Contrail Mitigation Decisions

Friends and Partners in Aviation Weather, Fall 2023

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Aviation's Contribution to Climate Change

- IPCC 6th Assessment Report was clear:
  - "Human influence has warmed the climate at a rate that is unprecedented in at least the last 2000 years."
  - "Global warming of 1.5°C and 2°C will be exceeded during the 21st century unless deep reductions in CO_2 and other greenhouse gas emissions occur in the coming decades."
  - **Aviation contributes to net warming with CO_2 and black carbon (particulate matter) emissions, as well as persistent warming contrail formation.**

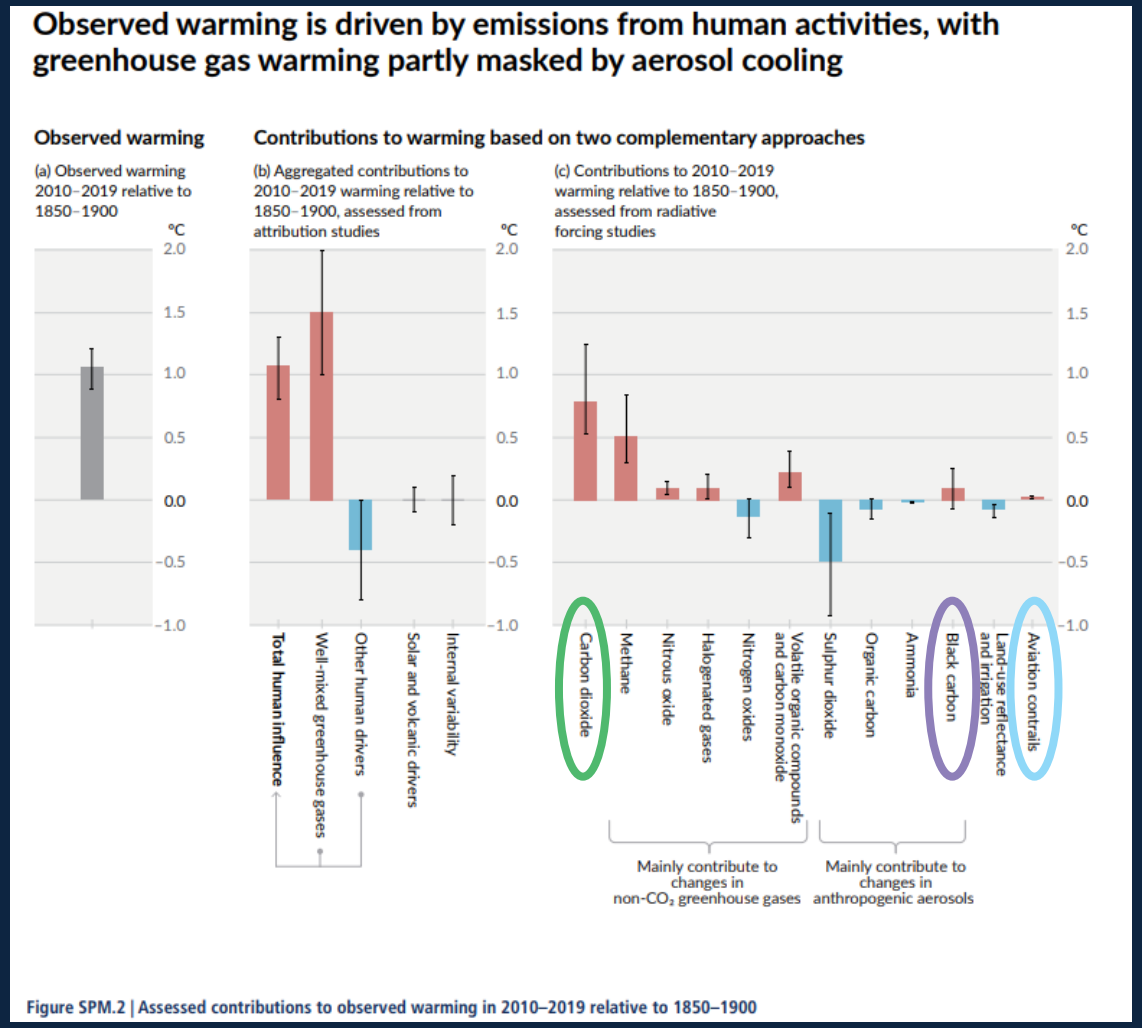

Figure SPM.2 | Assessed contributions to observed warming in 2010–2019 relative to 1850–1900

***Source**: IPCC WG1 6th Assessment Report Summary for Policymakers 2021*
https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM_final.pdf

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Europe Looking Beyond CO_2 Alone in Aviation Targets

European Union Emissions Trading System February 8, 2023 update:

- "Non-CO_2 effects on climate from aviation are at least as important as the impact of CO_2 alone. The agreement provides that the Commission will implement a monitoring, reporting and verification (MRV) system for non-CO_2 effects in aviation from 2025. By 2027, the Commission will submit a report based on the MRV and, by 2028, after an impact assessment, the Commission will make a proposal to address non-CO_2 effects."

Source: Council of the European Union, https://www.consilium.europa.eu/en/press/press-releases/2022/12/07/ets-aviation-council-and-parliament-strike-provisional-deal-to-reduce-flight-emissions/

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A Matter of Timescales and Other Considerations

Contrails

- Only cause warming at night.
- Do not always persist.
- Need to account for where they are created.
- Warming effects can last for **hours.**

Black Carbon / Particulate Matter Emissions

- Sensitive to fuel composition, engine design, and power setting.
- Need to account for where it is released.
- Warming effects can last for **days or weeks.**

CO_2 Emissions

- Always cause warming.
- Well-mixed (does not matter where it is released).
- Warming effects can last for **centuries.**

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Silos = Fundamental Research Sustainability

Silo 1

Operational adjustments to reduce contrail formation

Silo 2

Flight plans optimized to balance fuel consumption with schedule constraints

Silo 3

Particulate matter emissions standards with no consideration of modifying operations to reduce emissions

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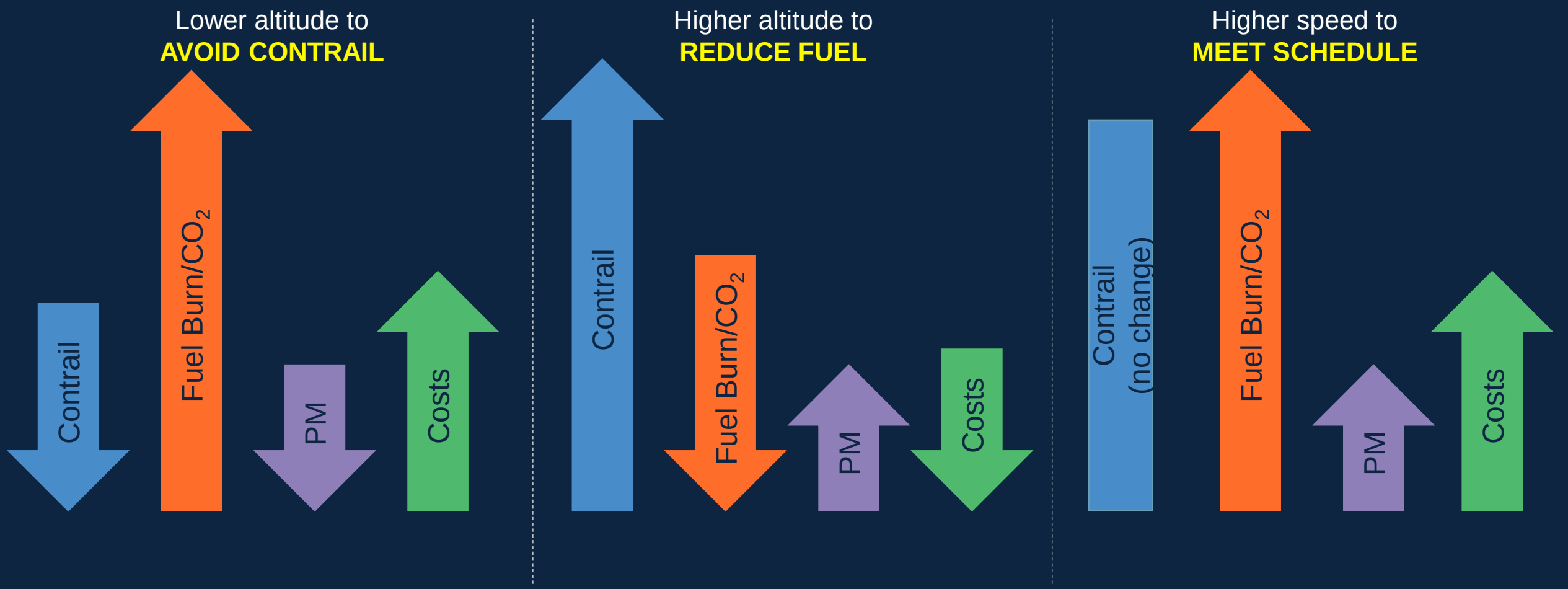
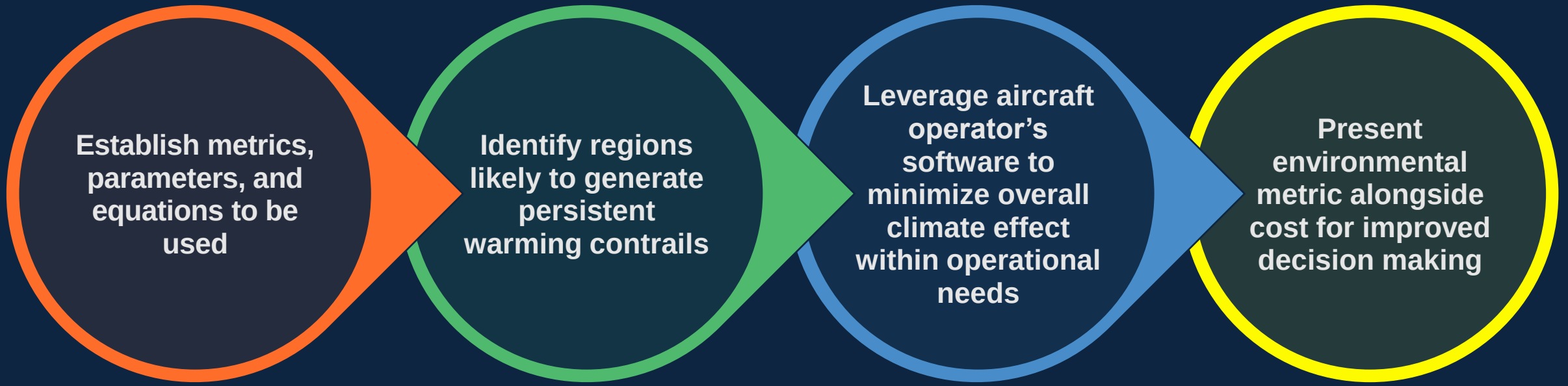
Context

This can have unintended consequences.



Integration Has a Multiplicative Effect

Initial Implementation: Pre-Flight Planning



Airline Flight Planning Trial

Goal: To evaluate feasibility of approach

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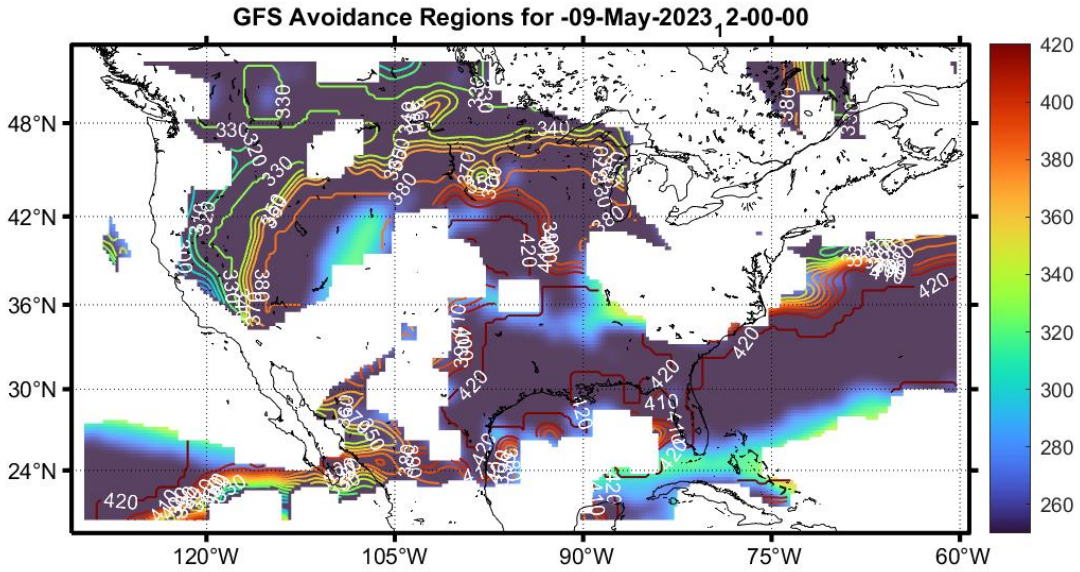
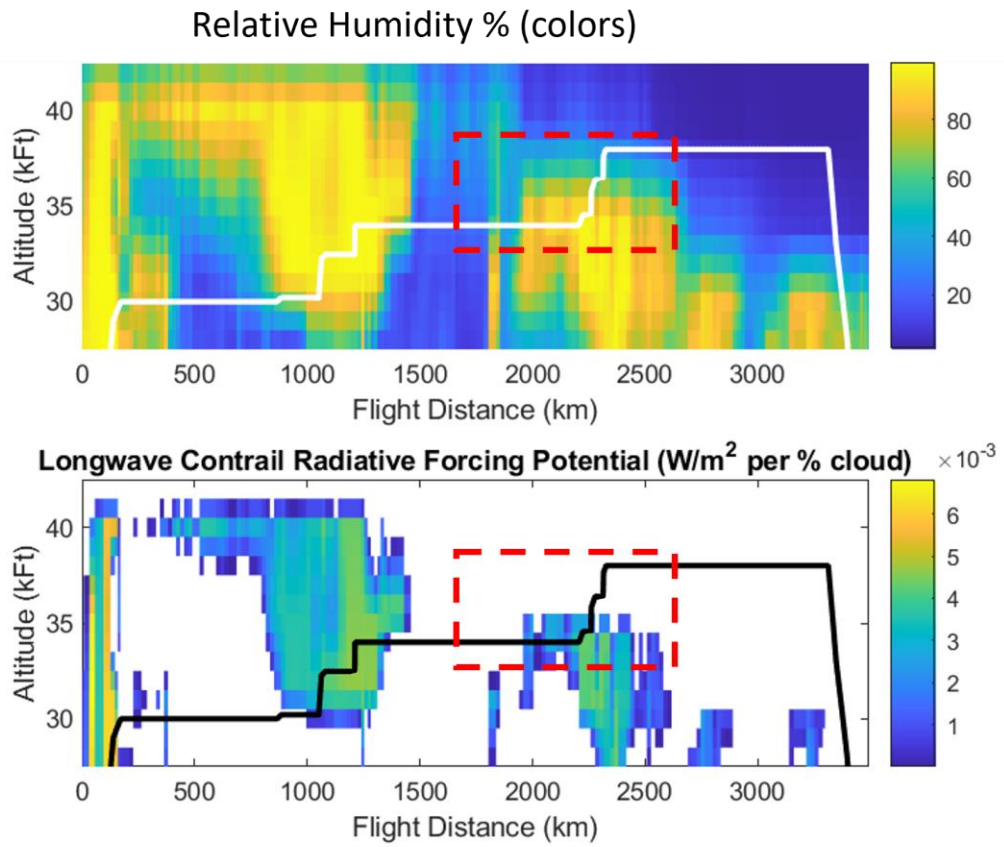
Airline Flight Planning Trial

- At 2 to 4 hours pre-departure:
  - Identified flights that may form persistent warming contrails.
  - Contrail avoidance regions loaded into airline's turbulence avoidance system.
- The airline prepared flight plans for the flights as usual.
- The airline prepared alternative flight plans that exclusively used altitude changes to minimize time in the forecasted contrail-producing areas.

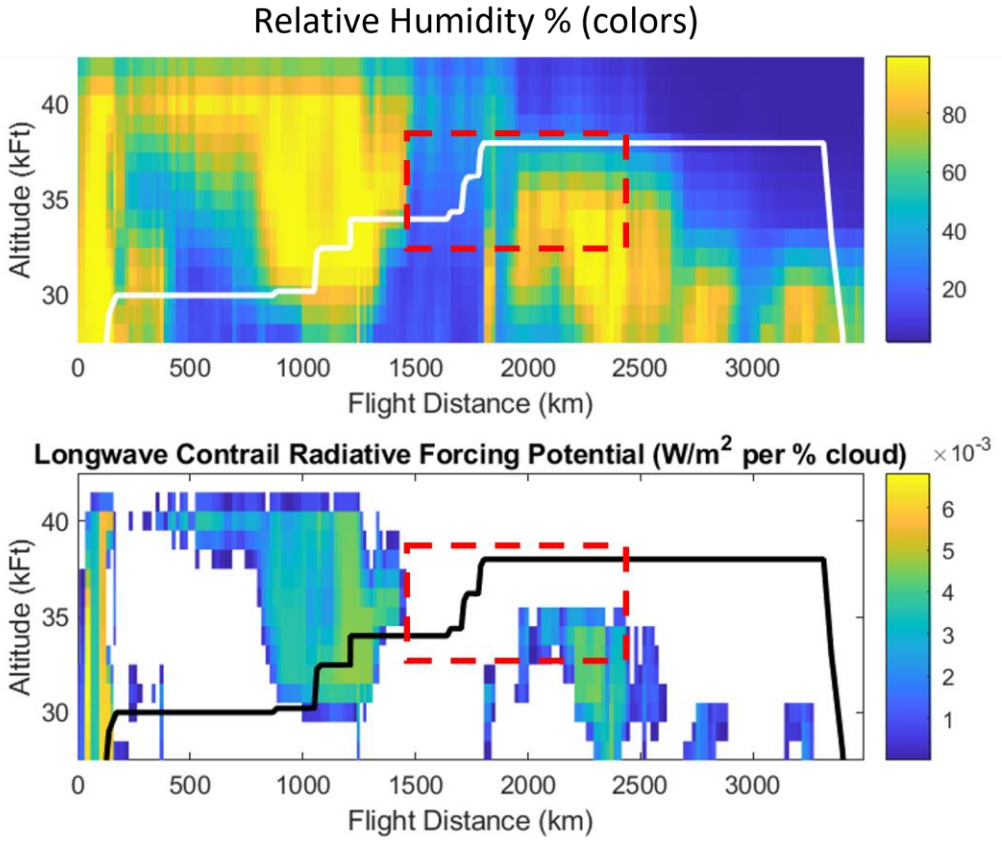


Sample Result

Filed Flight Plan



Mitigated Flight Plan



Sample Result

	ENERGY FORCING BY COMPONENT					
	Time Scale 1 (20-yr)			Time Scale 2 (100-yr)		
Units: 1.0×10^{13} J	Contrail Cirrus (all time scales)	CO_2 (20-yr)	BC (20-yr)	Contrail Cirrus (all time scales)	CO_2 (100-yr)	BC (100-yr)
Filed Flight Plan	**4.58**	**2.05**	**.0330**	**4.58**	**7.20**	**.0333**
Mitigated Flight Plan	**3.45** ↓	**2.03** ↓	**.0338** ↑	**3.45** ↓	**7.16** ↓	**.0341** ↑
Total	6.66×10^{13} J vs 5.51×10^{13} J			11.8×10^{13} J vs 10.6×10^{13} J		
Mitigation Difference	**-17.2%**			**-9.9%**		

	Change in Cost	Change in Time
Mitigated Flight Plan	Negligible Decrease	+1 Minute

Looking to the Future

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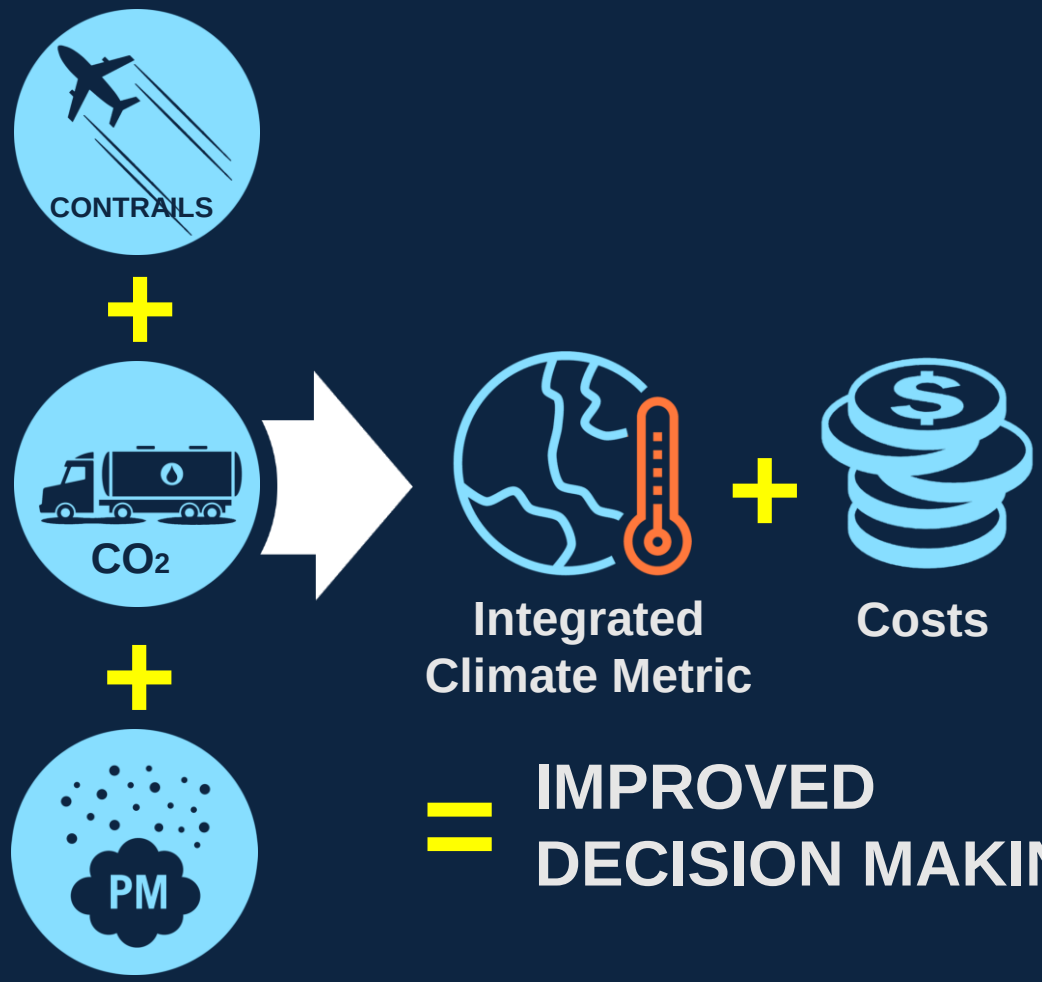
Further Integration Has a Greater Multiplicative Effect



TRAJECTORY-BASED OPERATIONS

Thoughts for FPAW

- Mitigating aviation's effects on the climate needs an integrated approach.
- Physics and chemistry of how contrails form becoming better understood.
- Prediction is limited by the fidelity of forecast humidity data by pressure level.
- How can we make it better?
  - Few aircraft are equipped with humidity sensors.
    - Even fewer are using the most accurate instruments.
  - Radiosonde observations occur only twice daily and are sparse.
  - Can next generation satellites help?
  - Have we gone as far as we can with numerical weather modeling without improved humidity observations?

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