Name of research institute or organization:

Federal Office of Meteorology and Climatology MeteoSwiss, Payerne

Title of project:

Global Atmosphere Watch Radiation Measurements

Project leader and team:

Dr. Laurent Vuilleumier, project leader
Dr. Rolf Philipona, Daniel Walker, Dr. Alain Heimo, Armand Vernez

Project description:

The major part of 2007 was devoted to the integration of the data acquisition infrastructure of the GAW Swiss Atmospheric Radiation Monitoring program (CHARM) in the main MeteoSwiss ground measurement network SwissMetNet (SMN). This required the interruption of the radiation monitoring while the infrastructure was renewed. Furthermore, the transition was more difficult than anticipated, and the interruption lasted longer than foreseen. CHARM radiation data monitoring at the Jungfraujoch was resumed end of October 2007. As a consequence, the data availability is below 10% for radiation parameters at the Jungfraujoch in 2007. In order to mitigate the impact of this transition, an independent and self-sufficient measuring system for short-wave global and long-wave downward radiation (used as travelling reference by the Alpine Surface Budget Network) has been installed to supply data at least for these two parameters during the interruption.

Currently, quality control and analysis is on-going on the data from the new system to ensure at least the same level of quality as in the previous setting. Because SMN will include all standard surface meteorological stations as well as other stations such as the CHARM stations with common data acquisition software, hardware, and a dedicated data transmission network, resources can be focused on insuring the reliability of this network, and CHARM will profit from it. In addition, this common network will improve the compatibility of CHARM data with other meteorological data, and the maintenance of CHARM will be simplified. Finally, this will insure that CHARM data acquisition hardware and software are updated with state-of-the-art technology. While the data acquisition infrastructure is renewed, the measurement program is maintained with the same parameters using the same instrument models (brand and version) so that only one component of the general infrastructure is changed at a time. Thus, the configuration is the same than described in the 2002 HFSJG Activity Report.

A project focused on analyzing the time evolution of aerosol optical depth (AOD) and shortwave radiation in Switzerland and Germany has been initiated in 2006. Solar irradiance from various regions around the globe show a decrease after the mid-1950s followed by an increasing trend since the mid-1980s [Ohmura, 2006]. This solar dimming and brightening can not be explained by variations of the sun radiative output [Foukal, et al., 2006], and is therefore rather expected to be a consequence of changing atmospheric transmission due to the increases and subsequent decreases in anthropogenic aerosol concentrations and possible related cloud effects. Aerosols are known to affect atmospheric transmission and hence temperature via the direct aerosol effect (scattering and absorption of sunlight by aerosol particles). However modeling studies expect indirect aerosol effects, like the cloud albedo effect (enhancement of cloud albedo due to smaller droplets) [Twomey, 1974] or the cloud lifetime effect (extension of cloud lifetime due to smaller droplets and less precipitation loss) [Albrecht, 1989] to have an even larger impact than the direct aerosol effect [Lohmann and Feichter, 2005; Solomon, et al., 2007].

Aerosol optical depth has been determined by sunphotometry in an automated and continuous way since the end of the 1980's in Germany [Weller and Leiterer, 1988], and the middle of the 1990's in Switzerland. The longest series of spectral AOD measurements from the German Weather Service and MeteoSwiss are used in this study from six sites covering mainland Europe from the Baltic Sea to the Alps. A BAS type sun photometer was used at the German sites Zingst (ZIN), Lindenberg (LIN) and Hohenpeissenberg (HOP), and SPM2000 sun photometers [Ingold, et al., 2001] and PFR precision filter radiometers were used at the Swiss sites Payerne (PAY), Davos (DAV) and Jungfraujoch (JUN). Figure 1 shows the AOD sites in orange (left) and AOD measurements at λ = 500 nm (right), ordered by increasing altitude from ZIN at sea level up to JUN at 3580 m a.s.l.

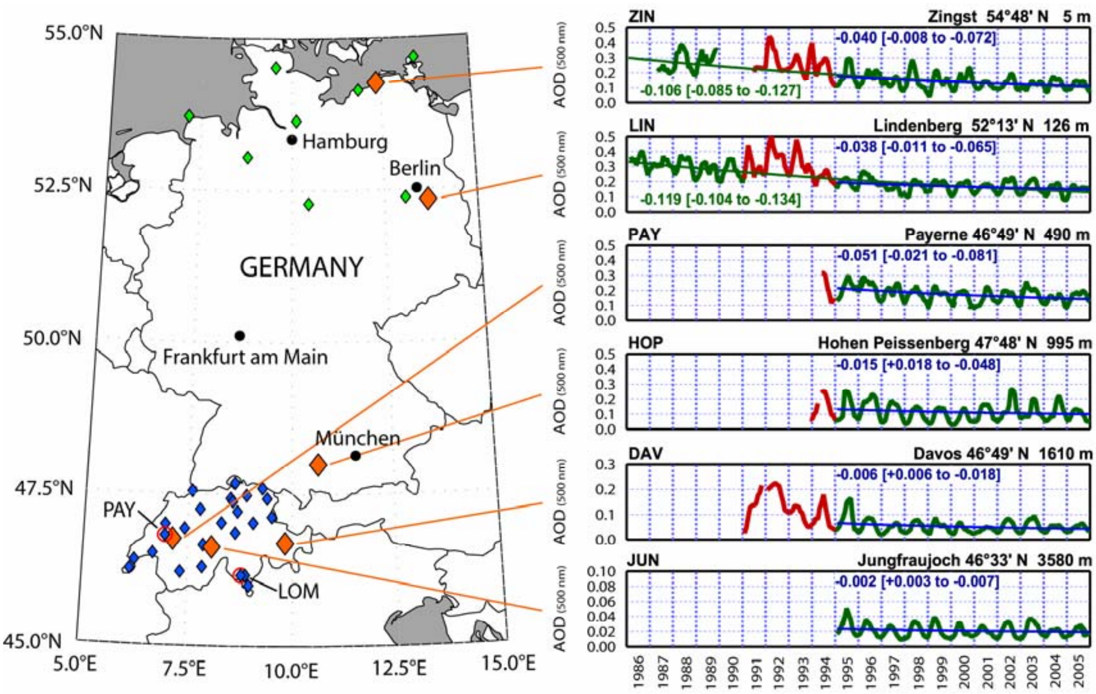

Figure 1. Left: location of surface observation sites in Germany and Switzerland used in this study (left). *AOD* sites are shown in orange, DWD (German Weather Service) radiation measuring sites in green, and MeteoSwiss sites in blue. Right: monthly mean *AOD* (smoothed with a three month running mean). Data included in the trend analysis are shown in green, data excluded from trend analysis (Pinatubo affected years 1991-1994) are shown in red. Trends in *AOD* are given per decade and are shown for different time periods (green 1986-2005, blue 1995-2005), and 95 percent confidence intervals are indicated in square brackets.

The longest data series are from ZIN and LIN, with LIN showing an uninterrupted record from February 1986 to 2005. Continuous records are available at all stations since January 1995. Monthly values are shown with a three month running mean to better illustrate AOD seasonality. Since AOD data are log-normally distributed, trends for different time periods were estimated by fitting the logarithm of the monthly mean AOD with a Least Mean Square (LMS) approximation. Trends are given per decade and in square brackets the 95 percent confidence interval. AOD data are illustrated in green except for the Pinatubo affected years 1991 to 1994 that are shown in red and which have been omitted from trend analyses.

A considerable decrease in AOD with a statistically significant trend is observed at Zingst and Lindenberg over the 1986 to 2005 measurement period (green). A statistically significant reduction is also observed for the 1995 to 2005 period (blue) at the three lowland stations ZIN, LIN, PAY. Despite a reduction in AOD at the alpine stations HOP, DAV and JUN over the same period, the trends are not statistically significant due to lower absolute AOD and larger relative variability.

Zingst and Lindenberg show an overall AOD decrease of about 60 percent from 1986 to 2005. From 1995 to 2005 AOD decreases between 20 and 30 percent at the three lowland stations, and by 10 to 15 percent at the higher sites. The large aerosol decrease at low altitude suggests declines that are primarily due to reduced anthropogenic aerosol emissions [Streets, et al., 2006]. Since around 2000 the AOD stabilizes at low values.

With decreasing AOD, global solar irradiance or shortwave downward radiation (SDR) is expected to increase particularly at low altitudes, where aerosol and hence solar transmission changes are largest. SDR measurements from low-altitude sites in Switzerland and Germany were used to study the relationship between AOD change and SDR change.

Anomalies with respect to the mean irradiance from 1981 to 2005, of cloud-free shortwave downward radiation appeared strongly related to the observed 60% decrease in AOD at low elevation (i.e. direct aerosol effect) from 1986 to 2005. By subtracting SDRcf from SDRas anomalies we obtained the changes in shortwave downward radiation anomalies that are due to changes in cloud cover (SDRcloud). SDRcloud anomalies show large year-to-year variability and the average trend of +1.84 Wm-2 dec-1, but it is strongly influenced by the summer 2003.

With the observed large AOD decreases SDRcloud increases are expected due to indirect aerosol cloud effects, but these cloud trends may also have been affected by long-term variations of large scale circulation patterns. The extreme summer 2003 however, is different from such long-term changes. Time series of shortwave radiation fluxes from 1981 to 2005, without the year 2003 were therefore used for computing changes, and the increase in the resulting modified SDRcloud is reduced by about one third and is no longer statistical significant. This reduction and hence the impact of 2003 is mainly affecting SDRcloud, whereas trends on cloud-free SDR radiation fluxes show almost no change and remain statistical significant.

Our analyses show solar brightening to be more affected by direct aerosol effects under cloud-free skies than by indirect aerosol cloud effects, and to affect mainly low-altitude sites. The fact that despite the 60 percent aerosol decline indirect aerosol cloud effects remain small is unexpected. It is though not impossible that part of the effect was balanced by increasing cloud amounts with changing large scale circulation. With respect to climate, direct aerosol forcing is found to be five times larger than cloud forcing, which is partly compensated by longwave cloud effects. Estimations of the impact of the observed radiative forcings on surface warming using mean climate sensitivity factors show, that with the observed strong aerosol decline the direct aerosol forcing and the indirect cloud forcing combined may have produced up to 50 percent of the recent rapid temperature increase observed in Central Europe since the 1980s.

References:

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Key words:

Solar irradiance, ultraviolet, visible, infrared, spectral irradiance, precision filter radiometer (PFR), pyranometer, pyrheliometer, UV biometer, total aerosol optical depth (AOD), integrated water vapor (IWV).

Internet data bases:

http://www.iapmw.unibe.ch/research/projects/STARTWAVE/startwave_dbs.html
(IWV STARWAVE data)
http://wrdc.mgo.rssi.ru/ (World Radiation Data Centre – WRDC)

Collaborating partners/networks:

Integrated water vapor data submitted to the NCCR Climate P2.4 STARTWAVE database at the Institute for Applied Physics, University of Bern.

Radiation data submitted to the World Radiation Data Centre (WRDC, St. Petersburg, Russian Federation) within the framework of the Global Atmosphere Watch.

Study of AOD evolution in collaboration with the German Weather Service (DWD) and the Institute for Applied Physics, University of Bern.

Scientific publications and public outreach 2007:

Refereed journal articles

Ruckstuhl, C., R. Philipona, J. Morland and A. Ohmura (2007). Observed relationship between surface specific humidity, integrated water vapor, and longwave downward radiation at different altitudes. *J. Geophys. Res.*, **112**, D03302, http://dxdoi.org/10.1029/2006JD007850.

Conference papers

Walker D., L. Vuilleumier and J. Staehelin: 2007. Short-term variability of erythemal UV radiation due to clouds. *Geophys. Res. Abstr.*, **9**, 11443. European Geosciences Union, General Assembly, Vienna, Austria, April 15 – 20, 2007.

Philipona, R. Solar brightening over Europe – a consequence of strong aerosol decline – is coming to an end. IUGG XXIV General Assembly, Perugia, Italy, July 2 – 13, 2007.

Ruckstuhl, C. and R. Philipona. Solar irradiance changes in Switzerland since 1981. IUGG XXIV General Assembly, Perugia, Italy, July 2 – 13, 2007.

Philipona, R. Declining aerosols – solar brightening – and the rapid temperature rise in Europe since the 1980s. 7th EMS Annual Meeting, San Lorenzo de El Escorial, Spain, October 01 – 05, 2007.

Data books and reports

“Ozone, rayonnement et aérosols (GAW)” in Annalen 2006 MeteoSchweiz, Zürich SZ ISSN 0080-7338 pp. 119–135.

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