Name of research institute or organization:

Physikalisch-Meteorologisches Observatorium Davos, World Radiation Center

Title of project:

Solar and atmospheric radiation measurements

Project leader and team

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Project description:

General:

Within the Swiss Atmospheric Radiation Monitoring (CHARM) program, PMOD/WRC in collaboration with MeteoSwiss and IACETH conducts solar and terrestrial surface radiation measurements at Jungfraujoch and Gornergrat mainly for radiation budget, UV-radiation and aerosol optical depth (AOD) investigations. Within the CHARM program, Jungfraujoch and Gornergrat are key stations of the Alpine Surface Radiation Budget (ASRB) network, where shortwave solar and longwave terrestrial radiation is accurately measured to determine the altitude dependence of the radiation budget and possible changes related to climate change. Jungfraujoch being the highest site within CHARM is also extensively used as reference and calibration station and for comparisons of radiation instruments.

Surface radiation budget shows greenhouse effect increase as prime cause for temperature rise in Europe

Since 1988, surface temperature over land in Europe increased three times faster than the northern hemisphere average. We therefore contrasted surface climatic and radiative parameters measured in central Europe over different time periods, including the extreme summer 2003, to pinpoint the role of individual radiative forcings in temperature increases. Interestingly, surface solar radiation (SDR) rather decreases since 1981. Also, on an annual basis no net radiative cooling or warming is observed under changing cloud amounts. However, high correlation (r_T = 0.86) to increasing temperature is found with total heating radiation (THR) at the surface, and very high correlation (r_T = 0.98) with cloud-free longwave downward radiation (LDR_{cf}). Preponderance of longwave downward radiative forcing suggests rapidly increasing greenhouse warming, which outweighs the decreasing solar radiation measured at the surface and drives rapid temperature increases over land.

In order to demonstrate that clouds have strong effects on shortwave and longwave radiation but not on the total heating effect of radiation, we contrast annual mean values of the individual radiative fluxes, averaged over the six stations, for the two periods 1995-2002 and 1995-2003 (Fig.1). The longwave cloud effect LCE in the first row shows a slight increase until 2002 demonstrating an increasing cloud amount, but a decrease if 2003 with few clouds during summer is added. Shortwave downward radiation SDR (second row) on the contrary, shows a decrease up until 2002 but an increase with the summer 2003. Longwave downward radiation (LDR) in the third

row shows an important increase until 2002 but with the low cloud amount during summer 2003, which allowed for strong emittance of longwave radiation to space, this increase is strongly reduced yet still positive.

THR in the fourth row stands for total heating radiation and represents LDR plus SDR minus the shortwave upward radiation SUR. It is remarkable, that despite the extreme changes of SDR and LDR during summer 2003, THR steadily increases with high significance of 3 respectively 4 standard deviations over the two periods. While THR and LUR both strongly increase from 1995 to 2003, total net radiation (TNR) in the sixth row, which is the difference of THR and LUR, shows only very small year-to-year variations and practically no increases nor decreases over the two periods.

The steady increase of THR and its high correlation with temperature indicates, that even though clouds strongly modulate SDR and LDR, shortwave and longwave cloud effects are opposite and by and large cancel each other on the annual mean. By subtracting the longwave cloud effect LCE from LDR we obtain the cloud-free longwave downward radiation (LDR_{cf}). LDR_{cf} (seventh row) has very similar year-to-year variations as LUR. The very high correlation of LDR_{cf} with temperature (0.99 and 0.96), and increases that are almost as high as THR, suggest that while SDR is decreasing (period 1981 to 2002), the increasing longwave downward radiation is by far the prime driver of temperature increases at Earth's surface.

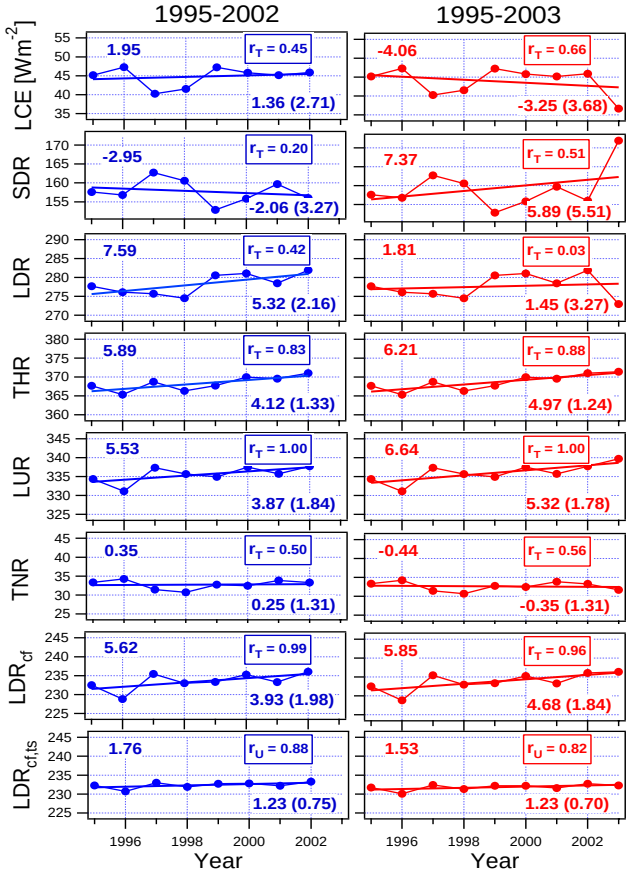

Figure 1: Annual means of individual radiative fluxes averaged over the six ASRB stations shown for the periods 1995-2002 (left) and 1995-2003 (right). Descending in the rows: longwave cloud effect (*LCE*), shortwave downward radiation (*SDR*), longwave downward radiation (*LDR*), total heating radiation (*THR*), longwave upward radiation (*LUR*) also corresponds to surface temperature, total net radiation (*TNR*), cloud-free longwave downward radiation (LDR_{cf}), temperature subtracted cloud-free longwave downward radiation ($LDR_{cf,ts}$). Numbers in framed boxes indicate the correlation index to temperature for the first 7 fluxes and to absolute humidity for $LDR_{cf,ts}$.

In order to show the warming effect caused by increasing greenhouse gases we subtract the effect of increased temperature at the surface from LDR_{cf}. This effect is determined by using the first derivative of the Stefan-Boltzmann law and the temperature increase over the periods, multiplied by the apparent cloud-free sky emittance. In the last row of figure 1 the cloud-free and temperature subtracted $LDR_{cf,ts}$ shows increases with still almost 2σ significance. The high correlation (0.88 and 0.82) between $LDR_{cf,ts}$ and absolute humidity measured at the stations, indicates that a dominant part of the increase of $LDR_{cf,ts}$ is due to increased water vapor.

Key words:

Surface radiation budget; Radiative forcing; Longwave cloud effect; Greenhouse effect;

Internet data bases:

http://www.pmodwrc.ch

Collaborating partners/networks:

MeteoSwiss (MCH)
Institute for Atmospheric and Climate Science at ETH (IACETH)

Scientific publications and public outreach 2004:

Refereed journal articles

Philipona, R., B. Dürr, and C. Marty, Greenhouse effect and altitude gradients over the Alps – by surface longwave radiation measurements and model calculated LOR, Theor. Appl. Climatol. **77**, 1-7, 2004.

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

Dürr, B., and R. Philipona, Automatic cloud amount detection by surface longwave downward radiation measurements, J. Geophys. Res. **109**, D05201 doi: 10.1029/2003 JD004182, 2004.

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Conference papers

Philipona, R., and B. Dürr, Exponential temperature increase in central Europe: Under decreasing solar– but strongly increasing greenhouse warming, American Geophysical Union, 2004 Joint Assembly, Montreal, Canada, May 17-21, 2004.

Philipona, R., Messung des Strahlungsantriebes an der Erdoberfläche bestätigen die Zunahme des Treibhauseffektes, DACH Meteorologentagung, Karlsruhe, Deutschland, September 7-10, 2004.

Theses

Dürr, B., The Greenhouse Effect in the Alps – by models and Observations, submitted to the Swiss Federal Institute of Technology, Zürich, pp.92, 2004.

Magazine and Newspapers articles

"Messung des Treibhauseffektes in den Alpen", Philipona, R., and A. Ohmura, ETH Bulletin, Magazin der Eidgenösischen Technischen Hochschule Zürich, Nr 293, Mai 2004.

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