Review of: AMT-2019-80

"The new BELUGA setup for collocated turbulence and radiation measurements using a tethered balloon: First applications in the cloudy Arctic boundary layer"

Ulrike Egerer, Matthias Gottschalk, Holger Siebert, André Ehrlich, and Manfred Wendisch

This paper presents an overview of a new balloon-borne measurement system for atmospheric boundary layer research with several, modular, component instrument packages. The measurement systems are well documented, and their capabilities nicely demonstrated through presentation of measurements from 3 different Arctic boundary layer cases.

The paper is clear and well written, and should be acceptable for publication with only minor revisions – mostly for clarity or corrections of minor typographical issues. These are documented below.

Detailed comments:

Page 2

Line 11: 'The majority of Arctic clouds is located...' -> 'The majority of Arctic clouds are located...'

Line 14: The phrasing 'In most climate models, turbulent and radiative fluxes in these low altitudes are underrepresented,' is ambiguous. This could mean 'under estimated', ie too small. Or 'poorly represented' - I think the intended meaning is the latter, and should be rephrased to make this clear.

Line 26: '...vertical resolution of typically 45m...' – 'typically' is perhaps the wrong work, imply most frequent. The resolution is instrument dependent, so varies, but is usually a few 10s to ~100m.

Line 29: 'Tethered balloon measurements enable to bridge the gap between surface based and aircraft measurements...' -> 'Tethered balloon measurements enable the gap between surface based and aircraft measurements to be bridged...'

Page 3

With respect to the discussion of UAV and tethered balloon systems in general, the recent paper by de Boer et al. 2018, (doi: 10.1175/BAMS-D-17-0156.1) is a useful reference, covering both tethered balloon and UAV measurements in Arctic Alaska.

Line 11: '...included substantial instrumentation of different research groups...' -> '...included substantial instrumentation from different research groups...'

Line 16: '...new setup are...' -> '...new system are...'

Line 18: '...discussion of limitation and...' -> '...discussion of the limitations and...'

Line 23: '...between the ground and...' -> '...between the surface and...' (pedantic, but your example data is over a sea ice surface, not 'the ground')

Line 26: '...and at light icing...' – 'at' should be 'in' or 'under'

Line 29: 'The packages can be deployed on the balloon considering three main configurations of turbulence and radiation measurements' – slightly awkward phrasing, suggest ' The packages are deployed in one of three main configurations, depending on the conditions and requirements for turbulence and radiation measurements'

Page 4

Line 5: '...to adjust...' -> '...adjustment of...'

Line 9: The quoted 'standard lapse rate' of 6.5 k km^{-1} is rather low, the dry lapse rate is approximately 9.8 K/km (AMS glossary), and at freezing point in just saturated air is 9.968 K/km. The value given here is approximately the wet adiabatic lapse rate. Ideally the wet/dry value should be used in/out of cloud to give most accurate height.

Page 6

Line 18: 'motion of the balloon within the' -> 'motion of the balloon with the'

Page 8

Figure 8 caption: 'measured on the mast in a height of...' -> 'measured on the mast at a height of...'

Line 12: move the value for uncorrelated noise for the balloon out of equation line and into text – as it is, it's easy to miss the value in equation, and text then appears to read that it can be calculated for the balloon, but only quoted for mast.

Page 12

Line 1: '...a slight flatten or...' -> '...a slight flattening or...'

Line 10: 'Finally, the same filter algorithm is...' -> 'Finally, the same filter algorithm was...'

Page 16

Line 24: regarding the averaging time for fixed altitude flux estimates. While the 620s periods is not unreasonable, it may be too short under some conditions. It is worth examining cospectra and ogives curves to evaluate whether all the low-frequency flux contributions are captured, and if not estimate the missing flux contribution. 30 minutes would be long enough to capture all the flux contributions under most conditions, but clearly must be traded off against the available time and number of levels you can sample.

Page 19

Line 21: '...cloud extend for...' -> '...cloud extent for...'

Line 33: in discussion of vertical wind, it is worth noting here that these regions of significant upward/downward motion cannot be mean motions, but the sampling of up/down moving portions of a large, boundary-layer scale eddy. It is notable, however, that their vertical location coincides with the regions of higher/lower horizontal wind. Possibly this too is sampling of a large scale eddy?

A minor issue of phrasing here (and in discussion of standard deviation of w) – the phrase 'wind speed' tends to imply a mean quantity, and thus 'vertical wind speed' seems inappropriate for w, for which simply 'vertical velocity' is perhaps better terminology.

Page 20

Figure 10 caption, last line: 'the cloud extend...' -> 'the cloud extent...'

Page 21

Figure 11 caption. Here and elsewhere I think the term 'terrestrial' to refer to the infra red irradiance is misleading, since much of the infra red budget has nothing to do with the surface. 'infra red' would be preferable.

Add an explicit reference to 'H_B' in the caption for buoyancy flux.

Line 10: the phrasing of "Contrarily to Eq. 9, here the net irradiance is defined as difference between upward and downward irradiance which is required to have a consistent definition of all fluxes and allows a calculation of the energy budget. Therefore, the upward directed net terrestrial irradiance is defined as positive" is awkward. Suggest rephrasing as: "In contrast to Eq. 9, here the net irradiance is defined at the difference between the upward and downward components, and in order to maintain consistency, we define upward fluxes as positive for all fluxes, radiative and turbulent."

Figure 11 and 14 – why do the solar irradiances stop at cloud top, while the infra red values extend above?

Page 22
Line 2 & figure 11. The strong negative buoyancy flux just below cloud top might be associated with entrainment. It is hard, however, to find a physical explanation for a strong upward flux just above cloud top – this might be an artefact of calculating an eddy covariance flux from a slant profile that crosses a strong and changing gradient at the inversion where perturbations from the 'mean' can result from changes in the mean rather than true turbulent fluctuations. I would treat this value with extreme caution.

Page 24
Line 6 – the negative peak in buoyancy flux 'inside the cloud' is located just below the inversion base – again possibly associated with entrainment mixing, though again, calculating a flux from a slant profile across a strong and changing gradient is problematic, and I would want to carefully select the portion of the profile used to stay below the inversion base.