Effects of Surface Orography and Land–Sea Contrast on the Madden–Julian Oscillation in the Maritime Continent: A Numerical Study Using ECHAM5-SIT

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1. Introduction

This study uses an atmospheric general circulation model, ECHAM5 coupled with the newly-developed Snow-Ice-Thermocline model (ECHAM5-SIT), which realistically simulated the major characteristics of the Madden–Julian Oscillation (MJO), to examine the effects of orography and land–sea contrast on the MJO in the Maritime Continent (MC) during boreal winter. Three experiments were conducted with realistic topography, without orography, and with oceans only in the MC region to evaluate the relative effects of orography and land–sea contrast.

2. Model and experiment description

- **Model:**

ECHAM5-SIT: a T213 AGCM (ECHAM5) coupled over the tropics to a one column ocean model (SIT); vertical resolution is 31 layer in the atmosphere and 38 layers in the ocean.

- **Experiment design:**

Three sets of experiments are conducted: realistic MC (CTL), aqua MC (AQUA), and flat MC (FLAT). Realistic land–sea contrast and orography in the MC were retained in the control experiment CTL, whereas the island grid points in AQUA are replaced by 200-m-depth ocean grid points in the region of 90°E–150°E, 11°S–8°N. In FLAT, the land grid points were retained but the orography was reduced to zero over 90°E–150°E, 11°S–8°N.

Abbreviation	Experiments
CTL	Control
FLAT	Flat Maritime Continent
AQUA	Aqua Maritime Continent

Table 1. The experiments

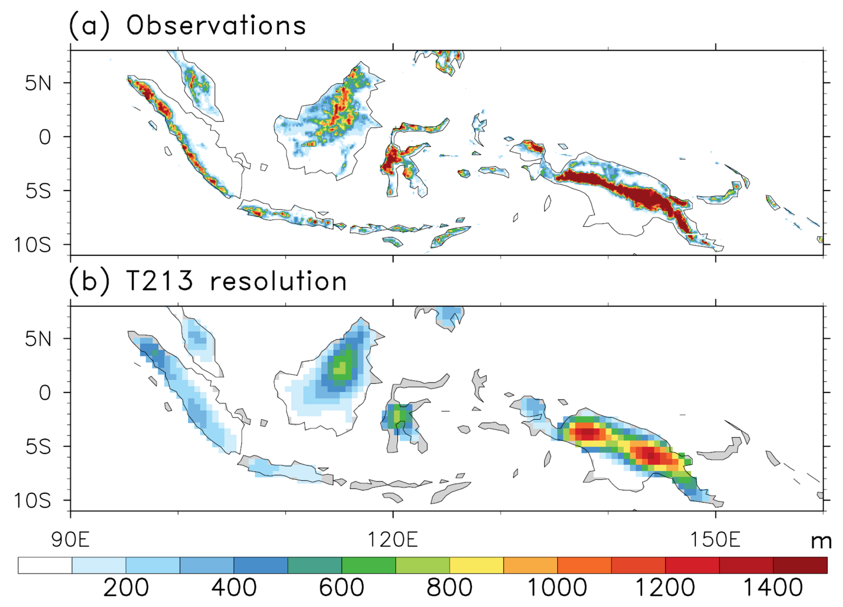

Fig 1. The topography (m) over the Maritime Continent

3. Mean State

Orography and land–sea contrast enhance (weaken) mean westerly 850-hPa zonal wind in the western MC/the eastern Indian Ocean (region east of the MC).

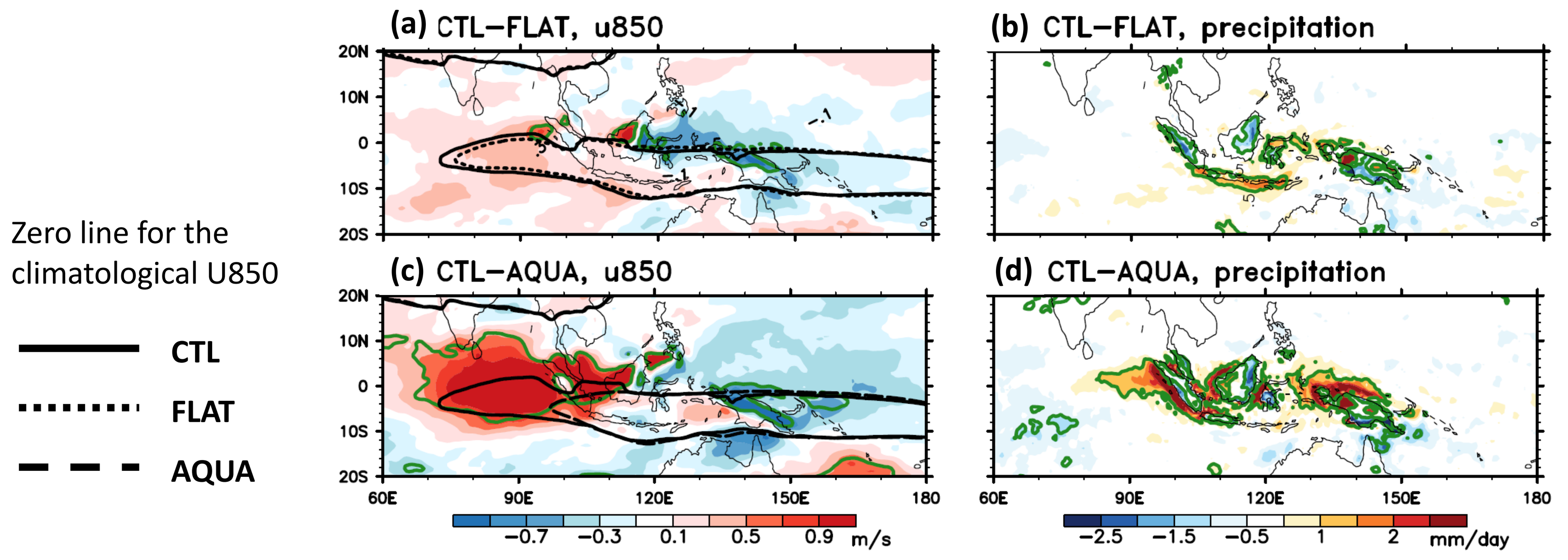

Fig 2. (a-b) U850; and (c-d) Precipitation. Differences within the green lines are significant at the 95% level.

4.1 Impact on Wavenumber–frequency spectra

- more realistic time and zonal scale, larger amplitude

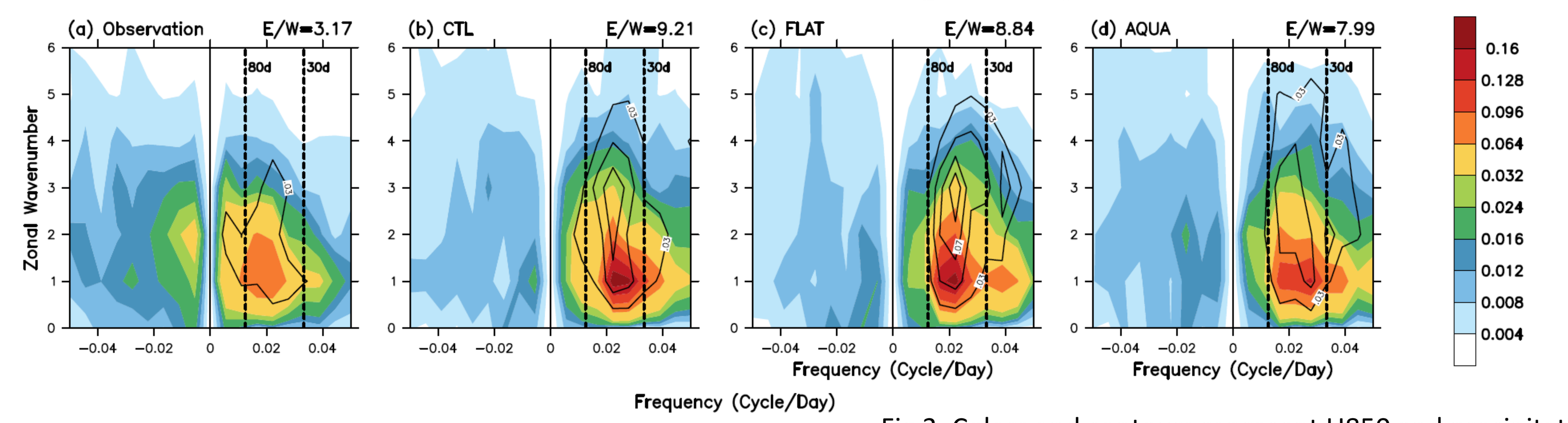

Fig 3. Colors and contours represent U850 and precipitation

4.2 Impacts on zonal and vertical structure

Precipitation and 925hPa wind

- geographically-locked downstream development and southward detour of convection and circulation

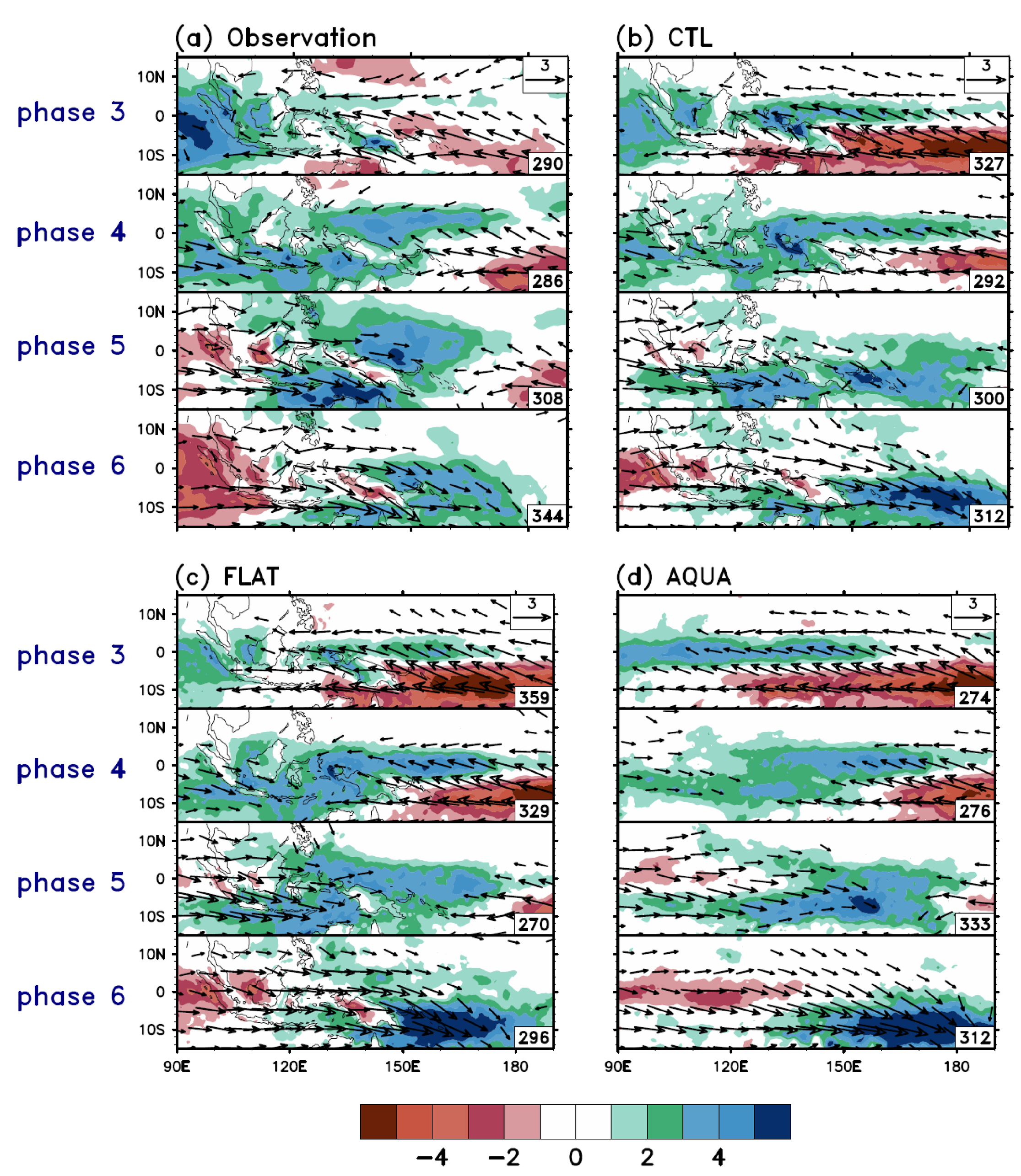

Fig 4. 925hPa wind and precipitation.

Q1 and moisture convergence (phase 3)

- larger Q1; shorter zonal scale; stronger moisture convergence

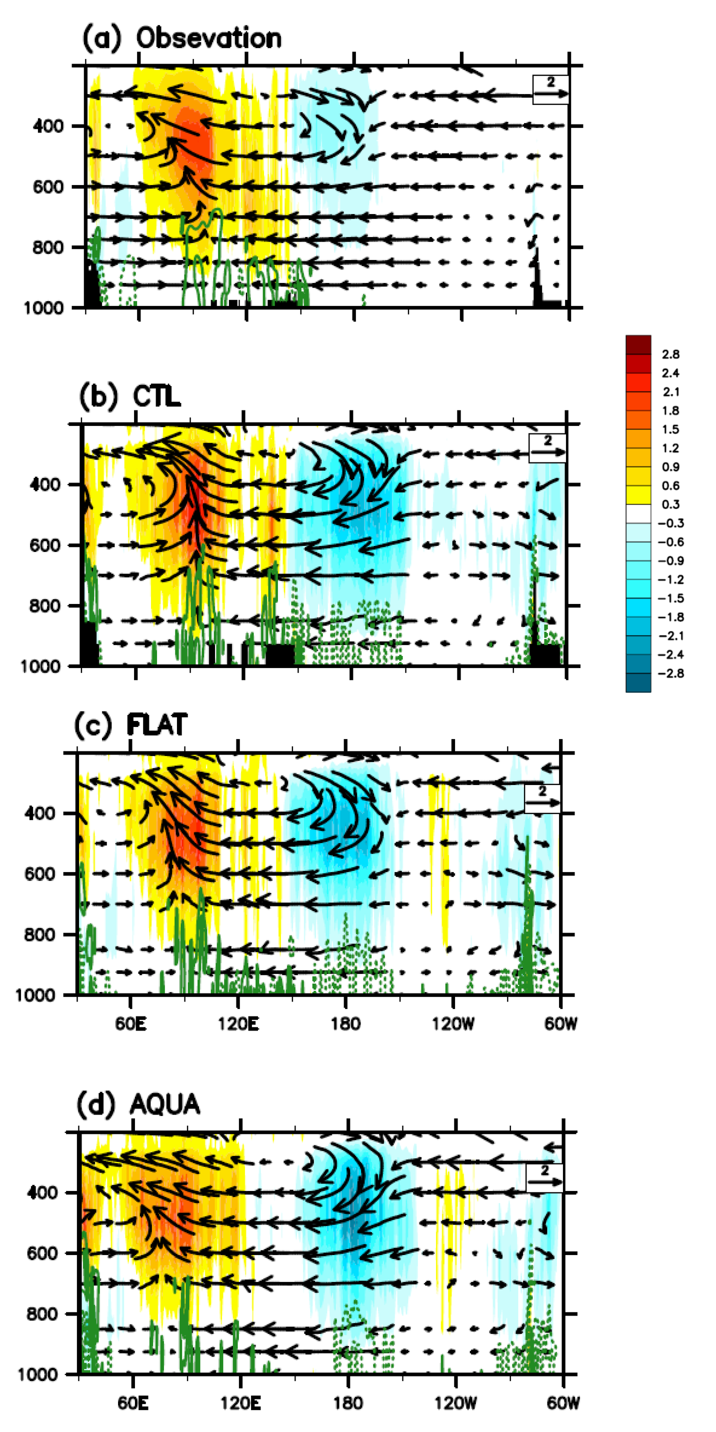

Fig 5. The 10°S–0°-averaged cross section.

5. Mechanisms

a. Obstacle effect

Interrupted propagation by flow bifurcation over mountainous islands and lee-side convergence

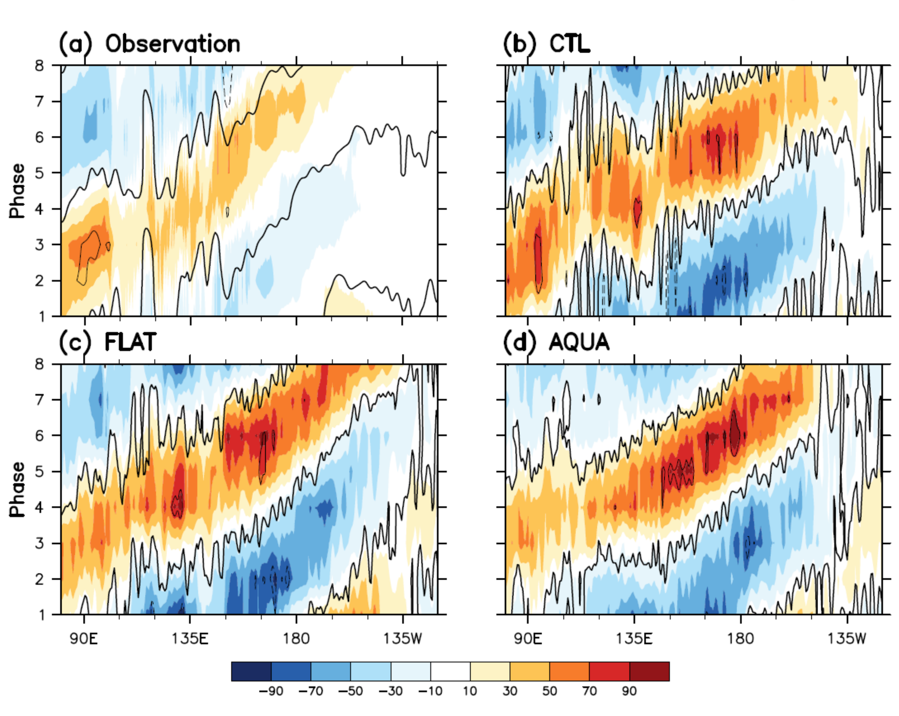

Fig 6. The 10°S–0°-averaged vertically integrated Q1 (w/m^2) at 1000–200 hPa (colors) and integrated moisture convergence at 1000–700 hPa (contours; unit, 10^{-6} g/kg 1/s kg/m^2; interval, 100) with phase evolution

b. Frictional effect

Enhancement of

- **low-level moisture convergence**
- **near-surface frictional and lifting effects**

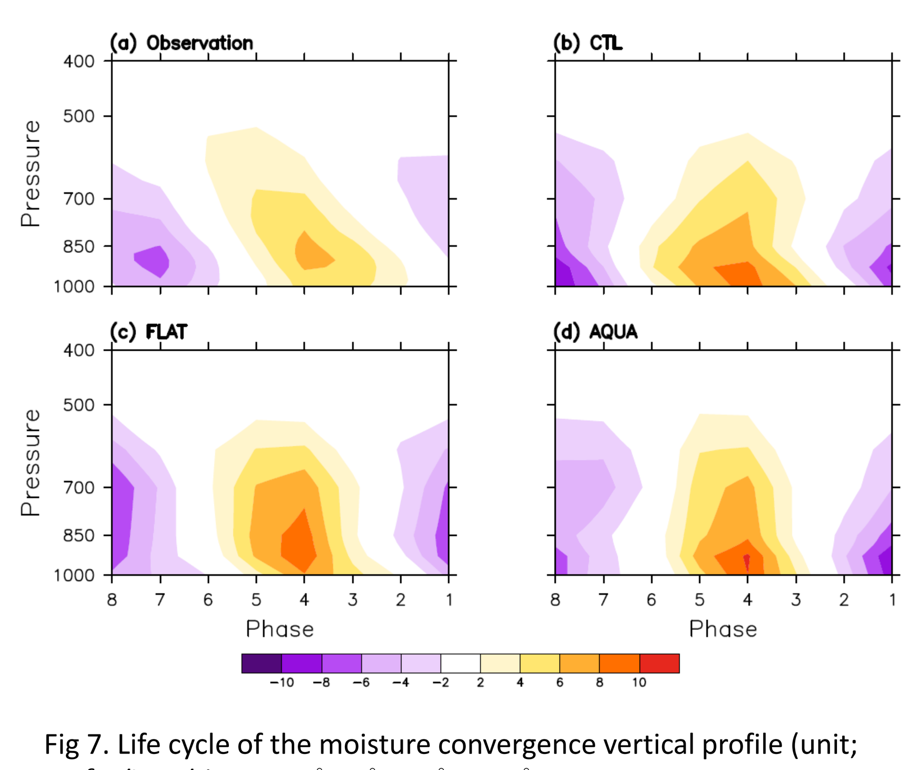

Fig 7. Life cycle of the moisture convergence vertical profile (unit; 10^{-6} g/kg 1/s) over 10°S–0°, 120°E–150°E.

6. Summary

- Orography and land–sea contrast has the following effects on the MJO in the MC:

1) larger amplitude
2) smaller zonal scale
3) more realistic periodicity and stronger eastward-propagating signals
4) stronger southward detour during the eastward propagation
5) a distorted coupled Kelvin–Rossby wave structure
6) larger low-level moisture convergence.

- The enhanced convection at the western and eastern end of the Maritime Continent led to the enhanced and weakened mean westerly and MJO, respectively, to the west and east of roughly 135°E.
- Current understanding of the MJO derived from theoretical and empirical studies was largely developed in the framework of an aqua planet. Thorough exploration of the effects of mountainous islands in the Maritime Continent would lead to better understanding and forecast of the MJO.

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