



Sensitivity of the Earth's middle atmosphere to short-term solar variability and its dependence on the choice of solar irradiance data set

A.V. Shapiro^{a,b*}, E. Rozanov^{a,b}, T. Egorova^a, A.I. Shapiro^a, Th. Peter^b, W. Schmutz^a

^aPhysikalisch-Meteorologisches Observatorium Davos/World Radiation Center, Davos, Switzerland

^bInstitute for Atmospheric and Climate Science ETH Zurich, Switzerland

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ABSTRACT

We simulate the time-evolution of the neutral and charged species in the terrestrial middle atmosphere using a 1-D radiative-convective model with interactive neutral and ion chemistry driven by four different sets of daily spectral solar irradiance (SSI) available in the literature for the year 2000. Obtained daily time series of ozone, hydroxyl and electron densities are used to calculate their sensitivity to the short-term SSI variability at 205 nm. All applied SSI data sets possess 27-day solar rotation cycle; however, its amplitude and phase as well as the correlation between considered SSI time series differ among data sets leading to the different behavior of the atmospheric response. Contrary, the ozone and hydroxyl sensitivities to the SSI changes during solar rotation cycle are almost identical for all applied SSI data sets in the stratosphere. In the mesosphere, the difference in correlation between SSI in Herzberg continuum and Lyman- α line in considered SSI data sets leads to substantial scatter of the sensitivity estimates based on 205 nm. Our results show that for the sensitivity analysis in the stratosphere based on the SSI at 205 nm any considered SSI data sets can be applied. For the mesosphere, where the sensitivity strongly varies among applied SSI data sets more robust results can be obtained using the sensitivity calculations based on the SSI in Lyman- α line.

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1. Introduction

Climate response to the solar spectral irradiance (SSI) variations has been under consideration for a long time. The most recent efforts were aimed at the analysis of the decadal scale solar signal in stratospheric ozone and temperature obtained from the observations and model simulations (Rozanov et al., 2004; Soukhanov and Hood, 2006; Randel and Wu, 2007; Austin et al., 2008; Randel et al., 2009). The results of these efforts revealed important convergence of the observed and simulated ozone and temperature response to the decadal scale variability of the spectral solar irradiance; however, noticeable discrepancies in the magnitude and shape of the simulated and observed solar signal still remain (Austin et al., 2008; Rozanov et al., 2008). One of the possible reasons for this disagreement is an application of the multiple linear regression analysis technique for the extraction of solar signal from the rather short time series covering only three full solar cycles. As SSI and ozone measurements are available for many solar rotational cycles, the analysis of the climate response caused by the 27-day solar rotation cycle is more promising. This

problem was addressed by many authors (Hood, 1986, 1999; Summers et al., 1990; Baranov, 1993; Fleming et al., 1995; Chen et al., 1997; Williams et al., 2001; Rozanov et al., 2006; Grudev et al., 2009). In particular, it was shown that ozone responses observed and simulated with 3-D models agree reasonably well in the middle stratosphere (Rozanov et al., 2006; Grudev et al., 2009). However, in the upper/lower stratosphere and mesosphere the uncertainty in the ozone response remains high. In addition, temperature response in the entire middle atmosphere is not robust (Rozanov et al., 2006; Grudev et al., 2009), which inspires further investigation of this problem. One of the issues to be considered is the representation of the SSI variability on daily time scale.

The solar rotation cycle in the solar irradiance is a manifestation of the spatial inhomogeneity in the distribution of the bright/dark features on the solar surface and differential rotation of the Sun. Different life cycle of the bright/dark features in combination with different dependences of their contrasts on the heliospheric angle lead to some phase lag between the variability of the solar irradiance at different wavelengths. The response of the atmospheric species is wavelength dependent (Fleming et al., 1995; Chen et al., 1997; Rozanov et al., 2002), therefore inappropriate representation of this phase lag in the applied SSI data can have an implication for the estimation of the response for different species. Most of the modeling studies (Fleming et al., 1995; Chen

* Corresponding author at: Physikalisch-Meteorologisches Observatorium Davos/World Radiation Center, Davos, Switzerland.

TEL: +41(0) 41 75 022; fax: +41(0) 41 75 100

E-mail addresses: avshapiro@pmo.dawc.ch (A.V. Shapiro).

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