QBO influence on East Asia winter climate

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QBO: Discovered in 1959

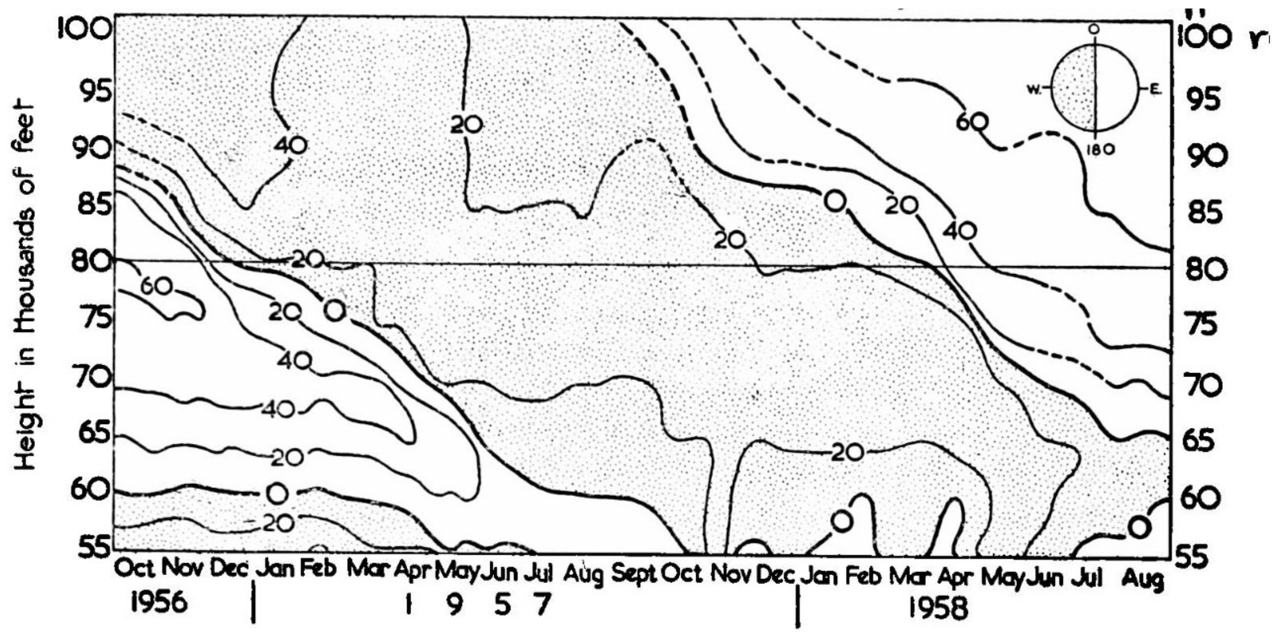


FIGURE 4—ZONAL COMPONENTS OF WINDS ABOVE THE TROPOPAUSE AT CHRISTMAS ISLAND USING 10-DAY MEANS

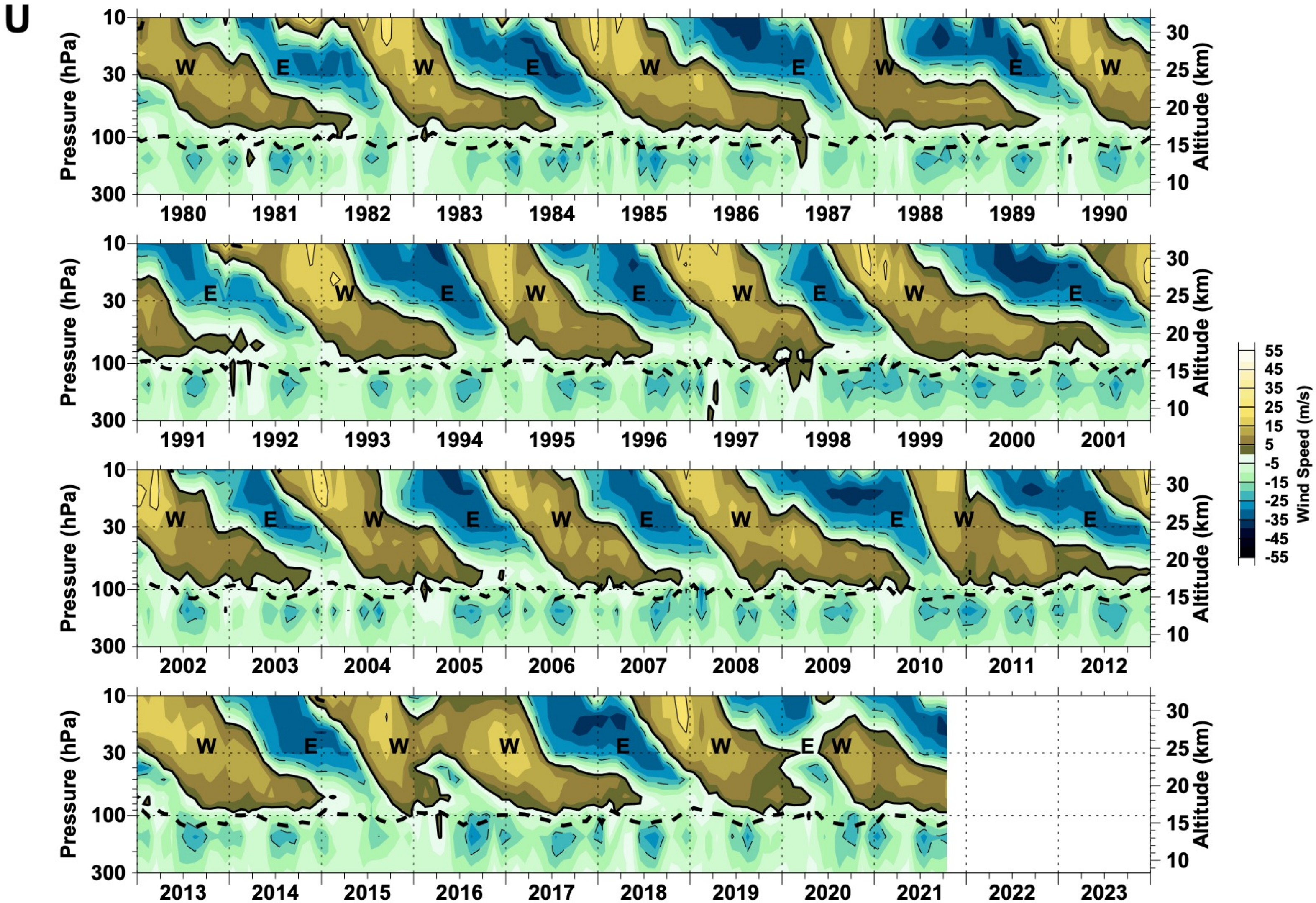
Met. Mag.

METEOROLOGICAL OFFICE DISCUSSION

Tropical Meteorology

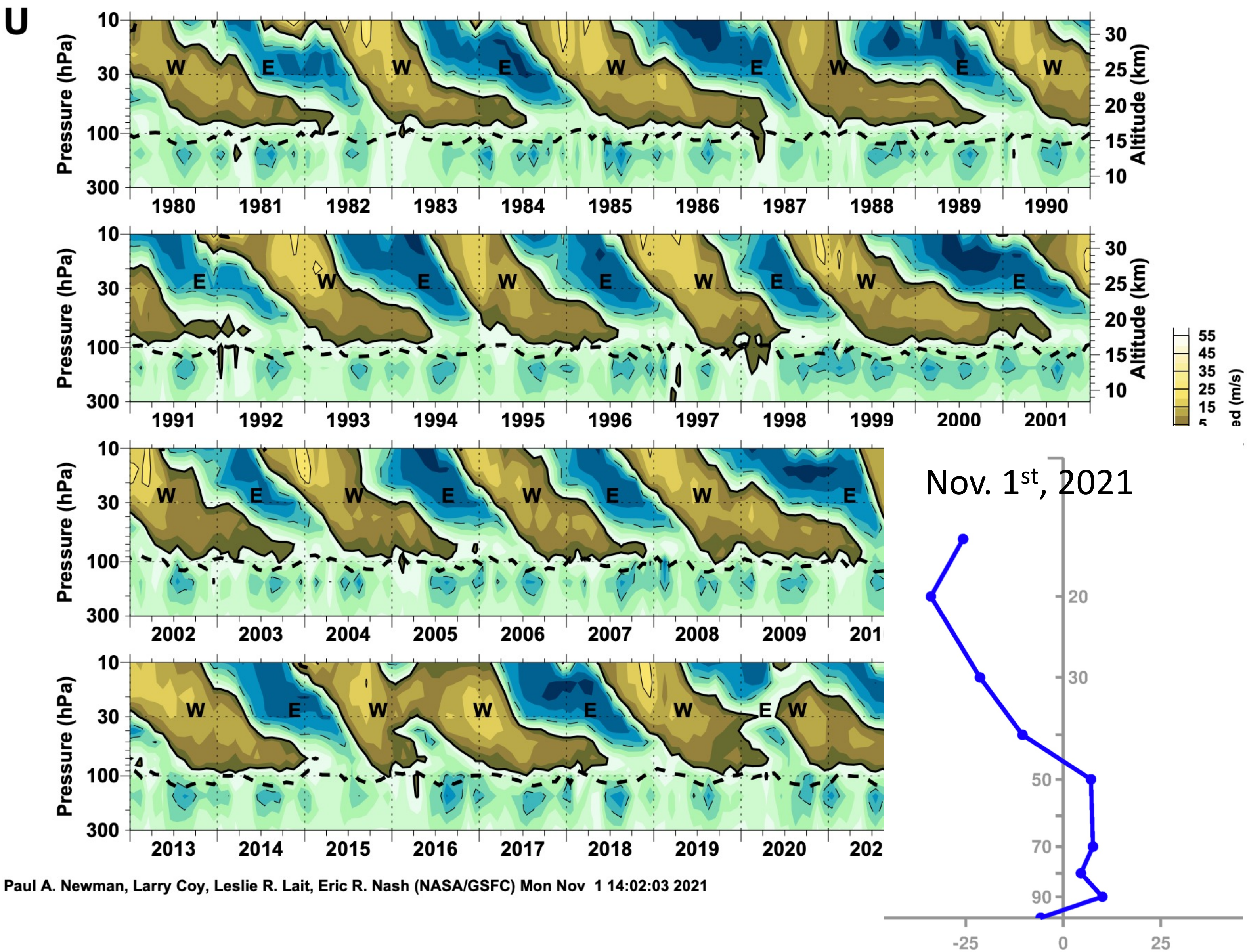
The subject for the Monday Discussion on 15 December 1958 was "Tropical meteorology". Dr. A. C. Best was in the Chair and the opening speakers were Mr. P. F. Emery and Mr. P. Graystone.

QBO: EOF1 in the stratosphere



Paul A. Newman, Larry Coy, Leslie R. Lait, Eric R. Nash (NASA/GSFC) Mon Nov 1 14:02:03 2021

QBO: EOF1 in the stratosphere



QBO: Downward influences

Gray et al. (2018ACP)

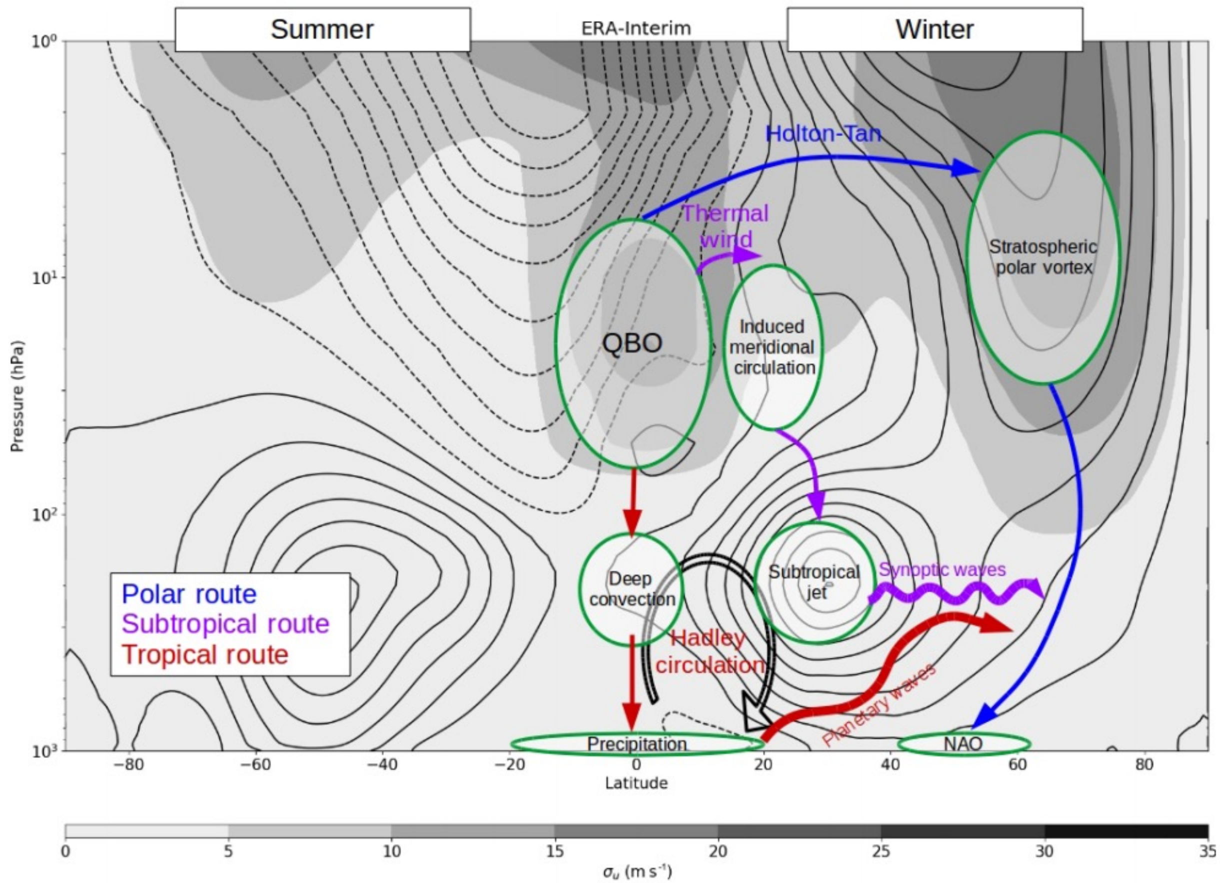


Figure 1. Schematic summarizing the three primary routes (tropical, subtropical, polar) for QBO influence at the Earth's surface. Contours show the December–January–February averaged, zonally averaged zonal winds for 1979–2016 from ERA-Interim data. The contour interval is 5 ms^{-1}; solid contours denote westerlies; dashed contours denote easterlies. Greyscale shows the standard deviation of the zonal winds in ms^{-1}.

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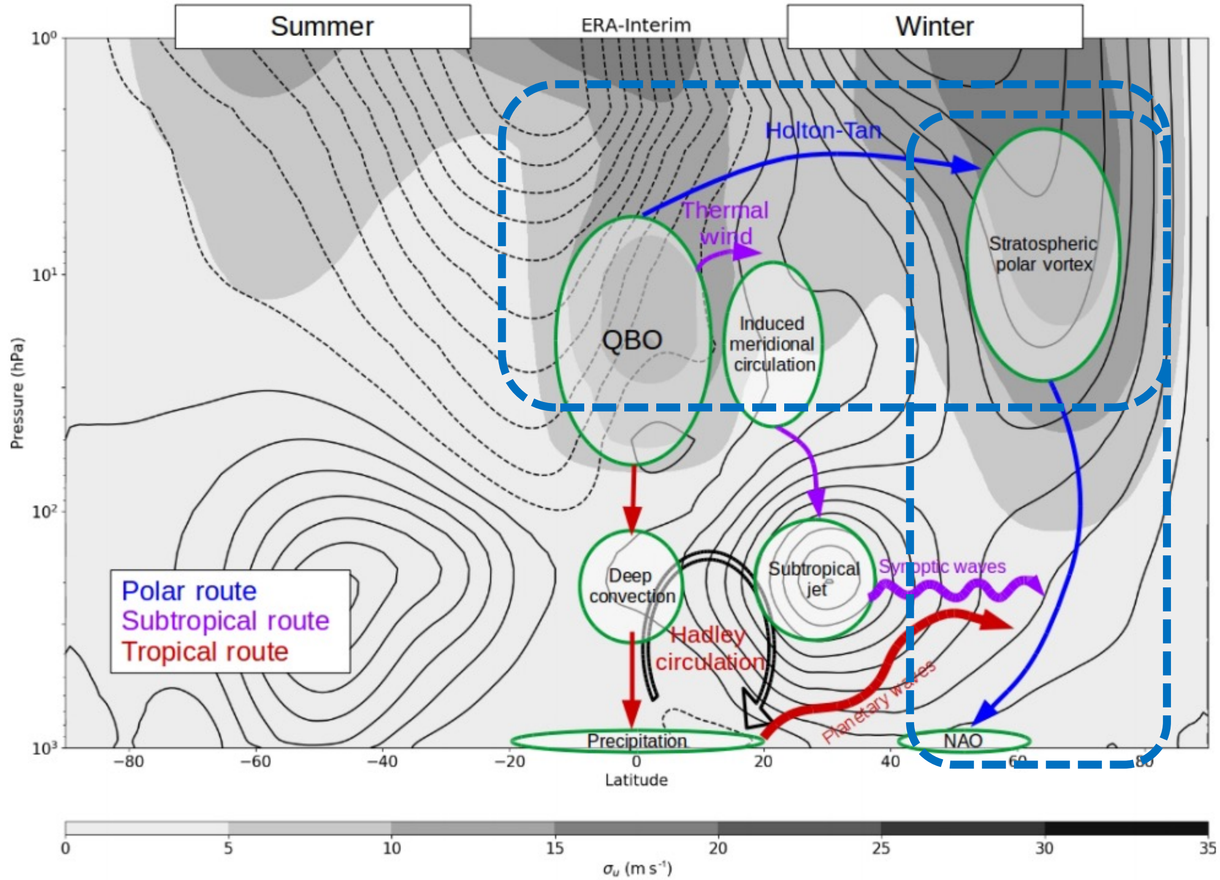

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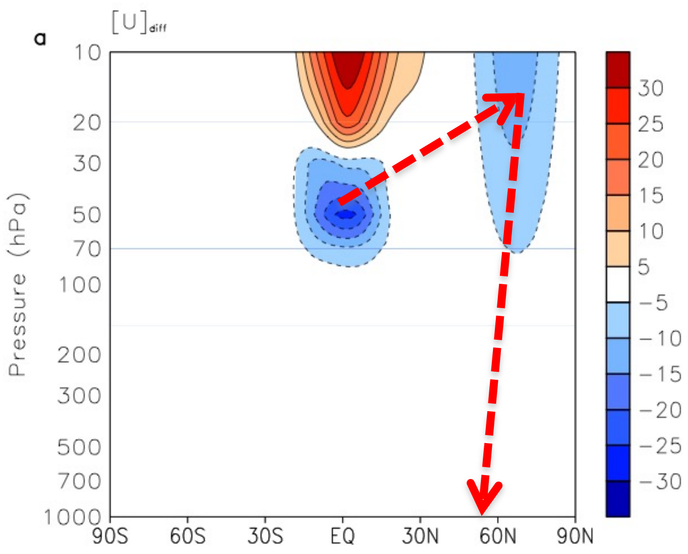
1. QBO-Polar Vortex-Negative AO



- Holton-Tan Effect: EQBO (U50<0) => weak equatorward wave propagation (anomalous poleward wave propagation) => weak polar vortex => negative NAM and its downward propagation (negative AO) => Cold Eurasia

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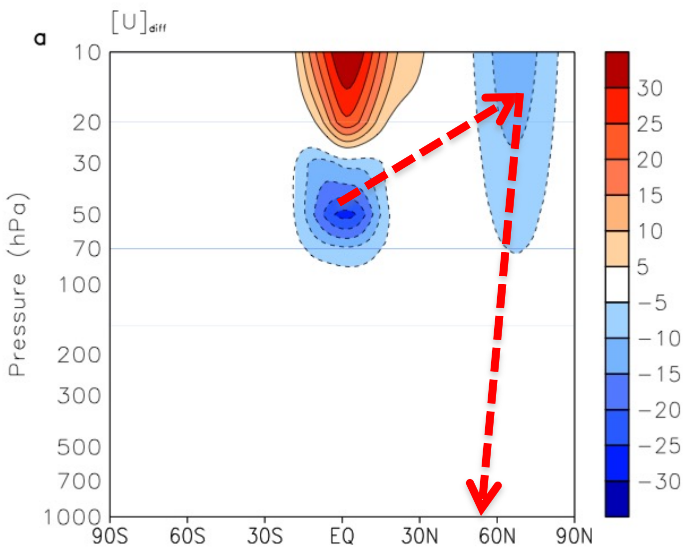

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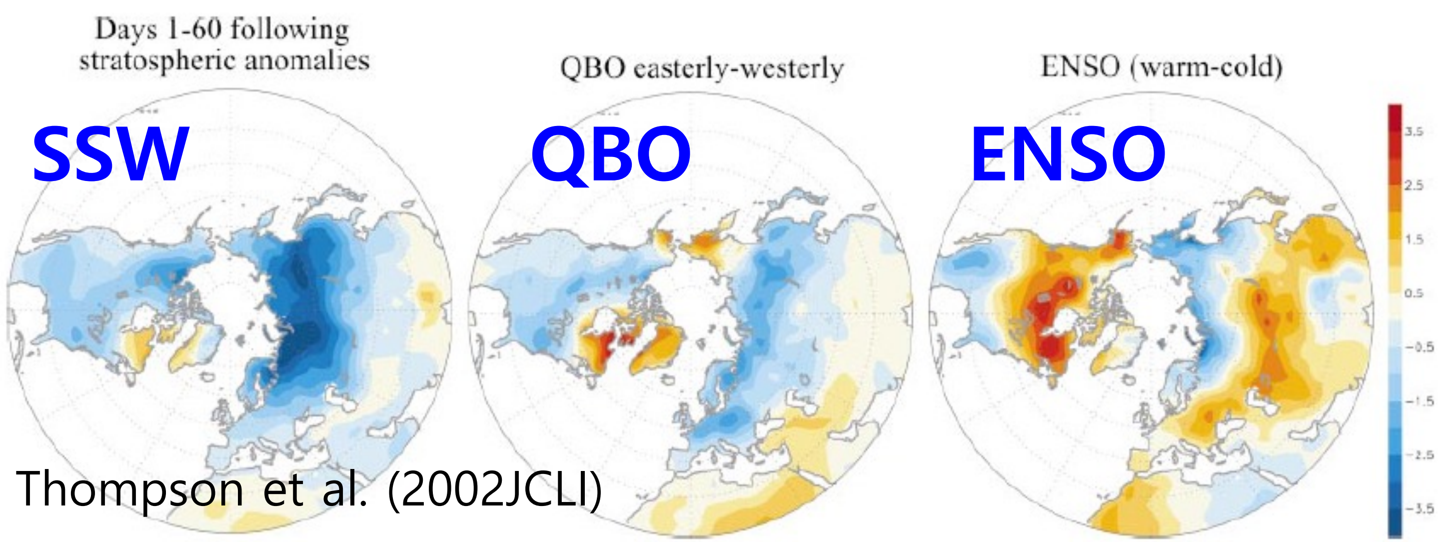
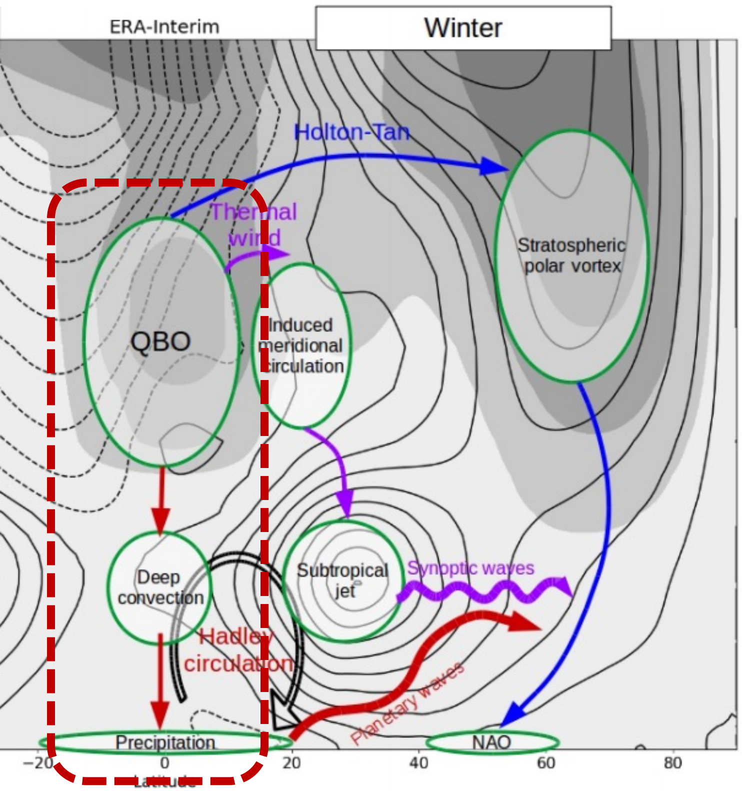


Thompson et al. (2002JCLI)

2. QBO-MJO

nature reviews earth & environment REVIEWS



Check for updates

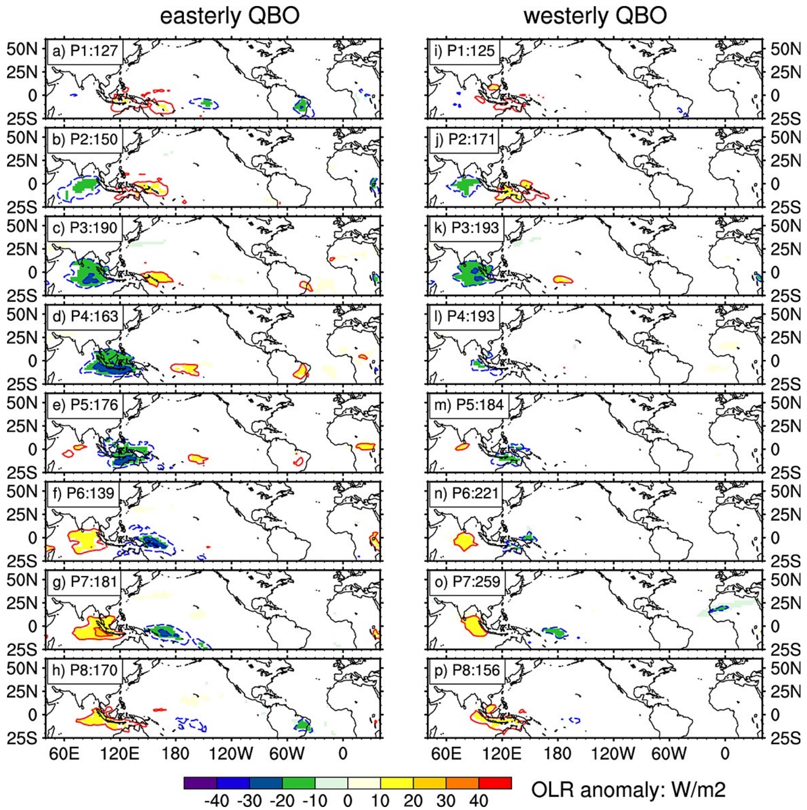
The influence of the quasi-biennial oscillation on the Madden–Julian oscillation

Zane Martin[1], Seok-Woo Son[2], Amy Butler[3], Harry Hendon[4], Hyemi Kim[5], Adam Sobel[6,7], Shigeo Yoden[8] and Chidong Zhang[9]

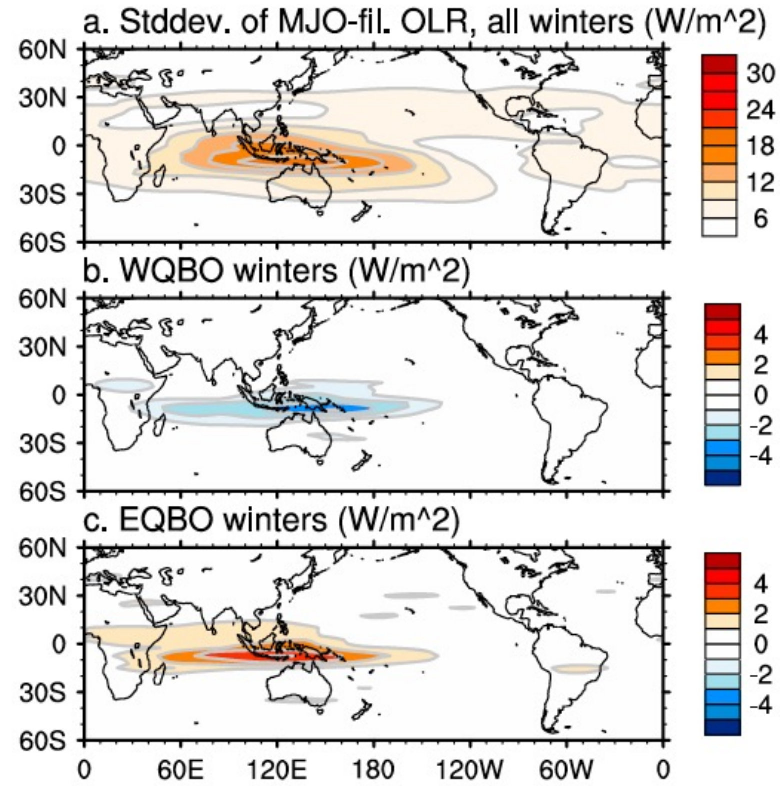
Abstract | The stratospheric quasi-biennial oscillation (QBO) and the tropospheric Madden–Julian oscillation (MJO) are strongly linked in boreal winter. In this Review, we synthesize observational and modelling evidence for this QBO–MJO connection and discuss its effects on MJO teleconnections and subseasonal-to-seasonal predictions. After 1980, observations indicate that, during winters when lower-stratospheric QBO winds are easterly, the MJO is ~40% stronger and persists roughly 10 days longer compared with when QBO winds are westerly. Global subseasonal forecast models, in turn, show a 1-week improvement (or 25% enhancement) in MJO prediction skill in QBO easterly versus QBO westerly phases. Despite the robustness of the observed QBO–MJO link and its global impacts via atmospheric teleconnections, the mechanisms that drive the connection are uncertain. Theories largely centre on QBO-related temperature stratification effects and subsequent impacts on deep convection, although other hypotheses propose that cloud radiative effects or QBO impacts on wave propagation might be important. Most numerical models, however, are unable to reproduce the observed QBO–MJO relationship, suggesting biases, deficiencies or omission of key physical processes in the models. While future work must strive to better understand all aspects of the QBO–MJO link, focus is needed on establishing a working mechanism and capturing the connection in models.

Martin et al. (2021NREE)

2. QBO-MJO



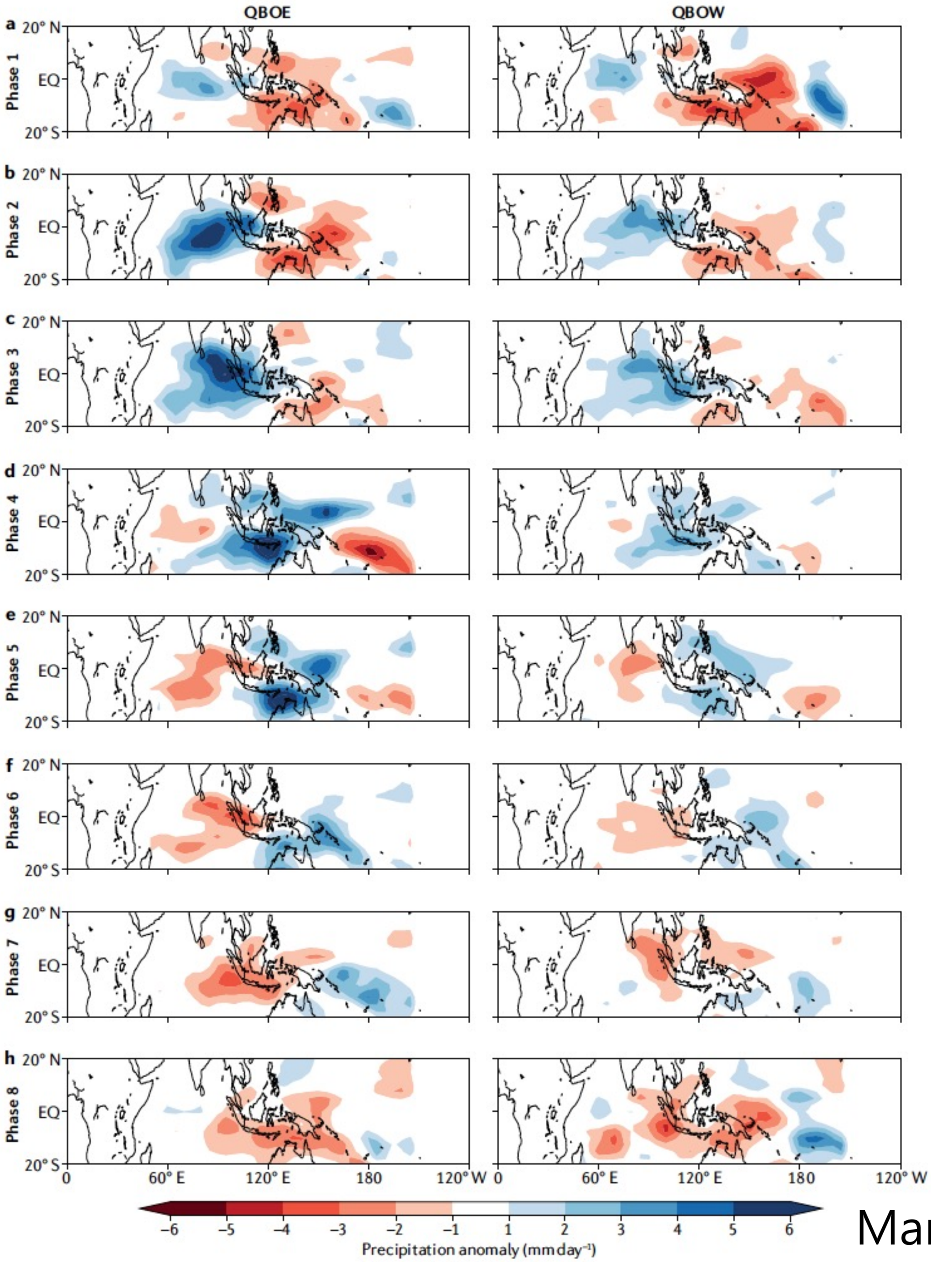
Liu et al. (2014JGR)

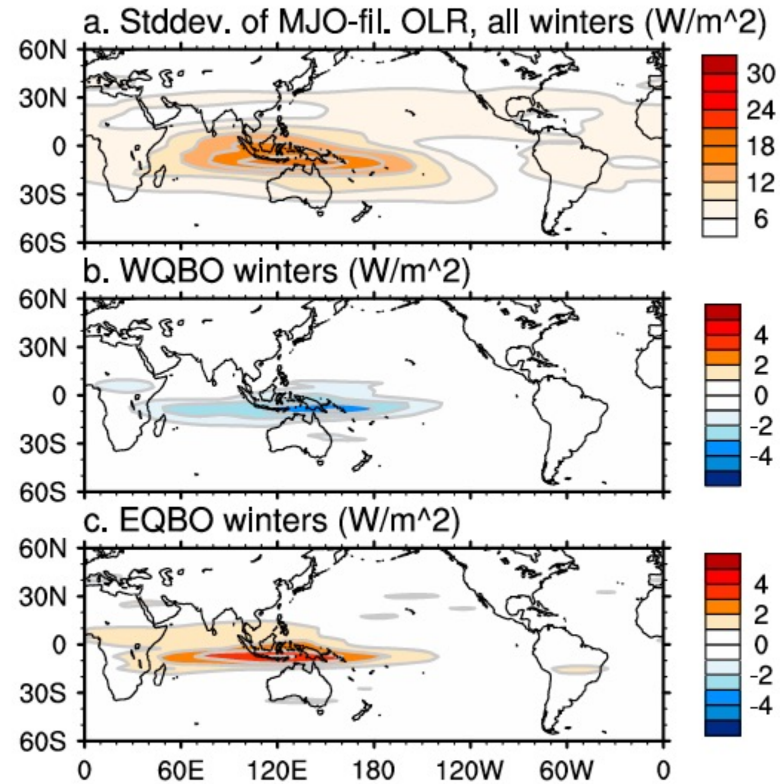


Yoo and Son (2016GRL)

- Stronger MJO activities in EQBO winters (U50<0) than in WQBO winters!

2. QBO-MJO





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Martin et al. (2021NREE)

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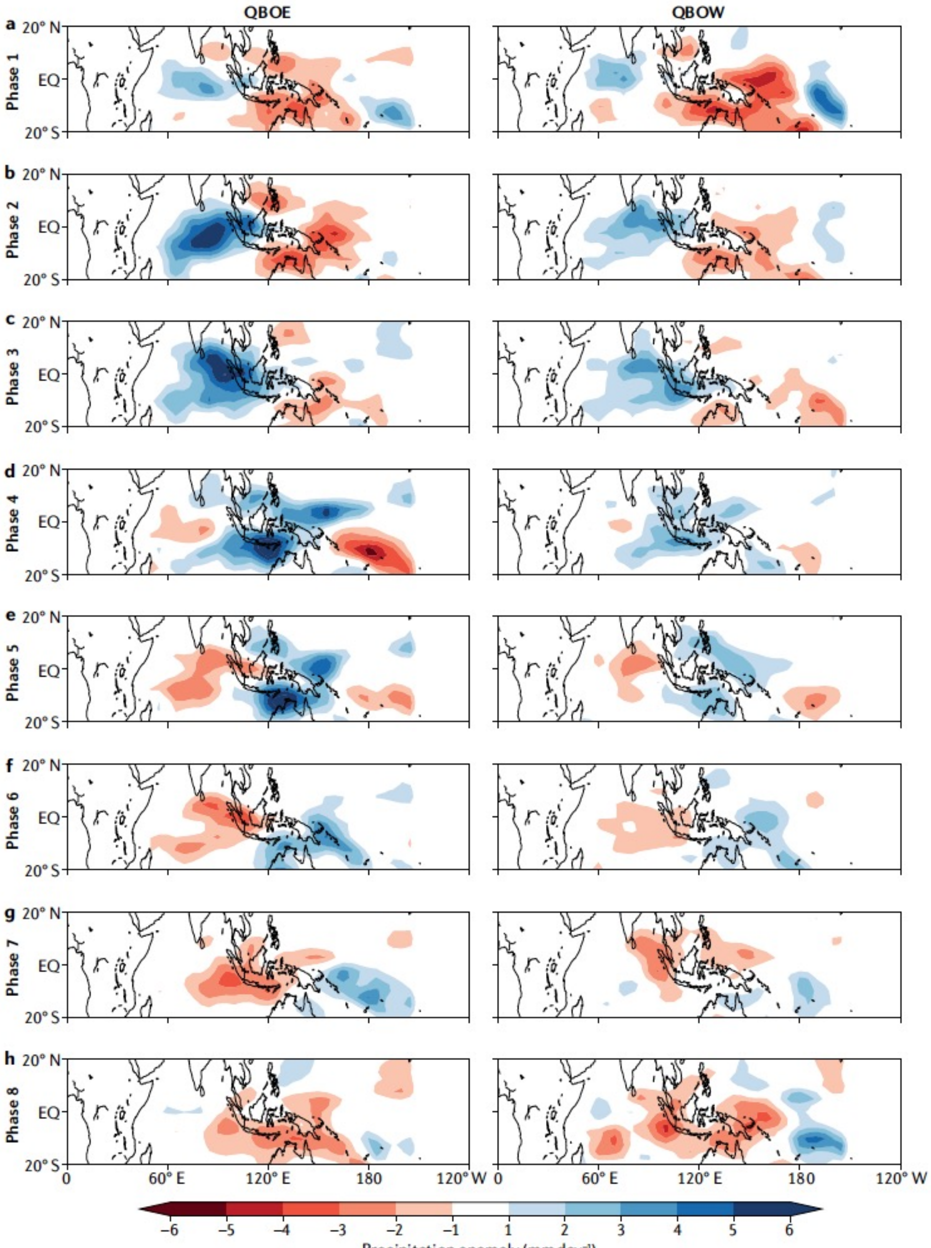
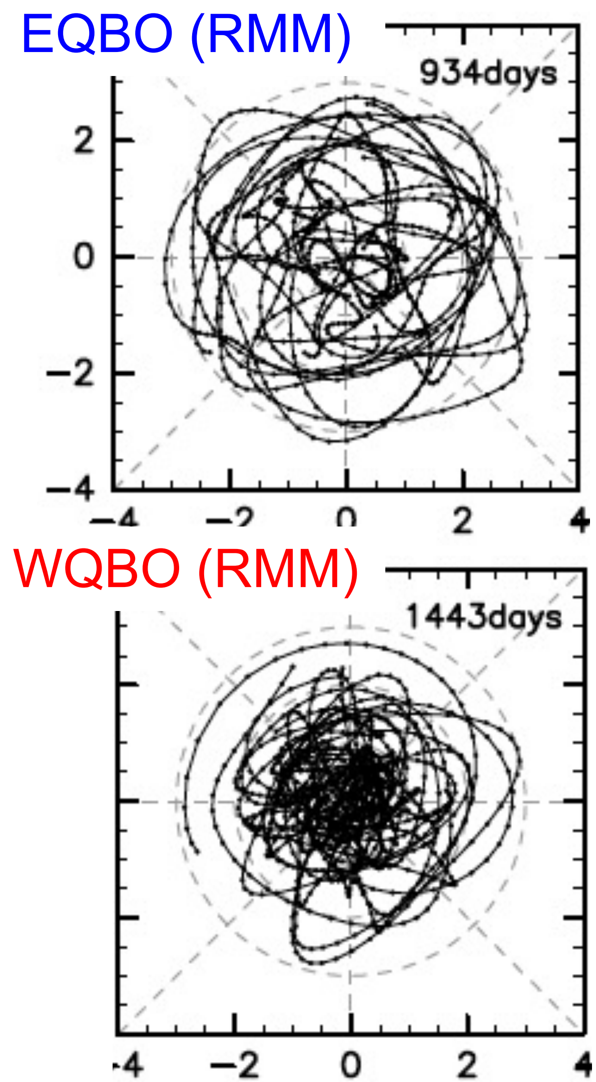
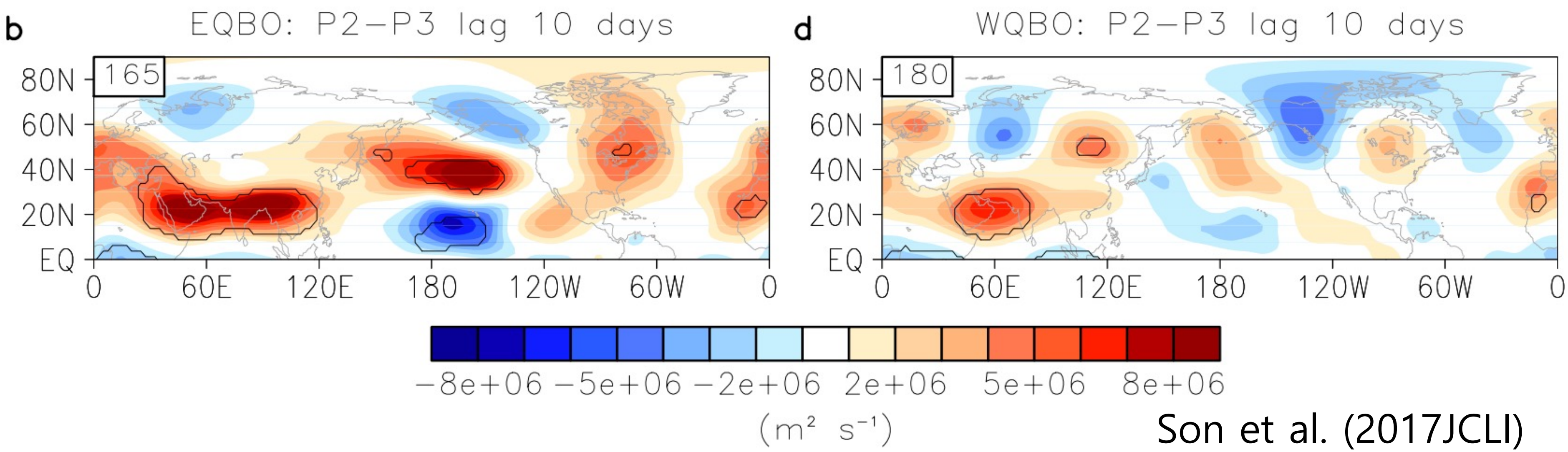




Nishimoto and Yoden (2017JAS)

2. QBO-MJO teleconnection

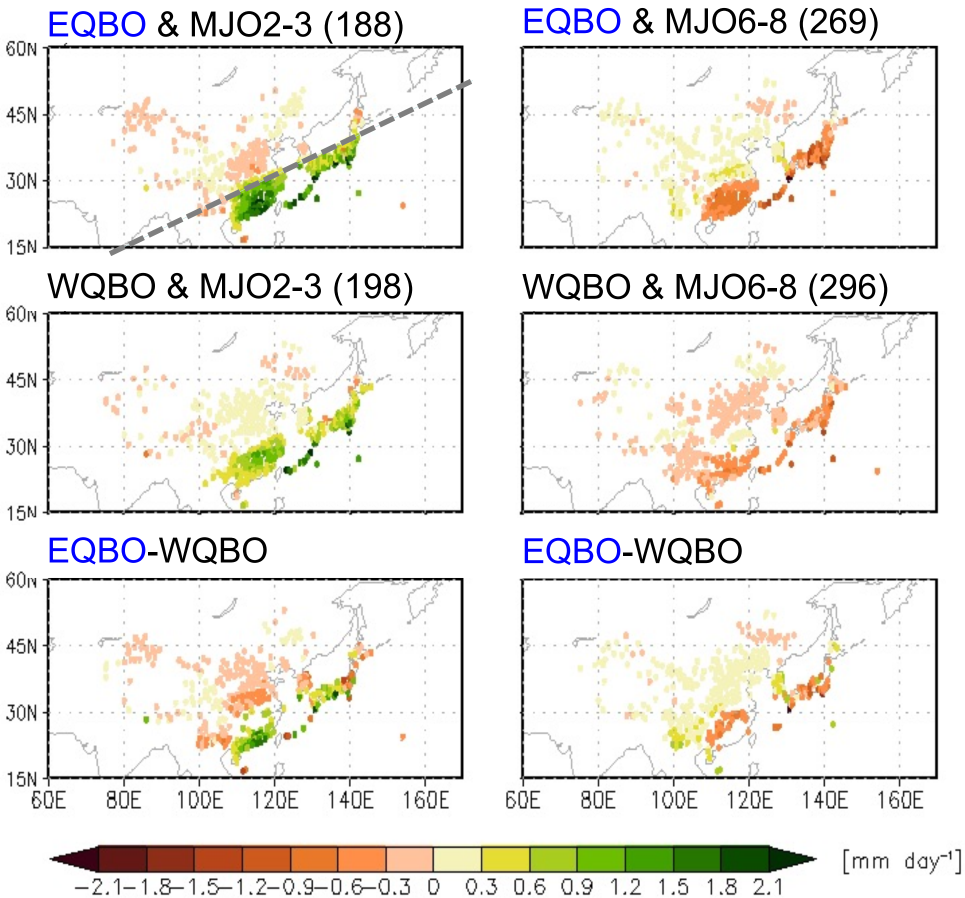


Son et al. (2017JCLI)

- More active MJO leads to a stronger MJO teleconnection in EQBO winters.

2. QBO-MJO teleconnection: East Asian Precip.

Precipitation Anomaly (lag +5 days)



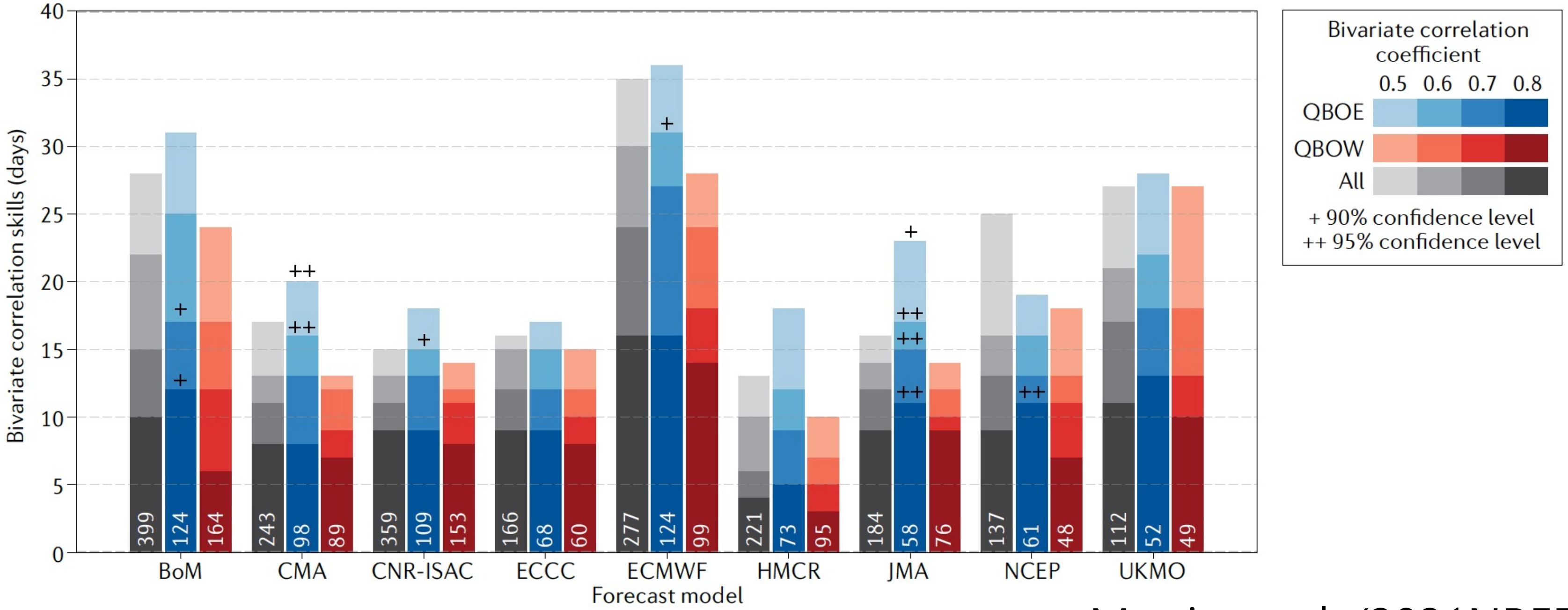
Kim et al. (2020JGR)

Precipitation Anomaly (Area 2)

	MJO P2-3 (mm day^{-1})	MJO P6-8 (mm day^{-1})
ALL	0.73	-0.26
EQBO	0.87	-0.44
WQBO	0.60	-0.26
(E-W)/ALL	37.0%	69.2%

- Stronger MJO-induced East Asian precipitation anomaly in EQBO winters.
- Stronger MJO-related subseasonal variability in EQBO winters

2. QBO-MJO: S2S models

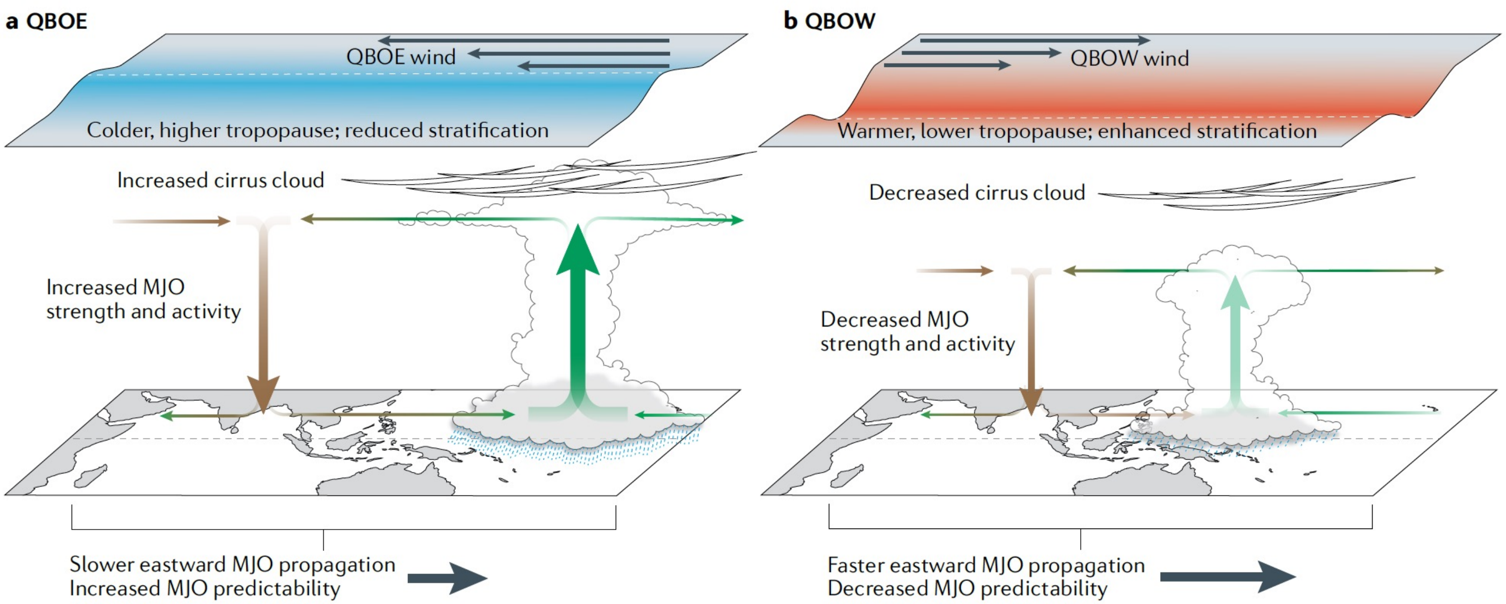


Martin et al. (2021NREE)

- S2S models show an improved MJO prediction skill in EQBO winters. The skill improvement is often statistically insignificant. It could result from initial condition not from QBO.

2. QBO-MJO: Summary

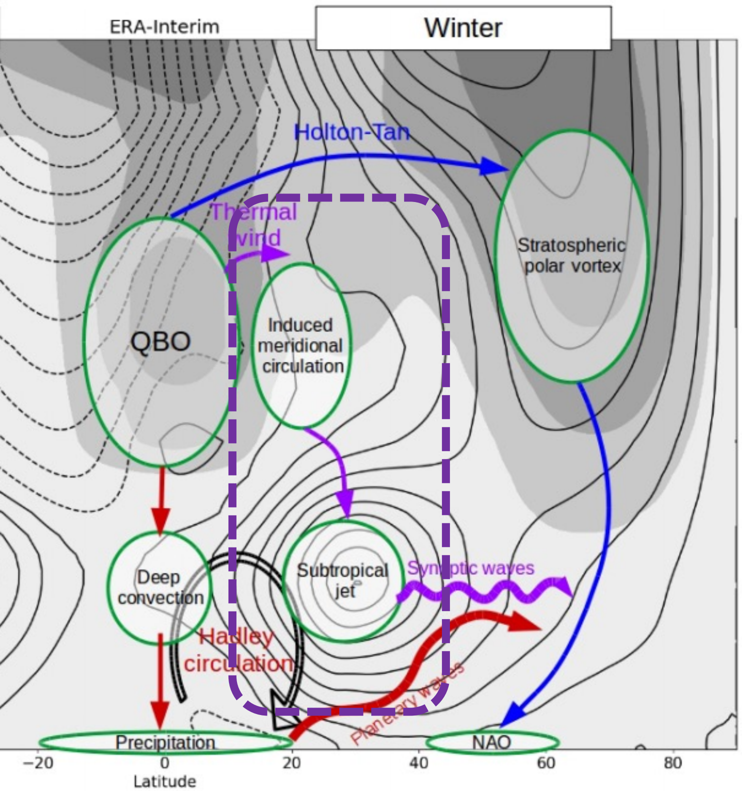
- In EQBO (U50<0) winters, MJO becomes stronger and more persistent than in WQBO winters. This causes a stronger MJO teleconnection and MJO-induced precipitation anomalies in East Asia.
- QBO-MJO connection is only weakly reproduced by the models. The mechanism is still unclear.

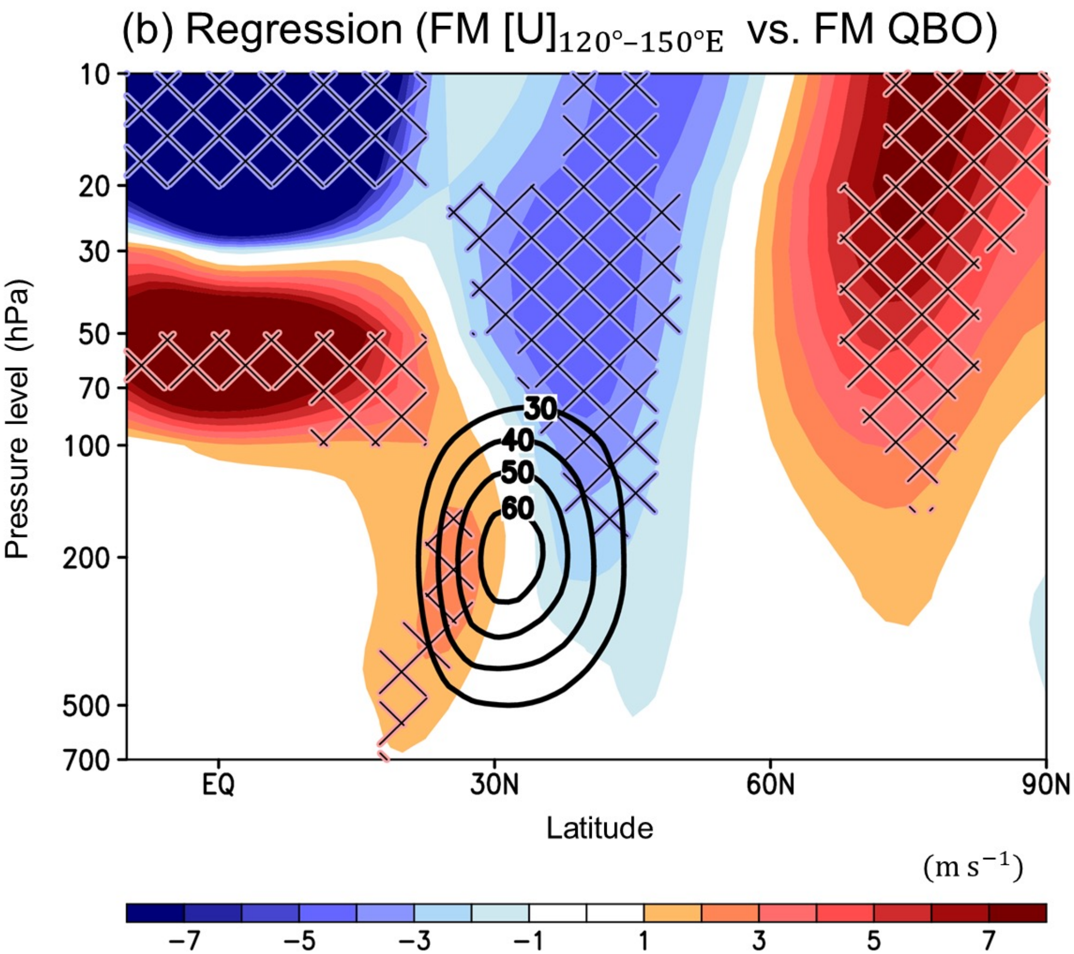


Martin et al. (2021NREE)

Fig. 5 | **Schematic illustration of the QBO–MJO connection.** Mechanisms and impacts of quasi-biennial oscillation (QBO)-Madden–Julian oscillation (MJO) coupling during QBO easterly (QBOE; panel **a**) and QBO westerly (QBOW; panel **b**) winds.

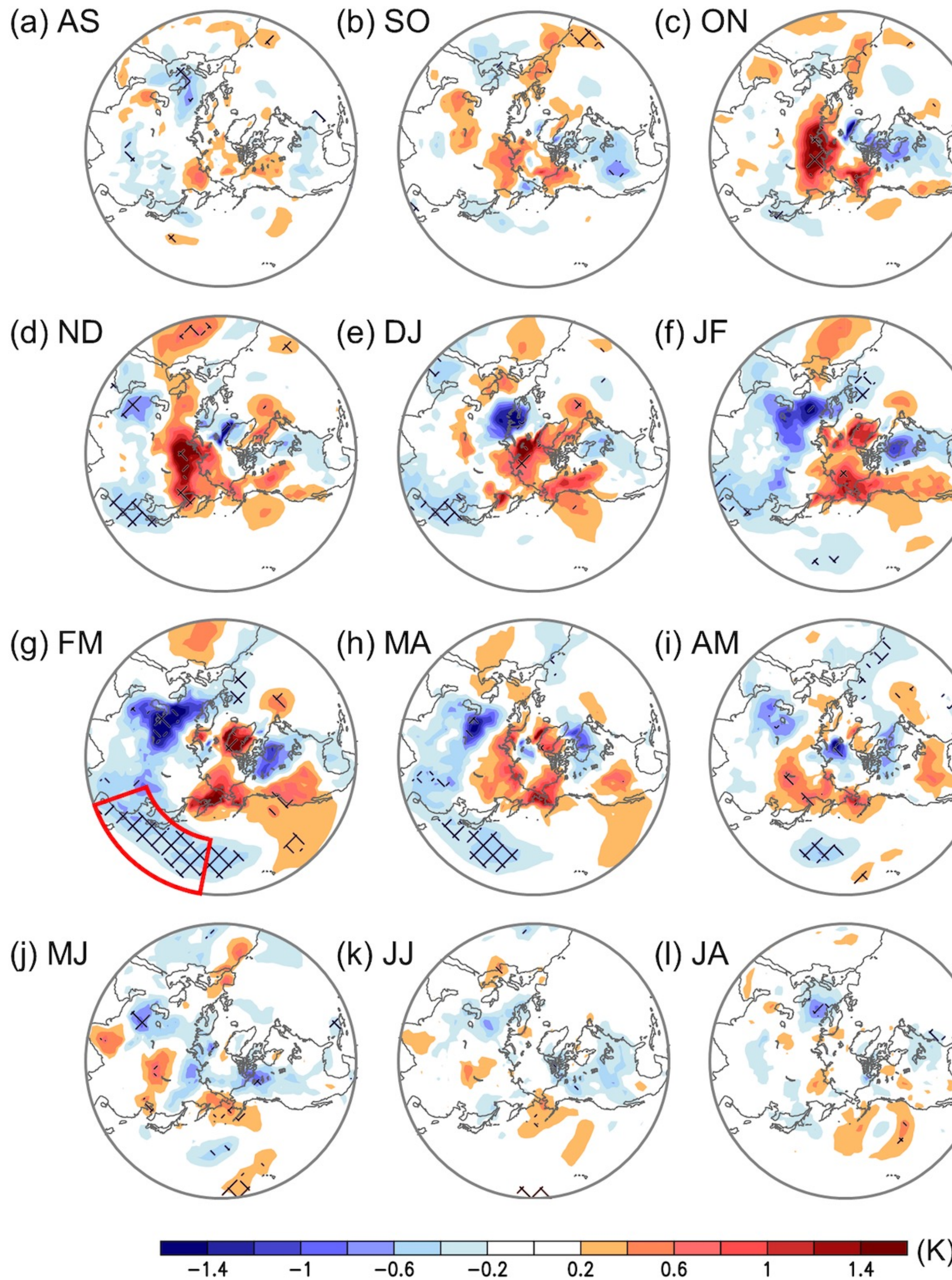
3. QBO-Asia Pacific Jet





3. QBO-Asia Pacific Jet

- WQBO (U70>0) winters tends to accompany cold temperature in East Asia in Feb-Mar.



Park et al. (2021 revised)

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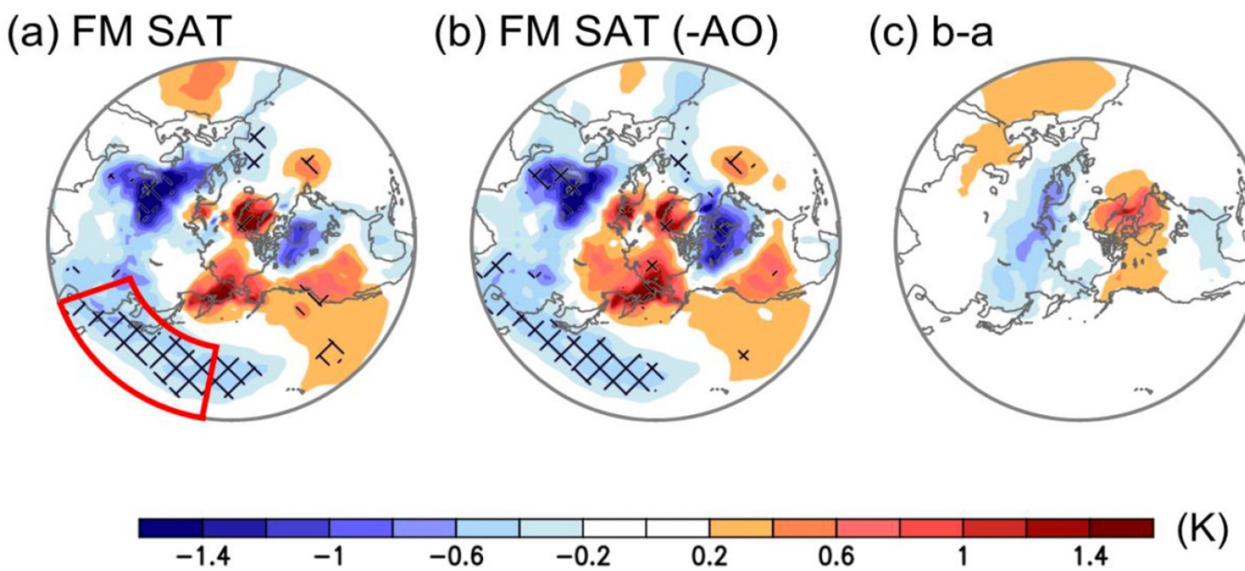

Park et al. (2021 revised)

- It differs from EQBO-polar vortex weakening-negative AO; WQBO indeed shows +AO signal in high latitudes. When +AO signal is removed, cold temperature in East Asia does not change much. East Asian temperature is more strongly influenced by QBO-Asia Pacific jet connection.

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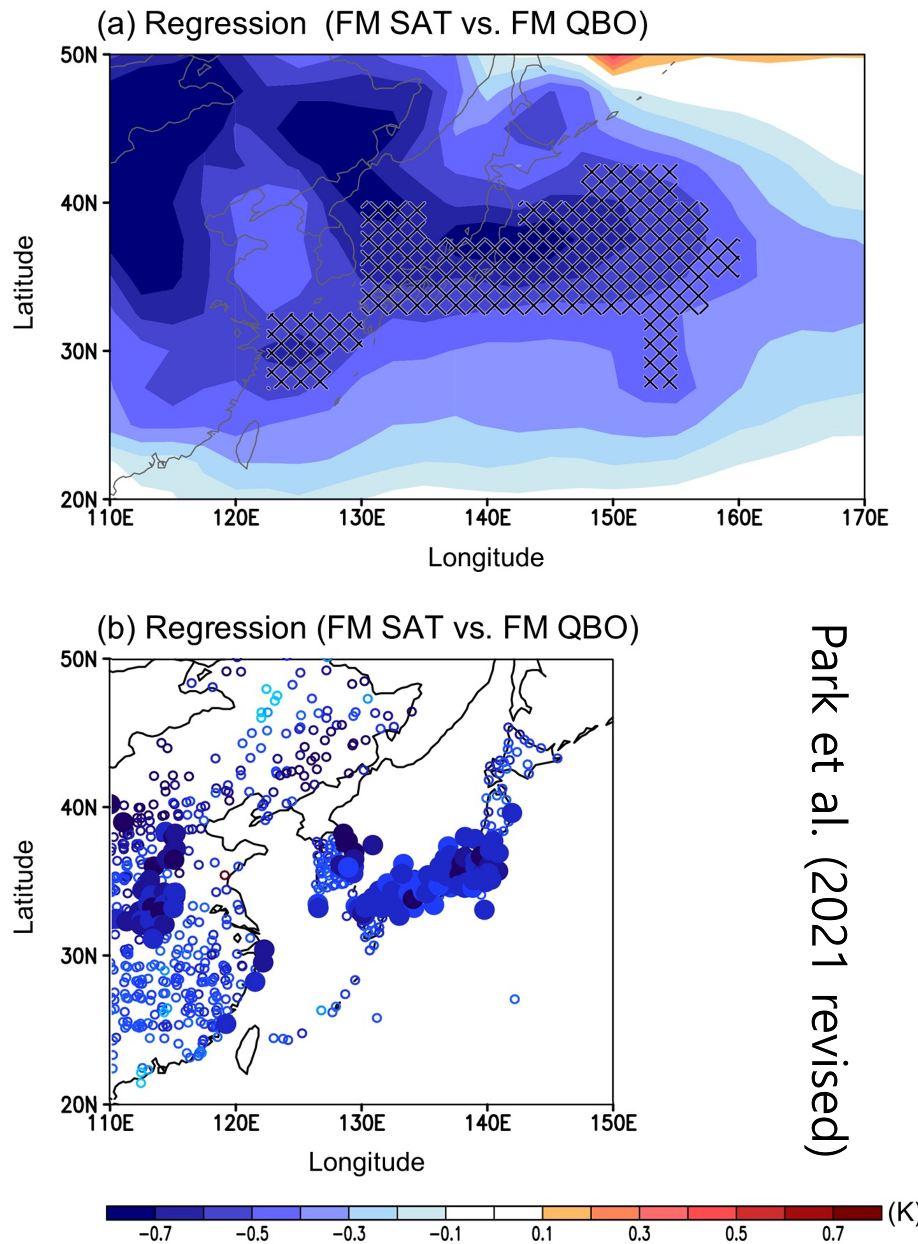

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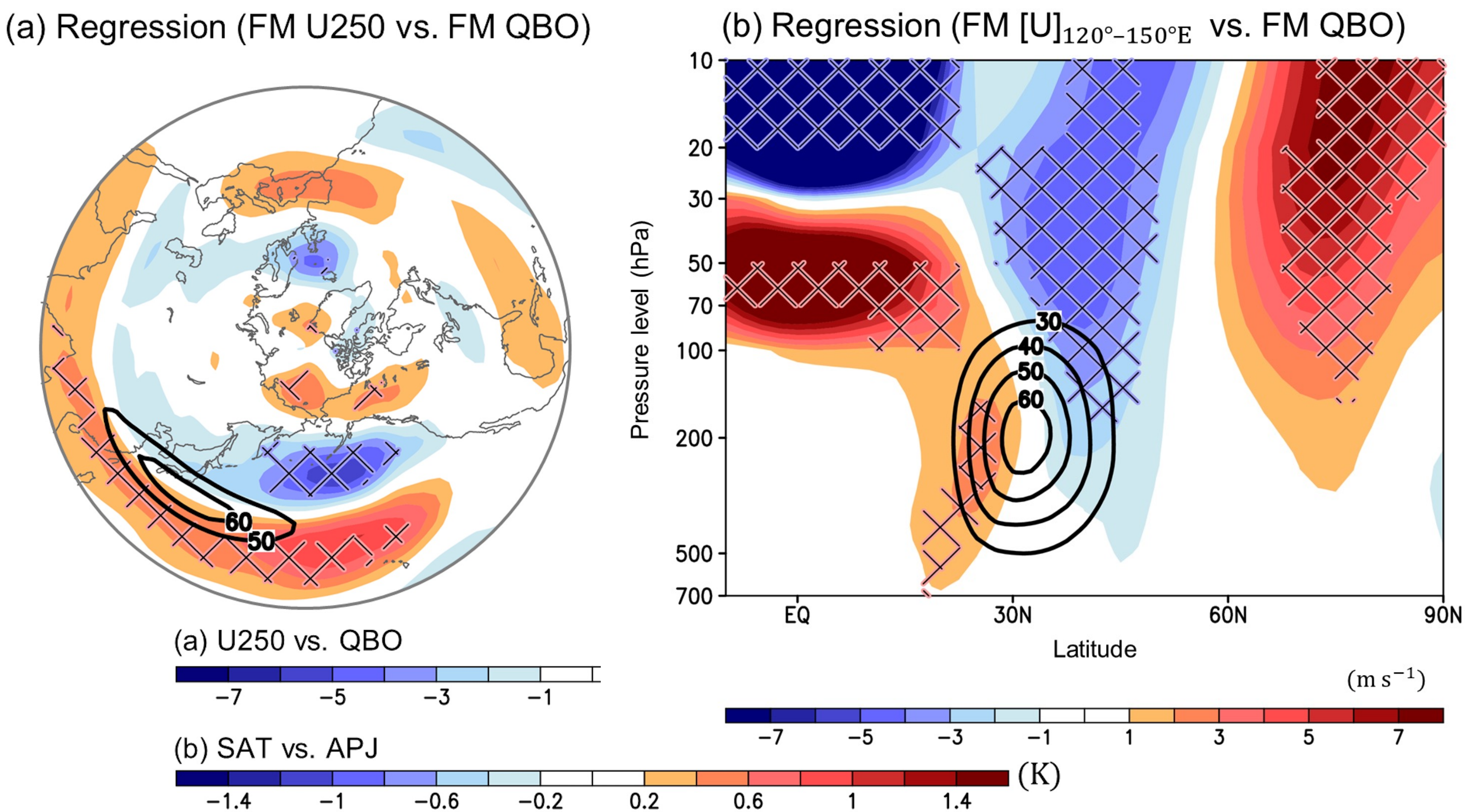
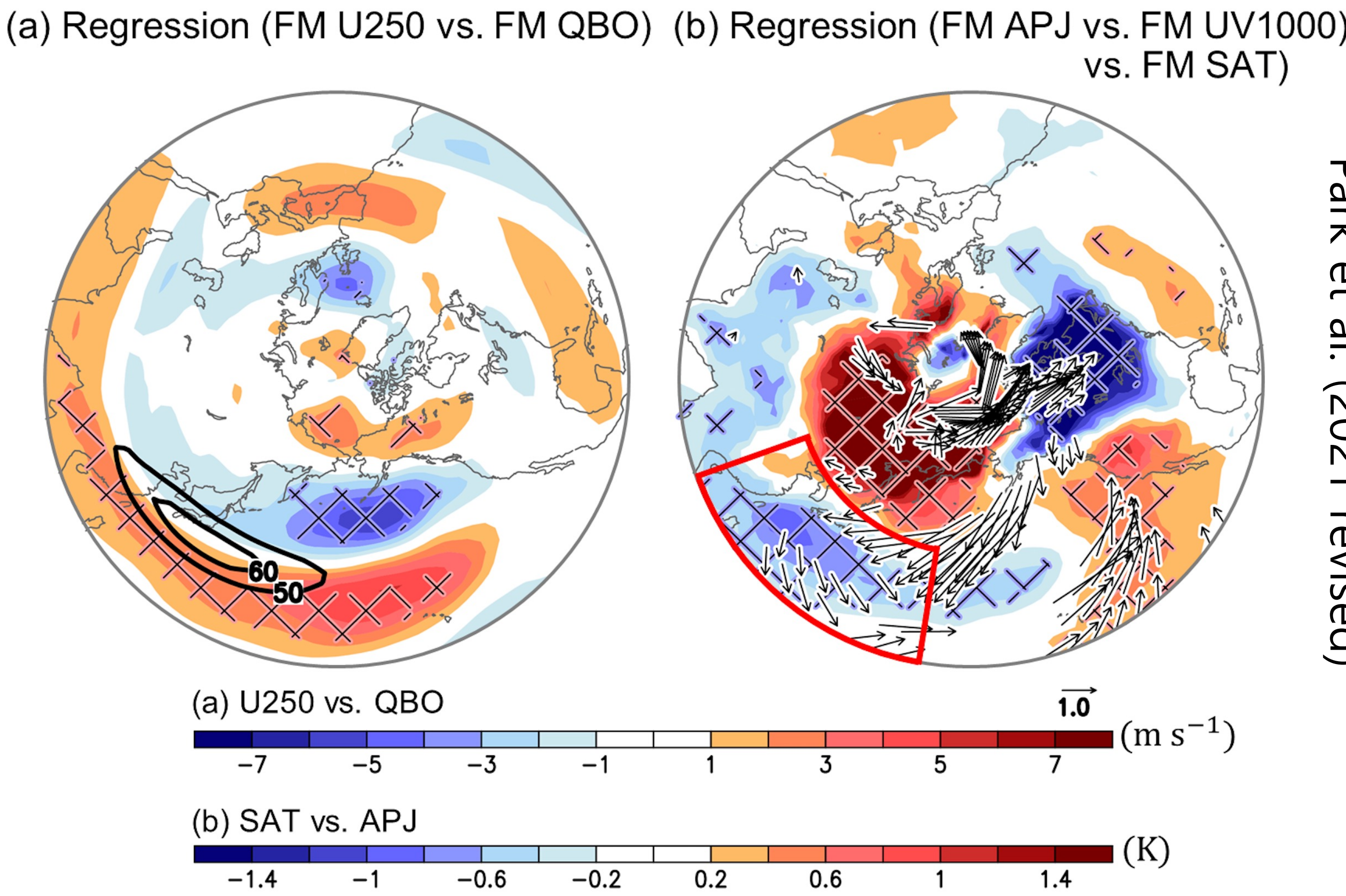


- WQBO (U70>0) is accompanied by an equatorward shift of the Asia-Pacific jet in Feb-Mar.

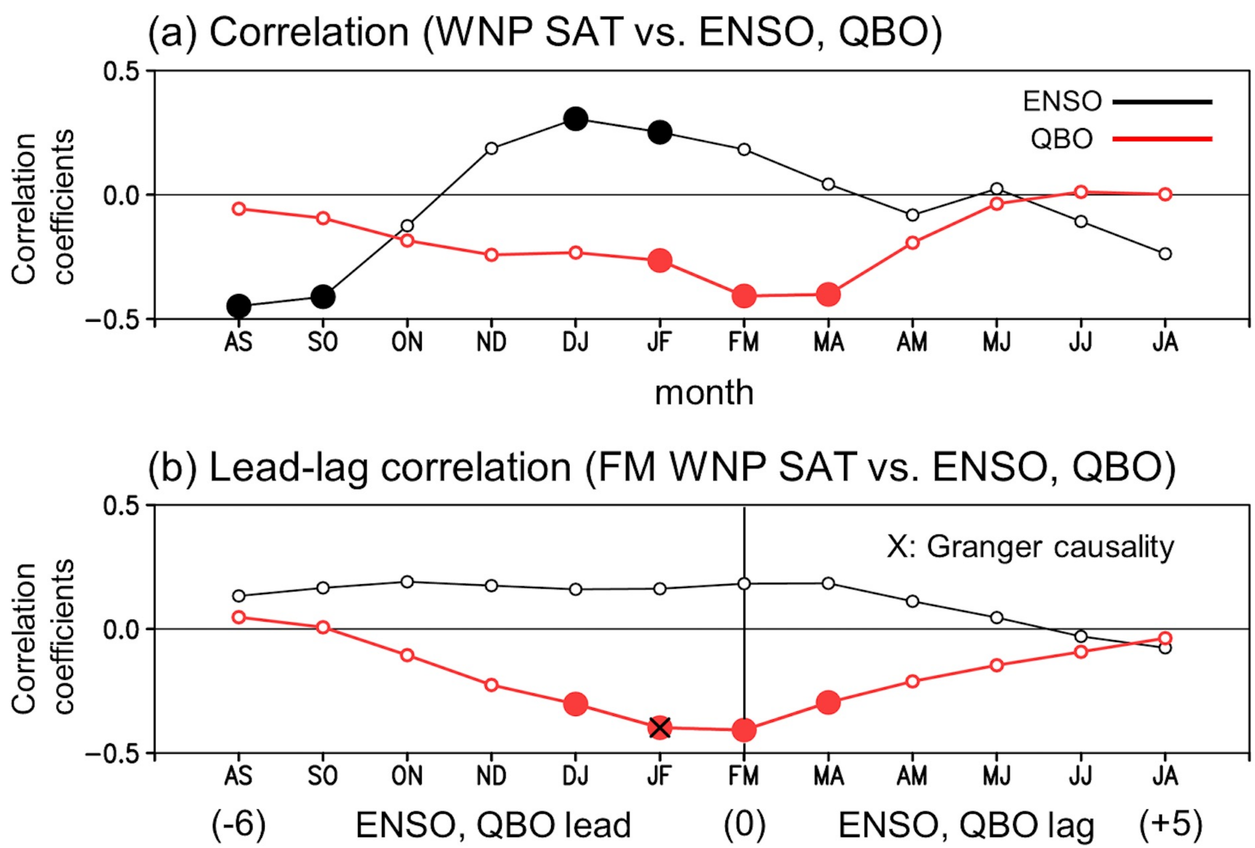
3. QBO-Asia Pacific Jet



Park et al. (2021 revised)

- An equatorward shift of the Asia-Pacific jet in Feb-Mar is accompanied by anticyclonic circulation anomaly in the North Pacific. The resultant cold advection from the north causes cold temperature anomaly in East Asia.

3. QBO-Asia Pacific Jet



Park et al. (2021 revised)

- Warm anomaly in El Nino winter vs. warm anomaly in EQBO (U70<0) late winter and early spring. The latter has a Granger causality.

3. QBO-Asia Pacific Jet: Summary

- In EQBO (U70<0) winters, the Asia-Pacific jet shifts poleward. The associated surface circulation change results in warm surface air temperature anomaly in late winter in East Asia.
- The mechanism is still unclear.

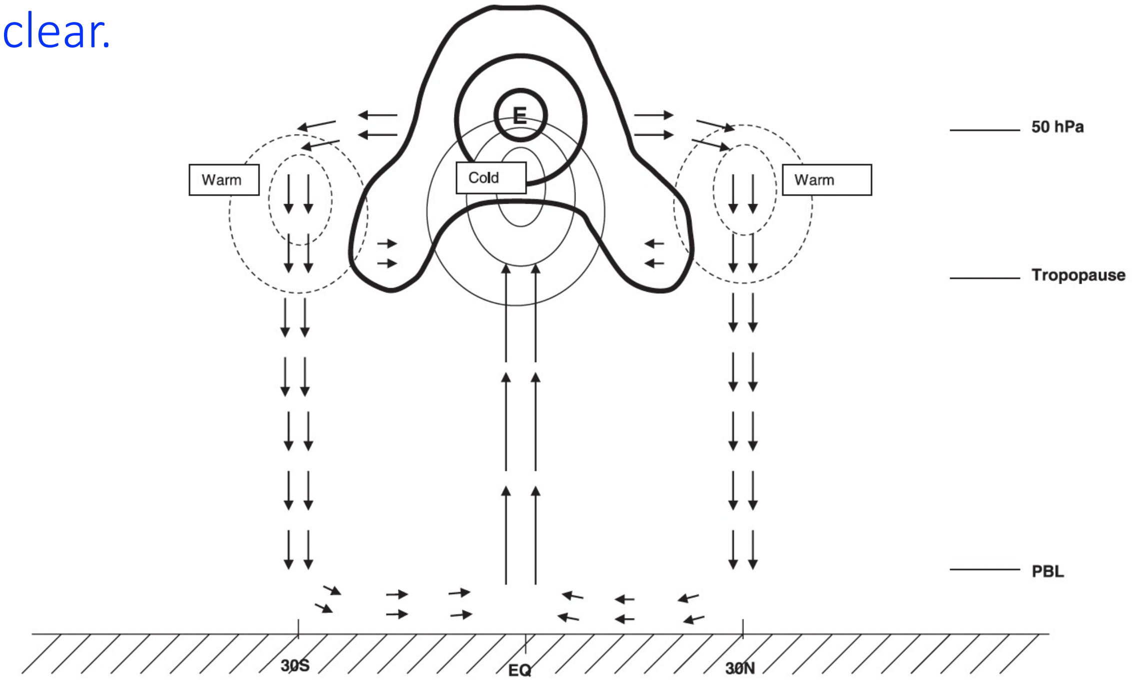
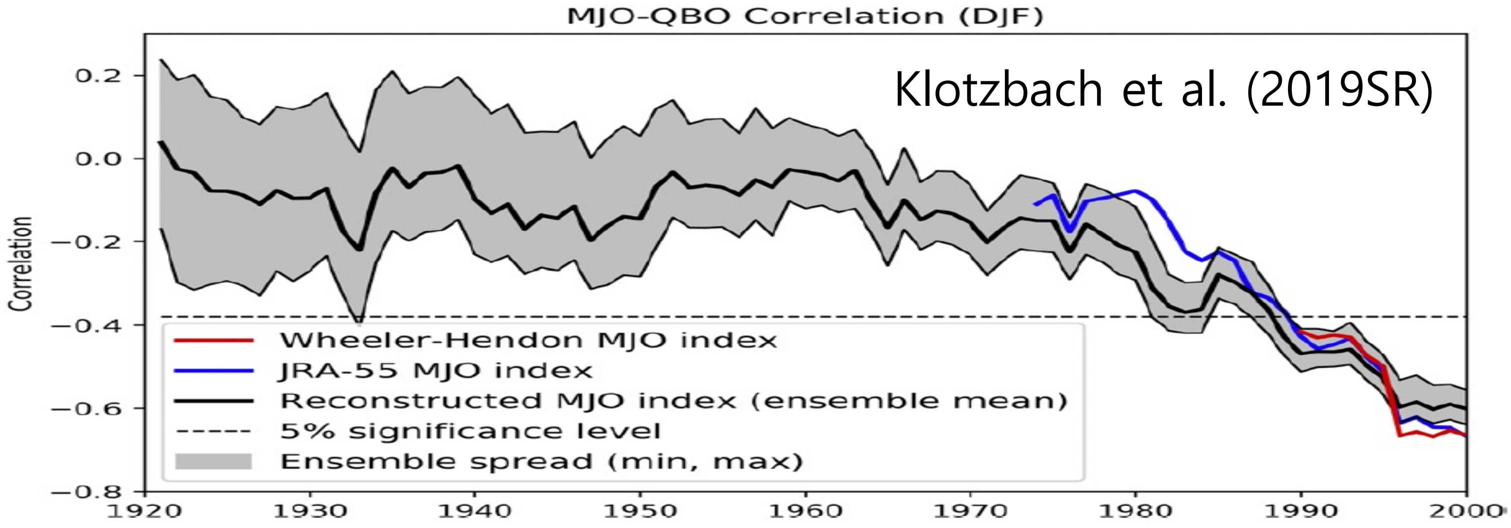


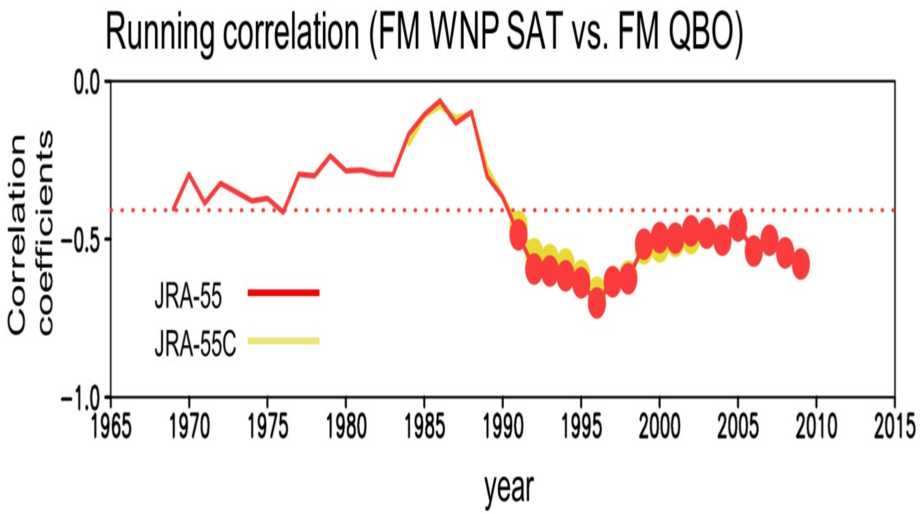
FIG. 4. Schematic of the zonally averaged circulation associated with the QBO in the absence of eddies. Arrows denote the mass weighted circulation. Thick (thin) contours are for zonal wind (temperature). All features, except for the easterly maxima at the equator, are a response to the EQBO winds rather than resulting directly from the externally imposed torque. The Coriolis force implies that part of the return circulation to the equator will occur by the downward-arching zonal wind anomalies above the tropopause, and momentum conservation implies that part of the return circulation to the equator will occur in the PBL.

Garfinkel and Hartmann (2011JAS)

Emergence of QBO downward influences



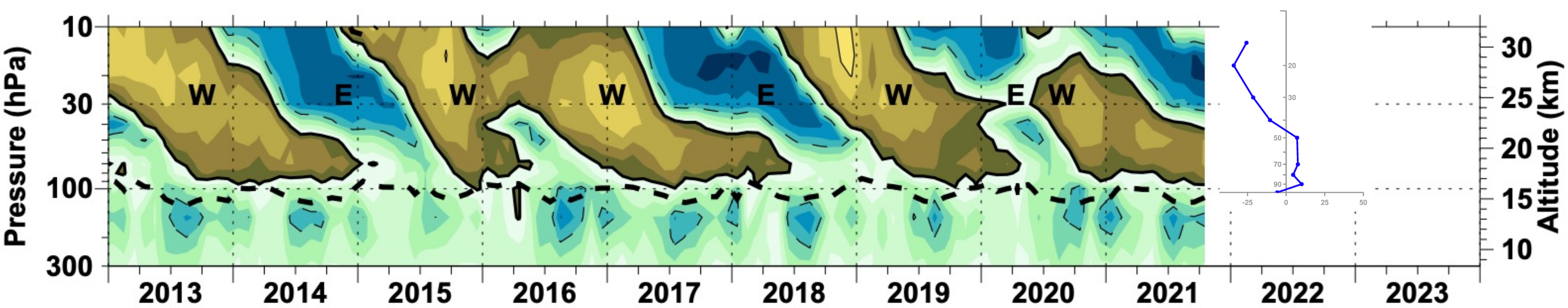
- QBO downward influence has only recently emerged!



Park et al. (2021 revised)

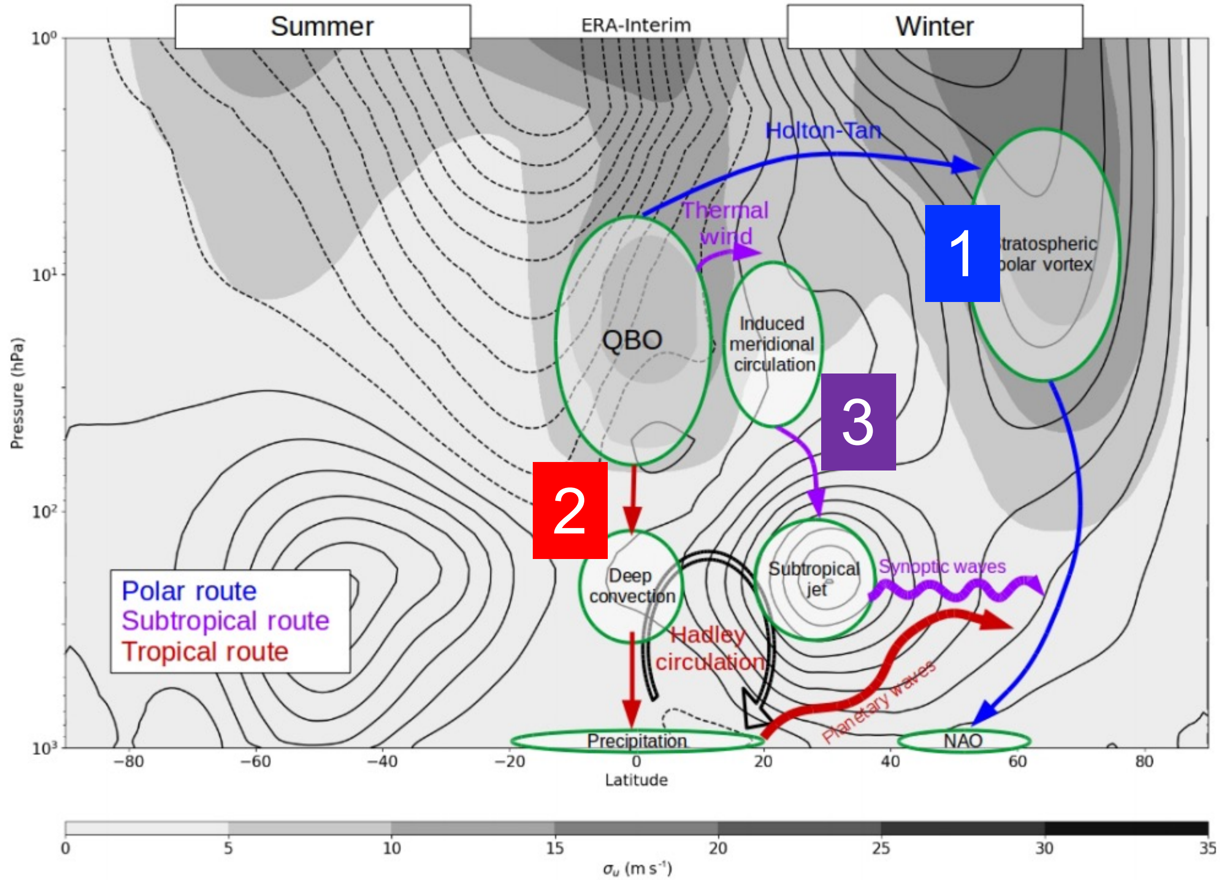
Implication to 2021/22 winter climate

- In EQBO (U50<0) winters, MJO becomes stronger and more persistent resulting in a stronger MJO-related subseasonal variability in East Asia.
- In EQBO (U70<0) winters, the Asia-Pacific jet shifts poleward which results in a warm temperature anomaly in late winter in East Asia.
- QBO phase in 2021/22 winter is likely in transition. This may imply no significant impacts of QBO on East Asian surface climate this winter.



QBO: Downward influences

Gray et al. (2018ACP)



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