Explanation of the contents of Supplement.zip

This supplement is for the paper by Fujiwara et al. titled:

Climatology of the terms and variables of transformed Eulerian-mean (TEM) equations from multiple reanalyses: MERRA-2, JRA-55, ERA-Interim, and CFSR

Supplement.zip contains the following three folders:

- 1.Reanalysis_Ensemble_Mean (Supplement Folder 1)
- 2.Each_Reanalysis (Supplement Folder 2)
- 3.Comparisons_for_major_variables_and_terms (Supplement Folder 3)
- 4.Zonal_accelerations_due_to_parameterizations (Supplement Folder 4)

Short descriptions of each folder are as follows:

Supplement Folder 1 ("1.Reanalysis_Ensemble_Mean") has the following four PDF files:

- REM_DJF.pdf: Figures for the TEM variables and terms of the REM for 30-year DJF means
- REM_JJA.pdf: Figures for the TEM variables and terms of the REM for 30-year JJA means
- REM_MAM.pdf: Figures for the TEM variables and terms of the REM for 30-year MAM means
- REM_SON.pdf: Figures for the TEM variables and terms of the REM for 30-year SON means

(Note that some of the figures for DJF and JJA are also shown in the main body of the paper. They are also archived here for completeness.)

Supplement Folder 2 ("2.Each_Reanalysis") has the following four folders:

- CFSR
- ERA-Interim
- JRA-55
- MERRA-2

and each of these folders has the following two types of PDF files, i.e. eight PDF files in total:

- [REANALYSIS-NAME]__[SEASON].pdf (e.g. CFSR__DJF.pdf): Figures for the same set of variables and terms for REM_[SEASON].pdf, but for the individual reanalysis
- [REANALYSIS-NAME]_minus_REM_[SEASON].pdf (e.g. CFSR_minus_REM_DJF.pdf): Figures for the same set of variables and terms for REM_[SEASON].pdf, but for anomalies of the reanalysis with respect to the REM

where [REANALYSIS-NAME] is either CFSR, ERA-Interim, JRA-55, or MERRA-2, and [SEASON] is either DJF, JJA, MAM, or SON.

Supplement Folder 3 (“3.Comparisons_for_major_variables_and_terms”) has the following four PDF files:

- Comparisons_[SEASON].pdf : Figures for comparison of the four reanalyses and for inter-reanalysis differences for selected TEM variables and terms, with one page for one variable/term

where [SEASON] is either DJF, JJA, MAM, or SON.

(Note that some of the figures for DJF and JJA are also shown in the main body of the paper. They are also archived here for completeness.)

Supplement Folder 4 (“4.Zonal_accelerations_due_to_parameterizations”) has the following four folders:

- DJF
- JJA
- MAM
- SON

and each of these folders has the following four PDFs:

- zonalaccel_CFSR_[SEASON].pdf
- zonalaccel_ERA-I_[SEASON].pdf
- zonalaccel_JRA-55_[SEASON].pdf
- zonalaccel_MERRA-2_[SEASON].pdf

where [SEASON] is either DJF, JJA, MAM, or SON.

The captions of all the figures in all the above PDF files are shown starting from the next page.

Supplement Folder 1 (“1.Reanalysis_Ensemble_Mean”)

Supplement Folder 1 (“1.Reanalysis_Ensemble_Mean”) has the following four PDF files:

- REM_DJF.pdf: Figures for the TEM variables and terms of the REM for 30-year DJF means
- REM_JJA.pdf: Figures for the TEM variables and terms of the REM for 30-year JJA means
- REM_MAM.pdf: Figures for the TEM variables and terms of the REM for 30-year MAM means
- REM_SON.pdf: Figures for the TEM variables and terms of the REM for 30-year SON means

(Note that some of the figures for DJF and JJA are also shown in the main body of the paper. They are also archived here for completeness.)

Each PDF file has the following 7 pages:

Page 1:

Variables and their contours are same as for Figure 1.

Page 2:

(a) $\overline{w}^*$. Contours are located at ±0.1, ±0.2, ±0.5, ±1, ±2, . . . mm s^{-1} with dotted contours for negative values.
(b) $\overline{w}^*_{\overline{v}^*}$. Contours are same as for (a).
(c) $\overline{\omega}^*$. Contours are located at ±0.02, ±0.05, ±0.1, ±0.2, ±0.5, . . . mPa s^{-1} with dotted contours for negative values.
(d) $\overline{\omega}^*_{\overline{v}^*}$. Contours are same as for (c).

Page 3:

Variables and their contours and colours are same as for Figure 3.

Page 4:

Variables and their contours and colours are same as for Figure 2.

Page 5:

(a) Zonal wind tendency term. Contours are located at ±0.1, ±0.2, ±0.5, ±1, ±2, . . . m s^{-1} day^{-1} with dotted contours for negative values in all panels; orange shading indicates values greater than 0.5 m s^{-1} day^{-1}, while light blue shading indicates values smaller than −0.5 m s^{-1} day^{-1} (i.e. same as for Figure 3).
(b) Summation of the Coriolis term, the term for meridional advection of zonal momentum, and the term for vertical advection of zonal momentum. Contours and colours are same as for (a).
(c) EP flux divergence term. Contours and colours are same as for (a).
(d) The residual term $\overline{\varepsilon_u}$. Contours and colours are same as for (a).

Page 6:

Variables and their contours and colours are same as for Figure 4.

Page 7:

(a) The residual term $\overline{\varepsilon_\theta}$. Contours are located at ±0.1, ±0.2, ±0.5, ±1, ±2, . . . K day^{-1} with dotted contours for negative values in all panels; orange shading indicates values greater than 0.5 K day^{-1}, while light blue shading indicates values smaller than −0.5 K day^{-1} (i.e. same as for Figure 4).
(b) The residual term $\bar{\chi}$ in Equation 12 of Martineau et al. (2018). Contours and colours are same as for (a).
(c) $\overline{\varepsilon_\theta}$ subtracted by $\bar{\chi}$. Contours and colours are same as for (a).

Supplement Folder 2 (“2.Each_Reanalysis”)

Supplement Folder 2 (“2.Each_Reanalysis”) has the following four folders:

- CFSR
- ERA-Interim
- JRA-55
- MERRA-2

and each of these folders has the following two types of PDF files, i.e. eight PDF files in total:

- [REANALYSIS-NAME]__[SEASON].pdf (e.g. CFSR__DJF.pdf): Figures for the same set of variables and terms for REM_[SEASON].pdf, but for the individual reanalysis
- [REANALYSIS-NAME]_minus_REM_[SEASON].pdf (e.g. CFSR_minus_REM_DJF.pdf): Figures for the same set of variables and terms for REM_[SEASON].pdf, but for anomalies of the reanalysis with respect to the REM

where [REANALYSIS-NAME] is either CFSR, ERA-Interim, JRA-55, or MERRA-2, and [SEASON] is either DJF, JJA, MAM, or SON.

Therefore, there are two types of figures. For both, the climatological tropopause location is obtained from each reanalysis data, not from the REM.

For the files [REANALYSIS-NAME]__[SEASON].pdf (e.g. CFSR__DJF.pdf), the variables and their contours and colours in each page are the same as for the REM_[SEASON].pdf files in Supplement Folder 1 (“1.Reanalysis_Ensemble_Mean”). Thus, please refer to the descriptions for Supplement Folder 1.

For the files [REANALYSIS-NAME]_minus_REM_[SEASON].pdf (e.g. CFSR_minus_REM_DJF.pdf), the variables in each page are the same as for the REM_[SEASON].pdf files, but their contours and colours may be different and thus are described fully below:

Page 1:

(a) For temperature. Contour interval is 0.5 K, with dotted contours for negative values; orange shading indicates values greater than 0.5 K, light blue shading indicates values smaller than −0.5 K.
(b) For potential temperature. Contour interval is 2 K, with dotted contours for negative values; orange shading indicates values greater than 2 K, while light blue shading indicates values smaller than −2 K.
(c) For zonal wind. Contour interval is 0.5 m s^{-1}, with dotted contours for negative values; orange shading indicates values greater than 1 m s^{-1}, while light blue shading indicates values smaller than −1 m s^{-1}.

(d) For $\bar{v}^*$. Contours are located at ±0.01, ±0.02, ±0.05, ±0.1, ±0.2, . . . m s^{-1} with dotted contours for negative values; orange shading indicates values greater than 0.05 m s^{-1}, while light blue shading indicates values smaller than −0.05 m s^{-1}.
(e) For $\bar{w}^*$. Contours are located at ±0.02, ±0.05, ±0.1, ±0.2, ±0.5, . . . mm s^{-1} with dotted contours for negative values; orange shading indicates values greater than 0.1 mm s^{-1}, while light blue shading indicates values smaller than −0.1 mm s^{-1}.
(f) For $\bar{w}^*_{\bar{v}^*}$. Contours and colours are same as for (e).
(g) For $\Psi^*_{\bar{v}^*}$. Contours are located at ±0.1, ±0.2, ±0.5, ±1, ±2, . . . kg m^{-1} s^{-1} with dotted contours for negative values; orange shading indicates values greater than 1 kg m^{-1} s^{-1}, while light blue shading indicates values smaller than −1 kg m^{-1} s^{-1}.
(h) For $\Psi^*_{\bar{\omega}^*}$. Contours and colours are same as for (g).

Page 2:

(a) For $\bar{w}^*$. Contours are located at ±0.02, ±0.05, ±0.1, ±0.2, ±0.5, . . . mm s^{-1} with dotted contours for negative values; orange shading indicates values greater than 0.1 mm s^{-1}, while light blue shading indicates values smaller than −0.1 mm s^{-1}.
(b) For $\bar{w}^*_{\bar{v}^*}$. Contours and colours are same as for (a).
(c) For $\bar{\omega}^*$. Contours are located at ±0.01, ±0.02, ±0.05, ±0.1, ±0.2, . . . mPa s^{-1} with dotted contours for negative values; orange shading indicates values greater than 0.02 mPa s^{-1}, while light blue shading indicates values smaller than −0.02 mPa s^{-1}.
(d) For $\bar{\omega}^*_{\bar{v}^*}$. Contours and colours are same as for (c).

Page 3:

(a) For total diabatic heating. Contour interval is 0.1 K day^{-1}, with dotted contours for negative values; orange shading indicates values greater than 0.1 K day^{-1}, while light blue shading indicates values smaller than −0.1 K day^{-1}.
(b) For longwave radiative heating. Contours and colours are same as for (a).
(c) For shortwave radiative heating. Contours and colours are same as for (a).
(d) For diabatic heating due to the processes other than radiative processes. Contours and colours are same as for (a).
(e) Vertical distribution of diabatic heating anomalies averaged globally (black: total; light blue: longwave radiative; orange: shortwave radiative; light green: other than radiative).
(f) Contour interval is 0.1 ppmv, with dotted contours for negative values; orange shading indicates values greater than 0.1 ppmv, while light blue shading indicates values smaller than −0.1 ppmv.

Page 4:

(a) For the zonal wind tendency term. Contours are located at ±0.01, ±0.02, ±0.05, ±0.1, ±0.2, . . . m s^{-1} day^{-1}

with dotted contours for negative values; orange shading indicates values greater than 0.05 m s^{-1} day^{-1}, while light blue shading indicates values smaller than −0.05 m s^{-1} day^{-1}.
(b) For the Coriolis term. Contours and colours are same as for (a).
(c) For the term for meridional advection of zonal momentum. Contours and colours are same as for (a).
(d) For the term for vertical advection of zonal momentum. Contours and colours are same as for (a).
(e) For the EP flux divergence term. Contours and colours are same as for (a).
(f) For the residual term $\overline{\varepsilon_u}$. Contours and colours are same as for (a).

Page 5:

(a) For the zonal wind tendency term. Contours are located at ±0.01, ±0.02, ±0.05, ±0.1, ±0.2, . . . m s^{-1} day^{-1} with dotted contours for negative values; orange shading indicates values greater than 0.05 m s^{-1} day^{-1}, while light blue shading indicates values smaller than −0.05 m s^{-1} day^{-1}.
(b) For summation of the Coriolis term, the term for meridional advection of zonal momentum, and the term for vertical advection of zonal momentum. Contours and colours are same as for (a).
(c) For the EP flux divergence term. Contours and colours are same as for (a).
(d) For the residual term $\overline{\varepsilon_u}$. Contours and colours are same as for (a).

Page 6:

(a) For the potential temperature tendency term. Contours are located at ±0.05, ±0.1, ±0.2, ±0.5, ±1, . . . K day^{-1} with dotted contours for negative values; orange shading indicates values greater than 0.2 K day^{-1}, while light blue shading indicates values smaller than −0.2 K day^{-1}.
(b) For the term for meridional advection of potential temperature. Contours and colours are same as for (a).
(c) For the term for vertical advection of potential temperature. Contours and colours are same as for (a).
(d) For the wave flux term of the TEM thermodynamic equation. Contours and colours are same as for (a).
(e) For the total diabatic heating term. Contours and colours are same as for (a).
(f) For the residual term $\overline{\varepsilon_\theta}$. Contours and colours are same as for (a).

Page 7:

(a) For the residual term $\overline{\varepsilon_\theta}$. Contours are located at ±0.05, ±0.1, ±0.2, ±0.5, ±1, . . . K day^{-1} with dotted contours for negative values; orange shading indicates values greater than 0.2 K day^{-1}, while light blue shading indicates values smaller than −0.2 K day^{-1}.
(b) For the residual term $\bar{\chi}$ in Equation 12 of Martineau et al. (2018). Contours and colours are same as for (a).
(c) Anomaly of $\overline{\varepsilon_\theta}$ subtracted by anomaly of $\bar{\chi}$. Contours and colours are same as for (a).

Supplement Folder 3 (“3.Comparisons_for_major_variables_and_terms”)

Supplement Folder 3 (“3.Comparisons_for_major_variables_and_terms”) has the following four PDF files:

- Comparisons_[SEASON].pdf: Figures for comparison of the four reanalyses and for inter-reanalysis differences for selected TEM variables and terms, with one page for one variable/term

where [SEASON] is either DJF, JJA, MAM, or SON.
(Note that some of the figures for DJF and JJA are also shown in the main body of the paper. They are also archived here for completeness.)

Each PDF file has 18 pages (one page for one variable as explained below), and each page has 6 panels (a)−(f), i.e. anomalies with respect to the REM for (a) MERRA-2, (b) JRA-55, (c) ERA-Interim, and (d) CFSR, and inter-reanalysis differences as presented in (e) standard deviation (SD) and (f) SD divided by absolute values of the REM in percent. See further details below:

Page 1:

For temperature. For (a)−(d), contour interval is 0.5 K, with dotted contours for negative values in all panels; orange shading indicates values greater than 0.5 K, while light blue shading indicates values smaller than −0.5 K. For (e), contour interval is 0.5 K, and light red shading marks values greater than 0.5 K. For (f), contour interval is 0.1 %, light red shading marks values greater than 0.2 %, and dark red shading indicates values greater than 1 %.

Page 2:

For zonal wind. For (a)−(d), contour interval is 0.5 m s^{-1}, with dotted contours for negative values in all panels; orange shading indicates values greater than 1 m s^{-1}, while light blue shading indicates values smaller than −1 m s^{-1}. For (e), contour interval is 0.5 m s^{-1}, and light red shading marks values greater than 1 m s^{-1}. For (f), contours are located at 1, 2, 5, 10, 20, . . . %, light red shading marks values greater than 5 %, and dark red shading marks greater than 50 %.

Page 3:

For $\bar{v}^*$. For (a)−(d), contours are located at ±0.01, ±0.02, ±0.05, ±0.1, ±0.2, . . . m s^{-1} with dotted contours for negative values in all panels; orange shading indicates values greater than 0.05 m s^{-1}, while light blue shading indicates values smaller than −0.05 m s^{-1}. For (e), contours are located at 0.01, 0.02, 0.05, 0.1, 0.2, . . . m s^{-1}, and light red shading marks values greater than 0.05 m s^{-1}. For (f), contours are located at 1, 2, 5, 10, 20, . . . %, light red shading marks values greater than 10 %, and dark red shading marks values greater than 50 %.

Page 4:

For $\bar{\omega}^*$. For (a)−(d), contours are located at ±0.01, ±0.02, ±0.05, ±0.1, ±0.2, . . . mPa s^{-1} with dotted contours for negative values in all panels; orange shading indicates values greater than 0.02 mPa s^{-1}, while light blue shading indicates values smaller than −0.02 mPa s^{-1}. For (e), contours are located at 0.01, 0.02, 0.05, 0.1, 0.2, . . . mPa s^{-1},

and light red shading marks values greater than 0.02 mPa s^{-1}. For (f), contours are located at 1, 2, 5, 10, 20, . . . %, light red shading marks values greater than 10 %, and dark red shading marks values greater than 50 %.

Page 5:

For $\overline{w}^*$. For (a)–(d), contours are located at ±0.02, ±0.05, ±0.1, ±0.2, ±0.5, . . . mm s^{-1} with dotted contours for negative values in all panels; orange shading indicates values greater than 0.1 mm s^{-1}, while light blue shading indicates values smaller than −0.1 mm s^{-1}. For (e), contours are located at 0.02, 0.05, 0.1, 0.2, 0.5, . . . mm s^{-1}, and light red shading marks values greater than 0.1 mm s^{-1}. For (f), contours are located at 1, 2, 5, 10, 20, . . . %, light red shading marks values greater than 10 %, and dark red shading marks values greater than 50 %.

Page 6:

For $\Psi^*_{\overline{v}^*}$. Contours and colours are same as for Figure 5.

Page 7:

For $\Psi^*_{\overline{\omega}^*}$. Contours and colours are same as for Figure 5.

Page 8:

For longwave heating. Contours and colours are same as for Figure 8.

Page 9:

For shortwave heating. Contours and colours are same as for Figure 9.

Page 10:

For total diabatic heating subtracted by radiative heating (i.e., diabatic heating due to cloud and diffusion processes). Contours and colours are same as for Figures 6 and 7.

Page 11:

For ozone. For (a)–(d), contour interval is 0.1 ppmv, with dotted contours for negative values in all panels; orange shading indicates values greater than 0.1 ppmv, while light blue shading indicates values smaller than −0.1 ppmv. For (e), contour interval is 0.1 ppmv, and light red shading marks values greater than 0.1 ppmv. For (f), contours are located at 1, 2, 5, 10, 20, . . . %, light red shading marks values greater than 5 %, and dark red shading marks values greater than 10 %.

Page 12:

For the Coriolis term. Contours and colours are same as for Figure 6.

Page 13:

For summation of the Coriolis term, the term for meridional advection of zonal momentum, and the term for

vertical advection of zonal momentum. Contours and colours are same as for Figure 6.

Page 14:

For the EP flux divergence term. Contours and colours are same as for Figure 7.

Page 15:

For the residual term $\overline{\varepsilon_u}$ of the TEM momentum equation. Contours and colours are same as for Figures 6 and 7.

Page 16:

For the vertical temperature advection term. Contours and colours are same as for Figure 10.

Page 17:

For the total diabatic heating term. Contours and colours are same as for Figure 11.

Page 18:

For the residual term $\overline{\varepsilon_\theta}$ of the TEM thermodynamic equation. Contours and colours are same as for Figures 10 and 11.

Supplement Folder 4 (“4.Zonal_accelerations_due_to_parameterizations”)

Supplement Folder 4 (“4.Zonal_accelerations_due_to_parameterizations”) has the following four folders:

- DJF
- JJA
- MAM
- SON

and each of these folders has the following four PDFs:

- zonalaccel_CFSR_[SEASON].pdf
- zonalaccel_ERA-I_[SEASON].pdf
- zonalaccel_JRA-55_[SEASON].pdf
- zonalaccel_MERRA-2_[SEASON].pdf

where [SEASON] is either DJF, JJA, MAM, or SON.

See e.g. Chapter 2 of SPARC (2022) for information on the parameterization schemes.
Shown are the 30-year seasonal means.
The contours and colour shading are the same as for Figure 2.

CFSR:

(a) Zonal acceleration due to all parameterizations.
(b) Zonal acceleration due to parameterized gravity wave drag (orographic only).
(c) Zonal acceleration due to convective mixing. (“Convective zonal momentum mixing acceleration”)
(d) Zonal acceleration due to vertical diffusion.

Notes: Data files are diabl06.gdas.* (“Monthly Mean (4 per day) of 6-hour Average (initial+0 to initial+6)”, and “2.5 deg. × 2.5 deg.”) taken from https://rda.ucar.edu/datasets/ds093.2/dataaccess/. Note that there is also a variable named “Convective gravity wave drag zonal acceleration” but this variable is filled with zero or fill/missing value and thus not included here.

ERA-Interim:

(a) Zonal acceleration due to all parameterizations.

Notes: Monthly mean zonal mean data were created by Marta Abalos for the paper by Abalos et al. (JGR, 2015) based on 6-hourly model-level data above the ~500 hPa level.

JRA-55:

(a) Zonal acceleration due to all parameterizations.

(b) Zonal acceleration due to parameterized gravity wave drag (orographic gravity wave drag only, plus a Rayleigh damping applied at pressures less than 50 hPa[(*1)].
(c) Zonal acceleration due to convective processes.
(d) Zonal acceleration due to vertical diffusion.

Notes: [(*1)] The Rayleigh damping applied at pressures less than 50 hPa is to mimic drag due to non-orographic gravity waves (Section 3.1of Sato and Hirano, 2019; private communication with Yayoi Harada and Chiaki Kobayashi of JMA, 2024). Data files are fcst_phy3m125_gwdua.*, fcst_phy3m125_cnvua.*, and fcst_phy3m125_vdfua.* taken from https://search.diasjp.net/en/dataset/JRA55 and https://data.diasjp.net/dl/storages/filelist/dataset:204

MERRA-2:

(a) Zonal acceleration due to all parameterizations.
(b) Zonal acceleration due to parameterized gravity wave drag (including both orographic and non-orographic gravity waves).
(c) Zonal acceleration due to moist processes.
(d) Zonal acceleration due to turbulence.

Notes: Data files have been taken from https://doi.org/10.5067/YSR6IA5057XX (MERRA-2 tavgM_3d_udt_Np: 3d,Monthly mean,Time-Averaged,Pressure-Level,Assimilation,Wind Tendencies V5.12.4 (M2TMNPUDT)).

References (for Supplement Folder 4):

Abalos, M., Legras, B., Ploeger, F., and Randel, W. J.: Evaluating the advective Brewer-Dobson circulation in three reanalyses for the period 1979–2012, J. Geophys. Res., 120, 7534–7554, https://doi.org/10.1002/2015JD023182, 2015.

Sato, K. and Hirano, S.: The climatology of the Brewer–Dobson circulation and the contribution of gravity waves, Atmos. Chem. Phys., 19, 4517–4539, https://doi.org/10.5194/acp-19-4517-2019, 2019.

SPARC: SPARC Reanalysis Intercomparison Project (S-RIP) Final Report, edited by Fujiwara, M., Manney, G. L., Gray, L. J., and Wright, J. S., SPARC Report No. 10, WCRP-6/2021, 612 pp., https://doi.org/10.17874/800dee57d13, available also at https://www.sparc-climate.org/sparc-report-no-10/ (last access: 16 February 2023), 2022.