SKYNET validation network and its activities

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The impact factors on estimation of the global warming are uncertainties of cloud, aerosol and its interaction in the global model. Increase in cloud amount can suppress global warming by carbon dioxide increasing from fossil fuels consumption and other warming gases, but its responsibility is not clear as shown in IPCC report. In order to estimate the global impact of these factors, highly accurate analysis of satellite data is required combined with ground-based observations, i.e. validation.

SKYNET is a network spread out in East Asia to accomplish these objectives. The SKYNET sites have several instruments mainly composed of sky radiometer, pyranometer and pyrgeometer. In several sites, intensive observations have been done by support of other projects, such as GAME project(Sri Samrong in Thailand and Hefei in China). These sites are operated in cooperation with the local institutes or observatories. Data observed are sent and analyzed at the data center, CEReS, Chiba University and CCSR, University of Tokyo. These data are shared openly with research groups and communities attended to this program.

The SKYNET data can give aerosol parameters deduced by sky radiance and radiation amounts in the East Asia. Then some typical size distribution of aerosols around the sites can be compiled and also downward solar radiation at the surface estimated from GMS-5 data is validated with SKYNET radiation data. The downward solar radiation depends strongly upon characteristics of aerosol and cloud, therefore the difference between the observed and estimated radiation gives some suggestion on observation and analysis system.

While the more accurate results from the satellite data are required for overall mapping of radiation budget, the SKYNET can play an important role in the research of the global warming and climate change.

1. Introduction

The important factors in the global climate change are uncertainties of cloud, aerosol and its interaction in the global model. Increase in cloud amount can suppress global warming by carbon dioxide increasing and other warming gases, but its responsibility is not clear as shown in IPCC report. The direct effect of aerosol is concerned with its amount(optical thickness) and its complex refractive index(absorptive or reflective), and these parameters have been observed and estimated for many years. On the other hand, an indirect effect has much more uncertainties in the climate system. The modification of cloud system due to aerosols can give an effect to the climate system , especially near the urbanized region.

The radiation budget is one of key parameters in the global climate change as well as water cycle, and the surface radiation is also basic. The global map of radiation should require satellite data, especially geo-stationary satellite data, such as a GMS. The SRB program has been performed for the surface radiation budget which used the ISCCP data basically. In this study GMS-5 data is used for estimation of downward solar radiation. In order to estimate the global impact of the climate change, highly accurate analysis of satellite data is required with a validation of ground-based observations.

The SKYNET observation network has been constructed to accomplish these purposes, aerosol detection and validation of solar radiation estimated from satellite data. The sites in the network are mainly located in the East Asia, because the AERONET operated by NASA has covered the wide areas over the world except for the Asian region.

2. SKYNET

The SKYNET is an observation network with several objectives such as validation for satellite products, supplies of basic data for atmospheric collection of satellite data, typical modeling of regional aerosol and so on. These network sites have been located mainly in the East Asia from Mongolia to Thailand, as shown in Fig.1. These sites can cover typical climate conditions from tropical to arid/semi-arid and grassland areas including an industrial area(Chiba).

There are three sites in China to observe a yellow sand event(Kosa) along one of major air flow lines from the west to the east in cooperation with sites in Japan. Another features of the SKYNET are to get the longitudinal data in the west Pacific Ocean using research vessels and commercial ships. These ships with a sky radiometer are continuously operated.

The basic observation system consists of sky radiometer for aerosol derivation, pyranometer (CM21 by Kipp & Zonen) and pyrgeometer(PIR by Eppley Lab.) for the global solar and terrestrial radiation. Also environmental temperature and humidity are observed continuously. In the sites, Si-Samrong in Thailand and Hefei in China are intensive field sites for the GAME project so both sites have special features such as net radiation instruments, microwave radiometer for water vapor and cloud liquid content and so on.

Observation itself can be done automatically, but several instruments should be taken care of, e.g., to wipe a dome glass of pyranometer and pyrgeometer. Therefore, each site is operated by local people who is with his institute or laboratory collaborated with our research center.

Collected data are stored in the CEReS, Chiba University and CCSR, the University of Tokyo, independently. These data is basically open to all community people after checking data. Quality control has been done carefully, because the clock of the computer at the observation site is sometimes unreliable. Recently, GPS receiver was introduced to the observation system of the Mandalgovi, Mongolia in order to adjust the system clock everyday. This modification could greatly improve the reliability of time stamp.

3. Asian Aerosol and its characteristics

Sky radiometer can give a size distribution and an optical thickness of aerosols which are derived from sky brightness of wavelength, 400, 500, 675, 870, and 1020nm(Nakajima et al., 1983,1996). An example of mean volume size distribution is shown in Fig.2.

The site of Minami-Torishima is more than 1800km southeast from Tokyo, and affected on a very low level by polluted air mass from the Asian continent. The pattern of size distribution can approximate a power law type roughly, such as Junge type, but in detail they have two or three mode depending on their source. The features of these distributions are that the density in an accumulation mode ranging around 0.1 to 0.2 um is lower than that of a giant particle mode over 1 um. This may be reasonable because the remote ocean area cannot have many sources of natural origin. The coarse mode might be made by natural sources, such as sea salt particles.

The third mode centered at 0.5 to 0.7um is found. After Pinatubo eruption, stratospheric aerosols were increasing temporarily and abruptly. This showed a similar mode(Remer and Kaufman, 1998), but the mode in our case may be not the stratospheric aerosols because three modes in the figure are increasing simultaneously.

Chiba and Tokyo Bay area have been industrialized and merchandized widely up to now. There are many manufacturers which consume huge energy, such as iron industries, oil plant, power plant and so on. Figure 3 shows mean volume size distributions observed at CEReS, Chiba Univ. Typical distribution shows a bi-modal distribution, accumulation and coarse mode. The mode centered around 1 um is not clear for lower density, but distinguished for relatively heavier cases. The source of this mode has been not identified and may be different from the remote maritime type. Accumulation mode is very clear and has a wide variety for seasons. As well-known, the mode has main part of second particles through a gas-to- particles process, such as sulfate particles, and can reflect the atmospheric pollution.

The seasonal variation of the size distribution is not so clear, but each season shows a little different distribution and density. The optical thickness in winter is relatively lower than that in other seasons, as shown in Table 1. This table shows also other related parameters for seasons. It should be noted the complex refractive index of aerosols are assumed to be 1.50-0.01i for all. The single scattering albedo(SSA) is strongly dependent upon it, so the SSA has almost similar value for all cases.

4. Surface radiation

4.1 Estimate of downward solar radiation at the surface

Surface solar radiation is the most sensitive to cloud amount as well as its optical thickness. Therefore, these are key parameters for retrieval of surface solar radiation from the satellite data. GMS-5 is a Japanese meteorological satellite which is one of geo-stationary network satellites in the world, and has four channels, wide visible, water vapor channel and split window channels. This can observe the Earth facing to the satellite every hour. It is the biggest advantage over the orbital satellite and is suitable for radiation study.

In this study, the analyzing area for estimation covers from 60° N, 80° E to 20° S, 160° E wide. The minimum basic unit in the analysis is 0.5 x 0.5 degree in Lat. and Lon. ECMWF(European Centre for Medium-range Weather Forecasts) objective analysis data is adopted for profiles of temperature, water vapor, and atmospheric pressure.

Cirrus which is detected by a split window technique was classified into the cases over 253 K and under 253 K. Optical thickness is assumed to be 2.2 and 7.4, respectively in warmer and colder case(Inoue, 1987). Water clouds are classified into 3 layers according to ISCCP category (Rossow and Garder, 1993). Cloud type, convective or stratus, is also checked by using auto-correlation technique. Cloud overlapping model is introduced such that maximum overlapping is used for convective cloud and random overlapping for stratus. Optical thickness of cloud can be retrieved by a reflection method of solar radiance, which was described in detail in Nakajima and Nakajima(1995).

Figure 4 shows an example of monthly averaged total cloud fraction in the northern summer (July, '97) and the northern winter (January, '97). In summer, a rain band from the Bay of Bengal to the Okhotsk Sea is shown apparently. Cloud due to the ITCZ is also seen from Philippine islands to the equator in the Central Pacific. Clouds found in the Japan sea in winter are convective due to heating from the warm sea covered by the Siberian clod air blow-off.

For computation of surface solar radiation, RSTAR5 code, developed by Nakajima et al.(1983, 1986 and 1988), is used. Lookup table for surface solar flux is composed of parameters of optical thickness of cloud, ratio of water cloud to ice cloud, optical thickness of aerosol, effective water vapor, solar zenith angle, and surface reflectance. Global Aerosol Data Set (GADS, Kopke et al., 1997) developed by the Max Planck Institute is adopted for aerosol data because of no information over land.

Figure 5 shows an example of a daily mean map of surface downward solar flux in summer and winter. The mean solar flux which is derived by integration of hourly incoming solar radiation can reflect the variation of cloud and aerosol amounts. Cloud forcing for solar radiation at the surface is shown in Fig. 6, which is defined by the daily mean flux (Fig.5) minus daily mean cloud free flux. In July, large negative values are shown from the Bay of Bengal to the Okhotsk Sea and around the Philippine islands, corresponding to the cloud amount described before. There are also large negative value in South of the equatorial and small value in the Bengal Sea in January. Small values are shown over the part of Australia.

4.2 Comparison between estimated and observed radiation

The estimated surface solar flux can be compared with that observed at sites of the SKYNET. The comparison is performed using a daily mean solar flux, because an hourly data is not so good accordance with each other due to brokenness of cloud in space and time(or locality in cloud).

Figure 7 shows the comparison of the

estimated flux in daily mean with the observed one. Figure 7a shows the cases under clear sky condition which is classified by surface observed data using pyranometer output. The data at Si-samrong in October 1997 shows the small difference between them, but in January 1998 the estimation is under the observation. The satellite solar flux under clear sky condition has a variation due to water vapor and aerosol amount. The observed flux is widely changeable in time and space rather than the estimated flux, because the latter one is used with a representative aerosol model and water vapor from ECMWF data. So, these parameters should be discussed to be appropriate or not. Further analyses using aerosol characteristics derived from the SKYNET data will solve the distinction between the satellite estimate and the observed solar flux.

Figure 7b is the same as Fig. 7a except for cloudy condition. The surface observed data at Shouxian in July, 1998 show wide variation from 46 to 312 W/m2, while the satellite solar flux varies from 162 to 301 W/m2. The figure shows the overestimation of satellite solar flux as a whole. In other words, the cloud amount and/or optical thickness may be under-estimated. The difference between the observed and estimated flux is relatively small for more than 250W/m2 while for less than around this value the difference become bigger when the observed value is smaller, i.e. cloud is heavier. This means that the cloud estimation including overlapping effect has some problems.

In the algorithm to infer the surface solar radiation, an optical thickness of cloud has been decided by choosing the median pixel which is the center of the histogram of the brightness temperature by thermal infrared channel in the unit area (0.5 x 0.5 deg in Lat and Lon.). This selection of the pixel for retrieving the optical thickness has no physical reason, but the pixel can represent the typical cloud brightness temperature, i.e., cloud height. The statistics in optical thickness in the unit area should be considered as well as the brightness temperature histogram. Another possibility of underestimation of cloud optical thickness is inhomogeneity. The rough surface of cloud top can make shadow to a neighboring cloud and can affect the estimation of optical thickness of cloud to be smaller. This effect will be estimated by highly resolved cloud images such as airborne data.

5. Summary

The SKYNET data can give information of aerosol at various sites in the east Asia. Typical aerosol models are compiled from these observations, and will be introduced into radiative process in the solar radiation estimation.

These are also used for validation of the downward solar radiation estimated from GMS-5 data. The comparison with ground-based observed data shows the relatively good accordance for clear sky days, but for the cloudy condition, the difference is much bigger than that for clear days. This suggests that the cloud estimation has some defects in the algorithm or data analysis processes.

References

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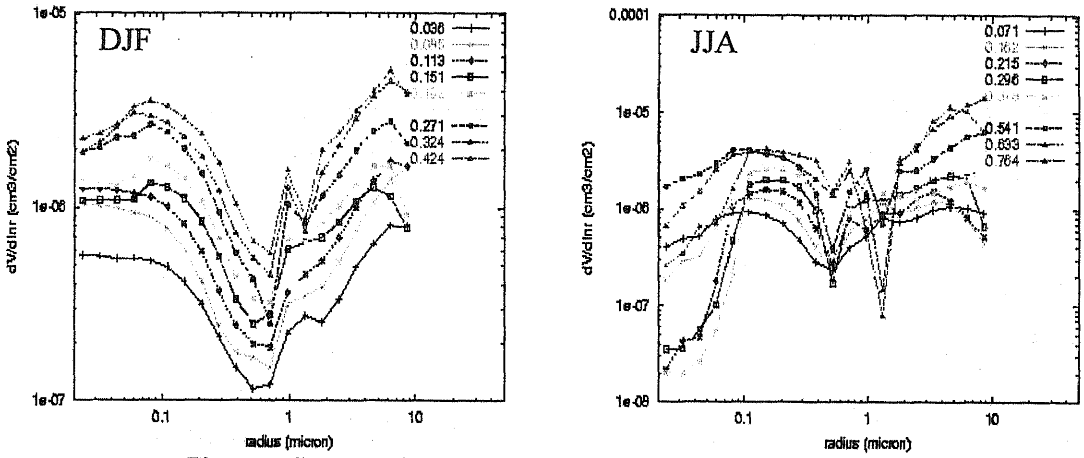

Figure 3 Same as Figure 2 but for Chiba. (Left: DJF, Right: JJA)

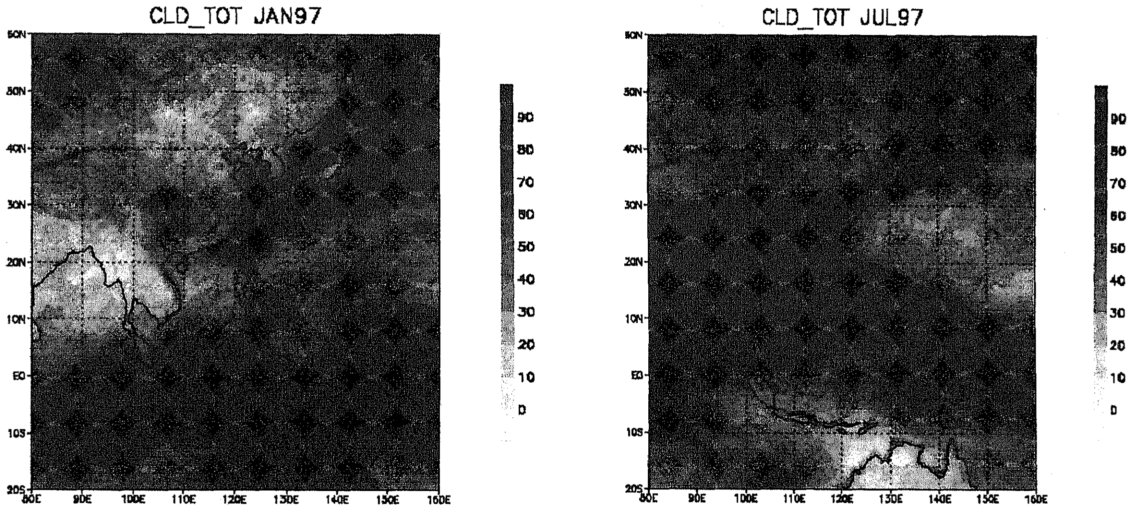

Figure 4. Total cloud amount for Jan.(Left) and for Jul.(Right)

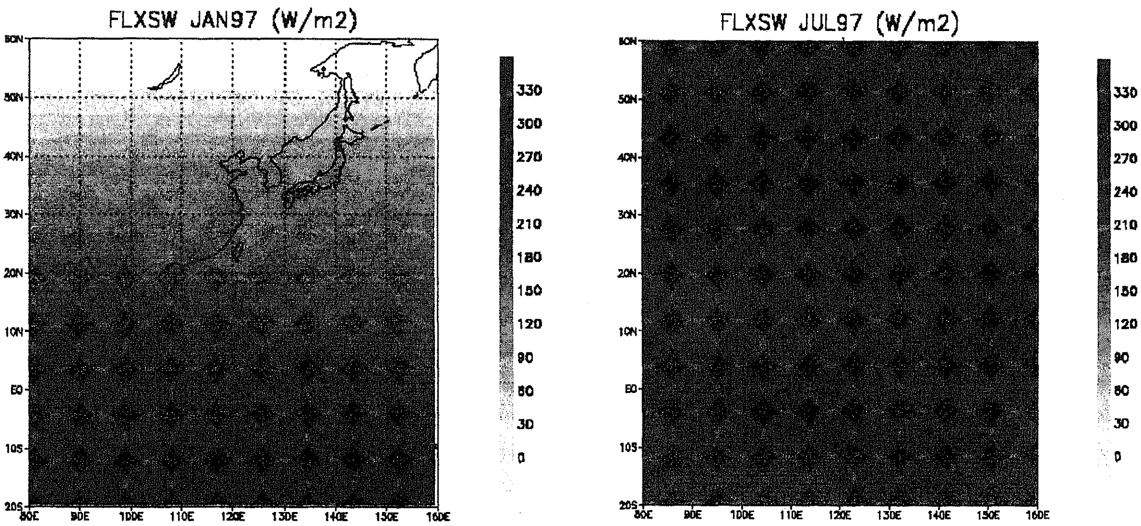

Figure 5. Daily mean downward surface solar radiation(Left:Jan.1997, Right: Jul. 1997)

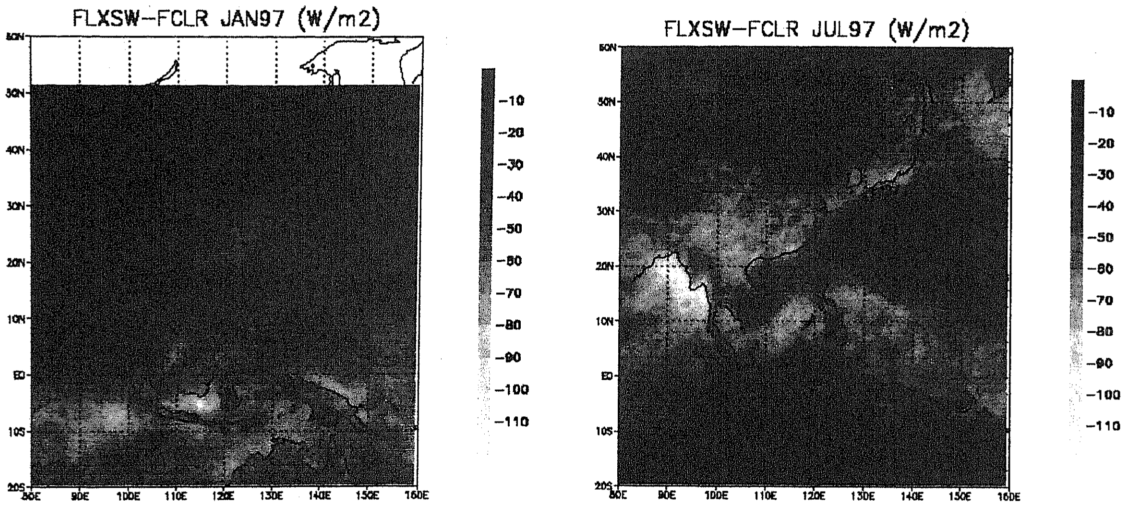

Figure 6. Radiative forcing(Fig. 5 minus clooud free downward flux)

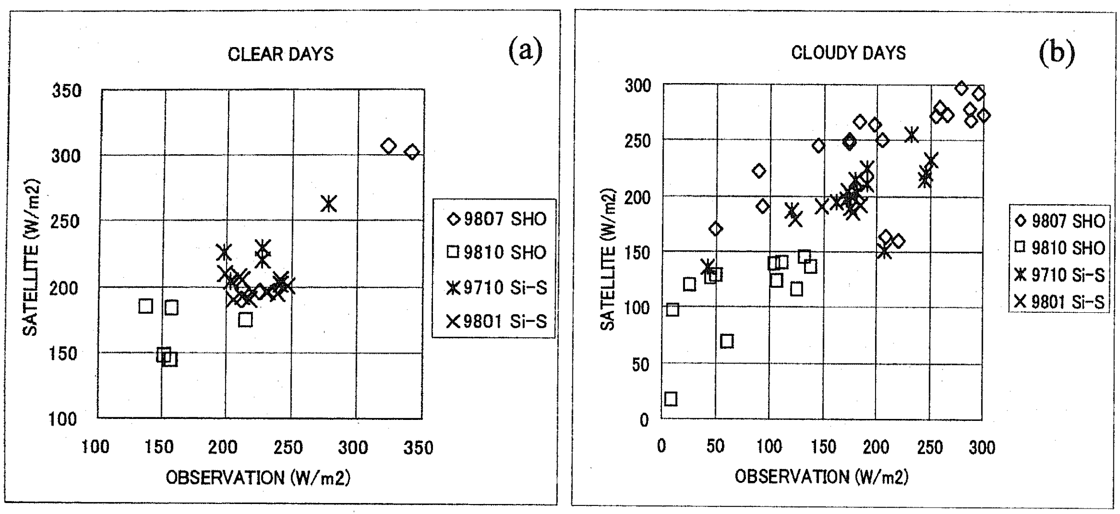

Figure 7. The comparison of the satellite solar flux with the surface observed solar flux.
The comparison is available in daily mean flux at Si-samrong in October 1997 (9710 Si-S) and January 1998 (9801 Si-S), and at Shouxian in July 1998 (9807 SHOI) and October 1998 (9810 SHO). (a) Daily mean solar flux in clear sky days. (b) Same as (a) but in cloudy days.

Table 1. Summary of optical parameters of aerosols. M=1.50-0.01i is assumed.

Location		Tau	SSA	G	Number	Location		Tau	SSA	G	Number
Chiba	DJF	0.251	0.873	0.636	2328	linami-Torishim	DJF	0.127	0.821	0.742	1397
	MAM	0.470	0.888	0.678	348		MAM	0.122	0.814	0.734	1544
	JJA	0.485	0.875	0.683	939		JJA	0.188	0.841	0.722	1505
	SON	0.284	0.886	0.673	1422		SON	0.100	0.816	0.737	1973
	Yr	0.319					Yr	0.132			
Dunhuang	DJF	0.318	0.819	0.754	2388	Mandalgovi	DJF	0.231	0.850	0.616	742
	-	-	-	-	-		MAM	0.242	0.876	0.650	1753
	-	-	-	-	-		JJA	0.393	0.853	0.667	1293
	SON	0.202	0.814	0.767	1767		SON	0.175	0.855	0.646	3125
	Yr	0.269					Yr	0.239			
Si-Samrong	DJF	0.469	0.879	0.661	1032	Yinchuan	DJF	0.323	0.821	0.754	8708
	MAM	0.330	0.824	0.702	417		MAM	0.298	0.827	0.749	4024
	JJA	0.534	0.885	0.639	345		JJA	0.524	0.820	0.763	4771
	SON	0.329	0.869	0.717	705		SON	0.290	0.811	0.760	1679
	Yr	0.415					Yr	0.365			