Proof of concept for turbulence measurements with SUMO

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Proof of concept for turbulence measurements with the RPAS SUMO during the BLLAST campaign

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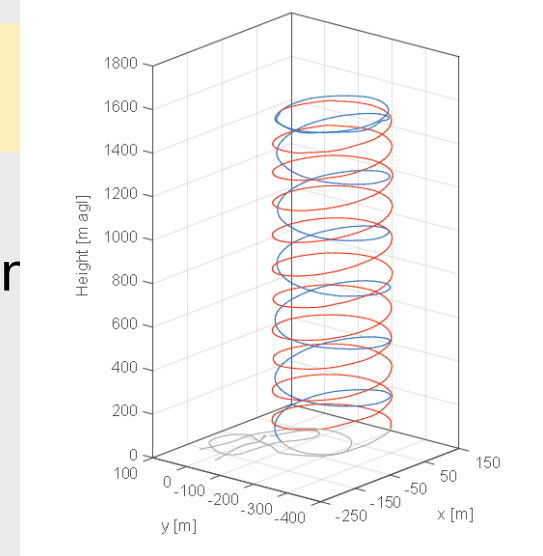
SUMO

5 hole turbulence probe on SUMO

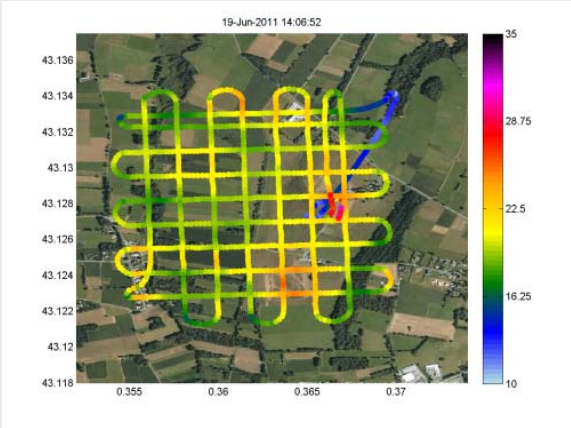
Micro Air Data System, commercially available by Aeroprobe
3D flow vector with 100 Hz resolution

SUMO during BLLAST

SUMO basically operated in 3 different flight mission

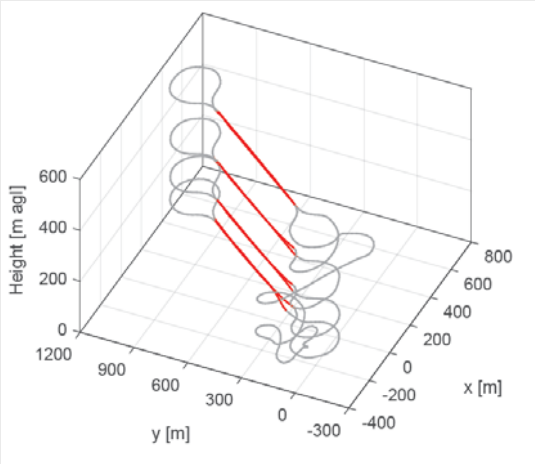


1) atmospheric profiles (up to 1600 m a.g.l.) (168 flights)



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

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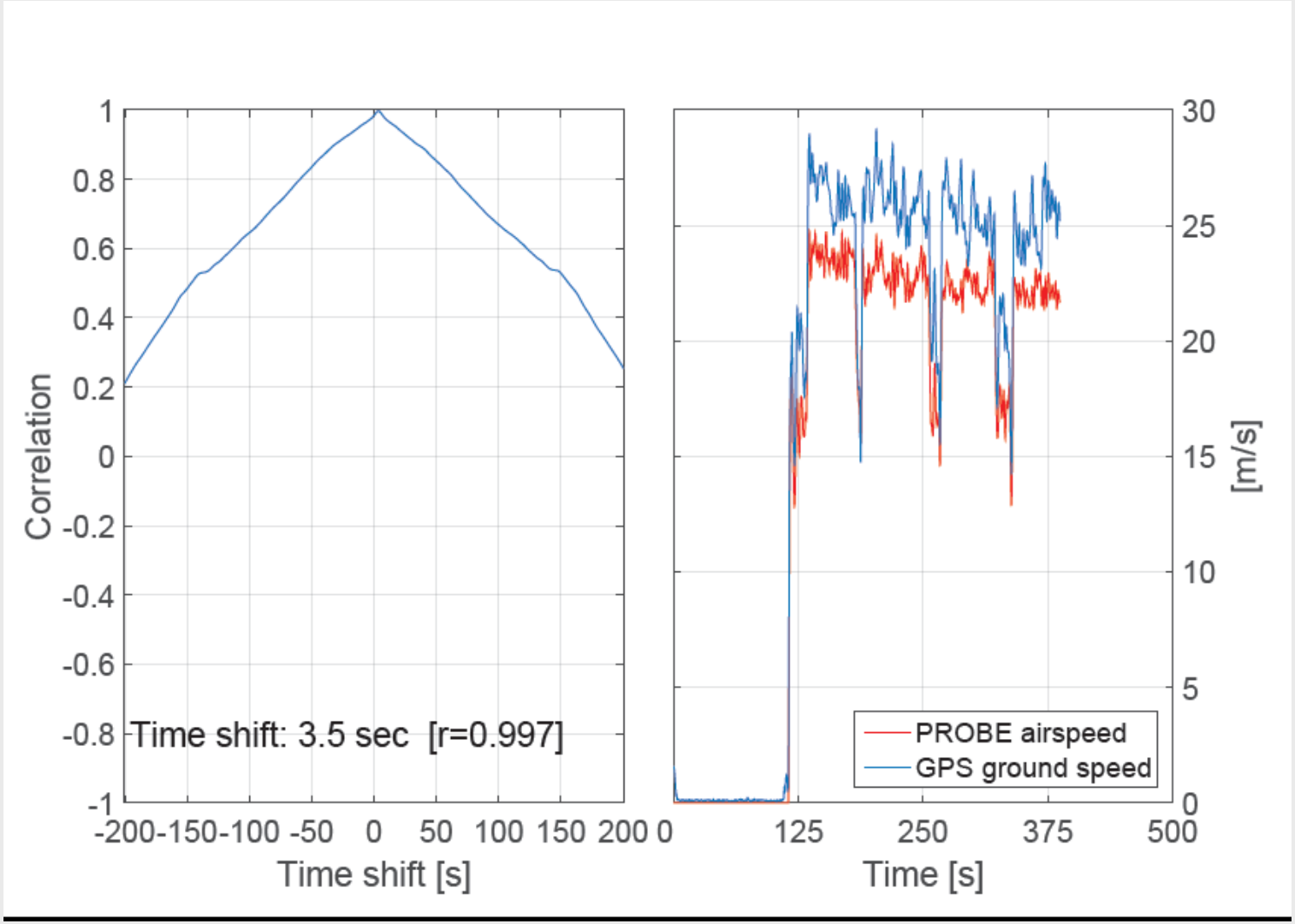
Challenges with the system during BLLAST

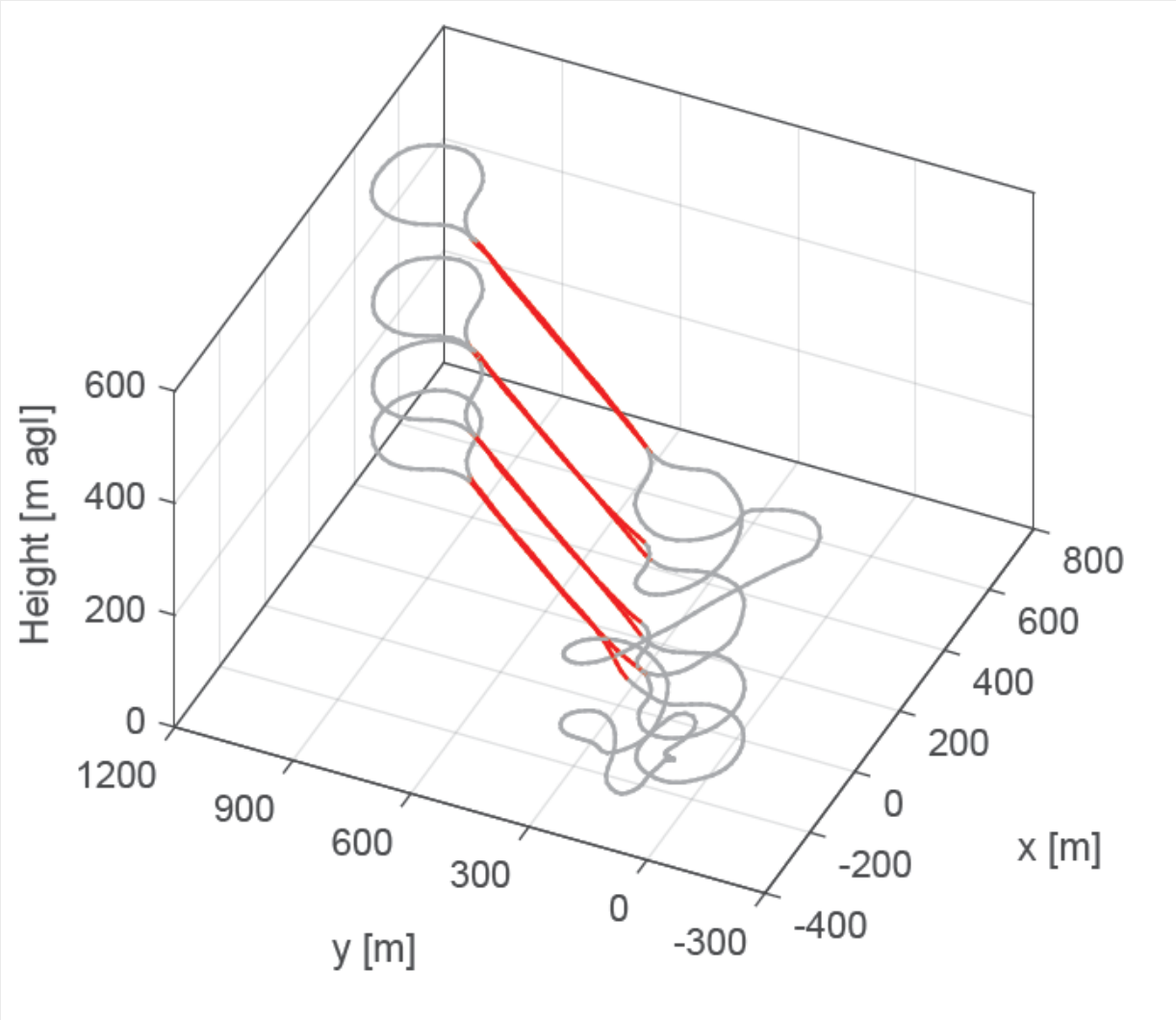
- aircraft attitude and flow probe record data on two unsynchronized data loggers
- altitude stabilization of the SUMO aircraft was not quite perfect
- the yaw angle is not measured but had to be estimated from the angle of sideslip measurements of the flow probe

- 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



SUMO flight patterns for turbulence measurements



Insufficient motion compensation of the vertical velocity

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

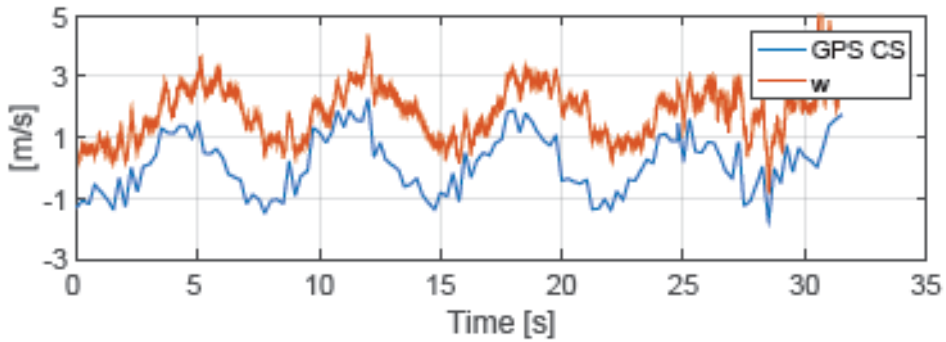
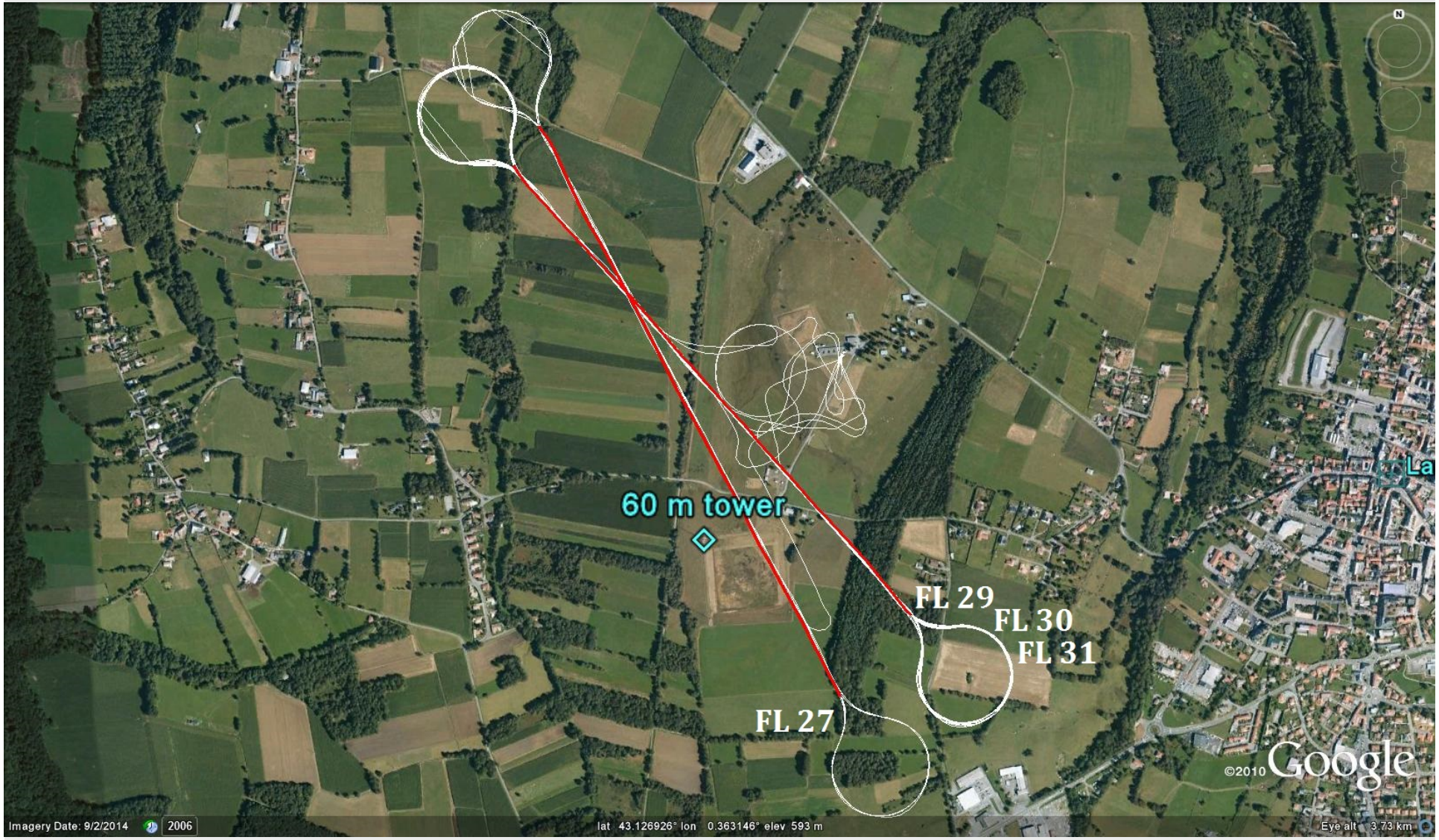
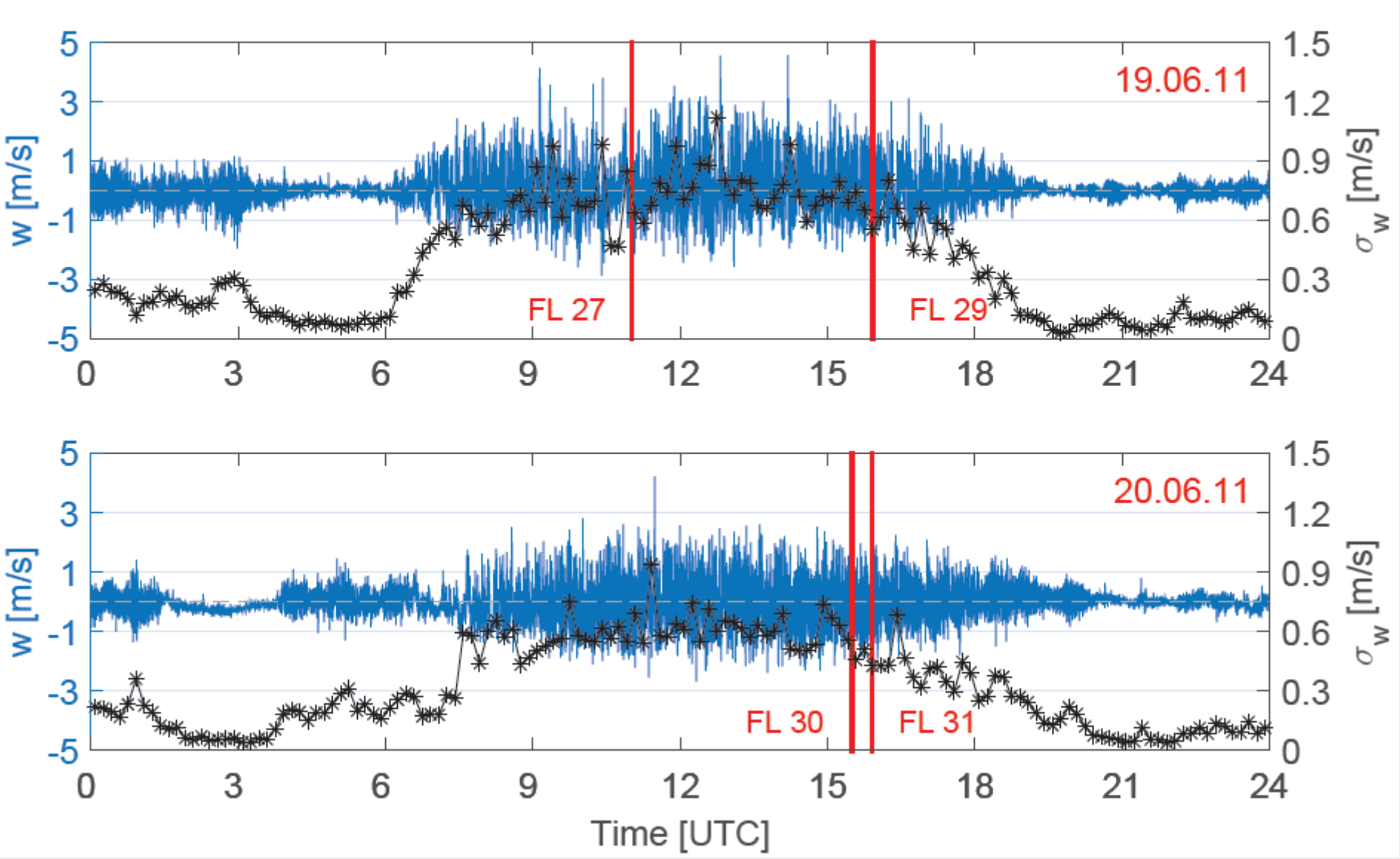


Figure 6. Example of the unfiltered vertical velocity component, w, and the GPS climb speed (GPS CS) for one single leg (about 1 km length) of flight # 38.

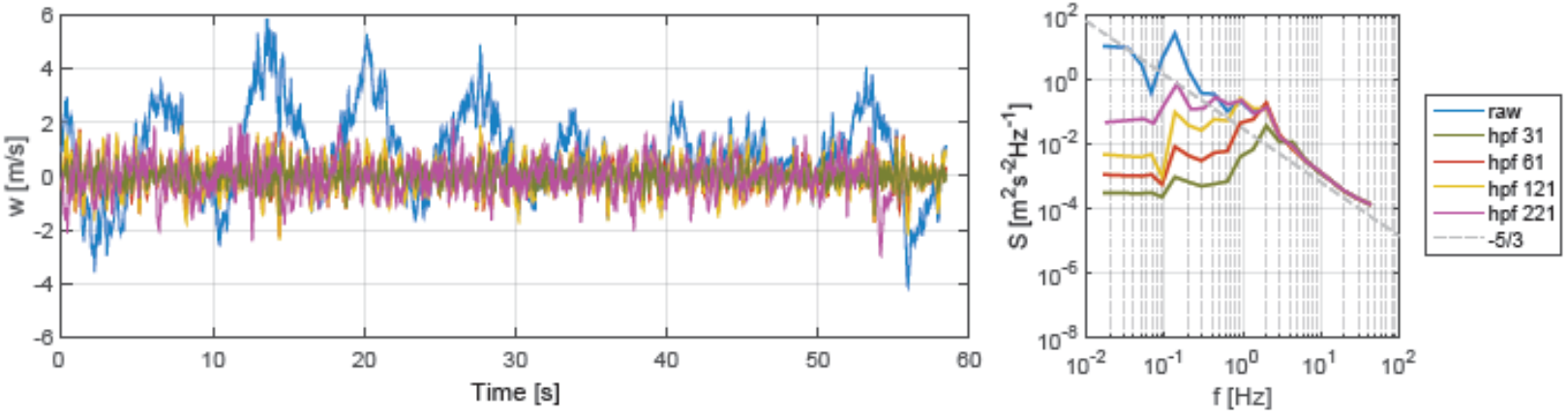
4 flights in the vicinity of the 60 m mast

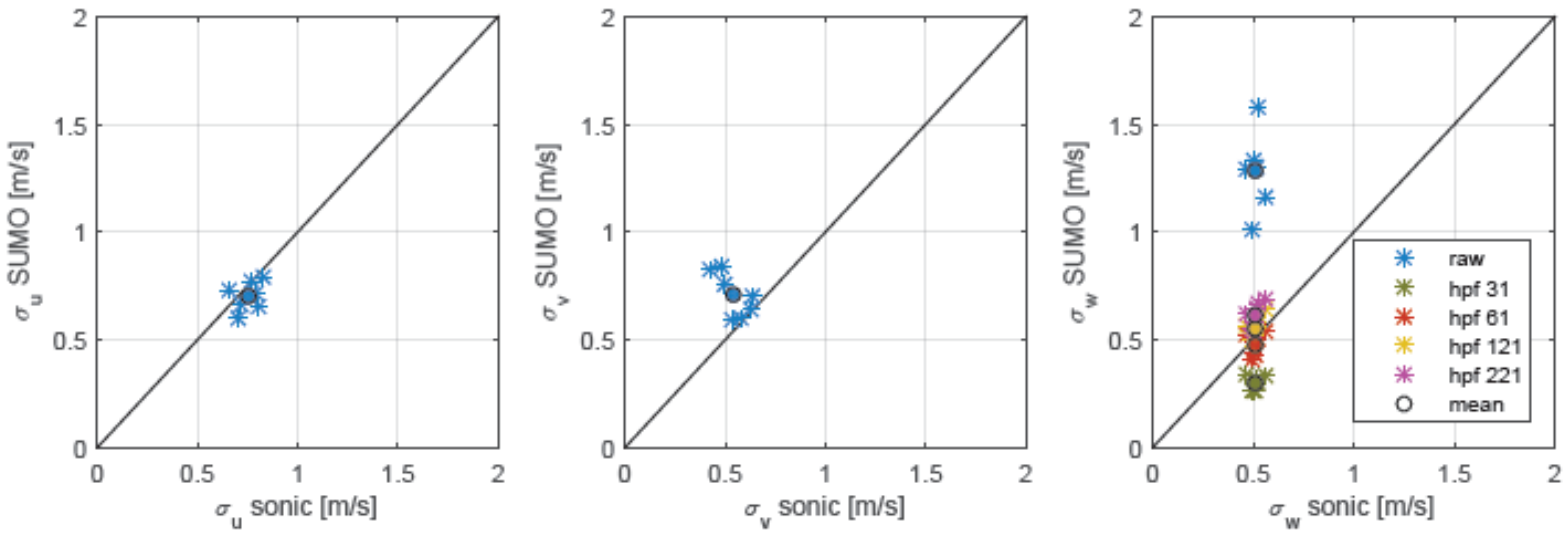


Derived time series for the different areas – site 1 raw

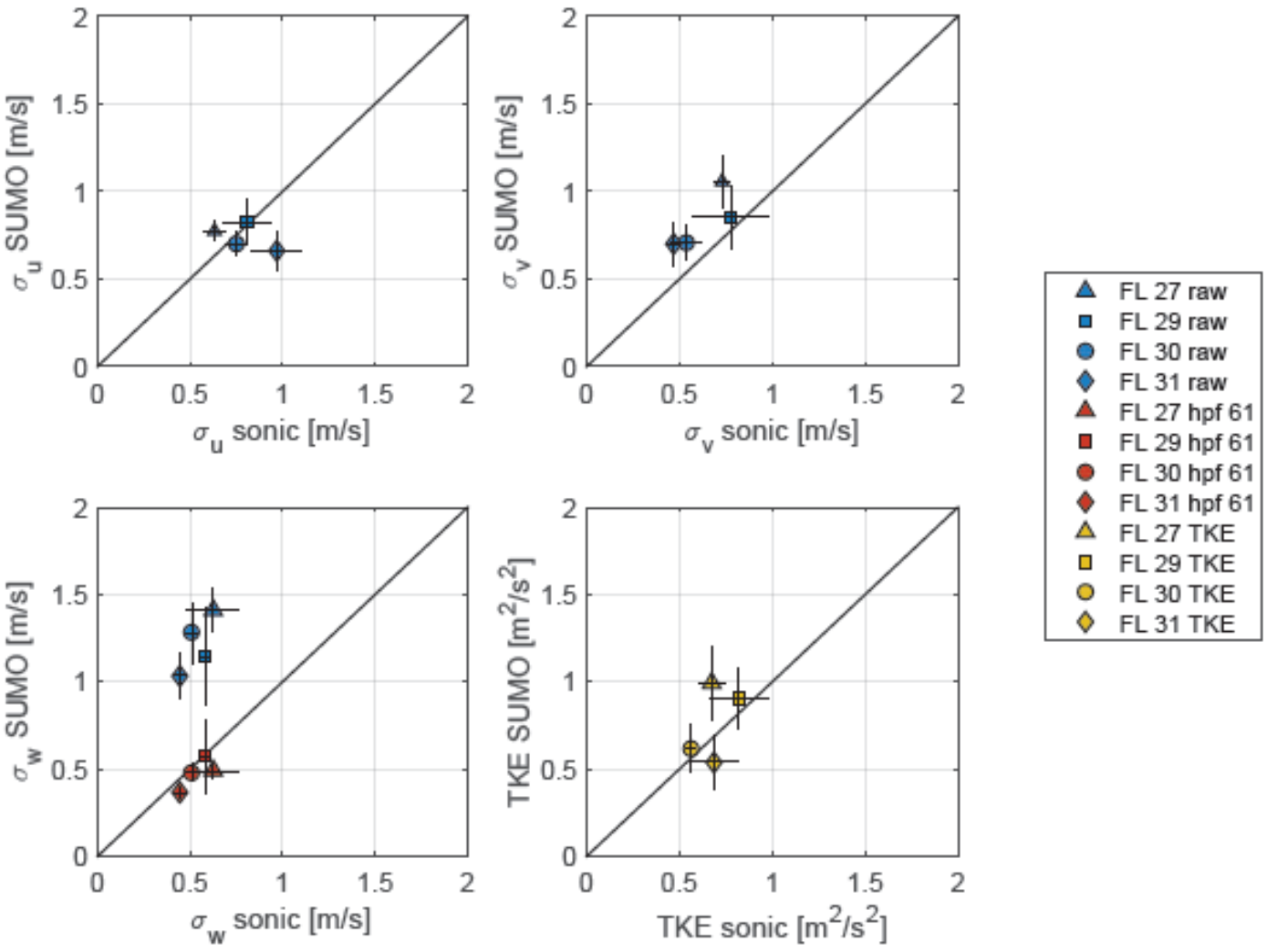


resulting velocity variances and TKE flight #30





resulting velocity variances and TKE – all flights



TKE profiles 27.06.2011 – Site 2

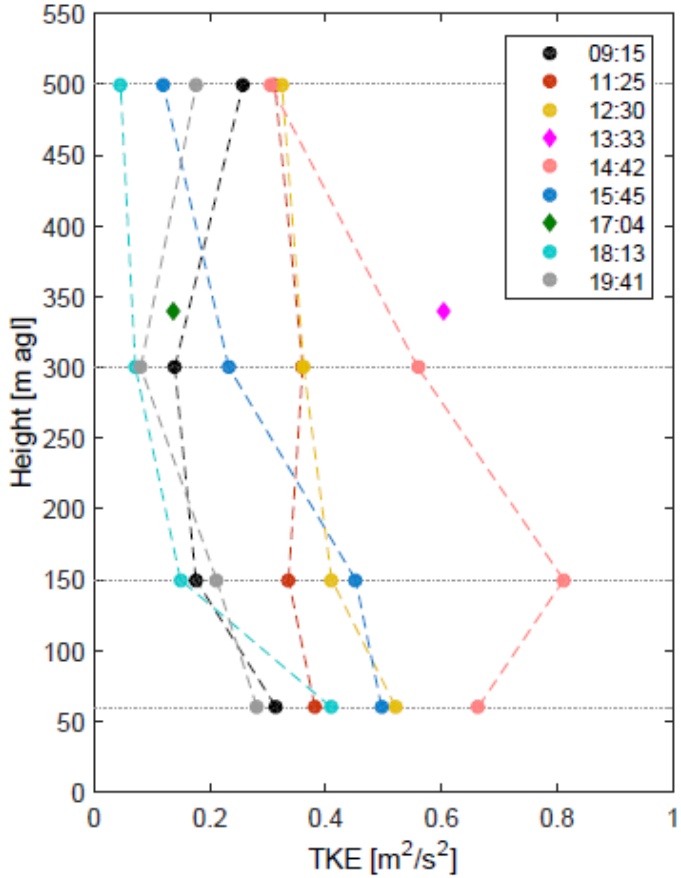


Figure 10. Profiles of TKE from 27 June at Site 2. Consecutive flights are separated by color. The average TKE value over two legs, for each altitude (60, 150, 300 and 500 m agl), is shown by the circles. For the two flights with straight legs in 340 m agl, the diamonds represent the average TKE values. The given flight times are all in UTC.

TKE time series at 2 levels for 15.06.2011 – Site 2

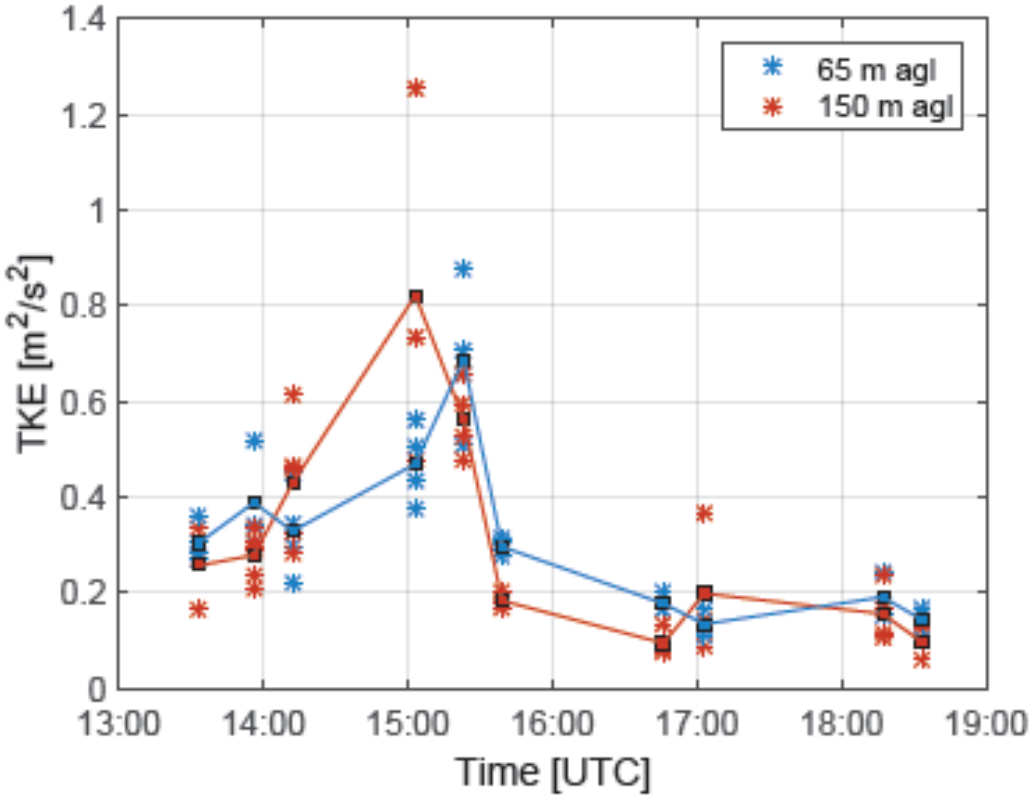


Figure 11. TKE from 15 June at Site 2. The average values of TKE over each straight leg is shown by the stars. The colors indicate the different altitudes of 65 (blue) and 150 (red) m agl. Corresponding mean TKE over all legs is shown by the squares.

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 (differnential GPS?)
  - full synchronization of flow and attitude sensors on 100 Hz

Platforms in use at GFI

Future work

turbulence mesurements 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)