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1 Modelling the effect of clouds on the shortwave radiation budget at global scale for the 17-year period 1984-2000

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A shortwave (SW) radiative transfer model was used together with long-term climatological data taken from global datasets, to compute the global distribution of SW cloud radiative forcing (CRF) at the top of atmosphere (TOA), within the atmosphere and at the Earth's surface, at 2.5˚x2.5˚ latitude-longitude resolution, and on a mean monthly basis. The global distributions of cloud properties, such as cloud cover and optical depth, were derived from the latest D2 series of the International Satellite Cloud Climatology Project (ISCCP) Project, which includes 15 types of clouds distinguishing between low-, mid- and high-level, as well as liquid and ice phase clouds. Supplementary 17-year climatological data for surface and atmospheric parameters were taken from NCEP/NCAR, ECMWF, ISCCP-D2, and TOVS datasets. Aerosol data were taken from the Global Aerosol Data Set (GADS) and the Total Ozone Mapping Spectrometer (TOMS). The clouds are found to produce generally a planetary cooling, by increasing the outgoing SW radiation at TOA by up to about 150 W m^{-2} at the pixel level and on monthly mean basis. However, they also induce significant planetary heating, by up to about 10 W m^{-2} over highly reflecting ice- or snow-covered areas, such as the polar regions during winter. Clouds also heat the atmosphere, by up to about 50 W m^{-2}, while their largest effect is found at the surface, where they are found to induce a large cooling, through scattering and absorption of solar radiation, equal to up to more than 200 W m^{-2}. On a mean annual and global scale, the clouds are found to cool the planet by 49.2 W m^{-2}, to heat the atmosphere by 12.1 W m^{-2} and to cool the surface by 61.3 W m^{-2}, over the 17-year period 1984-2000. The model CRF results were validated at TOA through extensive comparisons against high-quality ERBE-S4 CRF values over the 5-year period 1985-1989. The validation shows a good agreement between model and ERBE, with a mean bias of 2.7 W m^{-2}, a standard deviation of 17.4 W m^{-2}, and a correlation coefficient between the model results and ERBE data, equal to 0.85. The distribution of total cloud forcing to the low-, mid- and high-level clouds was also estimated by computing the CRF values for each cloud type, separately. It is found that at the top of the atmosphere and at the Earth's surface, the low-level clouds have the largest (cooling) effect on the SW radiation budget, and secondarily the high-level ones, while the effect of middle clouds is smaller. In the atmosphere, however, the (heating) effect of middle clouds becomes similar to that of high clouds, while the effect of low clouds is largest again. Time-series of monthly mean CRF values were constructed on mean hemispherical and global scales to study the interannual variability of cloud forcings. According to the model results using ISCCP-D2 data, the cooling effect of clouds at the top of atmosphere is found to have decreased by about 2 W m^{-2} (decadal-scale trend 1.2 W m^{-2}) over the 17-year period 1984-2000. Similarly, the atmospheric heating effect of clouds is also found to have decreased by 0.7 W m^{-2} (decadal-scale trend 0.4 W m^{-2}), while at the surface the cooling effect of clouds has undergone a decrease equal to 2.8 W m^{-2} (decadal-scale trend 1.7 W m^{-2}). These decreases in total cloud forcings are due to corresponding decreases in the ISCCP cloud cover, primarily that of low-level clouds, especially over tropical and subtropical areas.