Erhöhte Zuverlässigkeit der GPS Drohnennavigation dank einem integrierten Barometer

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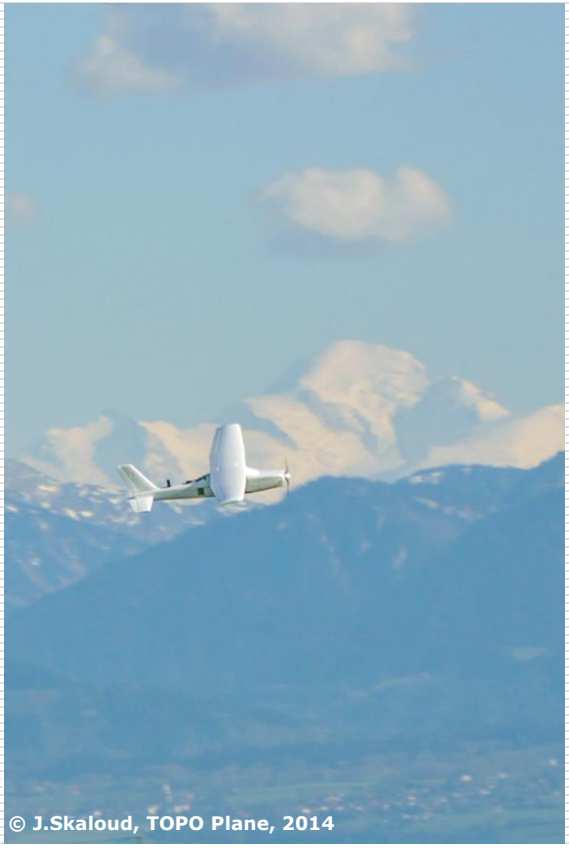


ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

AHORN
Garmisch-Partenkirchen 2016

Motivation

- River
- Highway
- Privat Movies
- …

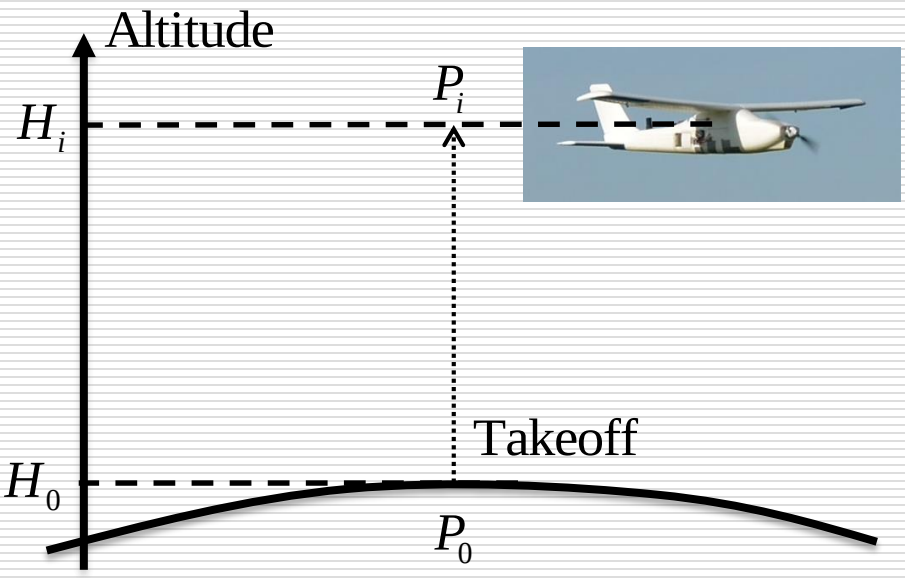
What's on the menu

- Barometer
  - Physics
  - Problems
- UAV Platform
- Methodology & testing
  - System calibration
- Performance with GNSS outage
- Conclusion

Barometer – Altitude determined via pressure

- Model of a "perfect" gas

$$H_i - H_0 = -\frac{RT_0}{Mg}\log\left(\frac{P_i}{P_0}\right)$$



R : universal gas constant

g : gravitational acceleration

M : molar mass of air

$T_{0:}$: air temperature

P_0 : reference pressure of takeoff

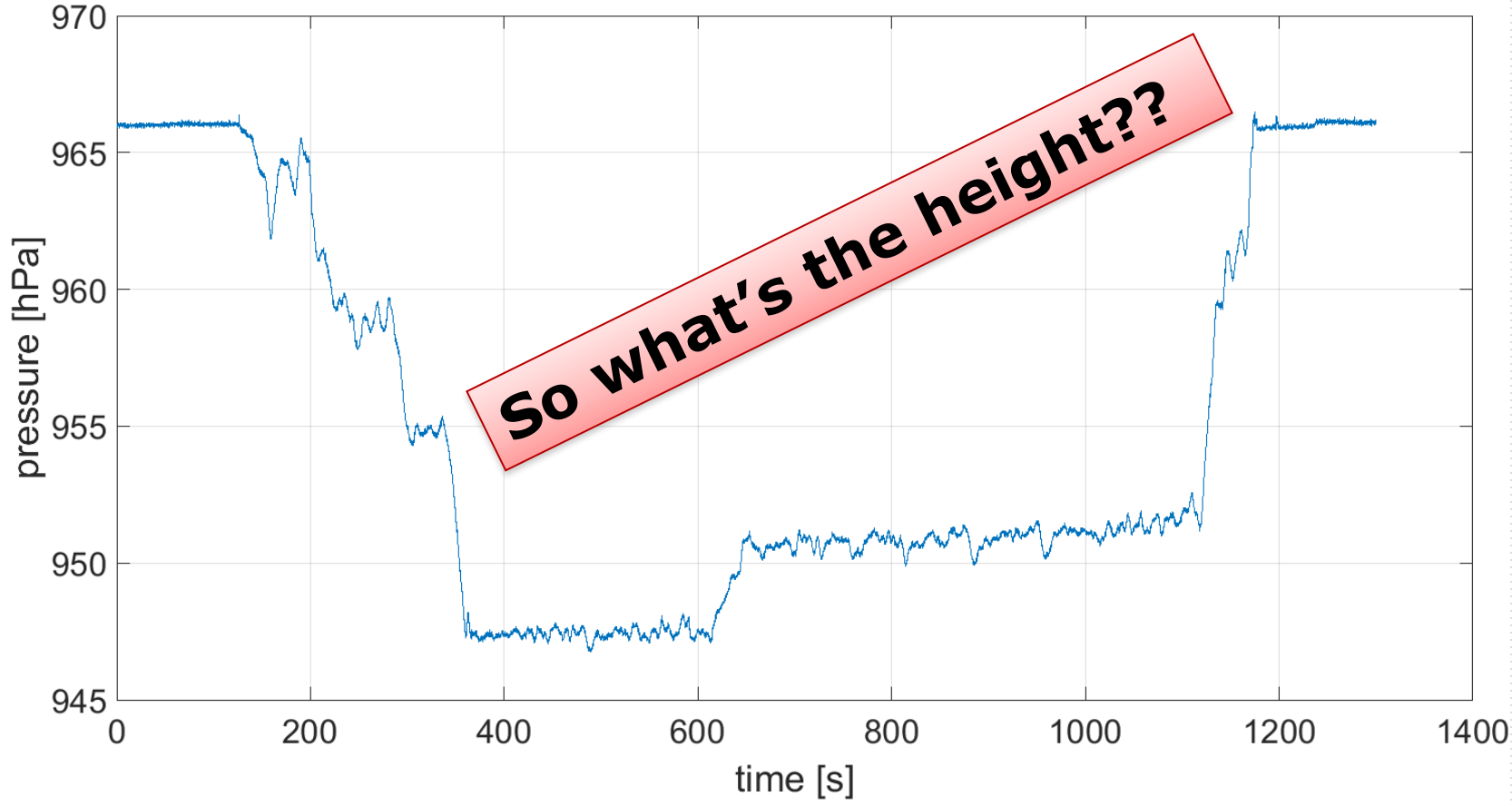
P_i : pressure at certain heigth

Barometer – Influence of parameter variations

$$H_i - H_0 = -\frac{RT_0}{Mg}\log\left(\frac{P_i}{P_0}\right)$$

	Unit	Typical value	Δ	ΔH [m]
T_0	K	293.15 ($= 20°C$)	±1	±0.61
P_i	hPa	950	±1	±8.84
P_0	hPa	970	±1	±9.02
M	kg/mol	0.029	±0.0001	±0.62
g	m/s^2	9.80665	±0.001	±0.02

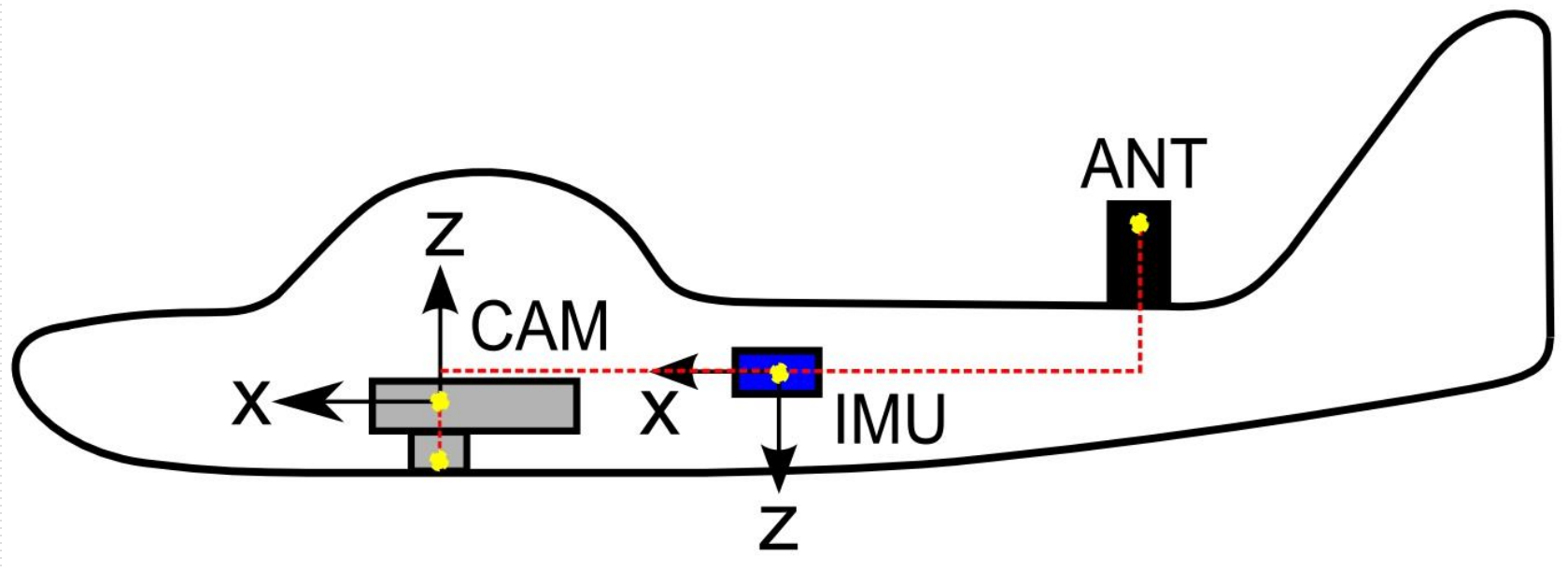
Barometer – Observations on typical flight



TOPO Plane – Characteristics

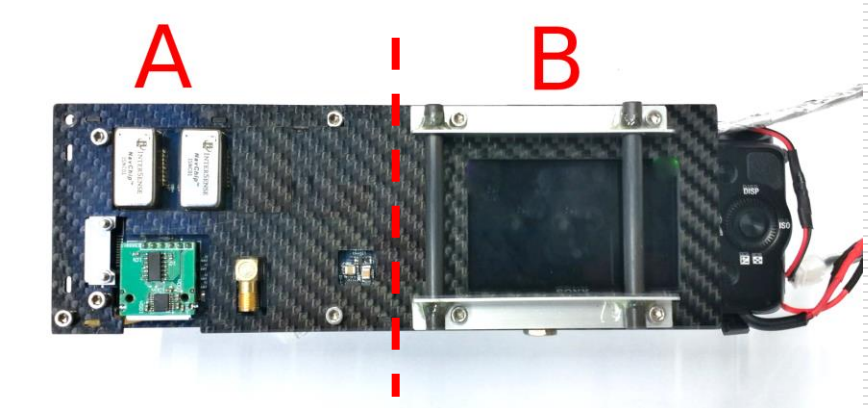
- Custom built
  - 150 € frame (as MAVinci)
  - Off-the-shelf components
- 1630 x 1170 mm
- Operational weight 2.8 kg
- Endurance of 40 min with 600g of payload
- Flying speed 16-20 m/s
- Pixhawk autopilot

TOPO Plane – Characteristics

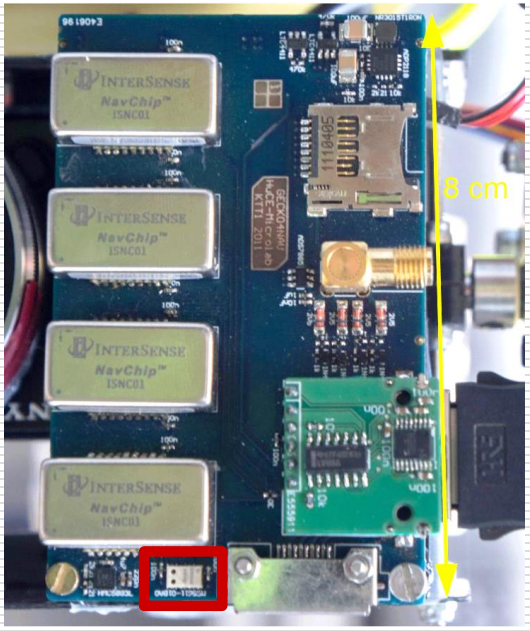


TOPO Plane – Payload

- Redundant-IMU (A)
  - FPGA board
  - 1-4 x MEMS IMU
  - 250 – 1000 Hz

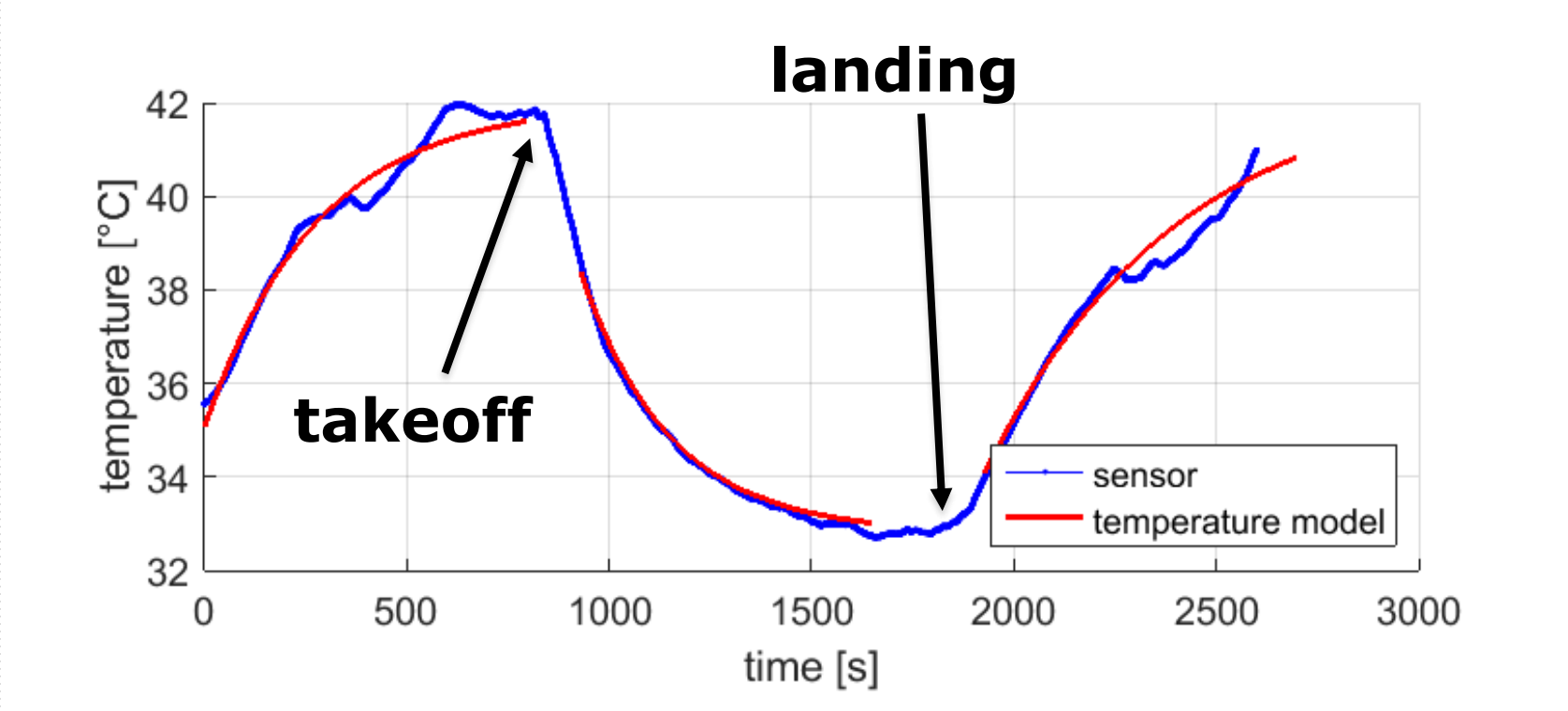


- Camera (B)
  - Sony NEX 5T camera (16 Mpx)
  - 16 mm lens (used in test)
  - synchronization module (flash)



- GNSS
  - multi freq., PPS, Event
  - GPS/Glonass L1/L2 antenna

Problem – Heating

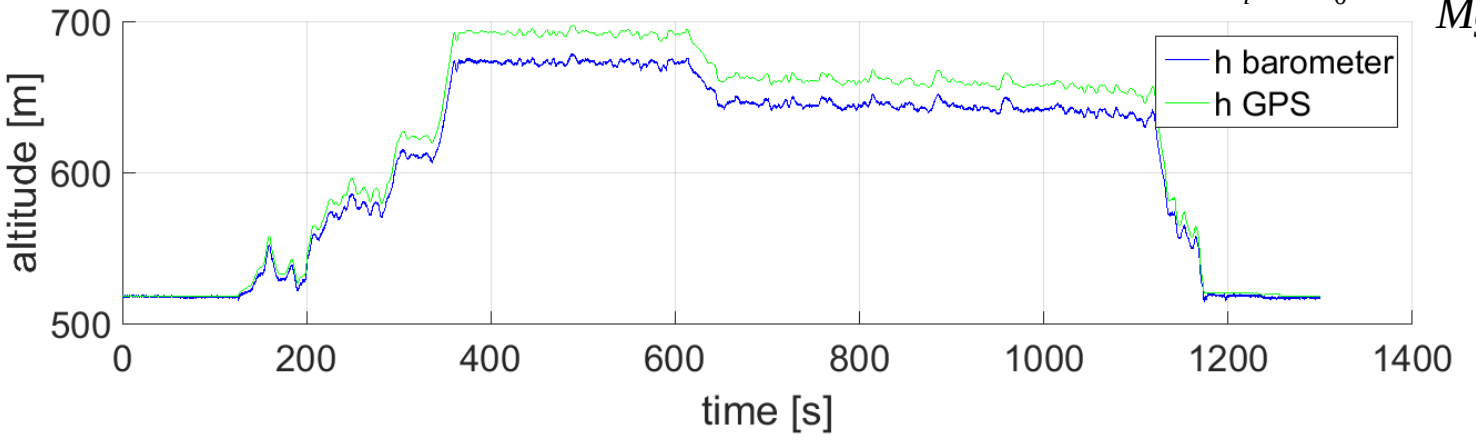


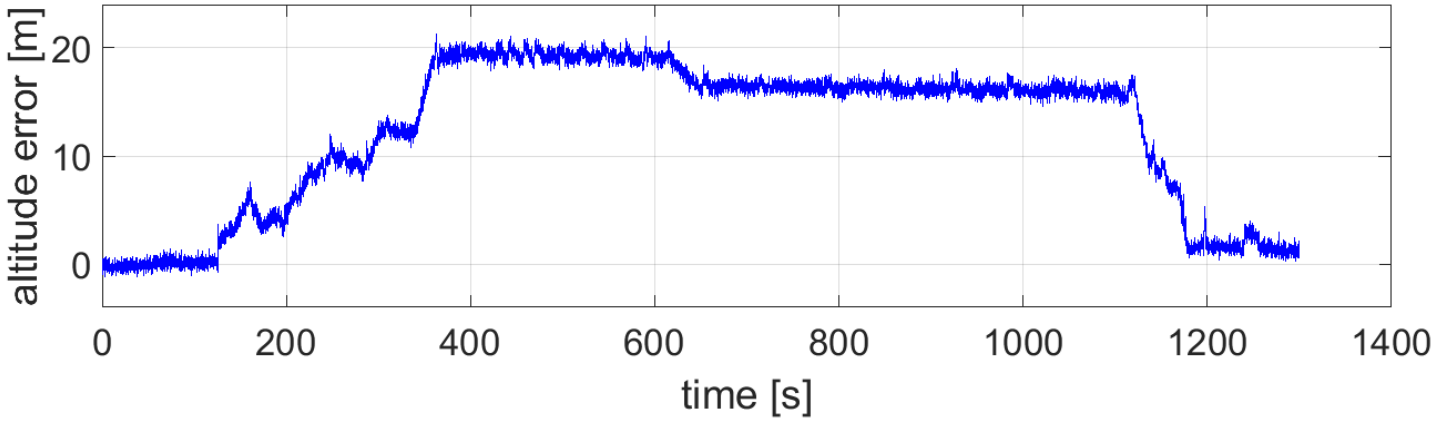
$$H_i - H_0 = -\frac{RT_0}{Mg}\log\left(\frac{P_i}{P_0}\right)$$

Problem – NO parameter calibration

- Used only standard values for M, T_0 and P_0

$$H_i - H_0 = -\frac{RT_0}{Mg}\log\left(\frac{P_i}{P_0}\right)$$





Problems

- Influence of temperature
- Influence of humidity
- Influence of reference pressure

$$H_i - H_0 = -\frac{RT_0}{Mg}\log\left(\frac{P_i}{P_0}\right)$$

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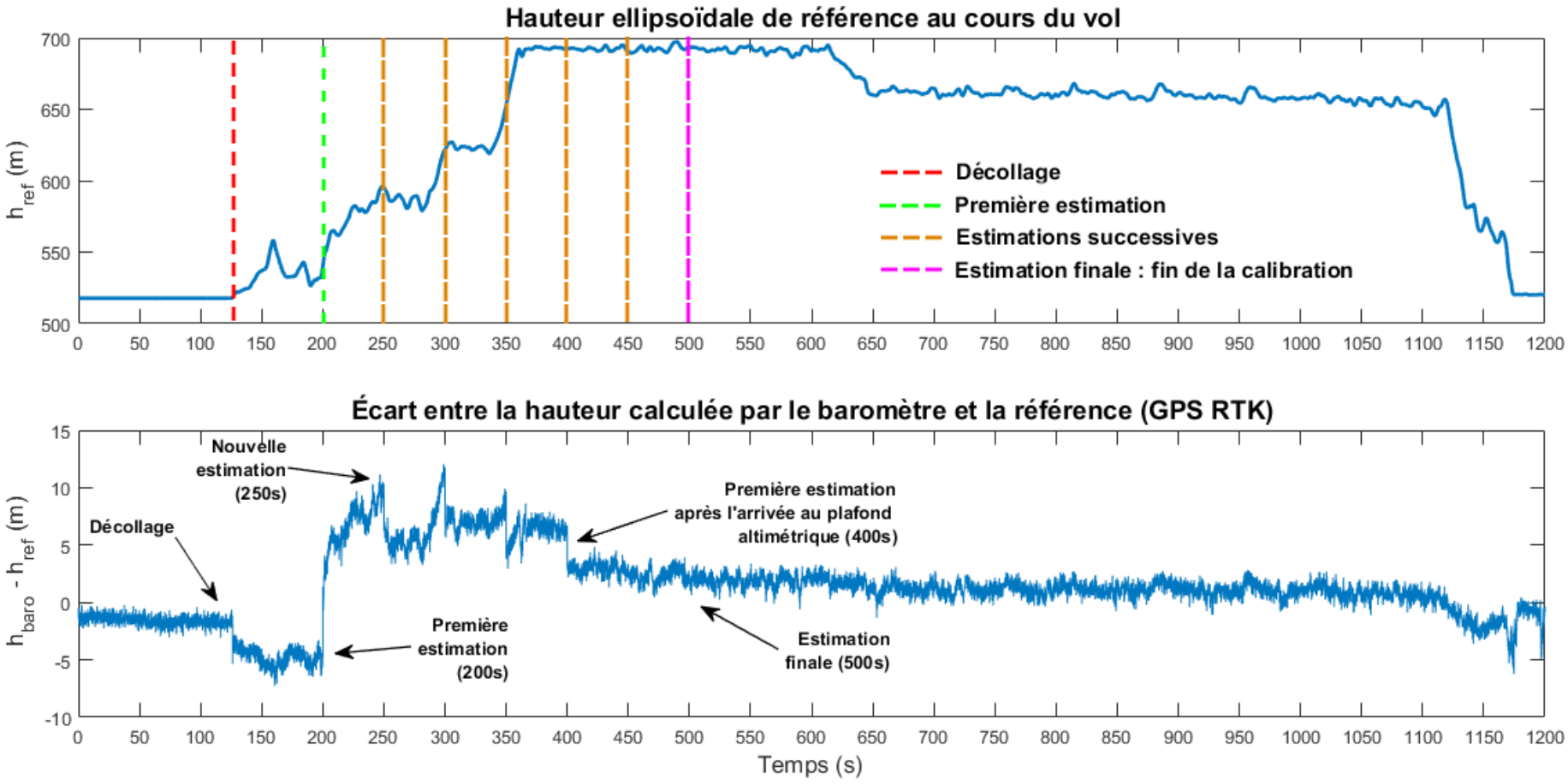
$$H_i - H_0 = -\frac{RK}{g}\log\left(\frac{P_i}{P_0}\right)$$

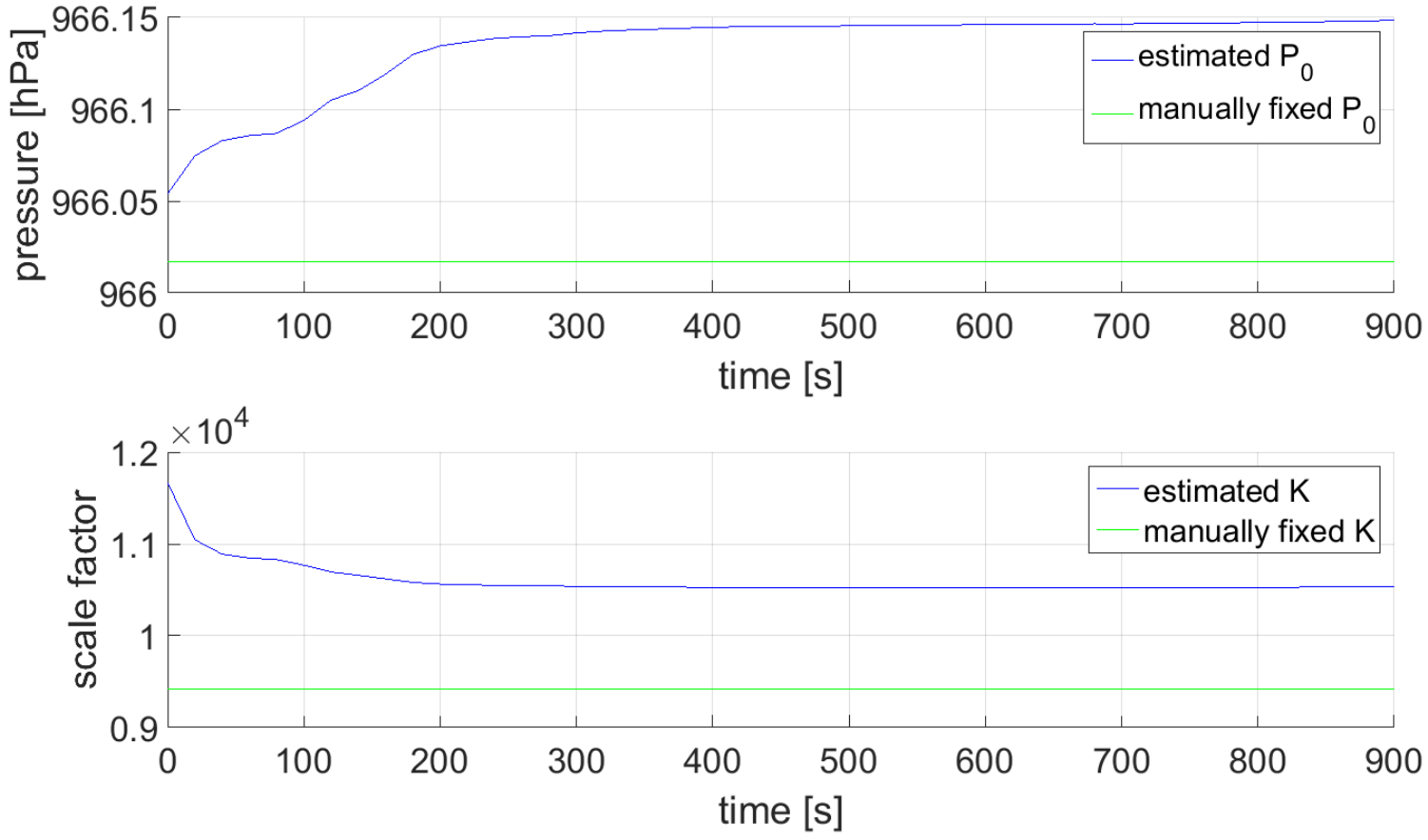
we want **we estimate**

we measure

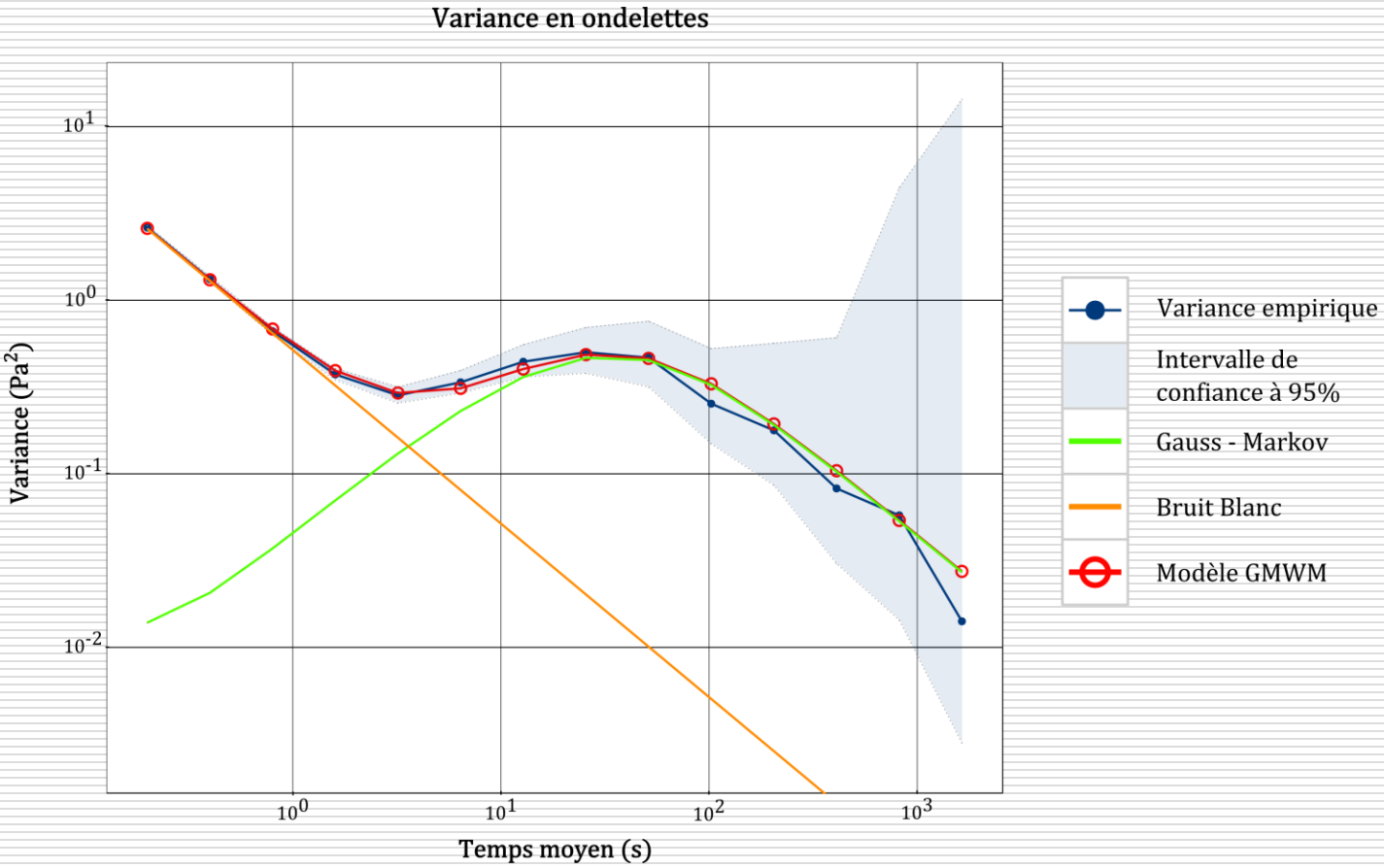
Least Squares with Code-measurements



Parameter estimation

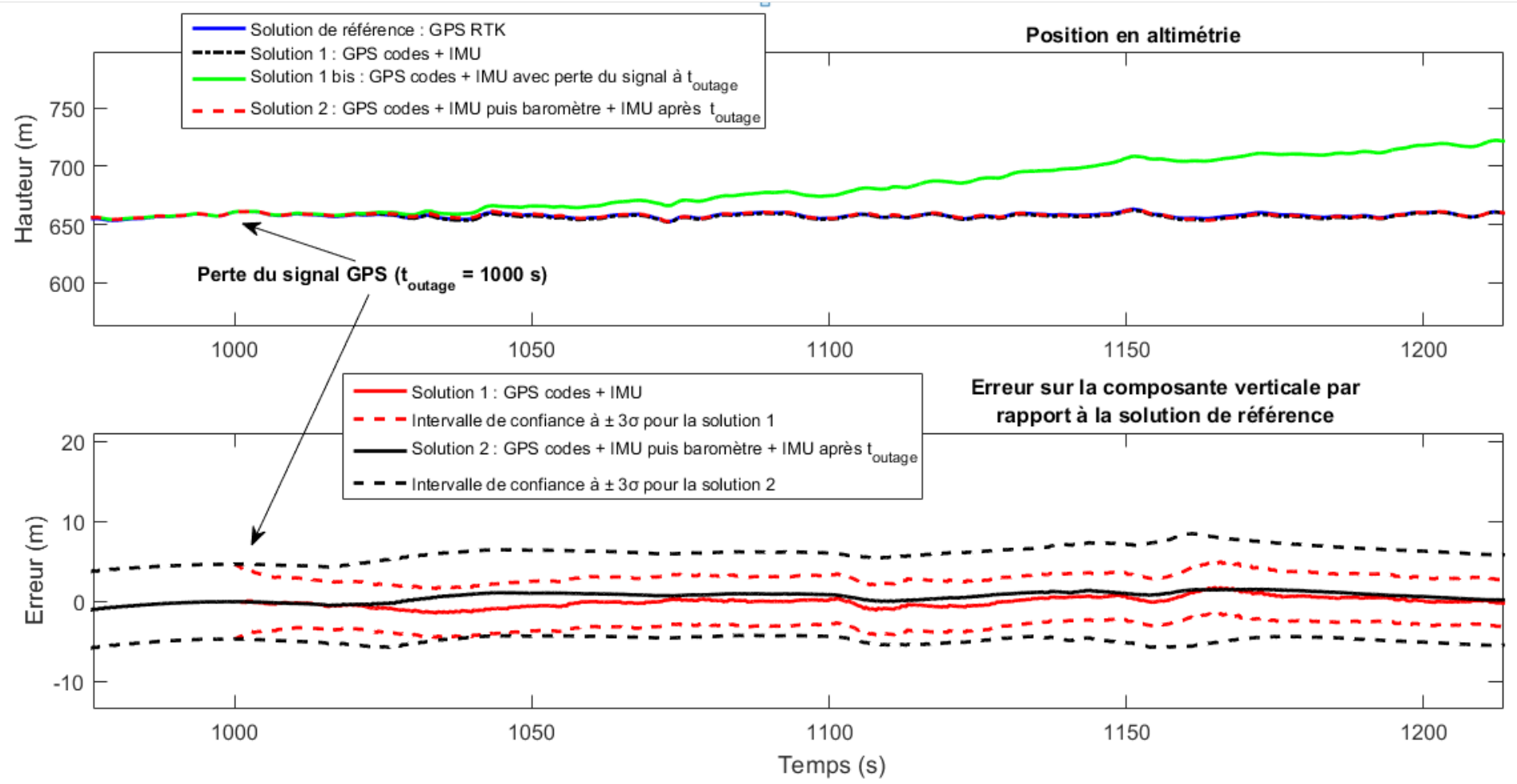


Stochastic Noise characteristics via GMWM



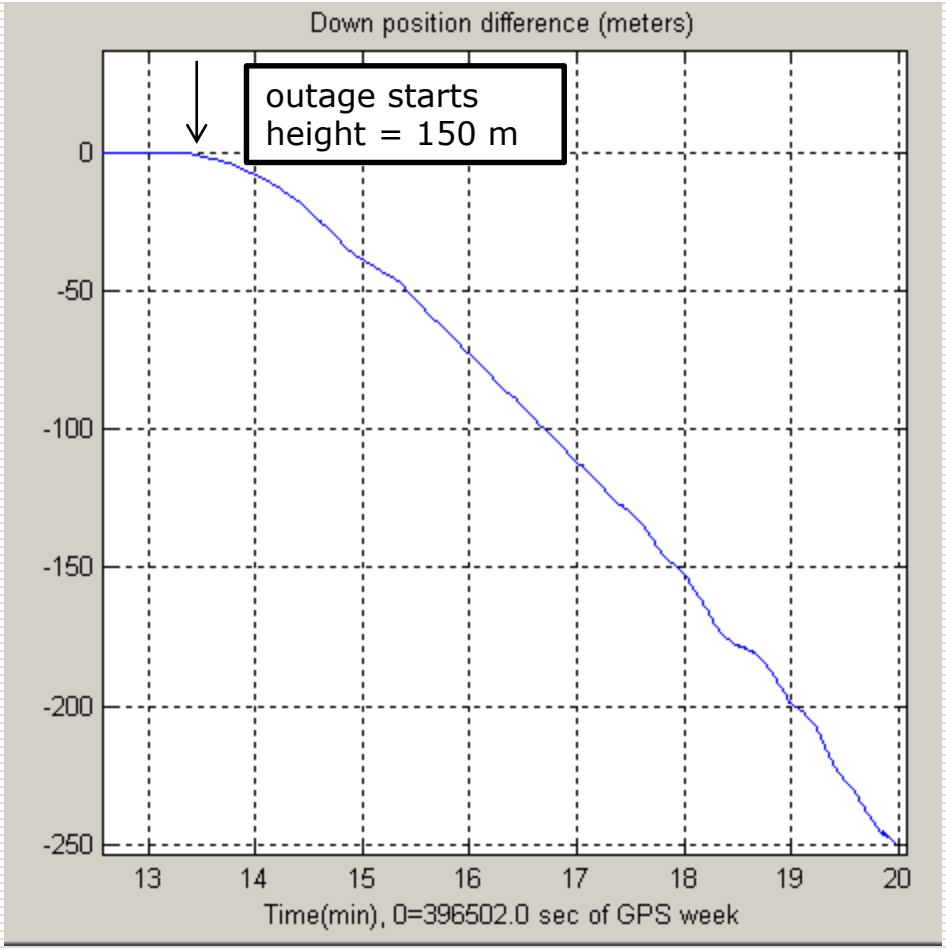
Guerrier, S., Skaloud, J., Stebler, Y. Victoria-Feser, M.-P. Wavelet-variance-based estimation for composite stochastic processes, **Journal of the American Statistical Association**, 108(503): 1021-1030.

Example – Impact in height with GPS outage (s)

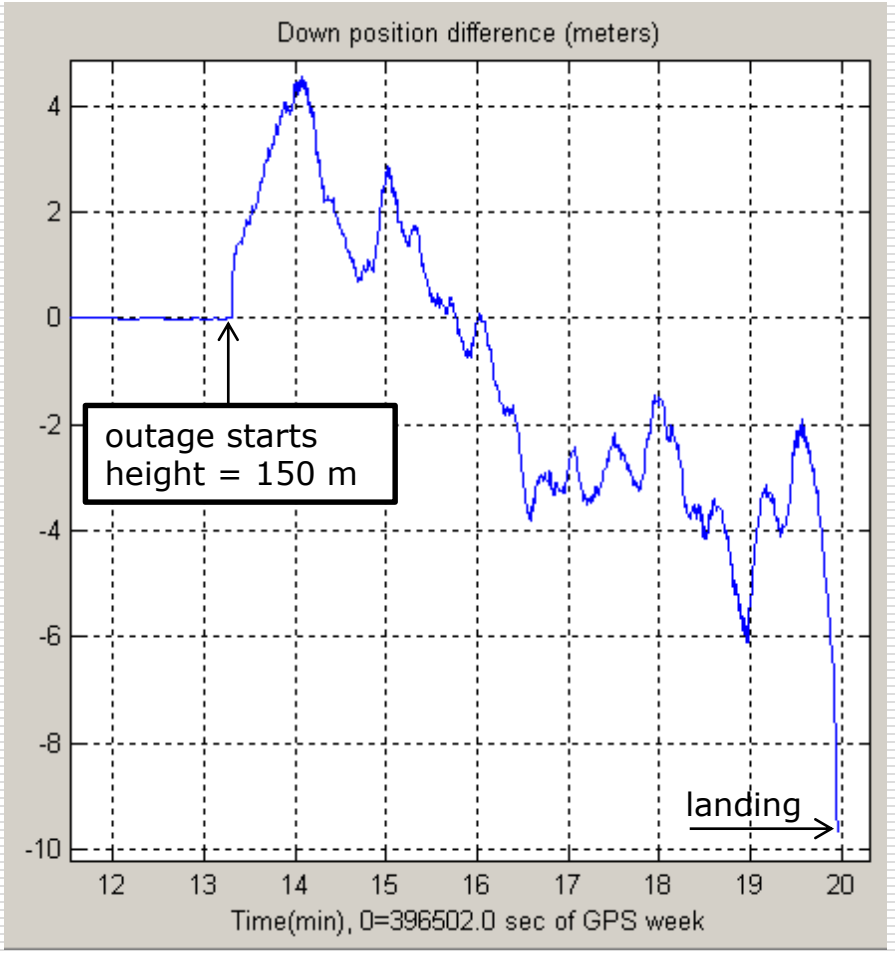


Example – Impact in height with GPS outage (min)

- Free INS – GPS, SPP



- Baro-aided INS – GPS, SPP



Processing requirements

- Correct time-synchronization of data
  - IMU
  - Barometer
  - GNSS
- Estimation of scale-factor K and initial pressure P_0 via GNSS measurements during flight
- System calibration with IMU/Barometer/GNSS
  - Noise characteristics
  - Position & attitude
  - Leverarms
  - Custom filter

Conclusion

- Increased Redundancy
- Better height uncertainty
  - Barometer better than GNSS-Code in height
- System calibration is needed
  - Deterministic
  - Stochastic
- Bridge certain length of GNSS gap
  - Return-home if problem is detected
  - Height accuracy better than single point positioning < 5 min of GNSS signal outage

Questions

Reference

- *Luiset, B., Clausen, P., Skaloud J., Développement d'un baromètre – altimètre à bord d'un drone, Projet de Master, 2016, EPFL, ESGT.*