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Modeling the Interaction of the MJO and the QBO

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Image: Adapted from Hand 2015, *Science*

Overview

- The MJO-QBO Relationship
- Modeling Approach
- Results & Summary

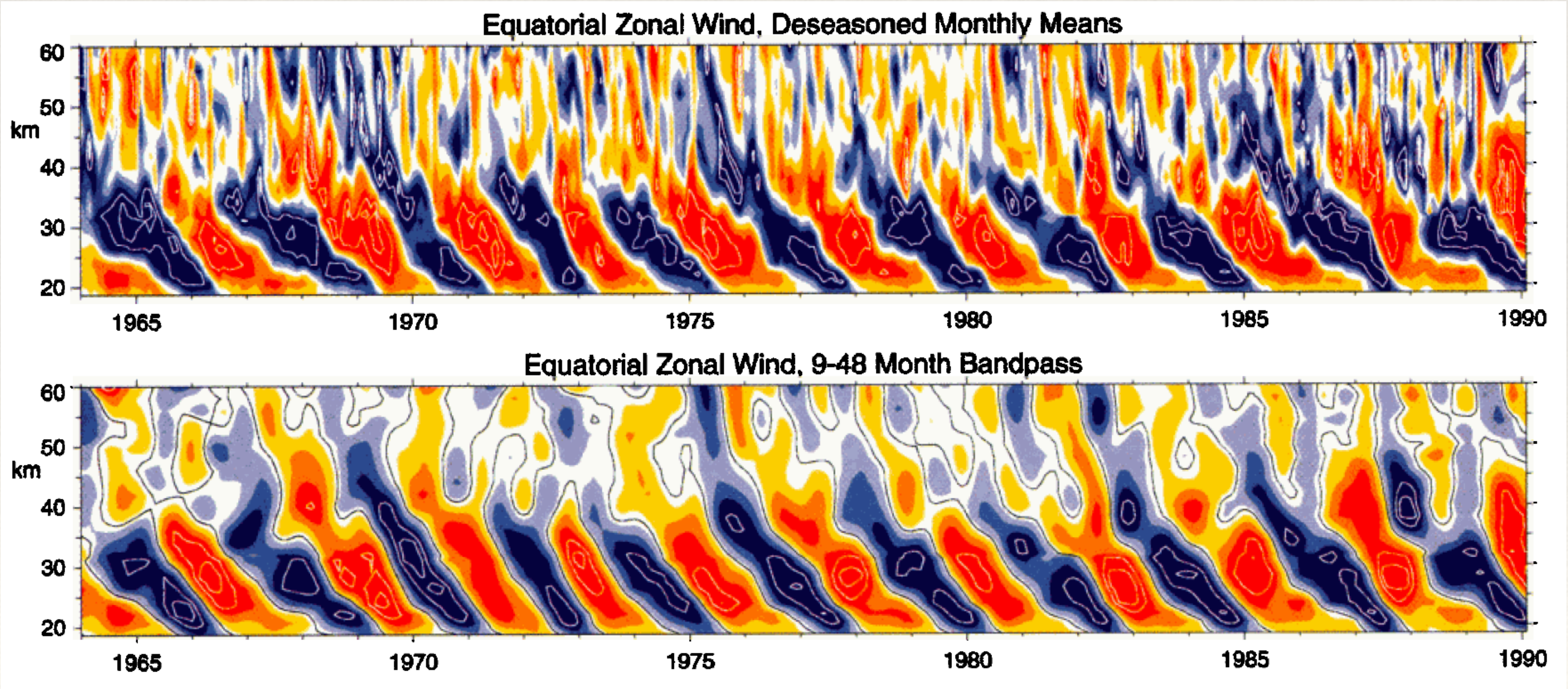


Image: Baldwin, M. P., et al., 2001: The quasi-biennial oscillation. Rev. Geophys., 39, 2, 179-229.

QBO-MJO Relationship

- During QBO easterly phase, boreal winter MJO is more active and lasts longer. Studies also indicate MJO may be more predictable.

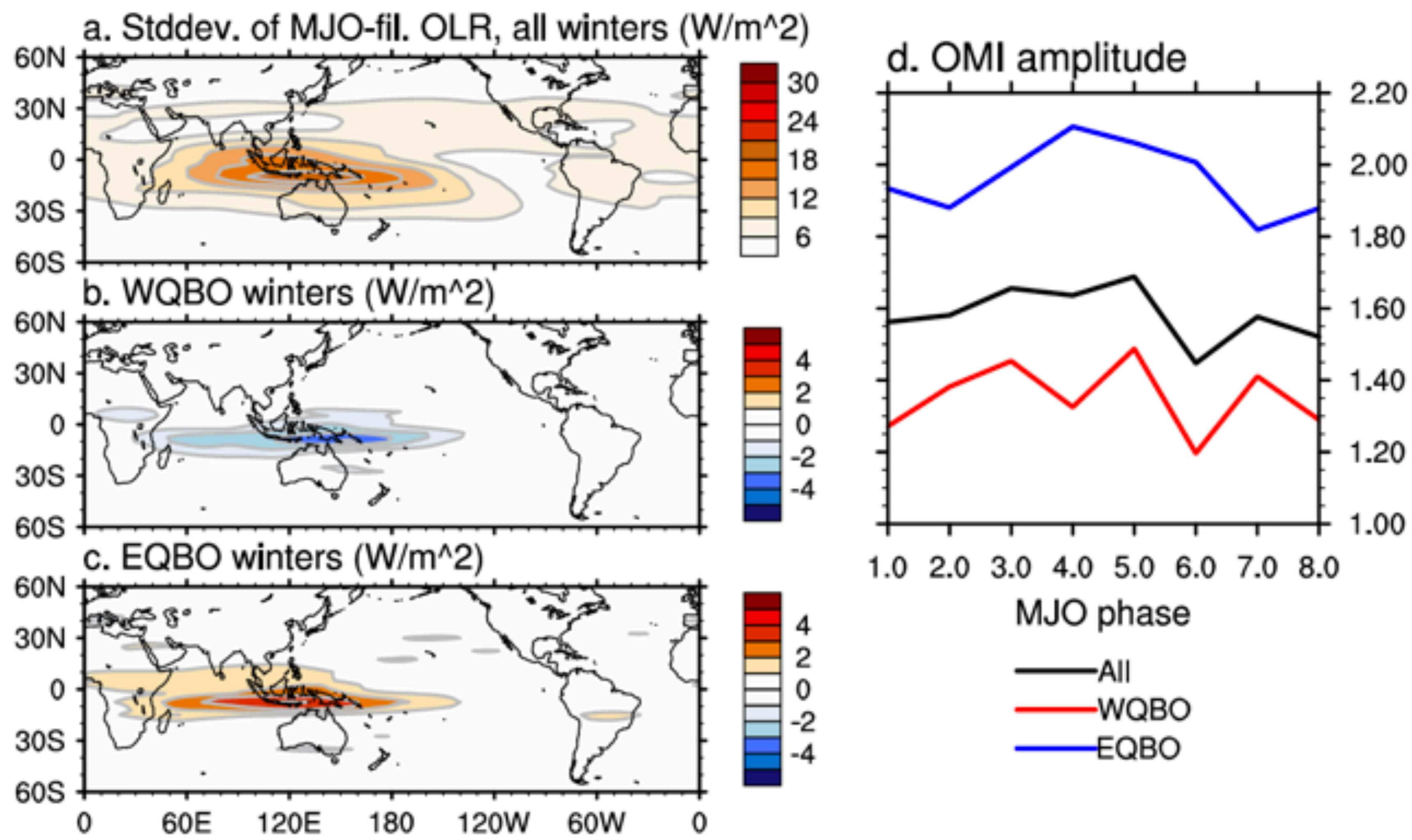


Figure 3. (a) The standard deviation of wintertime MJO-filtered OLR for all winters is shown, where the MJO filterin retrieves eastward propagating wave numbers 1–5 and periods 20–100 days. (b, c) As in Figure 3a but for the anomalies for the WQBO (EQBO) winters, respectively. (d) OMI amplitude composites are taken for eight MJO phases of all (black), WQBO (red), and EQBO (blue) winters for active MJO.

Image: Yoo, C., and S.-W. Son (2016), Modulation of the boreal wintertime Madden-Julian oscillation by the stratospheric quasi-biennial oscillation, Geophys. Res. Lett., 43, 1392–1398

QBO-MJO Mechanism

- Mechanism driving QBO-MJO relationship is difficult to determine from observations
- We explore two proposed mechanisms driving QBO-MJO interaction:
  - QBO wind anomalies
  - QBO-induced temperature anomalies

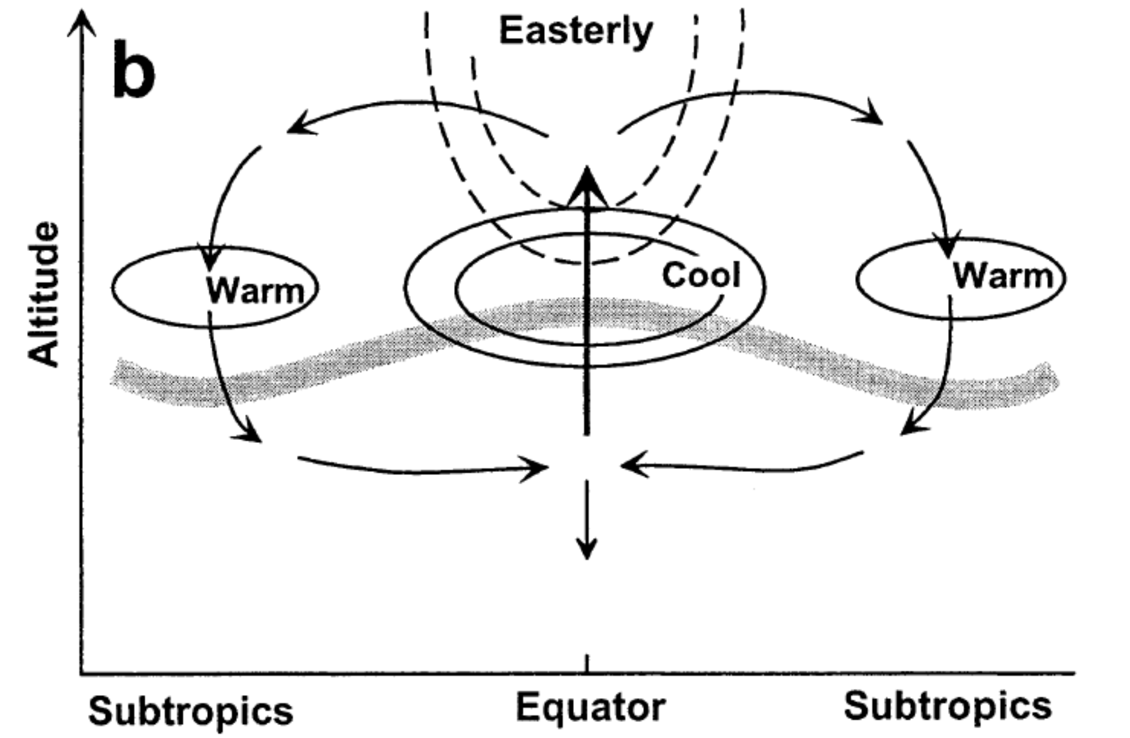


FIG. 1. Schematic representation of the mean meridional circulation driven by the QBO, after Trepte (1993). Dashed contours indicate isopleths of zonal velocity; solid contours represent anomaly isotherms. The thick, gray lines represent the tropopause. (a) Warm anomaly during descending zonal mean westerly shear; (b) cold anomaly during descending zonal mean easterly shear.

Image adapted from Collimore et al. (2003), On the relationship between the QBO and tropical deep convection, J. Climate 16, 2552–2567

Basic Modeling Approach

- WRF idealized, small domain, cloud-resolving model coupled to large-scale observational forcing
- Forcing data from the "DYNAMO" field campaign which captures 2 MJOs
- Weak temperature gradient (WTG) approximation made instead of specified vertical velocity:

$$\bar{w}\frac{\partial \bar{\theta}}{\partial z} = \frac{\bar{\theta} - \bar{\theta}_{\mathrm{ref}}(z,t)}{\tau}$$

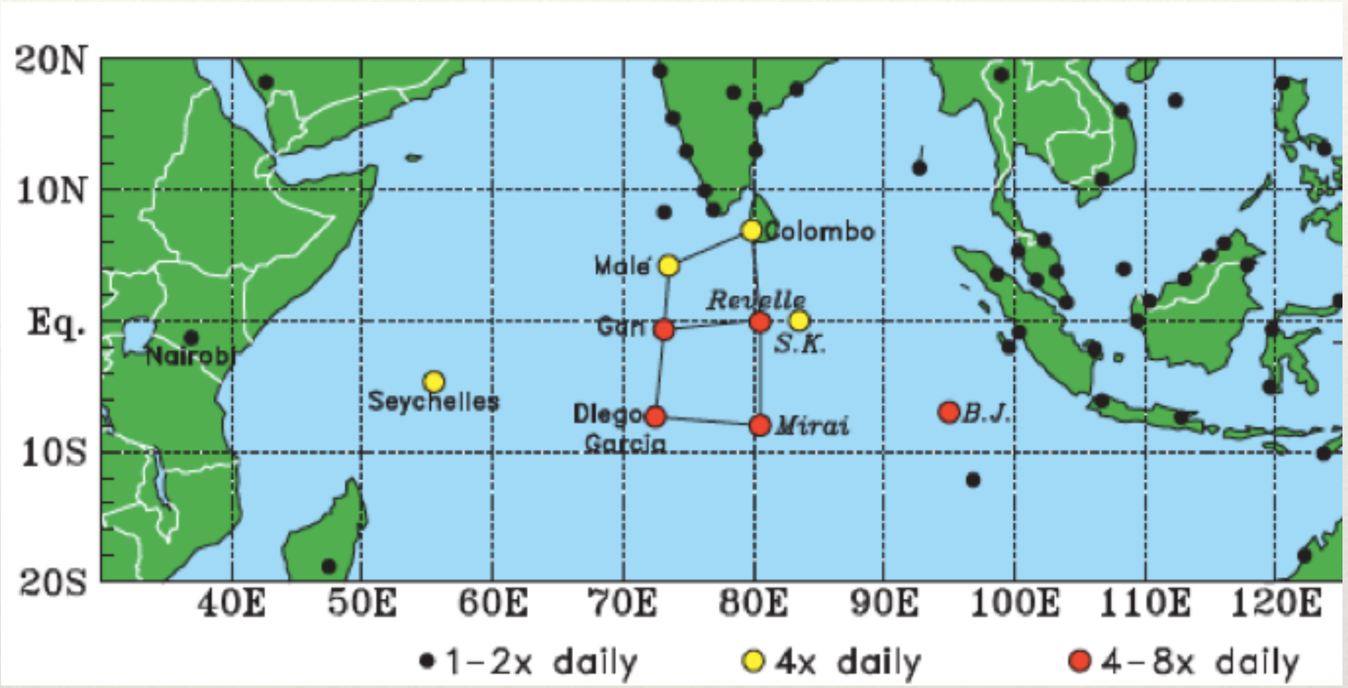


Image from: Johnson, R. H., and P. E. Ciesielski. 2013. "Structure and properties of Madden-Julian Oscillations deduced from DYNAMO sounding arrays." *J. Atmos. Sci.* 70: 3157-3179.

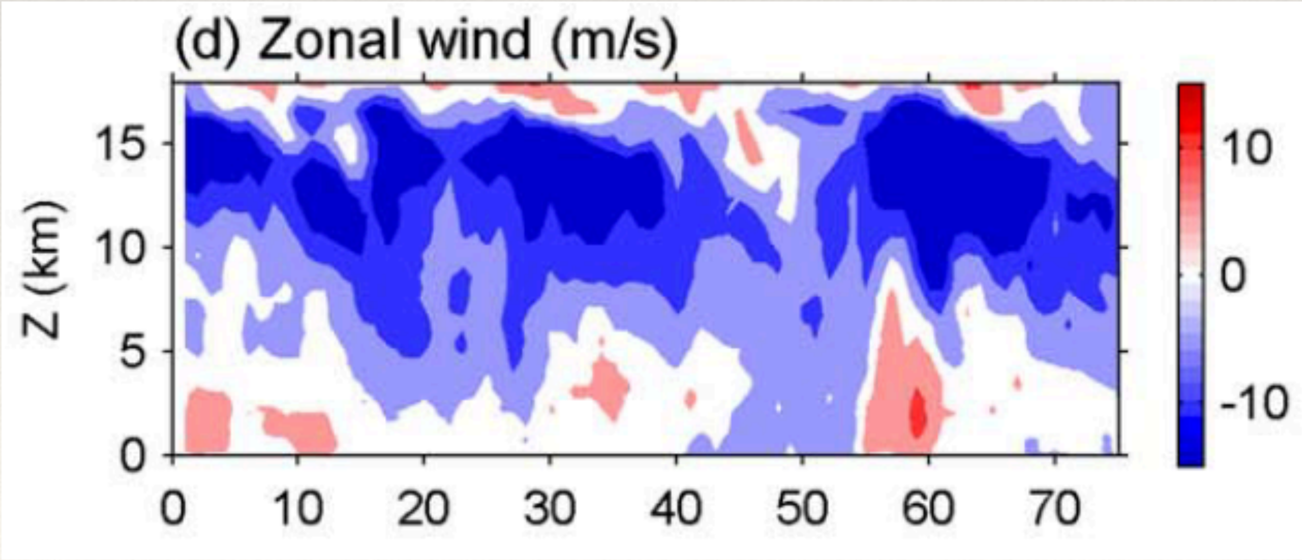
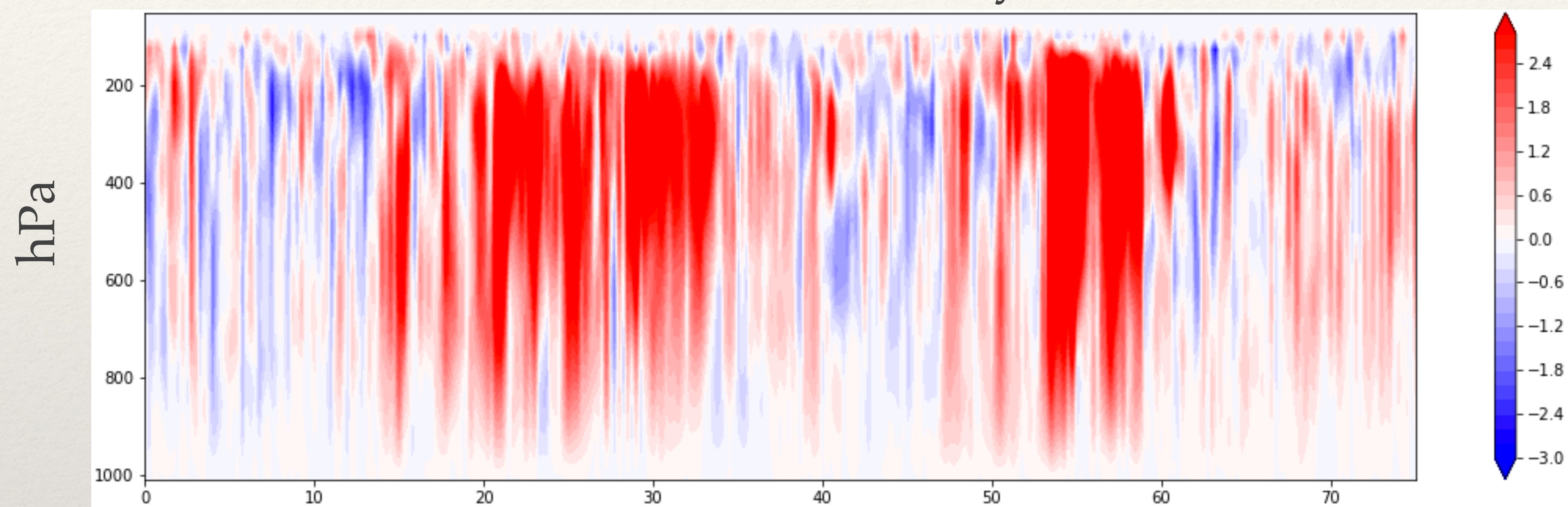


Image from Wang, S., A. H. Sobel, and J. Nie (2016), Modeling the MJO in a cloud-resolving model with parameterized large-scale dynamics: Vertical structure, radiation, and horizontal advection of dry air, J. Adv. Model. Earth Syst., 8, 121–139, doi:10.1002/2015MS000529.

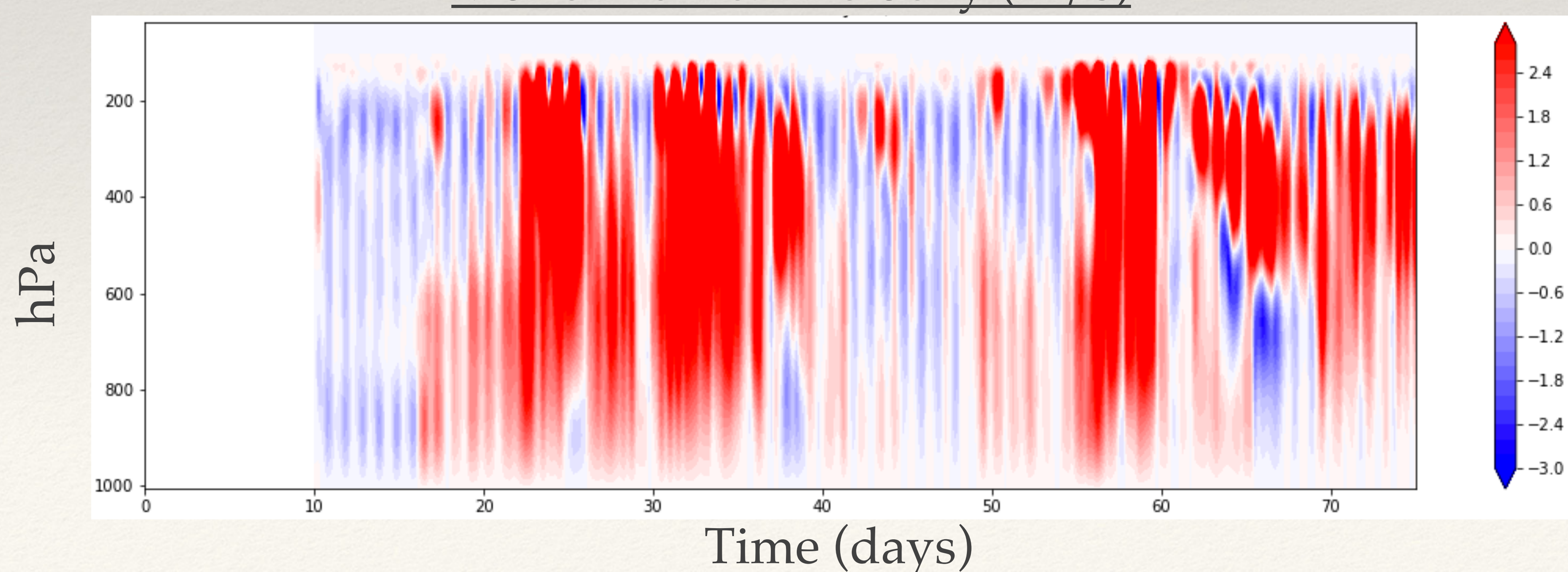
Model versus Observations

- Model simulates both observed MJOs, as evident in two periods of ascent

Observed Vertical Velocity (m/s)

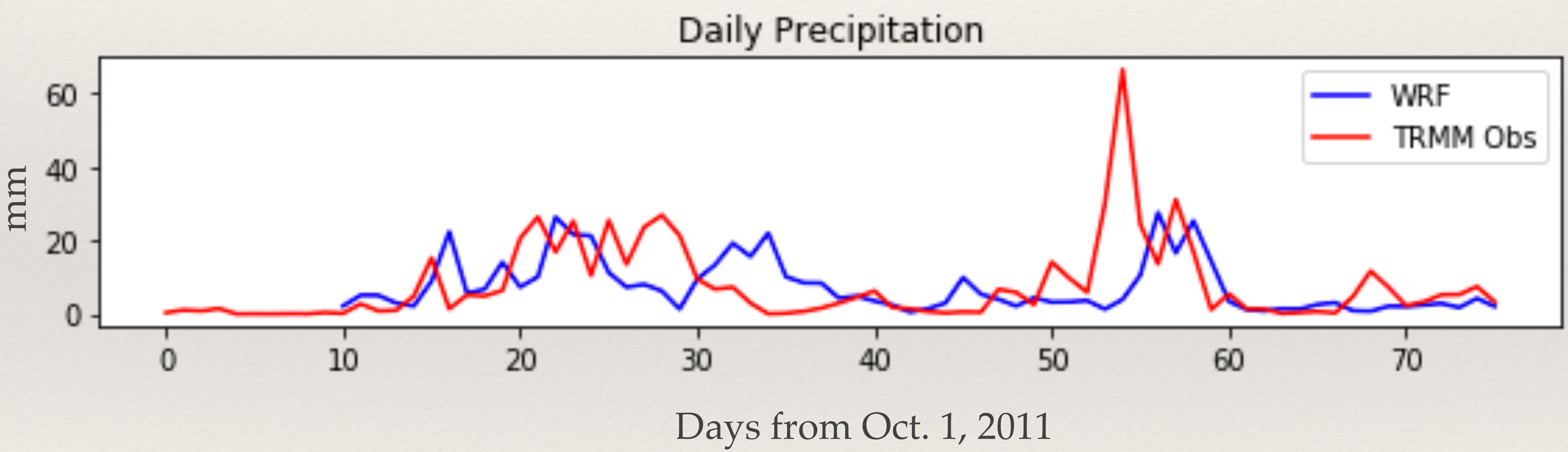


Model Vertical Velocity (m/s)



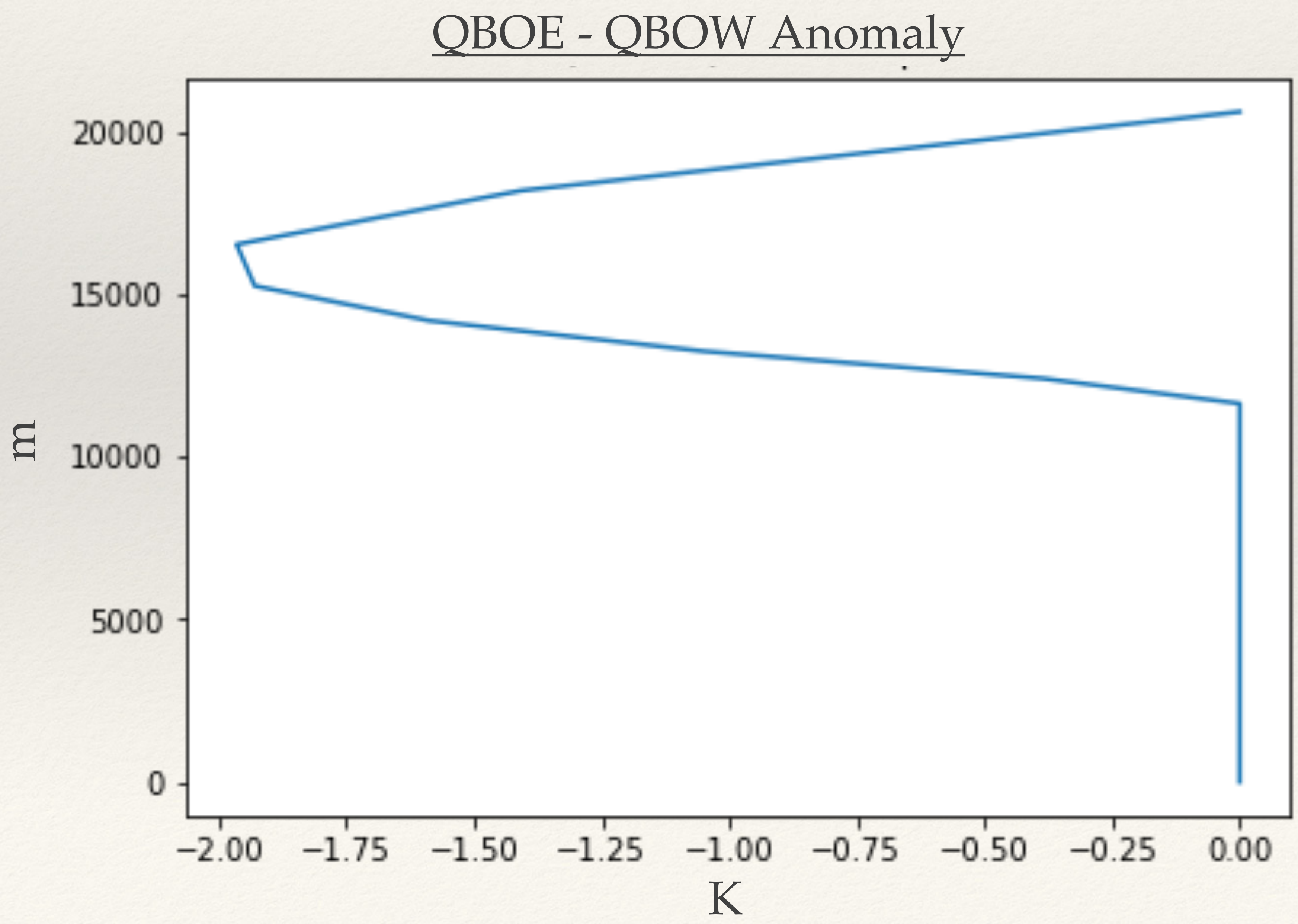
Model versus Observations

- Model simulates both observed MJOs, as evident in two periods of higher precipitation



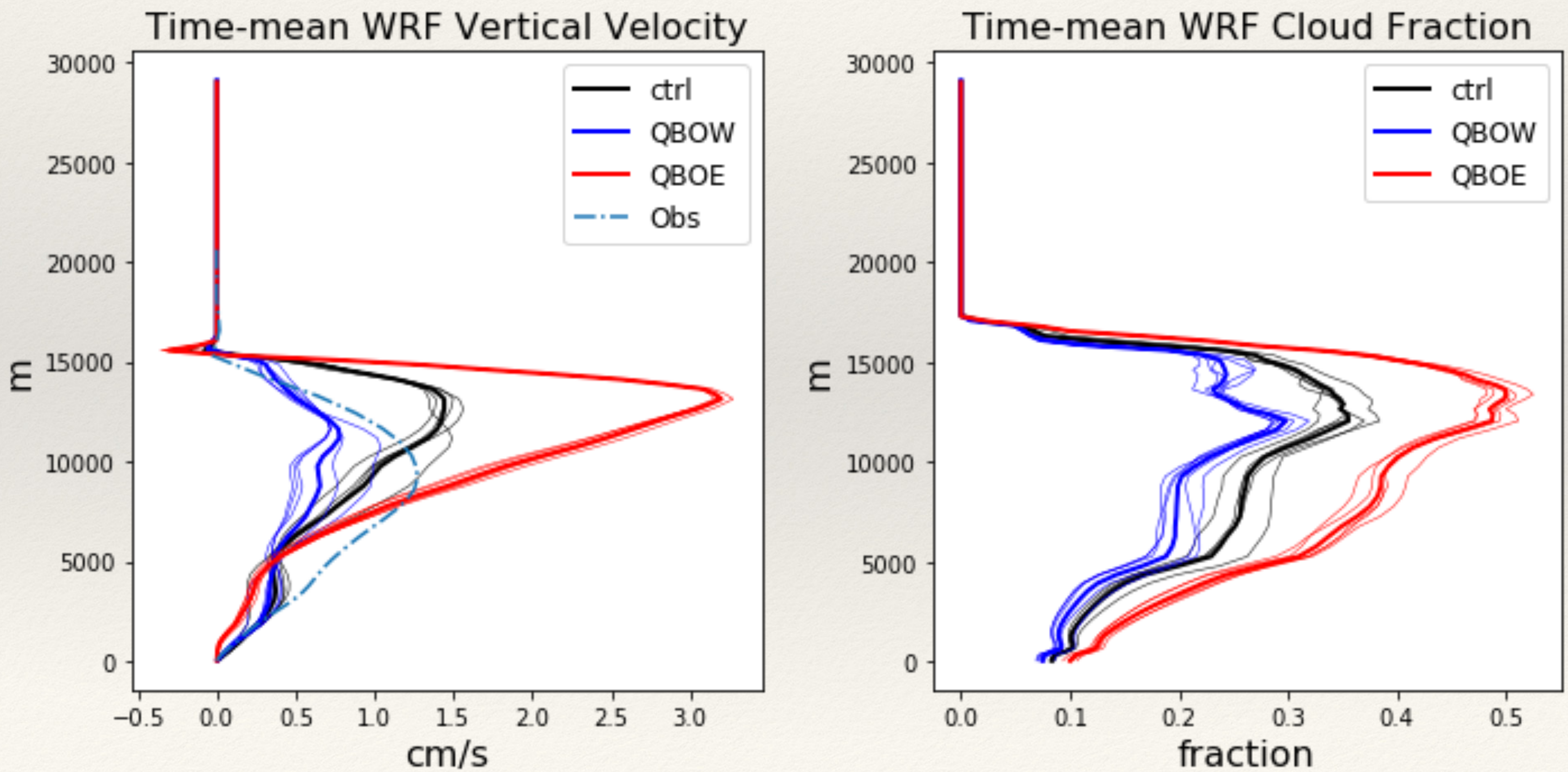
QBO Temperature Experiments

- Input idealized temperature anomaly consistent with QBOE/W signal
- (1) Control run without temperature anomaly; (2) QBOE with cold anomaly; (3) QBOW with warm anomaly. Wind field is unaltered



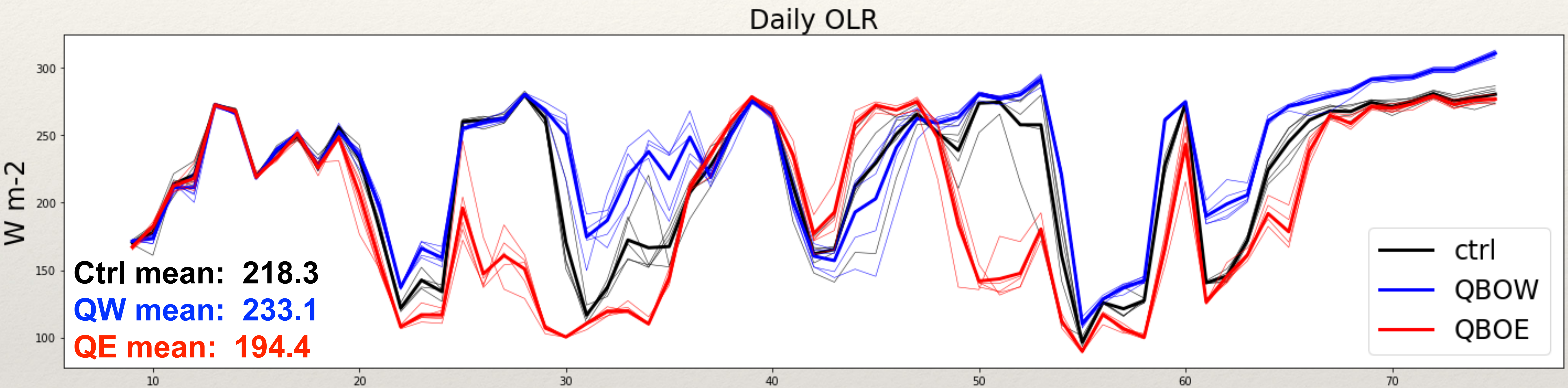
QBO Temperature Experiments

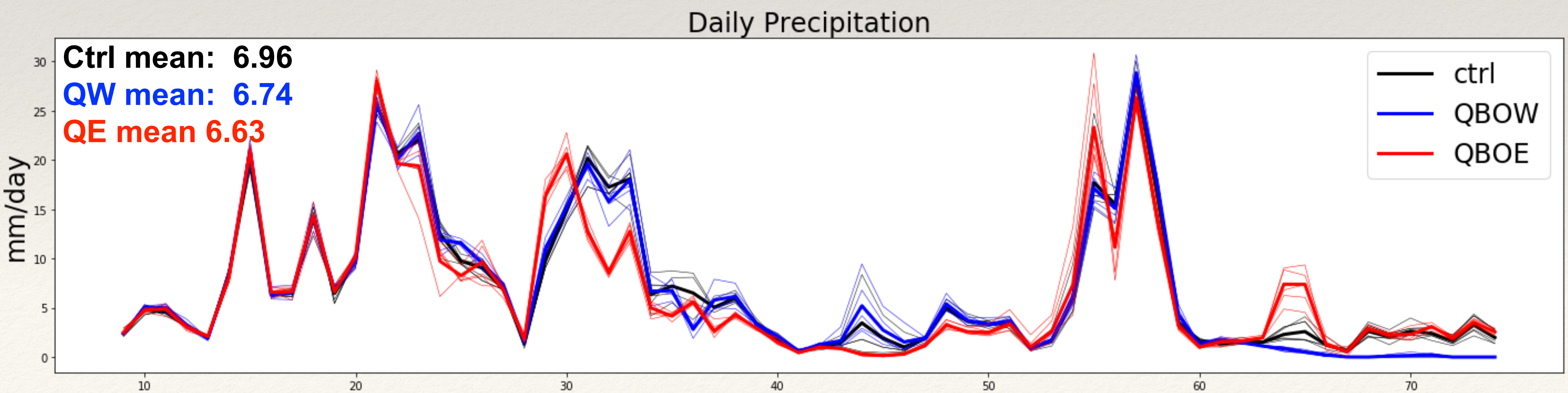
- Results show stronger upper level vertical velocity and cloud fraction during QBOE (red), opposite during QBOW (blue)



QBO Temperature Experiments

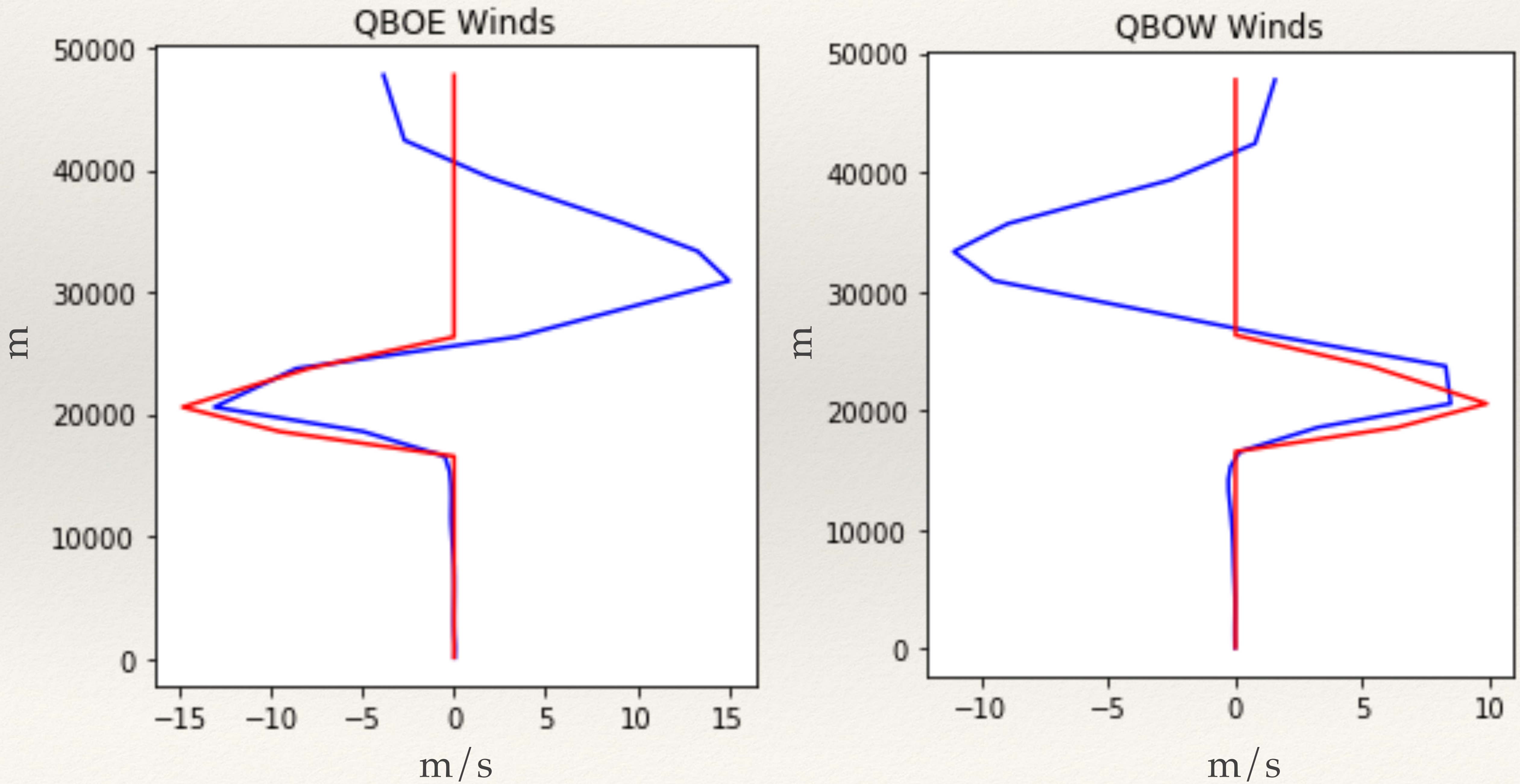
- QBO changes OLR are of same sign as observations. Changes to precipitation are *not* consistent with observed





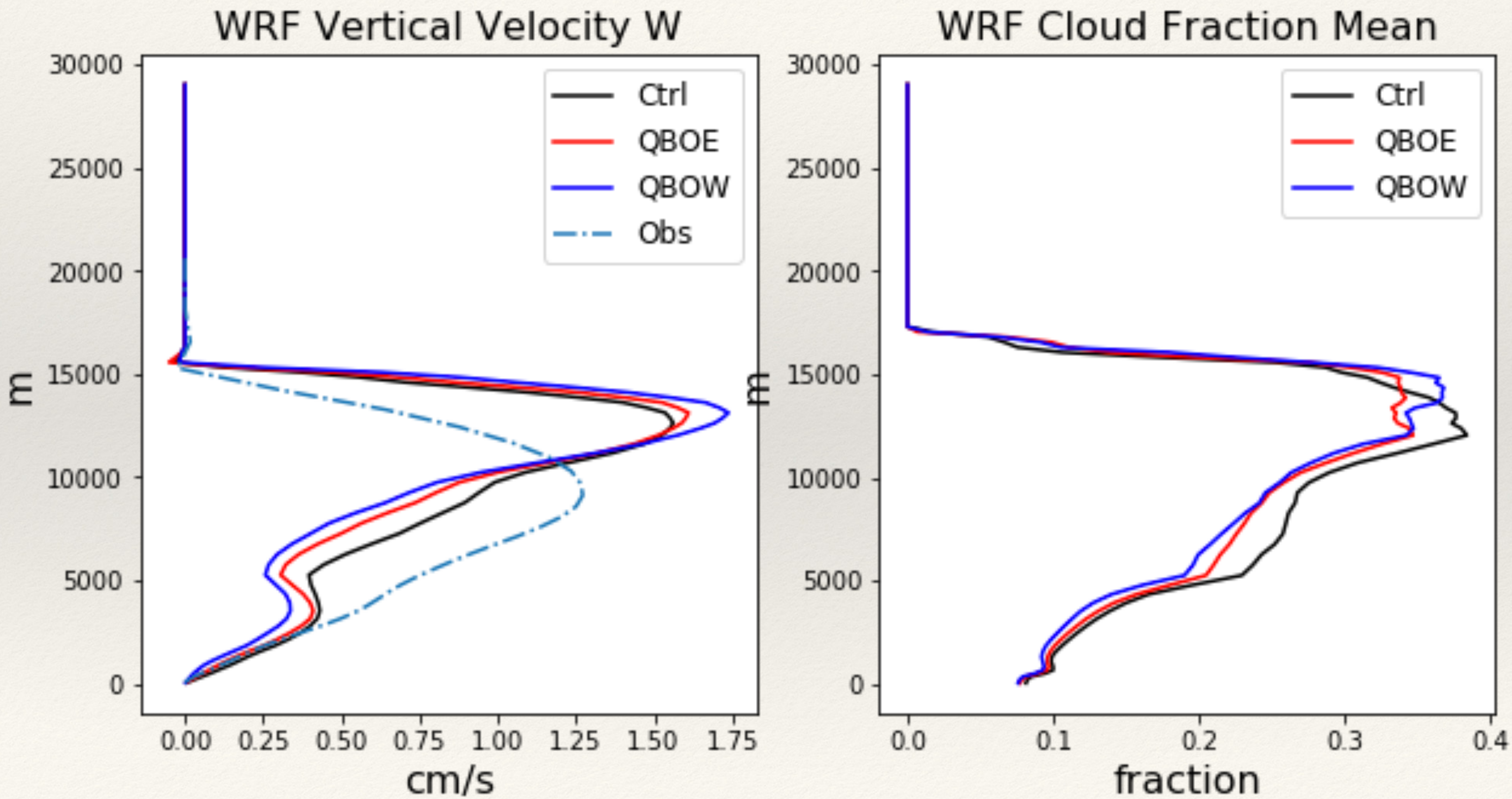
QBO Wind Experiments

- Input idealized wind anomalies (red) consistent with QBOE/W signal (blue) from ERA-Interim data. Temperature field unaltered.



QBO Wind Experiments

- Small change in vertical velocity, cloud fraction, also OLR & precip



Summary and Discussion

- The QBO modulates the MJO such that during the easterly QBO, the boreal winter MJO is stronger and more active.
- The QBO may exert its influence on the MJO through temperature anomalies which decrease the static stability and/or modify high cloud properties. The QBO wind anomalies seem to be of less importance.
- Most results from temperature experiments are qualitatively consistent with observations: increase in vertical velocity and cloud fraction and decrease in OLR during QBOE with opposite behavior during QBOW.
- Precipitation results are less conclusive and are being analyzed more.

Thank you!