2nd Year Progress Report for the
GEWEX Global Aerosol Climatology Project
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Proposal Title: Characterizing Clear-Sky Direct Radiative Forcing of Aerosols From Surface Broadband Solar Observations: A Long-Term Globally Distributed Validation Data Set.

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2nd Year Progress Report:

1. Case Study 1: July 1989 Manitoba Fire Case
   a. The Baum and Trepte (1999) smoke/fire/cloud mask was applied to AVHRR data for the afternoon overpasses from July 1, 1989 through August 13, 1989. This period represents the time period before and after the largest fire outbreak from July 17th – July 26th. First the algorithm was modified to better discriminate clouds/smoke and then an identification of scar pixels was also added to the algorithm. The additional identification of scar areas will impact the regions albedo and surface emissivity.
   b. An optical depth retrieval was added to the AVHRR analysis package. This was necessitated by the need to assess the effect of the fires on the surface radiation over a large region. The optical property of the aerosols were assumed to be comprised of a trimodal distribution of soluble, insoluble and soot aerosols giving a single-scattering albedo of approximately 0.9. The retrievals of the aerosol optical depth for this case were done in four classes (tau < 0.1, 0.1 < tau > 0.5, 0.5 < tau >1.0, tau > 1.0). The region of interest over Ontario of the fires was subdivided into ¼ degree x ¼ degree grid boxes. The fraction of the smoke optical depth class was computed in each grid box. The radiative forcing for the clear-sky part of each grid box was computed by using radiative transfer calculations to estimate the forcing each optical depth class. The fluxes were then weighted according to the smoke coverage fraction. In this way, the clear-sky radiative forcing from the smoke was estimated for each day during the fire period. The forcing in overcast skies are still being evaluated. Time series of the area averaged clear-sky direct aerosol forcing for this case were produced. Averaging all the days before, during and after the burning gave an estimate surface and top-of-atmosphere clear-sky radiative forcing of 8 W m^-2 and 2 W m^-2 respectively.
   c. Analysis of surface broadband radiometric data from the Canadian Climate Centre was continued to infer direct radiative effect of smoke aerosols for hourly data during the 1989 fire outbreak. The AVHRR analysis above, the backward trajectories from the LaRC Trajectory Model (LTM) were used to infer days of cloud-free/smoke covered overpasses over the radiometer sites. The measured hourly solar radiative flux measurements during smoke covered times were compared to those of clear-sky. At one particular radiometer site (Moosonee, July 23, 1989), the direct radiative aerosol forcing of the smoke was found to 240 W m^-2 at the time of the AVHRR overpass. The AVHRR analysis for that particular location showed a large cloud-free area of relatively uniform smoke. The hourly surface shortwave measurements showed a smooth but much reduced diurnal cycle relative to clear-sky days earlier in the month. Integration of the diurnal cycle gave a 145 W m^-2 difference (daytime hours) and a 110 W m^-2 daily averaged difference

(24 hour) from clear-sky. These estimates are attributed to the smoke aerosol forcing on this day.

d. Cloud properties at 1 degree x 2 degree resolution at this latitude are now available from the GEWEX Surface Radiation Budget (the computational grid of the GEWEX SRB various w/ latitude to give banded equi-area and will be replicated to produce the 1x1 degree data). These cloud properties are created from the ISCCP DX pixel data (Rossow and Schiffer, 1999). Cloud fractions, averaged radiances and cloud optical depths are determined from the ISCCP retrievals. These cloud properties were compared and contrasted to the cloud properties from the high resolution AVHRR data using Baum and Trepte. For the case at Moosonee, the grid box was designated as clear-sky despite the presence of the smoke. Depite this, GEWEX SRB SW estimates agreed well with the observations due to procedure of the GEWEX SW code (Pinker and Laszlo, 1992) to add aerosol optical depth to match calculated TOA albedo estimated from AVHRR radiances with the radiative transfer of energy through the atmosphere. Without this adjustment the estimated fluxes from that day would have suffered an error equivalent to the radiative forcing estimates noted above.

2. Case Study 2: Africa fires 1986.
   - Fluxes from the GEWEX SRB SW model using the new cloud properties at 1x1 degree resolution from the ISCCP DX were computed for the sites located in the tropical forests in the Congo. The new fluxes showed a reduction of the bias reported by Konzelman et al. 1996) of nearly 50 W m^-2. Months when smoke was not believed to be present gave very small biases (< 5 W m^-2) at these sites. This result implies that the smoke radiative forcing once believed to be near 100 W m^-2 is only about half of this value.
3. The DMSP-OLS instrument has been used to develop estimates of fires in South-east Asia and Australia. Data shortages and navigation errors are delaying preparation of composite maps for these areas.

The above work has lead to development of three separate papers that are to be submitted in year 3. Three conference papers/presentations were made/submitted.

<u>Future Plans for 1999-2000 (FORM A or FORM C):</u>

1. Now, that ISCCP based gridded cloud data is available from the GEWEX Surface Radiation Budget project, the remaining analysis and preliminary processing of the surface radiometric data shall be completed with an error analysis investigating the areas associated with the Solar Residual Flux quantities (SRF; difference between clear-sky no aerosol fluxes and observed fluxes in a clear-sky). Daily averaged Solar Residual Flux (SRF) climatologies are to be computed for at minimum the years 1986 and 1992. Part of the error analysis is conducted using the results from the 1989 Manitoba case study for which a large amount of surface and satellite observations have been collected and analyzed.
2. The initial LaRC Trajectory Model (LTM) calculations will be rerun using the ECMWF 15-year reanalysis (ERA-15) and the results from the AVHRR LAC analysis described above. First, an isentropic database required for the backward trajectory calculations will be constructed. The air mass origin calculations also require the specification of the global PBL depth. This will be determined from the ECMWF re-analysis using the surface buoyancy relative to the profile of equivalent potential temperature plus a small entrainment layer similar to Zhang and Anthes, [1982]. Further testing is planned for the feasibility of incorporating turbulent mixing within the PBL using a modified version of the Asymmetrical Convective Model (ACM) [Pleim and Chang, 1992] which was developed for application in regional or mesoscale atmospheric chemistry models. Initial testing of the PBL depth and ACM turbulent mixing parameterization constrained with equivalent potential temperature from the ERA-15 re-analysis shows promising results in representing the diurnal variation in PBL height and turbulent mixing over a wide range of boundary layer types.
3. The LTM will be used within the context of the 1989 Manitoba case study to construct a composite of air mass origin for selected Canadian surface radiometer sites. This involves; a) computing daily clustered back-trajectory calculations over a range of altitudes to determine

the latitude, longitude, and altitude history of air masses which are advected over each site, b) identifying which of these trajectories was recently within the Planetary Boundary Layer (PBL), and c) classifying the air masses with a surface type from the International Geosphere-Biosphere Project (IGBP) ecosystem data base. Air masses likely to contain smoke will be determined from AVHRR imagery and biomass source maps. Once the air masses have been classified, a statistical estimate of the altitude profile of source regions and air mass type is constructed for each SRB site by averaging the daily clustered back-trajectory results over the period of a month. These daily and monthly time series will be compared with the SRF for a set of surface sites for several different case studies comprising at least the 1989 Canadian fires, and extended to the 1986 African fires and the 1992 South American fires.

4. The AVHRR LAC processing results will be compared to results using AVHRR GAC (4 km) resolution and eventually to ISCCP resolution (4 km pixels at 25-30 km intervals). The LTM will be used to extend the region of study to the outer surface radiometric sites.
5. Finish the analysis of the OLS data to provide tropical maps of fire distributions to the fullest extent possible. European Space Agency ATSR fire maps, will be used to fill in fire patterns in any regions in which gaps exist. The result will be a detailed multi-year fire map which will document the entire spatial extent of fire in the tropics. This map, when gridded into a 1x1 degree map, will serve to identify air masses likely to contain smoke aerosols.

<u>GACP References:</u>

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Cox, S. J., P.W. Stackhouse, Jr., B. A. Baum, and M. Chiacchio, 2001: Derivation of surface and toa direct radiative forcing due to boreal forest fires using satellite retrievals and surface observations. A Millennium Symposium on Atmospheric Chemistry: Past Present and Future of Atmospheric Chemistry. American Meteorological Society. Albuquerque, New Mexico, 14-19 January.

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In Preparation:

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Stackhouse, P.W.,Jr., S.J. Cox, M. Chiacchio, M.P. Haeffelin, R.B. Pierce, V.L. Harvey, 2000: A solar residual flux approach to estimate clear-sky direct radiative forcing from historic pyranometric measurements: integrating surface measurements, satellite observations, and trajectory modeling (in preparation for JGR).

Miscellaneous References:

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Pleim, J.E. and J. S. Chang, A non-local closure model for vertical mixing in the convective boundary layer, Atmospheric Environment, 26a, 965-981, 1996.

Zhang, D. L., and Anthes, R. A., A high-resolution model of the planetary boundary layer-sensitivity tests and comparisons with SESAME-79 data. J. Appl. Met. 21, 1594-1606, 1982.