Topographic Effects on the Luzon Diurnal Cycle During the BSISO

Emily Riley Dellaripa, Eric Maloney, Benjamin Toms, Stephen Saleeby, and Susan van den Heever

Department of Atmospheric Science, Colorado State University

1. Introduction

- The boreal summer intraseasonal oscillation (BSISO) is a 30-90 day mode of tropical convection that generally initiates in the Indian Ocean and propagates NE over the Philippines before waning in the NW Pacific (Kickuchi et al. 2012)
- The diurnal cycle explains a large portion of tropical precipitation variance (Kickuchi and Wang 2008), but is not well represented in GCMs
- Topography has important impacts on the diurnal cycle (DC) of precipitation (e.g. elevated heating; Houze 2012)

Science Questions:

1. How does topography affect the DC over Luzon and surrounding seas?
2. How does (1) differ across BSISO active vs. suppressed conditions?

2. Method

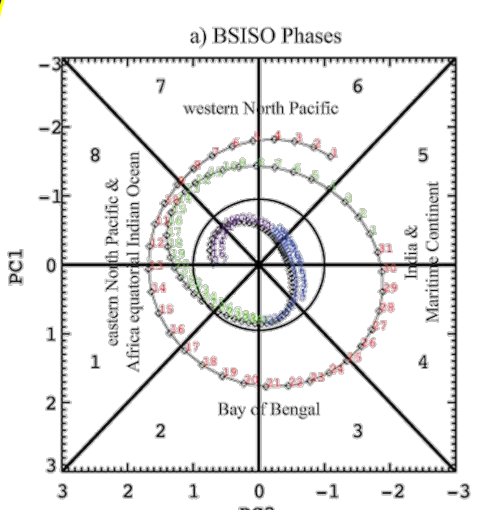


Figure 1: a) Bimodal intrasesonal oscillation index (Kikuchi et al. 2012) phases from July – October 2016. Red, green, blue, and purple colored numbers correspond to July, August, September, and October, respectively.

Model Description:

- July-August 2016 BSISO (Fig. 1) simulated with Regional Atmospheric Modeling System 6.2 (RAMS; Saleeby and van den Heever 2013)
- RAMS is a fully compressible, non-hydrostatic CRM
- Model domain is 1000 km x 1000 km centered over Luzon (Fig. 2)
- 2 km horizontal grid spacing. 42 stretched vertical levels up to 25 km
- Boundary forcing from ERA-5

Three experiments:

1. True Topography
2. Flat Topography
3. Doubled Topography

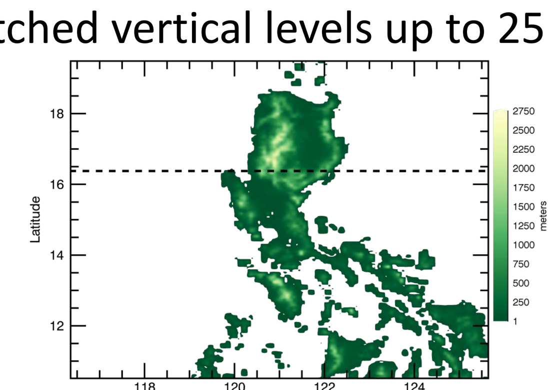


Figure 2: Model domain and topography used in the true topography experiment. Dashed line indicates northern Luzon.

3. Model Fidelity

RAMS generally reproduces the spatial and temporal evolution of the BSISO event (Fig. 3) with differences in the details (e.g., stronger DC during suppressed conditions)

Figs. 1 and 3 define large-scale conditions:

- **Suppressed conditions:** Phases 1-4
- **Active conditions:** Phases 5-8

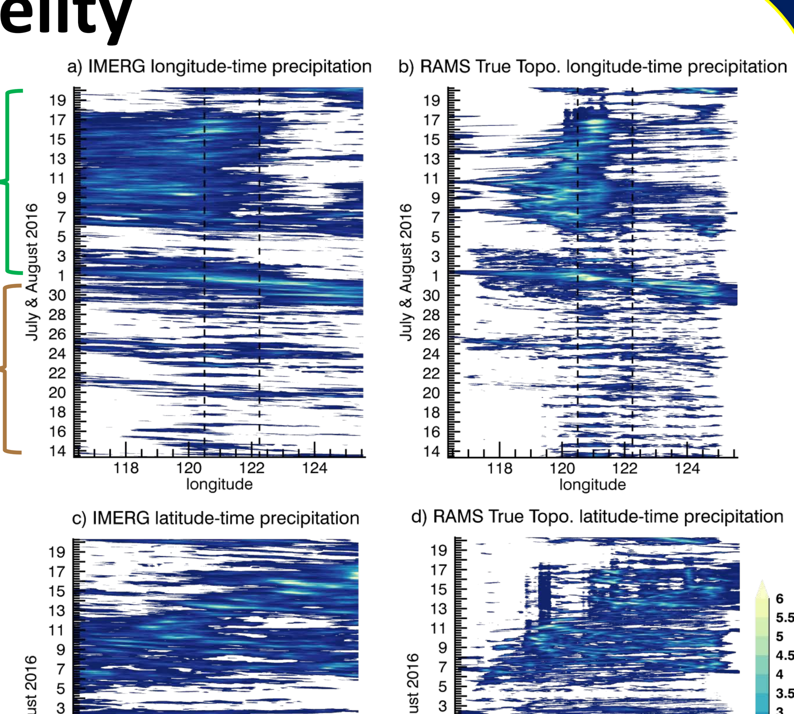
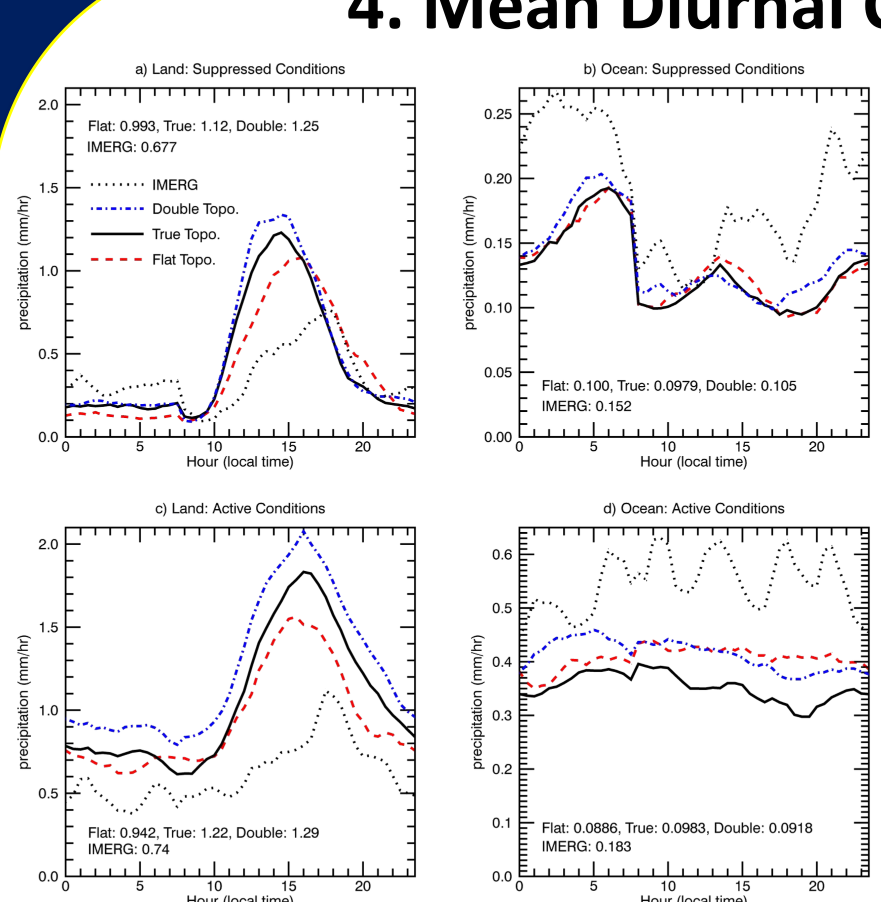


Figure 3: a) Time-longitude diagrams of precipitation averaged over the model domain latitudes for IMERG and b) the RAMS true topography simulation. c) Time-latitude diagrams of precipitation averaged over the model domain longitudes for IMERG and d) the RAMS true topography simulation. The dashed black lines in (a) and (b) indicate the approximate locations of northern Luzon's east and west coasts.

4. Mean Diurnal Cycle of Precipitation



Over land (Fig. 4):

- DC peak increases as topography increases
- Relative to the flat run, the topography runs have an earlier DC peak during suppressed conditions that shifts to later in the day during active conditions

Over ocean (Fig. 4):

- Muted DC

Figure 4 (left): The mean diurnal cycle of precipitation for the legend indicated source for suppressed conditions over land (a) and ocean (b) and active conditions over land (c) and ocean (d). The amplitude as measured by the maximum minus minimum mean DC precipitation value is indicated on each panel.

Suppressed conditions: Topography focuses rainfall over mountains (Fig. 5)

Active conditions: Topography dictates which domain half rain falls in (Fig. 5)

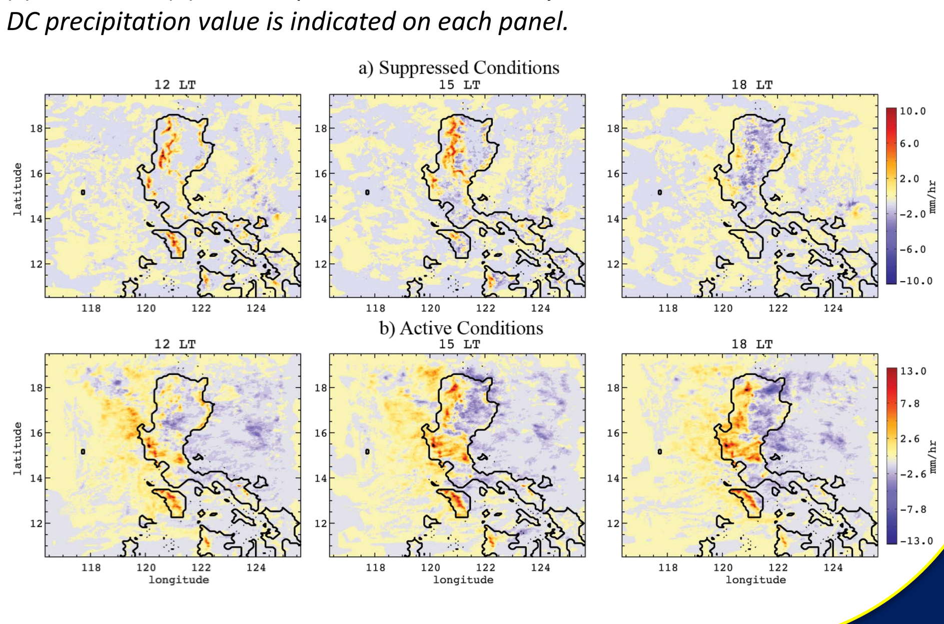
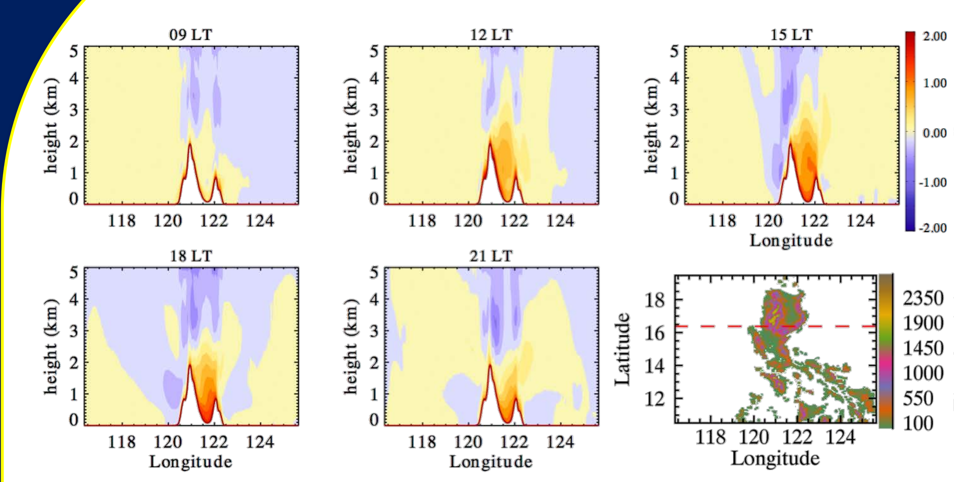


Figure 5 (right): The difference in precipitation between the doubled topography run and flat run during suppressed (a) and active (b) BSISO conditions for 3-hourly averaged time.

5. Suppressed Conditions Mechanisms



In topography runs, daytime elevated warm theta anomalies occur (Fig. 6)

Figure 6 (left): Differences in potential temperature averaged over northern Luzon (red dashed line last panel) between the doubled topography run and flat run during suppressed BSISO conditions for 3-hourly averaged time bins.

As topography increases:

- Sea-breeze height increases & inland propagation restricted (Figs. 7, 8)
- Vertical motions are stronger, sooner (Figs. 7, 8)

Differences lead to:

- Earlier, stronger convergence and rain in topography runs (Figs. 5, 8)

Changes driven by:

- Mechanical uplift as the sea-breeze hits the mountains (Fig. 8)
- Thermodynamically driven upslope flow from elevated heating (Fig. 6)

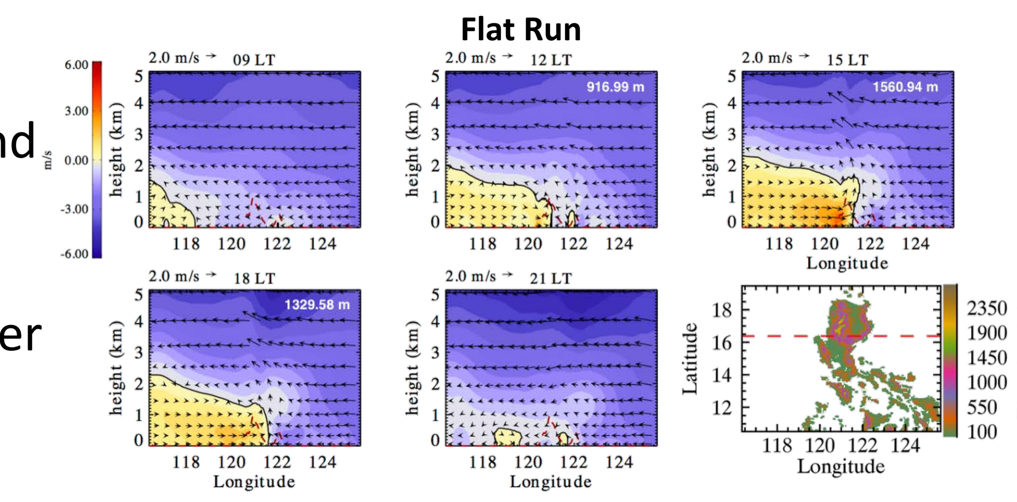


Figure 7: The flat run zonal wind (colored shading) and (u,w)-wind (vectors) averaged over northern Luzon during suppressed conditions for 3-hourly averaged time bins. The red dashed line is the average northern Luzon topography in the true topography run. Vertical velocities have been multiplied by 50 for clarity. The height of the sea-breeze over land is included in the upper left corner of the 12 LT, 15 LT, and 18 LT panels.

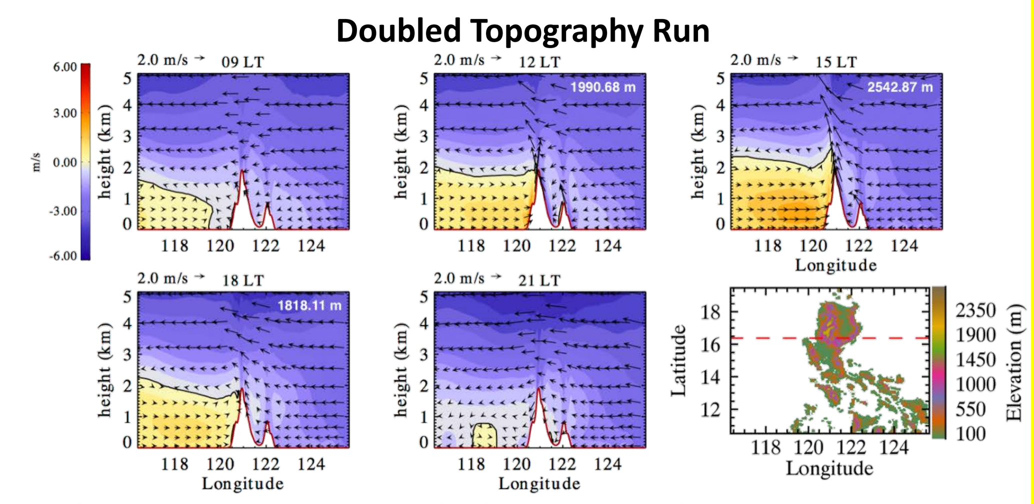
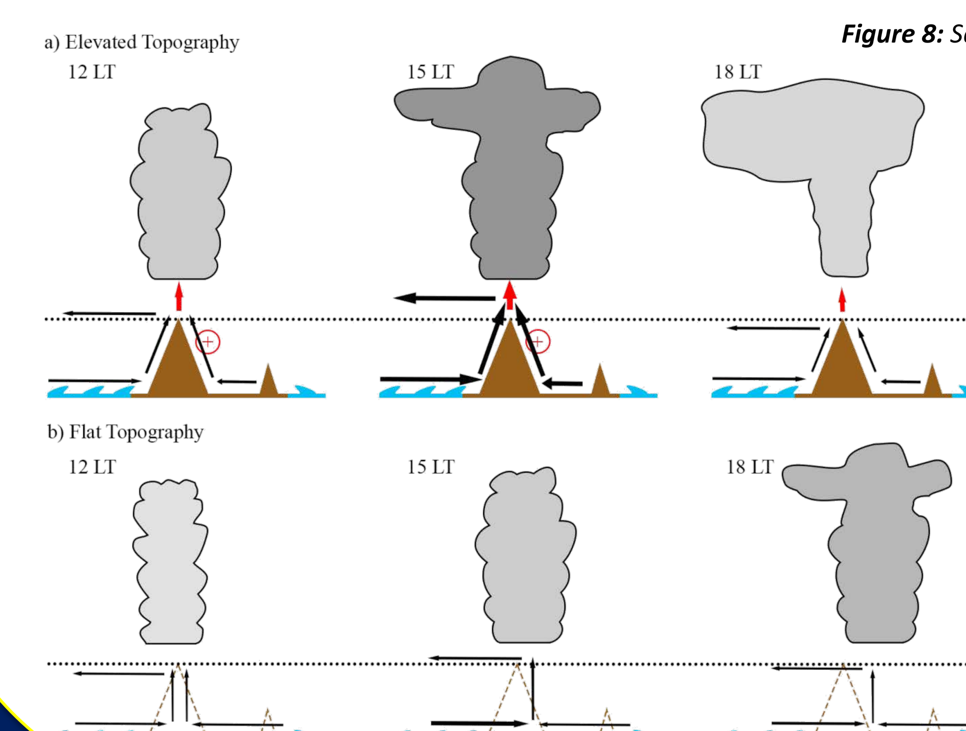


Figure 8: Same as Fig. 7, except the doubled topography run



Schematic (Fig. 9) depicts effect of topography on the DC during suppressed BSISO conditions

Figure 9 (left) : Schematic of the diurnal cycle of precipitation over Luzon during suppressed conditions. The arrows represent the sea- and valley-to-mountain breeze circulations. Arrow width indicates the relative strength of the flow. The vertical arrows in (a) are red to emphasize the combined effect of the sea-breeze and valley-to-mountain breeze converging over the mountain. The red plus sign indicates the anomalously warm elevated temperatures relative to the flat topography run. The dashed mountains in (b) represent the mountain locations. Grey shading indicates the relative strength of the precipitation. The horizontal dotted line is a reference for the depth of the sea-breeze and valley-to-mountain breeze.

6. Active Conditions Mechanisms

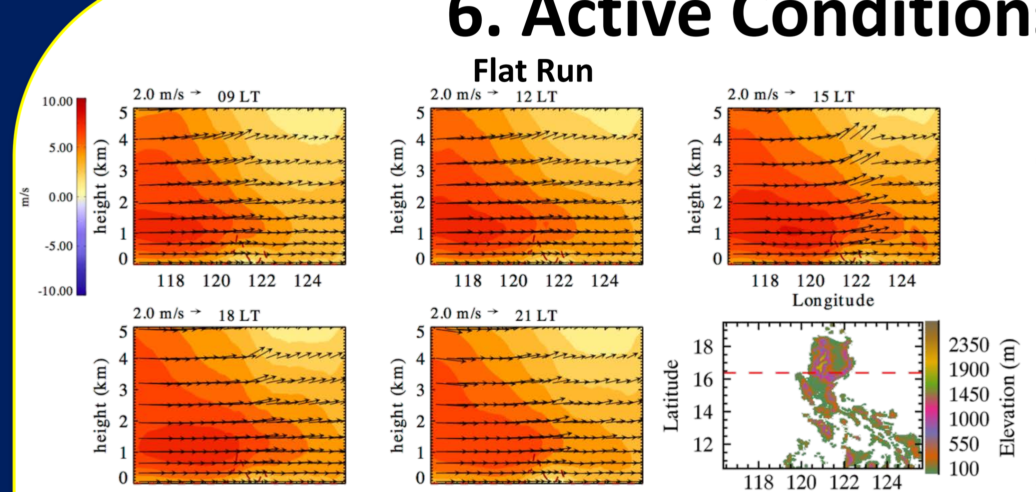


Figure 10: Same as Fig. 7, except for during the active conditions

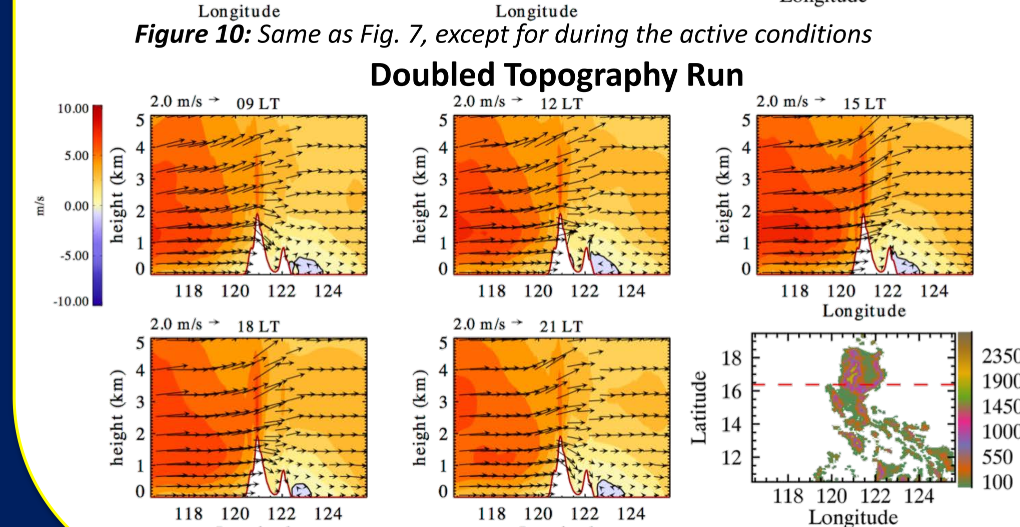


Figure 11: Same as Fig. 8, except for during the active conditions

- No obvious local circulation features that affect the timing of the mean DC peak like in suppressed conditions (Figs. 10, 11)
- Persistent background SW flow prevent sea-breeze from forming along west coast (Figs. 10, 11)
- Persistent southwesterlies lead to longer lasting high intensity precipitation (not shown) that likely delays DC peak relative to suppressed conditions

7. Summary and Future Work

- Topography affects the timing, intensity and location of the DC of rainfall
- During suppressed conditions, topography runs have a larger, earlier DC peak due to deeper, stronger sea- and valley-to-mountain breezes earlier in the day from mechanical uplift and elevated heating, respectively
- During active conditions, mechanical uplift in topography runs sustains precipitation at a high intensity longer leading to a delay in the DC peak relative to suppressed conditions
- Future work will examine how the DC changes due to ocean coupling

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