EFFECTS OF GLOBAL WARMING ON ENVIRONMENTAL POLLUTION: AN AREA WITH MANY KNOWLEDGE GAPS

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Summary

Global warming might aggravate stress from already existing factors (including acidification, rising tropospheric oxidant levels, stratospheric ozone depletion, the flux of heavy metals in soils and natural waters). Current international policies and protocols, such as those for sulfur and nitrogen emission reductions would need re-assessment. Also, risk assessments for a range of chemicals used in agriculture and silviculture might have to be re-evaluated. In general, even if the cycling of substances that act on the health of populations, and on the vitality of ecological systems, is not directly sensitive to climate change, these substances may nevertheless be climate-change sensitive if they are closely linked to organic compounds in soils and waters. This is because the turnover of organic compounds is directly sensitive to change in meteorological factors. Effects of global warming on the flux, behavior, fate, and effects of toxic metals and other substances in the environment might be of special concern in Eastern and Central Europe, and other regions with “hot-spot” areas, in particular if climate change manifests itself regionally as shifts in the frequency, intensity, and duration of weather anomalies.

However, these are issues that have been poorly studied so far. Therefore, research on the mechanisms, processes, and interactions involved is of high priority. Until knowledge gaps are narrowed, risk perceptions based on the precautionary principle should be adopted for assessing the effects of global warming on environmental pollution.

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1. Introductory observations

Globalizing the environmental policy agenda must not divert attention from concerns about unresolved, regional environmental problems. Global warming, albeit with unclear manifestations in regional and local climates, is likely to aggravate impacts from already existing environmental stress (including acidification, rising tropospheric oxidant levels, stratospheric ozone depletion, the flux of heavy metals in soils and waters). Among the first scientists to analyze these potential problems in some depth was Oppenheimer, in the late 1980s. In terms of noticeable awareness raising and policy-making, the issue area was first addressed by the German Parliament in 1989; see Figure 1 for a simplified illustration of connections between some of the many environmental impact categories that interact with global warming. Impact categories can be aggravated by, as well as aggravate, climate change (meteorological change). A wide range of climate-forcing substances (CO – carbon monoxide, NO_x – nitrogen oxides, CO_2 – carbon dioxide, CFCs – chlorofluorocarbons (freons), N_2O – nitrous oxide, halons – CFC-like substances containing bromine instead of chlorine, CCl_4 and CH_3CCl_3 – various chlorine-containing substances, CH_4 – methane, and several more) are involved in these interactions, directly or indirectly. Among a multitude of complex linkages, an example is the case wherein global warming (which implies an average warming of the troposphere, and an average cooling of the stratosphere) contributes to a lower temperature in the stratosphere, the ozone content of which then becomes more prone to destruction by chlorine; this is because lower stratospheric temperatures provide for an increasing occurrence of polar stratospheric cloud-particles, the surfaces of which interact with the ozone-depletion process. This, in turn, increases the amount of ultraviolet radiation reaching the Earths ground-near atmosphere, in turn leading to increased potential for build-up of photochemical oxidants that can affect forest growth. Reduced forest growth, in turn, implies a diminished capacity for vegetational uptake of carbon dioxide, which is a greenhouse gas. The greenhouse effect can then increase, leading to further cooling of the stratosphere, and thus to increasing UV-light penetration generating further increases of oxidants that affect forest growth, etc., hence this is an example of the potential for a vicious cycle between climate change, ground-near pollution, and natural resources deterioration.

Since the above illustration first appeared (Study Commission of the 11th German Parliament, *Preventive Measures to Protect the Earth's Atmosphere*, Bonn 1989) the number of observed and potential feedback linkages between the above realms (greenhouse effect, stratospheric ozone depletion, modifications of tropospheric chemistry) and many additional realms (aerosols, land use, demographic change including increasing coastal-zone urbanization, and others) has increased substantially. At the same time, several linkages have been understood to be much more complex than expected. One example is the role of atmospheric aerosols, a major factor behind recently revised climate-change scenarios (Intergovernmental Panel on Climate Change, Working Groups' Third Assessment Reports, 2001).

For example, external contributions to the deposition of contaminants, as well as of compounds from natural sources, are determined, among other things, by large-scale wind patterns and other climatic factors. Some of these factors, such as gale frequency, may already be changing. Were global warming to underpin such factors, a much debated but not yet fully resolved issue, current international policies and protocols for sulfur and nitrogen emissions reductions would need reassessment.

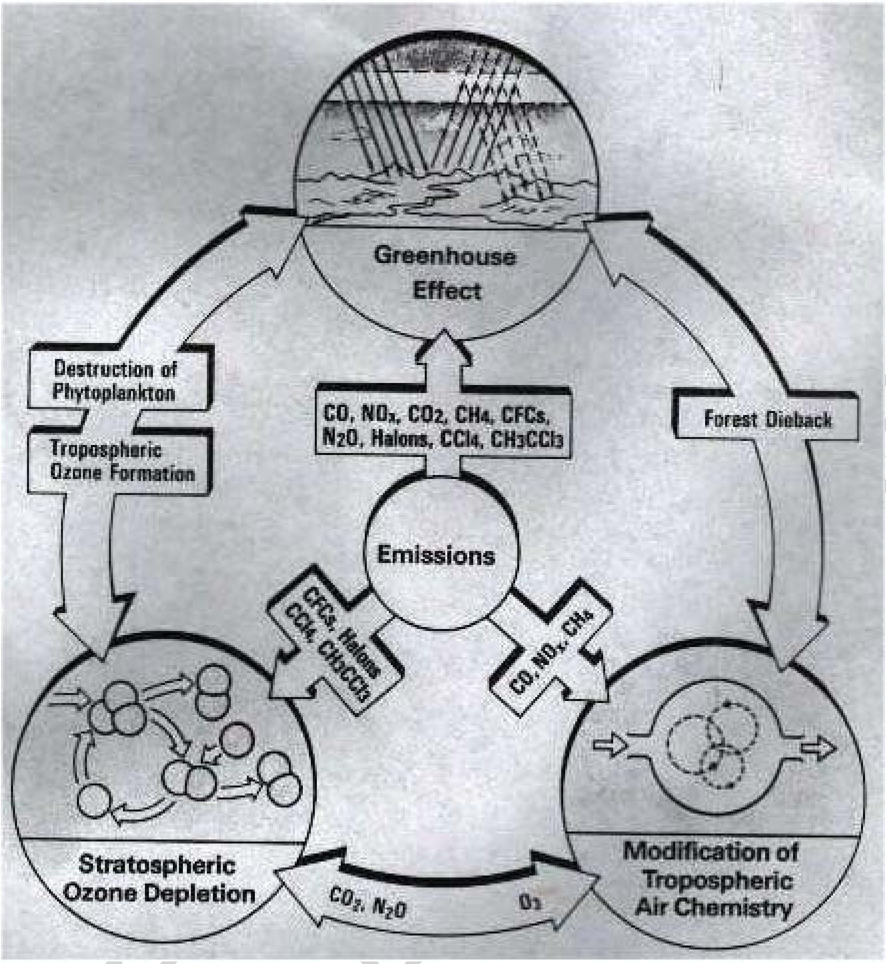

Figure 1. Simplified illustration of connections between some of the many environmental impact categories that interact with global warming.

The tolerance limits that we have begun to try to quantify, in terms of "critical loads" for sulfur and nitrogen, would change subject to additional and different influences. The change should not be expected to be linear. For instance, increasing soil temperatures would manifest themselves exponentially with ensuing effects on fluxes of mercury from the soil to the atmosphere, and from the atmosphere to the biota. Also, risk assessments for a range of chemicals used in agriculture and silviculture might have to be re-evaluated.

2. The Problem of Indirect and Direct Effects

Among the most obvious areas of concern to societies worldwide, with respect to facing the effects of climate change, is agriculture. Perhaps the challenges involved are often seen as one of agricultural sensitivity to "global warming as such", i.e., to increasing temperatures in terms of global averages. Very likely, this is a simplistic perception, however. While agricultural crops and practices might well be fairly easily adapted to not-too-fast changes in average values of meteorological parameters (temperature, precipitation, etc), the real implications of climate change may very likely pertain to shifts in the frequency distribution of these parameters. This would mean that agricultural crops and practices will be challenged by a much more difficult adaptation problem related to (perhaps rapidly changing) frequencies of weather anomalies. Coping with this side of the climate-change problem could lead to increasing demands in agriculture for energy, irrigation, transport, and chemicals, all of which are components and/or activities that belong to the area of "traditional" environmental pollution, and that can exacerbate such "traditional" and local-to-regional problems through increased emissions of toxic, acidifying, or compounds that cause eutrophication.

Therefore, it might well be that indirect and difficult-to-predict pollution effects will be as problematic in an era of climate change as will climate change itself. In addition, among the suggested policy responses to climate change are programs for the development and use of genetically modified organisms, which, unless thoroughly assessed with regard to environmental effects and inadvertent proliferation, might contribute additional complexity to the issue of global-warming effects on "traditional" problems.

As the above example from agricultural sensitivity illustrates, if changing patchiness in time and space would become a predominant characteristic of climate change, local-to-regional effects of climate change would introduce special problems. For instance, the occurrence and extensions of droughts, flooding, smog-formation, and fast melting of snow in montane areas could substantially increase the risks to human health as well as societal infrastructures and the vitality of ecosystems. However, the predictive capability of climate models in terms of temporal and spatial resolution is currently insufficient to enable in-depth analysis of the patchiness problem. This, in turn, further complicates analyses of global-warming effects on biogeophysical and biogeochemical mechanisms, and processes that determine the flows and cycles of environmental pollutants, such as heavy metals and acidifying compounds.

However, the above type of indirect and complex feedbacks between global warming is little researched. Moreover, and unfortunately, the current understanding of direct linkages between climate change and "traditional" environmental pollution is also remarkably limited. The interaction is still weak between the three essential natural-science communities that address, respectively, climate change, stratospheric ozone depletion, and troposphere/soil/water contamination.

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Bibliography

Bowman A.F. (ed) (1990) *Soils and the Greenhouse Effect.* John Wiley and Sons, New York. [This book presents the findings of four expert working groups, which address a multitude of existing or potential feedbacks between climate change, land-use, and soil carbon storage. Although there is an emphasis on the influence of land-use on climate (through greenhouse-gas emissions resulting from, *inter alia*, agricultural and silvicultural practices, climate-change effects on soil carbon storage are also explicitly and implicitly addressed, and important knowledge gaps are identified].
IPCC SAR (2nd Assessment Report) consists of the following reports:

IPCC (Intergovernmental Panel of Climate Change) (1996) *Climate Change 1995 - The Science of Climate Change, Contribution of Working Group I to the Second Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, U.K.

IPCC (Intergovernmental Panel of Climate Change) (1996) *Climate Change 1995 - Impacts, Adaptations and Mitigation of Climate Change: Scientific-Technical Analyses. Contribution of Working Group II to the Second Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press, Cambridge, U.K.

IPCC (Intergovernmental Panel of Climate Change) (1996) *Climate Change 1995 - Economic and Social Dimensions of Climate Change, Contribution of Working Group III to the Second Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, U.K.

[The three IPCC Volumes contributed important update information on the science and policy of climate-change research in relation to the IPCC Assessment Reports published in 1990 (and its follow-up supplements). Among particularly important components was the IPCC SAR's findings with respect to what is known as 'the attribution problem', i.e., that scientific progress "suggests a discernible human influence on global climate"].

IPCC TAR (Intergovernmental Panel on Climate Change, Third Assessment Reports) (2001) *Climate Change 2001: Contribution of Working Groups I, II, and III to the Third Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press, 2001, Cambridge (also compare with the draft reports February 19, 2001). [The Third Assessment Report (TAR) of the IPCC presents findings, in addition to those of IPCC SAR, that in many respects further clarify the attribution of observed climatic changes to societal activities, whilst at the same time, substantially widening the uncertainty with respect to the magnitude and timing of the effects of climatic change as predicted by a variety of climate models].

Lewis D.L., Garrison A.W., Wommack K.E., Whittemore A., Steudler P. and Melillo J. (1999) Influence of environmental changes on degradation of chiral pollutants in soils. *Nature* **401**, 898-901. [This paper is an example of research on the pathways and mechanisms of anthropogenic chemicals of environmental concern that are subjected to microbial activity in soils, which are in turn influenced by significant environmental changes such as global warming].

Lindberg S.E., Meyers T.P., Taylor Jr. G.E., Turner R.R. and Schroeder W.H. (1992) Atmosphere-surface exchange of mercury in a forest: results of modeling and gradient approaches. *Journal of Geophysical Research* **97**, 2519-2528.

Lindberg S.E., Zhang H., Gustin M., Vette A., Marsik F., Owens J., Casimir A., Ebinghaus R., Edwards G., Fitzgerald C., Kemp J., Kock H.H., London J., Majewski M., Poissant L., Pilote M., Rasmussen P., Schaedlich F., Schneeberger D., Sommar J., Turner R., Wallschläger D., and Xiao XZ. (1999) Increases in mercury emissions from desert soils in response to rainfall and irrigation. *Journal of Geophysical Research* **104**, 21,879-21,888.

[The above two research papers present findings with important implications for the role of changing regional climates on the biogeochemical cycling of mercury].

Lindgren E. (2000) *The New Environmental Context for Disease Transmission.* PhD Thesis, Department of Systems Ecology, Stockholm University, ISBN 91-7265-117-2. [A document that addresses the effects of climate change on observed and potential spread of, *inter alia*, insect-borne diseases (such as tick-borne encephalitis)].

MacDonald, G.J. (1998). *Climate and Catastrophic Weather Events*. Paper presented at the Engineering Academy of Japan, 980417. [A paper addressing and exemplifying various factors, in particular climatic change, that are likely to be conducive to changes in the occurrence, intensity, and location of observed and potential extreme weather events].

Nilsson J. and P. Grennfelt (eds) (1988) *Critical Loads for Sulphur and Nitrogen,* UN-ECE and the Nordic Council of Ministers. [One of several documents that marked the introduction of the concepts of 'critical concentrations' and 'critical loads' into the environmental-policy debate, therefore paving the way for a number of international protocols in the arena of acidification-abatement policymaking. However, the impacts of climate change on the critical levels (also known as environmental threshold levels) now need to be taken into due consideration.]

Oppenheimer M.(1989) Climate change and environmental pollution: Physical and biological interactions. *Climatic Change* **15**, 255-270. [Climate change is likely to aggravate impacts from already existing environmental stress; the above paper was among the first scientific contributions to analyze these potential problems].

Schlesinger W.H. (1997) *Biogeochemistry. An Analysis of Global Change.* Academic Press, London. [One of the classic textbooks on biogeochemical cycles and their relationships with climatic change].

Study Commission of the 11th German Parliament, *Preventive Measures to Protect the Earth's Atmosphere,* Bonn 1989. [In terms of noticeable awareness raising and policy-making, the linkages between climate change and 'traditional' environmental-pollution problems were first addressed by the above document].

United Nation's Environment Program (UNEP): *Environmental effects of ozone depletion: 1994 Assessment.* [An example of an authoritative science and policy evaluation of stratospheric ozone depletion; a document that also emphasized the needs for research into the several interactions that may occur between climate change, stratospheric-ozone depletion, acidification, and ground-near ozone formation].

Wang Chien, Prinn R.G. and Sokolov A. (1998). A global interactive chemistry and climate model: formulation and testing. *Journal of Geophysical Research* **103 (D3)**, 3399-3417. [This paper points to the risk that – due to not-unlikely trends in future anthropogenic trace-gas emissions, including climate-relevant gases – the concentration of the major tropospheric oxidizer (the hydroxyl free radical, OH; a 'cleansing agent in the atmosphere') might decrease substantially, resulting in strongly increasing concentrations of air pollutants, such as carbon monoxide and nitrogen oxides].

Wiman B.L.B., Unsworth M.H., Lindberg S.E., Bergkvist B., Jaenicke R. and Hansson H.-C. (1990) Perspectives on Aerosol Deposition to Natural Surfaces: interactions between aerosol residence times, removal processes, the biosphere and global environmental change. *Journal of Aerosol Science* **21 (3)**, 313-338. [This paper introduces and reviews the role of atmospheric aerosols (suspensions of particles in the size-range from nano-meters to micro-meters) in both affecting climate and being affected by climate change].

Wiman, B.L.B., Stripple, J., Chong, S.M. (eds) (2000). *From Climate Risk to Climate Security.* Faculty of Natural Sciences, Kalmar University, and Swedish Environmental Protection Agency. ISBN 91-630-9247-6 [This book provides multi-disciplinary analyses of climate change within the particular risk and security framework of Article 2 of the United Nations Framework Convention on Climate Change (UN FCCC), which requests a "stabilization of greenhouse gases in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system"].

World Resources Institute (1999) *World Resources 1998-99. Environmental Change and Human Health.* Oxford University Press, Oxford. [Among the several annual/bi-annual reports from the World Resources Institute, an organization that provides authoritative environmental statistics and data, and assessments based thereupon].

Zepp R.G., Callaghan T.V. and Erickson D.J. (1998) Effects of enhanced solar ultraviolet radiation on biogeochemical cycles. *Journal of Photochemistry and Photobiology B: Biology* **46**, 69-82. [This paper presents the results of research on mechanisms that involve the effects of ultraviolet radiation on the stability of metal complexes, and the mobility of metals, in water bodies].

Biographical Sketch

Bo L.B. Wiman, after an MSc in Electrical Engineering in 1973, added a few years of training in ecological and earth sciences, and in 1985 received a PhD in ecology. Appointments since the 1970s include advisory and specialist functions to the Swedish Ministry of Industry, the Ministry of Agriculture, and the Institute for Futures Studies. He was acting Professor in 1988 and 1989 at the Natural Resources Management Institute (NRMI), Stockholm University, and a member of the NRMI senior scientist staff 1988-1995. He has served as Associate Professor (environmental systems) at the Department of Environmental and Energy Systems Studies (IMES), Lund Institute of Technology at Lund University, and has been acting Professor (energy systems) at IMES. He has been a member of numerous PhD-thesis committees, and has published in the fields of atmospheric aerosols and of natural-resources management, including aspects of biogeography, theoretical ecology, and climate-change policy response, and has also published several books, on the topics of natural resources management; stabilization and change in ecological systems; and environmental and climate security. He is now Professor of natural resources management research, Kalmar University, Sweden, leading a team of senior scientists and PhD candidates at the Natural Resources Management Research Unit.