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The Atmosphere Subprogramme of the Finnish Research Programme on Climate Change (SILMU)

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1. Introduction

"Acid rain" was the first major anthropogenic environmental problem, in which the atmosphere played a crucial role. This problem, revealed already in the 1960s, is caused primarily by anthropogenic emissions of sulphur dioxide and nitrogen oxides. It is still with us but instead of soil acidification we may now speak more generally about the anthropogenic modification of the tropospheric air chemistry and its consequences to the soil and waters (see Fig. 1). In the 1970s and 1980s the problem of stratospheric ozone depletion entered the picture and it has now been convincingly shown to be caused primarily by the anthropogenic emissions of halocarbons (CFC´s). More recently, the possibility of man-made climate change due to anthropogenic enhancement of the atmospheric greenhouse effect via emissions of carbon dioxide and other greenhouse gases has received a lot of attention (e.g. *IPCC/WG1*, 1990, 1992, 1994, 1995), even though the problem was recognized already more than a century ago.

The three anthropogenic problems mentioned above are interconnected in fundamental ways (Fig. 1). For example, sulfur dioxide forms in the atmosphere sulfate particles. These reflect Sun´s light back to space. They thus cool the climate and by doing so tend to oppose the warming trend caused by the increase of the atmospheric greenhouse gas concentrations. The ozone problem is related to the acidification issue e.g. through the fact that a decrease of stratospheric ozone layer increases the ultraviolet radiation entering the troposphere and influences thus the tropospheric chemistry. On the other hand, it is connected with the greenhouse problem e.g. by the very fact that ozone, as well as the CFCs that destroy stratospheric ozone, are greenhouse gases and changes in their concentration cause a radiative forcing that tends to change the climate.

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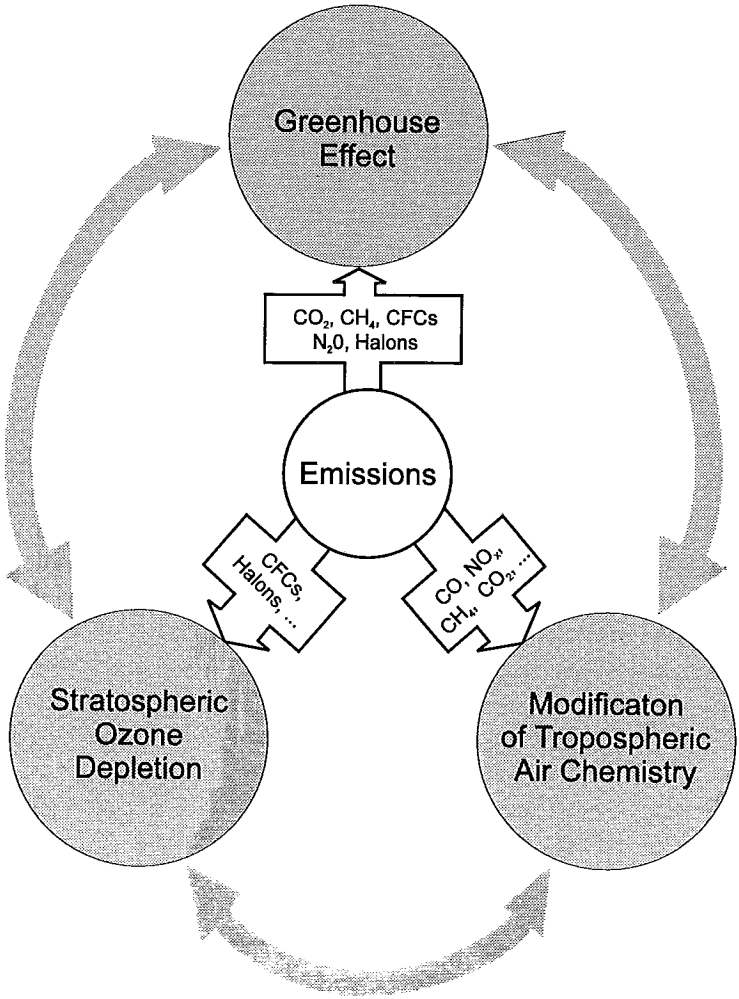

Fig. 1. Scheme illustrating connections between the three major anthropogenic global change problems involving the atmosphere: 1) modification of tropospheric air chemistry, 2) stratospheric ozone depletion and 3) intensification of the atmospheric greenhouse effect.

In *IPCC/WG1* (1994) an attempt has been made to quantify various radiative forcing factors relevant to climate change since preindustrial times. This assessment shows (see Fig. 2) that, for example, the observed increase of the "traditional" greenhouse gases and of the tropospheric ozone tends to warm the climate, whereas the stratospheric ozone depletion as well as the increase of tropospheric aerosols tend to cool it. In addition to the direct cooling effect caused by the scattering of solar radiation back to space the increased amounts of tropospheric aerosols may also have had an indirect cooling effect through their effect on cloud condensation nuclei; estimates of this indirect radiative forcing by aerosols are at present very uncertain, however.

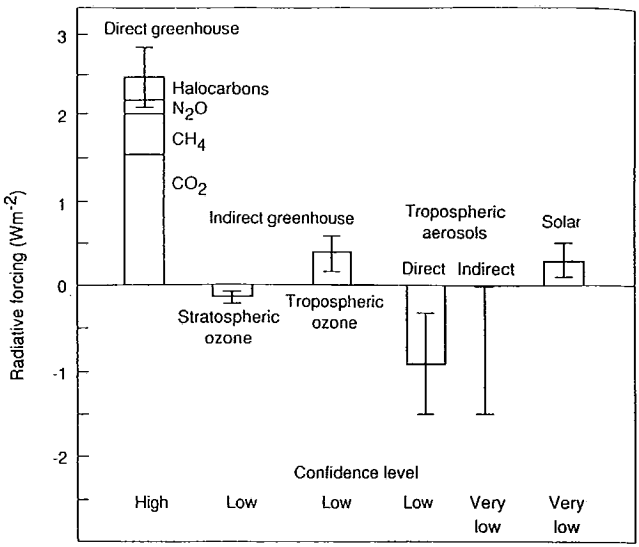

Fig. 2. Estimates of globally averaged radiative forcing due to changes in greenhouse gases and aerosols from pre-industrial times to the present, and changes in solar variability from 1850 to the present day. (From IPCC/WG1, 1994, Fig. 3).

The Finnish Research Programme on Climate Change (SILMU) in 1990-1995 consisted of four subprogrammes: (1) Atmosphere, (2) Waters, (3) Terrestrial ecosystems and (4) Human interactions. Three progress reports have been published about the whole silmu programme (*SILMU*, 1992, 1994, 1996). Here we give a brief overview of the SILMU-Atmosphere; the other papers in this issue of Geophysica will show some of the major results obtained in it. Some of the major results obtained in Waters subprogamme are found in *Kämäri* (1996), those for the Terrestrial ecosystems subprogramme in *Korpilahti et al.* (1996). From the Human interactions subprogramme of SILMU the paper on radiative forcing by *Sinisalo* and *Savolainen* (1996) is included in this issue of Geophysica.

From the very beginning of the SILMU programme it was clear that all three aspects illustrated in Fig. 1 must be addressed in SILMU-Atmosphere. The problems studied consisted of some 15 items falling in three groups A, B and C covering roughly the following topics:

A. Climate data and climate models

- Dendrocronological climate history of the Fennoscandian subarctic region
- The variation of carbon isotope ratios in the tree rings
- Microclimate models
- Climate changes in northern Europe
- Climate models and scenarios
- Statistical weather generator

B. Ozone
- Changes in the stratospheric ozone in northern Europe
- UV radiation in Finland
- Accurate measurements of the solar UV-radiation and the carcinogenic effects the radiation
- Tropospheric chemistry

C. Aerosols
- Chemical and physical aerosol processes in cold conditions, and the effect of radiation on these processes
- Mathematical models for atmospheric aerosol.

3. *Some highlights of the results obtained*

Some of the results obtained in in SILMU-Atmosphere are presented in this issue of Geophysica. Here, only one of the main results within each of groups A, B and C is mentioned:

A) Estimates of low frequency natural climate variability from tree rings

Tree rings in northern Finland are known to provide proxy data of summer temperatures. Within SILMU-Atmosphere, a 7500-year long time series of tree rings has been established (*Eronen* and *Zetterberg*, 1996), and these can provide estimates of natural low frequency variability of summer temperature in northern Europe. Such estimates are particularly important in connection with the "detection issue", i.e. in discussing the separation of the anthropogenic climate effects from low frequency natural climate variability.

B) Anthropogenic depletion of the Arctic ozone layer

Researchers in the Atmosphere subprogramme of SILMU have participated in international field campaigns and modelling studies aimed at finding out indications of possible anthropogenic depletion of the Arctic ozone layer; such depletion in the Antarctic atmosphere is by now well-known. Evidence for ozone depletion also in the northern hemisphere has indeed been found by SILMU-Atmosphere researchers in collaboration with foreign research groups (*Taalas et al.*, 1996).

C) The cooling effect of aerosols on climate

Studies within SILMU/ATMOSPHERE have shown that atmospheric aerosol particles generated by anthropogenic air pollution can change the optical thickness of some clouds, to increase their albedo and thus producing an indirect cooling effect on climate (*Kulmala et al.*, 1996).

In addition to findings A-C above one should note that SILMU-Atmosphere has provided scenarios for Finland's future climate for use in impact assessment (e.g. *Carter et al.*, 1996).

4. *General comment*

The usual difficulties of an interdisciplinary approach were encountered within SILMU, not only in the connections between the various subprogrammes but also between various projects. Nevertheless, the SILMU-Atmosphere created significant interaction between the various disciplines and institutes involved.

The International Conference on Past, Present and Future Climate was organized in Helsinki, Finland 22-25 August 1995 by SILMU-Atmosphere (*SILMU*, 1995). In addition to some 50 SILMU researchers it was attended by about 100 foreign experts. The papers by Rutter et al. and Cubasch and Hagerl of this present issue were originally presented in this Conference.

Acknowledgements

The contributions of several individual scientists and research groups in Finland and abroad, not directly involved in SILMU-Atmosphere, are gratefully acknowledged. In this regard, special thanks are due to Dr. Ulrich Cubasch (at DKRZ, Hamburg, Germany) who, among other things, participated in the two international conferences organized by SILMU-Atmosphere (*SILMU*, 1993,1995) as an invited lecturer.

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