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Solar activity cloudiness effect on NH warming for 1980–2095

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Abstract

We use a Thermodynamic Climate Model (TCM) to compute the Northern Hemisphere temperature anomaly for the period 1980–2095, corresponding to the global warming (GW) by the increase of the atmospheric CO_2; the GW is in turn diminished as a consequence of the negative anomaly of the solar activity (SA), giving a warming reduction (WR). So the CO_2 and the SA represent external climate forcings. The total solar irradiance (TSI) is the main manifestation of the SA and of course is the climate driver; the SA produces besides the solar wind that modulates the flux of galactic cosmic rays (GCR), which in turn modifies the low cloud cover, that by itself influences inversely the mid cloud cover; the combination of both cloudiness yields the so called relevant cloud cover. The GCR-cloudiness effect has a delay of ~1 yr with respect to TSI effect, which is the time for a SA change to reach the heliopause carried by the solar wind. In order to incorporate this climate mechanism, the TCM now includes the warming due to the vapor condensation by GCR, which causes a decrease in the magnitude of the WR. The TCM was improved by incorporating it new parameterizations of three mechanisms, which are activated by the GW: the atmospheric lapse rate changes; the water vapor emissivity between 8 and 12.5μ is computed with the E-Trans/HITRAN calculator; and changes in this emissivity band according to the relative humidity changes. The 11-yr variability of the TSI time series is filtered to get the trend along 21st century. Two IPCC (2001, 2007) CO_2 emission scenarios are used: the high A1FI and the low A1T. Emphasis is made on the results for two particular years: one corresponding to the deepest part of the TSI grand solar minimum in the year 2029, and the other to the end of the century, 2095. The main thermal feedbacks included in TCM are those due to the atmospheric greenhouse effect by water vapor, to the cryosphere-albedo and to cloudiness-albedo.

By 2100 the GW from the TCM is 5.1 °C for A1FI and 2.6 °C for A1T. On 2029 and including all the model forcings and feedbacks, and for those scenarios, the WR is 0.31 and 0.33 °C, respectively; by 2095, the corresponding values are ~0.17 and ~0.12 °C. When the warming due to vapor condensation induced by the GCR effect is excluded, for A1FI the WR increases from 0.31 to 0.53 °C by 2029, and from 0.17 to 0.29 °C by 2095; and for A1T from 0.33 to 0.65 °C by 2029, and from 0.12 to 0.23 °C by 2095. The net GW (including the WR) for both scenarios is within the range reported by the IPCC (2001). The WR is greater for the A1T on 2029, which indicates that an atmosphere with less CO_2 is more sensitive to the SA. Thus, we obtain the interesting result that the heat released in this process, masks to some degree the climate effect that these clouds have on the GW.

Keywords: Solar activity; Galactic cosmic rays; Climate model; Atmospheric CO_2; Warming reduction; Global warming

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1. Introduction

Many works have attempted to estimate the impact of solar variability on climate through solar or solar-associated phenomena such as the sunspots or geomagnetic activity (e.g. Dobrica et al., 2009; Paluš and Novotná, 2009; Souza-Echer et al., 2009; Kossobokov et al., 2010), the total solar irradiance (TSI) (e.g. Lean et al.,1995; Cubasch and Voss, 2000; Kristjánsson et al., 2002; Shindell et al., 2006; Mendoza and Velasco, 2009), the ultraviolet radiation (e.g. Haigh, 1996; Shindell et al.,1999), the solar wind modulation of the global-electric circuit (Tinsley, 2000), and the galactic cosmic rays (GCR) flux (e.g. Tinsley and Dean, 1991; Pudovkin and Veretenenko, 1995; Marsh and Svensmark, 2000; Pallé-Bagó and Butler, 2000; Svensmark, 2007).

Particularly, Svensmark and Friis-Christensen (1997) found a good correlation between cloud cover anomaly and GCR for the period 1983–1994, suggesting that GCR modulate the production of clouds on time scales of decades and longer. Afterwards, many others have also studied this possibility and the spectrum goes from the view that the GCR are the main contributor to radiative forcing through clouds (e.g. Svensmark, 2007) or that they can partially affect cloud formation (e.g. Voiculescu et al., 2006), to claim that GCR have a negligible effect on climate (e.g. Kristjánsson et al., 2008; Erlykin et al., 2009). Other simulations and calculations indicated that the contribution is negligible at global scale (e.g. Pierce and Adams, 2009; Erlykin and Wolfendale, 2011; Kazil et al., 2012). The data analysis of the Moderate Resolution Imaging Spectroradiometer (MODIS) by Laken et al. (2012) shows no statistically significant correlations between cloud anomalies and cosmic rays. However, also using the same MODIS data, Svensmark (2012) find a response of some cloud properties to Forbush GCR decreases. Thus, at the present time the question of whether GCR modulate climate through cloud anomaly remains controversial.

Solar activity (SA) phenomena have been measured as declining during the past two solar cycles. For instance, the sunspot number, the TSI and the open magnetic flux peaked around 1985–1987 and have declined since (Lockwood and Fröhlich, 2007). In particular, for the declining phase and minimum of solar cycle 23 (1996–2008) the measurements indicate that: The TSI has fallen below the minima seen during the previous two solar minima (Lockwood and Fröhlich, 2007). The Sun polar magnetic fields are half to third times weaker than for the previous two cycles and in general the heliospheric magnetic flux has decreased in comparison to the previous minimum (Smith and Balogh, 2008). Observations of solar wind from both large polar coronal holes during the satellite Ulysses' third orbit showed that the fast solar wind was slightly slower, significantly less dense, cooler, and had less mass and momentum flux than during the previous minimum (McComas et al., 2008). Moreover, the solar cycle 24, starting in 2009, either has reached its maximum in 2012 with ~58 sunspots or will during 2014 with ~85 sunspots, while the previous cycle 23 had a maximum of 120 sunspots (http://www.sidc.be/sunspot-data/). Other works have even estimated a future 21st century solar activity grand minimum (Jones et al., 2012; Velasco-Herrera et al., 2015). If the Sun is actually heading toward a grand minimum, such low SA may have consequences on the Earth´s climate.

In a previous paper and using a Thermodynamic Climate Model (TCM) (Mendoza et al., 2010), we assessed the effect of the SA on temperature, modeling its trend in the Northern Hemisphere (NH) for the years 2009–2029, corresponding to solar cycles 24 (2009–2020) and 25 (2021 to ~2032). The present work extends that study, modeling the NH temperature trend up to the year 2100, with the atmospheric CO_2 and the SA by means of the TSI as forcings, on considering that the latter has not only a direct effect on climate, but also an indirect one through the modulation of the low cloud cover. Two CO_2 emission scenarios are used, both published in the Third and Fourth IPCC (2001, 2007) Assessment Reports. One scenario has a high fossil fuel consumption (A1FI) with ~970 ppm by 2100 and the other presents a low fossil fuel consumption (A1T) with ~580 ppm at 2100. For the next one hundred years the TSI estimation by Velasco-Herrera et al. (2015) with a grand minimum by 2029 is used.

We define the global warming (GW) as the surface temperature anomaly due to the increase of atmospheric CO_2; the GW is in turn diminished as a consequence of the SA negative anomaly, giving a warming reduction (WR).

We assume that the cloud anomaly comes from two sources: the climatic internal process and an external one that we attribute to SA through GCR. Then, the effect of SA on climate would be twofold: higher/lower SA will produce an increase/decrease in the TSI with the consequent heating/cooling of the Earth's climate. This effect would be amplified by a decrease/increase in the cloud cover and therefore in the planetary albedo, produced by the decrease/increase of GCR. As the GCR flux is anticorrelated with TSI (Marsh and Svensmark, 2000; Ahluwalia, 2014), we can use either the TSI or the GCR to find the cloud cover.

The TCM used in the present work has been improved in two aspects: (a) in agreement with the IPCC (2007), we introduced a lapse rate that increases with the GW without changing the temperature at the top of the troposphere, and (b) we incorporated a parameterization of the emissivity (e) of the water vapor in the spectral interval of 8–12.5μ considering that the relative humidity (h) is not conserved during the climate change. This parameterization reproduces well the corresponding emissivity computed with the spectral calculator E-Trans with HITRAN database (http://www.jcdpublishing.com/software6.html), which is more sensitive than Ramanathan´s (1976).

The paper is organized as follows: Section 2 introduces the input data; Section 3 describes the TCM; Sections 4, 5 and 6 present the water vapour feedback, radiative