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How much do changes in emission height and total absorption contribute to the change in the greenhouse effect

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The greenhouse effect of the Earth's atmosphere is estimated using radiative transfer models since the end of the 1970's. Accurate line by line models allow to provide reference results for representative atmospheric profiles and results unambiguous show that an increase of the CO_2 concentration increases the greenhouse effect. However, this robust result is questioned again and again. A usual argument is that the CO_2 greenhouse effect is "saturated", it can not increase any more as CO_2 already absorbs all the radiation emitted by the surface in the spectral bands where it absorbs. Various studies have shown that this argument is erroneous firstly because absorption by CO_2 is currently not fully saturated and still increases with CO_2 concentration, and secondly because the change in "emission height" explains why the greenhouse effect may increase even if the absorption is "saturated". However, these explanations were only qualitative and the contributions of these two effects have not been quantified yet. In this article we first propose a way of quantifying these two effects and we illustrate which of the two dominates for a suite of simple idealized atmospheres. Then, using a line by line model and a representative standard atmospheric profile, we show that the increase of the green house effect due to an increase of CO_2 is primarily due (by about 90%) to the change in emission height and that this emission height increases by about 1 km for a doubling of the CO_2 concentration. For an increase of water vapour, the change in atmospheric absorptivity play a more important role (about 40%) but the change in emission height is still as large as 60%.