# Equatorial 2-Day Waves and Diurnal Variations during DYNAMO: Observation vs. Simulation

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## Introduction

This study analyzes model simulations and observations during DYNAMO to examine the dynamics and variability of equatorial 2-day waves and diurnal variations and their potential effects on the MJO.

The observations include the 8-km hourly CMORPH precipitation, the ECMWF-interim wind analyses and the 3-hourly DYNAMO soundings at the Gan Island during 1 October - 20 November 2011. The WRF model (v3.3.1) is used to perform a continuous convection-permitting simulation during this same period with 9-km grid spacing and 45 vertical levels up to 20 hPa. To prevent circulation drift, we use a spectral nudging method that nudges scales over 2000km for wind, temperature, moisture and geopotential toward ECMWF analyses.

The observed and simulated 2-day waves and diurnal variations are compared.

## Observed and Simulated Precipitation

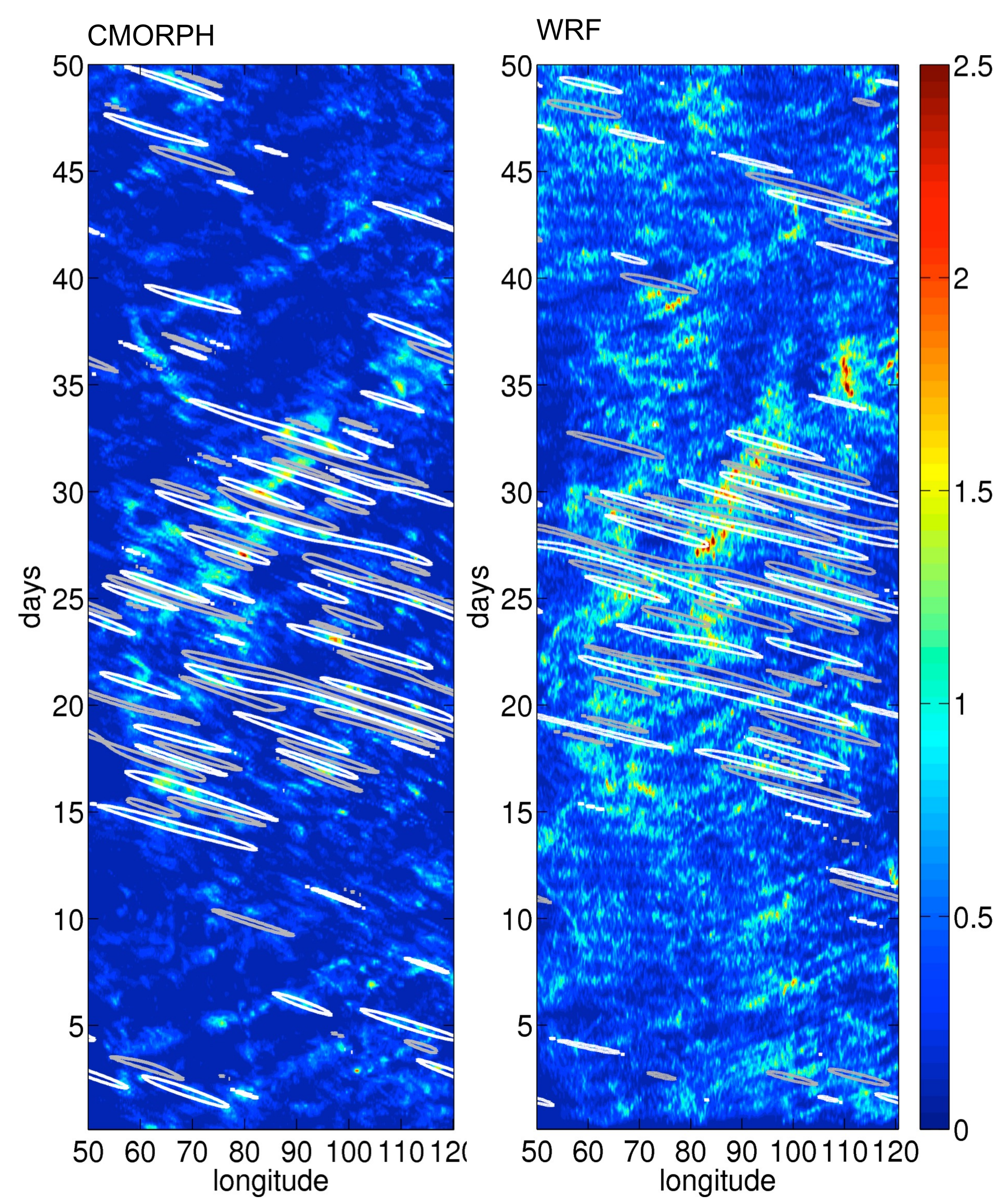


Fig. 1: Time-longitude diagrams of (a) CMORPH 8 km and (b) WRF-simulated 9 km precipitation during the 2011-10-01 to 2011-11-20 period. White (positive) and grey (negative) contours show the filtered 2-day waves (westward propagating inertia-gravity wave)

A complete MJO event was captured by both the observation and simulation (Fig. 1). The filtered high-frequency (2-day) waves are highlighted in Fig. 1 during this MJO event.

## Space-Time Spectra

A space-time spectral analysis is performed to extract different waves from the precipitation data (Fig. 2). Similar to Tulich and Kiladis (2012), the westward interio-gravity wave (WIG) signal can have a wavelength and period as small as 500 km and 8 h, respectively. Fig. 2 also shows a strong diurnal cycle in the WIG region of the observations.

The simulated results generally agree with the observations, except that the eastward signal is much stronger. The spurious eastward signal may be due to variations in SST or low-level vertical wind shear, but further investigation is required.

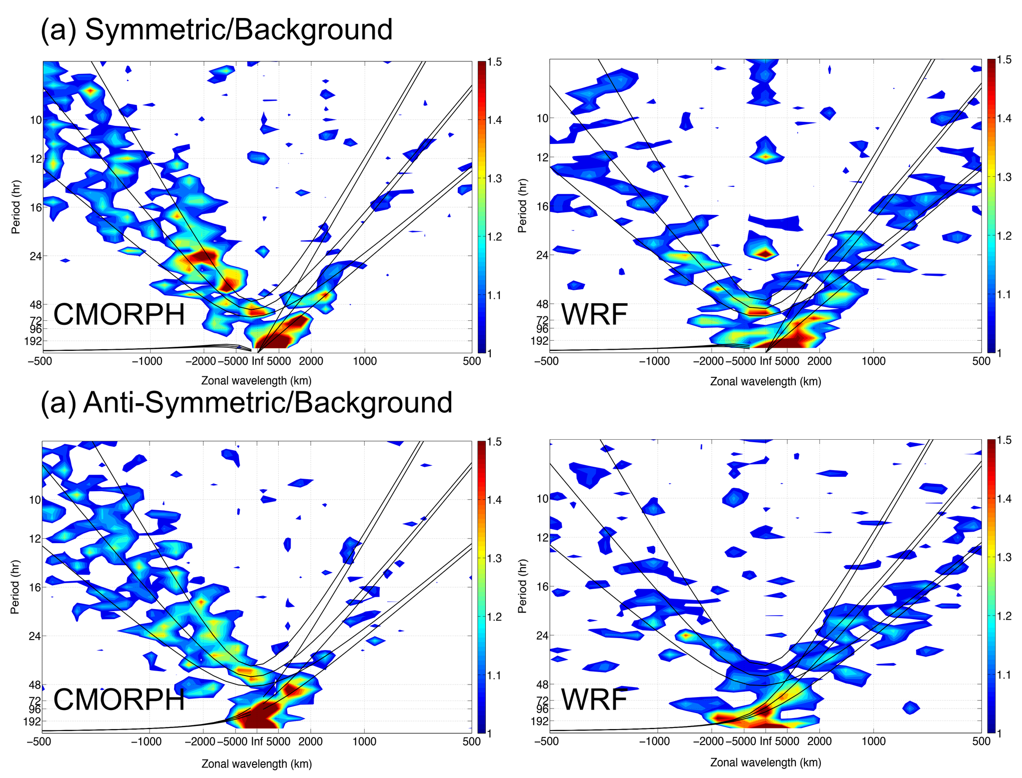


Fig. 2: Space-time spectra (Wheeler and Kiladis 1999) of observed and simulated precipitation. Reference lines of dispersion relation (shallow-water He=12, 25 and 50m) are shown.

## 2-Day Waves

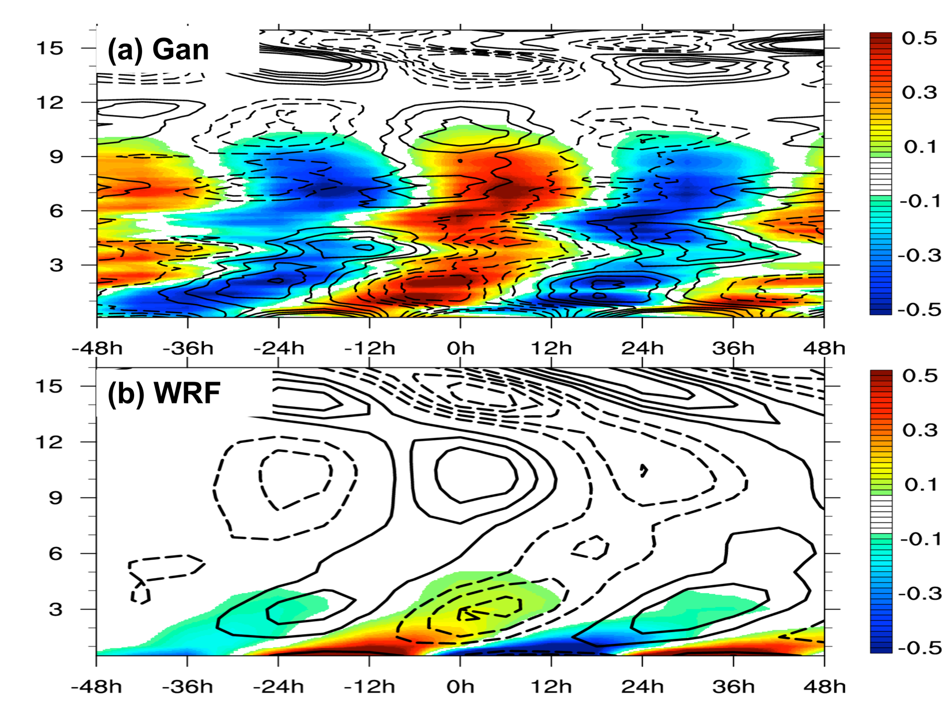


Fig. 3: Composite vertical structure of 2-day waves (temperature in contours and specific humidity in shadings) using (a) Gan island sounding data; (b) WRF simulation. Results are obtained from lagged linear regression of raw data onto 1.5~3 day band pass filtered precipitation time series for a set of 50 base point on the equator.

The vertical structure of a typical 2-day wave is plotted in Fig. 3a from the Gan Island soundings. The wave is accompanied by a temperature dipole and a quick buildup of moisture from the lower to upper levels.

The WRF simulation captures the temperature dipole and buildup of low-level moisture quite well (Fig. 3b) but mid-to-upper tropospheric (6-9km) moisture shown in the sounding, possibly due to a mid-level stratiform region, is noticeably absent from the simulation.

The 2-day wave has a horizontal length scale of about 2000 km, with a phase speed of about 15 m/s.

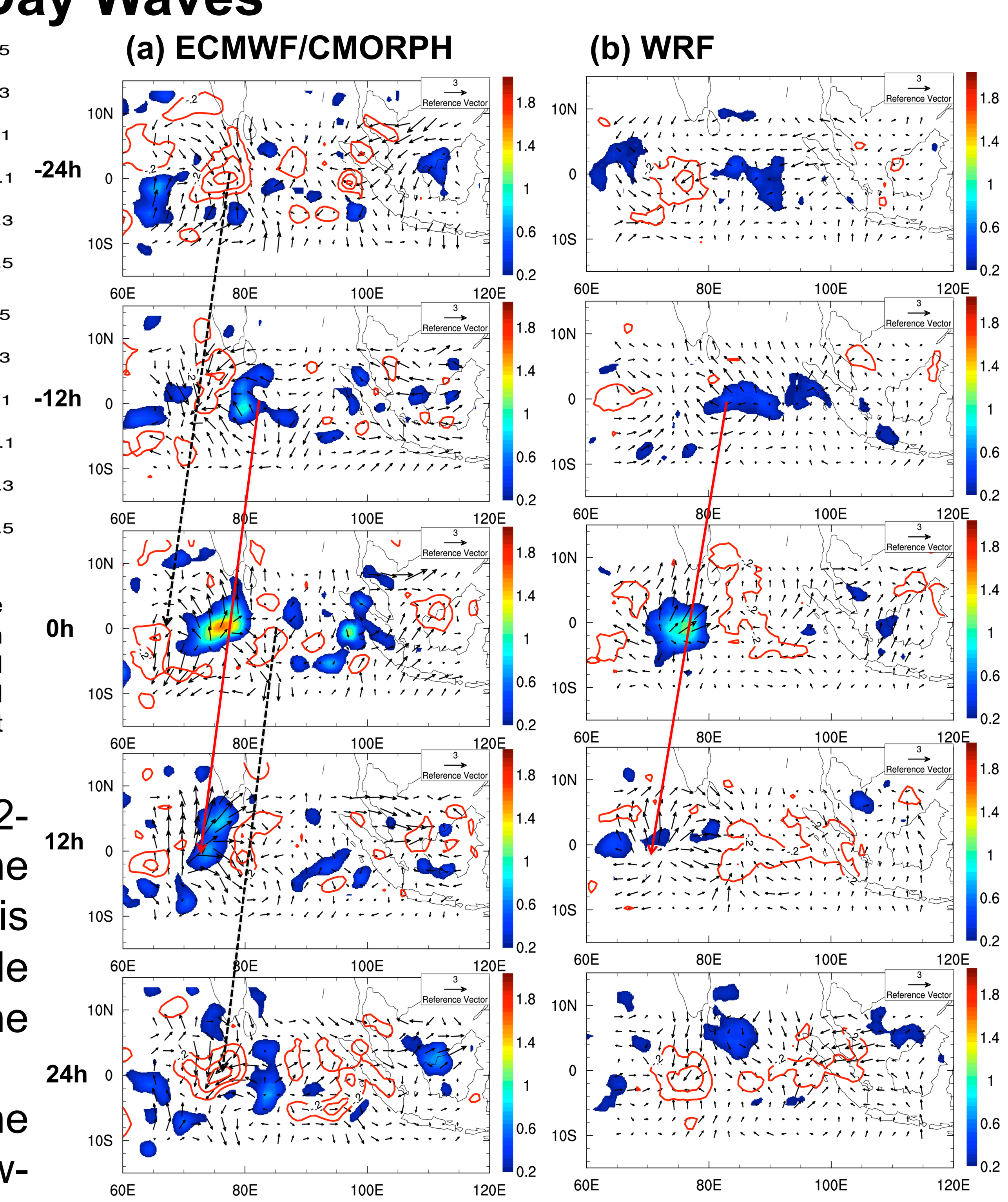


Fig. 3: Composite 200-hPa wind vectors and precipitation maps from -24 to 24h. (a) ECMWF-interim wind analysis and CMORPH precipitation; (b) WRF simulation. Positive value is shaded, contour is negative value from -0.2 to -1.0 with an interval of 0.4.

The signal is generally stronger at 60~70° E, and the model can catch most of the pattern with the exception of some details.

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## Diurnal Variations

The westward propagating diurnal variations over the maritime continental region (~100° E) are represented well by the model. The model, however, overestimates the precipitation over the Indian Ocean; a zonal wind bias in the simulations is one possible reason why the propagation over the ocean is not captured very well.

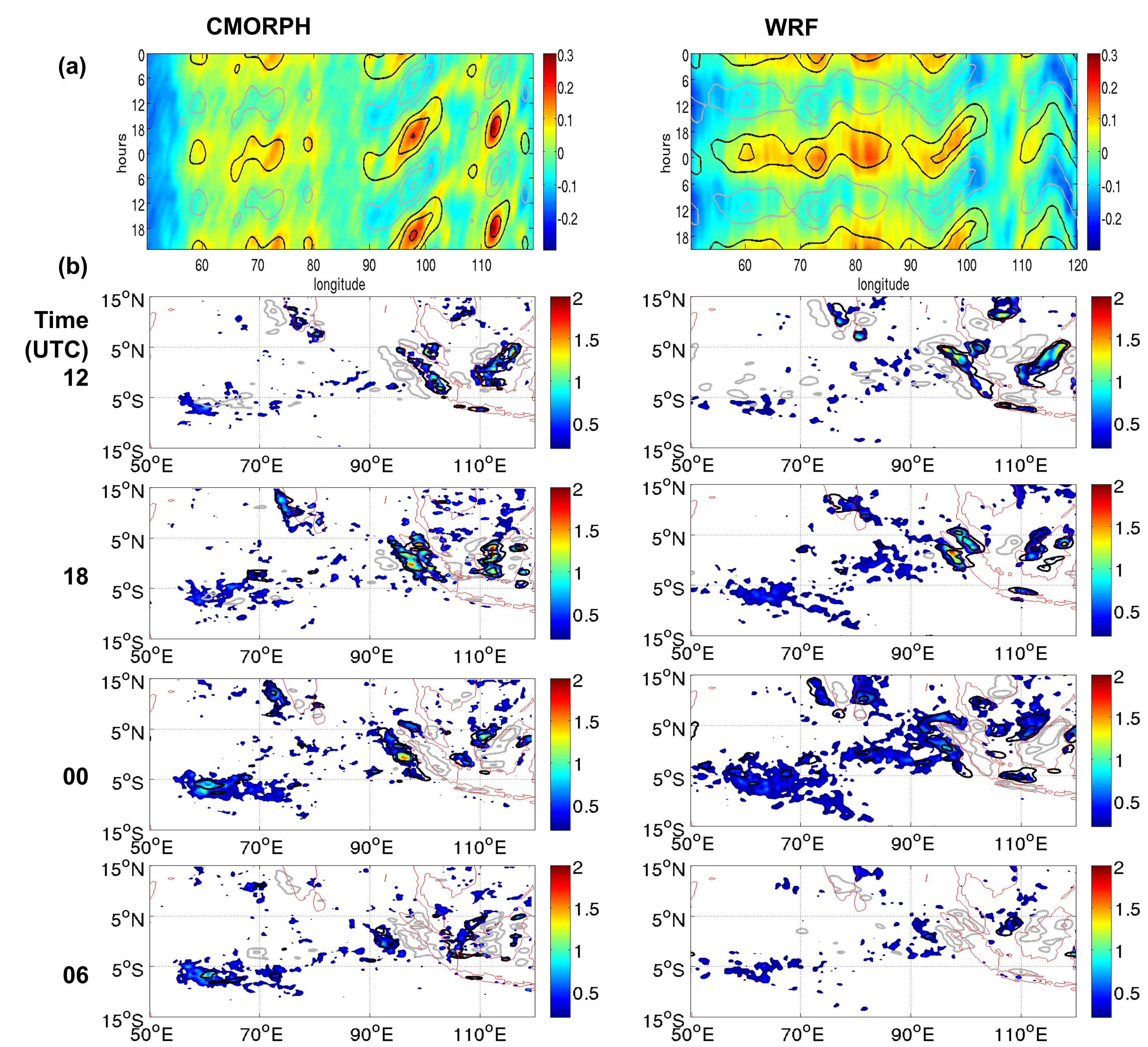


Fig. 5: (a) Longitude-time diagrams of 48-h composite mean of precipitation during the 2011-10-1 to 2011-11-20 period. (b) 6-hourly maps of composite mean precipitation. The black (gray) thick contours show the positive (negative) diurnal cycle anomalies extracted with a space-time filter.

## Concluding Remarks

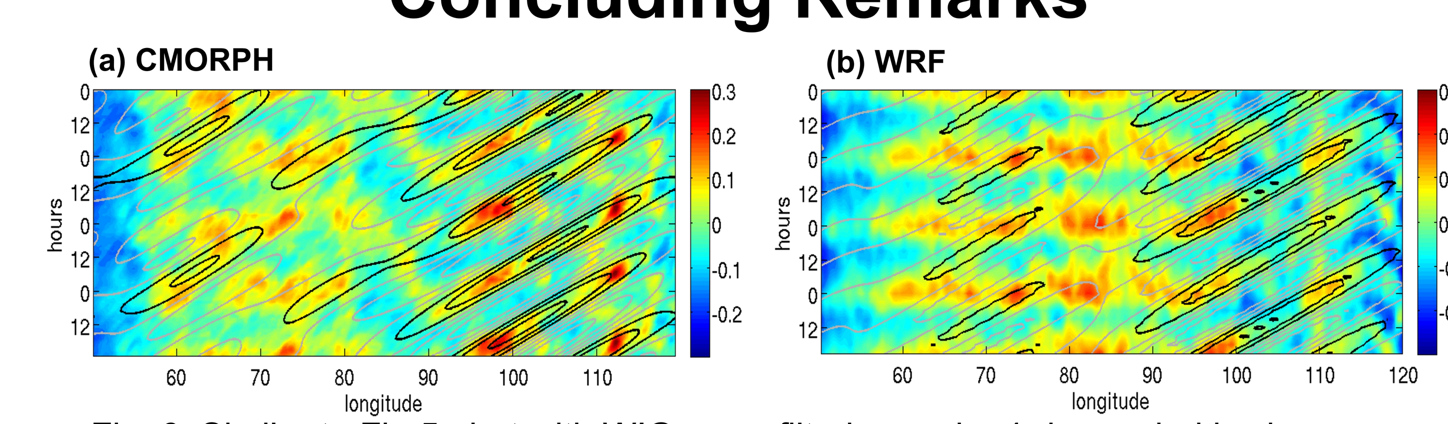


Fig. 6: Similar to Fig.5a but with WIG wave filtering and a 4-day period is shown.

The model simulation captured the general wave features of 2-day waves and diurnal variations, while missing some details for the 2-day and overestimating the eastward propagating WIGs.

We hypothesize that the strong precipitation diurnal cycle triggered over the Maritime Continents propagates westward in the form of WIG waves, and transitions into 2-day waves over the eastern Indian Ocean (Fig. 6a), possibly influencing the MJO initiation. However, the model still cannot capture this transition well (Fig. 6b), thus further investigation is needed.