Addressing short-lived climate-forcing pollutants for air quality and climate change

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"Short-Lived Climate-forcing Pollutants", or short "SLCPs": Most of you have probably heard the term already before today, but what exactly are SLCPs? And what makes them worthy of discussion? I'd like to give you some insights into the science behind SLCPs, and will do this by taking the term "Short-Lived Climate-Forcing Pollutants" apart, considering each of its aspects one by one.

Let's start backwards, beginning with the *pollutants* aspect. SLCPs are pollutants in the sense that they have negative impacts on health, agriculture, ecosystems, tourism, buildings and historic monuments. SLCPs include well-known pollutant gases such as ozone and sulfur dioxide, as well as tiny particles containing soot, sulfate, and other compounds. Note that a few non-pollutant greenhouse gases are usually included in the discussions around SLCPs, especially the hydrofluorocarbons, or HFCs, as well as methane, though the latter is an indirect pollutant by contributing to the production of ozone.

Many SLCPs have grave impacts on health. For instance, pollutant particles can be inhaled deep into the lungs and can even pass into the blood stream. Of particular concern is soot, which the World Health Organization has classified as carcinogenic. The WHO has estimated that in Europe, the average life expectancy is shortened by about 6 months due to particulate matter alone, despite existing regulations. Worldwide, these impacts are anticipated to get much worse; in fact, the OECD estimates that outdoor air pollution will soon become the main environmental cause of death, far surpassing unsafe water supply and sanitation.

SLCPs also cause crop losses, especially due to ozone, and natural ecosystems can be similarly affected. Finally, SLCP particles lead to reduced visibility, which impacts tourism by hiding the blue sky behind a gray-brown haze, and making entire mountain ranges such as the Himalayas disappear from view.

The second part of the name SLCPs is “climate-forcing”. The term “forcing” indicates that SLCPs influence (or drive) the climate in different ways, such as making it warmer or cooler, causing more or less precipitation, and so on. Sometimes “forcing” is left out of the name for simplicity, but I strongly prefer to include it in order to distinguish the multiple effects of SLCPs as “climate-forcers” *and* “air pollutants”, and not simply “climate-pollutants”.

SLCPs force the climate in five main ways; the first three are warming effects:

- Some SLCPs are greenhouse gases, similar to CO_2;
- Some SLCP particles, especially soot, absorb sunlight and warm the air around them;
- Soot also deposits on and darkens bright surfaces, especially snow and ice, making them melt faster;

There are also two cooling effects:

- Most particles like sulfate directly reflect sunlight;
- And particles also influence clouds, usually making them brighter.

Currently the sum of the warming effects is comparable in magnitude to the warming from CO_2, as can be seen on page 5 of your handout. The same applies for the cooling effects, but in the opposite direction. Together with CO_2 and other long-lived climate forcers, this all adds up to an anthropogenic global warming of about 0.7°C. Although there is a range in the estimated effects, it appears that the four main *warming* SLCPs, namely ozone, methane, soot and HFCs, contribute 30-40% of this current global warming, perhaps even more, while CO_2 contributes about 50%.

Finally, what really makes SLCPs special is the first part of the name: “short-lived”. We can best see what this means in comparison to CO_2: once CO_2 is emitted due to burning fossil fuels, it remains in the atmospheric climate system on average for centuries. The atmospheric lifetimes of SLCPs, on the other hand, are generally shorter than the climate timescale, which is defined by the World Meteorological Organization to be 30 years. Methane is on the long side of this, with a lifetime of approximately ten years, while many gases and aerosol particles have much shorter lifetimes, from several months down even to a single day.

The short life span is responsible for two effects. First, air pollution tends to be regionally concentrated, so that reductions of emissions primarily benefit the regions where the reductions are made.

Second, the short lifetime results in differences in the effectiveness of measures to reduce the emissions of CO_2 and SLCPs. In case you are following along in the handout, I’ve illustrated this effect in the figure on p. 7, which shows hypothetical trends for CO_2 and SLCPs for various scenarios. Since there is significantly more CO_2 in the atmosphere than any of the individual SLCPs, the graph is split into two areas, top and bottom.

Now, it turns out that the responses of CO_2 and SLCPs to mitigation are very different, and this basic principle applies generically to any of the SLCPs. Of course, if we continue on "business as usual", with increasing emissions of CO_2 and SLCPs, then both will continue to increase. But if we have a small success with mitigation efforts, and just keep the current emissions constant, then CO_2 would continue to increase, while the SLCP concentration would actually remain constant. If we managed to moderately decrease the emissions, for instance back to the 1990 levels, the CO_2 concentration would still continue to rise, while the SLCP concentration would instead decrease. And even if we were to completely stop all CO_2 and SLCP emissions, the amount of CO_2 would only go down very, very slowly, while the SLCP concentration would rapidly drop to their natural background concentrations, within a few weeks to decades, depending on the type of SLCP.

So given this great possibility of a rapid response, what measures are there to reduce SLCP emissions? In your handout I've included a table and some pictures of major sources for the main warming SLCPs, in Europe and worldwide. Two reports published in 2011 by UNEP and the WMO especially highlighted 16 measures for mitigating methane and black carbon, and compare these to the mitigation of CO_2. Again, those following along in the handout can find the results on p. 13. They show first that if we continue on with a "business as usual" scenario, the global average surface temperature is predicted to increase by nearly three degrees by 2070. If we were to *only* mitigate CO_2 emissions, then we would still expect global warming to exceed the 2 degree mark by 2070. On the other hand, if we were to implement *only* the UNEP measures for methane and soot, but not mitigate CO_2, then we would find a dramatic slow-down of global warming over the next couple decades. However, if the CO_2 concentrations were to continue to rise, then the CO_2 warming would quickly overtake the cooling due to SLCP mitigation, and here as well global warming would likely exceed 2 degrees by 2070. *Only* if we were to implement *both* the CO_2 measures and the SLCP measures would we expect to have a reasonable probability of keeping global warming below 2 degrees.

Now, one *could* think: 'great, let's get started on SLCPs, and that will buy us some time before we need to start reducing CO_2 emissions'. I have heard this idea being brought up in the past, so I asked my colleague Drew Shindell, the lead author of the study, if he could calculate another curve for exactly this case, that shows what we would expect to happen if we were to implement methane and soot measures right away, but waited 20 years before we got started on CO_2 measures. The result is an eye-opener, and it is shown on p. 14 of the handout: with just a 20-year delay in starting the CO_2 mitigation measures, the additional CO_2 that would be emitted would cause the temperature to be almost half a degree higher: that means that even if we start now to vigorously mitigate SLCPs, any significant delay in the CO_2 mitigation measures would make it likely that global warming would exceed 2 degrees already by 2070.

So there is a great potential through reducing SLCPs, not only for abating climate change, but also for reducing the health and agriculture risks I mentioned earlier. There is also great promise through various success stories, for instance, the reduction in acid rain which was accomplished through international collaboration in Europe. However, ongoing success at the air pollution and climate change nexus in Europe will take various concerted efforts, such as an improved capacity for continuous, consistent, and detailed air quality monitoring.

Concluding with a few take-home messages:

- SLCPs are air pollutants in the sense that they have significant impacts on health, agriculture, ecosystems, tourism and built structures;
- SLCPs are climate forcers in the sense that their current contribution to climate change is similar in magnitude to CO_2, but with warming and cooling effects in different regions;
- And SLCPs are short-lived in the sense that reducing their emissions results in rapid benefits, with effects often concentrated close to the source regions.

A great potential to reduce SLCPs in the atmosphere exists, even with already existing technologies, but to be effective on this front will require careful attention to integrative approaches to science and policy. These should ensure that efforts to reduce SLCPs do not compete or interfere with efforts to reduce CO_2. They should also aspire to the great challenge of integrating air pollution and climate change with other development goals like energy security, economic prosperity, health care, food security and social justice. Various programs to address SLCPs and their connection to these integrative issues are underway, and as sources of further information on this topic I'd like to point to four of them:

- The Climate and Clean Air Coalition, or CCAC
- The UNEP Atmospheric Brown Clouds project, or ABC
- The Air Pollution and Climate Change Initiative of the International Global Atmospheric Chemistry Project (IGAC),
- And our project ClimPol, along with other projects at the IASS in Potsdam.

With that I thank you for your attention and look forward to the discussion.