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Review

A review of parameterizations for modelling dry deposition and scavenging of radionuclides

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Abstract

This article aims at reviewing the state-of-the-science parameterizations for modelling dry deposition and scavenging of atmospheric tracers, with a focus on radionuclides. These parameterizations are key components of the numerical models that are used for environmental forecast. We present detailed models and parameterizations. Both are characterized by many uncertainties.

Keywords: Dispersion models; Dry deposition; Wet scavenging; Parameterizations

Contents

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0. Introduction

Dry deposition and scavenging processes (rainout and washout) are key processes for the evolution of radionuclides in the atmosphere. The current state-of-the-science dispersion models (the so-called chemistry-transport models) used for radionuclides strongly rely on parameterizations for these processes.

There are however many sources of uncertainty. The first source is related to the meteorological fields, especially the rain intensity or the cloud characteristics (liquid water content and diagnosis) for scavenging. The second source is related to the microphysical description of the processes. The behaviour of radionuclides is strongly related to their chemical form as they may be released in the atmosphere as gases and particles. For instance, it is usually assumed that most of cesium is bound to particles (aerosols) while iodine is either bound to atmospheric aerosols or in gaseous form (elemental form and organic iodine CH_3I). The partitioning between gaseous form and particles and the size distribution of aerosols strongly affect dry deposition and scavenging.

Wet scavenging is usually parameterized by $\mathrm{d}c/\mathrm{d}t = -\Lambda c$ with c the concentration and Λ the scavenging coefficient (in s^{-1}). One usually distinguishes in-cloud scavenging (*rainout*) and below-cloud scavenging by raindrops (*washout*). It is often recognized that the wet scavenging of radionuclides is mainly related to particles (Chamberlain, 1991, p. 133) and is more important for rainout. The parameterizations are highly uncertain due to the difficulty of characterizing the aerosol distribution and the uncertainties for rain intensity.

Dry deposition is often applied as a boundary condition for vertical turbulent diffusion through $K_z \nabla c \cdot \mathbf{n} = E - v_{\mathrm{dep}} c$ with K_z the eddy coefficient, E the surface emission (possibly for resuspension) and v_{dep} the dry deposition velocity. $\mathbf{n}$ is the unit vector oriented upwards. The deposition velocity depends on the surface meteorological fields, on the land use coverage and on the physical and chemical properties of the tracer.

Parameterization for Λ and v_{dep} are therefore required for 3D modelling. Many articles have already been devoted to these topics, ranging from theoretical studies focussed on detailed modelling to empirical parameterizations. The objective of this paper is to summarize the available parameterizations (to our knowledge), to underline the common characteristics and the differences and to investigate the uncertainties. The hope is that it may be useful for a modeller to have the synthesis of the majority of published data.

This article is structured as follows. We briefly summarize in Section 1 the key facts for the possible form of the radionuclides in the atmosphere. We emphasize on the measurements following the Chernobyl accident. Detailed and parameterized models are given in Sections 2 and 3 for dry deposition and wet scavenging, respectively. For each process, detailed models are presented and then empirical models, usually based on tuning to measurements. The focus is put on particles and wet scavenging. The article ends with conclusions.

1. Background for radionuclides

Three features have a strong impact for the loss properties of atmospheric radionuclides: the partitioning between gases and aerosols, the partitioning between the organic and inorganic forms and the aerosol size distribution.

Gas/aerosol partitioning: The radionuclides may be released into the atmosphere as gases and/or particles. The partitioning between both phases is a crucial issue for loss processes and there are many uncertainties reported in the literature, especially following the Chernobyl accident. For instance, short-range measurements (Ogorodnikov et al., 1994) indicate a gaseous fraction ranging from 30% to 90% of the total mass. Measurements in Great Britain (Clark and Smith, 1988) give a ratio of particle mass to gaseous mass ranging from $\frac{1}{3}$ to $\frac{1}{2}$. This ratio is estimated to range from $\frac{1}{5}$ to $\frac{1}{3}$ in Germany (München, Chamberlain, 1991, p. 124), to