Comparison of Long-term Downward Radiation Observations at Tateno with JRA-25 and ERA-40

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INTRODUCTION

Aerological Observatory of Japan Meteorological Agency (Tateno) has been carrying out long-term observation of shortwave and longwave radiation at surface since 1957, International Geophysical Year (IGY). Tateno is one of the stations of WCRP Baseline Surface Radiation Network (BSRN) (Ohmura et al., 1998) and has been providing accurate radiation data to researchers from 1996 via the BSRN data archive. In recent years, several long-term reanalyses were conducted to produce global homogeneous datasets of atmospheric physical parameters for more than several decades. Among of them, JRA-25 and ERA-40 provide high quality datasets with high temporal and spatial resolution (Onogi et al., 2007, Uppala et al., 2005). In these reanalyses, many atmospheric parameters such as surface air temperature and precipitation are well represented. In this study, the downward shortwave and longwave radiation at surface of the reanalyses are compared with observations at Tateno over a long period to assess their quality.

DATA

1) Tateno observations

Radiation observation started in 1957 at Tateno and downward shortwave and longwave radiation have been observed since then. For longwave radiation, the observation couldn't be carried out in daytime or in case of rain because of technical difficulty in instrument in early times. From 1976, all-day continuous observation has been carrying out for longwave radiation. For shortwave radiation, continuous observations are available from 1957, the start of radiation observation at Tateno. In the comparisons, the period from 1979 to 2004 are used for both shortwave and longwave radiation in accordance with the time coverage of the reanalyses.

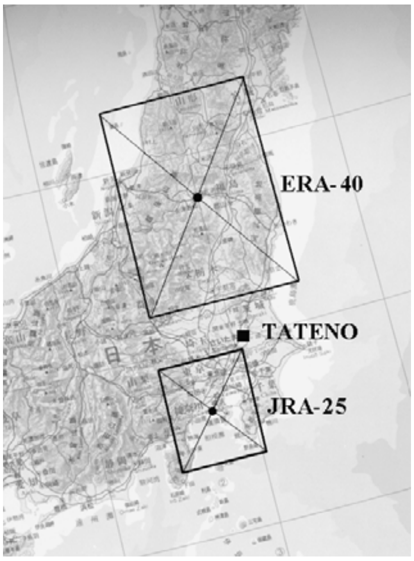

Figure 1 Location of Tateno and used grids of JRA-25 and ERA-40

Table 1 Latitude and Longitude (°) of Tateno and used grids of ERA-40 and JRA-25

Name	Latitude	longitude
Tateno	36.050° N	140.133° E
JRA-25	35.327° N	139.500° E
ERA-40	37.500° N	140.000° E

2) Reanalyses data

The nearest land grid points from Tateno of JRA-25 and ERA-40 are used in the comparisons. Figure 1 and Table 1 show locations of Tateno and used grids of JRA-25 and ERA-40. The spatial resolutions are T106, which is comparable to lat-lon grid with 110km interval, for JRA-25 and 2.5°x2.5° lat-lon grid for ERA-40. Used data periods are from 1979 to 2004 for JRA-25 and from 1979 to 2001 for ERA-40, respectively.

METHOD

The reanalyses data are compared with Tateno observations under two different sky conditions, all sky and clear sky condition.

In this study, clear sky is defined as 0 to 0.10 cloud coverage and we use 3-hourly eye observation for clouds at Tateno, which is available from 06LT to 21LT, in detecting clear sky. In the shortwave radiation comparisons under clear sky condition, the days of clear sky throughout the daytime (06, 09, 12, 15 and 18LT) are selected and annual mean daily clear sky value is compared. It is noted that clear sky days are mostly observed during the winter season at Tateno. On the other hand, annual mean nighttime (21-03LT) value is compared for longwave radiation. In this case, clear sky days are selected by using eye observation at 21LT. It should be noted that clear sky radiation data at surface (element names: CSDSFsfc, CSDLFsfc) on the clear sky days are used for JRA-25, while all sky radiation data at surface (element names: SSRDsfc, STRDsfc) on the clear sky days are used for ERA-40. It is considered that ERA-40 data used in comparisons under clear sky condition contain some cloud effects, so we cannot discuss in detail about the comparison results of ERA-40 under clear sky condition.

In the comparisons under all sky condition, annual mean daily values are compared for both shortwave and longwave radiation. Used element names of the reanalyses are DSWRFsfc and DLWRFsfc for JRA-25, and SSRDsfc and STRDsfc for ERA-40.

COMPARISONS OF DOWNWARD SHORTWAVE RADIATION

1) Conversion of reanalyses data

Before the comparison, the reanalyses data are converted to the value at Tateno according to the each grid center latitude, i.e. they are multiplied by the ratio between the daily total clear sky solar flux over Tateno and those over the center of the grids.

2) Results

The comparison results for downward shortwave radiation are shown in Figure 2. JRA-25 and ERA-40 have the same long-term trend under all sky and clear sky conditions. It is also shown that the reanalyses denote the same tendency as Tateno observations under the both conditions, in general. Under all sky condition, ERA-40 is well accorded with Tateno observations with very slight differences especially from the end of the 1980s under all sky condition. JRA-25 is well accorded with Tateno observations with a little overestimation (12.1W/m^2) under clear sky condition although it has rather a large overestimation (50.0W/m^2) under all sky condition. In JRA-25, subtropical marine stratocumulus off west coast is well represented by adopting a simple but competent stratocumulus parameterization (Kawai et al., 2006), but the result implies that JRA-25 underestimates cloud amount over Tateno.

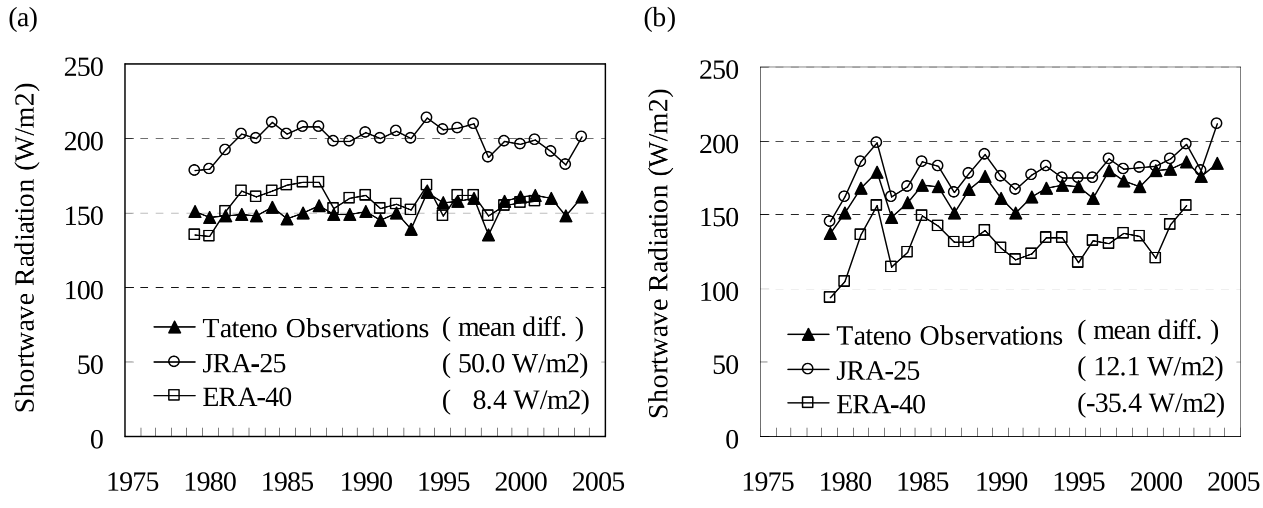

Figure 2 Time series of annual mean downward shortwave radiation, in W/m^2: (a) under all sky condition and (b) under clear sky condition. Mean differences (Reanalyses – Tateno Observations) for the whole comparison periods are also denoted.

COMPARISONS OF DOWNWARD LONGWAVE RADIATION

1) Bias estimation and correction of Tateno observations

The earlier types of instrument for longwave radiation have less quality and observations by these instruments contain biases. Before the comparisons, Tateno observations in nighttime (hourly mean data at 12UTC) under clear sky condition are compared with radiative transfer calculations and systematic biases due to instrument changes are estimated and corrected. As radiative transfer model, MODTRAN (Kneizys et al. 1996) is adopted. For temperature, pressure and water vapor profile, significant level radiosonde data at Tateno at 12UTC are used in the radiative transfer calculations. It is noted that the radiosonde data are used after applying bias correction according to results of simultaneous radiosonde measurements (World Meteorological Organization, 1996, The Aerological Division of JMA, 1983). To take long-term variability of carbon dioxide into consideration, monthly mean carbon dioxide total column amount in the mid latitude of the northern hemisphere (60° N-30° N), which are supplied by Atmospheric Environment Division of JMA, are used in the calculations. We use default profiles in the radiative transfer model for other greenhouse gases. For aerosol, only background stratospheric aerosol is taken into account in the calculations. Figure 3 shows differences of longwave radiation between Tateno observations and MODTRAN calculations. It is known that the most recent type of instrument has good quality with uncertainty less than about 3W/m^2 (Gröbner et al., 2007), so bias for each type of instrument is defined here as deviation from the most recent type of instrument (horizontal thick line in figure 3). To evaluate the bias correction, Tateno observations are compared with black body radiation emitted by a black body at surface air temperature (Figure 4). It is shown that Tateno observations are well accorded with blackbody radiation after the bias correction especially around 1980. From this result, it is confirmed that the bias correction for longwave radiation works well.

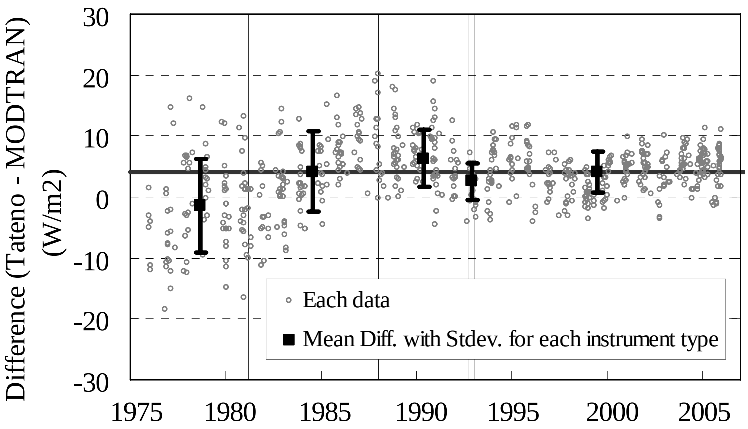

Figure 3 Differences of longwave radiation between Tateno observations and MODTRAN calculations, in W/m^2. The vertical lines represent the transition of instrument, and the square and the vertical bars represent the mean and the standard deviation for each instrument type, respectively. The horizontal thick line represents the mean difference of the most recent type of instrument.

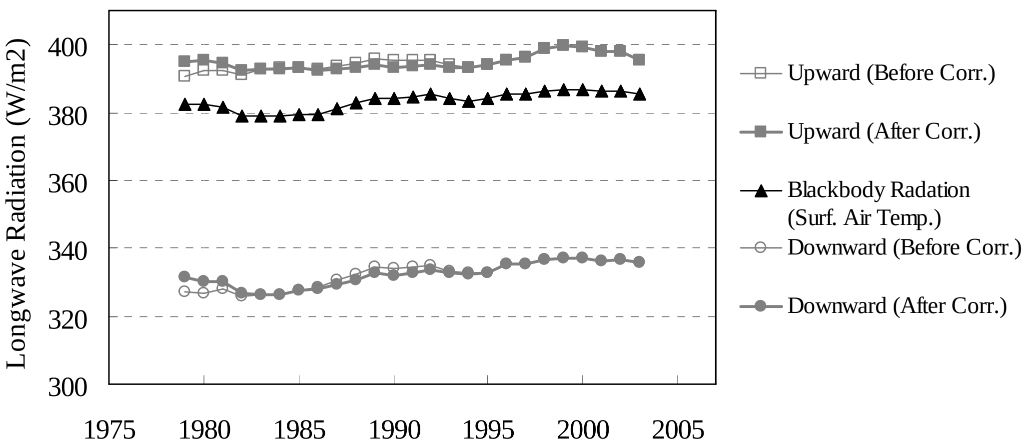

Figure 4 Time series of 5-year running mean upward, downward longwave radiation and blackbody radiation emitted by a blackbody with surface air temperature at Tateno, in W/m^2. Thick lines represent upward and longward radiation after applying the bias correction and thin lines represent those without the correction, respectively.

2) Results

The comparison results for downward longwave radiation are shown in Figure 5. The two reanalyses have the same long-term trend and tendency as Tateno observations for the whole period. The results also show that the both reanalyses have underestimations against Tateno observations as seen in ERA-15, which is the previous reanalysis at ECMWF, and other GCMs (Morcrette, 2001). JRA-25 seems to have a larger underestimation (-22.5W/m^2) than that of ERA-40 (-9.0W/m^2). To verify the assumption of the cloud amount underestimation in JRA-25 from the shortwave comparison results, we compare the differences between JRA-25 data and Tateno observations under the two conditions (Figure 6). It is shown that the difference under all sky condition (-22.5W/m^2) is greater than that under clear sky condition (-19.0W/m^2). This result corresponds with the assumption of the cloud amount underestimation in JRA-25.

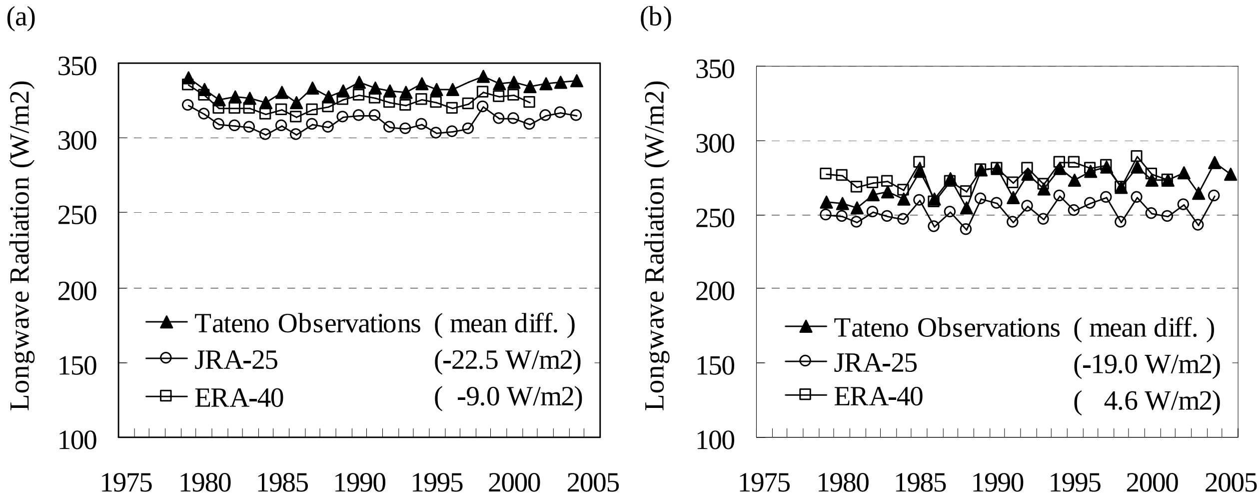

Figure 5 Time series of annual mean downward longwave radiation, in W/m^2: (a) under all sky condition and (b) under clear sky condition. Mean differences (Reanalyses – Tateno Observations) for the whole comparison periods are also denoted.

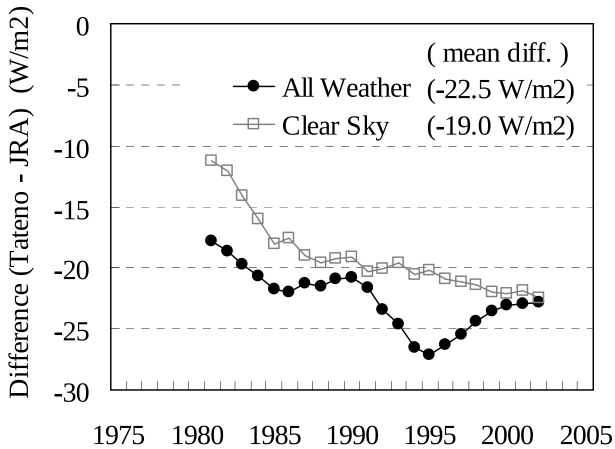

Figure 6 Comparison between 5-year running mean difference (JRA-25 - Tateno) under all sky condition and that under clear sky condition, in W/m^2. Mean differences (Reanalyses – Tateno Observations) for the whole comparison periods are also denoted.

SUMMARY

ERA-40 and JRA-25 surface radiation data are compared with Tateno observations over a long period. The results show that the reanalyses have the same long-term trend as Tateno observations in both shortwave and longwave radiation and well represent realistic long-term trend of shortwave and longwave radiation at surface, in general. For shortwave radiation, ERA-40 is well accorded with Tateno observations with little differences except before middle of 1980s under all sky condition. Comparisons of shortwave radiation under all sky and clear sky imply that JRA-25 may underestimate cloud amount. This assumption is consistent with the results of longwave radiation comparisons under all sky and clear sky conditions for JRA-25. There exist differences between Tateno observations and the reanalyses. An overestimation for shortwave radiation under all sky condition in JRA-25 is mainly due to an underestimation of cloud amount over Tateno. For longwave radiation, the both reanalyses have underestimations against observations as seen in other many reanalyses and GCMs. The cause may radiation process including cloud parameterizations in the model, and also atmospheric constituents which are not taken into account in the model such as aerosol.

ACKNOWLEDGEMENT

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