Radiation-transfer modeling of snow-pack photochemical processes during ALERT 2000

William R. Simpson\textsuperscript{a},\textsuperscript{*}, Martin D. King\textsuperscript{a},\textsuperscript{1}, Harald J. Beine\textsuperscript{b,2}, Richard E. Honrath\textsuperscript{b}, Xianliang Zhou\textsuperscript{c}

\textsuperscript{a} Department of Chemistry, International Arctic Research Center, Geophysical Institute, University of Alaska Fairbanks, Fairbanks, AK 99775-6160, USA
\textsuperscript{b} Department of Civil and Environmental Engineering, Michigan Technological University, 1400 Townsend Drive, Houghton, MI 49931, USA
\textsuperscript{c} Wadsworth Center/NYSDOH, and School of Public Health/SUNY at Albany, Albany, NY, USA

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Abstract

The delta-Eddington radiation transfer model is used to calculate actinic fluxes and photolysis rates within the snow pack during the ALERT 2000 field campaign. Actinic fluxes are enhanced within the snow pack due to the high albedo of snow and conversion of direct light to diffuse light. The conversion of direct to diffuse light is highly dependent on the solar zenith angle, as demonstrated by model calculations. The optical properties of Alert snow are modeled as 100\,\mu m radius ice spheres with impurity added to increase the absorption coefficient over that of pure water ice. Using these optical properties, the model achieves good agreement with observations of irradiance within the snow pack. The model is used to calculate the total actinic flux as a function of solar zenith angle and depth for either clear sky or cloudy conditions. The actinic flux is then used to calculate photochemical production of nitrogen oxides from nitrate photolysis assuming that nitrate in snow has the same absorption cross section and quantum yield in snow as in aqueous solution. Assuming all photo-produced nitrogen oxides are released to the gas phase, we derive a maximal flux of nitrogen oxides (\textit{NO}_x + \textit{HONO} and possibly other products) from the snow pack. The value of this maximal flux depends critically on the assumed quantum yield for production of \textit{NO}_2, which is unknown in ice. Depending on the assumed quantum yield, the calculated maximal flux varies between values four times smaller than the observed \textit{NO}_x + \textit{HONO} flux to five times larger than the \textit{NO}_x + \textit{HONO} flux. Therefore, it appears that the calculated flux is in approximate agreement with the observations with a great need for improved understanding of nitrogen photochemistry in snow. © 2002 Elsevier Science Ltd. All rights reserved.

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1. Introduction

Recent studies indicate that ultraviolet light drives photochemical processes within the snow pack (Couch et al., 2000; Honrath et al., 1999, 2000a, b; Hutterli et al., 1999; Jones et al., 1999, 2000; Sumner and Shepson, 1999). One of the goals of the ALERT 2000 campaign was to investigate the chemical fluxes produced by these photochemical processes. Specifically, we were interested in the production of \textit{NO}_x from snow-pack nitrate photolysis. This chemistry is one of the most clearly indicated snow-pack photochemical processes (Hoffman, 1996; Honrath et al., 1999, 2000a, b; Jones et al., 1999, 2000).

Radiation transfer in the snow pack controls the depth to which photochemical processes occur. The