Name of research institute or organization:

Physikalisch-Meteorologisches Observatorium Davos, World Radiation Center (PMOD/WRC)

Title of projects:

Cloud Climatology and Surface Radiative Forcing over Switzerland (CLASS)
Comprehensive Radiation Flux Assessment (CRUX)

Project leader and team:

Julian Gröbner, project leader
Stefan Wacker
Stephan Nyeki

Project description:

The CLASS project – financed by MeteoSwiss in the frame of the Swiss contribution to the Global Atmospheric Watch program (GAW-CH) - studied the changes in the short-wave and long-wave radiative fluxes over the past 17 years and the effect of clouds on the surface radiation budget as well as their changes in the past. The study was conducted on data from four stations including: Locarno-Monti, Payerne, Davos and Jungfraujoch. These stations belong to the Swiss Alpine Climate and Radiation Monitoring (SACRaM) network of MeteoSwiss which provides high quality radiation observations from the UV to the Infrared.

All-sky short-wave radiation at Jungfraujoch slightly decreased by 3 ± 8 Wm^{-2} since 1996 while all-sky long-wave radiation exhibited no distinct change. The net cloud radiative effect (CRE) showed a weak positive trend at 2 ± 4 Wm^{-2}/decade, which was derived from short- and long-wave radiation measurements and describes the changes in fractional cloud cover and cloud type. Since the magnitude of the annual CRE is negative which means a cooling of the surface, a positive trend implies a decrease in fractional cloud cover or a shift towards a different cloud type. Alternatively, a change in the aerosol optical depth (AOD) trend or magnitude may have occurred at Jungfraujoch. The latter was in fact observed in the 2005 – 2013 time series, and has been widely attributed to increased volcanic activity resulting in enhanced stratospheric AOD. This may partly explain the decrease in global short-wave radiation but conflicts with the observed decrease in CRE. The large uncertainites in the radiation measurements demonstrate that the observed trends are not conclusive. In fact, the lack of ground-based cloud observations and the insufficient precision to measure the relatively small changes in cloudiness and radiation over short periods impede the detection of natural trends as well as the ability to distinguish trends from the natural variability and/or instrumental artifacts. Therefore, more accurate observations and longer and homogeneous time series are required for future trend analysis.

In order to improve the accuracy of ground based cloud observations, we installed hemispherical sky cameras operating in the visible spectrum at Payerne, Davos and Jungfraujoch. The camera system allows the fractional cloud cover (FCC) to be accurately determined on a routine basis at high temporal resolution (see Activiy Report 2012). A comprehensive inter-comparison of FCC values derived from various techniques (sky camera, ceilometer, Meteosat, long-wave radiation measurements) for Payerne revealed FCC to be within +/- 1 octa in 70% of all cases when comparing the sky camera to the other methods. Besides the calculation of fractional cloud cover, the camera system allows the images to be classified into seven different sky conditions: cirrus-cirrostratus (ci-cs), cirrocumulus-altocumulus (cc-ac), stratus-altostratus (st-as), cumulus (cu), stratocumulus (sc), cumulonimbus-nimbostratus (cb-ns) and cloud-free (cf). The classification is performed using the k-nearest-neighbor (kNN) classifier. Images from Payerne were used to train the algorithm. The algorithm recognizes the correct class in over 90 % of cases if only one class is present in the image. The success rate decreases substantially at all stations if various

classes occur in an image but remains over 50% on average. Besides failure of the algorithm, misclassification by observers and the image selection procedure are the main sources of uncertainty. A particular situation can be observed at Jungfraujoch: Due to its high altitude (3580 m), the site is often within or above the cloud base. This is normally valid for low- and mid-level clouds. Consequently, all cloud classes except cirrus-cirrostratus can be affected. Indeed, the fraction of images classified as cumulonimbus-nimbostratus was 50 % or more for these classes (see Figure 1a). Therefore, the cloud classification scheme was modified for Jungfraujoch so that the algorithm only discriminates between cloud-free conditions, cirrus-cirrostratus, cirrocumulus-altocomulus, altostratus and fog. The term "fog" denotes situations when the station is completely in clouds. An additional training set comprising images from Jungfraujoch was generated to train the algorithm for these particular conditions. The performance of the algorithm was then evaluated using an independent test sample containing 195 images which do not necessarily show one unique class as the training sample does. The

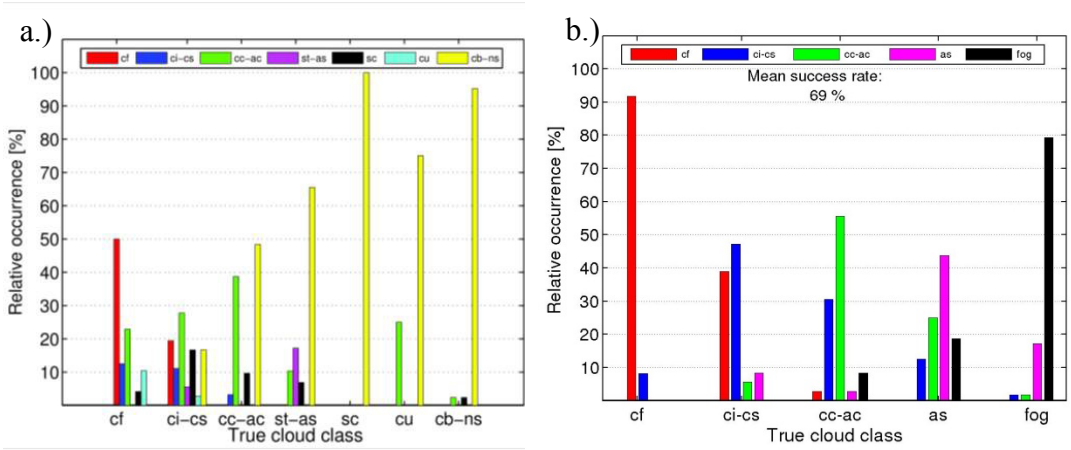

Figure 1. Scores of correctly and incorrectly classified images for the Jungfraujoch test set. The set contains 195 images. The x-axis denotes the true class as it was determined by the observers. The y-axis represents the relative occurrences of the classification as determined by the algorithm. For example in Figure 1a, 50 % of the cloud-free images were correctly classified, whereas 10 % were misclassified as cumulus. Figure 1a illustrates the results using the algorithm trained by the Payerne training set, whereas the individual Jungfraujoch training set was used in Figure 1b.

mean success rate significantly increased to 69 % (see Figure 1b). Situations when the station is completely in clouds and cloud-free conditions are correctly recognized in 80 and 92 % of cases, respectively. The classification of cirrus-cirrostratus, cirrocumulus-altocomulus and altostratus is more problematic: 47 % of the images classified by the observers as cirrus-cirrustratus were classified by the algorithm as this cloud class while the algorithm classified 39 % of these images as cloud-free and 6 and 8 % as cirrocumulus-altocumulus and altostratus, respectively. In the class "cirrocumulus-altocumulus", 56 % of the images classified by the observers as cirrocumulus-altocumulus were also classified by the algorithm as this cloud class while the algorithm classified 31 % of these images as cirrus-cirrostratus. The remaining 13 % of these images were classified as cloud-free, altostratus and fog. Finally, 44 % of the images showing the class "altostratus" were correctly classified by the algorithm. The remaining 56 % of these images were classified as cirrus-cirrostratus (12 %), cirrocumulus-altocomulus (25 %) and fog (19 %).

Further research will be conducted in the follow-up project Comprehensive Radiation Flux Assessment (CRUX) in which an all-sky thermal imaging camera system will be developed. This system will be able to record sky images and brightness temperature for cloud detection during day and night and thus will complement the existing visible sky camera system. Furthermore, existing records of short-wave and long-wave radiation will be homogenized in order to improve the accuracy of the trend analysis.

Key words:

Climate change, radiation, clouds, cloud cover, cloud type classification, sky cameras

Internet data bases:

ftp://ftp.pmodwrc.ch/stealth/002_payerne/liras/cloudcam/jf/

Collaborating partners/networks:

MeteoSwiss

Scientific publications and public outreach 2013:

Refereed journal articles and their internet access

Wacker, S., J. Gröbner, L. Vuilleumier, A method to calculate cloud-free long-wave irradiance at the surface based on radiative transfer modeling and temperature lapse rate estimates, Theoretical and Applied Climatology, doi: 10.2478/s11600-008-0019-9, 2013.
http://link.springer.com/article/10.1007/s00704-013-0901-5

Conference papers

Wacker, S., J. Gröbner, and L. Vuilleumier, Trends In Surface Radiation And Cloud Radiative Effect Over Switzerland In The Past 15 Years, AIP Conf. Proc. **1531**, 672-675, doi:10.1063/1.4804859, 2013.

Address:

PMOD/WRC
Dorfstrasse 33
CH-7260 Davos Dorf

Contacts:

Julian Gröbner
Tel.: +41 81 417 51 57
Fax: +41 81 417 51 00
e-mail: julian.groebner@pmodwrc.ch

Stephan Nyeki
Tel.: +41 81 417 51 39
Fax: +41 81 417 51 00
e-mail: stephan.nyeki@pmodwrc.ch

Stefan Wacker
e-mail: stefan.wacker@pmodwrc.ch