the VOLPE center

Assessing Fuel Burn and Emissions Reductions of RVSM

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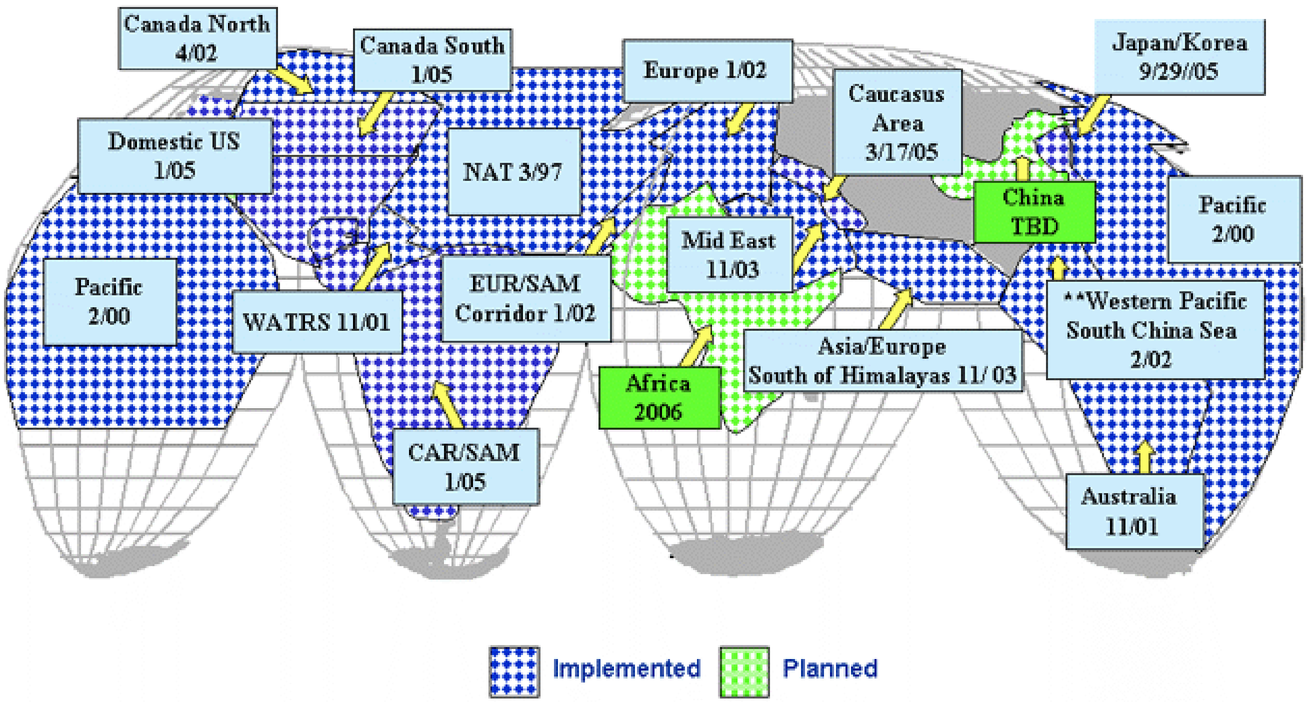
Motivation

- In 2005 FAA implemented the Reduced Vertical Separation Minimum (RVSM) for domestic operations
  - Increased number of available cruising altitudes
  - Allows more optimal flight profiles
  - Reduced fuel burn and costs

- Two prior studies (FAA-ATO and EUROCONTROL)
  - Used BADA aircraft performance models lacking appropriate altitude dependence
    - Small increase in average altitude: 400 ft
    - Small fuel burn benefits: 17-35 kg/flight
    - Small emissions benefits: 0.7%-1% NOx reduction

Motivation (cont.)



Objectives

- Investigate US-Domestic implementation of RVSM in January 2005
- Reduce uncertainties in BADA to measure small differences associated with RVSM
  - Inclusion of meteorological data
  - Inclusion of Altitude-Specific Specific Fuel Consumption (SFC) equation derived from Computer Flight Data Recorder (CFDR) analysis
  - Implemented within research version of FAA's Aviation Environmental Design Tool's System for assessing Aviation's Global Emissions (AEDT/SAGE)

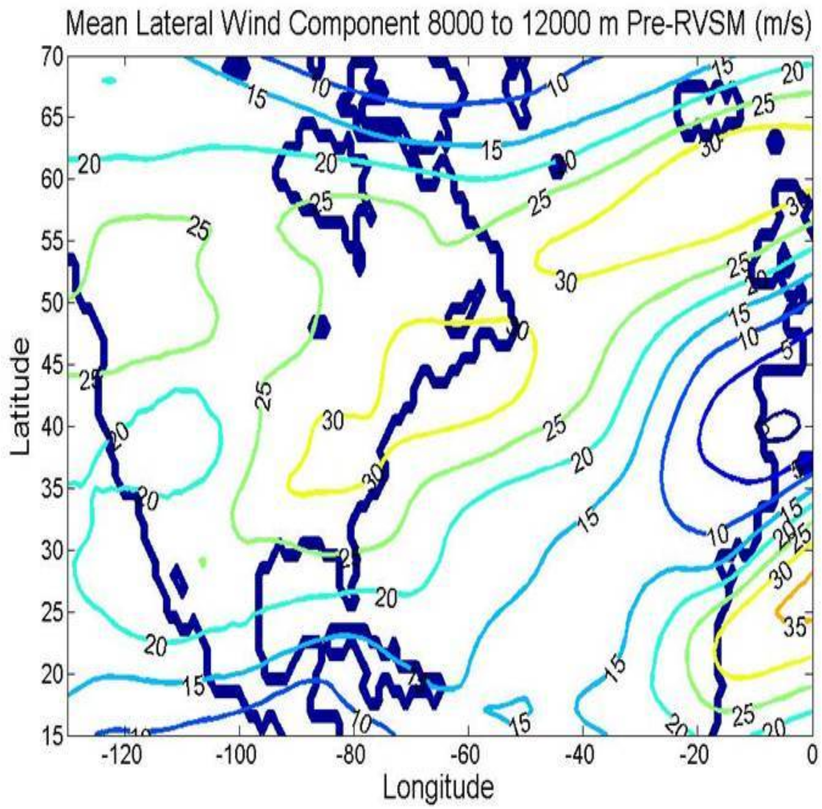
Available Flight Data

- Enhanced Traffic Management System (ETMS) utilized as source of schedule and radar (trajectory) data
  - One month prior
    1. 11/14/2004-11/20/2004
    2. 12/05/2004-12/18/2004
    3. 1/9/2005-1/15/2005
  - One month post
    1. 2/13/2005-3/12/2005
- Nearly 220,000 flights matched between Pre-RVSM and Post-RVSM for:
  - O/D pair
  - Aircraft type

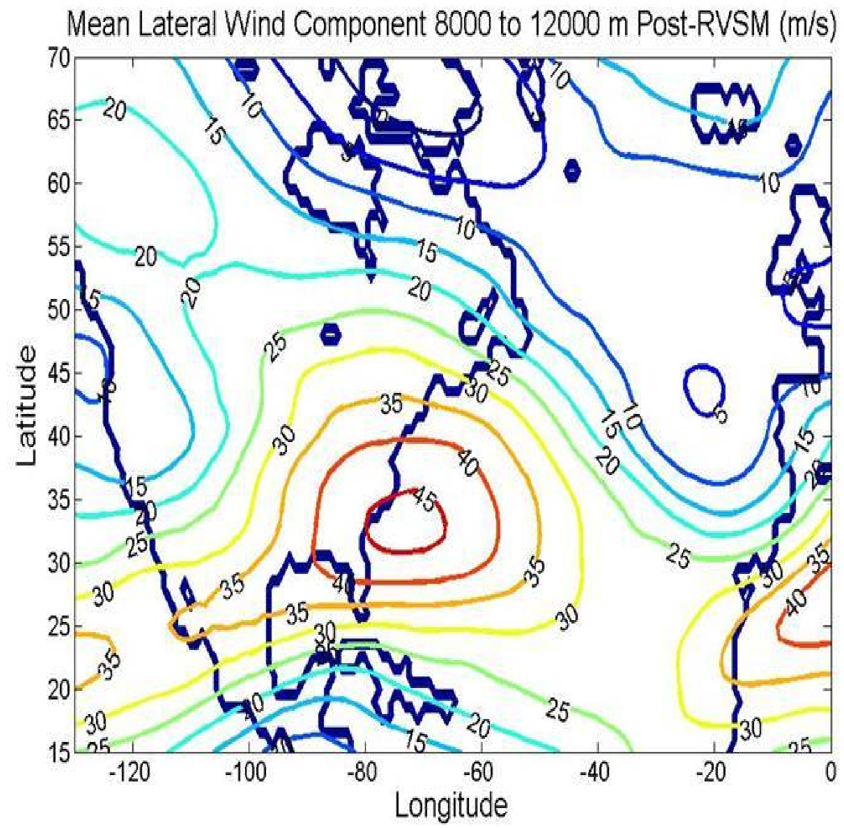
Meteorological Data

- Source: NASA Goddard
  - http://gmao.gsfc.nasa.gov/index.php
- Available Data: temperature, pressure, wind speed and direction
- Coverage: global, 1 x 1.25 degree grid, 6-hour frequency

Meteorological Data (cont.)



Pre-RVSM



Post-RVSM

BADA SFC Equation

BADA SFC Equation:

$$SFC = \frac{C_{f1}}{60000}\left(1 + \frac{1.9438V}{C_{f2}}\right)C_{fcr}$$

Where:

- V : Velocity
- *Cf*1, *Cf*2, and *Cf*cr: unique constants for each aircraft

Need to account for:

- Changes in meteorological conditions from sea level
    1. Temperature
    2. Pressure
- Changes in aircraft SFC with cruise altitude

CFDR Analysis

- Analyze 2500+ flights CFDR data to develop SFC equation
  - CFDR data includes: A319, A320, A321, A330, A340, B757, B767, B777, and AVRO RJX85
- Use statistical regression analysis to develop:
  - Aircraft-Specific SFC equation (for aircraft present in CFDR data)
  - Generic SFC equation (for other BADA aircraft types)

Derived SFC Equation

Derived SFC equation:

$$\frac{SFC}{\sqrt{\theta}} = \alpha + \beta_1 M + \beta_2 e^{-\beta_3 \left(\frac{\tau}{\delta^{\beta_4}} \right)^{\beta_5}}$$

Where:

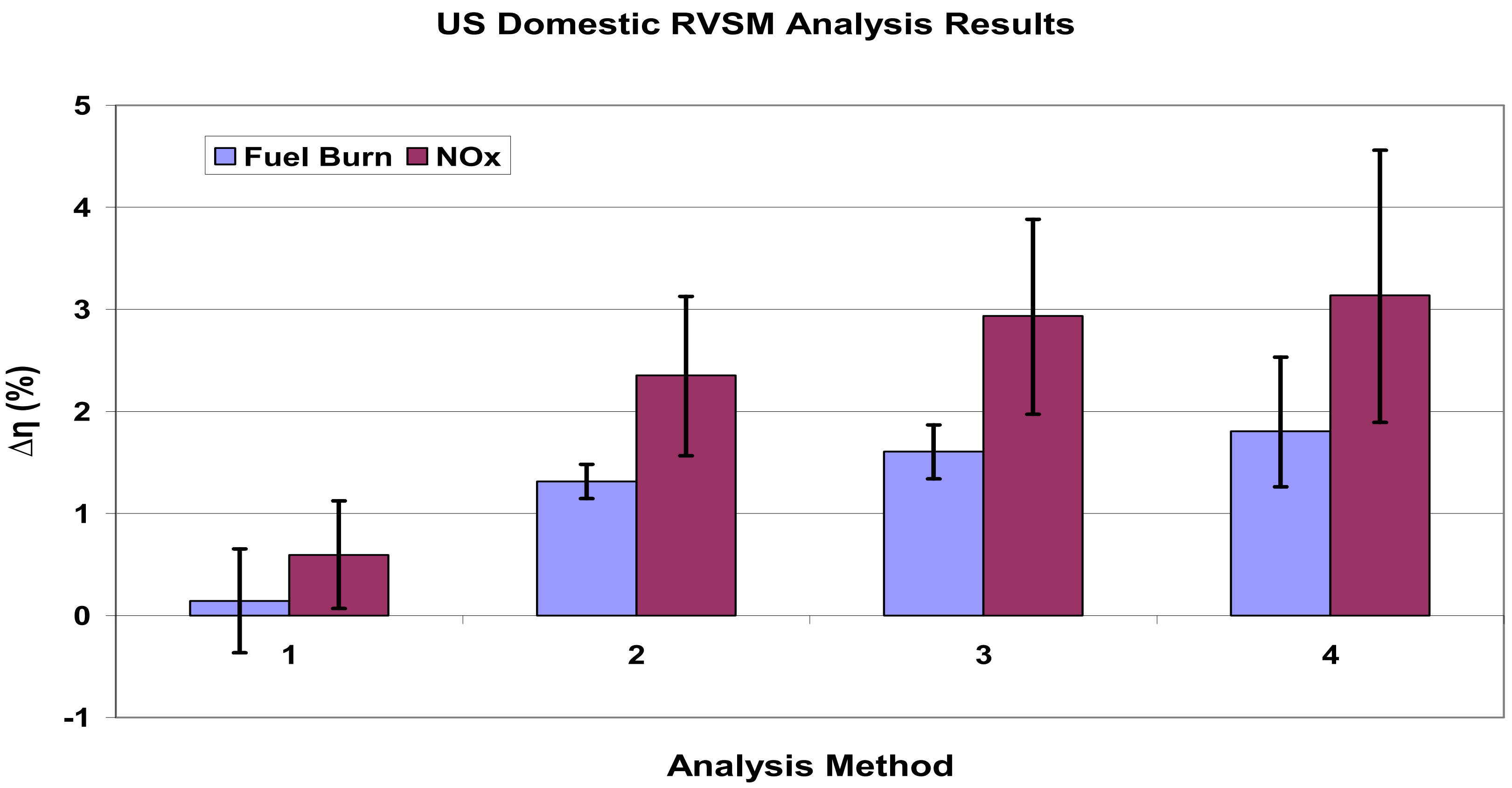
- , $_1$, $_2$, $_3$: statistically derived constants for each specific aircraft (generic values used for other)
- : temperature ratio with respect to sea level
- : pressure ratio with respect to sea level
- thrust ratio with respect to sea level

Analysis Methods

Four scenarios investigated to demonstrate the impact of meteorological data and derived SFC equation

1. BADA only
2. BADA with meteorological data
3. BADA with meteorological data and derived SFC equation
4. BADA with meteorological and derived SFC equation; efficiency measured as air distance traveled

Results


US Domestic RVSM Analysis Results
Fuel Burn
NOx
5
4
3
2
1
0
-1
Δη (%)
1
2
3
4
Analysis Method

Conclusion

- RVSM improves fuel burn and NOx efficiencies
  - 1.8% benefit for fuel burn
  - 3.1% benefit for NOx
- Inclusion of meteorological data most crucial in assessing RVSM; derived SFC equation also demonstrates small benefit