

Aerosol Emissions from Commercial Shipping

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OUTLINE

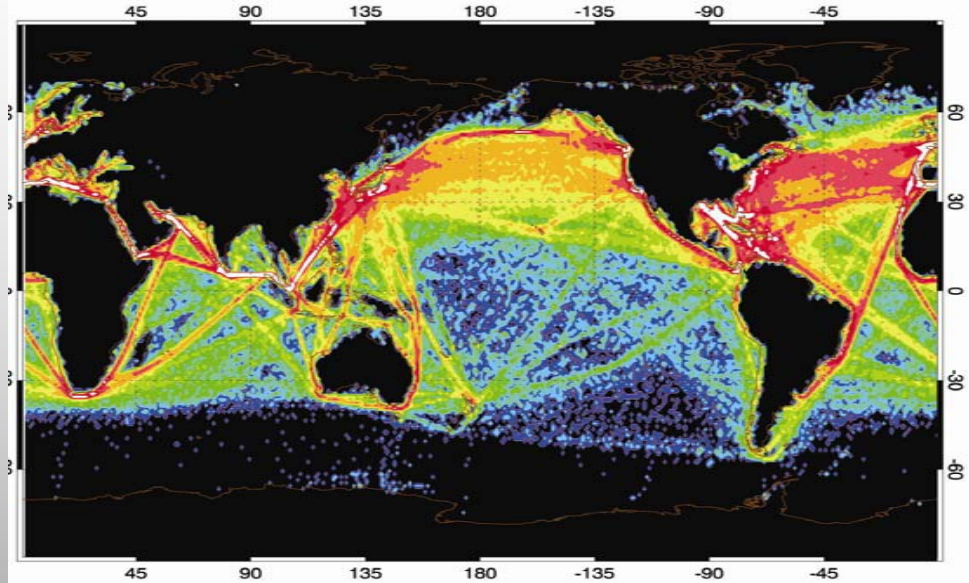
Contribution of shipping emissions.

GoMACCS 2006 - Measurements and Results.

Climate impacts of light absorbing carbon from shipping.

Shipping

Global / regional / local

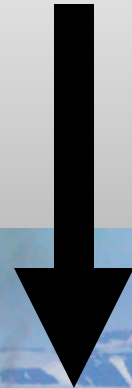
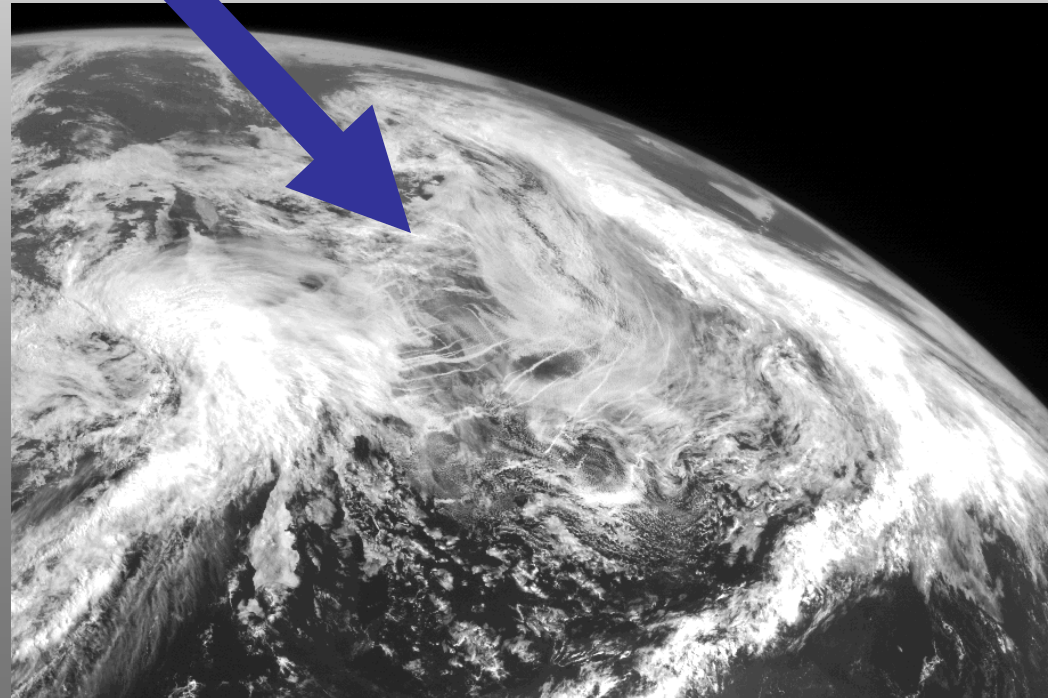
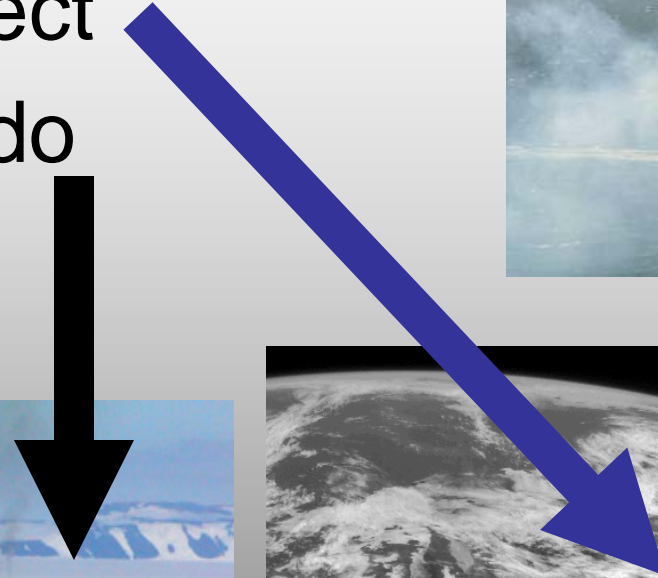


- Reason for concern?
 - Burn low quality residual fuels.
 - Little or no regulation.
 - Pollution contributions are large.



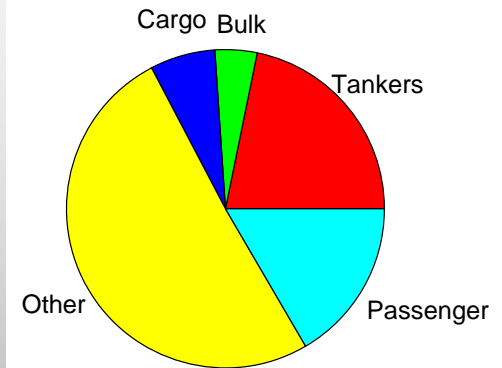
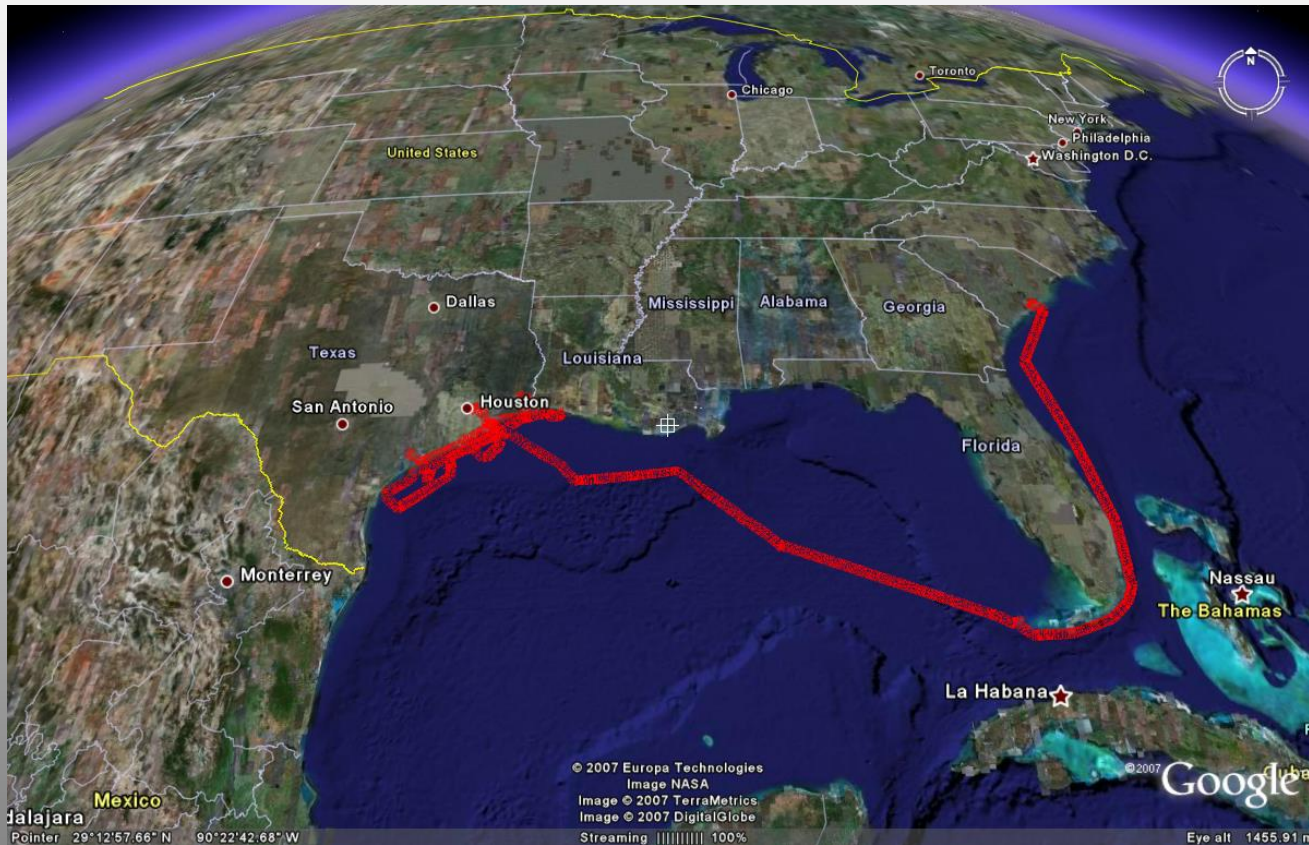
Climate Effects of Shipping

- Direct Effect
- Indirect Effect
- Snow Albedo

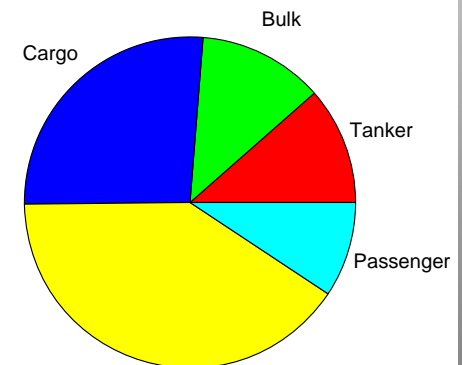


GoMACCS 2006

Over 1100 vessels encountered.



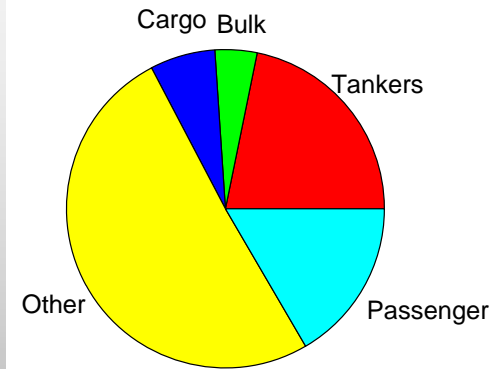
Total: 211



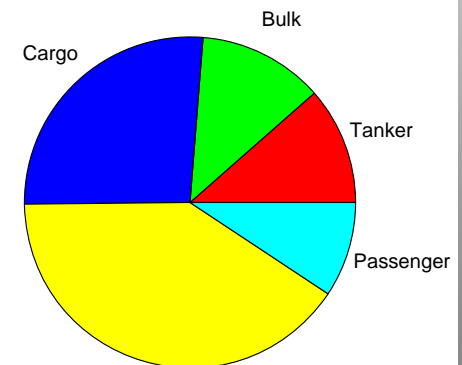
Total: 108,306 (Source: Corbett and Koehler, 2003)

GoMACCS 2006

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Total: 211



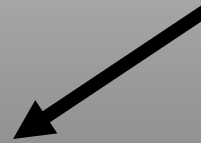
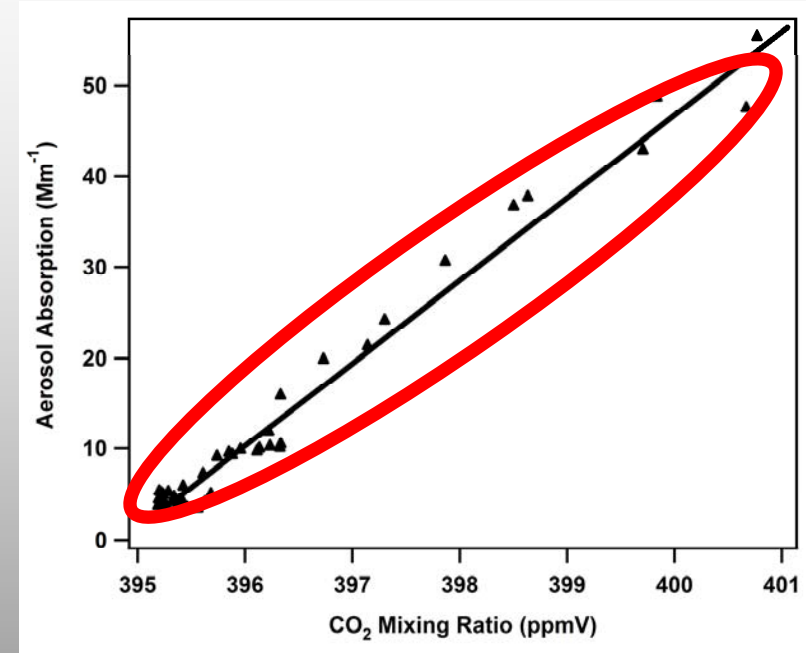
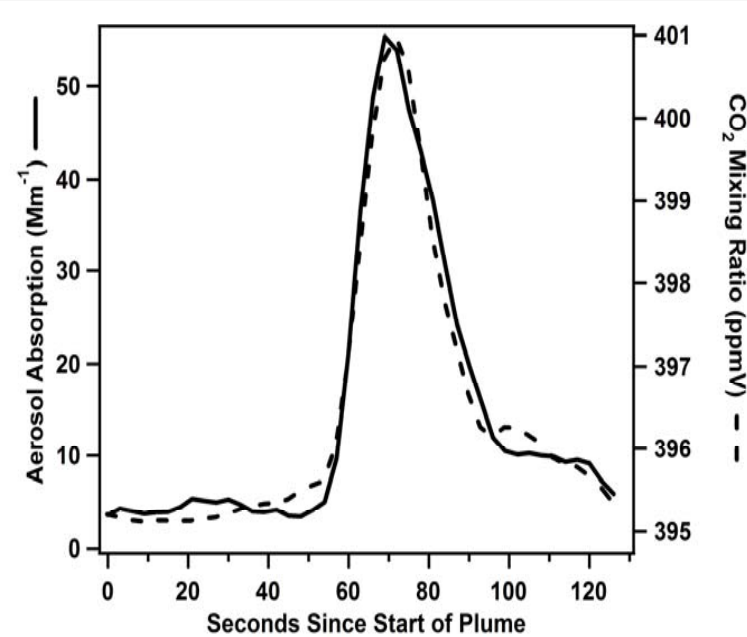
Total: 108,306 (Source: Corbett and Koehler, 2003)

Types of Emissions

- Chemical Properties
 - Sulfate, nitrate, ammonium, organic, light absorbing carbon
- Physical Properties
 - Aerosol number concentrations
 - Cloud condensation nuclei
- Optical Properties
 - Extinction @ 3 wavelengths
 - Extinction relative humidity dependence
 - Absorption @ 3 wavelengths
 - Single scatter albedo

Emission Factors

- Quantity of emission per kilogram of fuel burnt.



$$EF(gkg^{-1}) = \frac{\text{Absorption}(Mm^{-1})}{CO_2(ppmV)} \times \frac{1}{MAC} \times f_{fuel}$$

1.62 :

- CO₂ (ppmv) to mass of fuel
- assumes fuel is 86.5% C

7.75 (Bond and Bergstrom, 2006)

Light Absorbing Carbon

- Incomplete combustion.
- Absorbs radiation directly (8000X more absorbing than dust).
- Much less hydrophilic than most aerosol.
- LAC has unique reactive properties in the atmosphere.
- Types of combustion:

LAC Emission Factor

Global LAC Burden



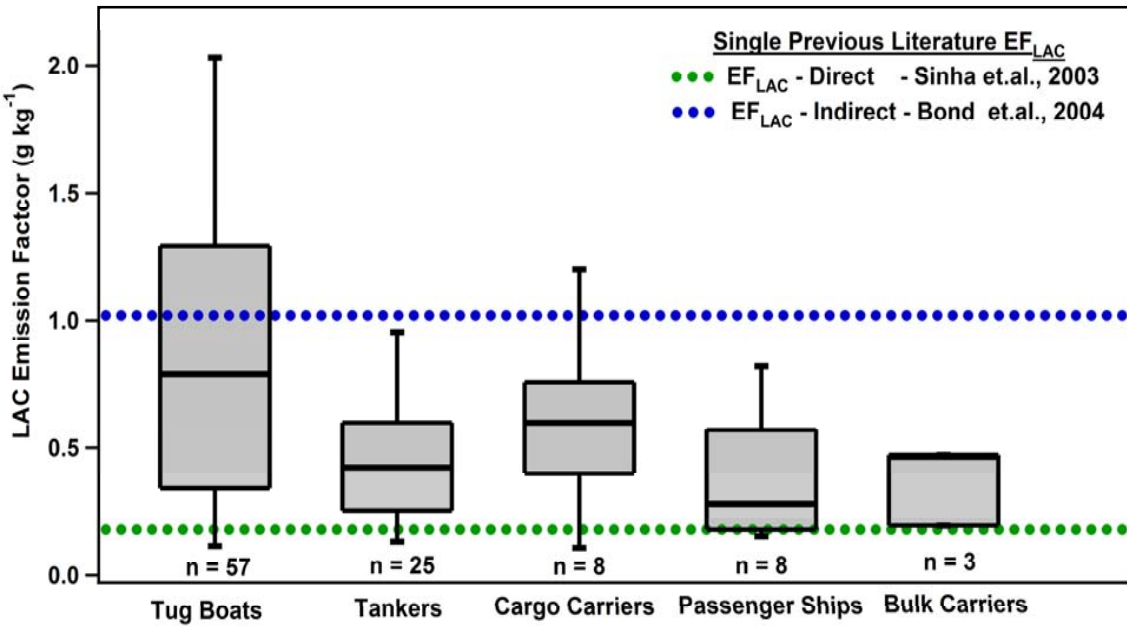
Shipping is a disproportionate contributor to anthropogenic LAC because of the fuel used.



LAC from Ships is very uncertain:

- Global LAC inventory (Bond et al., 2004):
 - $EF_{LAC} = EF_{PM} * X_{LAC} * X_{<1\mu m} = \sim 1 \pm 1 \text{ g kg}^{-1}$
- Two studies (Sinha et al., 2003, Petzold et al., 2007), of 3 ships gave 2 EF_{LAC}
 - $\sim 0.2 \text{ g kg}^{-1}$
- Vessel and fuel type, maintenance, operations all vary.

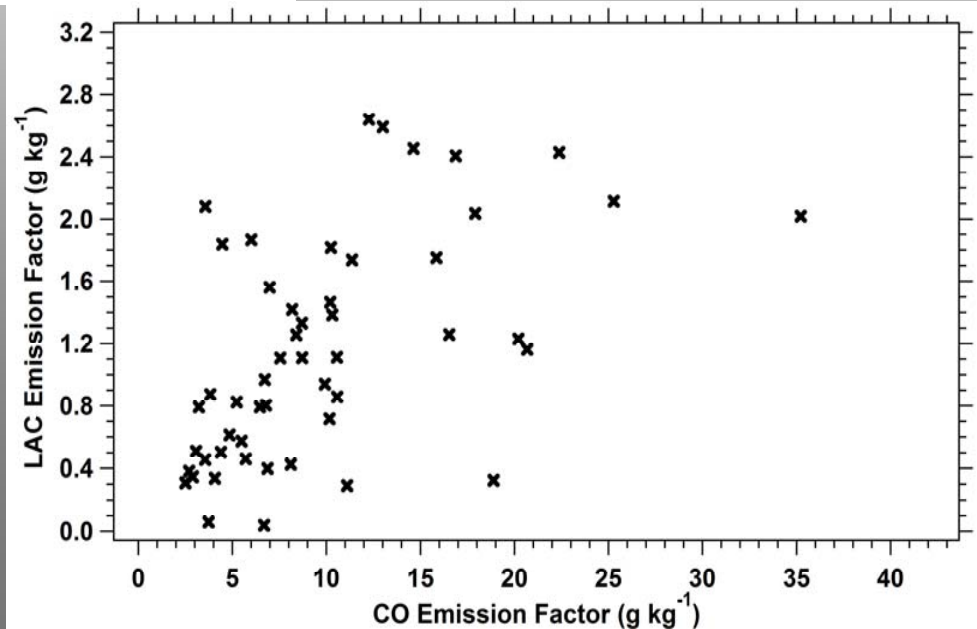
Results



We estimate shipping LAC contributes 133 Gg yr^{-1} (2%).

This compares to 130 Gg yr^{-1} used in 2007 IPCC modeling.

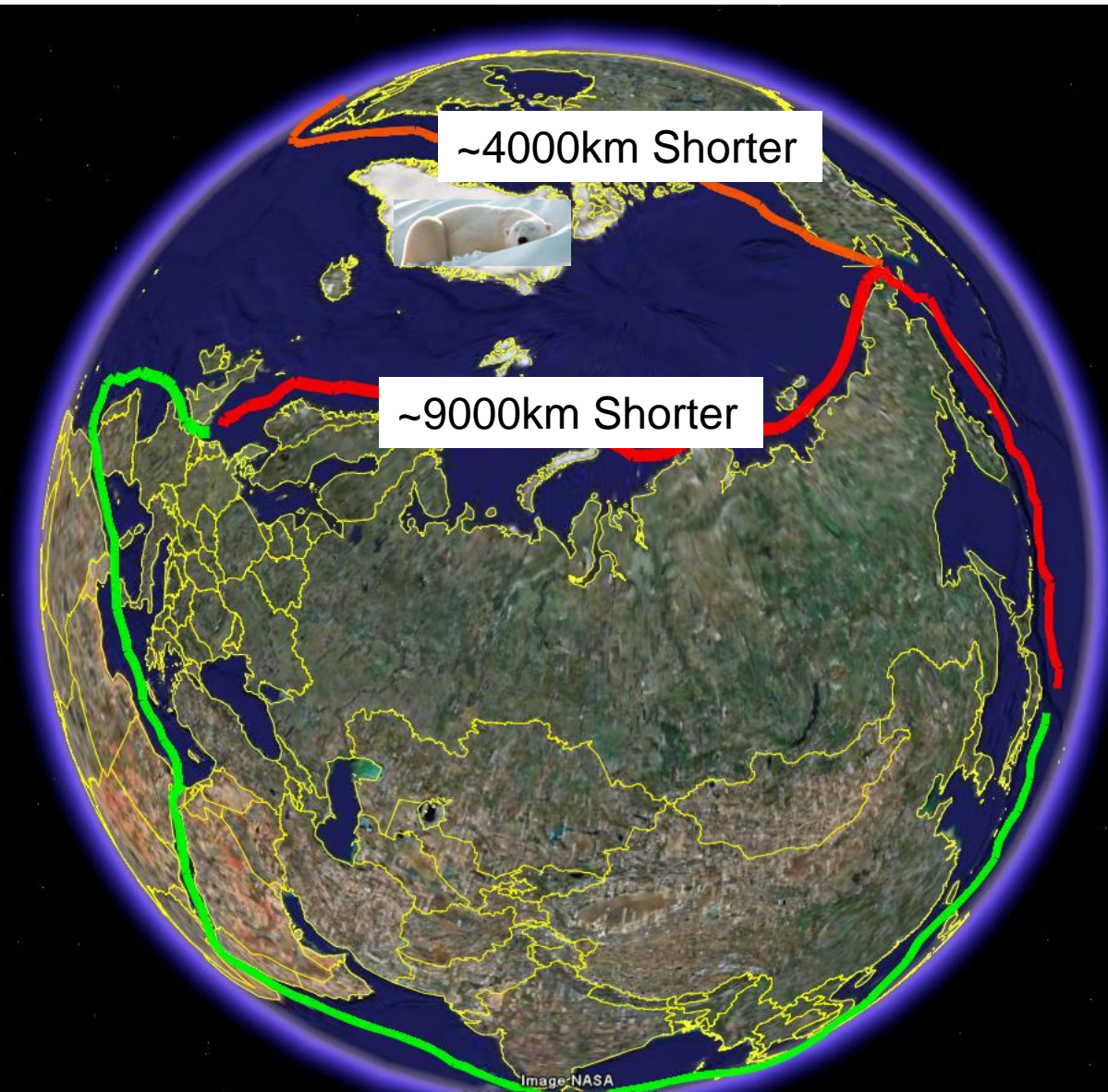
LAC related to CO emissions.



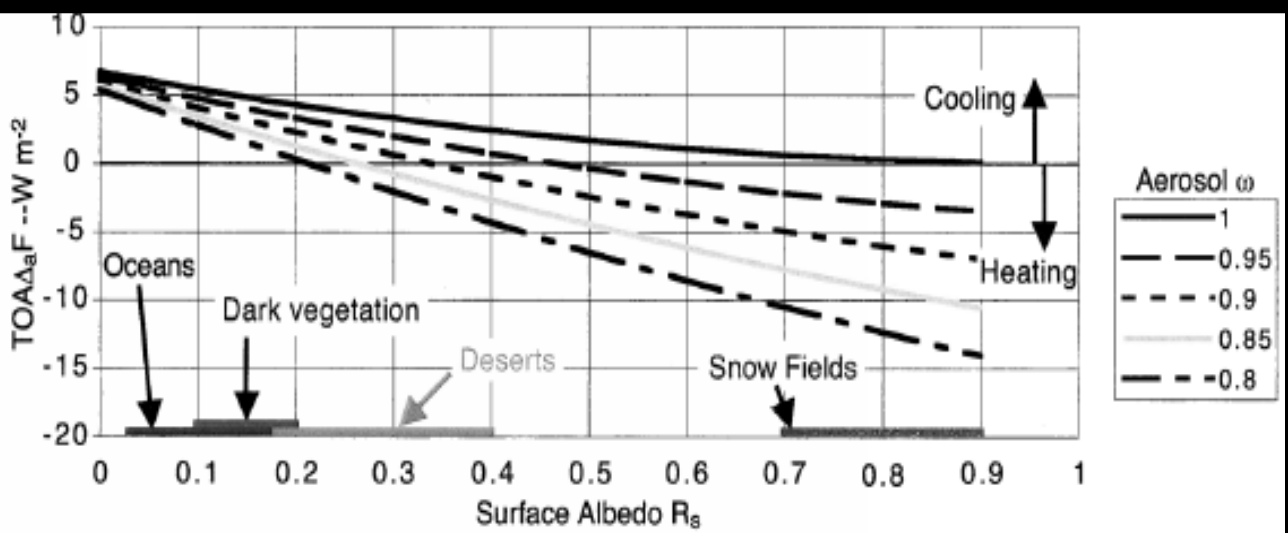
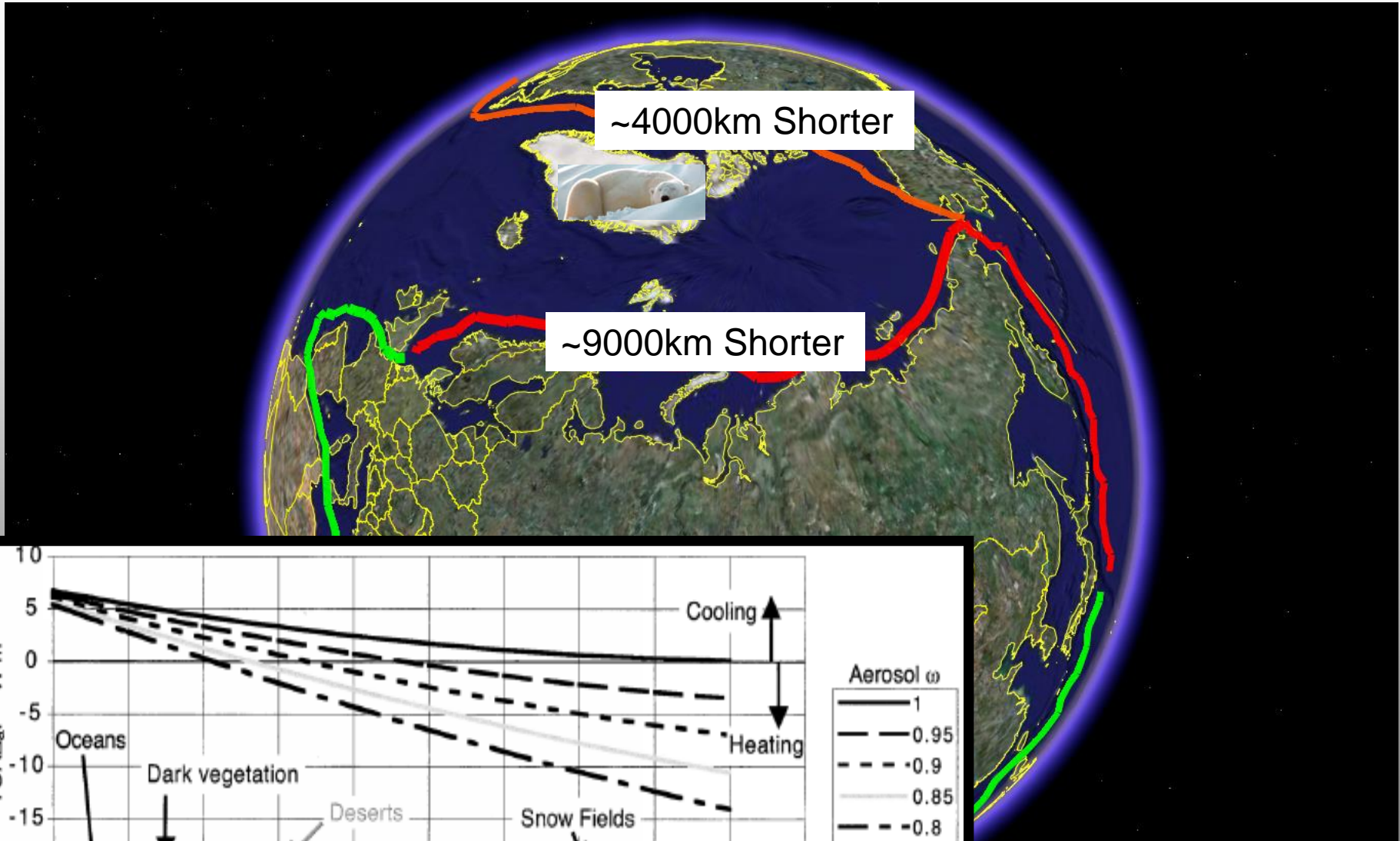
Arctic Climate



Arctic Climate



Arctic Climate



Summary

- GoMACCS study allowed us to measure the aerosol characteristics of emissions from commercial shipping.
- Over 200 unique vessels were sampled representative of the international fleet.
- Confirmed that the annual emission of LAC used in the recent IPCC assessment.
- Tug boats emit 2.5X LAC than most other vessels.
- Robust emission factors will be used in studies of the effect of LAC from shipping in the Arctic.

*Lack, D. A., B. Lerner, C. Granier, T. Baynard, E. Lovejoy, P. Massoli, A.R. Ravishankara, E. Williams (2008), **Light Absorbing Carbon Emissions from Commercial Shipping**, Submitted to Geophysical Research Letters*

Thanks to:

- Crew of the Ronald H Brown.
- Tim Bates, Trish Quinn, Derek Coffman, Dave Covert, Berko Sierau, Chuck Brock, Dan Murphy

