Modulation of subtropical stratospheric gravity waves by equatorial rainfall

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Introduction & Motivation

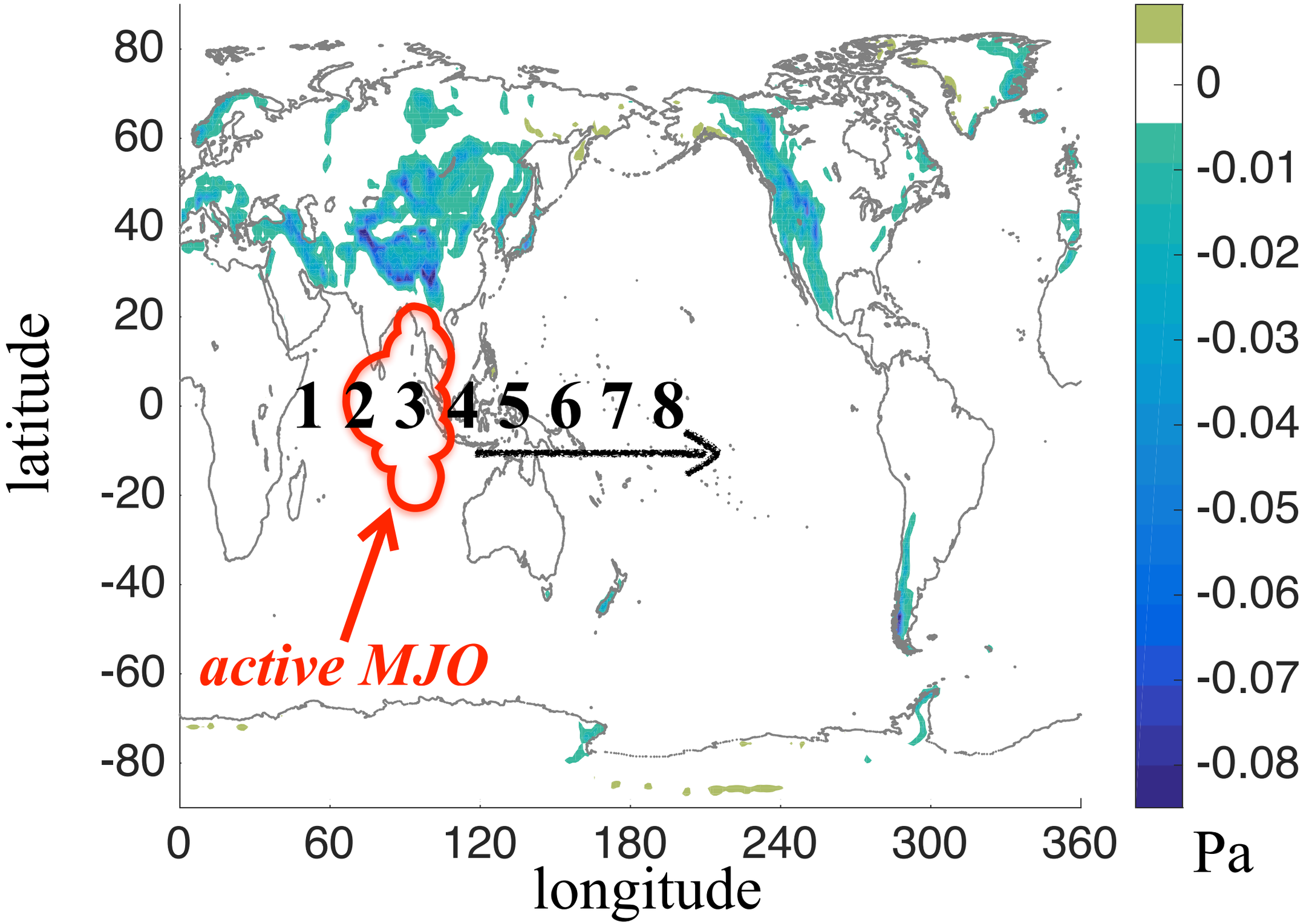
The Madden-Julian Oscillation (MJO) is the dominant mode of sub-seasonal variability in the equatorial atmosphere, while the Tibetan Plateau provides the largest source of gravity waves and orographic wave drag on Earth.

Both phenomena are highly important but operate in distinct domains and are not obviously physically related.

<u>Why should there be any relation between the two?</u>

Tropical rainfall and the extratropical waves

Integrated GWD (above 400hPa, MERRA DJF 1979-2012)



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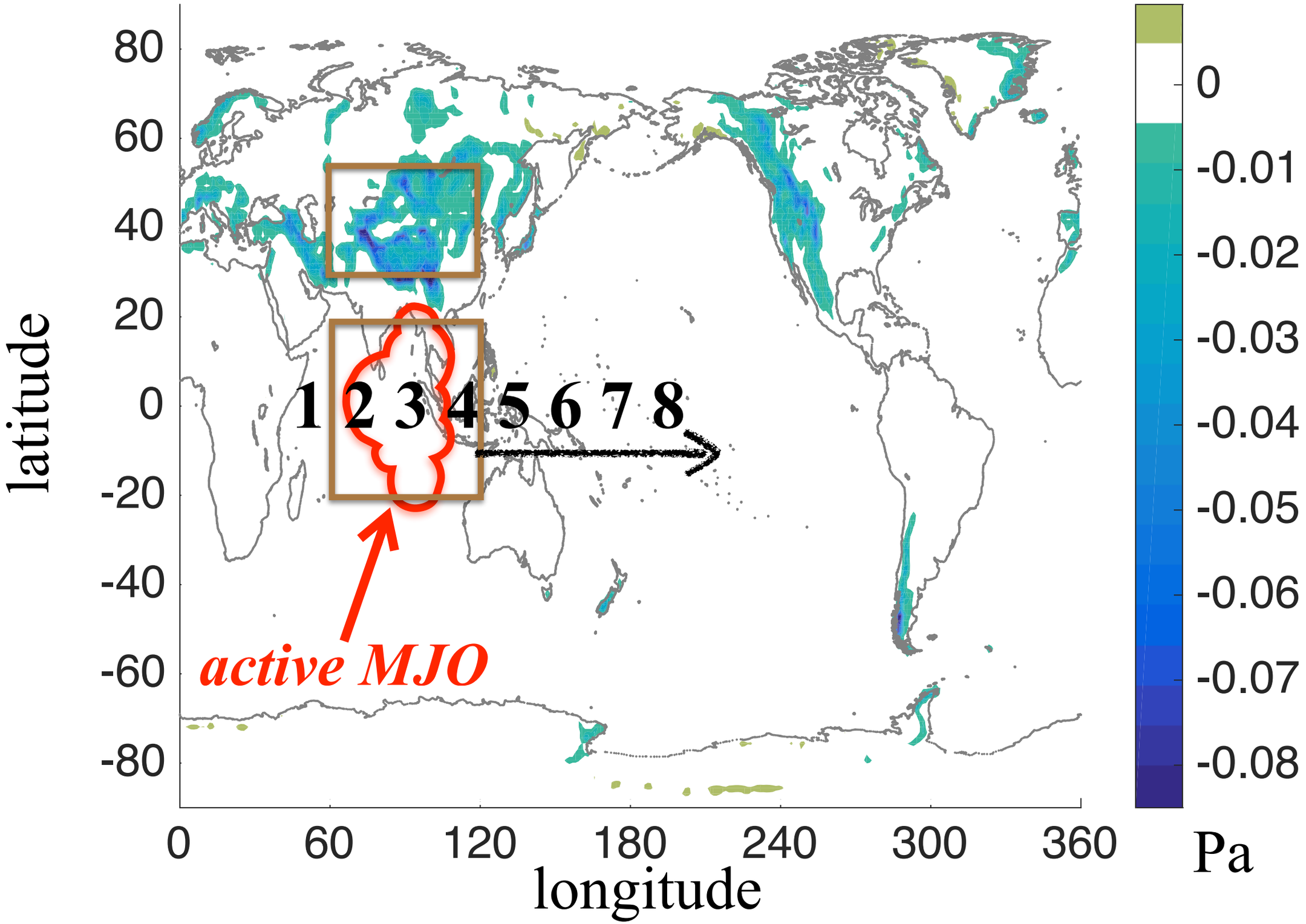
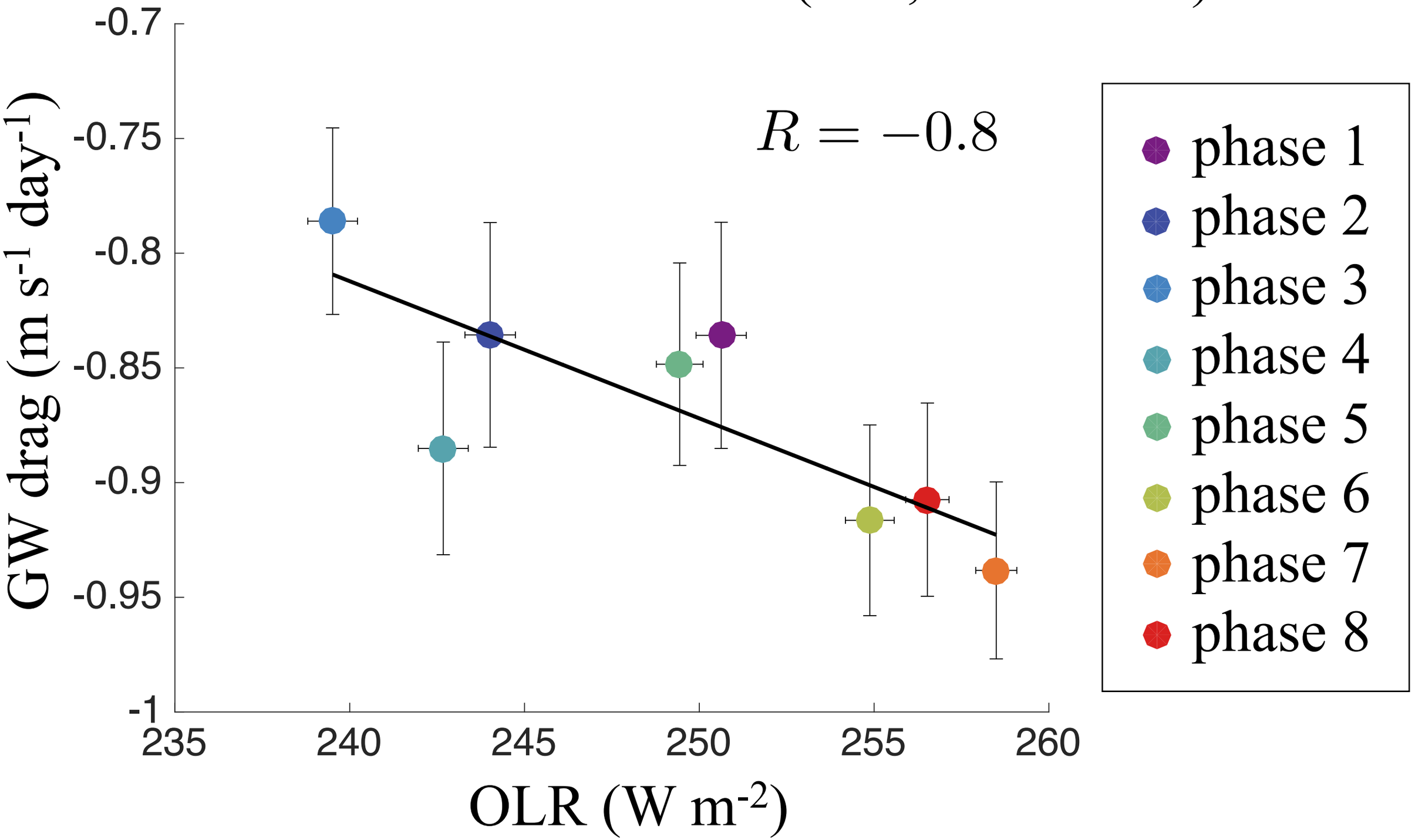


The statistical association between the MJO and GW drag over Tibet

MERRA & NOAA OLR (DJF, 1979-2013)



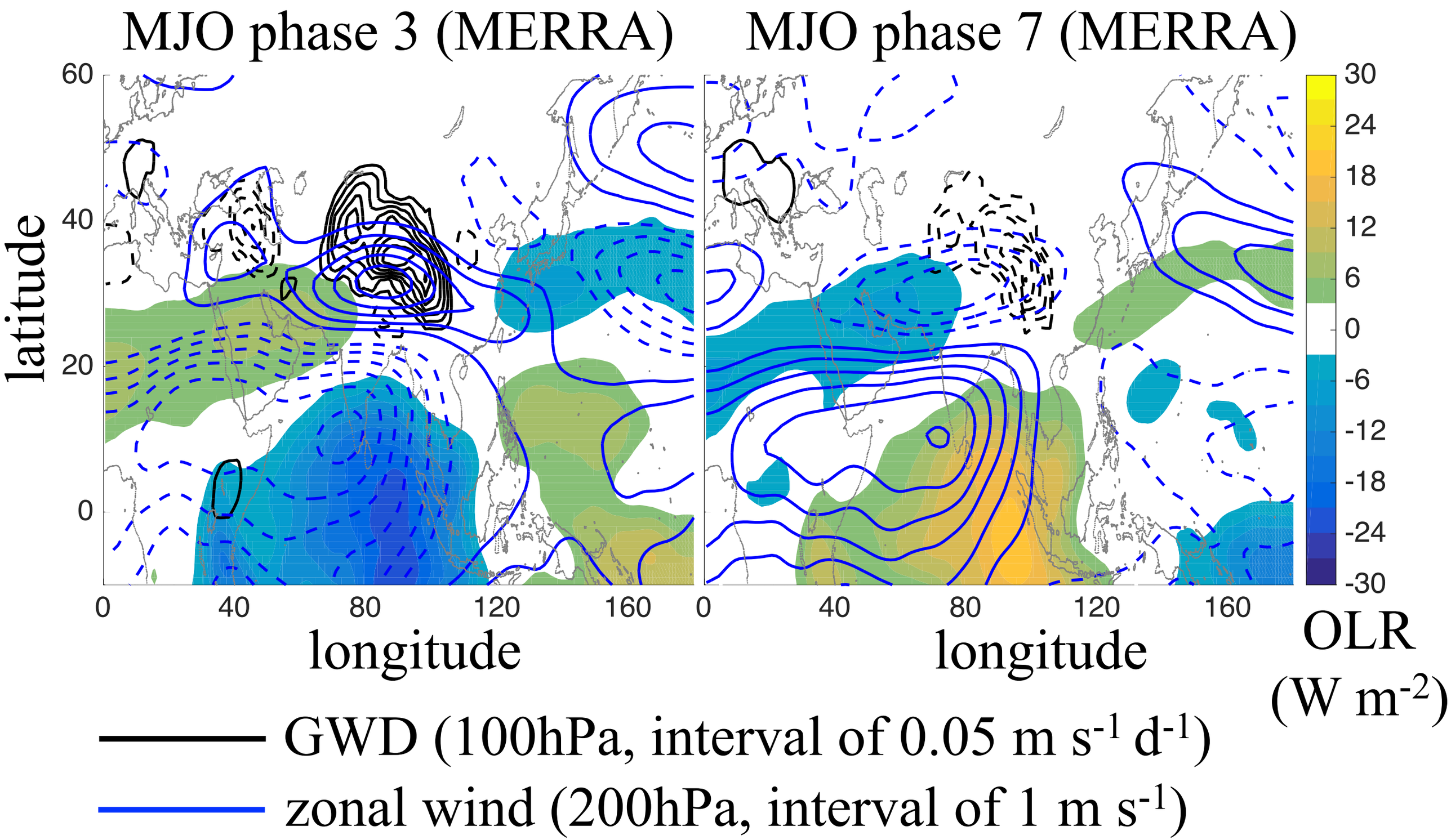
The statistical association between the MJO and GW drag over Tibet

GWD / OLR data source	Correlation
MERRA / NOAA OLR	-0.81
MERRA* / NOAA OLR	-0.78
MERRA / MERRA	-0.84
JRA55 / NOAA OLR	-0.82
JRA55* / NOAA OLR	-0.71
JRA55 / JRA55	-0.94

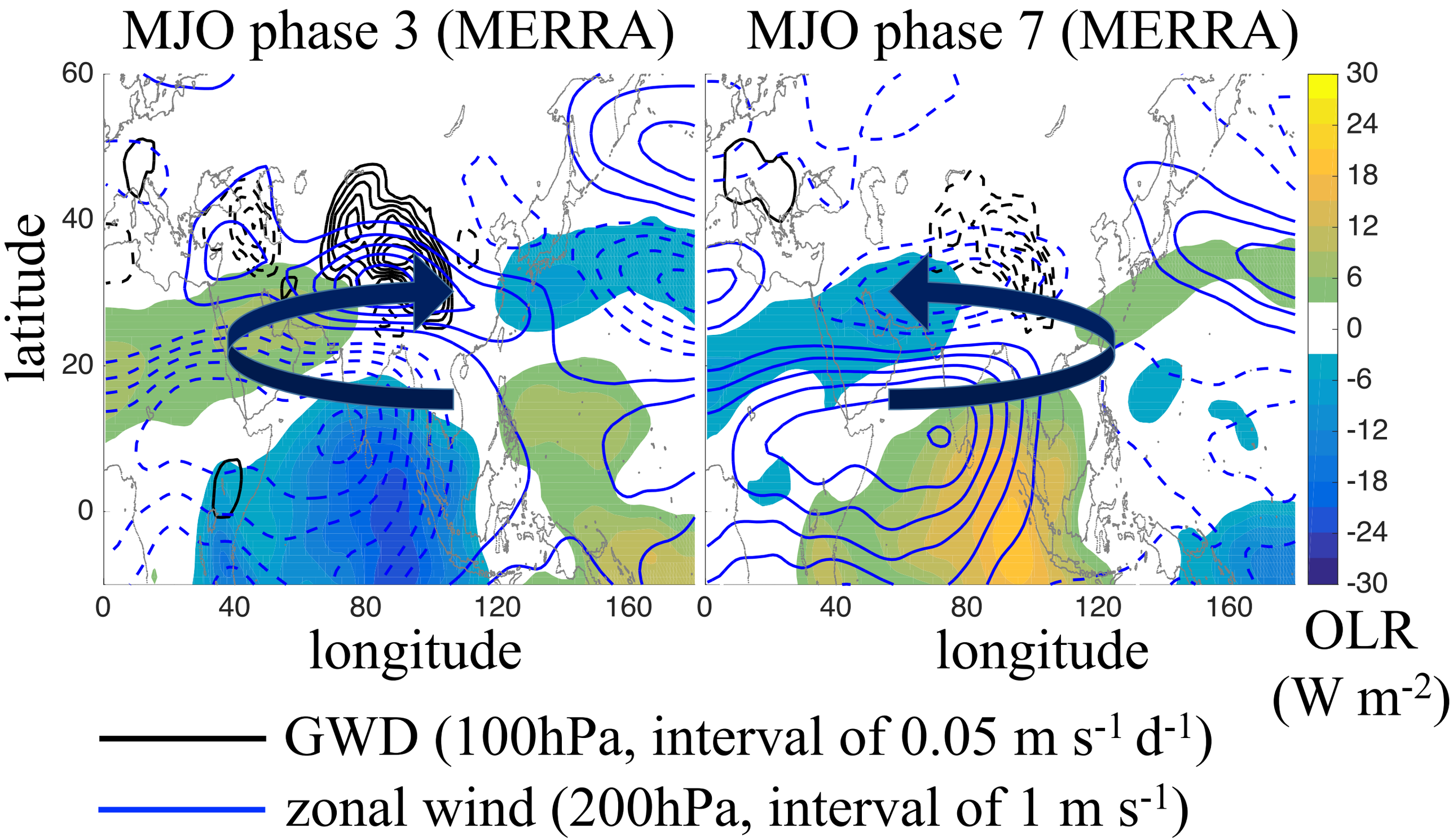
All linear regression slopes are negative and statistically significant

* “highly defined” MJO event

Horizontal structures of MJO and GW drag anomalies

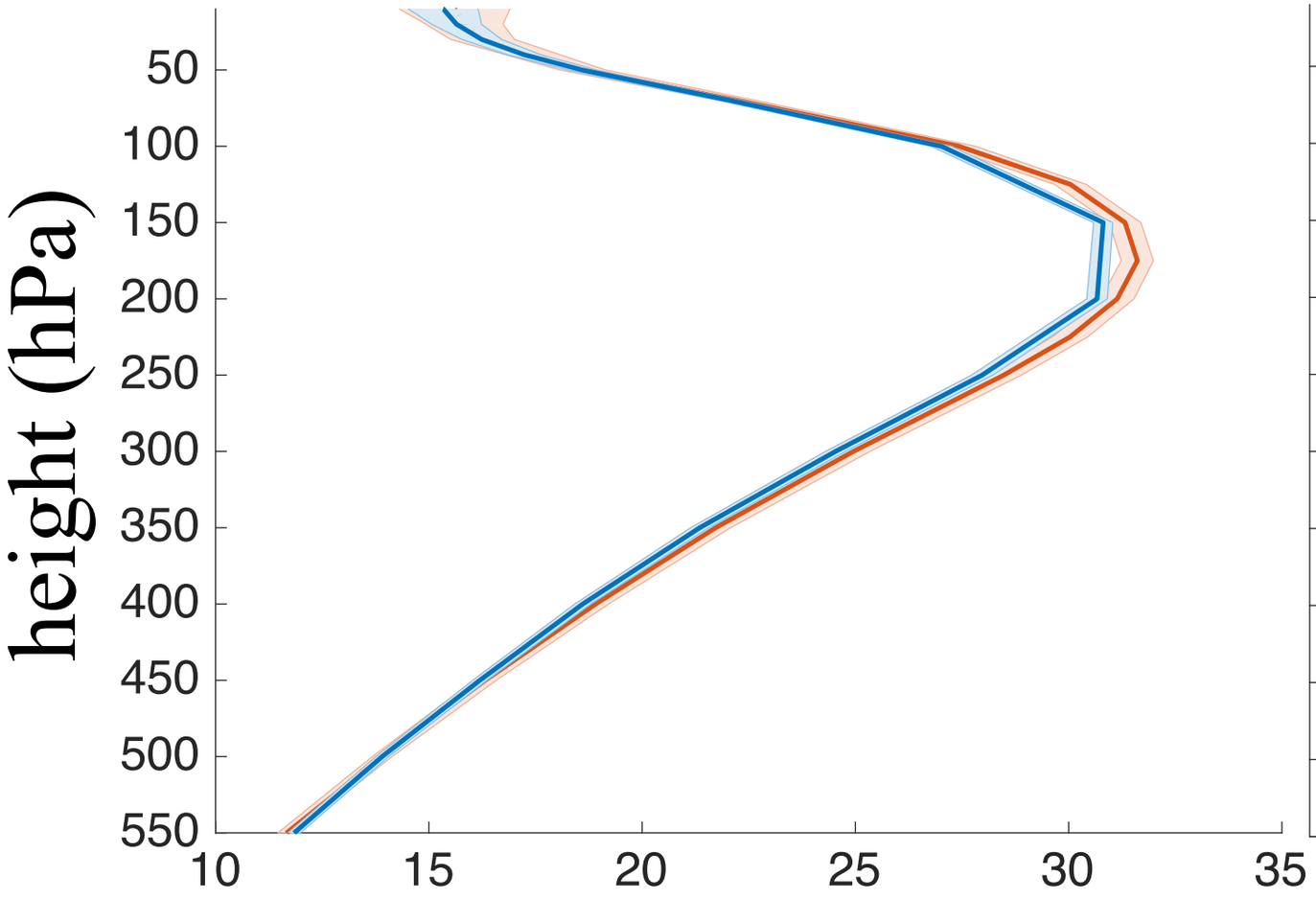


Horizontal structures of MJO and GW drag anomalies

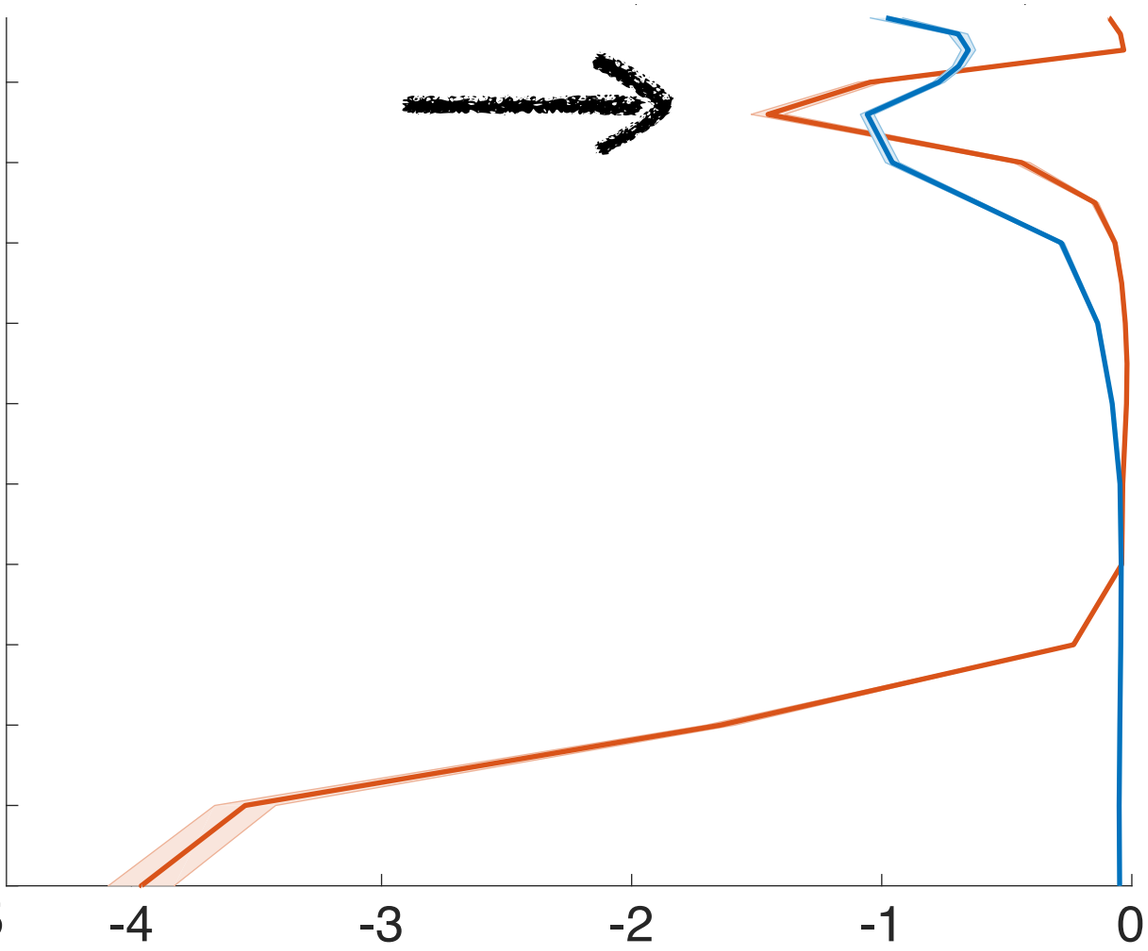


Vertical structures of the *climatological* zonal wind and GW drag over the Plateau

climatology



climatology



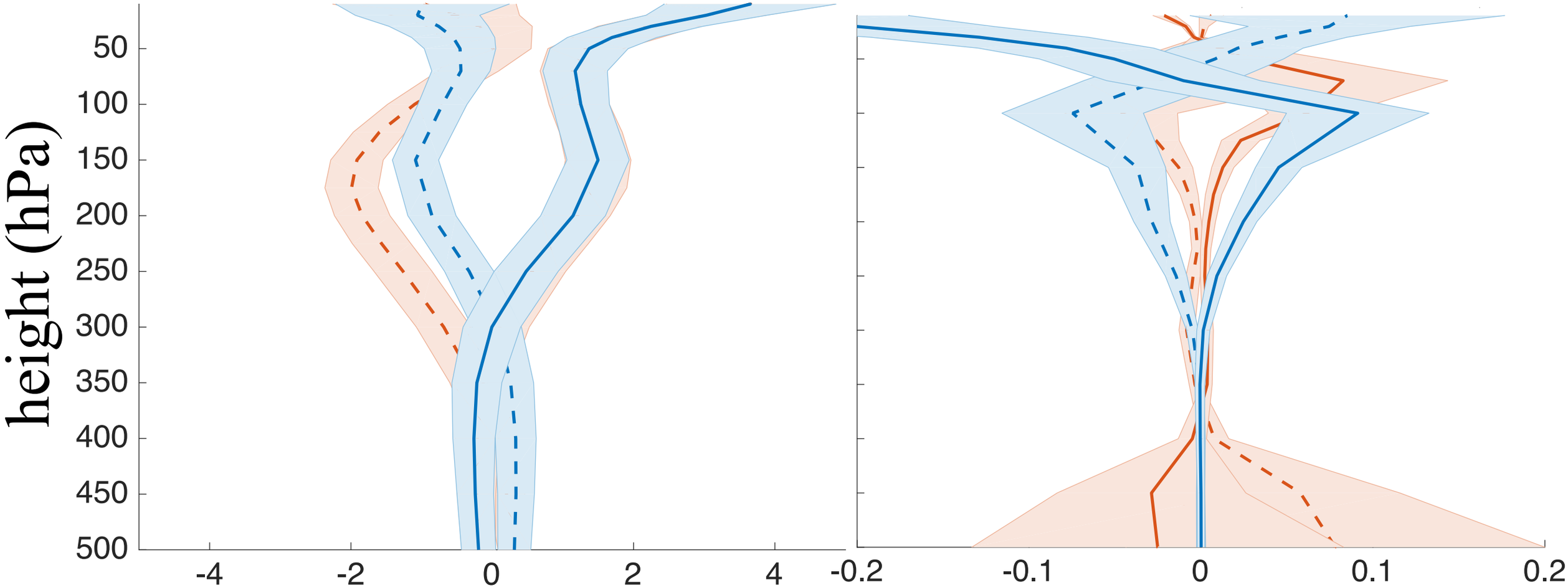
MERRA

JRA55

Vertical structures of the *anomalous* zonal wind and GW drag

anomalous

anomalous



MERRA (phase 3)

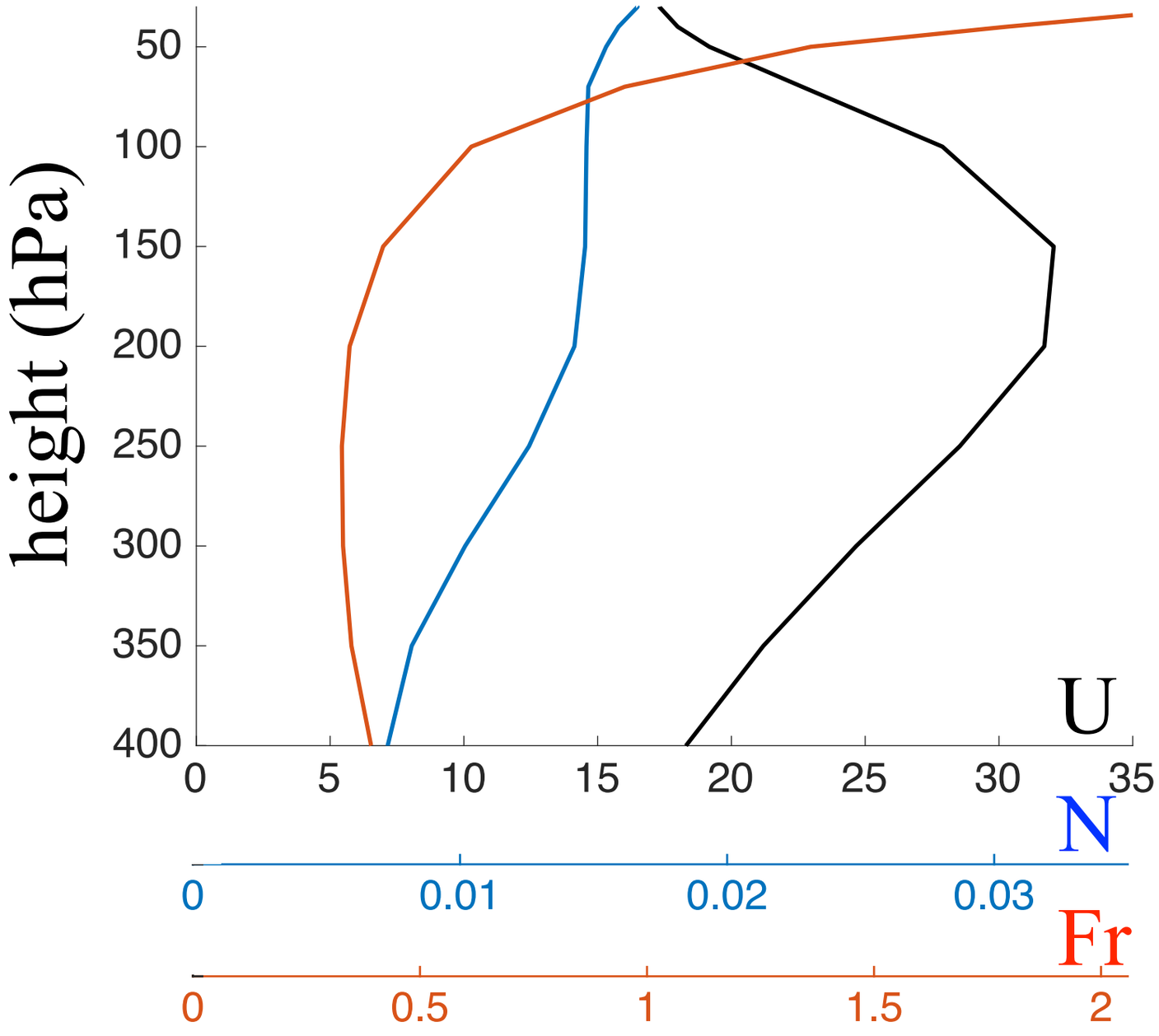
MERRA (phase 7)

JRA55 (phase 3)

JRA55 (phase 8)

Simple mechanism for the interaction

Stability criterion: $Fr = \left(\frac{Nh}{U}\right)\sqrt{\frac{\rho_0 N_0 U_0}{\rho N U}} \leq 1$



Climatological mean (DJF)

U (m s^{-1})

N (s^{-1})

Fr

Simple mechanism for the interaction

Stability criterion: $Fr = \left(\frac{Nh}{U}\right)\sqrt{\frac{\rho_0 N_0 U_0}{\rho N U}} \leq 1$

convectively suppressed MJO

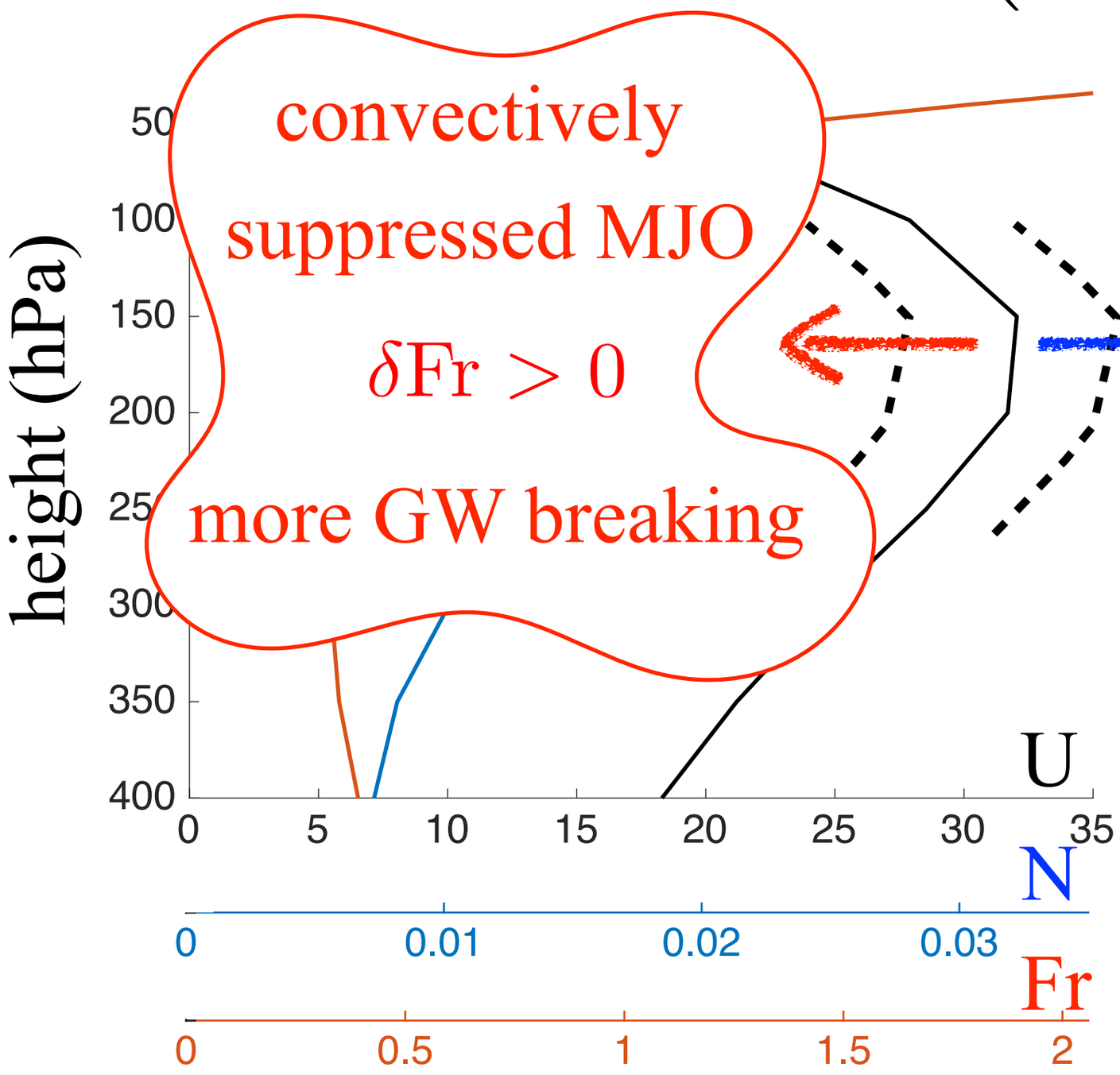
$\delta Fr > 0$

more GW breaking

convectively active MJO

$\delta Fr < 0$

less GW breaking



U (m s^{-1})

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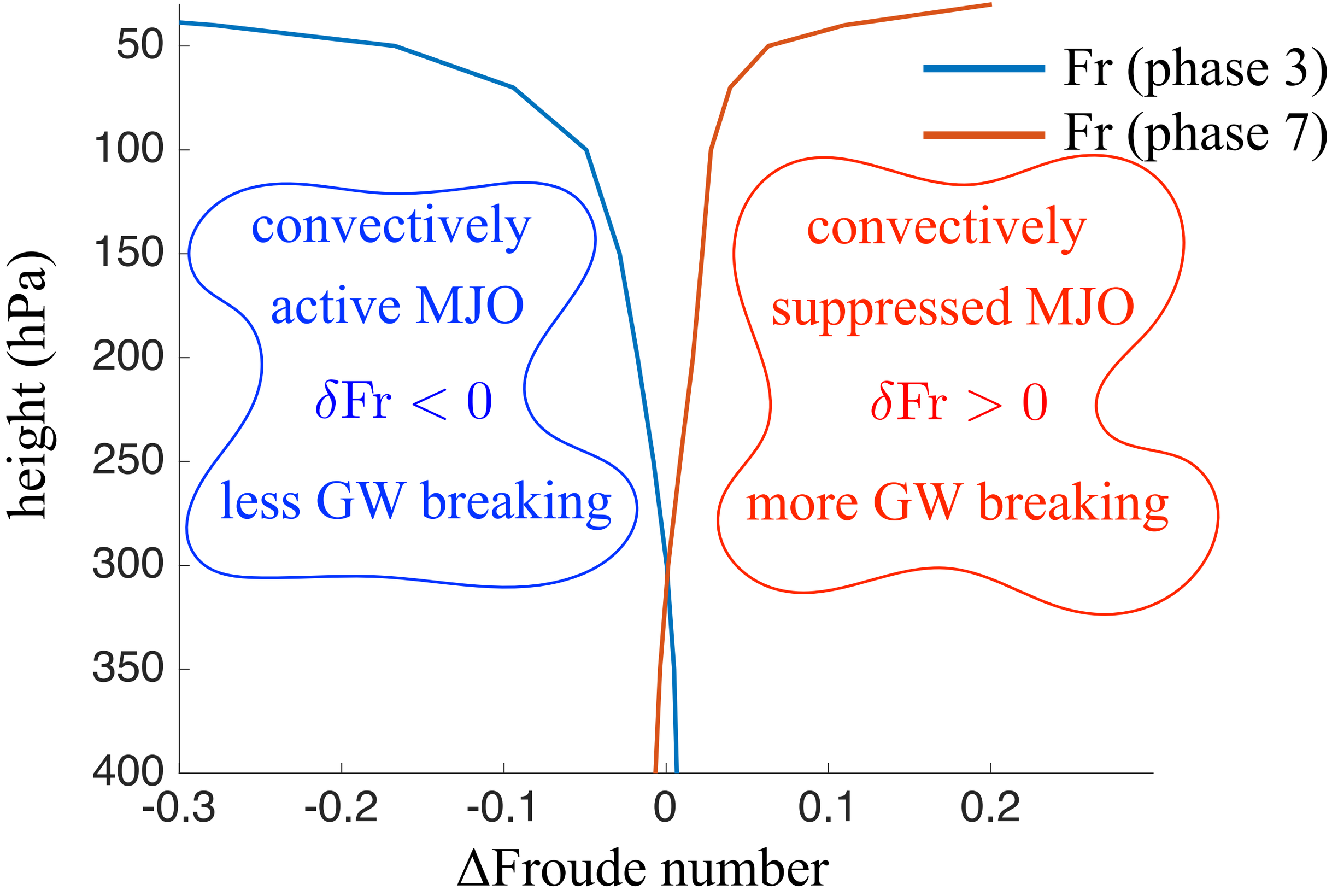
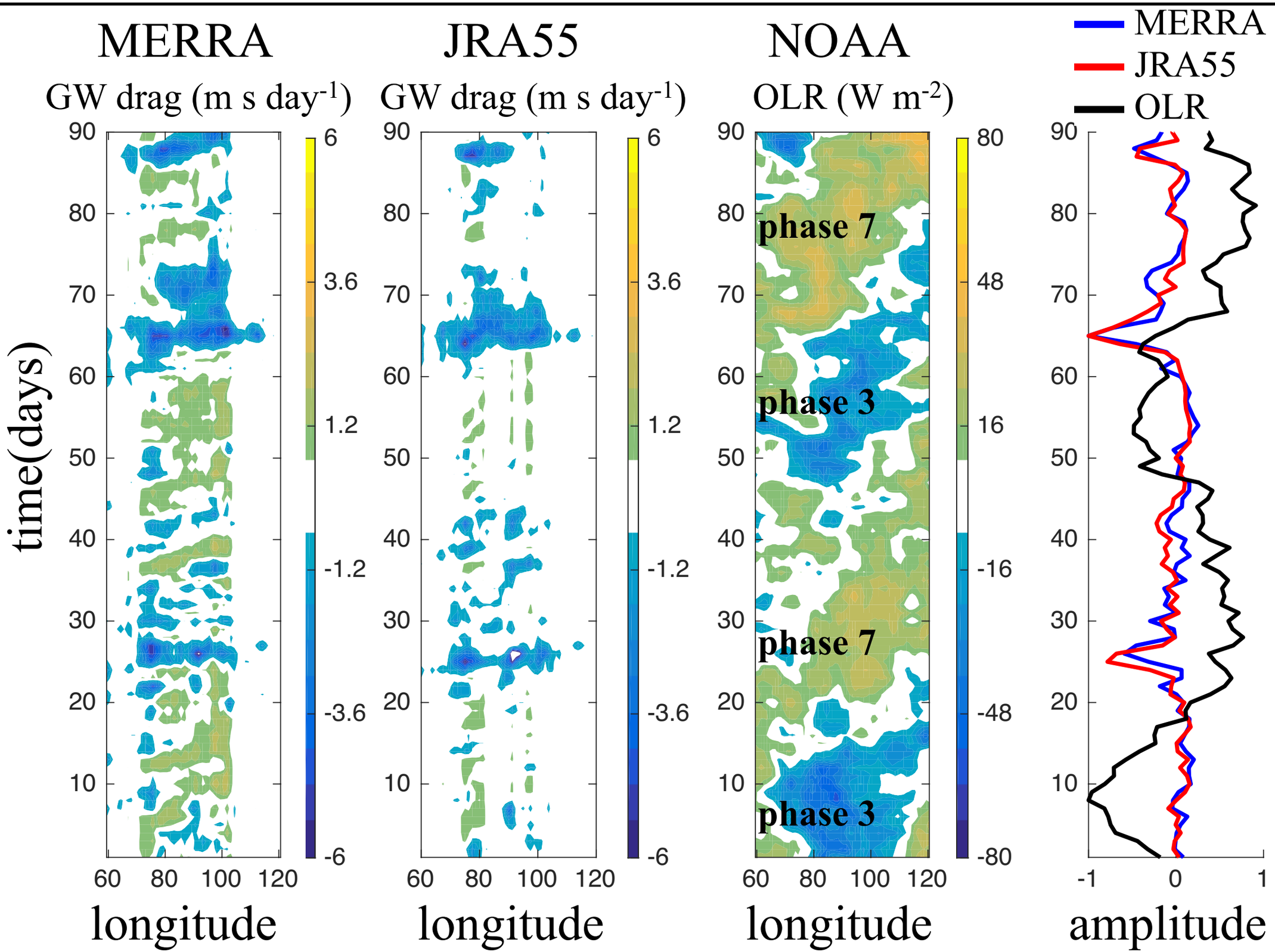


Daily GW drag and OLR anomalies during the winter of 1987-88



Key Points

(1) During winter the MJO affects vertical propagation of orographic gravity waves over the Tibetan plateau

(2) Gravity wave breaking is modulated by the MJO's effect on upper-level winds

(3) The wave drag shifts up and down with MJO phase while the vertically integrated drag is conserved

(4) This work raises new questions about how changes and trends in tropical rainfall affect stratospheric variability

Thank you!

AGU PUBLICATIONS

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