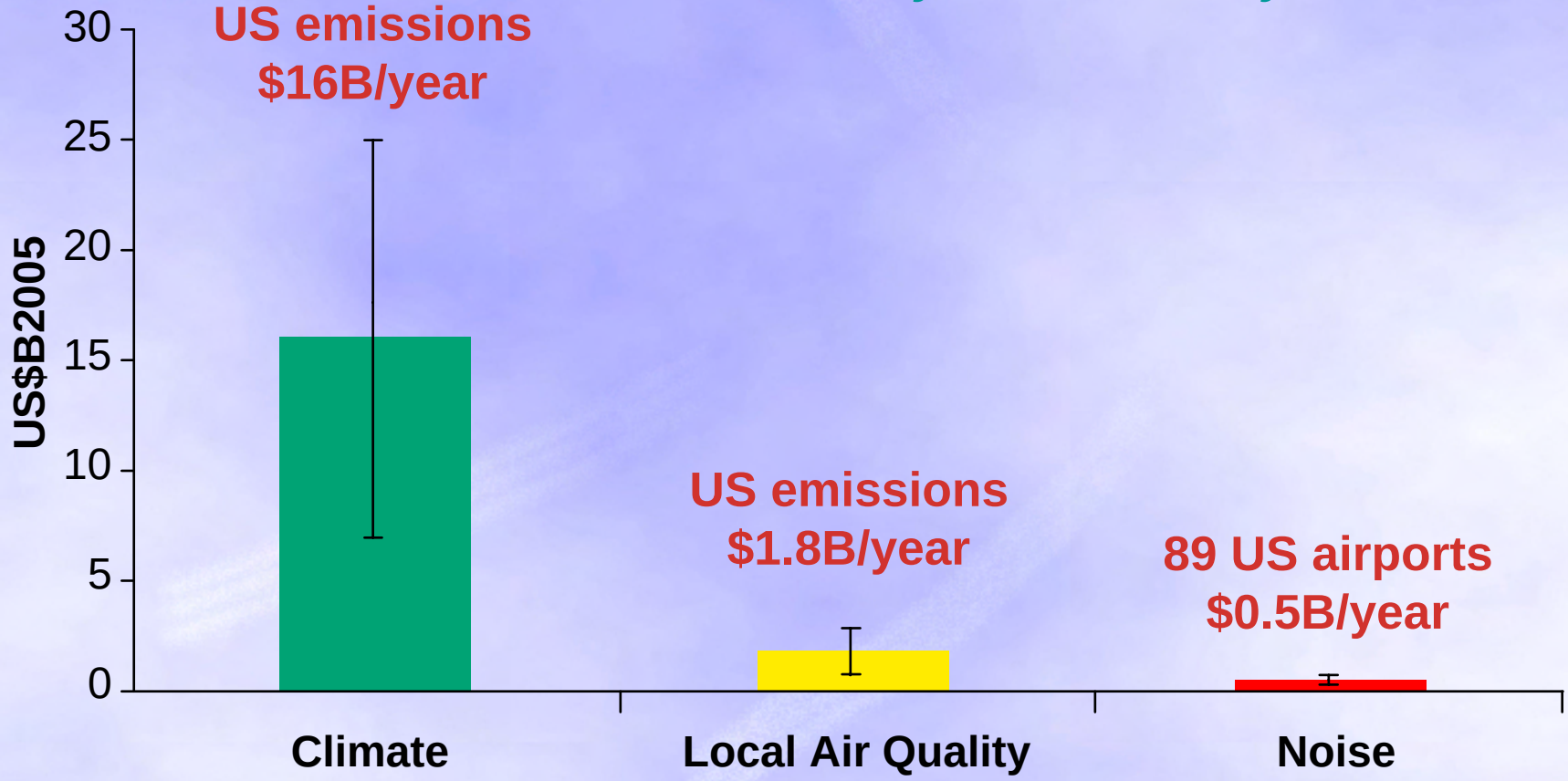

3% discount rate, $10B total noise costs annualized on a 30 year basis

Summary

- FAA has made a commitment to use these tools
  - to inform their decision-making for the ICAO/CAEP meeting in 2010
  - to help establish trades among noise, local air quality and climate impacts to better quantify and manage the impacts associated with US NextGen
- We are still developing and improving these methods
  - they are not accepted for CAEP decision-making
- Our purpose
  - is not to provide “one answer” or a single “best estimate”
  - but to provide a framework that may be used to communicate potential outcomes and uncertainties using a variety of metrics, under a variety of assumptions and scenarios

Final words

- These tools will not make decision-making easier (they may well make it harder)

- However, our goal is to make decision-making better informed (not to make it easier)