WHAT IS BLACK CARBON?

Black carbon particles, the major constituent of soot, absorb solar radiation and thus in the air heat the atmosphere. In addition, when deposited on snow and ice they darken the surfaces and accelerate melting. It has lately been estimated that black carbon is the second most important pollutant, after carbon dioxide, forcing the climate change.

Black carbon emissions are mostly caused by human activities, such as heating and transportation, when fossil fuels, biofuels and biomass are burnt incompletely.

Because of the short life-time, reductions of black carbon emissions could slow down the warming relatively quickly. Aerosols containing black carbon as well as methane (CH$_4$) and ozone (O$_3$) are commonly identified as short-lived climate forcers (SLCF). Aerosols remain in the atmosphere only from several days to few weeks.

The MACEB project was carried out with the contribution of the LIFE financial instrument of the European Community.
The mitigation of climate change caused by global warming is the most important environmental challenge for the moment.

To find solutions to mitigate Arctic warming, the MACEB project integrates black carbon emissions from different sources and areas with black carbon concentrations in surface and snow over Arctic areas and further with corresponding radiative forcing.

The method used in this project combines information from global (GAINS) and national (Finland, FRES) emission models, global (ECHAM5-HAM2) atmospheric model, and actual measurements of black carbon concentrations in surface air and snow. The modeling results are demonstrated in [www.maceb.fi](http://www.maceb.fi) -> Result viewer

### PROJECT OBJECTIVES

- To demonstrate the approach to mitigate warming of Arctic climate by black carbon (BC) emissions reduction at mid latitudes, especially in Europe.
- To assess the impact of the current air quality and climate relevant legislation in the northern hemisphere on BC emissions, their transport to the Arctic, and eventually Arctic warming.
- To transfer action procedures and experiences to assess and mitigate BC emissions from most important source sectors, e.g. small-scale wood burning.

### PROJECT ACTION DESCRIPTIONS

**A1** Project management and monitoring focused on the technical, financial management of the project and project monitoring. The components of the project management structure included Management board formed by the project partners, Steering group formed by external experts and stakeholders and Action groups formed by action managers and project personnel.

**A2** Surface monitoring BC concentrations in air were monitored continuously at different sites in Finland (Utö, Hyytiälä, Pallas, Virolahti and Kuopio) and campaign-wise for the deposition of BC onto snow and scattering of light by aerosol. Time series of BC concentrations and deposition was used to demonstrate the operation of the models and calculate light absorption.

**A3** Processing of emission modelling system developed base year (2005) emissions and projections for 2020 and 2030 of baseline air pollution and climate mitigation (CLEC and CLECC scenarios) and further reduction of air pollution in general and specifically black carbon (MTFR and BCadd scenarios). Costs assessment of the mitigation measures was carried out and non-technical measures in the domestic sector investigated.

**A4** Construction and demonstration of integrated system constructed an integrated system, by which BC emissions from different source categories and areas (e.g. Europe and Finland) can be linked with BC concentrations in surface and snow over Arctic areas and further with corresponding radiative forcing. The system combined information from global (GAINS) and national (Finland, FRES) emission models, global (ECHAM5-HAM) atmospheric models, and measurements of BC concentrations in surface air and snow.

**A5** Creating monthly averages concentrations maps for BC in air and snow simulated BC concentrations in surface air and snow for the current (2005) and future (2020 and 2030) climate with different emission scenarios using the integrated system developed in Action 4. Simulated BC concentrations were converted into corresponding monthly-mean concentration maps over Arctic areas.

**A6** Calculation of BC radiative forcing over the spring-summer period in the Arctic assessed BC radiative forcing for the spring-summer period which is the period when heating and surface melting by BC is the most effective over Arctic areas. Forcing was determined for both current and future climate and compared with forcing by greenhouse gases.

**A7** Assessment of country contribution and BC emission mitigation options used the integrated system developed in Actions 3 and 4 for estimating country specific BC emission contributions in the EU for the current (2005) and future (2020 and 2030) emission scenarios. The assessment was done running the integrated modelling system with and without the Finnish (FRES model results) and European (GAINS) emissions. The relationship between EU air pollution legislation and climate policies and BC emissions was analyzed.

**A8** Dissemination distributed the demonstration of end-products of Actions A2-A7 as well as general information about black carbon emissions and impacts to the stakeholders and the general public. In addition to global-to-national level modelling demonstration, the project participated in a local level information campaign in order to reduce black carbon emissions from residential wood combustion in Helsinki and general guidelines to design such local actions in other communities were constructed. All the information was made available via project web portal [www.maceb.fi](http://www.maceb.fi).

**A9** The project web portal and the result viewer generated during the project will be maintained and updated. The evaluation and publication of the results will also continue after the project. After one year, a symposium for stakeholders and researchers is organized to estimate the usefulness of the end-products, and to get feedback from users and from the audience of local level information campaigns for further development.
MODELING BLACK CARBON IN THE ARCTIC

EMISSIONS

The biggest emission sources in Europe and Northern America are households that burn solid fuels for heating and diesel engines in the transport sector. In developing countries also cooking stoves and traditional coke and brick making kilns are significant emission sources.

Efficient black carbon mitigation options include cleaner fuels and enhanced combustion devices for household heating and cooking and particulate filters for diesel engines. The MACEB project introduced emission mitigation by different scenarios, source sectors and world regions. An example of black carbon emissions and reduction potential is shown below.

BLACK CARBON CONCENTRATIONS

Black carbon concentrations will decrease in the future in Europe, North America and China, whereas substantial increases are predicted over India and Africa under the influence of current air pollution policies and legislation (CLEC scenario). With a scenario tailored for black carbon mitigation (BCadd), concentrations will decrease almost everywhere in the world.

CLIMATE EFFECTS

Although black carbon emissions will decrease in the Arctic countries in the future, the decrease of other air pollutants, especially sulfur dioxide, will cause a net positive top-of-the-atmosphere forcing compared to present day.

More results: [www.maceb.fi](http://www.maceb.fi)
Aerosol emissions from the European countries cause currently a cooling effect in the atmosphere*. The effect is largest in central Europe and extends to over Arctic.

Compared with the present-day situation, currently agreed policies affecting air pollutant emissions will reduce the aerosol cooling effect* (i.e. enhance warming) over both Europe and Arctic areas during the next couple of decades. Less future warming will be expected if emission reductions target the sources with high share of black carbon.

There is a significant reduction potential for black carbon emissions with technologies that are currently available.

It is not possible to reduce the emissions of warming black carbon alone. Emission reduction technologies and policies affect also cooling components, i.e. organic carbon and sulfur emissions.

Residential wood combustion is a major source of black carbon emissions. In addition to stove technology, user’s behavior in the form of stove operation and fuel quality has substantial impact on residential wood combustion emissions.

Black carbon emissions are at highest in winter and thus their effect on melting of snow and ice is pronounced.

The largest uncertainties in estimating the climatic effects of black carbon in Arctic areas arise from the difficulties in

- modeling the efficiency by which black carbon particles are transported from their source areas to the Arctic atmosphere
- understanding how the particles interact with Arctic clouds.

* A negative top-of-the-atmosphere direct aerosol forcing