

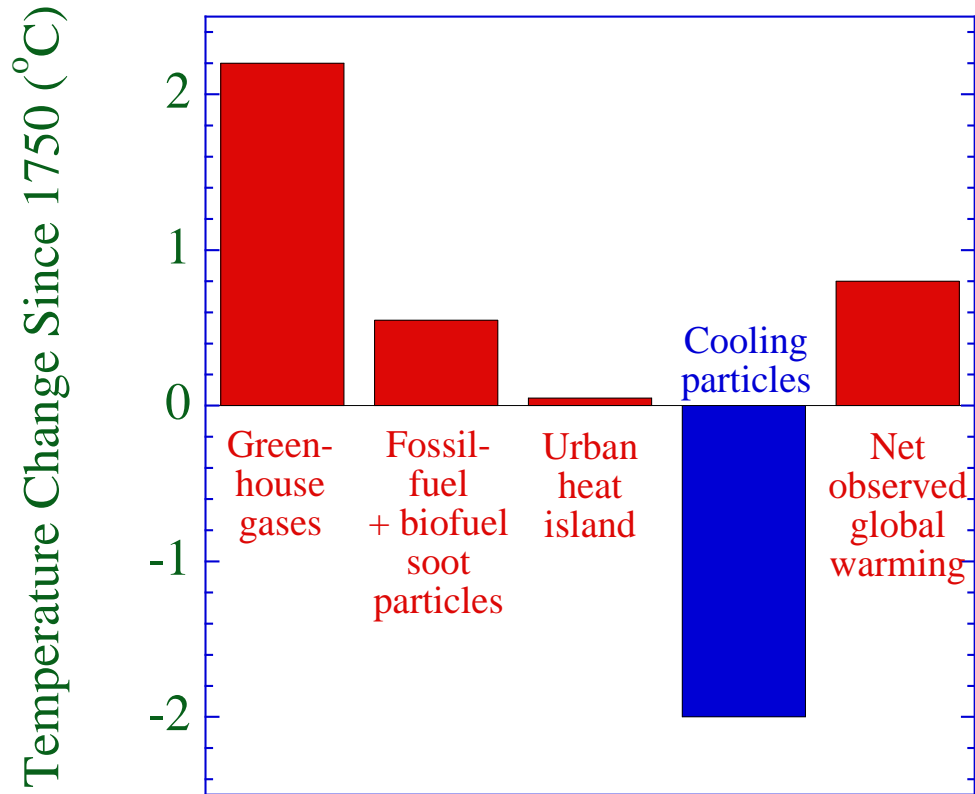
The Effects of Cross-Polar Flights on Arctic Black Carbon and Climate

Mark Z. Jacobson, Stanford University

**Black Carbon Webinar II: Arctic Black Carbon Science
Activities**

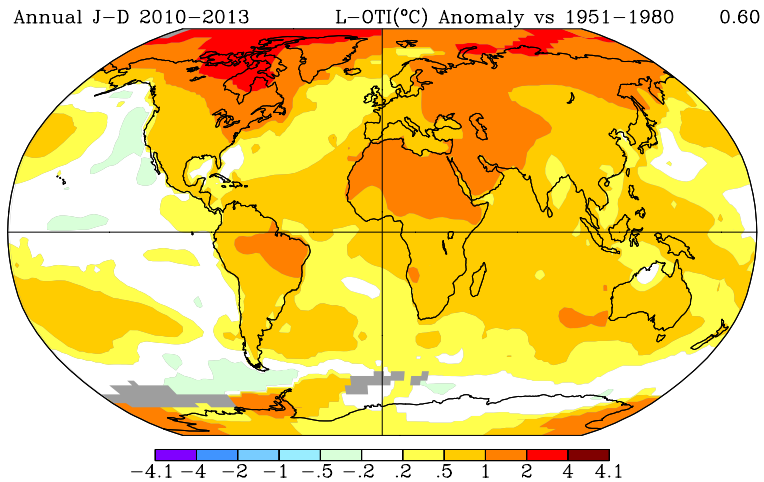
April 18, 2014

Primary Contributors to Net Observed Global Warming

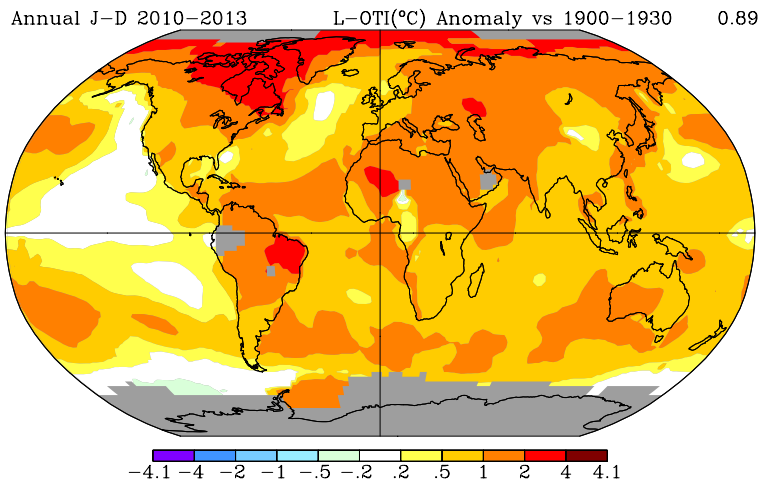
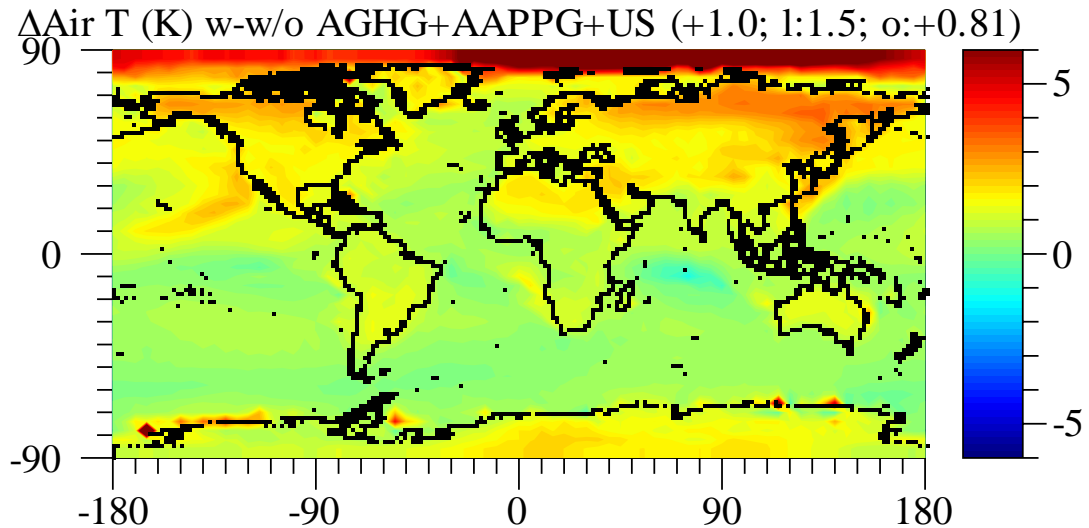


Data vs. Modeled Temperature Anomaly

GISS: 2010-2013 minus 1951-1980



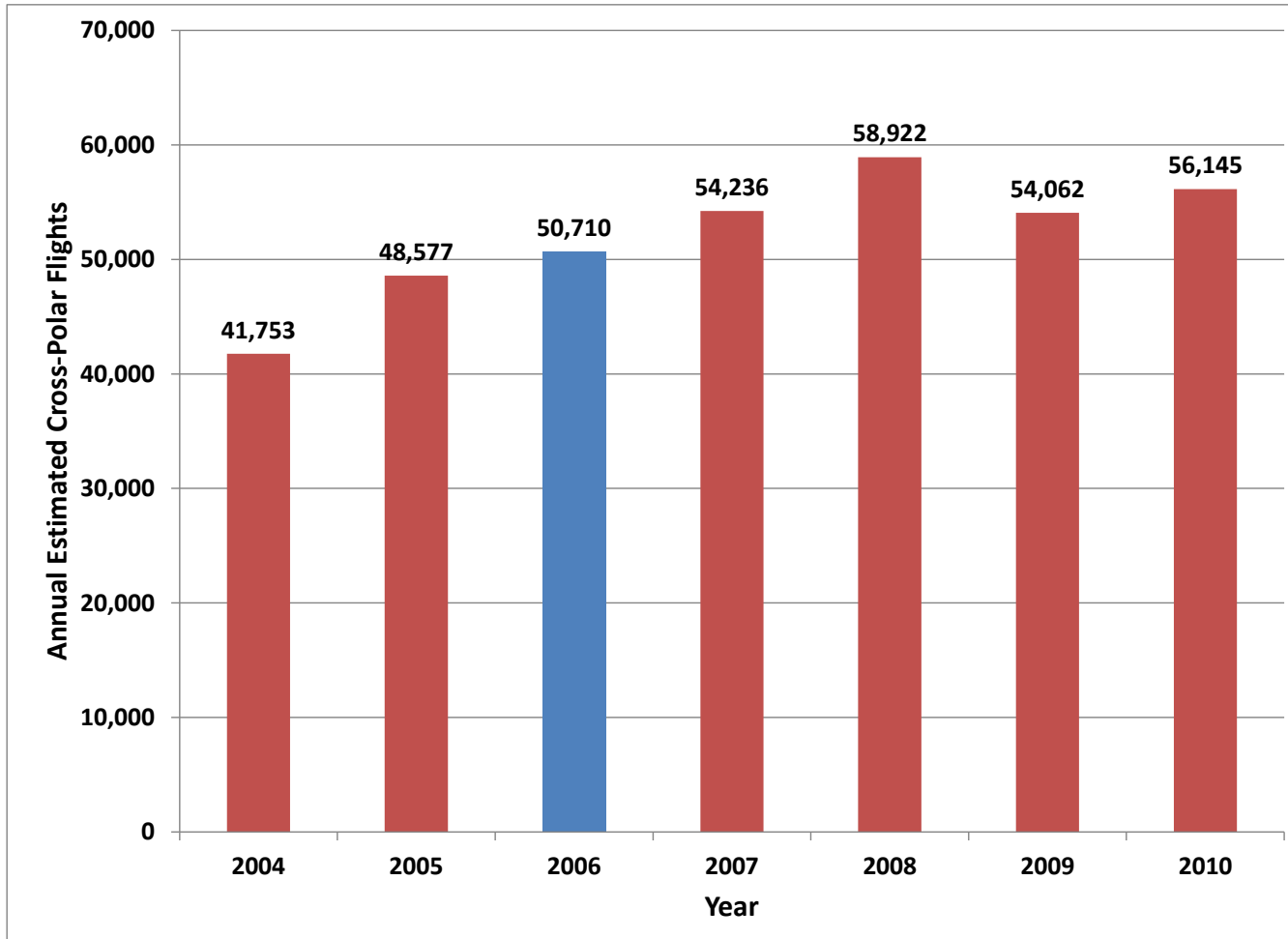
Model: 2013 minus 1850



GISS: 2010-2013 minus 1900-1930

Rerouting Aircraft

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

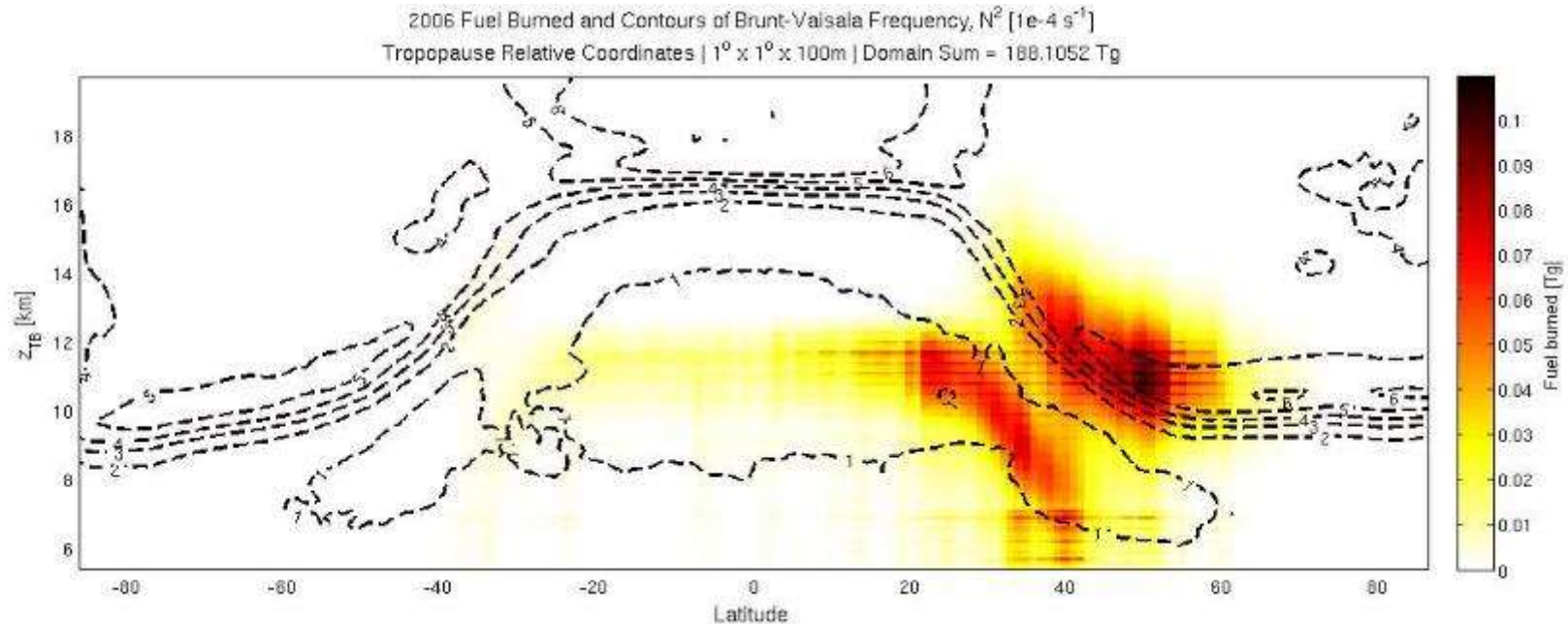


Number of cross-polar flights 2004-2010

Jacobson et al. (2012)

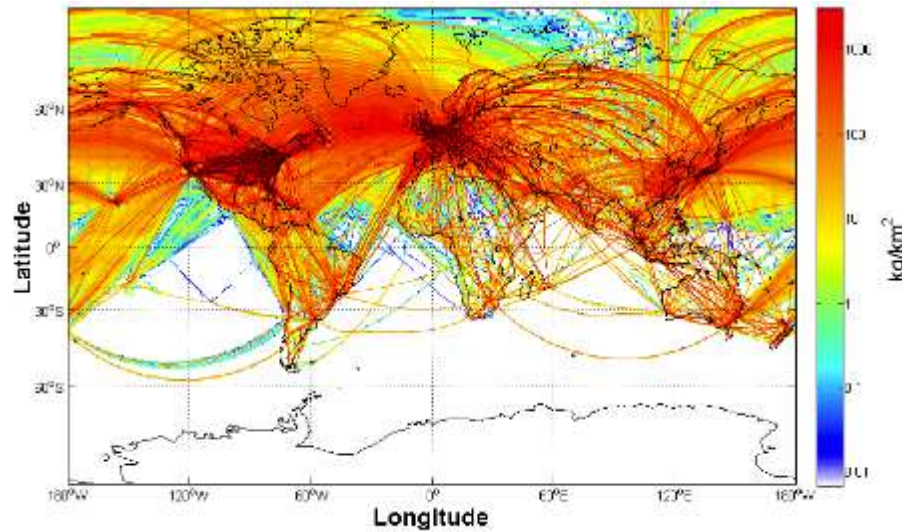
Annual, Zonal Static Stability and Aviation Emissions in Tropopause-Relative Coordinates

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

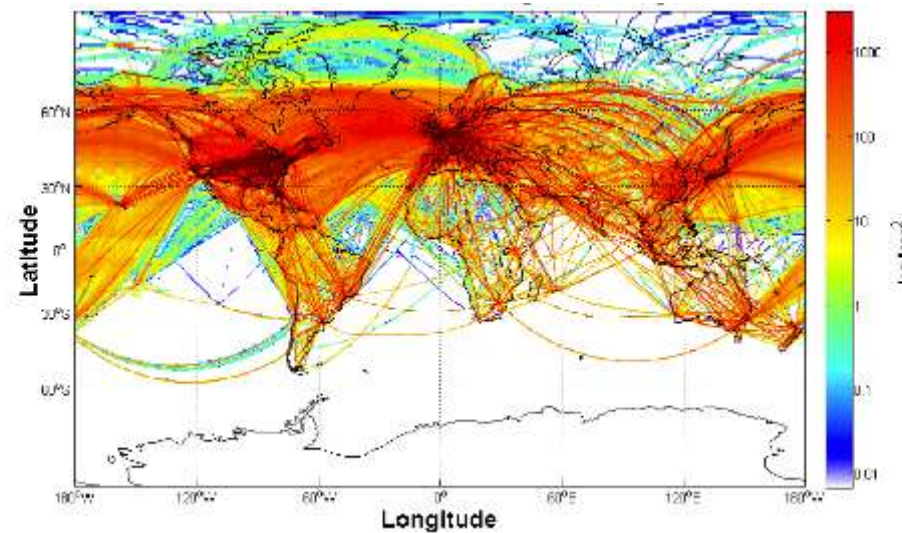


- 74% of emissions above Arctic Circle are in stratosphere
- 47% of emissions 40-90 N are in stratosphere
- 24% of global emissions are in strat (33% Jan, 13% Jul)
- 34% of global emissions in regions of high static stability

Rerouting Cross-Arctic Flights



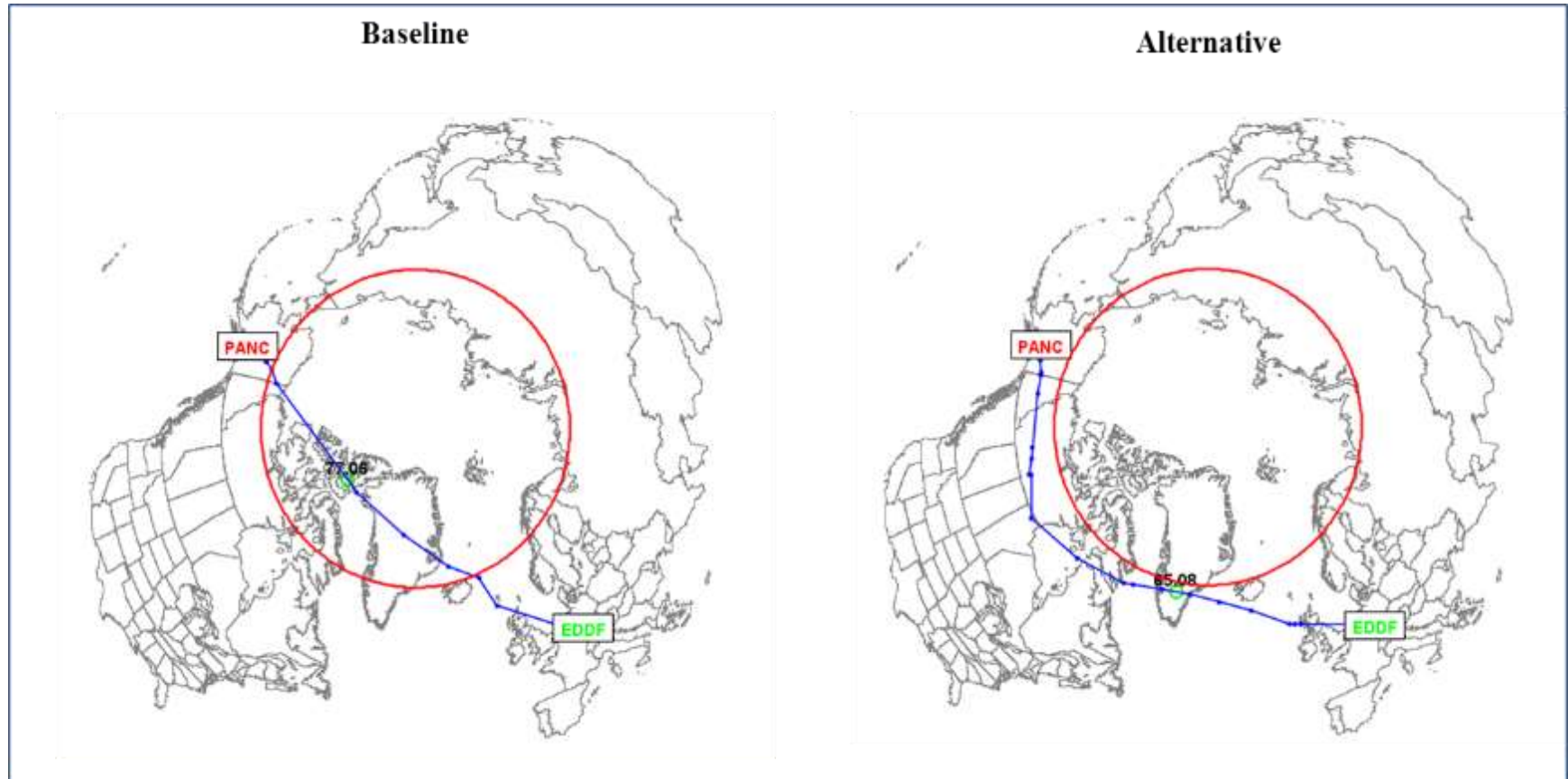
2006
Baseline
Inventory



2006
Rerouting
Inventory

Jacobson et al. (2012)

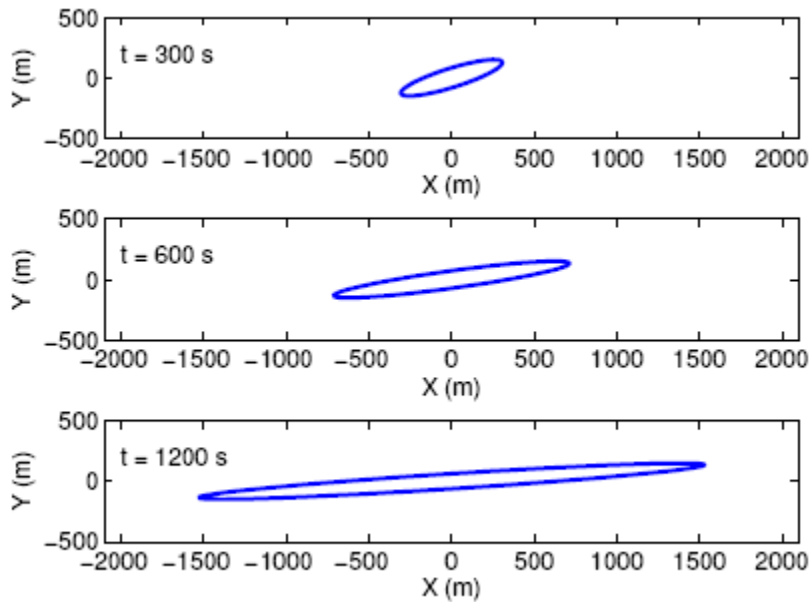
Rerouting One Flight (Frankfurt to Anchorage)



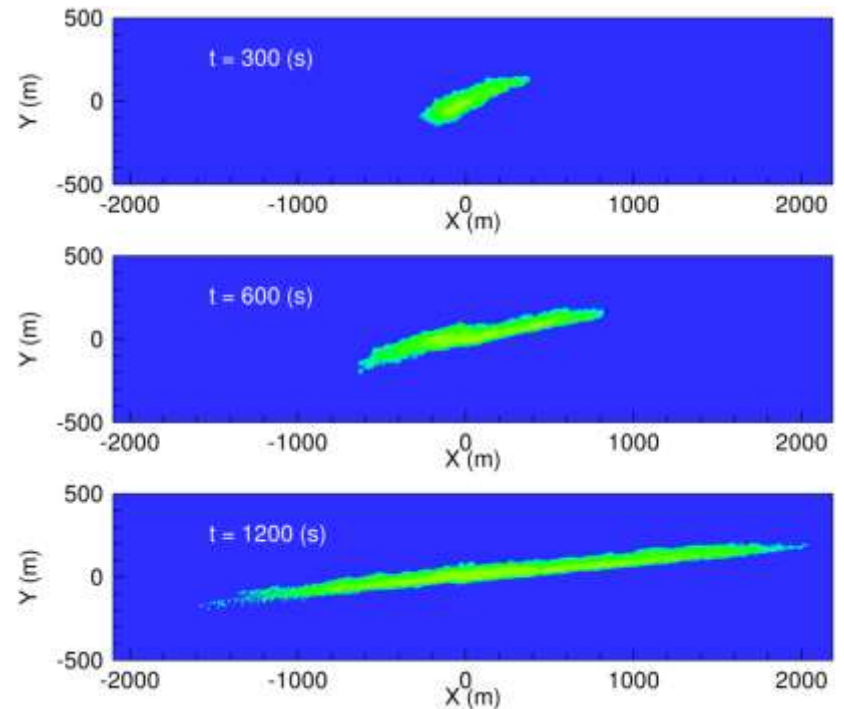
Cooper et al. (2011)

Subgrid Plume Model vs. LES

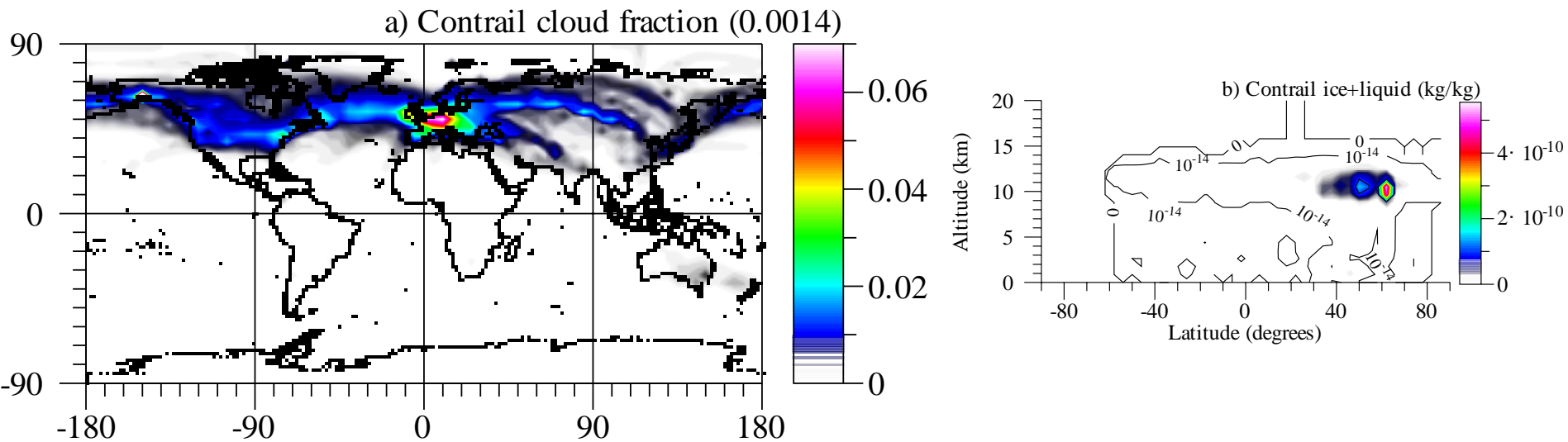
Subgrid Plume Model Plume cross-section



Large Eddy Simulation (LES) Contours of exhaust concentration

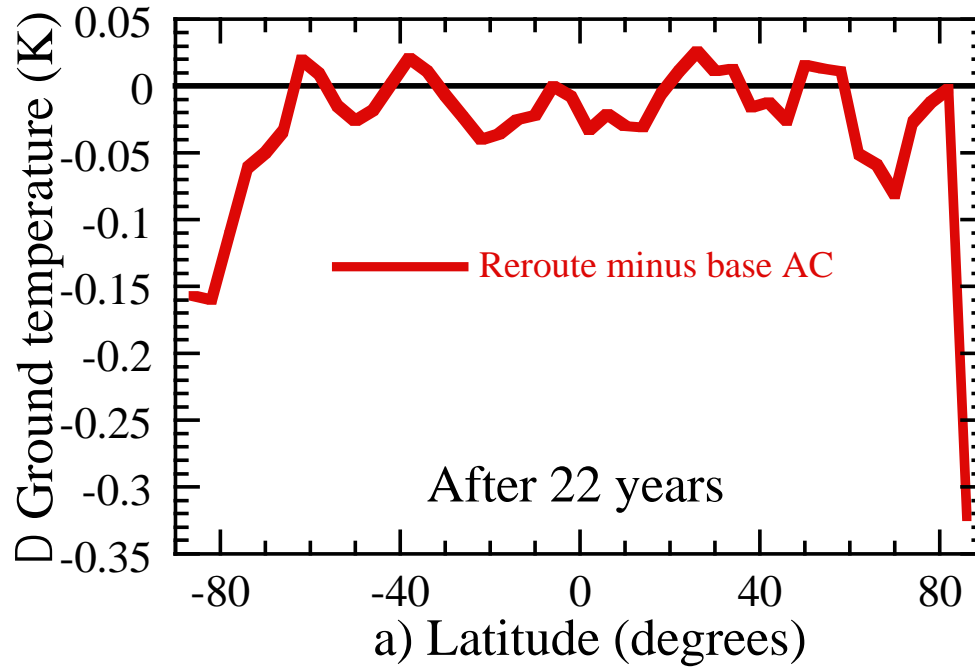


GATOR-GCMOM Contrail Cloud Fraction Treating Subgrid Contrails



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

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.