Introduction to Simulation Activity for CMDPS Evaluation Using Radiative Transfer Model

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Abstract

Satellite observed brightness temperature simulation using a radiative transfer model (here after, RTM) is useful for various fields, for example sensor design and channel selection by using theoretically calculated radiance data, development of satellite data processing algorithm and algorithm parameter determination before launch. This study is focused on elaborating the simulation procedure, and analyzing of difference between observed and modelled clear sky brightness temperatures. For the CMDPS (COMS Meteorological Data Processing System) development, the simulated clear sky brightness temperatures are used to determine whether the corresponding pixels are cloud-contaminated in cloud mask algorithm as a reference data. Also it provides important information for calibrating satellite observed radiances. Meanwhile, simulated brightness temperatures of COMS channels plan to be used for assessing the CMDPS performance test. For these applications, the RTM requires fast calculation and high accuracy. The simulated clear sky brightness temperatures are compared with those of MTSAT-1R observation to assess the model performance and the quality of the observation. The results show that there is good agreement in the ocean mostly, while in the land disagreement is partially found due to surface characteristics such as land surface temperature, surface vegetation, terrain effect, and so on.

KEY WORDS: Simulation data, radiative transfer model, clear sky brightness temperature, geostationary satellite.

1. Introduction

For the COMS Meteorological Data Processing System (CMDPS) development, the generation of the simulated clear sky brightness temperatures play an important role in previously check up usefulness and sensitivity of specification channels for producing of baseline products before the meteorological imager payload development. The simulated clear sky brightness temperatures are used to validate the CMDPS products and to monitor satellite observation data quality that this is known for sensor design and characteristics. For these application, the simulation data are usually processed to input of baseline products, such as cloud detection, Atmospheric Motion Vector (AMV), SST (Sea Surface Temperature) and so on.

To calculate for simulated brightness temperatures require a fast Radiative Transfer Model (RTM) which runs fast with high accuracy. Hence the parameterization model, the fast radiative transfer model(RTTOV-8) is used to produce for simulated brightness temperatures. It is calculate for RTM apply to input using the Korea Meteorological Administration (KMA) GDAPS (Global Data Assimilation Prediction System) profiles of temperature, humidity and surface data.

The numerical weather prediction (NWP) requires a good quality background fields. It is standard practice to use the radiances themselves and to assimilate them into NWP by adjusting the model fields to minimize the difference between the observed brightness temperatures and simulated by the model. This requires an accurate forward radiative transfer model to provide the simulated brightness temperature as well as knowledge of the error characteristics both of the model and of the data(English et al. 2000). Thus, a similar study, Mocrette (1991) compared model-simulated brightness temperature from Meteosat and for evaluating model-generated cloudiness. Recently, Chevallier and Kelly (2002) have compared Meteosat infrared window imagery with simulations using the current version of ECMWF model and the RTTOV. While, Yu et al. (1997) showed results for comparisons of model-simulated brightness temperature with GOES measurements.

The purpose of this study is to compare the simulated clear sky brightness temperatures with those of MTSAT-1R observation to assess the model performance and the quality of the observation. The satellite data and a fast radiative transfer model of the RTTOV-8 are described in section 2. The section 3 discusses the result of comparing simulation data with observation data. And the error analysis of spatial and temporal results present.

2. Data and method

This Study is focused on the comparison between clear sky observed brightness temperature by the infrared channel(10.8, 12.0, 6.7, 3.7 ㎛) onboard MTSAT-1R and their RTTOV-8 equivalent. The study is performed for four 15-days periods in 2007-1-15 January, 1-15 April, 2006-1-15 July, and 1-15 October sampling the seasonal cycle within the MTSAT-1R.

2.1 Satellite data

The MTSAT-1R is the Japanese geostationary satellite with imager which located at 140E. It has one visible channel(0.65 ㎛) and four infrared channels(10.8, 12.0, 6.7, 3.7 ㎛). The radiometric resolution increases from 8bits to 10bits, and the spatial resolution improves performance of 25%. The MTSAT-1R brightness temperatures are used here in the form of so-called CSBT (Clear Sky brightness temperature) produced by CMDPS. To derive the CSBT, the observed brightness temperature are screened for Neural Network cloud detection algorithm. Hereafter, the observed CSBT compared with simulated CSBT of calculating using RTM. Although the observed CSBT data are produced hourly, only 6 hourly brightness temperature will be compared with their RTM equivalent.

2.2 Model output

The simulated brightness temperatures are obtained from the GDAPS T426 background fields presented to the initial data processing. The model resolution has 40 levels with a horizontal grid spacing of about 30km. The 6-hourly model background fields used here correspond to model runs ranging for 6h forecast, starting at 00UTC times.

The generation of simulated brightness temperatures using radiative transfer model are obtained using the background profiles of temperature and humidity, skin temperature, and specified surface emissivity as input to RTTOV-8(Eyre 1991; Saunders et al. 1999). The cloud parameter of model is ignored in RTTOV-8, and thus the simulated brightness temperatures are always considered clear sky. A basic description of radiative transfer equation follows; the atmospheric upwelling clear-sky radiance, $L^{clr}(\nu,\theta)$, at frequency ν and viewing angle θ from zenith at surface is written as,

$$L^{clr}(\nu,\theta)=\tau_s(\nu,\theta)\varepsilon(\nu,\theta)B(\nu,T_s)+\int_{\tau_s}^{1}B(\nu,T)d\tau + (1-\varepsilon_s(\nu,\theta))\tau_s^2(\nu,\theta)\int_{\tau_s}^{1}\frac{B(\nu,T)}{\tau^2}d\tau \qquad (1)$$

Where, τ_s = the surface to space transmittances
τ = the layer to space transmittances
ε_s = the surface emissivity
B = the Planck radiance for a scene temperature
T, T_s = the layer mean temperature and the surface skin temperature

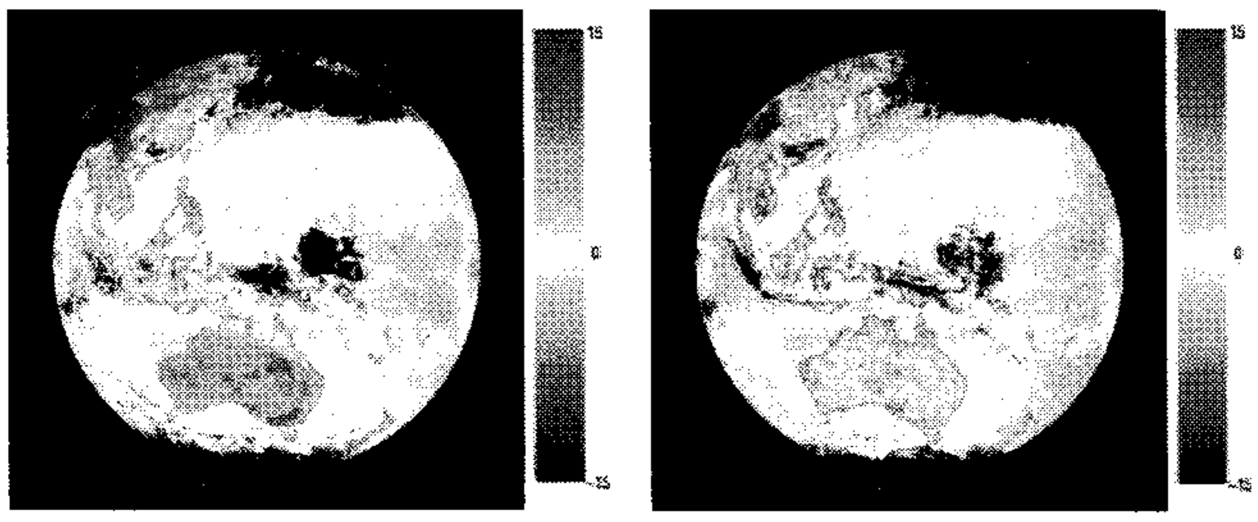
The first term is the emitted by the surface, the second term is the direct radiance emitted by the atmosphere, and the third term is the radiance reflected by the surface. To give the actual channel radiance is convolved with the response function of MTSAT-1R.

2.3 Method

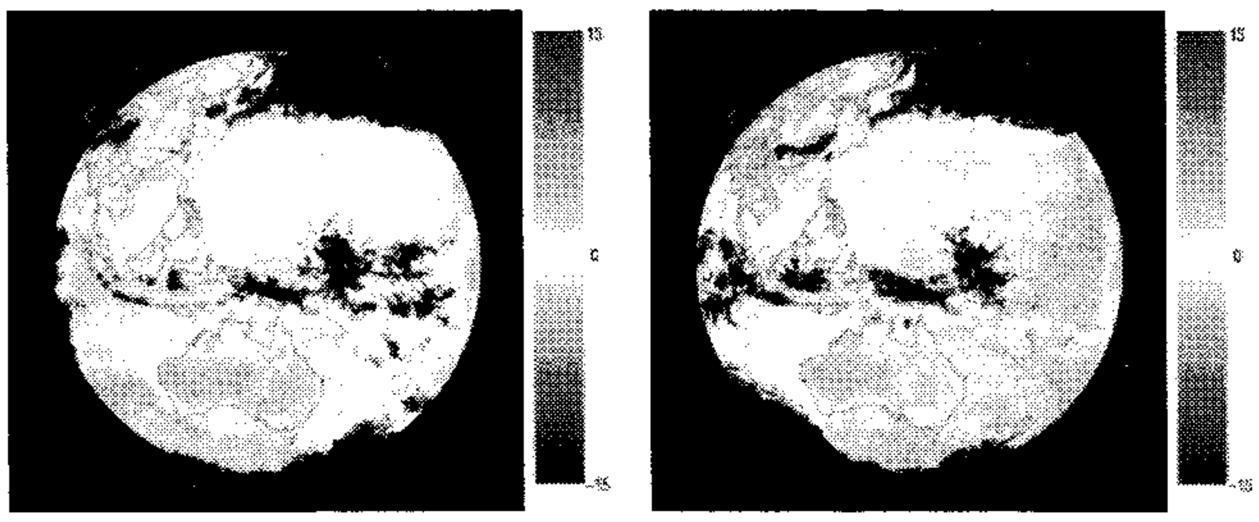
The comparison of observed and simulated brightness temperatures are carried out over the whole MTSAT-1R field of view within 65 degree areas of satellite zenith angle from the nadir point. These overall results show a clear sky brightness temperature except cloudy atmosphere. Also the detailed analysis of the difference observed and simulated brightness temperatures were studied taking into account a set of temporal and spatial property. Here a set of study area was selected so that at each time slot the atmospheric conditions and surface type within each region is fairly homogeneous. As for the difference characteristics from observed minus model clear sky brightness temperature, each areas are selected six regions which presented of desert, high elevation, tropic ocean, mid-latitude ocean, terrain effect region, and snow depth region of high-latitude, respectively.

3. Results

The mean bias(clear sky observed minus model brightness temperatures) averaged for each of the 15-day periods are shown in Fig. 1. The 00 UTC(12UTC) and 06 UTC(18 UTC) time slots are representative of the daytime(night-time) for MTSAT-1R. The April 00 and 06 UTC time slots show large areas where positive mean bias clearly dominate. These include most of the semiarid and desert Australia regions, most of mid-latitudes in west Asia and high latitudes in Russia. Over these regions the simulated brightness temperatures near their diurnal maximum tend to be colder then observations by 2 to 10K or larger Because of the diurnal cycle of simulated brightness temperatures for the window channel is mainly driven by the surface temperature. These show vast areas where the amplitude of the modelled surface temperature



(a) 00 UTC (b) 06 UTC



(c) 12 UTC (d) 18 UTC

Fig.1. The difference between observed for MTSAT-1R and RTM simulated data using GDAPS of the global distribution of clear sky brightness temperatures. The Bias is averaged for the period 1-15 April 2007 obtained for MTSAT-1R at (a) 0033, (b) 0533, (c) 1133, and (d) 1733 UTC.

is systematically underestimated. The differences between observed and simulated brightness temperatures for the nighttimes generally range from -5 to +5 K and over high elevated regions, the nighttimes' bias may reach up to 10K, associated with on overestimation of the model cooling over such high elevated terrain and to the smoothing of mountain topography in the model. In order to identify the main sources of systematic errors of the difference between observed and simulated brightness temperatures were analyzed for each of the regions selected in local characteristics (Table 1).

The time series of the difference in brightness temperature between observed and simulated data are plotted in Fig. 2 for the April period. The Australia desert regions (Fig. 2-(a)) are characterized by dry atmosphere and very low moisture. The high proportion of diurnal variability of the observed and modelled clear sky brightness temperature seems to be mirrored in diurnal fluctuations of difference values. Over dry region, the top of the atmosphere brightness temperature for 10.8 ㎛ channel are mostly driven by the surface, and thus, are driven indirectly by surface property. Fig. 2-(d), (e) and (f) was showed similar results. This seems to be associated with the respective dominant vegetation type and elevated terrain. Within the studied regions, the time series for the ocean areas (Fig. 2-(b) and (c)) exhibits the lowest fluctuation within ±3 K ranges.

Table. 1. Study areas within MTSAT-1R

Area	Surface characteristics
R 1	desert (Australia)
R 2	Tropic ocean
R 3	Mid-latitude ocean
R 4	High elevated terrain(West Asia)
R 5	The Plateau of China
R 6	Snow depth regions of high-latitude

4. Conclusion

The comparison between observed and simulated brightness temperatures here has two main purposes which are to identify problems with observational data and to assess the model quality. If CMDPS algorithms are implemented, The simulated brightness temperatures are used for assessing the CMDPS performance and the quality of the observation. Although it showed the difference between observed and simulated brightness temperatures, it would be anticipated the good simulation results according to improvement of NWP.

In this study, the temporal and spatial brightness temperatures differences are compared with observed brightness temperatures and generated for global regions. Over dry, clear sky regions, the atmosphere is fairly transparent for window channel of 11 ㎛. Consequently, the discrepancies between the simulated and brightness temperatures to a large extent reflect how well the skin temperature is simulated by the GDAPS model. Over land and under clear sky regions, the diurnal variations of the skin temperature are particularly sensitive to surface characteristics, such as surface type, vegetation and albedo. In those cases, the sensitivity during daytime tends to be higher than that for nighttimes, i.e., the amplitude of the modelled skin temperatures tends to be underestimated. It is inferred that there are uncertainties and simulation for land surface temperature extrapolation and applying real terrain in the model.

Under clear sky conditions, the diurnal cycle of 11 ㎛ brightness temperatures, and land surface temperature tends to be greatly underestimated by the model, particularly over semiarid, desert regions, and high elevated regions. On the other hand, the mean bias in the ocean represented the lowest fluctuation within ±3 K ranges.

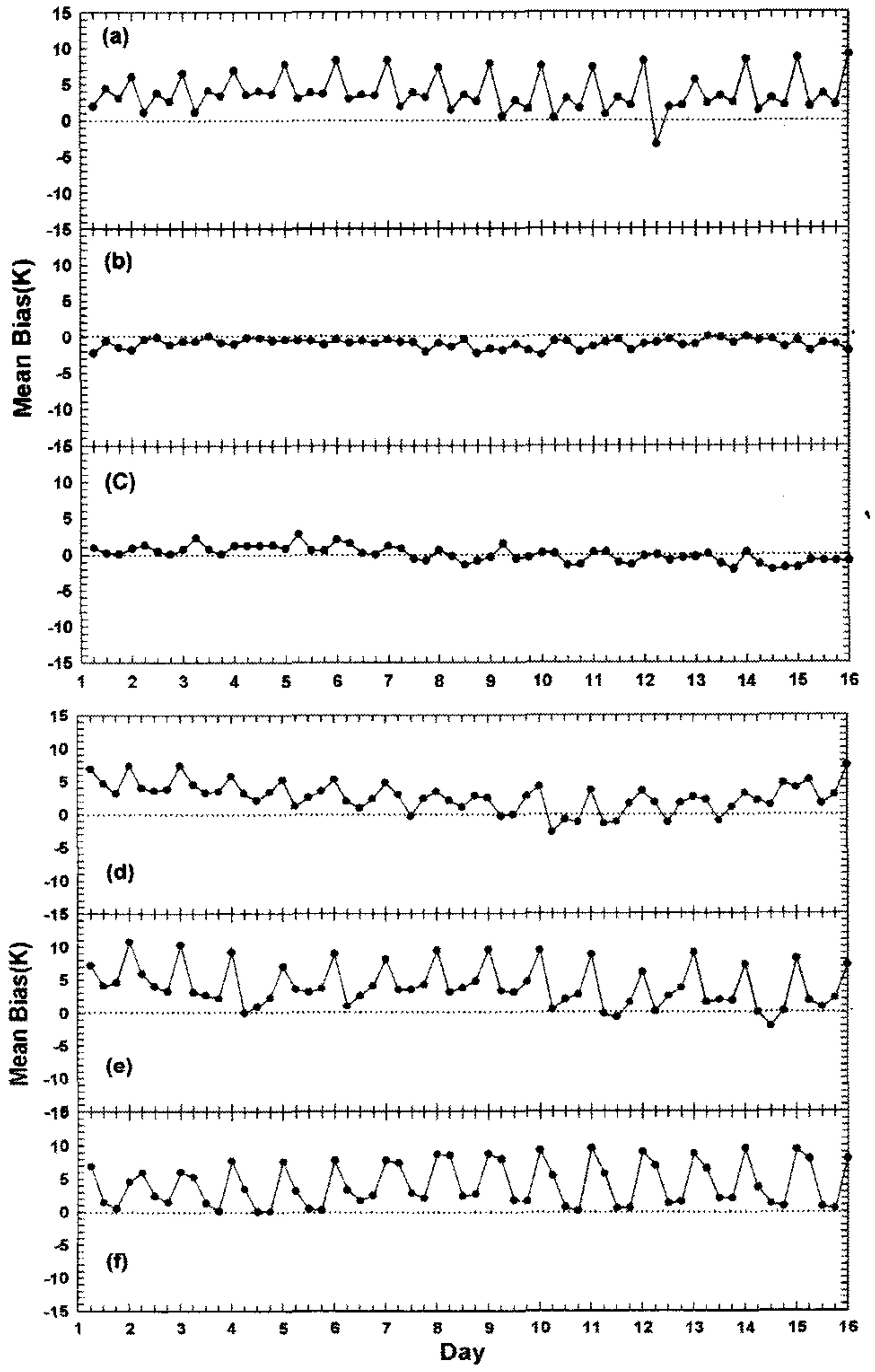


Fig. 2. Time series of observed minus calculated brightness temperature for MTSAT-1R in the period 1-15 April 2007. The results are presented for six areas within MTSAT-1R, (a) Australia desert, (b) Tropic ocean, (c) Mid-latitude ocean, (d) high elevated area of West Asia, (e) The Plateau of China, and (f) Snow depth regions of high latitude on Russia.

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