FORM A: GACP ACCOMPLISHMENT REPORT

Liepert, Beate G. and George Kukla

Lamont-Doherty Earth Observatory of Columbia University
Palisades, New York

SURFACE SOLAR RADIATION DATABASE

Abstract

The main goal of this study is to address the variability of the direct and indirect aerosol effect for the time period of space-based monitoring. We plan to analyze existing high-quality records of broad band solar radiation measurements worldwide. In the first step, a database of hourly surface monitoring will be developed for clear, partly cloudy and overcast sky conditions and stratified by solar zenith angle categories. Surface solar radiation climatologies will be calculated for these cloud cover conditions and for various "event strategies". The design of the database will be flexible for future needs. Changes over time of the direct aerosol radiative forcing will be addressed with clear sky climatologies. Changes over time of the indirect aerosol effect will be analyzed with overcast sky climatologies. In the second step, comparisons with satellite derived determinations and modeling results will be carried out. Finally, the candidate aerosol and aerosol forcing climatologies derived from satellite observations and model calculations will be validated with the surface climatologies and the uncertainties will be quantified. Together with the improved satellite retrievals and model calculations the investigations will enable more realistic aerosol climatologies which are needed for global climate change studies.

Goals

We plan to assess the direct and indirect aerosol effect on global climate and its temporal variability by studying surface solar radiation of selected historic records all over the world. We plan to produce climatologies of broadband solar radiation for various cloud conditions for the time period of three decades and plan to investigate their temporal changes in respect to changing aerosol concentrations. These climatologies will be compared with results from GCM experiments and satellite data, though they provide a ground based independent tool for the validation of candidate aerosol climatologies and the temporal changes within the last two to three decades.

Objectives

The objective of GACP is the quantitative assessment of radiative forcing caused by atmospheric aerosols during the 20-year period of satellite observations. This requires global satellite retrievals of sufficient accuracy as well as model calculations of key aerosol properties. Additional independent information on radiative forcing is needed to constrain the retrieved and calculated aerosol properties and its variability. To serve this need we plan to develop and analyze a broadband solar radiation database specifically designed for comparisons with satellite data and global climate models. Possible variations of the indirect and direct aerosol radiative forcing on a 30 years time scale will be addressed. We focus on comparisons of climatologies in contrast to single field experiments. The database will provide adequate climatologies to quantify uncertainties in satellite derived determinations. Moreover, aerosol transport models and emission scenarios will be tested with these analyzed data resulting in more realistic aerosol climatologies which are needed for global climate change studies.

Approach

We assess the aerosol radiative forcing and its changes over the last three decades by analyzing historic ground based solar radiation records. Total broadband solar radiation measurements exist since the early 1950's. The World Climate Research Program has established the Baseline Surface Radiation Network (BSRN) which collects current high quality solar radiation measurements. Historical data are also available on a monthly resolution from the Global Energy Balance Archive (GEBA) and from the National Weather Services worldwide.

Data Acquisition, Homogeneity Testing and Categorizing:

Long-term recordings with continuous calibration histories exist for several sites worldwide, which will be selected for our applications by using the GEBA archive. The existing surface solar radiation network has a poor density but on the other hand, covers the land areas where satellite retrievals of aerosol properties are still. The time series will be tested for homogeneity, and categorized by utilizing further meteorological elements. We will produce solar radiation climatologies of clear, partly cloudy and overcast sky conditions for the selected sites based on an hourly resolution and will perform detailed statistical time series analyses. Other "event strategies" will be added as addressed by the science team.

Model vs. Observation Comparisons:

We will perform comparisons with solar radiation climatologies from various GCM experiments. One comparison will be with the ECHAM4 model experiment of Lohmann et al. who investigated the indirect aerosol effect. In another study we will compare the temporal development of the direct aerosol forcing modeled by Tegen et al. with temporal changes in the direct and diffuse part of the insulation. This investigation will focus on the effect of varying anthropogenic aerosols within the last 30 years.

Comparisons of the Derived Climatologies with Intensive Field Campaigns:

Field campaigns provide a large variety of high-resolution measurements of aerosol and radiative parameters, whereas the climatological database of solar radiation constrains the overall long-term variability of a few key elements. Therefore we use intensive field campaigns to explain possible variations uncovered in the solar radiation climatologies. The strategy is to test the hypothesis drawn from the climatologies with specific case studies from intensive field campaigns.

Comparisons with Satellite Data:

Satellite derived climatologies of TOA solar fluxes for clear and overcast conditions will be compared with surface solar radiative fluxes to assess the atmospheric solar absorption. Potential other comparison strategies will be developed in cooperation with other members of GACP.

Tasks Completed

The comparisons with the indirect aerosol forcing model experiment performed by U. Lohmann et al. have been completed and a publication is under way. The results are summarized in chapter B.

The statistical analyses of the North American solar radiation time series for clear sky conditions are completed and the climatologies are currently analyzed with the model simulations performed by I. Tegen et al. We expect to finish the study and publish the results at the end of August. Significant highlights of this work will be presented in the next Science team meeting.

Future Plans

For the second year, we plan to analyze the available Canadian and Australian solar radiation data. The BSRN data set of the World Climate Research Program will be used to investigate cloud-radiation interactions on a long-term scale. We are particularly interested in the possible effect of broken cloudiness on enhanced absorption. For this purpose we will visit the World Radiation Monitoring Center in Zurich. Further model comparisons with U. Lohmann are also planed for the next year to investigate and validate the indirect aerosol effect. This analysis will focus on the Canadian data and on the improved model version, which includes other aerosol types than sulfate.

For the third year we plan to start cooperating with the V. Russak from the Estonian Academy of Science in Tallinn. We also plan to enlarge our database with European, Japanese and additional available records throughout the project. Climatologies will be produced and compared to model results similar to the U.S. American and German data. Cooperation with P. Stackhouse who is the PI of a similar project of the GACP will be established to deliver the data to NASA archives and make them publicly accessible.

Results

The statistical analysis of the 17 selected US recordings of broadband solar radiation from 1961 to 1990 shows the following results:

- No significant tendency in the clear solar radiation for the time period,
- But declines of solar radiation for overcast conditions.
- The clear sky ratio of direct to diffuse solar radiation increased by 8% from the years 1978-80 to 1988-90 implying less atmospheric scattering and/or more absorption possibly due to changes in the aerosol chemical characteristics. I. Tegen currently tests this hypothesis with model simulations.

The validation of the indirect aerosol effect of the ECHAM4 GCM cloud scheme (Lohmann) with North American and German solar radiation climatologies is described in form B.

FORM B: GACP SIGNIFICANT HIGHLIGHTS

Liepert, Beate G. and George Kukla

Lamont-Doherty Earth Observatory of Columbia University
Palisades, New York

Indirect Validation of the Indirect Aerosol Effect:
The change in cloud parameters due to increased anthropogenic aerosols and their precursor gases is referred to as "indirect aerosol effect". Its first estimates with general circulation models (GCM) describe an increasing number of cloud droplets with smaller radii when the aerosol concentration increases which eventually leads to an enhanced cloud albedo. In this study we compare GCM experiments with long-term surface observations to evaluate the indirect aerosol effect. The idea is to compare two different model experiments, one includes "pre-industrial" and the other one "present day " sulfate concentration. Both experiments are further compared with observations to test their validation. The analysis focuses on long-term records of cloud coverage, broadband solar radiation and precipitation rates.
The observational data stem from two independent archives of the U.S. and of Germany. Forty data sets have been selected for this study. The recordings cover the 30-year time interval from 1960 to 1990. The modeled data sets stem from the ECHAM4 GCM experiment performed by Lohmann and Feichter. Composites of global solar radiation for "all", "clear" and "overcast" sky conditions were produced and grouped into eight areas covering the U.S. and Germany. Climatologies for precipitation rates and total cloud coverage were also calculated for the two model experiments and the observational data. ECHAM4 predicts the clear sky solar radiation very well (see table). Nonetheless, the overcast solar radiation is considerably underestimated by the cloud scheme (about 20%). ECHAM4 underestimates the all sky solar radiation as well, however, by a smaller amount (6%). As expected, this difference enhances if the indirect aerosol forcing is considered. The total cloud coverage of 50% is exactly calculated as observed if the present-day sulfate concentrations are chosen and worsens slightly if pre-industrial aerosol is calculated. The cloud scheme seems not be able to keep the droplets long enough in the clouds, and the clouds start precipitating too early. This is indicated by the by the underestimated precipitation rate and the overestimated precipitation frequency. The frequency of clear sky events itself is also highly overestimated by the model. Also, the frequency of precipitation events increases with the increasing aerosol load. This is in contrast to observations of the suppression of drizzle due to the indirect aerosol effect (Hobbs). This discrepancy might be due to the incorrect vertical distribution of the cloud layers. Less low stratus clouds and more high level cirrus might reduce the optical thickness and increase the lifetime. Another reason might be the underestimation of the relative humidity in summer when the soil moisture content is too low compared to observations. This is indicated by the regional approach of the comparison.
In summary, the incorporation of the indirect aerosol forcing indeed improves the cloud parameterization slightly. However the overestimation of the surface solar radiation for all sky and especially overcast conditions is quite high. This is not primarily caused by

the cloud scheme itself rather the discrepancies are due to boundary conditions like soil moisture and/or the dynamics.

		Observation	Model Pre-industrial	Model Present-day
Cloud Category		**Global Solar Radiation**		
All	Mean W/m^2	181	171	168
	Correlation Coefficient		0.97	0.96
Clear	Mean W/m^2	228	227	227
	Correlation Coefficient		0.98	0.98
Overcast	Mean W/m^2	112	89	85
	Correlation Coefficient		0.86	0.85
		Fractional Cloud Cover		
	Mean %	50	49	50
	Correlation Coefficient		0.79	0.80
		Precipitation		
	Rate mm/d	3.8	2.1	2.2
	Frequency %	32	51	54

Table: Validation of the indirect aerosol forcing. Comparisons of two ECHAM4 GCM experiments (pre-industrial sulfate load of 0.18Tg S and present-day of 0.54Tg S) with observational data from eight areas covering the United States and Germany. Composites of annual means from 1960 to 1990 are considered for the observational data and 1985 to 1989 for the model.

FUTURE PLANS

Liepert, Beate G. and George Kukla

Lamont-Doherty Earth Observatory of Columbia University
Palisades, New York

Research Plan for the Second Year

In the second year we will finish the comparisons of the trend analysis of the US clear sky solar radiation climatologies with the modeled variations of the aerosol properties by I. Tegen. We also plan to analyze the long-term Canadian solar radiation and cloud cover recordings. The BSRN radiation archive will be used to study the solar radiation at broken cloudy conditions.

The main task for the second year however is the acquisition of additional data sets of solar radiation and cloud information. Therefore we plan to visit the World Radiation Monitoring Center in Zurich to inspect the GEBA and BSRN archives. We also plan to establish and intensify cooperation with the other GACP members who might want to use our processed database.

FORM D: GACP BIBLIOGRAPHY

Liepert, Beate G. and George Kukla

Lamont-Doherty Earth Observatory of Columbia University
Palisades, New York

Bibliography

a) List of Publications

Liepert, B., and U. Lohmann, 1999: An indirect validation of the indirect aerosol effect: GCM results vs. long-term observations. In preparation.

Liepert, B., and I. Tegen, 1999: The temporal variation of the direct aerosol radiative forcing as observed and modeled. In preparation.

b) List of Oral Presentations

Liepert, B., and U. Lohmann, 1999: Aerosol – cloud – radiation interaction: a comparison of GCM results vs. surface observations. Preprints, *EGS General Assembly*, The Hague the Netherlands, EGS.

Liepert, B., 1999: Changes in cloud and surface radiation in the last three decades. Preprint, *EGS General Assembly*, The Hague the Netherlands, EGS.