Authors’ response for egusphere-2022-1229:

Investigating multiscale meteorological controls and impacts of soil moisture heterogeneity on radiation fog in complex terrain using semi-idealised simulations

We want to thank the editor and all the five reviewers for their time and consideration given to this manuscript. We understand the reviewers' and the editor’s concerns regarding the grid spacing configuration of the simulations presented in the manuscript.

We acknowledge that the grid spacing used in this study falls in the “Grey Zone” of boundary layer modelling, which, as Reviewer #5 mentioned, has been a long-standing debate in the community. We understand the limitations of our current configuration, but decided to use PALM because it has the potential and high scalability to run the fog simulations at finer grid spacings. During the review process, we revised our model setup description. As mentioned by Reviewers #4 and #5, running simulations with fine grid spacing (finer than 10 m) is computationally expensive. Our configuration aims to conduct experiments quickly (although it could be less accurate) and to potentially provide additional insight into numerical weather prediction (NWP) of fog.

As discussed by the editor and Reviewer #4, to provide more confidence for our simulations and results, we have conducted sensitivity experiments on the vertical grid spacing and have presented the results in the supplements in this revision. In addition, we have revised the description of the model setup and the limitations of our configuration.

The editor’s comments have been listed below in *black italics* and responded to individually in *blue italics*. Revised sentences are in *red italics.*

1) *Check again that you explain as transparently as possible your decisions for the model setup and its limitations. The comments from reviewers 3-5 are certainly helpful for this.*

Along with the sensitivity test, we have provided an additional explanation for using the configurations in our simulations in the discussion:

Our simulations did not resolve large eddies, and hence, the turbulence transport could be expected to differ significantly from Maronga and Bosveld (2017). The grid spacing used in this study falls in the “Grey Zone” of turbulence (e.g., Honnert et al., 2020), which allows us to carry out multiple experiments relatively quickly over a large area, although the representation of the turbulence is less accurate. To provide more confidence in our simulations, we have carried out sensitivity experiments on the vertical grid spacing of D04 (from 18 m to 9 m and 6 m). Our conclusions remain unchanged when a finer vertical grid spacing is used (see supplements). In addition, running simulations over an area of approximately 17.5 km × 17.5 km with grid spacing finer than 4 m is not computationally feasible. Future work should therefore be carried out using a finer grid spacing when suitable computation resources become available.

2) *Include additional sensitivity experiments (e.g., in the form of an Appendix), as suggested by reviewer 4.*

We have conducted several sensitivity experiments and decided to attach the sensitivity experiments as supplements. The entire sensitivity experiments are also attached at the end *of this response. The sensitivity experiments are shown in Figures S1-S6. The results of the homogeneous simulation with simulation domain D04 of 18 m vertical grid spacing conducted using the Intel FORTRAN compilers are presented in Figures S7-S10.*

We conducted the fog simulations presented in the manuscript using the Cray Fortran compiler, which is no longer compatible with PALM revision 4829 after the major upgrade of our supercomputing facility earlier this year. For the sensitivity experiments presented here, we have used the Intel Fortran compiler instead. We acknowledge that the simulated results differ from those presented in the manuscript. Regarding the occurrence of fog, approximately 84.2% of the grid points remain unchanged. Around 7.5% of the grid points have fog simulated with the Cray Fortran compiler but do not have fog simulated when the Intel Fortran compiler is used. The remaining 8.3% of the grid points have the opposite results (have fog with the Intel compiler while no fog with the Cray compiler). Fog duration has reduced over the Port Hills area (PTH) by over 50 minutes, while the four locations Hagley Park (HAP), PTH, Southwest of Christchurch (SWC), and Waimakariri River (WMR) are still associated with the most recognisable fog events. This, however, does not change the conclusions of this study. To prove this, we conducted two fog simulations with the original domain configuration for HOM (homogeneous soil moisture) and HET12p (12-point adjustments of soil moisture heterogeneity).

In the sensitivity experiments, we have configured Domain 4 with a vertical grid spacing of 9 m and 6 m for HOM and HET12p. Reviewer 4 mentioned stretching of vertical grid spacing with the lowest level of around 1-2 m. However, this cannot be done in PALM with domain nesting for the time being. The computational cost increases dramatically with a finer vertical grid spacing. Hence, we cannot conduct a fog simulation with vertical grid spacing finer than 6 m within a sensible time frame. We have tried to run simulations with Domain 4 of 3 m vertical grid spacing. However, in our Cray XC50 supercomputing cluster, a 1-hour simulation of 3 m vertical grid spacing took over 6 hours of wall clock time on 369 Intel Xeon Skylake Gold 6148 processor cores, running at 2.4 GHz, meaning the entire simulation (48 hours / 2 days) will take at least 288 hours (12 days), which is not allowed with the enforced job time limit of 24-hour wall clock time. In our Cray CS400 supercomputing cluster, a 34-hour 6 m vertical grid spacing simulation took approximately 72 hours of wall clock time on 369 Intel Broadwell processer cores running at 2.1 GHz. The enforced job time limit for the Cray CS400 cluster is three days of wall clock time, meaning we cannot use this configuration for simulations with 3 m vertical grid spacing. We have tested other partitions in our cluster, for example, on the AMD EPYC Milan 7713 processer cores (2.0 GHz base clock, 3.675 GHz max boost clock), but

1) *PALM has MPI compatibility issues on these CPUs, and we cannot scale up the number of CPUs used;*
2) *A 2-minute simulation with 3 m vertical grid spacing took 6 hours of wall clock time on 244 AMD processer cores.*

Therefore, we decided to only conduct the sensitivity tests with a vertical grid spacing of 9 m, and 6 m. Our conclusions remain the same based on the sensitivity experiment results. In general, the change of vertical grid spacing does change the areas where fog occurred but does not alter our conclusions that the variation in soil moisture heterogeneity does not show a clear correlation with the change in fog duration.

Supporting information for "Investigating multiscale meteorological controls and impacts of soil moisture heterogeneity on radiation fog in complex terrain using semi-idealised simulations"

This document presents sensitivity experiments on the vertical spacing used for Domain 4 (D04) of the fog simulations presented in the main manuscript. The original simulation has a vertical grid spacing of 18 m for D04, and we conducted two sets of simulations with a vertical grid spacing of 9 m and 6 m, respectively. The sensitivity experiments are presented in Section 1 and Figures S1-S6. The original simulations presented in the manuscript were conducted using the Cray FORTRAN compilers, while the sensitivity experiments presented here were conducted using the Intel FORTRAN compilers. This does not change our conclusions. To provide more confidence, the results of the homogeneous simulation with D04 of 18 m vertical grid spacing conducted using the Intel FORTRAN compilers are presented in Section 2. The figures (Figures S7-S10) in Section 2 are similar to those in Section 4 of the main manuscript.

1. SENSITIVITY EXPERIMENTS

The vertical level configurations and computation time of the sensitivity experiments are shown in Table S1. For each of the three configurations, two simulations were conducted. One contains homogeneous soil moisture (HOM), and the other contains heterogeneous soil moisture with the 12-point adjustment (HET12p). Hereafter, we denote the simulations conducted with the vertical grid spacing of 18 m, 9 m, and 6 m as HOM-18m and HET12p-18m, HOM-9m and HET12p-9m, and HOM-6m and HET12p-6m, respectively.

The fog duration for HOM-18m, HOM-9m, and HOM-6m, and the fog duration difference between each HOM simulation and HET12p simulation are shown in Figure S1. As shown in Figure S1, the finer vertical grid spacing results in an increase in fog area and fog duration. However, the comparison between each HOM and HET12p simulation still does not show a direct correlation between spatial variations in soil moisture and the changes in fog duration. To provide more evidence supporting our conclusion, Figure S2 shows the time series of liquid water mixing ratio (ql) for Hagley Park (HAP), Port Hills (PTH), Southwest of Christchurch (SWC), and

Table S1. Vertical level configurations and computation time for the sensitivity experiments.

Vertical grid spacing (dz)	Vertical grid points (nz)	Simulation hours	CPU specification	Number of CPUs	Wall clock time
18 m	36	48 hours	Intel Xeon Skylake Gold 6148 processor cores (2.4 GHz)	396	8 hours
9 m	72	36 hours	Intel Xeon Skylake Gold 6148 processor cores (2.4 GHz)	396	24 hours
6 m	108	34 hours	Intel Broadwell processer cores (2.1 GHz)	396	72 hours

Waimakariri River (WMR). The vertical profiles of wind, potential temperature, and ql are shown in Figures S3, S4, S5, and S6 for HAP, PTH, SWC, and WMR, respectively.

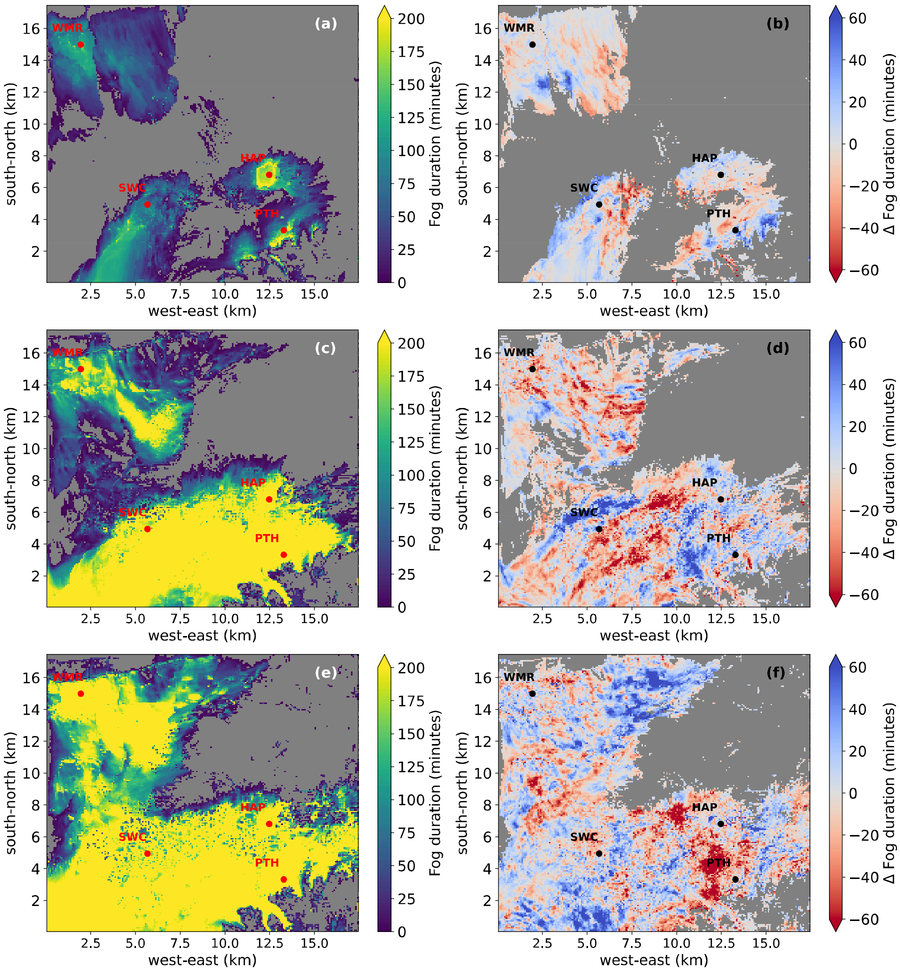

Fig. S1. (a), (b), (c), and (d) show fog duration in minutes for HOM-18m, HOM-9m, and HOM-6m, respectively. (b), (d), and (f) are fog duration differences in minutes between each HOM and HET12p simulation for the simulations with a vertical grid spacing of 18 m, 9 m, and 6 m, respectively. Hagley Park (HAP), Port Hills (PTH), Southwest of Christchurch (SWC), and Waimakariri River (WMR) are marked by dots in each panel.

2. RESULTS FOR THE HOMOGENEOUS SOIL MOISTURE SIMULATION WITH THE INTEL FORTRAN COMPILER

Figures S7, S8, S9, and S10 show the results for HOM-18m simulated using the Intel FORTRAN compiler.

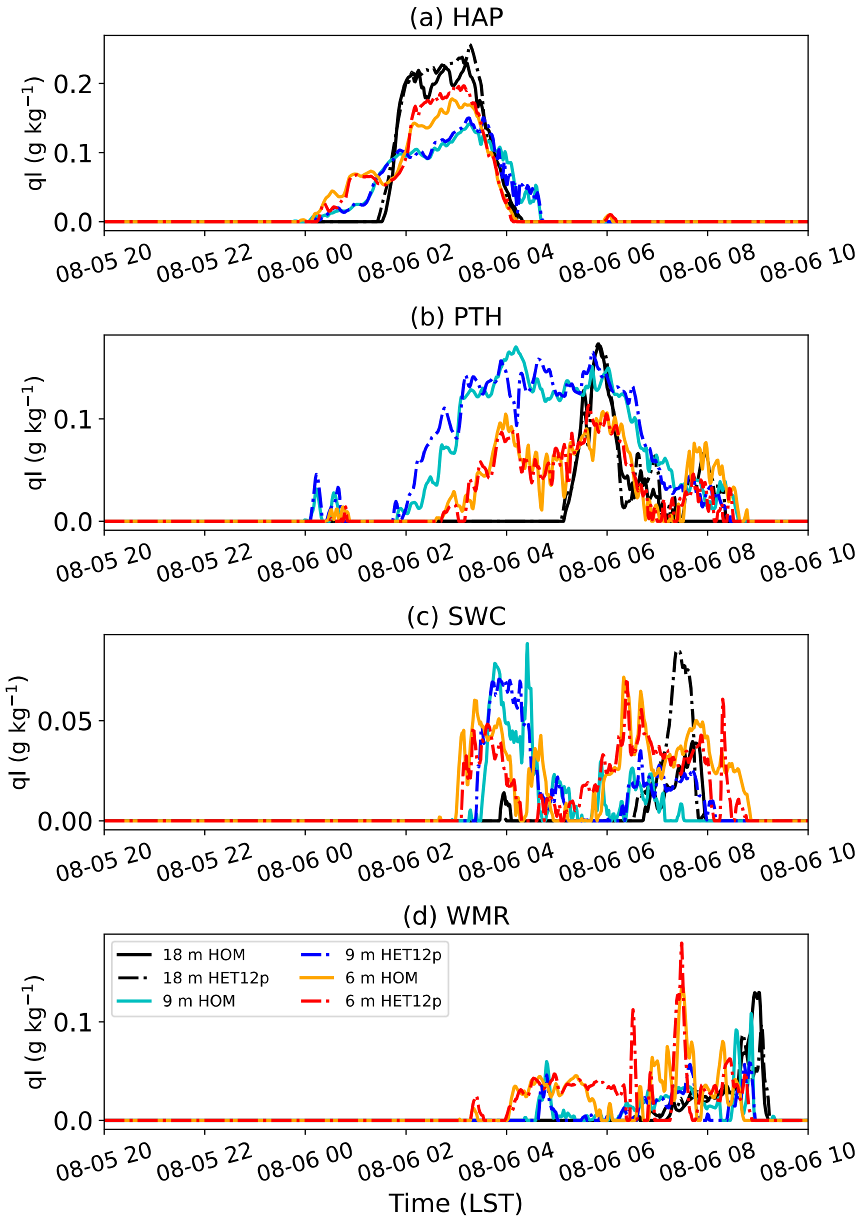

Fig. S2. Time series of liquid water mixing ratio (*ql*) for (a) HAP, (b) PTH, (c) SWC, and (d) WMR.

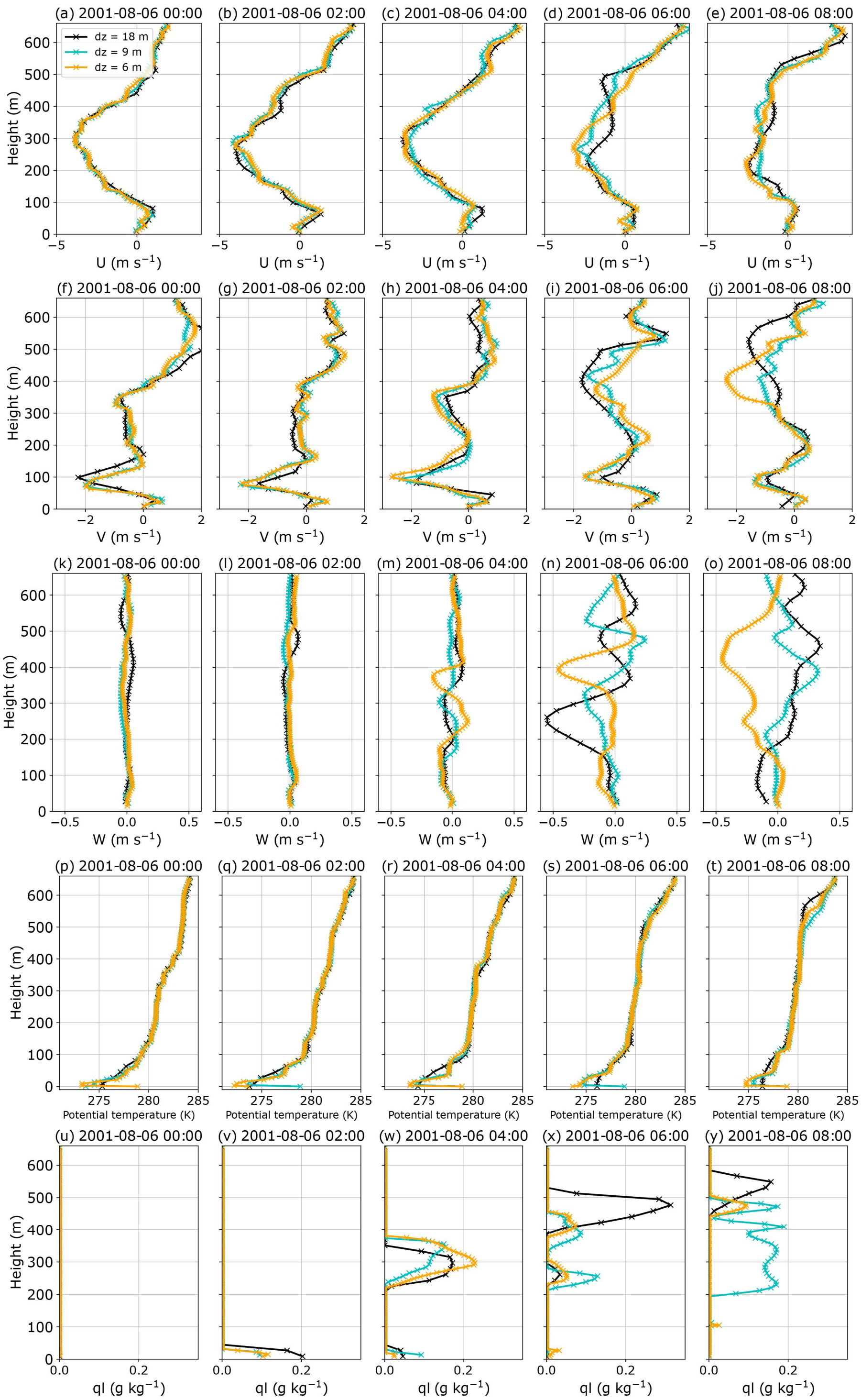

Fig. S3. Vertical profiles of the u component of winds (a–e), v component of winds (f–j), w component of winds (k–o), potential temperature (p-t), and *ql* (u-y) for HAP taken from HOM-18m, HOM-9m, and HOM-6m at the times indicated in the figures.

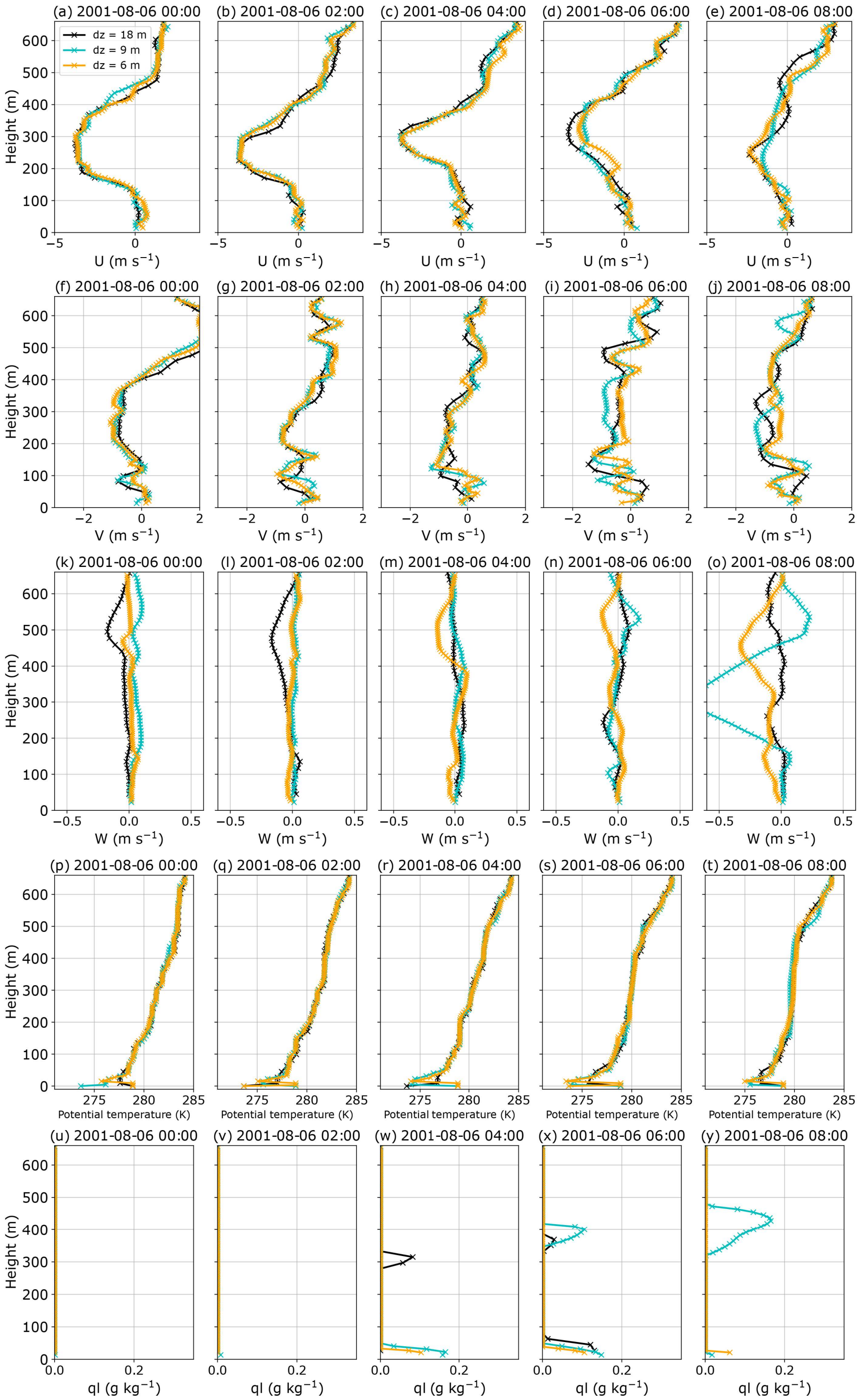

Fig. S4. Similar to S3, but for PTH.

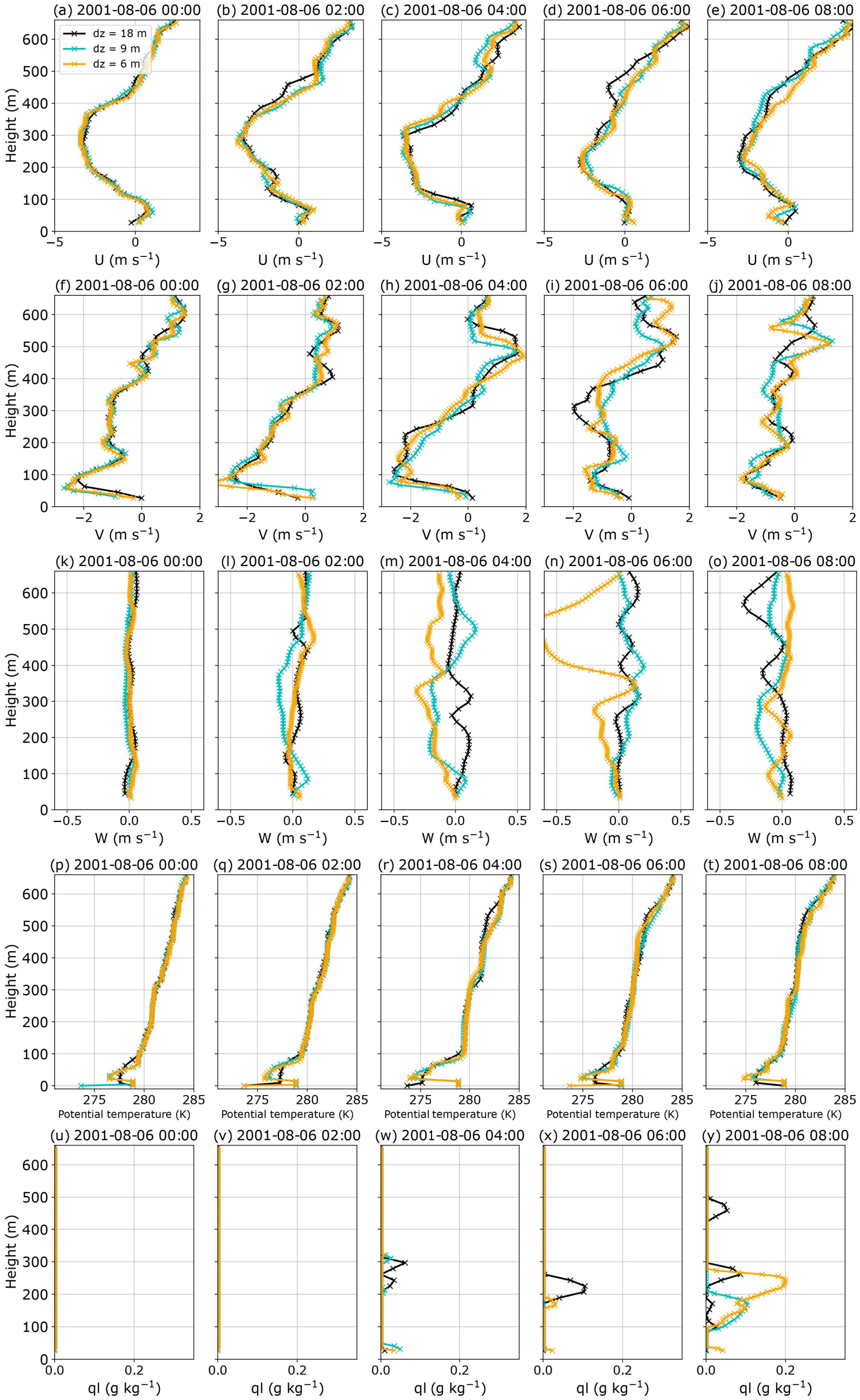

Fig. S5. Similar to S3, but for SWC.

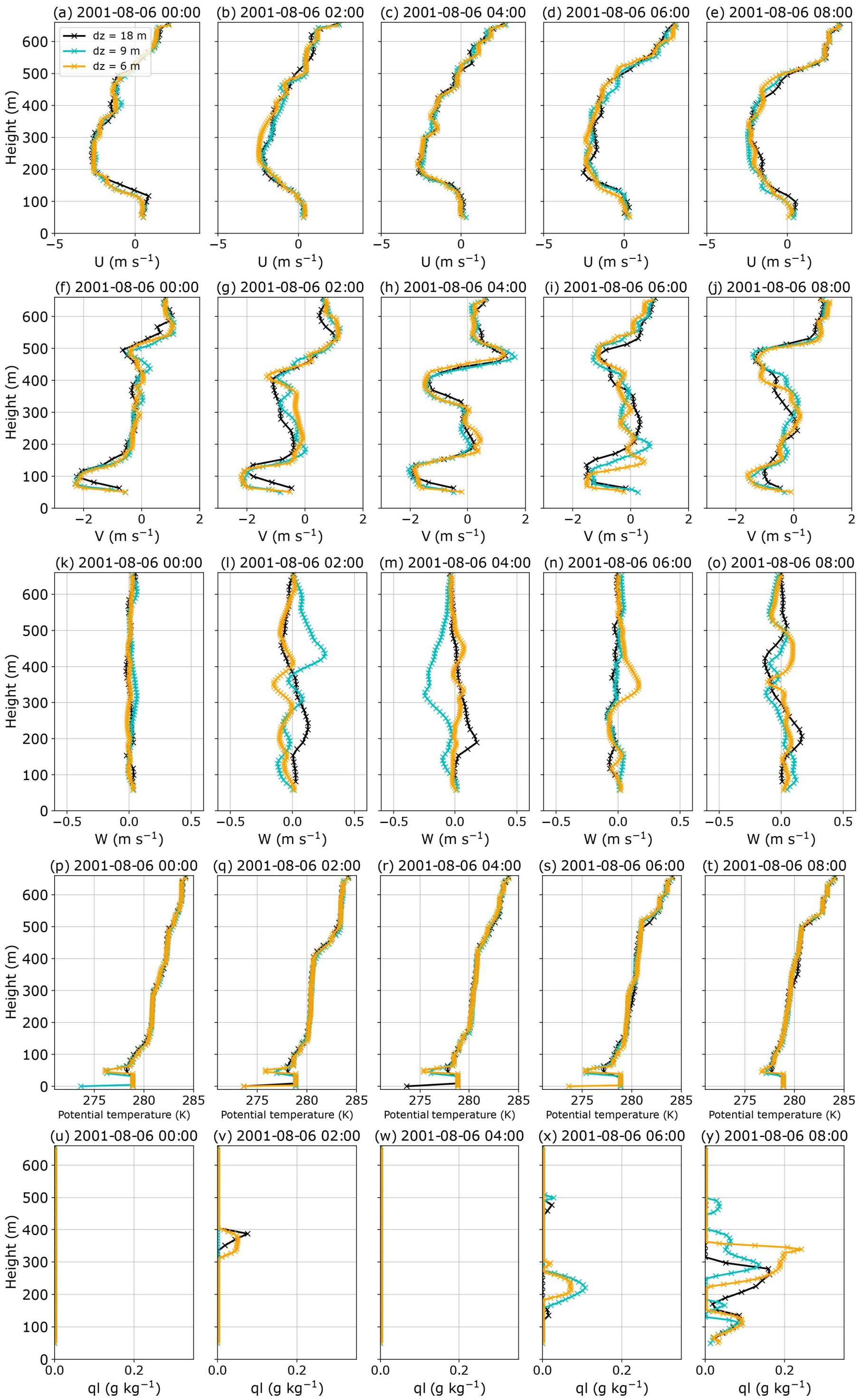

Fig. S6. Similar to S3, but for WMR.

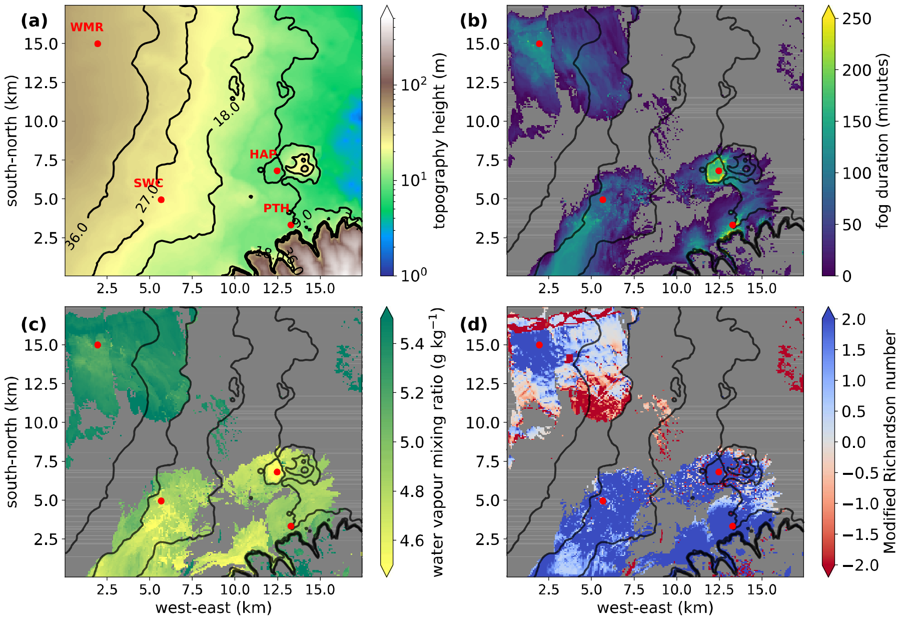

Fig. S7. Similar to Figure 3 in the main manuscript, but for HOM-18m simulated using the Intel FORTRAN compiler.

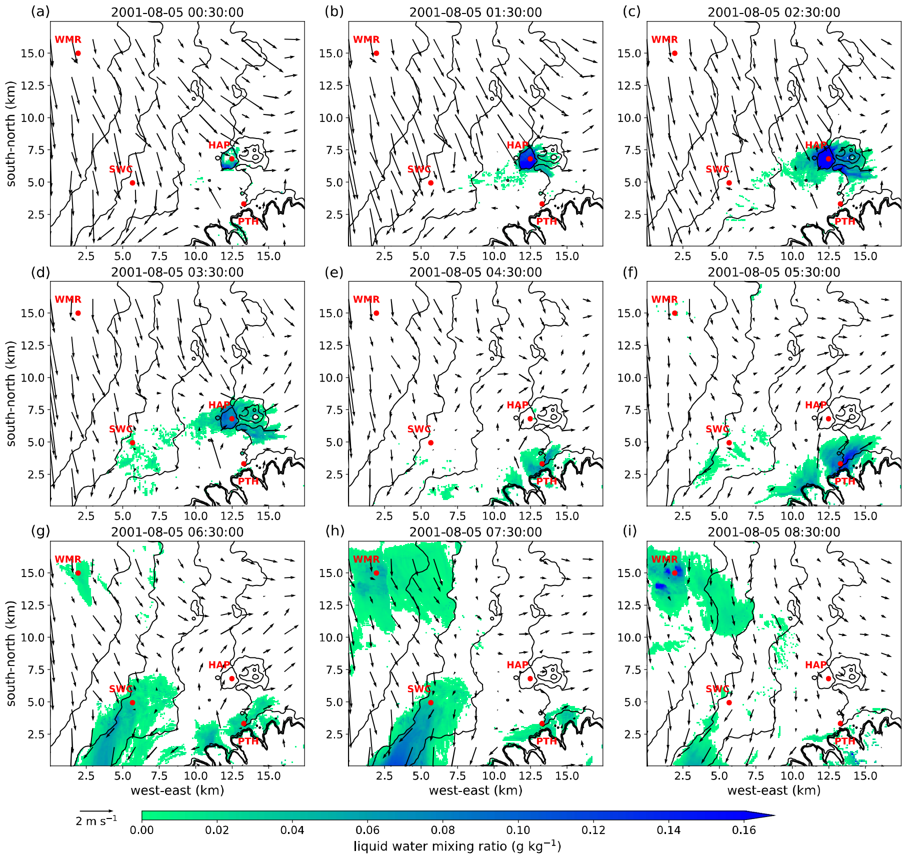

Fig. S8. Similar to Figure 4 in the main manuscript, but for HOM-18m simulated using the Intel FORTRAN compiler.

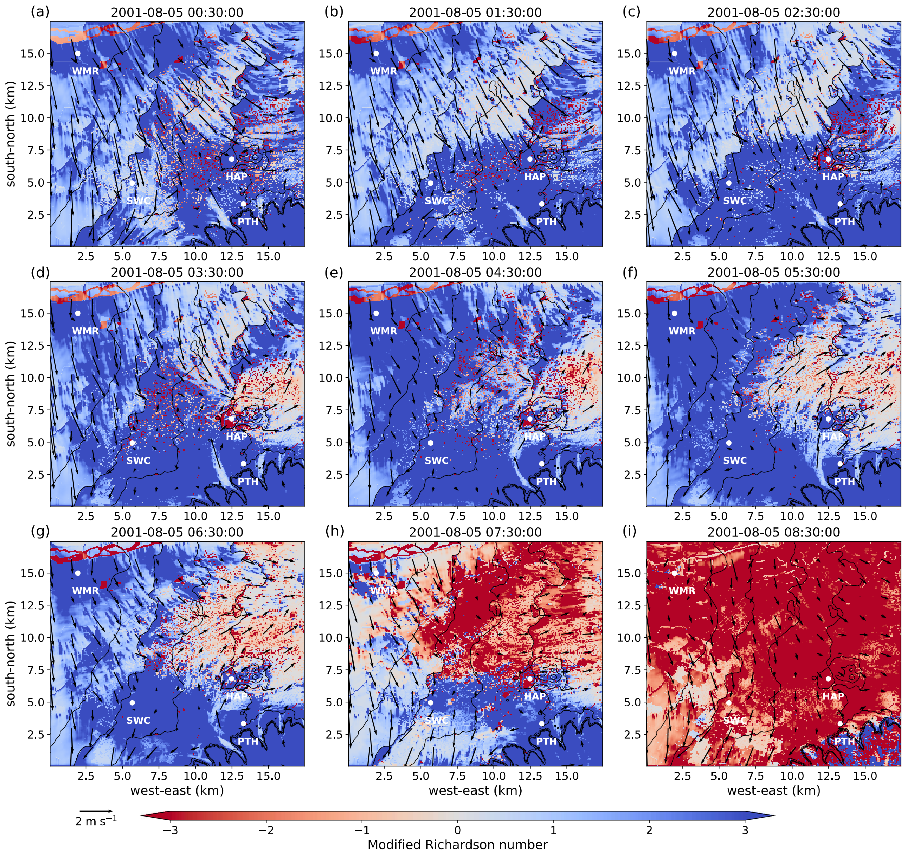

Fig. S9. Similar to Figure 5 in the main manuscript, but for HOM-18m simulated using the Intel FORTRAN compiler.

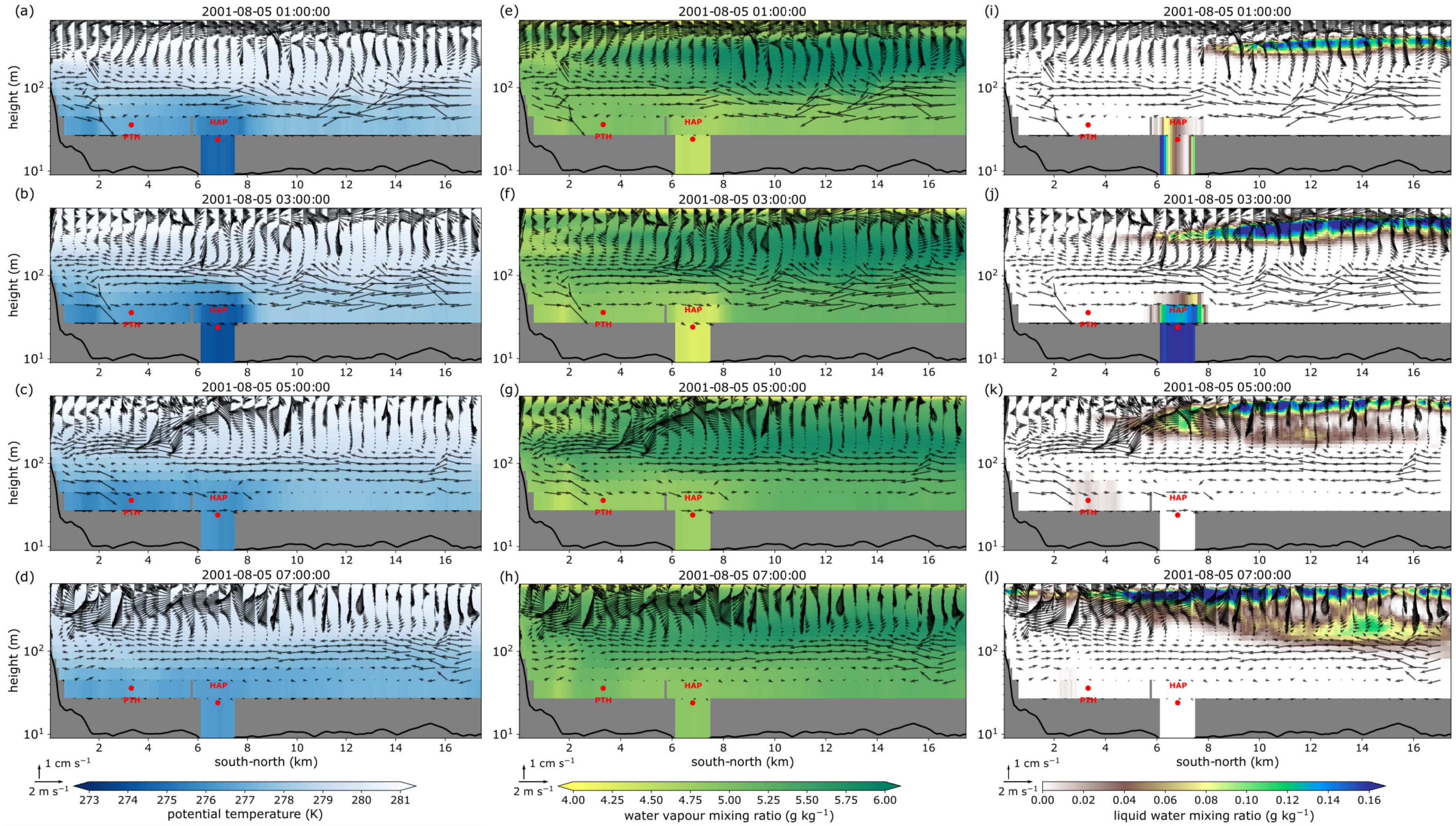

Fig. S10. Similar to Figure 6 in the main manuscript, but for HOM-18m simulated using the Intel FORTRAN compiler.