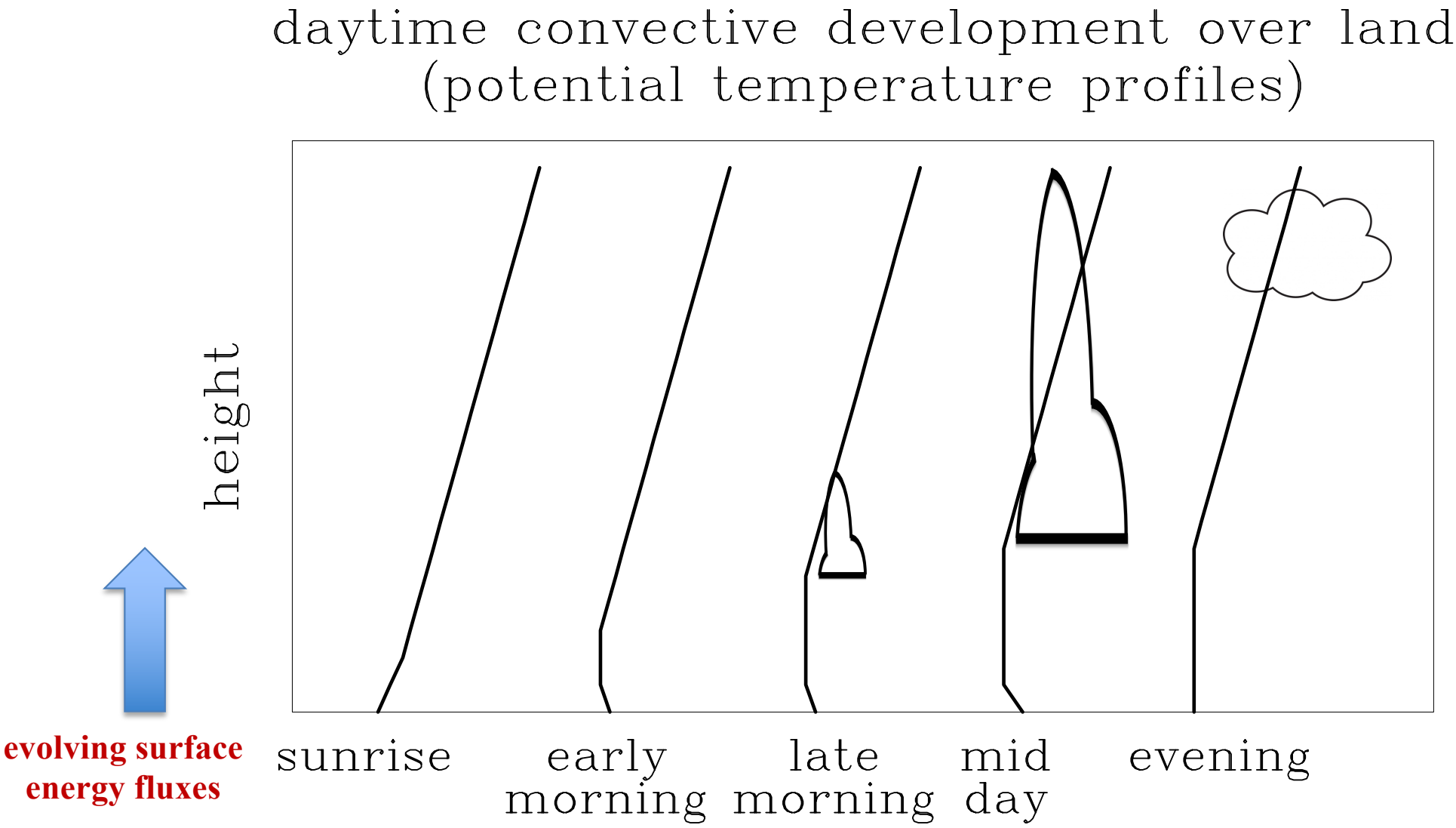
Daytime convective development over land: the role of surface forcing

Wojciech W. Grabowski

MMM Lab, NCAR, Boulder, Colorado, USA

This material is based upon work supported by the National Center for Atmospheric Research, which is a major facility sponsored by the National Science Foundation under Cooperative Agreement No. 1852977.

Diurnal cycle of convection (from dry to moist shallow and deep) is the strongest mode of short-term variability over the tropical, subtropical, and summertime midlatitude continents.



Diurnal cycle of convection (from dry to moist shallow and deep) is the strongest mode of short-term variability over the tropical, subtropical, and summertime midlatitude continents.

This comes from diurnal cycle of solar insolation and relatively low soil heat capacity when compared to the oceans.

Solar energy absorbed at the surface is passed to the atmosphere and drives of atmospheric convection. Soil storage is usually small.

The energy can be passed as either sensible or latent (water) surface heat flux. This talk is about the impact of the partitioning of the total energy flux into its sensible and latent components for the diurnal cycle of atmospheric convection.

Surface buoyancy flux as a function of the surface Bowen ratio:

$\theta_v = \theta(1 + \varepsilon\, q_v)$, $\varepsilon \sim 0.22$, virtual potential temperature

Surface buoyancy flux BF: $BF = \langle w\Theta_v \rangle \approx \langle w\Theta \rangle + \Theta_o \varepsilon \langle w\, q_v \rangle$

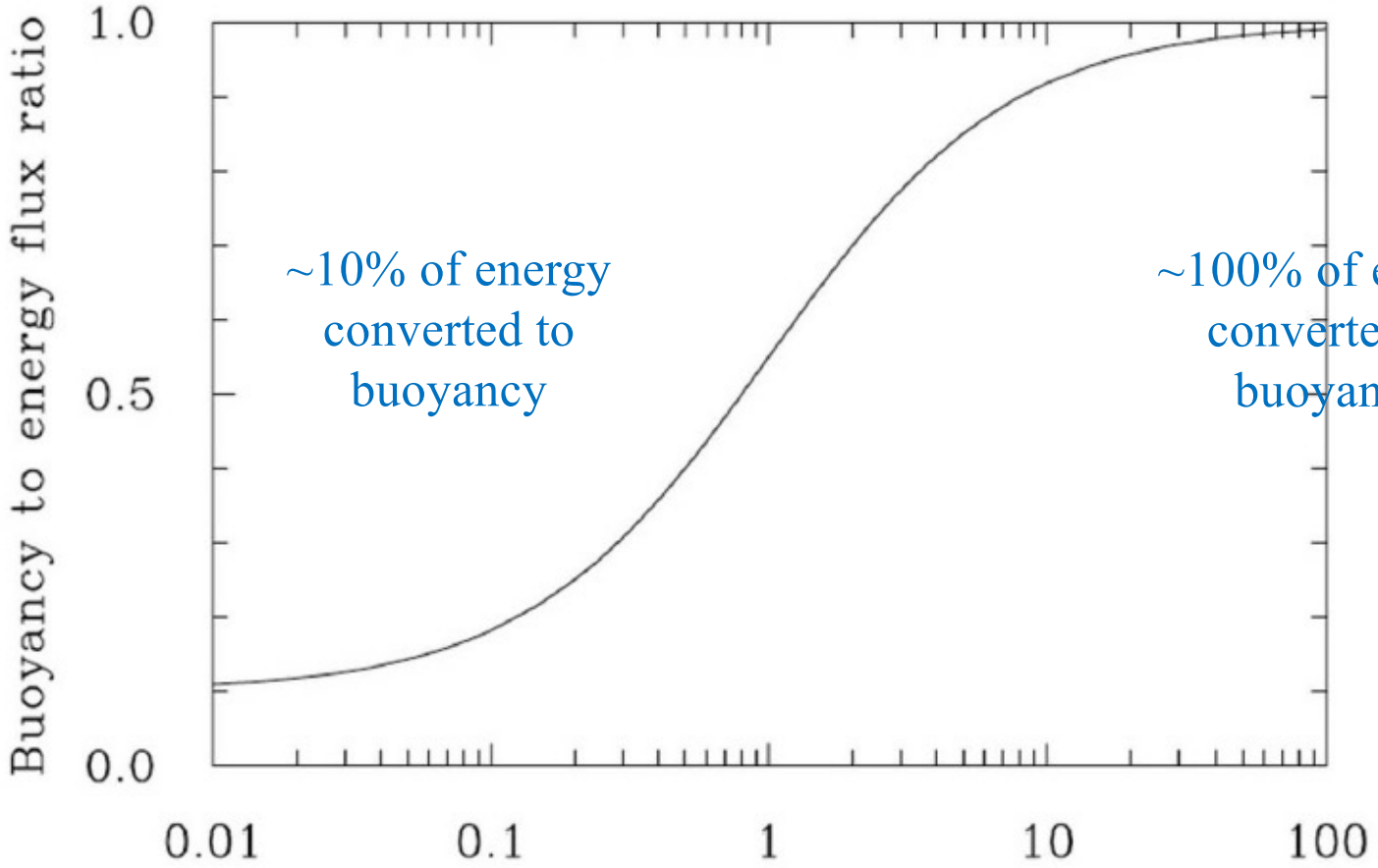
Moist static energy: $s = c_p\, \Theta + L\, q_v$

Surface moist static energy flux EF: $EF = \langle w\Theta \rangle + L/c_p \langle w\, q_v \rangle$

$BF/EF = (\alpha + B)/(1 + B)$ buoyancy to energy ratio

$\alpha = \Theta_o\, \varepsilon\, c_p/L \approx 0.1$

$B = c_p \langle w\Theta \rangle / L \langle w\, q_v \rangle$ - Bowen ratio, sensible to latent heat flux ratio



ocean:
~100 Wm^{-2} latent,
~10 Wm^{-2} sensible

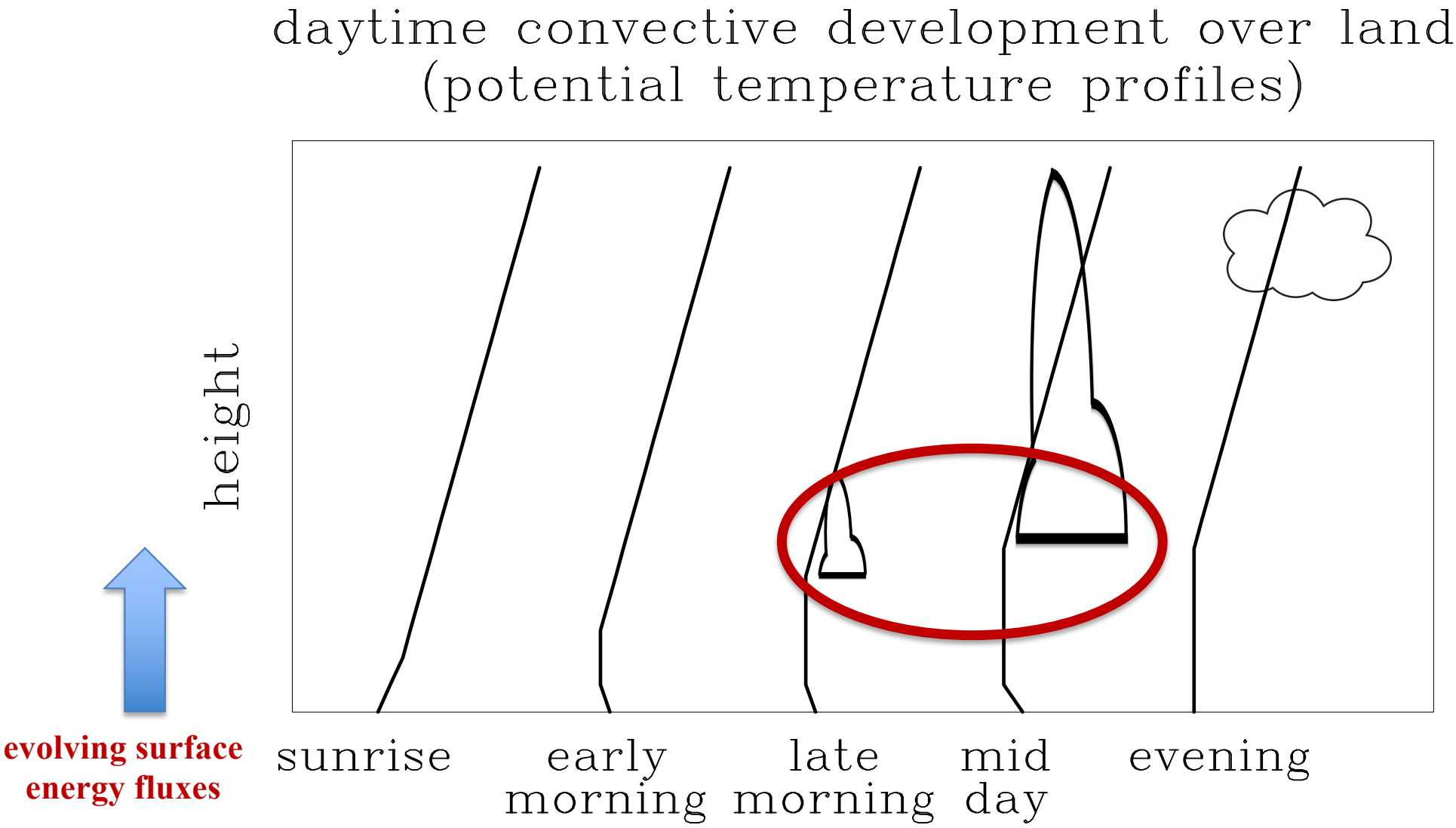
BL a few hundred m deep

desert:
~0 Wm^{-2} latent,
~1000 Wm^{-2} sensible

BL growing to several km deep

Thomas et al. *ACP* 2018

Diurnal cycle of convection (dry, moist shallow and deep) is the strongest mode of short-term variability over the tropical, subtropical, and summertime midlatitude continents.



Shallow convection:

Q. J. R. Meteorol. Soc. (2002), **128**, pp. 1075–1093

Large-eddy simulation of the diurnal cycle of shallow cumulus convection over land

By A. R. BROWN[1]*, R. T. CEDERWALL[2], A. CHLOND[3], P. G. DUYNKERKE[4], J.-C. GOLAZ[5], M. KHAIROUTDINOV[5], D. C. LEWELLEN[6], A. P. LOCK[1], M. K. MACVEAN[1], C.-H. MOENG[7], R. A. J. NEGGERS[8], A. P. SIEBESMA[8] and B. STEVENS[9]

Deep convection:

Q. J. R. Meteorol. Soc. (2006), **132**, pp. 317–344 doi: 10.1256/qj.04.147

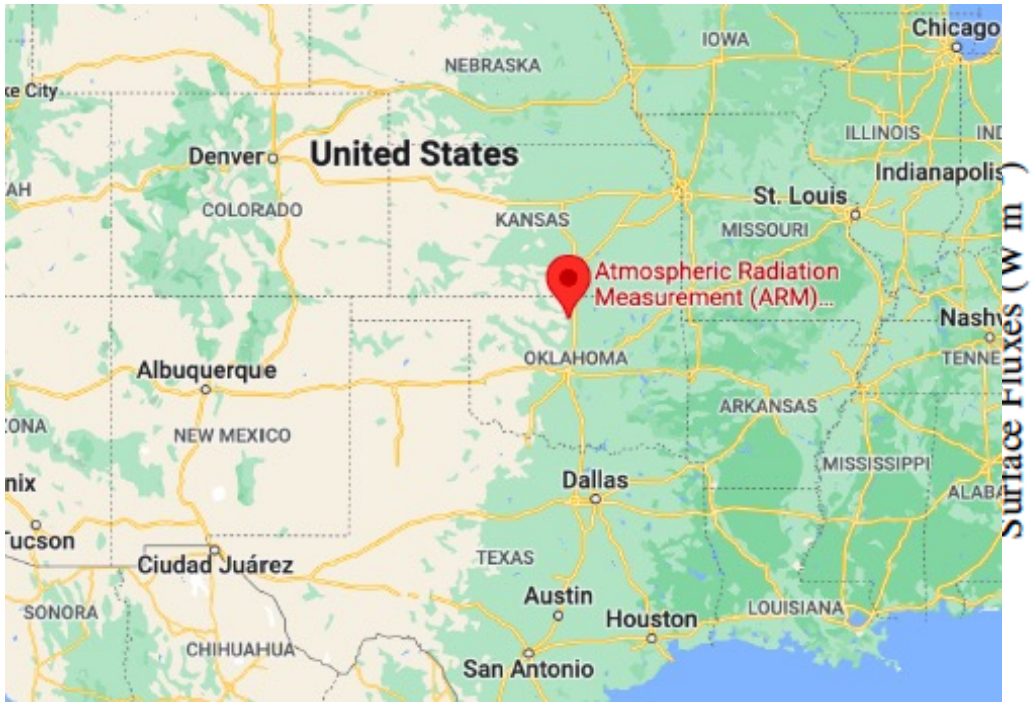
Daytime convective development over land: A model intercomparison based on LBA observations

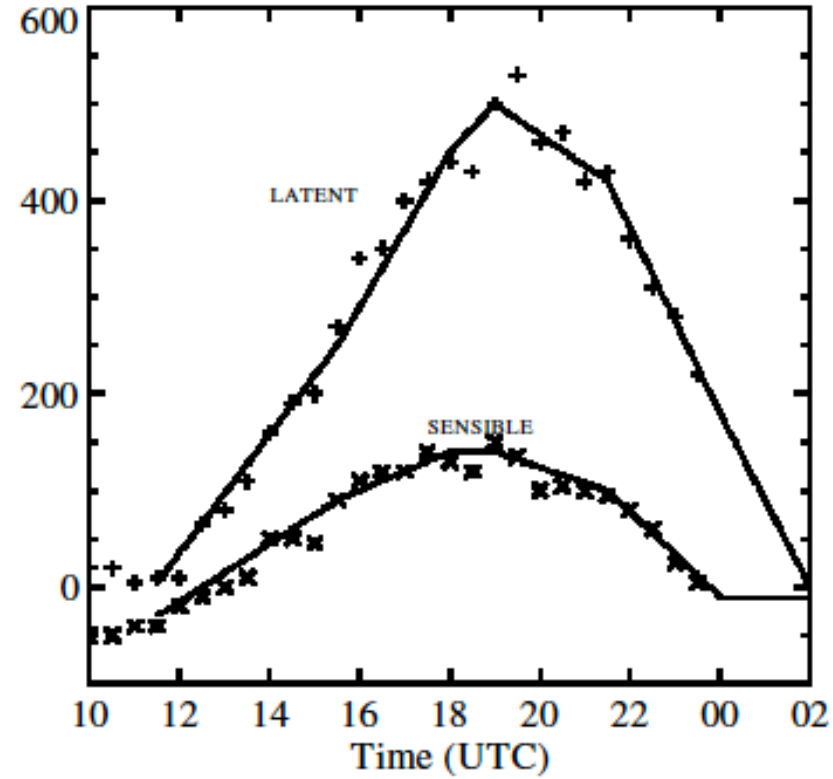
By W. W. GRABOWSKI[1]*, P. BECHTOLD[2], A. CHENG[3], R. FORBES[4], C. HALLIWELL[4], M. KHAIROUTDINOV[5], S. LANG[6], T. NASUNO[7], J. PETCH[8], W.-K. TAO[6], R. WONG[8], X. WU[9] and K.-M. XU[3]

Q. J. R. Meteorol. Soc. (2002), **128**, pp. 1075–1093

Large-eddy simulation of the diurnal cycle of shallow cumulus convection over land

By A. R. BROWN[1]*, R. T. CEDERWALL[2], A. CHLOND[3], P. G. DUYNKERKE[4], J.-C. GOLAZ[5], M. KHAIROUTDINOV[5], D. C. LEWELLEN[6], A. P. LOCK[1], M. K. MACVEAN[1], C.-H. MOENG[7], R. A. J. NEGGERS[8], A. P. SIEBESMA[8] and B. STEVENS[9]



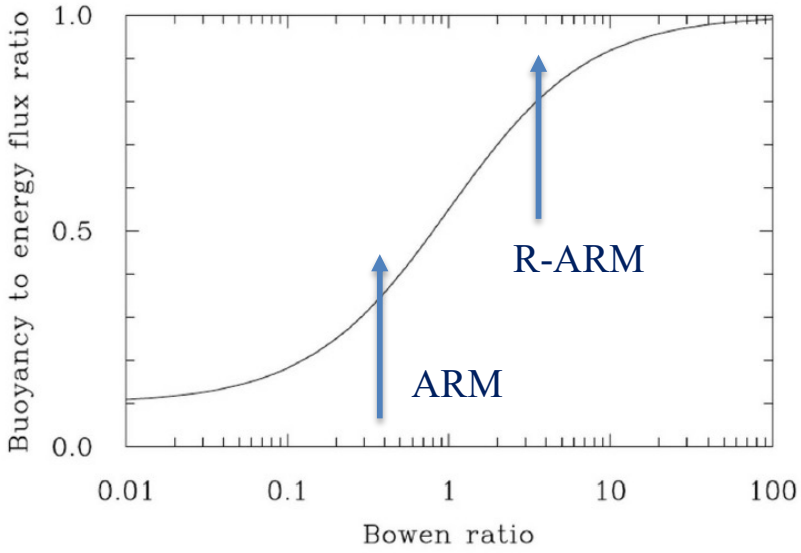


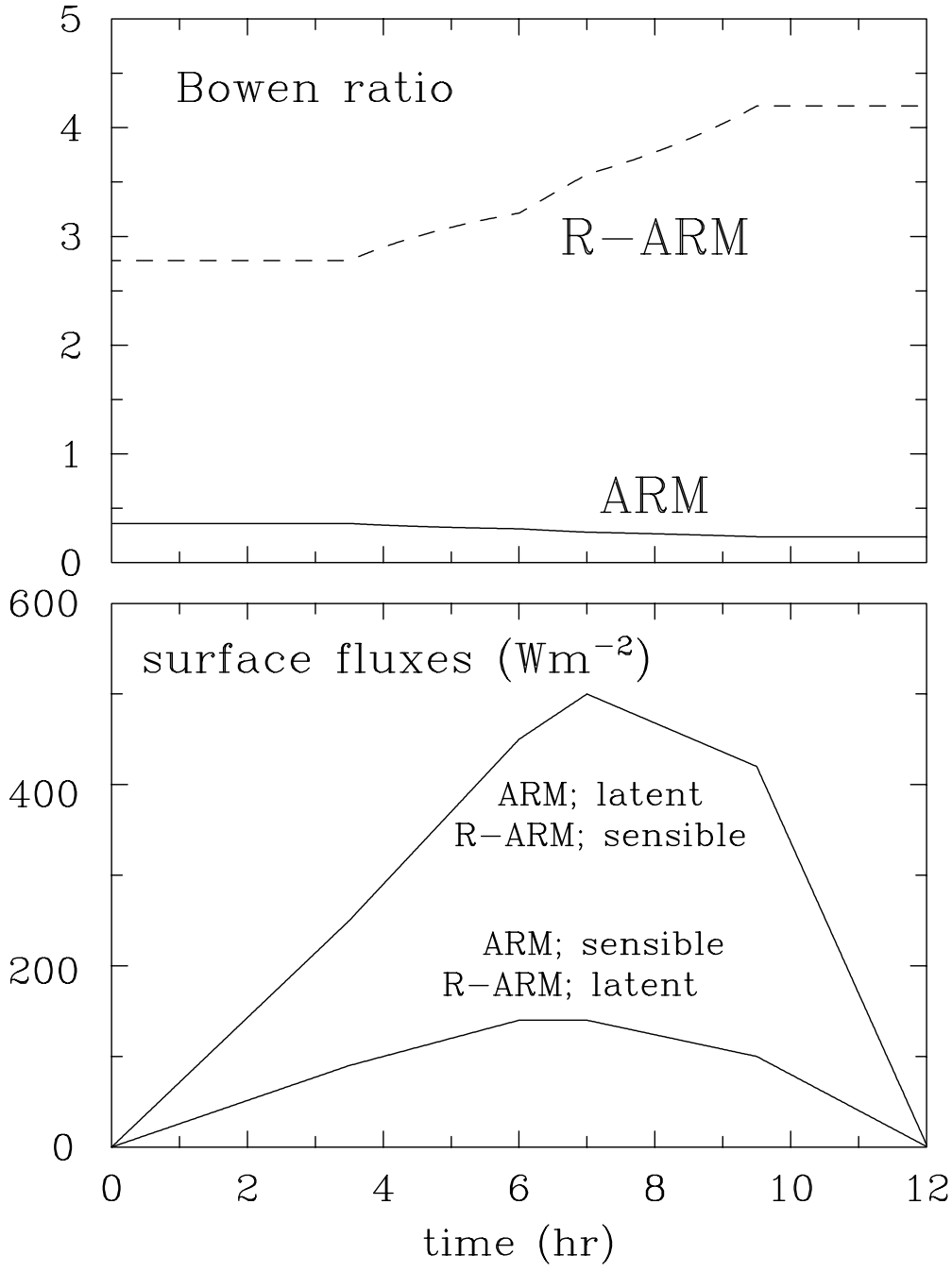
Local time: UTC - 6

The idea: replace sensible and latent surface heat fluxes to illustrate the role of surface forcing:

ARM – as in Brown et al.

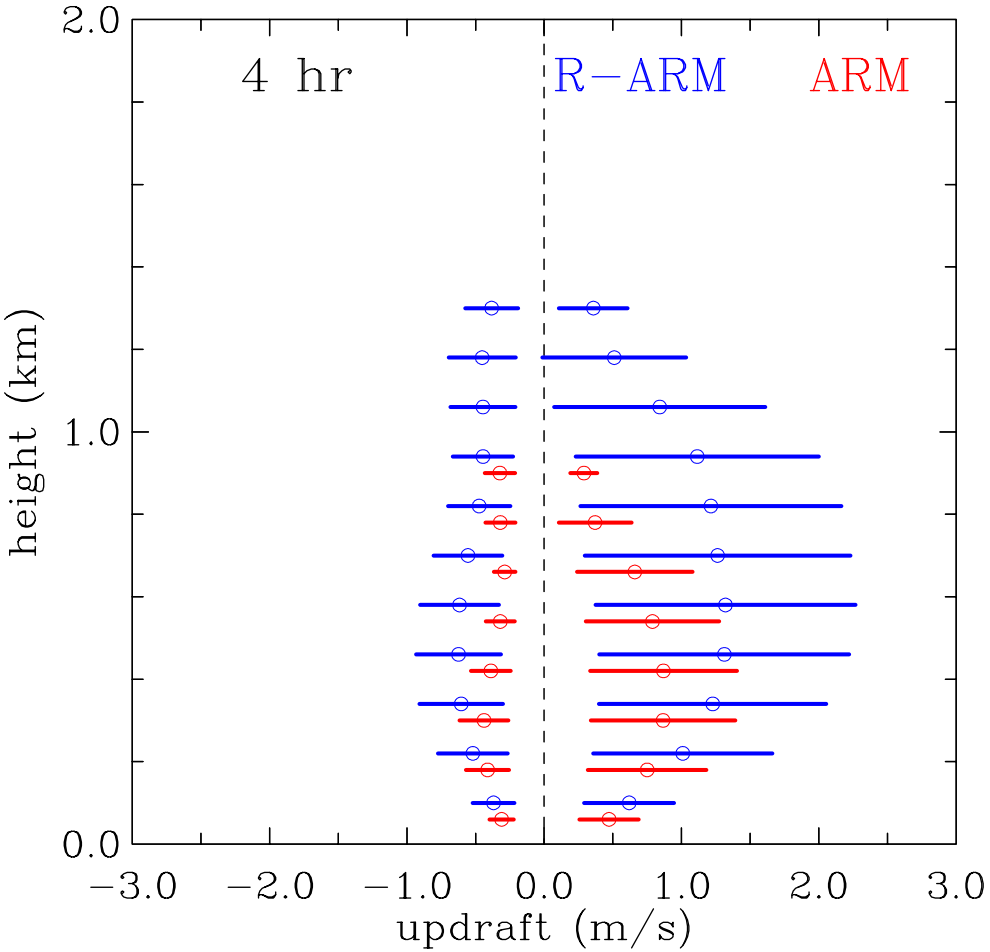
R-ARM – fluxes replaced (latent becomes sensible; sensible becomes latent)

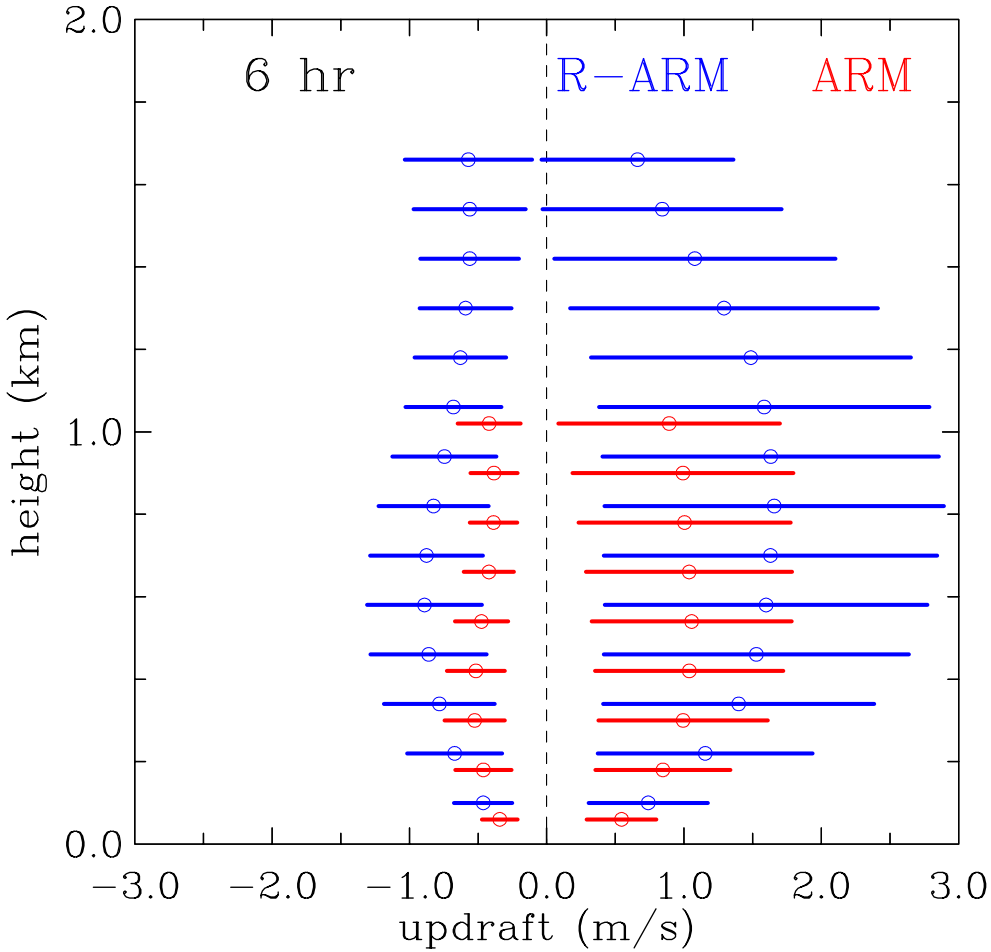




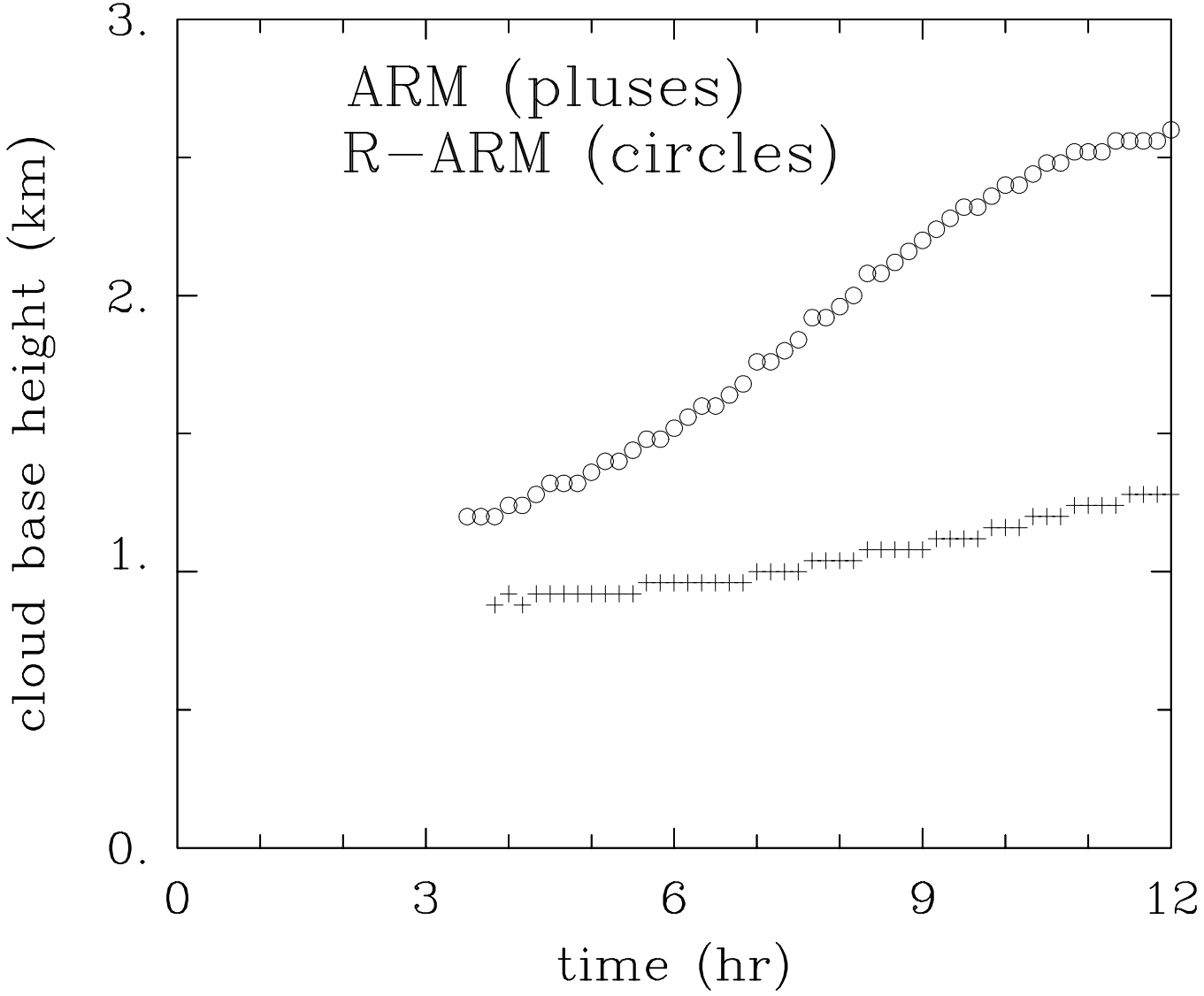
Vertical velocity statistics within convective boundary layer
updrafts: > 0.2 m/s; downdrafts: < -0.2 m/s

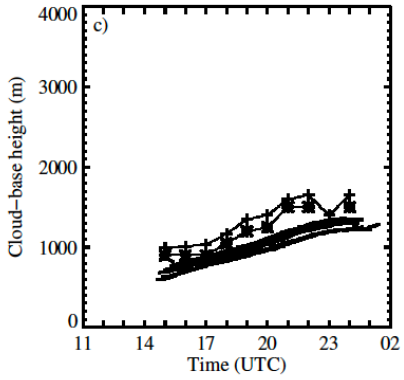
(circle– mean; bar – mean plus/minus one standard deviation)





Evolution of the cloud base height





Summary for shallow convection simulations:

Surface buoyancy flux in morning hours determines the growth rate of the convective boundary layer. Surface buoyancy flux depends on the surface flux Bowen ratio.

Cloud width at the cloud base (i.e., the size of the sub-cloud ascent) seems to increase with the increase of the boundary layer depth.