DEVELOPING CONSISTENT GLOBAL CHANGE SCENARIOS FOR FINLAND (FINSKEN)

Trends of Ozone and Acidifying Pollutants and Development of Ozone Exposure Scenarios

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Objectives

The aim of the study is to develop future scenarios of air pollution concentrations and depositions in Finland that are consistent with the up-to-date understanding of future global and regional emission scenarios and the effect of climate change on these emissions. An essential part of the research is to understand the emission-dispersion-deposition processes behind the present and past levels of pollutants.

The specific tasks of the study are:

1. Analysis of trends in surface ozone.
2. Development of scenarios of surface ozone.
3. Modelling and mapping the ecosystem-specific ozone dose.
4. Analysis of trends in acidifying air pollutants.

Results

<u>Tasks 1 and 4.</u>

Ambient air concentration trends of ozone and total nitrate were statistically analysed using the observations of the FMI monitoring network. During the 90's, total nitrate concentrations do not confirm the decreasing trends expected as a result of reported declining NO_x emissions. In the southern and central parts of Finland, average ozone concentrations during the second half of the 90's have been higher than during the first half of the decade because the concentrations in unpolluted and moderately polluted air masses have increased. Our results show that within uncertainties due to sampling protocol and analytical error, it is difficult to show significant trends of concentrations of C2-C6 volatile organic compounds or benzene.

<u>Task 2.</u> The most important modeling tool used in the calculation of future ozone concentrations and surface fluxes is the photochemical model of the EMEP-MSC-W at the Norwegian Meteorological Institute. This model is used to study the effects of increasing tropospheric ozone concentrations and European emission scenarios. Specific topics are the sensitivity of the ozone exposure to the tropospheric ozone concentrations and to the temperature via changes in biogenic VOC emissions. The agreed emission reductions (Gothenburg protocol) in Europe will result in a decrease in the harmful ozone concentrations.

The longer-term development will depend on both the regional and global emissions of ozone precursors. The modelling results based on the IPCC SRES scenarios emphasise the role of Eastern Europe on the photochemical pollutants experienced in Scandinavia during the 21st century (Tuovinen et al., 2002). The model calculations are sensitive to boundary conditions, and the assumed free-tropospheric O_3 concentrations. Global atmospheric chemistry studies simulate very high tropospheric ozone concentrations for the fossil fuel intensive A1FI leading to very high ozone exposure also in Finland. The increased air temperatures due to climate warming potentially enhance biogenic VOC emissions and thus affect ozone formation. This was examined by comparing the A1FI scenario run with a sensitivity run in which these emissions were not altered. Significant increases in ozone concentrations were found for a climate change scenario.

To study the sensitivity of local air pollution to atmospheric chemistry and climate factors process type models are used. The photochemical box model was run for four days in a summertime high pressure situation favourable for ozone formation. The results of the calculations showed that ozone production over Finland was reduced when the present day precursor emissions were replaced by the 2010 emissions according to the Gothenburg protocol. Further decrease was obtained for the year 2050 using the SRES A1T emission scenario. The fossil fuel intensive SRES A1FI scenario, on the other hand, has much higher precursor emissions resulting in ozone production over Finland close to the present day situation.

Task 3. The mapping of ozone fluxes and assessing their future development employs a new dry deposition module that has been developed for use within a regional-scale photochemical model to calculate ozone loss from the atmosphere to the ground as a function of land-cover and climate (Emberson et al., 2000). This module includes a partitioning of the total deposition flux between the stomatal and non-stomatal pathways, the former being the component most closely related to ozone impacts to vegetation. The use of flux-based approaches has been identified as the biologically most relevant option for the establishment of improved critical levels for ozone.

Comparison of the directly measured ozone fluxes (Tuovinen et al., 2001) with those calculated by the new EMEP deposition module (Emberson et al., 2000; Emberson et al., 2001; Simpson et al., 2001) showed a reasonable agreement. Measurements at a northern wetland site indicated that for this kind of surface, the traditional approaches of resistance parameterisation need to be revised (Tuovinen et al., 1998). Tuovinen (2000) studied the behaviour of the ozone exposure index AOT40 in the surface layer by combining ozone monitoring data to flux formulations and showed that the index is very sensitive to surface conditions. The high sensitivity was shown to arise from the mathematical properties of this type of threshold index (Sofiev and Tuovinen, 2001).

Consistency with SRES

The produced ozone scenarios used emissions scaled according to those presented by the IPCC SRES report (Nakicenovic and Swart, 2000). Simulations of the present day atmospheric composition use officially reported emissions for the year 1999 and meteorology for the years 1994-1996, simulations of the 2010 use the same meteorology and emissions according to the Gothenburg protocol. Two future scenarios for 2050 were defined based on the IPCC SRES scenarios within the A1 family: A1FI (fossil intensive) and A1T (non-fossil technologies). The emissions of ozone precursors were derived by starting from the SRES data for the A1FI and A1T scenarios and the EMEP database. The EMEP data include the emission reductions agreed within the Convention on Long-range Transboundary Air Pollution under the United Nations Economic Commission for Europe (UN/ECE, 1999). For the model calculations the emissions in the EMEP database for 2010 were scaled according to the relative changes between 2010 and 2050 in the SRES scenarios. We used the emissions derived from the MESSAGE model (Nakicenovic and Swart, 2000). The emissions given by the IMAGE model for these scenarios differ from the MESSAGE estimates. The ozone concentrations in the free troposphere and the background methane concentrations are based on the estimates presented in the IPCC Scientific Report (Houghton et al., 2001). For ozone, these are applied as a scaling factor of the current values in the EMEP model, while absolute mixing ratios are set for methane.

The climate change scenarios for the year 2050 were produced by adding an average temperature change obtained from climate change simulations while the other meteorological fields remained unchanged from the original data set. The reason for this was that air temperature is the only parameter whose change is statistically significant in summer among several climate change models. In addition, it is very difficult to get a climate control simulation which is consistent with the climatology of the meteorological fields used by the EMEP-model, which is the cornerstone of this study. The temperature change was derived from the results of the Europe ACACIA project (Hulme and Carter, 2000). The climate scenarios used in the ACACIA project are based on patterns from AOGCM simulations assuming increasing greenhouse gas forcing of 1% per annum, which were scaled according to the global mean temperature response across the range of preliminary SRES emissions scenarios.

The ozone scenarios produced in this project are consistent with the SRES-scenarios. The regional emissions scenarios produced for Europe only do not cover all ozone precursor species and it is difficult to link them to global emissions and atmospheric concentrations, which, however, have a great impact on the ozone concentrations in Finland.

Future work

To obtain reliable scenarios of future ozone concentrations in Finland, investigations on the causes of past trends are needed. The current increasing trend of ozone concentrations contradicts the relatively stable or decreasing concentration trends of the oxidised nitrogen species. If the ozone concentration continues to increase at the present rate, it cancels the beneficial regional abatement measures. Then, the regional emission reduction planning has to take into account the global emission scenarios. To exclude the effect of local or regional emissions on the contradicting trends, further studies on locally important atmospheric chemistry processes that are not taken into account in the regional modelling are needed. The photochemical trajectory model at the FMI will be used to investigate the possible role of local photochemical processes on long-term trends.

The ozone scenarios developed for this project will be published. An attempt will be made to get a wider set of scenarios in order to provide more significance to the obtained results.

This project is aiming at detailed ecosystem specific ozone fluxes. For that purpose we have actively participated in the development of the new dry deposition scheme of the EMEP model. The new module is well adapted to the Nordic conditions because during the development it has been tested against direct ozone flux measurements over Finnish ecosystems. This module is the basic tool when estimating ozone fluxes to the most important ecosystems in Finland. The new modeling environment at EMEP will be ready in 2002 and can be utilised to produce regional ozone flux maps for the vegetation effect studies.

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