Understanding the role of topography on the diurnal cycle of precipitation in the Maritime Continent during MJO propagation

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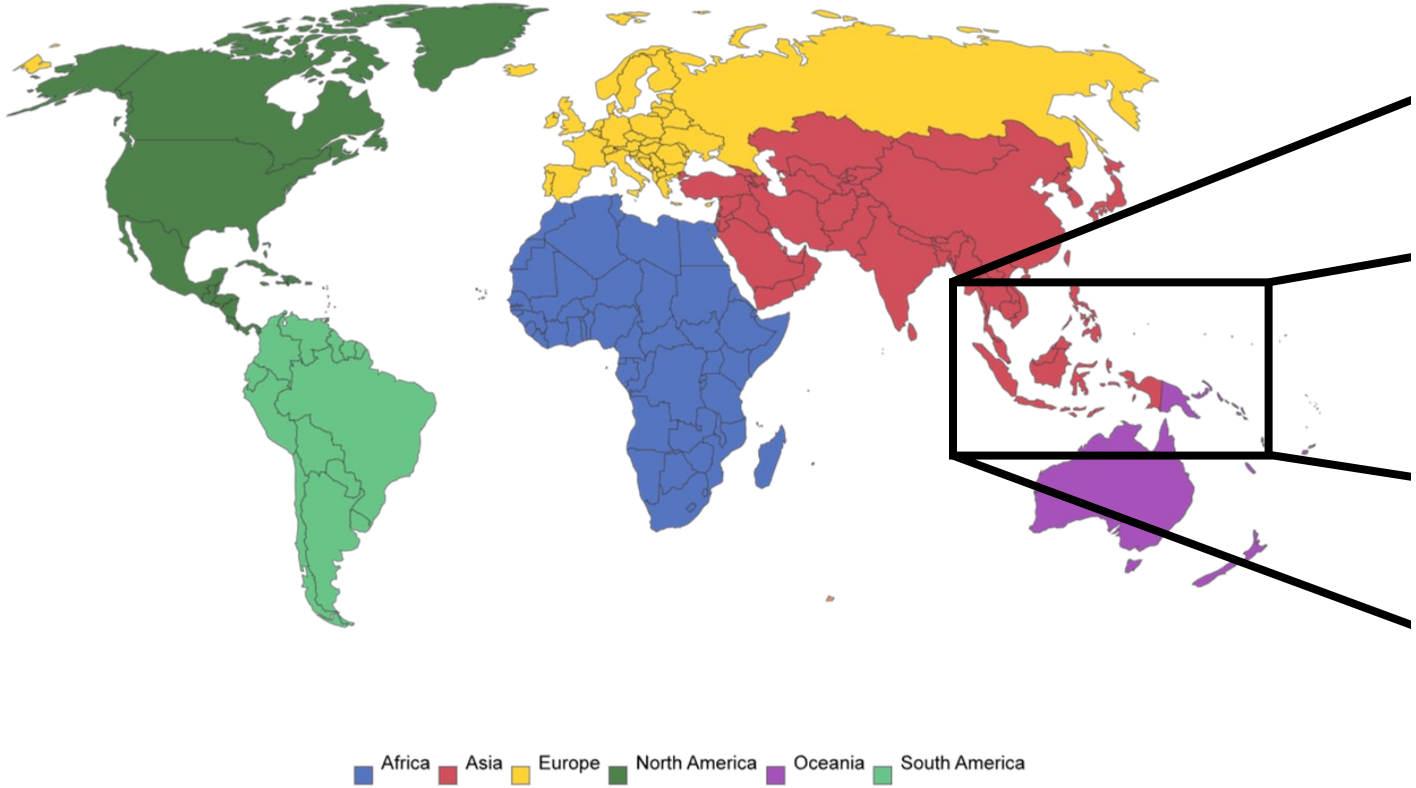
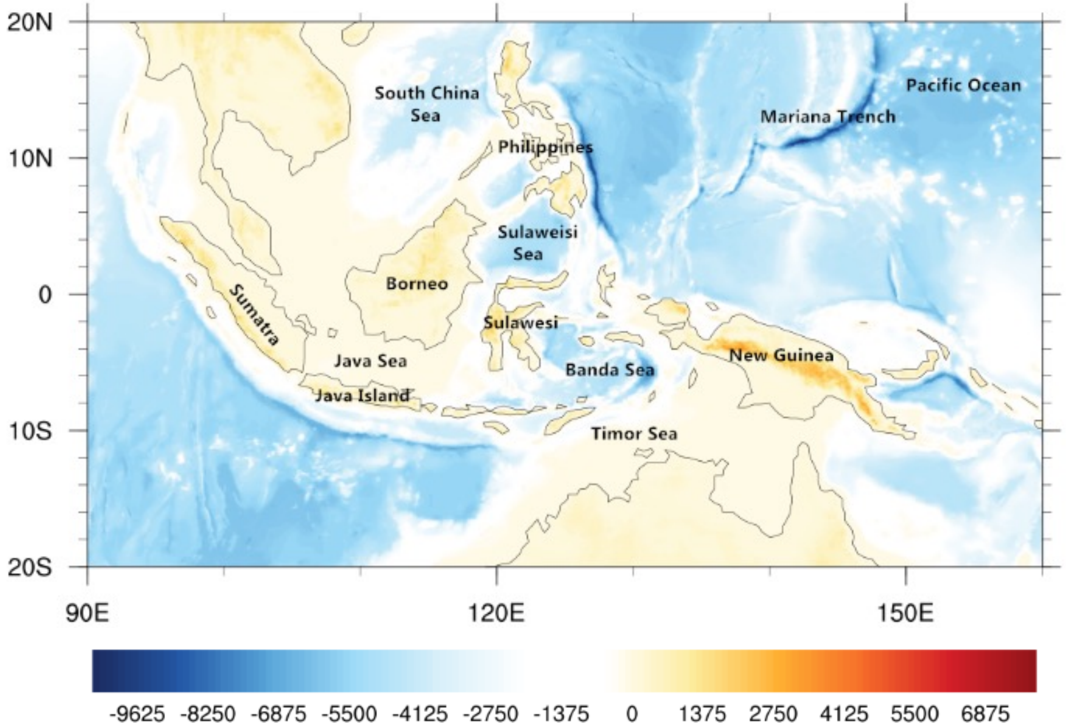
Outline

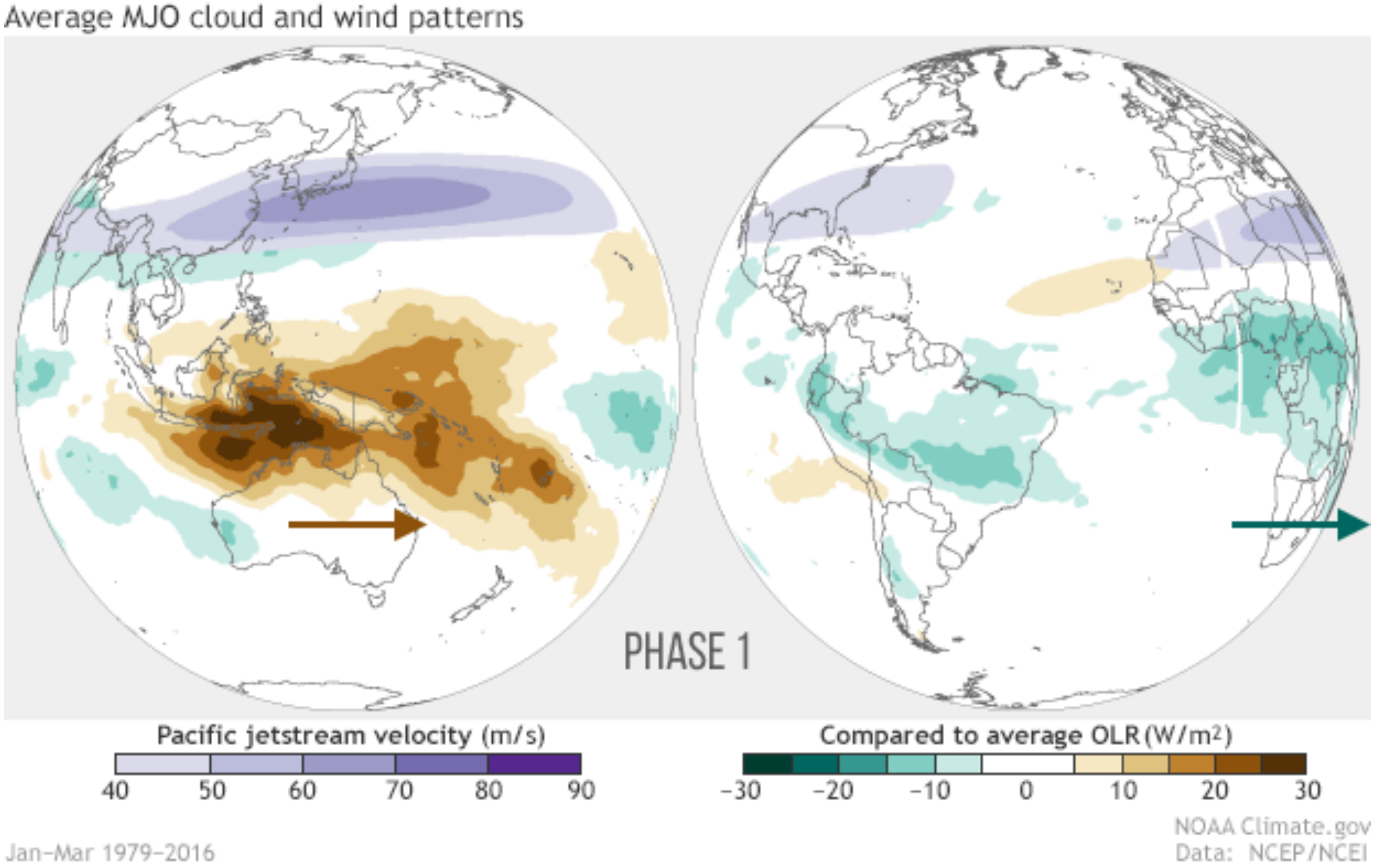
- Background
- Objectives
- Model and simulation design
- Results
  - ✓ Impact of topography on precipitation and its diurnal cycle
  - ✓ Physical processes of atmospheric moisture as a function of elevations
  - ✓ Diurnal variation of moisture from a budget perspective as a function of elevations
- Summary and conclusions

Maritime Continent





Madden-Julian Oscillation



- Primary mode in intraseasonal scale
- 40-50% of precipitation in the warm pool comes from MJO
- Propagation speed: 5m/s

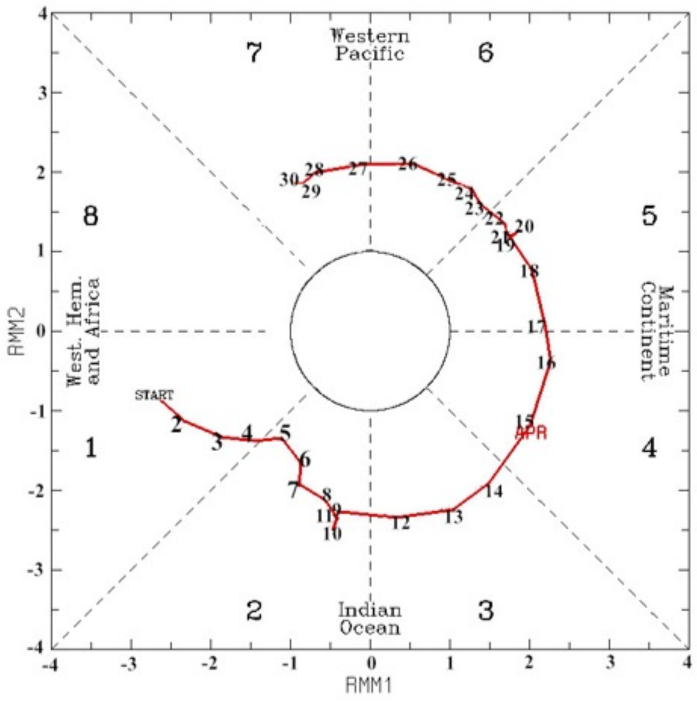
- Difficulties in simulating precipitation and its diurnal cycle in NWP model over MC
  - ✓ Model physics, coarse grid spacing can not represent complex topography
- High resolution models have shown that inadequate grid spacing and model physics may cause inaccurate representation of precipitation and its diurnal cycle
- Cloud-permitting simulations (4 km)
- Quantify the physical processes that control precipitation as a function of elevations
- Investigate the diurnal variation of moisture from a budget perspective

- April 2009 was chosen (a typical strong MJO event) in spring season.
- 1 domain, 2145 x 921 grid points with 4 km grid spacing. 41 vertical levels
- IC&BC: ERA-Interim reanalysis, 0.25°x0.25°, 6-hourly
- Obs: NOAA CPC MORPHing technique (**CMORPH**), 8km res, 30mins

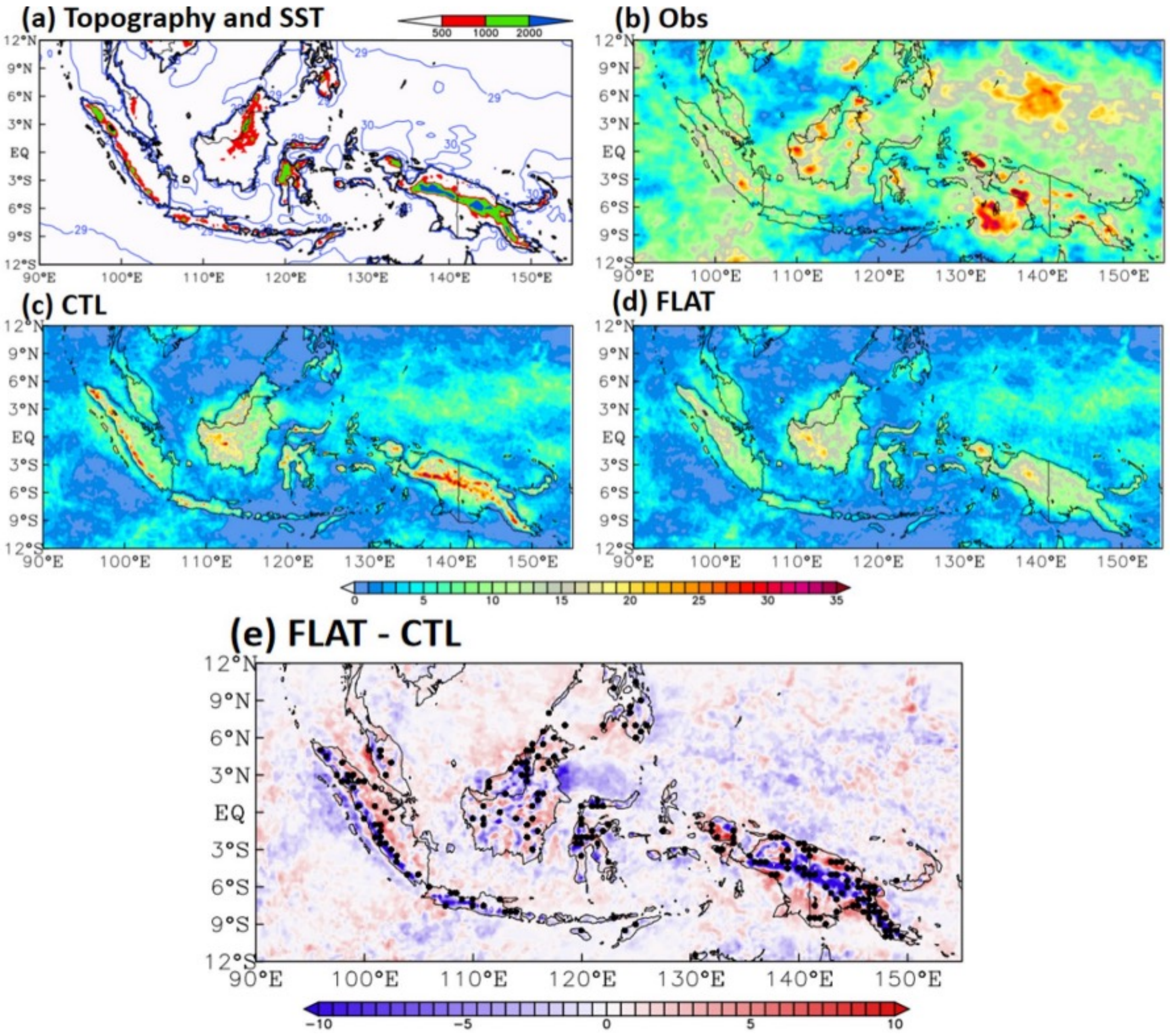
Experiment	Description
Control (CTL)	4 km, without cumulus parameterization
Flat (FLAT)	4 km, 2-m unified flat land

Progression of this MJO event

(a) RMM Index

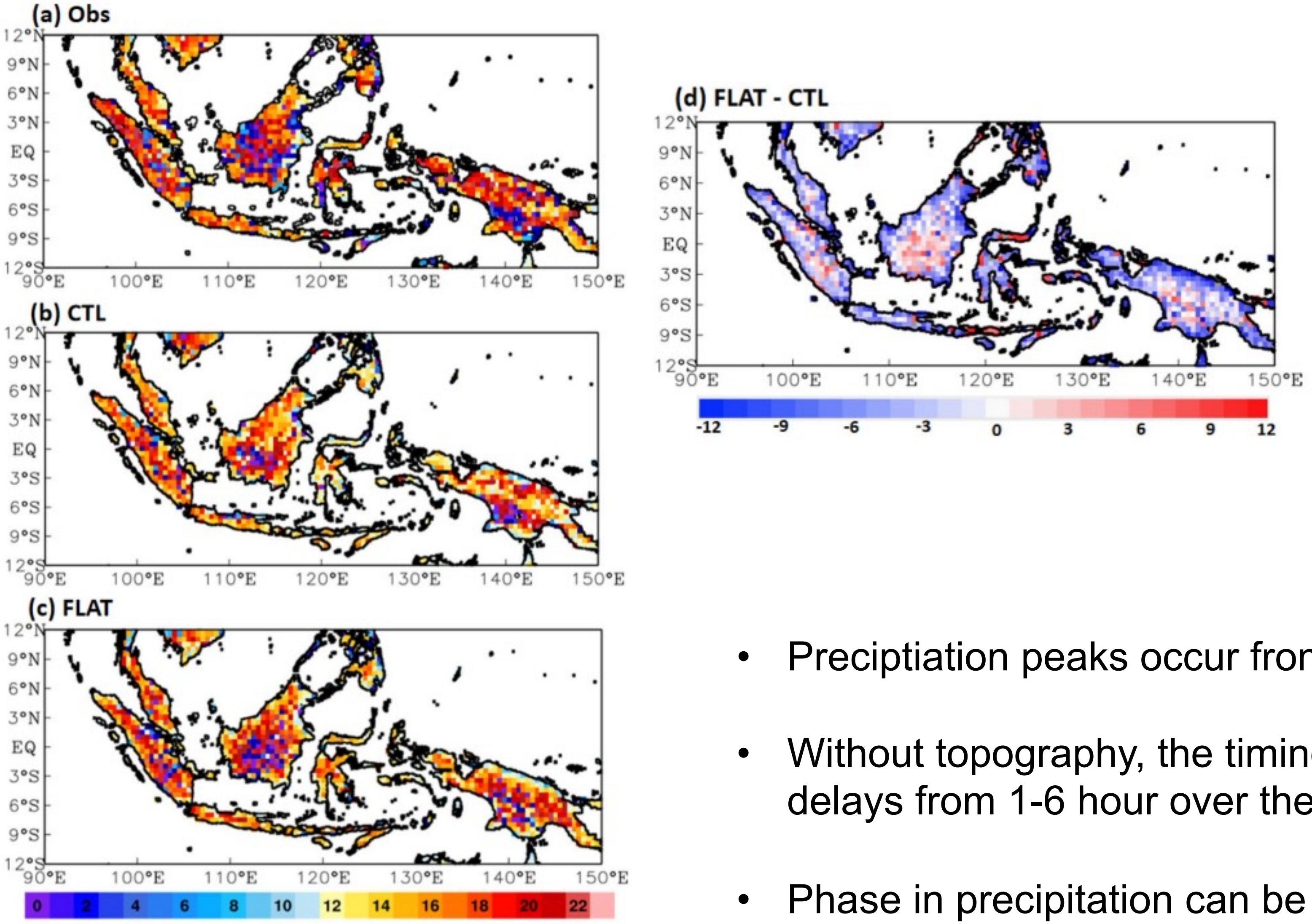


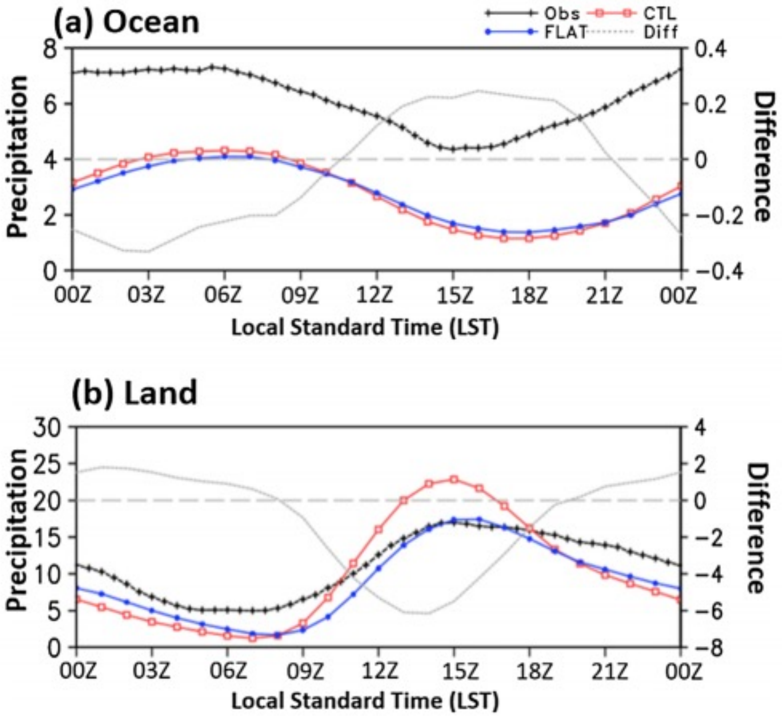
Observed and simulated precipitation



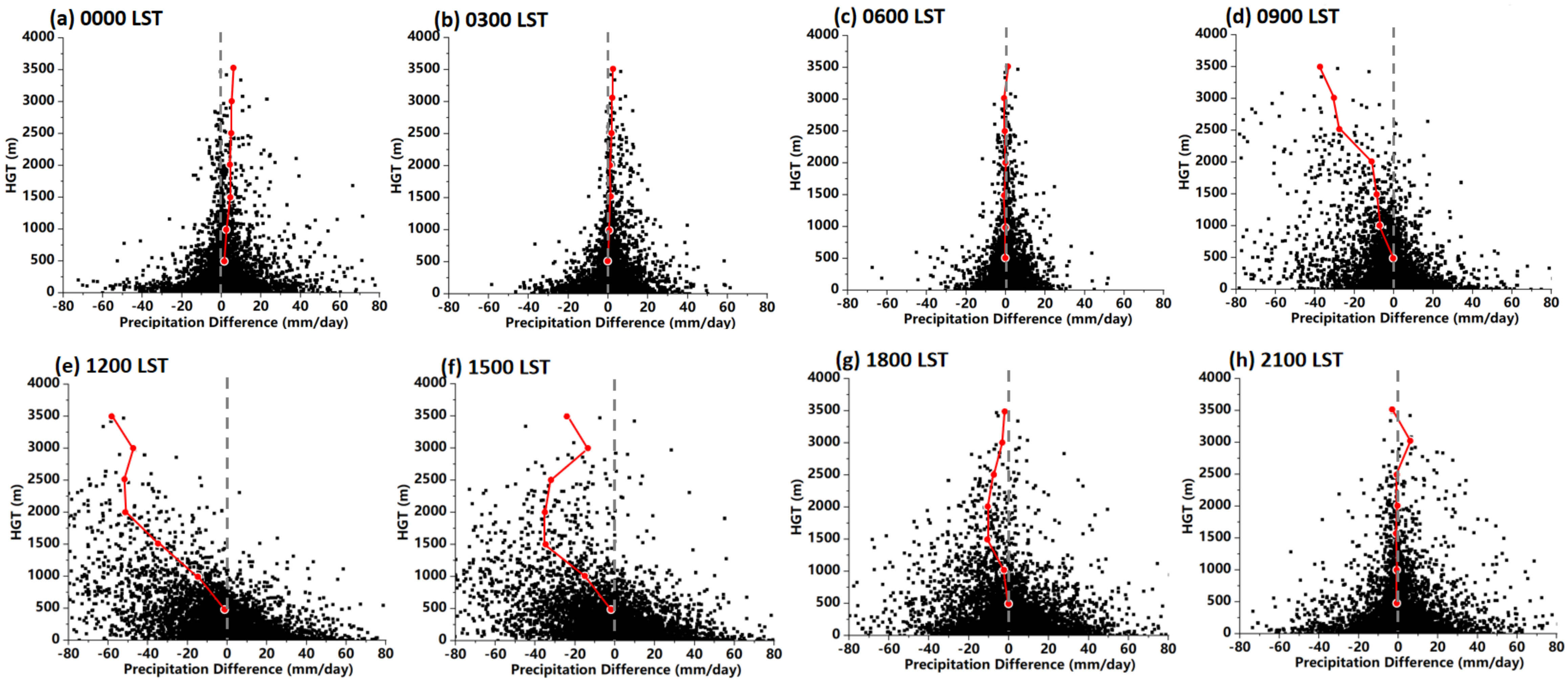
Precipitation	Obs	CTL	FLAT	FLAT-CTL
MC	5.0	4.0	3.8	– 0.2 (– 5%)
All Land	8.2	9.8	8.2	**– 1.6 (– 16%)**
All Ocean	4.5	2.8	2.7	– 0.1 (– 4%)
Sumatra	8.0	9.2	7.7	**– 1.5 (– 16%)**
Borneo	8.8	10.1	8.0	**– 2.1 (– 21%)**
New Guinea	9.3	10.4	8.4	**– 1.7 (– 16%)**

- Model underestimates over the ocean but overestimate over the land
- Overestimation due to boundary layer transfer and convective lifiting-condesation-precipitation are likely not well reproduced
- Precipitation weakens over land in FLAT mostly due to sea breeze fronts are not lifted by topography
- 16% decrease in precipitation due to topography

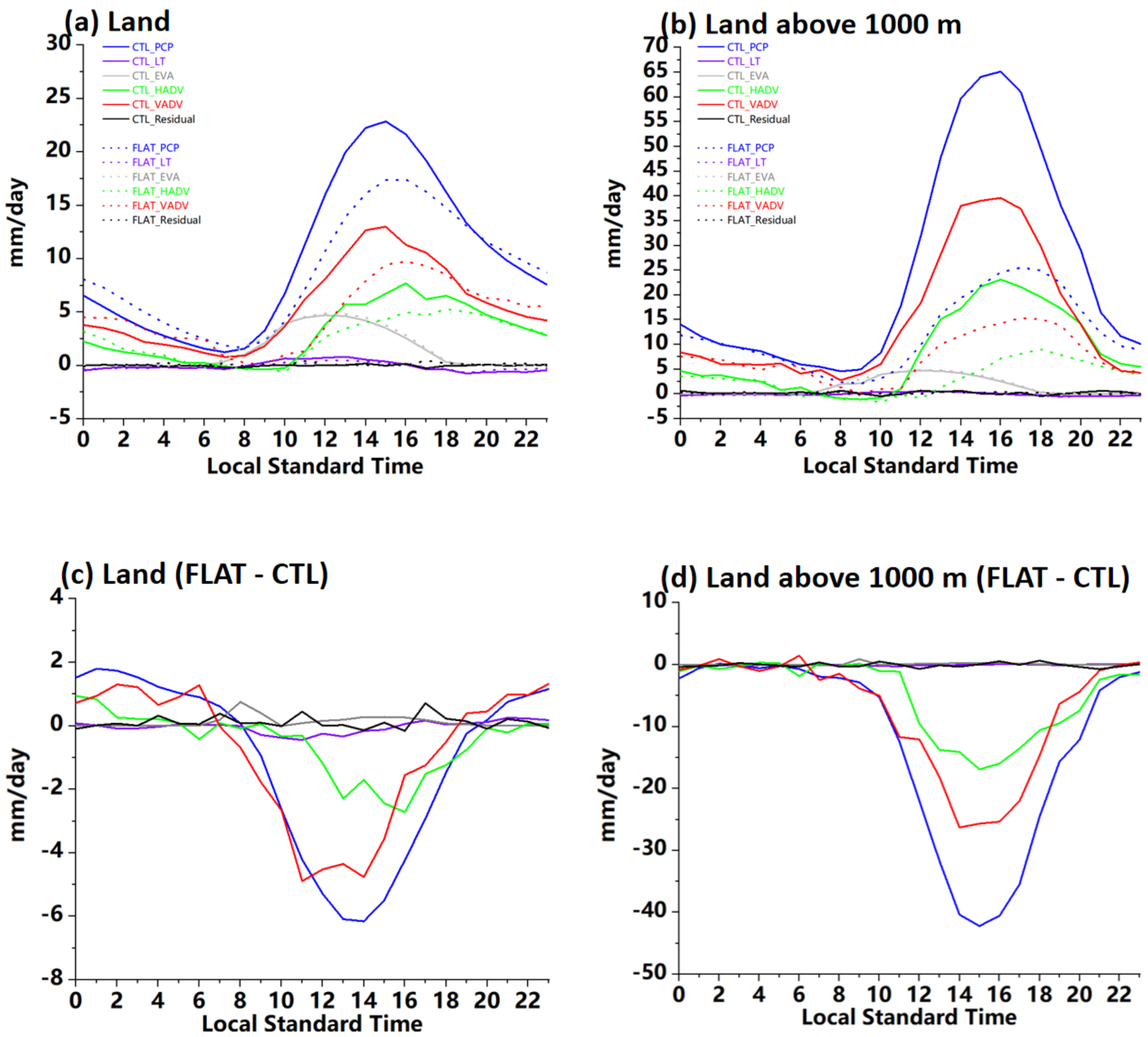




- Preciptiation peaks occur from afternoon to mid-night
- Without topography, the timing of maxima in the diurnal cycle delays from 1-6 hour over the center of major islands
- Phase in precipitation can be improved by higher model resolution
- Less precipitation in diurnal cycle without topography


(a) 0000 LST
(b) 0300 LST
(c) 0600 LST
(d) 0900 LST
(e) 1200 LST
(f) 1500 LST
(g) 1800 LST
(h) 2100 LST
HGT (m)
Precipitation Difference (mm/day)

The diurnal cycle of moisture budget terms



Moisture Budget:

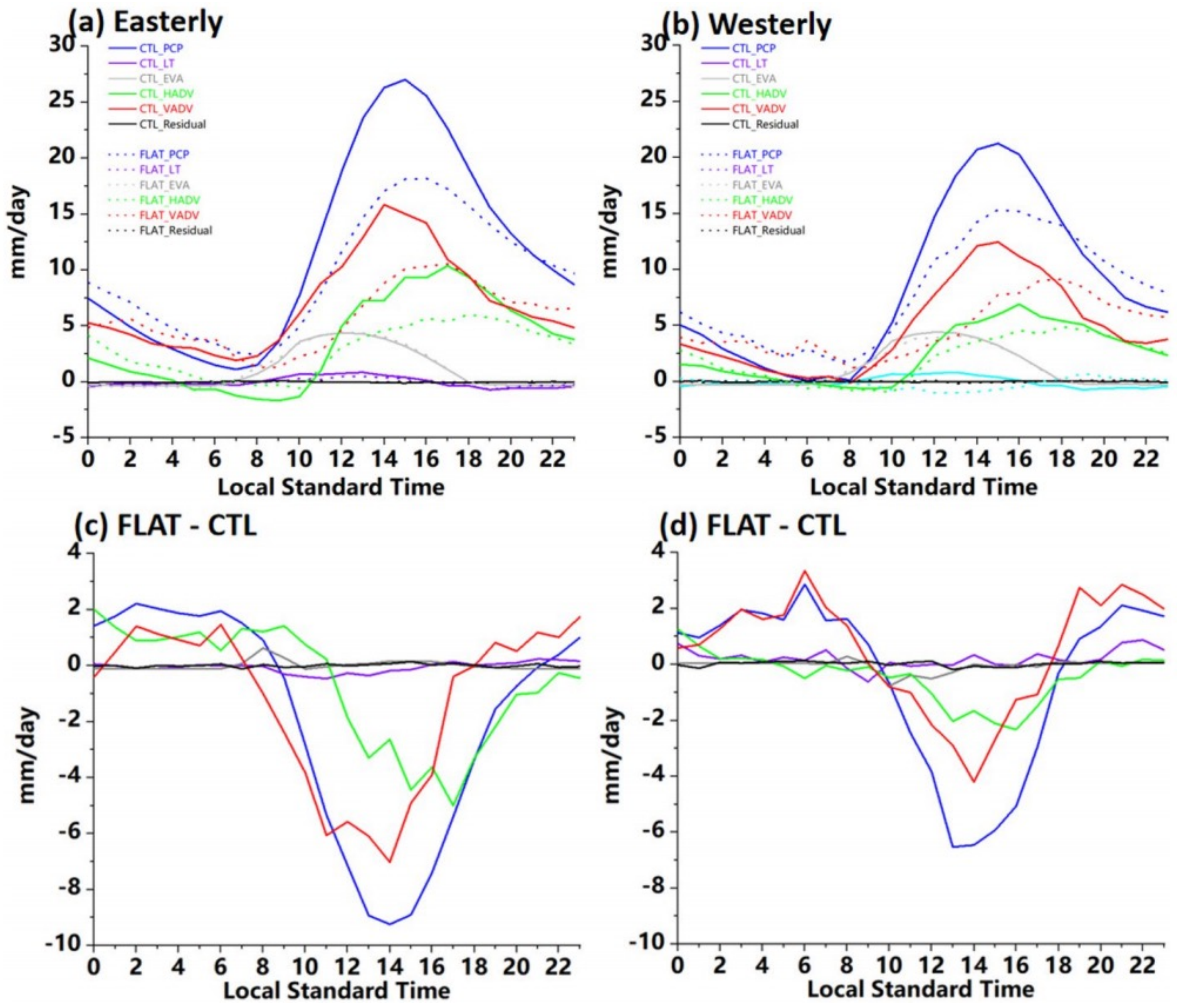
$$\left\langle \frac{\partial q}{\partial t} \right\rangle = -\langle v_h \cdot \nabla q \rangle - \left\langle \omega \frac{\partial q}{\partial p} \right\rangle + E - P + R$$

Moisture Tendency | Horizontal Moisture Advection (HADV) | Vertical Moisture Advection (VADV) | Evaporation | Precipitation | Residual

q: specific humidity, v_h: horizontal wind
ω: vertical velocity, E: Evaporation, P: Precipitation;
R: Residual
<>: vertical integration

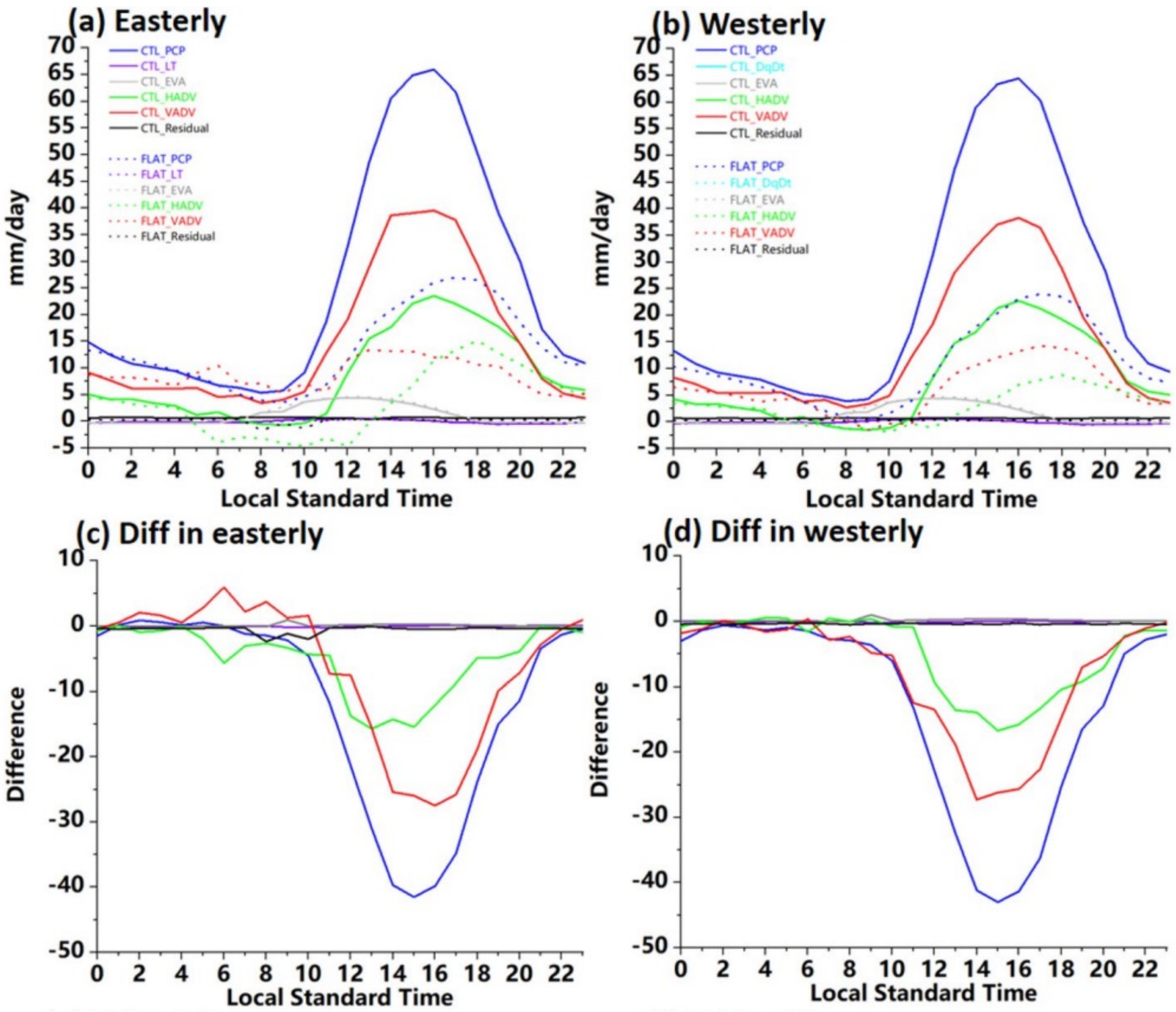
- **Precip**, **Local Tendency**, **Evaporation**, **HADV**, **VADV,** **Residual**
- Precipitation in CTL and FLAT is mostly balanced by HADV and VADV
- Timing of peak precipitation in FLAT lags of CTL by an hour
- Peak of HADV in CTL shifts from 1600 LST to 1900 LST in FLAT

The diurnal cycle of moisture budget terms (All lands)



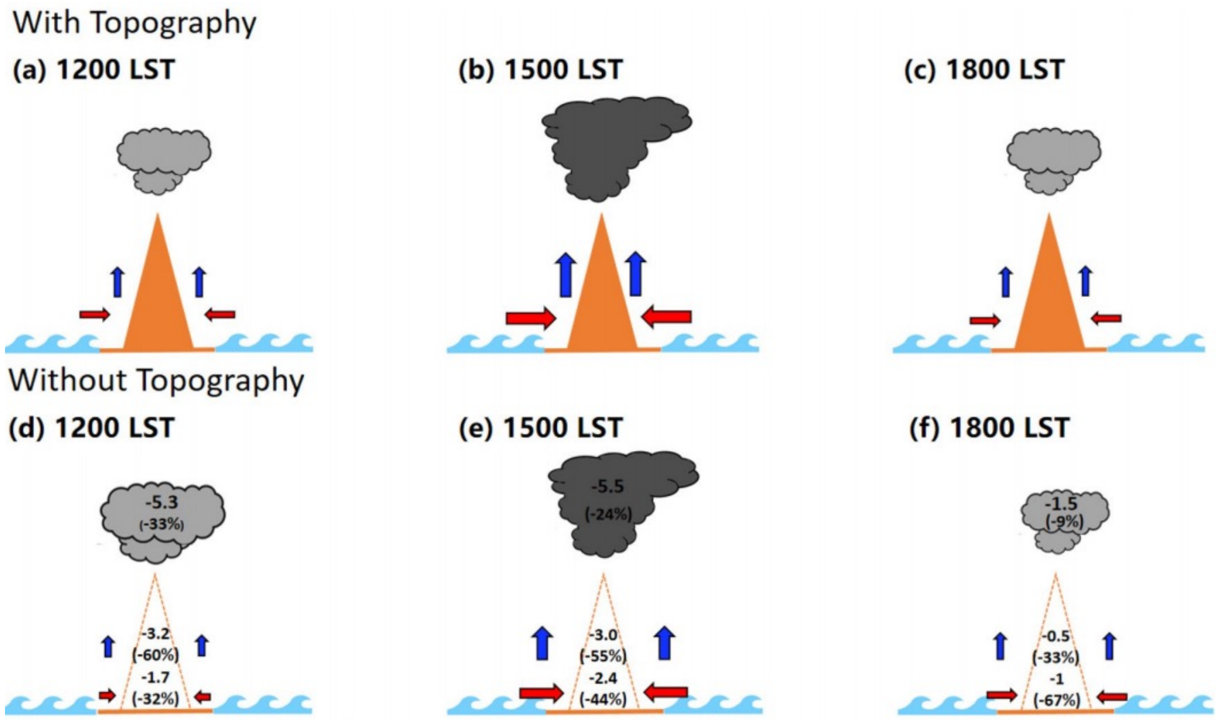
- **Precip**, **Local Tendency**, **Evaporation**, **HADV**, **VADV,** **Residual**
- MJO propagation (from easterlies to westerlies)
- Diurnal cycle is stronger in easterlies than westerlies. Peak precipitation reduces about 30%
- VADV almost follows the difference of precipitation in both easterlies and westerlies

The diurnal cycle of moisture budget terms (> 1000 m topo)



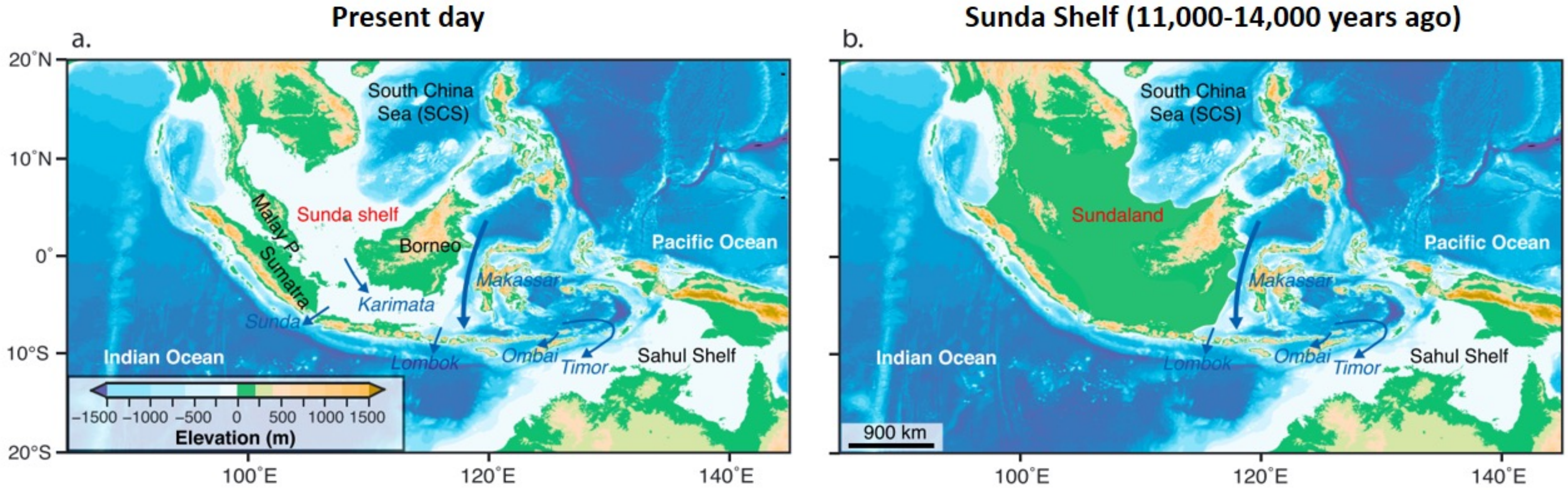
- **Precip**, **Local Tendency**, **Evaporation**, **HADV**, **VADV**, **Residual**
- Precipitation decreases less (8%)
- Other terms almost retain their characteristics in diurnal cycle during change of background winds
- Timing of VADV maxima shifted from 1300 LST during easterlies to 1800 LST during westerlies.

Schematic diagram of impact of topography on HADV (red arrow) and VADV (blue arrow)



- Topography plays a significant role in the timing, intensity, and location of precipitation and its diurnal cycle over land in MC
- 33% decrease in precipitation at 1200 LST, 24% at 1500 LST, and 9% at 1800 LST without topography
- VADV and HADV are influenced by topography. On higher topography area, the removal of topography can induce 50% less precipitation
- The background winds have a larger impact on the precipitation over low topography areas than over elevated areas.

- Provides a contribution to the understanding of the upscale evolution of cumulus into mesoscale convective systems affects the DCP, and might have some implications for the parameterization of organized convection in global climate models



- Paleoclimate aspect

- Limitations: one MJO event; short simulation period; lack of air-sea coupling