Supporting Information for "Towards the direct simulation of the quasi-biennial oscillation in a global storm-resolving model"

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Introduction As demonstrated by Kirchner (2005), aliasing can cause pronounced white-noise tailing in power spectra, which can be distorted even far below the Nyquist frequency. Therefore, we hypothesized that temporal aliasing may also be responsible for the noisy zonal wavenumber-frequency spectrum of the vertical Eliassen-Palm flux (EP flux) in the ICON simulation (see Fig. 12a). Fast and short gravity waves (GWs) can have periods as short as 10 minutes, which is well below the output interval of 3 h, making our instantaneous output strategy prone to temporal aliasing.

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To verify this hypothesis, we performed a simulation with the ICON model using the R2B8 horizontal grid ($\Delta x \approx 10\,\mathrm{km}$) and a model configuration comparable to that of the main simulation analyzed in the manuscript (see Sec. 2.1) with an output interval of 10 minutes[1] over a simulation period of 29 days. For this simulation, we calculated two different $5^\circ\,\mathrm{S} - 5^\circ\,\mathrm{N}$ mean zonal wavenumber-frequency spectra of the vertical EP flux at an altitude of 17 km: (1) based on all available instantaneous 10-minutely output, and (2) based on a set of 3-hourly subsampled instantaneous output. The spectra are shown in Figures S1 – S3.

This work confirms that the noisy zonal wavenumber-frequency spectrum of the ICON simulation is the imprint of temporal aliasing. As a consequence, the absolute east- and westward vertical EP flux for GWs with $|k| > 18$ is underestimated if calculated based on 3-hourly output compared to if calculated based on 10-minutely output.

References

Kirchner, J. W. (2005). Aliasing in $1/f^\alpha$ noise spectra: Origins, consequences, and remedies. *Physical Review E*, *71*(6). doi: 10.1103/physreve.71.066110

Notes

1. An output interval of 10 minutes has been found to be sufficient to capture all resolved GWs in an ICON simulation with the R2B8 grid

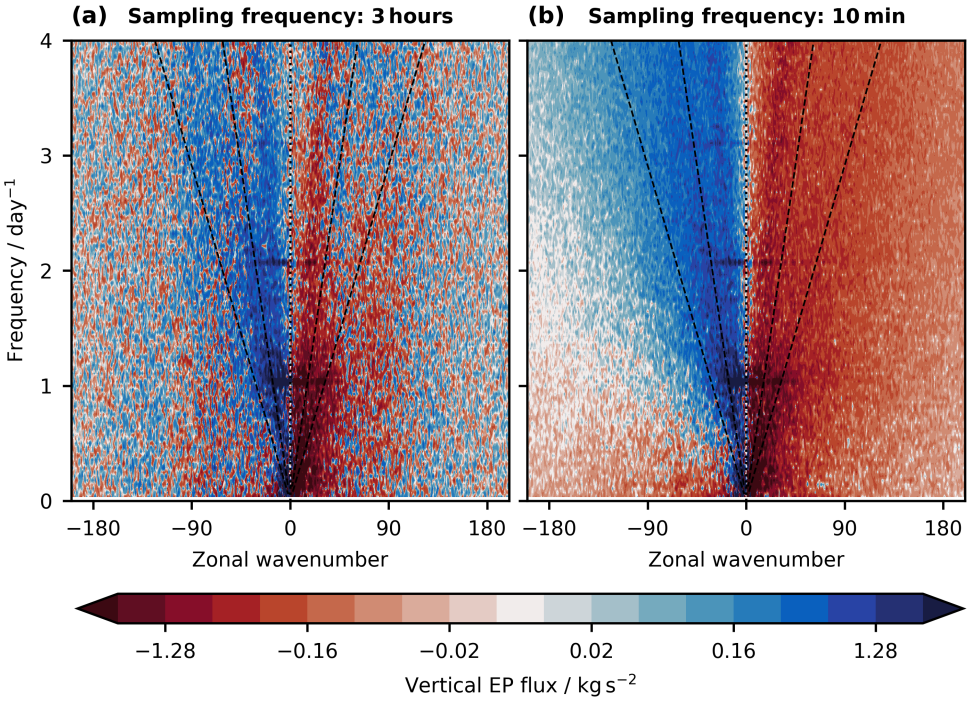

Figure S1. Zonal wavenumber-frequency spectrum of the $5° \text{ S} - 5° \text{ N}$ mean vertical EP flux at an altitude of 17 km calculated based on **(a)** 3-hourly and **(b)** 10-minutely instantaneous output fields from the same ICON simulation. The spectra are calculated based on 29 days.

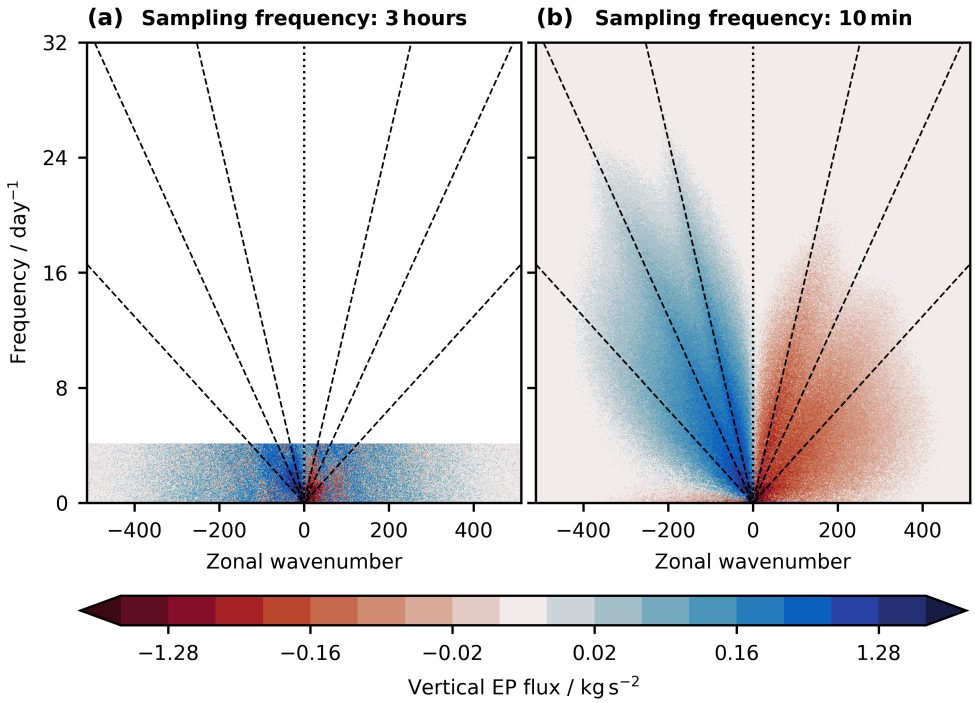

Figure S2. Zonal wavenumber-frequency spectrum of the 5° S – 5° N mean vertical EP flux at an altitude of 17 km calculated based on **(a)** 3-hourly and **(b)** 10-minutely instantaneous output fields from the same ICON simulation. The spectra are calculated based on 29 days.

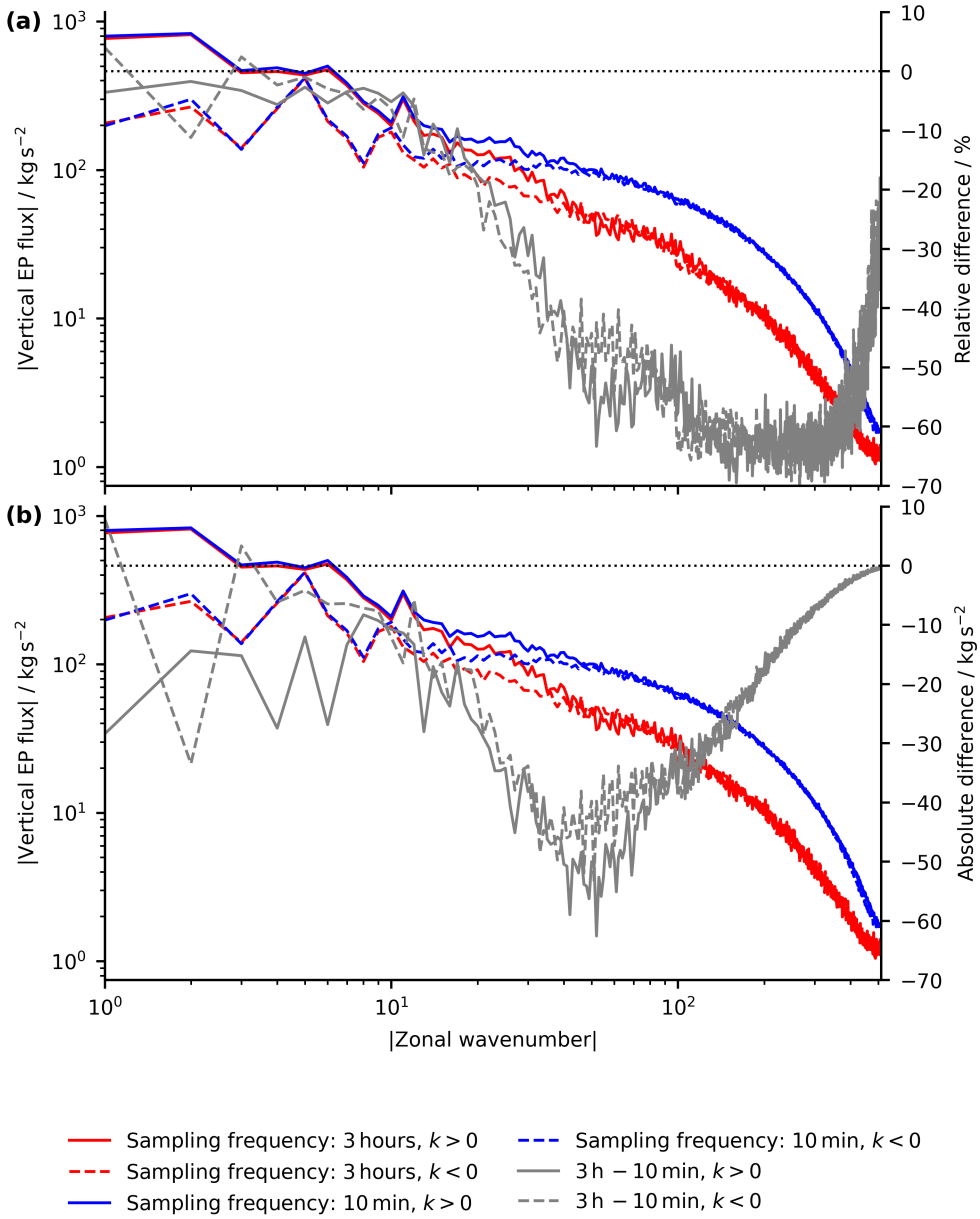

Figure S3. Zonal wavenumber spectra of the 5° S − 5° N mean vertical EP flux at an altitude of 17 km calculated based on 3-hourly and 10-minutely instantaneous output fields from the same ICON simulation. The spectra are calculated based on 29 days. The difference between the spectra based on 3-hourly and 10-minutely instantaneous output fields is plotted in gray lines with the y-axis given on the right-hand side of each panel: panel **(a)** showing the relative difference and panel **(b)** showing the absolute difference.