Cloud Climatology and Surface Radiative Forcing over Switzerland

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1. Objectives, data and methods

The project Cloud Climatology and Surface Radiative Forcing over Switzerland (CLASS) aims at estimating the effect of clouds on the surface radiation budget (short-wave and long-wave) by using a combination of instruments and measurement sites (see Figure 1):

- A 15 year dataset of Down-welling short-wave Radiation (DSR) and Down-welling long-wave radiation (DLR) measured at the surface will be used to determine the surface radiation budget at Locarno-Monti, Payerne, Zimmerwald, Davos and Jungfraujoch.
    - ➢Development of an improved long-wave cloud-free parameterization to determine the cloud radiative forcing from long-wave measurements (see Section 2) and a new cloud retrieval algorithm.
    - ➢Generation of an all-sky cloud radiative forcing climatology from re-analysis of the continuous dataset of DSR and DLR.
- Hemispherical sky cameras are currently being installed at all five sites to provide full hemispherical pictures of the sky. The sky pictures will be used to classify the cloud cover types (low, middle and high level clouds) and to determine the fractional cloud cover on a routine basis (see Section 3). These data will be needed to validate the cloud cover determined with the new algorithm.
- The cloud related products of different satellite platforms will be compared to the ground-based analysis.

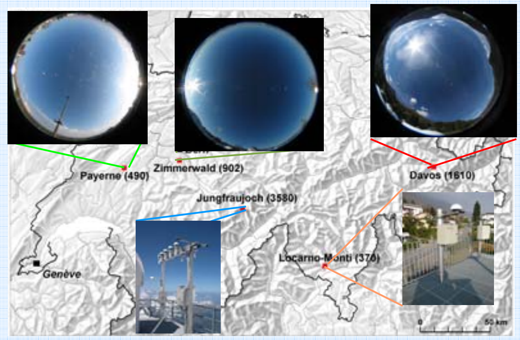

Figure 1: The five stations across Switzerland where the cloud radiative effect on the surface radiation budget will be studied.

2. Long-wave cloud-free parameterizations

- Brutsaert (1975):

$$DLR = A\left(\frac{e_0}{T_0}\right)^{1/7} \sigma T_0^4$$

- Prata (1996):

$$DLR = 1-(1+IWV)\exp\left(-(B+C\times IWV)^{1/2}\right)\sigma T_0^4$$

- New model (PMOD):

$$DLR = \int_{3\,\mu m}^{8\,\mu m} L(T_{eff},\lambda) + DLR_{8-14\,\mu m} + \int_{14\,\mu m}^{\infty} L(T_{eff},\lambda) - f(IWV)$$

- Du Pont (2008):

$$DLR = \left[\frac{A\left(\frac{e_0}{T_0}\right)^{1/7}}{a\log\left(\frac{(e_0T_0)^2}{IWV}\times 10^4\right)+b}\right]\sigma\left[\frac{T_0}{\left[c\log\left((T_0T_{\min})^4-0.99\right)+d\right]^{1/4}}\right]^4$$

New lapse rate correction introduced:
$T_{eff} = T_0 + \Delta T_{monthly}$

Legend:

e_0	water vapor pressure at screen level height [mbar}.
T_0	screen-level temperature [K].
Tmin	Temperature minimum during the day [K].
T_{eff} :	effective radiating temperature of the atmosphere derived from pyrgeometer measurements (Gröbner et al., 2009).
IWV	Integrated water vapor [cm].
$\Delta T_{monthly}$	monthly means of the difference between T_0 and ΔT_{eff}.
A, B, C, a,	b, c, d: empirical coefficients.
$DLR_{8-14\lambda m}$	Long-wave irradiances in the wavelength range from 8 to 14 λm derived from radiative transfer calculations.
L(T,λ)	Planck function.
f(IWV)	Water vapor correction term

Comparison of calculated and observed DLR:

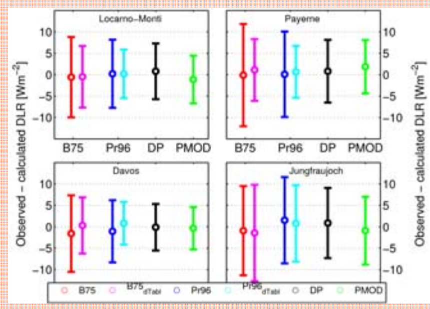

Figure 2: Mean differences (circles) and standard deviation between observed and calculated down-welling long-wave radiation using the models of Brutsaert (B75), Prata (Pr96), Dupont (DP) and the new PMOD model. A lapse rate correction was also applied to the Brutsaert and Prata model (magenta and cyan errorbars, respectively)

3. Cloud cover retrieved from sky cameras

•Cloud cover is computed from two pictures acquired with different exposure times.

•A simplified image from the original pictures is then generated. In this image, cloudy and cloud-free pixels are displayed in white and blue, respectively (see picture in the middle of Figure 3).

• Cloud cover is calculated as the ratio of the white pixels to the total number of pixels.

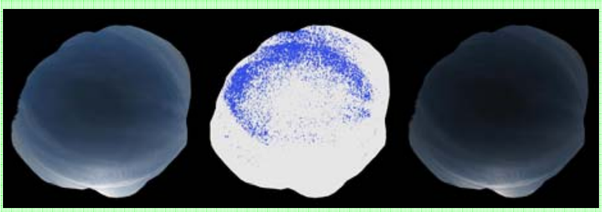

Figure 3: Normal exposed picture of the sky on April, 8 2010 at Davos (left). The underexposed picture was acquired just after the normal exposed picture (right). The image in the middle is generated from these two pictures. The blue pixels represent the cloud-free sky.

4. Long-wave cloud effect of cirrus clouds

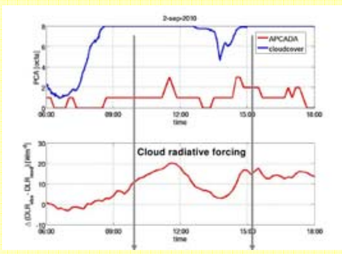

Figure 4:
Upper figure: Partial Cloud Amount (PCA) determined with the sky camera (blue) and APCADA (red) for September, 2 2010 at Davos. APCADA is not able to properly detect the cirrus clouds.
Bottom figure: Difference between observed and parameterized down-welling long-wave radiation (DLR), i. e. the long-wave cloud-radiative forcing, for the same period. The DLR was calculated using the new PMOD model. The cloud radiative forcing of these cirrus clouds is between 10 and 20 Wm-2.

Hemispherical cameras allow to detect thin cirrus clouds when conventional cloud detection algorithm based on radiation measurements (e.g., APCADA (Duerr and Philipona, 2004)) fail.

Conclusions and Outlook

- Cloud-free down-welling long-wave radiation can be calculated within ± 5 Wm^{-2} using modified parameterizations. Thus, the radiative effect of cirrus clouds can be properly assessed using such modified schemes.
- Hemispherical pictures from sky cameras are a powerful tool to determine cloud cover and cloud type during daytime and to validate cloud cover estimates derived from radiation measurements.
- First results demonstrate the need of a new cloud detection algorithm which properly detects cirrus clouds from surface radiation measurements.

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