meteomatics
Mastering the weather challenge

Meteodrones

Flying under icing conditions

Dr. Martin Fengler

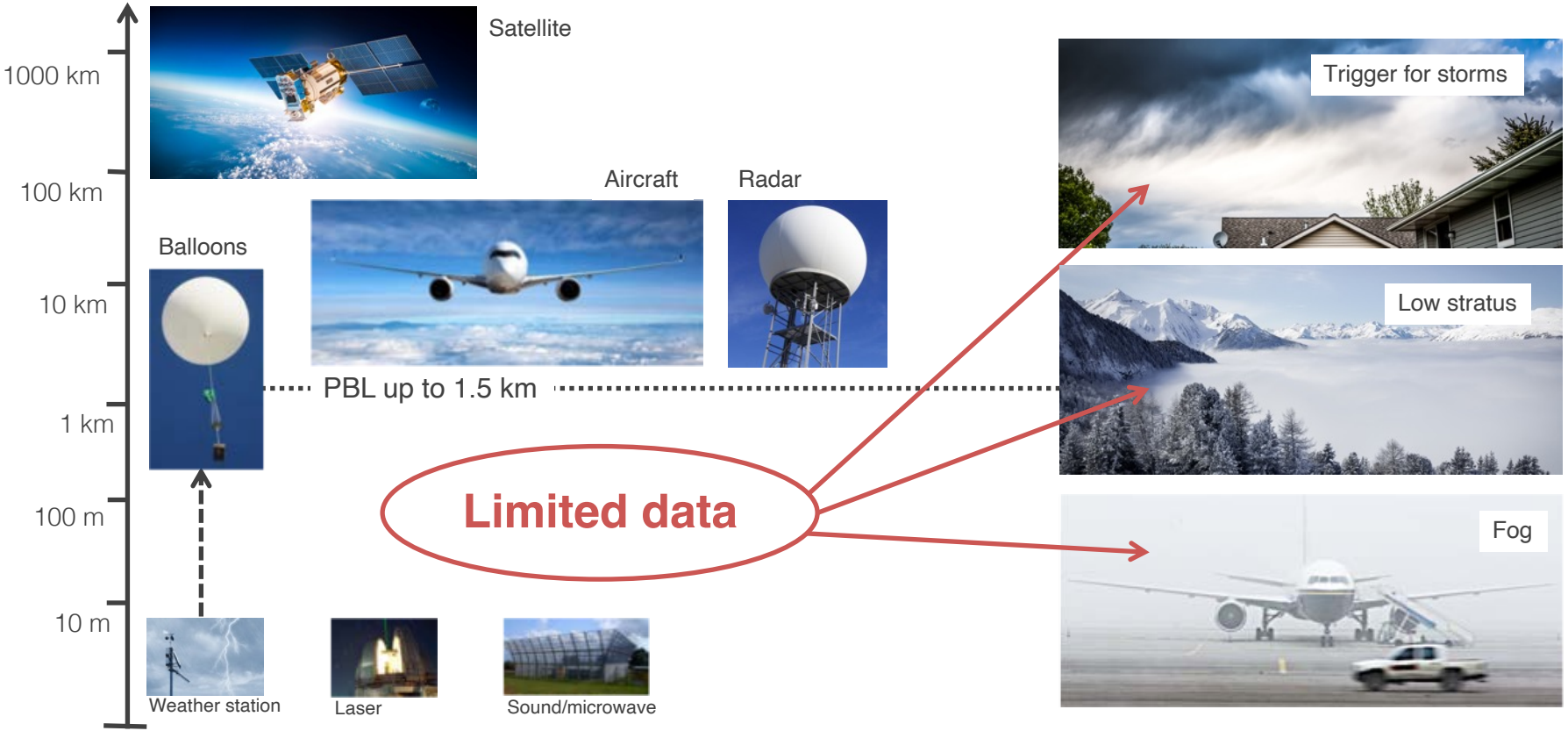
CEO

World class talent in meteorology, data science, drone development and service delivery

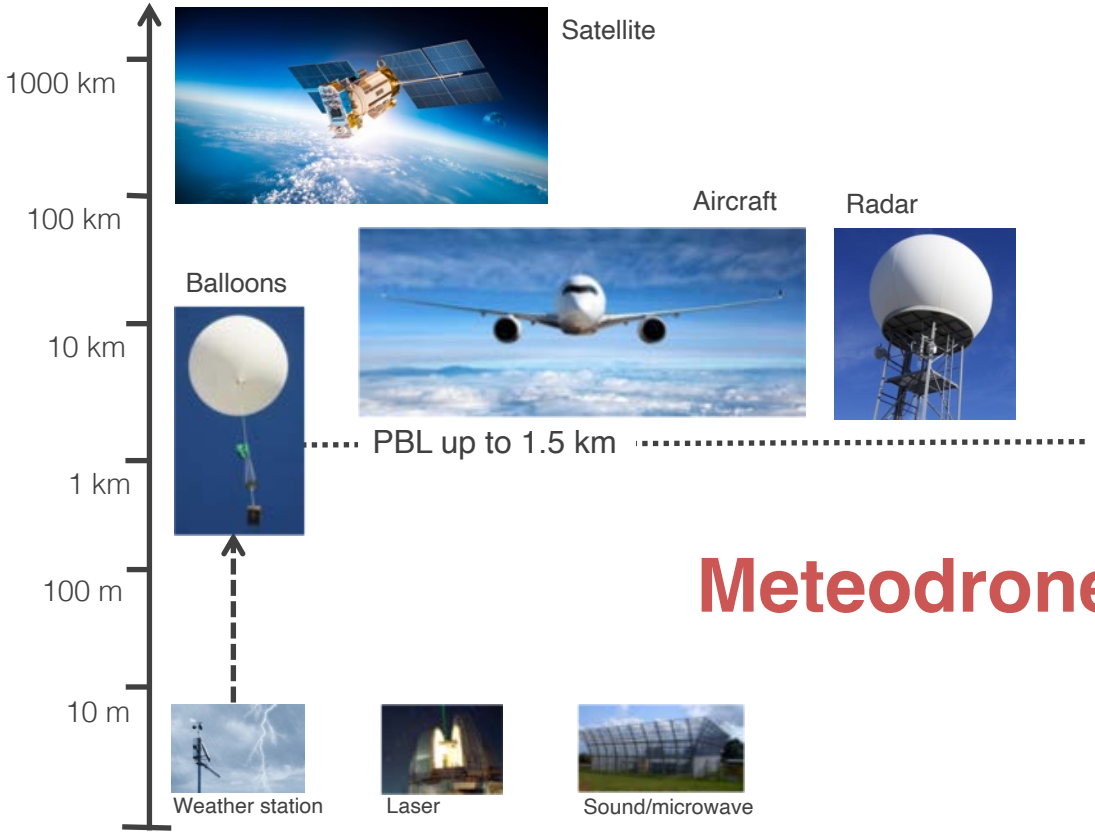
40 people | 3 offices | 3 countries | global partnerships

We are proud of Meteomatics' fair, hardworking, 'can-do' culture and a highly skilled multi-disciplinary team who rise to the challenge with our customers in a positive fashion. Creativity is a core skill whether it be in thinking, design, architecture or science.

Current data situation



Improving data situation



Meteodrone

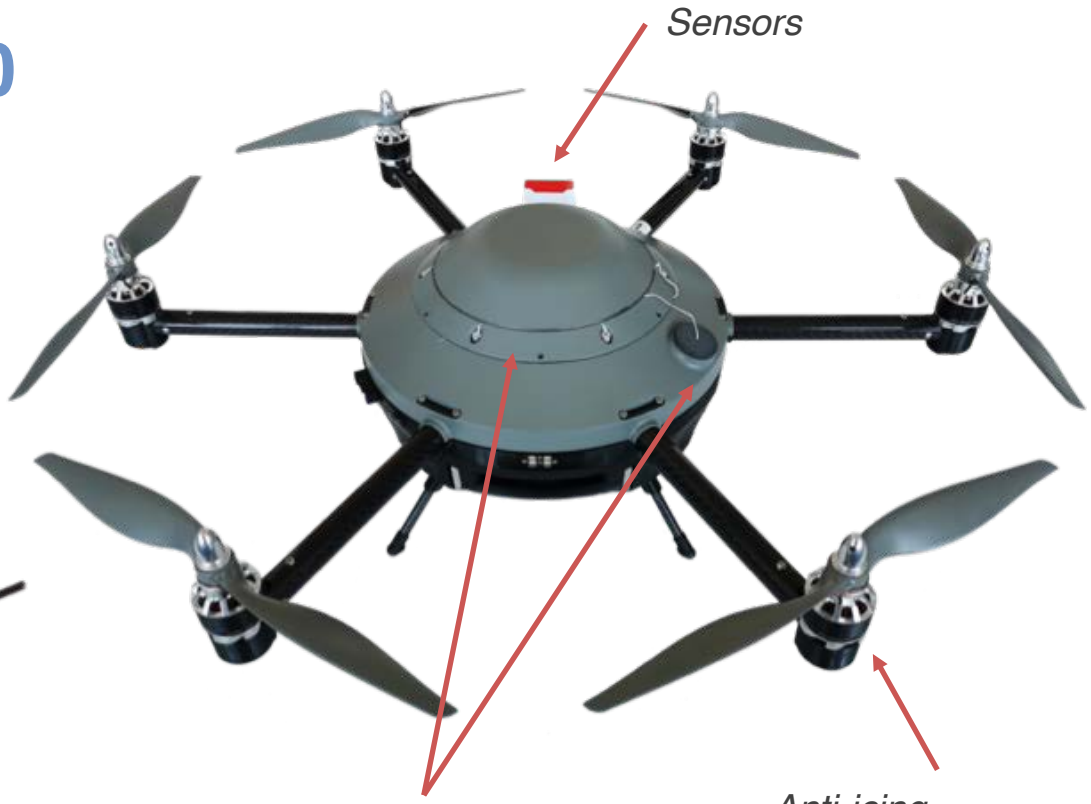
Meteodrone MM-670

Meteodrone / MM-670

Max. wind speed: 50kn / 90 km/h

Flight altitude: up to 6‘000m AMSL

Ø : ca- 70 cm; : 4.7 kg



Ground control station

Meteodrone sensors & flight profile

Pressure
Accuracy: 0.1 hPa
Response time: 250 ms

Dew point
Accuracy: 0.2 °C
Response time: < 4 s

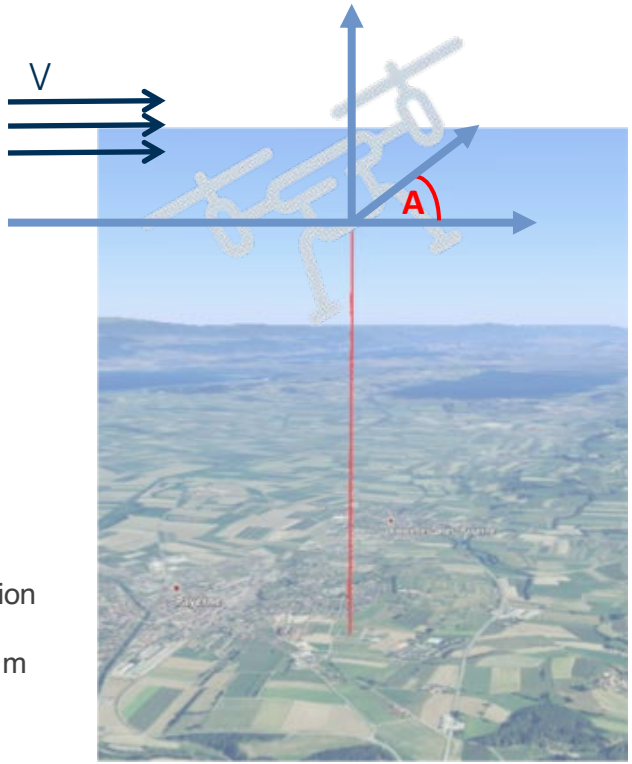
Temperature
Accuracy: 0.1 °C
Response time: 1 s

Wind speed & direction
Accuracy: < 1 m/s
Response time: 250 ms

The aircraft automatically compensates wind drag:

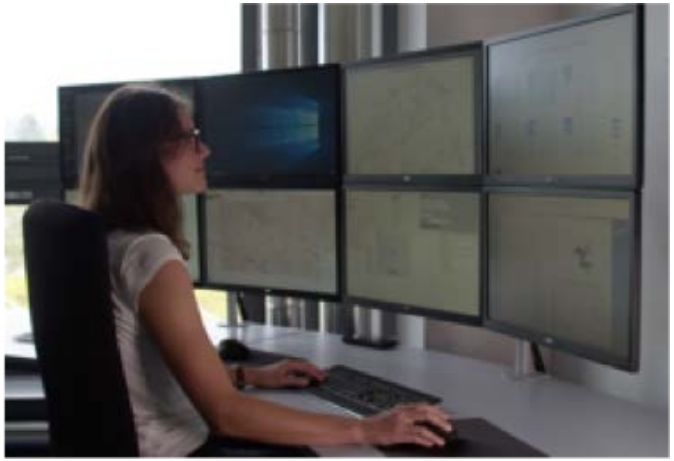
- Compute wind speed and direction from roll & nick angle
- Vertical flight profile up to 6'000 m

Relative humidity
Accuracy: < 2 %
Response time: < 4 s



Sensors are radiation-shielded and mounted in the rotor downwash.

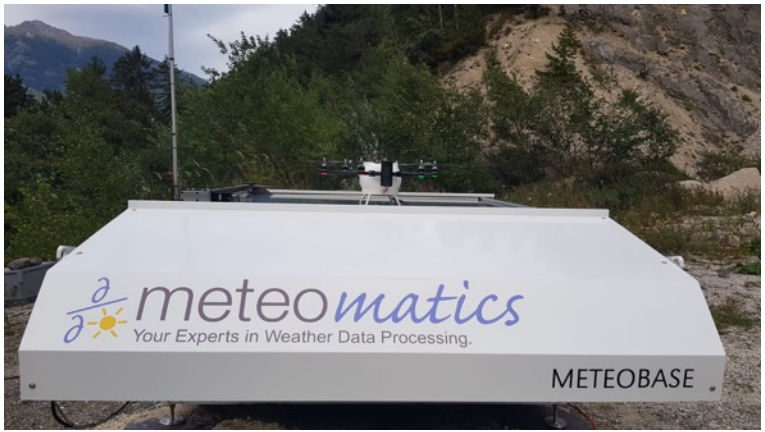
Meteobase – a remote platform



Our flight operation center

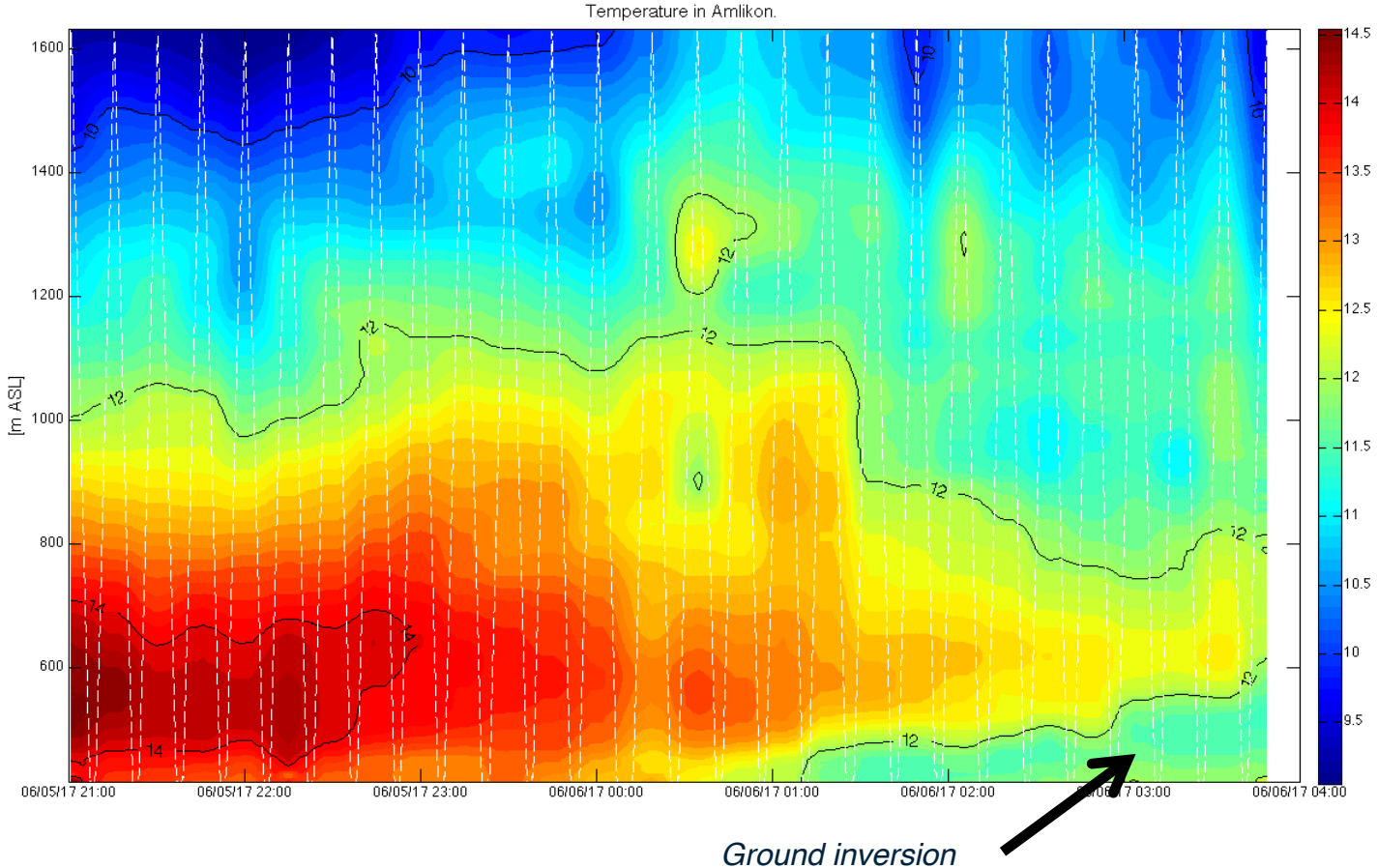
BVLOS certified by the Swiss Federal of Civil Aviation

Meteobase deployment at Illgraben

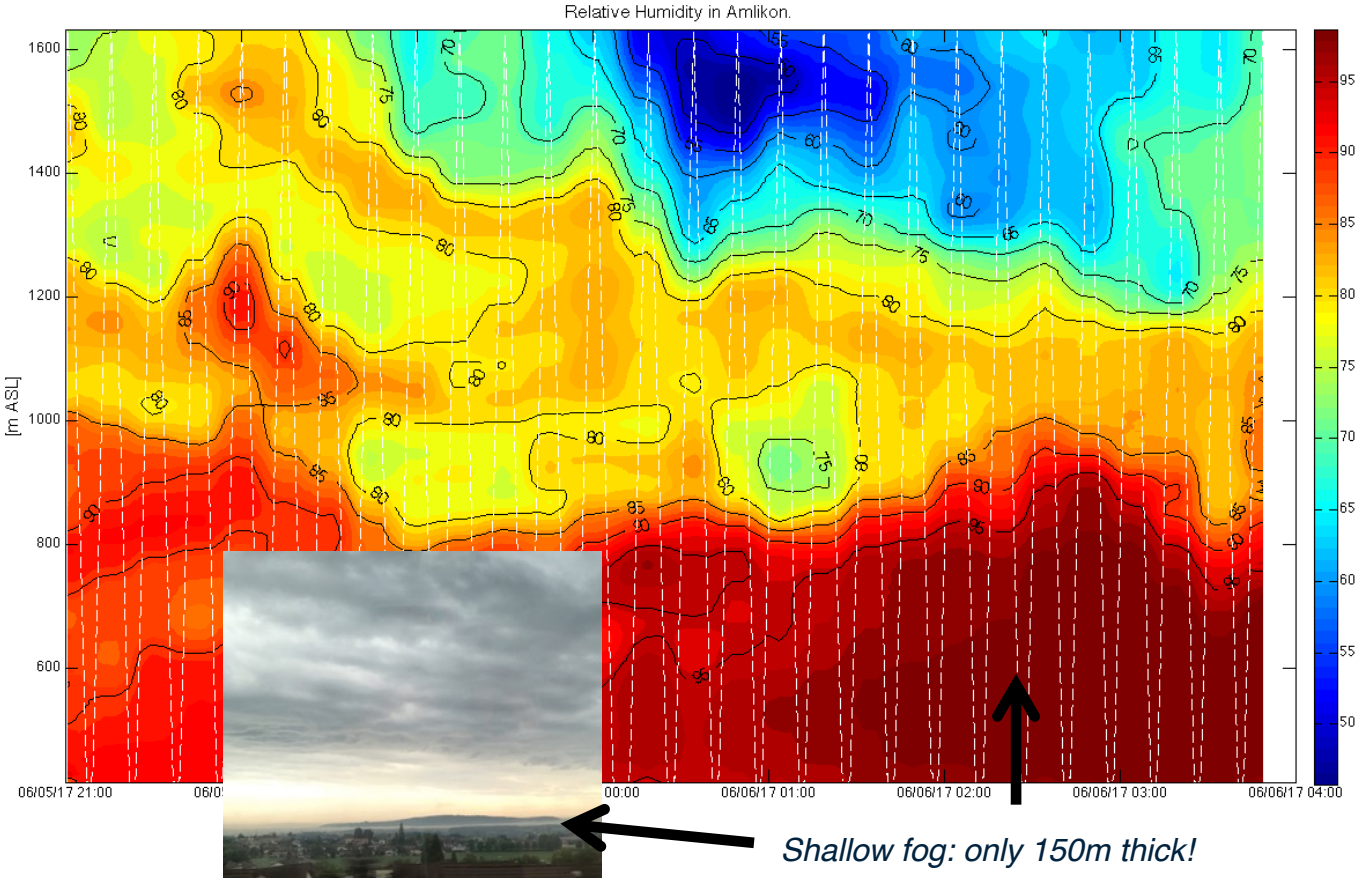



meteomatics
Your Experts in Weather Data Processing.
METEOBASE

Amlikon 5.6./6.6.2017: temperature



Amlikon 5.6./6.6.2017: relative humidity



Project DETAF

DETAF (Drone Enhanced Terminal Aerodrome Forecasts)

- Operating drones in 6 locations in the vicinity of and at Zurich airport
- Feeding data in real-time into SWISS1k
- Sending visibility & ceiling forecasts to Skyguide

Funded by:

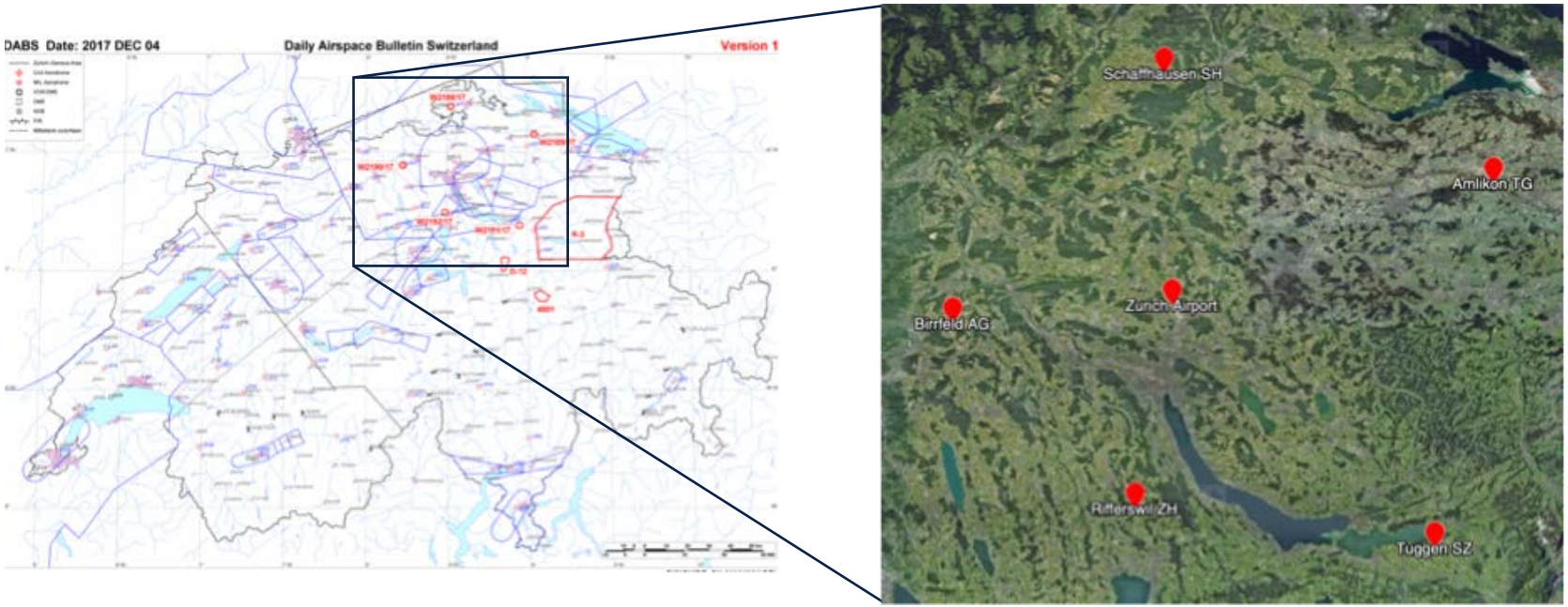
SWISS

ZURICH AIRPORT

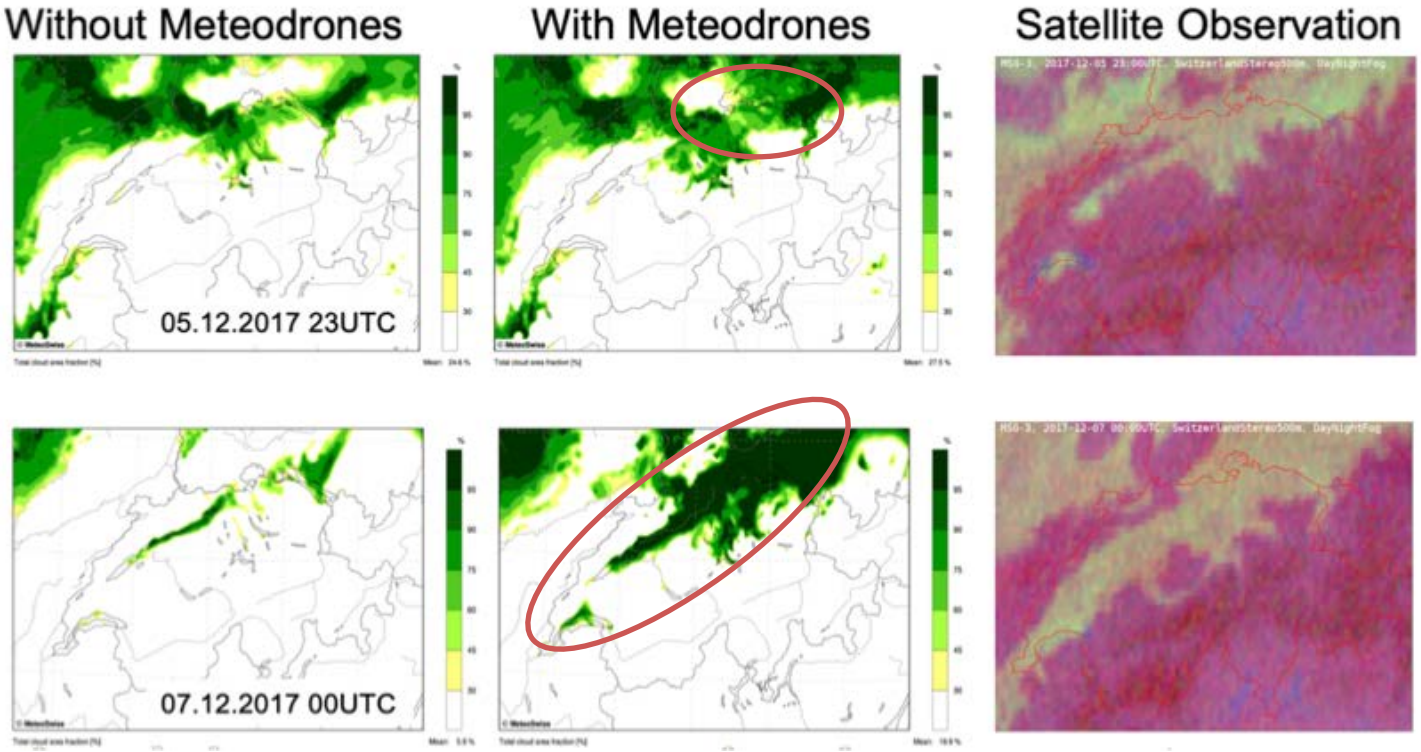
Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Bundesamt für Strassen ASTRA

DETAF Setup

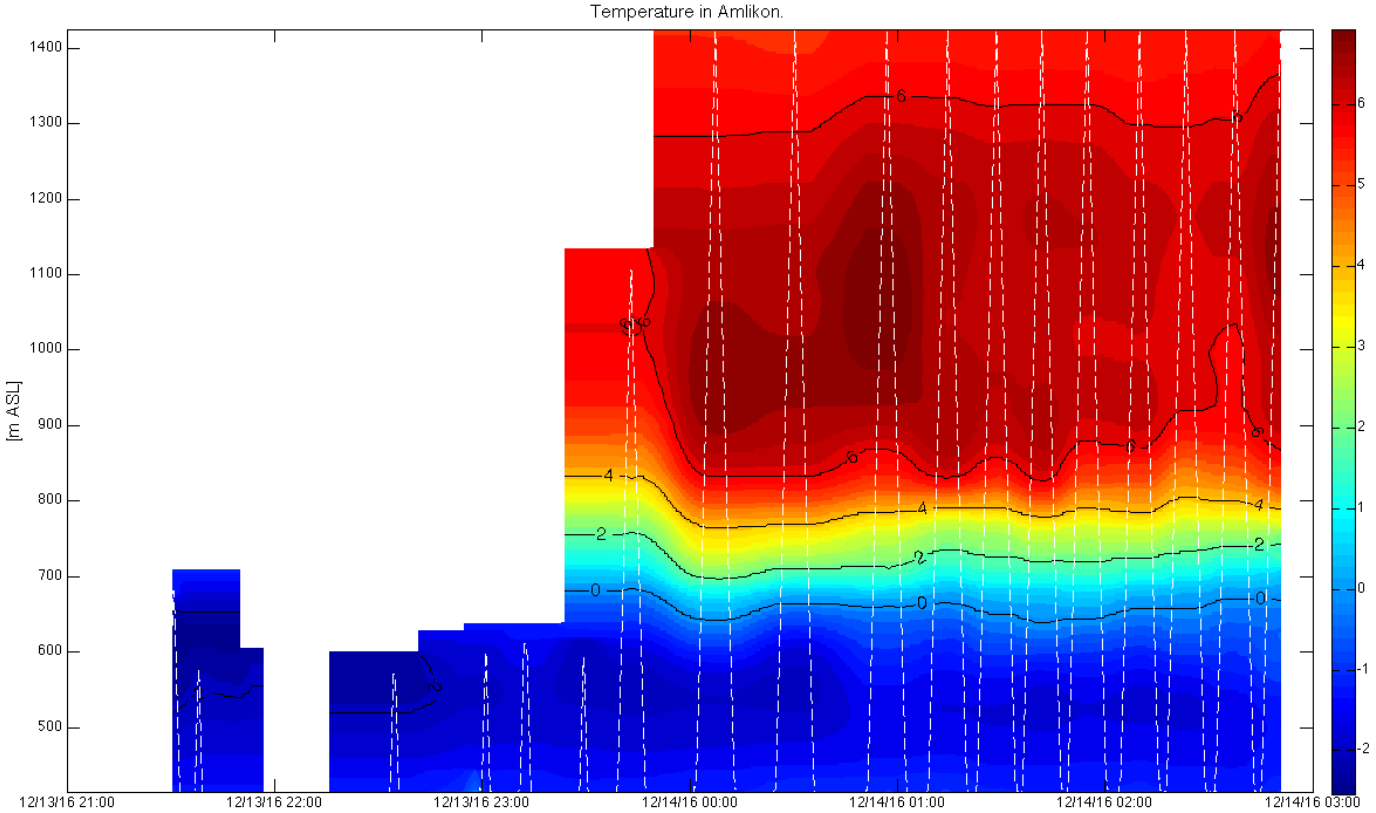

DABS Date: 2017 DEC 04
Daily Airspace Bulletin Switzerland
Version 1
Schaffhausen SH
Amlikon TG
Zurich Airport
Birrfeld AG
Rifferswil ZH
Tuggen SZ

Impact on Analysis Mean Cloudiness

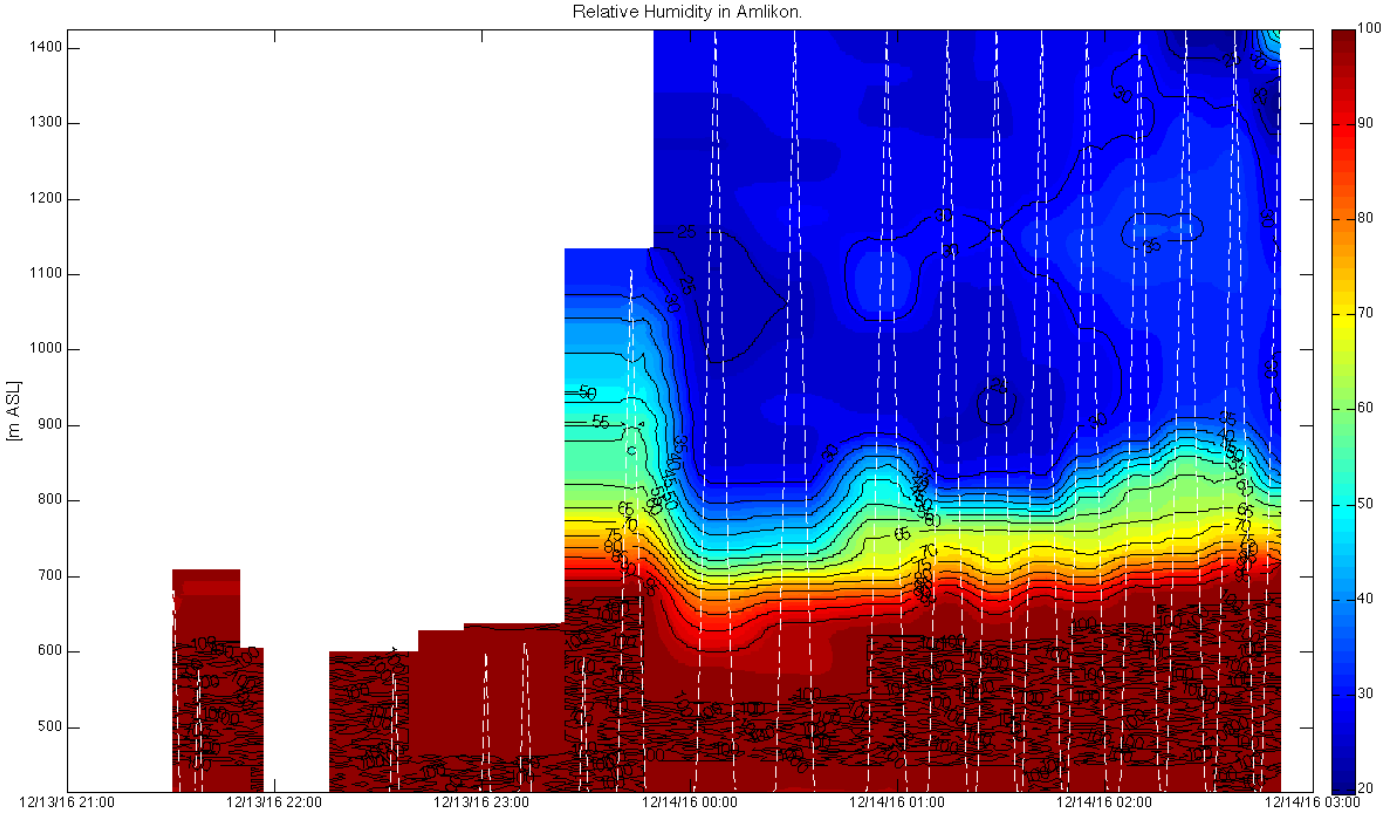


Source: Leuenberger et al., 2019: Improving High-Impact Numerical Weather Prediction with Lidar and Drone observations, BAMS (in press)

Amlikon 13.12./14.12.2016 - Icing



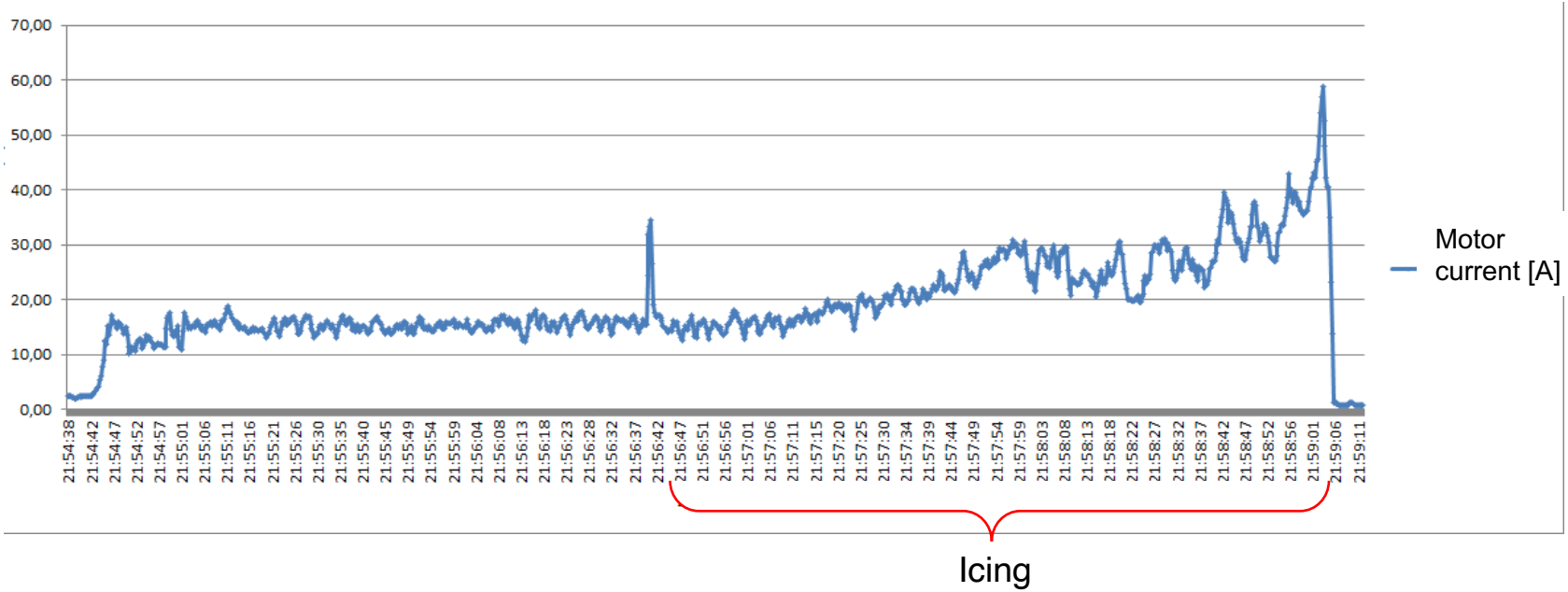
Amlikon 13.12./14.12.2016 - Icing



Test flights under real icing conditions

- Influence of Icing on power input

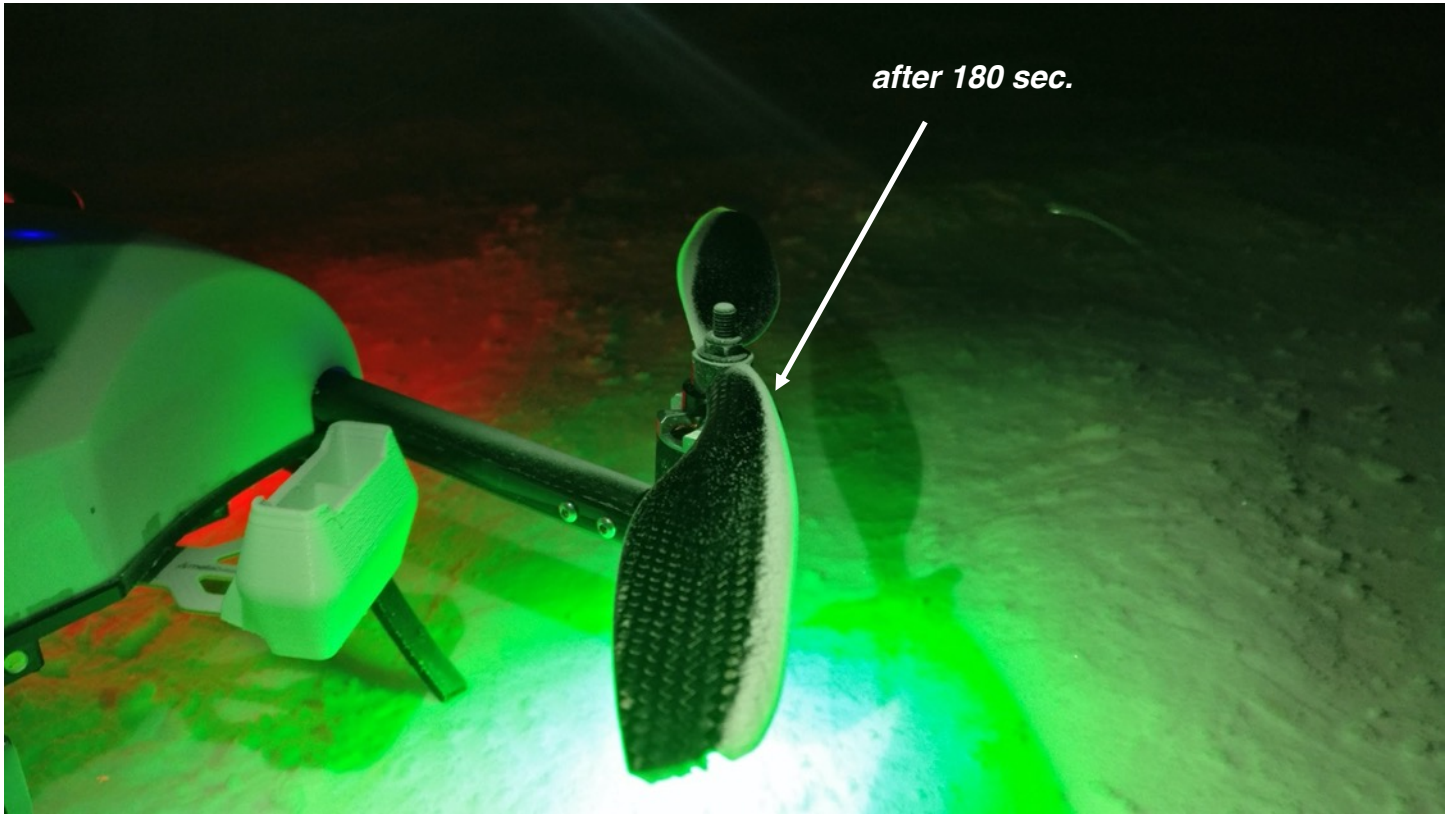
  → Power consumption increases while ice is aggregating.



Preliminary icing tests -4°C (clear ice)

After 120 sec.: water droplets (1-2°C) were sprayed

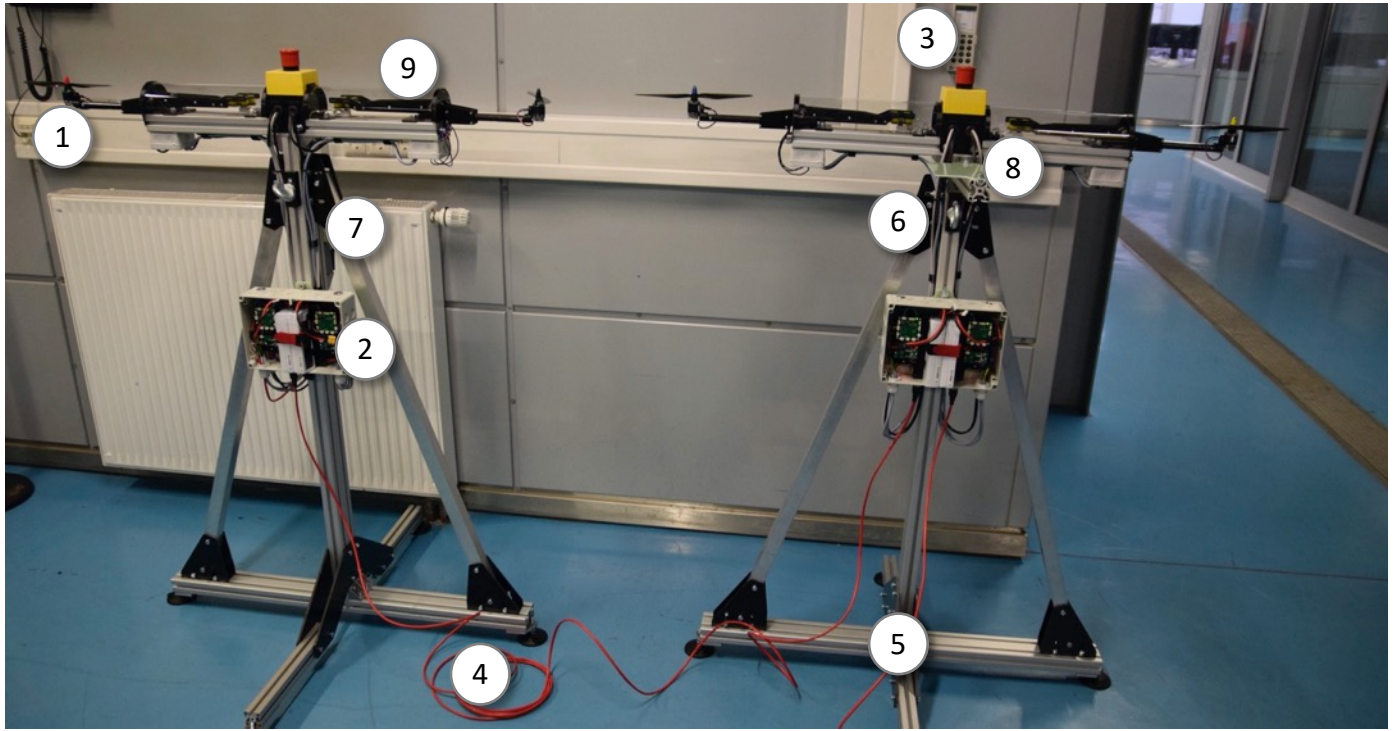
Icing at temperatures of -14°C (hard rime)



Rail Tech climate wind tunnel

Tests conducted at the Rail Tec climate wind tunnel

Tests in climate wind tunnel at Rail Tec in Vienna



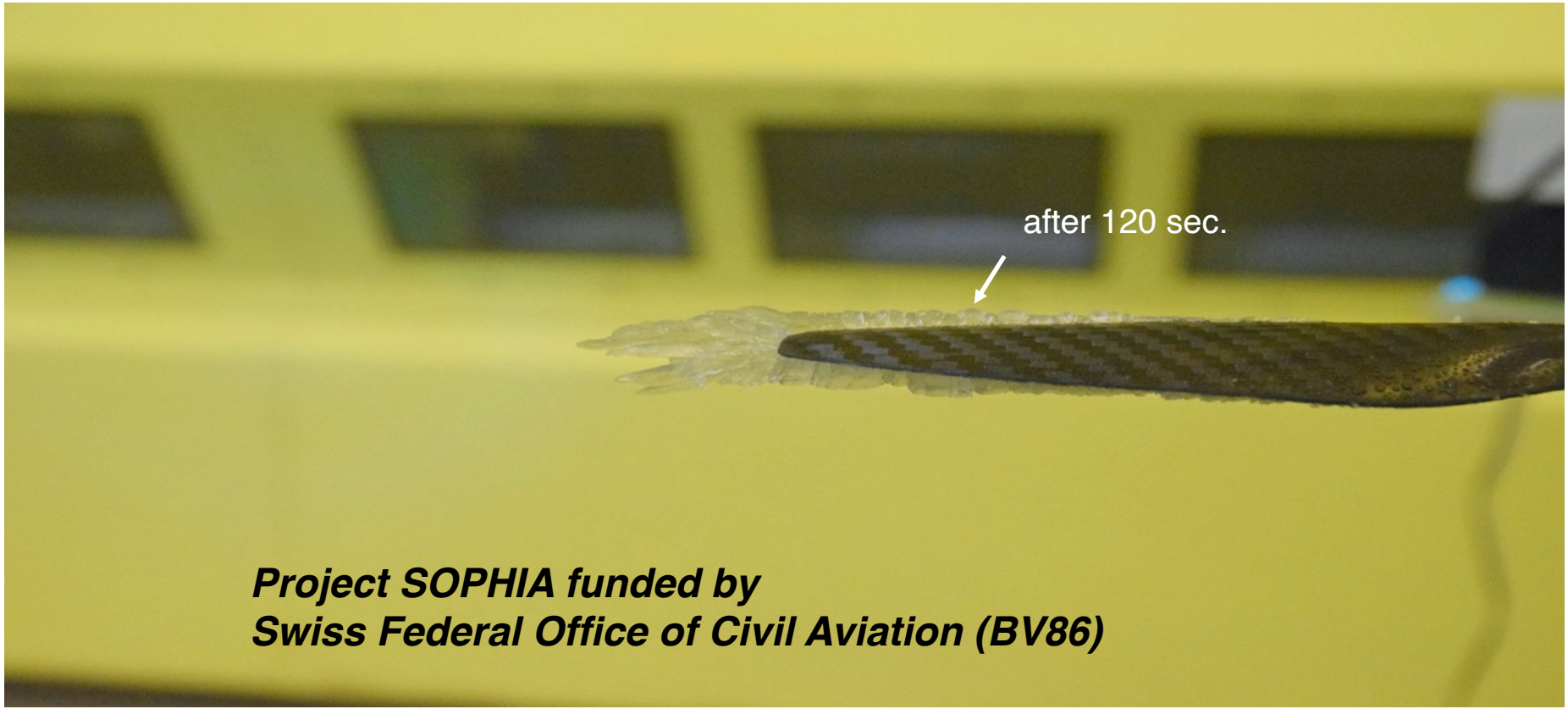
1: rocker with motor and propeller, 2: control unit, 3: emergency switch, 4: connection cable (30m to control room), 5: stable stand that can be fixated, 6: additional fixation points, 7: temperature/humidity sensor, 8: mount for LWC sensor, 9: waterproof cover of the rocker

Test Scenarios

No.	Start	End	Temperature	LWC	MVD	Condition
1	11:58	12:19	-2 °C	0.6 g/m^3	20 µm	Stratiform Cloud
2	13:12	13:31	-5 °C	0.5 g/m^3	20 µm	Stratiform Cloud
3	13:45	14:19	-5 °C	1.25 g/m^3	30 µm	Cumuliform Cloud
4	15:57	16:08	-10 °C	1.4 g/m^3	25 µm	Cumuliform Cloud
5	17:10	17:26	-20 °C	0.7 g/m^3	30 µm	Cumuliform Cloud
6	18:18	18:29	-10 °C	0.8 g/m^3	32.5 µm	Cumuliform Cloud

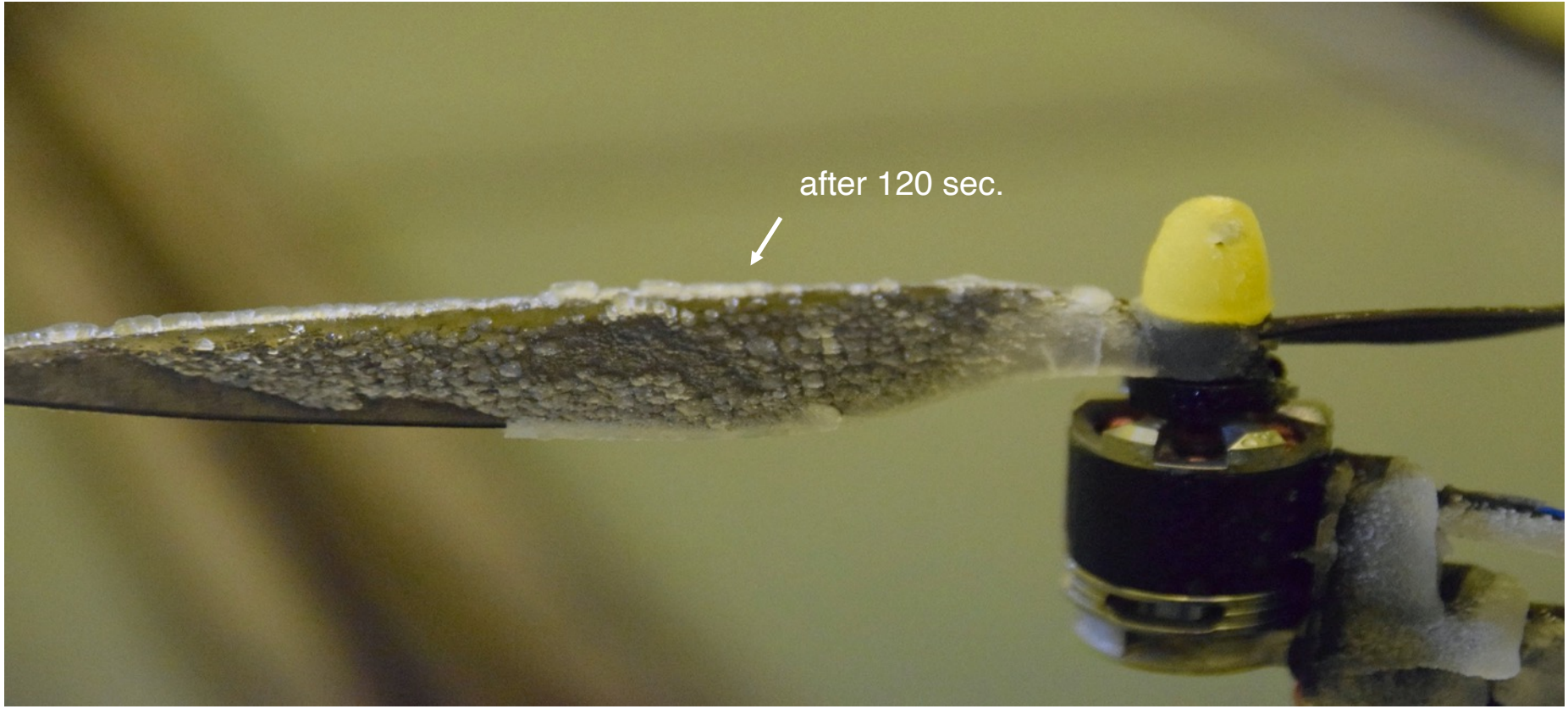
- The technical abilities of the VCWT limited the testable conditions
- Large diameters would have required a stronger wind in the tunnel but nobody could have been inside during tests (no ice observation/photos)
- Focus on smaller LWCs since they are more relevant for real clouds

Clear ice (-2°C, MVD=20μm, LWC=0.6g/m^3)

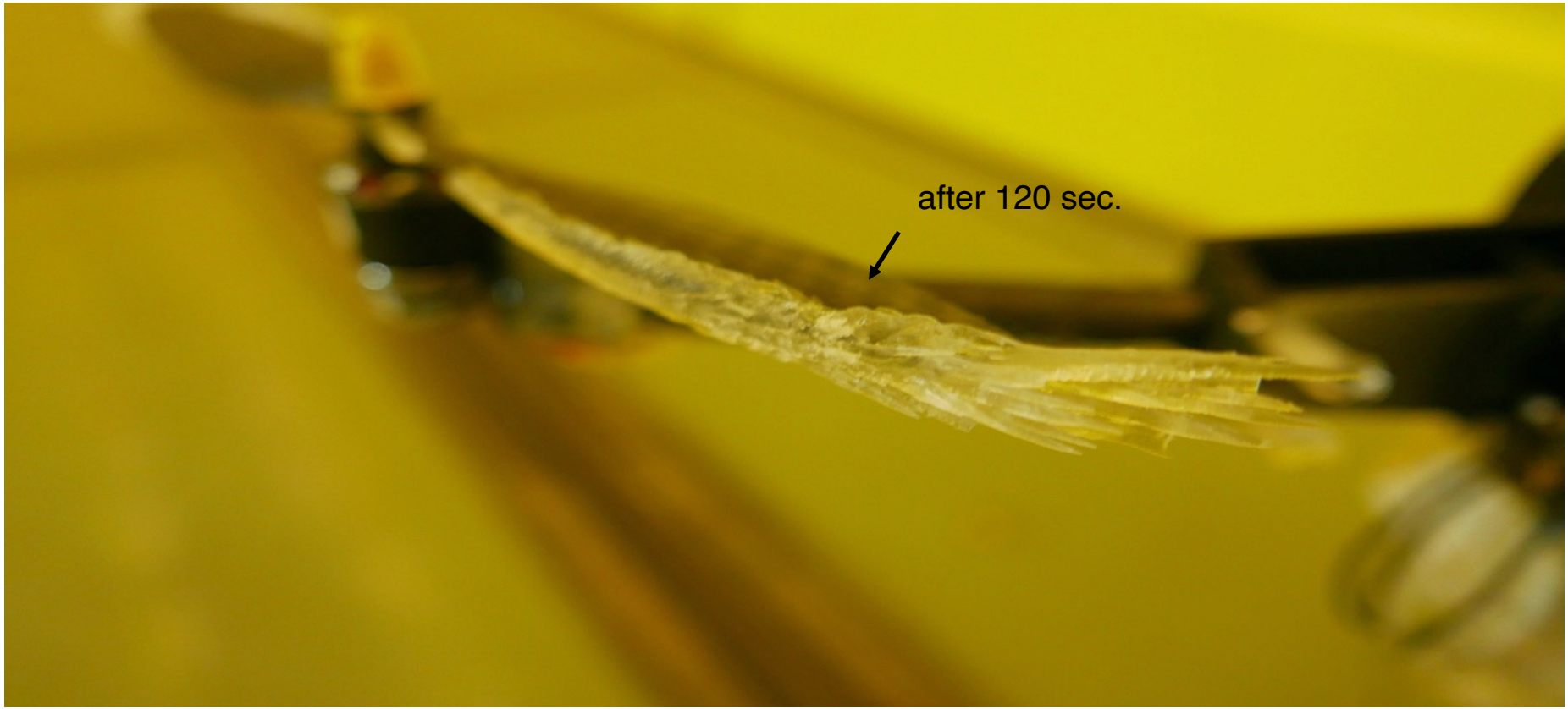


Project SOPHIA funded by
Swiss Federal Office of Civil Aviation (BV86)

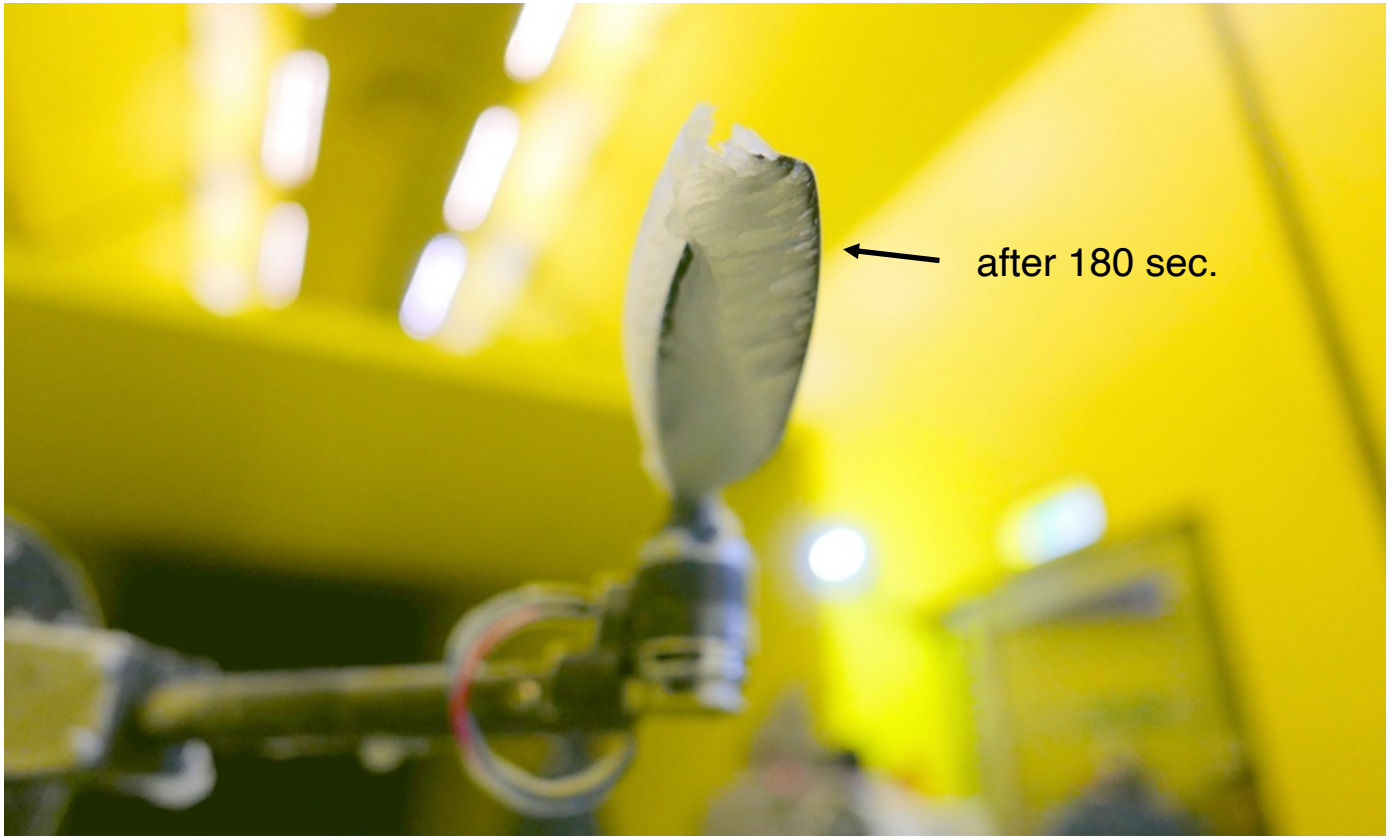
Ice cover (-5°C, MVD=20μm, LWC=0.5g/m^3)



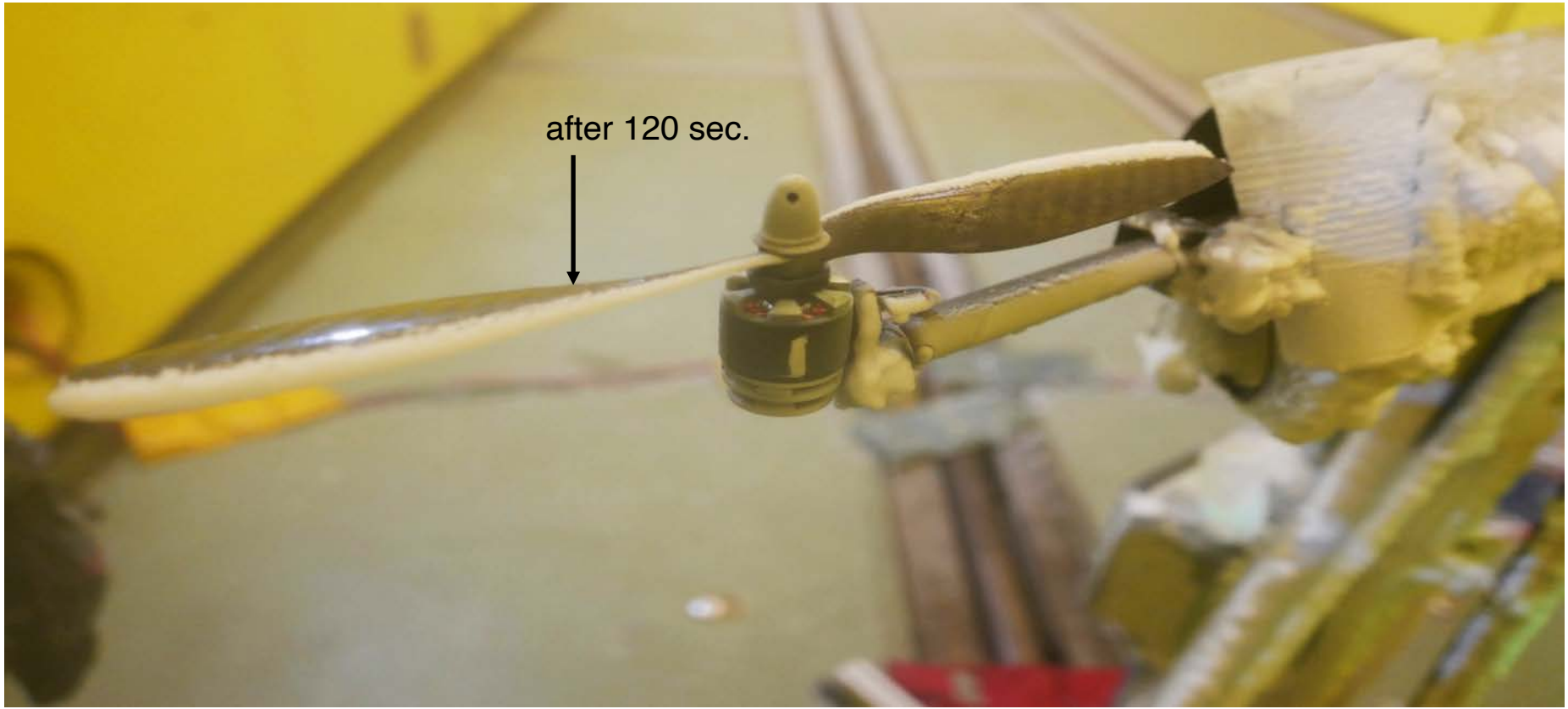
Extreme clear ice amount (-5°C, MVD=30μm, LWC=1.25g/m^3)



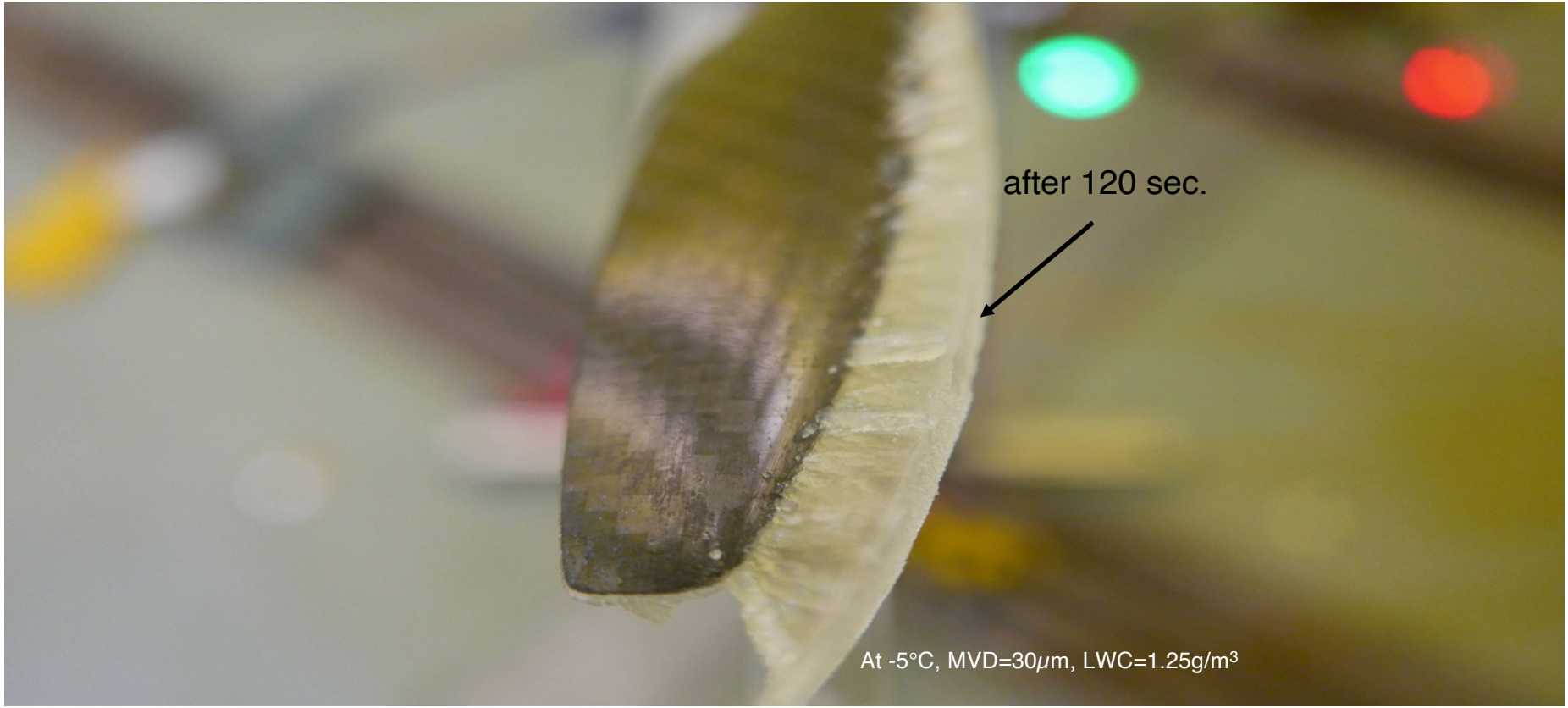
Icing at the downside of the propeller (-10°C, MVD=25μm, LWC=1.4g/m^3)



Hard rime (-20°C, MVD=30μm, LWC=0.7g/m^3)



Example – Extreme ice (> 4mm)



Anti-Icing measures

- Different de-icing and anti-icing agents were tested
- None of these showed full protective effect
- **Effect depends on viscosity**
  - low viscosity: agents 1,3 slipped from the props very fast, no effect
  - higher viscosity: agents 2,4 had a delaying effect on the ice (maybe 1 or 2 minutes)
- Not enough data to get clear evidence

1: wind shield defroster (de-Icing)
2: door rubber gasket protection (anti-Icing)
3: wind shield defroster (de-icing)
4: cooler protection concentrate (anti-icing)

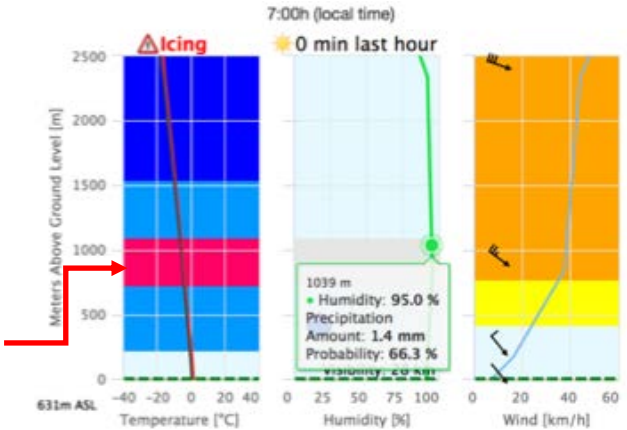
Propeller heating in action

Forecasting flight conditions:

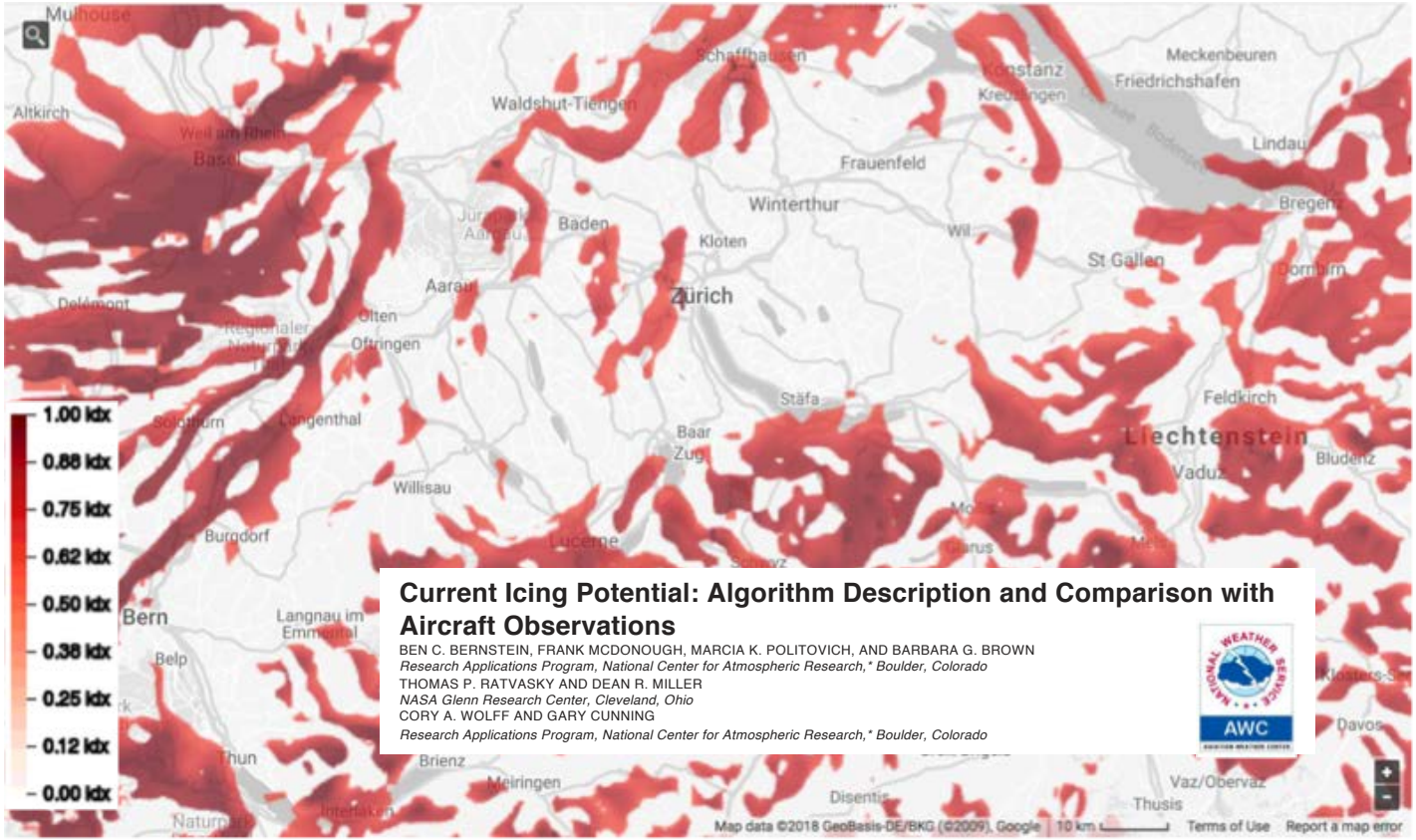
- Two conditions:
  1. **Air temperature < 0°C**
  2. Visible humidity:
     → **Relative humidity > 95%**

www.droneweather.ch

- Drone weather:
  - Forecasts of the meteorological parameters **temperature**, **relative humidity** and **wind** for every hour and different altitudes.
  - Icing conditions are highlighted in pink.
  - Is used for Meteo-briefings of drone pilots



Icing Potential at different pressure levels



Icing Index Method & Description

Current Icing Potential: Algorithm Description and Comparison with Aircraft Observations

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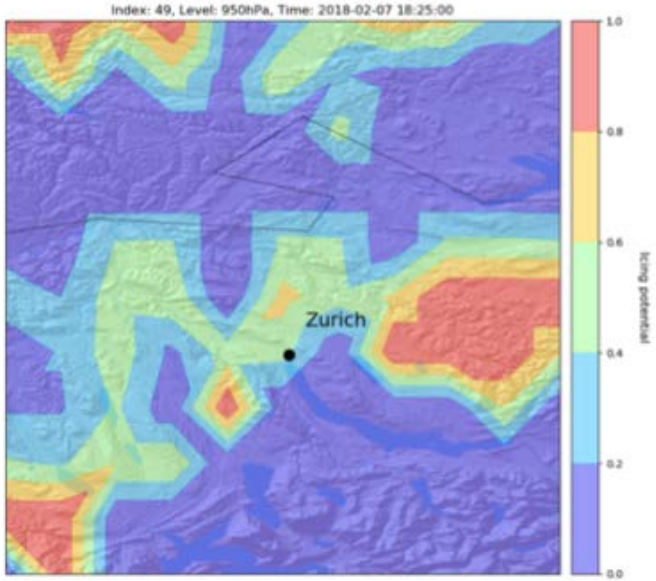
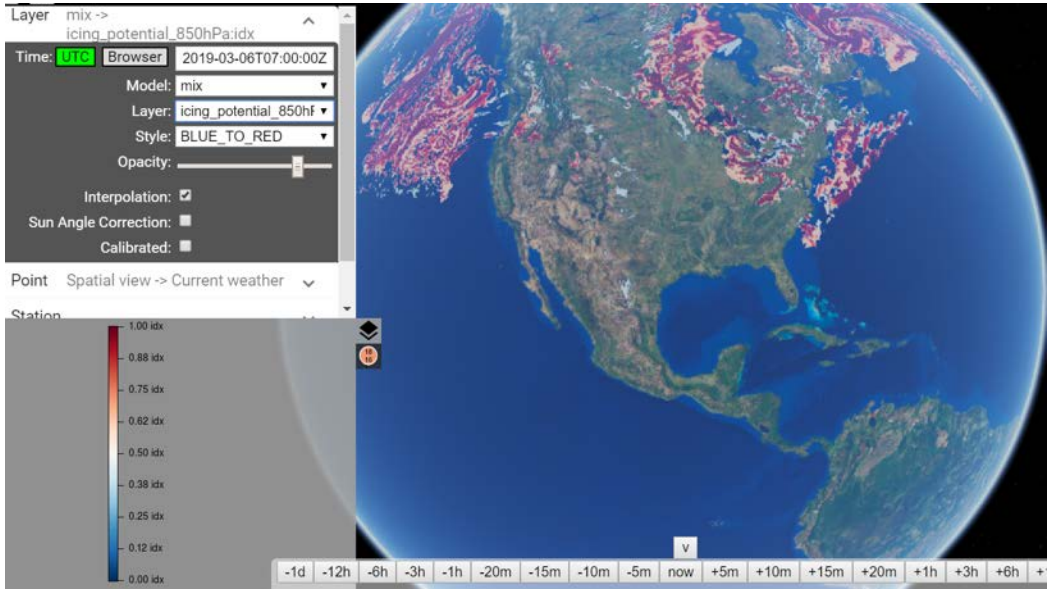
CORY A. WOLFF AND GARY CUNNING
Research Applications Program, National Center for Atmospheric Research, Boulder, Colorado*

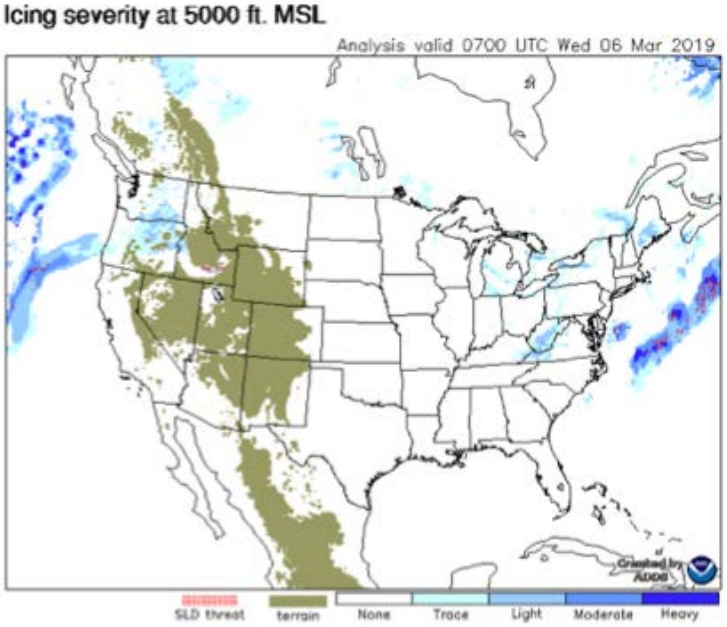
Index	Description
0.0-0.2	No icing
0.2-0.4	Traces
0.4-0.6	Light
0.6-0.8	Moderate
0.8-1.0	Heavy



Modeling icing: example at 850hPa/5'000ft

- Icing potential index over North America, 06 Mar 2019, 07:00 (nowcast) from Meteomatics (left) and NOAA (right). 850hPa respectively 5000ft.





Icing events summary

- The Swiss Federal Office of Civil Aviation (FOCA) allowed us to validate the icing forecasts against incidents
- Ca. 90% of 20 investigated events have been classified as icing incidents
- For most icing events the API predicts moderate to heavy icing potential in the area.
- For some icing events the location is not specified well enough, this makes validation more difficult.
- Icing might be underestimated due to a lack of supercooled liquid water content or too high temperatures or too low relative humidity in the model.

Icing on Arms

Flight on Jungfraujoch

After **2 minutes hard rime** has formed (-12°C, 100% relative humidity) on the propeller but also on the airframe: On those parts in the downwash.

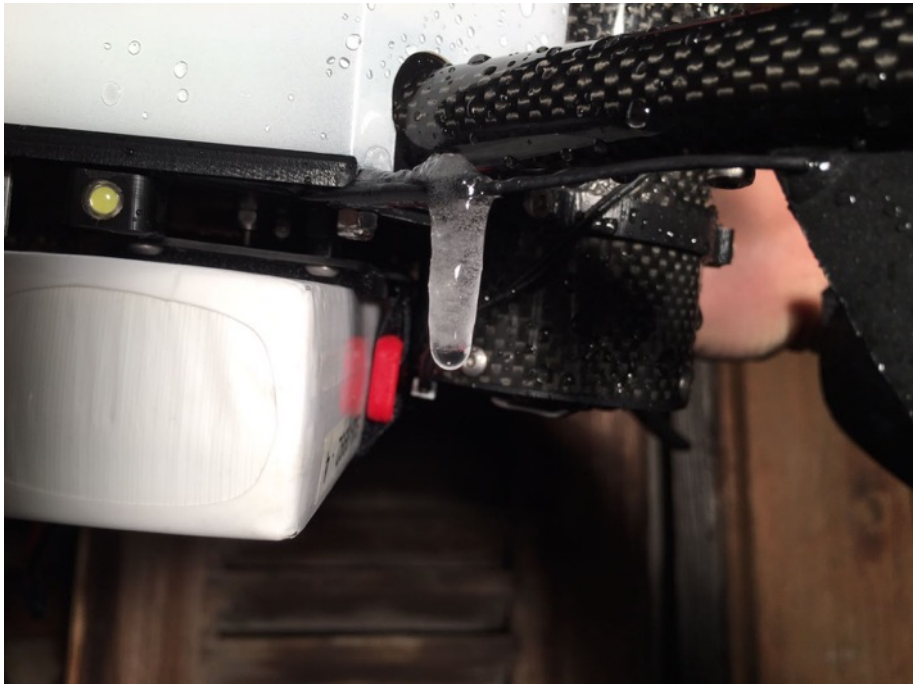
Meteodrone during Heavy Snowfall

Flight in Marbach

Snow started to stick on the Meteodrone (ca. 10min flight). Temperatures between -2°C..0°C.

Meteodrone in Heavy Snowfall

Flight in Marbach



Icicles started to build up (ca. 10min flight). Temperatures between -2°C..0°C.

Thank You for Your Attention!

Your Contact

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