Measurements with the UAV SUMO during BLLAST, COST-STSM-ECOST-STSM-ES0802-130611-009043

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1 Introduction

This COST Short Term Scientific Mission (STSM) was performed in the framework of the field campaign 'Boundary-Layer Late Afternoon and Sunset Turbulence' (BLLAST) through the COST Action ES 0802. The target of BLLAST was to investigate the transition between the daytime convective boundary layer and nighttime stable boundary layer. While these atmospheric regimes are considered relatively well understood the knowledge on the transition between the two is rather poor. During the campaign a vast range of meteorological instrumentation platforms was utilized, spanning from conventional weather masts, towers, radar units to manned aircraft and Unmanned Aerial Systems (UAS).

1.1 The UAS SUMO

The small unmanned meteorological observer (SUMO), an autonomous flying model aircraft with a length and wingspan of around 80 cm and a total weight of around 600 g, has been developed at the Geophysical Institute at the University of Bergen in collaboration with Martin Muller engineering, Germany. During the Boundary-Layer And Sunset Turbulence (BLLAST) campaign, which took place between 13th June to 9th July 2011, at Lannemezan, France, SUMO was used to perform vertical profiles as well as horizontal surveys in the atmospheric boundary layer. The atmospheric measurements of temperature, humidity and wind, will be of high value to improve our understanding of e.g. the stable nocturnal boundary layer. In addition, new sensors in the form of a five hole probe for atmospheric turbulence estimations and atmospheric charge and radioactivity sensors were tested. The SUMO measurements are considered to be highly complementary to those of conventional instrument platforms utilized during BLLAST.

2 Results

A total of 299 SUMO measurement flights were performed during the BLLAST campaign. The flights were done from two different geographical locations. Location 1 was the main site of BLLAST, where infrastructural facitilites in the form of a meteorological observatory, is located. The second site was located some few kilometres to the south of Site 1 and contains three well defined geopgrahical areas covered with moor, corn and a forest. From both locations, all three types of measurement flights were performed; vertical spiral, horizontal survey and horizontal transects. The vertical spirals were used to obtain information on the lower atmospheric column on stratification of temperature, relative humidity in addition to wind and pressure. The horizontal surveys were mainly used to map the horizontal surface temperature heteorogenity and the horizontal transects were used to obtain turbulence information. The turbulence information, which was sampled using a five hole probe, is mostly of qualitative value since the measurements are in SUMO not yet logged synchronously with the aircraft attitude data. Examples of all three flight trajectories are seen in Figure 2. For a complete overview over all flights done during BLLAST, see attached table.

The horizontal surveys can be used to extract information on the temporal variability and horizontal heterogenities in the surface temperature over different terrain types. An example of such

Figure 1: The Multiplex FunJet used as airframe for the SUMO system and the ground control station (laptop).

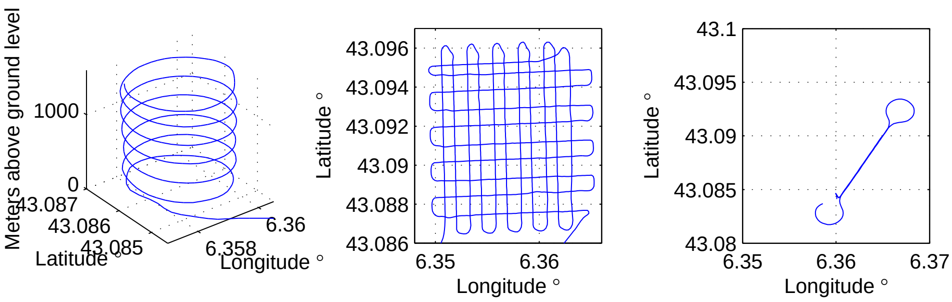

Figure 2: Examples of the three types of SUMO flight trajectories flown during the BLLAST campaign. From the left; profile flight, survey flight and transect.

measurements made at Site 2 is shown in Figure 4. It can can be seen that the corn reaches the higher maximum temperature of nearly 31 degrees around 1400 UTC. Corn is also the surface type associated with the most rapid temperature drop towards the evening. The forest is clearly the coldest field during daytime, with a less pronounced maximum temperature. During evening, the forest and corn fields have approximately the same temperatures.

The observed differences in the surface temperature over the three fields can likely be explained in terms of the soil and surface moisture contents; The moor is the driest of the three, associating it with a larger sensible to latent heat ratio (bowen ratio) than for the two other fields.

Figure 5 shows the evolution of temperature, relative humidity, wind speed and wind direction of the lowest 1600 m at Site 2 on 27.08.2011. In spite of near surface temperatures exceeding 30 degrees this day, the boundary layer only reached an average height of around 600-800 m.a.g.l. This can be seen as a corresponding temperature inversion at this level, and in late afternoon (1840 UTC), a drop in wind speed at higher levels (above 800 m.a.g.l.). The 1350 UTC profile is distinctly different from the others. It shows no clearly defined boundary layer in either of the measured quantities. This could be a sign of a meso- to synoptic scale perturbation and numerical simulations could illuminate this further. There are also signs of a thermally driven plain-mountain interaction in these profiles; The wind at lower levels shows sign of downslope (southerly) flow early in the morning hours with a gradual turn towards an upslope (northerly) direction during the course of the day. In the first and last profiles (0719 UTC and 1840UTC), a clear sign of a nocturnal surface inversion is seen in the temperature and partly also in the relative humidity profiles.

3 Summary

The BLLAST campaign turned out to be another successfull story in the operational time of SUMO. With a total of 299 flights, it is the campaign so far with the most flights and through the extensive data record a significant scientific contribution to the BLLAST dataset has been made. The campaign will be followed up with data analysis and numerical modelling of interesting weather situations from the campaign. Further more, SUMO data will be assimilated into the numerical weather model WRF and the feasibility of thereby improving the forecast will be investigated.

4 Acknowledgments

The author would like to express his gratitude towards the COST office for making his participation in the BLLAST campaign possible through the STSM funding. He would also like to thank all the members of the BLLAST society for a successfully performed campaign. Last but not least Christian Lindenberg and Martin Müller are thanked for their excellent contribution in the operation, maintenance and developing of the SUMO system.

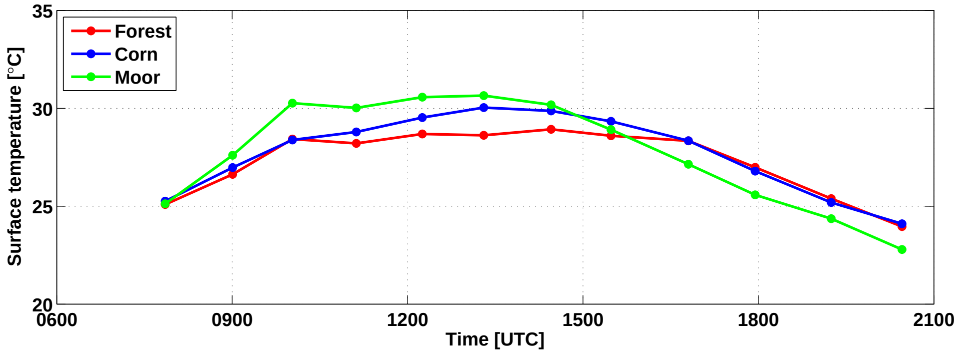

Figure 3: Measured infrared surface temperature evolution over moor, corn and forest at Site 2 27.07.2011.

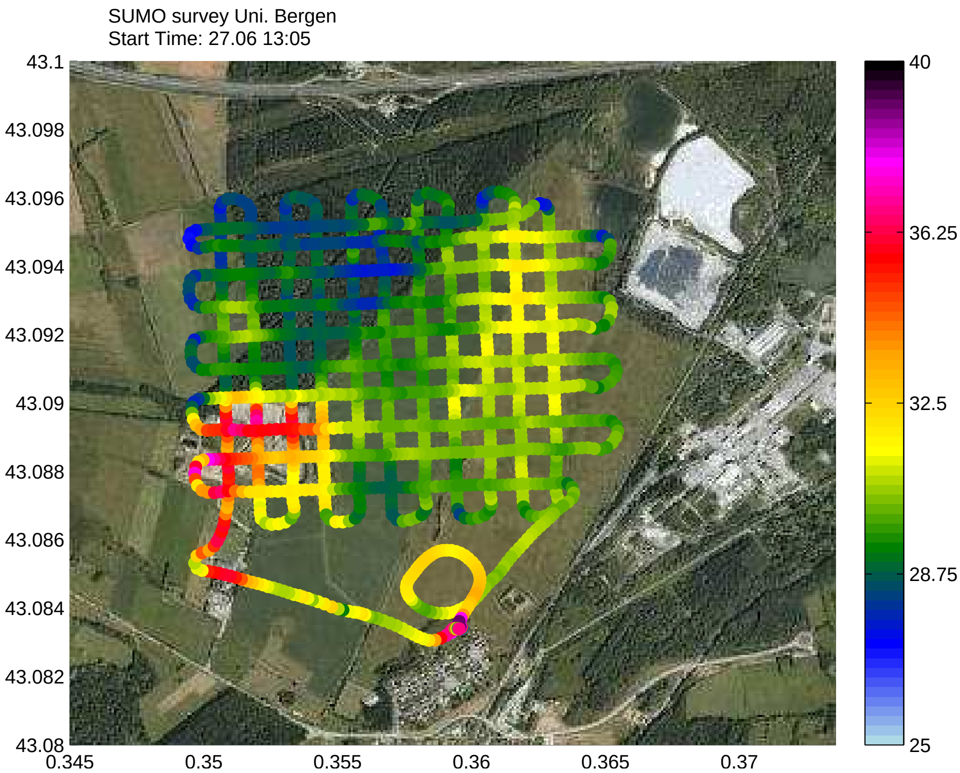

Figure 4: Measured infrared surface temperature at 1305 UTC at Site 2.

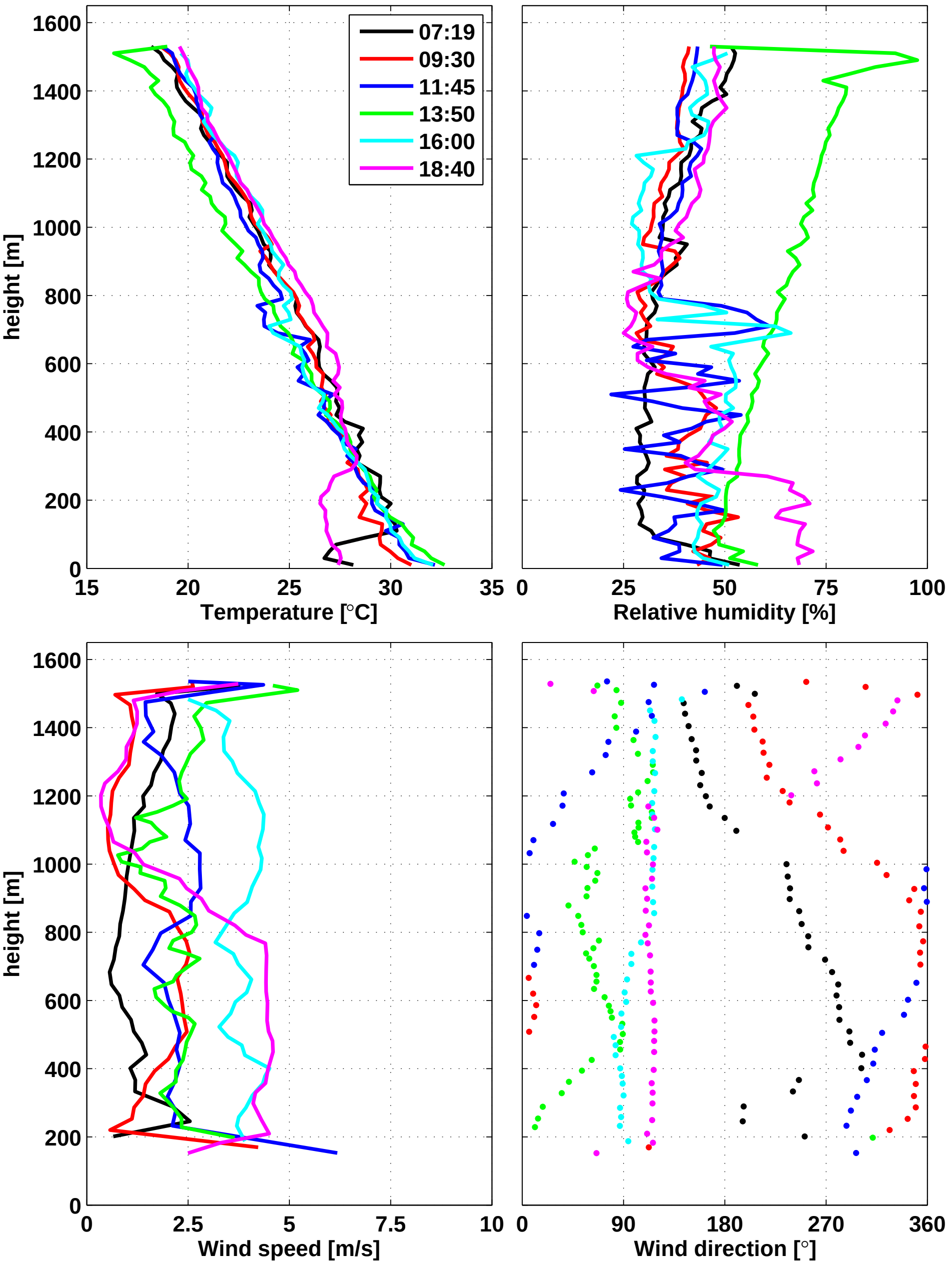

Figure 5: Temporal evolution of the lower atmospheric column as measured by SUMO 27.08.2011 at Site 2.

		total	test/kalib	profile	survey	transects	turbulence
13.06.2011		**7**	3				4
14.06.2011	IOP 0	**3**			1		2
15.06.2011	IOP 1	**22**	1		2		19
16.06.2011		**1**	1				
17.06.2011		**11**		7	2		2
18.06.2011		**5**		5			
19.06.2011	IOP 2	**28**		12	13		3
20.06.2011	IOP 3	**23**		11	10		2
21.06.2011		**8**		8			
22.06.2011		**0**					
23.06.2011		**2**		2			
24.06.2011	IOP 4	**12**		10	2		
25.06.2011	IOP 5	**23**	1	11	9		2
26.06.2011	IOP 6	**25**	1	11	8	1	4
27.06.2011	IOP 7	**35**		12	12		11
28.06.2011		**0**					
29.06.2011		**0**					
30.06.2011	IOP 8	**17**		12	5		
01.07.2011	IOP 9	**12**	1	6	5		
02.07.2011	IOP 10	**17**		14	3		
03.07.2011		**6**		6			
04.07.2011		**9**		9			
05.07.2011	IOP 11	**14**		13	1		
06.07.2011		**7**		7			
07.07.2011		**8**		8			
08.07.2011		**4**		4			
total:		**299**	**8**	**168**	**73**	**1**	**49**