From northern there

Description

Motivation

Over the past decades, issues related to global warming have become relevant. We consider the effect of the albedo of the snow cover on the Earth's surface, which leads to increased surface temperatures in the spring season.

Description of the technology for calculating radiation forcing (RF), associated with account for black carbon (BC) emissions

Estimates of additional RF are derived from changes in surface albedo. For this, we used the data of a historical experiment with the climate model INMCMC [1], as well as the one-dimensional model of radiation transfer in the snow layer SNOW-ICE-AERosol [2].

In a historical experiment with INMCMC, conducted as part of the CMIP6 project [3], the climate of the Earth system was modeled from 1850 to 2014. In this case, the external influence on the Earth's system was established as close as possible to the observable. Based on the monthly average data of the model on the height of the snow cover $n_i$, as well as on the flow of black carbon from the atmosphere $b_{down}$, provided that the precipitation of BC is evenly mixed in the snow, the BC concentration in each cell of the model grid was calculated using the following formula:

$$n_i = b_{down} = \frac{\Delta m_i}{\rho \Delta z_i},$$

where $t$ is time interval (1 month), $\rho$ is density

To clarify the results when calculating the mass of BC, its stocks from the previous month were taken into account. Let, there is a time series of values $\{b_{down}, m_i\}$ of the average monthly thickness of snow and the mass of precipitation BC in the cell covered with snow, respectively. Then for the specified mass of BC in the cell $M_i$ we have:

$$M_i = m_i + M_{i-1} \times \min \left( \frac{1}{\delta_{down}}, 1 \right), \text{ if } h_i > 0, \ h_{i-1} > 0;$$

Then, using the obtained BC concentrations and the SNICAR model, we calculated the changes in surface albedo and radiation forcing caused by BC emissions from forest fires. It was assumed that the cosine of the solar zenith angle for the northern hemisphere depends on the declination angle of the Sun and latitude as follows: $\delta = \delta_{down}$ is the declination angle of the Sun, $\psi$ is latitude, $\delta$ is the solar zenith angle.

$$\cos \theta = \cos (\psi - \delta), \text{ where: } \sin \theta = \sin \sin \left( \frac{\pi}{180} \delta \frac{90 - \psi}{90} \right)$$

Then: $cos \theta = 0.6$, where: $\theta = \sin \sin \left( \frac{\pi}{180} \delta \frac{90 - \psi}{90} \right)$.

$\delta = 23.45^\circ$ is the inclination of the Earth to the plane of the ecliptic, $d$ is the time (in days), $d_j = 80.5$. For each month, this value was calculated at noon on the 15th.

From the SNICAR model, we obtain albedo values corresponding to different wavelengths of incident radiation ($\alpha_{down}$ is the visible range, $\alpha_{down}$ is the near infrared range) corresponding to clean and dirty snow ($b_{down}$ and $\alpha_{down}$). Based on these results, radiation forcing was calculated using the following formula:

$$\Delta R_{down} = \alpha_{down} (\alpha_{down} - \alpha_{down}) \times \frac{0.5}{p_{down}} \times \frac{1}{p_{down}}, \text{ where } \Delta R_{down} \text{ is the incoming short-wave radiation flux in this mesh cell from the INMCMC model.}$$

Assessment of additional RF due to forest fires

Since anthropogenic emissions of black carbon significantly exceed emissions resulting from biomass burning, two seasons that differ in the intensity of forest fires were chosen to study the role of forest fires in the radiation balance. Based on GFED [4], 1998 and 2001 were chosen as such seasons (which corresponds to large and small emissions of BC at mid-latitudes into the atmosphere as a result of biomass burning, respectively). Moreover, it is known that the anthropogenic source for the specified period has changed slightly.

References:


