Ubiquitous nature of the diurnal cycle of precipitation and its representation in current generation climate and NWP models

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OUTLINE

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4. Diurnal Ubiquitous representation in GCMs
5. Summary

Typical understanding of tropical convection diurnal cycle

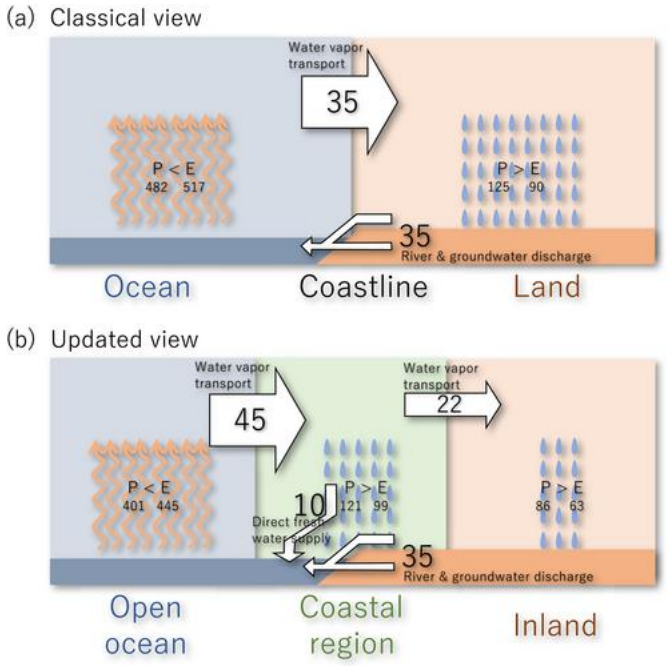
1. **Diurnal cycle amplitude is larger over land than ocean.** *Yang and Slingo 2001, Kikuchi and Wang 2008*
2. **Maximul diurnal amplitude is noted over summer northern hemisphere than southern hemisphere.**
3. **Maximum rainfall over land occurs around late-afternoons to late-nights.** *Mori et al. 2004, Jiang et al. 2006, Konduru et al. 2022*
4. **Over ocean around early mornings to afternoons.**

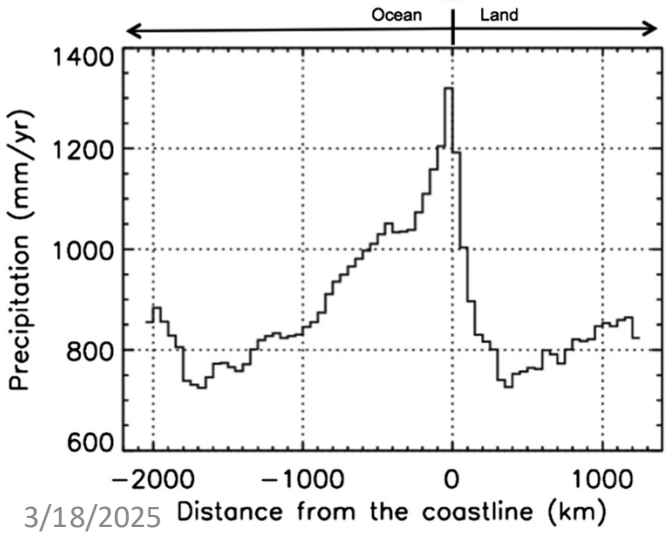
Difficult to generalize this complex nature of diurnal cycle globally

Using EOF aanalysis generalizes global diurnal cycle, EOF1 & EOF2 explains 89% of diurnal variability over land and ocean.
Oceanic regimes: early morning peak 0600-0900 LST
Land regimes: late-afternonn peak 1500-1800 LST
Landside coastal regime: 1200 to 2100 LST
Seaside coastal regime:2100 to 1200 LST

Kikuchi and Wang 2008

Ogino et al. 2016, 2017





How much we know about coastal rainfall diurnal cycle?

1. **Recent investigations reveals importance of coastal mechanism which can accumulate larger annual rainfall slightly offshore of coast.**
2. **There is no clear consensus on whether this larger annual accumulation occurs in the late-afternoons or earlymornings?**
3. **Need a clear understanding on the coastal diurnal cycle as per the concept of land/ocean/ coastal regimes point of view.**
4. **This study presents a very simple approach to investigate (2) and (3) aspects by using ultra-high resolution precipitation estimates by TRMM PR (Hirose et al. 2018)**
5. **We found ubiqutous pattern of diurnal convection, which can be treated as fundamental unit of global tropics precipitation.**

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Satellite observations employed in this study

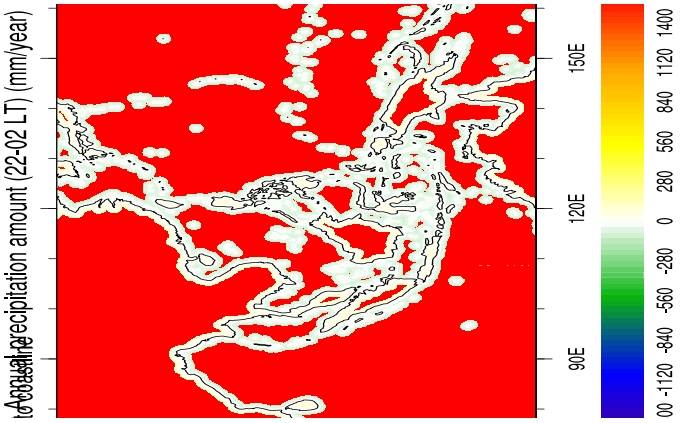
1. **16-year (1998-2014) 1-km and 10-km annual climatology and diurnal climatology of TRMM PR satellite sensed precipitation. (Hirose et al. 2018)**

2. **CCMP Satellite sensed ocean surface winds 6-hourly climatology (2000-2014)**

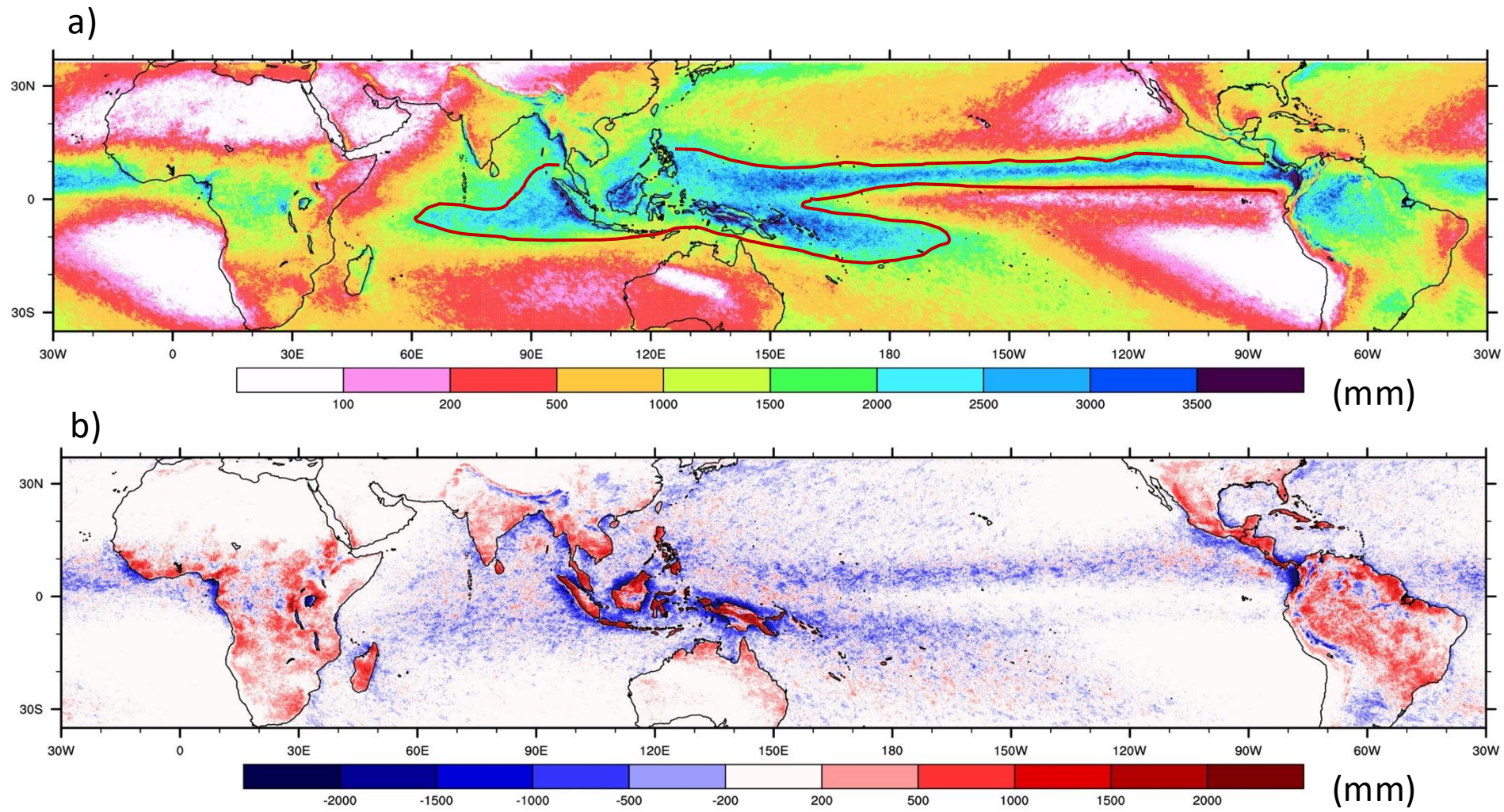
3. **ERA5 1-hourly climatology of surface winds and precipitation (2000-2014)**

4. **CMIP5, CMIP6, and HighResMIP 3-hourly mean precipitation (2000-2014)**

For global costal area 100-km is calculated.



3. Annual day/night spatial distribution of precipitation



Night (00-11 LST)

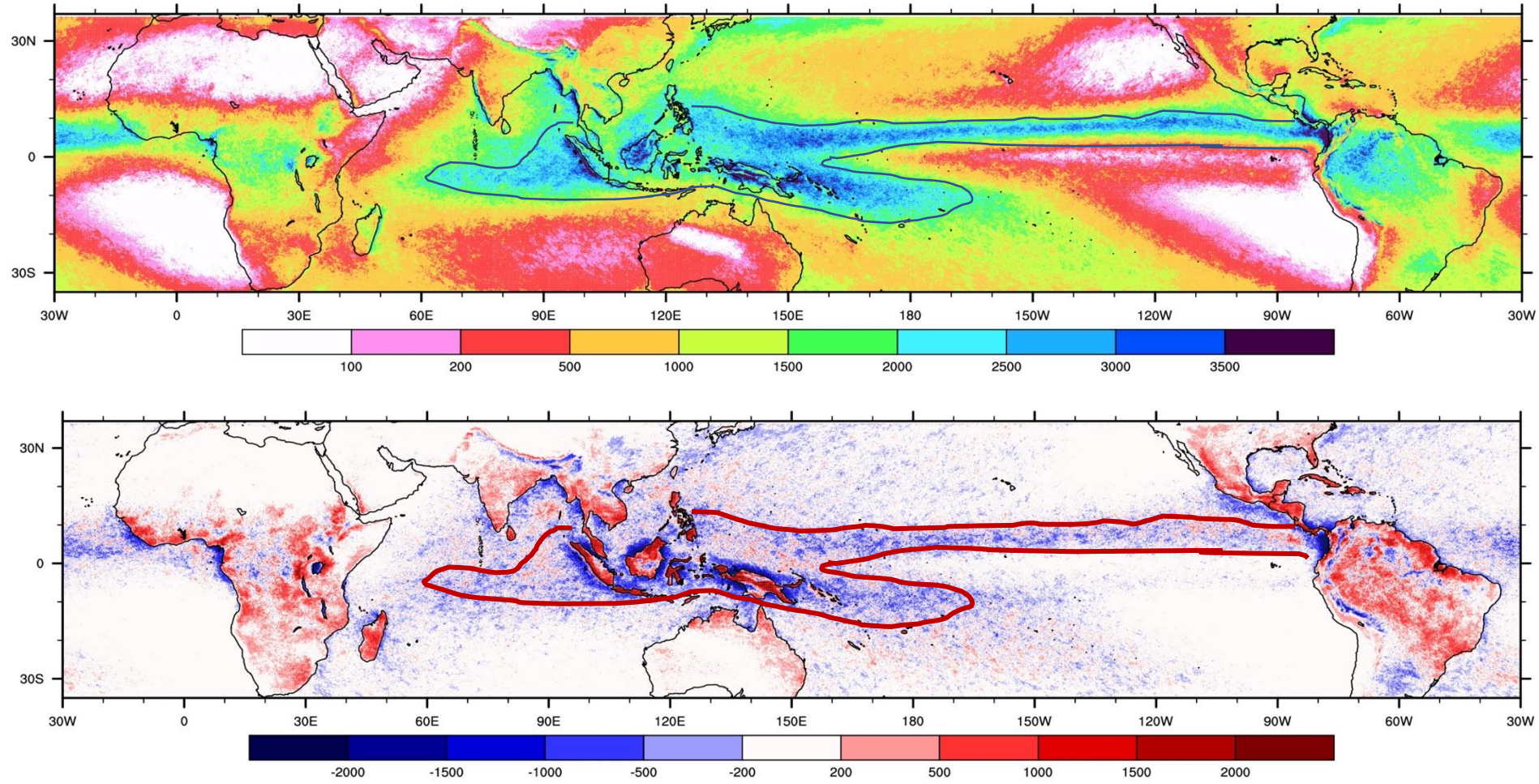
Day (12-23 LST)

Figure 1

a) Annual accumulation of precipitation (mm)

b) Night/Day difference of annual precipitation (mm)

Annual day/night spatial distribution of precipitation



Night

Day

a) Annual accumulation of precipitation

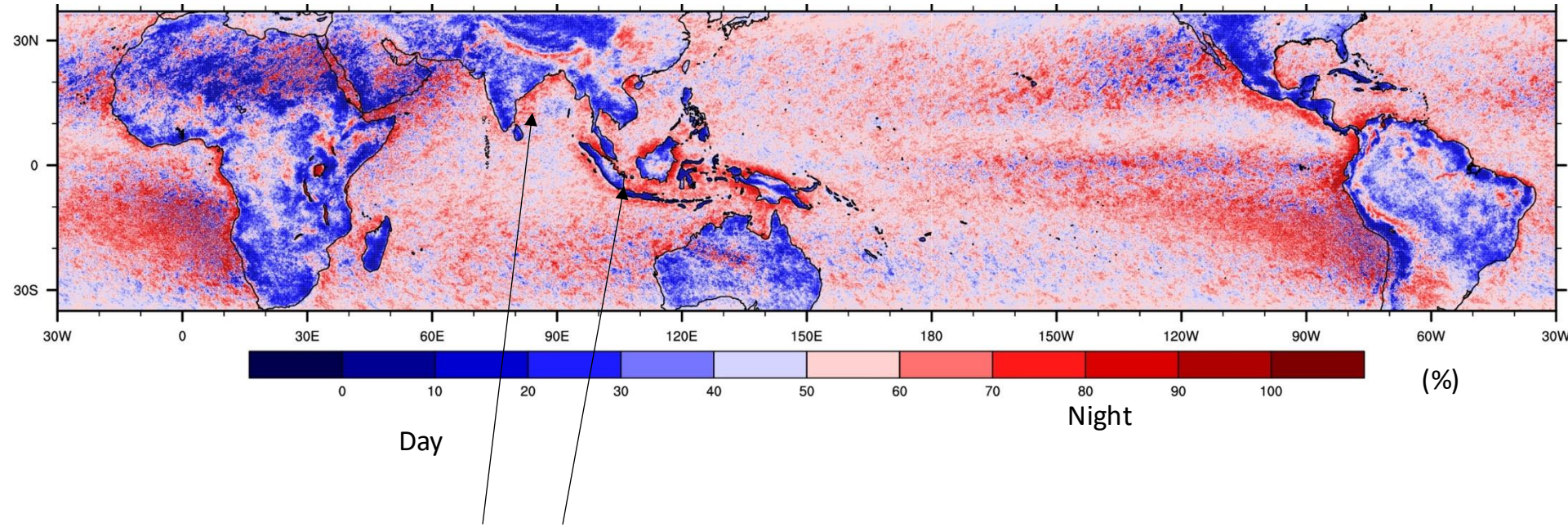
b) Night/Day contribution of annual precipitation

Figure 1

Nocturnal precipitation contribution

- Contribution is ratio of accumulated nocturnal (00-11) precipitation to the total precipitation.

Figure 2a Nocturnal accumulated precipitation Contribution to total annual precipitation

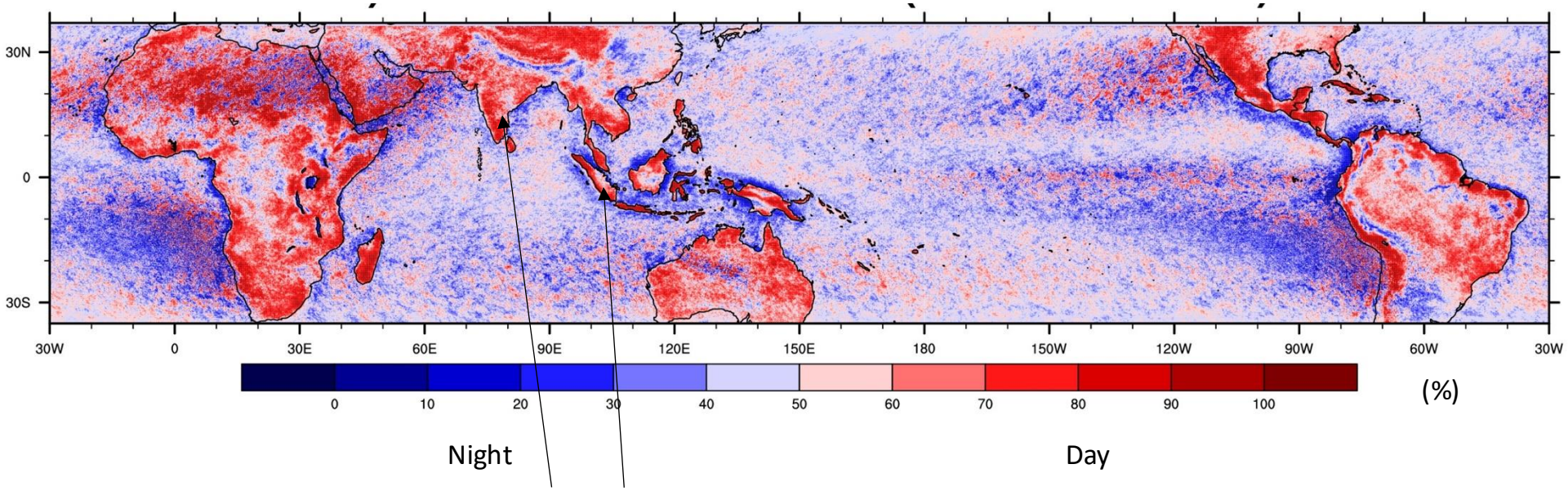


- ✓ **Contribution of coastal rainfall is 60-80% to the annual rainfall at night.**
- ✓ **Contribution of night rainfall over open ocean is ~50% of annual rainfall.**

Daytime precipitation contribution

- Contribution is ratio of accumulated daytime (12-23) precipitation to the total precipitation.

Figure 2b Daytime accumulated precipitation Contribution to total annual precipitation



- ✓ **Both inland and onshore coastal land rainfall contributes > 70% to the annual rainfall at daytime.**

- ✓ **Daytime contribution of open ocean rainfall over open ocean is < 30% of annual rainfall.**

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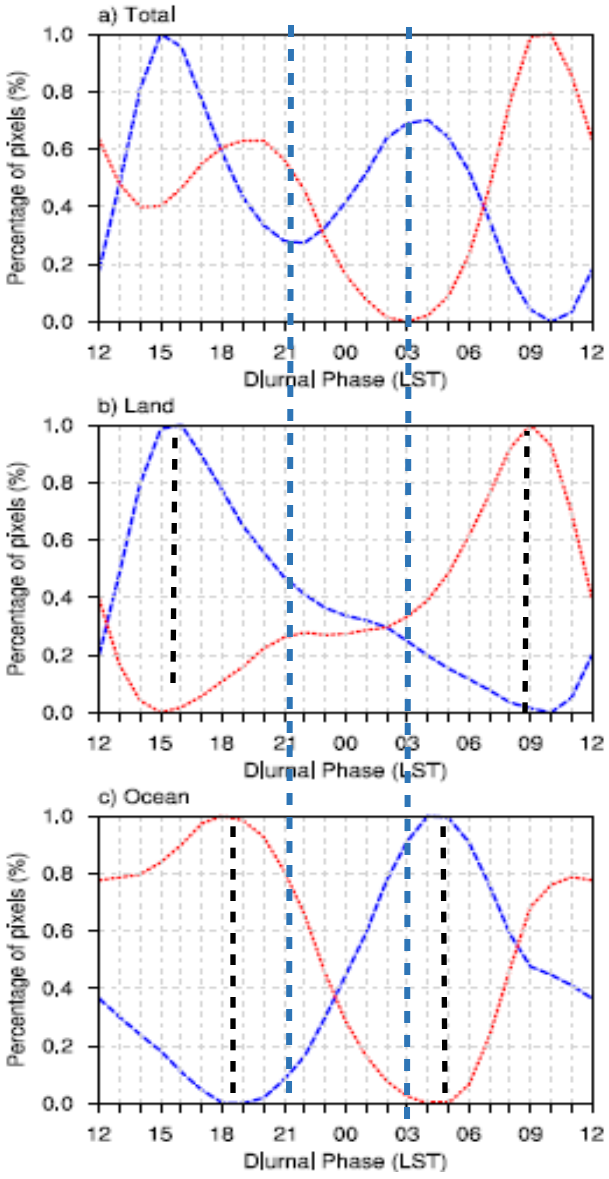
Hourly variation of max/min diurnal peak pixels

Figure 3. 16-year mean hourly variation of the maximum and minimum diurnal precipitation to the total number of pixels (Normalized)



Total number of pixels in the
Asia tropics (-20.:30N & 65E:170E): 525000

Global tropics(-30.:30N): 2160000

Land region contribution :
24.00% (30%)
Ocean region contribution :
76.00% (70%)

Land

Maximum pixels occur during afternoon-evening14-16 LST
Minimum pixels occur during morning hours 7-9 LST

Ocean

Maximum pixels occur during early morning hours 4-6 LST
Minimum pixels peak occur during afternoon-evening hours around16-18 LST

Maxima and minima intersection around 21-03 LST is seen over ~20% of the total pixels, which includes some pixels of coastal region.

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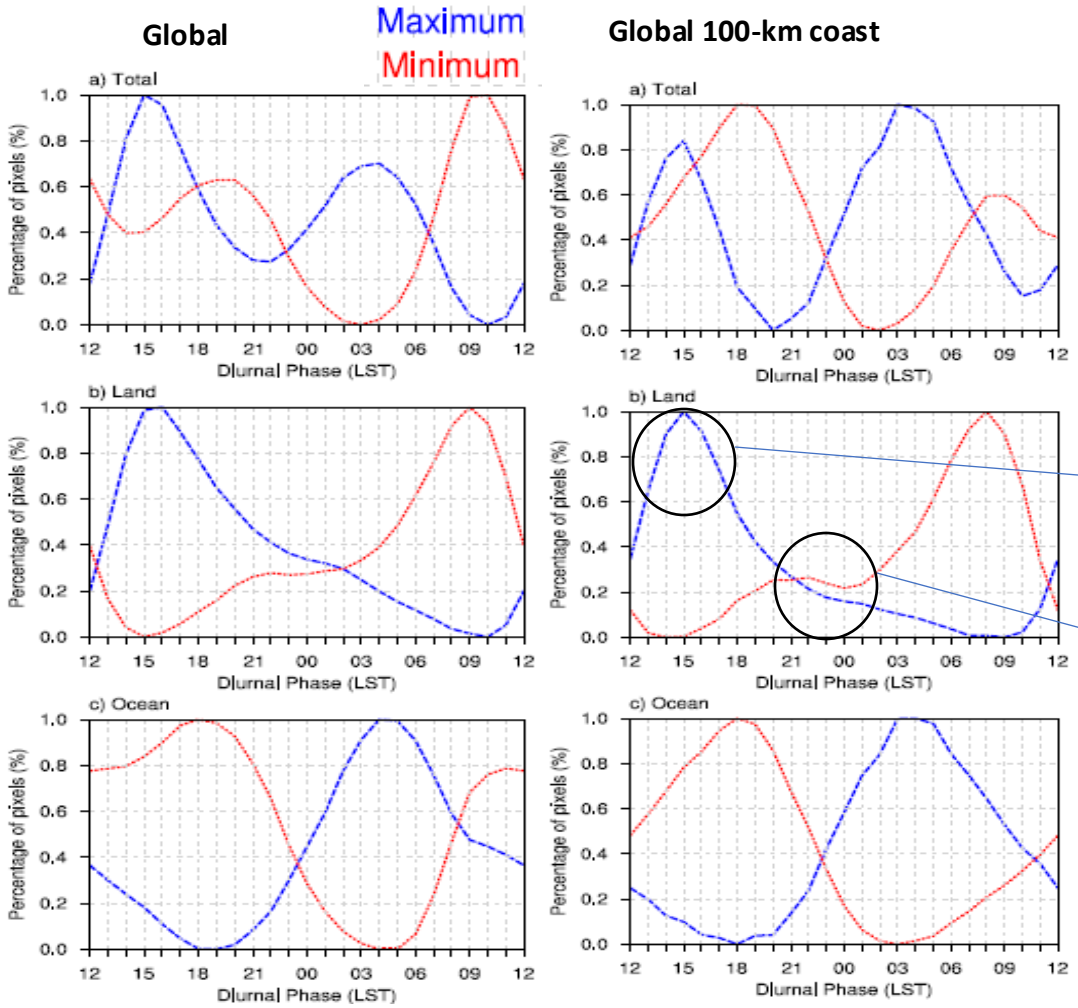
Figure 4. Similar to figure 3, shows global 100-km coastal regions in tropics.



20-25 % pixels of global tropics is coastal area (both onshore/offshore)

a) Global diurnal variation in max/min pixels.

b) Global diurnal variation in max/min pixels along 100-km coast.

Lower contribution comes from more number of pixels during afternoon.

Larger contribution comes from smaller number of pixels late-night/early morning

Hourly variation of max/min diurnal peak pixels

Annual diurnal maximum/minimum pixels over the global tropics (-30:30N)

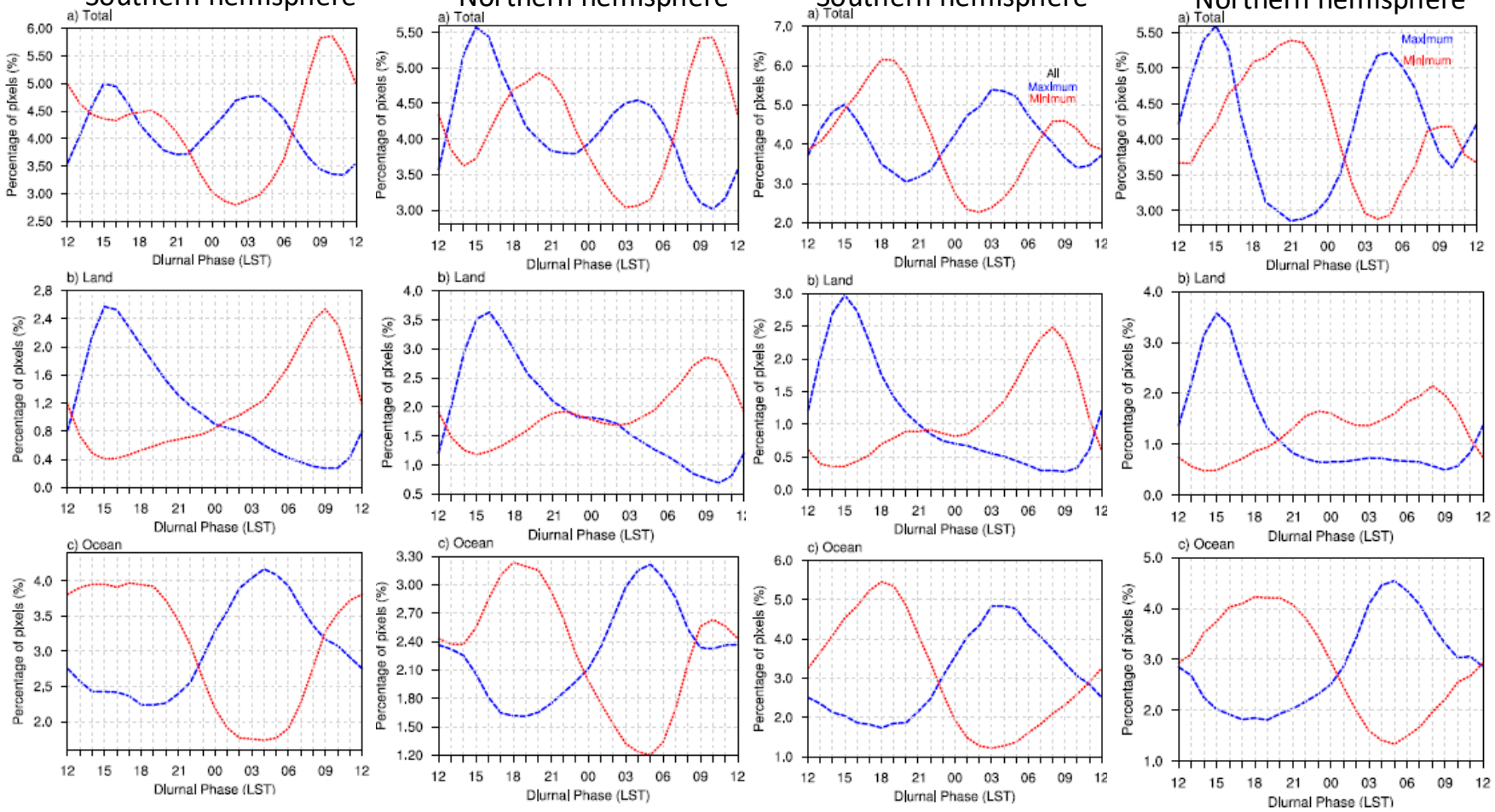
Maximum
Minimum

Only inland and open ocean

Southern hemisphere | Northern hemisphere

Only 100-km onshore and offshore coast

Southern hemisphere | Northern hemisphere

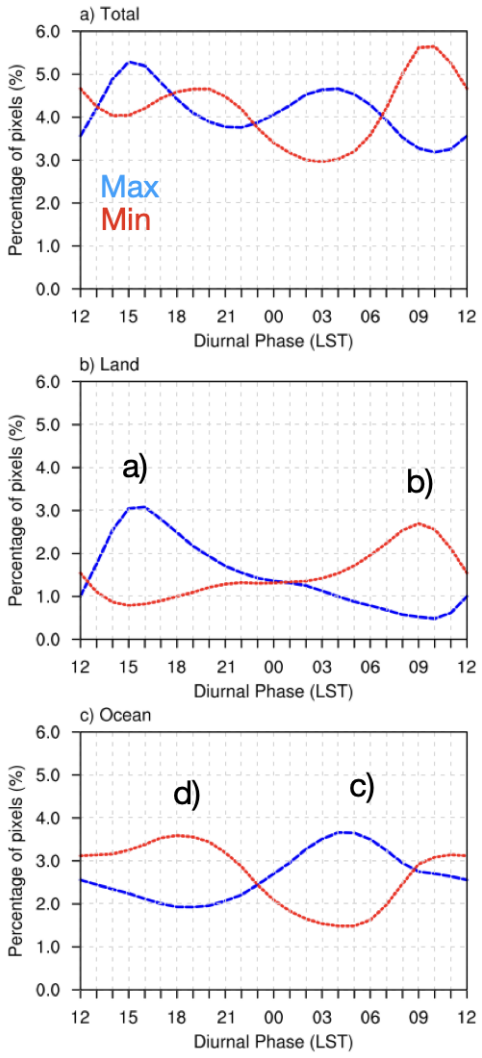


Maximum and minimum diurnal patterns doesn't change irrespective of hemisphere and topographical location resembling diurnal cycle ubiquitous nature.

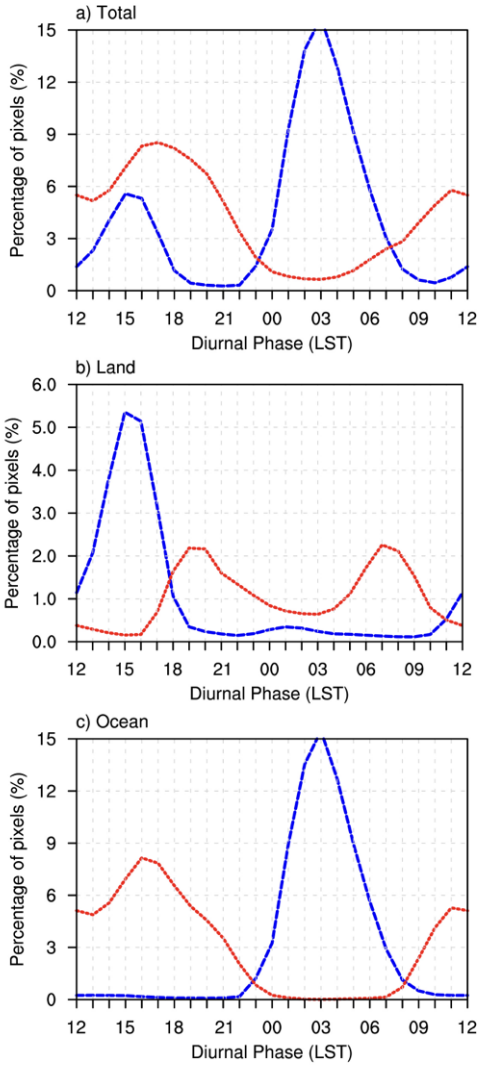
4. Reproducibility of the diurnal cycle ubiquitous pattern in the ERA5

Universal diurnal pattern

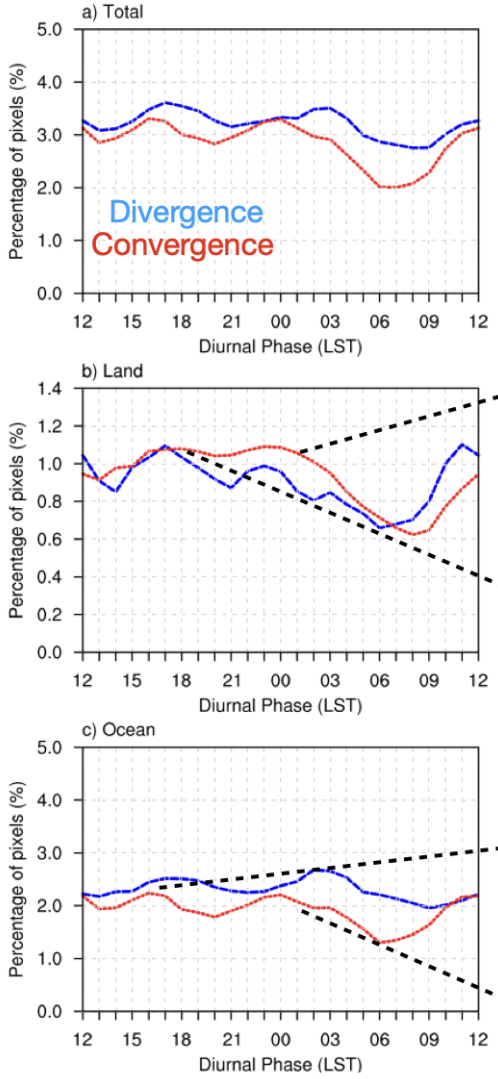
TRMM PR



ERA5



ERA5 surface winds convergence



ERA5 could not reproduce the diurnal cycle ubiquitous patter

Convergence near coast and along the mountains

Convergence over the land

Convergence over the open ocean during noon/ afternoon

Convergence near coast

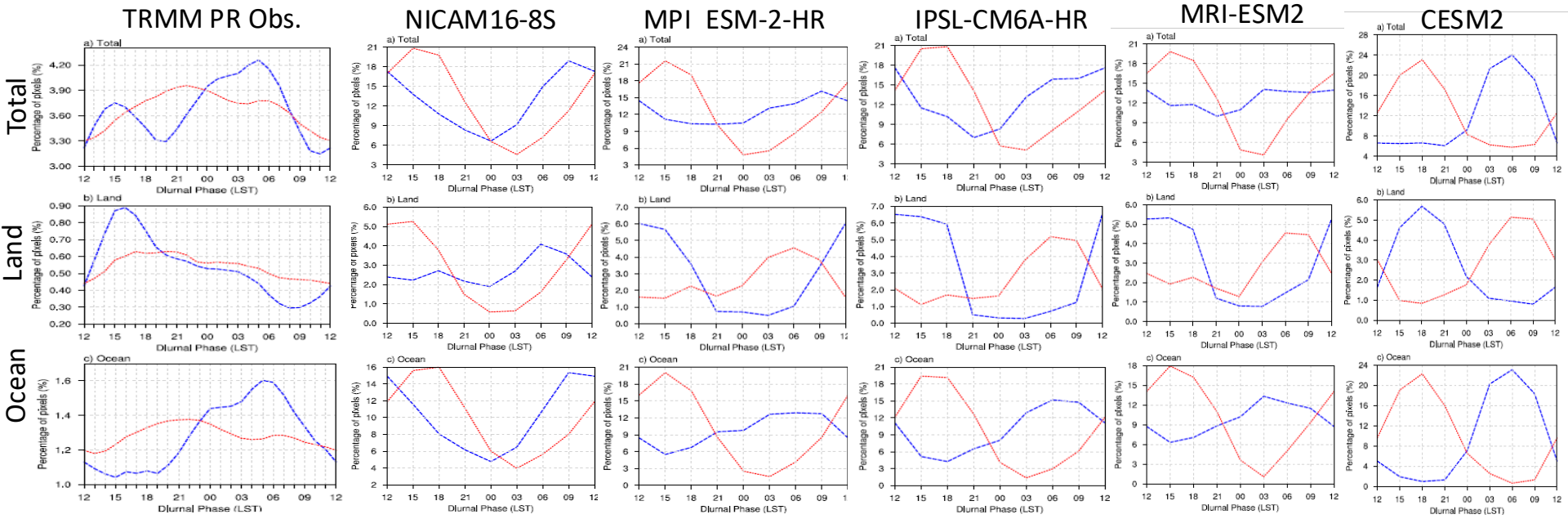
4. Reproducibility of the diurnal cycle ubiquitous pattern by the GCMs

How do current generation climate models can represent the classical diurnal pattern that we found?

Maximum
Minimum

June-September

CMIP6 High resolution MIP models (AMIP-2)



A fundamental uncertainty is seen in these climate models in the representation of classical diurnal cycle that we found

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Reproducibility of the diurnal cycle ubiquitous pattern by the GCMs

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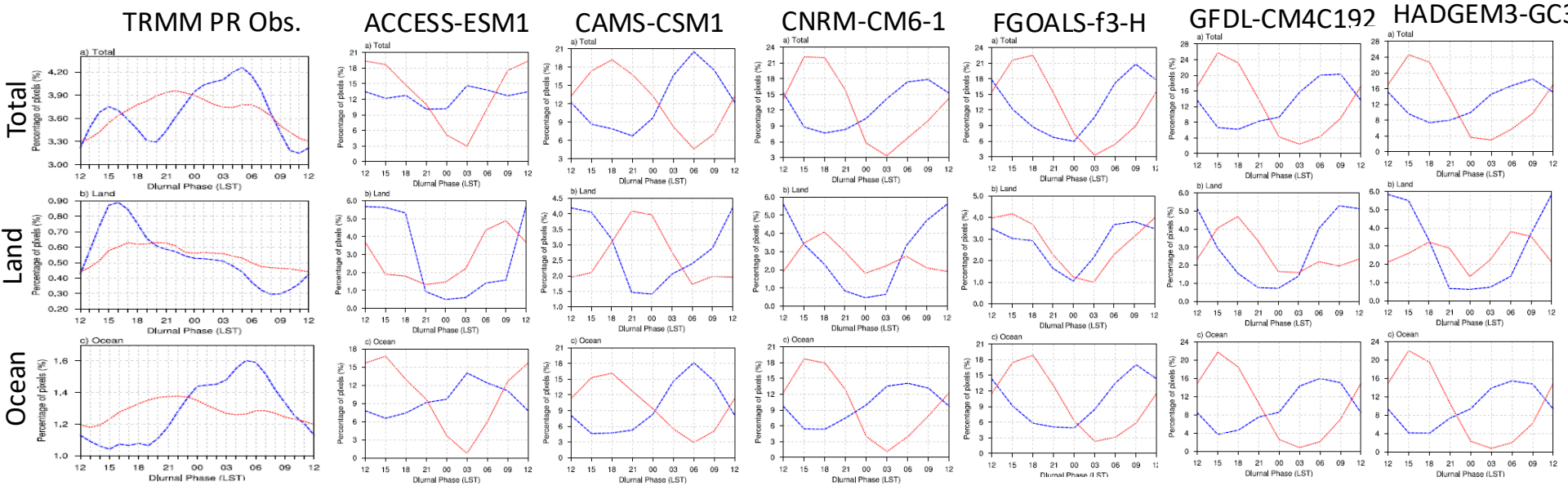

- ✓ A fundamental uncertainty is seen in these climate models in the representation of classical diurnal cycle that we found.
- ✓ This could drive not so accurate precipitation estimates in the models.
- ✓ This fundamental uncertainty could be due to improper representation of solar insolation and mslp diurnal cycle.
- ✓ Also, cumulus parameterization.

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5. Summary

1. **Diurnal cycle of precipitation can be generalized with its ubiqutous pattern, based on simple analysis.**

2. **Ubiqutous patter of diurnal cycle is mostly associated with the solar insolation based convection.**

3. **Coastal precipitation has both afternoon and late-night/early morning peaks**

4. **Large amount (34 % over Asian monsoon region) of coastal precipitation generates from smaller pixels over the global tropics**

5. **Late-night/early morning peaks can be associated with the offshore propagating systems under the influence of prevailing winds and gravity waves . (Yokoi et al. 2018; Konduru et al. 2022)**

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