Reply to Review #2

Thank you for your constructive comments, which are very helpful to improve the paper and clarify our points. Our point-by-point reply follows with the original comments quoted in `Courier` font.

Minor comments

`1. 2.2. How are surface fluxes prescribed / computed?`

The model supports different methodologies for specifying the subgrid fluxes at the lower boundary. They can be prescribed, calculated based on prescribed gradients, or prescribed surface properties. For the latter two, similarity functions are chosen to relate the fluxes at the surface to the grid-scale gradients there (Stevens et al., 2010). The similarity functions used by the model are as follows,

$$\Phi_h = \frac{\kappa z}{\theta_*}\frac{\partial\bar{\theta}}{\partial z} = \begin{cases} \Pr(1 + a_h\zeta) & \zeta > 0 \\ \Pr(1 - b_h\zeta)^{-1/2} & \zeta \le 0 \end{cases}$$

$$\Phi_m = \frac{\kappa z}{u_*}\frac{\partial\bar{u}}{\partial z} = \begin{cases} \Pr(1 + a_m\zeta) & \zeta > 0 \\ \Pr(1 - b_m\zeta)^{-1/2} & \zeta \le 0 \end{cases}$$

where $\zeta = \frac{a}{\lambda}, \lambda = \frac{\Theta_0}{gk}(\frac{{u_*}^2}{\theta_*})$ is the Monin-Obukov length scale. The similarity constants are $\Pr = 0.74, \kappa = 0.35, a_h = 7.8, a_m = 4.8, b_h = 12, b_m = 19.3$. In this article, we set specific surface properties to be over the ocean and prescribe surface temperature and specific humidity. We added the related descriptions (lines 138-140).

`2. Fig. 1. Is there any difference, in terms of detection, between fog and advection fog? The caption says fog but the section equates it to advection fog. Only in L219 there is a mention of a combined criterion for advection fog.`

We got advection fog by tracing back each fog observation. Compared to the advection fog frequency, the frequency of all fog is higher, especially over the Sea of Okhotsk (Fig. S9). However, the overall patterns are quite similar between the two. The observational discussions in this article are all related to advection fog, as well as the phenomena of ssH and ssC within advection fog. We revised the caption in Figs. 1 and 2 and clarified our choice of advection fog in lines 176-180.

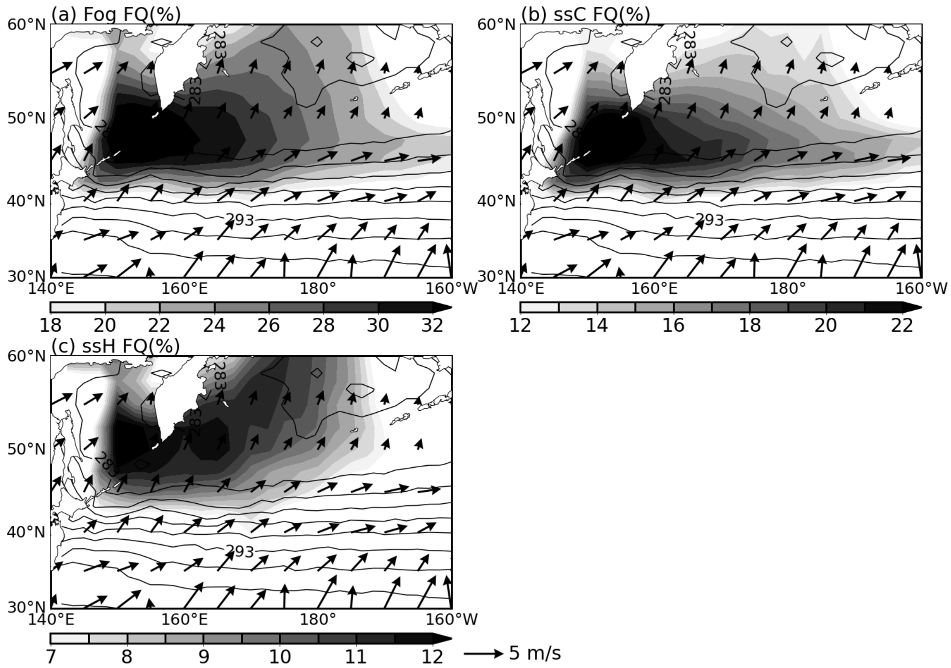

FIG. S9 Climatological SST (contours with 2-K intervals), surface winds (vectors, m s^{-1}), and frequencies (shading, %) of (a) fog, fog with (b) ssC and (c) ssH during June-July-August for 1998-2018. The SST and winds are based on ERA5, and the fog frequencies are obtained from ICOADS.

3. L240 Here it seems like there is enough information to make a timeseries of the observational SAT-SST. Would that be possible to add in order to compare the model results?

Very nice suggestion, Thanks. We added the time series of observational SAT-SST using ICOADS (Fig. 5) and the related descriptions (lines 232-236, 307-309, and 463-464).

4. More details about the LES configuration are needed. It references Yang et al. (2021) but the manuscript should be self contained. How are the initial profiles determined, is there any modification from the ERA5 vertical profiles? Is the initial profile cloudy or clear? Does the referenced paper work with the same case? I'm understanding that SST(t) is prescribed, are winds nudged?

We mentioned thesimulation setups in lines 264-280.

5. L244 Any reason to choose that value of divergence? I assume it can definitely affect the results by modifying the BL top height and LW cooling

The divergence is an averaged divergence along the trajectory in Fig. 4. We chose the realistic synoptic condition instead of the climatological divergence in Yang et al. (2021) to reproduce the advection fog with ssH (lines 267-270).

6. L255 Is this quick growth realistic when compared to observations?

Cloud–Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) passed through the fog area and observed cloud-top heights of about 300 m and 400 m on 0000 LST 02 July and 0100 LST 03 July, respectively (Fig. S10). The simulated grouth of fog thickness is very close to the CALIPSO observations. We mentioned this comparision in lines 290-293. In addition, we found the fog top reach its equilibrium after ~48 hours in our current simulation with higher vertical resolution, comparing 24 hours in our previous simulation.

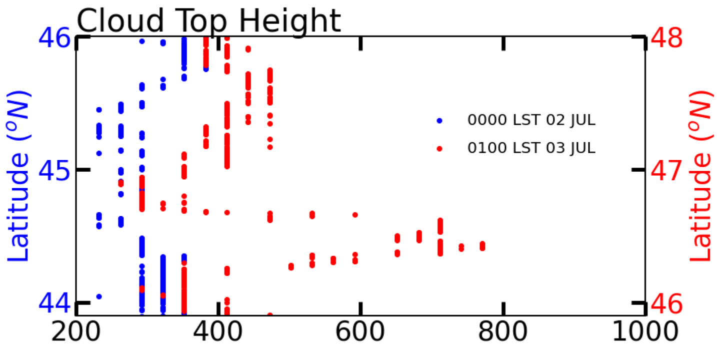

FIG. S10 Cloud-top height observed by CALIPSO data at 0000 LST 02 July (blue dots) and 0100 LST 03 July (red dots).

7. L256 Does the inversion strength grow due to BL cooling or to changes above the BL?

The fog layer cooling strengthens the inversion. The variation in free-atmospheric potential temperature is rather small (Fig. 7a, line 294).

8. L272 The four phases could be shown in the figures: Fig 5,7,10 as different shaded areas, and in Fig 6 as the labels (instead of times)

Revised (Figs. 6, 7, 8, and 11).

9. L278 Would a shorter averaging time window give sharper vertical profiles?

The vertical profiles change slightly between the soundings 2-hour averaged and at specific time (Fig. S11). We used the profiles at specific time in Fig. 7.

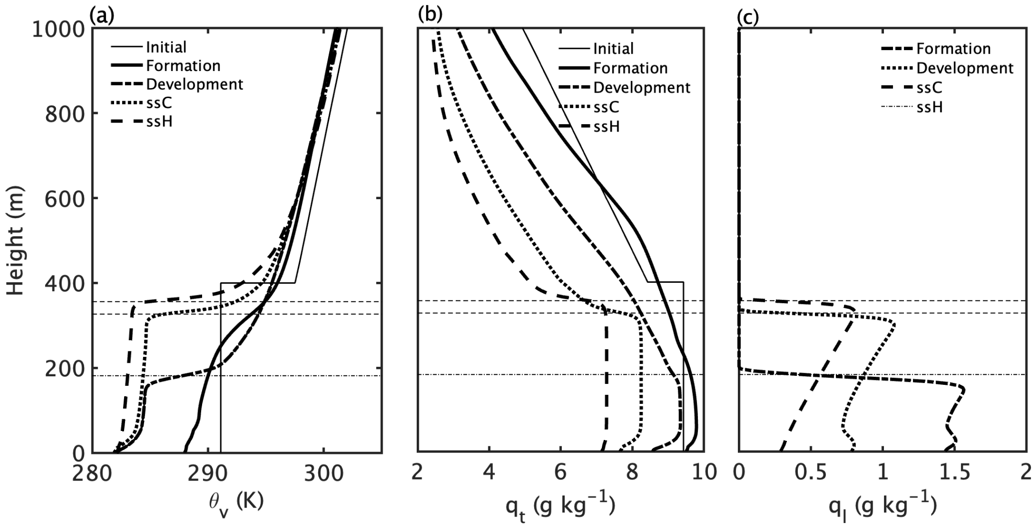

FIG. S11. Horizontal mean soundings at the specific times.

10. L309 Do you mean that LW cooling is directly related to a colder SST?

We revised this description (lines 349-351).

11. L336 Here I got a bit confused, so 'SH' is just the sensible heat flux and 'Ent' is w′ θ′ t(zi)? By integral do you mean across the BL?

Correct. 'SH' represents surface sensible heat flux and 'entrainment' is turbulence heat flux at fog top ($\overline{w'\theta'}_{z_i}$). We quantify the heat budget for the fog layer by integrating heat budget. We clarified this point in lines 379-381.

12. Fig. 10. Why include the diurnal case here? It has not been done for the previous figures

The diurnal case panel in Fig. 10 was moved to current Fig. 14.

13. L371 I don't follow this argument, is it related to LW cooling attenuation for having more water content above?

The TKE budgets have a bit differences in our current simulation with higher vertical resolution. We revised this description (lines 427-430).

14. L377 I'm not familiar with the interpretation of the thermal turbulence interface, what does it add to the discussion?

The thermal turbulence interface helps to separate the fog layer into the zones dominated by LWC and surface cooling. We also added the related descriptions of the method (lines 437-443).

15. 5. I wonder if this section can bring more questions, such as the effect of dynamical changes on the evolution of the fog layer. In the end, for fog lifetime, does it matter if it's modeled with constant solar irradiance? When the sun goes down, how long

does it take the layer to react? Does the stronger solar irradiance accelerate BL processes? How do these results compare to the observations?

Focusing on the simulation with diurnal variation, the maximum fog layer height is similar to the constant solar radiation simulation, as well as the daily averaged sea–air thermal and moist differences (Figs. 6 and 13). We calculated the heat budget for the integral fog layer for the simulation with diurnal solar radiation (Fig. S12). After fog formation, the LWC effect rapidly exceeds surface cooling 4 hours after fog formation and dominates the boundary layer cooling. The LWC at fog top has a clearer diurnal variation which dominates the SAT-SST (Fig. S13). About 3-5 hours before sunset, LWC at fog top reaches its weakest during a day, and then start to strengthen. The enhancement of LWC occurs approximately 3 hours earlier than the decline in air-sea temperature difference, ultimately causing the air temperature falls below the SST in the early hours of 03 July, consistent with the observed time of ssH fog occurrence (Fig. S13 and Fig. 5). We added the related descriptions (lines 466-471).

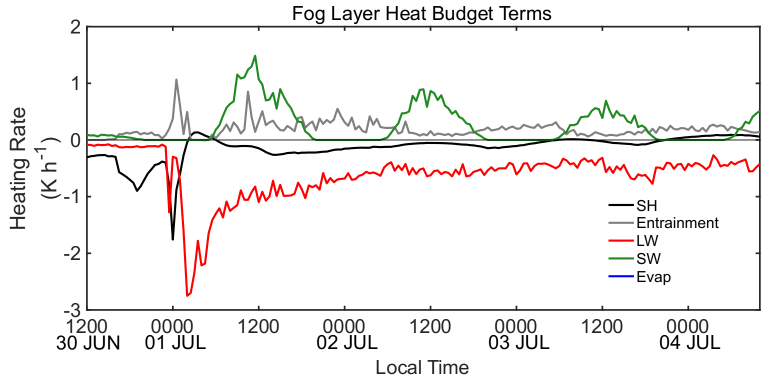

FIG. S12. Time series of horizontal mean heat budget terms (K h^{-1}) of the integral boundary layer for the simulation with diurnal solar radiation.

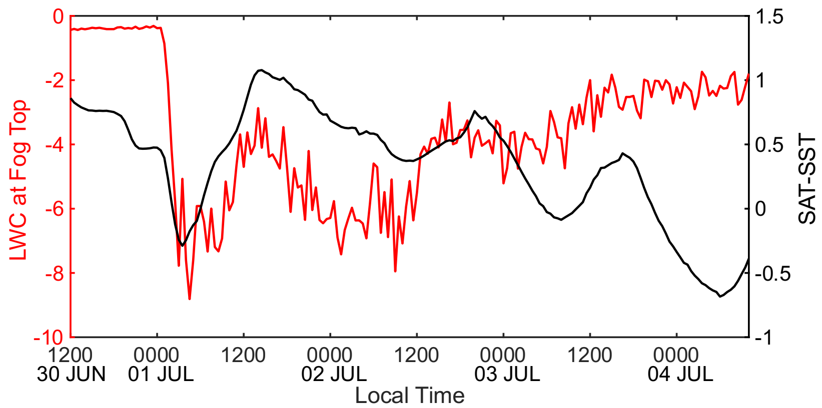

FIG. S13. Time series of horizontal mean LWC at fog top (red line) and SAT-SST (black line) for the simulation with diurnal solar radiation.

The insolation in the constant solar radiation experiment is 518 W m^{-2} at 2000 m (solar elevation angle is 63°), which is the diurnally averaged value from 30 June to 4 July 2013. We conducted a simulation with increased solar irradiance with 66° of solar elevation angle of. Sea fog dissipates 8 hours earlier than that in the standard solar radiation experiment and observations (Figs. S14, 5 and 6). Two hours before sea fog dissipation, there is the ssH fog occurrence, which appeares two hours earlier than in the standard solar irradiance experiment and in observations (Figs. S14, 5 and 6). Nevertheless, there are little changes in the evolution of the fog top height and the thermal/turbulent structure of the boundary layer during sea fog. We added descriptions in lines 477-482.

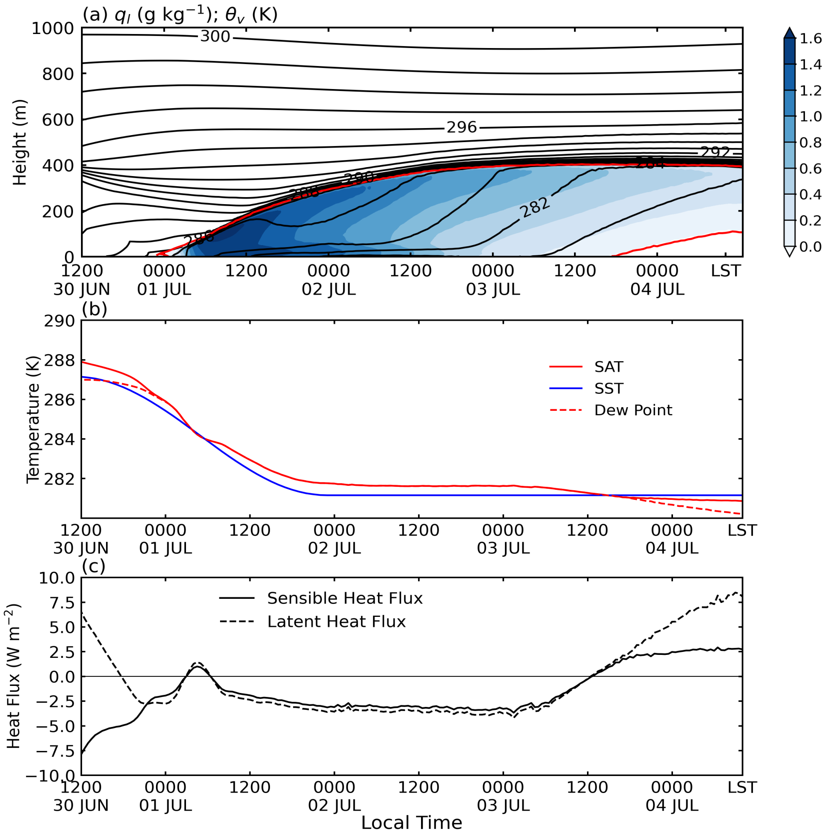

FIG. S14. Time series of horizontal mean LWC at fog top (red line) and SAT-SST (black line) for the simulation with diurnal solar radiation.

16. 6. In this section, many quantitative results for the constant solar irradiance are summarized, but not for the observational nor the varying solar case. It would be better to discuss the three if possible. How does this study relate to other modeling works other than Yang et al. (2021)? Is there anything novel in that regard to report? It would be good to not only include discussion with other works here but also in section 5, in order to support the description and explanations given. How do you propose that the modeling gap in larger models could benefit from this knowledge, in a practical sense?

We added more discussions in lines 507, 509, 522-559.

17. L453 I'm not sure where that comparison is

We revised the sentence in lines 560-565.

Writing comments / suggestions

1. In general, the manuscript is well written. Out of personal style, I'd recommend checking thoroughly the use of the article "the" over the document

   We revised the use of "the" throughout the manuscript.

2. L21 maybe it's better to say the difference, not sure if SAT-SST will be understood

   Revised (lines 21-22).

3. L26 "arrives at"

   Revised (line 26).

4. L28 "well simulates" means that it matches the observations, right?

   Revised (line 29).

5. (1) what is E?

   E in equation (1) is the amount of water vapor produced by liquid phase transition. Revised (line 159).

6. L52 It is unusual to start a sentence with a symbol, though this could be a matter of style, I'd suggest to use commas an evaluate the use of more "the" in this paragraph

   Revised (lines 49-52).

7. L132 Turbulent fluxes are not part of the prognostic variables, right?

   Turbulent fluxes are parameterized. Revised (lines 131-132).

8. L160 "moisture variations"

   Revised (line 166).

9. (3) Shouldn't the buoyant term only have u3?

   Revised (equation 3).

10. L170 "wind fields from ERA5"

Revised (line 176).

11. L173 "(ssC, when SAT-SST>0)"

Revised (line 179).

12. L190 "are positive" instead of "exceed 0°C"

Revised (line 196).

13. L306 "budget terms"

Revised (line 347).

14. Fig 8 “heat and moisture”

Revised (Fig. 9).

15. L330 “weakens and the turbulent mixing cooling dominates”

Revised (lines 372-373).

16. L432 “analyzed in the detail”

Revised (line 511).

17. L439 “column”

Revised (line 518).