FAA CENTER OF EXCELLENCE FOR ALTERNATIVE JET FUELS & ENVIRONMENT

Improving Climate Policy Analysis Tools

Project 21

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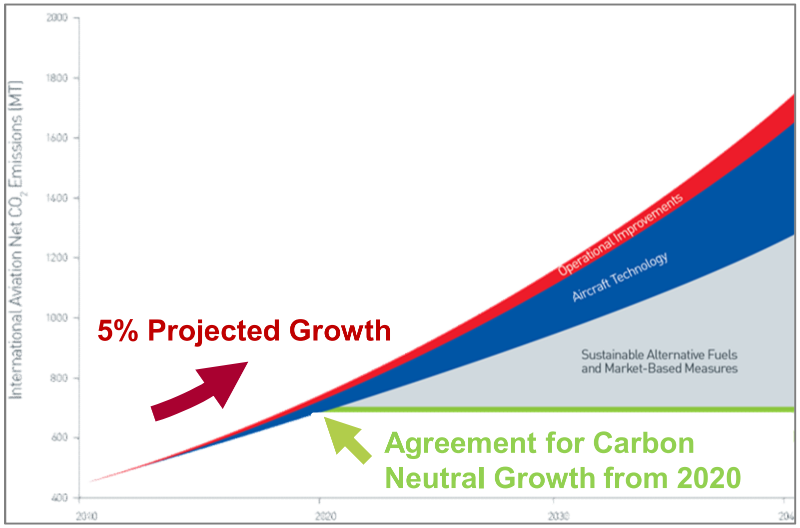
Motivation

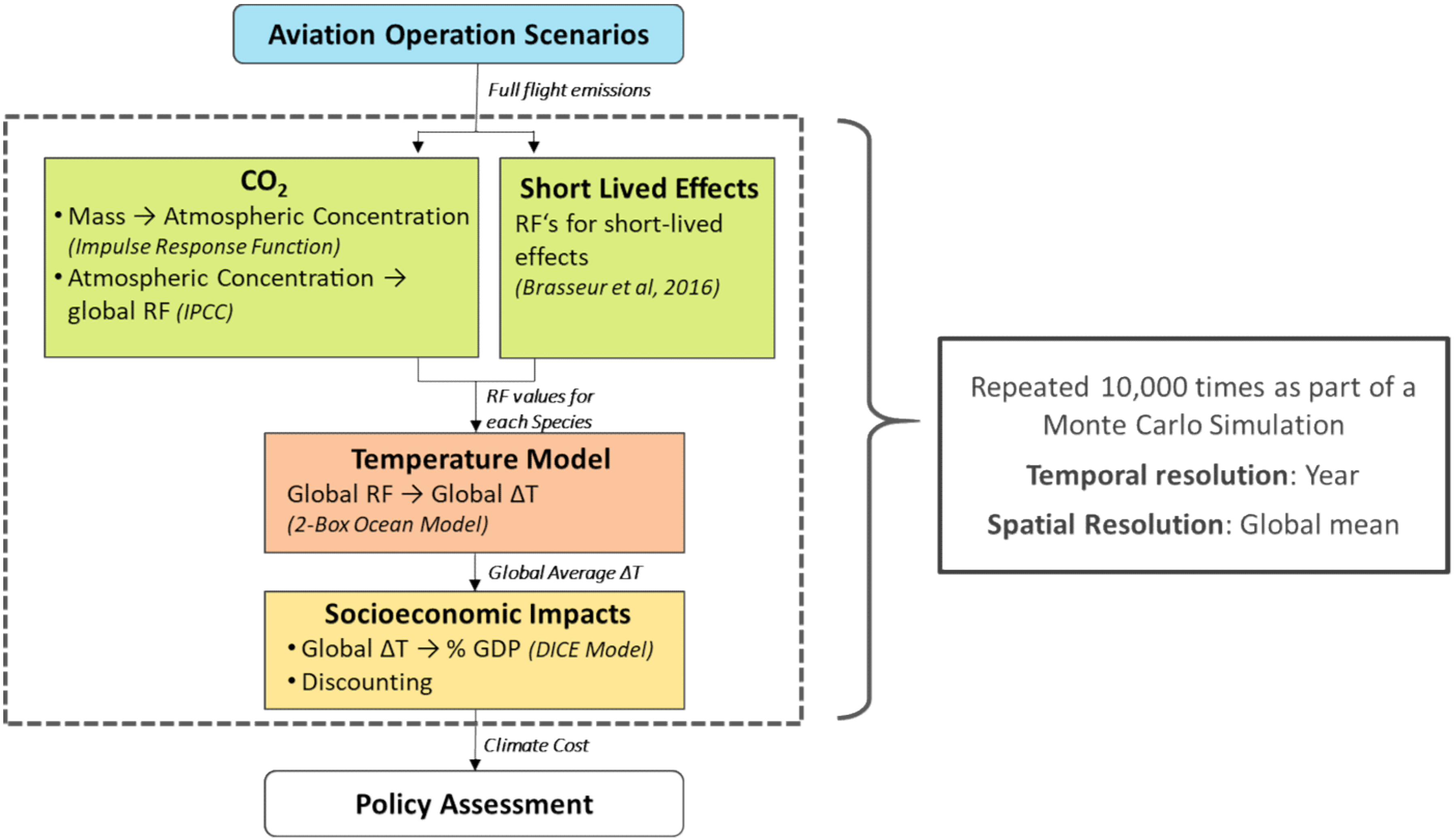
- Aviation is estimated to cause
  - 2% of the global **anthropogenic CO_2** emissions
  - 5% of the global **anthropogenic radiative forcing**
- Impact is expected to increase



Adapted from ICAO

- Tools to **quantify current and future climate impacts** of aviation required
- **APMT-Impacts Climate** is a reduced order climate modeling tool, which has been developed for this purpose
  - Last update cycle (v23) completed in 2015
  - Updates are necessary to capture latest scientific understanding

APMT-I Climate: Model overview



Year-2017 updates: Overview

APMT-Impacts Climate version 24 updates

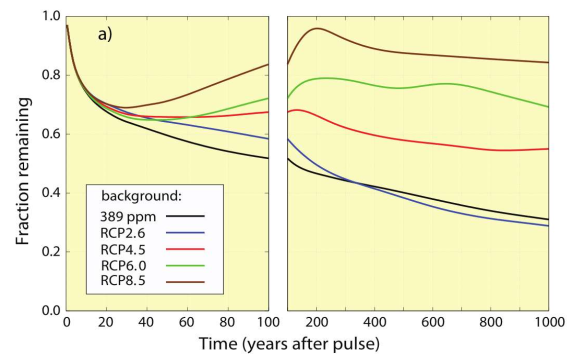
1. CO_2 model
2. Climate sensitivity distribution
3. Background temperature change
4. Short-lived forcer RF modeling
5. Nitrate aerosol cooling pathway

① CO_2 model

Motivation

- APMT-IC v23 uses a **linear impulse response function (IRF)** to model CO_2 sequestration; **non-linear** effects not considered
- Now: Capture the **non-linear** effects associated with **CO_2** sequestration

Impulse response functions under RCP scenarios (Joos et al. 2013)



Implementation

- Model for the Assessment of Greenhouse Gas Induced Climate Change (**MAGICC6**, Meinshausen et al. 2011) used to generate **IRFs**.

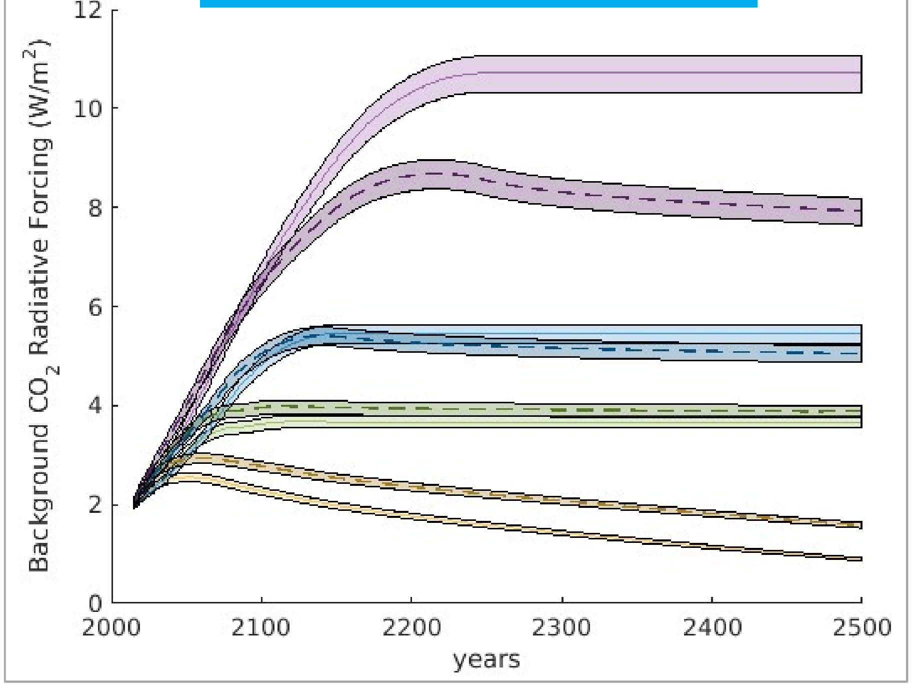
Run Baseline RCP Case with MAGICC6 → Run RCP Case with ΔCO_2 emission for a specific year → $IRF_{\text{Emission Year}}$ = (B) - (A)

Repeated for emission years, and different RCP Scenarios

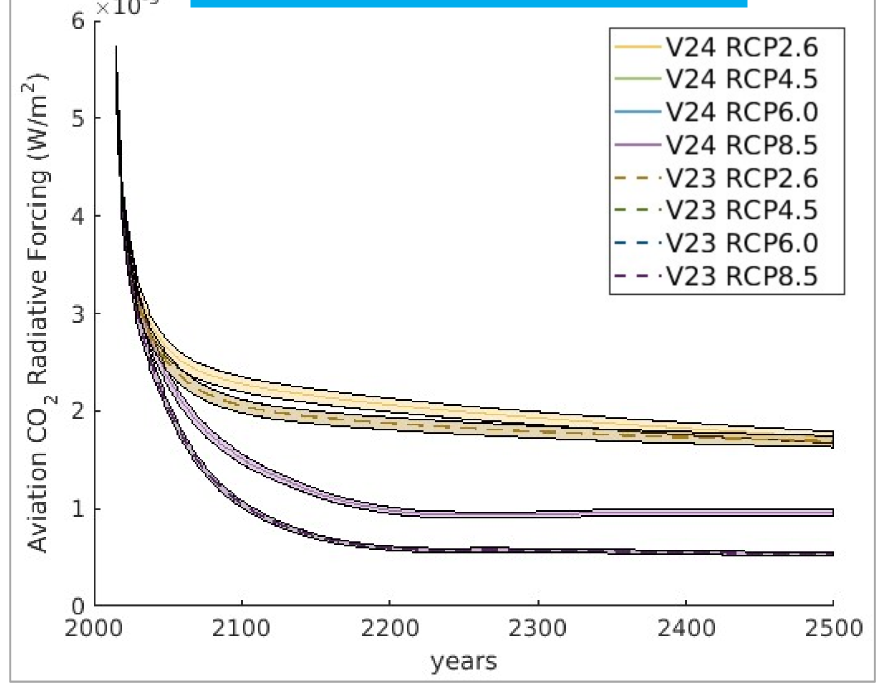
- MAGICC6 generated IRFs are loaded into APMT-IC as a **lookup table**.

❶ CO_2 model updates: Impacts

Background CO_2 RF



Aviation CO_2 RF



APMT-IC response to an emission pulse of 1 MTonne fuel burn in 2015.

Findings

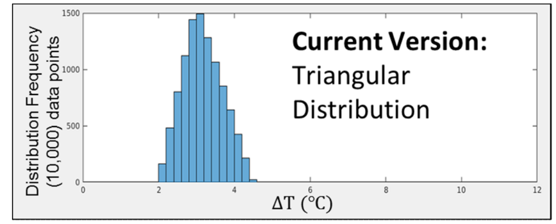
- For the background CO_2, the largest RF changes occurred for the RCP2.6 and RCP8.5 cases.
- The Aviation RF difference was highest for the RCP8.5 case.

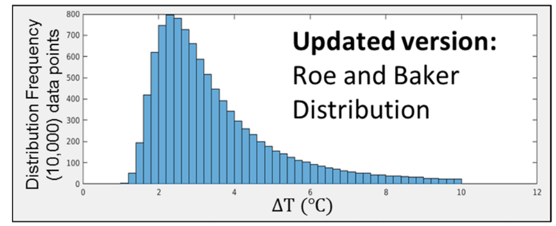
2 Climate sensitivity

Approach

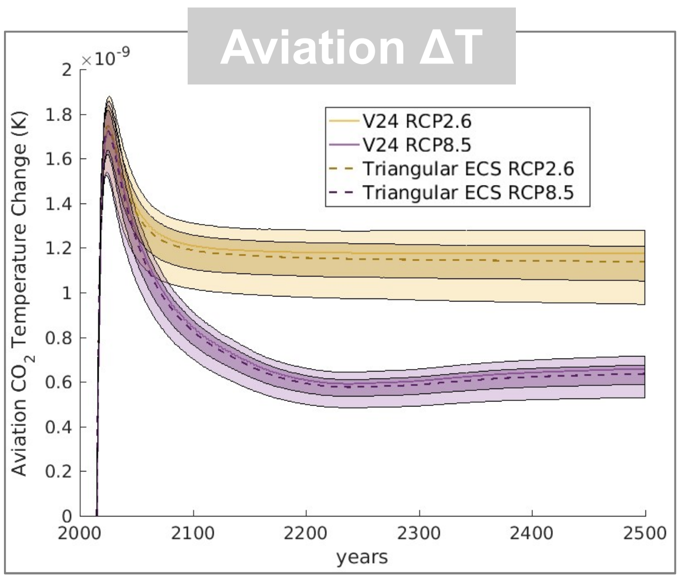
Bring **climate sensitivity distribution** in line with the peer-reviewed literature

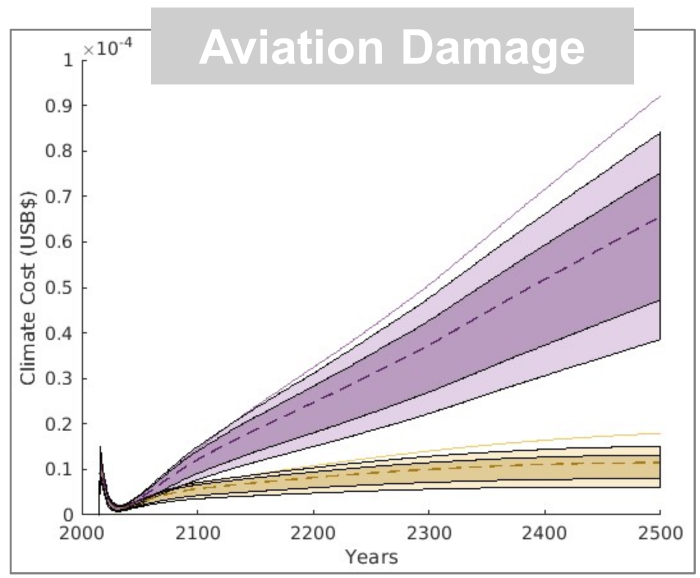
Update the APMT-IC climate sensitivity (formerly **triangular distribution**) with the **Roe and Baker** (2007) distribution





Impacts



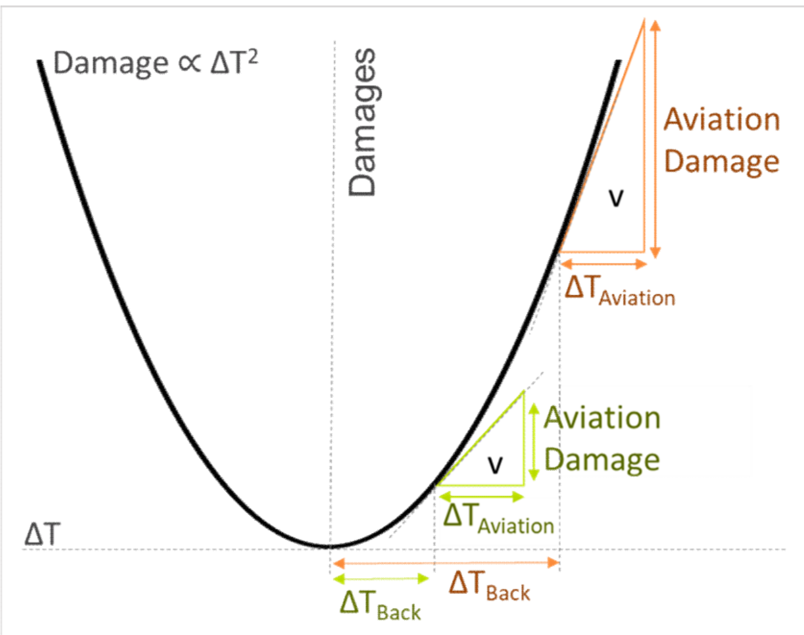


APMT-IC response to an emission pulse of 1 MTonne fuel burn in 2015.

3 Background temperature change I

Motivation

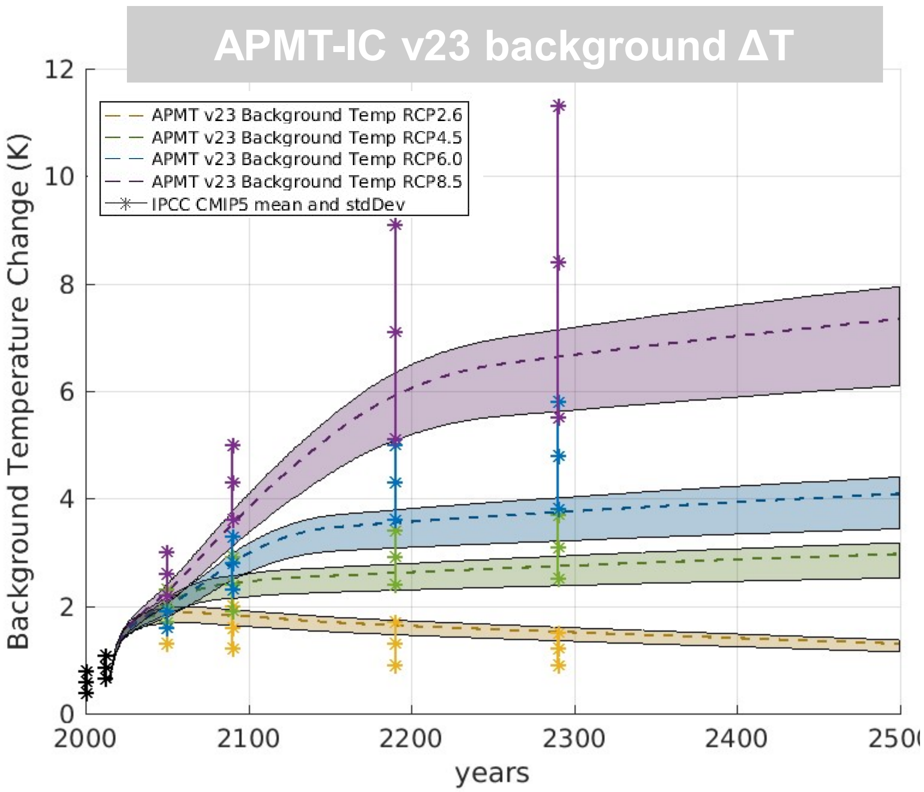
High significance of background temperature change due to **non-linear damage function**

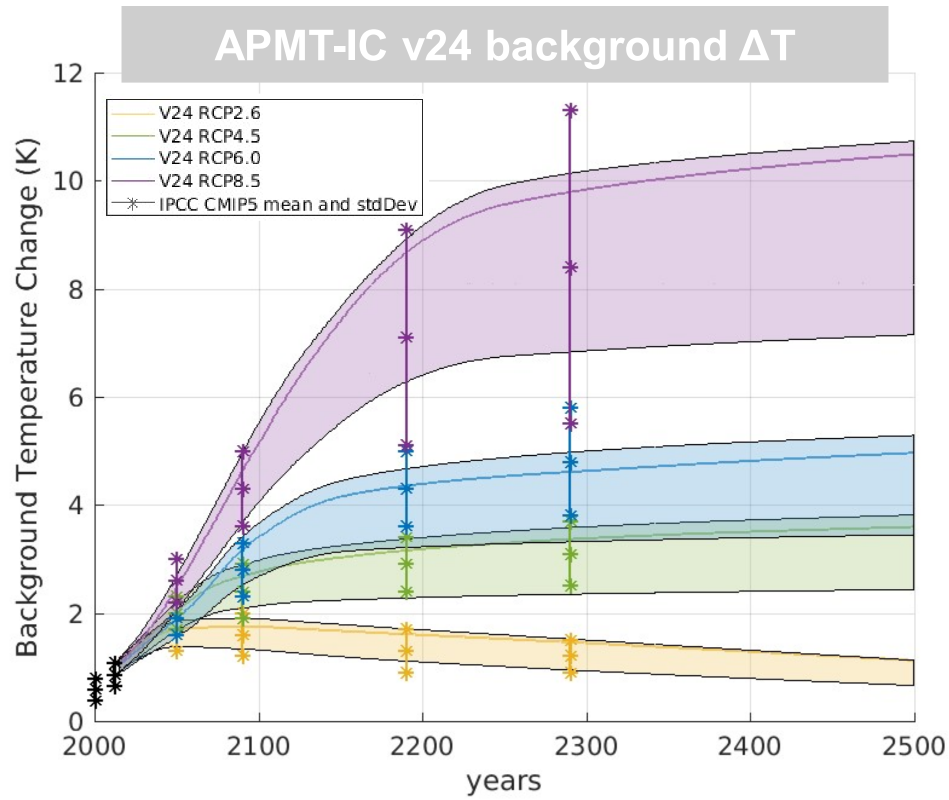


Implementation

- Create a **lookup table** for background temperature change for each **RCP** scenario and **different climate sensitivities** with **MAGICC6**
- **Uncertainty**:
  - Background ΔT uncertainty must be **correlated** with aviation ΔT
  - **Climate sensitivity** is strongest driver towards APMT-IC ΔT
  - Monte Carlo draw **climate sensitivity** is used to select a **background ΔT** from the MAGICC6 **lookup table**. Therefore if the Aviation ΔT is high, the background ΔT will also be high for that Monte Carlo draw

3 Background temperature change II





Findings

- When compared to APMT-IC v23, v24 ΔT is more representative of the IPCC 5th Coupled Model Intercomparison (CMIP5) study.
- Uncertainty is also correlated with aviation temperature change and also uses Roe and Baker (2007) uncertainty distribution.

④ Short-lived forcer RF modeling

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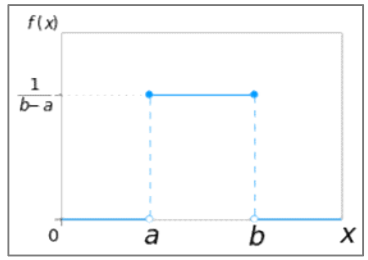
Motivation

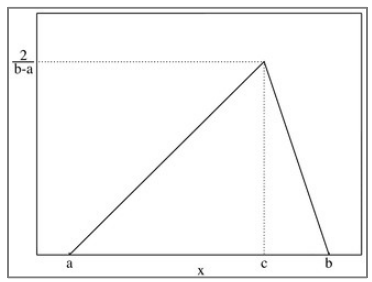
APMT-IC v23 used **triangular distributions** for all short-lived forcer **RF distributions**, which may lead to **underestimation of uncertainty** with limited data.

Solution

Use the following distribution assumptions:



If **2 values** are available in ACCRI (Brasseur et al., 2016) – Use **Uniform** Distribution



If **3 or more** values are available in ACCRI (Brasseur et al., 2016) – Use **Triangular** Distribution

Implementation

	APMT-IC v23 RF		**APMT-IC v24 RF**		**% Change**	
	mean	Std dev	mean	Std dev	% ΔRF	% ΔNPV
H_2O	1.67	0.14	1.65	0.97	-1%	-5%
Sulfates	-5.60	1.26	-5.60	1.26	0%	0%
Soot	0.67	0.25	0.80	0.93	18%	28%
Contrail Cirrus	38.53	15.65	43.43	13.94	12%	12%
Nitrate Aerosols	--	--	-5.25	1.13	--	
Total:	**43.2**	**--**	**42.65**	**--**	**-1%**	**0%**

⑤ Nitrate cooling pathway

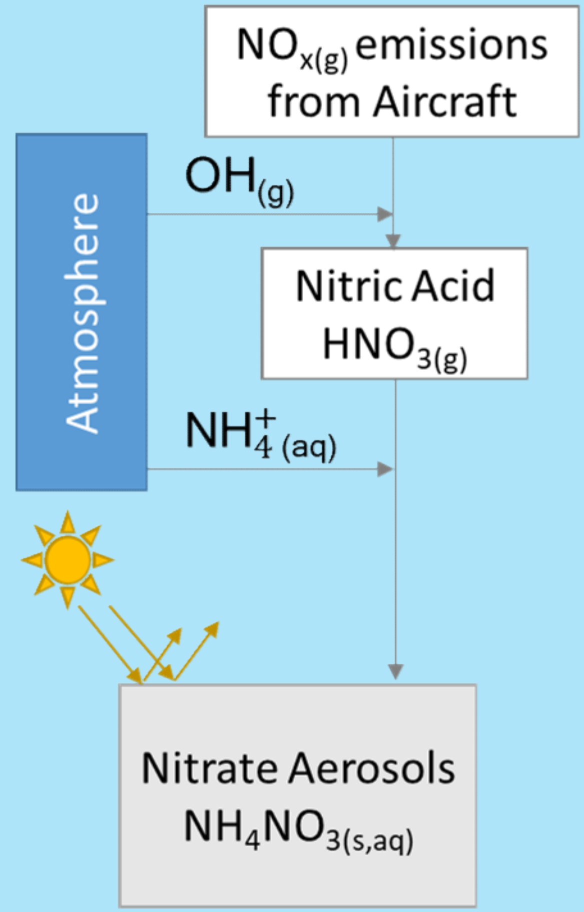
NO_x causes multiple climate impacts, most notably:

APMT-IC v23 & v24

1. **O_3 Short:** NO_x catalyzes formation of O_3 where aircraft fly (hours or days – Warming) (✓)
2. **CH_4 Short:** This leads to a increase in OH radicals, reducing CH_4 (~10 years - Cooling) (✓)
3. **O_3 Long:** CH_4 reduction leads to decrease in O_3 (~10 years - Cooling) (✓)

v24

4. **Nitrate Aerosols** (<1 year – Cooling) (New)



*APMT-IC Treats NO_x water vapor impacts along with direct emission water vapor

5 Nitrate Cooling Pathway - Impacts

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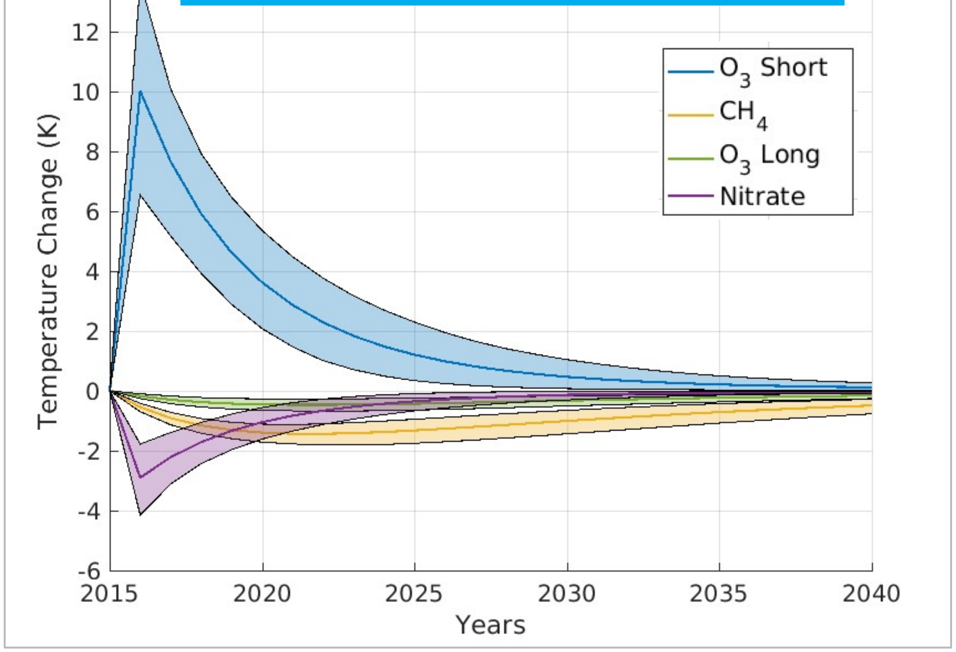
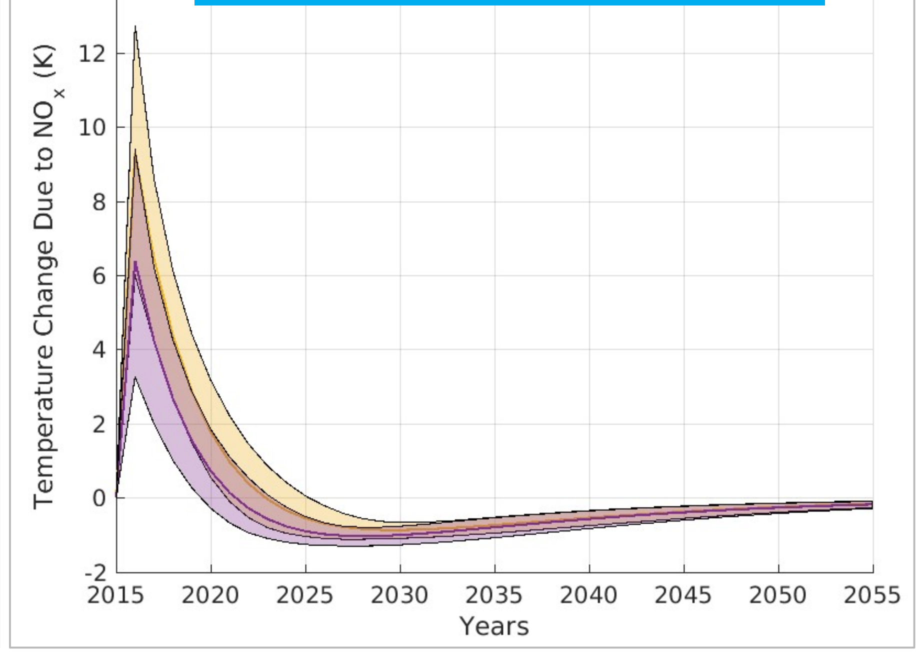
APMT-IC NO_x Components



APMT-IC NO_x Impact



APMT-IC response to an emission pulse of 1 MTonne fuel burn in 2015.

Findings

The computed NO_x temperature effect becomes negative, 1.5 years (or 25%) earlier.

Model Comparisons

Social Cost of Carbon for Emissions in 2020 (\$/1tonne CO_2 in 2007 USD)

	2.5% DR	3% DR	5% DR
APMT-IC v24 RCP4.5 Mid Lens (5^{th},95^{th} Range)	\$67 (\$13, \$173)	\$48 (\$11, \$122)	\$19 (\$5, \$47)
Recent Peer reviewed SCC (IAWG, 2016) (5^{th},95^{th} Range)	\$62 (\$6, \$181)	\$42 (\$2, \$123)	\$12 (\$0, \$38)

Findings

- In each case, the APMT-IC Social cost of carbon falls within the 5^{th} and 95^{th} percentile range of the Recent Peer Reviewed SCC (IAWG, 2016).
- The uncertainty ranges are in agreement

Summary

Summary

- Rapid, reduced-order assessment tool APMT-I climate has been **updated** to reflect latest state-of-the-science
- Update implements **recent scientific understanding** in the reduced-order modeling framework
- Model compares well against **peer-reviewed work**
- Note that a reduced-order tool requires constant **updating** to reflect the current state-of the science.

Next Steps

- **Regionalization of climate impacts** (distribution & regional sensitivities)
- **Lifecycle ground emission impacts** (Addition of higher fidelity lifecycle ground emission impact pathways)

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