Modeling the Environmental Impact of Air Traffic Operations

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Environmental Impact - Emissions

Aviation-induced environmental impacts include:

- Direct emissions: CO$_2$, Water vapor and other greenhouse gasses
- Indirect effects: NO$_x$ 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
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
- Aircraft Database
- Aircraft Parameters
- Engine Mapping
- Emission Data Bank
- Emission Model

SAGE Models

Fuel Burn Model

- 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%

Relative Humidity with respect to ice (RHi)

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

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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

FL420
FL400
FL380
FL360
FL340
FL320
FL300
FL280
FL260
FL240
FL220

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

08/01/2007

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

- \( \alpha = 80 \) most fuel efficient
- \( \alpha = 40 \)
- \( \alpha = 20 \)
- \( \alpha = 10 \)

Extra \( \text{CO}_2 \) Emission

Contrail Reduction

max reduction

0% 20% 40% 60%
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