The influence of biomass burning on the Arctic aerosol burden

A. Stohl
Arctic (short-lived) air pollution

In the 1950s, pilots discovered haze layers in the Arctic atmosphere

Explained in the 1970s: long-range transport of particles ("aerosols") from anthropogenic sources
“Dirty ice” reports by Nansen and Nordenskiöld

“Everywhere where the snow from last winter has melted away, a fine dust, gray in color, and, when wet, black or dark brown, is distributed over the inland ice in a layer which I should estimate at from 0.1 to 1 millimetre.”

Nordenskiöld, A. E., Science, 1883
Forcing mechanisms

Winter
- Longwave indirect effect
- Thin clouds
- Enhanced Cloud Longwave Emissivity $\Delta T_s > 0$

Spring
- BC snow albedo effect
- Less reflection from darkened snow and ice surfaces
- $\Delta T_s > 0$

Summer
- Aerosol indirect effect
- Stronger reflection: aerosols enhance cloud albedo
- Less radiation reaches the surface and leads to cooling, but net effect over bright surfaces small because little radiation is absorbed anyway

$\Delta T_s \approx 0$

$\Delta T_s < 0$

Reduced shortwave
- Enhanced longwave
- Net effect at surface can be positive or negative, depending on aerosol type and surface albedo

Aerosol direct effect
- Biomass burning or other pollution layers lead to shortwave absorption: $\Delta T_A > 0$

Earlier melting
Relative isolation of Arctic air means high-latitude sources primarily determine Arctic BC loads.
An Arctic source makes a 10-100 times larger impact than a midlatitude source of equal strength.
Model study on Arctic BC sources: Fire sources should dominate summer BC budget in the Arctic

(Stohl, 2006)

Continental BC contributions in dependence of tracer lifetime

BC inventories from T. Bond and D. Lavoue (boreal fires)

Lower troposphere

Total column

BC source contributions

Days back in time

pptm

European
American
Asian
Amer. fires
Asian fires
Europ. fires

European
American
Asian
Amer. fires
Asian fires
Europ. fires
Boreal forest fires in 2004


- 2004 was the worst boreal forest fire season in Alaska
- Severe season also in western Canada
- > 5 million hectares burned
FLEXPART tracer simulation:
Fire carbon monoxide (CO) total column

Actual time 20040629.120000

Barrow

Alert

0 500 1000 1500 2000 2500 3000 3500 4000
mg/m²
Comparison model / satellite image

5 July 2004

FLEXPART total CO column

MODIS satellite image
Barrow, Alaska

Aerosol Optical Depth (AOD) measurements (symbols) and FLEXPART CO column (line)

"normal" value

Measured BC concentrations (black line) and FLEXPART CO tracer at the surface (colors give the "age" since the emission)

Source analysis
Backward simulation from Barrow at the time of maximum measured pollution
Zeppelin, Spitsbergen

CO and BC measurements from May to September

![Graph showing light absorption and CO levels over time with a CO anomaly highlighted.]
Summit, Greenland

Aerosol Optical Depth (AOD) measurements (symbols) and FLEXPART CO column (line)

Measured BC concentrations (black line) and FLEXPART CO tracer at the surface (colors give the "age" since emission)
Effect on the snow albedo at Summit, Greenland
Agricultural fires pollute the Arctic

Stohl et al., ACP, 2007
Extreme air pollution

Picture courtesy: Ann-Christine Engvall
New air pollution records in Spitsbergen

Ozone, aerosol optical depth (both monitored since 15 years!)

Carbon monoxide, particles, black carbon, etc.

Ozone formation highly efficient!
The air pollution reduces the albedo

Deposition of polluted snow in and downwind of snowmobile track

Relatively clean snow

Wind direction

Stohl et al., ACP, 2007
New ozone record, 15 ppbv higher than any other value measured before.
Aircraft measurements during IPY confirm importance of BB layers in the free troposphere both in spring and summer – but normally BB layers do not reach the surface (Brock et al., 2011)
Model-supported extrapolation of aircraft-observed enhancement ratios suggests biomass burning suggests biomass burning is the dominant source of aerosols in spring

(Warneke et al., 2010)