An analysis of CanSat potential for in-situ parachute dropped and weather balloon measuring

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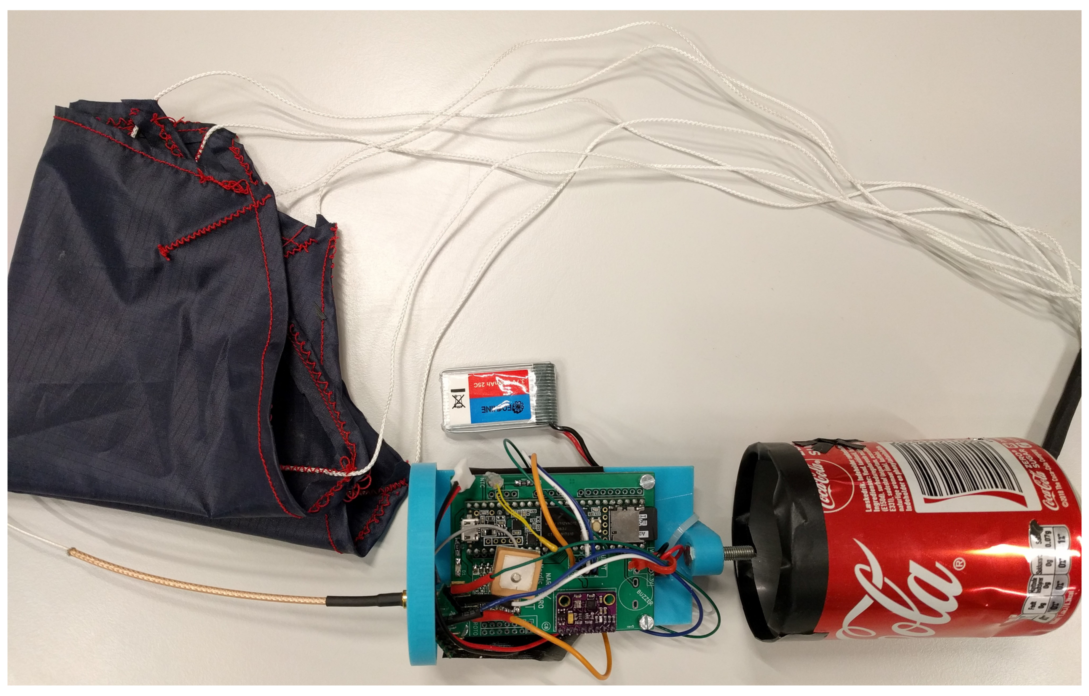
Abstract

A CanSat is a miniature satellite (Sat-in-a-can) consisting of a soda can with sensors and an Arduino and a parachute. It is an affordable way to perform atmospheric measurements. The CanSat has several components that are covered in this analysis:

- NTC termistor: Temperature,
- GY-91: Pressure, acceleration, gyration, magnetic field,
- RFM96 radio,
- Venus638FLPx_DS GPS receiver,
- 3.7V 600mAh battery.

This analysis contains three datasets, two of which are obtained by deployment from a drone from 350 m with a parachute in Adventdalen and one is obtained with a weather balloon going up to 26.2 km. The two drone measurements were done with different size parachutes, resulting in distinguishable dynamics. **The smaller parachute data is indicated in red, the larger one in blue.**

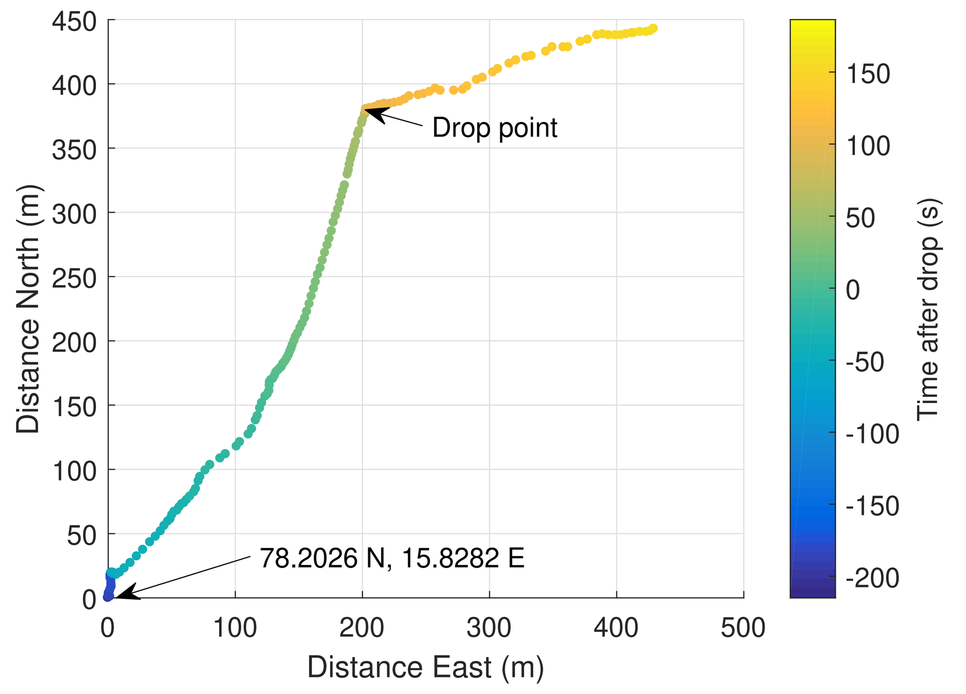


Testing procedures

- A temperature and pressure calibration was done at Breinosa weather station, by laying it outside KHO. The pressure did not have an offset, however the measured temperature was 10 degrees higher. This difference is corrected for in the hydrostatic approximation, but not for the temperature plot.
- The attitude directions were found by aligning the CanSat level and pointing North using a compass, which corresponds with a pitch, roll and yaw of 0°.

Position small parachute launch

The GPS position data of the large parachute launch contained several big jumps of 50 to 500 meters and also only has 5 satellite locks. The other launch locked with 12 satellites and had no jumps, so only this data is shown.



General results

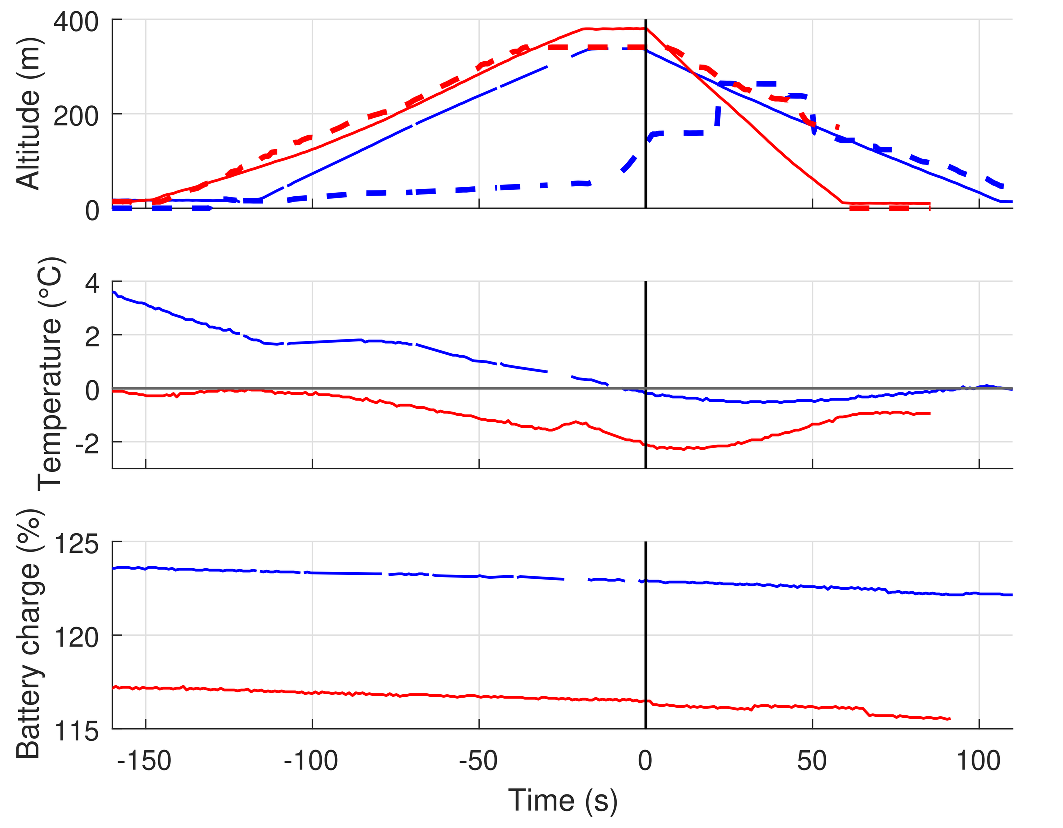
Altitude is plotted from GPS data (dashed line) and estimated using a hydrostatic approximation

$$h = \frac{T_1}{\alpha}\left(\frac{p}{p_1}^{\frac{-\alpha R}{g_0}} - 1\right) + h_1,$$

with T_1, p_1 and h_1 parameters from the Breinosa calibration, and α, g_0 and R constants. This approximation is smoother than the GPS data, which also seems to be lagging behind in the first launch.

The **temperature** readings are higher than the ambient temperature ($-2\,°C$), because the NTC was inside the can, along with the electronics. This also causes a response delay in the temperature (5 min), which could explain the small variation in temperature during the flight.

Power consumption is quite constant, with a consumption of about $3 \cdot 10^{-2}\,\mathrm{mA\,h\,s^{-1}}$. Assuming this constant rate, the CanSat can be used for 5.6 hours.



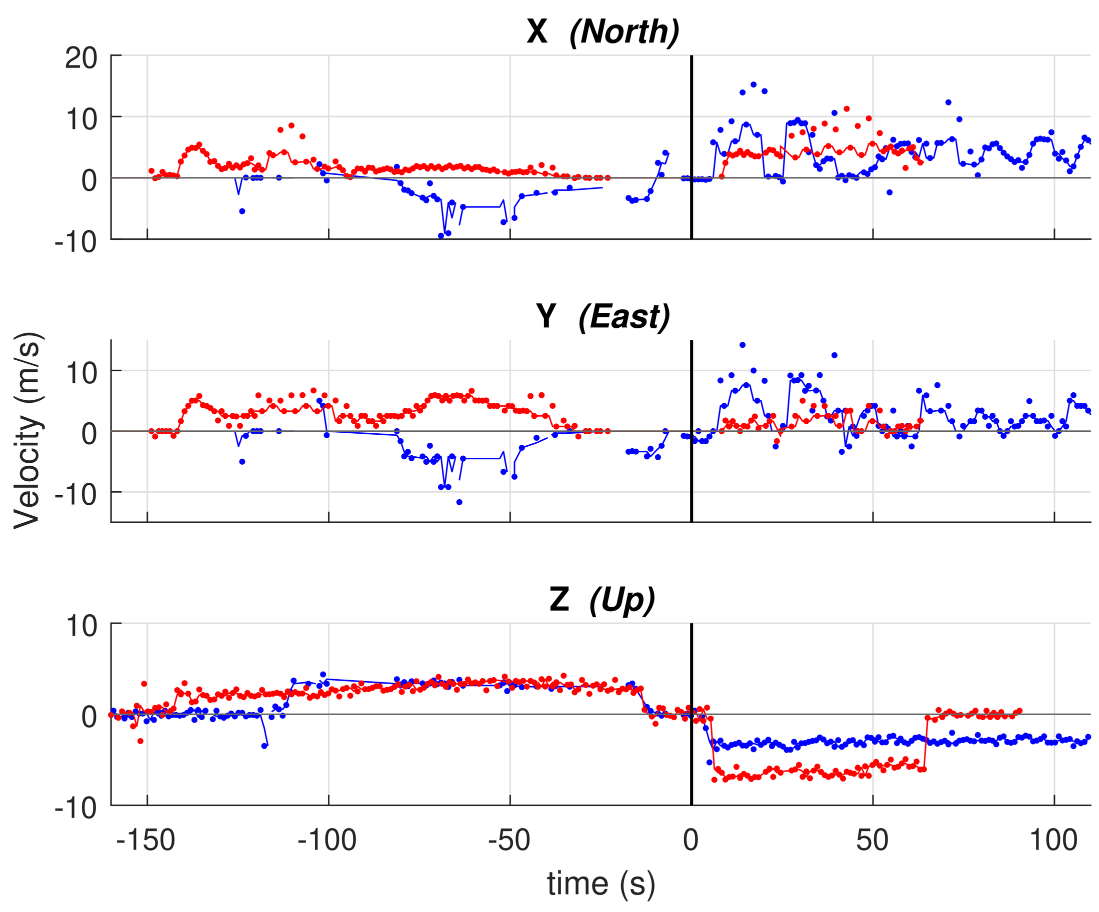
Dynamics

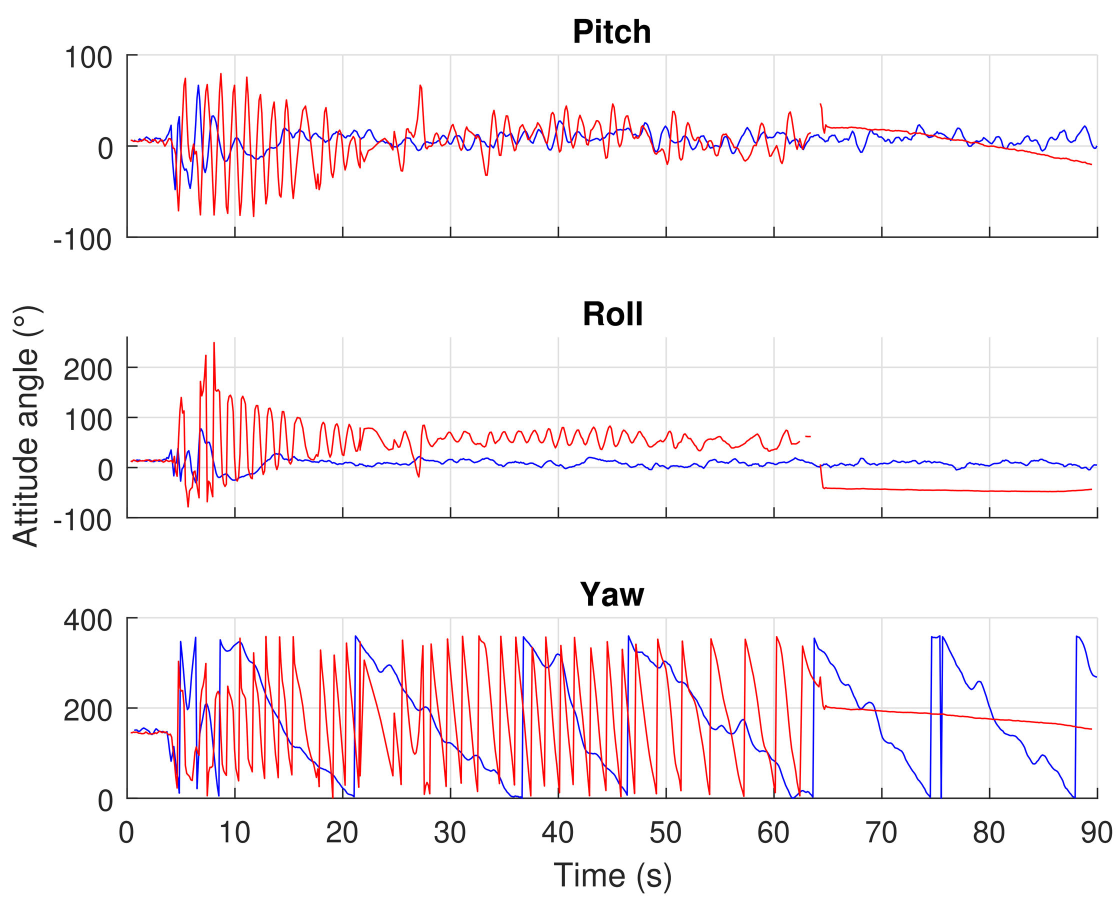
Velocity is acquired from GPS data for the horizontal velocities and from the hydrostatic approximation for the vertical velocity. The data is plotted as points, along with a line which is a 5-point median filter of the data, excluding zeroes. This shows that:

- The smaller parachute has a faster descend velocity: ($-3.0 \pm 0.3\,\mathrm{m\,s^{-1}}$, $-6.2 \pm 0.6\,\mathrm{m\,s^{-1}}$),
- 1/3 of GPS data does not update, producing zero velocity,
- Velocity of second flight clipped becauce of GPS jumps $\approx 100\,\mathrm{m\,s^{-1}}$.

Attitude is retrieved by on-board fusion of magnetometer, accelerometer and gyrometer data at 8 Hz sampling rate. A difference in dynamics for the different parachute sizes is visible because of the higher sampling rate:

- Faster oscillation for smaller parachute: (0.08 Hz, 0.9 Hz),
- Smaller parachute is more violently deployed and less level.





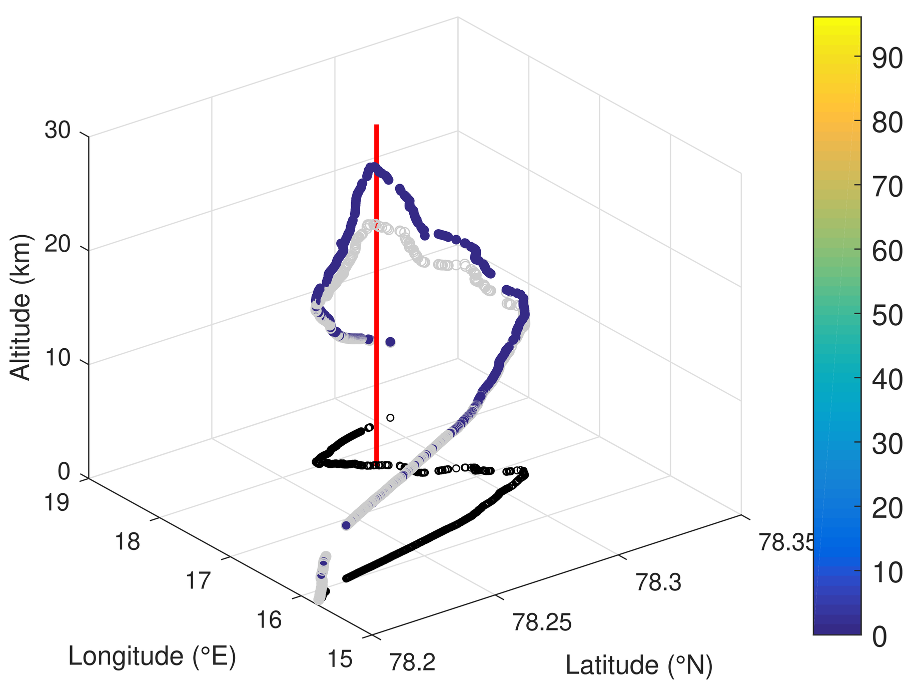
Weather balloon

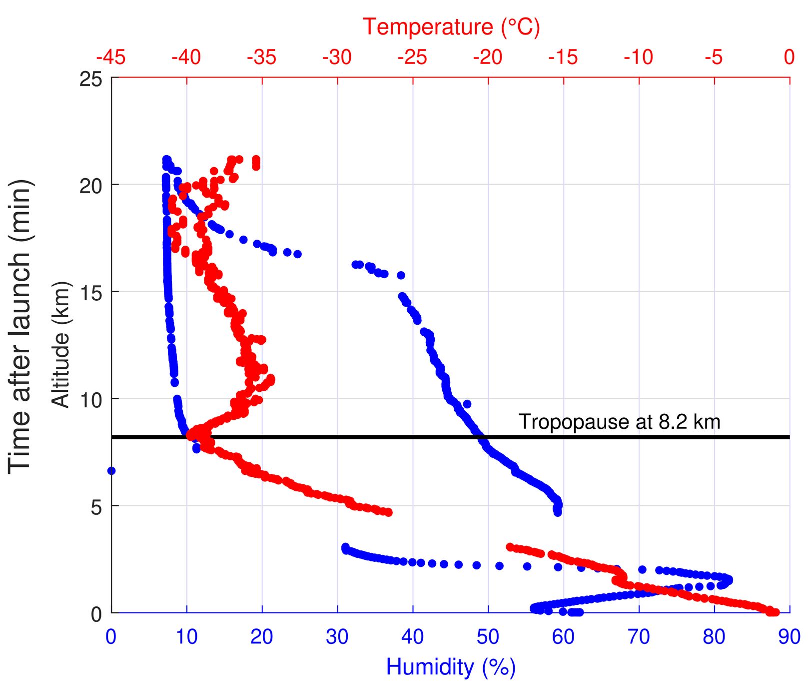
The **trajectory** of the balloon during the 90 minutes of flight time is shown in colored data points for the GPS data. Notable features are:

- The apogee using GPS data is at 26.2 km, while using the CanSat hydrostatic approximation (gray data) the apogee is 21.2 km,
- At the furthest point from the receiver (≈75 km), there was still enough signal strength (−101 dBm) to receive some data.

Temperature profile behaves as expected, showing a dip at the boundary layer and a minimum at the tropopause at 8.2 km using hydrostatic approximation.

Humidity profile shows an increase at 1.5 km, indicating a cloud layer. The way up shows an unexpected increase at 3 km, which is likely not to be a physical problem, but an instrumentation problem. This problem seems resolved on the way back.





Conclusions

The CanSat demonstrates the ability of an accessable way to measure atmospheric quantities, however more thorough testing and calibration is recommended, especially concerning the GPS positioning jumps and the NTC response. The higher sampling rate is succesful in clearly showing attitude dynamics in the single Hertz range. A further look into the humidity sensor is required in order to explain the recorded behaviour.