

Review of “Quantifying and Predicting the Mesosphere and Lower Thermosphere Density during Austral Summer”

By Liang Zhang et al

Recommendation: Reject

This study uses 24 years of SABER observations (2002-2025) to analyze the correlation between T80, a temperature-based proxy constructed from fused MLS and SABER temperature measurements, and the density variations in the mesosphere lower thermosphere (MLT) region. The authors show a robust correlation regarding interannual variability during November, December and January in some regions, especially the southern hemispheric mesopause region. They then try to extend this approach to day-to-day variability to test the applicability of the T80 proxy as a tool for density prediction in the MLT. Lastly, the authors also attempted to attribute density variations to natural drives, such as solar radio flux or CO₂.

I have several concerns with the study in its present form. The methodology is unclear and the results are largely overinterpreted. Specifically, the manuscript does not clearly establish the novelty of the relationship between the T80 index and the latitude dependent density profile compared with the results of Zhang et al, 2025c. The presented results appear largely derivative of the earlier study, with established temperature relationships extended to density through the ideal gas law and hydrostatic balance. Furthermore, the results from investigating the lagged correlation between T80 and density do not support the claim that T80 provides predictive capabilities. I also question the novelty of the proposed physical mechanisms “local thermal effect” and “column adjustment effect” as they appear to follow mainly from the assumption of an ideal gas and hydrostatic equilibrium.

Therefore, my recommendation is “reject”.

Major comments:

Methodology (Section 2):

- Section 2.1: It is mentioned that the density profile is calculated from SABER temperature and pressure profiles to cover the time period 2002-2025. Later, in Section 2.2 it is mentioned that the high-latitude coverage of SABER during boreal summer months is highly variable. Thus, a detailed description of how this issue is handled when computing the density profiles is necessary.
- Section 2.2: I am missing an explicit description of how the T80 index is calculated.

Results (Section 3):

- Section 3.2: The relation between T80 and the latitude dependent temperature profile was already investigated in Zhang et al, 2025c. The work in its present forms seems largely derivative of these results, extending them to density through ideal gas + hydrostatic balance.
- Section 3.3: The presented results, showing a lagged correlation between T80 and density, are not strong enough to support the claim of T80 having considerable predictive capabilities. In addition, using monthly means inherently benefits from low month to month variability. To actually demonstrate predictive capabilities, density anomalies should be considered instead.
- Section 3.4: Here, T80 is calculated from SABER temperature to relate it to density, also calculated from SABER temperature and pressure. This strong dependence does not

allow for an independent and meaningful analysis. Additionally, density perturbations should again be considered to truly test the predictive capabilities of T80.

Discussion (Section 4):

- Section 4.1: The study in its current form does not convincingly demonstrate that the effects “local thermal effect” and “column adjustment” are novel atmospheric mechanisms. To me, it seems more likely they directly follow from the treatment of the atmospheric column under the assumption of an ideal gas and hydrostatic balance.
- Section 4.3: In its current form, this analysis is not reproducible. I would include an explicit regression formula. Later, you state that the linear density trend contradicts the behavior expected from CO₂ cooling. You then attempt to explain this apparent inconsistency with a linear T80 trend that is insignificant. In addition, the claim that summer polar upwelling dominates the density variability is not supported by the results.
- Section 4.4: The authors mention that they intend to conduct the same analysis for NH summer months. It is unclear to me how this analysis would constitute a separate scientific contribution. Instead, I think it should be included in this study for additional robustness and generalization.
- Throughout the manuscript, it is frequently implied that T80 causes density related variability. This could be misleading because T80 is a metric, whereas upwelling is the physical process causing density-related variability.

Minor comments:

- Title: “Prediction” is an overstatement (see major comments on Section 3.3 and 3.4).
- Lines 29-30: “practical necessity for satellite drag and orbit determination”: I would change practical necessity to something like “understanding facilitates” as the MLT is still below LEO altitudes.
- Line 38: “Adiabatic dynamical processes” do not belong to external forcings.
- Figure 3: Inverting the density axis could lead to confusion when noting the anticorrelation between T80 and density. At first glance, the plot appears to show a strong correlation.
- Line 54: When introducing the T80 index, it would be more helpful for a reader if you only reference one paper, for example the paper where the T80 index is introduced for the first time.
- Lines 194-195: You demonstrate a lagged correlation of T80 and density based on monthly means. Thus, the analysis does not support the claim of enabling “skillful (...) prediction of MLT density anomalies”. Also, density anomalies were not investigated.
- Line 301: You mention that you want to isolate long-term CO₂ cooling. Since you show no explicit regression formula, it is unclear whether you actually included CO₂ cooling in your regression. This would need clarification as it is also of major importance for your derived conclusions.
- Line 307: That statement is misleading. From Figure 12a alone, I do not see, where the density is influenced by upwelling (which is proxied by T80).
- Lines 309-310: It is stated that no significant signal emerges, but Figure 12a indicates a significant area in exactly that region.