Atmospheric Chemistry and Physics Discussions

Atmos. Chem. Phys. Discuss., referee comment RC2
https://doi.org/10.5194/acp-2022-112-RC2, 2022

Comment on acp-2022-112

Anonymous Referee #2

Referee comment on "Significant enhancements of the mesospheric Na layer bottom below 75 km observed by a full-diurnal-cycle lidar at Beijing (40.41° N, 116.01° E), China" by Yuan Xia et al., Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2022-112-RC2, 2022

Review of Xia et al., 2022:

This paper contains interesting observations that should be published after major revision, but there are deficits in analysis and presentation and almost fatal flaws in scientific discussion and conclusions. The data seems to indicate a tide/gravity wave superposition as the source of the downwelling, not a planetary wave, although the PW could be a contributing factor. The entire discussion and conclusions need to be re-written.

Major comments:

1. This is not the lowest sodium observed. Sodium routinely gets below 75km at mid and high latitudes in winter (about 10% of the days at some sites), especially when the tides are strong. Here are a few examples from the literature.
   1. The DEEPWAVE aircraft Na lidar observed multiple Na layers descending to 70-72km over New Zealand in 2014 due to mountain waves as reported by Bossert et al., 2015, Fritts et al., 2016, and Fritts et al, 2018.
      1. Bossert, K., D. C. Fritts, D. Pautet, B. P. Williams, M. J. Taylor, Momentum Flux Estimates Accompanying Multi-Scale Gravity Waves over Mt. Cook, New Zealand on 13 July 2014 during the DEEPWAVE Campaign, JGR, 120, 9323–9337, 2015, doi.org/10.1002/2015JD023197.
      2. Fritts, D. C. et al., The Deep Propagating Gravity Wave Experiment (DEEPWAVE): An Airborne and Ground-Based Exploration of Gravity Wave Propagation and Effects from their Sources throughout the Lower and Middle Atmosphere, BAMS, https://doi.org/10.1175/BAMS-D-14-00269.1, 2016.
      3. Fritts, D. C., Vosper, S. B., Williams, B. P., Bossert, K., Plane, J. M. C., Taylor, M. J., et al. (2018). Largeâ□□amplitude mountain waves in the mesosphere accompanying weak crossâ□□mountain flow during DEEPWAVE Research Flight RF22. Journal of Geophysical Research: Atmospheres, 123. https://doi.org/10.1029/2017JD028250
   2. Li et al., 2021, Figure 8c shows sodium extending down to 73.5km in 2009.

Li, J., Collins, R., Lu, X., & Williams, B. (2021). Lidar observations of instability and estimates of vertical eddy diffusivity induced by gravity wave breaking in the Arctic mesosphere. Journal of Geophysical Research: Atmospheres, 126, e2020JD033450. https://doi.org/10.1029/2020JD033450

2. The paper uses Na density rather than Na mixing ratio which is a much better proxy for vertical motion. Bossert et al above has a discussion of Na mixing ratio and Na chemistry under wave downwelling.

3. LIne 200-202 and 332-335: This discussion is wrong. Waves move the whole neutral atmosphere up and down, not just the sodium. "Normal atmospheric conditions" don't stay at the same altitude. The chemical lifetime profile moves down too with motion. You are working in the wrong frame of references, atmospheric chemistry is best done in a parcel frame of reference. There seems to be a fundamental misunderstanding of wave-induced motion in the paper. This is one reason why most atmospheric chemistry and dynamics are done on pressure levels, rather than by geometric height (as measured by lidars).

4. The downwelling regions in Figure 2 seem to repeat on multiple days likely due to a tide plus the superposition of a shorter-period gravity wave that increases the downwelling on . These superpositions are known sources of strong downwelling.

5. Planetary waves induce little or no vertical motion and the periodicity is all wrong. Planetary waves can affect the overall atmospheric structure (stratwarms, etc.) but that kind of atmospheric compression would pull the entire Na layer down, and that does not appear to be happening.

6. When waves move a parcel of atmosphere down, the species mixing ratios, pressure, and temperature gradients move down with the parcel. The parcel will heat up at ~9.5K/km for adiabatic vertical motion. This is the main effect on the Na in the parcel. Over time, the Na mixing ratio will change due to the adiabatic heating affecting the chemical balance. Horizontal eddy diffusion will start affecting the Na in the parcel depending on the horizontal wavelength of the wave. Vertical eddy diffusion is largely unchanged for the parcel as wave breaking depends largely on the gradients and will move down as well, but for a short vertical wavelength wave, the vertical density gradients induced by the wave can have an effect.

7. While panetary waves could be changing the mean tempeature on Dec 17 and increasing the overall Na density for half a wave period, this would be a secondary effect. The downwelling is unlikely to extend over such a large area defiend by the planetary wave wavelength, though.

8. The SABER observations likely occur over a much larger horizontal area than the downwelling region (likely defined by the area of overlap of the tide and GW forcing the downwelling) and would be more indicative of the mean properties of the region rather than the chemical mixing ratios inside the downwelling parcels.

9. There are prior papers on the effect on SSW's on Na density, e.g. Feng et al, 2017, that shjould be referenced if you discuss PW.SSW effects on the Na layer.

Feng, W., B. Kaifler, D. R. Marsh, J. Hoffner, U.-P. Hoppe, B. P. Williams, J . M. C. Plane, Impacts of a sudden stratospheric warming on the mesospheric metal layers, JASTP, 162, 162-171, http://doi.org/10.1016/j.jastp.2017.02.004, 2017.

9. To understand this descending layer you need to answert the following questions:
1. What vertical motion do the streamlines of Na mixing ratio give you?

2. For that vertical motion, what is the adiabatic temperature change and how does that affect the Na chemistry in the parcel?

3. What is the estimated horizontal extent of the descending layer and how does that compare to the horizontal mixing time scale?

4. What is the estimated vertical wavelength of the forcing waves and how does that compare to the vertical mixing time scale?

It could be that horizontal and vertical mixing is not important here and the descending layer ends when the forcing vertical motion from the waves turns upward.