IBM Research

Characteristics of diurnal variations of rainfall cycle of Borneo during winter season

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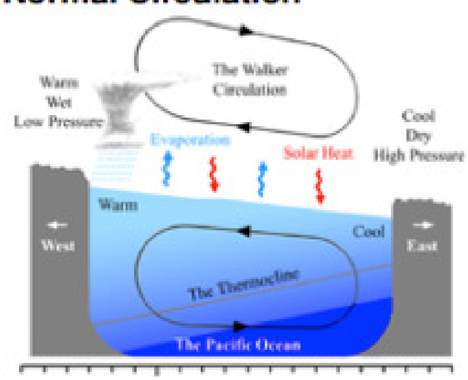
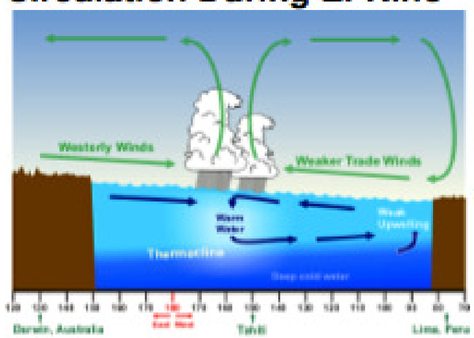
Region of Interest - Climate and Weather (Borneo)

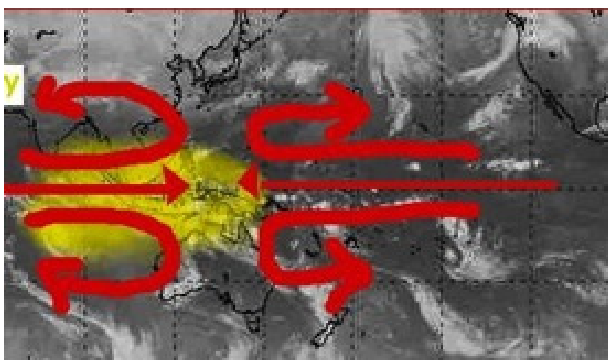
This region is subject to significant large-scale disturbances that vary over a wide range of time scales.

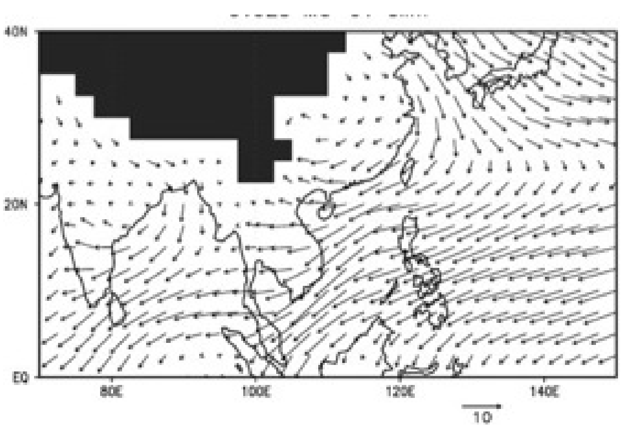
Normal Circulation



Circulation During El-Nino







- **Inter Annual Variability : modulates the rainfall over the Maritime Continent particularly during the warm phase of ENSO. As the warmest SSTs move out into the central Pacific, the strongest convection follows and generates an anomalous longitudinal circulation, leading to suppression over the Maritime Continent**

Focus of this work – winter season

- **Intra Season Variability : The Madden–Julian oscillation (MJO) often has peak amplitude during boreal winter over the Maritime Continent. The MJO causes alternating periods of large-scale active and inactive convective phases with a periodicity of 30–60 days as it propagates eastward through the equatorial South China Sea and Maritime Continent regions**

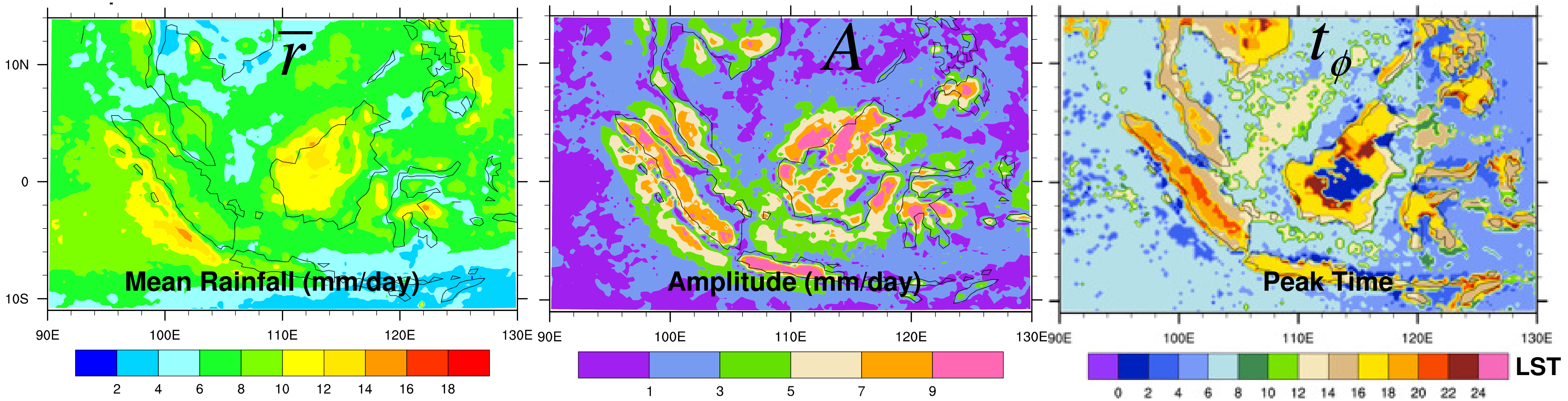
- **Seasonal Variability : Northeasterly cold surges dominate the low-level circulation patterns over the in winter season. The cold surge spreads equatorward around the eastern edge of low-level anticyclones located over eastern Asia. These cold surges can typically last from 5 to 14 days**

Diurnal Cycle

- The mean precipitation over the Maritime Continent (and its global response) is just the average of all the precipitating weather systems in the region -- dominated by the diurnal cycle
- TRMM 2008-2009-2010 data is used to represent the diurnal cycle in terms of the linear cosine curve (as the island receives a unique rainfall maxima in a day)

$$r = \bar{r} + A\cos\left\{\frac{2\pi(t - t_\phi)}{24}\right\}$$

As suggested by Love et al (2011,QJRMS)



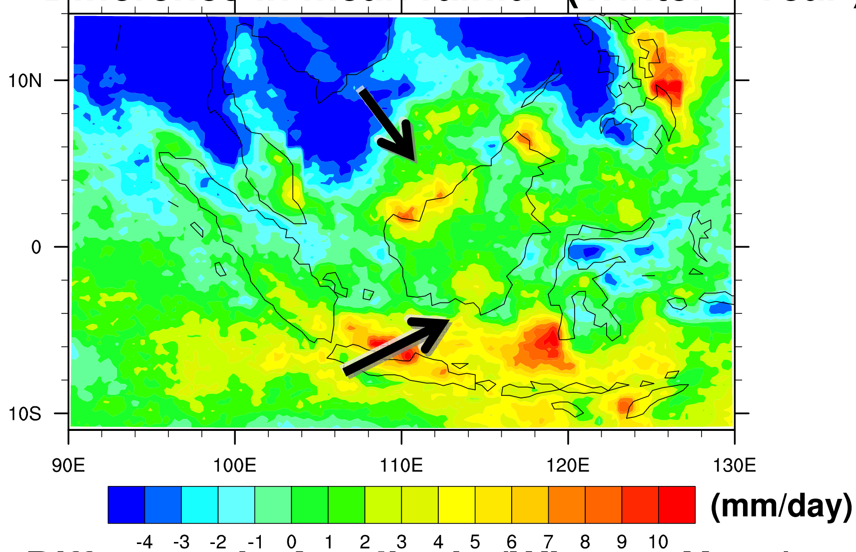
Observations :

- High rainfall rates concentrated to large islands – especially Borneo
- Amplitudes describing the variations to mean rainfall are as large as 10 mm/day over land in comparison to neighboring sea which is less than 2mm/day
- Dominant diurnal variation in rainfall with evening to midnight maxima over islands and early morning maxima over sea
- Also the signals of propagation of rainfall peak as gravity wave are visible

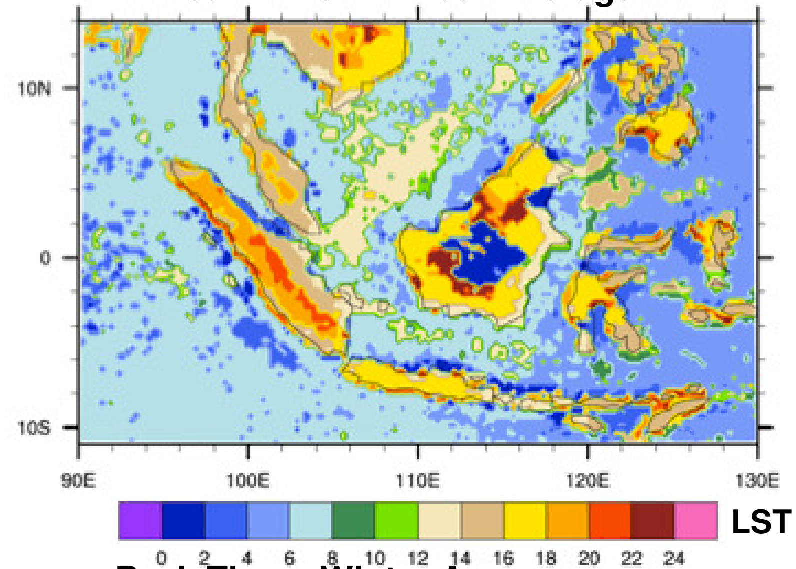
Winter Season vs. Annual Averages

- **Winter season is the most convectively active season for maritime continent specially the region surrounding Borneo**

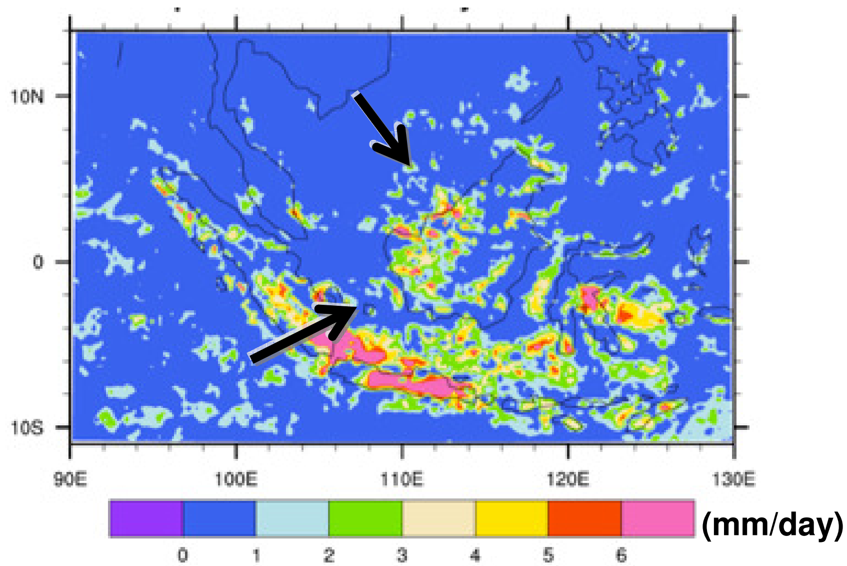
Difference in mean rainfall (Winter – Year)



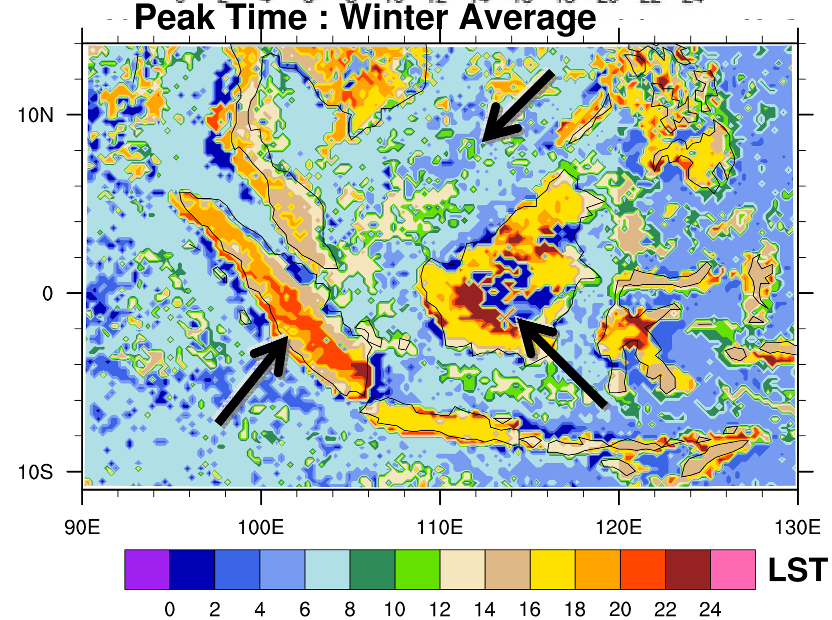
Peak Time : Annual Average



Difference in Amplitude (Winter – Year)



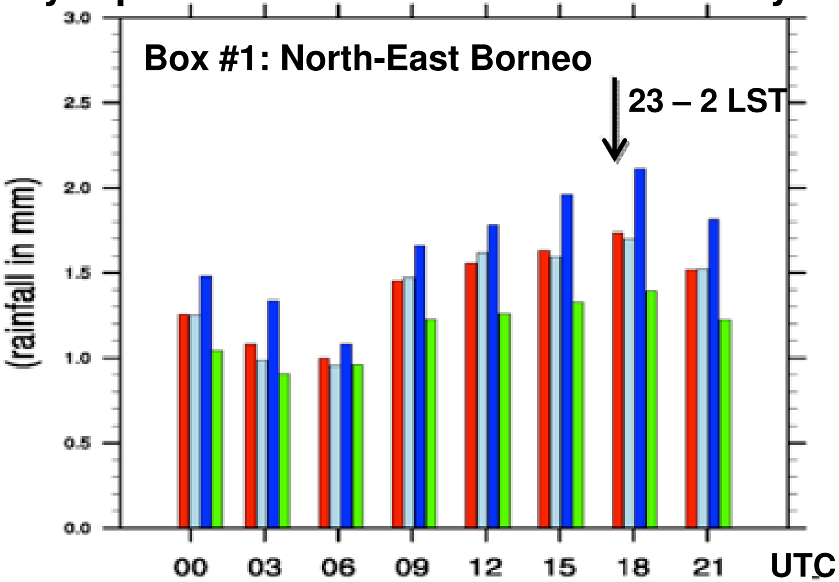
Peak Time : Winter Average

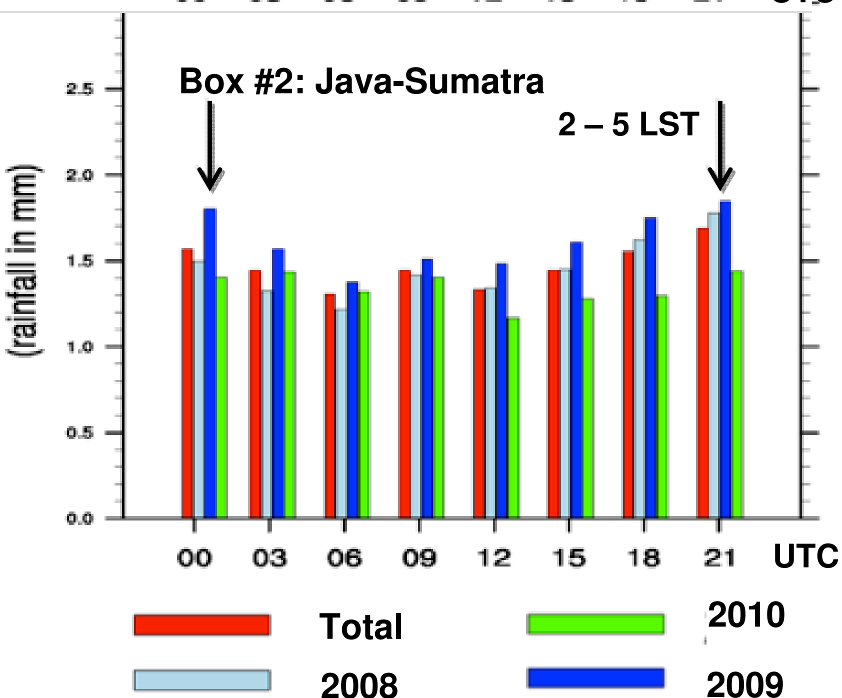


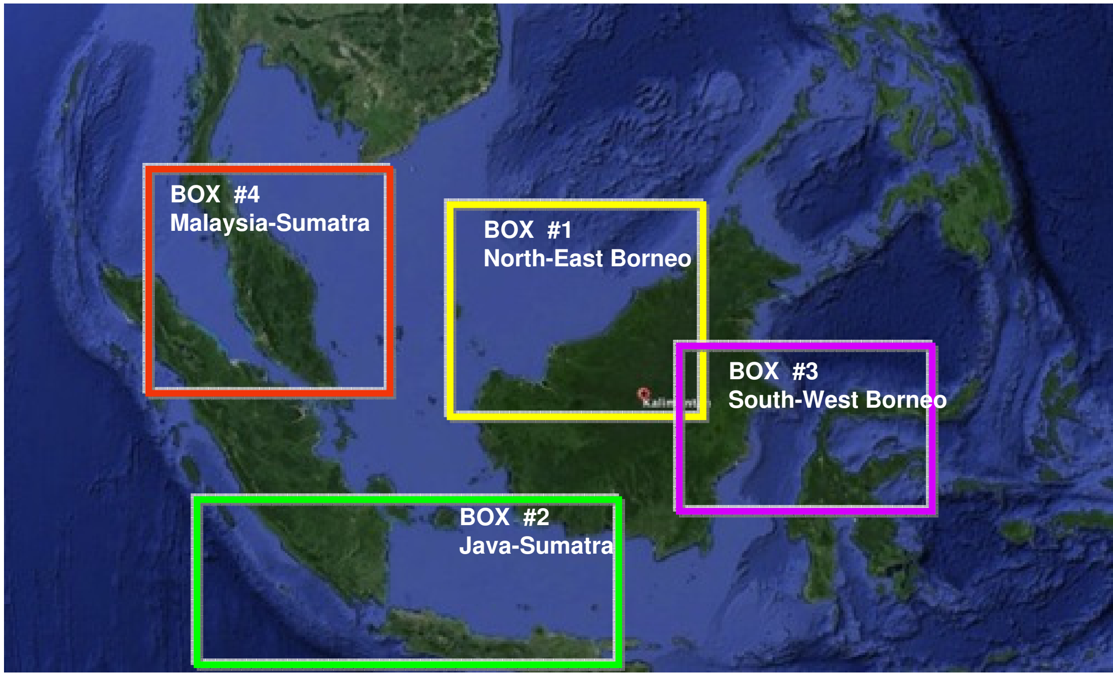
Main Objective: Substantial amount of variation exist in the diurnal cycle of rainfall during the winter season and the objective of this work is to quantify/ classify these differences

Winter season variations in rainfall – Vortex/Surge/MJO Day

Three winter season (DJF) data for three years are analyzed to estimate the quantitative effect of synoptic disturbances on the diurnal cycle



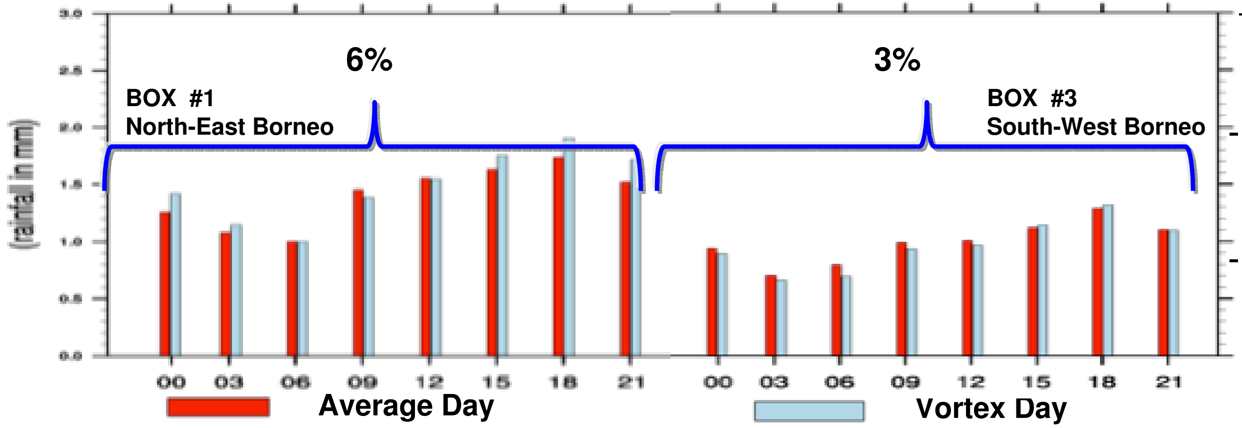




- Surge (weak and strong), vortex days are classified as the criteria given by Chang et al (MWR, 2004)
- MJO Data has been taken from the Australia BOM: http://www.bom.gov.au/climate/mjo/

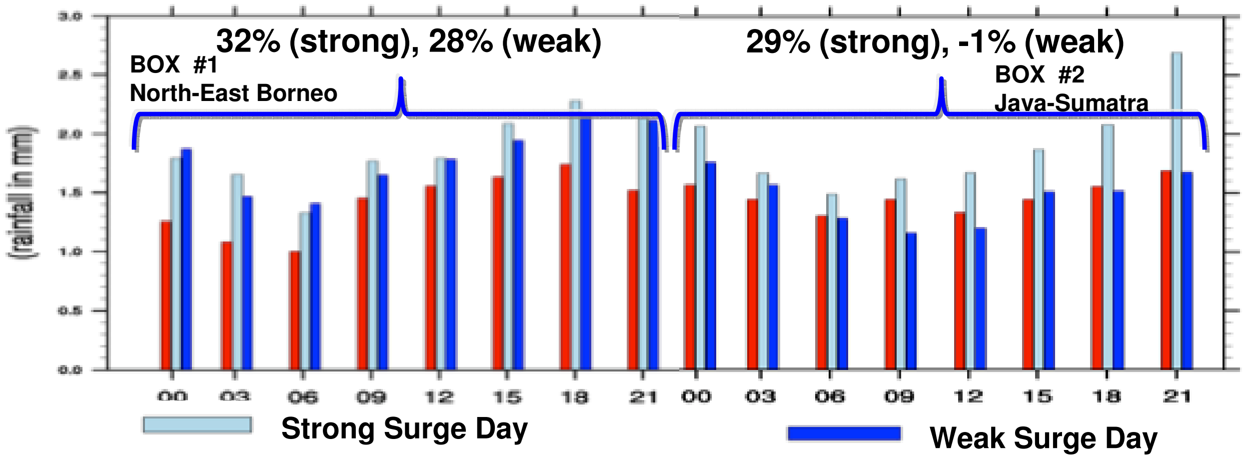
	2007-2008	2008-2009	2009-2010	Total
Total Days	91	90	90	271
Vortex Days	35	35	21	91
Surge Days	25	21	9	55
MJO (phase2&3)	25	3	6	34
Vortex +Surge	10	11	1	22
Vortex +MJO	5	0	4	9
Surge + MJO	2	0	0	2

Classification of Winter Season



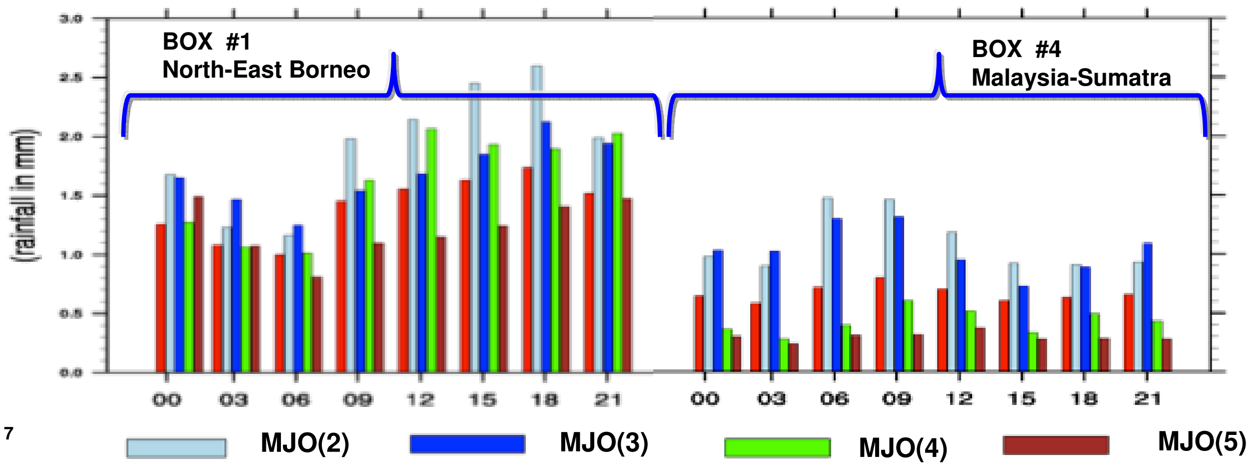
Comparison with only Vortex Days

- Box 1 , Box 2 and Box 4 showed enhancement in the rainfall due to presence of Vortex
- Box 3, lies on the other side of mountains and has negligible effect due to vortex presence



Comparison with Weak /Strong Surge

- Surge has maximum effect on Box 1 & 2. Rainfall enhancement is similar for strong and weak surge for Box 1
- Box 2 shows a clear rainfall enhancement in the strong surge days as expected
- During Strong surge days distinct diurnal peak is visible, which is not the case otherwise for Box 2

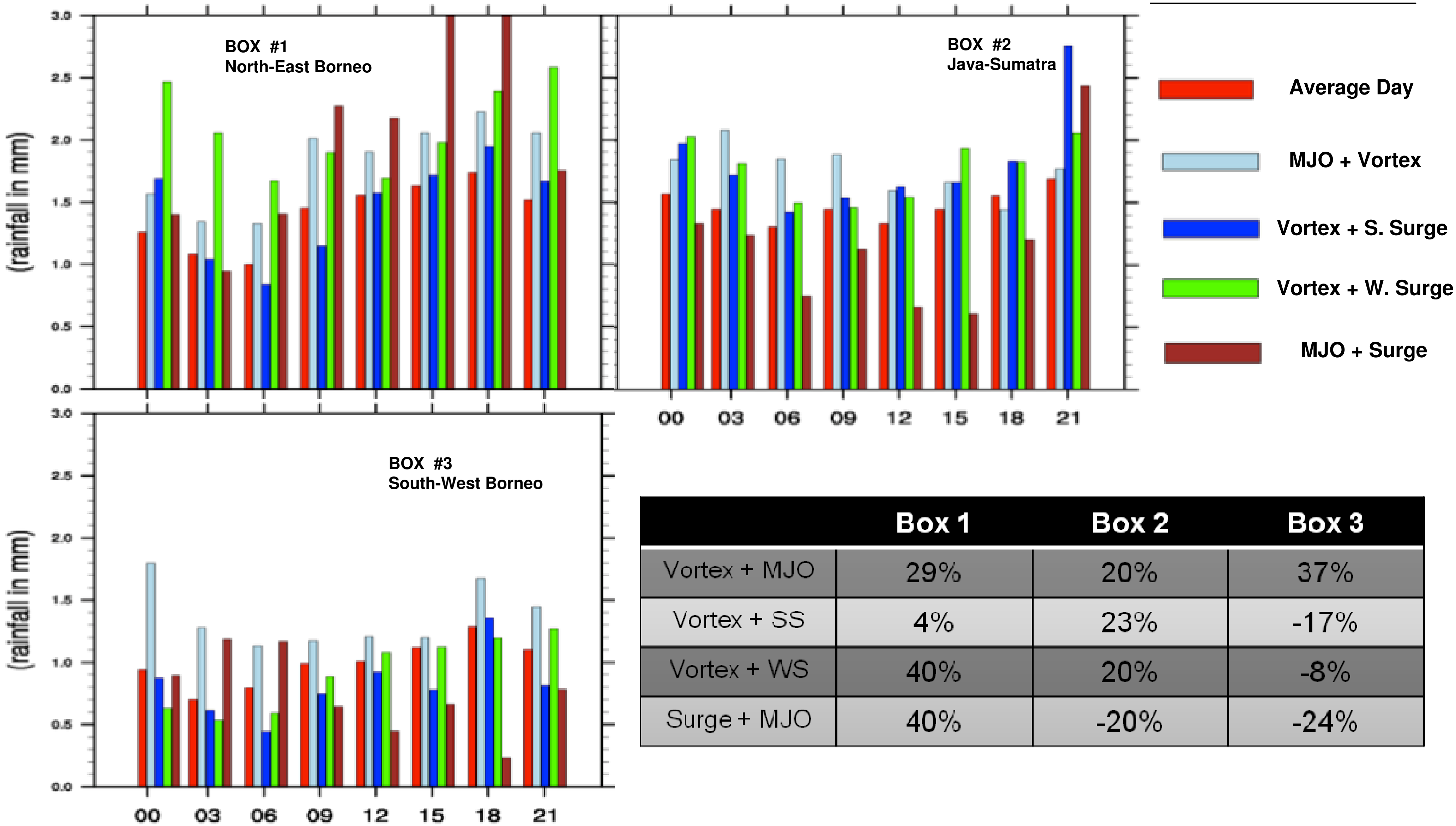


Comparison with relevant MJO phases

- Box 1 and Box 4 are the areas surrounding SCS. Both the boxes clearly advocates that the MJO phase 2 and 3 are the active MJO period for the winter monsoon region. (Area surrounding Box 1)

We will next consider the responses when they interact with each other

Classification of Winter Season

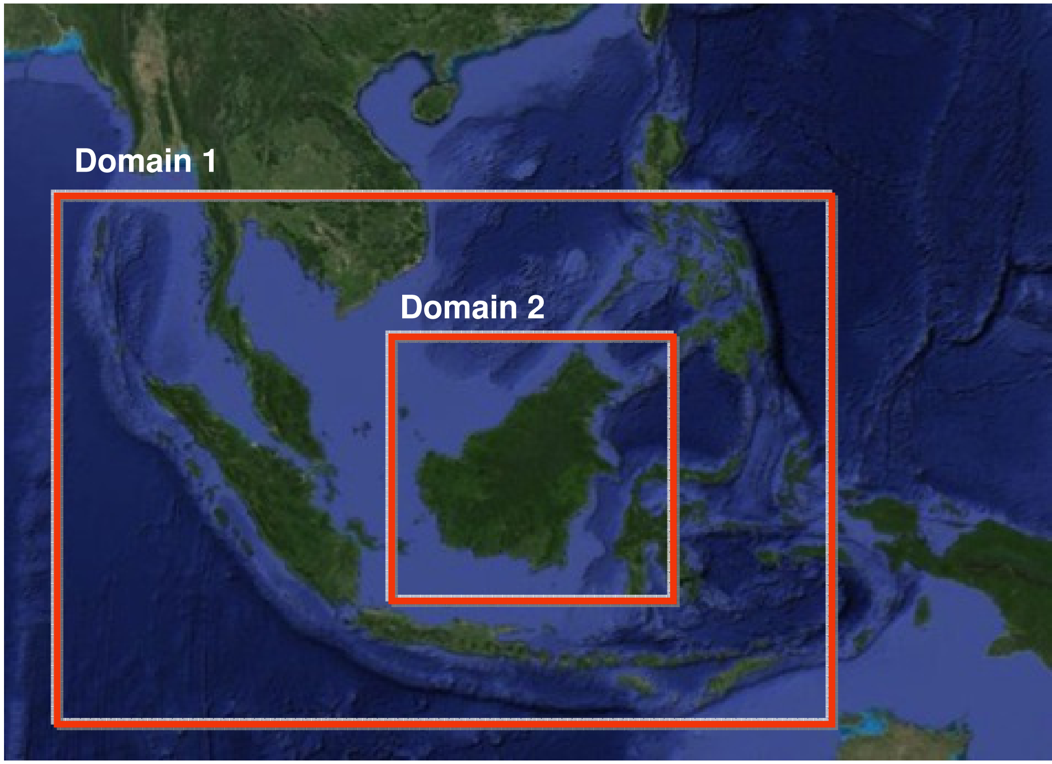


	Box 1	Box 2	Box 3
Vortex + MJO	29%	20%	37%
Vortex + SS	4%	23%	-17%
Vortex + WS	40%	20%	-8%
Surge + MJO	40%	-20%	-24%

- **Data points were too few for the overlap period between MJO and other synoptic disturbances**
- **To better understand the positive/negative impact on rainfall due to interactions between surge/vortex with MJO data from more years need to be analyzed**
- **Results of vortex and surge interactions demonstrates the impact of their presence/interaction on the local rainfall**

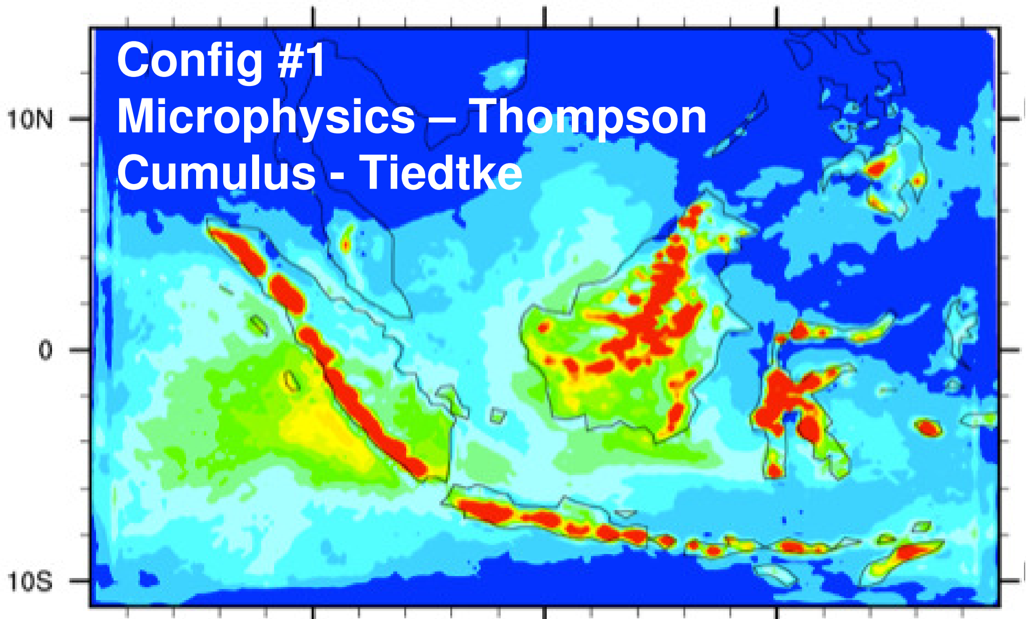
Winter Season Simulation using WRF as RCM

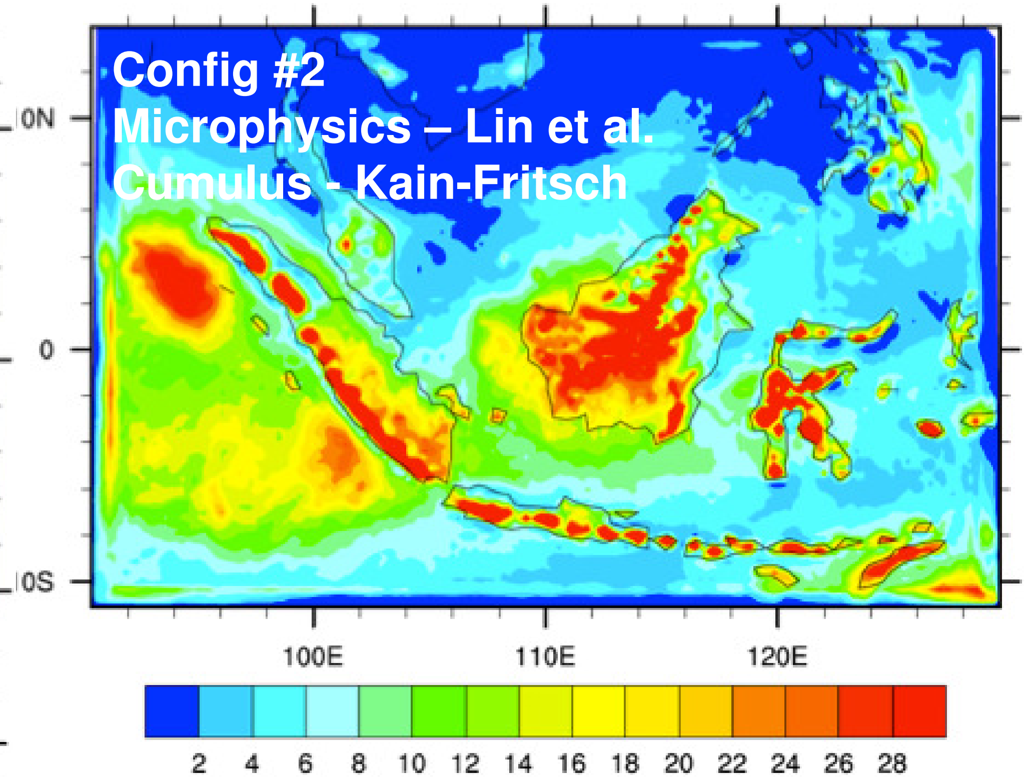
- **Model Configurations (WRF-3.4.1)**
  - Two 2-way nests at 27 and 9 km horizontal resolution focused on Brunei
  - 45 vertical levels with ~10 in the planetary boundary layer to ensure capturing of orographic effects
  - RRTMG long wave radiation and short wave radiation, MYJ PBL, NOAH LSM.
  - Thompson graupel, and Lin et al microphysics schemes are used
  - Kain-Fritsch, Tiedtke cumulus convections schemes are used in the experiments
  - Only wind is nudged through out the domain
  - Output is stored after every 6 hrs for Domain 1 and after every 3 hrs for Domain 2

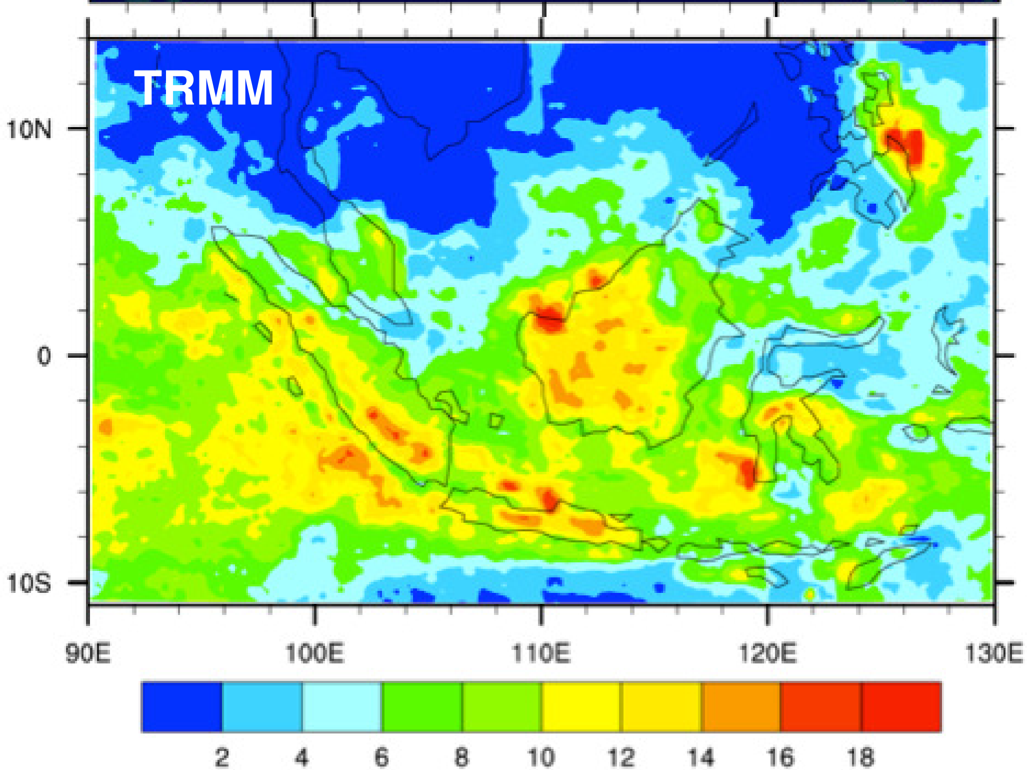


- **Experiment Design**:
  - Four experiments for three winters
  - 2007-2008, 2008-2009, 2009-2010 winters seasons- 1st November – 1st March are simulated.
  - NCEP-NCAR Reanalysis data is used as LBCs
  - SRTM-based model orography
  - 1/2-degree SSTs

WRF Simulated 2009-2010 Winter (Mean Rainfall)



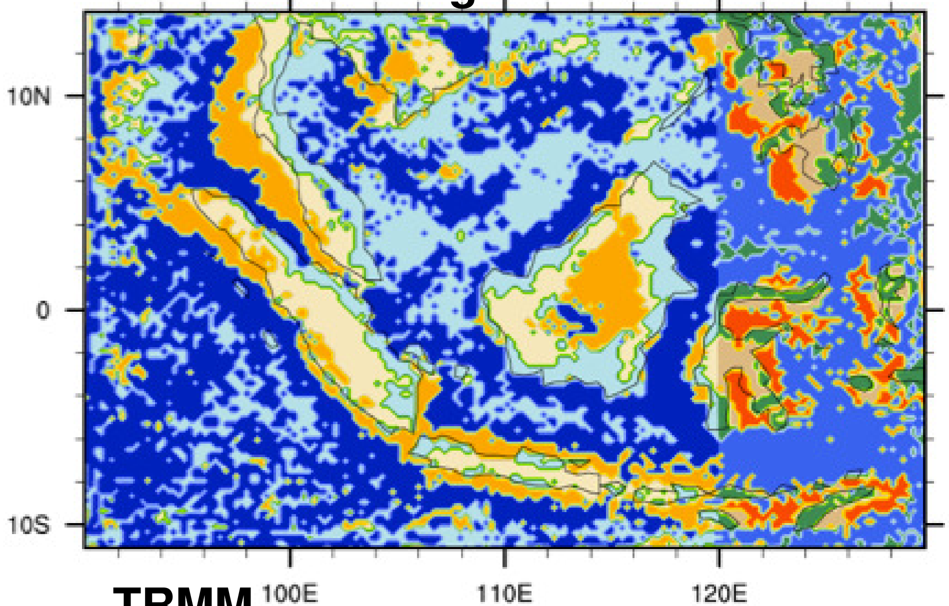




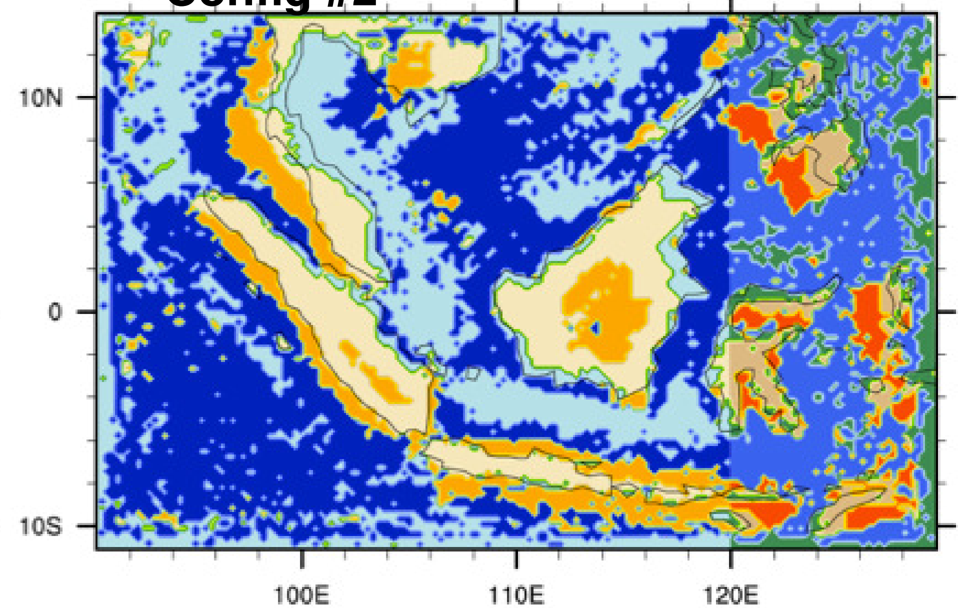
- WRF overestimates over the mountain
- Both the configurations captured the rainfall spatial distribution, but KF cumulus convection estimates for the mean rainfall are too large
- Average rainfall for TRMM, Config-1 and Config-2 are 6.17, 5.76 and 8.4 respectively

WRF Simulated 2009-2010 Winter

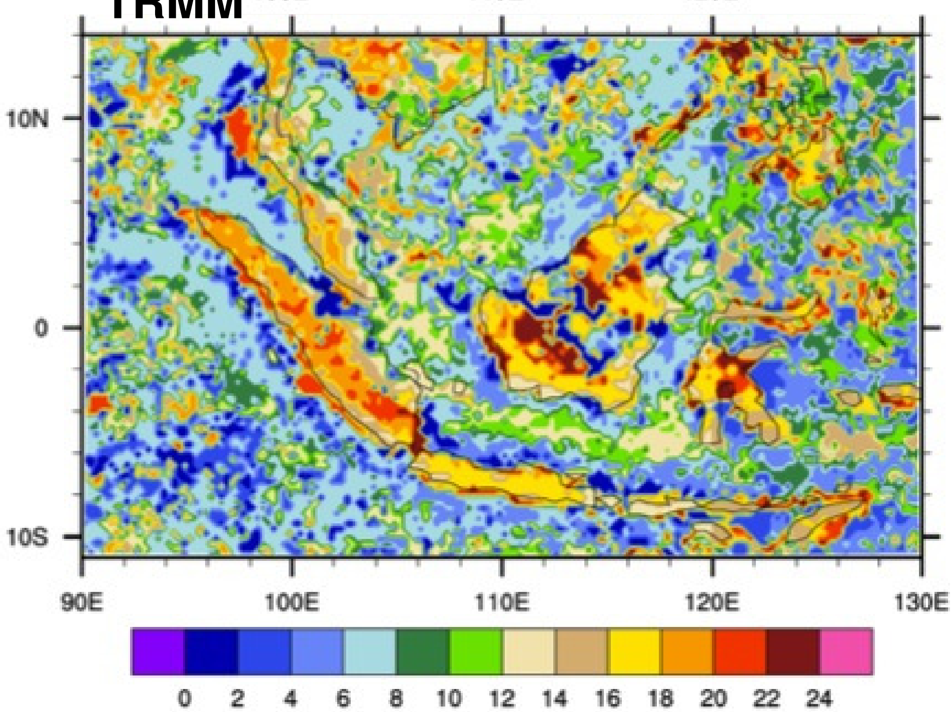
Config #1



Config #2



TRMM

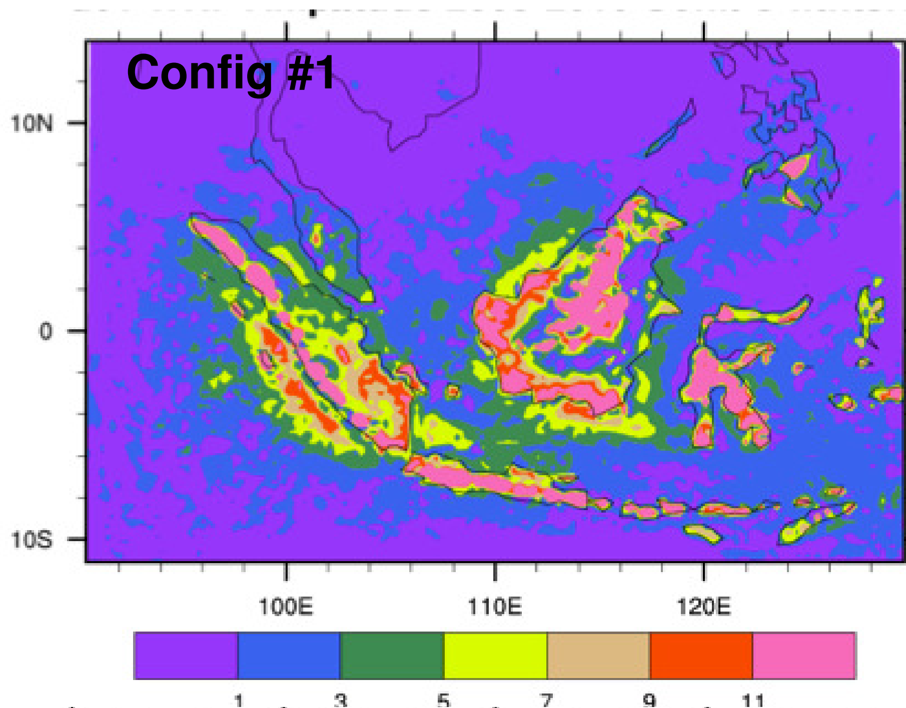


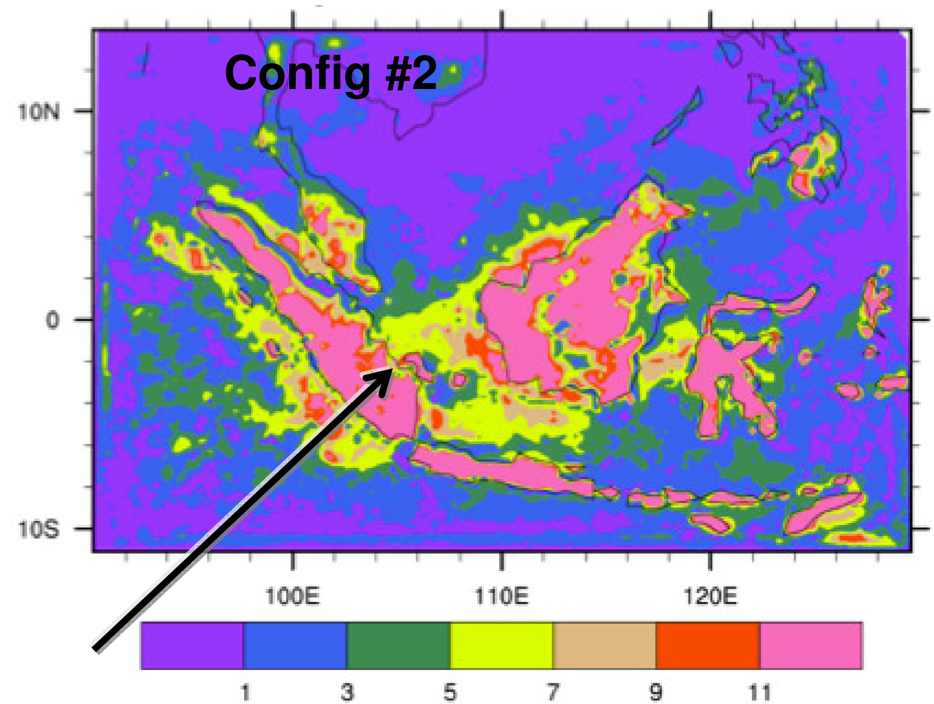
- WRF captures the early morning rainfall peaks over the ocean and the afternoon to midnight peaks over land very well

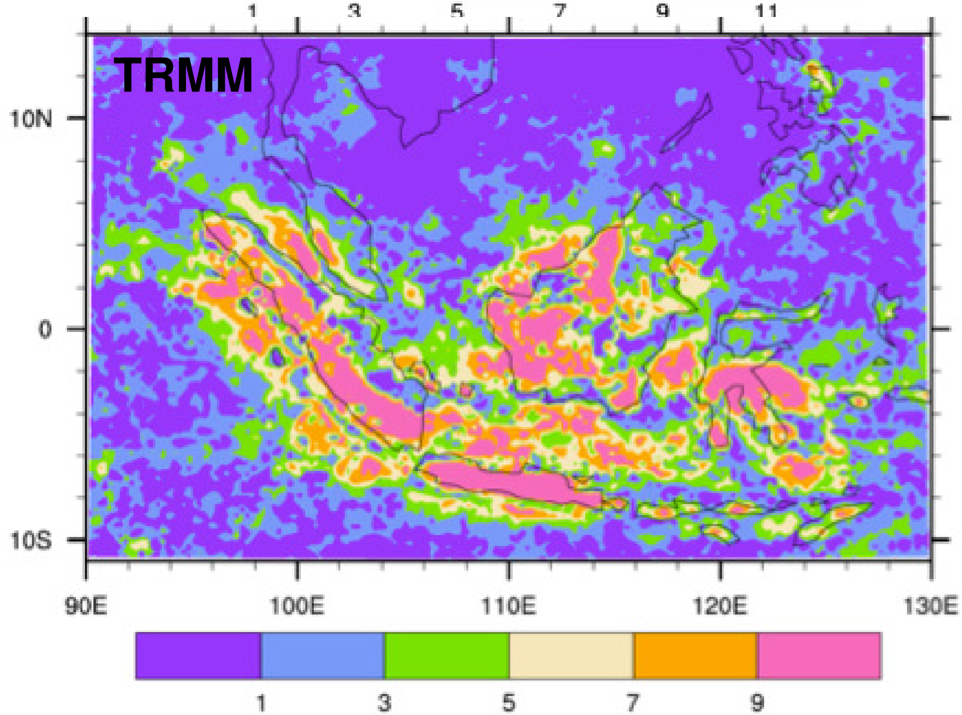
- The rainfall peak time is bit early in both the runs.

- A signature of complicated diurnal cycle over Borneo with midnight peaks over mountains is visible in Config #1 even at 27 km resolution.

WRF Simulated 2009-2010 Winter







- **Location of high amplitudes over lands is captured well by WRF but at the same time the amplitudes are too high in Config #2**

- **We have chosen Config #1 for the current and future detailed analysis of WRF performance in simulation of rainfall diurnal cycle**

Average Winter Season Characteristics Simulated by WRF

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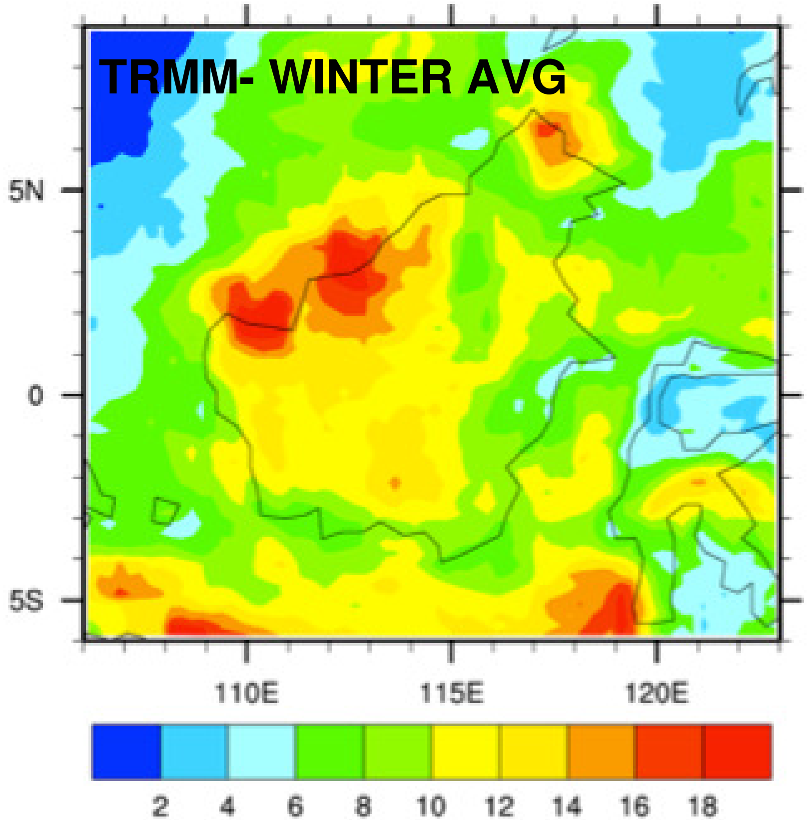
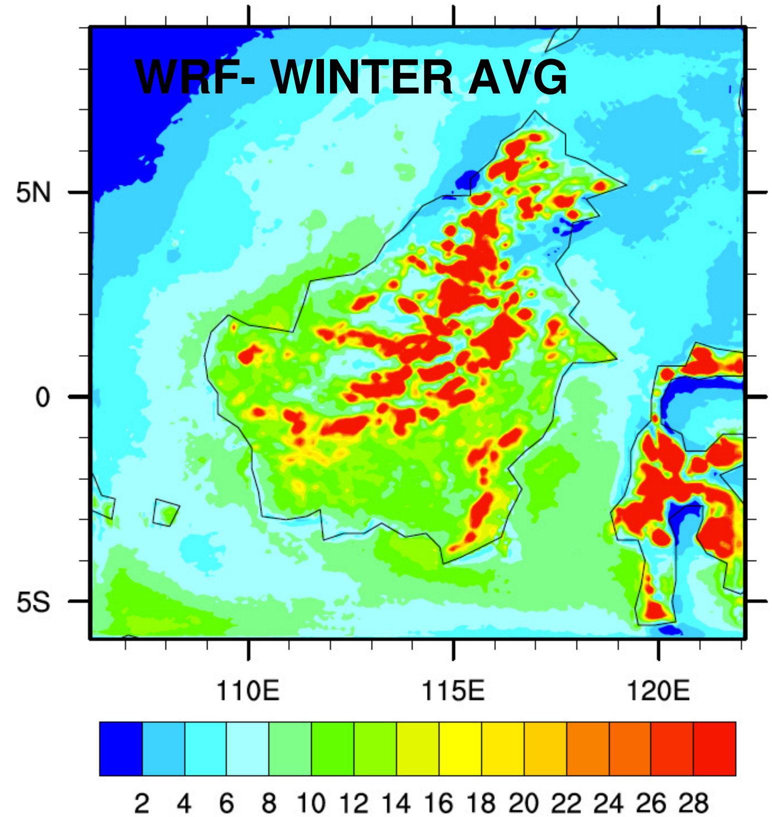
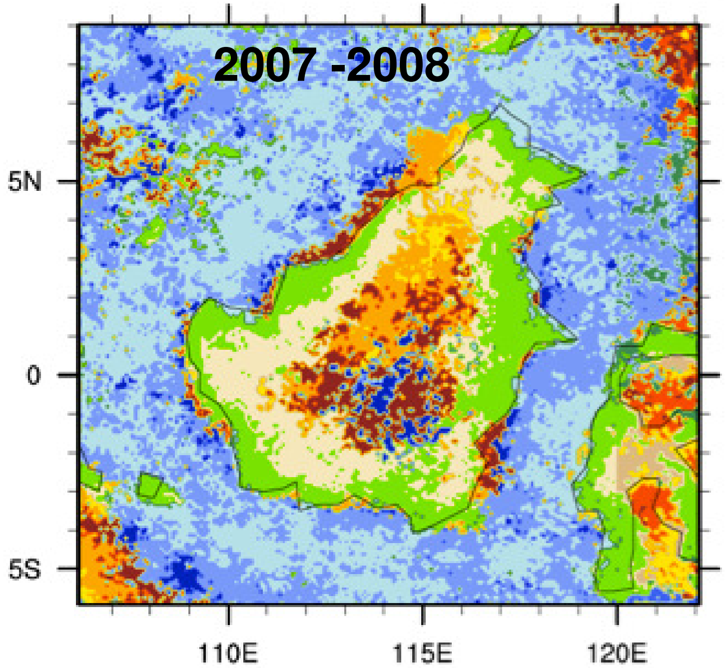


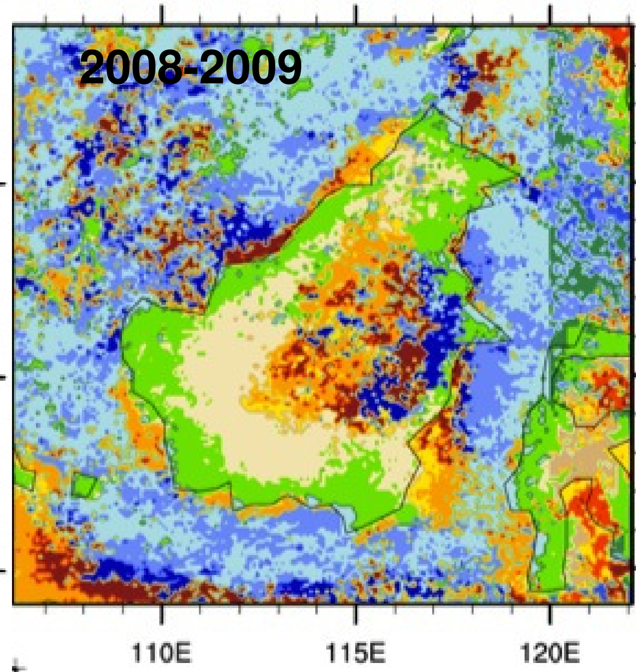


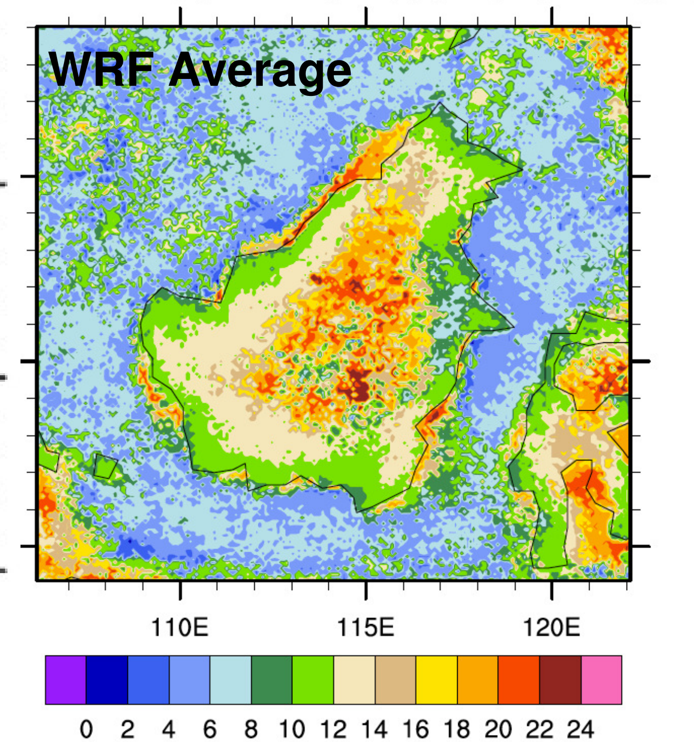
- **Chosen configuration is consistent in simulating the three winters (The maps show the average values for the three winter seasons.)**
- **Most of the convection is driven by the interaction of land-sea phenomena with the synoptic disturbance (vortex, surge)**
- **Convection may need to be resolved explicitly with higher spatial resolution**
- **Domain 2 mean rainfall from the three winter seasons simulated by WRF is 10.64 mm/day**
- **TRMM mean rainfall for Domain 2 is 8.7, which is close to the one predicted by WRF**

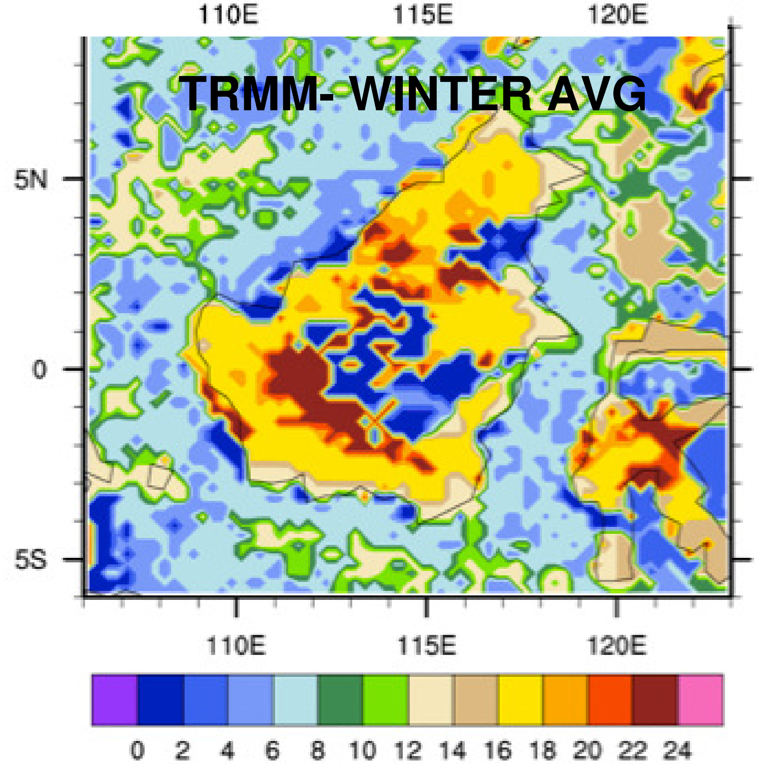
Average Winter Season Characteristics Simulated by WRF

IBM









- **Rainfall peak is very nicely captured in the 9 km nest over Borneo.**
- **Late night to midnight maximas over mountains are very similar to the ones observed in TRMM data**
- **Along the coast, the rainfall peaks are earlier than the observed time, which is expected to be improved with higher resolution runs (3km) with explicit convection**
- **Signature of gravity wave propagation of the rainfall peak are also visible towards SCS, which is also expected to improve with explicit convection**

Summary and Conclusions

- Analysis of TRMM satellite data (2008-2010) has been done to understand the main characteristics of the diurnal cycle of the Maritime continent
- In the winter season, high variability in the peak time, magnitude, and propagation of the diurnal rainfall cycle exist
- This variability is primarily associated to the synoptic-scale Borneo vortex, the northeast cold surge, and the intra-seasonal Madden–Julian Oscillation (MJO)
- The quantification of the winter season variability is done by systematic analysis of TRMM data categorized based on the occurrence of various combinations of Borneo vortex, the northeast cold surge, and the intra-seasonal MJO
- Our analysis confirms that the presence of Borneo vortex, surge and active MJO (phase 2 and 3) enhances deep convection over southern South China Sea (SCS) and Borneo whereas the data representing the interaction of MJO with the other two were less (i.e., more analysis is required)
- The WRF model has been configured with two nested domains to simulate the winter season of 3 years (outer domain covers MC at 27 km resolution and inner domain covers Borneo and surrounding ocean at 9 km resolution)
- The WRF model gives satisfactory results in simulating the variations in the diurnal cycle, but the magnitude is mostly overestimated and the variability in the propagation needs to be modeled with explicit convection