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 ^{o}C since 1980. In the same time period temperature over land in central Europe increased by 1.6 ^{o}C. A detailed analysis of the temperature evolution since 1900, shows an exponential increase in the 5^{o}x5^{o}grid 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

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.

A13A-03 1410h INVITED

Coupled Chemistry Climate Simulations: Past and Future

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Results from an ad hoc intercomparison of chemistry-climate models, recently published in WMO (2002 Ozone Assessment, 2003) and in expanded form in Austin et al. (Atmos. Chem. Phys, 3, 1-27, 2003) will be presented and discussed. Key diagnostics will be presented showing how tropospheric dynamics play a role in high-latitude stratospheric model performance, firstly in determining the heat flux into the stratosphere and via transport the temperature of the high latitude lower stratosphere. In turn, the high latitude lower stratospheric temperature directly influences the amount of heterogeneous ozone destruction as demonstrated in observations of the Arctic (Rex et al., GRL, in press, 2004) as well as more clearly in the Antarctic. Ozone amounts also play an important role in the radiative balance of the lower stratospheric region, resulting in a highly coupled system. The need to understand this system in more detail follows from suggestions of Baldwin and Dunkerton (JGR, 104, 30937-30946, 1999) and others of a possible downward propagation of the stratospheric signal thus implying that it is necessary to treat the atmosphere as a more complete system by including a reasonably detailed stratosphere in climate model simulations of the future. Some future suggestions for coupled model experiments will be given with the aim of establishing a stronger link between individual model simulations than has hitherto been possible. This would establish more rigorously the strengths and weaknesses of individual models, and in due course, allow improved models to be developed.

A13A-04 1430h

Sensitivity of Tropospheric Forecasts to Stratospheric Initial Conditions in Both Hemispheres.

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Although there has been much recent interest in the dynamical impact of the stratosphere on the troposphere much of this attention has been focussed on climate timescales. Data analysis results suggest that the largest impact of the stratosphere on the troposphere occurs on 10-60 day timescales. In this study the impact of the stratosphere on the troposphere on these timescales is investigated by considering the sensitivity of tropospheric ensemble forecasts to their stratospheric initial conditions. Using the standard ECMWF ensemble numerical weather prediction model a number of case studies of downward propagation events in the northern and southern hemispheres are examined, including the unprecedented Southern Hemisphere major warming in September 2002. In each case two forecast ensembles are run, one with the correct stratospheric initial conditions and one in which stratospheric initial conditions are replaced by a separate stratospheric analysis which has the opposite sign in the stratospheric annular mode index. In both the northern and southern hemisphere stratospheric initial conditions have a small, but statistically significant impact on the tropospheric annular mode, on 15-20 day timescales. Comparison of individual ensemble member forecasts shows that differences in the tropospheric forecast are concentrated on synoptic scales. In the northern hemisphere, consistent changes to the tropospheric flow occur in the North Atlantic in three different case studies. In the North Pacific there is little consistency in the pattern of tropospheric differences. In the Southern Hemisphere consistent changes to the tropospheric flow are also significantly non-annular. Using incorrect stratospheric initial conditions results in a statistically significant reduction in the 500hPa anomaly correlation of tropospheric forecasts.

A13A-05 1445h

Tropospheric influences on winter-time stratospheric variability

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Tropospheric height anomalies in autumn are found to often precede the downward propagation of winter-time stratospheric height and wind anomalies to the surface. The precursor anomalous wave pattern forces a series of energy perturbations that propagate through the troposphere and stratosphere, which leads to hemispheric-scale anomalies most closely associated with Arctic Oscillation. Because the dominant lower tropospheric height anomaly is centered over northern Eurasia, autumn snow cover variability in this region is important in influencing winter atmospheric variability both in the stratosphere and in the troposphere. First, diabatic cooling (heating) associated with snow cover anomalies over Siberia perturb local stationary wave energy forced by the high topography of Eurasia. The increased (decreased) upward energy flux perturbs the local troposphere, is propagated into the stratosphere, and eventually affects the remote troposphere. This process is consistent with current understanding of troposphere-stratosphere coupling. The proposed mechanism by which autumn Eurasian snow cover influences the subsequent winter climate is demonstrated by both observational and numerical simulation analyses.

A14A CC: 520 D Monday 1530h

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

Presiding: **M P Baldwin,** Northwest Research Associates**; J Austin,** Geophysical Fluid Dynamics Laboratory

A14A-01 1530h

Interpreting Observed Stratospheric ozone (1970-2000) - Chemistry, Dynamics, and Model Sensitivities

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The SPb-SB 2-D transport-chemistry model is used to investigate how interpretations of causes of past changes in stratospheric ozone (1970-2000) can depend on different model dynamics. The results from two different simulations of ozone are compared. Both use the same SPb-SB 2-D model framework, with the same chemistry treatment, the same solar UV variations, and the same stratospheric aerosol variability. The two simulations use different dynamics for transport, and different lower stratospheric temperatures. One uses dynamics based on the NCAR MACCM2, as we have used in previous published works, and the other uses dynamics based on the DNM model of the Department of Numerical Mathematics of the Russian Academy of Sciences. Both simulations compare reasonably well with TOMS and ground-based observations of total ozone during the period. We see that in these two simulations the relative role of dynamics is very different in giving rise to ozone variations. With DNM dynamics, Northern Hemisphere ozone decreases are much more a consequence of the year-to-year variability in the dynamics and transport than is the case with MACCM2 dynamics. In the Southern Hemisphere, ozone decreases are larger with MACCM2 dynamics and are more in line with observations. These results seem to be largely a consequence of the different degree of polar vortex isolation in the two general circulation models.

A14A-02 1545h

Changes in tropospheric and lower stratospheric temperatures in the Arctic: model and measurement comparison

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Efforts to understand the connection between the stratosphere and the surface rely, fundamentally, on an understanding of what is happening in both the free troposphere and the boundary layer. For the Arctic, the available temperature measurements by radiosonde offer some of our best insight into understanding the past forty years of change. Analysis of the NOAA's Forecasting Systems Laboratory's temperature sonde data from the North American Arctic shows features which are robust from station to station in the Arctic and which are not represented when examinating current global climate model projections. Some insight is offered into possible explanations for these differences between modeled and measured trends as well as possible future approaches to understanding emerging data.

A14A-03 1600h

Tropospheric Response to Stratospheric Cooling in a Simple AGCM: Impact of the Seasonal Cycle

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stratospheric cooling in a relatively simple AGCM that consists of a dry hydrostatic primitive-equation model with zonally symmetric boundary conditions and analytically specified physics. Using a time-independent thermal forcing in the stratosphere, it is found that, as the polar-winter stratosphere is cooled, the tropospheric jet shifts poleward to a remarkable degree. Surprisingly, the troposphere takes a long time to adjust to the stratospheric cooling in this simple model, typically over 300 days. Naturally, then, one is lead to ask whether the tropospheric jet response would be observed in the presence of seasonally varying, instead of time-independent, thermal forcing. We address this issue by repeating the forcing experiments with a seasonal cycle in the forcing: specifically, we impose a thermal forcing in the stratosphere that only occurs in the winter months. We find that, even when the stratospheric forcing is applied with a seasonal cycle, the tropospheric jets shift poleward. Although the magnitude of this response is somewhat smaller than in the time-independent forcing case, the ratio of the tropospheric response to the stratospheric forcing is the same as in the time-independent forcing case, in the annual mean. In this sense, the response appears to be linear in the strength of the stratospheric forcing.

A14A-04 1615h

SKYHI GCM Simulations of the Response to the 1991 Pinatubo Eruption to Test Arctic Oscillation Sensitivity and High-Latitude Climate Variability

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