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Authors' Responses to Reviewer 1 (RC1, anonymous)

Date: 20 July 2022

Title: Investigation of An Extreme Rainfall Event during 8-12 December 2018 over Central Vietnam. Part I: Analysis and Cloud-Resolving Simulation

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Firstly, **we thank the reviewer for spending valuable time reviewing the paper and giving us helpful comments that helped to improve the clarity of the paper.**

COMMENTS

Comment 01: Part 1: The overview of the article has not mentioned much about the situation causing heavy rain and the ability to solve the problem of heavy rain caused by this weather pattern in Vietnam.

Reply: Thank you for your comment. In the revision, we will try our best to add more analysis as much as we can to clarify better the situation causing heavy rainfall in central Vietnam as well as the ability to solve the problem of heavy rain caused by this weather pattern in Vietnam.

Comment 02: Part 2: It is necessary to describe more clearly the two options for removing terrain and not removing terrain in the experiment. Additional options for physics of Cress model.

Reply: Thank you for your suggestion. We have added more information to make it more clearly.

Table 1. The basic information of experiments.

Domain and Basic setup	
Model domain	3°–26°N; 98°–120°E
Grid dimension (*x*, *y*, *z*)	912 × 900 × 60
Grid spacing (*x*, *y*, *z*)	2.5 km × 2.5 km × 0.5 km*
Projection	Mercator
IC/BCs (including SST)	*NCEP GDAS/FNL Global Gridded Analyses and Forecasts (*0.25° × 0.25°, every 6 h, 26 pressure levels*)*
Topography (for CTRL only)	Digital elevation model by JMA at (1/120)° spatial resolution
Simulation length	114 h
Output frequency	1 hour
Model physical setup	
Cloud microphysics	Bulk cold-rain scheme (six species)
PBL parameterization	1.5-order closure with prediction of turbulent kinetic energy (Deardorff, 1980; Tsuboki and Sakakibara, 2007)
Surface processes	Energy and momentum fluxes, shortwave and longwave radiation (Kondo, 1976; Louis et al., 1982; Segami et al., 1989)
Soil model	41 levels, every 5 cm deep to 2 m

Comment 03: Part 3: analyzes a lot about the weather patterns that cause rain but still does not explain the cause of rain for this period.

Reply: Based on the thermodynamics obtained from ERA-5, we found out some key factors that caused this extreme rainfall event. (1) The interaction between the strong northeasterly winds, blowing from the Yellow Sea into the northern South China Sea (SCS), and easterly winds over the SCS in the lower troposphere (below 700 hPa). This interaction created strong low-level convergence, as the winds continued to blow into central Vietnam against the Truong Son Range, the low-level easterly flow reduced in speed and led to moisture flux convergence and rising motion along the coast of Vietnam persistently. These low-level convergence and rising motion were strong enough to trigger

most of the convection near the shoreline, instead of over the slopes (further inland) by forced uplift of the terrain. As a consequence, heavy rainfall occurred along the coast. (2) The strong easterly wind played an important role in transporting moisture from the western North Pacific across the Philippines and the SCS into central Vietnam at low-level atmosphere while the southeasterly winds between 700 hPa and 500 hPa also play important role in complementing moisture from the SCS into central Vietnam. (3) The Truong Son Range also contributed to this event due to its barrier effect. (4) In addition to cumulonimbus, the low-level precipitating clouds such as nimbostratus clouds were also major contributors to rainfall accumulation for the whole event.

Some of our results are also consistent with the identification of Dr. Hoang Phuc Lam - Deputy Director of the National Center for Meteorological Forecasting about this event on the Communist Party of Vietnam Online Newspaper (https://dangcongsan.vn/xa-hoi/mua-lon-tai-mien-trung-la-bieu-hien-ro-ret-cua-bien-doi-khi-hau---507626.html or English version:https://scienceinfo.net/rain-and-flood-in-central-region-why-do-not-forecast-rainfall-in-each-area.html). We will point out these in the revision.

Comment 04: Part 4: The forecasted rainy area with the case of keeping the topography (Ctl) gives the rain center deviation from reality and also does not simulate the rain well in the Truong Son mountain range. It should be noted that in this case of heavy rain, the topography is not the main factor, as evidenced by very heavy rains at coastal stations (400-600mm/day) and less rain at stations in mountainous areas.

Reply: Thank you for your comment. We will do our best to better clarify the deficiency of the model in heavy rainfall locations in the revision. Besides, to explain why the heavy rainfall only concentrates on narrowing coastal plain and coastal sea. We verified many aspects of this event using multiple data sources, such as thermodynamics obtained from ERA5 (Figs. 9 -11), satellite colour-enhanced infrared imageries of blackbody cloud-top temperatures and Column-maximum radar reflectivity (dBZ) over central Vietnam for every single day (supplement data). We found that the interaction between the strong northeasterly winds, blowing from the Yellow Sea into the northern South China Sea (SCS), and easterly winds over the SCS in the lower troposphere (below 700 hPa) created strong low-level convergence, as the winds continued to blow into central Vietnam against the Truong Son Range, the low-level easterly flow reduced in speed and led to moisture flux convergence and rising motion along the coast of Vietnam persistently. These low-level convergence and rising motion were strong enough to trigger most of the convection near the shoreline, instead of over the slopes (further inland) by forced uplift of the terrain. As a consequence, heavy rainfall occurred along the coast. Furthermore, the CReSS test

without the terrain (NTRN run) also indicates that the rainfall pattern is no longer parallel to the coastline and dissimilar to the observation. Therefore, we think in D18 event the terrain played an important role to block the low-level flow and led to moisture flux convergence and rising motion (to initiate convection repeatedly). We will do our best to point these out in the revision.

Comment 05: Note the activities of weather patterns such as the combination of cold air with the high easterly wind and the activity of the westerly wind channel.

Reply: Thank you for your comment. We will do our best to better clarify these activities of weather patterns in the revision.

Question

Question 01. It is necessary to clarify how many hours are the rain analysis periods of the cress model? Rain spreads from the north to the south, but it shows as cumulative rain in the article, so can the model describe this phenomenon?

Reply: The satellite and radar data (Figs. S1-6) show that the precipitating clouds, including cumulonimbi (Cb) and nimbostratus (Ns), produced long-lasting rainfall for hours in the study area. While the precipitation is not too intense, it falls persistently over many hours, leading to high 24-h rainfall accumulation at some locations. Compared with the CReSS CTRL results indicate that it is somewhat similar in the spatial distribution between 24-h model rainfall and precipitable clouds as well as radar reflectivity over coastal plain and coastal sea. Furthermore, Figs. 12a,d the rainfall moved from north to south in CTRL as observed with some location errors in the main rainband. Therefore, we think the model can simulate the D18 event, however, with some location errors in peak amounts.

Question 02. Compare the experiment with keeping the terrain with removing the terrain to explain what?

Reply: Many previous studies showed that the local topography plays an important role in the formation of heavy rainfall events in central Vietnam although the local mountains are not really height (< 3000 m). Furthermore, analyses of the thermodynamics of this event also indicate that the local topography plays an important role in this event due to its barrier effect. Hence, we executed these two experiments to verify it as well as to see how the

rainfall was distributed without the terrain. The result of these two experiments showed the important role of local terrain in the formation and distribution of rainfall in this event.

Question 03. In fact, the time of heavy rain of the rain being studied is short, the center of heavy rain moves from north to south, so the total of 3 days in the article is heavy rain on a large scale, not suitable for this rain. What is the cause of the occurrence of heavy rainfall in a short period of time on a small scale in this case?

Reply: The satellite and radar data indicated that the continuous development of precipitating clouds known as nimbostratus (Ns) produced long-lasting rainfall for hours. Although the precipitation is not too intense, it falls persistently over many hours, added by short spikes of intense rainfall from deep convection (Figs. S1-S6), leading to high 24-h rainfall accumulation at some locations.