A Case Study of a Flood Producing Heavy Rainfall Events in Malaysia

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Introduction

- Most high-profile flood producing *extreme rainfall events* in Malaysia can be associated to *synoptic circulation* modulated by *large scale climatic signals* (e.g. ENSO, IOD, MJO).

- It is crucial to understand the underlying processes:
  - What are the roles of *large scale* and *local forcings*?
  - How does the *warmer climate* alter the probabilities of these events?
  - Has local changes *augmented the severity* of the extremes
  - etc.

- Need *more test cases*.

- In previous meeting, we have reported a case study of the extreme rainfall event on *17 December 2014* based on *WRF simulation*. 
Maximum intensification of rainfall could be seen between 0900UTC and 1200UTC.

**FIGURE.** Rain rate (mm/hr) on 17 December 2014 from radar observation. (source: Malaysian Meteorological Department).
Numerical Experiments

- Using WRF Version 3.7.1
- Integrated over 36 hours, beginning from 16 Dec 2014, 1200 UTC until 18 Dec 2014, 0000 UTC
- Initial and boundary data:
  - GDAS 0.5°
  - 6-hour interval.
- 3 nested domains (36 km, 12 km and 4 km)
- Two-way nested run
- 30 vertical levels.
- Physics options:
  - WRF Single-Moment 3-class scheme for microphysics,
  - RRTM scheme and Dudhia scheme for atmospheric radiation,
  - 5-layer thermal diffusion for land surface
  - Yonsei University scheme for planetary boundary layer.
  - Different combination of cumulus parameterization schemes (Table 1) were used at different domains and the simulation result were examined.

FIGURE. Three nested domains configuration of the WRF simulation.
### Numerical Experiments

**TABLE 1.** Different combination of cumulus parameterization schemes.

<table>
<thead>
<tr>
<th>Exp</th>
<th>Parameterization schemes</th>
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<tbody>
<tr>
<td></td>
<td>Domain 1</td>
</tr>
<tr>
<td>1</td>
<td>Kain-Fritsch</td>
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<tr>
<td>2</td>
<td>Kain-Fritsch</td>
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<td>3</td>
<td>BMJ</td>
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<td>4</td>
<td>BMJ</td>
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<td>5</td>
<td>Multiscale KF</td>
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<td>6</td>
<td>Multiscale KF</td>
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<td>7</td>
<td>NSAS</td>
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<td>8</td>
<td>NSAS</td>
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<td>9</td>
<td>New Tiedtke</td>
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<tr>
<td>10</td>
<td>New Tiedtke</td>
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</tbody>
</table>
RESULT AND DISCUSSION (CPS)

The TRMM accumulated 24-hour rainfall (mm), (b) WRF simulation on 17 December 2014.

- The event simulation (intensity and location) is very sensitive to deep convection parameterizations.
- Kain-Fritsch scheme for outer domains and no cumulus scheme used at the inner most domain produces the best result.
• More test cases are needed for us to understand various extreme rainfall producing mechanism at different part of Malaysia.

• For the DMCC+ and UND project case study, we plan to add another recent extreme rainfall case occurred along the northern west coast of Peninsular Malaysia on 4-5th November 2017.

• Following slides provide an overview of the event.
Case Study 2: Northwestern Peninsular Malaysia, 4-5 Nov 2017

Timing: 4-5 Nov 2017
Evacuated >10000 people
Death toll: 7 death
Cost of damage >RM 300mil
November is typically a wet season in the northwestern part of Peninsular Malaysia.
Synoptic Overview

Wind circulation from 2-7 November 2017
00Z02NOV2017
Accumulated Rainfall from IMERG multi-satellite product

- Generally, 3 rainfall systems.
- Accumulated rainfall from GPM is rather low over northwestern Peninsular.
Rainfall Analysis by MMD

Radar Observation (mm/hr) at Sat Nov 4 14:30:00 2017

Radar Observation (mm/hr) at Sat Nov 4 21:40:00 2017

Radar Observation (mm/hr) at Sat Nov 4 23:50:00 2017

Radar Observation (mm/hr) at Sun Nov 5 06:00:00 2017
• 4th – Consistently larger rainfall over the northern part.
• Station Bangan Buaya (south) recorded largest rainfall (>450 mm daily rainfall).
The stations recorded rainfall

- First look at the hourly rainfall of all the stations.
- The rainfall episode lasted about a day from the noon of 4th to morning 5th November 2017.
- The episode has 2 distinctive rainfall peaks, one at the night of 4th and the other during the morning of 5th.
- The largest recorded hourly rainfall > 100mm/hr at Bagan Buaya.
- During the episode, most of the stations has recorded hourly rain rate of 20-30 mm/hr.
Comparing Satellite Data to Station records

- Satellite product is in grids and the values are representation of the grid averaged. Comparing the gridded product and the station scale record is difficult.
- However, generally the satellite data under-estimated the rainfall amount. Generally it gives only 30-40% of those recorded at the stations (>200mm on 4th November 2017).
- Nevertheless, the spatial variations suggested that the rainfall is larger over the northern region.
How was the weather forecast performs during the event

• GFS forecast initialized on the 00 UTC 3 November was examined.
• Given the coarse resolution the GFS was not able to forecast the location of the heavy rainfall correctly.
• However, it did forecasted the occurrence of heavy rainfall over the region despite much lower intensity compare to the station records.
• For 4th and 5th November daily rainfall, the centre of forecasted rainfall appeared slightly northward and southward respectively.
• Figure above shows general comparison between station rainfall, satellite products as well as the GFS forecast over the Penang areas.
• Generally both satellite and GFS forecast underestimate the station records, despite they consistently picked up the double peaks characteristics of the heavy rainfall episode.
Data collection

• Collected
  - 15 mins rainfall rate from 30 stations.
  - Radar images (CAPPI)
  - satellite data (IMERGE/GsMAP)

• In process of collection
  - Raw radar data
  - Land use?
Numerical Experiment (current status)

Nested Domain for D1 – 27km, D2 – 9km, D3 – 3km, D4 – 1km
WRF Configuration

- Initial and Boundary Conditions: ERA INTERIM
- Physics for Domain 3 & 4
  - **Cumulus Option** – No Cumulus Parameterization
  - **Microphysics Option** – WRF Single-Moment (WSM) 3-class simple ice scheme
  - **Surface Layer Option** - Monin-Obukhov Similarity scheme
  - **Land Surface Option** - Thermal Diffusion scheme
  - **Shortwave Radiation Option** - Dudhia scheme
  - **Longwave Radiation Option** – RRTM scheme: Rapid Radiative Transfer Model.
  - **Boundary Layer Option** – YSU Scheme
12 hour rainfall for Domain 3

4NOV2017_8am – 4NOV2017_8pm

4NOV2017_8pm – 5NOV2017_8am

5NOV2017_8am – 4NOV2017_8pm
12 hour rainfall for Domain 4
Remarks

• Still experimenting for the best model configuration.
• Questions of interest which require further analysis:
  • How is the quality of the simulations affected by model resolutions and moisture schemes?
  • How is the local topography influence the rainfall intensity?
  • Where does the system obtain its moisture from?
  • How does the Typhoon Damrey affected the events?
Increase of interannual variability

- Northern part of Peninsular Malaysia and Sabah has experienced an increase in interannual variability.
- In certain areas, the interannual variability has doubled.
- Accurate forecast of different time-scales is expected to become more crucial for disaster mitigation purposes.
The End