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Evaluation and comparison of hourly and daily Tropical Rainfall Measuring Mission (TRMM) precipitation products with the rain gauge data in the Sungai Baung district, South Sumatera

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Abstract. Precipitation is a highly dynamic process, constantly changing in form and intensity as it passes over a given area. Nowadays, rainfall data required for a wide range of scientific applications can be achieved through meteorological satellites. However, the satellite data require a validation by comparing with in-situ. This study is designed to evaluate and to compare the hourly and daily precipitation obtained from the Tropical Rainfall Measuring Mission (TRMM) satellite and an Automatic Weather System (AWS) located at the Sungai Baung district, South Sumatera. Due to instrument failure, only short period from 1 November 2013 to 31 December 2014 of rainfall data were obtained from the AWS. The correlation and regression analysis were used to examine the TRMM data in this study. The results revealed that the TRMM data have significant correlation with the AWS data. On the hourly timescale, the coefficient correlation of the precipitation data is r= 0.12 (significant at 99% r > 0.043). Furthermore, the correlation significantly increases on the daily timescale, which r= 0.64 (significant at 99% of r > 0.135). In general, TRMM data can be used for estimating the precipitation over the rural or unpopulated areas where rain gauge is unavailable.

1. Introduction
Indonesia is the maritime continent which characterized as one of the highest precipitation areas on Earth [1]. Split by the equator, Indonesia has an extreme variation of precipitation that is linked to the monsoons. This monsoon transports moisture from the surrounding ocean directly toward the center of the Indonesia's continent. In general, the westerly monsoonal wind of Indian Ocean dominates from December to February (wet season). On the other hand, in June through August (dry season), the moisture is primarily transported from the Pacific Ocean [2-4]. Therefore, understanding and monitoring of precipitations variability are important in reducing various impacts.

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There are three primary sources of precipitation observations; gauge measurement, ground-based radar, and satellite estimations. Gauge measurement provides the most accurate to measure precipitation. However, it is usually limited by their spatial coverage. Ground-based radar observations are excellent alternatives with relatively accuracy [5-6]. However, these ground instruments are relatively high costs of operation and maintenance and also leaving many unmeasured areas [7]. Thus, satellite observations may be the best solution for adequate temporal and spatial coverage of precipitation.

The launch of the Tropical Rainfall Measuring Mission (TRMM) satellite in November 1997 by the United State National Aeronautics and Space Administration (NASA) and the Japan Aerospace Exploration Agency (JAXA) provided a better understanding of precipitation over tropical and subtropical regions. One of the best retrieval algorithms is TRMM Multi-Satellite Precipitation Analysis (TMPA). Its algorithm has generated two main satellite precipitation products, that are post-real time (3B42) and near-real time (3B43). These products have been used in different applications and regions. However, it is necessary to quantify the biases of the TRMM products relative to any rain gauge measurements.

Several studies have been done to compare and to evaluate TRMM products with other rainfall measurements [8-9]. However, these studies are usually focused on monthly or seasonal scales. Shorter period, such as hourly and daily are more appropriate for flood monitoring or other hydrological applications. Comparison of precipitation products at daily scale have been carried out for the Europe, US, Australia, Asia, especially in Thailand [10-11]. The comparison over Indonesia, particularly in South Sumatera, is still lacking. Therefore, we evaluate and compare hourly and daily TRMM precipitation products with the rain gauge data in the Sungai Baung District in this study.

2. Data and methods

2.1. Data

The rain gauge data is obtained from an Automatic Weather System (AWS) which named HQ. Sei Baung. HQ. Sei Baung hosted by PT. OKI Pulp and Paper Mills HQ Sei Baung Palembang. It is lying between 2° 44’ 08” N and 105° 17’ 06” E with the altitude 11 m above sea level. Administratively, the AWS is located at the Sungai Baung District, northeast of South Sumatera, which closed to the Bangka Strait.

Satellite data obtained from the Global Satellite Mapping of Precipitation (GSMaP) project in the Global Rainfall Watch website (http://sharaku.eorc.jaxa.jp/GSMaP/). The Global Rainfall Watch is published by the Japan Aerospace Exploration Agency (JAXA) [12]. It is able to provide rainfall information on approximately 4-hours lag from the time of satellite monitor (quasi real-time basis) and on a global scale. The website takes rainfall and cloud cover products from several satellites that monitor these conditions. Its algorithm now produces 0.1 degrees of spatial resolution (latitude and longitude) and 1 hour of temporal resolution [13-14].

2.2. Methods

2.2.1. Data processing

The data period used in this study is from 1 November 2013 to 31 December 2014. Because of differences in spatial and temporal resolution among the two products, a direct comparison of these data is impossible in the original format of each dataset. Therefore, a data preprocessing is required because it performed a point-to-pixel analysis [15-16]. We extracted the satellite data to the point-based station location instead of interpolating the gauge data into a gridded product. Two temporal scales, that is hourly and daily, was conducted in this study.

2.2.2. Statistical analyses

There are five statistical analyses used to examine these precipitation products. Those are correlation coefficient (r) is used to evaluate the degree of agreement between satellite and gauge data, that has values ranging from -1 to 1, Mean Absolute Error (MAE). MAE is the average distance between each

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data sets and the mean, Root Mean Square Error (RMSE) is a frequently used to measure the average magnitude of the estimate error, Mean Bias Error (MBE) that is evaluates the systematic bias between satellite and gauge data. A positive MBE shows that the estimated precipitation is overestimated, while a negative sign shows underestimated, and Standard Deviation (STD) that is used to quantify the amount of variation of data value. Those statistical metrics were calculated as follows [17]:

$$r = \frac{1}{N-1}\sum_{i=1}^{N}\frac{\left(x-\bar{x}\right)\left(y-\bar{y}\right)}{s_x s_y} \tag{1}$$

$$\text{MAE} = \frac{1}{N}\sum_{i=1}^{N}\left|x_i - y_i\right| \tag{2}$$

$$\text{RMSE} = \sqrt{\left[\frac{1}{N}\sum_{i=1}^{N}\left(x_i - \langle \text{MBE} \rangle - y_i\right)^2\right]} \tag{3}$$

$$\text{MBE} = \frac{1}{N}\sum_{i=1}^{N}\left(x_i - y_i\right) \tag{4}$$

$$\text{STD} = \sqrt{\frac{\sum_{i=1}^{N}\left|x-\bar{x}\right|^2}{N}} \quad \text{or} \quad \text{STD} = \sqrt{\frac{\sum_{i=1}^{N}\left|y-\bar{y}\right|^2}{N}} \tag{5}$$

where x refers to the gauge measurement, y refers to satellite measurement, and N is the number of samples. S_x and S_y are the standard deviations of those two measurements. In addition, other statistical metrics were also included in this study, that is, slope coefficient of linear regression and coefficient determination (R^2). It can be described as follows [18]:

$$y_i = ax_i + b \tag{6}$$

$$R = \frac{\sum_{i=1}^{N}\left(x_i - x\right)\left(y_i - y\right)}{\sqrt{\sum_{i=1}^{N}\left(x_i - x\right)^2 \sum_{i=1}^{N}\left(y_i - y\right)^2}} \tag{7}$$

where a and b are the linear regression coefficient. If a is close to unity, a high level of consistency is expected between the satellite estimate and gauge measurement. R^2 is another widely used index for effective assessment of consistency [19]. It measures the relationship between the estimate and measurement.

3. Results and Discussions

This study examined precipitation data of TRMM satellite and AWS Sungai Baung. The evaluation was conducted at hourly and daily scales from 1 November 2013 to 31 December 2014. Comparison of hourly precipitation data is shown by figure 1. The hourly comparison is shows similar pattern. There are two rainfall peaks during this period. From figure 2, the highest rainfall intensity appears in the evening until early morning (22.00-05.00 Local Time/LT). Meanwhile, moderate rainfall intensity is occurring in the daytime (13.00-16.00 LT). High rainfall variability over the study area influenced by land-sea interaction [20-22], that is also known as land-sea breezes. The two breezes occur along coastal areas or areas with adjacent large water bodies. Sea takes more time to warm up and is able to retain the heat longer than that land. In the daytime, the land heats up quickly and the air above it warms up more than the air over the sea. The warm air over the land is less dense and begins to rise and it causes low pressure is created. The air pressure over the sea is higher with cold dense air, which moves to occupy the space created over the land. The cool air that comes along is called a sea breeze. Meanwhile, the land quickly releases the heat while the water retains its warmth in the night time. It causes the air over the water is warmer, less dense and begins to rise. Low pressure is created over the water. Cold and dense air over the land begins to move into the sea surface to replace the warmer rising air. The cool breeze from the land is called a land breeze. These phenomena causing high precipitation over the land in the nighttime. On the other hand, low or moderate precipitation occur over the land in the daytime. Generally, most of the TRMM satellite rainfall products shows overestimation, except in the daytime, which indicates AWS rainfall intensity higher than that satellite rainfall intensity (slight underestimation).

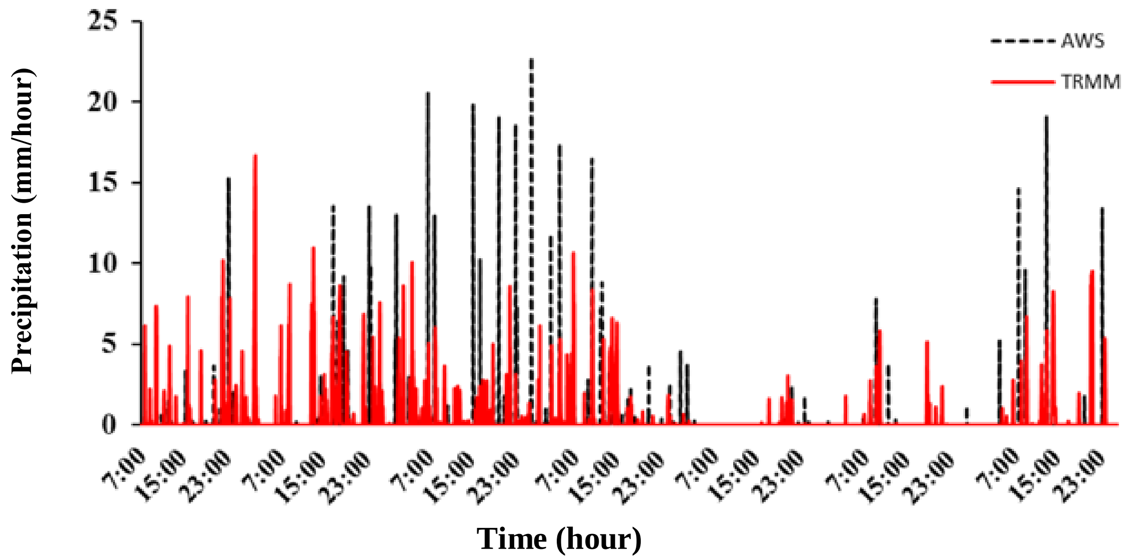

Figure 1. Hourly comparison of precipitation intensity between TRMM satellite and AWS Sungai Baung.

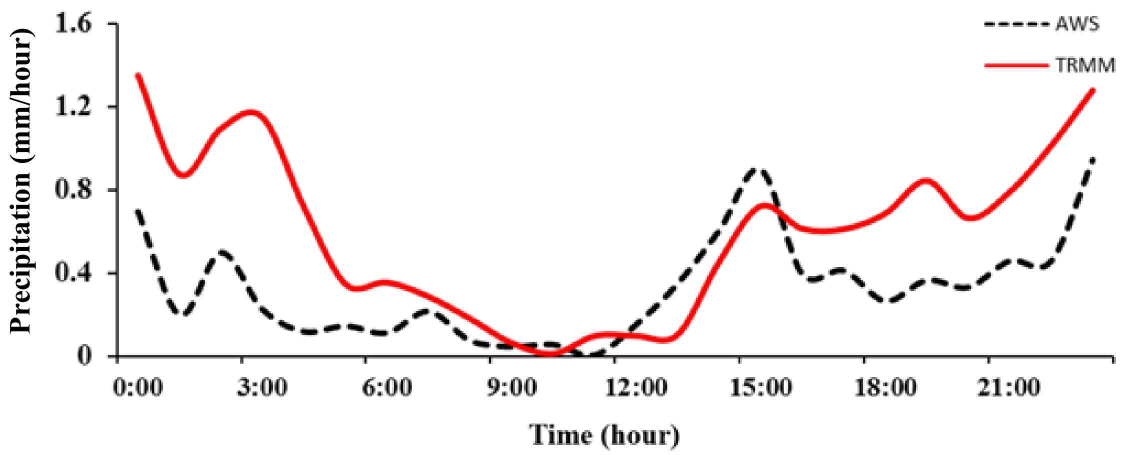

Figure 2. Diurnal climatology of precipitation intensity between TRMM satellite and AWS Sungai Baung.

Figure 3 shows the time series of daily comparison between TRMM satellite and AWS precipitation products. Daily precipitation estimates from those rain measurement process also indicates similar pattern. Although the double peaks in the rainy seasons are discernible, the variations at the daily scale are still quite prominent. All products captured high daily precipitation during December until January (first peak) and March until early May (secondary peak). By contrast, low daily precipitation showed during end of May until October. Moreover, the TRMM satellite rainfall products tend to overestimate daily precipitation almost in the whole periods.

Table 1 summarizes the results of statistical analysis that compare satellite rainfall estimates and rain gauge data at hourly and daily resolution. The best performance was observed by daily comparison. This comparison shows moderate correlation between TRMM satellite and AWS with coefficient correlation $r = 0.64$ (significant at 99%, $r > 0.135$). This result is consistent with the findings reported in Blue Nile Basin [23-24], Singapore [25], Thailand, Japan, and Korea [26]. On the other hand, low agreement between two data sets is demonstrated by hourly comparison, which $r = 0.12$. This correlation is also significant at 99% because of its coefficient, $r > 0.043$. Although the coefficient correlation of daily evaluation is better than that hourly evaluation, but statistical error between that comparison tend to increase in daily comparison. The MAE values of the hourly and daily comparisons are 0.56 mm/hour and 3.61 mm/day, respectively. The RMSE values of those comparison is 2.36 mm/hour (hourly comparison) and 7.16 mm/day (daily comparison). All comparison shows TRMM satellite products over estimated precipitation. That is indicated by a positive value of MBE, 0.14 mm/hour and 0.84 mm/day, hourly and daily comparison, respectively.

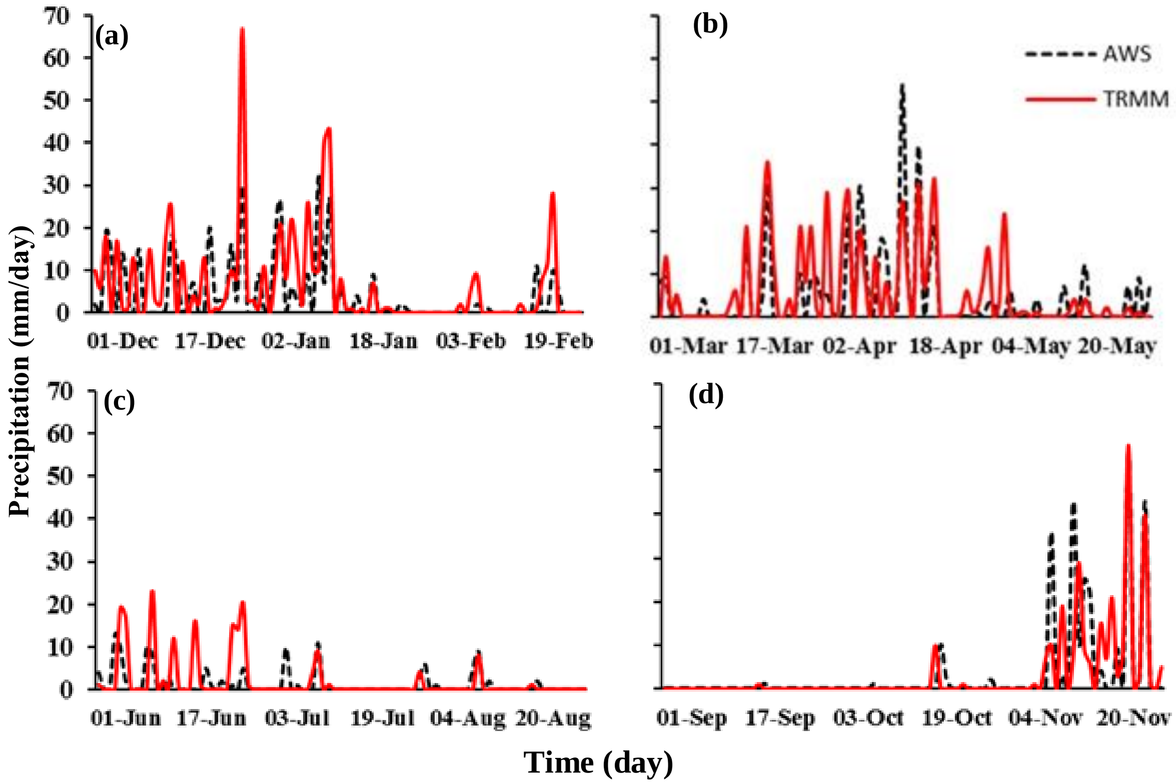

Figure 3. Daily comparison of precipitation intensity between TRMM satellite and AWS Sungai Baung: (a) December-February, (b) March-May, (c) June-August and (d) September-November.

The scatter plot of data from rain-gauge station against satellite-based rainfall estimates is shown in figure 4. Figure 4 (a) shows the relationship between TRMM satellite and AWS at hourly scale. The linear regression ($a = 0.11$) and the determination ($R^2 = 0.013$) coefficients demonstrated a low agreement between two datasets. But, the correspondence increases at daily scale (figure 4(b)). The TRMM satellite had a value of 0.71 with the rain gauge. The coefficient of determination in this period is $R^2 = 0.41$. These coefficients indicate a moderate correlation between TRMM satellite and AWS rainfall products. The correlation between evaluated satellite and measurement from gauge is still low and also moderate in hourly and daily precipitation estimation. A possible explanation is the limited number of gauge used by this study. In order to improve the satellite products, a more gauge station in study area should be developed and applied in the satellite bias correction. In addition, it also needs to investigate the correlation between both data for a monthly timescale.

Table 1. Statistical metrics of hourly and daily precipitation estimates from TRMM satellite and AWS.

Parameter		Hourly	Daily
r		0.12*	0.64*
MAE		0.56	3.61
RMSE		2.36	7.16
MBE		0.14	0.84
STD	TRMM Satellite	1.36	8.82
	AWS	2.06	6.64

*Significant level of correlation coefficient at 99%, which are $r > 0.043$ and $r > 0.135$, hourly comparison and daily comparison, respectively.

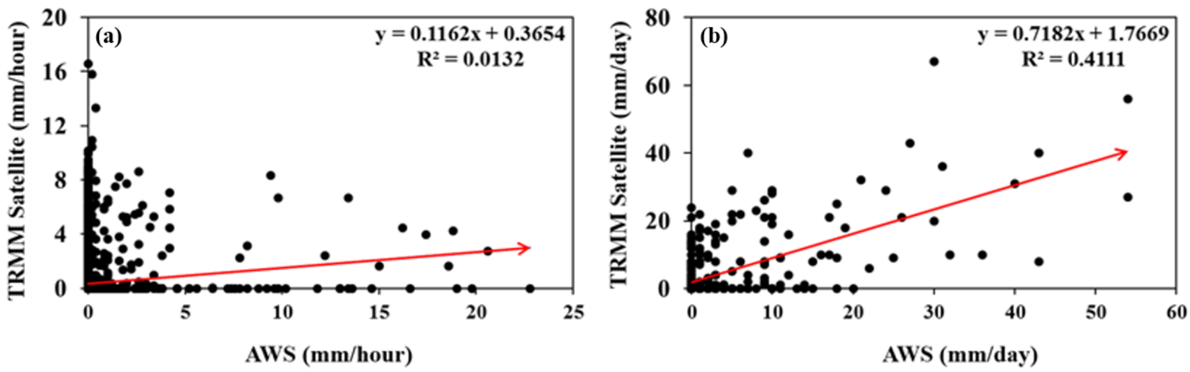

Figure 4. Scatter plot of hourly and daily comparisons between TRMM satellite and AWS products: (a) Hourly comparison and (b) Daily comparison.

4. Conclusion

The comparison of TRMM satellite precipitation product using rain gauge in the Sungai Baung District, South Sumatera during 1 November 2013 until 31 December 2014 is presented in this study. Hourly and daily comparisons were conducted by applying several statistical methods.

The results show low and moderate correlation between TRMM satellite and AWS precipitation products, with the coefficient correlation $r = 0.12$ (hourly timescale) and $r = 0.64$ (daily timescale), respectively. The relationship of those precipitation products was calculated with confidence intervals estimated at 99% confidence level. This agreement is also supported by regression and determination coefficient, with $a = 0.11$ and $R^2 = 0.013$ and $a = 0.71$ and $R^2 = 0.41$, in the hourly and daily timescales, respectively. Although the correlation (r, a, and R^2) of daily evaluation is better than that hourly evaluation, but the statistical error (MAE, RMSE, and MBE) in the daily scale increased. Overall, satellite-based precipitation product generally showed overestimation rainfall events. That is indicated by the time series of hourly and daily comparison and positive value of MBE (0.14 mm/hour and 0.84 mm/day) at both scales.

Finally, since one rain-gauge data used in this study, it is suggested that future studies to use more rain-gauge stations, so that the correlation between satellite-based rainfall product could show strong relationship and a pixel-to-pixel analysis can be applied to conduct in-depth analysis. Moreover, we recommend that an additional statistical correction, such as Probability of Detection (PoD), False

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Alarm Ratio (FAR), Critical Success Index (CSI), and Probability Density Function (PDF). These statistical analyses should be conducted to hourly and daily of TRMM satellite precipitation estimates before used in other interests.

References

[1] Ramage C S 1968 *Mon. Wea. Rev.* **96** 365
[2] Aldrian E and Susanto R D 2003 *Int. J. Climatol.* **23** 1435
[3] Chang C P, Wang Z, McBride J, and C H Liu 2005 *J. Clim.* **18** 287
[4] Sekaranom A B and Masunaga H 2017 *US Meteo. Soc.* **98** 1867
[5] Krajewski W F 2007 *Spring.* **8** 403
[6] Guo R and Liu Y 2016 *Water* **8** 281
[7] Durkee J 2010 *Geogr. Compass* **4** 956
[8] Chiu L, Liu Z, Rui H, and Teng W 2005a *E. Sci. Sat. Rem. Sens.* J Qu, *et al*. (Editors) Springer-Verlag (in press)
[9] Nur M and Iskandar I 2013 *Proc. Int. Sym. for Sust. Hum* Bengkulu ISSN 2008-9127 125
[10] Ebert E E 2002 *1st Intl. Prec. Work. Gr. (IPWG) Workshop* Madrid 23-27 September 2002
[11] Chokngamwong R and Chiu L 2005 *Fairfax* VA 22030-4444 USA
[12] Aonashi K *et al.* 2009 *J. of the Meteo. Soc. of Japan* **87A** 119
[13] Ushio T, Sasashige K, Kubota T, Shige S, Okamoto K, Aonashi K, Inoue T, Takahashi N and Iguchi 2009 *Journal of the Meteorological Society of Japan* **87A** 137
[14] T, Kachi M, Oki R, Morimoto T, and Kawasaki Z I 2009 *J. of the Meteo. Soc. of Japan* **87A** 203
[15] Cohen L, Matos T J, Boillat J L, and Schleiss A 2012 *Hyd. And E. Sys. Sci.* **16** 489
[16] Thiemig V R, Rojas, Zambrano-Bigiarini M, Levizzani V, and De Roo A 2012 *J. of Hyd.* **13** 1760
[17] Tan M L, Tan K C, Chua V P, and chan N W 2017 *Water* **9** 57
[18] Behrangi A, Khakbaz B, Jaw T C, Aghakouchak A, Hsu K, and Sorooshian S 2011 *J. Hydrol.* **397** 837
[19] Prakash S, Sathiyamoorthy V, Mahesh C, and Gairola R M 2014 *Int. J. Remote Sens.* **35** 3018
[20] Mori S 2004 *Month. W. Rev.* **132** 2021
[21] As-syakur A R, Tanaka T, Osawa T, and Mahendra M S 2013 *Int. J. Remote Sens.* **34** 7723
[22] McPherson R D 1970 *J. of Appl. Meteo.* **9** 767
[23] Sahlu D, Nikolopoulus E, Moges S, Anagnostou E N, and Hailu D 2016 *J. Hydrometeo.* **17** 2875
[24] Dembele M and Sander J Z 2016 *Remote Sens.* **37** 3995
[25] Tan M L and Duan Z 2017 *Remore Sens.* **9** 720
[26] Kim K, Park J, Baik J, and Choi M 2017 *Atmos. Res.* **187** 95