Towards improved simulations of tropical intraseasonal variability: Impacts of upper-ocean vertical resolution and air–sea coupling frequency

National Centre for Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL

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Objective

To evaluate the importance of sub-daily atmosphere–ocean interactions in the 30-50 day variability of the Indian summer monsoon, focusing on the strength and northward propagation of organized convective events.

1. Introduction

The intraseasonal (30–50 day) oscillation of the Indian monsoon produces sustained floods and droughts, which impact the livelihoods of hundreds of millions of people each summer. This oscillation manifests itself as organized convective events that propagate from the equatorial Indian Ocean to India (Fig. 1).

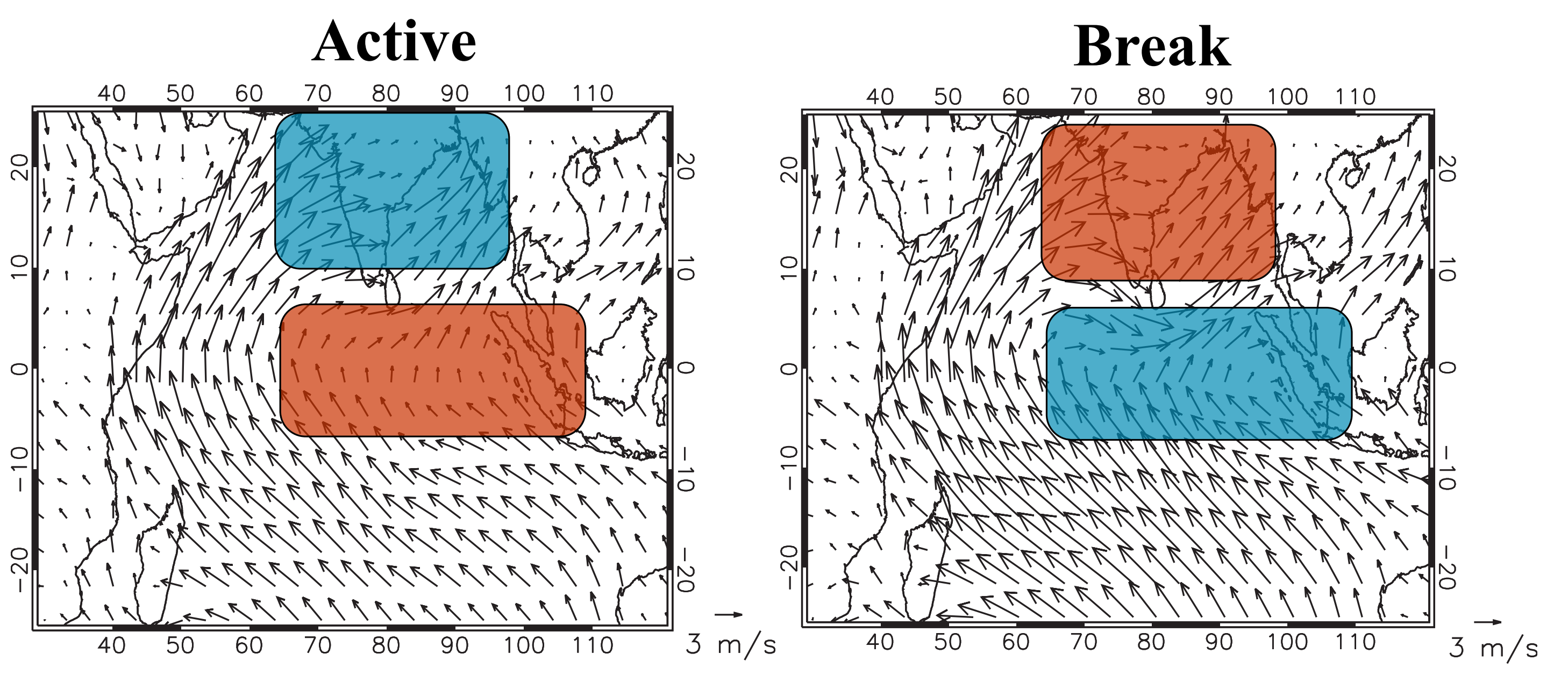
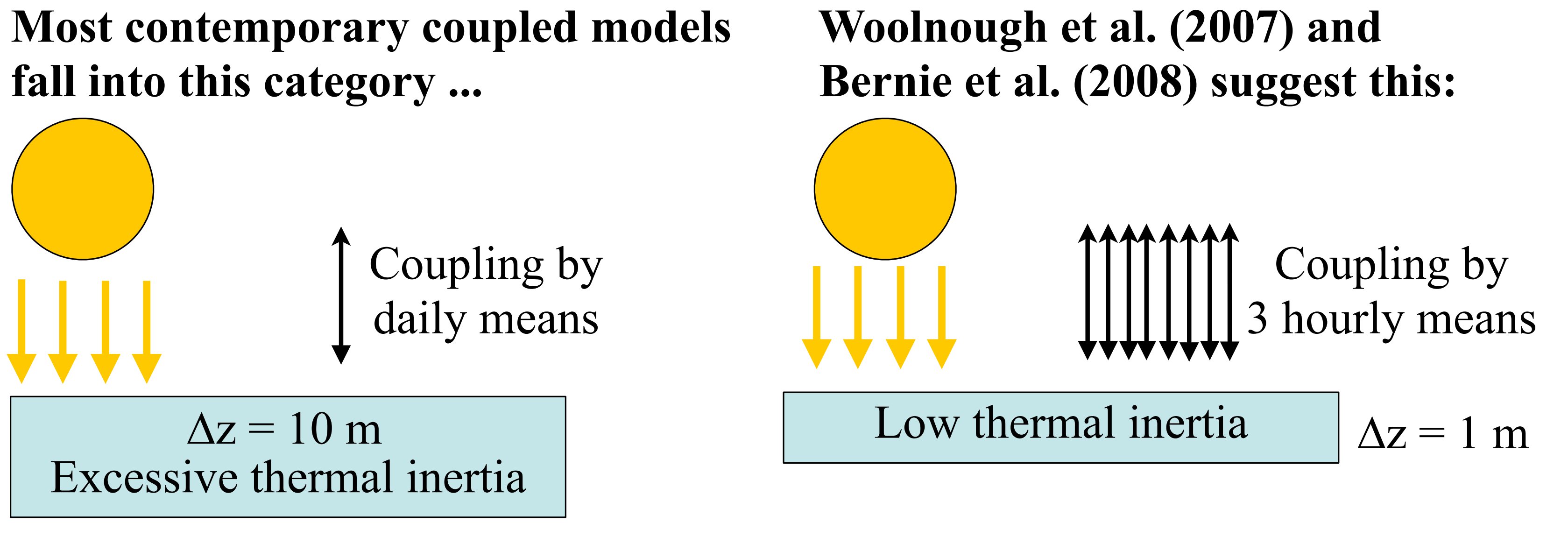


Figure 1. Ten-metre ERA-40 winds for an example (left) active and (right) break phase. Blue (red) boxes indicate regions of enhanced (suppressed) convection.

2. Motivation

Most contemporary coupled climate models underestimate the variance associated with the intraseasonal oscillation (Lin et al., 2008). Studies of the MJO have implicated these models' coarse, 10 metre near-surface ocean vertical resolution and once-daily coupling frequency (Fig. 2; Woolnough et al., 2007; Bernie et al., 2008).

The authors have assembled a coupled atmosphere–boundary-layer-ocean model called HadKPP, which is capable of economically running at fine ocean vertical resolution with a sub-daily coupling frequency.



Most contemporary coupled models fall into this category ...

Coupling by daily means

Δz = 10 m
Excessive thermal inertia

Woolnough et al. (2007) and Bernie et al. (2008) suggest this:

Coupling by 3 hourly means

Low thermal inertia

Δz = 1 m

Figure 2. Air–sea coupling frequency and near-surface ocean vertical resolution for (left) common contemporary coupled models and (right) the suggested configuration from past studies of the MJO.

3. Experiment Design

Four 30-member ensembles of HadKPP were run for the summer monsoon season (May–September) to test the sensitivity of intraseasonal variability to ocean vertical resolution and air–sea coupling frequency.

Ensemble	1M-3H	1M-24H	10M-3H	10M-24H
Ocean vertical resolution	1 metre	1 metre	10 metres	10 metres
Air–sea coupling frequency	3 hours	24 hours	3 hours	24 hours

References

Bernie, D. J., E. Guilyardi, G. Madec, J. M. Slingo, S. J. Woolnough and J. M. Cole, 2008: Impact of resolving the diurnal cycle in an ocean-atmosphere GCM. Part 2: A diurnally coupled CGCM. *Climate Dynamics,* **31**, 909-925.
Lin, J.-L., K. M. Weickman, G. N. Kiladis, B. E. Mapes, S. D. Schubert, M. J. Suarez, J. T. Bacmeister and M.-I. Lee, 2008: Subseasonal variability associated with Asian summer monsoon simulated by 14 IPCC AR4 coupled GCMs. *J. Clim.*, **21,** 4541-4567.
Woolnough, S. J., F. Vitart and M. A. Balmaseda, 2007: The role of the ocean in the Madden-Julian Oscillation: Implications for MJO prediction. *Quart. J. R. Meteorol. Soc.*, **133**, 117–128.

Conclusions

1) To improve the variance and coherence of intraseasonal convection, coupled models should refine their representation of air–sea exchange, via a reduced upper-ocean thermal inertia and a resolved diurnal cycle of coupling.

2) Sub-seasonal SST variability plays a key role in the strength and propagation of the intraseasonal oscillation of the Indian summer monsoon.

4. Results

10M-24H has poor intraseasonal SST variance (Fig. 3) and weak northward propagation (Fig. 4), compared to observations. Improved upper-ocean thermodynamics in 1M-3H (e.g., an enhanced diurnal cycle of SST; Fig. 5) not only increase SST variance on intraseasonal temporal scales, but result in coherent northward propagation. 10M-3H and 1M-24H demonstrate that adding only resolution or the diurnal cycle gives only slight improvements.

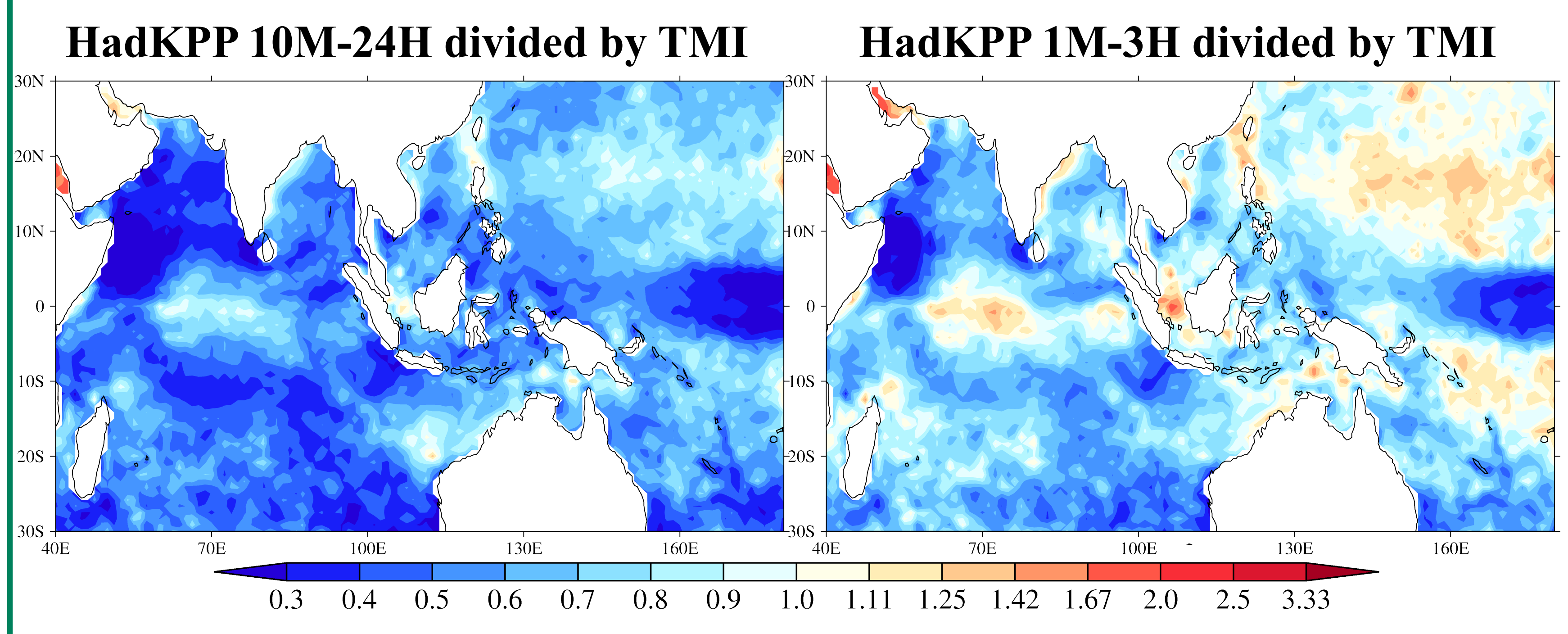


Figure 3. Ratios of the standard deviation in 30–50 day filtered sea-surface temperatures for July and August.

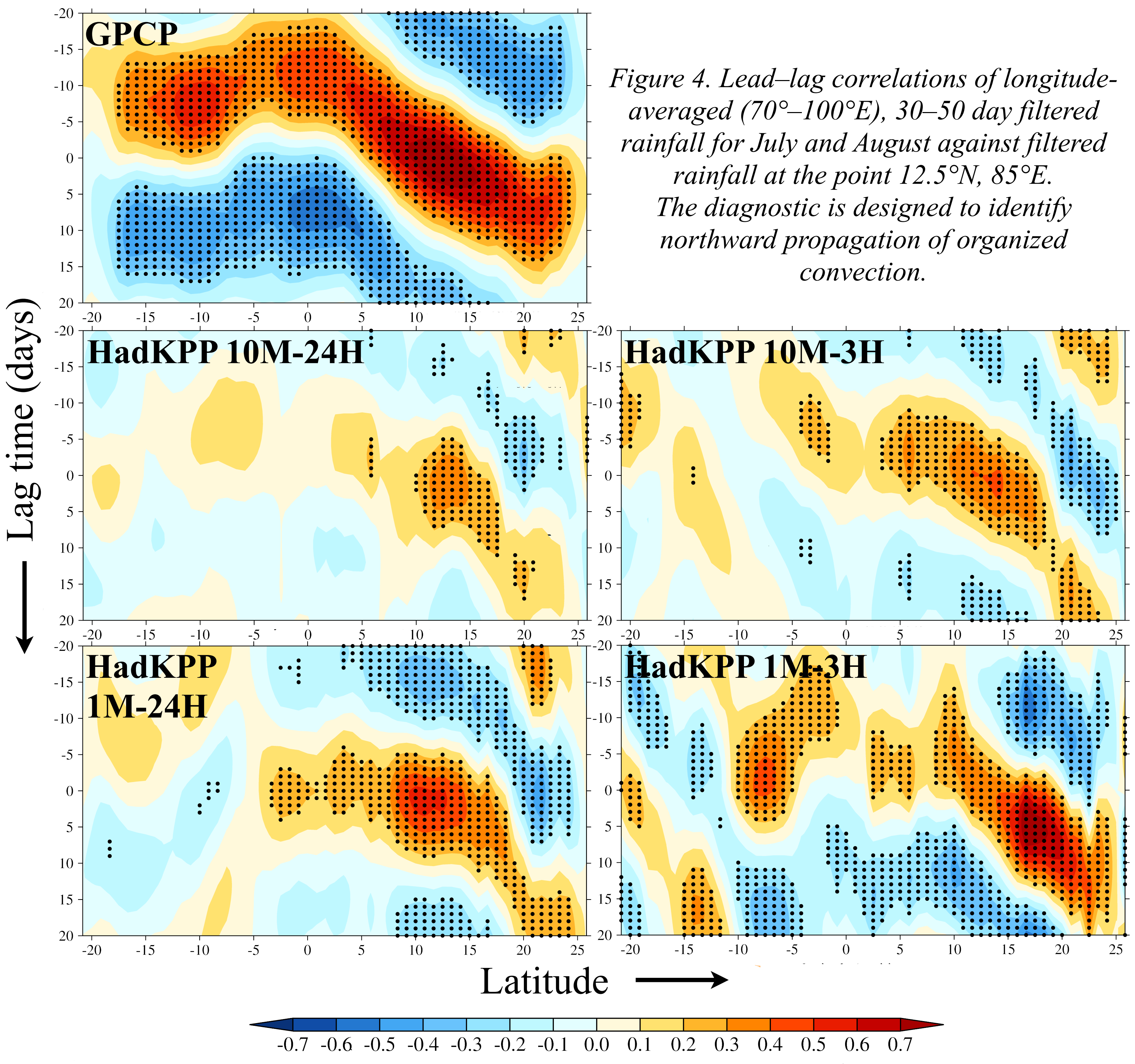


Figure 4. Lead–lag correlations of longitude-averaged (70°–100°E), 30–50 day filtered rainfall for July and August against filtered rainfall at the point 12.5°N, 85°E. The diagnostic is designed to identify northward propagation of organized convection.

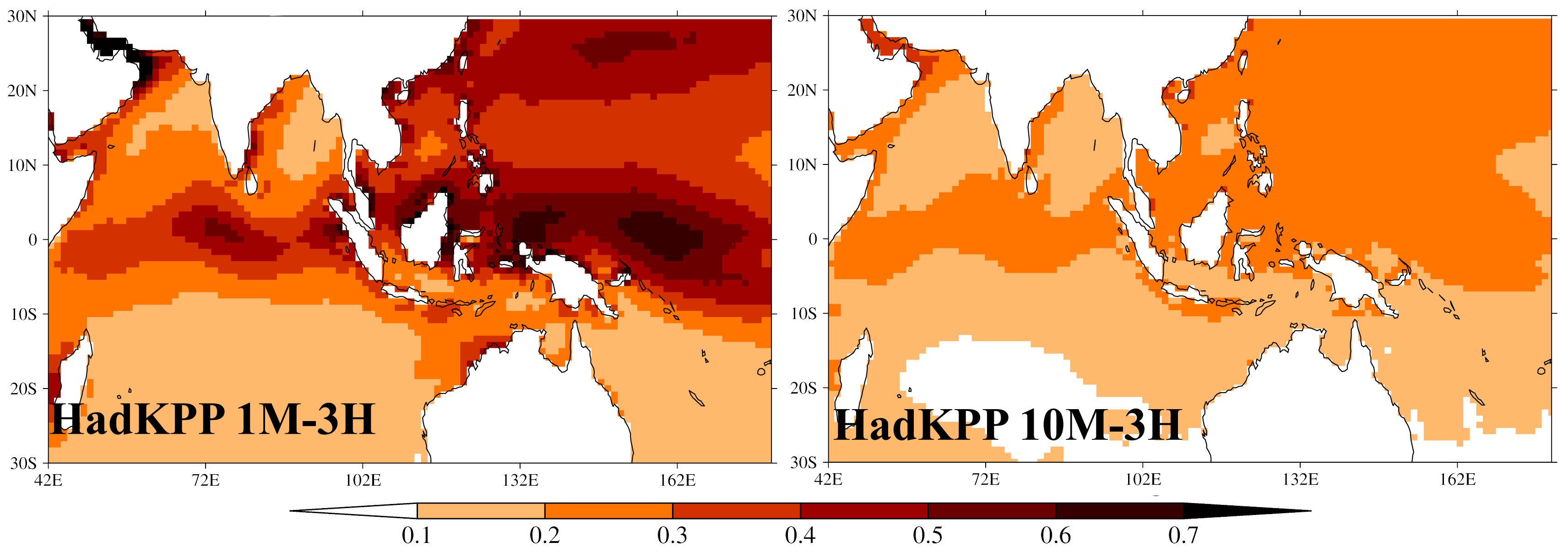


Figure 5. The mean amplitude (°C) of the diurnal cycle of sea-surface temperatures for June–September, computing using three-hourly means. The 1M-24H and 10M-24H ensembles have no diurnal amplitude of sea-surface temperatures.