Proof of concept for turbulence measurements with SUMO

Joachim Reuder\textsuperscript{1}, Line Båserud\textsuperscript{1}, Stephan Kral\textsuperscript{1}, Marius Jonassen\textsuperscript{1,2}, Mostafa Bakhoday Paskyabi\textsuperscript{1}, Marie Lothon\textsuperscript{3}

\textsuperscript{1}Geophysical Institute, University of Bergen, Norway
\textsuperscript{2}The University Centre Svalbard (UNIS), Longyearbyen
\textsuperscript{3}Laboratoire de Aerologie, University of Toulouse, CNRS, France
Proof of concept for turbulence measurements with the RPAS SUMO during the BLLAST campaign

Line Båserud¹, Joachim Reuder¹, Marius O. Jonassen¹,², Stephan T. Kral³,⁴, Mostafa Bakhoday Paskyabi¹, and Marie Lothon⁴

¹Geophysical Institute, University of Bergen, Allégaten 70, 5007 Bergen, Norway
²UNIS - The University Centre in Svalbard, 9171 Longyearbyen, Norway
³Finnish Meteorological Institute, Helsinki, Finland
⁴Laboratoire d’Aérologie, University of Toulouse, CNRS, France

Correspondence to: Line Båserud (line.baserud@uib.no)
SUMO

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5 hole turbulence probe on SUMO

Micro Air Data System, commercially available by Aeroprobe
3D flow vector with 100 Hz resolution
SUMO during BLLAST

SUMO basically operated in 3 different flight missions:

1) atmospheric profiles (up to 1600 m a.g.l.) (168 flights)

2) horizontal surveys of surface temperature (74 flights)

3) turbulence transects (49 flights)
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Exploring the potential of the RPA system SUMO for multi-purpose boundary layer missions during the BLLaST campaign

Joachim Reuder\textsuperscript{1}, Line Båserud\textsuperscript{1}, Marius O. Jonassen\textsuperscript{1,2}, Stephan T. Kral\textsuperscript{1}, and Martin Müller\textsuperscript{3}

\textsuperscript{1}Geophysical Institute, University of Bergen, and Bjerknes Centre for Climate Research, Allegaten 70, 5007 Bergen, Norway
\textsuperscript{2}UNIS - The University Centre in Svalbard, 9171 Longyearbyen, Norway
\textsuperscript{3}Lindenberg und Müller GmbH & Co. KG, Hohenhameln, Germany
Challenges with the system during BLLAST

- aircraft attitude and flow probe record data on two unsynchronized data loggers
- altitude stabilization of the SUMO aircraft was not quite perfect
- the yaw angle is not measured but had to be estimated from the angle of sideslip measurements of the flow probe

- the first two issues are solved now, but for the BLLAST data we had to develop a pragmatic approach to make use of the SUMO turbulence data
synchronization by cross-correlation

- Time shift: 3.5 sec  \([r=0.997]\)

Graph shows correlation and time shift [s] for PROBE airspeed and GPS ground speed.
SUMO flight patterns for turbulence measurements
Insufficient motion compensation of the vertical velocity

\[ w = - \frac{U_a}{(1 + \tan^2 \alpha + \tan^2 \beta)^{1/2}} \left[ \sin \theta \right. \\
\left. - \tan \beta \cos \theta \sin \phi - \tan \alpha \cos \theta \cos \phi \right] + w_{gs} \]

Figure 6. Example of the unfiltered vertical velocity component, \( w \), and the GPS climb speed (GPS CS) for one single leg (about 1 km length) of flight # 38.
4 flights in the vicinity of the 60 m mast
Derived time series for the different areas - site 1 raw

- 19.06.11
- FL 27
- FL 29
- 20.06.11
- FL 30
- FL 31
resulting velocity variances and TKE flight #30
resulting velocity variances and TKE - all flights
Figure 10. Profiles of TKE from 27 June at Site 2. Consecutive flights are separated by color. The average TKE value over two legs, for each altitude (60, 150, 300 and 500 m agl), is shown by the circles. For the two flights with straight legs in 340 m agl, the diamonds represent the average TKE values. The given flight times are all in UTC.
**Figure 11.** TKE from 15 June at Site 2. The average values of TKE over each straight leg is shown by the stars. The colors indicate the different altitudes of 65 (blue) and 150 (red) m agl. Corresponding mean TKE over all legs is shown by the squares.
Summary

- turbulence measurements with multihole probes are possible with small RPAS with a TOW of below 1 kg
- the pragmatic approach of motion correction leads to reasonable TKE values, both in terms of temporal evolution and vertical profiles
- some issues remain:
  - determination of the yaw angle (differential GPS?)
  - full synchronization of flow and attitude sensors on 100 Hz
Platforms in use at GFI
Future work

turbulence measurements from small RPAS:

- rotary wing based; requires probes that also work in relatively low flow speeds
- new probe has been extensively tested

- development of new sensor systems
  - light-weight sonic?
  - using the airframe itself as turbulence sensor
  - Lannemezan test with the Bebop parrot under the Paparazzi autopilot (512 Hz data of attitude and motor control)