P1.5 CLIMATOLOGY OF AEROSOL OPTICAL DEPTH OVER THE UNITED STATES

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1. INTRODUCTION

Natural as well as anthropogenic aerosols affect the global radiation balance by direct and indirect effects, and are a major source of uncertainty in estimating radiation budgets, calculating direct radiative forcing, and predicting climate change. Better knowledge of spatial and temporal extent of aerosol properties based on consistent and high quality sources of information over extended areas is needed.

Due to the growing recognition of the importance of aerosols in climate research, numerous efforts have been made to obtain information on aerosol optical depth (AOD). Use was made of ground-based observation, chemistry/transport models, and satellite retrieval techniques. Ground-based monitoring systems are considered to be the most accurate, but they are point measurements, limited in the spatial coverage. Use of models to obtain aerosol climatologies is very important because they allow interpolation and extrapolation of the local scale observation to larger scales, and they are presently the only tool to study past or future aerosol distributions and properties. Remote sensing of aerosols from space is also used to retrieve the AOD, and is becoming recognized as valuable because of its greater spatial coverage. In this study, ground observations and model data were combined to develop an AOD climatology over the United States.

2. DATA

Ground observations: Aerosol Robotic Network (AERONET)

The AERONET is a globally distributed federated network of ground-based observations representing a wide variety of atmospheric conditions, using state of the art sun photometers (Holben, et al., 1998). Standardization for measurement protocol, data processing and calibration are imposed, a consistent, reproducible and system-wide cloud screening procedure is applied, and frequent measurements of atmospheric aerosol optical properties at remote sites are performed. Since 1993, this real time globally distributed network has collected a long-term quality assured record of AOD, which can be used to obtain climatologies of AOD. About 68 stations over North America were selected for this study.

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Chemistry/Transport model

Transport models compute aerosol distributions from source emissions, using prescribed meteorological fields to calculate aerosol transport, mixing, transformation, and deposition. Tegen et al. (1997) combined soil dust (Tegen and Fung, 1994), sea salt Tegen et al. 1997), sulfate (Chin et al., 1996), and carbonaceous aerosol (Liousse et al., 1996) chemistry/transport models, to produce a global monthly mean AOD climatology.

3. METHODS AND RESULT

Several mathematical methods have been used, to merge the available information on AOD from these independent sources.

Successive Correction Method (SCM)

The SCM is a relatively simple, economical, and widely used interpolation method in objective analysis in meteorology. In SCM, the first estimate of the gridded field is given by the background (or first guess), and following iterations are obtained by "successive corrections", as:

$$f_i^0 = f_i^b$$

$$f_i^{n+1} = f_i^n + \frac{\sum_{k=1}^{K} w_{ik}^n (f_k^o - f_k^h)}{\sum_{k=1}^{K} w_{ik}^n + \varepsilon^2}$$

where f_i^b is the background field (model) evaluated at the grid point i; f_i^n is the n-th iteration estimation at the grid point i; f_k^o is the observation at the observation point k; f_k^n is the value of the n-th field estimate evaluated at the observation point k; ε^2 is an estimate of the ratio of the observation error variance to the background error variance.

Taking the model data as the first guess, f^b, and the AERONET observations over the United States as f^o, assuming the observations are perfect ($\varepsilon^2 = 0$), applied is the Barnes two-pass empirical version of the SCM interpolation scheme (Koch et al. 1983), to merge the observations with the model results. The weights given by the two-pass Barnes analysis are:

$$w_{ik} = \exp(-\frac{r_{ik}^2}{2 R_n^2})$$

where r_{ik} is the distance between the analysis grid point i , and the observation point k ; R_n is the radius of influence which is changed in each iteration, and $R_{n+1}^2 = \gamma R_n^2$. If r is chosen reasonably small, only two passes through the data are required to converge to the desired resolution.

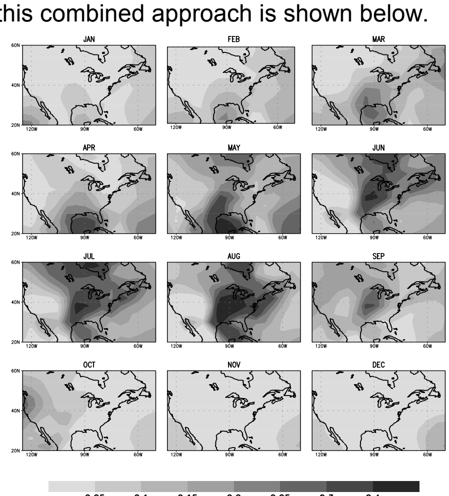
Empirical Orthogonal Functions

The transport model results include information about the physical processes responsible for aerosol emission, transport and deposition. This spatial distribution pattern can be used to interpolate and extrapolate observation in an inhomogeneous and anisotropic way. This can not be achieved by the SCM method, but can be done by using EOFs, namely, the use of EOFs, allows to take advantage of the spatial structure of the monthly mean AOD provided by the transport/chemistry model.

The EOF method fits the spatial structure observed in the model to the AERONET observations, and minimizes the error of this fit by least-squares best fit (Smith et al., 1996), or by reduced space optimal analysis (Ballabreba et al., 2001). Both methods try to minimize the projection of the error onto the space defined by the EOFs.

Combination of SCM and EOF

In this study, first the EOF method is applied and the results are used as a first guess for the SCM method. Interpolation using SCM is implemented to help to converge to the observations. Result of AOD at 500 nm using this combined approach is shown below.



These results are based on several years of numerous AERONET observations that represent a wide range of climatic conditions over the United States. Evaluation of these results is in progress, in the context of their effect on aerosol radiative forcing.

ACKNOWLEDGMENT:

This work was supported under grants NAG59634 from the NASA Radiation Sciences Program and NA06GP0404 from the NOAA Office of Global Programs.

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