Concepts and Challenges for Environmentally Friendly En route Operations

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National Challenges and Goals*

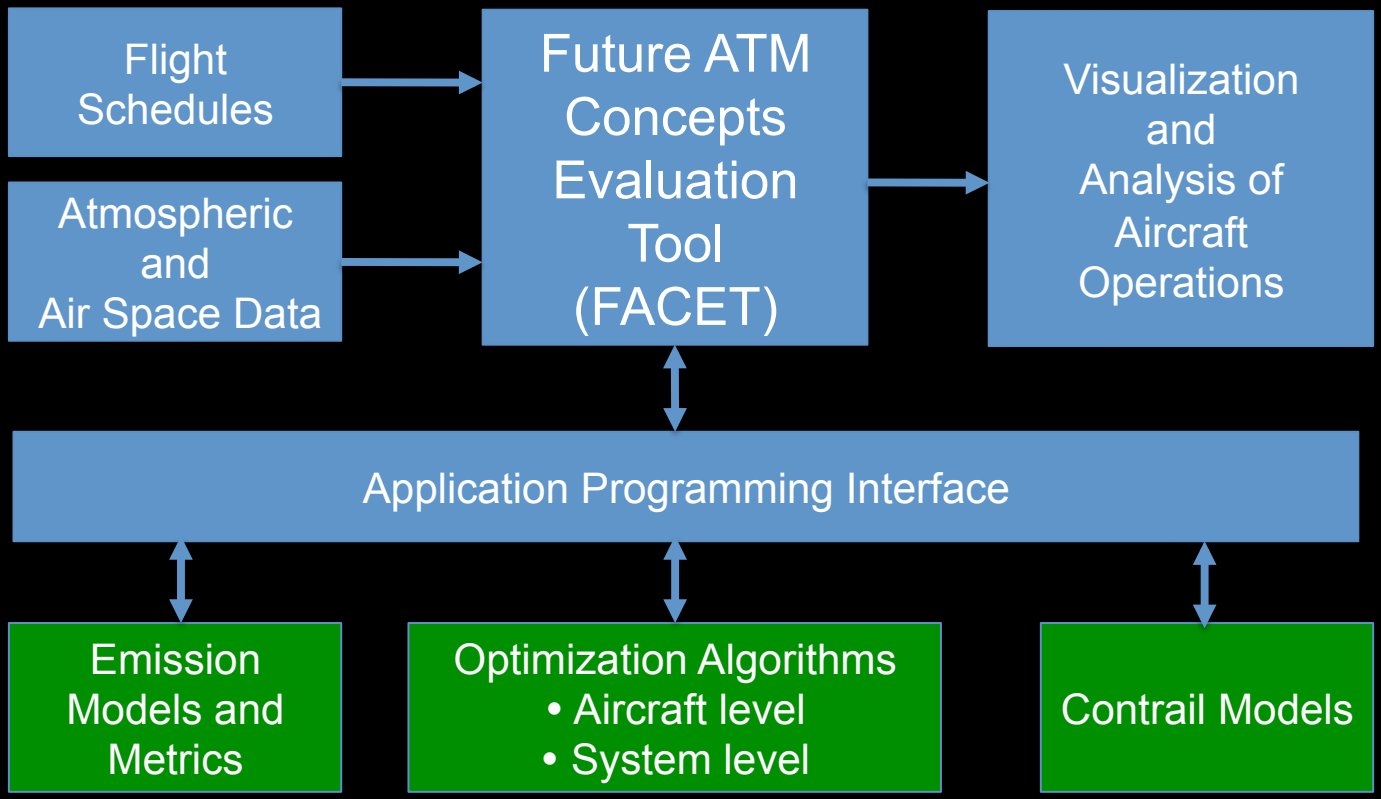
- Challenges
  - Understand the complex relationships between aircraft noise, emissions and fuel burn
  - Optimize aircraft noise, fuel efficiency and emission reductions using advanced technology, operational procedure and computational models
- Goals
  - Enable significant increases in the energy efficiency
  - Decrease the environmental impact

* National Aeronautics Research and Development Plan (February 2010)

Goals of Current Research

- Develop en route traffic flow concepts to reduce the environmental impact of aviation based on advances in fundamental research to understand the physics and chemistry in the Upper Troposphere / Lower Stratosphere region
  - Contrails and Cirrus
    - Regional models for contrail formation using weather forecast data
    - Routings to avoid regions with special chemistry (supersaturated air, cirrus, or polar)
  - Trade-offs amongst Emissions Impacting Climate
    - Flight altitude effects (effects on ozone and contrail formation)
    - NO_x reduction technology versus fuel efficiency (effects on CO_2)
    - Changing global distribution of aircraft fleet
    - Impact of night and day operations

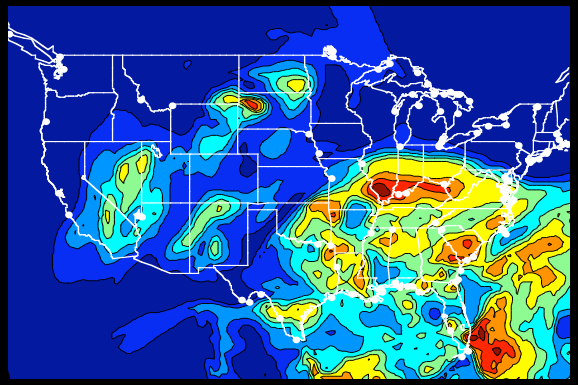
Trajectory simulation interaction with other modules



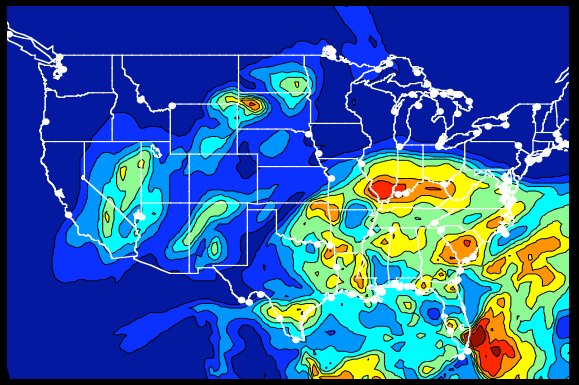
Contrails

- Occur if ambient temperature 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

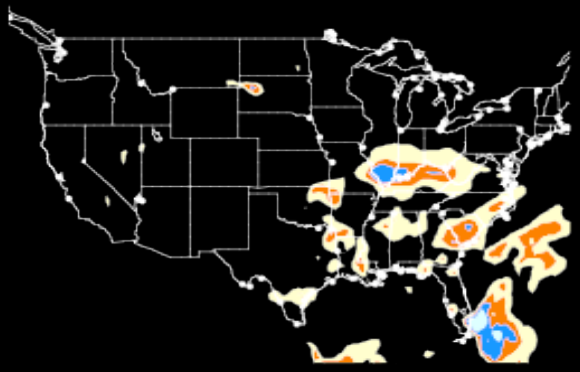
Persistent Contrail Formation Model



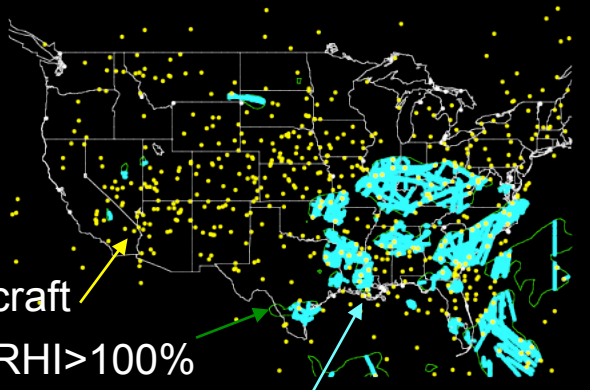
RHW Contours



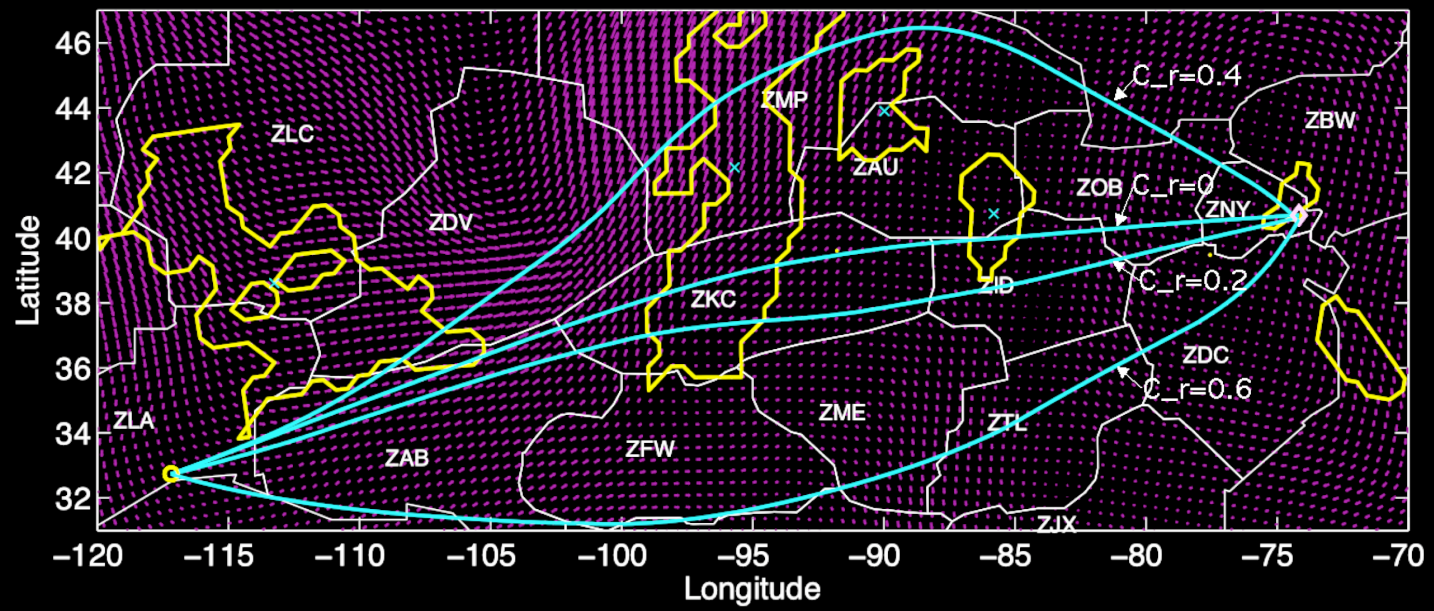
RHI Contours



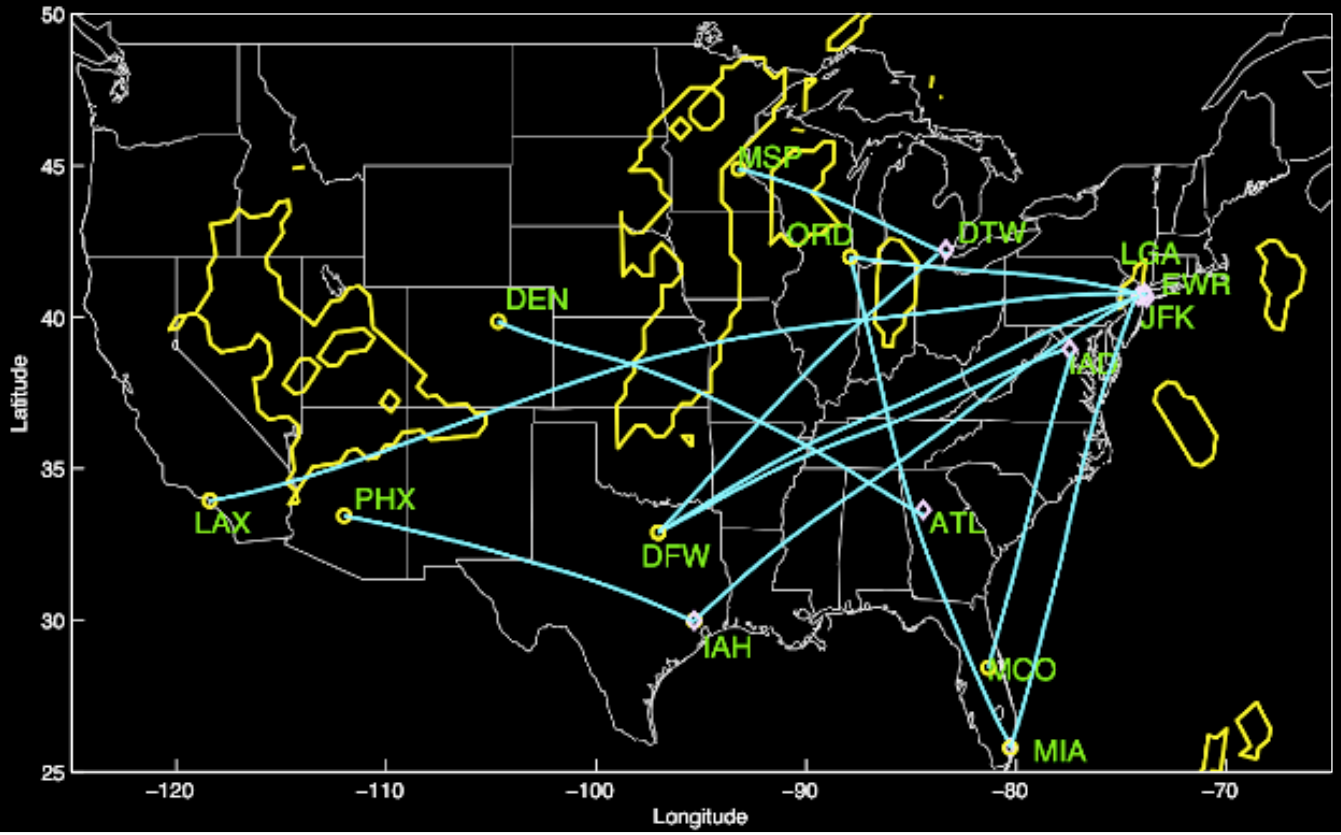
RHI>100% Contours



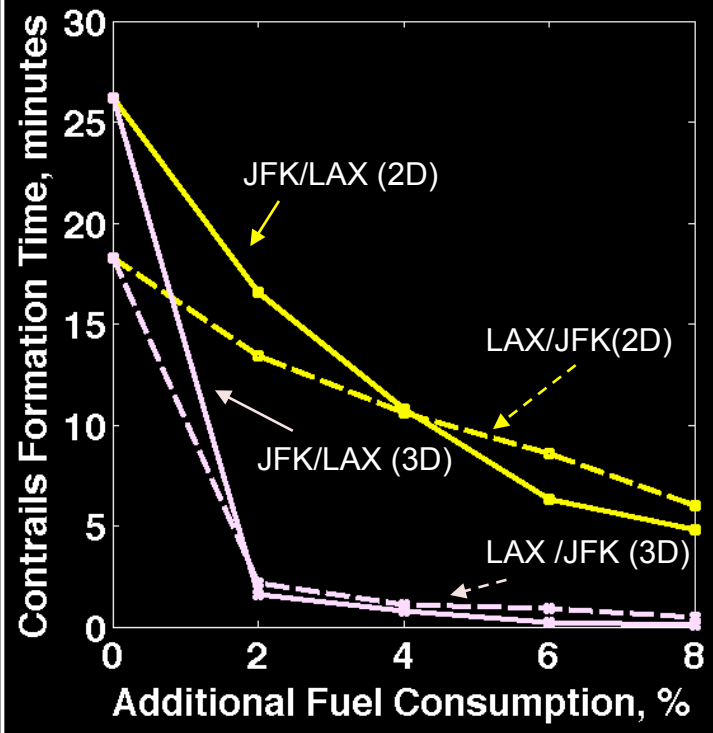
Contrail Reduction Aircraft Trajectories

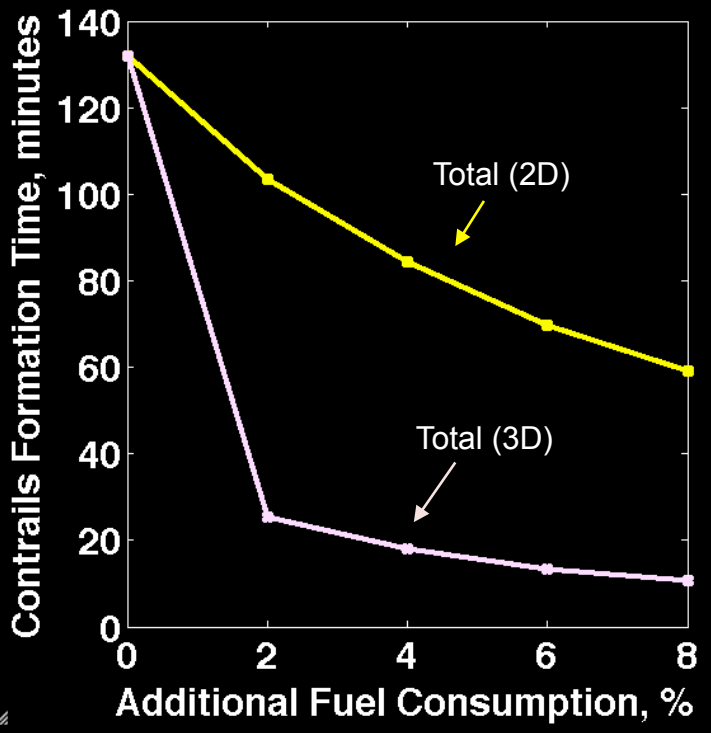


Travel between 12 City-pairs



Results for 12 City-pairs





Concluding Remarks

- Presented research on environmentally friendly en route traffic flow concepts incorporating models developed by basic climate research
- Integrated fuel flow and emissions model with FACET
  - Verified it against BADA and AEDT models
  - Ability to conduct system level analysis of Traffic Flow Management concepts with minimal environmental impact
- Developed an optimal contrail reduction trajectory concept
  - Presented initial results on the tradeoff between avoiding contrails versus extra fuel consumption

Additional Viewgraphs

Strategies for Avoiding Contrails

- Tactical
  - Requires pathfinder aircraft or 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)