Aerosol-cloud interactions in mixed-phase convective clouds. Part 2: Meteorological ensemble.
Supplementary Information

Annette K. Miltenberger[1], Paul R. Field[1,2], Adrian A. Hill[2], Ben J. Shipway[2], and Jonathan M. Wilkinson[2]

[1]Institute of Climate and Atmospheric Science, School of Earth and Environment, University of Leeds, United Kingdom
[2]Met Office, Exeter, United Kingdom

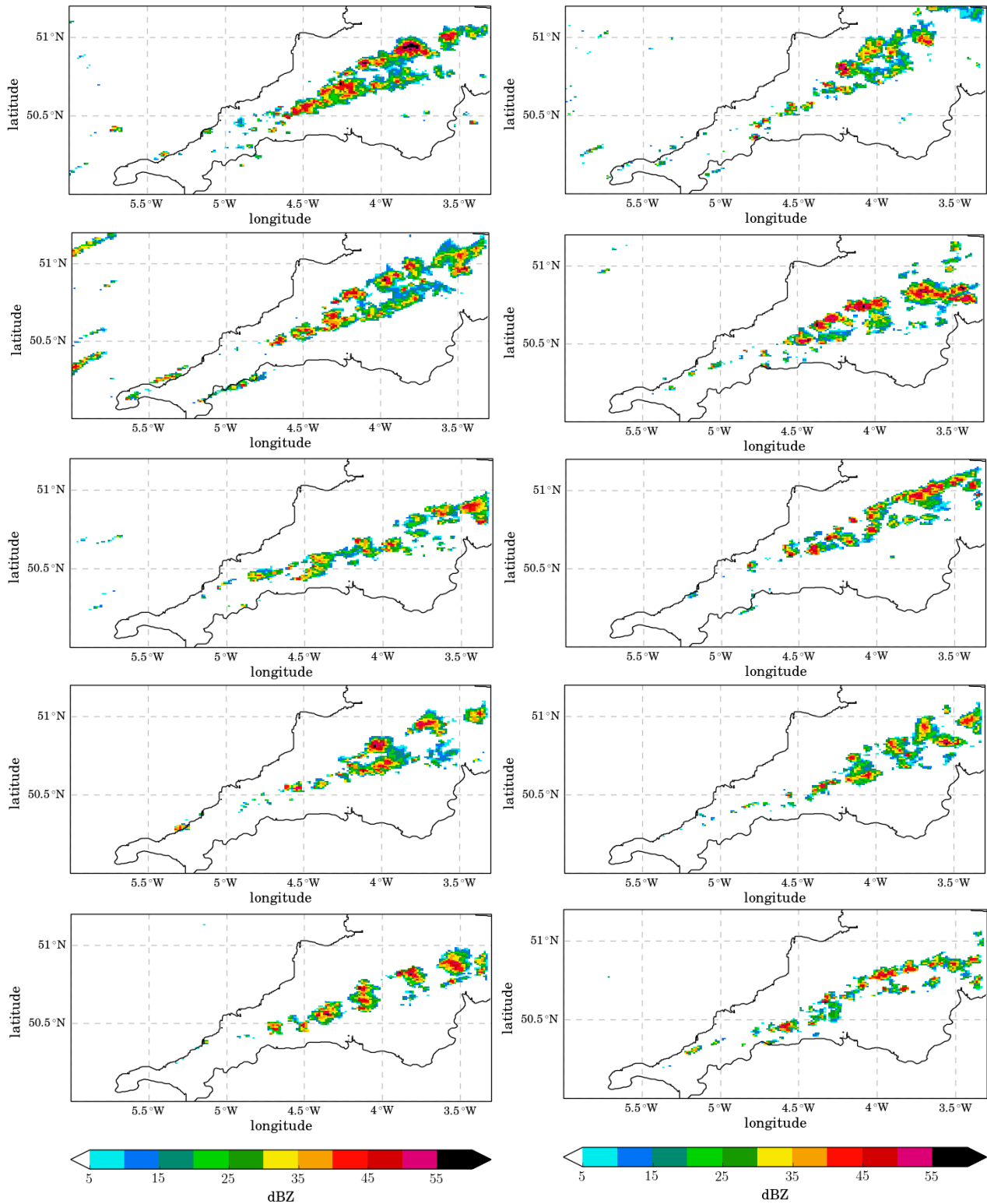*Correspondence to:* Annette K. Miltenberger (a.miltenberger@leeds.ac.uk)

Figure 1. Column maximum radar reflectivity over the COPE domain at 14 UTC from the control simulation (top left) and the 9 ensemble members using the standard aerosol profile.
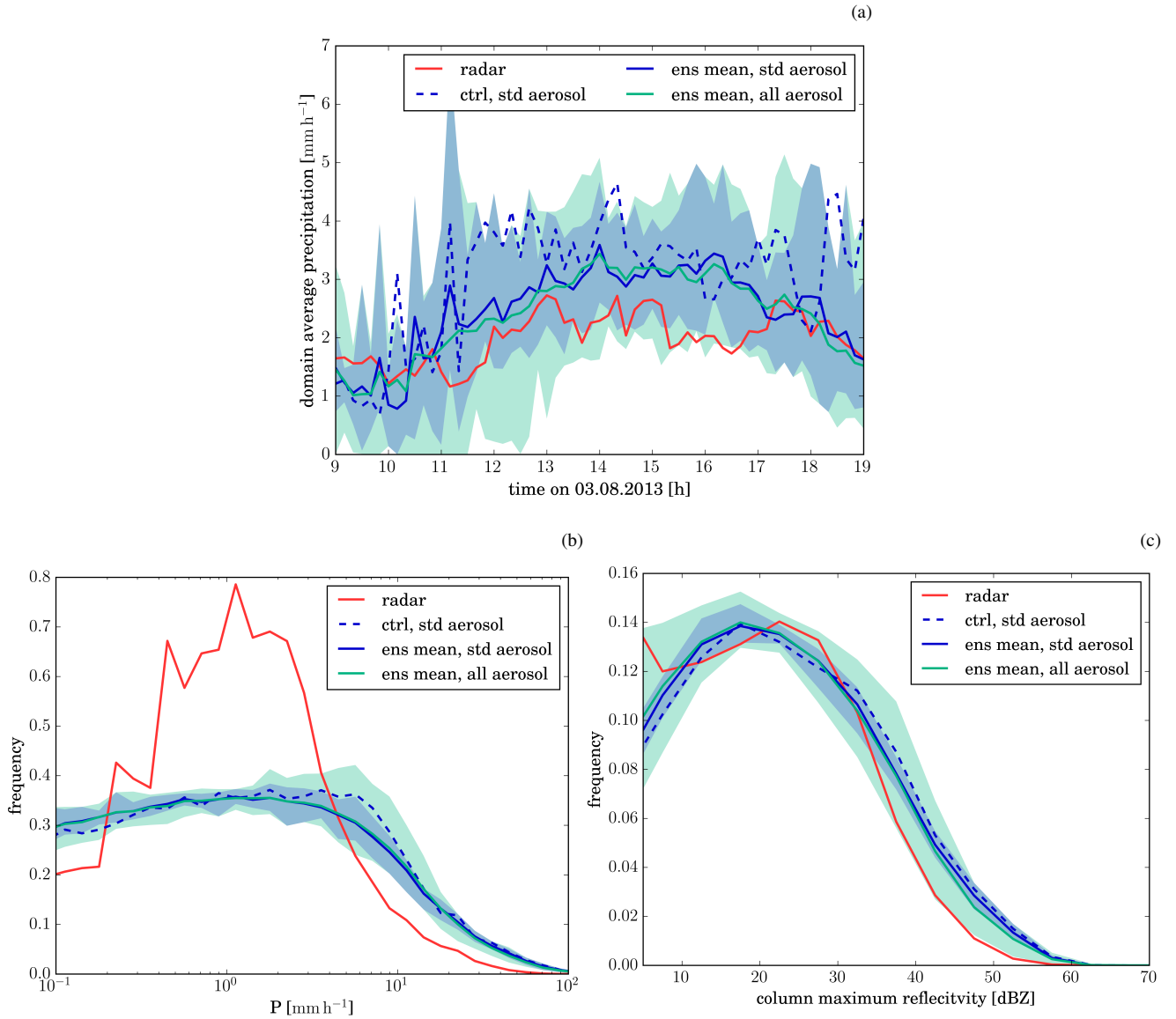
Figure 2. Comparison of the timeseries of cell-average surface precipitation (a), distribution of surface precipitation rate (b), and the distribution of column maximum radar reflectivity (c) in the model simulations and observational data. The distributions are considering cloudy grid-points only. The red solid line shows the distribution from radar observation, the dark blue dashed line the distribution from the control run with the standard aerosol profile, the dark blue solid line the mean distribution from all ensemble members with the standard aerosol profile and the cyan line the mean distribution from all ensemble members with all aerosol profiles. The shaded regions display the spread between the ensemble members. Simulated precipitation rates and radar reflectivity have been coarse-grained to the spatial resolution of the radar observations (1 km horizontal and 500 m vertical).
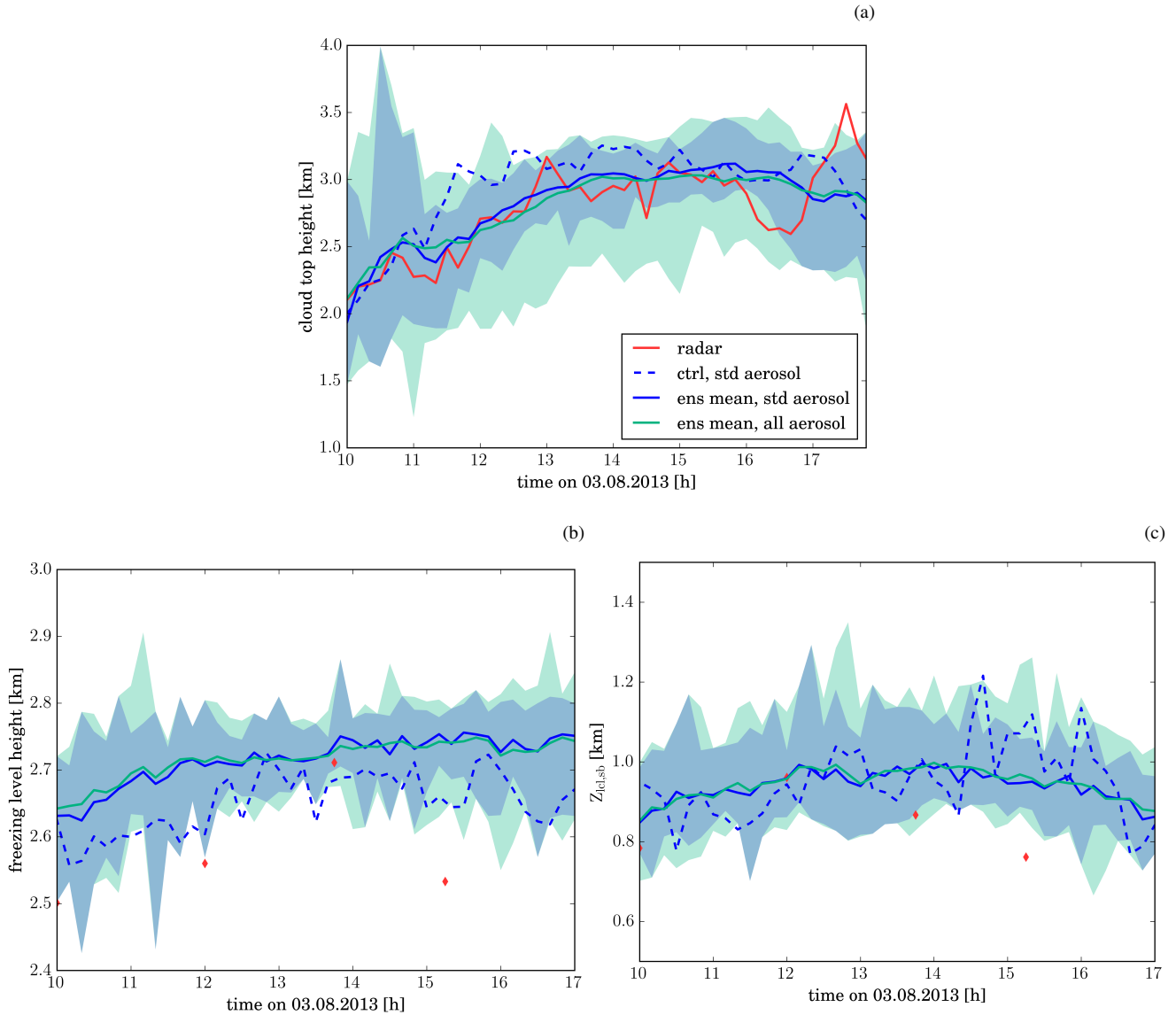
Figure 3. Comparison of cloud top height from the model simulation against radar data (a). Cloud top height is defined as the highest altitude at which the radar reflectivity reaches 18 dBZ. Timeseries of freezing level height (b) and lifting condensation level (c) from the radiosondings at Davidstow and the closest model grid-point. The red lines or diamonds represent the observation al data, the dark blue dashed line the control run with the standard aerosol profile, the dark blue solid line the mean distribution from all ensemble members with the standard aerosol profile and the cyan line the mean distribution from all ensemble members with all aerosol profiles. The shaded regions display the spread between the ensemble members.
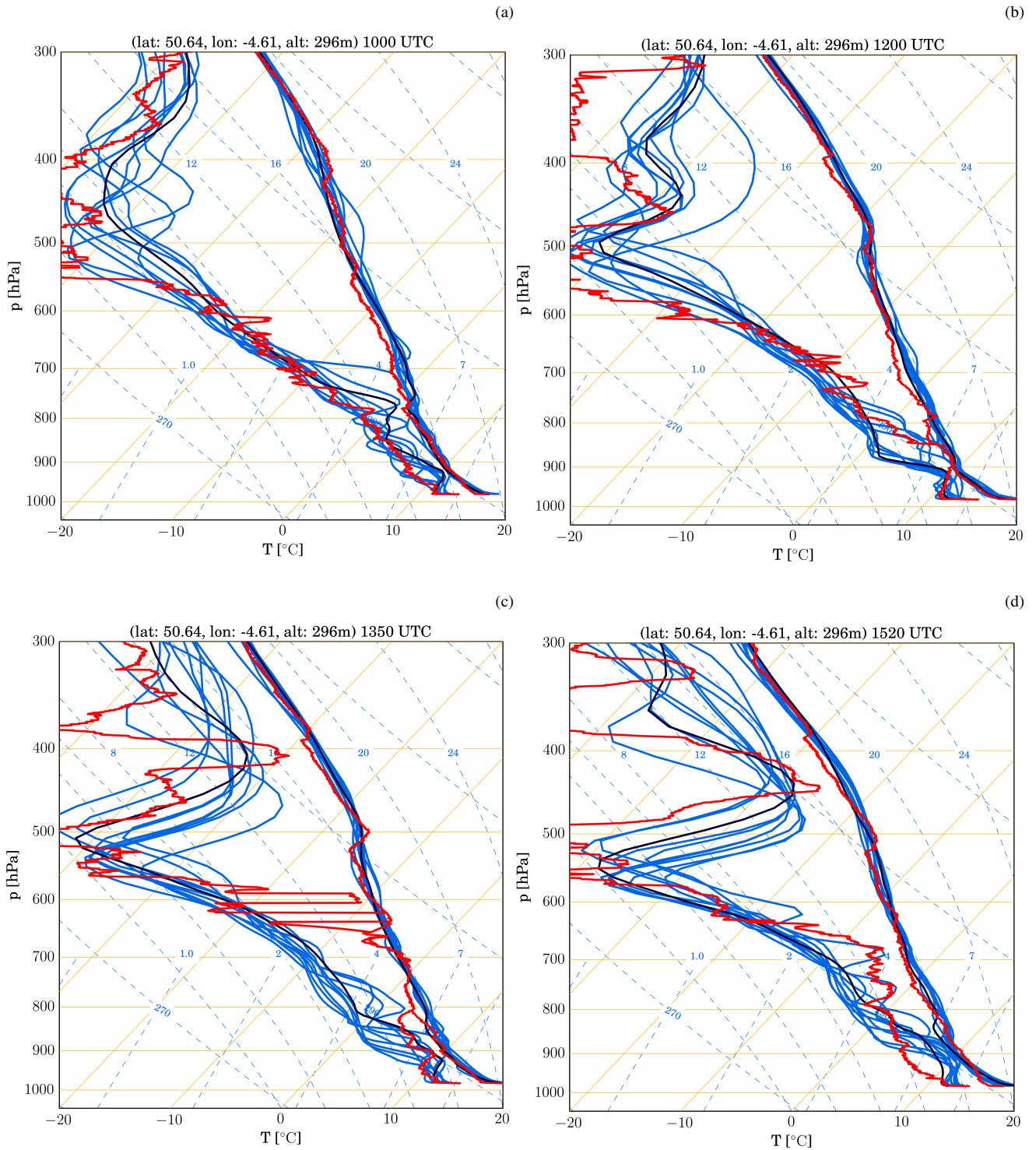
Figure 4. SkewT diagrams from radiosonde ascents at 1000 UTC (a), 120 UTC (b), 1350 UTC (c) and 1520 UTC. The red curves show the observational data, while the different blue curves show the thermodynamical profiles from the model grid column closest to the radiosonde release location for each ensemble member (standard aerosol profile). The dark blue line represents the control simulation.
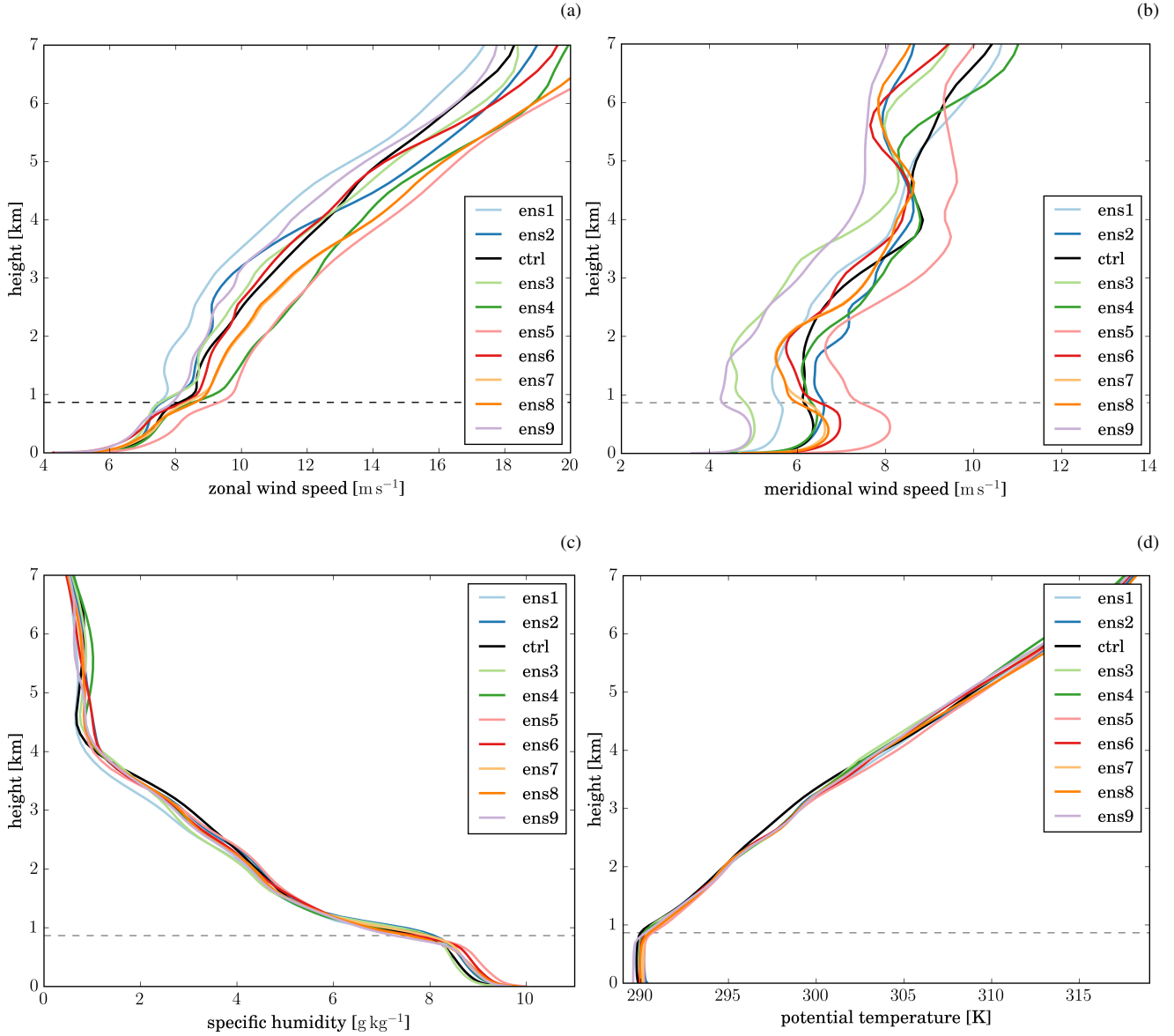
Figure 5. Comparison of upstream (western domain boundary) wind speed (a), wind direction (b), specific humidity (c), and potential temperature (d). The profiles are averaged over the time period between 10 UTC and 18 UTC. The different colours correspond to the individual ensemble members (including the control simulation).
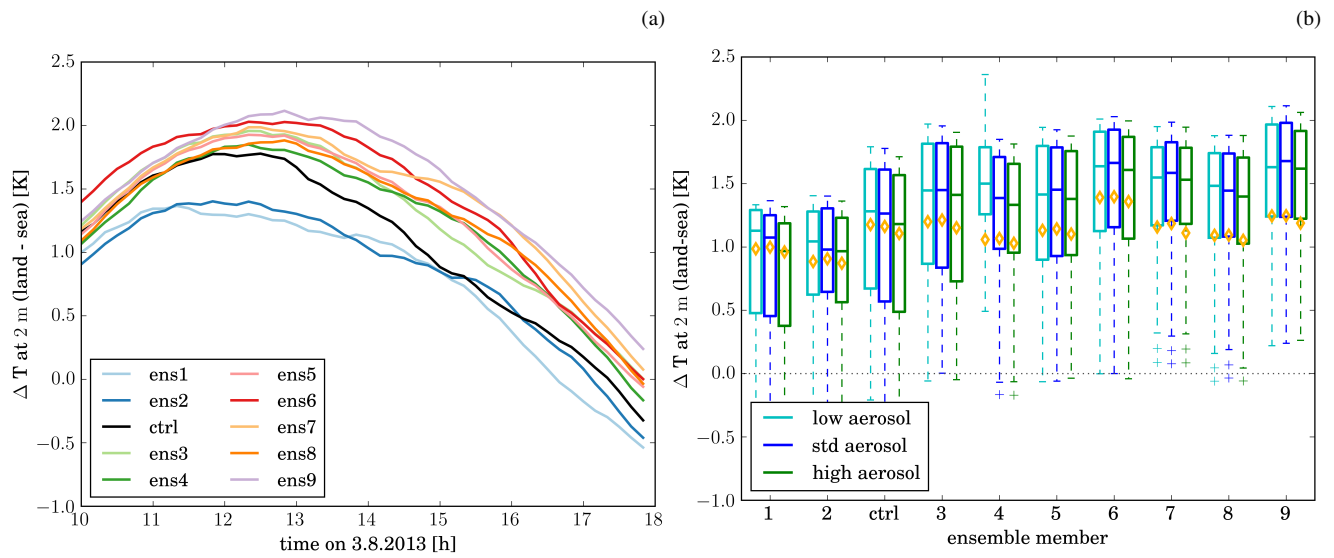
Figure 6. Temporal evolution of the temperature difference between land and sea in the different ensemble members using the standard aerosol profile (a). The variation of this temperature difference between ensemble members with different aerosol profiles is shown in panel (b). The box plots represent the temporal variabilitiy of each variable.
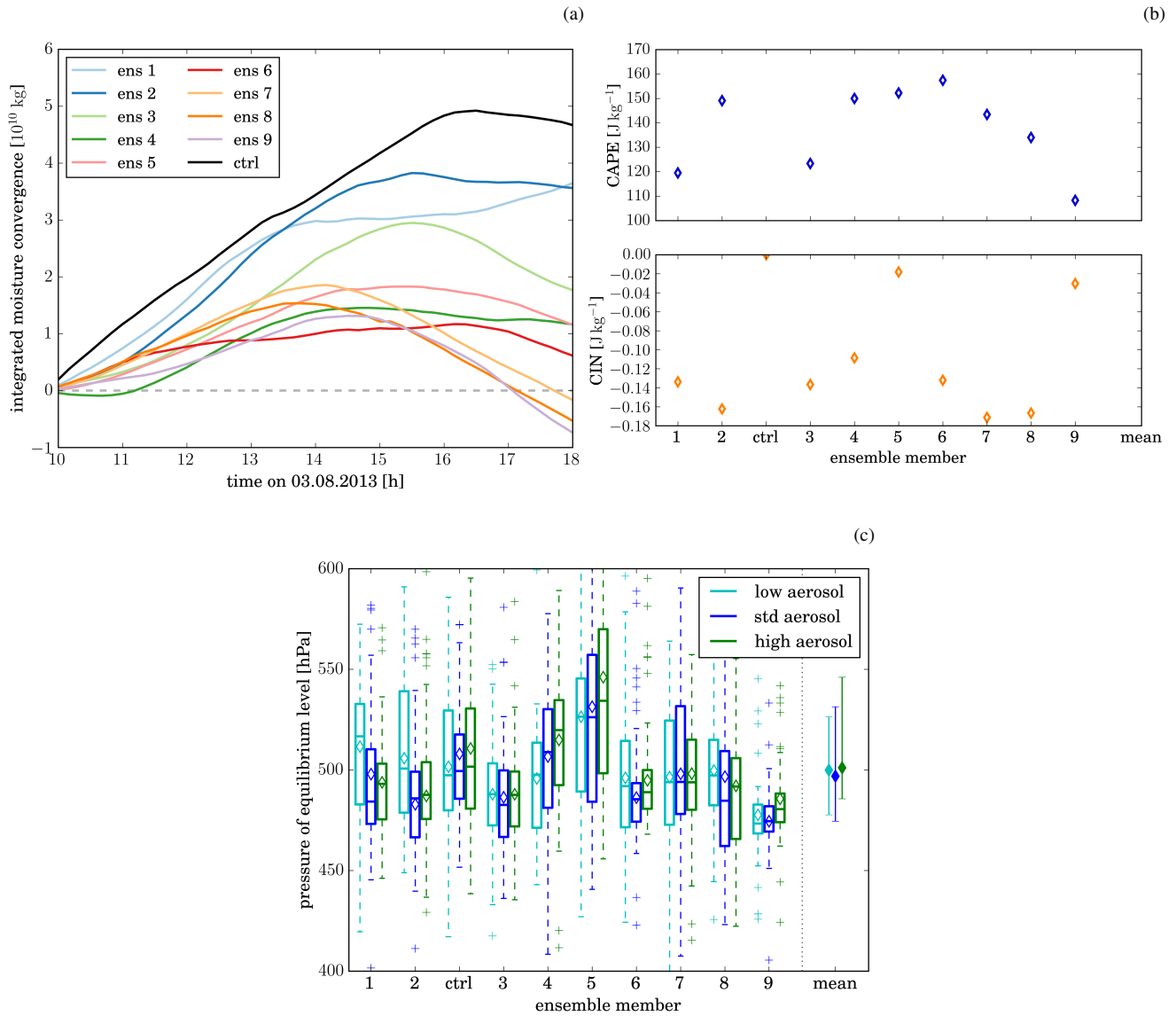
Figure 7. Timeseries of low-level moisture convergence for the different ensemble members (colours) using the standard aerosol profile (a). Average CAPE at upstream boundary for simulations with the standard aerosol profile (b). Pressure of equilibrium pressure level (c). The box plots represent the temporal variablitiy of each variable.
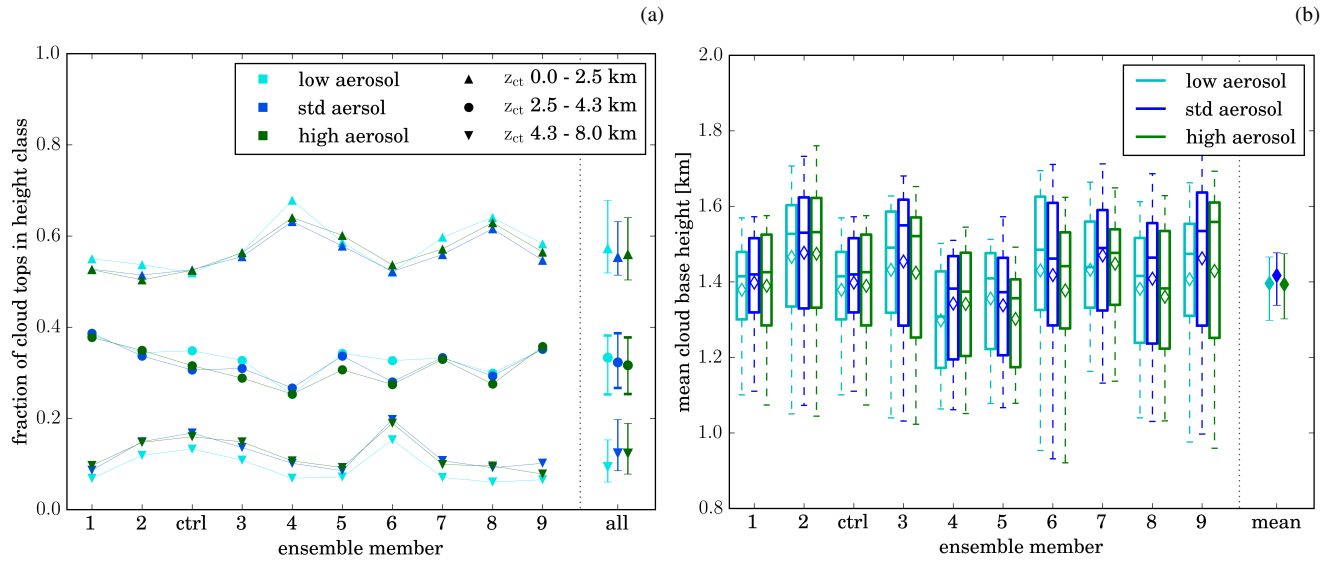
Figure 8. Fraction of cloud top in various height classes (a) and mean cloud base height (b). Cloud top height is the height of the highest vertical level in each grid column with a condensate mass mixing ratio larger than $1\,\mathrm{mg\,kg^{-1}}$. The fraction of grid columns with cloud top heights smaller than $2.5\,\mathrm{km}$ (upward pointing triangles), cloud top heights between $2.5 - 4.3\,\mathrm{km}$ (circles) and between $4.3 - 8.0\,\mathrm{km}$ is shown. The boundaries between the height classes are chosen based on the different sensitivities to aerosol in these ranges documented for the control run in part 1 of this study (Miltenberger et al., 2017). Cloud base height is the height of the lowest vertical level in each grid column with a cloud mass mixing ratio larger than $1\,\mathrm{mg\,kg^{-1}}$.
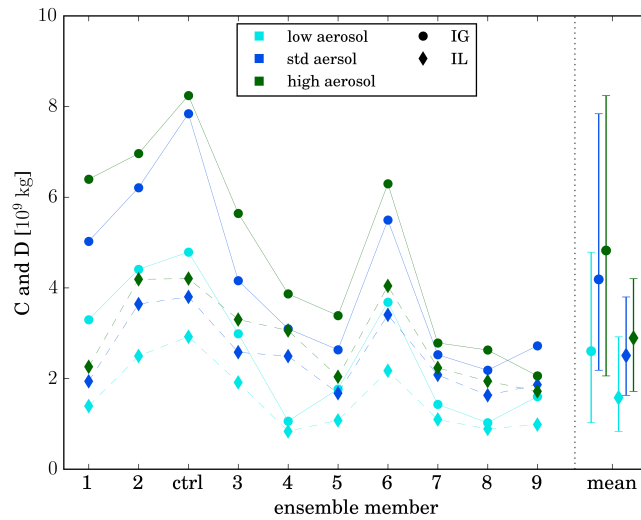

Figure 9. Domain accumulated condensation and deposition rate for the different ensemble members and aerosol scenarios.
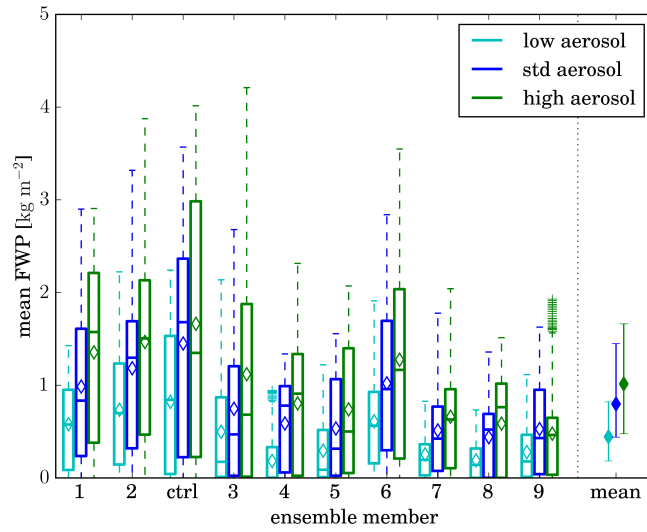
9

Figure 10. Mean frozen water path (ice, snow and graupel). The boxplots represent the temporal variability.
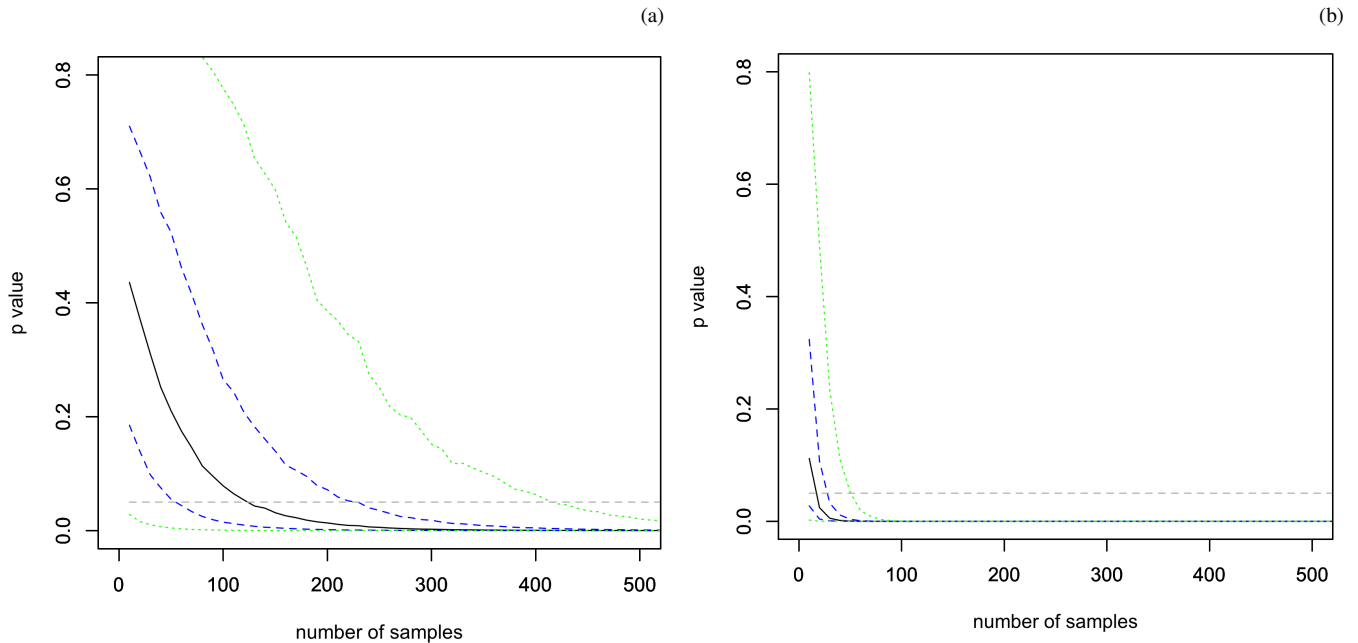

Figure 11. Statistical significance (p-value for two-sided t-test) of difference in accumulated surface precipitation between standard and low (a) and standard and high (b) aerosol scenario as a function of the number of observed days. The black solid line shows the median p-value from 10^4 realisations, the dashed blue lines the 25th and 75th percentiles of the p-value, and the green dashed lines the 5th and 95th.