

Editor comments:

I would like to clarify at the outset that the decision of “reconsider after major revisions” should not be interpreted as a rejection of the manuscript. At this stage, there is a technical issue for which I would like to receive clarification from the authors before asking the reviewers to undertake another full review. Following the editorial procedure, I therefore need to select “reconsider after major revisions” to allow the authors an opportunity to respond to and address this issue. If the authors' response and corresponding revisions satisfactorily resolve the concern described below, the revised manuscript can then proceed to another round of review.

An issue that remains unclear is the pronounced symmetry of the simulated fields about the domain centerline, $y=10$ km. In particular, the 13-h time-averaged surface precipitation exhibits this symmetry across the simulations, and a similar symmetry appears in the forward water-vapor trajectories. Given the stated periodic boundary condition in the y -direction, the domain has no physically distinguished location in y ; periodicity does not, by itself, select $y=10$ km as a preferred symmetry axis. Moreover, random perturbations are introduced to initiate turbulence.

While convective organization and cold-pool dynamics can certainly produce spatially heterogeneous and organized precipitation, it remains unclear why these processes would consistently produce reflection symmetry specifically about $y=10$ km across the simulations and over a 13-h averaging period. The authors should explain what physical or numerical mechanism selects the domain centerline.

Please also clarify the implementation of the y -direction boundary condition and whether any additional treatment (e.g., damping, relaxation, sponge layers, or other boundary-related forcing) is applied. In addition, the forward trajectories that reach a y -boundary appear to terminate rather than re-enter through the opposite boundary. Please explain how periodic boundary crossings are handled in the trajectory calculation and whether this behavior is solely a trajectory post-processing issue or reflects the boundary treatment used in the LES.

Reply: We agree with the editor that the pronounced symmetry in the original simulations warranted further examination. In response to this concern, we carefully re-examined the model configuration in response to these concerns. In the original simulations, random potential perturbations were not introduced because our aim was to maintain a highly controlled idealized

environment and to minimize the influence of stochastic initial disturbances on the responses to the lake, terrain, and prescribed background wind. In addition, the surface forcing, terrain, and prescribed background flow varied primarily in the x -direction and were homogeneous in the y -direction. Consequently, no initial perturbation was present to break this y -directional homogeneity, causing the simulated fields to retain a pronounced symmetry along the y -direction.

To eliminate this constraint and allow the development of more realistic spatial variability, we repeated all simulations with initial random potential temperature perturbations of 0.1 K. All figures and corresponding analyses in the revised manuscript have been updated based on these new simulations. The revised results no longer exhibit the pronounced reflection symmetry about $y = 10$ km observed in the original simulations. Importantly, the main characteristics of the lake-mountain interactions and the major conclusions of this study remain unchanged. The detailed revisions are described below.

(1) Symmetry in the y -direction

In the original simulations, random potential temperature perturbations were not applied. In addition, the terrain, lake surface properties, and prescribed background flow were homogeneous in the y -direction. Under this configuration, no initial perturbations were present to break the y -directional homogeneity. Consequently, the simulated fields retained a highly symmetric structure along the y -direction, accounting for the pronounced reflection symmetry observed in the original x - y distributions.

Previous idealized modeling studies have employed both perturbed and unperturbed initial conditions, depending on the specific objectives of the experiments. Unperturbed simulations are often used to maintain a controlled basic state and isolate the response to prescribed forcing, such as terrain or surface heterogeneity, without introducing additional stochastic variability. For example, Frame and Markowski (2006) used simulations without initial temperature perturbations to isolate the atmospheric response to idealized terrain. However, in the absence of a mechanism capable of breaking the initial horizontal homogeneity, such controlled configurations may retain a high degree of spatial symmetry. Similarly, idealized CM1 simulations discussed by Markowski and Bryan (2016) showed that the boundary layer can remain nearly laminar in the absence of

random initial perturbations, illustrating the important role of weak perturbations in promoting three-dimensional variability.

Following the editor's comments and suggestions, random potential temperature perturbations with an amplitude of 0.1 K were introduced throughout the three-dimensional model domain in all revised simulations. These perturbations break the y -directional homogeneity and allow three-dimensional variability to develop. As a result, the revised surface precipitation fields no longer exhibit the persistent reflection symmetry about $y = 10$ km observed in the original simulations. The detailed convective structures also show clear variability along the y -direction, while the main characteristics of the lake-mountain interactions and the overall conclusions of the study remain unchanged.

(2) Random perturbations

The revised simulations use random potential temperature perturbations with an amplitude of 0.1 K, which are applied throughout the three-dimensional model domain at initialization. The magnitude of these perturbations is small relative to the prescribed surface thermal contrast. Therefore, the perturbations are intended to introduce weak three-dimensional variability rather than to provide additional thermal forcing. The same perturbation configuration is applied consistently across all sensitivity experiments. The revised simulations show some changes in precipitation amount and detailed convective structures (Fig. R1). However, the key differences among the lake-mountain sensitivity experiments remain consistent with those in the original simulations, and the major conclusions of the study are unchanged. **A comparison of all analysis figures between the original and revised simulations is provided in the Supplements.**

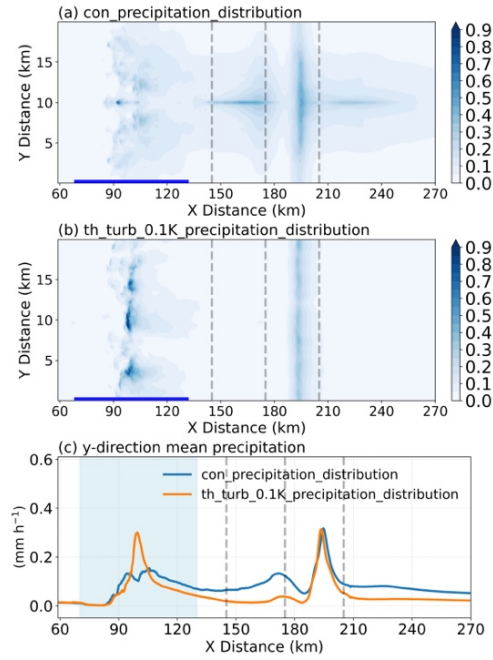


Figure R1. Time-mean surface precipitation (mm h^{-1}) in the x-y plane for (a) the unperturbed simulation and (b) the perturbed simulation with random potential-temperature perturbations of 0.1 K. (c) Corresponding y-averaged precipitation profiles for the unperturbed (blue) and perturbed (orange) simulations. Light-blue shading indicates the lake region, and gray dashed lines mark the windward slope, mountain crest, and leeward slope.

(3) Lateral boundary conditions and damping

Open-radiative boundary conditions are applied in the x -direction, while periodic boundary conditions are applied in the y -direction. For the LES fields, flow exiting through one y -boundary re-enters the domain through the opposite boundary. No horizontal Rayleigh damping, relaxation, sponge layer, or other lateral forcing is applied. Rayleigh damping is applied only within the uppermost 1 km of the model domain to absorb upward-propagating gravity wave energy and reduce artificial reflection from the model top back into the interior of the domain.

(4) Forward trajectory calculation and periodic boundary treatment

The forward trajectories are calculated offline using the resolved three-dimensional wind fields from the CM1 simulations. Although CM1 has been widely used for idealized atmospheric simulations, its native trajectory capability is limited, particularly for three-dimensional simulations over complex terrain. We therefore employed an offline trajectory calculation framework developed for CM1 output that enables the calculation of trajectories over complex terrain (Gowan, T. M., 2019: Trajectories, <https://github.com/tomgowan/trajectories>). The method uses a second-order semi-implicit discretization in space and time, following the trajectory integration scheme described

by Miltenberger et al. (2013). Parcel positions are determined from the resolved u , v , and w wind components using a predictor–corrector procedure. Thus, CM1 provides the Eulerian wind fields, while the offline trajectory calculation provides a Lagrangian representation of air-parcel motion. The water-vapor mixing ratio is subsequently interpolated from the Eulerian model fields to each
105 parcel position and used as a diagnostic variable along the trajectories.

Periodic boundary crossing was not accounted for in the original trajectory calculation. Therefore, although the LES itself uses periodic boundary conditions in the y -direction, parcels leaving the trajectory interpolation domain were not reintroduced through the opposite boundary. As a result, some trajectories appeared to terminate at the y -boundaries. This behavior was solely
110 an artifact of the trajectory post-processing procedure and did not reflect the actual boundary treatment in the LES. We have now modified the trajectory calculation to account for the periodic boundary conditions in the y -direction. When a parcel crosses a y -boundary, its position is mapped to the corresponding location at the opposite boundary, and the trajectory integration continues accordingly. All affected forward trajectories have been recalculated using this revised treatment.
115 This correction modifies the paths of some individual trajectories near the lateral boundaries but does not alter the main conclusions regarding moisture transport from the lake toward the mountain.

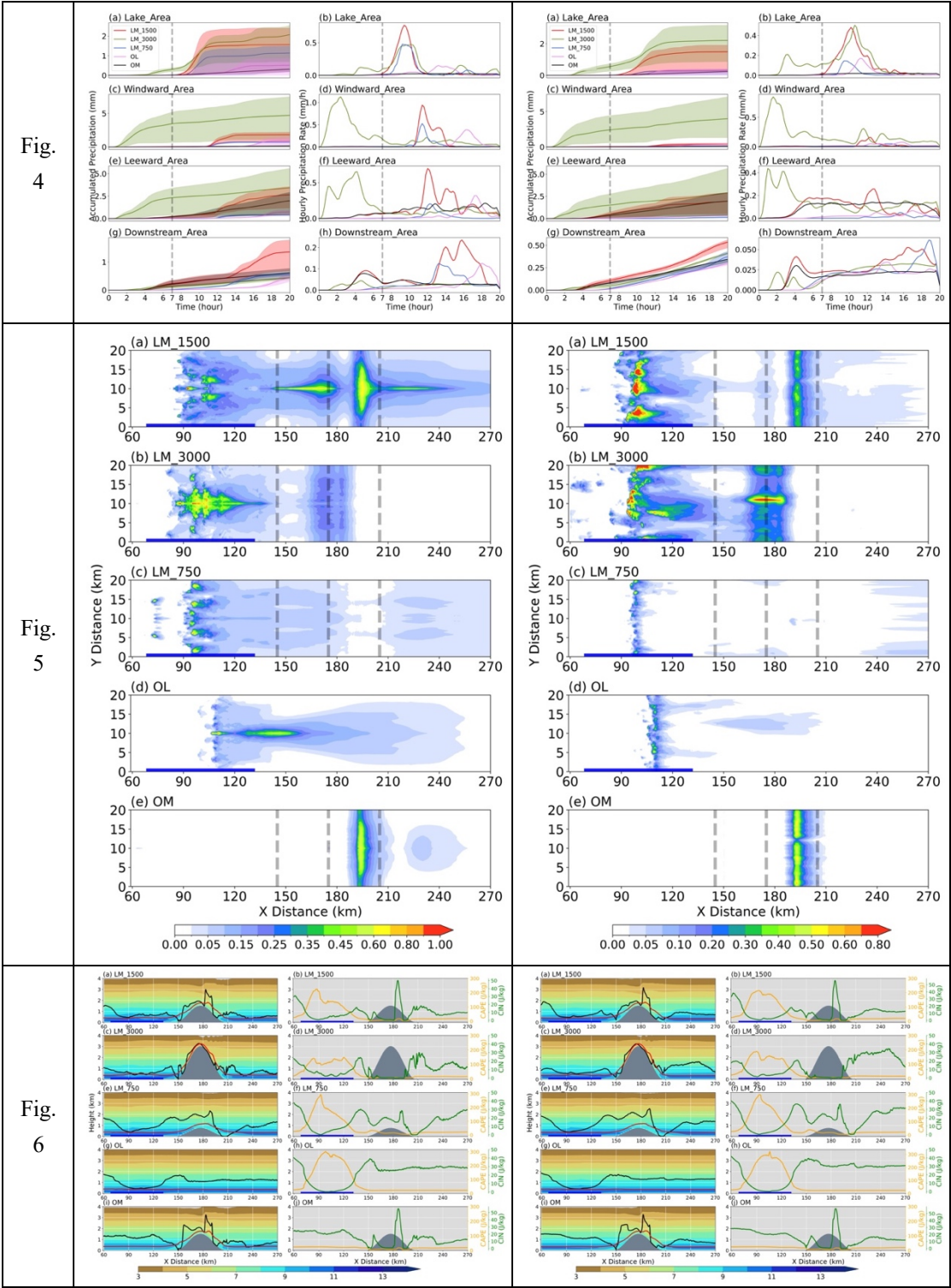
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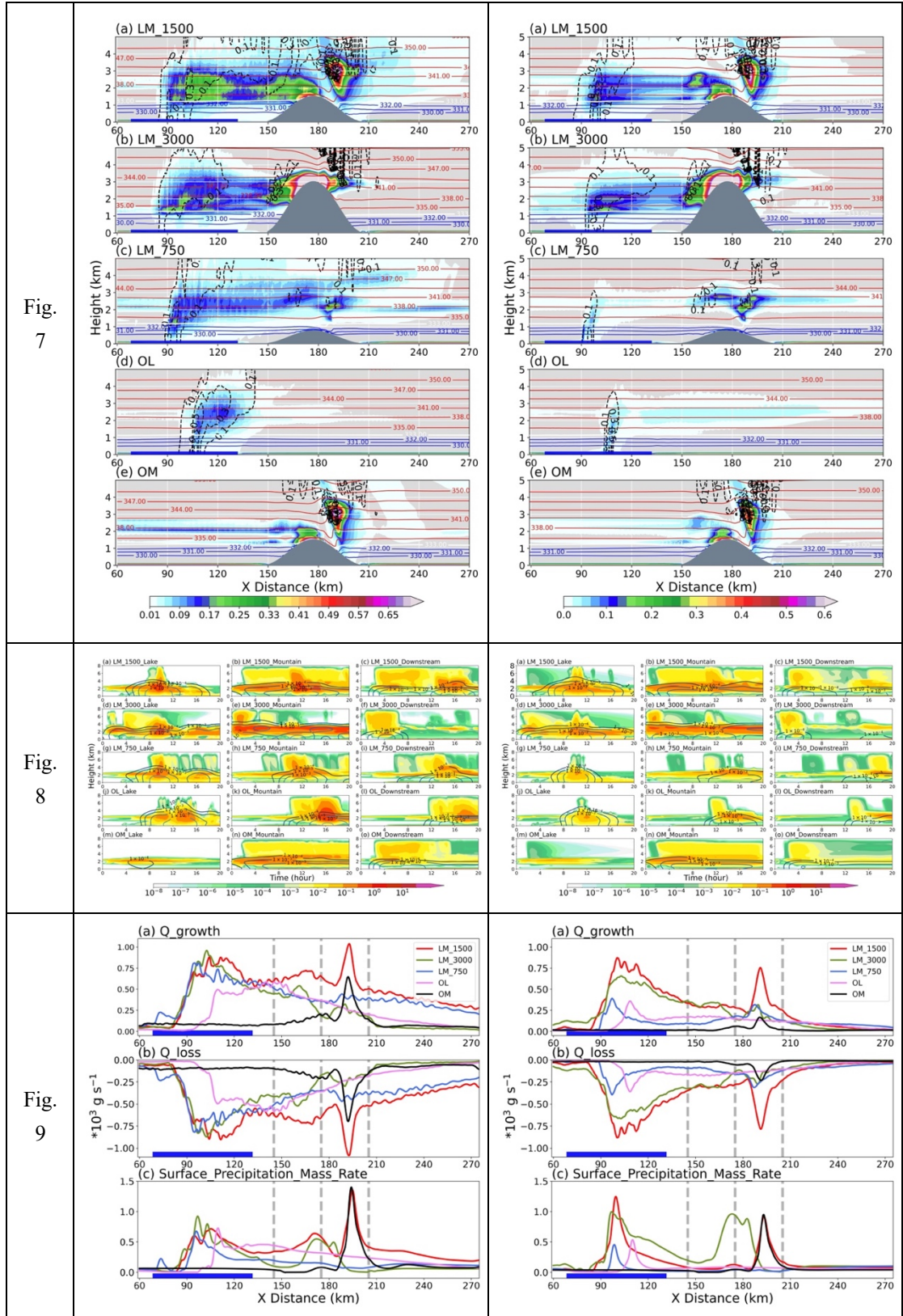
Frame, J. and Markowski, P.: The interaction of simulated squall lines with idealized mountain
120 ridges, *Mon. Weather Rev.*, 134, 1919–1941, <https://doi.org/10.1175/MWR3157.1>, 2006.

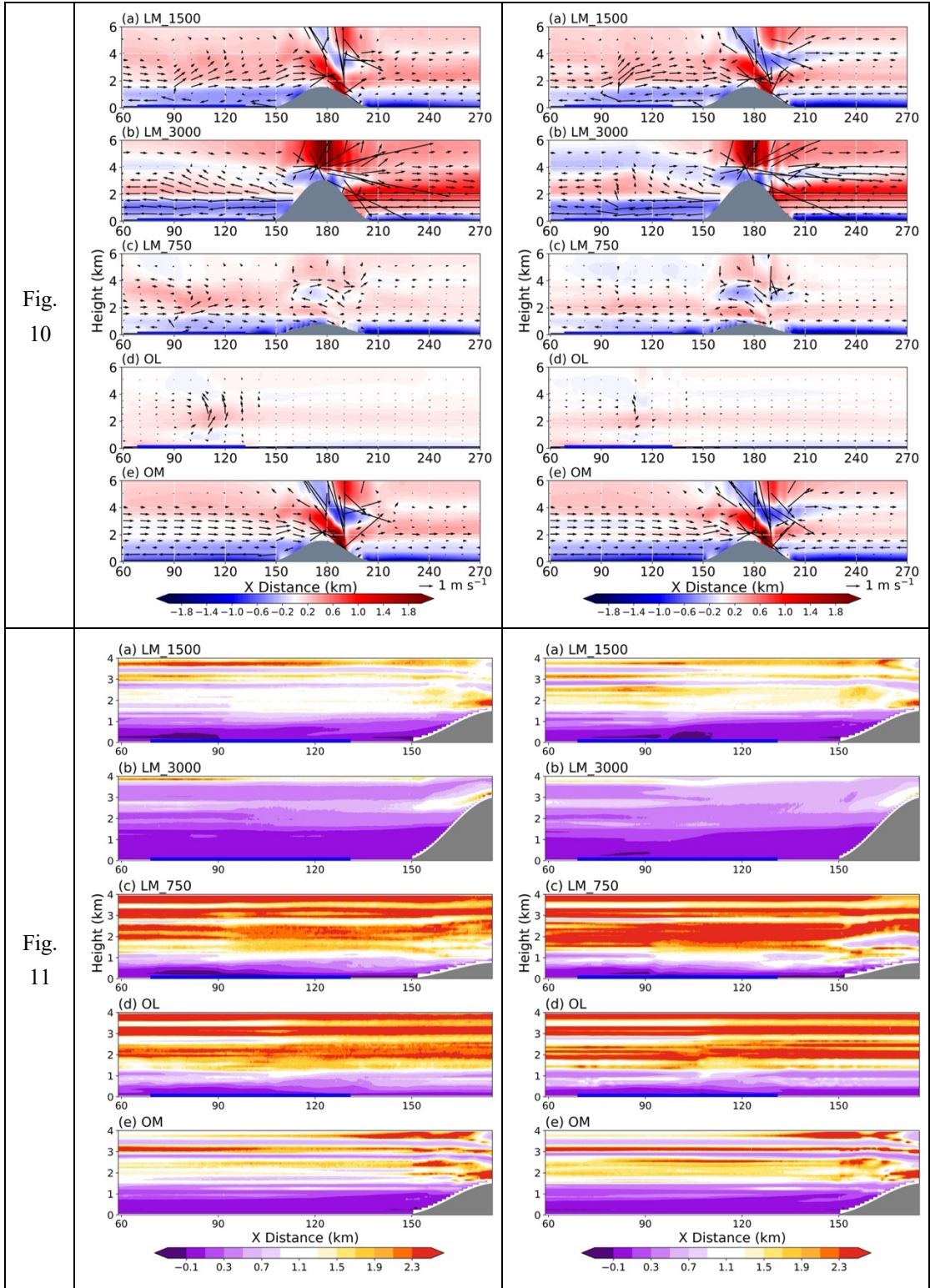
Markowski, P. M. and Bryan, G. H.: LES of Laminar Flow in the PBL: A Potential Problem for Convective Storm Simulations, *Mon. Weather Rev.*, 144, 1841–1850, <https://doi.org/10.1175/MWR-D-15-0439.1>, 2016.

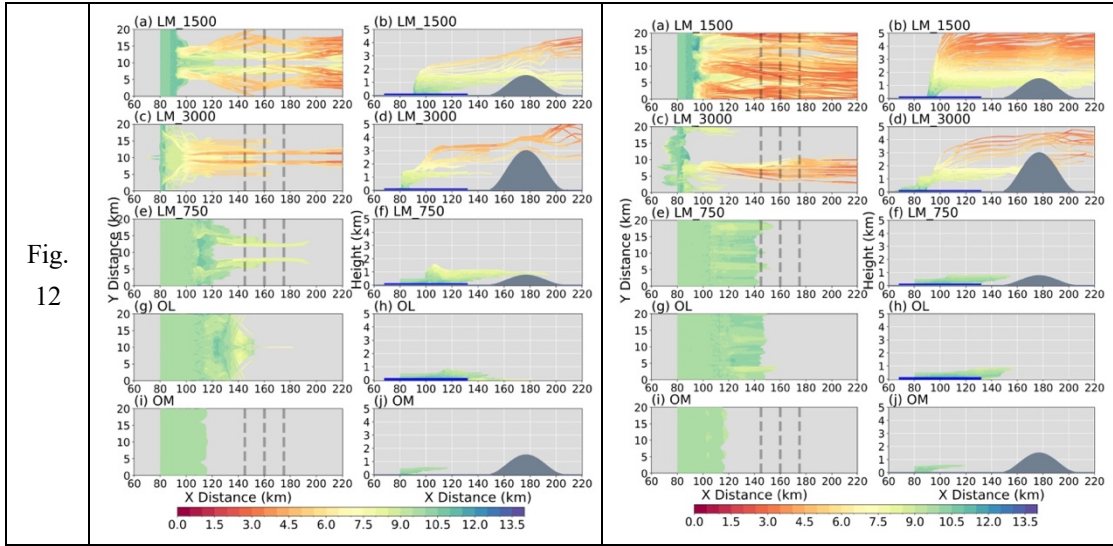
Miltenberger, A. K., Pfahl, S., and Wernli, H.: An online trajectory module (version 1.0) for the
125 nonhydrostatic numerical weather prediction model COSMO, *Geosci. Model Dev.*, 6, 1989–2004, <https://doi.org/10.5194/gmd-6-1989-2013>, 2013.

Figures 4-12 Comparisons of the simulated fields shown in the manuscript between the original experiments without random potential-temperature perturbations (left column) and the revised experiments with random potential-temperature perturbations of 0.1 K (right column).









Review of egusphere-2026-289 “Lake-Mountain synergy in convective clouds and precipitation over the Tibetan Plateau: a large eddy simulation study”

140 *This manuscript presents an interesting large-eddy simulation study of controls on convection over an idealised high-altitude lake-mountain study area representative of the Tibetan Plateau. Sensitivity experiments varying the height of the mountain and removing the mountain or the lake are conducted to disentangle the different interacting processes which control where and how strong the convection is. The approach is a methodical one and there are some strong aspects to the*
145 *analysis, but I do have some concerns about the model setup / results which need addressing, or at least justifying, in order for the reader to have confidence in the conclusions of the paper.*

Reply: We sincerely appreciate the time and effort you have devoted to reviewing our manuscript and providing valuable comments and suggestions, which have helped us improve its quality and clarity. In response to your comments, we have revised the manuscript to provide a more
150 detailed description of the model configuration and experimental design (lines 123-208 in the revised manuscript). We have also strengthened the physical interpretation of the results by further examining the mechanisms governing convective initiation, location, and intensity. In addition, we have expanded the discussion of the limitations associated with the idealized experimental setup and revised several statements in the Conclusions (lines 536-583 in the revised manuscript) to ensure
155 that they are fully supported by the simulations.

All comments have been carefully considered, and our detailed point-by-point responses are provided below.

Major comments:

160 *1) Initial / surface conditions: An initial temperature is given for the lake (284K) and a significantly warmer temperature for the land (300K). The initial near-surface air temperature (from the skew-T diagram in figure 3) is about 283K. This means there will initially be a significant positive surface heat flux from the land. How do the land (and lake) surface temperature and the surface fluxes evolve over time? Is there a diurnal cycle of radiation imposed? If so, what time of*
165 *day / day of year/ latitude is the model initialised with? Or are the surface temperatures fixed? It is import to be clear about this as the surface fluxes are ultimately driving the convection. If a diurnal*

cycle is not being imposed, how realistic is a 20 hour simulation with daytime surface conditions?

Reply: In our simulations, the lake surface temperature is fixed at 284 K, whereas the land surface temperature is initialized at 300 K and subsequently evolves interactively through the surface energy exchange with the atmosphere. No radiation scheme *is activated, and thus* no explicit diurnal cycle of solar radiation is imposed. The 20 h integration is therefore not intended to represent a realistic diurnal evolution, but rather represents a controlled idealized experiment designed to capture the timescale required for lake-supplied moisture to be transported toward the mountain, interact with terrain-induced lifting, and contribute to the development of precipitation over and downstream of the mountain.

(1) The initial atmospheric thermodynamic profile is based on the 08:00 Beijing Time radiosonde observation at Naqu Station. However, the model initialization time is not intended to represent the actual surface conditions at 08:00. The radiosonde profile is adopted to represent the background thermodynamic structure of the free atmosphere over the TP, while the prescribed initial land-air temperature contrast is designed to mimic the intense surface heating that typically develops during the afternoon, thereby providing the thermal forcing for lake-mountain interactions. Specifically, the land surface is initialized at 300 K, substantially warmer than the near-surface air temperature of approximately 283 K, resulting in a positive sensible heat flux during the early stage of the simulation. After initialization, the land surface temperature is not prescribed but evolves interactively through the surface energy balance calculated by the model surface scheme. In contrast, the lake surface temperature is fixed at 284 K, based on the observed water temperature at a depth of 6 m in Nam Co reported by Wang et al. (2020). This temperature is close to the initial near-surface air temperature. Given the large heat capacity of the lake, assuming a relatively stable lake temperature over the timescale considered here provides a reasonable idealization. The relatively small lake-air temperature difference produces weaker sensible heating over the lake than over land, while evaporation provides a persistent source of atmospheric moisture. This configuration was selected because our primary objective is to directly investigate the afternoon interaction among lake-induced moisture transport, lake-breeze circulation, and terrain-induced lifting, rather than to reproduce the complete diurnal transition from morning to afternoon.

(2) No radiation scheme is activated, and therefore no explicit diurnal cycle of solar radiation is imposed. This choice avoids introducing time-varying radiative forcing and cloud-radiation

feedbacks that could complicate the interpretation of the individual and combined effects of the lake and mountain in the sensitivity experiments. As described above, combining an observed morning sounding with an idealized afternoon-like surface thermal contrast allows us to separate the representative atmospheric background state from the imposed surface forcing. This controlled framework enables us to focus specifically on lake-mountain interactions rather than on the full diurnal evolution of radiative forcing. Similar prescribed or controlled surface thermal forcing has been widely adopted in idealized LES studies of sea- and lake-breeze circulations. For example, Antonelli and Rotunno (2007) imposed a constant surface heat flux over land and explicitly neglected its temporal variation; Crosman and Horel (2012) examined idealized lake- and sea-breeze sensitivity to prescribed land-surface sensible heat flux.

(3) The 20-h integration period should therefore not be interpreted as representing 20 h of realistic daytime heating. Instead, it was selected based on the characteristic timescales of moisture transport and convective development in the model. Sufficient integration time is required for air and moisture originating from the upstream lake region to be transported toward the mountain, interact with terrain-induced lifting, and subsequently contribute to precipitation formation over the mountain and in downstream regions. The first several hours primarily represent the adjustment of the model to the imposed initial thermal contrast. Therefore, our principal analysis focuses on 7-20 h, when the terrain-induced circulation has become well established and the more slowly developing lake-breeze circulation has had sufficient time to influence moisture transport and convective development.

We acknowledge that the absence of a radiative diurnal cycle limits the realism of the simulated timing and persistence of convection, and this limitation has been explicitly discussed in the revised manuscript. Nevertheless, the controlled forcing framework is designed to isolate the thermodynamic and dynamical mechanisms through which lake-induced moisture supply and terrain-induced lifting regulate convective initiation, organization, and precipitation development.

2) *Lateral (y-direction) boundary: according to the text, these are period, in which case I would expect to see much more uniform results in the y direction since there is no variation in the topography or land surface in the y direction either. The results however (e.g. figure 5) show a very strong variation in the y direction with almost all the precipitation close to the centre line of the*

domain. This seems physically implausible. Assuming the model description is correct this would imply that the limited domain width is having a significant and non-physical impact on the convection. Did you do any sensitivity tests on this? Given these issues with the boundary conditions and lack of uniformity in the y direction, it casts uncertainties on the rest of the results in the paper and so this issue needs to be resolved.

Reply: We agree that the strong y -direction concentration and symmetry in the original precipitation fields required further examination. We therefore re-examined both the lateral boundary treatment and the initial perturbation configuration.

(1) In the original simulations, no random potential-temperature perturbations were applied. At the same time, the terrain, lake surface properties, and prescribed background flow were homogeneous in the y -direction. Under this highly controlled configuration, there was no initial perturbation to break the imposed y -direction homogeneity. This allowed the simulated fields to retain a pronounced symmetric structure and contributed to the unrealistic concentration of precipitation near the domain centerline.

(2) Following this concern, we repeated all simulations with random potential temperature perturbations of 0.1 K applied throughout the three-dimensional model domain. The revised simulations no longer exhibit the pronounced reflection symmetry about $y = 10$ km. The detailed precipitation and convective structures now show clear variability along the y -direction. All figures and related analyses in the manuscript have been updated accordingly. More importantly, the main differences among the lake-mountain configurations and the physical interpretation remain unchanged. The revised results continue to show that lake-induced moisture supply favors convective development, while terrain lifting strongly regulates the location and intensity of precipitation.

(3) The x -direction uses open-radiative boundary conditions, whereas the y -direction uses periodic boundary conditions. No horizontal Rayleigh damping, relaxation, sponge layer, or other lateral forcing is applied. Rayleigh damping is used only within the upper 1 km of the model domain to reduce artificial reflection of upward-propagating gravity waves from the model top. Therefore, no additional lateral boundary treatment selects the domain centerline as a preferred location.

3) *Related to 2). Many of the results are averaged over the central 15km of the domain. Given the*

boundary conditions are periodic in the y direction there is no reason not to average over the whole width of the domain. However, given the clear non-uniformity in the y direction noted in 2) the choice of what width to average over will affect the results. The choice of 15km seems arbitrary.

260 **Reply:** We agree that the use of the central 15 km average in the original manuscript could make the results sensitive to the selected averaging width, particularly because the original simulations exhibited pronounced y-direction symmetry and a strong concentration of convection near the domain centerline.

As described in our response to Comment 2, we have repeated all simulations with initial
265 random potential temperature perturbations of 0.1 K. The revised simulations no longer show persistent reflection symmetry about $y=10$ km and exhibit clear three-dimensional variability in the y-direction. In addition, to remove any dependence on an arbitrarily selected central band, we have replaced the previous 15 km average with an average over the entire y-domain for all relevant diagnostics. All affected figures and corresponding analyses have been recalculated and updated in
270 the revised manuscript.

The full-domain averaging leads to some quantitative changes in the magnitude of individual fields, but the main spatial structures and the relative differences among the lake-mountain configurations remain consistent. Therefore, the main conclusions regarding lake-induced moisture supply, terrain-induced lifting, and their combined effects remain unchanged.

275

*4) Choice of averaging time. Many figures show results averaged over hours 7-20 of the simulation. While I appreciate the need to average LES results to produce the mean flow, this is quite a long period to average over. The flow is definitely not statistically stationary over this period (as can be seen from the time series, e.g. figure 4. Why this choice of averaging window? And what
280 are the implications of this on the results?*

Reply: The simulations are initialized from a cold start, and different components of the system develop on different timescales. Following initialization, the mountain-induced circulation responds relatively rapidly to the imposed mechanical and thermal forcing, whereas the lake-induced circulation and associated moisture transport require a longer adjustment period to develop. During
285 the first several hours, the simulated evolution is therefore strongly influenced by initial adjustment processes and by the largely independent development of the lake- and terrain-induced responses.

By approximately 7 h, lake-derived moisture has reached the mountain region, and the combined effects of lake moisture supply and terrain-induced lifting have become well established.

Accordingly, the 7-20 h period was selected to characterize the mean response associated with the coupled effects of lake moisture supply and terrain-induced lifting on cloud development, hydrometeor evolution, and precipitation distribution. Although convection continues to evolve during this period, applying the same averaging window to all experiments provides a consistent basis for comparing how modifications to the lake and terrain affect convective development. The resulting fields should therefore be interpreted as time-averaged responses during the established lake-mountain interaction stage, rather than as representations of a statistically stationary state.

5) *Averaging CAPE / CIN over pre / during and post convection. CAPE and CIN are primarily used to diagnose conditions conducive to convection and so I am not sure it makes sense to average these values over the whole 7-20 hours of the simulation which includes the convection (and post convection). To understand where and when convection occurs you need to study CAPE and CIN values before the convection initiates.*

Reply: The purpose of the averaging used in this study is not to diagnose only the convection triggering conditions, but rather to characterize the overall thermodynamic evolution during the mature lake-mountain convection process. In our simulations, convection is initiated and maintained through different mechanisms during the integration period. In particular, mountain-induced lifting can trigger convection at an earlier stage, whereas lake breeze circulation requires additional time to develop under sustained surface heating and contributes to later convection enhancement. Therefore, the 7-20 h period was selected to include the evolution of both mountain-driven and lake-driven convective processes.

To clarify this point, we have revised the manuscript to state that the time averaged CAPE and CIN values are used to represent the thermodynamic environment during the active convection period, rather than solely the conditions before convection initiation.

6) *Why the choice of a sheared background wind profile? This does give low wind speeds at low levels, but becomes much stronger higher up. The results of the OL experiment suggest that this background wind dominates over any thermally induced lake-land breezes, while the OM experiment*

suggests that wave trapping/ wave breaking is a key features of this setup which is again controlled by the background wind field alongside the stratification. In particular, a shear wind profile with wind speed increasing with height will promote wave trapping since the Scorer parameter decreases with height. This has a significant impact on the results over the mountain. Maybe this is realistic for the TP, but you should be clear about the rationale for the choice and the implications of that choice.

Reply: The prescribed background wind profile increases linearly with height, with relatively weak low-level winds and stronger winds aloft. This profile was designed to represent the typical vertical structure of the environmental flow over the TP rather than to reproduce a specific observed event.

The weak low-level winds are important because they allow thermally driven lake-land circulations to develop and enable lake evaporation to modify the near-surface thermodynamic environment. Meanwhile, the stronger winds aloft facilitate the downstream transport of lake-supplied moisture toward the mountain region, where terrain-induced lifting can further promote cloud development and precipitation formation. This configuration is broadly consistent with previous idealized studies of lake-mountain convection over the TP, which have emphasized the importance of interactions among the background flow, lake-breeze circulation, and topography in regulating moisture transport and convective initiation (Gerken et al., 2014).

We acknowledge that a vertically sheared wind profile can also influence mountain-wave propagation, wave trapping, and wave breaking through changes in the Scorer parameter. In our experiments, these dynamical effects are therefore not excluded but represent part of the mountain response under a realistic TP background environment. However, the objective of this study is not to isolate mountain-wave dynamics alone, but to quantify how lake-induced moisture supply interacts with terrain lifting under weak synoptic forcing. Since the same environmental wind profile is applied in all sensitivity experiments, the comparison primarily reflects the impacts of lake presence and terrain on convective development.

7) *Section 2.4.1. I'm not sure this section is correct. If perturbations are from a horizontal average, then what do you do over the mountain where the horizontal intersects the terrain? Looking at later figures of e.g. θ' , they can't be perturbations about a horizontal average as at a given level the*

values are all positive or negative (and by definition the horizontal average of a perturbation has to be zero). Is it perhaps perturbations from the background (upstream) profile or the initial profile? Please check and correct.

350 **Reply:** The original description in Sect. 2.4.1 was incorrect and could lead to the interpretation that the perturbations were defined relative to a horizontal mean. No horizontal averaging is used in the decomposition. Instead, each variable is decomposed point by point into a four-dimensional base component and a perturbation component, both of which retain their dependence on time, height, and the x- and y-directions.

355
$$\phi(t, z, x, y) = \phi_{base}(t, z, x, y) + \phi_{turb}(t, z, x, y)$$

Consequently, the perturbation field is not required to have a zero horizontal mean, and no special treatment is needed at levels that intersect the terrain. The averaging in the periodic y-direction is applied only after the decomposition when producing the two-dimensional cross-sections shown in the later figures. We have revised Sect. 2.4.1 and Eq. (2) and removed the
360 misleading references to horizontal and phase averaging.

8) *Explanation of cold air pooling, starting at line 475. Blocking can trap (potentially) cold air at low levels, but it cannot generate cooling. This must be through some diabatic process. It is not clear what the surface heat fluxes are (see comment 1 above), but it seems unlikely that that is the*
365 *cause of the cooling since it is not seen in the OL simulations. More likely is that the cooling is a result of evaporation / sublimation – possibly of precipitation since there is much less cooling in the OL simulation which contains less precipitations. Some further analysis is needed to properly determine the cause of this cooling.*

Reply: The terrain blocking itself cannot generate cooling; instead, it primarily influences the
370 transport and accumulation of near-surface cold air. Therefore, we have revised our description to distinguish the source and maintenance mechanisms of the cold pool. Additional analysis of hydrometeor and precipitation distributions suggests that the cold pool is mainly generated by precipitation-related diabatic cooling.

In the lake-mountain experiments, enhanced moisture transported from the lake increases cloud
375 and hydrometeor development over the mountain region. As shown in Fig. 7a-c, the LM experiments, particularly LM_3000, exhibit substantially enhanced hydrometeor concentrations over and

upstream of the mountain compared with the OL experiment (Fig. 7d). Correspondingly, stronger precipitation occurs over the mountain region in LM_3000, whereas precipitation is much weaker in OL (Fig. 6a-e). These results indicate that the enhanced lake moisture supply and terrain lifting promote precipitation formation, providing favorable conditions for evaporative cooling and ice-phase sublimation/melting cooling.

The resulting diabatic cooling produces negative near-surface temperature perturbations and contributes to the formation of the cold pool, as shown by the low-level cooling region in Fig. 10b. However, the terrain does not act as the cooling source. Instead, the mountain-induced blocking reduces the horizontal ventilation of the cooled air, allowing the cold air to accumulate and persist near the windward slope. This interpretation is also supported by the weaker cold pool in the OL simulation, where precipitation and hydrometeor development over the mountain are substantially reduced (Fig. 6d and Fig. 7d). Thus, our results suggest that precipitation-related diabatic cooling primarily generates the cold pool, whereas terrain blocking favors its accumulation and persistence.

9) *You talk about how the moistening affect N_m , but not how the changes in potential temperature affect the stability. Maybe this is less important since the changes (probably) happen after the convection and precipitation has occurred, but I can't be sure from the plots in the manuscript.*

Reply: We agree that the original discussion placed too much emphasis on the moisture contribution to N_m and did not sufficiently explain the role of thermal stratification. In addition to the moisture contribution, N_m is determined by both the thermal stratification term and the vertical distribution of water substances. Specifically, the vertical gradient of virtual potential temperature ($\frac{dT}{dz}$) controls the static stability of the atmosphere. Enhanced surface heating increases low-level potential temperature and can reduce the near-surface vertical θ gradient, thereby weakening static stability during the convective development stage. Conversely, stronger stratification increases N_m and suppresses vertical motion.

$$N_m = \sqrt{\frac{g}{T} \left(\frac{dT}{dz} + \Gamma_m \right) \left(1 + \frac{Lq_s}{RT} \right) - \frac{g}{1 + q_w} \frac{dq_w}{dz}}$$

In our simulations, all experiments use the same initial atmospheric thermodynamic profile and background conditions. Therefore, the differences in potential temperature among experiments

mainly arise from the different surface forcings associated with lake presence and terrain configuration. These thermodynamic differences are relatively limited compared with the changes in moisture distribution caused by evaporation from the lake and precipitation. The warmer land surface produces positive sensible heat fluxes and contributes to low-level destabilization during the convective development stage. Meanwhile, the evaporation of precipitation and mixed-phase processes can further modify the thermal structure after convection initiation. Therefore, the simulated N_m variations reflect the combined effects of thermal stratification, moisture availability, and the vertical distribution of total water, with the moisture-related contribution playing an important role in distinguishing the different lake-mountain configurations.

10) *Figure 11 shows a vertical cross section of moist Froude number. The Froude number is useful defined as a bulk measure across some layer (i.e. over the height of the mountain), as in equation 8. How do you define a Froude number at a particular height? And why is that useful? If you want a local measure of the profile stability then something like a Richardson number would be more usual.*

Reply: (1) The Fig. 11 is calculated locally as:

$$Fr_{m,loc}(z, x) = \frac{u(x, z)}{N_m(x, z)H_0}$$

where $u(x, z)$ and $N_m(x, z)$ retain their spatial and vertical variations, while H_0 is the prescribed mountain height. Because H_0 is constant, the vertical and horizontal variations of $Fr_{m,loc}$ mainly reflect changes in flow speed and moist stability. This local diagnostic allows us to identify regions where the background flow and moist stability are favorable or unfavorable for moisture transport and convective development, and to compare these features with the thermodynamic and hydrometeor structures.

Previous studies have demonstrated that the interaction between moist stability and terrain-induced flow plays an important role in controlling orographic convection and precipitation (Durran and Klemp, 1982; Jiang, 2003; Kirshbaum and Durran, 2004). In these studies, spatial variations of environmental flow and stability are commonly examined to interpret the dynamical regime over complex terrain. Following this concept, we calculate a local moist Froude number in the x-z band, where the wind speed and moist Brunt-Väisälä frequency retain their spatial variations.

(2) We agree that the Richardson number is widely used as a local measure of the balance

between stratification and vertical wind shear. However, diagnosing shear instability is not the
435 primary objective of the present analysis. Instead, our focus is on how moist atmospheric stability
modulates terrain-induced flow and the associated development of clouds and precipitation within
the lake-mountain system. The moist Brunt-Väisälä frequency is particularly relevant for this
purpose because it directly characterizes the buoyancy response of saturated air. Moreover, in our
formulation, it accounts for the effects of mixed-phase processes, which are particularly important
440 in the cold, high-altitude environment of the TP. Therefore, the moist Froude number provides a
more physically relevant diagnostic for the specific dynamical processes examined in this study than
a Richardson-number-based measure of shear instability.

Minor comments

445 1) *Line 62. “can profound influences” -> “can have profound influences”*

Reply: Thank you for pointing this out. We have corrected “can profound influences” to “can
have profound influences” in the revised manuscript.

2) *Fig 1. The blue line floating about the ground to mark the lake is a bit confusing. I would
450 suggest positioning this at the surface. Just ensure you make it thick enough that it stands out from
the grey of the land surface.*

Reply: In the revised Fig. 1, the blue line indicating the lake has been repositioned at the
surface and made thicker to improve its visibility. (Line 149)

455 3) *Figure 2 caption. “The different sizes of the lake are marked.” This seems a mistake. As far as
I can see only one size of lake is used.*

Reply: The statement “The different sizes of the lake are marked” was inaccurate, as only one
lake size is used in the present experiments. We have corrected the caption of Fig. 2 to avoid this
confusion. (Line 155)

460 4) *Figure 2. Why is the red dashed box bigger than the domain? Results are presumably only
reported within the domain. Also mark on the distance upstream of the lake where the box starts
(assuming that not all the domain is used).*

Reply: The red dashed box in the original Fig. 2 was intended only to schematically indicate the analysis region. However, its extent was not drawn accurately, which could have given the misleading impression that the analysis region extended beyond the model domain. In the revised Fig. 2, we have redrawn the box so that it lies entirely within the model domain. We have also indicated the upstream distance from the lake to the starting location of the analysis region to clarify the portion of the domain used for the reported diagnostics.

5) *Line 172. “Where” -> “where” (this is not the start of a sentence)*

Reply: *Corrected as suggested.*

6) *Line 201. Is this horizontal average in the x as well as the y direction? If so, how do you deal with terrain?*

Reply: The wording “horizontal average” in the original manuscript was misleading. The decomposition used here is not an average over both the x and y directions. Instead, each variable is decomposed into a base component and a turbulent component, both of which retain the full four-dimensional model structure variable (time, level, x, y). Therefore, no horizontal averaging across terrain is involved in the definition of the decomposition, and no special treatment of terrain-following or below-ground grid points is required for an x-y averaged field. We have revised the text to clarify this distinction. (Line 210-216)

7) *Line 201. I think you have θ' and θ the wrong way round here ($\langle\theta\rangle$ is the average of θ and θ' is the perturbation about this average).*

Reply: The original wording incorrectly described the relationship between the mean and perturbation quantities. In the revised manuscript, we revised the explanation of Eq. (2) by defining the decomposition as $\phi(t, z, x, y) = \phi_{base}(t, z, x, y) + \phi_{turb}(t, z, x, y)$, where $\phi_{base}(t, z, x, y)$ is the base component and $\phi_{turb}(t, z, x, y)$ is the turbulent fluctuation relative to this base component.

8) *Line 210. “Where” -> “where” (this is not the start of a sentence)*

Reply: *Corrected as suggested.*

9) Line 225. “Where” -> “where” (this is not the start of a sentence)

495 **Reply:** Corrected as suggested.

10) Line 225. Here I assume u is averaged over the layer $0-H_0$ (and the same for N)?

Reply: u and N_m are not vertically averaged over the H_0 layer. Both variables retain their vertical and x-direction dependence, with dimensions of (z, x) . The moist Froude number is therefore
500 calculated at each vertical level and x-location using the corresponding values of $u(z, x)$ and $N_m(z, x)$, together with the prescribed mountain height H_0 .

11) Line 230. “Where” -> “where” (this is not the start of a sentence)

Reply: Corrected as suggested.

505

12) Line 320. “precipitation appears as a narrow in the leeward, terrain-locked band with limited downstream growth”. This phrase is quite hard to understand. How about “precipitation appears as a narrow band locked to the terrain over the lee slope with limited downstream growth”

Reply: We agree that the original phrase was unclear, and we have modified the sentence in
510 the revised manuscript. (Line 298-302)

13) Figure 5. Missing label on y-axis. I assume this is distance in the y direction?

Reply: We have added the missing y-axis label in the revised Fig. 5. The y-axis now indicates the distance in the y-direction. (Line 310)

515

14) Figure 5 caption. “Time mean precipitation rate of 13h”. What does this mean? Do you mean the time mean precipitation rate between 7 and 20 hours?

Reply: The phrase “time-mean precipitation rate of 13-h” refers to the precipitation rate averaged over the 13-h period from 7 to 20 h. We have revised the caption to make this time interval
520 explicit.

15) Figure 5 caption. The caption talks about difference plots (c), (e), (g) and (i) but these are not shown in the figure. Please update the caption to correctly describe the plots.

Reply: We have revised the caption of Fig. 5 so that it correctly describes only the panels
525 shown in the figure. (Line 311-313)

16) Line 335. *“To diagnose the convective supply, instability” -> “To diagnose the convective supply and instability”*

Reply: Corrected as suggested.
530

17) Line 357. *“as mountain height increases, CAPE over the lake region increases”. I think this should be “CAPE over the lake decreases” from looking at figure 6? I don’t think the trends in CAPE and CIN are really clear. It depends a bit where over the lake you are looking. You might want to explain this logic more thoroughly.*

535 **Reply:** After reexamining Figs. 6b, 6d, and 6f, we agree that the original statement that “CAPE over the lake region increases with increasing mountain height” was incorrect. This was a misinterpretation of the CAPE distribution, and we have revised the corresponding description in the manuscript accordingly. (Line 337-339)

540 18) Line 358. *“exhibits the opposite tendency” is ambiguous as you are talking about two different tendencies in the previous line. I would be explicit and say “whereas precipitation over the lake increases.”*

Reply: We agree that the phrase “exhibits the opposite tendency” could be unclear. We now state explicitly that, as mountain height increases, precipitation becomes more concentrated over the
545 lake and windward slope, while its downstream extension is reduced.

19) Line 395 *“in the absence of lake” -> “in the absence of the lake”*

Reply: Corrected as suggested.

550 20) Line 396 *“deep convection occurs when moisture supports with suitable orographic lifting” does not make sense. Do you mean something like “deep convection occurs when moisture coincides with suitable orographic lifting”*

Reply: We have revised the sentence to clarify that deep convection occurs when sufficient

moisture coincides with suitable orographic lifting.

555

21) Line 408. *“Across the involving lake configurations” -> “Across the configurations with a lake present”*

Reply: Corrected as suggested.

560

22) Figure 8. *I assume the y axis here is height above ground level? Why not plot over the terrain as you do in other figures? At least you need to be explicit what you are plotting.*

Reply: We have revised the figure caption and axis label to explicitly state that the vertical coordinate in Fig. 8 is height above ground level. Figure 8 is different from the other x - z cross-section figures (rather than the cross section along x -direction) because it shows time-height profiles of hydrometeor mixing ratios averaged over three subregions: the lake, mountain, and downstream areas.

565

23) Line 444. *“results in the precipitation formation is inhabited” -> “results in the inhibition of precipitation formation” or “results in the suppression of precipitation formation”?*

570

Reply: Corrected as suggested.

24) Line 450 *“using an open water configuration comparable to OM”. I think you mean OL not OM? There is no lake in OM.*

Reply: Corrected as suggested.

575

25) Line 479. *“hydrometeor of condensate growth and transport” does not make sense. Maybe just “hydrometeor growth and transport”?*

Reply: Corrected as suggested. We have revised the sentence for clarity.

580

26) Line 481. *“enhanced hydrometeor” -> “enhanced hydrometeor mixing ratio”*

Reply: Corrected as suggested.

27) Figure 10. *Include a reference wind arrow on the plot to show wind speed?*

Reply: We have added a reference wind arrow to Fig. 10 and clarified this information in the revised caption.

28) *Line 502. “Nm. and” -> “Nm, and”*

Reply: Corrected as suggested.

29) *Figure 11 caption. “most Froude number” -> “moist Froude number”*

Reply: Corrected as suggested.

30) *Figure 11 caption. “As in (a)” -> “as in (a)” - it is not a new sentence.*

Reply: Corrected as suggested.

31) *Line 536. “most trajectories” -> “Most trajectories” - start of a new sentence.*

Reply: Corrected as suggested.

32) *Line 538. “lower than in the involving lake experiments” -> “lower than in the experiments involving the lake”*

Reply: Corrected as suggested.

33) *Figure 12. Is the colour here water vapor mixing ratio? If so, why is it not conserved along a trajectory? Is this due to condensation and cloud formation?*

Reply: The color in Fig. 12 represents the local water vapor mixing ratio. We used an offline trajectory calculation designed for CM1 output, which allows trajectories to be calculated over complex terrain (Gowan., 2019). The method uses a second-order semi-implicit discretization in space and time, following the trajectory integration scheme described by Miltenberger et al. (2013). The parcel positions are calculated from the resolved u, v, and w fields using a predictor-corrector procedure. CM1 provides the Eulerian wind fields, while the trajectory calculation provides a Lagrangian description of air-parcel motion. The trajectory calculation only provides the pathways of air motion based on the model wind field and does not track the evolution of water vapor contained within an individual air parcel. Therefore, the water vapor mixing ratio shown along the

trajectories is not expected to be conserved. Its variation reflects the spatial and temporal variability
615 of the Eulerian water vapor field encountered by the moving trajectories, which can be influenced
by moisture transport, surface evaporation, condensation, and mixing processes.

The purpose of Fig. 12 is to diagnose the transport pathways and vertical lifting of near-surface
moist air from the lake region toward the mountain and downstream areas, rather than to construct
a closed moisture budget. To avoid confusion, we have revised the caption and related text to clarify
620 that the trajectories are colored by local water vapor mixing ratio rather than representing water
vapor tracer particles.

34) *Figure 12 caption. “in experiments with lake presence” is not true – you also show results for
OM with no lake. Just remove this phrase?*

625 **Reply:** Removed as suggested.

35) *Line 559-561. This sentence is repeated. Just delete the second occurrence.*

Reply: Deleted as suggested.

630 **Reference:**

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660

Review of Lake-Mountain synergy in convective clouds and precipitation over the Tibetan

Plateau: a large-eddy simulation study

egusphere-2026-869

665 *General Comments*

Motivated by a better understanding of convection and precipitation associated with lake- mountain environments in the Tibetan Plateau, this manuscript presents results from CMI idealized large-eddy simulations of convection. The simulations vary the height of terrain and the presence of a lake
670 *located upstream of the terrain. There are a few key findings from this work, including that a lake provides the moisture source required to initiate convection and that the height of terrain downstream of the lake impacts the intensity and distribution of precipitation. This manuscript fits within the scope of Atmospheric Chemistry and Physics and would be suitable for publication after some modifications are made.*

675 **Reply:** We sincerely thank the reviewer for the encouraging and constructive assessment of our manuscript. We are pleased that the reviewer recognizes the relevance of this idealized LES study to lake-mountain convection and precipitation over the TP. We have carefully addressed all comments by clarifying the model setup and experimental design, improving figure descriptions, strengthening the physical interpretation of the results, and discussing the limitations of the idealized
680 simulations more explicitly. Our detailed point-by-point responses are provided below.

Major Comments

1. Characterization of the Tibetan Plateau geomorphology

685 *Much of the introduction focuses on important processes such as convection, cloud microphysics, lake breezes, and surface heterogeneity, which provides helpful background for the manuscript. However, the introduction lacks a discussion of the characteristics of the Tibetan Plateau itself. The authors should share some information about typical terrain elevations, typical lake sizes, the number of lakes, the fraction of the year during which the lake is frozen, general meteorological*
690 *characteristics, etc. The map in Fig. 1a can aid with this discussion.*

Reply: We have expanded the Introduction to describe the main characteristics of the TP and its lakes, including terrain elevation, lake size and distribution, seasonal frozen conditions, and general meteorological features. (Line 86-91)

695 “More than 1200 lakes larger than 1 km² are distributed across the TP, providing important local moisture sources (Zhang et al., 2020). These lakes experience seasonal ice cover due to the cold high-altitude climate, while strong land-lake thermal contrasts during the warm season can modify circulations and moisture transport (Kropáček et al., 2013). Given the relatively dry and low-density atmosphere over the TP, lake-induced moisture supply, together with the surrounding topography, may play an important role in regulating cloud development and precipitation (Ma et al., 2010; Wang et al., 2020a, b)”.

700

2. *Hydrometeor mass growth and loss (Figure 9)*

The authors should reexamine their calculation of Q_{growth} and Q_{loss} in Fig. 9. In the figure, it appears that these variables have the same magnitude, and Q_{loss} is simply $Q_{growth} \times -1$, which would make one of the subfigures redundant. Thinking about this physically, it is implausible for Q_{growth} and Q_{loss} to peak at the exact same time (as referenced in L440-442) when calculated over the same domain. It is most likely that the authors have either calculated Q_{growth} or Q_{loss} incorrectly. Following Eq. (6), Eq. (7), and Gowan et al. (2021), Q_{growth} and Q_{loss} should be calculated by integrating all instances in which q_{ten} is positive and negative, respectively. In the current manuscript, it appears that the authors may have calculated q_{tenpos} and simply multiplied that by -1 to find q_{tenneg} .

705

710

Reply: The Q_{loss} is not obtained by multiplying Q_{growth} by -1. We have carefully reexamined the calculation of Q_{growth} and Q_{loss} . At each model output interval and grid, the total hydrometeor tendency is first calculated as $\overline{q_{ten}} = \frac{\Delta q}{\Delta t}$. All positive values of q_{ten} are then independently extracted as $q_{ten, pos}$, while all negative values are extracted as $q_{ten, neg}$. These two components are subsequently averaged over 7-20 h and over the central 15 km in the y-direction, and then vertically integrated. We have revised Eqs. 5-7 and the corresponding text to clarify that the positive and negative values of Q_{ten} are identified and processed independently before averaging and vertical integration.

715

The similar spatial locations of enhanced Q_{growth} and Q_{loss} arise because hydrometeor

production and depletion can both be concentrated within the same region. However, their magnitudes and spatial distributions are not identical. To demonstrate this more clearly, we have added the net hydrometeor tendency ($Q_{growth}+Q_{loss}$) to Fig. R2.

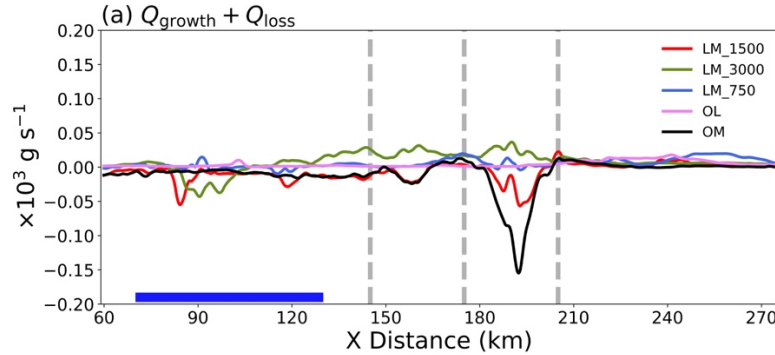


Figure R2. Zonal distributions of the 7-20 h time-mean, 15-km y-averaged (over the central domain) of (a) net hydrometeor mass tendency (10^2 kg s^{-1}) for the five experiments. The thick blue line indicates the lake area ($x=70$ - 130 km), and the gray dashed lines mark the windward foothill ($x=145 \text{ km}$), mountain summit ($x=175 \text{ km}$), and leeward foothill ($x=205 \text{ km}$).

3. Flow in Figure 10b.

In Fig. 10b, it appears that the zonal wind goes from the right side of the domain to the left. Is that correct? It is possible that the authors' use of the perturbation wind contributes to this. If so, what is the justification for the use of the perturbation wind? It seems to mislead a reader who would examine the figure without much other context.

Reply: The vectors shown in this figure represent the perturbation wind rather than the total wind field. Therefore, the apparent reversal in flow direction does not indicate a reversal of the background environmental wind, but instead reflects the circulation anomaly induced by the lake-mountain interaction. Specifically, enhanced moisture supplied by the lake promotes cloud and precipitation development over the mountain region. Precipitation-related diabatic cooling, including cooling associated with the evaporation of liquid hydrometeors and the sublimation or melting of ice-phase particles, contributes to negative near-surface temperature perturbations and the formation of a cold pool. Once established, the cold pool interacts with the terrain. The mountain barrier restricts the horizontal ventilation of the cooled air, favoring its accumulation near the windward slope. Stronger terrain blocking in the higher-mountain experiments further enhances this accumulation and is therefore associated with a stronger perturbation circulation near the mountain.

745 We acknowledge that displaying the perturbation wind alone may lead to confusion if it is interpreted as the total flow. We have therefore revised the description of Fig. 10b to explicitly state that the vectors represent the perturbation circulation associated with the lake-mountain interaction.

4. Moist Froude number (section 2.4.3 and Figure 11)

750 The authors should think more carefully about their use of the moist Froude number. First, in section 2.4.3, the authors provide a thorough derivation of the N_m and justify some modification of the standard Durran and Klemp (1983) equation due to the presence of mixed-phase clouds over the Tibetan Plateau. Could the authors consider placing this derivation in an appendix to not disrupt the flow of the manuscript? Figure 11 shows cross sections of time- and y -averaged FR_m . Typically, 755 though, the Froude number is calculated at a site upstream of the mountain range and uses a layer depth for the calculation of N_m and U . It is unclear how showing FR_m at 1 km and 4 km, for instance, gives insights into blocked or flow over regimes. Additionally, there is no utility to showing FR_m at a site on or downstream of the mountain range, which the current figure does. The authors should consider calculating N_m and U over a layer depth at a site upstream of the mountain and 760 presenting values in a table for each sensitivity study, rather than using cross sections to display FR_m .

Reply: The detailed derivation of the modified moist Brunt-Väisälä frequency (N_m) has been moved to the Supplement to improve the readability and flow of the manuscript. We have also revised Fig. 11 to better clarify the purpose and interpretation of the moist Froude number diagnostic.

765 We agree that the conventional moist Froude number is generally calculated using representative upstream values of wind speed and moist stability over a characteristic layer depth, and is commonly used to characterize the overall blocked or flow-over region. In this study, however, the purpose of the Fr_m analysis is different. We do not use the cross-sectional Fr_m values at individual levels to classify the overall flow regime. Instead, we use a local modified moist Froude number, 770 $Fr_{m,loc}(x, z)$, as a diagnostic quantity to examine how the spatially varying flow structure and moist stability interact within the lake-mountain system.

The quantity shown in Fig. 11 is calculated locally as

$$Fr_{m,loc}(x, z) = \frac{u(x, z)}{N_m(x, z)H_0}$$

where $u(x, z)$ and $N_m(x, z)$ retain their spatial and vertical variations, while H_0 is the prescribed mountain height. Therefore, the variations of $Fr_{m,loc}(x, z)$ along the cross-section reflect changes in background flow strength and moist stability associated with lake-induced moisture modification, terrain lifting, and mixed-phase cloud processes.

We retain the x - z distribution of $Fr_{m,loc}(x, z)$ because it provides additional information that cannot be obtained from a single upstream bulk value. In particular, the cross-sectional distribution allows us to identify where the moist dynamical environment is modified as airflow approaches and interacts with the mountain, and it can be directly compared with the circulation, thermodynamic, and hydrometeor structures shown in the preceding figures. This is especially important in our study because the lake modifies the thermodynamic environment before the flow reaches the mountain, and the resulting changes in moist stability are spatially heterogeneous. Spatially varying Froude number fields and vertical distributions have also been used to diagnose terrain-related flow and convection in previous studies (Burk and Thompson, 2004; Langhans et al., 2011; Li et al., 2025).

5. *Interpretation of trajectories*

There are dramatic differences in the trajectories in the different sensitivity studies, but the current discussion lacks a thorough comparison between them. The authors should discuss the lack of air parcel movement in the LM_750, OL, and OM trajectories and explain the lack of water vapor depletion in those, despite moderate precipitation amounts (especially in OM; Fig. S2).

Reply: We agree that the differences in trajectory behaviors among the sensitivity experiments require further clarification.

The trajectories released at $x = 80$ km represent air parcels originating from the lake region. They are used to diagnose the lake-induced circulation and the transport pathways of lake-modified air toward the mountain. As shown in Fig. 12a-j, LM_3000 exhibits pronounced horizontal transport and vertical ascent, indicating strong lake-mountain circulation and efficient transport of lake-modified moist air toward the mountain. In contrast, the weak displacement in LM_750, OL, and OM reflects the weaker circulation response. For LM_750, the reduced mountain height weakens the terrain-induced pressure perturbation and associated lake-mountain circulation. For OL and OM, the absence of lake forcing eliminates the additional thermal contrast between the lake and surrounding land, resulting in weaker low-level circulation and limited horizontal moisture transport.

The trajectories released at $x = 120$ km are designed to examine the evolution of air parcels approaching the mountain region (Fig. S4), where terrain-induced lifting becomes dominant. In LM_3000, these trajectories experience strong ascent as they approach the mountain, consistent with enhanced orographic lifting and precipitation development. In contrast, although moderate precipitation occurs in OM, the trajectories exhibit limited displacement and weak depletion of water vapor mixing ratio. This is because precipitation in OM is mainly produced by local terrain-induced lifting of the available background moisture rather than sustained moisture transport from the lake.

We further clarify that the trajectory colors in Fig. 12 and Fig. S4 represent the local water vapor mixing ratio interpolated from the Eulerian wind fields along the calculated trajectories. The trajectory calculation provides airflow pathways based on the simulated wind field, but it does not track the evolution of moisture within an individual air parcel. Therefore, the water vapor mixing ratio along the trajectories is not expected to be conserved. Its variation reflects the spatiotemporal changes of the Eulerian water vapor field encountered by the moving trajectories, which are affected by moisture transport, surface evaporation, condensation, and turbulent mixing processes. The purpose is to diagnose the transport pathways and vertical lifting of near-surface moist air from the lake region toward the mountain and downstream regions, rather than to establish a closed moisture budget for individual air parcels.

6. Supplemental material

1) While Fig. S1 could reasonably be placed in a supplement, the other supplemental figures should be included in the main text, as they are referred to in the text and help tell the manuscript's story. Fig. S2, which shows the precipitation distribution, is quite important and would be better placed in the main text. Additionally, that figure's caption has text "(c) Difference in time-mean precipitation rate (mm h^{-1}) between LM_3000 and LM_1500. (e), (g), (i) As in (c), but showing the differences for LML, OL, and OM relative to ML", which does not describe anything in the figure and should be removed. Additionally, for Fig. S2, the authors should discuss the precipitation patterns and why they appear. For instance, why are there local maxima in precipitation in the lee of the mountain peak in LM_1500 and OM? And on Fig. S2, the authors should label the y-axis and

include an outline of the bell-shaped mountain, rather than the dashed line showing where its
835 summit is.

Reply: (1) We have retained Fig. S2 in the Supplement because it shows the precipitation
distribution accumulated over the entire 0-20 h simulation period, whereas the main text already
presents the precipitation distribution during the primary analysis period of 7-20 h (Fig. 5). The 7-
20 h period was selected because it represents the established stage of lake-mountain interaction,
840 when lake-induced circulation and moisture transport have developed sufficiently to interact with
terrain-induced lifting. Therefore, the precipitation distribution and the associated physical
mechanisms are primarily discussed based on Fig. 5 in the main text. Including Fig. S2 in the main
text in addition to Fig. 5 would provide largely redundant information.

(2) We have revised Fig. S2 and its caption accordingly. The incorrect references to nonexistent
845 difference panels have been removed, and the y-axis label has been added.

(3) The bell-shaped mountain geometry is explicitly illustrated in the x - z cross sections
throughout the manuscript. Therefore, in the x - y precipitation distribution, we indicate the location
of the mountain rather than redundantly displaying the terrain profile.

(4) During the initial 0-7 h period, precipitation development is primarily influenced by terrain
850 forcing, while the lake-induced circulation and associated moisture transport develop more
gradually. Consequently, the precipitation accumulated over the full 0-20 h period in Fig. S2 retains
a pronounced contribution from the early terrain-driven precipitation. The local precipitation
maxima on the leeward side of the mountain crest in LM_1500 and OM are mainly associated with
terrain-induced lifting and the subsequent downstream transport of hydrometeors during this early
855 stage. Moisture is lifted as it approaches and passes over the mountain, promoting cloud formation
and hydrometeor growth. The resulting hydrometeors are subsequently advected downstream by the
background flow, contributing to enhanced precipitation on the leeward side of the mountain.

2) *In Fig. S3, does the NLM simulation really produce no precipitation at all? If so, this could be an
860 interesting finding suggesting that this environment requires a lake and/or mountain to generate
precipitation. It appears that the caption for Fig. S3 does not line up with the subfigures at all. The
authors should reread the caption and make adjustments to align with the subfigure letters.*

Reply: Yes, the NLM simulation does not produce precipitation. This result reflects the limited

moisture availability in the prescribed TP-like background environment. In the absence of lake-
induced moisture and thermal forcing, as well as terrain-induced lifting, the background atmosphere
alone is insufficient to initiate and sustain precipitating convection. The NLM experiment therefore
provides a useful baseline for isolating the individual and combined effects of the lake and mountain
on cloud and precipitation development under TP-like conditions. We have added this interpretation
to the revised manuscript. We have also carefully revised the caption of Fig. S3 to ensure that the
descriptions correspond correctly to the subfigure labels.

3) In Fig. S4, the caption refers to a left column, but the figure only includes a right column.

Reply: We have revised the caption to remove the reference to the left column and to describe
only the panels shown in the figure.

7. **Conclusions**

*From the literature review, it appears that there has not been much research on the lake- mountain
meteorology of the Tibetan Plateau, so the authors are making a useful, novel contribution to
atmospheric science by studying it. The conclusion summarizes the findings well, but the authors
should highlight how this work is new and how it could contribute to our understanding in other
regions.*

Reply: We have revised the conclusion section to better highlight the novelty and broader
implications of this study. Specifically, we now emphasize that this study systematically separates
the individual and combined effects of lake moisture supply and terrain forcing through controlled
idealized simulations, providing a process-based understanding of how lake-mountain interactions
regulate convective initiation, cloud development, and precipitation over the TP.

The TP provides a distinctive environment for investigating these processes because
convection develops in a low-density atmospheric environment with limited moisture availability
and is strongly modulated by the interplay among thermodynamic instability, moisture supply, and
complex terrain. The mechanisms identified in this study may also provide useful insights into other
high-altitude lake-mountain systems, where local water bodies can modify the thermodynamic and
moisture environment and thereby influence convective precipitation.

8. Grammar

895

There are several grammatical errors throughout the manuscript which impact its readability. The authors should carefully examine the manuscript for grammatical errors. Some examples:

1) L63: "... can profound influences..." should say "can have profound influences"

900

2) L275: "b" should say "by"

3) L320: "precipitation appears as a narrow in the leeward". A noun is required after "narrow".

4) L390: "shallower and hydrometeor ... is reduced" should say "hydrometeor mixing ratio is reduced".

905

5) L479-480: "... hydrometeor of condensate growth and transport ..." should say "condensate growth and hydrometeor transport"

6) L502-503: "the moisture supply leads to lower Nm. And further strengthen the FRm." These two sentences should be combined.

7) L558-559: This sentence is repeated.

8) Figure 11 caption: "most" should say "moist".

910

Reply: Thank you for pointing these out. All grammatical errors have been corrected as suggested.

Minor Comments

915

1) L155 and Table 1: In Table 1 the authors present 6 experiments that they conducted. However, the results from one such experiment (NLM) are never presented in the manuscript (aside from in the supplement). The authors should either modify the manuscript to present results from NLM or remove the mention of that experiment from Table 1. Additionally, in L173, the authors first mention that the control experiment is LM-1500. It would be helpful if this were highlighted in Table 1 as well.

920

Reply: We agree that listing NLM in Table 1 could be confusing because the corresponding results are not discussed in the main text and are only provided in the Supplement. To avoid this inconsistency, we have revised Table 1 to include only the experiments analyzed in the manuscript. In addition, we have highlighted LM_1500 as the control experiment in the revised Table 1. (Line

2) L189: How does this RKW-type wind profile compare with the Naqu Station radiosonde observations? Some justification of the RKW-type wind profile should be provided. Additionally, the authors should include the wind barbs for the profile in Fig. 3.

Reply: We have added a comparison between the prescribed wind profile and the radiosonde-
930 observed wind profile at Naqu Station (Fig. R3), and have also added wind barbs to Fig. 3 to illustrate the vertical wind structure more clearly.

The prescribed wind profile is not intended to reproduce a specific observed event, but rather to represent the characteristic background atmospheric structure over the TP. Radiosonde observations at Naqu Station, which is broadly representative of the central TP environment,
935 generally show relatively weak winds in the lower troposphere and increasing wind speeds with height. The idealized profile was therefore designed to retain this characteristic vertical structure, with weak low-level flow and stronger winds aloft, while preserving a simplified background environment suitable for isolating lake-mountain interactions.

The weak low-level flow is important because excessively strong background winds could
940 suppress thermally driven lake-land circulations and weaken the near-surface thermodynamic and moisture modifications induced by the lake. Meanwhile, the stronger winds aloft are consistent with the typical vertical variation of the TP background flow and provide a pathway for downstream moisture transport toward the mountain region, where terrain-induced lifting can further promote cloud development and precipitation formation.

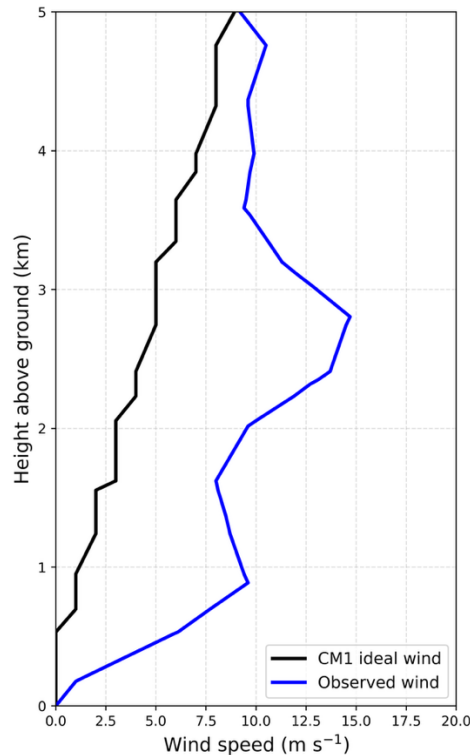


Figure R3. Vertical profiles of the idealized CM1 initial wind shear and observed wind speed. The black line represents the idealized zonal wind profile used in the CM1 simulation, which increases linearly from 0 to 15 m s⁻¹ within the lowest 8 km. The blue line denotes the observed wind speed profile from the 55299 sounding, with height referenced to the surface.

3) L270-275: This section is used to derive the moist Froude number and Nm . The equations, however, do not clearly flow in the text. To improve readability, the authors should modify this section so that Eq. 16 and 17 are part of sentences and clearly flow in the text.

Reply: We have revised explanations of Eqs. 16-17 so that the mixed-phase pseudo-adiabatic lapse rate and the corresponding moist Brun-Väisälä frequency are introduced as part of complete sentences. This revision improves readability and clarifies the logical sequence from the effective saturation mixing ratio and mixed-phase latent heat to the modified moist stability and moist Froude number. (Supplement Eqs. 1-11)

4) L293-294: “However, introducing the lake ... onset of convection.” This sentence feels out of place. The authors had just discussed LM_2000 in L292 and then transition to LM_1500, so there is no introduction of the lake.

Reply: The original sentence “introducing the lake” was inappropriate because the discussion was comparing different mountain-height configurations rather than lake/no-lake experiments. We have revised the text to clarify that the delayed convection in LM_1500 relative to LM_3000 is associated with weaker terrain-induced triggering and the increasing importance of lake-driven moisture transport. (Line 271-274)

5) L356-358: *Is this sentence correct? Looking at Figs. 6 (b), (d), and (f), it appears that as the mountain height increases, CAPE over the lake decreases. CIN does decrease, though, but rather than “weakens”, “decreases” would be better language to describe this.*

Reply: After reexamining Figs. 6b, 6d, and 6f, we agree that the original statement that “CAPE over the lake region increases with increasing mountain height” was incorrect. This was a misinterpretation of the CAPE distribution, and we have revised the corresponding description in the manuscript accordingly. (Line 336-338)

6) L384 and L395: *Fig. 7f is mentioned here but there is no Fig. 7f.*

Reply: Corrected as suggested.

7) L421: *Should the figure reference say “Fig. 8e” since the text is referring to the mountain?*

Reply: We have corrected the figure reference in the revised manuscript.

8) L564: *The “reduced condensate production” is being compared to what? Other mountainous regions?*

Reply: We have revised the sentence to remove the unclear comparison and to state explicitly that the reduced condensate production is caused by limited moisture availability in the idealized lake-mountain environment over the TP. (Line 550-553)

9) Figure 4: *What does the grey vertical dashed line represent in Fig. 4? The caption should clarify this.*

Reply: The gray vertical dashed line in Fig. 4 marks 7 h, which denotes the beginning of the lake-mountain synergy regime defined in this study. This timing corresponds to the stage when the

lake-breeze and mountain-induced circulations begin to interact more strongly, while cloud and precipitation processes become well developed and start to influence downstream regions. We have clarified this interpretation in the revised caption of Fig. 4.

10) Figure 5 caption: The caption in Fig. 5 references subfigures (f), (h), (g), and (i), but those subfigures are not included in the figure.

Reply: We have revised the caption so that it describes only the panels shown in the Fig. 5.

11) Figure 8: The font size of the y-axis labels on Fig. 8a should be increased. The first sentence in the caption is incomplete.

Reply: We have increased the font size of the y-axis labels and revised the caption in Fig. 8 to improve readability.

12) Figure 12: At some point in the manuscript, the authors should state how many trajectories are plotted, at what time in the simulation they are released, and for how long they are run.

Reply: We have added the trajectory configuration to the revised manuscript. A total of 6,000 forward trajectories were calculated by releasing air parcels from 40 vertical model levels and 150 locations in the y-direction, with all parcels initialized at $x = 80$ km. The parcels were released at 7 h of the simulation and integrated forward for 13 h, ending at 20 h. All trajectories were calculated using model output that had been uniformly filtered over $20 \times 20 \times 2$ grid points in the x, y, and vertical directions, respectively. This information has been added to the description of Fig. 12.

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