



The Efficient Early Warning with South East-Asia Oceania Flash Flood Guidance System (SAOFFGS)

Agie Wandala Putra, Nn. Ummul Choir Os,
and Imaduddin Salma Faalih

Abstract

The Southeastern Asia-Oceania Flash Flood Guidance (SAOFFG) system is a part of Global Flash Flood Guidance System (FFGS). Acting as regional centre of Southeastern Asia-Oceania Flash Flood Guidance, Indonesia has the responsibility to provide regional and national verification of SAOFFGS flash flood forecasts and warnings. This paper was conducted in order to explain the implementation of SAOFFG in Indonesia and to evaluate one of the FFGS threat products used by BMKG for monitoring and forecasting floods. The selected study time period and area are based on the availability of flash flood threat forecast data i.e. IFFT 1-, 3- and 6-h. Flood event data was obtained from flood report database of BMKG Weather Early-warning subdivision. In order to acquire the statistical results, contingency tables were constructed. Results indicate that approximately one-half of the flood events were correctly detected by positive values of IFFT (POD 0.66 for 6-h IFFT). The best skills, as indicated with a CSI 0.34 occur in the verification of FFG threat product (IFFT) 1-h and 3-h.

Keywords

Flash flood guidance • Flash flood forecast • Early warning • Evaluation • Indonesia

Introduction

The Southeastern Asia-Oceania Flash Flood Guidance (SAOFFG) system is a part of Global Flash Flood Guidance System (FFGS). In the Southeastern Asia-Oceania, flash floods play a role in causing significant number of casualties, material loss and infrastructure damage and require special attention. Referring to Indonesia National Agency for Disaster Management (BNPB) information, 385 flooding events occurred in 2019 resulting in the fatalities of 296, 2853 houses devastated, and 257 of damaged educational facilities. Consequently, relevant authorities need to improve the early warning system as a part of efforts to reduce vulnerability of regions to hydrometeorological hazards.

The planned establishment of SAOFFG regional centre has been started since February 2016 in the initial planning meeting held in Indonesia. SAOFFG is the result of collaboration between World Meteorological Organization (WMO), Hydrologic Research Centre (HRC), National Oceanic and Atmospheric Administration (NOAA), United States Agency for International Development (USAID), and Agency for Meteorological, Climatological and Geophysics (BMKG) aimed at enhancing National Meteorological Hydrological Services (NMHSs) capacities to issue timely and accurate flash flood warnings.

This paper was conducted in order to explain the implementation of SAOFFG in Indonesia and to evaluate one of the FFGS threat products used by BMKG for monitoring and forecasting floods even flash floods. Data sources used for product evaluation include a database of flood or flash flood reports collected by BMKG Weather Early-warning subdivision.

A. W. Putra (✉) · Nn. U. C. Os · I. S. Faalih
Agency for Meteorology, Climatology, and Geophysics, Centre
for Public Meteorology, Jl. Angkasa I No.2 Kemayoran, Jakarta,
10720, Indonesia
e-mail: agie.wandala@bmgk.go.id

Nn. U. C. Os
e-mail: ummul.choir@bmgk.go.id

I. S. Faalih
e-mail: imaduddin.faalih@bmgk.go.id

SAOFFG Operational

Mandate and Roles of BMKG

Member States of SAOFFGS are Indonesia which is acting as regional centre (RC), Malaysia, Brunei Darussalam, Timor Leste, Philippines and Papua New Guinea. According to WMO regulations, the RC has the responsibility to assist with tasks during the regional FFGS development and implementation phases, including: being focal point for the collection of the required historical hydro-meteorological and spatial data from the participating countries establishing data transfer tools via secure ftp, hosting high performance servers to run SAOFFG model and allow access to participating countries for SAOFFGS products, and to receive real-time data from various sources, and maintaining servers, operating systems and FFGS application software with the support of HRC (Fig. 1). In addition, the RC is asked to provide regional and national verification of SAOFFGS flash flood forecasts and warnings, and some others unstated responsibilities in this paper.

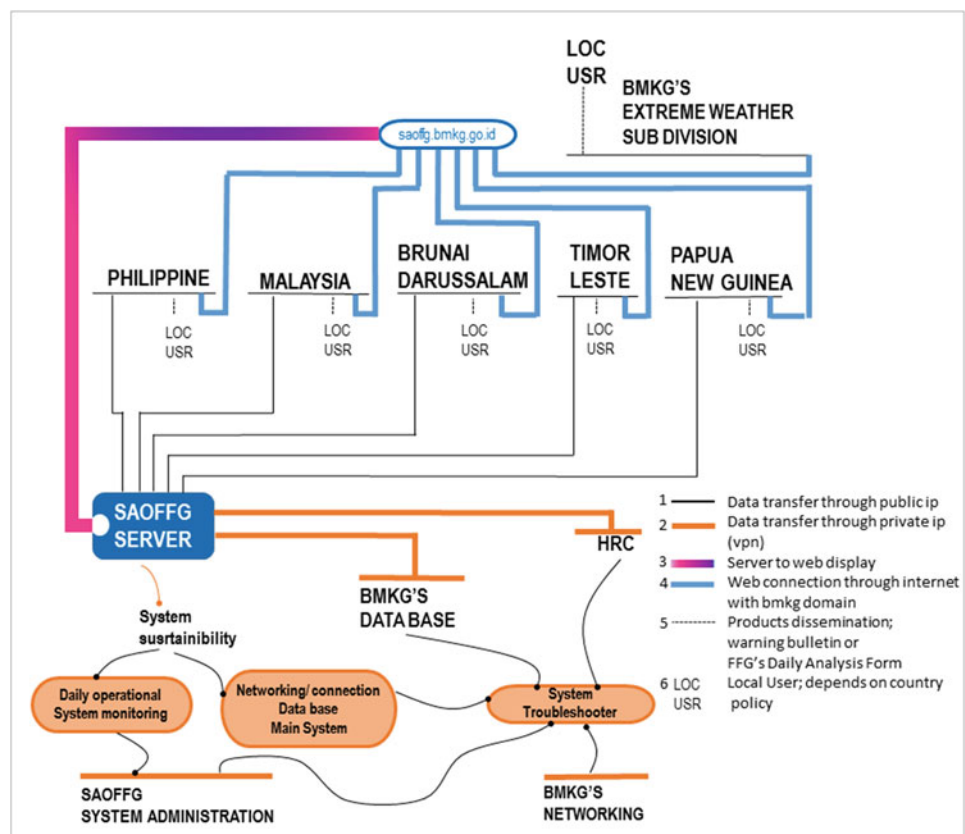
Operational Status

Implementation of SAOFFG at BMKG is divided into 3 stages i.e. the trial period beginning from May to October 2019, the operational period at National level in November 2019, and Operational period in Regional SAO level in March 2020. Daily analysis of SAOFFG report in BMKG is issued twice a day respectively at 00 and 12 UTC.

Flashflood Guidance System

Meteorological Organization (WMO)/UNESCO in International Glossary of Hydrology (WMO, N. 385 2012) define flood as follows: Rise, usually brief, in the water level of a stream or water body to a peak from which the water level recedes at a slower rate; Relatively high flow as measured by stage height or discharge. A flash flood is a rapid flooding of water over land caused by heavy rain or a sudden release of impounded water (e.g., dam or levee break) in a short period of time, generally within minutes up to several hours, a time scale that distinguishes it from fluvial floods (Hong et al.

Fig. 1 SAOFFG system flow



2013). In Indonesia, floods commonly occur by cause of the rain, overflowing water in rivers, lack of water absorption and high rainfall in the upstream areas.

Flash floods need to be treated as a hydrometeorological event requiring an integration of meteorology and hydrology in real time with an infusion of local information and expertise to deliver reliable flashflood warnings. The FFGS is designed in order to facilitate this requirement. The system products are made available to forecasters as a diagnostic tool to analyse weather-related events that can initiate flash floods and then to make a rapid evaluation for a flash flood occurrence at a location.

Analysis and flood forecast utilizing SAOFFG are carried out in accordance with the workflow in Fig. 2. The preliminary evaluation is conducted by condensing the analysis and forecast of rainfall, soil moisture above 50%, low FFG values, and areas of concern. Afterwards, referring to the meteorological and hydrological conditions of the area of concern is necessary. To assess the threat of a local flash flood, the FFGS is designed to allow product adjustments based on the forecaster's experience with local conditions, incorporation of other information and last minute local observations, or local observer report. The FFG is normally considered as only as guidance i.e. if the forecaster believes that a warning should be issued before the rainfall rate exceeds the FFG value a warning should be issued. In some parts of the country, quantitative precipitation estimation (QPE) exceeding FFG is used as a strict threshold for issuing a warning. In other areas, forecasters may wait for QPE to reach 125% or 150% of FFG before doing so (Hong and Gourley 2015). To conduct a flood early warning, there are several steps to effectively achieve the results. These stages (Werner et al. 2005) are detection, forecasting, warning and dissemination, and response. BMKG plays a predominant role for forecasting rainfall in forecasting stage. Utilization of SAOFFG providing hydrological data enables forecaster to prepare a flood forecast by previously discussing with several relevant agencies. Thus flood warnings could be issued and be disseminated to users which allowing action or response could be taken immediately.

In this study, an evaluation of one flash flood threat products was investigated. FFG refers generally to the volume of rain of a given duration necessary to cause minor flooding on small streams (Carpenter et al. 1999). FFG value indicating the total volume of rainfall over the given duration which is adequate to cause bankfull flow at the outlet of the draining stream. A flash flood threat index is the difference between the actual, persisted or forecast precipitation and the corresponding FFG diagnostic value for the basin and duration of interest (1, 3 and 6 h). Threat products generated in FFG are Imminent Flash Flood Threat (IFFT), Persistence Flash Flood Threat (PFFT), and Forecast Flash Flood Threat (FFFT).

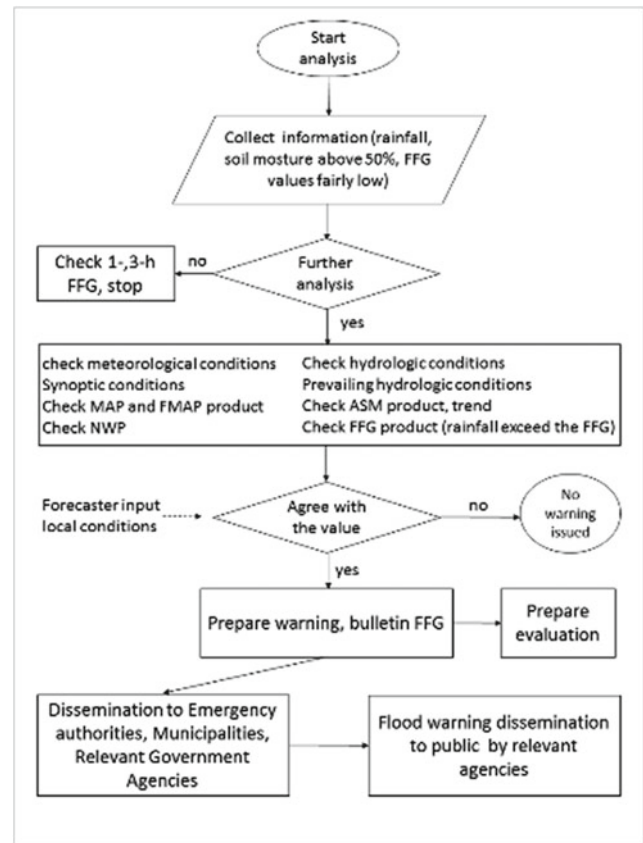


Fig. 2 Workflow of SAOFFG daily guidance at BMKG

Imminent Flash Flood Threat (IFFT)

The imminent flash flood threat index is a diagnostic index, which only includes uncertainties from estimated precipitation and land-surface model parameters (Georgakakos et al. 2019). Therefore, the uncertainty in these IFFT indices depends on the available data. IFFT products are available in image and text formats for 1, 3, and 6 h (mm) for respective basin. The IFFT value indicates the difference between Merged Mean Areal Precipitation (MAP) in the given duration and corresponds to the previous FFG model data with the same duration in each sub-basin. From this perspective, IFFT products can be considered as the current status of observation. Previous FFG products in periods 1, 3, and 6 h were carried out in conjunction with the Merged MAP in the calculation of IFFT.

- IFFT 01-h: difference from 01-h FFG from the previous navigation hour model calculation and 01-h Merged MAP observed over following 1 h (mm/1 h).
- IFFT 03-h: difference from 03-h FFG from previous navigation hour model calculations and 03-h Merged MAP observed over following 3 h (mm/3 h).

c. IFFT 06-h: difference from 06-h FFG from previous navigation hour model calculations and 06-h Merged MAP observed over following 6 h (mm/6 h).

Data and Methodology

The trial period of SAOFFG in BMKG has several constraints related to input data used in the running process. Numerical Weather Prediction (NWP) model resolution needs to be improved to be able to capture the meteorological events in local scale because this scale notably affects weather conditions in Indonesia region. Furthermore, the insufficient number of meteorological stations in Indonesia results in the less proportional observation data.

Considering the availability of SAOFFG data in the trial period at BMKG, this study used data from January to February 2020. Most regions in Indonesia, especially Java, experience rainy seasons in January and February. Asian cold monsoon transfers a mass of moisture air into Indonesia and the peak season of the tropical cyclone in South Indian Ocean (SIO) is within these months. The occurrence of tropical cyclones in the SIO is one of the factors that influences the pattern of weather formation in Indonesia. Heavy to extreme rain occur in these months which might induce floods.

Figure 3 shows the monthly rainfall amount in the time periode of study. The amount of January 2020 monthly

rainfall is in moderate to very high category, especially in Jakarta and Central Java. The next month, February 2020, increasing amount of monthly rainfall was indicated almost uniformly in the Java region with the category of high and very high monthly rainfall. Jakarta as the Indonesia's capital experienced flooding exceeding of five times within January–February 2020 period.

The selected study time period and area area based on the availability of flash threat food forecast data i.e. IFFT 1-, 3- and 6-h. Flood event data was obtained from flood report database of BMKG Weather Early-warning subdivision which routinely collects report on the basis of information sources from the BMKG stations and mass media. The flood data is in the form of location and time data including the hour of the incident.

In order to acquire the statistical results, contingency tables were constructed (Table 1). To verify the 1-, 3-, and 6-h-duration IFFT, it was assumed that the forecast was “yes” when the threat index was greater than zero. This verification process is carried out in 2 schemes, first calculating hits and misses obtained from the determination of flood event data in the study area. Based on the verification guidelines for FFGS product arranged by HRC, IFFT data used is only at or near the FFGS delineated basin outlets. In this scheme, IFFT indexes were matched with flood data to get hits and missed. In the next scheme, false alarms are calculated by collecting positive IFFT data in study period, subsequently eliminating data that have the similar time to flood events in the first scheme.

Fig. 3 Monthly rainfall analysis in study domain (Java) in Januari and Februari 2020 (BMKG)

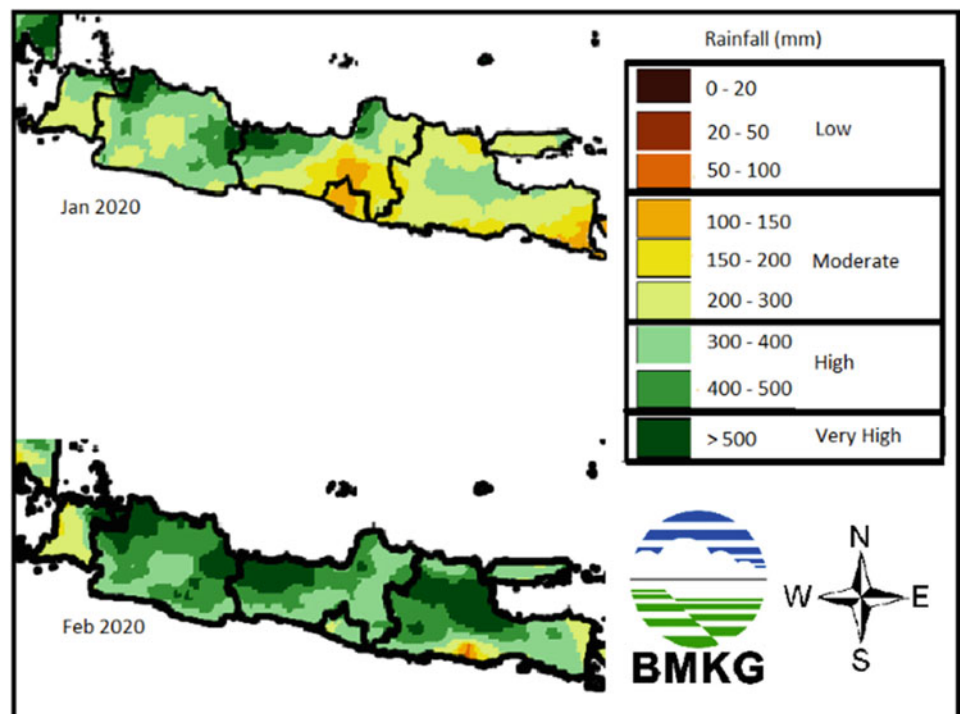


Table 1 A 2×2 contingency table

| | | Observation (event occurred) | |
|-----------|-----|------------------------------|------------------|
| | | Yes | No |
| Forecasts | Yes | Hits | False alarms |
| | No | Misses | Correct negative |

The scores provide the most meaningful information if they are computed from large enough samples of cases. However, severe weather occurrences are rare events, thus the number of forecasts and observations of severe weather may be small, which makes the task of verification not only more important but also more challenging (WMO-No. 1132, 2014). There were 47 flood events being verified throughout Java during the study period. In the second scheme, the basin involved for the data retrieval is adjusted to the basin monitored in the first scheme.

After processing table contingency respectively, hits, misses, and false alarm were included in statistical computation presenting:

$$PoD = \frac{Hits}{Hits + Misses} \quad (1)$$

The Probability of Detection (POD) describes the fraction of the observed flood events detected correctly by the IFFT forecast. The POD ranges from 0 indicates no skill to 1 indicates a perfect scores.

$$FAR = \frac{FalseAlarms}{Hits + FalseAlarms} \quad (2)$$

The False Alarm Ratio (FAR) corresponds to the fraction of flood events forecasted by IFFT but not matched with flood event observation. The FAR ranges from 0 to 1 indicates a perfect score.

$$CSI = \frac{Hits}{Hits + Misses + FalseAlarms} \quad (3)$$

Critical Success Index (CSI) describes skill of the IFFT to flood events observed. The CSI ranges from 0 to 1 indicates a perfect skill.

Results

Table 2 presents the results of statistical computation for IFFT. POD ranges from 0.36 with 1-h IFFT to 0.66 for 6-h IFFT, which indicates that approximately one-half of the flood events were correctly detected by positive values of IFFT. Referring to high FAR values which range from 0.55 to 1, there is an indication of over-forecasting, absence of flood event data as not reported or recorded in the database of BMKG Weather Early-warning subdivision, or

Table 2 Statistical Indices for IFFT

| IFFT | POD | FAR | CSI |
|------|------|------|------|
| 1 h | 0.36 | 1 | 0.34 |
| 3 h | 0.53 | 0.62 | 0.34 |
| 6 h | 0.66 | 0.55 | 0.28 |

combination of both. A high FAR value causes a low CSI value. The highest CSI values of 0.34 are associated with the 1-h and 3-h IFFT. The lowest CSI value of 0.28 for 6-h IFFT can be caused by false alarm values which is higher than those for 1-h and 3-h IFFT.

February 2020 Jakarta Flood

On 25 February 2020, Jakarta witnessed another flood worse than the January 2020 flood. Flood in urban areas can occur for two reasons; first, urban areas are flooded due to overflowing rivers crossing the city. Second, urban flooding can occur as a special case of flash floods caused by the inability of drainage to accommodate and drain rainfall.

Referring to the FFG products, the soil moisture fraction of the upper soil was higher than 0.50 from 16 to 24 February (Fig. 4). This condition had to be monitored for possible flash flood occurrence especially if the high rainfall was possible to occur after 24 February. IFFT represents an “nowcast” weather situation or indicates that a flash flood is occurring now or is about to occur immediately. IFFT 6-h at 24 February 2020 18 UTC and IFFT 3-h at 21 UTC were higher than 10 indicating the flash flood occurrence is most likely (Fig. 5). Moreover, the other FFG products and condition of Jakarta as an urban area were also taken into consideration in decision making of flood warning. Based on report collected by BMKG Weather Early-warning subdivision, the flood occurred starting around 25 February 2020 06 Local Time (24 February 2020 23 UTC).

This study conducts only one method of evaluating the flash flood threat product used in operational for monitoring and predicting floods in Indonesia. Derived results show the best skills, as indicated with a CSI 0.34 occurring in the verification of flash flood threat product (IFFT) 1-h and 3-h. FFG threat product is applicable in BMKG to be used by forecasters as an indicator of flood warning. Definitely forecasters need to have other consideration before issuing flood warning which is indicated from the FFG product. Disaster mitigation efforts require coordination and training from various stakeholders, such as BNPB, experts from universities or research institutions for hydrometeorological analysis and prediction, as well as relevant sector agencies for law enforcement according to spatial planning.

Fig. 4 FFG values indicates February 2020 flood events in Jakarta

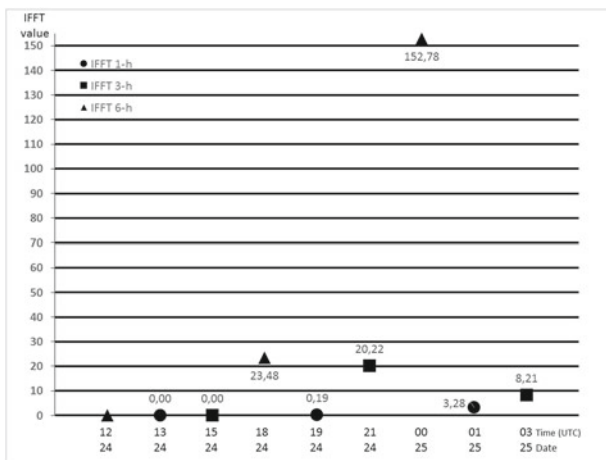
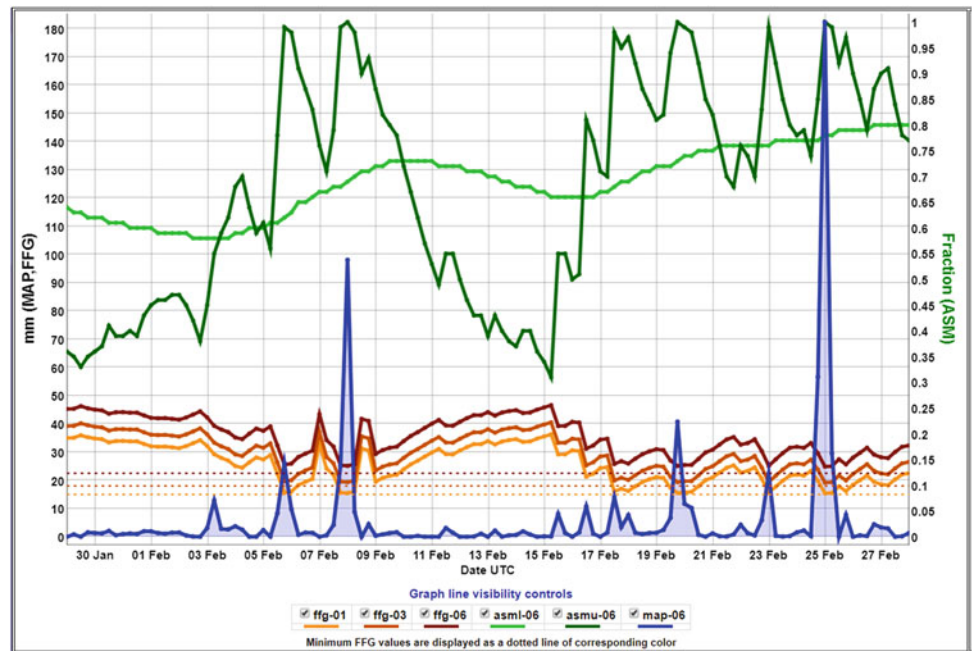


Fig. 5 IFFT values in basin 2042100129 from 24 February 2020 12 UTC to 25 February 2020 03 UTC

Communicating with user agencies is necessary for effective disaster risk reduction.

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