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.

Methods

The methods used in the tasks are:

<u>Tasks 1 and 4.</u> Statistical analysis of trends of ambient air concentrations of trace species and wet deposition data is carried out. Meteorological data, including trajectories and weather patterns, will be used to distinguish between factors related to meteorology and emissions. The results will be compared to trends observed in neighbouring areas.

<u>Task 2.</u> The most important modeling tool used in the calculation of future ozone concentrations and surface fluxes is the photochemical model used in the EMEP-MSC-W at the Norwegian Meteorological Institute. This model will be 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. Boundary conditions for the European model will be taken from a global Chemistry Transport Model. To study the influence of future changes in the global tropospheric air composition on the European scale, the EMEP-model has been coupled to the global CTM at the University of Oslo which provides the boundary conditions for the regional model (Jonson et al., 2001). This model system, including changes in tropospheric ozone concentrations, has been used to estimate the ozone concentrations near surface over Europe in 2010.

To study the sensitivity of local air pollution to atmospheric chemistry and climate factors process type models will be used. A model to calculate detailed emissions of biogenic Volatile Organic Compounds has been developed at the FMI (Lindfors et al., 2000). This model will be used to investigate the effect of climate change on the biogenic VOC emissions. The effect of emission changes on the photochemical processes and local ozone concentrations will be calculated using a photochemical box model (Lindfors et al., 1999) that has a much more detailed speciation of VOCs and a more complex chemistry scheme than the 3-D models.

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. The new deposition module, interlinked with a regional-scale photochemical model and a land cover database, provides a flexible tool for the mapping of ozone-induced risks, but requires extensive testing and validation to prove acceptable for such a task.

The deposition module builds on a multiplicative stomatal uptake model that describes the stomatal conductance as a function of plant species, phenology and four environmental variables (air temperature, solar radiation, water vapour pressure deficit, VPD, and soil moisture deficit). The stomatal conductance model has been parameterised for a number of European plant species. For the deposition module, the data were grouped into 13 representative land cover classes, these being complemented by 3 other vegetated and 4 non-vegetated classes. The module is being implemented in the 3-D photochemical long-range transport model of EMEP. The meteorological input data are obtained from a numerical weather prediction model.

Preliminary results

Tasks 1 and 4. Since the late 1980’s, ozone concentrations have increased in the southern and central parts of Finland. Both the concentrations exceeding 40 ppb, which contribute to the AOT40 vegetation exposure index, and especially the percentiles of the lower concentrations were higher during the late 1990’s compared to the first half of the decade. The fact that the clean air masses, which originate from the northern sea areas and arctic regions, have the highest rate, suggest an increase of the background ozone concentrations. The concentration increase was about 5 ppb during the 1990’s. We have not found any obvious meteorological reasons for the changes, based on a preliminary study only. The yearly average concentrations of nitrate in wet deposition show decreasing trends (20-year data) and the concentrations of oxidised nitrogen in ambient air are stable or increasing (11-year data), in accordance with the NOx emission estimates. In general, these decreases should result in lower ambient air ozone concentrations.

Task 2. We studied the sensitivity of the surface ozone exposures calculated by the Lagrangian photochemical CTM-model of the EMEP-MSC-W to the tropospheric ozone concentrations over Finland. The model results depend very much on these boundary conditions especially in the northern parts of Finland. In general, the model simulations show too low ozone exposures in Finland. The most probable reason is too low ozone concentrations used as boundary conditions. The biogenic VOC emission model has been further developed to include more environmental parameters that affect the emissions. Climate change has a direct influence on the biogenic emissions because the emissions are highly dependent on temperature and radiation.

Task 3. The overall performance of the new deposition module looks very promising when compared against field observations. For the northern ecosystems, the model predicts, on average, reasonably accurate deposition parameters. However, limitations in some process parameterisations were detected, mainly due to unrepresentative assumptions regarding the aggregated vegetation classes.

Sensitivity tests of the deposition module indicate that increasing temperatures may potentially have an enhancing effect on the stomatal conductance, especially for cereals. The direct temperature effect is compensated by an opposite effect due to increased water vapour pressure deficit, the degree of this compensation depending on the climatic conditions. According to the sensitivity analysis, an increase by 5 ºC would have a small net effect in southern Europe, but result in a significantly enhanced stomatal uptake of ozone in Finland.

Future work

To reach 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 will be calculated using the EMEP oxidant model when the emission scenarios are available. The sensitivity to the boundary conditions will be further studied as specific tasks.

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 adapted well to the Nordic conditions because during the development it has been tested against direct ozone flux measurements over Finnish ecosystems. The new scheme calculates the stomatal functioning and the ozone uptake using environmental parameters. Already, the effect of humidity and increasing temperatures on the ozone uptake has been studied. In the next phase, also other climate change related parameters, for example the soil moisture, will be investigated. This module is the basic tool when ozone fluxes to the most important ecosystems in Finland are calculated for the FINSKEN scenarios.

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FINSKEN-contributions

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