Atmospheric Sciences

A11A CC: 520 D Monday 0830h

Magnitude and Causes of Decreasing Surface Solar Radiation: The Global Picture *(joint with B, H, GC)*

Presiding: **S Cohen,** Institute of Soil, Water and Environmental Sciences, Agricultural Research Organization of Israel**; B G Liepert,** Lamont-Doherty Earth Observatory

A11A-01 0830h

Magnitude and Causes and Consequences of Decreasing Surface Solar Radiation in the Last Decades

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This paper presents an overview of the session's topic. A history of published papers on observed reductions of surface solar radiation will be presented and reviewed. Possible causes will be discussed and put into perspective. The role of anthropogenic aerosols and greenhouse gases versus natural changes in cloudiness and surface albedo is subject of this session and will be introduced. Climate simulations with general circulation models provide information on consequences of surface solar flux changes for the hydrological cycle. These processes and other possible consequences will be discussed.

A11A-02 0845h INVITED

Global Reduction of Solar Radiation by Absorbing Aerosols and Its Implications to Climate and Hydrological Cycle

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The Indian Ocean Experiment has clearly documented the large reduction in solar radiation reaching the surface due to absorbing aerosols, particularly black carbon and dust. The INDOEX data are combined with other field observations to estimate aerosol induced reduction worldwide. We have integrated the MODIS aerosols data with available field campaigns and emission sources to evaluate the globally averaged reduction is solar radiation. Regionally, the seasonally averaged reduction reaches values as large as 10 to 30 Wm-2. Using coupled ocean-atmosphere model developed at NCAR, we explore the implications of this reduction to the hydrological cycle. The main result is that the reduction leads to a significant reduction in land averaged rainfall. In addition the reduction has implications to frequency of deep convection and subsequent impacts on the aerosol life times and changes in vertical lapse rates.

A11A-03 0915h

Do satellites detect trends in surface solar radiation?

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Scarcity of environmental observations, both in time and space, hinder the ability to detect signals of climate change. The most frequently used parameter to test climate change hypotheses is shelter temperature, for which long term records are available. The major forcing function that determines the surface temperature is the solar radiation. Global trends in this parameter are very difficult to establish from ground observations due to instrument quality, small number of observing stations, and instrument maintenance and calibration. Most available estimates of large or global scale distributions of radiative fluxes come from synthesis of ground observations and from model estimates. At present, several efforts are underway to use satellite observations of the PATHFINDER type to estimate radiative fluxes both at the surface and at the top of the atmosphere. In addition to the methodology used to infer such fluxes, the accuracy of the derived values depends on the quality of the satellite data, instrument calibration, the spatial and temporal resolution of the satellite observation s that enter the computations, and the spatial and temporal resolution to which these estimates are amalgamated. There is a need for a systematic evaluation of all of the above issues and their impact on the large-scale estimates obtained. In this presentation, an attempt will be made to present large and global scale statistics of radiative fluxes derived with an inference scheme developed at the University of Maryland as driven with about twenty years of satellite observations from the NOAA/NASA Pathfinder ISCCP data at 2.5 degree spatial resolution at 3 hourly time resolution and optimally interpolated, using an EOF approach. The record will be analyzed for trends and ability to detect strong climatic signals within the twenty-year period.

A11A-04 0930h

Changes in the earth's reflectance over the past two decades

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Since 1998, earthshine measurements of the Earth's reflectance have been routinely carried out at Big Bear Solar Observatory. We correlate the overlapping period (1999 through mid-2001) of these observations with satellite observations of global cloud properties to construct from the latter a proxy measure of the Earth's global shortwave reflectance. This proxy shows a steady decrease in the earth's reflectance from 1984 to 2000, with a strong drop during the 1990's. During 2001-2003 only earthshine data are available, and they indicate a complete reversal of the decline. The radiative forcing implied by either of these decadal changes in reflectance is climatologically significant. and could explain the observed variability in surface solar radiation reported in the literature. Understanding how these changes are apportioned between natural variability, direct forcing and feedbacks, is thus fundamental to confidently assessing and predicting climate change.

A11A-05 0945h INVITED

Evidence for Trends, and Lack Thereof, in Surface Solar Irradiance as Seen in Calibration-error-free Records of Cloud Shortwave Transmission for the Past Three Decades at Five Globally Diverse Sites

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Prior to the mid 1970's there did not exist a method of making observations of solar irradiance to an absolute accuracy better than a few percent. Until the mid 1980s, even that low level of accuracy was only achievable through extraordinary effort because commercial pyranometers are known to drift in sensitivity by up to several percent per year under some conditions. To maintain a stable measurement it is necessary to physically relate routine field measurements to international reference standards using transfer standards. Prior to the early 1980s many of these transfer standards were of less than desirable stability, especially in some countries, and while at the same time international reference standards were just undergoing development. Since the early 1990's considerable effort has gone into maintaining the absolute accuracy of ground-based solar irradiance observations. A brief review of this documented history will be presented for background along with the long-term variability in a number of surface irradiance records. To further analyze long-term observational records extending back into the period of dubious calibration pedigree, rationing or differencing methods are often utilized where the parameter of interest is the short term change in radiation, often over diurnal cycles or between periods of clear and cloudy skies. These short term changes can be expressed in percent or as the ratio of the irradiance and hence only the linearity and zero of the irradiance sensor are required to be known and not sensor's correspondence to an absolute irradiance scale. In this manner, conditions that contribute to affecting the amount of solar irradiance reaching the ground can be monitored over the long term. Using this general differencing procedure, we have examined the long-term changes in clear sky and cloudy sky irradiance relative to closely associated reference irradiances thereby having a tool to continuously monitor the solar transmission of clouds or clear skies over the extended periods. We examine three decades of typically calibrated pyranometer data at five globally diverse sites and nearly 45 years of direct solar beam irradiance record at one site using these techniques and find interesting but small variations in cloud and clear sky transmittance over this time period. The surface records examined are from: Barrow, Alaska; Boulder, Colorado; Mauna Loa, Hawaii; American Samoa; and the South Pole. Since the early 1990s considerable effort has been expended by the international irradiance measurement community to greatly increase the routine accuracy of surface solar irradiance observations so that direct analysis of long term changes in irradiance will be more readily verifiable. The second portion of this paper summarizes a related recent paper in JGR/Atmos. by the author.

A12A CC: 520 D Monday 1030h

Magnitude and Causes of Decreasing Surface Solar Radiation: More Evidence *(joint with B, H, GC)*

Presiding: **R T Pinker,** University of Maryland**; M L Roderick,** Research School of Biologoical Scineces, Australian National University

A12A-01 1030h INVITED

Solar Forcing at the Earth's Surface : Extending the Record

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The small number, short duration and uneven spatial distribution of pyranometer measurements impose an important limitation to our understanding of changes in solar forcing at the Earth's surface; this contribution explores the methods available to extend the data base. The first approach discussed is the exploitation of hitherto unused pyranometer records some of which date from the beginning of the last century. The second approach uses long term series of widely measured parameters such as evaporation from open water surfaces, diurnal temperature range and visibility known to be causally and statistically related to global irradiance. The third approach discussed in some detail concerns the potentials and limitations in the use of sunshine duration records as a proxy for global and possibly direct solar irradiance. Preliminary results from analyses of the 20th century USA and Japanese national data bases and other, individual long term series are presented to show a common sensitivity of approximately 1.5 MJ m-2 per sunshine hour. The accuracy and limitations of estimates of annual changes based on sunshine duration measurements are discussed.

A12A-02 1045h

Means and Trends of Shortwave Irradiance at the Surface Estimated From GEBA and WRDC Data.

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On most continents, shortwave irradiance decreases on the order of 2% per decade. This result was obtained from an analysis of the observed time series of shortwave irradiances stored in the Global Energy Balance Archive (GEBA). These time series covered the period from 1950 through to 1990. For the reevaluation of the irradiance means and trends up to the present the pyranometer data stored in the GEBA are currently extended with data from the World Radiation Data Center (WRDC). The combination of these databases provides a comprehensive source of worldwide monthly irradiance values. Preliminary results of the analysis of the extended dataset will be presented.

A12A-03 1100h INVITED

Pan Evaporation in the Southern Hemisphere: What is Happening ?

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Pan evaporation has decreased throughout the northern hemisphere. The typical rate of decline is roughly 2 to 4 mm a-2, i.e., over the last 30 years the annual pan evaporation rate has decreased by between 60 to 120 mm a-1. However, whether this trend is restricted to the northern hemisphere, or whether it is a global trend is unknown because there have been no studies from the southern hemisphere. In this talk, we report data from Australia showing a decline in the pan evaporation rate over the last 30 years (- 4 mm a-2) of more or less the same magnitude as the northern hemisphere trends. These results show that regions of the southern hemisphere are becoming less arid just like the northern hemisphere. The most likely reason is the enhanced greenhouse effect.

A12A-04 1115h

Significant Decline in Solar Radiation Over China:Causes and Implications

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Of importance in the study of long-term climatic trends is the fraction of the solar radiation reaching the earth's surface. A number of studies show that significant reductions have occurred during the past half century. Principal reasons for the reductions have also been indicated. The primary purpose of this study is to present the evidence that significant declines have also occurred in China. It's based on the detailed evaluation of global, diffuse, and direct irradiances at 78 radiative stations over the period 1958 to 1992 in China. Analysis reveals a statistically significant decrease in 74% of the time series of global annual irradiances. The large decrease exceeding 6% per decade mainly concentrated on southeast region and most of the decrease has occurred since the end of 1970s. The decrease of global irradiance is principally resulted from significant decrease in direct irradiance. It's demonstrated by spatial and temporal coherence in trends of global and direct irradiances. With regard to diffuse irradiance, 60% of time series of diffuse irradiances show decreasing trend, but only half are statistically significant. Furthermore, diffuse irradiance increases significantly at 95% confidence level at 11 stations. Notable Decrease in total cloud amount over China has been reported by Kaiser (1998, 2001), which is supported by decreasing rain days in the majority of Chinese meteorological stations. The remarkable drop-off in total cloud amount and rain days begins since about 1980. The temporal pattern of total cloud amount and rain days is consistent with that of solar irradiances. Therefore,it seems that total cloud amount is not the principal cause for the reduction of solar irradiance in China. But it should be noted that,in most cases,the rain days is significantly correlated with global irradiance after the linear trends of both series are eliminated. The fact indicates that total cloud amount could play an important role in inter-annual variation of solar irradiance. The above discussion suggests that increase of aerosol loading might be the alternative to interpret the decline in solar irradiance in China. As a matter of fact, Luo et al. reported significant increase of aerosol loading, especially anthropogenic aerosols (2001). Analysis of visibility data in China also shows that total days with visibility greater than 20 km have decreased remarkably, also implying increase of aerosol loading. However,changes in scattering and absorption of solar irradiance by aerosol, aerosol's interactions with cloud physical and radiative properties remain unresolved. In addition, the implication for climate and agriculture deserves much attention.

A12A-05 1130h

Trends in Solar Radiation Over South Africa and Namibia During the Period 1957-1997.

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Spatial and temporal variability in global, diffuse, and horizontal direct irradiance and sunshine duration has been evaluated at ten stations in South Africa and two stations in Namibia where the time series range between 21 and 41 years. Global and direct irradiance and sunshine duration decrease from northwest to southeast; diffuse irradiance increases toward the east. Annually-averaged global irradiance (G_a) increased significantly by 0.46% per decade at Pretoria and decreased between 1.26% and 1.72% per decade at Bloemfontein, Cape Town, Durban, and Upington. Annually-averaged diffuse irradiance (D_a) decreased 5.20% per decade at Grootfontein and increased 2.51% per decade at Port Elizabeth. Annual direct irradiance (B_a) decreased 2.10% per decade at Cape Town and 2.83% per decade at Alexander Bay. A simultaneous decrease in annually-averaged daily sunshine duration (S_a) may have contributed to the decrease in B_a at Alexander Bay. Increases in aerosols may have contributed to the observed decrease in G_a at Cape Town and Durban, while the decrease in D_a at Grootfontein may be due to a decrease in aerosols. On average, variability in S_a explains 53.8%, 30.4%, and 48.8% of the variance in G_a, D_a, and B_a, respectively. The radiative response to changes in sunshine duration is greater for direct irradiance than for global and diffuse. In the two years following the 1963 Mount Agung eruption in Indonesia, responses in global were small and inconsistent. At eight stations, diffuse irradiance increased 22.80% on average and direct irradiance decreased 8.93%. After the 1982 El Chichon eruption in Mexico, global irradiance increased at two stations and decreased at seven stations. Eight stations witnessed an increase in diffuse averaging 7.20% and an average decrease in direct of 4.96%. Following the 1991 Mount Pinatubo eruption in the Philippines, diffuse irradiance increased an average of 19.20% at three stations and direct decreased by 7.57%.

A12A-06 1145h

Exponential Temperature Increase in Central Europe: Under Decreasing Solar- but Strongly Increasing Greenhouse Warming

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Annual northern hemispheric surface temperature increased by 0.5 ^oC since 1980. In the same time period temperature over land in central Europe increased by 1.6 ^oC. A detailed analysis of the temperature evolution since 1900, shows an exponential increase in the 5^ox5^ogrid point around the western Alps, with dominant increases during the winter half year up to 1995, which since shifted to even steeper increases during the summer half year. Here we show that these large temperature rises, which are accompanied by important water vapor increases, occur under decreasing shortwave downward radiation (SDR). Measurements at six radiation stations in the Alps show decreasing SDR trends since 1981, which remain negative in the years after 1995, except if the exceptionally warm summer of 2003 is included. In contrast longwave downward radiation (LDR) measurements, which are performed at the same stations since 1995, show important increases of longwave downward radiation (LDR). Cloud amount variations are observed since 1995 but increases of the radiative longwave cloud effect account for only about 20% of the large LDR increase. Hence temperature increases are most likely driven by radiative forcings that are caused by increasing greenhouse gases, predominantly increasing water vapor in the atmosphere. This fact is most convincingly demonstrated by the high correlation (0.96 summer and 0.78 winter) between the total surface absorbed irradiance (shortwave plus longwave) and the temperature measured at the surface.

A13A CC: 520 D Monday 1330h

Forcing of the High-Latitude Climate System by the Stratosphere I *(joint with OS, GC)*

Presiding: **V Ramaswamy,** NOAA Geophysical Fluid Dynamics Laboratory**; M A Geller,** Institute for Terrestrial and Planetary Atmospheres, Stony Brook University

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A13A-01 1330h INVITED

Evidence for Stratospheric Influence on Tropospheric Climate

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Is the stratosphere important for predicting changes in weather and climate? Although the role of the stratosphere has not been emphasized until recently, observations and models both indicate that the stratosphere acts to integrate high-frequency forcing from below, with long-lasting feedback effects on the troposphere. In this overview, I will show observational and modeling evidence that stratospheric circulation anomalies affect weather and climate in both hemispheres. The tropospheric response to lower stratospheric wind anomalies tends to look like the Northern Annular Mode pattern. Long-lasting stratospheric wind anomalies tend to induce shifts in the NAM index, leading to the possibility of using stratospheric information in extended-range weather forecasts. In the Southern Hemisphere, observations and models support the hypothesis that stratospheric ozone depletion has affected Antarctic surface climate during the late spring and summer. On climate change timescales, it appears that changes to the stratospheric circulation should be reflected in surface climate. However, prediction of these surface changes requires prediction of long-term changes to the stratospheric circulation a problem that is not yet solved.

URL: http://www.nwra.com/baldwin

A13A-02 1350h INVITED

The Relative Influence of Tropospheric Versus Stratospheric Climate Changes on the High Latitude Climate System

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We investigate in the GISS GCM the importance of stratospheric climate changes relative to tropospheric climate changes on influencing the Arctic Oscillation (AO) during Northern Hemisphere winter. We use as forcing for stratospheric changes ozone depletion, stratospheric water vapor increases, volcanic aerosols, and solar and CO2 changes with the sea surface temperatures not allowed to respond (hence only a clear stratospheric radiative response occurs). The same experiments when SSTs can respond are used to ascertain the importance of tropospheric forcing, along with Ice Age and Paleocene paleoclimate experiments. In this model, tropospheric warming (cooling) experiments generally produce a positive (negative) phase change for the AO, while stratospheric cooling (warming) experiments produce a positive (negative) phase change. The results for all the experiments show that stratospheric forcing by itself produces a significant correlation between AO-like phase changes at 100mb and the surface of similar sign, although the effects on the time-averaged sea level pressure field for the individual experiments are often not significant. When sea surface temperatures are allowed to respond, the correlation between changes in the lower stratosphere and at the surface is even stronger, and more of the individual changes are significant. Strong climate changes in the troposphere can reverse the sign of the AO response that the stratospheric forcing was driving. Examples of this are given, along with a discussion of the paleoclimate relationships, and the sensitivity of high latitude future climate to SSTs at both high and low latitudes.