Eidgenössische Technische Hochschule Zürich
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Drone Sounding Experiment

Climatological and Hydrological Field Work

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1 Introduction

The emergence of affordable drones provides an unprecedented opportunity to monitor the land surface or the near surface atmosphere. Drones are able to reach almost any location with little risk and are at the same time able to keep a fixed position over a period of time, making them promising mobile measurement platforms for scientific purposes. Unsurprisingly, a wide range of applications is emerging, for example in the forestry sector (Tang, 2015).

Drones are particularly promising measurement platform for atmospheric sciences, as they can be easily navigated in space. This is an advantage over balloon soundings, which can only rise at a constant rate and have their horizontal track controlled by winds. Additionally, free balloon soundings inherently involve loss of at least part of the material. First companies have therefore started to develop drones that routinely sample the boundary layer, thereby complementing or potentially even replacing balloon soundings (e.g., Meteomatics, 2019).

In this part of the module, we will use the commercial drone DJI Mavic 2 Pro (DJI, 2019) to sample the vertical structure of the surface layer and/or the spatial variability of the surface layer structure.

2 Sensor System

The drone is equipped with a BME680 sensor (Fig. 1; Bosch, 2019) to sample temperature, pressure, and relative humidity, and a Grove - GPS module (Seeed, 2019) to keep track of time and position. The sensors are mounted on top of a small sensor tower, which includes a battery, an Arduino Uno SMD microcontroller, and a Micro SD card. In addition, the drone itself is equipped with its own GPS system for navigation. As the GPS of the drone is more precise and has a much higher temporal resolution, we will only use the time information of the Grove - GPS for the moment. The position is extracted from the drone log files in the post-processing.

Table 6: Humidity parameter specification

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Operating Range[11]			-40	25	85	°C
			0		100	% r.H.
Full accuracy range			0		65	°C
			10		90	% r.H.
Supply Current	$I_{DD,H}$	1 Hz forced mode, temperature and humidity measurement		2.1	2.8	µA
Absolute Accuracy	A_H	20–80 % r.H., 25 °C, including hysteresis		±3		% r.H.
Hysteresis[12]	H_H	10→90→10 % r.H., 25°C		±1.5		% r.H.
Nonlinearity[13]	NL_H	10→90 % r.H., 25°C		1.7		% r.H.
Response time to complete 63% of step[14]	$\tau_{0\text{-}63\%}$	N_2 (dry) → 90 % r.H., 25°C		8		s
Resolution	R_H			0.008		% r.H.
Noise in humidity (RMS)	N_H	Highest oversampling		0.01		% r.H.
Long-term stability	ΔH_{stab}	10–90 % r.H., 25°C		0.5		% r.H./ year

Table 8: Temperature parameter specification

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Operating temperature range	T_A	operational	-40	25	85	°C
Supply current	$I_{DD,T}$	**1 Hz forced mode, temperature measurement only**		**1.0**		µA
Absolute accuracy temperature[17]	$A_{T,25}$	25 °C		±0.5		°C
	$A_{T,full}$	0–65 °C		±1.0		°C
Output resolution	R_T	API output resolution		0.01		°C
RMS noise	N_T	Lowest oversampling		0.005		°C

Figure 1: Technical details of relative humidity and temperature measurements of the BME 680 sensor.

3 Navigation

Besides the first-person view mode, in which the user manually navigates the drone, there is also the way point mode, in which the drone follows a predefined track. In order to maximize the comparability between the different flights, we will use the way point mode.

The Litchi app (VC Technology, 2019) has a way point mode which allows for stacking several way points on top of each other (i.e., at the same coordinates). Also, one can programme the drone to rest at a way point for up to 30 seconds.

4 Procedure

A measurement track sampling the surface layer up to a height of 120 m above ground over a grassland patch has already been programmed. The drone will visit the grassland patch and sample a vertical profile from 120 m to 15 m above ground in 15 m steps. It will hold each height for 30 seconds before moving to the next height level. The whole "measurement programme" takes roughly 10 min and can be run once before the balloon sounding and once after. Switch on the drone and make sure to attach the sensor tower before taking off. The sensor tower starts to collect data automatically once the USB cables are connected to the battery. After taking off you can change to the waypoint mode and load the program "Droneflight". Once you press the start bottom, the drone will execute the program described above and return to the starting point. Note that you can interrupt the program any time by hitting the stop bottom, should anything unexpected happen. For the data analysis, it will be useful if you document when the drone starts with the profiles and whether there are any special meteorological conditions occurring (e.g., shadow from a cloud while sampling).

5 Questions

- What are the advantages and disadvantages of sampling the atmosphere with a drone in comparison to a conventional balloon sounding? Do you think balloon soundings can eventually be replaced completely by drones? (Try to answer these questions after having read the script. The other questions are only relevant for the group doing the data analysis.)
- Whats the vertical structure of the boundary layer in terms of temperature, relative humidity etc.
- How does the surface layer evolve throughout the day?
- Are there any differences in the structure of the surface layer between the different days of the field course? Can you relate them to the weather conditions of the different days?
- How do the temperature and humidity measurements compare to the data of the field site? What could be the reason for the discrepancies you find? How could the sensor system of the drone be improved?
- What kind of problem did you encounter?

References

Bosch (2019). BME 680.

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