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## SCIENCE BRIEFS

### As Pure as Snow

By James E. Hansen — December 2003

*Be thou as chaste as ice, as pure as snow, thou shalt not escape calumny.* —William Shakespeare, *Hamlet*

Popular perceptions about the purity of fresh snow persist. However, examination under an electron microscope shows that the typical snowflake in the Northern Hemisphere contains thousands of aerosols (fine particles). The aerosols, mostly picked up as the snowflake falls, include soil dust and various chemicals, but perhaps the most important constituent is "soot".

Soot is carbonaceous matter that comes from incomplete combustion of fossil fuels and biofuels such as wood, field residue, cow dung and other organic matter. Soot usually includes light-colored organic carbon, but its dark appearance is caused by black carbon (BC). BC is responsible for the black smudge on chimneys, and it is visible in the exhaust plumes of diesel-powered trucks and buses.

In a new paper (Hansen and Nazarenko 2003), we suggest that the effect of soot on snow albedo (reflectivity), not included in climate studies such as those by the Intergovernmental Panel on Climate Change, is important. This contrasts with the impact of soot on cloud albedos, which has been shown to be small. In 1989, Twohy et al. noted that "about 1000 times higher concentrations of soot are needed for clouds than for snow to cause a given albedo reduction." The reason is that snow crystals are much larger than cloud drops and a snow deck has greater "optical depth", i.e., it is more opaque. Thus, typical photons of visible sunlight are scattered hundreds of times within a snow deck, so they have a good chance of being absorbed by a soot particle before they can escape.

A soot content of only a few parts per billion (ppb) is needed to reduce snow albedo by 1%. We estimate that soot reduces snow albedos about 3% in Northern Hemisphere land areas, 1.5% in the Arctic, and 0.6% in Greenland. Climate simulations show that this modest albedo effect would cause a global warming (see Fig. 3) that is more than a quarter of the warming observed in the past century (Fig. 4).

"It's just good clean soot", says Dick Van Dyke as the chimney-sweep in *Mary Poppins*. Environmentalists and climatologists are not as sanguine about soot, but they have devoted greater attention to sulfates, which cause "acid rain". However, soot may be a more all-around bad actor than has been appreciated.

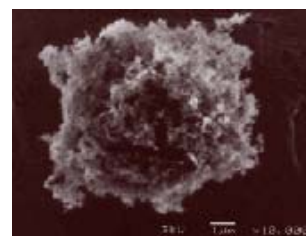
We suggest that, in addition to being a major cause of global warming, soot may directly contribute to near world-wide melting of ice that is usually attributed solely to global warming. For any given soot amount, its

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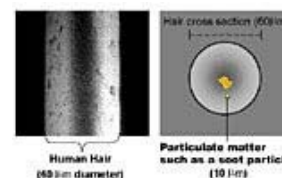
#### Snowflake Under a Microscope

(Image: USDA Beltsville Agricultural Research Center, Electron Microscopy Unit)



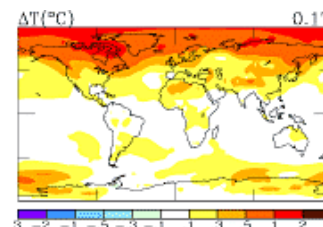
#### Soot Particle Under a Microscope

(Image: D.M. Smith, Univ. Denver)



#### Size of a Soot Particle

Soot particles are measured in micrometers ( $\mu\text{m}$ ), and are smaller than the diameter of a human hair. (Image: NASA)





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- + Twohy, C.H., A.D. Clarke, S.G. Warren, L.F. Radke and R.J. Charlson 1989. Light-absorbing material extracted from cloud droplets and its effect on cloud albedo. *J. Geophys. Res.* **94**, 8623-8631.

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