Estimate of the cloud and aerosol effects on the surface radiative flux based on the measurements and the transfer model calculations.
Part I: Shortwave forcing in Tateno, Japan

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In order to estimate the annual surface shortwave forcing by clouds+aerosols and aerosols, pyrheliometer and pyranometer measurements of the shortwave flux, radio-sonde atmospheric profile measurements, aerosol optical properties retrieved from the skyradiometer measurements were integrated with a high accuracy transfer model calculations.

Clear-sky flux was defined from transfer calculations for a pure Rayleigh scattering atmosphere with measured temperature and humidity profiles by radio-sonde observations. Monthly variation of the clear-sky flux due to the temperature and water vapor variation was 10-30 W/m2.

Cloud-plus-aerosol forcing was defined by the difference between the clear-sky flux and the observed flux. The annual mean values of the cloud-plus-aerosol surface shortwave forcing was estimated as -81W/m2 , which corresponds to about 24% of the solar insolation.

The aerosol-sky flux is defined with the transfer calculation using the aerosol optical depth retrieved from the skyradiometer measurements. Direct aerosol forcing was obtained from the differences between the aerosol-sky flux and the clear-sky flux. The mean direct aerosol forcing for 1996 but for March and April was estimated as -18 W/m2 , about 5% of the solar insolation. Surface flux calculation with the retrieved aerosol size distributions performed no better than those with the urban model size distribution. It is attributed to the overestimate of the fine particles as well as the gigantic particles.

Finally, we performed a sensitivity study of the aerosol-sky flux varying the ratio of soot in aerosol compositions. Among the selected soot ratio, the best estimates were obtained as 10% for January, February and July, 20% for from October through December, 5% for May, June and August, and 0% for September. These values are close to the measured seasonal variations of soot ratio in previous studies, and consistent with the relationship between the topography and the wind direction.

Data

1. One-minute average archives of the direct, diffuse and reflected shortwave flux measurements at the Aerological Observatory of the Japan Meteorological Agency 0.29-3.0 um
   Baseline Standard Radiation Network site

   pyrheliometerEppley NIP
   pyranometer EKO MS801F
   with traking shade disk

2. Humidity and Temperature profiles obtained from the rawinsonde and the surface observations at the Aerological Observatory.
3. Aerosol optical thickness and size distribution retrieved from the skyradiometer observations at NIES and at MRI.
   315 (O3), 400, 500, 870, 940 (H2O), 1040 nm

Analysis Period

January 1- December 31, 1996

skyradiometer : 1/1 - 2/7, 5/1-7/11, 7/31-12/31/96

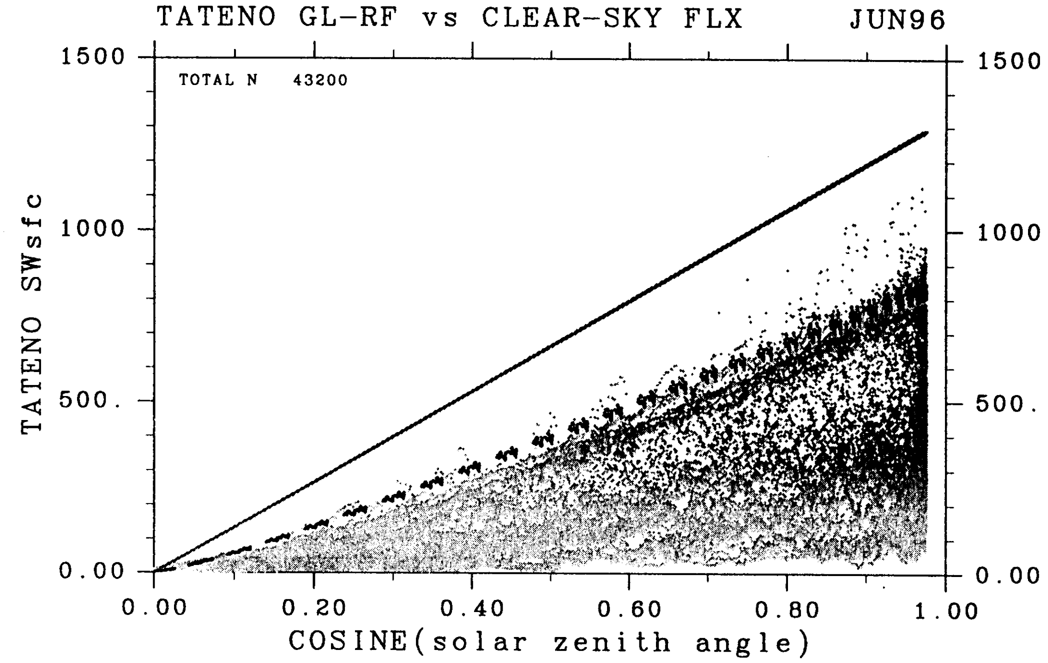

Fig.1

Observed net surface solar flux (light gray dots) and the calculated clear-sky surface shortwave flux (darker dots) plotted against the cosine of the solar zenith angle. Thick straight line depicts the shortwave insolation at the top of the atmosphere. Those for one month of June 1996 are shown.

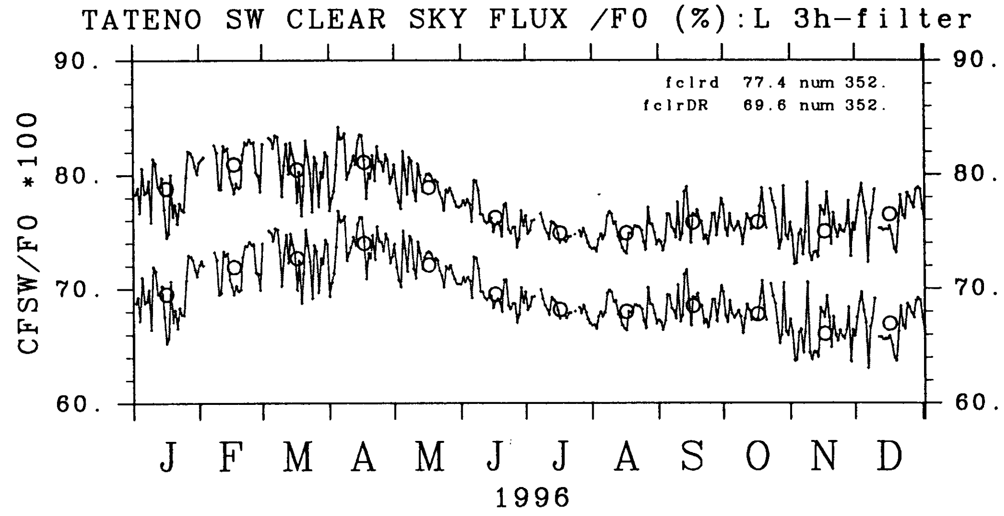

Fig.2

Time series of the calculated clear-sky total surface shortwave flux (upper curve) and the direct component (lower curve) in percent fraction relative to the TOA solar insolation for 1996. Daily averages are depicted with small dots connected with lines and open circles indicate the monthly average.

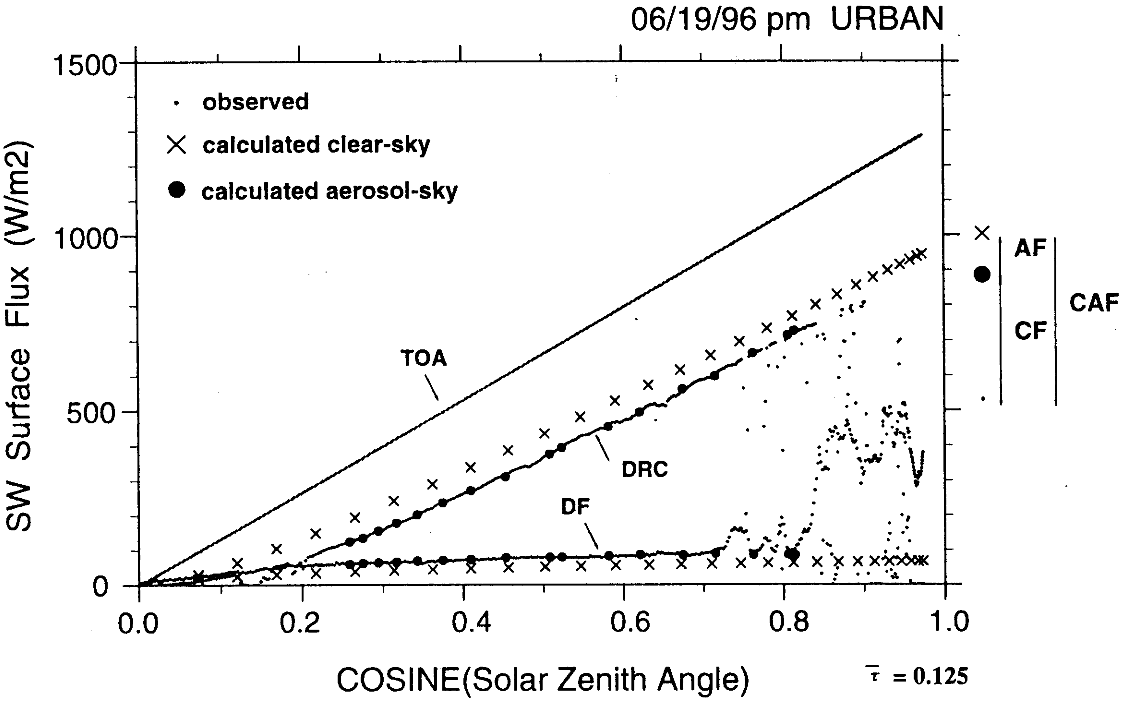

Fig.3

Direct and diffuse part of solar flux from 1-min. averaged pyrheliometer and pyranometer measurements (small dots), from clear-atmosphere calculations (crosses), and from aerosol-laden-atmosphere calculations (large dots) for the P.M. 19 June, 1996 plotted against the cosine of the solar zenigh angle. Straight line depicts the shortwave insolation at the top of the atmosphere. Mean aerosol optical thickness for 5um was 0.13.

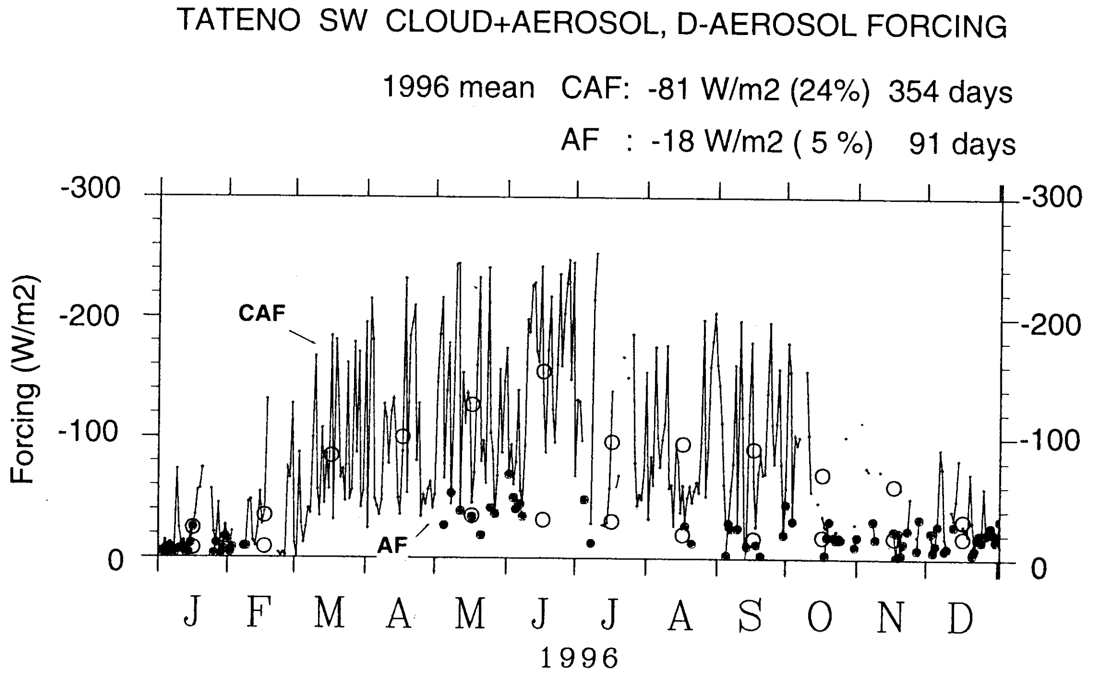

Fig.4

Time series of the cloud+aerosol, and aerosol solar radiative forcing at Tateno for 1996 depicted in W/m2. Daily means are depicted with small dots connected with lines and monthly means are depicted with open (for CAF) and closed (for AF) circles.

Table 1

Monthly means of TOA solar insolation (F0), surface cloud-plus-aerosol shortwave forcing (CAF), surface aerosol forcing (AF), and daily-mean-equivalent errors of aerosol-sky flux calculations for the global downward flux (AE_GL), direct component (AE_DRC) and diffuse component (AE_DF), respectively. N_day and N_obs indicate the numbers of days and observations included in the statistics of the aerosol-sky flux.

month	$F0$	CAF	AF	AE_{GL}	AE_{DRC}	AE_{DF}	N_{day}	N_{obs}
9601	186.7	-23.9	-7.3	8.6	8.4	0.2	14	337
9602	216.8	-29.9	-10.6	10.1	11.4	-1.3	1	24
9603	334.6	-84.5	–	–	–	–	0	0
9604	407.3	-99.9	–	–	–	–	0	0
9605	453.5	-127.0	-35.1	-4.0	-6.2	2.3	9	196
9606	471.6	-154.8	-31.9	-4.4	-5.3	0.9	5	114
9607	458.2	-105.8	-30.6	-15.1	-16.5	1.5	2	40
9608	420.9	-95.0	-19.9	3.9	4.4	-0.5	2	92
9609	358.1	-90.6	-16.4	6.1	8.7	-2.5	10	214
9610	278.6	-69.4	-18.0	5.7	4.8	0.9	10	271
9611	206.5	-58.2	-17.6	2.1	1.8	0.3	10	217
9612	183.4	-31.6	-17.6	1.7	2.1	-0.3	19	485
YRave	331.7	-80.9	-18.8	2.7	2.6	0.1	82	1990