Supplementary Material

Zonal asymmetry of the Quasi Biennial Oscillation

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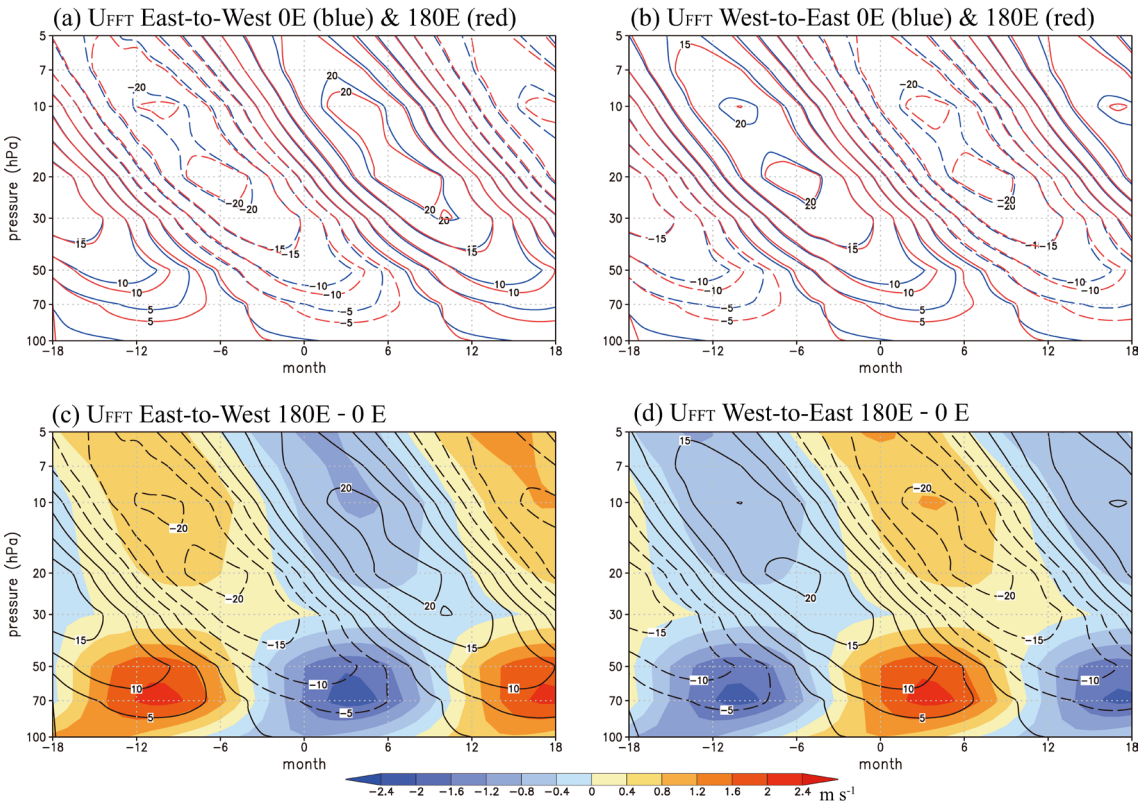
Supplementary material provided with this paper contains four supplementary figures (Figs. S1–S4), three supplementary tables (Tables S1–S3), and a description of the IGRA data processing procedure.



1

2 **Figure S1.** Same as Figure 1 but using U_{FFT}.

3

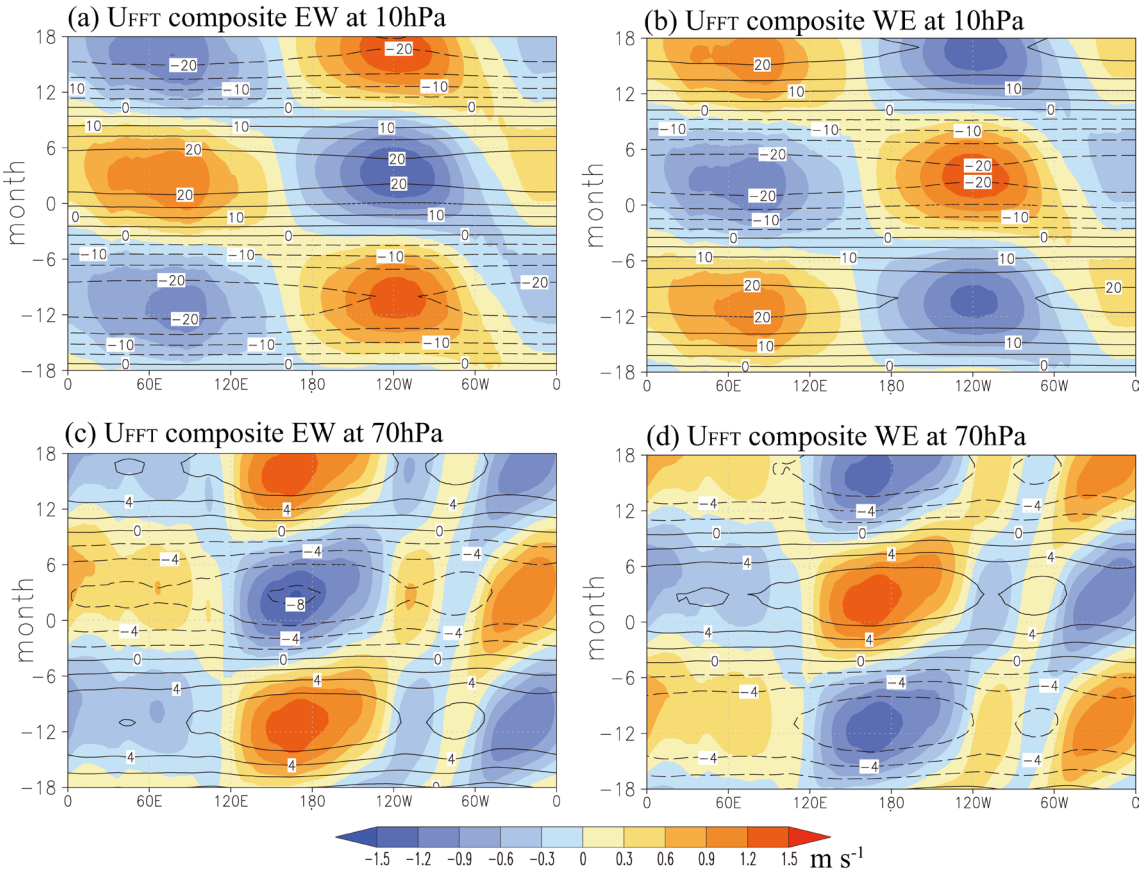


Figure S2. Same as Figure 3 but using U_{FFT}.

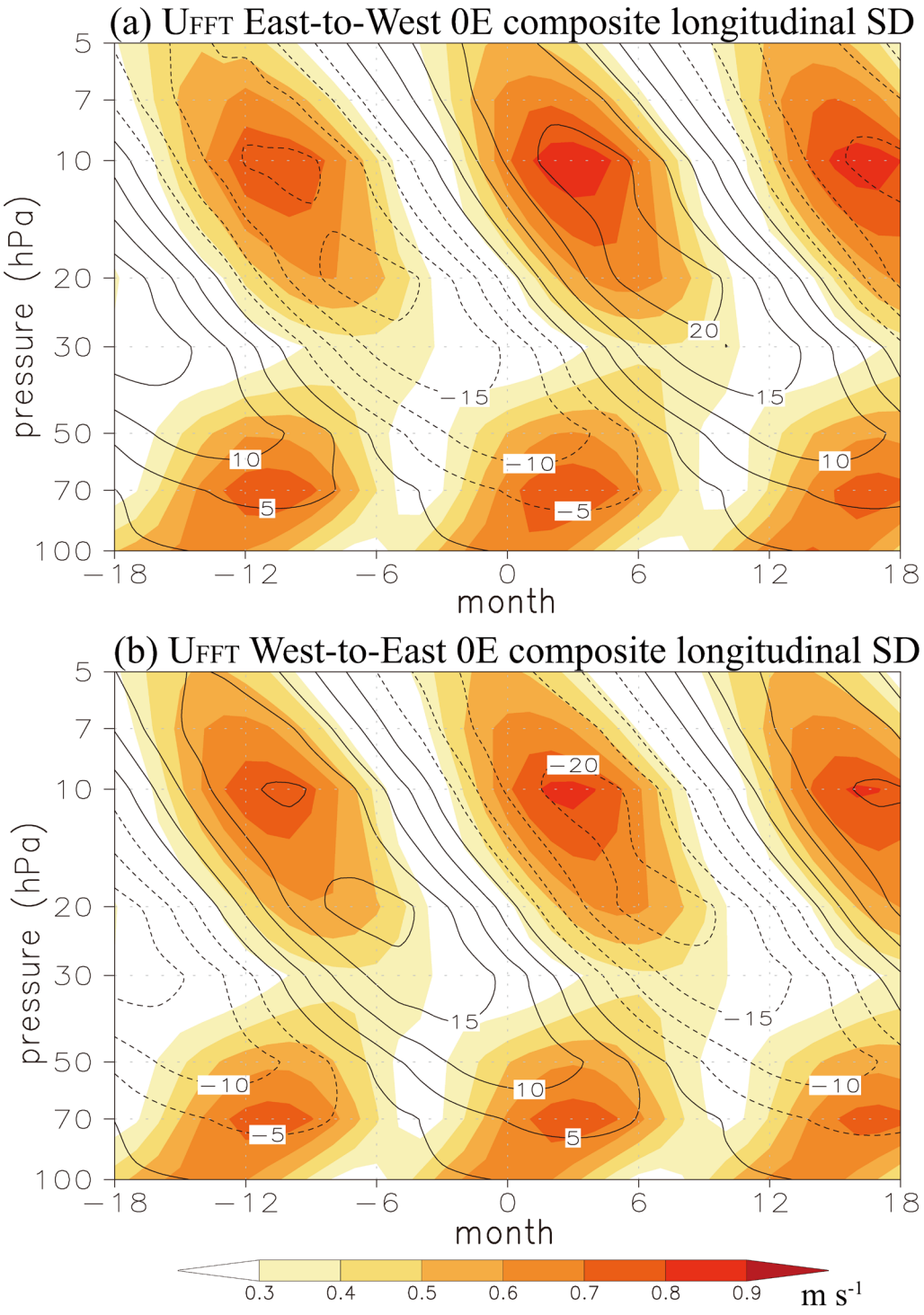
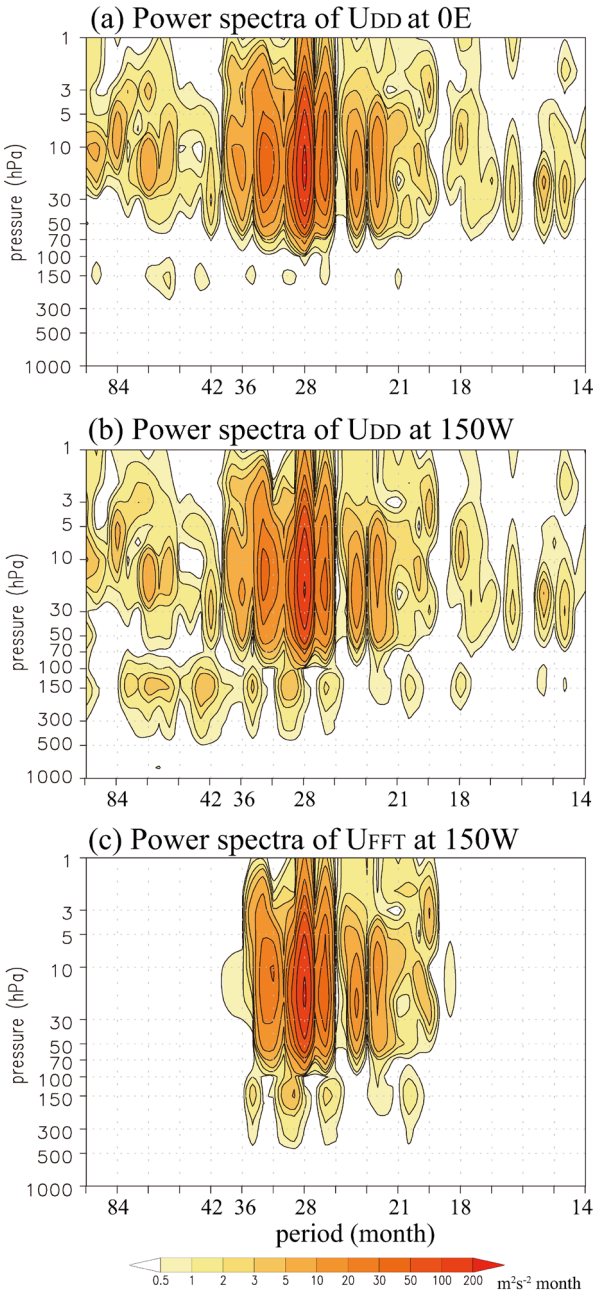


Figure S3. Same as Figure 4 but using U_{FFT}.

1



2

3 **Figure S4.** Power spectra of (a) U_{DD} at 0°E, (b) U_{DD} at 150°W, and (c) U_{FFT} at 150°W.

4 The vertical axis shows pressure (hPa) and the horizontal axis shows period (months).

5 Colors indicate spectral power ($m^2\ s^{-2}$ month), with color intervals as in the color

6 bar.

E to W DD	Month	W to E DD	Month
1	Apr 1959	1	Mar 1958
2	Dec 1960	2	Apr 1960
3	May 1963	3	Jan 1962
4	Jan 1966	4	Jun 1964
5	Sep 1968	5	Apr 1967
6	Oct 1970	6	Nov 1969
7	Nov 1972	7	Feb 1972
8	Jan 1975	8	Oct 1973
9	Jul 1977	9	May 1976
10	Dec 1979	10	Sep 1978
11	May 1982	11	Mar 1981
12	Sep 1984	12	May 1983
13	Jun 1987	13	Feb 1986
14	Nov 1989	14	Apr 1988
15	May 1992	15	Mar 1991
16	Aug 1994	16	Jun 1993
17	Oct 1996	17	Sep 1995
18	Sep 1998	18	Nov 1997
19	Aug 2001	19	Nov 1999
20	Oct 2003	20	Nov 2002
21	Dec 2005	21	Oct 2004
22	Nov 2007	22	Dec 2006
23	May 2010	23	Feb 2009
24	Sep 2012	24	May 2011
25	Mar 2015	25	Mar 2014

Table S1. Dates of easterly-to-westerly and westerly-to-easterly transitions in the deseasonalized and smoothed zonal-mean U_{DD} from JRA-55 reanalysis data.

E to W FFT	Month	W to E FFT	Month
1	Dec 1958	1	Apr 1958
2	Jan 1961	2	Jan 1960
3	May 1963	3	Mar 1962
4	Feb 1966	4	Oct 1964
5	Aug 1968	5	May 1967
6	Nov 1970	6	Oct 1969
7	Nov 1972	7	Nov 1971
8	Feb 1975	8	Dec 1973
9	Jun 1977	9	Apr 1976
10	Nov 1979	10	Aug 1978
11	May 1982	11	Feb 1981
12	Sep 1984	12	Jul 1983
13	May 1987	13	Feb 1986
14	Nov 1989	14	Jul 1988
15	Apr 1992	15	Mar 1991
16	Aug 1994	16	Jun 1993
17	Oct 1996	17	Sep 1995
18	Nov 1998	18	Oct 1997
19	Jul 2001	19	Feb 2000
20	Oct 2003	20	Sep 2002
21	Nov 2005	21	Nov 2004
22	Dec 2007	22	Dec 2006
23	Apr 2010	23	Feb 2009
24	Sep 2012	24	Jun 2011
25	Mar 2015	25	Dec 2013

Table S2. Same as Table S1, but for U_{FFT}.

E to W FUB/KIT	Month
1	Feb 1959
2	Sep 1960
3	May 1963
4	Dec 1965
5	Jul 1968
6	Oct 1970
7	Oct 1972
8	Nov 1974
9	May 1977
10	Oct 1979
11	May 1982
12	Aug 1984
13	May 1987
14	Nov 1989
15	Apr 1992
16	Aug 1994
17	Oct 1996
18	Aug 1998
19	Jul 2001
20	Sep 2003
21	Nov 2005
22	Nov 2007
23	Jun 2010
24	Aug 2012
25	Mar 2015

Table S3. Dates of easterly-to-westerly transitions in the deseasonalized and smoothed U_{DD} from FUB/KIT radiosonde data.

Description of IGRA data processing

Monthly mean zonal wind data at 70 hPa were obtained from stations located within 10° latitude of the equator, using the Integrated Global Radiosonde Archive (IGRA), version 2.2 (NOAA NCEI; https://www.ncei.noaa.gov/products/weather-balloon/integrated-global-radiosonde-archive). For each station, the 00 and 12 UTC time series were processed independently. A centered five-month running mean was applied to each series to interpolate isolated missing months. When both 00 and 12 UTC observations were available in a given month, their average was used as the monthly value; if only one observation was available, that value was used. Months with no available data were left missing.

QBO amplitudes were calculated from the resulting continuous monthly series, but only for QBO cycles with complete monthly data; incomplete cycles were assigned missing. The QBO cycle was defined using deseasonalized and smoothed 20 hPa zonal wind data from the FUB/KIT dataset (Naujokat, 1986), maintained by the Freie Universität Berlin (FUB) and the Karlsruhe Institute of Technology (KIT). Months of transition from easterly-to-westerly winds were identified (Table S3). Each interval between two successive easterly-to-westerly transitions was treated as one QBO cycle. To examine the climatological QBO amplitude at each station, only stations with at least eight complete cycles during the analysis period (1958–2015; 24 cycles in total) were included. This threshold corresponds to a minimum of about 30% coverage. A total of 27 stations within 10°S–10°N met this criterion.

The QBO amplitude exhibits a maximum over the equator, with a meridional half-width of approximately 12° (Baldwin et al., 2001). To examine longitudinal variations in the observed QBO amplitude, an equatorial adjustment was applied. The meridional

structure of the climatological zonal-mean QBO amplitude was derived from JRA-55 data for 1958–2015. Each station's amplitude was scaled to the equator by applying a factor that converts the typical amplitude at the station's latitude to the typical equatorial amplitude. This latitudinal adjustment enabled fair comparisons of amplitudes across stations located at different latitudes within the equatorial band.