We thank both reviewers for their relevant comments, which helped us to improve the manuscript.
Below is a copy of their comments (in italic belw), with included answers to each point.
References are made to the revised manuscript.

Reply to comments made by Reviewer 1

The authors should consider combining Sections 2 and 4. The observations provide a way of illustrating the various transition periods that are defined in Section 2 and I found it difficult to comment on Section 2 without referring to the plots described in the figures accompanying section 4. The Section on the sites and instruments would not be affected by combining these two sections.

We have wished to clearly separate section 2 from section 4:
Section 2 is focused on past results (reviewing and discussing the afternoon transition issue, based only on past studies), and section 4 is focused on the potential of BLLAST dataset (illustrating BLLAST dataset and its potential to address those issues).

From Reviewer 1 comment, we realized that this was not very clear in the manuscript. Thus we made it clearer in the revised version.

The paper outline, including the difference between section 2 and 4, is explained at the end of section 1. And we stressed on the role of section 2 in a short introduction of this section.

Section 2 The addressed issues.

1. Figure 8 shows that the afternoon transition lasts from 5 to 8 hours. This is a large proportion of the daylight hours and so it is not clear that it is appropriate to consider this a transition period, it should probably be considered as being the convective boundary layer, albeit with a decreasing heat flux. Figure 12 shows the TKE decreases gradually (after 1500 UTC). An important question is whether this decrease can be considered to be a quasi-steady response to the decreasing surface buoyancy flux, i.e does the TKE continue to scale with the convective velocity scale after 1500 UTC. If it does this period can be considered as a convective boundary layer that is evolving quasi-steadily rather than a transition period.

It is true that the period that we are considering is quite long. By definition actually, the time from maximum surface heat flux to zero flux corresponds to a long period. But that is the period that we wish to consider for our study, in order to investigate the evolution of turbulence with decreasing flux. Since one of our questions is whether the evolution is gradual, we are interested not only around the sunset, but also several hours before. Therefore, we have decided to adopt definitions used in previous studies. (In the revised version, we improved the definitions given in section 2, clarifying those given in past studies).

Is it legitimate to call the afternoon BL behaviour a “transition”? Originally Grimsdell and Angevine (2002) chose this term to call attention to the inadequacy of the idea of “collapse” of the boundary layer and/or of turbulence near the surface, at or near sunset. The questions arised by Grimsdell and Angevine had to do with whether the transition was gradual or sudden, whether it originated at the surface or aloft, and when. From a boundary-layer-top perspective, they found that the transition was gradual and started at the top, often several hours before sunset.

Whether the CBL remains quasi-steady and typically scaled with with convective (e.g. Deardorff) scaling, and for how long, is a very relevant question that falls among the BLLAST objectives. We do not intend to fully answer it in this article, but to show why it deserves to be raised. We have improved the discussion about this important question in the revised text, and added a figure (Fig. 12b) that partly addresses it (see further in this reply).

In the revised manuscript, we added those two relevant questions in section 2.

2. The late afternoon transition is defined to be when the '... vertical structure starts to decouple ...'. This definition comes from remote sensing and is illustrated in Fig 10. for three days. However, from the plots I wasn't certain when the decoupling took place. My guess is that the LAT starts around 1600 UTC. However it is difficult to be sure what the significance of the decrease in the depth of the darker colours actually means. A simple quasi-steady reduction in the TKE might also look like this. A more precise definition of the LAT as shown by Figs 10a-c should be given.

We agree that the LAT definition was somewhat too vague here. The goal was to distinguish the definition based on the deceasing surface flux, and that based on the boundary-layer top behaviour discussed in point 1 above. We have modified the text in section 2 to make the definitions clearer and all based on previous studies.

Additionally, we have removed the LAT definition, as there is no specific definition of the so-called "late afternoon" in the literature. Also, we avoided mixing definitions from previous studies, with definitions that we consider in section 4 for our overview analysis.
We therefore used only AT and ET terminology in section 2, and most of section 4. We precise the LAT later in the revised text.

Figure 10 is discussed in section 4 only, and should not be discussed in section 2 yet. "Decoupling" may not be the appropriate term here, and it is true that the term is not accurately defined. We have modified the text accordingly.
We meant that we observe a separation between the top inversion detected by the profiler, and an isoline of dissipation rate estimate found close to the top in midday. If not "decoupling", at least one can see a top-down evolution of the decrease of dissipation on some days in BLLAST (1st of July is a good example), as also found by Grimsdell and Angevine 2002. Several days show it clearly in our dataset, and this will be further analyzed in future studies.
We have improved the color-scale of Fig. 10 to have the lower values of dissipation rate better emphasized.

The figures below show this top-down decay of dissipation rate more clearly.

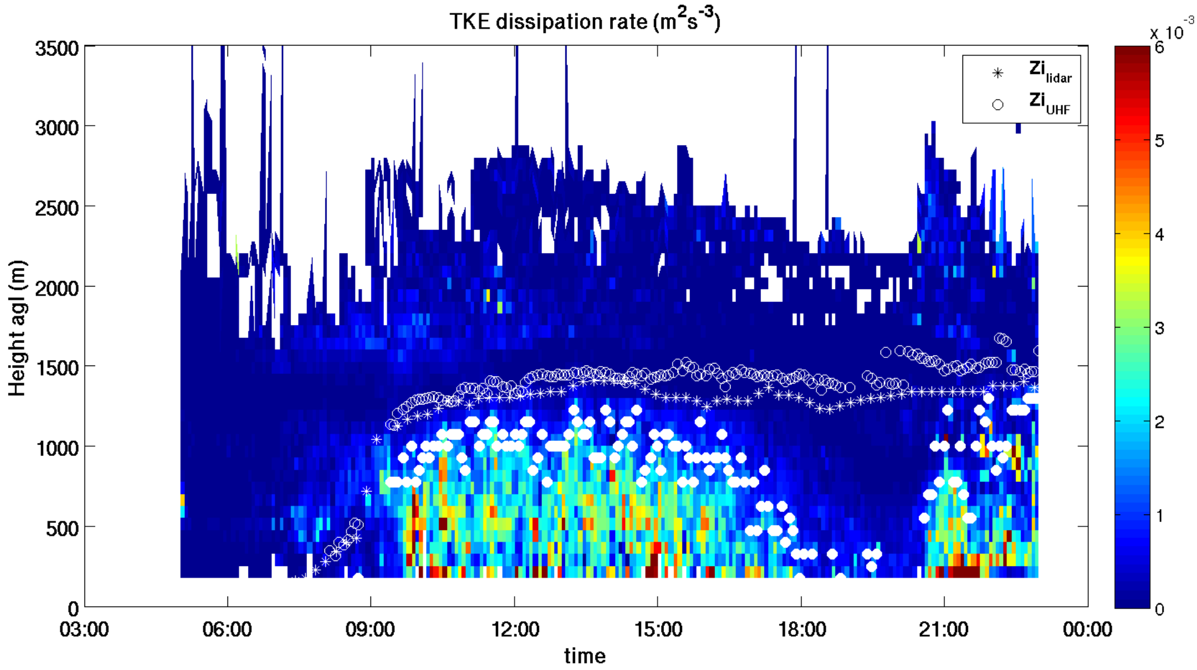

Figure A. Height-time section of the dissipation rate estimated from UHF wind profiler on 1st July 2011. The white dots indicate the first level down from Zi that has dissipation rate larger than 10^{-3} m^2s^{-3}. Estimates of Zi (white crosses and circles) are based on lidar backscatter or UHF profiler reflectivity data.

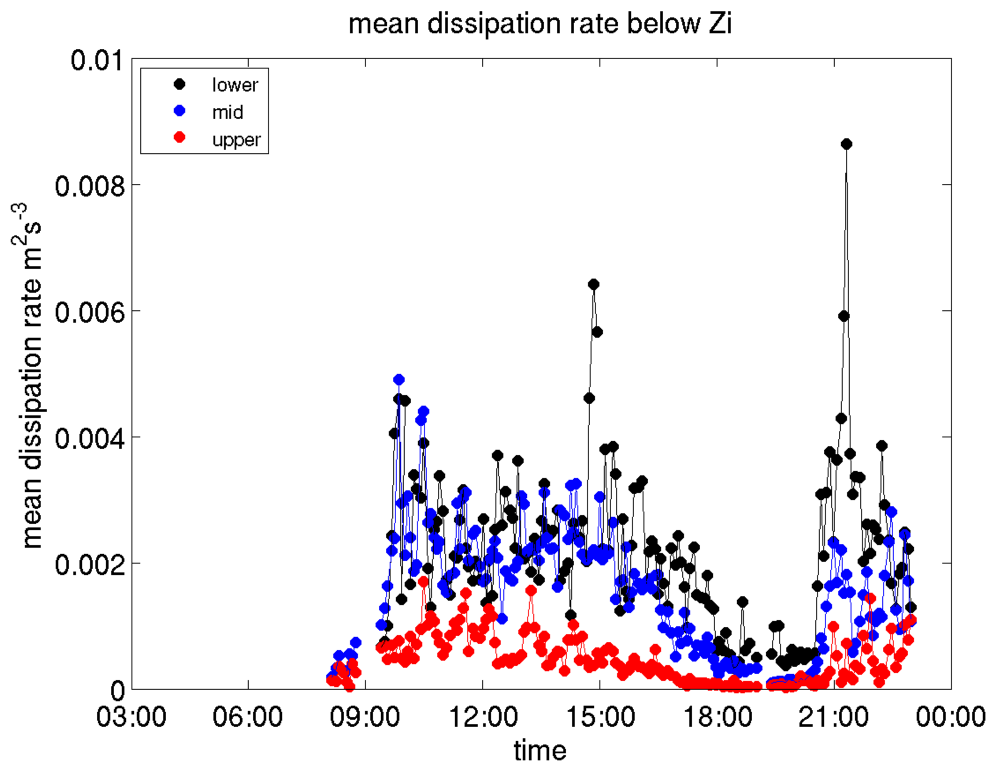

Figure B. In this figure, each profile of TKE dissipation rate from the day shown in Figure A is averaged over height within three layers: (black) 0 to Zi/3, (blue) Zi/3 to 2/3 Zi, and (red) 2.3 Zi to Zi. It is clear here that the upper dissipation rate is starting to decrease earlier at upper level.

Comments on Section 4. Potential of the BLLAST dataset.

1. Page 10812 line 13 : It would be useful to say something more about the heat fluxes on the warm days. Figure 7c suggests that there is a substantial flux into the ground (particularly noticeable over night) which reduces the available energy and therefore the sensible heat flux.

Small sensible heat fluxes for those days do not correspond to larger ground flux, but larger latent heat flux. That is, the warmer the air along those days, the smaller the super-adiabatism close to surface and the smaller the sensible heat flux. Due to the soil moisture available in the ground, this leads to larger latent heat flux (Fig. C).

Fig. C shows that on the moor, corn and grass sites, the 100 W m^{-2} decrease of sensible heat flux observed on the 27th compared to the 24th, is actually balanced by a 100 Wm^{-2} increase of latent heat flux between those two days.
As shown in Fig. D., the flux into the ground is not significantly different during those days, due to the large availability of moisture in the soil.

We decided to add the series of latent heat flux in former Fig. 7 (now split into two figures, Figs 6 and 7*) of the revised manuscript.

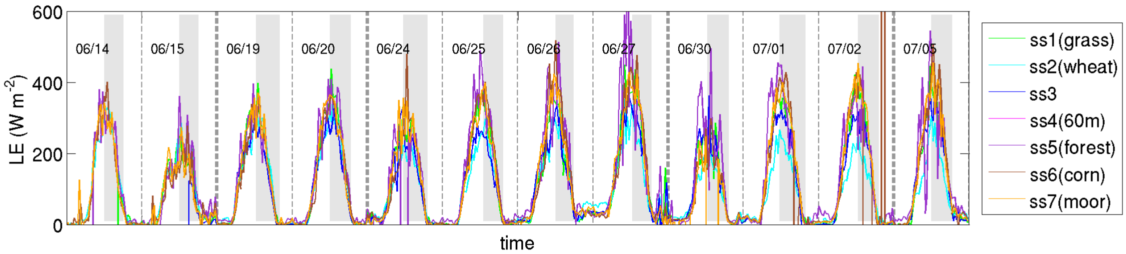

Figure C: Latent heat flux during BLLAST IOP days.

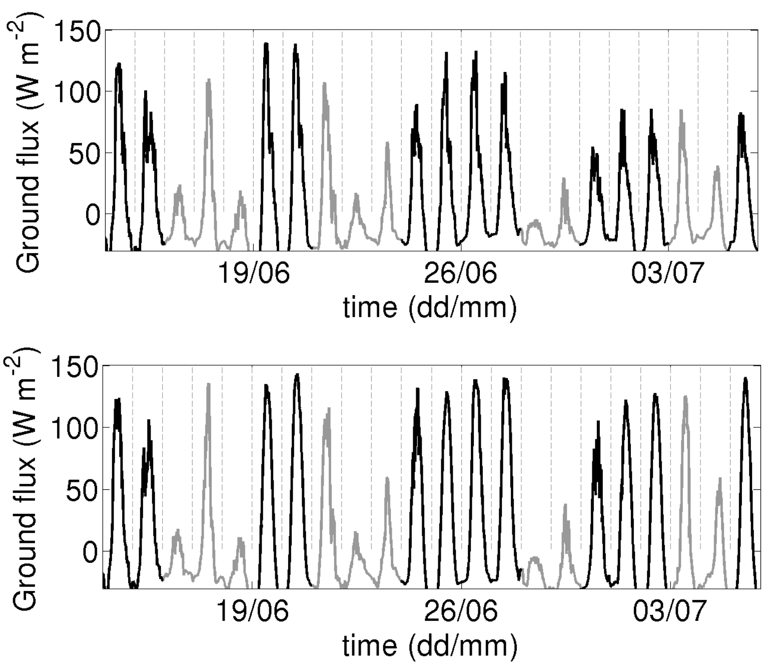

Figure D: Ground heat flux at corn site (upper panel) and at moor site (bottom panel). BLLAST IOP days are indicated in black.

* Note that former Figure 5 has been removed in the revised version, following the suggestion of Reviewer 2.

Note that for this period, we found smaller potential temperature jump at the top of the CBL, revealing stronger subsidence (that would then imply larger entrainment velocity), which is consistent with the forecast model large scale vertical velocity estimates. In addition to that, there is less wind shear at the CBL top for those days.
We have enlarged the discussion regarding this aspect in section 4.1.3.

2. Page 10813 line 1: The paper says that the boundary layer was particularly shallow on the warm days. However, Fig 7e suggests that the maximum depth of the boundary layer during the warm period were generally similar to those on the other days (maybe shallower on 25th). The statement needs to be clarified.

Former Figure 7 has been improved in order to better show the evolution of the variables: we have extended width and aspect ratio of each sub-panel. The space between the IOP days has been reduced. As we added the series of latent heat flux, we also split the figure into two figures (Figs. 6 and 7 in revised version), each of which has 3 sub-panels.

We do find smaller CBL depth for those warm days in average, even if the CBL top does reach 1000 m during a short time on the 26th and 27th.

3. Section 4.1.2 : Figure 8 shows that the length of the AT is generally very long, and occupies a significant fraction of the daylight hours. Is it really correct to term such a period a transition period. Should it really be taken to be the convective boundary layer in the afternoon. It needs to be shown that the properties of the boundary layer are significantly different to what might be expected for a convective boundary layer through this period.

See our answer to comment 1 above.

4. Page 10815 line 10-15 : I don't understand what decoupling refers to. There do not appear to be any particular changes in behaviour of the dissipation rate in Figs 10a and b between 1400 and 1600. The period between 1600 and 1800 could be interpreted in terms of a reduction in dissipation which the colour scale turns into an apparent decoupling between the turbulent layer and the inversion. The significance of these changes needs to be discussed in more detail

See our answer to comment 2 above.

In both Fig. 10 a and Fig. 10b, the dissipation rate clearly decreases first at the top, then in lower layers. If not "decoupling", we do observe a “top-down” decay, i.e. the decrease of turbulence dissipation rate starts first close to the top during those days.

5. Page 10815 Para starting line 17. The profiles in Fig 11b for the 1 July look like a convective boundary layer exists until 1800 UTC when the evening transition starts. There doesn't seem to be anything strange occurring during the LAT apart from a small decrease in the height of the inversion. However, this is probably could just be a consequence of the reduced entrainment *due to the reduced surface flux. How the evolution of these profiles differs from this quasi-steady view should be made clear.*

The goal of this classification is to describe the conditions encountered during the field campaign, and separate in main groups of days, according to the evolution of the CBL along the day.

The fact that the mean profiles remain typical of well-mixed convective layer is not incompatible with a change of the turbulence structure during this period. (It is very difficult to determine from mean profiles alone whether the layer is in fact currently being mixed by turbulence.)
That is one question that we wish to address with BLLAST dataset.

6. Page 10816 Para starting line 3. I don't understand how the boundary layer depth could be estimated at 1km (Figure 10c) from the profiles in Fig 11c. I would say it was around 500m for most of the time. The structure on this day and the estimates of boundary layer depth need more discussion since the structure is very different from that of the classic convective boundary layer.

According to the soundings and UHF wind profiler (the aerosol lidar was not functioning that day), the PBL depth did reach 1 km in the afternoon (around 1330 UTC), but started to decrease shortly after (around 1400 UTC).
Figure E below shows the evolution of the PBL depth estimates, based on various criteria, from SUMO, radiosounding and UHF profiler measurements. All the estimates agree showing that the CBL grew up to 1 km, and rapidly decayed afterward. The strength of the decrease varies with the criteria and measurements used.

This is visible in former Fig 7e (now Fig. 7c), but was not clear in the manuscript. We have improved former Fig. 7e (now Fig7c), extending its width and aspect ratio, in order to better show this evolution.
In Fig. 11c, we had previously selected a few soundings among those that were available (10:50, 12:30, 14:10, 15:30, 17:00, 18:30, 20:10 UTC – that is one from site 1, six from site 2), to show the evolution. In the revised version, we have now selected a different set of soundings to show this evolution more clearly (10:50, 13:30, 14:10, 15:30, 17:00, 18:30, 20:10 UTC – that is two from site 1, five from site 2).
Putting all the soundings on the figure would make it overloaded.

Note that we have slightly edited Figs. 11a and 11b as well (title with more standard data format, 'UTC' label added in Fig. 11a).

This day (26 June 2011) is indeed peculiar: very warm, small buoyancy flux at the surface, large ground flux, small turbulent kinetic energy amount in the CBL, kind of collapse of the CBL. The very warm air of the whole troposphere, with small super-adiabatism, small surface buoyancy flux, is at the origin of the poorly-convective conditions of this day (as well as 27 June, and partly 25 June).

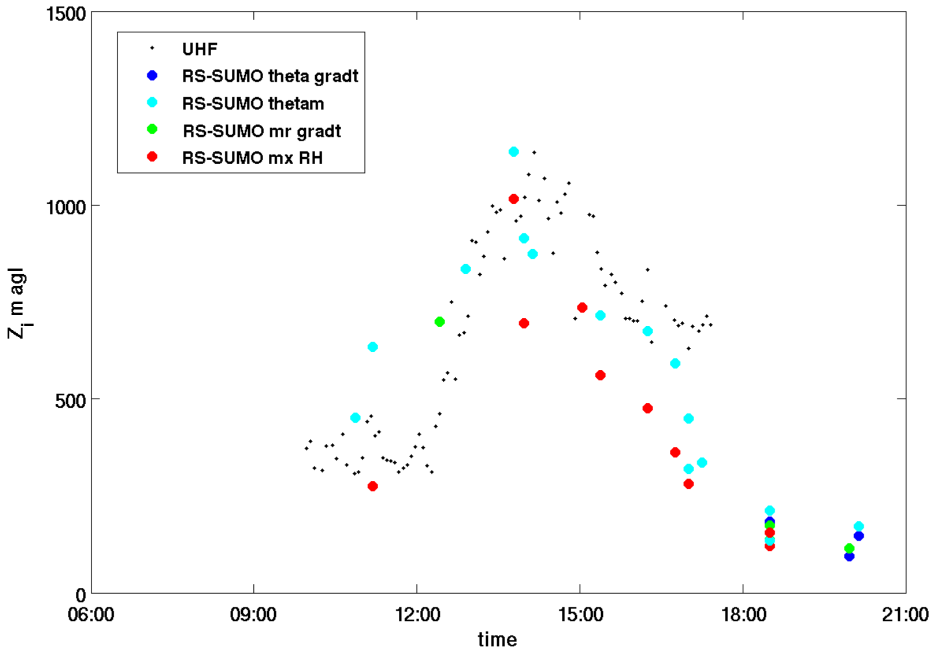

Figure E: Estimates of Zi from various criteria and instruments for 26 June.

7. Page 10816 Para starting line 9. The difference between groups 1 and 2 is the stratification of the residual layer. Since the difference in the growth of the boundary layer seems to be simply explained by this stratification a more interesting question is where does this stratification come from. The profiles for 24/06 show some stratification in the early evening profiles, is this the origin of the difference. Grant (1997) also found stratification developed during the LAT/ET.

The objective of this section was to give an overview of the various PBL growth behaviours that the field experiment sampled. The stratification of the troposphere in the early morning or preceding night is of course a key factor. We have added a sentence to underline this aspect in section 4.1.3.
Note that on 24 June, we do not have soundings in early morning or previous night.

8. Page 10817 Para starting line 11. During the initial slow decay does the TKE scale with the convective velocity scale. If so the first part of the AT can be simply described in terms of the quasi-steady evolution of the boundary layer in response to the decreasing surface heat flux. This would reduce the significance of the AT.

For the three first hours of the AT, the TKE does seem to scale with the convective velocity scale. During the slow decay phase (around 15 UTC), it starts to depart from this scaling, as shown in Figure F below (dark grey shaded area). We have compared this scaling to the typical representation used (TKE/ $w*_0$), which does not take into account the evolving convective velocity scale.
We have added this figure in the revised manuscript (Fig. 12b), because it does address the question of quasi-steadiness, at least in the surface layer. We discuss it in section 4.2.

In Figure G below, we have also plotted the normalized TKE as a function of normalized time. This figure is a little difficult to read, because time is not monotonically linked with the reduced time t'/t*. But this figure shows that we cannot scale the TKE decay only based on the convective scaling.

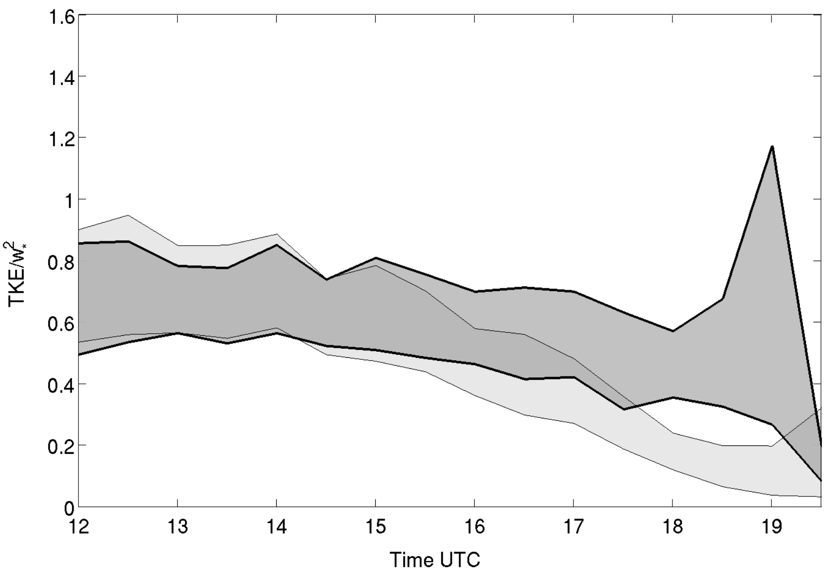

Figure F: Evolution of reduced TKE over the afternoon for all IOP days over 5 different surfaces. The shaded areas represent the quartiles from 25% to 75% of surface estimates. The dark grey shaded area corresponds to TKE/w, and the light grey shaded area corresponds to TKE/w*$_0$, where w*$_0$ is the convective velocity scale at the time of maximum buoyancy flux.*

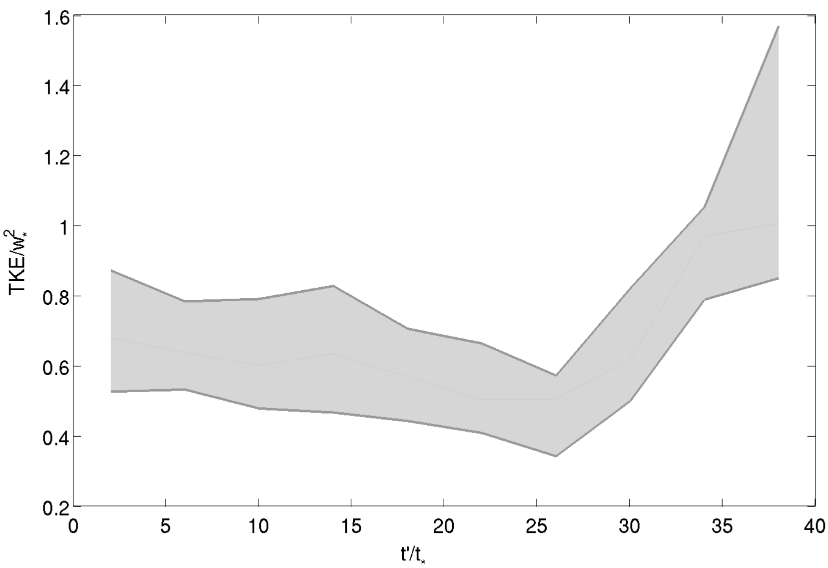

Figure G: reduced TKE over the afternoon for all IOP days over 5 different surfaces versus reduced time. t is the convective timescale, and t'=t-12h. The shaded area represents the quartiles from 25% to 75% of surface estimates.*

9. Page 10817 Para starting line 22. It would be useful to see the average time variation of the heat flux from at least one of the sites to see whether the onset of the rapid decrease of TKE corresponds to anything in the heat flux. It might also be worth marking the approximate times of the start of the LAT and ET on the plot.

We do not find appropriate to add either the surface flux evolution or the timings of start and end of the AT on this figure, because of their very large variability from one surface to the other, and from one IOP to the other.

However, we have considered in BLLAST dataset analyses how the TKE decay was in phase with the surface heat flux decay. This is partly shown in figure H. The coefficient indicated in the X and Y axes is equivalent to the power coefficient of the time evolution (TKE ~t^n). The main results are that when the surface flux starts to decrease (blue surrounding oval), the TKE does not change much, then the TKE starts to slowly decay (first slow phase with n=-2 in Nadeau et al. 2011) -(green surrounding oval), and after the inflection point of the surface flux, the TKE sharply decays (corresponding to the rapid phase with n=-6 in Nadeau et al. (2011)) -(purple surrounding oval).

In the overview paper, we do not intend to go into details of this analysis. But we have added a discussion of this aspect in the revised manuscript (section 4.2).

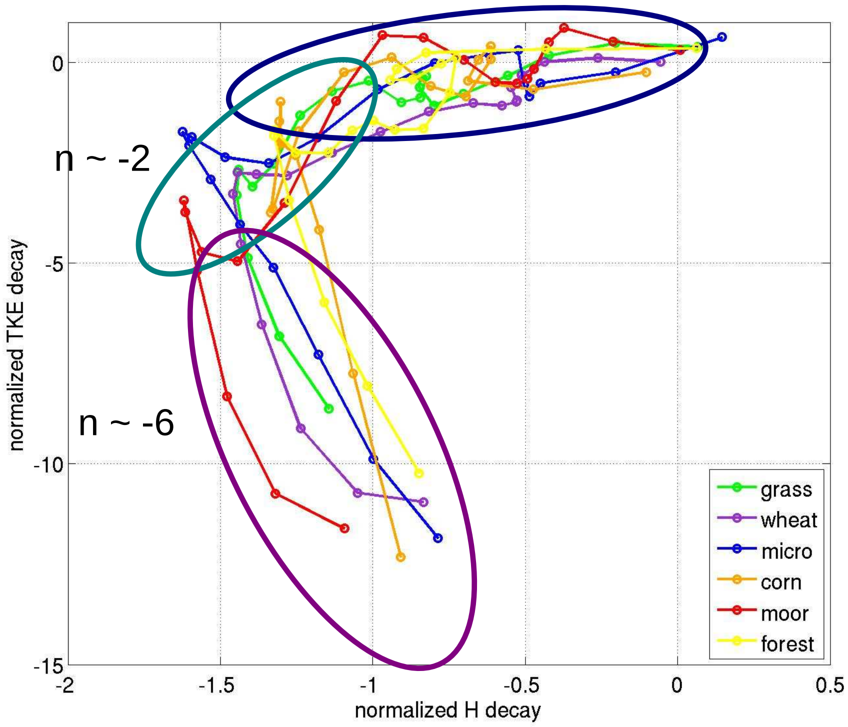

Figure H: decay rate of the TKE as a function of the decay rate of the sensible heat flux (power law coefficient of the decay).
To take account of all surfaces and IOPs, both have been normalized around a normalized time (t=0 when H is maximum, and t=1 when H is zero).

10. Figure 10c. It would be useful to alter the colour scale to show the evolution of the turbulence more clearly.

Fig 10c has been improved with darker colour for low dissipation rates, and altitude restricted to 2 km.

Reply to comments made by Reviewer 2

1. It is not very clear why the location near the Pyrenees was selected for the experiment? It is probably due to practical and logistical reasons. The problem with this location is that it consists of complex terrain with height variability and heterogeneous vegetation cover. No doubt it will induce a complex meso-scale flow with its own diurnal cycle which will be difficult to disentangle from the evening transition. Meso-scale and LES models will help but also in these models it will be a challenge to prescribe a boundary condition, that is realistic and does justice to the variability in momentum, heat and moisture fluxes. The current manuscript is glossing over this issue, but it would be good to dedicate more discussion to this point, because I feel that a strategy is needed to handle the effects of meso-scale variability.

In synoptically forced regimes, with significant wind, the topography naturally produces a strong complex forcing to the PBL processes.
In weak-wind synoptic conditions, which were the conditions of most of the BLLAST cases, the diurnal cycle that is imposed by the presence of nearby mountain generates very calm conditions during the late afternoon and evening, that are actually quite favourable to the AT study. Of course the diurnal cycle of the low level wind and the associated wind reversal needs to be considered with the transition processes.
Jiménez and Cuxart (2014a, 214b) have studied the wind reversal and influence of the Aure valley south of the Plateau: downslope winds are generated in the Aure valley and the air accumulated in the bottom of the valley generates down-valley winds. The later reach Lannemezan a few hours later, around 2100 UTC in the simulations. The large-scale advection during the evening are found smaller than during the central part of the day/night when upslope/downslope winds are present.
The large-scale subsidence might also show a diurnal cycle, according to previous studies (Whiteman, 1990) and to the first analyses of BLLAST dataset.
Several studies have started to address those issues and take account of the large scale forcing that is partly due to the influence of the mountains nearby (Blay-Carreras et al., 2014a, Pietersen et al., 2014, Darbieu et al. 2014).

We have added more discussion relative to this aspect (section 4.1.1 and 4.1.3).

2. Fig. 5 is nice, but perhaps not all that informative and therefore not necessary.

Figure 5 has been removed from the manuscript.

3. Fig. 7 is an important figure because it documents the meso-scale variability in surface fluxes. Unfortunately, the figure is too small and the individual lines are impossible to distinguish. Also the legend is difficult to read. I also suggest to have the same stations for all panels (except perhaps e), i.e. have solar radiation and wind also for the other stations.

Figure 7 (now Figs. 6 & 7) has been extended in width, and the space kept for the time of non-IOP days has been reduced to just a line separating the days, with thicker line when non-IOP days are skipped.

We have added other stations for the wind speed and wind direction, even if it is quite similar over the various surfaces.

Superimposing the measurements of the downward solar irradiance did not make much sense to us. One can see from just one station whether a given day was clear or had some cumulus clouds.

4. In Fig. 9, the thick black lines can be distinguished form the other lines, but the thick and thin grey lines look too similar.

Figure 9 has been put in colour for more clarity.

References

Blay-Carreras, E., Pino, D. Van de Boer, A., De Coster, O. Darbieu, C. Hartogensis, O. Lohou, F. Lothon, M. Pietersen, H. Vilà-Guerau de Arellano, J.: Role of the residual layer and large-scale subsidence on the development and evolution of the convective boundary layer. Atmos. Chem. Phys., 13, 31527-31562, 2014.

Darbieu, C., Lohou, F., Lothon, Vilà-Guerau de Arellano, J., Durand, P., Blay, E., Pino, D.: Turbulence vertical structure of the boundary layer during the late afternoon transition, in preparation for Atmos. Chem. Phys. Discuss., 2014.

Grimsdell, A. W. and Angevine, W. M.: Observations of the afternoon transition of the convective boundary layer, J. Appl. Meteorol., 41, 3–11, 2002.

Jiménez, M. A. and Cuxart, J.: A study of the nocturnal flows generated in the north side of the Pyrénées, Atmos. Res., 145-146, 244-254, DOI: 10.1016/j.atmosres.2014.04.010, 2014a.
Jiménez, M. A. and Cuxart, J.: Downslope and down-valley winds during the BLLAST'11 campaign, In preparation for Atmos. Chem. Phys. Discuss., 2014b.

Pietersen, H. P., Vilà-Guerau de Arellano, J., Augustin, P., de Coster, O., Delbarre, O., Durand, P., Fourmentin, M., Gioli, B., Hartogensis, O., Lothon, M., Lohou, F., Pino, D., Ouwersloot, H. G, Reuder, J., and van de Boer, A.: Study of a prototypical convective boundary layer observed during BLLAST: contributions by large-scale forcing, submitted to Atmos. Chem. Phys. Discuss. 14, 19247-19291, doi:10.5194/acpd-14-19247-2014, 2014.

Whiteman, C. D.,: Observations of Thermally Developed Wind Systems in Mountainous Terrain. Chapter 2 in Atmospheric Processes Over Complex Terrain, (W. Blumen, Ed.), Meteorological Monographs, 23, no. 45. American Meteorological Society, Boston, Massachusetts, 5-42, 1990.