The Effects of Black and Brown Carbon on Clouds and Global Climate

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Important Research Questions

Can controlling black & brown carbon emissions from fossil-fuel sources or all gas and particle emissions from solid biofuel or open biomass burning slow the loss of Arctic sea ice?

What are the impacts of these sources on cloud burnoff versus enhancement?

Soot (BC+POM+SVI) Impacts on Climate

Impacts on clear sky

Soot absorbs solar radiation. Absorption increases with coating

Impacts on clouds

Soot increases number, reduces size of cloud drops (indirect effects)

Soot in/between cloud drops heats clouds (cloud absorption effects)

Soot stabilizes air, reducing water/heat transfer to cloud (semidirect)

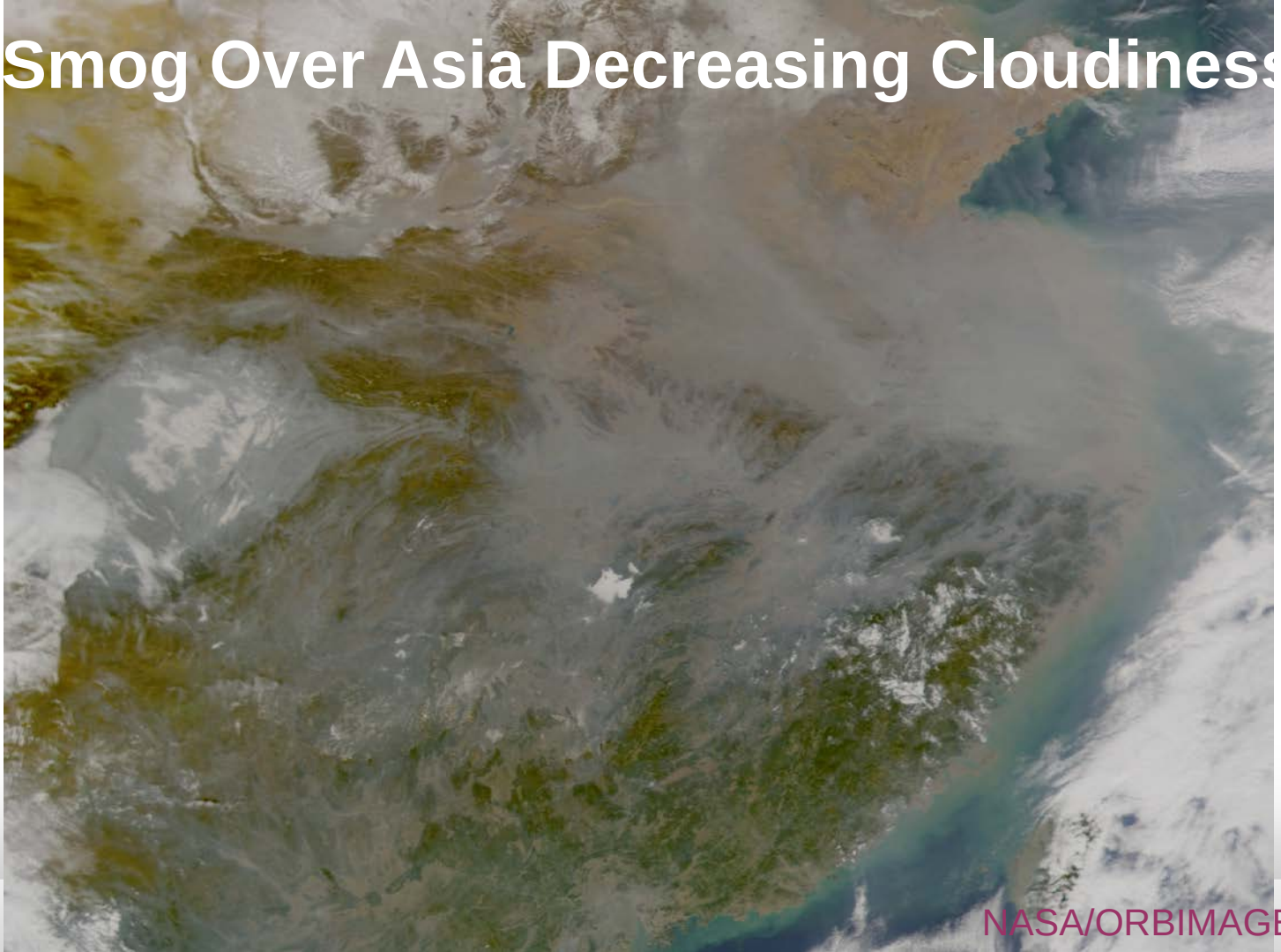
Impacts on surfaces

Soot deposits to snow/sea ice, reducing their albedos

Soot's air/surface warming evaporates surface water, a GHG

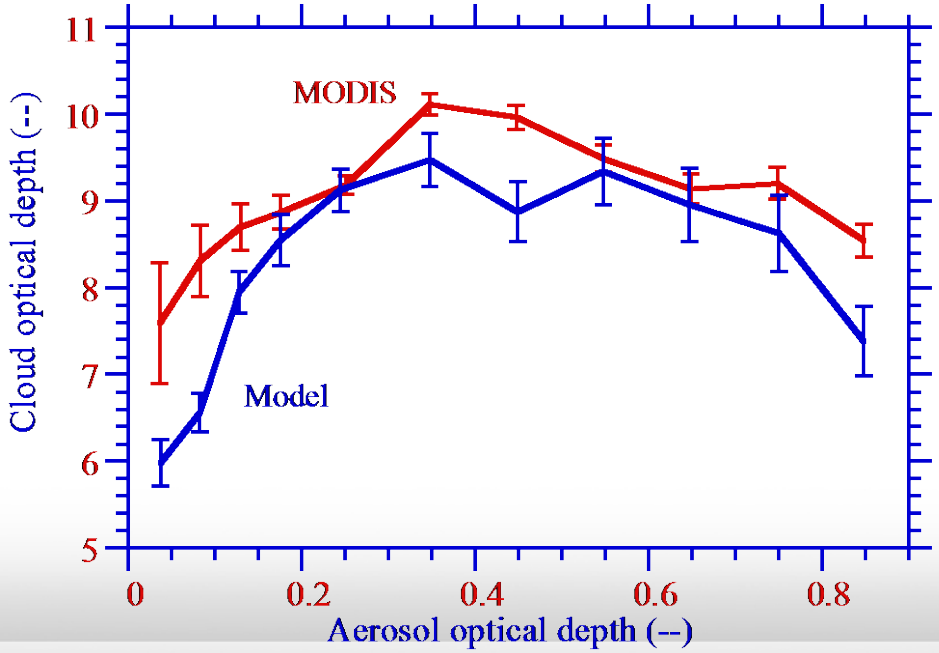
Linfen, China

Smog Over Asia Decreasing Cloudiness



NASA/ORBIMAGE

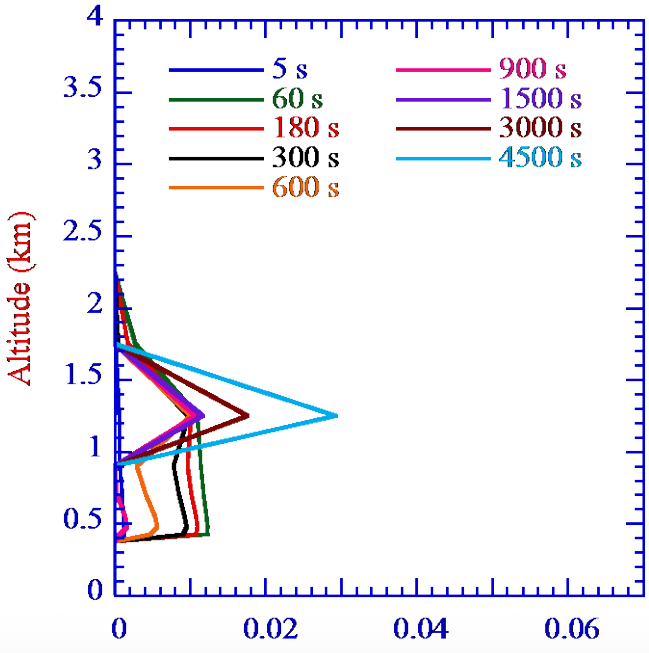
Boomerang Curve
Indirect + Cloud Absorption+ Semidirect Effects
COD v. AOD Over Biomass Burning in Brazil Sept ‘06



Ten Hoeve et al. ACP 11, 3021 (2011)

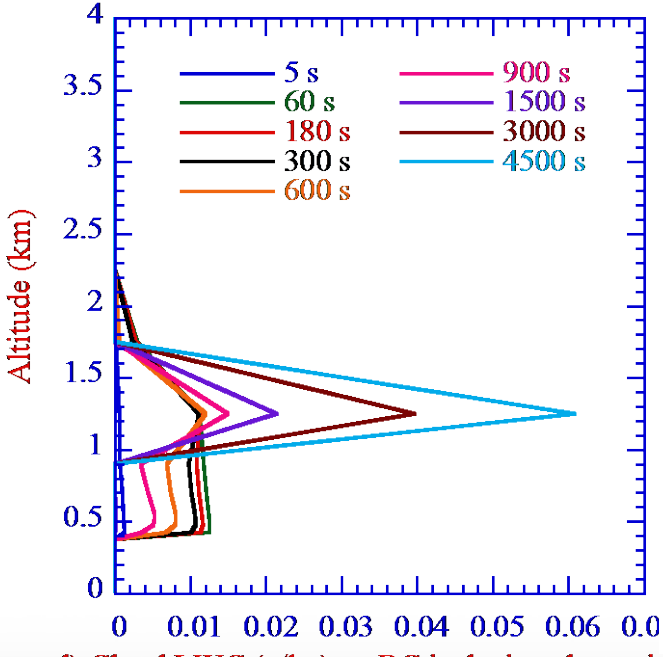
Cloud Evolution With Versus Without Absorption by BC Inclusions

With Absorption



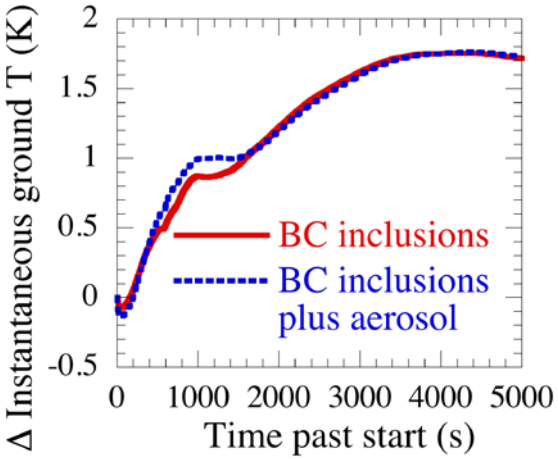
c) Cloud LWC (g/kg) with BC inclusion absorption

Without Absorption



d) Cloud LWC (g/kg) no BC inclusion absorption

Instantaneous dT due to inclusions only and inclusions+aerosol (accounting for indirect effects)



Absorption by BC inclusions speed up cloud dissipation, allowing more sunlight to reach surface in positive feedback

Processes to Account For to Obtain Full Climate Responses

Open biomass burning and solid biofuel burning

- Heat and water vapor of combustion
- Tarballs and other brown carbon
- All gas and particle components; cloud absorption effects

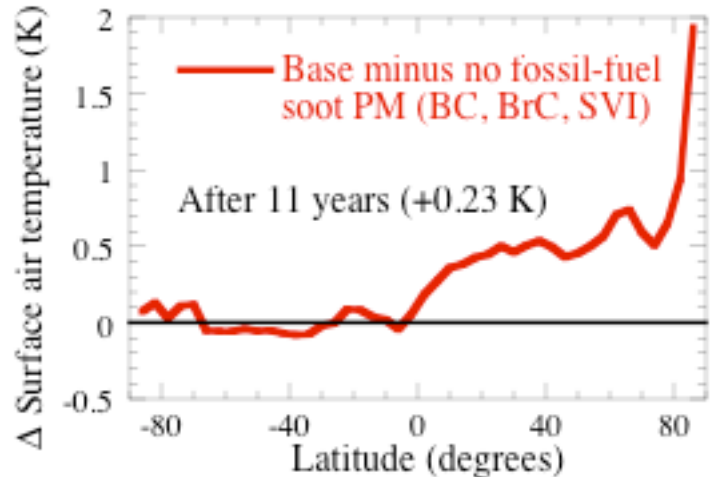
Fossil fuel plants

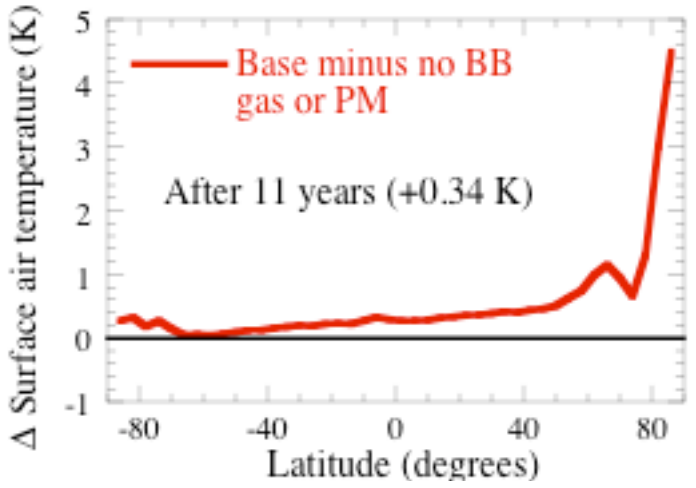
- Heat and water vapor of combustion
- Water vapor from cooling
- All gas and particle components; cloud absorption effects

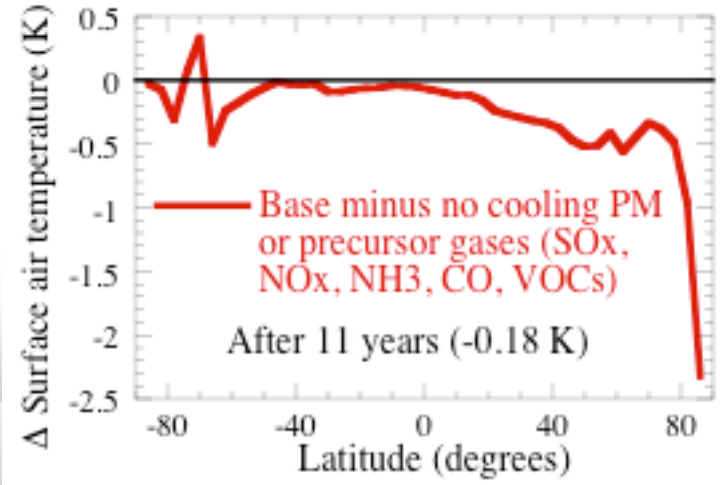
Transportation

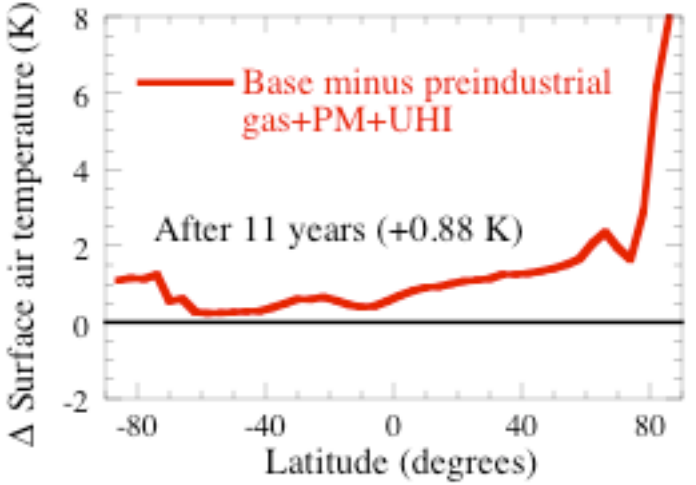
- Heat and water vapor of combustion
- All gas and particle components; cloud absorption effects

Zonal T Changes Due to Emissions

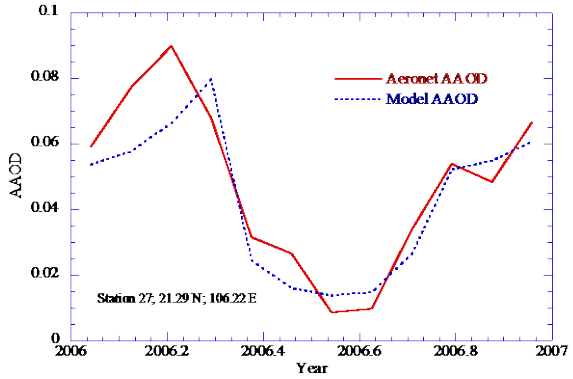


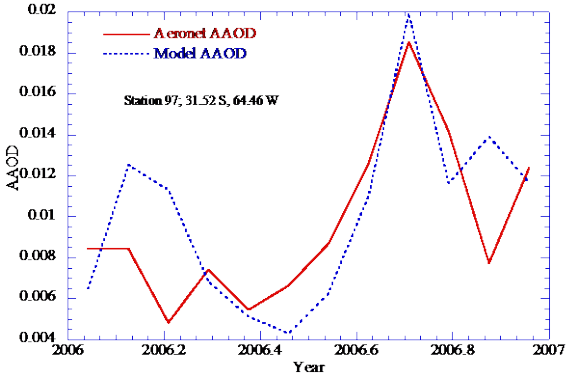


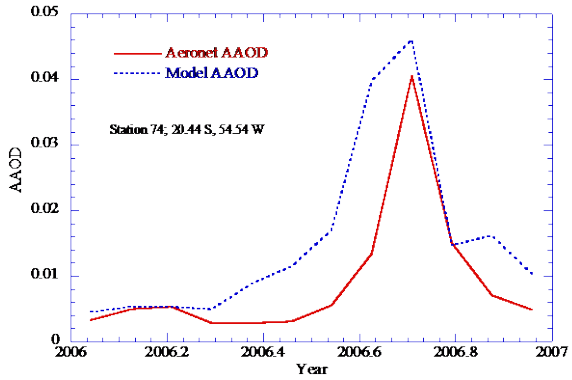


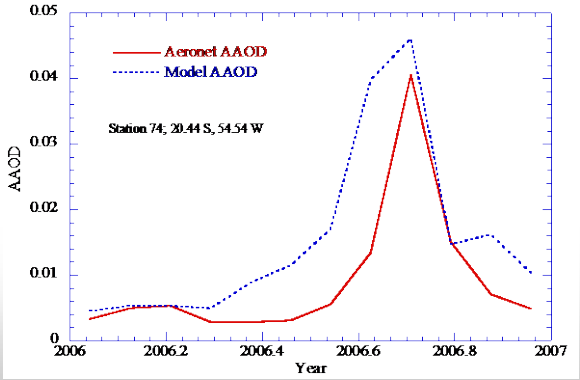


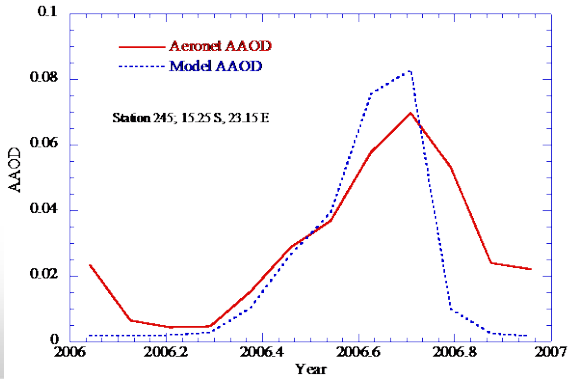
Modeled (4ºx5º) Versus AERONET AAOD

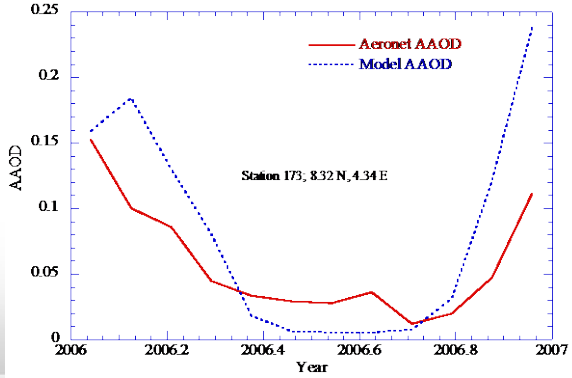












Summary

Arctic sea ice is diminishing rapidly. Controlling fossil-fuel soot particles, biomass and biofuel burning gases and particles should slow the loss of Arctic ice faster than any other control method.

BC and BrC cause clouds to burn off more than indirect effects enhance cloudiness. As a cloud is burning off, surface temperature increases.

Other factors needed to account fully for atmospheric heating and cloud burnoff include heat and water vapor of combustion and water vapor during power plant cooling.

http://www.stanford.edu/group/efmh/jacobson/Articles/VII/CloudAbsorption.html