Modeling the Environmental Impact of Air Traffic Operations

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Environmental Impact - Emissions

Aviation-induced environmental impacts include

- Direct emissions: CO\textsubscript{2}, Water vapor and other greenhouse gasses
- Indirect effects: NO\textsubscript{x} affecting distributions of Ozone and Methane
Environmental 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
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
- Emission Indices
- Engine Type
- Aircraft Parameters

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

Rapid Update Cycle (RUC) Data

Relative Humidity with respect to water (RHw)

Temperature

RHw>critical humidity and RHi>100%

Contrail Favorable Regions

Relative Humidity with respect to ice (RHi)
Optimization Algorithms

- Partial Contrail Reduction
- Wind Optimal
- Complete Contrail Reduction
Air Traffic System Model

Future ATM Concept Evaluation Tool (FACET)

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

Environmental Impact Model

Fuel Burn and Emission Models

Optimization Algorithms
  • Aircraft level
  • System level

Contrail Models
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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Extra CO\textsubscript{2} Emission

Contrail Reduction

\(\alpha = 80\) most fuel efficient

\(\alpha = 20\)

\(\alpha = 40\)

\(\alpha = 10\)

max reduction

0% 20% 35% 40% 52% 60%

0.7% 1.0% 2.0% 2.7% 3.0%
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