

Role of middle atmospheric gravity wave sources for the austral mesospheric polar vortex

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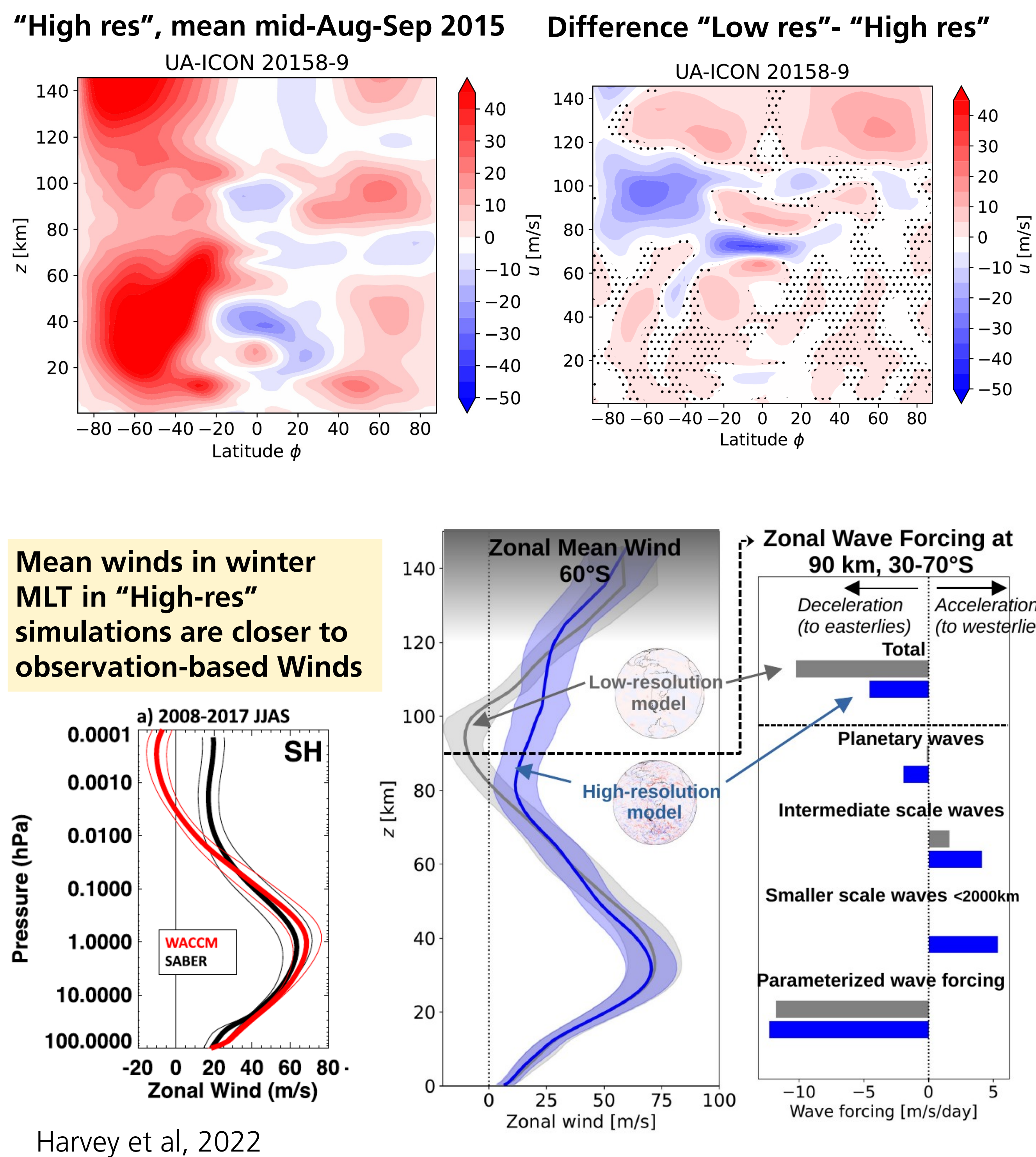
Gravity waves are of major importance in the MLT region. With increasing computational power, gravity wave resolving model simulation of the atmosphere from the surface to the MLT become feasible – allowing to study gravity wave processes, and their role for global circulation, thus far unresolved and neglected by gravity wave parameterizations.

- **Model UA-ICON** (Borchert et al, 2019), extending to 150 km (sponge above 120 km)
- two resolutions: **“High res”**: horizontal ~20 km, vertical 250 levels;
“Low res”: horizontal ~160 km, vertical 120 levels;
- **Simulations** for one austral winter/spring: initialized on August 15, 2015, run through October
- including oro. and non-oro. gravity wave parameterizations

Method for wave decomposition by phase speed:

- estimation of zonal phase speed from wavevector (k, l, m) via dispersion relationship at a given time step
- applied for 2000km-lat-lon-boxes
- Up/Downward separation via energy flux $p'w'$

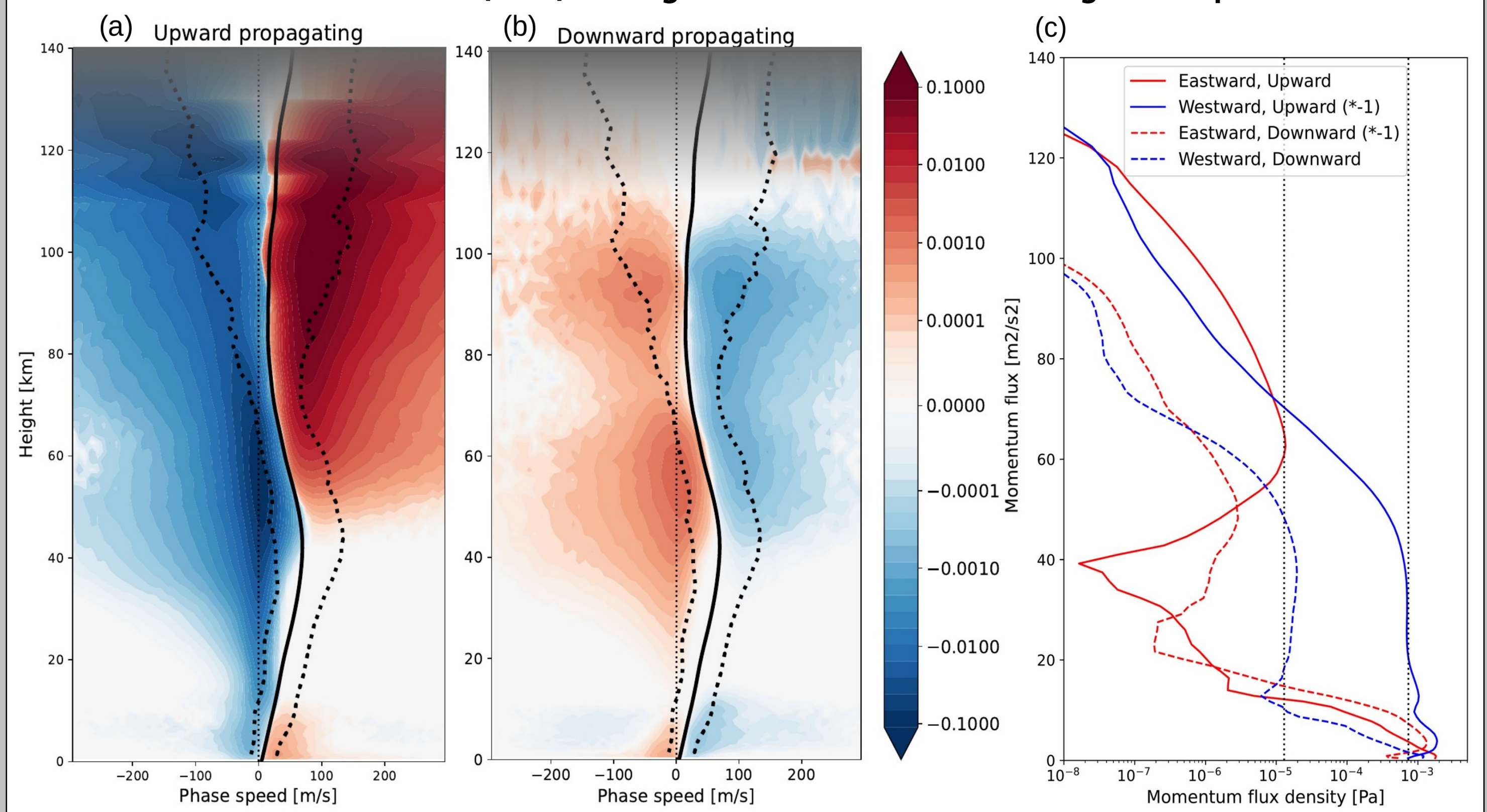
Impact of resolved gravity waves on mean zonal winds



The westerly winds in the winter MLT are maintained by acceleration from waves with scales <2000 km (only resolved in the “High res” simulation)

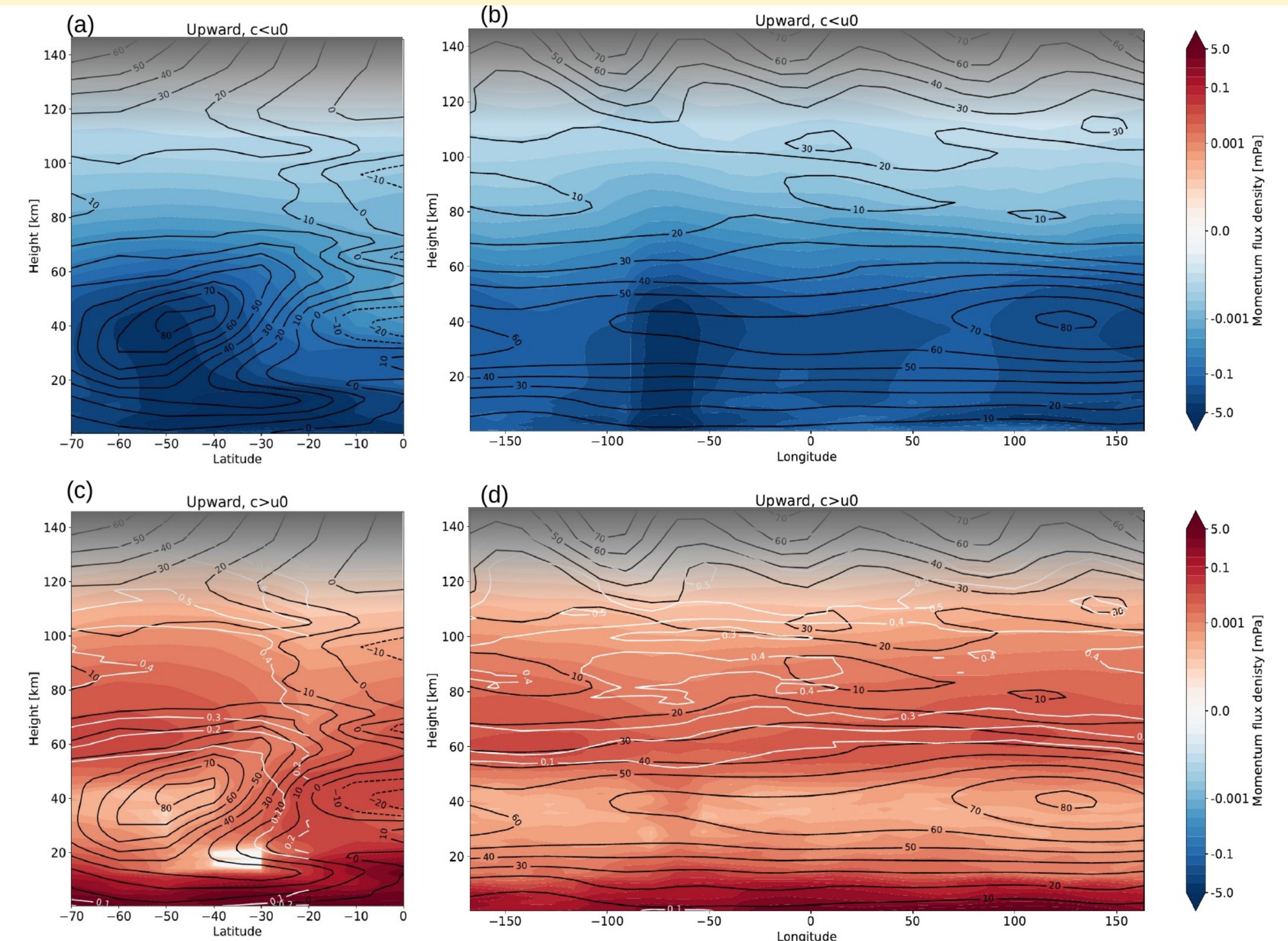
Resolved gravity wave fluxes by zonal phase speed

Momentum fluxes ($u'w'$) averaged over 40-70°S and 25 Aug – 10 Sep

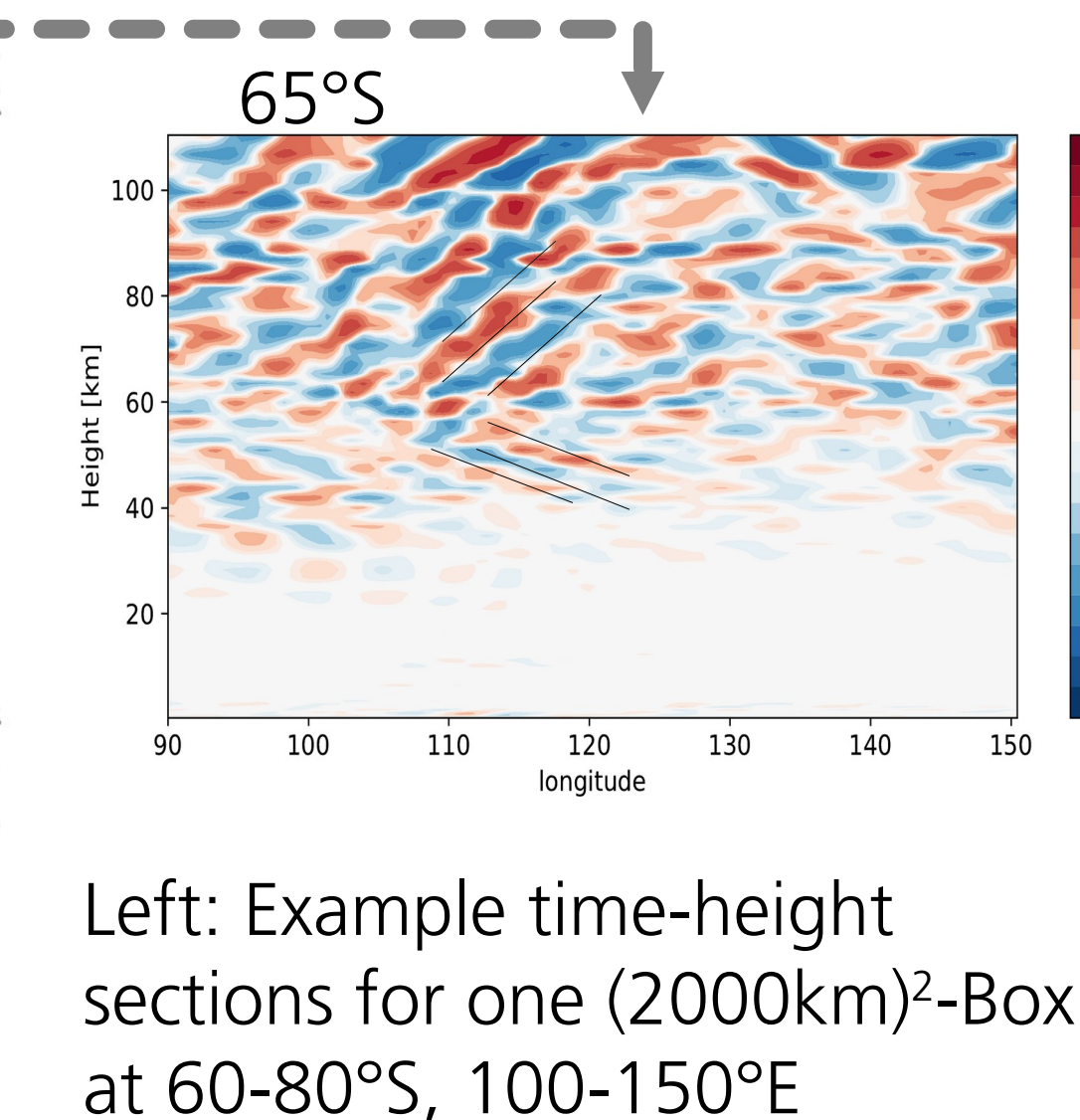


Eastward propagating waves are generated within the middle atmosphere at around 60 km height, at the upper flank of the polar vortex.

(in agreement with Koshin et al, 2025)



Sources of gravity waves?

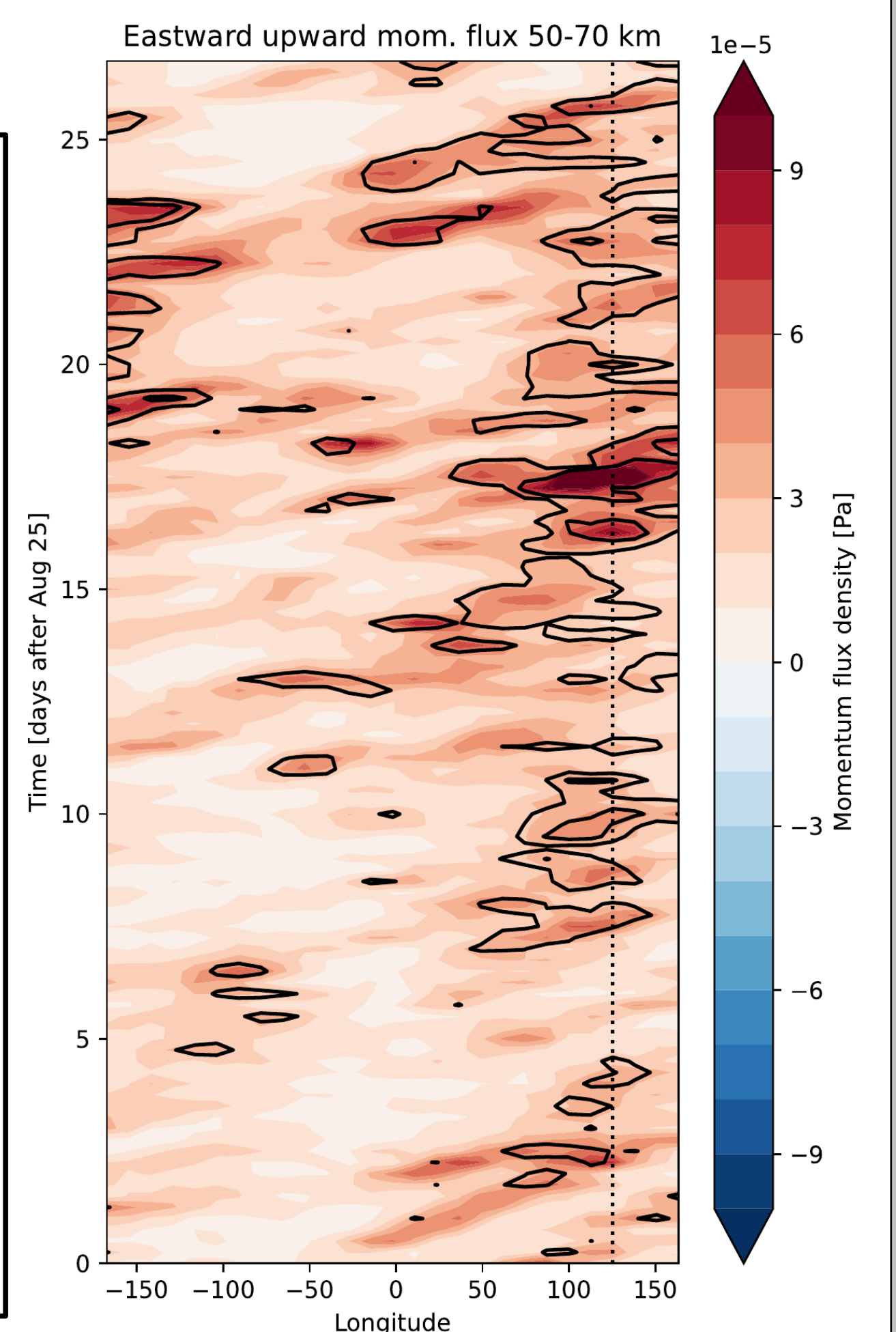


Left: Example time-height sections for one (2000km)²-Box at 60-80°S, 100-150°E

Top: Example of temperature perturbation cross-section on day 16 at 65°S

- Wave generation occurs at all longitudes, and maximizes at higher latitudes
→ **unlikely secondary waves from mountain wave breaking**

- Co-occurrence of wave generation with regions of high Lagrangian Rossby wave number occurrence and with positive vertical shear term of “mesoscale kinetic energy source (MKS)” (Becker et al, 2022)
→ **likely wave generation by imbalanced flow**



References

- Borchert, S., Zhou, G., Baldauf, M., Schmidt, H., Zängl, G., and Reinert, D., 2019: The upper-atmosphere extension of the ICON general circulation model (version: ua-icon-1.0). Geosci. Model Dev., 12, 3541–3569, <https://doi.org/10.5194/gmd-12-3541-2019>
- Harvey, V. L., Pedatella, N., Becker, E., & Randall, C., 2022a: Evaluation of polar winter mesopause wind in WACCMX+DART. Journal of Geophysical Research: Atmospheres, 127, e2022JD037063. <https://doi.org/10.1029/2022JD037063>

- Koshin, D., Pedatella, N. M., Smith, A. K., & Liu, H.-L. (2025). Contribution of gravity waves to the lower thermospheric winter-to-summer meridional circulation in high-resolution WACCM-X. Journal of Geophysical Research: Atmospheres, 130, e2025JD044600. <https://doi.org/10.1029/2025JD044600>

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