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Research Paper

A VERIFICATION OF HEAVY RAINFALL EVENS FORECAST SKILL OF IFS MODEL AT THE MIDDLE CENTRAL OF VIET NAM

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ABSTRACT

The paper presents the verification of capacity of heavy rainfall forecast IFS model by using the dataset of 75 automatic rain gauges collected of 59 heavy rainfall events of 2011-2018 rainfall seasons. The verification results based on ME, MAE, RMSE, R, BIAS, POD, FAR and ETS indices shown that the heavy rain forecast of IFS has good skill in forecast range of 1-3 days ahead. In addition, rainfall forecast of IFS model is over-estimated at small and medium rainfall thresholds and under-estimated in large and extreme large rainfall thresholds. The extreme rainfall forecast predictability of IFS model is good in some heavy rainfall events that caused by large-scale weather patterns.

Keywords: *Heavy rainfall forecast, verification, IFS model.*

1. Introduction

According to statistics in the last 20 years, The big floods occurred in November and December 1999 in the Central region of Viet Nam which engulfed hundreds of villages, causing deaths and huge material losses. In 1999, within just over 1 month (from November 1st to December 6th), in most provinces of Central Vietnam, there were 2 extremely heavy rainfall events causing 2 rare floods in wide area in history. As a result, more than 700 people died, nearly 500 were injured, tens of thousands of households lost their houses and assets, the damage was estimated at nearly 5,000 billion of VND, far exceeding the level of damage occurred in 1996. The natural disasters in the Central region are mainly associated with flood phenomena, which are mainly caused by heavy rains event in the Central region of Viet Nam. Therefore, accurate rain forecast for the Central region is a prerequisite for serving disaster prevention and mitigation.

In the past 10 years, rain forecast products from numerical weather forecast systems in global and regional scale in both of deterministic and ensemble prediction approachs have been widely used in daily operations. There are a lot of applied research and development of rain forecast technologies for the central region of Viet Nam has been carried out in the past 10 years (Cuong et al., 2008; Hang and Xin, 2007; Hoa, 2016; Hoa et al., 2002, 2007; Tang et al., 2017). The research results have shown that the rain forecast problem in the Central region, especially the heavy rain forecast, is still challenging and requires more technological breakthroughs for quality to improve heavy rain forecast and meet social requirements.

In order to improve the weather prediction skill in Viet Nam from short to seasonal scale, the products and dataset of global intergrated forecast system (IFS) of European Centre for Medium range Weather Forecast (ECMWF) had been purchasing and using in daily operations at Viet Nam weather forecast offices from national

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to provincal level. However, the verification of forecast quilaty of IFS model has been carried out for medium, monthly and seasonal range (Tang et al., 2014; Hoa, 2016). In fact, the short range forecast products of IFS model has been widely using in daily rainfall forecast operations in all weather forecast offices. Hence, the verification of rainfall forecast of IFS model is really necessary and important.

The paper present the results of verfification of short range heavy rainfall forecast (1-5 days ahead) of IFS model for the middle central region of Viet Nam basing on the 59 heavy rainfall events during 2011-2018 rainfall season. The following sections will present the dataset and verification method. The verification results will be deeply analyzied in 3rd section. Final is some conclusions and remarks.

2. Data and methodology

2.1. Rainfall foreacst verification method

In order to verify the heavy rainfall forecast quality of IFS model, the vefication space at observation station is chosen basing on as the following:

- Preserving the observed rainfall value and keep the data truthful

- The rainfall value at the grid node is essentially the rainfall value of the atmospheric column with size equal to the resolution of the model and the mesh node is centered. Hence, taking the forecasted rain value at the grid node to assign it to the point in the grid with the grid node as the center does not change the forecast value of the model.

The neareast point interpolation method is used in order to take rainfall forecast from model grid points to observation station. According to this method, from the position of the interpolation point, the algorithm will calculate the distance of the nearest model grid point and use the value at this grid point to assign the interpolation point (see Figure 1). To limit the effects of the gradient smoothing effect along the coast, land/sea masks are used to determine whether the selected mesh nodes are land or sea. Using the wrong mesh node to interpolate (especially in the nearest interpolation method) can lead to large errors. For example, if the station point is on land, while the nearest grid point is on the sea, it may cause errors in rain forecast because the characteristics of rain on land are different from that at sea due to the different thermal, moisture and physical characteristics.

This research used the 24hrs accumlated rainfall amount (here after is R24) to verify for forecast range at 24hrs (daily rainfall of 1st day), 48hrs (daily rainfall of 2nd day), 72hrs (daily rainfall of 3th day), 96hrs (daily rainfall of 4th day) and 120hrs (daily rainfall of 5th day). Although the object of the study is heavy rainfall, in order to evaluate the overall rain forecasting skills, in the following assessments we will use four threshold to verify rainfall phase forecast skill including: light rainfall event (0.1mm/24hrs $< R24 \leq$ 15mm/24hrs), moderate rainfall event (16mm/24hrs $< R24 \leq$50mm/24hrs), heavy rainfall event (51mm/24hrs $< R24 \leq$ 100mm/24hrs) and extreme heavy rainfall event ($R24 >$ 100mm/24h). The rainfall phase forecast verification indices is ultilizaed including frequence bias (BIAS), probability of detection/hit rate (POD), false alarm ratio (FAR) and equitable threat score/Gilbert skill score (ETS). For quantitative precipitation forecast skill verification purpose, we uses 4 indices including mean error (ME), mean absolute error (MAE), root mean square error (RSME) and correlation (R). The more detail about these verfication indices can see in Wilks (2006). The indices is calculated for hole verification area by using all dataset from all of give stations (aggregate data of all stations into a unique series of evaluation data).

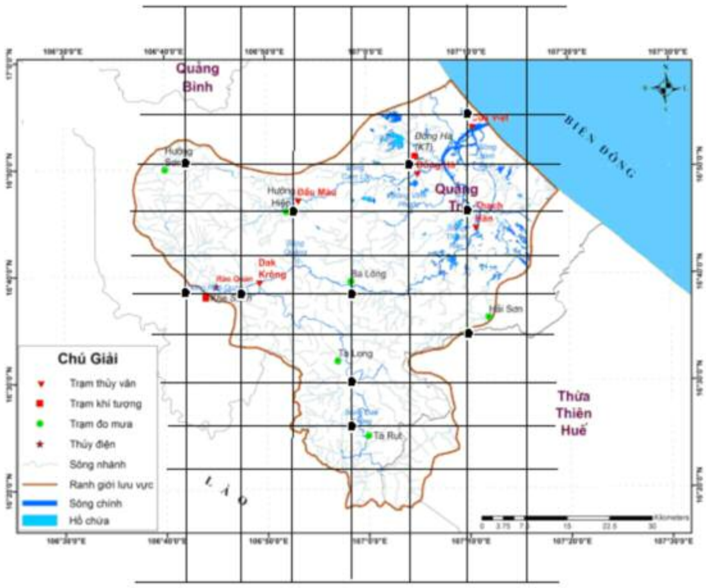

Fig. 1. The demontrative scheme of neareast point interpolation method

2.2. Verification dataset

The observed 24hrs accumulated rainfall data at 75 automatic rain gauges is collected during the days of 59 heavy rainfall events during 2011-2018 rainfall seasons. The spatial distribution of used 74 automatic rain gauges is shown in Fig. 2 and the some spatial characteristics is given out in Table 1. The rain forecast data from the IFS model with a resolution of 0.125 degrees x 0.125 degrees (approximately 14km) was collected as GRIB2 code files. The predicted rainfall amount of IFS model is accumulation of rainfall every 6 hours and provided up to 5-day forecast ahead. The rain forecast data from IFS model at 00GMT analysis time (7am local time) is used. To ensure that there is enough sample size for long-term forecasting periods (4-5 days), we taken rain forecast data started from three to four days prior to the onset of heavy rainfall (the rainfall forecasts started from 12GMT are not used because the forecasting quality at this analysis time is not as good as the time of 00GMT and it is difficult to match the forecasted rainfall to observed 24hrs accumulated rainfall (usually taken from 00GMT of previous day to 00GMT of the next day).

Table 2 gives out the number of heavy rainfall events for each of year in 2011-2018 period. In each of heavy rainfall event, the criteria of day that satisfy heavy rainfall threshold is at least 2/3 of rain gauge station in given area in which has observed 24hrs rainfall amount is greater than 50mm. In 59 given heavy rainfall events, the longgest heavy rainfall events is last in 8 days. In everage, heavy rainfall events in 2011-2018 period is last 3-4 days. Table 2 presents the number of heavy rainfall events for each of year. The 2015 and 2017 respectively are the year has smallest and largest number of heavy rainfall is used to verify

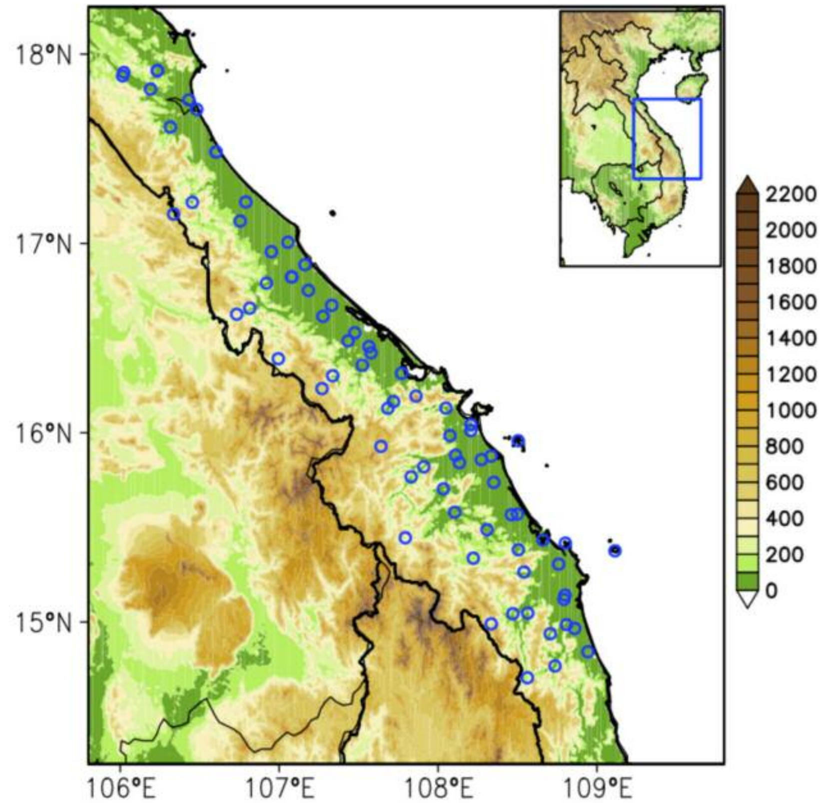

Fig. 2. The spatial distribution of used 74 automatic rain gauges in the the middle central region of Viet Nam

Table 1. The spatial characteristics of 75 automatic rain gauge network in the middle central region of Viet Nam

No.	Province name	Area Size (km^2)	Number of rain gauge station	Ratio of area size/station (km^2)	Average distance between stations (km)
1	Da Nang	1285	4	321.25	17.92
2	Quang Binh	8065	13	620.38	24.91
3	Quang Nam	10438	19	549.37	23.44
4	Quang Ngai	5153	15	343.53	18.53
5	Quang Tri	4740	12	395.00	19.87
6	Thua Thien Hue	5033	12	419.42	20.48

Table 2. The number of heavy rainfall event for each of year in 2011-2018 period is used to verify heavy rainfall phase forecast skill

Year	2011	2012	2013	2014	2015	2016	2017	2018
Number of heavy rainfall event	7	8	8	7	5	7	9	8

3. Verification results

The results of calculation of ME, MAE, RMSE and R index is respectively given out in Table 1 to Table 4. In verification period, the rainfall forecast of IFS model is usually over-estimated at light and moderate rainfall threshold and under-estimated at heavy and extreme heavy rainfall threshold. For MAE and RMSE index, the longer the forecast range, the larger the forecast error magnitude, and the longer the forecast range, the more correlation decreases. These results is found when considering the relation between verification indices and rainfall threshold. That is, at a given forecast range, the larger the rainfall amount, the larger the forecast error magnitude. Basing on MAE and RMSE index, it can be found that the error in rainfall forecast of IFS model is more stable because the different between MAE and RMSE index is not large. It means that there was no extreme large error in all cases of given verification dataset. The predicted rainfall amount from IFS model is quite well correlated with observed rainfall at 24hrs, 48hrs and 72hrs forecast range and at light, moderate and heavy rainfall threshold (Table 6).

For the rainfall phase forecast skill, the verification results is given out in Tables 7 to 10 shown out at light and moderate rainfall thresholds, the IFS model has overforecast tendency (frequency of forecasting occurred events is greater than observed frequency). In contrast, the underforecast tendency is found at heavy and extreme heavy rainfall thresholds (Table 7). The IFS model has good ability in detecting light, moderate and heavy rainfall event at 24hrs, 48hrs and 72hrs forecast ranges (POD is about 0.5 to 0.7). However, ability of correct detection of occurred rainfall events at extreme heavy rainfall threshold is not good (see Table 8). The similar result is found when analyzing POD index at heavy rainfall threshold and 96hrs and 120hrs forecast range. In spite of having good occurred rainfall event detection ability at short-range forecast range and some rainfall thresholds, IFS model also has quite large false alarm ratio at light and moderate rainfall thresholds (see table 9). However, at heavy and extreme heavy rainfall thresholds, the FAR is near rezo. Finally, the overall rainfall phase forecast skill of IFS model is quite good for light and moderate rainfall threshold at all forecast range and for heavy rainfall threshold at 24hrs, 48hrs and 72hrs forecast ranges (see table 10). At extreme heavy rainfall threshold, the ETS is eventhough near rezo or negative value at 72hrs, 96hrs and 120hrs leadtime. It means that there is no forecast skill at given forecast ranges.

Beside of above-mentioned verication results for quantitative rainfall forecast and rainfall phase forecast of some given thresholds, we had also verified the rainfall forecast skill of IFS model according to weather patterns that caused 59 heavy rainfall events during 2011-2018 rainfall seasons. The analysis of weather patterns that caused heavy rainfall events in the middle central region during 2011-2018 period shown out that there were some key weather patterns as following:

- The alone direct or indirect influence of tropical cyclone including tropical deppresion and tropical storm;
- The alone activity of cold surge;
- The alone activity of Intertropical Convergence Zone (ITCZ);
- The alone strong activity of east wind field;
- The combination of at least 2 weather pattern is mentioned above.

The verification results based on above-mentioned indices shown out that the IFS model has better predictability when heavy rainfall event caused by cold surge or ITCZ. For heavy rainfall event caused by tropical cyclone, rainfall forecast of IFS model is usually wrong in rainfall area and under-estimated in quantitative precipitation forecast. The predictability of IFS model in case of strong activity of east wind field or combination of at least 2 above mentioned weather patterns is worse than these other. If comparison of heavy rainfall forecast skill for cases of combination of at least 2 weather patterns, then the IFS model has best predictability in case of heavy rainfall event caused by the combination of tropical cyclone with cold surge. The heavy rainfall predictability of IFS model is worst in case of alone strong activity of east wind field. The reason for results like this may be due to limitations in the physical parameterization schemes of the IFS model or can derived from the horizontal resolution that not enough high to capture all sub-grid scale physical processes.

Table 3. The ME index for verification based on 59 heavy rainfall event in the middle central region of Viet Nam during 2011-2018 period

Rain type/Leadtime	1st day (+24hrs)	2nd day (+48hrs)	4th day (+96hrs)	4th day (+96hrs)	5th day (+120hrs)
Ligh rain	5.5	8.9	16.2	20.1	30.5
Moderate rain	6.2	11.5	19.3	25.4	31.2
Heavy rain	-8.2	-15.6	-22.5	-29.5	-35.6
Extreme heavy rain	-17.2	-28.3	-35.8	-42.6	-65.4

Table 4. The MAE index for verification based on 59 heavy rainfall event in the middle central region of Viet Nam during 2011-2018 period

Rain type/Leadtime	1st day (+24hrs)	2nd day (+48hrs)	4th day (+96hrs)	4th day (+96hrs)	5th day (+120hrs)
Ligh rain	5.8	10.5	18.3	24.6	34.5
Moderate rain	9.3	15.4	25.4	32.6	40.5
Heavy rain	12.2	25.4	32.1	49.5	55.6
Extreme heavy rain	19.1	28.3	45.8	52.2	70.2

Table 5. The RMSE index for verification based on 59 heavy rainfall event in the middle central region of Viet Nam during 2011-2018 period

Rain type/Leadtime	1st day (+24hrs)	2nd day (+48hrs)	4th day (+96hrs)	4th day (+96hrs)	5th day (+120hrs)
Ligh rain	6.2	8.9	16.2	20.1	30.5
Moderate rain	10.2	16.5	27.3	33.4	41.8
Heavy rain	15.5	28.3	35.6	52.1	58.3
Extreme heavy rain	20.3	30.1	46.7	55.8	75.4

Table 6. The R index for verification based on 59 heavy rainfall event in the middle central region of Viet Nam during 2011-2018 period

Rain type/Leadtime	1st day (+24hrs)	2nd day (+48hrs)	4th day (+96hrs)	4th day (+96hrs)	5th day (+120hrs)
Ligh rain	0.75	0.60	0.41	0.35	0.27
Moderate rain	0.68	0.58	0.39	0.32	0.22
Heavy rain	0.62	0.56	0.35	0.30	0.20
Extreme heavy rain	0.45	0.38	0.19	-0.05	-0.15

Table 7. The BIAS index for verification based on 59 heavy rainfall event in the middle central region of Viet Nam during 2011-2018 period

Rain type/Leadtime	1st day (+24hrs)	2nd day (+48hrs)	4th day (+96hrs)	4th day (+96hrs)	5th day (+120hrs)
Ligh rain	0.35	0.30	0.26	0.2	0.18
Moderate rain	0.28	0.25	0.18	0.12	0.10
Heavy rain	0.13	0.10	0.06	0.01	0.01
Extreme heavy rain	0.08	0.00	0.00	-0.12	-0.18

Table 8. The POD index for verification based on 59 heavy rainfall event in the middle central region of Viet Nam during 2011-2018 period

Rain type/Leadtime	1st day (+24hrs)	2nd day (+48hrs)	4th day (+96hrs)	4th day (+96hrs)	5th day (+120hrs)
Ligh rain	0.85	0.72	0.63	0.56	0.45
Moderate rain	0.72	0.63	0.58	0.49	0.43
Heavy rain	0.55	0.52	0.43	0.35	0.30
Extreme heavy rain	0.41	0.36	0.30	0.22	0.18

Table 9. The FAR index for verification based on 59 heavy rainfall event in the middle central region of Viet Nam during 2011-2018 period

Rain type/Leadtime	1st day (+24hrs)	2nd day (+48hrs)	4th day (+96hrs)	4th day (+96hrs)	5th day (+120hrs)
Ligh rain	0.71	0.65	0.54	0.46	0.41
Moderate rain	0.62	0.55	0.43	0.38	0.33
Heavy rain	0.15	0.10	0.10	0.00	0.00
Extreme heavy rain	0.00	0.00	0.00	0.00	0.00

Table 10. The FAR index for verification based on 59 heavy rainfall event in the middle central region of Viet Nam during 2011-2018 period

Rain type/Leadtime	1st day (+24hrs)	2nd day (+48hrs)	4th day (+96hrs)	4th day (+96hrs)	5th day (+120hrs)
Ligh rain	0.35	0.30	0.26	0.2	0.18
Moderate rain	0.28	0.25	0.18	0.12	0.10
Heavy rain	0.13	0.10	0.06	0.01	0.01
Extreme heavy rain	0.08	0.00	0.00	-0.12	-0.18

4. Conclusions

The rainfall forecast from global intergrated forecast system (IFS) of European Centre for Medium range Weather Forecast (ECMWF) had been using in daily operations at Viet Nam for weather prediction from short to seasonal range forecast since 2011. However, there was a little verification research that was done in order to show out the heavy rainfall forecast skill of IFS model in Viet Nam region. The paper was carried out verification of heavy rainfall forecast of IFS model by using the dataset of 75 automatic rain gauges is collected during the days of 59 heavy rainfall events of 2011-2018 rainfall seasons. The verification results based on ME, MAE, RMSE, R, BIAS, POD, FAR and ETS indices shown that the heavy rain forecast of IFS has good skill in forecast range of 1-3 days ahead. For larger leadtime, the predictability of IFS is not good, eventhough is negative skill. In addition, rainfall forecast of IFS model is over-estimated at small and medium rainfall thresholds and under-estimated in large and extreme large rainfall thresholds in quantitative precipitation forecast aspect. For rainfall phase forecast, IFS model is overforecast in light and moderate rainfall thresholds (frequency of forecasting occurred events is greater than observed frequency) and under-forecast in heavy and extreme heavy rainfall thresholds. The extreme rainfall forecast predictability of IFS model is good in some heavy rainfall events that caused by large-scale weather patterns. In order to have more detail view of heavy rainfall forecast of IFS model, it should be needed to verify with larger sample size. In addition, the assessment should be continued using other methods to provide additional results of forecasting quality accroding to spatial and temporal aspects.

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