The Effects of Cross-Polar Flights on Arctic Black Carbon and Climate

Mark Z. Jacobson, Stanford University

Black Carbon Webinar II: Arctic Black Carbon Science Activities

April 18, 2014
Primary Contributors to Net Observed Global Warming

- Greenhouse gases
- Fossil-fuel + biofuel + soot particles
- Urban heat island
- Cooling particles
- Net observed global warming
Data vs. Modeled Temperature Anomaly

GISS: 2010-2013 minus 1951-1980

Model: 2013 minus 1850

GISS: 2010-2013 minus 1900-1930
Rerouting Aircraft

Reroute flights >500 mi, >50 seats, and with both origin and destination airports below Arctic Circle.

Number of cross-polar flights 2004-2010

Jacobson et al. (2012)
Annual, Zonal Static Stability and Aviation Emissions in Tropopause-Relative Coordinates

\[ z_{TR}(t) = z_{MS}(t) + z_{TH\text{Mean}} - z_{TH}(t) \] (Whitt et al., 2011)

74% of emissions above Arctic Circle are in stratosphere
47% of emissions 40-90 N are in stratosphere
24% of global emissions are in strat (33% Jan, 13% Jul)
34% of global emissions in regions of high static stability
Rerouting Cross-Arctic Flights

2006 Baseline Inventory

2006 Rerouting Inventory

Jacobson et al. (2012)
Rerouting One Flight (Frankfurt to Anchorage)
Subgrid Plume Model vs. LES

Subgrid Plume Model
Plume cross-section

Large Eddy Simulation (LES)
Contours of exhaust concentration

Naiman et al. (2010)
Contrails form primarily over mid latitudes and in the upper troposphere. Some form over North Pole (Jacobson et al., 2011)
Global Modeled Temperature Change Due to Rerouting Arctic Flights

Rerouting may reduce loss of Arctic ice and cool global temperatures on average at low cost relative to benefit.

Jacobson et al. (2012)
Summary of Rerouting

Increases fuel use by 0.056%; distance by +0.026%
Reduces fuel use in Arctic Circle by 83%
Baseline cost of jet fuel worldwide: $122 billion/yr
Added costs due to rerouting: +$99 mil/yr (68 fuel +31 operational)
Estimated global warming cost to U.S. in 2025: $271 billion/yr (severe weather, real estate, energy, water)
Reduction global warming by rerouting 1.7-2% →
Reduce costs to U.S. of $4.7-5.4 billion/yr = 47-55 times world cost of rerouting.