Deep convective transport in a two-dimensional model: Effects on lower stratospheric aerosols and ozone

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Abstract

Two-dimensional (2D) photochemical models are a widely used tool to study tracer species distribution in the middle-atmosphere. On the other hand, many features of the lower stratosphere are driven by troposphere-stratosphere exchanges at the tropical tropopause. Here 2D models suffer for the lack of appropriate mixing mechanisms in the troposphere, in particular cumulonimbus convection. It is developed here a first-order parameterization of this tropospheric mixing process, with the purpose of making these kind of models more meaningful for studies focusing on lower stratospheric chemistry. A validation is made with Rn-222 profiles from observations and three-dimensional calculations. Another validation is made using sulphur dioxide and sulphate. It is shown that inclusion of deep convection helps reconcile the calculated stratospheric aerosol load with SAGE-II observations: a factor of two increase of stratospheric sulphate mass is predicted with respect to a ‘standard’ 2D simulation without convection. The effects of the ‘convectively’ enhanced stratospheric aerosol surface area density on heterogeneous chemistry and ozone are also discussed: absence of tropospheric convection would produce a 3% overestimate of total ozone with respect to the realistic case including both convection and sulphate aerosol feedback on NO\(_x\) and chlorine/bromine chemistry. The deep convection scheme adopted here is validated only for tracers of continental origin, but it could be easily extended also to oceanic source tracers.

1 Introduction

Photochemical two-dimensional models (2D) have been extensively used in the last two decades for sensitivity studies on the chemical composition of the stratosphere (NASA, 1988; NASA, 1993). Several theoretical and modeling studies were made to show that a physically sound representation of species transport is possible in the middle atmosphere using zonally averaged models.