AGF 223 Flight Campaign: CuteSat

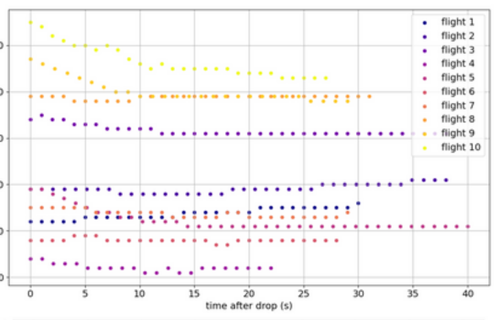
Selma Kiefersauer

Objective

The objective is to measure atmospheric properties with a CanSat during descend and see if we can relate the results of the measurements to the standard atmosphere model. In addition to properties like humidity, temperature and pressure the GNSS data can be used to derive windspeeds along the trajectory. The CanSat gets flown up with a drone to a height of 120m and then dropped with a deployed parachute while telemetry gets transmitted to our groundsation. We did 10 flights at KHO Breinosa (520m above sea level) and three flights in Adventdalen (15m above sea level). Just two flights in Adventdalen gave reasonable data, as we had huge data gaps in the second flight. I will not include the flights in Adventdalen in the analysis as they didn`t give any new insights.

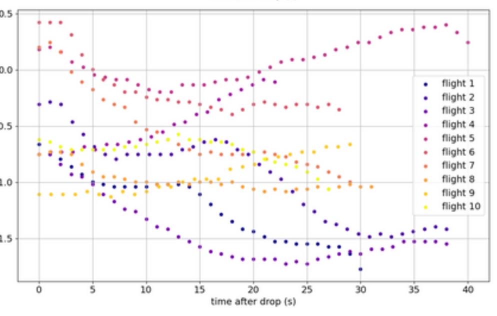
Humidity

As mentioned in “Calibration of the sensors” the time constant is way too long, the output is basically constant. What can be seen in the data is that the CanSat got filled up with snow during the landings which then melted and gave some very high humidity measurements during some flights.



Temperature sensor

The 9s time constant delays and falsifies the measurement. It can not be used directly to obtain the temperature at different heights. The general range of temperatures of -1.5˚C to 0.5˚C we obtained agrees with the reference sensor outside KHO. Expected result for change in temperature: lapse rate in the troposphere is -6.5K/1km so -0.78˚C for 120m height difference.



CuteSat technical data

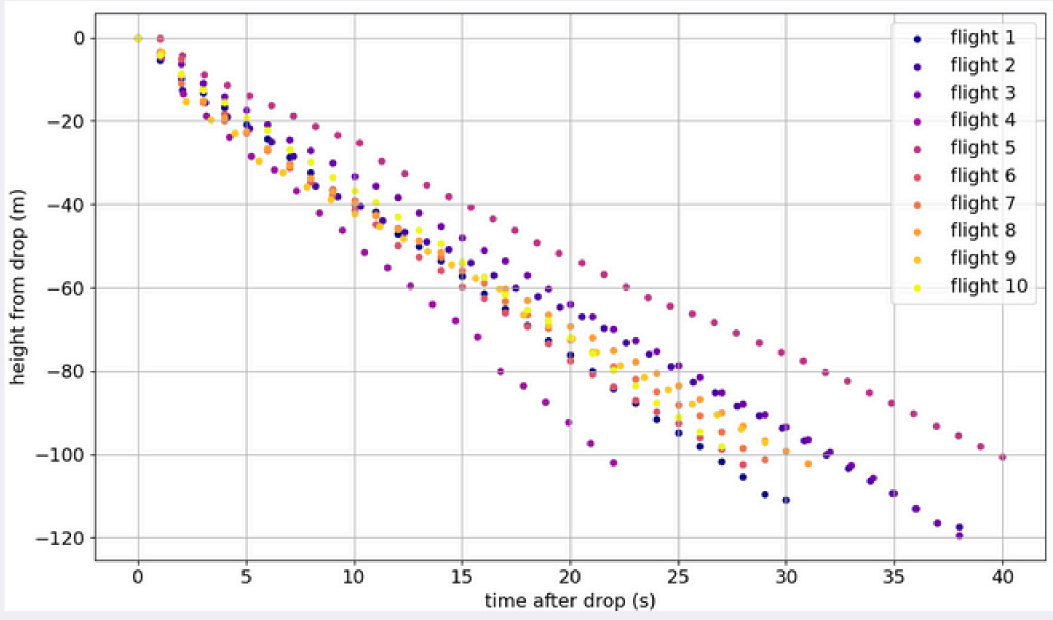
- RFM96 LoRa Radio 433MHz (transmitting and receiving)
- GNSS receiver (GPS, GLONASS, GALILEO, QZSS)
- BME280 sensor (pressure, humidity, temperature)
- Orientation IMU (uses accelerometers, gyroscopes and magnetometers to compute orientation)
- NTC resistor/ thermistor
- Receiver/Groundstation

Pressure

The results proved quite useful, they can be used to calculate the height during the flight. The drop of the CanSat is clearly visible in the data, therefore I used this to define the point of the drop in all the data.
Formula to calculate height from pressure (from hydrostatic equlibrium):

$$z_2 - z_1 = \frac{R_a T}{g} \ln\left(\frac{p_1}{p_2}\right)$$

Here we assume a constant temperature, which seems reasonable over a distance of 120m. The expected change in temperature over 120m is 0.78˚C according to the atmospheric standard model.



Calibration of the sensors

Humidity and temperature sensor have a very long time constant: several minutes. Part of the problem is the sensors being inside the Can, so the air needs a long time to reach the sensor when entering a new airlayer or a different environment. In addition the electronics of the CanSat produce warmth which leads to a 2-3 degree difference compared to reference sensors.

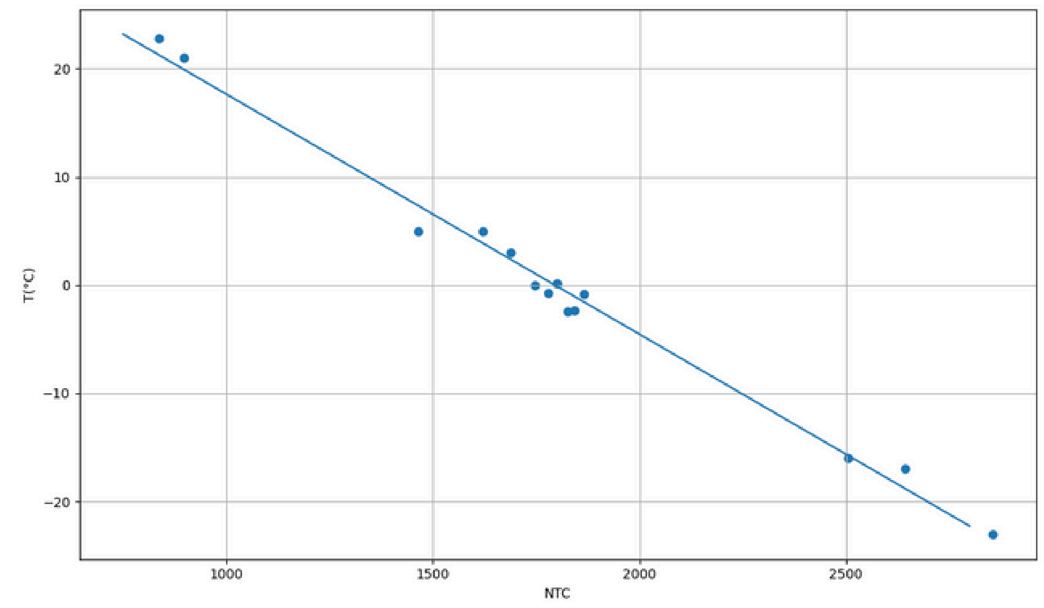
The NTC sensor has a time-constant of 9s, so too long for the 30-40s flights but otherwise helpful if the sensor stays in a place for some time and has time to adjust. The sensor is outside the CanSat and it gives a ADC value for the change in voltage that then can be converted into a temperature reading. But it needs to be calibrated and a curve needs to be fitted to give a meaningful temperature (see below).

NTC Calibration:

We can get the temperature from the NTC value by taking several reference measurements and then fit a curve to the data.
The formula to calculate the temperature from the NTC value that we get that way is:

T = - 0.02218 * NTC + 39.8125

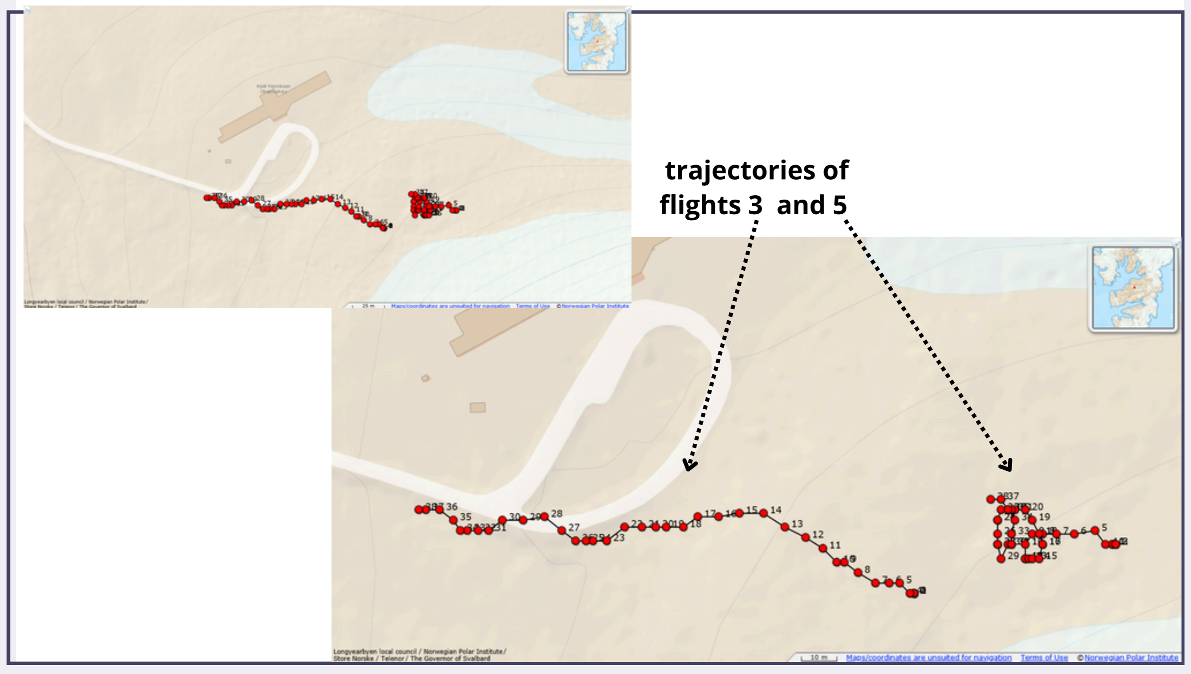
- Uncertainty: from the fit: [0.00065, 1.2289]
- uncertainty in the temperature T: 1.34 ˚C

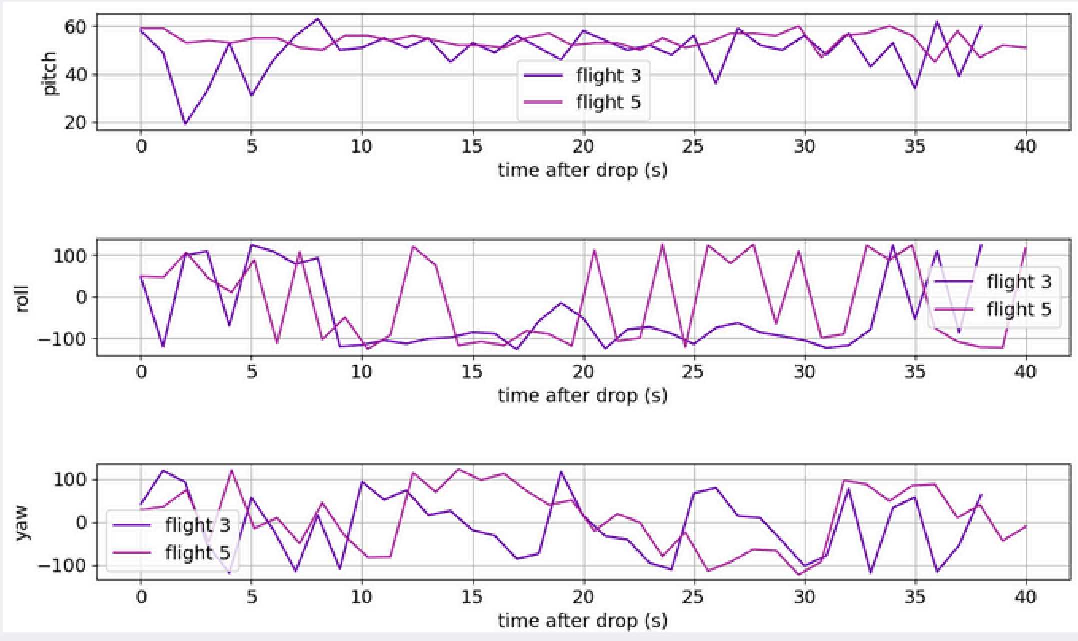


GNSS module

GNSS data can be used to plot a track of the flight on TopoSvalbard, this way there can also be checked if there are big jumps in the GNSS data.

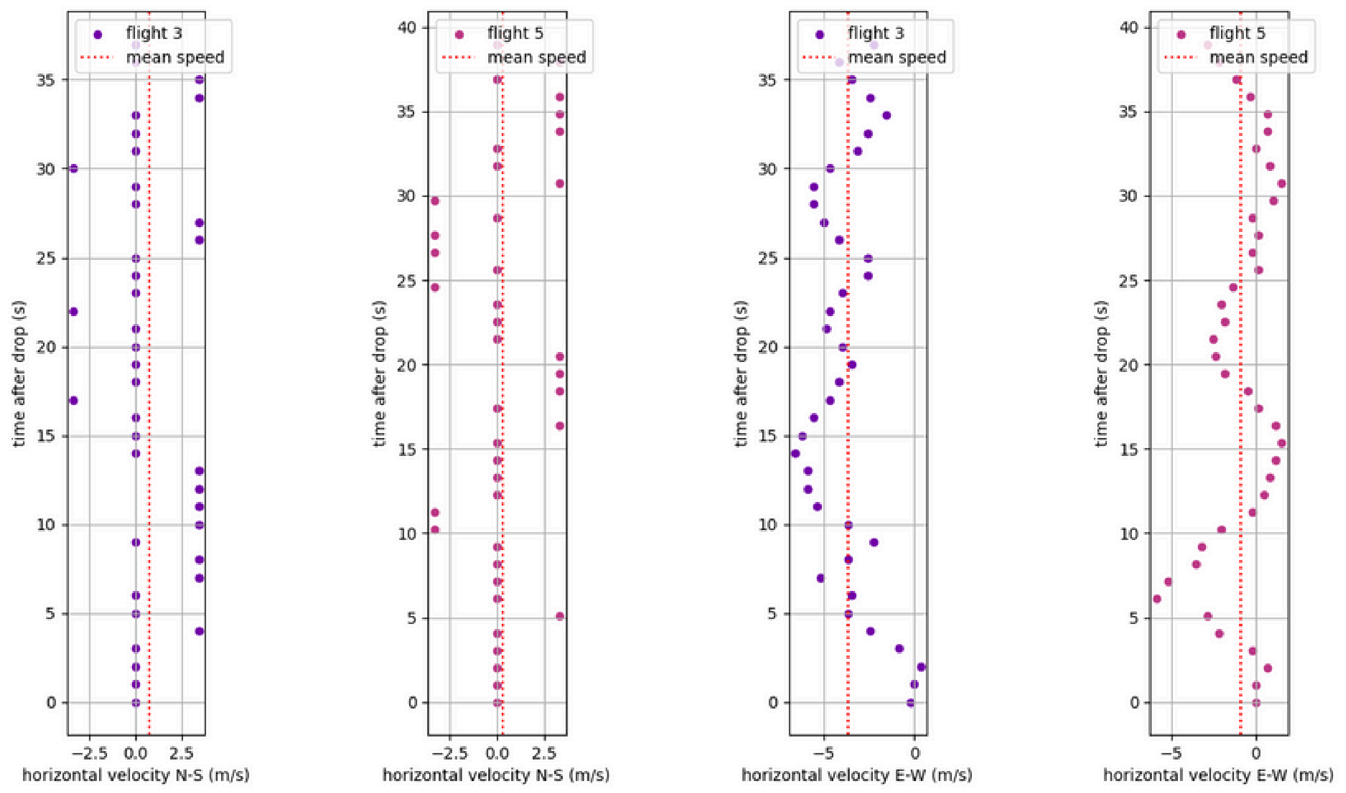
- Standard deviation: latitude 6.3m, longitude 5.3m (measured at UNIS)
- The data is not useful to display the height of the CanSat directly as it clearly does not give the 120m height difference during the flight but distances between -10 and 50m
- Position can be used to derive wind direction and speed by converting the position in degrees to meters and taking the derivative (I used timesteps of 1s and the forward derivative for discrete data)





Winds from GNSS data

As the CanSat moves with the wind on the descend, due to it being attached to a parachute and slowly floating down, the local windconditions can be seen in the movements of the CanSat.
We chose two flights with quite different trajectories to compare the flight tracks and the velocities in north-south and east-west direction.
There is not a big difference in N-S, as is also evident in the TopoSvalbard-tracks, the mean speed is close to zero, but in E-W direction there is a clear difference: about zero for flight 5 and almost -4 m/s for flight 3. This fits quite well with the track on the map which covers a much larger distance than flight 3.



Pitch, Yaw and Roll

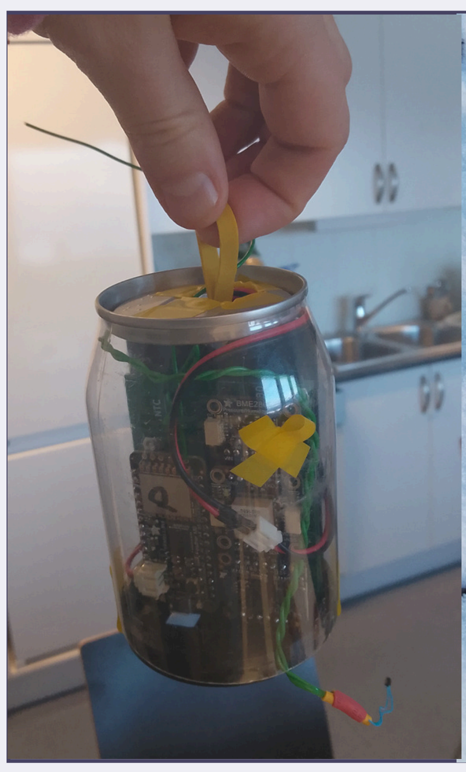
Our flights were quite stable, even though the attitude measurements are more chaotic.This is due to the position of the can during flight and the definition of the zero points: zero is when the sensor is horizontal and the board parallel to the ground. Therefor the numbers jump a lot when the CanSat is upright. Small variations can be seen from from flight to flight, showing the movement of the CanSat.

References

TopoSvalbard, *https://toposvalbard.npolar.no/*

David G. Andrews. *An introduction to Atmospheric Physics.* Cambridge University Press, 2010.

Andøya Space: *Balloon Data vs. Standard Atmosphere Model.* 2025.



Conclusion

- The data for atmospheric pressure were very accurate and could be converted to a height difference or a flight trajectory that agreed very well with what we expected
- The convertion of the NTC value to a meaningful temperature was successful, but the time constant of the sensor is too long to be useful during a short flight with a fast descend. In addition are the uncertainties for NTC too large to show the subtle changes in temperature over a 120m drop
- The GNSS module can be used to plot the trajectory, even though it has uncertainties of a few meters or can have unexpected jumps. But the height measurement is very unreliable
- Humidity and BME temperature did not give helpful data, their placement in the Can leads too a very long time constant of several minutes
- The data that we aquired and that does give meaningful results does fit the standard atmosphere model

possible improvements:

- We could try to correct for the time delay in the thermistor, for example by waiting 10s with the drone before drop
- We should have done another GNSS calibration at KHO Breinosa before the flights, then we would have a better standarddeviation for that day and that location instead of using the one from the measurement at UNIS
- It might also be interesting to try fly the CanSat higher up to get larger changes in the data