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Research Paper

IMPROVING THE QUALITY OF SEVERE WEATHER WARNING WITH HIGHRESOLUTION NUMERICAL WEATHER PREDICTION PRODUCTS FOR THE WMO-SEVEREWEATHER FORECASTING DEMONSTRATION PROJECT IN SOUTHEAST ASIA

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ARTICLE HISTORY

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ABSTRACT

WMO mission to Hanoi in February 2011 determined that the NCHMF appeared to have an excellent development potential to undertake the role of the Regional Forecasting Support Centre (RFSC) in the Severe Weather Forecasting Demonstration Project for Southeast Asia project. To provide better product for developing the guidances for SWFDP-SeA, based on new capacities of High Performance Computing (HPC) of VNMHA, this paper presents new high-resolution numerical weather prediction products including very high-resolution deterministic products (WRF3kmIFS) and high-resolution regional ensemble systems (SREPS-32). WRF3kmIFS is configed by using the recently released version of Weather Research and Forecasting model with ARW dynamical core - WRF-ARW (version 3.9.1.1) with IFS (ECMWF) for boudary conditions while SREPS-32 is a set of combination of physical parameterizations. Some improved performances are shown relating to heavy rainfall and tropical cyclone over Southeast Asian domain and for the South East Asia Flash Flood Guidance Systems.

Keywords: *SWFPD-SeA, RFSC's Hanoi, High-resolution regional products.*

1. Introduction

The Severe Weather Forecasting Demonstration Project (SWFDP) is a WMO Commission of Basic Systems (CBS) initiative, commenced in 2005, to demonstrate how warning services provided by NMHSs in developing countries can be enhanced and links with disaster management authorities improved through cooperative work among meteorological centers. The scope of the project is to test the usefulness of currently available and promising experimental products available from Numerical Weather Prediction (NWP) centers in improving severe weather forecasting services in countries where sophisticated model outputs are either not available, or not effectively used (GDPFS, 2010).

The first meeting of the SWFDP-SeA Regional Subproject Management Team (RSMT) to develop an implementation strategy for the SWFDP-SeA was held in September 2010 in Tokyo. The meeting reviewed a draft SWFDP-SeA Implementation Plan which proposed three types of Regional Centers with the roles: regional forecasting support (Hanoi), training and technical support (Hong Kong Observatory, HKO), and tropical cyclone forecasting support (RSMCs Tokyo and New Delhi). Although the National Centre for Hydrological

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and Meteorological Forecasting (NCHMF) in Hanoi is not a designated RSMC within the WMO GDPFS, the SWFDP concept of operation requires an operational regional centre to support severe weather forecasting in the participating NMHSs. A follow-up WMO mission to Hanoi in February 2011 determined that the NCHMF Hanoi appeared to have an excellent development potential to undertake the role of the Regional Forecasting Support Centre (RFSC) in a SWFDP-SeA project. It is proposed that NCHMF Hanoi be designated the Regional Forecasting Support Centre to perform the function of the lead regional centre for the SWFDP-SeA.

The SWFDP implements a cascading forecasting approach via the three-tier GDPFS network of global, regional and national meteorological centers. Global centers provide NWP products, including probabilistic forecasts, and other forecasting guidance, while Regional Centres interpret this information often from multiple sources, and produce regional-scale products to guide National Meteorological and Hydrological Services (NMHSs) in their forecasting functions for their respective countries. For the main purposes of SWFDP regarding to the enhance of supplying regional scale products, with the new HPC system, in 2019, the regional NWP products have been significantly upgraded, especially of very high resolution of deterministic forecast (3km, Southeast Asia domain, named WRF3kmIFS) with better boundary conditions (from ECMWF) and higher resolution of regional ensemble forecast (10km, Southeast Asia domain, named SREPS-32). The product of SWFDP-SeA can be seen with link in reference list (SWFDP-SEA).

Section 2 will provide technical information for WRF3kmIFS and SRESP-32. The performances of these systems will be shown in section 3 and some remarked conclusions are shown in section 4.

2. Materials and Methodology

2.1. WRF-3kmIFS

This study used the recently released version of Weather Research and Forecasting model with ARW dynamical core WRF-ARW (version 3.9.1.1) with multi-nested grids and two-way interactive options. One of the most important things is that the WRF model has been a very flexible and useful tool for both researchers and operational forecasters as it is integrated with various recent advances in physics, numerics, and data assimilation contributed by scientists and developers from the expansive research community.

2.2. SREPS-32 system and boundary conditions

A set of combination of physical parameterizations has been generated based on (a) the modified KF and BMJ cumulus parameterization schemes; (b) the Goddard and Dudhia schemes for the shortwave radiation; (d) the YSU and MYJ planetary boundary and (e) the Lin, WSM3, WSM5 and WSM6 schemes for the cloud micro-physics.

There are maximum 32 different configuration forecasts. The other options are the Monin-Obukhov surface layer scheme and the Rapid Radiative Transfer Model scheme for longwave radiation. Note that with MYJ scheme, the surface layer option will be switched to Janjic-Eta-Monin-Obukhov scheme which based on similar theory with viscous sub-layers both over solid surfaces and water points. Skamarock et al. (2008) provided the detailed description of the WRF-ARW model. The performances of different members can be found in Tien et al. (2019) regarding to the heavy rainfall over the northern part of Vietnam.

For SREPS-32, WRF-ARW is set to 10km for horizontal resolution and the GFS model by NCEP is used to provide boundary conditions for WRF-ARW and be prepared every three hours at pressure levelsfrom 1000hPa to 1hPa. More information for GFS data can be found at:

https://www.nco.ncep.noaa.gov/pmb/products/gfs/.

2.3. WRF3kmIFS system and boundary conditions

With WRF3kmIFS, there is no cumulus parameterization. Using WSM6, MYJ and the Goddard and Dudhia schemes, WRF-ARW is set to 3km for horizontal resolution and the IFS model by ECMWF is used to provide boundary conditions for WRF-ARW and be prepared every three hours at 27 pressure levelsfrom 1000hPa to 1hPa. The IFS has been bought by VNMHA since 2011.

3. Results and Discussion

3.1 Performance of high resolution NWP products

To examine the performance of numerical weather prediction products, a number of deterministic and ensemble models will be briefly assessed in two cases studies in this section. The event of heavy rainfall in the northern Vietnam occurred on 23 June 2019. Fig. 1 illustrates the surface analysis chart at 00Z UTC with a low pressure trough which was squizzled by the high pressure in China. As a result of the southward movement of this trough, the north of Vietnam experienced moderate to heavy rain in the night of 24 Jun 2019 in the mountainous and midland area, especially very heavy rain was observed in some places. The common rainfall is about 40-80mm/24h, particularly in Lai Chau, Ha Giang and Bac Giang regions, rainfall is up to 80 - 1600mm/24h (Fig. 1a).

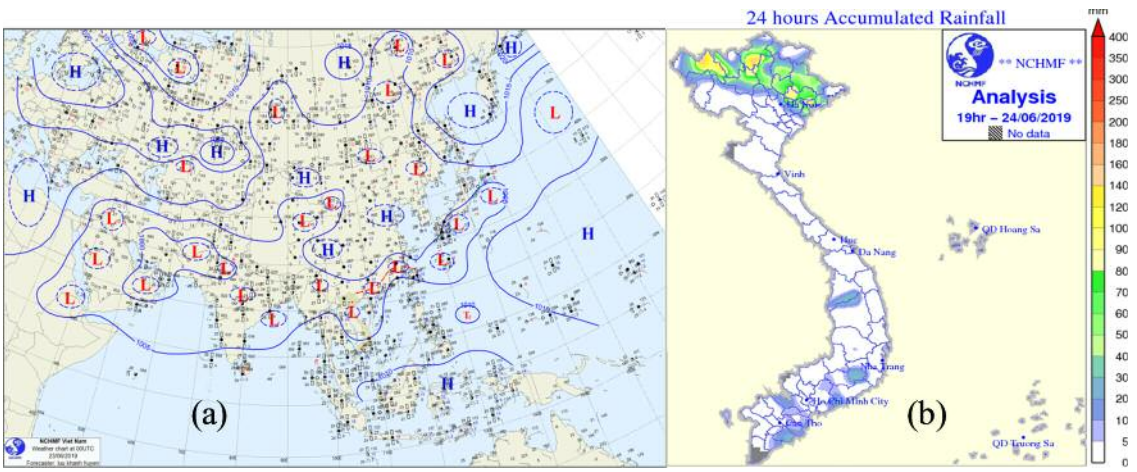

Fig. 1. Surface analysis chart on 00z 23 Jun 2019

Regarding the determistic models in Fig. 2, it is clear that WRF3kmIFS provided the best forecast among all the NWP models. The amount of rain with threshold 60-80mm/24hours was forecasted by GSM and IFS models in the north and northeast of Northern Vietnam respectively, whereas the GFS model only forecast the rain with the amount of 10-40mm/24 hours. In comparison with global models, both of WRF model forecast (using IFS and GFS)provided the more widespread heavy rain area with the common rainfall occurred at 60-80mm/24h all over the northwest, northeast and upper north of Vietnam.

Ensemble products also reveals the high probability of heavy rain in the north of Vietnam in Fig. 3. For SREPS, the probability of heavy rain with threshold over 20mm/24 hours was at 40-60%, while this figure for threshold over 50mm/24 hours was slightly lower, at 30-40%. Similarly, ECMWF ensemble products also predicted the heavy rain in the Northern Vietnam even though the heavy rain area was forecasted to occur in the northeast. In ECMWF products, 80-90% of rainfall at over 20mm/24h and 30-60% of rainfall at over 50mm/24 hours were forecasted, mainly in the northeast of Northern Vietnam

Based on numerical products, SWFDP warnings for short range was issued (Fig. 4).

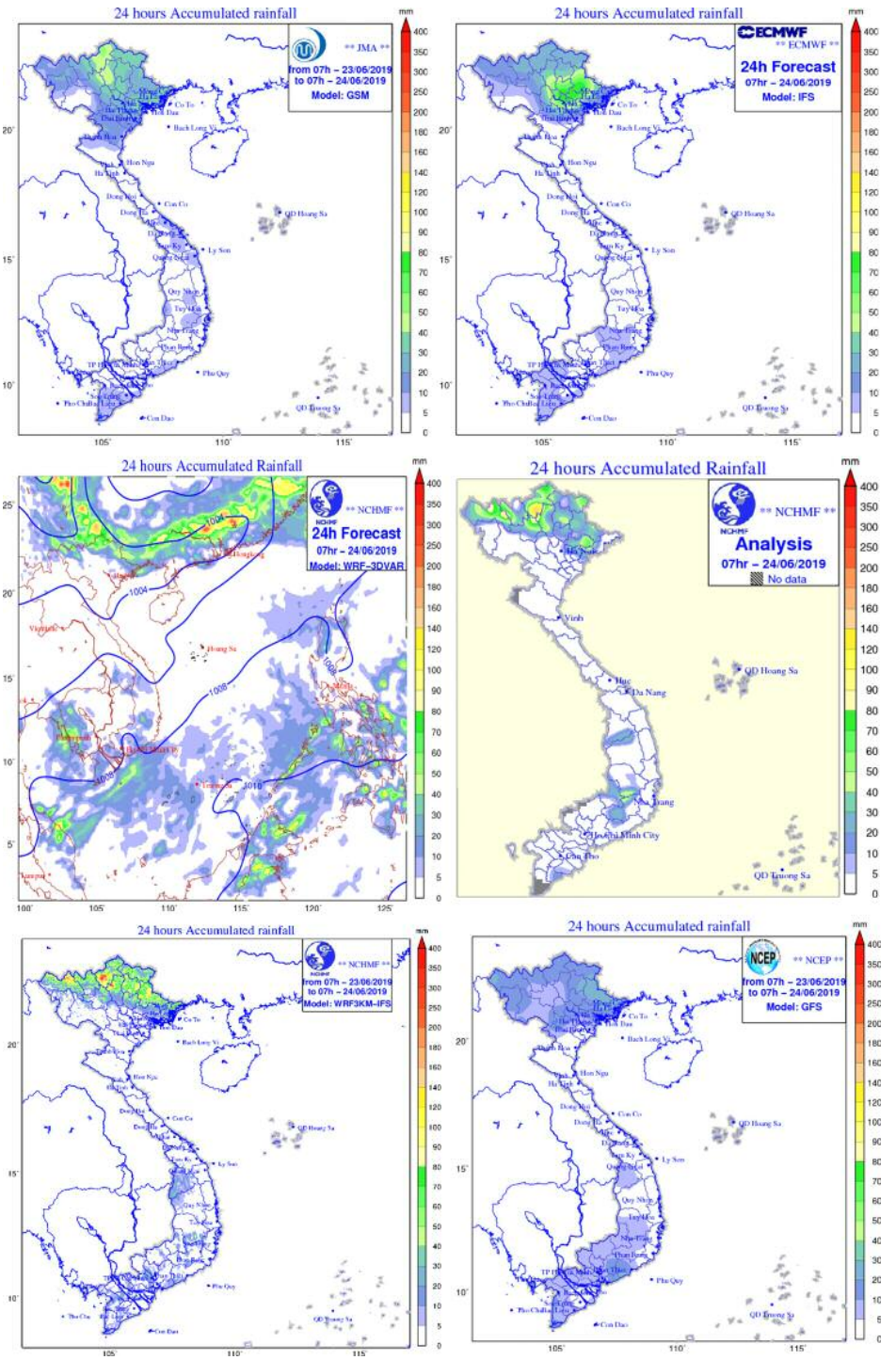

Fig. 2. Illustration of Comparison of global and regional models for heavy rainfall over the northern Vietnam in 24/6/2019

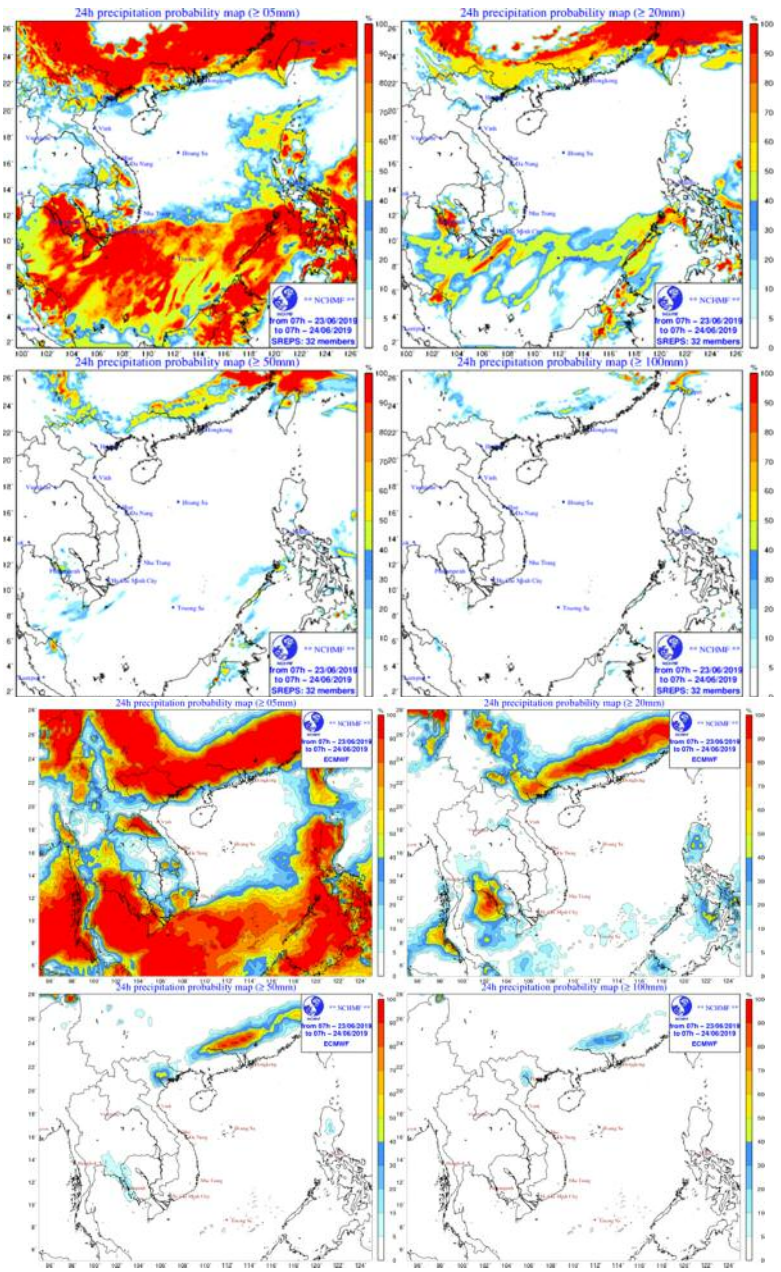

Fig. 3. Ensemble products

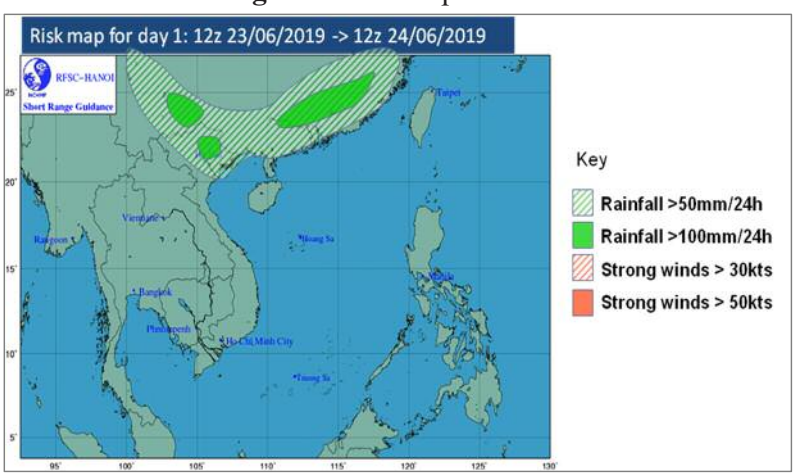

Fig. 4. Warning map from SWFDP-SeA with new NWP products

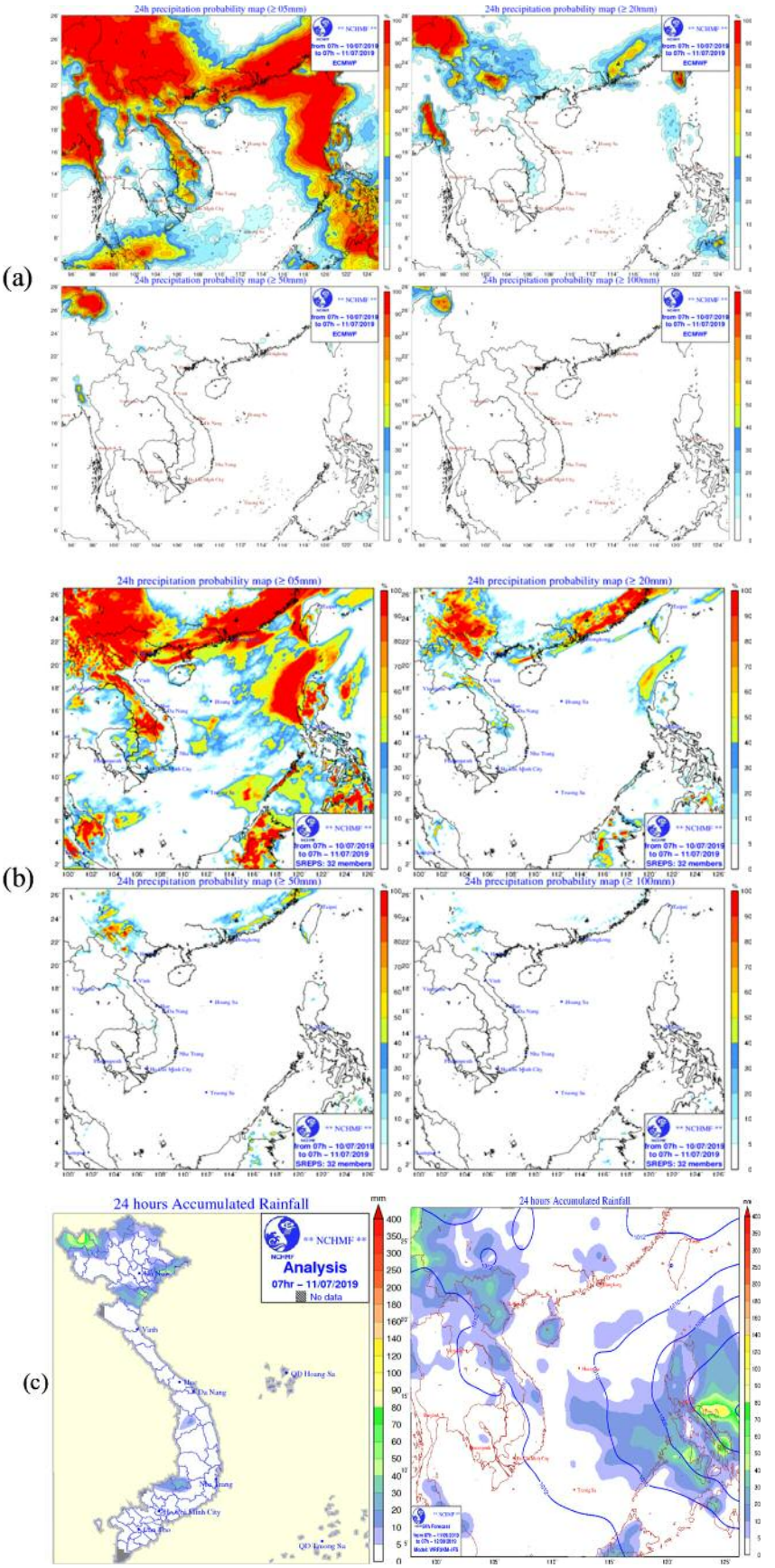

Fig. 5. Illustration of SREPS-32 (b) in case of providing better forecast for heavy rainfall Event over the Northwest of Vietnam than ensemble-ECWMF-51 in 11/7/2019, (a) is observation of precipitation

Another example can be seen in Fig. 5, for the heavy rain event on 11 July 2019, WRF3km and SREPS-32 still showed the improved forecast in the heavy rain warning. Both ensemble products provided the high probability of heavy rainfall in the northwest of Vietnam with 60-80% at the amount of over 20mm/24 hours and 40-50% at the amount of over 50mm/24 hours. Similarly WRF3kmIFS forecasted the common rainfall of 50-70mm/24 hours in the northwest. The final warning map is shown in Fig. 7.

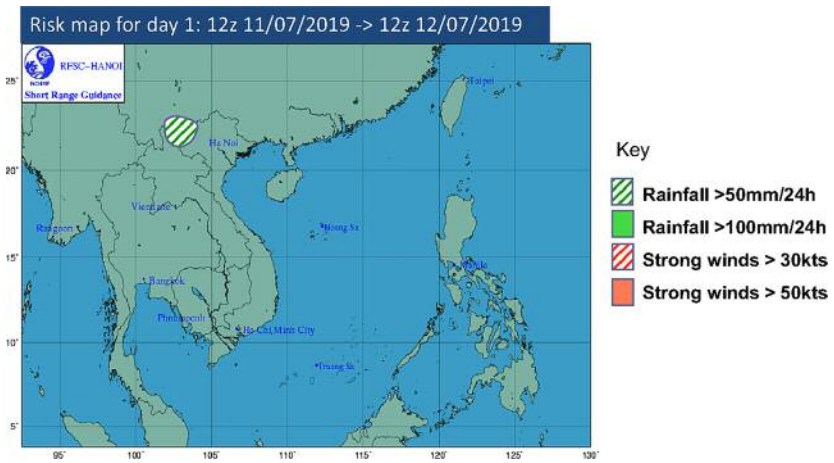

Fig. 6. Warning map regarding to the event in 11/7/2019

3.2 High resolution precipitation forecast for the South East Asia Flash Flood Guidance Systems

During 30 September 11 October, 2019 a delegation from Hydrologic Research Center (HRC) and the World Meteorological Organization (WMO) visited the national hydrological and meteorological offices of Lao-PDR, Vietnam, Cambodia and Thailand. The main objective for these visits was to establish the real-time data transfer of the key datasets to the South East Asia Flash Flood Guidance Systems (SeASIA-FFGS) and to assemble historical datasets that are needed for the FFGS development.

As of October 4, 2019, we are receiving WRF-ARS 3 km2 rainfall forecast extending out to 72 hour in 6-hour intervals for the entire domain of the SeAsiaFFGS. The files are in NetCDF format that can be ingested into the FFGS. The forecast is updated twice daily (00:00 and 12:00 UTC) using a cold start and boundary conditions from ECMWF. This WRF was developed with WMO support as part of the Severe Weather Demonstration Initiative. VNMHA is also producing a ten members WRF ensemble at a 10-km resolution using the GFS for boundary conditions. The output of this ensemble is readily available and was offered for the FFGS.

An example of using higher resolution of deterministic forecast (3km) in providing better precipitation forecast for landslide warning can be seen in Fig. 7.

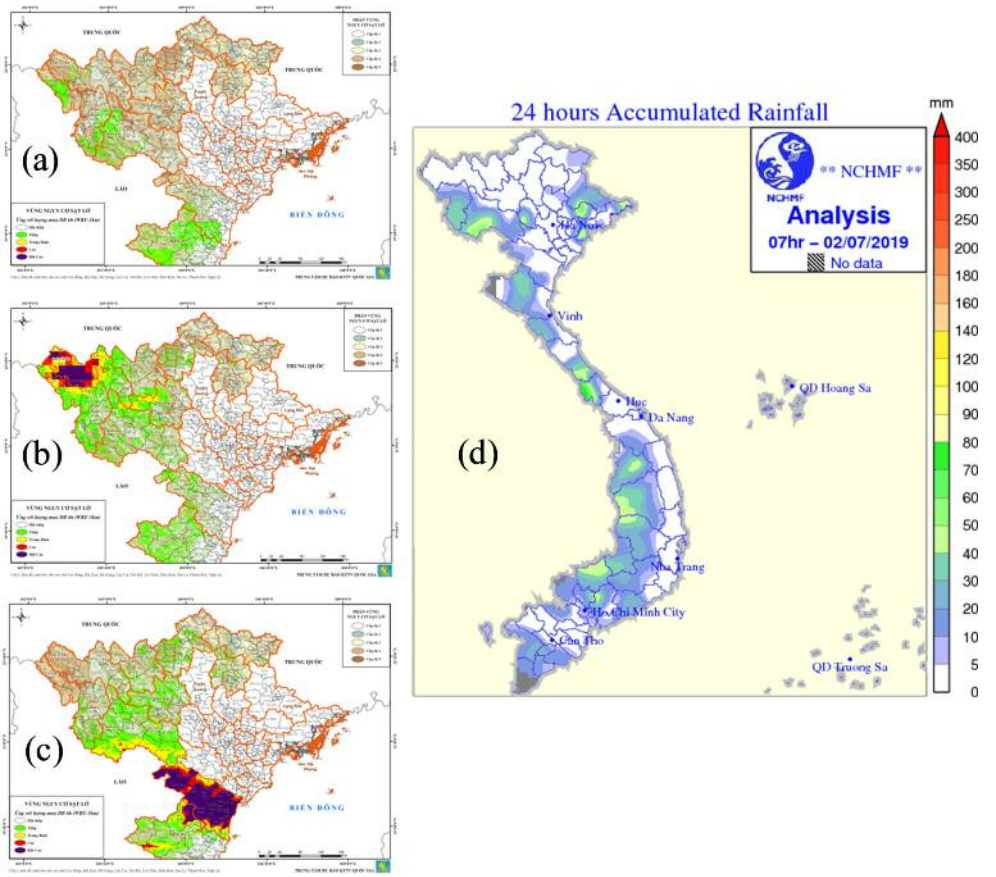

Fig. 7. The detail of landslide warning based on different rainfall meteorological model forecast: (a) GFS, (b) IFS, (c) WRF3km-IFS, 02-Jun-2019 and (d) observation

4. Conclusion

Based on new capacities of HPC of VNMHA, the new high-resolution numerical weather prediction products including very high-resolution deterministic products (WRF3kmIFS) and high-resolution regional ensemble systems (SREPS-32) showed improving performances relating to heavy rainfall and tropical cyclone over Southeast Asian domain and for the South East Asia Flash Flood Guidance Systems. Next steps, further detail verifications of WRF3kmIFS and SREPS-32 will be conducted.

Conflicts of Interest: The authors declare that they have no conflict of interest.

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