We would like to thank the Editor for the careful and insightful comments, which were essential in improving the clarity of our manuscript. Please find our responses to the Editor's comments highlighted in blue..

Page 11: The description of the new sensitivity analysis for the clustering does not make it entirely clear how the feature perturbation was applied. It suggests a constant shift that would be compensated by the StandardScaler, resulting in identical clusters.

R: Thank you for calling our attention to this.
We applied the shift after scaling, so the StandardScaler did not subtracted the shift, that's why we've got changes, and the clusters were not exactly identical. But the editor's point remains and we understand it: a constant shift applied to all features simultaneously, even post-scaling, acts as a global translation, and centroids would not be modified. Consequently +/- 1SD basically tested only a global offset. While this shows how points move relative to fixed centroids, it does not fully capture the stability of the cluster boundaries.Therefore we have revised our sensitivity analysis strategy. To increase the robustness of our assessment we adopt a set of tests in order to test numerical stability, sampling robustness, clusters reproducibility, separation quality and presence of transitional regimes(from line 428, marked version):

1) First, a jitter robustness test was conducted by adding Gaussian noises testing different uncertainty possibilities (5%, 10%, 20%) to the standardized feature matrix and re-running the clustering algorithm multiple times (Table 1). The resulting partitions were compared with the original clustering using the Adjusted Rand Index (ARI), which quantifies agreement between cluster assignments while correcting for chance. This procedure assesses the sensitivity of the clustering structure to minor perturbations in feature space (mimicking features uncertainties).

2) Second, a bootstrap robustness analysis was implemented by repeatedly resampling the dataset with replacement and recomputing the clustering solution for each resampled dataset. The ARI between the original and bootstrap-derived clusterings was calculated to evaluate the dependence of the clustering structure on specific samples and to test its reproducibility under data variability.

   In general the mean ARI results for both the jitter robustness and bootstrap robustness analysis (Table 1) presented values around 0.85, which indicate high similarity between the originally predicted clusters and the perturbed. This shows that the random noise added did not significantly affect the clustering structure.

3) Cluster-level stability was further quantified using a cluster retention score, defined as the average probability that members of an original cluster remain grouped together

across perturbation runs. This metric allows identification of highly stable regimes as well as potentially transitional or mixed clusters.
With most of the cluster retention scores above 0.95(4 out of 5, Table 2) this test results show that we have extremely stable cluster regimes. The exception is cluster 3, which presents a retention score of 0.88, which can be considered stable but somewhat overlapping.

4) Finally, a consensus (co-assignment) matrix was constructed by computing, for every pair of samples, the proportion of runs in which the two samples were assigned to the same cluster. From this matrix, mean intra-cluster and inter-cluster co-assignment probabilities were derived to quantify internal cohesion and external separation (Table 3).

   The results of high intra-cluster probability (>0.85) and low inter-cluster probability (<0.10) corroborate the quality of our clustering results by showing that in general members of the same cluster consistently grouped together.

Together, we believe that these diagnostics provide a comprehensive evaluation of our clustering stability, reproducibility, and structural robustness.

For the sake of the manuscript size, these test descriptions and results (Tables S3, S4, S5) are displayed in the supplementary material while discussed in the manuscript. A script specifically dedicated to these sensitivity tests is added to the list of programs used to produce the results of this manuscript.

Table 1

Random Perturbation	**Jitter Robustness (5%/ 10% / 20%)**	**Bootstrap**
Mean ARI	0.8570 / 0.8511 / 0.8183	0.8405
Std ARI	0.2039 /0.1887 / 0.1698	0.1925
Min ARI	0.4823 / 0.4821/ 0.4801	0.4646
Max ARI	0.9813 / 0.9650 / 0.9215	0.9837

Table 2

Cluster-wise Stability	**5%**	**10%**	**20%**
Cluster 0	0.9692	0.9638	0.9456
Cluster 1	0.9916	0.9844	0.9721
Cluster 2	0.9905	0.9907	0.9851

Cluster 3	0.8890	0.8922	0.8830
Cluster 4	0.9292	0.9377	0.9339

Table 3

Co-assignment matrix	**5%**	**10%**	**20%**
Mean Intra-cluster probability	0.9302	0.9276	0.9087
Mean Inter-cluster probability	0.0512	0.0500	0.0561

Section 2.2: Please state the total number of AERONET observations used. Currently, this can only be inferred from Tables 3 and 4, which seem to disagree on this number.

R: The total number of AERONET retrievals (Table 3) used in the clustering process is now stated (4395) at line 301/302 of the marked version.

And the total number of AERONET x MERRA-2 collocated combination time series is also stated at line 497 of the marked version, and between lines 500 and 502 the amount for training and test are displayed.

We realized a typing error for Cluster 4 counting. It has effectively 609 points instead of 604 (Table 3), which we corrected. Therefore, the sum of total AERONET is 4395 (sum of clusters points in table 3).

Minor adjustment was also needed for the counting of the training and test clusters(Table 4) without significant implication for the results.

Lines 775, 776, 778: The references to figure "SS1" should read "Fig. S2 in the supplement". Also, there seems to be no reference to Fig. S1 in the supplement within the present version of the main text; please add one and clarify the AOD data source in the caption.

R: The references to Fig. S2 were corrected (from line 819 marked version) and the reference to Fig. S1 was included at lines 861-862, and as recommended the AOD data source mentioned in the caption of the Fig. S1 in the supplement.

Obs: Figures were adjusted to attend the requirement to make figures, graphs, and images accessible to color-blind users.