Satellite Estimates of Surface Radiative Fluxes for the Extended San Pedro Basin: Sensitivity to Aerosols

R. T. Pinker (1), I. Laszlo (1), D. Goodrich (2), and G. Pandithurai(1)

(1) Department of Meteorology, University of Maryland, College Park, MD, 20742

(2) USDA-Agricultural Research Service, Southwest Watershed Research Center, 2000 E. Allen Road, Tucson, AZ, 85719

Abstract

Surface downwelling and upwelling radiative fluxes are important inputs into hydrologic models that evaluate water budgets, and into land surface data assimilation schemes which are driven with radiative fluxes. For large-scale needs, only remote sensing methods can provide such information. The accuracy of the derived fluxes depends on the inference schemes and on the quality of auxiliary input parameters. At present, information on surface short-wave radiative fluxes over the United States is produced in real time by the National Oceanic and Atmospheric Administration (NOAA)/National Environmental Satellite Data and Information Service (NESDIS) at 0.5 degree resolution, at hourly time intervals, using independently derived auxiliary inputs. Information on aerosol properties and their temporal variability is not available, and at best, is only estimated. During 1997 information on aerosol optical properties was collected at the USDA-Agricultural Research Service Walnut Gulch Experimental Watershed, Arizona, in preparation for future validation efforts in support of new satellite observations (e. g., ADEOS-II). This data set was used to test the sensitivity of a radiation inference scheme to aerosols, in particular, on the determination of clear sky fluxes and the surface albedo. Data from the Arizona Meteorological Network (AZMET) have been utilized to evaluate the satellite estimates for 1997. It was found that the current satellite estimates are within 70 Wm^{-2} of the ground observations on an hourly time scale and within 24 Wm^{-2} on a daily time scale. In the latter case this is less than 10% of the mean. Use of actual observations of aerosols, as compared to climatological values, reduces the bias substantially, while less significant changes in the rms were found.

Keywords: radiative fluxes, aerosols, remote sensing

1. Background

1.1 Site and history

The Semi-Arid Land-Surface-Atmosphere (SALSA) Program seeks to evaluate the consequences of natural and human-induced changes in semi-arid environments (Renard et al., 1993; Goodrich and Simanton, 1995; Goodrich et al., this issue). Current SALSA research is focused on the Upper San Pedro Basin (USPB) which spans the border area between northern Sonora, Mexico and southeastern Arizona, United States. This region exhibits significant land-use differences, and therefore, is well suited for investigating impacts of anthropogenic change on feedbacks into the regional hydrology and climate (Goodrich et al., 1998). The watershed also experiences significant seasonal to interannual climate variability, much of which is due to the influence of the Mexican monsoon and established linkage to the El Niño-Southern Oscillation (Zhang et al., 1996; Cayan et al., 1998). The basin is embedded in the larger Arizona/Sonora semi-arid region which has been the focus of numerous environmental studies, and therefore, has a rich source of information for validating remote sensing methods that estimate surface parameters. More details on the ecological importance of this basin, as well as on the SALSA program and relevant geographical information, are presented in Goodrich et al. (this issue; also see the SALSA home-page at http://www.tucson.ars.ag.gov/salsa/salsahome.html). Information on remote sensing activities in this region is presented in Moran et al. (1998). The adaptation of the diagnostic, near real time mode of the Regional Atmospheric Modeling System (RAMS) mesoscale model (Pielke et al., 1992) for the San Pedro Basin, is discussed in Toth et al. (1998). In addition, issues related to estimating area averages of turbulent surface fluxes are discussed in Chehbouni et al. (1999).

Surface downwelling and upwelling radiative fluxes play an important role as inputs into hydrologic models aimed at evaluating water budgets. Therefore, it is important to determine how well such fluxes can be derived from satellite observations. First estimates of short-wave (SW) surface radiative fluxes (global irradiance) by satellite methods for this region were attempted during the Monsoon '90 experiment (Kustas et al., 1991; Kustas and Goodrich, 1994) and have been reported on in Pinker et al. (1994). Subsequently, the capabilities to derive such fluxes have been expanded to cover the entire United States in support of the Global Energy and Water Budget Experiment (GEWEX) (WCRP-67, 1992) Continental-scale International Project (GCIP) (Leese, 1994; 1997) aimed at the determination of the water budgets in the Mississippi river basin. Due to the importance of the diurnal cycle, observations from the geostationary satellite GOES have been found to be most useful for obtaining long term and systematic information on radiative fluxes. Since 1996, real time estimates of SW radiative fluxes, both at the surface and at the top of the atmosphere (TOA) have been produced by the National Oceanic and Atmospheric Administration (NOAA)/National Environmental Satellite Data and Information Service (NESDIS). The inference scheme was developed at the Dept. of Meteorology, Univ. of Maryland (UMD) (Pinker et al., 1999). NOAA/NESDIS developed the interface between the satellite data and the inference models, and is running the model in real-time on an hourly basis, using observations from the visible (0.52-0.72 μm) channel of the

GOES Imager (Tarpley et al., 1996). Atmospheric input parameters produced by the NOAA/National Centers for Environmental Prediction (NCEP), as available from the Eta model analyzed output fields (Rogers et al., 1996) are also used. Both model input and output parameters are archived at UMD where the satellite estimates of the radiative fluxes are evaluated against ground truth. The inferred short-wave radiative fluxes include downwelling and upwelling global and diffuse quantities, as well as spectral components (e.g., the photosynthetically active radiation (PAR)). In Figure 1, an example of surface short-wave fluxes (global irradiance) for each month, averaged for 1996 and 1997, for the Arizona/N. Sonora region is illustrated. Outlined is the region of the San Pedro Basin, as used in the RAMS model runs (Toth et al., 1998) and the location of Tucson (32^o 57' N, 110^o 57' W). As evident from Figure 1, the spatial distribution of global surface short-wave fluxes has a zonal structure in the winter months of November-February; southern latitudes are gradually receiving more radiation. For the other months of the year, the spatial distribution exhibits a longitudinal structure with a strong west-east gradient. The minimum value (~60 W m^{-2}) is found in January at the northeast corner of the area shown in Figure 1, while the maximum (~380 W m^{-2}) occurs in May and June at the southwest corner, over the northern tip of the Gulf of California. The monthly mean integrated values for the state of Arizona, as well as for the San Pedro Basin, are presented in Table 1. Averaged for the year, the San Pedro Basin receives about 5 Wm^{-2} more global irradiance than the extended Arizona region. Although this difference in the yearly amount of global irradiance is not statistically significant at the 0.05 level, the monthly difference can be as high as 20 W m^{-2} (January). It is interesting to note that the excess radiation in the yearly average for the San Pedro Basin is not contributed by higher values during the summer months. During the months of June, July and August the global irradiance for the San Pedro Basin is 10-15 W m^{-2} less than that for the extended Arizona region.

1.2 Linkage to related activities

The Upper San Pedro Basin has been established as the North American semi-arid site for assessing the impacts of climatic variation and for calibrating and validating algorithms and process-based models to be implemented with NASA EOS observations. For example, the basin was selected by the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) instrument team as a semi-arid validation site as well as a NASA Global Land Cover Test Site. It was also selected as the primary focus site for the EOS interdisciplinary science hydrology team at the University of Arizona and Centre d'Etudes Spatiales de la Biosphere (CESBIO), France. Two Sonora research groups have been involved in research in the USPB: Instituto del Medio Ambiente y Desarrollo Sustentable del Estado de Sonora (IMADES), and Instituto Tecnológico de Sonora (ITSON). Numerous proposals have been funded for research as well as for remotely sensed data acquisition in the basin, which range from ERS-2, SPOT4, ADEOS-II, and for a mesoscale meteorological modeling initiative. Modeling activity focuses on exploring the potential of coupling parameters derived by methods of remote sensing to mesoscale atmospheric models, to aid in diagnosing the spatial distribution of surface fluxes over the entire San Pedro Basin at a 4 x 4 kilometer grid spacing (Toth, 1997).

2. Radiative fluxes used in this study

2.1 Remotely sensed data

The estimated surface SW radiative fluxes (global irradiance) used in this study are produced by NOAA/NESDIS, using the University of Maryland methodology (Pinker and Laszlo, 1992; Pinker et al., 1999). The algorithm is driven by observations made from the GOES-8 Imager, at hourly time intervals and at 0.5 degree spatial resolution over the domain of 25°-50° N, 67°-125° W. Each 0.5-degree grid cell is covered with 72 pixels of about 4 km resolution, which are used to determine whether it is clear or cloudy over the target. The satellite estimates of global irradiance have been previously evaluated on hourly, daily and monthly time scales against observations made at about fifty stations during the year of 1996 (Pinker et al., 1999). For the interpretation of the satellite observations, use is made of the pre-launch calibration of GOES-8, as discussed in Weinreb et al., (1997). In the present study, validation over Arizona was expanded to include data from 1997, when aerosol optical depths were also observed. The satellite estimates used in this study are distributed via the World Wide Web and an anonymous ftp site, as described at: http://www.meto.umd.edu/~srb/gcip.

The full archive maintained at the University of Maryland contains additional parameters, that as yet, are not distributed. Specifically, the following types of information are archived:

- satellite based information, used to drive the model;
- auxiliary data used to drive the model;
- Eta model output products relevant for hydrologic modeling; and,
- independently derived satellite products.

It is planned to expand the number of parameters currently distributed via the World Wide Web to include,e. g., cloud amounts).

2.2 Validation data

2.2.1 Radiative fluxes

A comprehensive evaluation of the model was done using data for the entire year of 1996 from several sources (Pinker et al., 2000). Data available from the Surface Radiation Monitoring Network (SURFRAD) (Hicks et al., 1996), the Illinois State Water Survey (Hollinger et al., 1994) and the Arizona Meteorological Network (AZMET) (Brown, 1989) were used. In this study, only AZMET stations, as illustrated in Figure 2, have been used. The relative location of each ground station in respect to the satellite grid is different and no attempts have been made to adjust the observed values as appropriate for the center of the satellite grid. The Arizona stations are clustered between the latitudes of 32.25 to 33.75 degrees N and longitudes of 107 to 120 degrees W. Most stations observe only downwelling short-wave radiation (global irradiance) at different sampling frequencies which are subsequently integrated at hourly time intervals. Results from evaluation of the NOAA/NESDIS product against observations made at the AZMET stations, are illustrated in Figure 3. Due to the large amount of hourly data for 21 stations, only one month of hourly comparisons are included in Figure 3(a). The daily values in Figure 3(b) are based on three months of data. As evident, on an hourly time scale the rms is about 70 Wm^{-2}, while on the daily time scale it is only about 24 Wm^{-2}. On the average, the satellite-estimated radiative fluxes are smaller than those observed on the ground; on an hourly time scale, the “satellite-ground” bias is -19 Wm^{-2}; on a daily time scale it is -10 Wm^{-2}.

2.2.2 Aerosol observations at Walnut Gulch

In December of 1996 a CIMEL sunphotometer was installed at the USDA-ARS Walnut Gulch Experimental Watershed to provide information on aerosol optical depths and other aerosol optical parameters (Figure 4). This instrument is an automatic sun-tracking sky radiometer capable of measuring both sun and sky radiance, and by using a combination of spectral filters and azimuth/zenith viewing controlled by a microprocessor, enables to derive aerosol properties, total column water vapor and ozone. The CIMEL instrument was operated in the framework of the Aerosol Robotic Network (AERONET) that was established to obtain coherent observations of aerosol optical properties at various locations over the globe, in support of NASA’s Earth Observing System (EOS) program. The data are transmitted via the GOES satellite to Goddard Space Flight Center, where they are centrally archived and pre-processed (Holben et al., 1998). We have subjected the data to additional quality control and the monthly mean values of aerosol optical depth used in this study are presented in Table 2. The Walnut Gulch watershed was selected for the aerosol measurements to avoid urban influences, and because personnel was available at the site. Surface radiation measurements from the closest AZMET station (Tucson, AZ) were used. It should be noted that the Tucson AZMET station is located approximately 110 km northwest of Walnut Gulch, is at a lower elevation (710 m versus 1370 m at Walnut Gulch), and is within a urban area. More details on the measurements and data analysis in Arizona are provided in Pandithurai et al. (1999).

3. Aerosol sensitivity experiments

3.1 Issues

Satellite inference schemes that use physical models require information on radiances as observed by the satellite sensor in relevant spectral channels, as well as information on the state of the atmosphere and the surface. Such information has been available for some of the needed parameters from numerical weather prediction models (e. g., on water vapor) or from independently derived satellite quantities (e. g., ozone). Typically the least amount of information in known about aerosols. Therefore, most inference schemes use some type of aerosol climatology. We have followed a two-step approach in the process of inferring surface SW radiative fluxes. Initially, we use an average value of clear sky radiance as derived from about two weeks of clear sky observations. We assume a climatological value of aerosol optical depth (WCP-55, 1983) and derive from the clear sky composite a surface albedo.

Subsequently, we use each clear sky pixel from the beginning of the retrieval time interval (one month segments at a time) and the initially derived surface albedo to subsequently derive an aerosol optical thickness from each clear sky pixel. The corresponding flux at the surface will be selected from a look-up table as the one that is appropriate for all the derived values of input parameters, as well as the inferred aerosol optical depth. This approach was used to produce the surface fluxes presented in Figure 1, and should be considered only as temporary, until better information on aerosols becomes available. Yet, this approach has proven to be better than other available options (Laszlo and Pinker, 1990). Because the evaluation of satellite retrieval techniques requires longer time series for statistical significance, there was no opportunity in past studies, to evaluate the aerosol retrieval procedure. In what follows, we will describe the experiments conducted in this study.

3.2 Aerosol experiments

We have performed an experiment to evaluate the sensitivity of surface SW radiative flux parameters to aerosol information. An off-line version of the GCIP/SRB model was run for the entire year of 1997. All the satellite input parameters, as well as the atmospheric and surface parameters were the same as used by NOAA/NESDIS in the real time runs for 1997 and as archived at the University of Maryland. The only difference was that the climatological aerosol optical depth values used to initialize the retrieval process were replaced by the monthly mean observed values, as presented in Table 2. We will describe such impacts on the clear sky fluxes (cloudless global irradiance), all sky fluxes (global irradiance) and surface albedo. In this experiment we were exploring how different assumptions about the amount of aerosols used for initialization in a particular retrieval scheme, will affect the derived surface irradiance and albedo for a given geographical region (an inverse problem). Sensitivity of the surface irradiance to aerosol as a forward problem has already been extensively studied, (e.g., Coakley and Cess, 1983; Pinker and Ewing, 1985). It has also been shown (e.g., Laszlo and Pinker, 1989) that in the forward problem, both the top of atmosphere (TOA) albedo and the surface irradiance vary non-linearly with aerosol optical depth. They change rapidly for small values of the optical depth and level-off at large values, namely, the TOA albedo and the surface irradiance are more sensitive to errors in the aerosol optical depth at small values of optical depth. This conclusion is also valid in the inverse problem case as long as the aerosol optical depth used for initialization is not much different from the actual value. A relevant question is how much is the error in the derived irradiance, if the optical depth used for initialization is far off from the actual value. Indeed, if the error in the initial optical depth is large, the error in the irradiance will also be large, regardless of the value of the optical depth.

4. Results

4.1 Surface fluxes

In Figure 5a, a comparison between instantaneous clear-sky radiative fluxes as derived from

GOES-8 observations over a satellite grid closest to Tucson is presented for the month of June 1997. One set of inferred values was obtained from the control run, using aerosol climatology (optical depth, τ_c), while the other set was obtained with off-line run, using monthly mean observed values of aerosol optical depth (τ_o). The mean of the instantaneous fluxes from the "control" run was 789.0 Wm^{-2}, while the observed aerosol climatology yielded a 14.0 Wm^{-2} higher value (803.0 Wm^{-2}). Since the assumed average aerosol optical depth climatology for June was 0.230, while the measured value was 0.057, the effect should indeed be to increase the downward fluxes at the surface. June 1997 was a predominantly clear month, therefore, the results for the all-sky cases (Figure 5b) are similar. The mean instantaneous fluxes from the control run and from the experimental run were 750.1 Wm^{-2} and 763.5 Wm^{-2}, respectively. Using the Student's *t* test on paired data, for both clear and cloudy skies, has shown that the above means are significantly different at the 0.05 level.

A comparison of hourly mean estimated global irradiance with ground truth as obtained from the control run, is presented in Figures 6 for all sky (a) and clear sky (b) cases independently. In Figure 7, the comparison was repeated using results from the experimental run. For clear sky there is a clustering of data because the solar zenith angle is changing only by a small amount at a particular instant from one day to another (the same clustering is observed in Figure 5a). For all-sky conditions, the gaps between the clear-sky clusters are filled with values observed for different levels of cloudiness. The correlation between satellite derived fluxes and those measured at the ground is very high for both cloudy and cloudless conditions (0.96-0.99) which is due to the dominance of the external solar forcing from one hour to another. The largest scatter occurs in the gaps between the clear-sky clusters, pointing to existing uncertainties in the retrieval of global irradiance for cloudy conditions. The use of observed values of aerosol optical depth reduced the bias for both all sky and clear sky cases by about 12-13 Wm^{-2}, and improves the rms by about 4-7 $Wm-^{2}$. The smaller rms errors suggest that the reduction in bias is not purely because of better cancellation of errors. Just as it has been found for the satellite-estimated instantaneous global irradiance, Student's *t* test on paired data showed that the hourly mean fluxes estimated from the two initializations are significantly different at the 0.05 level. The probability of obtaining a *t* value larger than that obtained (–15.4 for all sky, -14.7 for clear sky) by chance alone when the two means are not different is negligible ($3*10^{-40}$ for all sky, $4*10^{-39}$ for clear sky).

4.4 Surface albedo

The GCIP/SRB model produces surface downwelling and upwelling SW radiative fluxes (global and reflected radiation), and their ratio is termed "albedo". At instantaneous time scales, the albedo represents the value at the time of the observation. In order to derive a daily value, the downwelling and upwelling fluxes are averaged and their ratio is taken. Since the surface fluxes are computed independently for clear and cloudy pixels, it is possible to produce "clear sky" albedos and all-sky albedos. Preliminary evaluations show that these two values are quite close to each other. In Figure 8, ten predominantly clear days in June were selected to study the diurnal variation of the surface albedo over Tucson, Arizona and to evaluate the effect of aerosol initialization. In the left panel climatological aerosol values were used; in the middle panel, the observed values were used; and the right panel represents the difference. As evident, the albedos are somewhat higher when aerosol observations are used. This is consistent with the fact that the observed aerosol optical depth was found to be lower than the assumed climatological value. Therefore, the decreased aerosol contribution to the satellite observed top of the atmosphere albedo had to be compensated by an increase of surface albedo. In Figure 8, only values from 10 a.m. to 4 p.m. were plotted. The observations at lower sun elevation angles show spurious values, as has been extensively observed from ground observations (Rosenberg et al, 1983). In Figure 9, a scattergram of the two albedos described in Figure 8 is presented, using all the instantaneous fluxes under all-sky conditions in June and July of 1997. On the average, the surface albedo increased by about 0.02 (17%) when the measured aerosol optical thickness was used for initialization (the mean values obtained from the two initializations are 0.118 and 0.134, respectively). Lower values of the surface albedo are affected more because their contribution to the top of the atmosphere albedo is small relative to the reflection by aerosols in the atmosphere. When the dominant atmospheric factors contributing to the top of the atmosphere albedo are changed, the surface albedos need to further compensate for more of the observed top of the atmosphere albedo changes.

5. Discussion

Radiative fluxes at the earth's surface determine the surface energy budget, and therefore, the rate of evapotranspiration (Dickinson, 1986; Avissar and Verstraete, 1990; Henderson-Sellers, 1993; Sellers et al., 1996; Wood et al., 1997). In semi-arid regions, dominated by clear sky conditions, the affect of aerosols on surface fluxes is more significant than in mostly cloudy areas. Therefore, it is important to assess these effects in a quantitative manner. Such an attempt was undertaken in this study. It was found that when the radiative flux retrieval from satellite observations is initialized with observed aerosol climatology the flux estimates compared better with ground observations. We have also investigated how the selection of the initial aerosol value will affect the retrieval of surface albedo. It was found that using measured values to initialize the aerosol optical depth in the retrieval of surface global irradiance, the surface albedo increased by about 0.02 on the average. No surface albedo measurements were available for comparison, and moreover, a single point measurement of surface albedo is generally not representative of the much larger region observed by the satellite. There is however some evidence that the mean surface albedo of the region in question should be somewhat larger than the value retrieved with climatological initialization (0.12). The seasonal land albedo map of Matthews (1985) suggests values ranging from 0.12 to 0.28, depending on the exact location within the grid.

In addition to better aerosol information, there is a need for improved calibration of satellite sensors. It is believed that some degradation of satellite instruments might have occurred. Preliminary estimates of such degradation are as high as 15%. Experiments were performed to evaluate the possible impact of such degradation on the derived surface fluxes (Meng et al., 1999). The off-line version of the inference model was run for three months by adjusting the calibration by 15%, namely, by increasing the observed radiance values. The results from this experiment were evaluated against ground observations as obtained at the Atmospheric Radiation Measurement (ARM) program sites in Oklahoma and at the Cooperative Atmosphere-Surface Exchange Study (CASES) experiment conducted in Kansas. Short-wave radiative fluxes for a three month period (May 1 to July 31, 1997) were used for the ARM/CART/SAP, and observations for the period from May 1-23, 1997 were used for CASES. It was found that on an hourly time scale, for clear-sky conditions, the rms was in the range of 11 to 7%, if satellite sensor degradation was assumed. For all-sky condition, the rms range was between 20 to 11%. For all-sky conditions, the range of the rms was between 10 to 9% on a daily time scale; while on a monthly time scale, it was between 8 to 4%. Adjustments for estimated satellite sensor degradation substantially reduced the bias at all time scales, for both clear-and all-sky conditions, to about 1% (Meng et al., 1999).

6. Summary

Regions classified as semi-arid or arid constitute about one-third of the total global land cover. Often these regions are subjected to soil erosion, wind-storms, and variable aerosol loading. Aerosols are important in altering the radiation that reaches the surface and therefore, they are a source of error in the interpretation of satellite signals. This is particularly true in the visible region of the spectrum. Routine and continuous information on atmospheric aerosol content is lacking. However, such data are becoming available on regional scales under observational initiatives like the Tropospheric Aerosol Radiative Forcing Observational Experiment (TARFOX) (Russel et al., 1999), AERONET (Holben et al., 1998), SKYNET (Takamura, 1996); and will become available on global scale under new satellite observational programs like MODIS (King et al., 1999), ADEOS and ADEOS-II (http://www.eorc.nasda.go.jp/index.html); and under integrating initiatives like the Global Aerosol Climatology Project (GACP) (Curran et al., 1998; Curran, 1999). Many landscapes in the southwest United States and northern Mexico are being altered from activities such as groundwater mining and overgrazing. Lack of information on aerosols can therefore introduce errors in our ability to estimate from space how much the surface has changed. In the framework of the SALSA Program objectives for long-term monitoring of human-induced change on the hydrological and ecological resources of semi-arid regions, we have conducted an experiment to assess the current uncertainties in aerosol optical depths on such parameters as surface short-wave fluxes and surface albedos. This is important because these parameters influence the modeling of hydrological processes that control the exchange of heat, water vapor and CO_2. It was found that using observed aerosol climatology improved radiative flux retrieval from satellite observations and subsequent computation of flux estimates. In addition, it was found that using measured values to initialize the aerosol optical depth in the retrieval of surface global irradiance, the surface albedo increased by about 0.02 on the average. Comparison of satellite estimates of radiative flux were made with data from the Arizona Meteorological Network (AZMET) for 1997 to evaluate the procedures described. It was found that the current satellite estimates are within 70 Wm^{-2} of the ground observations on an hourly time scale and within 24 Wm^{-2} on a daily time scale. In the latter case this is less than 10% of the mean.

Use of actual observations of aerosols, as compared to climatological values, reduces the bias substantially, while less significant changes in the rms were found. In summary, this study demonstrated that on a local scale, characterizations of aerosols, based even on a limited observational periods is preferred to estimates based on large-scale climatologies.

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Figure 9. A scatter diagram of the two albedos described in Figure 8, derived from the ratios of the instantaneous upward and downward shortwave fluxes, under all conditions.

TABLE 1

Monthly-mean global irradiance (Wm^{-2}) averaged for the state of Arizona and for the San Pedro Basin. The monthly averages were obtained by averaging two years of data.

Month	Arizona	San Pedro Basin (RAMS domain)
January	126.7	148.2
February	169.1	179.1
March	238.1	242.9
April	281.2	290.4
May	326.7	334.6
June	336.8	327.0
July	297.4	283.1
August	268.5	257.1
September	239.0	243.4
October	202.7	202.7
November	148.0	160.2
December	123.2	136.7

TABLE 2

Monthly-mean spectral aerosol optical depths observed with the CIMEL Sky radiometer over Tombstone, Arizona during 1997. No measurements are available for April (λ is the wavelength).

λ (μm) Month	0.340	0.380	0.440	0.500	0.670	0.870	1.020
Jan	0.054	0.048	0.039	0.029	0.017	0.017	0.017
Feb	0.058	0.055	0.045	0.035	0.023	0.024	0.021
Mar	0.073	0.075	0.055	0.042	0.028	0.029	0.023
May	0.109	0.106	0.081	0.067	0.050	0.047	0.041
Jun	0.102	0.102	0.070	0.057	0.039	0.035	0.027
Jul	0.173	0.166	0.119	0.099	0.068	0.058	0.051
Aug	0.189	0.182	0.125	0.102	0.066	0.051	0.043
Sep	0.208	0.195	0.143	0.116	0.072	0.049	0.039
Oct	0.071	0.077	0.045	0.036	0.025	0.020	0.016
Nov	0.056	0.065	0.037	0.030	0.022	0.018	0.015
Dec	0.068	0.065	0.045	0.034	0.022	0.014	0.013