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

Project description:

As mentioned in the 2007 report of the Global Atmosphere Watch radiation measurements program to the International Foundation HFSJG, the radiation measurement infrastructure was integrated in the main MeteoSwiss ground measurement network SwissMetNet (SMN) in 2007. Following this integration, the operation of the GAW radiation measuring program was successful in 2008 for most parameters, except for the solar photometry (i.e., aerosol optical depth monitoring). For solar photometry, incompatibilities between the instruments and the data acquisition infrastructure complicated the task. The data availability for radiation parameters reached 96.5% at the Jungfraujoch in 2008 (01.11.2007 –31.10.2008), except for solar photometry.

The quality control and analysis procedures have also been improved in 2008. Efforts have been focused toward building an expert system able to perform a battery of tests on radiation measurements and instrument housekeeping monitoring data, so that suspicious or invalid data can be automatically identified. Human intervention is still needed to validate decisions made by the expert system. This system is still being improved, and will in the near future allow a quicker detection of problems and failures, as well as lead to an improved data quality.

A project focused on analyzing the time evolution of aerosol optical depth (AOD) and total shortwave radiation in Switzerland and Germany was initiated in 2006 and was the focus of the year 2007. Most results of this project are described in the 2007 report of the Global Atmosphere Watch radiation measurements program to HFSJG. In 2008, the results of this study were published in Geophysical Research Letters and presented at several conferences.

The radiation monitoring program is also involved in a study of the applicability of erythemal ultraviolet (UV) reconstruction techniques in Switzerland. This project is a contribution to the European COST action 726 aiming at establishing a European-wide UV climatology. Since observed time series are both too short and spatially too sparse for such purpose, UV irradiance at the ground is estimated using reconstruction techniques based on ancillary data and radiative transfer models. Such techniques involve establishing relationships between ancillary data, corresponding model output and UV observations. The established relationships are then used for estimating (reconstructing) UV ground irradiance at times when and locations where UV radiation is not measured. The spatial representativity of a European-wide UV climatology is enhanced if reconstruction techniques developed and tested for a given location can be generalized for being applied at different locations with similar environments. Therefore, it is crucial to evaluate the adequacy of such generalization and to test the accuracy of a reconstruction technique when applied in environments not identical to the locations where the method was derived. Switzerland is a particularly challenging environment for such techniques because of its very complex topography and wildly differing conditions. Our project tests such a technique at four locations where erythemal UV is operationally measured: Davos, Jungfraujoch, Locarno-Monti and Payerne.

In 2008, particular attention was devoted to the evaluation of the ground surface reflectance (albedo), which is a difficult task in the Alps. The albedo can strongly influence UV radiation, since it affects the amount of downwelling radiation due to multiple reflections between the earth's surface and the atmosphere. In the UV range, the majority of soils have an albedo below 10%. The outstanding exception is snow, able to reflect up to 90% of the incoming UV radiation, especially in case of fresh and clean snow. When considering multiple reflection processes, an effective albedo should be used that characterizes the regional surface reflectance. While the local albedo can be determined by up- and downward radiation measurements, the effective albedo is much more difficult to establish. Because of the binary character of the albedo in the UV (presence or absence of snow), knowledge about the regional snow cover distribution is crucial.

The relationship between albedo and the resulting UV enhancement is significant but still limited (i.e., a large change in albedo results in comparatively modest change in UV radiation). Enhancement of erythemal UV radiation can reach up to 30% for an effective albedo of 70% (Smolskaia et al., 2003). This amplification shows a wavelength dependency reaching a peak around 320 nm.

The average effective UV albedo can be derived by different methods using observed UV radiation or information about the regional snow coverage. A common method to find the effective UV albedo is by comparing observed and modeled UV radiation (e.g. Weihs et al., 2001). Considering spectral dependencies or not, the albedo, which is an influential input parameter of the radiation transfer model, is adapted to match the observed UV radiation. However, such techniques can lead to uncertainty up to ±0.15. On the other hand, the average surface reflectance around a specific location can also be derived by considering the regional snow distribution. The snow information from the surrounding topography is integrated using for each pixel a distance weighted local albedo. This approach is less dependent on UV observation and modeling. Finally, the snow information can be derived by remote sensing methods based on satellite observations, numerical weather prediction models or the use of snow depth observations in (geo-) statistical approaches.

A method for estimating snow-coverage in Switzerland was developed using daily estimations of the snow-line altitude in five different Swiss climatic regions. This information is linked with a high-resolution digital elevation model (gtopo30 DEM) to derive the regional snow distribution on a daily base. The snow line altitude is determined for each region by fitting a robust linear regression of snow depth against the altitudes of the measurement locations, and deducing the altitude corresponding to a snow depth threshold of 5cm. The number of measurement stations used for this analysis is relatively constant since the beginning of the 1980’s, as well as the manual measurement technique. The land surface above the snow line altitude is flagged as snow covered while the one below is assumed to be snow free. The daily effective UV albedo for any Swiss area can then be derived from an empirical relationship between snow cover fraction and albedo.

The snow coverage was validated against satellite snow maps and by the means of a cross-validation within our data set. In four case studies during the winter seasons 2002-2005, the post-agreements (Wilks, 1995) between modeled and satellite-observed snow flags range between 69 and 85% for snow predictions and between 91 and 97% for predictions of absence of snow (Table 1). In a second step, observed snow depths were used to cross-validate the modeled snow flags at the altitude of the different stations. Depending on the region, a probability of detection of 90 to 98% and a false alarm rate between 8 and 18% were found. The results of the cross-validation for the five regions in Switzerland are summarized in Table 2. The rather high false alarm rates and positive bias are caused by the tendency of our model to overestimate the presence of snow at low altitudes where it occurs only rarely.

Table 1: Post-agreements (PAGs) for predicted snow-free (left part) and -covered areas with satellite snow maps from the AVHRR sensors. This skill factor describes up to which extent modeled snow-free (-covered) pixels are actually snow-free (-covered) using the satellite retrievals as reference. On the last row, the average PAGs for all cases are shown. The analysis is based on four case studies chosen during winter seasons 2002-2005. Case #1: 1/8 November 2002, case #2: 24 February 2003, case #3: 15 March 2004, and case #4: 21 March 2005. NE, NW: lowland regions in the north-east and north-west of Switzerland. SW, S and SE: mainly alpine regions in the southern part of Switzerland.

| | p(obs="no snow" \| mod="no snow") | | | | | p(obs="snow" \| mod="snow") | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | NE | NW | SW | S | SE | NE | NW | SW | S | SE |
| case 1 | 98 | 100 | 99 | 93 | 98 | 69 | 71 | 64 | | 67 |
| case 2 | 65 | 90 | 82 | 100 | | 89 | 82 | 92 | 71 | 91 |
| case 3 | 100 | 97 | 100 | 99 | | 81 | 85 | 90 | 90 | 96 |
| case 4 | 100 | 99 | 100 | | 96 | 58 | 67 | 82 | 47 | 86 |
| all | 91 | 97 | 95 | 97 | 97 | 74 | 76 | 82 | 69 | 85 |

Table 2: Results of the cross-validation of the snow line altitudes in the five different regions of Switzerland (see caption Table 1). HR: hit rate, POD: probability of detection, FAR: false alarm rate, n: number of stations in each region. On the last row, the weighted averages are shown.

| | HR | POD | FAR | BIAS | n |
|---|---|---|---|---|---|
| NE | 0.92 | 0.96 | 0.18 | 1.01 | 39 |
| NW | 0.92 | 0.90 | 0.16 | 1.04 | 24 |
| SW | 0.87 | 0.98 | 0.08 | 1.05 | 14 |
| S | 0.88 | 0.96 | 0.14 | 1.12 | 25 |
| SE | 0.90 | 0.98 | 0.08 | 1.08 | 23 |
| all | 0.91 | 0.96 | 0.15 | 1.05 | 125 |

**References**

Smolskaia, I., D. Masserot, J. Lenoble, C. Brogniez, and A. de la Casinière (2003), Retrieval of the ultraviolet effective snow albedo during 1998 winter campaign in the French Alps, Appl. Opt., 42, 9, 1583-1587.

Weihs, P., et al. (2001), Modeling the effect of an inhomogeneous surface albedo on incident UV radiation in mountainous terrain: determination of an effective surface albedo, Geophys. Res. Lett., 28(16), 3111–3114.

Wilks, D. S.: Statistical Methods in the Atmospheric Sciences - An Introduction, vol. 59, Academic Press, Inc., 1995.

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

Collaborating partners/networks:

- 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.
- Study of solar photometry (aerosol optical depth) and longwave infrared radiative forcing in collaboration with the "Physikalisch-Meteorologisches Observatorium Davos" (PMOD) World Radiation Center (WRC).

Scientific publications and public outreach 2008:

**Refereed journal articles and their internet access**

Ruckstuhl, C., R. Philipona, K. Behrens, M. Collaud Coen, B. Dürr, A. Heimo, C. Mätzler, S. Nyeki, A. Ohmura, L. Vuilleumier, M. Weller, C. Wehrli, and A. Zelenka: 2008, Aerosol and cloud effects on solar brightening and the recent rapid warming. Geophys. Res. Lett., **35**, L12708, doi:10.1029/2008GL034228.
http://dx.doi.org/10.1029/2008GL034228

**Conference papers**

Philipona, R., C. Ruckstuhl, K. Behrens, S. Nyeki, M. Weller, C. Mätzler, and L. Vuilleumier: 2008, Aerosol and cloud effects on solar brightening and the recent rapid warming. Geophys. Res. Abstr., Vol. 10, EGU2008-A-03023. European Geosciences Union General Assembly 2008 Vienna, Austria, 13 – 18 April 2008. SRef-ID: 1607-7962/gra/EGU2008-A-03023

Philipona, R. et al.: 2008 Aerosol and cloud effects on solar brightening and the recent rapid warming in Europe (poster). 10th BSRN Science and Review Workshop, 7–11 July 2008, KNMI, De Bilt, The Netherlands.

Vuilleumier, L.: 2008. Long-term comparisons of collocated ground irradiance flux measurements. 10th BSRN Science and Review Workshop, 7–11 July 2008, KNMI, De Bilt, The Netherlands.

Walker, D. and L. Vuilleumier: 2008. Effect of clouds on erythemal UV radiation. Quadrennial Ozone Symposium QOS 2008, Tromsø, Norway, June 29th - July 5th, 2008.

**Data books and reports**

“Ozone, rayonnement et aérosols (GAW)” in Annalen 2007 MeteoSchweiz, Zürich SZ ISSN 0080-7338 pp. 113–130.

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