Concepts and Challenges for Environmentally Friendly En route Operations

Banavar Sridhar
NASA
National Challenges and Goals*

• **Challenges**
  – Understand the complex relationships between aircraft noise, emissions and fuel burn
  – Optimize aircraft noise, fuel efficiency and emission reductions using advanced technology, operational procedure and computational models

• **Goals**
  – Enable significant increases in the energy efficiency
  – Decrease the environmental impact

* National Aeronautics Research and Development Plan (February 2010)
Goals of Current Research

• Develop en route traffic flow concepts to reduce environmental impact of aviation based on advances in basic research on climate science
  – Contrails and Cirrus
  – Trade-offs amongst emissions impacting climate
Traffic Flow Simulation Interaction with Other Modules

- Flight Schedules
- Atmospheric and Air Space Data
- Future ATM Concepts Evaluation Tool (FACET)
- Visualization and Analysis of Aircraft Operations
- Application Programming Interface
  - Emission Models and Metrics
  - Optimization Algorithms
    - Aircraft level
    - System level
  - Contrail Models
Contrails

• Occur if ambient conditions along the aircraft trajectory is colder and moister than a threshold defined by thermodynamic parameters
• Contrails persist under certain conditions (Relative humidity with respect to ice >100%)
• Effect different during night and day
Persistent Contrail Formation Model

RHW Contours

RHI Contours

RHI>100% Contours

Persistent Contrail

Aircraft

RHI>100%
Strategies for Avoiding Contrails

- **Tactical**
  - Requires on-board sensors to detect super-saturated air
  - Research aircraft equipped with sensors at DLR
  - Air Traffic Service Provider (ATSP) needs to accommodate changes to the flight plans

- **Strategic**
  - Models for predicting contrails

- Both strategies may result in extra fuel burn
- Research question: How to trade off the extra fuel burn with the environmental impact of going through contrails?
  - Impact of non-CO$_2$ components of aviation on climate change is significant, but large uncertainty in the contribution of contrails
  - Time scales in the effects of CO$_2$ (decades) and contrails (hours)
Contrail Reducing Aircraft Trajectories

- Partial Contrail Reduction
- Wind Optimal
- Complete Contrail Reduction
Travel between 12 City-pairs
Tradeoff between Contrail Reduction and Extra Fuel Consumption

![Graph showing the tradeoff between contrail reduction and extra fuel consumption. The x-axis represents additional fuel consumption as a percentage, ranging from 0 to 8%. The y-axis represents contrails formation time, ranging from 0 to 30 minutes for JFK/LAX (2D), JFK/LAX (3D), LAX/JFK (2D), and LAX/JFK (3D). Each graph has a line for total (2D) and total (3D) contrails formation time.](image)
Concluding Remarks

• Presented research on environmentally friendly en route traffic flow concepts incorporating models developed by basic climate research
• Developed an optimal contrail reduction trajectory concept
• Integrated fuel flow, emissions and optimization models with FACET
  – Verified it against FAA emission models
  – Ability to conduct system level analysis of Traffic Flow Management concepts with minimal environmental impact