Zusammenfassung

The surface radiation budget plays a fundamental role in the climate system of the Earth. It determines the exchange of energy between the surface and the atmosphere and controls the atmospheric and oceanic circulations and hence, the climate. Therefore, an accurate determination of the surface radiation budget and the analysis of its temporal evolution is essential to study changes in the climate system.

The Long-wave Infrared Radiative forcing Trend Assimilation over Switzerland project was initiated and financed by the National Weather Service of Switzerland, MeteoSwiss, in the framework of the Swiss Global Atmospheric Watch program. This program is the contribution of Switzerland to the Global Atmospheric Watch program which is coordinated by the World Meteorological Organization of the United Nations. In a collaboration with the Institute of Applied Physics of the University of Bern, the project aims to analyze an almost 15 year time series of down-welling long-wave and short-wave radiation measurements provided by four stations of the Alpine surface radiation budget network in Switzerland. Thereby, the project focuses mainly on down-welling long-wave radiation which is a key component in the surface radiation budget and directly related to the greenhouse effect. Consequently, it will experience the largest change of all components of the surface radiation budget when the concentration of greenhouse gases in the atmosphere increases. Thus, the down-welling long-wave radiation is the predestined parameter to detect and monitor greenhouse gas induced climate change.

The main objective of the project is to produce consistent and quality assessed trend estimates of down-welling long-wave radiation through the assimilation of these radiation observations with a large ancillary data set including additional long-wave radiation measurements performed in the wavelength range between 8 and 14 microns (main atmospheric window). These ancillary long-wave radiation measurements were initiated in 2007 at five stations across Switzerland. In a comprehensive radiative closure study, radiative transfer calculations were compared to the measurements in the main atmospheric window and additionally, to broadband integrated observations. The model calculations were found to be consistent within 2 Wm^{-2} with the observations if accurate vertical temperature and humidity profiles derived from radiosondes were applied to the radiative transfer models. When surface temperature and humidity data were used in the absence of such detailed vertical profile information instead, the calculations in the atmospheric window are still within 5 Wm^{-2}, whereas in the broadband long-wave range, the mean difference between observations and model exceeds 5 Wm^{-2}. Thus, using these ancillary long-wave observations in combination with model calculations, it might be possible to determine more precisely the radiative effect of thin cirrus clouds in the future than with common broadband measurements and models.

Furthermore, the long-wave measurements in the main atmospheric window in combination with the broadband observations allow to derive the effective radiative temperature of the atmospheric boundary layer and hence, its diurnal variability with respect to the surface. The atmospheric boundary layer is the layer closest to the ground. It directly interacts with the ground and thus, has a large impact on the surface radiation budget in general and on the down-welling long-wave radiation in particular since the former is mainly emitted from this layer. The study demonstrates that the performance of conventional empirical models to calculate the cloud-free down-welling long-wave radiation at the surface can be substantially improved by taking the temperature variability of the atmospheric boundary layer explicitly into account. Indeed, the discrepancies between such modified model calculations and observations reduce to 5 Wm^{-2} which corresponds to the measurement uncertainty. Furthermore, a new cloud-free long-wave model is proposed based on radiative transfer calculations in the wavelength range between 8 and 14 microns. In contrast to the empirical schemes, the new approach does not include any empirical coefficients. The performance of the new model is comparable to the modified empirical schemes. The application of these modified empirical models and the new model in combination with statistical tools

allows to disentangle the trends in the observed down-welling long-wave radiation induced directly by an increase of anthropogenic greenhouse gases and indirectly by the changes of temperature, clouds and water vapor due to changes in the atmospheric state.

The long-term data analysis revealed no significant change of all-sky down-welling long-wave radiation in the last 12 years even though air temperature and specific humidity have been significantly increasing by 1 °C and 0.3 gkg^{-1} per decade, respectively. It is likely that a decreasing long-wave cloud effect masks the all-sky long-wave trend that could be expected from the corresponding temperature and humidity increases. Indeed, the analysis of the long-wave cloud effect using a modified empirical scheme revealed a significant negative trend. In contrast to the all-sky down-welling long-wave radiation, the trend analysis of cloud-free down-welling long-wave radiation yielded a consistent and - on the 95 % confidence level - significant increase of 3.5 Wm^{-2} per decade in the last 12 years at all four stations. Monthly cloud-free trends, however, tend to be negative in winter, whereas an upward tendency can be observed in summer except in August. The monthly trends of down-welling long-wave radiation can be enhanced by a factor up to ten compared to the overall trend. They are consistent with the corresponding monthly temperature and humidity trends. The application of a modified empirical down-welling long-wave model indicates that about 70 % of the observed long-wave trends are temperature and humidity induced. Less than 10 % are directly caused by rising CO_2 concentrations. The model indicates that the remaining long-wave trends must be due to changes in high level clouds in some single months. The model suggests a decrease in the radiative effect of high level clouds South of the Alps, whereas the northern sites revealed an increase.

Publications:

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