

Report Working Group 1

## **Climate benefits and dis-benefits of air pollution (PM and ozone) control**

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### **There is a need for jointly assessing air pollution and climate change policies**

Levels of particulate matter (PM) have to be reduced to protect human health. Policies are already effective in the developed world, while this is expected to happen also in the developing world. This will have immediate impacts on climate.

On the other hand, strong CO<sub>2</sub> reductions are required, up to 90% in the developed world by 2050 compared to 1990. The needed restructuring of the energy and other sectors will lead to significant reductions of air pollution as well, with, again, impacts on climate that will materialized faster than those from CO<sub>2</sub> reductions.

Policy makers need to be aware of potential short term climate effects induced by changes in air pollution caused by the above mentioned policy actions. They need to assess possibilities of avoiding or enhancing these effects by more targeted air pollution policies. In this process, they need to consider not only effects on temperature, but also effects on precipitation, melting of glaciers, etc. They further need to consider the sensitivity of specific regions to these effects. The regional character of air pollution leads to impacts on climate also on a regional scale.

### **There are observations that indicate an impact of air pollution (policies) on climate**

Global, hemispheric and regional temperature trends show the cooling effect of increasing pollution after world war II and the warming when air pollution was addressed in the developed world from the 80ies onwards. This cooling and warming is related to the issues of “global dimming” and “global brightening”.

In order to fully explain these trends one need to consider both cooling from e.g. sulfate (SO<sub>4</sub>) and organic carbon (OC) aerosols, and warming from black carbon (BC) aerosols and ozone.

### **The radiative forcing of most chemical atmospheric substances has been identified, but ...**

The IPCC 4AR has listed the global radiative forcing of individual chemical components, including long-lived and short-lived species. The estimates mainly results from modeling studies using estimates for pre-industrial and present day emissions of these species. The uncertainty on the effects of aerosols on clouds, resulting in a large negative forcing (hence: cooling), is particularly large. However there is independent evidence from satellite observations that the

anthropogenic aerosols are causing a radiative forcing of  $-1.2 \text{ W/m}^2$ , hence tend to cool the Earth. This constrains the uncertainty somewhat but their remains still a large uncertainty on how much the different aerosol component contribute.

The IPCC 4AR shows that reducing one (set of) species will have secondary radiative forcing effects on other species. This is particularly the case in the  $\text{NO}_x$ -VOC- $\text{O}_3$  system. This means that it is not immediately clear whether a reduction of, e.g., an ozone precursor is a no-regret option or not. The latter depends further on the sector and the regions in which such a reduction would take place. Now that peak ozone levels seem to be under control, by regional  $\text{NO}_x$  and VOC control, attention should be paid to background ozone, which becomes a significant part of the integrated ozone to which humans and ecosystems are exposed.

Reducing  $\text{O}_3$  concentrations will cool the climate. Lower ozone concentrations will probably as well improve the  $\text{CO}_2$  uptake in the biosphere. Reduction of methane, to reduce in particular background ozone, is a no regret policy. It should therefore be tackled [also] in regional air pollution policy frameworks such as CLRTAP.

It is as yet unclear whether reducing BC concentrations will have a cooling effect. This is primarily due to the large uncertainty regarding the interactions of aerosols (including BC) on clouds. As mentioned before, additional climate effects, such as those on the hydrological cycle and the melting of ice, should be considered as well.

### **... radiative forcing created by individual sectors is more relevant for policy making**

Combustion is the dominating source of  $\text{CO}_2$ , particles, soot and ozone precursors and is found in most sectors emitting pollutants. All sources/sectors emit a mix of short-lived substances, so it is not realistic to think to control one species at the time. However the warming to cooling ratio of the emissions varies from sector to sector. Preliminary calculations show how present day emissions of short lived species and their precursors in the power and industrial sectors lead to a negative forcing, whereas the domestic and transport sector lead to a positive forcing. Such estimates must be repeated by other groups, and, when applied to the future, they should assume the best available technologies for emission controls. In any case there is a handle on controlling climate in the short term, by favoring controls in one sector or the other.

Obviously the importance of sectors depends strongly on where they emit. E.g., in 2000 the dominant sectors emitting BC were, in India: domestic (biofuel use), in China: industrial (small boilers) and in the Developed World; transport (diesel).

Sectors have also different effects on burdens and climate, depending on whether they emit over oceans or land, in clean or polluted regions. E.g. ships lead to more ozone per ton of  $\text{NO}_x$  when emitted in the clean air over the open oceans, as compared to close to continents. Equally, sulfur emission from ships has a stronger cooling effect over the dark ocean, than over land.

In conclusion, effective coordinated abatement strategies of the short lived air pollutants have to be developed regionally as the influence, both on climate as well as on air quality, are strongly dependent on the sources and the geographical circumstances of each region. It is clear that abatement of aerosols will give an increased warming. A specific abatement of soot is difficult as it is so closely related to other particulate components. It is possible to partly counteract the warming by lowering the ozone concentrations. Including methane in an abatement strategy will probably be necessary to fully balance the climate effect by particles and it has a direct influence on ozone concentrations.

### **Recommendations for policy**

- Air quality abatement, including particles, is absolutely needed due to its large effects on health and ecosystems. But coordination of climate and air quality abatement is needed as any abatement will affect both areas considerably..
- All chemical species contributing to particulate matter must be further reduced, for their health impacts. Simultaneously, and in order to avoid fast further warming, the BC to (OC+SO<sub>4</sub>) ratio of the overall emissions, should be reduced by selecting controls in appropriate sectors.
- In the light of the above, more emission reductions could be needed from domestic heating and cooking, and from transport.
- In addition to PM , tropospheric ozone and methane concentrations must be reduced to achieve climate neutral (or even friendly) air pollution policies, and avoid fast climatic changes.
- The emissions from different sectors vary between different geographical regions. The effects on climate and air quality are as well dependent on the specific meteorology. Regional coordinated abatement strategies have to be established to reach the most efficient and suitable plan for improved air quality and climate change mitigation. Specific policy actions that reduce impact on vulnerable regions should have a priority, i.e. BC reduction north of 40°N, to protect the Arctic.

### **Recommendations for research**

- Reducing the uncertainty on aerosol forcing would help in reducing the uncertainty on the climate sensitivity. The latter prevents us from making more accurate climate productions. Especially the many effects of aerosols on the hydrological cycle need to be elucidated, better quantified and taken on board in climate models.
- More chemically resolved emission data are required for most sectors, in order to assess the impact on radiative forcing factors.

- The climate dis-benefit of NO<sub>x</sub> reductions, is likely to be more complicated than what is mentioned by IPCC AR4. The issue must be addressed region by region and sector by sector.
- Scientists must come to a more fundamental understanding why atmospheric models poorly represent PM and BC in particular. One issue is the vertical distribution of air pollutants, including the exchange between the boundary layer and free troposphere. Another issue is the availability of realistic emission inventories (see above). In the latter context, inconsistencies in definitions and measurements of BC, between emission and immission communities must be resolved.
- In certain areas of the world (e.g. China) emissions and the BC to (OC+SO<sub>4</sub>) ratio of the aerosol have been changing fast. This offer a good opportunity to quantify the climate effect of such changes.
- Effect of non-linearities in transformation of SO<sub>2</sub> to sulfate should be considered, especially in the countries in transition, in assessing the effect of policies on aerosol burdens and their effects.