Name of research institute or organization:

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

Title of project:

Comprehensive Radiation Flux Assessment (CRUX)

Part of this programme:

GAW-CH

Project leader and team:

Julian Gröbner, project leader
Christine Aebi, Laurent Vuilleumier, Stephan Nyeki, Stefan Wacker

Project description:

The objective of the CRUX project (Comprehensive Radiation Flux Assessment) is to analyse the effect of clouds on the radiation budget of the Earth and therefore on the climate system. One of the work-packages concerns an updated trend analysis of shortwave and longwave radiation as well as meteorological parameters in order to establish a climatology over the last 20 years at four MeteoSwiss SACRAM stations: Jungfraujoch (JFJ, 3471 m asl), Davos (DAV, 1590 m asl), Payerne (PAY, 490 m asl) and Locarno (LOC, 367 m asl).

Downward longwave radiation (DLR) emitted by the Earth's atmosphere is a particularly important term in the surface radiation budget and is fundamental in understanding the climate effect of increasing greenhouse gas concentrations. However, long-term measurements are still lacking. A previous study at these four SACRAM stations and four for 1995 – 2002 found that DLR increased by an average of 5.2 and 4.2 W m^{-2} during all-sky (i.e. cloudy and clear-sky) and clear-sky conditions, respectively (Philipona et al., 2004). A later study (Wacker et al., 2011) found an average increase of 3.5 W m^{-2} for the 1996 – 2007 period at the four stations in this study. It was estimated that >50% of the DLR trend was due to the trends in temperature and humidity while the remainder was probably due to the radiative effect of high-level clouds.

Time-series of ambient temperature (T_{2m}; 2m above ground), integrated water vapour (IWV), downward shortwave radiation (DSR) and DLR were obtained with a 1-min or 10-min resolution for the 1996 – 2015 period from MeteoSwiss. Trend analyses were performed using several methods. The first is the linear least squares method by Weatherhead et al. (1998), using de-seasonalized monthly average values. The second method uses the seasonal Kendall test and Sen's slope estimator. In order to check the homogeneity of the time-series, three statistical tests were applied: the Buishand test (parametric), the Pettitt test (non-parametric), and the standard normal homogeneity test (SNHT; parametric). When correctly used, these tests can locate when a possible shift in a time-series occurred.

The time-series of DLR at two of the four stations for all-sky and clear-sky conditions are shown in Figure 1. Annual cycles in DLR, mainly as a result of atmospheric temperature and IWV, are clearly evident. A summary of the trend analyses is shown in Table 1. Trends for both methods are seen to be similar (column 1 vs. 2, and 3 vs. 4), as well their significance at the 90% and 95% confidence levels which gives confidence in the use of both methods.

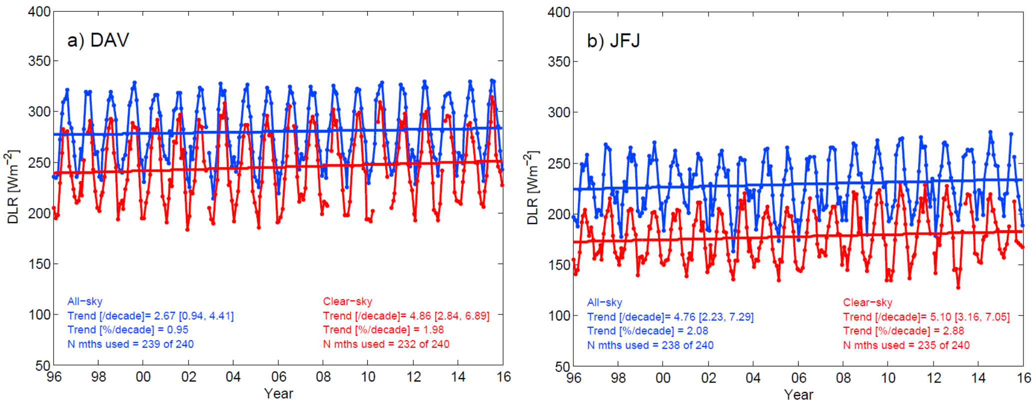

Figure 1. Monthly average DLR values during all-sky (blue) and clear-sky (red) conditions at: a) Davos and b) Jungfraujoch. Each panel also shows trend results from linear least squares analysis. Values in brackets represent the upper and lower bounds of the 90% confidence interval.

Table 1. Trend analysis of selected parameters for the 1996 – 2015 period at the indicated stations during all-sky and clear-sky conditions. Trend values in bold (grey) are significant at the 95% (90%) level.

Parameter	Station	All-sky least squares slope/decade	All-sky Sen's slope slope/decade	Clear-sky least squares slope/decade	Clear-sky Sen's slope slope/decade
Temp. (°C)	DAV	0.30	0.35	0.50	**0.38**
	JFJ	0.34	0.19	0.08	0.35
	LOC	**0.43**	**0.46**	**0.55**	**0.68**
	PAY	0.35	**0.38**	**0.63**	**0.46**
IWV (mm)	DAV	**0.63**	**0.68**	**0.76**	**0.82**
	JFJ	**0.67**	**0.70**	**0.50**	**0.46**
	LOC	0.37	0.68	0.45	0.46
	PAY	0.41	0.40	0.53	**1.1**
DSR (W m^{-2})	DAV	3.0	4.2	4.9	4.8
	JFJ	2.4	0.4	-	-
	LOC	4.3	6.4	3.3	**4.6**
	PAY	3.5	**2.9**	**11.0**	**8.5**
DLR (W m^{-2})	DAV	**2.7**	**3.0**	**4.9**	**5.7**
	JFJ	**4.8**	**4.5**	**5.1**	**6.3**
	LOC	2.5	**3.0**	**3.0**	**2.9**
	PAY	1.4	0.8	**3.4**	**3.5**

Trends in T_{2m} and IWV are virtually all positive during all-sky and clear-sky conditions. While about half the trends in meteorological parameters are significant at the >90% confidence level, it is interesting to note that more trends are significant during clear-sky conditions. Clear-sky values of T_{2m} and IWV have increased at all four stations (except T_{2m} at JFJ) on average by almost 1°C and 1 mm, respectively, during the last 20 years. While trends in DSR are also mainly positive, few are significant. On the other hand, DLR trends are all positive and significant at the >90% confidence level except during all-sky conditions at PAY. All-sky DLR trends at the four stations range from 0.8 – 4.8 W m^{-2}/decade. Larger trends are found for clear-sky conditions, ranging from 2.9 – 6.3 W m^{-2} /decade while all trends are significant at the 95% confidence level. These results for DLR are important and confirm previous conjecture by Wacker et al. (2011) that the long-term DLR trend is positive.

A homogeneity analysis of all meteorological and radiation time-series was also conducted. Results from the SNHT, Buishand and Petitt tests indicate that T_{2m} time-series from all four stations were homogeneous with significance values of $p > 0.32$, $p > 0.92$ and $p > 0.17$, respectively. Concurrent values for DLR were $p > 0.19$, $p > 0.11$ and $p > 0.15$ while values for other parameters were similar. This suggests that no significant shifts in any of the time-series at any station occurred due to climatic or non-climatic (e.g. change of instrument or data acquisition system, relocation) effects. Further efforts are underway to determine the trends in the cloud radiative effect at all stations.

CRUX is financed by the Swiss contribution to the Global Atmosphere Watch Programme (GAW-CH) of the WMO.

References:

Philipona, R., B. Dürr, C. Marty, A. Ohmura, and M. Wild (2004), Radiative forcing - measured at Earth's surface corroborate the increasing greenhouse effect, Geophys. Res. Lett., 31, L03202, doi:10.1029/ 2003GL018765.

Wacker, S., J. Gröbner, K. Hocke, N. Kämpfer, and L. Vuilleumier (2011), Trend analysis of surface clear-sky downwelling long-wave radiation from four Swiss sites, J. Geophys. Res., 116, D10104, doi:10.1029/2010JD015343.

Weatherhead, E. C., G. C. Reinsel, G. C. Tiao, X.-Li Meng, D. Choi, W.-K. Cheang, T. Keller, J. DeLuisi, D. J. Wuebbles, J. B. Kerr, A. J. Miller, S. J. Oltmans, and J. E. Frederick (1998), Factors affecting the detection of trends: Statistical consideration and applications to environmental data, J. Geophys. Res., 103 (D14), 17,149–17,161, doi:10.1029/98JD00995.

Key words:

Climate change, radiation

Collaborating partners/networks:

MeteoSwiss

Address:

PMOD/WRC
Dorfstrasse 33
CH-7260 Davos Dorf

Contacts:

Julian Gröbner
Tel.: +41 58 467 5157
Fax: +41 58 467 5100
e-mail: julian.groebner@pmodwrc.ch

Christine Aebi
e-mail: christine.aebi@pmodwrc.ch

Stephan.Nyeki
e-mail: stephan.nyeki@pmodwrc.ch