

Reviewer comments in italics.

Author comments in upright text.

1 General Comments

In this manuscript, the author makes two novel points:

- 1. He shows how clear-sky constraints on anvil altitude can be reconciled with the radiatively driven outflow of the anvil clouds.*
- 2. He shows that the profile of atmospheric stability constrains the anvil outflow to occur near the tropopause.*

I think both points are of interest to the scientific community and that publication in ACP is justified.

The main shortcoming of the manuscript in its current form is, in my opinion, that those points are hard to extract. The readability is hampered by poor sentence structure, and the author presents a lot of evidence without directly using it to make a point. The manuscript could be much improved by restructuring it to make the key takeaways more visible (See Section 2.2).

Response: I sincerely appreciate the efforts and insightful comments of Dr. Jakob Deutloff on this manuscript. Your constructive suggestions have greatly improved this work. I have carefully considered all your comments and revised and reorganized the manuscript accordingly.

2 Specific Comments

2.1 Language

Not being a native English speaker myself, I know that getting the wording of every sentence right can be hard. Nevertheless, I think the language of the manuscript needs to be improved. Some simple means to achieve this are to limit the length of sentences, use fewer abbreviations, and use AI tools to check and improve the wording.

Response: Thanks. Long sentences have been split into shorter ones. The language and readability of the manuscript have been carefully checked based on AI tools.

2.2 Structure

One possible way of restructuring the paper could be the following:

Introduction: *Point out more clearly that clear-sky constraints on anvil altitude are hard to reconcile with the radiatively driven outflow postulated by Lilly (1988).*

Data and Methods: *Separate data and methods sections more clearly (see Section 2.3).*

Reconciling clear-sky constraints with the radiatively driven anvil outflow (new section): *Use Figures 1 and 2 to show that Eq. 4 works for clear-sky areas and in non-precipitating anvils. Most striking to me is the resemblance of the divergence profiles (Figure 2 c and f). The author could put more emphasis on this and quantify how well convergence in clear-sky regions and divergence in cloudy regions compensate. To me, this is a really interesting finding that demands more visibility.*

Stability constrains radiatively driven anvil outflow: *I suggest explaining this constraint after showing the equivalence between the divergence/convergence in cloudy/clear-sky areas, since the stability structure of the atmosphere constrains both. Figure 4 could appear in this section, since the author uses it to argue that the stability profile constrains the outflow to happen at around 12 km, even though radiative heating/cooling can occur at any altitude where a cloud resides. I also suggest changing Figure 5 to prove the stability constraint in a statistical sense (see Section 2.7).*

I want to emphasise that this structure is just a recommendation and I do not expect the author to follow it strictly. However, I think some restructuring is necessary to improve the clarity of the manuscript.

Response: Thanks for providing constructive comments regarding the content and structure of this manuscript. The background mechanisms and motivation of this work have been clarified in the introduction. The Data and Methods section has been reorganized to present the datasets and methods separately. In Sect. 3.1, the definition, physical implication, and mathematical expression of SCRAOL are introduced at the beginning. Because stability imposes unified constraints on cloudy divergence and clear-sky convergence, SCRAOL in convective and clear-sky regimes is discussed separately in Sect. 3.2 and Sect. 3.3, respectively. Figures 3 and 4 have been moved to Sect. 4.1, and their order has been rearranged. As suggested, a new Sect. 4.2 has been added to demonstrate the associations between anvil macrophysical

properties and the thermodynamic constraints of SCRAOL.

This manuscript has been reorganized as follows:

- (1) For introduction (Sect. 1), the mechanism and uncertainty of previous clear-sky constraints have been introduced more clearly. In particular, it has been argued that the clear-sky constraints might be not entirely robust (Jeevanjee, 2022), since they are not necessarily the direct driver of anvil outflow processes. However, the direct physical link between the anvil outflow and atmospheric thermal stratification has not been fully clarified. Thereby, this work focuses on how anvil outflow is driven by radiation and constrained by environmental stability.
- (2) For data and methods (Sect. 2), data and methods have been introduced separately. The datasets used in this work include: Sect. 2.1, infrared images from the Geostationary Multi-functional Transport Satellite-1 Replacement and 2 Replacement (MTSAT-1R and -2R); Sect. 2.2, satellite-based precipitation estimates from the Global Precipitation Measurement (GPM); Sect. 2.3, the A-Train Constellation for retrieving cloud and radiative profiles. Section 2.4 introduces the method to identify anvil clouds that are organized within MCSs, nearly non-precipitating and produced from convective-top outflow. Section 2.5 describes the study domain.
- (3) Section 3 mainly investigates radiative and thermodynamic factors driving D and C . Sect. 3.1 introduces the stability-constrained radiative-dynamic effects for anvil outflow; Sect. 3.2 explores radiative-dynamic effects for convective-top outflow and the stability constraints on these effects; Sect. 3.3 explores the stability-constrained radiation-driven clear-sky C .
- (4) Section 4 further investigates thermodynamic constraints on anvil macrophysical properties. Sect. 4.1 provides the key potential thermodynamic constraints of SCRAOL; Section 4.2 further demonstrates the associations of thermodynamic constraints of SCRAOL with not only anvil clouds but also tropical high-level clouds in general.

I find that quantifying the compensation between clear-sky convergence and convective divergence may merit a dedicated separate study. And it involves many intriguing points. Under clear-sky cloudless regimes, the convergence is largely driven by radiation to compensate the convective divergence. However, in convective regions, the latent heating is major driver of the circulation ascending, particularly for convective heavy-precipitating cores. Radiation further imposes dynamic effects on this circulation. Furthermore, their compensation may be further achieved by their dominated coverage areas. Quantifying compensation between convective divergence and clear-sky convergence remains for future studies. Nevertheless, for this revised manuscript, contributions of latent heating and radiation to convective divergence are discussed in Sect. 3.1. And it is highlighted that only the contribution of radiation is focused in this work. Furthermore, only those nearly non-precipitating anvil clouds organized in MCSs and produced from convective top are focused on. Discussions of SCRAOL under convective and clear-sky

regimes are separated into Sect. 3.2 and 3.3, respectively.

2.3 Data description

The description of the data and methods in section 2.1 is hard to parse. In its current form, the introduction of the satellite products that are used is mixed with the method for identifying MCS and anvil clouds and a more detailed description of the data. This should be disentangled. I suggest first introducing the satellite observations in detail and making clear which variables are used and how they are derived from the observations. This section can be followed by the method of identifying MCS and anvil clouds, and another section in which the author explains why he limits the study to the TWP and daytime-only observations.

In section 2.2 the author states that ERA5 is used to calculate potential temperature, but ERA5 is also used to calculate stability, right? If so, this should be stated, and the formula used to calculate stability should be referenced (I guess it will be one of the equations in L41). I suggest not including EAS as a as another measure of stability, but just using stability itself for clarity (see section 2.6).

Response: Thanks. As suggested, Sect. 2 has been reorganized. Data and methods have been introduced separately. Sect. 2.1-2.3 introduces satellite observations for infrared images, precipitation estimates and profiles of clouds and radiation, respectively. Sect. 2.4 introduces methods of merging these satellite observations to identify anvil clouds that are organized in MCSs, non-precipitating and produced from the convective top. Section 2.5 describes the study domain.

Furthermore, as suggested, EAS is no longer used in the analyses of the revised manuscript. Instead, atmospheric thermal stratification is characterized by the magnitudes and altitudes of $1/S$ and its vertical gradient. The stability constraints on anvil outflow and the macrophysical properties of anvil clouds have been further investigated in a statistical sense. Please see additional details in the responses to Comments 2.7.

2.4 Discuss Neglect of Latent Heating

Latent heating is neglected in Eq. 4, which needs to be discussed in more detail. Jeevanjee (2022) argue that latent heating can't be neglected, even in the clear-sky atmosphere. The author neglect it also in cloudy areas, which is a strong assumption. This simplification should be stated more clearly, and Figures 1 and 2 can be used to argue that it seems to be a valid assumption.

Response: Thanks. As suggested, the latent heating has been discussed in Sect. 3.1. Specifically, diabatic heating (Q) is primarily contributed by latent heat (L) and radiation (R). Contributions of L and R to divergence (D) can be separated:

$$D = \frac{\partial}{\partial p} \left(\frac{L+R}{s} \right) = \frac{\partial}{\partial p} \left(\frac{L}{s} \right) + \frac{\partial}{\partial p} \left(\frac{R}{s} \right) = D_L + D_R.$$

D_L and D_R represent D contributed by L and R , respectively. Under cloudless conditions, L can be reasonably neglected. Deep convective cores of heavy precipitation are largely dominated by L through condensation heating. For nearly non-precipitating anvil clouds in the upper troposphere, R is a fundamental driver of anvil outflow (Lilly, 1988; Gasparini et al., 2019). Note that L may also play an important role for these anvil clouds through evaporative cooling, as its magnitude can be comparable to that of radiative cooling (Lutsko et al., 2021; Jeevanjee and Zhou, 2022). Overall, L and R are two primary sources of Q and drivers of D . This work focuses primarily on D_R . It corresponds to the second stage of anvil outflow, which is further sustained by R , following the initial intrusion of outflowing air from the convective top.

2.5 Quantify Compensation of Divergence and Convergence

I think the paper would be strengthened if the author could show to what degree the cancellation between divergence in cloudy regions and the convergence in clear-sky regions holds. To this end, I suggest integrating convergence/divergence over the respective clear-sky/cloudy region and comparing the numbers. Discrepancies should be discussed. Possible explanations for such discrepancies are the convective cores, which will have a strong divergence, the neglect of latent heating, or horizontal density gradients.

Response: Thanks for this very insightful comment. I agree that the latent heating cannot be neglected particularly for the precipitating cores. The final divergence contributed by both latent heating and radiative heating balances the clear-sky convergence. And the coverage area and durations dominated precipitating cores, non-precipitating anvil clouds and clear-sky surroundings are also important for achieving the final balance. Quantifying the compensation between and convective divergence may merit a dedicated separate study. In the revised manuscript, it has been clarified that only the radiation-driven divergence is focused on in Sect. 3.1. Furthermore, only those nearly non-precipitating anvil clouds organized in MCSs and produced from convective top are studied. SCRAOL under convective and clear-sky regimes have been discussed separately. The primary focus is laid on the radiative impacts on the divergence and convergence and the stability constraint on it.

2.6 Only use Stability and not EAS

It is not clear to me why the author introduces EAS as another measure of stability, rather than using stability itself. I think it would improve the clarity of the paper if only stability were used, which is the key metric for the stability constraint introduced in this study.

Response: As suggested, the EAS is no longer used for analyses in the revised manuscript. Instead, SCRAOL provides novel thermodynamic constraints on anvil clouds, corresponding to the layer between the levels of $(\frac{1}{s})_{max}$ and $(\frac{\partial}{\partial p}(\frac{1}{s}))_{max}$. The magnitudes and altitudes of these two maxima constitute the key constraints. This thermodynamic constraint based on SCRAOL is discussed separately under convective (Fig. 7 in the revised manuscript) and clear-sky regimes (Fig. 9 in the revised manuscript). Please see additional details in the responses to Comments 2.7.

2.7 Update Figure 5

If I understand the author correctly, the main point of Figure 5 is to show that anvil altitude varies with the stability profile of the atmosphere. I generally find it desirable to show how well the stability constraint on anvil altitude holds in a statistical sense. However, I think Figure 5 could be improved by not using EAS and Z_{EAS} , which are somewhat unconnected to the rest of the paper, but rather use $\max(\frac{1}{s})$ and $\max(\frac{\partial}{\partial p}\frac{1}{s})$ as the predictors of anvil cloud height, to be consistent with the rest of the paper. One possibility would be to define Z_s as the altitude between $\max(\frac{1}{s})$ and $\max(\frac{\partial}{\partial p}\frac{1}{s})$, i.e. the altitude at which we expect anvils to occur from the stability constraint. This could be used to plot a 2D histogram of Z_s and Z_{anvil} to see how well the actual anvil altitude is predicted from the stability constraint.

Response: The author greatly appreciates this comment. As suggested, the magnitudes and altitudes of $(\frac{1}{s})_{max}$ and $(\frac{\partial}{\partial p}(\frac{1}{s}))_{max}$ constitute the key thermodynamic constraints of SCRAOL. It also provides unified thermodynamic constraints for convective and clear-sky regions. Thus, this constraint is discussed separately under convective and clear-sky regimes in a statistical sense.

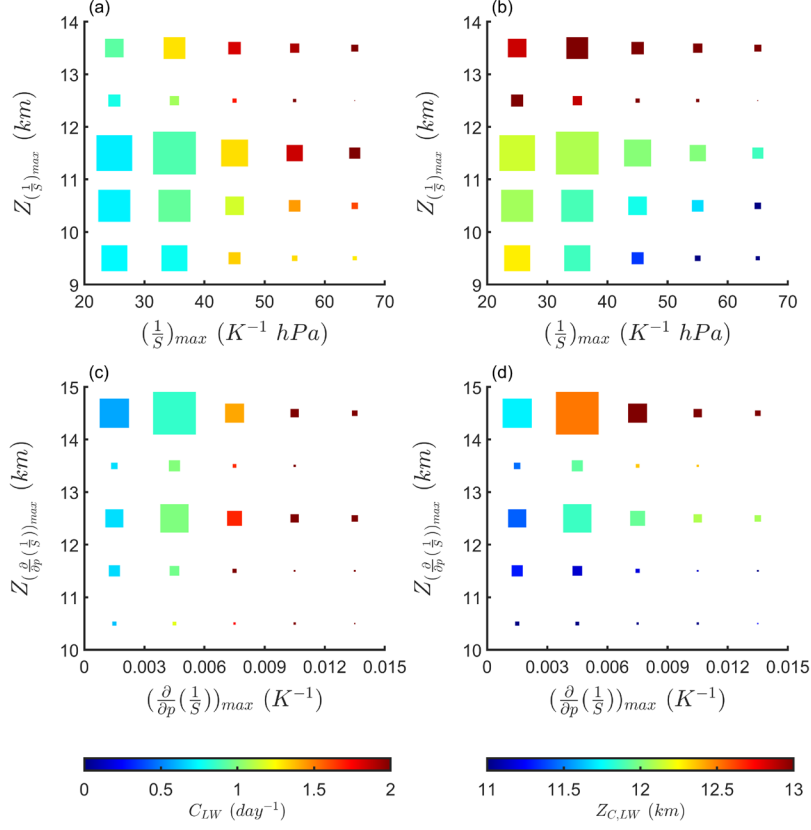


Figure 1. Thermodynamic constraints of SCRAOL under the clear-sky regime derived from the CCCM dataset. (a) Average C_{LW} and (b) $Z_{C,LW}$ in each bin of magnitude and altitude of $(\frac{1}{S})_{max}$. The size of each square is proportional to the sample count. (c-d) Same as (a-b), but for $(\frac{\partial}{\partial p}(\frac{1}{S}))_{max}$.

First, for clear-sky regions, the thermodynamic constraints of SCRAOL are examined for the LW-contributed C (C_{LW}) and its altitude ($Z_{C,LW}$). Here, C_{LW} and $Z_{C,LW}$ denote the magnitude and altitude of its vertical maximum. The thermodynamic constraints of SCRAOL are represented by the magnitude and altitude of $(\frac{1}{S})_{max}$ (Fig. 1a-b; shown below) and $(\frac{\partial}{\partial p}(\frac{1}{S}))_{max}$ (Fig. 1c-d). Consistent with Chae and Sherwood (2010), Fig. 1a-b shows that neither C_{LW} nor $Z_{C,LW}$ is fully fixed; instead, both vary with near-tropopause stability changes, such as $(\frac{1}{S})_{max}$. Note that $(\frac{1}{S})_{max}$ primarily constrains the C_{LW} caused by the vertical gradient of LW cooling. Provided the same magnitude of $(\frac{1}{S})_{max}$, the upward shift of this maximum implies a less stable environment at higher altitudes. As a result, in Fig. 1a, C_{LW} is primarily linked to $(\frac{1}{S})_{max}$, but the upward shift of this maximum also makes a positive contribution to C_{LW} . The enhanced stability (smaller $(\frac{1}{S})_{max}$) reduces C_{LW} , which is well consistent with the stability iris effect (Bony et al., 2016; Saint-

Lu et al., 2020). In Fig. 1b, it is reasonable that higher $Z_{C,LW}$ is primarily associated with the rise of the $(\frac{1}{S})_{max}$ altitude. On the other hand, smaller $(\frac{1}{S})_{max}$ also contributes to the increase in $Z_{C,LW}$. For explanation, note that the maximum vertical gradient of LW cooling, $(-\frac{\partial R}{\partial p})_{max}$, occurs above the altitude of $(\frac{1}{S})_{max}$. Smaller $(\frac{1}{S})_{max}$ implies weaker constraints on the C_{LW} driven by $(-\frac{\partial R}{\partial p})_{max}$. Thus, for smaller $(\frac{1}{S})_{max}$, $Z_{C,LW}$ tends to reach the level of $(-\frac{\partial R}{\partial p})_{max}$ and is thereby higher. Similarly, in Fig. 1c-d, $(\frac{\partial}{\partial p}(\frac{1}{S}))_{max}$ constrains another important component related to LW cooling, C_{LW} and $Z_{C,LW}$ are primarily associated with the magnitude and altitude of $(\frac{\partial}{\partial p}(\frac{1}{S}))_{max}$, respectively. Overall, C_{LW} is constrained within the SCRAOL and modulated by not only stability but also its vertical gradient.

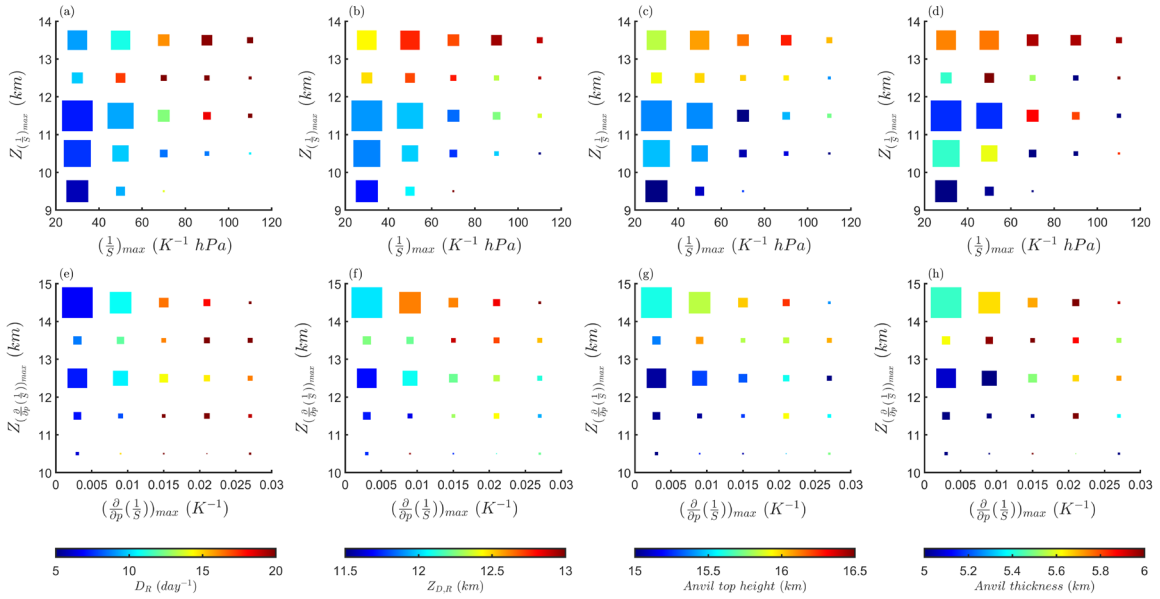


Figure 2. Associations of anvil clouds with the SCRAOL constraints. (a-d) Average D_R , $Z_{D,R}$, anvil top height and anvil thickness in each bin of magnitude and altitude of $(\frac{1}{S})_{max}$, respectively. The size of each square is proportional to the sample count. (e-h) Same as (a-d), but for $(\frac{\partial}{\partial p}(\frac{1}{S}))_{max}$.

Moreover, under convective regimes, the direct linkages between anvil clouds and the SCRAOL are examined. Here, the thermodynamic constraints of SCRAOL are quantified by variations in the magnitude and altitude of $(\frac{1}{S})_{max}$ in Fig. 2a-d and of $(\frac{\partial}{\partial p}(\frac{1}{S}))_{max}$ in Fig. 2e-h. Variations in anvil outflow are represented by the magnitude and altitude of its vertical maximum, i.e., D_R and $Z_{D,R}$. Note that radiation can impose diurnal variations in anvil clouds. Thus, to exclude such diurnal variability, only observations at approximately 13:30 local time are used in Fig. 2.

For anvil macrophysical properties in the horizontal direction, D_R is primarily correlated with the magnitudes of $(\frac{1}{S})_{max}$ (Fig. 2a) and $(\frac{\partial}{\partial p}(\frac{1}{S}))_{max}$ (Fig. 2e). Changes in the altitudes of $(\frac{1}{S})_{max}$ and $(\frac{\partial}{\partial p}(\frac{1}{S}))_{max}$ barely influence D_R . Thus, weaker stability and a stronger vertical gradient of stability contribute to enhanced D_R to produce more anvil clouds and vice versa. Consistently, Wang and Yuan (2025) found that the magnitude of the minimum stability associated with the convective-to-radiative transition (leading to $(\frac{1}{S})_{max}$) is well correlated with the tropical high-level ice cloud coverage.

For anvil macrophysical properties in the vertical direction, $Z_{D,R}$ is primarily correlated with the altitudes of $(\frac{1}{S})_{max}$ and $(\frac{\partial}{\partial p}(\frac{1}{S}))_{max}$. Higher altitudes of $(\frac{1}{S})_{max}$ and $(\frac{\partial}{\partial p}(\frac{1}{S}))_{max}$ contribute to the rise of $Z_{D,R}$ (Fig. 2b and 2f), which further explains the increase in anvil-top height (Fig. 2c and 2g) and anvil thickness (Fig. 2d and 2h). Moreover, the variations in the magnitudes of $(\frac{1}{S})_{max}$ and $(\frac{\partial}{\partial p}(\frac{1}{S}))_{max}$ barely change the anvil-top height, but may influence $Z_{D,R}$ and anvil thickness. Note that stronger $(\frac{1}{S})_{max}$ and $(\frac{\partial}{\partial p}(\frac{1}{S}))_{max}$ may indicate a less stable environment, favoring both the peak of vertical outflow and the entire outflow layer. Thus, reduced stability and an intensified vertical gradient of stability (smaller $(\frac{1}{S})_{max}$ and $(\frac{\partial}{\partial p}(\frac{1}{S}))_{max}$) correspond to a rise of $Z_{D,R}$ and thicker anvil clouds.

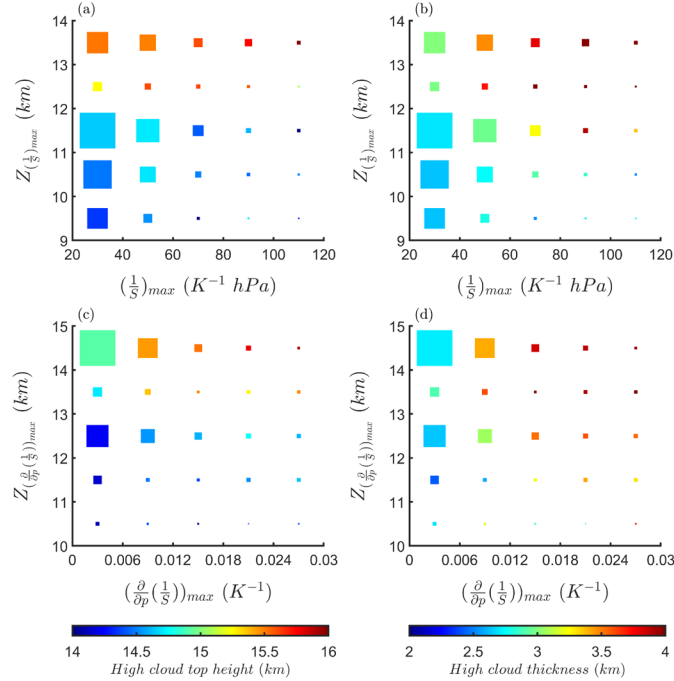


Figure 3. Associations of tropical high-level clouds with the SCRAOL constraints. (a-b) Average high cloud top height and thickness in each bin of magnitude and altitude of $(\frac{1}{S})_{max}$, respectively. The size of each square is proportional to the sample count. (c-d) Same as (a-b), but for $(\frac{\partial}{\partial p}(\frac{1}{S}))_{max}$.

Furthermore, the thermodynamic constraints of SCRAOL may apply not only to anvil clouds but also to tropical high-level clouds in general. Here, tropical high clouds are identified as those with cloud-base height exceeding 5 km. For those non-convective high-level clouds not organized by deep convective dynamics, their formation and development may depend more strongly on radiation and are thereby more constrained by SCRAOL. Thus, for tropical high clouds, changes in their top heights are strongly associated with the variation in the altitudes of $(\frac{1}{S})_{max}$ and $(\frac{\partial}{\partial p}(\frac{1}{S}))_{max}$ (Fig. 3a and 3c). Furthermore, consistent with the above discussion, the rise of the SCRAOL altitude and less stable SCRAOL both contribute to the increase in the cloud thickness (Fig. 3b and 3d).

2.8 Include Nighttime Observations

The author limits the analysis to the daytime overpass of the A-train satellites. Including nighttime observations would significantly strengthen the manuscript. There is no obvious reason why the stability constraint should not hold at nighttime. Reproducing Figures 1, 2, and 4 for nighttime would be easiest, but they would need to be included in a supplement. An alternative could be to produce one additional figure to show the similarity (or differences) between day and night. Maybe convergence, radiative heating and 1/S during the day and the night.

Response: Thanks for this valuable insight. At the diurnal timescale, SW radiation exhibits substantial variations. SW contributes strongly to daytime convective-top outflow, but this contribution vanishes at night. For nighttime, only LW radiation is present. Thus, the net radiation R is decomposed into LW and SW radiative components for analyses:

- (1) If LW and SW radiation-contributed divergence and convergence are both constrained by stability, this stability constraint can hold at both daytime and nighttime;
- (2) There is no doubt that a strong diurnal cycle in SW radiation is imposed on the anvil outflow. Thus, the diurnal difference in anvil production can be explained by the diurnal variation of SCRAOL.

For the first point, D_R is further separated into LW and SW components driven by radiative destabilization and heating, respectively:

$$D_R = (D_{RD, LW} + D_{RD, SW}) + (D_{RH, LW} + D_{RH, SW}).$$

The subscripts “RD” and “RH” denote the divergence components inducted by radiative destabilization and radiative heating, respectively. The subscripts “LW” and “SW” denote the LW and SW components.

Owing to the stability constraint, the PDF peaks of their contributions (Fig. 4) are largely confined to the region between the levels of $(\frac{1}{s})_{max}$ and $(\frac{\partial}{\partial p}(\frac{1}{s}))_{max}$, approximately 12-14 km. For both LW and SW radiation, only near this vertical region do their contributions to anvil outflow become effective. This may help shape the anvil clouds in convective systems. On the other hand, LW radiation contributes primarily to D_R below approximately 13 km, whereas SW radiation promotes outflow at relatively higher altitudes.

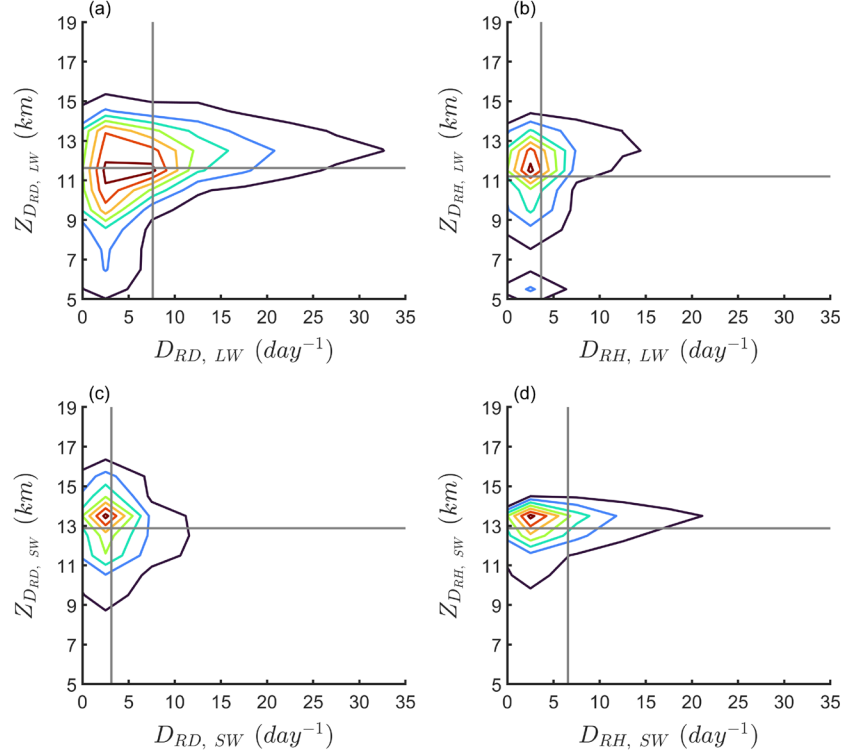


Figure 4. LW and SW radiative contributions to SCRAOL via heating and destabilization at 13:30 local time. Joint PDFs of the magnitude and altitude of D_R for LW destabilization (a), LW heating (b), SW destabilization (c), and SW heating (d). The PDFs are normalized by dividing its maximum value. Contours of the joint PDF are plotted from 0.05 to 0.95 at intervals of 0.10 toward the interior. The vertical and horizontal grey lines correspond to the average magnitude and altitude of different D_R components, respectively.

To further demonstrate the second point, Figure 5 shows the diurnal differences in anvil-outflow and SCRAOL altitudes (Z_{anvil} and Z_{SCRAOL}), as well as their relationships. Here, Z_{anvil} is defined as the vertical centroid of the outflow anvil layer from MCSs derived from the GATM dataset. The centroid is simply

computed as the vertically averaged altitude of a layer. Z_{SCRAOL} refers to the altitude of the vertical maximum of SCRAOL caused by net radiation. At around 01:30 local time (dashed contours in Fig. 5), with no SW radiation present, Z_{SCRAOL} decreases in altitude relative to the daytime Z_{SCRAOL} (solid contours in Fig. 5). Variations in Z_{anvil} are consistent with those in Z_{SCRAOL} , which also shifts toward lower altitudes at around 01:30 local time. This suggests that SW radiation can not only enhance the anvil production but also raise the anvil-outflow level at the diurnal timescale.

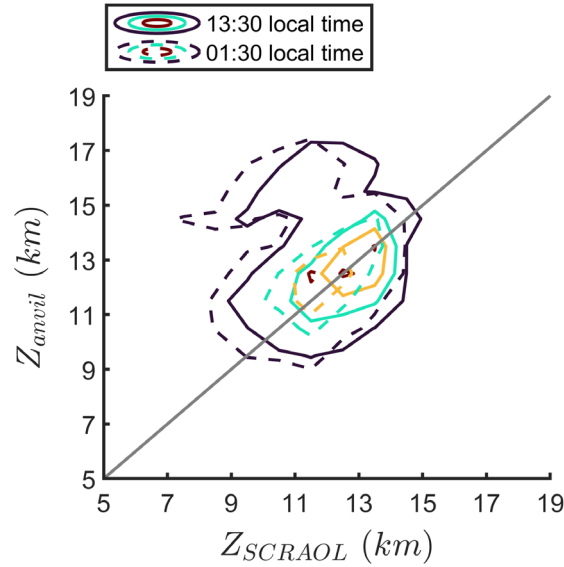


Figure 5. Joint PDF of Z_{anvil} and Z_{SCRAOL} at 13:30 (solid contours) and 01:30 (dashed contours) local time based on the GATM dataset. The PDFs are normalized by dividing its maximum value. Contours of the joint PDF are shown from 0.05 to 0.95 at intervals of 0.30. The grey solid line indicates the reference line $y = x$.

3 Technical Comments

L8: This seems like an overstatement since geostationary satellite observations and the A-train satellites have been available for many years. What is new in this paper is that they are combined to investigate anvil formation. This should be specified.

Response: This sentence has been removed. Instead, the abstract focuses on the novel thermodynamic constraints of SCRAOL and its comparison with previous clear-sky indirect constraint. But the advantages of the combined GEO-A-Train observations for identifying anvil clouds have been clarified in the main text in Sect. 2.4: the linkage between anvil clouds and their convective origins can be clearly established

even under two circumstances: (1) the A-Train CloudSat and CALIPSO only overpasses the edges of an MCS and fails to sample convective pillars; and (2) multiple convective cells are spatially clustered and their produced anvil clouds are connected in complex organizations.

L20: To be more precise, I suggest using "anvil cloud altitude" rather than "anvil-radiation feedback".

Response: Following above comments, the associations of anvil macrophysical properties (coverage, altitude and thickness) with the SCRAOL have been further discussed in the revised manuscript. Thus, the SCRAOL may be used for not only altitude but also coverage and thickness feedback. This sentence has been revised as: "Overall, SCRAOL establishes physical links between radiation-driven anvil outflow and atmospheric thermal stratification, thereby providing novel thermodynamic constraints on radiative feedback of anvil macrophysical properties."

L41: Show only the equation for stability that you are using (pressure coordinates, I guess).

Response: It has been revised as: " $-\frac{T}{\theta} \frac{\partial \theta}{\partial p}$ in pressure coordinates; θ and T are potential temperature and temperature".

L49: This link was already established in earlier papers, which should be cited here. For example Bony et al. (2016); Jeevanjee (2022).

Response: Citations have been added in the revised manuscript.

L62: This paragraph does not include any support for the claim that model parameterisations of anvil outflow lack observational evidence to be improved. While I believe this statement is true, some citation would be necessary to prove this. Otherwise, I suggest removing the statement, since it does not seem essential for the following arguments.

Response: This sentence has been removed.

L119: Please include the citation for ERA5: Hersbach et al. (2020). L120: Isn't the horizontal grid spacing of ERA5 0.25°?

Response: This section for introducing ERA5 has been removed, since EAS is no longer used for analyses in the revised manuscript.

L150-L152: This should be moved to the data and methods section, where the study region and time period are introduced.

Response: It has been moved to the section of data and methods.

Figure 3: I really like this figure! The convergence label on the blue arrow is somewhat confusing since it is placed between clear skies and cloudy skies. It should be all the way in the cloudy box to make sense.

Response: Thanks! This figure has been revised as shown below.

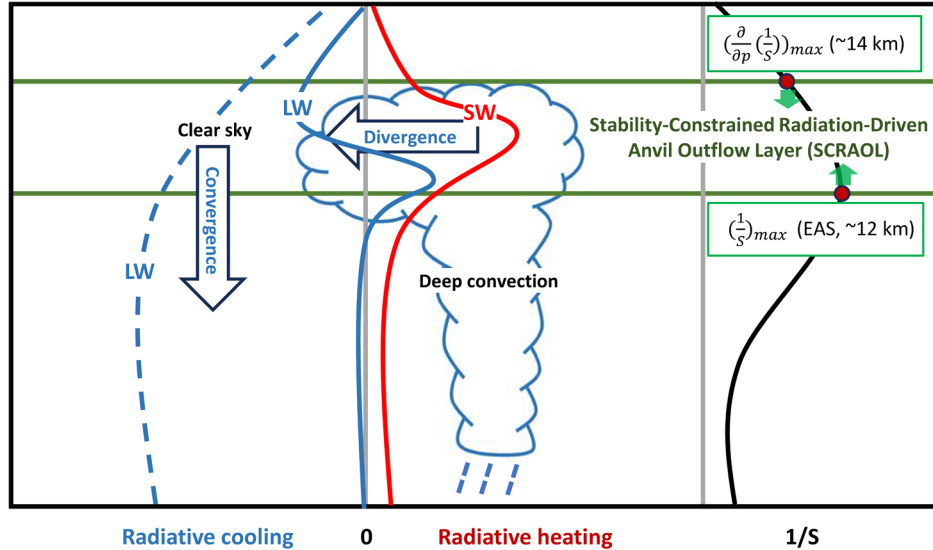


Figure 6. Illustration of SCRAOL constraints on anvil clouds. Solid blue and red lines denote the LW and SW radiative heating profiles for anvil clouds, respectively. The dashed blue line indicates the clear-sky LW cooling. The arrows represent the convergence and divergence driven by radiation. The primary radiation-driven anvil outflow and clear-sky convergence are both constrained between the levels of $(\frac{1}{S})_{max}$ and $(\frac{\partial}{\partial p}(\frac{1}{S}))_{max}$.

L253: "Away from this layer, anvil production is suppressed by the environmental stability." This is a key sentence that is proven by Figure 4. This should be pointed out more clearly. I would put Figure 4 before Figure 3 and use Figure 4 to carefully explain this point and then pick it up again in some kind of summary based on the schematic (now Figure 3).

Response: As suggested, the order of these two figures is modified accordingly.

Figure 4: Is this only data for 13:30 local time? Please specify. Red and blue lines are not introduced in the caption, and the contours of stability are grey, not black.

Response: The caption of this figure has been modified as: "Thermodynamic constraints of SCRAOL under the convective regime based on deep convective and anvil clouds identified in the GATM dataset at 13:30 local time. R , $\frac{\partial R}{\partial p}$ and D_R associated with LW (a-c), SW (d-f) and net (g-i) radiation, respectively. The solid

gray contours denote $\frac{1}{s}$, with the units of $K^{-1} hPa$. The red and blue lines mark the levels of $(\frac{1}{s})_{max}$ and $(\frac{\partial}{\partial p}(\frac{1}{s}))_{max}$. The dashed black lines indicate convective-top height.”.

L321: ”for” identifying convection ..., not ”of”. Same for ”of” detecting.

Response: It has been corrected.

L324: It is a bit hard to believe that nobody has published anything substantial on the radiatively driven anvil outflow process between 1988 and 2025. I suggest checking for other references and citing them here and in the introduction.

Response: More references have been added.

References

- Bony, S., Stevens, B., Coppin, D., Becker, T., Reed, K. A., Voigt, A., and Medeiros, B.: Thermodynamic control of anvil cloud amount, *Proc Natl Acad Sci U S A*, 113, 8927-8932, 10.1073/pnas.1601472113, 2016.
- Chae, J. H. and Sherwood, S. C.: Insights into Cloud-Top Height and Dynamics from the Seasonal Cycle of Cloud-Top Heights Observed by MISR in the West Pacific Region, *Journal of the Atmospheric Sciences*, 67, 248-261, 10.1175/2009jas3099.1, 2010.
- Gasparini, B., Blossey, P. N., Hartmann, D. L., Lin, G., and Fan, J.: What Drives the Life Cycle of Tropical Anvil Clouds?, *Journal of Advances in Modeling Earth Systems*, 11, 2586-2605, 10.1029/2019ms001736, 2019.
- Jeevanjee, N.: Three Rules for the Decrease of Tropical Convection With Global Warming, *Journal of Advances in Modeling Earth Systems*, 14, e2022MS003285, <https://doi.org/10.1029/2022MS003285>, 2022.
- Jeevanjee, N. and Zhou, L.: On the Resolution-Dependence of Anvil Cloud Fraction and Precipitation Efficiency in Radiative-Convective Equilibrium, *Journal of Advances in Modeling Earth Systems*, 14, e2021MS002759, <https://doi.org/10.1029/2021MS002759>, 2022.
- Lilly, D. K.: Cirrus Outflow Dynamics, *Journal of the Atmospheric Sciences*, 45, 1594-1605, 10.1175/1520-0469(1988)045<1594:Cod>2.0.Co;2, 1988.
- Lutsko, N., Sherwood, S. C., and Zhao, M.: Precipitation Efficiency and Climate Sensitivity (Invited Chapter for the AGU Geophysical Monograph Series “Clouds and Climate”), ESS Open Archive, 2021, doi:10.1002/essoar.10507822.1, 2021.
- Saint-Lu, M., Bony, S., and Dufresne, J.-L.: Observational Evidence for a Stability Iris Effect in the Tropics, *Geophysical Research Letters*, 47, e2020GL089059, <https://doi.org/10.1029/2020GL089059>, 2020.
- Wang, Z. and Yuan, J.: A Novel Thermodynamical Predictor of Tropical High-Cloud Area Coverage: Estimated Anvil-Outflow Stability, *Geophysical Research Letters*, 52, e2025GL115026, <https://doi.org/10.1029/2025GL115026>, 2025.