The Impact of Longwave Radiation on the Morning T

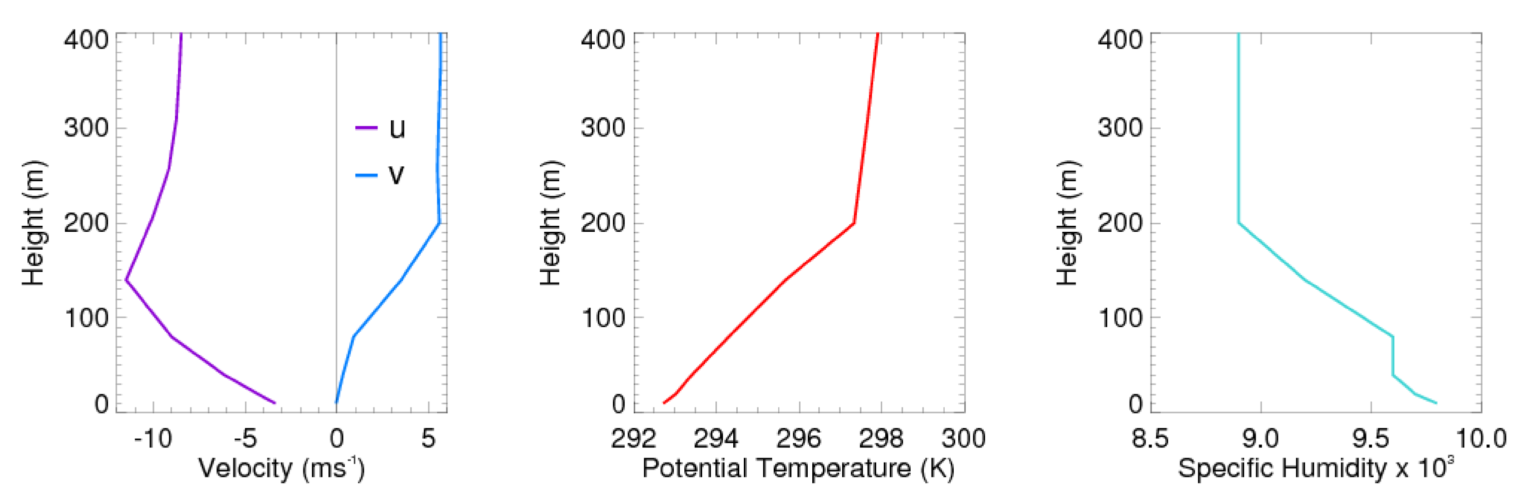
J. M. Edwards, S. Basu, F. C. Bosveld and A. A. M. Holtslag

Summary

The GABLS3 intercomparison (Bosveld et al., 2014) comprises two cases for modelling studies: an SCM case covering the full duirnal cycle and an LES case covering the developed SBL and the morning transition. Atmospheric radiative interactions are not considered in the standard LES case. Here we investigate the impact of including radiation in the simulation.

Initial and Boundary Conditions and Forcing

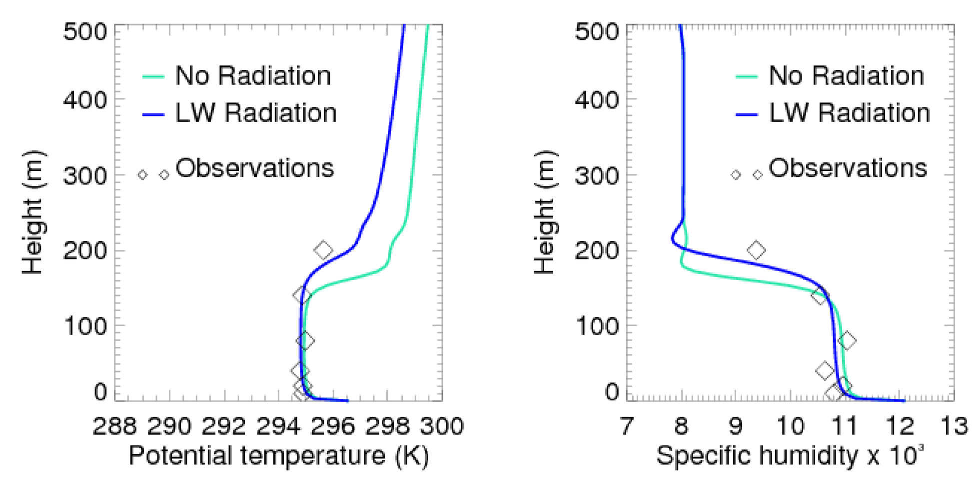
The simulation is initialized as a developed SBL at 00 UTC and runs until 09 UTC. θ and q at 0.25 m are prescribed as the lower boundary conditions. A geostrophic wind field, varying in time and height, and large-scale advective tendencies are imposed.



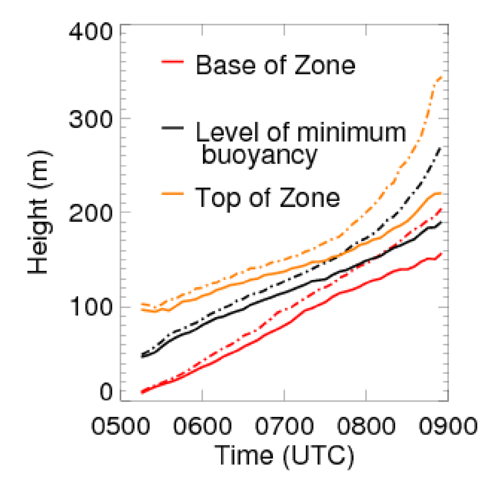
Initial profiles of wind, potential temperature and specific humidity.

The Structure of the BL

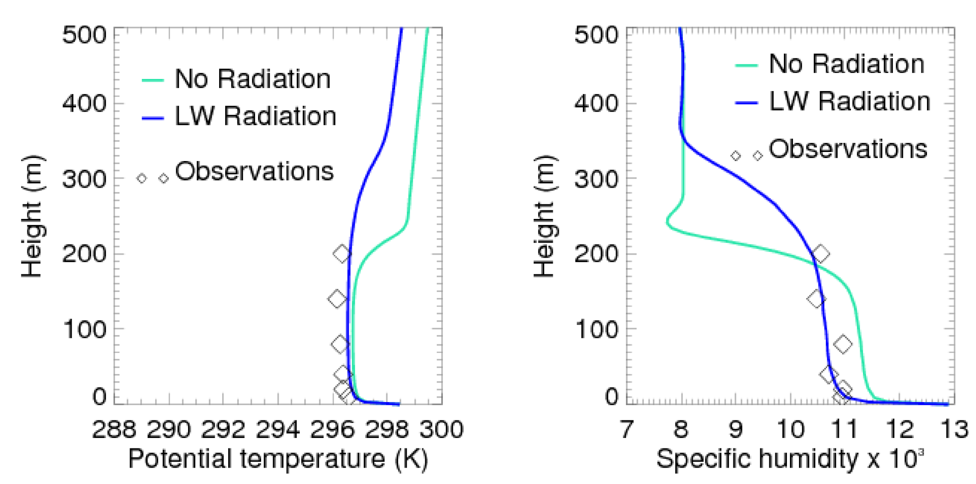
Five hours in to the simulation, the surface buoyancy flux changes sign and a mixed layer forms, subsequently growing and eroding the SBL during the morning transition. The inclusion of LW radiation causes significant deepening and drying of the mixed layer and the entrainment zone through the transition, leading to better agreement with observations made from a 200-m tower.



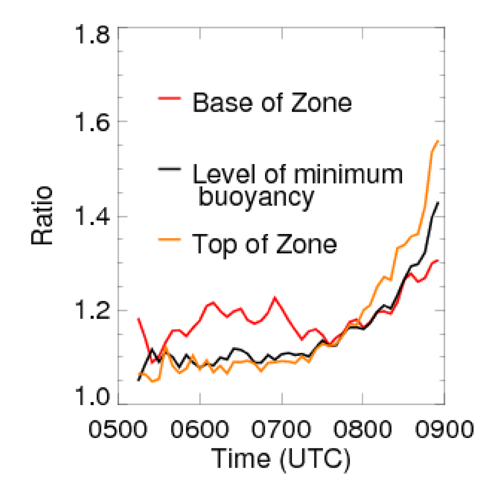
Potential Temperature and Specific Humidity at 08 UTC.



Growth of the entrainment zone: broken lines with LW radiation



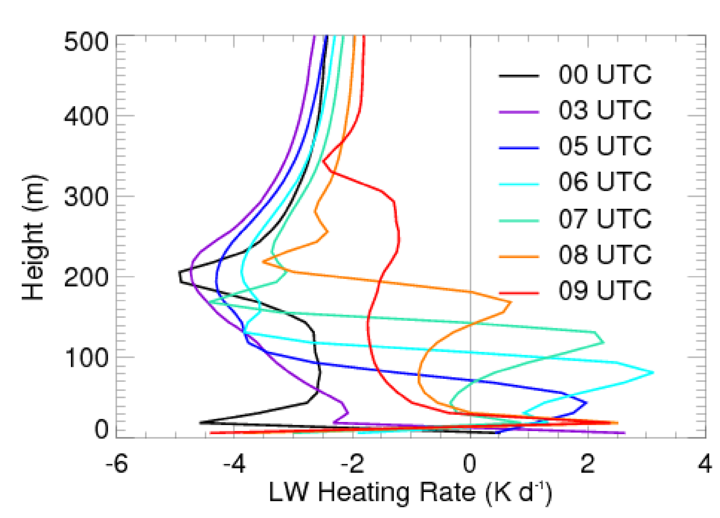
Potential Temperature and Specific Humidity at 09 UTC.



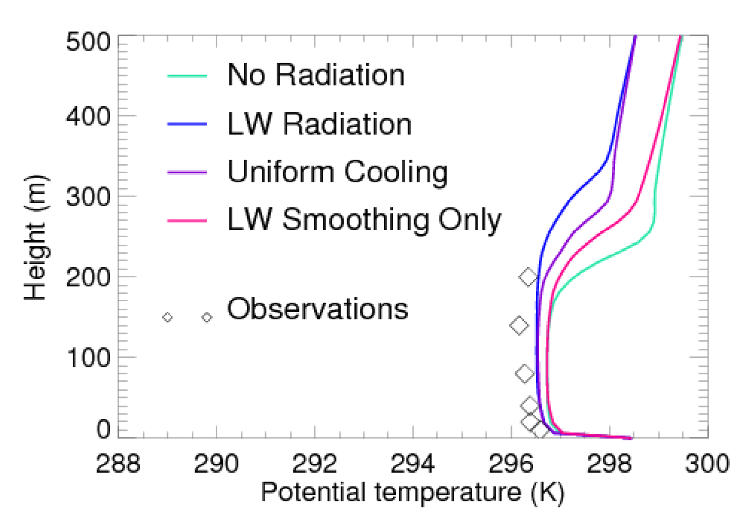
Growth of the entrainment zone: ratios of heights

LW Radiative Heating Rates and the Buoyancy Jump

Since the near-surface air temperature is prescribed, background LW radiative cooling of just over 2 Kd^{-1} causes relative cooling of the residual layer, reducing the buoyancy jump, as does radiative smoothing of the temperature profile around the top of the SBL. The reduced buoyancy jump results in faster growth of the mixed layer. The impact of these two contributions can be determined separately.



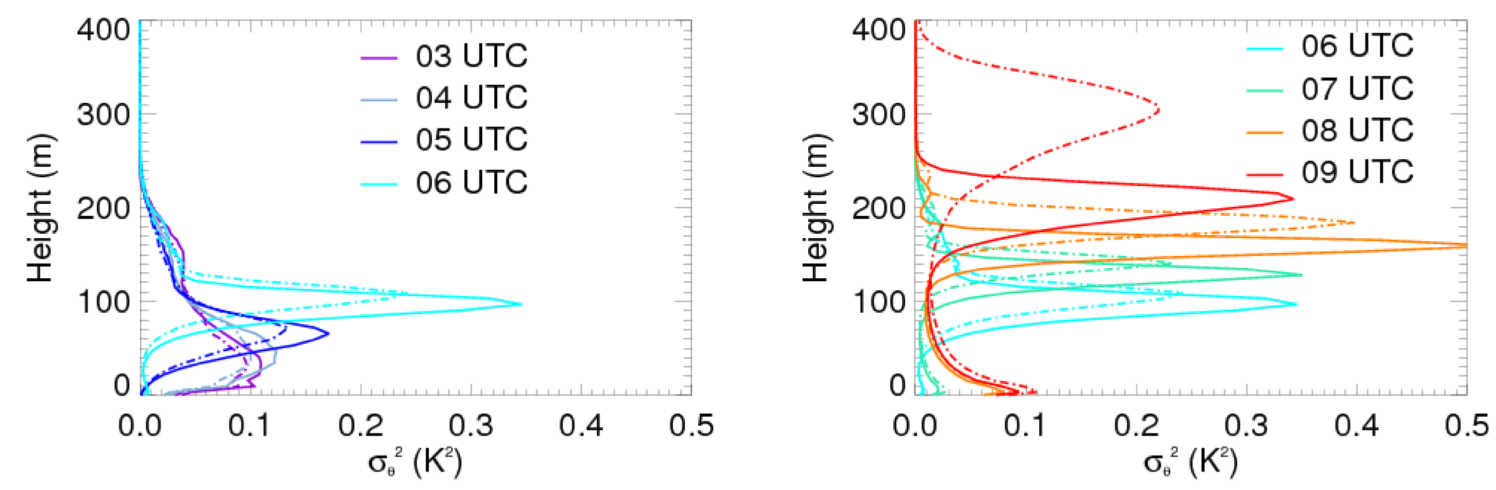
Radiative heating rates at hourly intervals.



Separating the impact of background cooling and smoothing at the top of the SBL.

The Impact of LW Radiation on Turbulence

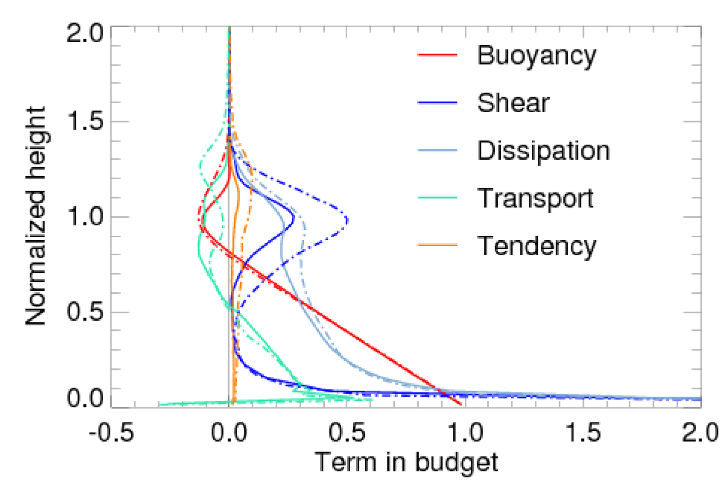
Including radiation reduces the peak values of σ_θ^2 in the SBL and in the entrainment zone during the transition, mainly because the weaker temperature gradients reduce the rate of production of σ_θ^2. There is no systematic impact on the shape of the turbulent spectra.



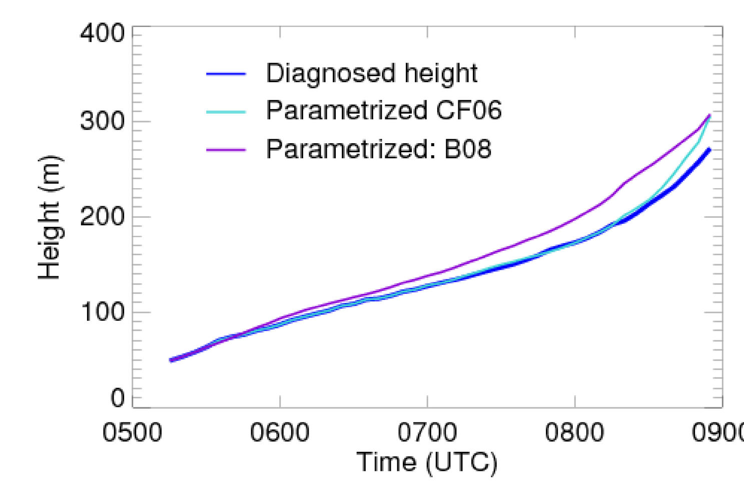
σ_θ^2 at hourly intervals:solid with LW radiation, dashed without.

The Budget of TKE and the Entrainment Rate

The budget of TKE controls the entrainment of more buoyant air into the mixed layer. This is not qualitatively affected by radiation and standard parametrizations of the entrainment rate, applied with the diagnosed buoyancy jump, yield realistic results. Here we illustrate the parametrizations of Conzemius and Fedorovich (2006) and Beare (2008) on the simulation including LW radiation. Note the importance of shear production in the entrainment zone.



Terms in the budget of TKE, 0830–0900 UTC, normalized by the surface buoyancy flux, against height normalized by boundary-layer depth: solid with LW radiation, dashed without.



The height of the inversion predicted with published parametrization schemes.

The Impact of SW Radiation

SW radiation has a much smaller impact than LW radiation. In this simulation it leads to a warming of the residual layer relative to the prescribed near-surface temperature and so slightly increases the inversion jump, retarding the growth of the mixed layer.

Conclusions

LW radiative cooling in the atmosphere significantly affects the growth of the mixed layer through the morning transition and should be considered in LES of the transition. Its inclusion in the GABLS3 simulation led to better agreement with observed profiles of potential temperature and specific humidity.

References

Beare RJ (2008) The role of shear in the morning transition boundary layer. Boundary-Layer Meterol 129:395–410.

Bosveld FC, Baas P, van Meijgaard E, de Bruijn EIF, Steeneveld GJ, Holtslag AAM (2014) The third GABLS intercomparison case for evaluation studies of boundary-layer models. Part A: case selection and set-up. Boundary-Layer Meteorol, to appear.

Conzemius RJ, Fedorovich E (2006) Dynamics of sheared convective boundary layer entrainment. Part I: methodological background and large-eddy simulation. J Atmos Sci 63:1151–1178.

Edwards JM, Basu S, Bosveld FC, Holtslag AAM (2014) Impact of Radiation on the GABLS3 Large-Eddy Simulation through the Night and during the Morning Transition. Boundary-Layer Meteorol, to appear.

Met Office FitzRoy Road, Exeter, Devon, EX1 3PB United Kingdom
Tel: 01392 885680 Fax: 01392 885681
Email: john.m.edwards@metoffice.gov.uk