Modeling the Environmental Impact of Air Traffic Operations

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Environmental Impact - Emissions

Aviation-induced environmental impacts include

- Direct emissions: $\text{CO}_2$, Water vapor and other greenhouse gasses
- Indirect effects: $\text{NO}_x$ affecting distributions of Ozone and Methane

$\text{CO}_2, \text{H}_2\text{O, SO}_2$
$\text{NO}_x, \text{CO, HC}$

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Environental Impact - Contrails

Aviation-induced environmental impacts also include effects associated with contrail formation.
Contributions

- Integrate environmental models to air traffic system models
- Enable trade-offs study among contrail formations and emissions
- Provide capability for evaluation of environmental policy based on scientific findings
Outline

- Environmental Impact Model
- Air Traffic System Model
- Integrated System
- Trade-off Study
- Conclusions
Environmental Impact Model

- Fuel Burn and Emission Models
- Optimization Algorithms
  - Aircraft level
  - System level
- Contrail Models
Fuel Burn and Emission Models

Use FAA’s System for Accessing Aviation’s Global Emissions (SAGE) Models

Aircraft Information
- Type
- Speed
- Altitude
- Mass

SAGE Models
- Aircraft Database
- Fuel Burn Model
- Emission Model
- Engine Mapping
- Emission Data Bank

Fuel Burn Rate
- CO₂, H₂O, SO₂, NOₓ, CO, HC
Contrail Models

Rapid Update Cycle (RUC) Data

Relative Humidity with respect to water (RHw)

Temperature

Relative Humidity with respect to ice (RHi)

RHw > critical humidity and RHi > 100%

Contrail Favorable Regions
Optimization Algorithms

Partial Contrail Reduction

Wind Optimal

Complete Contrail Reduction
Air Traffic System Model

Future ATM Concept Evaluation Tool (FACET)

Flight Schedules → Air Traffic System Model → Visualization and Analysis of Aircraft Operations

Atmospheric and Air Space Data
Integrated System

Future ATM Concept Evaluation Tool (FACET)

- Flight Schedules
- Atmospheric and Air Space Data
- Air Traffic System Model
- Visualization and Analysis of Aircraft Operations

Fuel Burn and Emission Models

Optimization Algorithms
- Aircraft level
- System level

Contrail Models

Environmental Impact Model
Integrated System Display - Emissions

Entire US

Zoom-In around New York Area
Integrated System Display – Contrails
Trade-off Study – Contrails and Emissions

- Reduce contrail formation by changing aircraft pre-departure cruising altitudes
  1. find aircraft at the same cruising altitude
  2. compute total contrails formed and emissions at different cruising altitudes
  3. select altitude with least contrails

- Contrail reductions result in extra emissions
Contrail Reduction Strategy

Contrails

Emissions

Threshold = \frac{\text{contrail reduction (nmi)}}{\text{extra CO}_2 \text{ emission (1000kg)}}
Result of the Trade-offs Study

\[ \alpha = \frac{\text{contrail reduction (nmi)}}{\text{extra CO}_2 \text{ emission (1000kg)}} \]

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Conclusions

- Integrate environmental models to air traffic system models
- Enable trade-offs study among contrail formations and emissions
- Provide capability for decision maker to evaluate environmental policy based on scientific findings