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A new method to diagnose the contribution of anthropogenic activities to temperature: temperature tagging

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Abstract. This study presents a new methodology, called temperature tagging. It keeps track of the contributions of individual processes to temperature within a climate model simulation. As a first step and as a test bed, a simple box climate model is regarded. The model consists of an atmosphere, which absorbs and emits radiation, and of a surface, which reflects, absorbs and emits radiation. The tagging methodology is used to investigate the impact of the atmosphere on surface temperature. Four processes are investigated in more detail and their contribution to the surface temperature quantified: (i) shortwave influx and shortwave atmospheric absorption ("sw"), (ii) longwave atmospheric absorption due to non-CO_2 greenhouse gases ("nC"), (iii) due to a base case CO_2 concentration ("bC"), and (iv) due to an enhanced CO_2 concentration ("eC"). The differential equation for the temperature in the box climate model is decomposed into four equations for the tagged temperatures. This method is applied to investigate the contribution of longwave absorption to the surface temperature (greenhouse effect), which is calculated to be 68 K. This estimate contrasts an alternative calculation of the greenhouse effect of slightly more than 30 K based on the difference of the surface temperature with and without an atmosphere. The difference of the two estimates is due to a shortwave cooling effect and a reduced contribution of the shortwave to the total downward flux: the shortwave absorption of the atmosphere results in a reduced net shortwave flux at the surface of 192 W m^{-2}, leading to a cooling of the surface by 14 K. Introducing an atmosphere results in a downward longwave flux at the surface due to atmospheric absorption of 189 W m^{-2}, which roughly equals the net shortwave flux of 192 W m^{-2}. This longwave flux is a result of both the radiation due to atmospheric temperatures and its longwave absorption. Hence the longwave absorption roughly accounts for 91 W m^{-2} out of a total of 381 W m^{-2} (roughly 25%) and therefore accounts for a temperature change of 68 K. In a second experiment, the CO_2 concentration is doubled, which leads to an increase in surface temperature of 1.2 K, resulting from a temperature increase due to CO_2 of 1.9 K, due to non-CO_2 greenhouse gases of 0.6 K and a cooling of 1.3 K due to a reduced importance of the solar heating for the surface and atmospheric temperatures. These two experiments show the feasibility of temperature tagging and its potential as a diagnostic for climate simulations.

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