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The Influence of Climate on Ozone Risk for Vegetation

Jenny Klingberg, 2011
Institutionen för växt- och miljövetenskaper
Naturvetenskapliga fakulteten

Akademisk avhandling för filosofie doktorsexamen i Tillämpad miljövetenskap, som med tillstånd från Naturvetenskapliga fakulteten kommer att offentligt försvaras onsdagen den 1 juni 2011 kl. 10:00 i Hörsalen, Institutionen för växt- och miljövetenskaper, Carl Skottsbergs gata 22B, Göteborg.

Fakultetsopponent: Dr Lisa Emberson, Stockholm Environment Institute (SEI) & Environment Department, University of York, UK
Examinator: Professor Leif Klemedtsson, Institutionen för växt- och miljövetenskaper, Göteborgs universitet

ISBN: 978-91-85529-47-6

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Department of Plant and Environmental Sciences, University of Gothenburg

Abstract: Ground-level ozone (O_3) is a harmful air pollutant causing reduced crop yield and quality, reduced forest growth and negative effects on human health in large parts of the world. O_3 is generally seen as a regional scale air pollution problem, but O_3 concentration ([O_3]) variation on a smaller geographical scale can be considerable. Knowledge of the size of this local scale variation and the underlying causes is important in environmental monitoring and assessments of O_3 exposure. The local scale variation in [O_3] in Sweden was investigated and described in relation to local climate and site characteristics such as altitude, topography, vicinity to the coast and local NO emissions based on measurements of [O_3] and meteorology with a mobile monitoring station. In addition, [O_3] and [NO_2] were measured with passive diffusion samplers and [O_3] data from permanent monitoring stations were analysed. The strength of nocturnal temperature inversions was found to be crucial in determining the differences in average [O_3] and diurnal [O_3] range (DOR) at rural sites in southern Sweden. Inland low sites experienced stronger nocturnal temperature inversions, lower average [O_3] and larger DOR compared to inland high and coastal sites. In addition, the underlying surface (important for the deposition rate), advection of O_3-rich marine air and local NO emissions also influence the local scale variation of [O_3]. The negative effects of O_3 on vegetation are more closely related to the plant uptake of O_3 through the stomata than to the [O_3] in the ambient air. Environmental factors such as humidity, temperature and light, influence the degree of stomatal opening and thus the stomatal O_3 flux into the leaf interior. The flux-based POD_Y-index (phytotoxic O_3 dose above a flux threshold Y) was used to assess the O_3 risk for vegetation. It allows modification of O_3 uptake by climatic conditions to be incorporated in O_3 risk assessment for vegetation. A large part of the local scale variation in [O_3] in southern Sweden occurs during night-time. At night the stomatal O_3 uptake by vegetation is low and the risk of O_3 damage is therefore not greatly influenced. Thus, plant stomatal O_3 uptake and O_3 risk for vegetation are less influenced by the site position in the landscape than 24-hour average [O_3]. At the coastal sites the [O_3] were higher also during daytime, which implies an increased risk of negative effects of O_3 on vegetation compared to inland sites. The influence of potential future climate change on the flux-based risk of negative effects of O_3 on vegetation in Europe was investigated with modelled future [O_3] from the chemistry transport model MATCH and meteorology from the regional climate model RCA3. The future plant O_3 uptake and risk of O_3 damage to vegetation was predicted to remain unchanged or decrease in Europe, despite substantially increased modelled [O_3] in Central and Southern Europe. The expected reduction in stomatal conductance with rising atmospheric [CO_2] is of large importance for this result. However, the magnitude of the CO_2 effect is uncertain, especially for trees. If the CO_2 effect will turn out to be small, future climate change has the potential to dramatically increase the flux-based O_3 risk for vegetation in Northern and Central Europe.

Keywords: local climate, topography, nocturnal temperature inversions, ozone spring peak, passive diffusion sampler, AOT40, stomatal ozone flux, stomatal conductance, phytotoxic ozone dose, EMEP, MATCH, RCA3, climate change

ISBN: 978-91-85529-47-6
http://hdl.handle.net/2077/25120