

Assessment of the MJO's Southward Detour in CMIP6 models

Yumi Choi

Korea Institute of Science and Technology

Daehyun Kang

`dkang@kist.re.kr`

Korea Institute of Science and Technology

Daehyun Kim

Seoul National University

Frédéric Vitart

European Centre for Medium-Range Weather Forecasts

Jiwoo Lee

Lawrence Livermore National Laboratory

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Abstract

The Madden-Julian oscillation (MJO) is the dominant mode of tropical intraseasonal variability, affecting both regional and global weather and climate systems. In boreal winter, MJO convection often propagates southward around the Maritime Continent (MC). This southward detour of the MJO remains poorly represented in climate models despite its marked influence on diabatic heating, thereby limiting the predictability of the MJO and its teleconnections. This study evaluates the representation of the MJO's southward detour in 35 Coupled Model Intercomparison Project Phase 6 (CMIP6) models using a new MC detour metric. Our analysis reveals that 71% of the CMIP6 models underestimate the observed detour, with the multi-model mean MC detour index of 0.64 compared with the observed value of 1.0. We further examine how model background states influence the simulated MJO detour by comparing models with different performance in reproducing eastward propagation and the southward detour. We find that successful simulation of the southward detour is associated with a stronger interhemispheric moisture gradient and enhanced background moisture over the Australian monsoon region, while eastward propagation is linked to an enhanced background zonal moisture gradient east of the MC. These results highlight that an accurate representation of the background moisture fields is essential for improving MJO simulations across the MC.

Introduction

The Madden-Julian Oscillation (MJO) is the most prominent mode of tropical intraseasonal variability, characterized as a tropical planetary-scale oscillation that propagates eastward at approximately 5 m s^{-1} with a period of 30–60 days from the Indian Ocean (IO) to the eastern Pacific^{1,2}. As a major driver of tropical deep convection, the MJO exerts widespread influences on global weather and climate by modulating atmospheric circulation through the Rossby wave response to its diabatic heating^{3–6}. The MJO modulates tropical cyclone (TC) activity^{7–9}, monsoons^{10–12}, and extratropical teleconnections¹³. Because the MJO acts as the primary source of tropical diabatic heating, its diverse propagation pathways across the MC induce varying extratropical responses^{10,14,15}. Consequently, accurately representing these pathways is essential for reliable weather and climate prediction^{10,13}. In particular, the meridional displacement of MJO convection associated with the southward detour may influence its regional and remote impacts by altering the location to tropical diabatic heating¹⁵.

Over the past several decades, numerous theories have been proposed to explain the physical processes determining the salient features of the MJO^{16,17}. Among these theories, the moisture-mode theory^{18–20} and the trio-interaction theory²¹ emphasize how the moisture anomalies associated with the MJO propagate and maintain. However, despite these advances, it has been a challenge to understand its behavior over the Maritime Continent (MC), which is characterized by complex land–sea contrast, elevated topography, and the widespread deep convection over the Indo-Pacific warm pool^{10,16,22–24}. As the MJO propagates from the IO toward the MC, nearly half of the events fail to cross the region, and even the successful events tend to weaken²³. This phenomenon, known as the MC barrier effect, has

been attributed to insufficient moisture supply due to limited surface heat flux, complex land-sea contrast, steep topography, and vigorous diurnal cycle of land convection^{23–31}.

Moreover, eastward-propagating MJO convection from the IO often exhibits a distinct latitudinal shift over the MC. This feature, referred to as the “MJO detour”, is characterized by a shift of the main MJO propagation pathway toward the summer hemisphere^{22,23,28,32–35} in boreal winter. The moist and westerly background conditions over the southern MC, associated with the Australian monsoon, favor enhanced moisture-precipitation coupling and wind-evaporation feedback, thereby increasing the sensitivity of MJO precipitation to moisture anomalies^{35,36}. During the MJO propagation, this southward shift in MJO propagation pathway is associated with greater moisture recharge over the southern MC than over the equatorial MC. This enhanced moisture recharge has been attributed to the steeper zonal gradient in the background moisture field over the southern MC³⁷.

Owing to the complex processes governing MJO propagation through the MC, accurately simulating MJO behavior over the MC remains a persistent challenge for global climate models^{10,23,24,28,38–41}. In observations, the boreal-winter MJO often exhibits a southward displacement in both convection and circulation as it propagates across the MC, reflecting its characteristic southward detour. In contrast, the Coupled Model Intercomparison Project Phase 5 (CMIP5)⁴² models tend to confine MJO convection near the equator, demonstrating limited skill in reproducing the observed meridional shift²⁷. Chen et al. (2020)²⁷ examined this behavior in the context of the MC barrier effect by comparing individual MJO events that successfully crossed the MC with those that were blocked, rather than quantitatively evaluating the climatological southward detour as a distinct propagation characteristic.

Recent studies have emphasized that the mean state moisture is a key factor governing MJO behavior across the MC in the global climate models^{40,43–46}. For example, Gonzalez and Jiang (2017)⁴⁷ and Jiang (2017)⁴⁴ showed that models that more realistically simulate the mean state moisture distribution around the MC area tend to better represent the eastward propagation of the MJO across the MC with enhanced moistening due to horizontal moisture advection⁴⁰. To quantitatively assess the simulated eastward propagation of the MJO over the MC, Ahn et al. (2020a)⁴⁰ developed the MC propagation metric, which quantifies the strength of MJO propagation by integrating positive lag-regression coefficients over the equatorial MC from lag days 0 to 25. Using this metric they showed that CMIP6 models generally outperform CMIP5 models in representing MJO propagation across the MC because of their improved mean state moisture distribution.

However, the MC propagation metric primarily evaluates the zonal propagation of the MJO and does not explicitly quantify its meridional propagation characteristics. Consequently, although substantial progress has been made in understanding and evaluating the simulated eastward propagation of the MJO, its southward detour over the MC remains largely unexplored in global climate models. Addressing this gap requires a quantitative metric that captures not only eastward propagation but also the meridional displacement of MJO convection over the MC.

Here, we propose a new MC detour metric to quantitatively evaluate the southward detour of the MJO. By combining this new metric with the MC propagation metric of Ahn et al. (2020a)⁴⁰, we systematically evaluate MJO propagation in 35 CMIP6 models (Table S1). Specifically, this study addresses two questions: (1) How well do CMIP6 models reproduce the observed southward detour of the MJO over the MC? and (2) Which aspects of the background moisture field are most closely associated with the successful simulation of the MJO's southward detour? By answering these questions, we aim to provide an objective assessment of the MJO southward detour in CMIP6 models and offer new insights into the processes controlling MJO propagation across the MC, thereby helping improve its representation in global climate models.

Results

An MC detour metric for quantifying the MJO southward detour

To quantitatively assess the ability of CMIP6 models to reproduce the observed southward detour of the MJO during boreal winter, we develop a MC detour metric based on a lag-regression of outgoing longwave radiation (OLR) anomalies. Unlike previous metrics that primarily assesses eastward propagation, the MC detour metric tracks the trajectory of MJO-related convection and quantifies its preferential meridional pathway across the MC. The procedure is summarized below (see Methods for details):

- 1) Compute lead-lag regressions of 20–100-day bandpass-filtered OLR anomalies onto the area-averaged OLR over the IO domain (5°S–5°N, 85–95°E) (Supplementary Fig. 1)
- 2) At each lag day, the regression coefficients are normalized by the maximum in the domain (Supplementary Fig. 2). For the CMIP6 models, the regression coefficients are normalized by the observed maximum to avoid identifying spurious propagation signals in models with weak MJO activity.
- 3) The MJO-related convection is defined when the normalized coefficient is larger than 0.5 (Fig. 1)
- 4) At each grid point, the lag-accumulated occurrence of the “MJO convection” is calculated between lag – 9 and 27 days, then the latitude of the maximum occurrence is identified at each longitude (Fig. 2a).
- 5) The difference in the MJO convection occurrence between southern MC (SMC; 15–5°S, 110–150°E) and equatorial MC (EQMC; 5°S–5°N, 110–150°E) is defined as the “MC detour index” (Fig. 3d).

The detailed procedures and implications of the detour metric are discussed with the results below.

Figure 1a shows the observed MJO-related convection identified by the MC detour metric at each lag. The detected MJO convection successfully captures the canonical propagation of the MJO from the IO to the WP (Fig. 1). Accordingly, the accumulated occurrence of MJO convection reproduces the well-

known boreal winter propagation pathway, with a clear southward displacement around Sumatra and Java (Fig. 2a). The latitude of maximum occurrence at each longitude (black dots) clearly delineates the observed southward detour.

The MC detour metric also captures the seasonal evolution of MJO propagation (Supplementary Fig. 3). While the MJO's pathway remains near the equator over the IO throughout the year (Supplementary Fig. 4a), it shifts toward approximately 10°S during boreal winter and toward 10°N during boreal summer as it crosses the MC (Supplementary Fig. 4b). These seasonal changes are consistent with previous studies^{32,35}. During boreal winter, the MJO's propagation pathway in the WP follows the South Pacific Convergence Zone (SPCZ) (Supplementary Fig. 4c). The southward detour is most pronounced during December to March (DJFM), resulting in the largest positive MC detour index (Supplementary Fig. 5). Therefore, the following analysis focuses on DJFM, when the observed southward detour is strongest.

Evaluation of CMIP6 in simulating the MJO's southward detour

Using the MC detour metric, we first evaluate MJO propagation in the 35 CMIP6 historical simulations against observational data. The multi-model ensemble (MME) reproduces MJO convection over the IO reasonably well but exhibits a rapid weakening of convection across the MC and WP (Fig. 2b; individual model results are provided in Supplementary Fig. 6). Consistent with previous studies showing that global climate models tend to exaggerate the MC barrier effect^{27,40,47,48}, the longitudinal distribution of MJO convection occurrence indicates that CMIP6 models generally underestimate MJO propagation across the MC and WP (Figs. 3a-c).

We next evaluate the MC detour index across the 35 CMIP6 models (Fig. 3d). The MC detour indices are normalized by the corresponding observed value, such that the observation equals 1. Of the 35 models, 25 (71%) underestimate the observed detour, whereas only 10 (29%) overestimate it. Consequently, the CMIP6 MME reproduces only 64% of the observed southward detour (Fig. 3d).

However, because the detour index depends on the existence of eastward propagation, interpreting the detour bias requires distinguishing between weak eastward propagation and failure to reproduce the southward displacement itself. Thus, distinguishing these effects is essential for isolating the mechanisms controlling the southward detour. Therefore, we additionally employ the MC propagation index of Ahn et al. (2020a)⁴⁰ (see Methods for details), which independently quantifies the strength of eastward propagation.

Figure 4a compares the MC propagation and detour indices for the observations and all CMIP6 models. The MME underestimates eastward propagation, with a propagation index of 0.48. This value is lower than that reported by Ahn et al. (2020a)⁴⁰, likely because our metric is based on OLR during DJFM, whereas Ahn et al. (2020a)⁴⁰ used precipitation during November-April.

Using the MC propagation and detour indices, we classify the CMIP6 models according to their ability to reproduce the observed MJO's eastward propagation and southward detour. Models with propagation indices greater than 0.5 are classified as propagating, whereas those with propagation indices below 0.5 are classified as non-propagating. Similarly, models with detour indices above 1.2 are classified as detouring, whereas those below 0.4 are classified as non-detouring. Based on these criteria, the models fall into three representative groups: (1) 6 detour-propagating (DP) models (i.e., both propagating and detouring: AWI-ESM-1-1-LR, CESM2-FV2, E3SM-1-0, MPI-ESM-1-2-HAM, MPI-ESM1-2-HR, and NESM3), (2) 6 eastward-propagating (EP) models (i.e., propagating but non-detouring: BCC-ESM1, CESM2-WACCM-FV2, CMCC-CM2-HR4, EC-Earth3, EC-Earth3-AerChem, and EC-Earth3-CC), and (3) 8 non-propagating (NP) models (i.e., neither propagating nor detouring: ACCESS-ESM1-5, CanESM5, CMCC-CM2-SR5, CMCC-ESM2, INM-CM4-8, INM-CM5-0, IPSL-CM5A2-INCA, and MRI-ESM2-0) (Fig. 4). Notably, only one model is classified as non-propagating but detouring, suggesting that successful eastward propagation of the MJO is a prerequisite for reproducing the observed southward detour.

Figures 4b-d illustrate the characteristic propagation pathways of the three model groups. The DP models (Fig. 4b) closely reproduce the observed trajectory shown in Fig. 2a, with MJO convection shifting southward around Sumatra and propagating through the Timor Sea into the WP. In contrast, the EP models maintain eastward propagation but fail to reproduce the observed southward displacement. Instead, the propagation pathway shifts northward around Sumatra and Borneo (Fig. 4c). The NP models exhibit rapid decay of MJO convection over the MC (Fig. 4d). These results demonstrate that successful eastward propagation alone is insufficient to reproduce the observed southward pathway of the MJO during boreal winter and highlight the need to separately investigate the processes governing eastward propagation and the southward detour.

Role of background moisture fields in the MJO detour

To identify the background conditions responsible for differences in MJO propagation (Figs. 4b-d), we compare the mean moisture and circulation fields among the three model groups. Because the total atmospheric moisture varies substantially among models, precipitable water is normalized by the average over the tropical Indo-Pacific (10°S – 10°N , 40°E – 80°W) to emphasize differences in the horizontal moisture distribution rather than the absolute moisture amount. Figure 5 shows the normalized background moisture and low-level wind anomalies of each group relative to the CMIP6 multi-model mean.

Figure 5 reveals distinct background moisture patterns associated with the three categories of MJO propagation behavior. In the DP models with both strong eastward propagation and southward detour, enhanced mean moisture over the Australian summer monsoon region is accompanied by northwesterly anomalies over the Timor Sea and cyclonic circulation over the southeastern IO (Fig. 5a). This higher background moisture in the southern MC with stronger Australian monsoon can enhance the conversion efficiency of moisture anomalies into precipitation anomalies over the southern MC, thereby supporting

the MJO's southward detour across the region^{35,37}. Additionally, the enhanced westerlies in the Timor Sea contribute to convection enhancement during the active phase of MJO^{35,36}.

In contrast, the EP models exhibit a pronounced zonal moisture dipole across the MC, characterized by relatively dry conditions over the IO and wet conditions over the WP (Fig. 5b). This pattern strengthens the zonal background moisture gradient across the MC by increasing background moisture east of the MC, thereby favoring eastward propagation through stronger moisture-convection coupling. However, the lack of enhanced background moisture over the southern MC prevents the models from reproducing the observed southward detour. Conversely, the NP models exhibit the opposite zonal moisture pattern, with relatively wet conditions over the IO and dry conditions over the WP, accompanied by anomalous easterlies over the MC (Fig. 5c). This pattern weakens the zonal background moisture gradient across the MC, suppressing eastward propagation of the MJO. Consequently, these models fail to reproduce both the eastward propagation and the southward detour.

Taken together, these results indicate that realistic representation of the MJO's eastward propagation is primarily associated with the zonal background moisture gradient across the MC, whereas the southward detour is linked to a stronger meridional moisture gradient, characterized by enhanced background moisture over the southern MC. These background moisture patterns are tightly connected to inter-model differences in background SSTs. Specifically, the moisture pattern associated with the southward detour of the MJO corresponds to a La Niña-like SST pattern together with a stronger interhemispheric SST gradient (Supplementary Fig. 7a), whereas the zonal moisture gradient favoring eastward propagation is associated with an El Niño-like SST pattern (Supplementary Fig. 7b). Furthermore, models that fail to reproduce realistic MJO propagation across the MC exhibit anomalous surface warming over the MC islands (Supplementary Fig. 7c). Such warming may strengthen the diurnal cycle of land convection, which has previously been shown to inhibit eastward MJO propagation across the MC^{23,27,29}.

Summary and Discussion

This study introduces a new MC detour metric that enables an objective evaluation of the meridional propagation pathway of the MJO across the MC. Unlike existing diagnostics that primarily assess eastward propagation, the MC detour metric explicitly quantifies the observed southward displacement of MJO convection over the MC. By combining the MC detour metric with the MC propagation metric of Ahn et al. (2020a)⁴⁰, we separately evaluate the simulated eastward propagation and southward detour of the MJO in 35 CMIP6 models, providing a more comprehensive framework for assessing MJO propagation across the MC. This framework provides a basis for distinguishing the physical processes governing the southward detour from those controlling eastward propagation.

The primary finding of this study is that the eastward propagation and southward detour of the MJO are associated with different aspects of the background moisture field. This distinction has not been

explicitly demonstrated in previous studies because existing diagnostics primarily focused on eastward propagation. Our analysis reveals that successful eastward propagation is associated with a stronger zonal background moisture gradient across the MC, whereas the southward detour is linked to a stronger interhemispheric (meridional) moisture gradient, characterized by enhanced background moisture over the southern MC. The latter aspect of the background state is associated with a stronger Australian summer monsoon and relatively dry conditions over the equatorial eastern Pacific, which likely enhance moisture–convection coupling over the Timor Sea and the SPCZ, thereby providing favorable conditions for the MJO’s detour toward the southern MC.

Successful eastward propagation appears to be a prerequisite for the MJO to establish a southward detour, as only one CMIP6 model reproduced the detour without realistic eastward propagation. However, the MC detour index is only moderately correlated with the MC propagation index across the 35 models ($r = 0.35$). This suggests that the strength of the southward detour is not necessarily coupled to that of eastward propagation, indicating that the two propagation characteristics are governed by distinct background conditions. This interpretation is supported by the recent findings of Sekizawa et al. (2026)⁴⁹, who showed that strong eastward MJO propagation preferentially occurs during weak Australian monsoon years, suggesting that environmental conditions favoring eastward propagation may differ from those promoting the southward detour.

Our findings further suggest that models exhibiting a stronger southward MJO detour preferentially simulate a La Niña-like SST pattern together with an enhanced Australian summer monsoon. This is consistent with previous studies that suggest that La Niña-like conditions provide a more favorable environment for the MJO’s southward detour, whereas El Niño-like conditions promote faster and more symmetric eastward propagation along the equator^{50–54}. Because ENSO strongly modulates the background SST and moisture gradients across the Indo-Pacific, it provides a physically consistent mechanism linking the large-scale mean state to different MJO propagation pathways. These findings suggest that improving the simulation of the tropical Pacific background state may provide an effective strategy for a more realistic representation of MJO propagation across the MC.

Although the present analysis identifies robust inter-model relationships between background moisture fields and MJO propagation characteristics, these relationships are based on statistical comparisons and do not by themselves establish causality. Targeted sensitivity experiments that independently modify zonal and meridional background moisture gradients will be necessary to directly test the mechanisms proposed here. Future analyses using large ensemble simulations or multi-decadal data would be valuable for assessing the spread of the detour index and distinguishing the influence of internal variability to the simulated MJO detour.

Methods

MC detour metric

We adopt a lag-regression diagnostic method^{40,55,56} to evaluate propagation behaviors of periodic MJO convection. Daily OLR anomalies are computed by removing the annual mean and climatological seasonal cycle (i.e., the first three harmonics) and then bandpass filtered to retain 20–100-day variability. A reference timeseries is constructed by averaging the filtered OLR anomalies over the IO (5°S–5°N, 85–95°E) where the equatorial MJO convective envelopes initiate before propagating toward the WP. The intraseasonal OLR anomalies at each grid point are regressed onto the reference timeseries from lag – 9 to + 27 days (Supplementary Fig. 1). To prevent the MJO signal from weakening over time, the regression coefficients are normalized by the maximum observed coefficient within the analysis domain (30°S–30°N, 50°E–150°W) for both the observation (Supplementary Fig. 2) and CMIP6 models.

MJO-related convection is identified at grid points where the normalized regression coefficient exceeds 0.5 (Fig. 1). Its occurrence is accumulated over the 37-day period from lag – 9 to + 27 days at each grid point (shading in Fig. 2). To characterize the meridional pathway of MJO convection, we track the latitude of maximum accumulated occurrence at each longitude (black dots in Fig. 2). Starting at 90°E, the candidate latitude with the highest occurrence is identified and the pathway is subsequently tracked by selecting the latitude with the highest occurrence within $\pm 10^\circ$ of the latitude selected at the preceding longitude. When multiple latitudes share the maximum occurrence, their mean latitude is calculated and the closest candidate is selected. Tracking is restricted to 20°S and 20°N and terminated when zero occurrence is found at two or more consecutive longitudes.

Finally, the MC detour index is defined as the meridional difference in the lag-accumulated MJO-related convection occurrence between the southern MC (SMC; 15–5°S, 110–150°E) and equatorial MC (EQMC; 5°S–5°N, 110–150°E) (Supplementary Fig. 5). For the 35 CMIP6 models, the MC detour index is normalized by the corresponding observational value (Fig. 3d).

MC propagation metric

The MC propagation metric based on intraseasonal precipitation anomalies was first proposed by Ahn et al. (2020a)⁴⁰ to evaluate the ability of model simulations to represent MJO propagation across the MC. To compute the MC propagation index, we continue to use the same lag-regression coefficients of 20–100-day bandpass-filtered OLR anomalies regressed onto the reference timeseries from 30-lead to 30-lag days as used for the MC detour metric. We then integrate the positive regression coefficients averaged latitudinally from 10°S to 10°N over the MC region (100–150°E) from 0- to 25-lag days. This integrated value is finally normalized by the corresponding observational value to yield the MC propagation metric for the 35 CMIP6 models (Fig. 4a).

Data

To detect MJO-related convection, we utilize the daily NOAA Interpolated OLR reanalysis data during the period of 1979–2018 as observational reference⁵⁷. To assess the performance of MJO propagation and

detouring behavior in contemporary climate models, we use daily historical simulations from 35 CMIP6 models with the r1i1p1f1 experiment configuration⁵⁸ (Table S1). The boreal winter (December–March) OLR, precipitable water vapor, and surface temperature data are analyzed during the period of 1975–2014. Due to the strong variability of precipitable water vapor and surface temperature in the tropics, their anomalies are normalized by the area-average over the tropical region (10°S–10°N, 40°E–80°W). All datasets are interpolated to a horizontal resolution of 2.5° by 2.5°.

Data Availability

The historical simulations produced by the 35 CMIP6 models were obtained from the ESGF data archive (<https://aims2.llnl.gov/search/cmip6>). The NOAA Interpolated Outgoing Longwave Radiation (OLR) reanalysis data was downloaded from the NOAA PSL website (<https://psl.noaa.gov/data/gridded/data.olrcdr.interp.html>).

Code Availability

The codes used to produce the results are publicly available on Zenodo at [DOI: TBA].

Declarations

Competing Interests

All authors declare no Competing Financial or Non-Financial Interests. Author D. Kim serves as Editorial Board Member of this journal and had no role in the peer-review or decision to publish this manuscript.

Author Contribution

D. Kang and D. Kim conceptualized the study. Y. Choi and D. Kang analyzed the data and prepared the figures. Y. Choi drafted the manuscript. All authors contributed to the writing and approved the final version of the manuscript.

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Figures

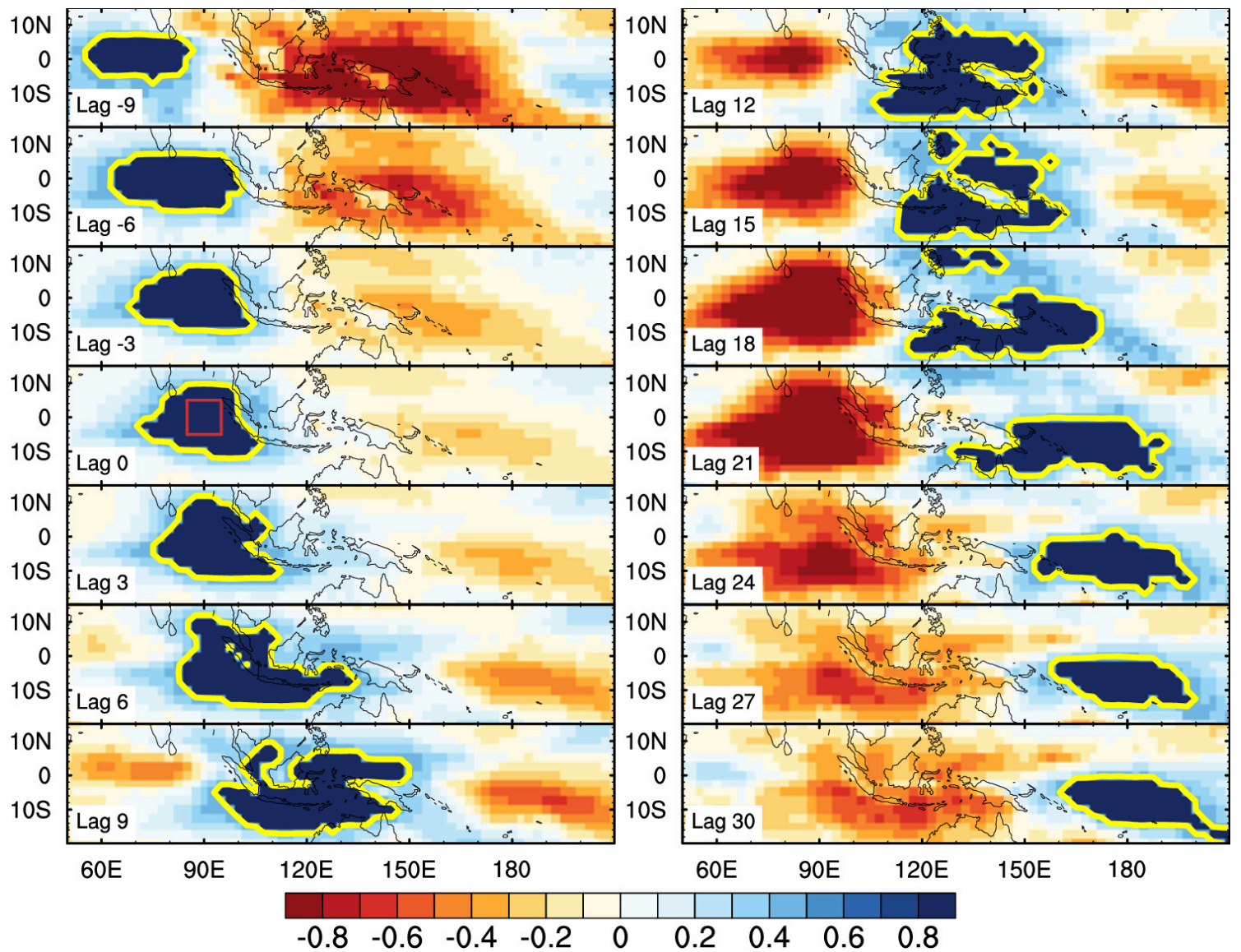


Figure 1

Observational MJO-related convection during boreal winter (December–March) for the period of 1979–2018. Spatial distributions of lag-regression coefficients of 20–100-day bandpass-filtered OLR anomalies onto the area-averaged OLR anomalies over the reference IO (red square at lag 0; 5°S–5°N, 85–95°E) where the equatorial MJO convective envelopes initiate and propagate toward the WP. The regression coefficients are normalized by the maximum value at each lag day within the analysis domain (30°S–30°N, 50°E–150°W). The MJO-related convection is highlighted within yellow line, which is identified when the normalized regression coefficients exceed 0.5 and is assigned a value of 1.

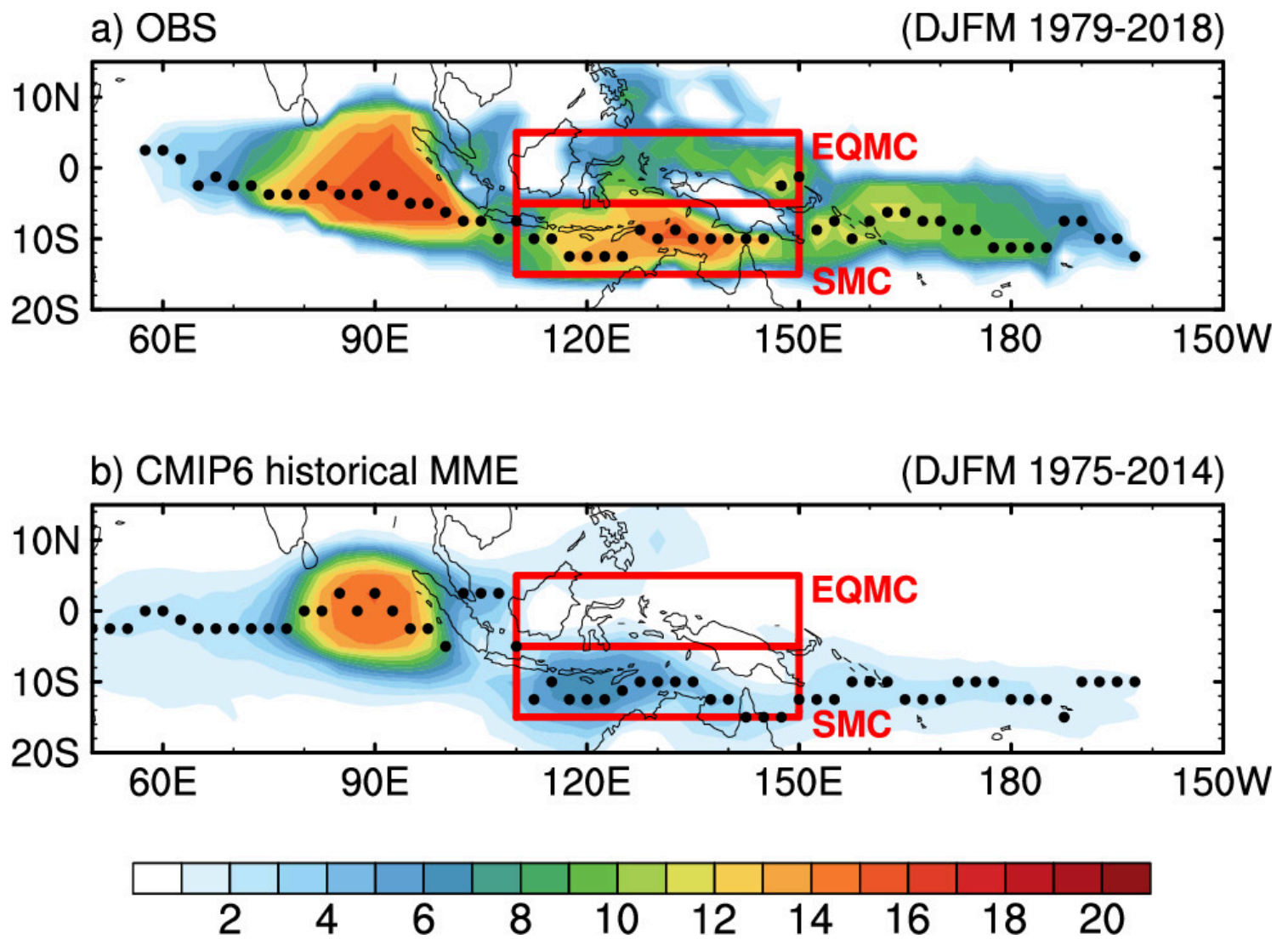


Figure 2

Spatial distributions of lag-accumulated occurrences of MJO propagation. Lag-accumulated occurrences (shading) of the MJO-related convection from 9-lead to 27-lag days, and the peak latitudes (black dots) indicating the most frequent MJO-related convection for (a) observation (OBS) and (b) CMIP6 historical multi-model ensemble (MME).

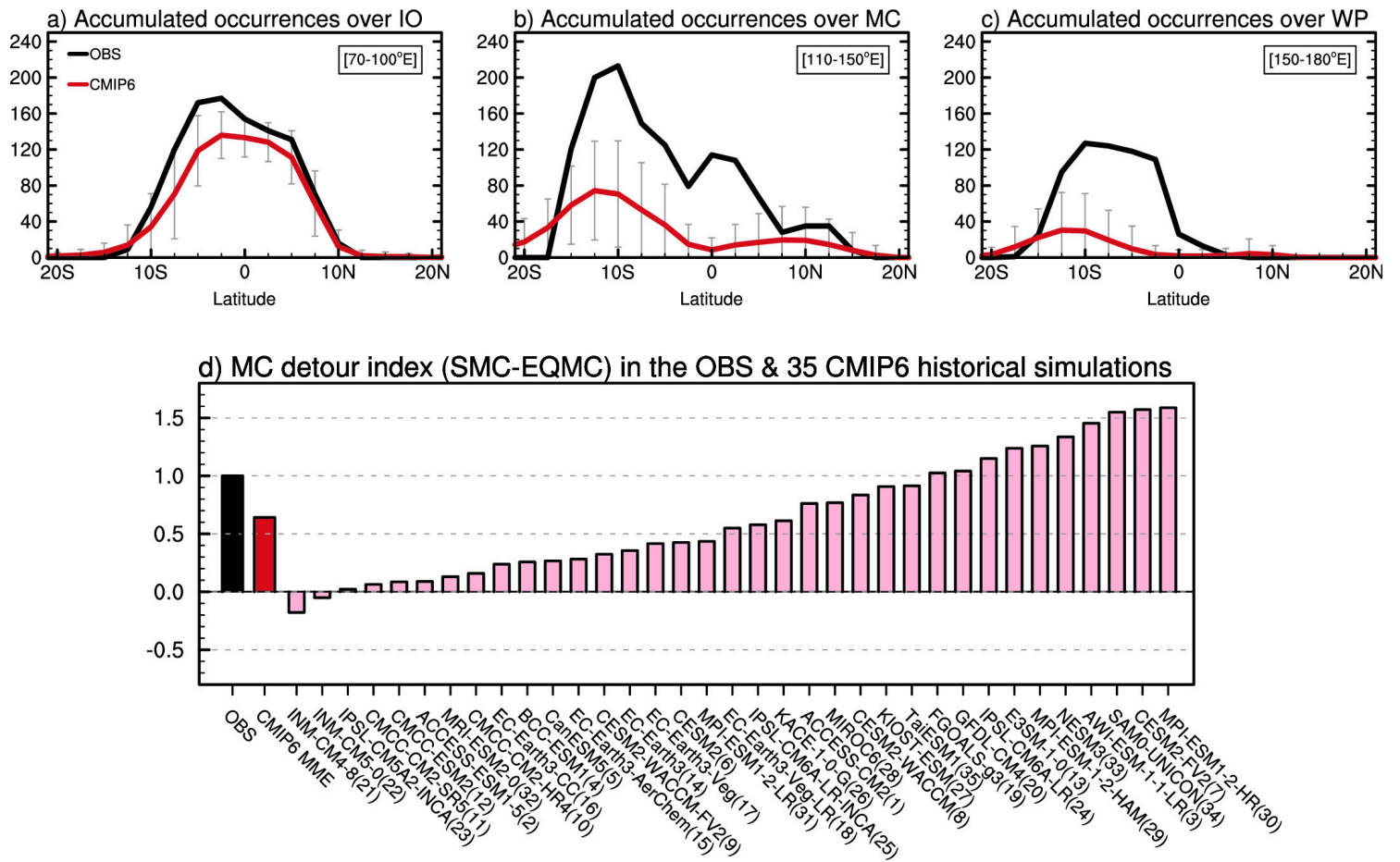


Figure 3

Assessment of MC propagation and detour in CMIP6 historical simulations. (a-c) Longitudinally integrated lag-accumulated occurrences of MJO-related convection over the (a) Indian Ocean (IO; 70–100°E), (b) Maritime Continent (MC; 110–150°E), and (c) western Pacific (WP; 150–180°E) for OBS (black) and CMIP6 historical MME (red) with gray error bars indicating one standard deviation. (d) MC detour index for CMIP6 MME and 35 individual models (arranged in ascending order) normalized by the OBS. The MC detour index is defined as the meridional difference in the lag-accumulated occurrences of MJO-related convection integrated between the southern MC (SMC; 15–5°S, 110–150°E) and equatorial MC (EQMC; 5°S–5°N, 110–150°E).

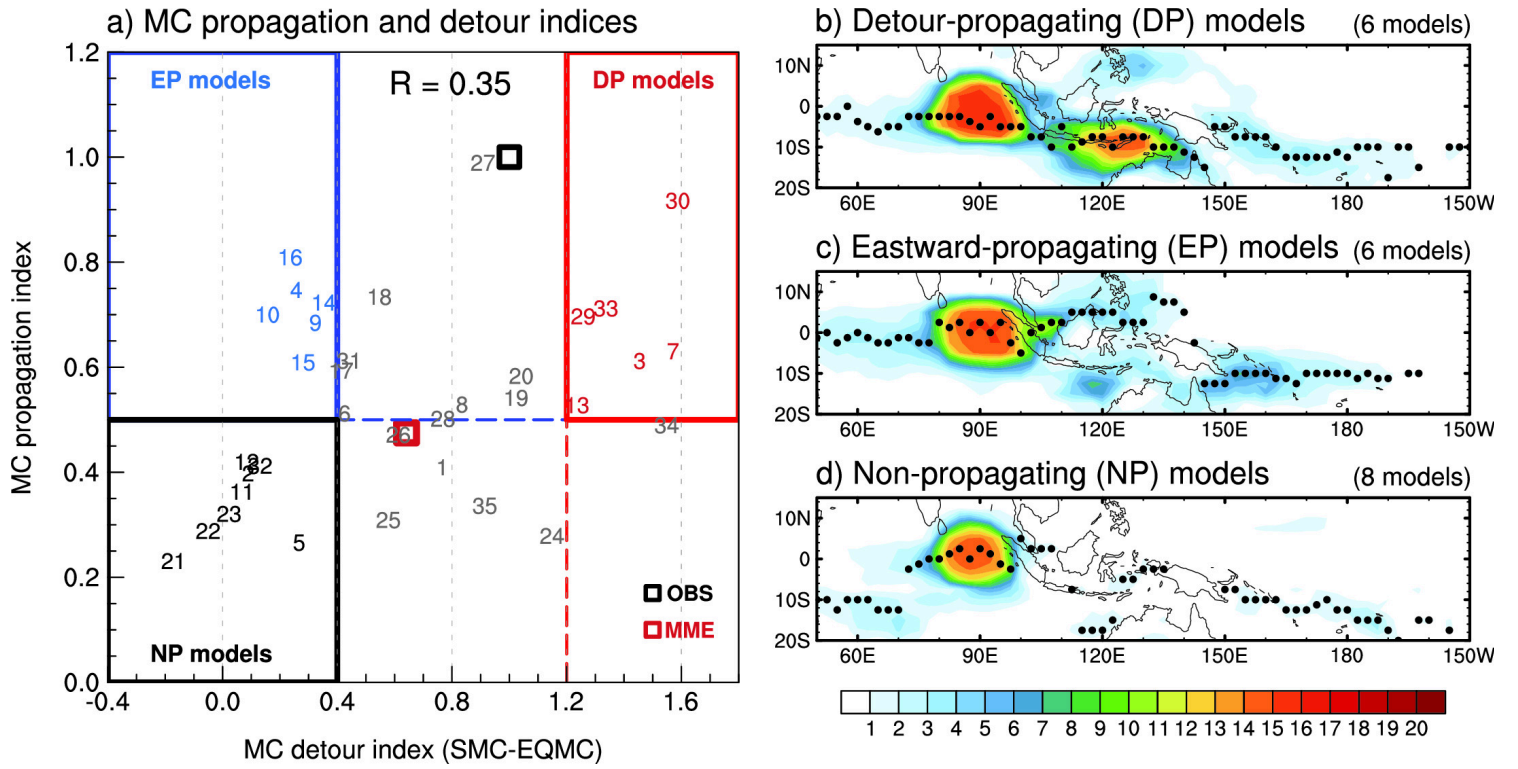


Figure 4

Clustering of MJO simulations based on the success of eastward propagation and southward detour. (a) Scatter plot of MC propagation index versus MC detour index for the 35 CMIP6 models normalized by the OBS. The MC propagation index is defined as the integration of positive tropical averaged (10°S–10°N) regression coefficients over the MC (100–150°E) during 0–25-lag days (Ahn et al. 2020a)⁴⁰. Black and red squares denote the OBS and CMIP6 MME, respectively. (b-d) Same as Fig. 2, except for (b) detour-propagating models (DP models; 6 models with MC propagation index > 0.5 and MC detour index > 1.2), (c) eastward-propagating models (EP models; 6 models with MC propagation index > 0.5 and MC detour index < 0.4), and (d) non-propagating models (NP models; 8 models with MC propagation index < 0.5 and MC detour index < 0.4).

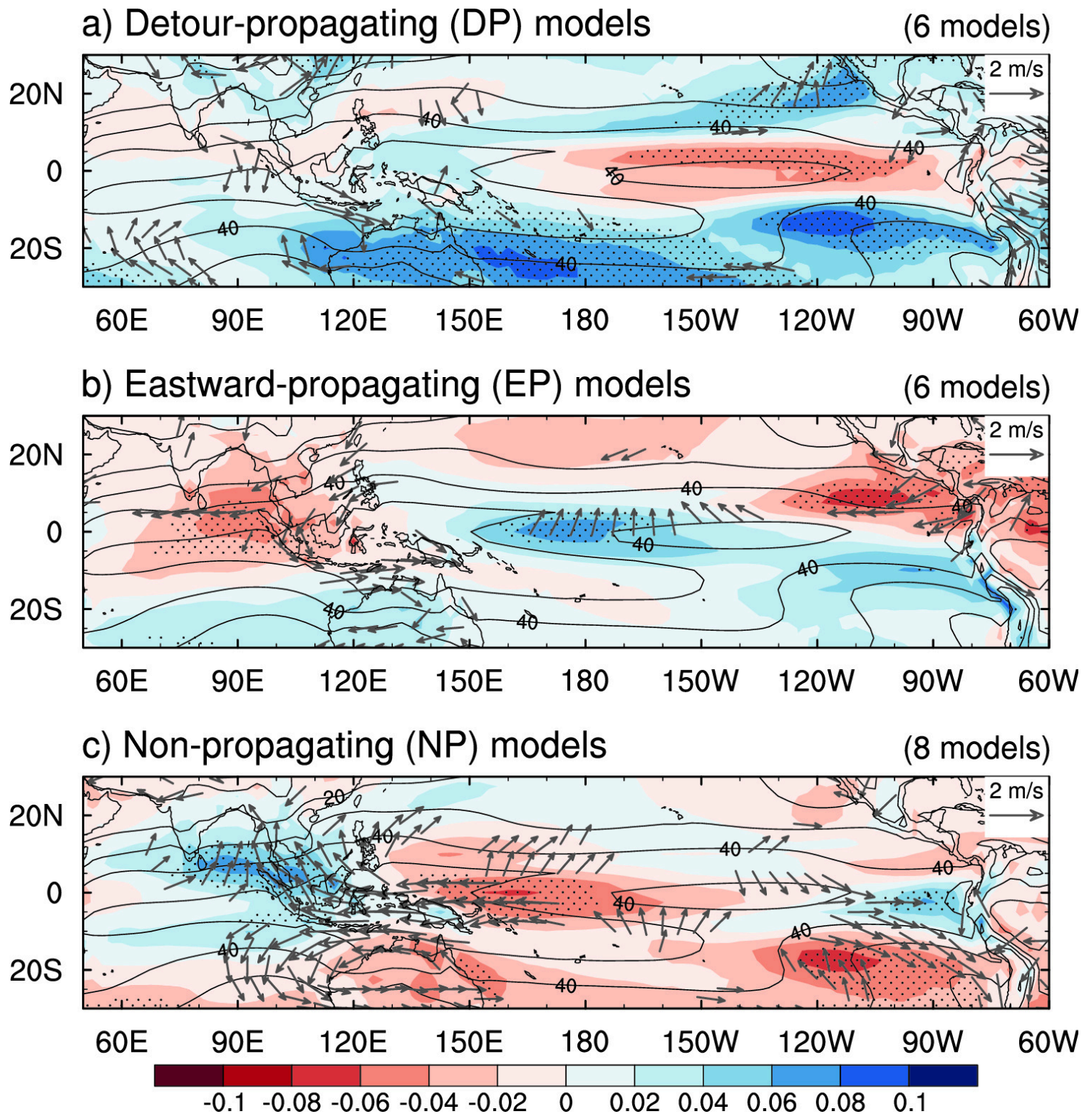


Figure 5

Background fields of moisture and wind anomalies from the CMIP6 MME based on the success of eastward propagation and southward detour. Composite maps of normalized precipitable water vapor anomalies (shading) by the area-average over the tropical region (10°S–10°N, 40°E–80°W) and 850-hPa wind anomalies (vector) in the (a) detour-propagating models (DP models; 6 models), (b) eastward-propagating models (EP models; 6 models), and (c) non-propagating models (NP models; 8 models).

The contours indicate the 35 CMIP6 MME climatology of precipitable water vapor. The dots denote the statistical significance at the 90% confidence level. The wind vectors in either zonal or meridional component are plotted at the 90% confidence level.

Supplementary Files

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