Simulation of daily variation of precipitation during anomalously-wet dry season event over the western Maritime Continent

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Abstract. Local seas play a significant role in causing anomalously wet of the dry season over the Indonesia Maritime Continent (10°S–8°N, 95°–145°E). As a result, modeling the anomalously-wet dry season over Indonesia lead challenges due to several subregional processes over local seas could not be captured well in the regional climate model. This study explores subregions processes of sea-air interaction over the western Maritime Continent by simulating diurnal precipitation using Cubic Conformal Atmospheric Model (CCAM) with a spatial resolution of 32 km during the anomalously-wet dry season periods during May-to-September (MJJAS ) 2020. The simulated results were confirmed by precipitation data from Tropical Rainfall Measuring Mission (TRMM) satellite observation. The results show anomalous circulation patterns induce anomalous regional precipitation over western MC over four keys of seas subregion, i.e., Indian Ocean, South China Sea, southern Sumatra (Lampung and Sunda strait), and the Java Sea. Furthermore, the anomalous circulation also modulates anomalous local circulation and enhances surface water vapor by an increased surface latent heat flux.

1. Introduction
Precipitation over the Maritime Continent (MC) alters on different both of space and time scales. In meridionally, the northern part of the MC has more considerable total amount of precipitation rather than its southern part due to the existence of an intertropical convergence zone (ITCZ) over that region [1]. Conversely, in zonally, the distribution of the precipitation is not homogenous because the complexity of topography over the land may have a significant role in concentrating precipitation rather than sea surface temperature (SST) role [2].

However, the influence of local SST on the precipitation over the MC during boreal summer or dry season period (May-October) may have a broad consideration in previous studies [1], [3]. It should be noted that due to the basic theory, decrease (increase) of SST affected to increase (decrease) surface pressure and surface divergence, then as a result is diminish (enlarged) precipitation [4], [5].

Detail documentation of the enlarge precipitation during the dry season period over MC have established in the previous study in term of summer precipitation variability, so-called “anomalously-wet dry season” over the Maritime Continent (MC), which is clustered by sub-region areas which were found as a critical factors related to the local SST role [1]. It should be noted from the result that anomalously wet dry season over western MC was primarily controlled by the south-east Indian Ocean (Subregion II) [1], such as Indian Ocean Dipole Mode rather than La Niña [3], [6]. Interestingly, the anomalous atmospheric circulation patterns, including Gill-type as responses to the patterns of sea
surface temperature anomaly are responsible for explaining the formation of the anomalously-wet dry season over Subregion II [1].

However, the data analysis still needs to be explored more due to its consistency with some real cases using a proper regional climate model. In this research, we interest to investigate the western MC (subregion II) regarding dense population issues in this region, besides increase of hydrometeorological disasters during several years (2010, 2013, 2017) which experienced with anomalously-wet dry season have been reported by National Disaster Mitigation Agency [7]. We also need to explore other regions that should be determinant regions over western MC. On the other hand, we also need to test our skill of regional model prediction by its capability to capture the anomalously-wet dry season with a case study of the anomalously-wet dry season in 2020.

2. Data and method
In this study, we used Cubic Conformal Atmospheric Model (CCAM) model with 32 km spatial resolution to simulate precipitation during May-October 2020 with the initial condition of SST prediction (April) was revealed from the POAMA data product. To confirm the model results, we make a set of further analyses with Hovmöller, time series, and spatial from daily and monthly of precipitation data of GSMaP (0.25° x 0.25°) [8] and zonal and meridional wind at 850 mb revealed from the Era 5 ECMWF (0.25° x 0.25°) [9].

3. Results and discussion
3.1 Anomalously-wet dry season observed
A significant precipitation induced by intensive cloud activity during the dry season period (May-October 2020) occurred over mainly MC region (Figure 1). However, in meridionally, the northern part of MC (e.g., South China Sea, Java Sea) have larger precipitation (Figure 1a,b) compare to the southern part of MC (Figure 1c,d).

Those conditions related to a convective activity are reduced gradually from north-south in the term of meridional orientation (Figure 1e-h). These results suggest that SST, as well as incoming solar radiation, may play a vital role in controlling the precipitation during that period due to northern part of MC has mainly composed of as an oceanic region and receive a larger of solar radiation rather than the southern part.

The large precipitation during the anomalously-wet dry season of 2020 could have been simulated qualitatively well in agreement with satellite observation in both zonal distribution and daily variation (Figure 2). However, it should be noted that the model results are consistently underestimated compare to observation results. On the other hand, the model skill appeared better over the southern part rather
than the northern part of MC, also quite well simulated over the regions that primarily consist of land in place of ocean.

Figure 2. Same as Figure 1, but for daily rainfall accumulation data from May to October 2020: a)-d) GSMaP satellite; e)-h) CCAM model.

3.2 Vortices induced precipitation during dry season

Moreover, closer inspection of model skill in capturing spatial distribution of precipitation need to be confirmed by the satellite observation and reanalysis product (Figure 3). In this case, the model could simulate the existence of the Borneo Vortex from May to September and dissipate in October 2020 (Figure 3b). It is also interesting to notice that due to discrepancies between model result and satellite observation in capturing precipitation in the term of underestimated value of the model result, overestimated of precipitation predicted in September by the model over the southern part of MC (i.e., around Java). It might be related to the discrepancy between model and observation while simulated a lifetime and the existence of the Borneo Vortex.

The model somehow simulated the Borneo Vortex in a mature phase and tend to shift over the southern region of the South China Sea in September. On the other hand, satellite observation capture the pre-dissipation stage of the Borneo Vortex and exist relatively over the northern part of the South China Sea. The discrepancies also could be described in more detail with a 10-days variation of a lifetime of the Borneo Vortex (Figures 4-5). While the reanalysis product showed that the Borneo Vortex dissipates in 1–10 September, the model result simulated Borneo Vortex reach the mature stage in 21–30 September (Figure 5).

However, in June-July, the model simulated the best in capturing a lifetime of vortices in both of Indian Ocean and Borneo Vortex, which were used in further analysis to understand the process related to enhancing precipitation over western MC in that periods (Figure 6). We then also noted that the co-existence of the Borneo Vortex might play a crucial role in enhancing precipitation in several regions, such as: Sumatra, Kalimantan, Java, compare to the monthly climatology data of June-July (Figure 6).
Figure 3. a) Spatial monthly distribution of rainfall (shaded) and wind at 850 mb (streamline) from May to September 2020 based on GSMaP data and ERA5 ECMWF reanalysis dataset, b) as a) but for model results.
Figure 4. As Figure 3 but for 10 days variation of streamline wind data at 850 during May-July 2020 for: a) ERA5 ECMWF reanalysis dataset, b) CCAM model.
Figure 5. As Figure 4, but for August-October 2020.
Figure 6. Same as Figure 5, but for divergence and streamline wind at 850: a) June of monthly climatology; b)-d) 10 days of June 2020; e) July of monthly climatology; f)-h) 10-days of July 2020.

It is also important to note that besides sub-region II (Xu et al., 2019), during the dry season period of 2020, some regions appeared different patterns due to explain the relationship between enhance precipitation and warmer SST (Figure 7). Precipitation over region D (following Xu et al., 2019) clearly showed consistent was influenced directly by local SST, which is exhibited by the same phase between those of precipitation and SST.

However, region B (South China Sea) and C (Java Sea) described out of phase between precipitation and SST data. This condition may be related to the air-sea interaction process, which could modulated diurnal precipitation over Java island [10]. For region B and C, the difference of sensible and latent heat fluxes in the term of pattern and value also interest to investigated more for better study using a high-resolution of the coupled model.
4. Conclusions
We have investigated the case of the anomalously-wet dry season of 2020 using the regional climate model of CCAM. The anomalously-wet dry season observed by satellite observations and reanalysis data could be quantitatively well-simulated by the model results. In this period, synoptic conditions due to the existence of vortices both of the Indian Ocean and Borneo Vortex the influence to low-level convergent in some regions such as Sumatra, Kalimantan, and Jawa, thus enhance the precipitation over those regions.

The result in agreement with previous studied that mentioned about influence of the Borneo Vortex to enhance the convective activity and increase precipitation around the region [11]. This study also noted consistently underestimated in simulating precipitation by the model. On the other hand, the model skill appeared better over the regions that mainly consisting of land in place of ocean. Due to the inconsistency issue for predict overestimated precipitation during September, this study described that it was influenced by some discrepancies while the model simulated both a lifetime and a central location
of the Borneo Vortex (see Figure 5). It should be noted that the model inconsistent captured circulation produced by relative motion which is driven by the low-pressure system due to difference of sea surface temperature. Moreover, the model also still a low capability to simulated processes from the mature to decay phase of the vortex. This problem explained in previous studies related to the positioning of the boundary of the model domain which is controlled by the life cycle of simulated vortices [12] and the size of the domain [12], [13], [14], [15].

In this case, the sensitivity test regarding domain size for the optimum domain in capturing the vortex should be done in the future study. This study also suggests that several regions should be investigated more in the further analysis due to preliminary results found in this case study related to out of phase between precipitation and SST data. This condition may be confirmed as an air-sea interaction process which that could enhance precipitation and triggered the anomalously-wet dry season over western MC. It should be noted that La Nina start develops from end August/early September 2020.

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